CITY-COUNTY OF BUTTE-SILVER BOW

2020 Preliminary Engineering Report

Basin Creek Dam #1 and #1 Site Improvements

Prepared by:

GreatWest engineering®

June 2020

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Basin Creek Dam #1 Rehabilitation

June 2020

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City-County of Butte-Silver Bow

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1.0 EXECUTIVE SUMMARY

1.1 Introduction and Background

Basin Creek Dam #1 is a curved masonry core dam with a concrete cap/buttress and earth fill impounding Basin Creek Reservoir, approximately 10 miles south of Butte. The dam's primary function is to manage the critical storage of water for the City-County of Butte - Silver Bow's (BSB) public water supply. The dam provides water to the recently constructed Basin Creek Water Treatment Plant (WTP) on a gravity system, which minimizes pumping needs and related costs. In August of 2010, BSB received a notice from Montana DEQ rescinding the filter exemption that had been in place for nearly twenty years and began a seven-year effort that culminated in the opening of a 30 million dollar water treatment plant in order to meet increasingly strict regulations surrounding municipal water. Ancillary uses of the dam include flood control, downstream irrigation usage, and fisheries/wildlife habitat. The dam is considered "high-hazard", meaning that if failure occurs the resulting effects would likely be a direct loss of human life and extensive property damage.

As observed over the past five to ten years, increased concrete deterioration on the dam, specifically on the concrete cap and parapet wall, has progressed to the point necessitating rehabilitation. The most recent 5-year dam inspection, completed in July of 2019, provided BSB with recommendations to address the deteriorating concrete. BSB took the recommendations seriously and subsequently obtained a planning grant through the DNRC RRGL program to assist in completing a structural analysis of the dam. This analysis was then used to develop more specific recommendations for how best to address the identified concerns. This project will address the condition of dam features, specifically poor-quality concrete condition on the upstream dam face and parapet wall. Additionally, an anchorage system will be installed to ensure dam stability during the Probable Maximum Flood (PMF) event. Structurally sound concrete on the dam face is an essential component to a safe and functioning dam system. If the upstream dam face (or parapet wall) were to fail because of deteriorated concrete, significant flooding would occur downstream in Basin Creek. Such flooding would have a significant impact on public health and safety and economic consequences. A partial (or full) dam failure would also have a substantial impact on water quality and aquatic life, and cause significant erosion and sediment loading in the creek. It is important to note that the dam's primary purpose is to provide public

drinking water to Butte. Thus, ensuring the integrity and proper function of the dam is essential to managing water delivery to Butte and its citizens.

1.2 Problem Definition

This PER provides a thorough description and detailed analysis of the current condition of the dam and its associative water delivery components to (and including) the Basin Creek WTP. Specific analysis, evaluation and description of water delivery downstream of the Basin Creek WTP is not a focus of this report. The primary deficiencies identified in this report are as follows:

- Basin Creek Dam #1 is classified as a high hazard dam by the State of Montana. Therefore, the facility must be operated under the provisions of an Operating Permit issued by the Dam Safety Section of the Montana Department of Natural Resources and Conservation (DNRC). As a result of the high hazard designation, BSB is required to have Basin Creek Dam #1 inspected by a Professional Engineer every 5 years. The 2019 Periodic Inspection Report (September 30, 2019, Appendix K) prepared by Pioneer Technical Services, Inc. described numerous cracks, spalls, and signs of severe deterioration of the concrete on the upstream face of the dam including surface voids approximately 12 inches in height, 6 inches deep, and varying in width up to 6 feet. The deterioration was also evident in photos from the 2014 and 2009 Periodic Inspection Reports; however, the rate of deterioration has increased considerably in the past few years.

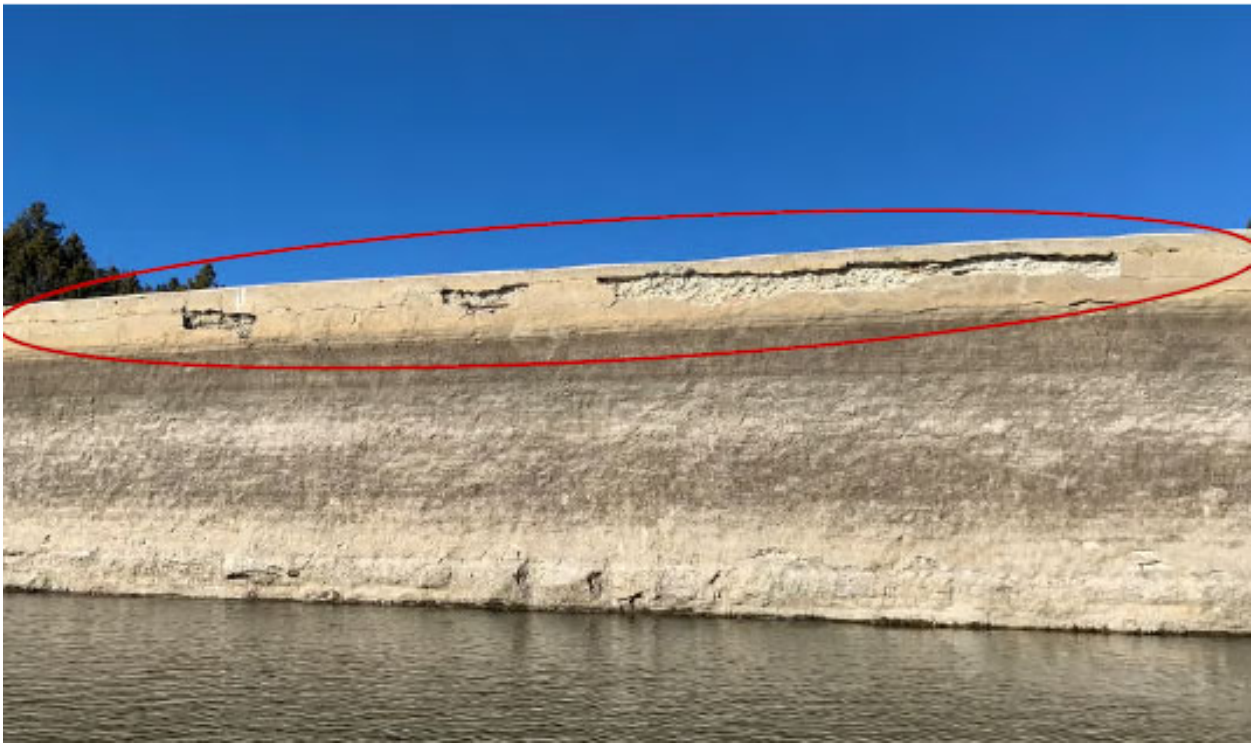

Figure 1-1: View of general concrete deterioration along the upper face of the Basin Creek Dam. (2020 Basin Creek Dam Structural Assessment)

- The comments provided by Montana DNRC on the 2019 Draft Periodic Inspection Report expressed concern regarding the concrete deterioration and that if left unaddressed, would likely result in Montana DNRC imposing a reservoir level restriction to lower the reservoir and reduce the risk downstream of the dam from the PMF or overtopping events. This reduction in reservoir elevation would also have considerable implications to the operation of the Basin Creek WTP. Unless repairs are made, BSB will likely be forced to reduce the maximum operation level of the dam to an elevation below the deteriorated concrete—reducing the reservoir's storage capacity from nearly 1000 acre-feet to less than 460 acre-feet. The resulting loss in water volume will reduce the driving force necessary to provide gravity flow through the treatment process and the limited remaining capacity in the reservoir would be quickly depleted.

  The deterioration of the concrete appears to be accelerating which could impact the ability of the dam to withstand overtopping and that the top several feet could fail in an extreme storm event. The Montana DNRC comments also indicated that further investigation into the concrete deterioration will be a permit condition and suggested that BSB consider

applying for an initial study grant under the Renewable Resource Grant and Loan (RRGL) program.

In November 2019, BSB was awarded an RRGL grant to help with expenses associated with contracting a concrete deterioration expert to provide a professional assessment of the concrete condition and prepare an inspection report. This structural analysis was started in the fall of 2019 by Gannett-Fleming and submittal of the final report occurred in January 2020. The report examined the stability of the dam and the existing concrete condition and identified three retrofit alternatives to remediate the poor concrete condition along the upper dam face and provide stability during overtopping events associated with the Probable Maximum Flood (PMF) or upstream reservoir failure. An adequate bond between the mass concrete and the masonry core is necessary to ensure sliding and rotational stability. The alternatives ranged from repairs to the parapet along the upper dam face with the addition of post-tensioned anchorages to a major rehabilitation project involving fully removing the upper 13' of the dam and replacing it with a design that meets current design standards. An intermediate rehabilitation project consisting of the removal of the existing parapet and the installation of a concrete overlay on the upstream dam face with post-tensioned anchorages was also recommended.

The final Basin Creek Dam Structural Assessment Report is included in Attachment J of this application.

1.3 Alternatives Considered

The alternative screening process considered various alternatives for the dam improvements to mitigate the poor existing concrete condition and provide stability during the PMF or dam overtopping event. After an initial evaluation, some alternatives were determined to be non-viable for BSB and were eliminated from further review. Alternatives that were determined viable and therefore discussed in greater detail include the following:

Alternative 1: Concrete parapet replacement (top of dam crest). Installation of post tensioned anchors through the existing concrete into the masonry core.

Alternative 2: Concrete parapet replacement (top of dam crest). Full structural concrete overlay over the upstream dam face. Installation of post tensioned anchors through the existing concrete into the masonry core.

Alternative 3: Full removal and replacement of the 13-foot deep mass concrete cap to the masonry interface. Installation of an adequate anchorage system from the new mass concrete section into the masonry core.

1.4 Preferred Alternative

Each of the alternatives listed above are analyzed in detail in this report. A decision matrix was developed to compare alternatives and to select a preferred alternative. The matrix includes a comparison of life cycle costs, maintenance, permitting/environmental issues and public health and safety.

BSB's highest priorities are protecting public health and safety and financial feasibility. With this goal in mind, BSB's preferred alternative is as follows:

- **Alternative 2** - Concrete parapet removal and replacement with a full structural concrete overlay on the upstream dam face. Post tensioned anchors will be installed through the existing concrete into the masonry core.

The concrete parapet removal/replacement and full upstream dam face concrete overlay addresses superficial and structural deficiencies related to the concrete deterioration. The installation of post tensioned anchors addresses the susceptibility of the dam to sliding and overturning during the PMF event. The overall proposed project addresses BSB's highest priorities, improves public health and safety, and is economically feasible.

1.5 Project Costs and Budget

The total estimated cost for the proposed project is $2,030,052. Detailed cost estimates are included in subsequent sections. Various funding sources for the improvements are considered in subsequent sections and include a variety of grant sources available to BSB. The recommended funding strategy includes utilizing the following grant programs:

- TSEP Grant: $500,000
- DNRC Grant: $125,000

The remainder of the project costs will be provided from BSB's budget.

2.0 PROJECT PLANNING

2.1 Location

Basin Creek Dam #1 is located in the City-County of Butte-Silver Bow, Montana and is built across the Basin Creek and Bear Gulch drainages in the Upper Clark Fork River basin. The storage reservoir, known as Basin Creek Reservoir, is fully located within the County extents and is located at the end of Basin Creek Road. The nearest city is Butte, which is 10 miles to the north. The Dam is more specifically located at:

Latitude/Longitude	45.854456°N Latitude, -112.545725°W Longitude
Township/Range/Section	Township 1 North, Range 8 West, Section 12
Dam Crest Elevation	5889.06 (NAVD88)

The Basin Creek WTP is located in the City-County of Butte-Silver Bow, Montana and was built in 2017. The WTP is located approximately 2.5 miles north of Basin Creek Dam #1 along Basin Creek Road. The Basin Creek system is the sole source of water for the treatment plant. The plant is more specifically located at:

Latitude/Longitude	45.887022° °N Latitude, -112.539879 °W Longitude
Township/Range/Section	Township 2 North, Range 8 West, Section 36
Water Treatment Plant Elevation	5710 (NAVD88)

Figure 2-1, below, shows the approximate location of Basin Creek Dam #1 and the Water Treatment Plant. Refer to additional location maps included in Appendix A.

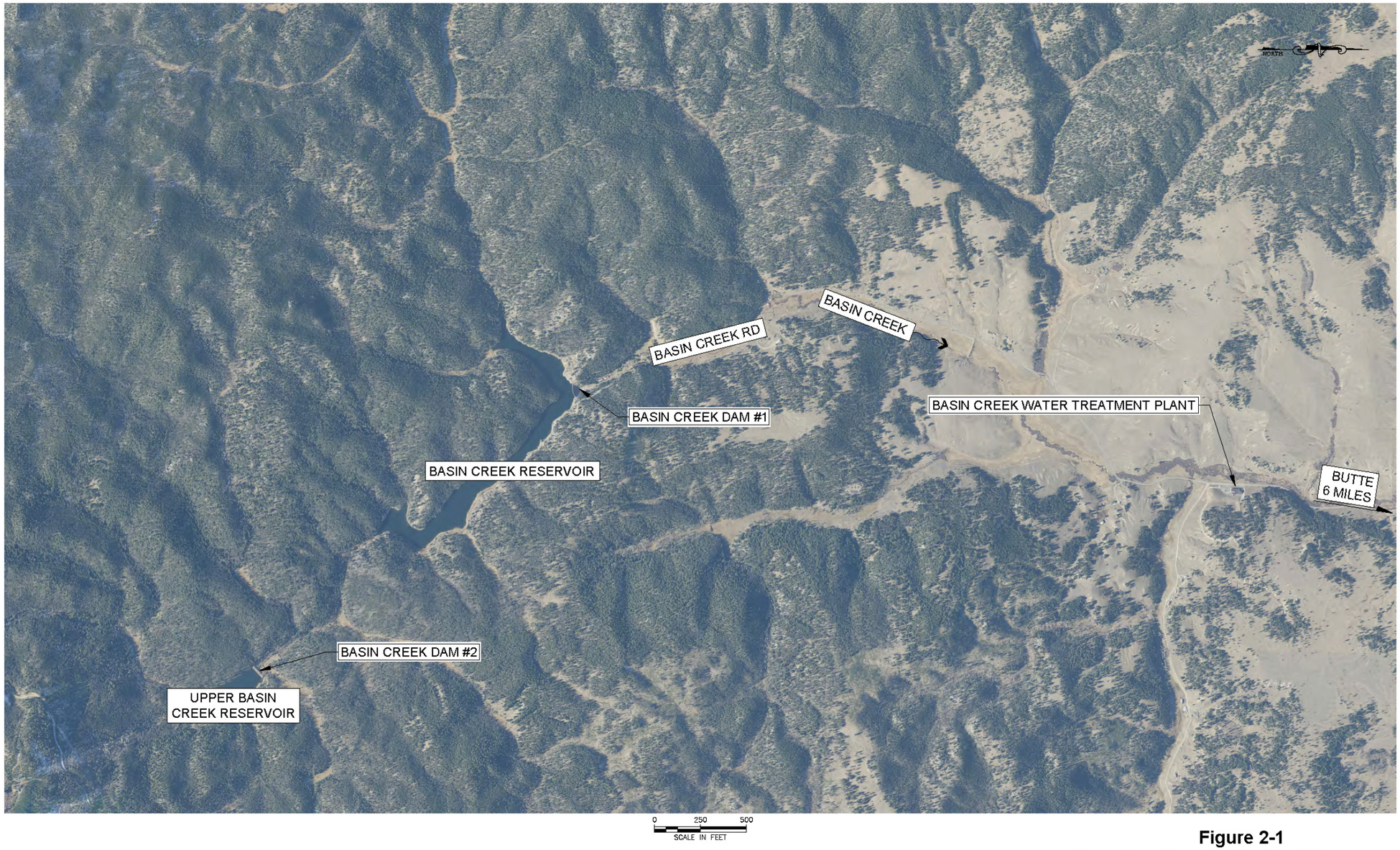

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Figure 2-1
Location Map- Basin Creek Dams and Basin Creek Water Treatment Plant

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BASIN CREEK DAM #1 REHABILITATION PER

Figure 2-1: Project Location Map

Figure 2-2: General view of Basin Creek Dam #1 from above the right abutment (2005 Hydraulics and Hydrology Study, Appendix O)

Figure 2-3: View of the dam face and downstream embankment (2019 5-Year Inspection, Pioneer Technical Services, Appendix K)

Figure 2-4: View of the upstream dam crest
(2019 5-Year Inspection, Pioneer Technical Services, Appendix K)

Figure 2-5: View of the recently constructed Basin Creek WTP

2.2 Environmental Resources Present

As part of any potential construction project, the impacts of the project on the surrounding environment should be considered and provisions made to mitigate any negative impacts. The Uniform Application streamlines the process by utilizing a standard procedure called the Uniform Environmental Checklist. The Uniform Environmental Checklist combined with some additional environmental review questions will serve as an Environmental Assessment (EA) for this project. An EA must be completed in order to comply with the Montana Environmental Policy Act (MEPA). A completed EA for the proposed Basin Creek Dam #1 rehabilitation project is included in Appendix B.

As part of quantifying the impacts to various environmental resources, the EA process includes sending letters to interested local, state, and federal agencies requesting comments on any potential environmental impacts as a result of potential improvements. A copy of the letters along with responses are included in Appendix C. The following is a list of agencies that were contacted:

- City-County of Butte Silver-Bow Floodplain Administrator
- City-County of Butte Silver-Bow Planner
- U.S. Fish and Wildlife Service
- U.S. Army Corps of Engineers
- Montana Department of Environmental Quality
- Montana Department of Natural Resources and Conservation
- Montana Fish, Wildlife & Parks
- Montana Natural Habitat Program
- Montana Sage Grouse Habitat Conservation Program
- State Historic Preservation Office (SHPO)
- U.S. Forest Service

2.2.1 Geology, Soils and Land Use

2.2.1.1 Geology

According to the USGS Montana Geological Map, the dam is located in a widespread granitic formation formed in the Cretaceous period (66-145 million years ago). This granite formation is typical to the northern end of the Highland Mountains. Visible granitic rock outcroppings are present adjacent to the existing dam abutment interfaces.

No existing boring logs in the dam vicinity are available, however, as-built plans of the dam do show bedrock in relative proximity to the base of the dam. Depending on the selected

rehabilitation alternative, borings may occur as part of the final design process to determine the dam substrate and its competency. Recent geological surface investigations (see Appendix N) yield that the foundation and abutment bedrock at the site consists of coarse to very coarse grained, light to medium grey, massive granite. The observable rock was found to be of "good" quality.

Figure 2-6: View of Existing Granite Composition at Right Dam Abutment (Basin Creek Site Inspection, URS, 2005, Appendix N)

2.2.1.2 Soils

The NRCS Web Soil Survey was used to generate a map showing the soils in the area around the dam (see Appendix D). The native soils generally found in the proximity of the dam are comprised of gravels, sands, and loams. The predominant soil types identified within the proximity of the dam are listed below:

- *Ambrant-Rochester families – Complex, low relief mountain slopes and ridges (75GAF)*
- *Cryofluvents-Finn family – Water complex, rolling stream terraces and floodplains* (64JG1)

Information is available for each soil unit to describe physical and chemical properties of the soils typically found within the unit.

An important property of the soils that may affect the project is the propensity of the soils to corrode concrete and/or steel. Therefore, each of these properties was analyzed. According to the NRCS:

> 'Risk of corrosion' [of concrete] pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens concrete. The rate of corrosion of concrete is based mainly on the sulfate and sodium content, texture, moisture content, and acidity of the soil. Special site examination and design may be needed if the combination of factors

> results in a severe hazard of corrosion. The concrete in installations that intersect soil boundaries or soil layers is more susceptible to corrosion than the concrete in installations that are entirely within one kind of soil or within one soil layer.

Soils within the primary dam area are rated as “moderate” risk of corrosion to concrete. A report listing the risk of corrosion to concrete is included in Appendix D.

The propensity to corrode steel for each of the soils was also evaluated. According to the NRCS:

> ‘Risk of corrosion’ [of steel] pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens uncoated steel. The rate of corrosion of uncoated steel is related to such factors as soil moisture, particle-size distribution, acidity, and electrical conductivity of the soil. Special site examination and design may be needed if the combination of factors results in a severe hazard of corrosion. The steel in installations that intersect soil boundaries or soil layers is more susceptible to corrosion than the steel in installations that are entirely within one kind of soil or within one soil layer.

The native soils in the direct vicinity of the dam had a rating of “low” for risk of corrosion to steel. A report listing the risk of corrosion to steel is included in Appendix D.

It should be noted that additional embankment was placed on the downstream face of the dam in the 1930’s. The source and chemical properties of this earthen material is unknown. If deemed necessary based on the selected rehabilitation alternative, soil sampling and testing will be completed to determine the relative corrosivity of the embankment soil.

2.2.1.3 Land Use

Prime farmland is defined by the USDA as land best suited to food, feed, forage, fiber, and oilseed crops. It may be cultivated land, pasture, woodland, or other land, but it is not urban land or built-up land for water uses.

Basin Creek Dam #1 is located in a forested area. Due to its source as the BSB’s water supply, BSB owns the property immediately surrounding the reservoir and dam. Outside of dam-related infrastructure and buildings, there is no other infrastructure within the dam proximity. Preliminary investigations indicate that the land surrounding the dam is not prime farmland, as designated by the NRCS. There are some agricultural operations approximately 0.8 miles to the north of the dam, primarily consisting of small grass hay operations. As the proposed dam improvement

project is not expected to impact adjacent soils (outside of minimal impact in the dam vicinity), no negative impact to agricultural lands or farmlands is anticipated.

There is a considerable acreage of Beaverhead-Deerlodge National Forest lands located to the east, west and south of the dam. The nearest USFS boundary to the project site is approximately 400 feet northwest of the dam. There are no current active logging activities on public lands in the vicinity, however, logging has occurred in the past (most recently in 2008), which resulted in approximately 1000-1500 acres of logging activities near the headwaters of Basin Creek. Additionally, considerable beetle kill has occurred in the forest surrounding the reservoir, of which Russ Walker, USFS Forester, indicated that 50-80% of trees are likely dead in the drainage from pine beetle kill.

2.2.2 Biological Resources

Based on consultation with the Montana Natural Heritage Program and Montana Field Guides, the vegetative land cover in the dam vicinity is classified as:

- Rocky Mountain Montane Douglas-fir Forest and Woodland
- Rocky Mountain Ponderosa Pine Woodland and Savanna
- Insect Killed Forest

These systems are associated with a dry to submesic continental climate regime with annual precipitation ranging from 20 to 40 inches, with a peak in winter or late spring. Wildlife in the area generally consists of elk, deer, coyote, fox, mountain lion, bobcat, rabbit, porcupine, skunk, raccoon, mice, other small mammals, and a wide variety of birds.

Pine beetles have killed a substantial amount of conifer trees in the adjacent Beaverhead – Deerlodge National Forests. As previously stated, 50-80% of the trees in the drainage basin are estimated to be dead from pine beetle kill.

A search of the Montana Natural Resources and Information System (NRIS) was conducted and consultation with the U.S. Fish and Wildlife Service occurred. Eleven animal species of concern and four plant/tree species of concern were identified in the project area. The species of concern data can be found in Appendix H. Most of these species do not frequent the limited habitat found at the dam site. Because the proposed improvements will take place on the existing dam infrastructure, minimal adverse impacts are anticipated for the listed species of concern.

The project does not fall within the general habitat for greater sage grouse, as defined by the Montana Sage Grouse Habitat map, which depicts the areas that fall under the Executive Order. As such, Sage Grouse are not anticipated to be adversely affected by this work. Following the award of grant funds, and within 12 months of the proposed construction date, BSB will consult with the Montana Sage Grouse Habitat Program regarding the work to confirm no impact.

2.2.3 Water Resources

2.2.3.1 Groundwater

In the direct vicinity of the dam, there are three drilled wells based on information obtained from the Groundwater Information Center (GWIC) and the Montana Bureau of Mines and Geology (included in Appendix E). One well is adjacent to the reservoir and is reservoir influenced. Of the two wells downstream of the dam, one was drilled to 300 feet, exhibited a static water surface of 135 feet and a flow rate of 5 gallons per minute (GPM). The other well was drilled to 500 feet and was dry.

Groundwater is not required for the project and will not be adversely impacted by construction activities.

2.2.3.2 Surface Water

Basin Creek Reservoir impounds the Basin Creek and Bear Gulch drainages. Both Basin Creek and Bear Gulch originate in the USGS West Region Drainage Basin at the northern end of the Highland Mountain range along the Continental Divide. Measured from the reservoir, Basin Creek has a drainage basin area of 8.7 square miles and has one other impoundment, Upper Basin Creek Reservoir (Basin Creek Dam #2), located 1.5 miles south (upstream) of the dam. From the reservoir, Bear Gulch has a drainage basin area of 3.3 square miles. Basin Creek continues 10 miles to the north before its confluence with Blacktail Creek in the City of Butte.

There is a diversion pipeline that conveys a maximum of approximately 5 cfs from the Fish Creek drainage (Butte Water System Master Plan, March 1988) on the east side of the Continental Divide over the divide into the Basin Creek drainage. The diversion inflow into the Basin Creek drainage is a considerable portion of base flow. A trans-basin diversion supplements the Basin Creek production by diverting water from the Fish Creek drainage on the east side of the Continental Divide to the Basin Creek drainage on the west side of the Continental Divide. The Fish Creek diversion takes water from two branches of Mammoth Creek

and drainage from the Ballarat Tunnel, routes the combined flow into a 12-inch diameter steel and 16” ductile iron line that carries the water by gravity over the Continental Divide, and discharges it into the headwaters of the Upper Basin Creek Drainage. However, BSB is the junior water right holder from May 1st thru September 30th. If the senior water right holder is able to get their allocated 5 cfs, BSB can take 5 cfs. Otherwise, BSB has to reduce the amount diverted to Basin Creek accordingly. The water sourced from the Fish Screen drainage can constitute a significant amount of base flow for the Basin Creek system and the storage capacity of the reservoir is an important component of the system to maximize storage early in the year.

Downstream of the reservoir, Basin Creek provides a yearlong source of water for irrigation, livestock and domestic needs. Nearing the city of Butte, the stream flows through and, in two cases, under the Bert Mooney Airport. There are no active United States Geological Survey (USGS) stream gaging stations on Basin Creek.

Refer to the Hydraulics and Hydrology report in Appendix O for additional information related to the watershed hydrology and hydraulics related to the dam.

2.2.4 Floodplains

The dam and surrounding lands upstream and downstream of the dam occur in FEMA floodplain map panel 30093C0456E (Effective January 2012). The dam and reservoir are located in designated Zone D (areas in which flood hazards are undetermined, but possible). Zone A (special flood hazard area) floodplain in Basin Creek starts approximately 1.4 riverine miles to the north (downstream) of the dam. This project is not anticipated to alter the flow patterns or otherwise negatively impact Basin Creek. Therefore, no impact to floodplains are anticipated. This FIRM index map is included in Appendix I.

The proposed work addresses structural deficiencies of the dam to ensure the continued operation of the dam which will maintain the ancillary flood prevention and water release capabilities of the reservoir.

2.2.5 Wetlands

Due to the scope of the work and general lack of vegetation in the project vicinity, minimal vegetation is anticipated to be disturbed for implementation of the project. Based on information from the USFWS Survey National Wetlands Inventory (excluding the adjacent Basin Creek Reservoir), there are riverine wetlands present on Basin Creek, located just downstream of the

spillway terminus. Wetland impacts on Basin Creek downstream of the dam are not anticipated due to the proximal location of the work on the dam face and dam crest. The construction contractor will be required to, the extent feasible, avoid wetlands in and around the project site that may be affected by construction activities. If required, during the permitting process in the design phase, a detailed wetland investigation will occur in the project vicinity. Refer to the USFWS wetland map included in Appendix G.

2.2.6 Cultural Resources

Cultural resources include historic and prehistoric archaeological sites, historic architecture, engineering features and structures, and resources of significance to Native Americans. The Montana State Historical Preservation Office (SHPO) was provided with a map of the planning area and the proposed improvements to conduct a search of the area to determine whether there are significant historical and cultural resources in this area. SHPO did not identify any pre-recorded sites of historical significance in the area. However, based on the age of the dam [late 1800's], SHPO indicated that they recommend the dam be recorded and determination of its eligibility be made prior to disturbance or rehabilitation taking place.

During the pre-design process, investigation into the eligibility of recordation will occur with qualified subconsultants. If necessary, recordation and cultural resource investigations will occur.

The SHPO response information can be found in Appendix C.

2.2.7 Socio-economic and Environmental Justice Issues

Based on data collected by Montana's Department of Natural Resources and Conservation (DNRC) for its 2018 Statewide Water and Wastewater Rate Study (http://dnrc.mt.gov/divisions/cardd/news/2018-statewide-water-and-wastewater-rate-study), Butte residents pay one of Montana's highest monthly water rates. Of the 211 communities that participated in the study, 162 (77%) charged a lower monthly user rate than Butte-Silver Bow. When compared to the consequences of Basin Creek Dam failing, preserving the long-term viability of the dam will help to keep water rates as affordable as possible. The proposed project represents a beneficial impact to each resident of Butte, especially those residents that live in poverty or have low monthly incomes.

Butte-Silver Bow's median household income is $37,686, and 20-percent of its residents live below the federal poverty level. (2015, U.S. Census, American Community Survey). Basin Creek

Dam #1 provides up to 60-percent of Butte's drinking water. Butte-Silver Bow has examined expanding the capacity of its other water resources, including the Big Hole River, South Fork Reservoir, and Moulton Reservoir. However, their studies found that neither of these sources represents a cost-effective replacement for Basin Creek. Using groundwater is also not an option because portions of the aquifers beneath Butte cannot be used for drinking water due to contamination from decades of mining.

The proposed project is necessary to protect Butte's low-income residents from the potentially devasting environmental and financial effects that would result if Basin Creek Dam failed, and Butte lost a significant source of its drinking water.

2.3 Population Trends

The population of Butte-Silver Bow is closely related to the vitality of the mining industry. The population of Butte-Silver Bow started to decline in the 1920s and continued into the 1990s. The 2000 Census recorded a slight uptick in the population, but in 2010, the population once again dipped slightly. Since 2010, however, Census data indicates the population has increased by 2.4%. Table 2.1 summarizes Butte-Silver Bow's the past 18 years of population data.

Table 2-1: Historic Population Data

Historical Population Data		
Year	Population	Total Period Growth
2000	34,606	2.0%
2010	34,209	-1.15%
2018	34,993	2.3%

The Butte-Silver Bow Comprehensive Plan Draft – April 1, 2020, expects Butte-Silver Bow's population to continue "a steady, but slow trend upward" over the next 15 to 20 years. Therefore, for planning purposes, a 1% annual growth rate is assumed for the 20-year planning period.

Table 2-2: Butte-Silver Bow Population Projections

Butte-Silver Bow Population Projections		
Year	Population	Total Period Growth
2020	35,696	
2025	37,517	5.1%
2030	39,393	5.0%
2040	43,332	10.0%

2.4 Community Engagement

Butte's residents had several ways of participating in the NEPA process. On June 3, 2020, at one of its two regular monthly meetings, the Butte-Silver Bow Council of Commissioners reviewed the draft Environmental Assessment (EA) and reviewed the PER. Meeting notices are posted in The Montana Standard newspaper and on the Butte-Silver Bow website http://co.silverbow.mt.us. The EA and PER were also available for review on the website.

The Council of Commissioners' conducted its meeting remotely via video-teleconferencing, and residents of Butte-Silver Bow were able to view the meeting live at https://www.co.silverbow.mt.us/2149/MEDIA. The Council of Commissioners has a call-in line which is active during its sessions. Citizens wanting to comment can dial (406) 497-5009. The public could also email comments to be read into the record by sending them to public-input@bsb.mt.gov. Written comments could be sent by mail or dropped off in the box located in the vestibule near the west entrance to the courthouse. The Council also accepted public comment on-line through the Butte-Silver Bow website.

3.0 EXISTING FACILITIES

3.1 Location Map

A general schematic map of the Basin Creek Dam and Basin Creek WTP have been previously provided as Figure 2-1. Additional location maps can be seen in Appendix A. Specific details of the existing systems can be seen in Section 3.3.

3.2 Project Operation, Management and Capabilities

As previously referenced, the focus of this report is on the condition of the Basin Creek Dam #1, its impact on water delivery to the recently constructed Basin Creek WTP and potential natural resource impacts due to loss of the dam/reservoir. Brief descriptions of the system wide water treatment and delivery utilized by BSB will be provided for familiarization of the system.

3.2.1 Overall Operation of BSB Water Treatment and Delivery

Currently, BSB sources public drinking water from three primary sources: the Big Hole Water Treatment Plant (Feeley Hill), the Moulton Water Treatment Plant, and the Basin Creek Water Treatment Plant. These sources are shown on Figure 3-2, below.

Figure 3-1: Big Hole Pump Station.

Courtesy: Historic American Engineering Record, C., Butte Water Company, Nordberg Manufacturing Company, City And County Of Butte-Silver Bow, S., Perrin, N. K., Miller, H. L. & Historical Research Associates, I., Lowe, J. & Hager, K., photographer. (1968) Big Hole Pump Station, 816 Pumphouse Road Old Highway 43, Divide, Silver Bow County, MT. Divide Montana Silver Bow County, 1968. Documentation Compiled After. [Photograph] Retrieved from the Library of Congress, https://www.loc.gov/item/mt0093/.

The Big Hole Water Treatment Plant (Feeley Hill) is primarily fed by a pumping operation at the Big Hole River as well as a small amount of water collected in the South Fork Reservoir. Water from the Big Hole River is pumped approximately 11.5 miles to the Big Hole WTP, where treatment occurs. After being treated, the water is pumped 9.6 miles over the Continental Divide to the Colorado Hill Tank, then gravity fed 2.2 miles to Swamp Tee (distribution system).

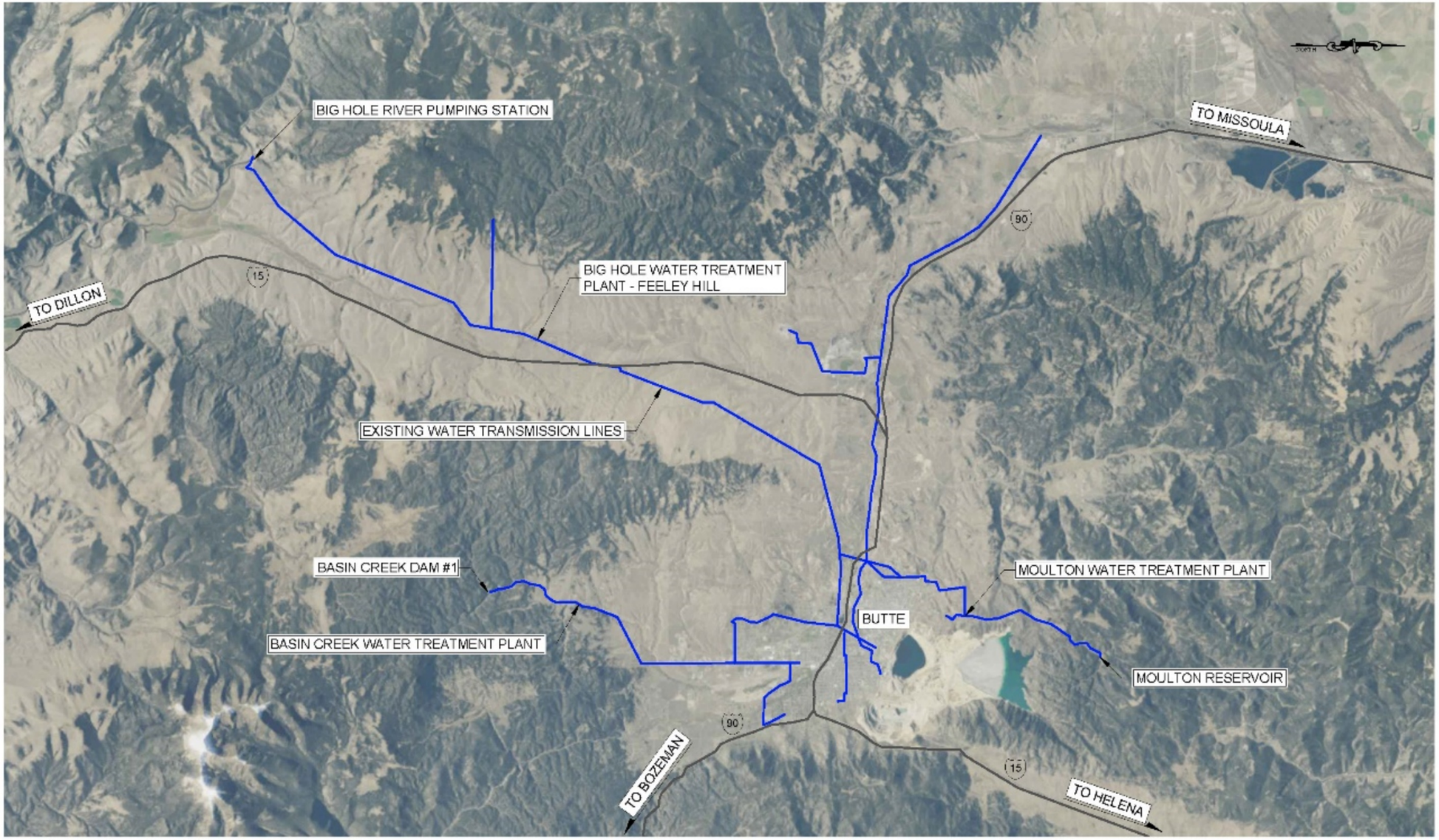
The pumping operation at the Big Hole River was constructed over a period of a decade in the late 1890's and early 1900's, with modifications in 2011 consisting of a new diversion and pumps. The Big Hole WTP at Feeley was brought online in 1995. It is rated at 16 MGD (Million Gallons Per Day) but under best case operating conditions, can generally produce around 12 MGD.

The Moulton Water Treatment Plant treats water sourced from the Moulton Reservoir and several small streams. The smallest of Butte's three water treatment facilities, it has a 2 MGD capacity but averages less than 1 MGD. Its primary purpose in the Butte Water System is to serve high pressure zones that would otherwise require costly pumping operations if fed by the Big Hole or Basin Creek sources.

The Basin Creek Water Treatment Plant is a gravity powered ceramic filtration plant rated for 7 MGD constructed in 2017. When the Basin Creek Reservoir is full (or nearly full), the Basin Creek WTP is capable of operating as a gravity feed system to feed the Basin Creek pressure zone. Because the system is fed by gravity, it is Butte's most economical source of water and typically provides up to 60% of Butte's annual water supply. The new Southside Pump Station also allows excess water from the Basin Creek WTP to be fed into the rest of the Butte Water System. This allows the Big Hole source to be seasonally supplemented or replaced with the Basin Creek source during periods when the Big Hole water is more difficult and costly to treat. The Basin Creek WTP is discussed in more detail below.

BSB provides water delivery through a network of approximately 1.1 million feet of pipe. Other tanks, pipes and pumping infrastructure representing minor components of the greater water system are not the focus of this project and are not specifically discussed in this report.

Water delivery for BSB currently only includes surface water sources due to adverse mining impacts from Berkeley Pit and associated underground mining complexes. Development of alternative groundwater sources is not viable due to widespread groundwater contamination.



SCALE: 1" = 2.5 MILES

NOTE: INTENT OF THIS FIGURE IS A VISUAL REPRESENTATION OF THE BUTTE-SILVER BOW WATER SYSTEM.

GreatWest engineering

Figure 3-2
Butte-Silver Bow Overall Water Delivery Infrastructure Map

CITY-COUNTY OF BUTTE-SILVER BOW
BASIN CREEK DAM #1 REHABILITATION PER

Figure 3-2: Overall BSB Water Treatment Locations

3.2.2 Operation and Management of Basin Creek Dam #1 and Basin Creek Water Treatment Plant

The Basin Creek source is hugely important to the Butte Water System in terms of providing a reliable source or water that is easily treated and readily available for distribution into the greater Butte Water system.

The Basin Creek Reservoir and Basin Creek Dam are owned and operated by BSB and are operated in tandem with the Basin Creek WTP. The reservoir provides approximately 364 million gallons of storage and when at full pool, provides enough hydraulic head to operate the water treatment plant by gravity with very little pumping required.

As the primary source for the Basin Creek Treatment Plant, the Basin Creek Reservoir provides storage and hydraulic head for the gravity feed system. The reservoir's level and outflow can be carefully controlled via the dam's primary infrastructure control components (upstream valves, downstream valves, and spillway gate). There are maintenance and operational structures that are frequented on a regular basis by BSB staff. A recently installed (2018) submersible transmitter gage near the right abutment of the dam provides a real-time feed of water surface elevations in the reservoir. Reservoir water elevations are monitored continuously and sent via radio telemetry to the Basin Creek and Big Hole Water Treatment Plants. BSB employs fourteen operators and one electrician to operate and maintain the three water treatment plants, associated facilities and industrial water system.

3.3 Existing Site Components

3.3.1 Basin Creek Dam Components

Table 3-1: Basin Creek Dam #1 Components

BASIN CREEK DAM #1 COMPONENTS	
GENERAL DATA	
MDT Dam ID #	MT-00374
Classification	High Hazard
Construction, Rehabilitation and Repairs	1897 (Initial Masonry Construction) 1913 (Concrete Cap/Buttress) 1930's (Earth Embankment on Downstream Face) 1979 (Parapet Reconstruction) 1980's (Shotcrete – Dam Face) 1999 (Outlet valve repairs) 2005-2006 (Spillway & Gate, Conduit Slipline, Valves, Misc.)
BASIN CREEK RESERVOIR	
Normal Reservoir Capacity at Spillway Crest	1,115 Acre-Feet
Maximum Reservoir Capacity at Dam Crest	1,170 Acre-Feet
PRINCIPAL SPILLWAY (LEFT ABUTMENT)	
Type	Obermayer Crest Gate on rectangular concrete spillway discharging to a concrete lined chute
Crest Elevation (Gate Open)	5884.56 (NAVD88)
Spillway Width	9 feet
Capacity	203 cfs
OUTLET WORKS	
Conduit	(3) 20-in. Diameter Cast-Iron-Pipes (Original), slip lined with 16-in. HDPE (2006). Two feed water system. One returns to creek. Total pipe line of approximate 100 feet. Max. capacity of 60 CFS according to O&M manual.
Upstream Gates	Pneumatically operated pinch valves (2006)
Downstream Gates	Butterfly gate valves (2006)
DAM	
Type	Curved rock masonry arch w/concrete buttress and earthfill
Crest Length	275 Feet
Crest Width	~5 Feet (Includes Parapet Wall)
Crest Elevation	5889.06 (NAVD88)
Structural Height	~74 Feet
Upstream Slope	Vertical (Masonry & Concrete)
Downstream Slope	1 Vertical: 1.6 Horizontal

As noted in the *2020 Basin Creek Dam Structural Assessment* [Appendix J], there have been two elevation datums utilized for the dam. The “local datum” is used in record drawings, standard Operating procedures and past inspection reports. The ‘NAVD88’ datum was used for the Basin Creek WTP, bathymetric survey, structural assessment and breach mapping. All references made in this report will be NAVD88 (feet) unless noted otherwise. Conversion from the local datum to NAVD88 is the following: local datum elevation plus 16.06 feet.

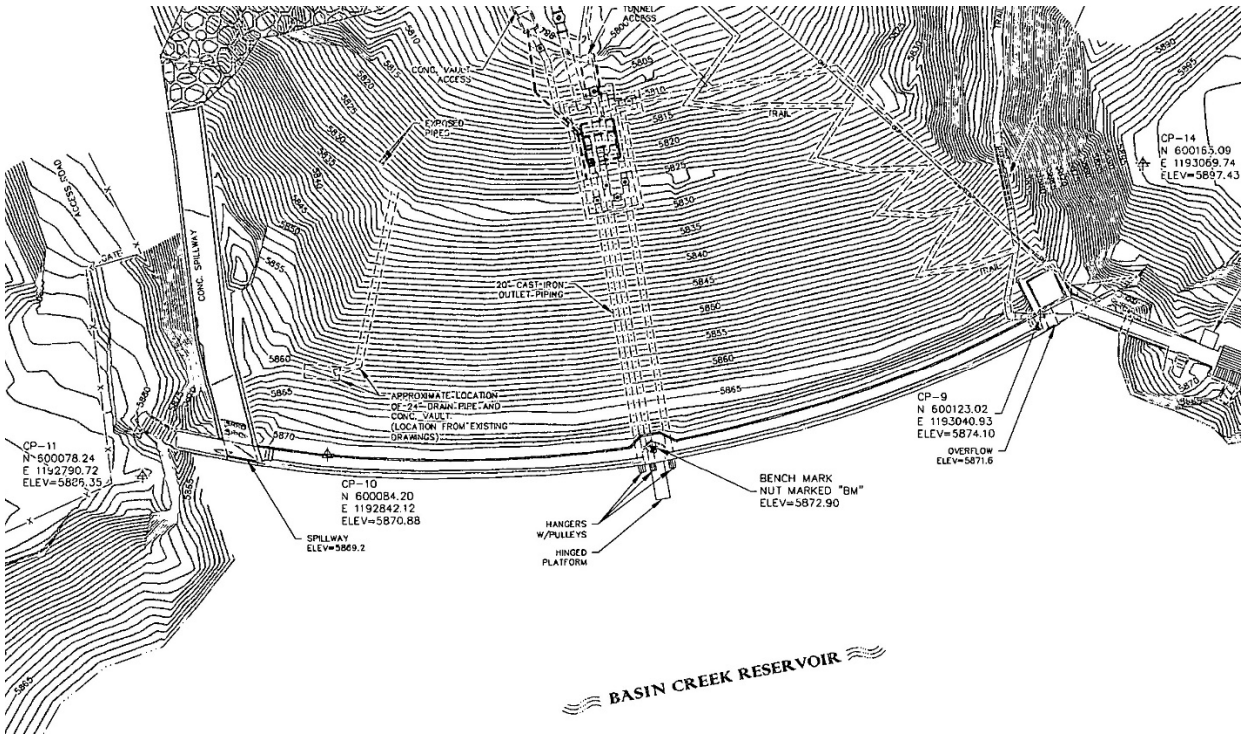


Figure 3-3: Plan View of Dam (2006 As-Built Drawings, DOWL, Appendix Q)

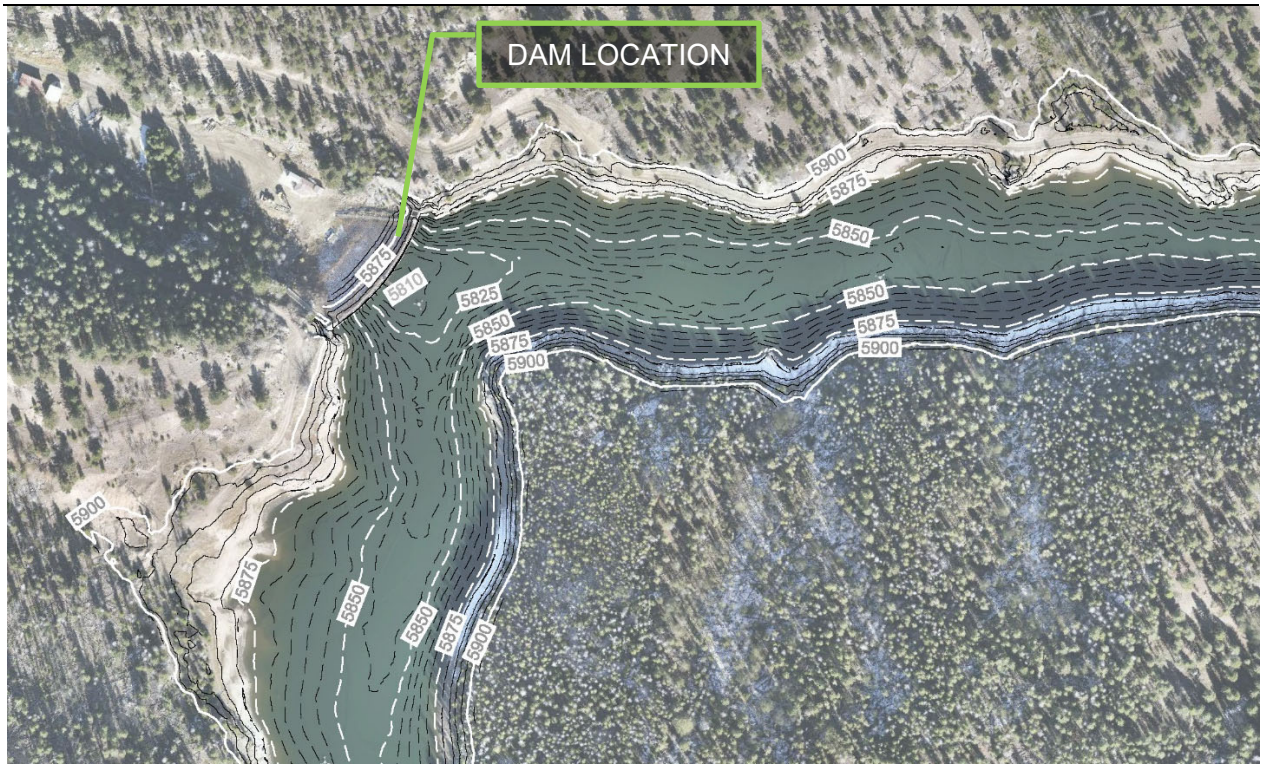


Figure 3-4: Aerial View of Reservoir w/Bathymetric Elevations (2019 Basin Creek Reservoir Bathymetric Survey, WET, Appendix L)

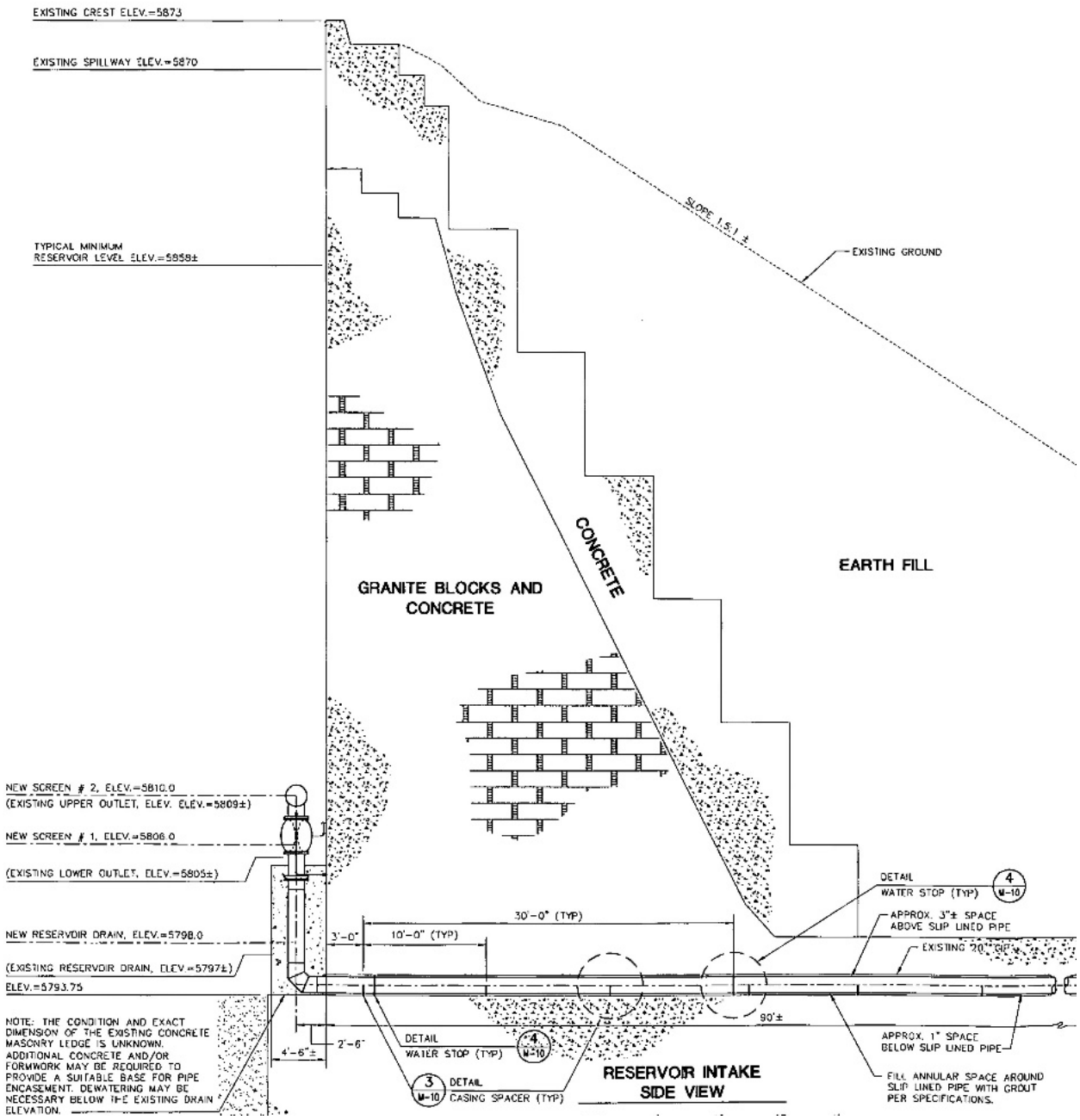


Figure 3-5: Side view of dam (2006 As-Built Drawings, DOWL, Appendix Q)

3.3.2 Water Treatment Plant Characteristics

Table 3-2: Basin Creek WTP Characteristics

BASIN CREEK WTP CHARACTERISTICS	
GENERAL DATA	
Construction	2017
Filter Type	Ceramic Membrane
Composition	Four Main Units, One Recovery Unit
Capacity	7 MGD
Backwash/Waste	0.5% (@7 MGD Capacity)

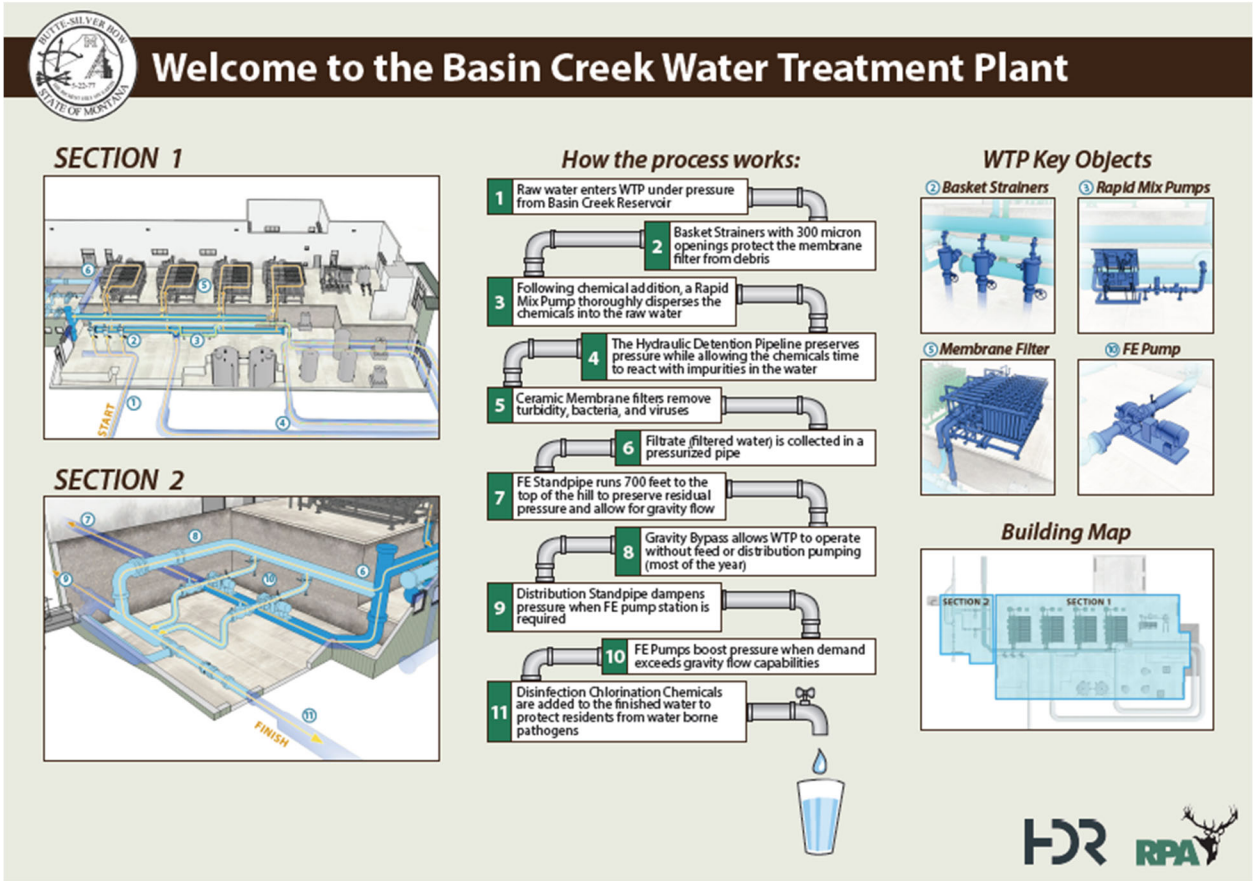


Figure 3-6: Basin Creek WTP process diagram. (Courtesy HDR and RPA).

Figure 3-7: New Basin Creek WTP ceramic filtration system (recovery unit).

Figure 3-8: The membrane is a series of ceramic membrane elements (one of four main units shown).

Figure 3-9: Wastewater produced during filter backwash is processed through the plate settler (shown above).

3.4 History

3.4.1 Dam History

Basin Creek Dam #1 was built by the Butte Water Company with the intent to provide water to mining operations and secondarily to the community. It was initially completed in 1897 as a 75-foot tall curved masonry dam with a crest elevation of 5876.06 feet (NAVD88). The dam was constructed using solid granite blocks that were quarried nearby.

Figure 3-10: View of downstream dam face during construction in 1890's.

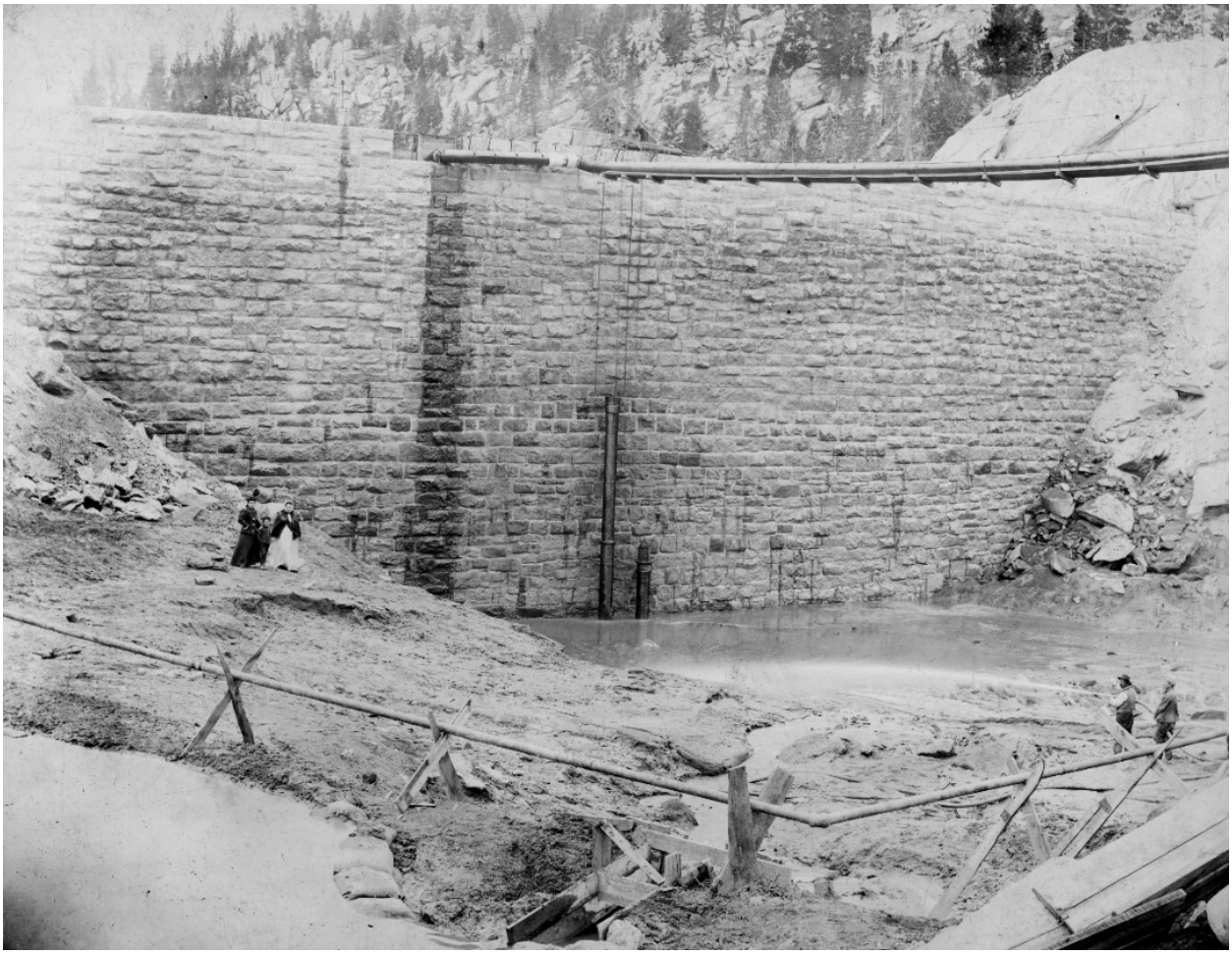


Figure 3-11: View of upstream dam face nearing initial completion in the 1890's.

In 1901, the Anaconda Copper Mining Company purchased the Butte City Water Co. In 1913, the dam was raised 13 feet to its current top elevation of 5989.06 feet (NAVD88) by constructing a concrete cap and monolithic concrete tiers on the downstream face.

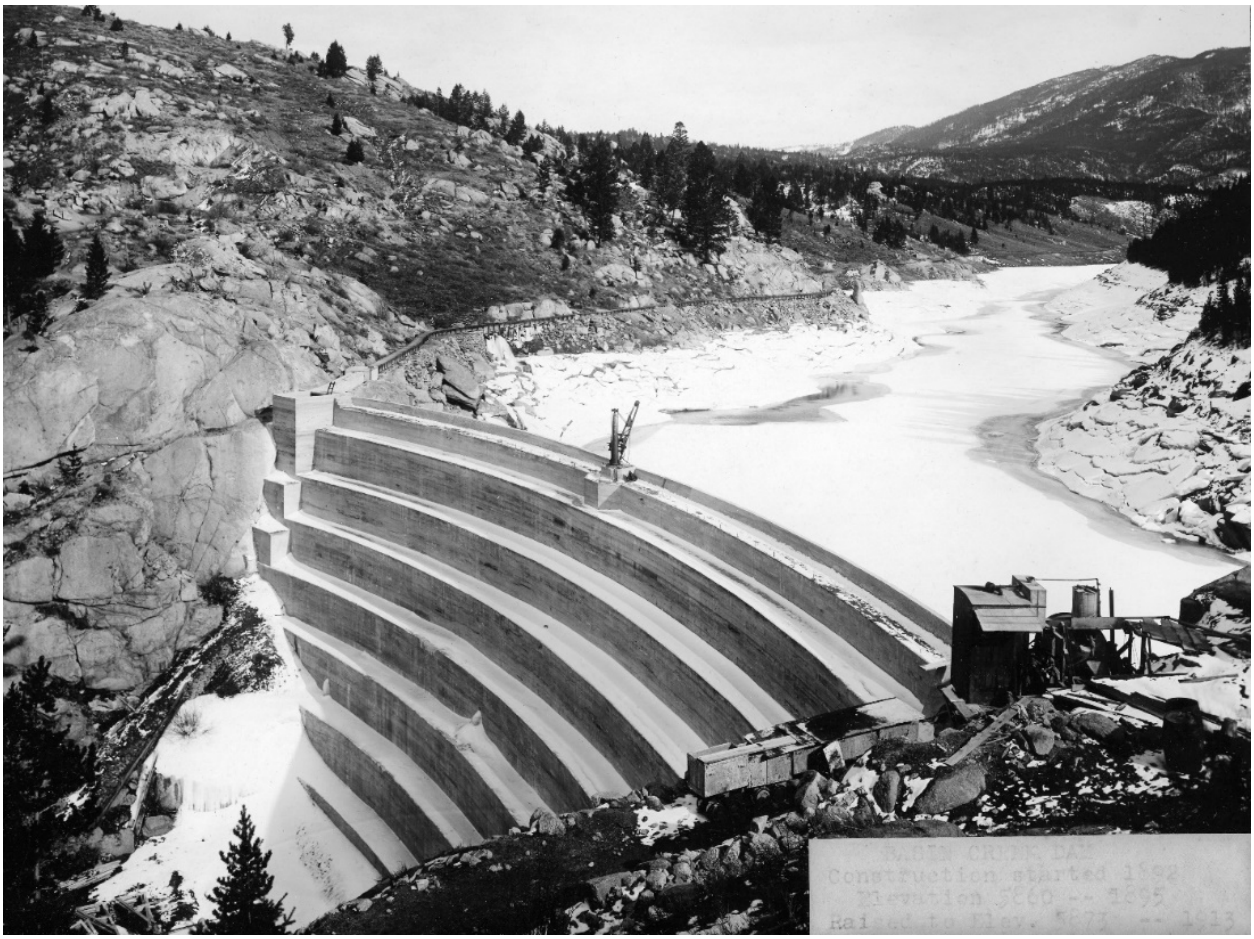


Figure 3-12: Basin Creek Dam #1 shortly after concrete cap and buttress placement in 1913.

The dam was modified in the 1930's with earthen fill placed on the downstream side to prevent concrete deterioration. Financial difficulties forced the sale of the Anaconda Mining Company to Atlantic Richfield Co. (ARCO) in 1977. In 1979, the concrete parapet wall was repaired. In the early-to-mid 1980's, shotcrete was applied to the upstream dam face to mitigate concrete deterioration. In 1986, Dennis Washington purchased the Anaconda Company (and Butte Water) from ARCO. In 1992, the City-County of Butte-Silver Bow took over ownership of the potable water system as well as the Silver Lake water system. In 1999, BSB crews replaced an outlet valve on the discharge pipe. From 2005 to 2006, the spillway and outlet works underwent a major rehabilitation to perform necessary upgrades for conformance to Montana Dam Safety Regulations. The primary components of this work consisted of:

- Spillway reconstruction and installation of an Obermayer spillway crest gate;
- Slip lining the three existing 20" diameter cast iron conduits with new 16" diameter HDPE pipes;
- Installation of new butterfly gate valves at outlet and reconstruction of outlet works;
- Installation of new upstream pinch valves and a bubbler system;

- New mechanical building;
- Installation of a lake level gage;
- Access improvements.

The new spillway passes approximately 203 cfs, with the gate open, which can accommodate up to the 500-year flood without the dam crest being overtopped.

Figure 3-13 : View of valve replacements on the upstream dam face (2005).

Refer to additional historic dam photographs in Appendix P.

3.4.2 Basin Creek Dam Water Treatment History

From the time the dam was built in the 1890's until May of 2017, the Basin Creek water source was operated as an unfiltered water supply that provided up to 40% of Butte's municipal water needs. The Basin Creek watershed has provided the city of Butte with clean water for over 100 years since it was originally tapped. Originating in the high mountain peaks south of Butte, Basin Creek has remained relatively unpolluted due to its high elevation and long-standing status as Butte's most reliable source of drinking water. The only treatment required for water sourced from

the Basin Creek drainage consisted of gas chlorination at the chlorination/feeder building just downstream (north) of the dam. Refer to specifics on dam (and treatment) history above in Section 3.4.1. The Basin Creek source operated under a filtration waiver from the Montana Department of Environmental Quality (MDEQ), meaning that the water was exempt from normal filtration requirements for municipal water systems. On August 18, 2010, the MDEQ issued BSB notice that the filtration waiver for the Basin Creek Supply was being rescinded due to tests indicating higher than allowable levels of HAA5's (Haloacetic Acids). On May 16, 2017, the new Basin Creek WTP was brought online and began providing filtered water from the Basin Creek supply for the first time.

3.5 Condition of Existing Facilities

3.5.1 Basin Creek Dam #1

3.5.1.1 Existing Conditions

As referenced in the history section above, the existing dam is a conglomeration of construction components and methodologies, as is common with dams of older initial construction periods. Available condition documentation from the 2018 Basin Creek Dam yearly inspection, 2019 Basin Creek Dam 5-Year inspection report and 2020 Basin Creek Dam Structural Assessment was thoroughly reviewed.

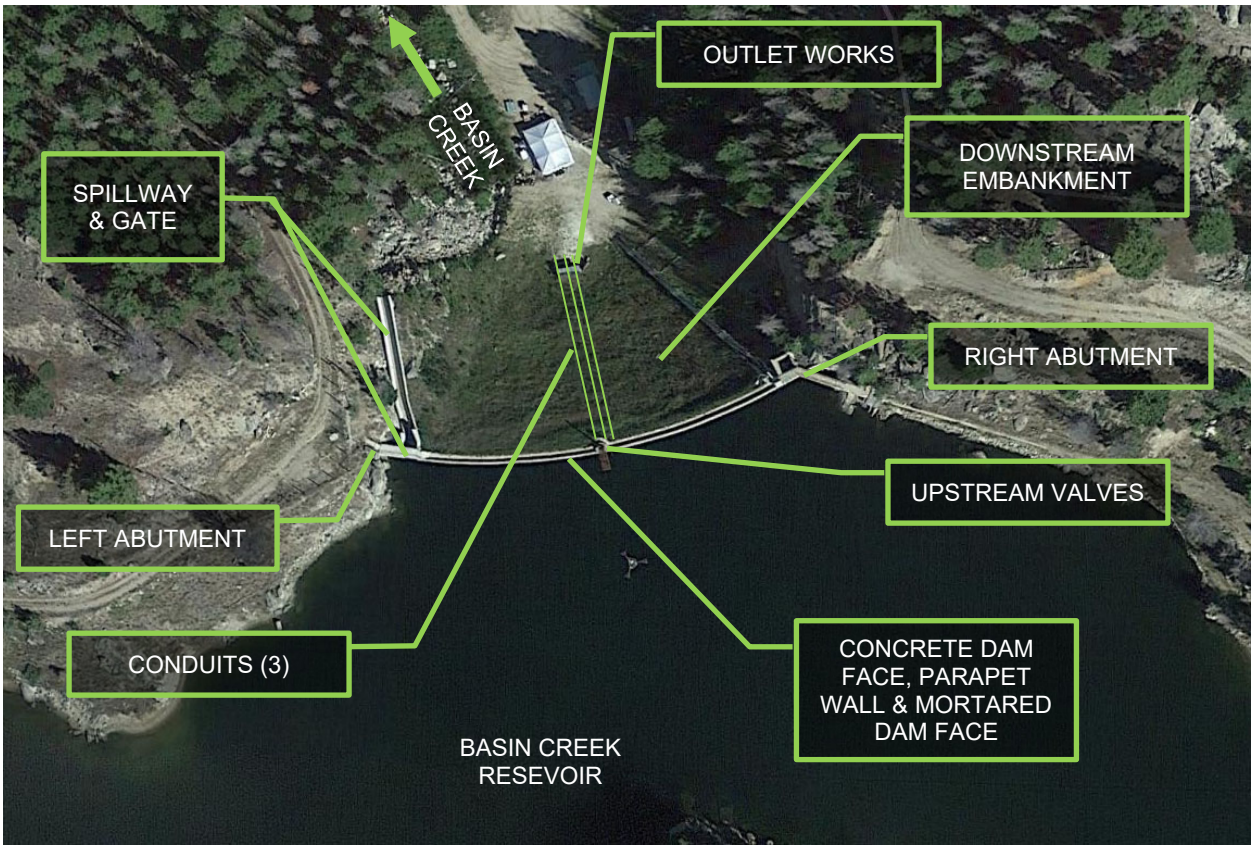


Figure 3-14: Aerial view of Basin Creek Dam #1 with primary components

A condition description of the primary existing dam components is outlined below:

Concrete Parapet Wall & Concrete Dam Face

It should be noted that due to the earth fill and paver installation on the crest and downstream face, most of the mass concrete cap and buttress that was installed in 1913 is not visible. Portions of visible concrete include the upstream dam face and parapet wall. As previously noted, improvements were done to the parapet wall in 1979 and the upstream dam face had shotcrete installed in the 1980's. Specific anchorage of this shotcrete to the dam face is unknown, though wire mesh and some rebar is visible. The parapet wall is the upper approximate 3' of the dam crest, as shown in the diagram below. The remainder of the concrete dam face extends 11 feet vertically below the bottom of the parapet wall as shown in the figures below.

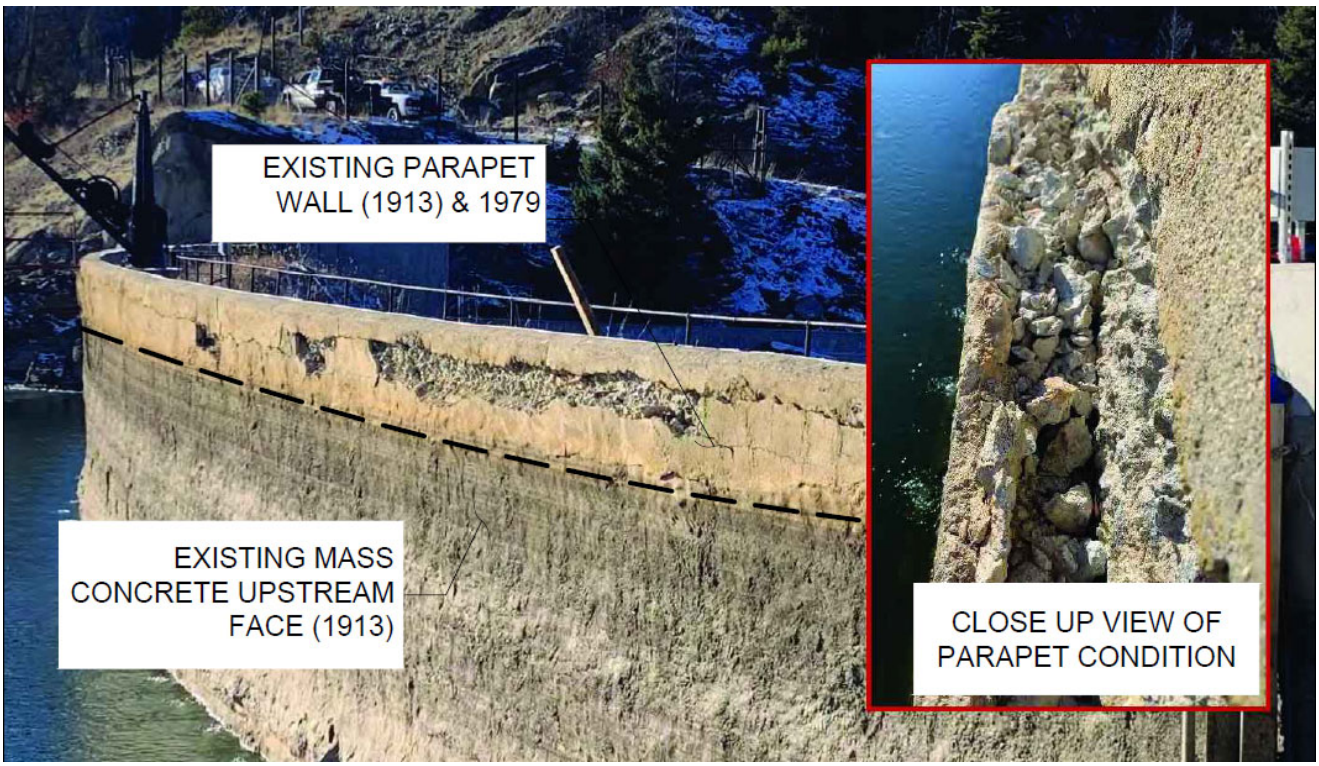


Figure 3-15: General view of parapet wall and dam face.
(Basin Creek Dam Structural Assessment, Gannett Fleming, 2020, Appendix J)

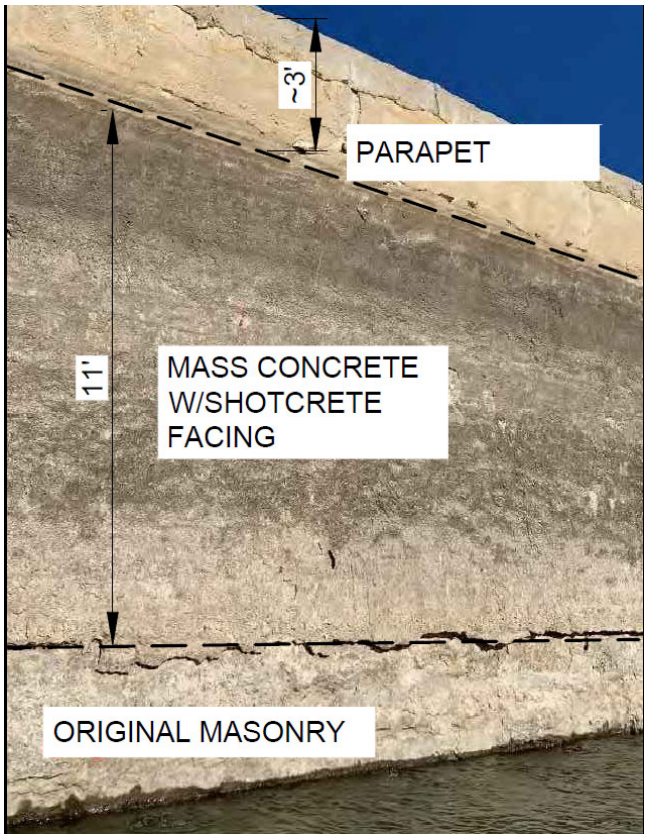


Figure 3-16: Close up view of dam face and parapet wall.
(Basin Creek Dam Structural Assessment, Gannett Fleming, 2020, Appendix J)

In general, as has been previously noted in recent dam inspections and illustrated in the figures above and below, the parapet wall is in very poor condition and is as the end of its functional life, with significant deterioration across the length of the dam. These deterioration issues range from areas of full section loss to areas of spalling. As part of the 2020 Basin Creek Dam #1 Structural Analysis (provided in Appendix J), four concrete cores were extracted so lab testing could determine the structural properties of the existing concrete. The cores were extracted from abutments, parapet wall and the crest of the dam. The advanced petrographic analysis testing found that the concrete exhibits severe freeze-thaw damage, likely due to its high estimated water-cement ratio as well as the lack of air entrainment. For purposes of the analysis, the compressive strength of the concrete was assumed to be 3000 psi. No specific Alkali Silica Reactivity (ASR) was identified, although it was noted that the rock type used in the coarse aggregate can be susceptible to ASR.

Figure 3-17: Upstream view of parapet wall condition (near spillway).
(Basin Creek Dam Structural Assessment, Gannett Fleming, 2020, Appendix J)

Due to reservoir elevations, specific inspection of the upstream dam face has not been noted in recent 5-year dam inspection reports. To facilitate the 2020 Basin Creek Dam #1 Structural Analysis (Appendix J) – BSB lowered the reservoir elevation to allow inspection of the upstream concrete face. The shotcrete near the masonry wall/concrete interface was in poor condition and could be knocked away. Numerous voids were visible. Significant freeze thaw damage was visible with areas of section loss. Vertical corings taken at the parapet in an area where the surface is detached from the shotcrete surface to a fracture such that the core represents a partial thickness of the parapet wall identified macroscopic and microscopic cracking and moderate potential to alkali-silica reactivity.

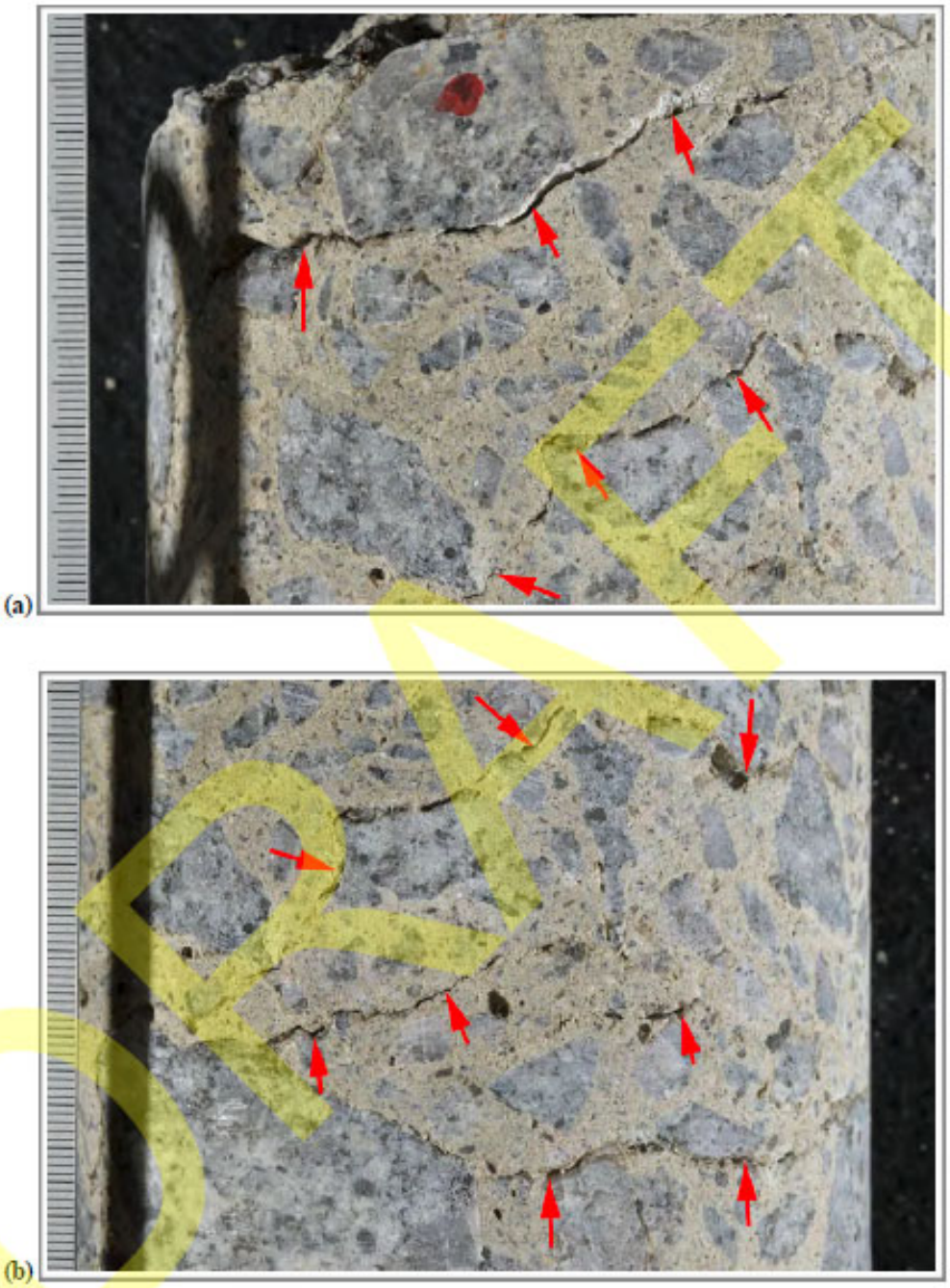


Figure 3-18: Photographs of the side of the parapet core showing the sub-horizontal cracks (red arrows) in the middle of the core; scale in millimeters. (From the Petrographic Analysis Report, Basin Creek Dam #1 Structural Analysis, Gannett Fleming, 2020, Appendix J)

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Figure 3-19: Close up view of dam face and noted spalling and section loss in shotcrete locations (Basin Creek Dam Structural Assessment, Gannett Fleming, 2020, Appendix J)

Figure 3-20: Close up view of dam face, shotcrete deterioration and section loss of shotcrete. (Basin Creek Dam Structural Assessment, Gannett Fleming, 2020, Appendix J)

Mortared Stone Dam Face

The original mortared granite block (1890's) is only visible at the dam face during dewatered dam conditions. As such, specific comments on the mortar and rock condition were not included in the available 5-year dam inspections. Construction photos during the full dewatering event in 2005/2006 were reviewed for condition of the mortared granite block on the upstream face. In general, cursory review indicates that the mortared stone and jointing appears to be in satisfactory condition, given its age.

Figure 3-21: View of the upstream masonry face during 2005/2006 dewatering activities

While no data is readily available for the in-place granite blocks, they were quarried near the dam site. Additionally, as identified in the 2006 geological site visit (Appendix N), observations indicate that the granite rock quality at the dam site (near the right abutment) is classified as 'good' rock with relatively high compressive strengths.

Downstream Embankment

The downstream embankment slope (installed in 1930's) appears to be in satisfactory condition. Minor issues include one identified area of seepage at the stair location near the right abutment. A few sporadic rodent holes were noted. Vegetation appears good with grasses and woody shrubs. Some remnant rotting tree stumps were visible, likely from past removal activities.

Figure 3-22: View of the downstream face
(2019 5-Year Inspection, Pioneer Technical Services, Appendix K)

Dam Abutments/Toe

No specific issues were noted at the dam abutments or toe. It is worth noting that the dam has an underdrain system to control sediment buildup near the outlet intake. From the 2019 Dam Safety Report, *"The dam has an underdrain system that is used from a water operation perspective [sp] to control sediment buildup near the outlet intakes. The underdrain system has bladder valves and screens on its upstream end which are typically kept in an open position. Flow through the underdrain system is controlled by a keyed valve located on the downstream end. When the valves [sp] are open, sediment is flushed through the underdrain system thus reducing sediment load through the outlet pipes to the water treatment system. The underdrain system is not part of the dam safety or embankment stability portion of the dam. Butte-Silver Bow reported that valves for the underdrain system were exercised and video inspected in 2018."*

Outlet Works, Intake Structure, Conduit

As previously indicated, the outlet works, intake structure, and conduit were all rehabilitated or replaced during construction activities in 2005/2006. BSB has indicated that the downstream butterfly valves and upstream pneumatically operated pinch valves were operating effectively. The HDPE slip lined conduit was not inspected during the 2019 5-year inspection, but due to age, no issues are anticipated. The installed bubbler system on the upstream face appears to be working to prevent icing conditions.

Figure 3-23: View of the outlet works building and downstream slope (2019 5-Year Inspection, Pioneer Technical Services, Appendix K)

Primary Spillway & Gate

The primary spillway consists of a rectangular spillway with an Obermeyer crest gate. The spillway, upstream crest and chute were all reconstructed as part of the construction/rehabilitation activities in 2005/2006 and the Obermeyer gate was installed at that time. No particular deficiencies have been identified on the concrete spillway condition or the gate condition. Previous reports (2014) identified areas of erosion and undermining, which have since been repaired. BSB reports that the Obermeyer gate is functioning well.

Figure 3-24: View of the dam spillway and gate
(2019 5-Year Inspection, Pioneer Technical Services, Appendix K)

Ancillary Items:

The concrete walkway on the dam crest, consisting of concrete pavers of unknown age, are in poor condition, with voids, cracks and poor concrete condition.

The handrail at the downstream of the crest is original to the concrete placement in 1913 and exhibits significant pitting and corrosion.

The gantry crane on the center of the dam crest is a relic of previous dam infrastructure and was used to operate valves on the upstream face. It is no longer in use with the current dam operation.

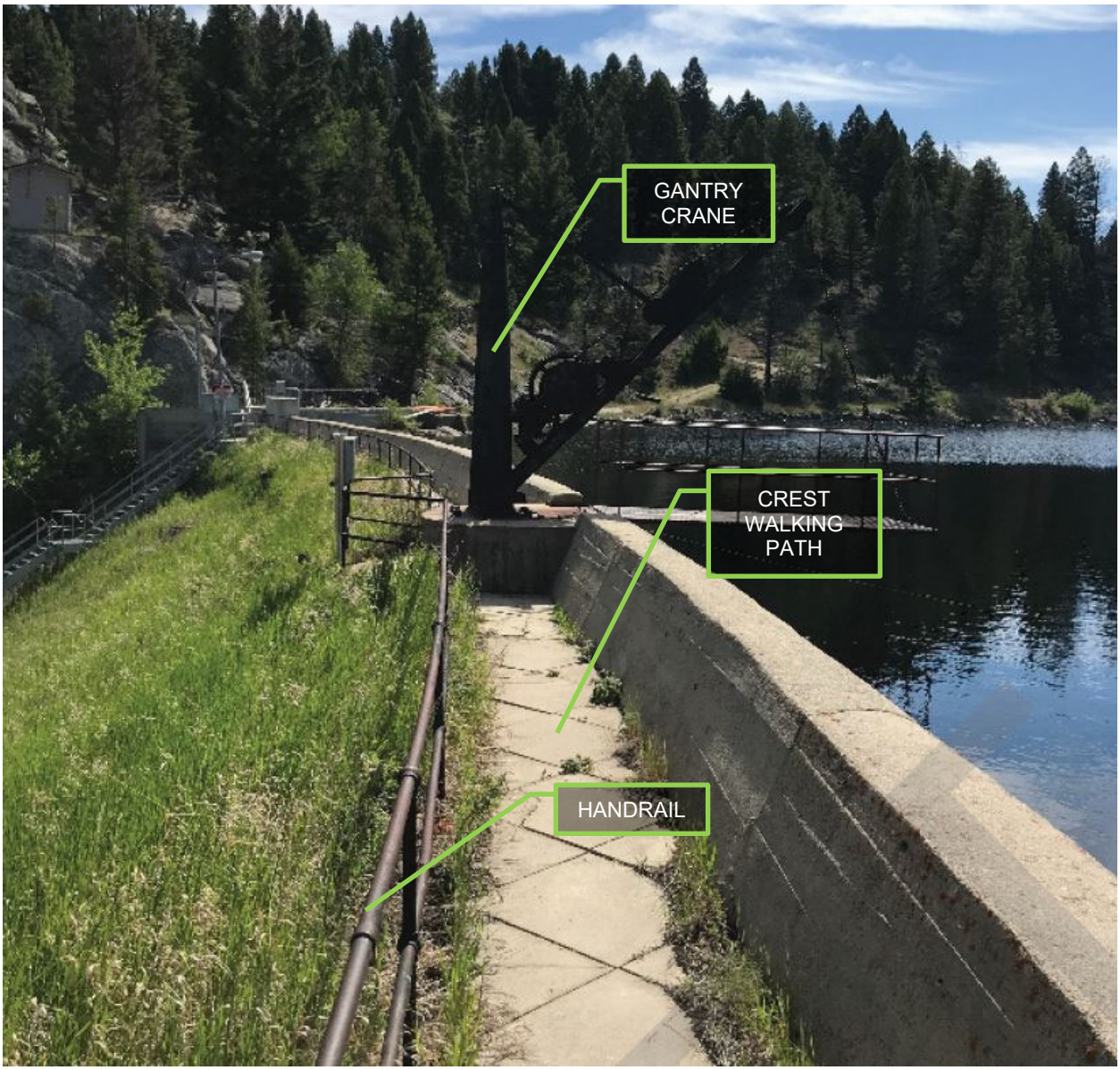


Figure 3-25: View of dam crest – note rail, walkway and gantry crane (2019 5-Year Inspection, Pioneer Technical Services, Appendix K)

The dam located further up the Basin Creek Drainage, Basin Creek Dam #2 (Upper Basin Creek Reservoir) is in poor condition.

3.5.1.2 On-Going and Past Efforts

Refer to a description of construction work completed above in Section 3.4.1.

There have been considerable past inspections, technical reports and studies on the dam. The following represents a list of these documents, which can be made available upon request:

- 2020 Basin Creek Dam Structural Assessment (included in Appendix J)
- 2020 Basin Creek Dam Emergency Action Plan
- 2019 Basin Creek Dam 5-Year Inspection Report (included in Appendix K)
- 2019 Basin Creek Dam Bathymetric Survey Report (included in Appendix L)
- 2019 Basin Creek Dam Breach Analysis (included in Appendix M)
- 2019 Basin Creek Dam Maintenance and Operating Procedures
- 2018 Basin Creek Dam Yearly Inspection Report
- 2015 Basin Creek Dam Stability Analysis and Geological Investigation (included in Appendix N)
- 2014 Basin Creek Dam 5-Year Inspection Report
- 2009 Basin Creek Dam 5-Year Inspection Report
- 2005 Basin Creek Dam Hydraulic and Hydrologic Study (included in Appendix O)
- 2004 Basin Creek Dam 5-Year Inspection Report

3.5.2 Water Delivery Network from Dam and Basin Creek Water Treatment Plant

3.5.2.1 Existing Conditions

The regulating infrastructure on the dam, including valves and outlet works pipes, were replaced or rehabilitated in 2005 and are in good condition. Rehabilitation of the outlet works pipes included slip lining the original cast iron pipes with HDPE liners. The existing infrastructure from the outlet works at the base of the dam to the Basin Creek WTP is in good condition. The water treatment plant has only been in operation since 2017 and is in like-new condition. The delivery system downstream of the plant is in good condition with recent improvements to a major pressure reducing valve and pump station to regulate the flow of water into the greater BSB water distribution system. By addressing the identified deficiencies at the Basin Creek #1 Dam, BSB will be able to ensure that a vital component of their water system remains reliable and functional.

3.5.2.2 On-Going and Past Efforts

Refer to a description of recent construction work completed above in Section 3.4.1.

There have been considerable past inspections, technical reports and studies specifically on the Basin Creek WTP and ancillary water delivery throughout the BSB system. The following represents a limited list of these documents, which can be made available upon request [note that due to project scope focus of the dam and the downstream water treatment plant, not all water related documents are listed]:

- City-County of Butte-Silver Bow – Water Master Plan Update (Ongoing, HDR)
- City-County of Butte-Silver Bow – Basin Creek Water Treatment and Ancillary Facilities Preliminary Design Report (June 2014, HDR & Robert Peccia and Associates)

3.6 Financial Status of any Existing Facilities

3.6.1 Basin Creek Dam #1 & Basin Creek WTP

Due to complexity of the BSB water system, specific data cannot be easily broken out individually for the Basin Creek Dam and Basin Creek WTP. Refer to Section 7.6 (Annual Operating Budget) for a detailed breakdown for the income and expenditures of BSB's Public Works – Water Purification and Treatment Division. Refer to additional supporting data in Appendix U for the Purification & Treatment (P&T) system.

4.0 NEED FOR PROJECT

Based on the most recent 5-year dam inspection performed in 2019 and the subsequent 2020 structural analysis of the dam, there are significant issues that need to be addressed for the dam to continue to operate safely and effectively.

4.1 Health, Sanitation, Security and Environment

Following the 5-year inspection of the dam that occurred in July of 2019, Montana DNRC notified BSB that a reservoir level restriction could be placed on the dam to reflect the poor concrete condition along the dam face and susceptibility to sliding and overturning at the PMF if the deficiencies were not adequately addressed. Specifically, the operating permit would require that BSB lower the reservoir level to reduce the threat of overtopping at the PMF that would cause catastrophic damage to the dam. As a high hazard dam, Basin Creek Dam #1 represents a significant threat to the public as well as public and private infrastructure downstream of the dam, including the new, $30 million Basin Creek WTP.

BSB has taken the dam condition situation seriously and initiated the Basin Creek Dam Structural Investigation, which was finalized in January 2020 and provided a structural analysis, expansive testing of existing concrete, and development of alternatives. Remedying the Montana DNRC concerns regarding concrete condition and stability not only ensures that the dam will be able to operate at its full capacity but will reduce the likelihood of a catastrophic dam failure and improve the safety downstream of the dam.

The new Basin Creek WTP has significantly improved the operation of the entire system by providing up to 7 MGD that can be used to feed the Basin Creek pressure zone by gravity flow. A new pumping station in the Basin Creek pressure zone of the distribution system has also allowed BSB to take advantage of the excess supply that is often available from the Basin Creek source. As a result, BSB has been able to meet nearly 60% of the City's municipal water needs from the Basin Creek supply. This has resulted in a dramatic reduction in the pumping required from the Big Hole River pumping station, located on the other side of the Continental Divide approximately 26 miles south of Butte. Refer to Figure 4-1 below which represents water pumped from the Big Hole River for over 100 years and clearly shows the dramatic reduction since the new Basin Creek WTP came online in May of 2017. Since this point, Big Hole River withdrawals have decreased drastically. BSB generally does not have to pump from the Big Hole River until July and most of the water for the Feeley WTP is processed from the South Fork Reservoir.

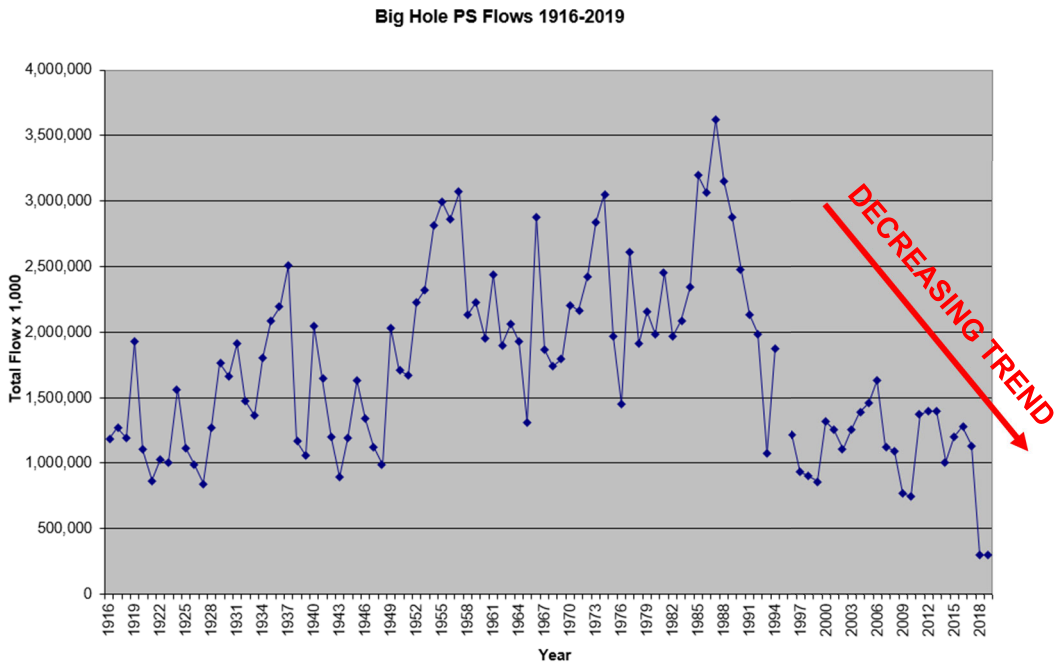


Figure 4-1: Volume of water pumped from the Big Hole River to feed the BSB municipal water supply over time.

A reduction in withdrawals from the Big Hole River has also increased water volume benefiting local fish populations, including Arctic Grayling. According to the U.S. Fish & Wildlife Service, the "remaining confirmed, viable population (of Arctic Grayling) resides in the Big Hole River, upstream of Divide, Montana." Higher flows help alleviate stressors caused by increased water temperatures often associated with low river volume. Due to changes in western Montana's climate, reducing BSB's need for water from the Big Hole represents a significant natural resource benefit. It supports the efforts of the Fluvial Arctic Working Group (FAWG). Since 1995, several State and Federal agencies, including the DNRC, have participated in a Fluvial Arctic Grayling Restoration Plan to conserve the remaining fluvial grayling population in the Big Hole River and re-establish four additional populations. For the past decade, the FAWG has been actively implementing restoration projects in the Big Hole River Watershed to protect and enhance the grayling habitat and the remaining population in the Big Hole River.

In addition to protecting public safety by preventing a breach of Basin Creek Dam #1 during a probable maximum flood (PMF), the objective of the project is to conserve water in the Basin Creek drainage and the Big Hole River by avoiding a restriction of the Reservoir's operating level by the DNRC. As stated in the previous section, if the DNRC were to impose a limitation of the Reservoir's operating level, BSB would likely be forced to reduce the maximum operation level of the dam to an elevation below the deteriorated concrete. The subsequent reduction of the

Reservoir's storage capacity from nearly 1,000 acre-feet to less than 460 acre-feet would reduce the driving force necessary to provide gravity flow through Basin Creek WTP. The limited remaining capacity in the Reservoir would be depleted quickly, forcing BSB to pump water from the Big Hole River. Drawing more water from the Big Hole would likely have serious implications. Particularly in late summer, for agricultural producers and anglers that are attracted to the River's world-class trout fishing and the State of Montana's efforts to protect and enhance Arctic Grayling habitat.

A reduction in the storage capacity of the Basin Creek Reservoir could also negatively affect the pure strain of Westslope Cutthroat Trout (WCT) that live in and above the Reservoir. Caleb Uerling, a fisheries biologist for the Montana Department of Fish, Wildlife and Parks, when asked to comment on the project's impact on the pure strain of (WCT) that live in the Reservoir, stated in an email (Appendix W) that he recommends that Basin Creek Dam #1, continues to be operated to protect WCT above the dam "against Brook Trout invasion." He added, "maintaining the reservoir level would be a benefit to the WCT population" because " the lower the reservoir depth, the less habitat there will be."

The reduced reliance on the Big Hole water source has also allowed BSB to realize significant reduction in energy consumption and associated costs. Figures 4.2 and 4.3 below show power in kW (kilowatt) usage by the primary BSB water treatment and pumping operations since 2012 and exhibit a significant downward trend of overall power use since the Basin Creek WTP came online in May 2017. Basin Creek WTP Chief Operator, Jim Keenan, (Appendix V) has calculated that the increase in production from the Basin Creek supply has saved 1.2-million kWh of electricity per year since June 2017. Based on the current fee of 11.2 cents/kWh, this conservation of electricity saves BSB approximately $134,000 per year and is enough to power an average of nearly 120 Montana households for one year. Figure 4.4 below illustrates the stark difference between the Basin Creek WTP and pumping water from the Big Hole River to Butte.

Refer to Appendix V for specifics on BSB power usage, including monetary charges for each treatment plant and pumping operation.

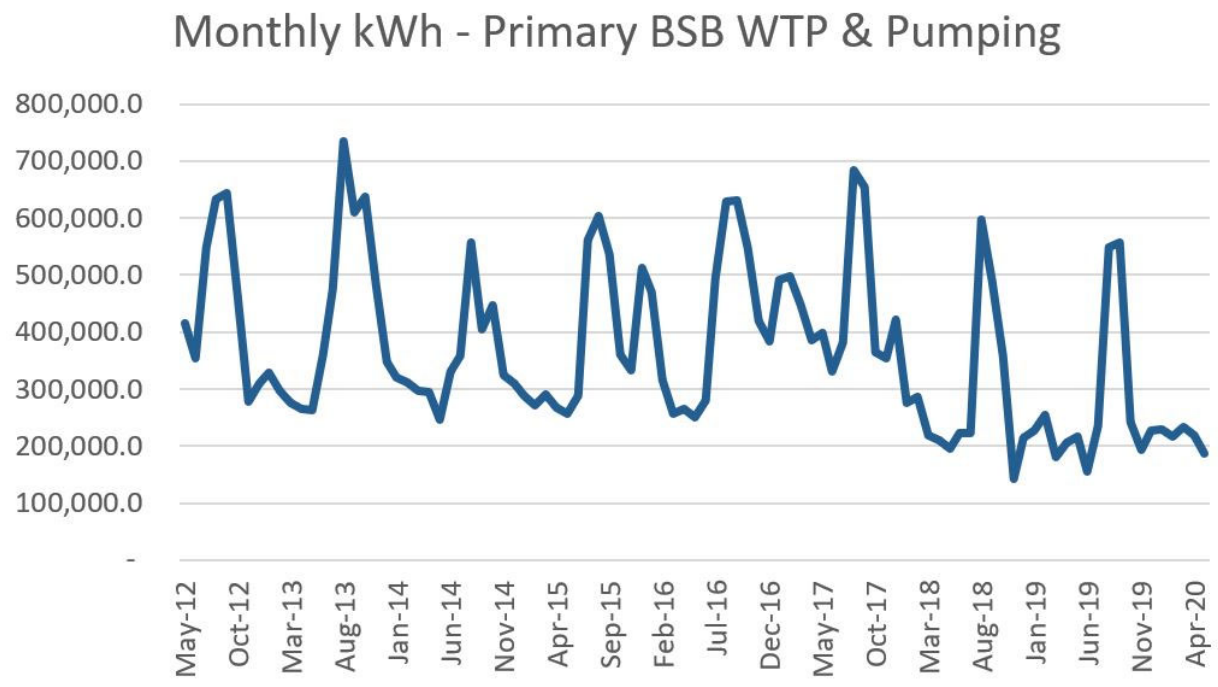


Figure 4-2: Monthly kWh – Primary BSB WTP & Pumping Operations

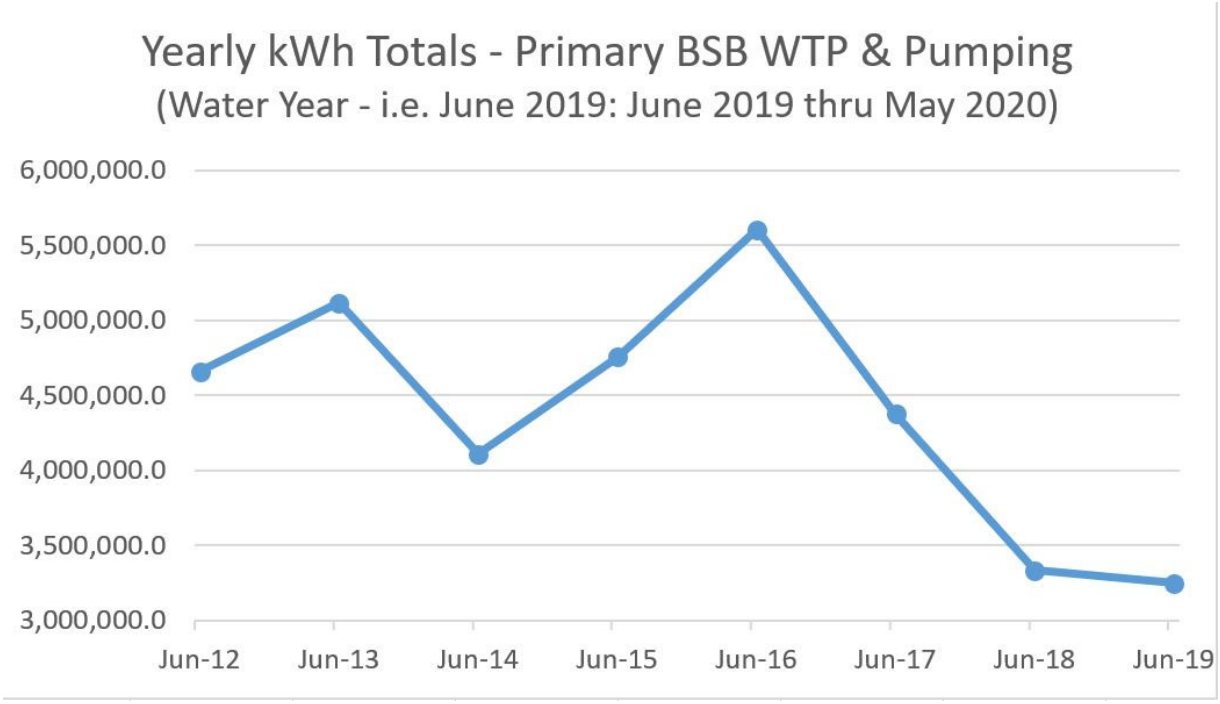


Figure 4-3: Yearly kWh – Primary BSB WTP & Pumping Operations

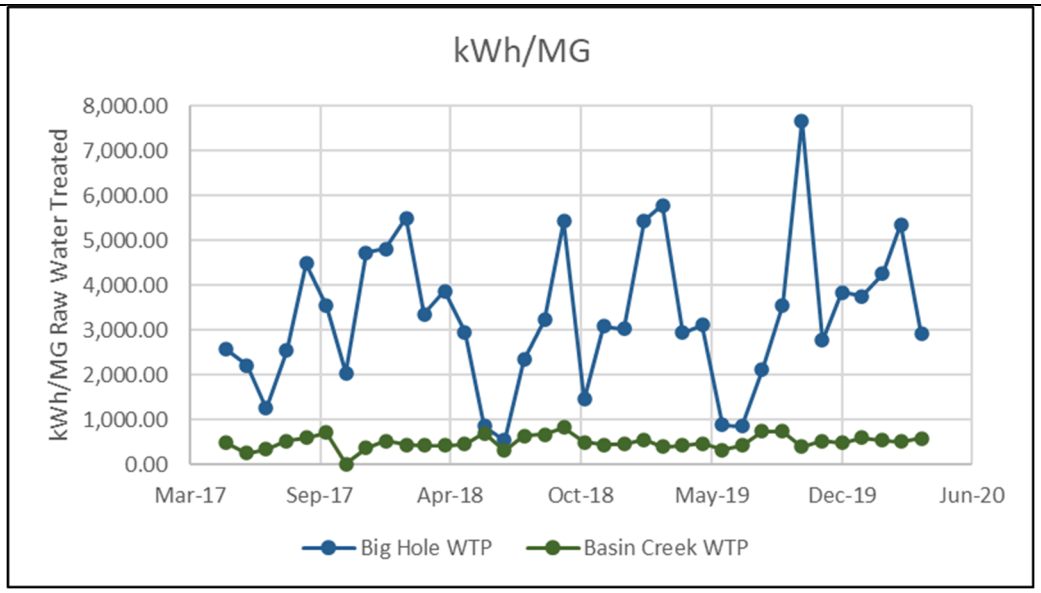


Figure 4-4: Comparison of Big Hole WTP vs Basin Creek WTP in electric usage (kWh) per MG of water treated

4.2 Aging Infrastructure

Basin Creek Dam #1 was initially constructed in the late 1800's out of locally quarried granite rock. The dam was subsequently raised in 1913 by adding mass concrete to the downstream face and to the crest. Earthen embankment was added to the downstream dam face in the 1930's to protect the concrete from freeze-thaw damage and general weathering. Various other rehabilitation projects (specifically a major rehabilitation in 2005) have addressed dam infrastructure components such as the dam conduits, spillway and outlet works.

The visible portions of the mass concrete along the upper dam face that was added in 1913 is in poor condition and is deteriorating rapidly. As the concrete is generally over 100 years old and lacks the freeze-thaw resistance and compressive strength of modern concrete, its service life is dwindling and requires remediation.

Furthermore, in the late 1800's, at the time of construction, many of the design practices for dam design and construction that are now commonplace had not been developed. The selected alternative will ensure the dam meets the current best-practice design standards for resistance to sliding and overturning. All new concrete will be adequately designed to ensure adequate bonding, strength and freeze thaw resistance.

4.3 Reasonable Growth

Growth and project population estimates are discussed in detail in Section 2.3. An annual growth rate of 1% has been assumed for the 20-year planning period (2040) to allow for additional growth in BSB. This correlates to a design year population of 43,332 persons. Due to Butte's ties with the mining industry, BSB's population was on a downward trend from the 1920's until the 1990s. Recently, the population has been increasing slightly. Continuing to perform necessary improvements to the Basin Creek Dam (and subsequently operate the Basin Creek WTP) will allow BSB to maintain this critical public water supply infrastructure and facilitate growth. Growth would encourage and aid current businesses and keep the Community sustainable.

5.0 ALTERNATIVES CONSIDERED

The *2019 5-Year Dam Inspection* report and the *2020 Basin Creek Dam Structural Analysis* identified several deficiencies ranging in complexity and severity. A few of these deficiencies can be addressed through straightforward repair items while others are more serious and will require additional investigation and alternatives development. A description of primary deficiencies is listed below:

- Poor condition of the concrete parapet wall
- Poor condition of the exposed concrete dam face
- Inadequate dam stability during an overtopping Probable Maximum Flood (PMF) event, specifically related to the interface between the mass concrete and granite masonry core. (The interface of the masonry core to the existing bedrock has been shown to be stable during the PMF).

It should be noted that the condition of the concrete pavers on the dam crest was observed as being poor, with apparent voids underneath several sections. This is not considered a primary deficiency, but the condition of the pavers will be addressed within the specific alternative analyses. Additionally, regular monitoring and routine maintenance items identified in the *2019 5-Year Dam Inspection* report are not discussed below for brevity.

5.1 Alternative Screening

5.1.1 Alternative Screening – Concrete Improvements

<u>No Action</u>

The no action alternative would continue to allow the degradation of the concrete condition of the parapet wall and deterioration of the shotcrete overlay and concrete dam face. Continued degradation of the concrete condition, as previously described in DNRC's comments regarding issuance of an operational permit, could result in permanent lowering of the allowable reservoir surface due to structural concerns of the dam and create issues regarding stability during potential overtopping events. The lowering of the reservoir would result in significant impacts to the operation of the downstream gravity fed Basin Creek WTP as previously described in Sections 1.2 and 4.1.

Additionally, as previously described, Basin Creek Dam #2 (Upper Basin Creek Reservoir) is in poor condition. DNRC has requested lowering of the reservoir water surface elevations which has resulted in loss of the "High Hazard" dam classification if water elevations are kept to those levels. However, an overtopping or failure event at Basin Creek Dam #2 could still potentially cause an overtopping event at Basin Creek Dam #1.

Due to significant concerns of the poor concrete condition of the dam in regard to public health and safety and due to the importance of the dam as a primary water source for BSB public water infrastructure, the no action alternative will not be investigated further.

Select Superficial Patching of Poor Concrete Condition Areas

This alternative would consist of superficial surface patching (non-structural) on the existing parapet surfaces and concrete dam face surfaces. The patching would consist of concrete removal of the poor condition concrete (to the extent possible), cleaning and surface patching of these areas to return them to their original elevations.

However, given the concrete's current poor condition with no (apparent) reinforcing, existing age and proximity to the waterline (and subsequent freeze/thaw processes), the longevity of simple unreinforced surface patches is relatively minimal (3 to 8 years). Therefore, this alternative will not be evaluated further.

Replacement of Concrete Parapet

This alternative would consist of full removal of the concrete parapet section and replacement with a new high-strength concrete parapet. Sufficient anchorage and design considerations would be necessary to attach the parapet wall to the existing portion of original mass concrete. This alternative would likely require relatively minimal reservoir lowering. Debris containment would be utilized to prevent materials from entering the reservoir. It is estimated that lifespan of the concrete replacement would be 50 years.

Upstream Dam Face – Structural Concrete Overlay

This alternative would consist of the structural rehabilitation of approximately 240 linear feet of upstream dam face (below the parapet wall). The alternative would consist of:

- Full removal of the installed shotcrete facing and any remnant anchorages
- Removal of areas of poor condition concrete across the entire dam face

- Installation of anchored dowels into the existing concrete
- Installation of reinforced concrete facing

It is assumed that portions of the existing mass concrete will be removed from the surface to get to a base layer that is relatively unimpacted by freeze/thaw or surface delamination. After removal, the surface will be cleaned, and all debris removed. As no rebar is apparently present in the mass concrete, anchorages will be installed in competent sections of concrete. A structural concrete mix will be designed based on the results of the concrete testing results and installed in a way to effectively provide constructability and bonding interface to ensure long-term success.

Lowering of the reservoir will be required for this alternative to effectively complete this work. Debris containment will be utilized to prevent materials from entering the reservoir. It is estimated that lifespan of the concrete overlay would be 50 years.

Replace Mass Concrete Above the Masonry Interface

This alternative would consist of the removal and replacement of the entire mass concrete section above the masonry interface (approximately 14’ tall x 240’ wide):

- Full removal of the existing mass concrete above the masonry interface. The spillway and mass concrete under the spillway are not anticipated to be modified during construction. It is anticipated that the spillway section would be shored/stabilized during construction.
- Removal of ancillary items on the dam surface (walkway, handrail, gantry crane)
- Temporary removal of downstream slope embankment material
- Installation of new structural concrete mass section
- Properly anchor new concrete into the original masonry dam to meet stability criteria during the PMF
- New handrail/safety considerations
- Re-installation of downstream slope embankment material

Lowering of the reservoir will be required for this alternative to effectively complete this work. Debris containment will be utilized to prevent materials from entering the reservoir. It is estimated that lifespan of the mass concrete replacement would be 75 years.

5.1.2 Alternative Screening – Improvements to Meet Overtopping/PMF

No Action

As previously described, the upstream Basin Creek Dam #2 (Upper Basin Creek Reservoir) is in poor condition. DNRC has requested lowering of the reservoir water surface elevations which has resulted in loss of the "High Hazard" dam classification if water elevations are kept to those levels. However, an overtopping or failure event at Basin Creek Dam #2 could still potentially cause an overtopping event at Basin Creek Dam #1.

As delineated in the *2020 Basin Creek Dam Structural Analysis*, the dam *does not currently* meet safety standards regarding overtopping/PMF event primarily due to the assumed competency of the anchorage between the mass concrete and masonry core.

Due to public health and safety *and* due to the importance of the dam as a primary water source for BSB public water infrastructure, the no action alternative will not be investigated further in regard to dam improvements to meet the overtopping/PMF event.

Increasing Spillway Capacity

As indicated in the *2020 Basin Creek Dam Structural Analysis*, the recently reconstructed spillway (2006) can pass the 500-year flood event. Increasing the spillway capacity at Basin Creek Dam #1 could be done by increasing the width of the current spillway or by installing an additional spillway to pass the PMF without dam overtopping. The dam has adequate safety for reservoir levels below the top of the parapet wall according to stability calculations. However, due to the extensive crest length of the required spillway to pass the PMF event, this alternative is not viable, according to the *2020 Basin Creek Dam Structural Analysis*.

Anchor Mass Concrete

According to the *2020 Basin Creek Dam Structural Analysis,* the existing anchorage (if any) from the 1913 concrete to the 1897 masonry core is unknown and assumed to be non-existent due to construction methodology and design knowledge at the time. Ensuring stability during the PMF requires a sufficient anchorage from the mass-concrete to the granite masonry core to prevent sliding and overturning as described in detail in the *2020 Basin Creek Dam Structural Analysis.* This method of anchorage in dams is commonly done by using a post tensioned anchorage configuration (either via strand cables or solid bar anchorage). Typically, post tensioned strand cable anchorages are utilized when doing longer depth installations or installations into unsuitable

material types (clays, silts, etc). As the assumption is that the anchorage would extend into the existing solid masonry dam interface with relatively minimal depth, solid bar anchors are preferred for both constructability and cost savings. Ancillary items associated with this alternative would include paver and handrail removal and replacement due to access considerations required for the post tension anchor drilling equipment.

5.2 Dam Rehabilitation Alternatives

The dam rehabilitation alternatives discussed below do not represent equivalent selections in terms of construction cost, construction effort, and the anticipated life expectancy of such efforts. Therefore, the alternatives represent a *good, better, best* scenario and will be evaluated on the basis of balancing upfront initial costs with a reasonable life expectancy.

5.2.1 Alternative 1 – Replacement of the Parapet Wall and Installation of Post-Tensioned Anchors

This alternative includes full removal and replacement of the parapet wall and installation of post tensioned anchorages through the mass concrete into the masonry core. Replacement of the parapet wall would prevent ongoing maintenance of the freeze/thaw damage and reduce the concerns for parapet failure during the PMF. The post tensioned anchorages would provide additional sliding and overturning stability during the PMF to meet current standards. Gannett Fleming has indicated that based on their conceptual analysis, a total of fourteen 2” diameter post-tension anchor rods, each rated to 140 KIPS, will be required. The anticipated total length of each rod is 40 feet.

Repairs to the dam face (outside of the parapet area) are not included in this alternative.

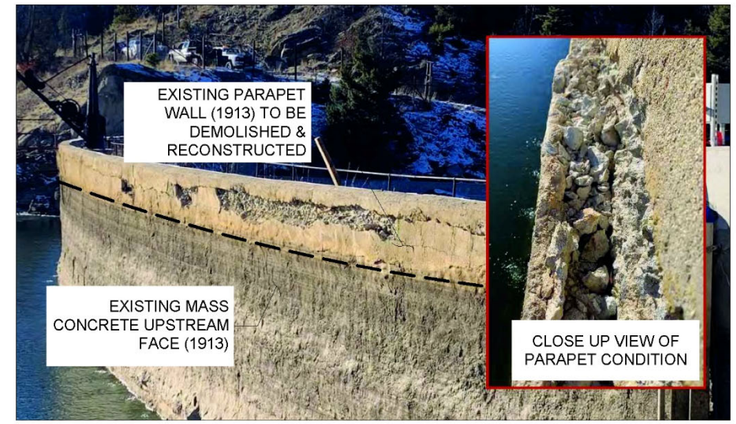
Design Criteria

The dam improvement design will follow best practice guidelines for similar public dam infrastructure improvement projects. Additionally, the dam design will meet applicable criteria furnished by DNRC and will be subject to review by DNRC Dam Safety during the design process before re-issuance of the operating permit. Alternatives will be evaluated for relevant seismic loading during the final design stage pertaining to structural improvements and anchorage design.

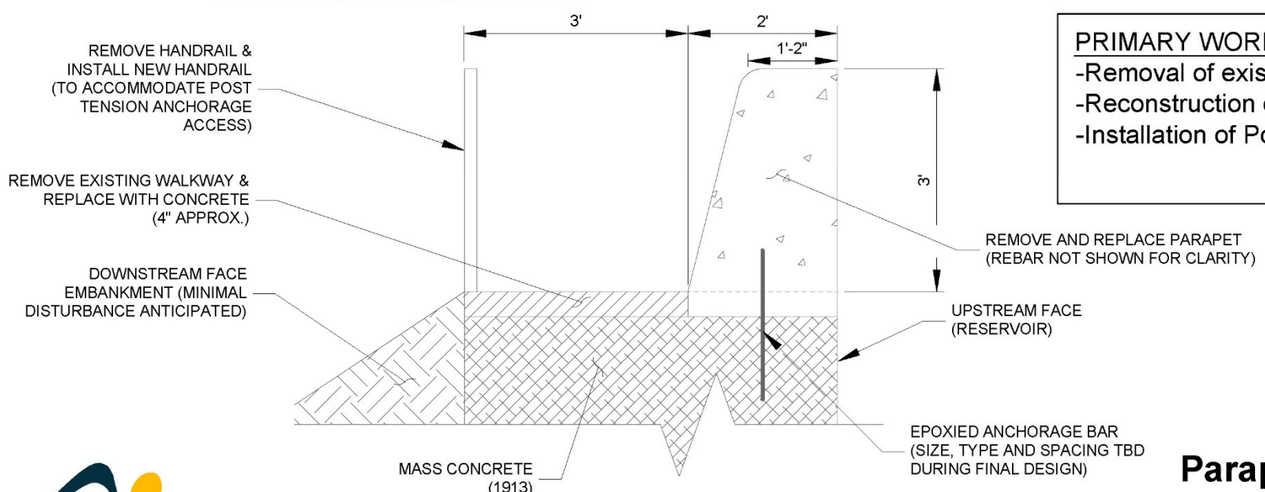
Design Schematic:

See Alternative 1 schematic drawings shown below.

Existing Parapet Wall



View of Existing Upstream Face & Parapet Wall



Parapet Rehabilitation Detail Section View (NTS)

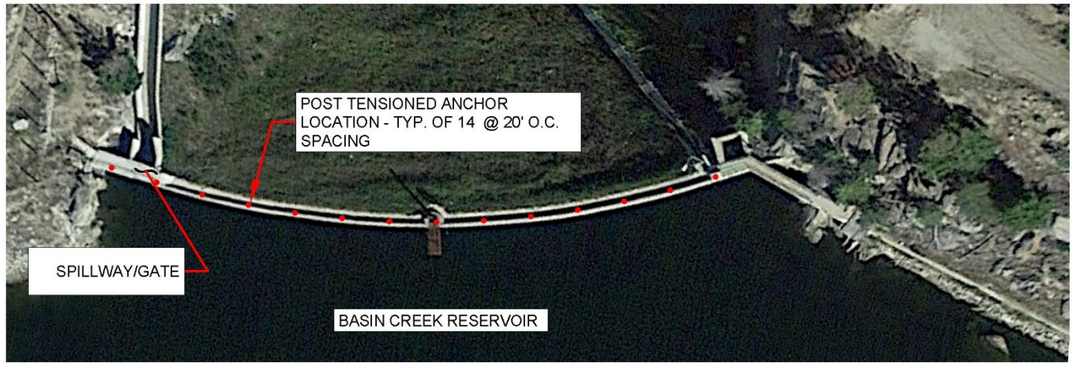
PRIMARY WORK ITEMS:
-Removal of existing concrete parapet
-Reconstruction of concrete parapet w/anchorage to dam
-Installation of Post Tensioned anchors thru dam into masonry

GreatWest engineering®

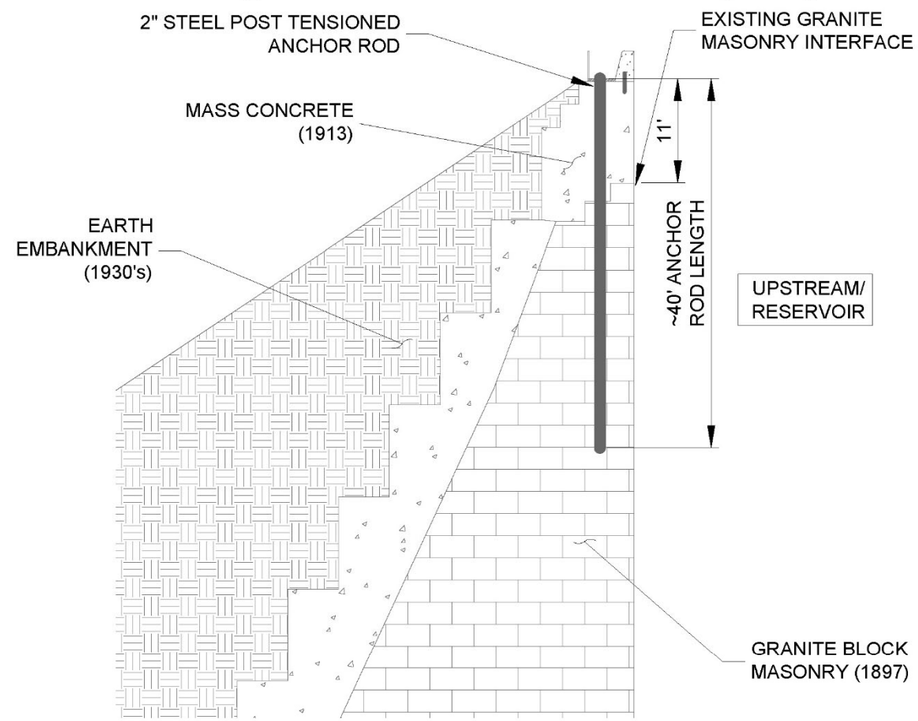
Parapet Removal & Reconstruction, Installation of Post Tensioned Anchors

CITY-COUNTY OF BUTTE-SILVER BOW
BASIN CREEK DAM #1 REHABILITATION

Figure 5-1: Alternative 1 – Design Schematic 1



Plan View of Dam - Showing Prelim. Anchor Locations (NTS)



Section View of Dam
Showing Prelim. Anchor Configuration (NTS)

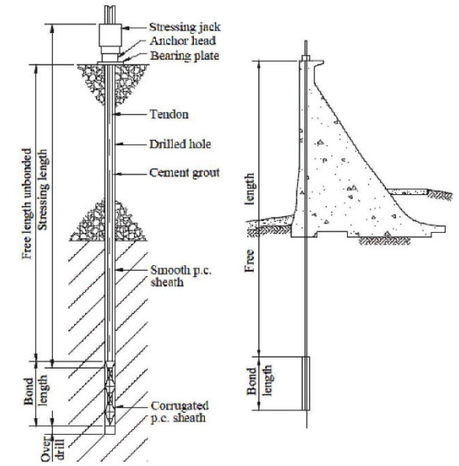


Fig. 1. Components of a typical large, permanent, post-tensioned dam rock anchor (Cavill, 1997).

Anchorage Schematic
Journal of Rock Mechanics & Geotechnical Eng.

Typical Drill Rig
SOURCE: THIRD POST-TENSIONED ANCHORS STABILIZATION AT OLMOS DAM

CITY-COUNTY OF BUTTE-SILVER BOW
BASIN CREEK DAM #1 REHABILITATION

Figure 5-2: Alternative 1 – Design Schematic 2 (Anchorage)

Environmental Impacts

The Montana DEQ requires an asbestos inspection be performed by an accredited inspector prior to component demolition/removal. The MDEQ may exercise its right to waive the asbestos inspection requirement depending on the type of structure and its components.

During the design phase, if deemed necessary by the Corps of Engineers, a wetland delineation may be performed in order to map potential wetland impacts. However, no known wetlands are anticipated due to the relatively limited work area on the existing dam and history of periodic disturbance.

During the design phase, it may be necessary to complete an inventory for Whitebark Pine at the project site, if requested by the USFWS. However, no known Whitebark Pine are in the project vicinity and no trees are currently present within the expected project impact area.

During the design phase, if deemed necessary by the lead federal agency, an independent consultant will perform a historic recordation of the Basin Creek Dam and/or cultural investigation in the dam vicinity.

A minor amount of reservoir lowering may be required to facilitate parapet removal and replacement, depending on existing water surface conditions at the time of construction.

This alternative would not generate residuals or wastes that would have to be managed. Some air quality problems with dust may arise during the construction; however, they would be temporary. Similarly, there will be temporary noise during construction, especially during concrete removal and drilling activities. Debris containment will be required to mitigate any potential debris from entering the reservoir. The contract documents shall also require that Best Management Practices (BMP) be employed before, during, and after construction until all areas of disturbance have been fully reclaimed and/or vegetated (if required). For these reasons, environmental impacts are considered minimal and no permanent, negative environmental impacts are anticipated.

Land Requirements

All project work will occur within a relatively confined area of pre-disturbed land on the dam crest and the dam face. The dam and lands immediately surrounding the dam and reservoir are all property of BSB. Refer to the cadastral map in Appendix R. No adverse impacts to adjacent landowners or land purchase will be required as a result of this alternative. Construction access

routes in the vicinity of the dam are also BSB property and staging areas for construction will likely be similar to those utilized during the 2005/2006 rehabilitation work (see staging/construction access delineated in Appendix Q – 2006 Construction Drawings for Basin Creek Reservoir Improvements).

Potential Construction Problems

While the project is proximally located to Butte, a relatively major populated area in Montana, construction equipment access for this alternative is challenging due to the location of the crest of the dam. It is likely that construction equipment, especially the drilling rigs for the installation of the post tensioned anchors, will be required to be craned into the site from either access road. Additionally, the limited width of the dam crest creates challenging issues for access and may require specialized drilling rigs due to available width. Preliminary consultation with specialty subcontractors that perform similar post-tension anchor installation indicate the site access is "challenging" and will result in higher mobilization and contingency costs due to access. Higher budgetary and contingency moneys have been estimated to address this situation.

Removal of the concrete for the parapet wall will require debris containment but is anticipated to be completed from the topside of the dam crest.

A geotechnical analysis is also included in the cost estimate as potential analysis may be required to further determine design and adequate anchorage of the post tensioned anchorage system into the granite masonry core. Information previously presented on the number and depth of rods is preliminary and may change depending on additional analyses performed. Higher budgetary and contingency moneys have been estimated to address unknowns.

High water table, water rights, or existing resource or site impairment issues are not anticipated with this alternative.

Sustainability Considerations

Water and Energy Efficiency

Not applicable to this alternative.

Green Infrastructure

Stormwater management during the project will include temporary erosion and sediment control measures including the installation and maintenance of temporary measures to reduce or

eliminate the erosion of soils and transport of sediment offsite as a result of construction activities. Due to the limited surface area of work, minimal impacts are anticipated.

Cost Estimates

Table 5-1, below, presents estimated project costs. Annual operation and maintenance costs are not included, as they are not components of this rehabilitation work. Contingency costs of 20% were utilized for the development of the final project cost. As described above, this contingency is justified due to challenging site access and unknown final configuration of the anchorages.

Table 5-1: Opinion of Probable Cost – Alternative 1

TABLE 5-1 OPINION OF PROBABLE COST BASIN CREEK DAM #1 REHABILATION ALTERNATIVE 1 - CONCRETE PARAPET REPLACEMENT AND POST-TENSIONED ANCHOR INSTALLATION					
#	**BID ITEM**	**QTY**	**UNITS**	**UNIT PRICE [1]**	**TOTAL**
1	Concrete Removal, Surface Preparation & Debris Containment - 240 Linear Feet of Parapet	1	LS	$ 23,750.00	$ 23,750
2	Structural Concrete, Reinforcing and Anchorage Into Existing Mass Concrete	50	CY	$ 1,425.00	$ 71,250
3	Supply and Installation of Post Tensioned Anchor Rods, 40' Length	14	EA	$ 30,000.00	$ 420,000
4	Removal & Disposal of Existing Handrail	240	LF	$ 10.00	$ 2,400
5	Removal & Disposal of Existing Walkway	720	SF	$ 4.00	$ 2,880
6	Install New Walkway (3' width x 4" depth assumed)	720	SF	$ 12.00	$ 8,640
7	Install New Handrail	240	LF	$ 60.00	$ 14,400
	Direct Construction Subtotal				**$ 543,300**
	Mobilization & Demobilization		15%		$ 81,500
	Contingency		20%		$ 125,000
	Construction Subtotal				**$ 749,800**
	2023 Construction Cost [2]		9.18%		$ 818,600
	Historic Recordation/Cultural Investigation				$ 6,000
	Engineering (Permitting, Design & Analysis)				$ 199,960
	Engineering (Contract Construction Administration)				$ 127,466
	Asbestos Testing				$ 750
	Geotechnical Investigation				$ 25,000
	Grant Administration				$ 18,745
	TOTAL				**$ 1,196,521**

[1] Estimated unit costs are based upon estimates from suppliers and bid tabs for similar projects throughout the western United States.
[2] The ENR 20 year average Construction Cost Index is +3.06% (as of November 2011), so capital costs are projected to an anticipated construction date in 2023 using a 3.06% yearly inflation rate.

5.2.2 Alternative 2 – Replacement of the Parapet Wall, Full Concrete Overlay over Dam Face and Installation of Post-Tensioned Anchors

This alternative includes full removal and replacement of the parapet wall, concrete overlay over the dam face and installation of post tensioned anchorages through the mass concrete into the masonry core. Replacement of the parapet wall would prevent ongoing maintenance of the freeze/thaw damage and reduce the concerns for parapet failure during the PMF. Rehabilitation of the dam face will also reduce future maintenance concerns and increase longevity of the mass concrete section. The post tensioned anchorages would provide additional sliding and overturning stability during the PMF to meet current standards. Gannett Fleming has indicated that based on their conceptual analysis, a total of fourteen 2” diameter post-tension anchor rods, each rated to 140 KIPS, will be required. The anticipated total length of each rod is 40 feet.

Design Criteria

The dam improvement design will follow best practice guidelines for similar public dam infrastructure improvement projects. Additionally, the dam design will meet applicable criteria furnished by DNRC and will be subject to review by DNRC Dam Safety during the design process before re-issuance of the operating permit. Alternatives will be evaluated for relevant seismic loading during the final design stage pertaining to structural improvements and anchorage design.

Design Schematic:

See Alternative 2 schematic drawings shown below.

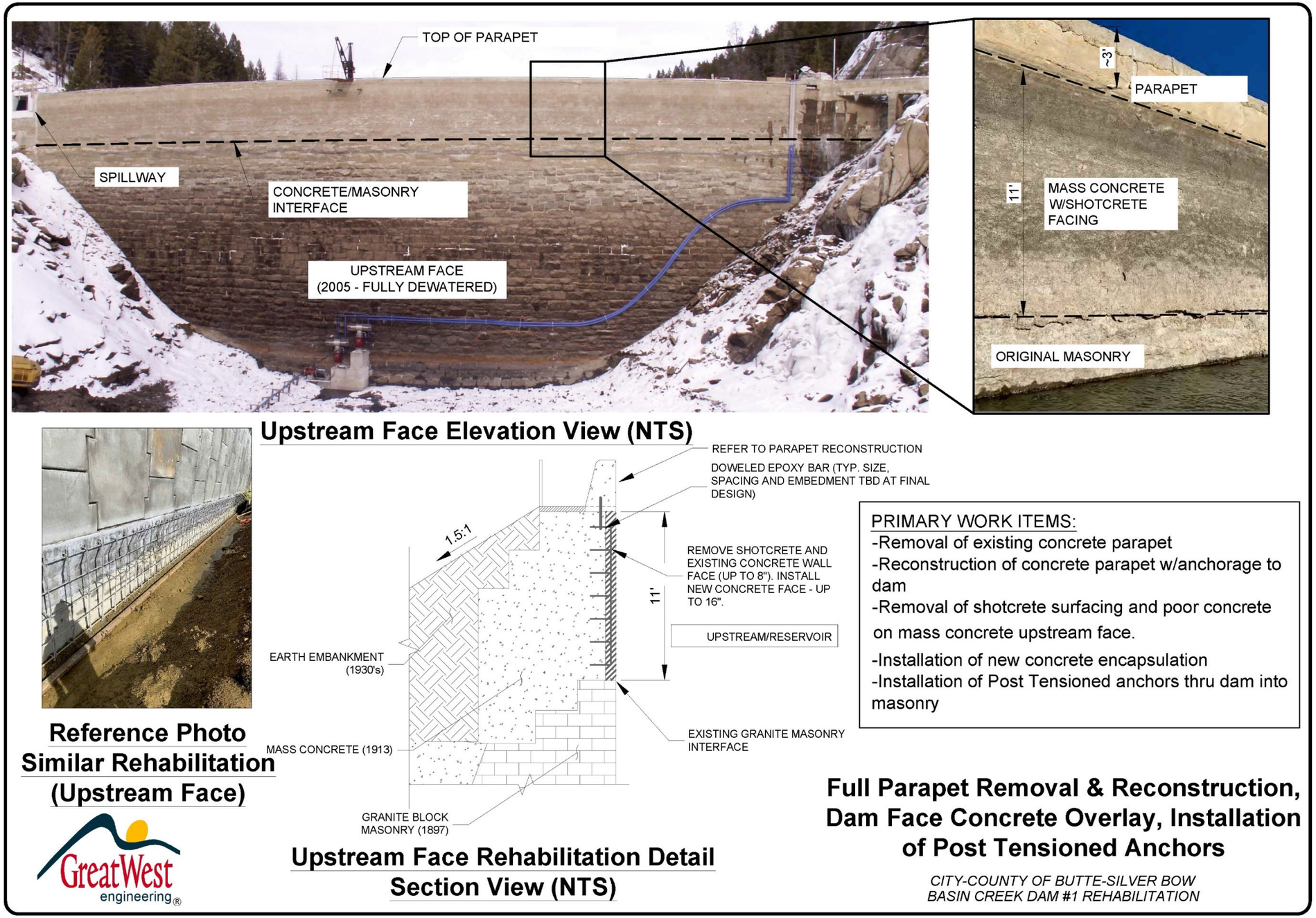
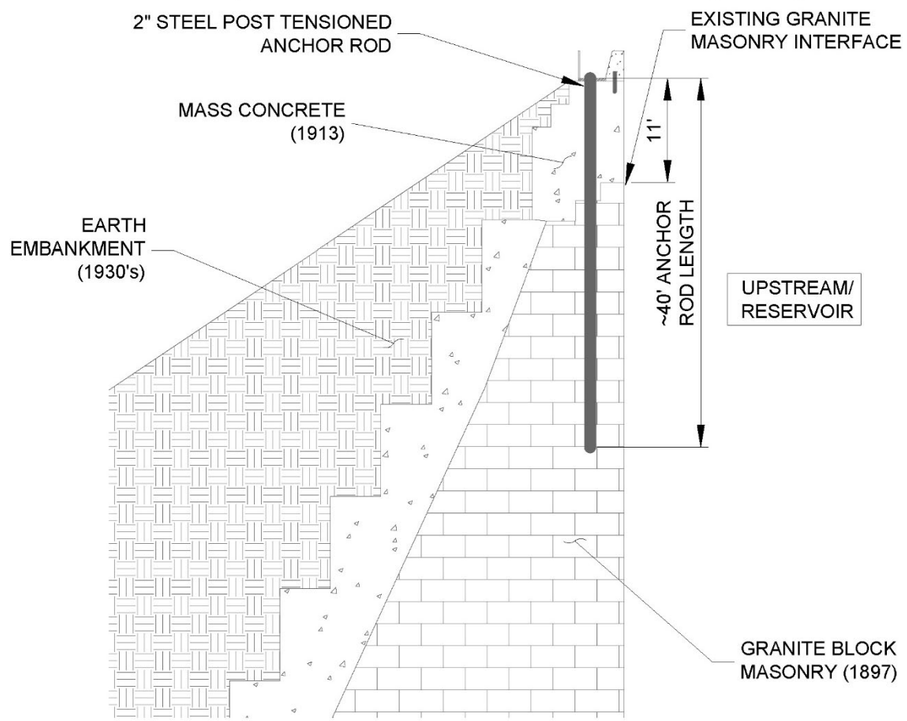


Figure 5-3: Alternative 2 – Design Schematic 1

Plan View of Dam - Showing Prelim. Anchor Locations (NTS)



Section View of Dam
Showing Prelim. Anchor Configuration (NTS)

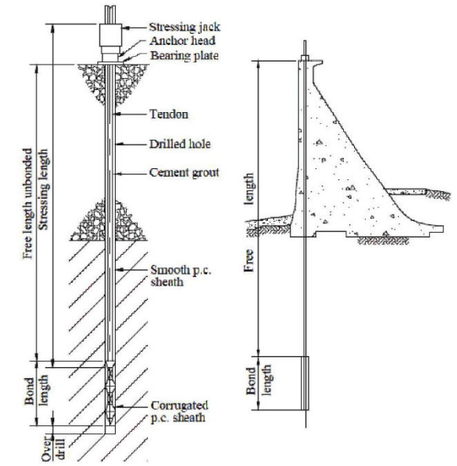


Fig. 1. Components of a typical large, permanent, post-tensioned dam rock anchor (Cavill, 1997).

Anchorage Schematic
Journal of Rock Mechanics & Geotechnical Eng.

Typical Drill Rig
SOURCE: THIRD POST-TENSIONED ANCHORS STABILIZATION AT OLMOS DAM

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BASIN CREEK DAM #1 REHABILITATION

Figure 5-4: Alternative 2 – Design Schematic 2 (Anchorage)

Environmental Impacts

The Montana DEQ requires an asbestos inspection be performed by an accredited inspector prior to component demolition/removal. The MDEQ may exercise its right to waive the asbestos inspection requirement depending on the type of structure and its components.

During the design phase, if deemed necessary by the Corps of Engineers, a wetland delineation may be performed in order to map potential wetland impacts. However, no known wetlands are anticipated due to the relatively limited work area on the existing dam and history of disturbance.

During the design phase, it may be necessary to complete an inventory for Whitebark Pine at the project site, if requested by the USFWS. However, no known Whitebark Pine are in the project vicinity and no trees are currently present within the expected project impact area.

During the design phase, if deemed necessary by the lead federal agency, an independent consultant will perform a historic recordation of the Basin Creek Dam and/or cultural investigation in the dam vicinity.

Reservoir lowering to just below the concrete/masonry interface (approximately 14 vertical feet from the top parapet wall) will be required to complete the dam face improvement work in “dry conditions”.

This alternative would not generate residuals or wastes that would have to be managed. Some air quality problems with dust may arise during the construction; however, it would be temporary. Similarly, there will be temporary noise during construction, especially during concrete removal and drilling activities. Debris containment will be required to mitigate any potential debris from entering the reservoir. The contract documents shall also require that Best Management Practices (BMP) be employed before, during, and after construction until all areas of disturbance have been fully reclaimed and/or vegetated. For these reasons, environmental impacts are considered minimal and no permanent, negative environmental impacts are anticipated.

Land Requirements

All project work will occur within a relatively confined area of pre-disturbed land on the dam crest and the dam face. The dam and lands immediately surrounding the dam and reservoir are all property of BSB, refer to the cadastral map in Appendix R. No adverse impacts to adjacent landowners or land purchase will be required as a result of this alternative. Construction access routes in the vicinity of the dam are also BSB property and staging areas for construction will likely

be similar to those utilized during the 2005/2006 rehabilitation work (see staging/construction access delineated in Appendix Q – 2006 Construction Drawings for Basin Creek Reservoir Improvements).

Potential Construction Problems

While the project is proximally located to Butte, a relatively major populated area in Montana, construction equipment access for this alternative is challenging due to the location of the crest of the dam. It is likely that construction equipment, especially the drilling rigs for the installation of the post tensioned anchors, will be required to be craned into the site from either access road. Additionally, the limited width of the dam crest creates challenging issues for access and may require specialized drilling rigs due to available width. Preliminary consultation with specialty subcontractors that perform similar post-tension anchor installation indicate the site access is "challenging" and will result in higher mobilization and contingency costs due to access. Higher budgetary and contingency moneys have been estimated to address this situation.

Removal of the concrete for the parapet wall is anticipated to be completed from the topside of the dam crest. Removal of the concrete/shotcrete for the dam face rehabilitation will likely be completed from the reservoir side and may require an access barge (dependent on contractor's means and methods). The exact condition of the entire upstream dam face concrete under the shotcrete layer is not known and assumptions have been made for anticipated removal amounts. Due to this, higher budgetary and contingency moneys have been estimated. Debris containment will be required to prevent materials from entering the reservoir.

A geotechnical analysis is also included in the cost estimate as potential analysis may be required to further determine design and adequate anchorage of the post tensioned anchorage system into the granite masonry core. Information previously presented on the number and depth of rods is preliminary and may change depending on additional analyses performed. Higher budgetary and contingency moneys have been estimated to address unknowns.

High water table, water rights, or existing resource or site impairment issues are not anticipated with this alternative.

Sustainability Considerations

Water and Energy Efficiency

Not applicable to this alternative.

Green Infrastructure

Stormwater management during the project will include temporary erosion and sediment control measures including the installation and maintenance of temporary measures to reduce or eliminate the erosion of soils and transport of sediment offsite as a result of construction activities. Due to the limited surface area of work, minimal impacts are anticipated.

Cost Estimates

Table 5-2, below, presents estimated project costs. Annual operation and maintenance costs are not included, as they are not components of this rehabilitation work. Contingency costs of 20% were utilized for the development of the final project cost. As described above, this contingency is justified due to challenging site access, estimated removal quantities of dam face concrete and unknowns pertaining to the final configuration of the anchorage.

Table 5-2: Opinion of Probable Cost – Alternative 2

TABLE 5-2

OPINION OF PROBABLE COST

BASIN CREEK DAM #1 REHABILATION

ALTERNATIVE 2 - CONCRETE PARAPET REPLACEMENT, DAM FACE OVERLAY AND POST-TENSIONED ANCHOR INSTALLATION

#	BID ITEM	QTY	UNITS	UNIT PRICE [1]	TOTAL
1	Concrete Removal, Surface Preparation & Debris Containment - 240 Linear Feet of Parapet (Parapet Only)	1	LS	$ 20,000.00	$ 20,000
2	Structural Concrete, Reinforcing and Anchorage Into Existing Mass Concrete (Parapet Only)	50	CY	$ 1,425.00	$ 71,250
3	Concrete/Shotcrete Removal, Surface Preparation & Debris Containment - 2640 SF of dam face (240' long x 11' high) (Dam Face Only)	1	LS	$ 105,600.00	$ 105,600
4	Structural Concrete, Reinforcing and Anchorage Into Existing Mass Concrete - 2640 SF of dam face. Assume 16" thick facing - (Dam Face Only)	132	CY	$ 2,350.00	$ 310,200
5	Supply and Installation of Post Tensioned Anchor Rods, 40' Length (PMF)	14	EA	$ 30,000.00	$ 420,000
6	Removal & Disposal of Existing Handrail	240	LF	$ 10.00	$ 2,400
7	Removal & Disposal of Existing Walkway	720	SF	$ 4.00	$ 2,880
8	Install New Walkway (3' width x 4" depth - assumed)	720	SF	$ 12.00	$ 8,640
9	Install New Handrail	240	LF	$ 60.00	$ 14,400
	Direct Construction Subtotal				**$ 955,400**
	Mobilization & Demobilization		15%		$ 143,300
	Contingency		20%		$ 219,700
	Construction Subtotal				**$ 1,318,400**
	2023 Construction Cost [2]		9.18%		$ 1,439,400
	Historic Recordation/Cultural Investigation				$ 6,000
	Engineering (Permitting, Design & Analysis)				$ 313,680
	Engineering (Contract Construction Administration)				$ 224,128
	Asbestos Testing				$ 750
	Geotechnical Investigation				$ 25,000
	Grant Administration				$ 21,094
	TOTAL				**$ 2,030,052**

[1] Estimated unit costs are based upon estimates from suppliers and bid tabs for similar projects throughout the western United States.

[2] The ENR 20 year average Construction Cost Index is +3.06% (as of November 2011), so capital costs are projected to an anticipated construction date in 2023 using a 3.06% yearly inflation rate.

5.2.3 Alternative 3 – Full Removal of 13-foot deep mass concrete cap to the masonry interface. Installation of new mass concrete section with anchorage system into the masonry core.

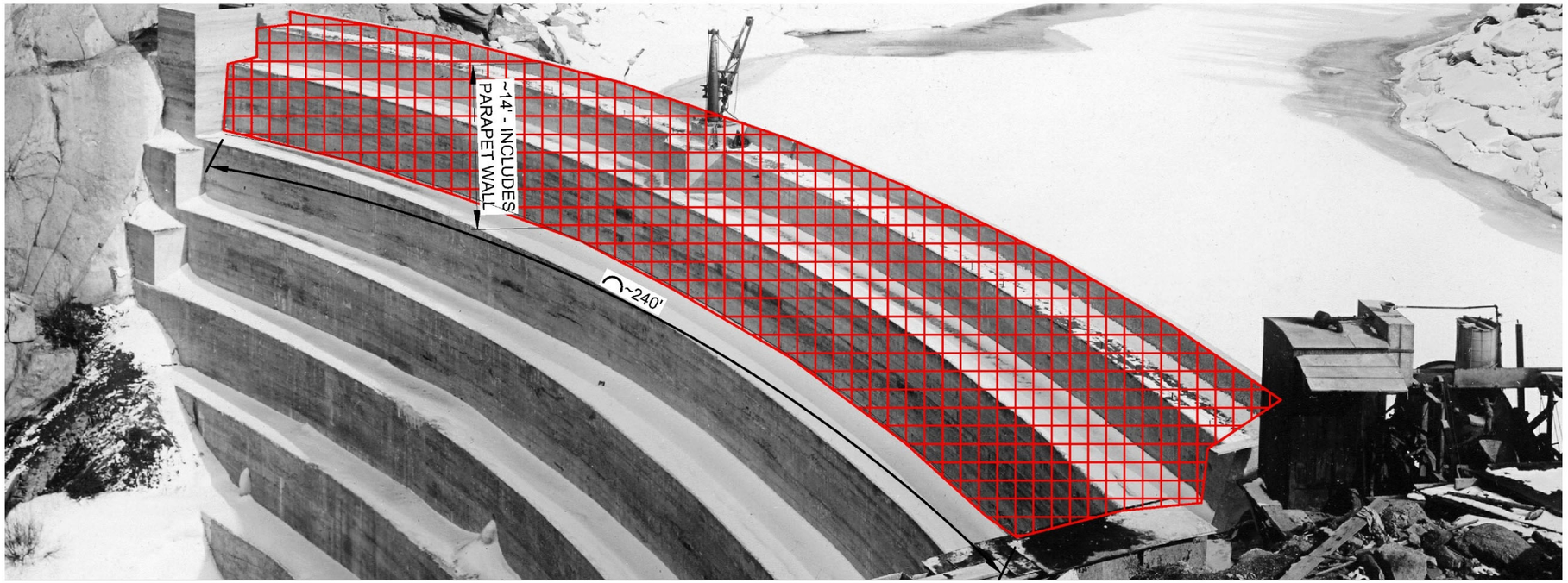
This alternative includes full removal and replacement of the mass concrete section over the masonry core. This alternative would remove the entire 1913 concrete cap and replace with new, air-entrained, high-strength concrete. The remainder of the 1913 concrete buttress at lower dam elevations would remain in place. Sufficient anchorage would be designed from the new mass concrete section into the masonry core to provide sliding and overturning stability during the PMF and to meet current standards. As the design of a new mass concrete section requires considerable design and analysis, assumptions for replacement in the preliminary engineering report assumes that the new concrete structure will generally match the existing configuration of the replaced structure. Determination of the most efficient and cost-effective replacement section will occur during final design.

Design Criteria

The dam improvement design will follow best practice guidelines for similar public dam infrastructure improvement projects. Additionally, the dam design will meet applicable criteria furnished by DNRC and will be subject to review by DNRC Dam Safety during the design process before re-issuance of the operating permit. Alternatives will be evaluated for relevant seismic loading during the final design stage pertaining to structural improvements and anchorage design.

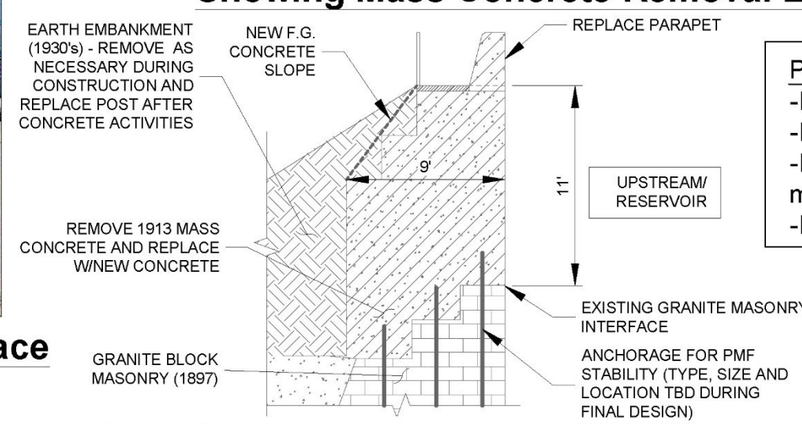
Design Schematic:

See Alternative 3 schematic drawings shown below.



View of Dam - Pre Downstream Embankment Placement (1910's)
Showing Mass Concrete Removal Extents

Existing Downstream Face



Mass Concrete Replacement Detail
Section View (NTS)

PRIMARY WORK ITEMS:
- -Removal of existing mass concrete to masonry interface
- -Removal of earth embankment on downstream face
- -Installation of new concrete, including anchorage to masonry
- -Reinstallation of earthen embankment material

Full Mass Concrete Removal and Replacement (Includes Anchorage into Masonry)

CITY-COUNTY OF BUTTE-SILVER BOW
BASIN CREEK DAM #1 REHABILITATION

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Figure 5-5: Alternative 3 – Design Schematic

Environmental Impacts

The Montana DEQ requires an asbestos inspection be performed by an accredited inspector prior to component demolition/removal. The MDEQ may exercise its right to waive the asbestos inspection requirement depending on the type of structure and its components.

During the design phase, if deemed necessary by the Corps of Engineers, a wetland delineation may be performed in order to map potential wetland impacts. However, no known wetlands are anticipated due to the relatively limited work area on the existing dam and history of disturbance.

During the design phase, it may be necessary to complete an inventory for Whitebark Pine at the project site, if requested by the USFWS. However, no known Whitebark Pine are in the project vicinity and no trees are currently present within the expected project impact area.

During the design phase, if deemed necessary by the lead federal agency, an independent consultant will perform a historic recordation of the Basin Creek Dam.

Reservoir lowering to just below the concrete/masonry interface (approximately 14 vertical feet from the top parapet wall) will be required to complete the project improvement work in “dry conditions”.

This alternative would not generate residuals or wastes that would have to be managed. Some air quality problems with dust may arise during the construction; however, they would be temporary. Similarly, there will be temporary noise during construction, especially during concrete removal and drilling activities. Debris containment will be required to mitigate any potential debris from entering the reservoir. The contract documents shall also require that Best Management Practices (BMP) be employed before, during, and after construction until all areas of disturbance have been fully reclaimed and/or vegetated. For these reasons, environmental impacts are considered minimal and no permanent, negative environmental impacts are anticipated.

Land Requirements

All project work will occur within a relatively confined area of pre-disturbed land on the dam crest, dam face and downstream slope. The dam and lands immediately surrounding the dam and reservoir are all property of BSB, refer to the cadastral map in Appendix R. No adverse impacts to adjacent landowners or land purchase will be required as a result of this alternative. Construction access routes in the vicinity of the dam are also BSB property and staging areas for construction will likely be similar to those utilized during the 2005/2006 rehabilitation work (see

staging/construction access delineated in Appendix Q – 2006 Construction Drawings for Basin Creek Reservoir Improvements).

Potential Construction Problems

While the project is proximally located to Butte, a relatively major populated area in Montana, construction equipment access for this alternative is challenging due to the location of the crest of the dam. It is possible that construction equipment will be required to be craned into the site from either access road. Additionally, the limited width of the dam crest creates challenging issues for access. Consultation with dam contractors indicate that the site is somewhat challenging with access considerations and will result in higher mobilization and contingency costs due to access. Higher budgetary and contingency moneys have been estimated to address this situation.

Removal of the concrete is anticipated to be completed from the crest area. Debris containment will be required to prevent materials from entering the reservoir. A significant amount of concrete (over 1000 cubic yards) will need to be removed for this alternative. Additionally, over 1000 cubic yards of downstream embankment slope material will need to be removed and temporarily stockpiled before being replaced on the downstream slope. Note that the quantity of embankment material removal and replacement will be subject to change dependent on the means and methods of the contractor.

A geotechnical analysis is also included in the cost estimate as potential analysis may be required to further determine design and adequate anchorage of the new mass concrete section to the granite masonry core. Higher budgetary and contingency moneys have been estimated to address unknowns in anchorage techniques (which will be further determined in final design).

High water table, water rights, or existing resource or site impairment issues are not anticipated with this alternative.

Sustainability Considerations

Water and Energy Efficiency

Not applicable to this alternative.

Green Infrastructure

Stormwater management during the project will include temporary erosion and sediment control measures including the installation and maintenance of temporary measures to reduce or

eliminate the erosion of soils and transport of sediment offsite as a result of construction activities. Due to the relatively limited surface area of work, minimal impacts are anticipated.

Cost Estimates

Table 5-3, below, presents estimated project costs. Annual operation and maintenance costs are not included, as they are not components of this rehabilitation work. Contingency costs of 20% were utilized for the development of the final project cost. As described above, this contingency is justified due to challenging site access, assumptions related to final anchorage configuration and unknowns related to the new dam face design.

Table 5-3: Opinion of Probable Cost – Alternative 3

TABLE 5-3 OPINION OF PROBABLE COST BASIN CREEK DAM #1 REHABILATION ALTERNATIVE 3 - FULL REMOVAL AND REPLACEMENT OF MASS CONCRETE					
#	**BID ITEM**	**QTY**	**UNITS**	**UNIT PRICE [1]**	**TOTAL**
1	Concrete Removal, Surface Preparation & Debris Containment - Entire Dam Face (Approx. 1200 CY concrete)	1	LS	$ 450,000.00	$ 450,000
2	Structural Concrete, Reinforcing and Anchorage Into Masonry Core (Includes Top Concrete Surface as Walkway)	1,265	CY	$ 1,250.00	$ 1,581,250
3	Temporary Removal and Stockpile of Downstream Slope Embankment to Facilitate Activities	1,200	CY	$ 14.00	$ 16,800
4	Replacement and Compaction of of Downstream Slope Embankment (Assumes Re-Use)	1,200	CY	$ 20.00	$ 24,000
5	Removal & Disposal of Existing Handrail	240	LF	$ 10.00	$ 2,400
6	Removal & Disposal of Existing Walkway	720	SF	$ 4.00	$ 2,880
7	Removal & Disposal of Gantry Crane	1	LS	$ 1,000.00	$ 1,000
8	Install New Handrail	240	LF	$ 60.00	$ 14,400
			Direct Construction Subtotal		**$ 2,092,700**
	Mobilization & Demobilization		15%		$ 313,900
	Contingency		20%		$ 481,300
	Construction Subtotal				**$ 2,887,900**
	2023 Construction Cost [2]		9.18%		$ 3,153,000
	Historic Recordation/Cultural Investigation				$ 6,000
	Engineering (Permitting, Design & Analysis)				$ 569,822
	Engineering (Contract Construction Administration)				$ 462,064
	Asbestos Testing				$ 750
	Geotechnical Investigation				$ 15,000
	Grant Administration				$ 21,659
	TOTAL				**$ 4,228,295**

[1] Estimated unit costs are based upon estimates from suppliers and bid tabs for similar projects throughout the western United States.

[2] The ENR 20 year average Construction Cost Index is +3.06% (as of November 2011), so capital costs are projected to an anticipated construction date in 2023 using a 3.06% yearly inflation rate.

6.0 SELECTION OF AN ALTERNATIVE

Each of the technically feasible alternatives considered meet the design criteria and applicable regulations identified in the alternative description. This section will examine advantages and disadvantages of each in terms of life cycle costs, maintenance considerations, environmental/permitting impacts and public health and safety.

6.1 Life Cycle Cost Analysis

The cost of extensive capital improvements to meet minimum health and safety requirements, applicable regulations, and environmental impacts is a great concern to communities with limited budgets and resources. At the same time, some alternatives may have a low capital cost but high maintenance (or replacement) costs that will put a continual burden on the community. A life cycle cost analysis provides a method to compare the costs of each alternative to one another.

To complete the life cycle cost analysis, the anticipated annual increase due to maintenance and additional project costs are completed for a 75-year design life. Salvage values are not assumed due to the projects not consisting of tangible salvageable items and are largely cast-in-place concrete or anchoring systems through the dam. Design life for new dams is generally assumed to be 75 to 100-years, so usage of 75-year design life is assumed.

6.2 Ranking Criteria

A matrix to compare each alternative objectively against the other will be developed to select the preferred alternative. Each alternative will be given a score ranging from 0 to 10 for a number of criteria, with 0 representing a negative impact and 10 representing the maximum benefit to the community. The alternatives will begin with a score of 5 for each criterion, and then the score will be adjusted up or down relative to the benefit of the particular alternative in relation to the other alternatives.

In addition to scoring each alternative, the criteria themselves with be weighted in relation to one another. Weighting factors ranging from 1 to 10 will be used to give greater importance to items such as cost. This is appropriate, as often times higher investments are made to overcome many other problems such as reliability or to mitigate problems with technical feasibility or environmental concerns.

6.2.1 Life Cycle Costs

The cost of extensive capital improvements to meet minimum health and safety requirements, applicable regulations, and environmental impacts is a great concern to communities with limited budgets and resources. Life cycle costs also include anticipated increases to ongoing maintenance costs.

Accordingly, this criterion will be provided with the maximum weighting factor of 10. This represents over 30% of the total weighting.

In addition to providing the maximum emphasis on costs, a method must be utilized to provide an objective comparison of costs for each alternative relative to one another and not just an overall comparison. Given a range of costs for various alternatives, the relative cost of any alternative can be determined using the lowest cost and the highest cost from the range of costs and the following equation.

$$5 \times [(\text{Lowest Cost}) / (\text{Cost}) + (\text{Highest Cost} - \text{Cost}) / (\text{Highest Cost})]$$

For example, if a number of alternatives were compared having life cycle costs of $500,000, $1,000,000 and $2,000,000, the above equation would provide scores of 8.8, 5.0, and 1.3, respectively. The utilization of a formula to score the 75- year life cycle costs in the matrix eliminates any subjectivity and provides a consistent, relative comparison of costs.

Tables 6-1 through 6-3 below show development of 75-year costs for each of the alternatives.

Table 6-1: 75-Year Present Worth Analysis – Alternative 1

TABLE 6-1 75-YEAR PRESENT WORTH ANALYSIS - ALTERNATIVE 1			
Maintenance/Project Description	**Frequency (years)**	**Cost per Repair**	**Total Cost**
Periodic Concrete Face Repair (Year 0-5).	5	$12,500	$25,000
Full Dam Face Structural Overlay (Year 5)	50	$850,000	$850,000
Parapet & Dam Face Repairs (Year 55-75)	5	$12,500	$50,000
Useful Life (years)	75		
Maintenance/Projects			$ 925,000
CAPITAL COSTS			$ 1,196,521
TOTAL (75 YEAR COST)			**$ 2,121,521**

Table 6-2: 75-Year Present Worth Analysis – Alternative 2

TABLE 6-2 75-YEAR PRESENT WORTH ANALYSIS - ALTERNATIVE 2			
Maintenance/Project Description	**Frequency (years)**	**Cost per Repair**	**Total Cost**
Parapet & Dam Face Repairs (Year 50-75)	5	$12,500	$62,500
Useful Life (years)	75		
Maintenance/Projects			$ 62,500
CAPITAL COSTS			$ 2,030,052
TOTAL (75 YEAR COST)			**$ 2,092,552**

Table 6-3: 75-Year Present Worth Analysis – Alternative 3

TABLE 6-3 75-YEAR PRESENT WORTH ANALYSIS - ALTERNATIVE 3			
Maintenance/Project Description	**Frequency (years)**	**Cost per Repair**	**Total Cost**
Misc. Minor Concrete Repairs	25	$5,000	$25,000
Useful Life (years)	75		
Maintenance/Projects			$ 25,000
CAPITAL COSTS			$ 4,228,295
TOTAL (75 YEAR COST)			**$ 4,253,295**

6.2.2 Maintenance Considerations

Maintenance is an important issue when considering dam rehabilitation alternatives. The costs for maintenance associated with the alternatives is included in the 75 year present worth costs compared under the financial feasibility, but there are other considerations that must be weighed for the maintenance associated with each alternative.

BSB has limited resources and manpower, and some alternatives may have maintenance requirements that drastically tax those limited resources creating deficiencies in other areas.

The selected alternatives have negligible operational costs are they are largely permanent structural installations with no automation or inherent operational items.

This criterion will be provided with a weighting factor of 5.

6.2.3 Environmental Impacts and Permitting Requirements

While the alternatives generally are related to improvements on the dam face/crest area, some may have more permitting requirements or potential environmental impacts than others. Environmental impacts for each alternative, whether detrimental or beneficial, need to be considered in the final selection of a preferred alternative. Consideration for these concerns will be given under this criterion.

This criterion will be provided with a weighting factor of 7.

6.2.4 Public Health and Safety

Alternatives that do not meet the public health and safety requirements as required by state agencies were eliminated during the alternative development. The alternatives retained for the alternative analysis are designed to meet public health and safety, so the scoring for each alternative under this criterion would be expected to be fairly high. However, addressing public health and safety concerns is the main purpose of the entire report, so this category will be given the maximum weighting.

This criterion will be provided with a weighting factor of 10.

6.3 Scoring of Rehabilitation Alternatives

Three rehabilitation alternatives were considered to meet the needs of the project. They are:

- Alternative 1: Replacement of the Parapet Wall and Installation of Post-Tensioned Anchors
- Alternative 2: Replacement of the Parapet Wall, Full Structural Concrete Overlay over Dam Face and Installation of Post-Tensioned Anchors
- Alternative 3: Full Removal of 13-foot deep mass concrete cap to the masonry interface. Installation of new mass concrete section with anchorage system into the masonry core.

6.3.1 Life Cycle Costs

The life cycle costs were calculated and are as follows:

- Alternative 1: 7.4
- Alternative 2: 7.5
- Alternative 3: 2.5

Refer to Table 6-4 below for calculations:

Table 6-4: Basin Creek Dam #1 Rehabilitation Alternatives – Life Cycle Costs

Table 6-4 - Basin Creek Dam #1 Rehabilitation Alternatives - Life Cycle Costs				
Alternative	Initial Capital Cost	75-Year PW Increase	75 -Year Cost	Criteria Score
Structural Rehabilitation Alternatives				
1	$1,196,521	$925,000	$2,121,521	**7.4**
2	$2,030,052	$62,500	$2,092,552	**7.5**
3	$4,228,295	$25,000	$4,253,295	**2.5**

6.3.2 Maintenance Considerations

Due to the nature of the proposed rehabilitation, maintenance considerations for each alternative is variable. Alternative 1 exhibits the most ongoing maintenance due to lack of addressing the poor condition of the upstream concrete dam face. Alternative 3 exhibits the least maintenance due to replacement of the entire upper 13-feet of mass concrete.

- Alternative 1: 4
- Alternative 2: 9
- Alternative 3: 10

6.3.3 Environmental Impacts and Permitting Requirements

The permitting and environmental issues associated with each alternative vary slightly. Alternative 1 will likely have the least impact due to the minimal amount of on-site material removal and assumption that most work can be done from the dam crest and minimal modifications to the reservoir surface level would be required. Alternative 2 and 3 will have more impact due to additional removal quantities, lowering of the reservoir and possible access considerations from the reservoir. The alternatives were scored as follows:

- Alternative 1: 9
- Alternative 2: 7
- Alternative 3: 7

6.3.4 Public Health and Safety

The public health and safety impacts associated with each alternative are similar, however Alternative 1 does not completely address the poor condition of the upstream dam face, which would need to be addressed in the near future (approximately 5 years assumed), if not completed.

- Alternative 1: 8
- Alternative 2: 10
- Alternative 3: 10

6.4 Decision Matrix and Selection of Preferred Alternative

Table 6-5 was developed to provide a concise comparison of the alternatives using the criteria, scoring, and weighting factors previously described.

The decision matrix indicates that the Alternative 2 is the best a rehabilitation alternative for BSB. The primary factors influencing the selection of the preferred alternative are life cycle costs, maintenance considerations, and public health and safety. A detailed description of the preferred alternative is provided in Chapter 7.

Table 6-5: Decision Matrix

	Life Cycle Costs		Maintenance		Environmental/ Permitting		Public Health and Safety		TOTAL
	Weight:	10	Weight:	5	Weight:	7	Weight:	10	
Alternative	Score	Wtd.	Score	Wtd.	Score	Wtd.	Score	Wtd.	
Basin Creek Dam #1 Rehabilitation Alternatives									
1	7.4	74	4	20	9	63	8	80	**237**
2	7.5	75	9	45	7	49	10	100	**269**
3	2.5	25	10	50	7	49	10	100	**224**

It is important to note that the above scoring and weighting are subjective. Alternatives that score overall within 10 pts of each other may essentially hold the same degree of preference.

7.0 PROPOSED PROJECT

Based on the alternatives analysis, Alternative 2 is the preferred alternative and includes full removal and replacement of the parapet wall, structural concrete overlay over the dam face and installation of post tensioned anchorages through the mass concrete into the masonry core. Replacement of the parapet wall would prevent ongoing maintenance of the freeze/thaw damage and reduce the concerns for parapet failure during the PMF. Rehabilitation of the dam face will also reduce future maintenance concerns and increase longevity of the mass concrete section. The post tensioned anchorages would provide additional sliding and overturning stability during the PMF to meet current standards. Gannett Fleming has indicated that based on their conceptual analysis, a total of fourteen 2” diameter post-tension anchor rods, each rated to 140 KIPS, will be required. The anticipated total length of each rod is 40 feet.

7.1 Preliminary Project Design

Design criteria for each alternative was discussed in detail in Chapter 5. The following sections provide a summary of the design criteria relevant to the preferred alternative. The preferred alternative is shown in Figures 7-1 and 7-2.

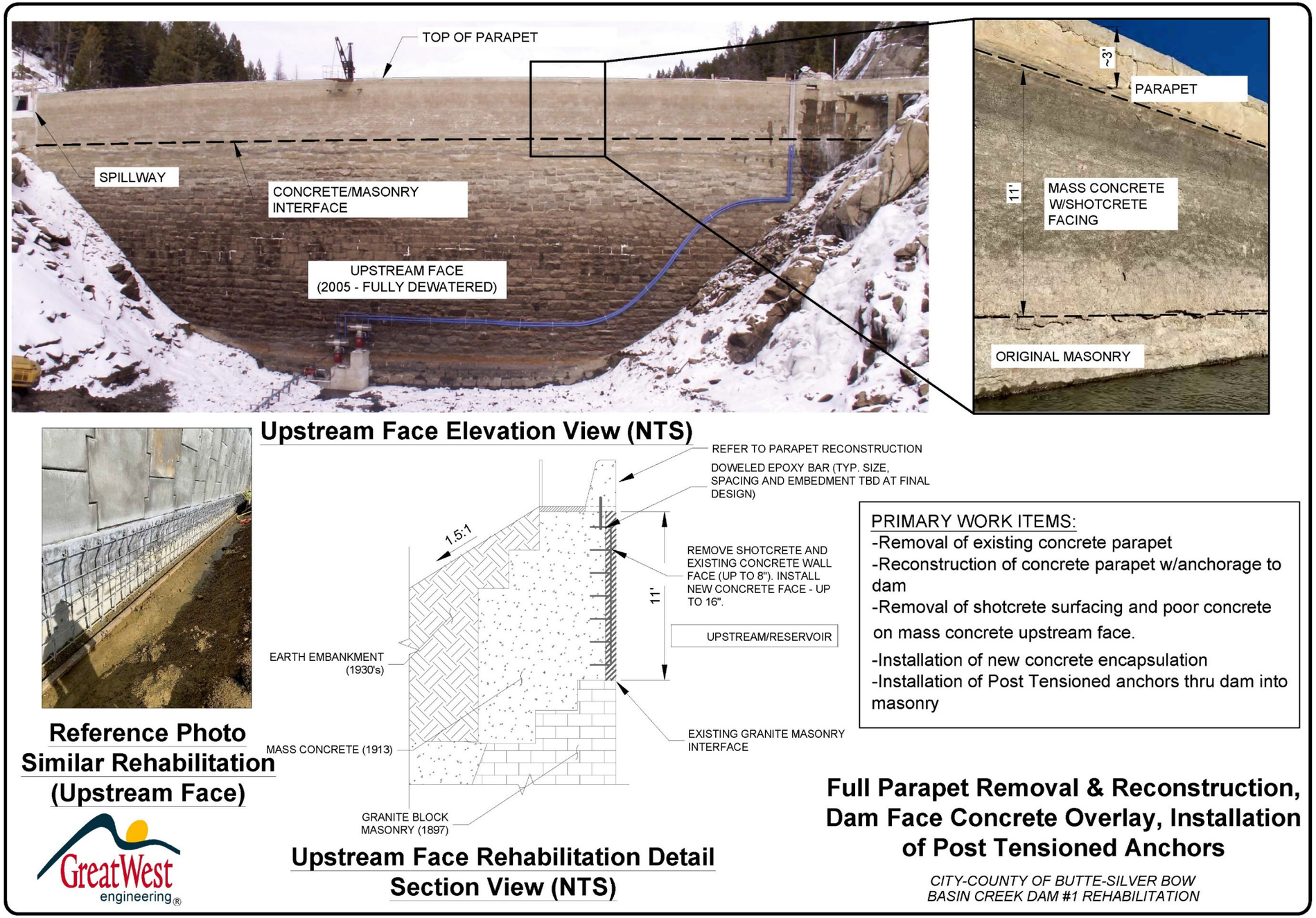
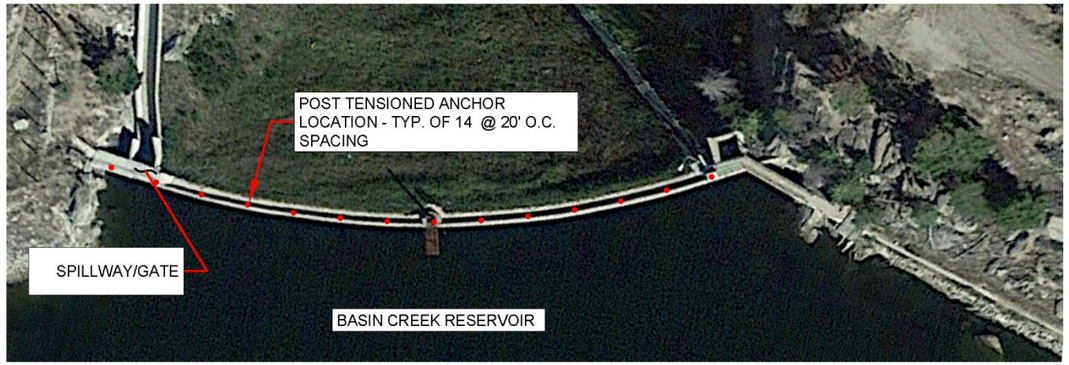
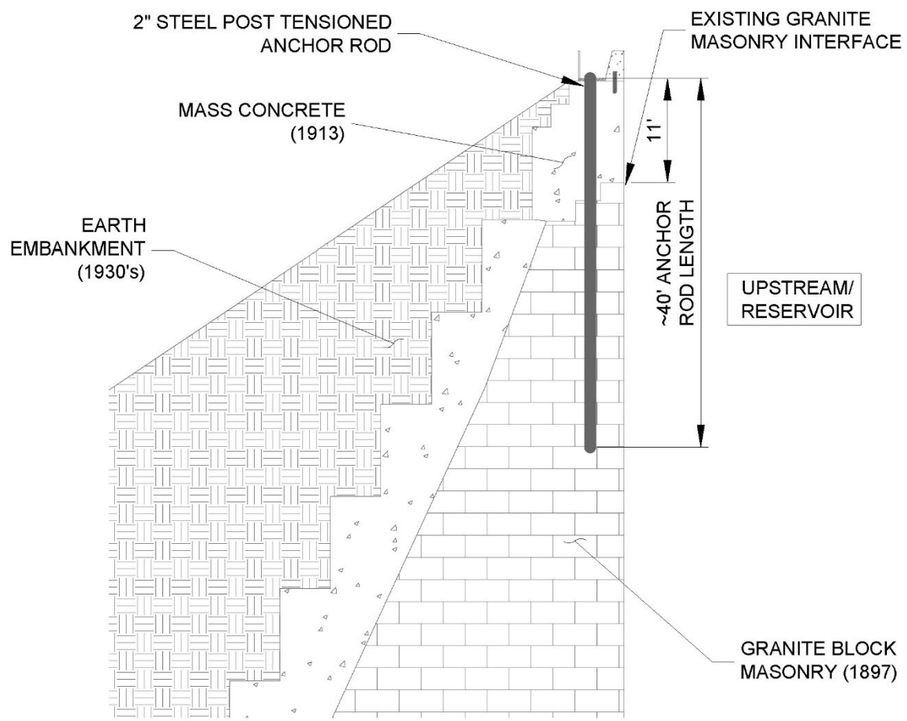


Figure 7-1: Selected Alternative: Full Parapet Removal & Reconstruction, Dam Face Concrete Overlay, Installation of Post Tensioned Anchors



Plan View of Dam - Showing Prelim. Anchor Locations (NTS)



Section View of Dam
Showing Prelim. Anchor Configuration (NTS)

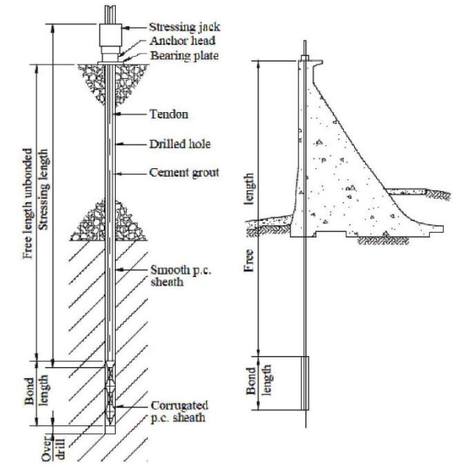


Fig. 1. Components of a typical large, permanent, post-tensioned dam rock anchor (Cavill, 1997).

Anchorage Schematic
Journal of Rock Mechanics & Geotechnical Eng.

Typical Drill Rig
SOURCE: THIRD POST-TENSIONED ANCHORS STABILIZATION AT OLMOS DAM

CITY-COUNTY OF BUTTE-SILVER BOW
BASIN CREEK DAM #1 REHABILITATION

Figure 7-2: Selected Alternative: Anchorage System

7.1.1 Design Criteria

The dam improvement design will follow best practice guidelines for similar public dam infrastructure improvement projects. Additionally, the dam design will meet applicable criteria furnished by DNRC and will be subject to review by DNRC Dam Safety during the design process before re-issuance of the operating permit. During the final design stage, seismic loading analysis will occur for structural improvements and anchorage design.

7.2 Project Schedule

Chapter 8 of this report includes a detailed implementation schedule. Tasks associated with implementation of the project include securing funding, permitting, design, bidding, and construction. It is anticipated that funding will become available in July of 2021. BSB funding for the project will occur in FY 2023, which begins in July 2022, at which point permitting and design will commence. Design plans and specifications for the rehabilitation project will be submitted to DNRC and other required agencies for approval in winter of 2023. Bidding of the project will occur in Spring 2023 and construction of the project will occur in Fall of 2023.

7.3 Permit Requirements

Coordination and consultation with the United States Army Corps of Engineers, BSB Floodplain Administrator, DEQ and MT FWP will determine the extent of permitting required for the necessary improvements. Specific permitting requirements will be determined during the permitting portion of the Project Design Phase.

The Montana DEQ requires an asbestos inspection be performed by an accredited inspector prior to component demolition/removal. The MDEQ may exercise its right to waive the asbestos inspection requirement depending on the type of structure and its components.

During the design phase, if deemed necessary by the Corps of Engineers, a wetland delineation may be performed in order to map potential wetland impacts. However, no known wetlands are anticipated due to the relatively limited work area on the existing dam and history of disturbance.

During the design phase, it may be necessary to complete an inventory for Whitebark Pine at the project site, if requested by the USFWS. However, no known Whitebark Pine are in the project vicinity and no trees are currently present within the expected project impact area.

During the design phase, if deemed necessary by the lead federal agency, an independent consultant will perform a historic recordation of the Basin Creek Dam and/or cultural investigation in the dam vicinity.

All contractor staging areas are assumed to be on BSB property or within established right-of-ways/easements. No easements (temporary or permanent) or land acquisition is anticipated for this project due to the relatively limited area of construction.

7.4 Sustainability Considerations

The rehabilitation project will ensure the existing dam can function with the minimal amount of material removal and modification to the structure. Keeping the recently constructed Basin Creek WTP operational presents environmental, social, and economic benefits for local residents by retaining water quality, energy efficiency, fire suppression and providing a public utility that can effectively accept growth.

7.4.1 Green Infrastructure

Stormwater management during the project will include temporary erosion and sediment control measures including the installation and maintenance of temporary measures to reduce or eliminate the erosion of soils and transport of sediment offsite as a result of construction activities. Due to the limited surface area of work, minimal impacts are anticipated.

7.5 Total Project Cost Estimate

Table 7-1 provides a total project cost estimate for the proposed project.

Table 7-1: Opinion of Probable Cost – Preferred Alternative

TABLE 7-1 OPINION OF PROBABLE COST - PREFERRED ALTERNATIVE BASIN CREEK DAM #1 REHABILATION ALTERNATIVE 2 - CONCRETE PARAPET REPLACEMENT, DAM FACE OVERLAY AND POST-TENSIONED ANCHOR INSTALLATION					
#	BID ITEM	QTY	UNITS	UNIT PRICE [1]	TOTAL
1	Concrete Removal, Surface Preparation & Debris Containment - 240 Linear Feet of Parapet (Parapet Only)	1	LS	$ 20,000.00	$ 20,000
2	Structural Concrete, Reinforcing and Anchorage Into Existing Mass Concrete (Parapet Only)	50	CY	$ 1,425.00	$ 71,250
3	Concrete/Shotcrete Removal, Surface Preparation & Debris Containment - 2640 SF of dam face (240' long x 11' high) (Dam Face Only)	1	LS	$ 105,600.00	$ 105,600
4	Structural Concrete, Reinforcing and Anchorage Into Existing Mass Concrete - 2640 SF of dam face. Assume 16" thick facing - (Dam Face Only)	132	CY	$ 2,350.00	$ 310,200
5	Supply and Installation of Post Tensioned Anchor Rods, 40' Length (PMF)	14	EA	$ 30,000.00	$ 420,000
6	Removal & Disposal of Existing Handrail	240	LF	$ 10.00	$ 2,400
7	Removal & Disposal of Existing Walkway	720	SF	$ 4.00	$ 2,880
8	Install New Walkway (3' width x 4" depth - assumed)	720	SF	$ 12.00	$ 8,640
9	Install New Handrail	240	LF	$ 60.00	$ 14,400
	Direct Construction Subtotal				**$ 955,400**
	Mobilization & Demobilization		15%		$ 143,300
	Contingency		20%		$ 219,700
	Construction Subtotal				**$ 1,318,400**
	2023 Construction Cost [2]		9.18%		$ 1,439,400
	Historic Recordation/Cultural Investigation				$ 6,000
	Engineering (Permitting, Design & Analysis)				$ 313,680
	Engineering (Contract Construction Administration)				$ 224,128
	Asbestos Testing				$ 750
	Geotechnical Investigation				$ 25,000
	Grant Administration				$ 21,094
	TOTAL				**$ 2,030,052**

[1] Estimated unit costs are based upon estimates from suppliers and bid tabs for similar projects throughout the western United States.

[2] The ENR 20 year average Construction Cost Index is +3.06% (as of November 2011), so capital costs are projected to an anticipated construction date in 2023 using a 3.06% yearly inflation rate.

7.6 Financial Status of Existing Facilities

A summary of the Water Utility Division's operating expenses and revenue for the past three years is included in Table 7-2. Detailed revenue and expense reports are included in Appendix U. Almost all of the revenue comes from charges for services, investment earnings, and interest income. Expenses include items such as personnel, operation and maintenance, and depreciation. In the fiscal year 2019, BSB invested $565,000 to purchase fixed assets ranging from fencing and window replacements to new telemetry and controls. For the fiscal year 2020, BSB has approved the investment of $859,460 of fixed assets, including roof repairs, groundwater restoration, and a variety of other improvements. The Water Utility Division has only one loan. DEQ issued the State Revolving Funding loan for $2.2 million in 2011. The current balance is $1.6 million, and the annual debt service is $157,000.

The average residential user rate for drinking water is $52.07/user/month. The monthly residential sewer rate is $28.50. The Water Utility currently has 12,743 hookups with 11,246 residential connections.

Table 7-2: Summary of Revenues and Operating Expenses

City-County of Butte-Silver Bow Water Utility Division Summary of Revenues and Operating Expenses			
Description	**2017**	**2018**	**2019**
Revenues	**$8,610,444**	**$9,149,257**	**$9,872,064**
Operating Expenses			
Personnel Services	$3,744,400	$3,832,447	$3,287,181
Operation and Maintenance	$2,717,635	$2,437,462	$2,414,195
Depreciation	$3,834,080	$4,960,821	$4,997,915
Total Operating Expenses	$10,296,115	$11,230,730	$10,699,291
Operating Income	($1,685,671)	($2,081,473)	($827,227)
Total Non-Operating Revenues (Expenses)	$86,166	($379,689)	$195,677
Income (Loss) Before Capital Grants & Transfers	($1,599,505)	($2,461,162)	($631,550)
Capital Grants	$10,548,864	$1,477,801	$215,326
Transfers In	-	-	$20,000
Transfers Out	($311,343)	($316,013)	($320,684)
Change in Net Position	**$8,638,016**	**($1,394,243)**	**($716,908)**
Net Position, Beginning of Year	**$75,579,076**	**$84,217,092**	**$82,822,849**
Net Position, End of Year	**$84,217,092**	**$82,822,849**	**$82,105,941**

8.0 CONCLUSIONS AND RECOMMENDATIONS

The previous sections of this report have focused on the need for the project, physical and socioeconomic characteristics of BSB, project costs, and more extensively the technical viability. This section will focus on the financial strategy and implementation schedule. One of the main goals of a comprehensive PER is to provide a workable funding plan for recommended improvements included in the Preferred Alternative. This section will discuss available funding sources as well as develop various funding scenarios. Ultimately, a preferred funding scenario will be selected and further analyzed along with an associated implementation plan.

8.1 Funding

Due to the high cost of the proposed improvements, BSB plans to pursue outside assistance to fund the project in the form of grants and/or loans. Before examining the funding sources available to the project, it is essential to understand the concept of "Target Rate" as established by the Montana Department of Commerce (MDOC). The target rate is used to determine whether or not a municipality is paying its fair share of a project's cost. To apply for grant funding from the MDOC, the user rates after completion of the project must meet or exceed the established target rates.

The target rates are calculated as a percentage of the median household income (MHI) for the municipality, as listed in the 2015 American Community Survey. The MDOC has determined, based on surveying communities that have undergone recent upgrades to their water and/or wastewater systems that the "fair share" of cost per user after completing a project should be approximately 1.4% of the median household income for water only, 0.9% for wastewater only, or 2.3% for water and wastewater combined.

According to MDOC's website, the MHI for BSB is $37,686, and the combined target rate is $72.23. BSB's average monthly residential water rate is $52.07, and the average residential sewer rate is $28.50. The combined rate of $80.57 is 112% of the MDOC target rate for BSB, which qualifies the project for a $500,000 grant from Montana's Treasure State Endowment Program.

8.1.1 Funding Sources

The following sections provide a brief description of the potential funding sources and whether or not BSB would be eligible for those funds.

Treasure State Endowment Program (TSEP)

TSEP is a state funded grant program, which is administered by the Montana Department of Commerce (MDOC). TSEP provides financial assistance to local governments for infrastructure improvements. Grants can be obtained from TSEP for up to $500,000 if the projected user rates are less than 125% of the target rate, for up to $625,000 if projected user rates are between 125% and 150% of the target rate, and for up to $750,000 if the projected user rates are over 150% of the target rate. TSEP grant recipients are required to match the grant dollar for dollar, but the match may come from a variety of sources including other grants, loans, or cash contributions.

As previously described, BSB's monthly average water and wastewater rate of $80.57 or 112% of the MDOC's target rate, which qualifies the project for a $500,000 TSEP grant.

Renewable Resource Grant and Loan Program (RRGL)

RRGL is a state program that is funded through interest accrues on the Resource Indemnity Trust Fund and the sale or Coal Severance Tax Bonds and is administered by the Montana Department of Natural Resources and Conservation (DNRC). The primary purpose of the RRGL is to enhance Montana's renewable resources. For public facilities projects that conserve, manage, develop, or protect renewable resources, grants of up $125,000 are available.

Although the RRGL program is competitive, the proposed project will be promoting benefits to renewable resources. Therefore, the maximum of $125,000 is considered in the funding package for this project.

Community Development Block Grant (CDBG)

CDBG is a federally funded program that is also administered by the Montana Department of Commerce (MDOC). The primary purpose of CDBG funds is to benefit low to moderate income (LMI) families. Hence, a municipality must have an LMI of 51% or greater. This is usually determined by the current Census. However, under certain circumstances, the MDOC may allow an income survey to be completed (such as there have been major economic changes since the Census or if a community is only slightly under the required LMI percentage).

The CDBG grant funds can be applied for in an amount of up to $450,000 with a limit of $15,000 per LMI household, so a community needs 30 LMI households to apply for the maximum grant funds. The use of CDBG funds requires a 25% local match that can be provided through cash funds, loans, or a combination thereof.

Based on the 2015 American Community Survey data, BSB does not qualify for CDBG funding. For that reason, the preferred funding strategy assumes no CDBG funds will be available for the proposed project.

State Revolving Fund (SRF)

SRF provides low-interest loan funds for both water and wastewater projects through the Drinking Water State Revolving Fund (DWSRF) and the Water Pollution Control State Revolving Fund (WPCSRF), respectively. The SRF program is administered by the Montana Department of Environmental Quality. Current loan terms include an interest rate of 2.5% for a 20-year period.

SRF also has a limited amount of "principal forgiveness" funds available for projects. For water projects, 50% of the SRF funding for a project, up to $500,000 may be obtained, depending on the availability of funds. However, because of the impact of COVID-19 on the local economy, BSB's leadership decided that the proposed project must be done without debt to avoid adding additional strain to a fragile economy and to maintain public support for the project.

USDA Rural Development (RD)

RD provides grant and loan funding to municipalities for water and wastewater projects that improve the quality of life and promote economic development in Rural America. Municipalities with a population of less than 10,000 are eligible to apply, though; priority is given to those with a population of less than 5,500.

With a population of 33,671 (2015, American Community Survey) BSB is not eligible to apply for funding from USDA Rural Development.

Montana Coal Board

The Coal Board provides grant funding to municipalities to adequately provide for the expansion of public services or facilities needed as a direct consequence of coal development activities. Butte-Silver Bow is located outside of Montana's Coal Impact Area and therefore, not eligible to receive funding from the Coal Board.

Economic Development Administration (EDA)

EDA provides grant funding for projects that can demonstrate that EDA's investment would directly create high-paying long-term jobs or retain existing high-paying jobs. The proposed project will not directly create long-term employment and for that reason, BSB did not consider EDA funding for the project.

INTERCAP

INTERCAP provides loan funds at a low cost, variable interest rate to local governments. INTERCAP is administered by the Montana Board of Investments and is very flexible in the variety of funding which would include both water and wastewater projects. There is no funding cycle (funds are always available), however, the maximum loan term is limited to 15 years and the interest rate is currently 2.5%.

Because of the impact of COVID-19 on the local economy, BSB's leadership the proposed project would done without debt and for that reason the INTERCAP Program was not considered as a source of funding for the project.

BRIC Program

This fall, FEMA is expected to release the Notice of Funding Opportunity (NOFO) for its BRIC Program. BRIC is a new FEMA pre-disaster hazard mitigation program that replaces the existing Pre-Disaster Mitigation (PDM) program. Given the condition of Basin Creek Dam #1 and the potential impact on public safety, it appears the proposed project would be competitive for BRIC funding. BRIC funding requires a 25% non-federal match. If BRIC funding is obtained, TSEP and DNRC RRGL funds could be utilized to provide a portion of this non-federal match. BSB will consider this option when FEMA issues the NOFO this fall.

If BSB applies for the funding and is successful, it would allow the development of the project to begin in 2021 rather than 2022.

8.1.2 Funding Strategy

Numerous options have been identified as potential funding sources for the project. Due to the importance of the project to protect public health and safety as well as the benefits to Montana's natural resources, BSB has a good chance in obtaining funds through TSEP and DNRC. BSB's preferred funding package and recommended by this PER includes:

- $500,000 TSEP Grant
- $125,000 DNRC Grant
- $1,405,052 BSB

Table 8-1: Project Budget

Completed By: Great West Engineering BSB - Basin Creek #1 Dam Rehabilitation				
Administrative/Finance Costs	Source: TSEP	Source: DNRC-RRGL	Source: Butte-Silver Bow	Total:
Personnel Costs				$ -
Office Costs				$ -
Professional Services			$ 21,094	$ 21,094
Legal Costs				$ -
Travel & Training				$ -
ADMIN/FINANCE COSTS:	$ -	$ -	$ 21,094	$ 21,094
Cultural Investigation		$ 6,000		$ 6,000
Asbestos Testing		$ 750		$ 750
Geotechnical Investigation		$ 25,000		$ 25,000
Engineering Basic Services – Pre-Design, Final Design, Permitting)	$ 237,694	$ 75,986		$ 313,680
Engineering - Construction Services			$ 224,128	$ 224,128
Construction	$ 262,306	$ 17,264	$ 940,130	$ 1,219,700
Contingency			$ 219,700	$ 219,700
ACTIVITY COSTS	$ 500,000	$ 125,000	$ 1,383,958	$ 2,008,958
TOTAL PROJECT COSTS	**$ 500,000**	**$ 125,000**	**$ 1,405,052**	**$ 2,030,052**

8.2 Implementation

Prior to implementation of the proposed project, all funding must be in place. As noted earlier, the proposed funding package for BSB utilizes TSEP and DNRC grants. Tasks associated with implementation of the project include securing funding, permitting, design, bidding, and construction. It is anticipated that funding will become available in July of 2021. BSB funding for the project will occur in FY 2023, which begins in July 2022, at which point permitting and design will commence. Design plans and specifications for the rehabilitation project will be submitted to DNRC and other required agencies for approval in winter of 2023. Bidding of the project will occur in Spring 2023 and construction of the project will occur in Fall of 2023.

Table 8-2 provides a summary of the Project Implementation Schedule.

Table 8-2: Project Implementation Schedule

Butte-Silver Bow – Basin Creek Dam #1 Rehabilitation Project Implementation Schedule	
Action	**Date**
Public Hearing on Draft PER & EA	June 2020
Apply for TSEP & DNRC Grants	June 2020
Finalize Grant Financing	May/June 2021
Begin Design	July 2022
Design Basis Report/Cost Estimates to BSB	December 2022
Submit Design Plans and Specifications to DNRC	February 2023
DNRC Review & Approval	March 2023
Advertise for Bids	April 2023
Start Construction	July/August 2023
Complete Construction	October/November 2023

9.0 REFERENCES

Montana Department of Environmental Quality, 2020-a. Air Quality Nonattainment Information. http://deq.mt.gov/Air/2017Air/Standards/airnonattainment

Montana Department of Environmental Quality, 2020-b. Interactive web mapping application. http://svc.mt.gov/deq/wmadst/default.aspx?type=SWP

Montana State Library, 2020. Montana Cadastral. http://svc.mt.gov/msl/mtcadastral/

State of Montana, 2020. Montana Sage Grouse Habitat Conservation Map. https://sagegrouse.mt.gov/ProgramMap

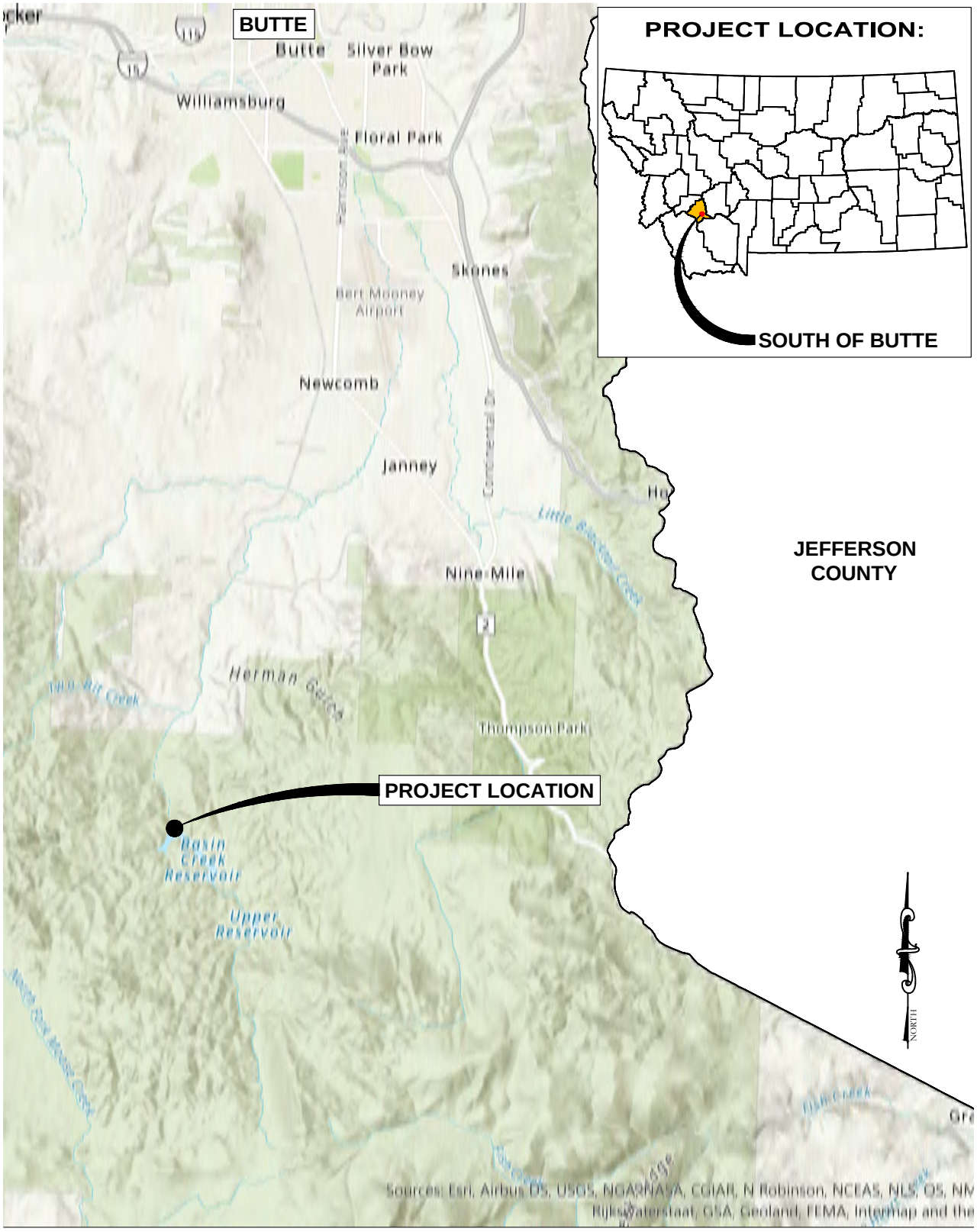
US Department of Agriculture, Natural Resources Conservation Service, 2020. Soil Resource Report. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

US Department of Homeland Security, Federal Emergency Management Agency, 2020. FEMA Flood Map Service Center. https://msc.fema.gov/portal/search

US Fish and Wildlife Service, 2020. National Wetlands Inventory, Wetlands Mapper. https://www.fws.gov/wetlands/data/mapper.html

APPENDIX A

Site Maps and Topographic Maps



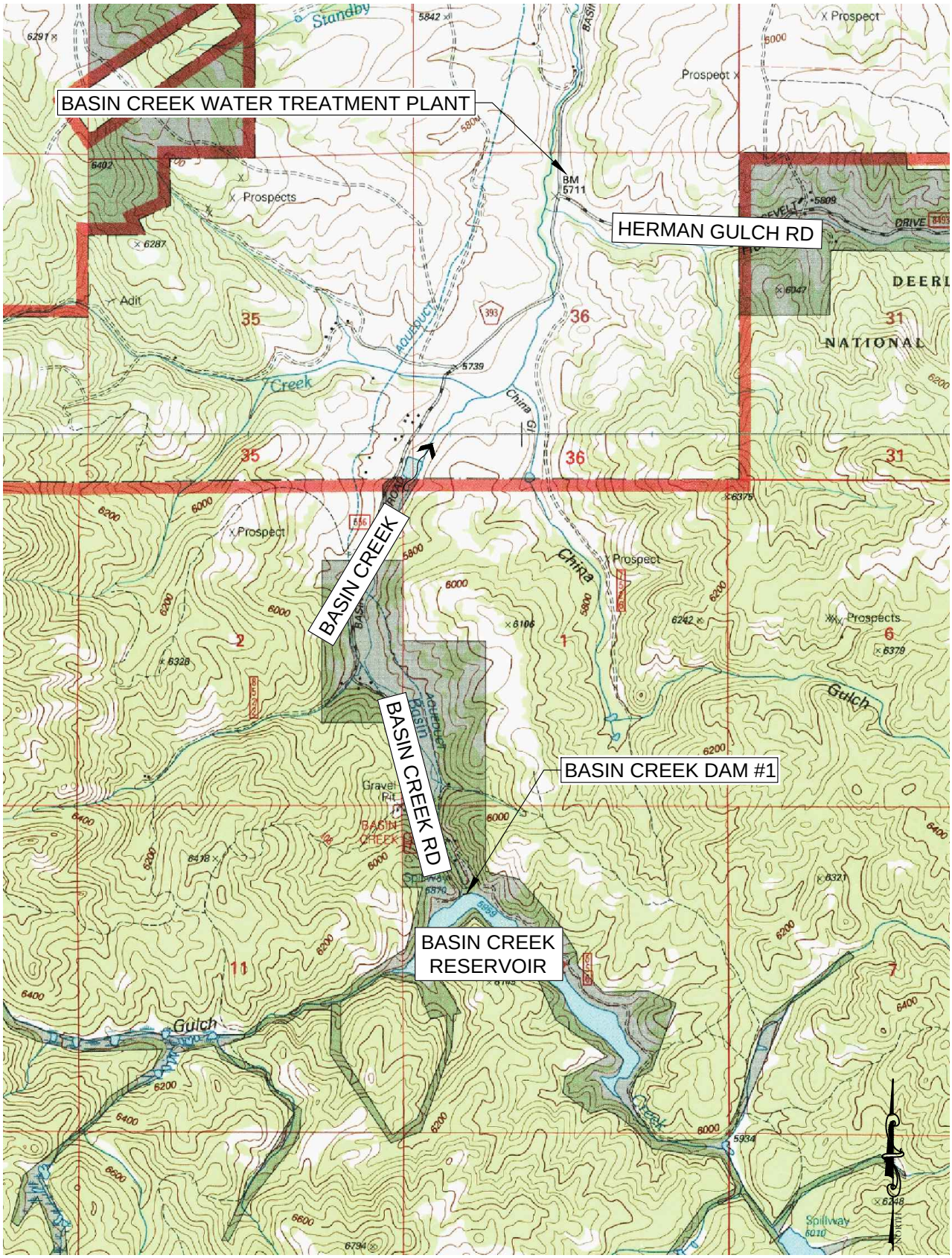
0 5000 10000
SCALE IN FEET

Figure 1
Basin Creek Dam #1
Project Location

CITY-COUNTY OF BUTTE-SILVER BOW
BASIN CREEK DAM #1 REHABILITATION PER

GreatWest engineering®

F:\1-20131-BSB RRGL Grant Application\CADD 1-20131\Exhibits\BSB-State Map.dwg



NOT TO SCALE

Figure 2
Basin Creek Dam #1
General Topography

CITY-COUNTY OF BUTTE-SILVER BOW
BASIN CREEK DAM #1 REHABILITATION PER

GreatWest engineering®

F:\1-20131-BSB RRGL Grant Application\CADD 1-20131\Exhibits\BSB-Topo Map.dwg

APPENDIX B

Uniform Environmental Checklist

CITY-COUNTY OF BUTTE - SILVER BOW
Basin Creek Dam #1 Rehabilitation

Proposed Action: Basin Creek Dam #1 is a 123-year old structure originally built to assist with water supply for the City of Butte. Subsequent uses involve flood prevention, irrigation, and fish and wildlife storage. The City-County of Butte-Silver Bow [BSB] proposes to repair/rehabilitate the primary structural deficiencies associated with the recent 5-year dam inspection report, recent yearly inspections and the 2020 dam structural analysis. The improvements will protect public health and safety, continue to ensure public water storage, allow downstream irrigation usage and continue to allow fish/wildlife storage.

UNIFORM ENVIRONMENTAL CHECKLIST

DRAFT

As the Engineer that prepared the Preliminary Engineering Report, I, Ryan Elliott, PE have reviewed the information presented in this checklist and believe that it accurately identifies the environmental resources in the area and the potential impacts that the project could have on those resources. In addition, the required state and federal agencies were provided with the required information about the project and requested to provide comments on the proposed public facility project. Their comments have been incorporated into and attached to the Preliminary Engineering Report.

Engineer's Signature: _____

Date: _____

UNIFORM ENVIRONMENTAL CHECKLIST

NAME OF PROJECT:	Basin Creek Dam #1 Rehabilitation
PROPOSED ACTION:	Dam Improvements
OWNER:	City-County of Butte – Silver Bow, Montana

Key Letter:		
N: No Impact; **B:** Potentially Beneficial; **A:** Potentially Adverse; **P:** Approval/Permits Required; **M:** Mitigation Required		
PHYSICAL ENVIRONMENT		
KEY	**I**	**Soil Suitability, Topographic and/or Geologic Constraints (e.g., soil slump, steep slopes, subsidence, seismic activity)**
N		*Response and source of information:*
		NRCS Soil Maps indicate the native soil at the dam site is classified as Ambrant-Rochester families, complex, low relief mountain slopes and ridges. The soil is comprised of gravelly and sandy loams. There are no identified soil or topographical constraints. The dam is located in an outcropping of hard, massive granite. The dam abutments are keyed into granite and per the original drawings, a layer of granitic bedrock is located within close proximity to the bottom of the structure. Basin Creek Dam #1 is located within the northern section of the Intermountain Seismic Belt (ISB), a north trending zone of seismicity in the western United States. The seismic resistivity of the existing dam is already established with the geographic location of the dam and the materials and construction techniques utilized. Therefore, the proposed dam infrastructure improvements, consisting of structural and non-structural concrete repairs, are expected to have minimal impact to any future seismic related issues. During the design process, seismic analysis will be completed on any structural concrete repairs and post-tensioned anchor designs. No specific existing seismic analysis of the dam was available, nor were previous soil borings (logs) to determined suitability of adjacent soils and depth to rock. If post tension anchor designs are proposed for use in final design, soil/rock borings may be obtained to determine competency of the underlying materials. - Ryan Elliott, P.E. - USDA National Cooperative Soil Survey

Key Letter:		
N: No Impact; **B:** Potentially Beneficial; **A:** Potentially Adverse; **P:** Approval/Permits Required; **M:** Mitigation Required		
KEY	**2**	**Hazardous Facilities (e.g., power lines, EPA hazardous waste sites, acceptable distance from explosive and flammable hazards including chemical/petrochemical storage tanks, underground fuel storage tanks, and related facilities such as natural gas storage facilities & propane storage tanks)**
N		*Response and source of information:*
		A file search of the State Hazard Mapping (DEQ) and State Digital Atlas (NRIS) revealed no underground storage tanks, petroleum leak sites, hazardous substance release sites, or related facilities in the direct project vicinity. It is unknown if there are propane storage tanks in the proximity of the BSB owned dam related buildings and infrastructure. During the pre-design and survey process, identification of any hazardous items (including propane tanks) and overhead utilities will occur. Depending on the type of identified hazard, appropriate steps will be taken to mitigate these during the construction process. Prior to construction, a detailed inspection will be undertaken by contacting a utility location service. If underground utilities are located within the affected area, they will be relocated. Typically, such relocations are completed by the utility company at no cost to BSB. - Ryan Elliott, P.E. - Digital Mapping Index, Montana DEQ

Key Letter:		
N: No Impact; **B:** Potentially Beneficial; **A:** Potentially Adverse; **P:** Approval/Permits Required; **M:** Mitigation Required		
KEY	**3**	**Effects of Project on Surrounding Air Quality or Any Kind of Effects of Existing Air Quality on Project (e.g., dust, odors, emissions)**
N		*Response and source of information:*
		The project is not located in an air quality Attainment area, as set by the U.S. Environmental Protection Agency's National Ambient Air Quality Standards. The only anticipated impacts on air quality are anticipated to be temporary dust during construction. The contractor will be responsible for necessary dust control. The project is not anticipated to impact surrounding air quality or pose concerns regarding the national standards. - Ryan Elliott, P.E. - EPA
KEY	**4**	**Groundwater Resources & Aquifers (e.g., quantity, quality, distribution, depth to groundwater, sole source aquifers)**
N		*Response and source of information:*
		Given the nature of the construction activities, the proposed project is not anticipated to have any impact on groundwater resources and aquifers. - Ryan Elliott, P.E.
KEY	**5**	**Surface Water/Water Quality, Quantity & Distribution (e.g., streams, lakes, storm runoff, irrigation systems, canals)**
P		*Response and source of information:*
		BSB intends to work with the Contractor to coordinate the proposed project so that as much of the work as possible can be implemented during periods of low reservoir levels. Some temporary reservoir lowering, depending on the selected alternative, may be required. Due to the type of anticipated rehabilitation, dewatering utilizing cofferdams or other means is not anticipated. Emphasis will be placed on completing any in-water work in the shortest amount of time possible. Limited temporary adverse effects to water quality are expected during construction of the repairs. Debris containment measures will be required to prevent construction debris/materials from entering the waterway. No refueling of equipment will take place within 100 feet of the ordinary high-water reservoir mark or any wetland boundary. The Contractor will be required to have spill kits (minimum of 5-gallon capacity) on board each piece of equipment at all times when working near water. The Contractor will be required to inspect all equipment for oil, gas, diesel, antifreeze, hydraulic fluid, or other petroleum leaks prior to entering the construction site. If a leak is detected, the leak will be repaired prior to the equipment being allowed to work on the project site. No construction equipment will operate within the lake unless it is specifically permitted to do so. All of the potential rehabilitation alternatives are anticipated to disturb less than one acre of existing ground. As a result, a Storm Water Permit is not anticipated to be required at this time. All additional necessary permits will be acquired prior to construction and the contractor will be required to abide by the conditions set forth by these permits.

Key Letter:		
N: No Impact; **B:** Potentially Beneficial; **A:** Potentially Adverse; **P:** Approval/Permits Required; **M:** Mitigation Required		
		- Ryan Elliott, P.E.
KEY	**6**	**Floodplains & Floodplain Management (Identify any floodplains within one mile of the boundary of the project.)**
N		*Response and source of information:*
		The dam and surrounding lands upstream and downstream of the dam occur in FEMA floodplain map panel 30093C0456E (Effective January 2012). The dam and reservoir are located in designated Zone D (areas in which flood hazards are undetermined, but possible). Zone A (special flood hazard area) floodplain in Basin Creek starts approximately 1.4 riverine miles to the north (downstream) of the dam. No impacts to Basin Creek are anticipated as a result of this project and therefore no impact to floodplains are anticipated. - Ryan Elliott, P.E. - FEMA Community Panels

Key Letter:		
N: No Impact; **B:** Potentially Beneficial; **A:** Potentially Adverse; **P:** Approval/Permits Required; **M:** Mitigation Required		
KEY	**7**	**Wetlands Protection (Identify any wetlands within one mile of the boundary of the project.)**
P		*Response and source of information:*
		Based on information from the USFWS Survey National Wetlands Inventory (excluding the adjacent Basin Creek Reservoir), there may be riverine wetlands present on Basin Creek, located just downstream of the spillway terminus. Wetland impacts on Basin Creek downstream of the dam are not anticipated due to the proximal location of the work on the dam face. Christina Schroeder of the Army Corps of Engineers indicates, *"…it appears regulated activities may be proposed and jurisdictional waters of the U.S. are present within the project area. If your final design includes the placement of fill material in any jurisdictional area described above, or otherwise requires authorization by a DA permit, please submit a Montana Joint Permit Application to this office prior to starting any work. After a review of the materials submitted we will determine what type of permit, if any, will be required."* If deemed necessary by the Army Corps of Engineers, a wetland delineation will be performed to document any jurisdictional wetlands at the site vicinity during the design phase of the project. The entire footprint of the proposed construction disturbance will be evaluated for the presence of wetlands and those wetlands will be delineated and mapped in accordance with the Corps 1987 Delineation Manual (and applicable Regional Supplement). Wetlands boundaries will be flagged in the field and numbered. Flag numbers and locations will be surveyed using a sub-meter GPS and depicted on the delineation map. The Contractor will be required, to the extent feasible, to avoid wetlands in and around the project site that may be affected by construction activities. The Contract will require the Contractor to minimize wetland disturbance wherever possible and implement BMPs to avoid impacts such as material inputs and sedimentation to wetlands or to Basin Creek Reservoir. At this time, and based upon the preliminary information available, it is anticipated that less than one-tenth of an acre of wetlands will be disturbed as a result of the proposed project. All project work will require debris containment to prevent debris or concrete materials from entering live water in Basin Creek Reservoir or any adjacent wetlands (if present). Additionally, Jodi Bush from the USFWS adds, *"If wetlands will be affected by the project, the Service recommends keeping wetland disturbances to the minimum extent and duration possible, with as much occurring 'in the dry' as possible. This would reduce impacts to aquatic species relative to disturbance and sediment inputs. We also recommend that appropriate erosion and sediment control efforts and measures be implemented during and following construction to avoid introducing sediments or other contaminants to adjacent waters."* - Ryan Elliott, P.E. - USFWS National Wetlands Inventory - Jodi Bush, USFWS - Christina Schroeder, Army Corps of Engineers

KEY	8	**Agricultural Lands, Production, & Farmland Protection (e.g., grazing, forestry, cropland, prime or unique agricultural lands) (Identify any prime or important farm ground or forest lands within one mile of the boundary of the project.)**
B		*Response and source of information:*
		Basin Creek Dam #1 is located in a forested area. Due to it being the source of Butte – Silver Bow's water suppy, BSB owns the property immediately surrounding the reservoir and dam. Outside of dam related infrastructure and buildings, there is no other infrastructure within the dam proximity. Preliminary investigations indicate that the land surrounding the dam is not prime farmland, as designated by the NRCS. There are some agricultural operations beginning 0.8 miles to the north of the dam, primarily consisting of small grass hay operations. As the proposed dam improvement project is not expected to impact adjacent soils (outside of minimal impact in the dam vicinity), no negative impact to agricultural lands or farmlands is anticipated. Retaining the functionality of the dam will provide a benefit to downstream irrigators. There is a considerable acreage of Beaverhead-Deerlodge National Forest lands located to the east, west and south of the dam. The nearest USFS boundary to the project site is approximately 400 feet northwest of the dam. There are no current active logging activities on public lands in the vicinity, however, logging has occurred in the past (most recently in 2008), which resulted in approximately 1000-1500 acres of logging activities near the headwaters of Basin Creek. Additionally, considerable beetle kill has occurred in the forest surrounding the reservoir, of which Russ Walker, USFS Forester, indicated that 50-80% of trees are likely dead in the drainage from pine beetle kill. - Ryan Elliott, P.E. - USDA, NRCS Soil Survey - Russ Walker, USFS Forester
KEY	9	**Vegetation & Wildlife Species & Habitats, Including Fish and Sage Grouse (e.g., terrestrial, avian and aquatic life and habitats)**
P		*Response and source of information:*
		A database search conducted using the Montana Natural Heritage Program website and by the USFWS found fifteen possible species of special concern in the area: Wolverine, Canada Lynx, Grizzly Bear, Hoary Bat, Little Brown Myotis, Northern Goshawk, Cassin's Finch, Clark's Nutcracker, Brewer's Sparrow, Westslope Cutthroat Trout, Bull Trout, Whitebark Pine, Sapphire Rockcress, Meadow Larkspur, and Idaho Sedge. Jodi Bush of the United States Fish and Wildlife Service [USFWS] stated, *"We do not expect bull trout to be present in Basin Creek within the Project vicinity. Considering that the Project consists of rehabilitation of an existing structure with little to no new ground disturbance, we expect minimal effects to habitat for any listed species. Grizzly bears, Canada lynx, and wolverines are wide-ranging species and could occasionally move through the general Project area, but are not expected to occur commonly in the immediate Project vicinity. If any tree removal is necessary, we recommend that the area be surveyed for whitebark pine and that any whitebark pines be avoided, if possible."* Jodi Bush of the USFWS also stated, *"The Service recommends implementation of the following (or similar) conservation measures to manage potential bear attractants and reduce the risk of human-grizzly bear conflicts related to this project:* *• Promptly clean up any project related spills, litter, garbage, debris, etc.* *• No overnight camping within the project vicinity, except in designated campgrounds, by any crew member or other personnel associated with this project.*

		• Store all food, food related items, petroleum products, antifreeze, garbage, personal hygiene items, and other attractants inside a closed, hard-sided vehicle or commercially manufactured bear resistant container. *• Remove garbage from the project site daily and dispose of it in accordance with all applicable regulations.* *• Notify the Project Manager of any animal carcasses found in the area.* *• Notify the Project Manager of any bears observed in the vicinity of the project."* The USFWS also recommended that the proposed project follow guidelines outlined in the Migratory Bird Treaty Act (MBTA). The Service was not explicitly aware of any eagle nests in the project vicinity. Based on a review of the Montana Sage Grouse Habitat Conservation Program Mapper (https://sagegrouse.mt.gov/projects), the proposed project is not mapped in an Executive Order (EO) Area for Sage Grouse Habitat. As such, Sage Grouse are not anticipated to be adversely affected by this work. The proposed project is not expected to have any significant permanent adverse effects on vegetation and wildlife. No significant migratory bird nesting areas are anticipated to be affected by the proposed project, as tree removal is anticipated to be limited and disturbance generally limited to pre-disturbed areas on the dam face. Any temporary construction effects on plant species will be re-seeded to promote revegetation and reduce erosion. All necessary permits will be acquired prior to construction, and the Contractor will be required to adhere to the permit documents, including guidance on protection or mitigation measures that the USACE feels are reasonable and prudent. In the pre-design and survey period, site investigation into Whitebark Pine will occur per direction from USFWS. Specific guidance on Grizzly Bears will be inserted in the project special provisions. - Ryan Elliott, P.E. - Jodi Bush, USFWS - Montana FWP, Region 3 - Montana Natural Heritage Program - Montana Sage Grouse Habitat Conservation Program
KEY	**10**	**Unique, Endangered, Fragile, or Limited Environmental Resources, Including Endangered Species (e.g., plants, fish or wildlife)**
P		*Response and source of information:*
		A database search conducted using the Montana Natural Heritage Program website and by the USFWS found fifteen possible species of special concern in the area: Wolverine, Canada Lynx, Grizzly Bear, Hoary Bat, Little Brown Myotis, Northern Goshawk, Cassin's Finch, Clark's Nutcracker, Brewer's Sparrow, Westslope Cutthroat Trout, Bull Trout, Whitebark Pine, Sapphire Rockcress, Meadow Larkspur and Idaho Sedge. Jodi Bush of the United States Fish and Wildlife Service [USFWS] stated, *"We do not expect bull trout to be present in Basin Creek within the Project vicinity. Considering that the Project consists of rehabilitation of an existing structure with little to no new ground disturbance, we expect minimal effects to habitat for any listed species. Grizzly bears, Canada lynx, and wolverines are wide-ranging species and could occasionally move through the general Project area, but are not expected to occur commonly in the immediate Project vicinity. If any tree removal is necessary, we recommend that the area be surveyed for whitebark pine and that any whitebark pines be avoided, if possible."*

		Jodi Bush of the USFWS also stated, *"The Service recommends implementation of the following (or similar) conservation measures to manage potential bear attractants and reduce the risk of human-grizzly bear conflicts related to this project:* *• Promptly clean up any project related spills, litter, garbage, debris, etc.* *• No overnight camping within the project vicinity, except in designated campgrounds, by any crew member or other personnel associated with this project.* *• Store all food, food related items, petroleum products, antifreeze, garbage, personal hygiene items, and other attractants inside a closed, hard-sided vehicle or commercially manufactured bear resistant container.* *• Remove garbage from the project site daily and dispose of it in accordance with all applicable regulations.* *• Notify the Project Manager of any animal carcasses found in the area.* *• Notify the Project Manager of any bears observed in the vicinity of the project."* The USFWS also recommended that the proposed project follow guidelines outlined in the Migratory Bird Treaty Act (MBTA). The Service was not explicitly aware of any eagle nests in the project vicinity. Based on a review of the Montana Sage Grouse Habitat Conservation Program Mapper (https://sagegrouse.mt.gov/projects), the proposed project is not mapped in an Executive Order (EO) Area for Sage Grouse Habitat. As such, Sage Grouse are not anticipated to be adversely affected by this work. The proposed project is not expected to have any significant permanent adverse effects on vegetation and wildlife. No significant migratory bird nesting areas are anticipated to be affected by the proposed project, as tree removal is anticipated to be limited and disturbance generally limited to pre-disturbed areas on the dam face. Any temporary construction effects on plant species will be re-seeded to promote revegetation and reduce erosion. All necessary permits will be acquired prior to construction, and the Contractor will be required to adhere to the permit documents, including guidance on protection or mitigation measures that the USACE feels are reasonable and prudent. In the pre-design and survey period, site investigation into Whitebark Pines will occur per direction from USFWS. Specific guidance on Grizzly Bears will be inserted in the project special provisions. - Ryan Elliott, P.E. - Jodi Bush, USFWS - Montana FWP, Region 3 - Montana Natural Heritage Program - Montana Sage Grouse Habitat Conservation Program
KEY	**11**	**Unique Natural Features (e.g., geologic features)**
N		*Response and source of information:*
		There are no unique natural features located in the vicinity of the proposed project. *- Ryan Elliott, P.E.*

KEY	**12**	**Access to, and Quality of, Recreational & Wilderness Activities, Public Lands and Waterways and Public Open Space**
N		*Response and source of information:*
		No impacts are anticipated. - Ryan Elliott, P.E.
HUMAN POPULATION		
KEY	**1**	**Visual Quality – Coherence, Diversity, Compatibility of Use and Scale, Aesthetics**
B		*Response and source of information:*
		As the primary project focus is on repairing/replacing poor condition concrete (visibly cracked and crumbling) throughout the dam face and dam parapet, the improved aesthetics of the repaired areas should be considered a benefit of the project, as the infrastructure was already in place. - Ryan Elliott, P.E.
KEY	**2**	**Nuisances (e.g., glare, fumes)**
N		*Response and source of information:*
		The proposed project may cause temporary nuisances such as noise, dust, and exhaust fumes from construction equipment while construction is occurring. However, no long-term impacts have been identified and efforts will be made to minimize nuisances and address specific problems as they occur. - Ryan Elliott, P.E.

KEY	3	**Noise - suitable separation between noise sensitive activities (such as residential areas) and major noise sources (aircraft, highways & railroads).**
N		*Response and source of information:*
		The nearest residence/structure not owned by Butte-Silver Bow is located 0.8 miles from the project. There will be construction noise related to the project, but as no residential areas are located in the direct vicinity of the dam, impacts are anticipated to be minimal. No additional permanent increase in noise will occur as a result of construction activities and these activities are anticipated to be short-term and will occur during daylight hours. All local ordinances will be followed by the contractor regarding construction equipment operation. - Ryan Elliott, P.E.
KEY	4	**Historic Properties, Cultural, and Archaeological Resources**
M		*Response and source of information:*
		Basin Creek Dam #1 was originally constructed in 1897 as a curved masonry dam. With the need for increased water storage due to water needs and adherence to regulations, subsequent improvements to the dam were made in 1913, 1930's, 1980's, and 2006. The 1913 improvements consisted of a mass concrete cap/buttress which raised the dam 13 feet. The 1930's improvements consisted of placement of earthen fill on the downstream dam slope. In the mid-1980's, due to poor concrete condition, shotcrete was installed on the upper 3 feet of dam face and parapet. The 2006 improvements entailed the construction of a new concrete spillway with crest gate, slip-lining the existing conduits, and rehabilitation of the outlet works. Damon Murdo, SHPO Cultural Records Manager states, *"It is SHPO's position that any structure over fifty years of age is considered historic and is potentially eligible for listing on the National Register of Historic Places. The dam has not been previously recorded. If the Basin Creek Dam is going to be rehabilitated we would recommend that it be recorded, and a determination of its eligibility be made prior to any disturbance or rehabilitation taking place."* Christina Schroeder, USACE states, *"Due to the age of the Dam, the Dam and the proposed impacts will need to be evaluated in order for the Corps to consult with the Montana State Historic Preservation Office (MT SHPO) prior to permit issuance. Appropriate documentation for the consultation process should be submitted with the joint application and the Corps will use that documentation to consult with MT SHPO."* Thus, during the pre-design process, investigation into the eligibility of recordation will occur with qualified subconsultants. If necessary, recordation and cultural resource investigations will occur. There are no other historic sites that are located in the same section as the Dam. - Ryan Elliott, P.E. - Damon Murdo, State Historical Preservation Office (SHPO) - Christina Schroeder, USACE

KEY	5	**Changes in Demographic (population) Characteristics (e.g., quantity, distribution, density)**
N		*Response and source of information:*
		The proposed project is not anticipated to affect any changes in demographics to the area. The project will ensure long term success of the recent construction of the Basin Creek Water Treatment Plant, which is a gravity water delivery system from the Dam. - Ryan Elliott, P.E
KEY	6	**Environmental Justice – (Does the project avoid placing lower income households in areas where environmental degradation has occurred, such as adjacent to brownfield sites?)**
N		*Response and source of information:*
		No residents will be relocated as part of this project. - Ryan Elliott, P.E.
KEY	7	**General Housing Conditions - Quality, Quantity, Affordability**
B		*Response and source of information:*
		The dam rehabilitation will ensure that the downstream Basin Creek Water Treatment Plant remains operational, which will ensure property and housing values. Additionally, ensuring long term stability of the dam will ensure that housing downstream of the dam in the inundation area remains a safe. - Ryan Elliott, P.E.
KEY	8	**Displacement or Relocation of Businesses or Residents**
B		*Response and source of information:*
		By ensuring the downstream Basin Creek Water Treatment Plant remains operational, the dam rehabilitation will provide for existing businesses to remain and for new businesses to open. - Ryan Elliott, P.E.
KEY	9	**Public Health and Safety**
B		*Response and source of information:*
		Based on recent inspections, the exposed concrete dam face is in poor condition. However, continuous maintenance is necessary for a dam with such a varied construction, rehabilitation and repair history as the Basin Creek Dam. The primary focus of the proposed project is on structural concrete rehabilitation and stability during the probable maximum flood (PMF). Ongoing projects such as these are necessary to ensure the safe operation and functionality of the dam. Therefore, completion of this rehabilitation ensures the ongoing public health and safety of the users of the Butte - Silver Bow public water supply and for the downstream residents who depend on the dam to provide safe, stable infrastructure and to prevent downstream flooding. - Ryan Elliott, P.E.

KEY	10	**Lead Based Paint and/or Asbestos**
M		*Response and source of information:*
		There is no known lead based paint or asbestos at this site. However, requirements from Montana DEQ require an inspection for asbestos (performed by an accredited inspector) prior to any demolition taking place. This inspection may be waived depending on the type of structure and components being removed. - Ryan Elliott, P.E.
KEY	11	**Local Employment & Income Patterns – Quantity and Distribution of Employment, Economic Impact**
B		*Response and source of information:*
		BSB may experience short term benefits if contractors choose to hire local residents. Local businesses may benefit from the presence of construction crews, who would patronize local businesses. Longer term benefits may be experienced by the community as a result of the presence of an improved and stable infrastructure. Additionally, as a source of water storage, the dam provides downstream irrigators a means of long-term stability for dependable flows from Basin Creek to utilize for hay operations and livestock watering. Ensuring the continued safe operation of the dam means continued irrigation opportunities for downstream agricultural operations. The water system operation downstream of the dam provides employment opportunities. Continued viability of the dam will continue to provide these jobs for the local economy. - Ryan Elliott, P.E.
KEY	12	**Local & State Tax Base & Revenues**
B		*Response and source of information:*
		The dam rehabilitation project will continue to allow the functional use of the Basin Creek Water Treatment Plant. This will continue to allow commercial and industrial growth to occur, therefore expanding the Local and State tax base and revenues. - Ryan Elliott, P.E.
KEY	13	**Educational Facilities - Schools, Colleges, Universities**
B		*Response and source of information:*
		The dam rehabilitation project will continue to allow the functional use of the Basin Creek Water Treatment Plant, which provides an on-demand water system that can service up to 60% of Butte's water supply. - Ryan Elliott, P.E. - Jim Keenan, Butte - Silver Bow Water Operations
KEY	14	**Commercial and Industrial Facilities - Production & Activity, Growth or Decline**
N		*Response and source of information:*

		The dam rehabilitation project will continue to allow the functional use of the Basin Creek Water Treatment Plant. This will continue to allow commercial and industrial growth to occur. - Ryan Elliott, P.E.
KEY	**15**	**Health Care – Medical Services**
N		*Response and source of information:*
		No impacts are anticipated. - Ryan Elliott, P.E.
KEY	**16**	**Social Services – Governmental Services (e.g., demand on)**
N		*Response and source of information:*
		No impacts are anticipated. - Ryan Elliott, P.E.
KEY	**17**	**Social Structures & Mores (Standards of Social Conduct/Social Conventions)**
N		*Response and source of information:*
		The proposed project should not have any impact on social structures and mores. - Ryan Elliott, P.E.

KEY	18	**Land Use Compatibility (e.g., growth, land use change, development activity, adjacent land uses and potential conflicts)**
B		*Response and source of information:*
		Maintaining the structural integrity of the dam will ensure downstream land use can remain as currently utilized. Over the years, there have been considerable growth in areas downstream of the dam. However, the proposed rehabilitation is not anticipated to contribute to or impact growth or future planning activities in the area. - Ryan Elliott, P.E.
KEY	19	**Energy Resources - Consumption and Conservation**
B		*Response and source of information:*
		Maintaining the structural integrity of the dam and allowing reservoir water surface elevations to remain relatively high will ensure that the downstream Basin Creek Water Treatment Plant can continue to operate as a gravity system. If rehabilitation is not completed and DNRC requires lowered reservoir levels due to concern about the concrete condition, the downstream water treatment plant could become impacted due to water levels that are too low and additional pumping costs would occur, or water would have to be sourced from the Big Hole Water Treatment Plant. Jim Keenan states, *"This would not only result in more pumping from the Basin Creek WTP, but also a large increase in pumping from the Big Hole River. Water from the river is treated at the Big Hole WTP and is pumped over the Continental Divide a distance of 26 miles to get [to] the distribution system. Since construction, the Basin Creek WTP has been able to meet about 60% of Butte's water requirement--most of it supplied by gravity."* - Ryan Elliott, P.E. - Jim Keenan, Butte - Silver Bow Water Operations
KEY	20	**Solid Waste Management**
N		*Response and source of information:*
		Not applicable to this project. - Ryan Elliott, P.E.
KEY	21	**Wastewater Treatment - Sewage System**
N		*Response and source of information:*
		Not applicable to this project. - Ryan Elliott, P.E.
KEY	22	**Storm Water – Surface Drainage**
N		*Response and source of information:*
		The proposed repairs will take BMP's into account. - Ryan Elliott, P.E.

KEY	23	**Community Water Supply**
B		*Response and source of information:*
		As the Basin Creek Reservoir serves as an important water source for the City of Butte, keeping the reservoir in operable condition is critical to ensure reliability of the water source. The dam rehabilitation project will continue to ensure that the Basin Creek Water Treatment Plant remains functional. - Ryan Elliott, P.E.
KEY	24	**Public Safety – Police**
B		*Response and source of information:*
		By maintaining the structural stability of the dam by rehabilitating the concrete and addressing anchorage for resistance the Probable Maximum Flood (PMF), the risk is lessened for high flows downstream as a result of damage. This provides a benefit to public safety. - Ryan Elliott, P.E.
KEY	25	**Fire Protection – Hazards**
B		*Response and source of information:*
		The dam rehabilitation project will continue to allow the functional use of the Basin Creek Water Treatment Plant. This will continue to allow this water source to be utilized as an on-demand water source for fire flows in the event of fire fighting activities. - Ryan Elliott, P.E.
KEY	26	**Emergency Medical Services**
B		*Response and source of information:*
		By maintaining the structural stability of the dam by rehabilitating the concrete and addressing anchorage for resistance the Probable Maximum Flood (PMF), the risk is lessened for high flows downstream as a result of damage. This provides a benefit to public safety. - Ryan Elliott, P.E.

KEY	27	**Parks, Playgrounds, & Open Space**
N		*Response and source of information:*
		No impacts anticipated. - Ryan Elliott, P.E.
KEY	**28**	**Cultural Facilities, Cultural Uniqueness & Diversity**
M		*Response and source of information:*
		Basin Creek Dam #1 was originally constructed in 1897 as a curved masonry dam. With the need for increased water storage due to water needs and adherence to regulations, subsequent improvements to the dam were made in 1913, 1930's, 1980's, and 2006. The 1913 improvements consisted of a mass concrete cap/buttress which raised the dam 13 feet. The 1930's improvements consisted of placement of earthen fill on the downstream dam slope. In the mid-1980's, due to poor concrete condition, shotcrete was installed on the upper 3 feet of dam face and parapet. The 2006 improvements entailed the construction of a new concrete spillway with crest gate, slip-lining the existing conduits, and rehabilitation of the outlet works. Damon Murdo, SHPO Cultural Records Manager states, *"It is SHPO's position that any structure over fifty years of age is considered historic and is potentially eligible for listing on the National Register of Historic Places. The dam has not been previously recorded. If the Basin Creek Dam is going to be rehabilitated we would recommend that it be recorded, and a determination of its eligibility be made prior to any disturbance or rehabilitation taking place."* Christina Schroeder, USACE states, *"Due to the age of the Dam, the Dam and the proposed impacts will need to be evaluated in order for the Corps to consult with the Montana State Historic Preservation Office (MT SHPO) prior to permit issuance. Appropriate documentation for the consultation process should be submitted with the joint application and the Corps will use that documentation to consult with MT SHPO."* Thus, during the pre-design process, investigation into the eligibility of recordation will occur with qualified subconsultants. If necessary, recordation and cultural resource investigations will occur. There are no other historic sites that are located in the same section as the Dam. - Ryan Elliott, P.E. - Damon Murdo, State Historical Preservation Office (SHPO) - Christina Schroeder, USACE

KEY	**29**	**Transportation Networks and Traffic Flow Conflicts (e.g., rail; auto including local traffic; airport runway clear zones - avoidance of incompatible land use in airport runway clear zones)**
N		*Response and source of information:*
		The proposed project is not anticipated to adversely affect current transportation networks and traffic flow conflicts. - Ryan Elliott, P.E.
KEY	**30**	**Consistency with Local Ordinances, Resolutions, or Plans (e.g., conformance with local comprehensive plans, zoning, or capital improvement plans)**
B		*Response and source of information:*
		The proposed project will comply with local ordinances, resolutions and/or plans in design and during construction. - Ryan Elliott, P.E.
KEY	**31**	**Is there a Regulatory Action on Private Property Rights as a Result of this Project? (Consider options that reduce, minimize, or eliminate the regulation of private property rights.)**
N		*Response and source of information:*
		The proposed project should not have any impact on private property rights. All project work is anticipated to occur on property currently owned by BSB. - Ryan Elliott, P.E.

I. Environmental Report (ER) with Categorical Exclusion (CE)

Depending on the sources of funding, once the Preliminary Engineering Report (PER) has been completed and the potential environmental impacts have been determined, projects may have no additional environmental requirements other than obtaining appropriate permits. However, if the project is being funded by the USDA Rural Development Community Facility Programs, an Environmental Report must be completed. Depending on the outcome of the Environmental Report, either a Categorical Exclusion (CE) will need to be completed or an Environmental Assessment (EA) or Environmental Impact Statement (EIS) will be required. Projects funded through the State Revolving Fund Loan Program, the Treasure State Endowment Program, or the Community Development Block Grant Program also require a Categorical Exclusion or an Environmental Assessment before construction can be authorized. Contact the funding agencies involved for details.

The USDA RD program has a guide available to assist you in preparing the Environmental Report. See Guide to Applicants for Preparing Environmental Reports for Categorical Exclusions under § 1970.54 RD Instruction 1970-B, Exhibit C, FINAL RULE 81 FR 11000 Published March 2, 2016 with an Effective Date April 1, 2016. The Guide can be obtained by contacting the RD program staff, or at the following Internet address:

https://www.rd.usda.gov/files/1970b.pdf

RD Instruction 1970-B, Exhibit C provides specific guidance for preparing the ER including the format and information required; the environmental issues that must be considered during the proposed project's planning and design activities; the sources for locating the required information; and the documentation required to determine that there are no extraordinary circumstances that require a higher level of review including an EA or an EIS.

II. Environmental Assessment with FONSI

Depending on the sources of funding, once the Preliminary Engineering Report (PER) has been completed and potential environmental impacts associated with the project have been identified, proposed projects may require an Environmental Assessment (EA). For projects that anticipate funding through the USDA Rural Development Community Facility Programs, the State Revolving Fund Loan Programs, the Treasure State Endowment Program, or the Community Development Block Grant Program, an EA must be completed if the environmental review identifies potential environmental impacts beyond those qualifying for a Categorical Exclusion. Depending on the findings of the EA, either a Finding of No Significant Impact (FONSI) must be published or an Environmental Impact Statement (EIS) prepared. Assuming the EA determines there are no significant environmental impacts, the funding agency will prepare the FONSI and direct the applicant to publish it. The following chart provides specific program requirements for publishing the FONSI.

	CDBG	DNRC	RD	SRF	TSEP
Notice of Availability of EA	Contact CDBG staff	Not Required	Publish once; 30-day comment period required*	Not Required	Contact TSEP Staff
Notice of FONSI	Contact CDBG staff	Provide copy of FONSI.	Publish once; no comment period required	Publish once; 30-day comment period required	Contact TSEP Staff

*RD requires a Notice of Availability of the Environmental Assessment to be published once, which allows for a 30-day comment period prior to publishing the FONSI.

If two or more agencies provide funding for a project, a combined publication notice may possibly be used to satisfy the requirements of all agencies. Check with the applicable agencies to determine if a combined publication notice is possible.

ENVIRONMENTAL NARRATIVE

1. **Provide a narrative evaluation of the potential adverse environmental impacts for all project alternatives, including the preferred alternative. Environmental analysis of each alternative does not have to be as detailed as the analysis for the preferred alternative. Use the checklist on the following pages as a guide in your consideration of environmental impacts.**

   There were two primary focus areas investigated for the project, condition of the dam face concrete and stability of the dam during the probable maximum flood (PMF).

   Three alternatives were initially explored to address the condition of the concrete and stability of the dam during the PMF Event:
   1. Concrete parapet replacement and installation of post tensioned anchors.
   2. Concrete parapet replacement, full structural concrete overlay over the concrete face and installation of post tensioned anchors.
   3. Fully removing the 13' deep mass concrete cap to the masonry interface and installation of structural anchorage to the masonry dam.

   To ensure long-term stability and operation of the dam within the allowable budget it is in the best interest of BSB to complete Alternative 2 above.

   The environmental review found no adverse impacts for any of the project alternatives, including the preferred alternatives. Several benefits to resources were summarized in the review. Failure (or damage) to the dam would not only impact the public water supply but could also damage homes, public roads, and pose a threat to life. The proposed project will provide a long-term positive benefit to public health and safety for the area.

2. **Describe and document the environmental resources of the area affected. Include any environmental assessments or analyses previously completed in addition to the completed environmental checklist.**

   The dam was originally completed as water storage for the City of Butte in the late 1800's. Incidentally, it provides flood prevention, downstream irrigation water, and fish and wildlife resources. Residential housing and developmental growth have substantially increased in areas downstream of the project area (within the dam failure inundation area), increasing the potential for loss of life or property if the dam were to fail.

   Contract documents will require contractors to follow the requirements of any necessary permits issued to perform the work. Contract documents for construction will require contractors to follow the requirements of the permits, any specified construction window, necessary utility location, and adhere to Best Management Practices (BMP's) during construction to protect natural aquatic resources.

   The Montana DEQ requires an asbestos inspection be performed by an accredited inspector prior to component demolition/removal. The MDEQ may exercise its right to waive the asbestos inspection requirement depending on the type of structure and its components.

   During the design phase, if deemed necessary by the Corps of Engineers, a wetland delineation may be performed in order to map potential wetland impacts.

   During the design phase, it may be necessary to complete an inventory for Whitebark Pine at the project site.

   During the design phase, if deemed necessary by the lead federal agency, an independent consultant will perform a historic recordation of the Basin Creek Dam.

3. **Identify the sources consulted for the completion of the environmental evaluation. Sources may include studies, plans, documents, or the persons, organizations, or agencies contacted for assistance.**

   <u>Agencies Contacted for Consultation Included:</u>
   - City-County of Butte - Silver Bow Floodplain Administrator
   - City-County of Butte - Silver Bow Planner
   - U.S. Fish and Wildlife Service
   - U.S. Army Corps of Engineers
   - Montana Department of Environmental Quality
   - Montana Department of Natural Resources and Conservation
   - Montana Fish, Wildlife & Parks
   - Montana Natural Habitat Program
   - Montana Sage Grouse Habitat Conservation Program
   - State Historic Preservation Office (SHPO)
   - U.S. Forest Service

   Additional sources included:
   Montana Department of Environmental Quality, 2020-a. Air Quality Nonattainment Information. http://deq.mt.gov/Air/2017Air/Standards/airnonattainment

Montana Department of Environmental Quality, 2020-b. Interactive web mapping application. http://svc.mt.gov/deq/wmadst/default.aspx?type=SWP

Montana State Library, 2020. Montana Cadastral. http://svc.mt.gov/msl/mtcadastral/

State of Montana, 2020. Montana Sage Grouse Habitat Conservation Map. https://sagegrouse.mt.gov/ProgramMap

US Department of Agriculture, Natural Resources Conservation Service, 2020. Soil Resource Report. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

US Department of Homeland Security, Federal Emergency Management Agency, 2020. FEMA Flood Map Service Center. https://msc.fema.gov/portal/search

US Fish and Wildlife Service, 2020. National Wetlands Inventory, Wetlands Mapper. https://www.fws.gov/wetlands/data/mapper.html

Appendices (Refer to PER Appendices)

Copies of Mailed Comment Letters
Received Comments
Other Environmental Information

APPENDIX C

Agency Correspondence

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, OMAHA DISTRICT
HELENA REGULATORY OFFICE
10 WEST 15TH STREET, SUITE 2200
HELENA, MONTANA 59626

REPLY TO
ATTENTION OF

May 4, 2020

Regulatory Branch
Montana State Program
Corps No. **NWO-2020-00852-MTM**

Subject: City-County of Butte-Silver Bow – Basin Creek Dam #1 Rehabilitation

Ryan Elliott, P.E.
Great West Engineering
P.O. Box 4817
Helena, Montana 59604

Dear Mr. Elliott:

We are responding to your request for comments regarding the above-referenced project. Specifically, you are proposing to rehabilitate portions of the Basin Creek Dam #1. The project is located at Latitude 45.854464°, Longitude -112.545739°, on Basin Creek Dam, within Section 12, Township 1 N, Range 8 W, Silver Bow County, Montana.

The mission of the U.S. Army Corps of Engineers (Corps) Regulatory Program is to protect the Nation's aquatic resources while allowing reasonable development through fair, flexible and balanced permit decisions. In particular, under Section 404 of the Clean Water Act, we work to protect the biological, physical, and chemical integrity of the Nation's aquatic resources. Projects are evaluated on a case-by-case basis to determine the potential benefits and detriments that may occur as a result of the proposal. In all cases an applicant must avoid and minimize impacts to aquatic resources to the greatest extent practicable.

Under the authority of Section 404 of the Clean Water Act (CWA), DA permits are required for the discharge of fill material into waters of the U.S. Waters of the U.S. include the area below the ordinary high water mark of stream channels and lakes or ponds connected to the tributary system, and wetlands adjacent to these waters. Isolated waters and wetlands, as well as man-made channels, may be waters of the U.S. in certain circumstances, which must be determined on a case-by-case basis.

Based on the information provided in your submittal, it appears regulated activities may be proposed and jurisdictional waters of the U.S. are present within the project area. If your final design includes the placement of fill material in any jurisdictional area described above, or otherwise requires authorization by a DA permit, please submit a Montana Joint Permit Application to this office prior to starting any work. After a review of the materials submitted we will determine what type of permit, if

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any, will be required. You can obtain a Montana Joint Permit Application Form at the following address: http://www.dnrc.mt.gov/licenses-and-permits/stream-permitting. If you do not have internet access please contact our office at the address below to obtain more information.

Due to the age of the Dam, the Dam and the proposed impacts will need to be evaluated in order for the Corps to consult with the Montana State Historic Preservation Office (MT SHPO) prior to permit issuance. Appropriate documentation for the consultation process should be submitted with the joint application and the Corps will use that documentation to consult with MT SHPO.

Note that this letter is not a DA authorization to proceed. It only informs you of your need to obtain a DA permit if waters of the U.S. will be affected. If waters of the U.S. will not be affected by a jurisdictional activity a DA permit will not be required for the project.

Please refer to identification number NWO-2020-00852-MTM in any correspondence concerning this project. If you have any questions, please contact Christina Schroeder at 1600 North Avenue West, Suite 105, Missoula, Montana 59801, by email at Christina.L.Schroeder@usace.army.mil, or telephone at (406) 459-9719.

Sincerely,

Christina Schroeder
Senior Project Manager

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Montana Ecological Services Field Office
585 Shepard Way, Suite 1
Helena, Montana 59601–6287

In Reply Refer to:
FWS/IR05/IR07
M29 Federal Activities;
06E11000-2020-TA-0343

April 15, 2020

Ryan Elliott, P.E.
Great West Engineering, Inc.
2501 Belt View Drive
Helena, Montana 59604

Dear Mr. Elliott:

Thank you for your letter, dated March 16, 2020, and received in our office on March 18, 2020, requesting U.S. Fish and Wildlife Service (Service) comment on the City-County of Butte-Silver Bow Basin Creek Dam Number 1 Rehabilitation Project (Project). The proposed Project would rehabilitate the concrete cap at the crest of an existing dam, which was installed in 1913 and is in poor condition. The dam is located approximately 10 miles south of Butte in Silver Bow County, Montana. The dam functions primarily to manage water storage in Basin Creek for municipal, irrigation, and recreational purposes. Little to no previously undisturbed ground would be affected by the Project.

Our comments are prepared under the authority of, and in accordance with, the provisions of the Endangered Species Act (ESA; 16 U.S.C. 1531 et. seq.), Migratory Bird Treaty Act (MBTA; 16 U.S.C. 703 et seq.), and Bald and Golden Eagle Protection Act (BGEPA; 16 U.S.C. 668-668d, 54 Stat. 250). We offer the following comments for your consideration.

Threatened and Endangered Species

The current list of candidate, proposed, threatened or endangered species, and designated critical habitat occurring in Silver Bow County, Montana is as follows:

Scientific Name	***Common Name***	***Status****
Salvelinus confluentus	Bull Trout	LT
Lynx canadensis	Canada Lynx	LT
Ursus arctos horribilis	Grizzly Bear	LT
Gulo gulo luscus	Wolverine	P
Pinus albicaulis	Whitebark Pine	C

*LE=Listed as Endangered, LT=Listed Threatened, P=Proposed, C=Candidate CH=Critical Habitat

Additional information may be obtained using the Service's Information for Planning and Consultation (IPaC) project-planning tool, at https://ecos.fws.gov/ipac/.

We do not expect bull trout to be present in Basin Creek within the Project vicinity. Considering that the Project consists of rehabilitation of an existing structure with little to no new ground disturbance, we expect minimal effects to habitat for any listed species. Grizzly bears, Canada lynx, and wolverines are wide-ranging species and could occasionally move through the general Project area, but are not expected to occur commonly in the immediate Project vicinity. If any tree removal is necessary, we recommend that the area be surveyed for whitebark pine and that any whitebark pines be avoided, if possible.

The Service recommends implementation of the following (or similar) conservation measures to manage potential bear attractants and reduce the risk of human-grizzly bear conflicts related to this project:

- Promptly clean up any project related spills, litter, garbage, debris, etc.
- No overnight camping within the project vicinity, except in designated campgrounds, by any crew member or other personnel associated with this project.
- Store all food, food related items, petroleum products, antifreeze, garbage, personal hygiene items, and other attractants inside a closed, hard-sided vehicle or commercially manufactured bear resistant container.
- Remove garbage from the project site daily and dispose of it in accordance with all applicable regulations.
- Notify the Project Manager of any animal carcasses found in the area.
- Notify the Project Manager of any bears observed in the vicinity of the project.

If a Federal agency authorizes, funds, or carries out a proposed action, the responsible Federal agency, or its delegated agent, is required to evaluate whether the action "may affect" listed species or critical habitat. If the Federal agency or its designated agent determines the action "may affect, is likely to adversely affect" listed species or critical habitat, the responsible Federal agency shall request formal section 7 consultation with this office. If the evaluation shows a "may affect, not likely to adversely affect" determination, concurrence from this office is required. If the evaluation shows a "no effect" determination for listed species or critical habitat, further consultation is not necessary. If a private entity receives Federal funding for a construction project, or if any Federal permit or license is required, the Federal agency may designate the fund recipient or permittee as its agent for purposes of informal section 7 consultation. The funding, permitting, or licensing Federal agency is responsible to ensure that its actions comply with the ESA, including obtaining concurrence from the Service for any action that may affect a threatened or endangered species or designated critical habitat.

A Federal nexus exists whenever an activity is conducted, funded, licensed, or permitted by a Federal agency. Private individuals and companies are required to ensure that their actions do not result in "take" of federally listed animals. It is the responsibility of the Federal agency to ensure that its actions are in compliance with the ESA. Further technical assistance can be provided if you have additional questions regarding project impacts to listed species, or future ESA responsibilities.

Migratory Birds

The MBTA prohibits the purposeful taking, killing, possession, and transportation, (among other actions) of migratory birds, their eggs, parts, and nests, except when specifically permitted. If work is proposed to take place in migratory bird habitats that may result in take of migratory birds, their eggs, or active nests, the Service recommends that the project proponent take all practicable measures to avoid and minimize take, such as maintaining adequate buffers, to protect the birds until the young have fledged. Active nests may not be removed. The Service has developed, and continues to revise and develop, general and industry-specific conservation measures for avoiding and minimizing impacts to birds (https://www.fws.gov/birds/management/project-assessment-tools-and-guidance/conservation-measures.php). We recommend that the proposed project consider and incorporate these measures into project design, construction, and documentation as appropriate.

Bald and Golden Eagles

Although the Service is not aware of active eagle nests or territories within the proposed project area, we provide the following for your information.

The bald eagle (*Haliaeetus leucocephalus*) and golden eagle (*Aquila chrysaetos*) are protected from a variety of harmful actions via take prohibitions in both the MBTA[1] (16 U.S.C. 703-712) and the BGEPA. The BGEPA, enacted in 1940 and amended several times, prohibits take of bald eagles and golden eagles, including their parts, nests, young or eggs, except where otherwise permitted pursuant to Federal regulations. Incidental take of eagles from actions such as electrocutions from power lines or wind turbine strikes are prohibited unless specifically authorized via an eagle incidental take permit from the Service.

BGEPA provides penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle ... [or any golden eagle], alive or dead, or any part, nest, or egg thereof." The BGEPA defines take to include the following actions: "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb." The Service expanded this definition by regulation to include the term “destroy” to ensure that “take” also encompasses destruction of eagle nests. Also, the Service defined the term disturb which means to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, (1) injury to an eagle, (2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or (3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior.

---

[1] On December 22, 2017, the Department of the Interior’s (DOI) Office of the Solicitor Memorandum M-37050 titled The Migratory Bird Treaty Act Does Not Prohibit Incidental Take https://www.doi.gov/sites/doi.gov/files/uploads/m-37050.pdf) concludes that the MBTA’s prohibitions on pursuing, hunting, taking, capturing, killing, or attempting to do the same apply only to affirmative actions that have as their purpose the taking or killing of migratory birds, their nests, or their eggs. The MBTA list of protected species includes bald and golden eagles, and the law has been an effective tool to pursue incidental take cases involving eagles. However, the primary law protecting eagles is the Bald and Golden Eagle Protection Act (BGEPA) (16 U.S. Code § 668), since the bald eagle was delisted under the Endangered Species Act in 2007. Memorandum-37050 does not affect the ability of the Service to refer entities for prosecution that have violated the take prohibitions for eagles established by the BGEPA.

The Service has developed guidance for the public regarding means to avoid take of bald and golden eagles:

- The 2007 National Bald Eagle Management Guidelines serve to advise landowners, land managers, and others who share public and private lands with bald eagles when and under what circumstances the protective provisions of BGEPA may apply. They provide conservation recommendations to help people avoid and/or minimize such impacts to bald eagles, particularly where they may constitute "disturbance," which is prohibited by the BGEPA.

  https://www.fws.gov/northeast/ecologicalservices/pdf/NationalBaldEagleManagementGuidelines.pdf

- The 2013 Eagle Conservation Plan Guidance, Module 1- Land-based Wind Energy, Version 2 is specific to wind energy development and provides in-depth guidance for conserving bald and golden eagles in the course of siting, constructing, and operating wind energy facilities. Development of an Eagle Conservation Plan per these guidelines may serve as the basis for applying for an eagle incidental take permit for wind energy facilities. Applications for such eagle incidental take permits must include an Eagle Conservation Plan.

  https://www.fws.gov/migratorybirds/pdf/management/eagleconservationplanguidance.pdf

The Service also has promulgated new permit regulations under BGEPA:

- New eagle permit regulations, as allowed under BGEPA, were promulgated by the Service in 2009 (74 FR 46836; Sept. 11, 2009) and revised in 2016 (81 FR 91494; Dec. 16, 2016). The regulations authorize the limited take of bald and golden eagles where the take to be authorized is associated with otherwise lawful activities. These regulations also establish permit provisions for intentional take of eagle nests where necessary to ensure public health and safety, in addition to other limited circumstances. The revisions in 2016 included changes to permit issuance criteria and duration, definitions, compensatory mitigation standards, criteria for eagle nest removal permits, permit application requirements, and fees in order to clarify, improve implementation and increase compliance while still protecting eagles. https://www.gpo.gov/fdsys/pkg/FR-2016-12-16/pdf/2016-29908.pdf

The Service's Office of Law Enforcement carries out its mission to protect eagles through investigations and enforcement, as well as by fostering relationships with individuals, companies, industries and agencies that have taken effective steps to avoid take, including incidental take of these species, and encouraging others to implement measures to avoid take. The Office of Law Enforcement focuses its resources on investigating individuals and entities that take eagles without identifying and implementing all reasonable, prudent and effective measures to avoid that take.

Those individuals and entities are encouraged to work closely with Service biologists to identify available protective measures, and to implement those measures during all activities or situations where their action or inaction may result in the take of an eagle(s).

In addition to the above guidance, the 2010 Montana Bald Eagle Management Guidelines: An Addendum to Montana Bald Eagle Management Plan (1994) developed by Montana Fish, Wildlife and Parks (FWP) also provides guidance for avoiding and minimizing the risk for bald eagle take (http://fwp.mt.gov/fwpDoc.html?id=44181).

Additional Comments

If wetlands will be affected by the project, the Service recommends keeping wetland disturbances to the minimum extent and duration possible, with as much occurring "in the dry" as possible. This would reduce impacts to aquatic species relative to disturbance and sediment inputs. We also recommend that appropriate erosion and sediment control efforts and measures be implemented during and following construction to avoid introducing sediments or other contaminants to adjacent waters.

In addition to coordination with the Service, we recommend coordination with FWP and the Montana Natural Heritage Program. These agencies may be able to provide updated, site-specific information regarding fish, wildlife, and sensitive plant resources occurring in the proposed project area. Contact information for these two agencies is below:

Montana Fish, Wildlife and Parks
1420 East Sixth Avenue
P.O. Box 200701
Helena, Montana 59620-0701
Phone: (406) 444-2535

Montana Natural Heritage Program
1515 East 6th Avenue, Box 201800
Helena, Montana 59620-1800
Phone: (406) 444-5354

Thank you for the opportunity to comment on the proposed project. The Service appreciates your efforts to incorporate fish and wildlife resource concerns into your project planning. If you have further questions related to this letter, please contact Jacob Martin at 406-449-5225, extension 215 or jacob_martin@fws.gov.

Sincerely,

for Jodi L. Bush
Office Supervisor

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION

STEVE BULLOCK
GOVERNOR

DIRECTOR'S OFFICE (406) 444-2074
TELEFAX NUMBER (406) 444-2684

STATE OF MONTANA

WATER RESOURCES DIVISION (406) 444-6601
TELEFAX NUMBERS (406) 444-0533 / (406) 444-5918
http://www.dnrc.mt.gov

1424 9TH AVENUE
PO BOX 201601
HELENA, MONTANA 59620-1601

April 8, 2020

Ryan Elliott
Great West Engineering
PO Box 4817
Helena, MT 59604

RE: Basin #1 Rehabilitation – request for comments

Dear Ryan:

I am familiar with the City-County of Butte Silver Bow's plans to rehabilitate Basin #1. The Dam Safety Program has been working with the City closely in the last several months on Basin #1. I am not aware of any adverse environmental impacts from rehabilitation of the dam. Note that failure to complete the project in a reasonable period could have impacts, as we may be forced to implement a reservoir level restriction to reduce the risk of dam failure due to the poor condition of the concrete. A reservoir level restriction could have several adverse impacts.

Since Basin #1 is classified as a high hazard dam, the City-County will be required to obtain a Construction Permit from the Dam Safety Program. We have a detailed design review process in place. As part of this process, we will be involved in all stages of the design to assure appropriate standards are followed.

Please call or email if you need additional information.

Sincerely,

Michele Lemieux, PE
Montana Dam Safety Section Supervisor
mlemieux@mt.gov
406-444-6613

MT Fish, Wildlife & Parks
Region 3 Headquarters
1400 S 19th Avenue
Bozeman, MT 59718

April 13, 2020

Ryan Elliott
Great West Engineering PO Box 4817
Helena, MT 59604
relliott@greatwesteng.com

RE: Basin Creek Dam #1 - Rehabilitation

Dear Ryan Elliott:

Montana Fish, Wildlife & Parks has no comment currently regarding the proposed Basin Creek Dam #1 - Rehabilitation.

Thank you for the opportunity to comment.

Sincerely,

Montana Fish Wildlife & Parks
Region 3 HQ Office, Bozeman

Big Sky. Big Land. Big History.
Montana
Historical Society

FILE SEARCH INVOICE

Montana State Historic Preservation Office
1301 E. Lockey Ave, PO Box 201202
Helena, MT 59620-1202
(406)444-7715
montanahistoricalsociety.org

DATE: 19-Mar-20

SHPO Invoice #: 2020031901

Bill To:

Contact Name: Ryan Elliot
Organization: Great West Engineering
Address: PO Box 4817
City/State/Zip: Helena MT 59604

File Search Fee Structure
$25 / Section
For questions contact: **Damon Murdo** dmurdo@mt.gov **406-444-7767**

Total Cost:	**$25.00**

Project Name:	CITY-COUNTY OF BUTTE-SILVER BOW – BASIN CREEK DAM #1-REHABILITATION

Total sections searched for SHPO Project #: 2020031901	**1**

Please make all checks payable to:
Montana Historical Society
PO Box 201201
Helena, MT 59620

PAY ONLINE HERE

Due upon receipt. Please pay within 30 days.

Ryan Elliott

From: Murdo, Damon <dmurdo@mt.gov>
Sent: Thursday, March 19, 2020 11:13 AM
To: Ryan Elliott
Subject: CITY-COUNTY OF BUTTE-SILVER BOW – BASIN CREEK DAM #1-REHABILITATION
Attachments: 2020031901.pdf; Reports.pdf

Follow Up Flag: Follow up
Flag Status: Flagged

Big Sky. Big Land. Big History.
Montana
Historical Society

March 19, 2020

Ryan Elliot
Great West Engineering
PO Box 4817
Helena MT 59604

RE: CITY-COUNTY OF BUTTE-SILVER BOW – BASIN CREEK DAM #1-REHABILITATION. SHPO Project #: 2020031901

Dear Mr. Elliot:

I have conducted a cultural resource file search for the above-cited project located in Section 12, T1N R8W. According to our records there have been no previously recorded sites within the designated search locale. However, there have been a few previously conducted cultural resource inventories done in the area. I've attached a list of the reports. If you would like any further information regarding the reports, you may contact me at the number listed below.

It is SHPO's position that any structure over fifty years of age is considered historic and is potentially eligible for listing on the National Register of Historic Places. The dam has not been previously recorded. If the Basin Creek Dam is going to be rehabilitated we would recommend that it be recorded, and a determination of its eligibility be made prior to any disturbance or rehabilitation taking place.

If you have any further questions or comments, you may contact me at (406) 444-7767 or by e-mail at dmurdo@mt.gov. Thank you for consulting with us.

Sincerely,

Damon Murdo
Cultural Records Manager
State Historic Preservation Office

File: LOCAL/OTHER/2020

STATE HISTORIC PRESERVATION OFFICE
Montana Cultural Resource Database

CRABS Township,Range,Section Results

Report Date:3/19/2020

Township:1 N Range:8 W Section: 12

STEERE PETER L., ET AL.

9/7/1979 CULTURAL RESOURCE INVENTORY AND EVALUATION BASIN CREEK PROJECT

CRABS Document Number: SB 4 9613 Agency Document Number: RS393-1(1)

Township:1 N Range:8 W Section: 12

CHERULLO TAMMY L. AND GREGORY R.LEETZ

5/7/2003 BEAVERHEAD-DEERLODGE NATIONAL FOREST HISTORIC PRESERVATION AND MANAGEMENT PLAN ANNUAL REPORT OF IMPLEMENTATION (R.O.I.) 2002

CRABS Document Number: ZZ 1 26528 Agency Document Number: 02-BD-4-25

Township:1 N Range:8 W Section: 12

RYAN J. MICHAEL & TAMMY CHERULLO

2/25/2006 BEAVERHEAD-DEERLODGE NATIONAL FOREST 2005 ANNUAL HERITAGE REPORT AND REPORT OF IMPLEMENTATION

CRABS Document Number: ZZ 1 28983 Agency Document Number:

Township:1 N Range:8 W Section: 12

ANONYMOUS

1/1/1997 97-BD-4-21 1998 ROUNDWOOD SALES - HIGHLANDS INTERIM REPORT

CRABS Document Number: SB 1 36017 Agency Document Number: 97-BD-4-21

Township:1 N Range:8 W Section: 12

CHERULLO TAMMY

3/10/2003 BASIN/SOUTH BUTTE FUELS REDUCTION

CRABS Document Number: SB 1 35643 Agency Document Number: 02-BD-4-24

Township:1 N Range:8 W Section: 12

CHERULLO TAMMY

2/8/2006 BASIN/SOUTH BUTTE TIMBER SALE

CRABS Document Number: SB 1 35808 Agency Document Number: 05-BD-4-9

Township:1 N Range:8 W Section: 12

ANONYMOUS

1/1/1997 97-BD-4-10 HIGHLAND WINDTHROW SALVAGE (A) TRACTOR LOGGING UNITS (B) HELICOPTER LOGGING UNITS

CRABS Document Number: SB 1 36058 Agency Document Number: 97-BD-4-10

Township:1 N Range:8 W Section: 12

ANONYMOUS

1/1/1998 LITTLE CAMP-HIGHLAND PASTURE FENCE

CRABS Document Number: SB 1 36070 Agency Document Number: 98-BD-4-23

Township:1 N Range:8 W Section: 12

ANONYMOUS

1/1/1997 1998 (HIGHLAND) ROUNDWOOD SALES FINAL REPORT

CRABS Document Number: SB 1 36085 Agency Document Number: 98-BD-4-21

From:	Ryan Elliott
To:	Ryan Elliott
Subject:	Memo to file - Discussion with Russ Walker - USFS - Logging
Date:	Tuesday, April 28, 2020 2:58:48 PM

I spoke with the USFS of the Forest Service on use around Basin Creek Reservoir.

- They indicated that they don't have any current or future logging plans in the drainage.
- The last project was about 1000 acres of logging towards the head of the drainage in 2008.
- Russ indicated that approximately 50-80% of the trees are dead in the drainage due to pine beetle.
    - He mentioned that he was aware of potential water quality concerns regarding pine beetle kill, but didn't know exact specifics.

Ryan Elliott, PE | Project Manager

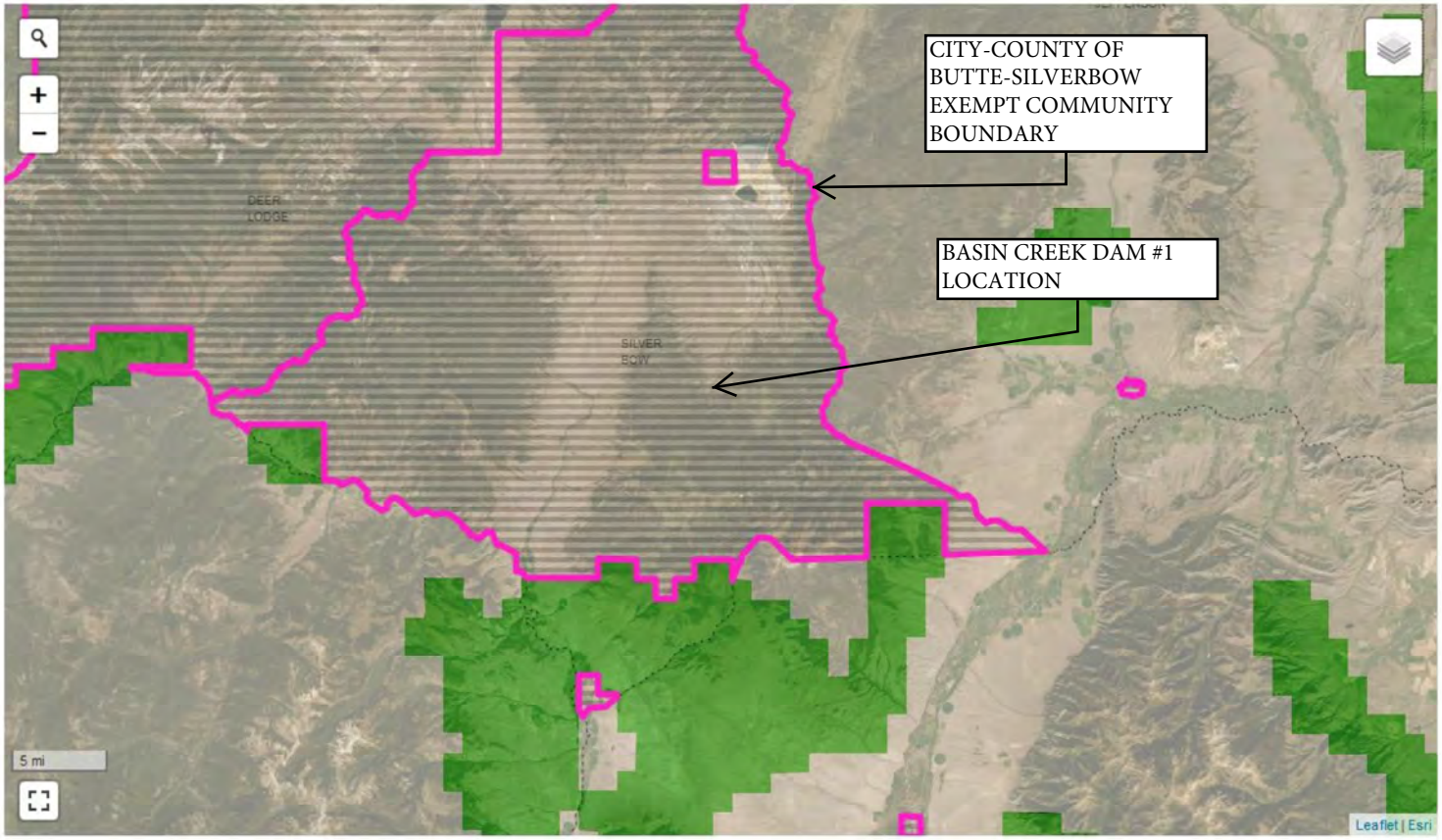
Great West Engineering, Inc.
PO Box 4817
2501 Belt View Drive
Helena, MT 59604

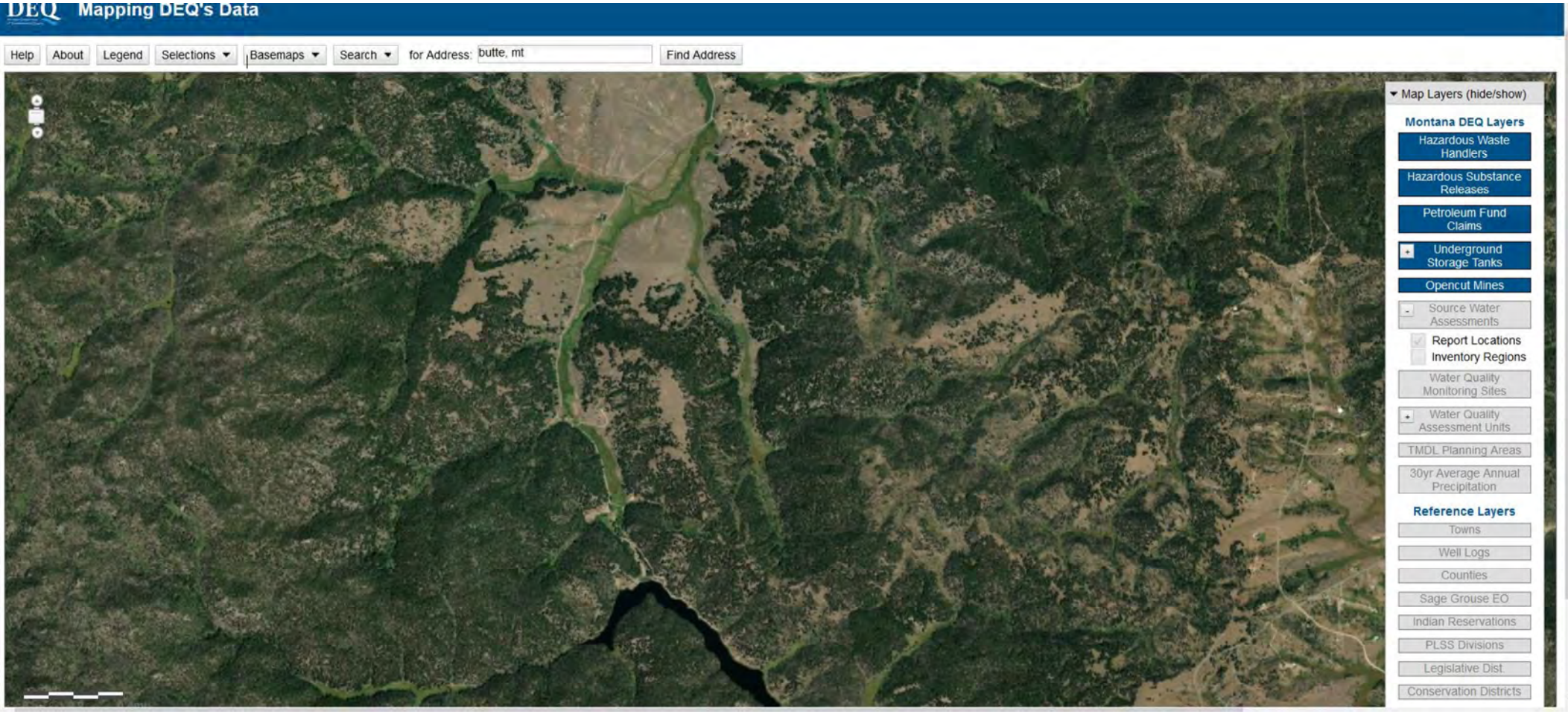
CELL: 406-600-0689
FAX: 406-449-8631
OFFICE: 406-449-8627

www.greatwesteng.com

MT Sage Grouse Habitat Conservation Program ABOUT FAQ MAP

If your project is close to designated sage grouse habitat or BLM Priority area, or if you are unsure your project is within designated sage grouse habitat or BLM Priority area, please submit your project for review as permitting agencies will be checking to see if your project is located within these designated sage grouse habitats. If your permitting agency requires evidence that your project is outside of designated sage grouse habitat, we recommend that you log in and start a project application and take a screenshot of your project's location.





NO TANKS, WASTE HANDLERS, HAZARDOUS SUBSTANCE RELEASE OR OPENCUT MINES ARE LOCATED WITHIN 1 MILE OF THE PROJECT SITE

HELENA
PO Box 4817 ▪ 2501 Belt View Drive
Helena, MT 59604
406.449.8627 ▪ Fax 406.449.8631
www.greatwesteng.com

GreatWest engineering ®

March 16th, 2020

U.S. Army Corps of Engineers
10 West 15th Street, Suite 2200
Helena, Montana 59626

RE: City-County of Butte-Silver Bow – Basin Creek Dam #1 – Rehabilitation

To Whom It May Concern:

The City-County of Butte-Silver Bow (BSB) is investigating the feasibility of the rehabilitation to portions of the Basin Creek Dam #1. Specifically, the project will make improvements to rehabilitate the concrete cap on the dam crest, which was installed in 1913 and is in poor condition.

Basin Creek Dam #1 is located approximately 10 miles south of Butte, Montana. The project is located in Section 12, Township 1 North, and Range 8 West. The latitude and longitude of the project location are 45.854464°N, 112.545739°W. Project location maps and photographs of the dam are attached.

The proposed project will ensure the long-term resilience of the historic Basin Creek Dam #1, protect public drinking water, protect natural resources and reduce potential public safety concerns. The Dam's primary function is to manage the storage water elevation of Basin Creek Reservoir for public water supply to Butte, provide downstream irrigation water, and provide recreational opportunities. BSB intends to submit a TSEP Grant Application and DNRC Renewable Resource Grant and Loan application for funding assistance for the proposed project.

Please take a few moments to review the proposed project and provide a written response detailing any comments you (or your agency) may have regarding the project and any potential environmental impacts that should be considered in the project design, avoidance, or mitigation measures. All necessary permits will be applied for during the design phase following receipt of grant monies. It is anticipated that very little, if any, previously undisturbed ground will be impacted by this project.

Please return your written comments to Ryan Elliott, *relliott@greatwesteng.com* or at the following address:

BILLINGS
6780 Trade Center Ave.
Billings, MT 59101
406.652.5000
Fax 406.248.1363

BOISE
3050 N. Lakeharbor Ln.
Suite 201
Boise, ID 83703
208.576.6646

GREAT FALLS
702 2nd Street South #2
Great Falls, MT 59405
406.952.1109

SPOKANE
9221 N. Division St.,
Suite F
Spokane, WA 99218
509.413.1430

Ryan Elliott
Great West Engineering
PO Box 4817
Helena, MT 59604

Due to the time restrictions associated with the preparation of the grant application, we would greatly appreciate your reply as soon as possible. If you have any questions you may call me at (406) 495-6168.

Sincerely,

Great West Engineering, Inc.

Ryan Elliott

Ryan Elliott, PE
Project Manager

Attachments: Location Map
Site Photos

cc: File

HELENA
PO Box 4817 ▪ 2501 Belt View Drive
Helena, MT 59604
406.449.8627 ▪ Fax 406.449.8631
www.greatwesteng.com

March 16th, 2020

Ms. Lori Casey
Butte-Silver Bow Floodplain Administrator
155 W. Granite Room 108
Butte, Montana 59701

RE: City-County of Butte-Silver Bow – Basin Creek Dam #1 – Rehabilitation

Dear Ms. Casey:

The City-County of Butte-Silver Bow (BSB) is investigating the feasibility of the rehabilitation to portions of the Basin Creek Dam #1. Specifically, the project will make improvements to rehabilitate the concrete cap on the dam crest, which was installed in 1913 and is in poor condition.

Basin Creek Dam #1 is located approximately 10 miles south of Butte, Montana. The project is located in Section 12, Township 1 North, and Range 8 West. The latitude and longitude of the project location are 45.854464°N, 112.545739°W. Project location maps and photographs of the dam are attached.

The proposed project will ensure the long-term resilience of the historic Basin Creek Dam #1, protect public drinking water, protect natural resources and reduce potential public safety concerns. The Dam's primary function is to manage the storage water elevation of Basin Creek Reservoir for public water supply to Butte, provide downstream irrigation water, and provide recreational opportunities. BSB intends to submit a TSEP Grant Application and DNRC Renewable Resource Grant and Loan application for funding assistance for the proposed project.

Please take a few moments to review the proposed project and provide a written response detailing any comments you (or your agency) may have regarding the project and any potential environmental impacts that should be considered in the project design, avoidance, or mitigation measures. All necessary permits will be applied for during the design phase following receipt of grant monies. It is anticipated that very little, if any, previously undisturbed ground will be impacted by this project.

Please return your written comments to Ryan Elliott, *relliott@greatwesteng.com* or at the following address:

BILLINGS
6780 Trade Center Ave.
Billings, MT 59101
406.652.5000
Fax 406.248.1363

BOISE
3050 N. Lakeharbor Ln.
Suite 201
Boise, ID 83703
208.576.6646

GREAT FALLS
702 2nd Street South #2
Great Falls, MT 59405
406.952.1109

SPOKANE
9221 N. Division St.,
Suite F
Spokane, WA 99218
509.413.1430

Ryan Elliott
Great West Engineering
PO Box 4817
Helena, MT 59604

Due to the time restrictions associated with the preparation of the grant application, we would greatly appreciate your reply as soon as possible. If you have any questions you may call me at (406) 495-6168.

Sincerely,

Great West Engineering, Inc.

Ryan Elliott

Ryan Elliott, PE
Project Manager

Attachments: Location Map
Site Photos

cc: File

HELENA
PO Box 4817 ▪ 2501 Belt View Drive
Helena, MT 59604
406.449.8627 ▪ Fax 406.449.8631
www.greatwesteng.com

GreatWest engineering ®

March 16th, 2020

Permitting and Compliance Division
Department of Environmental Quality
1520 E. 6th Avenue
P.O. Box 200901
Helena, MT 59620-0901

RE: City-County of Butte-Silver Bow – Basin Creek Dam #1 – Rehabilitation

To Whom It May Concern:

The City-County of Butte-Silver Bow (BSB) is investigating the feasibility of the rehabilitation to portions of the Basin Creek Dam #1. Specifically, the project will make improvements to rehabilitate the concrete cap on the dam crest, which was installed in 1913 and is in poor condition.

Basin Creek Dam #1 is located approximately 10 miles south of Butte, Montana. The project is located in Section 12, Township 1 North, and Range 8 West. The latitude and longitude of the project location are 45.854464°N, 112.545739°W. Project location maps and photographs of the dam are attached.

The proposed project will ensure the long-term resilience of the historic Basin Creek Dam #1, protect public drinking water, protect natural resources and reduce potential public safety concerns. The Dam's primary function is to manage the storage water elevation of Basin Creek Reservoir for public water supply to Butte, provide downstream irrigation water, and provide recreational opportunities. BSB intends to submit a TSEP Grant Application and DNRC Renewable Resource Grant and Loan application for funding assistance for the proposed project.

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Project Manager

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March 16th, 2020

Mr. Marc Pitman
Department of Natural Resources and Conservation
DNRC Helena Regional Office
Attention: Resource Development Bureau Engineer
1625 11th Avenue
P.O. Box 201601
Helena, Montana 59620-1601

RE: City-County of Butte-Silver Bow – Basin Creek Dam #1 – Rehabilitation

Dear Mr. Pitman:

The City-County of Butte-Silver Bow (BSB) is investigating the feasibility of the rehabilitation to portions of the Basin Creek Dam #1. Specifically, the project will make improvements to rehabilitate the concrete cap on the dam crest, which was installed in 1913 and is in poor condition.

Basin Creek Dam #1 is located approximately 10 miles south of Butte, Montana. The project is located in Section 12, Township 1 North, and Range 8 West. The latitude and longitude of the project location are 45.854464°N, 112.545739°W. Project location maps and photographs of the dam are attached.

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Sincerely,

Great West Engineering, Inc.

Ryan Elliott

Ryan Elliott, PE
Project Manager

Attachments: Location Map
Site Photos

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March 16th, 2020

Ms. Lori Casey
Butte-Silver Bow Floodplain Administrator
155 W. Granite Room 108
Butte, Montana 59701

RE: City-County of Butte-Silver Bow – Basin Creek Dam #1 – Rehabilitation

Dear Ms. Casey:

The City-County of Butte-Silver Bow (BSB) is investigating the feasibility of the rehabilitation to portions of the Basin Creek Dam #1. Specifically, the project will make improvements to rehabilitate the concrete cap on the dam crest, which was installed in 1913 and is in poor condition.

Basin Creek Dam #1 is located approximately 10 miles south of Butte, Montana. The project is located in Section 12, Township 1 North, and Range 8 West. The latitude and longitude of the project location are 45.854464°N, 112.545739°W. Project location maps and photographs of the dam are attached.

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Sincerely,

Great West Engineering, Inc.

Ryan Elliott

Ryan Elliott, PE
Project Manager

Attachments: Location Map
Site Photos

cc: File

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March 16th, 2020

Mr. Jon Axline
Montana Department of Transportation
2701 Prospect Avenue
P.O. Box 201001
Helena, MT 59620-1001

RE: City-County of Butte-Silver Bow – Basin Creek Dam #1 – Rehabilitation

Dear Mr. Axline:

The City-County of Butte-Silver Bow (BSB) is investigating the feasibility of the rehabilitation to portions of the Basin Creek Dam #1. Specifically, the project will make improvements to rehabilitate the concrete cap on the dam crest, which was installed in 1913 and is in poor condition.

Basin Creek Dam #1 is located approximately 10 miles south of Butte, Montana. The project is located in Section 12, Township 1 North, and Range 8 West. The latitude and longitude of the project location are 45.854464°N, 112.545739°W. Project location maps and photographs of the dam are attached.

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Helena, MT 59604

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Great West Engineering, Inc.

Ryan Elliott

Ryan Elliott, PE
Project Manager

Attachments: Location Map
Site Photos

cc: File

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March 16th, 2020

Mr. Regan Dean
Region 3 Fisheries Biologist
Department of Fish, Wildlife, and Parks
1400 S. 19th Avenue
Bozeman, Montana, 59718

RE: City-County of Butte-Silver Bow – Basin Creek Dam #1 – Rehabilitation

Dear Mr. Dean:

The City-County of Butte-Silver Bow (BSB) is investigating the feasibility of the rehabilitation to portions of the Basin Creek Dam #1. Specifically, the project will make improvements to rehabilitate the concrete cap on the dam crest, which was installed in 1913 and is in poor condition.

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Great West Engineering, Inc.

Ryan Elliott

Ryan Elliott, PE
Project Manager

Attachments: Location Map
Site Photos

cc: File

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March 16th, 2020

Mr. Damon Murdo
Cultural Records Manager
State Historic Preservation Office
1410 8th Avenue
P.O. Box 201202
Helena, MT 59620-1202

RE: City-County of Butte-Silver Bow – Basin Creek Dam #1 – Rehabilitation

Dear Mr. Murdo:

The City-County of Butte-Silver Bow (BSB) is investigating the feasibility of the rehabilitation to portions of the Basin Creek Dam #1. Specifically, the project will make improvements to rehabilitate the concrete cap on the dam crest, which was installed in 1913 and is in poor condition.

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Attachments: Location Map
Site Photos

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March 16th, 2020

Ms. Jodi Bush
U.S. Fish and Wildlife Service
Ecological Services
585 Shepard Way, Suite 1
Helena, Montana 59601

RE: City-County of Butte-Silver Bow – Basin Creek Dam #1 – Rehabilitation

Dear Ms. Bush:

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Sincerely,

Great West Engineering, Inc.

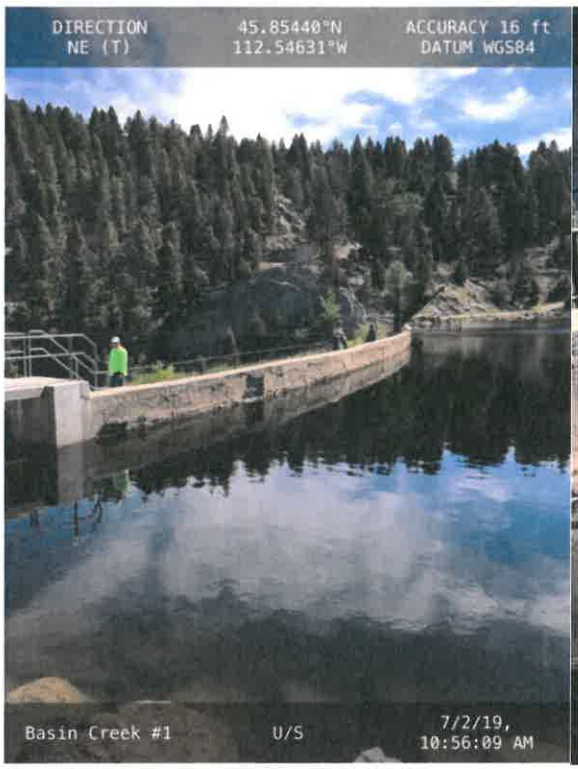
Ryan Elliott

Ryan Elliott, PE
Project Manager

Attachments: Location Map
Site Photos

cc: File

DIRECTION
W (T)
45.85453°N
112.54542°W
ACCURACY 16 ft
DATUM WGS84
Basin Creek #1
U/S face
7/2/19,
11:44:05 AM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112.54631°W
ACCURACY 16 ft
DATUM WGS84
Basin Creek #1
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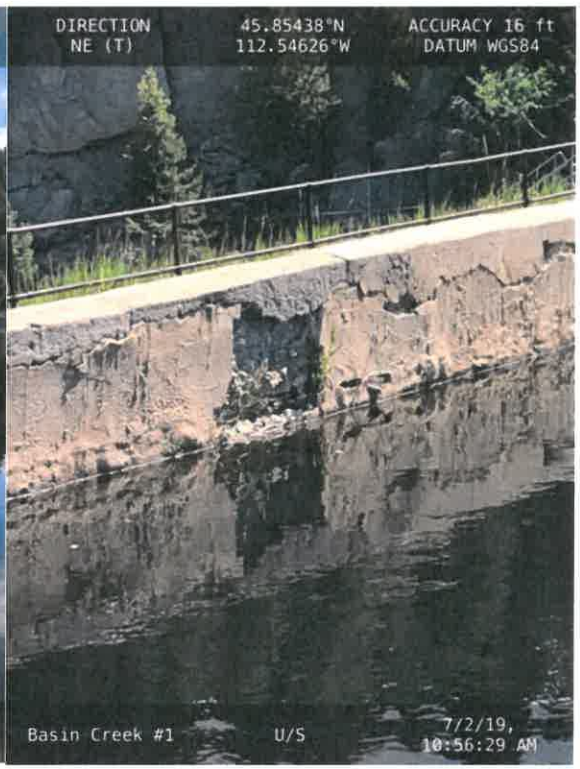
7/2/19,
10:56:09 AM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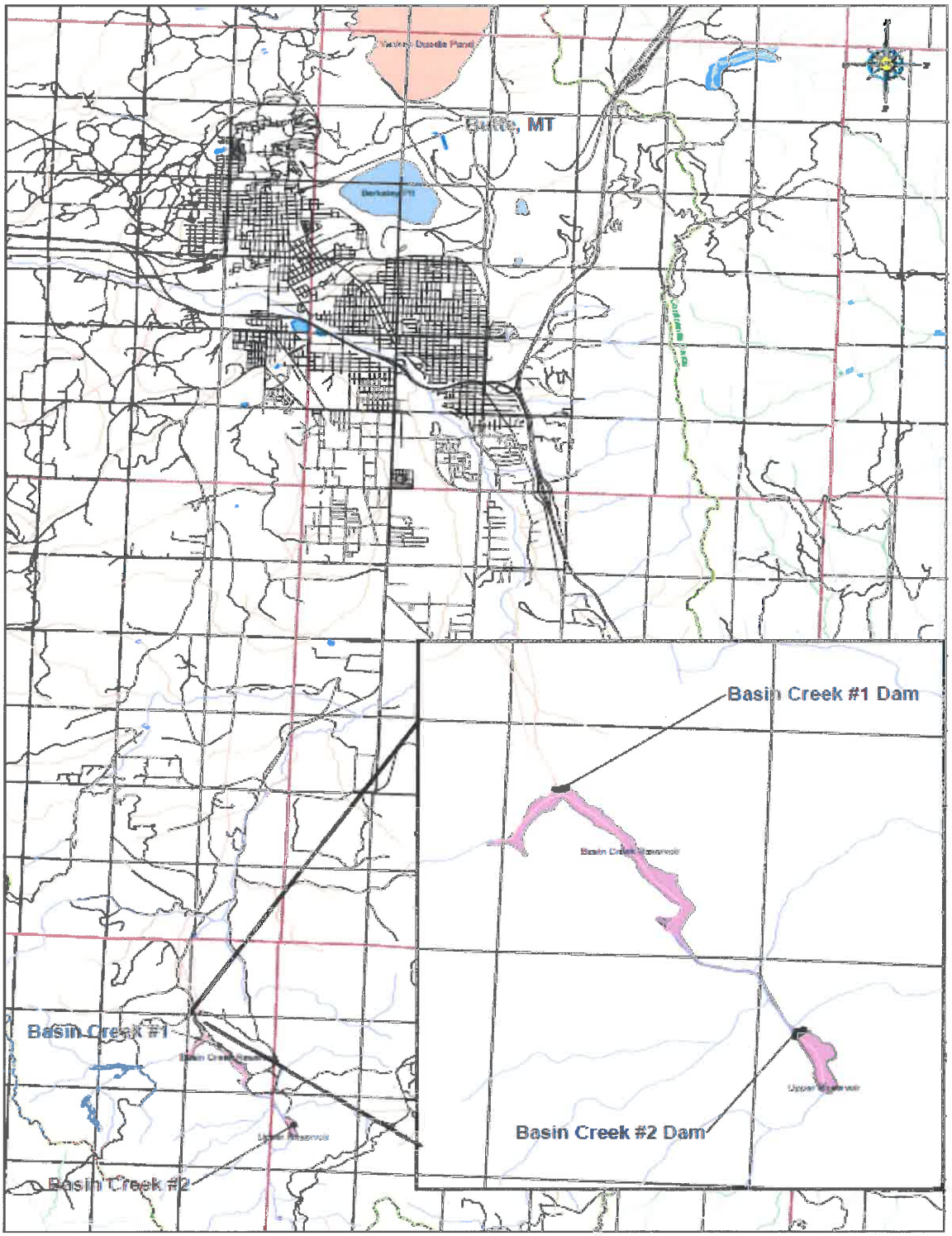
NE (T)
45.85438°N
112.54626°W
ACCURACY 16 ft
DATUM WGS84
Basin Creek #1
U/S
7/2/19,
10:56:29 AM



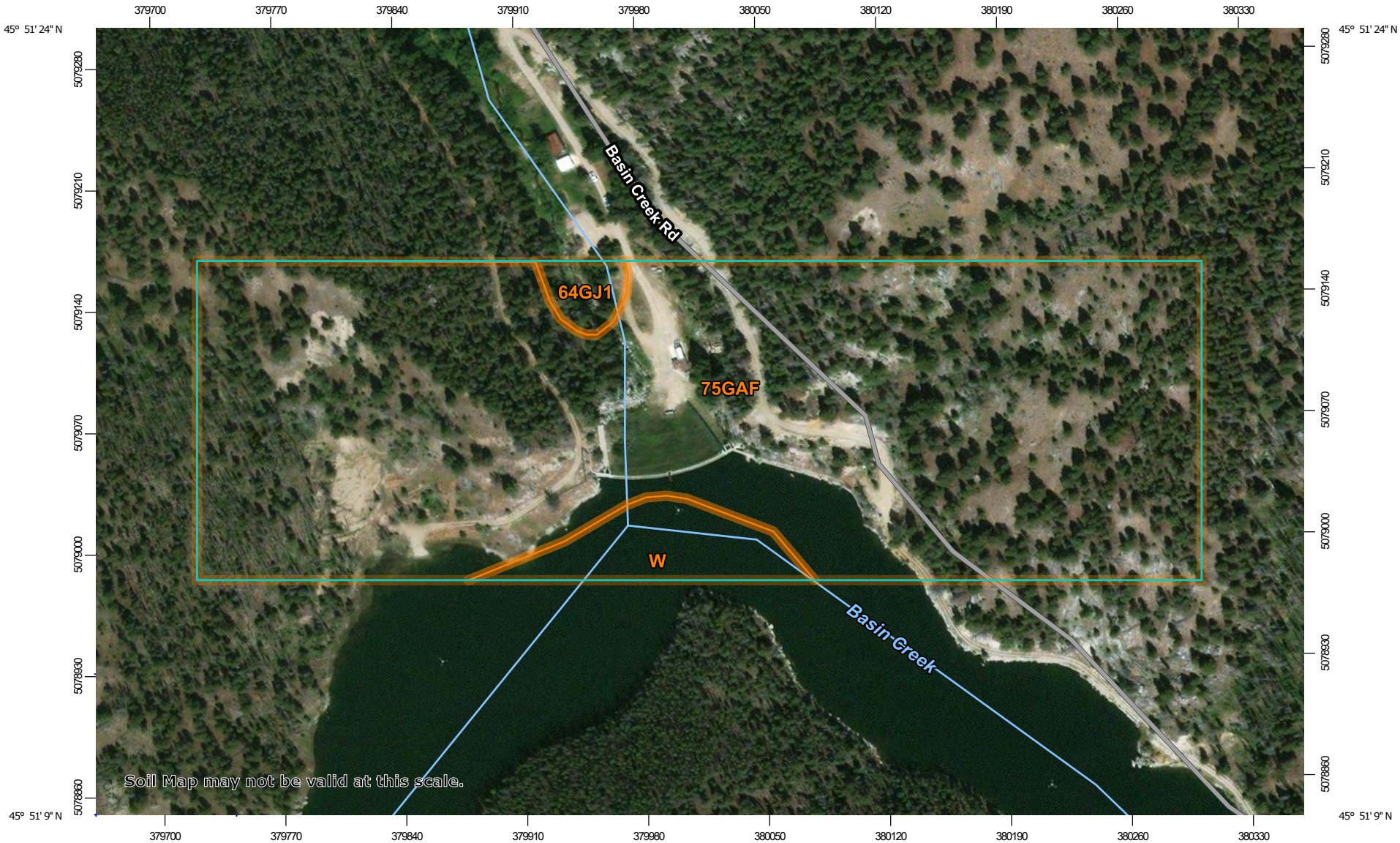
Location Map Basin Creek Dams 1&2

0 3,000 6,000 12,000 18,000 24,000 Feet

APPENDIX D

Soils Data

Soil Map—Deer Lodge National Forest Area, Montana
(Basin Creek Dam #1 - Soils)



Map Scale: 1:3,200 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 45 90 180 270

Feet: 0 150 300 600 900

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Unit Polygons

Soil Map Unit Lines

Soil Map Unit Points

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Deer Lodge National Forest Area, Montana
Survey Area Data: Version 18, Sep 16, 2019

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

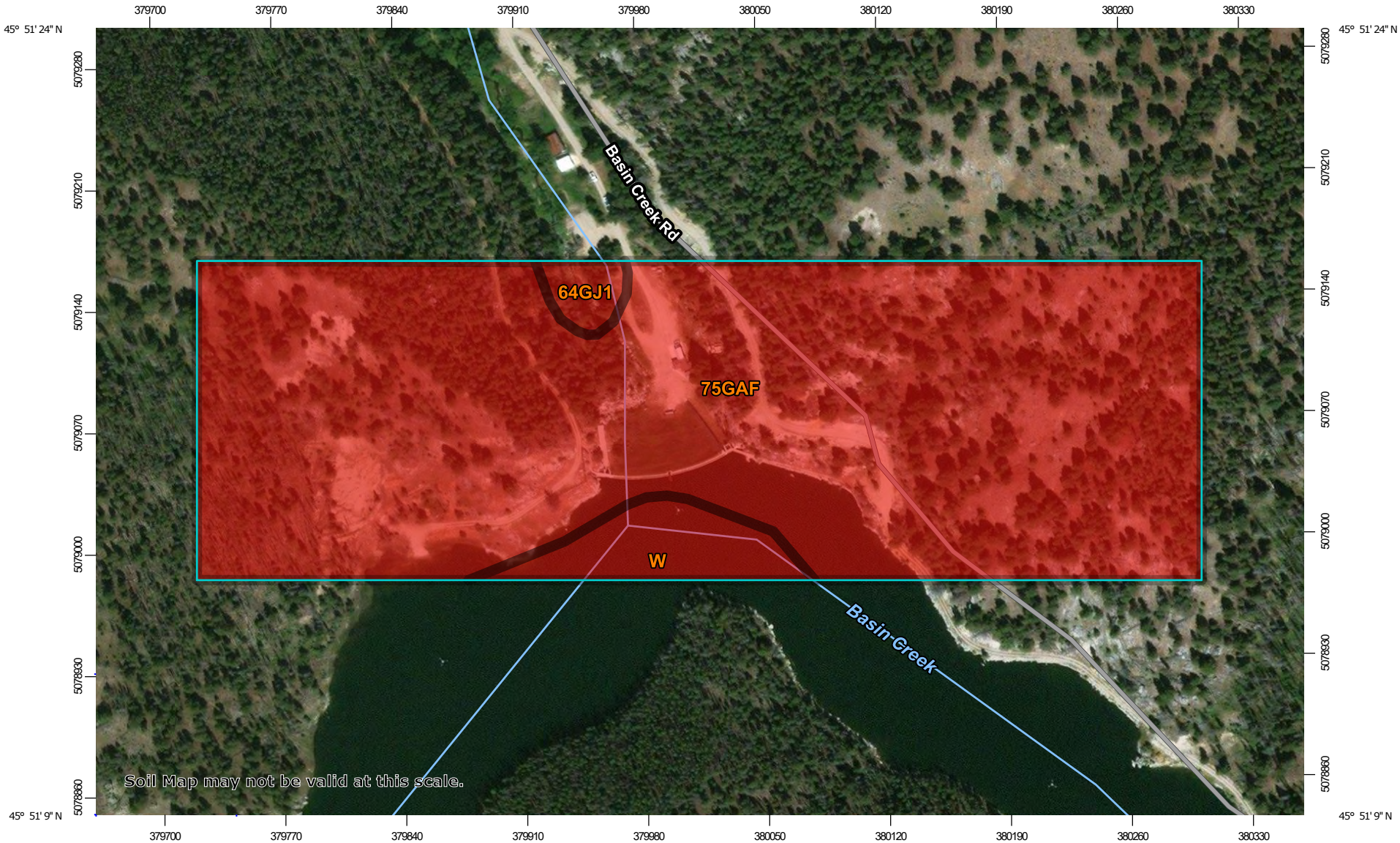
Date(s) aerial images were photographed: Mar 24, 2013—Sep 25, 2016

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
64GJ1	Cryofluvents-Finn family-Water complex, rolling stream terraces and flood plains	0.4	1.6%
75GAF	Ambrant-Rochester families, complex, low relief mountain slopes and ridges	24.7	93.1%
W	Water	1.4	5.3%
Totals for Area of Interest		**26.6**	**100.0%**

Farmland Classification—Deer Lodge National Forest Area, Montana
(Basin Creek Dam #1 - Farmland Classification)



Map Scale: 1:3,200 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 45 90 180 270

Feet: 0 150 300 600 900

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

Soil Rating Polygons

- Not prime farmland
- All areas are prime farmland
- Prime farmland if drained
- Prime farmland if protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated
- Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated and drained
- Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season
- Prime farmland if subsoiled, completely removing the root inhibiting soil layer
- Prime farmland if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- Prime farmland if irrigated and reclaimed of excess salts and sodium
- Farmland of statewide importance
- Farmland of statewide importance, if drained
- Farmland of statewide importance, if protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if irrigated
- Farmland of statewide importance, if drained and either protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if irrigated and drained
- Farmland of statewide importance, if irrigated and either protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if subsoiled, completely removing the root inhibiting soil layer
- Farmland of statewide importance, if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- Farmland of statewide importance, if irrigated and reclaimed of excess salts and sodium
- Farmland of statewide importance, if drained or either protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if warm enough, and either drained or either protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if warm enough
- Farmland of statewide importance, if thawed
- Farmland of local importance
- Farmland of local importance, if irrigated
- Farmland of unique importance
- Not rated or not available

Soil Rating Lines

- Not prime farmland
- All areas are prime farmland
- Prime farmland if drained
- Prime farmland if protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated
- Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated and drained
- Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season

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- Farmland of statewide importance, if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- Farmland of statewide importance, if irrigated and reclaimed of excess salts and sodium
- Farmland of statewide importance, if drained or either protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if warm enough, and either drained or either protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if warm enough
- Farmland of statewide importance, if thawed
- Farmland of local importance
- Farmland of local importance, if irrigated
- Farmland of unique importance
- Not rated or not available

Soil Rating Points

- Not prime farmland
- All areas are prime farmland
- Prime farmland if drained
- Prime farmland if protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated
- Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated and drained
- Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season
- Prime farmland if subsoiled, completely removing the root inhibiting soil layer
- Prime farmland if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- Prime farmland if irrigated and reclaimed of excess salts and sodium
- Farmland of statewide importance
- Farmland of statewide importance, if drained
- Farmland of statewide importance, if protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if irrigated

- Farmland of statewide importance, if drained and either protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if irrigated and drained
- Farmland of statewide importance, if irrigated and either protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if subsoiled, completely removing the root inhibiting soil layer
- Farmland of statewide importance, if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- Farmland of statewide importance, if irrigated and reclaimed of excess salts and sodium
- Farmland of statewide importance, if drained or either protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if warm enough, and either drained or either protected from flooding or not frequently flooded during the growing season
- Farmland of statewide importance, if warm enough
- Farmland of statewide importance, if thawed
- Farmland of local importance
- Farmland of local importance, if irrigated
- Farmland of unique importance
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Deer Lodge National Forest Area, Montana
Survey Area Data: Version 18, Sep 16, 2019

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 24, 2013—Sep 25, 2016

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Farmland Classification

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
64GJ1	Cryofluvents-Finn family-Water complex, rolling stream terraces and flood plains	Not prime farmland	0.4	1.6%
75GAF	Ambrant-Rochester families, complex, low relief mountain slopes and ridges	Not prime farmland	24.7	93.1%
W	Water	Not prime farmland	1.4	5.3%
Totals for Area of Interest			**26.6**	**100.0%**

Description

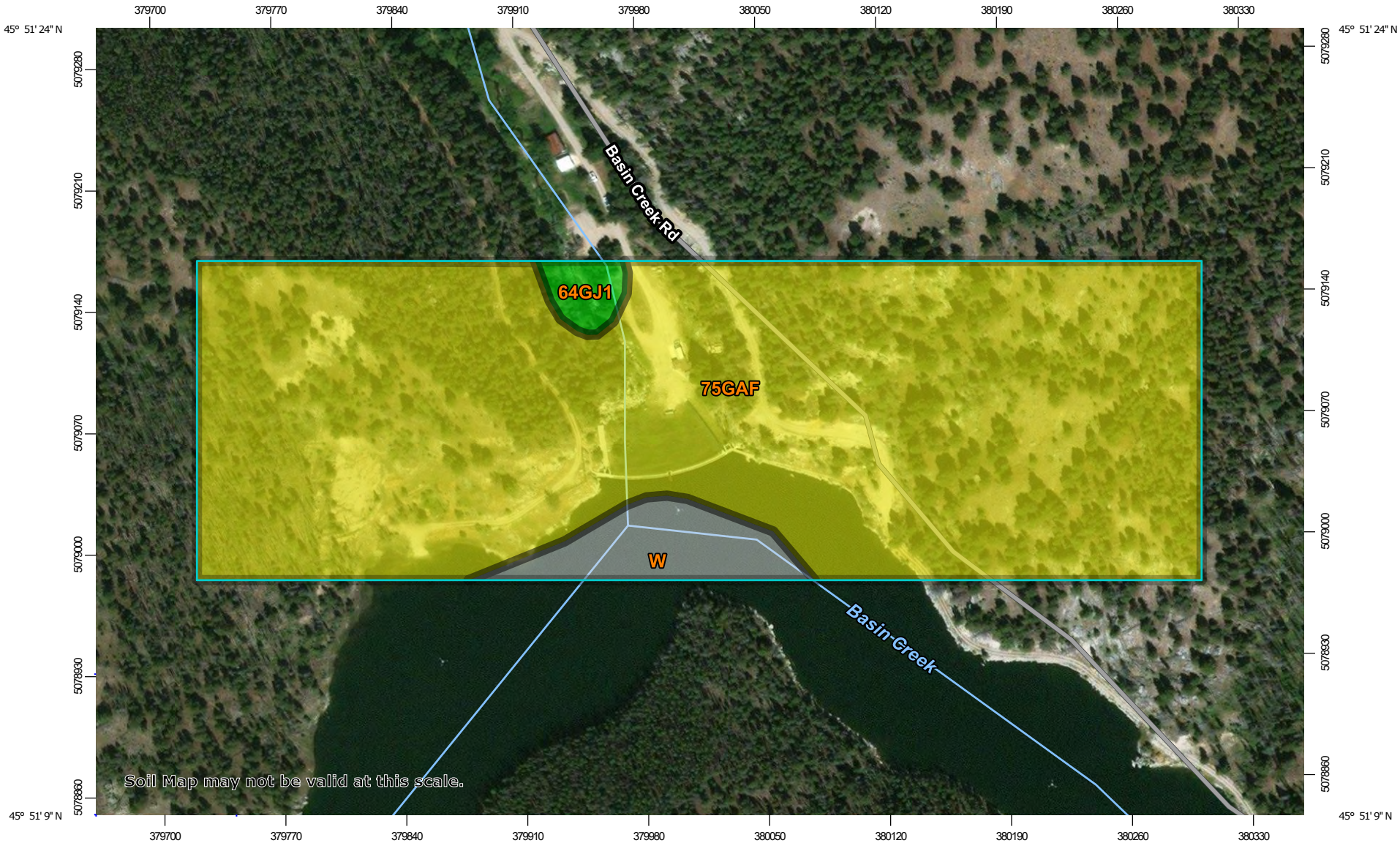
Farmland classification identifies map units as prime farmland, farmland of statewide importance, farmland of local importance, or unique farmland. It identifies the location and extent of the soils that are best suited to food, feed, fiber, forage, and oilseed crops. NRCS policy and procedures on prime and unique farmlands are published in the "Federal Register," Vol. 43, No. 21, January 31, 1978.

Rating Options

Aggregation Method: No Aggregation Necessary

Tie-break Rule: Lower

Corrosion of Concrete—Deer Lodge National Forest Area, Montana
(Basin Creek Dam #1 - Corrosion of Concrete)



Map Scale: 1:3,200 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 45 90 180 270

Feet: 0 150 300 600 900

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

High

Moderate

Low

Not rated or not available

Soil Rating Lines

High

Moderate

Low

Not rated or not available

Soil Rating Points

High

Moderate

Low

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

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This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Deer Lodge National Forest Area, Montana
Survey Area Data: Version 18, Sep 16, 2019

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 24, 2013—Sep 25, 2016

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Corrosion of Concrete

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
64GJ1	Cryofluvents-Finn family-Water complex, rolling stream terraces and flood plains	Low	0.4	1.6%
75GAF	Ambrant-Rochester families, complex, low relief mountain slopes and ridges	Moderate	24.7	93.1%
W	Water		1.4	5.3%
Totals for Area of Interest			**26.6**	**100.0%**

Description

"Risk of corrosion" pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens concrete. The rate of corrosion of concrete is based mainly on the sulfate and sodium content, texture, moisture content, and acidity of the soil. Special site examination and design may be needed if the combination of factors results in a severe hazard of corrosion. The concrete in installations that intersect soil boundaries or soil layers is more susceptible to corrosion than the concrete in installations that are entirely within one kind of soil or within one soil layer.

The risk of corrosion is expressed as "low," "moderate," or "high."

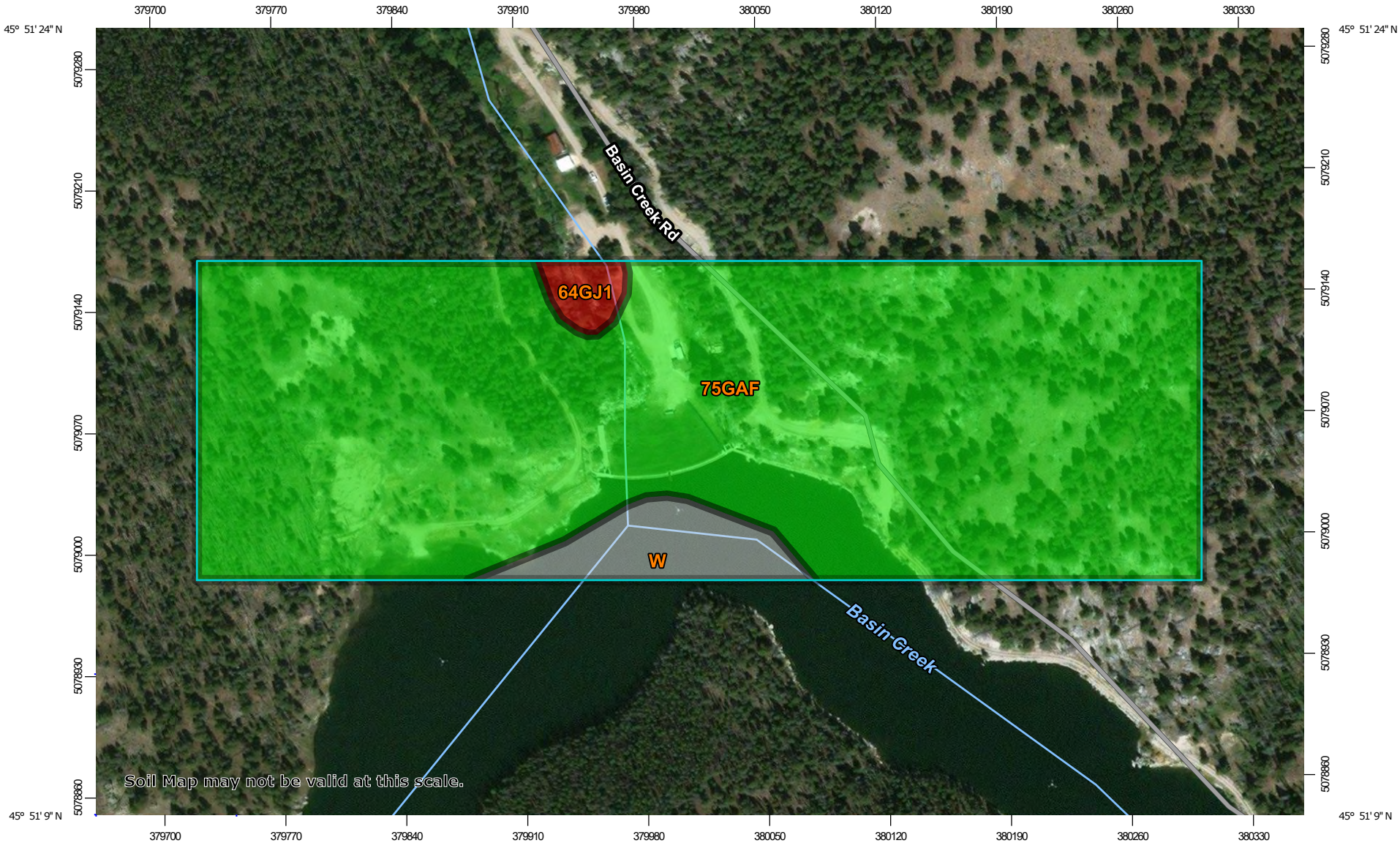
Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Corrosion of Steel—Deer Lodge National Forest Area, Montana
(Basin Creek Dam #1 - Corrosion of Steel)



Map Scale: 1:3,200 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 45 90 180 270

Feet: 0 150 300 600 900

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

High

Moderate

Low

Not rated or not available

Soil Rating Lines

High

Moderate

Low

Not rated or not available

Soil Rating Points

High

Moderate

Low

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Deer Lodge National Forest Area, Montana
Survey Area Data: Version 18, Sep 16, 2019

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 24, 2013—Sep 25, 2016

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Corrosion of Steel

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
64GJ1	Cryofluvents-Finn family-Water complex, rolling stream terraces and flood plains	High	0.4	1.6%
75GAF	Ambrant-Rochester families, complex, low relief mountain slopes and ridges	Low	24.7	93.1%
W	Water		1.4	5.3%
Totals for Area of Interest			**26.6**	**100.0%**

Description

"Risk of corrosion" pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens uncoated steel. The rate of corrosion of uncoated steel is related to such factors as soil moisture, particle-size distribution, acidity, and electrical conductivity of the soil. Special site examination and design may be needed if the combination of factors results in a severe hazard of corrosion. The steel in installations that intersect soil boundaries or soil layers is more susceptible to corrosion than the steel in installations that are entirely within one kind of soil or within one soil layer.

The risk of corrosion is expressed as "low," "moderate," or "high."

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Engineering Properties

This table gives the engineering classifications and the range of engineering properties for the layers of each soil in the survey area.

Hydrologic soil group is a group of soils having similar runoff potential under similar storm and cover conditions. The criteria for determining Hydrologic soil group is found in the National Engineering Handbook, Chapter 7 issued May 2007(http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba). Listing HSGs by soil map unit component and not by soil series is a new concept for the engineers. Past engineering references contained lists of HSGs by soil series. Soil series are continually being defined and redefined, and the list of soil series names changes so frequently as to make the task of maintaining a single national list virtually impossible. Therefore, the criteria is now used to calculate the HSG using the component soil properties and no such national series lists will be maintained. All such references are obsolete and their use should be discontinued. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to a seasonal high water table, saturated hydraulic conductivity after prolonged wetting, and depth to a layer with a very slow water transmission rate. Changes in soil properties caused by land management or climate changes also cause the hydrologic soil group to change. The influence of ground cover is treated independently. There are four hydrologic soil groups, A, B, C, and D, and three dual groups, A/D, B/D, and C/D. In the dual groups, the first letter is for drained areas and the second letter is for undrained areas.

The four hydrologic soil groups are described in the following paragraphs:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Depth to the upper and lower boundaries of each layer is indicated.

Texture is given in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. "Loam," for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, "gravelly."

Classification of the soils is determined according to the Unified soil classification system (ASTM, 2005) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO, 2004).

The Unified system classifies soils according to properties that affect their use as construction material. Soils are classified according to particle-size distribution of the fraction less than 3 inches in diameter and according to plasticity index, liquid limit, and organic matter content. Sandy and gravelly soils are identified as GW, GP, GM, GC, SW, SP, SM, and SC; silty and clayey soils as ML, CL, OL, MH, CH, and OH; and highly organic soils as PT. Soils exhibiting engineering properties of two groups can have a dual classification, for example, CL-ML.

The AASHTO system classifies soils according to those properties that affect roadway construction and maintenance. In this system, the fraction of a mineral soil that is less than 3 inches in diameter is classified in one of seven groups from A-1 through A-7 on the basis of particle-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in content of fines (silt and clay). At the other extreme, soils in group A-7 are fine grained. Highly organic soils are classified in group A-8 on the basis of visual inspection.

If laboratory data are available, the A-1, A-2, and A-7 groups are further classified as A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-7-5, or A-7-6. As an additional refinement, the suitability of a soil as subgrade material can be indicated by a group index number. Group index numbers range from 0 for the best subgrade material to 20 or higher for the poorest.

Percentage of rock fragments larger than 10 inches in diameter and 3 to 10 inches in diameter are indicated as a percentage of the total soil on a dry-weight basis. The percentages are estimates determined mainly by converting volume percentage in the field to weight percentage. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Percentage (of soil particles) passing designated sieves is the percentage of the soil fraction less than 3 inches in diameter based on an ovendry weight. The sieves, numbers 4, 10, 40, and 200 (USA Standard Series), have openings of 4.76, 2.00, 0.420, and 0.074 millimeters, respectively. Estimates are based on laboratory tests of soils sampled in the survey area and in nearby areas and on estimates made in the field. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Liquid limit and *plasticity index* (Atterberg limits) indicate the plasticity characteristics of a soil. The estimates are based on test data from the survey area or from nearby areas and on field examination. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

References:

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Report—Engineering Properties

Absence of an entry indicates that the data were not estimated. The asterisk '*' denotes the representative texture; other possible textures follow the dash. The criteria for determining the hydrologic soil group for individual soil components is found in the National Engineering Handbook, Chapter 7 issued May 2007(http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba). Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Engineering Properties–Deer Lodge National Forest Area, Montana														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
64GJ1—Cryofluvents-Finn family-Water complex, rolling stream terraces and flood plains														
Cryofluvents	55	A/D	0-2	Sandy loam	SM	A-2-4, A-4	0- 0- 0	0- 0- 0	100-100-100	100-100-100	60-65-70	30-35-40	20-23-25	NP-3 -5
			2-9	Loam, sandy loam, fine sandy loam	CL-ML, SC-SM, CL	A-4	0- 0- 0	0- 0- 0	100-100-100	100-100-100	60-75-90	35-50-65	25-28-30	5-8 -10
			9-36	Sandy loam, loam, very fine sandy loam	CL-ML, SC-SM, SM	A-2-4, A-4	0- 0- 0	0- 0- 0	100-100-100	100-100-100	60-75-90	30-48-65	20-25-30	NP-5 -10

Engineering Properties–Deer Lodge National Forest Area, Montana														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
			36-60	Very gravelly loamy sand, very cobbly loamy sand, very gravelly sand	SM, SP-SM	A-1-a	0- 0- 0	15-28-40	50-55-60	40-48-55	20-30-40	5-10- 15	20-23-25	NP-3 -5
Finn	30	B/D	0-1	Slightly decomposed plant material	PT	A-8	0- 0- 0	0- 0- 0	100-100-100	100-100-100	100-100-100	100-100-100	—	—
			1-11	Gravelly loam	CL-ML, GC-GM, SC-SM, GC	A-4	0- 0- 0	0- 5- 10	60-70-80	55-65-75	45-58-70	35-45-55	25-28-30	5-8 -10
			11-17	Very gravelly loam, very gravelly sandy loam	GC-GM, GC	A-4, A-2, A-2-4	0- 0- 0	10-18-25	40-50-60	35-45-55	20-35-50	15-28-40	25-28-30	5-8 -10
			17-23	Very gravelly sandy clay loam, very gravelly sandy loam, very gravelly loam	GC-GM, GC	A-2, A-4, A-2-4	0- 0- 0	15-23-30	40-53-65	35-45-55	20-35-50	15-28-40	25-28-30	5-8 -10
			23-60	Very gravelly sandy clay loam, very cobbly sandy clay loam, extremely cobbly sandy loam	GC-GM, GC	A-2, A-2-4	0- 0- 0	20-33-45	35-48-60	30-43-55	20-35-50	10-20-30	25-28-30	5-8 -10

Engineering Properties–Deer Lodge National Forest Area, Montana														
Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
75GAF—Ambrant-Rochester families, complex, low relief mountain slopes and ridges														
Ambrant, extremely bouldery	50	A	0-4	Gravelly sandy loam	GM, SM	A-1-b, A-2	0- 0- 0	0- 3- 5	55-70-85	50-63-75	30-43-55	15-23-30	20-23-25	NP-3 -5
			4-20	Gravelly loamy coarse sand, gravelly coarse sandy loam	GM, SM	A-1-b, A-2	0- 0- 0	0- 3- 5	55-70-85	50-63-75	25-43-60	10-18-25	20-23-25	NP-3 -5
			20-39	Gravelly sandy loam, gravelly coarse sandy loam	SM, GM	A-1-b, A-2	0- 0- 0	0- 3- 5	55-70-85	50-63-75	30-43-55	15-23-30	20-23-25	NP-3 -5
			39-60	Very gravelly sand, very gravelly loamy sand, very gravelly coarse sand	SP-SM, SP, GP-GM, GP	A-1-a	0- 0- 0	0- 0- 0	50-58-65	25-38-50	10-23-35	0- 5- 10	20-22-24	NP-2 -5
Rochester, very stony	35	A	0-3	Very stony sandy loam	GM, SM	A-1-b	15-20-25	25-33-40	45-58-70	40-53-65	25-35-45	10-18-25	20-23-25	NP-3 -5
			3-14	Extremely stony loamy sand, very stony loamy sand	GM, SP-SM, SM, GP-GM	A-2, A-1-b	20-25-30	10-18-25	40-58-75	35-53-70	20-38-55	5-13- 20	20-23-25	NP-3 -5
			14-60	Very stony loamy sand, very cobbly loamy sand, extremely stony loamy sand	SP-SM, SM, GP-GM, GM	A-1-a	20-25-30	25-28-30	40-50-60	35-45-55	20-30-40	5-10- 15	20-23-25	NP-3 -5

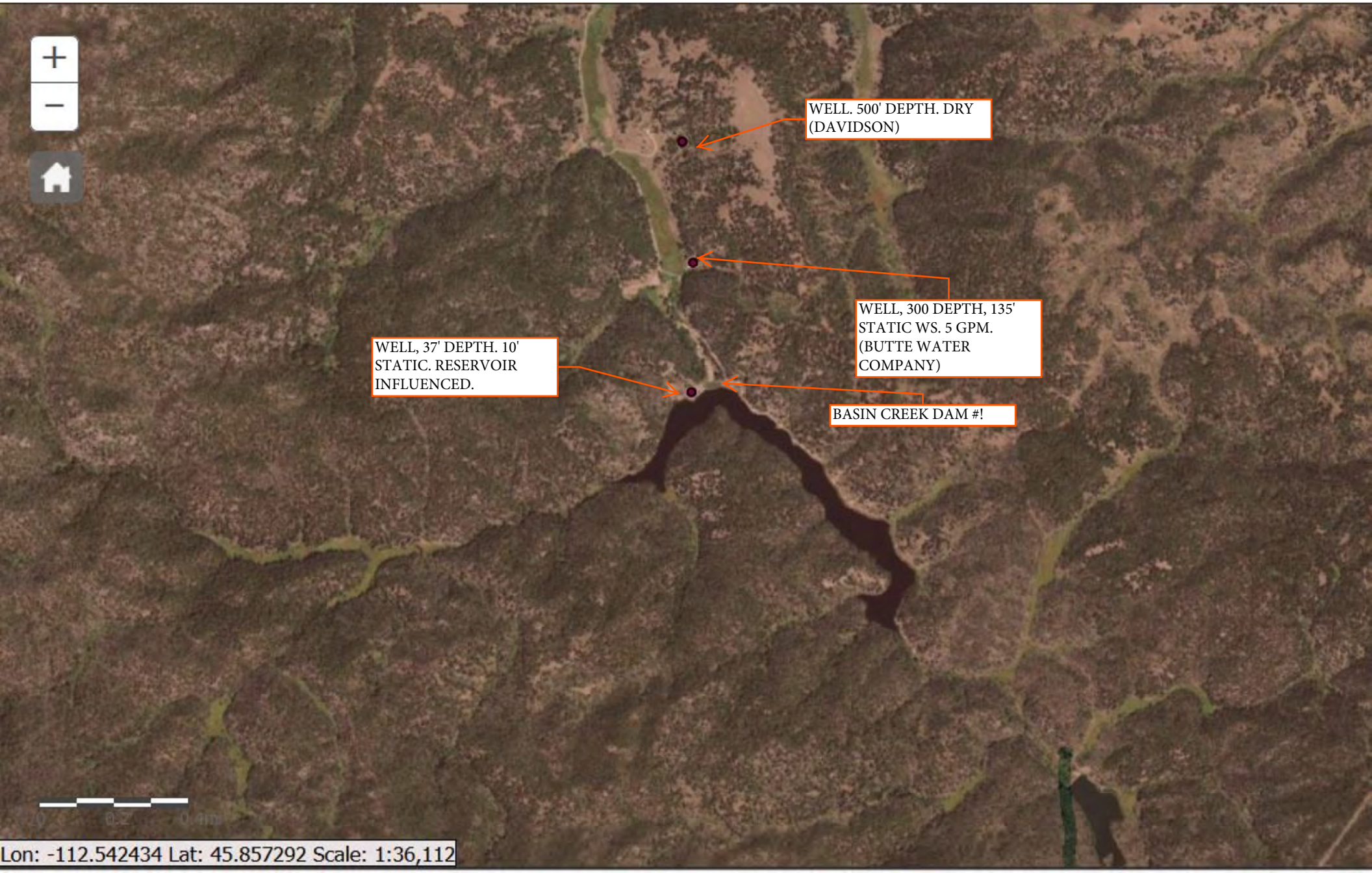
Data Source Information

Soil Survey Area: Deer Lodge National Forest Area, Montana
Survey Area Data: Version 18, Sep 16, 2019

APPENDIX E

Groundwater

(GWIC Summary of Area Wells)


WELL. 500' DEPTH. DRY (DAVIDSON)
WELL, 300 DEPTH, 135' STATIC WS. 5 GPM. (BUTTE WATER COMPANY)
WELL, 37' DEPTH. 10' STATIC. RESERVOIR INFLUENCED.
BASIN CREEK DAM #!
Lon: -112.542434 Lat: 45.857292 Scale: 1:36,112

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Go to GWIC website
Plot this site in State Library Digital Atlas
Plot this site in Google Maps
View hydrograph for this site
View field visits for this site
View water quality for this site
View scanned well log (8/24/2006 3:40:46 PM)

Site Name: BUTTE WATER COMPANY
GWIC Id: 120699

Section 1: Well Owner(s)

1) BUTTE WATER COMPANY (MAIL)
670 BASIN CREEK RD
BUTTE MT 59701 [08/23/1990]

Section 2: Location

Township	Range	Section	Quarter Sections
01N	08W	1	SW¼ SE¼ SW¼ SW¼

County	Geocode
SILVER BOW	

Latitude	Longitude	Geomethod	Datum
45.8594	-112.546	NAV-GPS	NAD27

Ground Surface Altitude	Ground Surface Method	Datum	Date
5770			7/10/2001

Measuring Point Altitude	MP Method	Datum	Date Applies
5772.2			7/10/2001 5:45:00 PM

Addition	Block	Lot

Section 3: Proposed Use of Water

DOMESTIC (1)

Section 4: Type of Work

Drilling Method: AIR ROTARY
Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Thursday, August 23, 1990

Section 6: Well Construction Details

There are no borehole dimensions assigned to this well.

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
1.5	18	6	0.25			STEEL
14	300	4				PVC

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
260	300	4			SAW SLOTS

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	18	BENTONITE	

Section 7: Well Test Data

Total Depth: 300
Static Water Level: 135
Water Temperature:

Pump Test *

Depth pump set for test _ feet.
_5_ gpm pump rate with _ feet of drawdown after _8_ hours of pumping.
Time of recovery _ hours.
Recovery water level _ feet.
Pumping water level _ feet.

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log

Geologic Source

211BDBT - BOULDER BATHOLITH

From	To	Description
0	2	TOPSOIL
2	10	SANDY GRAVEL
10	21	ROCK DECOMPOSED GRANITE
21	25	DECOMPOSED RED GRANITE
25	65	ROCK
65	75	SOFT ROCK
75	165	ROCK (SEEPAGE 150')
165	168	SOFT ROCK
168	300	ROCK (SEEPAGE 270'- 4 GPM AT 275')

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: DAN OKEEFE
Company: OKEEFE DRILLING CO
License No: WWC-462
Date Completed: 8/23/1990

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Go to GWIC website
Plot this site in State Library Digital Atlas
Plot this site in Google Maps
View scanned well log (8/24/2006 3:40:59 PM)

Site Name: DAVIDSON JOHN G
GWIC Id: 206815

Section 1: Well Owner(s)

1) DAVIDSON, JOHN G. (WELL)
634 BASIN CREEK RD
N/A MT N/A [09/10/2003]
2) DAVIDSON, JOHN G. (MAIL)
1830 HOLMES
BUTTE MT 59701 [09/10/2003]

Section 2: Location

Township	Range	Section	Quarter Sections
01N	08W	1	NW¼ SW¼

County	Geocode
SILVER BOW	

Latitude	Longitude	Geomethod	Datum
45.864021	-112.547461	TRS-SEC	NAD83

Ground Surface Altitude	Ground Surface Method	Datum Date

Addition	Block	Lot

Section 3: Proposed Use of Water

DOMESTIC (1)

Section 4: Type of Work

Drilling Method: ROTARY
Status: DRY WELL

Section 5: Well Completion Date

Date well completed: Wednesday, September 10, 2003

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	18	8.875
18	500	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	18	6			WELDED	STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
18	500	6			OPEN HOLE

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	18	BENTONITE CHIPS	

Section 7: Well Test Data

Total Depth: 500
Static Water Level:
Water Temperature:

Unknown Test Method *

Yield _ gpm.
Pumping water level _ feet.
Time of recovery _ hours.
Recovery water level _ feet.

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log

Geologic Source

Unassigned

From	To	Description
0	2	TOPSOIL
2	500	DECOMPOSED GRANITE (DRY HOLE)

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: DAN DURAN
Company: OKEEFE DRILLING CO
License No: WWD-82
Date Completed: 9/10/2003

APPENDIX F

Meteorological Data

BUTTE BERT MOONEY AP, MONTANA (241318)

Period of Record Monthly Climate Summary

Period of Record : 04/02/1894 to 06/09/2016

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	30.1	34.3	41.0	51.1	60.4	69.4	79.9	78.3	67.2	55.4	40.6	31.6	53.3
Average Min. Temperature (F)	7.4	10.7	17.8	27.0	34.7	41.8	47.0	45.1	36.8	28.5	18.0	9.6	27.0
Average Total Precipitation (in.)	0.59	0.52	0.80	1.08	1.91	2.30	1.26	1.15	1.10	0.80	0.62	0.58	12.71
Average Total SnowFall (in.)	8.5	7.3	10.2	6.9	3.7	0.5	0.0	0.1	1.1	3.7	6.5	8.4	56.8
Average Snow Depth (in.)	4	4	4	0	1	0	0	0	0	166	1	3	15

Percent of possible observations for period of record.
Max. Temp.: 86.9% Min. Temp.: 86.7% Precipitation: 87.1% Snowfall: 87.1% Snow Depth: 54.6%
Check Station Metadata or Metadata graphics for more detail about data completeness.

Western Regional Climate Center, wrcc@dri.edu

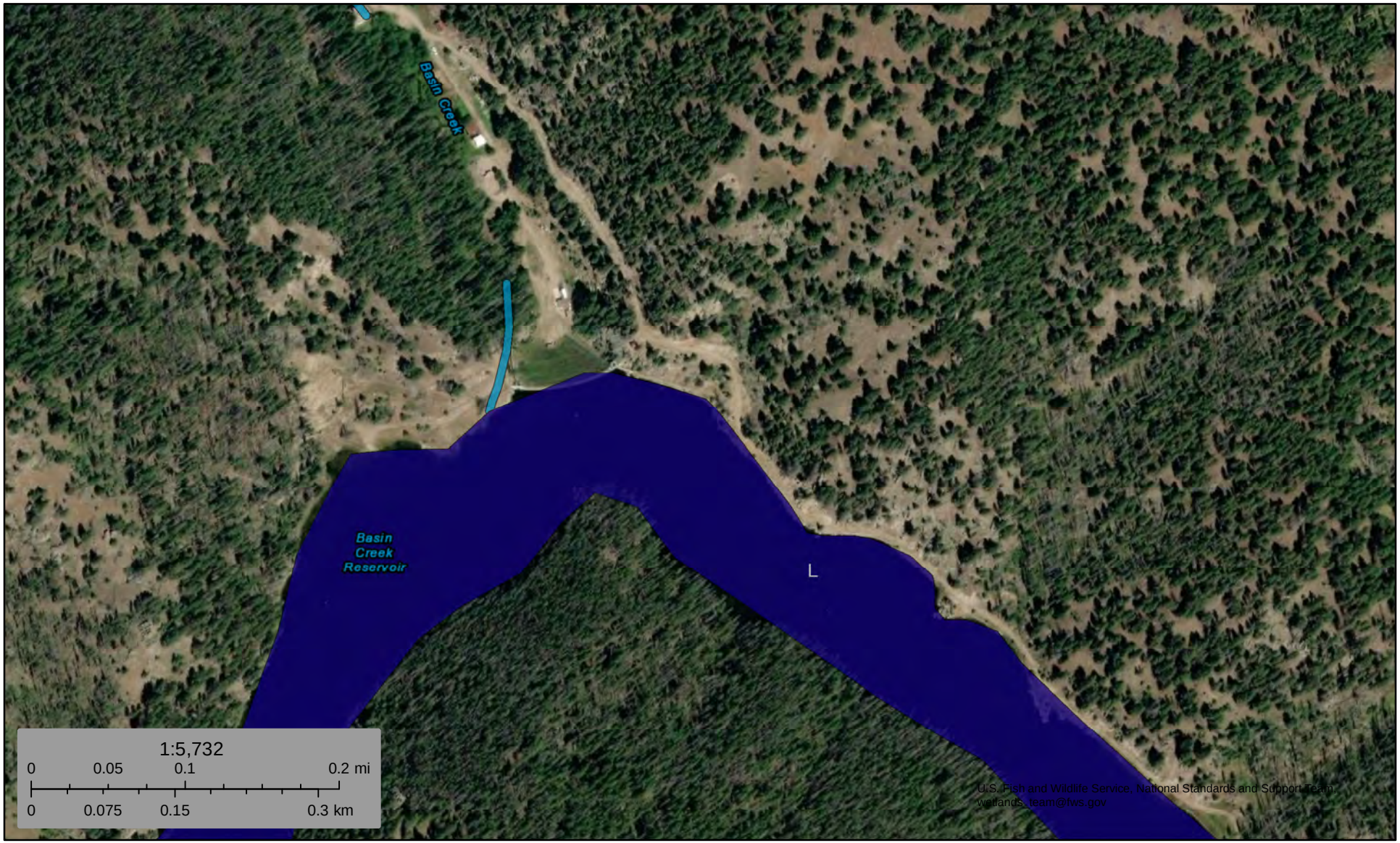
GWE note: Apparent reporting error.

APPENDIX G

Wetlands

U.S. Fish and Wildlife Service
National Wetlands Inventory

Basin Creek Dam #1 - Wetlands



April 26, 2020

Wetlands

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

National Wetlands Inventory (NWI)
This page was produced by the NWI mapper

APPENDIX H

Natural Heritage Data

Montana Natural Heritage - SOC Report Species List Last Updated **04/16/2020**

Animal Species of Concern

8 Species of Concern
Filtered by the following criteria:
Township = 001N008W (based on mapped Species Occurrences)

MONTANA Natural Heritage Program

A program of the Montana State Library's Natural Resource Information System **operated by the** University of Montana.

Expand All | Collapse All

Introduction

Species of Concern

Species of Concern
8 Species
Filtered by the following criteria:
Township = 001N008W (based on mapped **Species Occurrences**)

MAMMALS (MAMMALIA)

3 SPECIES
TOWNSHIP = 001N008W (based on mapped **Species Occurrences**)

SCIENTIFIC NAME / COMMON NAME / TAXA SORT	FAMILY (SCIENTIFIC) / FAMILY (COMMON)	GLOBAL RANK	STATE RANK	USFWS	USFS	BLM	FWP SWAP	% OF GLOBAL BREEDING RANGE IN MT	% OF MT THAT IS BREEDING RANGE	HABITAT
Gulo gulo Wolverine	**Mustelidae** Weasels	G4	S3	P	Proposed on Forests (BD, BRT, CG, HLC, KOOT, LOLO)	SENSITIVE	SGCN3	0%	37%	Boreal Forest and Alpine Habitats
		Species Occurrences verified in these Counties: Beaverhead, Broadwater, Carbon, Cascade, Deer Lodge, Flathead, Gallatin, Glacier, Granite, Jefferson, Judith Basin, Lake, Lewis and Clark, Lincoln, Madison, Meagher, Mineral, Missoula, Park, Pondera, Powell, Ravalli, Sanders, Silver Bow, Stillwater, Sweet Grass, Teton, Wheatland								
Lasiurus cinereus Hoary Bat	**Vespertilionidae** Bats	G3G4	S3			SENSITIVE	SGCN3	2%	100%	Riparian and forest
		Species Occurrences verified in these Counties: Beaverhead, Big Horn, Blaine, Broadwater, Carbon, Carter, Cascade, Chouteau, Custer, Daniels, Dawson, Deer Lodge, Fallon, Fergus, Flathead, Gallatin, Garfield, Glacier, Golden Valley, Granite, Hill, Jefferson, Judith Basin, Lake, Lewis and Clark, Liberty, Lincoln, Madison, Mccone, Meagher, Mineral, Missoula, Musselshell, Park, Petroleum, Phillips, Pondera, Powder River, Powell, Prairie, Ravalli, Richland, Roosevelt, Rosebud, Sanders, Sheridan, Silver Bow, Stillwater, Sweet Grass, Teton, Toole, Treasure, Valley, Wheatland, Wibaux, Yellowstone								
Myotis lucifugus Little Brown Myotis	**Vespertilionidae** Bats	G3	S3				SGCN3	3%	100%	Generalist
		Species Occurrences verified in these Counties: Beaverhead, Big Horn, Blaine, Broadwater, Carbon, Carter, Cascade, Chouteau, Custer, Daniels, Dawson, Deer Lodge, Fallon, Fergus, Flathead, Gallatin, Garfield, Glacier, Golden Valley, Granite, Hill, Jefferson, Judith Basin, Lake, Lewis and Clark, Lincoln, Madison, Mccone, Meagher, Mineral, Missoula, Musselshell, Park, Petroleum, Phillips, Pondera, Powder River, Powell, Prairie, Ravalli, Richland, Roosevelt, Rosebud, Sanders, Sheridan, Silver Bow, Stillwater, Sweet Grass, Teton, Toole, Treasure, Valley, Wheatland, Wibaux, Yellowstone **State Rank Reason:** Species is common and widespread, but under significant threat of catastrophic declines due to White-Nose Syndrome, a fungal disease responsible for the collapse of populations of this species in the eastern US.								

BIRDS (AVES)

4 SPECIES
TOWNSHIP = 001N008W (based on mapped **Species Occurrences**)

SCIENTIFIC NAME / COMMON NAME / TAXA SORT	FAMILY (SCIENTIFIC) / FAMILY (COMMON)	GLOBAL RANK	STATE RANK	USFWS	USFS	BLM	FWP SWAP	% OF GLOBAL BREEDING RANGE IN MT	% OF MT THAT IS BREEDING RANGE	HABITAT
Accipiter gentilis Northern Goshawk	**Accipitridae** Hawks / Kites / Eagles	G5	S3	MBTA			SGCN3	2%	68%	Mixed conifer forests
		Species Occurrences verified in these Counties: Beaverhead, Big Horn, Broadwater, Carbon, Carter, Cascade, Deer Lodge, Fergus, Flathead, Gallatin, Glacier, Granite, Jefferson, Judith Basin, Lake, Lewis and Clark, Liberty, Lincoln, Madison, Meagher, Mineral, Missoula, Park, Pondera, Powder River, Powell, Ravalli, Rosebud, Sanders, Silver Bow, Stillwater, Sweet Grass, Teton, Wheatland								
Haemorhous cassinii Cassin's Finch	**Fringillidae** Finches	G5	S3	MBTA; BCC10			SGCN3	11%	62%	Drier conifer forest
		Species Occurrences verified in these Counties: Beaverhead, Big Horn, Broadwater, Carbon, Cascade, Chouteau, Custer, Deer Lodge, Fergus, Flathead, Gallatin, Glacier, Golden Valley, Granite, Jefferson, Judith Basin, Lake, Lewis and Clark, Lincoln, Madison, Meagher, Mineral, Missoula, Musselshell, Park, Petroleum, Phillips, Powder River, Powell, Ravalli, Rosebud, Sanders, Silver Bow, Stillwater, Sweet Grass, Teton, Wheatland, Yellowstone **State Rank Reason:** Data show recent short-term declines in population for this species								
Nucifraga columbiana Clark's Nutcracker	**Corvidae** Jays / Crows / Magpies	G5	S3	MBTA	Species of Conservation Concern on Forests (FLAT)		SGCN3	9%	84%	Conifer forest
		Species Occurrences verified in these Counties: Beaverhead, Big Horn, Broadwater, Carbon, Carter, Cascade, Chouteau, Custer, Deer Lodge, Fergus, Flathead, Gallatin, Glacier, Golden Valley, Granite, Jefferson, Judith Basin, Lake, Lewis and Clark, Liberty, Lincoln, Madison, Meagher, Mineral, Missoula, Musselshell, Park, Petroleum, Phillips, Pondera, Powder River, Powell, Ravalli, Sanders, Silver Bow, Stillwater, Sweet Grass, Teton, Toole, Wheatland, Yellowstone								
Spizella breweri Brewer's Sparrow	**Passerellidae** New World Sparrows	G5	S3B	MBTA; BCC10; BCC17		SENSITIVE	SGCN3	12%	100%	Sagebrush
		Species Occurrences verified in these Counties: Beaverhead, Big Horn, Blaine, Broadwater, Carbon, Carter, Chouteau, Custer, Dawson, Deer Lodge, Fallon, Fergus, Flathead, Gallatin, Garfield, Glacier, Golden Valley, Granite, Hill, Jefferson, Lake, Lewis and Clark, Liberty, Lincoln, Madison, Mccone, Meagher, Missoula, Musselshell, Park, Petroleum, Phillips, Pondera, Powder River, Powell, Prairie, Ravalli, Richland, Roosevelt, Rosebud, Sanders, Sheridan, Silver Bow, Stillwater, Sweet Grass, Teton, Toole, Treasure, Valley, Wheatland, Wibaux, Yellowstone **State Rank Reason:** Species faces threats from loss of sagebrush habitats it is dependent on as a result of habitat conversion for agriculture and increased frequency of fire as a result of weed encroachment and drought.								

FISH (ACTINOPTERYGII)

1 SPECIES
TOWNSHIP = 001N008W (based on mapped **Species Occurrences**)

SCIENTIFIC NAME / COMMON NAME / TAXA SORT	FAMILY (SCIENTIFIC) / FAMILY (COMMON)	GLOBAL RANK	STATE RANK	USFWS	USFS	BLM	FWP SWAP	% OF GLOBAL BREEDING RANGE IN MT	% OF MT THAT IS BREEDING RANGE	HABITAT
Oncorhynchus clarkii lewisi Westslope Cutthroat Trout	**Salmonidae** Trout	G5T4	S2		Sensitive - Known on Forests (BD, BRT, CG, HLC, KOOT, LOLO)	SENSITIVE	SGCN2		34%	Mountain streams, rivers, lakes
		Species Occurrences verified in these Counties: Beaverhead, Broadwater, Cascade, Chouteau, Deer Lodge, Fergus, Flathead, Gallatin, Glacier, Granite, Jefferson, Judith Basin, Lake, Lewis and Clark, Lincoln, Madison, Meagher, Mineral, Missoula, Park, Pondera, Powell, Ravalli, Sanders, Silver Bow, Teton, Wheatland **State Rank Reason:** The Westslope Cutthroat trout is currently ranked "S2" in Montana because it is at risk due to very limited and/or potentially declining population numbers, range and/or habitat, making it vulnerable to extirpation in the state.								

Potential Species of Concern

Special Status Species

Additions To Statewide List

Species Removed From Statewide List

Species of Greatest Inventory Need

Citation for data on this website:
Montana Animal Species of Concern Report. Montana Natural Heritage Program and Montana Fish, Wildlife and Parks. Retrieved on 4/26/2020, from http://mtnhp.org/SpeciesOfConcern/?AorP=a

Montana Natural Heritage - SOC Report Species List Last Updated **04/16/2020**

Plant Species of Concern

3 Species of Concern
2 Potential Species of Concern - Species Occurrences are not maintained for Animal PSOC, therefore we cannot filter these species geographically
Filtered by the following criteria:
Township = 001N008W (based on mapped Species Occurrences)

MONTANA Natural Heritage Program

A program of the Montana State Library's Natural Resource Information System **operated by the** University of Montana.

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Introduction

Species of Concern

Species of Concern
3 Species
Filtered by the following criteria:
Township = 001N008W (based on mapped **Species Occurrences**)

FLOWERING PLANTS - DICOTS (MAGNOLIOPSIDA) — **2 SPECIES**
TOWNSHIP = 001N008W (based on mapped **Species Occurrences**)

SCIENTIFIC NAME / COMMON NAME / TAXA SORT	OTHER NAMES	FAMILY (SCIENTIFIC) / FAMILY (COMMON)	GLOBAL RANK	STATE RANK	USFWS	USFS	BLM	MNPS THREAT CATEGORY	HABITAT
Boechera fecunda Sapphire Rockcress	**Arabis fecunda**	**Brassicaceae** Mustards	G2	S2		Sensitive - Known on Forests (BD) Sensitive - Suspected on Forests (BRT, LOLO)	SENSITIVE	1	Rocky, calcareous, montane slopes
			Species Occurrences verified in these Counties: Beaverhead, Ravalli, Silver Bow **State Rank Reason:** Sapphire rockcress is a state endemic known from several locations in southwest Montana where it is restricted to specific and localized habitats. Encroachment of spotted knapweed threatens several populations, particularly in Ravalli County. It is unclear whether grazing has significant negative impacts						
Delphinium burkei Meadow Larkspur	**[including] Delphinium distichum**	**Ranunculaceae** Buttercup Family	G4	S1S2					Meadows (Moist, low-elevation)
			Species Occurrences verified in these Counties: Beaverhead, Flathead, Silver Bow **State Rank Reason:** Only known from a few collections from the western half of the state.						

FLOWERING PLANTS - MONOCOTS (LILIOPSIDA) — **1 SPECIES**
TOWNSHIP = 001N008W (based on mapped **Species Occurrences**)

SCIENTIFIC NAME / COMMON NAME / TAXA SORT	OTHER NAMES	FAMILY (SCIENTIFIC) / FAMILY (COMMON)	GLOBAL RANK	STATE RANK	USFWS	USFS	BLM	MNPS THREAT CATEGORY	HABITAT
Carex idahoa Idaho Sedge	**Carex parryana ssp. idahoa**	**Cyperaceae** Sedges	G3	S3		Sensitive - Known on Forests (BD)	SENSITIVE	2	Wetland/Riparian
			Species Occurrences verified in these Counties: Beaverhead, Broadwater, Deer Lodge, Gallatin, Madison, Powell, Silver Bow **State Rank Reason:** Idaho sedge is a regional endemic known from several dozen sites in Montana which cluster into approx 15-20 populations, most on public lands. The estimated number of stems is in the tens of thousands, but total occupied habitat has been estimated at less than 200 acres. The species is palatable, and populations may be affected by heavy grazing. Other risks are competition from exotic species, hydrologic alterations, agricultural development and road construction/maintenance. Updated population data and related site information are needed.						

Potential Species of Concern

Potential Species of Concern
2 Species
Filtered by the following criteria:
Township = 001N008W (based on mapped **Species Occurrences**)

FLOWERING PLANTS - DICOTS (MAGNOLIOPSIDA) — **2 SPECIES**
TOWNSHIP = 001N008W (based on mapped **Species Occurrences**)

SCIENTIFIC NAME / COMMON NAME / TAXA SORT	OTHER NAMES	FAMILY (SCIENTIFIC) / FAMILY (COMMON)	GLOBAL RANK	STATE RANK	USFWS	USFS	BLM	MNPS THREAT CATEGORY	HABITAT
Delphinium glaucescens Electric Peak Larkspur		**Ranunculaceae** Buttercup Family	G3G4	S3S4					
			Species Occurrences verified in these Counties: Beaverhead, Deer Lodge, Granite, Madison, Park, Silver Bow **State Rank Reason:** Occurs in southwest Montana at relatively high elevations. Though it has a restricted distribution, it may not be that uncommon.						
Ranunculus hyperboreus High Northern Buttercup	**Ranunculus natans**	**Ranunculaceae** Buttercup Family	G5	S3S4					Wetland/Riparian (Montane)
			Species Occurrences verified in these Counties: Beaverhead, Carbon, Deer Lodge, Gallatin, Jefferson, Madison, Missoula, Silver Bow, Valley **State Rank Reason:** Known from several southwest and south-central counties in Montana. See rank details for additional information.						

Special Status Species

Additions To Statewide List

Species Removed From Statewide List

Citation for data on this website:
Montana Plant Species of Concern Report. Montana Natural Heritage Program. Retrieved on 4/26/2020, from http://mtnhp.org/SpeciesOfConcern/?AorP=p

APPENDIX I

Floodplain Map

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) Report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS Report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study Report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study Report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study Report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was State Plane Zone (FIPS zone 2500). The **horizontal datum** was NAD 83, GRS 1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov, or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713- 3242**, or visit its website at http://www.ngs.noaa.gov.

Base map information shown on this FIRM was derived from NAIP Orthophotography produced with a one meter ground resolution from photography dated 2005.

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables for multiple streams in the Flood Insurance Study Report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

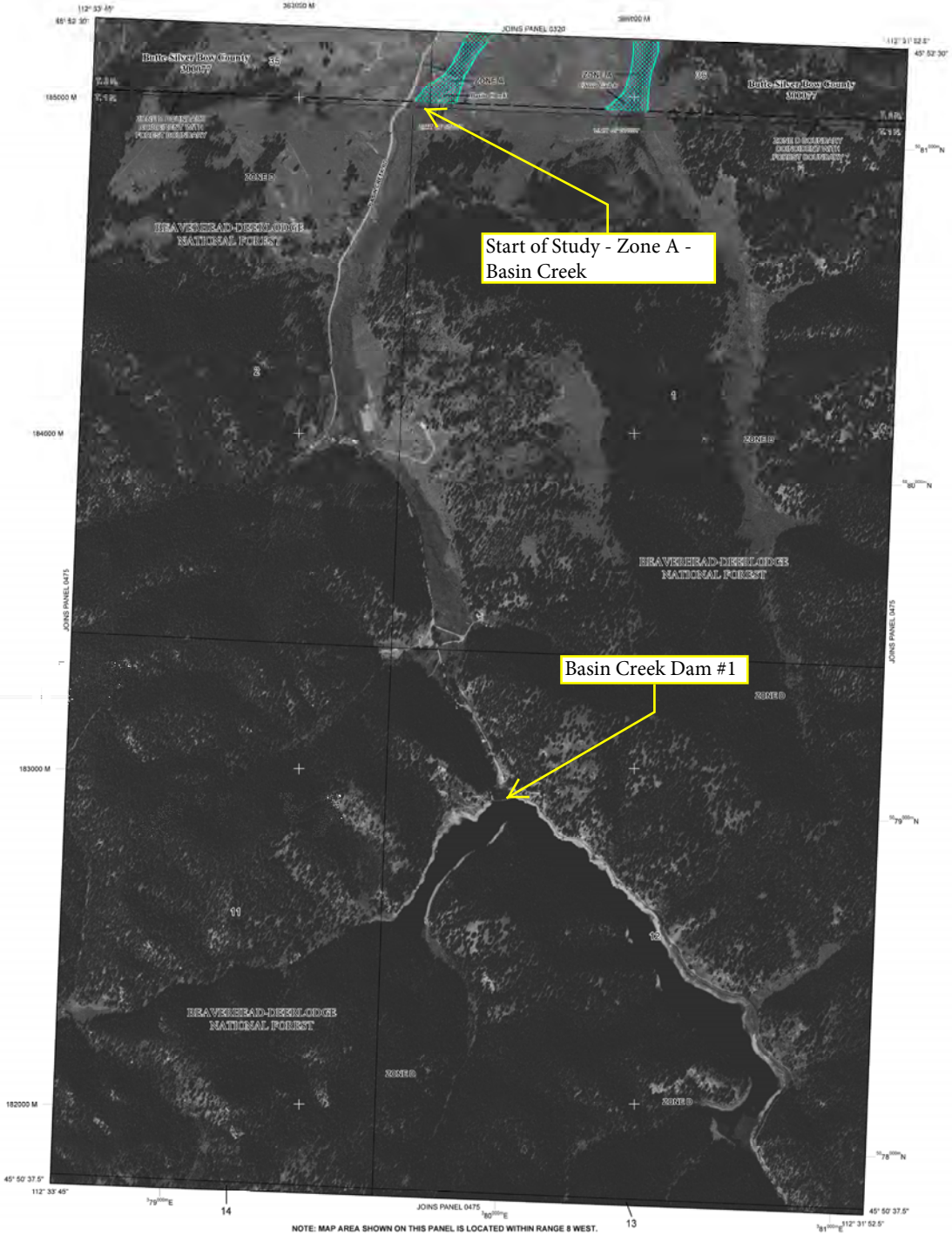
For information on available products associated with this FIRM visit the **Map Service Center (MSC)** website at http://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the MSC website.

If you have **questions about this map,** how to order products, or the National Flood Insurance Program in general, please call the **FEMA Map Information eXchange (FMIX)** at **1-877-FEMA-MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip.

Butte-Silver Bow County Vertical Datum Offset Table

Flooding Source	Vertical Datum Offset (ft)	Flooding Source	Vertical Datum Offset (ft)
Basin Creek	4.2	Reese Canyon	4.2
Big Hole River	3.9	Sand Creek	4.2
Blacktail Creek	4.2	Silver Bow Creek (Near Butte)	4.2
Brookside Canyon	4.2	Silver Bow Creek (Near Fairmont)	4.0
Gregson Creek	4.0	Silver Bow Creek (Near Rocker)	4.2
Grove Gulch Creek	4.2	Tramway Gulch	4.3
Moose-5 Canyon	4.3		

Example: To convert Basin Creek elevations to NAVD 88, 4.2 feet were added to the NGVD 29 elevations.



NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN RANGE 8 WEST.

LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

1% Annual Chance Floodplain Boundary

0.2% Annual Chance Floodplain Boundary

Floodway boundary

Zone D boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths, or flood velocities.

513 — Base Flood Elevation line and value; elevation in feet*

(EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A Cross section line

23 - - - - - 23 Transect line

45° 02' 08", 93° 02' 12" Geographic coordinates referenced to the North American Datum of 1983 (NAD 83) Western Hemisphere

4989000 M 1000-meter ticks: State Plane Zone (FIPS Zone 2500), Lambert Conformal Conic projection

5000000 N 1000-meter Universal Transverse Mercator grid values, zone 12

DX5510 × Bench mark (see explanation in Notes to Users section of this FIRM panel)

• M1.5 River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
January 6, 2012

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 500'

250 0 500 1000 FEET

150 0 150 300 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0456E

FIRM

FLOOD INSURANCE RATE MAP

BUTTE-SILVER BOW COUNTY, MONTANA (ALL JURISDICTIONS)

PANEL 456 OF 700

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BUTTE-SILVER BOW COUNTY	300077	0456	E

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
30093C0456E

EFFECTIVE DATE
JANUARY 6, 2012

Federal Emergency Management Agency

APPENDIX J

2020 Basin Creek Dam Structural Assessment

Submitted to:

City-County of Butte Silver Bow

GF Job No.: 066557

BASIN CREEK DAM

STRUCTURAL ASSESSMENT

January 24, 2020

Submitted by:

Gannett Fleming

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1.0 INTRODUCTION

1.1 DAM DESCRIPTION

Basin Creek Dam is owned and operated by the City-County of Butte-Silver Bow (BSB) and forms Basin Creek Reservoir. The dam is located in Silver Bow County, Montana approximately 10 miles south of Butte. The dam was designed and constructed in the late 1800s and early 1900s and is a combined earth, masonry, and concrete structure. The original dam (completed in 1897) was an 88-foot-high rubble masonry structure with a base elevation of El. 5788.06 (NAVD88 Datum, El. 5772 local datum) and a crest elevation of El. 5876.06 (NAVD88 Datum, El. 5860 local datum). In 1939, monolithic concrete tiers were added to the face of the dam, heightened the dam to 101 feet tall to El. 5889.06 (NAVD88 Datum, El. 5873 local datum). The dam has a crest length of approximately 275 feet. In the 1930s, earthfill cover with a slope of approximately 1.6 horizontal (H) to 1.0 vertical (V) was placed on the downstream face.

A 2-foot-high parapet wall was constructed along the upstream crest during the raising of the dam with concrete in 1913. Basin Creek Reservoir (impounded by Basin Creek Dams No. 1 and No. 2) provides up to approximately 60 percent of Butte's drinking water. Section and plan views of the dam are shown in Drawing A - 1 and Drawing A - 2, respectively, found in Appendix A.

It should be noted there have been two elevation datums used for the dam. The 'local' datum is used in record drawings, Operations Procedures, and past inspection reports. The 'NAVD88' datum was used for the Basin Creek water treatment plant as well as a dam breach analysis and inundation mapping currently underway. BSB desires to use the NAVD88 datum for all work moving forward. All elevations in this document are in feet and referenced to the NAVD88 datum, unless otherwise noted. The NAVD88 datum is related to the 'local' datum as follows: elevation in NAVD88 datum equals elevation in 'local' datum plus 16.06 feet.

1.2 PROJECT HISTORY

Basin Creek Dam No. 1 was designed and constructed in the late 1800s and subsequently modified in 1913. The original construction of the dam was completed in 1897 and consisted of an 88-foot-high curved masonry dam. Modifications to the dam were performed in 1913 and consisted of adding mass concrete to the downstream face and crest. The modification increased the height of the dam 13 feet (including 2-foot-high parapet at the upstream face). Further modifications were completed in the 1930s, which included placing an earthfill embankment on the downstream slope of the dam for added stability. The downstream slope of the embankment is approximately 1.6:1.0 (H:V).

The 2005 and 2006 rehabilitation work primarily consisted of constructing a new concrete spillway with operable crest gate (crest El. 5888.06 NAVD88, El. 5872 local), rehabilitating the outlet works with new intake pneumatic valves, and slip-lining the existing conduits with new high-density polyethylene (HDPE) pipe. The spillway crest elevation is at El. 5884.56 (NAVD88, El. 5868.5 local) and has a width of 9.0 feet. The new spillway passes approximately 215 cfs, with the gate open, which can accommodate up to the 500-year flood without the dam crest being overtopped.

1.3 PURPOSE

During recent inspections, significant deterioration of the mass concrete has been noted along the upstream face of the dam. In addition, the rate of deterioration has increased over the past couple of years. The purpose of this work is to assess the stability of the upper mass concrete dam considering the effects of the concrete deterioration and to make recommendations for repairs to the deteriorated concrete.

Note that the current configuration is such that the probable maximum flood (PMF) event is estimated to overtop the parapet by 3.8 feet. It is considered very likely that the earthfill embankment placed along the downstream slope of the dam will be washed away. This assessment considers the impact the downstream fill has on the stability of the upper mass concrete portion of the dam.

1.4 PREVIOUS STUDIES

There have been several recent studies of Basin Creek Dam. The conclusion of these studies is that the dam is stable for the Usual and Unusual (PMF) load conditions without the embankment load on the downstream face. Therefore, this investigation focuses on the upper mass concrete portion of the dam, which is where the deterioration is actively occurring.

1.4.1 2005 Three-Dimensional Analysis – URS

In 2005, a three-dimensional analysis of Basin Creek Dam was performed using the USBR Arch Dam Stress Analysis System (ADSAS) computer program [1]. This study evaluated both the masonry and mass concrete dam as a composite section.

The conclusions from these structural stability studies are summarized below:

- For the usual loading condition acting on the current dam configuration, with the embankment on the downstream face, the dam has adequate factors of safety against overstressing and sliding for all assumed loading and material conditions.
- For the unusual loading condition acting on the assumed dam configuration, without the embankment on the downstream face, the dam has an adequate factor of safety against overstressing but an inadequate factor of safety against sliding for an effective friction angle of 49 degrees.
- Further investigation is required to better assess the condition of the dam/foundation interface.

The report made recommendations for further studies and are summarized below:

- Assess the condition of the foundation. A detailed study should be performed to obtain a more accurate estimate of the friction angle at the dam foundation interface. This study would include a site visit to visually inspect the roughness of the foundation and other relevant foundation properties. It would also include performing several direct shear tests of material from different locations near the dam/foundation interface. Performing these studies would yield better information about the condition of the foundation and might indicate that the dam is stable based on this study.

- Perform a fully three-dimensional finite element study of the dam. Should the stability of the dam still be in doubt upon performing the above studies, a three-dimensional finite element analysis may yield a more accurate assessment of the condition of the dam than the ADSAS study summarized in the report.

1.4.2 2006 Site Inspection - URS

In 2006, a detailed study of the foundation was performed to more accurately estimate the friction angle at the dam foundation interface [2]. This study was in response to the recommendations made in the 2005 analysis discussed in Section 1.4.1.

The conclusions from these structural stability studies are summarized below:

- The shear strength of the dam/foundation interface should be simulated using an effective friction angle of approximately 66 degrees and zero (0) cohesion.
- The results from the updated stability analysis using the refined friction angle indicate that the dam has adequate safety for sliding for both the Usual and Unusual (PMF) loading conditions without the embankment on the downstream face.

2.0 DAM INSPECTION

2.1 FIELD INSPECTION

Inspection of Basin Creek Dam was conducted by Aimee Corn, P.E. of Gannett Fleming, Inc. on November 22, 2019. Ms. Corn was accompanied by Jim Keenan of the City-County of Butte-Silver Bow (BSB). Weather conditions at the time of the inspection were blue skies and between 35^0F and 45^0F.

In general, the condition of the dam was considered to be in poor condition. Inspection of the dam was relatively easy with all exposed features recognizable. The dam and its features are shown in Photo No. 1 in Appendix B. Inspection observations are highlighted below.

2.1.1 Inflows

Inflows to the reservoir come from Basin Creek and Bear Creek. There did not appear to be significant inflow at the time of the inspection.

2.1.2 Reservoir Area

At the time of the inspection, the reservoir level was at approximately El. 5875.56 (NAVD88, El. 5859.5 local), a few inches below the concrete/masonry interface. The reservoir rim was inspected from the dam crest and abutments. There were no observed signs of instability or continuous fault/joints that would suggest a large volume of material could enter the reservoir. The reservoir was covered in ice; however, the bubbler on the upstream face of the dam was operational, and therefore there was no ice on the upstream face on the dam. The reservoir rim is shown on Photo No. 2.

2.1.3 Abutments and Downstream Toe

The abutments and downstream toe were covered in snow and shown in Photo No. 3. Erosion control measures are in place as a result of recent maintenance and repairs to the reservoir bypass pipeline, which appear to be in good condition. The spillway channel is along the left abutment and outfalls downstream of the dam. The channel, Photo No. 4, appears to be in good condition.

2.1.4 Dam Crest

The crest of the dam was covered in ice and snow, and therefore, visibility was limited to areas that were cleared for drilling, as shown in Photo No. 5. The walkway is overlaid with concrete pavers as shown in the inset of Photo No. 5 which insulates the crest from the elements reducing the risk of freeze-thaw damage. The downstream face of the parapet along the crest was in good condition. There was no noted separation of construction joints as shown in Photo No. 6.

2.1.5 Upstream Face

The upstream face of the dam was inspected by boat. Large areas of spalling and cracking near the crest of the dam was visible along the majority of the upstream face, as shown in Photo No. 7 through Photo No. 9. The mass concrete portion of the dam has been covered in shotcrete with wire reinforcement. The shotcrete near the masonry/concrete interface was in poor condition

and could easily be knocked away. Numerous voids were visible on the shotcrete, as shown in Photo No. 10 through Photo No. 12.

2.1.6 Downstream Face

The downstream face of the dam is covered in an earthfill cover. No unusual movement of the dam was observed and there was no active leakage observed on the downstream face during the inspection. The downstream face is shown in Photo No. 3.

2.1.7 Instrumentation

No instrumentation was observed at the dam.

2.1.8 Site Access

Basin Creek Dam is located at the end of Basin Creek Road, approximately 7 miles south of the intersection with Harrison Avenue. There are two roads that lead to the crest of the dam, one along the left abutment and one along the right abutment. Snow and ice create hazardous conditions, and four-wheel drive is recommended during snow/icy conditions.

3.0 CONCRETE CORING RESULTS

Four cores were extracted from Basin Creek Dam and were subjects of petrographic examination. The purpose of the investigation was to characterize the general composition and condition of the concrete and determine the mechanism(s) associated with cracking. This section summarizes the findings from the examination, the full report is found in Appendix D.

The findings from this work indicate that all four cores show evidence of severe freeze-thaw damage. The damage manifests as cracking and microcracking that is sub-parallel to the exposed surface of the cores. Most of the cracks cut around coarse aggregate particles.

Several properties of the concrete make it susceptible to freeze-thaw damage, as noted below.

- The paste has a high water-cement ratio (w/c) that facilitates the penetration of moisture, which diminishes the freeze-thaw durability of concrete. ACI 201 *Guide to Durable Concrete* recommends a maximum w/c ratio of 0.45 for frost durability. Although it is not possible to quantitatively estimate the w/c of the present concrete due to its historical nature, the properties of the paste are consistent with modern concretes where the w/c is greater than 0.60.
- The concrete is non-air-entrained, which is typical for historical concretes that pre-date the use of modern air-entraining admixtures. The estimated total air content of the cores is less than 3%. Such concrete is not expected to provide freeze-thaw durability if it is saturated and exposed to freeze-thaw cycles as expected for a hydraulic dam in Butte, Montana.

The composition and proportioning of the components used to produce the concrete are consistent with each other. The paste contains hydrated Portland cement; no fly ash, slag cement or other supplemental cementitious materials were observed. The hydration is advanced. The water-cement ratio (w/c) was not estimated quantitatively due to the age of the concrete and the historical nature of the cement, but the properties of the paste are consistent with modern concretes that have high w/c (greater than 0.60). The concrete is non-air entrained and contains less than 3% total estimated air content. The coarse aggregate is a crushed granodiorite that has a 75 mm (3 in.) nominal top size. The fine aggregate is a natural siliceous sand that consists mostly of the same granodiorite observed in the coarse aggregate.

Secondary deposits include ettringite and carbonation. Core RADS show evidence of pervasive carbonation to a depth of 5-15 mm (1/4 – 5/8 in.) from the outer surface. The remaining three cores show slight carbonation throughout the length of the cores. Deposits of ettringite were observed in voids, open fractures, cracks and microcracks throughout the length of the cores. These deposits indicate the concrete was exposed to high levels of saturation for a prolonged period of time. No evidence of ASR was observed.

4.0 STRUCTURAL EVALUATION OF MASS CONCRETE DAM

4.1 METHODOLOGY

A structural stability evaluation was performed for static loading conditions of the 13-foot mass concrete section atop the masonry section. The gravity method of analysis was used to simulate the static loading combinations.

4.1.1 Treatment of Base

The base of the section analyzed is considered the interface between the original masonry dam at El. 5876.06 (NAVD88 Datum, El. 5860 local datum). The section is considered to have a horizontal analysis plane though the mass concrete. The friction angle is assumed to be 54 degrees at the base of the section (i.e., sliding plane).

4.1.2 Analysis Assumptions

The following assumptions are used for this evaluation:

- There are no drawings or photographs of construction that indicate rebar or reinforcement within the mass concrete. Reinforcement was encountered during the coring of the parapet and steel was encountered within the shotcrete during the site visit. The analysis assumes there is no reinforcement within the dam and there is no reinforcement or doweling between the original masonry dam and the newer mass concrete.
- The concrete is assumed to have zero (0) tensile strength.
- Cohesion is assumed to be zero (0) along evaluated failure planes.
- Although the downstream berm provides both a horizontal and vertical load, the horizontal load of the soil was conservatively neglected.
- Overtopping of the dam would erode out the embankment dam, and therefore, no downstream embankment load was included for a reservoir level higher than the top of the parapet.

4.2 MATERIAL PROPERTIES

4.2.1 Concrete Properties

The dam material parameter assumptions were taken from the previous stability evaluation done in 2005 by URS [1] and are summarized in Table 4-1.

The unit weight of the concrete is assumed to be 150 lb/ft^3.

The compressive strength and tensile strength for the dam was assumed to be 3,000 lb/in^2 [3] and 300 lb/in^2 [4], respectively. For this evaluation, the tensile strength of concrete is assumed to be zero.

Table 4-1 Summary of Assumed Concrete Properties

Description	Value	
Unit Weight	150	lb/ft^3
Compressive Strength	3,000	lb/in^2
Tensile Strength	0	lb/in^2
Internal Friction Angle	54	degrees

4.3 LOADS AND LOAD COMBINATIONS

4.3.1 Individual Loads

The structural analysis evaluated the behavior of the dam for static loads.

Table 4-2 Summary of Individual Loads

Load	Description
Gravity	Dead weight of concrete.
Reservoir	Hydrostatic water pressure applied to the upstream face of the dam.
Tailwater	Hydrostatic water pressure applied to the downstream face of the dam. *(Not evaluated)*
Sediment	Silt pressure applied to the upstream face of the dam. *(Not evaluated)*
Embankment	Soil pressure applied to the downstream face of the dam.
Uplift	Hydrostatic pressure applied to the analysis plane to simulate the internal hydrostatic (uplift) pressures.

4.3.1.1 Gravity

The gravity load is based on the unit weight of the concrete which is assumed equal to 150 lb/ft^3 as discussed in section 4.2.1 Concrete Properties.

4.3.1.2 Reservoir

The hydrostatic load corresponding to the reservoir level is applied using a fluid density of 62.5 lb/ft^3.

The usual (normal) load combinations assumed that the maximum normal water surface (NWS) is approximately El. 5888.06 (NAVD88 Datum, El. 5872 local datum).

The reservoir level due to the probable maximum flood (PMF) is at El. 5892.86 (NAVD88 Datum, El. 5876.8 local datum).

4.3.1.3 Tailwater

The hydrostatic load corresponding to the tailwater level is applied using a fluid density of 62.5 lb/ft^3. There is no tailwater load on the mass concrete section, and therefore, tailwater was ignored for this stability evaluation.

4.3.1.4 Sediment

The total vertical density is assumed to equal 120 lb/ft^3. The total horizontal equivalent density is assumed equal to 85 lb/ft^3. There is no sediment load on the mass concrete section, and therefore, this load was ignored in this stability evaluation.

4.3.1.5 Embankment

The embankment load on the downstream face of the dam is assumed to have an equivalent vertical unit weight of 120 lb/ft^3 and the horizontal component was conservatively neglected. To account for the slope and the possibility of unsaturated soil in the embankment, a vertical unit weight of 60 lb/ft^3 was applied in the relevant load cases.

4.3.1.6 Uplift

Uplift is the internal hydrostatic pressure that acts on the base of the dam or a horizontal plane within the structure. The uplift pressure was assumed to vary linearly from the full reservoir pressure at the upstream heel of the dam to the tailwater pressure at the downstream toe (zero for this study).

In the case where the analysis indicates that cracks develop, full reservoir head was assumed to develop in the crack from the upstream face to the predicted crack tip (end of tension zone in analysis).

4.3.2 Load Combinations

The structural capacity of the dam was evaluated for static conditions as summarized in Table 4-3.

Table 4-3 Summary of Loading Combinations

Loading Combinations
Usual Load Combination (USLC-1) Dead weight due to gravity (concrete) Hydrostatic pressures due to the reservoir level El. 5888.06 (NAVD88) Vertical Embankment load Uplift Pressure
Unusual (Flood) Load Combination (UNLC-1) Dead weight due to gravity (concrete) Hydrostatic pressures due to reservoir level El. 5889.06 (top of parapet, NAVD88) Vertical Embankment load Uplift Pressure
Unusual (PMF) Load Combination (UNLC-2) Dead weight due to gravity (concrete) Hydrostatic pressures due to the PMF reservoir level El. 5892.86 (NAVD88) Uplift Pressure

4.4 EVALUATION CRITERIA

The structural stability assessment of Basin Creek Dam was based on the identified failure modes, as summarized below:

- Structural Capacity. Comparison of the computed stresses to the allowable strength of the concrete to evaluate if the material will crack or crush.
- Rotational Stability. Also called overturning stability, or moment equilibrium. The overturning moments due to the load must be less than or equal to the resisting moments primarily due to the weight of the structure. Included in this evaluation is the potential for separation (i.e., cracking) at the masonry/concrete interface. For rotational stability to be satisfied, a crack must stabilize prior to extending through the full thickness of the section. If necessary, the uplift pressure along the crack is modified for the cracked base condition (i.e., full reservoir pressure within the cracked portion of the section).
- Sliding Stability. Evaluates the sliding stability of the dam along the analysis plane or at an internal plane of analysis based on the minimum allowable factors of safety.

4.4.1 Structural Capacity Criteria

The structural analysis is used to estimate the stress on the face of the dam. The calculated stress is then compared to the capacity of the concrete to determine if there is a potential for cracking or crushing of the concrete. Although the stresses on both the upstream and downstream face of the dam are evaluated, the primary concern is the potential for cracking due to the development of tensile stresses on the upstream face.

The allowable strength of mass concrete is based on the concrete strength presented in Table 4-1 divided by the appropriate material strength reduction factor for the corresponding loading condition. The material strength reduction factors for mass concrete are 3.0 for usual loads and 2.0 for unusual loads [3].

This study assumes the concrete has zero (0) tensile strength. The allowable compressive strength is 1,000 lb/in^2 for the usual loads and 1,500 lb/in^2 for unusual loads.

4.4.2 Rotational Stability

Rotational stability, also referred to as overturning stability or moment equilibrium, is satisfied if the summation of moments about the toe shows that the resisting moment is greater than or equal to the overturning moment. Initially the analysis assumes that the sections in the dam are homogeneous and can develop both compressive and tensile stresses. However, if the capacity of the concrete is exceeded, then a crack may develop, which is in direct communication with the reservoir. Therefore, cracks in the dam are assumed to allow the development of full reservoir pressures (uplift), which may cause crack propagation towards the downstream face.

Moment equilibrium, or overturning, is satisfied if the results show that the crack stabilizes and does not propagate through the entire thickness of the section [4].

4.4.3 Sliding Stability

Sliding stability was evaluated by calculating the sliding factor of safety (SFOS). The effects of cohesion were neglected for these evaluations. The SFOS was calculated using Equation 4-1.

Equation 4-1
Sliding Factor of Safety

$$FS = \frac{(C \times A) + \left(\sum N - \sum U\right) \times \tan\phi}{\sum V}$$

where:

FS =	Sliding Factor of safety
C =	Unit cohesion, assumed equal to zero (0)
A =	Intact base area
ΣN =	Summation of normal forces
ΣU =	Summation of uplift forces
φ =	Effective angle of friction
ΣV =	Summation of driving (horizontal) forces

The safety of the dam against a sliding stability failure is evaluated using minimum required factors of safety in accordance with the FERC guidelines [4] as summarized in Table 4-4. Note that a calculated SFOS less than 1.0 indicates instability.

Table 4-4 FERC Recommended Minimum Sliding Factors of Safety

Load	Description
Worst Static Case	1.5
Flood Case, if flood is PMF	1.3

Note: The current state-of-the-practice for the evaluation of concrete dam sliding stability neglects cohesion, primarily due to the uncertainties in estimating the cohesive bond at the contact.

4.5 RESULTS

The gravity method of analysis was used to evaluate the static usual and unusual loading conditions. The computed loads acting on the evaluated section were used to estimate the stress distribution along selected planes within the section and along the base.

The results for each load combination are summarized on plots. There are two values located to the left of each elevation and at the base. These values represent the computed stress at the upstream and downstream face for an intact (uncracked) section. At the base of the section, there are two values located to the right, which represent the stress at the crack tip and downstream toe for a cracked base condition, if applicable. A negative stress value indicated by parentheses, (##), denotes compression, and a positive value without parentheses, ##, denotes tension.

Beneath each section plot, there is a plot of the assumed uplift distribution. The solid blue line represents the initial uplift assumption for an uncracked base, and if applicable, the dashed red line shows the assumed uplift distribution for the cracked base condition.

4.5.1 Structural Capacity

The stress distributions from the upstream face to downstream face were evaluated at selected analysis planes for the usual (USLC-1) and unusual (UNLC-1 and UNLC-2) studies. The peak stresses for the selected analysis planes are summarized in Table 4-5. Allowable tensile strengths of intact concrete for the loading conditions are listed for comparison.

Table 4-5 Summary of Stress Distribution for Selected Elevations

Elevation	Stress Results					
	USLC-1		UNLC-1		UNLC-2	
	U/S Face	D/S Face	U/S Face	D/S Face	U/S Face	D/S Face
	lb/in^2	lb/in^2	lb/in^2	lb/in^2	lb/in^2	lb/in^2
Allowable Tensile Strength[1]						
	+0		+0		+0	
Allowable Compressive Strength[1]						
	(1,000)		(1,500)		(1,500)	
Select Analysis Planes[2,3,4]						
El. 5862.0	(3)	(9)	(1)	(11)	+6	(14)
El. 5864.0	(4)	(5)	(2)	(6)	+3	(7)
El. 5866.2	(1)	(8)	+1	(10)	+12	(19)
El. 5869.0	(2)	(2)	(1)	(3)	+3	(6)
El. 5871.2	(2)	(1)	(1)	(2)	+5	(6)

Notes:
1. Allowable concrete strength taken from Section 4.4.1, Structural Capacity Criteria.
2. Negative value (shown in parenthesis) denotes compression and positive value denotes tension.
3. "--" (dashes) indicate that the section cracked through the entire thickness.
4. Elevations listed in 'local' datum

4.5.1.1 Usual Load – USLC-1

The results due to load USLC-1 (Figure C - 1) show that all computed stresses in the structure are compressive and less than the allowable compressive strength of the concrete, as shown in Table 4-5. These results indicate that the concrete strength would be sufficient to support the load due to the usual loading condition and cracking would not be expected.

4.5.1.2 Unusual Load – UNLC-1 (Reservoir at top of Parapet)

The results due to load UNLC-1 (Figure C - 2) show that all computed compressive stress in the structure are less than the allowable compressive strength of the concrete, as shown in Table 4-5.

The results show there is an isolated area on the upstream face of the dam that develops tension (1 psi). This tensile stress is very small, and the concrete is considered adequate to support this load.

Therefore, these results indicate that the concrete strength would be sufficient to support the load due to the unusual loading condition and cracking would not be expected.

4.5.1.3 Unusual Load – UNLC-2 (PMF)

The results due to load UNLC-2 (Figure C - 3) show that all computed compressive stresses are less than the allowable compressive strength of the concrete, as shown in Table 4-5.

The results show that tensile stress develops at the upstream face of the structure. Concrete under a tensile stress can develop cracking if the concrete strength is less than assumed. This study assumes the concrete does not have any tensile strength and the mass concrete does not contain reinforcement. Under these assumptions, it is anticipated cracking of the mass concrete section could occur during the PMF.

4.5.2 Rotational Stability

4.5.2.1 Usual Load – USLC-1

The results from the structural evaluation of the usual load combination are summarized in Table 4-6.

Table 4-6 Stability Analysis, Usual Load Combination

Description	Value	
Dam Height	13	feet
Reservoir Elevation		
NAVD88	El. 5888.06	feet
Local	El. 5872.00	feet
Base Elevation		
NAVD88	El. 5876.06	feet
Local	El. 5860.00	feet
Summation of Forces		
Horizontal Load	4.5	kips
Vertical Load w/o Uplift	(14.8)	kips
Uplift Load (uncracked base)	3.7	kips
Moment about D/S Toe	(38.7)	kip-feet
Uncracked Stress Distribution at Base		
Upstream Heel	(1)	lb/in^2
Downstream Toe	(15)	lb/in^2
Cracked Base Analysis		
Percent Cracked (% Base Length)	0	percent
Sliding Stability		
Computed Factor of Safety	3.4	
Required Factor of Safety	1.5	

Notes: 1. Negative value (shown in parenthesis) denotes compression and positive value denotes tension.

2. "--" (dashes) indicate that the section cracked through the entire thickness.

The results due to load combination USLC-1 show that the base remains in compression and therefore separation at the masonry/concrete interface is not anticipated to occur.

4.5.2.2 Unusual Load – UNLC-1 (Reservoir at top of Parapet)

The results from the structural evaluation of UNLC-1, reservoir at the top of the parapet, are summarized in Table 4-7.

Table 4-7 Stability Analysis, Unusual Load Combination 1

Description	Value	
Dam Height	13	feet
Reservoir Elevation		
NAVD88	El. 5889.06	feet
Local	El. 5873.00	feet
Base Elevation		
NAVD88	El. 5876.06	feet
Local	El. 5860.00	feet
Summation of Forces		
Horizontal Load	5.3	kips
Vertical Load w/o Uplift	(14.8)	kips
Uplift Load (uncracked base)	4.1	kips
Moment about D/S Toe	(31.7)	kip-feet
Uncracked Stress Distribution at Base		
Upstream Heel	+2	lb/in^2
Downstream Toe	(17)	lb/in^2
Cracked Base Analysis		
Percent Cracked (% Base Length)	17	percent
Sliding Stability		
Computed Factor of Safety	2.6	
Required Factor of Safety	1.3	

Notes: 1. Negative value (shown in parenthesis) denotes compression and positive value denotes tension.

2. "--" (dashes) indicate that the section cracked through the entire thickness.

The results due to load combination UNLC-1 show that tensile stress develops at the upstream heel of the section. Since the masonry/concrete interface cannot develop tension, the base would be expected to separate (crack). A cracked base analysis was performed incorporating increased uplift pressure in accordance with the FERC Guidelines. The results of the cracked base analysis indicate that the base will crack approximately 17-percent of the thickness and

then stabilize as shown in Figure C - 2. Therefore, rotational stability is satisfied for the UNLC-1 condition.

4.5.2.3 Unusual Load – UNLC-2 (PMF)

The results from the structural evaluation of UNLC-2, probable maximum flood, are summarized in Table 4-8.

Table 4-8 Stability Analysis, Unusual Load Combination 2

Description	Value	
Dam Height	13	feet
Reservoir Elevation		
NAVD88	El. 5892.86	feet
Local	El. 5876.80	feet
Base Elevation		
NAVD88	El. 5876.06	feet
Local	El. 5860.00	feet
Summation of Forces		
Horizontal Load	8.4	kips
Vertical Load w/o Uplift	(13.3)	kips
Uplift Load (uncracked base)	5.2	kips
Moment about D/S Toe	(30.2)	kip-feet
Uncracked Stress Distribution at Base		
Upstream Heel	+11	lb/in^2
Downstream Toe	(22)	lb/in^2
Cracked Base Analysis		
Percent Cracked (% Base Length)	100	percent
Sliding Stability		
Computed Factor of Safety	--	
Required Factor of Safety	1.3	

Notes: 1. Negative value (shown in parenthesis) denotes compression and positive value denotes tension.

2. "--" (dashes) indicate that the section cracked through the entire thickness.

The results due to load combination UNLC-2 show that tensile stress develops at the upstream heel of the section. Since the masonry/concrete interface cannot develop tension, the base would be expected to separate (crack). A cracked base analysis was performed incorporating increased uplift pressure in accordance with the FERC Guidelines. The results show that the crack

does not stabilize and may propagate through to the downstream face as shown in Figure C - 3. This indicates that the section does not satisfy rotational stability criteria for the probable maximum flood.

4.5.3 Sliding Stability

The sliding stability of the mass concrete section for the usual and unusual load combinations used an effective friction angle of 54 degrees (effects of cohesion were neglected).

4.5.3.1 Usual Load – USLC-1

The computed sliding factor of safety (SFOS) for the usual loading combination is 3.4 (see Table 4-6) which is greater than the FERC required value of 1.5. This indicates that the section satisfies sliding stability criteria for the usual loading condition.

4.5.3.2 Unusual Load – UNLC-1 (Reservoir at top of Parapet)

The computed SFOS for the unusual loading combination with the reservoir at the top of the parapet is 2.6 (see Table 4-7), which is greater than the FERC required value of 1.3. This indicates that the section satisfies sliding stability criteria for this loading condition.

4.5.3.3 Unusual Load – UNLC-2 (PMF)

As described in Section 4.5.2.3, results indicate that the base cracking may not stabilize. This indicates that the section does not satisfy sliding stability criteria for the PMF.

4.6 SENSITIVITY STUDIES

Two sensitivity studies were performed on the mass concrete section. The first study was to determine the affect deterioration has on the parapet stability and the second study was to determine the reservoir level that causes the mass concrete section to become unstable.

4.6.1 Parapet Study

In this study, the reservoir level was held constant at the top of the parapet (i.e., no overtopping) and the section thickness was incrementally reduced. The study indicates the section is stable for approximately up to 10-inches of deterioration, with a reservoir level at the top of the parapet. This indicates the parapet can handle up to 10-inches of deterioration and a reservoir level up to the parapet before a loss of stability.

4.6.2 Flood Threshold Level

In this study, the reservoir level was incrementally increased until the base of the section became unstable. This study indicates the section can handle approximately 1-foot of overtopping before the section becomes unstable.

5.0 SUMMARY AND RECOMMENDATIONS

5.1 ANALYSIS SUMMARY

An analysis was performed to evaluate the stability of the mass concrete section of Basin Creek Dam. The static loads were simulated using the gravity method of analysis. These studies were used to evaluate the following typical potential failure modes (PFMs) for concrete gravity dams: overstressing, overturning, and sliding. The following list summarizes the findings from these studies.

- The results show the mass concrete section has adequate capacity against overstressing for a reservoir level between the normal water surface elevation (El. 5888.06 NAVD88) and the top of the parapet (El. 5889.06 NAVD88).
- The results show the section satisfies rotational stability for a reservoir level between normal water surface elevation (El. 5888.06 NAVD88) and the top of the parapet (El. 5889.06 NAVD88).
- The results show the section has adequate stability against sliding for a reservoir level between normal water surface elevation (El. 5888.06 NAVD88) and the top of the parapet (El. 5889.06 NAVD88). The estimated sliding factors of safety are greater than the FERC recommended values for these load cases.
- The results show tensile stresses develop on the upstream face during the probable maximum flood and it is anticipated cracking of the mass concrete section could occur.
- The results show the section does not satisfy rotational stability for the probable maximum flood. Results indicate that cracking along the base does not stabilize and may propagate through to the downstream face.
- The results show the section does not satisfy sliding stability for the probable maximum flood because base cracking was not shown to stabilize.
- The sensitivity study of the parapet indicates the parapet can withstand approximately 10-inches of deterioration with the reservoir level at the top of the parapet before becoming unstable.
- The sensitivity study of the flood threshold level indicates the section can withstand approximately 1-foot of overtopping before becoming unstable.

5.2 RETROFIT ALTERNATIVES

During recent inspections, significant deterioration of the mass concrete has been noted along the upstream face of the dam. In addition, the rate of deterioration has increased over the past couple of years. The purpose of this work was to assess the stability of the dam considering the effects of the concrete deterioration and to make recommendations for repairs to the deteriorated concrete.

Viable options to address these issues are presented in terms of concrete repair alternatives, alternatives to address overtopping, and refined analysis.

5.2.1 Concrete Repair Alternatives

The concrete deterioration has been noted in inspection reports for over a decade. Stability calculations indicate there is an urgency to repair the mass concrete portion of the dam. Below are four alternatives to retrofit the mass concrete.

5.2.1.1 Patch Spalled Areas

This option would be the minimal amount of work necessary to repair the concrete. The spalled areas of the dam would need to be cleaned and cleared of loose material and reinforcement added as necessary. New concrete would then be placed to return the dam to the original design state. This work would become an ongoing maintenance project at the dam because the concrete will continue to experience freeze-thaw and patching will not stop this process.

5.2.1.2 Replace Parapet

The second option would be to remove the existing parapet and replace with concrete that meets current design standards. This option would greatly reduce the risk of additional freeze thaw damage in the parapet. Design detailing would be necessary to properly dowel the new parapet to the existing dam without further exposing the mass concrete to additional freeze-thaw damage.

5.2.1.3 Replace Mass Concrete above Original Dam

The third, and likely most costly option, is to fully remove the top 13-feet of the dam and replace with concrete that meets current design standards. This section should be designed to properly anchor into the original masonry dam to meet stability criteria for the probable maximum flood.

5.2.1.4 Upstream Concrete Overlay

This option would involve removing the deteriorated shotcrete and deteriorated concrete from the upstream face of the mass concrete. A reinforced concrete overlay would be placed and anchored to the upstream face of the existing dam. This option would prevent future freeze-thaw damage along the upstream face of the mass concrete.

5.2.2 Alternatives to Address Overtopping

Stability concerns for the upper mass concrete dam arise when the dam begins to overtop. There are two alternatives to address this concern.

5.2.2.1 Increase Spillway Capacity

The spillway can currently pass approximately the 500-year flood. This alternative would involve increasing the spillway capacity by either increasing the length of the current spillway or adding an additional spillway to be able to pass the PMF without overtopping the dam. Stability calculations indicate the dam has adequate safety for reservoir levels below the top of the parapet. The crest length of the required spillway to pass the PMF makes this a non-viable option.

5.2.2.2 Anchor Mass Concrete

This study did not account for any doweling or any form of a connection between the original masonry dam and the mass concrete raise. Installing post-tensioned anchors (PTA) (i.e., strand

PTA or rod PTA) to anchor the mass concrete portion of the dam to the masonry dam would increase the stability of the section and allow it to withstand overtopping from the PMF.

5.2.3 Refined Analysis

This study assumes the upper mass concrete dam behaves two-dimensionally. Due to the slight arch shape and three-dimensional affects, it is possible the upper mass concrete could meet stability criteria when analyzed as a three-dimensional structure. However, there tends to be less three-dimensional interaction at the top of arch dams, and the cutout for the spillway could limit any three-dimensional benefits at the top of the dam. Therefore, a refined study to further assess the stability of the upper mass concrete dam is not recommended.

5.3 RECOMMENDATIONS

There are three retrofit alternatives recommended for BSB's consideration. It should be noted that each retrofit should be evaluated for the relevant seismic loading conditions.

5.3.1 Alternative One

This alternative recommends the concrete parapet be replaced and post-tensioned anchors be installed. Replacement of the parapet would prevent ongoing maintenance of the freeze-thaw damage within the parapet and reduce concerns for failure of the parapet during the PMF. Post-tensioned anchors are recommended for added stability for the PMF.

5.3.2 Alternative Two

This alternative recommends removal of the existing concrete parapet and installing the concrete overlay along the upstream face of the mass concrete. The concrete overlay would extend above the crest of the dam to replace the parapet (maintain top of parapet El. 5889.06). Post-tensioned anchors are recommended for added stability for the PMF.

5.3.3 Alternative Three

This alternative recommends fully removing the top 13-feet of the dam (upper mass concrete dam) and replacing it with a concrete design that meets current design standards. The new concrete would prevent ongoing maintenance of the freeze-thaw damage and provide adequate stability for the upper mass concrete dam for the PMF load condition. The surrounding embankment material would have to be removed during construction and replaced once construction was completed.

6.0 REFERENCES

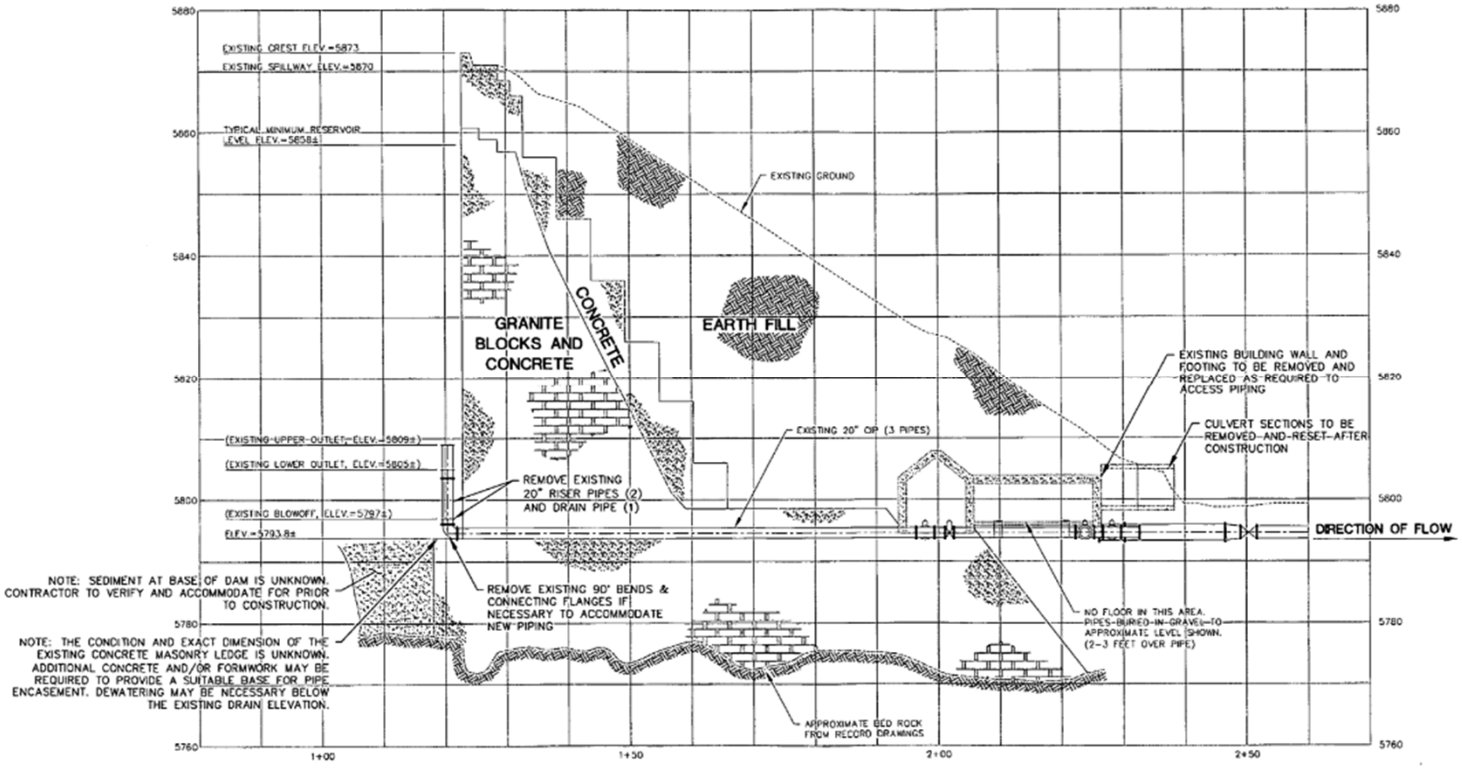
[1] URS, "Basin Creek Dam #1 Stability Anlaysis," Denver, February, 2005.

[2] URS, "Basin Creek Dam, Site Inspection," Denver, February, 2006.

[3] United States Department of the Interior, Bureau of Reclamation, Engineering Monograph No. 19, Design Criteria for Concrete Arch and Gravity Dams, Denver: GPO, 1977.

[4] FERC, Engineering Guidelines for the Evaluation of Hydropower Project: Gravity Dams, Chapter 3, Washington DC: GPO, 2016.

Appendix A: Select Record Drawings



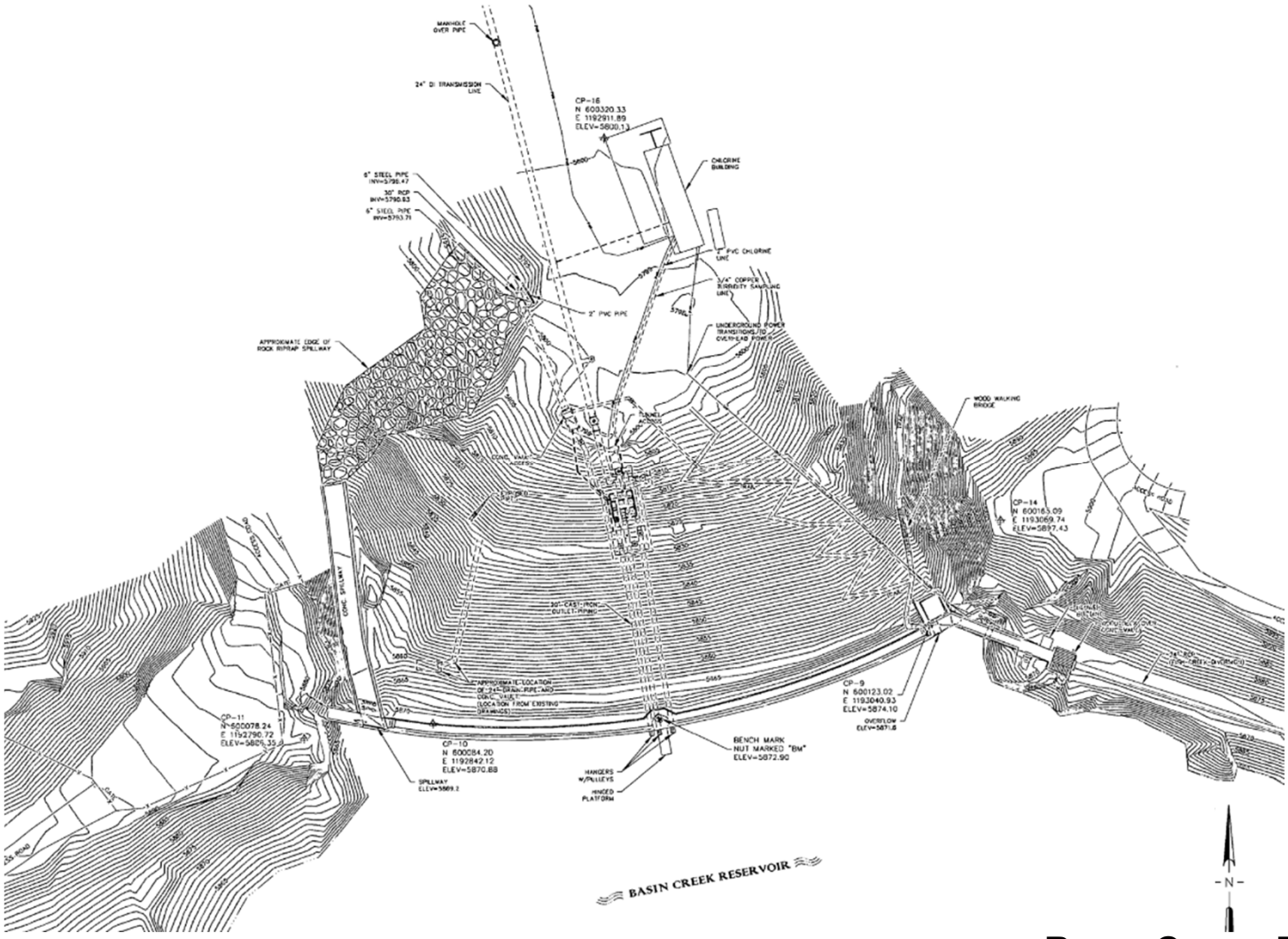
BASIN CREEK DAM

Section Showing Masonry,
Mass Concrete, and Earth Fill

Gannett Fleming

Excellence Delivered As Promised

Drawing A - 1



BASIN CREEK DAM

Plan of Dam

Gannett Fleming

Excellence Delivered As Promised

Drawing A - 2

Appendix B: Inspection Photos

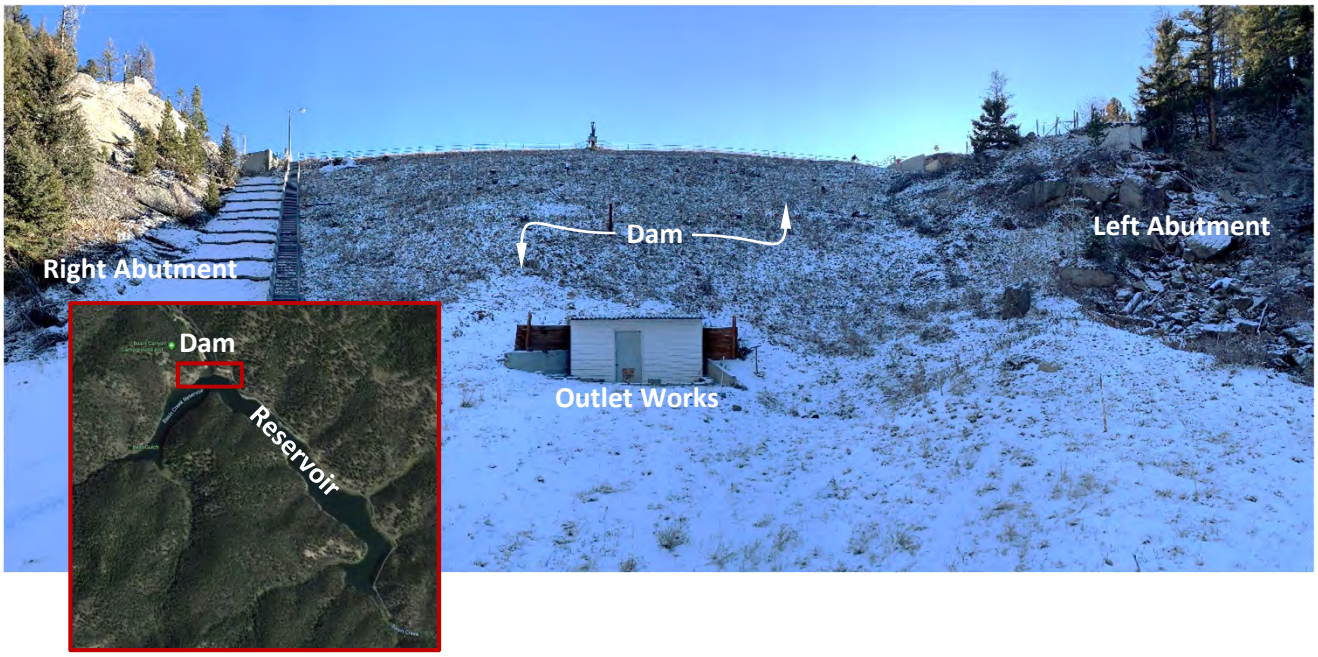


Photo No. 1 Project features identified with inset of aerial photograph of the Project.

Photo No. 2 View of the reservoir looking upstream looking southeast (left) and southwest (right).

Photo No. 3 View of downstream face of dam with erosion control and spillway channel called out.

Photo No. 4 Spillway channel along left abutment.

BASIN CREEK DAM

Inspection Photographs

Photo No. 5 View of the crest of the dam looking towards the left abutment with inset showing pavers.

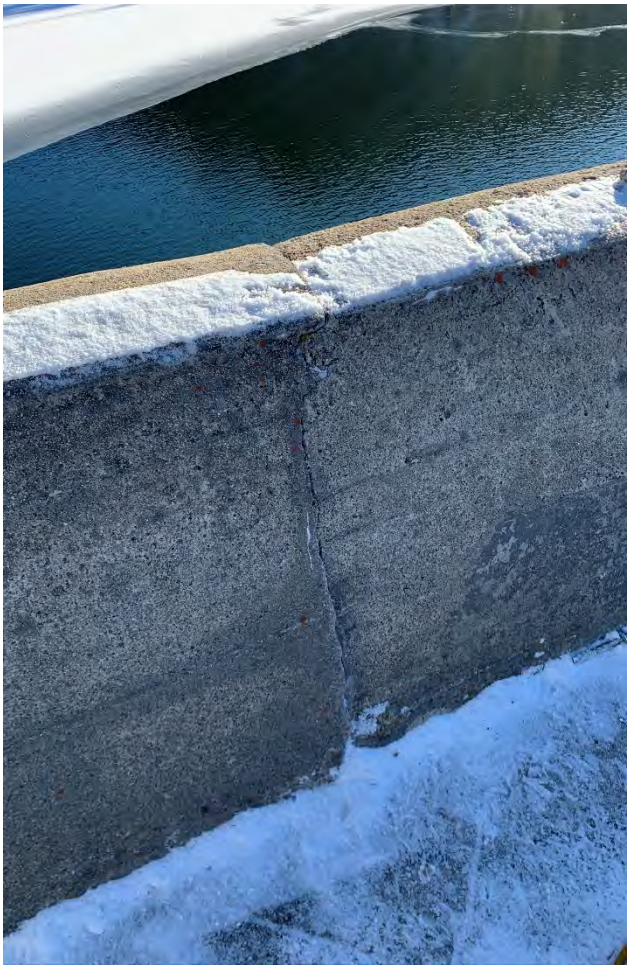


Photo No. 6 View of the parapet construction joints along the crest of the dam.

BASIN CREEK DAM

Inspection Photographs

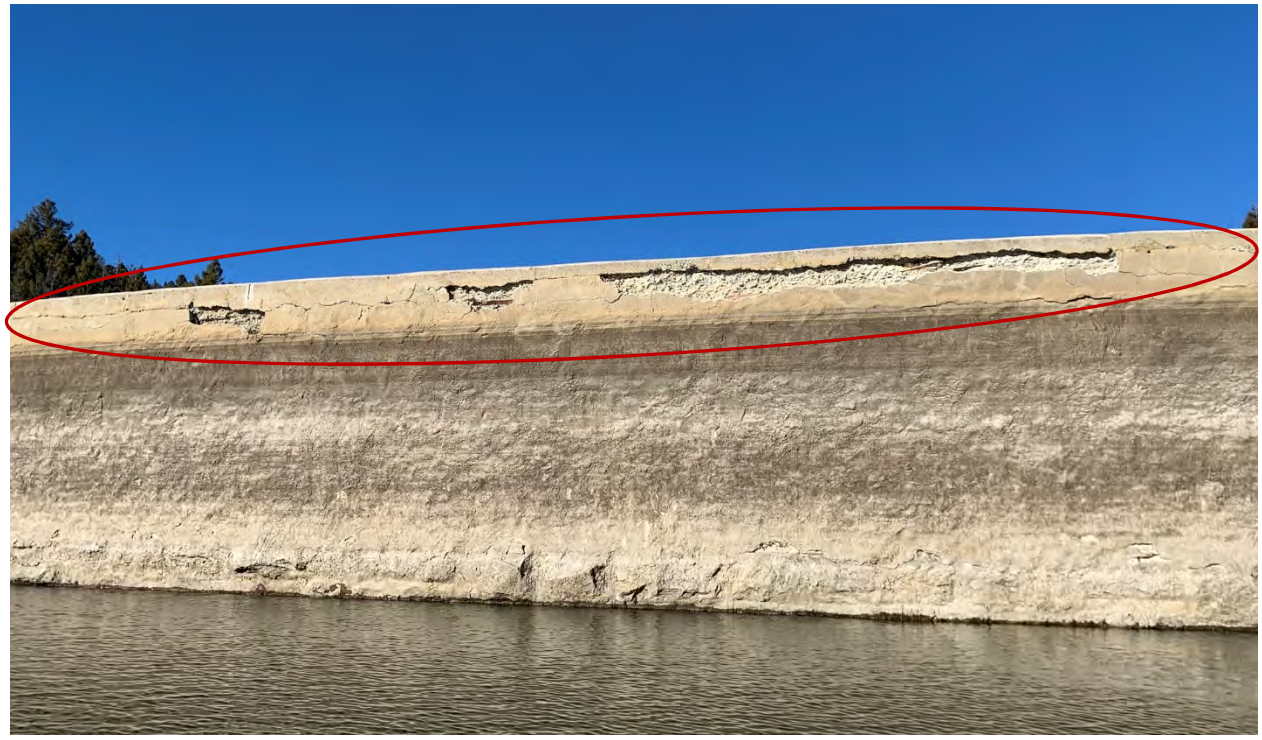


Photo No. 7 View of the upstream face of the dam from the reservoir with spalling and cracking called out.

Photo No. 8 View of the upstream face of the dam from the left abutment with spalling called out.

Photo No. 9 View of the upstream face of the dam from the right abutment with view of spalling from the crest of the dam (inset).

Photo No. 10 View of the upstream face of the dam showing areas of spalling in shotcrete.

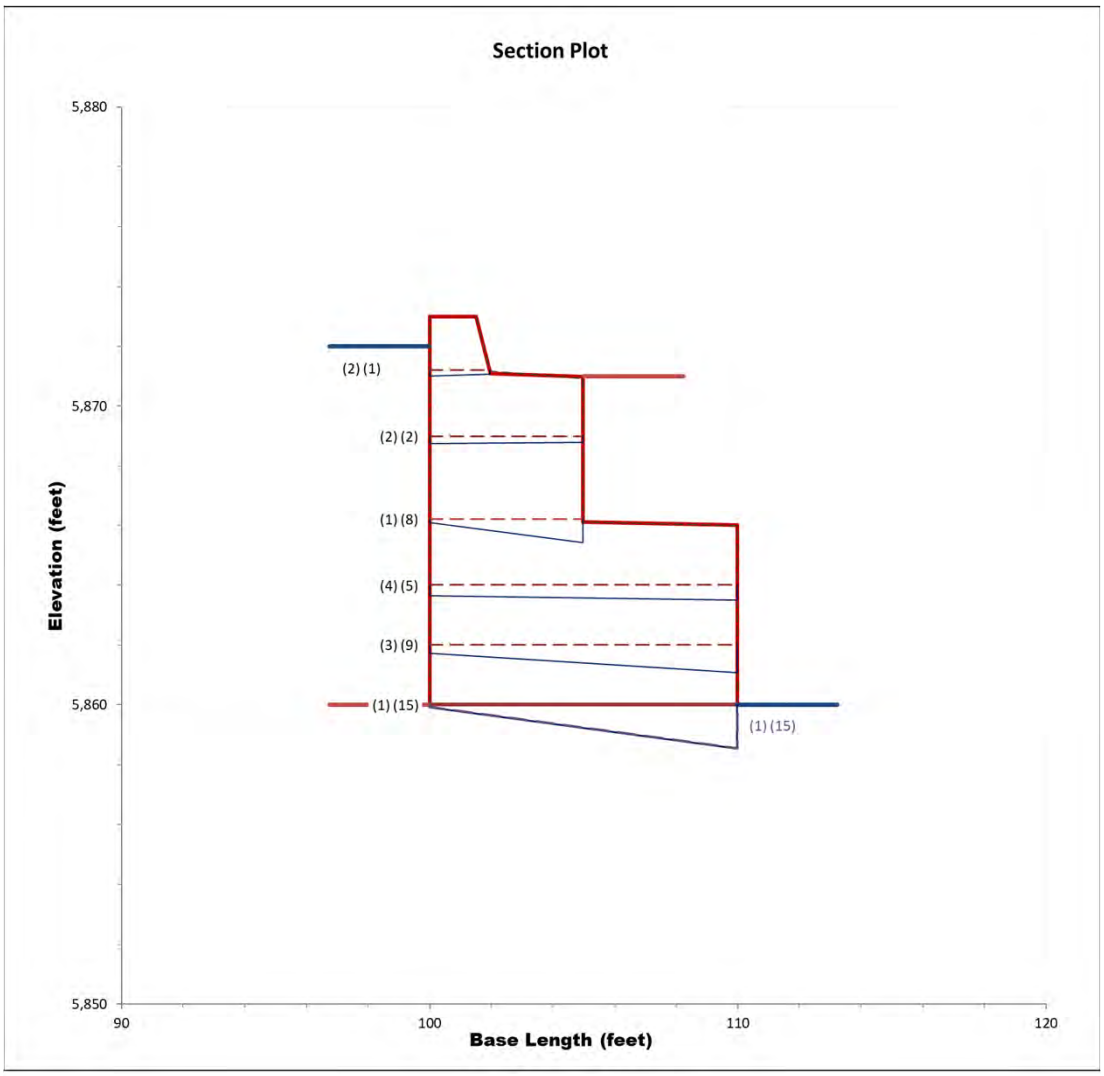
Photo No. 11 Upstream face of dam from left abutment showing original masonry dam and mass concrete raise, note the mass concrete has a layer of shotcrete on top.

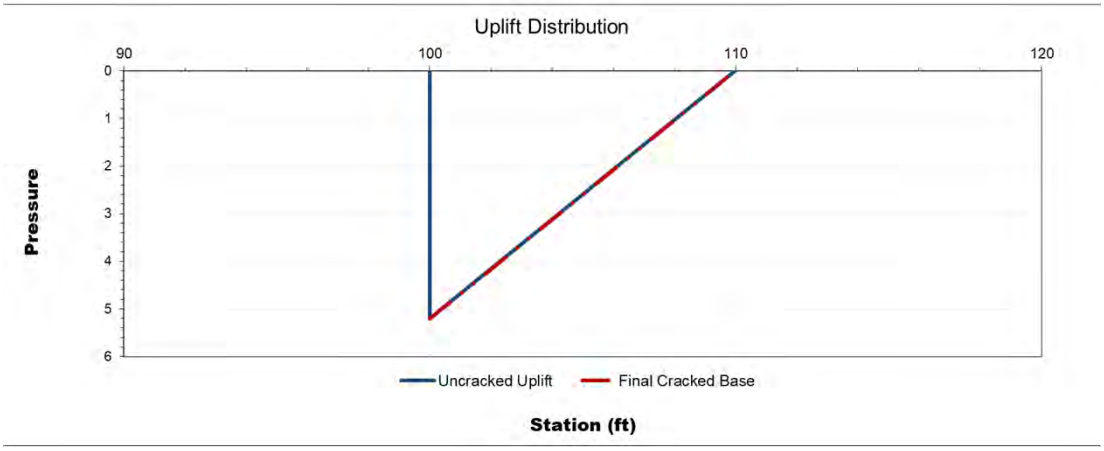
Photo No. 12 Voids at the base of the shotcrete near the original masonry dam.

BASIN CREEK DAM

Inspection Photographs

Appendix C: Figures





BASIN CREEK DAM

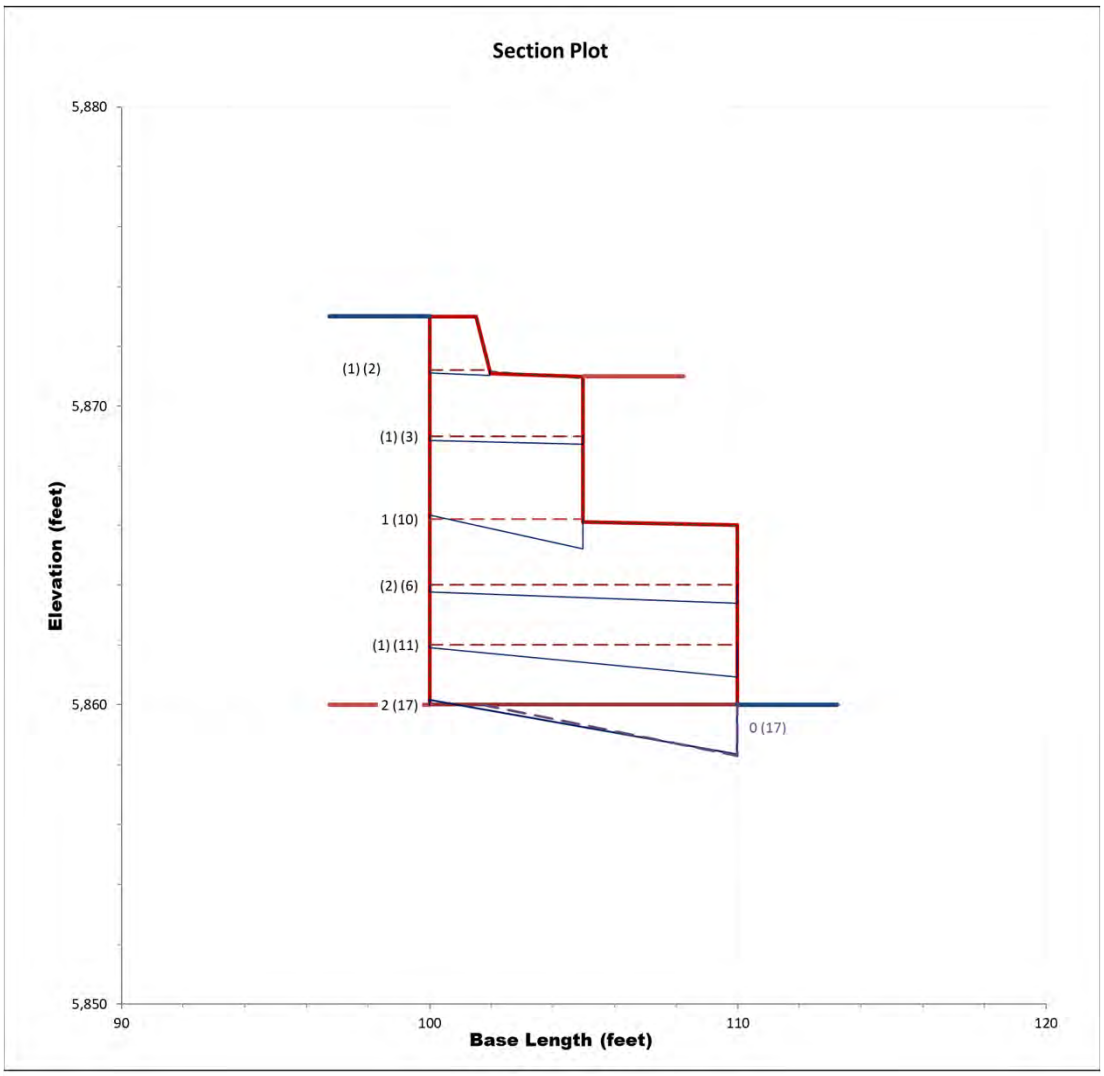
Structural Evaluation

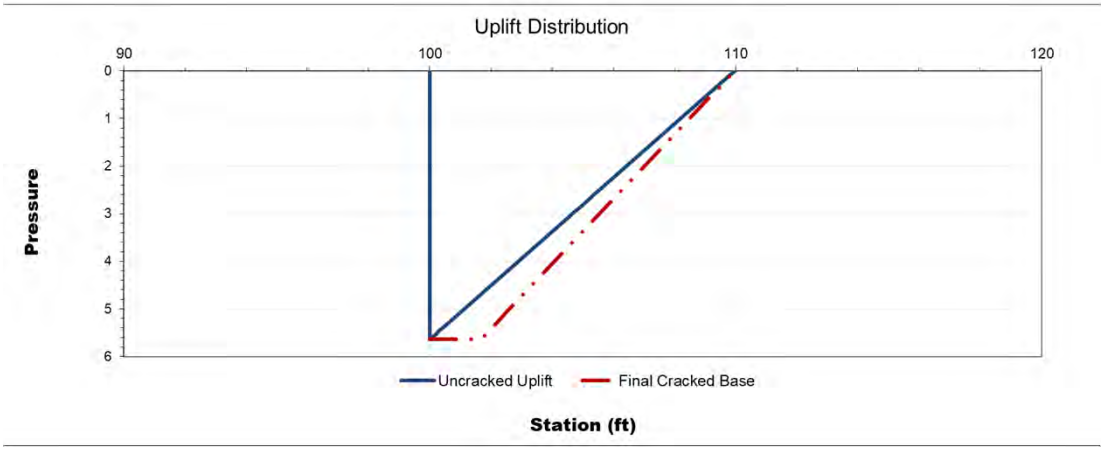
Usual Load Case 1

(Elevation in Local Datum)

Gannett Fleming

Figure C - 1





BASIN CREEK DAM

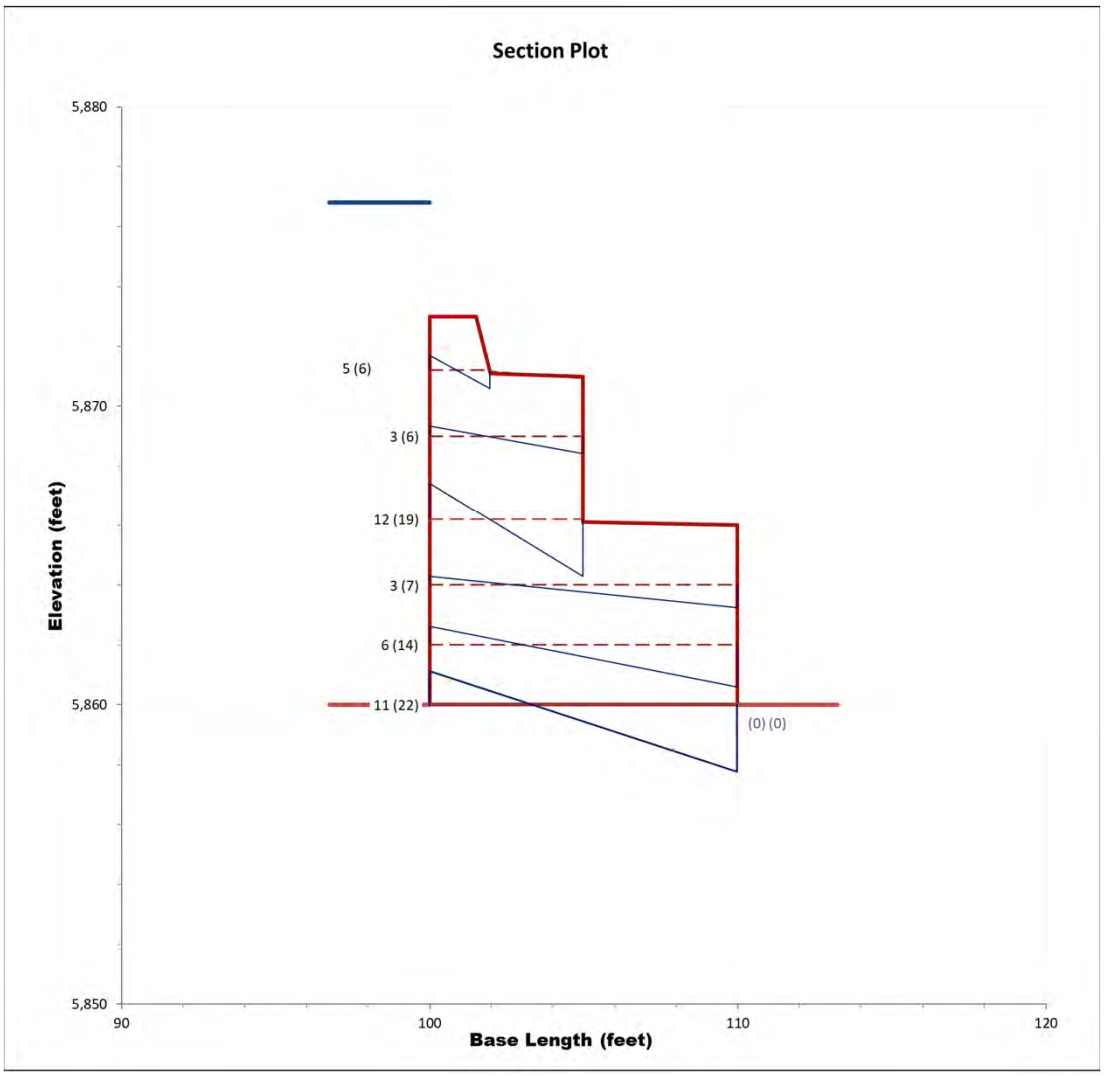
Structural Evaluation

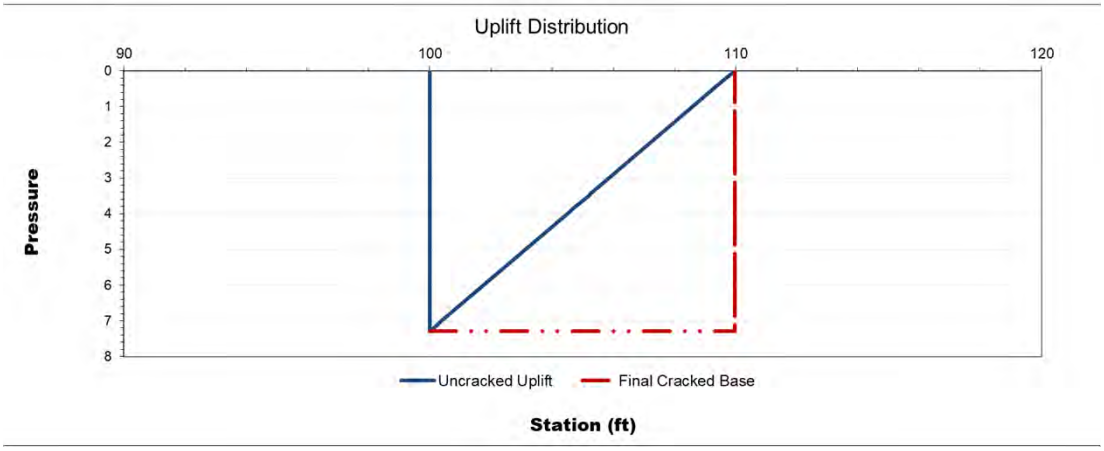
Unusual Load Case 1

(Elevation in Local Datum)

Gannett Fleming

Figure C - 2





BASIN CREEK DAM

Structural Evaluation

Unusual Load Case 2

(Elevation in Local Datum)

Gannett Fleming

Figure C - 3

Appendix D: Petrographic Investigation Report

A Twining Company

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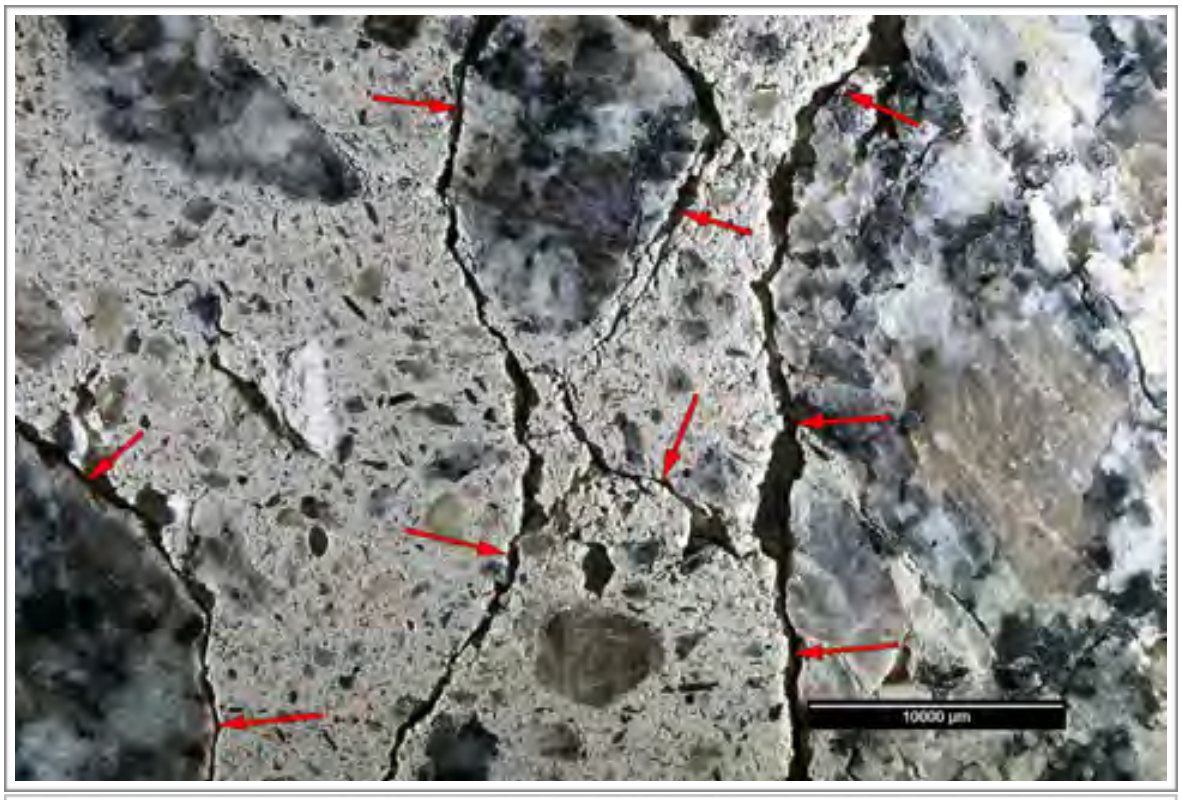
Petrographic Investigation of Concrete Cores Extracted from the Basin Creek Dam Located in Butte, Montana



Prepared for

Jim Keenan
Butte/Silver Bow County
Butte, Montana

Prepared by

David Rothstein, Ph.D., P.G., FACI
Chunyu (Joe) Qiao, Ph.D.
Report No. 197398.d
10 January 2020

EXECUTIVE SUMMARY

Four (4) cores extracted from Basin Creek Dam located in Butte, Montana are subjects of petrographic examination per ASTM C856. The purpose of the investigation is to characterize the general composition and condition of the concrete represented by the cores and determine the mechanism(s) associated with cracking. The cores were extracted from abutments, a parapet wall and the crest of the dam.

The findings from this scope of work indicate that all four cores show evidence of severe freeze-that damage. The damage manifests as cracking and microcracking that is sub-parallel to the exposed surface of the cores. The cracks and microcracks occur over the full length of the cores and range up to 750 µm (30 mil) wide and are up to 120 mm (4 ¾ in.) long. Most of the cracks cut around coarse aggregate particles.

Several properties of the concrete make it susceptible to freeze-thaw damage, as noted below.

- The paste has a high water-cement ratio (w/c) that facilitates the penetration of moisture, which diminishes the freeze-thaw durability of concrete. ACI 201 *Guide to Durable Concrete* recommends a maximum w/c of 0.45 for frost durability. Although it is not possible to quantitatively estimate the w/c of the present concrete due to its historical nature, the properties of the paste are consistent with modern concretes where the w/c is greater than 0.60.

- The concrete is non-air-entrained, which is typical for historical concretes that pre-date the use of modern air-entraining admixtures. The estimated total air content of the cores is less than 3%. Such concrete is not expected to provide freeze-thaw durability if it is saturated and exposed to freeze-thaw cycles as expected for a hydraulic dam in Butte, Montana.

The composition and proportioning of the components used to produce the concrete are consistent with each other. The paste contains hydrated portland cement; no fly ash, slag cement or other supplemental cementitious materials were observed. The hydration is advanced. The water-cement ratio (w/c) was not estimated quantitatively due to the age of the concrete and the historical nature of the cement, but the properties of the paste are consistent with modern concretes that have high w/c (greater than 0.60). The concrete is non-air entrained and contains less than 3% total estimated air content. The coarse aggregate is a crushed granodiorite that has a 75 mm (3 in.) nominal top size. The fine aggregate is a natural siliceous sand that consists mostly of the same granodiorite observed in the coarse aggregate.

Secondary deposits include ettringite and carbonation. Core RADS shows evidence of pervasive carbonation to a depth of 5-15 mm (¼ – ⅝ in.) from the outer surface. The remaining three cores shows slight carbonation throughout the length of the cores. Deposits of ettringite were observed in voids, open fractures, cracks and microcracks throughout the length of the cores. These deposits indicate the concrete was exposed to high levels of saturation for a prolonged period of time. No evidence of ASR was observed.

1.0 INTRODUCTION

Mr. Jim Keenan of Butte/Silver Bow County (**BSB)** located in Butte, Montana requested DRP, a Twining Company (**DRP**) to investigate the condition of concrete represented by cores extracted from Basin Creek Dam located in Butte, Montana. The purpose of the investigation is to characterize the general composition and condition of the concrete represented by the cores and determine the mechanism(s) associated with cracks.

On 2 December 2019 **DRP** received two (2) cores from **BSB**. On 5 December 2019 DRP received another two (2) cores from **BSB**. **Table 1** summarizes information regarding the identification, location and condition of the cores.

Table 1. Summary of sample information

DRP No.	BSB No.	Location	As-received Condition
23YD10348	RADS	Right Abutment, Downstream Dace	Received in two pieces; recovered as single piece
23YD10349	LAUS	Left Abutment, Upstream Face	Received and recovered in three pieces
23YD10356	Crest	Dam Crest	Very poor core recovery; received in multitude of pieces in three separate bags
23YD10358	Parapet	Parapet wall	Recovered and received in two pieces

Basin Creek Dam was originally constructed as a masonry dam in 1895 and was raised with a concrete placement in 1913. No information was provided regarding the concrete mix design or construction records or results of other testing done since the original construction.

2.0 Scope of Work

The testing involved petrographic examinations according to ASTM C856 [**1**]. The hardened air content of the cores was estimated from visual and microscopical observations but was not measured per ASTM C457 [**2**]. *Appendix A* to *Appendix D* contain the notes, photographs and micrographs from the petrographic examinations and *Appendix E* describes the procedures used to perform this scope of work. The petrographic work was performed by a senior petrographer and reviewed by the principal petrographer.

1 *Standard Practice for Petrographic Examination of Hardened Concrete.* Annual Book of ASTM Standards, Vol. 4.02., ASTM C856-18.

2 *Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete*, Annual Book of ASTM Standards, Vol. 4.02, ASTM C457-16.

3.0 FINDINGS

3.1 ***Orientation, Dimensions & As-Received Condition*** Core RADS and Core LAUS are horizontal in orientation, measure ~ 120 mm (4 ¾ in.) in diameter and range from 280-410 mm (11-16 ⅛ in.) in length. Both cores span from a formed surface to a fracture such that they represent a partial thickness of the abutments. Core LAUS includes a layer of shotcrete on the outer surface of the core. The shotcrete layer is ~ ~ 140 mm (5 ⅝ in.) thick and the the concrete section measures ~ 270 mm (10 ⅝ in.) long.

The Crest Core and the Parapet Core are vertical in orientation and measure ~ 120 mm (4 ¾ in.) in diameter. Both cores span from a rough surface to a fracture such that they cores represent a partial thickness of the dam crest and the parapet wall. The Parapet Core measures 385 – 410 mm (15 ⅛ – 16 ⅛ in.) long. The length of the the Crest Core was not measured due to the poor recovery of the core sample. The Parapet Core includes a layer of shotcrete on the top surface that is 145–160 mm (5 ¾-6 ¼ in.) thick. The concrete section of the core is 230–240 mm (9–9 ½ in.) long. **Figure 1** shows photographs of the cores in their as-received condition and the polished surfaces from the cores.

(a) **(b)**

Figure 1. (a) Photograph showing oblique view of the outer surface and side of Core RADS in as-received condition. (b) Photograph showing the polished surface from Core RADS. The red and blue dots indicate the orientation of the saw cuts used to prepare the sample for petrography. The yellow scale in each photo is ~ 150 mm (6 in.) long; the small and large divisions on the yellow scale are in centimeters and inches, respectively.

(c)

(d)

(e)

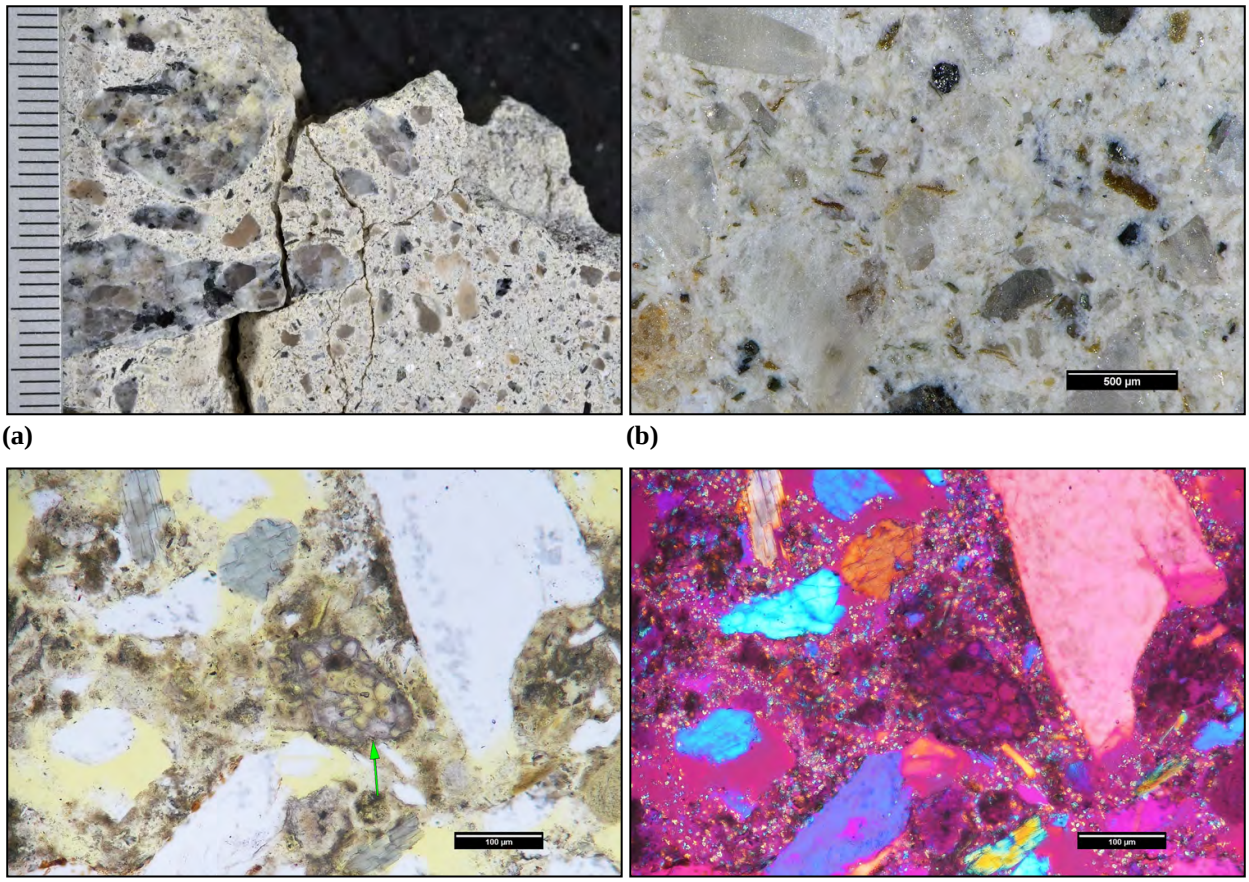
(f)

(g)

(h)

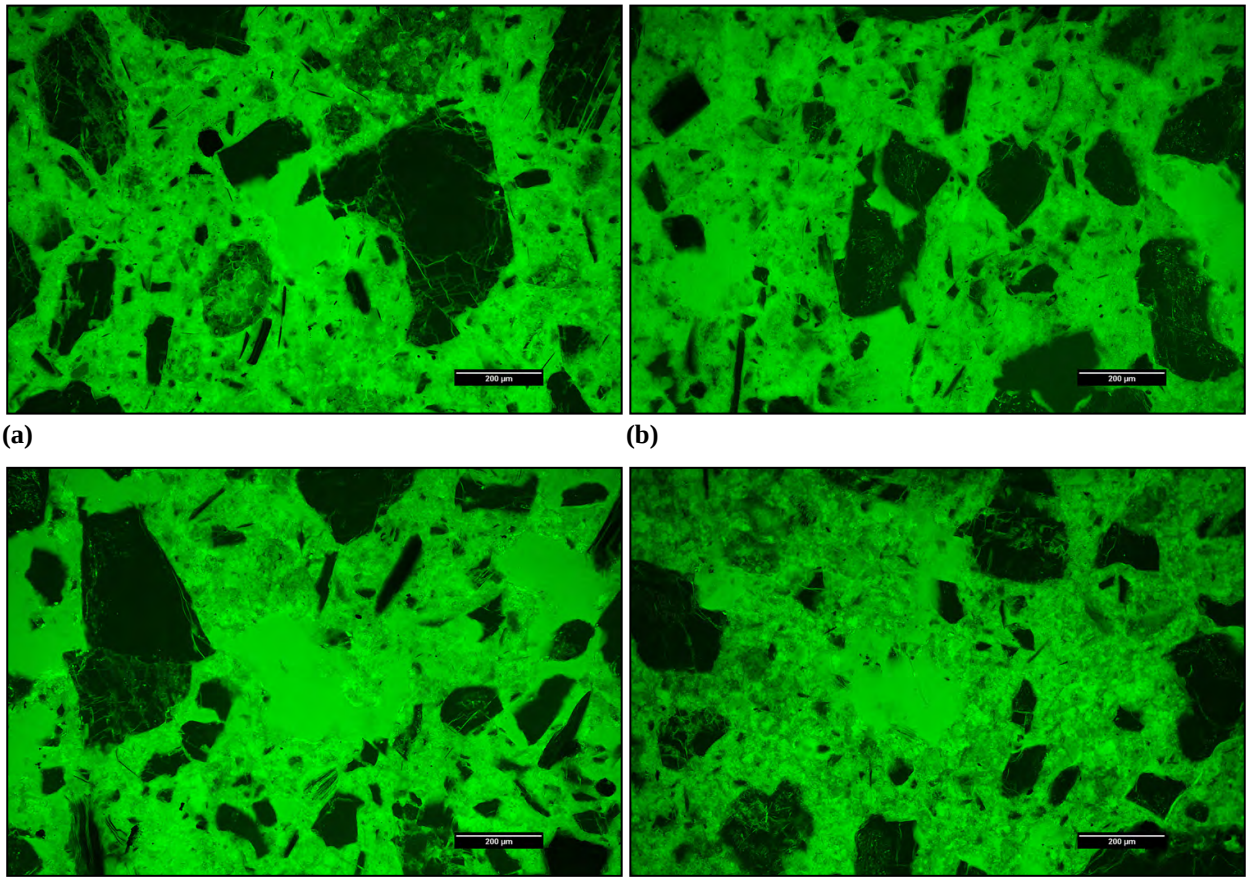
Figure 1 (Cont'd). (c) Photograph showing overview of the side of Core LAUS in as-received condition. (d) Photograph showing the polished surface from Core LAUS. (e) Photograph showing oblique overview of multiple pieces of The Crest Core in as-received condition. (f) Photograph showing the polished surface from The Crest Core. (g) Photograph showing oblique view of the top surface and side of The Parapet Core in as-received condition. (h) Photograph showing the polished surface from The Parapet Core. The red and blue dots indicate the orientation of the saw cuts used to prepare the sample for petrography. The yellow scale in each photo is ~ 150 mm (6 in.) long; the small and large divisions on the yellow scale are in centimeters and inches, respectively.

3.2 ***Components: Paste*** The properties of the paste are consistent in all four cores. The paste is white and moderately soft (Mohs ~ 2.5). The paste contains hydrated portland cement; no fly ash, slag cement or other supplemental cementitious materials were observed. The hydration is normal for historical concrete with coarse clusters of belite observed occasionally. The water-cement ratio (w/c) was not estimated quantitatively due to the age of the concrete and the historical nature of the cement. The properties of the paste, such as hardness and capillary porosity, are consistent with modern concretes that have high w/c (greater than 0.60). **Figure 2** shows details of the paste in the Crest Core as an example of paste properties and **Figure 3** shows fluorescent light photomicrographs of the paste from all four cores.



(a) **(b)** **(c)** **(d)**

Figure 2. Paste characteristics in the Crest Core. (a) Photograph of the polished surface showing overview of paste in the middle of the core; scale in millimeters. (b) Reflected light photomicrograph of the polished surface showing detail of the paste in the middle of the core. (c) Plane-polarized transmitted light photomicrograph of thin section showing detail of the paste. The green arrow indicate relict and residual belite. (d) Cross-polarized transmitted light photomicrograph of thin section with gypsum plate inserted showing detail of the paste. Note the calcium carbonate in the paste matrix in (d).



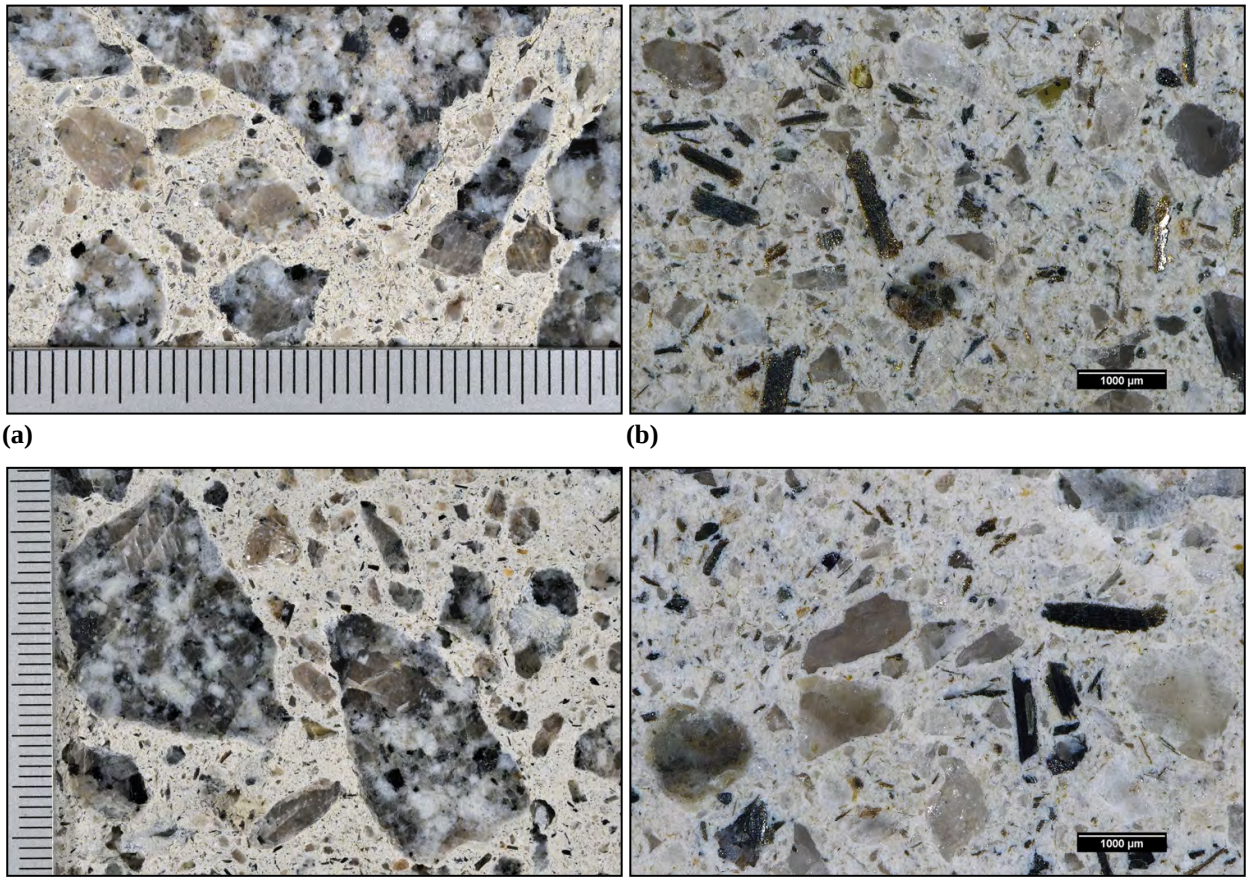
(a) (b)

(c) (d)

Figure 3. Transmitted fluorescent light photomicrographs of thin sections showing detail of capillary porosity. The black areas correspond to aggregate that has very low or effectively zero percent porosity and the bright green circles are air voids filled with epoxy that have 100% porosity. The variations in green between these end members reflect variations in the capillary porosity or micro-density of the paste. (a) Core RADS; (b) Core LAUS; (c) the Crest Core; and (d) the Parapet Core.

3.3 ***Components: Air Voids*** All four cores are non-air-entrained with less than 3% total estimated air contents. The cores are well consolidated with no major entrapped voids, bleed voids or water voids observed.

3.4 ***Components: Aggregates*** The cores contain similar aggregates. The coarse aggregate is a crushed granodiorite that has a 75 mm (3 in.) nominal top size. The rocks are hard and competent. The fine aggregate is a natural sand that is siliceous in composition and consists mostly of the same granodiorite observed in the coarse aggregate. Granodiorite is potentially susceptible to alkali-silica reaction (ASR) but no evidence of such reactions was observed in any core. **Figure 4** shows details of the aggregate.



(a) **(b)**

(c) **(d)**

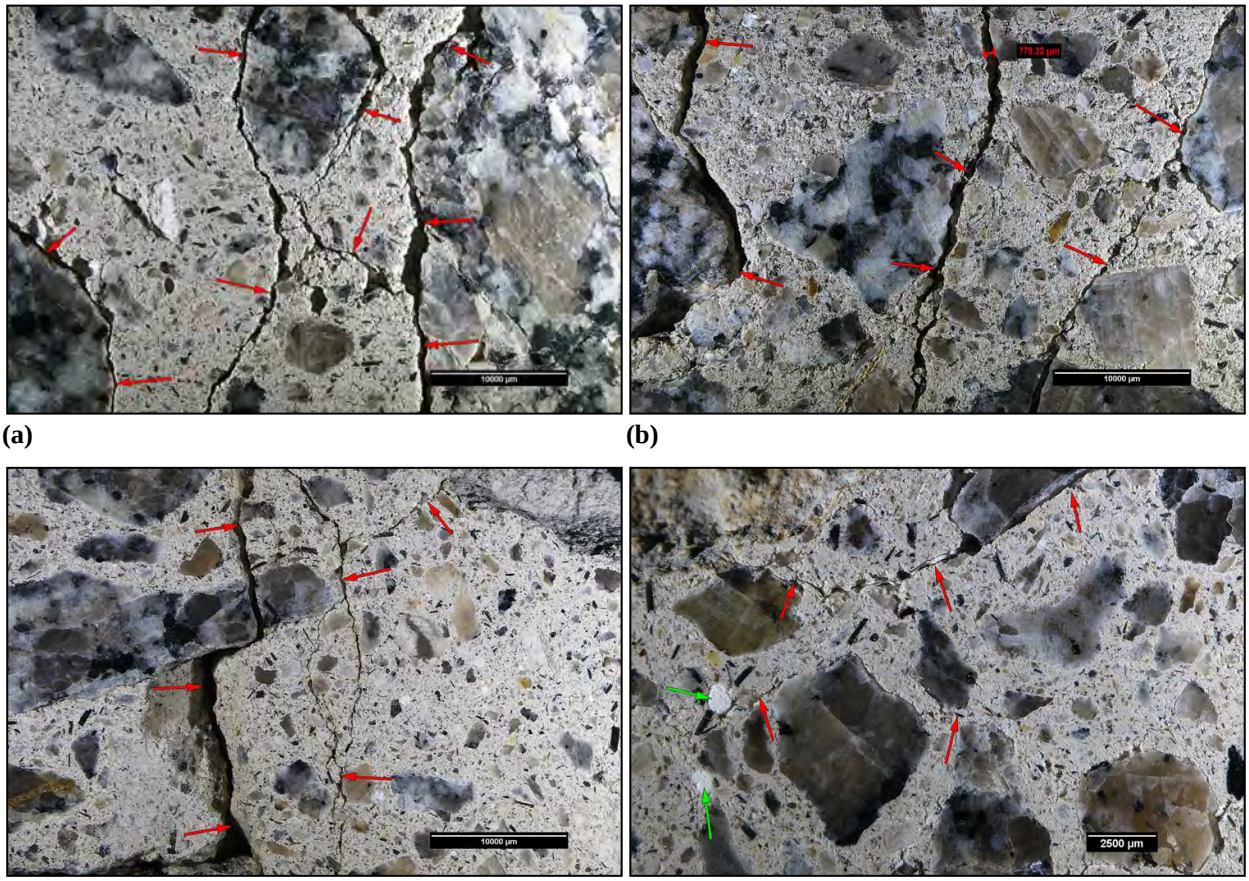
Figure 4. (a) Photograph and (b) reflected light photomicrograph of polished surface of Core RADS showing coarse and fine aggregate, respectively. (c) Photograph and (d) reflected light photomicrograph of polished surface of the Parapet Core showing coarse and fine aggregate, respectively. The scale in (a) and (c) is in millimeters.

3.5 *Cracking & Microcracking*

All four cores were received by two or more pieces. The open fractures cut around coarse aggregate particles and show deposits of ettringite.

All four cores show cracks through the full length of the core that are mainly parallel to the exposed surface. The cracks measure up to 750 µm (30 mil) wide and are up to 120 mm (4 ¾ in.) long. The cracks cut mostly around coarse aggregate particles. The open fractures commonly contain deposits of ettringite while closed cracks sporadically show deposits of ettringite. **Figure 5** shows details of the cracking.

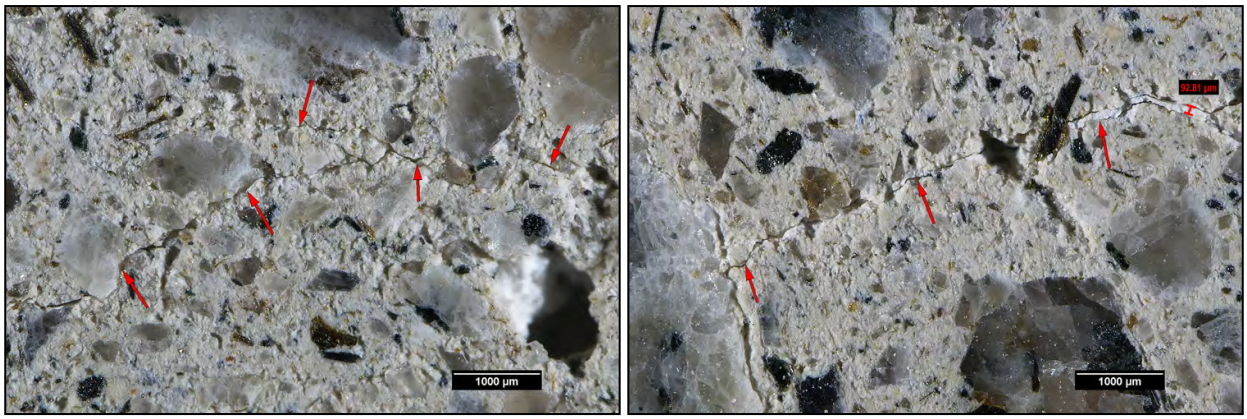
An abundance of microcracks was observed over the entire length of all four cores. The microcracks range up to 100 µm (4 mil) wide and are up to 75 mm (3 in.) long. They cut around aggregate particles and are occasionally to commonly filled with ettringite. **Figure 6** shows details of the microcracks.



(a) (b)

(c) (d)

Figure 5. Reflected light photomicrographs of the polished surface of (a) Core RADS, (b) Core LAUS, (c) the Crest Core, and (d) the Parapet Core showing cracks (red arrows). Note the deposits of ettringite (green arrows) filling voids in (d).



(a) (b)

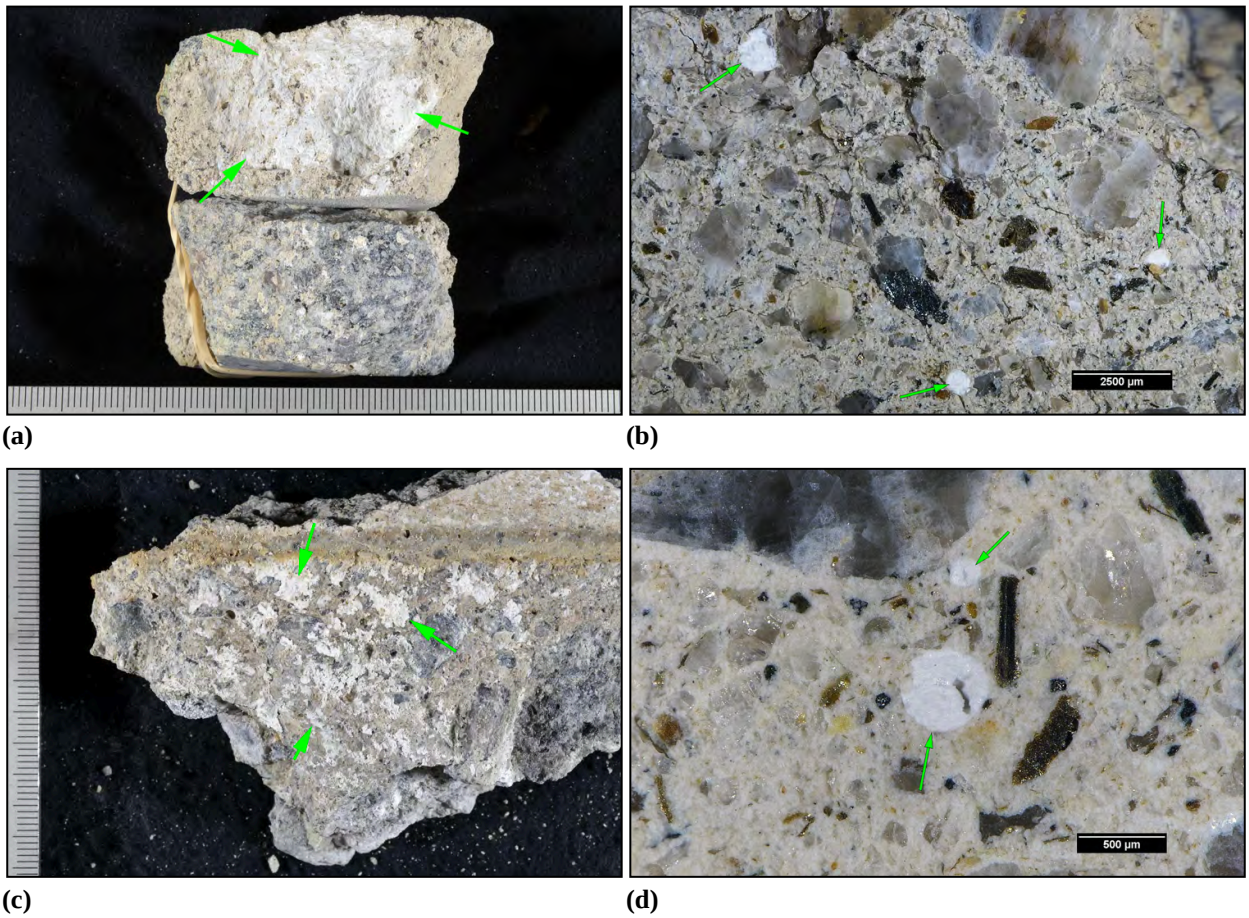
Figure 6. Reflected light photomicrographs of the polished surface of (a) the Crest Core and (b) the Parapet Core showing microcracks (red arrows) in the middle of the core. The microcrack in (b) is filled with ettringite.

3.6 ***Secondary Deposits*** Secondary deposits consist of carbonation and ettringite.

Deposits of ettringite were observed lining or filling voids, on open fractures, in cracks and in microcracks. Ettringite is a hydrous calcium sulfoaluminate mineral ($Ca_6Al_2(SO_4)_3(OH)_{12}$•26 H_2O) that commonly forms in portland cement concrete when it is exposed to high levels of moisture for prolonged periods of time. It is commonly observed in concrete affected by freeze-thaw damage and records the interaction of moisture with the cement paste but in such cases is not a cause of cracking or microcracking. **Figure 7** shows details of the ettringite mineralization.

Pervasive carbonation was observed to a depth of 5-15 mm (¼ – ⅝ in.) from the outer surface of Core RADS. The remaining three cores show evidence of partial carbonation based on the faint purple staining from phenolphthalein. In thin section fine crystallites of calcium carbonate were observed commonly in all four cores, indicating the onset of carbonation that is consistent with the faint purple staining observed from phenolphthalein. **Figure 8** shows photographs of the phenolphthalein stained surfaces.

No deposits of ASR gel or other evidence of ASR was observed in any of the cores.



(a) (b)

(c) (d)

Figure 7. (a) Photograph of a fracture surface from Core LAUS showing deposits of ettringite (green arrows); scale in millimeters. (b) Reflected light photomicrograph of the polished surface of Core LAUS showing voids with deposits of ettringite in the middle of the core. (c) Photograph of a fracture surface from the Parapet Core showing deposits of ettringite (green arrows); scale in millimeters. (d) Reflected light photomicrograph of the polished surface of the Parapet Core showing voids with deposits of ettringite in the middle of the core.

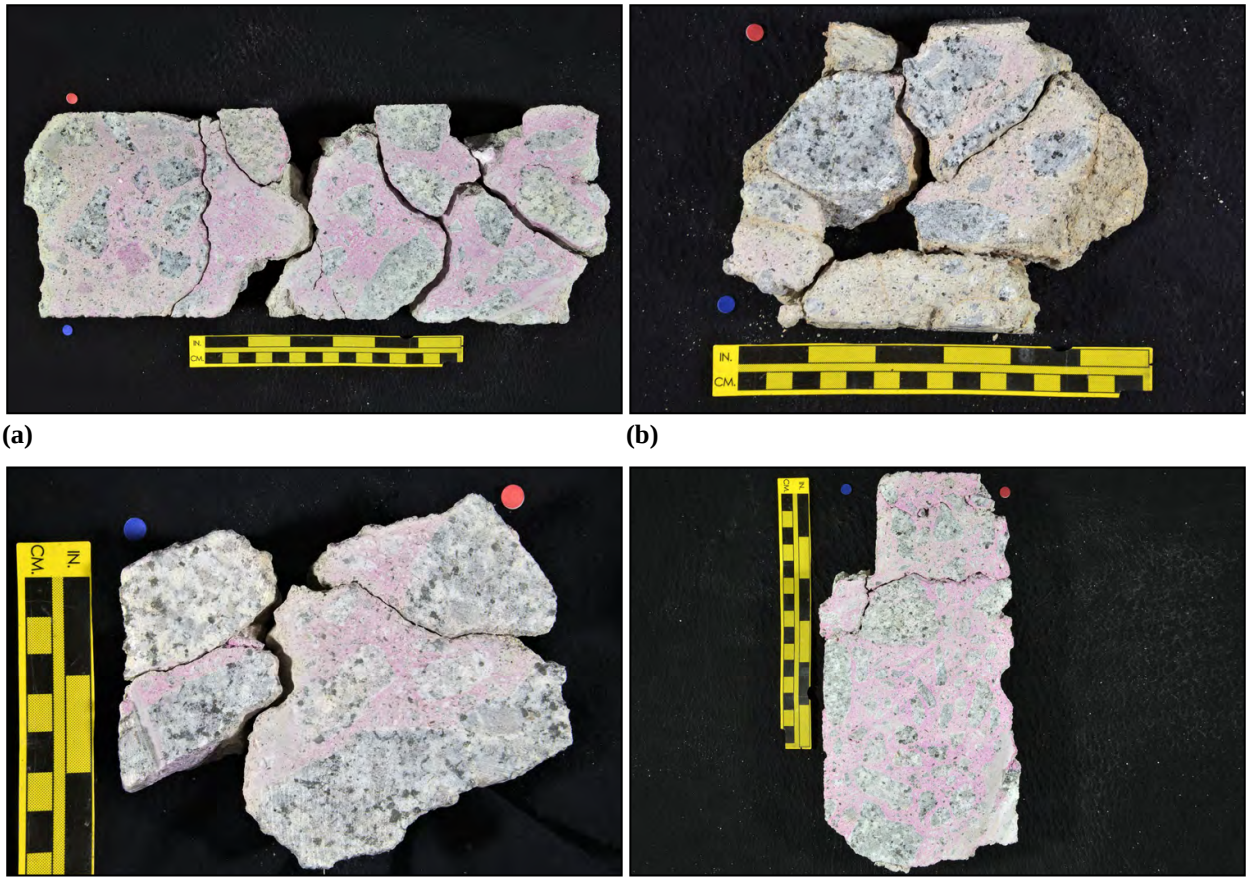


Figure 8. Photographs showing overview of phenolphthalein-stained surface of (a) Core RADS, (b) Core LAUS, (c) the Crest Core, and (d) the Parapet Core. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively.

4.0 CONCLUSIONS

The findings described above indicate that all four cores show evidence of severe freeze-that damage. The damage manifests as cracking and microcracking that is sub-parallel to the exposed surface of the cores. The cracks and microcracks occur over the full length of the cores and range up to 750 µm (30 mil) wide and are up to 120 mm (4 ¾ in.) long. Most of the cracks cut around coarse aggregate particles.

Several properties of the concrete make it susceptible to freeze-thaw damage, as noted below.

- The paste has a high w/c that facilitates the penetration of moisture, which diminishes the freeze-thaw durability of concrete. ACI 201 *Guide to Durable Concrete* recommends a maximum w/c of 0.45 for frost durability. Although it is not possible to quantitatively estimate the w/c of the present concrete due to its historical nature, the properties of the paste are consistent with modern concretes where the w/c is greater than 0.60.

- The concrete is non-air-entrained, which is typical for historical concretes that pre-date the use of modern air-entraining admixtures. The estimated total air content of the cores is less than 3%. Such concrete is not expected to provide freeze-thaw durability if it is saturated and exposed to freeze-thaw cycles as expected for a hydraulic dam in Butte, Montana.

The composition and proportioning of the components used to produce the concrete are consistent with each other. The paste contains hydrated portland cement; no fly ash, slag cement or other supplemental cementitious materials were observed. The hydration is advanced. The water-cement ratio (w/c) was not estimated quantitatively due to the age of the concrete and the historical nature of the cement, but the properties of the paste are consistent with modern concretes that have high w/c (greater than 0.60). The concrete is non-air entrained and contains less than 3% total estimated air content. The coarse aggregate is a crushed granodiorite that has a 75 mm (3 in.) nominal top size. The fine aggregate is a natural siliceous sand that consists mostly of the same granodiorite observed in the coarse aggregate.

Secondary deposits include ettringite and carbonation. Core RADS shows evidence of pervasive carbonation to a depth of 5-15 mm (¼ – ⅝ in.) from the outer surface. The remaining three cores shows slight carbonation throughout the length of the cores. Deposits of ettringite were observed in voids, open fractures, cracks and microcracks throughout the length of the cores. These deposits indicate the concrete was exposed to high levels of saturation for a prolonged period of time. No evidence of ASR was observed.

This concludes work performed on this project to date.

David Rothstein, Ph.D., P.G., FACI
Principal Petrographer

Chunyu (Joe) Qiao, Ph.D.
Senior Petrographer

Basin Creek Dam Core Petrography

Appendices

Appendix A	**RADA 1 Petrography (ASTM C856)**
Appendix B	**LAUS (1-3) Petrography (ASTM C856)**
Appendix C	**Crest Petrography (ASTM C856)**
Appendix D	**Parapet Petrography (ASTM C856)**
Appendix E	**Procedures**

1. Received Condition	
Orientation & Dimensions	Horizontal core extracted from the right abutment of the downstream face measures ~ 120 mm (4 ¾ in.) in diameter and is 280-320mm (11-12 ½ in.) long (**Figure A1, Figure A2**).
Surfaces	The core spans from a formed surface to a fracture such that the core represents a partial thickness of the abutment.
General Condition	The concrete is hard and compact and rings lightly when sounded with a hammer. The concrete core was received in two pieces with a fracture at 110-140 mm (4 ⅜ - 5 ½ in.) from the outer surface. Deposits of ettringite were observed lining the open fracture surfaces and inner surface (**Figure A3**).

2. Embedded Objects	
General	None observed.

3. Cracking	
Macroscopic	Several sub-vertical cracks that are parallel to the outer surface were observed throughout the entire core (**Figure A4**). The cracks commonly cut across the entire diameter of the core and measure up to 500 µm (20 mil) wide. The cracks dominantly cut around coarse aggregate particles and are mainly free of secondary deposits. One sub-horizontal crack was observed ~ 210 mm (8 ¼ in.) from the outer surface. The crack is perpendicular to the outer surface. It measures ~ 100 mm (4 in.) long and 100-250 µm (4-10 mil) wide. It cuts around aggregate particles and is free of secondary deposits.
Microscopic	Numerous microcracks were observed over the full length of the core (**Figure A5**). They measure up to 75 mm (3 in.) long and up to 100 µm (4 mil) wide. They cut around aggregate particles and ettringite was occasionally was observed lining microcracks.

4. Voids	
Void System	Concrete is non-air-entrained and contains less than 3% total air as estimated from visual and microscopical observations. The concrete is well consolidated with a few voids that measure up to 10 mm (⅜ in.) across.
Void Fillings	Voids occasionally to commonly contain deposits of ettringite (**Figure A6**).

5. Coarse Aggregate	
Physical Properties	The coarse aggregate is a crushed rock that has a 75 mm (3 in.) nominal top size (**Figure A7**). The rocks are hard and competent. The particles range from sub-equant to elongated with aspect ratios up to 2:1 observed. The particles are angular to sub-angular. The gradation and distribution are impossible to describe due to the coarse aggregate size and the core size.
Rock Types	The aggregate is siliceous in composition and consists primarily of coarse-grained granodioritic rocks. Granodioritic rocks are potentially susceptible to alkali-silica reaction (ASR).
Other Features	No deleterious coatings or incrustations observed. No low w/c mortar coatings were observed. No evidence of ASR was observed.

6. Fine Aggregate

Physical Properties	The fine aggregate is a natural sand that consists of rocks that are hard and competent (**Figure A8**). The particles are mostly sub-equant to slightly elongated in shape with sub-rounded to sub-angular edges. The grading and distribution are relatively even.
Rock Types	The sand is siliceous in composition and consists primarily of rocks similar to those observed in the coarse aggregate. The fines include abundant fragments of quartz, feldspar, amphibole and biotite.
Other Features	No deleterious coatings or incrustations observed. No evidence of ASR was observed.

7. Paste Observations

Polished Surface	Paste is white (Munsell 10YR/8/1), has a smooth texture and a dull luster (**Figure A9**). The paste is soft (Mohs ~ 2.5).
Fresh Fracture	The fresh fracture is white, has a granular texture and a dull luster (**Figure A10**). It dominantly cuts around coarse aggregate particles. Deposits of ettringite were observed lining the fracture surface.
Thin Section	The paste contains hydrated portland cement with no fly ash, slag cement, silica fume or other SCM observed. The hydration is normal. The paste contains less than 4% RRCG that consist primarily of clusters of belite grains with interstitial aluminoferrite (**Figure A11**). CH is fine grained and distributed relatively evenly and makes up less than 4% of the paste. The capillary porosity of the paste is moderate and relatively homogeneous (**Figure A12**).
Estimated w/cm	Greater than 0.60.

** Abbreviations as follows: DSL = densified surface layer; RRCG = relict and residual cement grains; SCM = supplemental cementitious materials; CH = calcium hydroxide; ITZ = interfacial transition zone. Modal abundances are based on visual estimations.*

8. Secondary Deposits

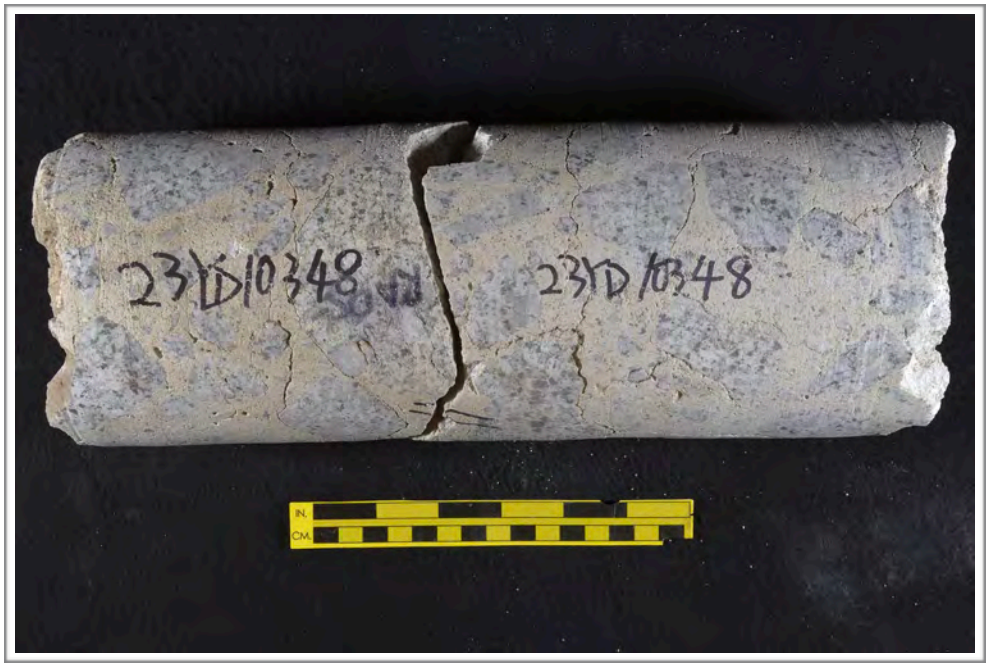
Phenolphthalein	No purple staining for 5-15 mm (¼ – ⅝ in.) from the outer surface (**Figure A13**).
Secondary Deposits	Carbonation was observed for 5-15 mm (¼ – ⅝ in.) from the outer surface. Deposits of ettringite were occasionally to commonly observed filling voids and lining microcracks and open fracture surfaces.

FIGURES

(a)

(b)

Figure A1. Photographs of the core in as-received condition showing (a) an oblique view of the outer surface and side of the concrete with identification labels and (b) the outer surface of the concrete. The red and blue dots show the orientation of the saw cuts used to prepare the core. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively.



(c)

(d)

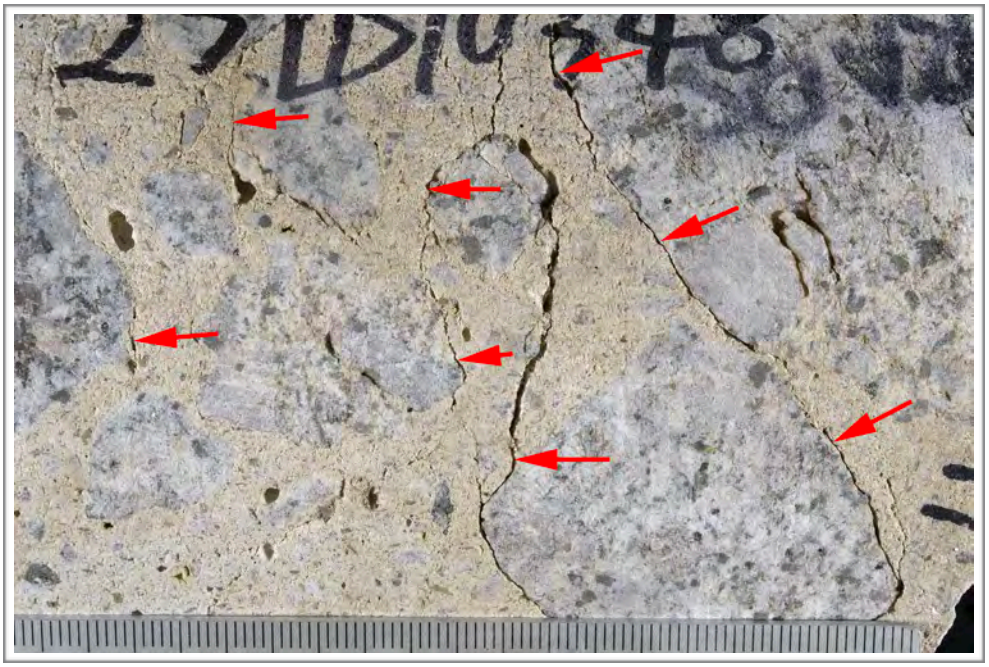
Figure A1 (cont'd). Photographs of the core in as-received condition showing (c) the side of the concrete and (d) the inner surface of the core. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively. Note the open fracture in the middle of the core in (c).

Figure A2. Photograph of the polished surface. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively. The core is horizontal in orientation; the outer surface is towards upwards.

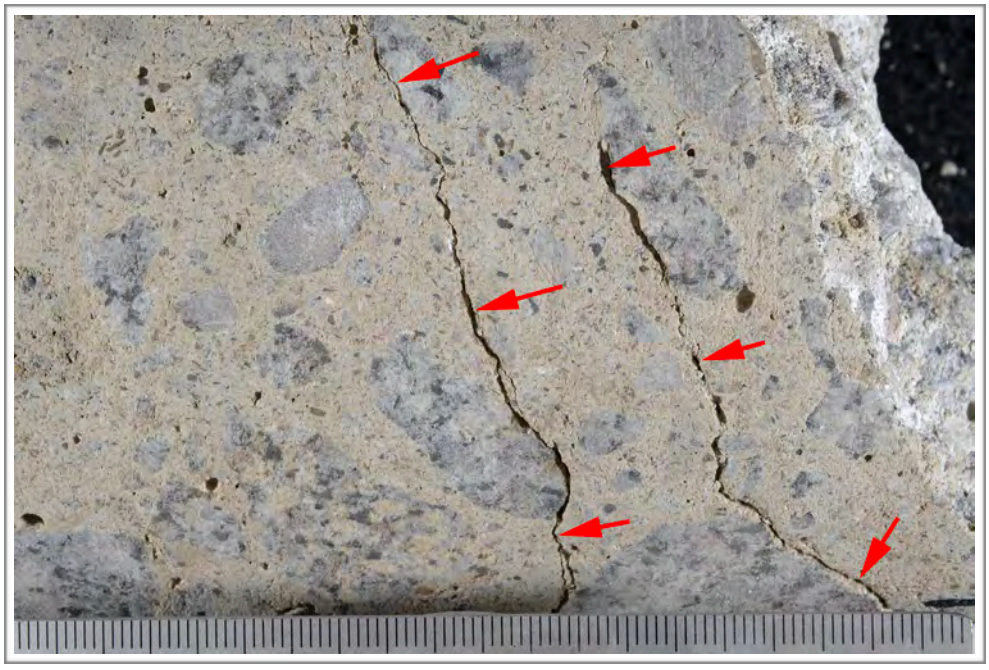
(a)

(b)

Figure A3. Photographs of the core in as-received condition showing overview of deposits of ettringite (green arrows) (a) at the open fracture surface and (b) the inner surface of the core. The scale in both images is in millimeters.

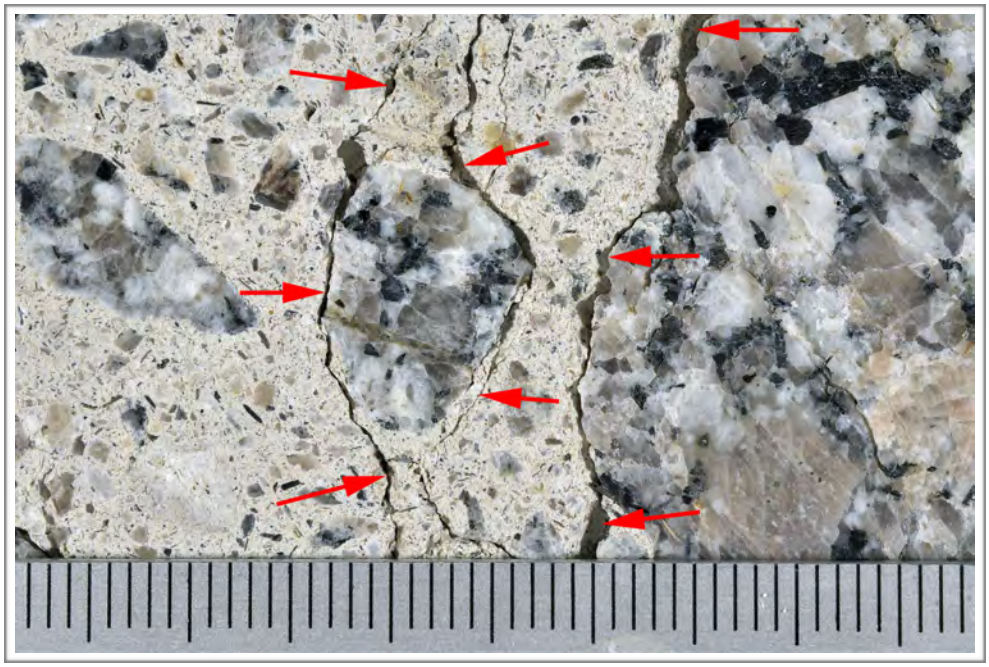


(a)

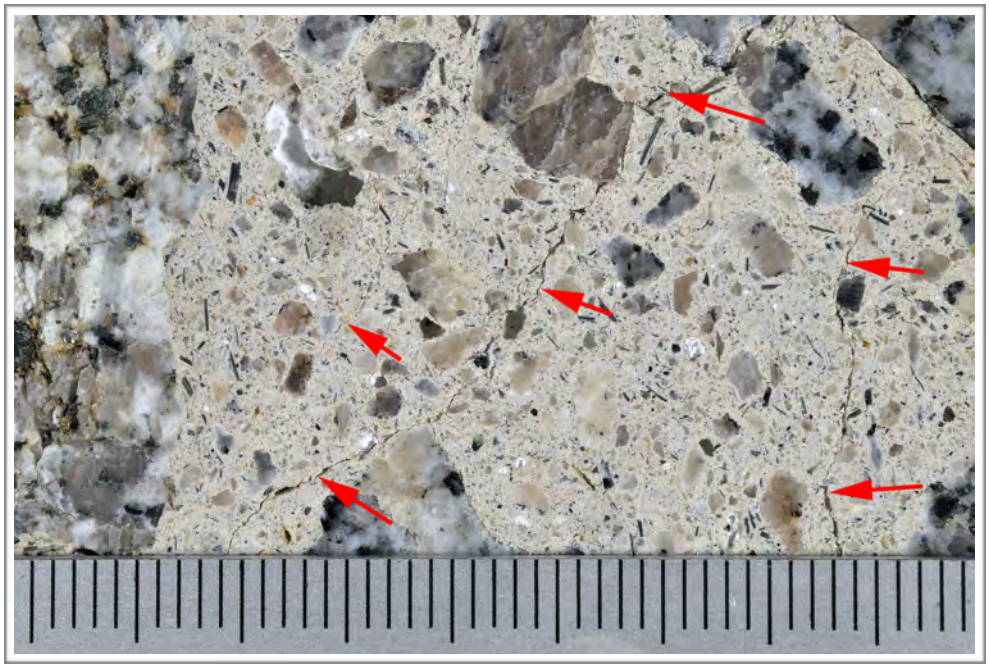


(b)

Figure A4. Photographs of the side of the core showing the sub-vertical cracks (red arrows) in the middle of the core; scale in millimeters.

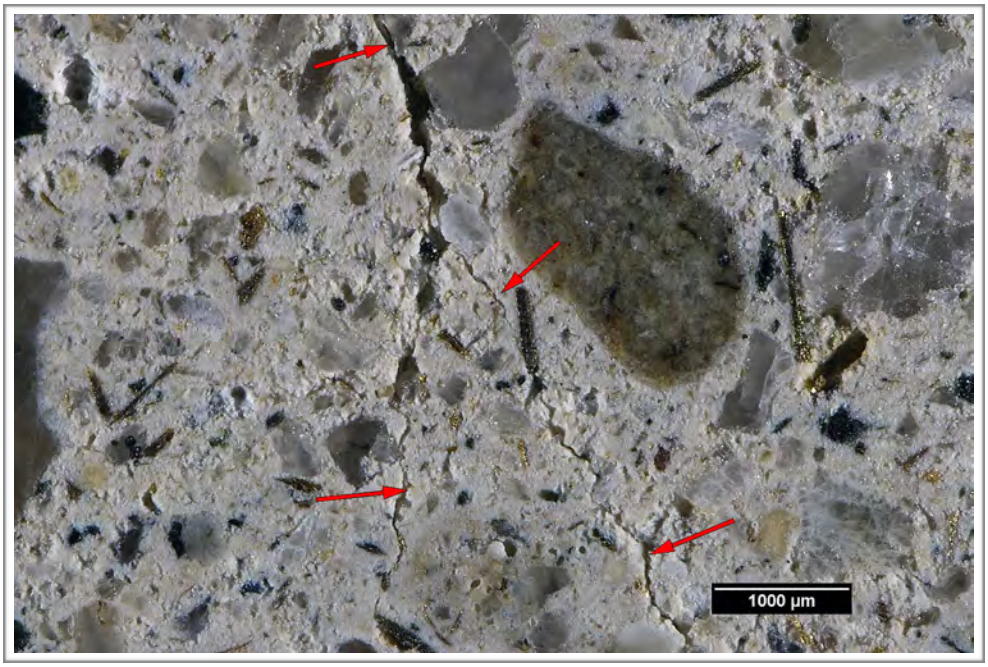


(c)

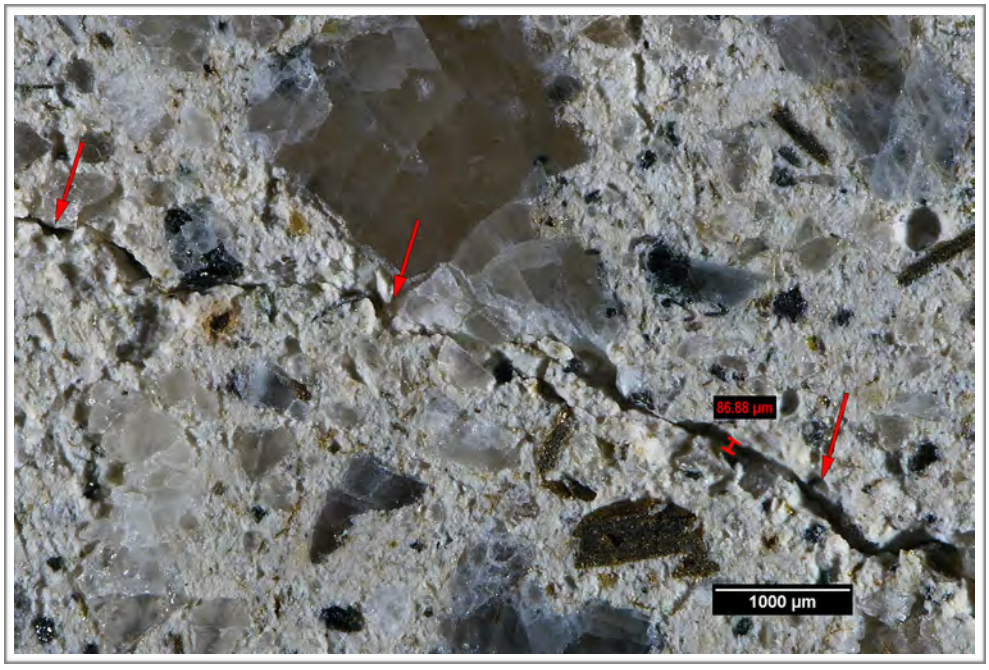


(d)

Figure A4 (Cont'd). Reflected light photomicrographs of the polished surface showing the sub-vertical cracks (red arrows) in the middle of the core.

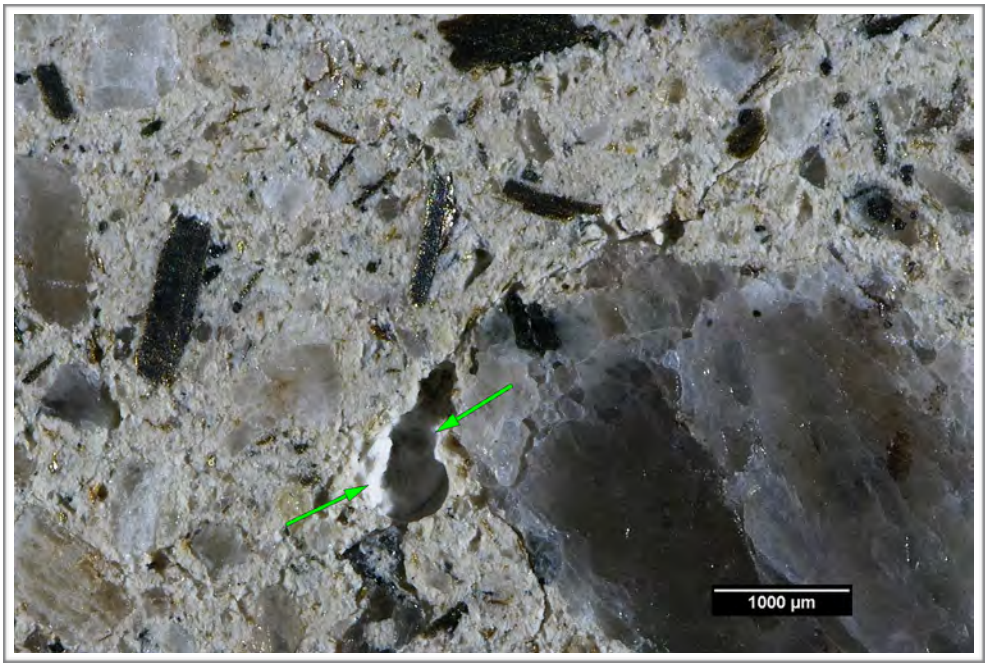


(a)

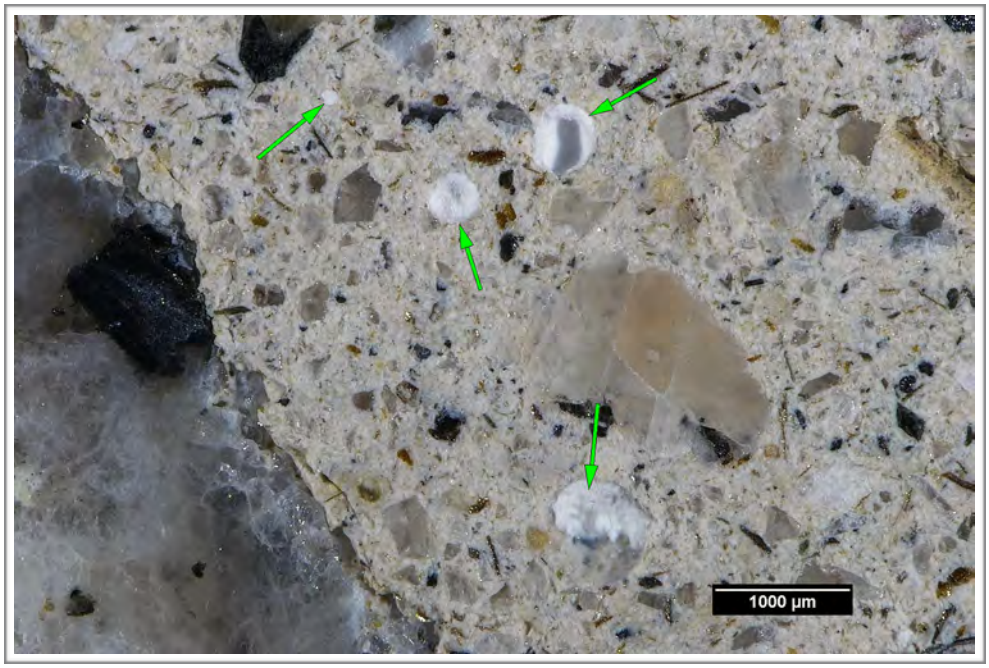


(b)

Figure A5. Reflected light photomicrographs of the polished surface showing the sub-vertical and sub-horizontal microcracks (red arrows) in the middle of the core. The red bar indicates the width of the microcrack in (b).



(a)



(b)

Figure A6. Reflected light photomicrographs of the polished surface showing deposits of ettringite (green arrows) filling voids in the middle of the core.

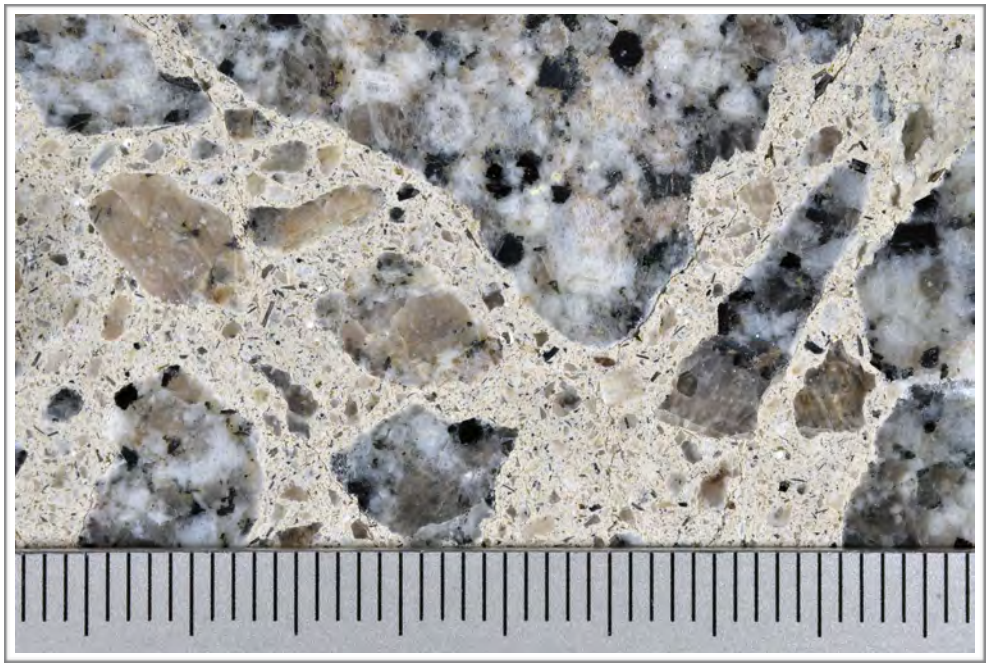
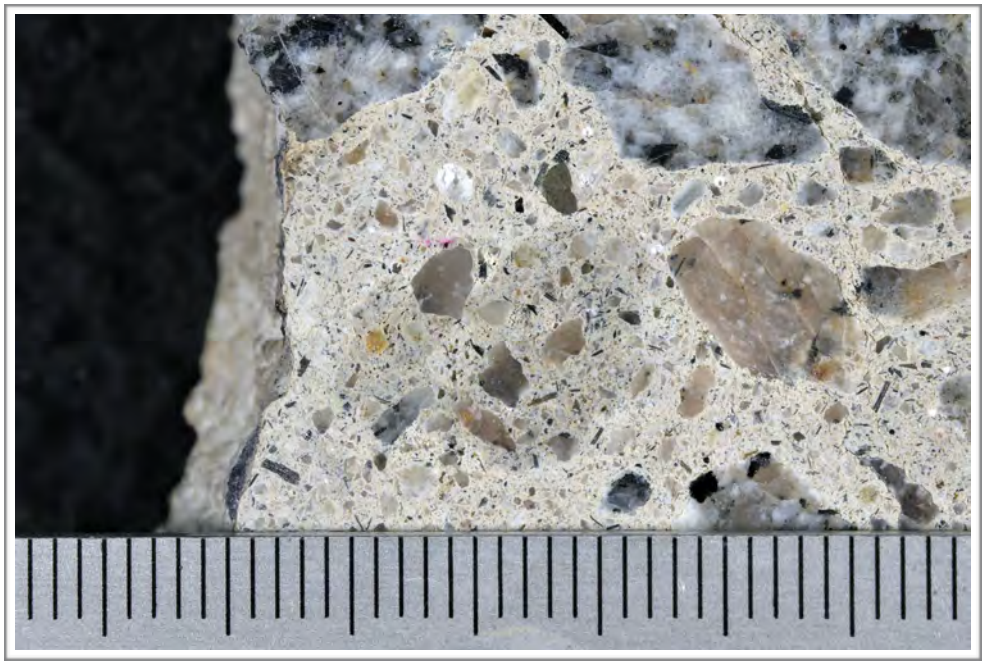


Figure A7. Photograph of the polished surface showing overview of the coarse aggregate; scale in millimeters.

Figure A8. Reflected light photomicrograph of the polished surface showing fine aggregate.

(a)



(b)

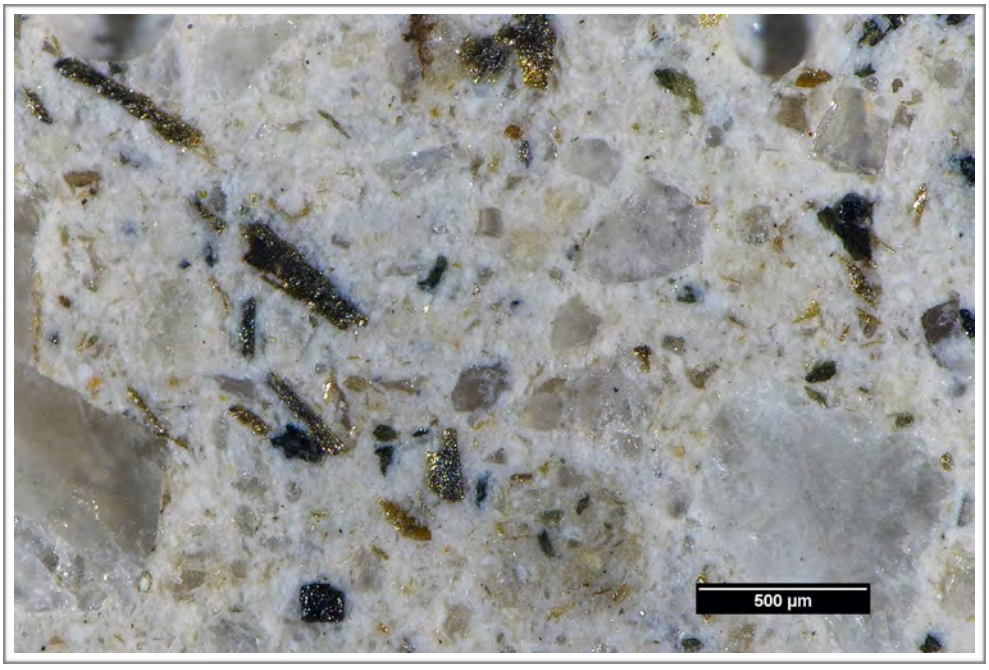
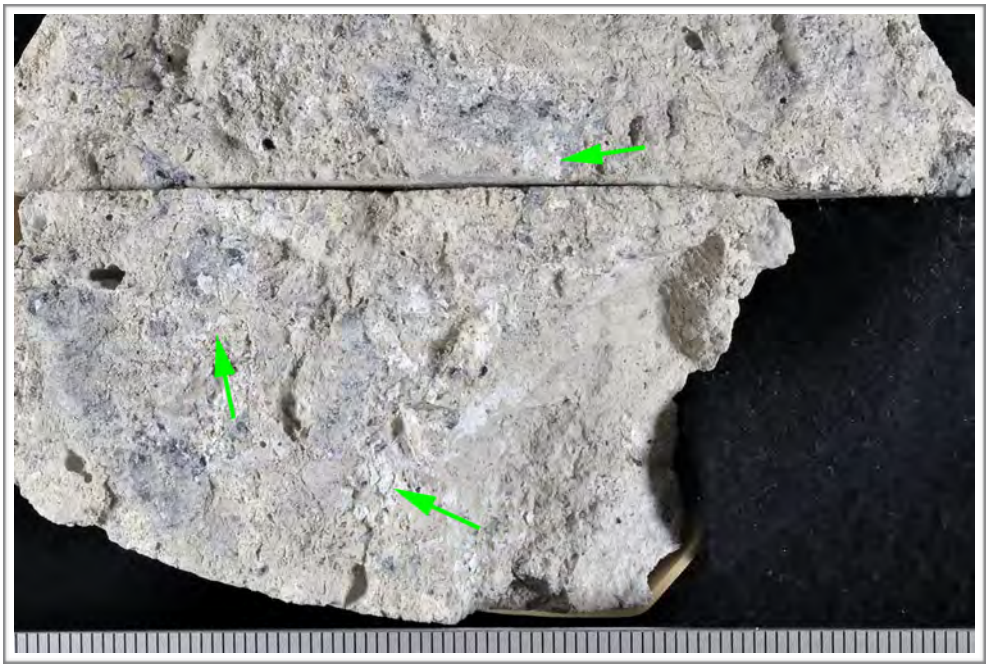


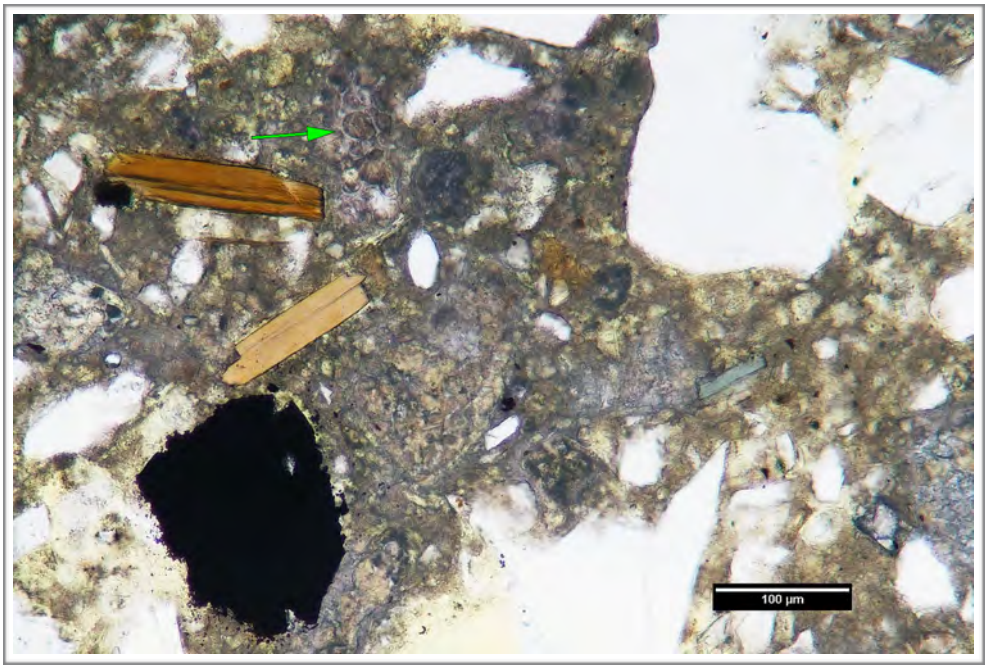
Figure A9. (a) Photograph of the polished surface showing overview of paste at the outer surface of the polished surface; scale in millimeters. (b) Reflected light photomicrograph of the polished surface showing detail of paste in the middle of the core.

(a)

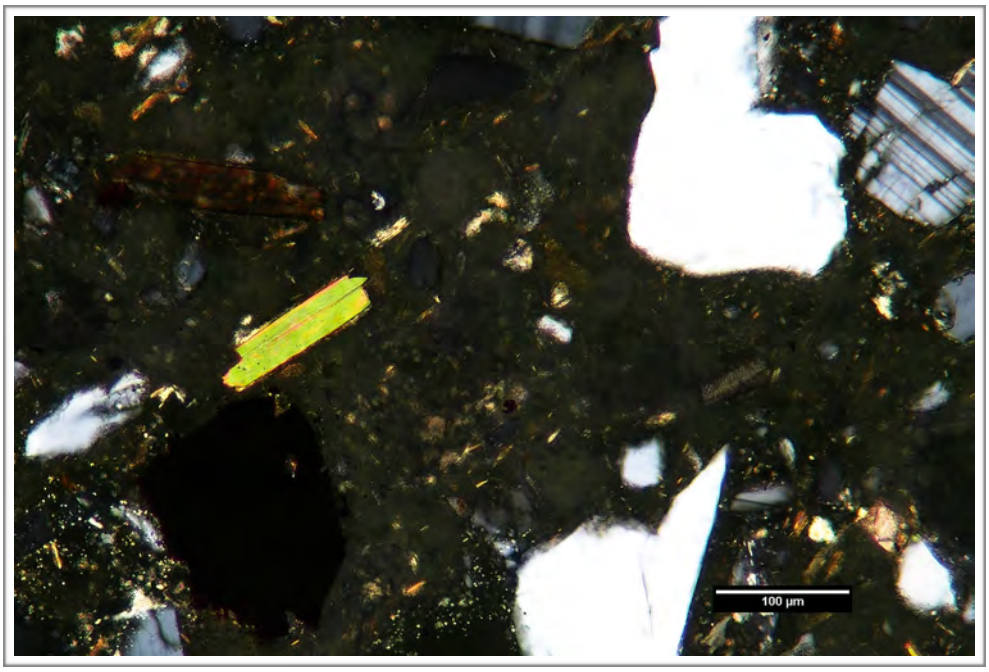


(b)

Figure A10. Photographs showing (a) overview and (b) detail of the fresh fracture surface; scale in millimeters. The green arrows in (b) indicate deposits of ettringite.

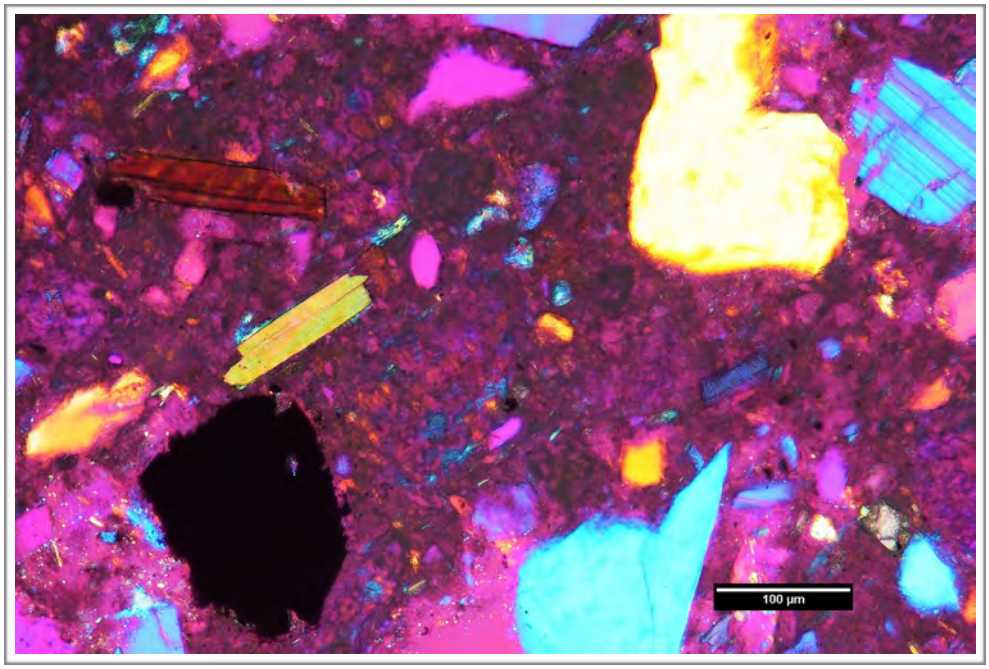


(a)

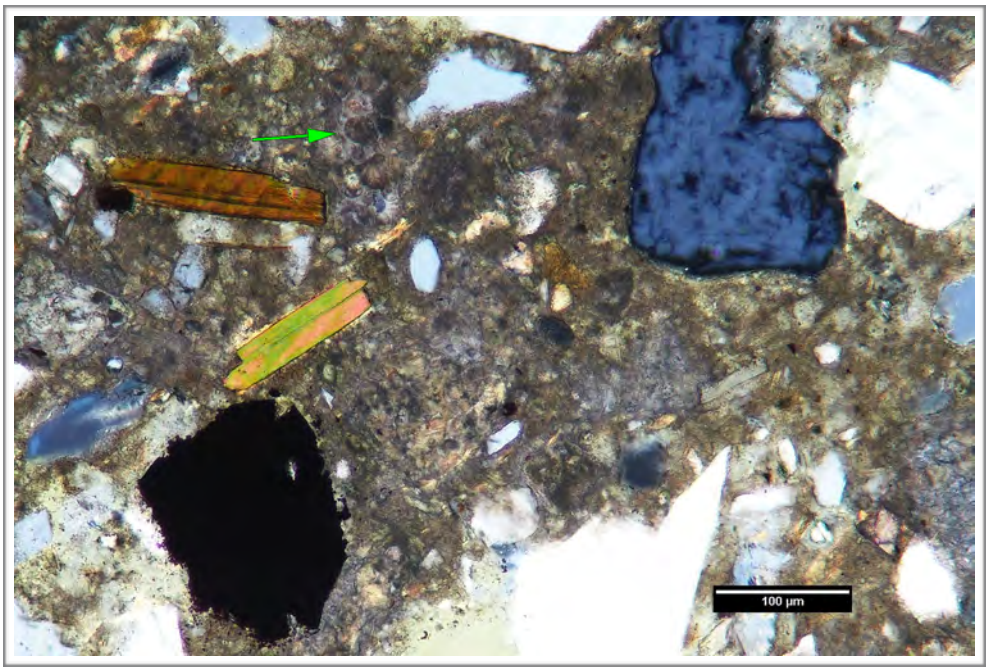


(b)

Figure A11. Transmitted light photomicrographs of thin section showing detail of paste in the middle of the thin section in (a) plane-polarized and (b) cross-polarized light. In (a) the green arrow indicates belite.



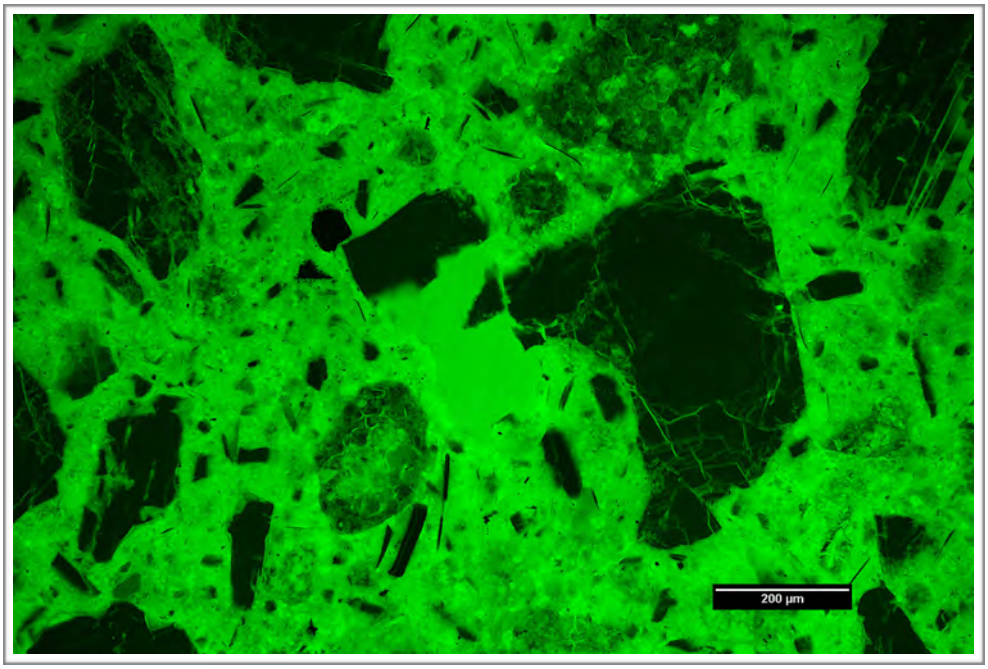
(c)



(d)

Figure A11 (cont'd). Transmitted light photomicrographs of thin section showing detail of paste in the middle of the thin section in (c) cross-polarized light with the gypsum plate inserted and (d) cross-polarized light with the quarter wavelength plate inserted. In (c) the white arrows indicate calcium hydroxide. In (d) the green arrow indicates belite.

(a)



(b)

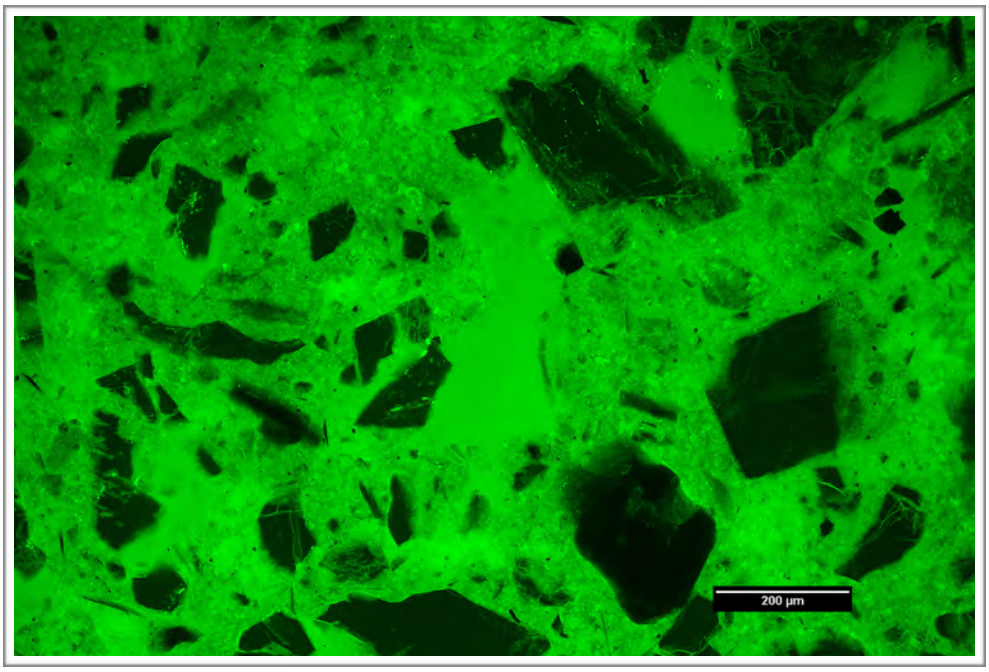
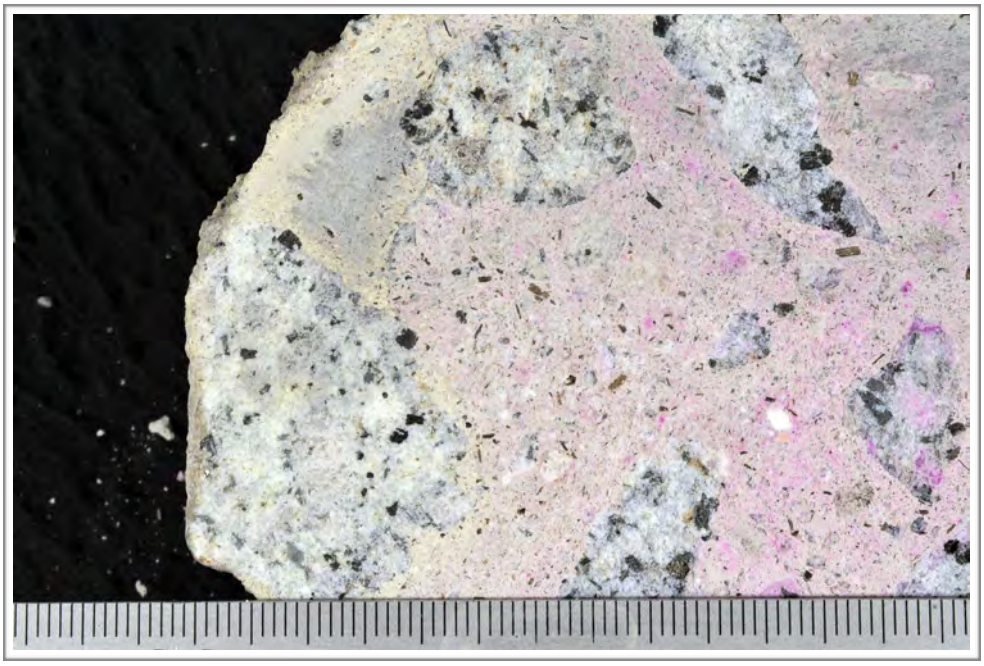


Figure A12. Transmitted fluorescent light photomicrographs of thin section showing detail of the capillary porosity of the paste in the middle of the thin section. The black areas correspond to aggregate that has very low porosity and the bright green circles are air voids filled with epoxy. The variations in green between these end members reflect variations in paste capillary porosity or micro-density.

(a)



(b)

Figure A13. Photographs showing (a) overview of phenolphthalein-stained surface and (b) detail of surface near the outer surface of the core. The yellow scale in (a) is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively. The scale in (b) is in millimeters.

1. Received Condition	
Orientation & Dimensions	Horizontal core extracted from the right abutment of the downstream face measures ~ 120 mm (4 ¾ in.) in diameter and is ~ 410 mm (16 ⅛ in.) long (**Figure B1, Figure B2**).
Surfaces	The core spans from a formed surface that is covered with shotcrete to a fracture such that the core represents a partial thickness of the abutment.
General Condition	The concrete is hard and compact and rings lightly when sounded with a hammer. The outer shotcrete and underlying concrete measures ~ 140 mm (5 ⅝ in.) and ~ 270 mm (10 ⅝ in.) long, respectively. The concrete core was received in multiple pieces. Deposits of ettringite were observed lining fracture surfaces (**Figure B3**).

2. Embedded Objects	
General	None observed.

3. Cracking	
Macroscopic	Other than the numerous open fractures, multiple sub-vertical cracks that are parallel to the outer surface were observed throughout the entire depth of the core (**Figure B4**). The cracks measure up to 80 mm (3 ¼ in) long and up to 750 µm (30 mil) wide. The cracks dominant cut around coarse aggregate particles and are mainly free of secondary deposits.
Microscopic	Numerous microcracks were observed over the full length of the core. They measure up to 50 mm (2 in.) long and up to 100 µm (4 mil) wide. They cut around aggregate particles and ettringite was occasionally was observed lining microcracks.

4. Voids	
Void System	Concrete is non-air-entrained and contains less than 3% total air as estimated from visual and microscopical observations. The concrete is well consolidated with a few voids that measure up to 10 mm (⅜ in.) across.
Void Fillings	Voids occasionally to commonly contain deposits of ettringite (**Figure B5**).

5. Coarse Aggregate	
Physical Properties	The coarse aggregate is a crushed rock that has a 75 mm (3 in.) nominal top size (**Figure B6**). The rocks are hard and competent. The particles range from sub-equant to elongated with aspect ratios up to 2:1 observed. The particles are angular to sub-angular. The gradation and distribution are impossible to describe due to the coarse aggregate size and the core size.
Rock Types	The aggregate is siliceous in composition and consists primarily of coarse-grained granodioritic rocks. Granodioritic rocks are potentially susceptible to alkali-silica reaction (ASR).
Other Features	No deleterious coatings or incrustations observed. No low w/c mortar coatings were observed. No evidence of ASR was observed.

6. Fine Aggregate

Physical Properties	The fine aggregate is a natural sand that consists of rocks that are hard and competent (**Figure B7**). The particles are mostly sub-equant to slightly elongated in shape with sub-rounded to sub-angular edges. The grading and distribution are relatively even.
Rock Types	The sand is siliceous in composition and consists primarily of rocks similar to those observed in the coarse aggregate. The fines include abundant fragments of quartz, feldspar, amphibole and biotite.
Other Features	No deleterious coatings or incrustations observed. No evidence of ASR was observed.

7. Paste Observations

Polished Surface	Paste is white (Munsell 10YR/8/1), has a smooth texture and a dull luster (**Figure B8**). The paste is soft (Mohs ~ 2.5).
Fresh Fracture	The core is too friable to produce a fresh fracture.
Thin Section	The paste contains hydrated portland cement with no fly ash, slag cement, silica fume or other SCM observed. The hydration is normal. The paste contains less than 4% RRCG that consist primarily of clusters of belite grains with interstitial aluminoferrite (**Figure B9**). CH is fine grained and distributed relatively evenly and makes up less than 4% of the paste. Calcium carbonate was observed in the paste due to slight carbonation. The capillary porosity of the paste is moderate and relatively homogeneous (**Figure B10)**.
Estimated w/cm	Greater than 0.60.

** Abbreviations as follows: DSL = densified surface layer; RRCG = relict and residual cement grains; SCM = supplemental cementitious materials; CH = calcium hydroxide; ITZ = interfacial transition zone. Modal abundances are based on visual estimations.*

8. Secondary Deposits

Phenolphthalein	The entire surface stains light purple (**Figure B11**).
Secondary Deposits	Slight carbonation was observed throughout the entire core. Deposits of ettringite were occasionally to commonly observed filling voids and lining microcracks and open fracture surfaces.

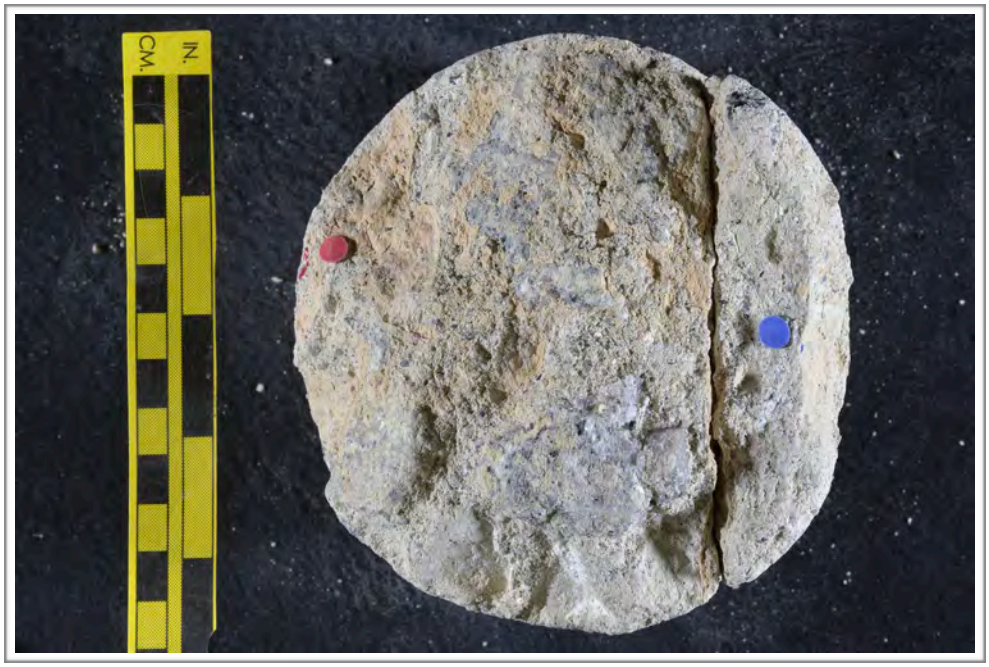
FIGURES

(a)

(b)

Figure B1. Photographs of the core in as-received condition showing (a) overview of the multiple pieces and (b) an oblique view of the outer surface and side of the portion with identification labels for petrographic examination. The red and blue dots show the orientation of the saw cuts used to prepare the core. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively.

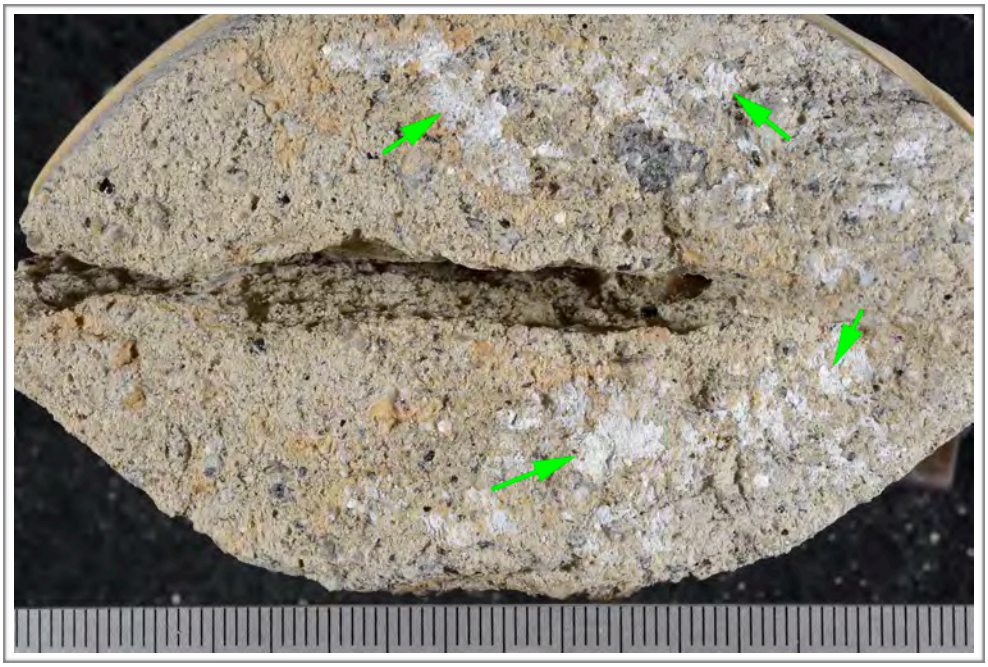
(c)



(d)

Figure B1 (cont'd). Photographs of the core in as-received condition showing (c) the outer surface of the portion for petrographic examination and (d) the inner surface of the portion for petrographic examination. The red and blue dots show the orientation of the saw cuts used to prepare the core. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively.

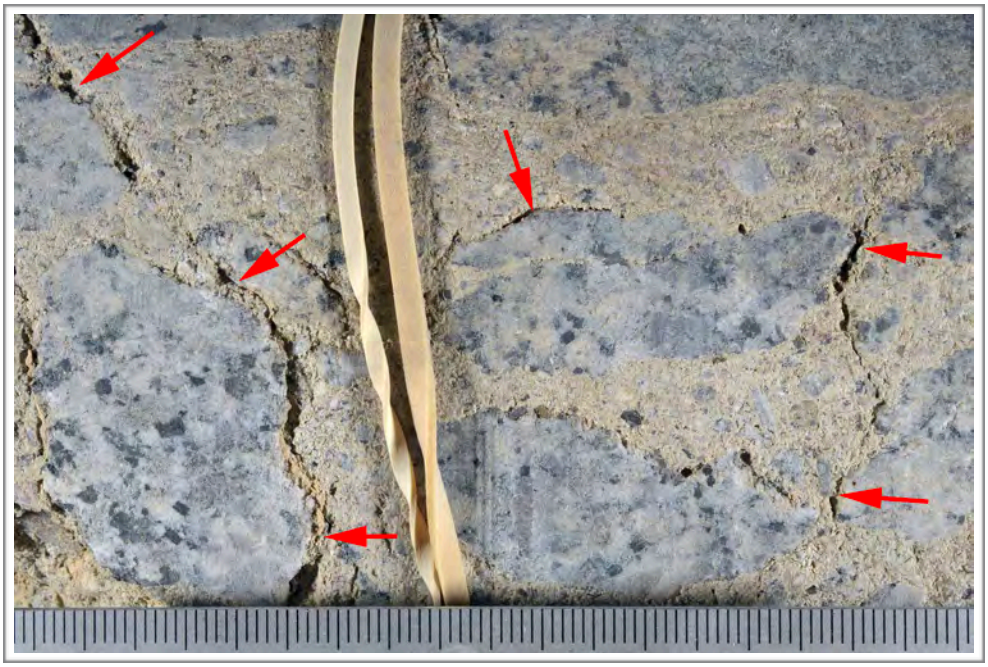
Figure B2. Photograph of the polished surface. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively. The core is horizontal in orientation; the outer surface is towards upwards.



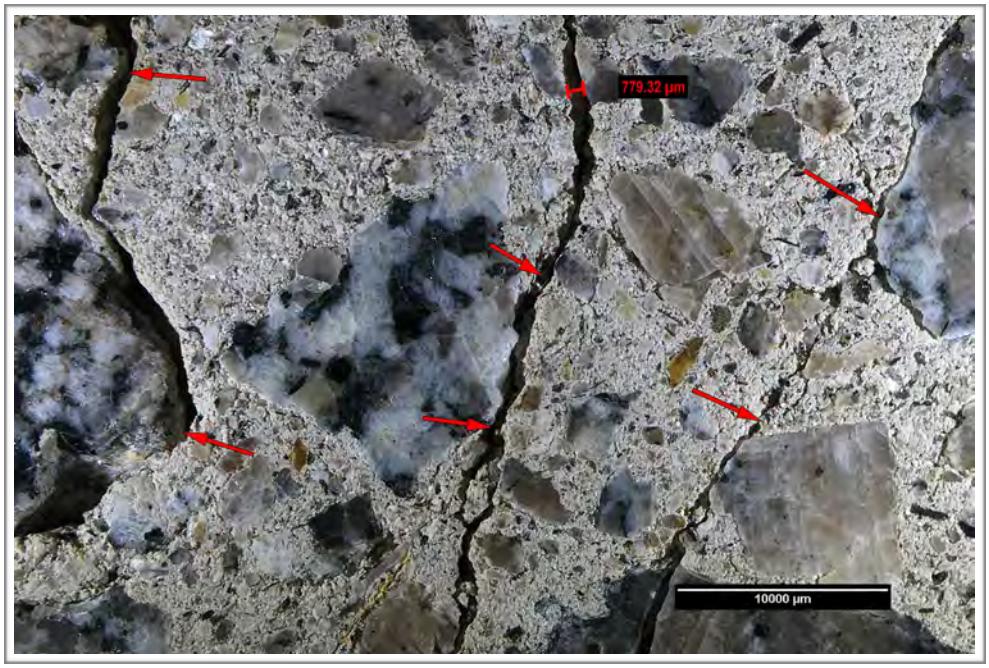
(a)

(b)

Figure B3. Photographs of the core in as-received condition showing overview of deposits of ettringite (green arrows) at the open fracture surfaces. The scale in both images is in millimeters.

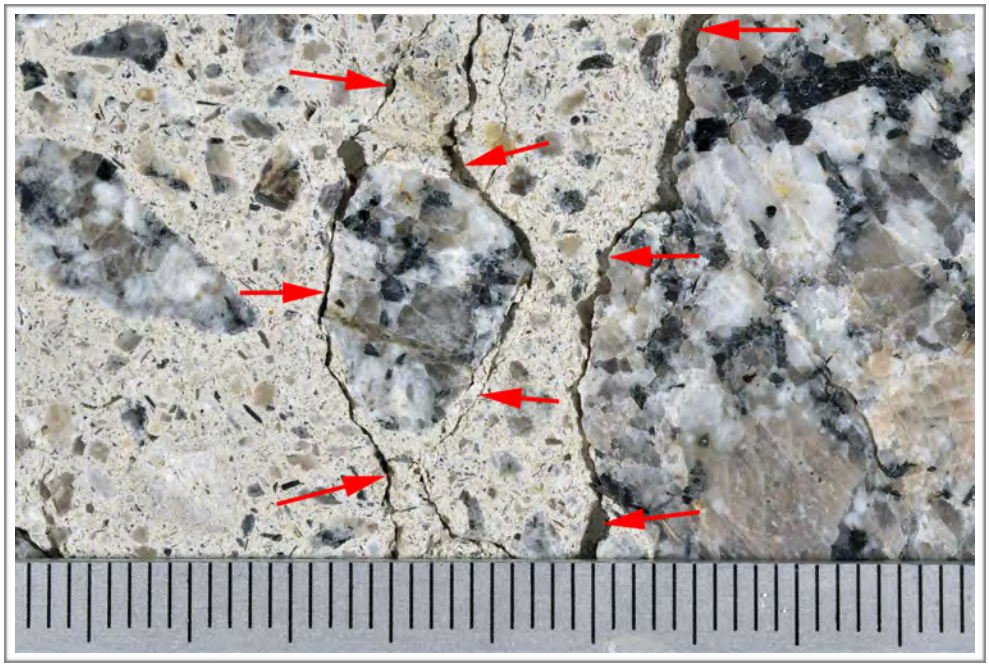


(a)

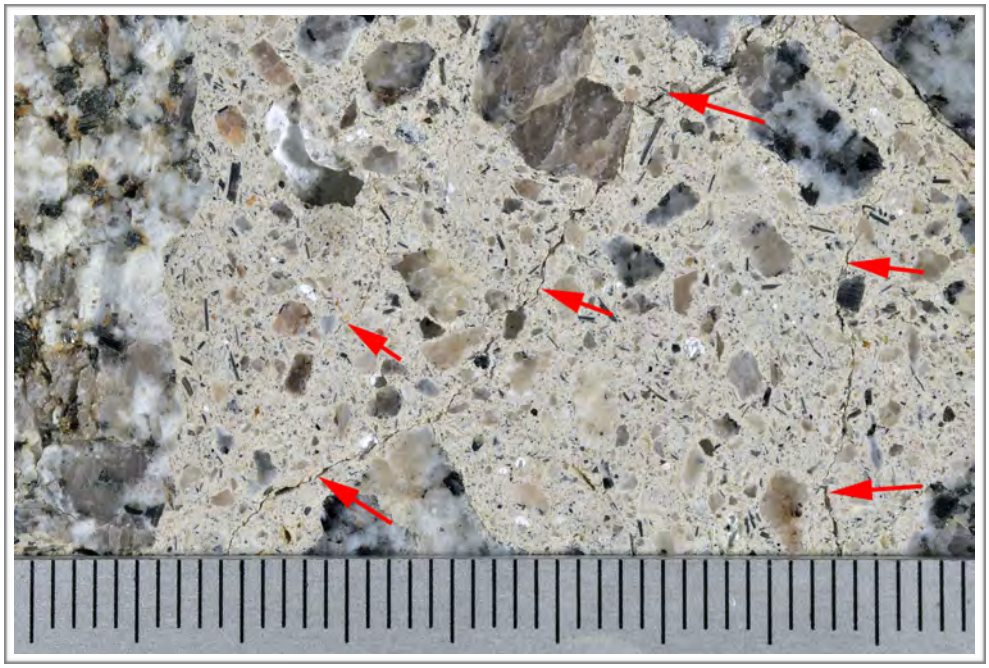


(b)

Figure B4. Photographs of the side of the core showing the sub-vertical cracks (red arrows) in the middle of the core; scale in millimeters.

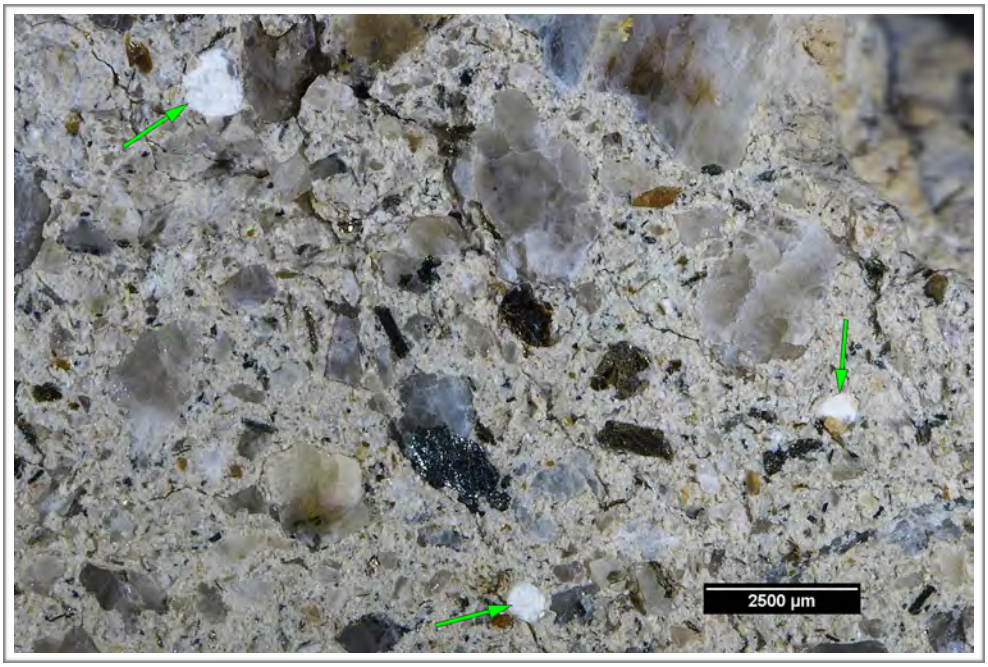


(c)



(d)

Figure B4 (Cont'd). Reflected light photomicrographs of the polished surface showing the sub-vertical cracks (red arrows) in the middle of the core.



(a)

(b)

Figure B5. Reflected light photomicrographs of the polished surface showing deposits of ettringite (green arrows) filling voids in the middle of the core.

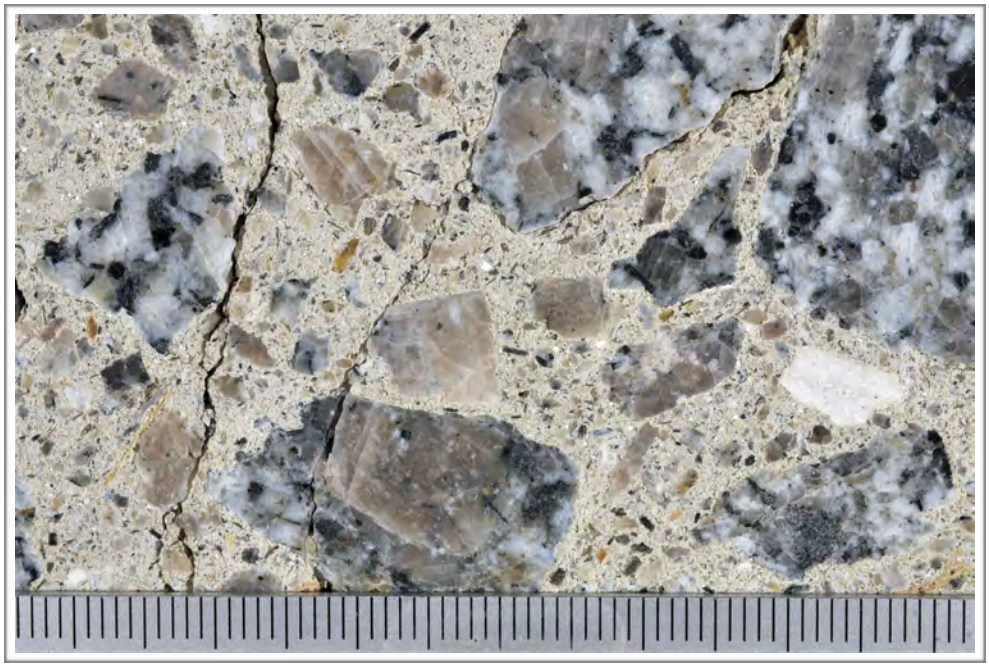


Figure B6. Photograph of the polished surface showing overview of the coarse aggregate; scale in millimeters.

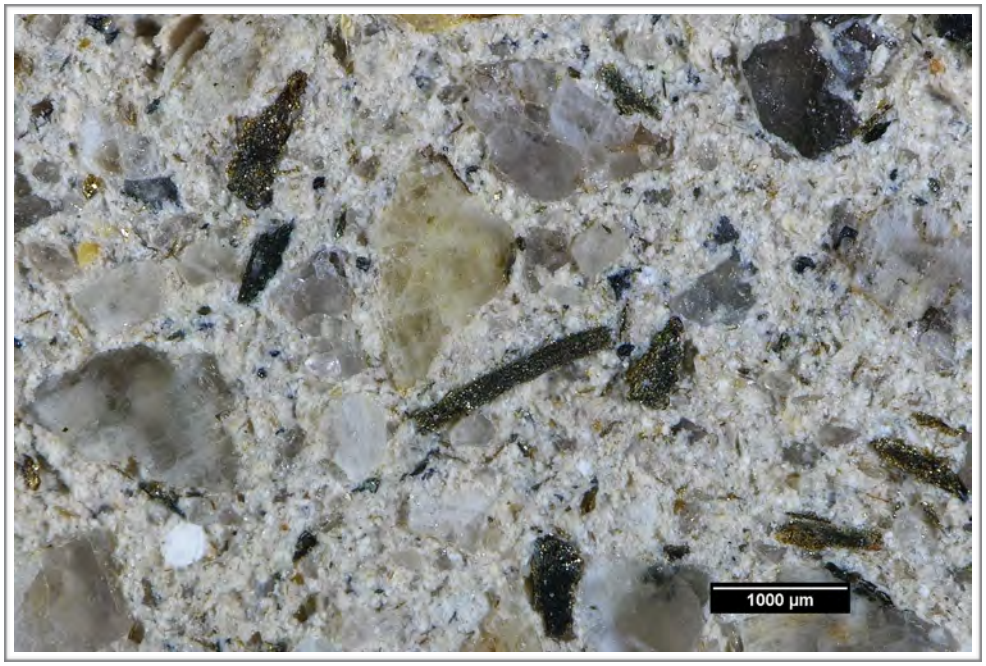


Figure B7. Reflected light photomicrograph of the polished surface showing fine aggregate.

(a)

(b)

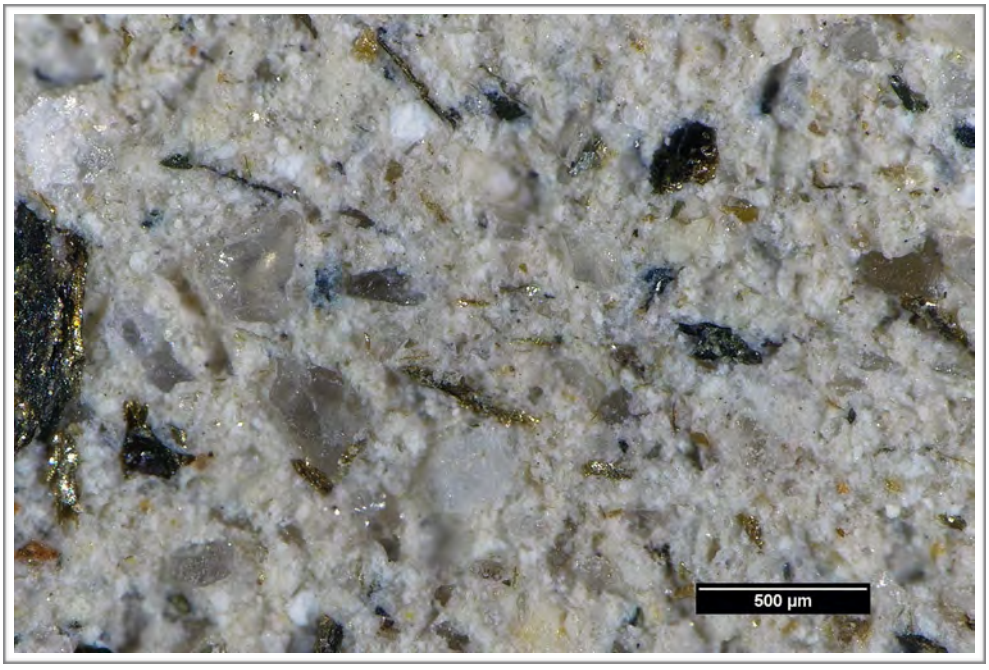
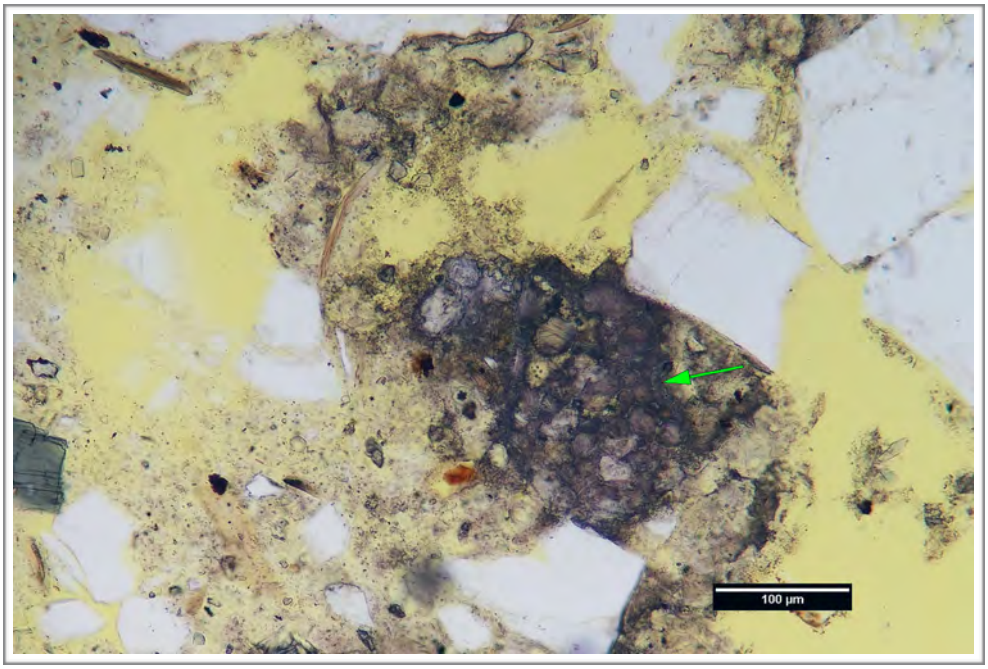
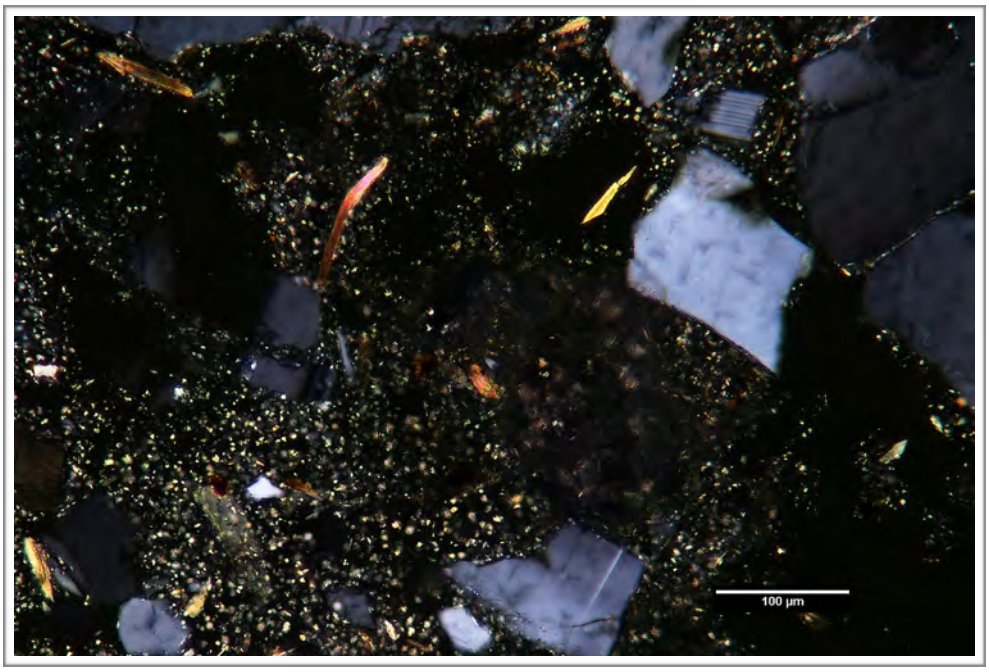


Figure B8. (a) Photograph of the polished surface showing overview of paste at the outer surface of the polished surface; scale in millimeters. (b) Reflected light photomicrograph of the polished surface showing detail of paste in the middle of the core.



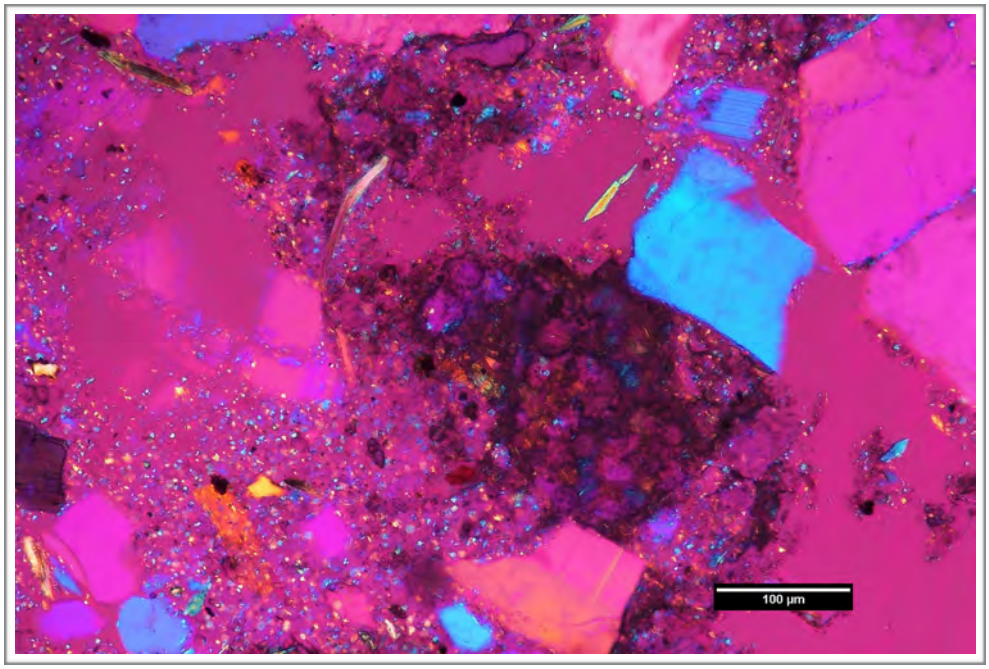
(a)



(b)

Figure B9. Transmitted light photomicrographs of thin section showing detail of paste in the middle of the thin section in (a) plane-polarized and (b) cross-polarized light. In (a) the green arrow indicates belite.

(c)



(d)

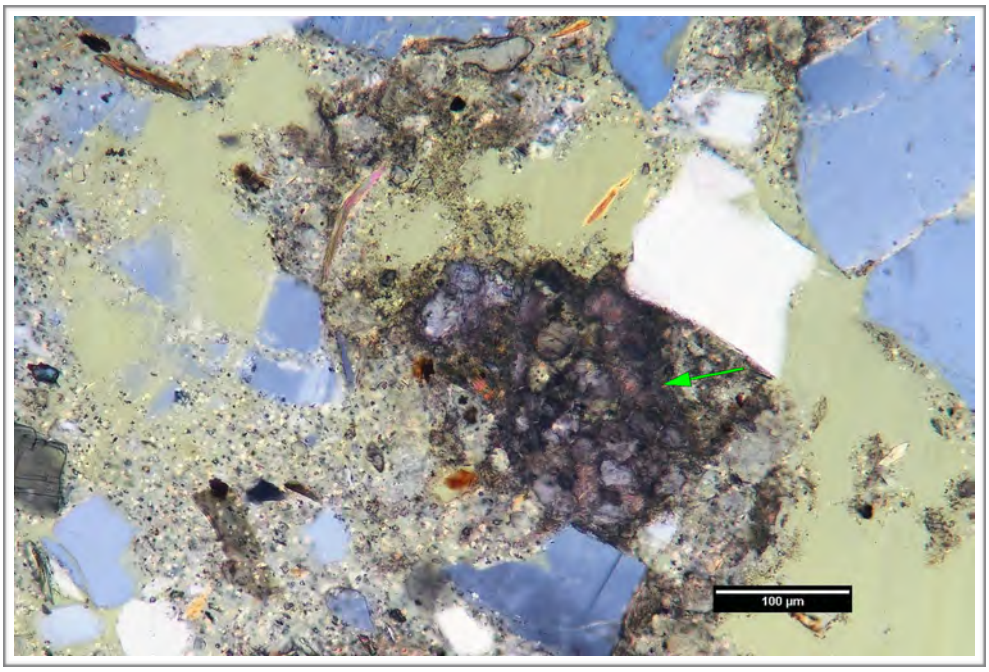
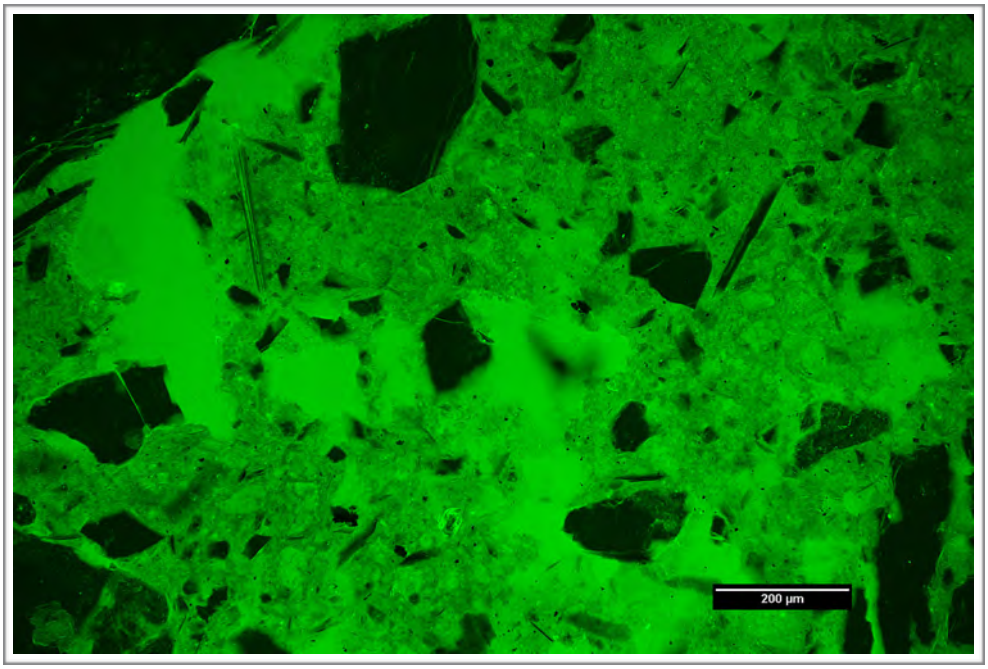


Figure B9 (cont'd). Transmitted light photomicrographs of thin section showing detail of paste in the middle of the thin section in (c) cross-polarized light with the gypsum plate inserted and (d) cross-polarized light with the quarter wavelength plate inserted. In (c) the white arrows indicate calcium hydroxide. In (d) the green arrow indicates belite.

(a)



(b)

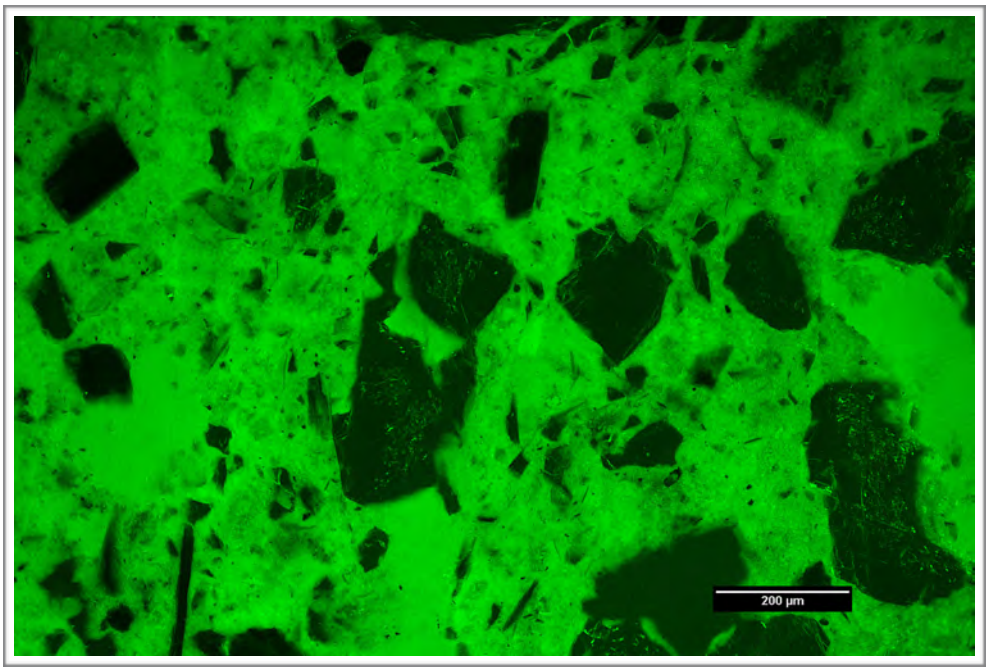
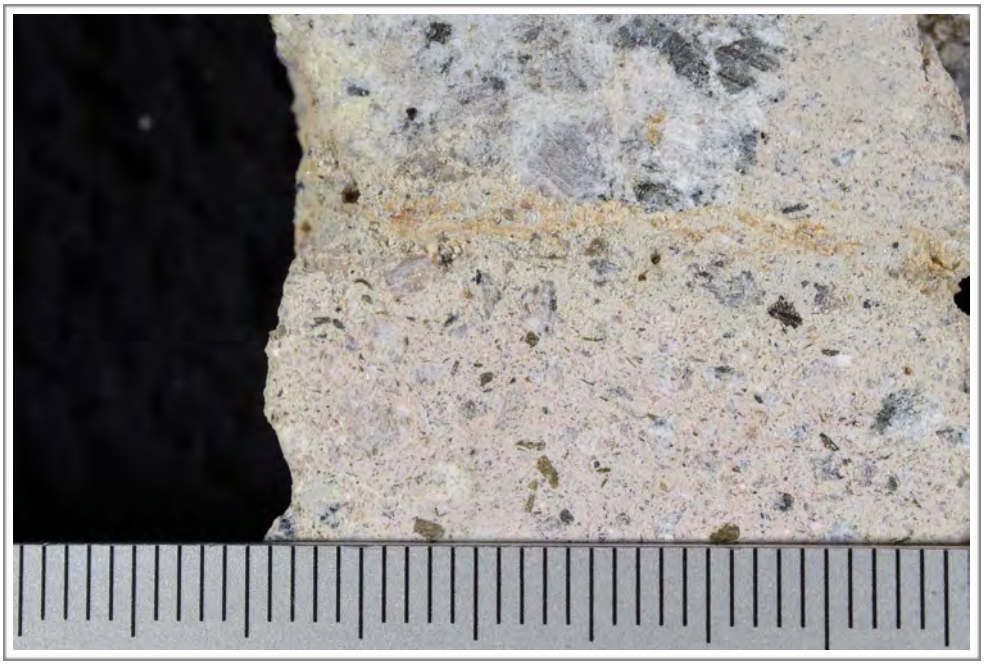


Figure B10. Transmitted fluorescent light photomicrographs of thin section showing detail of the capillary porosity of the paste in the middle of the thin section. The black areas correspond to aggregate that has very low porosity and the bright green circles are air voids filled with epoxy. The variations in green between these end members reflect variations in paste capillary porosity or micro-density.

(a)



(b)

Figure B11. Photographs showing (a) overview of phenolphthalein-stained surface and (b) detail of surface near the outer surface of the core. The yellow scale in (a) is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively. The scale in (b) is in millimeters.

1. Received Condition	
Orientation & Dimensions	Vertical core extracted from the crest measures ~ 120 mm (4 ¾ in.) in diameter (**Figure C1, Figure C2**). The length is not measurable.
Surfaces	The core spans from a surface that is impossible to identify due to the condition of the as-received core to a fracture such that the core represents a partial thickness of the crest.
General Condition	The concrete is hard and compact and rings lightly when sounded with a hammer. The concrete core was received in numerous pieces. Deposits of ettringite were observed lining fracture surfaces (**Figure C3**).

2. Embedded Objects	
General	None observed.

3. Cracking	
Macroscopic	Several sub-vertical and sub-horizontal cracks were observed throughout on the polished surface (**Figure C4**). The cracks measure up to 50 mm (2 in.) long and up to 250 µm (10 mil) wide. The cracks dominant cut around coarse aggregate particles and are mainly free of secondary deposits.
Microscopic	Multiple microcracks were observed throughout the entire core (**Figure C5**). They measure up to 20 mm (¾ in.) long and up to 50 µm (2 mil) wide. They cut around aggregate particles and are occasionally filled with ettringite.

4. Voids	
Void System	Concrete is non-air-entrained and contains less than 3% total air as estimated from visual and microscopical observations. The concrete is well consolidated with a few voids that measure up to 10 mm (⅜ in.) across.
Void Fillings	Voids commonly contain deposits of ettringite (**Figure C6**).

5. Coarse Aggregate	
Physical Properties	The coarse aggregate is a crushed rock that has a 75 mm (3 in.) nominal top size (**Figure C7**). The rocks are hard and competent. The particles range from sub-equant to elongated with aspect ratios up to 2:1 observed. The particles are angular to sub-angular. The gradation and distribution are impossible to describe due to the coarse aggregate size and the core size.
Rock Types	The aggregate is siliceous in composition and consists primarily of coarse-grained granodioritic rocks. Granodioritic rocks are potentially susceptible to alkali-silica reaction (ASR).
Other Features	No deleterious coatings or incrustations observed. No low w/c mortar coatings were observed. No evidence of ASR was observed.

6. Fine Aggregate

Physical Properties	The fine aggregate is a natural sand that consists of rocks that are hard and competent (**Figure C8**). The particles are mostly sub-equant to slightly elongated in shape with sub-rounded to sub-angular edges. The grading and distribution are relatively even.
Rock Types	The sand is siliceous in composition and consists primarily of rocks similar to those observed in the coarse aggregate. The fines include abundant fragments of quartz, feldspar, amphibole and biotite.
Other Features	No deleterious coatings or incrustations observed. No evidence of ASR was observed.

7. Paste Observations

Polished Surface	Paste is white (Munsell 10YR/8/1), has a smooth texture and a dull luster (**Figure C9**). The paste is soft (Mohs ~ 2.5).
Fresh Fracture	The concrete is too friable to produce a fresh fracture surface.
Thin Section	The paste contains hydrated portland cement with no fly ash, slag cement, silica fume or other SCM observed. The hydration is normal. The paste contains less than 4% RRCG that consist primarily of clusters of belite grains with interstitial aluminoferrite (**Figure C10**). CH is fine grained and distributed relatively evenly and makes up less than 4% of the paste. Calcium carbonate was observed in the paste due to slight carbonation. The capillary porosity of the paste is moderate and relatively homogeneous (**Figure C11**).
Estimated w/cm	Greater than 0.60.

** Abbreviations as follows: DSL = densified surface layer; RRCG = relict and residual cement grains; SCM = supplemental cementitious materials; CH = calcium hydroxide; ITZ = interfacial transition zone. Modal abundances are based on visual estimations.*

8. Secondary Deposits

Phenolphthalein	The entire surface stains light purple (**Figure C12**).
Secondary Deposits	Slight carbonation was observed throughout the core. Deposits of ettringite were commonly observed filling voids and occasionally lining open fracture surfaces.

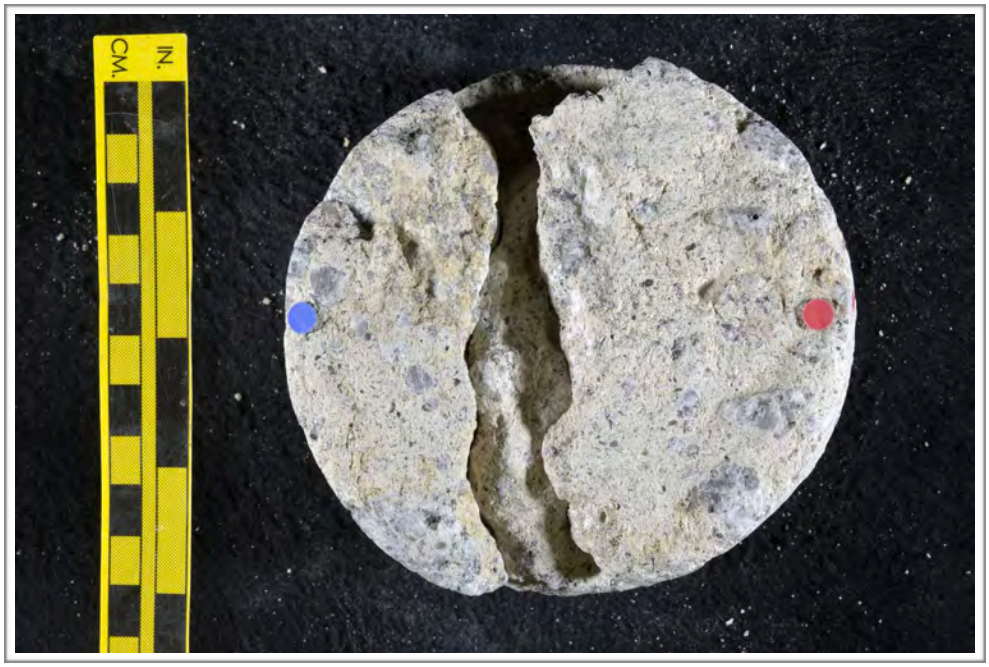
FIGURES

(a)

(b)

Figure C1. Photographs of the core in as-received condition showing (a) overview of the multiple pieces and (b) an oblique view of the top surface and side of the portion with identification labels for petrographic examination. The red and blue dots show the orientation of the saw cuts used to prepare the core. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively.

(c)

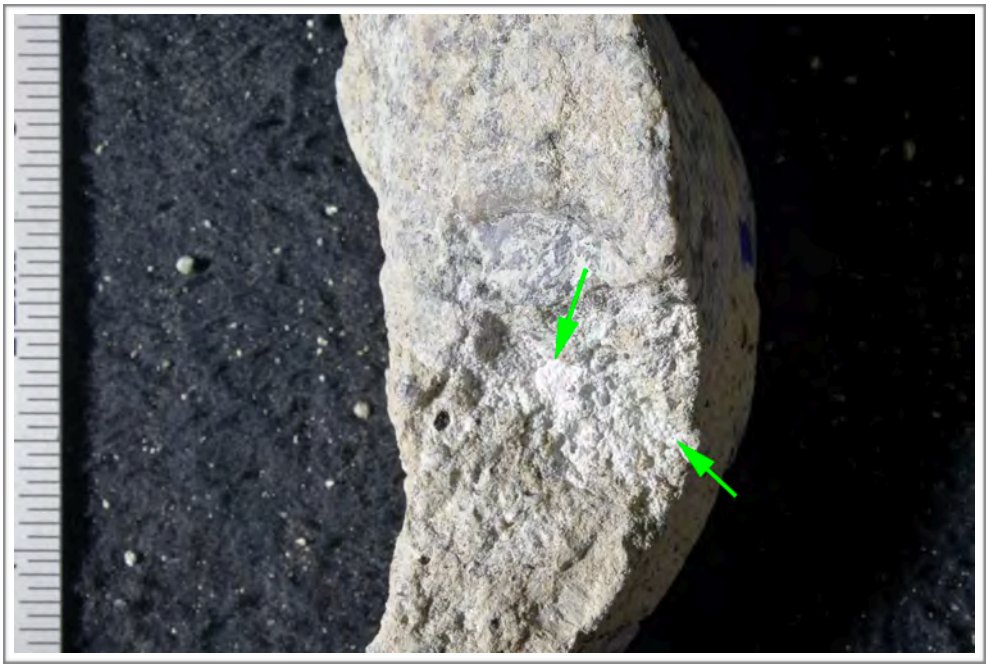


(d)

Figure C1 (cont'd). Photographs of the core in as-received condition showing (c) the top surface of the portion for petrographic examination and (d) the bottom surface of the portion for petrographic examination. The red and blue dots show the orientation of the saw cuts used to prepare the core. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively.

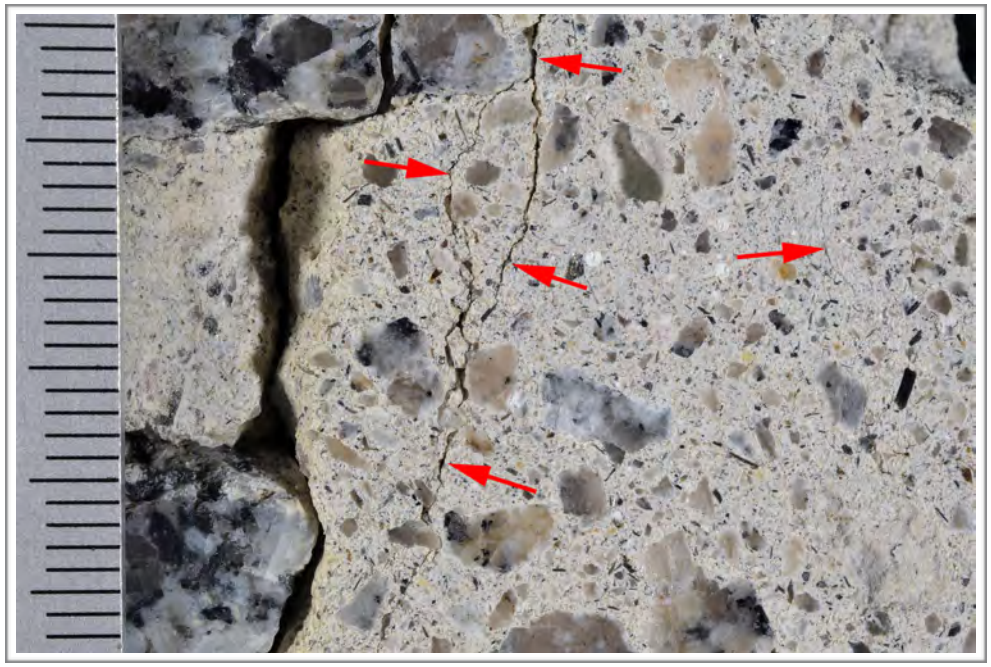
Figure C2. Photograph of the polished surface. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively.

(a)

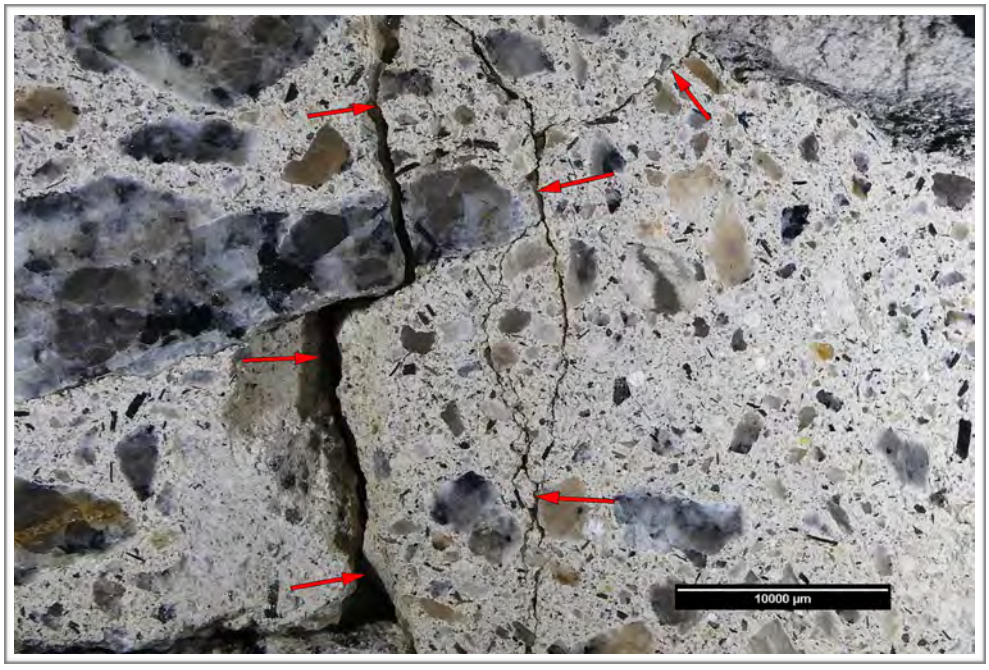


(b)

Figure C3. Photographs of the core in as-received condition showing overview of deposits of ettringite (green arrows) at open fracture surfaces. The scale in both images is in millimeters.



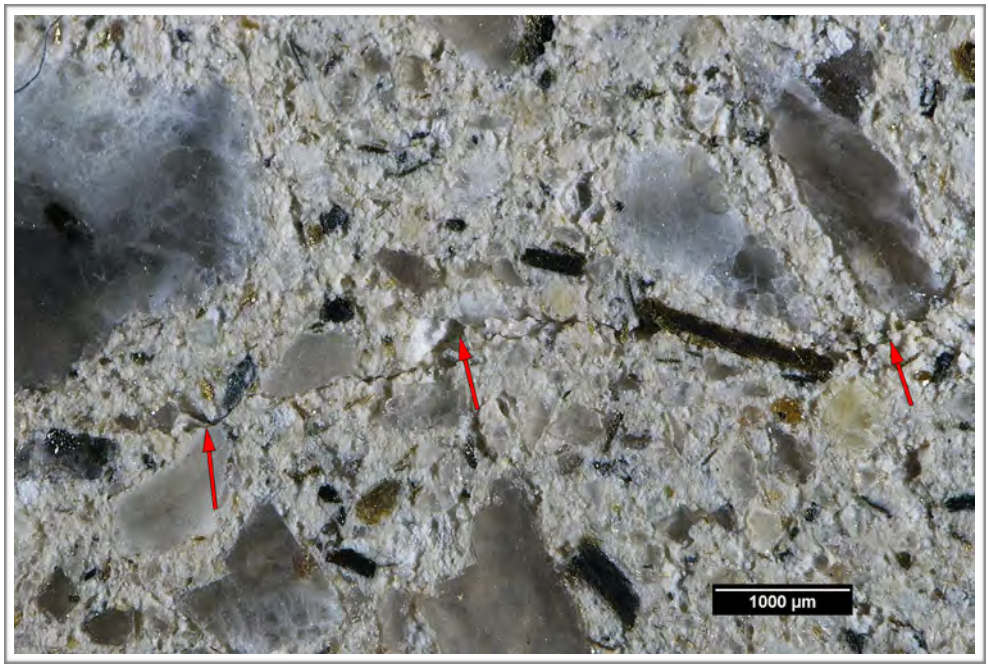
(a)



(b)

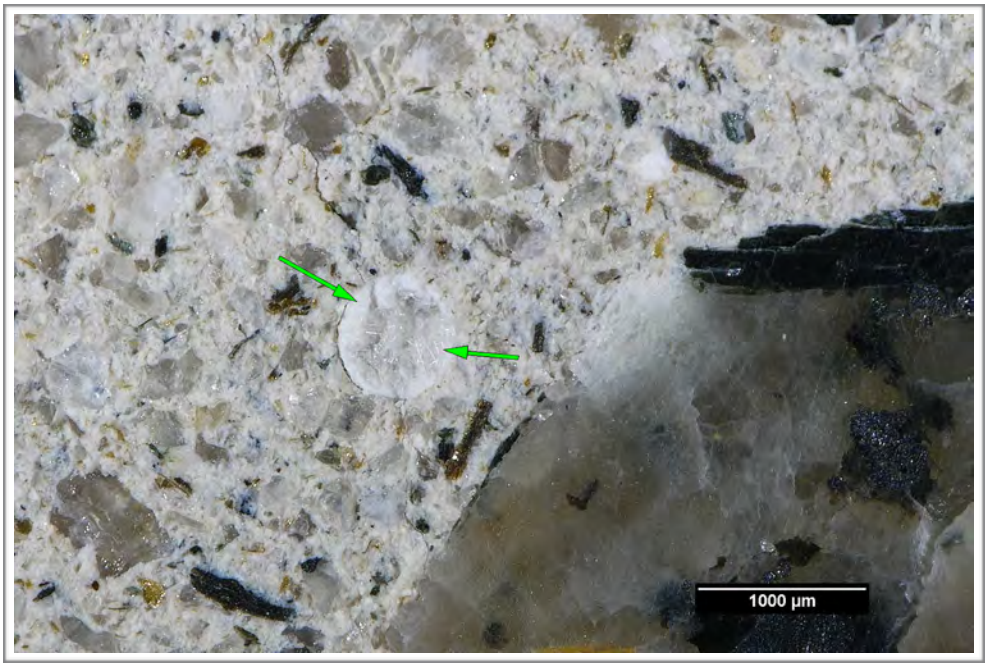
Figure C4. (a) Photograph of the polished surface of the core showing the cracks (red arrows) in the middle of the core; scale in millimeters. (b) Reflected light photomicrograph of the polished surface showing the crack (red arrows) with a scaly and bifurcation in the middle of the core.

(a)

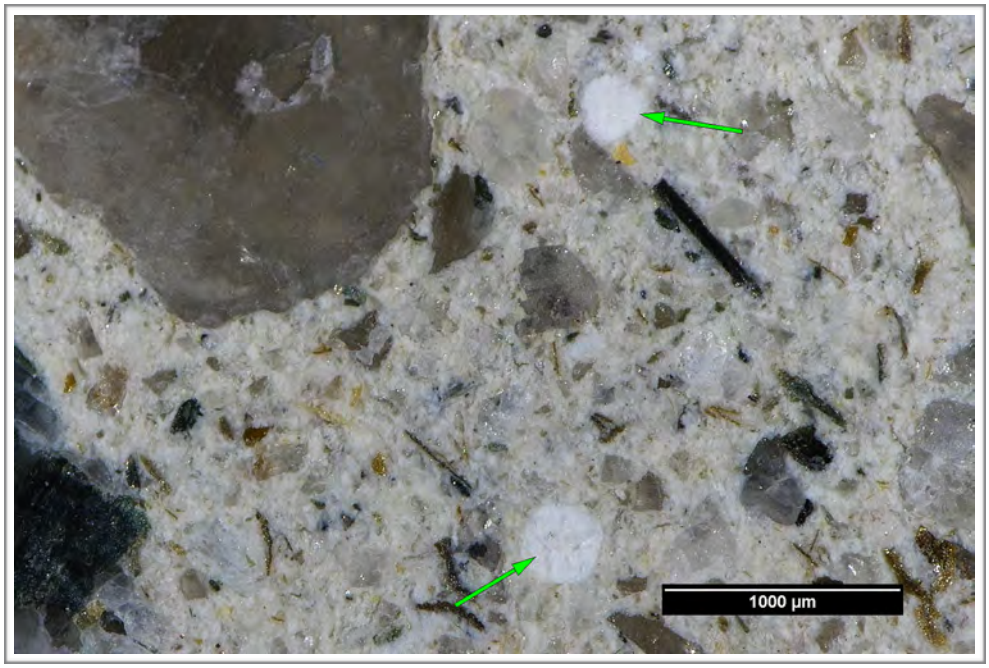


(b)

Figure C5. Reflected light photomicrographs of the polished surface showing the sub-horizontal microcracks (red arrows) in the middle of the core.



(a)



(b)

Figure C6. Reflected light photomicrographs of the polished surface showing deposits of ettringite (green arrows) filling voids in the middle of the core.

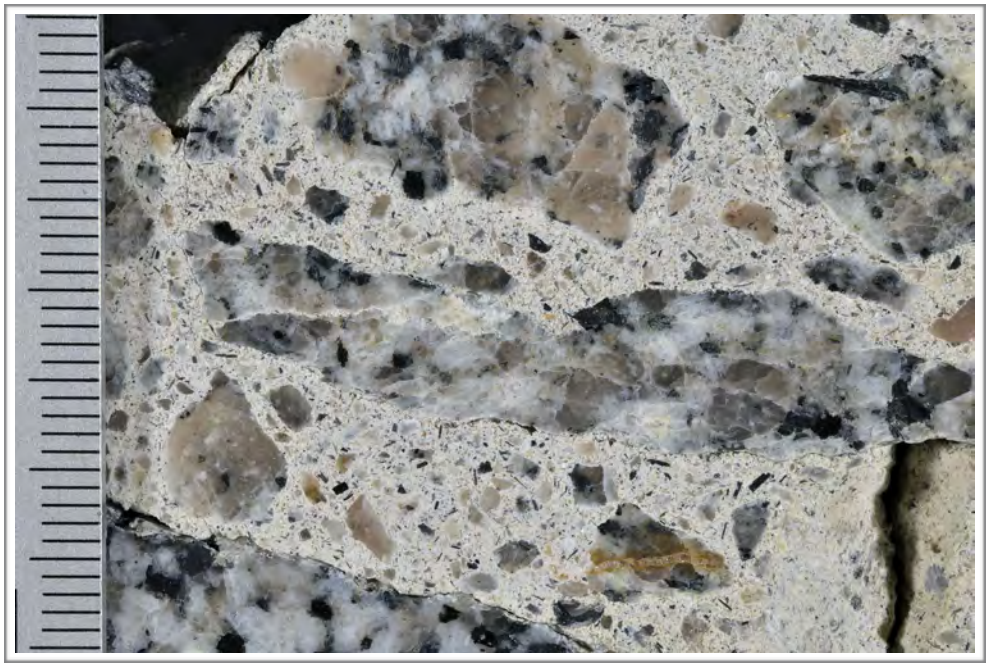


Figure C7. Photograph of the polished surface showing overview of the coarse aggregate; scale in millimeters.

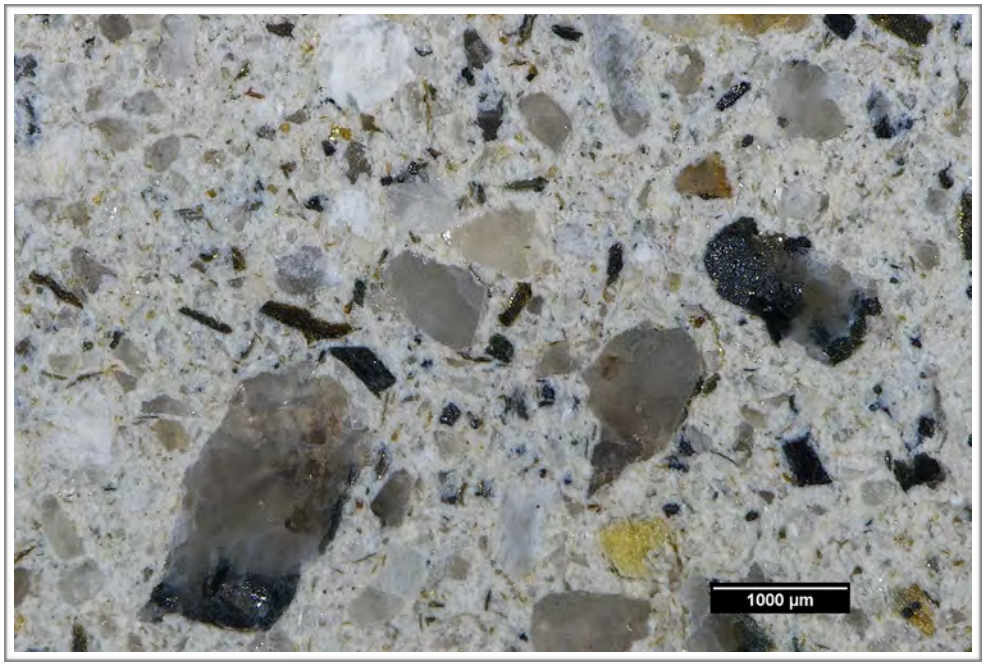
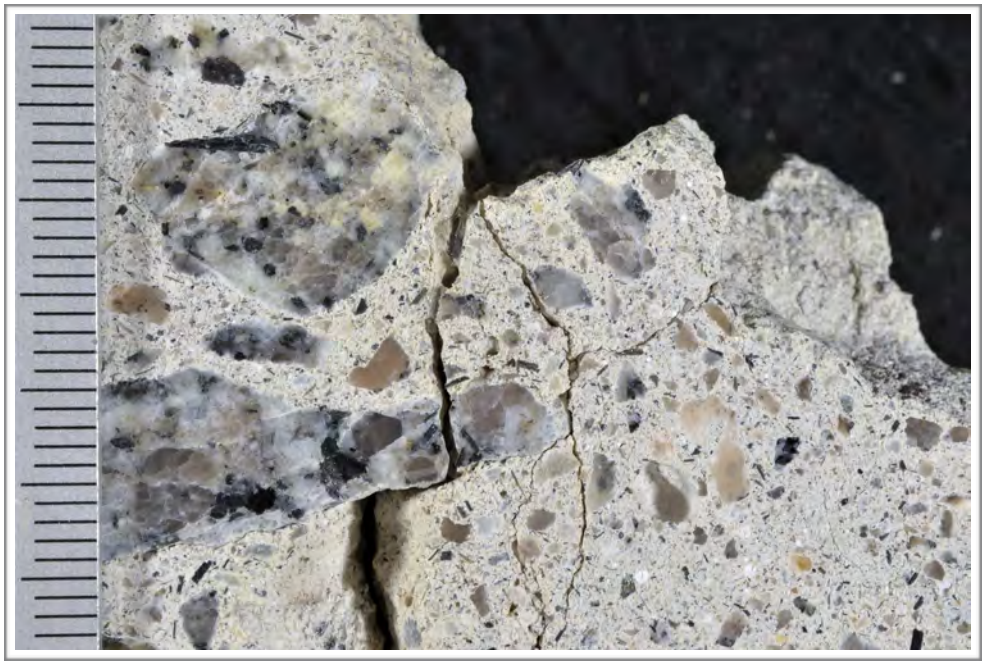
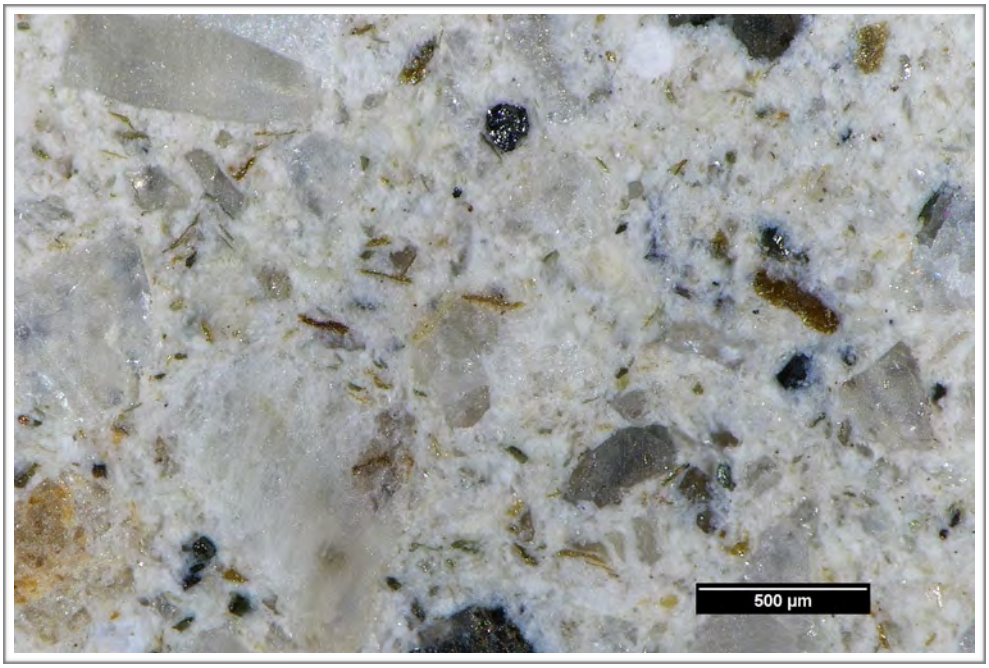


Figure C8. Reflected light photomicrograph of the polished surface showing fine aggregate.

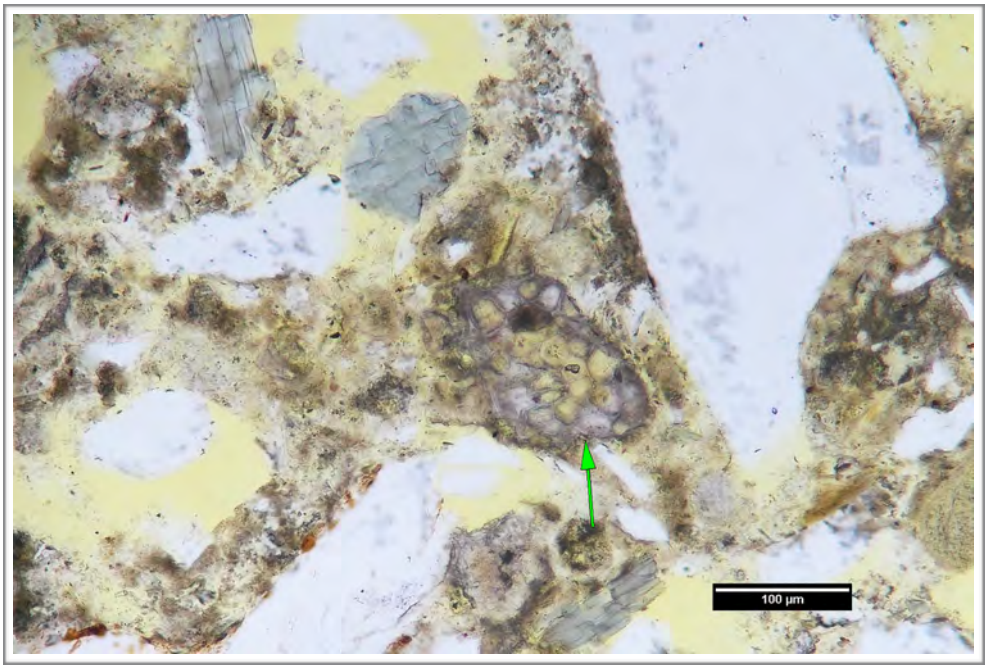


(a)

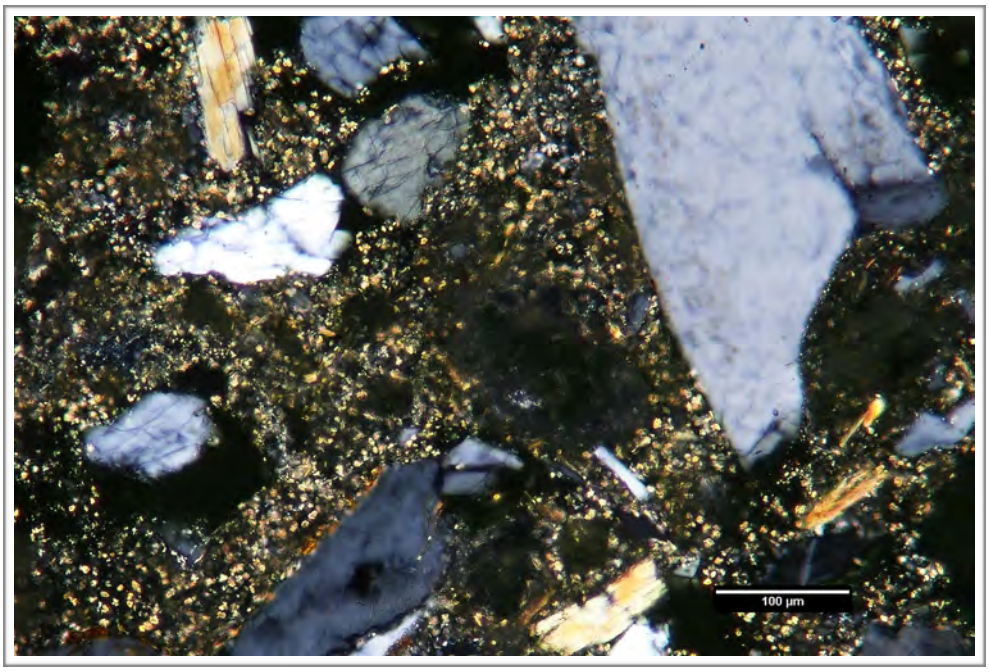


(b)

Figure C9. (a) Photograph of the polished surface showing overview of paste at the top of the polished surface; scale in millimeters. (b) Reflected light photomicrograph of the polished surface showing detail of paste in the middle of the core.



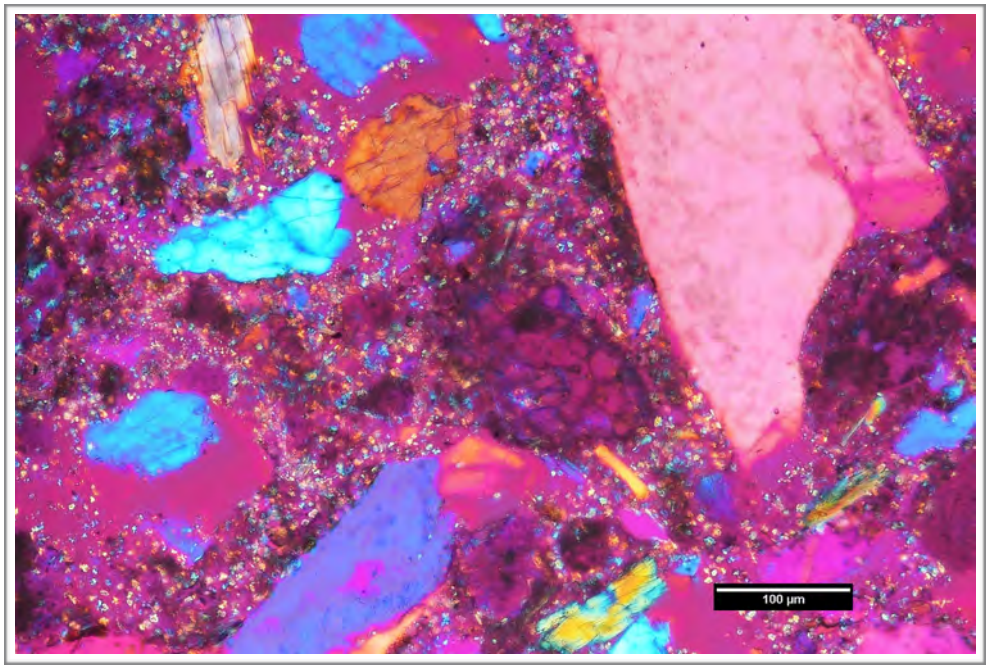
(a)



(b)

Figure C10. Transmitted light photomicrographs of thin section showing detail of paste in the middle of the thin section in (a) plane-polarized and (b) cross-polarized light. In (a) the green arrow indicates belite.

(c)



(d)

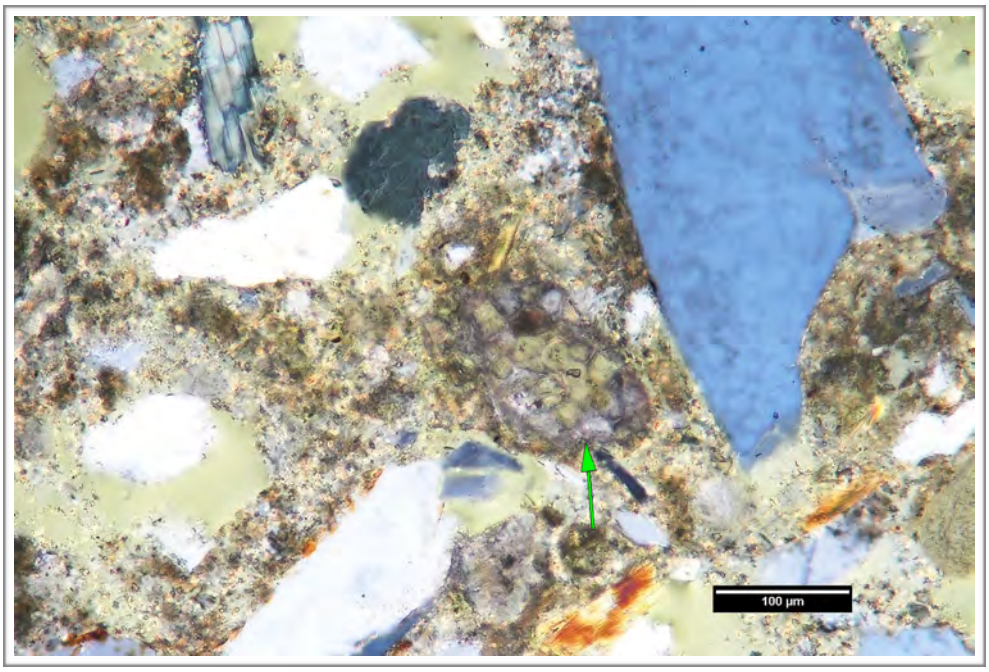
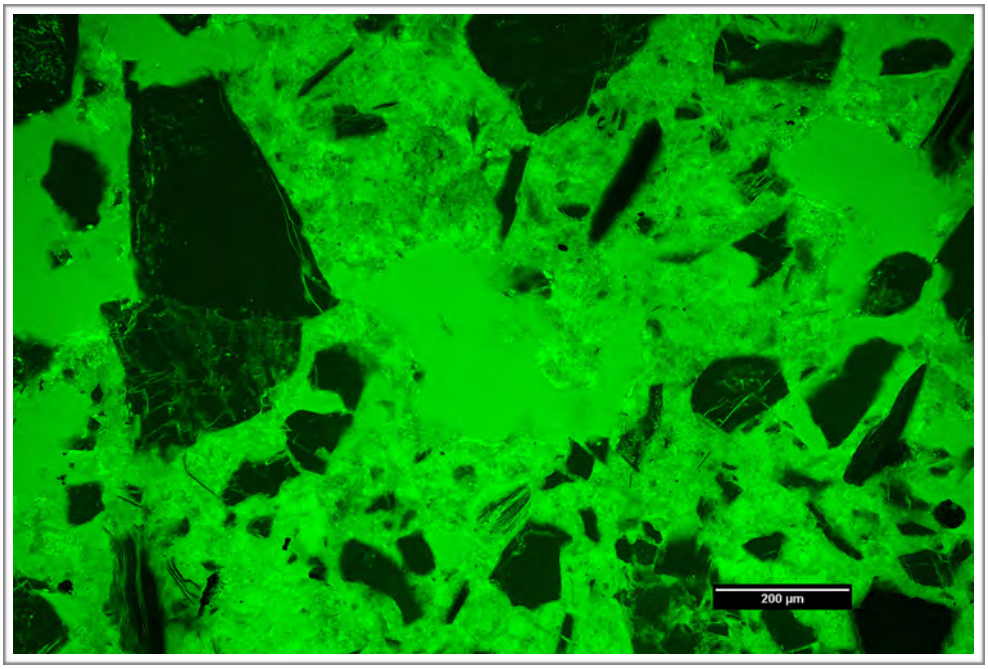
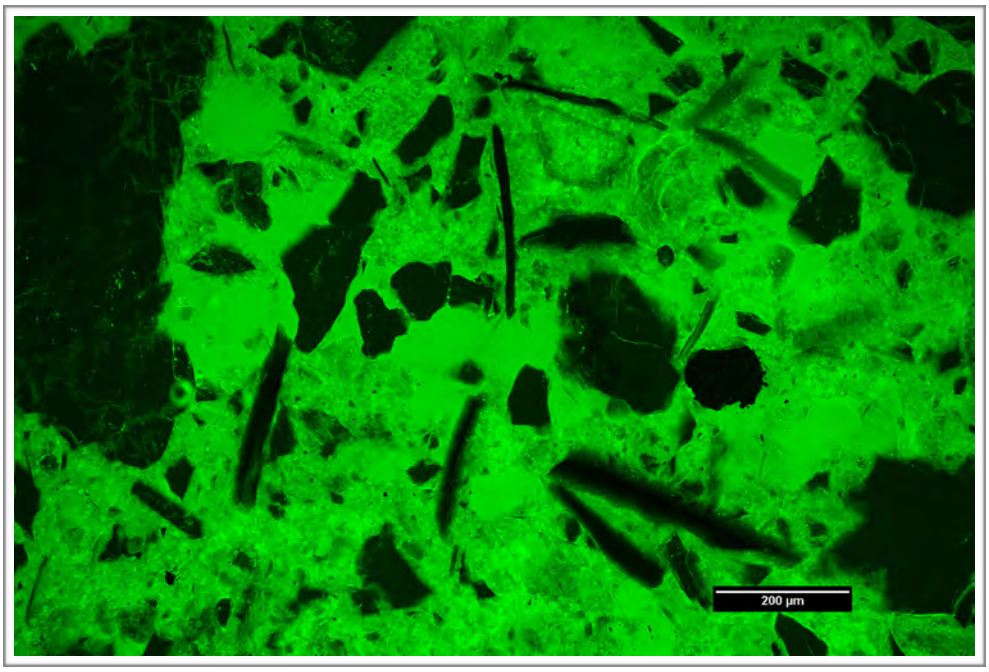


Figure C10 (cont'd). Transmitted light photomicrographs of thin section showing detail of paste in the middle of the thin section in (c) cross-polarized light with the gypsum plate inserted and (d) cross-polarized light with the quarter wavelength plate inserted. In (c) the white arrows indicate calcium hydroxide. In (d) the green arrow indicates belite.



(a)



(b)

Figure C11. Transmitted fluorescent light photomicrographs of thin section showing detail of the capillary porosity of the paste in the middle of the thin section. The black areas correspond to aggregate that has very low porosity and the bright green circles are air voids filled with epoxy. The variations in green between these end members reflect variations in paste capillary porosity or micro-density.

(a)

(b)

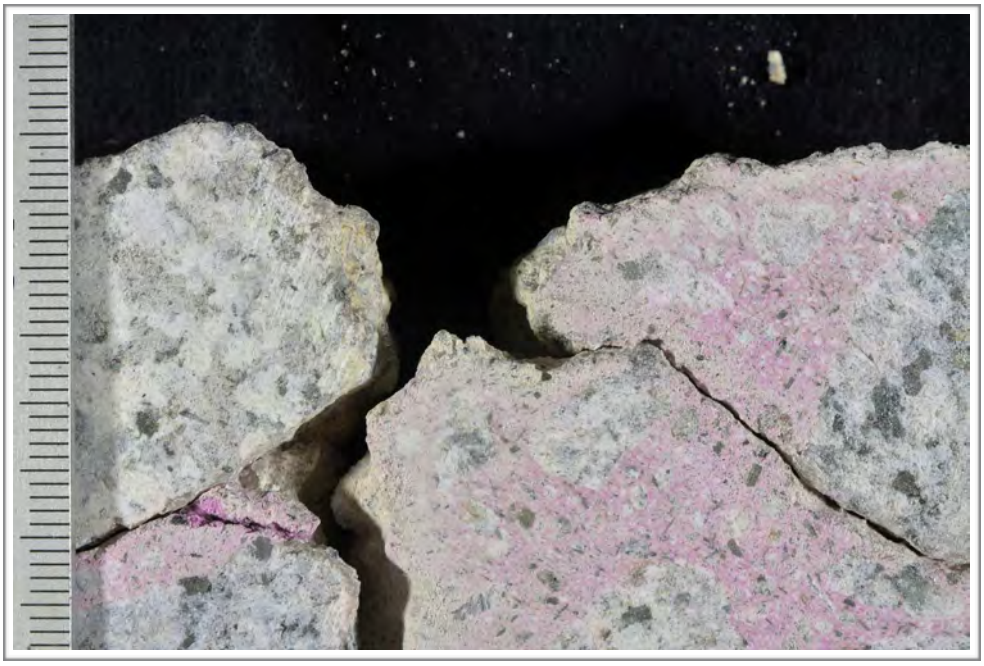


Figure C12. Photographs showing (a) overview of phenolphthalein-stained surface and (b) detail of surface near the top of the core. The yellow scale in (a) is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively. The scale in (b) is in millimeters.

1. Received Condition

Orientation & Dimensions	Vertical core extracted from the parapet wall measures ~ 120 mm (4 ¾ in.) in diameter and 385 – 410 mm (15 ⅛ – 16 ⅛ in.) in length (**Figure D1, Figure D2**).
Surfaces	The core spans from a surface that is detached from the shotcrete to a fracture such that the core represents a partial thickness of the parapet wall.
General Condition	The concrete is hard and compact and rings lightly when sounded with a hammer. The concrete core was received in two pieces which are separated at the interface between the shotcrete and the concrete. The overlaying shotcrete measures 145 – 160 mm (5 ¾ - 6 ¼ in.) and the concrete measures 230 – 240 mm (9 – 9 ½ in.) long, respectively. A piece of chip was observed separated by a sub-vertical fracture near the interface between the shotcrete and the concrete. Deposits of ettringite were observed lining the fracture surfaces, interface and the bottom surface of the core (**Figure D3**).

2. Embedded Objects

General	Two sets of steel rebars were observed in the shotcrete 50 – 65 mm (2 – 2 ⅝ in.) from the outer surface of the core. It measures 12.5 mm (½ in.) in diameter. Another steel bar was observed in concrete ~ 125 mm (5 in.) from the interface between the shotcrete and the concrete. Surficial corrosion was observed in the reinforcement elements.

3. Cracking

Macroscopic	Several sub-horizontal cracks were observed throughout on the length of the concrete (**Figure D4**). The cracks measure up to 120 mm (4 ¾ in) long and up to 750 µm (30 mil) wide. The cracks dominantly cut around coarse aggregate particles and deposits of ettringite were occasionally lining the cracks.
Microscopic	Numerous microcracks were observed throughout the entire core (**Figure D5**). They measure up to 30 mm (1 ¼ in.) long and up to 100 µm (4 mil) wide. They cut around aggregate particles and are occasionally filled with ettringite.

4. Voids

Void System	Concrete is non-air-entrained and contains less than 3% total air as estimated from visual and microscopical observations. The concrete is well consolidated with a few voids that measure up to 8 mm (320 mil) across.
Void Fillings	Voids occasionally contain deposits of ettringite (**Figure D6**).

5. Coarse Aggregate

Physical Properties	The coarse aggregate is a crushed rock that has a 75 mm (3 in.) nominal top size (**Figure D7**). The rocks are hard and competent. The particles range from sub-equant to elongated with aspect ratios up to 2:1 observed. The particles are angular to sub-angular. The gradation and distribution are impossible to describe due to the coarse aggregate size and the core size.
Rock Types	The aggregate is siliceous in composition and consists primarily of coarse-grained granodioritic rocks. Granodioritic rocks are potentially susceptible to alkali-silica reaction (ASR).
Other Features	No deleterious coatings or incrustations observed. No low w/c mortar coatings were observed. No evidence of ASR was observed.

6. Fine Aggregate

Physical Properties	The fine aggregate is a natural sand that consists of rocks that are hard and competent (**Figure D8**). The particles are mostly sub-equant to slightly elongated in shape with sub-rounded to sub-angular edges. The grading and distribution are relatively even.
Rock Types	The sand is siliceous in composition and consists primarily of rocks similar to those observed in the coarse aggregate. The fines include abundant fragments of quartz, feldspar, amphibole and biotite.
Other Features	No deleterious coatings or incrustations observed. No evidence of ASR was observed.

7. Paste Observations

Polished Surface	Paste is white (Munsell 10YR/8/1), has a smooth texture and a dull luster (**Figure D9**). The paste is soft (Mohs ~ 2.5).
Fresh Fracture	The fresh fracture is white, has a granular texture and a dull luster (**Figure D10**). It dominantly cuts around coarse aggregate particles. Deposits of ettringite were observed lining the fracture surface.
Thin Section	The paste contains hydrated portland cement with no fly ash, slag cement, silica fume or other SCM observed. The hydration is normal. The paste contains less than 4% RRCG that consist primarily of clusters of belite grains with interstitial aluminoferrite (**Figure D11**). CH is fine grained and distributed relatively evenly and makes up less than 4% of the paste. Calcium carbonate was observed in the paste due to slight carbonation. The capillary porosity of the paste is moderate and relatively homogeneous (**Figure D12**).
Estimated w/cm	Greater than 0.60.

** Abbreviations as follows: DSL = densified surface layer; RRCG = relict and residual cement grains; SCM = supplemental cementitious materials; CH = calcium hydroxide; ITZ = interfacial transition zone. Modal abundances are based on visual estimations.*

8. Secondary Deposits

Phenolphthalein	The entire surface stains purple (**Figure D13**).
Secondary Deposits	Slight carbonation was observed in the thin section. Deposits of ettringite were occasionally observed filling voids and lining cracks/microcracks and open fracture surfaces.

FIGURES

(a)

(b)

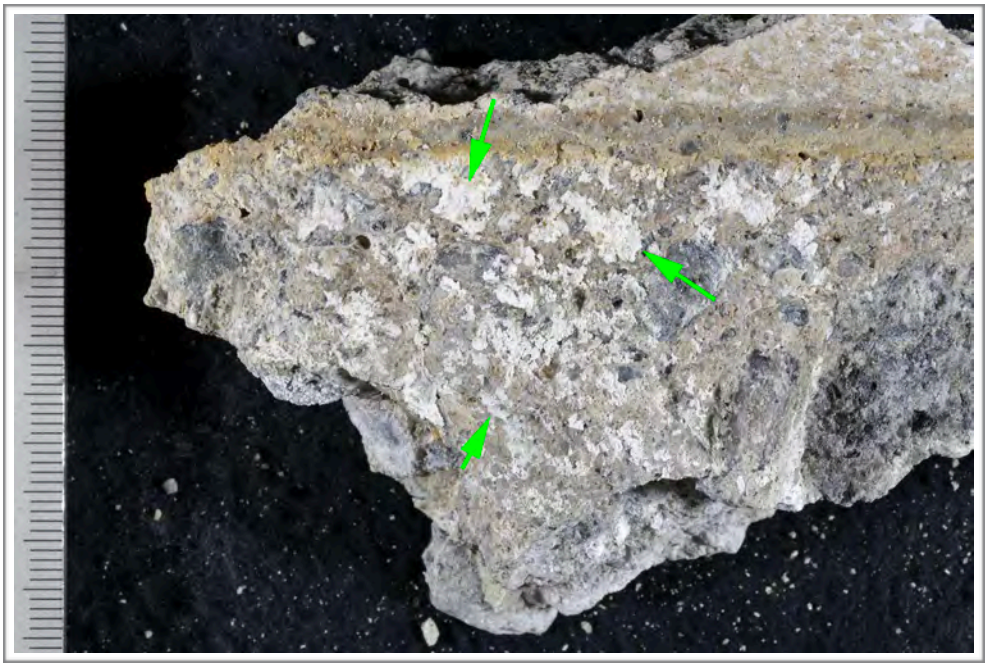
Figure D1. Photographs of the core in as-received condition showing (a) an oblique view of the top surface and side of the concrete with identification labels and (b) the top surface of the concrete. The red and blue dots show the orientation of the saw cuts used to prepare the core. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively.

(c)

(d)

Figure D1 (cont'd). Photographs of the core in as-received condition showing (c) the side of the shotcrete and concrete and (d) the bottom surface of the core. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively.

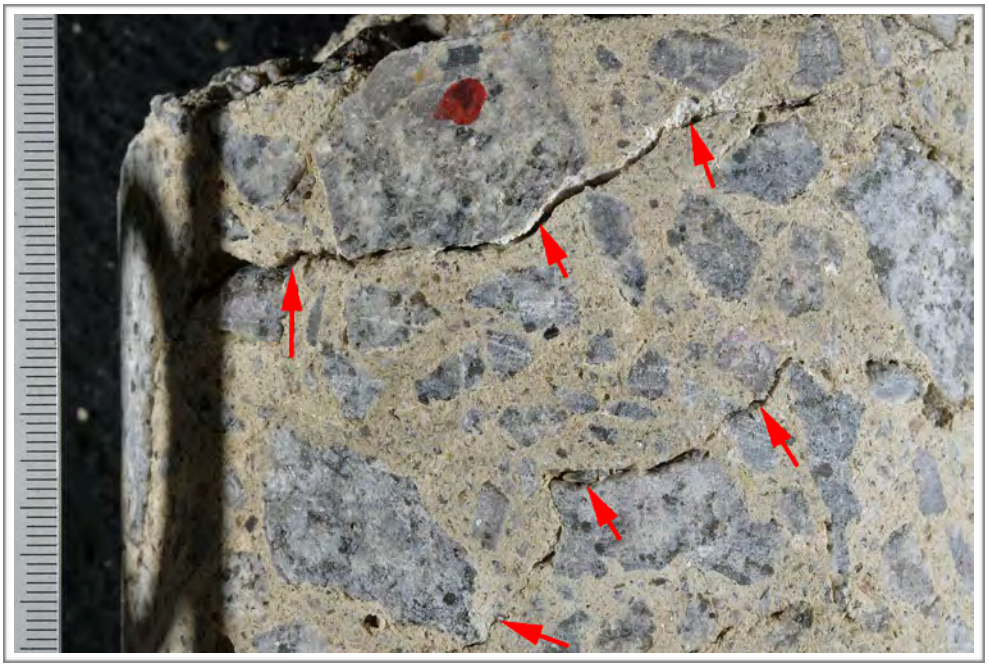
Figure D2. Photograph of the polished surface. The yellow scale is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively.



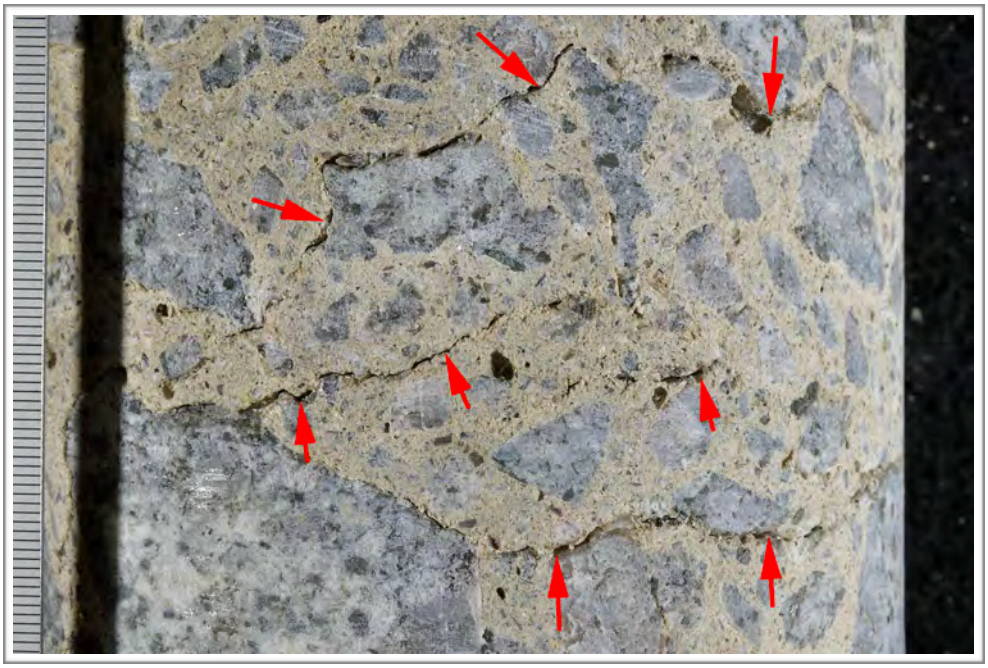
(a)

(b)

Figure D3. Photographs of the core in as-received condition showing overview of deposits of ettringite (green arrows) (a) at the open fracture surface and (b) the bottom of the core. The scale in both images is in millimeters.



(a)



(b)

Figure D4. Photographs of the side of the core showing the sub-horizontal cracks (red arrows) in the middle of the core; scale in millimeters.

(c)

(d)

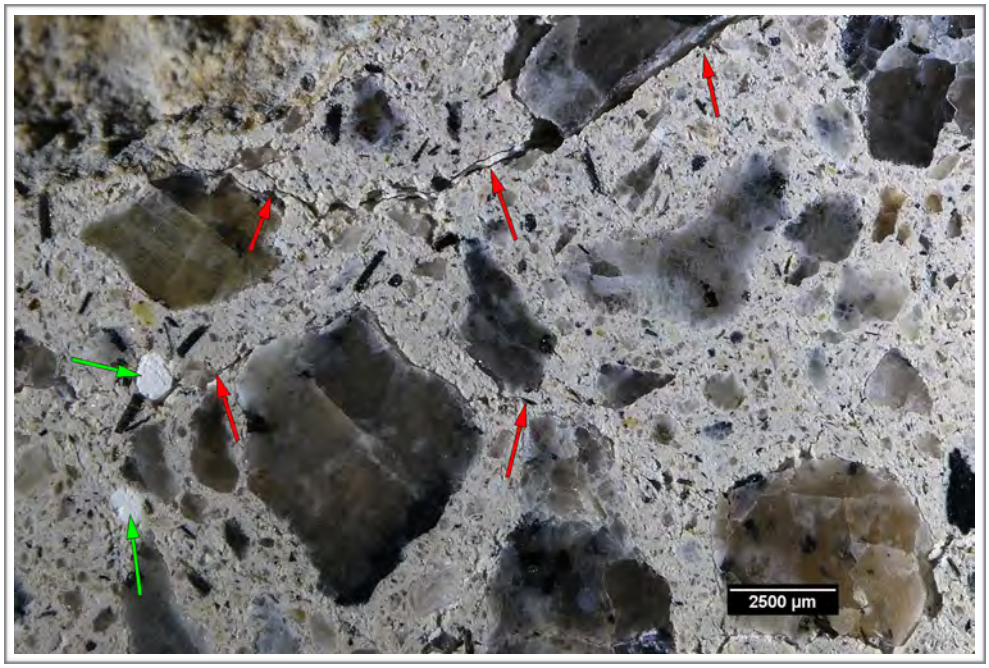
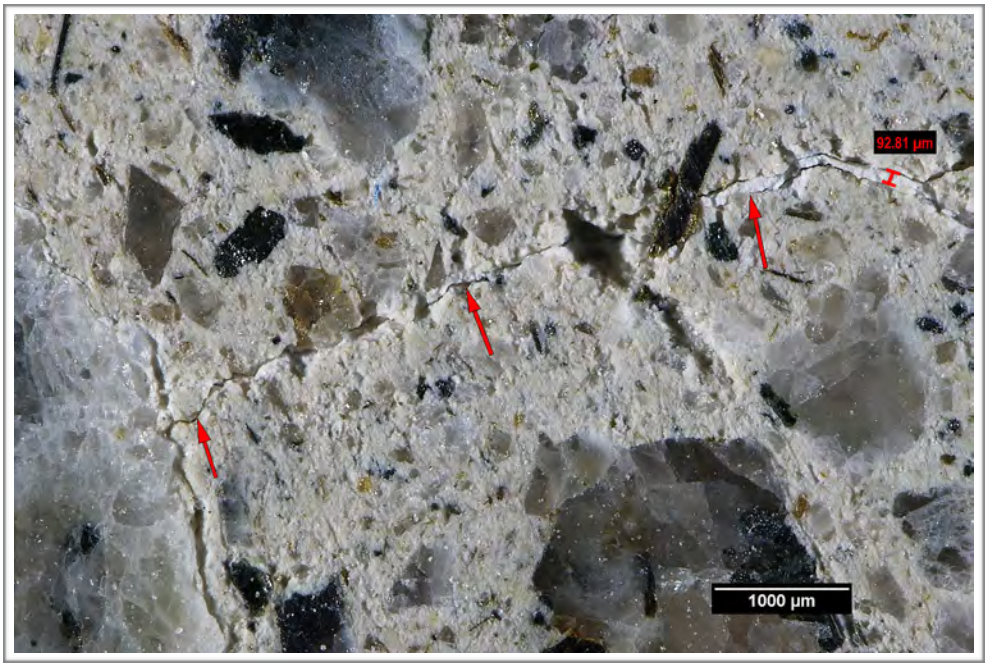
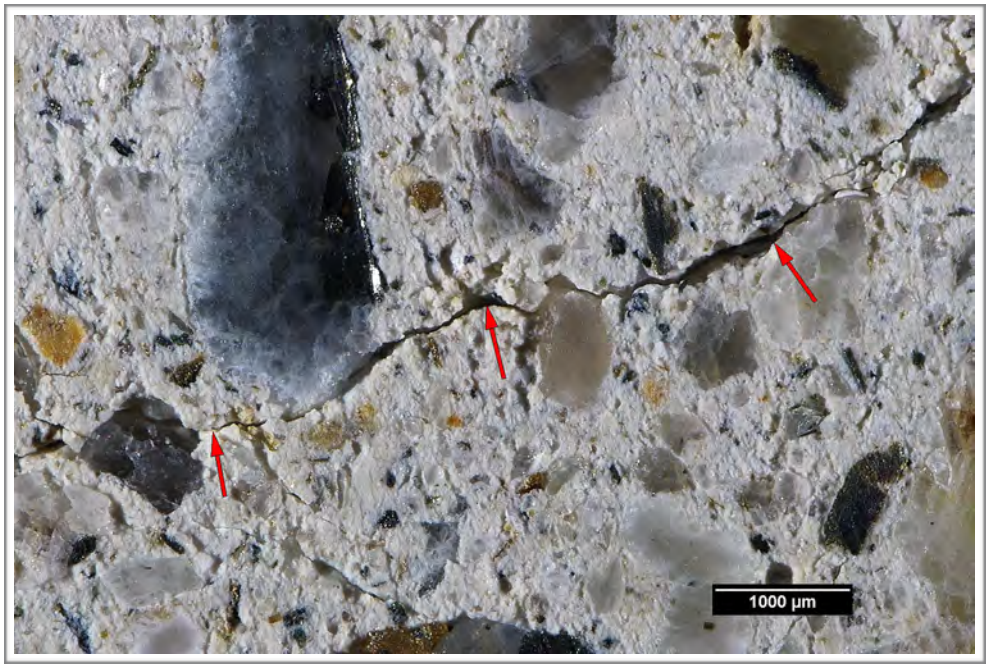


Figure D4 (Cont'd). Reflected light photomicrographs of the polished surface showing the crack (red arrows) in the middle of the core. Note the deposits of ettringite in the crack and voids (green arrows) in (d).



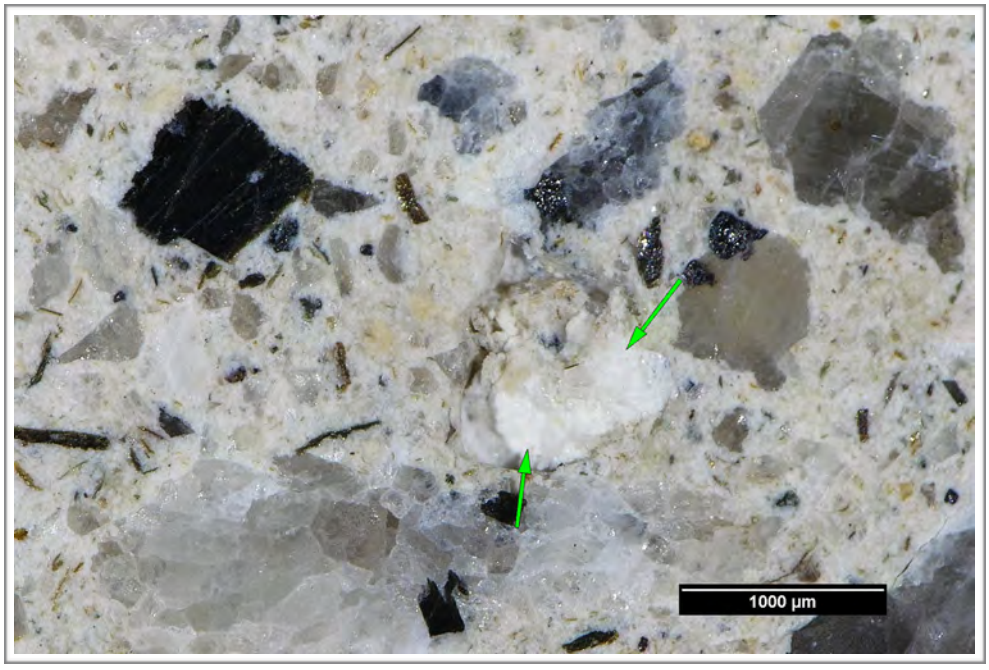
(a)



(b)

Figure D5. Reflected light photomicrographs of the polished surface showing the sub-horizontal microcracks (red arrows) in the middle of the core.

(a)



(b)

Figure D6. Reflected light photomicrographs of the polished surface showing deposits of ettringite (green arrows) filling voids in the middle of the core.

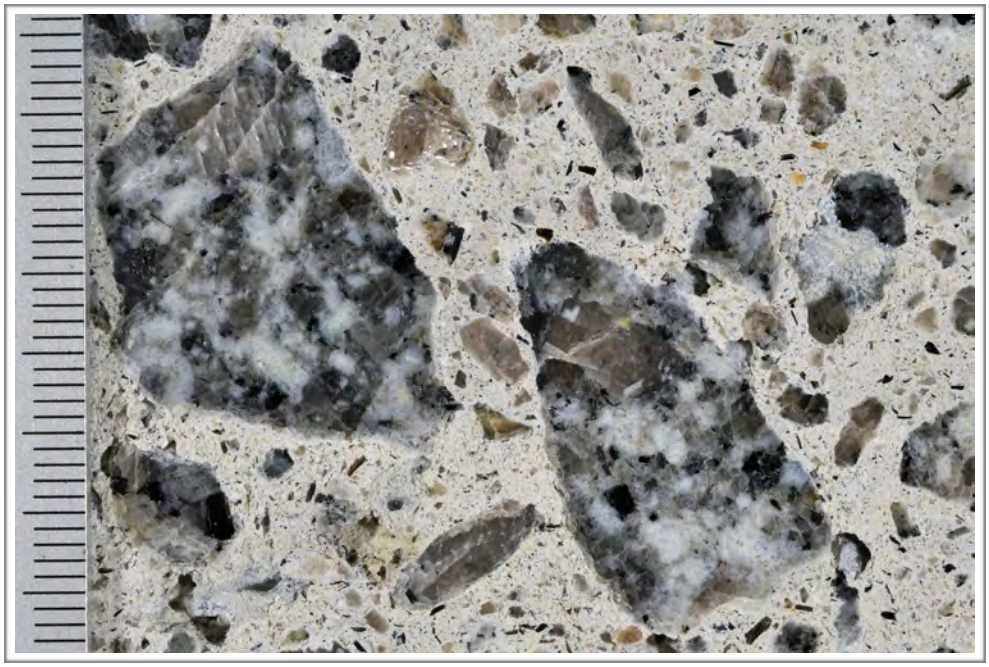


Figure D7. Photograph of the polished surface showing overview of the coarse aggregate; scale in millimeters.

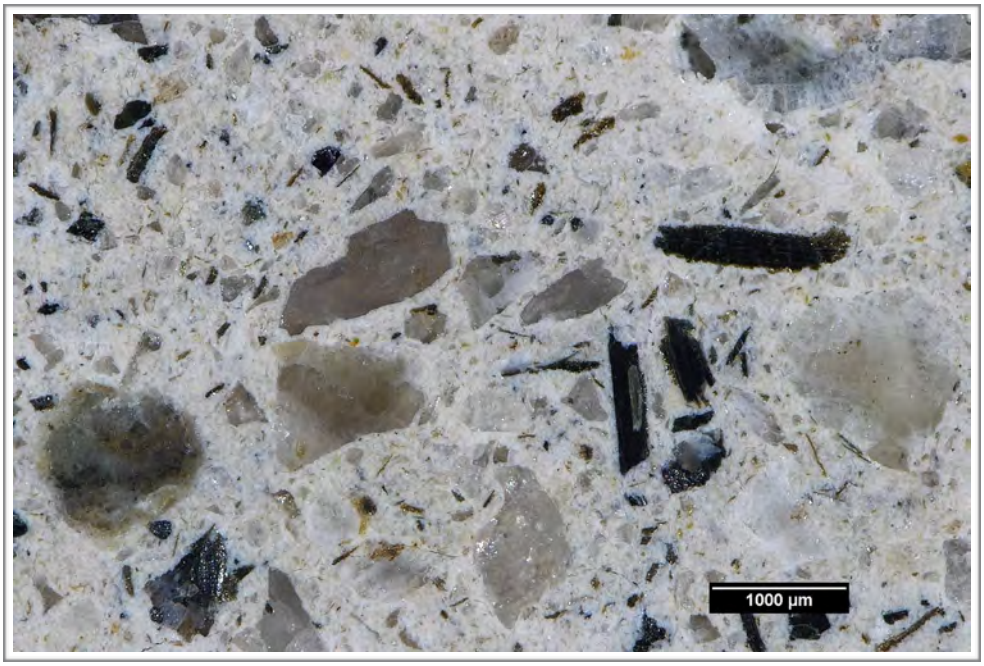
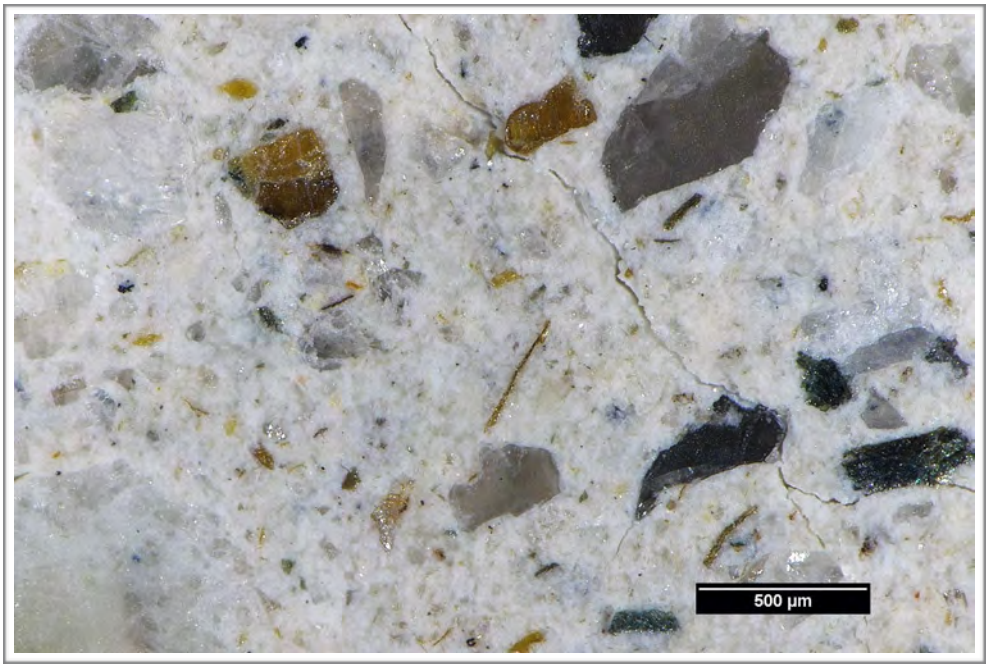


Figure D8. Reflected light photomicrograph of the polished surface showing fine aggregate.

(a)



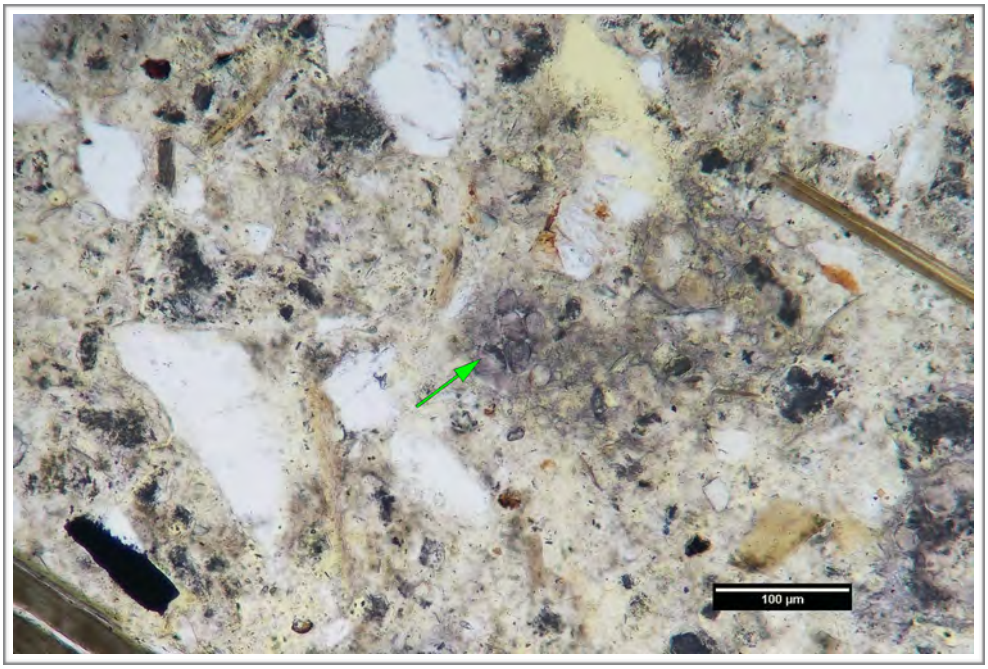
(b)

Figure D9. (a) Photograph of the polished surface showing overview of paste at the top of the polished surface; scale in millimeters. (b) Reflected light photomicrograph of the polished surface showing detail of paste in the middle of the core.

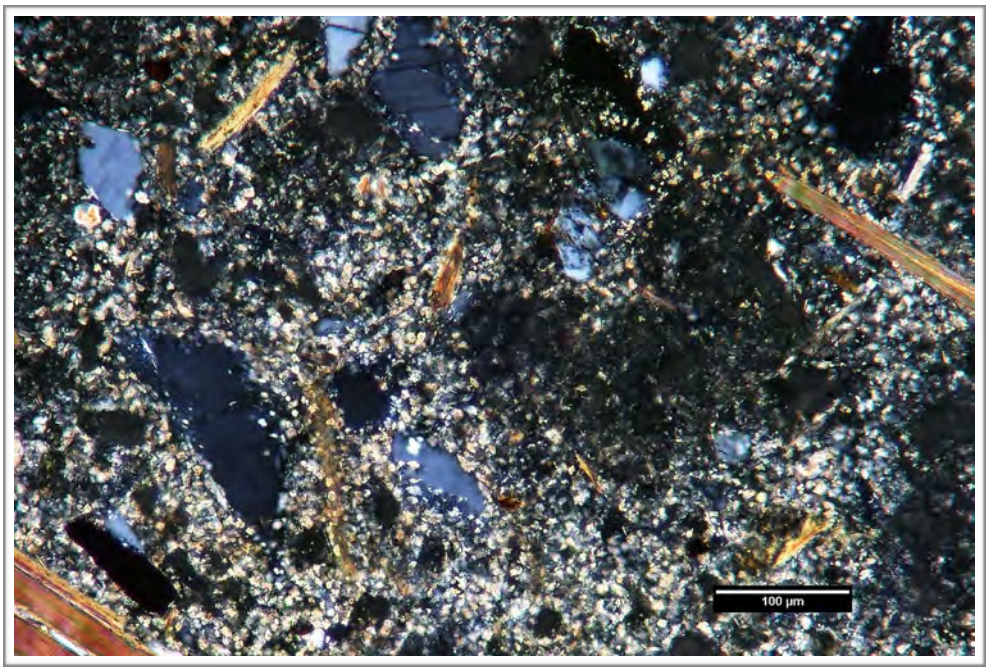
(a)

(b)

Figure D10. Photographs showing (a) overview and (b) detail of the fresh fracture surface; scale in millimeters. Note deposits of ettringite lining the fracture surface.



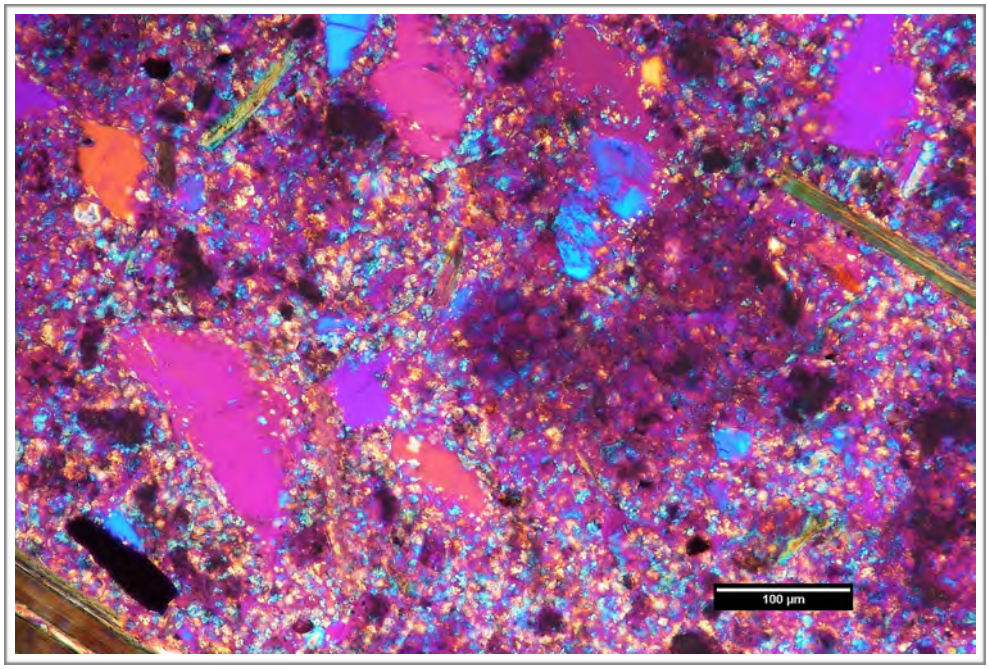
(a)



(b)

Figure D11. Transmitted light photomicrographs of thin section showing detail of paste in the middle of the thin section in (a) plane-polarized and (b) cross-polarized light. In (a) the green arrow indicates belite.

(c)



(d)

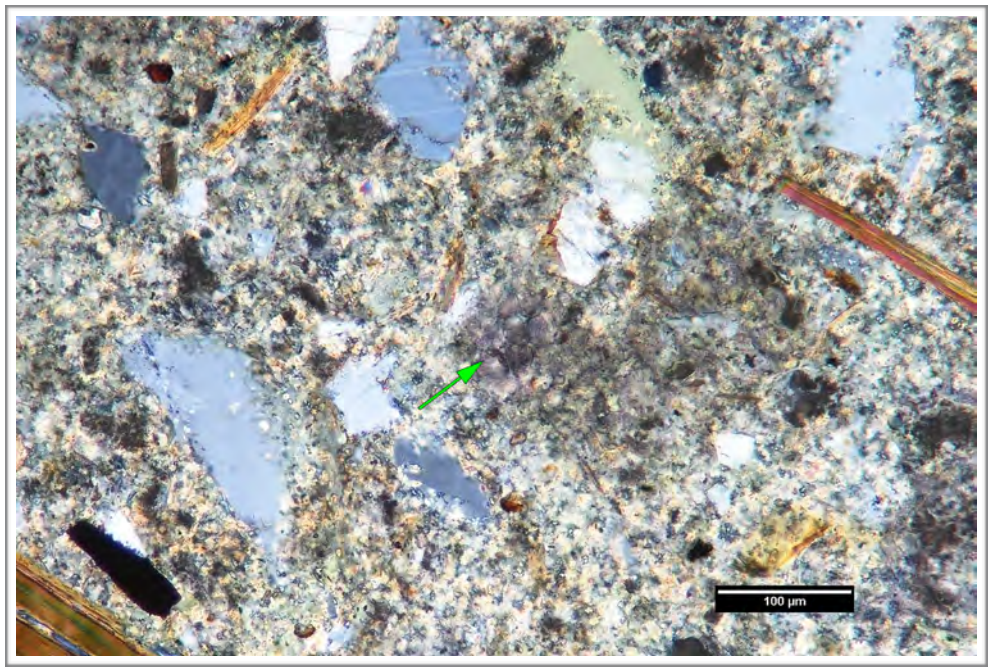
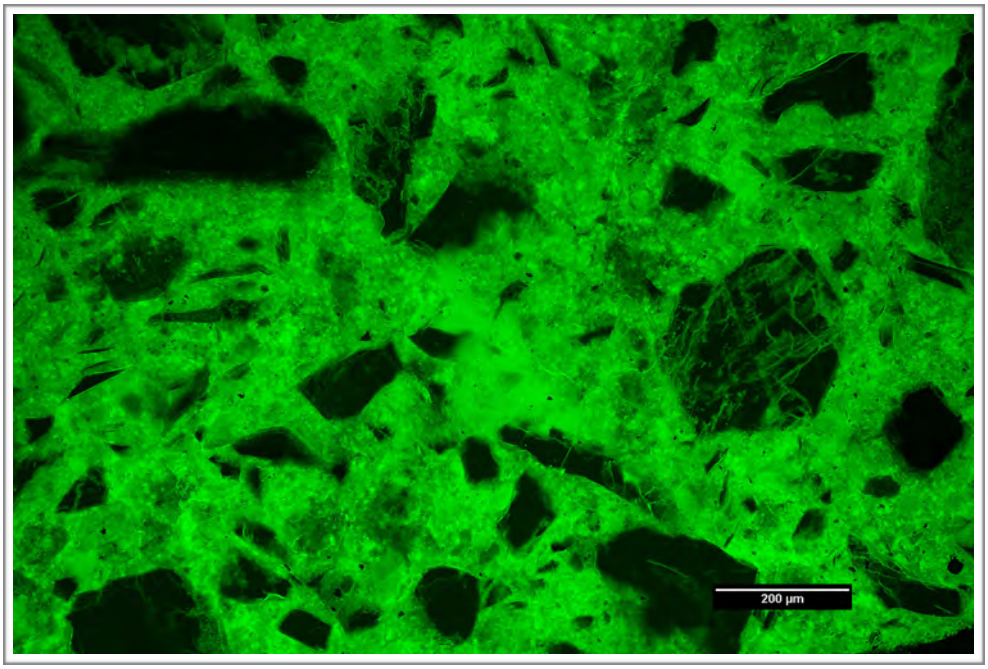


Figure D11 (cont'd). Transmitted light photomicrographs of thin section showing detail of paste in the middle of the thin section in (c) cross-polarized light with the gypsum plate inserted and (d) cross-polarized light with the quarter wavelength plate inserted. In (c) the white arrows indicate calcium hydroxide. In (d) the green arrow indicates belite.

(a)



(b)

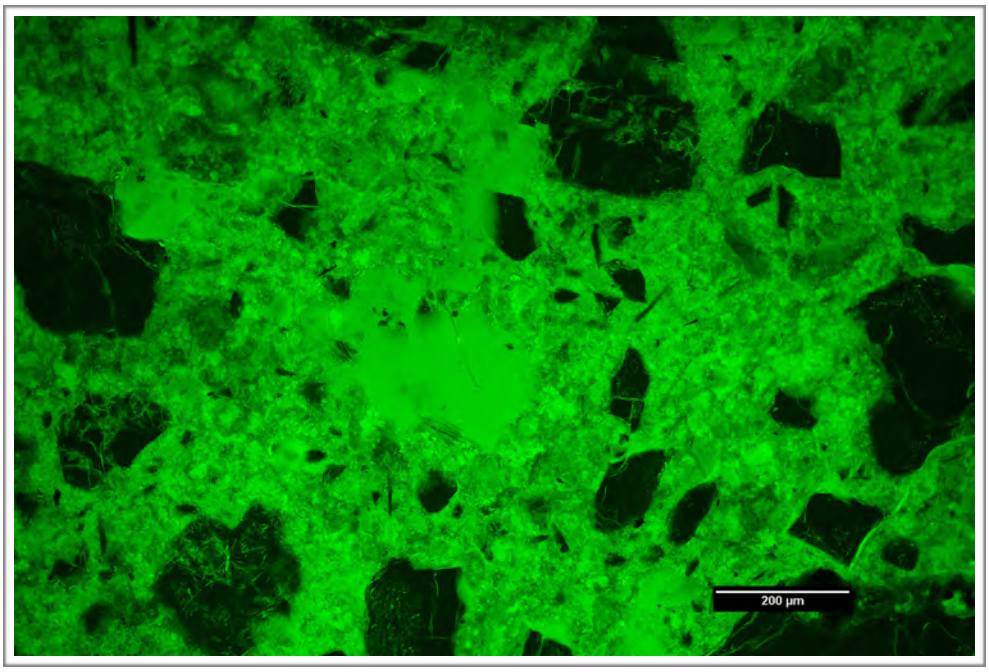


Figure D12. Transmitted fluorescent light photomicrographs of thin section showing detail of the capillary porosity of the paste in the middle of the thin section. The black areas correspond to aggregate that has very low porosity and the bright green circles are air voids filled with epoxy. The variations in green between these end members reflect variations in paste capillary porosity or micro-density.

(a)

(b)

Figure D13. Photographs showing (a) overview of phenolphthalein-stained surface and (b) detail of surface near the top of the core. The yellow scale in (a) is ~ 150 mm (6 in.) long; the small and large divisions are in centimeters and inches, respectively. The scale in (b) is in millimeters.

PROCEDURES

ASTM C856--Petrographic Analysis The petrographic work was done following ASTM C856 [**1**] with sample preparation done at **DRP** in the following manner. After writing the unique **DRP** sample number on each sample near the received label, the samples were measured and inspected visually and with a hand lens. The orientation of the saw cuts used to prepare the samples was then indicated on each sample with blue and red dots. The samples were then photographed in their as-received condition.

A slab representing a longitudinal cross section of each sample was cut from the central portion of the core using a Diamond Pacific® TR-24, a 24-inch diameter oil-lubricated saw. This produced three (3) longitudinal sections for each core. These sections were rinsed in an aqueous solution with a detergent to remove the cutting oil and oven dried overnight in a Gilson® Bench Top laboratory oven at ~ 40°C (~ 105°F) to remove remaining traces of the oil. After drying, each piece was labelled with the appropriate **DRP** sample number. One piece was set aside for phenolphthalein staining and the other was set aside for thin section preparation.

The central slab was then lapped and polished on a Diamond Pacific® RL-18 Flat Lap machine. This machine employs an 18-inch diameter cast iron plate onto which Diamond Pacific® Magnetic Nova Lap discs with progressively finer grits are fixed. The Nova Lap discs consist of a $^{1}/_{16}$ in. backing of solid rubber containing magnetized iron particles that is coated with a proprietary Nova resin-bond formula embedded with industrial diamonds of specific grit. The slab preparation involved the use of progressively finer wheels to a 3000 grit (~4 μm) final polish following procedures outlined in ASTM C457 [**2**]. An aqueous lubricant is used in the lapping and polishing process. The polished slab from each sample was examined visually and with a Nikon® SMZ-25 stereomicroscope with 3-158 magnification capability following to the standard practice set forth in ASTM C856.

Phenolphthalein was applied to a freshly saw-cut surface from each sample to assess the extent of carbonation, along with thin section analysis. Phenolphthalein is an organic stain that colors materials with pH of greater than or equal to ~ 9.5 purple. Portland cement concrete generally has a pH of ~ 12.5. Carbonation lowers the pH of the paste below 9.5, so areas not stained by phenolphthalein are an indicator of carbonation. The depth of paste not stained by phenolphthalein was measured from each exposed surface.

1 *Standard Practice for Petrographic Examination of Hardened Concrete.* Annual Book of ASTM Standards, Vol. 4.02., ASTM C856-17.

2 *Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete*, Annual Book of ASTM Standards, Vol. 4.02, ASTM C457-16.

Petrographic thin sections were prepared by cutting billets from the remaining longitudinal section. Outlines marking the area of the billets were drawn with a marker on the saw-cut surface after visual and microscopical examination of saw-cut and polished surfaces. The billets were labeled with the unique **DRP** number assigned to the sample and impregnated with epoxy. The impregnated billets were then fixed to glass slides with epoxy. After the epoxy cured, the slides were trimmed and ground on a Pelcon® Automatic Thin Section machine to a thickness of 20-25 µm (0.80-1 mil). The thin sections were examined with a Nikon® E-Pol 600 petrographic microscope equipped to provide a 20-1000x magnification range following the standard practice set forth in ASTM C856.

Capillary Porosity Measurement Measurement of the capillary porosity was done using image analysis methods and fluorescent microscopy of thin sections. Images were collected using constant lighting conditions. The images were binarized and analyzed using *Image J*, a freeware program available through the National Institute of Health (https://imagej.nih.gov/ij/download.html). The fluorescent signal recorded by each pixel in an image is tabulated to provide a distribution and a peak corresponding the paste is obtained. A peak corresponding to voids, which have a porosity of 100%, is used as a reference datum to provide a numerical measurement of the average porosity of the paste.

Gannett Fleming

*Excellence Delivered **As Promised***

M E M O R A N D U M

Date:	
To:	Mr. Jim Keenan Operations Manager Silver Bow Water Treatment 447 Basin Creek Road Butte, MT 59701
From:	Ms. Aimee Corn, P.E. Mr. Bradley Dawson, P.E.
Subject:	Basin Creek Dam Structural Assessment Report - Response to Comments

This memorandum summarizes the Montana State Dam Safety comments on their review of the Basin Creek Dam Structura Assessment Report – Draft and Gannett Flemings responses to comments.

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1. Section 5.2.2 alternatives to address overtopping states that the dam relies on the downstream embankment fill for additional stability. I was under the impression that the downstream fill was only placed there to prevent freeze thaw damage and wasn't included in the prior stability analysis. I could be incorrect on this, I just remember an HKM discussion that they planned on the fill eroding away during an overtopping event, and did not see that as an impact to stability. Section 4.1.2 mentions that no downstream load for the embankment was included.

   Response: Agreed, an additional site visit report was found that concludes the dam is adequate for the UNLC load case without the embankment. It is unclear if the upper mass concrete dam acts homogeneously with the lower dam, because doweling (and condition of dowels if installed) is unknown. Thus, the evaluation focused on the upper dam and assumed the interface between the upper mass concrete dam and lower masonry dam had zero tensile strength. This statement was meant to focus on the upper mass concrete dam and section 5.2.2 was be reworded as follows:

   > *Stability concerns for the upper mass concrete dam arise when the dam begins to overtop. ~~The dam relies on the embankment for additional stability and a few inches of overtopping could erode the downstream embankment.~~ There are two alternatives to address this concern.*

2. I liked the two recommendations that Gannett Fleming made - they seemed reasonable and achievable. It seems like it would be helpful if they could flesh those out just a tad more. For example, Alternative two wasn't clear to me if the elevations would remain the same – the ability of the dam to pass the PMF is based on the elevation of the top of the parapet. If for some reason the crest of the parapet is lower, than the ability of the dam to pass the PMF may be impacted. Not a huge deal, just that the hydrology would need to be revisited if project elevations used in the hydrology analysis are changed. It is likely that HKM made some conservative assumptions in assessing the PMF, so there may be some flexibility. It would also help if Gannett Fleming could provide a bit more general explanation on what it would take to physically accomplish the alternatives. This will be helpful for your upcoming RRGL planning grant and will be needed by the engineer you hire to write the bigger grants due later this year. If Gannett Fleming could provide a range of costs for the alternatives it would be helpful. Very few Montana engineers will be able to pin a number on what it would take to put in post tensioned anchors, and you will need to have some idea of the costs and efforts for the bigger grant applications.

   Response: We (Gannett) also discussed the impact on H&H if elevations were to change. We recommend not changing the elevations – the top of the overlay would be the same elevation as the existing parapet. This has been clarified in the report. We discussed on the conference call how to address the effort and cost range. An email to BSB will be provided detailing an estimated range of costs to assist in the grant writing. In addition, Section 5.3.2 of the report will be reworded as follows:

The concrete overlay would extend above the crest of the dam to replace the parapet (maintain top of parapet El. 5889.06).

3. It sounds like they did not recommend replacement of the top 13 feet of mass concrete. If they could flesh this out a bit more from a design life point of view it will be helpful. In other words, the two alternatives they recommended will buy Basin #1 __X____# years of safe operation, where as complete replacement of the top 13 feet will buy Basin #1 __Y__ years of safe operation. That should play a roll in your decision.

   Response: That is correct, a replacement of the top 13 feet of the dam is not one of the recommendations being made to retrofit the mass concrete portion of the dam. As part of our due diligence, a rough cost estimate will be made to BSB as to what this would cost. Note that after discussions with BSB, the full replacement of the top 13 feet of the mass concrete was added to the report as Alternative three. Regarding the design life of the structure, we don't have exact values as to how many years of safe operation each alternative would guarantee. The following information has been included in a memorandum to BSB in conjunction with the cost memorandum, but summarized here as well:

   - Alternative 1 would address the immediate visual concerns (i.e., deterioration of the parapet) and would prolong the life of the dam but additional maintenance to the upstream face may be necessary down the road. The anchors would address the stability concerns in the upper mass concrete.
   - Alternative 2 has the same benefits as Alternative 1, with the advantage of significantly mitigating the need for maintenance of the upstream face due to freeze thaw damage.
   - Alternative 3 has the same benefits as Alternative 2.

   Below is a visual that may help visualize the various alternatives. Alternative 1 could be considered preventative maintenance and Alternative 2 could be considered Essential maintenance, both extending the service life of the dam, Alternative 2 just longer than Alternative 2.

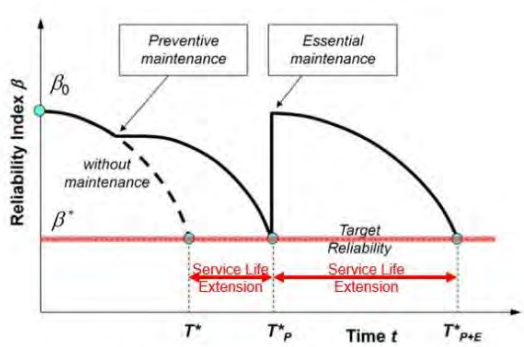

Figure 2-1 – Service Life Extension and Reliability Chart

4. On the refined analysis – section 5.2.3, Gannett Fleming states that a 3 dimensional study is necessary to assist with the design of the anchors. Since anchors are involved in both alternatives, can they give some rough costs for doing the 3 dimensional study? I assume even for removal of the top 13 feet, post tension anchors would still be needed. So no matter what alternative is chosen, a 3 dimensional study is needed? May be worth clarifying this with Gannett Fleming.

   Response: After further discussion, it should be possible to design the anchors without needing a 3D model. The original intent of this recommendation was to refine the analysis to determine the impact of 3D affects on the stability of the mass concrete. Review of the 2D analysis results indicate 3D affects from a 3D model may not provide enough added stability to offset the construction costs (i.e., reducing the number and/or length of anchors). The estimated cost of a model for the design phase will be provided to BSB in the above-mentioned memo. Section 5.2.3 will be modified as follows:

   > *This study assumes the upper mass concrete dam behaves two-dimensionally. Due to the slight arch shape and three-dimensional affects, it is possible the upper mass concrete could meet stability criteria when analyzed as a three-dimensional structure. However, there tends to be less three-dimensional interaction at the top of arch dams, and the cutout for the spillway could limit any three-dimensional benefits at the top of the dam. Therefore, a refined study to further assess the stability of the upper mass concrete dam is not recommended. ~~A refined study alone is not recommended. It should be noted a three-dimensional study would be necessary to assist in the design of the anchors.~~*

5. Lastly, I did not see much mention of stability of the dam during an earthquake, is that not a concern or simply out of scope of Gannett Fleming's analysis? Should this be something Butte should consider before choosing an alternative? In other words, would that be a reason to go with replacement of the top 13 feet, as opposed to the two recommended alternatives? Note that we never assume an earthquake and a flood occur at the same time, so the fact that the dam is basically stable at normal conditions and the instability arises during overtopping, maybe that is a mute point. Just something I was wondering about, grant reviewers may wonder the same thing. A few words of clarification would help. A seismic analysis on a concrete structure could be expensive – sometimes spending the money on concrete & steel is money better spent then funding another engineering analysis.

   Response: A seismic study was not a part of the scope for this work. The 10,000-year earthquake has a PGA of 0.39g (USGS). This load case would be evaluated for the retrofit design(s). A conservative 2D analysis could be performed to show both stability of the entire dam for the post-earthquake load condition (appears to be no analysis of record for the dam) and to ensure the anchor design is adequate for the upper mass concrete dam.

APPENDIX K

2019 Basin Creek Dam 5-Year Inspection Report

RESTORING OUR ENVIRONMENT • DESIGNING OUR FUTURE

Basin Creek Dam #1
2019 Periodic Inspection Report

Prepared for:
City and County of Butte-Silver Bow
Department of Public Works
Water Utility Division
155 West Granite
Butte, MT 59701

Prepared by:
Pioneer Technical Services, Inc.
1101 S. Montana Street
Butte, MT 59701

September 30, 2019

Basin Creek Dam #1

2019 Periodic Inspection Report

Prepared for:

City and County of Butte-Silver Bow
Department of Public Works
Water Utility Division
155 West Granite
Butte, MT 59701

Prepared by:

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1101 S. Montana Street
Butte, MT 59701

September 30, 2019

Michael Browne, P.E.
Pioneer Technical Services, Inc.

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Revision No.	Author	Version	Description	Date
Rev 0	Todd Kuxhaus/ Mike Browne	Draft	Issued for Client Review	8/29/2019
Rev 1	Mike Browne	Final	Issued for submittal to DNRC	9/30/2019

1 INTRODUCTION

Pioneer Technical Services, Inc. (Pioneer) performed a visual site inspection to review the conditions at Basin Creek Dam #1 on July 2, 2019 on behalf of the City and County of Butte-Silver Bow (BSB). The work was conducted as part of the five-year periodic inspection required for renewal of the Montana Department of Natural Resources and Conservation (DNRC) Operation Permit for High Hazard Dams. The following individuals were in attendance for this inspection:

- Mark Neary – BSB
- Jim Keenan – BSB
- Jim Dennehy - BSB
- Mike Browne P.E. – Pioneer
- Todd Kuxhaus P.E. – Pioneer
- Michele Lemieux, P.E. – DNRC

2 LOCATION AND BACKGROUND

Basin Creek Dam #1 is located approximately 9 miles southwest of Butte, Montana, in Silver Bow County, Section 12, Township 1 North, Range 8 West. The dam is on Basin Creek at the confluence of Bear Gulch Creek, which is a tributary to Silver Bow Creek. Basin Creek Dam #1 is located at the end of Basin Creek Road, approximately 7 miles south of the intersection with Harrison Avenue. The dam is owned and operated by the BSB Department of Public Works/ Water Utility Division. The primary purpose of the reservoir is to store and release municipal drinking water.

The dam is a rock masonry arch that was originally completed to a top NAVD88 elevation of 5,876.06 feet (5,860 local datum) in the 1890s. In 1913, the downstream face was buttressed with concrete along with the dam being raised 13 feet to its current top NAVD88 elevation of 5,889.06 feet (local datum 5,873). In the 1930s, earth fill was added on the downstream side of the dam to protect the exposed concrete face. A major rehabilitation was completed in 2006 to bring the structure into compliance with Montana Dam Safety Regulations.

Note: two elevation datums have been used for the dam. The 'local' datum which is used in record drawings, Operations Procedures, and past inspection reports. The 'NAVD88' datum was used for the Basin Creek water treatment plant as well as a dam breach analysis and inundation mapping currently underway. The 'local' datum plus 16.06 feet is equal to 'NAVD88' datum. BSB desires to use the NAVD88 datum for all work moving forward.

The 2005 and 2006 rehabilitation work primarily consisted of constructing a new concrete spillway with operable crest gate, rehabilitating the outlet works with new intake pneumatic valves, and slip-lining the existing conduits with new high-density polyethylene (HDPE) pipe.

3 PREVIOUS INSPECTION REPORT REVIEW

Table 1 summarizes recommendations made in the previous documents reviewed as part of the dam inspection:

- July 2014 - Periodic Inspection by Michael Browne, P.E. of Pioneer.
- August 2009 - Periodic Inspection by Jason Thom, P.E. of DOWL HKM.
- September 2004 - Periodic Inspection by Jason Thom, P.E. of DOWL HKM.
- May 2000 - Preliminary Engineering Report (PER) by Joel Gerhart, P.E. of Pioneer.
- 1999 - Periodic Inspection by Joel Gerhart, P.E. of Pioneer.

Table 1. Summary of Previous Recommendations

Basin Creek Dam #1 Summary of Previous Recommendations		
Source	**Description**	**Status**
2002 PER	Remove new trees as they begin to grow on the embankment.	Ongoing
2002 PER	Remove rodent burrows in the embankment as they are discovered.	Ongoing
2002 PER	Monitor existing stumps and roots in the embankment to determine if seepage paths develop.	Ongoing
2002 PER	Monitor the small washouts or slumps for any change.	Ongoing
2002 PER	Monitor seepage in the outlet stream for changes.	Ongoing
2002 PER	Repair spalling areas of parapet wall.	Repairs still need to be done.
2002 PER	Repair spalling concrete crest at the east abutment.	Repairs still need to be done.
2002 PER	Monitor seepage inside valve and drainage gallery.	Ongoing
2002 PER	Monitor seeps and cracks in valve gallery.	Ongoing
2002 PER	Monitor separation between valve gallery and entrance.	Ongoing
2004 Inspection	Repair or replace parapet, deteriorated concrete, including the right abutment contact.	Repairs still need to be done.
2014 Inspection	Fix spalling and cracked concrete on the upstream face of the dam. This concrete appears to have deteriorated a significant amount in the last couple years. It is important to repair the concrete in a timely manner before it becomes a critical dam safety concern. The repair should be designed and approved by a professional engineer with experience in hydraulic structures.	Repairs still need to be done.
2014 Inspection	Fix undercutting on the spillway apron and back cutting of native embankment adjacent to the left downstream-most spillway wall. The spillway apron is currently structurally sound. These repairs should be performed in a timely manner before the undercutting could potentially compromise the structural integrity of the spillway apron.	Done

2014 Inspection	Plug opening on right side of dam face with a water-tight, structurally sound seal (i.e., stop logs, gate, or concrete plug).	Done with concrete plug
2014 Inspection	Raise concrete at the right abutment (behind opening on the right side of the dam face) to be at least the height of the parapet wall.	Done with concrete plug
2014 Inspection	Monitor damp area on the right downstream embankment near the stairs, to see if seepage increases or more sloughing occurs.	Ongoing
2014 Inspection	Monitor hollow area under the walkway behind the gantry crane	Done during 2019 inspection, walkway continues to deteriorate.

4 CATEGORIZED AS A HIGH HAZARD DAM

Basin Creek Dam #1 is classified in the State of Montana as a high hazard dam. Because of this hazard determination, the facility must be operated under the provisions of an Operating Permit issued by the Dam Safety Section of the Montana DNRC.

5 DOWNSTREAM HAZARD AND LOSS-OF-LIFE ANALYSIS

Loss of Life calculation was completed as part of the 2005 rehabilitation project by HKM. The DNRC estimated the Loss of Life from a breach of Basin Creek Dam #1 to be 26. The "26 Loss-of-Life flood" was calculated to have a peak inflow of 1,076 cubic feet per second (cfs) which would result in overtopping of the parapet. Floods with a less frequent occurrence than the 500-year inflow will overtop the dam crest, which will likely cause erosion of the downstream earth fill embankment. However, the stability analysis, which assumed that the downstream embankment was not in place, indicated that, at the Probable Maximum Flood (PMF) maximum water surface NAVD88 elevation of 5,892.86 feet (local datum 5,876.8), the dam meets the required factor of safety even without the downstream embankment force on the downstream face of the dam. Although the new spillway does not pass the 26 Loss-of-Life flood without overtopping, the dam should be considered in compliance with the Montana Spillway Standards because the stability factor of safety requirements are met.

Pioneer understands BSB is under contract with others to perform a updated dam breach analysis and inundation mapping for Basin Creek Dams #1 and #2. The work is scheduled to be completed by June 2020.

6 HYDROLOGIC AND STRUCTURAL ADEQUACY

A detailed hydrologic and hydraulic analysis was performed by HKM as part of the design for the 2005 rehabilitation and is included in the June 2005 *Basin Creek Dam #1 Hydrologic and Hydraulic Study*. Based on the calculation of the flood inflows, the new spillway was designed to pass the 500-year flood without overtopping the dam crest. The 500-year flood is the minimum acceptable design flood in the Montana Dam Safety Administrative Rules. The 500-year inflow was calculated at 318 cfs with a maximum reservoir NAVD88 elevation of 5,889.06 (5,873.0 feet local datum), which is equal to the dam crest. Note: Pioneer has not reviewed or possess the *Basin Creek Dam #1 Hydrologic and Hydraulic Study*, the values reported herein were obtained from the *2009 Inspection Report*.

The structural stability of the dam was analyzed by Piedmont Engineering, Inc. in the report *Stability Analysis of Basin Creek Dam No. 1* dated January 11, 2000. This analysis indicated the dam would withstand overtopping of up to 12 feet over the top of the parapet for a few hours.

Pioneer understands BSB is under contract with others to perform a dam breach analysis and inundation mapping for Basin Creek Dams #1 and 2. The work is scheduled to be completed by June 2020.

Thorough reevaluation of the hydraulic and structural adequacy was beyond Pioneer's current scope of work. The dam appears to have adequate hydraulic and structural capacity based on Pioneer's limited review of documents (listed above) in conjunction with site inspection observations. Reevaluation of hydraulic adequacy should be reevaluated after completion of the dam breach analysis and inundation mapping.

7 INSPECTION SUMMARY

The inspection encompassed embankment, abutment, outlet, spillway, control and instrumentation, and downstream conditions. Field notes from the July 2, 2019 inspection are included in Appendix A. Photographs taken during the inspection are included in Appendix B.

7.1 Embankment

The upstream face of the dam is concrete, and the downstream embankment is vegetated earth fill over concrete. The water level in the reservoir at the time of inspection was 5,886.3 feet. This is 3 feet below the top of the parapet and 0 feet below the top of the spill crest gate. Please note, the data have changed since the previous inspection.

7.1.1 Upstream Face

The upstream face is concrete and only the portion above the water line was inspected. The visible portion of the concrete face showed no settlement or misalignment; however, the concrete has numerous cracks, spalling, and generally shows signs of severe deterioration. The cracks observed during the 2019 inspection were also evident in photos from the 2014 and 2009 inspections. Butte-Silver Bow staff indicated the concrete deteriorated considerably in the last couple of years. In several places there are surface voids approximately 12 inches in height, 6

inches deep, and varying in width up to 6 feet. Metal reinforcement was observed in several of the voids. The deterioration appears to be worsening from that observed from the 2014 inspection.

The walkway behind the gantry crane appeared to have a hollow sound during the 2014 inspection. As observed during the 2019 inspection, the walkway continues to deteriorate and have a hollow sound when impacted with a hard object.

In 2011, the dam overtopped near the right abutment and caused significant erosion on the downstream slope. Staff report that this happened when water flowed through a rectangular opening in the right side of the dam face. Behind this opening is a designed open space that pools water and subsequently flowed over the top of the right abutment. The rectangular opening and pooling area are remnants of past operations. The rectangular opening has since been closed to address this issue.

Some of the concrete voids and deterioration discussed above may have also been present during the past inspections; however, they may not have previously been visible due to operating the dam with a slightly higher water elevation.

7.1.2 Embankment Downstream Slope

The downstream embankment is earthen fill with adequate grass cover. The right portion of the embankment suffered significant erosion when the dam overtopped in 2011 and was subsequently repaired. In 2018, BSB crews replaced the water bypass pipeline located near the right abutment. This work disturbed embankments soils which were subsequently regraded and reseeded. Straw waddles are still present in the reclaimed area.

No longitudinal or transverse cracks were observed in the downstream face. A damp area on the right side (near the stairs) was observed, with slight sloughing in the area. No significant seepage was observed. Small rodent burrows were observed; however, no damage due to animal traffic was present.

The dam has an underdrain system that is used from a water operation prospective to control sediment buildup near the outlet intakes. The underdrain system has bladder values and screens on its upstream end which are typically kept in an open position. Flow through the underdrain system is controlled by a keyed valve located on the downstream end. When the values are open, sediment is flushed through the underdrain system thus reducing sediment load through the outlet pipes to the water treatment system. The underdrain system is not part of the dam safety or embankment stability portion of the dam. Butte-Silver Bow reported that valves for the underdrain system were exercised and video inspected in 2018.

7.1.3 Vegetation on the Dam

Observed vegetation on the dam included grass, some small woody vegetation, and old decaying stumps.

7.2 Abutment Contacts

No erosions, differential movement cracks, or seepage were observed during the inspection.

7.3 Outlet Works

The outlet works consist of three 20-inch diameter cast iron pipes through the base of the dam. As part of the 2005 rehabilitation of the outlet works, each of the three outlet pipes were slip lined and had new pneumatic isolation valves and screens installed on the upstream end of the pipes. The valves are buried and located in the downstream toe area. Two of the pipes are feeding the water supply line and one is for discharge into the downstream creek.

The dam also contains a valve gallery at the toe of the downstream slope. The valve gallery contains chlorination feed points and valves from original construction. The valves are abandoned and have HDPE pipe slip lined through the valve. The chlorination feed points are also abandoned.

7.3.1 Intake Structure

The intake structure was under water and not observable.

7.3.2 Conduit

The conduits are not observable. Staff report that the existing valves are in good working order. No video inspection of the conduits was performed as part of this inspection.

7.3.3 Gates and Tower

A gantry crane is located on the crest of the dam; however, BSB staff indicate it is not used in normal operation of the dam. The crest gate for the spillway is operational and the controls are lubricated. No leakage around the gate was observed.

7.3.4 Stilling Basin

No stilling basin is present.

7.3.5 Downstream Channel

The downstream channel appears to be in good working condition. No eroding, back cutting, or obstructions were observed in the channel. No undercutting of bank erosion was observed at the outlet.

7.4 Spillway

The spillway is located on the left abutment. The spillway was rebuilt as part of the 2005 rehabilitation project with a new crest gate, concrete crest, and concrete chute.

7.4.1 Evaluation

The concrete chute and crest are in good condition and no concrete spalling, cracks, sloughing, exposed reinforcement, displacement of joints, loss of joint material, or leakage at the joints were

observed. No obstructions or debris were present in the chute. Significant erosion was observed during the 2014 inspection under the downstream apron and back cutting against the left earthen bank. The back cutting and erosion has since been repaired. The 2019 inspection did not observe any erosion near the left earthen bank.

7.4.2 Energy Dissipators

Energy dissipators consist of large boulders below the concrete chute. The boulders appear to be stable and in good condition.

7.4.3 Emergency Spillway

The dam does not have an emergency spillway.

7.5 Reservoir Control

No new development has occurred upstream or downstream of Basin Creek Dam #1. No slides were observed or reported in the reservoir area. No debris was observed in the reservoir. Upstream of Basin Creek Dam #1 is Basin Creek Dam #2 (see separate 2019 Periodic Inspection Report by Pioneer regarding Basin Creek Dam #2). Since the 2011 overtopping event that caused the erosion on the right side of the dam, BSB staff reported they have kept the water elevation lower (generally 1 to 2 feet lower than historical normal pool levels) to prevent additional overtopping incidences.

7.6 Instrumentation

Butte-Silver Bow staff maintain operation records of the reservoir. The records are maintained by personnel in the Department of Public Works. Sonar is used to monitor the depth of the reservoir. A submersible pressure transmitter is mounted off the crest of the dam and a display readout box is located in the mechanical building located near the downstream toe.

7.7 Downstream Condition

Downstream land use is mixed residential and open space.

8 ENGINEER REVIEW

Pioneer reviewed the following documents as part of the 2019 Inspection:

- BSB's *Emergency Action Plan Basin Creek Dams #1 and #2* (EAP) dated January 8, 2019.
  - Pioneer recommends the EAP be updated to include results of the dam breach analysis and inundation mapping when results are available.
  - Specifics of the Basin Creek Dam #1 were not discussed with BSB during the inspection.
  - The inspection team did discuss general EAPs for all BSB dams particularly regarding planning, updating with new inundation maps, and performing table-top exercises.

- BSB's *Operating Procedures Basin Creek Dams #1 and #2* dated January 2019.
- BSB's *Maintenance Procedures Basin Creek Dams #1 and #2* dated January 2019
- BSB's *Dam Owner's Inspection Checklist* dated July 9, 2018. A general comment for consideration on future owner inspections is to take photos during the inspection and include in the report.
- Photos of the upstream face of the dam displaying concrete deterioration. Photos were taken when the reservoir was partially drawn down hence exposing more of the dam face.
- As-built Drawings titled, *Basin Creek Reservoir Improvements Sheet G-5R (Site Plan), M-6R (Existing Dam Section and Demolition), and M-7R (Intake Sections and Details)* prepared by HKM Engineering and dated September 21, 2006.

9 Recommendations to be Completed in the Next Year

Pioneer recommends the following action be completed within the next year:

- Develop plan to address spalling and cracked concrete on the upstream face of the dam, deterioration of concrete walkway across top of dam, hollow area under walkway behind gantry crane.
    - This concrete continues to deteriorate and should be addressed before it becomes a critical dam safety concern. The deteriorated concrete may extend several feet below the crest. Repairs may require considerable removal and replacement of concrete along crest and upstream face of dam.
    - The repair should be designed and approved by a professional engineer with experience in hydraulic structures.
    - Planning and funding to investigate the work should be initiated immediately. DNRC Renewable Resource Grant and Loan planning grant is open and a viable source to fund the investigation. Pending funding approval, the investigation of should be performed in fall 2019 while the reservoir pool is drawn down.
- Update the EAP with new dam breach analysis and inundation mapping.

10 Five-Year Recommendations

Pioneer recommends the following actions before the next five-year inspection:

- Remove trees in the downstream embankment as encountered.
- Remove rodent burrows in the downstream embankment as encountered.
- Monitor existing stumps and roots in the downstream embankment to determine if seepage paths develop.
- Monitor seepage in the outlet stream for changes. Consult engineer if changes to seepage are noted.
- Monitor for seeps and cracks in the valve gallery. Consult engineer if changes to seepage are noted.
- Perform annual owner inspections of the dam.
- Update Operation Procedure manual to reflect NAVD88 elevations.

The next periodic five-year inspection should be scheduled for 2024. Changes in the condition of the dam may warrant a periodic inspection prior to 2024.

Appendix A. Inspection Field Notes

DAM SAFETY INSPECTION REPORT
NAME OF DAM: Basin Creek Dam #1
DATE: July 2, 2019

Dam Inspected By:	Mike Browne, Todd Kuxhaus, & Michele LeMieux
Owner Representative:	Jim Dennehy, Kim Keenan, & Mark Neary
Weather:	Sunny

Inventory No:	MT 00374	Owner:	Butte-Silver Bow County
Hazard Category:	High	Operator:	Butte-Silver Bow County
Type of Dam:	Rock masonry arch with concrete buttress and earthfill	Stream(s):	Basin Creek
Year Built:	1897, 1913, 1930's, 2006	Drainage Area:	13.6 square miles
Year Rehabilitated:	2006	Per operating procedure: Local Datum Dam #1 + 16.06 ft = NAVD88 Elevation	

RESERVOIR STORAGE STATUS		
	Water Surface Elevation (Feet)	Storage (Acre-Feet)
At Time of Inspection:	5886.3 (NAVD 83)	950.6 (at elev 5886.0)
At Spillway Crest:	Gate closed: 5,872 Gate open: 5868.5 (local datum)	See storage table below
At Min Dam Crest Elevation:	5873 (local datum) 5889.06 (NAVD 83)	~1,072.5

LOWER BASIN CREEK RESERVOIR STAGE/STORAGE

Depth	NAVD88 Elevation	Old Reservoir Datum Elevation	Total Vol (cu. ft)	Total Vol (Ac-ft)	Total Vol (MGal)
0	5809.0	5792.94	-	-	-
1	5810.0	5793.94	505	0.0116	0.0038
5	5814.0	5797.94	13,360	0.3067	0.0999
10	5819.0	5802.94	56,449	1.2959	0.4223
15	5824.0	5807.94	133,791	3.0714	1.0008
20	5829.0	5812.94	257,949	5.9217	1.9296
25	5834.0	5817.94	461,535	10.5954	3.4525
30	5839.0	5822.94	810,825	18.6140	6.0654
35	5844.0	5827.94	1,406,450	32.2877	10.5210
40	5849.0	5832.94	2,349,519	53.9375	17.5756
45	5854.0	5837.94	3,701,882	84.9835	27.6920
50	5859.0	5842.94	5,663,874	130.0247	42.3687
55	5864.0	5847.94	8,710,870	199.9741	65.1618
60	5869.0	5852.94	13,550,556	311.0780	101.3652
65	5874.0	5857.94	20,018,227	459.5553	149.7467
70	5879.0	5862.94	28,003,875	642.8805	209.4835
75	5884.0	5867.94	37,337,156	857.1432	279.3013
75.5	5884.5	5868.44	38,337,709	880.1127	286.7860
76	5885.0	5868.94	39,350,299	903.3586	294.3607
76.5	5885.5	5869.44	40,374,624	926.8738	302.0232
77	5886.0	5869.94	41,409,805	950.6383	309.7669
77.5	5886.5	5870.44	42,454,602	974.6236	317.5825
78	5887.0	5870.94	43,507,857	998.8030	325.4614
78.5	5887.5	5871.44	44,569,449	1,023.1738	333.4027
79	5888.0	5871.94	45,639,921	1,047.7484	341.4103
79.5	5888.5	5872.44	46,719,854	1,072.5403	349.4888

From WET *Basin Creek Reservoirs – Bathymetric Survey*, dated July 8, 2019

General Notes:

- Replaced instrumentation recently (new level instrument)
- BSB further breached Upper Basin Creek Dam #2 approximately 1 foot in 2017
- Basin #2 has underdrain pipe to minimize sediment entering outlet pipes.
  - Upstream end had bladder valves (open all the time) and screen
  - Flow control with valve (key controlled) located near downstream toe.
- Bubbler system to keep ice from damaging equipment on upstream face of dam.

1. Embankment

A. Crest

Height: 73 Width: 5

Length: 275 Surface: Concrete walk

#	ITEM	YES	NO	REMARKS
1	Settlement	☐	☒	
2	Misalignment	☐	☒	
3	Transverse Cracking	☐	☒	
4	Longitudinal Cracking	☐	☒	
5	Traffic or Roadway Damage	☐	☒	
6	Animal Damage	☐	☒	
7	Erosion	☐	☒	
8	Nuisance Vegetation	☐	☒	
9	Other	☒	☐	Deterioration of concrete walk. Hollow sounding beneath concrete, particularly near gantry crane.

B. Concrete/Granite Block Upstream Face

Upper Slope Ratio: vertical Lower Slope Ratio: NA

#	ITEM	YES	NO	REMARKS
1	Erosion	☐	☐	NA
2	Longitudinal Cracks	☐	☐	NA
3	Transverse Cracks	☐	☐	NA
4	Adequate Riprap Protection	☐	☐	NA
5	Riprap Deterioration	☐	☐	NA
6	Settlement/Depressions	☐	☐	NA
7	Slumps/Sloughs	☐	☐	NA
8	Nuisance Vegetation	☐	☐	NA
9	Animal Damage	☐	☐	NA
10	Debris	☐	☐	NA
11	Other	☒	☐	Considerable concrete deterioration

C. Downstream Face

Note: Dam is a granite block and concrete dam. Earth fill placed on downstream slope at a later date to protect concrete. Dam is structurally stabile without earth fill.

Slope Ratio: 1.5H:1V

#	ITEM	YES	NO	REMARKS
1	Erosion	☐	☒	
2	Longitudinal Cracks	☐	☒	
3	Transverse Cracks	☐	☒	
4	Settlement/Depressions	☐	☒	
5	Slumps/Sloughs	☐	☒	
6	Seepage	☒	☐	Damp area noted on right side of dam near stairs. Minor slumping observed in area.

7	Adequate Vegetation Cover	☒	☐	
8	Nuisance Vegetation	☐	☒	
9	Animal Damage	☐	☒	Minor, Some small rodent holes
10	Debris	☒	☐	
11	Other	☐	☒	

2. Abutment and Toe

A. Downstream Toe

#	ITEM	YES	NO	REMARKS
1	Seepage	☐	☒	
2	Depressions/Bulges	☐	☒	
3	Boils	☐	☒	
4	Toe Drain in Good Condition	☐	☐	NA
5	Toe Drain Flowing	☐	☐	NA
6	Relief Wells Flowing	☐	☐	NA
7	Erosion	☐	☒	
8	Animal Damage	☐	☒	
9	Nuisance Vegetation	☐	☒	
10	Other	☐	☒	

B. Upstream Abutment

#	ITEM	YES	NO	REMARKS
1	Erosion	☐	☐	Not Visible
2	Cracking	☐	☐	Not Visible
3	Slides/Depressions	☐	☐	Not Visible
4	Sinkholes	☐	☐	Not Visible
5	Nuisance Vegetation	☐	☐	Not Visible
6	Animal Damage	☐	☐	Not Visible
7	Debris	☐	☐	Not Visible
8	Other	☐	☐	Not Visible

C. Downstream Abutment

#	ITEM	YES	NO	REMARKS
1	Erosion	☐	☒	
2	Cracking	☐	☒	
3	Slides/Depressions	☐	☒	
4	Seepage	☐	☒	
5	Drains Flowing	☐	☐	No drains
6	Nuisance Vegetation	☐	☒	
7	Animal Damage	☐	☒	
8	Debris	☐	☒	
9	Other	☐	☒	

3. Outlet Works

Location: Through center of dam. Maximum Discharge: Estimated at 60 cfs per Operating Manual with reservoir at dam crest.

Note: Outlet works consists of 3 outlet conduits: 2 pipes go to water treatment plant, one pipe discharges into stream.

A. Intake Structure: No Intake structure

Visible: Date Last Inspected: Type:

#	ITEM	YES	NO	REMARKS
1	Settlement	☐	☐	
2	Concrete Cracking	☐	☐	
3	Concrete Spalling	☐	☐	
4	Concrete Erosion	☐	☐	
5	Exposed Reinforcement	☐	☐	
6	Joint Displacement	☐	☐	
7	Problems with Trash Rack	☐	☐	
8	Corrosion of Trash Rack	☐	☐	
9	Erosion Around Intake	☐	☐	
10	Deposition Around Intake	☐	☐	
11	Other	☐	☐	

B. Upstream Conduit

Accessible: no Type: Three 20” diameter cast iron pipes which were slip lined with 16” HDPE pipes in 2006 Size: 16”

#	ITEM	YES	NO	REMARKS
1	Concrete Cracking	☐	☐	NA
2	Concrete Spalling	☐	☐	NA
3	Concrete Erosion	☐	☐	NA
4	Exposed Reinforcement	☐	☐	NA
5	Joint Displacement	☐	☐	Not Visible
6	Loss of Joint Material	☐	☐	Not Visible
7	Open Joints or Holes in the Wall	☐	☐	Not Visible
8	Leakage	☐	☐	Not Visible
9	Calcium Deposits	☐	☐	Not Visible
10	Corrosion of Metal	☐	☐	Not Visible
11	Wear of Protective Coatings	☐	☐	Not Visible
12	Misalignment of Conduit	☐	☐	Not Visible
13	Material Deposition	☐	☐	Not Visible
14	Other	☐	☐	

C. Downstream Conduit

Accessible: no Type: Three 20” diameter cast iron pipes which were slip lined with 16” HDPE pipes in 2006 Size: 16”

#	ITEM	YES	NO	REMARKS
1	Concrete Cracking	☐	☐	NA
2	Concrete Spalling	☐	☐	NA
3	Concrete Erosion	☐	☐	NA
4	Exposed Reinforcement	☐	☐	NA
5	Joint Displacement	☐	☐	No Visible
6	Loss of Joint Material	☐	☐	No Visible
7	Open Joints or Holes in the Wall	☐	☐	No Visible
8	Leakage	☐	☐	No Visible
9	Calcium Deposits	☐	☐	No Visible
10	Corrosion of Metal	☐	☐	No Visible
11	Wear of Protective Coatings	☐	☐	No Visible
12	Misalignment of Conduit	☐	☐	No Visible
13	Material Deposition	☐	☐	No Visible
14	Other	☐	☐	

D. Valve Gallery

#	ITEM	YES	NO	REMARKS
1	Vandalism	☐	☒	NA
2	Ladder in Good Condition	☐	☐	NA
3	Grating in Good Condition	☐	☐	NA
4	Fall Protection in Good Condition	☐	☐	NA
5	Seepage from Tower Walls	☒	☐	
6	Debris in Bottom of the Tower	☐	☒	
7	Pooling Water in Bottom of Tower	☒	☐	
8	O&M and EAP Available	☒	☐	
9	Other	☐	☐	

E. Pneumatically Operated Pinch Valves on Upstream End of Conduits

#	ITEM	YES	NO	REMARKS
1	Operated During Inspection	☐	☒	NA
2	Leakage from Gate	☐	☒	No reported leakage
3	Gate Leaf in Good Condition	☐	☐	Not visible
4	Other	☐	☐	No reported problems from BSB

F. Operating Gate

Inspected current year: no
Type: Butterfly
Not inspected current year:
Size: 16
Stem, pre-inspected, in:
Stem, during inspection, in:
Stem, during guard gate operation, in:
Stem, post-inspection, in:

#	ITEM	YES	NO	REMARKS
1	Operator Operational	☒	☐	Per BSB operated in 2018
2	Operator Lubricated	☐	☐	
3	Stem in Good Condition	☐	☐	
4	Gate Housing in Good Condition	☐	☐	
5	Leakage from Flanges	☐	☐	
6	Leakage from Cylinder	☐	☐	
7	Leakage from Gate	☐	☐	
8	Gate Leaf in Good Condition	☐	☐	
9	Air Vent in Good Condition	☐	☐	
10	Cavitation Damage	☐	☐	
11	Other	☐	☐	

G. Outlet and Stilling Basin

Type:
Dewatered for inspection: No

#	ITEM	YES	NO	REMARKS
1	Concrete Cracking	☐	☒	
2	Concrete Spalling	☐	☒	
3	Concrete Erosion	☐	☒	
4	Exposed Reinforcement	☐	☒	
5	Exposed Water Stops	☐	☒	
6	Displacement or Offset of Joints	☐	☒	
7	Seepage	☐	☒	
8	Debris	☐	☒	
9	Riprap Protection Stable	☐	☒	
10	Other	☐	☒	

H. Downstream Channel

#	ITEM	YES	NO	REMARKS
1	Seepage	☐	☒	
2	Erosion	☐	☒	
3	Riprap Protection Stable	☐	☐	
4	Deterioration of Riprap	☐	☐	
5	Nuisance Vegetation	☐	☐	
6	Debris	☐	☐	
7	Overtopping	☐	☐	
8	Grade Problems	☐	☐	
9	Other	☐	☐	

4. Primary Spillway

Location: Left abutment
Type: Concrete
Operating: Yes
Maximum Discharge: 370 cfs
At Res. El.: Dam crest

A. Approach Area

Visible During Inspection: Yes

#	ITEM	YES	NO	REMARKS
1	Deposition/Debris	☐	☒	
2	Nuisance Vegetation	☐	☒	
3	Obstructions	☐	☒	
4	Other	☐	☐	

B. Weir

Location: crest
Type of Weir: Pneumatically operated Obermeyer spillway crest gate
Sharp crested weir (gate closed)
Broad crested weir (gate open)

Operating: Yes. Approximately 0.02' water flowing at downstream end of concrete chute.
Length: 9 ft

#	ITEM	YES	NO	REMARKS
1	Concrete Cracking	☐	☒	
2	Concrete Spalling	☐	☒	
3	Exposed Reinforcement	☐	☒	
4	Exposed Water Stops	☐	☒	
5	Blockage of Drains	☐	☒	
6	Nuisance Vegetation	☐	☒	
7	Debris	☐	☒	
8	Other	☐	☒	

C. Chute

Accessible: Yes
Width: 5.5
Length: ~100 ft

#	ITEM	YES	NO	REMARKS
1	Concrete Cracking	☐	☒	
2	Concrete Spalling	☐	☒	
3	Concrete Erosion	☐	☒	
4	Exposed Reinforcement	☐	☒	
5	Exposed Water Stops	☐	☒	
6	Displacement or Offset of Joints	☐	☒	
7	Joint Sealant in Good Condition	☐	☒	
8	Deterioration of Dissipaters	☐	☒	
9	Drains in Good Condition	☐	☒	
10	Seepage from Drains	☐	☐	NA

11	Seepage (not from drains)	☐	☒	
12	Deposition of Material	☐	☒	
13	Energy Dissipaters	☐	☒	
14	Erosion of Stilling Basin	☐	☐	NA
15	Debris in Stilling Basin	☐	☐	NA
16	Other	☐	☐	

D. Downstream Channel

Spillway discharges onto a riprap lined rock slope

Accessible: Yes Width: ~10 to 40 ft Length: ~110 ft

#	ITEM	YES	NO	REMARKS
1	Erosion	☐	☒	Minor erosion noted during 2014 inspection, repairs were subsequently made.
2	Nuisance Vegetation	☐	☒	
3	Debris	☐	☒	
4	Seepage	☐	☒	
5	Other	☐	☐	

5. Reservoir Control

A. Development and Changes

#	ITEM	YES	NO	REMARKS
1	Recent Upstream Development	☐	☒	
2	Recent Downstream Development	☐	☒	
3	Slides in Reservoir Area	☐	☒	
4	Changes in Basin Hydrology	☒	☐	Lots of beetle kill pine trees in basin. Operators noted more turbidity in recent years; possibly due to increased runoff.
5	Change in Reservoir Operation	☐	☒	
6	Large Impoundment Upstream	☒	☐	Basin Creek #2
7	Significant Debris in Reservoir	☐	☒	
8	Other	☐	☒	

6. Instrumentation

Reservoir and Piezometers Monitored Manually: No piezometers

Reservoir and Piezometers Monitored Automatically: Yes. Sonic water level

7. Downstream Condition

A. Downstream Land Use

No change from previous.

Report completed by: Todd Kuxhaus and Michael Browne

Appendix B. Inspection Photographs

Picture #: 1	Description: Looking at downstream face of dam.

Picture #: 2	Description: Looking across the crest of the dam.

Picture #: 3	Description: Extensive spalling on face of the dam.

Picture #: 4	Description: Extensive spalling on face of the dam.

Picture #: 5	Description: Upstream face.

Picture #: 6	Description: Walkway deterioration of the crest near the gantry crane.

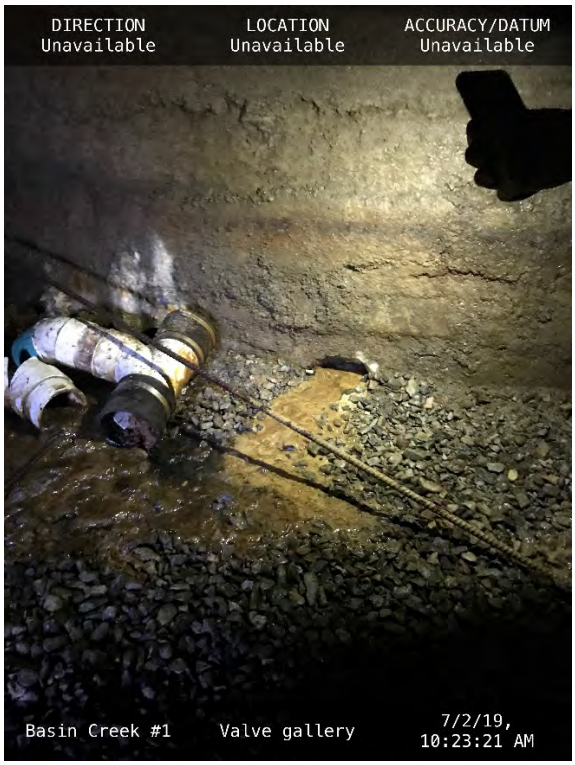
Picture #: 7	Description: Upstream face.

Picture #: 8	Description: Spillway chute.

Picture #: 9	Description: Spillway inlet.

Picture #: 10	Description: Repair made along edge of spillway.

Picture #: 11	Description: Crest of dam.



Picture #: 12	Description: Valve gallery, note seepage.

Picture #: 13	Description: Valve gallery.

Picture #: 14	Description: Chlorination points in valve gallery.

Picture #: 15	Description: Repair/reseed of right abutment due to utility (bypass pipeline) replacement by BSB in 2018

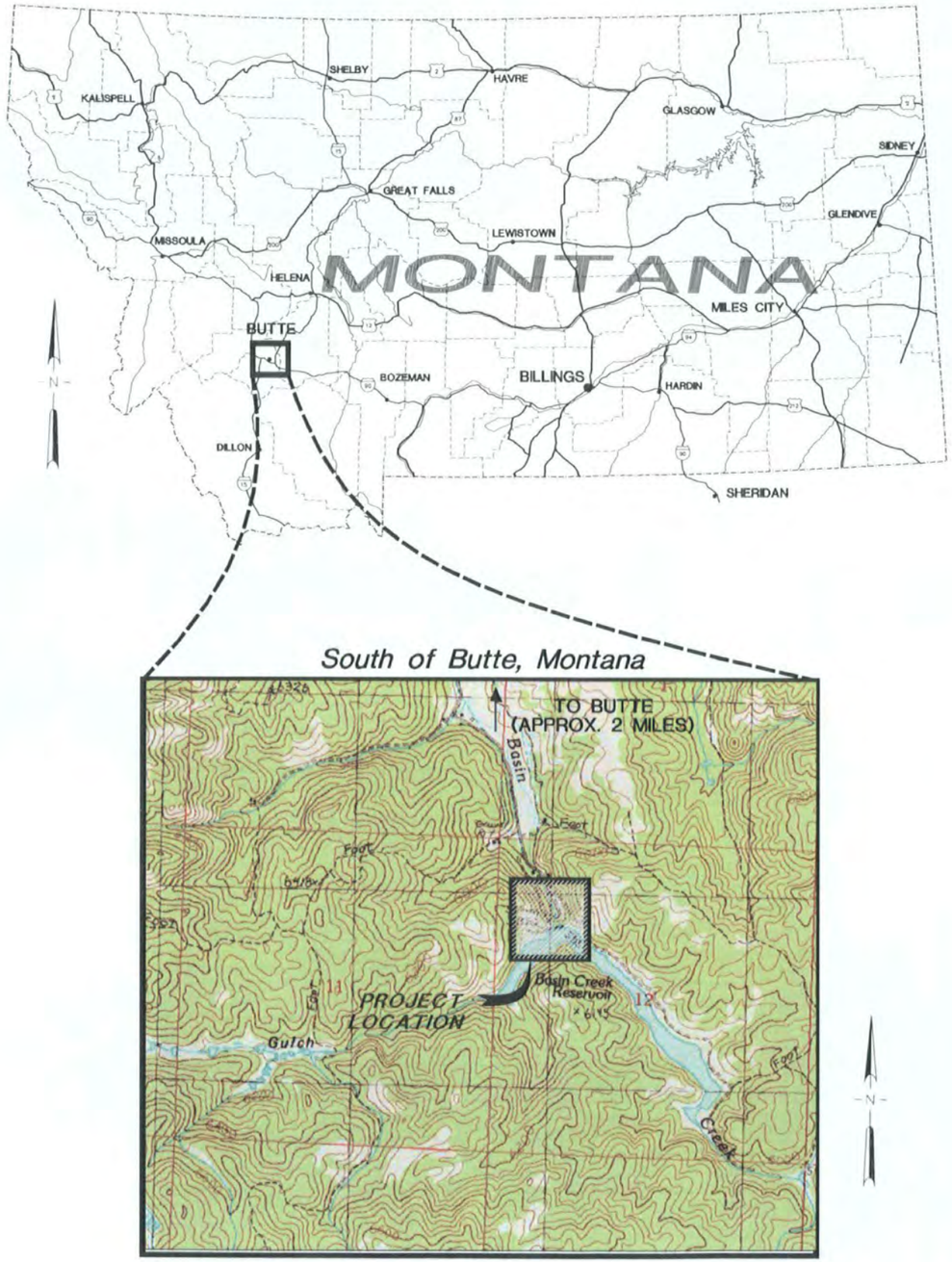
Picture #: 16	Description: Outlet channel.

Picture #: 17	Description: Downstream face.

Picture #: 18	Description: Repair to raise dam crest height at right abutment. This is the location water overflowed the dam in 2011 causing embankment erosion.

Picture #: 19	Description: Spillway channel rock drop from below.

Appendix C. Record Drawings



LOCATION MAP

NOT TO SCALE

Construction Drawings for BASIN CREEK RESERVOIR IMPROVEMENTS

BUTTE - SILVER BOW (BSB), MONTANA

PREPARED FOR:
BUTTE - SILVER BOW PUBLIC WORKS DEPARTMENT

FUNDED BY:
NATURAL RESOURCE DAMAGE PROGRAM

PREPARED BY:

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PROJECT NO. 15M424.117

MONTANA RUSSELL CHRISTIAN REED 15740PE LICENSED PROFESSIONAL ENGINEER

RUSSELL C. REED 15740 P.E.
Project Manager
HKM ENGINEERING Inc.

JULY 2005

RECORD DRAWING
SEPTEMBER 2006

Sheet No.
G-1R

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LEGEND

- 5870 = EXISTING GROUND CONTOURS
- = EXISTING CONCRETE
- OHP = EXISTING OVERHEAD POWER
- PWR = EXISTING UNDERGROUND POWER
- x = EXISTING FENCE
- CP-16 = SURVEY CONTROL POINT

PIPING LEGEND

- LARGER PIPING (4" AND OVER)
- FLANGED CONNECTION
- BUTTERFLY VALVE
- GATE VALVE

SHEET INDEX

SHT. NO.	TITLE
G-1R	COVER SHEET
G-2R	SHEET INDEX, LEGEND, & ABBREVIATIONS
G-3R	PROJECT OVERVIEW
G-4R	EXISTING SITE CONDITIONS
G-5R	SITE PLAN AND SHEET REFERENCES
S-1R	GENERAL STRUCTURAL NOTES AND STANDARD DETAILS
S-2R	SPILLWAY PLAN VIEW DEMOLITION DETAILS
S-3R	SPILLWAY STRUCTURE PLAN AND PROFILE
S-4R	SPILLWAY STRUCTURE PLAN
S-5R	SPILLWAY STRUCTURE SECTIONS
S-6R	SPILLWAY STRUCTURE DEMOLITION AND SECTIONS
S-7R	STAIRCASE PLAN, PROFILE AND DETAILS
S-8R	STAIRCASE SECTIONS AND DETAILS
XS-1R	SPILLWAY CROSS SECTIONS STATIONS 1+20 TO 1+60
XS-2R	SPILLWAY CROSS SECTIONS STATIONS 1+65 TO 2+00
M-1R	MECHANICAL BUILDING PLAN, ELEVATIONS AND DETAILS
M-2R	MECHANICAL BUILDING LAYOUT
M-3R	MECHANICAL BUILDING SECTIONS AND MATERIALS DESCRIPTION
M-4R	AIR LINE DETAILS DAM PENETRATION
M-5R	FACE OF DAM CONDUIT LAYOUT AND DETAILS
M-6R	EXISTING DAM SECTION AND DEMOLITION
M-7R	INTAKE SECTIONS AND DETAILS
M-8R	OUTLET WORKS DEMOLITION DETAILS AND LIMITS
M-9R	NEW PIPING PLAN
M-10R	MISCELLANEOUS DETAILS
E-1	MECHANICAL BUILDING LIGHTING & POWER PLANS
E-2	ELECTRICAL ONE-LINE DIAGRAM
E-3	ELECTRICAL SCHEDULES AND LEGEND

ABBREVIATIONS

ASS'Y	ASSEMBLY	N.T.S.	NOT TO SCALE
AVV	AIR/VACUUM VALVE	O.C.	ON CENTER
BM	BENCH MARK	PCP	PLANT CONTROL PANEL
BTM	BOTTOM	PE	PLAIN END
BFV	BUTTERFLY VALVE	PSI	POUNDS PER SQUARE INCH
CONC.	CONCRETE	PVC	POLYVINYL CHLORIDE PIPE
D.I.P.	DUCTILE IRON PIPE	PWR	UNDER GROUND POWER
DIA.	DIAMETER	RED'R	REDUCER
E	EASTING	R/W	RIGHT OF WAY
ELEV.	ELEVATION	REST.	RESTORATION
EXIST.	EXISTING	RT	RIGHT
FLG.	FLANGE	SCH	SCHEDULE
FT	FEET	SP	SLUDGE PUMP
GAL	GALLON	SR	SHORT RADIUS
GPD	GALLONS PER DAY	SURF.	SURFACE
GPH	GALLONS PER HOUR	TEL	UNDER GROUND TELEPHONE
GPM	GALLONS PER MINUTE	TYP.	TYPICAL
G.S.P.	GALVENIZED STEEL PIPE	V	VOLT
HP	HORSEPOWER	W	WATER
LF	LINEAL FEET	W/	WITH
LR	LONG RADIUS	W.S.	WELDED STEEL
MCC	MOTOR CONTROL CENTER	WTP	WATER TREATMENT PLANT
N	NORTHING	X-ING	CROSSING
NPT	NATIONAL PIPE THREAD		

RECORD DRAWING
SEPTEMBER 2006

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

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● Project No. 15M424.117 ● G2 LEGEND.DWG ● Date JULY 2005 ● Designed KRJ ● Drawn RDH ● Checked RCR ● Approved RCR

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SHEET INDEX, LEGEND, AND ABBREVIATIONS

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G-2R

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HKM SURVEY CONTROL POINTS

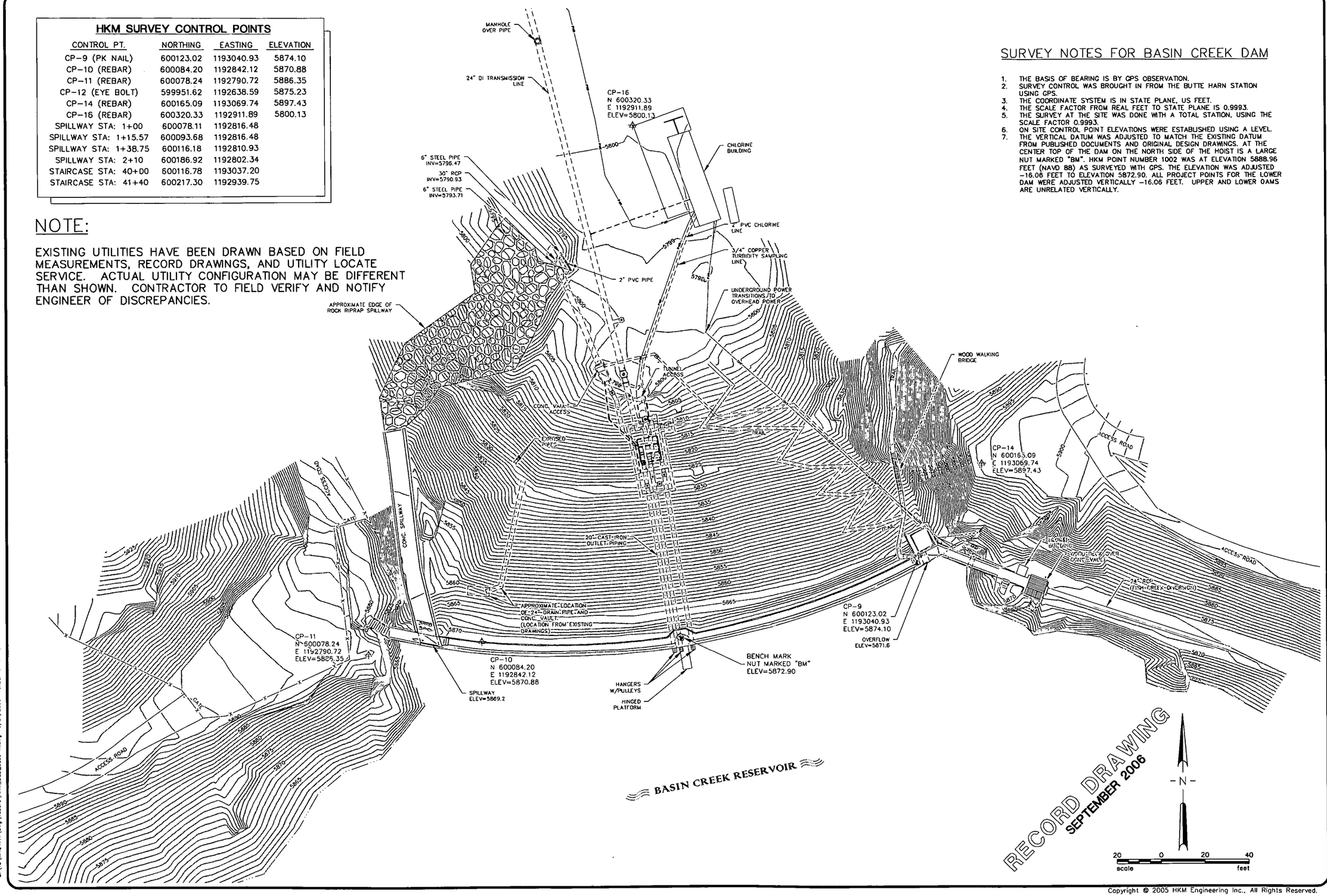
CONTROL PT.	NORTHING	EASTING	ELEVATION
CP-9 (PK NAIL)	600123.02	1193040.93	5874.10
CP-10 (REBAR)	600084.20	1192842.12	5870.88
CP-11 (REBAR)	600078.24	1192790.72	5886.35
CP-12 (EYE BOLT)	599951.62	1192638.59	5875.23
CP-14 (REBAR)	600165.09	1193069.74	5897.43
CP-16 (REBAR)	600320.33	1192911.89	5800.13
SPILLWAY STA: 1+00	600078.11	1192816.48	
SPILLWAY STA: 1+15.57	600093.68	1192816.48	
SPILLWAY STA: 1+38.75	600116.18	1192810.93	
SPILLWAY STA: 2+10	600186.92	1192802.34	
STAIRCASE STA: 40+00	600116.78	1193037.20	
STAIRCASE STA: 41+40	600217.30	1192939.75	

NOTE:

EXISTING UTILITIES HAVE BEEN DRAWN BASED ON FIELD MEASUREMENTS, RECORD DRAWINGS, AND UTILITY LOCATE SERVICE. ACTUAL UTILITY CONFIGURATION MAY BE DIFFERENT THAN SHOWN. CONTRACTOR TO FIELD VERIFY AND NOTIFY ENGINEER OF DISCREPANCIES.

SURVEY NOTES FOR BASIN CREEK DAM

1. THE BASIS OF BEARING IS BY GPS OBSERVATION.
2. SURVEY CONTROL WAS BROUGHT IN FROM THE BUTTE HARN STATION USING GPS.
3. THE COORDINATE SYSTEM IS IN STATE PLANE, US FEET.
4. THE SCALE FACTOR FROM REAL FEET TO STATE PLANE IS 0.9993.
5. THE SURVEY AT THE SITE WAS DONE WITH A TOTAL STATION, USING THE SCALE FACTOR 0.9993.
6. ON SITE CONTROL POINT ELEVATIONS WERE ESTABLISHED USING A LEVEL.
7. THE VERTICAL DATUM WAS ADJUSTED TO MATCH THE EXISTING DATUM FROM PUBLISHED DOCUMENTS AND ORIGINAL DESIGN DRAWINGS. AT THE CENTER TOP OF THE DAM ON THE NORTH SIDE OF THE HOIST IS A LARGE NUT MARKED "BM". HKM POINT NUMBER 1002 WAS AT ELEVATION 5888.96 FEET (NAVD 88) AS SURVEYED WITH GPS. THE ELEVATION WAS ADJUSTED -16.06 FEET TO ELEVATION 5872.90. ALL PROJECT POINTS FOR THE LOWER DAM WERE ADJUSTED VERTICALLY -16.06 FEET. UPPER AND LOWER DAMS ARE UNRELATED VERTICALLY.



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1	REC. INFO	RCR	9/21/06

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

EXISTING SITE CONDITIONS

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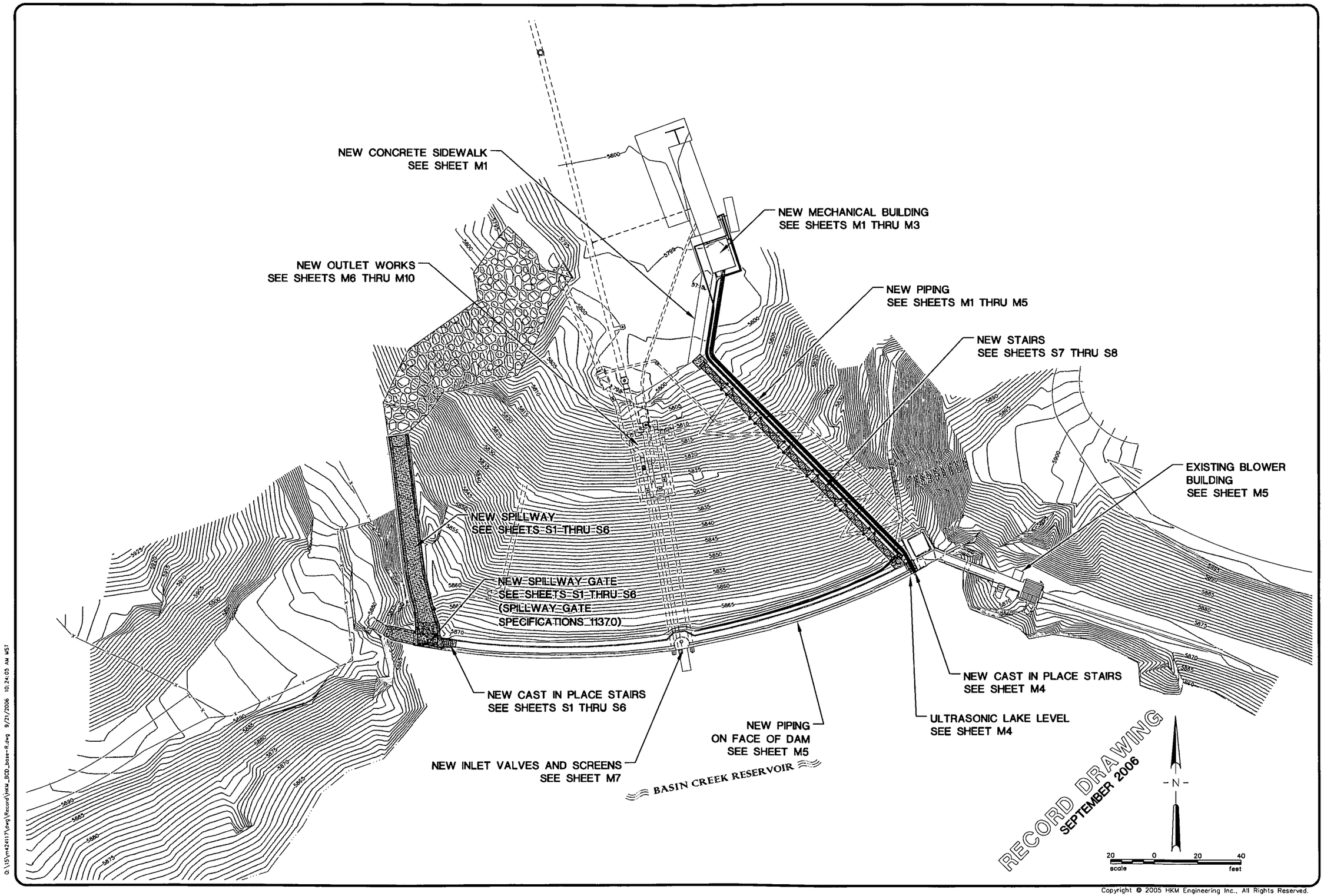

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1	REC. INFO	RCR	9/21/06

WARNING
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SITE PLAN AND SHEET REFERENCES

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GENERAL STRUCTURAL NOTES

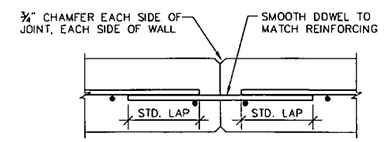
1. APPLICABLE SPECIFICATIONS AND CODES
   CONSTRUCTION AND DESIGN SHALL BE IN ACCORDANCE WITH THE AMERICAN CONCRETE INSTITUTE SPECIFICATIONS AND THE REQUIREMENTS NOTED AS FOLLOWS.
2. CONSTRUCTION LOADS
   PROVIDE TEMPORARY BRACING, SHORING OR OTHER SUPPLEMENTAL SUPPORT DURING CONSTRUCTION AS NECESSARY TO PROTECT THE STRUCTURES FROM EXCESSIVE CONSTRUCTION LOADS.
3. CONCRETE
   a. CONCRETE CONSTRUCTION SHALL CONFORM TO THE AMERICAN CONCRETE INSTITUTE BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE (ACI 318).
   b. DETAILING, FABRICATION AND PLACEMENT OF REINFORCEMENT SHALL CONFORM TO DETAILS AND DETAILING OF CONCRETE REINFORCEMENT (ACI 315).
   c. MATERIALS
      i. STRUCTURAL CAST-IN-PLACE CONCRETE ----- f'c = 4,000 PSI
      ii. REINFORCING BARS ---------- ASTM A615, GRADE 60
   d. ALL BENT REINFORCING BARS SHALL BE SHOP FABRICATED ONLY. REBENDING OR WELDING OF REINFORCEMENT SHALL NOT BE PERMITTED UNLESS AUTHORIZED BY ENGINEER.
   e. END HOOKS IN REINFORCING BARS, SHOWN ON THE DRAWINGS BUT NOT DIMENSIONED, SHALL CONFORM TO ACI 318.
   f. CONCRETE COVER OVER REINFORCEMENT SHALL BE 2" CLEAR, EXCEPT CONCRETE PLACED AGAINST AND PERMENENTLY IN CONTACT WITH EARTH SHALL BE 3" CLEAR.
   g. REINFORCEMENT SPLICES NOT PERMITTED EXCEPT AS DETAILED OR AUTHORIZED BY ENGINEER. LAP REINFORCING BARS THE FOLLOWING MINIMUMS AT ALL SPLICES, CORNERS AND INTERSECTIONS, UNLESS OTHERWISE INDICATED. TOP BARS ARE HORIZONTAL BARS WITH MORE THAN 12" OF CONCRETE CAST BELOW THE BAR.

BAR SIZE	REG. BARS	TOP BARS
#3	1'-3"	1'-7"
#4	1'-7"	2'-1"
#5	2'-0"	2'-7"
#6	2'-5"	3'-1"
#7	3'-6"	4'-6"
#8	4'-0"	5'-2"
#9	4'-6"	5'-10"
#10	5'-1"	6'-7"

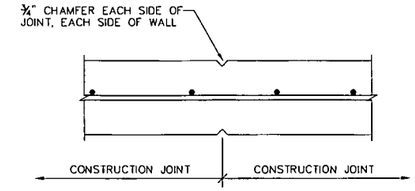
   h. STAGGER ADJACENT REINFORCEMENT LAP SPLICES IN WALLS 18" MINIMUM.
   i. PROVIDE BAR SUPPORTS TO PROPERLY SECURE AND SUPPORT REINFORCING BARS AT POSITIONS SHOWN ON THE DRAWINGS. IN ADDITION TO NORMAL ACCESSORIES PROVIDE #5 STANDEES AT 36" O.C. TO SUPPORT TOP REINFORCEMENT IN BASE SLABS, AND #3 U OR Z SHAPE SPACERS AT 72" O.C. EACH WAY IN WALLS WITH TWO CURTAINS OF REINFORCEMENT.
   j. DOWELS, PIPES AND OTHER INSTALLED MATERIALS AND ACCESSORIES SHALL BE HELD SECURELY IN POSITION DURING CONCRETE PLACEMENT.
   k. REINFORCING BARS AND ACCESSORIES SHALL NOT BE IN CONTACT WITH ANY PIPE, PIPE FLANGE OR METAL PART EMBEDDED IN CONCRETE. PROVIDE 2" CLEARANCE IN ALL CASES UNLESS OTHERWISE INDICATED. NO EMBEDDED ITEM SHALL BE SUSPENDED FROM, SUPPORTED BY, OR BRACED IN PLACE FROM THE STRUCTURAL REINFORCEMENT.
   l. LOCATE CONSTRUCTION JOINTS AT 15'-0" O.C. , WHERE SHOWN ON THE DRAWINGS OR AS AUTHORIZED BY ENGINEER. SLABS, JOISTS AND BEAMS SHALL NOT HAVE JOINTS IN A HORIZONTAL PLANE EXCEPT WHERE DETAILED ON DRAWINGS.
   m. THOROUGHLY CLEAN BY SANDBLASTING ALL BONDED CONSTRUCTION JOINTS PRIOR TO PLACING CONCRETE IN ADJACENT POUR.
   n. BEGIN SPACING OF BARS WHICH PARALLEL CONSTRUCTION AND EXPANSION JOINTS 2" CLEAR FROM EACH SIDE OF JOINT.
   o. UNLESS OTHERWISE SHOWN, PLACE 2-#5 (1 EACH FACE) WITH 2'-0" PROJECTIONS AROUND ALL OPENINGS IN CONCRETE WALLS OR SLABS.
   p. PROVIDE AN ADDITIONAL 100 LINEAL FEET OF #5 REINFORCING BARS FOR USE AS DIRECTED DURING CONSTRUCTION.
   q. CHAMFER ALL EXPOSED CONCRETE EDGES 3/4", UNLESS OTHERWISE INDICATED.
4. STRUCTURAL STEEL
   a. STRUCTURAL STEEL CONSTRUCTION SHALL CONFORM TO THE AMERICAN INSTITUTE OF STEEL CONSTRUCTION SPECIFICATION FOR THE DESIGN, FABRICATION AND ERECTION OF STRUCTURAL STEEL FOR BUILDINGS.
   b. ALL WELDING SHALL CONFORM TO AMERICAN WELDING SOCIETY STRUCTURAL WELDING CODE-STEEL (AWS D1.1), AND SHALL BE PERFORMED BY WELDERS QUALIFIED BY THE APPROPRIATE AWS TEST FOR THE WELDING PERFORMED.
   c. ALL EXPOSED STEEL SHALL HAVE A HOT-DIP ZINC COATING IN ACCORDANCE WITH ASTM A123.
   d. ADHESIVE ANCHORS SHALL BE HILTI HVA ADHESIVE ANCHORS WITH HAS 316 SS RODS OR APPROVED EQUAL.
5. EXISTING CONSTRUCTION
   a. DIMENSIONS, ELEVATIONS AND DETAILS OF EXISTING CONSTRUCTION HAVE BEEN OBTAINED FROM FIELD INVESTIGATIONS AND AS-CONSTRUCTED DOCUMENTS. THE CONTRACTOR SHALL VERIFY ALL EXISTING CONDITIONS NECESSARY TO PROPERLY COORDINATE NEW AND EXISTING CONSTRUCTION, AND SHALL NOTIFY THE ENGINEER OF ALL VARIATIONS IN THE DETAILS, DIMENSIONS AND ELEVATIONS OF EXISTING CONSTRUCTION WITH THAT SHOWN ON THE DRAWINGS.
   b. CLEAN AND PREPARE ALL EXISTING SURFACES WHICH WILL BE IN CONTACT WITH NEW CONSTRUCTION AS INDICATED AND AS ACCEPTABLE TO ENGINEER. APPLY BONDING COMPOUND TO ALL EXISTING CONCRETE SURFACES WHICH WILL BE IN CONTACT WITH NEW CONCRETE IMMEDIATLEY PRIOR TO PLACEMENT.
   c. PROTECT EXISTING MATERIALS FROM DAMAGE DURING CONSTRUCTION.
   d. FURNISH AND INSTALL TEMPORARY SHORING OR BRACING AS NECESSARY TO PROVIDE SUPPORT AND STABILITY FOR EXISTING WALLS AND FRAMING DURING DEMOLITION AND CONSTRUCTION.

GENERAL STRUCTURAL ABBREVIATIONS

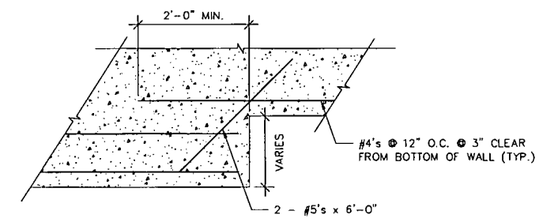
O.C.	ON CENTER
T.O.C.	TOP OF CONCRETE
T.O.F.	TOP OF FOOTING
T.O.S.	TOP OF SLAB
T.O.W.	TOP OF WALL
STD.	STANDARD
TYP.	TYPICAL
MIN.	MINIMUM
SIM.	SIMILAR
REINF.	REINFORCEMENT
SPA.	SPACES
EA.	EACH
EL.	ELEVATION
CLR.	CLEAR



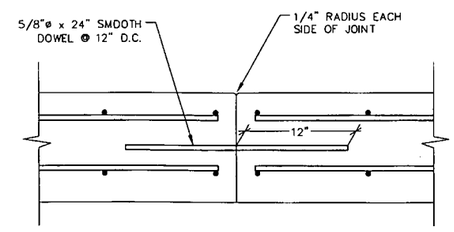
1 / S-1 DETAIL
TYPICAL SPILLWAY WALL CONSTRUCTION JOINT
NOT TO SCALE



2 / S-2 DETAIL
TYPICAL SPILLWAY WALL CONTROL JOINT
NOT TO SCALE

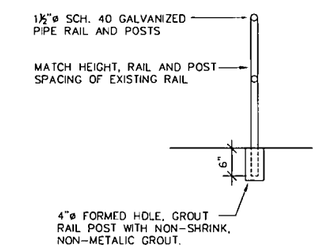


3 / S-1 DETAIL
TYPICAL STEP IN WALL
NOT TO SCALE



NOTE:
FLOOR JOINTS SHALL BE CONSTRUCTED ACROSS THE SPILLWAY AT 15-FOOT SPACING TO MATCH THE SPILLWAY WALL JOINTS.

5 / S-1 DETAIL
TYPICAL SPILLWAY FLOOR CONSTRUCTION JOINT
NOT TO SCALE



4 / S-1 DETAIL
TYPICAL PIPE RAILING
NOT TO SCALE

RECORD DRAWING
SEPTEMBER 2006

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
0 ½ 1
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

GENERAL STRUCTURAL NOTES AND STANDARD DETAILS

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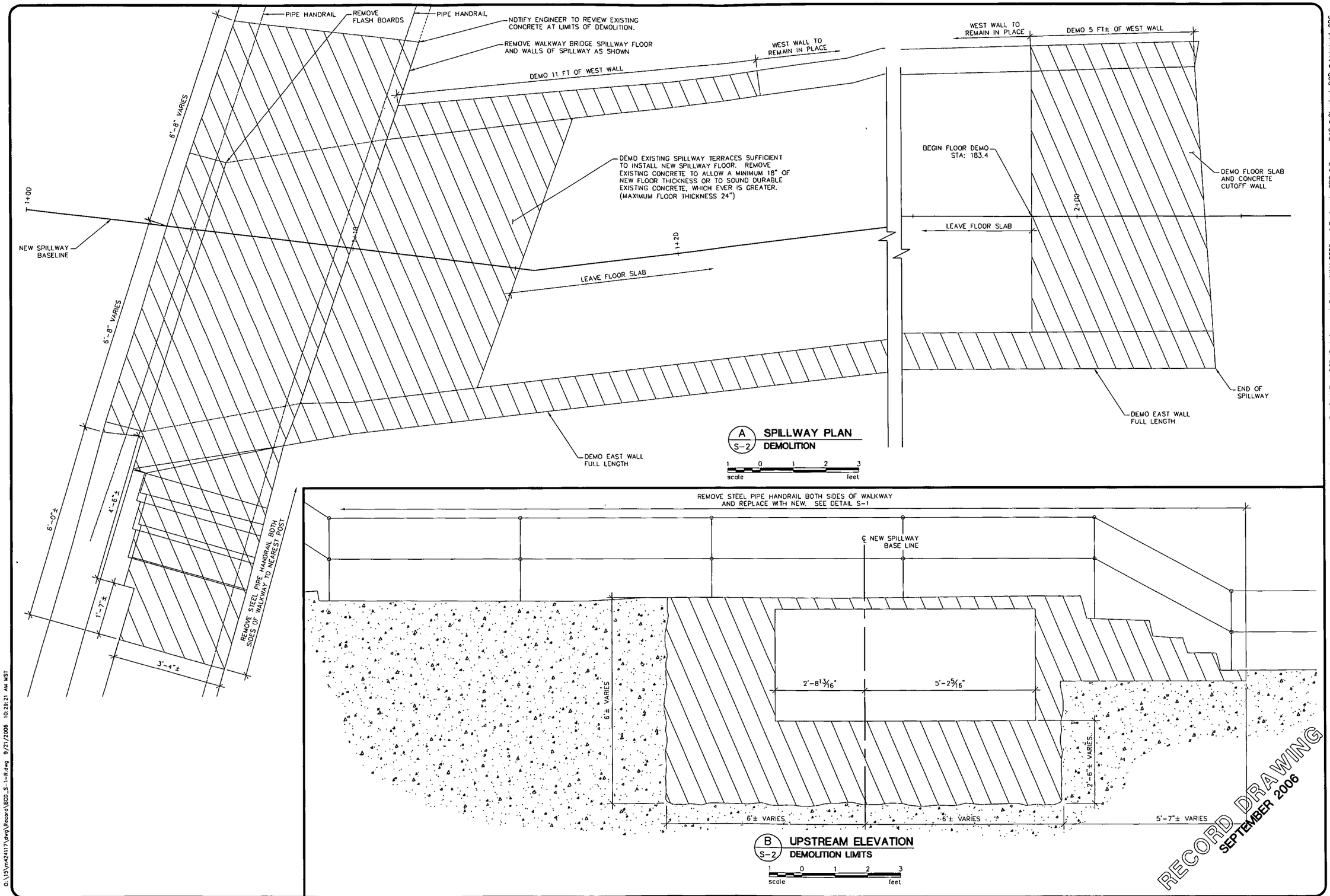

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1	REC. INFO	RCR	9/21/06

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY PLAN VIEW DEMOLITION DETAILS

● Project No. 15M424.117 ● BCD_S-1.dwg ● Date JULY 2005 ● Designed CRS ● Drawn DAS ● Checked RCR ● Approved CRS

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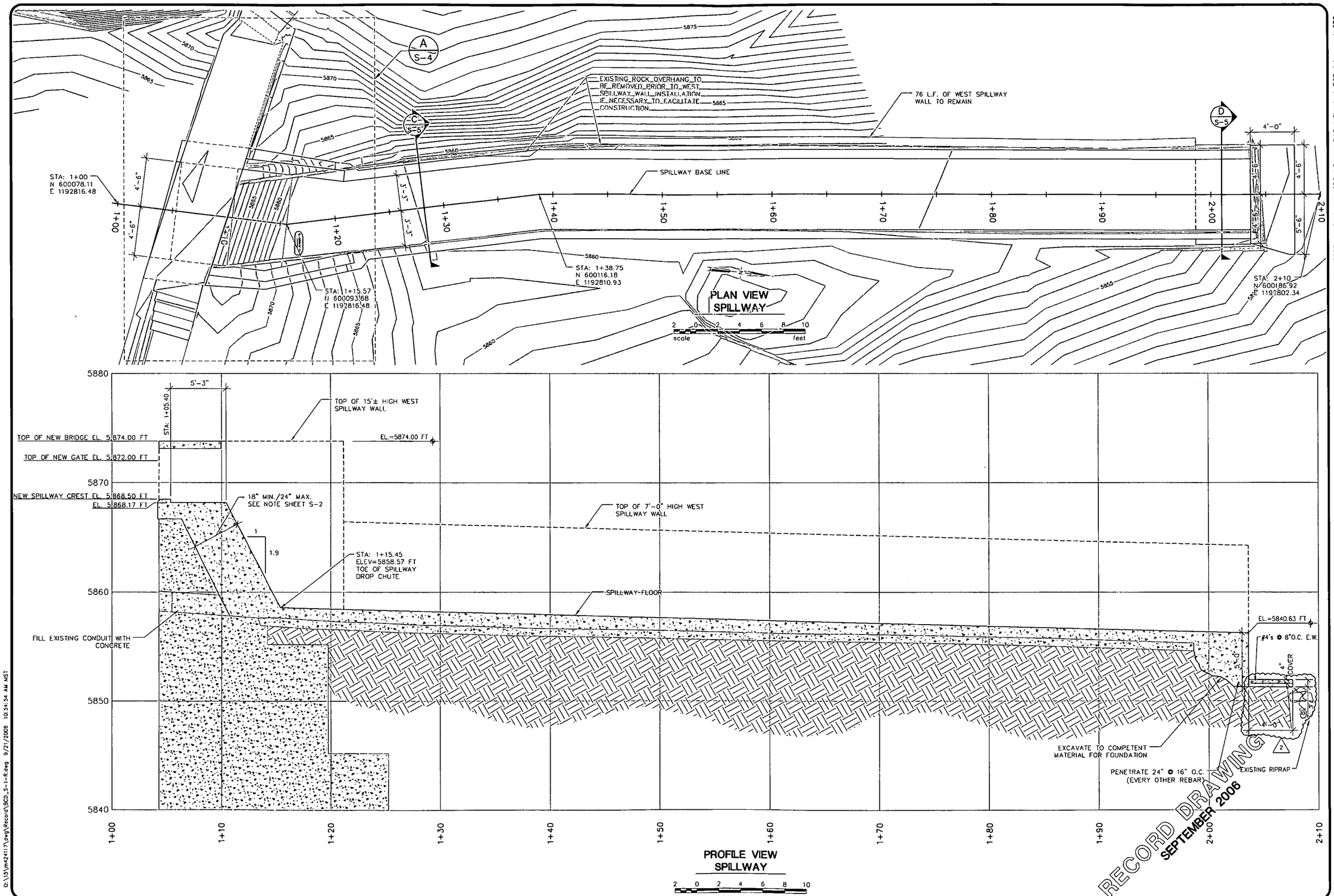

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2	REC. INFO	RCR	9/21/06
1	CO-1	RCR	9/26/05

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE PLAN AND PROFILE

• Project No. 15M424.117 • BCD_S-1.dwg • Date JULY 2005 • Designed CRS • Drawn DAS • Checked RCR • Approved CRS

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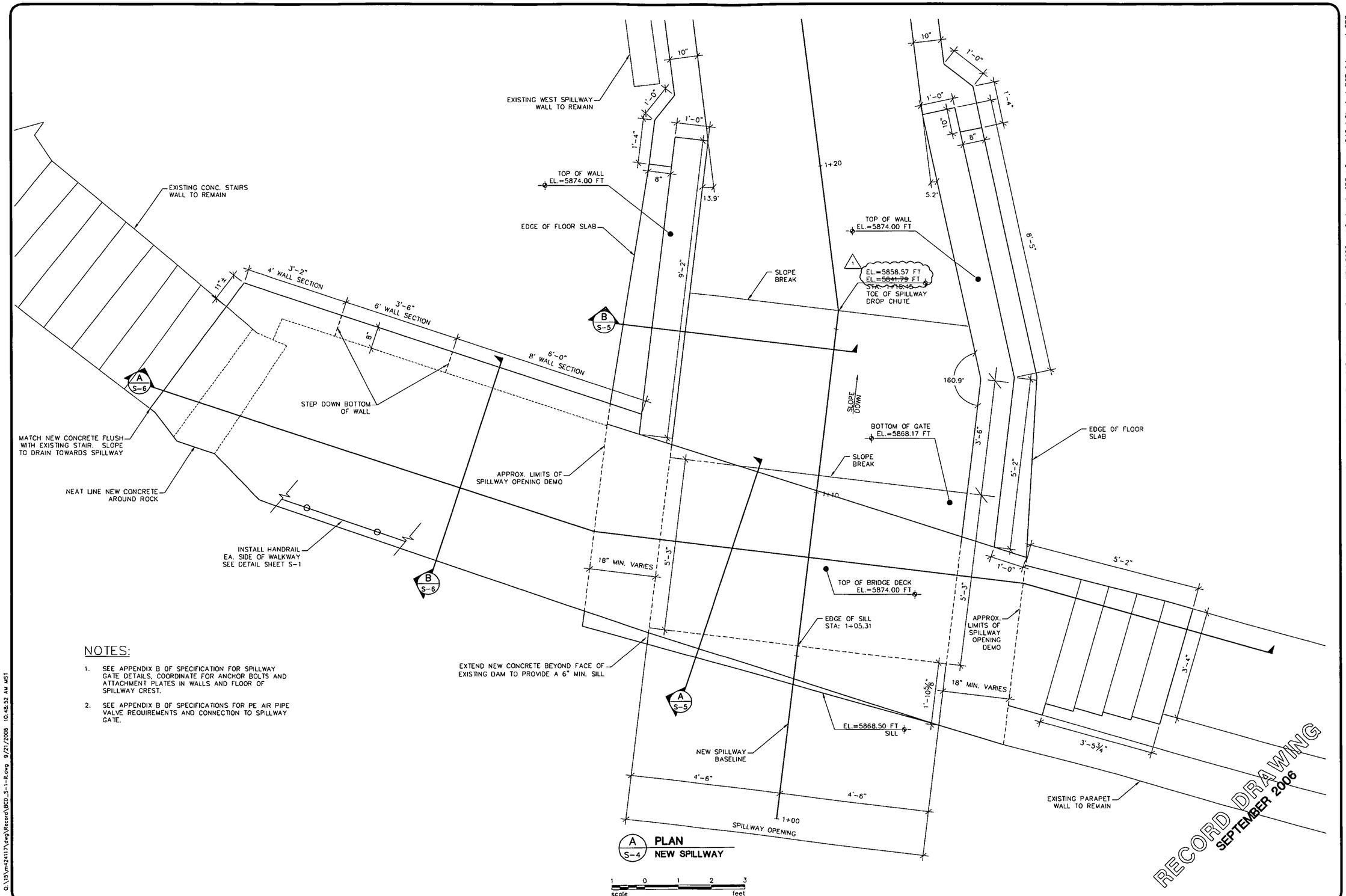

NOTES:

1. SEE APPENDIX B OF SPECIFICATION FOR SPILLWAY GATE DETAILS, COORDINATE FOR ANCHOR BOLTS AND ATTACHMENT PLATES IN WALLS AND FLOOR OF SPILLWAY CREST.
2. SEE APPENDIX B OF SPECIFICATIONS FOR PE AIR PIPE VALVE REQUIREMENTS AND CONNECTION TO SPILLWAY GATE.

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE PLAN

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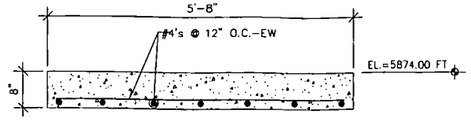

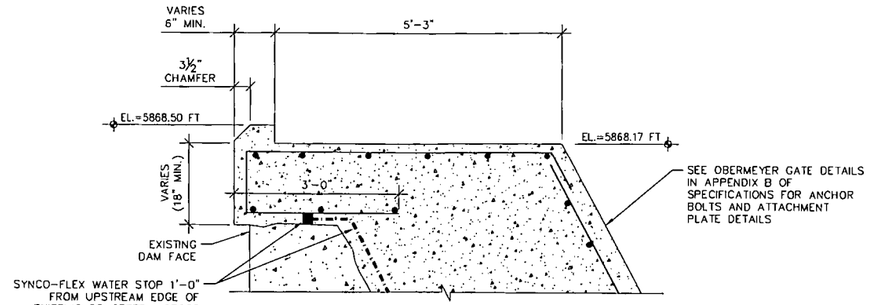

A / S-5 **SECTION**
BRIDGE

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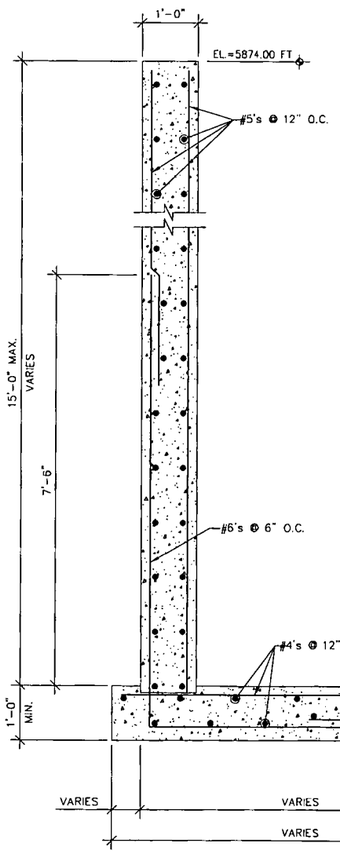
scale feet



B / S-5 **SECTION**
SPILLWAY - STA: 1+29 TO STA: 1+20.9

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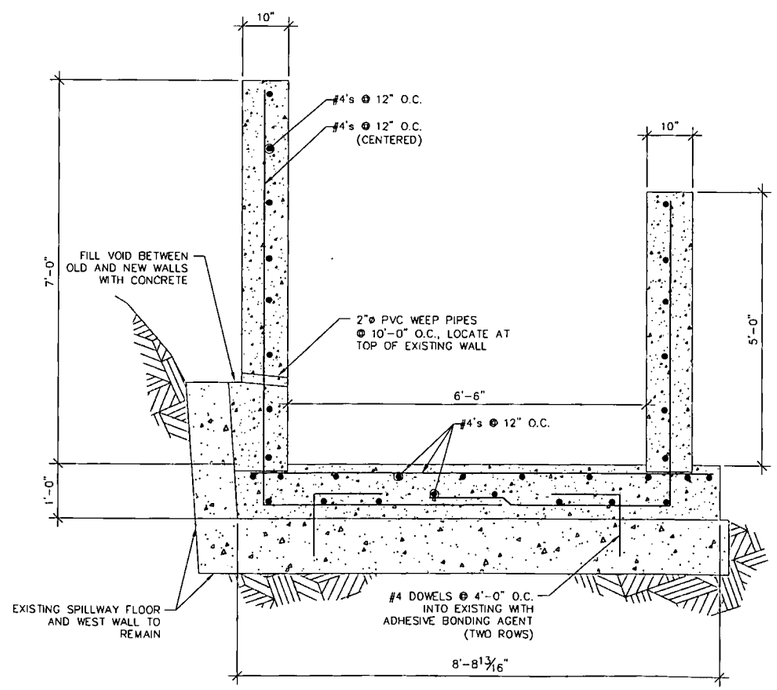
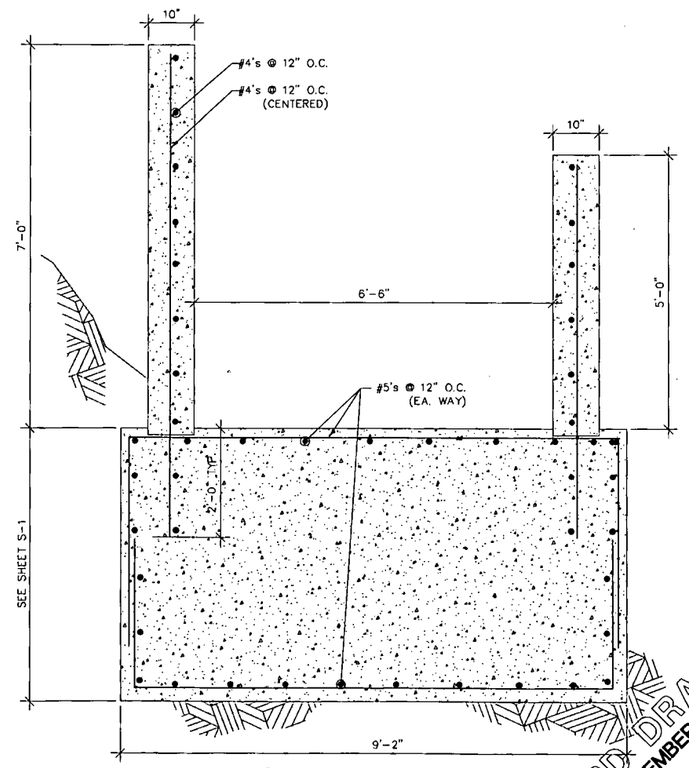
scale feet



C / S-5 **SECTION**
TYPICAL SPILLWAY - STA: 1+20.9 TO STA: 1+98.6

1 0 1 2 3
scale feet



D / S-5 **SECTION**
TYPICAL SPILLWAY - STA: 1+98.6 TO STA: 2+03.6

1 0 1 2 3
scale feet

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE SECTIONS

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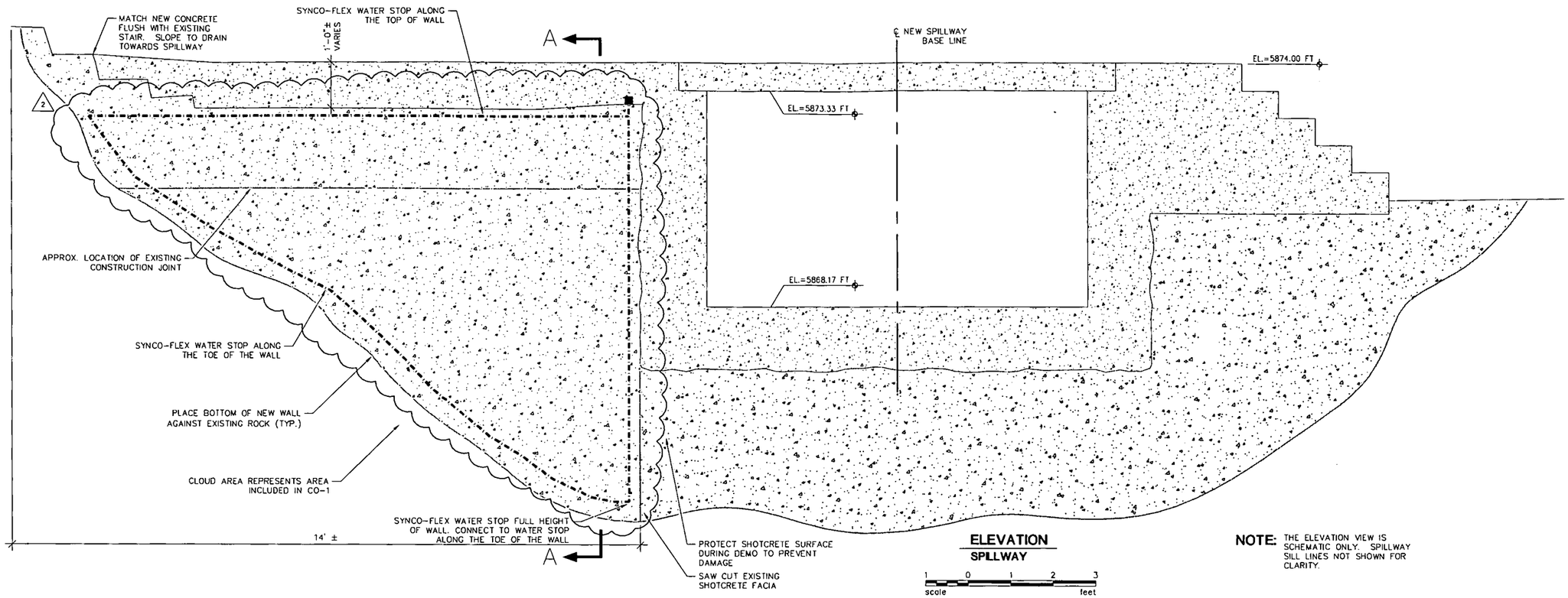
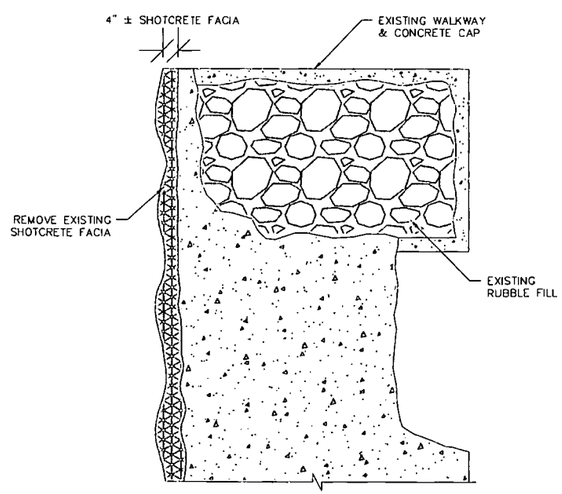
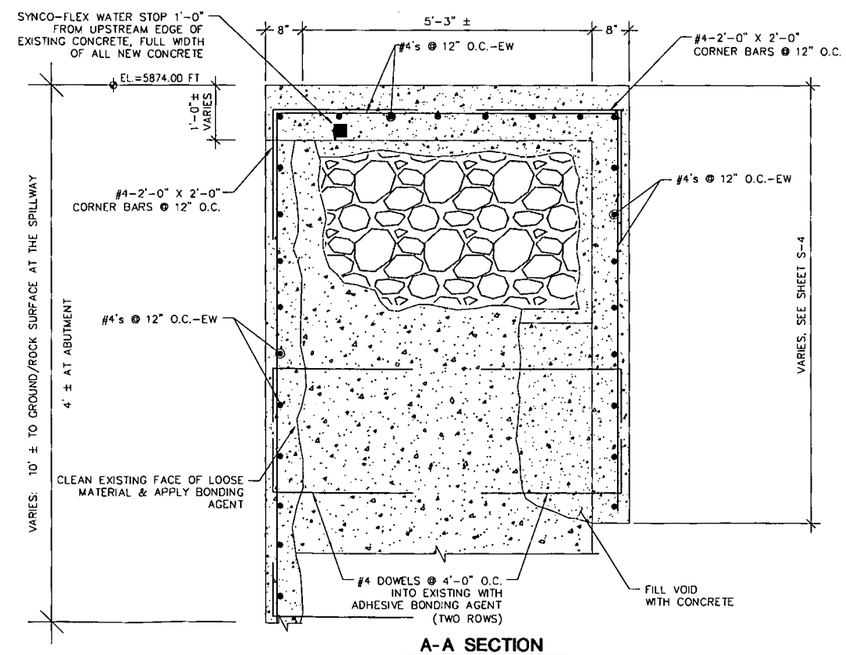


ELEVATION
SPILLWAY

NOTE: THE ELEVATION VIEW IS SCHEMATIC ONLY. SPILLWAY SILL LINES NOT SHOWN FOR CLARITY.



A-A SECTION
WALKWAY - EXISTING & DEMO



A-A SECTION
WALKWAY - NEW

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE DEMOLITION AND SECTIONS

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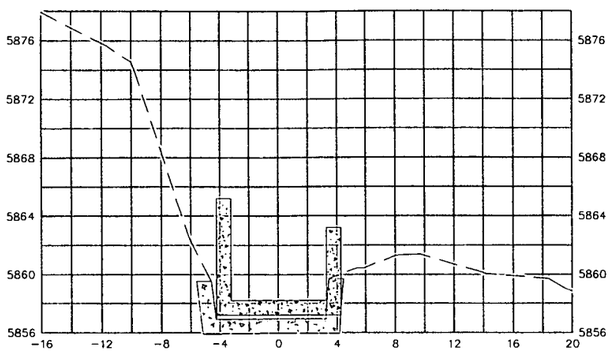
1+30



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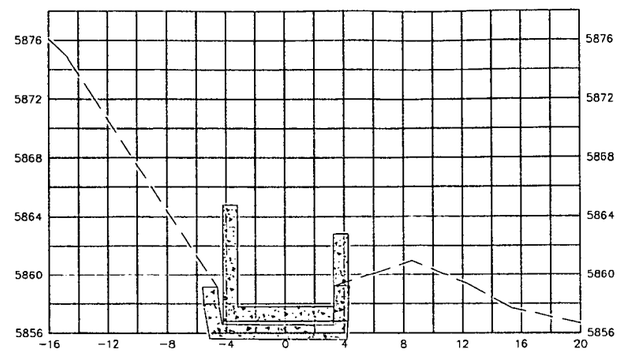

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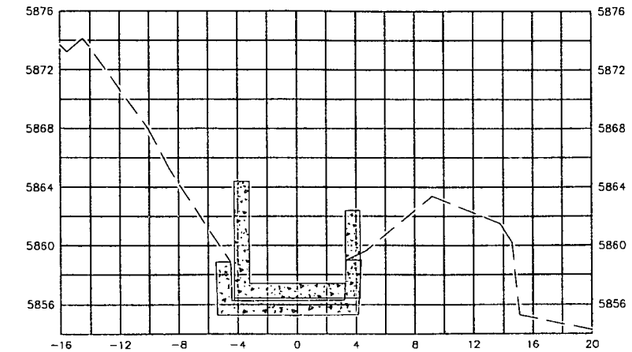

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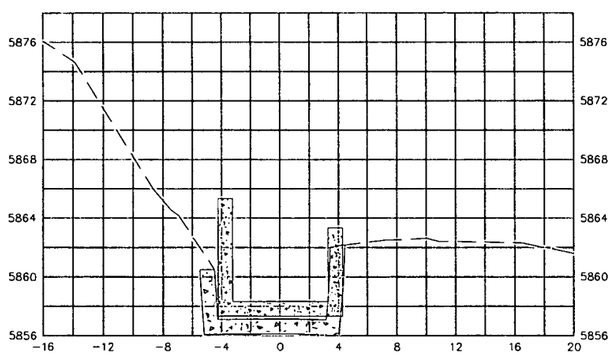

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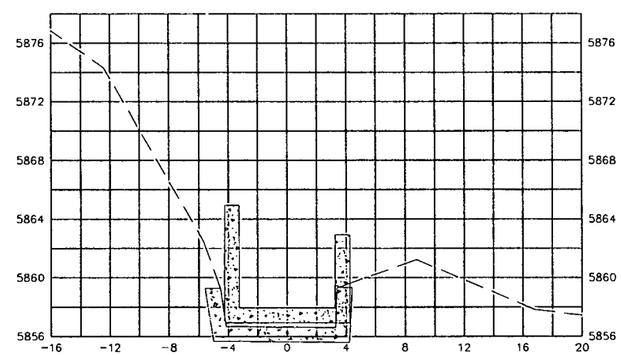

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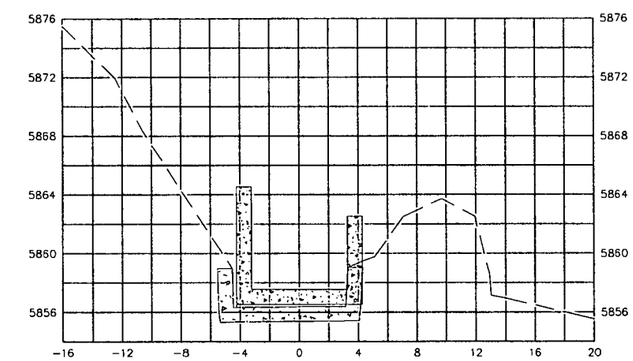

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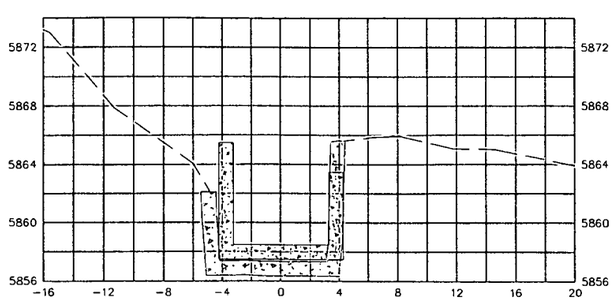

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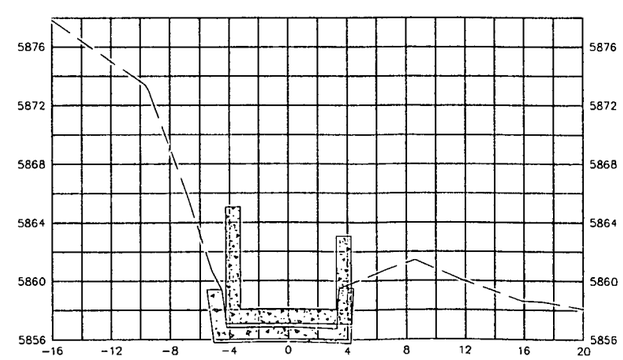

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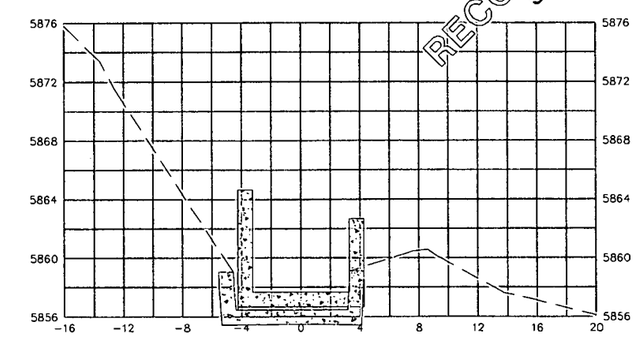

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY CROSS SECTIONS
STATIONS 1+20 TO 1+60

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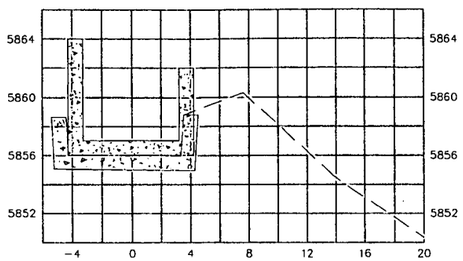
1+75



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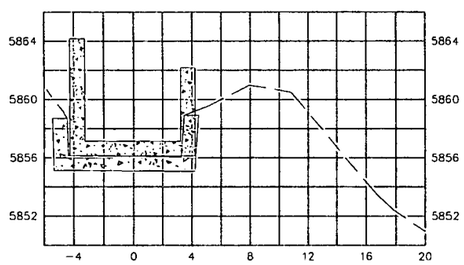

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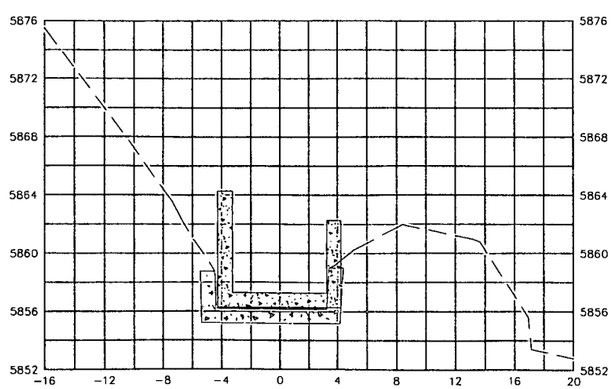

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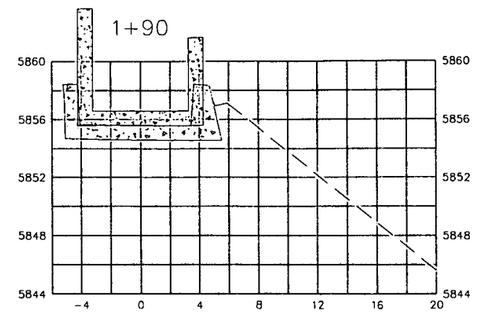

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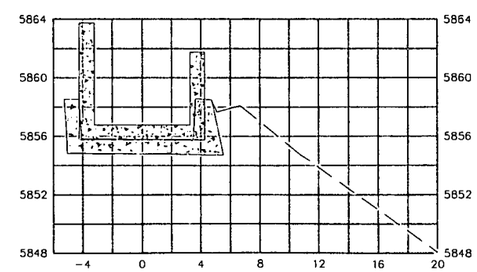

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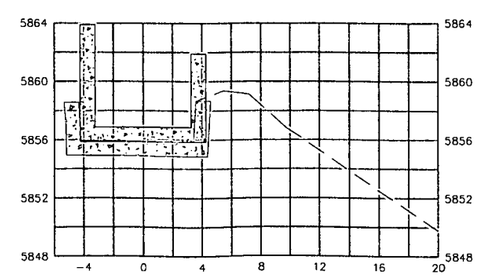
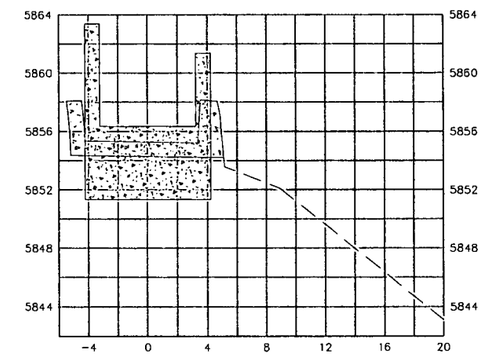


2+00



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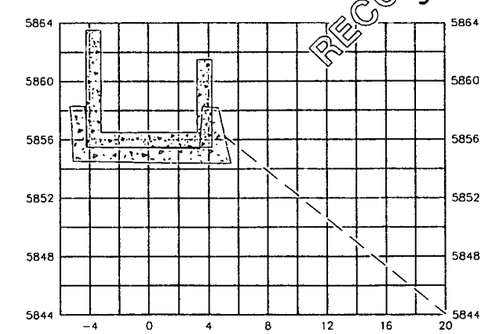

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY CROSS SECTIONS
STATIONS 1+65 TO 2+00

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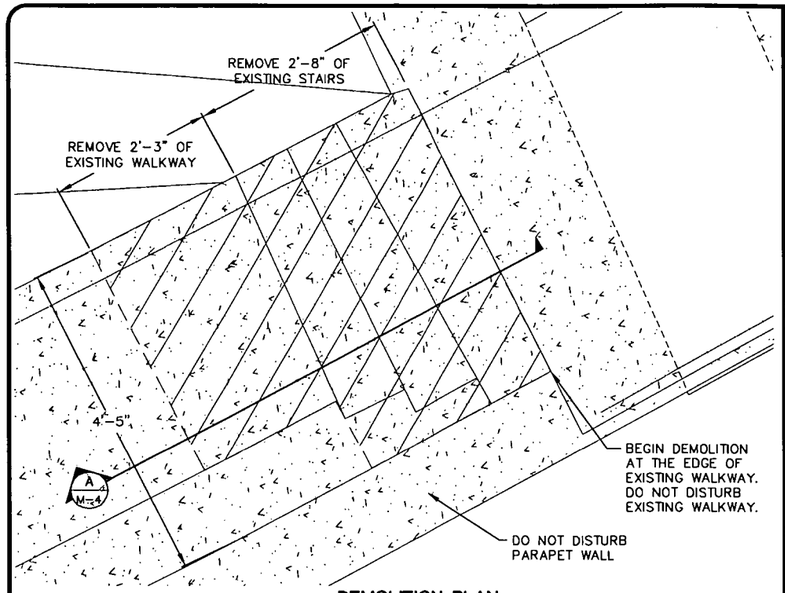
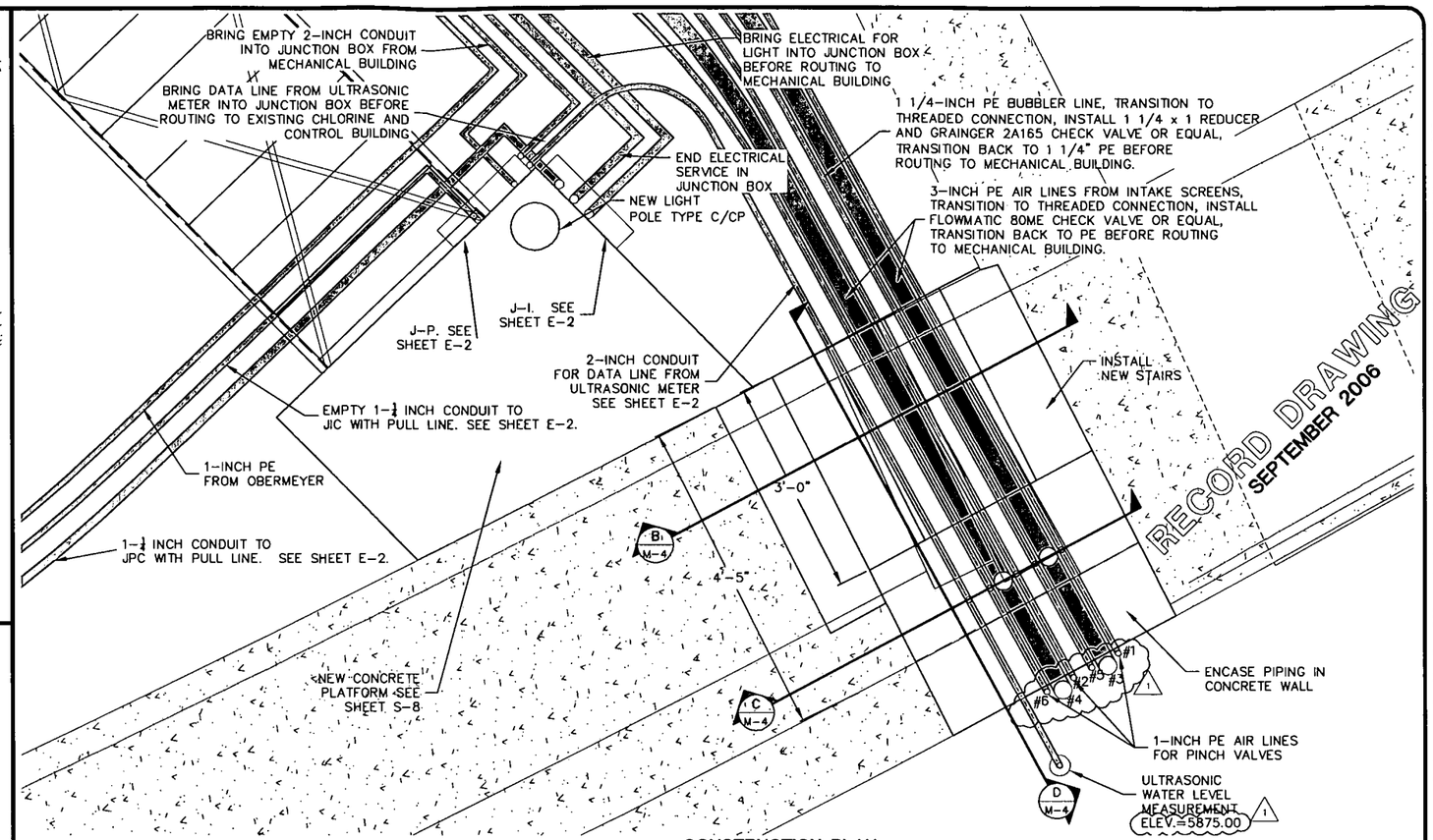
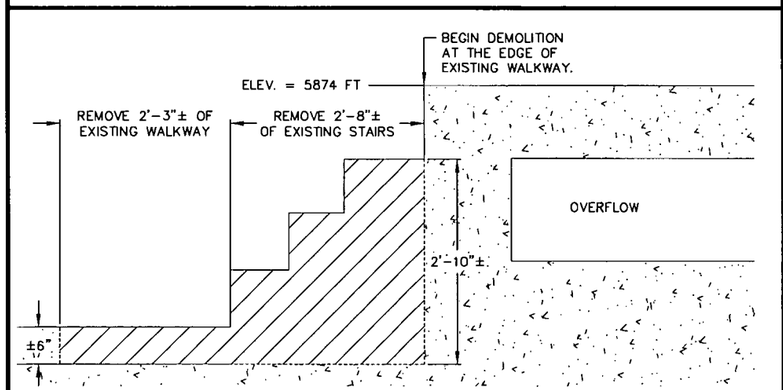


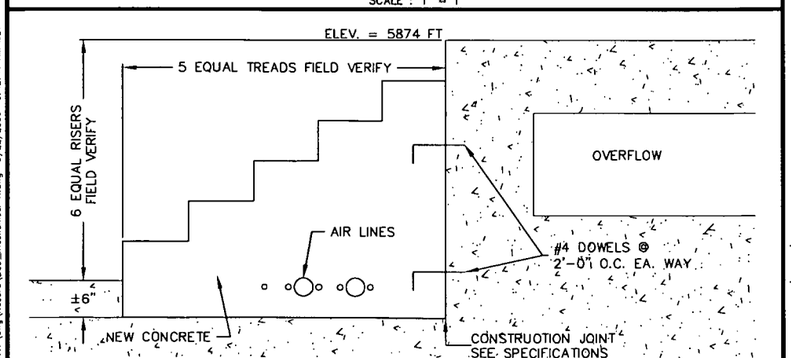
DEMOLITION PLAN
SCALE : 1" = 1'



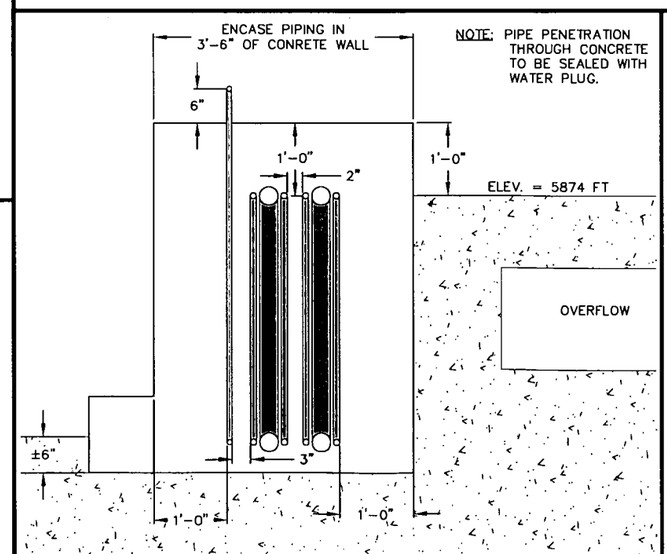
CONSTRUCTION PLAN
SCALE : 1" = 1'



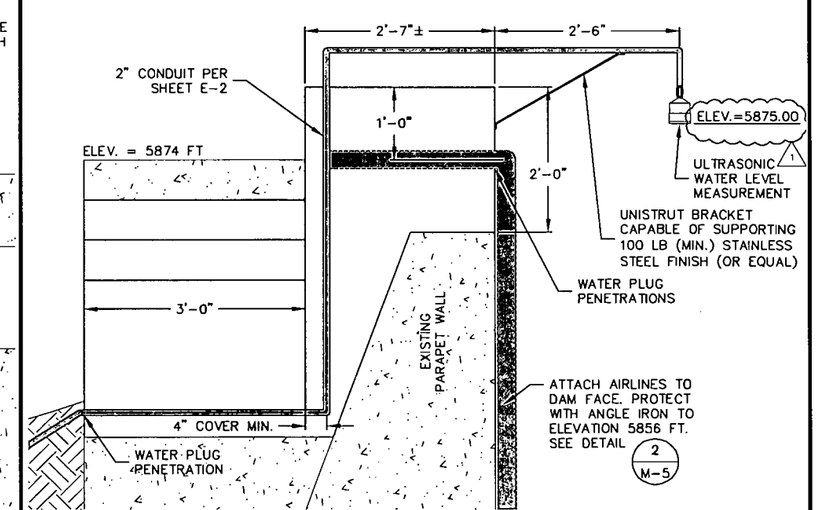
A M-4 SECTION
DEMOLITION
SCALE : 1" = 1'



B M-4 SECTION
NEW STAIR CONSTRUCTION
SCALE : 1" = 1'



C M-4 SECTION
NEW WALL CONSTRUCTION
SCALE : 1" = 1'



D M-4 SECTION
NEW CONDUIT
SCALE : 1" = 1'

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

AIR LINE DETAILS
DAM PENETRATION

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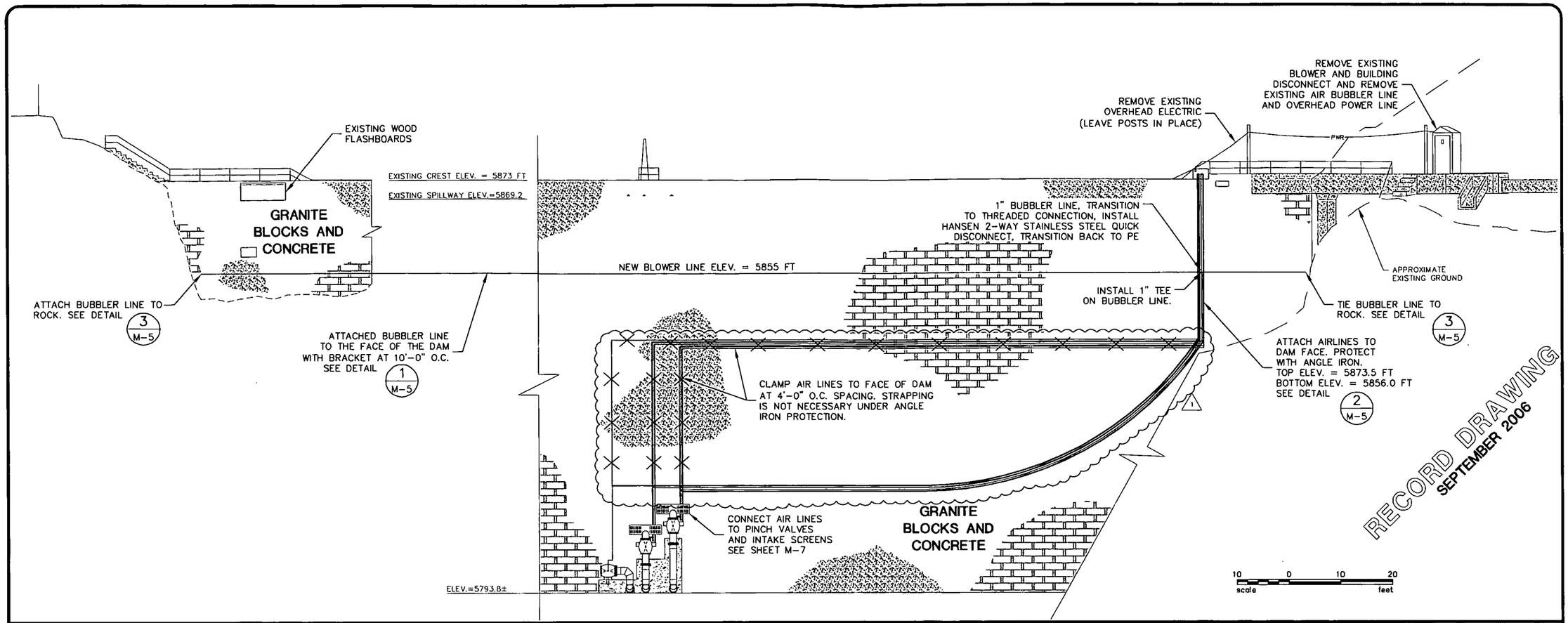
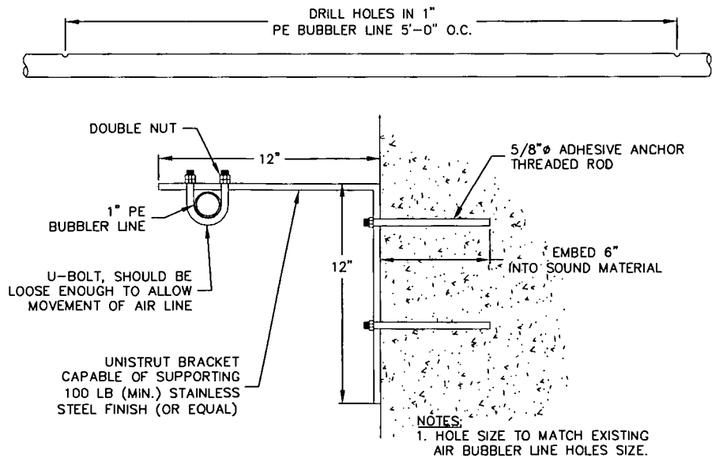
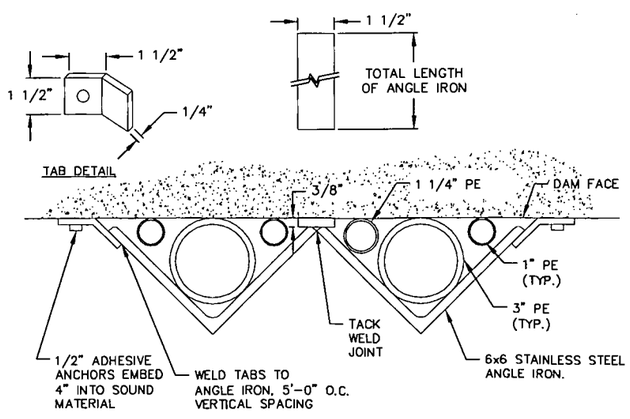


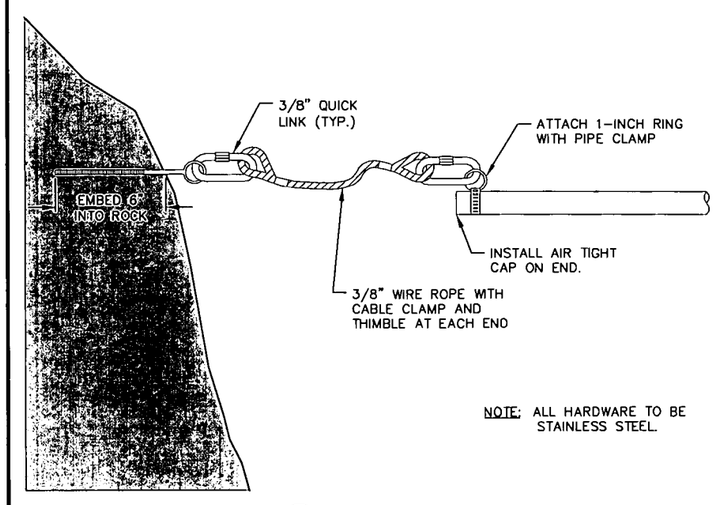


NOTES:
1. HOLE SIZE TO MATCH EXISTING AIR BUBBLER LINE HOLES SIZE.
2. SPACE HDPE SUPPORTS AT 10'-0" O.C.

1/M-5 DETAIL
BUBBLER LINE ATTACHMENT
SCALE : NOT TO SCALE



2/M-5 DETAIL
ANGLE IRON PROTECTION
SCALE : NOT TO SCALE



NOTE: ALL HARDWARE TO BE STAINLESS STEEL.

3/M-5 DETAIL
BUBBLER LINE END
SCALE : NOT TO SCALE

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
D 1/2
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

Project No. 15M424.117 ● BCD_mechanical.dwg ● Date JULY 2005 ● Designed SMJ ● Drawn SMJ ● Checked RCR ● Approved RCR

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

FACE OF DAM CONDUIT LAYOUT AND DETAILS

RUSSELL CHRISTIAN RETTIGH 15740PE PROFESSIONAL ENGINEER MONTANA

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M-5R

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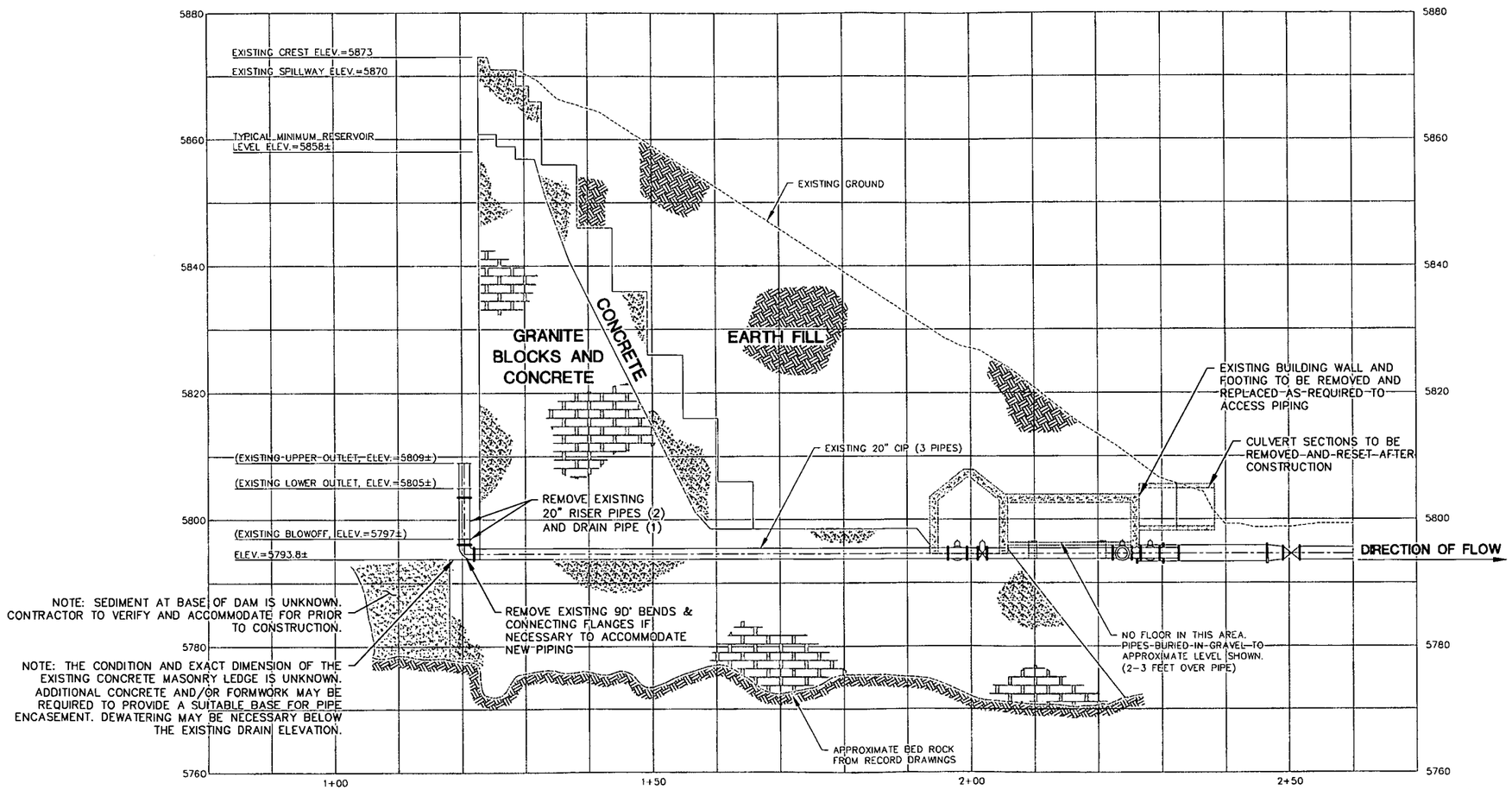

EXISTING RESERVOIR INTAKE SECTION

10 0 10 20
scale feet

RECORD DRAWING
SEPTEMBER 2006

● Project No. 15M424.117 ● EX-2.dwg ● Date JULY 2005 ● Designed KRJ ● Drawn RJA ● Checked PAS ● Approved RCR

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
0 ½ 1
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

EXISTING DAM SECTION AND DEMOLITION

MONTANA KEVIN R. JOHNSON 14863 PE PROFESSIONAL ENGINEER

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M-6R

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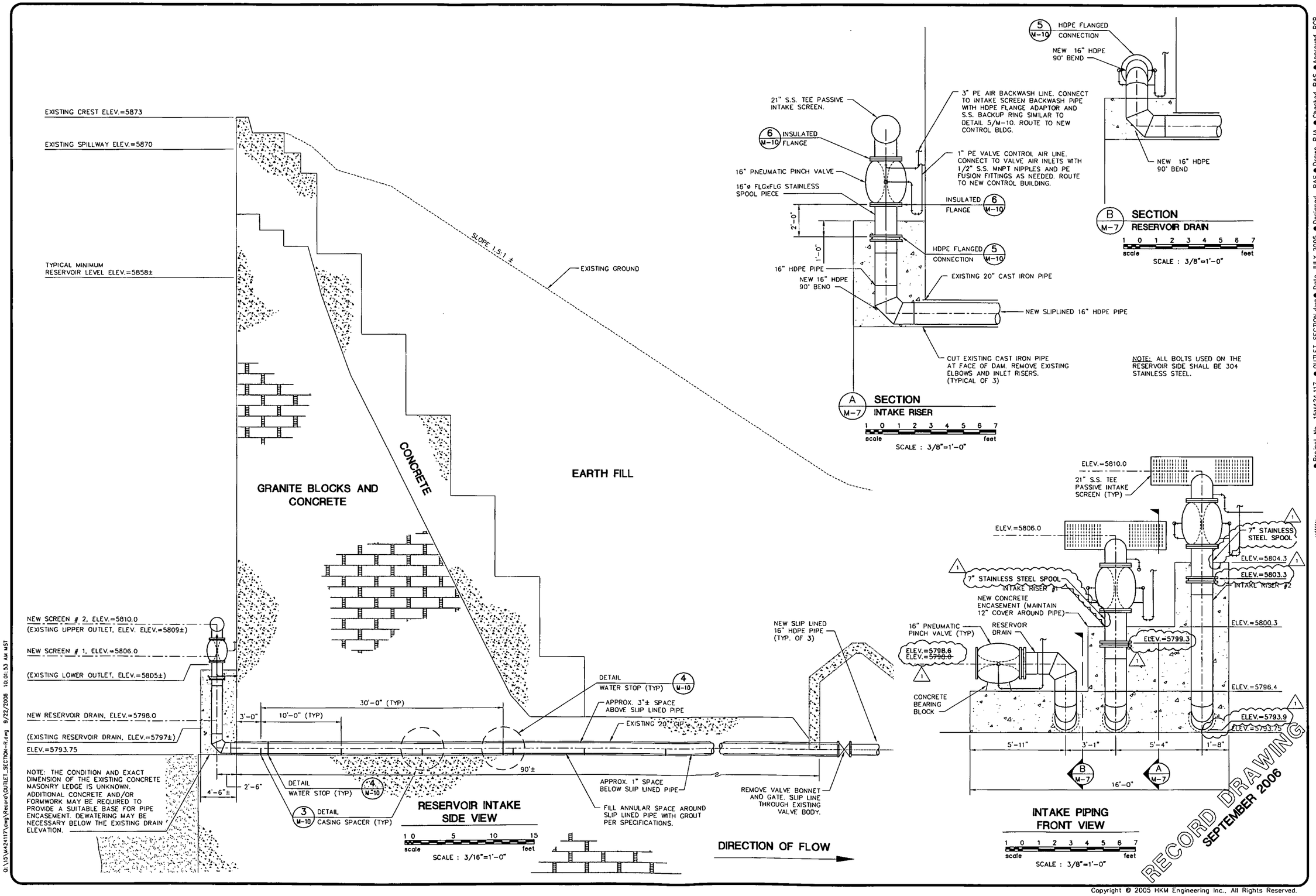

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING 0 ½ 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

INTAKE SECTIONS AND DETAILS

● Project No. 15M424.117 ● OUTLET_SECTION.dwg ● Date JULY 2005 ● Designed PAS ● Drawn RJA ● Checked PAS ● Approved RCR

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M-7R

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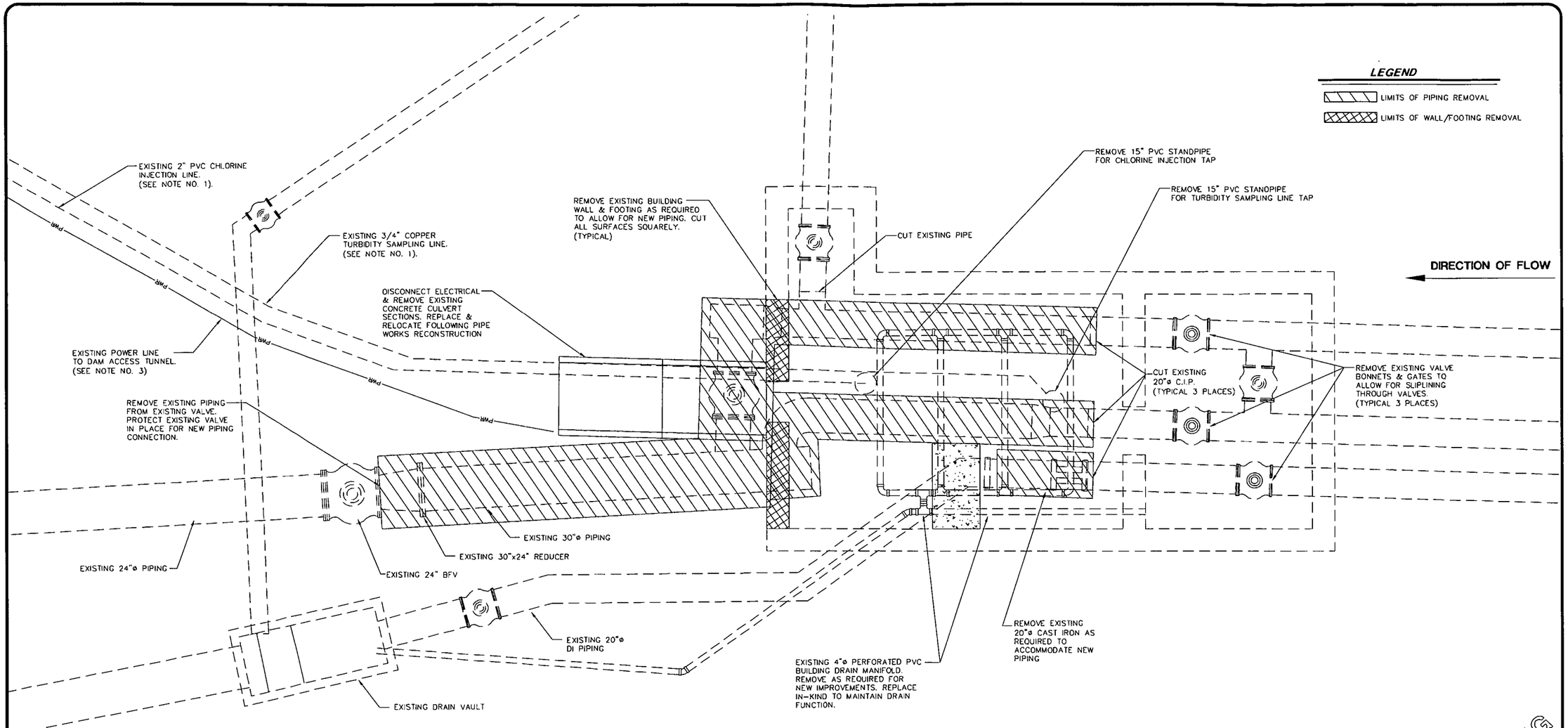

NOTES:

1. REMOVE AND REPLACE AS INDICATED IN THE NEW CONSTRUCTION DRAWINGS. CONTRACTOR TO COORDINATE WITH BUTTE-SILVER BOW PRIOR TO REMOVAL OF EXISTING LINES.

2. EXISTING UTILITIES HAVE BEEN DRAWN BASED ON FIELD MEASUREMENTS, RECORD DRAWINGS, AND UTILITY LOCATE SERVICE. ACTUAL UTILITY CONFIGURATION MAY BE DIFFERENT THAN SHOWN. CONTRACTOR TO FIELD VERIFY AND NOTIFY ENGINEER OF DISCREPANCIES.

3. EXTEND, RELOCATE, OR REROUTE THE EXISTING CIRCUITS AS REQUIRED BY THE CONSTRUCTION. MATCH EXISTING CONDUIT AND CONDUCTOR SIZE AND TYPE FOR ANY REPLACEMENTS. CIRCUIT SPLICES SHALL BE KEPT TO A MINIMUM, AND SHALL BE ACCOMPLISHED ABOVE GRADE WHEREVER POSSIBLE. ANY REQUIRED SPLICES SHALL BE IN JUNCTION BOXES, WITH COPPER COMPRESSION CONNECTORS, AND SHALL BE WATERPROOF.

RECORD DRAWING
SEPTEMBER 2006

3 0 3 6
scale feet

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
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● Project No. 15M424.117 ● DEM-1.DWG ● Date JULY 2005 ● Designed KRJ ● Drawn RDH ● Checked RCR ● Approved RCR

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

OUTLET WORKS
DEMOLITION DETAILS AND LIMITS

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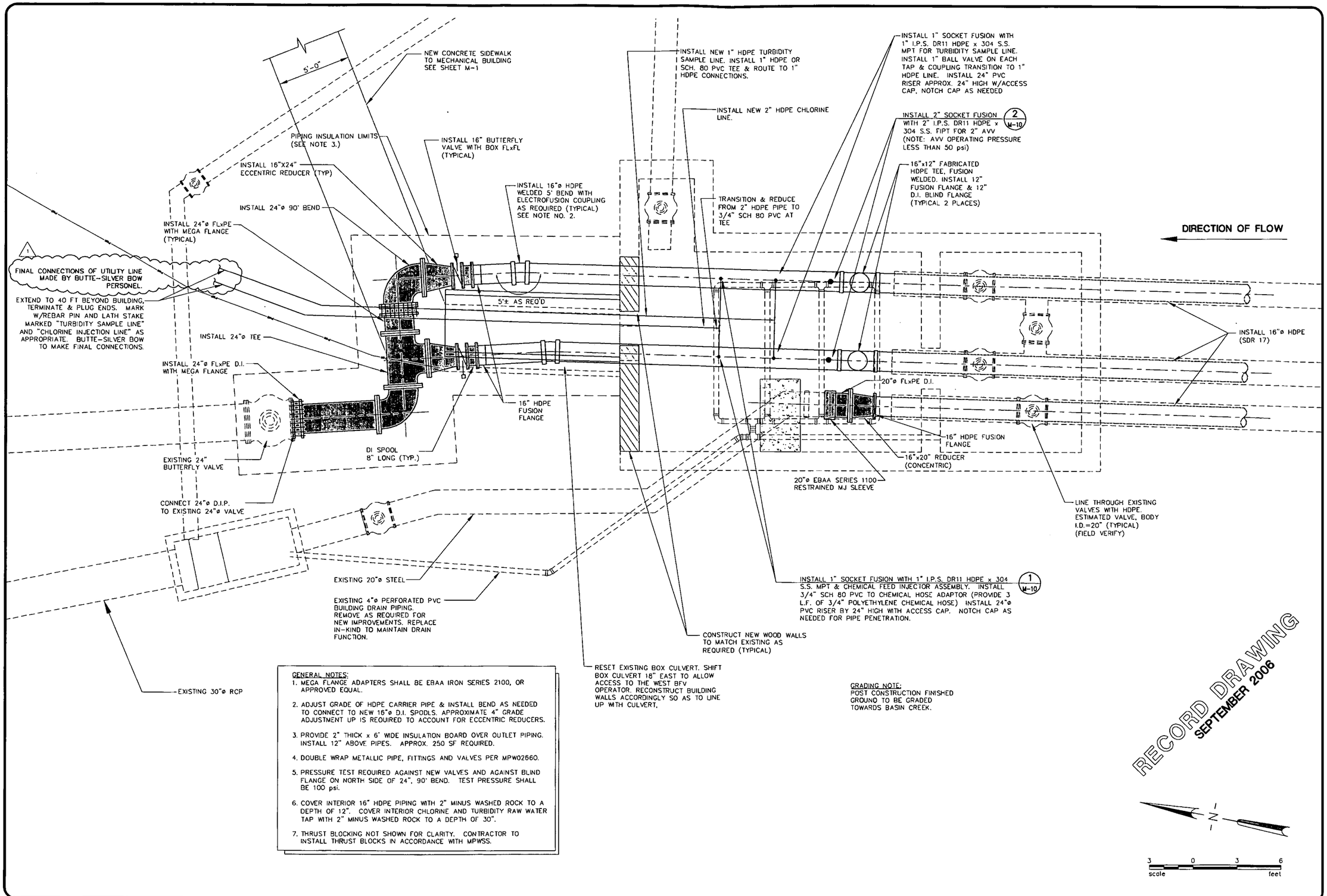

GENERAL NOTES:

1. MEGA FLANGE ADAPTERS SHALL BE EBAA IRON SERIES 2100, OR APPROVED EQUAL.
2. ADJUST GRADE OF HDPE CARRIER PIPE & INSTALL BEND AS NEEDED TO CONNECT TO NEW 16"ø D.I. SPOOLS. APPROXIMATE 4" GRADE ADJUSTMENT UP IS REQUIRED TO ACCOUNT FOR ECCENTRIC REDUCERS.
3. PROVIDE 2" THICK x 6' WIDE INSULATION BOARD OVER OUTLET PIPING. INSTALL 12" ABOVE PIPES. APPROX. 250 SF REQUIRED.
4. DOUBLE WRAP METALLIC PIPE, FITTINGS AND VALVES PER MPW02660.
5. PRESSURE TEST REQUIRED AGAINST NEW VALVES AND AGAINST BLIND FLANGE ON NORTH SIDE OF 24", 90° BEND. TEST PRESSURE SHALL BE 100 psi.
6. COVER INTERIOR 16" HDPE PIPING WITH 2" MINUS WASHED ROCK TO A DEPTH OF 12". COVER INTERIOR CHLORINE AND TURBIDITY RAW WATER TAP WITH 2" MINUS WASHED ROCK TO A DEPTH OF 30".
7. THRUST BLOCKING NOT SHOWN FOR CLARITY. CONTRACTOR TO INSTALL THRUST BLOCKS IN ACCORDANCE WITH MPWSS.

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1	REC. INFO	RCR	9/21/06

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

NEW PIPING PLAN

• Project No. 15M424.117 • OUTLET_ PIPING PLAN.dwg • Date JULY 2005 • Designed KRJ • Drawn RDH • Checked RCR • Approved RCR

MONTANA REGISTERED PROFESSIONAL ENGINEER
KEVIN R. JOHNSON
14863 PE

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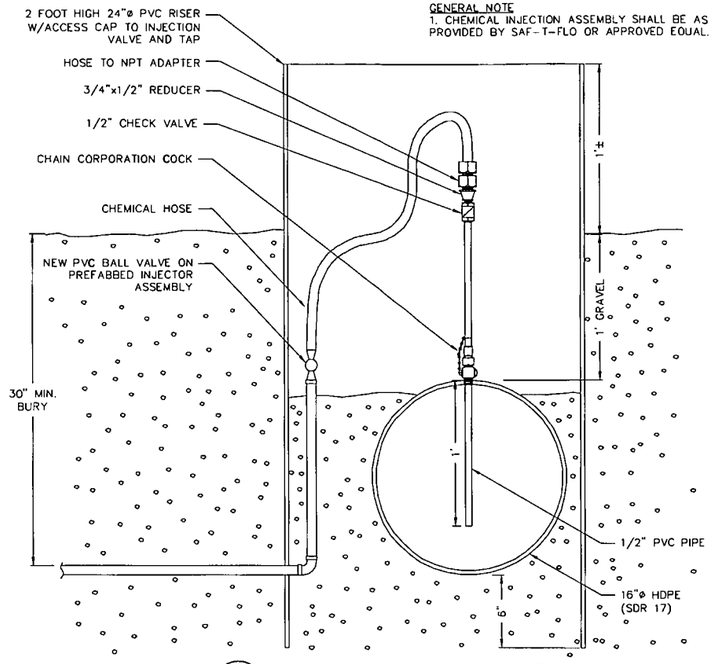
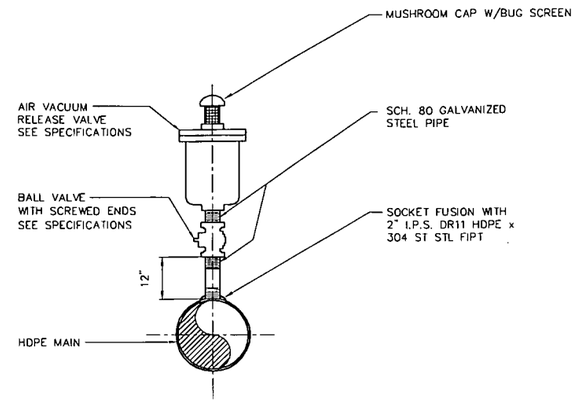
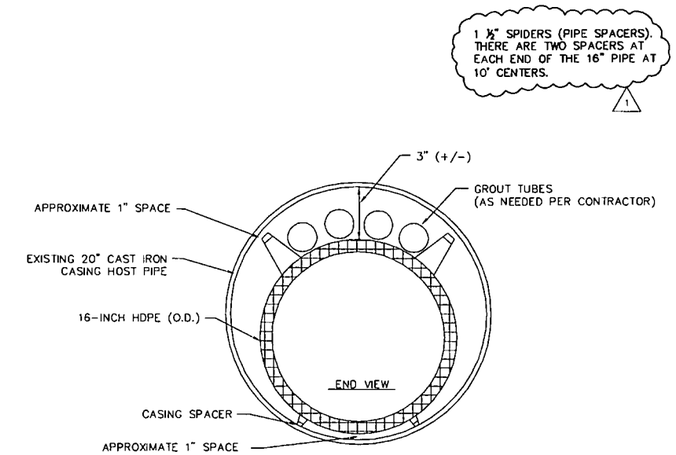
GENERAL NOTE
1. CHEMICAL INJECTION ASSEMBLY SHALL BE AS PROVIDED BY SAF-T-FLO OR APPROVED EQUAL.



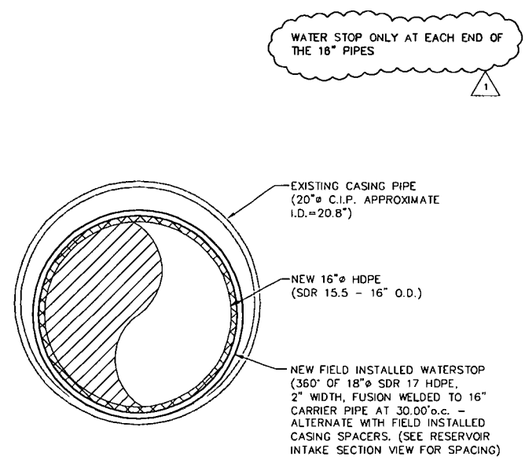
1 M-10 **DETAIL - CHLORINE INJECTOR**
SCALE : NONE



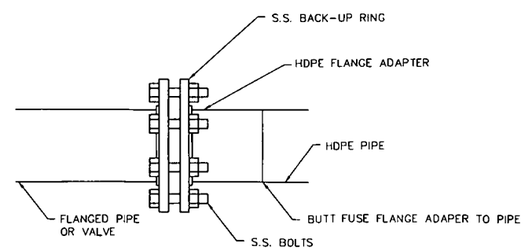
2 M-10 **DETAIL - AIR-VACUUM VALVE**
SCALE : NONE



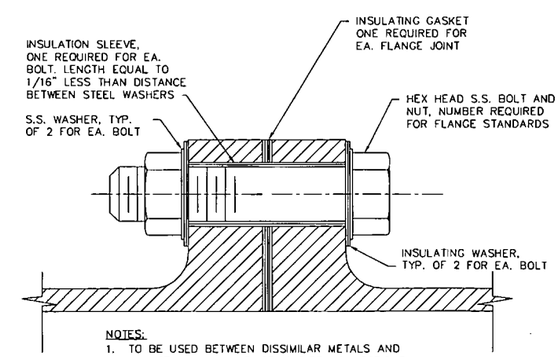
3 M-10 **DETAIL - FIELD INSTALLED CASING SPACER**
SCALE : NONE



4 M-10 **DETAIL - FIELD INSTALLED WATERSTOP**
SCALE : NONE



5 M-10 **DETAIL**
HDPE FLANGED CONNECTION
NOT TO SCALE



NOTES:
1. TO BE USED BETWEEN DISSIMILAR METALS AND BETWEEN NEW AND EXISTING PIPE CONNECTIONS.
2. INSULATING FLANGE SHALL BE COATED WITH MATERIAL COMPATABLE WITH REMAINDER OF PIPE WHERE APPLICABLE.
3. BOLTS AND NUTS SHALL BE STAINLESS STEEL. FOLLOW TORQUE REQUIREMENTS OF GASKET MANUFACTURER.

RECORD DRAWING
SEPTEMBER 2006

6 M-10 **DETAIL**
INSULATING FLANGE
NOT TO SCALE

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

MISCELLANEOUS DETAILS

● Project No. 15M424.117 ● D-1 DETAILS.dwg ● Date JULY 2005 ● Designed KRJ ● Drawn RDH ● Checked RCR ● Approved RCR

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Sheet No.
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APPENDIX L

2019 Basin Creek Dam Bathymetric Survey Report

Providing Technical Solutions for a Complex World

Water & Environmental Technologies

TO: Jim Keenan, Jim Dennehy - Butte-Silver Bow Department of Public Works – Water Division

FROM: Stephen Frazee, PE

DATE: July 8, 2019

RE: **Basin Creek Reservoirs – Bathymetric Survey**

Water and Environmental Technologies (WET) has completed the bathymetric surveys of Upper and Lower Basin Creek Reservoirs. WET surveyed the Lower Reservoir on June 4, 2019 and the Upper Reservoir on June 5, 2019. The topography data (above the water surface) for both reservoirs was derived from aerial Lidar data collected by Quantum Spatial on September 27, 2018. The bathymetry and topography data were merged to create a continuous elevation model for the entire depth range of both reservoirs. Using this data, WET developed Stage/Storage tables for both reservoirs.

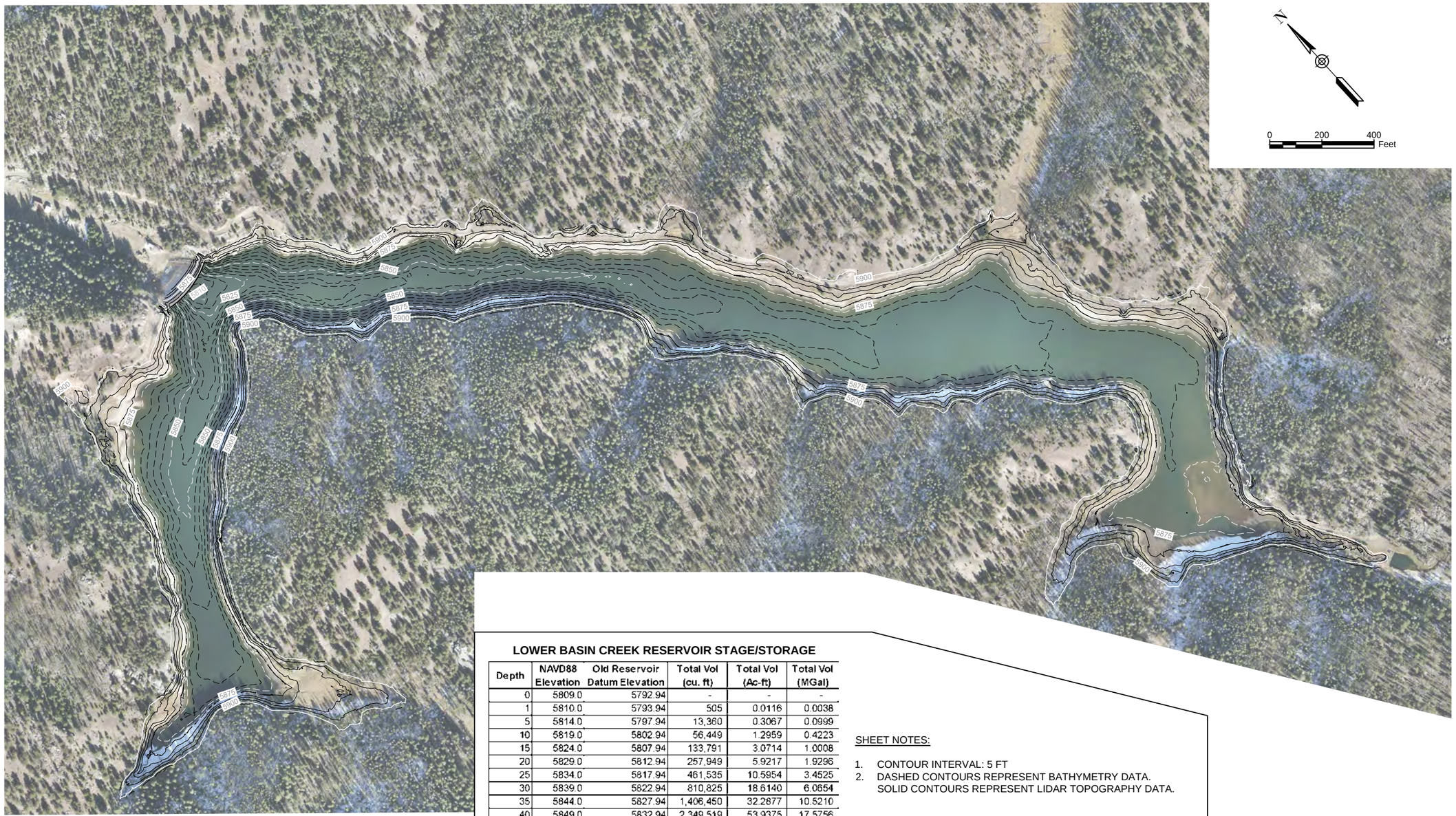
Attached for your review, please find the following:

- Sheet C1 – Lower Basin Creek Reservoir Bathymetric/Topographic Contours
- Sheet C2 – Upper Basin Creek Reservoir Bathymetric/Topographic Contours
- Sheet P1 – Upper Basin Creek Reservoir Section View
- Table 1 – Lower Basin Creek Reservoir Stage/Storage
- Table 2 – Upper Basin Creek Reservoir Stage/Storage
- CAD File - Basin Creek Bathymetry.dwg
- Video – Basin Creek Bathymetry Model

Sheets C1 and C2 contain the topographic and bathymetric contours of each reservoir and a simplified stage/storage table. These sheets also contain relevant survey notes/information such as datums, water levels, and other pertinent elevations and dates. Sheet P1 contains a profile/section view of the Upper Reservoir Dam. Tables 1 and 2 contain detailed stage/storage information for each reservoir. These include storage volumes at 0.5 feet increments. The CAD file contains the survey points and surfaces used to calculate the storage volumes for each reservoir. The video file provides a visual of the elevation model used to calculate the storage volumes.

If you have any questions, please don't hesitate to contact me at 497-8680 or sfrazee@waterenvtech.com.

Attachments



LOWER BASIN CREEK RESERVOIR STAGE/STORAGE

Depth	NAVD88 Elevation	Old Reservoir Datum Elevation	Total Vol (cu. ft)	Total Vol (Ac-ft)	Total Vol (MGal)
0	5809.0	5792.94	-	-	-
1	5810.0	5793.94	505	0.0116	0.0038
5	5814.0	5797.94	13,360	0.3067	0.0999
10	5819.0	5802.94	56,449	1.2959	0.4223
15	5824.0	5807.94	133,791	3.0714	1.0008
20	5829.0	5812.94	257,949	5.9217	1.9296
25	5834.0	5817.94	461,535	10.5954	3.4525
30	5839.0	5822.94	810,825	18.6140	6.0654
35	5844.0	5827.94	1,406,450	32.2877	10.5210
40	5849.0	5832.94	2,349,519	53.9375	17.5756
45	5854.0	5837.94	3,701,882	84.9835	27.6920
50	5859.0	5842.94	5,663,874	130.0247	42.3687
55	5864.0	5847.94	8,710,870	199.9741	65.1618
60	5869.0	5852.94	13,550,556	311.0780	101.3652
65	5874.0	5857.94	20,018,227	459.5553	149.7467
70	5879.0	5862.94	28,003,875	642.8805	209.4835
75	5884.0	5867.94	37,337,156	857.1432	279.3013
75.5	5884.5	5868.44	38,337,709	880.1127	286.7860
76	5885.0	5868.94	39,350,299	903.3586	294.3607
76.5	5885.5	5869.44	40,374,624	926.8738	302.0232
77	5886.0	5869.94	41,409,805	950.6383	309.7669
77.5	5886.5	5870.44	42,454,602	974.6236	317.5825
78	5887.0	5870.94	43,507,857	998.8030	325.4614
78.5	5887.5	5871.44	44,569,449	1,023.1738	333.4027
79	5888.0	5871.94	45,639,921	1,047.7484	341.4103
79.5	5888.5	5872.44	46,719,854	1,072.5403	349.4888

SHEET NOTES:

1. CONTOUR INTERVAL: 5 FT
2. DASHED CONTOURS REPRESENT BATHYMETRY DATA. SOLID CONTOURS REPRESENT LIDAR TOPOGRAPHY DATA.

SURVEY NOTES:

1. VERTICAL DATUM: NAVD88
2. HORIZONTAL DATUM: MONTANA STATE PLANE NAD83
3. LINEAR UNIT: INTERNATIONAL FEET
4. TBM ELEVATION (NAVD88) OF 5889.18 WAS USED FOR "X" IN NW CAP NUT MARKED "BM", ON BOLTED CRANE PIVOT BASE.
5. BATHYMETRY SURVEY CONDUCTED ON JUNE 4, 2019 BY WET.
6. TOPOGRAPHY DATA WAS COLLECTED VIA AERIAL LIDAR ON SEPTEMBER 27, 2018.
7. AERIAL IMAGERY COLLECTED ON OCTOBER 17, 2018.
8. THE OLD RESERVOIR DATUM ELEVATIONS LISTED IN THE TABLE WERE DERIVED BY SUBTRACTING 16.06 FT FROM THE NAVD88 ELEVATIONS. THIS CONVERSION IS LISTED IN THE BSB PUBLIC WORKS OPERATING PROCEDURES (JANUARY 2019) FOR BASIN CREEK DAMS #1 AND #2.

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480 E. Park Street
Butte, MT 59701
(406) 782-5220
WATERENVTECH.COM

LOWER BASIN CREEK RESERVOIR STAGE/STORAGE

PROJECT NAME: BASIN CREEK RESERVOIR BATHYMETRY
LOCATION: BUTTE, MONTANA
FILE NO. SC-BM01-BSBPWM126.dwg

JOB NO:	BSBPWM126
DATE:	7/8/19
DRAFTER:	SWF
CHECKED BY:	BAS

SHEET
C1

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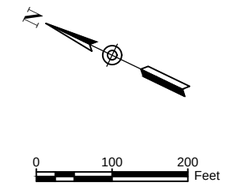

SHEET NOTES:

1. CONTOUR INTERVAL: 2 FT
2. DASHED CONTOURS REPRESENT BATHYMETRY DATA. SOLID CONTOURS REPRESENT LIDAR TOPOGRAPHY DATA.

SURVEY NOTES:

1. VERTICAL DATUM: NAVD88
2. HORIZONTAL DATUM: MONTANA STATE PLANE NAD83
3. LINEAR UNIT: INTERNATIONAL FEET
4. TBM ELEVATION OF 5889.18 WAS USED FOR "X" IN NW CAP NUT MARKED "BM", ON BOLTED CRANE PIVOT BASE.
5. BATHYMETRY SURVEY CONDUCTED ON JUNE 5, 2019 BY WET.
6. TOPOGRAPHY DATA WAS COLLECTED VIA AERIAL LIDAR ON SEPTEMBER 27, 2018.
7. AERIAL IMAGERY COLLECTED ON OCTOBER 17, 2018.
8. WATER SURFACE ELEVATION AT TIME OF SURVEY ON JUNE 5, 2019 WAS 6009.1
9. ON 7/2/2019, WET SURVEYED 4 CONTROL POINTS SET BY HKM (5000, 5001, 5003, AND 5004). THE AVERAGE DIFFERENCE BETWEEN WET ELEVATIONS (NAVD88) AND HKM ELEVATIONS WAS -183.68 FT. THIS IS THE SAME DIFFERENCE THAT HKM REFERENCED ON HKM SHEET 1 (EXISTING RESERVOIR CAPACITY) FROM OCTOBER 2009. AS SUCH, THE OLD RESERVOIR DATUM ELEVATIONS LISTED IN THE TABLE BELOW WERE DERIVED BY ADDING 183.68FT TO THE NAVD88 ELEVATIONS.

UPPER BASIN CREEK RESERVOIR STAGE/STORAGE

Depth	NAVD88 Elevation	Old Reservoir Datum Elevation	Total Vol (cu. ft)	Total Vol (Ac-ft)	Total Vol (MGal)
0.0	5987.5	6171.2	-	-	-
5.0	5992.5	6176.2	72,791	1.6711	0.5445
10.0	5997.5	6181.2	423,209	9.7155	3.1658
15.0	6002.5	6186.2	1,344,963	30.8761	10.0610
20.0	6007.5	6191.2	3,019,904	69.3275	22.5905
20.5	6008.0	6191.7	3,234,303	74.2494	24.1943
21.0	6008.5	6192.2	3,458,144	79.3881	25.8687
21.5	6009.0	6192.7	3,693,149	84.7830	27.6267
22.0	6009.5	6193.2	3,941,855	90.4925	29.4871
22.5	6010.0	6193.7	4,199,915	96.4168	31.4175
23.0	6010.5	6194.2	4,466,266	102.5314	33.4100
24.0	6011.5	6195.2	5,027,438	115.4141	37.6078
25.0	6012.5	6196.2	5,618,176	128.9756	42.0269
26.0	6013.5	6197.2	6,231,592	143.0577	46.6155
27.0	6014.5	6198.2	6,867,280	157.6511	51.3708
28.0	6015.5	6199.2	7,524,194	172.7317	56.2849
29.0	6016.5	6200.2	8,203,145	188.3183	61.3638
30.0	6017.5	6201.2	8,903,306	204.3918	66.6014
31.0	6018.5	6202.2	9,621,739	220.8847	71.9756
31.5	6019.0	6202.7	9,988,888	229.3133	74.7221

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(406) 782-5220
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UPPER BASIN CREEK RESERVOIR STAGE/STORAGE

PROJECT NAME: BASIN CREEK RESERVOIR BATHYMETRY
LOCATION: BUTTE, MONTANA
FILE NO. SC-BM01-BSBPWM126.dwg

JOB NO:	BSBPWM126
DATE:	7/8/19
DRAFTER:	SWF
CHECKED BY:	BAS

SHEET
C2

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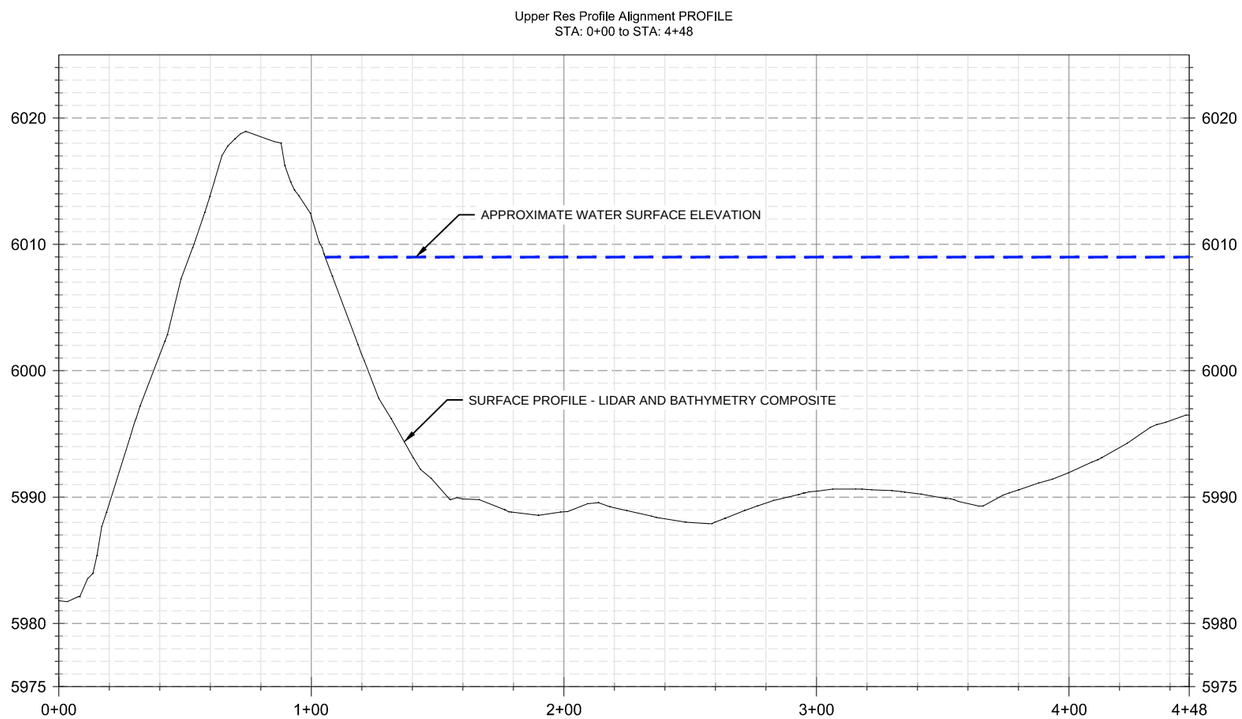

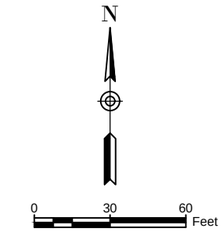

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UPPER BASIN CREEK RESERVOIR SECTION VIEW

PROJECT NAME: BASIN CREEK RESERVOIR BATHYMETRY
LOCATION: BUTTE, MONTANA
FILE NO. SC-BM01-BSBPWM126.dwg

JOB NO:	BSBPWM126
DATE:	7/8/19
DRAFTER:	SWF
CHECKED BY:	BAS

SHEET
P1

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Table 1: Lower Basin Creek Reservoir Stage/Storage - June 2019						
Depth (ft)	NAVD88 Elevation	Old Reservoir Datum Elevation	Total Vol (cu. Yd)	Total Vol (cu. ft)	Total Vol (Ac-ft)	Total Vol (MGal)
0	5809	5792.94	0	0	0.0000	0.0000
0.5	5809.5	5793.44	2.33	62.91	0.0014	0.0005
1	5810	5793.94	18.7	504.9	0.0116	0.0038
1.5	5810.5	5794.44	47.79	1290.33	0.0296	0.0097
2	5811	5794.94	86.95	2347.65	0.0539	0.0176
2.5	5811.5	5795.44	134.05	3619.35	0.0831	0.0271
3	5812	5795.94	188.33	5084.91	0.1167	0.0380
3.5	5812.5	5796.44	250.23	6756.21	0.1551	0.0505
4	5813	5796.94	321.02	8667.54	0.1990	0.0648
4.5	5813.5	5797.44	402.03	10854.81	0.2492	0.0812
5	5814	5797.94	494.83	13360.41	0.3067	0.0999
5.5	5814.5	5798.44	599.76	16193.52	0.3718	0.1211
6	5815	5798.94	715.75	19325.25	0.4436	0.1446
6.5	5815.5	5799.44	843.03	22761.81	0.5225	0.1703
7	5816	5799.94	982.69	26532.63	0.6091	0.1985
7.5	5816.5	5800.44	1135.15	30649.05	0.7036	0.2293
8	5817	5800.94	1300.14	35103.78	0.8059	0.2626
8.5	5817.5	5801.44	1478.25	39912.75	0.9163	0.2986
9	5818	5801.94	1669.49	45076.23	1.0348	0.3372
9.5	5818.5	5802.44	1873.61	50587.47	1.1613	0.3784
10	5819	5802.94	2090.72	56449.44	1.2959	0.4223
10.5	5819.5	5803.44	2319.71	62632.17	1.4378	0.4685
11	5820	5803.94	2559.95	69118.65	1.5867	0.5170
11.5	5820.5	5804.44	2811.57	75912.39	1.7427	0.5679
12	5821	5804.94	3074.71	83017.17	1.9058	0.6210
12.5	5821.5	5805.44	3350.09	90452.43	2.0765	0.6766
13	5822	5805.94	3638.74	98245.98	2.2554	0.7349
13.5	5822.5	5806.44	3942.04	106435.08	2.4434	0.7962
14	5823	5806.94	4262.24	115080.48	2.6419	0.8609
14.5	5823.5	5807.44	4600.09	124202.43	2.8513	0.9291
15	5824	5807.94	4955.24	133791.48	3.0714	1.0008
15.5	5824.5	5808.44	5328.23	143862.21	3.3026	1.0762
16	5825	5808.94	5720.74	154459.98	3.5459	1.1554
16.5	5825.5	5809.44	6133.2	165596.4	3.8016	1.2387
17	5826	5809.94	6563.24	177207.48	4.0681	1.3256
17.5	5826.5	5810.44	7009.18	189247.86	4.3445	1.4157
18	5827	5810.94	7472.45	201756.15	4.6317	1.5092
18.5	5827.5	5811.44	7955.24	214791.48	4.9309	1.6068
19	5828	5811.94	8463.35	228510.45	5.2459	1.7094
19.5	5828.5	5812.44	8996.33	242900.91	5.5762	1.8170
20	5829	5812.94	9553.66	257948.82	5.9217	1.9296
20.5	5829.5	5813.44	10137.71	273718.17	6.2837	2.0476
21	5830	5813.94	10752.83	290326.41	6.6650	2.1718
21.5	5830.5	5814.44	11399.61	307789.47	7.0659	2.3024
22	5831	5814.94	12079.09	326135.43	7.4870	2.4397
22.5	5831.5	5815.44	12800.16	345604.32	7.9340	2.5853
23	5832	5815.94	13564.68	366246.36	8.4079	2.7397
23.5	5832.5	5816.44	14375.55	388139.85	8.9105	2.9035

Table 1: Lower Basin Creek Reservoir Stage/Storage - June 2019						
Depth (ft)	NAVD88 Elevation	Old Reservoir Datum Elevation	Total Vol (cu. Yd)	Total Vol (cu. ft)	Total Vol (Ac-ft)	Total Vol (MGal)
24	5833	5816.94	15234.27	411325.29	9.4427	3.0769
24.5	5833.5	5817.44	16139.34	435762.18	10.0037	3.2597
25	5834	5817.94	17093.89	461535.03	10.5954	3.4525
25.5	5834.5	5818.44	18098.71	488665.17	11.2182	3.6555
26	5835	5818.94	19158.98	517292.46	11.8754	3.8696
26.5	5835.5	5819.44	20281.08	547589.16	12.5709	4.0963
27	5836	5819.94	21460	579420	13.3017	4.3344
27.5	5836.5	5820.44	22703.05	612982.35	14.0721	4.5854
28	5837	5820.94	24014.54	648392.58	14.8850	4.8503
28.5	5837.5	5821.44	25394.61	685654.47	15.7405	5.1291
29	5838	5821.94	26853.17	725035.59	16.6445	5.4236
29.5	5838.5	5822.44	28400.33	766808.91	17.6035	5.7361
30	5839	5822.94	30030.56	810825.12	18.6140	6.0654
30.5	5839.5	5823.44	31742.63	857051.01	19.6752	6.4112
31	5840	5823.94	33535.21	905450.67	20.7863	6.7732
31.5	5840.5	5824.44	35421.74	956386.98	21.9556	7.1543
32	5841	5824.94	37423.97	1010447.19	23.1967	7.5587
32.5	5841.5	5825.44	39551.71	1067896.17	24.5155	7.9884
33	5842	5825.94	41810.82	1128892.14	25.9158	8.4447
33.5	5842.5	5826.44	44193.22	1193216.94	27.3925	8.9259
34	5843	5826.94	46698.79	1260867.33	28.9455	9.4319
34.5	5843.5	5827.44	49329.8	1331904.6	30.5763	9.9633
35	5844	5827.94	52090.75	1406450.25	32.2877	10.5210
35.5	5844.5	5828.44	54975.6	1484341.2	34.0758	11.1036
36	5845	5828.94	57999.17	1565977.59	35.9499	11.7143
36.5	5845.5	5829.44	61166.8	1651503.6	37.9133	12.3541
37	5846	5829.94	64466.33	1740590.91	39.9585	13.0205
37.5	5846.5	5830.44	67891.17	1833061.59	42.0813	13.7123
38	5847	5830.94	71445.43	1929026.61	44.2844	14.4301
38.5	5847.5	5831.44	75133.69	2028609.63	46.5705	15.1751
39	5848	5831.94	78958.97	2131892.19	48.9415	15.9477
39.5	5848.5	5832.44	82920.41	2238851.07	51.3969	16.7478
40	5849	5832.94	87019.22	2349518.94	53.9375	17.5756
40.5	5849.5	5833.44	91264.34	2464137.18	56.5688	18.4330
41	5850	5833.94	95660.19	2582825.13	59.2935	19.3209
41.5	5850.5	5834.44	100210.84	2705692.68	62.1142	20.2400
42	5851	5834.94	104927.42	2833040.34	65.0377	21.1926
42.5	5851.5	5835.44	109812.37	2964933.99	68.0655	22.1792
43	5852	5835.94	114872.36	3101553.72	71.2019	23.2012
43.5	5852.5	5836.44	120118.89	3243210.03	74.4539	24.2609
44	5853	5836.94	125569.11	3390365.97	77.8321	25.3617
44.5	5853.5	5837.44	131230.24	3543216.48	81.3411	26.5051
45	5854	5837.94	137106.74	3701881.98	84.9835	27.6920
45.5	5854.5	5838.44	143198.32	3866354.64	88.7593	28.9223
46	5855	5838.94	149504.05	4036609.35	92.6678	30.1959
46.5	5855.5	5839.44	156032.17	4212868.59	96.7142	31.5144
47	5856	5839.94	162829.1	4396385.7	100.9271	32.8873
47.5	5856.5	5840.44	169945.63	4588532.01	105.3382	34.3246

Table 1: Lower Basin Creek Reservoir Stage/Storage - June 2019						
Depth (ft)	NAVD88 Elevation	Old Reservoir Datum Elevation	Total Vol (cu. Yd)	Total Vol (cu. ft)	Total Vol (Ac-ft)	Total Vol (MGal)
48	5857	5840.94	177308.65	4787333.55	109.9021	35.8117
48.5	5857.5	5841.44	184949.46	4993635.42	114.6381	37.3550
49	5858	5841.94	192891.55	5208071.85	119.5609	38.9591
49.5	5858.5	5842.44	201161.04	5431348.08	124.6866	40.6293
50	5859	5842.94	209773.11	5663873.97	130.0247	42.3687
50.5	5859.5	5843.44	218743.35	5906070.45	135.5847	44.1805
51	5860	5843.94	228114.8	6159099.6	141.3935	46.0733
51.5	5860.5	5844.44	237893.33	6423119.91	147.4545	48.0483
52	5861	5844.94	248171.12	6700620.24	153.8251	50.1241
52.5	5861.5	5845.44	258990.83	6992752.41	160.5315	52.3094
53	5862	5845.94	270328.67	7298874.09	167.5591	54.5994
53.5	5862.5	5846.44	282298.02	7622046.54	174.9781	57.0169
54	5863	5846.94	295030.68	7965828.36	182.8703	59.5885
54.5	5863.5	5847.44	308452.17	8328208.59	191.1894	62.2993
55	5864	5847.94	322624.81	8710869.87	199.9741	65.1618
55.5	5864.5	5848.44	337654.98	9116684.46	209.2903	68.1975
56	5865	5848.94	353418.05	9542287.35	219.0608	71.3813
56.5	5865.5	5849.44	369914.24	9987684.48	229.2857	74.7131
57	5866	5849.94	387037.91	10450023.57	239.8995	78.1716
57.5	5866.5	5850.44	404760.27	10928527.29	250.8845	81.7511
58	5867	5850.94	423024.5	11421661.5	262.2053	85.4400
58.5	5867.5	5851.44	441902.03	11931354.81	273.9062	89.2527
59	5868	5851.94	461288.76	12454796.52	285.9228	93.1684
59.5	5868.5	5852.44	481260.01	12994020.27	298.3017	97.2020
60	5869	5852.94	501872.44	13550555.88	311.0780	101.3652
60.5	5869.5	5853.44	523121.65	14124284.55	324.2490	105.6570
61	5870	5853.94	544959.84	14713915.68	337.7850	110.0677
61.5	5870.5	5854.44	567331.47	15317949.69	351.6517	114.5862
62	5871	5854.94	590238.67	15936444.09	365.8504	119.2129
62.5	5871.5	5855.44	613728.58	16570671.66	380.4103	123.9572
63	5872	5855.94	637983.43	17225552.61	395.4443	128.8561
63.5	5872.5	5856.44	663004.83	17901130.41	410.9534	133.9098
64	5873	5856.94	688624.01	18592848.27	426.8331	139.0842
64.5	5873.5	5857.44	714770.68	19298808.36	443.0397	144.3651
65	5874	5857.94	741415.82	20018227.14	459.5553	149.7467
65.5	5874.5	5858.44	768546.63	20750759.01	476.3719	155.2265
66	5875	5858.94	796168.8	21496557.6	493.4931	160.8054
66.5	5875.5	5859.44	824415.24	22259211.48	511.0012	166.5105
67	5876	5859.94	853288.39	23038786.53	528.8978	172.3421
67.5	5876.5	5860.44	882719.71	23833432.17	547.1403	178.2865
68	5877	5860.94	912668.31	24642044.37	565.7035	184.3353
68.5	5877.5	5861.44	943100.87	25463723.49	584.5667	190.4819
69	5878	5861.94	974003.96	26298106.92	603.7215	196.7235
69.5	5878.5	5862.44	1005362.56	27144789.12	623.1586	203.0571
70	5879	5862.94	1037180.56	28003875.12	642.8805	209.4835
70.5	5879.5	5863.44	1069467.16	28875613.32	662.8929	216.0046
71	5880	5863.94	1102275.19	29761430.13	683.2284	222.6310
71.5	5880.5	5864.44	1135736.38	30664882.26	703.9688	229.3893

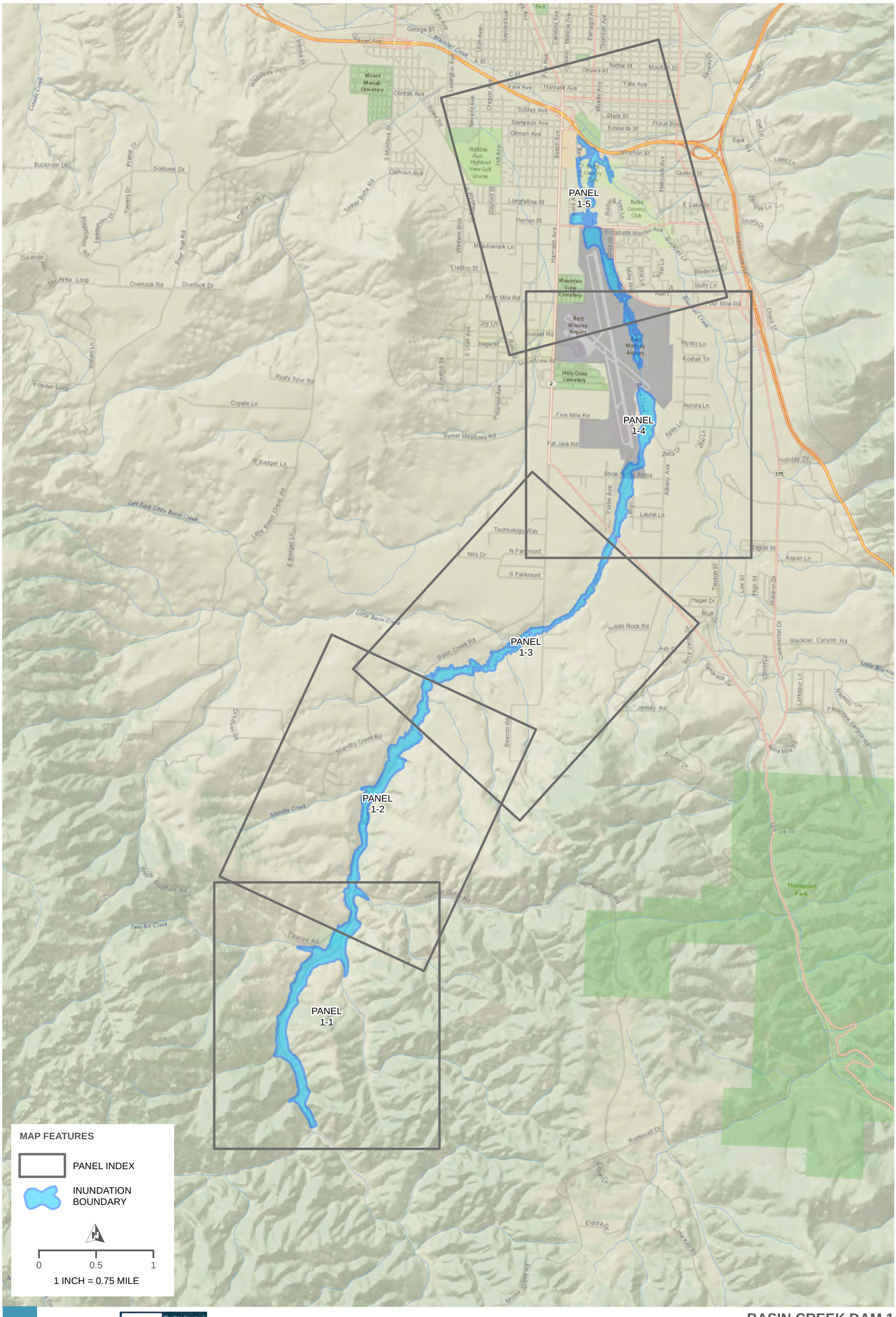
Table 1: Lower Basin Creek Reservoir Stage/Storage - June 2019						
Depth (ft)	NAVD88 Elevation	Old Reservoir Datum Elevation	Total Vol (cu. Yd)	Total Vol (cu. ft)	Total Vol (Ac-ft)	Total Vol (MGal)
72	5881	5864.94	1169719.45	31582425.15	725.0327	236.2530
72.5	5881.5	5865.44	1204153.28	32512138.56	746.3760	243.2077
73	5882	5865.94	1239024.64	33453665.28	767.9905	250.2508
73.5	5882.5	5866.44	1274327.87	34406852.49	789.8726	257.3811
74	5883	5866.94	1310066.54	35371796.58	812.0247	264.5994
74.5	5883.5	5867.44	1346243.35	36348570.45	834.4484	271.9062
75	5884	5867.94	1382857.64	37337156.28	857.1432	279.3013
75.5	5884.5	5868.44	1419915.15	38337709.05	880.1127	286.7860
76	5885	5868.94	1457418.47	39350298.69	903.3586	294.3607
76.5	5885.5	5869.44	1495356.43	40374623.61	926.8738	302.0232
77	5886	5869.94	1533696.49	41409805.23	950.6383	309.7669
77.5	5886.5	5870.44	1572392.68	42454602.36	974.6236	317.5825
78	5887	5870.94	1611402.12	43507857.24	998.8030	325.4614
78.5	5887.5	5871.44	1650720.34	44569449.18	1023.1738	333.4027
79	5888	5871.94	1690367.46	45639921.42	1047.7484	341.4103
79.5	5888.5	5872.44	1730364.98	46719854.46	1072.5403	349.4888

Table 2: Upper Basin Creek Reservoir Stage/Storage - June 2019						
Depth (ft)	NAVD88 Elevation	Old Reservoir Datum Elevation	Total Vol (cu. Yd)	Total Vol (cu. ft)	Total Vol (Ac-ft)	Total Vol (MGal)
0	5987.5	6171.18	0	0	0	0
0.5	5988	6171.68	3.58	96.66	0.0022	0.0007
1	5988.5	6172.18	28.41	767.07	0.0176	0.0057
1.5	5989	6172.68	101.21	2732.67	0.0627	0.0204
2	5989.5	6173.18	249.06	6724.62	0.1544	0.0503
2.5	5990	6173.68	465.97	12581.19	0.2888	0.0941
3	5990.5	6174.18	748.06	20197.62	0.4637	0.1511
3.5	5991	6174.68	1112.2	30029.4	0.6894	0.2246
4	5991.5	6175.18	1560.94	42145.38	0.9675	0.3153
4.5	5992	6175.68	2094.44	56549.88	1.2982	0.4230
5	5992.5	6176.18	2695.97	72791.19	1.6711	0.5445
5.5	5993	6176.68	3364.06	90829.62	2.0852	0.6795
6	5993.5	6177.18	4106.22	110867.94	2.5452	0.8293
6.5	5994	6177.68	4940.3	133388.1	3.0622	0.9978
7	5994.5	6178.18	5917.11	159761.97	3.6676	1.1951
7.5	5995	6178.68	7064.36	190737.72	4.3787	1.4268
8	5995.5	6179.18	8381.6	226303.2	5.1952	1.6929
8.5	5996	6179.68	9859.19	266198.13	6.1111	1.9913
9	5996.5	6180.18	11549.38	311833.26	7.1587	2.3327
9.5	5997	6180.68	13491.08	364259.16	8.3622	2.7248
10	5997.5	6181.18	15674.4	423208.8	9.7155	3.1658
10.5	5998	6181.68	18096.81	488613.87	11.2170	3.6551
11	5998.5	6182.18	20703.63	558998.01	12.8328	4.1816
11.5	5999	6182.68	23486.36	634131.72	14.5577	4.7436
12	5999.5	6183.18	26484.03	715068.81	16.4157	5.3491
12.5	6000	6183.68	29740.13	802983.51	18.4340	6.0067
13	6000.5	6184.18	33249.31	897731.37	20.6091	6.7155
13.5	6001	6184.68	37023.25	999627.75	22.9483	7.4777
14	6001.5	6185.18	41040.35	1108089.45	25.4382	8.2891
14.5	6002	6185.68	45296.17	1222996.59	28.0761	9.1487
15	6002.5	6186.18	49813.46	1344963.42	30.8761	10.0610
15.5	6003	6186.68	54575.13	1473528.51	33.8276	11.0228
16	6003.5	6187.18	59658.51	1610779.77	36.9784	12.0495
16.5	6004	6187.68	65102.25	1757760.75	40.3526	13.1490
17	6004.5	6188.18	70862.97	1913300.19	43.9233	14.3125
17.5	6005	6188.68	76943.7	2077479.9	47.6924	15.5406
18	6005.5	6189.18	83325.22	2249780.94	51.6479	16.8295
18.5	6006	6189.68	89980.06	2429461.62	55.7728	18.1736
19	6006.5	6190.18	96928.51	2617069.77	60.0797	19.5770
19.5	6007	6190.68	104229.66	2814200.82	64.6052	21.0517
20	6007.5	6191.18	111848.31	3019904.37	69.3275	22.5905
20.5	6008	6191.68	119789.01	3234303.27	74.2494	24.1943
21	6008.5	6192.18	128079.42	3458144.34	79.3881	25.8687
21.5	6009	6192.68	136783.29	3693148.83	84.7830	27.6267
22	6009.5	6193.18	145994.62	3941854.74	90.4925	29.4871
22.5	6010	6193.68	155552.39	4199914.53	96.4168	31.4175
23	6010.5	6194.18	165417.26	4466266.02	102.5314	33.4100
23.5	6011	6194.68	175623.84	4741843.68	108.8578	35.4715

Table 2: Upper Basin Creek Reservoir Stage/Storage - June 2019						
Depth (ft)	NAVD88 Elevation	Old Reservoir Datum Elevation	Total Vol (cu. Yd)	Total Vol (cu. ft)	Total Vol (Ac-ft)	Total Vol (MGal)
24	6011.5	6195.18	186201.4	5027437.8	115.4141	37.6078
24.5	6012	6195.68	197033.61	5319907.47	122.1283	39.7957
25	6012.5	6196.18	208080.58	5618175.66	128.9756	42.0269
25.5	6013	6196.68	219331.89	5921961.03	135.9495	44.2993
26	6013.5	6197.18	230799.69	6231591.63	143.0577	46.6155
26.5	6014	6197.68	242473.79	6546792.33	150.2937	48.9734
27	6014.5	6198.18	254343.7	6867279.9	157.6511	51.3708
27.5	6015	6198.68	266404.23	7192914.21	165.1266	53.8067
28	6015.5	6199.18	278673.85	7524193.95	172.7317	56.2849
28.5	6016	6199.68	291141.01	7860807.27	180.4593	58.8029
29	6016.5	6200.18	303820.17	8203144.59	188.3183	61.3638
29.5	6017	6200.68	316702	8550954	196.3029	63.9656
30	6017.5	6201.18	329752.08	8903306.16	204.3918	66.6014
30.5	6018	6201.68	342967.91	9260133.57	212.5834	69.2706
31	6018.5	6202.18	356360.71	9621739.17	220.8847	71.9756
31.5	6019	6202.68	369958.83	9988888.41	229.3133	74.7221

APPENDIX M

2019 Basin Creek Dam Breach Analysis



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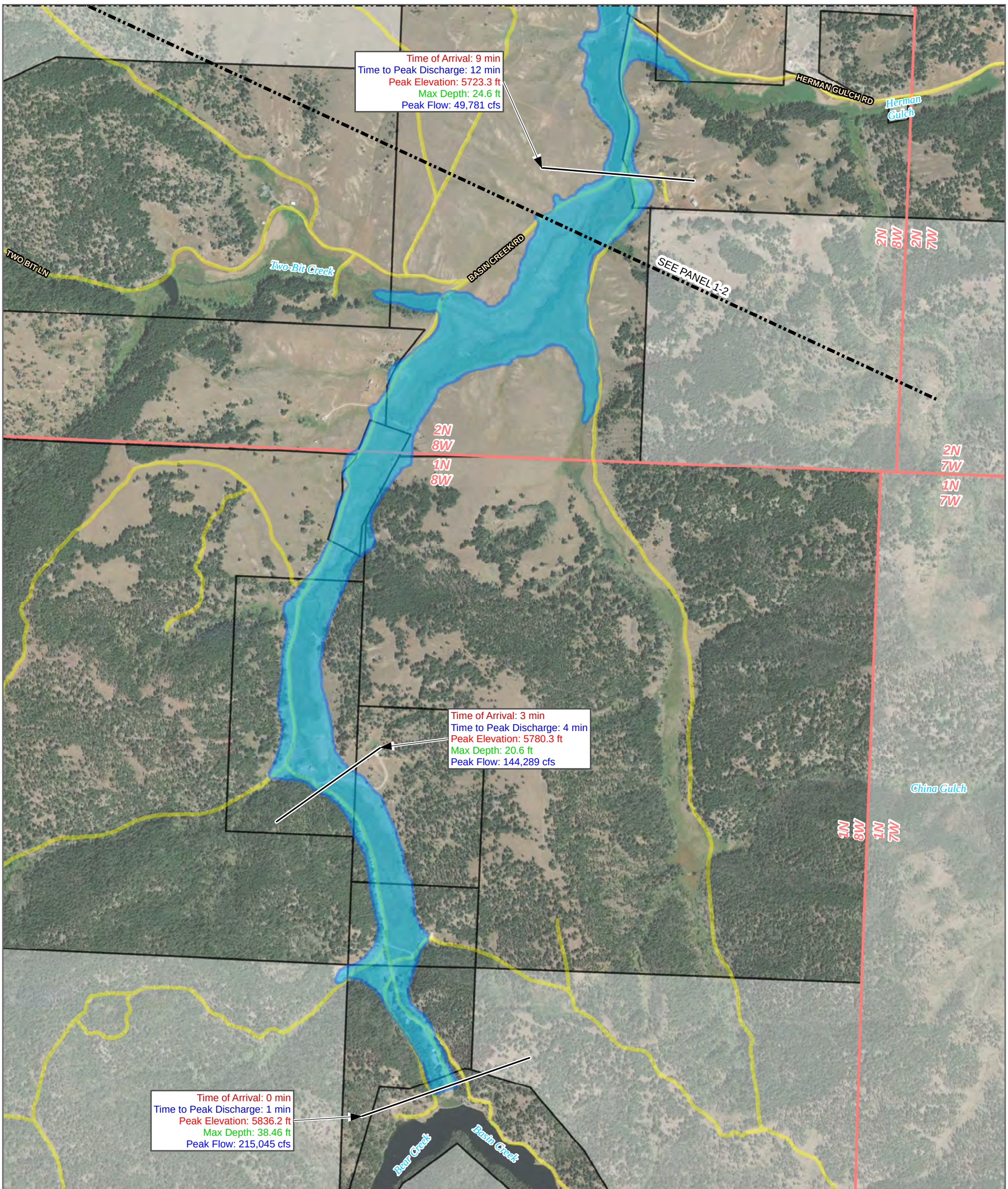
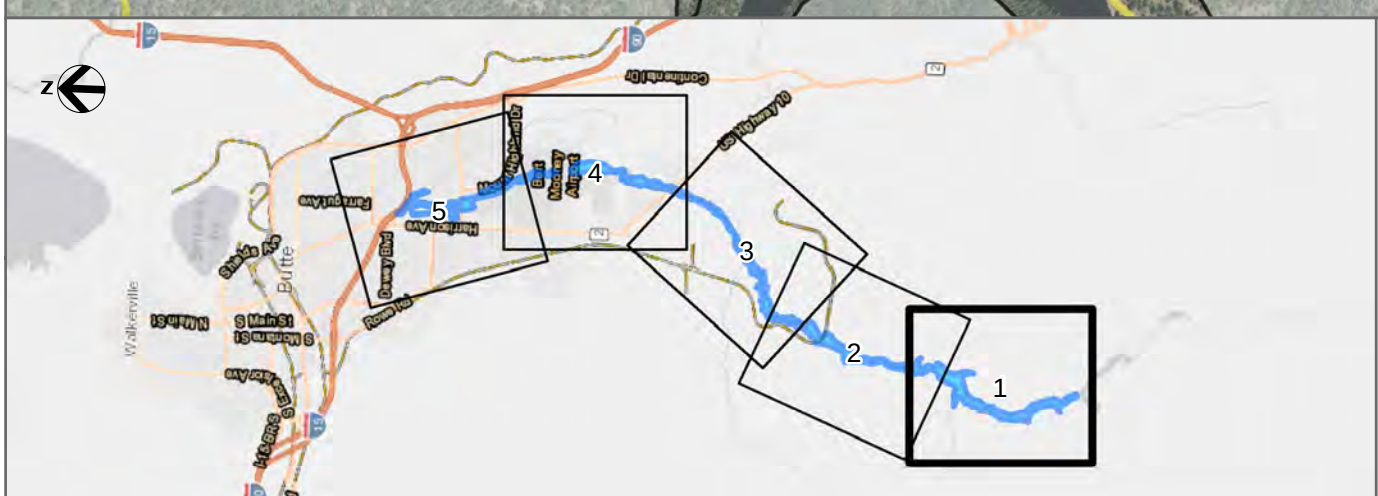
MAP PROJECTION: NAD 1983 MONTANA FIPS 2500, INTERNATIONAL FOOT DEFINITION

BASIN CREEK DAM 1
BREACH ANALYSIS
INUNDATION BOUNDARY

MAPBOOK INDEX





MAP FEATURES

- PANEL BOUNDARY
- POLICE DEPT
- SHELTER
- HEALTHCARE
- SCHOOL
- FIRE DEPTARTMENT
- INUNDATION BOUNDARY
- IMPACTED PARCELS
- TOWNSHIP LINES
- ROADS

COUNTY: SILVER BOW

0 500 1,000
1 INCH = 1,000 FEET

The City-County of BUTTE SILVER BOW

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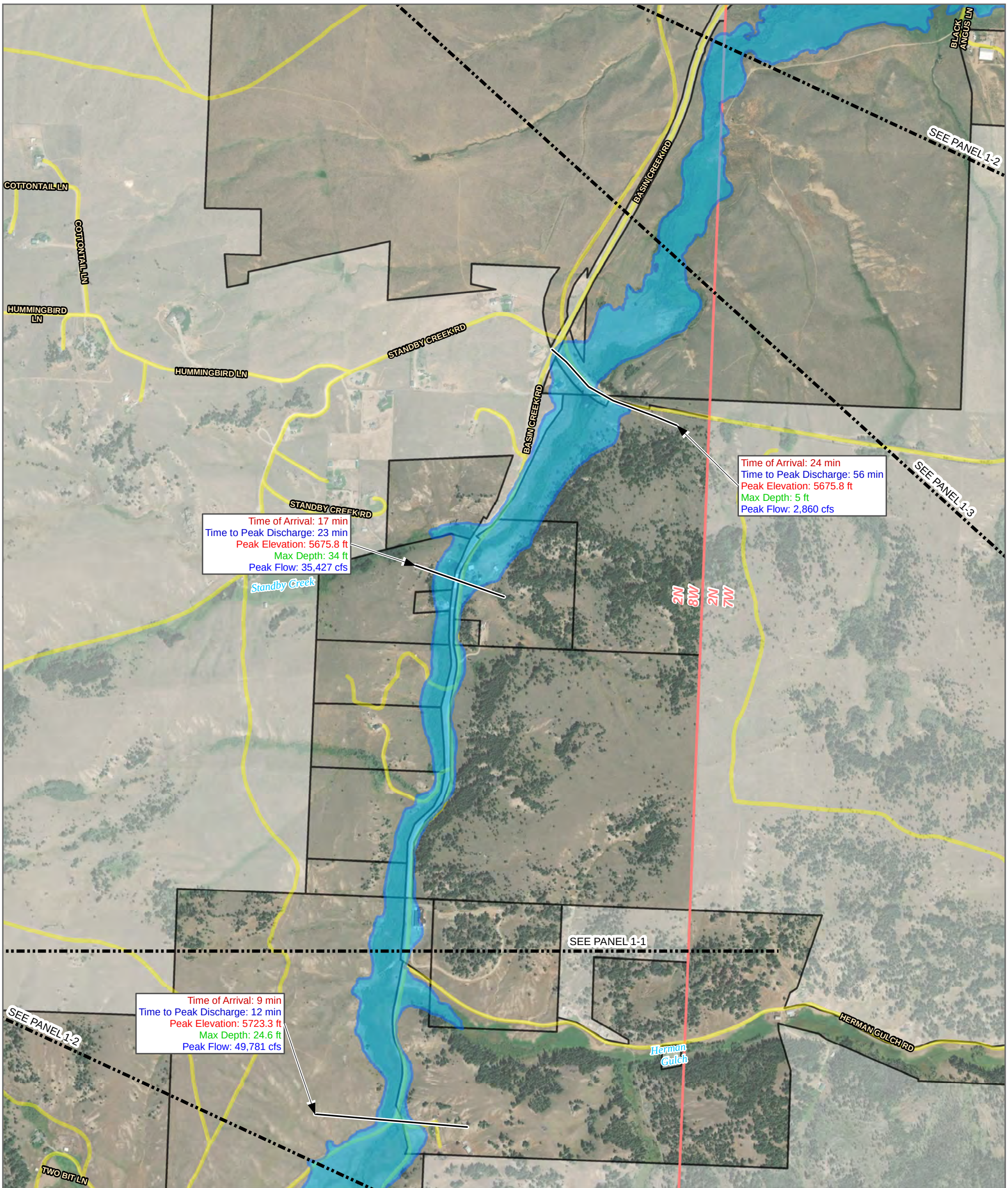
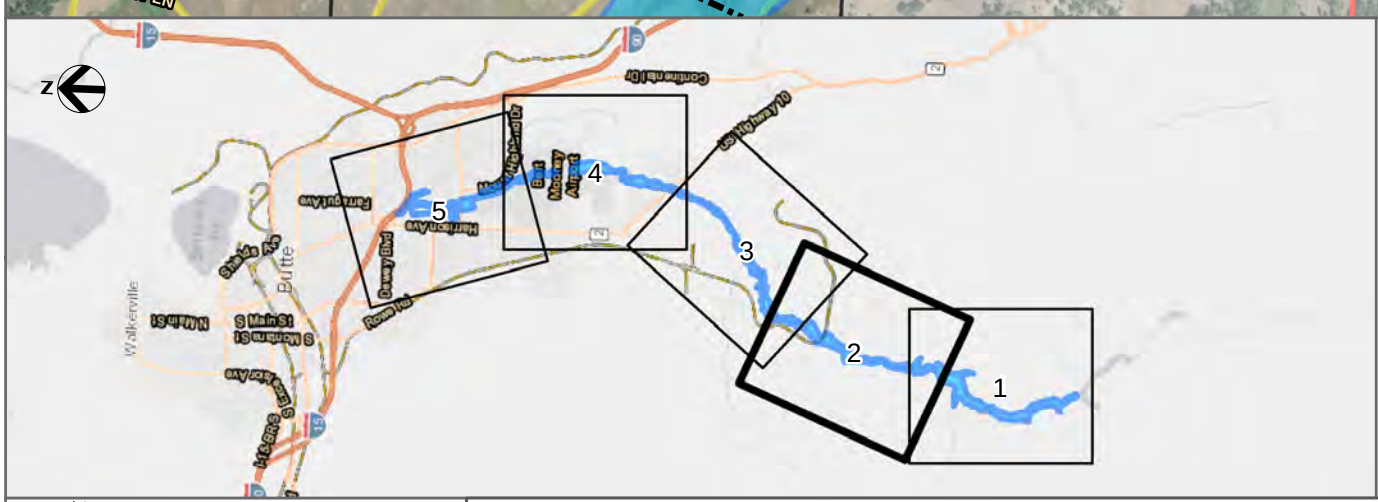
BASIN CREEK DAM 1
BREACH ANALYSIS

ISSUED: 11/19/2019

PANEL 1-1





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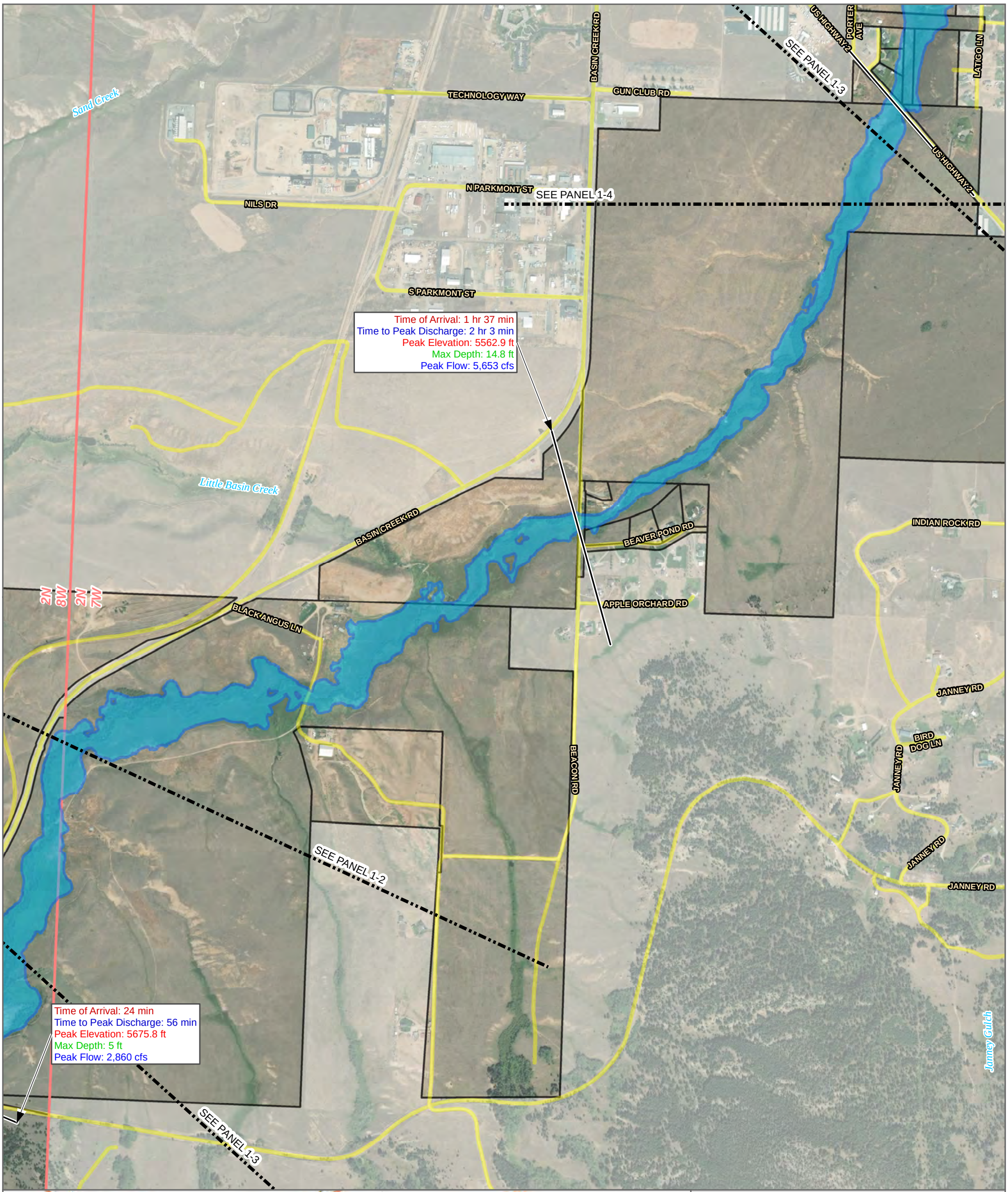
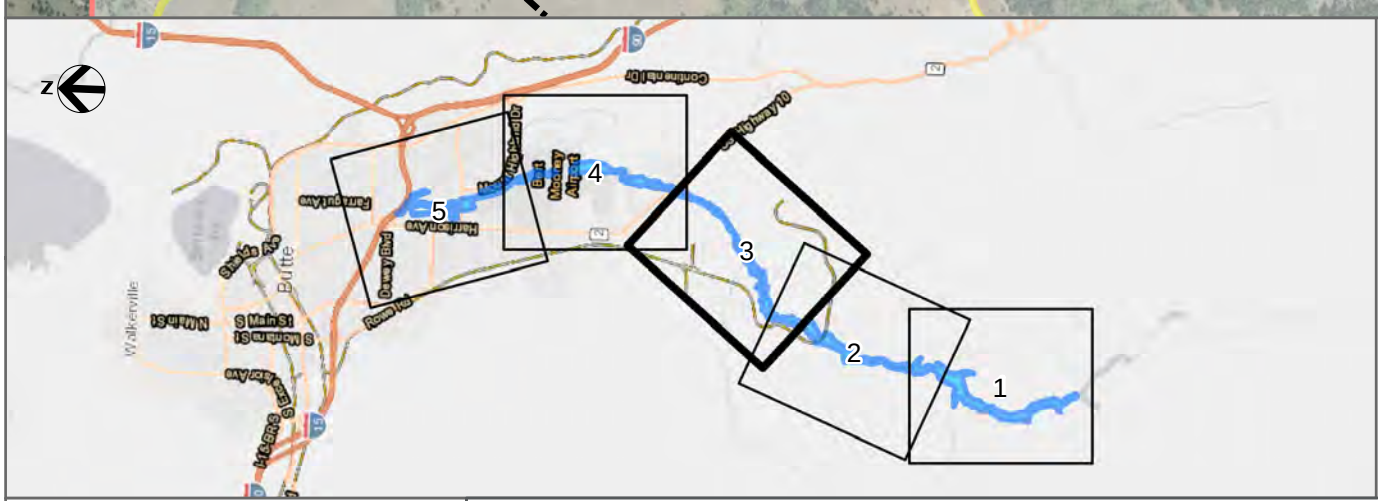
BASIN CREEK DAM 1
BREACH ANALYSIS

ISSUED: 11/19/2019

PANEL 1-2





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BASIN CREEK DAM 1
BREACH ANALYSIS

ISSUED: 11/19/2019

PANEL 1-3

Time of Arrival: 4 hr 39 min
Time to Peak Discharge: 8 hr 7 min
Peak Elevation: 5499.1 ft
Max Depth: 1.9 ft
Peak Flow: 151 cfs

Time of Arrival: 2 hr 55 min
Time to Peak Discharge: 3 hr 17 min
Peak Elevation: 5528.1 ft
Max Depth: 1 ft
Peak Flow: 1,002 cfs

Time of Arrival: 2 hr 20 min
Time to Peak Discharge: 2 hr 39 min
Peak Elevation: 5535.3 ft
Max Depth: 2.3 ft
Peak Flow: 1,500 cfs

SEE PANEL 1-5

SEE PANEL 1-3

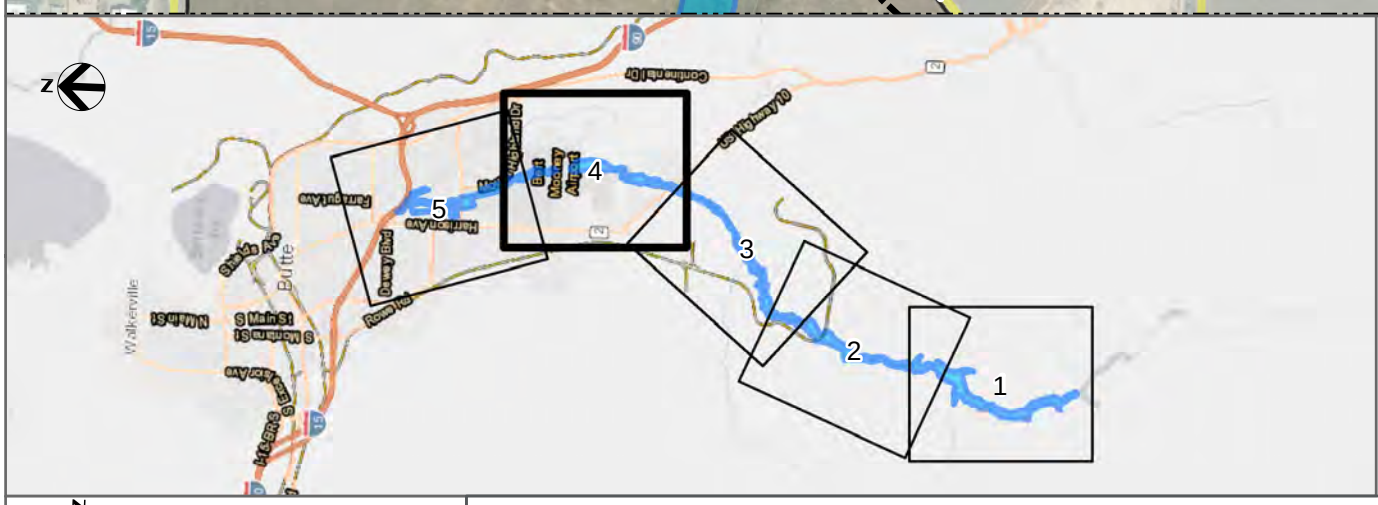
HIGHLANDS COLLEGE MONTANA TECH

Basin Creek

Sand Creek

Blacktail Creek

FOUR MILE RD
PAXSON AVE
MOUNTAIN VW
MILKY WAY
3N 7W
2N 7W
VICTORIA LN
OLYMPIC WAY
THREE BEARS DR
CONTINENTAL DR
EXIT 228 OFF RAMP
HARRISON AVE
SUNSET RD
AIRPORT RD
S AIRPORT RD
MOTOR VIEW RD
WANNE AVE
HOLY CROSS LN
WATERLINE RD
FIVE MILE RD
SWEET MEADOWS RD
FAT JACK RD
SHOESTRING ANNIE RD
YELLOW ROSE LN
PORTER AVE
US HIGHWAY 2
BASIN CREEK RD
LAST CHANCE ST
LEMONS DR
ALBANY AVE
CRYING GEORGE RD
LAUREL RD
LATICO LN
SHAWNA LN
RODEO DR
TECHNOLOGY WAY
GUN CLUB RD
N PARKMONT ST
TRENTON ST
LYNDALE LN
WAGON ST
HARP RD
BLARNEY BLVD
GENEVA LN
BLACKTAIL LOOP
MYSTIC LN
CASPIAN LN
KODIAK TRL
EVERGREEN WAY
RIALTO WAY
OMEGA WAY
KETCHUM LN
COFFEE CT
RENDEZVOUS DR
AURORA LN
SAPPHIRE LN
BROOKSTONE TRL
APEX LN
ZOO LN
SAFARI DR
PAINTED MDWS
ZELLA DR
KELSEY LN



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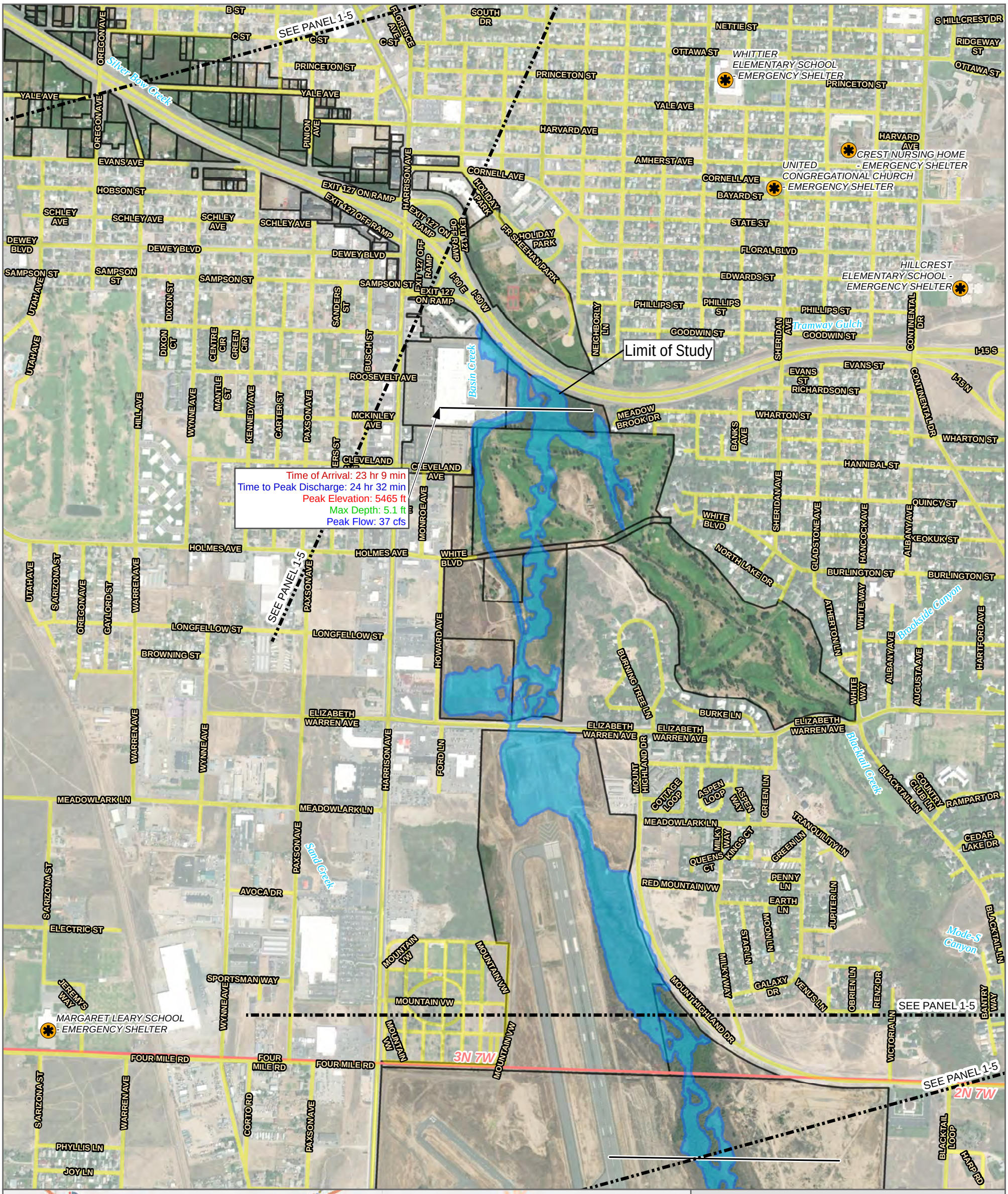
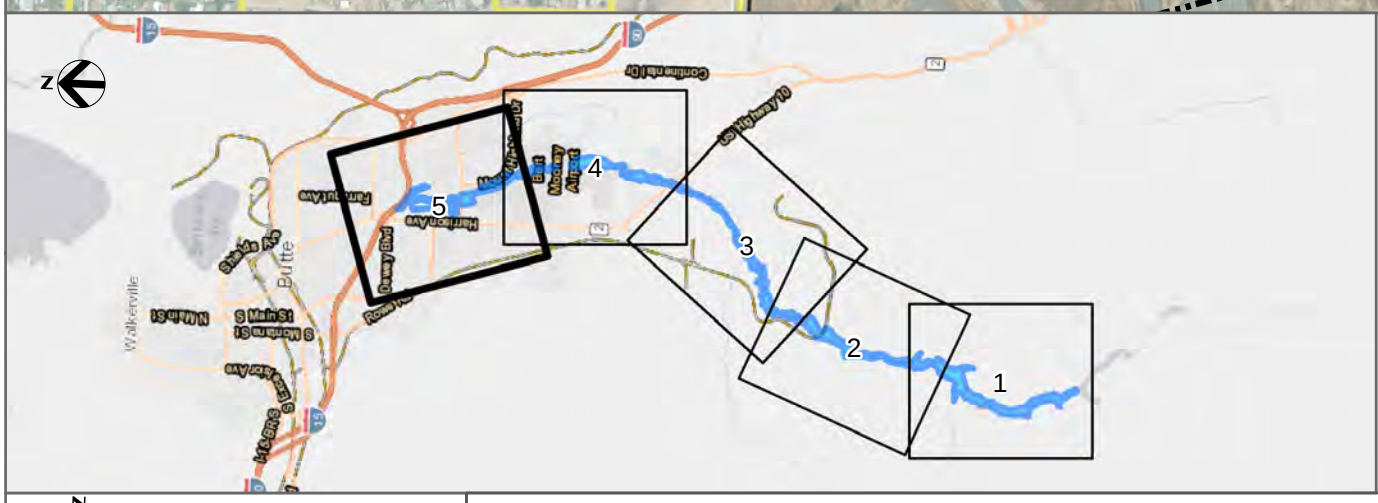
BASIN CREEK DAM 1
BREACH ANALYSIS

ISSUED: 11/19/2019

PANEL 1-4





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BASIN CREEK DAM 1
BREACH ANALYSIS

ISSUED: 11/19/2019

PANEL 1-5

APPENDIX N

2015 Basin Creek Dam Stability Analysis and Geological Investigation

URS

Memorandum

To: Guy S. Lund, P.E / URS Denver

From: Scott Jones, P.E. / URS Denver

Office: Denver

Date: February 21, 2005

Subject: Basin Creek Dam No. 1 Stability Analysis
Project No. 22237805.00001

1.0 PROJECT DESCRIPTION

1.1 Description of Dam

Basin Creek Dam No. 1 is located in Silver Bow County, approximately 10 miles south of Butte, Montana. The dam was designed and constructed in the late 1800's and modified in the early 1900's. The original construction of the dam was completed in 1897, and consisted of an 88-foot-high curved masonry dam with the base at elevation of 5772 mean sea level (msl) and the crest at elevation 5860 msl. Modifications to the dam were performed in 1913, and consisted of adding mass concrete to the downstream face and crest. The modification raised the crest to elevation 5871 msl, plus a 2-foot-high parapet wall (elevation 5773 msl) on the upstream edge of the crest. In the 1930's, final modifications were completed, and consisted of placing an earthfill embankment on the downstream slope of the dam for added stability. The downstream slope of the embankment is approximately 1.6 horizontal (H) to 1.0 vertical (V). The embankment addition did not change the operating level of the reservoir.

Basin Creek Dam No. 1 is classified by the Department of Natural Resources & Conservation, Montana Dam Safety Program, as a HIGH hazard structure. The operating capacity of the reservoir is approximately 1170 acre-feet. Plan and section views of the dam are shown in Figure 1.

1.2 Scope of Work

There are currently no records available regarding the structural stability of Basin Creek Dam No. 1. The state of Montana Dam Safety Rules require that the dam meet U.S. Bureau of Reclamation (USBR) safety criteria for concrete dams. No information was available regarding the structural behavior or safety of the dam, therefore, a structural analysis was

URS Corporation
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Tel: 303.69.2770 and 303.740.2600
FAX: 303.694.3946

performed to estimate the safety of the project.

URS was retained by HKM Engineering, Inc. to perform a three-dimensional analysis of Basin Creek Dam No. 1 using the trial-load method of analysis.

The structural adequacy of concrete arch dams is evaluated for the following potential failure modes:

- **Concrete Overstressing**. The ability of the concrete to adequately support the assumed loads without cracking or crushing of the material. The computed stresses from the analysis are compared to the maximum allowable stresses for the material, in accordance with safety criteria, to determine if the material will be overstressed during the assumed load.
- **Sliding Stability**. The sliding stability of the dam is evaluated along the dam/foundation interface. The computed forces from the analysis are used to determine the sliding factor of safety, which is compared to the minimum allowable factors of safety in accordance with safety criteria.

The U.S. Bureau of Reclamation computer program **ADSAS** (Arch Dam Structural Analysis System) was used to perform the study. The purpose of the analyses is to determine the adequacy of the structure to safely support the unusual (flood) loading condition.

This memorandum presents the assumptions and methodology used in the analysis.

2.0 MATERIAL PROPERTIES

2.1 Dam Material Properties

The dam material parameter assumptions were taken from data supplied by HKM, Inc. *[10]*, and published data on material properties for similar types of dams. The material properties of the masonry/concrete dam were assumed to be consistent through the structure and are summarized in Table 1.

TABLE 1.
DAM MATERIAL PROPERTIES

Properties	Values
Compressive Strength	3,000 lbs/in^2
Tensile Strength	300 lbs/in^2
Sustained Modulus of Elasticity	3.0×10^6 lbs/in^2
Unit Weight	150 lbs/ft^3
Poisson's Ratio	0.20
Coefficient of Thermal Expansion	5.6×10^{-6} in/in/°F

The compressive strength and tensile strength of the dam material were assumed to be 3,000 lbs/in^2 *[1]* and 300 lbs/in^2 *[2]* respectively. Although the intact strength of masonry taken from the rock at the site is typically greater than these values, the overall strength assumptions were based on the weaker material (mortar) strength.

The unit weight of the dam was assumed equal to average unit weight of the masonry and mortar *[4]*. This assumed unit weight is considered conservative because the dam is primarily composed of the heavier granite.

The modulus of elasticity and Poisson's Ratio were assumed based on published data *[1]*. The assumed value of coefficient of thermal expansion for the dam was also estimated based on published data *[8]*. .

2.2 Foundation Properties

The foundation strength parameter assumptions were taken from data supplied by HKM, Inc. *[10]*.

The effective angle of friction was assumed equal to the base internal angle of friction plus a surface roughness angle. The average base angle of friction was assumed equal to 38 degrees. The increase in the friction angle due to surface roughness was estimated to range from 11 to 23 degrees, as computed using Equation 1 *[5]*.

Equation 1

$$i = JRC \times Log_{10}\left(\frac{\sigma_R}{\sigma_N}\right)$$

where: i = Surface Roughness Angle

JRC = Joint Roughness coefficient, estimated to range from 5-10

σ_R = Unconfined compressive strength of rock, 9,000 lbs/in^2

σ_N = Average Normal stress from study, 50 lbs/in^2

The average intact modulus of elasticity for the foundation was reported to be about 1,400,000 lbs/in^2. Studies have shown that the in situ modulus of deformation for rock mass foundation can range from 20 to 60 percent of the intact modulus *[6]*. For these studies the deformation of the rock mass was assumed to be 60 percent of the average intact modulus based on estimated high rock quality designation (RQD) values for the foundation rock (i.e. excess of 75 percent). Table 2 summarizes the foundation properties.

TABLE 2.
FOUNDATION MATERIAL PROPERTIES

Properties	Values	
Compressive Strength	9,000	lbs/in^2
Base Internal Angle of Friction	38	degrees
Surface Roughness Angle	11 to 23	degrees
Effective Angle of Friction	49 to 61	degrees
Cohesion	0.0	lbs/in^2
Deformation Modulus	850,000	lbs/in^2
Poisson's Ratio	0.20	

3.0 LOADS

The loads include gravity, normal and probable maximum flood (PMF) reservoir levels, temperature, embankment, and uplift. The loads are summarized in Table 3 and described in the following paragraphs.

TABLE 3.
INDIVIDUAL LOADS

Load	Description
Gravity	Dead weight of dam.
Temperature	Loads due to the effect of expansion and contraction created by temperature changes.
NWS	Hydrostatic water pressure applied to the upstream face of the dam to simulate the normal reservoir water surface.
PMF	Additional hydrostatic water pressure applied to the upstream face of the dam to simulate the probable maximum flood.
Embankment	Vertical and horizontal pressure applied to downstream face of the dam from earth backfill.
Uplift	Internal hydrostatic water pressure acting normal to the base.

3.1 Gravity

The gravity load of the dam was based on an assumed unit weight of 150 lbs/ft^3.

3.2 Temperature

Temperature loads are the loads created by volumetric expansion and contraction due to temperature changes from a stress free temperature. The stress free temperature condition of the masonry/concrete dam was assumed equal to 43.9 degrees Fahrenheit, and corresponds to the mean annual ambient air temperature for Butte, Montana *[11]*.

For these studies the temperature load was assumed equal to the stress free temperature of the masonry/concrete dam, and simulates the spring/fall condition when the dam is transitioning from the colder winter months to the warmer summer months. The PMF event typically occurs in the spring, therefore, the stress-free temperature condition was used for the analysis of the unusual PMF loading condition.

3.3 NWS

The hydrostatic load due to the reservoir was simulated using a fluid unit weight of 62.5 lb/ft^3. The maximum normal operating water surface (NWS) for Basin Creek Dam is at elevation 5872 msl.

3.4 PMF

The probable maximum flooding (PMF) is simulated by increasing the water elevation to 5876.8 msl, and is 3.8 feet above the top of the parapet wall on the crest of the dam.

3.5 Embankment

Typically the sedimentation loads are assumed to have an equivalent horizontal unit weight equal to 85 lbs/ft^3 and vertical unit weight equal to 120 lbs/ft^3, as recommended by the USBR *[1]*. For these studies, the downstream embankment was assumed to be unsaturated, with a total unit weigh of 120 lb/ft^3. If the surface of the embankment were horizontal (i.e. level), then the estimated equivalent horizontal unit weight would be 60 lb/ft^3, which assumes an at-rest pressure coefficient equal to 0.5. The surface of the embankment is not horizontal. The surface is sloped at about 1.6 H: 1.0 V. therefore, the equivalent horizontal unit weight was reduced to an estimated value of 35 lb/ft^3, to account for the sloped embankment.

3.6 Uplift

The ADSAS computer program does not include the effects of uplift in the computations of stress within the dam. This is appropriate for the stress evaluation of the dam since studies have shown that the uplift force has a negligible impact on the stresses in the dam *[1]*. However, uplift can have a significant impact on the sliding stability at the dam and foundation contact. Therefore, uplift was included in the stability evaluation of the dam, and assumed to vary linearly form the full reservoir head at the upstream heel of the dam, to zero at the downstream toe of the dam. This loading may be under conservative for the PMF loading condition because the effects of tailwater are neglected.

4.0 LOAD COMBINATIONS

The loading combinations used in these studies are based on the standard practice for the design and analysis of arch dams *[7]*. Three load combinations representing the various usual and unusual loading conditions were evaluated. All load combinations are presented in Table 4.

TABLE 4.
LOAD COMBINATIONS
ANALYSIS OF BASIN CREEK DAM NO. 1

Load Combination	USLC-1a (1)	USLC-1b	UNLC-1a (2)	UNLC-1b
Gravity	X	X	X	X
Reservoir				
NWS	X	X		
PMF			X	X
Temperature				
Spring/Fall	X	X	X	X
Embankment				
35 lb/ft^3		X		X

Note (1): USLC-1a refers to the Usual Load Combination No. 1, study a
Note (2): UNLC-1a refers to the Unusual Load Combination No. 1, study a

5.0 EVALUATION CRITERIA

The safety of Basin Creek Dam No. 1 was evaluated for two potential failure modes, as listed below:

- Allowable Stress of the concrete.
- Sliding stability of the dam/foundation contact.

5.1 Allowable Dam Stress Criteria

The structural capacity of the uncracked dam was evaluated by comparing the calculated stresses from the trial-load analysis to the allowable tensile and compressive stresses of the masonry/concrete, which is in accordance with current safety criteria *[1]*. The values are summarized in Table 5.

TABLE 5.
MAXIMUM ALLOWABLE STRESS

Properties	Values
Compressive Stress	
Usual Load Combination	1,000 lbs/in^2
Unusual Load Combination	1,500 lbs/in^2
Tensile Stress	
Usual Load Combination	100 lbs/in^2
Unusual Load Combination	150 lbs/in^2

5.2 Sliding Stability Criteria

In some recorded project case histories, curved dams have become unstable due to the shear forces acting along the dam/foundation interface. Although this scenario has only been observed in thin arch dam dams, with flat sloping abutments, it is prudent to evaluate this potential failure mode for curved concrete dams.

For Basin Creek Dam the sliding stability along the dam/foundation interface was evaluated using the normal and shear forces computed from the three-dimensional trial-load analysis. The stability of the dam was determined by comparing a computed sliding factor of safety to the minimum allowable factor of safety, as recommended by the FERC guidelines *[2]*. The minimum allowable factors of safety are summarized in Table 6.

TABLE 6.
MINIMUM ALLOWABLE
SLIDING STABILITY FACTOR OF SAFETY

Load	Value
Usual Load Combination	1.5
Unusual Load Combination	1.5

The resulting forces were computed by the three-dimensional trial-load analysis for a 1-foot wide base corresponding to each cantilever The normal uplift pressures were added to the results, and the transformed normal and driving forces were computed. The sliding stability factor of safety was then computed using Equation 2.

Equation 2

$$Q = \frac{c \times A + F_N \times TAN(\phi)}{F_D}$$

where:	Q =	Sliding Factor of Safety
	c =	Effective foundation cohesion, zero in this study
	A =	Area of base in contact at dam/foundation interface
	Tan(ϕ) =	Effective coefficient of friction along failure plane
	F_N =	Normal force to dam/foundation interface
	F_D =	Driving force parallel to dam/foundation interface

In arch dams, the normal forces transmitted from the arches into the foundation typically provide adequate frictional resistance to counteract the shear forces. If failure due to sliding is predicted in one arch, the loads are typically transferred to other arches, increasing the normal and shear forces along the dam/foundation interface. In some cases, considering this load transfer in a progressive stability analysis will indicate that the dam is stable even though the minimum factor of safety, as calculated above, is below the acceptable value. In cases where the minimum factor of safety is below acceptable limits, a progressive stability analysis is recommended.

6.0 METHOD OF ANALYSIS

The three dimensional analysis of Basin Creek Dam No. 1 was performed using the USBR Arch Dam Stress Analysis System (ADSAS) computer program *[9]*. This program is a computerized version of the Trial-Load Method of analyzing arch dams. The method was originally developed prior to 1940 and has been confirmed by extensive prototype measurements. The Trial-Load method assumes that the dam is divided into a system of vertical and horizontal elements with each system occupying the entire thickness of the dam, independently of the other. The loads applied to the dam are then divided between these systems in such a way that geometrical continuity is attained throughout the structure. The representative horizontal elements are called arches and vertical elements are called cantilevers.

7.0 RESULTS

The results from ADSAS are given in two different formats: cantilever and arch stresses, and forces at the abutment with their corresponding angles at that point.

Cantilever stresses are parallel to the upstream and downstream face of the dam and act primarily in the vertical direction. Arch stresses are primarily horizontal and oriented such that they are normal to the radius of the arch on the extrados (upstream) and intrados (downstream) face of the dam. The computed arch and cantilever stresses are compared to the maximum allowable stress of the dam to determine if cracking or crushing of the material due to the assumed loading condition will occur.

The computed resultant forces along the dam/foundation contact were transformed into forces normal and tangential to the abutment. The ADSAS program does not include the effects of uplift in the analysis. Due to the thickness of Basin Creek Dam No. 1, however, uplift could have a significant effect on the stability. Therefore, the uplift load was computed by hand and added to the normal and tangential forces taken from the ADSAS results. The normal and tangential forces, including uplift, were then used to compute the factor of safety and compare it to the minimum required factor of safety. A range of effective angles of friction for the rock mass were used to compute an envelope of sliding stability factor of safety.

7.1 Usual Load Combination 1

The usual load combination 1 (USLC-1) consists of the gravity, NWS, spring/fall temperature conditions, and the following two different embankment loading conditions:

- Without the embankment load (USLC-1a), which simulates the condition on the dam prior to the 1930's,
- Includes the embankment load (USLC-1b), with equivalent horizontal unit weight of 35 lb/ft^3.

Evaluating the dam for the usual spring/fall temperature loads develops a basis from which engineers can evaluate the structural behavior due to other loads, such as the PMF flooding event. Table 7 summarizes the maximum computed arch and cantilever stresses from the analysis, and compares the stresses with the allowable strength of the masonry/concrete dam. The computed cantilever and arch stress results for all three embankment conditions are shown in Figure 2 through Figure 5.

TABLE 7.
USLC-1
SUMMARY OF MAXIMUM STRESS

Description	Maximum Stresses on Face of Dam (lbs/in^2)				Maximum Allowable Stress (lbs/in^2)
	USLC-1a		USLC-1b		
	US	DS	US	DS	
Compression Stress					
Cantilevers	66	616	79	335	1,000
Arches	49	87	35	58	1,000
Tensile Stress					
Cantilevers	- -	- -	- -	- -	100
Arches	34	15	23	10	100

7.1.1 Allowable Stress

The results from the ADSAS analysis using USLC-1 show that the computed stresses in the model are less than the allowable strength of the masonry/concrete dam for the two loading conditions. This indicates that the dam will not experience cracking or crushing; therefore, the dam is considered to have adequate safety against overstressing for USLC-1.

TABLE 8.
USLC-1
COMPUTED SLIDING FACTOR OF SAFETY

Elevation	Station	USLC-1a		USLC-1b	
		Minimum	Maximum	Minimum	Maximum
5871	-110.0	1.5	2.4	1.5	2.4
5856	-106.0	1.8	2.8	2.5	3.9
5826	-87.3	0.6	0.9	1.5	2.3
5806	-69.2	0.8	1.3	3.5	5.4
5789	-34.6	0.3	0.5	6.1	9.5
5772	0.0	1.9	2.9	27.1	42.4
5789	34.6	0.3	0.5	6.3	9.9
5806	69.2	0.8	1.2	3.3	5.2
5826	97.5	0.8	1.3	2.4	3.8
5856	126.6	3.3	3.5	3.1	4.9
5871	137.5	1.3	2.1	1.3	2.1

7.1.2 Sliding Stability

The computed sliding stability factors of safety for USLC-1 are summarized in Table 8. The table shows the sliding factor of safety for the estimated range of effective friction angles (minimum of 49 degrees and maximum of 61 degrees) in the foundation with zero cohesion.

In cases where the sliding factors of safety for the individual areas are less than the allowable factor of safety, a progressive stability analysis was performed. The structural characteristics of the dam result in the areas along the dam/foundation interface to be physically connected to the adjacent areas. This prevents differential movement. Therefore, the less stable areas will gain some additional stability from more stable adjacent areas of the dam. When the computed sliding factors of safety for and individual area is less than the allowable factor of safety, then adjacent areas are averaged together in a process called progressive stability analysis. If the results from the progressive stability analysis indicate that the overall average sliding factor of safety is greater than the minimum required value then the dam is considered to have adequate stability against sliding.

The results from load USLC-1a, without the embankment on the downstream face, show that the computed factors of safety are less than the allowable factor of safety for both the

assumed minimum and maximum friction angles. In performing a progressive stability analysis for the minimum effective friction angle of 49 degrees, the average computed factor of safety is still less than the allowable factor of safety and thus does not satisfy safety criteria for sliding stability. Given that the dam operated for around 50 years (1880's – 1930's) under these conditions, these results indicate that the minimum assumed friction angle may be overly conservative. Similarly, the progressive stability analysis for the results using the maximum effective friction angle of 61 degrees shows that the overall average sliding factor of safety is greater than required by the safety criteria and thus is considered to have adequate safety against sliding.

The results from USLC-1b, with the embankment on the downstream face of the dam, show an increase in the computed sliding factor of safety compared to load USLC-1a. The effects of the embankment cause a reduction in the shear forces along the abutment and an increase in the sliding factor of safety. The results from USLC-1b also show one area located on the upper abutment at the crest of the dam where the computed factor of safety is less than the minimum allowable value of 1.5. However, when a progressive stability analysis is performed, the results show that the overall sliding factor of safety is greater than the minimum required value. Based on these results, the dam is considered to have adequate safety against sliding for the assumed loading with the embankment on the downstream face of the dam.

7.2 Unusual Load Combination-1 (UNLC-1)

The unusual load combination 1 (UNLC-1) consists of the gravity, NWS, spring/fall temperature conditions, and the following two different embankment loading conditions:

- Without the embankment load (UNLC-1a), which simulates the condition on the dam prior to the 1930's and the likely condition of the dam during the PMF overtopping event (assuming erosion of the embankment),
- Includes the embankment load (UNLC-1b), with equivalent horizontal unit weight of 35 lb/ft^3.

The PMF is most likely to occur during the spring season and hence the spring/fall temperature conditions were used in the analysis. Table 9 summarizes the maximum computed arch and cantilever stresses from the analysis, and compares the stresses with the allowable strength of the masonry/concrete dam. The computed cantilever and arch stress results for this load combination are shown in Figure 8 and Figure 9.

TABLE 9
UNLC-1 MAXIMUM ALLOWABLE STRESS

Description	Maximum Stresses on Face of Dam (lbs/in^2)				Maximum Allowable Stress (lbs/in^2)
	UNLC-1a		UNLC-1b		
	US	DS	US	DS	
Compression Stress					
Cantilevers	63	764	75	483	1,000
Arches	63	118	48	90	1,000
Tensile Stress					
Cantilevers	- -	- -	9	- -	100
Arches	50	17	40	12	100

7.2.1 Allowable Stress

The results show that the computed stress is less than the allowable stress of the dam for all assumed embankment loading condition. These results suggest that the that the dam will not experience cracking or crushing due to the assumed UNLC-1 loading condition, and therefore, the dam is considered to have adequate safety against overstressing.

TABLE 10
UNLC-1
COMPUTED SLIDING FACTOR OF SAFETY

Elevation	Station	UNLC-1a		UNLC-1b	
		Minimum	Maximum	Minimum	Maximum
5871	-110.0	1.3	2.1	1.3	2.0
5856	-106.0	1.5	2.3	1.8	2.8
5826	-87.3	0.5	0.8	1.2	1.9
5806	-69.2	0.7	1.1	2.8	4.4
5789	-34.6	0.2	0.3	4.9	7.7
5772	0.0	1.6	2.5	20.0	31.4
5789	34.6	0.2	0.4	5.1	7.9
5806	69.2	0.7	1.1	2.7	4.2
5826	97.5	0.7	1.1	1.9	3.0
5856	126.6	1.7	2.7	2.1	3.2
5871	137.5	1.2	1.8	1.1	1.7

7.2.2 Sliding Stability

The computed sliding stability factors of safety are shown in Table 10. This table shows the sliding factor of safety for the assumed range of effective friction angles (minimum of 49 degrees and maximum of 61 degrees) in the foundation with zero cohesion.

The results from load UNLC-1a, without the embankment on the downstream face, show that the computed factors of safety are less than the allowable factor of safety for both the assumed minimum and maximum friction angles. In performing a progressive stability analysis for the minimum effective friction angle of 49 degrees, the average computed factor of safety is still less than the allowable factor of safety and thus does not satisfy safety criteria for sliding stability. Similarly, the progressive stability analysis for the results using the maximum effective friction angle of 61 degrees shows that the overall average sliding factor of safety is greater than required by the safety criteria and thus is considered to have adequate safety against sliding. Based on these results, further work should be done to better estimate the effective friction angle at the dam/foundation interface. This better estimate would then result in a refinement in the analysis and a more accurate assessment of the factor of safety against sliding.

The results from UNLC-1b, with the embankment on the downstream face of the dam, show that the computed factors of safety are less than the allowable factor of safety for the assumed minimum friction angle. However, when a progressive stability analysis is performed, the results show that the overall sliding factor of safety is greater than the minimum required value. Based on these results, the dam is considered to have adequate safety against sliding for the assumed loading with the embankment on the downstream face of the dam. Modifications would need to be performed on the downstream face of the embankment to ensure the embankment would stay in place during the PMF overtopping event.

8.0 CONCLUSIONS

The conclusions from these structural stability studies are summarized below:

- For the usual loading condition acting on the current dam configuration, with the embankment on the downstream face, the dam has adequate factors of safety against overstressing and sliding for all assumed loading and material conditions.
- For the unusual loading condition acting on the assumed dam configuration, without the embankment on the downstream face, the dam has an adequate factor of safety against overstressing but an inadequate factor of safety against sliding for an effective friction angle of 49 degrees.
- Further investigation is required to better assess the condition of the dam/foundation interface.

Based on these studies, the stability of the dam satisfies safety criteria for the usual spring/fall conditions but not for the assumed unusual loading conditions. Recommendations for further studies are summarized below.

9.0 RECOMMENDATIONS

At least one of the three studies outlined below should be performed.

- **Assess the condition of the foundation.** A detailed study should be performed to obtain a more accurate estimate of the friction angle at the dam foundation interface. This study would include a site visit to visually inspect the roughness of the foundation and other relevant foundation properties. It would also include performing several direct shear tests of material from different locations near the dam/foundation interface. Performing these studies would yield better information about the condition of the foundation and might indicate that the dam is stable based on this study.

- **Perform a fully three-dimensional finite element study of the dam.** Should the stability of the dam still be in doubt upon performing the above studies, a three-dimensional finite element analysis may yield a more accurate assessment of the condition of the dam than the ADSAS study summarized in this report.

10.0 REFERENCES

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11.0 LIST OF FIGURES

Figure 1. Basin Creek Dam No. 1 Section and View

Figure 2. Basin Creek Dam No. 1 USLC-1a Cantilever Stresses

Figure 3. Basin Creek Dam No. 1 USLC-1a Arch Stresses

Figure 4. Basin Creek Dam No. 1 USLC-1b Cantilever Stresses

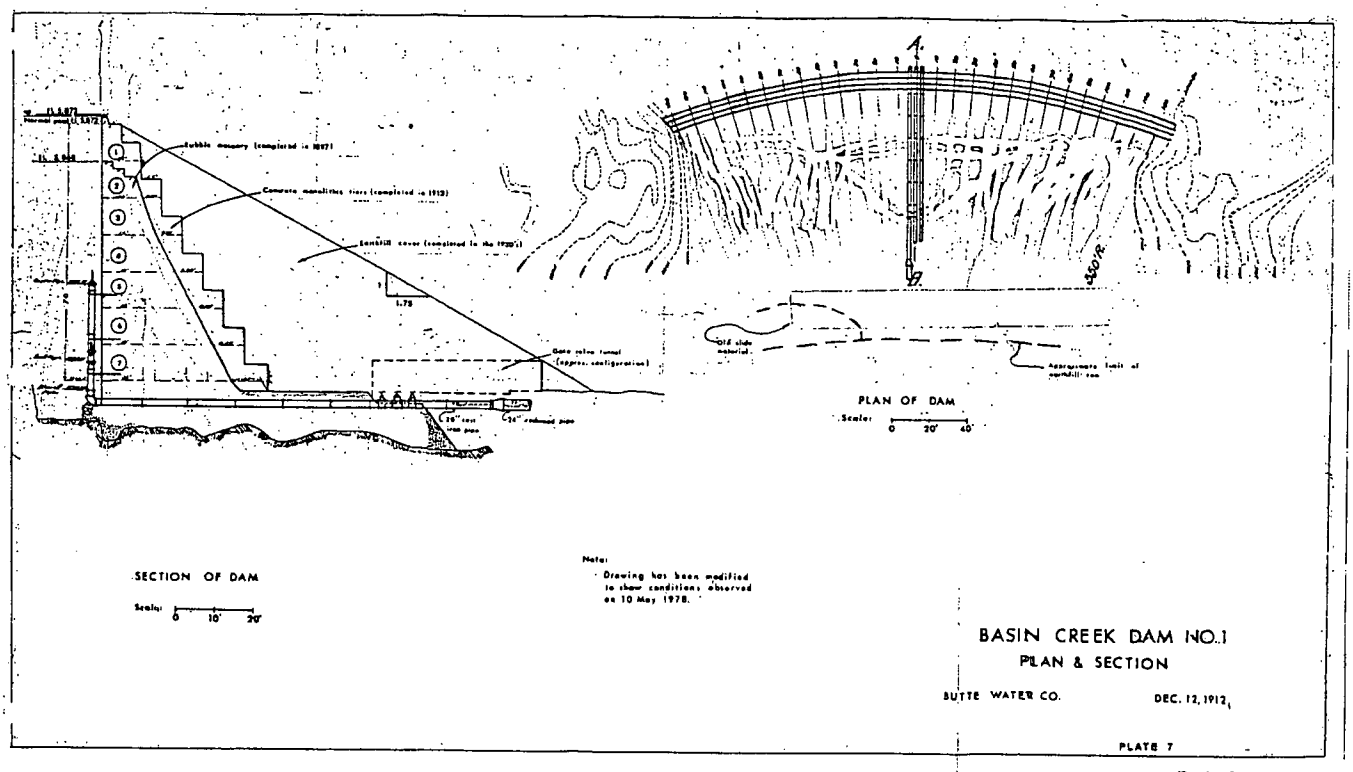
Figure 5. Basin Creek Dam No. 1 USLC-1b Arch Stresses

Figure 6. Basin Creek Dam No. 1 UNLC-1a Cantilever Stresses

Figure 7. Basin Creek Dam No. 1 UNLC-1a Arch Stresses

Figure 8. Basin Creek Dam No. 1 UNLC-1b Cantilever Stresses

Figure 9. Basin Creek Dam No. 1 UNLC-1b Arch Stresses



Basin Creek Dam #1

Section and Plan View

Figure No. 1

USLC-1a

Cantilever Stresses Parallel to the Face of the Dam

Looking Upstream

ELEV	STA	1127.06	1098.96	1070.25	1035.43	1000.00	964.57	929.75	911.42	891.88	
	TAU	0.									
5871.	U	0.	0.	0.	0.	0.	0.	0.	0.	0.	TAU
	D	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	TAU	13.									
5856.	U	10.	10.	14.	9.	8.	10.	15.	12.	12.	TAU
	D	16.	17.	11.	18.	19.	16.	10.	14.	21.	
										4.	
		TAU	24.								
5826.		U	22.	21.	6.	8.	10.	30.	25.	TAU	
		D	40.	41.	61.	59.	57.	29.	34.		
									24.		
			TAU	39.							
5806.			U	32.	12.	13.	16.	33.	TAU		
			D	59.	616.	599.	574.	46.			
								38.			
				TAU	-23.		-21.	TAU			
5789.				U	50.	50.	51.				
				D	36.	22.	32.				
					TAU	18.					
5772.					U	66.					
					D	36.					

Basin Creek Dam #1

USLC-1a

Cantilever Stresses

Figure No. 2

USLC-1a

Arch Stresses Parallel to the Face of the Dam

Looking Upstream

ELEV	STA	1137.44	1127.06	1098.96	1070.25	1035.43	1000.00	964.57	929.75	911.42	891.88	885.77	
	TAU	10.										16.	TAU
5871.	E	-18.	2.	25.	46.	48.	48.	49.	42.	24.	-7.	-32.	
	I	58.	43.	34.	24.	32.	34.	27.	23.	34.	62.	87.	
		TAU	13.								13.	TAU	
5856.		E	-15.	14.	43.	42.	43.	45.	39.	13.	-34.		
		I	53.	32.	11.	20.	21.	15.	11.	34.	79.		
			TAU	27.						32.	TAU		
5826.			E	-29.	26.	37.	36.	39.	20.	-30.			
			I	55.	3.	-6.	-5.	-9.	8.	56.			
				TAU	32.				34.	TAU			
5806.				E	24.	26.	23.	26.	23.				
				I	-4.	-9.	-7.	-9.	-3.				
					TAU	22.		23.	TAU				
5789.					E	18.	22.	18.					
					I	-9.	-15.	-9.					

Basin Creek Dam #1

USLC-1a

Arch Stresses

Figure No. 3

USLC-1b

Cantilever Stresses Parallel to the Face of the Dam

Looking Upstream

ELEV	STA	1127.06	1098.96	1070.25	1035.43	1000.00	964.57	929.75	911.42	891.88	
	TAU	0.								0.	TAU
5871.	U	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	D	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	TAU	9.								8.	TAU
5856.	U	13.	14.	16.	14.	13.	15.	17.	16.	20.	
	D	15.	14.	11.	14.	15.	13.	10.	12.	7.	
		TAU	16.						15.	TAU	
5826.		U	35.	36.	32.	33.	34.	42.	43.		
		D	39.	38.	44.	43.	41.	30.	29.		
			TAU	27.				23.	TAU		
5806.			U	53.	48.	50.	51.	61.			
			D	56.	335.	323.	309.	43.			
				TAU	-40.		-39.	TAU			
5789.				U	56.	57.	57.				
				D	101.	69.	99.				
					TAU	26.					
5772.					U	79.					
					D	77.					

Basin Creek Dam #1

USLC-1b

Cantilever Stresses

Figure No. 4

USLC-1b

Arch Stresses Parallel to the Face of the Dam

Looking Upstream

ELEV	STA	1137.44	1127.06	1098.96	1070.25	1035.43	1000.00	964.57	929.75	911.42	891.88	885.77	
	TAU	7.										11.	TAU
5871.	E	-11.	0.	18.	31.	34.	35.	35.	28.	16.	-6.	-22.	
	I	37.	30.	22.	19.	22.	23.	19.	17.	23.	42.	58.	
		TAU	9.								9.	TAU	
5856.		E	-11.	10.	27.	30.	31.	31.	25.	8.	-23.		
		I	36.	21.	10.	13.	14.	10.	9.	23.	53.		
			TAU	15.						19.	TAU		
5826.			E	-18.	14.	25.	25.	26.	10.	-19.			
			I	34.	5.	-5.	-5.	-6.	8.	35.			
				TAU	21.				23.	TAU			
5806.				E	15.	15.	15.	15.	15.				
				I	-5.	-6.	-6.	-6.	-4.				
					TAU	15.		15.	TAU				
5789.					E	9.	13.	9.					
					I	-6.	-10.	-6.					

Basin Creek Dam #1

USLC-1b

Arch Stresses

Figure No. 5

UNLC-1a

Cantilever Stresses Parallel to the Face of the Dam

Looking Upstream

ELEV	STA	1127.06	1098.96	1070.25	1035.43	1000.00	964.57	929.75	911.42	891.88	
	TAU	0.								0.	TAU
5871.	U	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	D	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	TAU	15.								14.	TAU
5856.	U	6.	4.	5.	2.	1.	3.	7.	7.	19.	
	D	23.	26.	24.	28.	29.	27.	22.	22.	9.	
		TAU	22.						20.	TAU	
5826.		U	27.	24.	17.	17.	19.	33.	37.		
		D	51.	54.	65.	63.	61.	43.	37.		
			TAU	34.				29.	TAU		
5806.			U	43.	34.	35.	37.	55.			
			D	70.	483.	472.	449.	53.			
				TAU	-46.		-44.	TAU			
5789.				U	53.	53.	54.				
				D	113.	76.	110.				
					TAU	29.					
5772.					U	75.					
					D	83.					

Basin Creek Dam #1

UNLC-1a

Cantilever Stresses

Figure No. 6

UNLC-1a

Arch Stresses Parallel to the Face of the Dam

Looking Upstream

ELEV	STA	1137.44	1127.06	1098.96	1070.25	1035.43	1000.00	964.57	929.75	911.42	891.88	885.77	
	TAU	13.										20.	TAU
5871.	E	-24.	0.	28.	44.	47.	47.	48.	42.	26.	-9.	-40.	
	I	61.	42.	29.	26.	33.	34.	28.	22.	29.	59.	90.	
		TAU	14.								15.	TAU	
5856.		E	-18.	17.	37.	39.	40.	41.	36.	14.	-34.		
		I	52.	25.	13.	19.	20.	15.	10.	28.	74.		
			TAU	19.						24.	TAU		
5826.			E	-21.	19.	30.	30.	32.	14.	-23.			
			I	41.	4.	-5.	-5.	-8.	8.	43.			
				TAU	26.				28.	TAU			
5806.				E	19.	18.	18.	19.	18.				
				I	-6.	-7.	-6.	-7.	-6.				
					TAU	18.		18.	TAU				
5789.					E	11.	15.	11.					
					I	-7.	-12.	-7.					

Basin Creek Dam #1

UNLC-1a

Arch Stresses

Figure No. 7

UNLC-1b

Cantilever Stresses Parallel to the Face of the Dam

Looking Upstream

ELEV	STA	1127.06	1098.96	1070.25	1035.43	1000.00	964.57	929.75	911.42	891.88	
	TAU	0.									
5871.	U	0.	0.	0.	0.	0.	0.	0.	0.	0.	TAU
	D	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	TAU	19.									
5856.	U	3.	-0.	3.	-3.	-4.	-1.	5.	4.	17.	TAU
	D	24.	29.	24.	32.	33.	30.	22.	24.	19.	
										5.	
		TAU	30.						29.		
5826.		U	13.	9.	-9.	-8.	-5.	21.	29.	TAU	
		D	52.	57.	82.	80.	76.	42.	31.		
			TAU	47.				40.			
5806.			U	22.	-3.	-1.	2.	39.	TAU		
			D	74.	764.	748.	713.	48.			
				TAU	-28.		-27.				
5789.				U	46.	46.	48.	TAU			
				D	47.	29.	43.				
					TAU	21.					
5772.					U	63.					
					D	42.					

Basin Creek Dam #1

UNLC-1b

Cantilever Stresses

Figure No. 8

UNLC-1b

Arch Stresses Parallel to the Face of the Dam

Looking Upstream

ELEV	STA	1137.44	1127.06	1098.96	1070.25	1035.43	1000.00	964.57	929.75	911.42	891.88	885.77	
	TAU	17.										25.	TAU
5871.	E	-31.	2.	35.	60.	62.	60.	63.	55.	33.	-11.	-50.	
	I	82.	55.	40.	32.	42.	45.	36.	28.	40.	79.	118.	
		TAU	18.								19.	TAU	
5856.		E	-22.	21.	53.	52.	52.	55.	50.	19.	-45.		
		I	69.	35.	14.	25.	28.	19.	12.	38.	100.		
			TAU	31.						38.	TAU		
5826.			E	-33.	31.	43.	41.	45.	23.	-33.			
			I	62.	3.	-6.	-5.	-10.	9.	63.			
				TAU	36.				39.	TAU			
5806.				E	27.	29.	25.	29.	27.				
				I	-5.	-10.	-8.	-11.	-4.				
					TAU	25.		25.	TAU				
5789.					E	20.	24.	20.					
					I	-11.	-17.	-10.					

Basin Creek Dam #1

UNLC-1b

Arch Stresses

Figure No. 9

URS

ATTACHMENT 1:
ADSAS RESULTS FOR LOAD CASE USLC-1A

URS

```
INPUT FILE (bcd1.dat    ) FOR ADSAS  02/11/**  12:03:12


CARD            1         2         3         4         5         6         7         8  CARD
NO.    12345678901234567890123456789012345678901234567890123456789012345678901234567890  NO.

 1     1   0     BASIN CREEK DAM (BUTTE, MT)   16         0                        9701   1
 2     2   0     111101100000000000000000000                                       9701   2
 3     3   0     300000000000000  1.400  .200  5.60 150.00  0.850  .200  .00 43.90 9701   3
 4     4   0      5772.000 5871.000 5872.000 5772.000 5871.000 5871.000 5772.000   9701   4
 5     1   1     000000000000000000010000000000000000000                           9701   5
 6     3   1        0.00000 101.20000    0.0000    0.0000  350.0000     .0000  3  19701   6
 7     5   1 1 1   5871.00000      .00000      .00000      .00000      .00000      9701   7
 8     5   1 2 1   5797.50000    -0.80000      .00000      .00000      .00000      9701   8
 9     5   1 2 2   5798.50000   -37.80000      .00000      .00000      .00000      9701   9
10     5   1 2 3   5816.00000    -0.63000      .00000      .00000      .00000      9701  10
11     5   1 2 4   5856.00000    -0.55000      .00000      .00000      .00000      9701  11
12     5   1 2 5   5868.50000    -0.32000      .00000      .00000      .00000      9701  12
13     5   1 2 6   5871.00000      .00000      .00000      .00000      .00000      9701  13
14     5   1 3 1   5871.00000      .00000      .00000      .00000      .00000      9701  14
15     5   1 4 1   5871.00000      .00000      .00000      .00000      .00000      9701  15
16     6   1          .00000    6.00000     .00000     .00000     .00000     .00000 9701  16
17     7   110000 5772.00000  .0000  .0000  .0000  .0000   .00   .00  .00  .00      9701  17
18     7   100000 5789.00000 5.8000 5.8000  .0000  .0000   .00   .00  .00  .00      9701  18
19     7   100000 5806.0000011.500011.5000  .0000  .0000   .00   .00  .00  .00      9701  19
20     7   100000 5826.0000016.200014.5000  .0000  .0000-10.30   .00  .00  .00      9701  20
21     7   100000 5856.0000020.800017.7000  .0000  .0000-16.70   .00  .00  .00      9701  21
22     7   100000 5871.0000022.500018.7000  .0000  .0000-17.90   .00  .00  .00      9701  22
23     1   2     0000001000000000000000000000000000000000000000000000000000000      9701  23

CARD            1         2         3         4         5         6         7         8  CARD
NO.    12345678901234567890123456789012345678901234567890123456789012345678901234567890  NO.
```

URS

```
* * * * * * * * * * * * * * * * * * * * * * * * *
*                                               *
*                UNITED STATES                  *
*           DEPARTMENT OF THE INTERIOR          *
*             BUREAU OF RECLAMATION             *
*               DENVER, COLORADO                *
*                                               *
*            ARCH DAM STRESS ANALYSIS           *
*                      OF                       *
*  BASIN CREEK DAM (BUTTE, MT)     STUDY A-16   *
*              PROBLEM NUMBER 9701              *
*      COMPUTATIONS PERFORMED ON 02/11/**       *
*                                               *
* * * * * * * * * * * * * * * * * * * * * * * * *
```

URS

DESIGN CRITERIA

1. DATA WILL BE PREPARED FOR A COMPLETE ADJUSTMENT.

2. THE SHAPE WILL BE CONSIDERED NONSYMMETRIC.

4. TEMPERATURE LOADING IS PRESENTED IN TABULAR FORM (SEE TABLE ON PAGE 1, LINK 1 OUTPUT).

5. THE GROUTING TEMPERATURE= 43.90 DEGREES FAHRENHEIT.

6. THE EFFECTS OF TAILWATER, UPLIFT, SILT AND ICE LOADING, IF ANY, ARE NOT INCLUDED.

7. NO EARTHQUAKE LOADING WILL BE APPLIED.

8. TWO LINES OF CENTERS WILL BE USED TO DESCRIBE THE DAM.

9. MODULUS OF ELASTICITY OF THE ROCK IS CONSTANT FROM TOP TO BOTTOM OF THE DAM.

10. EFFECTS OF THE CONSTRUCTION PROGRAM ARE NOT INCLUDED IN THIS STUDY.

11. PHYSICAL PROPERTIES OF THE CONCRETE

A. YOUNGS MODULUS OF ELASTICITY= 1.400 MILLION POUNDS/SQUARE INCH.
B. POISSONS RATIO= .200.
C. COEFFICIENT OF THERMAL EXPANSION, .000005600 FOOT/FOOT/DEGREE FAHRENHEIT.
D. UNIT WEIGHT OF CONCRETE= 150.00 POUNDS/CUBIC FOOT.

12. PHYSICAL PROPERTIES OF THE ABUTMENT ROCK

A. YOUNGS MODULUS OF ELASTICITY= .850 MILLION POUNDS/SQUARE INCH.
B. POISSONS RATIO= .200.

13. THE BASE ELEVATION OF THE DAM IS 5772.000.

14. THE TOP ELEVATION OF THE DAM (AS DEFINED ON THE PLANE OF CENTERS) IS 5871.000.

15. THE RESERVOIR WATER SURFACE ELEVATION IS 5872.000.

16. THE TAILWATER SURFACE ELEVATION IS 5772.000.

17. THE DAM IS GROUTED TO ELEVATION 5871.000.

18. THE ELEVATION OF TOP OF CONCRETE IS 5871.000.

19. THE ELEVATION OF BOTTOM OF CONCRETE IS 5772.000.

URS

OUTPUT OF ARCH DAM STRESS ANALYSIS PROGRAMS LINK 8- * STRESS PROGRAM * PROBLEM NUMBER 9701
VERSION 2.00 COLLECTED DATE 02/11/**
ON 09/17/88 STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT) PAGE 1

RESOLUTION OF FORCES AND MOMENTS ON ABUTMENTS

DEFINITIONS

R-XY,R-XZ,R-YZ,R-XYZ = RESULTANT FORCES ON A ONE FOOT WIDE FOUNDATION.

A-XY,A-XZ,A-YZ,A-XYZ = ANGULAR LOCATIONS OF FORCES,I.E.,A-XY IS THE ANGLE MEASURED FROM X(TANGENTIAL) TOWARD Y(RADIAL). (+)A-XY IS UPSTREAM. A-XZ,A-YZ, AND A-XYZ ARE THE DIPS OF THE RESULTANTS. (+) IS DOWNWARD.

ECC = ECCENTRICITY OF R-XYZ FROM THE CENTER OF THICKNESS ON THE FOUNDATION. (+) IS UPSTREAM.

Q = SHEAR FRICTION FACTOR OF SAFETY ALONG THE PLANE OF THE ABUTMENT. Q1 IS IN THE RADIAL DIRECTION (+ IS UPSTREAM), Q2 IS IN THE DIRECTION NORMAL TO RADIAL(+ IS DOWN).

NOTE - THE ELEVATIONS ARE LISTED SEQUENTIALLY DOWN THE RIGHT SIDE OF THE DAM AND THEN UP THE LEFT SIDE LOOKING UPSTREAM.

ELEVATION	XY PLANE		XZ PLANE		YZ PLANE		XYZ PLANE		ECC	Q	
	R	A	R	A	R	A	R	A		Q1	Q2
5871.00	25150.	-21.0	23487.	.0	8994.	.0	25150.	.0	-2.024	-30.005	999.999
5856.00	32102.	-24.8	30337.	16.1	15867.	32.0	33186.	14.7	-5.076	-33.136	-70.682
5826.00	93854.	-61.3	84312.	57.7	108874.	40.9	117836.	37.2	-5.916	-14.382	47.114
5806.00	122645.	-69.9	172081.	75.8	202748.	55.4	207076.	53.7	-3.626	-15.063	31.736
5789.00	198320.	-81.2	323207.	84.6	376785.	58.7	377995.	58.4	6.804	-20.073	32.857
5772.00	153167.	-90.4	566352.	89.9	586695.	74.9	586696.	74.9	10.660	30.393	1042.853
5789.00	199797.	-82.2	321653.	85.1	376686.	58.3	377672.	58.1	6.376	-19.872	32.296
5806.00	132785.	-72.8	175960.	77.1	213363.	53.5	216930.	52.3	-4.527	-13.698	35.075
5826.00	84395.	-60.7	94333.	64.1	112333.	49.0	119666.	45.2	-5.051	-16.159	58.709
5856.00	25571.	-24.6	26832.	29.9	17092.	51.5	28861.	27.6	-4.416	-41.776	-99.711
5871.00	18245.	-18.5	17298.	.0	5801.	.0	18245.	.0	-1.778	-45.984	999.999

URS

STRESSES(PSI) FOR ARCH NO 1 AT ELEVATION 5871.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1137.44	-18.	58.	-18.	58.	10.
1127.06	2.	43.	2.	43.	
1098.96	25.	34.	25.	34.	
1070.25	46.	24.	46.	24.	
1035.43	48.	32.	48.	32.	
1000.00	48.	34.	48.	34.	
964.57	49.	27.	49.	27.	
929.75	42.	23.	42.	23.	
911.42	24.	34.	24.	34.	
891.88	-7.	62.	-7.	62.	
885.77	-32.	87.	-32.	87.	16.

STRESSES(PSI) FOR ARCH NO 2 AT ELEVATION 5856.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1127.06	-15.	53.	-15.	53.	13.
1098.96	14.	32.	14.	32.	
1070.25	43.	11.	43.	11.	
1035.43	42.	20.	42.	20.	
1000.00	43.	21.	43.	21.	
964.57	45.	15.	45.	15.	
929.75	39.	11.	39.	11.	
911.42	13.	34.	13.	34.	
891.88	-34.	79.	-34.	79.	13.

STRESSES(PSI) FOR ARCH NO 3 AT ELEVATION 5826.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1098.96	-29.	55.	-29.	55.	27.
1070.25	26.	3.	26.	3.	
1035.43	37.	-6.	37.	-6.	
1000.00	36.	-5.	36.	-5.	
964.57	39.	-9.	39.	-9.	
929.75	20.	8.	20.	8.	
911.42	-30.	56.	-30.	56.	32.

URS

STRESSES(PSI) FOR ARCH NO 4 AT ELEVATION 5806.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1070.25	24.	-4.	24.	-4.	32.
1035.43	26.	-9.	26.	-9.	
1000.00	23.	-7.	23.	-7.	
964.57	26.	-9.	26.	-9.	
929.75	23.	-3.	23.	-3.	34.

STRESSES(PSI) FOR ARCH NO 5 AT ELEVATION 5789.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1035.43	18.	-9.	18.	-9.	22.
1000.00	22.	-15.	22.	-15.	
964.57	18.	-9.	18.	-9.	23.

URS

STRESSES(PSI) FOR CANTILEVER NO 16

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	21.	3.	21.	4.

MAXIMUM ROCK PLANE SHEAR STRESS= 12.

STRESSES(PSI) FOR CANTILEVER NO 17

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	12.	12.	12.	14.
5826.00	34.	18.	34.	24.

MAXIMUM ROCK PLANE SHEAR STRESS= 25.

STRESSES(PSI) FOR CANTILEVER NO 18

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	15.	9.	15.	10.
5826.00	30.	22.	30.	29.
5806.00	46.	26.	46.	38.

MAXIMUM ROCK PLANE SHEAR STRESS= 33.

STRESSES(PSI) FOR CANTILEVER NO 19

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	10.	14.	10.	16.
5826.00	10.	43.	10.	57.
5806.00	16.	58.	16.	574.
5789.00	51.	12.	51.	32.

MAXIMUM ROCK PLANE SHEAR STRESS= -21.

URS

STRESSES(PSI) FOR CANTILEVER NO 20

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	8.	16.	8.	19.
5826.00	8.	45.	8.	59.
5806.00	13.	60.	13.	599.
5789.00	50.	14.	50.	22.
5772.00	66.	22.	66.	36.

MAXIMUM ROCK PLANE SHEAR STRESS= 18.

STRESSES(PSI) FOR CANTILEVER NO 21

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	9.	15.	9.	18.
5826.00	6.	47.	6.	61.
5806.00	12.	62.	12.	616.
5789.00	50.	13.	50.	36.

MAXIMUM ROCK PLANE SHEAR STRESS= -23.

STRESSES(PSI) FOR CANTILEVER NO 22

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	14.	10.	14.	11.
5826.00	21.	32.	21.	41.
5806.00	32.	41.	32.	59.

MAXIMUM ROCK PLANE SHEAR STRESS= 39.

STRESSES(PSI) FOR CANTILEVER NO 23

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	10.	14.	10.	17.
5826.00	22.	31.	22.	40.

MAXIMUM ROCK PLANE SHEAR STRESS= 24.

URS

STRESSES(PSI) FOR CANTILEVER NO 24

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	10.	14.	10.	16.

MAXIMUM ROCK PLANE SHEAR STRESS= 13.

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 25

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-18.	0	0	0.	58.	0	0	5871.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 24

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	2.	0	0	0.	43.	0	0	5871.0
5856.0	30.	-35.	-33	45	-7.	76.	-31	49	5856.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 23

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	25.	0	0	0.	34.	0	0	5871.0
5856.0	-8.	32.	41	53	-4.	52.	-37	14	5856.0
5826.0	30.	-37.	-19	52	13.	82.	-39	1	5826.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 22

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	46.	0	0	0.	24.	0	0	5871.0
5856.0	11.	46.	18	16	27.	-5.	44	55	5856.0
5826.0	9.	38.	40	1	53.	-8.	25	30	5826.0
5806.0	68.	-12.	-42	13	92.	-37.	30	18	5806.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 21

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	48.	0	0	0.	32.	0	0	5871.0
5856.0	9.	42.	1	23	16.	22.	-35	40	5856.0
5826.0	4.	40.	14	42	64.	-8.	10	17	5826.0
5806.0	-4.	42.	36	4	626.	-18.	6	56	5806.0
5789.0	53.	15.	-16	26	43.	-17.	20	44	5789.0

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 20

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	48.	0	0	0.	34.	0	0	5871.0
5856.0	8.	43.	0	40	18.	22.	19	25	5856.0
5826.0	8.	36.	0	41	59.	-5.	-1	3	5826.0
5806.0	13.	23.	-4	11	599.	-7.	0	24	5806.0
5789.0	50.	22.	0	1	22.	-15.	0	33	5789.0
5772.0	66.	0.	0	0	36.	0.	0	26	5772.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 19

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	49.	0	0	0.	27.	0	0	5871.0
5856.0	10.	45.	6	32	23.	8.	42	21	5856.0
5826.0	6.	44.	19	37	61.	-13.	14	27	5826.0
5806.0	-4.	46.	38	59	587.	-23.	8	30	5806.0
5789.0	54.	15.	-15	48	41.	-18.	22	40	5789.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 18

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	42.	0	0	0.	23.	0	0	5871.0
5856.0	6.	49.	27	53	-13.	34.	-44	23	5856.0
5826.0	46.	4.	-37	38	52.	-14.	35	50	5826.0
5806.0	79.	-10.	-37	35	82.	-47.	35	43	5806.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 17

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	24.	0	0	0.	34.	0	0	5871.0
5856.0	-12.	37.	44	43	-7.	55.	-35	33	5856.0
5826.0	44.	-39.	-19	57	-2.	81.	-33	45	5826.0

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 16

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-7.	0	0	0.	62.	0	0	5871.0
5856.0	37.	-50.	-25	51	-12.	95.	-22	28	5856.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 15

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-32.	0	0	0.	87.	0	0	5871.0

URS

PRINCIPAL STRESSES (PSI) PARALLEL TO THE FACES AT THE ABUTMENTS

LEFT ABUTMENT (LOOKING UPSTREAM)

AT THE UPSTREAM FACE						AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	CANT NO	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-18.	0	0	25	0.	58.	0	0	5871.0
5856.0	30.	-35.	-33	45	24	-7.	76.	-31	49	5856.0
5826.0	30.	-37.	-19	52	23	13.	82.	-39	1	5826.0
5806.0	68.	-12.	-42	13	22	92.	-37.	30	18	5806.0
5789.0	53.	15.	-16	26	21	43.	-17.	20	44	5789.0
5772.0	66.	0.	0	0	20	36.	0.	0	26	5772.0

RIGHT ABUTMENT (LOOKING UPSTREAM)

AT						AT THE UPSTREAM FACE				AT THE DOWNSTREAM FACE
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	CANT NO	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-32.	0	0	15	0.	87.	0	0	5871.0
5856.0	37.	-50.	-25	51	16	-12.	95.	-22	28	5856.0
5826.0	44.	-39.	-19	57	17	-2.	81.	-33	45	5826.0
5806.0	79.	-10.	-37	35	18	82.	-47.	35	43	5806.0
5789.0	54.	15.	-15	48	19	41.	-18.	22	40	5789.0

URS

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

CANTILEVER STRESSES PARAL
LOOKING

ELEV	STA	1127.06	1098.96	1070.25	1035.43	1000.00
	TAU	0.				
5871.	U	0.	0.	0.	0.	0.
	D	0.	0.	0.	0.	0.
	TAU	13.				
5856.	U	10.	10.	14.	9.	8.
	D	16.	17.	11.	18.	19.
		TAU	24.			
5826.		U	22.	21.	6.	8.
		D	40.	41.	61.	59.
			TAU	39.		
5806.			U	32.	12.	13.
			D	59.	616.	599.
				TAU	-23.	
5789.				U	50.	50.
				D	36.	22.
					TAU	18.
5772.					U	66.
					D	36.

URS

(9701) RUN 02/11/**

LEL TO THE FACE OF THE DAM
UPSTREAM

964.57	929.75	911.42	891.88	
			0.	TAU
0.	0.	0.	0.	
0.	0.	0.	0.	
			12.	TAU
10.	15.	12.	21.	
16.	10.	14.	4.	
		25.	TAU	
10.	30.	34.		
57.	29.	24.		
	33.	TAU		
16.	46.			
574.	38.			
-21.	TAU			
51.				
32.				

URS

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

ARCH STRESSES PARALLEL
LOOKING

ELEV	STA	1137.44	1127.06	1098.96	1070.25	1035.43	1000.00
	TAU	10.					
5871.	E	-18.	2.	25.	46.	48.	48.
	I	58.	43.	34.	24.	32.	34.
		TAU	13.				
5856.		E	-15.	14.	43.	42.	43.
		I	53.	32.	11.	20.	21.
			TAU	27.			
5826.			E	-29.	26.	37.	36.
			I	55.	3.	-6.	-5.
				TAU	32.		
5806.				E	24.	26.	23.
				I	-4.	-9.	-7.
					TAU	22.	
5789.					E	18.	22.
					I	-9.	-15.

URS

(9701) RUN 02/11/**

TO THE FACE OF THE DAM
UPSTREAM

964.57	929.75	911.42	891.88	885.77	
				16.	TAU
49.	42.	24.	-7.	-32.	
27.	23.	34.	62.	87.	
			13.	TAU	
45.	39.	13.	-34.		
15.	11.	34.	79.		
		32.	TAU		
39.	20.	-30.			
-9.	8.	56.			
	34.	TAU			
26.	23.				
-9.	-3.				
23.	TAU				
18.					
-9.					

URS

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OUTPUT OF ARCH DAM STRESS ANALYSIS PROGRAMS      LINK  8- *       STRESS PROGRAM       *            PROBLEM NUMBER 9701
VERSION   2.00 COLLECTED                                                                            DATE  02/11/**
ON  09/17/88                                STUDY A-16   OF BASIN CREEK DAM (BUTTE, MT)            PAGE   11

                                                TIME IN MINUTES FOR LINK 8

                                          1.  COMPUTATION OF STRESSES        =    .000
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URS

Project: BASIN CREEK DAM
Feature: ADSAS Study "B-1"
Detail: Sliding Stability - Usual Load (Normal Reservoir Elevation)
File: SLIDING2

Job No: 24773.00 Sheet #:
By: S. Jones Date: 14-Feb-05
Chkd.By: Date:

1. Reservoir Water Surface Elevation:

Reservoir Elevation = 5872.0 feet
Unit Weight of Water = 62.5 pcf

2. Foundation Strengths:

Min Effective Frictiion Angle = 49.0 degrees
Max Effective Frictiion Angle = 61.0 degrees

3. Foundation Drain Efficiency:

Foundation Drain Efficiency = 0.0%

4. Percent of Base Cracked

Base Cracked = 0.0%

4. ADSAS Results - Abutment Thrusts

		XY Plane		Thrust		XZ Plane		Thrust		YZ Plane		Thrust	
Elevation	Station	Resultant	Angle	X-Direction	Y-Direction	Resultant	Dip	X-Direction	Z-Direction	Resultant	Dip	Y-Direction	Z-Direction
(feet)	(feet)	(lbs)	(degrees)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(lbs)
5871.00	-110.0	25,150	-21.0	23,480	9,013	23,487	0.0	23,487	0	8,994	0.0	8,994	0
5856.00	-106.6	32,102	-24.8	29,141	13,465	30,337	16.1	29,147	8,413	15,867	32.0	13,456	8,408
5826.00	-87.3	93,854	-61.3	45,071	82,324	84,312	57.7	45,052	71,266	108,874	40.9	82,293	71,284
5806.00	-69.2	122,645	-69.9	42,148	115,175	172,081	75.8	42,213	166,823	202,748	55.4	115,129	166,889
5789.00	-34.6	198,320	-81.2	30,340	195,985	323,207	84.6	30,416	321,773	376,785	58.7	195,747	321,947
5772.00	0.0	153,167	-90.4	-1,069	153,163	566,352	89.9	988	566,351	586,695	74.9	152,837	566,438
5789.00	34.6	199,797	-82.2	27,116	197,948	321,653	85.1	27,475	320,477	376,686	58.3	197,938	320,489
5806.00	69.2	132,785	-72.8	39,266	126,847	175,960	77.1	39,283	171,519	213,363	53.5	126,913	171,513
5826.00	97.5	84,395	-60.7	41,301	73,598	94,333	64.1	41,205	84,858	112,333	49.0	73,697	84,779
5856.00	126.5	25,571	-24.6	23,250	10,645	26,832	29.9	23,261	13,375	17,092	51.5	10,640	13,376
5871.00	137.5	18,245	-18.5	17,302	5,789	17,298	0.0	17,298	0	5,801	0.0	5,801	0

5. Local Components of Thrust

			XY Plane		
Elevation	Station	Embankment Load	Tangential X-Direction	Radial Y-Direction	Vertical Z-Direction
(feet)	(feet)	(lbs)	(lbs)	(lbs)	(lbs)
5871.00	-110.0	0	23,483	9,003	0
5856.00	-106.6	0	29,144	13,461	8,411
5826.00	-87.3	0	45,062	82,308	71,275
5806.00	-69.2	0	42,180	115,152	166,856
5789.00	-34.6	0	30,378	195,866	321,860
5772.00	0.0	0	-40	153,000	566,395
5789.00	34.6	0	27,295	197,943	320,483
5808.00	69.2	0	39,274	126,880	171,516
5826.00	97.5	0	41,253	73,648	84,818
5856.00	126.5	0	23,255	10,642	13,378
5871.00	137.5	0	17,300	5,795	0

6. Uplift Forces

					XY Plane		
Elevation	Station	Arch Thickness	Dam/Fnd Contact Angle	Normal Uplift Force	Tangential X-Direction	Radial Y-Direction	Vertical Z-Direction
(feet)	(feet)	(feet)	(degrees)	(lbs)	(lbs)	(lbs)	(lbs)
5871.00	-110.0	6.00	59.00	-188	-161	0	-97
5856.00	-106.6	10.00	59.00	-5,000	-4,286	0	-2,575
5826.00	-87.3	26.50	53.00	-38,094	-30,423	0	-22,925
5806.00	-69.2	38.30	36.00	-78,994	-46,431	0	-63,907
5789.00	-34.6	87.60	36.00	-227,213	-133,552	0	-183,819
5772.00	0.0	101.20	0.00	-316,250	0	0	-316,250
5789.00	34.6	87.60	33.00	-227,213	-123,749	0	-190,556
5806.00	69.2	38.30	33.00	-78,994	-43,023	0	-66,250
5826.00	97.5	26.50	42.00	-38,094	-25,490	0	-28,309
5856.00	126.5	10.00	53.00	-5,000	-3,993	0	-3,009
5871.00	137.5	6.00	53.00	-188	-150	0	-113

URS

7. Resultant Thrusts (Includes uplift)

Elevation	Station	Dam/Fnd Contact Angle	Resultant Tangential X-Direction	Resultant Radial Y-Direction	Resultant Vertical Z-Direction	Resultant XY Plane Resultant	Resultant XY Plane Angle	Resultant XZ Plane Resultant	Resultant XZ Plane Dip	Resultant YZ Plane Resultant	Resultant YZ Plane Dip	Normal
(feet)	(feet)	(degrees)	(lbs)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(degrees)	(lbs)	(degrees)	(lbs)
5871.00	-110.0	59.00	23,323	9,003	-97	25,000	-21.1	23,323	-0.2	9,004	-89.4	19,942
5858.00	-106.6	59.00	24,858	13,461	5,835	28,269	-28.4	25,534	13.2	14,671	66.6	24,313
5826.00	-87.3	53.00	14,639	82,308	48,350	83,600	-79.9	50,517	73.2	95,459	59.6	40,788
5806.00	-69.2	36.00	-4,251	115,152	102,949	115,231	87.9	103,037	-87.6	154,462	48.2	80,789
5789.00	-34.6	36.00	-103,174	195,866	138,041	221,378	62.2	172,337	-53.2	239,622	54.8	51,034
5772.00	0.0	0.00	-40	153,000	250,145	153,000	90.0	250,145	-90.0	293,226	31.5	250,145
5789.00	34.6	33.00	-96,454	197,943	129,927	220,193	64.0	161,815	-53.4	236,775	56.7	58,433
5806.00	69.2	33.00	-3,749	126,880	105,266	126,935	88.3	105,333	-88.0	164,862	50.3	86,242
5826.00	97.5	42.00	15,763	73,648	56,509	75,316	-77.9	58,667	74.4	92,829	52.5	52,542
5856.00	126.5	53.00	19,262	10,642	10,367	22,007	-28.9	21,875	28.3	14,857	45.8	21,622
5871.00	137.5	53.00	17,150	5,795	-113	18,103	-18.7	17,151	-0.4	5,796	-88.9	13,629

8. Sliding Factor of Safety

Elevation	Station	Arch Thickness	Normal Force	Tangential Driving Force	Radial Driving Force	Total Driving Force	Sliding Factor of Safety Minimum	Sliding Factor of Safety Maximum	Require Friction Angle for FOS = 1.5 Resultant
(feet)	(feet)	(feet)	(lbs)	(lbs)	(lbs)	(lbs)			(degrees)
5871.00	-110.0	6.00	19,942	12,095	9,003	15078	1.5	2.4	48.6
5856.00	-106.6	10.00	24,313	7,801	13,461	15558	1.8	2.8	43.8
5826.00	-87.3	26.50	40,788	-29,804	82,308	82308	0.6	0.9	71.7
5806.00	-69.2	38.30	80,789	-63,951	115,152	115152	0.8	1.3	64.9
5789.00	-34.6	87.60	51,034	-164,608	195,866	195866	0.3	0.5	60.1
5772.00	0.0	101.20	250,145	-40	153,000	153000	1.9	2.9	42.5
5789.00	34.6	87.60	56,433	-151,656	197,943	197943	0.3	0.5	79.2
5806.00	69.2	38.30	86,242	-60,476	126,880	126880	0.8	1.2	66.6
5826.00	97.5	26.50	52,542	-26,098	73,648	73648	0.8	1.3	64.6
5856.00	126.5	10.00	21,622	3,313	10,642	11146	2.2	3.5	37.7
5871.00	137.5	6.00	13,629	10,411	5,795	11916	1.3	2.1	52.7

URS

ATTACHMENT 2:
ADSAS RESULTS FOR LOAD CASE USLC-1B

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INPUT FILE (bcd7.dat    ) FOR ADSAS  02/11/**  12:20:36


CARD              1         2         3         4         5         6         7         8  CARD
NO.     12345678901234567890123456789012345678901234567890123456789012345678901234567890  NO.

  1     1   0     BASIN CREEK DAM (BUTTE, MT)   16         0                        9701   1
  2     2   0     1111011000000000000000000000                                      9701   2
  3     3   0     300000100000000  1.400  .200  5.60 150.00  0.850  .200  .00 43.90 9701   3
  4     4   0      5772.000 5871.000 5872.000 5772.000 5871.000 5871.000 5772.000   9701   4
  5     1   1     00000000000000000010000000000000000000                            9701   5
  6     3   1        0.00000 101.20000    0.0000    0.0000  350.0000     .0000  3  19701   6
  7     5   1 1 1   5871.00000      .00000      .00000      .00000      .00000      9701   7
  8     5   1 2 1   5797.50000    -0.80000      .00000      .00000      .00000      9701   8
  9     5   1 2 2   5798.50000   -37.80000      .00000      .00000      .00000      9701   9
 10     5   1 2 3   5816.00000    -0.63000      .00000      .00000      .00000      9701  10
 11     5   1 2 4   5856.00000    -0.55000      .00000      .00000      .00000      9701  11
 12     5   1 2 5   5868.50000    -0.32000      .00000      .00000      .00000      9701  12
 13     5   1 2 6   5871.00000      .00000      .00000      .00000      .00000      9701  13
 14     5   1 3 1   5871.00000      .00000      .00000      .00000      .00000      9701  14
 15     5   1 4 1   5871.00000      .00000      .00000      .00000      .00000      9701  15
 16     6   1           .00000    6.00000     .00000     .00000     .00000     .000009701  16
 17     7   110000 5772.00000  .0000  .0000  .0000  .0000 -5.50   .00  .00  .00     9701  17
 18     7   100000 5789.00000 5.8000 5.8000  .0000  .0000 -5.30   .00  .00  .00     9701  18
 19     7   100000 5806.0000011.500011.5000  .0000  .0000 -9.50   .00  .00  .00     9701  19
 20     7   100000 5826.0000016.200014.5000  .0000  .0000-14.70   .00  .00  .00     9701  20
 21     7   100000 5856.0000020.800017.7000  .0000  .0000-23.50   .00  .00  .00     9701  21
 22     7   100000 5871.0000022.500018.7000  .0000  .0000-28.40   .00  .00  .00     9701  22
 23     1   2     0000001000000000000000000000000000000000000000000000000000000      9701  23

CARD              1         2         3         4         5         6         7         8  CARD
NO.     12345678901234567890123456789012345678901234567890123456789012345678901234567890  NO.
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URS

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*                                               *
*                UNITED STATES                  *
*           DEPARTMENT OF THE INTERIOR          *
*             BUREAU OF RECLAMATION             *
*               DENVER, COLORADO                *
*                                               *
*            ARCH DAM STRESS ANALYSIS           *
*                      OF                       *
*  BASIN CREEK DAM (BUTTE, MT)     STUDY A-16   *
*              PROBLEM NUMBER 9701              *
*      COMPUTATIONS PERFORMED ON 02/11/**       *
*                                               *
* * * * * * * * * * * * * * * * * * * * * * * * *
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URS

DESIGN CRITERIA

1. DATA WILL BE PREPARED FOR A COMPLETE ADJUSTMENT.

2. THE SHAPE WILL BE CONSIDERED NONSYMMETRIC.

4. TEMPERATURE LOADING IS PRESENTED IN TABULAR FORM (SEE TABLE ON PAGE 1, LINK 1 OUTPUT).

5. THE GROUTING TEMPERATURE= 43.90 DEGREES FAHRENHEIT.

6. SILT LOADING WILL BE APPLIED.

7. NO EARTHQUAKE LOADING WILL BE APPLIED.

8. TWO LINES OF CENTERS WILL BE USED TO DESCRIBE THE DAM.

9. MODULUS OF ELASTICITY OF THE ROCK IS CONSTANT FROM TOP TO BOTTOM OF THE DAM.

10. EFFECTS OF THE CONSTRUCTION PROGRAM ARE NOT INCLUDED IN THIS STUDY.

11. PHYSICAL PROPERTIES OF THE CONCRETE

    A. YOUNGS MODULUS OF ELASTICITY= 1.400 MILLION POUNDS/SQUARE INCH.
    B. POISSONS RATIO= .200.
    C. COEFFICIENT OF THERMAL EXPANSION, .000005600 FOOT/FOOT/DEGREE FAHRENHEIT.
    D. UNIT WEIGHT OF CONCRETE= 150.00 POUNDS/CUBIC FOOT.

12. PHYSICAL PROPERTIES OF THE ABUTMENT ROCK

    A. YOUNGS MODULUS OF ELASTICITY= .850 MILLION POUNDS/SQUARE INCH.
    B. POISSONS RATIO= .200.

13. THE BASE ELEVATION OF THE DAM IS 5772.000.

14. THE TOP ELEVATION OF THE DAM (AS DEFINED ON THE PLANE OF CENTERS) IS 5871.000.

15. THE RESERVOIR WATER SURFACE ELEVATION IS 5872.000.

16. THE TAILWATER SURFACE ELEVATION IS 5772.000.

17. THE DAM IS GROUTED TO ELEVATION 5871.000.

18. THE ELEVATION OF TOP OF CONCRETE IS 5871.000.

19. THE ELEVATION OF BOTTOM OF CONCRETE IS 5772.000.

URS

OUTPUT OF ARCH DAM STRESS ANALYSIS PROGRAMS LINK 8- * STRESS PROGRAM *
VERSION 2.00 COLLECTED
ON 09/17/88

PROBLEM NUMBER 9701
DATE 02/11/**
PAGE 1

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

RESOLUTION OF FORCES AND MOMENTS ON ABUTMENTS

DEFINITIONS

R-XY,R-XZ,R-YZ,R-XYZ = RESULTANT FORCES ON A ONE FOOT WIDE FOUNDATION.

A-XY,A-XZ,A-YZ,A-XYZ = ANGULAR LOCATIONS OF FORCES,I.E.,A-XY IS THE ANGLE MEASURED FROM X(TANGENTIAL) TOWARD Y(RADIAL). (+)A-XY IS UPSTREAM. A-XZ,A-YZ, AND A-XYZ ARE THE DIPS OF THE RESULTANTS. (+) IS DOWNWARD.

ECC = ECCENTRICITY OF R-XYZ FROM THE CENTER OF THICKNESS ON THE FOUNDATION. (+) IS UPSTREAM.

Q = SHEAR FRICTION FACTOR OF SAFETY ALONG THE PLANE OF THE ABUTMENT. Q1 IS IN THE RADIAL DIRECTION (+ IS UPSTREAM), Q2 IS IN THE DIRECTION NORMAL TO RADIAL(+ IS DOWN).

NOTE - THE ELEVATIONS ARE LISTED SEQUENTIALLY DOWN THE RIGHT SIDE OF THE DAM AND THEN UP THE LEFT SIDE LOOKING UPSTREAM.

ELEVATION	XY PLANE		XZ PLANE		YZ PLANE		XYZ PLANE		ECC	Q	
	R	A	R	A	R	A	R	A		Q1	Q2
5871.00	16905.	-21.3	15750.	.0	6142.	.0	16905.	.0	-2.035	-43.308	999.999
5856.00	21010.	-23.3	21411.	25.7	12463.	48.1	22969.	23.8	-4.915	-53.101	-491.086
5826.00	54795.	-58.3	91695.	71.7	98745.	61.8	102861.	57.8	-2.958	-25.378	24.797
5806.00	66158.	-67.2	219022.	83.3	225911.	74.3	227358.	73.1	-.817	-28.720	18.263
5789.00	96144.	-80.2	528732.	88.2	536903.	79.8	537152.	79.7	2.067	-42.467	17.782
5772.00	40187.	-91.0	849735.	90.0	850684.	87.3	850684.	87.3	5.637	119.376	614.726
5789.00	96973.	-81.3	527962.	88.4	536392.	79.7	536593.	79.6	1.878	-41.964	17.685
5806.00	71682.	-70.4	225776.	83.9	234430.	73.3	235659.	72.3	-1.378	-26.022	19.832
5826.00	48018.	-56.9	107456.	75.9	111690.	68.9	114733.	65.3	-2.149	-29.663	27.082
5856.00	16547.	-22.8	20509.	41.9	15131.	64.9	21487.	39.6	-3.796	-68.853	499.763
5871.00	12071.	-18.3	11462.	.0	3785.	.0	12071.	.0	-1.716	-69.708	999.999

URS

STRESSES(PSI) FOR ARCH NO 1 AT ELEVATION 5871.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1137.44	-11.	37.	-11.	37.	7.
1127.06	0.	30.	0.	30.	
1098.96	18.	22.	18.	22.	
1070.25	31.	19.	31.	19.	
1035.43	34.	22.	34.	22.	
1000.00	35.	23.	35.	23.	
964.57	35.	19.	35.	19.	
929.75	28.	17.	28.	17.	
911.42	16.	23.	16.	23.	
891.88	-6.	42.	-6.	42.	
885.77	-22.	58.	-22.	58.	11.

STRESSES(PSI) FOR ARCH NO 2 AT ELEVATION 5856.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1127.06	-11.	36.	-11.	36.	9.
1098.96	10.	21.	10.	21.	
1070.25	27.	10.	27.	10.	
1035.43	30.	13.	30.	13.	
1000.00	31.	14.	31.	14.	
964.57	31.	10.	31.	10.	
929.75	25.	9.	25.	9.	
911.42	8.	23.	8.	23.	
891.88	-23.	53.	-23.	53.	9.

STRESSES(PSI) FOR ARCH NO 3 AT ELEVATION 5826.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1098.96	-18.	34.	-18.	34.	15.
1070.25	14.	5.	14.	5.	
1035.43	25.	-5.	25.	-5.	
1000.00	25.	-5.	25.	-5.	
964.57	26.	-6.	26.	-6.	
929.75	10.	8.	10.	8.	
911.42	-19.	35.	-19.	35.	19.

URS

STRESSES(PSI) FOR ARCH NO 4 AT ELEVATION 5806.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1070.25	15.	-5.	15.	-5.	21.
1035.43	15.	-6.	15.	-6.	
1000.00	15.	-6.	15.	-6.	
964.57	15.	-6.	15.	-6.	
929.75	15.	-4.	15.	-4.	23.

STRESSES(PSI) FOR ARCH NO 5 AT ELEVATION 5789.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1035.43	9.	-6.	9.	-6.	15.
1000.00	13.	-10.	13.	-10.	
964.57	9.	-6.	9.	-6.	15.

URS

STRESSES(PSI) FOR CANTILEVER NO 16

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	20.	7.	20.	7.

MAXIMUM ROCK PLANE SHEAR STRESS= 8.

STRESSES(PSI) FOR CANTILEVER NO 17

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	16.	11.	16.	12.
5826.00	43.	25.	43.	29.

MAXIMUM ROCK PLANE SHEAR STRESS= 15.

STRESSES(PSI) FOR CANTILEVER NO 18

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	17.	9.	17.	10.
5826.00	42.	26.	42.	30.
5806.00	61.	35.	61.	43.

MAXIMUM ROCK PLANE SHEAR STRESS= 23.

STRESSES(PSI) FOR CANTILEVER NO 19

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	15.	12.	15.	13.
5826.00	34.	34.	34.	41.
5806.00	51.	45.	51.	309.
5789.00	57.	49.	57.	99.

MAXIMUM ROCK PLANE SHEAR STRESS= -39.

URS

STRESSES(PSI) FOR CANTILEVER NO 20

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	13.	13.	13.	15.
5826.00	33.	35.	33.	43.
5806.00	50.	47.	50.	323.
5789.00	57.	50.	57.	69.
5772.00	79.	56.	79.	77.

MAXIMUM ROCK PLANE SHEAR STRESS= 26.

STRESSES(PSI) FOR CANTILEVER NO 21

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	14.	13.	14.	14.
5826.00	32.	36.	32.	44.
5806.00	48.	48.	48.	335.
5789.00	56.	50.	56.	101.

MAXIMUM ROCK PLANE SHEAR STRESS= -40.

STRESSES(PSI) FOR CANTILEVER NO 22

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	16.	10.	16.	11.
5826.00	36.	32.	36.	38.
5806.00	53.	44.	53.	56.

MAXIMUM ROCK PLANE SHEAR STRESS= 27.

STRESSES(PSI) FOR CANTILEVER NO 23

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	14.	12.	14.	14.
5826.00	35.	33.	35.	39.

MAXIMUM ROCK PLANE SHEAR STRESS= 16.

URS

STRESSES(PSI) FOR CANTILEVER NO 24

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	13.	13.	13.	15.

MAXIMUM ROCK PLANE SHEAR STRESS= 9.

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 25

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-11.	0	0	0.	37.	0	0	5871.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 24

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	0.	0	0	0.	30.	0	0	5871.0
5856.0	25.	-22.	-29	25	-2.	52.	-33	31	5856.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 23

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	18.	0	0	0.	22.	0	0	5871.0
5856.0	26.	-2.	-40	23	-2.	37.	-39	44	5856.0
5826.0	39.	-21.	-13	41	59.	14.	41	14	5826.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 22

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	31.	0	0	0.	19.	0	0	5871.0
5856.0	12.	31.	28	14	23.	-1.	43	28	5856.0
5826.0	40.	10.	-21	2	45.	-2.	22	29	5826.0
5806.0	66.	2.	-27	17	74.	-23.	25	40	5806.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 21

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	34.	0	0	0.	22.	0	0	5871.0
5856.0	14.	30.	5	2	17.	10.	39	46	5856.0
5826.0	37.	20.	-32	17	46.	-7.	12	13	5826.0
5806.0	54.	9.	-21	18	344.	-15.	9	10	5806.0
5789.0	57.	9.	-7	30	103.	-8.	6	54	5789.0

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 20

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	35.	0	0	0.	23.	0	0	5871.0
5856.0	13.	31.	-1	19	15.	13.	-29	16	5856.0
5826.0	33.	25.	1	20	43.	-5.	0	48	5826.0
5806.0	50.	15.	0	41	323.	-6.	0	26	5806.0
5789.0	57.	13.	0	0	69.	-10.	0	9	5789.0
5772.0	79.	0.	0	0	77.	0.	0	7	5772.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 19

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	35.	0	0	0.	19.	0	0	5871.0
5856.0	14.	32.	11	28	18.	5.	37	38	5856.0
5826.0	40.	20.	-33	38	45.	-10.	15	31	5826.0
5806.0	58.	9.	-21	41	322.	-18.	10	57	5806.0
5789.0	58.	8.	-7	20	101.	-8.	7	16	5789.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 18

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	28.	0	0	0.	17.	0	0	5871.0
5856.0	8.	35.	36	18	27.	-8.	44	10	5856.0
5826.0	47.	5.	-20	28	43.	-5.	31	9	5826.0
5806.0	75.	1.	-25	17	67.	-28.	30	0	5806.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 17

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	16.	0	0	0.	23.	0	0	5871.0
5856.0	29.	-6.	-38	42	-4.	40.	-37	31	5856.0
5826.0	48.	-24.	-14	38	7.	58.	-41	36	5826.0

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 16

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-6.	0	0	0.	42.	0	0	5871.0
5856.0	30.	-33.	-23	44	-4.	64.	-24	11	5856.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 15

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-22.	0	0	0.	58.	0	0	5871.0

URS

PRINCIPAL STRESSES (PSI) PARALLEL TO THE FACES AT THE ABUTMENTS

LEFT ABUTMENT (LOOKING UPS

AT THE DOWNSTREAM FACE						AT THE UPSTREAM FACE				ACE
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	CANT NO	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-11.	0	0	25	0.	37.	0	0	5871.0
5856.0	25.	-22.	-29	25	24	-2.	52.	-33	31	5856.0
5826.0	39.	-21.	-13	41	23	59.	14.	41	14	5826.0
5806.0	66.	2.	-27	17	22	74.	-23.	25	40	5806.0
5789.0	57.	9.	-7	30	21	103.	-8.	6	54	5789.0
5772.0	79.	0.	0	0	20	77.	0.	0	7	5772.0

RIGHT ABUTMENT (LOOKING UPSTREAM)

AT THE UPSTREAM FACE						AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	CANT NO	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-22.	0	0	15	0.	58.	0	0	5871.0
5856.0	30.	-33.	-23	44	16	-4.	64.	-24	11	5856.0
5826.0	48.	-24.	-14	38	17	7.	58.	-41	36	5826.0
5806.0	75.	1.	-25	17	18	67.	-28.	30	0	5806.0
5789.0	58.	8.	-7	20	19	101.	-8.	7	16	5789.0

URS

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

CANTILEVER STRESSES PARAL
LOOKING

ELEV	STA	1127.06	1098.96	1070.25	1035.43	1000.00
	TAU	0.				
5871.	U	0.	0.	0.	0.	0.
	D	0.	0.	0.	0.	0.
	TAU	9.				
5856.	U	13.	14.	16.	14.	13.
	D	15.	14.	11.	14.	15.
	TAU		16.			
5826.	U		35.	36.	32.	33.
	D		39.	38.	44.	43.
	TAU			27.		
5806.	U			53.	48.	50.
	D			56.	335.	323.
	TAU				-40.	
5789.	U				56.	57.
	D				101.	69.
	TAU					26.
5772.	U					79.
	D					77.

URS

(9701) RUN 02/11/**

LEL TO THE FACE OF THE DAM
UPSTREAM

964.57	929.75	911.42	891.88	
			0.	TAU
0.	0.	0.	0.	
0.	0.	0.	0.	
			8.	TAU
15.	17.	16.	20.	
13.	10.	12.	7.	
		15.	TAU	
34.	42.	43.		
41.	30.	29.		
	23.	TAU		
51.	61.			
309.	43.			
-39.	TAU			
57.				
99.				

URS

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

ARCH STRESSES PARALLEL
LOOKING

ELEV	STA	1137.44	1127.06	1098.96	1070.25	1035.43	1000.00
	TAU	7.					
5871.	E	-11.	0.	18.	31.	34.	35.
	I	37.	30.	22.	19.	22.	23.
	TAU		9.				
5856.	E		-11.	10.	27.	30.	31.
	I		36.	21.	10.	13.	14.
	TAU			15.			
5826.	E			-18.	14.	25.	25.
	I			34.	5.	-5.	-5.
	TAU				21.		
5806.	E				15.	15.	15.
	I				-5.	-6.	-6.
	TAU					15.	
5789.	E					9.	13.
	I					-6.	-10.

URS

(9701) RUN 02/11/**

TO THE FACE OF THE DAM
UPSTREAM

964.57	929.75	911.42	891.88	885.77	
				11.	TAU
35.	28.	16.	-6.	-22.	
19.	17.	23.	42.	58.	
			9.	TAU	
31.	25.	8.	-23.		
10.	9.	23.	53.		
		19.	TAU		
26.	10.	-19.			
-6.	8.	35.			
	23.	TAU			
15.	15.				
-6.	-4.				
15.	TAU				
9.					
-6.					

URS

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

TIME IN MINUTES FOR LINK 8

1. COMPUTATION OF STRESSES = .000

URS

Project: BASIN CREEK DAM
Feature: ADSAS Study "B-7"
Detail: Sliding Stability - Usual Load (Normal Reservoir Elevation)
File: SLIDING2

Job No: 24773.00 Sheet #:
By: S. Jones Date: 14-Feb-05
Chkd.By: Date:

1. Reservoir Water Surface Elevation:

Reservoir Elevation = 5872.0 feet
Unit Weight of Water = 62.5 pcf

2. Foundation Strengths:

Min Effective Friction Angle = 49.0 degrees
Max Effective Friction Angle = 61.0 degrees

3. Foundation Drain Efficiency:

Foundation Drain Efficiency = 0.0%

4. Percent of Base Cracked

Base Cracked = 0.0%

4. ADSAS Results - Abutment Thrusts

		XY Plane		Thrust		XZ Plane		Thrust		YZ Plane		Thrust	
Elevation	Station	Resultant	Angle	X-Direction	Y-Direction	Resultant	Dip	X-Direction	Z-Direction	Resultant	Dip	Y-Direction	Z-Direction
(feet)	(feet)	(lbs)	(degrees)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(lbs)
5871.00	-110.0	16,905	-21.3	15,750	6,141	15,750	0.0	15,750	0	6,142	0.0	6,142	0
5856.00	-106.6	21,010	-23.3	19,297	8,310	21,411	25.7	19,293	9,285	12,463	48.1	8,323	9,276
5826.00	-87.3	54,795	-58.3	28,793	46,620	91,695	71.7	28,792	87,058	98,745	61.8	46,662	87,024
5806.00	-69.2	66,158	-67.2	25,637	60,989	219,022	83.3	25,553	217,526	225,911	74.3	61,132	217,483
5789.00	-34.6	96,144	-80.2	16,365	94,741	528,732	88.2	16,608	528,471	536,903	79.8	95,077	528,418
5772.00	0.0	40,187	-91.0	-701	40,181	849,735	90.0	0	849,735	850,684	87.3	40,073	849,740
5789.00	34.6	96,973	-81.3	14,668	95,857	527,962	88.4	14,742	527,756	536,392	79.7	95,908	527,748
5806.00	69.2	71,682	-70.4	24,046	67,529	225,776	83.9	23,992	224,498	234,430	73.3	67,366	224,542
5826.00	97.5	48,018	-56.9	26,223	40,226	107,456	75.9	26,178	104,219	111,690	68.9	40,208	104,202
5856.00	126.5	16,547	-22.8	15,254	6,412	20,509	41.9	15,265	13,697	15,131	64.9	6,419	13,702
5871.00	137.5	12,071	-18.3	11,461	3,790	11,462	0.0	11,462	0	3,785	0.0	3,785	0

5. Local Components of Thrust

			XY Plane		
Elevation	Station	Embankment Load	Tangential X-Direction	Radial Y-Direction	Vertical Z-Direction
(feet)	(feet)	(lbs)	(lbs)	(lbs)	(lbs)
5871.00	-110.0	0	15,750	6,141	0
5856.00	-106.6	3360	19,295	8,317	12,641
5826.00	-87.3	37560	28,792	46,641	124,601
5806.00	-69.2	87960	25,595	61,060	305,464
5789.00	-34.6	360120	16,486	94,909	888,564
5772.00	0.0	410520	-351	40,127	1,260,257
5789.00	34.6	360120	14,705	95,883	887,872
5806.00	69.2	87960	24,019	67,447	312,480
5826.00	97.5	37560	26,200	40,217	141,770
5856.00	126.5	3360	15,260	6,415	17,059
5871.00	137.5	0	11,461	3,788	0

6. Uplift Forces

					XY Plane		
Elevation	Station	Arch Thickness	Dam/Fnd Contact Angle	Normal Uplift Force	Tangential X-Direction	Radial Y-Direction	Vertical Z-Direction
(feet)	(feet)	(feet)	(degrees)	(lbs)	(lbs)	(lbs)	(lbs)
5871.00	-110.0	6.00	59.00	-188	-161	0	-97
5856.00	-106.6	10.00	59.00	-5,000	-4,288	0	-2,575
5826.00	-87.3	26.50	53.00	-38,094	-30,423	0	-22,925
5806.00	-69.2	38.30	36.00	-78,994	-46,431	0	-63,907
5789.00	-34.6	87.60	36.00	-227,213	-133,552	0	-183,819
5772.00	0.0	101.20	0.00	-316,250	0	0	-316,250
5789.00	34.6	87.60	33.00	-227,213	-123,749	0	-190,556
5806.00	69.2	38.30	33.00	-78,994	-43,023	0	-66,250
5826.00	97.5	26.50	42.00	-38,094	-25,490	0	-28,309
5856.00	126.5	10.00	53.00	-5,000	-3,993	0	-3,009
5871.00	137.5	6.00	53.00	-188	-150	0	-113

URS

7. Resultant Thrusts (Includes uplift)

Elevation	Station	Dam/Fnd Contact Angle	Resultant Tangential X-Direction	Resultant Radial Y-Direction	Resultant Vertical Z-Direction	Resultant XY Plane Resultant	Resultant XY Plane Angle	Resultant XZ Plane Resultant	Resultant XZ Plane Dip	Resultant YZ Plane Resultant	Resultant YZ Plane Dip	Normal
(feet)	(feet)	(degrees)	(lbs)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(degrees)	(lbs)	(degrees)	(lbs)
5871.00	-110.0	59.00	15,589	6,141	-97	16,755	-21.5	15,590	-0.4	6,142	-89.1	13,313
5856.00	-106.6	59.00	15,009	8,317	10,066	17,159	-29.0	18,072	33.8	13,057	39.6	18,049
5826.00	-87.3	53.00	-1,631	46,641	101,676	46,670	88.0	101,689	-89.1	111,863	24.6	59,888
5806.00	-69.2	36.00	-20,836	61,060	241,557	64,517	71.2	242,454	-85.1	249,155	14.2	183,177
5789.00	-34.6	36.00	-117,066	94,909	704,746	150,706	39.0	714,402	-80.6	711,108	7.7	501,342
5772.00	0.0	0.00	-351	40,127	944,007	40,128	89.5	944,007	-90.0	944,860	2.4	944,007
5789.00	34.6	33.00	-109,044	95,883	697,316	145,203	41.3	705,790	-81.1	703,877	7.8	525,429
5806.00	69.2	33.00	-19,004	67,447	246,230	70,073	74.3	246,963	-85.6	255,301	15.3	196,156
5826.00	97.5	42.00	711	40,217	113,461	40,223	-89.0	113,463	89.6	120,378	19.5	84,793
5856.00	126.5	53.00	11,266	6,415	14,050	12,965	-29.7	18,010	51.3	15,446	24.5	17,453
5871.00	137.5	53.00	11,312	3,788	-113	11,929	-18.5	11,312	-0.6	3,789	-88.3	8,966

8. Sliding Factor of Safety

Elevation	Station	Arch Thickness	Normal Force	Tangential Driving Force	Radial Driving Force	Total Driving Force	Sliding Factor of Safety Minimum	Sliding Factor of Safety Maximum	Require Friction Angle for FOS = 1.5 Resultant
(feet)	(feet)	(feet)	(lbs)	(lbs)	(lbs)	(lbs)			(degrees)
5871.00	-110.0	6.00	13,313	8,112	6,141	1017.4	1.5	2.4	48.9
5856.00	-106.6	10.00	18,049	-898	8,317	8317	2.5	3.9	34.7
5826.00	-87.3	26.50	59,888	-82,183	46,641	46641	1.5	2.3	49.4
5806.00	-69.2	38.30	183,177	-158,840	61,060	61060	3.5	5.4	26.6
5789.00	-34.6	87.60	501,342	-508,947	94,909	94909	6.1	9.5	15.9
5772.00	0.0	101.20	944,007	-351	40,127	40127	27.1	42.4	3.6
5789.00	34.6	87.60	525,429	-471,237	95,883	95883	6.3	9.9	15.3
5806.00	69.2	38.30	196,156	-150,045	67,447	67447	3.3	5.2	27.3
5826.00	97.5	26.50	84,793	-75,392	40,217	40217	2.4	3.8	35.4
5856.00	126.5	10.00	17,453	-4,441	6,415	6415	3.1	4.9	28.9
5871.00	137.5	6.00	8,966	6,898	3,788	7869	1.3	2.1	52.8

URS

ATTACHMENT 3:
ADSAS RESULTS FOR LOAD CASE UNLC-1A

URS

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INPUT FILE (bcd3.dat    ) FOR ADSAS  02/11/**  12:09:16

CARD            1         2         3         4         5         6         7         8  CARD
NO.    12345678901234567890123456789012345678901234567890123456789012345678901234567890  NO.

 1     1   0     BASIN CREEK DAM (BUTTE, MT)   16         0                        9701   1
 2     2   0     111101100000000000000000000                                       9701   2
 3     3   0     300000000000000  1.400  .200  5.60 150.00  0.850  .200  .00 43.90 9701   3
 4     4   0      5772.000 5871.000 5876.800 5772.000 5871.000 5871.000 5772.000   9701   4
 5     1   1     000000000000000000010000000000000000000                           9701   5
 6     3   1        0.00000 101.20000    0.0000    0.0000  350.0000     .0000  3  19701   6
 7     5   1 1 1   5871.00000      .00000      .00000      .00000      .00000      9701   7
 8     5   1 2 1   5797.00000    -0.80000      .00000      .00000      .00000      9701   8
 9     5   1 2 2   5798.50000   -37.80000      .00000      .00000      .00000      9701   9
10     5   1 2 3   5816.00000    -0.63000      .00000      .00000      .00000      9701  10
11     5   1 2 4   5856.00000    -0.55000      .00000      .00000      .00000      9701  11
12     5   1 2 5   5868.50000    -0.32000      .00000      .00000      .00000      9701  12
13     5   1 2 6   5871.00000      .00000      .00000      .00000      .00000      9701  13
14     5   1 3 1   5871.00000      .00000      .00000      .00000      .00000      9701  14
15     5   1 4 1   5871.00000      .00000      .00000      .00000      .00000      9701  15
16     6   1           .00000    6.00000     .00000     .00000     .00000     .000009701  16
17     7   110000 5772.00000  .0000  .0000  .0000  .0000 -5.50   .00  .00  .00      9701  17
18     7   100000 5789.00000 5.8000 5.8000  .0000  .0000 -5.30   .00  .00  .00      9701  18
19     7   100000 5806.0000011.500011.5000  .0000  .0000 -9.50   .00  .00  .00      9701  19
20     7   100000 5826.0000016.200014.5000  .0000  .0000-14.70   .00  .00  .00      9701  20
21     7   100000 5856.0000020.800017.7000  .0000  .0000-23.50   .00  .00  .00      9701  21
22     7   100000 5871.0000022.500018.7000  .0000  .0000-28.40   .00  .00  .00      9701  22
23     1   2     0000001000000000000000000000000000000000000000000000000000000      9701  23

CARD            1         2         3         4         5         6         7         8  CARD
NO.    12345678901234567890123456789012345678901234567890123456789012345678901234567890  NO.
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URS

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* * * * * * * * * * * * * * * * * * * * * * * * *
*                                               *
*                UNITED STATES                  *
*            DEPARTMENT OF THE INTERIOR         *
*             BUREAU OF RECLAMATION             *
*               DENVER, COLORADO                *
*                                               *
*            ARCH DAM STRESS ANALYSIS           *
*                      OF                       *
*  BASIN CREEK DAM (BUTTE, MT)     STUDY A-16   *
*              PROBLEM NUMBER 9701              *
*      COMPUTATIONS PERFORMED ON 02/11/**       *
*                                               *
* * * * * * * * * * * * * * * * * * * * * * * * *
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URS

DESIGN CRITERIA

1. DATA WILL BE PREPARED FOR A COMPLETE ADJUSTMENT.

2. THE SHAPE WILL BE CONSIDERED NONSYMMETRIC.

4. TEMPERATURE LOADING IS PRESENTED IN TABULAR FORM (SEE TABLE ON PAGE 1, LINK 1 OUTPUT).

5. THE GROUTING TEMPERATURE= 43.90 DEGREES FAHRENHEIT.

6. THE EFFECTS OF TAILWATER, UPLIFT, SILT AND ICE LOADING, IF ANY, ARE NOT INCLUDED.

7. NO EARTHQUAKE LOADING WILL BE APPLIED.

8. TWO LINES OF CENTERS WILL BE USED TO DESCRIBE THE DAM.

9. MODULUS OF ELASTICITY OF THE ROCK IS CONSTANT FROM TOP TO BOTTOM OF THE DAM.

10. EFFECTS OF THE CONSTRUCTION PROGRAM ARE NOT INCLUDED IN THIS STUDY.

11. PHYSICAL PROPERTIES OF THE CONCRETE

A. YOUNGS MODULUS OF ELASTICITY= 1.400 MILLION POUNDS/SQUARE INCH.
B. POISSONS RATIO= .200.
C. COEFFICIENT OF THERMAL EXPANSION, .000005600 FOOT/FOOT/DEGREE FAHRENHEIT.
D. UNIT WEIGHT OF CONCRETE= 150.00 POUNDS/CUBIC FOOT.

12. PHYSICAL PROPERTIES OF THE ABUTMENT ROCK

A. YOUNGS MODULUS OF ELASTICITY= .850 MILLION POUNDS/SQUARE INCH.
B. POISSONS RATIO= .200.

13. THE BASE ELEVATION OF THE DAM IS 5772.000.

14. THE TOP ELEVATION OF THE DAM (AS DEFINED ON THE PLANE OF CENTERS) IS 5871.000.

15. THE RESERVOIR WATER SURFACE ELEVATION IS 5876.800.

16. THE TAILWATER SURFACE ELEVATION IS 5772.000.

17. THE DAM IS GROUTED TO ELEVATION 5871.000.

18. THE ELEVATION OF TOP OF CONCRETE IS 5871.000.

19. THE ELEVATION OF BOTTOM OF CONCRETE IS 5772.000.

URS

OUTPUT OF ARCH DAM STRESS ANALYSIS PROGRAMS LINK 8- * STRESS PROGRAM *
VERSION 2.00 COLLECTED
ON 09/17/88

PROBLEM NUMBER 9701
DATE 02/11/**
PAGE 1

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

RESOLUTION OF FORCES AND MOMENTS ON ABUTMENTS

DEFINITIONS

R-XY,R-XZ,R-YZ,R-XYZ = RESULTANT FORCES ON A ONE FOOT WIDE FOUNDATION.

A-XY,A-XZ,A-YZ,A-XYZ = ANGULAR LOCATIONS OF FORCES,I.E.,A-XY IS THE ANGLE MEASURED FROM X(TANGENTIAL) TOWARD Y(RADIAL). (+)A-XY IS UPSTREAM. A-XZ,A-YZ, AND A-XYZ ARE THE DIPS OF THE RESULTANTS. (+) IS DOWNWARD.

ECC = ECCENTRICITY OF R-XYZ FROM THE CENTER OF THICKNESS ON THE FOUNDATION. (+) IS UPSTREAM.

Q = SHEAR FRICTION FACTOR OF SAFETY ALONG THE PLANE OF THE ABUTMENT. Q1 IS IN THE RADIAL DIRECTION (+ IS UPSTREAM), Q2 IS IN THE DIRECTION NORMAL TO RADIAL(+ IS DOWN).

NOTE - THE ELEVATIONS ARE LISTED SEQUENTIALLY DOWN THE RIGHT SIDE OF THE DAM AND THEN UP THE LEFT SIDE LOOKING UPSTREAM.

ELEVATION	XY PLANE		XZ PLANE		YZ PLANE		XYZ PLANE		ECC	Q	
	R	A	R	A	R	A	R	A		Q1	Q2
5871.00	32498.	-25.8	29253.	.0	14156.	.0	32498.	.0	-2.211	-19.267	999.999
5856.00	40480.	-28.4	36701.	14.0	21209.	24.8	41445.	12.4	-5.418	-23.305	-50.270
5826.00	109317.	-61.2	90217.	54.3	120644.	37.4	131614.	33.8	-7.024	-12.392	54.438
5806.00	137249.	-69.5	175291.	74.1	212019.	52.7	217390.	50.9	-5.143	-13.513	34.311
5789.00	219201.	-81.1	324347.	84.0	388551.	56.1	390014.	55.8	4.936	-18.171	33.647
5772.00	166176.	-90.5	566350.	89.9	590222.	73.6	590224.	73.6	9.307	28.013	1104.680
5789.00	220928.	-82.1	322471.	84.6	388555.	55.7	389725.	55.5	4.438	-17.976	32.936
5806.00	149115.	-72.6	178635.	75.6	224004.	50.6	228389.	49.2	-6.146	-12.226	38.175
5826.00	99062.	-60.8	99304.	60.9	122522.	45.1	131694.	41.2	-6.437	-13.789	74.799
5856.00	32788.	-28.8	32062.	26.4	21286.	42.0	35750.	23.5	-5.038	-28.237	-61.498
5871.00	23847.	-23.6	21849.	.0	9554.	.0	23847.	.0	-2.025	-28.161	999.999

URS

STRESSES(PSI) FOR ARCH NO 1 AT ELEVATION 5871.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE EXTRADOS	NORMAL TO RE INTRADOS	PARALLEL TO FACES EXTRADOS	PARALLEL TO FACES INTRADOS	TXYM MAX.
1137.44	-31.	82.	-31.	82.	17.
1127.06	2.	55.	2.	55.	
1098.96	35.	40.	35.	40.	
1070.25	60.	32.	60.	32.	
1035.43	62.	42.	62.	42.	
1000.00	60.	45.	60.	45.	
964.57	63.	36.	63.	36.	
929.75	55.	28.	55.	28.	
911.42	33.	40.	33.	40.	
891.88	-11.	79.	-11.	79.	
885.77	-50.	118.	-50.	118.	25.

STRESSES(PSI) FOR ARCH NO 2 AT ELEVATION 5856.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE EXTRADOS	NORMAL TO RE INTRADOS	PARALLEL TO FACES EXTRADOS	PARALLEL TO FACES INTRADOS	TXYM MAX.
1127.06	-22.	69.	-22.	69.	18.
1098.96	21.	35.	21.	35.	
1070.25	53.	14.	53.	14.	
1035.43	52.	25.	52.	25.	
1000.00	52.	28.	52.	28.	
964.57	55.	19.	55.	19.	
929.75	50.	12.	50.	12.	
911.42	19.	38.	19.	38.	
891.88	-45.	100.	-45.	100.	19.

STRESSES(PSI) FOR ARCH NO 3 AT ELEVATION 5826.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE EXTRADOS	NORMAL TO RE INTRADOS	PARALLEL TO FACES EXTRADOS	PARALLEL TO FACES INTRADOS	TXYM MAX.
1098.96	-33.	62.	-33.	62.	31.
1070.25	31.	3.	31.	3.	
1035.43	43.	-6.	43.	-6.	
1000.00	41.	-5.	41.	-5.	
964.57	45.	-10.	45.	-10.	
929.75	23.	9.	23.	9.	
911.42	-33.	63.	-33.	63.	38.

URS

STRESSES(PSI) FOR ARCH NO 4 AT ELEVATION 5806.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1070.25	27.	-5.	27.	-5.	36.
1035.43	29.	-10.	29.	-10.	
1000.00	25.	-8.	25.	-8.	
964.57	29.	-11.	29.	-11.	
929.75	27.	-4.	27.	-4.	39.

STRESSES(PSI) FOR ARCH NO 5 AT ELEVATION 5789.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1035.43	20.	-11.	20.	-11.	25.
1000.00	24.	-17.	24.	-17.	
964.57	20.	-10.	20.	-10.	25.

URS

STRESSES(PSI) FOR CANTILEVER NO 16

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	19.	5.	19.	5.

MAXIMUM ROCK PLANE SHEAR STRESS= 17.

STRESSES(PSI) FOR CANTILEVER NO 17

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	4.	21.	4.	24.
5826.00	29.	24.	29.	31.

MAXIMUM ROCK PLANE SHEAR STRESS= 29.

STRESSES(PSI) FOR CANTILEVER NO 18

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	5.	19.	5.	22.
5826.00	21.	32.	21.	42.
5806.00	39.	33.	39.	48.

MAXIMUM ROCK PLANE SHEAR STRESS= 40.

STRESSES(PSI) FOR CANTILEVER NO 19

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	-1.	26.	-1.	30.
5826.00	-5.	59.	-5.	76.
5806.00	2.	72.	2.	713.
5789.00	48.	16.	48.	43.

MAXIMUM ROCK PLANE SHEAR STRESS= -27.

URS

STRESSES(PSI) FOR CANTILEVER NO 20

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	-4.	29.	-4.	33.
5826.00	-8.	61.	-8.	80.
5806.00	-1.	75.	-1.	748.
5789.00	46.	18.	46.	29.
5772.00	63.	26.	63.	42.

MAXIMUM ROCK PLANE SHEAR STRESS= 21.

STRESSES(PSI) FOR CANTILEVER NO 21

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	-3.	28.	-3.	32.
5826.00	-9.	63.	-9.	82.
5806.00	-3.	77.	-3.	764.
5789.00	46.	17.	46.	47.

MAXIMUM ROCK PLANE SHEAR STRESS= -28.

STRESSES(PSI) FOR CANTILEVER NO 22

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	3.	21.	3.	24.
5826.00	9.	44.	9.	57.
5806.00	22.	51.	22.	74.

MAXIMUM ROCK PLANE SHEAR STRESS= 47.

STRESSES(PSI) FOR CANTILEVER NO 23

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	-0.	25.	-0.	29.
5826.00	13.	40.	13.	52.

MAXIMUM ROCK PLANE SHEAR STRESS= 30.

URS

STRESSES(PSI) FOR CANTILEVER NO 24

	VERTICAL STRESSES		PARALLEL STRESSES	
ELEVATION	US FACE	DS FACE	US FACE	DS FACE
5871.00	0.	0.	0.	0.
5856.00	3.	21.	3.	24.

MAXIMUM ROCK PLANE SHEAR STRESS= 19.

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 25

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-31.	0	0	0.	82.	0	0	5871.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 24

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	2.	0	0	0.	55.	0	0	5871.0
5856.0	35.	-54.	-36	43	-11.	104.	-33	25	5856.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 23

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	35.	0	0	0.	40.	0	0	5871.0
5856.0	-18.	39.	33	54	-4.	68.	-42	12	5856.0
5826.0	25.	-45.	-24	20	15.	99.	-41	34	5826.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 22

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	60.	0	0	0.	32.	0	0	5871.0
5856.0	0.	57.	13	47	40.	-1.	37	53	5856.0
5826.0	0.	40.	28	27	69.	-9.	22	49	5826.0
5806.0	-20.	70.	43	22	110.	-41.	29	17	5806.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 21

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	62.	0	0	0.	42.	0	0	5871.0
5856.0	-3.	52.	1	10	34.	24.	23	45	5856.0
5826.0	-11.	44.	10	16	84.	-8.	8	59	5826.0
5806.0	-16.	42.	28	37	774.	-20.	6	21	5806.0
5789.0	50.	15.	-20	37	55.	-18.	18	53	5789.0

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 20

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	60.	0	0	0.	45.	0	0	5871.0
5856.0	-4.	52.	0	33	34.	27.	-13	7	5856.0
5826.0	-8.	41.	0	26	80.	-5.	0	56	5826.0
5806.0	-1.	25.	-1	48	748.	-8.	0	23	5806.0
5789.0	46.	24.	0	2	29.	-17.	0	32	5789.0
5772.0	63.	0.	0	0	42.	0.	0	27	5772.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 19

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	63.	0	0	0.	36.	0	0	5871.0
5856.0	-2.	55.	4	57	35.	14.	30	3	5856.0
5826.0	-8.	49.	14	19	81.	-15.	12	54	5826.0
5806.0	-15.	47.	31	54	727.	-25.	7	50	5806.0
5789.0	52.	15.	-19	38	51.	-19.	20	43	5789.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 18

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	55.	0	0	0.	28.	0	0	5871.0
5856.0	-4.	60.	22	34	48.	-14.	40	35	5856.0
5826.0	-2.	46.	43	26	66.	-15.	32	59	5826.0
5806.0	83.	-17.	-41	17	97.	-53.	34	48	5806.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 17

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	33.	0	0	0.	40.	0	0	5871.0
5856.0	-22.	45.	38	15	-10.	72.	-39	55	5856.0
5826.0	42.	-47.	-23	8	-2.	97.	-35	34	5826.0

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 16

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-11.	0	0	0.	79.	0	0	5871.0
5856.0	46.	-71.	-28	17	-19.	125.	-24	18	5856.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 15

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-50.	0	0	0.	118.	0	0	5871.0

URS

PRINCIPAL STRESSES (PSI) PARALLEL TO THE FACES AT THE ABUTMENTS

LEFT ABUTMENT (LOOKING UPSTREAM)

AT THE UPSTREAM FACE						AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	CANT NO	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-31.	0	0	25	0.	82.	0	0	5871.0
5856.0	35.	-54.	-36	43	24	-11.	104.	-33	25	5856.0
5826.0	25.	-45.	-24	20	23	15.	99.	-41	34	5826.0
5806.0	-20.	70.	43	22	22	110.	-41.	29	17	5806.0
5789.0	50.	15.	-20	37	21	55.	-18.	18	53	5789.0
5772.0	63.	0.	0	0	20	42.	0.	0	27	5772.0

RIGHT ABUTMENT (LOOKING UPSTREAM)

AT THE UPSTREAM FACE						AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	CANT NO	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-50.	0	0	15	0.	118.	0	0	5871.0
5856.0	46.	-71.	-28	17	16	-19.	125.	-24	18	5856.0
5826.0	42.	-47.	-23	8	17	-2.	97.	-35	34	5826.0
5806.0	83.	-17.	-41	17	18	97.	-53.	34	48	5806.0
5789.0	52.	15.	-19	38	19	51.	-19.	20	43	5789.0

URS

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

CANTILEVER STRESSES PARAL
LOOKING

ELEV	STA	1127.06	1098.96	1070.25	1035.43	1000.00
	TAU	0.				
5871.	U	0.	0.	0.	0.	0.
	D	0.	0.	0.	0.	0.
	TAU	19.				
5856.	U	3.	-0.	3.	-3.	-4.
	D	24.	29.	24.	32.	33.
		TAU	30.			
5826.		U	13.	9.	-9.	-8.
		D	52.	57.	82.	80.
			TAU	47.		
5806.			U	22.	-3.	-1.
			D	74.	764.	748.
				TAU	-28.	
5789.				U	46.	46.
				D	47.	29.
					TAU	21.
5772.					U	63.
					D	42.

URS

(9701) RUN 02/11/**

LEL TO THE FACE OF THE DAM
UPSTREAM

964.57 929.75 911.42 891.88

			0.	TAU
0.	0.	0.	0.	
0.	0.	0.	0.	
			17.	TAU
-1.	5.	4.	19.	
30.	22.	24.	5.	
		29.	TAU	
-5.	21.	29.		
76.	42.	31.		
	40.	TAU		
2.	39.			
713.	48.			
-27.	TAU			
48.				
43.				

URS

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

ARCH STRESSES PARALLEL LOOKING

ELEV	STA	1137.44	1127.06	1098.96	1070.25	1035.43	1000.00
	TAU	17.					
5871.	E	-31.	2.	35.	60.	62.	60.
	I	82.	55.	40.	32.	42.	45.
	TAU		18.				
5856.	E		-22.	21.	53.	52.	52.
	I		69.	35.	14.	25.	28.
	TAU			31.			
5826.	E			-33.	31.	43.	41.
	I			62.	3.	-6.	-5.
	TAU				36.		
5806.	E				27.	29.	25.
	I				-5.	-10.	-8.
	TAU					25.	
5789.	E					20.	24.
	I					-11.	-17.

URS

(9701) RUN 02/11/**

TO THE FACE OF THE DAM
UPSTREAM

964.57	929.75	911.42	891.88	885.77	
				25.	TAU
63.	55.	33.	-11.	-50.	
36.	28.	40.	79.	118.	
			19.	TAU	
55.	50.	19.	-45.		
19.	12.	38.	100.		
		38.	TAU		
45.	23.	-33.			
-10.	9.	63.			
	39.	TAU			
29.	27.				
-11.	-4.				
25.	TAU				
20.					
-10.					

URS

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OUTPUT OF ARCH DAM STRESS ANALYSIS PROGRAMS      LINK  8- *       STRESS PROGRAM        *          PROBLEM NUMBER 9701
VERSION   2.00 COLLECTED                                                                           DATE  02/11/**
ON  09/17/88                                STUDY A-16   OF BASIN CREEK DAM (BUTTE, MT)           PAGE   11

                                                TIME IN MINUTES FOR LINK 8

                                          1.  COMPUTATION OF STRESSES        =    .000
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URS

Project: BASIN CREEK DAM
Feature: ADSAS Study "B-3"
Detail: Sliding Stability - Unusual Load (PMF Reservoir Elevation)
File: SLIDING2

Job No: 24773.00 **Sheet #:**
By: S. Jones **Date:** 30-Jun-05
Chkd.By: **Date:**

1. Reservoir Water Surface Elevation:

Reservoir Elevation = 5876.8 feet
Unit Weight of Water = 62.5 pcf

2. Foundation Strengths:

Min Effective Friction Angle = 49.0 degrees
Max Effective Friction Angle = 61.0 degrees

3. Foundation Drain Efficiency:

Foundation Drain Efficiency = 0.0%

4. Percent of Base Cracked

Base Cracked = 0.0%

4. ADSAS Results - Abutment Thrusts

		XY Plane		Thrust		XZ Plane		Thrust		YZ Plane		Thrust	
Elevation	Station	Resultant	Angle	X-Direction	Y-Direction	Resultant	Dip	X-Direction	Z-Direction	Resultant	Dip	Y-Direction	Z-Direction
(feet)	(feet)	(lbs)	(degrees)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(lbs)
5871.00	-110.0	32,498	-25.8	29,259	14,144	29,253	0.0	29,253	0	14,156	0.0	14,156	0
5856.00	-106.6	40,480	-28.4	35,608	19,253	36,701	14.0	35,611	8,879	21,209	24.8	19,253	8,896
5826.00	-87.3	109,317	-61.2	52,864	95,795	90,217	54.3	52,645	73,264	120,644	37.4	95,841	73,276
5806.00	-69.2	137,249	-69.5	48,066	128,557	175,291	74.1	48,023	168,585	212,019	52.7	128,481	168,655
5789.00	-34.6	219,201	-81.1	33,913	216,562	324,347	84.0	33,903	322,570	388,551	56.1	216,712	322,502
5772.00	0.0	166,176	-90.5	-1,450	166,170	566,350	89.9	988	566,349	590,222	73.6	166,644	566,208
5789.00	34.6	220,928	-82.1	30,365	218,831	322,471	84.6	30,347	321,040	388,555	55.7	218,961	320,985
5806.00	69.2	149,115	-72.6	44,591	142,292	178,635	75.6	44,425	173,023	224,004	50.6	142,182	173,095
5826.00	97.5	99,082	-60.8	48,328	86,473	99,304	60.9	48,295	86,769	122,522	45.1	86,485	86,787
5856.00	126.5	32,788	-28.8	28,732	15,798	32,062	26.4	28,718	14,256	21,286	42.0	15,819	14,243
5871.00	137.5	23,847	-23.6	21,853	9,547	21,849	0.0	21,849	0	9,554	0.0	9,554	0

5. Local Components of Thrust

			XY Plane		
Elevation	Station	Embankment Load	Tangential X-Direction	Radial Y-Direction	Vertical Z-Direction
(feet)	(feet)	(lbs)	(lbs)	(lbs)	(lbs)
5871.00	-110.0	0	29,256	14,150	0
5856.00	-106.6	0	35,609	19,253	8,887
5826.00	-87.3	0	52,655	95,818	73,270
5806.00	-69.2	0	48,044	128,519	168,620
5789.00	-34.6	0	33,908	216,637	322,536
5772.00	0.0	0	-231	166,407	566,279
5789.00	34.6	0	30,356	218,896	321,012
5806.00	69.2	0	44,508	142,237	173,059
5826.00	97.5	0	48,312	86,479	86,778
5856.00	126.5	0	28,725	15,807	14,250
5871.00	137.5	0	21,851	9,551	0

6. Uplift Forces

					XY Plane		
Elevation	Station	Arch Thickness	Dam/Fnd Contact Angle	Normal Uplift Force	Tangential X-Direction	Radial Y-Direction	Vertical Z-Direction
(feet)	(feet)	(feet)	(degrees)	(lbs)	(lbs)	(lbs)	(lbs)
5871.00	-110.0	6.00	59.00	-1,088	-932	0	-560
5856.00	-106.6	10.00	58.00	-6,500	-5,572	0	-3,348
5826.00	-87.3	26.50	53.00	-42,069	-33,598	0	-25,318
5806.00	-69.2	38.30	36.00	-84,739	-49,808	0	-68,555
5789.00	-34.6	87.60	36.00	-240,353	-141,276	0	-194,449
5772.00	0.0	101.20	0.00	-331,430	0	0	-331,430
5789.00	34.6	87.60	33.00	-240,353	-130,905	0	-201,577
5806.00	69.2	38.30	33.00	-84,739	-46,152	0	-71,088
5826.00	97.5	26.50	42.00	-42,069	-28,149	0	-31,263
5856.00	126.5	10.00	53.00	-6,500	-5,191	0	-3,912
5871.00	137.5	6.00	53.00	-1,088	-869	0	-654

URS

7. Resultant Thrusts (includes uplift)

Elevation	Station	Dam/Fnd Contact Angle	Resultant Tangential X-Direction	Resultant Radial Y-Direction	Resultant Vertical Z-Direction	Resultant XY Plane Resultant	Resultant XY Plane Angle	Resultant XZ Plane Resultant	Resultant XZ Plane Dip	Resultant YZ Plane Resultant	Resultant YZ Plane Dip	Normal
(feet)	(feet)	(degrees)	(lbs)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(degrees)	(lbs)	(degrees)	(lbs)
5871.00	-110.0	59.00	28,324	14,150	-560	31,662	-26.5	28,329	-1.1	14,161	-87.7	23,990
5856.00	-106.6	59.00	30,038	19,253	5,540	35,679	-32.7	30,544	10.4	20,034	73.9	28,601
5826.00	-87.3	53.00	19,057	95,818	47,952	97,695	-78.8	51,600	68.3	107,147	63.4	44,078
5806.00	-69.2	36.00	-1,764	128,519	100,065	128,531	89.2	100,081	-89.0	162,881	52.1	79,917
5789.00	-34.6	36.00	-107,368	216,637	128,087	241,784	63.6	167,135	-50.0	251,670	59.4	40,515
5772.00	0.0	0.00	-231	166,407	234,849	166,407	89.9	234,849	-89.9	287,828	35.3	234,849
5789.00	34.6	33.00	-100,549	218,896	119,436	240,885	65.3	156,125	-49.9	249,360	61.4	45,404
5806.00	69.2	33.00	-1,644	142,237	101,991	142,246	89.3	102,004	-89.1	175,024	54.4	84,842
5826.00	97.5	42.00	20,162	86,479	55,515	88,798	-76.9	59,063	70.0	102,765	57.3	54,747
5856.00	126.5	53.00	23,534	15,807	10,338	28,350	-33.9	25,705	23.7	18,887	56.8	25,017
5871.00	137.5	53.00	20,982	9,551	-654	23,054	-24.5	20,992	-1.8	9,573	-86.1	18,363

8. Sliding Factor of Safety

Elevation	Station	Arch Thickness	Normal Force	Tangential Driving Force	Radial Driving Force	Total Driving Force	Sliding Factor of Safety Minimum	Sliding Factor of Safety Maximum	Require Friction Angle for FOS = 1.5 Resultant
(feet)	(feet)	(feet)	(lbs)	(lbs)	(lbs)	(lbs)			(degrees)
5871.00	-110.0	6.00	23,990	15,068	14,150	20670	1.3	2.1	52.3
5856.00	-106.6	10.00	28,601	10,722	19,253	22037	1.5	2.3	49.1
5826.00	-87.3	26.50	44,078	-26,828	95,818	95818	0.5	0.8	73.0
5806.00	-69.2	38.30	79,917	-60,244	128,519	128519	0.7	1.1	67.5
5789.00	-34.6	87.60	40,515	-162,150	216,637	216637	0.2	0.3	82.9
5772.00	0.0	101.20	234,849	-231	166,407	166407	1.6	2.5	46.7
5789.00	34.6	87.60	45,404	-149,377	218,896	218896	0.2	0.4	82.1
5806.00	69.2	38.30	84,642	-56,927	142,237	142237	0.7	1.1	68.4
5826.00	97.5	26.50	54,747	-22,163	86,479	86479	0.7	1.1	67.1
5856.00	126.5	10.00	25,017	5,907	15,807	16875	1.7	2.7	45.3
5871.00	137.5	6.00	18,363	13,150	9,551	16252	1.2	1.8	56.1

URS

ATTACHMENT 4:
ADSAS RESULTS FOR LOAD CASE UNLC-1B

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INPUT FILE (bcd9.dat    ) FOR ADSAS  02/11/**  12:21:47

CARD            1         2         3         4         5         6         7         8  CARD
NO.    12345678901234567890123456789012345678901234567890123456789012345678901234567890  NO.

 1     1   0     BASIN CREEK DAM (BUTTE, MT)   16         0                        9701   1
 2     2   0     1111011000000000000000000000                                      9701   2
 3     3   0     300000100000000  1.400  .200  5.60 150.00  0.850  .200  .00 43.90 9701   3
 4     4   0      5772.000 5871.000 5876.800 5772.000 5871.000 5871.000 5772.000   9701   4
 5     1   1     0000000000000000000100000000000000000000                          9701   5
 6     3   1        0.00000 101.20000    0.0000    0.0000  350.0000     .0000  3  19701   6
 7     5   1 1 1   5871.00000      .00000      .00000      .00000      .00000      9701   7
 8     5   1 2 1   5797.50000    -0.80000      .00000      .00000      .00000      9701   8
 9     5   1 2 2   5798.50000   -37.80000      .00000      .00000      .00000      9701   9
10     5   1 2 3   5816.00000    -0.63000      .00000      .00000      .00000      9701  10
11     5   1 2 4   5856.00000    -0.55000      .00000      .00000      .00000      9701  11
12     5   1 2 5   5868.50000    -0.32000      .00000      .00000      .00000      9701  12
13     5   1 2 6   5871.00000      .00000      .00000      .00000      .00000      9701  13
14     5   1 3 1   5871.00000      .00000      .00000      .00000      .00000      9701  14
15     5   1 4 1   5871.00000      .00000      .00000      .00000      .00000      9701  15
16     6   1           .00000    6.00000     .00000     .00000     .00000     .000009701  16
17     7   110000 5772.00000  .0000  .0000  .0000  .0000 -5.50   .00  .00  .00      9701  17
18     7   100000 5789.00000 5.8000 5.8000  .0000  .0000 -5.30   .00  .00  .00      9701  18
19     7   100000 5806.0000011.500011.5000  .0000  .0000 -9.50   .00  .00  .00      9701  19
20     7   100000 5826.0000016.200014.5000  .0000  .0000-14.70   .00  .00  .00      9701  20
21     7   100000 5856.0000020.800017.7000  .0000  .0000-23.50   .00  .00  .00      9701  21
22     7   100000 5871.0000022.500018.7000  .0000  .0000-28.40   .00  .00  .00      9701  22
23     1   2     0000001000000000000000000000000000000000000000000000000000000      9701  23

CARD            1         2         3         4         5         6         7         8  CARD
NO.    12345678901234567890123456789012345678901234567890123456789012345678901234567890  NO.
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URS

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*                                               *
*                UNITED STATES                  *
*            DEPARTMENT OF THE INTERIOR         *
*             BUREAU OF RECLAMATION             *
*               DENVER, COLORADO                *
*                                               *
*            ARCH DAM STRESS ANALYSIS           *
*                      OF                       *
*  BASIN CREEK DAM (BUTTE, MT)     STUDY A-16   *
*              PROBLEM NUMBER 9701              *
*      COMPUTATIONS PERFORMED ON 02/11/**       *
*                                               *
* * * * * * * * * * * * * * * * * * * * * * * * *
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URS

DESIGN CRITERIA

1. DATA WILL BE PREPARED FOR A COMPLETE ADJUSTMENT.

2. THE SHAPE WILL BE CONSIDERED NONSYMMETRIC.

4. TEMPERATURE LOADING IS PRESENTED IN TABULAR FORM (SEE TABLE ON PAGE 1, LINK 1 OUTPUT).

5. THE GROUTING TEMPERATURE= 43.90 DEGREES FAHRENHEIT.

6. SILT LOADING WILL BE APPLIED.

7. NO EARTHQUAKE LOADING WILL BE APPLIED.

8. TWO LINES OF CENTERS WILL BE USED TO DESCRIBE THE DAM.

9. MODULUS OF ELASTICITY OF THE ROCK IS CONSTANT FROM TOP TO BOTTOM OF THE DAM.

10. EFFECTS OF THE CONSTRUCTION PROGRAM ARE NOT INCLUDED IN THIS STUDY.

11. PHYSICAL PROPERTIES OF THE CONCRETE

A. YOUNGS MODULUS OF ELASTICITY= 1.400 MILLION POUNDS/SQUARE INCH.
B. POISSONS RATIO= .200.
C. COEFFICIENT OF THERMAL EXPANSION, .000005600 FOOT/FOOT/DEGREE FAHRENHEIT.
D. UNIT WEIGHT OF CONCRETE= 150.00 POUNDS/CUBIC FOOT.

12. PHYSICAL PROPERTIES OF THE ABUTMENT ROCK

A. YOUNGS MODULUS OF ELASTICITY= .850 MILLION POUNDS/SQUARE INCH.
B. POISSONS RATIO= .200.

13. THE BASE ELEVATION OF THE DAM IS 5772.000.

14. THE TOP ELEVATION OF THE DAM (AS DEFINED ON THE PLANE OF CENTERS) IS 5871.000.

15. THE RESERVOIR WATER SURFACE ELEVATION IS 5876.800.

16. THE TAILWATER SURFACE ELEVATION IS 5772.000.

17. THE DAM IS GROUTED TO ELEVATION 5871.000.

18. THE ELEVATION OF TOP OF CONCRETE IS 5871.000.

19. THE ELEVATION OF BOTTOM OF CONCRETE IS 5772.000.

URS

OUTPUT OF ARCH DAM STRESS ANALYSIS PROGRAMS LINK 8- * STRESS PROGRAM *
VERSION 2.00 COLLECTED
ON 09/17/88

PROBLEM NUMBER 9701
DATE 02/11/**
PAGE 1

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

RESOLUTION OF FORCES AND MOMENTS ON ABUTMENTS

DEFINITIONS

R-XY,R-XZ,R-YZ,R-XYZ = RESULTANT FORCES ON A ONE FOOT WIDE FOUNDATION.

A-XY,A-XZ,A-YZ,A-XYZ = ANGULAR LOCATIONS OF FORCES,I.E.,A-XY IS THE ANGLE MEASURED FROM X(TANGENTIAL) TOWARD Y(RADIAL). (+)A-XY IS UPSTREAM. A-XZ,A-YZ, AND A-XYZ ARE THE DIPS OF THE RESULTANTS. (+) IS DOWNWARD.

ECC = ECCENTRICITY OF R-XYZ FROM THE CENTER OF THICKNESS ON THE FOUNDATION. (+) IS UPSTREAM.

Q = SHEAR FRICTION FACTOR OF SAFETY ALONG THE PLANE OF THE ABUTMENT. Q1 IS IN THE RADIAL DIRECTION (+ IS UPSTREAM), Q2 IS IN THE DIRECTION NORMAL TO RADIAL(+ IS DOWN).

NOTE - THE ELEVATIONS ARE LISTED SEQUENTIALLY DOWN THE RIGHT SIDE OF THE DAM AND THEN UP THE LEFT SIDE LOOKING UPSTREAM.

ELEVATION	XY PLANE		XZ PLANE		YZ PLANE		XYZ PLANE		ECC	Q	
	R	A	R	A	R	A	R	A		Q1	Q2
5871.00	24305.	-27.7	21516.	.0	11304.	.0	24305.	.0	-2.277	-23.785	999.999
5856.00	29371.	-28.7	27543.	20.8	17165.	34.7	30951.	18.4	-5.552	-31.490	-126.342
5826.00	70246.	-58.8	96219.	67.8	107479.	56.0	113456.	51.7	-4.567	-19.735	26.729
5806.00	80788.	-67.0	221510.	81.8	231531.	71.3	233666.	69.8	-2.278	-23.583	19.090
5789.00	117027.	-80.2	529648.	87.8	541691.	77.7	542057.	77.5	.866	-34.898	18.008
5772.00	53198.	-91.0	849733.	89.9	851395.	86.4	851396.	86.4	4.738	90.181	635.058
5789.00	118103.	-81.4	528610.	88.1	541072.	77.5	541357.	77.4	.616	-34.451	17.873
5806.00	88020.	-70.5	227847.	82.6	240693.	69.8	242482.	68.7	-3.014	-21.205	20.786
5826.00	62652.	-57.9	111235.	72.6	118670.	63.4	123250.	59.4	-3.845	-22.526	30.102
5856.00	23742.	-29.2	25333.	35.1	18620.	51.5	27858.	31.5	-4.938	-38.272	-230.553
5871.00	17698.	-25.2	16013.	.0	7538.	.0	17698.	.0	-2.066	-35.306	999.999

URS

STRESSES(PSI) FOR ARCH NO 1 AT ELEVATION 5871.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1137.44	-24.	61.	-24.	61.	13.
1127.06	0.	42.	0.	42.	
1098.96	28.	29.	28.	29.	
1070.25	44.	26.	44.	26.	
1035.43	47.	33.	47.	33.	
1000.00	47.	34.	47.	34.	
964.57	48.	28.	48.	28.	
929.75	42.	22.	42.	22.	
911.42	26.	29.	26.	29.	
891.88	-9.	59.	-9.	59.	
885.77	-40.	90.	-40.	90.	20.

STRESSES(PSI) FOR ARCH NO 2 AT ELEVATION 5856.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1127.06	-18.	52.	-18.	52.	14.
1098.96	17.	25.	17.	25.	
1070.25	37.	13.	37.	13.	
1035.43	39.	19.	39.	19.	
1000.00	40.	20.	40.	20.	
964.57	41.	15.	41.	15.	
929.75	36.	10.	36.	10.	
911.42	14.	28.	14.	28.	
891.88	-34.	74.	-34.	74.	15.

STRESSES(PSI) FOR ARCH NO 3 AT ELEVATION 5826.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1098.96	-21.	41.	-21.	41.	19.
1070.25	19.	4.	19.	4.	
1035.43	30.	-5.	30.	-5.	
1000.00	30.	-5.	30.	-5.	
964.57	32.	-8.	32.	-8.	
929.75	14.	8.	14.	8.	
911.42	-23.	43.	-23.	43.	24.

URS

STRESSES(PSI) FOR ARCH NO 4 AT ELEVATION 5806.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1070.25	19.	-6.	19.	-6.	26.
1035.43	18.	-7.	18.	-7.	
1000.00	18.	-6.	18.	-6.	
964.57	19.	-7.	19.	-7.	
929.75	18.	-6.	18.	-6.	28.

STRESSES(PSI) FOR ARCH NO 5 AT ELEVATION 5789.00
STRESSES PRINTED FROM LEFT ABUTMENT TO RIGHT ABUTMENT LOOKING UPSTREAM

STATION	NORMAL TO RE		PARALLEL TO FACES		TXYM
	EXTRADOS	INTRADOS	EXTRADOS	INTRADOS	MAX.
1035.43	11.	-7.	11.	-7.	18.
1000.00	15.	-12.	15.	-12.	
964.57	11.	-7.	11.	-7.	18.

URS

STRESSES(PSI) FOR CANTILEVER NO 16

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	19.	8.	19.	9.

MAXIMUM ROCK PLANE SHEAR STRESS= 14.

STRESSES(PSI) FOR CANTILEVER NO 17

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	7.	20.	7.	22.
5826.00	37.	31.	37.	37.

MAXIMUM ROCK PLANE SHEAR STRESS= 20.

STRESSES(PSI) FOR CANTILEVER NO 18

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	7.	19.	7.	22.
5826.00	33.	36.	33.	43.
5806.00	55.	41.	55.	53.

MAXIMUM ROCK PLANE SHEAR STRESS= 29.

STRESSES(PSI) FOR CANTILEVER NO 19

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	3.	24.	3.	27.
5826.00	19.	49.	19.	61.
5806.00	37.	59.	37.	449.
5789.00	54.	53.	54.	110.

MAXIMUM ROCK PLANE SHEAR STRESS= -44.

URS

STRESSES(PSI) FOR CANTILEVER NO 20

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	1.	26.	1.	29.
5826.00	17.	51.	17.	63.
5806.00	35.	62.	35.	472.
5789.00	53.	54.	53.	76.
5772.00	75.	60.	75.	83.

MAXIMUM ROCK PLANE SHEAR STRESS= 29.

STRESSES(PSI) FOR CANTILEVER NO 21

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	2.	25.	2.	28.
5826.00	17.	52.	17.	65.
5806.00	34.	63.	34.	483.
5789.00	53.	54.	53.	113.

MAXIMUM ROCK PLANE SHEAR STRESS= -46.

STRESSES(PSI) FOR CANTILEVER NO 22

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	5.	21.	5.	24.
5826.00	24.	44.	24.	54.
5806.00	43.	53.	43.	70.

MAXIMUM ROCK PLANE SHEAR STRESS= 34.

STRESSES(PSI) FOR CANTILEVER NO 23

ELEVATION	VERTICAL STRESSES US FACE	VERTICAL STRESSES DS FACE	PARALLEL STRESSES US FACE	PARALLEL STRESSES DS FACE
5871.00	0.	0.	0.	0.
5856.00	4.	23.	4.	26.
5826.00	27.	42.	27.	51.

MAXIMUM ROCK PLANE SHEAR STRESS= 22.

URS

STRESSES(PSI) FOR CANTILEVER NO 24

	VERTICAL STRESSES		PARALLEL STRESSES	
ELEVATION	US FACE	DS FACE	US FACE	DS FACE
5871.00	0.	0.	0.	0.
5856.00	6.	20.	6.	23.

MAXIMUM ROCK PLANE SHEAR STRESS= 15.

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 25

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-24.	0	0	0.	61.	0	0	5871.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 24

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	0.	0	0	0.	42.	0	0	5871.0
5856.0	29.	-40.	-34	39	-5.	80.	-35	3	5856.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 23

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	28.	0	0	0.	29.	0	0	5871.0
5856.0	-11.	32.	36	22	53.	-2.	44	31	5856.0
5826.0	33.	-28.	-18	55	76.	16.	40	8	5826.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 22

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	44.	0	0	0.	26.	0	0	5871.0
5856.0	2.	40.	16	29	35.	2.	35	12	5856.0
5826.0	34.	9.	-38	39	62.	-4.	20	6	5826.0
5806.0	65.	-3.	-34	28	92.	-28.	25	14	5806.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 21

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	47.	0	0	0.	33.	0	0	5871.0
5856.0	2.	40.	2	36	30.	17.	19	22	5856.0
5826.0	13.	34.	25	30	67.	-8.	10	3	5826.0
5806.0	46.	7.	-33	8	492.	-16.	7	36	5806.0
5789.0	54.	10.	-9	58	115.	-9.	7	18	5789.0

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 20

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	47.	0	0	0.	34.	0	0	5871.0
5856.0	1.	40.	0	48	29.	20.	-6	52	5856.0
5826.0	17.	30.	0	56	64.	-5.	0	44	5826.0
5806.0	35.	18.	1	44	472.	-6.	0	23	5806.0
5789.0	53.	15.	0	0	76.	-12.	0	11	5789.0
5772.0	75.	0.	0	0	83.	0.	0	8	5772.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 19

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	48.	0	0	0.	28.	0	0	5871.0
5856.0	2.	42.	6	28	31.	11.	25	50	5856.0
5826.0	13.	38.	30	13	65.	-12.	13	17	5826.0
5806.0	50.	6.	-32	22	461.	-20.	9	12	5806.0
5789.0	55.	10.	-9	38	112.	-9.	7	45	5789.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 18

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	42.	0	0	0.	22.	0	0	5871.0
5856.0	-1.	45.	25	26	41.	-9.	38	22	5856.0
5826.0	43.	3.	-30	57	58.	-7.	28	45	5826.0
5806.0	75.	-2.	-31	2	82.	-34.	29	52	5806.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 17

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	26.	0	0	0.	29.	0	0	5871.0
5856.0	-15.	36.	40	47	-7.	57.	-42	32	5856.0
5826.0	45.	-30.	-18	45	6.	74.	-42	24	5826.0

URS

PRINCIPAL STRESSES (PSI) ON CANTILEVER 16

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-9.	0	0	0.	59.	0	0	5871.0
5856.0	38.	-53.	-27	30	-12.	94.	-26	3	5856.0

PRINCIPAL STRESSES (PSI) ON CANTILEVER 15

AT THE UPSTREAM FACE					AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	ALPHA MIN	P1	P2	ALPHA DEG	ALPHA MIN	ELEV
5871.0	0.	-40.	0	0	0.	90.	0	0	5871.0

URS

PRINCIPAL STRESSES (PSI) PARALLEL TO THE FACES AT THE ABUTMENTS

LEFT ABUTMENT (LOOKING UPS

AT THE DOWNSTREAM FACE						AT THE UPSTREAM FACE				ACE
ELEV	P1	P2	ALPHA DEG	MIN	CANT NO	P1	P2	ALPHA DEG	MIN	ELEV
5871.0	0.	-24.	0	0	25	0.	61.	0	0	5871.0
5856.0	29.	-40.	-34	39	24	-5.	80.	-35	3	5856.0
5826.0	33.	-28.	-18	55	23	76.	16.	40	8	5826.0
5806.0	65.	-3.	-34	28	22	92.	-28.	25	14	5806.0
5789.0	54.	10.	-9	58	21	115.	-9.	7	18	5789.0
5772.0	75.	0.	0	0	20	83.	0.	0	8	5772.0

RIGHT ABUTMENT (LOOKING UPSTREAM)

AT THE UPSTREAM FACE						AT THE DOWNSTREAM FACE				
ELEV	P1	P2	ALPHA DEG	MIN	CANT NO	P1	P2	ALPHA DEG	MIN	ELEV
5871.0	0.	-40.	0	0	15	0.	90.	0	0	5871.0
5856.0	38.	-53.	-27	30	16	-12.	94.	-26	3	5856.0
5826.0	45.	-30.	-18	45	17	6.	74.	-42	24	5826.0
5806.0	75.	-2.	-31	2	18	82.	-34.	29	52	5806.0
5789.0	55.	10.	-9	38	19	112.	-9.	7	45	5789.0

URS

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

CANTILEVER STRESSES PARAL
LOOKING

ELEV	STA	1127.06	1098.96	1070.25	1035.43	1000.00
	TAU	0.				
5871.	U	0.	0.	0.	0.	0.
	D	0.	0.	0.	0.	0.
	TAU	15.				
5856.	U	6.	4.	5.	2.	1.
	D	23.	26.	24.	28.	29.
		TAU	22.			
5826.		U	27.	24.	17.	17.
		D	51.	54.	65.	63.
			TAU	34.		
5806.			U	43.	34.	35.
			D	70.	483.	472.
				TAU	-46.	
5789.				U	53.	53.
				D	113.	76.
					TAU	29.
5772.					U	75.
					D	83.

URS

(9701) RUN 02/11/**

LEL TO THE FACE OF THE DAM
UPSTREAM

964.57 929.75 911.42 891.88

			0.	TAU
0.	0.	0.	0.	
0.	0.	0.	0.	
			14.	TAU
3.	7.	7.	19.	
27.	22.	22.	9.	
		20.	TAU	
19.	33.	37.		
61.	43.	37.		
	29.	TAU		
37.	55.			
449.	53.			
-44.	TAU			
54.				
110.				

URS

STUDY A-16 OF BASIN CREEK DAM (BUTTE, MT)

ARCH STRESSES PARALLEL LOOKING

ELEV	STA	1137.44	1127.06	1098.96	1070.25	1035.43	1000.00
	TAU	13.					
5871.	E	-24.	0.	28.	44.	47.	47.
	I	61.	42.	29.	26.	33.	34.
	TAU		14.				
5856.	E		-18.	17.	37.	39.	40.
	I		.52.	25.	13.	19.	20.
	TAU			19.			
5826.	E			-21.	19.	30.	30.
	I			41.	4.	-5.	-5.
	TAU				26.		
5806.	E				19.	18.	18.
	I				-6.	-7.	-6.
	TAU					18.	
5789.	E					11.	15.
	I					-7.	-12.

URS

(9701) RUN 02/11/**

TO THE FACE OF THE DAM
UPSTREAM

964.57	929.75	911.42	891.88	885.77

				20.	TAU
48.	42.	26.	-9.	-40.	
28.	22.	29.	59.	90.	
			15.	TAU	
41.	36.	14.	-34.		
15.	10.	28.	74.		
		24.	TAU		
32.	14.	-23.			
-8.	8.	43.			
	28.	TAU			
19.	18.				
-7.	-6.				
18.	TAU				
11.					
-7.					

URS

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OUTPUT OF ARCH DAM STRESS ANALYSIS PROGRAMS      LINK  8- *       STRESS PROGRAM       *          PROBLEM NUMBER 9701
VERSION   2.00 COLLECTED                                                                          DATE  02/11/**
ON  09/17/88                                STUDY A-16   OF BASIN CREEK DAM (BUTTE, MT)          PAGE   11

                                                TIME IN MINUTES FOR LINK 8

                                        1.  COMPUTATION OF STRESSES        =    .000
```

URS

Project: BASIN CREEK DAM
Feature: ADSAS Study "B-9"
Detail: Sliding Stability - Unusual Load (PMF Reservoir Elevation)
File: SLIDING2

Job No: 24773.00 Sheet #:
By: S. Jones Date: 14-Feb-05
Chkd.By: Date:

1. Reservoir Water Surface Elevation:

Reservoir Elevation = 5876.8 feet
Unit Weight of Water = 62.5 pcf

2. Foundation Strengths:

Min Effective Friction Angle = 49.0 degrees
Max Effective Friction Angle = 61.0 degrees

3. Foundation Drain Efficiency:

Foundation Drain Efficiency = 0.0%

4. Percent of Base Cracked

Base Cracked = 0.0%

4. ADSAS Results - Abutment Thrusts

		XY Plane		Thrust		XZ Plane		Thrust		YZ Plane		Thrust	
Elevation	Station	Resultant	Angle	X-Direction	Y-Direction	Resultant	Dip	X-Direction	Z-Direction	Resultant	Dip	Y-Direction	Z-Direction
(feet)	(feet)	(lbs)	(degrees)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(lbs)	(lbs)	(degrees)	(lbs)	(lbs)
5871.00	-110.0	24,305	-27.7	21,519	11,298	21,516	0.0	21,516	0	11,304	0.0	11,304	0
5856.00	-106.6	29,371	-28.7	25,763	14,105	27,543	20.8	25,748	9,781	17,165	34.7	14,112	9,772
5826.00	-87.3	70,246	-58.8	36,389	60,086	96,219	67.8	36,355	89,086	107,479	56.0	60,101	89,104
5806.00	-69.2	80,788	-67.0	31,566	74,366	221,510	81.8	31,594	219,245	231,531	71.3	74,232	219,309
5789.00	-34.6	117,027	-80.2	19,919	115,319	529,648	87.8	20,332	529,258	541,691	77.7	115,397	529,257
5772.00	0.0	53,198	-91.0	-928	53,190	849,733	89.9	1,483	849,732	851,395	86.4	53,460	849,715
5789.00	34.6	118,103	-81.4	17,661	116,775	528,610	88.1	17,526	528,319	541,072	77.5	117,109	528,246
5806.00	69.2	88,020	-70.5	29,382	82,971	227,847	82.6	29,346	225,949	240,693	69.8	83,111	225,889
5826.00	97.5	62,652	-57.9	33,293	53,074	111,235	72.6	33,264	106,145	118,670	63.4	53,136	106,109
5856.00	126.5	23,742	-29.2	20,725	11,583	25,333	35.1	20,726	14,567	18,620	51.5	11,591	14,572
5871.00	137.5	17,698	-25.2	16,014	7,535	16,013	0.0	16,013	0	7,538	0.0	7,538	0

5. Local Components of Thrust

			XY Plane		
Elevation	Station	Embankment Load	Tangential X-Direction	Radial Y-Direction	Vertical Z-Direction
(feet)	(feet)	(lbs)	(lbs)	(lbs)	(lbs)
5871.00	-110.0	0	21,518	11,301	0
5856.00	-106.6	3360	25,755	14,108	13,136
5826.00	-87.3	37560	36,372	60,094	126,655
5806.00	-69.2	87960	31,580	74,299	307,237
5789.00	-34.6	360120	20,126	115,358	889,377
5772.00	0.0	410520	277	53,325	1,260,243
5789.00	34.6	360120	17,593	116,942	888,403
5806.00	69.2	87960	29,364	83,041	313,879
5826.00	97.5	37560	33,278	53,105	143,687
5856.00	126.5	3360	20,726	11,587	17,929
5871.00	137.5	0	16,013	7,537	0

6. Uplift Forces

					XY Plane		
Elevation	Station	Arch Thickness	Dam/Fnd Contact Angle	Normal Uplift Force	Tangential X-Direction	Radial Y-Direction	Vertical Z-Direction
(feet)	(feet)	(feet)	(degrees)	(lbs)	(lbs)	(lbs)	(lbs)
5871.00	-110.0	6.00	59.00	-1,088	-932	0	-560
5856.00	-106.6	10.00	59.00	-6,500	-5,572	0	-3,348
5826.00	-87.3	26.50	53.00	-42,069	-33,598	0	-25,318
5806.00	-69.2	38.30	36.00	-84,739	-49,808	0	-68,555
5789.00	-34.6	87.60	36.00	-240,353	-141,276	0	-194,449
5772.00	0.0	101.20	0.00	-331,430	0	0	-331,430
5789.00	34.6	87.60	33.00	-240,353	-130,905	0	-201,577
5806.00	69.2	38.30	33.00	-84,739	-46,152	0	-71,068
5826.00	97.5	26.50	42.00	-42,069	-28,149	0	-31,263
5856.00	126.5	10.00	53.00	-6,500	-5,191	0	-3,912
5871.00	137.5	6.00	53.00	-1,088	-869	0	-654

URS

7. Resultant Thrusts (Includes uplift)

Elevation (feet)	Station (feet)	Dam/Fnd Contact Angle (degrees)	Resultant Tangential X-Direction (lbs)	Resultant Radial Y-Direction (lbs)	Resultant Vertical Z-Direction (lbs)	Resultant XY Plane Resultant (lbs)	Resultant XY Plane Angle (degrees)	Resultant XZ Plane Resultant (lbs)	Resultant XZ Plane Dip (degrees)	Resultant YZ Plane Resultant (lbs)	Resultant YZ Plane Dip (degrees)	Normal (lbs)
5871.00	-110.0	59.00	20,586	11,301	-560	23,484	-28.8	20,593	-1.6	11,315	-87.2	17,357
5856.00	-106.6	59.00	20,184	14,108	9,788	24,626	-35.0	22,432	25.9	17,171	55.2	22,342
5826.00	-87.3	53.00	2,775	60,094	101,338	60,158	-87.4	101,376	88.4	117,816	30.7	63,203
5806.00	-69.2	36.00	-18,228	74,299	238,682	76,502	76.2	239,377	-85.6	249,979	17.3	182,383
5789.00	-34.6	36.00	-121,150	115,358	694,928	167,287	43.6	705,409	-80.1	704,438	9.4	490,998
5772.00	0.0	0.00	277	53,325	928,813	53,325	-89.7	928,813	90.0	930,343	3.3	928,813
5789.00	34.6	33.00	-113,312	116,942	686,826	162,835	45.9	696,111	-80.6	696,711	9.7	514,307
5806.00	69.2	33.00	-16,788	83,041	242,811	84,721	78.6	243,391	-86.0	256,618	18.9	194,495
5826.00	97.5	42.00	5,129	53,105	112,424	53,352	-84.5	112,541	87.4	124,335	25.3	86,979
5856.00	126.5	53.00	15,534	11,587	14,018	19,380	-36.7	20,924	42.1	18,187	39.6	20,842
5871.00	137.5	53.00	15,145	7,537	-654	16,916	-26.5	15,159	-2.5	7,565	-85.0	11,701

8. Sliding Factor of Safety

Elevation (feet)	Station (feet)	Arch Thickness (feet)	Normal Force (lbs)	Tangential Driving Force (lbs)	Radial Driving Force (lbs)	Total Driving Force (lbs)	Sliding Factor of Safety Minimum	Sliding Factor of Safety Maximum	Require Friction Angle for FOS = 1.5 Resultant (degrees)
5871.00	-110.0	6.00	17,357	11,082	11,301	15628	1.3	2.0	53.8
5856.00	-106.6	10.00	22,342	2,005	14,108	14250	1.8	2.8	43.7
5826.00	-87.3	26.50	63,203	-79,262	60,094	60094	1.2	1.9	55.0
5806.00	-69.2	38.30	182,383	-155,041	74,299	74299	2.8	4.4	31.4
5789.00	-34.6	87.60	490,998	-506,481	115,358	115358	4.9	7.7	19.4
5772.00	0.0	101.20	928,813	277	53,325	53325	20.0	31.4	4.9
5789.00	34.6	87.60	514,307	-469,104	116,942	116942	5.1	7.9	18.8
5806.00	69.2	38.30	194,495	-146,324	83,041	83041	2.7	4.2	32.6
5826.00	97.5	26.50	86,979	-71,415	53,105	53105	1.9	3.0	42.5
5856.00	126.5	10.00	20,842	-1,846	11,587	11587	2.1	3.2	39.8
5871.00	137.5	6.00	11,701	9,637	7,537	12234	1.1	1.7	57.5

February 27, 2006

Mr. Russell C. Reed, P.E.
Project Manager
HKM Engineering, Inc.
1015 South Montana St.
Butte, Montana 59701

Subject: Basin Creek Dam
Site Inspection
Project No. 22237805

Dear Russ:

This letter documents the URS site visit and additional analysis regarding the stability of Basin Creek Dam. During the site visit particular attention was given to the foundation rock and abutments of the dam. This letter documents the findings from that site visit and the additional stability analyses performed on the dam using the updated information on the foundation rock strength parameters and conclusions regarding the stability of the dam.

SITE VISIT

URS engineers Mr. Guy S. Lund, P.E. and Ms. Kelly J. Young participated in a site visit of Basin Creek Dam on January 12 and 13, 2006. The weather was partly cloudy and cold.

The primary objectives of the site visit included observing the dam and foundation rock to gain a more thorough understanding of the site conditions and perform visual observations of the geologic data on the abutments for input to an assessment of rock strength.

The site visit found the dam to be in good condition, and observation concurred with the assumptions that were used in the previous stability evaluation, regarding the layout of the dam (see URS memorandum dated February 21, 2005 *[6]*).

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Offices Worldwide

FOUNDATION

Local Geology

The foundation and abutment bedrock at the site consists of coarse to very coarse grained, light to medium grey, massive granite. The granite is exposed along both abutments and the reservoir bottom. The granite is composed of quartz, orthoclase, plagioclase, and biotite, with a pyrite accessory. Three primary joint sets were observed, and will be discussed later in this letter report. Horizontal foliation was observed. Blows from a geologist pick yielded a "thud" sound on exposed surfaces, and highly weathered to decomposed granite appears to have formed over weathered to fresh granite. The weathered to fresh granite, exposed from sledgehammer blows, had a "ping" sound.

Photographs taken during the original construction, supplied by HKM, suggest the dam was built on abutments of weathered to fresh granite. The photographs indicate that the weathered and decomposed rock on the abutments and foundation was removed to expose the stronger granite.

Joint Sets

Three primary joint sets were observed in the foundation rock mass, and are summarized in Table 1. Figure No. 1 shows joint sets super-imposed on a plan view of the dam.

Table 1
Summary of Observed Joint Sets

Joint	Strike	Dip
Joint Set 1	N 62° E	83° NW
Joint Set 2	N 26° W	80° SW
Joint Set 3	N 46° E	47° SE

Rock Quality Designation

A line survey was performed on a rock outcrop located on the right abutment to estimate the rock quality designation (RQD) for the granite. The rock outcrop appeared to be representative of the undisturbed rock mass at the site. The measurements from the line survey are summarized in Table 2.

Table 2
Summary of Observed Joint Sets

Description	Field Measurement	Converted Field Measurement	Intact Rock Measurement	Aperature Width	Note
	(feet)	(inch)	(inch)	(inch)	
Begin Survey – Granite	0	0			
Granite-Discontinuity – Vertical Joint	4.4	52.8	52.8		
Discontinuity-Granite	4.9	58.8		6	Weathered joint
Granite-Discontinuity – Vertical Joint	11.3	135.6	76.8		
Discontinuity-Granite	12.4	148.8		13.2	Weathered joint
Granite-Discontinuity – Vertical Joint	17.9	214.8	66.0		
Discontinuity-Granite	18.5	222.0		7.2	Weathered joint
Granite-Discontinuity-Granite	21.2	254.4	--	--	Tight joint
Granite-Discontinuity – Vertical Joint	22.9	274.8	52.8		
Discontinuity-Granite	23.7	284.4		9.6	Weathered joint
End Survey	25	300	15.6		
Total Length			254.0	36.0	

The observations at the site indicate that the rock was generally massive. The results from the line survey estimate the RQD to be 88 percent, and can be classified as "good" rock.

Compressive Strength

Several rock samples were field tested with a portable point-load testing machine to estimate the compressive strength of the rock. A sledgehammer was used to break large blocks of rock into smaller samples that could be used in the point load apparatus. The rock samples were moderately weathered to fresh and measured between 1.5 to 3.5 inches in length and diameter. Results of the point load tests are summarized in the attached Table 3.

Table 3
Summary of Point Load Tests

Sample	Diameter	Length	Maximum Pressure (1)	Platen Separation D	D^2	P (2)	I_S (3)	k (4)	Estimated Compressive Strength σ_C (5)	Foliation (6)
	(inch)	(inch)	(lb/in^2)	(inch)	(in^2)	(lb)	(lb/in^2)		(lb/in^2)	
Right Abutment										
1	1.38	2.25	76	1.110	1.23	380	308	19.9	6,137	Parallel
2	1.38	2.50	83	1.050	1.10	415	376	19.9	7,491	Parallel
3	1.00	2.50	55	0.863	0.74	275	369	18.2	6,720	Parallel
4	2.38	1.50	85	1.800	3.24	425	131	24.8	3,253	Parallel
5	1.75	2.00	232	1.314	1.73	1160	672	21.7	14,579	Perpendicular
6	1.38	1.75	85	1.079	1.16	425	365	19.9	7,264	Parallel
Left Abutment										
7	1.50	3.00	83	1.195	1.43	415	291	20.6	5,987	Parallel
8	1.25	2.25	67	1.326	1.76	335	191	19.4	3,696	Parallel
9	1.75	3.00	58	1.477	2.18	290	133	21.7	2,885	Parallel
10	1.50	3.00	112	1.935	3.74	560	150	20.6	3,081	Parallel
11	2.00	3.00	70	1.518	2.30	350	152	22.7	3,448	Parallel
12	1.50	2.5	160	1.453	2.11	800	379	20.6	7,806	Parallel
13	1.75	2.75	250	1.263	1.60	1250	784	21.7	17,004	Perpendicular
14	1.75	3.50	195	1.441	2.08	975	470	21.7	10,189	Perpendicular
15	2.00	2.00	109	1.675	2.81	545	194	22.7	4,410	Parallel
16	2.50	2.00	67	1.916	3.67	335	91	25.3	2,309	Parallel
17	2.00	1.75	103	0.612	0.37	515	1375	22.7	31,213	Perpendicular
18	2.00	2.00	263	2.066	4.27	1315	308	22.7	6,993	Parallel

(1) Pressure from the gauge on the point load test apparatus at failure.
(2) Maximum pressure at failure multiplied by 5.0 square inches (constant from platen area)
(3) "P" divided by "D^2"
(4) Correlation factor from Franklin, et. al (1972)
(5) Compressive strength equals "I_S" multiplied by "k"
(6) Orientation of foliation in the rock sample with load direction

The point-load test results were used to estimate the compressive strength of the rock. The samples that had a platen separation less than 1-inch were neglected, per the point load manual recommendation. The test results indicate that the compressive strength of the rock ranges between approximately 2,300 and 31,200 lb/in^2. The results show a correlation between strength and the orientation of the foliation. The compressive strength of the tested rock samples, with the foliation rock parallel to the direction of compressive load, ranged between 2,300 to 7,800 lb/in^2, with a median value of approximately 5,000 lb/in^2. The compressive strength of the tested rock samples, with the foliation rock perpendicular to the direction of compressive load, ranged between 10,200 to 17,000 lb/in^2, with a median value of approximately 13,600 lb/in^2.

Shear Strength

The shear strength of the rock depends on the mode of failure. For sliding planes along discontinuities, the shear strength will depend on the basic friction angle of the rock combined with an increase in the angle due to the surface roughness, which is directly related to asperities along the discontinuity. For sliding planes that occur in the rock mass the shear strength can be computed using the empirical Hoek-Brown methodology *[1]*.

Effective Friction Angle

The effective angle of internal friction (ϕ_e) for failure planes along discontinuities is computed by summing the basic friction angle (ϕ_b) for the rock and the effect of surface roughness (i) *[1, 2]*. Published data indicates that the surface irregularities on joints have a significant influence on the effective friction angle when the normal stresses are low compared to the unconfined compressive strength of the rock. The surface irregularities contribute a roughness angle that is added to the basic friction angle, thus increasing the effective friction angle for the structure.

A typical friction angle for granite can range from 31 to 35 degrees *[1, pp 100]*. The basic friction angle for these design studies was assumed to be 33 degrees, which is the median value for the typical ranges.

The roughness angle can be estimated using the Equation 1:

Equation 1

$$i = JRC \times \log_{10}\left(\frac{\sigma_j}{\sigma_n}\right)$$

where:

i = Roughness angle
JRC = Joint roughness coefficient (JRC)
σ_j = Unconfined compressive strength of joint
σ_n = Normal stress from structural analysis

The previous stability analysis *[6]* indicated that the average normal (confining) stress along the dam/foundation interface would be approximately 50 lb/in^2.

The joint roughness coefficient (JRC) is a factor that helps characterize roughness of the discontinuity. During the site visit, an estimate of roughness for several discontinuities was measured. Two measurements were taken along fresh faces, which were exposed due to recent construction at the dam site. Three measurements were taken from weathered exposed rock faces on the left abutment above the dam. Plots of the roughness measurements are shown on Figure No. 2. The data indicates that the JRC values for the weathered faces are 15 (Joint Face 1), 12 (Joint Face 2), and 5 (Joint Face 3). For the freshly excavated faces the JRC values are 12 (Fresh Face 1) and 20 (Fresh Face 2). Because the historical photographs indicate that the dam was placed on freshly excavated rock, it is reasonable to assume that the JRC of the dam/foundation interface would be better represented by the measurements from the fresh faces. Therefore, the analysis should used the median JRC value of 16, as taken from the asperity measurements along the fresh faces.

The average compressive strength with the foliation parallel to the confining force (i.e. 5,000 lb/in^2), average confining stress from the dam (i.e. 50 lb/in^2), and average JRC value (i.e. 13) were used to compute a roughness angle of 32 degrees. Using the assumed basic friction angle and the computed roughness angle, the effective friction angle ($\phi_b + i$) of the rock was estimated to be equal to approximately 65 degrees.

Generalized Hoek-Brown Criterion

Reliable estimates of the strength and deformation characteristics of rock masses can also be estimated using the Hoek-Brown failure criterion *[1, 2]*. The methodology uses the following equation and estimates of the strength of jointed rock masses, based upon an assessment of the interlocking of rock blocks and the condition of the surfaces between these blocks.

Equation 2

$$\sigma'_1 = \sigma'_3 + \sigma_{ci} \cdot \left(m_b \cdot \frac{\sigma'_3}{\sigma_{ci}} + s \right)^a$$

where:

σ'_1 = Maximum effective stress at failure (MPa)
σ'_3 = Minimum effective stress at failure (MPa)
σ_{ci} = Uniaxial compressive strength
m_b = Hoek-Brown constant for the rock mass
s = Constant that depend on rock mass characteristic, 1.00
a = Constant that depend on rock mass characteristic, 0.50

The Hoek-Brown constant for intact rock, m_b, was estimated from published data *[2]*. For granite type rocks the m_b, value is typically estimated to be approximately 33, and this value was used for these evaluations. The value for Geological Strength Index (GSI) was also estimated based on published data and field observations for the rock masses. Field observations, asperity measurements and estimated RQD suggest that the surface conditions were generally good, and the joints surfaces are slightly weathered to smooth in some areas, and the rock mass structure ranged from blocky to very blocky. Based on this information, the GSI was estimated to range from 55 to 65.

As noted previously, the unconfined compressive strength was based on previous point load tests, and was assumed to be approximately 5,000 lb/in^2. The normal confining stress from the dam, based on preliminary calculations, was estimated to be approximately 50 lb/in^2. The estimated friction angle and cohesion for the rock mass computed by the Hoek-Brown Criterion is summarized in Table 4, along with the other rock characteristics used in the computations. The friction angle and cohesion are for the tangent line at the expected normal confining stress, as shown in Figure No. 4.

Table 4
Summary of Hoek-Brown Criterion

Item	Value	
Lower Bound Strength		
Geological Strength Index, GSI	55	
Hoek-Brown Constant, m_b	33	
Unconfined Compressive Strength	5,000	lb/in^2
Confining Stress	50	lb/in^2
Tangent Friction Angle	66	degrees
Tangent Cohesion	53	lb/in^2
Upper Bound Strength		
Geological Strength Index, GSI	65	
Hoek-Brown Constant, m_b	33	
Unconfined Compressive Strength	5,000	lb/in^2
Confining Stress	50	lb/in^2
Tangent Friction Angle	67	degrees
Tangent Cohesion	76	lb/in^2

Recommended Shear Strength

For the stability evaluation of Basin Creek Dam, the recommended strength parameter is 66 degrees and zero (0) cohesion. This corresponds to the average friction angle as determined using the Hoek-Bray equation for roughness along discontinuities (i.e. 65 degrees), and the tangent friction angle at the confining stress from the Hoek-Brown failure envelop (i.e. 66 and 67 degrees). Our previous studies have established the minimum sliding factor of safety for static loads as 1.5, based on current Federal Energy Regulatory Commission (FERC) guidelines. However, the guidelines require cohesive strength of the rock mass to be neglected when using the allowable factor of safety equal to 1.5. For this reason the estimated cohesion as computed by the Hoek-Brown failure criterion was neglected.

STABILITY

The stability analysis for Basin Creek Dam was performed using the USBR Arch Dam Stress Analysis System (ADSAS) computer program, again as discussed in the previous stability report *[6]*. The results from ADSAS studies were used to computed the sliding stability factors of safety for the assumed

loading conditions. These computations were updated using the new recommended effective friction angle of 66 degrees. The resulting sliding factors of safety are summarized in Table 5.

Table 5.
Computed Sliding Factor of Safety

Elevation	Station	USLC-1b (1)	UNLC-1a (2)
5871	-110.0	2.9	2.6
5856	-106.0	4.9	2.9
5826	-87.3	2.9	1.0
5806	-69.2	6.7	1.4
5789	-34.6	11.9	0.4
5772	0.0	52.8	3.2
5789	34.6	12.3	0.5
5806	69.2	6.5	1.3
5826	97.5	4.7	1.4
5856	126.6	6.1	3.3
5871	137.5	2.6	2.3

(1) Usual Load consists of gravity, normal reservoir El. 5872, uplift pressure and the embankment load on the downstream face of the dam.

(2) Unusual Load 1a consists of gravity, PMF reservoir El. 5876.8, uplift pressure and no embankment load on the downstream face of the dam.

The results from USLC-1b, with the embankment on the downstream face of the dam, show that all factors of safety are greater than the minimum allowable value of 1.5. Based on these results, the dam is considered to have adequate safety against sliding for the assumed loading with the embankment on the downstream face of the dam.

The results from load UNLC-1a, without the embankment on the downstream face, show that the computed factors of safety for isolated area of the dam/foundation interface are less than the allowable factor of safety. The construction of the dam did not include vertical contraction joints, which were noted during the site visit and recorded in the photograph shown in Figure No. 5. The lack of vertical contraction joints in the dam will cause adjacent sections of the dam to interact with each other. This prevents differential movement. Therefore, the less stable areas will gain some additional stability from more stable adjacent areas of the dam. When the computed sliding factor of safety for an individual area is less than the allowable factor of safety, then adjacent areas are averaged together in a process called

progressive stability analysis. If the results from the progressive stability analysis indicate that the overall average sliding factor of safety is greater than the minimum required value then the dam is considered to have adequate stability against sliding.

The results from UNLC-1a were evaluated in the progressive stability analysis. The results show that the overall sliding factor of safety is greater than the minimum required value of 1.5. Based on these results, the dam is considered to have adequate safety against sliding for the assumed UNLC-1a loading condition, which does not include the effects of the embankment on the downstream face of the dam.

CONCLUSIONS

Based on the observations, point load testing, and measurements taken during the site visit, it is concluded that the shear strength of the dam/foundation interface should be simulated using an effective friction angle of approximately 66 degrees. The effective friction angle of 66 degrees is based on two method of computed the effective friction angle. First, the roughness for the undulating dam/foundation interface was assumed to be an unweathered, freshly excavated rock surface, and measurements of the asperities taken from freshly excavated rock surfaces during the site visit indicate that the effective friction angle would be approximately 65-degrees. Second, the rock mass strength envelop was computed using the Hoek-Brown failure criterion, and the tangent line to the failure envelope at the anticipated normal stress (which is very small compared to the strength of the rock) was computed to have an effective friction angle of between 66 and 67 degrees, with an effective cohesion between 53 and 76 lb/in^2.

The results from the stability analysis indicate that the dam has adequate safety against sliding for both the usual USLC-1b and unusual UNLC-1a loading conditions. The previous studies *[6]* showed that the dam had adequate safety against overstressing. Based on these studies, Basin Creek Dam satisfies the recommended safety guidelines, and no further modifications are required.

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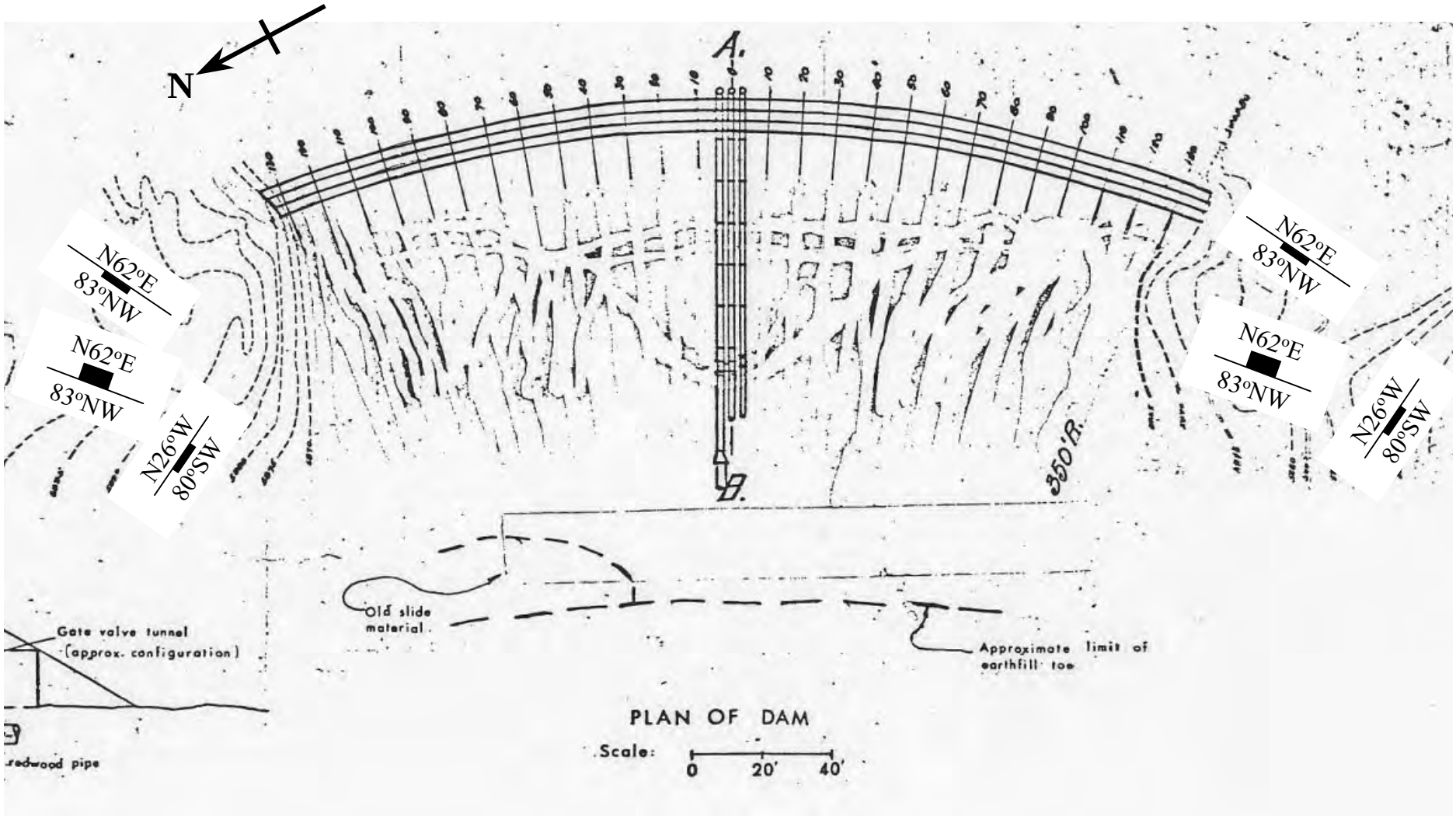
URS wants to thank HKM Engineering Inc. for the opportunity to participate in this study with you. I hope that we can find ways to work together again in the near future. If you have any questions regarding the information in this letter, please do not hesitate to call me at (303) 740-3902.

Sincerely,

Guy S. Lund, P.E.
Principal Civil/Structural Engineer

Kelly J. Young
Engineering Geologist

GSL:gsl



BASIN CREEK DAM
Plan
Joint Sets Orientation

Figure No. 1

A

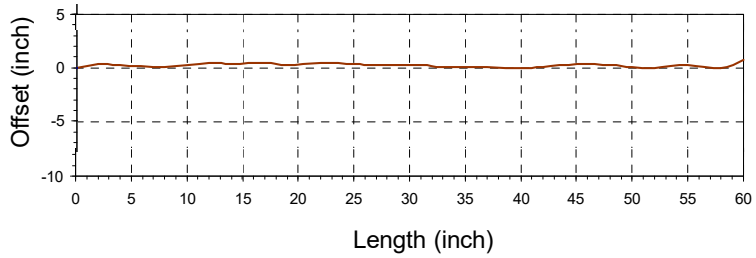
A

A

A

BASIN CREEK DAM
Line Survey
RQD Estimate

Figure No. 2



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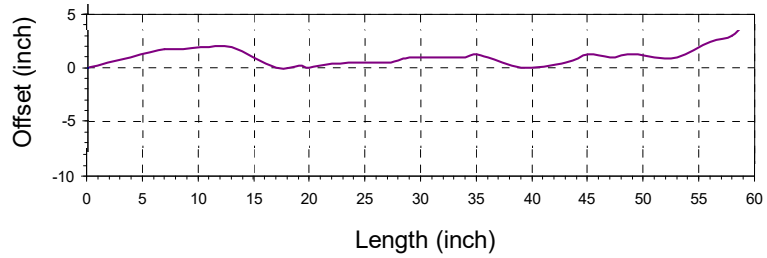
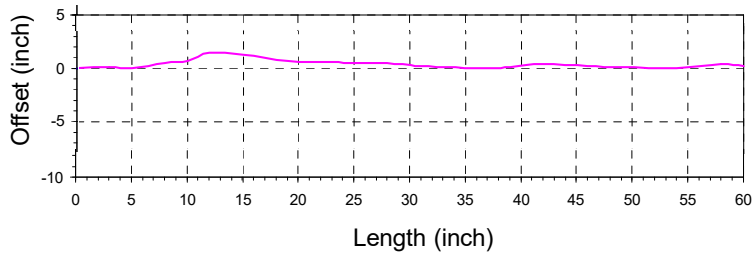


Fresh Face 2



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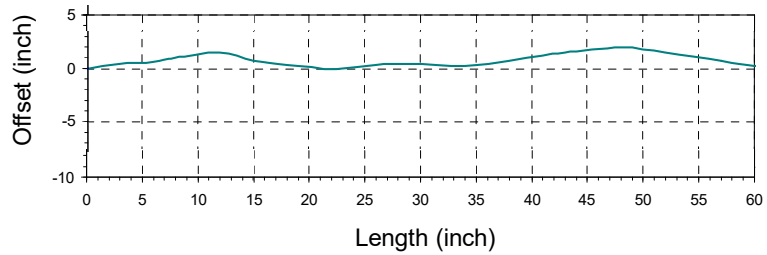
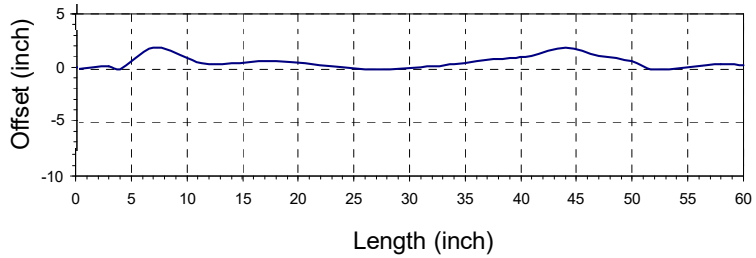


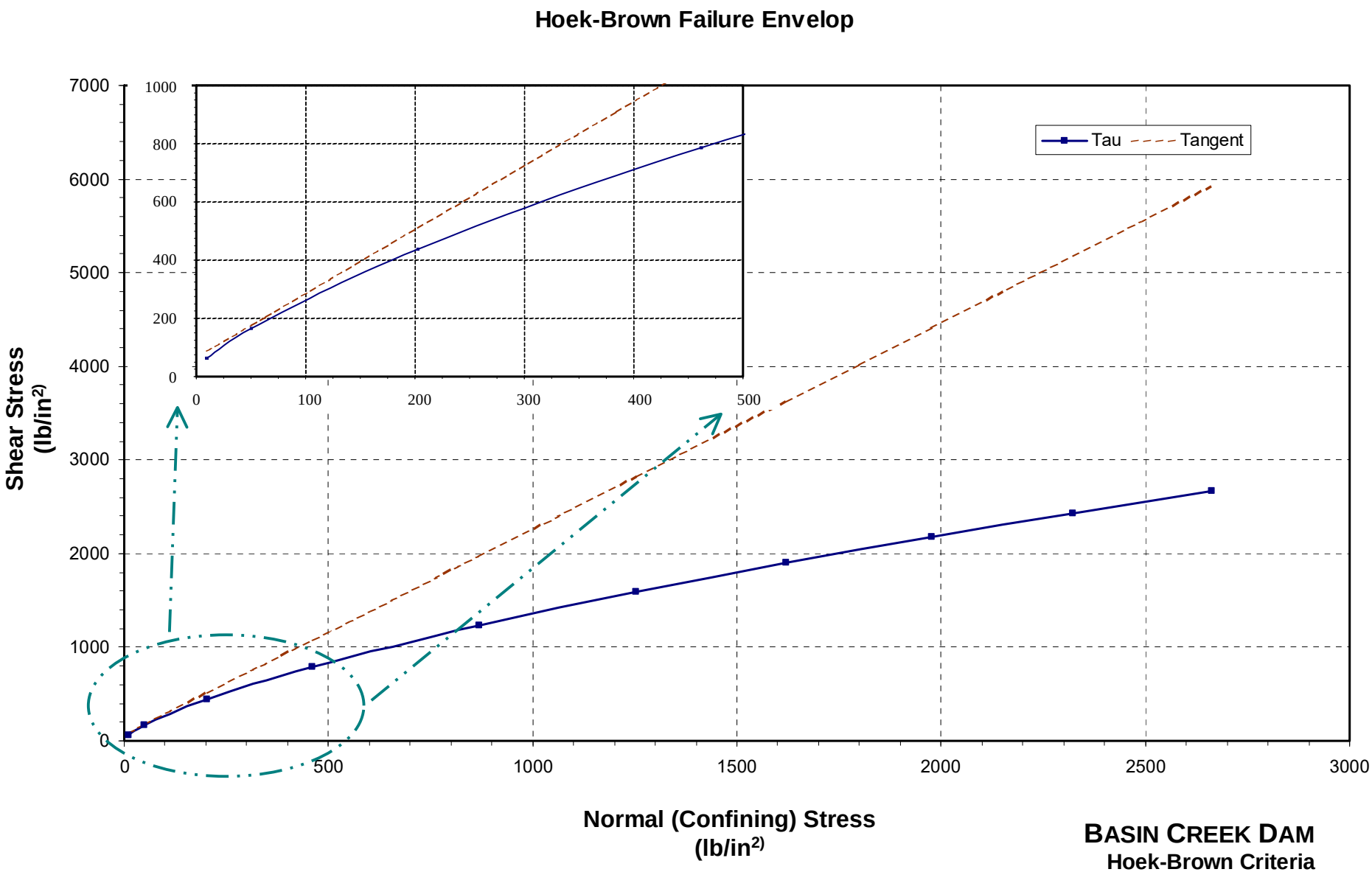
Fresh Face 1



Joint 1

BASIN CREEK DAM
Asperities
Field Measurements

Figure No. 3



BASIN CREEK DAM
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Tangent at Confining Stress
Figure No. 4

BASIN CREEK DAM
Photograph
Upstream Face of Dam

Figure No. 5

APPENDIX O

2005 Basin Creek Dam Hydraulic and Hydrologic Study

BASIN CREEK DAM NO. 1

HYDROLOGIC AND HYDRAULIC STUDY

JUNE 2005

For

Butte-Silver Bow

Butte, MT 59701

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1.0 EXECUTIVE SUMMARY/CONCLUSIONS

This report contains an evaluation of flood hydrology and spillway hydraulics associated with Basin Creek Dam No. 1 (lower dam), as it exists in February 2005. Basin Creek Dam No. 1 is an arch dam located in the Beaverhead – Deer Lodge National Forest, approximately 6 miles south of Butte, Montana, Silver Bow County (BSB). Water from this reservoir currently serves as an unfiltered potable source for BSB, and satisfies approximately 30% of BSB's domestic water supply during the summer months.

Analysis of the existing (2005) condition shows that the existing spillway and overflow can not successfully pass the 50 year frequency of occurrence flood without overtopping the dam, assuming the reservoir is at normal pool elevation (5,872 ft) at the beginning of the flood inflow. Comparison of the spillway and overflow peak discharge before overtopping occurs (approximately 25 cfs) to the two year flood magnitude indicates that the reservoir and spillway may overtop for floods as frequent as the two year occurrence. Even though the spillway capacity is so limited, there are no records of the dam having been overtopped in all its years of operation. BSB actively monitors the reservoir water surface elevation and regulates spillway discharge by removing stop logs as needed.

A failure of Basin Creek Dam No. 1 would flood inhabited structures and overtop numerous paved roads. Based on studies performed by the Montana DNRC (Department of Natural Resources and Conservation), the loss of life due to dam failure is calculated to be 26 people (January 26, 2005 correspondence). Stability analysis of Basin Creek Dam No. 1 results in an inconclusive determination of stability under the probable maximum flood (PMF) loading condition. Please refer to the supplemental report *Basin Creek Dam No. 1, Structural Stability Analysis*, prepared by URS Corporation dated February 2005, and amended June 2005. Additional geotechnical investigations are recommended to refine the variables used in the stability analysis so that compliance with stability criteria can be conclusively determined.

The general storm and local storm PMP (Probable Maximum Precipitation) were analyzed to determine which storm produces the more severe hydraulic loading condition on the dam. The general storm produces a larger peak inflow and, consequently, a larger peak outflow. Additionally, the May 1999 Technical Decisions were used to determine the minimum allowable precipitation from which to develop the reservoir inflow hydrograph to determine compliance

with the current Montana Spillway Standards. The current reservoir/spillway configuration has a risk factor of approximately two, which is significantly less than the 100 threshold that triggers an immediate action recommendation.

A spillway will has been designed with a crest elevation of 5,868.5 ft (approximately one foot lower than the current spillway) and a width of 9.0 ft (approximately one foot wider than the current spillway). An Obermeyer Spillway Gate with a crest elevation of 5,872 ft (normal pool elevation) will be installed at the entrance to the improved spillway. The new spillway and existing overflow will pass approximately 215 cfs, with the gate open, which can accommodate up to the 500 year flood (routed through the reservoir) without the dam crest being overtopped.

The proposed condition will not ensure compliance with the current Montana Spillway Standards, but it will provide improved active spillway management controls. The improved spillway controls will provide an improved level of protection against dam crest overtopping and, hence, reduced risk to the downstream population.

2.0 BACKGROUND

The dam was originally built in 1897 from mortared quartz monzonite blocks to an elevation of 5,860 ft. The outlet works from the reservoir was (and still is today) a series of three 20-inch pit cast, cast iron pipes. The pipes penetrate the dam, elbow upwards, and terminate at three different elevations; a low level outlet to drain the reservoir and two water delivery lines. In 1913, monolithic concrete tiers were added to the downstream slope, and the dam crest was raised to its current elevation of 5,873 ft. When the dam crest was raised, a new spillway was constructed near the left abutment. The spillway crest elevation is approximately 5,869.5 ft, and has a width of approximately eight feet. Between the right abutment and a concrete overflow structure, the dam crest was constructed at elevation 5,872.4 ft for approximately seven feet, which is the controlling elevation for discharge over the dam crest. However, for computational purposes, the lower section of wall has not been included in the computed stage vs. discharge relationship. While there are no records to indicate the parapet wall crest has been overtopped, without a doubt this lower section of the dam crest has overtopped. The downstream face of the dam was covered with soil in the 1930's to reduce the rate of concrete deterioration.

Basin Creek Reservoir is currently owned and operated by BSB, and supplies approximately 30% of BSB's domestic water needs throughout the summer months. There is a filtration waiver for Basin Creek Reservoir water, and the only treatment that the water receives is chlorine disinfection before being sent on to the users for consumption. Basin Creek Reservoir water is the most cost effective water supply available to BSB. Consequently, BSB actively manages the reservoir to store as much water as possible. Stop logs are used to increase the pool elevation above the spillway crest to elevation 5,872 ft, which is approximately one foot below the dam crest elevation of 5,873 ft (top of parapet wall).

HKM Engineering Inc. (HKM) was retained by Butte-Silver Bow (BSB) to evaluate the flood hydrology, spillway hydraulics and hazard classification of Basin Creek Dam No. 1; this report summarizes that evaluation.

- The location of Lower Basin Creek Reservoir and Dam No. 1 is shown in Figure 2-1.
- The drainage basin associated with the dam is shown in Figure 2-2.
- An existing site conditions map of the dam is provided in Appendix A.

Much of the background data collected for this work was obtained from:

- "Moulton Creek Dam No. 1, MT-1467, and Basin Creek Dams No's 1 and 2, MT-374 and MT-868, Butte, Montana," (1979) prepared by the Seattle District of the U.S. Army Corps of Engineers, which used HMR No. 43 and the National Weather Bureau's 1967 memorandum to develop the probable maximum flood estimate;

- Hydrologic Studies Basin Creek Dam No. 1 Butte, Montana, (October 1981) prepared by the Anaconda Company;

- Dam safety inspection report prepared by MSE, Inc.;

- Dam safety inspection report prepared by Pioneer Technical Services, Inc.;

- and drawings and documents provided by BSB.

All documentation used to develop background data is available through the Montana DNRC Dam Safety Program or BSB.

All of the design drawings, hydrologic and hydraulic studies, and dam safety inspection reports available for Basin Creek Dam No. 1 establish the crest elevation of the parapet wall as 5,873 ft, normal pool elevation as 5,872 ft, and other points of vertical interest, i.e. outlet works, based on a datum specified as Mean Sea Level (MSL) in the April 1979 Corps of Engineers Report. As part of this project, HKM carried in survey control with respect to the North American Vertical Datum 1988 (NAVD 88). The National Geodetic Vertical Datum of 1929 (NGVD 29) was established from MSL, and the conversion for NGVD 29 to NAVD 88 in the Butte area is approximately 4.0± ft. However, HKM's survey of Basin Creek Dam No. 1 established the parapet wall and spillway crest elevations approximately 16.06 ft higher than what is reported in all other documentation, which is significantly greater than the anticipated 4.0± ft difference between NAVD 88 and NGVD 29. Consequently, HKM has adjusted all vertical references to be consistent with previously published documents and record drawings. Refer to "Survey Notes for Basin Creek Dam" on Figure 2-3.

The hydrologic study completed by the Corps of Engineers in 1979 and by the Anaconda Copper Company in 1981 both relied on HMR 43 for development of the probable maximum precipitation and the Soil Conservation Service (SCS) unit hydrograph to develop the reservoir inflow hydrograph for the probable maximum flood. However, the current standard of analysis requires the use of HMR 57 west of the Continental Divide to determine the probable maximum precipitation, and a variety of more recent publications for development of the rainfall hyetograph and reservoir inflow hydrograph. Use of the current hydrological analysis tools and unit hydrograph development procedures leads to significantly reduced (as much as 75% reduced) predicted peak runoff rates from what were historically predicted during the late 1970's and early 1980's.

3.0 FLOOD-FREQUENCY

3.1 METHODOLOGY

Basin Creek Dam No. 1 is located in the Deer Lodge National Forest approximately 6 miles south of Butte, MT. The reservoir normal pool elevation is approximately 5872 ft (spillway crest elevation = 5872.36 ft), has a tributary area of 12.0 mi^2, and a basin average annual precipitation of approximately 20.9 inches (Appendix B1-2). There is a diversion pipeline that conveys a maximum of approximately 5 cfs from the Fish Creek drainage (Butte Water System Master Plan, March 1988) on the east side of the Continental Divide over the divide into the Basin Creek drainage. The diversion inflow into the Basin Creek drainage was considered a component of base flow during the development of the flood hydrology.

Based on Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998 Report Plate 1 (Appendix B1-84) the Lower Basin Creek Reservoir is located in the West Region. Flood magnitude at the dam was determined for several frequencies of occurrence using the USGS Regional Flood Frequency Regression Equations, the Local Regression Equations (derived from eight gaging stations within the West Region), and the USGS Method for Ungaged Sites on Gaged Streams (using the coefficient for the West Region).

Basin characteristics used for the regression equations (i.e. tributary area, average annual precipitation, and mean basin elevation) were determined using the appropriate USGS 7.5' Quadrangle Maps and Sheet 7 of the State of Montana Average Annual Precipitation 1941-1970 Base report. The Local Regression Equations developed for the reservoir are based on current Montana Department of Transportation (MDT) methods, and were created from spreadsheet templates developed by the Hydraulics Section of MDT (Appendix B1-3). Table 3.1-1 presents the results of the flood magnitude methods used.

Table 3.1 - 1 Flood Magnitude Results - Lower Dam

Flood Frequency	USGS Regional Flood Frequency Regression (cfs)	Local Regression (cfs)	USGS Ungaged Sites on Gaged Streams	
			Gaged = Silver Bow Creek (cfs)	Gaged = Blacktail Creek (cfs)
2	35.0	40.9	23.8	37.8
5	63.0	71.9	41.1	52.8
10	87.0	96.7	54.2	63.4
25	118.0	132.1	72.3	77.7
50	143.0	161.7	86.6	87.7
100	171.0	194.2	101.7	98.4
200	199.0	229.6	117.6	109.7
500	242.0	281.0	139.9	125.1

The value of the 100 year flood magnitude for each calculation method in the above table were compared in order to determine which method is most appropriate for Basin Creek Dam No. 1. The USGS Method for Ungaged Sites on Gaged Streams provides an estimate lower than both regression methods, and was dismissed from further consideration. The Local Regression Method was evaluated for up to three variables; area, precipitation, and mean basin elevation. Calculations with two and three variables appear to overestimate the flood magnitude; Table 3.1-1 shows only the single variable (area) calculation.

The USGS Regional Flood Frequency Regression Equations provide a lower standard error (23.8%) than the Local Regression Method (37.85%) for the 100 year flood magnitude; however the Local Regression Method was chosen as the design method for Basin Creek Dam No. 1 because it is more conservative (predicts a higher peak). A graphical comparison of each method is presented in Appendix B1-1.

4.0 RAINFALL-RUNOFF MODEL

4.1 STATEMENT OF PURPOSE

The purpose of this analysis is to determine the Probable Maximum Precipitation (PMP) and corresponding Probable Maximum Flood (PMF) for the drainage basin tributary to Basin Creek Dam No. 1. Additional rainfall runoff analysis includes application of the May 1999 Technical Decisions and Spillway Standards to determine the risk based design precipitation and runoff/inflow hydrograph.

4.2 STATEMENT OF SCOPE

Tasks are as follows:

- Estimate Unit Hydrograph (UHG) parameters
- Estimate infiltration parameters
- Determine PMP for General Storm (72-hour)
- Determine PMP for Local Storm (6-hour)
- Develop depth-duration curve for each storm
- Develop PMP hyetograph for each storm
- Develop PMF
- Determine baseflow for selected storm
- Determine the risk based design precipitation (P_s)
- Determine the P_s hyetograph
- Develop the runoff/inflow hydrograph resulting from P_s

4.3 ANALYSIS

A rainfall-runoff response model describing the PMP runoff inflow to Lower Basin Creek Reservoir was developed using the USGS hydrograph methodology and the Corps of Engineers HEC-HMS program. Peak hydrologic loading rates on Basin Creek Dam No. 1 were determined for both the General and Local PMP Storm Events, as they apply to unit hydrographs created using the USGS methodology. In addition, the peak runoff rate for a range of precipitation

frequencies was plotted on a log-probability scale against computed flood magnitudes for the same frequencies of occurrence (Appendix B1-1).

4.3.1 PMP – Probable Maximum Precipitation

4.3.1.1 General Storm (72-hour) PMP and Depth-Duration Curve

The General Storm PMP is a regional storm with a duration of 72 hours, and is developed using the procedures as described in Hydrometeorological Report No. 57 (HMR57). PROBABLE MAXIMUM PRECIPITATION – PACIFIC NORTHWEST STATES Columbia River and Pacific Coastal Drainages (U.S. Dept. of Commerce, et al., 1994). From Map 2 of HMR-57 and the grid method (Appendix C1-1 and C1-12), the all-season 10-mi^2, 24-hour index PMP depth is determined to be 20.6 inches. Per Figures 15.9 (Appendix C1-13) and 3.2 (Appendix C1-14) of HMR-57, Basin Creek Dam No. 1 falls in regional subdivision 6 and sub-region "Orographic." Table 15.1 of HMR-57 (Appendix C1-15) is then used to create the depth-duration curve values to be used for this site. Because the tributary area to Basin Creek Dam No. 1 is relatively close to 10-mi^2, tributary area = 12.0 mi^2, area reduction factors have not been applied to the index precipitation, HMR-57 Figure 15.10 (Appendix C1-16). The total PMP depth at the end of the 72 hour General Storm is 28.22 inches.

4.3.1.2 Local Storm (6-hour) PMP and Depth-Duration Curve

The 1-hour, 1-mi^2 index PMP estimate for elevations = 6,000 ft is approximately 7.88 inches, Plate VIa in HMR-57 (Appendix C1-17). The mean drainage basin elevation of Basin Creek Dam No. 1 is 6,659 ft (Appendix B1-5). A nine percent reduction for each 1,000 ft above 6,000 ft is then applied; the result is a mean drainage elevation adjustment factor of 0.94. Because the tributary area to Basin Creek Dam No. 1 is greater than 1-mi^2, tributary area = 12.0 mi^2, an area reduction factor of 0.84 was applied to the index precipitation, HMR-57 Figure 15.39 (Appendix C1-18). The resulting adjusted 1-hour PMP estimate is 6.23 inches. Application of the temporal factors from HMR-57, Figure 15.38, (Appendix C1-19) to the adjusted depth yields the depth duration curve ordinates presented below in Table 4.3-1.

Table 4.3 - 1 Local PMP Depth-Duration Table

Duration (hrs)	0.25	0.5	0.75	1	2	3	4	5	6
% PMP Depth	50%	74%	90%	100%	110%	112%	114%	115%	115%
Total Depth (in)	3.1	4.6	5.6	6.2	6.8	7.0	7.1	7.1	7.2

4.3.1.3 Develop PMP Hyetographs

Rainfall hyetographs for both the local and general storms are generated from the depth-duration curves. The total rainfall depths are read from the curves for every 15-minute interval and the previous total rainfall depth is subtracted to obtain the incremental rainfall depth. For the general storm hyetograph, the incremental precipitation values are read from the depth-duration curve and arranged with the largest increment beginning at hour 36, and then alternating the remaining incremental values in descending order to the front and back of this value, as discussed in USGS WRIR 98-4100. The resulting general storm PMP hyetograph is presented as Appendix C1-2. Conversely, the local storm hyetograph is developed by assuming the storm is "front" loaded, with the largest incremental precipitation occurring during the first 15 minutes of the storm and the subsequent 15-minute increments stepping down in precipitation throughout the six hour storm event. The local storm hyetograph is presented in Appendix C1-2.

4.3.2 Extreme Storm Precipitation

The USGS completed a study in 1997 entitled, "Regional Analysis of Annual Precipitation Maxima in Montana." This study provides a means for constructing a site-specific synthetic storm within the state, given the mean annual precipitation for the site. Lower Basin Creek Reservoir is located in Region 1 (Appendix C2-17), and the maximum precipitation depth for a 6-hour storm (0.74 inches) can be determined through the following equation (Appendix C2-19):

$$P_{max6} = 0.60 + (0.0067)(MAP)$$

Where: P_{max6} = 6-hour duration storm depth (in)

MAP = mean annual precipitation (in)

The mean annual precipitation (20.9 inches) is estimated from Plate 2 in WRIR 97-4004 and the grid method (Appendix B1-2).

For each flood frequency (50, 100, 200, 500, 1,000, 2,000 and 5,000 year), the dimensionless storm depth was determined from Figure 12 in WRIR 97-4004 (Appendix C2-18). When these values are multiplied by the P_{max6} value, as directed in WRIR 97-4004, the total precipitation depth for each event is found. Because the drainage basin is 12.0 mi^2, depth-area adjustments are necessary, refer to Figure 17 in "Characteristics of Extreme Storms in Montana and Methods for Constructing Synthetic Storm Hyetographs," USGS, WRIR 98-4100, 1998 (Appendix C2-24).

The dependent durations (in hours) for the 6-hour independent duration (storm length of interest) and 2-hour kernel duration storm are obtained from Table 13 in WRIR 98-4100 (Appendix C2-22) The dependent durations describe incremental storm durations within the total storm duration, which is three times the independent storm duration (6 x 3 = 18 hours). The kernel duration is defined as "[a]n incremental durations that is used as a basis for calculating dimensionless precipitation depths for other incremental duration in the construction of probabilistic depth-duration curves" (USGS, 1998, p. vi). Using these dimensionless depth values for a storm with an exceedance probability of 0.2, a new table is developed to determine the order in which the depth values for different dependent durations fall, from largest to smallest (Appendix C2).

While a given recurrence interval precipitation event does not necessarily generate the same recurrence interval flood event (i.e. 100 year precipitation causes the 100 year flood), it is interesting to compare the calculated precipitation and flood magnitude for a given recurrence interval. Appendix B1-6 presents the flood frequency and the computed peak runoff rate for a given frequency of occurrence.

4.3.3 Unit Hydrographs

4.3.3.1 USGS Montana Unit Hydrograph

The USGS completed a study in 1993 entitled, "Estimation of Unit Hydrographs for Large Floods at Ungaged Sites in Montana." This study provides a means for creating a site specific unit hydrograph, based on the Clark method, within the state. A regression analysis of related basin characteristics for 26 locations with stream-gage data within the state was performed. Equations were determined from this analysis to create a unit hydrograph using either the Clark method or the dimensionless unit hydrograph method.

The appropriate equation for the study site is selected by locating the site in either a "plains" or "mountains" region. Basin Creek Dam No. 1 is located in the "mountains" region.

4.3.3.2 Clark Unit Hydrograph Parameters

To apply the equations to determine the Clark unit hydrograph parameters required to create the unit hydrograph for Basin Creek Dam No. 1, the extents of the drainage basin are first determined using USGS topographic maps, specifically, the Mount Humbug, MT and Pipestone Pass, MT, Quadrangles, 7.5 minute maps Figure 2-2. The parameters that are calculated include the R-coefficient and the time of concentration (T_c). The state/site specific equation used for the Clark unit hydrograph R-coefficient is (Appendix C3-3):

$$R = 2.90A^{0.31}$$

Where: R = basin-storage coefficient for Montana "mountains" site in hours

A = drainage area in sq. miles = 12.0

The state/site specific equation used for the Clark unit hydrograph time of concentration is (Appendix C3-3):

$$T_c = 0.298A^{0.65}$$

Where: T_c = time of concentration in hours

A = drainage area in sq. miles

The results of the basin characteristic calculations above are presented in Appendix C3-1.

4.3.4 Probable Maximum Flood

The computed PMP for both the local and general storms was applied to the USGS unit hydrograph parameters to determine the local and general storm PMP inflow hydrographs. Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), (version 2.2.2) along with the PMP hyetographs were used in order to determine the PMF inflow hydrograph to the reservoir. The parameters used in the modeling were:

- the Clark Unit Hydrograph parameters (R-coefficient and T_c), determined using the methods presented in OFR 93-168;
- and the characteristic basin parameters (initial loss, infiltration, and impervious cover).

The initial loss, infiltration, and impervious cover used in the HEC-HMS model of Lower Basin Creek Reservoir were determined using a process of trial and error. A first guess for each parameter was entered into the model, and the resulting flood magnitudes were compared to our computed values for the 50, 100, 200, and 500-year flood flows. The basin parameters were then changed until the modeled flows closely match the computed flows. The final, or "calibrated", values used for initial loss, infiltration, and impervious cover are 0.12 in, 0.9 in/hr, and 6%, respectively, and appear reasonable. Base inflow used in the final model is 7.52 cfs, and was calculated by combining the Basin Creek base flow with water diverted from Fish Creek into Lower Basin Creek Reservoir (5 cfs). Basin Creek base flow (2.52 cfs) was determined by taking the highest average monthly flow (June) for Blacktail Creek (USGS gage #12323240) and applying an area adjustment factor (Appendix C4-1).

A summary of the results of the HEC-HMS PMF computations are provided below in Table 4.3-2, and the summary output files are included (Appendix C4-3 and C4-4).

Table 4.3 - 2 PMF Computation Summary

Precipitation	Unit Hydrograph	Peak Inflow (cfs)	Peak* Outflow (cfs)	Peak Stage (ft)
Local Storm	USGS	5,583	5,315	5,876.7
General Storm		5,605	5,538	5,876.8

*Peak outflow based on the existing reservoir capacity and spillway configuration. Refer to Section 5.1 of this report.

4.4 Risk Based Design Precipitation

Per the May 1999 Technical Decisions and Montana Spillway Standards, Montana is implementing a risk based hydrologic standard for spillway design criteria. Consequently, for dams with an estimated loss of life less than 1,000, such as Basin Creek Dam No. 1 (estimated loss of life (LOL) is 26, per January 26, 2005 correspondence from the DNRC), the spillway design precipitation is less than the PMP, as defined by the following equations:

$$P_s = P_{5,000}(10^{rd})$$

$$r = -0.304 + 0.435 \text{ Log}(LOL)$$

$$d = \text{Log}(PMP) - \text{Log}(P_{5,000})$$

Where; P_s = Design precipitation to meet spillway standard

$P_{5,000}$ = 5,000 year recurrence interval precipitation

PMP = Probable maximum precipitation

Using the methods discussed in Regional Analysis of Annual Precipitation Maxima in Montana, WRIR 97-4004, the 5,000 year recurrence interval precipitation has been computed for the two, six, and 24 hour storm durations (Appendix C5). Because the 24 hour PMP storm depth (general storm) results in a more severe hydrologic loading than the six hour PMP storm depth (local storm), it has been assumed that the two hour storm duration is not the controlling storm and it has not been considered further. The following table presents the six hour and 24 hour $P_{5,000}$ and the corresponding P_s.

Table 4.4 - 1 Risk Based Design Precipitation

	6 Hour Storm Duration	24 Hour Storm Duration
$P_{5,000}$	3.60 in	4.80 in
P_s	4.27 in	7.53 in

Hyetographs for the six hour and 24 hour design precipitation depths were developed using the procedures as previously described in Section 4.3.2 of this report, and are presented in Appendix C5.

5.0 SPILLWAY HYDRAULICS

5.1 EXISTING SPILLWAY

Overflow discharge from Lower Basin Creek Reservoir is primarily through a spillway located near the left (west) abutment of the dam (Figure 2-3). The spillway flows from south to north and is approximately 100-ft long by approximately 8.0 ft wide. The spillway entrance is approximately 8.5-ft wide by 0.5-ft high with a crest elevation of approximately 5,872.36 ft with stop logs in place, and 5,869.27 ft (sill elevation) without stop logs. There is a 10-ft stepped drop from the spill entrance to the spillway channel, which is severely weathered and deteriorated. The existing spillway channel has a supercritical slope (s = 0.02 ft/ft), and is littered with debris and slough from the adjacent hillside. The obstructions in the spillway channel are an impediment to efficient conveyance. Water exits the spillway onto a steep riprap lined slope.

Existing spillway capacity is limited by the opening between the top of the stop logs and the concrete walkway over the spillway entrance; this entrance was modeled using the sharp crested (stop logs) weir equation for water surface elevations up to submergence by the walkway (approximately 0.5 ft) and the orifice equation for water surface elevations above the walkway elevation. The spillway rating curve is included as Appendix D1-1 and the stage-discharge calculations (assuming the stop logs are in place) are included as Appendix D1-2. The capacity of the existing spillway is approximately 12 cfs before the dam is overtopped (25 cfs total discharge includes the overflow structure near the right abutment, but excludes the lower section of parapet wall). The 50, 100, 200, and 500-year floods (six hour independent duration, 18 hour dependent duration) and the six hour and 24 hour (independent durations) design storms (P_{s6hr} and P_{s24hr}) were routed through the reservoir and spillway using the HEC-HMS model with a stage/storage/discharge relationship reflective of the normal operating condition (stop logs in place). The routed flows are shown in Appendix D1, D1-3 – D1-6.

Comparison of the peak inflow rates for the two design storm precipitations (P_{s6hr} vs Ps_{24hr}) shows that the six hour independent storm duration is the controlling precipitation; hence, the dam and spillway should be considered stable for inflow hydrographs resulting from storms up to the P_{s6hr} magnitude (4.27 in). However, the hydrologic and hydraulic modeling indicates that the existing spillway capacity is significantly inadequate, and can not successfully pass even the reasonably more frequent inflow flood hydrographs, i.e. < 50 year, before the dam crest is

overtopped (parapet wall crest elevation = 5,873.0 ft). The results of the inflow hydrograph reservoir routing computations (HEC-HMS) are presented in the table below.

Table 5.1 - 1 Inflow Hydrograph Reservoir Routing Summary

Precipitation	Unit Hydrograph	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Stage (ft)
50 Year	USGS	142	84	5,873.1
100 Year		189	125	5,873.1
200 Year		244	170	5,873.2
500 Year		318	231	5,873.3
P_{s6hr}		1,358	1,195	5,874.4
P_{s24hr}		546	454	5,873.6

5.1.1 Estimated Risk & Spillway Compliance

Basin Creek Dam No. 1 has been in service in its current configuration since the 1930's (including the earth embankment), and there has been no record of overtopping. However, it has only been in the last few decades that the facility has been operated with a normal pool elevation of 5,872 ft, which may explain why there is not a history of overtopping. Additionally, because this facility is such an important component of the BSB water supply system, the reservoir is closely monitored and the stop logs are actively managed to retain as much water as possible. When the reservoir stage increases too rapidly, BSB personnel remove stop logs to allow greater discharges through the spillway than what have been used for the current hydraulic analysis. The discussion of risk assessment and determination of compliance with Montana Spillway Standards assumes passive spillway management with a crest elevation equal to the normal pool elevation of 5,872 ft.

The risk factor is defined as the ratio of the flood recurrence interval that the spillway can currently pass to the estimated loss of life associated with the spillway failure. Assuming the 50 year inflow hydrograph is the most frequent flood that results in overtopping of the parapet wall, the risk factor (RF) of the existing spillway is approximately two (50 ÷26 LOL ˜ 2). The May 1999 Technical Decisions recommend immediate action for facilities with a risk factor less than 100.

It may be argued that "failure" is that condition that results in a loss of life, and that it is not likely that there will be a loss of life downstream of Basin Creek Dam No. 1 due to overtopping as a result of the 50 year flood; if so, the risk factor for Basin Creek Dam No. 1 may be considered to be higher (less risk) than two. However, to achieve the minimum risk factor for which immediate action would not be recommended, the dam should be stable while passing the 2,626 year flood recurrence interval (2,626 RI = RF 101 * 26 LOL) inflow hydrograph.

To satisfy the requirements of the May 1999 Technical Decisions, the reservoir and spillway must safely store and pass the runoff resulting from the P_{s6hr} precipitation inflow hydrograph. A plot of Reservoir Stage and Discharge vs. Time (Appendix D1-7) shows that there will be significant discharge over the parapet wall (Q > 200 cfs) for approximately 15 hours as a result the P_{s6hr} precipitation. It is difficult to accurately predict the erosive effect of discharge over the parapet wall, but it is reasonable to assume that such significant uncontrolled discharge over a 15 hour period will mobilize a significant portion of the downstream embankment material. While the arch shape of the dam provides greater stability for the structure, the geometry is such that overtopping flows will tend to be "funneled" towards the center of the arch, focusing the erosive forces and maximizing erosion potential. The length and steepness of the downstream earth embankment (approximately 100 ft horizontal distance at a slope of 2H:1V) is such that flow velocities will significantly exceed the maximum permissible velocity (typically 4 to 8 ft/sec, Chow, 1959) to resist erosion on a vegetated slope.

When the hydrologic and hydraulic analyses are combined with the stability analysis conducted by URS Corporation (Basin Creek Dam No.1, Structural Stability Analysis, February 2005, and amended June 2005), it is unclear if Basin Creek Dam No. 1 satisfies stability criteria under the minimum design flood loading condition. Per the stability analysis, under normal pool loading, without the downstream embankment the average factors of safety against sliding are 1.2 to 1.6 (using a minimum effective angle of friction = 49°), which marginally satisfy Federal Energy Regulatory Commission (FERC) stability criteria. Furthermore, per URS amendment (June 2005), under the PMF hydraulic loading (WSEL = 5,876.8 ft), the average factors of safety against sliding range from 1.0 to 1.1 (effective friction angle = 49°), and do not satisfy FERC stability criteria ($FS_{min} \geq 1.5$). However, if the effective angle of friction is 61°, then average factors of safety against sliding under the PMF loading range from 1.6 to 1.7, which does satisfy

FERC stability criteria. Consequently, at this time, due to the uncertainty of the effective angle of friction, it is inconclusive as to whether or not Basin Creek Dam No. 1 is in compliance with the current Montana Spillway Standards.

5.2 SPILLWAY ALTERNATES

Because Basin Creek Reservoir is an important domestic water supply, BSB operates the reservoir to maximize storage, and a passive spillway with a sill crest elevation below elevation 5,872 ft is not acceptable to BSB. Furthermore, with only one foot of freeboard between normal pool and the dam crest elevation, it is physically not possible, without increasing the dam crest elevation, to construct a spillway that will successfully pass the design flood (Q=1,358 cfs). Consequently, a spillway configuration that will pass the minimum acceptable spillway design flood allowed by the May 1999 Technical Decisions (500 year) and continuation of the active spillway control/management operation plan are proposed.

Several alternate spillway crest configurations were evaluated by developing stage-discharge relationships (Appendix E1-1 through E1-6), and routing flood flows through the improved spillway configurations using HEC-HMS (Appendix E1-7 through E1-18). Designs with gate open crest elevations of 5,868.5 ft and 5,866.0 ft and spillway entrance widths of 8.0 ft, 9.0 ft, and 10 ft were considered. The existing spillway entrance is 8.5 ft wide, and a narrower entrance is not recommended; hence, the 8.0 ft spillway entrance configuration was dismissed from further consideration.

The routed peak stage for each alternative is equal to or less than the dam crest elevation (5,873 ft) for the 500 year flood. A 9.0 ft wide spillway entrance with a sill crest/open gate elevation of 5,868.5 ft was selected as the preferred alternative. The 9.0 ft wide opening with a sill elevation approximately one foot below that of the existing sill elevation is the configuration with the least impact to the existing dam structure that will pass the 500 year flood without overtopping the dam crest. The improved opening design consists of an Obermeyer Spillway Crest Gate, with a gate closed crest elevation of 5,872 ft (normal pool). During significant floods, the gate can be opened to pass up to approximately 215 cfs with 4.5 ft of head (broad crested weir coefficient of 2.63). The table below presents a comparison of the various gate configuration alternatives evaluated.

Table 5.2 - 1 Spillway Crest Gate Alternatives

Gate Configuration			Routed 500 Year Flood Performance	
Length	**Height**	**Sill Elevation**	**Peak Stage**	**Peak Discharge**
9 ft	5 ft	5,867.0 ft	5,872.6 ft	278.4 cfs
10 ft			5,872.6 ft	300.8 cfs
9 ft	3.5 ft	5,868.5 ft	5,873.0 ft	212.9 cfs
10 ft			5,872.9 ft	229.4 cfs

Improvements will also be made to the spillway channel beyond the crest gate. At the head of the spillway, a new drop chute and splash walls will be constructed to contain the surface nappe of the peak spillway discharge. A new 6.5 feet wide spillway channel will be constructed within the existing 8.0± ft spillway channel. The west wall of the new spillway channel will be constructed adjacent to the existing west wall, and will be 7.0 feet high to prevent material that sloughs from the steep west side slope from entering the channel. The existing east wall of the spillway channel will be demolished, and a new five foot wall constructed in its place. The floor of the new spillway channel will be poured over the existing floor to a finished grade slope of 2.62% (super critical slope). Normal depth of the new channel will be approximately 1.58 ft (Froude Number = 2.93), for a spillway discharge of 215 cfs, leaving almost 3.5 ft of freeboard down the channel to allow the water to reach normal depth and contain wave splash.

It can not be stated that the recommended spillway configuration will ensure that Basin Creek Dam No. 1 is in compliance with the current Montana Spillway Standards; however, with active spillway management in conjunction with other proposed improvements, such as real time lake level monitoring capabilities, the recommended configuration will provide a 500 year level of protection against dam crest overtopping and is a significant improvement over the existing condition.

6.0 REFERENCES

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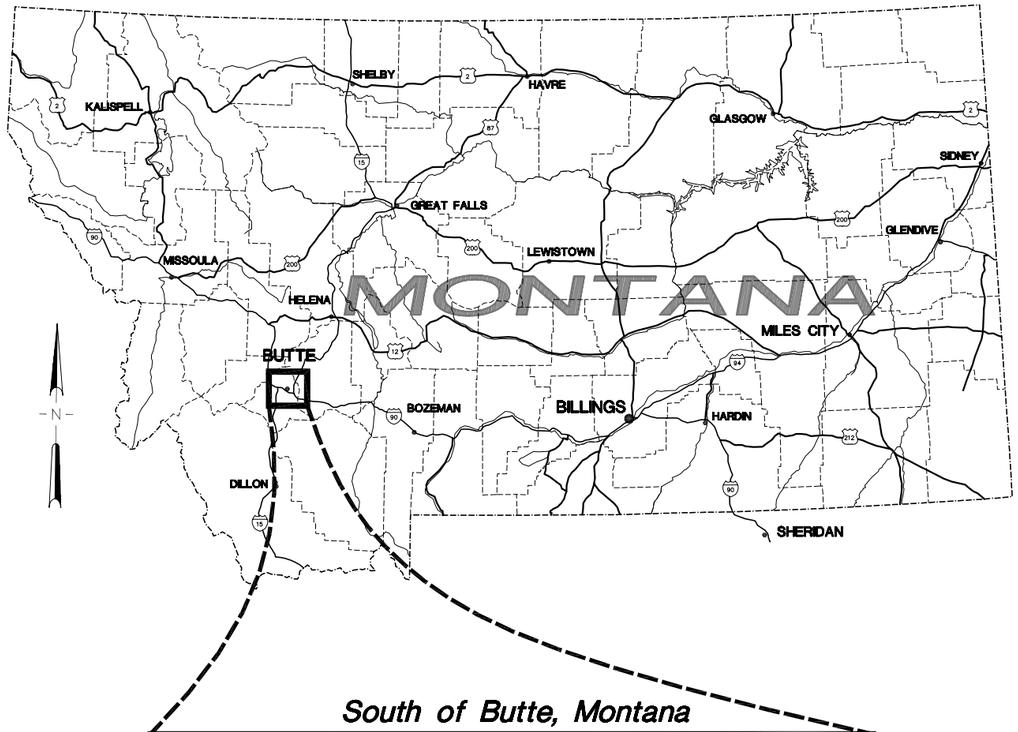
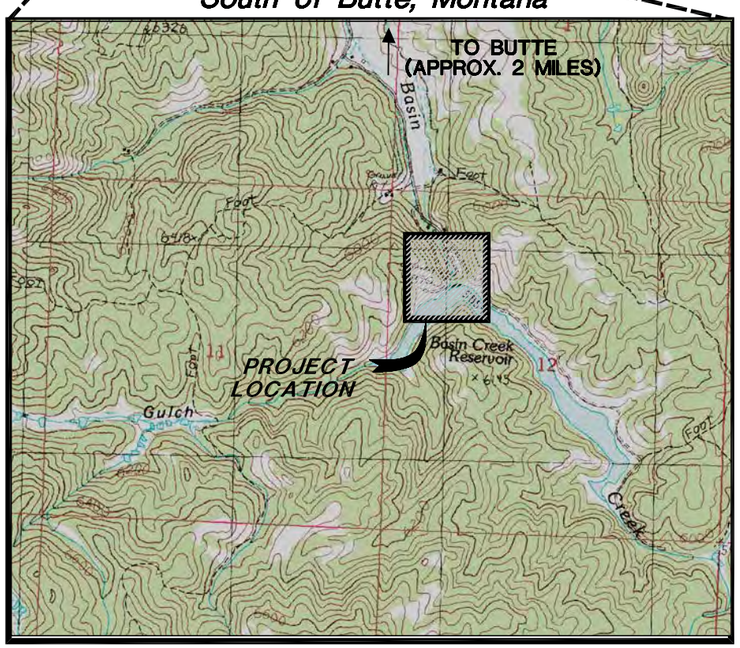
APPENDIX A1

CONSTRUCTION DRAWINGS



South of Butte, Montana



LOCATION MAP

NOT TO SCALE

Construction Drawings
for
BASIN CREEK
RESERVOIR IMPROVEMENTS

BUTTE - SILVER BOW (BSB), MONTANA

PREPARED FOR:
BUTTE - SILVER BOW PUBLIC WORKS DEPARTMENT

FUNDED BY:
NATURAL RESOURCE DAMAGE PROGRAM

PREPARED BY:

HKM Engineering Inc.
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PROJECT NO. 15M424.117

JUNE 2005

MONTANA RUSSELL CHRISTIAN REED 15740PE LICENSED PROFESSIONAL ENGINEER

RUSSELL C. REED 15740 P.E.
Project Manager
HKM ENGINEERING Inc.

JUNE 2005

FOR DNRC REVIEW ONLY
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Sheet No.
G-1

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LEGEND

5870	= EXISTING GROUND CONTOURS
	= EXISTING CONCRETE
OHP	= EXISTING OVERHEAD POWER
PWR	= EXISTING UNDERGROUND POWER
X	= EXISTING FENCE
CP-16	= SURVEY CONTROL POINT

PIPING LEGEND

- LARGER PIPING (4" AND OVER)
- FLANGED CONNECTION
- BUTTERFLY VALVE
- GATE VALVE

SHEET INDEX

SHT. NO.	TITLE
G-1	COVER SHEET
G-2	SHEET INDEX, LEGEND, & ABBREVIATIONS
G-3	PROJECT OVERVIEW
G-4	EXISTING SITE CONDITIONS
G-5	SITE PLAN AND SHEET REFERENCES
S-1	GENERAL STRUCTURAL NOTES AND STANDARD DETAILS
S-2	SPILLWAY PLAN VIEW DEMOLITION DETAILS
S-3	SPILLWAY STRUCTURE PLAN AND PROFILE
S-4	SPILLWAY STRUCTURE PLAN
S-5	SPILLWAY STRUCTURE SECTIONS
S-6	SPILLWAY STRUCTURE DEMOLITION AND SECTIONS
S-7	STAIRCASE PLAN, PROFILE AND DETAILS
S-8	STAIRCASE SECTIONS AND DETAILS
XS-1	SPILLWAY CROSS SECTIONS STATIONS 1+20 TO 1+60
XS-2	SPILLWAY CROSS SECTIONS STATIONS 1+65 TO 2+00
M-1	MECHANICAL BUILDING PLAN, ELEVATIONS AND DETAILS
M-2	MECHANICAL BUILDING LAYOUT
M-3	MECHANICAL BUILDING SECTIONS AND MANIFOLD SCHEDULE
M-4	AIR LINE DETAILS DAM PENETRATION
M-5	FACE OF DAM CONDUIT LAYOUT AND DETAILS
M-6	EXISTING DAM SECTION AND DEMOLITION
M-7	INTAKE SECTIONS AND DETAILS
M-8	OUTLET WORKS DEMOLITION DETAILS AND LIMITS
M-9	NEW PIPING PLAN
M-10	MISCELLANEOUS DETAILS

ABBREVIATIONS

ASS'Y	ASSEMBLY	N.T.S.	NOT TO SCALE
AVV	AIR/VACUUM VALVE	O.C.	ON CENTER
BM	BENCH MARK	PCP	PLANT CONTROL PANEL
BTM	BOTTOM	PE	PLAIN END
BFV	BUTTERFLY VALVE	PSI	POUNDS PER SQUARE INCH
CONC.	CONCRETE	PVC	POLYVINYL CHLORIDE PIPE
D.I.P.	DUCTILE IRON PIPE	PWR	UNDER GROUND POWER
DIA.	DIAMETER	RED'R	REDUCER
E	EASTING	R/W	RIGHT OF WAY
ELEV.	ELEVATION	REST.	RESTORATION
EXIST.	EXISTING	RT	RIGHT
FLG.	FLANGE	SCH	SCHEDULE
FT	FEET	SP	SLUDGE PUMP
GAL	GALLON	SR	SHORT RADIUS
GPD	GALLONS PER DAY	SURF.	SURFACE
GPH	GALLONS PER HOUR	TEL	UNDER GROUND TELEPHONE
GPM	GALLONS PER MINUTE	TYP.	TYPICAL
G.S.P.	GALVENIZED STEEL PIPE	V	VOLT
HP	HORSEPOWER	W	WATER
LF	LINEAL FEET	W/	WITH
LR	LONG RADIUS	W.S.	WELDED STEEL
MCC	MOTOR CONTROL CENTER	WTP	WATER TREATMENT PLANT
N	NORTHING	X-ING	CROSSING
NPT	NATIONAL PIPE THREAD		

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SHEET INDEX, LEGEND, AND ABBREVIATIONS

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EXISTING CHLORINE FACILITY WILL BE IN OPERATION DURING SPILLWAY CONSTRUCTION. CONTRACTOR TO COORDINATE SAFETY BARRIERS AND SAFETY PLANS WITH BUTTE-SILVER BOW PERSONNEL

NOTE:
DEMOLITION DEBRIS STORAGE AREA TO BE COORDINATED WITH BUTTE-SILVER BOW PERSONNEL DEMOLITION DEBRIS TO BE STOCKPILED ON SITE AND REMOVED BY BSB FORCES.

CONTRACTOR TO IMPLEMENT BMP'S AS NECESSARY TO PROTECT BASIN CREEK FROM SEDIMENT.

DAM OPERATIONS ENCLOSURE

PARKING LOT AVAILABLE TO CONTRACTOR FOR ADDITIONAL STAGING AREA AFTER LABOR DAY

ACCESS LIMITS

MUD AND SILT FROM LAKE BOTTOM CAN BE DISPOSED IN EXISTING BORROW AREA COORDINATE WITH BSB

ACCESS TO WEST GATE IS THROUGH THE PARK. CONTRACTOR TO RECLAIM ALL DISTURBANCES IN THE PARK TO PRE-DISTURBED CONDITION OR BETTER.

ACCESS LIMITS

STAGING AREA

STAGING AREA

ACCESS ROAD

ACCESS ROAD

ACCESS ROAD

BASIN CREEK

BASIN CREEK

PARK AREA

PARK AREA

GATE

GATE

GATE

GATE

MAIN ACCESS GATE

CHLORINE BUILDING

CP-14

CP-9

CP-16

CP-10

CP-11

SPILLWAY

FISH CREEK DIVERSION

BASIN CREEK DAM

BASIN CREEK RESERVOIR

BENCH MARK
NUT MARKED "BM"
ELEV=5872.90

6080
6040
6000
5960
5920
5880
5840
5800

N

60 0 60 120
scale feet

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

PROJECT OVERVIEW

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HKM SURVEY CONTROL POINTS

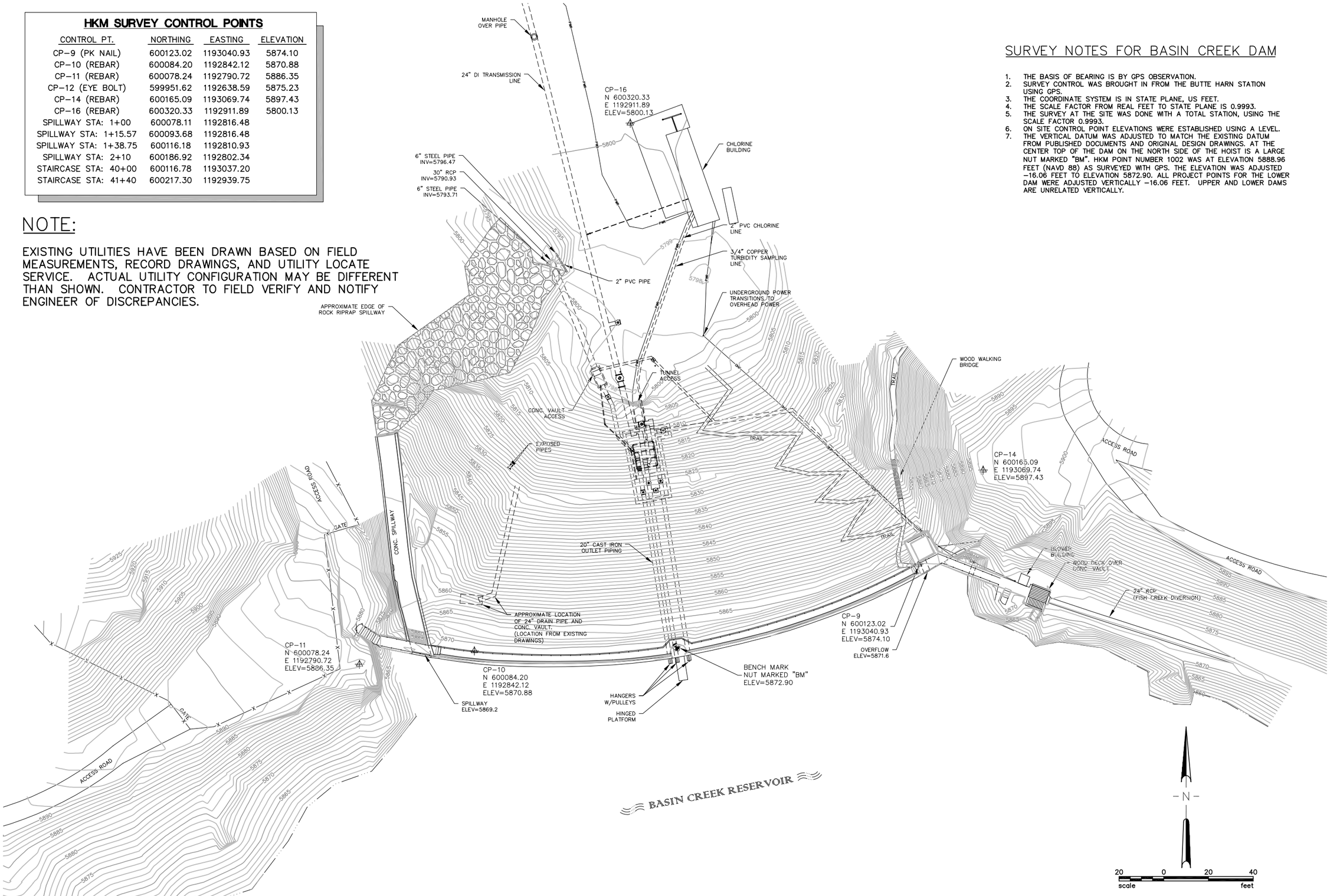
CONTROL PT.	NORTHING	EASTING	ELEVATION
CP–9 (PK NAIL)	600123.02	1193040.93	5874.10
CP–10 (REBAR)	600084.20	1192842.12	5870.88
CP–11 (REBAR)	600078.24	1192790.72	5886.35
CP–12 (EYE BOLT)	599951.62	1192638.59	5875.23
CP–14 (REBAR)	600165.09	1193069.74	5897.43
CP–16 (REBAR)	600320.33	1192911.89	5800.13
SPILLWAY STA: 1+00	600078.11	1192816.48	
SPILLWAY STA: 1+15.57	600093.68	1192816.48	
SPILLWAY STA: 1+38.75	600116.18	1192810.93	
SPILLWAY STA: 2+10	600186.92	1192802.34	
STAIRCASE STA: 40+00	600116.78	1193037.20	
STAIRCASE STA: 41+40	600217.30	1192939.75	

NOTE:

EXISTING UTILITIES HAVE BEEN DRAWN BASED ON FIELD MEASUREMENTS, RECORD DRAWINGS, AND UTILITY LOCATE SERVICE. ACTUAL UTILITY CONFIGURATION MAY BE DIFFERENT THAN SHOWN. CONTRACTOR TO FIELD VERIFY AND NOTIFY ENGINEER OF DISCREPANCIES.

SURVEY NOTES FOR BASIN CREEK DAM

1. THE BASIS OF BEARING IS BY GPS OBSERVATION.
2. SURVEY CONTROL WAS BROUGHT IN FROM THE BUTTE HARN STATION USING GPS.
3. THE COORDINATE SYSTEM IS IN STATE PLANE, US FEET.
4. THE SCALE FACTOR FROM REAL FEET TO STATE PLANE IS 0.9993.
5. THE SURVEY AT THE SITE WAS DONE WITH A TOTAL STATION, USING THE SCALE FACTOR 0.9993.
6. ON SITE CONTROL POINT ELEVATIONS WERE ESTABLISHED USING A LEVEL.
7. THE VERTICAL DATUM WAS ADJUSTED TO MATCH THE EXISTING DATUM FROM PUBLISHED DOCUMENTS AND ORIGINAL DESIGN DRAWINGS. AT THE CENTER TOP OF THE DAM ON THE NORTH SIDE OF THE HOIST IS A LARGE NUT MARKED "BM". HKM POINT NUMBER 1002 WAS AT ELEVATION 5888.96 FEET (NAVD 88) AS SURVEYED WITH GPS. THE ELEVATION WAS ADJUSTED –16.06 FEET TO ELEVATION 5872.90. ALL PROJECT POINTS FOR THE LOWER DAM WERE ADJUSTED VERTICALLY –16.06 FEET. UPPER AND LOWER DAMS ARE UNRELATED VERTICALLY.



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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

EXISTING SITE CONDITIONS

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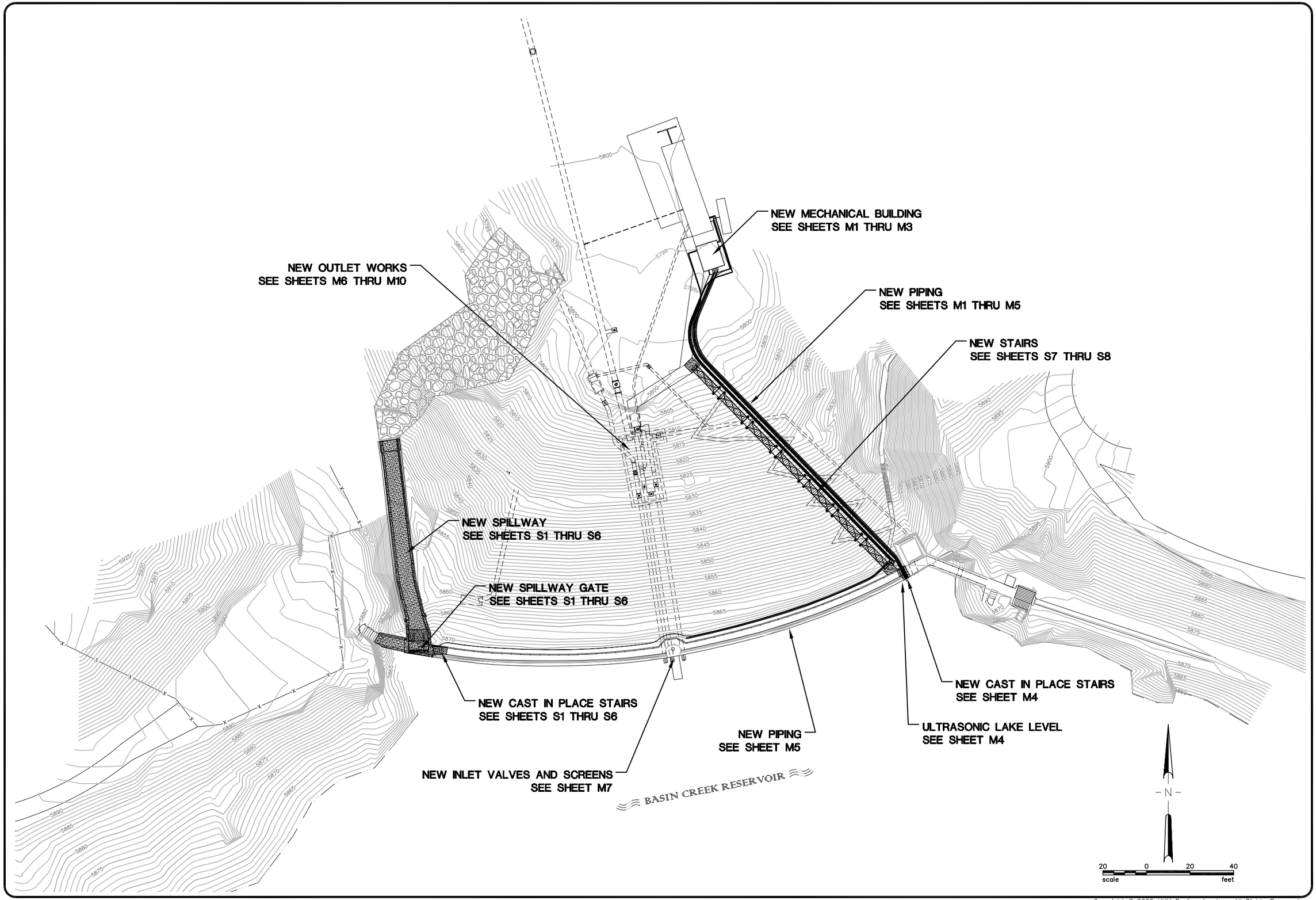

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SITE PLAN AND SHEET REFERENCES

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GENERAL STRUCTURAL NOTES

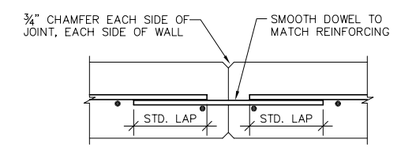
1. APPLICABLE SPECIFICATIONS AND CODES
   CONSTRUCTION AND DESIGN SHALL BE IN ACCORDANCE WITH THE AMERICAN CONCRETE INSTITUTE SPECIFICATIONS AND THE REQUIREMENTS NOTED AS FOLLOWS.
2. CONSTRUCTION LOADS
   PROVIDE TEMPORARY BRACING, SHORING OR OTHER SUPPLEMENTAL SUPPORT DURING CONSTRUCTION AS NECESSARY TO PROTECT THE STRUCTURES FROM EXCESSIVE CONSTRUCTION LOADS.
3. CONCRETE
   a. CONCRETE CONSTRUCTION SHALL CONFORM TO THE AMERICAN CONCRETE INSTITUTE BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE (ACI 318).
   b. DETAILING, FABRICATION AND PLACEMENT OF REINFORCEMENT SHALL CONFORM TO DETAILS AND DETAILING OF CONCRETE REINFORCEMENT (ACI 315).
   c. MATERIALS
      i. STRUCTURAL CAST-IN-PLACE CONCRETE ----- $f'c$ = 4,000 PSI
      ii. REINFORCING BARS ---------- ASTM A615, GRADE 60
   d. ALL BENT REINFORCING BARS SHALL BE SHOP FABRICATED ONLY. REBENDING OR WELDING OF REINFORCEMENT SHALL NOT BE PERMITTED UNLESS AUTHORIZED BY ENGINEER.
   e. END HOOKS IN REINFORCING BARS, SHOWN ON THE DRAWINGS BUT NOT DIMENSIONED, SHALL CONFORM TO ACI 318.
   f. CONCRETE COVER OVER REINFORCEMENT SHALL BE 2" CLEAR, EXCEPT CONCRETE PLACED AGAINST AND PERMENENTLY IN CONTACT WITH EARTH SHALL BE 3" CLEAR.
   g. REINFORCEMENT SPLICES NOT PERMITTED EXCEPT AS DETAILED OR AUTHORIZED BY ENGINEER. LAP REINFORCING BARS THE FOLLOWING MINIMUMS AT ALL SPLICES, CORNERS AND INTERSECTIONS, UNLESS OTHERWISE INDICATED. TOP BARS ARE HORIZONTAL BARS WITH MORE THAN 12" OF CONCRETE CAST BELOW THE BAR.

BAR SIZE	REG. BARS	TOP BARS
#3	1'-3"	1'-7"
#4	1'-7"	2'-1"
#5	2'-0"	2'-7"
#6	2'-5"	3'-1"
#7	3'-6"	4'-6"
#8	4'-0"	5'-2"
#9	4'-6"	5'-10"
#10	5'-1"	6'-7"

   h. STAGGER ADJACENT REINFORCEMENT LAP SPLICES IN WALLS 18" MINIMUM.
   i. PROVIDE BAR SUPPORTS TO PROPERLY SECURE AND SUPPORT REINFORCING BARS AT POSITIONS SHOWN ON THE DRAWINGS. IN ADDITION TO NORMAL ACCESSORIES PROVIDE #5 STANDEES AT 36" O.C. TO SUPPORT TOP REINFORCEMENT IN BASE SLABS, AND #3 U OR Z SHAPE SPACERS AT 72" O.C. EACH WAY IN WALLS WITH TWO CURTAINS OF REINFORCEMENT.
   j. DOWELS, PIPES AND OTHER INSTALLED MATERIALS AND ACCESSORIES SHALL BE HELD SECURELY IN POSITION DURING CONCRETE PLACEMENT.
   k. REINFORCING BARS AND ACCESSORIES SHALL NOT BE IN CONTACT WITH ANY PIPE, PIPE FLANGE OR METAL PART EMBEDDED IN CONCRETE. PROVIDE 2" CLEARANCE IN ALL CASES UNLESS OTHERWISE INDICATED. NO EMBEDDED ITEM SHALL BE SUSPENDED FROM, SUPPORTED BY, OR BRACED IN PLACE FROM THE STRUCTURAL REINFORCEMENT.
   l. LOCATE CONSTRUCTION JOINTS AT 15'-0" O.C. , WHERE SHOWN ON THE DRAWINGS OR AS AUTHORIZED BY ENGINEER. SLABS, JOISTS AND BEAMS SHALL NOT HAVE JOINTS IN A HORIZONTAL PLANE EXCEPT WHERE DETAILED ON DRAWINGS.
   m. THOROUGHLY CLEAN BY SANDBLASTING ALL BONDED CONSTRUCTION JOINTS PRIOR TO PLACING CONCRETE IN ADJACENT POUR.
   n. BEGIN SPACING OF BARS WHICH PARALLEL CONSTRUCTION AND EXPANSION JOINTS 2" CLEAR FROM EACH SIDE OF JOINT.
   o. UNLESS OTHERWISE SHOWN, PLACE 2-#5 (1 EACH FACE) WITH 2'-0" PROJECTIONS AROUND ALL OPENINGS IN CONCRETE WALLS OR SLABS.
   p. PROVIDE AN ADDITIONAL 100 LINEAL FEET OF #5 REINFORCING BARS FOR USE AS DIRECTED DURING CONSTRUCTION.
   q. CHAMFER ALL EXPOSED CONCRETE EDGES 3/4", UNLESS OTHERWISE INDICATED.
4. STRUCTURAL STEEL
   a. STRUCTURAL STEEL CONSTRUCTION SHALL CONFORM TO THE AMERICAN INSTITUTE OF STEEL CONSTRUCTION SPECIFICATION FOR THE DESIGN, FABRICATION AND ERECTION OF STRUCTURAL STEEL FOR BUILDINGS.
   b. ALL WELDING SHALL CONFORM TO AMERICAN WELDING SOCIETY STRUCTURAL WELDING CODE-STEEL (AWS D1.1), AND SHALL BE PERFORMED BY WELDERS QUALIFIED BY THE APPROPRIATE AWS TEST FOR THE WELDING PERFORMED.
   c. ALL EXPOSED STEEL SHALL HAVE A HOT-DIP ZINC COATING IN ACCORDANCE WITH ASTM A123.
   d. ADHESIVE ANCHORS SHALL BE HILTI HVA ADHESIVE ANCHORS WITH HAS 316 SS RODS OR APPROVED EQUAL.
5. EXISTING CONSTRUCTION
   a. DIMENSIONS, ELEVATIONS AND DETAILS OF EXISTING CONSTRUCTION HAVE BEEN OBTAINED FROM FIELD INVESTIGATIONS AND AS-CONSTRUCTED DOCUMENTS. THE CONTRACTOR SHALL VERIFY ALL EXISTING CONDITIONS NECESSARY TO PROPERLY COORDINATE NEW AND EXISTING CONSTRUCTION, AND SHALL NOTIFY THE ENGINEER OF ALL VARIATIONS IN THE DETAILS, DIMENSIONS AND ELEVATIONS OF EXISTING CONSTRUCTION WITH THAT SHOWN ON THE DRAWINGS.
   b. CLEAN AND PREPARE ALL EXISTING SURFACES WHICH WILL BE IN CONTACT WITH NEW CONSTRUCTION AS INDICATED AND AS ACCEPTABLE TO ENGINEER. APPLY BONDING COMPOUND TO ALL EXISTING CONCRETE SURFACES WHICH WILL BE IN CONTACT WITH NEW CONCRETE IMMEDIATLEY PRIOR TO PLACEMENT.
   c. PROTECT EXISTING MATERIALS FROM DAMAGE DURING CONSTRUCTION.
   d. FURNISH AND INSTALL TEMPORARY SHORING OR BRACING AS NECESSARY TO PROVIDE SUPPORT AND STABILITY FOR EXISTING WALLS AND FRAMING DURING DEMOLITION AND CONSTRUCTION.

GENERAL STRUCTURAL ABBREVIATIONS

O.C.	ON CENTER
T.O.C.	TOP OF CONCRETE
T.O.F.	TOP OF FOOTING
T.O.S.	TOP OF SLAB
T.O.W.	TOP OF WALL
STD.	STANDARD
TYP.	TYPICAL
MIN.	MINIMUM
SIM.	SIMILAR
REINF.	REINFORCEMENT
SPA.	SPACES
EA.	EACH
EL.	ELEVATION
CLR.	CLEAR



1 S-1 **DETAIL**
TYPICAL SPILLWAY WALL CONSTRUCTION JOINT
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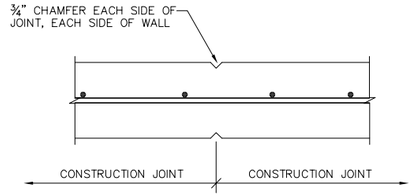
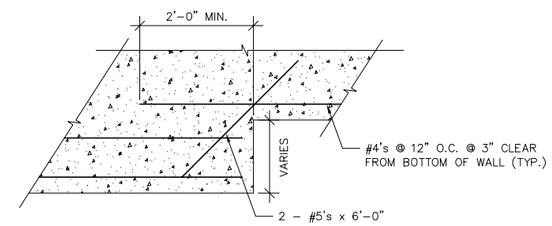
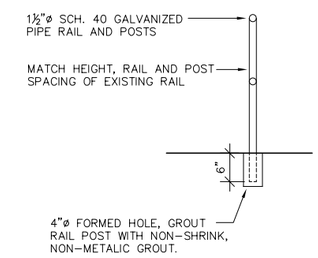


2 S-2 **DETAIL**
TYPICAL SPILLWAY WALL CONTROL JOINT
NOT TO SCALE



3 S-1 **DETAIL**
TYPICAL STEP IN WALL
NOT TO SCALE



4 S-1 **DETAIL**
TYPICAL PIPE RAILING
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

GENERAL STRUCTURAL NOTES AND STANDARD DETAILS

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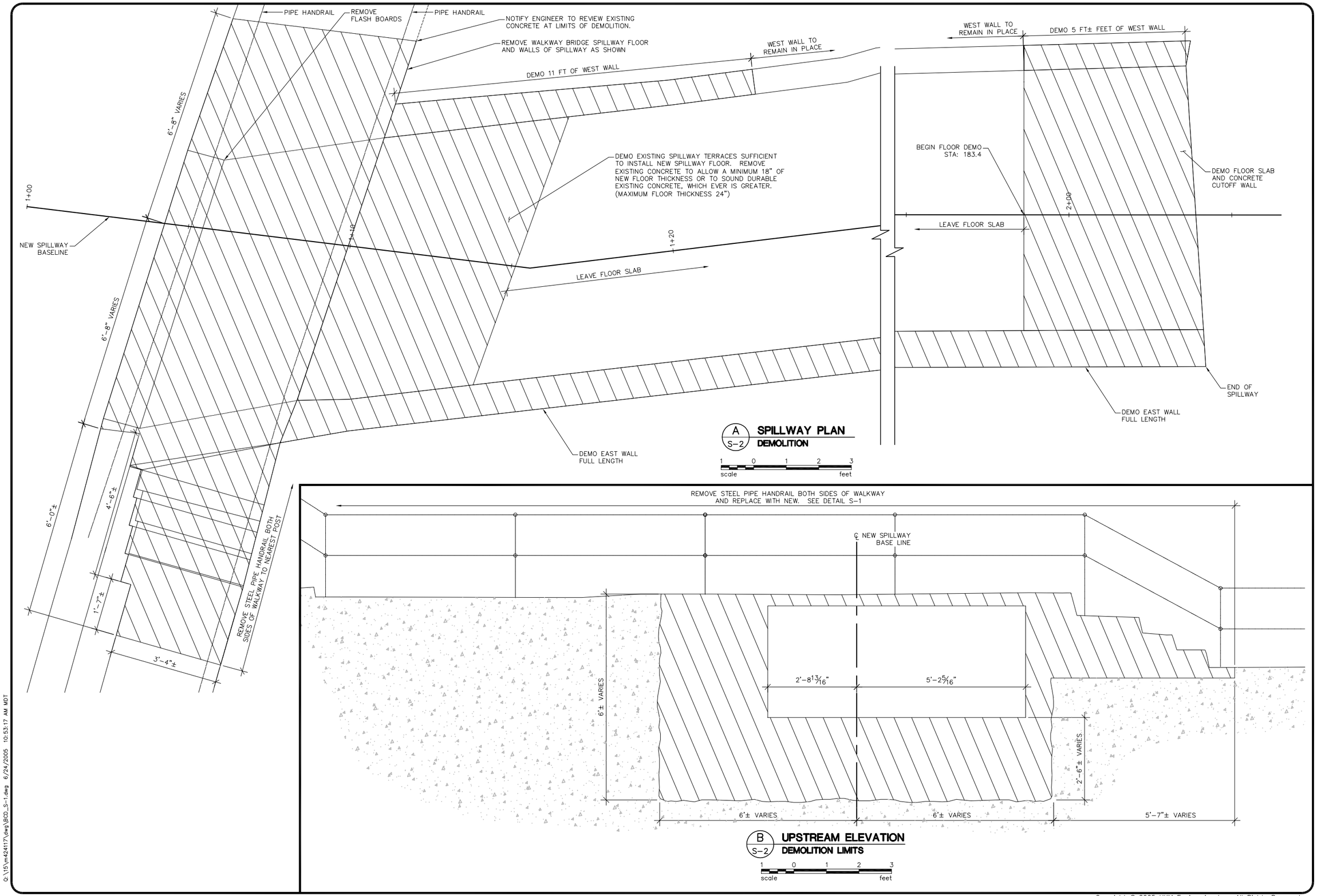

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY PLAN VIEW
DEMOLITION DETAILS

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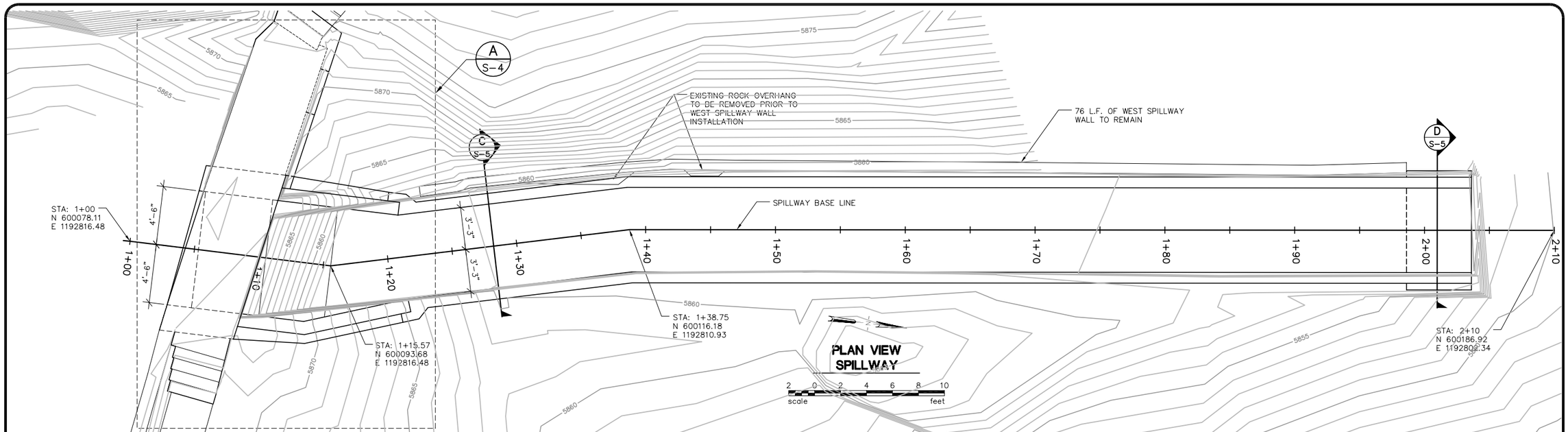

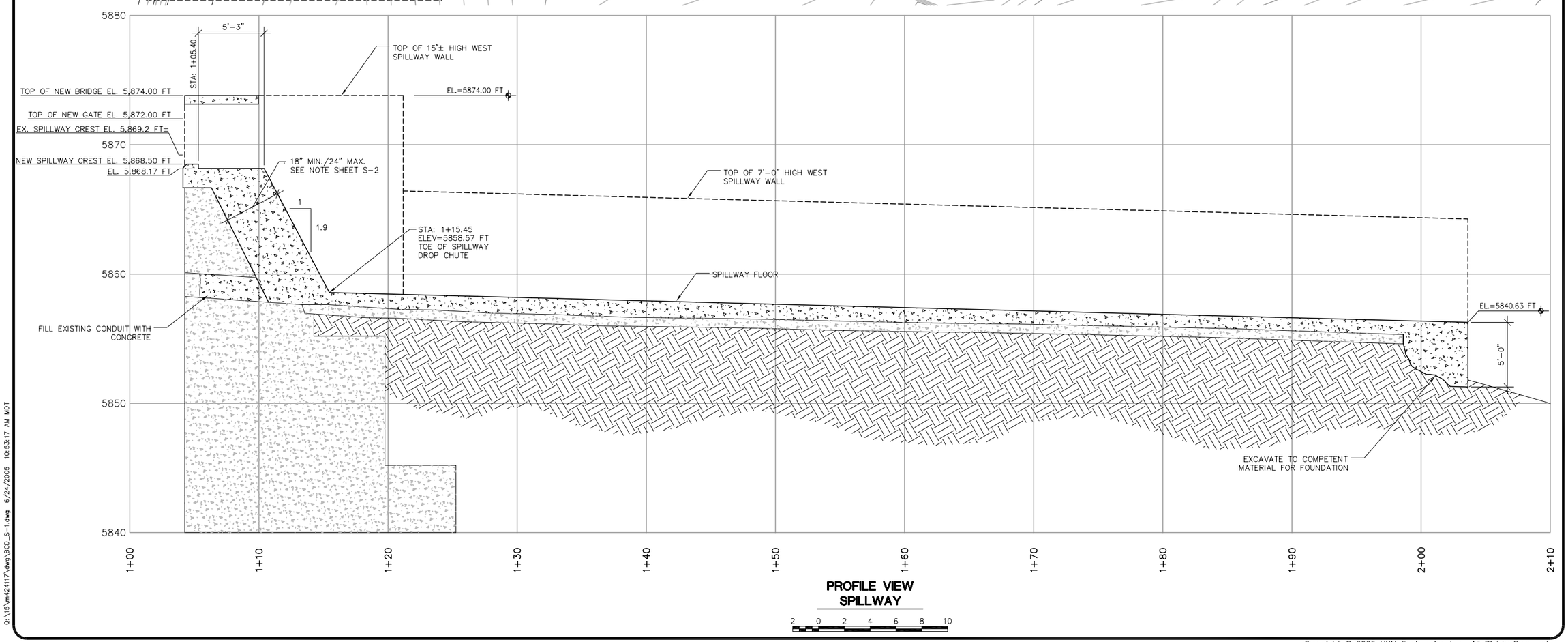

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE
PLAN AND PROFILE

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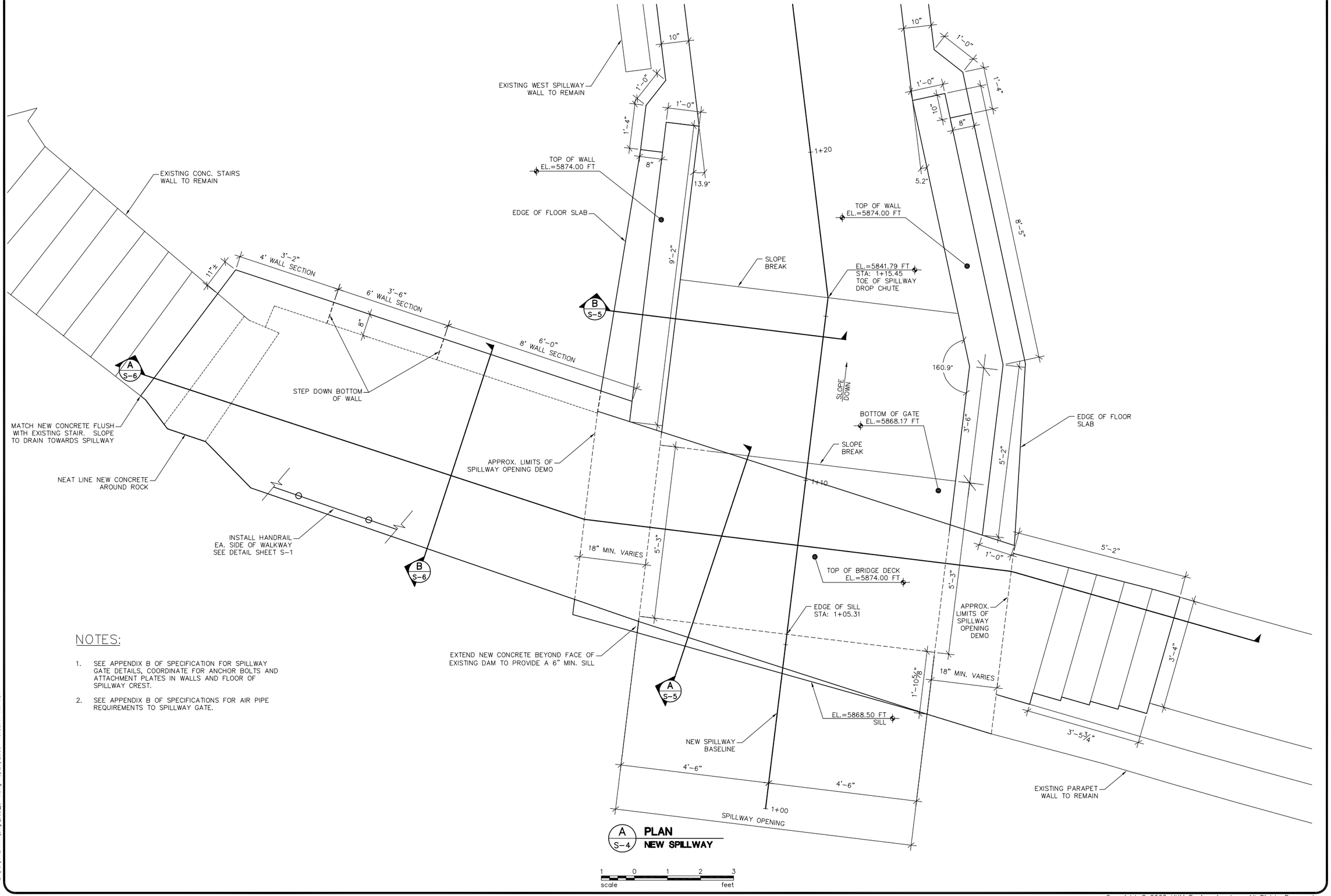

NOTES:

1. SEE APPENDIX B OF SPECIFICATION FOR SPILLWAY GATE DETAILS, COORDINATE FOR ANCHOR BOLTS AND ATTACHMENT PLATES IN WALLS AND FLOOR OF SPILLWAY CREST.
2. SEE APPENDIX B OF SPECIFICATIONS FOR AIR PIPE REQUIREMENTS TO SPILLWAY GATE.

No.	Revision	By	Date

Project No. 15M424.117 ● BCD_S-1.dwg ● Date JUNE 2005 ● Designed CRS ● Drawn DAS ● Checked RCR ● Approved CRS

WARNING 0 ½ 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE PLAN

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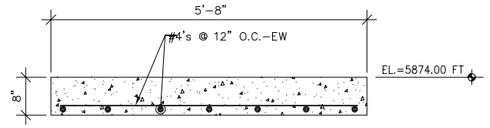
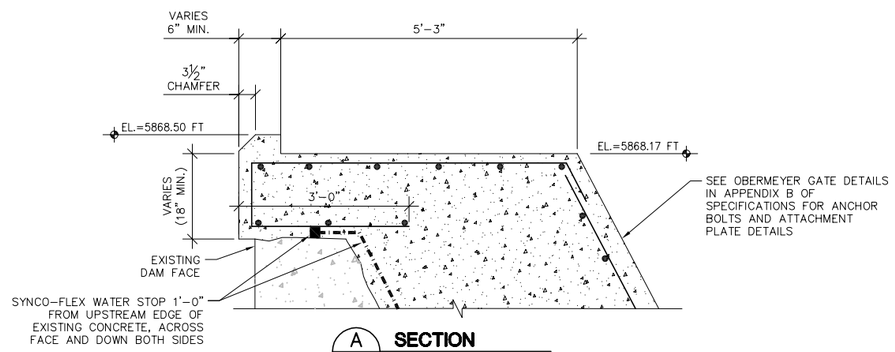
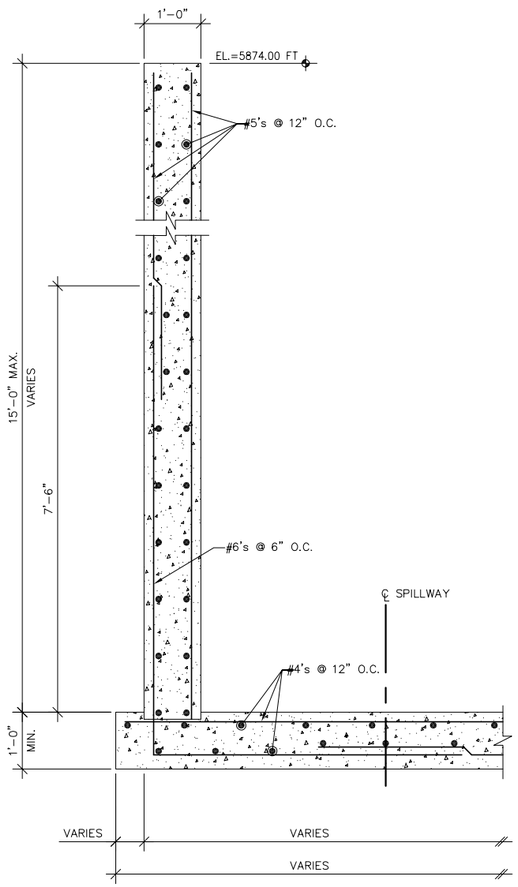




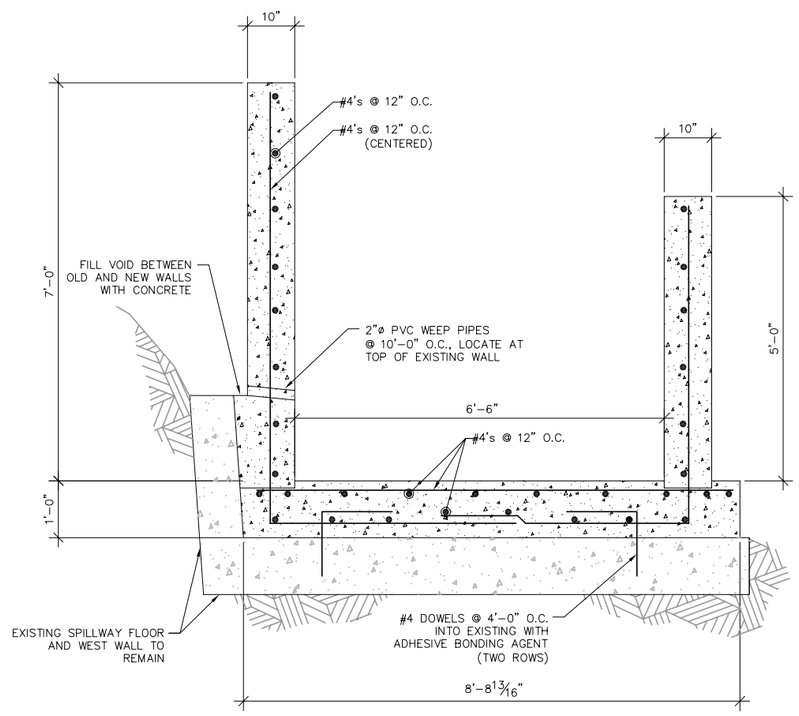
A / S-5 **SECTION**
BRIDGE

1 0 1 2 3
scale feet



B / S-5 **SECTION**
SPILLWAY - STA: 1+29
TO STA: 1+20.9

1 0 1 2 3
scale feet



C / S-5 **SECTION**
TYPICAL SPILLWAY - STA: 1+20.9
TO STA: 1+98.6

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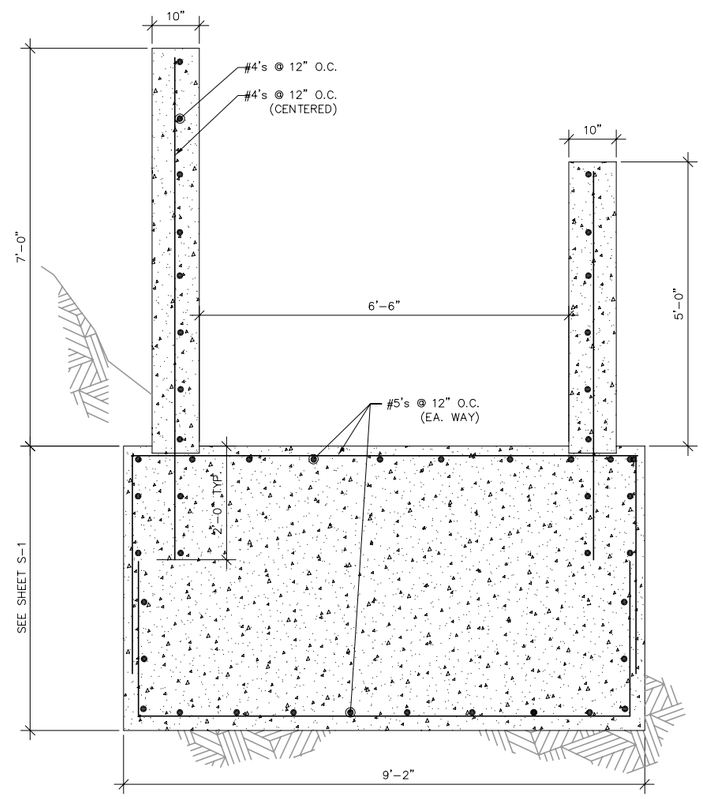
scale feet



D / S-5 **SECTION**
TYPICAL SPILLWAY - STA: 1+98.6
TO STA: 2+03.6

1 0 1 2 3
scale feet

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE SECTIONS

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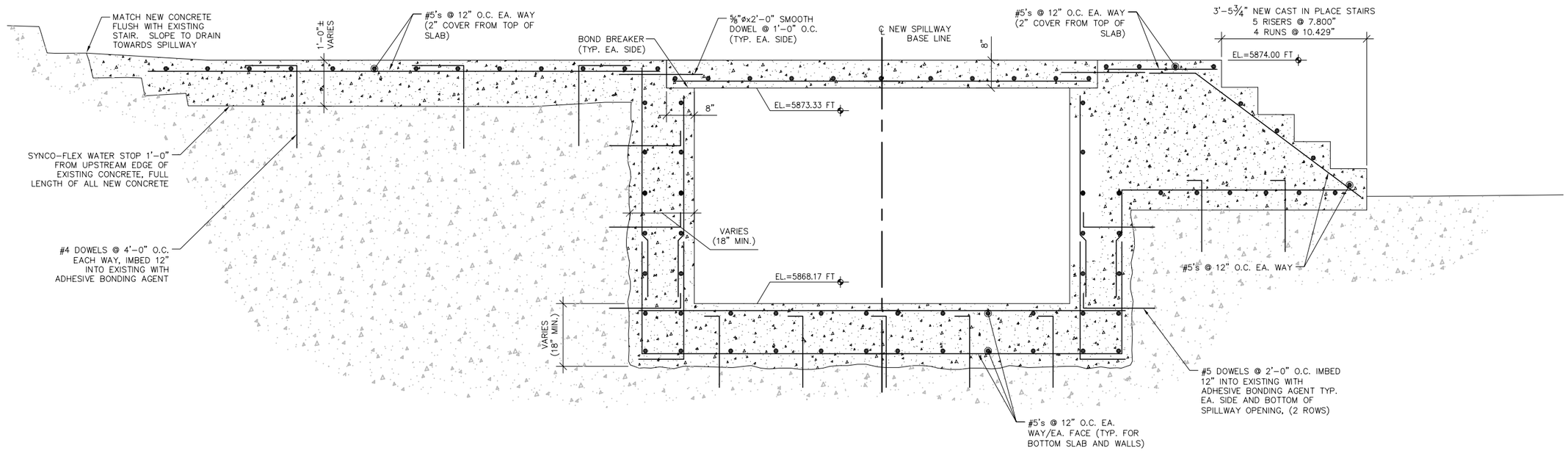

A / S-6 **SECTION SPILLWAY**

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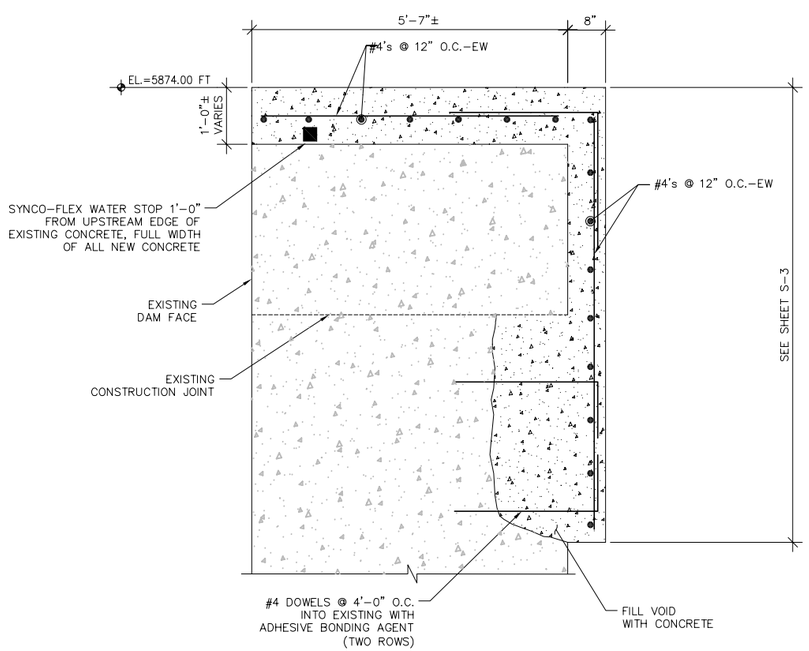
scale feet



B / S-6 **SECTION WALKWAY**

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WARNING
0 ½ 1
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE
DEMOLITION AND SECTIONS

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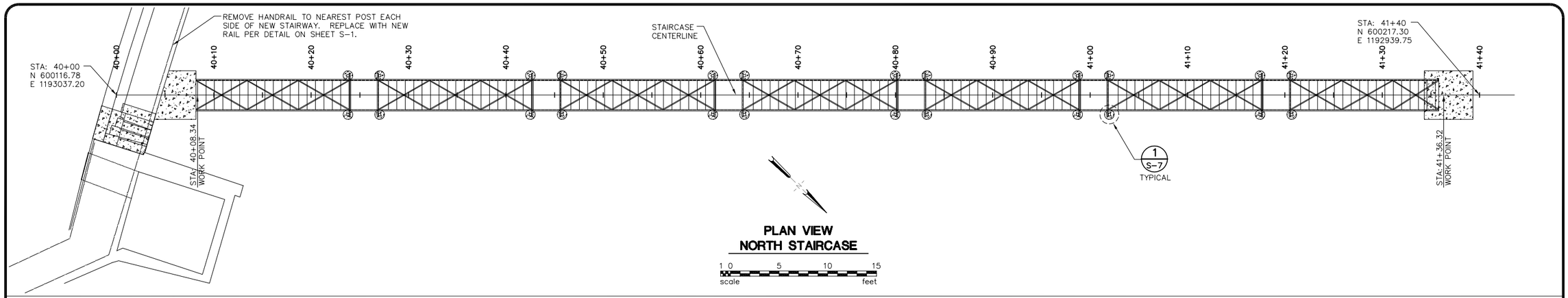
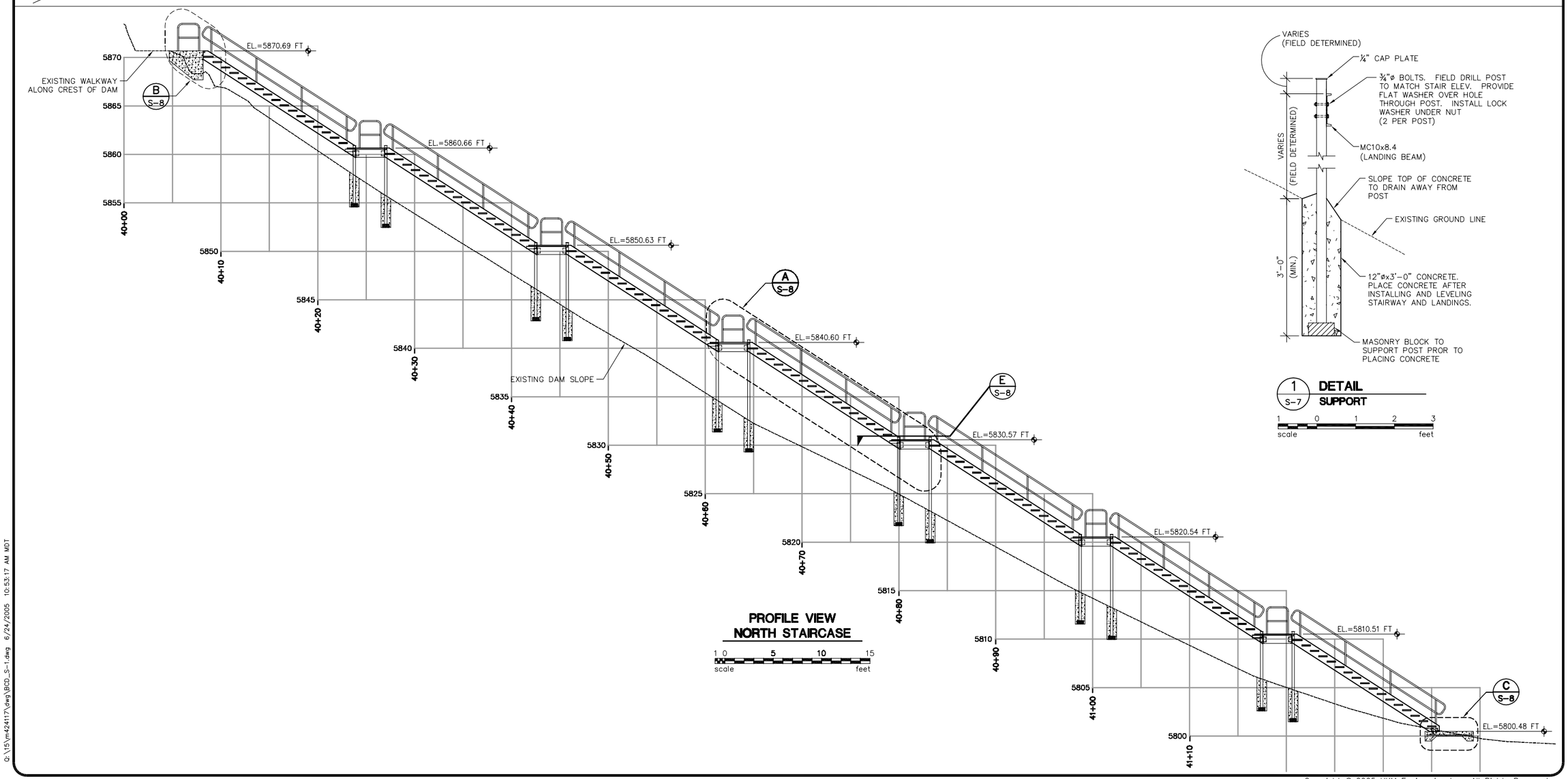


PLAN VIEW
NORTH STAIRCASE

1 0 5 10 15
scale feet



PROFILE VIEW
NORTH STAIRCASE

1 0 5 10 15
scale feet

1 S-7 **DETAIL**
SUPPORT

1 0 1 2 3
scale feet

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WARNING
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

STAIRCASE PLAN, PROFILE AND DETAILS

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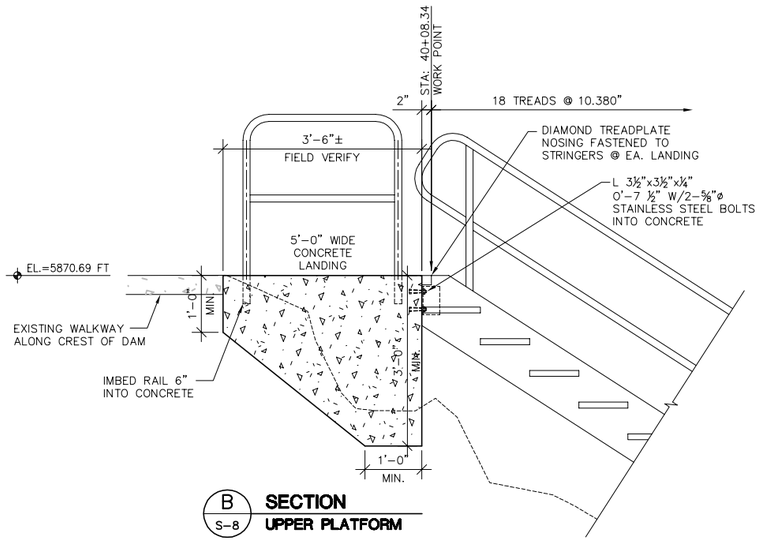
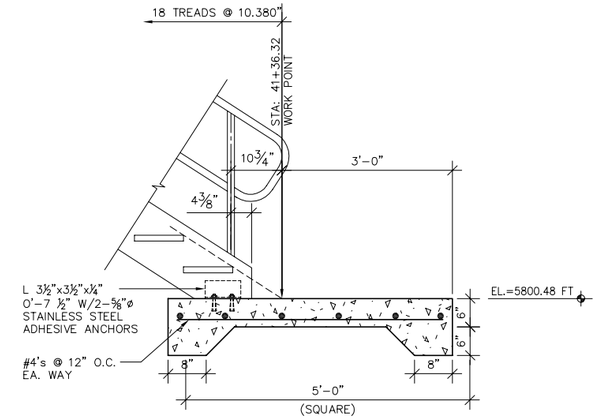


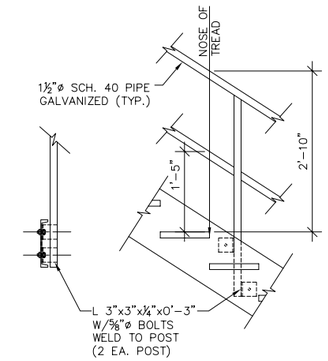
B S-8 **SECTION UPPER PLATFORM**

scale 1 0 1 2 3 feet



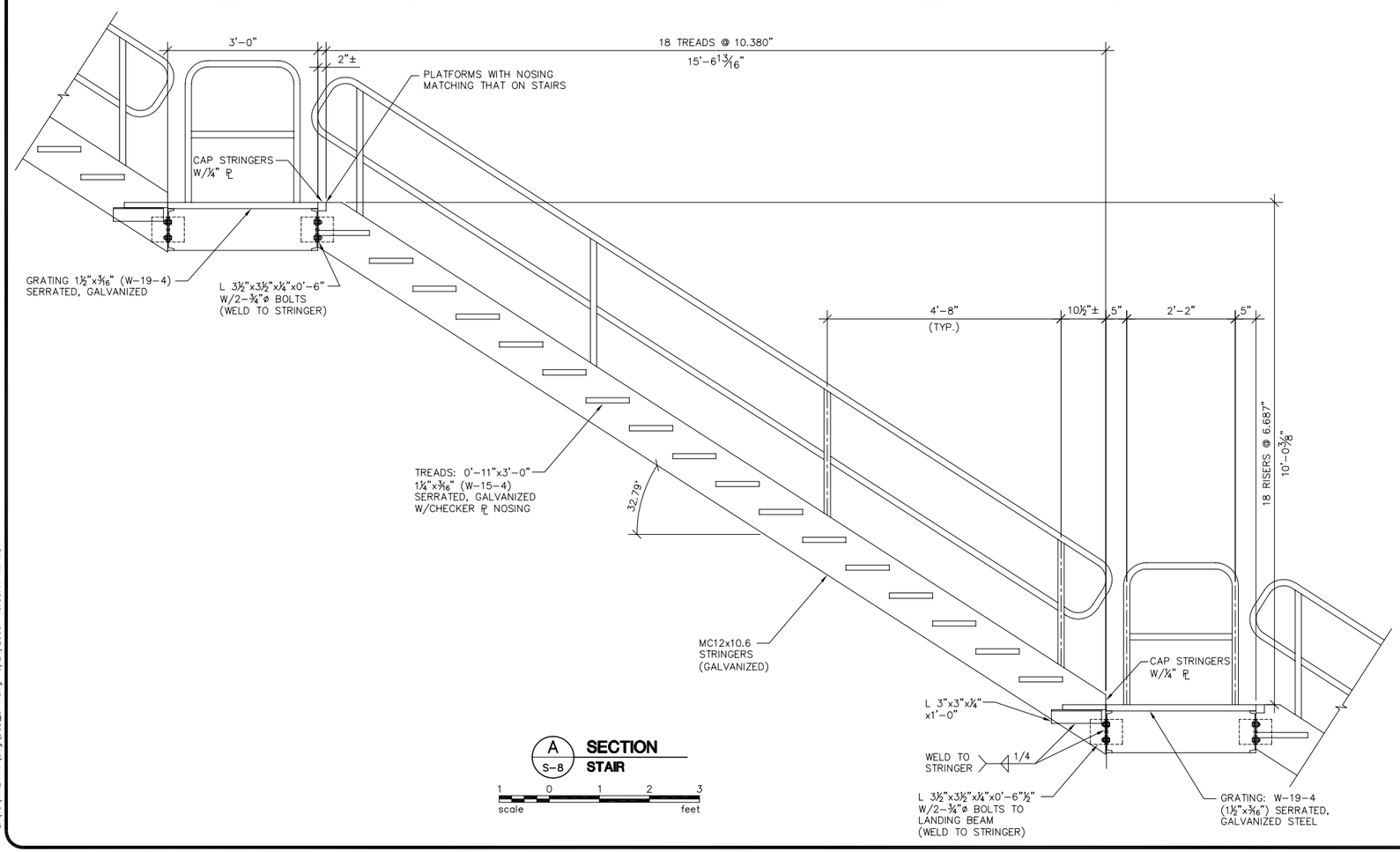
C S-8 **SECTION LOWER PLATFORM**

scale 1 0 1 2 3 feet



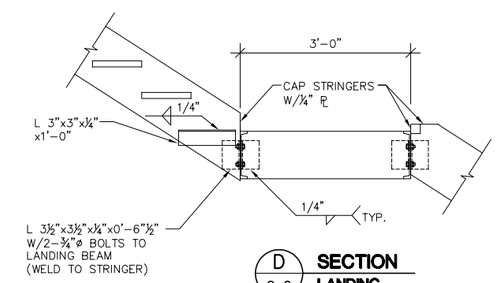
1 S-8 **DETAIL RAILING**

scale 1 0 1 2 3 feet



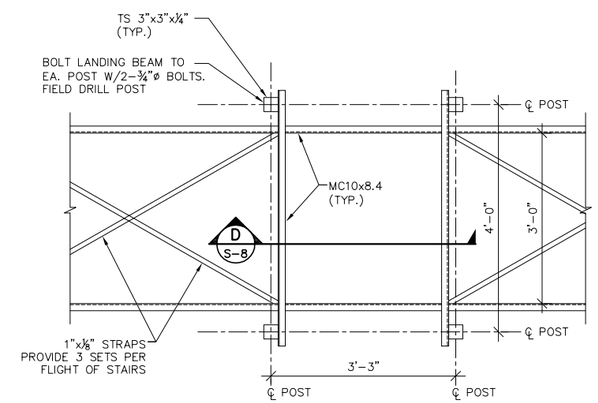
A S-8 **SECTION STAIR**

scale 1 0 1 2 3 feet



D S-8 **SECTION LANDING**

scale 1 0 1 2 3 feet



E S-8 **PLAN LANDING**

scale 1 0 1 2 3 feet

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

STARCASE
SECTIONS AND DETAILS

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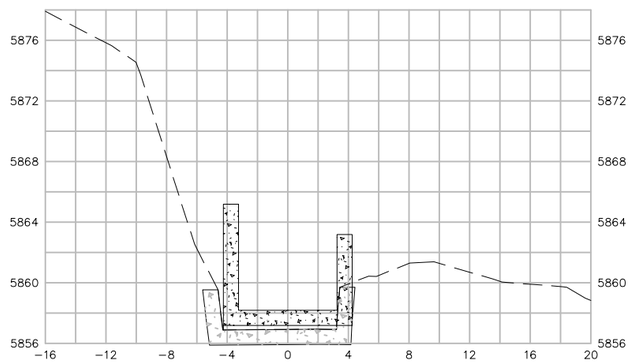
1+30



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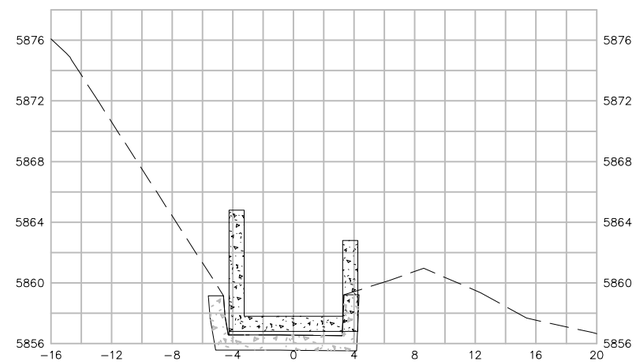

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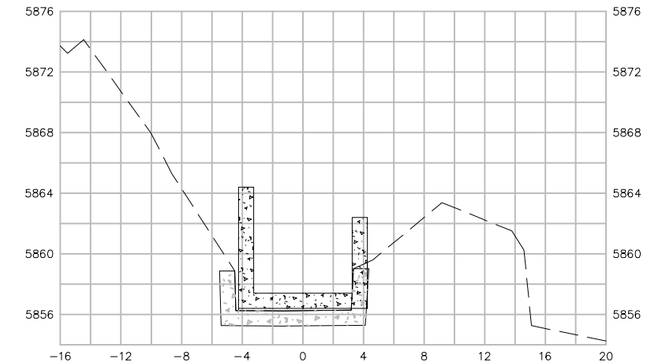

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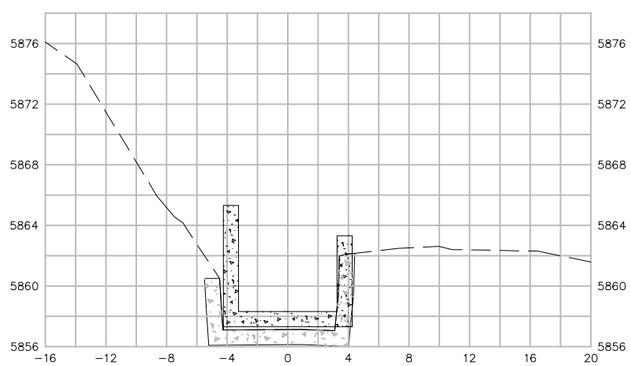

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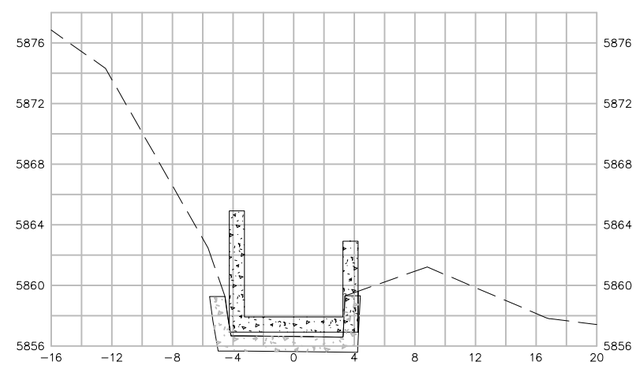

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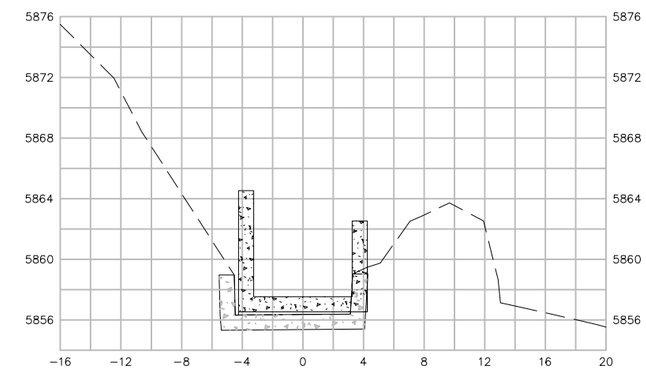

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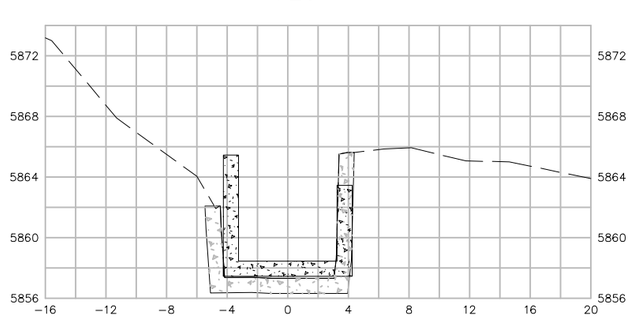

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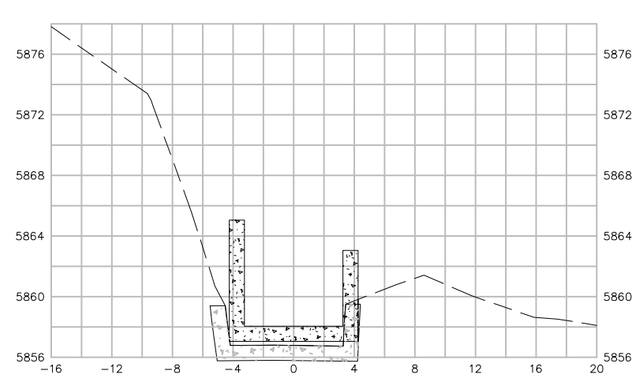

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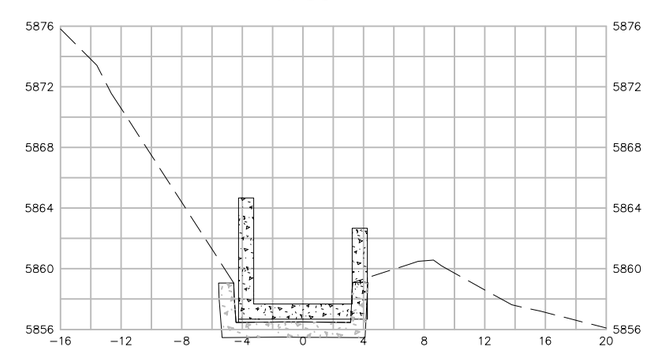

No.	Revision	By	Date

WARNING
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY CROSS SECTIONS
STATIONS 1+20 TO 1+60

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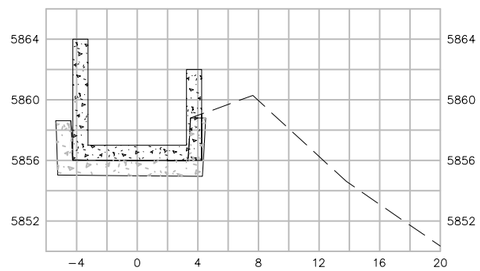
1+75



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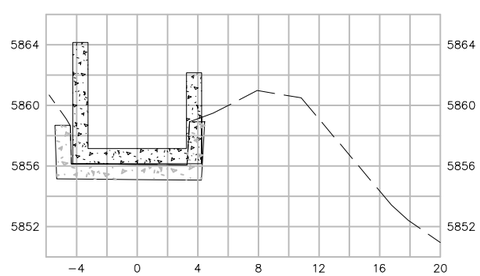

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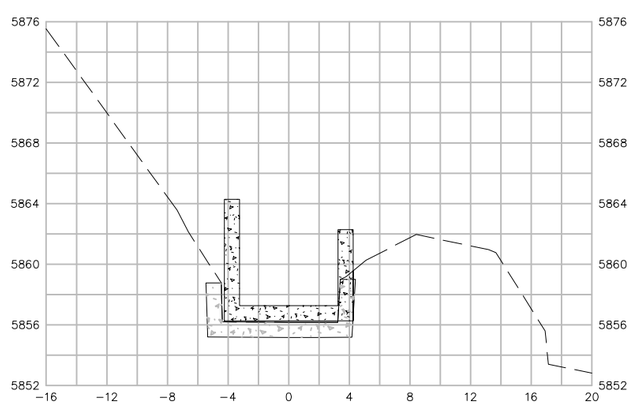

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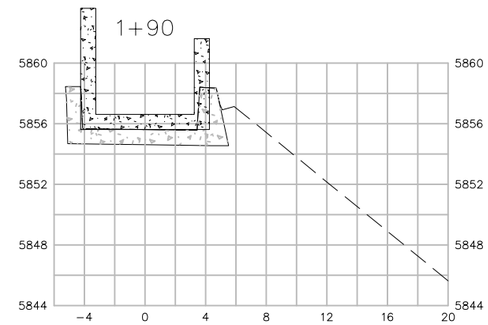

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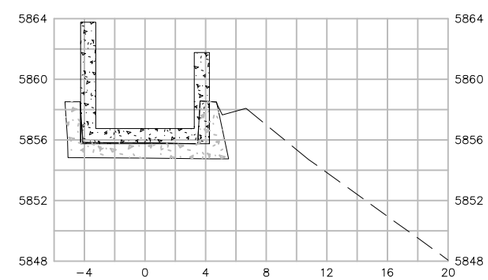

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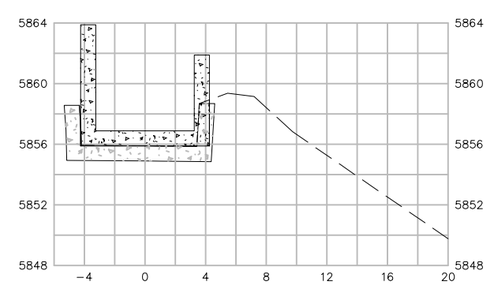

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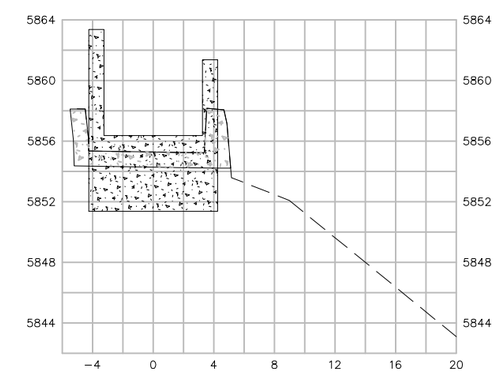

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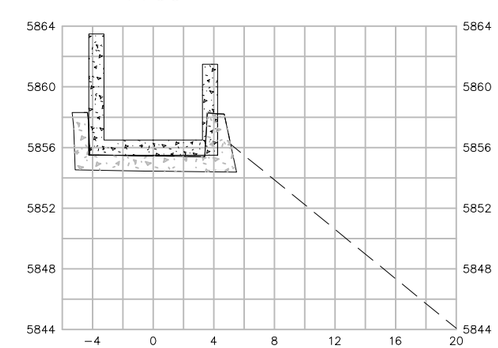

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY CROSS SECTIONS
STATIONS 1+65 TO 2+00

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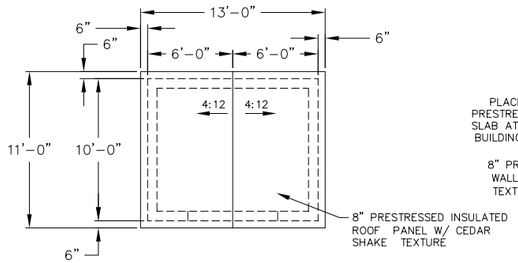
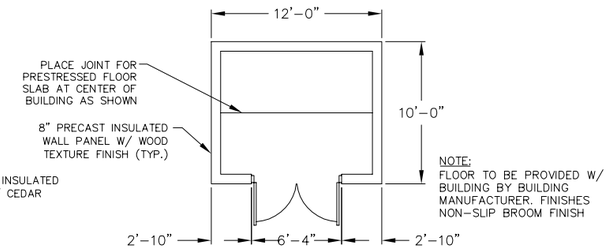
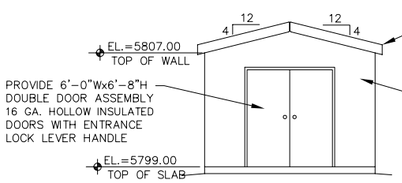


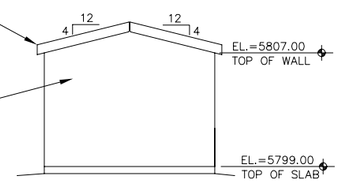
ROOF PLAN
SCALE: NONE



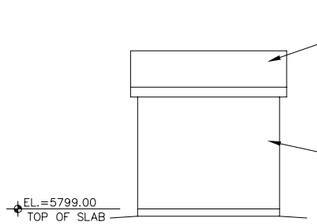
BUILDING PLAN
SCALE: NONE



SOUTH ELEVATION
SCALE: NONE



NORTH ELEVATION
SCALE: NONE



WEST ELEVATION
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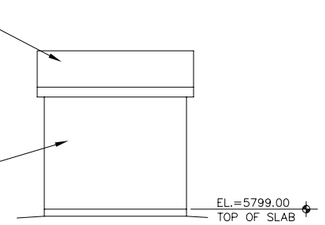
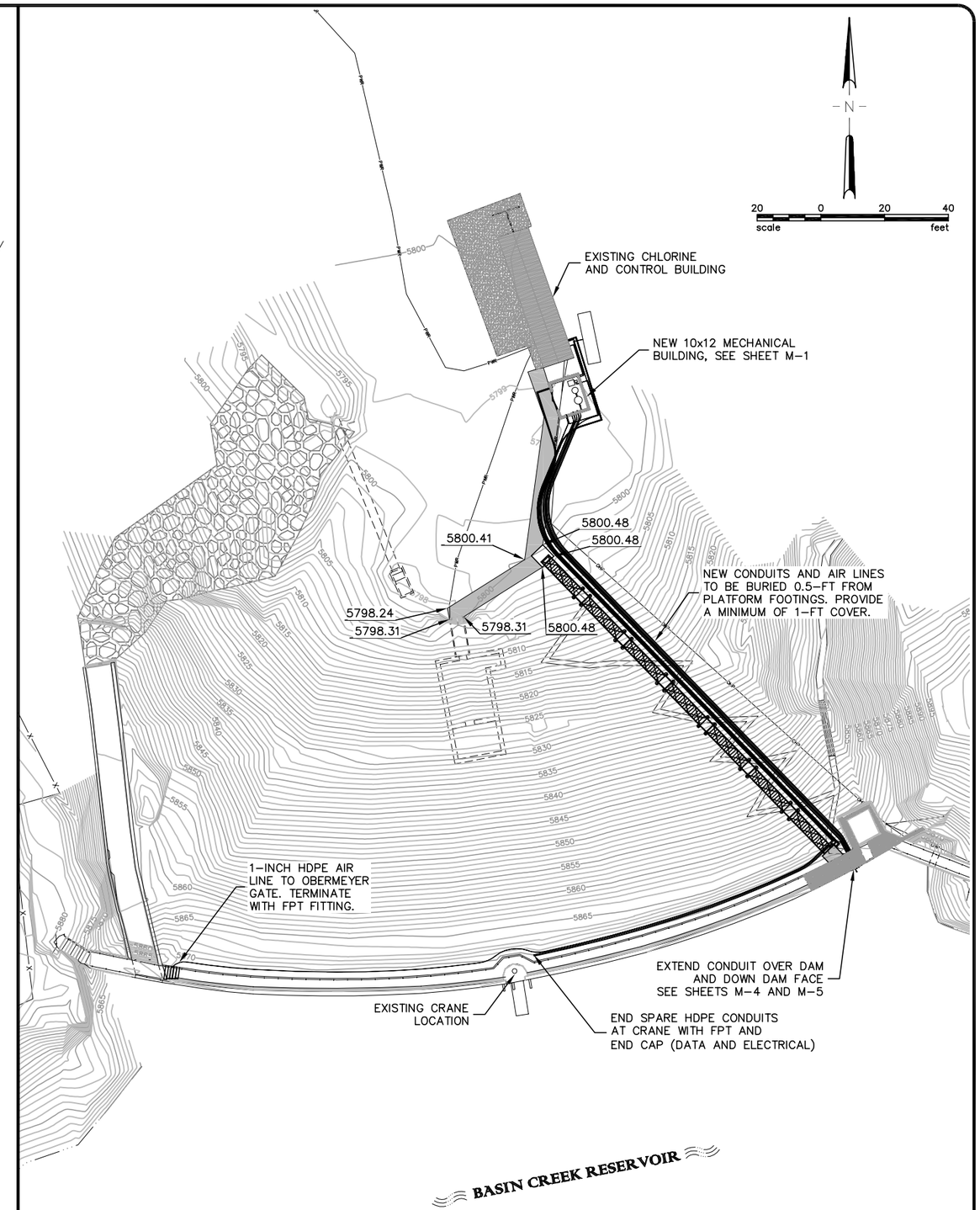


EAST ELEVATION
SCALE: NONE

NOTES:

1. SEE SECTION 13126 OF THE SPECIFICATIONS FOR BUILDING REQUIREMENTS.
2. SET BUILDING LEVEL AND TO PROPER ELEVATION. BSB WILL PROVIDE FILL MATERIAL TO ELEVATION OF BASE COURSE MATERIAL.
3. SET BUILDING ON PREPAIRED BASE. PROVIDE 1'-0" LAYER OF ¾" MINUS CRUSHED BASE COURSE PER MPWSS SECTION 02235 OR APPROVED EQUAL.
4. COMPACT BASE MATERIAL TO 95% MAX. DRY DENSITY PER ASTM D698.



SITE PLAN

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

MECHANICAL BUILDING
PLAN, ELEVATIONS AND DETAILS

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Sheet No.
M-1

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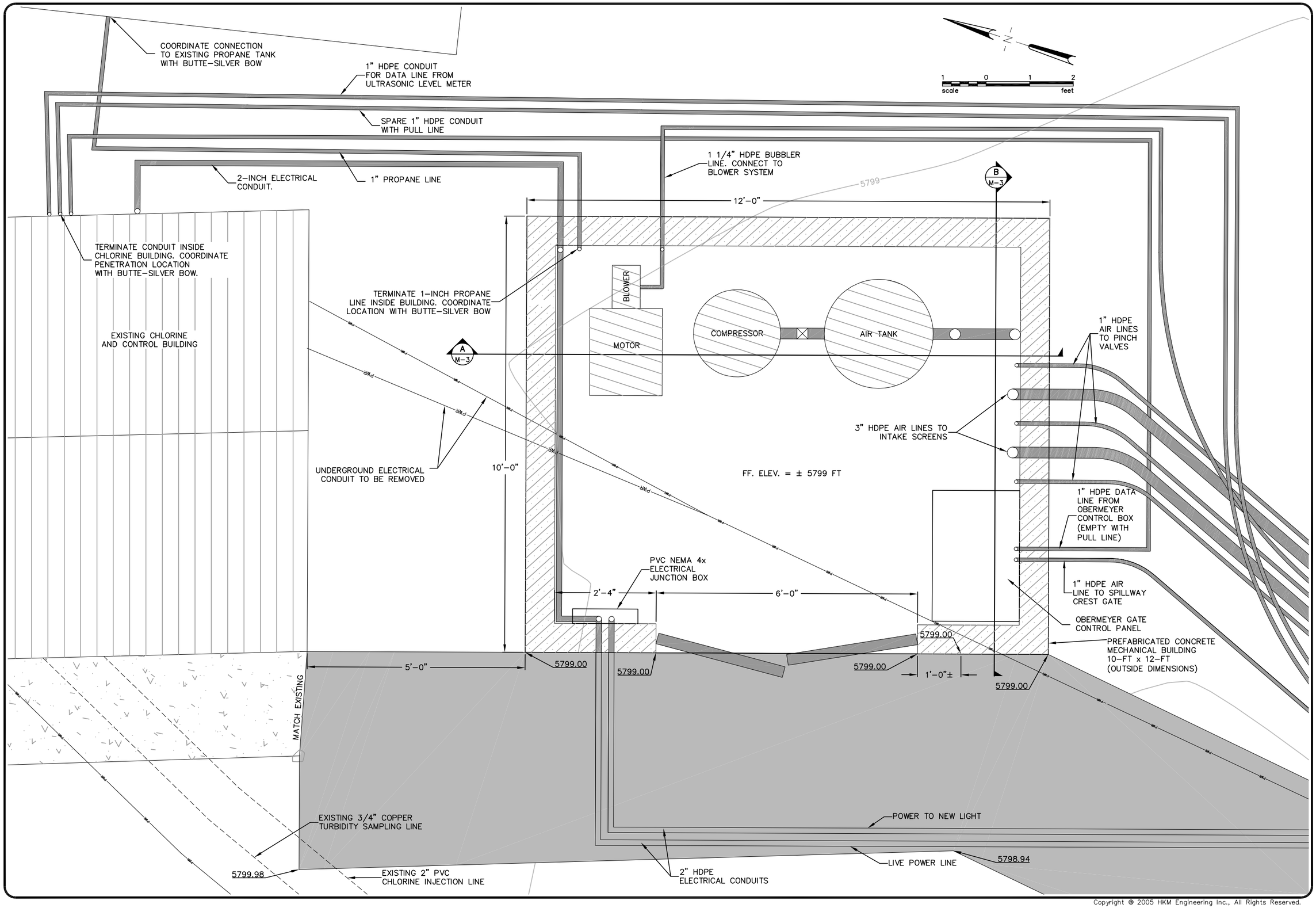

No.	Revision	By	Date

WARNING
0 ½ 1
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Project No. 15M424.117 ● BCD_mechanical.dwg ● Date JUNE 2005 ● Designed SMJ ● Drawn SMJ ● Checked RCR ● Approved RCR

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

MECHANICAL BUILDING LAYOUT

MONTANA RUSSELL CHRISTIAN REED 15740PE PROFESSIONAL ENGINEER

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Sheet No.
M-2

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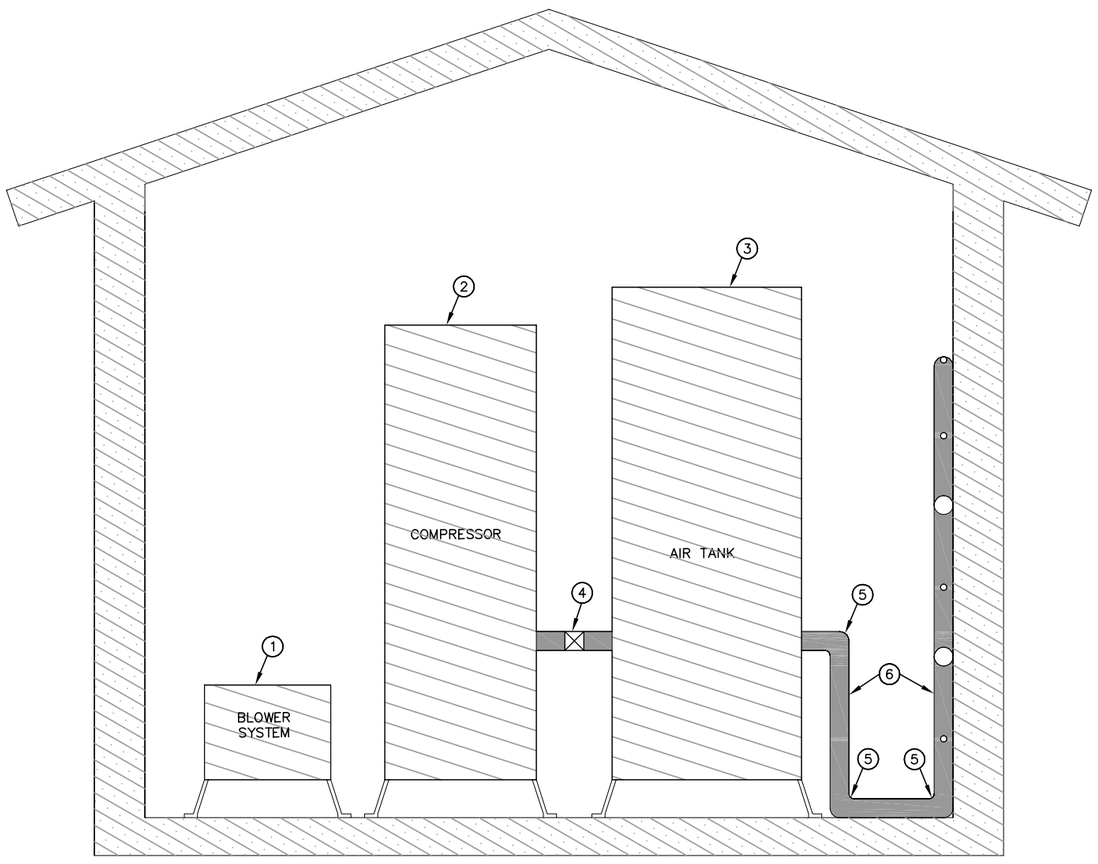
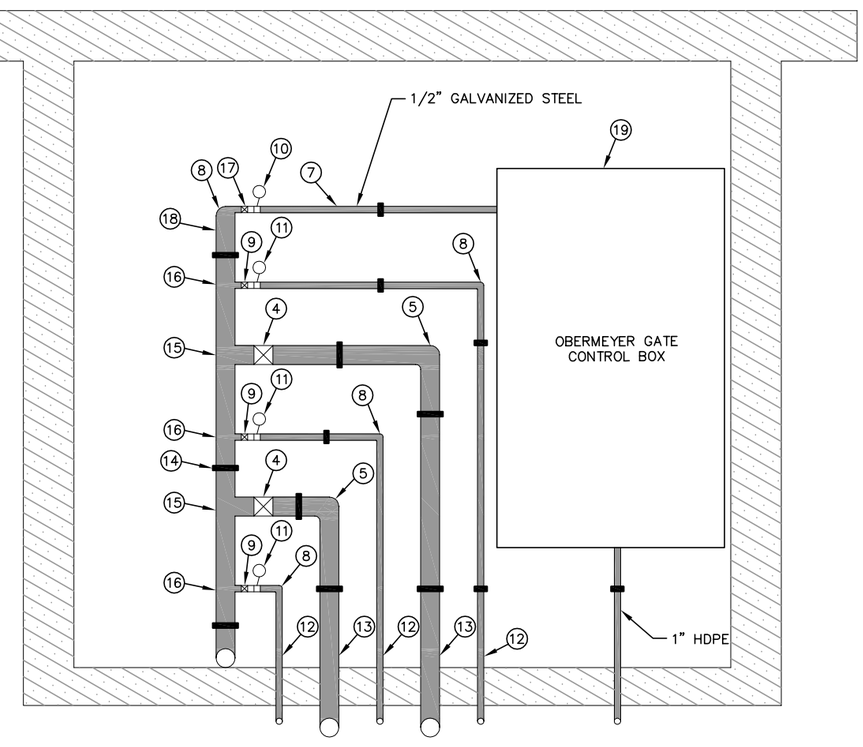
MATERIALS LIST

NO.	SIZE	MATERIAL	DESCRIPTION
1	–	–	SUTORBILT BLOWER PACKAGE OR APPROVED EQUAL (SEE CONTRACT DOCUMENTS)
2	–	–	COMPRESSOR (SEE CONTRACT DOCUMENTS)
3	–	–	240 GALLON AIR AIR TANK (SEE CONTRACT DOCUMENTS)
4	3"	GALVANIZED STEEL	NYLON SEATED LOCKING BALL VALVE
5	3"	GALVANIZED STEEL	90–DEGREE ELBOW
6	–	GALVANIZED STEEL	AIRLINE AND AIR MANIFOLD
7	–	GALVANIZED STEEL	1 x 1/2 REDUCER
8	1"	GALVANIZED STEEL	90–DEGREE ELBOW
9	1"	GALVANIZED STEEL	NYLON SEATED LOCKING BALL VALVE
10	1"	–	GRAINGER 6B206 FILTER REGULATOR (SET AT 30 PSI) WITH 5WZ19 PRESSURE GAGE OR EQUAL
11	1"	–	GRAINGER 6B206 FILTER REGULATOR (SET AT 60 PSI) WITH 5WZ19 PRESSURE GAGE OR EQUAL
12	1"	–	HDPE – GALVANIZED STEEL TRANSITION FITTING
13	3"	–	HDPE – GALVANIZED STEEL TRANSITION FITTING
14	–	–	PIPE STRAPS
15	3"	GALVANIZED STEEL	3 x 3 TEE
16	–	GALVANIZED STEEL	3 x 1 TEE
17	1"	GALVANIZED STEEL	NYLON SEATED LOCKING BALL VALVE
18	–	GALVANIZED STEEL	3 x 1 REDUCER
19	–	–	OBERMEYER GATE CONTROL PANEL



SEE MATERIALS LIST THIS SHEET

A / M–3 **SECTION**
COMPRESSOR AND BLOWER SYSTEMS
SCALE : 1" = 1'



SEE MATERIALS LIST THIS SHEET

B / M–3 **SECTION**
AIR LINE MANIFOLD
SCALE : 1" = 1'

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

MECHANICAL BUILDING SECTIONS AND MANIFOLD SCHEDULE

MONTANA LICENSED PROFESSIONAL ENGINEER
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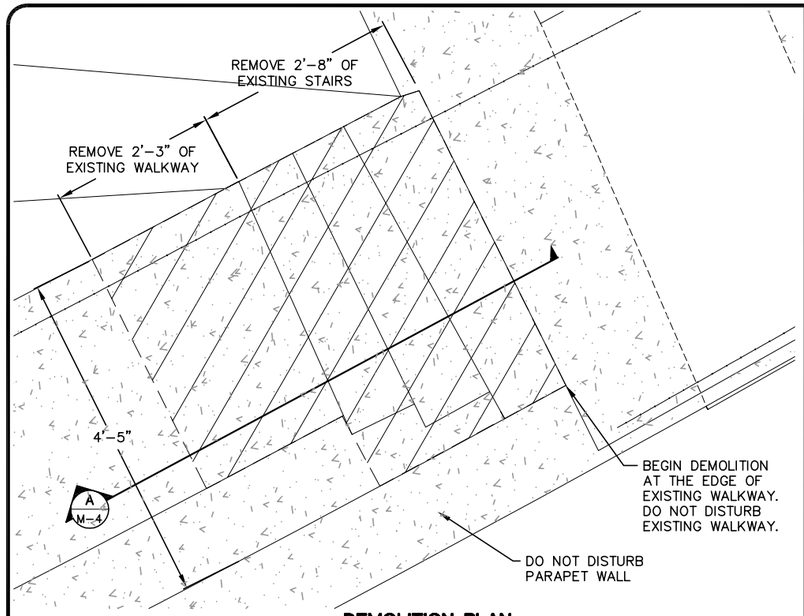
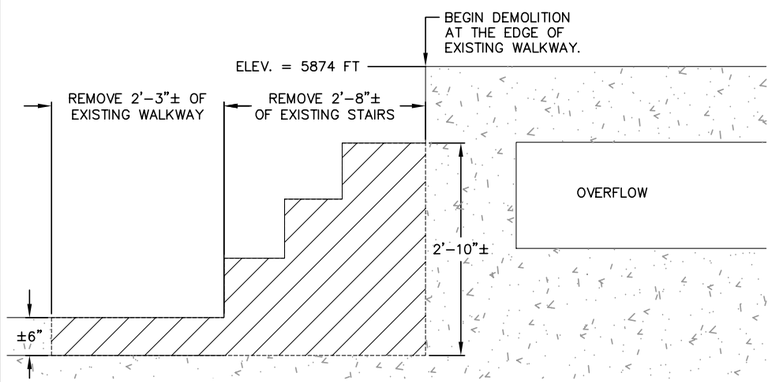
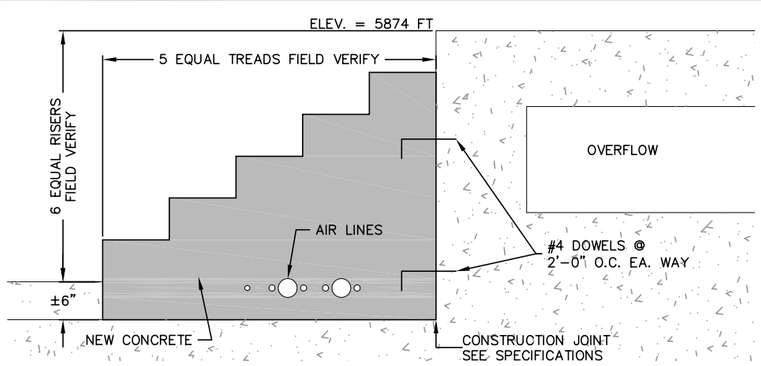


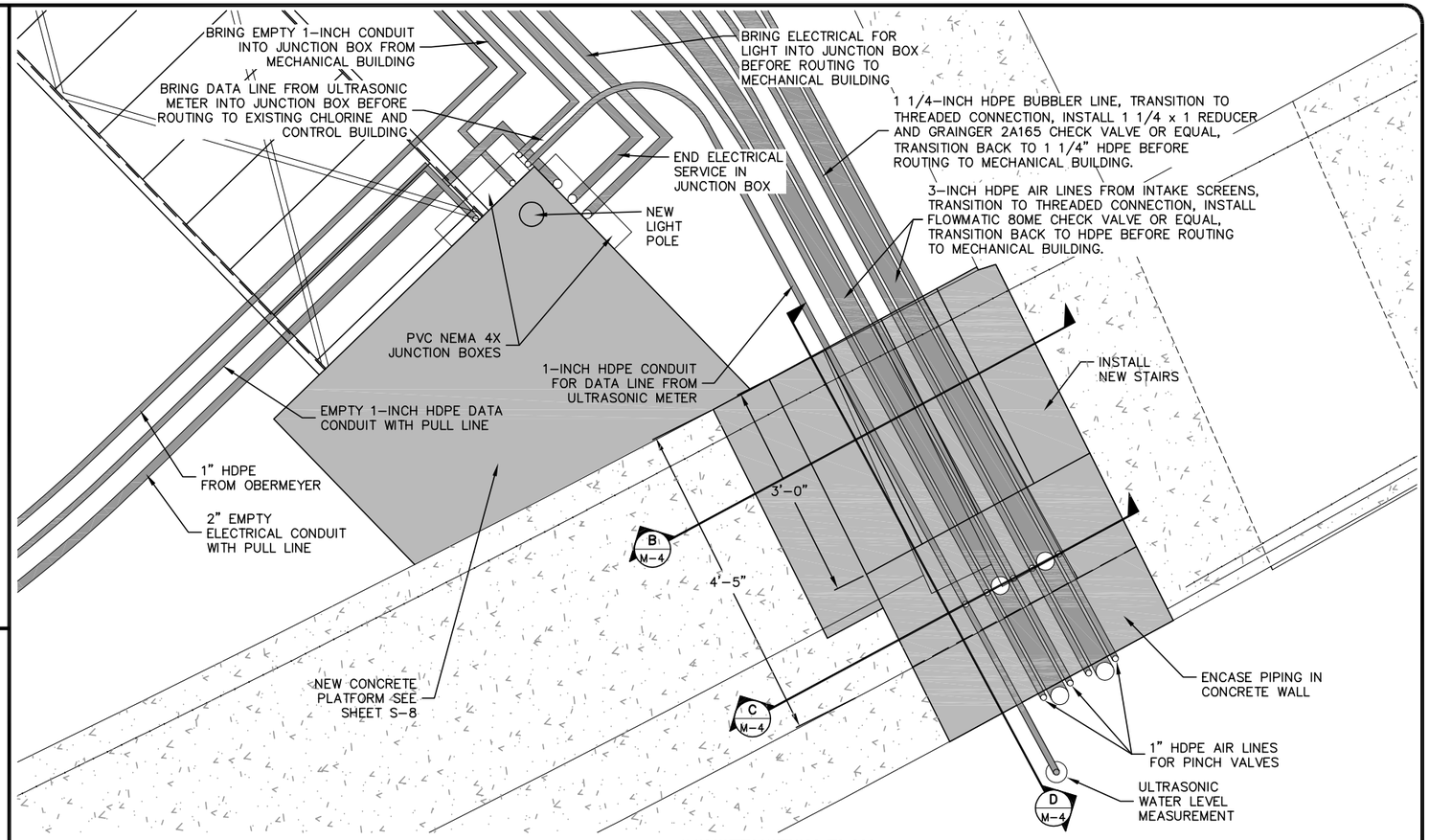
DEMOLITION PLAN
SCALE : 1" = 1'



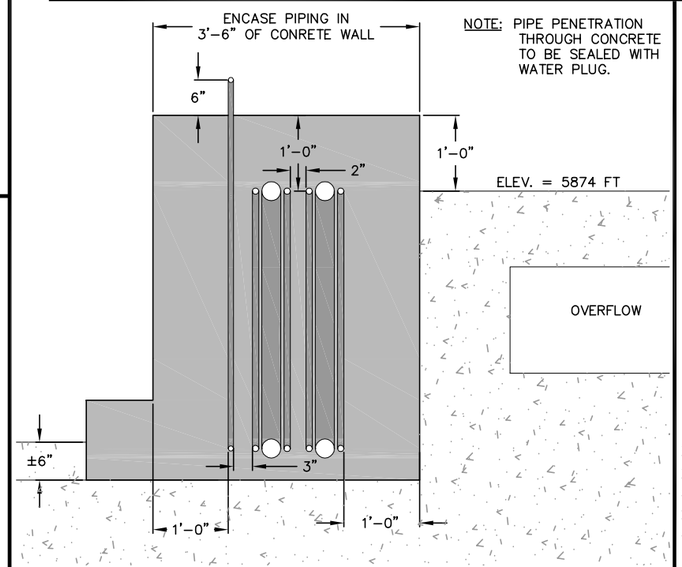
A M-4 **SECTION**
DEMOLITION
SCALE : 1" = 1'



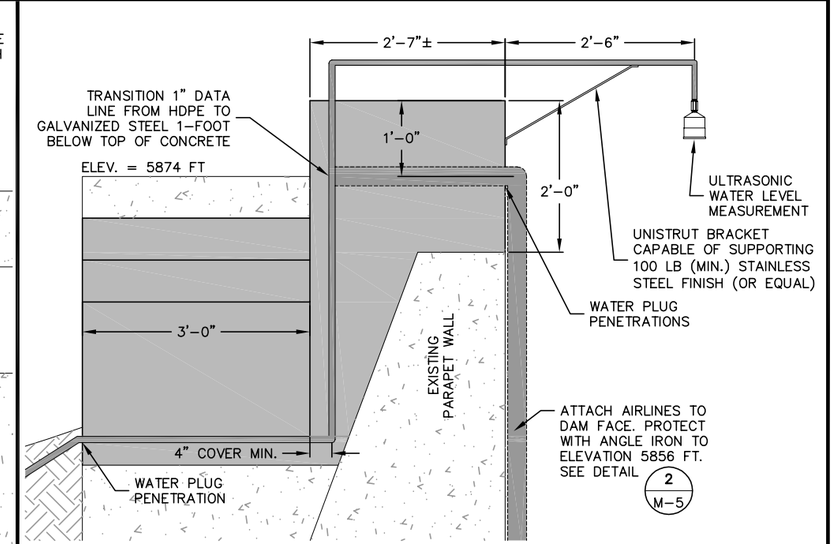
B M-4 **SECTION**
NEW STAIR CONSTRUCTION
SCALE : 1" = 1'



CONSTRUCTION PLAN
SCALE : 1" = 1'



C M-4 **SECTION**
NEW WALL CONSTRUCTION
SCALE : 1" = 1'



D M-4 **SECTION**
NEW CONDUIT
SCALE : 1" = 1'

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WARNING
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

AIR LINE DETAILS
DAM PENETRATION

● Project No. 15M424.117 ● BCD_mechanical.dwg ● Date JUNE, 2005 ● Designed ??? ● Drawn DAS ● Checked RCR ● Approved ???

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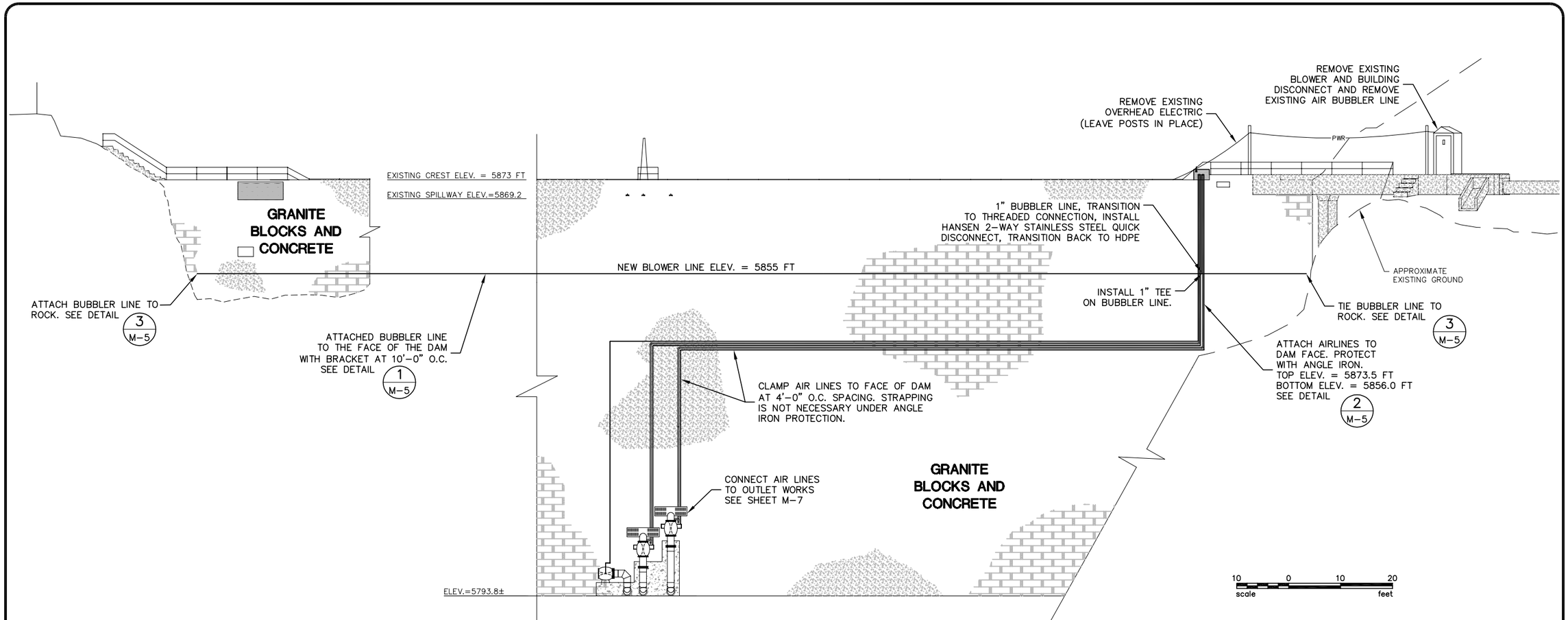
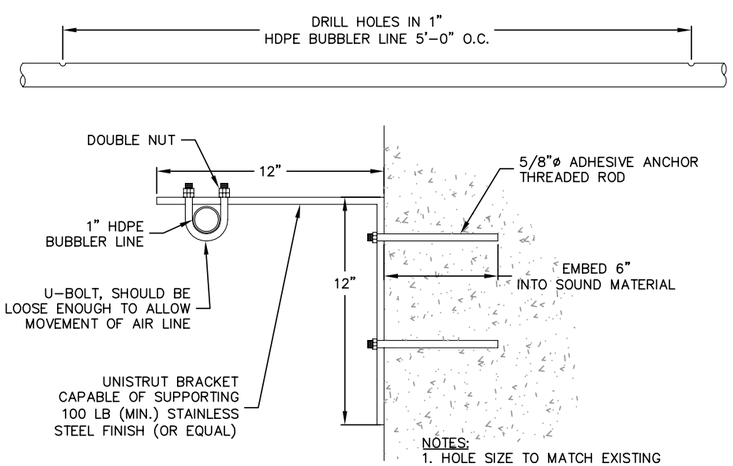
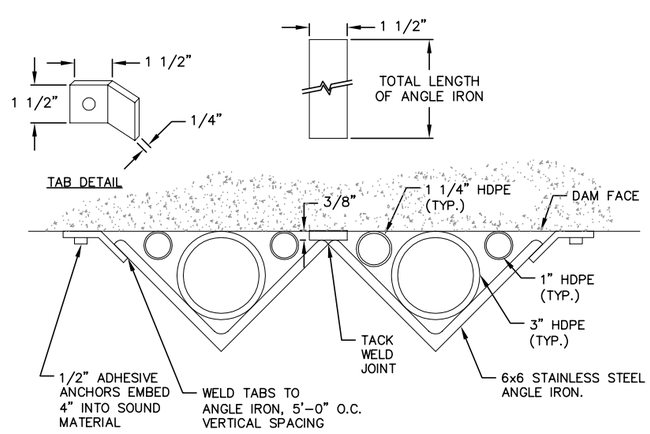


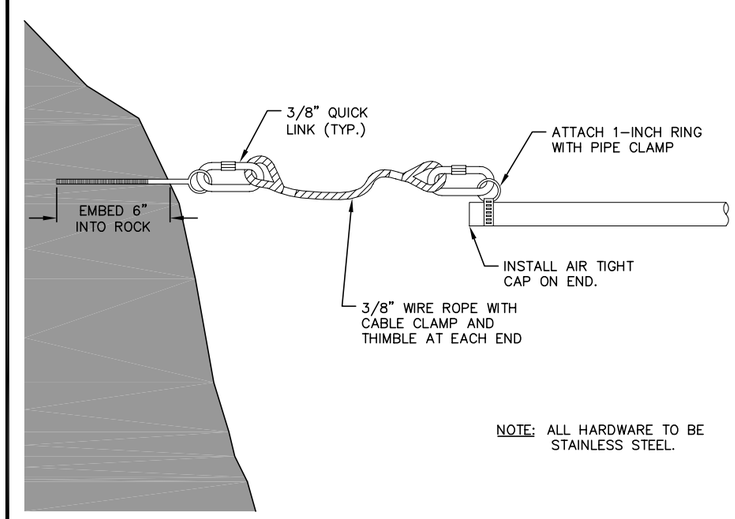


NOTES:
1. HOLE SIZE TO MATCH EXISTING AIR BUBBLER LINE HOLES SIZE.
2. SPACE HDPE SUPPORTS AT 10'-0" O.C.

1/M-5 DETAIL
BUBBLER LINE ATTACHMENT
SCALE : NOT TO SCALE



2/M-5 DETAIL
ANGLE IRON PROTECTION
SCALE : NOT TO SCALE



NOTE: ALL HARDWARE TO BE STAINLESS STEEL.

3/M-5 DETAIL
BUBBLER LINE END
SCALE : NOT TO SCALE

No.	Revision	By	Date

WARNING
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

FACE OF DAM CONDUIT LAYOUT AND DETAILS

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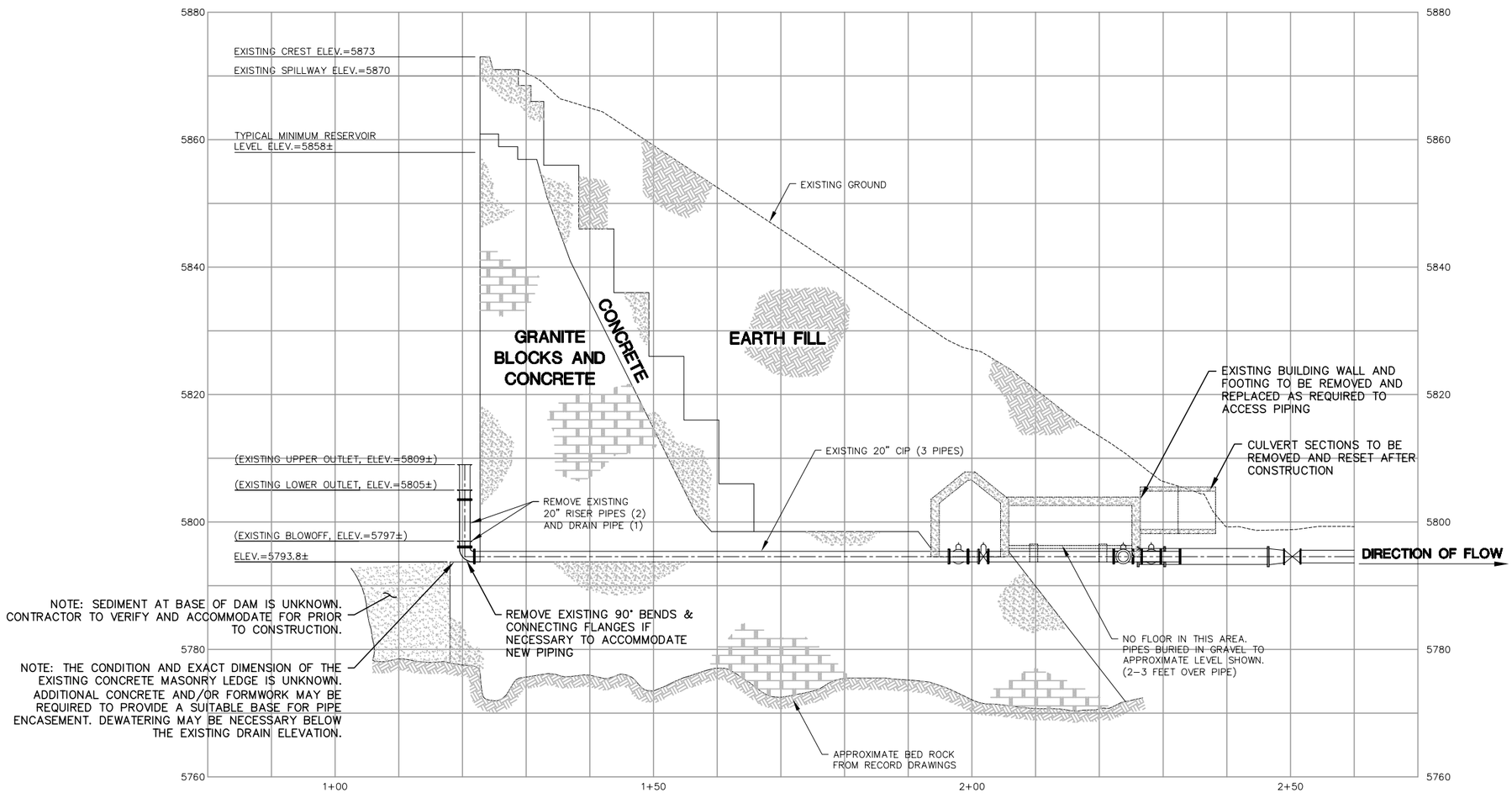

EXISTING RESERVOIR INTAKE SECTION

10 0 10 20
scale feet

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● Project No. 15M424.117 ● EX-2.dwg ● Date JUNE 2005 ● Designed KRJ ● Drawn RJA ● Checked PAS ● Approved RCR

No.	Revision	By	Date

WARNING
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

EXISTING DAM SECTION AND DEMOLITION

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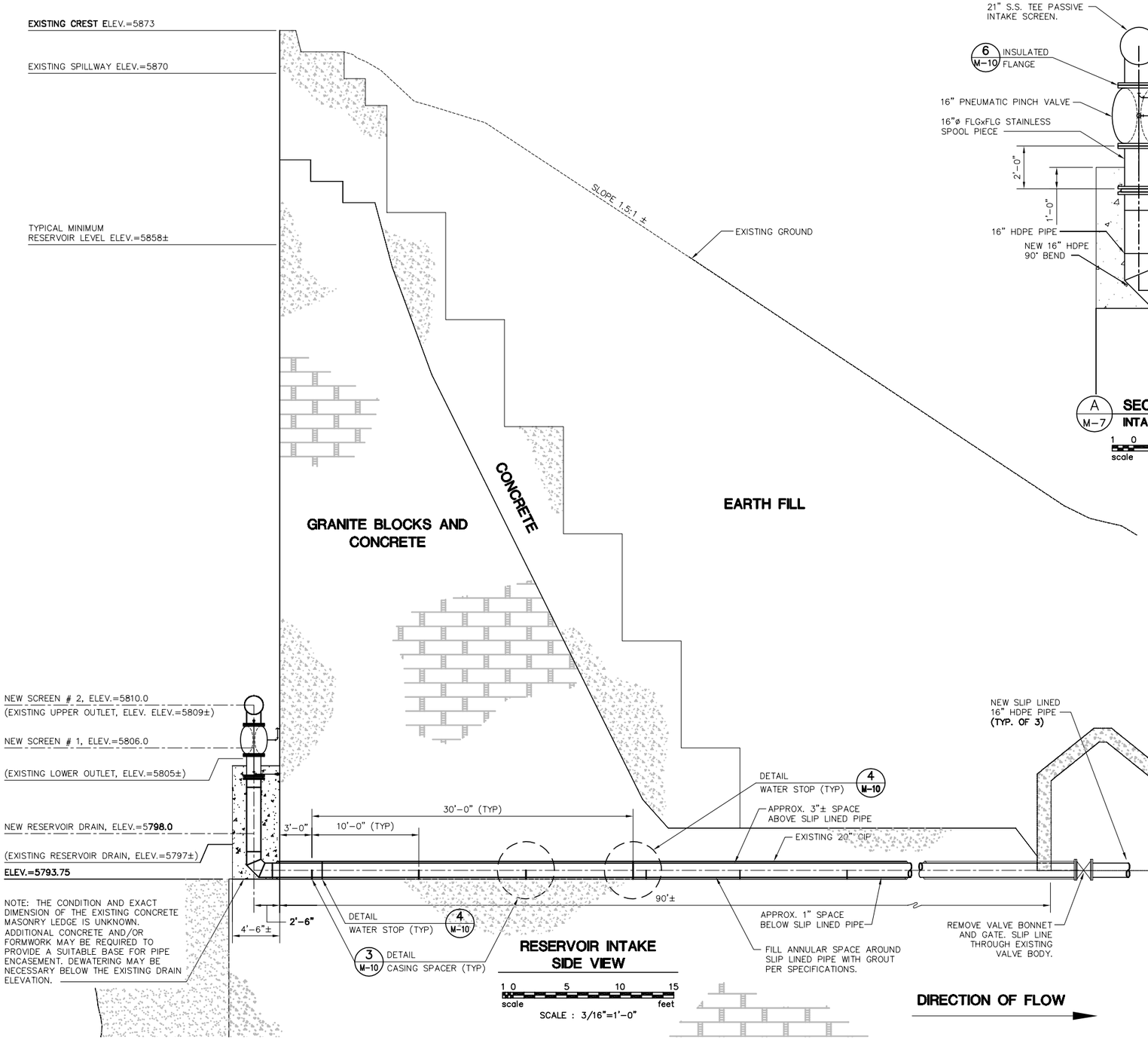
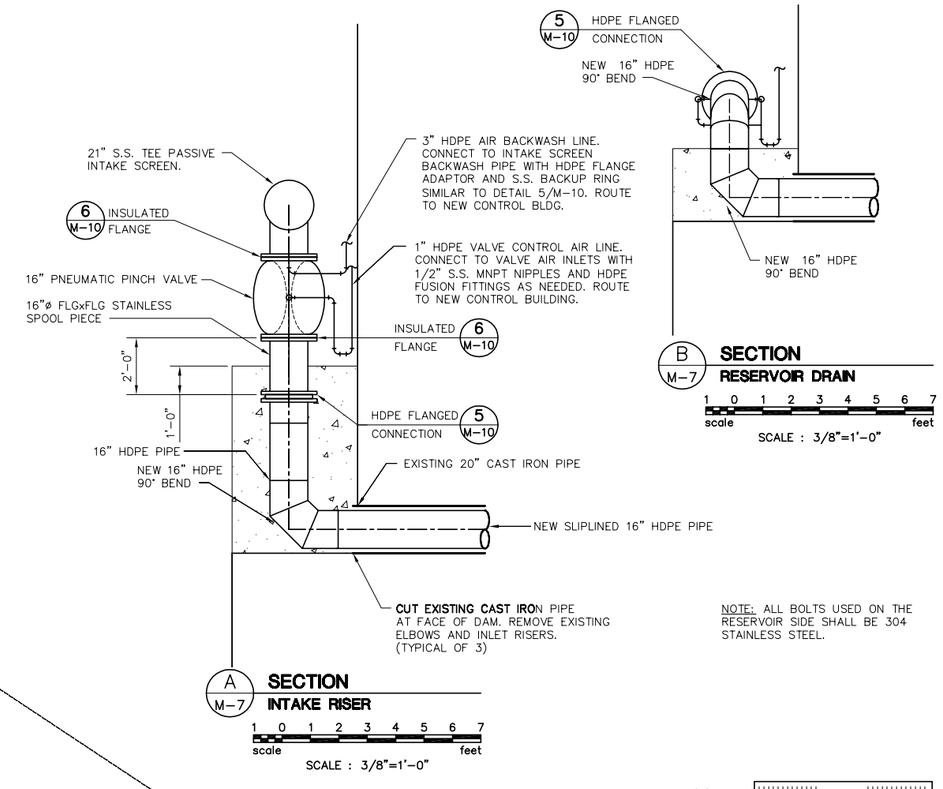


RESERVOIR INTAKE SIDE VIEW

1 0 5 10 15
scale feet
SCALE : 3/16"=1'-0"



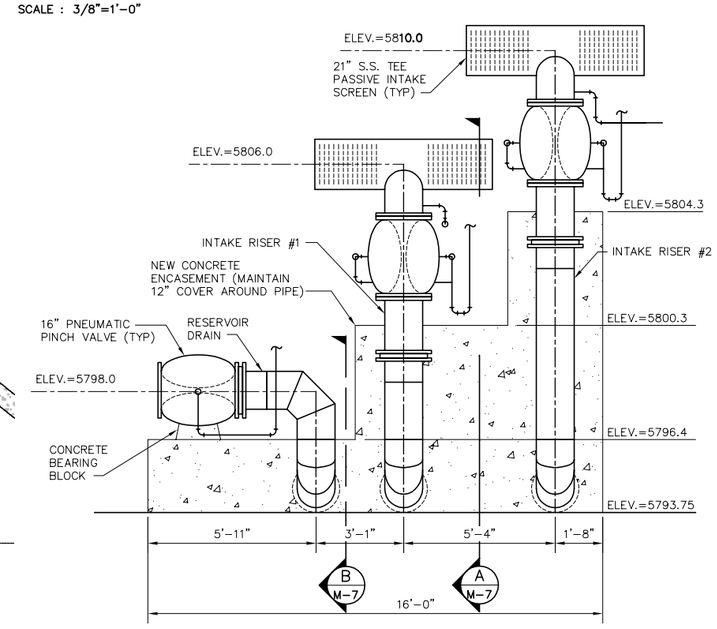
NOTE: ALL BOLTS USED ON THE RESERVOIR SIDE SHALL BE 304 STAINLESS STEEL.

A M-7 SECTION INTAKE RISER

1 0 1 2 3 4 5 6 7
scale feet
SCALE : 3/8"=1'-0"

B M-7 SECTION RESERVOIR DRAIN

1 0 1 2 3 4 5 6 7
scale feet
SCALE : 3/8"=1'-0"



INTAKE PIPING FRONT VIEW

1 0 1 2 3 4 5 6 7
scale feet
SCALE : 3/8"=1'-0"

No.	Revision	By	Date

Project No. 15M424.117 ● OUTLET_SECTION.dwg ● Date JUNE 2005 ● Designed PAS ● Drawn RJA ● Checked PAS ● Approved RCR

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

INTAKE SECTIONS AND DETAILS

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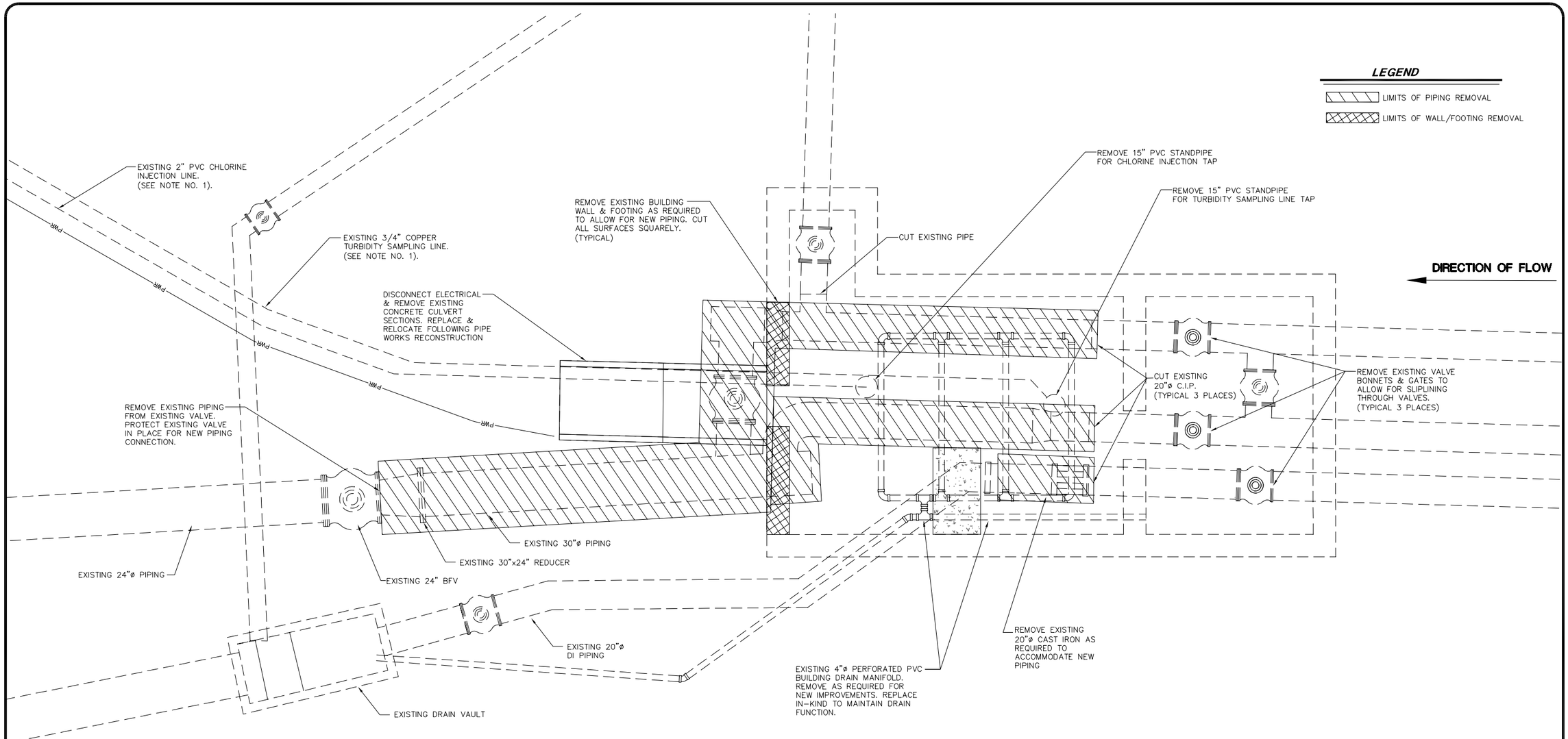

GENERAL NOTES:
1. REMOVE AND REPLACE AS INDICATED IN THE NEW CONSTRUCTION DRAWINGS. CONTRACTOR TO COORDINATE WITH BUTTE-SILVER BOW PRIOR TO REMOVAL OF EXISTING LINES.

2. EXISTING UTILITIES HAVE BEEN DRAWN BASED ON FIELD MEASUREMENTS, RECORD DRAWINGS, AND UTILITY LOCATE SERVICE. ACTUAL UTILITY CONFIGURATION MAY BE DIFFERENT THAN SHOWN. CONTRACTOR TO FIELD VERIFY AND NOTIFY ENGINEER OF DISCREPANCIES.

N

3 0 3 6
scale feet

No.	Revision	By	Date

WARNING
0 ½ 1
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

OUTLET WORKS
DEMOLITION DETAILS AND LIMITS

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● Project No. 15M424.117 ● DEM-2.DWG ● Date DEC. 2004 ● Designed KRJ ● Drawn RDH ● Checked RCR ● Approved RCR

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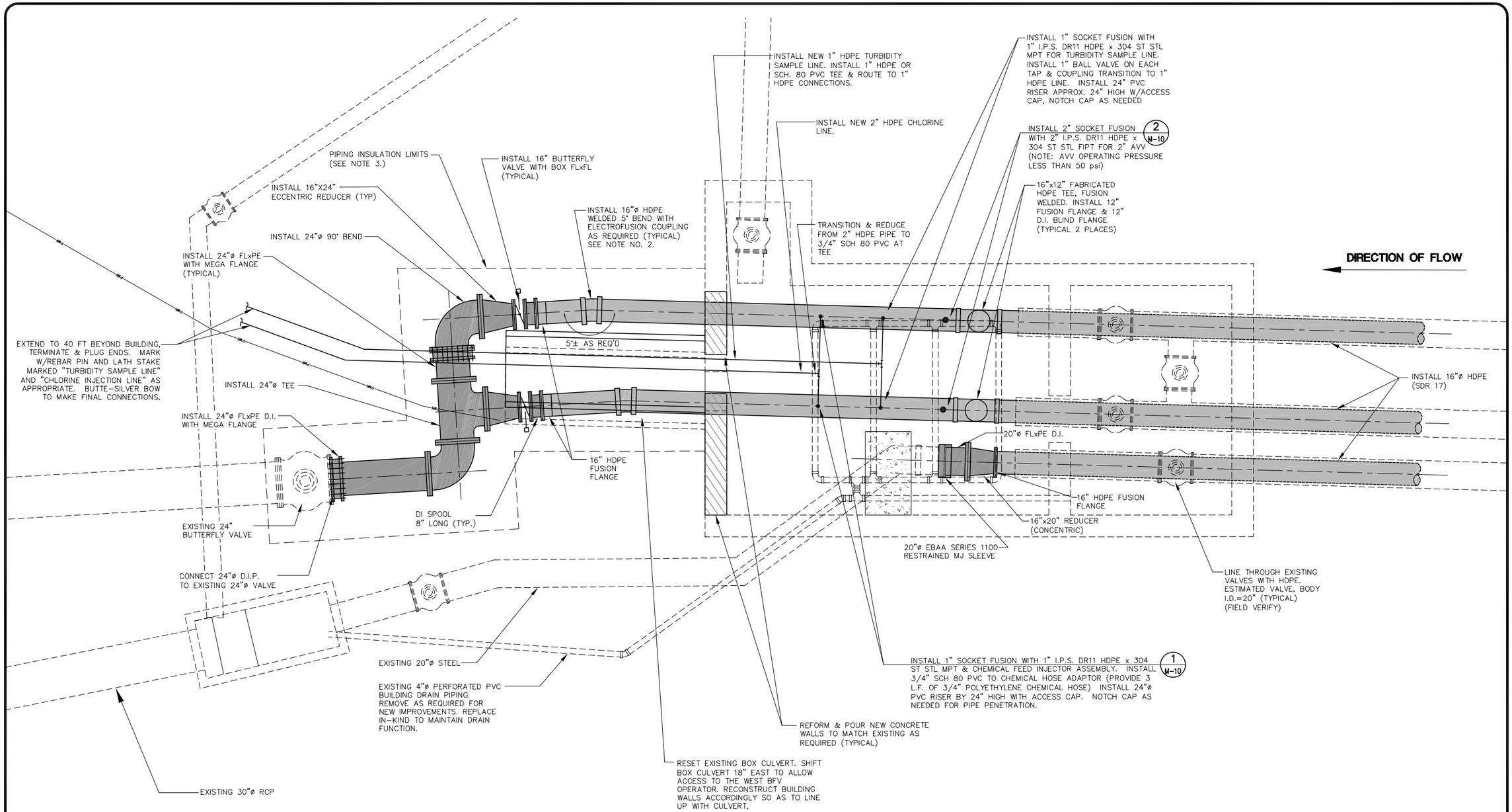

GENERAL NOTES:

1. MEGA FLANGE ADAPTERS SHALL BE EBAA IRON SERIES 2100, OR APPROVED EQUAL.

2. ADJUST GRADE OF HDPE CARRIER PIPE & INSTALL BEND AS NEEDED TO CONNECT TO NEW 16"ø D.I. SPOOLS. APPROXIMATE 4" GRADE ADJUSTMENT UP IS REQUIRED TO ACCOUNT FOR ECCENTRIC REDUCERS.

3. PROVIDE 2" THICK x 6' WIDE INSULATION BOARD OVER OUTLET PIPING. INSTALL 12" ABOVE PIPES. APPROX. 250 SF REQUIRED.

4. DOUBLE WRAP METALLIC PIPE, FITTINGS AND VALVES PER MPW02660.

5. PRESSURE TEST REQUIRED AGAINST NEW VALVES AND AGAINST BLIND FLANGE ON NORTH SIDE OF 24", 90° BEND. TEST PRESSURE SHALL BE 100 psi.

6. COVER INTERIOR PIPING WITH 2" MINUS WASHED ROCK TO A DEPTH OF 12".

N

3 0 3 6
scale feet

No.	Revision	By	Date

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

NEW PIPING PLAN

● Project No. 15M424.117 ● OUTLET_ PIPING PLAN.dwg ● Date JUNE 2005 ● Designed KRJ ● Drawn RDH ● Checked RCR ● Approved RCR

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Sheet No.
M-9

Q:\15\M424117\dwg\OUTLET_PIPING PLAN.dwg 6/20/2005 9:05:22 AM MDT

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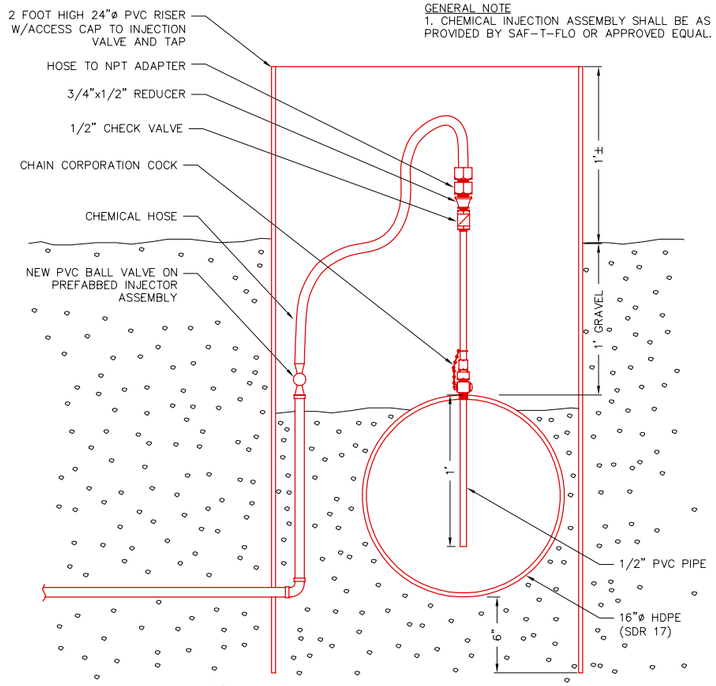
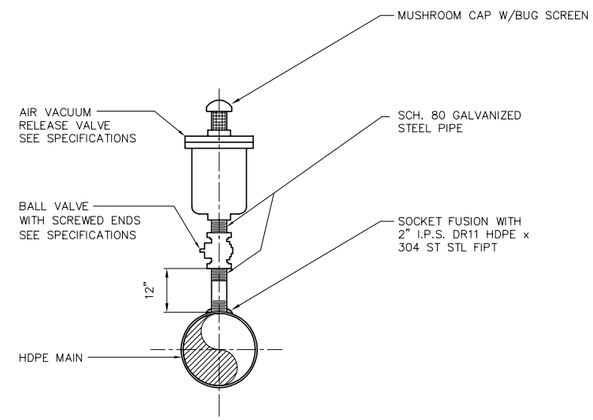
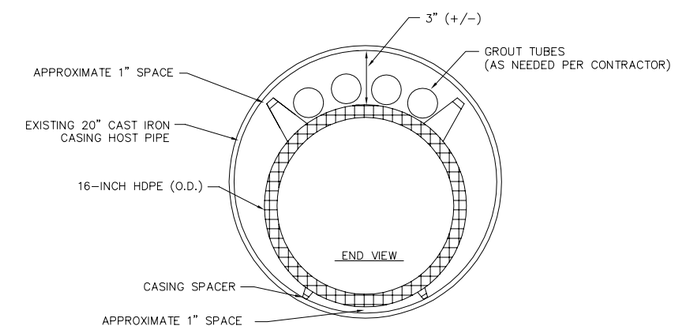
GENERAL NOTE
1. CHEMICAL INJECTION ASSEMBLY SHALL BE AS PROVIDED BY SAF-T-FLO OR APPROVED EQUAL.



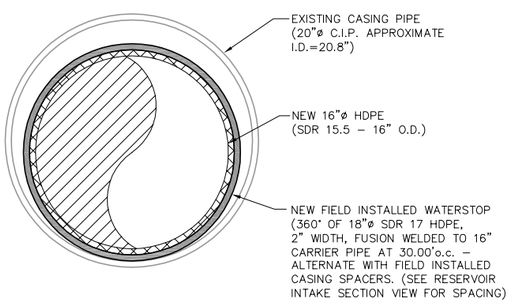
1 M-10 **DETAIL - CHLORINE INJECTOR**
SCALE : NONE



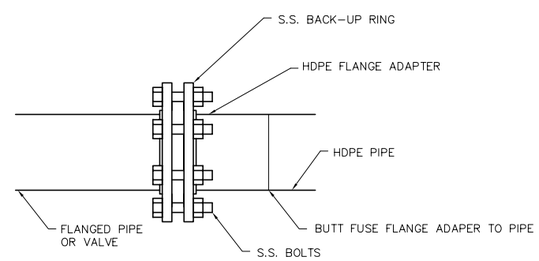
2 M-10 **DETAIL - AIR-VACUUM VALVE**
SCALE : NONE



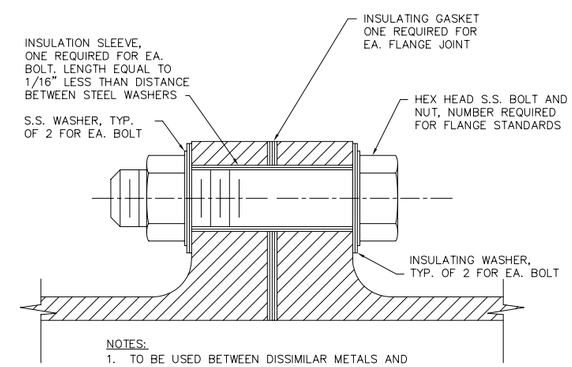
3 M-10 **DETAIL - FIELD INSTALLED CASING SPACER**
SCALE : NONE



4 M-10 **DETAIL - FIELD INSTALLED WATERSTOP**
SCALE : NONE



5 M-10 **DETAIL**
HDPE FLANGED CONNECTION
NOT TO SCALE



NOTES:
1. TO BE USED BETWEEN DISSIMILAR METALS AND BETWEEN NEW AND EXISTING PIPE CONNECTIONS.
2. INSULATING FLANGE SHALL BE COATED WITH MATERIAL COMPATABLE WITH REMAINDER OF PIPE WHERE APPLICABLE.
3. BOLTS AND NUTS SHALL BE STAINLESS STEEL. FOLLOW TORQUE REQUIREMENTS OF GASKET MANUFACTURER.

6 M-10 **DETAIL**
INSULATING FLANGE
NOT TO SCALE

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● Project No. 15M424.117 ● D-1 DETAILS.dwg ● Date JUNE 2005 ● Designed KRJ ● Drawn RDH ● Checked RCR ● Approved RCR

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

MISCELLANEOUS DETAILS

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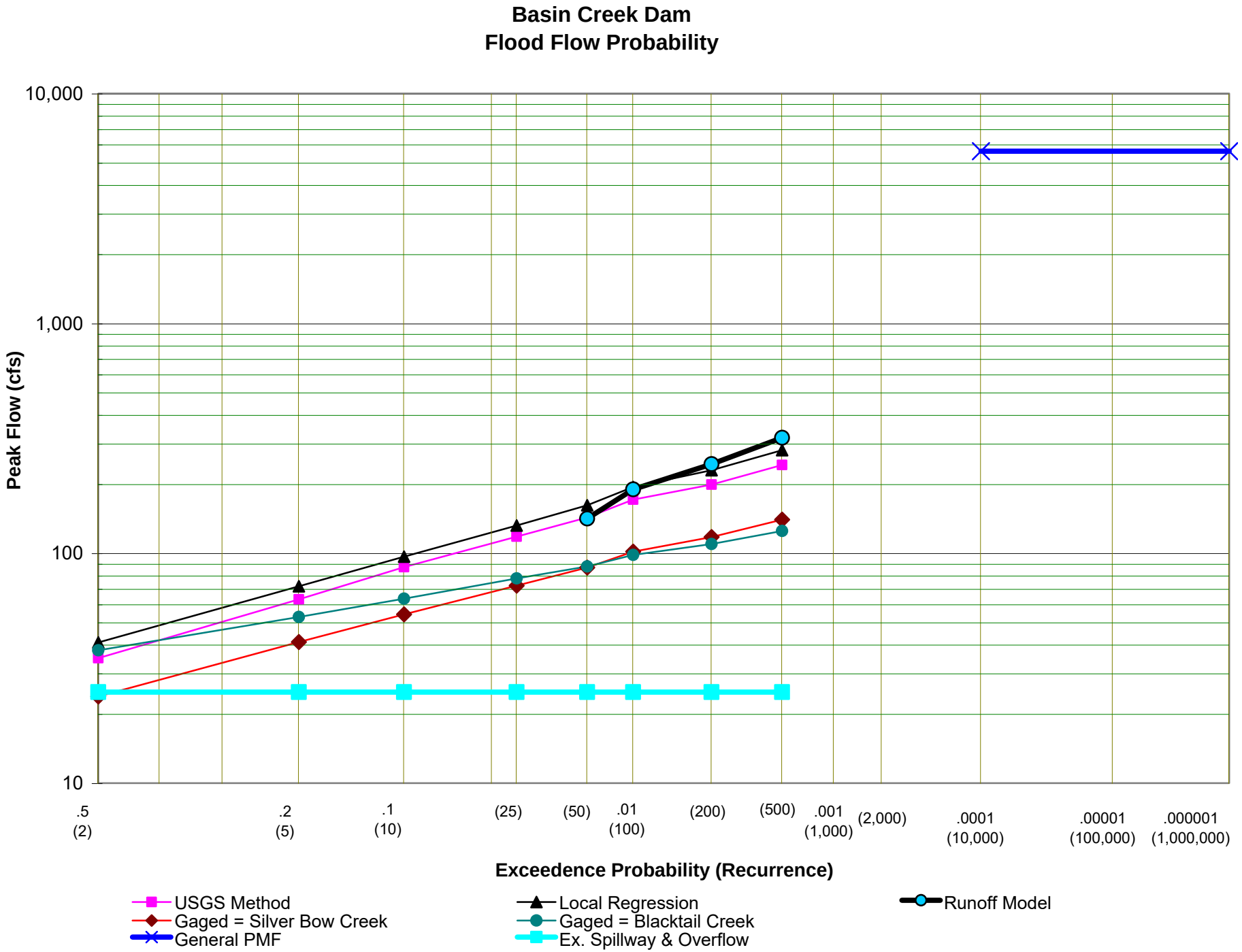
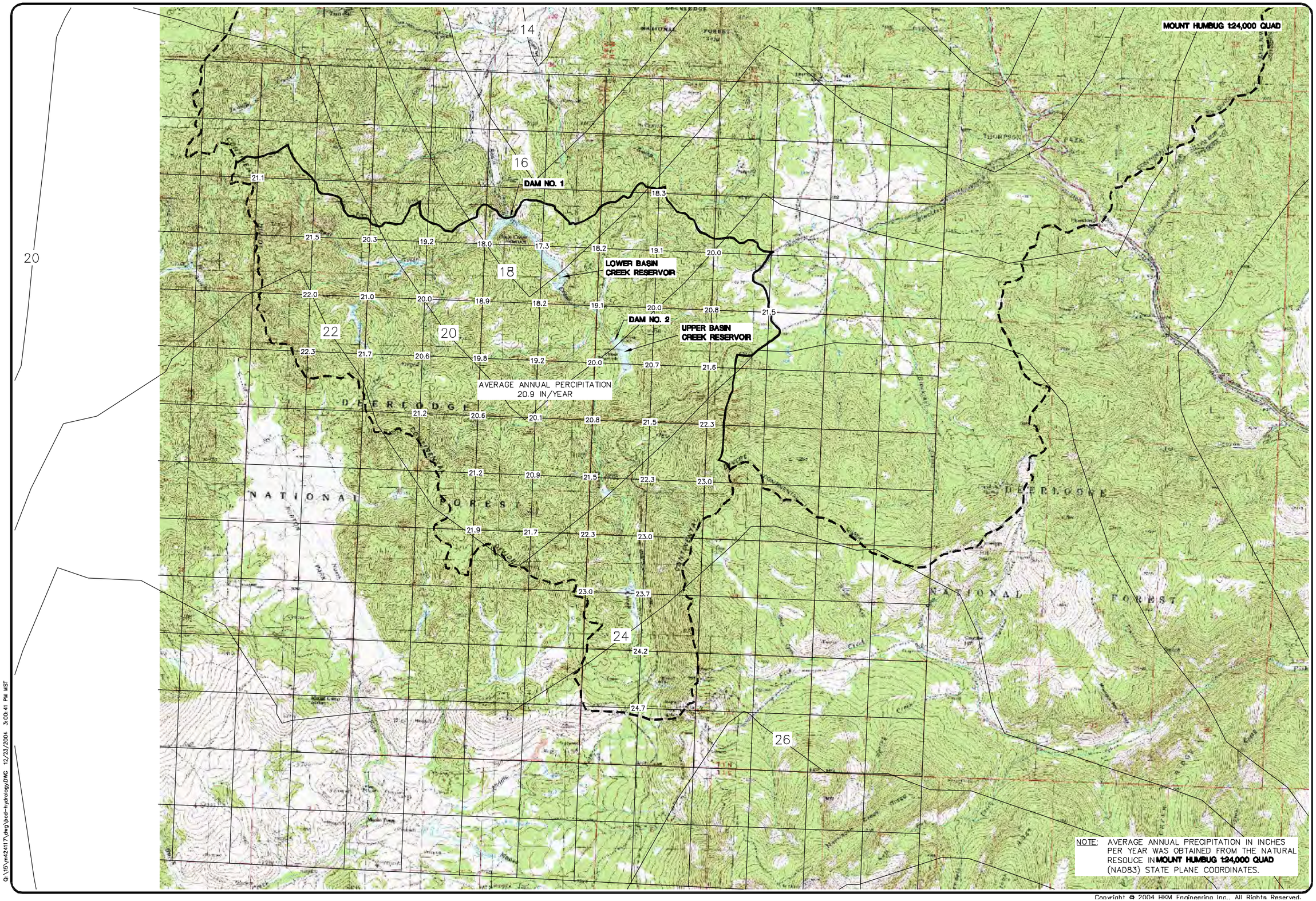
Sheet No.
M-10

APPENDIX B1

FLOOD FREQUENCY ANALYSIS


Basin Creek Dam
Flood Flow Probability
10,000
1,000
100
10
Peak Flow (cfs)
.5
(2)
.2
(5)
.1
(10)
(25)
(50)
.01
(100)
(200)
(500)
.001
(1,000)
(2,000)
.0001
(10,000)
.00001
(100,000)
.000001
(1,000,000)
Exceedence Probability (Recurrence)
USGS Method
Gaged = Silver Bow Creek
General PMF
Local Regression
Gaged = Blacktail Creek
Ex. Spillway & Overflow
Runoff Model



NOTE: AVERAGE ANNUAL PRECIPITATION IN INCHES PER YEAR WAS OBTAINED FROM THE NATURAL RESOUCE IN **MOUNT HUMBUG 1:24,000 QUAD** (NAD83) STATE PLANE COORDINATES.

No.	Revision	By	Date

WARNING
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BASIN CREEK DAM
BUTTE, MONTANA

AVERAGE ANNUAL PRECIPITATION GRID CALCULATIONS

HKM Engineering Inc.
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Sheet No.
B1-2

● Project No. 15M424.117 ● BCD-HYDROLOGY.DWG ● Date JAN. 2005 ● Designed SMJ ● Drawn SMJ ● Checked RR ● Approved RR

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Methods for Estimating Flood Frequency in Montana
Based on Data through Water year 1998
Water-Resources Investigations Report 03-4308

By Charles Parrett and D.R. Johnson

West Region: Regression Equations Based on Basin Characteristics

$$Q_2 = 0.268A^{0.927}P^{1.60}(F+1)^{-0.508}$$

$$Q_5 = 15.4A^{0.884}P^{1.35}(F+1)^{-0.577}$$

$$Q_{10} = 3.63A^{0.86}P^{1.25}(F+1)^{-0.605}$$

$$Q_{25} = 8.50A^{0.835}P^{1.14}(F+1)^{-0.639}$$

$$Q_{50} = 13.2A^{0.823}P^{1.09}(F+1)^{-0.652}$$

$$Q_{100} = 18.7A^{0.812}P^{1.06}(F+1)^{-0.664}$$

$$Q_{200} = 24.7A^{0.804}P^{1.04}(F+1)^{-0.674}$$

$$Q_{500} = 35.4A^{0.792}P^{1.02}(F+1)^{-0.69}$$

A = Drainage Area, mi^2
P = Mean Annual Precipitation, in.
F = Percentage of Basin Covered by forest

Valid Range of Basin Parameters

A	Min.	0.86
	Max.	2,378
P	Min.	12
	Max.	79
F	Min.	0
	Max.	100

Parameter Input:

A =	12.0	mi^2, Valid?	Yes
P =	20.9	in, Valid?	Yes
F =	95	%, Valid?	Yes

Flood Frequency Output:

Q_2=	35 cfs	Q_{50}=	143 cfs
Q_5=	63 cfs	Q_{100}=	171 cfs
Q_{10}=	87 cfs	Q_{200}=	199 cfs
Q_{25}=	118 cfs	Q_{500}=	242 cfs

Methods for Estimating Flood Frequency in Montana
Based on Data through Water year 1998
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By Charles Parrett and D.R. Johnson

Southwest Region: Regression Equations Based on Basin Characteristics

$$Q_2 = 3.02A^{0.881}(E_{6000}+1)^{0.0981}$$

$$Q_5 = 17.1A^{0.80}(E_{6000}+1)^{-0.104}$$

$$Q_{10} = 41.9A^{0.765}(E_{6000}+1)^{-0.214}$$

$$Q_{25} = 109A^{0.728}(E_{6000}+1)^{-0.332}$$

$$Q_{50} = 201A^{0.704}(E_{6000}+1)^{-0.408}$$

$$Q_{100} = 351A^{0.682}(E_{6000}+1)^{-0.476}$$

$$Q_{200} = 582A^{0.66}(E_{6000}+1)^{-0.537}$$

$$Q_{500} = 1{,}060A^{0.636}(E_{6000}+1)^{-0.611}$$

A = Drainage Area, mi^2
E6000 = percentage of basin above 6,000 ft elevation

Valid Range of Basin Parameters

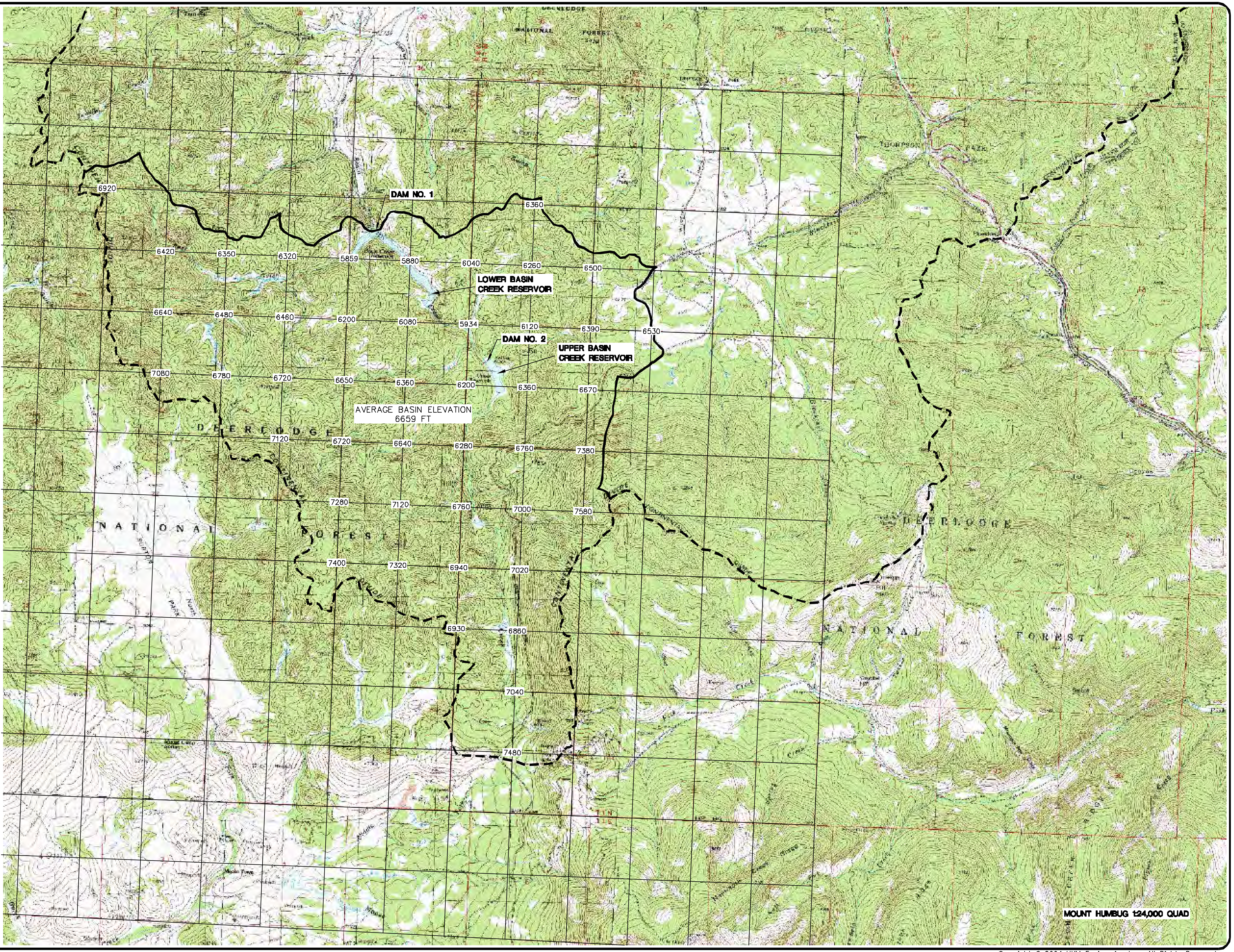
A	Min.	0.39
	Max.	2,476
E_{6000}	Min.	0
	Max.	100

Parameter Input:

A =	12.0	mi^2, Valid?	Yes
E_{6000} =	96	%, Valid?	Yes

Flood Frequency Output:

Q_2=	43 cfs	Q_{50}=	179 cfs
Q_5=	78 cfs	Q_{100}=	217 cfs
Q_{10}=	106 cfs	Q_{200}=	258 cfs
Q_{25}=	146 cfs	Q_{500}=	315 cfs



BASIN CREEK DAM
BUTTE, MONTANA

AVERAGE BASIN ELEVATION GRID CALCULATIONS

● Project No. 15M424.117 ● BCD-HYDROLOGY.DWG ● Date JAN. 2005 ● Designed SMJ ● Drawn SMJ ● Checked RR ● Approved RR

No.	Revision	By	Date

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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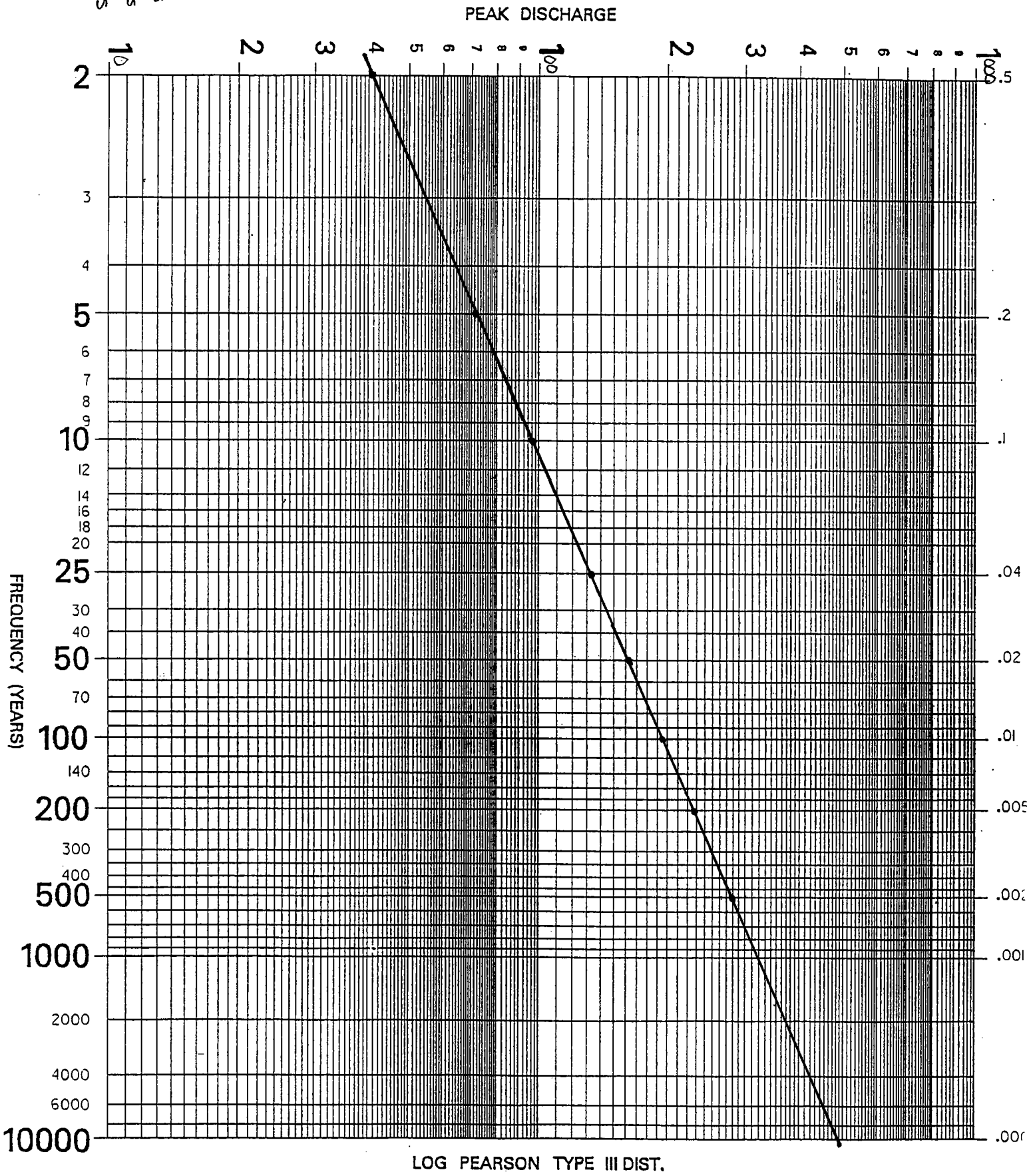
Q:\15\m424117\dwg\bcd-hydrology.DWG 12/23/2004 3:00:41 PM MST

Q_2 = 40.9 cfs
Q_5 = 71.9 cfs
Q_{10} = 96.7 cfs
Q_{25} = 132.1 cfs
Q_{50} = 161.7 cfs
Q_{100} = 194.2 cfs
Q_{200} = 229.6 cfs
Q_{500} = 281.0 cfs

MDT
HYDRAULICS SECTION
FREQUENCY CURVE

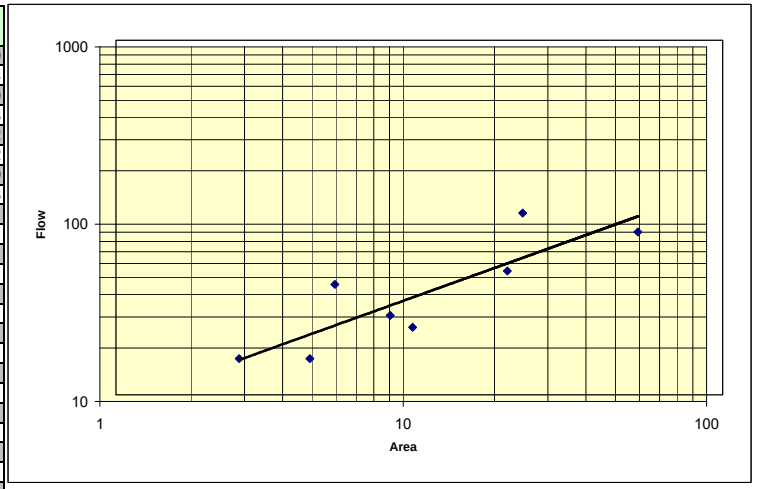


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q2	2var Q2	3var Q2
BCD	12.017	20.9	6.659	40.9	37.1	51.3

	Area^ 0.61619878	Area^ 0.614235345	Area^ 0.382874911
	x 8.84067389	Precip^ 0.508245741	Precip^ 1.017641907
		x 1.717020162	Ave elev^ 2.388604766
			x 0.009690348
Correlation Coef.	0.857	0.891	0.946
Std. Error	40.66%	39.15%	28.92%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q2**	**Q2**	Gf	**Q2**	Gf	**Q2**	Gf
12301997	9.5	29	4.46		24	35.4	0.7	37.9	0.6	25.1	1.0
12304120	5.27	34	5		42	24.6	1.7	28.6	1.5	31.0	1.4
12323300	4.36	12	6.06		16	21.9	0.7	15.0	1.1	15.8	1.0
12325500	52.6	24	6.8		83	101.6	0.8	98.5	0.8	109.2	0.8
12348500	21.9	29	6.62		106	59.2	1.8	63.3	1.7	88.8	1.2
12351400	19.5	21	5.59		50	55.1	0.9	50.0	1.0	40.8	1.2
12353400	8.02	33	4.76		28	31.9	0.9	36.5	0.8	31.4	0.9
12389150	2.55	30	5.02		16	15.7	1.0	17.2	0.9	20.8	0.8

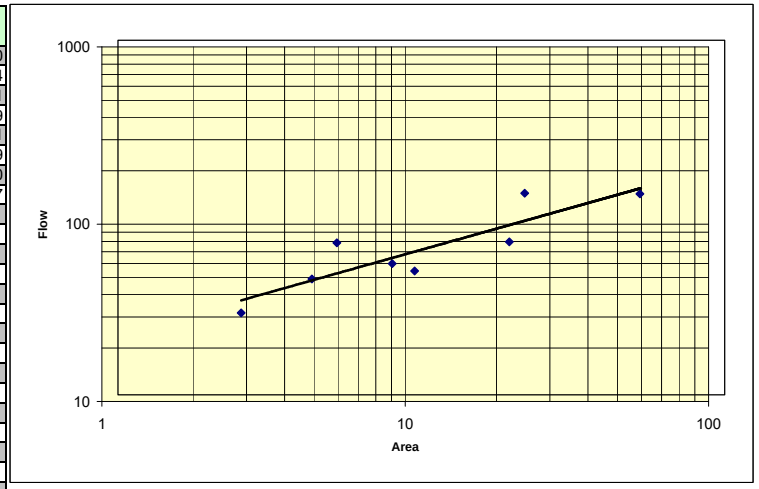


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q5	2var Q5	3var Q5
BCD	12.017	20.9	6.659	71.9	69.9	87.0

	Area^ 0.47999019	Area^ 0.479446659	Area^ 0.323745104
	x 21.785628	Precip^ 0.140695475	Precip^ 0.483510248
		x 13.84045867	Ave elev^ 1.607489527
			x 0.424611833
Correlation Coef.	0.886	0.890	0.932
Std. Error	27.17%	29.25%	24.37%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q5**	**Q5**	Gf	**Q5**	Gf	**Q5**	Gf
12301997	9.5	29	4.46		50	64.2	0.8	65.4	0.8	49.6	1.0
12304120	5.27	34	5		72	48.4	1.5	50.4	1.4	53.2	1.4
12323300	4.36	12	6.06		45	44.2	1.0	39.8	1.1	41.2	1.1
12325500	52.6	24	6.8		136	146.0	0.9	144.7	0.9	155.1	0.9
12348500	21.9	29	6.62		137	95.8	1.4	97.6	1.4	122.6	1.1
12351400	19.5	21	5.59		73	90.7	0.8	88.2	0.8	77.0	0.9
12353400	8.02	33	4.76		55	59.2	0.9	61.4	0.9	55.5	1.0
12389150	2.55	30	5.02		29	34.1	0.8	35.0	0.8	39.8	0.7

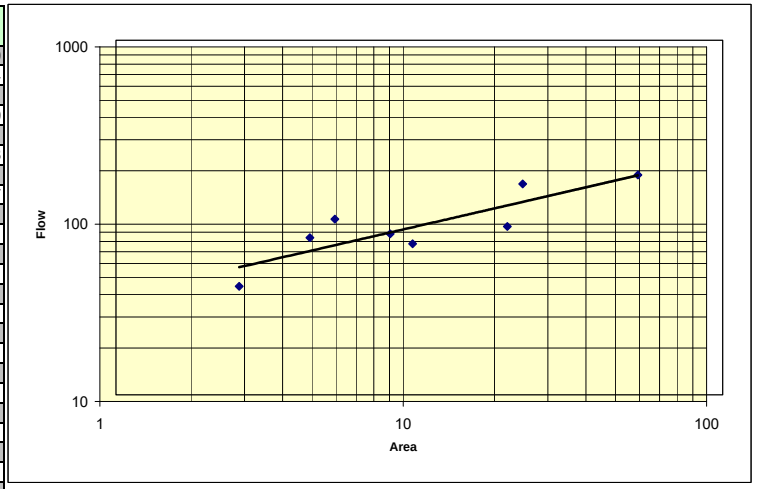


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q10	2var Q10	3var Q10
BCD	12.017	20.9	6.659	96.7	97.2	115.5

	Area^ 0.39473974	Area^ 0.394842216	Area^ 0.271680116
	x 36.225587	Precip^ -0.026525451	Precip^ 0.244645814
		x 39.46024002	Ave elev^ 1.271546628
			x 2.507438785
Correlation Coef.	0.858	0.858	0.890
Std. Error	25.51%	27.99%	26.13%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q10**	**Q10**	Gf	**Q10**	Gf	**Q10**	Gf
12301997	9.5	29	4.46		71	88.1	0.8	87.8	0.8	70.5	1.0
12304120	5.27	34	5		98	69.8	1.4	69.3	1.4	72.2	1.4
12323300	4.36	12	6.06		77	64.8	1.2	66.1	1.2	67.9	1.1
12325500	52.6	24	6.8		174	173.1	1.0	173.4	1.0	183.2	0.9
12348500	21.9	29	6.62		155	122.5	1.3	122.1	1.3	146.2	1.1
12351400	19.5	21	5.59		89	117.0	0.8	117.6	0.8	105.6	0.8
12353400	8.02	33	4.76		81	82.4	1.0	81.8	1.0	75.5	1.1
12389150	2.55	30	5.02		41	52.4	0.8	52.2	0.8	57.8	0.7

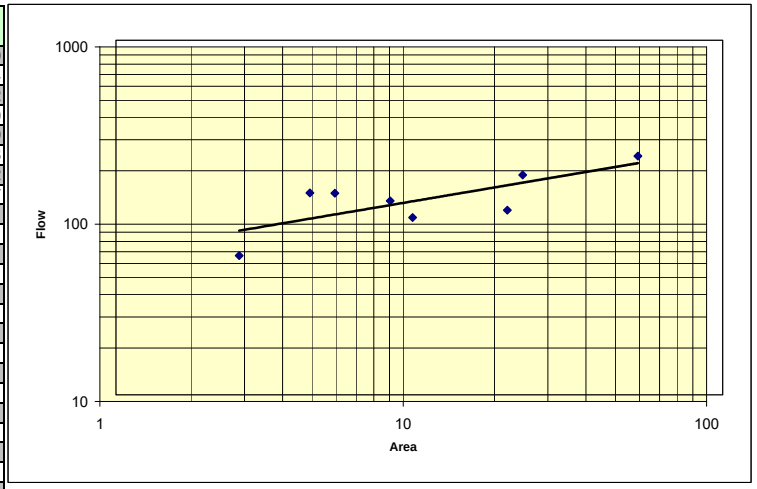


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q25	2var Q25	3var Q25
BCD	12.017	20.9	6.659	132.1	137.6	157.0

	Area^ 0.28972735	Area^ 0.290533015	Area^ 0.196406649
	x 64.2961495	Precip^ -0.20855159	Precip^ -0.001309543
		x 125.9578624	Ave elev^ 0.971776735
			x 15.32761604
Correlation Coef.	0.743	0.766	0.783
Std. Error	28.19%	29.71%	30.54%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q25**	**Q25**	Gf	**Q25**	Gf	**Q25**	Gf
12301997	9.5	29	4.46		100	123.4	0.8	120.0	0.8	101.5	1.0
12304120	5.27	34	5		137	104.1	1.3	97.8	1.4	101.0	1.4
12323300	4.36	12	6.06		138	98.5	1.4	115.1	1.2	117.5	1.2
12325500	52.6	24	6.8		222	202.7	1.1	205.3	1.1	214.1	1.0
12348500	21.9	29	6.62		174	157.2	1.1	153.0	1.1	175.6	1.0
12351400	19.5	21	5.59		110	152.0	0.7	158.2	0.7	145.7	0.8
12353400	8.02	33	4.76		124	117.5	1.1	111.2	1.1	104.6	1.2
12389150	2.55	30	5.02		61	84.3	0.7	81.3	0.7	88.0	0.7

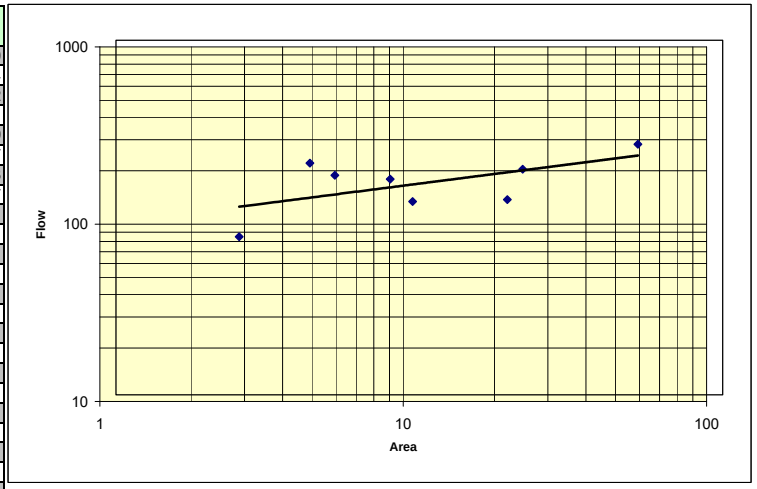


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q50	2var Q50	3var Q50
BCD	12.017	20.9	6.659	161.7	172.4	192.1

	Area^ 0.21994633	Area^ 0.221218948	Area^ 0.144159009
	x 93.6133744	Precip^ -0.329423734	Precip^ -0.159757568
		x 270.7937779	Ave elev^ 0.79558002
			x 48.27753683
Correlation Coef.	0.588	0.663	0.663
Std. Error	32.83%	33.33%	35.76%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q50**	**Q50**	Gf	**Q50**	Gf	**Q50**	Gf
12301997	9.5	29	4.46		123	153.6	0.8	147.0	0.8	128.1	1.0
12304120	5.27	34	5		173	134.9	1.3	122.4	1.4	125.7	1.4
12323300	4.36	12	6.06		203	129.4	1.6	165.4	1.2	168.3	1.2
12325500	52.6	24	6.8		259	223.8	1.2	228.4	1.1	236.4	1.1
12348500	21.9	29	6.62		187	184.6	1.0	176.8	1.1	197.9	0.9
12351400	19.5	21	5.59		126	179.9	0.7	191.6	0.7	179.1	0.7
12353400	8.02	33	4.76		165	148.0	1.1	135.7	1.2	129.0	1.3
12389150	2.55	30	5.02		78	115.0	0.7	108.6	0.7	115.8	0.7



PROJECT NAME	Regression
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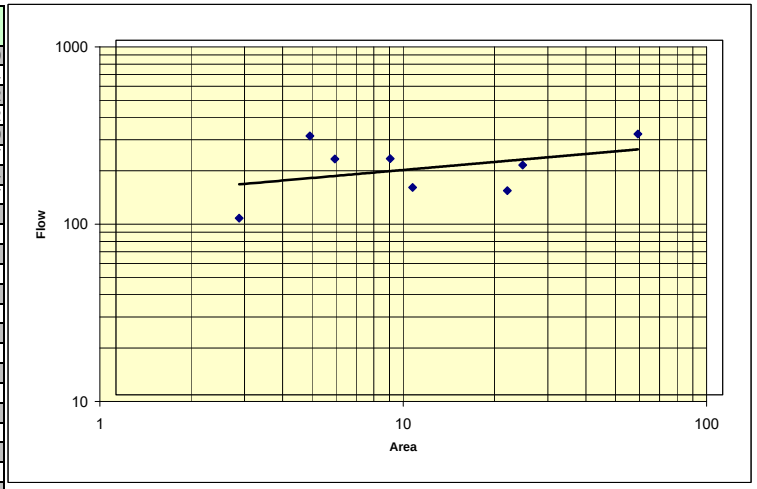
Name	Area	Precip	Ave elev	Area Q100	2var Q100	3var Q100
BCD	12.017	20.9	6.659	194.2	211.4	230.6

	Area^ 0.15010288	Area^ 0.151790736	Area^ 0.089746518
	x 133.693762	Precip^ -0.436911383	Precip^ -0.300305975
		x 546.9274591	Ave elev^ 0.640555137
			x 136.4469466
Correlation Coef.	0.397	0.564	0.548
Std. Error	37.85%	37.29%	40.95%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q100**	**Q100**	Gf	**Q100**	Gf	**Q100**	Gf
12301997	9.5	29	4.46		148	187.4	0.8	176.8	0.8	158.3	0.9
12304120	5.27	34	5		214	171.6	1.2	150.8	1.4	154.0	1.4
12323300	4.36	12	6.06		289	166.8	1.7	230.9	1.3	234.1	1.2
12325500	52.6	24	6.8		296	242.3	1.2	249.0	1.2	256.0	1.2
12348500	21.9	29	6.62		198	212.5	0.9	200.7	1.0	219.7	0.9
12351400	19.5	21	5.59		142	208.8	0.7	227.0	0.6	215.0	0.7
12353400	8.02	33	4.76		215	182.7	1.2	162.8	1.3	156.4	1.4
12389150	2.55	30	5.02		99	153.9	0.6	142.6	0.7	150.2	0.7



PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
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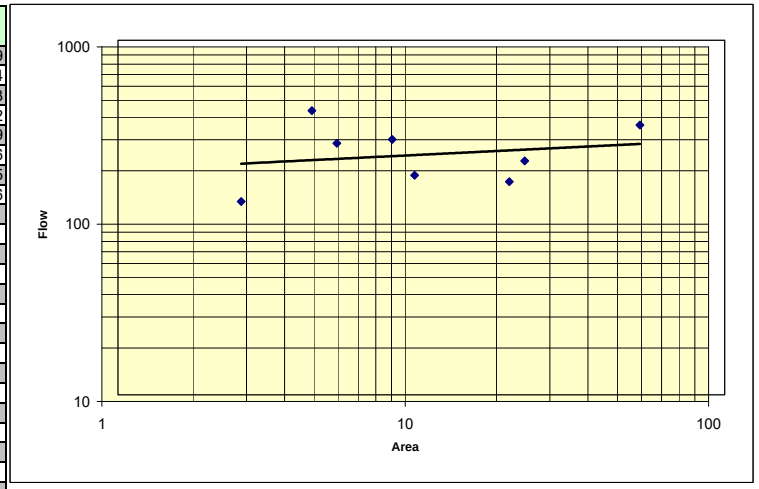
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q200	2var Q200	3var Q200
BCD	12.017	20.9	6.659	229.6	254.8	273.7

	Area^ 0.0845078	Area^ 0.086580824	Area^ 0.03580702
	x 186.108509	Precip^ -0.5366137	Precip^ -0.424822843
		x 1050.027346	Ave elev^ 0.524197456
			x 337.104268
Correlation Coef.	0.209	0.506	0.477
Std. Error	43.35%	41.82%	46.48%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q200**	**Q200**	Gf	**Q200**	Gf	**Q200**	Gf
12301997	9.5	29	4.46		173	225.1	0.8	209.5	0.8	191.4	0.9
12304120	5.27	34	5		262	214.2	1.2	182.8	1.4	186.0	1.4
12323300	4.36	12	6.06		401	210.8	1.9	314.4	1.3	318.0	1.3
12325500	52.6	24	6.8		333	260.1	1.3	268.9	1.2	275.1	1.2
12348500	21.9	29	6.62		209	241.6	0.9	225.2	0.9	242.5	0.9
12351400	19.5	21	5.59		159	239.2	0.7	265.1	0.6	253.5	0.6
12353400	8.02	33	4.76		276	221.9	1.2	192.6	1.4	186.3	1.5
12389150	2.55	30	5.02		123	201.4	0.6	183.6	0.7	191.5	0.6



PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
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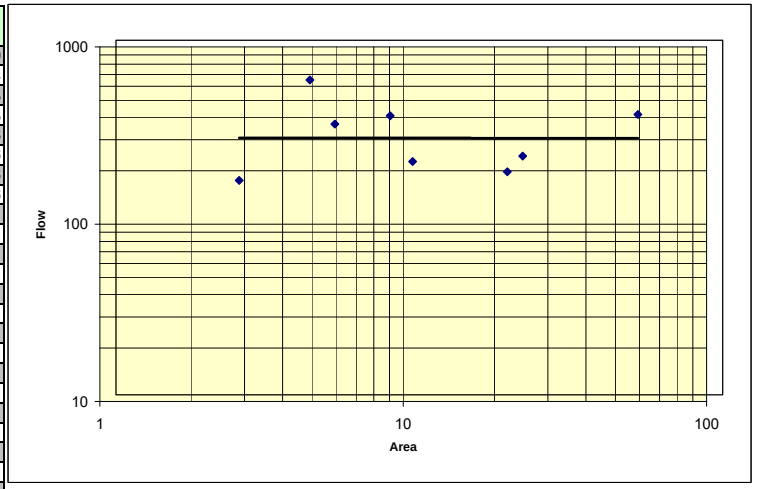
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q500	2var Q500	3var Q500
BCD	12.017	20.9	6.659	281.0	319.0	337.6

	Area^ -0.0010908	Area^ 0.001435611	Area^ -0.038904882
	x 281.730433	Precip^ -0.653966972	Precip^ -0.565147582
		x 2320.604011	Ave elev^ 0.416482166
			x 940.9336322
Correlation Coef.	0.002	0.495	0.458
Std. Error	50.72%	48.09%	53.91%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q500**	**Q500**	Gf	**Q500**	Gf	**Q500**	Gf
12301997	9.5	29	4.46		207	281.0	0.7	257.4	0.8	239.6	0.9
12304120	5.27	34	5		337	281.2	1.2	231.8	1.5	235.0	1.4
12323300	4.36	12	6.06		598	281.3	2.1	457.9	1.3	462.0	1.3
12325500	52.6	24	6.8		382	280.5	1.4	292.1	1.3	297.4	1.3
12348500	21.9	29	6.62		222	280.8	0.8	257.7	0.9	273.4	0.8
12351400	19.5	21	5.59		181	280.8	0.6	318.2	0.6	307.2	0.6
12353400	8.02	33	4.76		375	281.1	1.3	236.5	1.6	230.4	1.6
12389150	2.55	30	5.02		162	281.4	0.6	251.3	0.6	259.9	0.6



USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

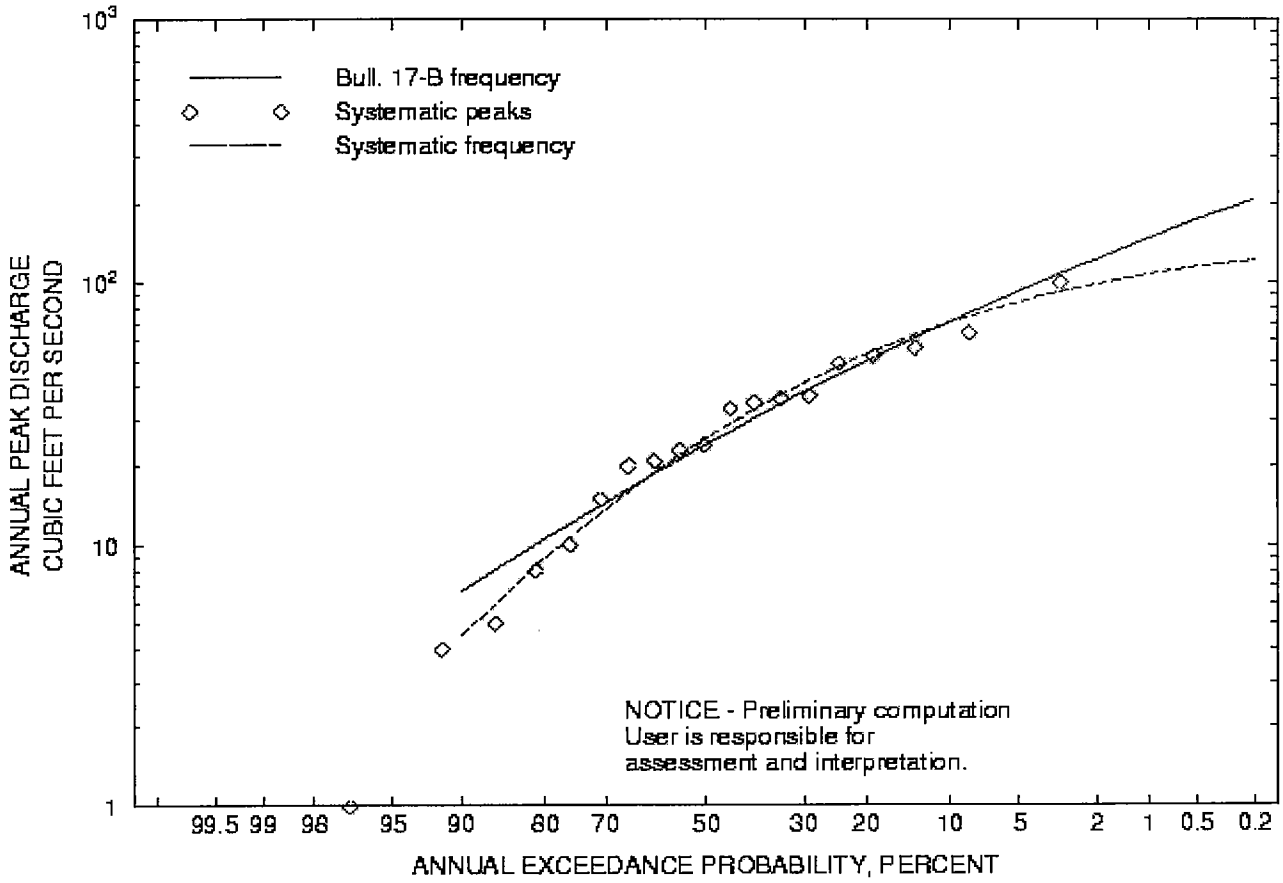
The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

12301997 Richards Creek near Libby, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

--	--	--	7	11	24	50	71	100	123	148	173
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

12301997 Richards Creek near Libby, MT

```
Location.-- Lat 48 15'31", Long 115 11'57", Hydrologic Unit 17010102.
Drainage area.--     9.50 square miles.
Datum of gage.--     2720.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1973	1973	0.31	5.0	--	--

1974	Apr. 26, 1974	1.11	49	--	--
1975	May 14, 1975	0.95	36	--	--
1976	May 11, 1976	0.90	24	--	--
1977	Apr. 25, 1977	0.10	1.0	--	--
1978	Mar. 31, 1978	0.53	8.0	--	--
1979	May 6, 1979	0.95	21	--	--
1980	June 14, 1980	0.96	52	--	--
1981	May 22, 1981	0.68	20	--	--
1982	May 18, 1982	1.57	64	--	--
1983	Apr. 25, 1983	1.11	56	--	--
1984	May 21, 1984	0.39	4.0	--	--
1985	June 7, 1985	1.30	100	--	--
1986	Mar. 31, 1986	0.95	35	--	--
1987	Apr. 18, 1987	0.73	15	--	--
1988	Apr. 7, 1988	0.63	10	--	--
1989	Apr. 22, 1989	1.06	23	--	--
1990	May 30, 1990	1.47	37	--	--
1991	May 18, 1991	1.36	33	--	--

Basin Characteristics:

Value	Abbrev	Explanation
443.0	SLOPE	Main channel slope, in ft per mile
5.04	LENGTH	Total stream length, miles
4460.0	ELEV	Mean basin elevation, ft above msl
0.0	EL6000	Percent of basin above 6,000 ft, msl
0.0	STORAGE	Percent of basin in lakes, ponds, and swamps
90.0	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
48.25861111	LAT_GAGE	Latitude of gage, in decimal degrees
115.19916667	LNG_GAGE	Longitude of gage, in decimal degrees
29.0	PRECIP	Mean annual precipitation, in inches
1.6	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
9.0	JANMIN	Mean minimum January temperature, in degrees F
6.8	WAC	Width of active channel, in feet
--	W2	Mean depth for active channel, in feet
11.0	WBF	Width of bankfull channel, in feet
--	W4	Mean depth of bankfull channel, in feet

0.786

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

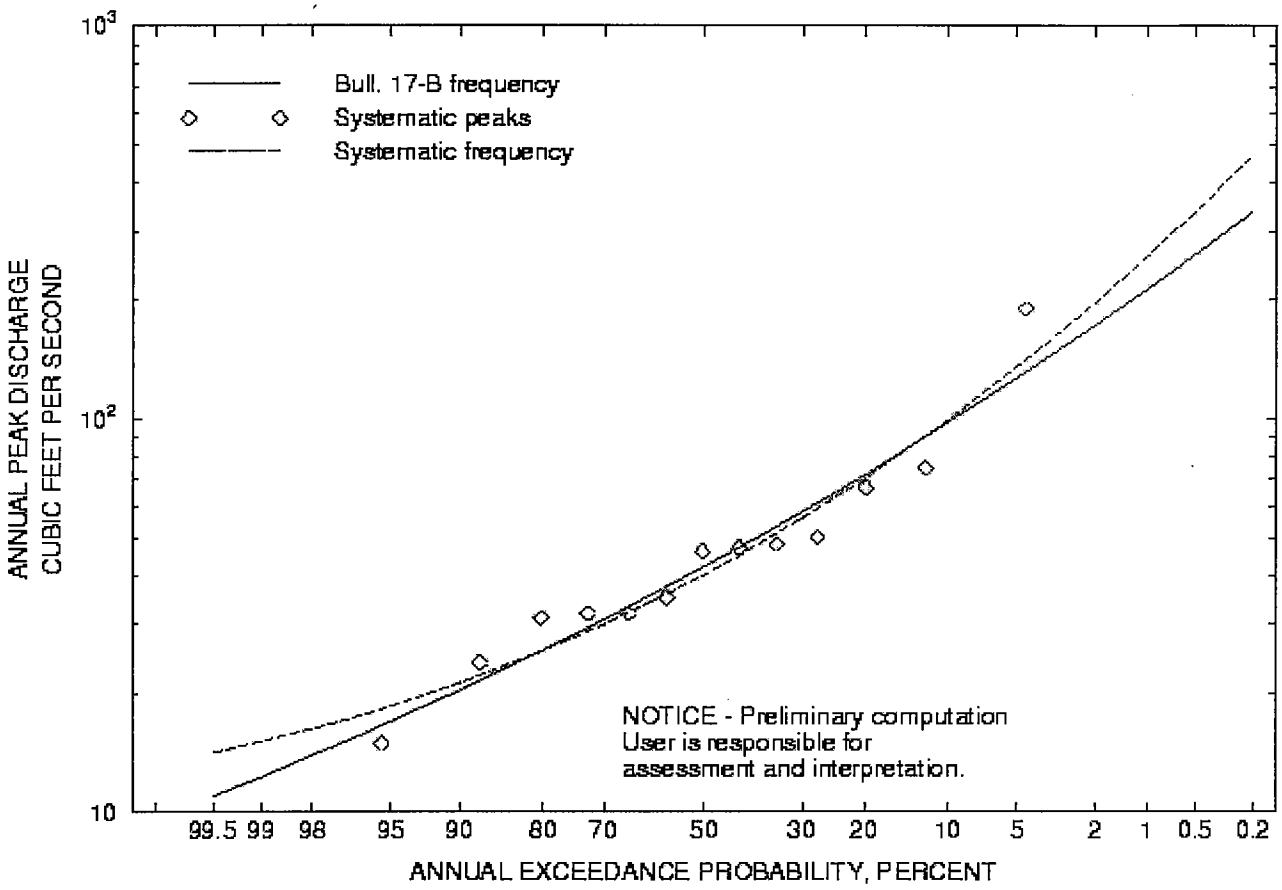
The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

12304120 Zulu Creek near Yaak, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

11	12	17	20	26	42	72	98	137	173	214	262
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

12304120 Zulu Creek near Yaak, MT

```
Location.-- Lat 48 43'49", Long 115 38'30", Hydrologic Unit 17010103.
Drainage area.--     5.27 square miles.
Datum of gage.--     3680.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1972	1972	2.56	190	--	--

1973	1973	1.12	32	--	--
1974	May 9, 1974	1.30	47	--	--
1975	May 14, 1975	1.09	32	--	--
1976	May 11, 1976	1.38	67	--	--
1977	Apr. 25, 1977	0.88	15	--	--
1978	May 15, 1978	1.29	46	--	--
1979	May 5, 1979	1.12	31	--	--
1980	Apr. 20, 1980	1.04	24	--	--
1981	May 10, 1981	1.16	35	--	--
1982	May 25, 1982	1.30	50	--	--
1983	1983	1.32	48	--	--
1984	May 20, 1984	1.49	75	--	--

Basin Characteristics:

Value	Abbrev	Explanation
484.0	SLOPE	Main channel slope, in ft per mile
3.37	LENGTH	Total stream length, miles
5000.0	ELEV	Mean basin elevation, ft above msl
12.0	EL6000	Percent of basin above 6,000 ft, msl
0.0	STORAGE	Percent of basin in lakes, ponds, and swamps
94.0	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
48.73027778	LAT_GAGE	Latitude of gage, in decimal degrees
115.64166667	LNG_GAGE	Longitude of gage, in decimal degrees
34.0	PRECIP	Mean annual precipitation, in inches
2.1	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
12.0	JANMIN	Mean minimum January temperature, in degrees F
8.5	WAC	Width of active channel, in feet
--	W2	Mean depth for active channel, in feet
13.0	WBF	Width of bankfull channel, in feet
--	W4	Mean depth of bankfull channel, in feet

0.323

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

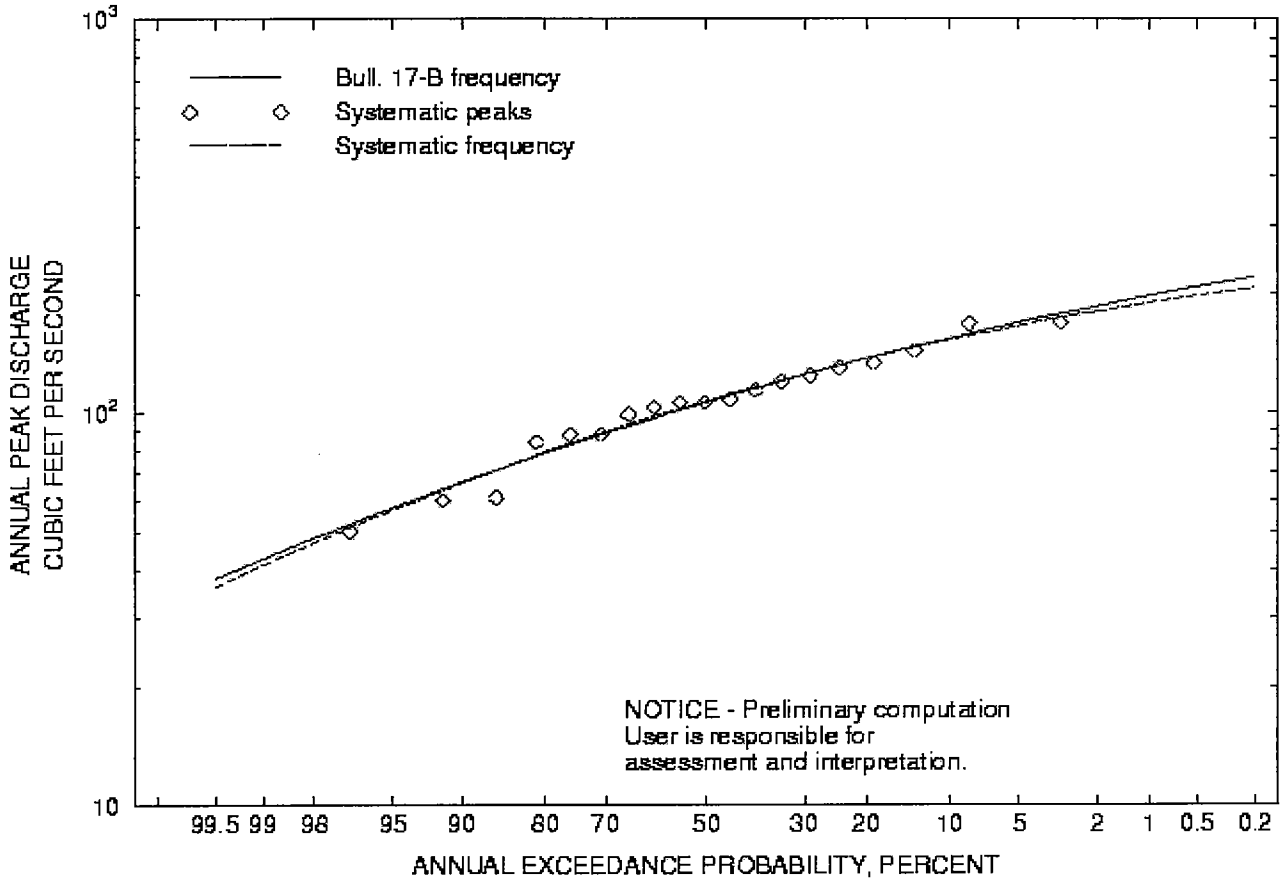
The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

12348500 Willow Creek near Corvallis, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

38	43	57	67	79	106	137	155	174	187	198	209
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

12348500 Willow Creek near Corvallis, MT

```
Location.-- Lat 46 17'40", Long 113 59'40", Hydrologic Unit 17010205.
Drainage area.--   21.90 square miles.
Datum of gage.--    4130.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1920	June 22, 1920	--	60	--	--

1921	June 9, 1921	--	114	--	--
1922	June 15, 1922	--	130	--	--
1958	May 28, 1958	2.70	103	--	--
1959	June 21, 1959	2.56	84	--	--
1960	June 3, 1960	2.60	99	--	--
1961	May 30, 1961	2.60	88	--	--
1962	June 13, 1962	2.56	88	--	--
1963	June 21, 1963	2.60	106	--	--
1964	June 17, 1964	2.70	144	--	--
1965	June 12, 1965	2.87	168	--	--
1966	May 28, 1966	1.39	61	--	--
1967	June 6, 1967	2.06	134	--	--
1968	June 2, 1968	1.81	106	--	--
1969	May 21, 1969	1.83	108	--	--
1970	June 5, 1970	1.94	124	--	--
1971	May 13, 1971	1.80	120	--	--
1972	June 2, 1972	2.31	170	--	--
1973	June 14, 1973	1.27	50	--	--

Basin Characteristics:

Value	Abbrev	Explanation
450.0	SLOPE	Main channel slope, in ft per mile
7.14	LENGTH	Total stream length, miles
6620.0	ELEV	Mean basin elevation, ft above msl
72.0	EL6000	Percent of basin above 6,000 ft, msl
0.18	STORAGE	Percent of basin in lakes, ponds, and swamps
78.0	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
46.29444444	LAT_GAGE	Latitude of gage, in decimal degrees
113.99444444	LNG_GAGE	Longitude of gage, in decimal degrees
29.0	PRECIP	Mean annual precipitation, in inches
1.6	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
14.0	JANMIN	Mean minimum January temperature, in degrees F
16.5	WAC	Width of active channel, in feet
0.8	W2	Mean depth for active channel, in feet
21.0	WBF	Width of bankfull channel, in feet
2.3	W4	Mean depth of bankfull channel, in feet

0.369

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

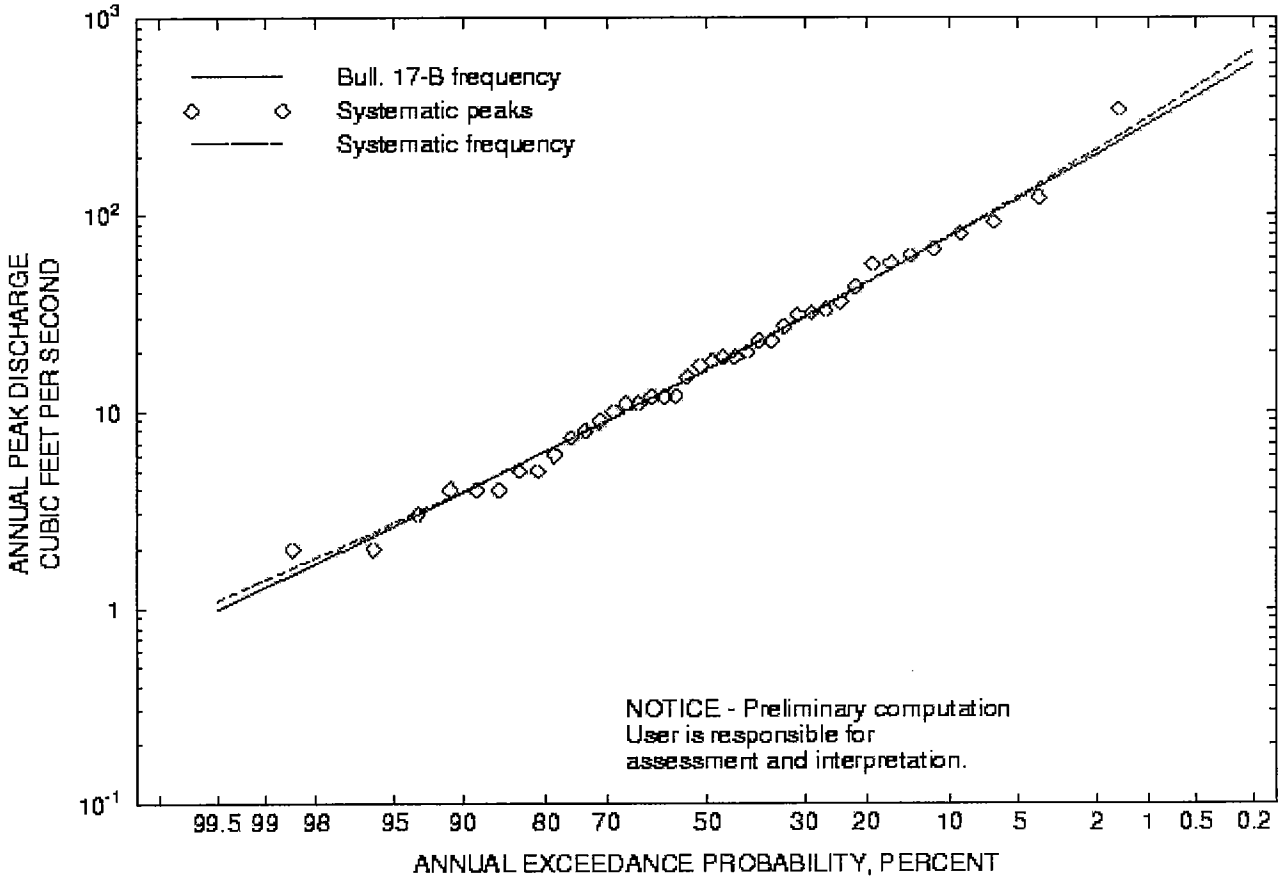
The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

12323300 Smith Gulch near Silver Bow, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

1	1	3	4	6	16	45	77	138	203	289	401
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

12323300 Smith Gulch near Silver Bow, MT

```
Location.-- Lat 45 57'00", Long 112 40'00", Hydrologic Unit 17010201.
Drainage area.--     4.36 square miles.
Datum of gage.--     5510.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1959	1959	--	5.0 _/2	--	--

1960	Mar. 21, 1960	1.97	43	--	--
1961	Sept.11, 1961	4.56	67	--	--
1962	Apr. 14, 1962	1.70	32	--	--
1963	Feb. 4, 1963	4.91	80	--	--
1964	Mar. 30, 1964	3.04	10	--	--
1965	Dec. 23, 1964	5.75	123	--	--
1966	Mar. 30, 1966	3.04	9.0	--	--
1967	May 8, 1967	3.28	19	--	--
1968	Feb. 21, 1968	2.77	2.0	--	--
1969	June 9, 1969	4.31	56	--	--
1970	June 12, 1970	3.34	19	--	--
1971	Feb. 12, 1971	3.30	18	--	--
1972	Mar. 17, 1972	3.12	12	--	--
1973	Apr. 22, 1973	3.11	11	--	--
1974	Jan. 15, 1974	3.73	33	--	--
1975	June 9, 1975	4.54	62	--	--
1976	Mar. 17, 1976	4.78 _/1	23	--	--
1977	Apr. 7, 1977	2.97	5.0	--	--
1978	Apr. 1, 1978	3.30	17	--	--
1979	May 5, 1979	2.77	4.0	--	--
1980	May 25, 1980	2.89	6.0	--	--
1981	May 22, 1981	3.06	11	--	--
1982	Apr. 14, 1982	3.12	12	--	--
1983	Mar. 2, 1983	3.48	23	--	--
1984	Apr. 20, 1984	3.38	20	--	--
1985	Apr. 2, 1985	4.40	57	--	--
1986	Feb. 24, 1986	5.20	92	--	--
1987	May 25, 1987	3.21	15	--	--
1988	Apr. 13, 1988	2.68	4.0	--	--
1989	Apr. 22, 1989	3.12	12	--	--
1990	Apr. 21, 1990	2.73	3.0	--	--
1991	Mar. 30, 1991	2.80	4.0	--	--
1992	June 30, 1992	9.32	345	--	--
1993	Mar. 18, 1993	2.92	8.0	--	--
1994	Apr. 22, 1994	2.61	2.0	--	--
1995	Feb. 19, 1995	3.55	27	--	--
1996	Feb. 9, 1996	3.66	31	--	--
1997	Mar. 20, 1997	3.81	36	--	--
1998	May 23, 1998	2.91 _/2	7.4	--	--

_/ Explanation of the footnotes used for Gage height data:
1 Gage height affected by backwater.
2 Gage height not the maximum for the year.

_/ Explanation of the footnotes used for Discharge data:
2 Discharge is an estimate.

Basin Characteristics:

Value	Abbrev	Explanation
136.0	SLOPE	Main channel slope, in ft per mile
5.9	LENGTH	Total stream length, miles
6060.0	ELEV	Mean basin elevation, ft above msl
55.0	EL6000	Percent of basin above 6,000 ft, msl

0.0	STORAGE	Percent of basin in lakes, ponds, and swamps
24.1	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
45.95	LAT_GAGE	Latitude of gage, in decimal degrees
112.66666667	LNG_GAGE	Longitude of gage, in decimal degrees
12.0	PRECIP	Mean annual precipitation, in inches
1.2	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
5.0	JANMIN	Mean minimum January temperature, in degrees F
3.0	WAC	Width of active channel, in feet
0.2	W2	Mean depth for active channel, in feet
5.5	WBF	Width of bankfull channel, in feet
0.5	W4	Mean depth of bankfull channel, in feet

0.309

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

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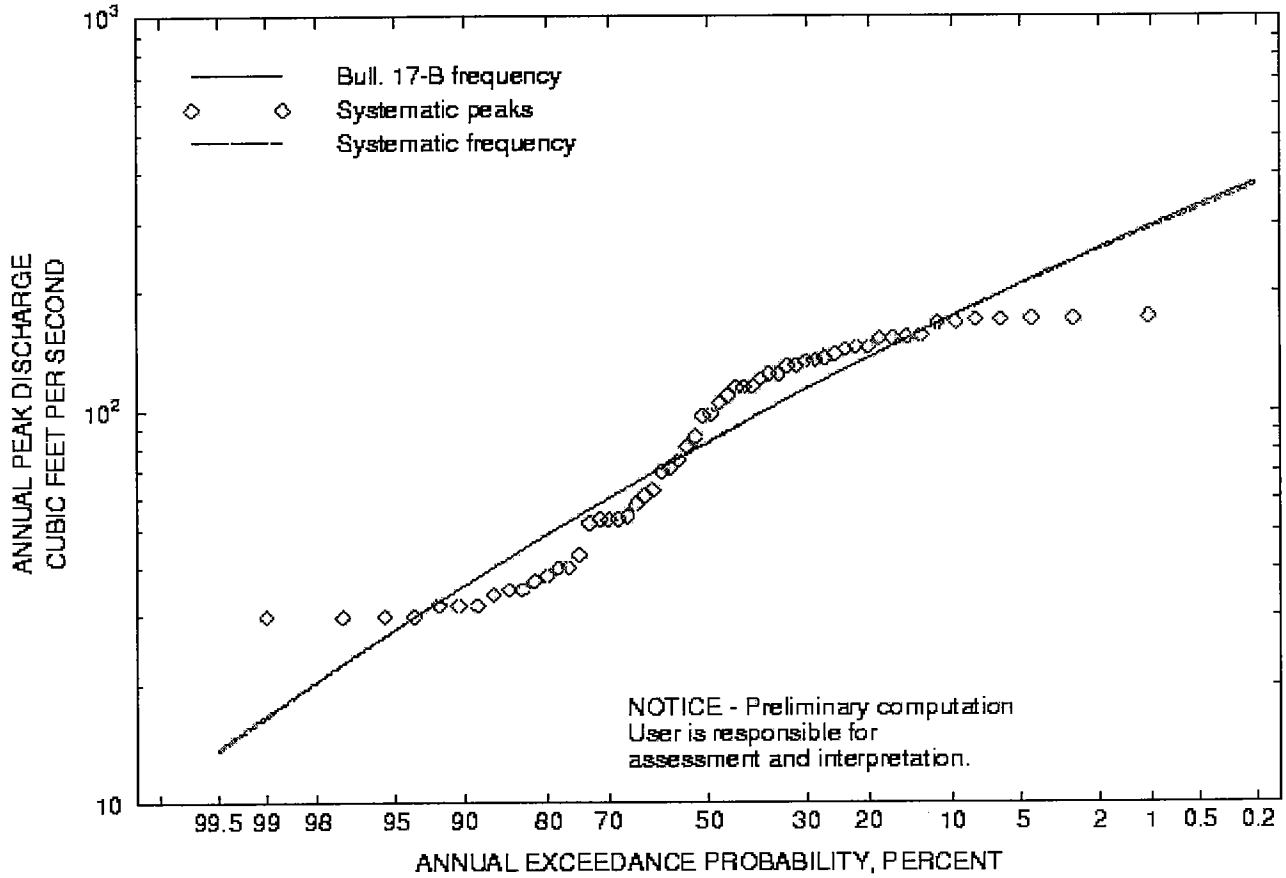
For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

12325500 Flint Creek near Southern Cross, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

14	17	28	36	48	83	136	174	222	259	296	333
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

12325500 Flint Creek near Southern Cross, MT

```
Location.-- Lat 46 13'59", Long 113 17'56", Hydrologic Unit 17010202.
Drainage area.--    52.60 square miles.
Datum of gage.--     5630.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s		Date of Max. gage height	Maximum gage height (ft)
1941	Oct. 1, 1940	0.85	32	_/5	--	--

1942	June 13, 1942	1.86		174	_/5	--	--
1943	Mar. 15, 1943	1.78		146	_/5	--	--
1944	June 9, 1944	1.73		137	_/5	--	--
1945	Dec. 1, 1944	0.91		40	_/5	--	--
1946	Feb. 25, 1946	0.83		32	_/5	--	--
1947	June 19, 1947	1.22		53	_/5	--	--
1948	June 4, 1948	1.78		146	_/5	--	--
1949	May 6, 1949	1.68		124	_/5	--	--
1950	June 1, 1950	0.82		30	_/5	--	--
1951	July 11, 1951	1.65		168	_/5	--	--
1952	July 14, 1952	1.65		116	_/5	--	--
1953	June 17, 1953	--		130	_/5	--	--
1954	June 12, 1954	0.88		34	_/5	--	--
1955	July 25, 1955	0.98		43	_/5	--	--
1956	June 2, 1956	0.84	_/2	32	_/5	Aug. 27, 1956	0.86
1957	May 29, 1957	0.94		38	_/5	--	--
1958	June 28, 1958	1.93		153	_/5	--	--
1959	Sept.28, 1959	0.78	_/2	30	_/5	May 4, 1959	0.83
1960	Oct. 30, 1959	1.18		54	_/5	--	--
1961	May 24, 1961	0.86		30	_/5	--	--
1962	June 14, 1962	4.56	_/2	35	_/5	Sept. 1, 1962	3.64
1963	July 2, 1963	1.78		135	_/5	--	--
1964	June 20, 1964	2.00		171	_/5	--	--
1965	June 20, 1965	1.84		155	_/5	--	--
1966	Oct. 1, 1965	4.16		40	_/5	--	--
1967	June 21, 1967	1.55		81	_/5	--	--
1968	June 6, 1968	1.96		153	_/5	--	--
1969	June 26, 1969	2.15		140	_/5	--	--
1970	June 29, 1970	1.95		156	_/5	--	--
1971	July 17, 1971	1.25		63	_/5	--	--
1972	May 19, 1972	1.50		86	_/5	--	--
1973	May 18, 1973	0.90		37	_/5	--	--
1974	May 29, 1974	--		35	_/5	--	--
1975	July 19, 1975	--		171	_/15	July 6, 1975	2.58
1976	June 22, 1976	2.30		134	_/15	--	--
1977	June 15, 1977	1.20		53	_/5	--	--
1978	June 11, 1978	2.00		109	_/5	--	--
1979	Oct. 1, 1978	1.22		53	_/15	--	--
1980	June 19, 1980	2.60		172	_/15	--	--
1981	June 10, 1981	2.26		131	_/5	--	--
1982	July 14, 1982	2.14		121	_/5	--	--
1983	July 14, 1983	1.86		98	_/5	--	--
1984	June 21, 1984	2.08		115	_/5	--	--
1985	Nov. 2, 1984	1.22		52	_/5	--	--
1986	June 8, 1986	2.19		124	_/5	--	--
1987	June 10, 1987	1.49		70	_/5	--	--
1988	Aug. 13, 1988	1.53		72	_/5	--	--
1989	July 4, 1989	1.32		58	_/5	--	--
1990	June 3, 1990	1.86		97	_/5	--	--
1991	June 4, 1991	1.37		61	_/5	--	--
1992	Aug. 15, 1992	0.89		30	_/5	--	--
1993	June 15, 1993	1.90		105	_/5	--	--
1994	May 27, 1994	1.53		75	_/5	--	--
1995	June 6, 1995	2.53		172	_/5	--	--
1996	May 28, 1996	1.92		115	_/5	--	--
1997	June 22, 1997	2.41		169	_/5	--	--
1998	June 26, 1998	2.38		144	_/5	--	--

_/ Explanation of the footnotes used for Gage height data:

```
        2  Gage height not the maximum for the year.

_/ Explanation of the footnotes used for Discharge data:
        1  Discharge is maximum daily average.
        5  Discharge affected to unknown degree by regulation or diversion.
```

Basin Characteristics:

Value	Abbrev	Explanation
116.0	SLOPE	Main channel slope, in ft per mile
8.6	LENGTH	Total stream length, miles
6800.0	ELEV	Mean basin elevation, ft above msl
100.0	EL6000	Percent of basin above 6,000 ft, msl
7.16	STORAGE	Percent of basin in lakes, ponds, and swamps
84.0	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
46.23305556	LAT_GAGE	Latitude of gage, in decimal degrees
113.29888889	LNG_GAGE	Longitude of gage, in decimal degrees
24.0	PRECIP	Mean annual precipitation, in inches
1.7	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
12.0	JANMIN	Mean minimum January temperature, in degrees F
12.0	WAC	Width of active channel, in feet
0.7	W2	Mean depth for active channel, in feet
17.5	WBF	Width of bankfull channel, in feet
1.1	W4	Mean depth of bankfull channel, in feet

0.312

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

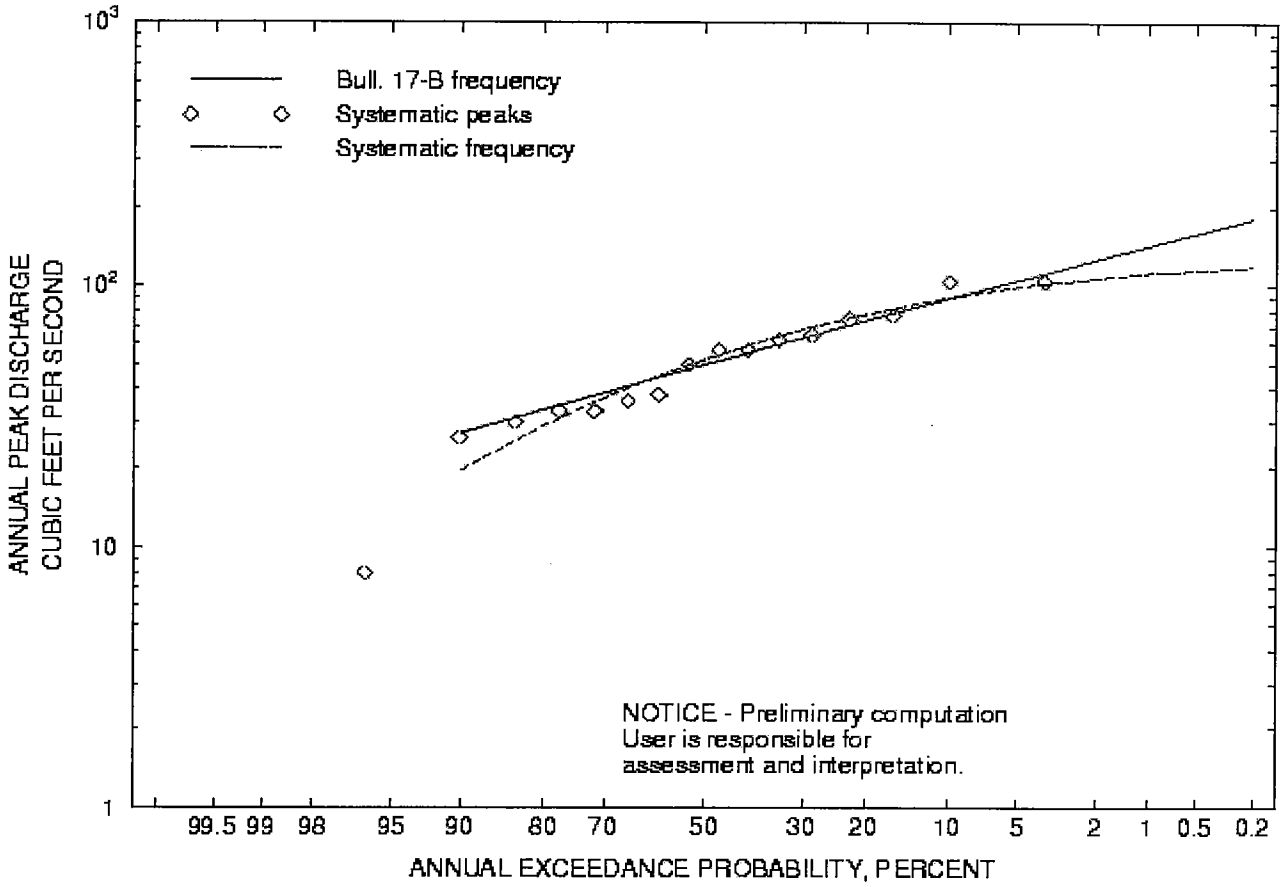
The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

12351400 Eightmile Creek near Florence, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

--	--	--	27	34	50	73	89	110	126	142	159
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

12351400 Eightmile Creek near Florence, MT

```
Location.-- Lat 46 39'10", Long 113 57'30", Hydrologic Unit 17010205.
Drainage area.--   19.50 square miles.
Datum of gage.--    3800.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1958	May 13, 1958	2.72	62	--	--

1959	June 6, 1959	2.06	33	--	--
1960	Apr. 10, 1960	2.03	30	--	--
1961	May 30, 1961	2.19	38	--	--
1962	May 25, 1962	2.27	36	--	--
1963	May 26, 1963	1.98	26	--	--
1964	June 8, 1964	3.60	104	--	--
1965	May 12, 1965	3.63	75	--	--
1966	Mar. 27, 1966	3.28	57	--	--
1967	June 6, 1967	2.89	57	--	--
1968	May 5, 1968	2.33	33	--	--
1969	May 20, 1969	2.70	50	--	--
1970	June 5, 1970	4.25	104	--	--
1971	May 5, 1971	3.75	65	--	--
1972	May 14, 1972	3.91	77	--	--
1973	June 14, 1973	2.08	8.0	--	--

Basin Characteristics:

Value	Abbrev	Explanation
207.0	SLOPE	Main channel slope, in ft per mile
7.79	LENGTH	Total stream length, miles
5590.0	ELEV	Mean basin elevation, ft above msl
35.0	EL6000	Percent of basin above 6,000 ft, msl
0.0	STORAGE	Percent of basin in lakes, ponds, and swamps
86.5	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
46.65277778	LAT_GAGE	Latitude of gage, in decimal degrees
113.95833333	LNG_GAGE	Longitude of gage, in decimal degrees
21.0	PRECIP	Mean annual precipitation, in inches
1.4	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
13.0	JANMIN	Mean minimum January temperature, in degrees F
10.0	WAC	Width of active channel, in feet
0.7	W2	Mean depth for active channel, in feet
16.0	WBF	Width of bankfull channel, in feet
2.7	W4	Mean depth of bankfull channel, in feet

0.315

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

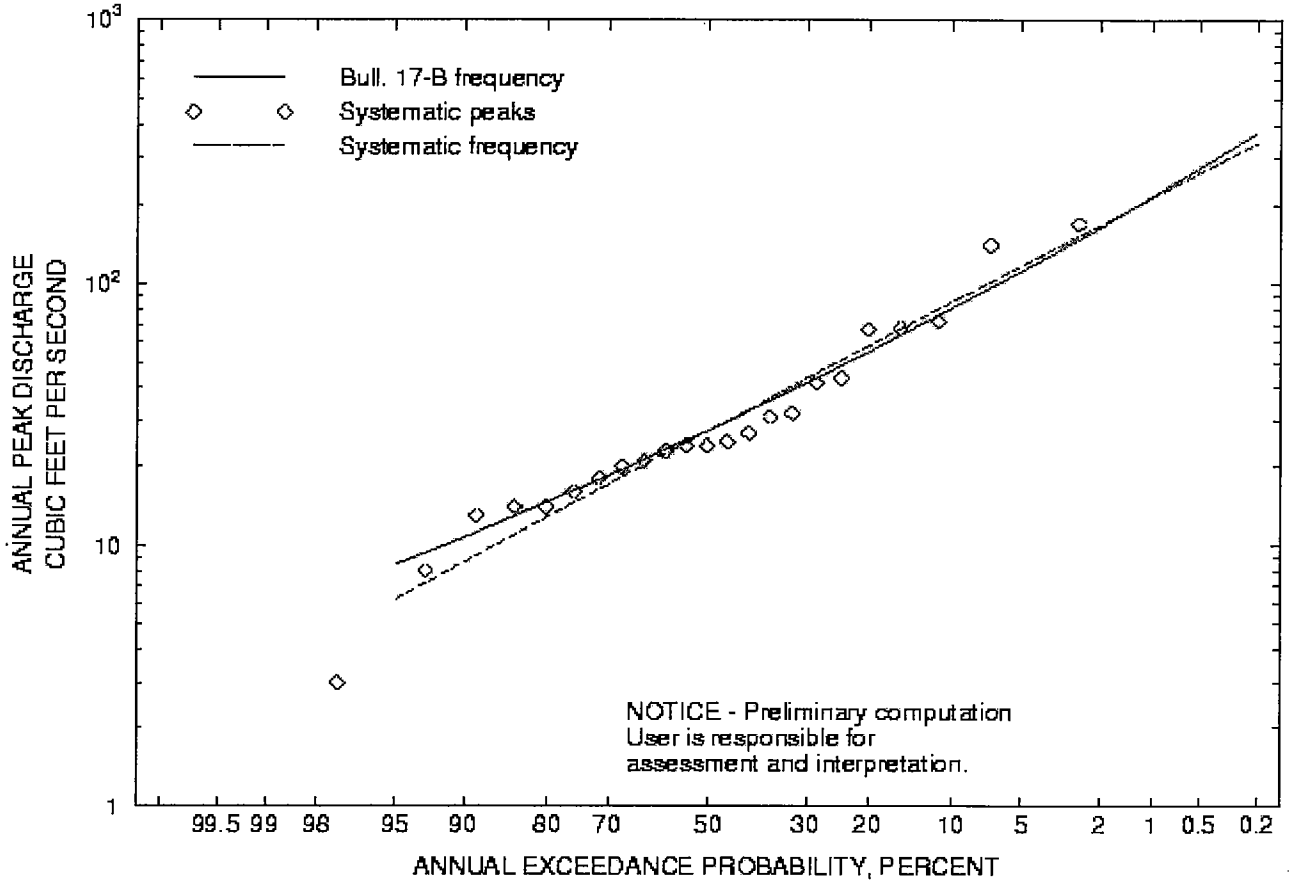
The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

12353400 Negro Gulch near Alberton, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

--	--	8	11	15	28	55	81	124	165	215	276
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

12353400 Negro Gulch near Alberton, MT

```
Location.-- Lat 47 01'00", Long 114 32'00", Hydrologic Unit 17010204.
Drainage area.--     8.02 square miles.
Datum of gage.--     3000.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1959	1959	0.70	23	--	--

1960	Apr. 6, 1960	0.80	27	--	--
1961	May 2, 1961	0.74	24	--	--
1962	May 29, 1962	0.54	16	--	--
1963	May 6, 1963	0.59	18	--	--
1964	June 9, 1964	1.01	67	--	--
1965	Apr. 28, 1965	2.05	170	--	--
1966	Mar. 30, 1966	0.45	20	--	--
1967	May 11, 1967	0.47	21	--	--
1968	May 5, 1968	0.28	8.0	--	--
1969	Apr. 10, 1969	0.62	32	--	--
1970	May 16, 1970	1.80	142	--	--
1971	May 5, 1971	0.65	42	--	--
1972	Mar. 17, 1972	1.02	68	--	--
1973	May 17, 1973	0.05	3.0	--	--
1984	May 21, 1984	0.57	25	--	--
1985	May 2, 1985	0.49	24	--	--
1986	Feb. 26, 1986	0.99	72	--	--
1987	Apr. 22, 1987	0.30	14	--	--
1988	Apr. 15, 1988	0.31	14	--	--
1989	Apr. 8, 1989	0.58	31	--	--
1990	Apr. 23, 1990	0.27	13	--	--
1991	Apr. 1, 1991	0.74	44	--	--

Basin Characteristics:

Value	Abbrev	Explanation
580.0	SLOPE	Main channel slope, in ft per mile
4.3	LENGTH	Total stream length, miles
4760.0	ELEV	Mean basin elevation, ft above msl
8.0	EL6000	Percent of basin above 6,000 ft, msl
0.0	STORAGE	Percent of basin in lakes, ponds, and swamps
81.6	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
47.01666667	LAT_GAGE	Latitude of gage, in decimal degrees
114.53333333	LNG_GAGE	Longitude of gage, in decimal degrees
33.0	PRECIP	Mean annual precipitation, in inches
2.0	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
12.0	JANMIN	Mean minimum January temperature, in degrees F
8.0	WAC	Width of active channel, in feet
0.5	W2	Mean depth for active channel, in feet
13.0	WBF	Width of bankfull channel, in feet

1.5	W4	Mean depth of bankfull channel, in feet

0.299

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

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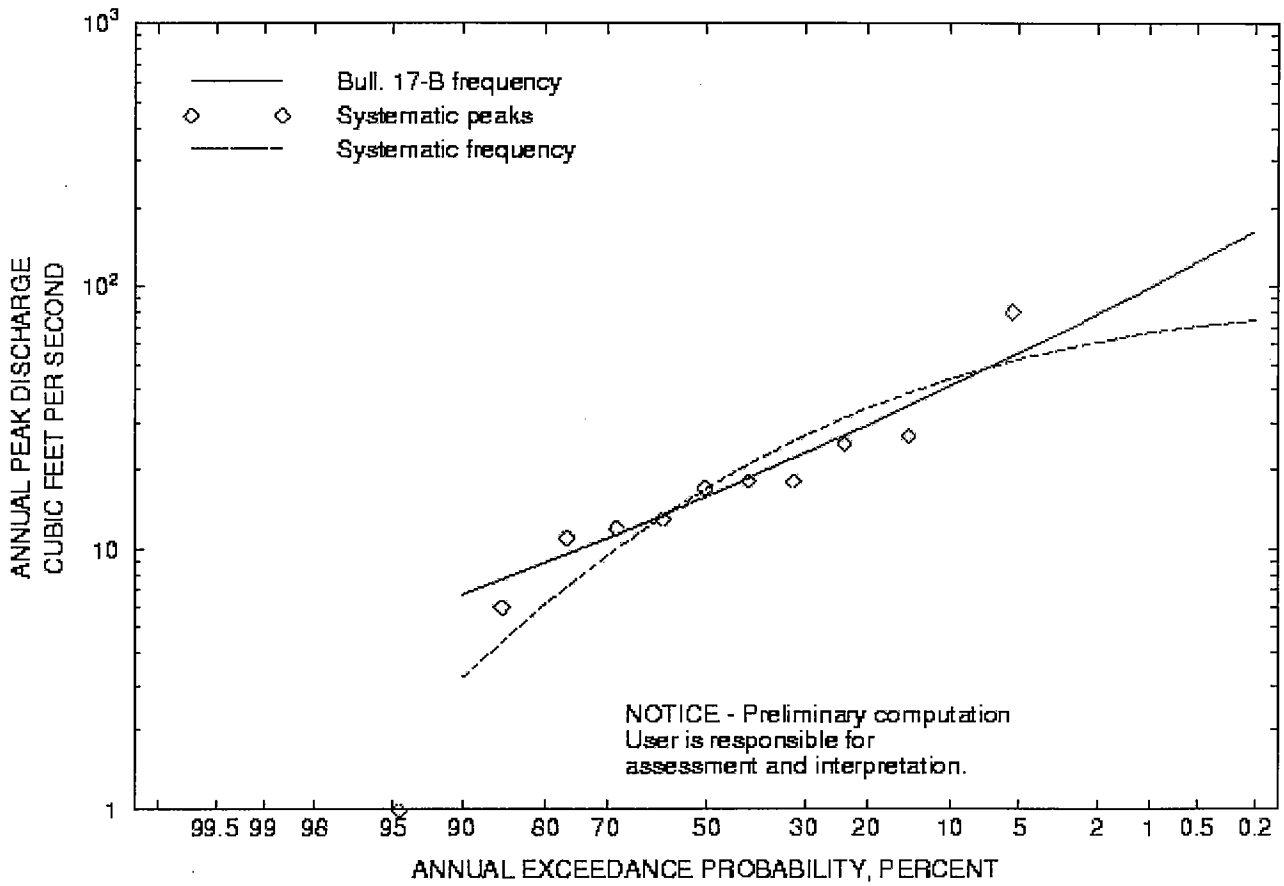
Phone: 406-457-5928 or by e-mail.

12389150 McGsegor Creek trib near Marion, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

--	--	--	7	9	16	29	41	61	78	99	123
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

12389150 McGsegor Creek trib near Marion, MT

```
Location.-- Lat 48 01'44", Long 114 55'54", Hydrologic Unit 17010213.
Drainage area.--     2.55 square miles.
Datum of gage.--     3850.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1972	1972	2.60	80	--	--

1973		1973	0.92		13		--	--
1974	June 12,	1974	1.07		17		--	--
1975	June 24,	1975	0.83		11		--	--
1976	May 11,	1976	--	_/4	12	_/2	--	--
1977	Apr. 26,	1977	--	_/4	1.0	_/2	--	--
1978	Mar. 31,	1978	--	_/4	6.0	_/2	--	--
1979	May 6,	1979	0.95		18		--	--
1980	June 14,	1980	1.15		27		--	--
1981	May 23,	1981	1.10		25		--	--
1982	May 18,	1982	0.98		18		--	--

_/ Explanation of the footnotes used for Gage height data:
4 Gage height below minimum recordable elevation.

_/ Explanation of the footnotes used for Discharge data:
2 Discharge is an estimate.

Basin Characteristics:

Value	Abbrev	Explanation
458.0	SLOPE	Main channel slope, in ft per mile
2.37	LENGTH	Total stream length, miles
5020.0	ELEV	Mean basin elevation, ft above msl
5.0	EL6000	Percent of basin above 6,000 ft, msl
0.0	STORAGE	Percent of basin in lakes, ponds, and swamps
100.0	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
48.02888889	LAT_GAGE	Latitude of gage, in decimal degrees
114.93166667	LNG_GAGE	Longitude of gage, in decimal degrees
30.0	PRECIP	Mean annual precipitation, in inches
1.9	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
10.0	JANMIN	Mean minimum January temperature, in degrees F
5.2	WAC	Width of active channel, in feet
--	W2	Mean depth for active channel, in feet
9.2	WBF	Width of bankfull channel, in feet
--	W4	Mean depth of bankfull channel, in feet

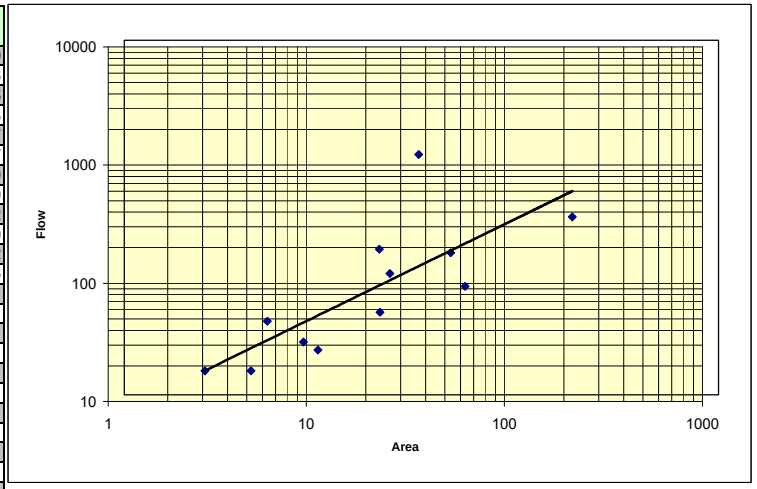
0.291

PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q2	2var Q2	3var Q2
BCD	12.017	20.9	6.659	56.9	58.4	93.1

Area^ 0.81898411	Area^ 0.80263121	Area^ 0.638113845
x 7.4275053	Precip^ -0.250572526	Precip^ 0.246258641
	x 17.00768303	Ave elev^ 3.057196636
		x 0.027371906
Correlation Coef. 0.769	0.772	0.797
Std. Error 97.07%	102.94%	97.49%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q2**	**Q2**	Gf	**Q2**	Gf	**Q2**	Gf
12301997	9.5	29	4.46		24	46.9	0.5	44.6	0.5	25.5	0.9
12304120	5.27	34	5		42	29.0	1.4	26.7	1.6	25.8	1.6
12323300	4.36	12	6.06		16	24.8	0.6	29.8	0.5	31.9	0.5
12325500	52.6	24	6.8		83	190.7	0.4	184.6	0.4	263.3	0.3
12348500	21.9	29	6.62		106	93.0	1.1	87.1	1.2	145.3	0.7
12351400	19.5	21	5.59		50	84.6	0.6	86.1	0.6	74.3	0.7
12353400	8.02	33	4.76		28	40.9	0.7	37.7	0.7	28.8	1.0
12389150	2.55	30	5.02		16	16.0	1.0	15.4	1.0	15.9	1.0
6068500	44.4	12	5.9		159	166.0	1.0	191.6	0.8	129.1	1.2
6071000	183	24	5.84		321	529.4	0.6	502.0	0.6	366.4	0.9
6030500	19.4	20	6.93		171	84.2	2.0	86.8	2.0	141.2	1.2
6033000	30.6	19	6.64		1080	122.4	8.8	126.7	8.5	163.6	6.6

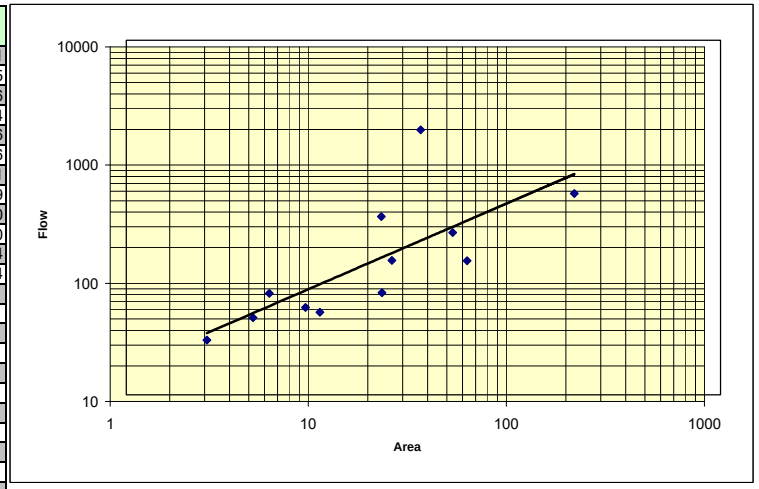


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q5	2var Q5	3var Q5
BCD	12.017	20.9	6.659	102.3	107.3	163.5

	Area^ 0.7247984	Area^ 0.69478797	Area^ 0.546069893
	x 16.8762956	Precip^ -0.459642268	Precip^ -0.01048979
		x 77.14431212	Ave elev^ 2.764074314
			x 0.230048516
Correlation Coef.	0.738	0.750	0.771
Std. Error	94.21%	98.08%	94.46%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q5**	**Q5**	Gf	**Q5**	Gf	**Q5**	Gf
12301997	9.5	29	4.46		50	86.3	0.6	78.4	0.6	47.3	1.1
12304120	5.27	34	5		72	56.3	1.3	48.4	1.5	47.0	1.5
12323300	4.36	12	6.06		45	49.1	0.9	68.5	0.7	72.9	0.6
12325500	52.6	24	6.8		136	298.3	0.5	280.9	0.5	387.5	0.4
12348500	21.9	29	6.62		137	158.1	0.9	140.1	1.0	222.5	0.6
12351400	19.5	21	5.59		73	145.3	0.5	149.9	0.5	131.3	0.6
12353400	8.02	33	4.76		55	76.3	0.7	65.7	0.8	51.6	1.1
12389150	2.55	30	5.02		29	33.3	0.9	31.0	0.9	32.0	0.9
6068500	44.44	12	5.9		236	264.0	0.9	343.7	0.7	240.4	1.0
6071000	183	24	5.84		504	736.4	0.7	668.1	0.8	502.6	1.0
6030500	19.4	20	6.93		323	144.8	2.2	152.8	2.1	237.3	1.4
6033000	30.6	19	6.64		1740	201.4	8.6	214.7	8.1	270.5	6.4

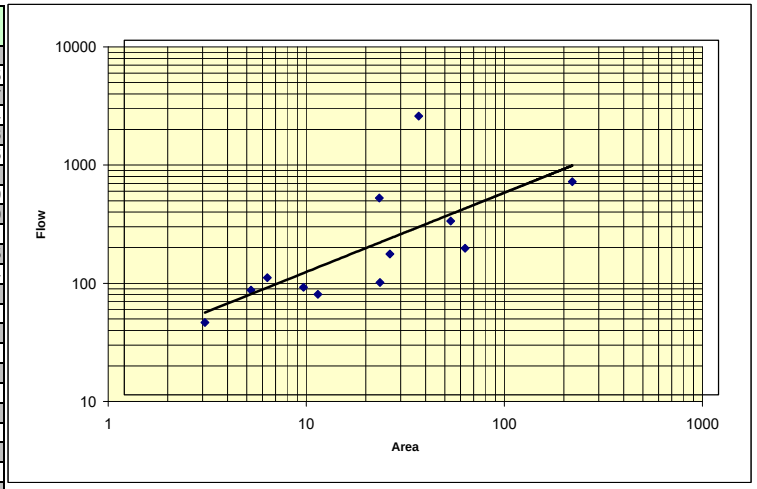


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q10	2var Q10	3var Q10
BCD	12.017	20.9	6.659	140.5	149.0	222.8

	Area^ 0.6702006	Area^ 0.633072856	Area^ 0.491093708
	x 26.5365387	Precip^ -0.568651583	Precip^ -0.139851754
		x 173.9417408	Ave elev^ 2.638824569
			x 0.675083903
Correlation Coef.	0.705	0.725	0.745
Std. Error	96.07%	98.82%	96.29%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q10**	**Q10**	Gf	**Q10**	Gf	**Q10**	Gf
12301997	9.5	29	4.46		71	120.0	0.6	106.6	0.7	65.8	1.1
12304120	5.27	34	5		98	80.8	1.2	67.1	1.5	65.2	1.5
12323300	4.36	12	6.06		77	71.2	1.1	107.5	0.7	114.1	0.7
12325500	52.6	24	6.8		174	377.8	0.5	350.8	0.5	476.8	0.4
12348500	21.9	29	6.62		155	210.0	0.7	180.9	0.9	281.3	0.6
12351400	19.5	21	5.59		89	194.3	0.5	201.9	0.4	177.9	0.5
12353400	8.02	33	4.76		81	107.1	0.8	89.0	0.9	70.6	1.1
12389150	2.55	30	5.02		41	49.7	0.8	45.5	0.9	46.9	0.9
6068500	44.44	12	5.9		295	337.4	0.9	467.6	0.6	332.5	0.9
6071000	183	24	5.84		637	871.2	0.7	772.4	0.8	588.6	1.1
6030500	19.4	20	6.93		463	193.6	2.4	206.9	2.2	315.1	1.5
6033000	30.6	19	6.64		2280	262.8	8.7	284.3	8.0	354.6	6.4

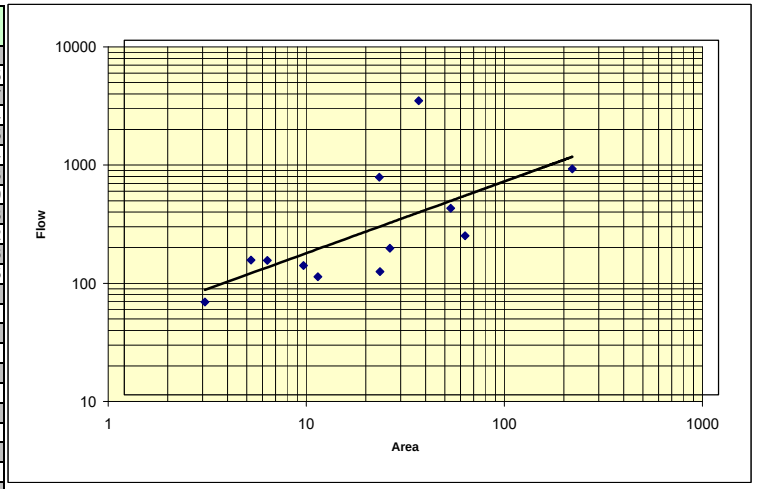


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q25	2var Q25	3var Q25
BCD	12.017	20.9	6.659	197.7	212.7	312.5

	Area^ 0.60733461	Area^ 0.561614071	Area^ 0.425754946
	x 43.6795643	Precip^ -0.700259531	Precip^ -0.289943153
		x 442.4062594	Ave elev^ 2.525077826
			x 2.181240413
Correlation Coef.	0.655	0.690	0.706
Std. Error	100.66%	101.95%	100.70%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q25**	**Q25**	Gf	**Q25**	Gf	**Q25**	Gf
12301997	9.5	29	4.46		100	171.4	0.6	148.2	0.7	93.5	1.1
12304120	5.27	34	5		137	119.9	1.1	95.2	1.4	92.7	1.5
12323300	4.36	12	6.06		138	106.8	1.3	177.5	0.8	187.9	0.7
12325500	52.6	24	6.8		222	484.7	0.5	442.4	0.5	593.5	0.4
12348500	21.9	29	6.62		174	284.7	0.6	236.9	0.7	361.5	0.5
12351400	19.5	21	5.59		110	265.3	0.4	278.2	0.4	246.5	0.4
12353400	8.02	33	4.76		124	154.7	0.8	123.1	1.0	98.7	1.3
12389150	2.55	30	5.02		61	77.1	0.8	69.1	0.9	71.3	0.9
6068500	44.44	12	5.9		378	437.6	0.9	653.9	0.6	471.9	0.8
6071000	183	24	5.84		817	1033.6	0.8	891.1	0.9	687.1	1.2
6030500	19.4	20	6.93		692	264.5	2.6	287.1	2.4	429.2	1.6
6033000	30.6	19	6.64		3080	348.8	8.8	384.4	8.0	474.8	6.5

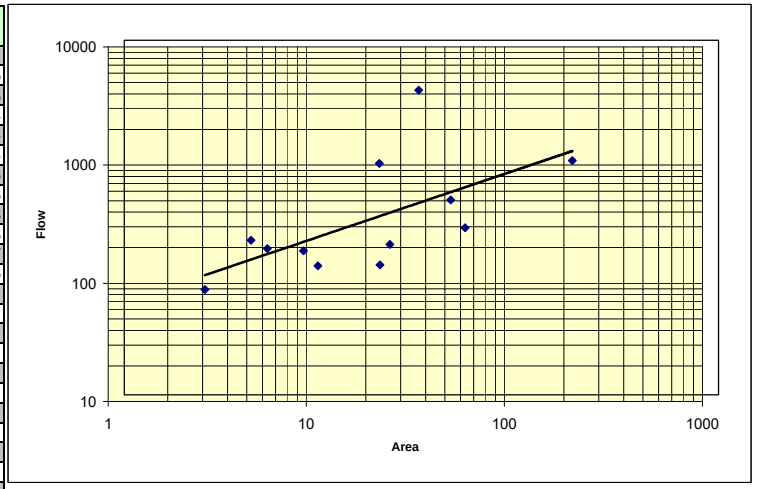


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q50	2var Q50	3var Q50
BCD	12.017	20.9	6.659	247.3	268.6	391.6

	Area^ 0.56635329	Area^ 0.514601387	Area^ 0.381490685
	x 60.4925782	Precip^ -0.792636418	Precip^ -0.390620719
		x 831.5614507	Ave elev^ 2.473995627
			x 4.565091614
Correlation Coef.	0.615	0.662	0.677
Std. Error	105.32%	105.53%	105.11%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q50**	**Q50**	Gf	**Q50**	Gf	**Q50**	Gf
12301997	9.5	29	4.46		123	216.5	0.6	183.6	0.7	116.9	1.1
12304120	5.27	34	5		173	155.1	1.1	119.5	1.4	116.4	1.5
12323300	4.36	12	6.06		203	139.3	1.5	247.5	0.8	261.6	0.8
12325500	52.6	24	6.8		259	570.7	0.5	514.6	0.5	686.2	0.4
12348500	21.9	29	6.62		187	347.4	0.5	282.2	0.7	426.9	0.4
12351400	19.5	21	5.59		126	325.3	0.4	343.3	0.4	304.9	0.4
12353400	8.02	33	4.76		165	196.7	0.8	151.9	1.1	122.4	1.3
12389150	2.55	30	5.02		78	102.8	0.8	90.8	0.9	93.6	0.8
6068500	44.44	12	5.9		446	518.7	0.9	817.4	0.5	593.7	0.8
6071000	183	24	5.84		958	1156.2	0.8	977.6	1.0	757.7	1.3
6030500	19.4	20	6.93		909	324.4	2.8	355.9	2.6	527.8	1.7
6033000	30.6	19	6.64		3780	419.9	9.0	468.7	8.1	576.5	6.6

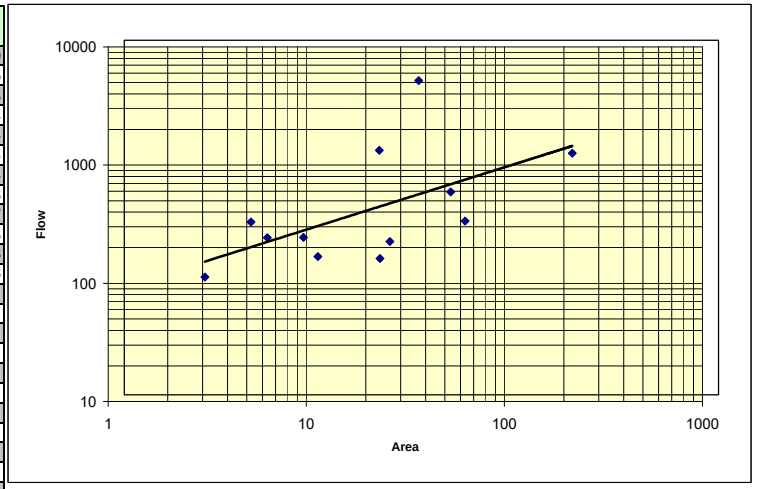


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q100	2var Q100	3var Q100
BCD	12.017	20.9	6.659	303.7	332.9	481.1

	Area^ 0.52719958	Area^ 0.46974534	Area^ 0.339693571
	x 81.8819262	Precip^ -0.879973833	Precip^ -0.487196604
		x 1502.426121	Ave elev^ 2.417142296
			x 9.295957534
Correlation Coef.	0.573	0.635	0.647
Std. Error	110.55%	109.68%	110.17%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q100**	**Q100**	Gf	**Q100**	Gf	**Q100**	Gf
12301997	9.5	29	4.46		148	268.3	0.6	223.5	0.7	143.7	1.0
12304120	5.27	34	5		214	196.7	1.1	147.3	1.5	143.5	1.5
12323300	4.36	12	6.06		289	178.0	1.6	336.9	0.9	355.7	0.8
12325500	52.6	24	6.8		296	661.4	0.4	589.8	0.5	781.2	0.4
12348500	21.9	29	6.62		198	416.7	0.5	330.8	0.6	495.8	0.4
12351400	19.5	21	5.59		142	392.0	0.4	416.2	0.3	370.6	0.4
12353400	8.02	33	4.76		215	245.4	0.9	184.2	1.2	149.1	1.4
12389150	2.55	30	5.02		99	134.1	0.7	116.9	0.8	120.3	0.8
6068500	44.44	12	5.9		521	605.2	0.9	1002.7	0.5	733.7	0.7
6071000	183	24	5.84		1110	1276.3	0.9	1059.3	1.0	825.9	1.3
6030500	19.4	20	6.93		1170	390.9	3.0	433.4	2.7	636.9	1.8
6033000	30.6	19	6.64		4570	497.1	9.2	561.6	8.1	687.5	6.6

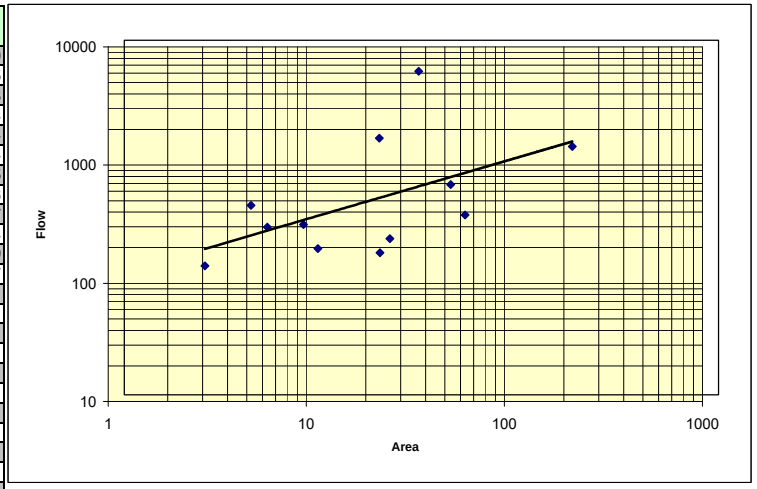


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q200	2var Q200	3var Q200
BCD	12.017	20.9	6.659	367.0	405.8	583.4

	Area^ 0.48952139	Area^ 0.426587921	Area^ 0.298319173
	x 108.649291	Precip^ -0.963894131	Precip^ -0.57650191
		x 2631.103644	Ave elev^ 2.38400307
			x 17.45491227
Correlation Coef.	0.530	0.608	0.618
Std. Error	116.18%	114.20%	115.47%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q200**	**Q200**	Gf	**Q200**	Gf	**Q200**	Gf
12301997	9.5	29	4.46		173	327.1	0.5	267.7	0.6	173.2	1.0
12304120	5.27	34	5		262	245.1	1.1	178.6	1.5	174.1	1.5
12323300	4.36	12	6.06		401	223.4	1.8	449.5	0.9	474.2	0.8
12325500	52.6	24	6.8		333	755.9	0.4	666.7	0.5	879.7	0.4
12348500	21.9	29	6.62		209	492.3	0.4	382.3	0.5	569.7	0.4
12351400	19.5	21	5.59		159	465.1	0.3	496.6	0.3	442.9	0.4
12353400	8.02	33	4.76		276	301.1	0.9	219.9	1.3	178.5	1.5
12389150	2.55	30	5.02		123	171.8	0.7	147.8	0.8	152.1	0.8
6068500	44.44	12	5.9		602	696.1	0.9	1210.2	0.5	889.3	0.7
6071000	183	24	5.84		1260	1391.7	0.9	1134.7	1.1	887.7	1.4
6030500	19.4	20	6.93		1480	463.9	3.2	519.3	2.8	759.2	1.9
6033000	30.6	19	6.64		5450	579.9	9.4	662.7	8.2	809.1	6.7

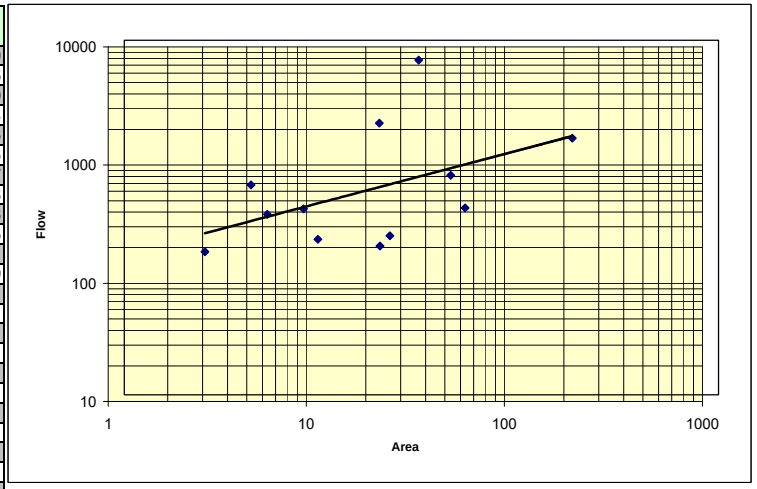


PROJECT NAME	Regression
PROJECT NUMBER	15m424.117
DATE	############
DESIGNER	SMJ

Name	Area	Precip	Ave elev	Area Q500	2var Q500	3var Q500
BCD	12.017	20.9	6.659	462.7	517.3	740.4

Area^	0.44314712	Area^	0.373368037	Area^	0.246722368
x	153.753765	Precip^	-1.068742227	Precip^	-0.686251966
		x	5266.162273	Ave elev^	2.353836526
				x	37.2251601
Correlation Coef.	0.473		0.574		0.582
Std. Error	124.52%		121.12%		123.44%

						Area Calcualted		2 Variables		3 Variables	
Gage Number	**Drainage Area**	**Precip**	**Ave elev 1000**		**Q500**	**Q500**	Gf	**Q500**	Gf	**Q500**	Gf
12301997	9.5	29	4.46		207	417.0	0.5	333.9	0.6	217.2	1.0
12304120	5.27	34	5		337	321.1	1.0	226.1	1.5	220.4	1.5
12323300	4.36	12	6.06		598	295.3	2.0	641.0	0.9	675.8	0.9
12325500	52.6	24	6.8		382	890.2	0.4	774.4	0.5	1018.3	0.4
12348500	21.9	29	6.62		222	603.7	0.4	456.1	0.5	676.3	0.3
12351400	19.5	21	5.59		181	573.5	0.3	616.7	0.3	550.8	0.3
12353400	8.02	33	4.76		375	386.8	1.0	273.0	1.4	222.2	1.7
12389150	2.55	30	5.02		162	232.8	0.7	197.1	0.8	202.7	0.8
6068500	44.44	12	5.9		721	826.1	0.9	1525.3	0.5	1125.2	0.6
6071000	183	24	5.84		1480	1546.8	1.0	1233.5	1.2	968.0	1.5
6030500	19.4	20	6.93		1990	572.2	3.5	648.4	3.1	943.4	2.1
6033000	30.6	19	6.64		6800	700.2	9.7	812.0	8.4	988.8	6.9



USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin·17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

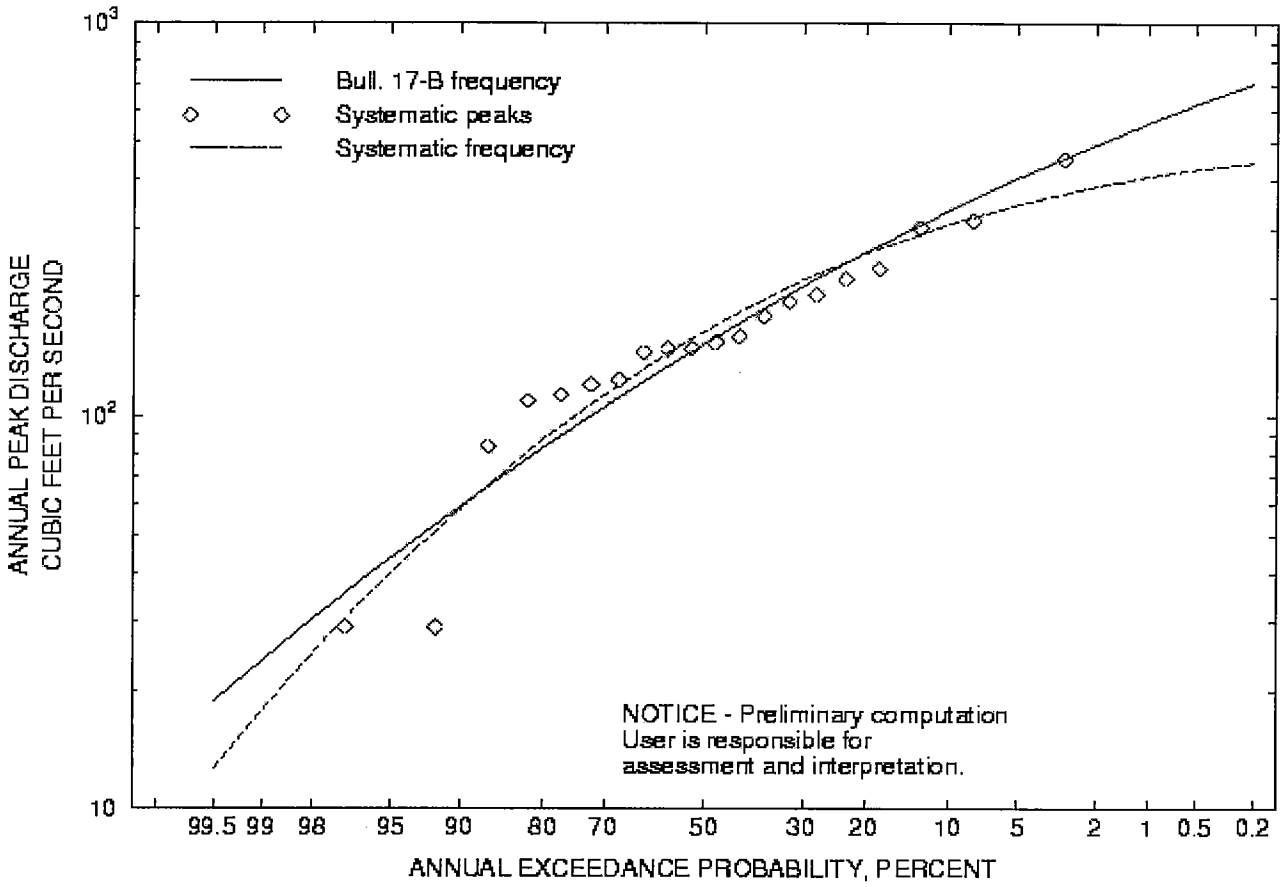
The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

06068500 Little Prickly Pear Cr near Marysville, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

--	--	--	--	111	159	236	295	378	446	521	602
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

06068500 Little Prickly Pear Cr near Marysville, MT

```
Location.-- Lat 46 47'00", Long 112 24'00", Hydrologic Unit 10030101.
Drainage area.--    44.40 square miles.
Datum of gage.--     4700.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1913	May 28, 1913	3.20	315	--	--

1914	May 17, 1914	2.50	196	--	--
1915	June 16, 1915	2.40	180	--	--
1916	June 5, 1916	2.55	204	--	--
1917	May 25, 1917	3.80	454	--	--
1918	May 5, 1918	2.10	124	--	--
1919	May 2, 1919	1.30	29	--	--
1920	May 18, 1920	2.08	155	--	--
1921	May 21, 1921	2.08	160	--	--
1922	May 20, 1922	2.10	224	--	--
1923	May 25, 1923	1.54	84	--	--
1924	May 17, 1924	1.84	149	--	--
1925	May 21, 1925	1.70	114	--	--
1926	Apr. 20, 1926	1.84	149	--	--
1927	June 8, 1927	2.30	303	--	--
1928	May 9, 1928	2.05	238	--	--
1929	May 24, 1929	1.64	146	--	--
1930	Apr. 25, 1930	1.60	121	--	--
1931	May 17, 1931	92.00	29	--	--
1932	May 14, 1932	1.44	110	--	--

Basin Characteristics:

Value	Abbrev	Explanation
255.0	SLOPE	Main channel slope, in ft per mile
6.2	LENGTH	Total stream length, miles
5900.0	ELEV	Mean basin elevation, ft above msl
55.0	EL6000	Percent of basin above 6,000 ft, msl
0.0	STORAGE	Percent of basin in lakes, ponds, and swamps
97.1	FOREST	Percent of basin in forest
4.9	SOIL_INF	Soil index, in inches
46.78333333	LAT_GAGE	Latitude of gage, in decimal degrees
112.4	LNG_GAGE	Longitude of gage, in decimal degrees
12.0	PRECIP	Mean annual precipitation, in inches
1.4	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
9.0	JANMIN	Mean minimum January temperature, in degrees F
14.0	WAC	Width of active channel, in feet
1.7	W2	Mean depth for active channel, in feet
24.0	WBF	Width of bankfull channel, in feet
2.8	W4	Mean depth of bankfull channel, in feet

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

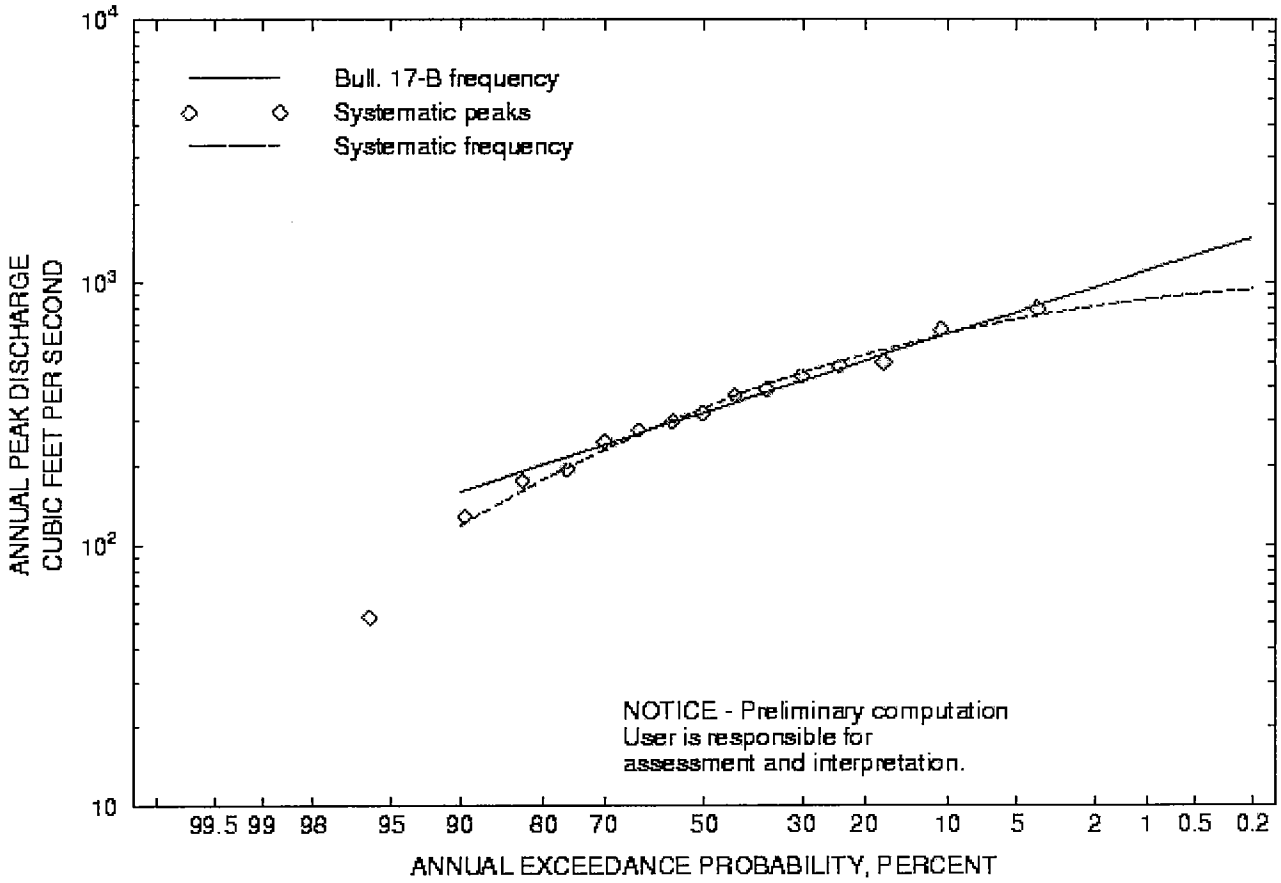
The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

06071000 Little Prickly Pear Cr near Canyon Cr, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

--	--	--	160	204	321	504	637	817	958	1110	1260	
99.5	99	95	90	80	50	20	10	4	2	1	0.5	



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

06071000 Little Prickly Pear Cr near Canyon Cr, MT

```
Location.-- Lat 46 49'00", Long 112 15'00", Hydrologic Unit 10030101.
Drainage area.--  183.00 square miles.
Datum of gage.--    4240.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1909	May 28, 1909	--	485	--	--

1910	Apr. 19, 1910	--	176		--	--
1911	June 1, 1911	--	129		--	--
1913	May 29, 1913	--	665		--	--
1914	May 19, 1914	--	296		--	--
1915	June 19, 1915	--	250		--	--
1916	June 30, 1916	--	395		--	--
1917	May 16, 1917	--	800	_/2	--	--
1918	May 7, 1918	3.10	372		--	--
1919	Aug. 1, 1919	1.20	53		--	--
1920	May 14, 1920	3.40	445		--	--
1921	May 20, 1921	2.80	319		--	--
1922	May 20, 1922	3.42	498		--	--
1923	May 27, 1923	2.30	195		--	--
1924	May 17, 1924	2.60	276		--	--

_/ Explanation of the footnotes used for Discharge data:
2 Discharge is an estimate.

Basin Characteristics:

Value	Abbrev	Explanation
83.8	SLOPE	Main channel slope, in ft per mile
15.1	LENGTH	Total stream length, miles
5840.0	ELEV	Mean basin elevation, ft above msl
43.0	EL6000	Percent of basin above 6,000 ft, msl
0.11	STORAGE	Percent of basin in lakes, ponds, and swamps
70.0	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
46.81666667	LAT_GAGE	Latitude of gage, in decimal degrees
112.25	LNG_GAGE	Longitude of gage, in decimal degrees
23.0	PRECIP	Mean annual precipitation, in inches
1.3	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
8.0	JANMIN	Mean minimum January temperature, in degrees F
24.0	WAC	Width of active channel, in feet
1.0	W2	Mean depth for active channel, in feet
37.0	WBF	Width of bankfull channel, in feet
2.5	W4	Mean depth of bankfull channel, in feet

0.314

USGS

Montana Flood-Frequency and Basin-Characteristic Data

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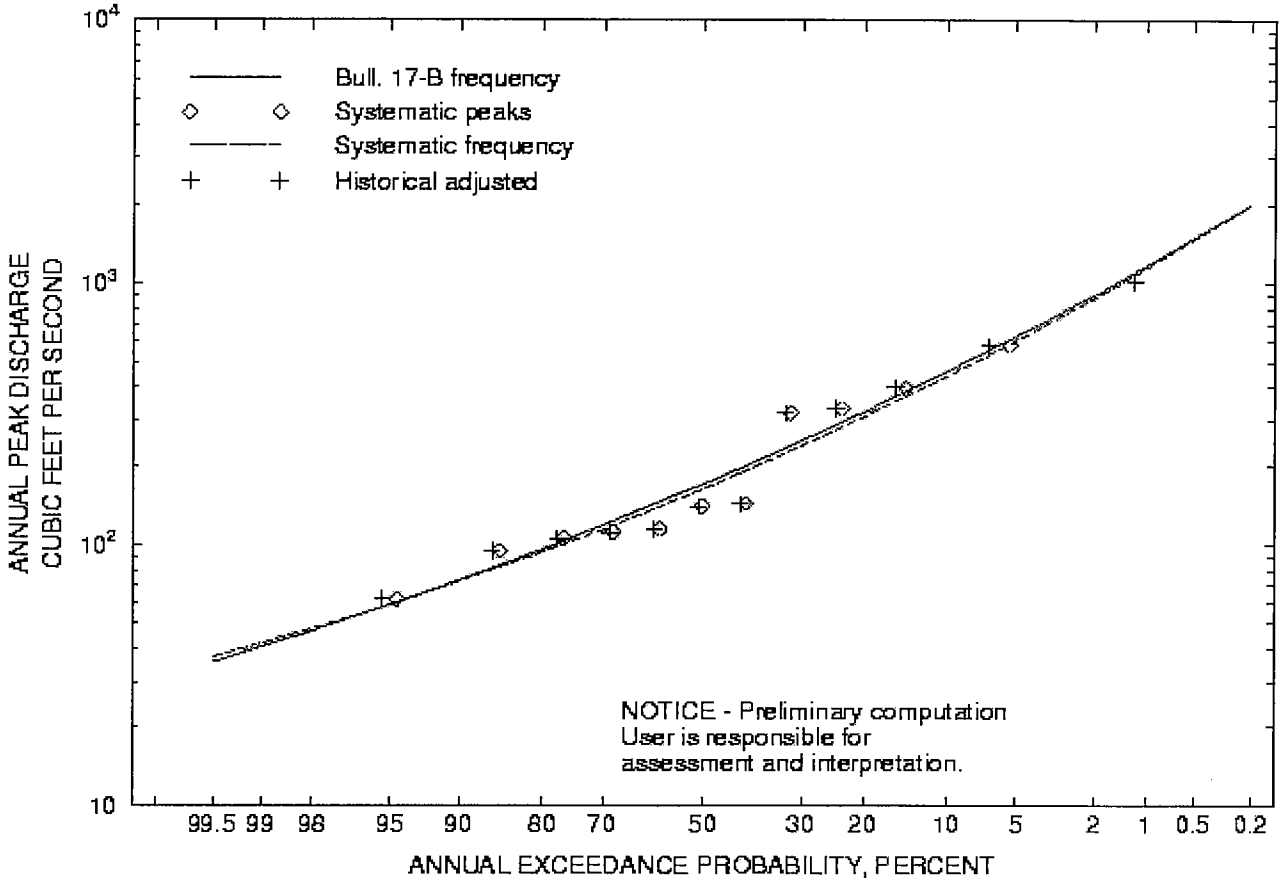
For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

06030500 Boulder River ab Rock Cr near Basin, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

36	41	59	73	96	171	323	463	692	909	1170	1480
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

06030500 Boulder River ab Rock Cr near Basin, MT

```
Location.-- Lat 46 15'12", Long 112 30'00", Hydrologic Unit 10020006.
Drainage area.--   19.40 square miles.
Datum of gage.--    6260.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1947	June 10, 1947	2.84	143	--	--

1948	May 19, 1948	3.72		582		--		--
1949	May 15, 1949	2.16		62		--		--
1950	May 16, 1950	2.50		95		--		--
1951	May 12, 1951	2.58		115		--		--
1952	Apr. 26, 1952	3.34		321		--		--
1953	June 3, 1953	3.39		334		--		--
1955	May 12, 1955	2.70	_/2	112		May 8, 1955	2.88	_/1
1956	May 22, 1956	2.47		106		--		--
1957	May 20, 1957	2.65		140		--		--
1975	June 19, 1975	3.45		400		--		--
1981	May 22, 1981	5.31		1020	_/7	--		--

_/ Explanation of the footnotes used for Gage height data:
2 Gage height not the maximum for the year.

_/ Explanation of the footnotes used for Discharge data:
7 Discharge is an historic peak.

_/ Explanation of the footnotes used for Maximum gage height data:
1 Gage height due to backwater.

Basin Characteristics:

Value	Abbrev	Explanation
85.2	SLOPE	Main channel slope, in ft per mile
7.2	LENGTH	Total stream length, miles
6930.0	ELEV	Mean basin elevation, ft above msl
100.0	EL6000	Percent of basin above 6,000 ft, msl
0.0	STORAGE	Percent of basin in lakes, ponds, and swamps
92.4	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
46.25333333	LAT_GAGE	Latitude of gage, in decimal degrees
112.5	LNG_GAGE	Longitude of gage, in decimal degrees
20.0	PRECIP	Mean annual precipitation, in inches
1.2	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
9.0	JANMIN	Mean minimum January temperature, in degrees F
15.0	WAC	Width of active channel, in feet
--	W2	Mean depth for active channel, in feet
19.0	WBF	Width of bankfull channel, in feet
--	W4	Mean depth of bankfull channel, in feet

0.321

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

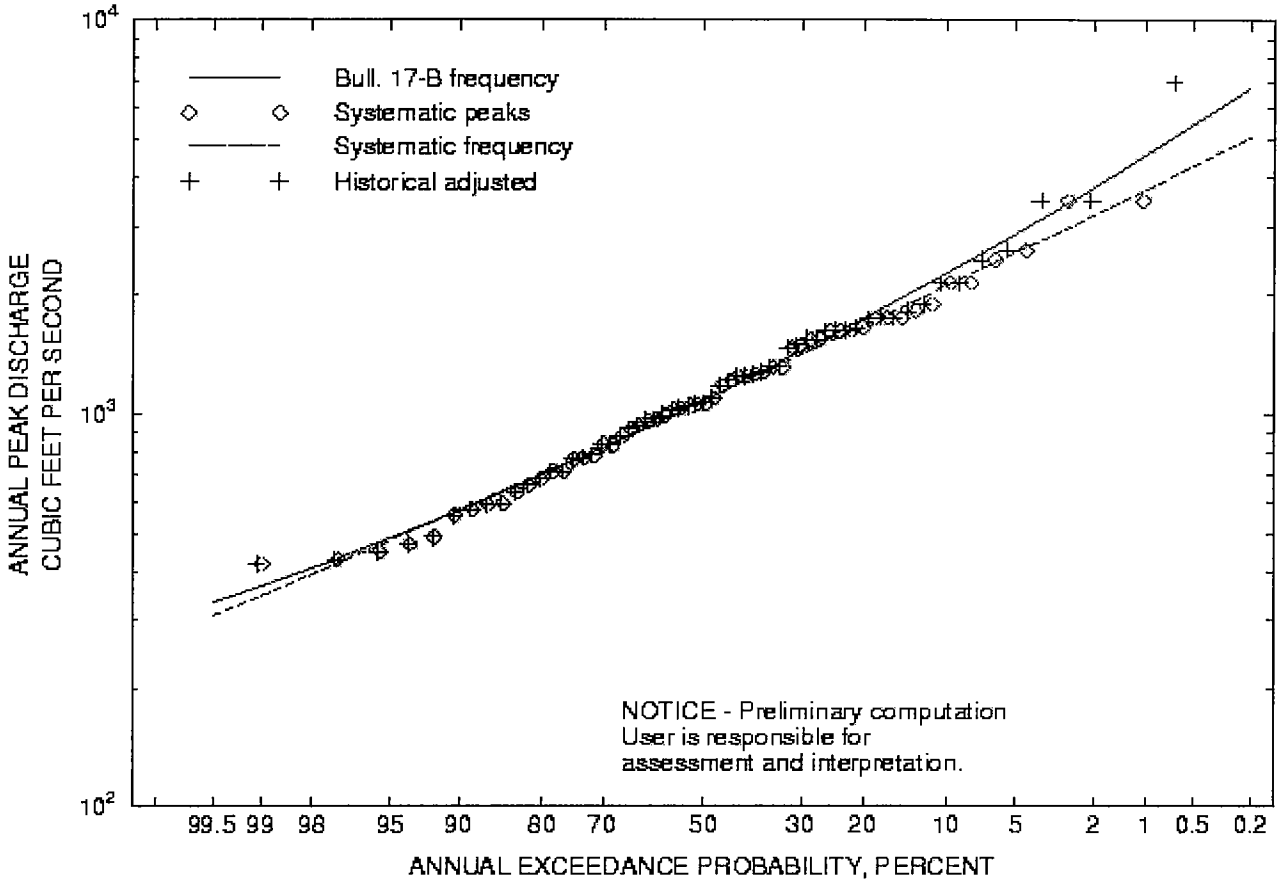
The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

06033000 Boulder River near Boulder, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

332	366	485	570	701	1080	1740	2280	3080	3780	4570	5450
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

06033000 Boulder River near Boulder, MT

```
Location.-- Lat 46 12'40", Long 112 05'27", Hydrologic Unit 10020006.
Drainage area.--  381.00 square miles.
Datum of gage.--    4810.00 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1929	May 25, 1929	9.90	1480	--	--

1930	Apr. 26, 1930	8.60	778		--	--
1931	May 18, 1931	7.86	418		--	--
1932	May 14, 1932	9.02	962		--	--
1934	Apr. 25, 1934	8.06	468		--	--
1935	May 24, 1935	8.12	488		--	--
1936	June 7, 1936	8.12	448		--	--
1937	May 10, 1937	7.86	430		--	--
1938	May 28, 1938	10.24	1830		--	--
1939	Apr. 30, 1939	--	769		--	--
1940	May 11, 1940	8.46	662		--	--
1941	June 6, 1941	8.36	592		--	--
1942	May 26, 1942	9.98	1640		--	--
1943	May 29, 1943	9.78	1630		--	--
1944	June 16, 1944	8.94	790		--	--
1945	June 11, 1945	8.56	595		--	--
1946	May 28, 1946	8.43	555		--	--
1947	May 9, 1947	9.69	1620		--	--
1948	May 22, 1948	10.37	2620		--	--
1949	May 17, 1949	8.64	878		--	--
1950	June 16, 1950	8.95	1040		--	--
1951	May 24, 1951	9.33	1250		--	--
1952	May 4, 1952	9.08	1060		--	--
1953	June 3, 1953	9.91	1900		--	--
1954	May 20, 1954	8.26	634		--	--
1955	June 17, 1955	8.71	839		--	--
1956	May 22, 1956	9.71	1760		--	--
1957	May 20, 1957	9.01	1030		--	--
1958	May 21, 1958	9.37	1280		--	--
1959	June 7, 1959	9.39	1260		--	--
1960	May 13, 1960	9.21	1180		--	--
1961	May 27, 1961	9.37	1220		--	--
1962	May 24, 1962	8.82	839		--	--
1963	May 26, 1963	9.42	1320		--	--
1964	June 9, 1964	10.90	3490		--	--
1965	June 25, 1965	10.05	2160		--	--
1966	May 11, 1966	3.74	936		--	--
1967	May 31, 1967	10.03	2150		--	--
1968	June 12, 1968	9.65	1660		--	--
1969	July 7, 1969	9.25	1250		--	--
1970	May 27, 1970	9.59	1760		--	--
1971	May 29, 1971	9.49	1550		--	--
1972	June 2, 1972	9.71	1750		--	--
1975	June 19, 1975	10.90	3500		--	--
1981	May 22, 1981	12.30	7000	_/7	--	--
1985	May 4, 1985	7.06	718		--	--
1986	May 29, 1986	7.58	1100		--	--
1987	May 28, 1987	7.02	687		--	--
1988	May 14, 1988	7.08	718		--	--
1989	May 11, 1989	7.42	974		--	--
1990	May 30, 1990	7.45	997		--	--
1991	May 19, 1991	7.90	1320		--	--
1992	June 16, 1992	6.88	575		--	--
1993	May 16, 1993	7.65	1070		--	--
1994	Apr. 23, 1994	7.42	915		--	--
1995	June 6, 1995	9.34	2480		--	--
1996	May 18, 1996	8.16	1500		--	--
1997	May 17, 1997	8.32	1550		--	--
1998	June 19, 1998	7.62	1050		--	--

```
_/ Explanation of the footnotes used for Discharge data:
      7  Discharge is an historic peak.
```

Basin Characteristics:

Value	Abbrev	Explanation
66.0	SLOPE	Main channel slope, in ft per mile
31.3	LENGTH	Total stream length, miles
6640.0	ELEV	Mean basin elevation, ft above msl
80.0	EL6000	Percent of basin above 6,000 ft, msl
0.03	STORAGE	Percent of basin in lakes, ponds, and swamps
89.1	FOREST	Percent of basin in forest
5.2	SOIL_INF	Soil index, in inches
46.21111111	LAT_GAGE	Latitude of gage, in decimal degrees
112.09083333	LNG_GAGE	Longitude of gage, in decimal degrees
19.0	PRECIP	Mean annual precipitation, in inches
1.5	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
4.0	JANMIN	Mean minimum January temperature, in degrees F
45.0	WAC	Width of active channel, in feet
1.5	W2	Mean depth for active channel, in feet
60.0	WBF	Width of bankfull channel, in feet
3.5	W4	Mean depth of bankfull channel, in feet

0.302

Methods for Estimating Flood Frequency in Montana
Based on Data through Water year 1998
Water-Resources Investigations Report 03-4308

By: Charles Parrett and D.R. Johnson

West Region: Ungaged Sites on Gaged Streams

Method Reliablity

DA_U	12.017	Equation is likely to be unreliable if DA_U/DA_G is less than 0.5 or greater than 1.5.		
DA_G	95.4	DA_U/DA_G	0.126	**Results are likely to be unreliable.**

$$Q_{T,U} = Q_{T,G}\left(\frac{DA_U}{DA_G}\right)^{exp_T}$$

Gaged Site # 12323240
Gaged Site Name Blacktail Creek at Butte
Ungaged Site Name Basin Creek Reservoir

Frequency	exp_T	$Q_{T,G}$ (cfs)	$Q_{T,u}$ (cfs)
2	0.851	139	23.8
5	0.818	224	41.1
10	0.798	283	54.2
25	0.776	361	72.3
50	0.761	419	86.6
100	0.747	478	101.7
200	0.734	538	117.6
500	0.717	618	139.9

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Method Reliablity

DA_U	12.017	Equation is likely to be unreliable if DA_U/DA_G is less than 0.5 or greater than 1.5.		
DA_G	103	DA_U/DA_G	0.117	**Results are likely to be unreliable.**

$$Q_{T,U} = Q_{T,G}\left(\frac{DA_U}{DA_G}\right)^{exp_T}$$

Gaged Site # 12323250
Gaged Site Name Silver Bow Cr bl Blacktail Cr at Butte, MT
Ungaged Site Name Basin Creek Reservoir

Frequency	exp_T	$Q_{T,G}$ (cfs)	$Q_{T,u}$ (cfs)
2	0.851	235	37.8
5	0.818	306	52.8
10	0.798	352	63.4
25	0.776	408	77.0
50	0.761	450	87.7
100	0.747	490	98.4
200	0.734	531	109.7
500	0.717	584	125.1

Methods for Estimating Flood Frequency in Montana
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Ungaged Sites on Gaged Streams - Coefficient Derivation

Method Reliability

DA_1	103	Equation is likely to be unreliable if DA_U/DA_G is less than 0.5 or greater than 1.5.
DA_2	95.4	DA_U/DA_G 1.080

$$Q_{T,1} = Q_{T,2}\left(\frac{DA_1}{DA_2}\right)^{exp_T}$$

1st Gaged Site # 12323250
1st Gaged Site Name Silver Bow Cr bl Blacktail Cr at Butte, MT
2nd Gaged Site # 12323240
2nd Gaged Site Name Blacktail Creek at Butte

exp_T was back calculated using gaged stations on the Boulder River

Frequency	exp_T	$Q_{T,1}$ (cfs)	$Q_{T,2}$ (cfs)
2	6.8507	235	139
5	4.0696	306	224
10	2.8465	352	283
25	1.5967	408	361
50	0.9312	450	419
100	0.3235	490	478
200	0.1709	531	538
500	0.7383	584	618

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Ungaged Sites on Gaged Streams - Coefficient Derivation

Method Reliablity

DA_1	19.4	Equation is likely to be unreliable if DA_U/DA_G is less than 0.5 or greater than 1.5.		
DA_2	381	DA_U/DA_G	0.051	**Results are likely to be unreliable.**

$$Q_{T,1} = Q_{T,2}\left(\frac{DA_1}{DA_2}\right)^{exp_T}$$

1st Gaged Site # 06030500
1st Gaged Site Name Boulder River above Rock Creek, near Basin
2nd Gaged Site # 06033000
2nd Gaged Site Name Boulder River near Boulder

Frequency	exp_T	$Q_{T,1}$ (cfs)	$Q_{T,2}$ (cfs)
2	0.6190	171	1080
5	0.5656	323	1740
10	0.5354	463	2280
25	0.5015	692	3080
50	0.4786	909	3780
100	0.4576	1170	4570
200	0.4378	1480	5450
500	0.4127	1990	6800

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Ungaged Sites on Gaged Streams - Coefficient Derivation

Method Reliablity

DA_1	44.4	Equation is likely to be unreliable if DA_U/DA_G is less than 0.5 or greater than 1.5.		
DA_2	183	DA_U/DA_G	0.243	**Results are likely to be unreliable.**

$$Q_{T,1} = Q_{T,2}\left(\frac{DA_1}{DA_2}\right)^{exp_T}$$

1st Gaged Site # 06068500
1st Gaged Site Name Little Prickely Pear Creek near Marysville
2nd Gaged Site # 06071000
2nd Gaged Site Name Little Prickely Pear Creek near Canyon Creek

Frequency	exp_T	$Q_{T,1}$ (cfs)	$Q_{T,2}$ (cfs)
2	0.4961	159	321
5	0.5357	236	504
10	0.5435	295	637
25	0.5442	378	817
50	0.5398	446	958
100	0.5341	521	1110
200	0.5215	602	1260
500	0.5078	721	1480

Methods for Estimating Flood Frequency in Montana
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Ungaged Sites on Gaged Streams - Using calculated exp_T values

$$Q_{T,U} = Q_{T,G}\left(\frac{DA_U}{DA_G}\right)^{exp_T}$$

Basin Creek Dam DA 12.017

	Site #	DA	Record Q_{100}	100 year exp_T	Basin Creek Dam Q_{100}	
					12323250	12323240
West Region	---	---	---	0.747	98.4	101.7
Silver Bow Cr bl Blacktail Cr at Butte, MT	12323250	103	490	0.323	244.6	244.6
Blacktail Creek at Butte	12323240	95.4	478			
Boulder River above Rock Creek, near Basin	06030500	19.4	1170	0.458	183.3	185.2
Boulder River near Boulder	06033000	381	4570			
Little Prickely Pear Creek near Marysville	06068500	44.4	521	0.534	155.6	158.1
Little Prickely Pear Creek near Canyon Creek	06071000	183	1110			

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

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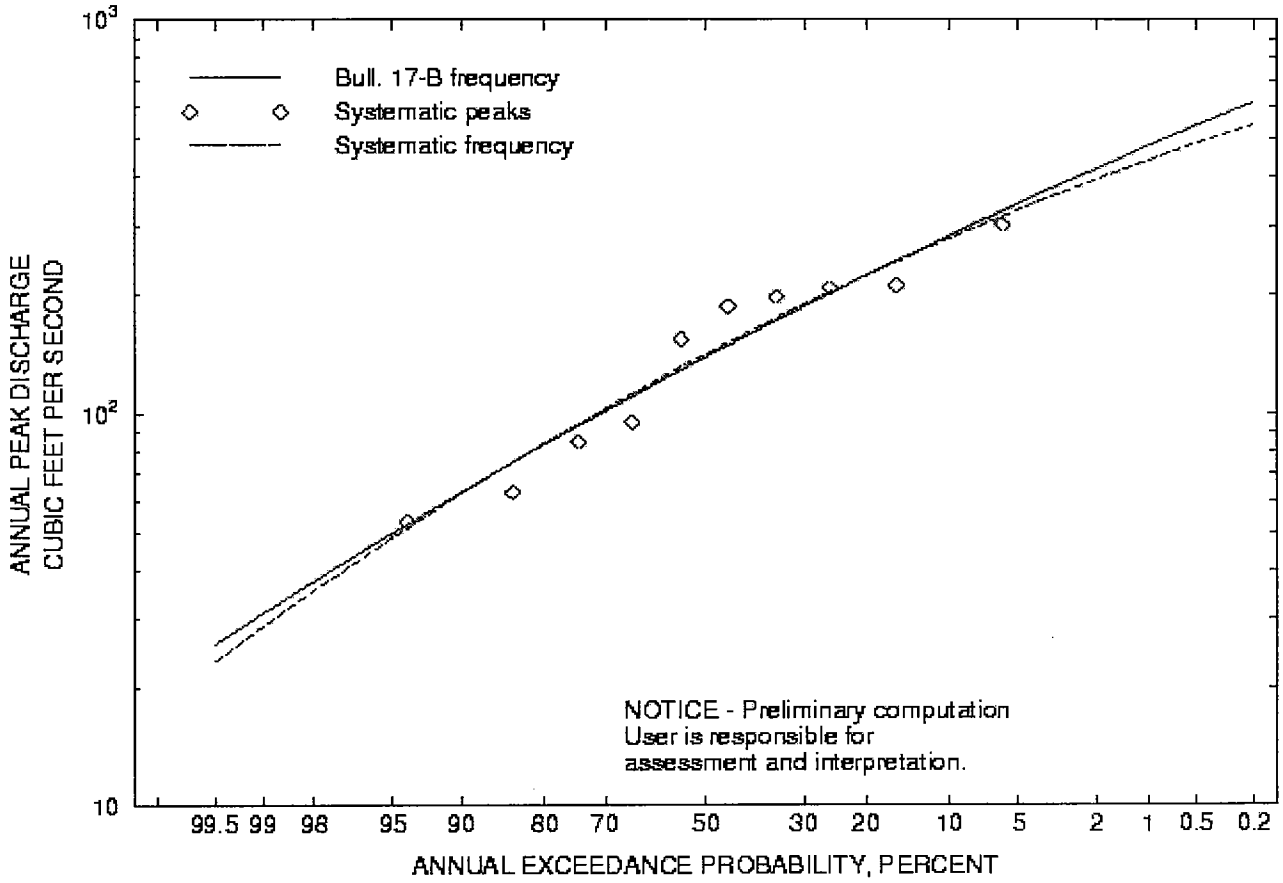
For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

12323240 Blacktail Creek at Butte

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

26	31	50	63	83	139	224	283	361	419	478	538
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

12323240 Blacktail Creek at Butte

```
Location.-- Lat 45 54'38", Long 112 31'38", Hydrologic Unit 17010201.
Drainage area.--     95.4 square miles.
Datum of gage.--        5430 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1989	Mar. 10, 1989	2.85	63	--	--

1990	May 29, 1990	3.55	85	--	--
1991	May 18, 1991	2.50	53	--	--
1992	June 11, 1992	3.81	95	--	--
1993	June 15, 1993	3.69 _/2	155	Aug. 13, 1993	4.29 _/1
1994	July 6, 1994	4.64	209	--	--
1995	Feb. 19, 1995	5.28	303	--	--
1996	Feb. 8, 1996	4.31	212	--	--
1997	Mar. 20, 1997	4.20	188	--	--
1998	July 30, 1998	4.16	199	--	--

_/ Explanation of the footnotes used for Gage height data:
2 Gage height not the maximum for the year.

_/ Explanation of the footnotes used for Maximum gage height data:
1 Gage height due to backwater.

Basin Characteristics:

Value	Abbrev	Explanation
--	SLOPE	Main channel slope, in ft per mile
--	LENGTH	Total stream length, miles
--	ELEV	Mean basin elevation, ft above msl
--	EL6000	Percent of basin above 6,000 ft, msl
--	STORAGE	Percent of basin in lakes, ponds, and swamps
--	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
45.91055556	LAT_GAGE	Latitude of gage, in decimal degrees
112.52722222	LNG_GAGE	Longitude of gage, in decimal degrees
--	PRECIP	Mean annual precipitation, in inches
--	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
--	JANMIN	Mean minimum January temperature, in degrees F
--	WAC	Width of active channel, in feet
--	W2	Mean depth for active channel, in feet
--	WBF	Width of bankfull channel, in feet
--	W4	Mean depth of bankfull channel, in feet

0.302

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

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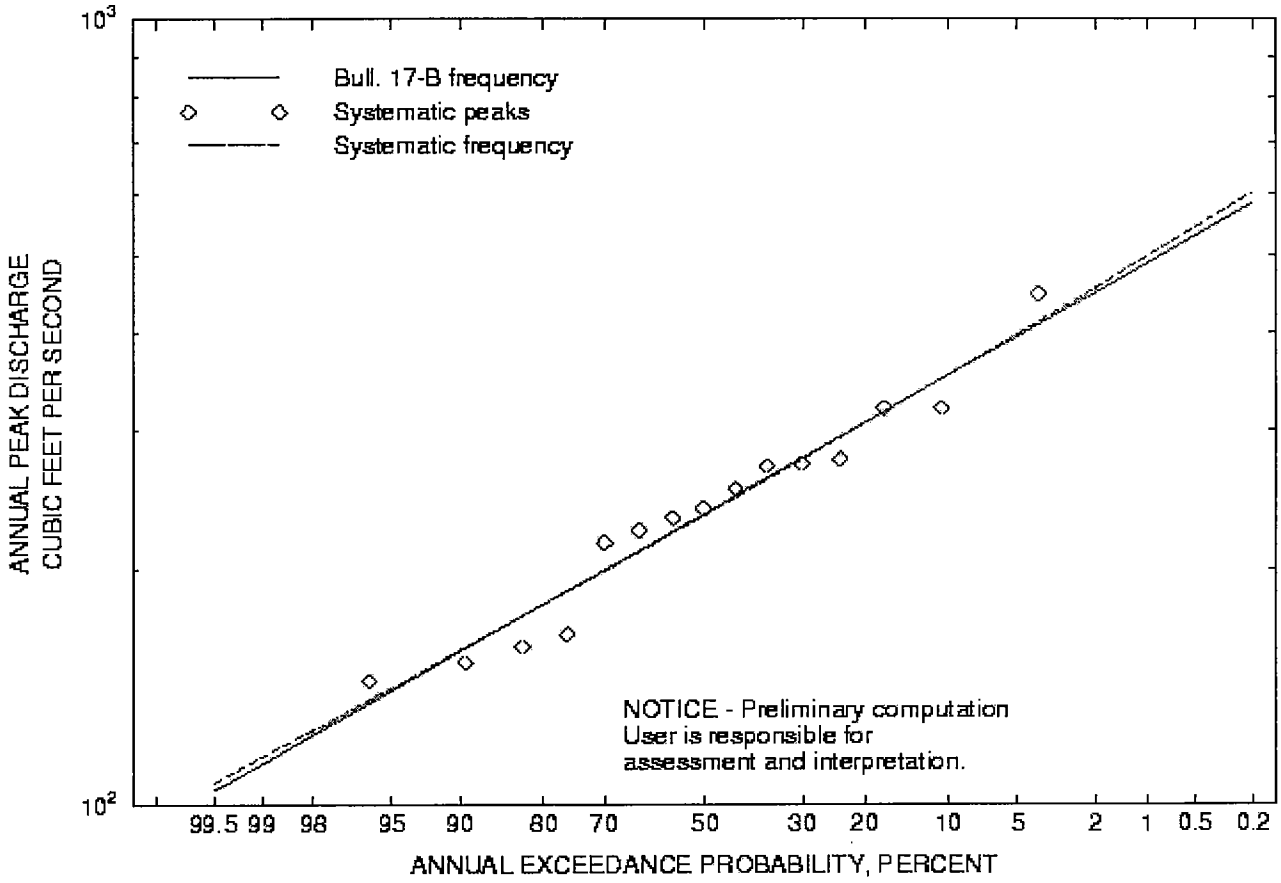
For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

12323250 Silver Bow Cr bl Blacktail Cr at Butte, MT

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

105	113	140	157	180	235	306	352	408	450	490	531
99.5	99	95	90	80	50	20	10	4	2	1	0.5



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systema flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency cu often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilitie for all peaks.

Recorded Annual Peak Discharge:

12323250 Silver Bow Cr bl Blacktail Cr at Butte, MT

```
Location.-- Lat 45 59'49", Long 112 33'43", Hydrologic Unit 17010201.
Drainage area.--  103.00 square miles.
Datum of gage.--     5410.8 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)
1984	June 11, 1984	2.77	144	--	--

1985	July 16, 1985	3.34		239	--	--
1986	Sept.18, 1986	3.41	_/2	253	June 28, 1986	3.91 _/1
1987	May 25, 1987	3.49		270	--	--
1988	Apr. 18, 1988	3.26		224	--	--
1989	Mar. 10, 1989	2.83		152	--	--
1990	May 29, 1990	3.72		320	--	--
1991	June 22, 1991	3.18		216	--	--
1992	June 11, 1992	3.62		232	--	--
1993	June 15, 1993	3.14		165	--	--
1994	July 6, 1994	3.33		159	--	--
1995	Feb. 20, 1995	3.72		320	--	--
1996	Feb. 9, 1996	3.50		272	--	--
1997	June 13, 1997	3.66		276	--	--
1998	July 30, 1998	8.11		447	--	--

_/ Explanation of the footnotes used for Gage height data:
2 Gage height not the maximum for the year.

_/ Explanation of the footnotes used for Maximum gage height data:
1 Gage height due to backwater.

Basin Characteristics:

Value	Abbrev	Explanation
--	SLOPE	Main channel slope, in ft per mile
--	LENGTH	Total stream length, miles
--	ELEV	Mean basin elevation, ft above msl
--	EL6000	Percent of basin above 6,000 ft, msl
--	STORAGE	Percent of basin in lakes, ponds, and swamps
--	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
45.99694444	LAT_GAGE	Latitude of gage, in decimal degrees
112.56194444	LNG_GAGE	Longitude of gage, in decimal degrees
--	PRECIP	Mean annual precipitation, in inches
--	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
--	JANMIN	Mean minimum January temperature, in degrees F
--	WAC	Width of active channel, in feet
--	W2	Mean depth for active channel, in feet
--	WBF	Width of bankfull channel, in feet
--	W4	Mean depth of bankfull channel, in feet

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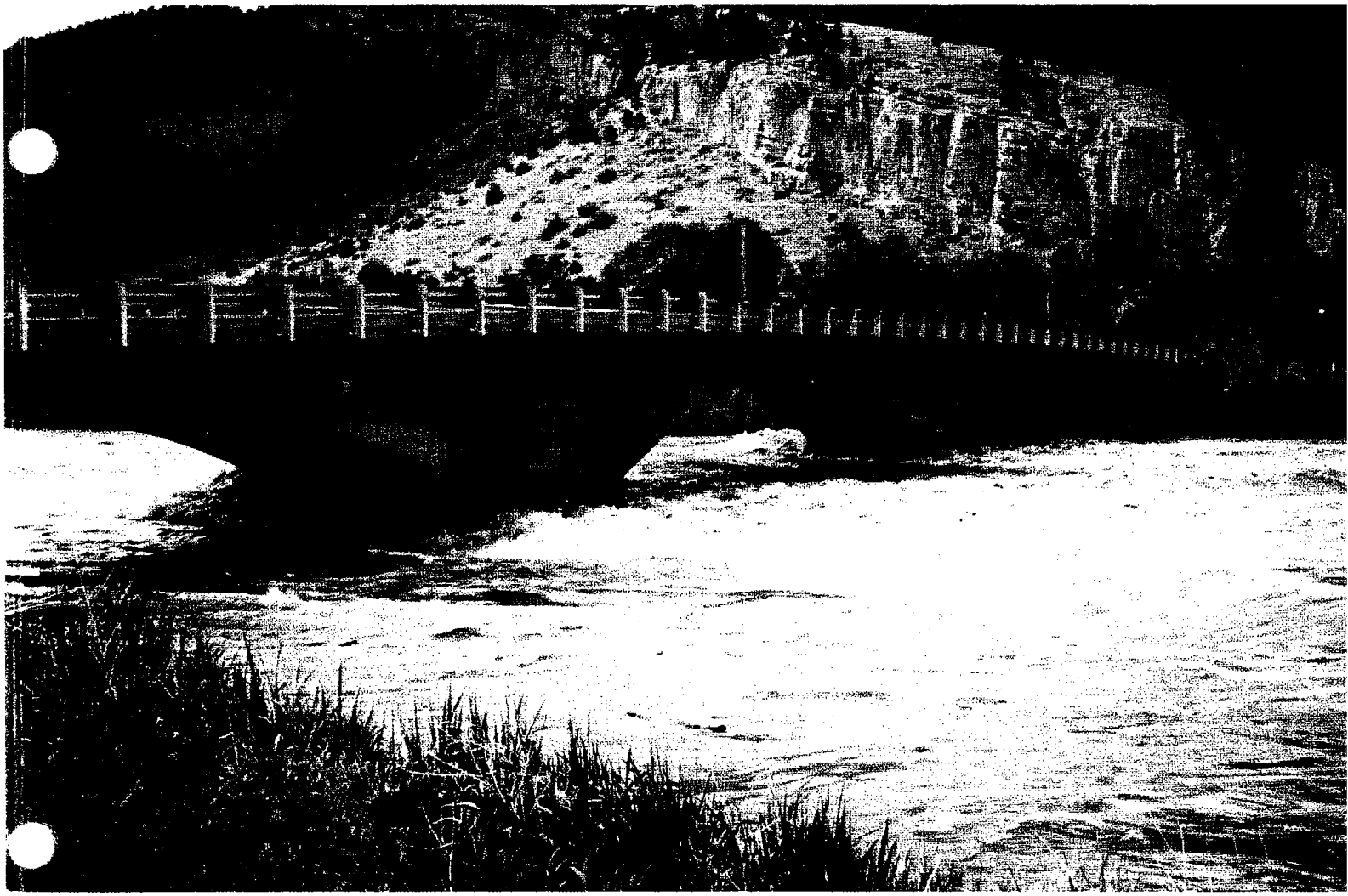
science for a changing world

In cooperation with the
BUREAU OF INDIAN AFFAIRS, BUREAU OF LAND MANAGEMENT,
CONFEDERATED SALISH AND KOOTENAI TRIBES,
MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION,
MONTANA DEPARTMENT OF TRANSPORTATION, and the
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE

Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998

Water-Resources Investigations Report 03-4308



U.S. Department of the Interior
U.S. Geological Survey

B1-75

Similarly, equation 3a can be expressed in terms of actual variable values as:

$$Q_T = K' x^a, \tag{4a}$$

where all terms are as previously described.

The solution to the general regression equations (3 and 3a) can be obtained using matrix algebra for both OLS and GLS regression methods. Because intermediate matrices in the solution are required for determination of measures of regression reliability and confidence limits, the matrices required to solve equations 3 and 3a are described in the Appendix (back of the report). Also described in the Appendix are the intermediate solution matrices and how they are used to calculate regression reliability and confidence limits.

Basin-Characteristics Regression Analysis

Basin characteristics that previously had been measured for gaged sites in Montana (Omang, 1992) and that were considered as possible explanatory variables in multiple regression equations in this study were:

A	drainage area, in mi^2;
L	main channel length, in mi;
S	main channel slope, in ft/mi;
P	mean annual precipitation, in in.;
F	percentage of basin covered by forest;
E	mean basin elevation, in ft;
E_{6000}	percentage of basin above 6,000 ft elevation; and
$JANMIN$	average mean January minimum temperature in the basin, in degrees F.

Basin characteristics that were found to be significant in any of the regional regression equations were drainage area (A), mean annual precipitation (P), mean basin elevation (E), percentage of the basin above 6,000 ft elevation (E_{6000}), and percentage of basin covered by forest (F). For gaged sites, drainage area was determined by planimetry of the basin boundary on a suitable-scale USGS quadrangle map. For small basins with drainage areas smaller than about 100 square miles, 1:24,000 quadrangle maps were used. For larger basins, the map scale ranged from 1:48,000 to 1:250,000. Mean annual precipitation for gaged basins was determined by first overlaying a transparent grid on a map showing basin boundary and contours of mean annual precipitation developed by the NRCS, formerly U.S. Soil Conservation Service (U.S. Soil Conservation Service, 1981). The grid size varied depending upon the basin size. In general, the grid size was selected to ensure that at least 10 grid intersections were within the basin boundary. The mean annual precipitation value at each grid intersection within the basin boundary was summed and then divided by the total number of grid intersections to produce a basin average value for mean annual precipitation. Mean basin elevation at gaged sites was determined in a similar manner by overlaying a variable-sized transparent grid on a USGS quadrangle map showing the basin boundary, summing the elevation found at each grid intersection, and dividing by the total number of grid intersections. Percentage of basin above 6,000 ft in elevation was determined by planimetry (on a suitable-scale USGS quadrangle map) of the area of the gaged basin above the 6,000-ft contour line and dividing by the total drainage area. A suitable map scale was determined on the basis of basin size in the same manner as for drainage area. In a similar manner, percentage of basin covered by forest was determined by planimetry (on a suitable-scale USGS quadrangle map) of the green-colored area of the gaged basin and dividing by the total drainage area.

To ensure that all values of the basin characteristics would be greater than zero before transformation to base 10 logarithms (logarithm of 0 is undefined), 1.0 was added to all values of E_{6000} and F prior to the regression analysis. In addition, to ensure that the regression coefficient for mean basin elevation would be reasonably large, all values of E were divided by 1,000 prior to the regression analysis.

The use of computerized Geographic Information Systems (GIS) enables rapid computation of basin and climatic characteristics at ungaged sites. However, depending on map scale and the relative coarseness of the digital elevation maps used to determine elevation-based characteristics, GIS measurements may not be comparable to

characteristics measured from maps at the gaged sites. Likewise, various maps of mean annual precipitation based on data more recent than the NRCS map used in this report are now generally available for GIS determination of mean annual precipitation. However, these maps generally do not have the detailed precipitation data for mountainous areas that were used to develop the maps used for this report. Thus, GIS-measured characteristics, including mean annual precipitation values from other sources, should be compared at several gaged sites to those shown in this report before using GIS-measured characteristics at ungaged sites to estimate flood frequency from the regression equations. For convenience, the maps of mean annual precipitation developed by the NRCS using data from 1941-70 (U.S. Soil Conservation Service, 1981) are reproduced in this report (fig. 6 on pl. 1) for the regions where mean annual precipitation was a significant explanatory variable.

The hydrologic flood regions used for the regression analyses (fig. 1) are based largely on previous flood-frequency analyses for Montana (Omang and others, 1986; Omang, 1992). Some slight modifications to those previously determined regional boundaries were made for this report primarily to ensure that physiographic and climatic conditions were similar within each region. Regions whose boundaries are slightly different from those shown in Omang (1992) are the West, Southeast, Upper Yellowstone-Central Mountain, and Southwest Regions.

Results of the regression analyses based on basin characteristics for all regions are presented in table 4 (back of the report). Measures of the overall reliability of the regression equations included in table 4 are the average sampling error variance, the model error variance, the average standard error of prediction (*SEP*), and the estimated equivalent years of record (*EYR*). The average sampling error variance provides an indication of the error associated with the *T*-year flood as a result of the variability of annual peak discharges at the gaged sites. The model error variance provides a measure of the error associated with the regression model. The average *SEP* (in base 10 log units) is the square root of the sum of the model error variance and average sampling error variance (both in log units) and indicates the overall average prediction error for any estimated Q_T in each region based on the data used to develop the regression equation. Overall, smaller values of average *SEP* indicate better reliability of the regression equations than do larger values of average *SEP*. The average *SEP*, which is commonly expressed in percent rather than log units, can be converted from log units to percent using the following equation:

$$SEP\ (\text{percent}) = [100\,(e^{(5.3018\,SEP(\log)^2)} - 1)]^{0.5}, \tag{5}$$

where

e	is the natural logarithmic base (approximately 2.71828), and
SEP (log)	is the *SEP* in base 10 log units.

The *EYR* indicates the number of years of record that would be needed at a gaged site in the region to provide the same reliability for Q_T as the regression estimate. Regions with highly variable annual peak discharges and resultant large time-sampling errors at the gaged sites will tend to have larger average *SEP* than regions where annual peak discharges are less variable. For this reason, *EYR* probably is a better indicator of overall regression reliability among regions. However, calculation of *EYR* also is based on the assumption that the annual peak discharges at a site can be described by the log-Pearson Type III probability distribution. As previously described, the log-Pearson Type III distribution is not generally applicable in the Northwest Region because annual floods result from two different causes (mixed populations). Accordingly, values of *EYR* are not shown in table 4 for the Northwest Region, and, therefore, values of average *SEP* are used to make most comparisons among regions.

Although the average *SEP* provides an indication of the average reliability of a regression equation within a region, the reliability of a particular estimate rather than the average reliability of all estimates is more useful. Calculation of the standard error of prediction for a particular estimate (SEP_i) is described in the Appendix.

Once the SEP_i has been calculated for a particular estimate, the SEP_i can further be used to calculate a confidence interval for the estimate using the following equation:

$$CI_{i,a} = \pm\, t_{(a/2,n-p)}\,(SEP_i), \tag{6}$$

where

$CI_{i,a}$ is the confidence interval, in log units, for an estimate at site i for a confidence level of a,

$t_{(a/2,n-p)}$ is the Student's t value for a confidence level of $100(1-a)$ percent and $(n-p+1)$ degrees of freedom, and

n and p are the number of sites used in the regression equation and the number of independent variables used in the regression equation, respectively.

If the discharge estimate at site i, $Q_{T,i}$ is converted to a logarithm, log $Q_{T,i}$, the confidence interval can be expressed in units of discharge using the following equation:

$$10^{(\log Q_{T,i} - Cl_{cl,i})} \leq \text{true} Q_{T,i} \leq 10^{(\log Q_{T,i} + Cl_{cl,i})}, \tag{7}$$

where true $Q_{T,i}$ is the true or actual value of the T-year flood at site i.

For example, assume an estimated Q_T at site i of 200 cubic feet per second has an $SEP_i = 0.225$ log units. Further assume that the estimate is in a region where the number of sites used in the regression analysis is 40 and the number of independent variables in the regression equation is 2. The 90-percent confidence interval for this estimate would be computed as follows:

First, from a table in any statistics textbook, the value of Student's t for $a/2 = 0.05$ and $(n-p) + 1 = 39$ is determined to be 1.68.

Then, from equation 6,

$$CI_{i,ca} = \pm 1.68\ (0.225),$$
$$= \pm\ 0.378.$$

Then, from equation 7,

$$10^{\log 200 - 0.378} \leq \text{true } Q_{T,i} \leq 10^{\log 200 + 0.378},$$
$$10^{2.301 - 0.378} \leq \text{true } Q_{T,i} \leq 10^{2.301 + 0.378},$$
$$10^{1.923} \leq \text{true } Q_{T,i} \leq 10^{2.679},$$

84 cubic feet per second ≤ true $Q_{T,i}$ ≤ 480 cubic feet per second.

Table 5 shows the range of $(n-p)$ among the three regression methods (basin characteristics, active-channel width, and bankfull width) in each region. This small variation in $(n-p)$ among methods results in no change to the Student's t value for a confidence interval of 90 percent. Thus, values of Student's t for a confidence interval of 90 percent within any region can be determined from table 5 and used for any of the different regression methods.

Table 5. Student's t for a confidence interval of 90 percent for different regions

[Abbreviations: n, number of stations used in the regression analysis; p, number of explanatory (independent) variables used in the regression analysis]

Region	Range of $(n-p)$	Student's t for 90-percent confidence interval
West	89-93	1.66
Northwest	28-33	1.69
Northwest Foothills	21-23	1.73
Northeast Plains	38-55	1.68
East-Central Plains	76-83	1.66
Southeast Plains	59-67	1.67
Upper Yellowstone-Central Mountain	81-90	1.66
Southwest	41-42	1.68

Within each region, the average *SEP* values (in percent) generally decrease with increasing recurrence interval (T) from $T = 2$ years to about $T = 25$ years (table 4). From $T = 25$ years to $T = 500$ years, the average *SEP* values increase. For all regions, the highest *SEP* is for the extreme recurrence intervals ($T = 2$ or $T = 500$ years), and the lowest *SEP* is for the mid-range recurrence intervals ($T = 5$, 10, 25, or 50 years). The West Region had average *SEP* values that generally were smaller than those for all other regions except the Northwest Region. The Northwest Region had the smallest values of *SEP* for all recurrence intervals. The smallest value of average *SEP* for any Q_T in any region was 37.4 percent for estimation of Q_{50} in the Northwest Region, and the largest value of average *SEP* for any Q_T in any region was 134.1 percent for estimation of Q_2 in the Southeast Plains Region.

The *EYR* increased with increasing recurrence interval to $T = 100$ years in all regions except the Northwest Regions where *EYR* was indeterminate. For the Northwest Foothills and East-Central Plains Regions, the maximum *EYR* was for a recurrence interval of $T = 50$ years or $T = 100$ years. For all other regions, the maximum *EYR* was for a recurrence interval of $T = 200$ or $T = 500$ years. Among regions, the Northwest Foothills and Upper Yellowstone-Central Mountain Regions had the largest *EYR* for recurrence intervals greater than about 5 years and the West Region had the smallest *EYR* for all recurrence intervals. Overall, the EYR ranged from 0.9 year for the equations for estimation of Q_2 in the West and Southwest Regions to 23.8 years for the equations for estimation of Q_{50} and Q_{100} in the Northwest Foothills Region.

Multiple regression equations may not be reliable if the values of any explanatory variables are outside the range of values used to develop the equations. The range of values for each basin characteristic (explanatory variable) can be used as a guide for deciding when the equations may not be applicable (table 6). Regression estimates also may not be reliable for some combinations of values of explanatory variables that define a location far from the center of the joint distribution of all values of the explanatory variables even though each value is within the ranges shown in table 6. The $\mathbf{x_i}^T(\mathbf{X}^T\mathbf{X})^{-1}\mathbf{x_i}$ matrix for OLS regression and the $\mathbf{x_i}^T(\mathbf{X}^T\Lambda^{-1}\mathbf{X})^{-1}\mathbf{x_i}$ matrix for GLS regression, terms that are described in the Appendix and used for the calculation of SEP_i, provide a measure of how far a set of particular explanatory variables is from the center of the joint distribution of all values of the explanatory variables. If values of these matrices are greater than about $2p/n$, where p and n are the number of explanatory variables and number of data points in the regression, respectively, the regression results may not be reliable.

Table 6. Range of values of basin characteristics used to develop regression equations

[Abbreviations: *A*, drainage area, in square miles; *E*, mean basin elevation, in feet; E_{6000}, percentage of basin above 6,000 feet in elevation; *F*, percentage of basin covered by forest; *P*, mean annual precipitation, in inches; Min, minimum value; Max, maximum value. Symbol: --, not applicable]

Region	*A*		*E*		E_{6000}		*F*		*P*	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
West	0.86	2,378	--	--	--	--	15	100	12	79
Northwest	.14	1,548	--	--	--	--	--	--	15	95
Northwest Foothills	.25	1,041	--	--	--	--	--	--	--	--
Northeast Plains	.11	1,208	2,060	4,860	--	--	--	--	--	--
East-Central Plains	.22	2,447	2,090	4,250	--	--	--	--	--	--
Southeast Plains	.14	1,974	--	--	--	--	0	67	--	--
Upper Yellowstone-Central Mountain	.47	2,032	--	--	0	100	--	--	--	--
Southwest	.39	2,476	--	--	--	--	0	100	--	--

even within the mountainous super-region GLS regression is considered to be the best approach for flood estimation for the following reasons: (1) use of the ROI regression procedure requires use of a computer program or access to the USGS Montana District home page for calculation (http://montana.usgs.gov/freq), neither of which may be readily available for in-the-field application, and (2) ROI regression may provide flood discharge estimates for different recurrence intervals that are inconsistent because the equations may be based on different basin variables. Consequently, the ROI regression procedure was not further developed for use in Montana.

Estimating Flood Frequency on Gaged Streams

Ungaged Sites on Gaged Streams

If an ungaged site of interest is near a gaged site on the same stream, flood-frequency data for the gaged site can be used to estimate flood frequency for the ungaged site using a drainage-area ratio adjustment. The T-year flood at the ungaged site ($Q_{T,U}$) is calculated using the following equation:

$$Q_{T,U} = Q_{T,G}\left(\frac{DA_U}{DA_G}\right)^{\exp_T}, \tag{19}$$

where

$Q_{T,G}$ is the T-year flood at the gaged site, in cubic feet per second,

DA_U is the drainage area at the ungaged site, in square miles,

DA_G is the drainage area at the gaged site, in square miles, and

$\exp_T$ is the regression coefficient for a simple OLS regression relating the log of T-year flood to log of drainage area within each region (table 13).

Table 13. Regression coefficients for ordinary least squares (OLS) regressions relating T-year flood (Q_T) to drainage area

T-year flood	Regression coefficient relating T-year flood to drainage area for indicated region							
	West Region	Northwest Region	Northwest Foothills Region	Northeast Plains Region	East-Central Plains Region	Southeast Plains Region	Upper Yellowstone-Central Mountain Region	Southwest Region
Q_2	0.851	0.884	0.609	0.620	0.464	0.516	0.877	0.894
Q_5	.818	.822	.587	.564	.459	.478	.768	.776
Q_{10}	.798	.789	.577	.536	.454	.458	.712	.720
Q_{25}	.776	.747	.566	.506	.446	.433	.656	.661
Q_{50}	.761	.722	.560	.486	.439	.418	.618	.622
Q_{100}	.747	.700	.555	.469	.432	.403	.587	.585
Q_{200}	.734	.685	.551	.453	.426	.389	.557	.550
Q_{500}	.717	.665	.547	.433	.417	.371	.523	.510

Equation 19 can be used to estimate flood-frequency characteristics at ungaged sites on large streams, where the regression equations are not applicable because their large drainage areas fall outside the range of values used to develop the equations. However, equation 19 is likely to be unreliable if the value of DA_U/DA_G is less than 0.5 or greater than 1.5. For ungaged sites where the values are beyond those limits, the regression equations in table 4 generally are considered to provide more reliable estimates of $Q_{T,U}$ than equation 19.

Estimates for *T*-year floods at ungaged sites on gaged streams also can be made using channel-width ratio adjustments in a manner similar to the use of drainage-area ratio adjustments. The *T*-year flood at the ungaged site ($Q_{T,U}$) is calculated using an equation similar to equation 19:

$$Q_{T,U} = Q_{T,G}\left(\frac{W_U}{W_G}\right)^{\exp_T}, \tag{20}$$

where

W_U is the channel width (either W_{ac} or W_{bf}) at the ungaged site, in feet,

W_G is the channel width (either W_{ac} or W_{bf}) at the gaged site, in feet, and,

$\exp_T$ is the regression coefficient for either W_{ac} or W_{bf} for the *T*-year flood found in table 7 or table 8.

Use of the drainage-area ratio adjustment or the channel-width ratio adjustment to estimate *T*-year floods at an ungaged site on a nearby stream might be appropriate in some instances. For example, an ungaged site might be located on a stream that is known to have flood characteristics similar to those on a nearby gaged stream. If the flood characteristics at the gaged site are not generally similar to those at other gaged sites in the region, use of the drainage-area ratio adjustment or the channel-width adjustment might provide a more reliable estimate than use of the regional regression equations. Without some additional knowledge about flood characteristics in a specific area of application, however, use of regional regression equations is considered to provide more reliable estimates of *T*-year floods at sites on ungaged streams.

If an ungaged site of interest is between two gaged sites on the same stream, the logarithms of flood-frequency characteristics at the ungaged site can be linearly interpolated between logarithms of flood-frequency characteristics at the two gaged sites using logarithms of drainage area as the basis for interpolation as follows:

$$\log Q_{T,U} = \log Q_{T,G1} + [(\log Q_{T,G2} - \log Q_{T,G1})/(\log DA_{G2} - \log DA_{G1})](\log DA_U - \log DA_{G1}), \tag{21}$$

where

log is the base 10 logarithm,

$Q_{T,U}$ is the *T*-year flood at the ungaged site, in cubic feet per second,

$Q_{T,G1}$ is the *T*-year flood at the upstream gaged site, in cubic feet per second,

$Q_{T,G2}$ is the *T*-year flood at the downstream gaged site, in cubic feet per second,

DA_{G2} is the drainage area at the downstream gaged site, in square miles,

DA_{G1} is the drainage area at the upstream gaged site, in square miles, and

DA_U is the drainage area, at the ungaged site, in square miles.

Equation 21 also can be used to estimate flood-frequency characteristics at ungaged sites on large streams where the use of regression equations is not applicable because their drainage areas fall outside the range of values used to develop the equations. The obvious limitation on the use of equation 21 is the need to have a gaged site both upstream and downstream from the ungaged site. Application of equation 21 may provide unreliable estimates if the two gaged sites have different periods of record with insufficient overlap.

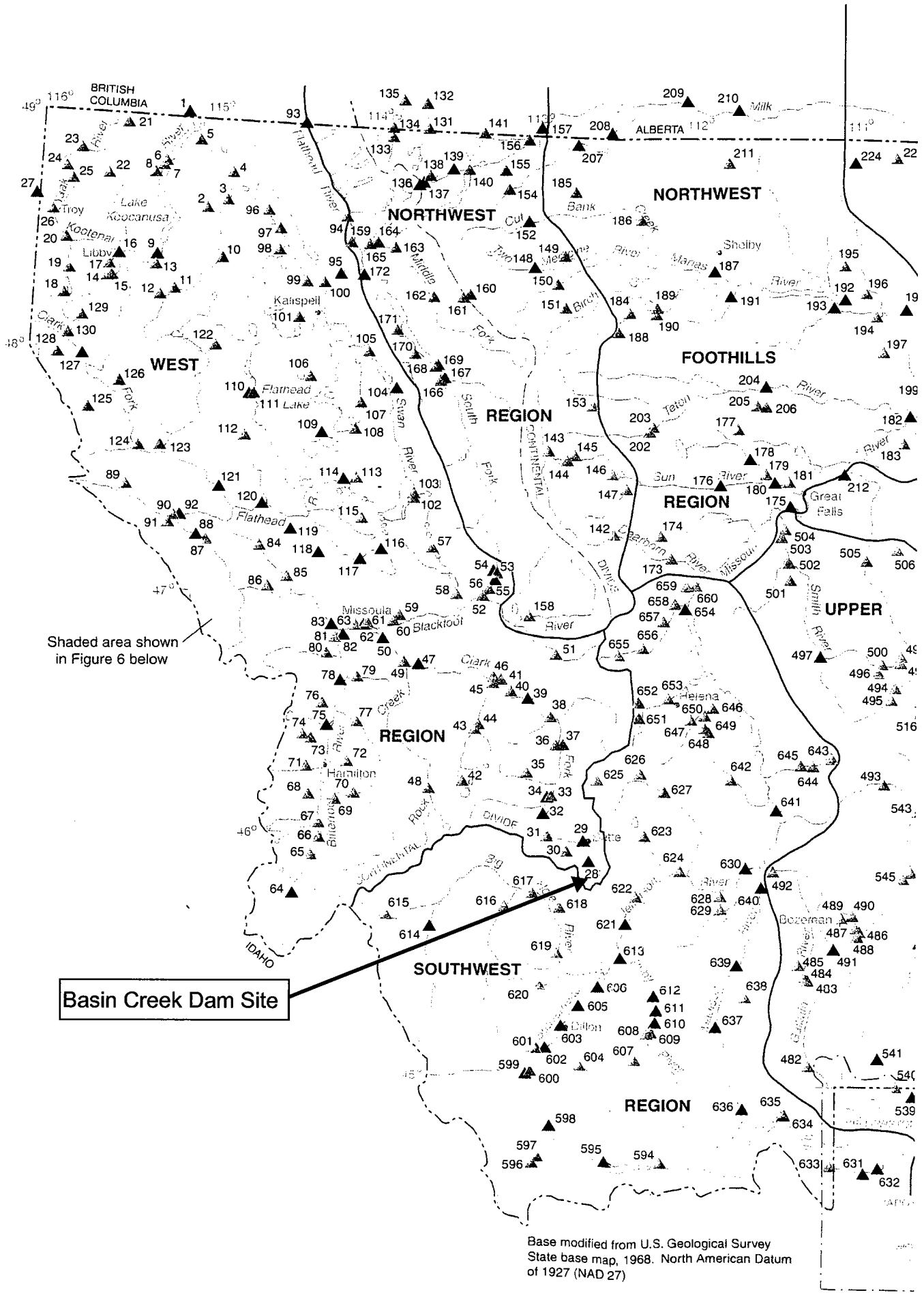
Table 4. Regression equations based on basin characteristics

[Abbreviations: n, number of stations used in the regression analysis; Q_T, annual peak discharge, in cubic feet per second, for recurrence interval T, in years; A, drainage area, in square miles; P, mean annual precipitation, in inches; F, percentage of basin covered by forest; E, mean basin elevation, in feet; E_{6000}, percentage of basin above 6,000 feet in elevation; *SEP*, standard error of prediction; *EYR*, equivalent years of record. Symbol: --, not applicable]

Regression equation	Error variance, log units		Average *SEP*, in log units	Average *SEP*, in percent	*EYR*
	Average sampling	Model			
West Region (n = 96)					
$Q_2 = 0.268\,A^{0.927}\,P^{1.60}\,(F+1)^{-0.508}$	0.003	0.056	0.242	60.5	0.9
$Q_5 = 1.54\,A^{0.884}\,P^{1.36}\,(F+1)^{-0.577}$	.003	.048	.224	55.4	1.4
$Q_{10} = 3.63\,A^{0.86}\,P^{1.25}\,(F+1)^{-0.605}$	.003	.046	.221	54.3	1.9
$Q_{25} = 8.50\,A^{0.835}\,P^{1.14}\,(F+1)^{-0.639}$	.003	.046	.222	54.6	2.7
$Q_{50} = 13.2\,A^{0.823}\,P^{1.09}\,(F+1)^{-0.652}$	.003	.048	.227	56.0	3.1
$Q_{100} = 18.7\,A^{0.812}\,P^{1.06}\,(F+1)^{-0.664}$	.004	.052	.235	58.5	3.4
$Q_{200} = 24.7\,A^{0.804}\,P^{1.04}\,(F+1)^{-0.674}$	.004	.058	.248	62.2	3.6
$Q_{500} = 35.4\,A^{0.792}\,P^{1.02}\,(F+1)^{-0.69}$	.005	.067	.267	67.9	3.7
Northwest Region (n = 35)					
$Q_2 = 0.128\,A^{0.918}\,P^{1.33}$	.003	.038	.202	49.2	--
$Q_5 = 1.19\,A^{0.846}\,P^{0.954}$	.002	.025	.164	39.2	--
$Q_{10} = 4.10\,A^{0.807}\,P^{0.72}$	.002	.024	.161	38.4	--
$Q_{25} = 15.8\,A^{0.76}\,P^{0.51}$	.002	.024	.161	38.4	--
$Q_{50} = 31.2\,A^{0.733}\,P^{0.445}$	.002	.023	.157	37.4	--
$Q_{100} = 56.4\,A^{0.71}\,P^{0.403}$	.002	.026	.168	40.2	--
$Q_{200} = 97.0\,A^{0.694}\,P^{0.364}$	.003	.033	.190	46.0	--
$Q_{500} = 175\,A^{0.674}\,P^{0.347}$	.004	.049	.230	56.9	--
Northwest Foothills Region (n = 24)					
$Q_2 = 14.2\,A^{0.598}$	.016	.114	.360	99.5	2.7
$Q_5 = 53.6\,A^{0.546}$	.010	.047	.239	59.6	8.7
$Q_{10} = 105\,A^{0.546}$	.010	.034	.210	51.3	15.5
$Q_{25} = 208\,A^{0.538}$	.012	.032	.208	50.8	22.2
$Q_{50} = 318\,A^{0.536}$	.014	.036	.223	55.0	23.8
$Q_{100} = 462\,A^{0.537}$	.016	.044	.244	61.0	23.8
$Q_{200} = 649\,A^{0.54}$	.019	.053	.268	68.2	23.1
$Q_{500} = 977\,A^{0.544}$	.023	.068	.302	79.0	21.8
Northeast Plains Region (n = 57)					
$Q_2 = 30.5\,A^{0.601}\,(E/1000)^{-0.913}$	.008	.106	.337	91.0	3.0
$Q_5 = 143\,A^{0.547}\,(E/1000)^{-1.12}$	.007	.087	.306	80.3	4.3
$Q_{10} = 293\,A^{0.52}\,(E/1000)^{-1.19}$	.007	.088	.309	81.3	5.5
$Q_{25} = 579\,A^{0.493}\,(E/1000)^{-1.21}$	.009	.098	.326	87.2	6.6
$Q_{50} = 860\,A^{0.477}\,(E/1000)^{-1.21}$	.010	.109	.345	93.9	7.2
$Q_{100} = 1{,}190\,A^{0.462}\,(E/1000)^{-1.20}$	.011	.122	.365	101.4	7.5
$Q_{200} = 1{,}570\,A^{0.45}\,(E/1000)^{-1.17}$	.013	.137	.386	109.9	7.7
$Q_{500} = 2{,}130\,A^{0.435}\,(E/1000)^{-1.13}$	.015	.159	.417	123.2	7.7

Table 4. Regression equations based on basin characteristics (Continued)

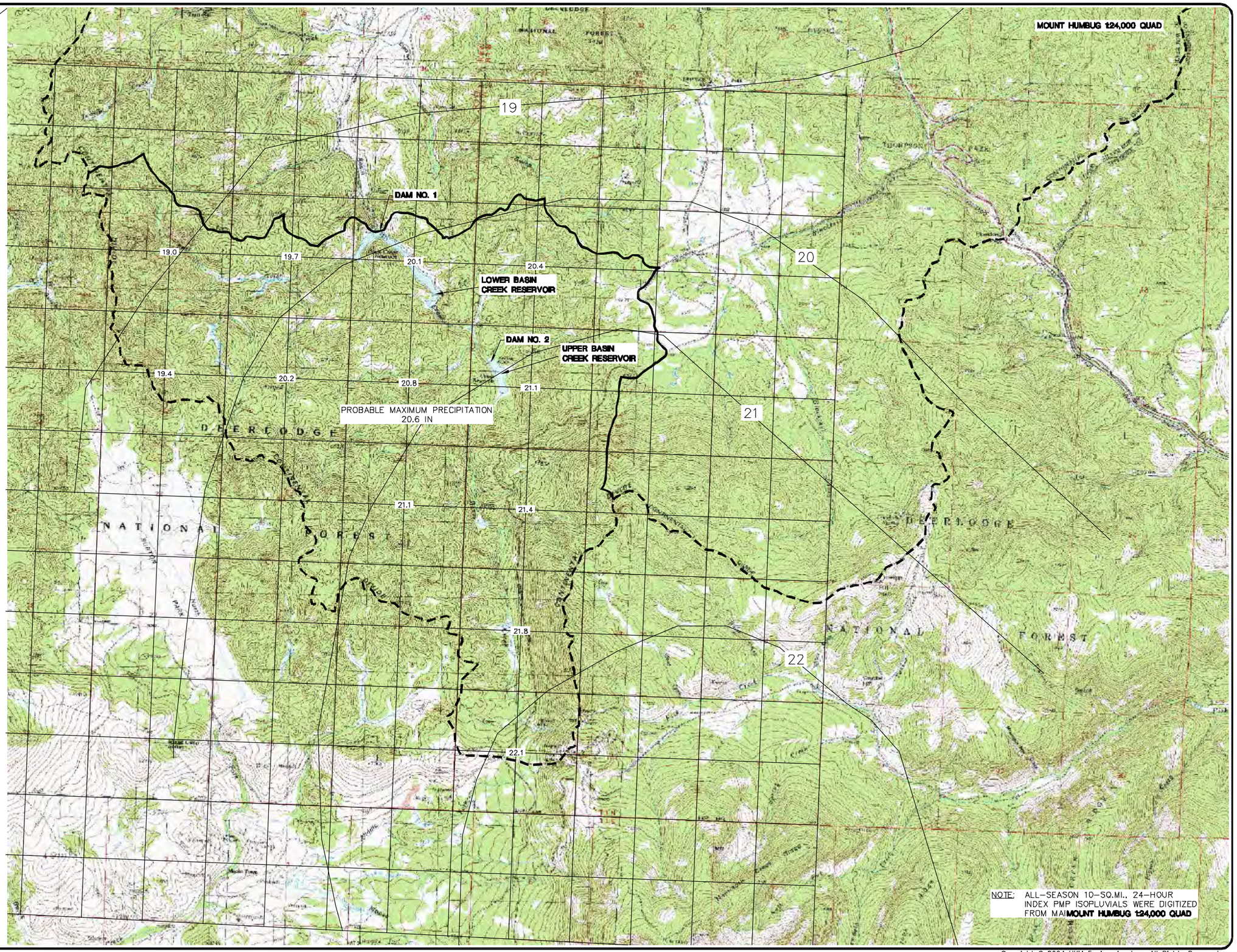
Regression equation	Error variance, log units: Average sampling	Error variance, log units: Model	Average *SEP*, in log units	Average *SEP*, in percent	*EYR*
East-Central Plains Region (n = 85)					
$Q_2 = 141\ A^{0.495}\ (E/1000)^{-1.85}$	.008	.123	.361	99.9	3.1
$Q_5 = 661\ A^{0.49}\ (E/1000)^{-2.09}$	.006	.080	.293	76.0	5.7
$Q_{10} = 1{,}300\ A^{0.482}\ (E/1000)^{-2.11}$	.006	.071	.278	71.4	8.3
$Q_{25} = 2{,}360\ A^{0.47}\ (E/1000)^{-2.05}$	.007	.074	.285	73.4	10.7
$Q_{50} = 3{,}240\ A^{0.462}\ (E/1000)^{-1.96}$	.008	.082	.301	78.6	11.6
$Q_{100} = 4{,}120\ A^{0.454}\ (E/1000)^{-1.84}$	.009	.094	.322	85.7	12.0
$Q_{200} = 4{,}950\ A^{0.446}\ (E/1000)^{-1.72}$	.011	.109	.346	94.3	11.9
$Q_{500} = 5{,}940\ A^{0.435}\ (E/1000)^{-1.53}$	.012	.133	.381	107.8	11.6
Southeast Plains Region (n = 69)					
$Q_2 = 29.0\ A^{0.60}\ (F+1)^{-0.424}$	.010	.183	.440	134.1	1.5
$Q_5 = 83.1\ A^{0.547}\ (F+1)^{-0.352}$	.008	.130	.371	103.9	2.6
$Q_{10} = 142\ A^{0.517}\ (F+1)^{-0.309}$	.007	.112	.346	94.3	4.0
$Q_{25} = 249\ A^{0.483}\ (F+1)^{-0.264}$	.008	.102	.331	88.9	6.0
$Q_{50} = 355\ A^{0.461}\ (F+1)^{-0.236}$	.008	.102	.332	89.1	7.3
$Q_{100} = 486\ A^{0.441}\ (F+1)^{-0.212}$	.009	.106	.338	91.6	8.3
$Q_{200} = 645\ A^{0.422}\ (F+1)^{-0.19}$	.009	.114	.351	96.1	9.0
$Q_{500} = 905\ A^{0.401}\ (F+1)^{-0.166}$	.011	.130	.375	105.5	9.3
Upper Yellowstone-Central Mountain Region (n = 92)					
$Q_2 = 5.84\ A^{0.832}\ (E_{6000}+1)^{0.098}$	.005	.115	.348	94.9	1.5
$Q_5 = 21.7\ A^{0.782}\ (E_{6000}+1)^{-0.0295}$	.004	.076	.282	72.7	3.2
$Q_{10} = 42.3\ A^{0.758}\ (E_{6000}+1)^{0.0915}$	.004	.060	.252	63.4	5.6
$Q_{25} = 82.6\ A^{0.733}\ (E_{6000}+1)^{-0.148}$	.004	.049	.230	57.1	9.5
$Q_{50} = 126\ A^{0.716}\ (E_{6000}+1)^{-0.182}$	.004	.047	.226	55.9	12.2
$Q_{100} = 181\ A^{0.702}\ (E_{6000}+1)^{-0.211}$	.005	.048	.229	56.8	14.2
$Q_{200} = 252\ A^{0.689}\ (E_{6000}+1)^{-0.238}$	.005	.052	.239	59.5	15.4
$Q_{500} = 375\ A^{0.674}\ (E_{6000}+1)^{-0.271}$	.006	.061	.258	65.2	15.9
Southwest Region (n = 44)					
$Q_2 = 3.02\ A^{0.881}\ (E_{6000}+1)^{0.0981}$	.010	.110	.346	94.4	.9
$Q_5 = 17.1\ A^{0.80}\ (E_{6000}+1)^{-0.104}$	.008	.083	.302	79.0	1.7
$Q_{10} = 41.9\ A^{0.765}\ (E_{6000}+1)^{-0.214}$	.009	.077	.292	75.9	2.4
$Q_{25} = 109\ A^{0.728}\ (E_{6000}+1)^{-0.332}$	.010	.076	.292	75.6	3.4
$Q_{50} = 201\ A^{0.704}\ (E_{6000}+1)^{-0.408}$	.010	.078	.297	77.4	4.0
$Q_{100} = 351\ A^{0.682}\ (E_{6000}+1)^{-0.476}$	.012	.082	.306	80.3	4.5
$Q_{200} = 582\ A^{0.66}\ (E_{6000}+1)^{-0.537}$	.013	.088	.316	83.8	4.9
$Q_{500} = 1{,}060\ A^{0.636}\ (E_{6000}+1)^{-0.611}$	.014	.097	.334	89.9	5.3



Base modified from U.S. Geological Survey State base map, 1968. North American Datum of 1927 (NAD 27)

APPENDIX C1

PROBABLE MAXIMUM PRECIPITATION



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No.	Revision	By	Date

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

Project No. 15M424.117 • BCD-HYDROLOGY.DWG • Date JAN. 2005 • Designed SMJ • Drawn SMJ • Checked RR • Approved RR

BASIN CREEK DAM
BUTTE, MONTANA

PROBABLE MAXIMUM PRECIPITATION
GRID CALCULATIONS

HKM Engineering Inc.
1015 S. Montana St.
P.O. Box 3588
Butte, MT 59702
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FAX (406) 723-8328

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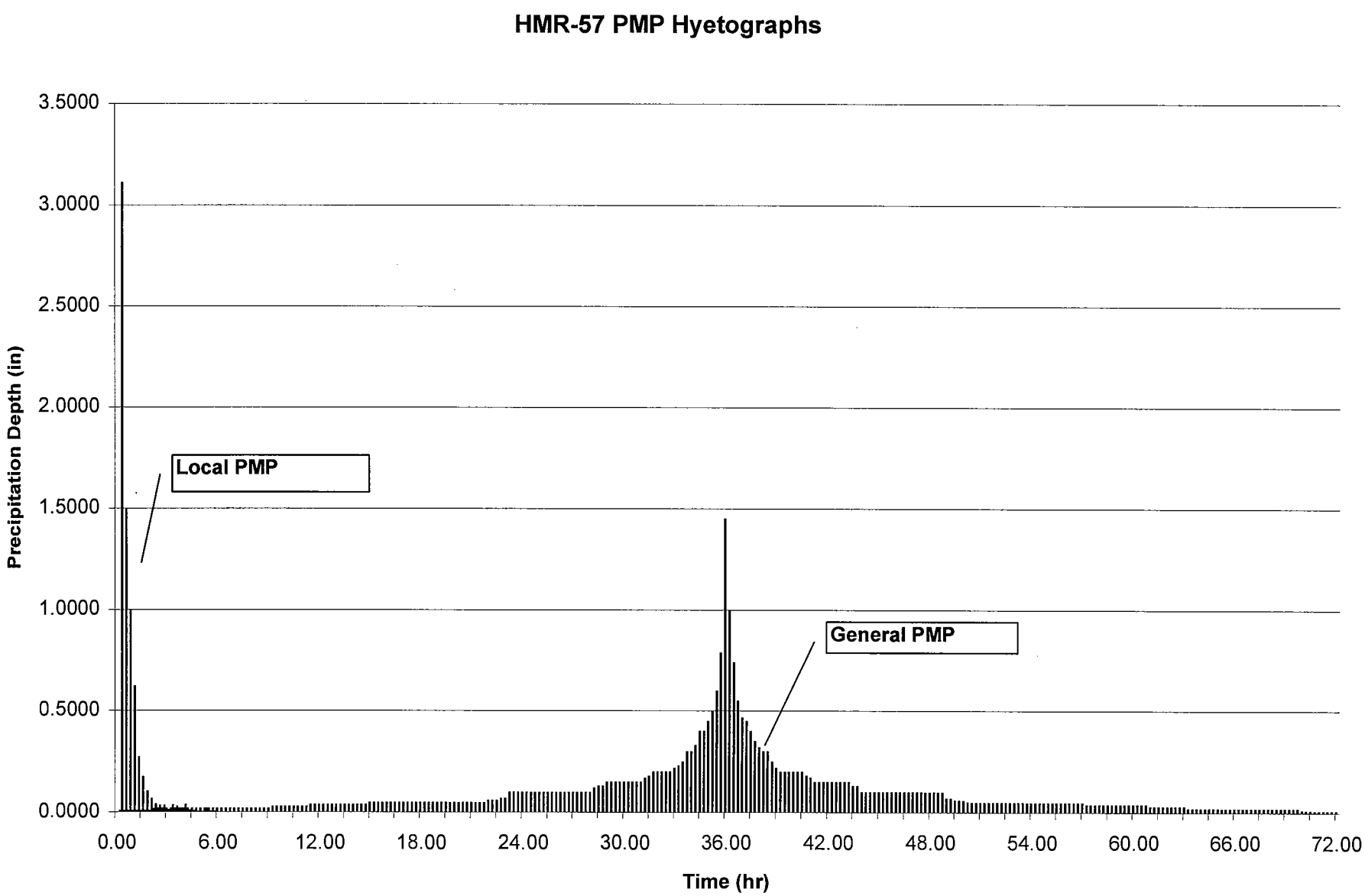
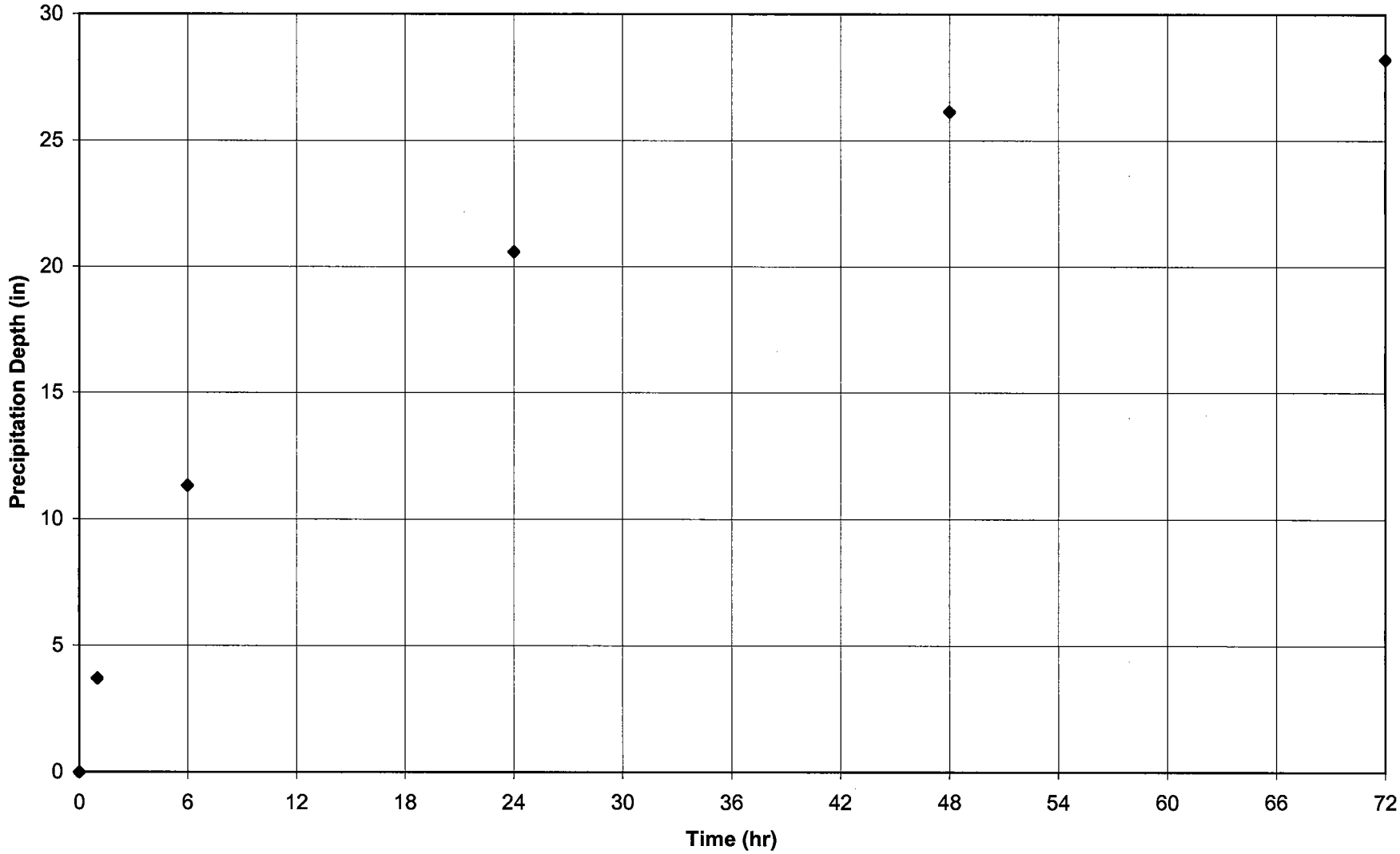
Sheet No.
C1-1

Q:\15\m424117\dwg\bcd-hydrology.DWG 12/23/2004 3:00:41 PM MST


HMR-57 PMP Hyetographs
Precipitation Depth (in)
3.5000
3.0000
2.5000
2.0000
1.5000
1.0000
0.5000
0.0000
Local PMP
General PMP
0.00
6.00
12.00
18.00
24.00
30.00
36.00
42.00
48.00
54.00
60.00
66.00
72.00
Time (hr)

HMR-57 General Storm PMP Depth-Duration Curve



General PMP Depth Duration Table

10-mi^2, 24-hour index PMP depth 20.6 in
Calculated using Map 2 of HMR-57 and the grid meth

Regional Subdivision 6 west sloped of the Rockies, orographic
From HMR-57 figure 15.9

Subregion Orographic
From HMR-57 figure 3.2

Area Reduction Factor 100%
From HMR-57 figure 15.10

Duration (hrs)	Depth (in)	Ratio
1	3.708	0.18
6	11.330	0.55
24	20.600	1.00
48	26.162	1.27
72	28.222	1.37

HMR-57 General PMP Hyetograph Ordinates

Time	Ordered Precip (in)
0.00	0.0000
0.25	0.0100
0.50	0.0100
0.75	0.0100
1.00	0.0100
1.25	0.0100
1.50	0.0100
1.75	0.0100
2.00	0.0100
2.25	0.0180
2.50	0.0200
2.75	0.0200
3.00	0.0200
3.25	0.0200
3.50	0.0200
3.75	0.0200
4.00	0.0200
4.25	0.0200
4.50	0.0200
4.75	0.0200
5.00	0.0200
5.25	0.0200
5.50	0.0200
5.75	0.0200
6.00	0.0200
6.25	0.0200
6.50	0.0200
6.75	0.0200
7.00	0.0200
7.25	0.0200
7.50	0.0200
7.75	0.0200
8.00	0.0200
8.25	0.0200
8.50	0.0200
8.75	0.0200
9.00	0.0200
9.25	0.0300
9.50	0.0300
9.75	0.0300
10.00	0.0300
10.25	0.0300
10.50	0.0300
10.75	0.0300
11.00	0.0300
11.25	0.0300
11.50	0.0400
11.75	0.0400
12.00	0.0400
12.25	0.0400
12.50	0.0400

Time	Ordered Precip (in)
12.75	0.0400
13.00	0.0400
13.25	0.0400
13.50	0.0400
13.75	0.0400
14.00	0.0400
14.25	0.0400
14.50	0.0400
14.75	0.0400
15.00	0.0500
15.25	0.0500
15.50	0.0500
15.75	0.0500
16.00	0.0500
16.25	0.0500
16.50	0.0500
16.75	0.0500
17.00	0.0500
17.25	0.0500
17.50	0.0500
17.75	0.0500
18.00	0.0500
18.25	0.0500
18.50	0.0500
18.75	0.0500
19.00	0.0500
19.25	0.0500
19.50	0.0500
19.75	0.0500
20.00	0.0500
20.25	0.0500
20.50	0.0500
20.75	0.0500
21.00	0.0500
21.25	0.0500
21.50	0.0500
21.75	0.0500
22.00	0.0600
22.25	0.0600
22.50	0.0600
22.75	0.0700
23.00	0.0700
23.25	0.1000
23.50	0.1000
23.75	0.1000
24.00	0.1000
24.25	0.1000
24.50	0.1000
24.75	0.1000
25.00	0.1000
25.25	0.1000

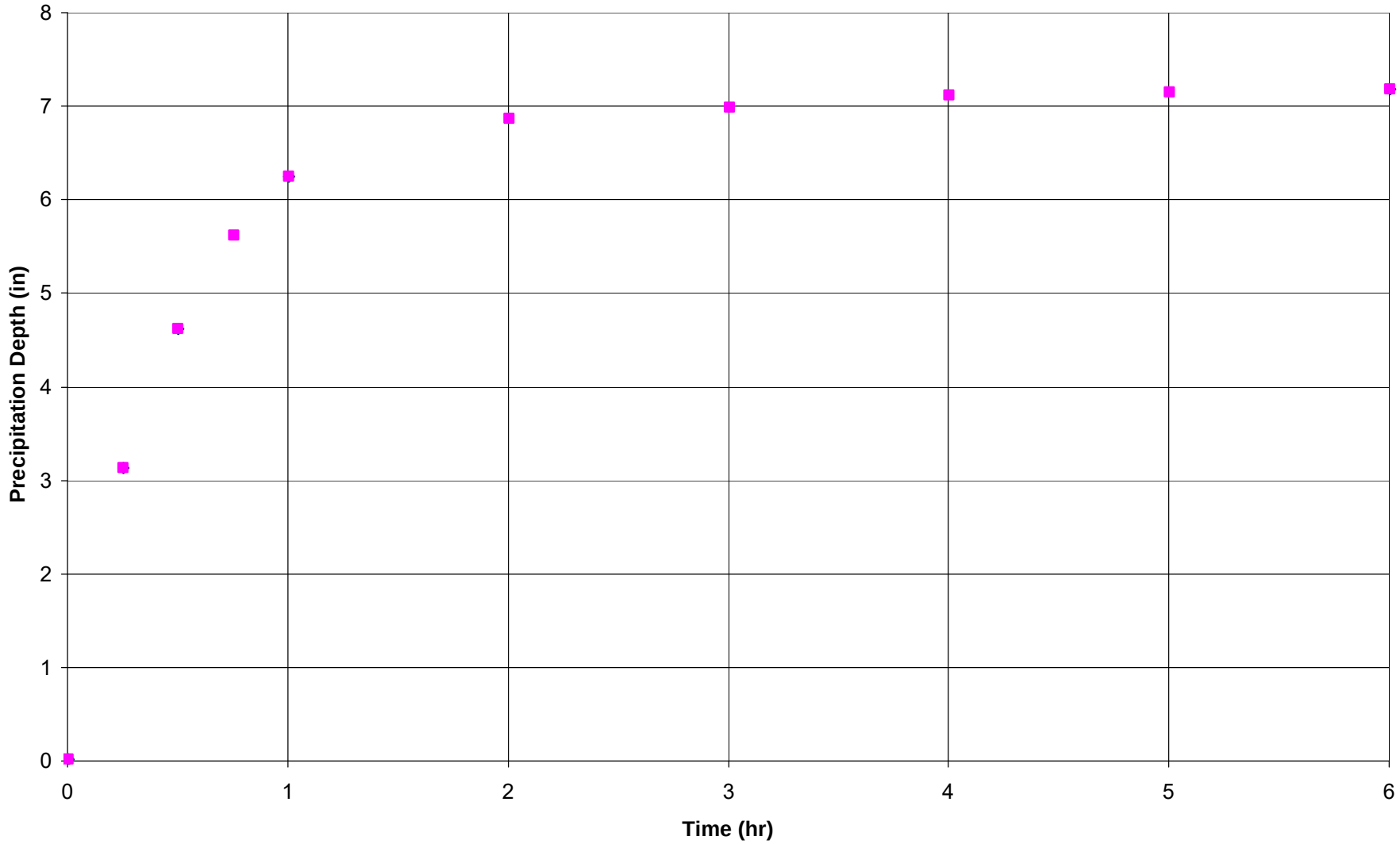
Time	Ordered Precip (in)
25.50	0.1000
25.75	0.1000
26.00	0.1000
26.25	0.1000
26.50	0.1000
26.75	0.1000
27.00	0.1000
27.25	0.1000
27.50	0.1000
27.75	0.1000
28.00	0.1000
28.25	0.1200
28.50	0.1300
28.75	0.1300
29.00	0.1500
29.25	0.1500
29.50	0.1500
29.75	0.1500
30.00	0.1500
30.25	0.1500
30.50	0.1500
30.75	0.1500
31.00	0.1500
31.25	0.1700
31.50	0.1800
31.75	0.2000
32.00	0.2000
32.25	0.2000
32.50	0.2000
32.75	0.2000
33.00	0.2200
33.25	0.2300
33.50	0.2500
33.75	0.3000
34.00	0.3000
34.25	0.3300
34.50	0.4000
34.75	0.4000
35.00	0.4500
35.25	0.5000
35.50	0.6000
35.75	0.7900
36.00	1.4500
36.25	1.0000
36.50	0.7420
36.75	0.5500
37.00	0.4680
37.25	0.4500
37.50	0.4000
37.75	0.3500
38.00	0.3200

Time	Ordered Precip (in)
38.25	0.3000
38.50	0.3000
38.75	0.2500
39.00	0.2200
39.25	0.2000
39.50	0.2000
39.75	0.2000
40.00	0.2000
40.25	0.2000
40.50	0.2000
40.75	0.1800
41.00	0.1700
41.25	0.1500
41.50	0.1500
41.75	0.1500
42.00	0.1500
42.25	0.1500
42.50	0.1500
42.75	0.1500
43.00	0.1500
43.25	0.1500
43.50	0.1300
43.75	0.1300
44.00	0.1000
44.25	0.1000
44.50	0.1000
44.75	0.1000
45.00	0.1000
45.25	0.1000
45.50	0.1000
45.75	0.1000
46.00	0.1000
46.25	0.1000
46.50	0.1000
46.75	0.1000
47.00	0.1000
47.25	0.1000
47.50	0.1000
47.75	0.1000
48.00	0.1000
48.25	0.1000
48.50	0.1000
48.75	0.1000
49.00	0.0700
49.25	0.0700
49.50	0.0600
49.75	0.0600
50.00	0.0600
50.25	0.0520
50.50	0.0500
50.75	0.0500

Time	Ordered Precip (in)
51.00	0.0500
51.25	0.0500
51.50	0.0500
51.75	0.0500
52.00	0.0500
52.25	0.0500
52.50	0.0500
52.75	0.0500
53.00	0.0500
53.25	0.0500
53.50	0.0500
53.75	0.0500
54.00	0.0500
54.25	0.0500
54.50	0.0500
54.75	0.0500
55.00	0.0500
55.25	0.0500
55.50	0.0500
55.75	0.0500
56.00	0.0500
56.25	0.0500
56.50	0.0500
56.75	0.0500
57.00	0.0500
57.25	0.0400
57.50	0.0400
57.75	0.0400
58.00	0.0400
58.25	0.0400
58.50	0.0400
58.75	0.0400
59.00	0.0400
59.25	0.0400
59.50	0.0400
59.75	0.0400
60.00	0.0400
60.25	0.0400
60.50	0.0400
60.75	0.0400
61.00	0.0300
61.25	0.0300
61.50	0.0300
61.75	0.0300
62.00	0.0300
62.25	0.0300
62.50	0.0300
62.75	0.0300
63.00	0.0300
63.25	0.0200
63.50	0.0200

Time	Ordered Precip (in)
63.75	0.0200
64.00	0.0200
64.25	0.0200
64.50	0.0200
64.75	0.0200
65.00	0.0200
65.25	0.0200
65.50	0.0200
65.75	0.0200
66.00	0.0200
66.25	0.0200
66.50	0.0200
66.75	0.0200
67.00	0.0200
67.25	0.0200
67.50	0.0200
67.75	0.0200
68.00	0.0200
68.25	0.0200
68.50	0.0200
68.75	0.0200
69.00	0.0200
69.25	0.0200
69.50	0.0200
69.75	0.0200
70.00	0.0120
70.25	0.0100
70.50	0.0100
70.75	0.0100
71.00	0.0100
71.25	0.0100
71.50	0.0100
71.75	0.0100
72.00	0.0100

HMR-57 Local Storm PMP Depth-Duration Curve



Local PMP Depth Duration Table

1-hour 1-mi^2, PMP estimate 7.88 in for elevations to 6000 ft.
From HMR-57 Plate Via - Figure 15.36

Mean Drainage Elev. 6659
using grid method

MDE Adjustment Factor 94%
based on nine percent reduction for each 1000 ft. above 6000 ft.

Area 12.017 mi^2

Area Reduction Factor 84%
From HMR-57 Figure 15.39

Elevation and Area adjusted -- 1-hour 1-mi^2, PMP estimate 6.23 in

Duration (hrs)	Depth (in)	Time Ratio
0.25	3.113	0.500
0.5	4.608	0.740
0.75	5.604	0.900
1	6.227	1.000
2	6.849	1.100
3	6.974	1.120
4	7.098	1.140
5	7.129	1.145
6	7.161	1.150

Table D1-3: HMR-57 Local PMP Hyetograph Ordinates

Time	Ordered Precip. (in)
0	0.00000
0.25	3.11300
0.5	1.49500
0.75	0.99600
1	0.62300
1.25	0.27300
1.5	0.17500
1.75	0.10500
2	0.06900
2.25	0.04100
2.5	0.03800
2.75	0.03600
3	0.03500
3.25	0.03500
3.5	0.03000
3.75	0.02100
4	0.02000
4.25	0.01400
4.5	0.01200
4.75	0.01000
5	0.00500
5.25	0.00500
5.5	0.00500
5.75	0.00400
6	0.00100

HMR-57 Local Storm
PMP Depth-Duration

Time	Accum. Precip (in.)
0.25	3.11
0.5	4.61
1	6.23
6	7.16

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC
ADMINISTRATION

U.S. DEPARTMENT OF INTERIOR
BUREAU OF RECLAMATION

U.S. DEPARTMENT OF ARMY
CORPS OF ENGINEERS

HYDROMETEOROLOGICAL REPORT NO. 57

(SUPERCEDES HYDROMETEOROLOGICAL REPORT NO. 43)

PROBABLE MAXIMUM PRECIPITATION - PACIFIC NORTHWEST STATES

Columbia River (including portions of Canada), Snake River and Pacific Coastal Drainages

Prepared By

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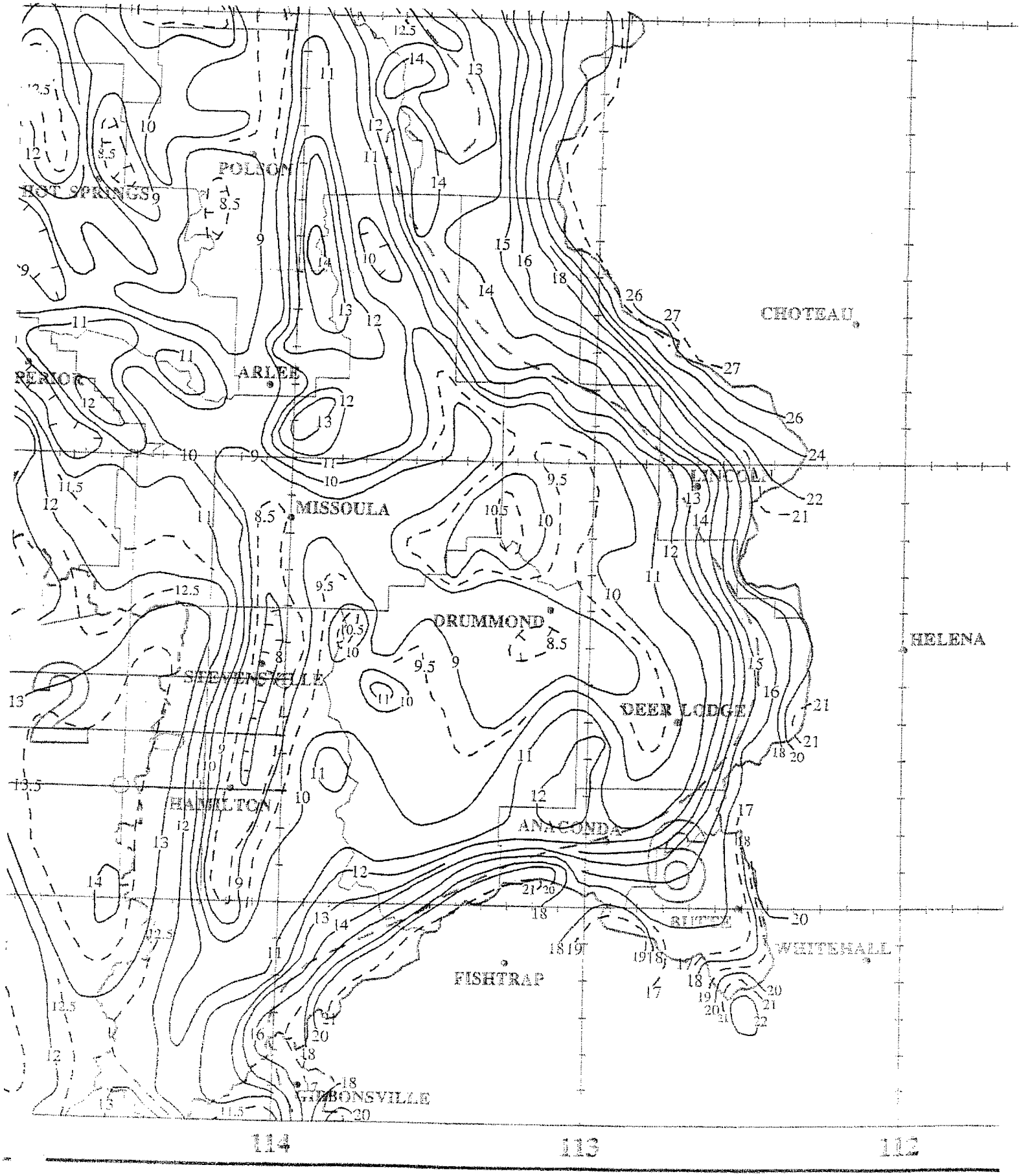
Earth Sciences Division
Bureau of Reclamation

Published by
National Weather Service
Silver Spring, MD
October 1994


POLSON
HOT SPRINGS
ARLEE
PERMA
MISSOULA
CHOTEAU
LINCOLN
DRUMMOND
HELENA
STEVENSVILLE
DEER LODGE
HAMILTON
ANACONDA
BUTTE
WHITEHALL
FISHTRAP
GIBBONSVILLE
114
113
112

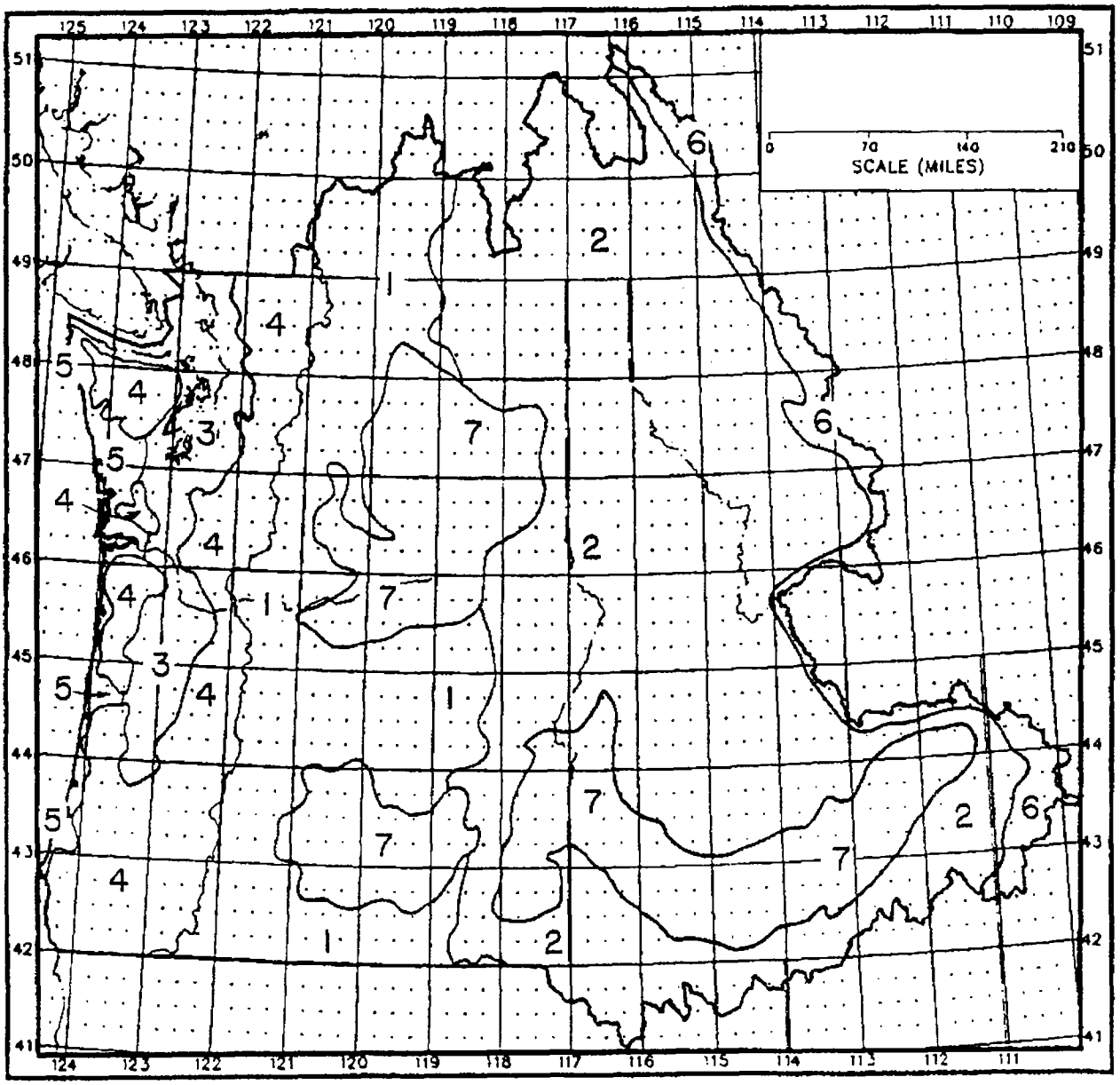


Figure 15.9.--Subregions adopted for this study; 1 = east slopes of the Cascades, orographic; 2 = orographic; 3 = least orographic, west of the Cascades; 4 = orographic, west of Cascades ridgeline; 5 = coastal orographic; 6 = west slopes of the Rockies, orographic, and 7 = least orographic, east of the Cascades (Section 10.3.2).

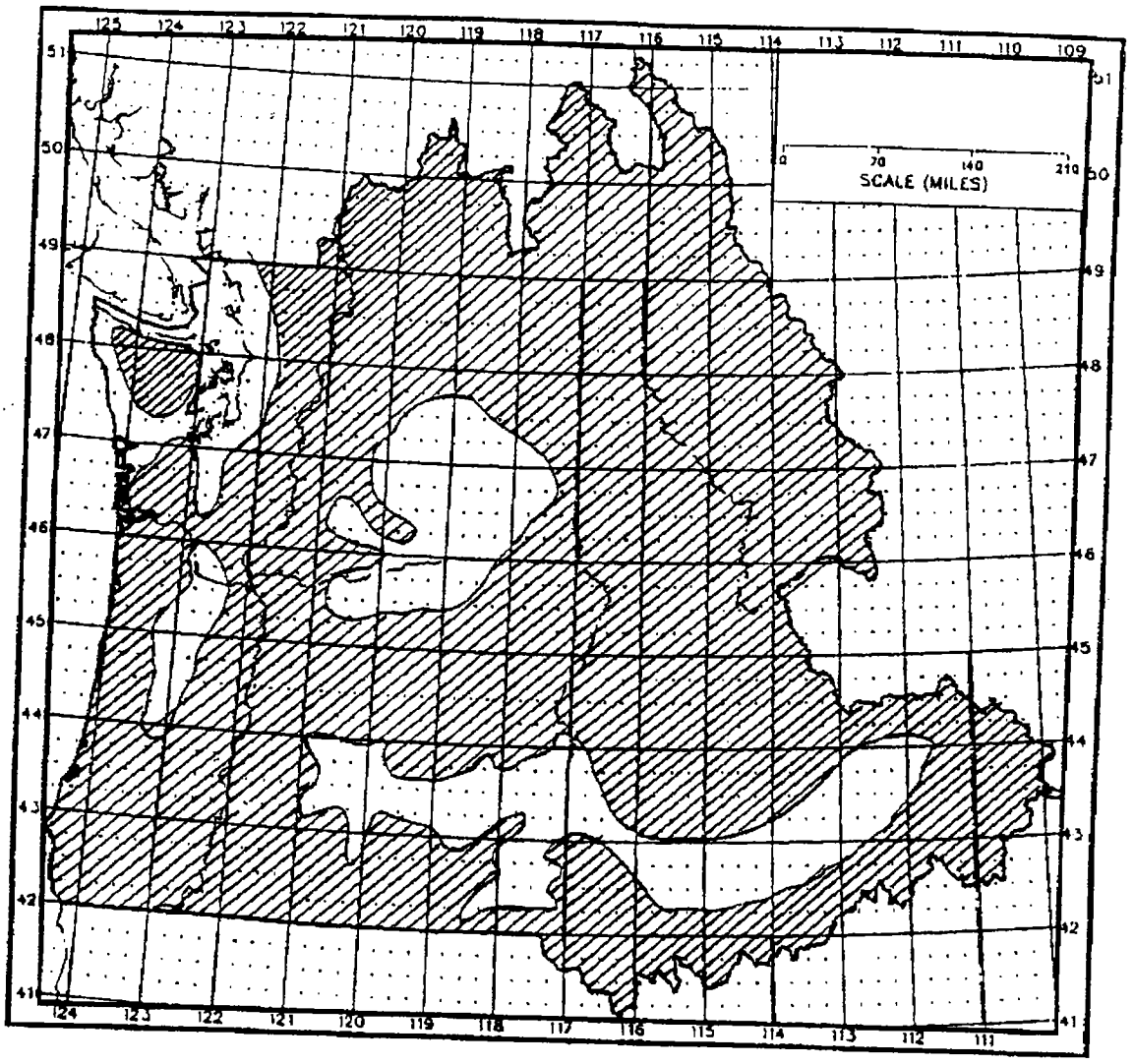


Figure 3.2.--Least orographic (non-hatched) and orographic regions (hatched).

the drainage of interest. The resulting monthly estimates can be plotted and a smooth curve drawn to verify consistency and provide for temporal interpolation. The user is reminded that in Figures 15.2-15.8, any portion of a drainage covered by an isoline of 90 percent or higher is treated as equivalent to the all-season value. Multiply the all-season PMP average from step 3 by the percentage determined from this step.

5. **Depth-duration**

As discussed in Section 10.3, depth-duration varies according to regional subdivisions shown in Figure 15.9. These subregions are also delineated on charts 1 to 4. For the subregion containing the drainage of interest, read the corresponding depth-durational ratios from Table 15.1 and multiply each by the 24-hour results obtained from either step 3, or step 4. In the event that a particular drainage involves more than one subregion, obtain proportionately weighted results.

Table 15.1.--Adopted depth-duration ratios of 24-hour amounts for subregions in Figure 15.9 (Section 10.3.2.).

Subregion	Duration (hours)				
West of Cascades	1	6	24	48	72
4	.10	.40	1.00	1.49	1.77
5	.11	.43	1.00	1.37	1.58
3	.12	.44	1.00	1.23	1.35
East of Cascades					
1	.16	.52	1.00	1.40	1.55
2	.16	.52	1.00	1.31	1.45
6	.18	.55	1.00	1.27	1.37
7	.20	.59	1.00	1.20	1.30

6. **Areal reduction factors**

Take the 1-, 6-, 24-, 48- and 72-hours, 10-mi^2 basin average estimates from step 5, and use Figure 15.10 (orographic) or Figure 15.11 (least orographic) to determine areal reduction percentages for the drainage of interest. Multiply these reduction percentages by the corresponding 10-mi^2 amounts from step 5. If a particular drainage includes both orographic and least orographic subregions, again use proportionately weighted results.

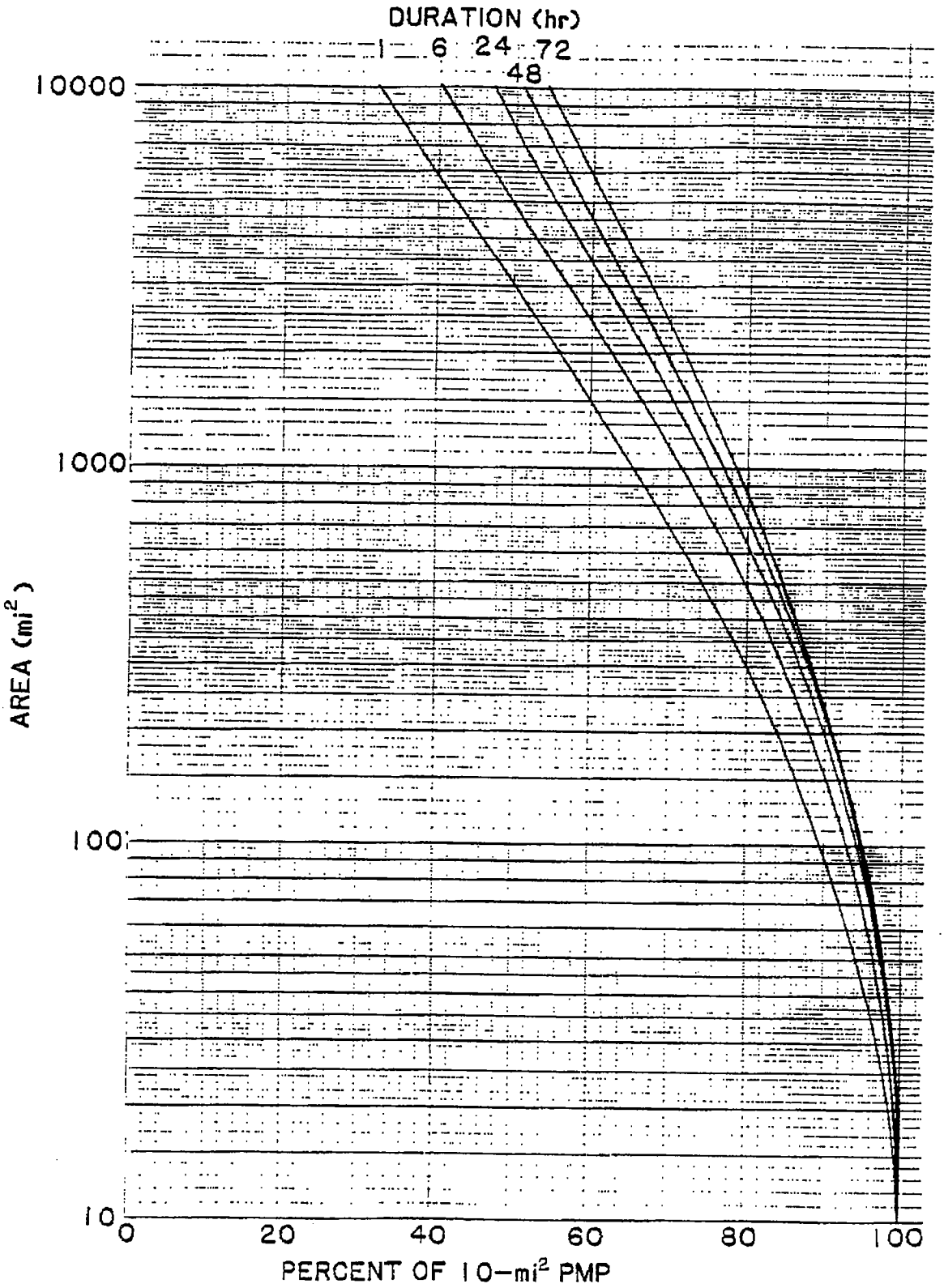


Figure 15.10.--Adopted depth-area relations for orographic subregions (Section 10.2.1).

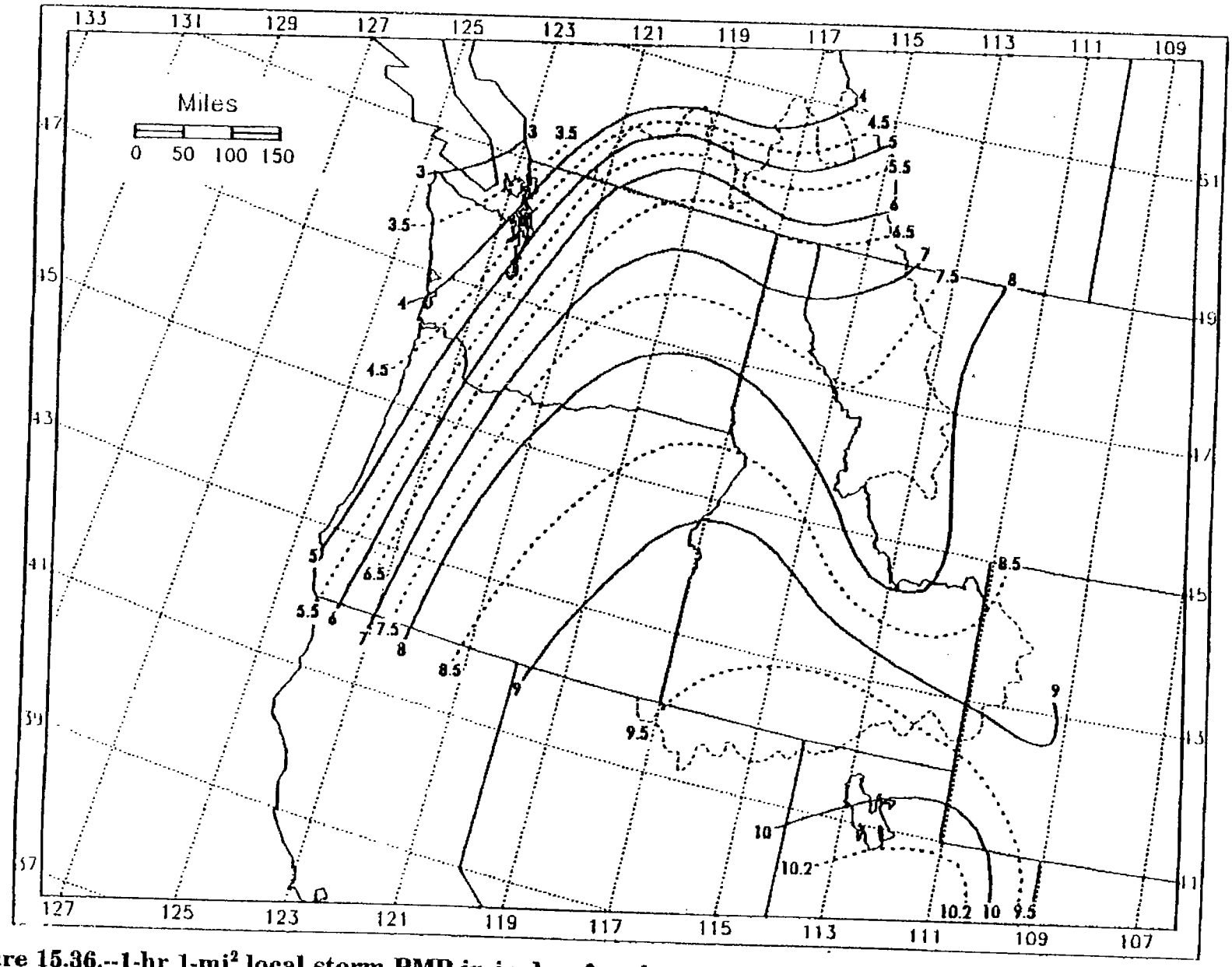


Figure 15.36.--1-hr 1-mi² local storm PMP in inches for elevations to 6000 ft.

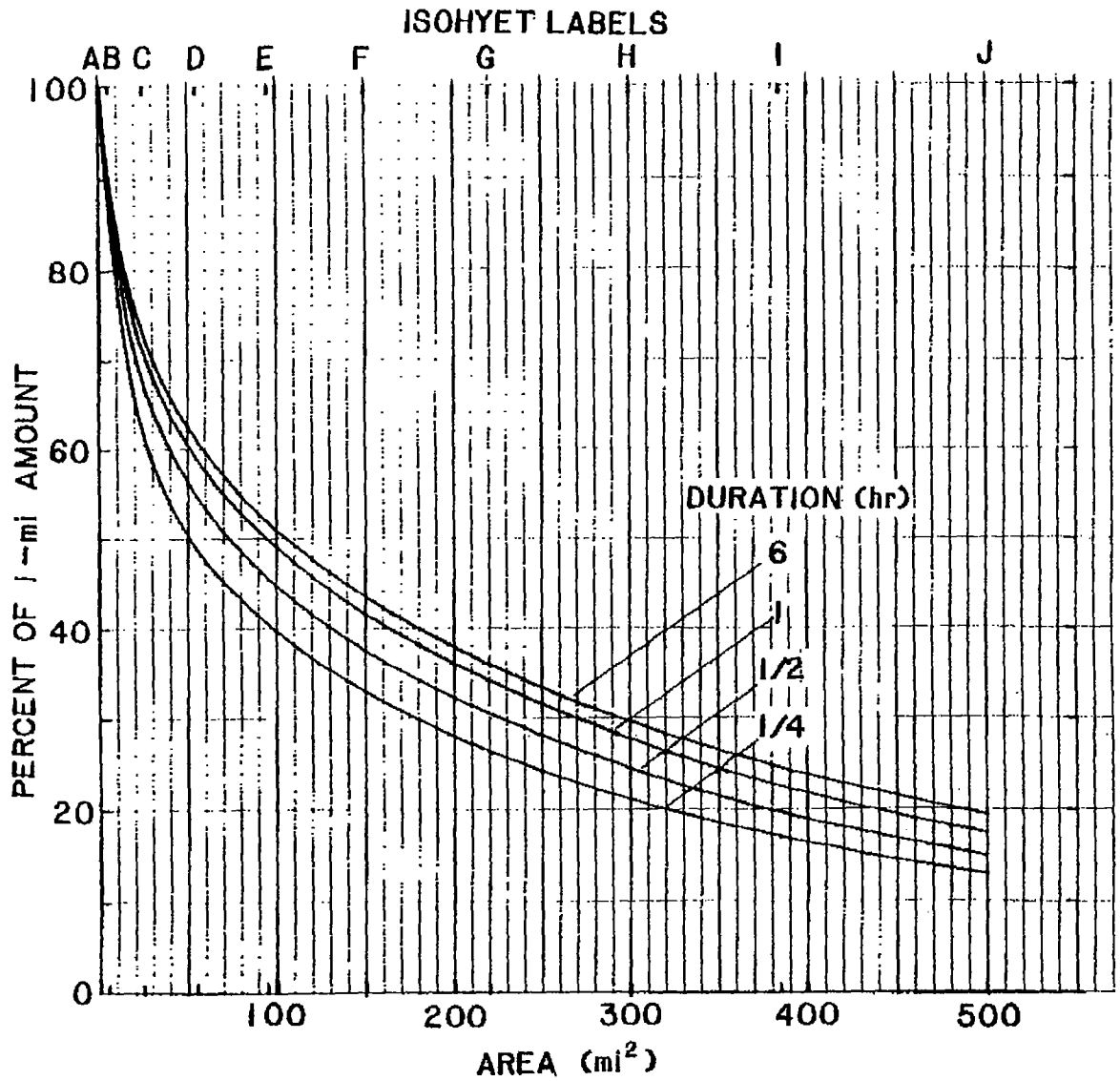


Figure 15.39.--Depth-area relations for local storm PMP Pacific Northwest states (Section 11.8).

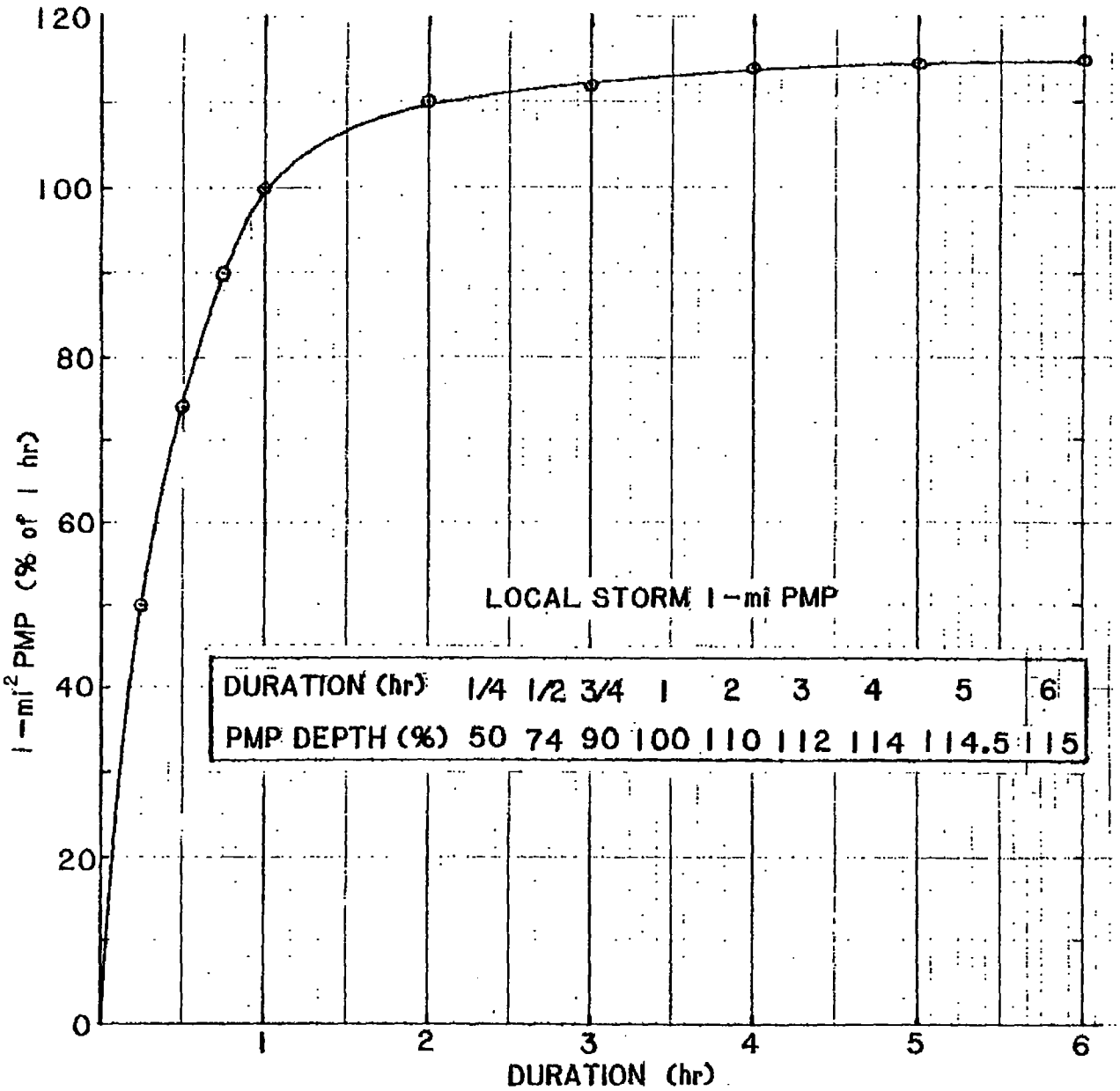


Figure 15.38.--Depth-duration relationship for 1-mi² PMP Pacific Northwest states (Section 11.7.2).

APPENDIX C2

EXTREME FREQUENCY PRECIPITATION

Regional Analysis of Annual Precipitation Maxima in Montana
USGS Water-Resources Investigations Report 97-4004

By: Charles Parrett

6-Hour Storm - Extreme Precipitation Values - Region 1

$$P_{max6} = 0.60 + (0.0067)(MAP)$$

MAP	20.9	in/year	Mean Annual Precipitation
P_{max6}	0.74	in	6-Hour Storm Depth

Dimensionless Storm Depth Taken from *Figure 12 USGS WRIR 97-404*

Frequency	Dimensionless Storm Depth	P_{max6} Depth (in)
50	2.00	1.48
100	2.29	1.69
200	2.60	1.92
500	3.00	2.22
1000	3.33	2.47
2000	3.76	2.78
5000	4.33	3.21

Worksheet for Developing USGS 50-yr. Hyetograph

Dimensionless Precip.	P_{max6}	Product
2.00	0.74	1.48

Incremental Duration (hrs)	Dimensionless Depth (in)	Depth-Area Adjustment	Adjusted Dimensionless Depth	Accum. Depth (in)	Inc. Time (hrs)	Inc. Dimensionless Depth	Periods in Inc.	Dimensionless Depth per Period	Depth per Period (in)
0	0.000	0.00	0.000	0.000					
					0.25	0.239	1	0.2394	0.3543
0.25	0.269	0.89	0.239	0.354					
					0.25	0.091	1	0.0908	0.1344
0.5	0.371	0.89	0.330	0.489					
					0.25	0.075	1	0.0748	0.1106
0.75	0.445	0.91	0.405	0.599					
					0.25	0.078	1	0.0777	0.1150
1	0.519	0.93	0.483	0.714					
					1	0.189	4	0.0472	0.0699
2	0.707	0.95	0.672	0.994					
					1	0.121	4	0.0302	0.0447
3	0.817	0.97	0.792	1.173					
					3	0.178	12	0.0148	0.0219
6	1.000	0.97	0.970	1.436					
					3	0.065	12	0.0054	0.0080
9	1.067	0.97	1.035	1.532					
					3	0.046	12	0.0038	0.0057
12	1.103	0.98	1.081	1.600					
					3	0.034	12	0.0029	0.0042
15	1.138	0.98	1.115	1.651					
					3	0.007	12	0.0006	0.0008
18	1.145	0.98	1.122	1.661					

Worksheet for Developing USGS 100-yr. Hyetograph

Dimensionless Precip.	P_{max6}	Product
2.29	0.74	1.69

Incremental Duration (hrs)	Dimensionless Depth (in)	Depth-Area Adjustment	Adjusted Dimensionless Depth	Accum. Depth (in)	Inc. Time (hrs)	Inc. Dimensionless Depth	Periods in Inc.	Dimensionless Depth per Period	Depth per Period (in)
0	0.000	0.00	0.000	0.000					
					0.25	0.239	1	0.2394	0.4057
0.25	0.269	0.89	0.239	0.406					
					0.25	0.091	1	0.0908	0.1538
0.5	0.371	0.89	0.330	0.560					
					0.25	0.075	1	0.0748	0.1267
0.75	0.445	0.91	0.405	0.686					
					0.25	0.078	1	0.0777	0.1317
1	0.519	0.93	0.483	0.818					
					1	0.189	4	0.0472	0.0801
2	0.707	0.95	0.672	1.138					
					1	0.121	4	0.0302	0.0512
3	0.817	0.97	0.792	1.343					
					3	0.178	12	0.0148	0.0251
6	1.000	0.97	0.970	1.644					
					3	0.065	12	0.0054	0.0092
9	1.067	0.97	1.035	1.754					
					3	0.046	12	0.0038	0.0065
12	1.103	0.98	1.081	1.832					
					3	0.034	12	0.0029	0.0048
15	1.138	0.98	1.115	1.890					
					3	0.007	12	0.0006	0.0010
18	1.145	0.98	1.122	1.902					

Worksheet for Developing USGS 200-yr. Hyetograph

Dimensionless Precip.	P_{max6}	Product
2.60	0.74	1.92

Incremental Duration (hrs)	Dimensionless Depth (in)	Depth-Area Adjustment	Adjusted Dimensionless Depth	Accum. Depth (in)	Inc. Time (hrs)	Inc. Dimensionless Depth	Periods in Inc.	Dimensionless Depth per Period	Depth per Period (in)
0	0.000	0.00	0.000	0.000					
					0.25	0.239	1	0.2394	0.4606
0.25	0.269	0.89	0.239	0.461					
					0.25	0.091	1	0.0908	0.1747
0.5	0.371	0.89	0.330	0.635					
					0.25	0.075	1	0.0748	0.1438
0.75	0.445	0.91	0.405	0.779					
					0.25	0.078	1	0.0777	0.1495
1	0.519	0.93	0.483	0.929					
					1	0.189	4	0.0472	0.0909
2	0.707	0.95	0.672	1.292					
					1	0.121	4	0.0302	0.0581
3	0.817	0.97	0.792	1.525					
					3	0.178	12	0.0148	0.0285
6	1.000	0.97	0.970	1.866					
					3	0.065	12	0.0054	0.0104
9	1.067	0.97	1.035	1.991					
					3	0.046	12	0.0038	0.0074
12	1.103	0.98	1.081	2.080					
					3	0.034	12	0.0029	0.0055
15	1.138	0.98	1.115	2.146					

Worksheet for Developing USGS 500-yr. Hyetograph

Dimensionless Precip.	P_{max6}	Product
3.00	0.74	2.22

Incremental Duration (hrs)	Dimensionless Depth (in)	Depth-Area Adjustment	Adjusted Dimensionless Depth	Accum. Depth (in)	Inc. Time (hrs)	Inc. Dimensionless Depth	Periods in Inc.	Dimensionless Depth per Period	Depth per Period (in)
0	0.000	0.00	0.000	0.000					
					0.25	0.239	1	0.2394	0.5315
0.25	0.269	0.89	0.239	0.532					
					0.25	0.091	1	0.0908	0.2015
0.5	0.371	0.89	0.330	0.733					
					0.25	0.075	1	0.0748	0.1660
0.75	0.445	0.91	0.405	0.899					
					0.25	0.078	1	0.0777	0.1725
1	0.519	0.93	0.483	1.072					
					1	0.189	4	0.0472	0.1049
2	0.707	0.95	0.672	1.491					
					1	0.121	4	0.0302	0.0671
3	0.817	0.97	0.792	1.759					
					3	0.178	12	0.0148	0.0328
6	1.000	0.97	0.970	2.153					
					3	0.065	12	0.0054	0.0120
9	1.067	0.97	1.035	2.298					
					3	0.046	12	0.0038	0.0085
12	1.103	0.98	1.081	2.400					
					3	0.034	12	0.0029	0.0063
15	1.138	0.98	1.115	2.476					
					3	0.007	12	0.0006	0.0013
18	1.145	0.98	1.122	2.491					

Worksheet for Developing USGS 1,000-yr. Hyetograph

Dimensionless Precip.	P_{max6}	Product
3.33	0.74	2.47

Incremental Duration (hrs)	Dimensionless Depth (in)	Depth-Area Adjustment	Adjusted Dimensionless Depth	Accum. Depth (in)	Inc. Time (hrs)	Inc. Dimensionless Depth	Periods in Inc.	Dimensionless Depth per Period	Depth per Period (in)
0	0.000	0.00	0.000	0.000					
					0.25	0.239	1	0.2394	0.5906
0.25	0.269	0.89	0.239	0.591					
					0.25	0.091	1	0.0908	0.2239
0.5	0.371	0.89	0.330	0.814					
					0.25	0.075	1	0.0748	0.1844
0.75	0.445	0.91	0.405	0.999					
					0.25	0.078	1	0.0777	0.1917
1	0.519	0.93	0.483	1.191					
					1	0.189	4	0.0472	0.1165
2	0.707	0.95	0.672	1.657					
					1	0.121	4	0.0302	0.0745
3	0.817	0.97	0.792	1.955					
					3	0.178	12	0.0148	0.0365
6	1.000	0.97	0.970	2.393					
					3	0.065	12	0.0054	0.0134
9	1.067	0.97	1.035	2.553					
					3	0.046	12	0.0038	0.0094
12	1.103	0.98	1.081	2.666					
					3	0.034	12	0.0029	0.0071
15	1.138	0.98	1.115	2.751					
					3	0.007	12	0.0006	0.0014
18	1.145	0.98	1.122	2.768					

Worksheet for Developing USGS 2,000-yr. Hyetograph

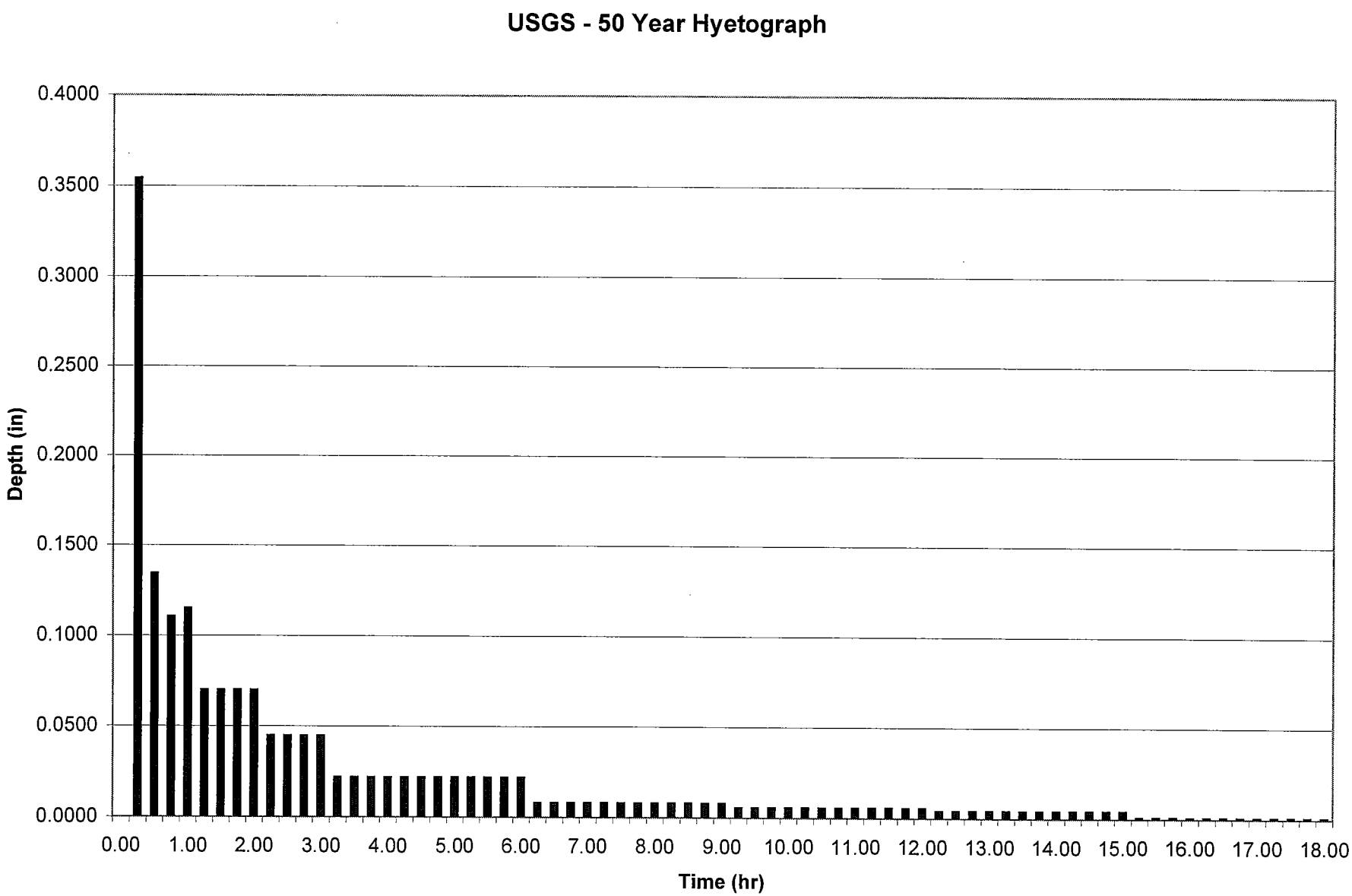
Dimensionless Precip.	P_{max6}	Product
3.76	0.74	2.78

Incremental Duration (hrs)	Dimensionless Depth (in)	Depth-Area Adjustment	Adjusted Dimensionless Depth	Accum. Depth (in)	Inc. Time (hrs)	Inc. Dimensionless Depth	Periods in Inc.	Dimensionless Depth per Period	Depth per Period (in)
0	0.000	0.00	0.000	0.000					
					0.25	0.239	1	0.2394	0.6662
0.25	0.269	0.89	0.239	0.666					
					0.25	0.091	1	0.0908	0.2526
0.5	0.371	0.89	0.330	0.919					
					0.25	0.075	1	0.0748	0.2080
0.75	0.445	0.91	0.405	1.127					
					0.25	0.078	1	0.0777	0.2163
1	0.519	0.93	0.483	1.343					
					1	0.189	4	0.0472	0.1315
2	0.707	0.95	0.672	1.869					
					1	0.121	4	0.0302	0.0841
3	0.817	0.97	0.792	2.205					
					3	0.178	12	0.0148	0.0412
6	1.000	0.97	0.970	2.699					
					3	0.065	12	0.0054	0.0151
9	1.067	0.97	1.035	2.880					
					3	0.046	12	0.0038	0.0107
12	1.103	0.98	1.081	3.008					
					3	0.034	12	0.0029	0.0080
15	1.138	0.98	1.115	3.103					
					3	0.007	12	0.0006	0.0016
18	1.145	0.98	1.122	3.122					

Worksheet for Developing USGS 5,000-yr. Hyetograph

Dimensionless Precip.	P_{max6}	Product
4.33	0.74	3.21

Incremental Duration (hrs)	Dimensionless Depth (in)	Depth-Area Adjustment	Adjusted Dimensionless Depth	Accum. Depth (in)	Inc. Time (hrs)	Inc. Dimensionless Depth	Periods in Inc.	Dimensionless Depth per Period	Depth per Period (in)
0	0.000	0.00	0.000	0.000					
					0.25	0.239	1	0.2394	0.7677
0.25	0.269	0.89	0.239	0.768					
					0.25	0.091	1	0.0908	0.2911
0.5	0.371	0.89	0.330	1.059					
					0.25	0.075	1	0.0748	0.2397
0.75	0.445	0.91	0.405	1.299					
					0.25	0.078	1	0.0777	0.2492
1	0.519	0.93	0.483	1.548					
					1	0.189	4	0.0472	0.1515
2	0.707	0.95	0.672	2.154					
					1	0.121	4	0.0302	0.0969
3	0.817	0.97	0.792	2.541					
					3	0.178	12	0.0148	0.0474
6	1.000	0.97	0.970	3.111					
					3	0.065	12	0.0054	0.0174
9	1.067	0.97	1.035	3.319					
					3	0.046	12	0.0038	0.0123
12	1.103	0.98	1.081	3.466					
					3	0.034	12	0.0029	0.0092
15	1.138	0.98	1.115	3.576					
					3	0.007	12	0.0006	0.0018
18	1.145	0.98	1.122	3.598					


USGS - 50 Year Hyetograph
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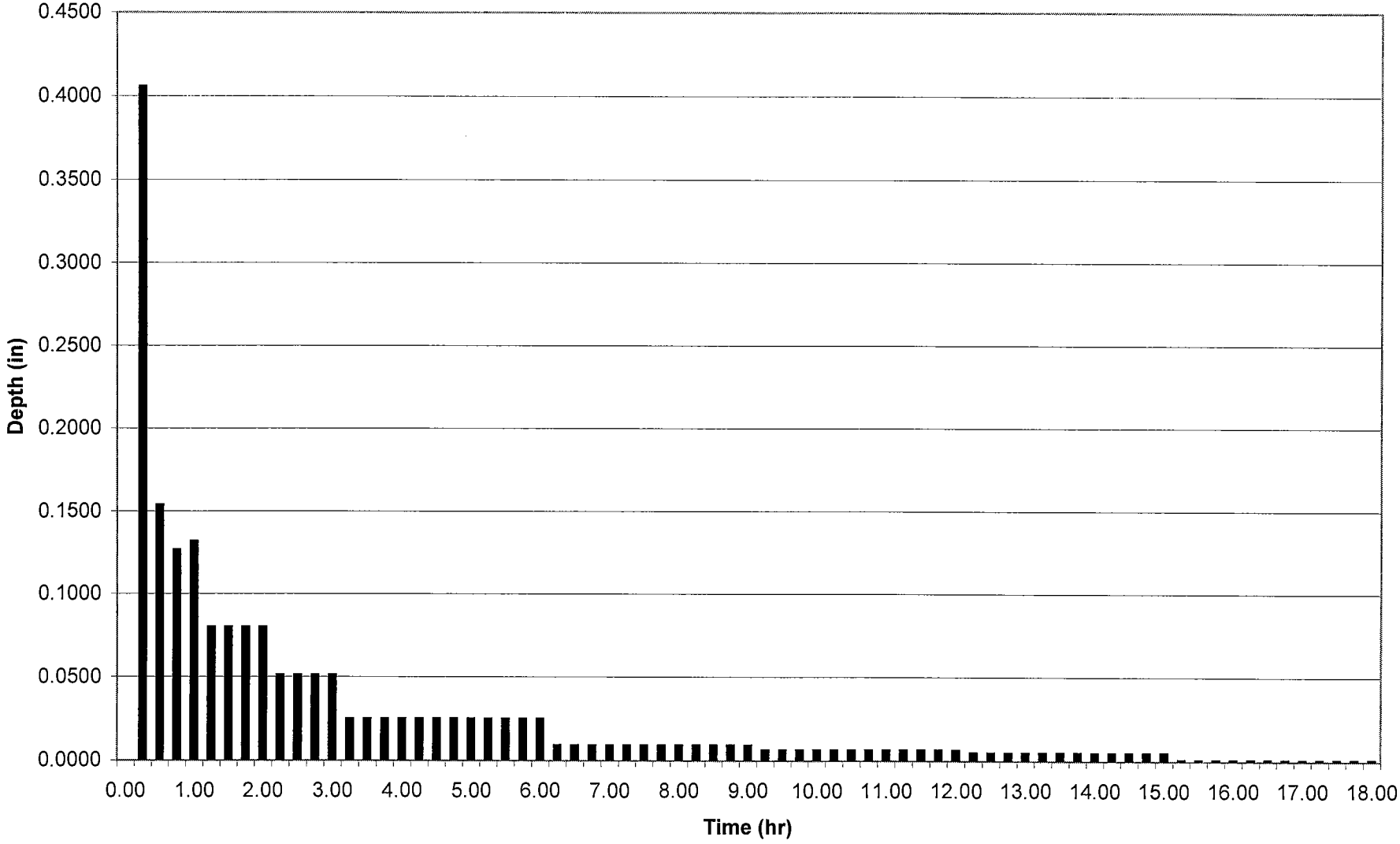
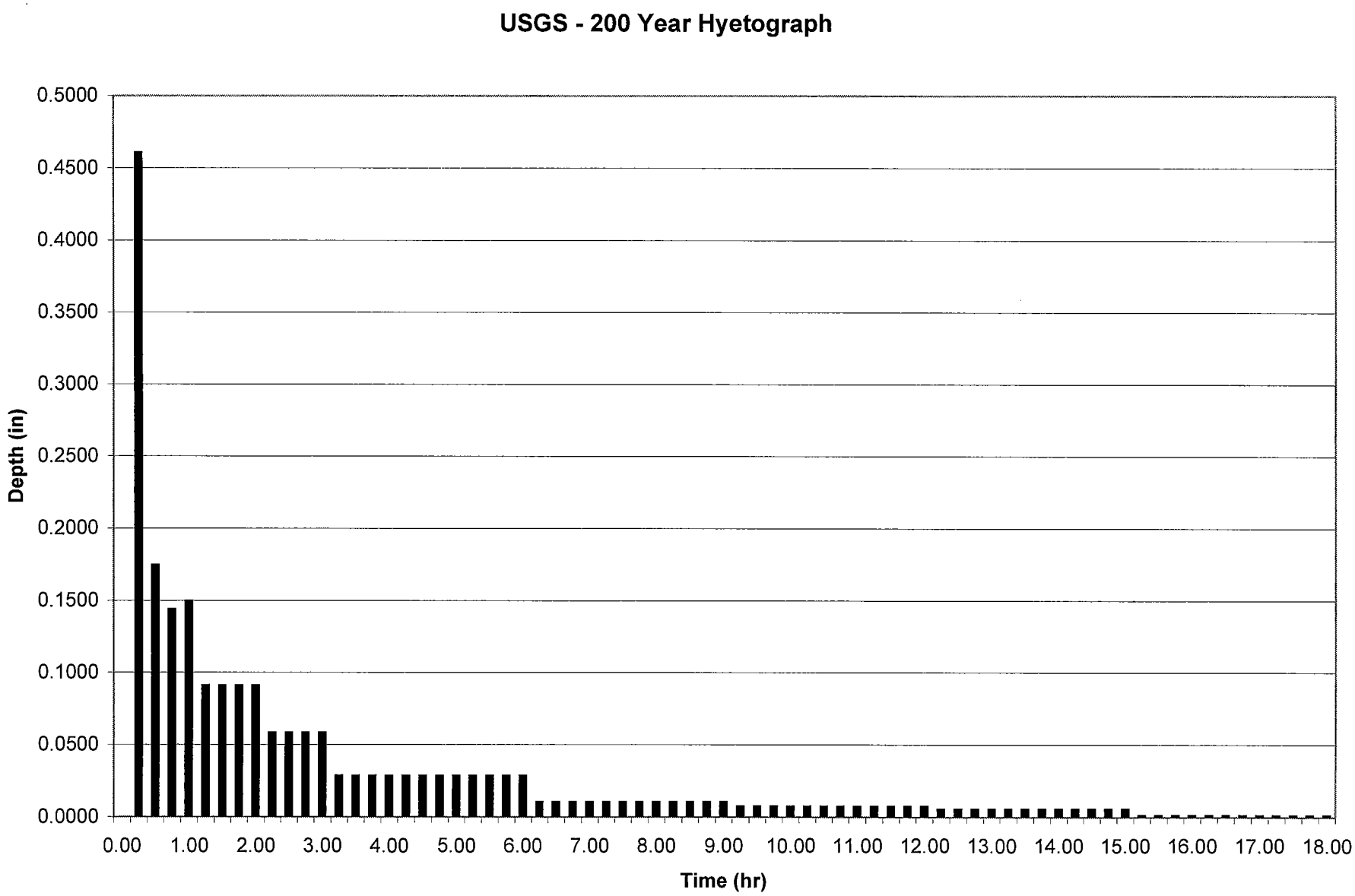
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
Time (hr)

USGS - 100 Year Hyetograph




USGS - 200 Year Hyetograph
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0.3000
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0.1500
0.1000
0.0500
0.0000
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
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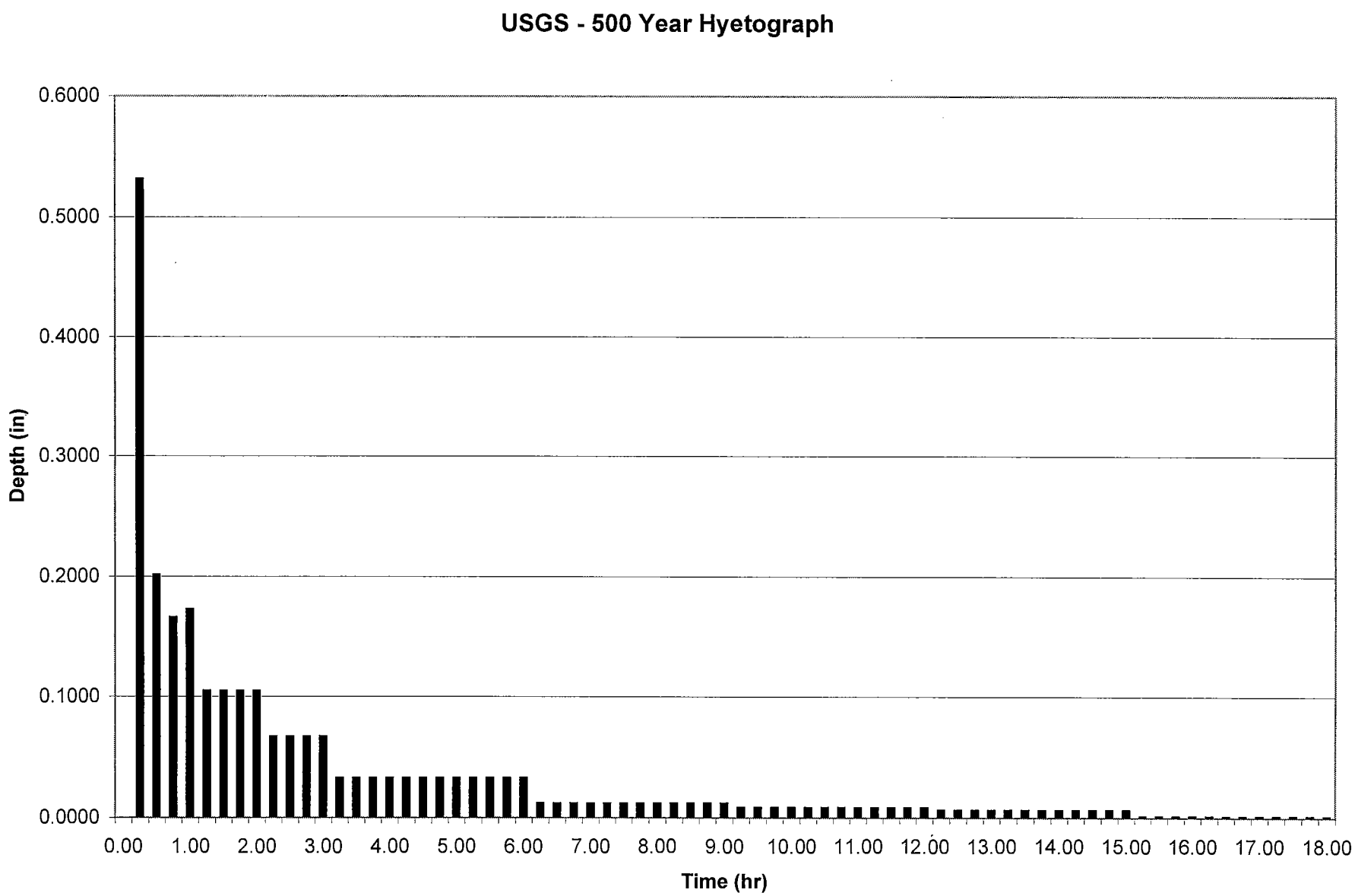
17.00
18.00
Time (hr)


USGS - 500 Year Hyetograph
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2.00
3.00
4.00
5.00
6.00
7.00
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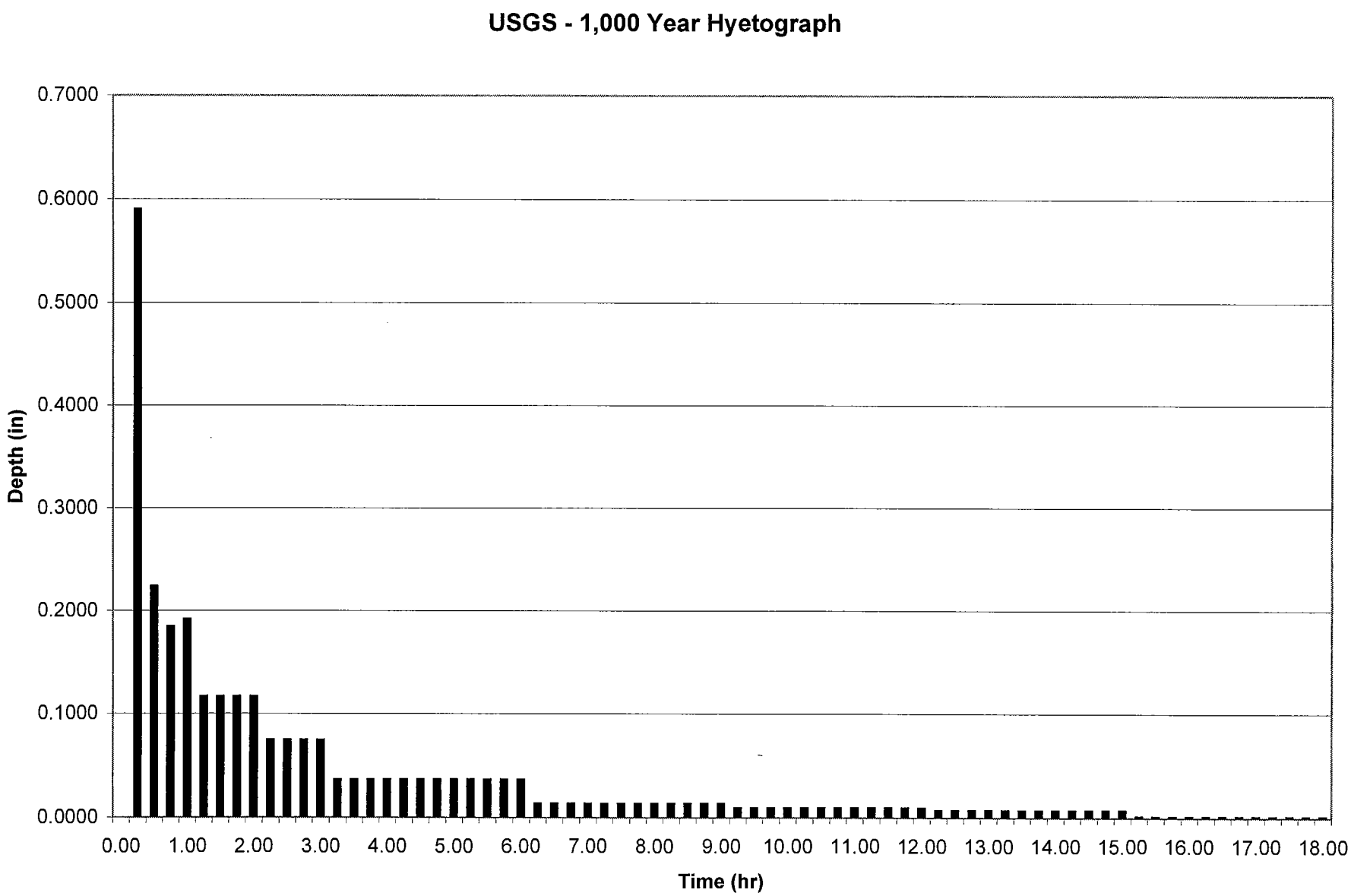
17.00
18.00
Time (hr)


USGS - 1,000 Year Hyetograph
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3.00
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6.00
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17.00
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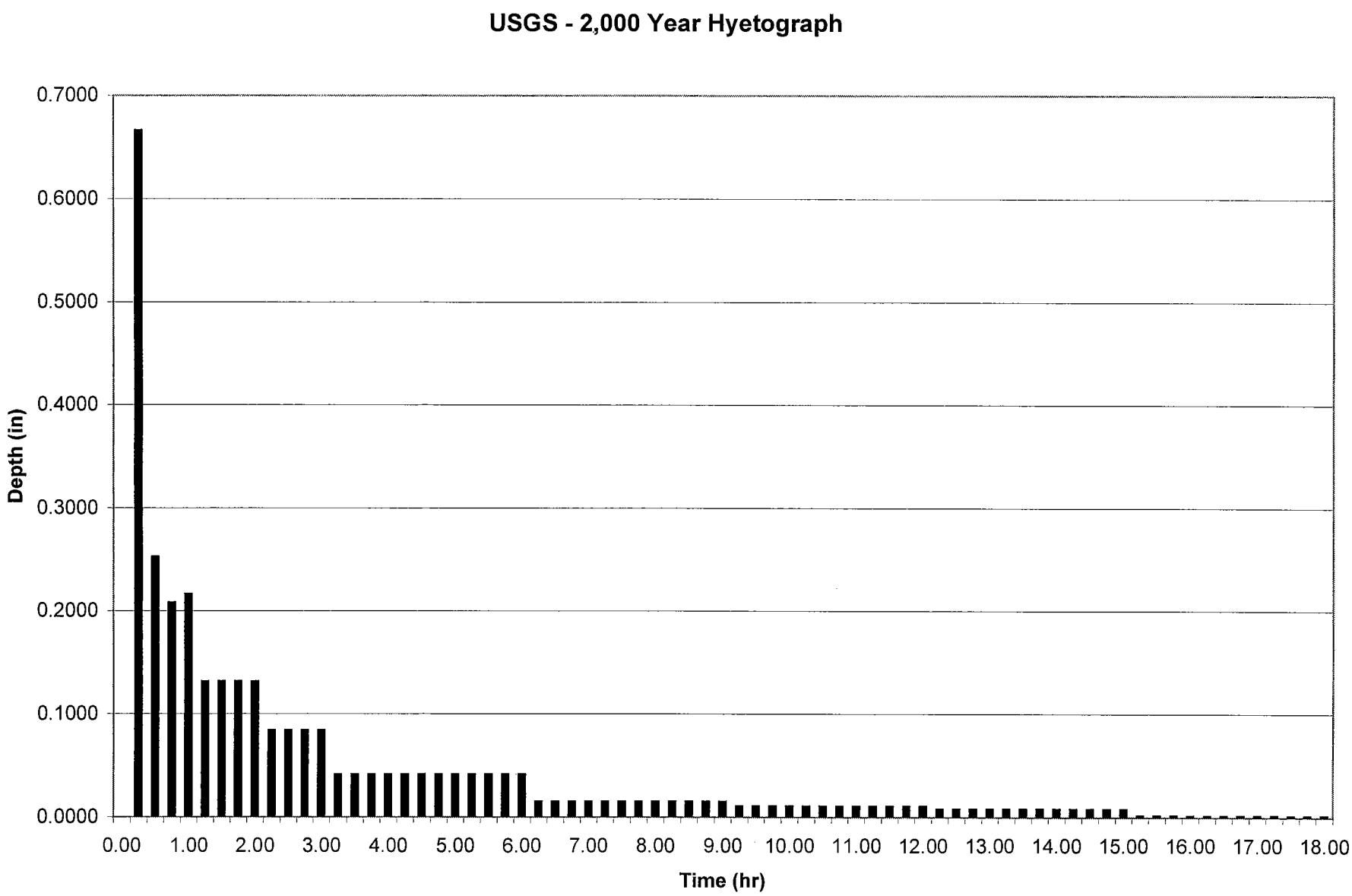
Time (hr)


USGS - 2,000 Year Hyetograph
Depth (in)
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0.3000
0.2000
0.1000
0.0000
0.00
1.00
2.00
3.00
4.00
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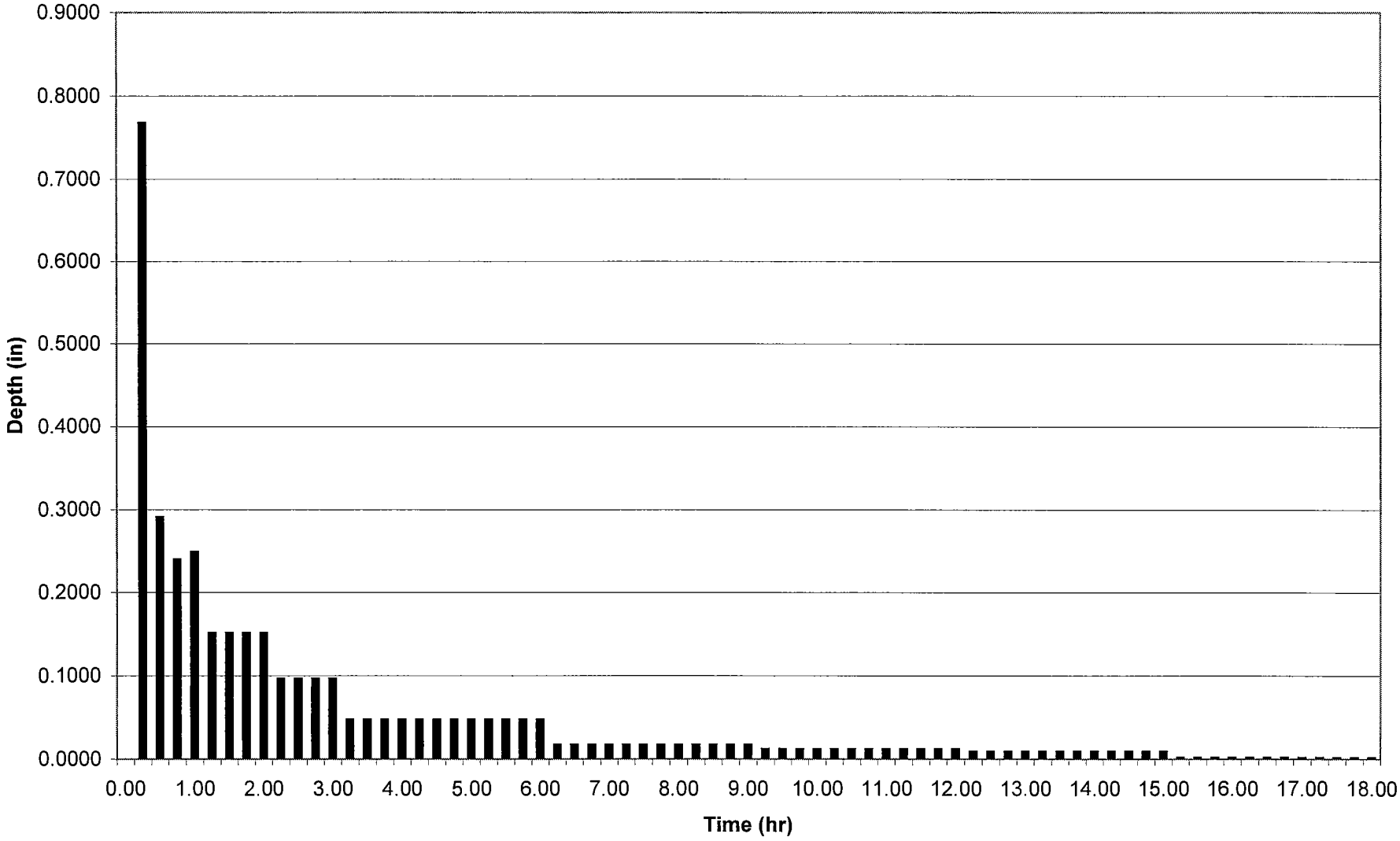
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
Time (hr)

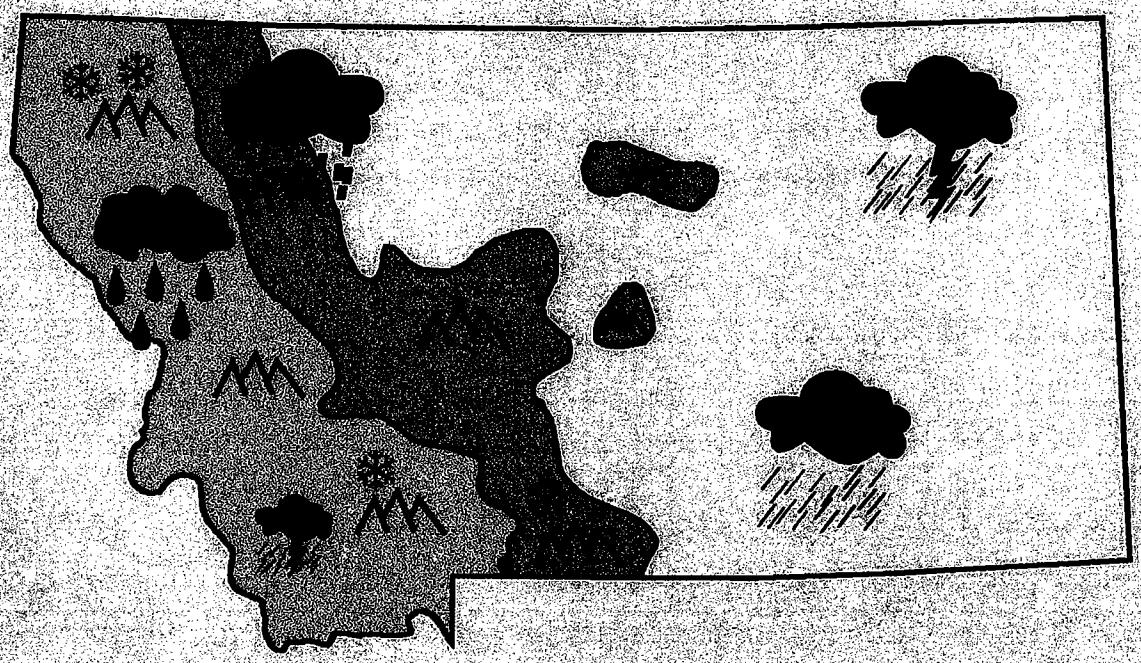
USGS - 5,000 Year Hyetograph



REGIONAL ANALYSIS OF ANNUAL PRECIPITATION MAXIMA IN MONTANA

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS REPORT 97-4004



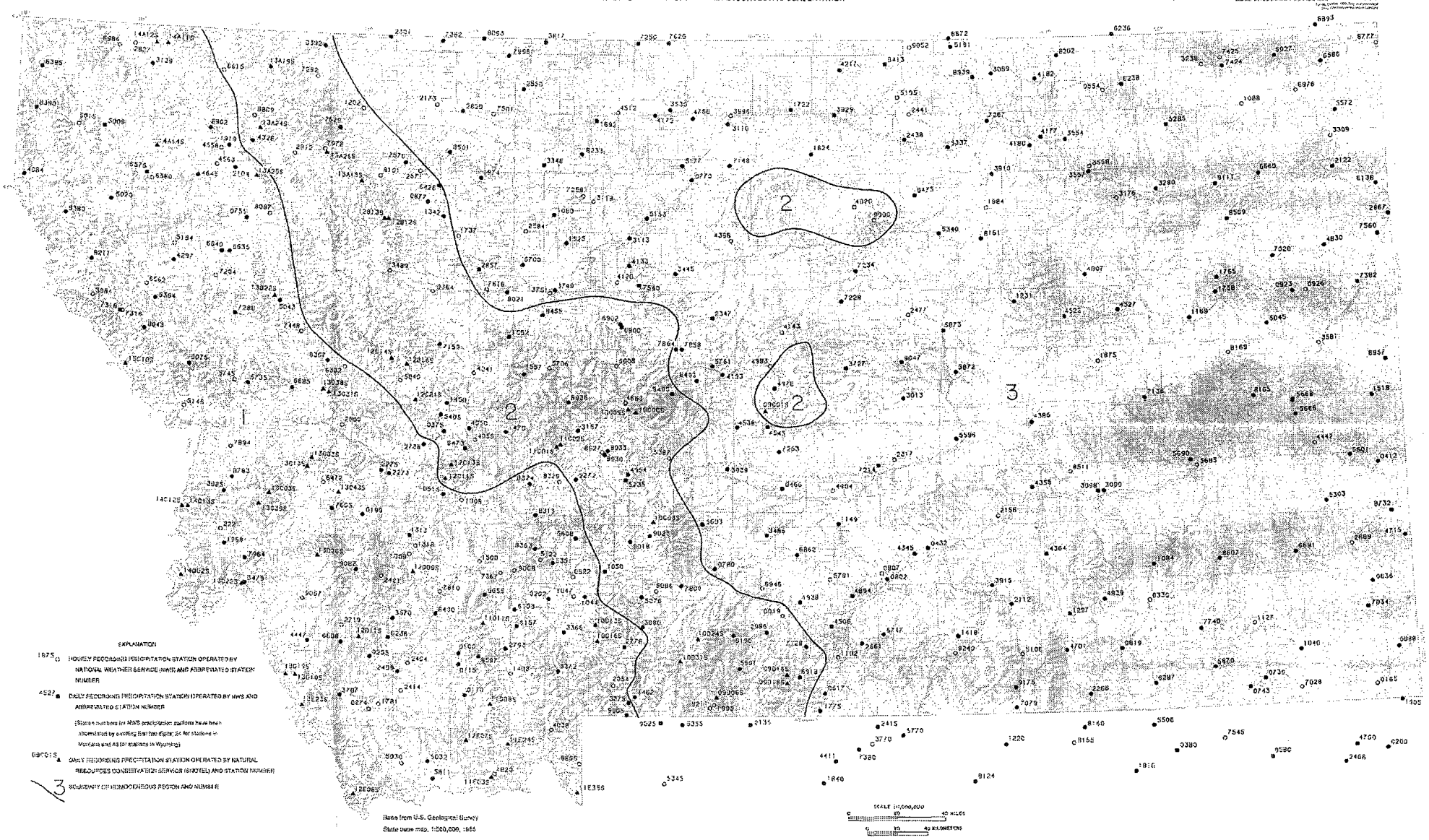
PREPARED IN COOPERATION WITH THE

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

WATER-RESOURCES INVESTIGATIONS REPORT 97-4004
PLATE 1



MAP SHOWING LOCATIONS AND TYPES OF ANNUAL-MAXIMA PRECIPITATION STATIONS, MONTANA AND NORTHERN WYOMING, AND HOMOGENEOUS REGIONS, MONTANA

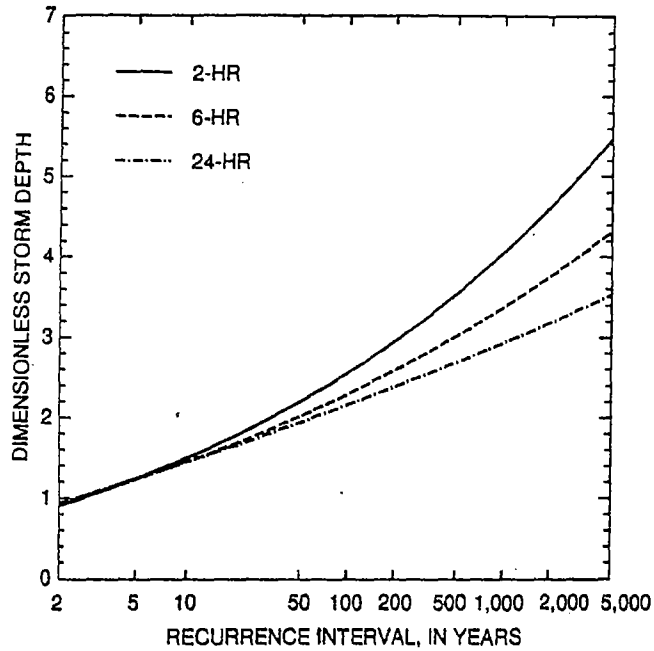


Figure 12. Regional frequency curves for dimensionless annual storm depths in Region 1, Montana.

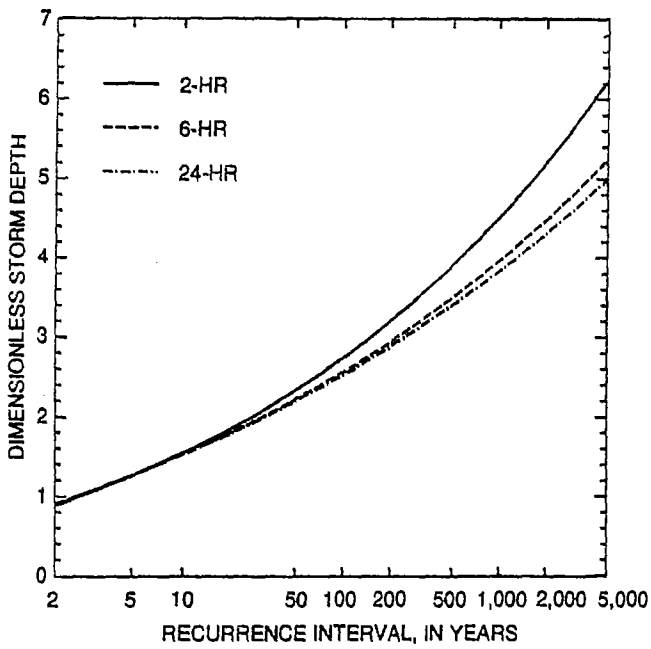


Figure 13. Regional frequency curves for dimensionless annual storm depths for Region 2, Montana.

Table 10. Total station-years of storm-depth record and effective record length by duration and region, Montana

Duration, in hours	Region	Total station-years of record	Effective record length, in years	Effective record length, in percent of total station-years
2	1	1,375	1,300	95
	2	685	600	88
	3	1,874	1,800	96
6	1	1,574	1,500	95
	2	762	500	66
	3	2,185	1,900	87
24	1	5,593	4,000	72
	2	2,906	1,900	65
	3	10,014	5,100	51

Table 11. Regression equations for estimation of mean storm depth for indicated duration in Montana

[Regression equation: *Pmax*t, storm depth in inches, with t indicating duration in hours; *LAT*, site latitude, in decimal degrees minus 40; *LONG*, site longitude, in decimal degrees minus 100; and *MAP*, mean annual precipitation, in inches, as determined from State maps prepared from digital data from Oregon State University Climate Center (pl. 2)]

Region	Equation	Standard error, inches	Coefficient of determination, R^2
1	$Pmax2 = 0.44 + (0.0027 \times MAP)$	0.05	0.10
	$Pmax6 = 0.60 + (0.0067 \times MAP)$	0.07	0.31
	$Pmax24 = 1.0 + (0.078 \times LAT) - (0.059 \times LONG) + (0.025 \times MAP)$	0.16	0.80
2	$Pmax2 = 0.69 + (0.034 \times LAT) - (0.029 \times LONG)$	0.09	0.16
	$Pmax6 = 0.75 + (0.087 \times LAT) - (0.041 \times LONG)$	0.12	0.30
	$Pmax24 = 1.4 + (0.18 \times LAT) - (0.13 \times LONG) + (0.019 \times MAP)$	0.27	0.52
3	$Pmax2 = 0.70 + (0.031 \times LAT) - (0.040 \times LONG) + (0.0087 \times MAP)$	0.08	0.62
	$Pmax6 = 0.85 + (0.031 \times LAT) - (0.038 \times LONG) + (0.015 \times MAP)$	0.08	0.59
	$Pmax24 = 0.62 + (0.039 \times LAT) - (0.016 \times LONG) + (0.058 \times MAP)$	0.16	0.49

USGS
science for a changing world

In cooperation with the
MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

Characteristics of Extreme Storms in Montana and Methods for Constructing Synthetic Storm Hyetographs

Water-Resources Investigations Report 98-4100

U.S. Department of the Interior
U.S. Geological Survey

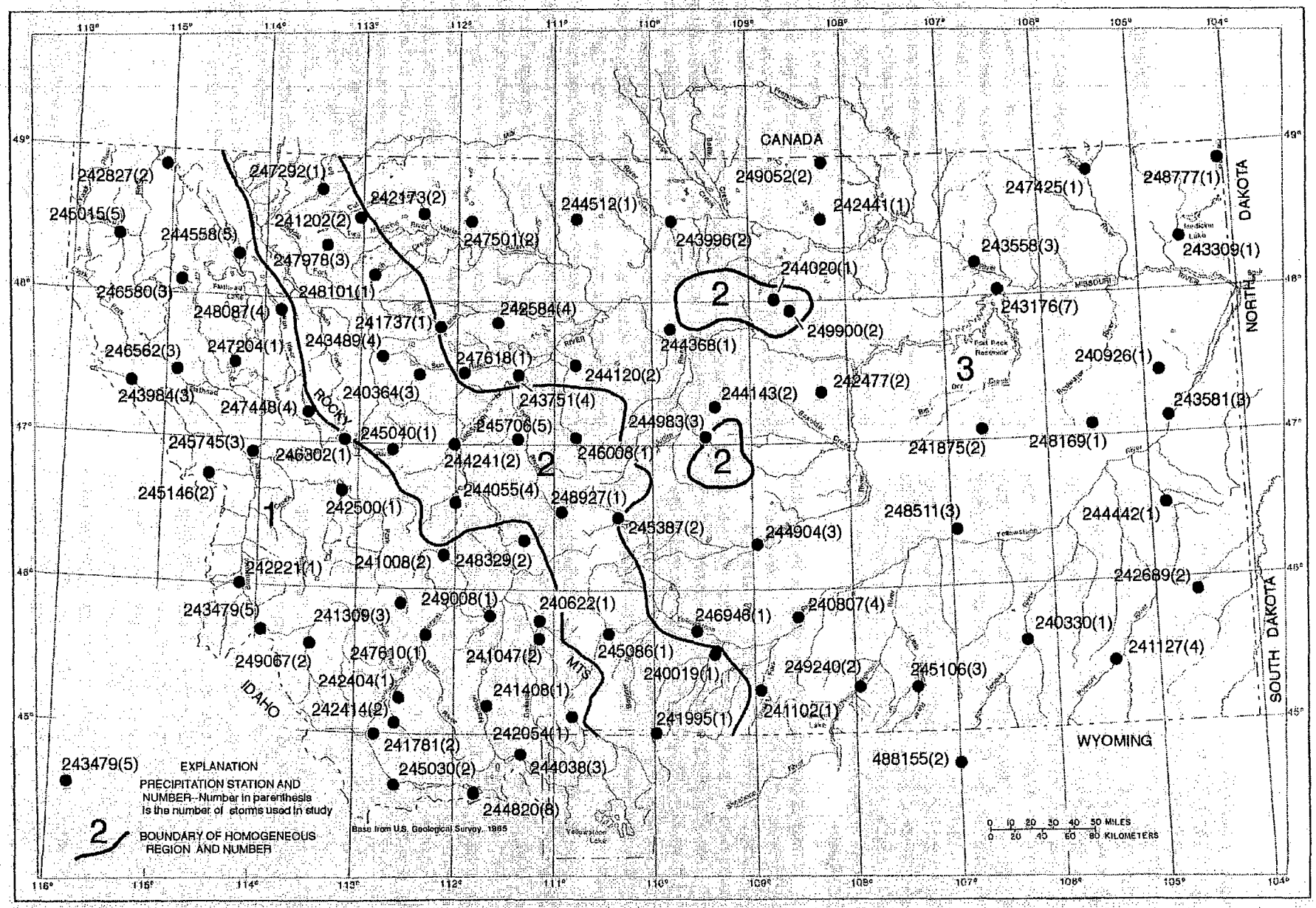


Figure 1. Location of precipitation stations, station number, number of storms used at each station, and regional boundaries, Montana and northern Wyoming.

Table 13. Dimensionless depths for various durations and exceedance probabilities, Region 1, Montana

2-hour independent duration 0.50-hour kernel duration									
Dependent duration (hours)	Exceedance probability								
	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
0.0833	0.139	0.186	0.219	0.246	0.270	0.291	0.312	0.332	0.354
.167	.225	.304	.358	.403	.441	.476	.510	.543	.580
.25	.291	.393	.465	.522	.573	.618	.663	.706	.754
.50	.515	.607	.671	.723	.768	.809	.849	.888	.931
.75	.667	.733	.779	.816	.849	.878	.907	.935	.966
1.0	.789	.830	.859	.882	.902	.920	.938	.956	.975
1.5	.935	.947	.955	.961	.967	.972	.977	.982	.987
2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
3	1.058	1.048	1.042	1.037	1.032	1.028	1.024	1.020	1.016
4	1.073	1.062	1.053	1.047	1.041	1.036	1.031	1.026	1.021
5	1.073	1.062	1.053	1.047	1.041	1.036	1.031	1.026	1.021
6	1.073	1.062	1.053	1.047	1.041	1.036	1.031	1.026	1.021

6-hour independent duration 2-hour kernel duration									
Dependent duration (hours)	Exceedance probability								
	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
0.25	0.084	0.123	0.152	0.176	0.199	0.221	0.244	0.269	0.303
.50	.152	.196	.230	.259	.283	.310	.339	.371	.412
.75	.218	.264	.300	.330	.356	.384	.414	.445	.487
1.0	.273	.331	.368	.399	.428	.456	.486	.519	.562
2	.437	.494	.536	.571	.604	.636	.670	.707	.756
3	.601	.647	.680	.708	.735	.760	.787	.817	.856
6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9	1.116	1.106	1.098	1.092	1.086	1.080	1.074	1.067	1.058
12	1.177	1.161	1.150	1.140	1.131	1.122	1.112	1.103	1.096
15	1.203	1.189	1.179	1.170	1.162	1.155	1.147	1.138	1.126
18	1.228	1.217	1.208	1.197	1.182	1.168	1.153	1.145	1.132

24-hour independent duration 6-hour kernel duration									
Dependent duration (hours)	Exceedance probability								
	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
1	0.094	0.106	0.118	0.128	0.140	0.152	0.165	0.182	0.206
2	.138	.165	.189	.205	.222	.240	.260	.285	.321
3	.180	.220	.250	.275	.301	.325	.352	.386	.433
6	.313	.346	.377	.406	.437	.470	.508	.554	.620
9	.440	.469	.490	.520	.550	.580	.610	.650	.710
12	.561	.586	.609	.632	.655	.680	.709	.745	.795
18	.822	.836	.845	.855	.865	.880	.901	.920	.947
24	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
36	1.113	1.102	1.092	1.083	1.073	1.062	1.054	1.045	1.040
48	1.147	1.139	1.132	1.125	1.117	1.109	1.100	1.089	1.080
60	1.182	1.175	1.172	1.167	1.160	1.150	1.140	1.130	1.120
72	1.211	1.205	1.203	1.201	1.200	1.190	1.180	1.170	1.160

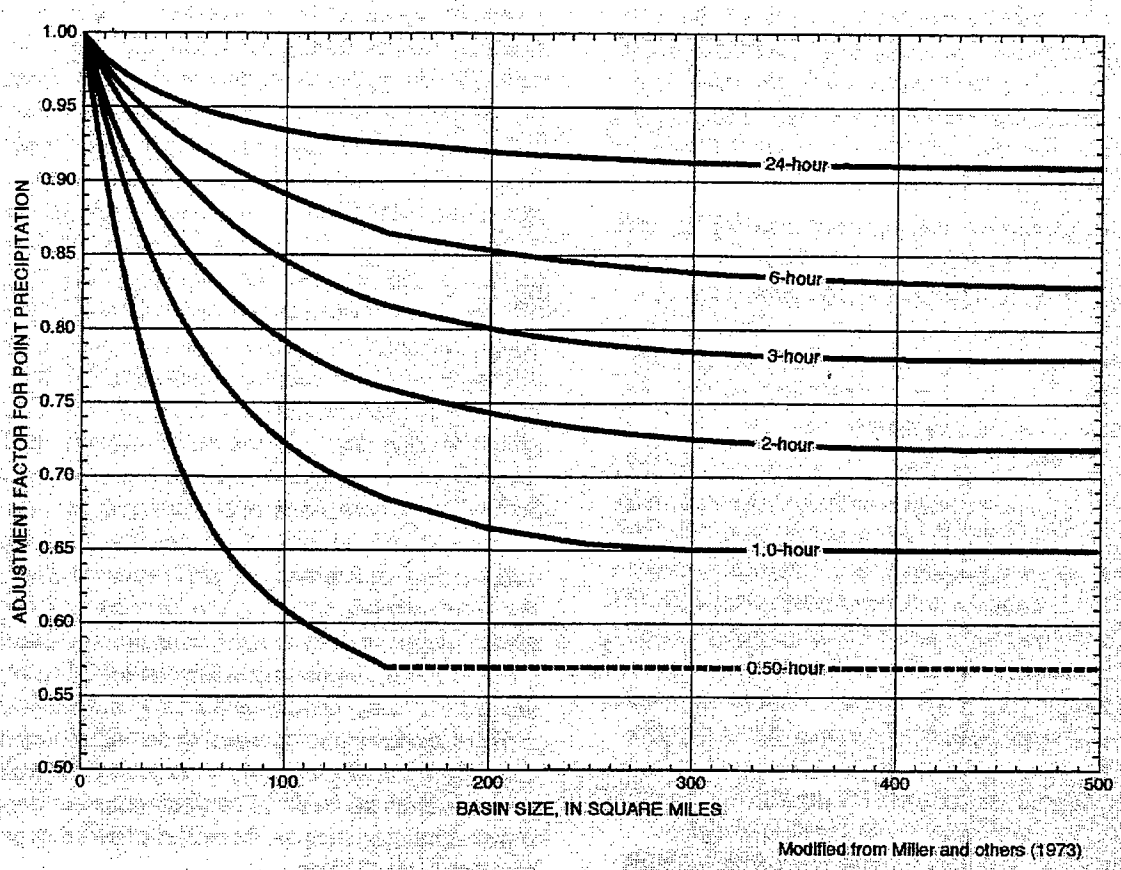


Figure 17. Depth-area adjustment curves for Montana.

0.5 hour. To adjust point precipitation for incremental durations less than 0.5 hour, use of the adjustment curve for 0.5 hour is considered to provide reasonable, but conservatively large estimates. In addition, the largest area used by Miller and others (1973) for the 0.5-hour adjustment was 150 square miles. Use of the value shown for 150 square miles for larger areas (dashed line in figure 17) also is considered to be conservatively reasonable. Depth-area adjustments vary with incremental duration; consequently, the curves in figure 17 need to be applied to dimensionless depth-duration data used to construct synthetic hyetographs rather than the hyetographs themselves. Use of the curves in figure 17 to adjust point precipitation will be illustrated in the Application Examples section of the report.

Application Examples

To construct a specific synthetic storm hyetograph for use in rainfall-runoff modeling studies, a calculated precipitation depth determined from methods described by Parrett (1997) is used together with appropriate dimensionless probabilistic depth-duration data and temporal characteristics and a depth-area adjustment factor. As described earlier, the recurrence interval of the precipitation depth is the primary factor that determines the overall exceedance probability of the storm and needs to be determined administratively. Once an appropriate recurrence interval for precipitation depth has been selected and storm depth has been determined, the appropriate exceedance probability for the temporal distribution of the precipitation depth needs to be determined. Once again, the determination

APPENDIX C3

USGS UNIT HYDROGRAPH

Procedures for Estimating Unit Hydrographs for Large Floods at Ungaged Sites in Montana

USGS Water-Supply Paper 2420

By: Stephen R. Holnbeck and Charles Parrett

Basin Characteristics used to estimate the Unit Hydrograph

A	12.017	mi^2
E_{6000}	96	%
F	95	%
TYPE	Mountains	

$$T_C = 0.298A^{0.65}$$

$$R_{Mountains} = 2.90A^{0.31}$$

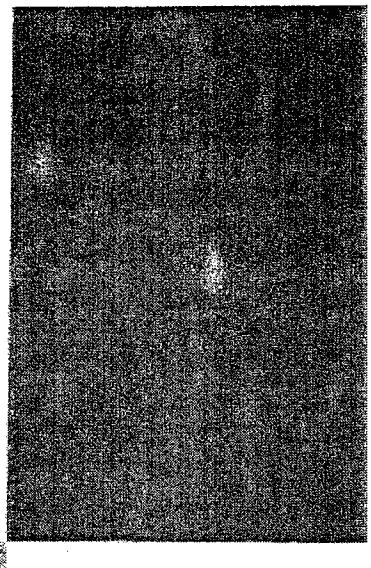
$$R_{Plains} = 1.30A^{0.31}$$

$$t_p = 0.393A^{0.58}$$

$$q_p = 7.24\,A^{0.10}$$

		Unit	StdErr
T_c	1.500	hours	0.160
R	6.268	hours	0.390
t_p	1.662	hours	0.168
q_p	9.284		0.164

Procedures for Estimating Unit Hydrographs for Large Floods at Ungaged Sites in Montana



United States Geological Survey Water-Supply Paper 2420

Prepared in cooperation with the Montana Department of Natural Resources and Conservation

Table 4. Results of regression analysis for selected unit-hydrograph variables for stream sites in Montana

[T_c, time of concentration, in hours; A, drainage area, in square miles; R, basin-storage coefficient, in hours; t_p, Snyder standard lag, in hours; q_p, peak of dimensionless unit hydrograph; L, main channel length, in miles; L_{ca}, distance from basin centroid to mouth, in miles; S, main channel slope, in feet per mile]

Equation			Coefficient of determination (r^2)	Standard error (logarithm, base 10)	Equation number
T_c	=	$0.298\,A^{0.65}$	0.91	0.160	8
R	=	$2.90\,A^{0.31}$ ("mountains" sites)	.47	.390	9
R	=	$1.30\,A^{0.31}$ ("plains" sites)	.47	.390	10
t_p	=	$0.393\,A^{0.58}$	.88	.168	11
q_p	=	$8.46\,(LL_{ca}/\sqrt{S})^{0.10}$	.30	.153	12
q_p	=	$7.24\,A^{0.10}$	.19	.164	13

95 percent). The computerized regression procedure also provided standard errors of estimate and coefficients of determination as measures of the regression reliability. In general, the larger the coefficient of determination and the smaller the standard error of estimate, the more reliable is the estimating equation.

The results of the regression analysis (equations 8–13 in table 4) indicate that only one explanatory variable was significant in each equation, and that, in all instances but one, the significant variable was drainage area. The single exception was the equation for q_p where $LL_{ca}/\sqrt{S}$ was the only significant variable. Because this variable requires substantially more time to measure and calculate than does drainage area, a second equation for q_p was derived wherein all explanatory variables were considered for inclusion except $LL_{ca}/\sqrt{S}$. In this instance, drainage area was the most significant variable, and the coefficient of determination and the standard error for the equation using drainage area were not substantially worse than for the equation using $LL_{ca}/\sqrt{S}$.

On the basis of standard error and coefficient of determination, the equations for estimating T_c and t_p are the most reliable, and the equations for estimating R and q_p are the least reliable. The regression data and regression lines defined by the equations are plotted in figures 15 through 19. Visual inspection of the plotted data confirms that the equations for estimating T_c and t_p provide the best fit to the data, and that the equations for estimating R and q_p provide the worst fit.

As indicated by the large value of standard error shown for equations 9 and 10 in table 4 and the plot shown in figure 16, the values for R show a large scatter about the regression lines. One value of R for a mountains site and two values of R for plains sites plot well below the regression lines and may be anomalously small. Elimination of those values would result in very flat slopes for the regression lines for both mountains and plains indicating little or no relation between R and A and perhaps little or no distinction between mountains and plains. Users are thus cautioned that the equations for R, although statistically significant, may not always provide reliable results. The same is true for the equations for q_p (12 and 13), where the plots (fig. 18-19) show only a small amount of scatter but very flat slopes for the regression lines. The flat slopes indicate only weak relations between q_p and $LL_{ca}/\sqrt{S}$ and between q_p and A. Therefore, use of an average value for q_p may be just as reliable as the use of equations 12 or 13.

Average Dimensionless Unit Hydrograph

The ordinates of the 26 individual dimensionless unit hydrographs were averaged in the same manner that individual unit hydrographs are averaged at a single site (Linsley and others, 1975, p. 238) to produce the average dimensionless unit hydrograph shown in figure 20. Values of the abscissae and ordinates of the average dimensionless unit hydrograph are given in table 5.

Equations 17, 18, and 19 thus can be used to adjust the average dimensionless unit hydrograph for any calculated q_p ($q_p \geq 8.0$) for any point on the dimensionless time scale. For example, if q_p is calculated from equation 13 as 19.5, the adjustment factor for $t = 125$ would be calculated from equation 17 as follows:

$$AF_{125} = -0.42 + 0.22 \log 125 + (1.42 - 0.22 \log 125) \cdot (19.5/13.6)$$

$$AF_{125} = -0.42 + 0.22\,(2.097) + [1.42 - 0.22\,(2.097)] \cdot (19.5/13.6)$$

$$AF_{125} = -0.42 + 0.46 + [1.42 - 0.46]\,(1.43)$$

$$AF_{125} = 0.04 + 0.96\,(1.43)$$

$$AF_{125} = 1.41.$$

From table 5, the dimensionless discharge on the average dimensionless unit hydrograph for $t = 125$ is 11.8. The adjusted dimensionless discharge for this time thus would be 11.8 multiplied by 1.41 or 16.6.

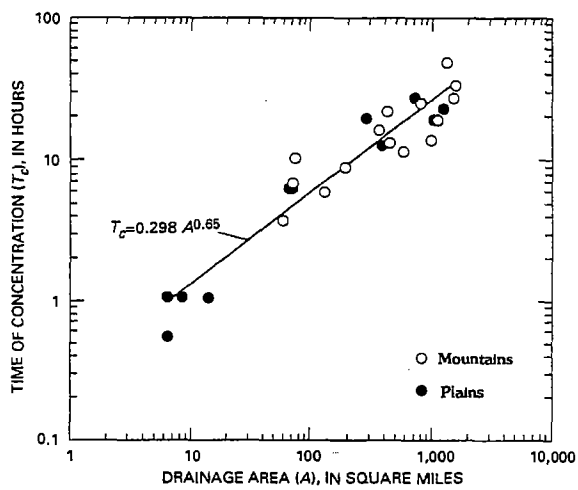


Figure 15. Regression relation for time of concentration (T_c) for stream sites in Montana.

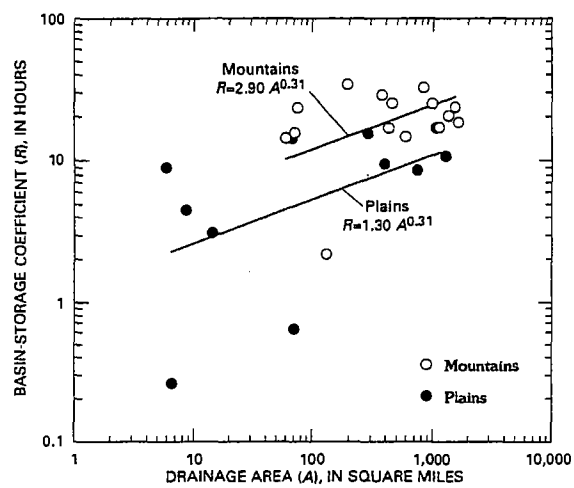


Figure 16. Regression relation for basin-storage coefficient (R) for stream sites in Montana.

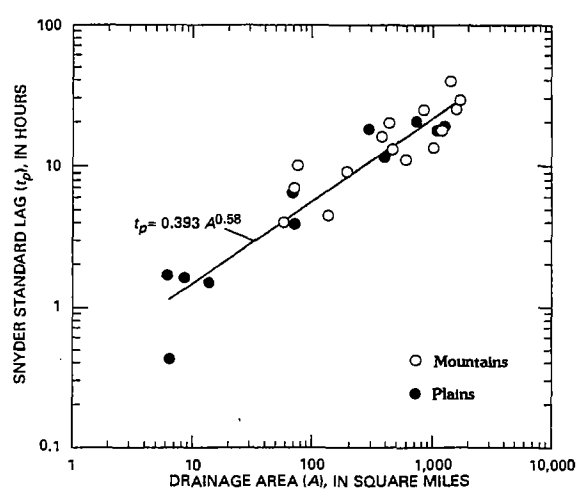


Figure 17. Regression relation for Snyder standard lag (t_p) for stream sites in Montana.

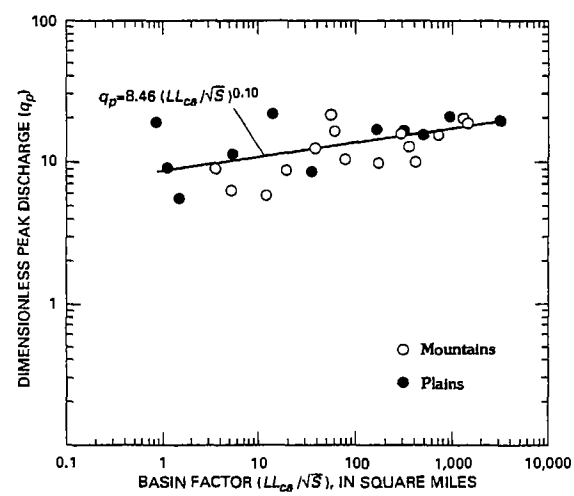


Figure 18. Regression relation for dimensionless peak discharge (q_p) versus basin factor for stream sites in Montana.

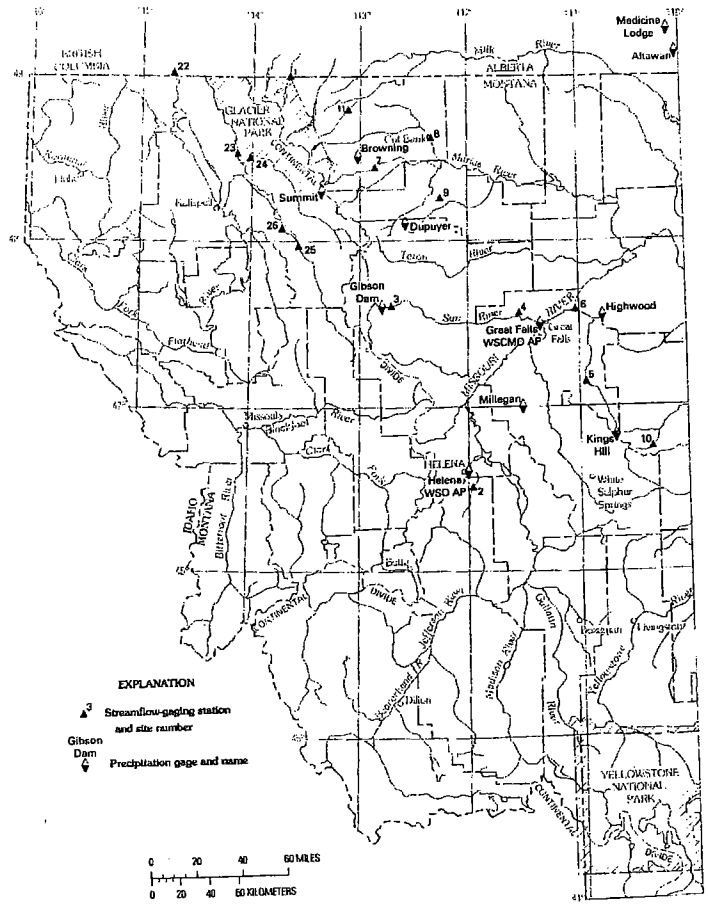
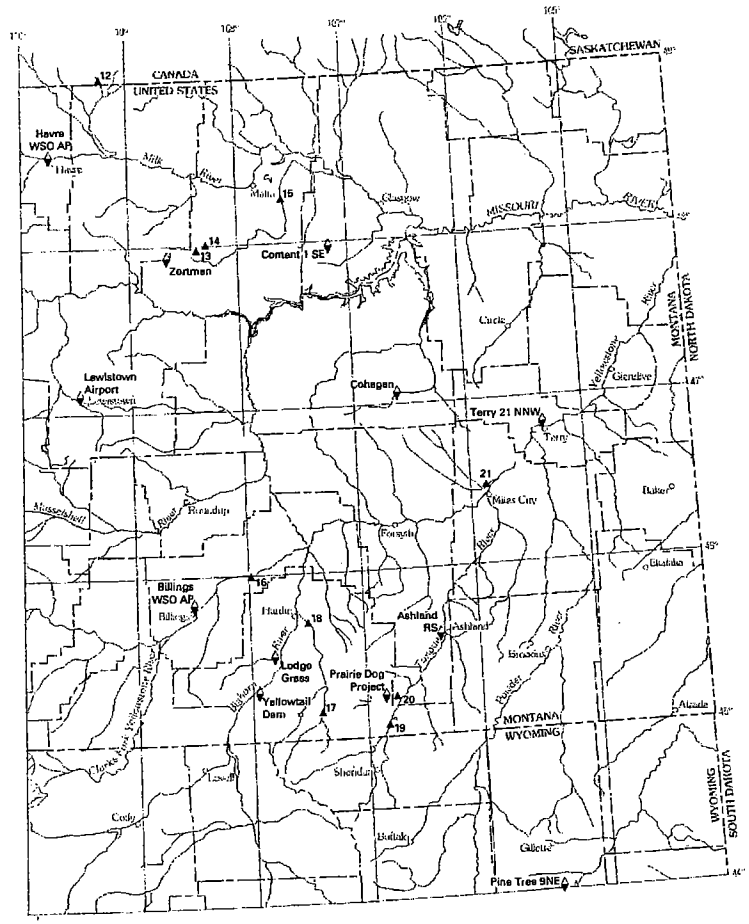


Figure 7. Location of study sites used for unit-hydrograph analysis.



APPENDIX C4

HEC-HMS PMF COMPUTATIONS USGS UNIT HYDROGRAPHS

Natural Baseflow Calculation - From Blacktain Creek

Method Reliablity

DA_U	12.017		
DA_G	95.4	DA_U/DA_G	0.126

$$Q_{T,U} = Q_{T,G}\left(\frac{DA_U}{DA_G}\right)$$

Gaged Site #	12323240
Gaged Site Name	Blacktail Creek at Butte
Ungaged Site Name	Basin Creek Reservoir

$Q_{T,G}$ =	20.0	cfs	Taken from USGS Monthly Streamflow Statistics for June
$Q_{T,U}$ =	2.52	cfs	

Water Resources

Data Category: Surface Water | Geographic Area: Montana | go

Monthly Streamflow Statistics for Montana

USGS 12323240 Blacktail Creek at Butte MT

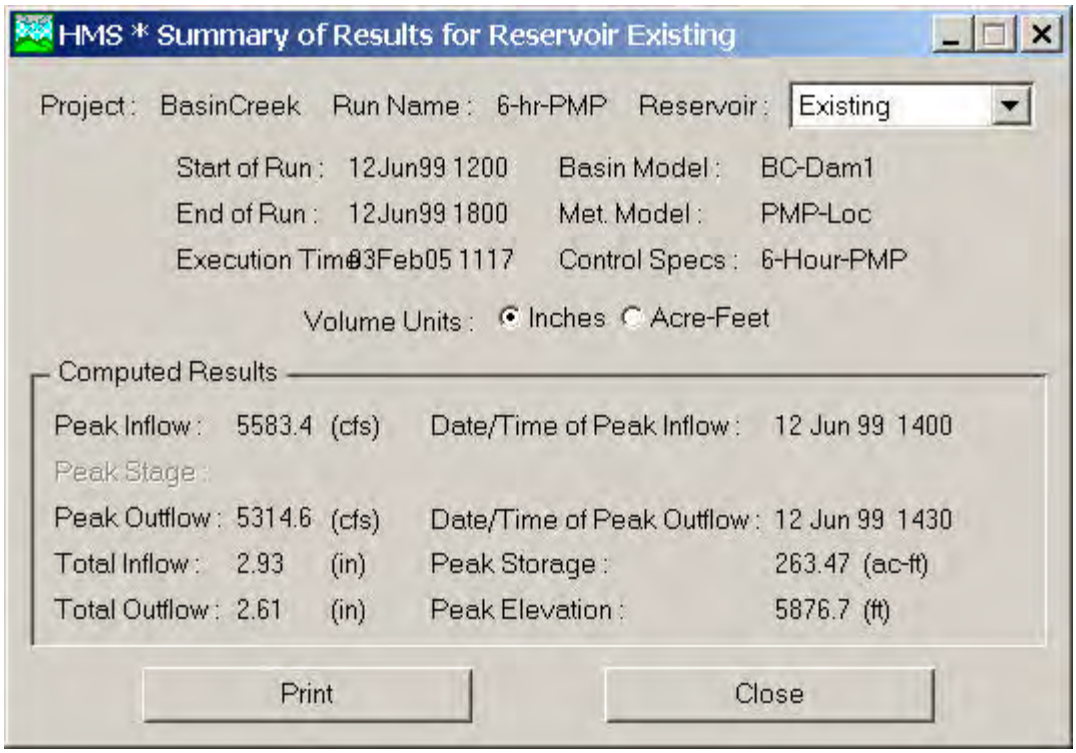
Available data for this site: Surface-water: Monthly streamflow statistics | GO

Silver Bow County, Montana
Hydrologic Unit Code 17010201
Latitude 45°59'40.81", Longitude 112°32'08.57" NAD27
Drainage area 95.4 square miles
Gage datum 5,430 feet above sea level NGVD29

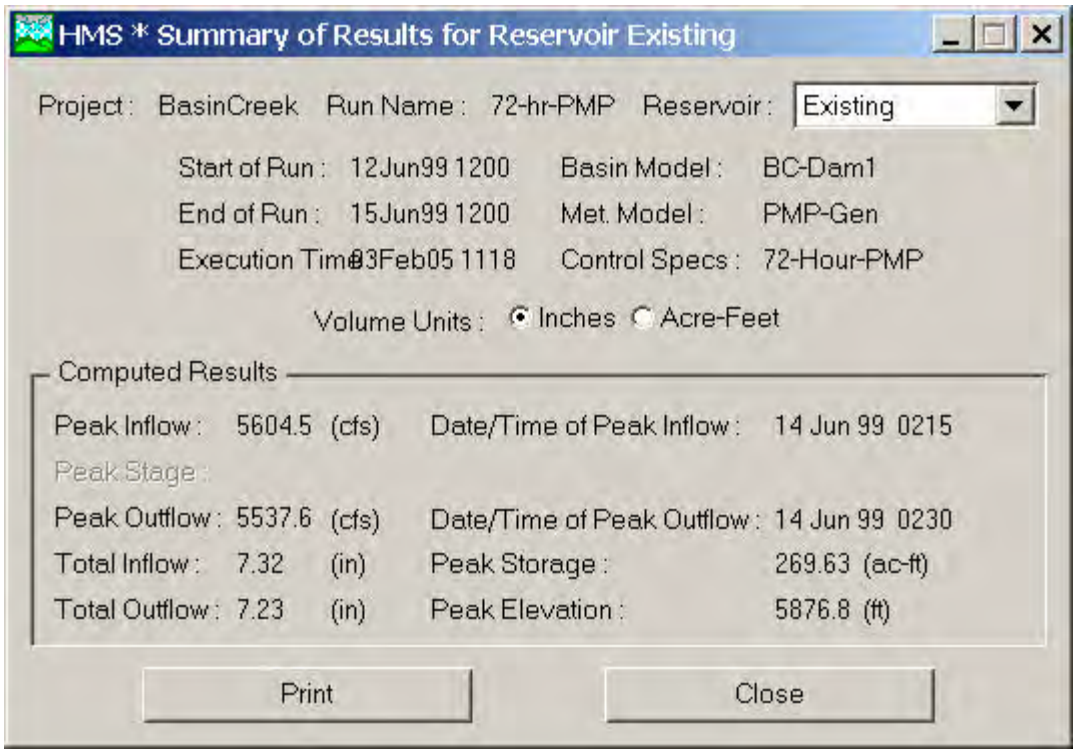
Output formats

- HTML table of all data
- Tab-separated data
- Reselect output format

YEAR	Monthly mean streamflow, in ft^3/s											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988										9.03	9.37	8.55
1989	7.81	7.12	14.5	17.5	17.0	11.8	8.60	11.3	10.6	11.5	9.78	9.27
1990	9.75	9.27	10.2	14.1	13.4	13.0	8.42	9.23	8.49	8.68	9.17	7.65
1991	7.85	8.11	7.42	10.9	18.7	17.4	7.87	9.19	8.72	8.17	9.36	8.40
1992	8.09	8.40	10.8	9.36	7.31	9.94	8.20	6.70	5.98	8.17	7.79	7.86
1993	6.96	6.33	11.8	11.6	12.1	17.0	13.8	15.2	9.60	11.4	9.63	8.21
1994	7.79	7.84	11.4	19.0	18.3	10.4	10.4	6.35	5.98	8.84	8.91	8.69
1995	7.29	25.5	13.7	14.9	41.9	61.5	24.5	10.5	13.6	13.0	13.7	11.2
1996	9.30	21.8	21.8	28.6	30.1	20.5	10.4	8.93	9.76	11.0	11.4	10.3
1997	12.5	10.5	29.9	22.7	31.9	39.9	26.0	17.7	13.0	15.0	12.9	11.7
1998	11.4	11.4	20.1	27.0	31.3	34.0	20.1	12.4	11.8	13.1	13.9	12.6
1999	12.6	12.8	18.2	19.3	24.6	25.0	10.6	11.6	10.0	10.3	11.0	10.5
2000	9.97	10.9	11.6	13.8	12.4	8.11	8.43	5.28	6.60	8.15	6.90	7.17
2001	7.37	7.39	11.3	14.1	10.7	11.0	7.85	6.02	7.09	6.98	7.54	7.08
2002	7.17	7.17	9.05	11.6	9.15	11.3	6.19	8.19	7.11	7.30	7.72	7.14
2003	8.09	7.96	19.6	17.2	14.7	8.76	6.07	7.49	6.47			
Mean of monthly streamflows	8.93	10.8	14.8	16.8	19.6	20.0	11.8	9.74	8.99	10.0	9.94	9.09



Basin Creek Dam
USGS Unit Hydrograph
Local Storm
Full PMF



Basin Creek Dam
USGS Unit Hydrograph
General Storm
Full PMF

APPENDIX C5

Risk Based Design Precipitation

$P_S = P_{5000}(10^{rd})$ $\qquad r = -0.304 + 0.435 \log(LOL)$

P_S = SPILLWAY DESIGN PRECIP. $\qquad d = \log(PMP) - \log(P_{5000})$

P_{5000} = 5,000 YEAR PRECIP.

LOL = LOSS OF LIFE

PMP = PROB. MAX. PRECIP.

$P_{5000} = q(F_{5000})\ P_{24MAX}$

FROM REGIONAL ANALYSIS OF ANNUAL PRECIPITATION MAXIMA IN MONTANA

$F_{5000} = 1 - \frac{1}{5000} = 0.9998$ $\qquad F_{5000}$ = 5,000 YEAR EXCEEDANCE PROBABILITY

$q(F_{5000}) = \xi + \alpha(\{1-(-\log F)^K\}/K)$ $\qquad \xi, \alpha, \& K$ ARE PARAMETERS OF THE GENERALIZED EXTREME VALUE (GEV) DISTRIBUTION

FROM TABLE 9 (PAGE 17) FOR REGION 1

	6 HRS	24 HRS
ξ	0.830	0.839
α	0.242	0.258
K	-0.114	-0.047

$q(F_{5000})_{24HR} = 3.87$

$q(F_{5000})_{6HR} = 4.87$

FROM TABLE 11 (PAGE 27)

MAP = MEAN ANNUAL PRECIP.

LAT = LATITUDE (DECIMAL) - 40

LONG = LONGITUDE (DECIMAL) - 100

$P_{MAX6} = 0.60 + (0.0067\ MAP)$

$P_{MAX24} = 1.0 + (0.078\ LAT) - (0.059\ LONG) + (0.025\ MAP)$

$P_{MAX6} = 0.60 + (0.0067(20.9)) = 0.74\ IN$

LATITUDE = 45.8167

LONGITUDE = 112.5147

$P_{MAX24} = 1.0 + (0.078(5.8167)) - (0.059(12.5147)) + 0.025(20.9) = 1.24\ IN$

$P_{5000_{6HR}} = 4.87(0.74\,IN) = 3.60\,IN$

$P_{5000_{24HR}} = 3.87(1.24\,IN) = 4.80\,IN$

$P_S = P_{5000}(10^{rd})$

$r = -0.304 + 0.435\,Log(LOL)$
$= -0.304 + 0.435\,Log(26)$ — 26 LOL FM DNRC CORRESPONDENCE
$= 0.31$ DATED JAN 26, 2005

$d = Log(PMP) - Log(P_{5000})$

$PMP_{24HR} = 20.60\,IN$ ($10\,mi^2$ INDEX PMP W/ 1.0 AREA FACTOR)

$PMP_{6HR} = 6.23\,IN$ ($1\,mi^2$ INDEX PMP ADJUSTED FOR AREA & ELEVATION)

$d_{24HR} = Log(20.60) - Log(4.80) = 0.63$

$d_{6HR} = Log(6.23) - Log(3.60) = 0.24$

$P_{S_{6HR}} = 3.60(10^{(0.31)(0.24)}) = 4.27\,IN$

$P_{S_{24HR}} = 4.80(10^{(0.31)(0.63)}) = 7.53\,IN$

CURRENT RISK FACTOR: $RF = \frac{RI_{SW}}{LOL}$

RI_{SW} = FLOOD RECURRENCE THAT THE SPILLWAY CAN PASS

$\frac{RI_{SW}}{LOL} = \frac{2}{26} = 0.08 < 100$ ∴ SPILLWAY WORK IS RQ'D

HOWEVER, FAILURE DOES NOT OCCUR FROM OVERTOPPING @ THE TWO YEAR FLOOD.

Worksheet for Developing USGS 6-hr. Ps Hyetograph

Dimensionless Precip.	P_{max6}	P_{s6hr}
		4.27

Incremental Duration (hrs)	Dimensionless Depth (in)	Depth-Area Adjustment*	Adjusted Dimensionless Depth	Accum. Depth (in)	Inc. Time (hrs)	Inc. Dimensionless Depth	Periods in Inc.	Dimensionless Depth per Period	Depth per Period (in)
0	0.000	1.00	0.000	0.000					
					0.25	0.269	1	0.2690	1.1486
0.25	0.269	1.00	0.269	1.149					
					0.25	0.102	1	0.1020	0.4355
0.5	0.371	1.00	0.371	1.584					
					0.25	0.074	1	0.0740	0.3160
0.75	0.445	1.00	0.445	1.900					
					0.25	0.074	1	0.0740	0.3160
1	0.519	1.00	0.519	2.216					
					1	0.188	4	0.0470	0.2007
2	0.707	1.00	0.707	3.019					
					1	0.110	4	0.0275	0.1174
3	0.817	1.00	0.817	3.489					
					3	0.183	12	0.0153	0.0651
6	1.000	1.00	1.000	4.270					
					3	0.067	12	0.0056	0.0238
9	1.067	1.00	1.067	4.556					
					3	0.036	12	0.0030	0.0128
12	1.103	1.00	1.103	4.710					
					3	0.035	12	0.0029	0.0125
15	1.138	1.00	1.138	4.859					
					3	0.007	12	0.0006	0.0025
18	1.145	1.00	1.145	4.889					

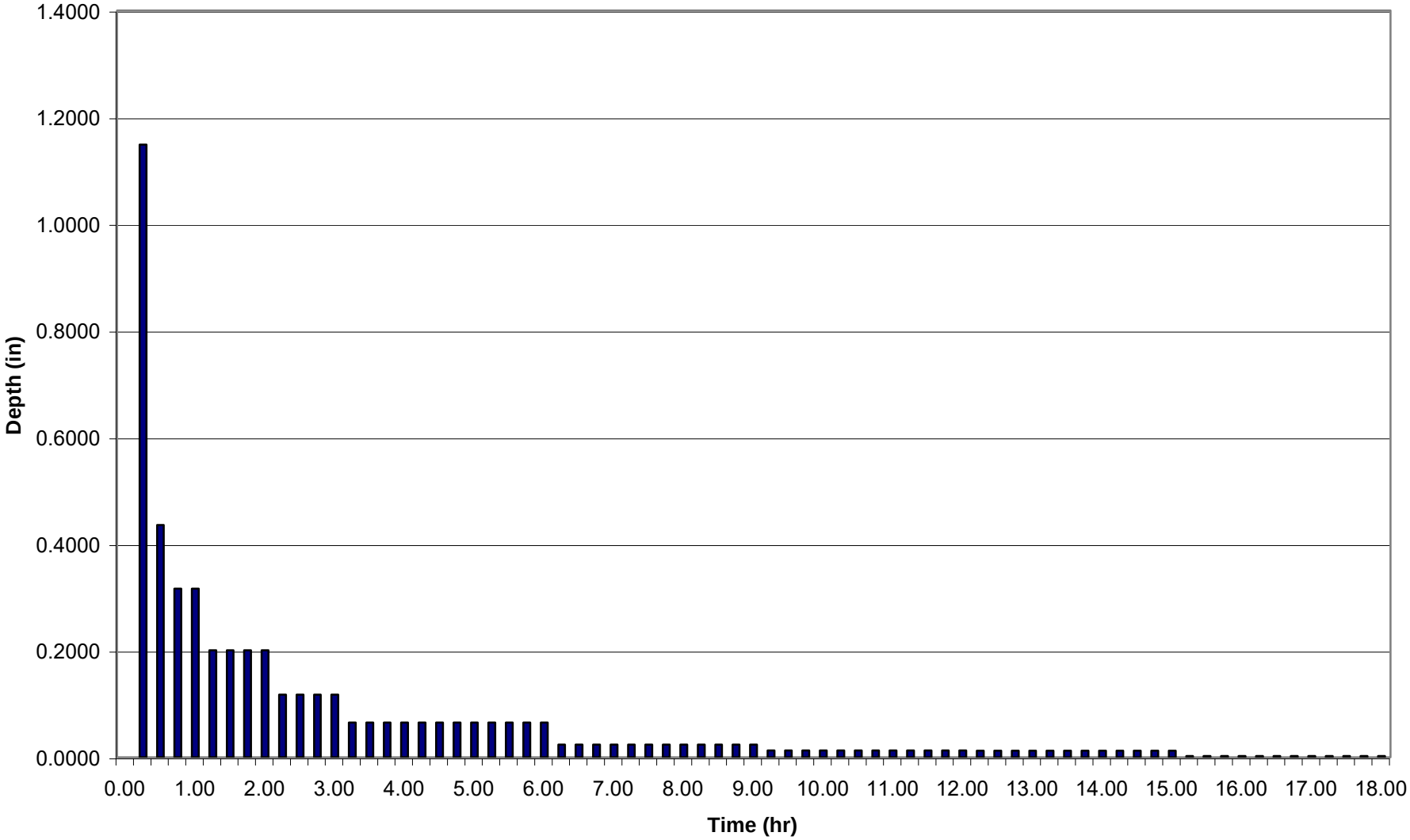
*Area Adjustment factor included in PMP value used to compute Ps.

Worksheet for Developing USGS 24-hr. Ps Hyetograph

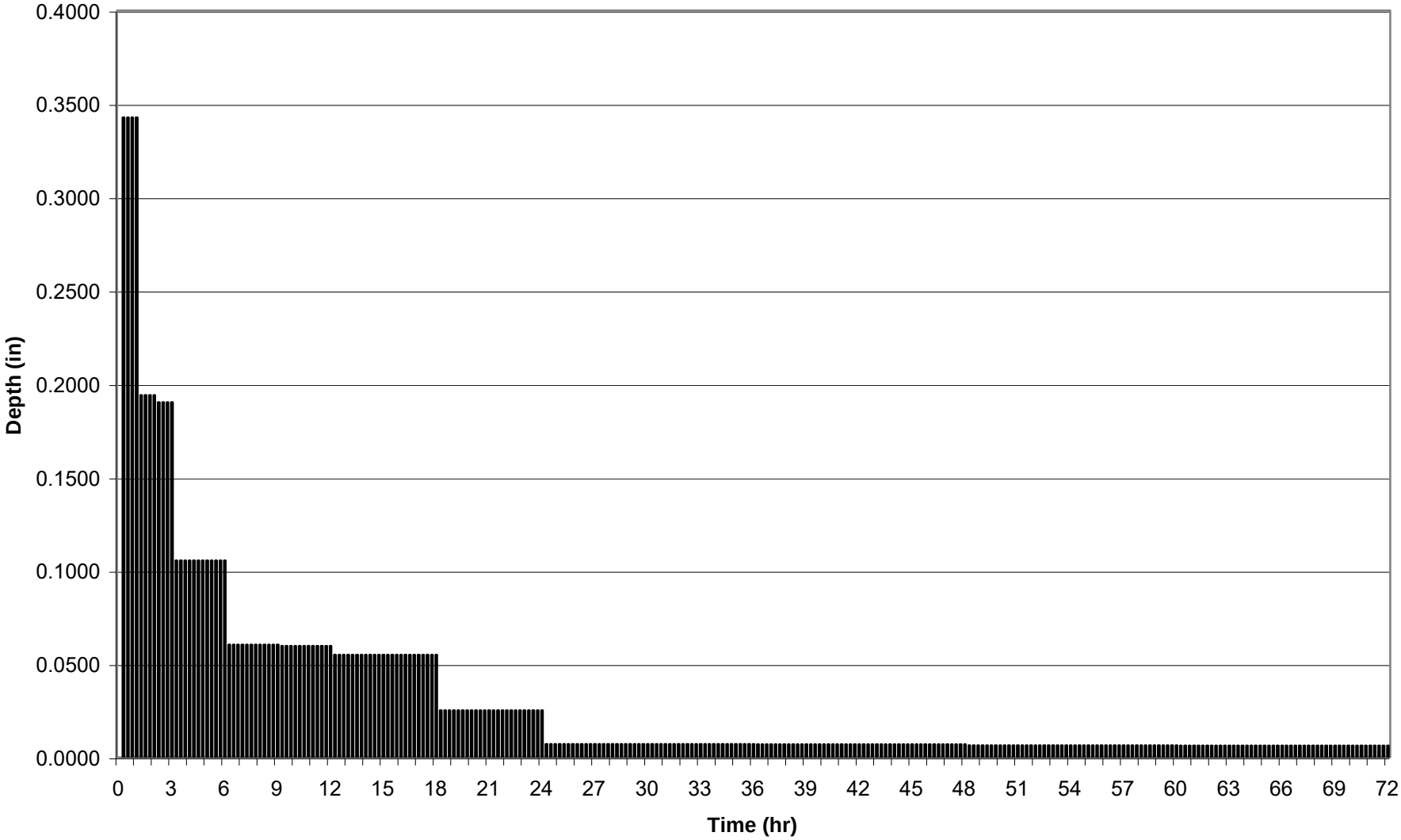
		Dimensionless Precip.	P_{max6}	P_{s24hr}					
				7.53					
Incremental Duration (hrs)	Dimensionless Depth (in)	Depth-Area Adjustment*	Adjusted Dimensionless Depth	Accum. Depth (in)	Inc. Time (hrs)	Inc. Dimensionless Depth	Periods in Inc.	Dimensionless Depth per Period	Depth per Period (in)
0	0.000	1.00	0.000	0.000					
					1	0.182	4	0.0455	0.3426
1	0.182	1.00	0.182	1.370					
					1	0.103	4	0.0258	0.1939
2	0.285	1.00	0.285	2.146					
					1	0.101	4	0.0253	0.1901
3	0.386	1.00	0.386	2.907					
					3	0.168	12	0.0140	0.1054
6	0.554	1.00	0.554	4.172					
					3	0.096	12	0.0080	0.0602
9	0.650	1.00	0.650	4.895					
					3	0.095	12	0.0079	0.0596
12	0.745	1.00	0.745	5.610					
					6	0.175	24	0.0073	0.0549
18	0.920	1.00	0.920	6.928					
					6	0.080	24	0.0033	0.0251
24	1.000	1.00	1.000	7.530					
					12	0.045	48	0.0009	0.0071
36	1.045	1.00	1.045	7.869					
					12	0.044	48	0.0009	0.0069
48	1.089	1.00	1.089	8.200					
					12	0.041	48	0.0009	0.0064
60	1.130	1.00	1.130	8.509					
					12	0.040	48	0.0008	0.0063
72	1.170	1.00	1.170	8.810					

*Area Adjustment factor included in PMP value used to compute Ps.

USGS - 6 Hour Risk Based Hyetograph (P_{s6hr})



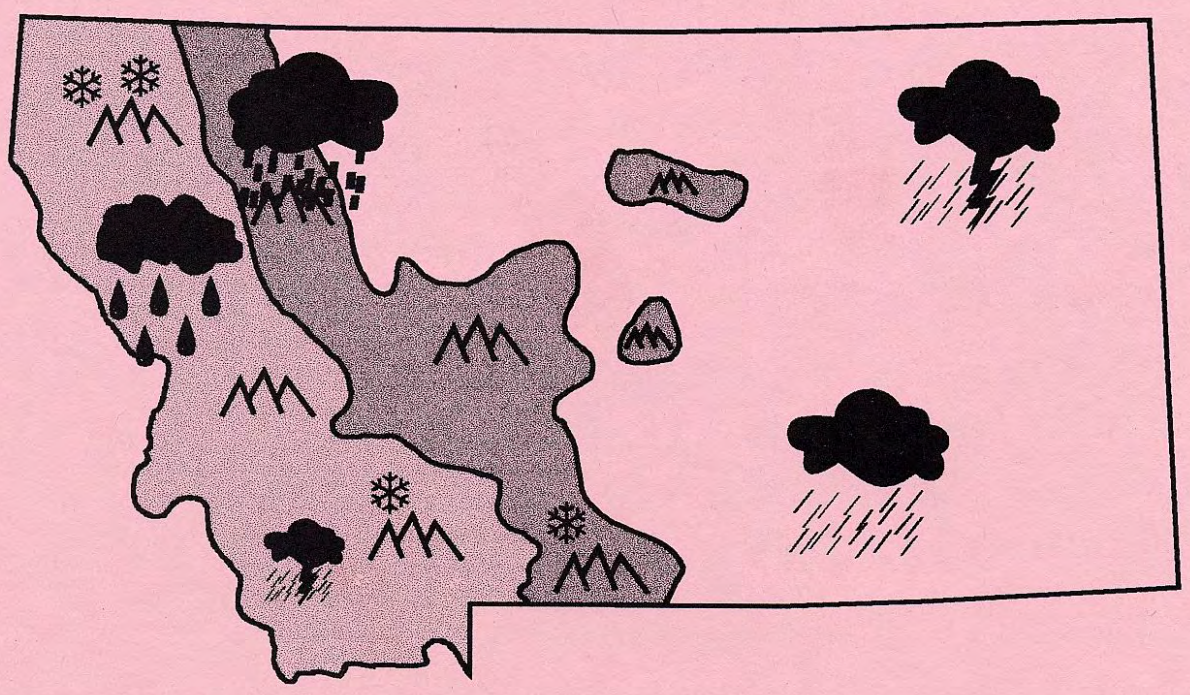
USGS - 24 Hour Risk Based Hyetograph (P_{s24hr})



REGIONAL ANALYSIS OF ANNUAL PRECIPITATION MAXIMA IN MONTANA

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS REPORT 97-4004



PREPARED IN COOPERATION WITH THE

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

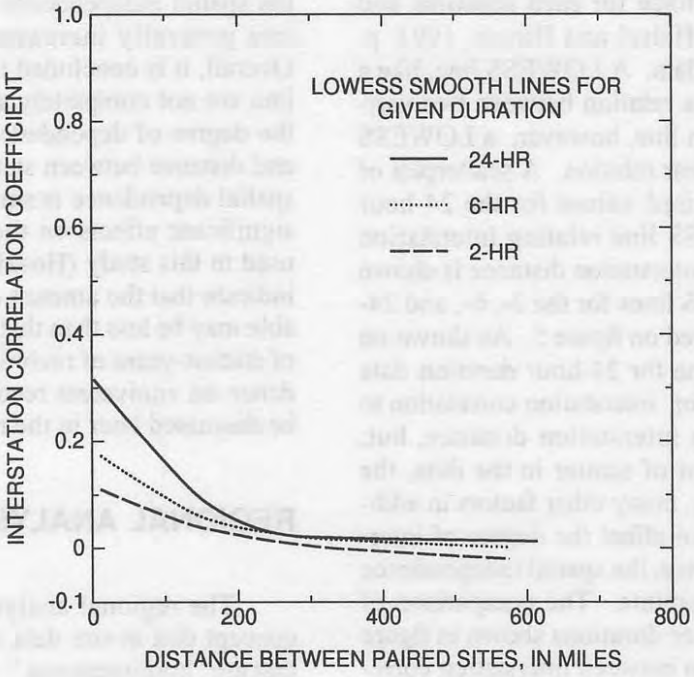


Figure 5. LOWESS trend lines for interstation correlation coefficient versus distance between sites for annual precipitation maxima, Montana and northern Wyoming.

resultant frequency curves for at-site data are identical, except for a site-specific scaling factor, at all sites in a region. The at-site mean value commonly is used as the scaling factor in regional analyses. Key elements in a regional analysis include: (1) determination of homogeneous regions, (2) determination of regional frequency curves, and (3) a method for estimation of the at-site mean (scaling factor) at any location in a region. The use of *L*-moment statistics aids in completion of the first two elements. The following sections include brief discussions of the theories of regional frequency curves and *L*-moments and the application of the key elements of a regional analysis to the current study in Montana.

Theory of Regional Frequency Curves

In flood-frequency analysis, the use of dimensionless frequency curves within homogeneous regions is well documented (Dalrymple, 1960; Wallis, 1989). In recent years, dimensionless frequency curves have increasingly been used in analyses of precipitation maxima (Alila and others, 1992; Hosking and Wallis, 1993; Schaefer, 1990; Vogel and Lin, 1992). The mean value of the at-site annual floods or storm depths was used as the scaling factor in each of these studies.

In general, for an analysis of storm depths, the quantiles Q of non-exceedance probability F at any site i in a region (Hosking and Wallis, 1993) can be expressed as:

$$Q_i(F) = \mu_i q(F) , \qquad (1)$$

where

$Q_i(F)$ is the quantile of non-exceedance probability F at site i,

μ_i is the mean value of storm depth at site i, and

$q(F)$ is the regional quantile of non-exceedance probability F.

The regional quantiles $q(F)$, $0 < F < 1$, form a "regional growth curve" that is common to all sites in the region.

Determination of the regional quantiles, $q(F)$, in equation (1) is dependent upon the type of probability distribution that fits the regional data. For example, the relation between the quantile function and the 3-parameter Generalized Extreme Value (GEV) probability distribution (Hosking, 1990) is as follows:

$$q(F) = \xi + \alpha(\{1-(-\log F)^k\}/k) , \qquad (2)$$

where

ξ, α, and k are the parameters of the GEV distribution, and

$\log F$ is the natural logarithm of non-exceedance probability.

Table 8. Regional average *L*-moment ratios for 6-hour data in Region 2, Montana

	L-CV	*L*-Skew	*L*-Kurtosis
Unadjusted	0.207	0.225	0.184
Adjusted	0.221	0.260	0.210
Percent change	+6.8	+15.6	+7.1

criterion. The probability distribution that most often satisfied the goodness-of-fit test was the GEV. To ensure consistency among durations and regions, the GEV was selected as the appropriate distribution for use in all regions for all durations. For the 6-hour duration data in Region 2, the adjusted values of *L*-CV and *L*-Skew were used to calculate parameters of the GEV distribution. Table 9 shows the parameters of the GEV distribution for each region and duration.

L-moment ratio diagrams were prepared for each duration and region to provide a visual indication of how well the GEV distribution fit the regional data (figs. 9-11). In each figure, paired values of at-site *L*-Skew and *L*-Kurtosis were plotted together with the regional average paired value and lines representing the theoretical relation between *L*-Skew and *L*-Kurtosis for three probability distributions. A distribution is considered to have an acceptable fit to the regional data if the theoretical relation between *L*-Skew and *L*-Kurtosis is acceptably close to the regional average value. The three selected probability distributions, GEV, GLO, and GNO, were those most frequently found to satisfy the goodness-of-fit test. As indicated by figures 9-11, the regional average paired value of *L*-Skew and *L*-Kurtosis was relatively close to the line for the GEV distribution for all durations and regions.

While there is substantial scatter of L-moment data pairs in figures 9-11, this degree of scatter is entirely consistent with the variability expected from sample statistics. This same type of scatter was observed when computer simulations were used to generate data sets from known distributions with known population parameters (Hosking, 1990). The important feature in figures 9-11 is the relation between the regional mean and the GEV distribution line.

The values of the GEV parameters shown in table 9 were used in equation 2 to calculate regional quantiles for various non-exceedance probabilities up to 0.9998. Regional frequency curves were developed by plotting the calculated quantiles (Y axis) against selected results from equations 3 and 4 (X axis) and are shown on figures 12-14 grouped by region and on figures 15-17 grouped by duration. For example, using the GEV parameters in table 9 for 2-hour duration in Region 1 and solving equation 2 for a non-exceedance probability of 0.99 yields the following:

$$q(F) = \xi + \alpha\,(\{1 - (-\log F)^{k}\}/k)$$

$$\begin{aligned} q(0.99) &= 0.803 + 0.258\,(\{1-(-\log 0.99)^{-0.159}\}/-0.159) \\ &= 0.803 + 0.258\,(1-(0.010)^{-0.159})/-0.159) \\ &= 0.803 + 0.258\,(1-2.080)/-0.159 \\ &= 0.803 + 0.258\,(-1.080)/(-0.159) \\ &= 0.803 + 0.258\,(6.792) \\ q(0.99) &= 2.55 \end{aligned}$$

The recurrence interval for a non-exceedance probability of 0.99 is 1/(1 - 0.99), or 100 years.

To make the frequency curve more linear, non-exceedance probability is converted to GRV using equation 3 as follows:

$$\begin{aligned} \text{GRV} &= -\log(-\log F) \\ &= -\log(-\log 0.99) \\ &= -\log(0.010) \\ &= 4.60 \end{aligned}$$

Thus, the quantile value, which corresponds to a dimensionless storm depth, is plotted 2.55 units from the origin on the Y-axis and 4.60 units, corresponding to a recurrence interval of 100 years, from the origin on the X-axis (figs. 12 and 15). After plotting the complete frequency curve, the X-axis labels are expressed in terms of recurrence intervals rather than GRV.

Table 9. Parameters for Generalized Extreme Value (GEV) distribution applied to 2- 6-, and 24-hour duration storm depths in Montana

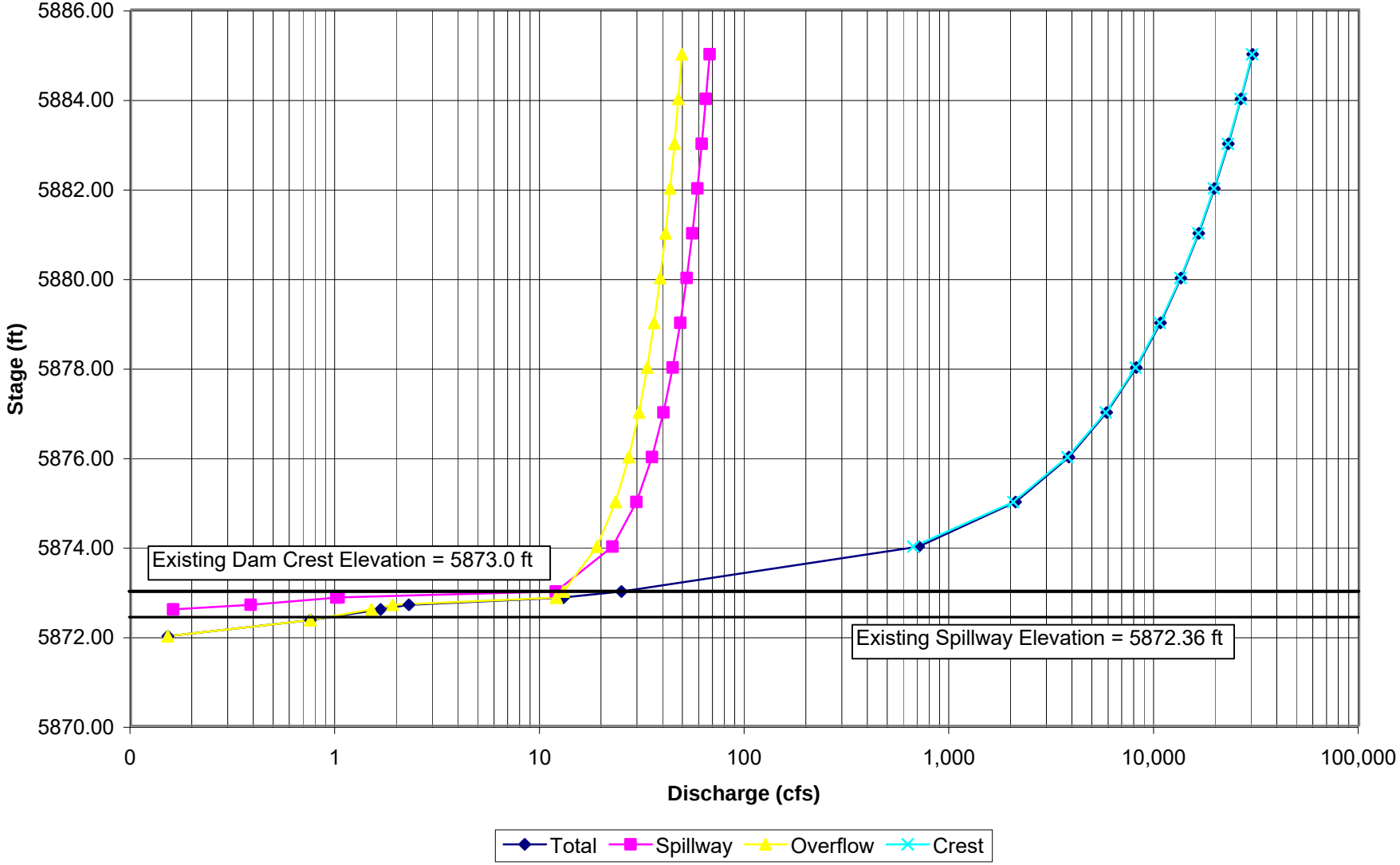
[ξ, α, and **k** are parameters for the GEV distribution]

REGION	Duration, in hours								
	2			6			24		
	ξ	α	k	ξ	α	k	ξ	α	k
1	0.803	0.258	-0.159	0.830	0.242	-0.114	0.839	0.258	-0.047
2	.783	.276	-.176	.79	.275	-.135	.801	.280	-.120
3	.765	.314	-.150	.791	.300	-.109	.799	.304	-.076

APPENDIX D1

EXISTING SPILLWAY HYDRAULICS

Existing Rating Curve



Spillway Discharge Calculations - Existing Conditions

Weir Flow

$$Q = CLH^{\frac{3}{2}}$$

C	Discharge Coefficient
L	Width of Weir (ft)
H	Head (ft)

Orifice Flow

$$Q = CA\sqrt{2gH}$$

C	Discharge Coefficient
A	Area of Orifice (ft^2)
H	Head (ft)
g	Acceleration of Gravity (32.2 ft/s^2)

Discharge Coeff. =	3.33	Sharp Crested Weir	Normally accepted value.
	2.63	Broad Crested Weir	Most conservative acceptable value.
	0.6	Orifice	Normally accepted value.

Crest Elev. =	Dam	5873.00	ft
	Spillway	5872.36	ft
	Overflow	5871.60	ft

Crest Length =	Dam	252	ft	= 5874
		274	ft	> 5874
	Spillway	8.56	ft	
	Overflow	2.84	ft	

Orifice Center Elev. =	Spillway	5872.61	ft
	Overflow	5872.10	ft

Orifice Height =	Spillway	0.5	ft
	Overflow	1	ft

No. of Contractions =	2

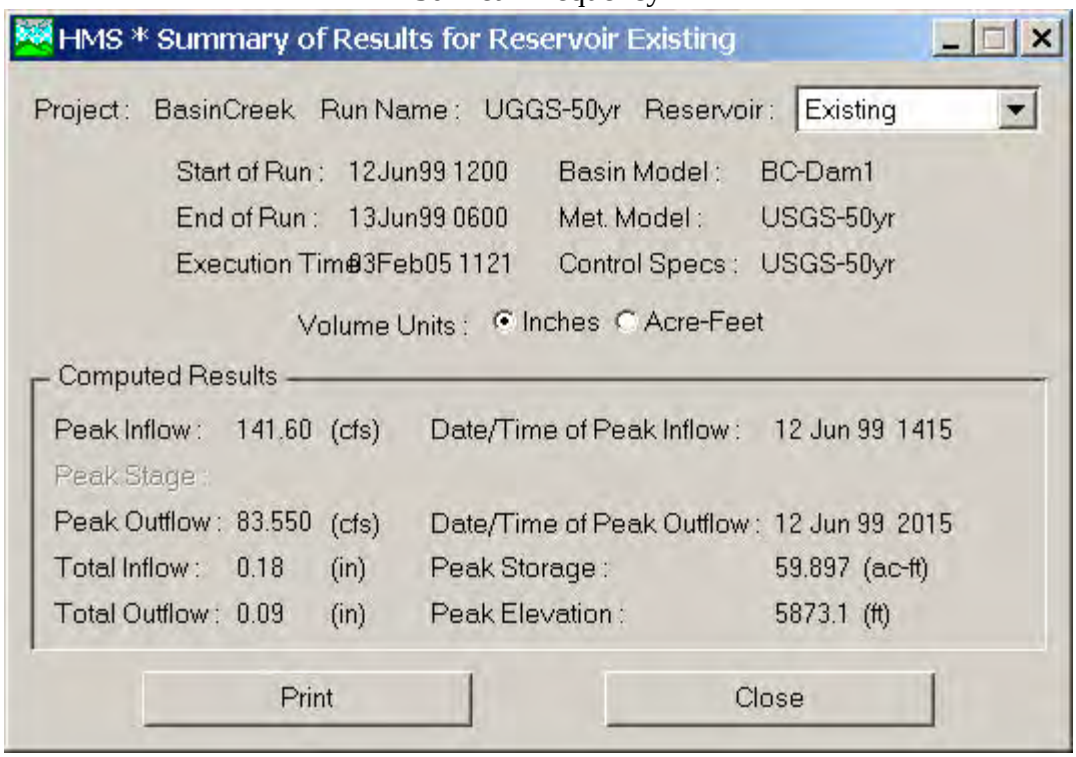
Orifice Area =	Spillway	3.96	ft^2
	Overflow	2.84	ft^2

$$L_{eff} = L - [(0.1)(No.Contractions)(H)]$$

Stage (ft)	Area (ac)	?Volume (ac-ft)	Storage (ac-ft)	Spillway Q (cfs)	Overflow Q (cfs)	Crest Q (cfs)	Total Q (cfs)
5871.60	55	0	0	0	0	0	0
5872.00	55	0	0	0	0	0	0
5872.36	55	20	20	0	1	0	1
5872.60	55	13	33	0	1	0	2
5872.70	55	6	39	0	2	0	2
5872.86	55	9	47	1	12	0	13
5872.87	55	0	48	1	12	0	13
5873.00	55	7	55	12	13	0	25
5874.00	55	55	110	22	19	662	703
5875.00	56	56	166	29	23	2,041	2,094
5876.00	56	56	222	35	27	3,750	3,812
5877.00	56	56	278	40	30	5,773	5,843
5878.00	57	56	334	44	33	8,068	8,146
5879.00	57	57	391	48	36	10,606	10,690
5880.00	57	57	448	52	38	13,365	13,455
5881.00	57	57	505	55	41	16,329	16,425
5882.00	58	57	563	58	43	19,484	19,586
5883.00	58	58	620	61	45	22,820	22,927
5884.00	58	58	678	64	47	26,328	26,439
5885.00	58	58	736	67	49	29,998	30,114

Existing Spillway Routing

50-Year Frequency



HMS * Summary of Results for Reservoir Existing

Project: BasinCreek Run Name: UGGS-50yr Reservoir: Existing

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-50yr
Execution Time: 03Feb05 1121 Control Specs: USGS-50yr

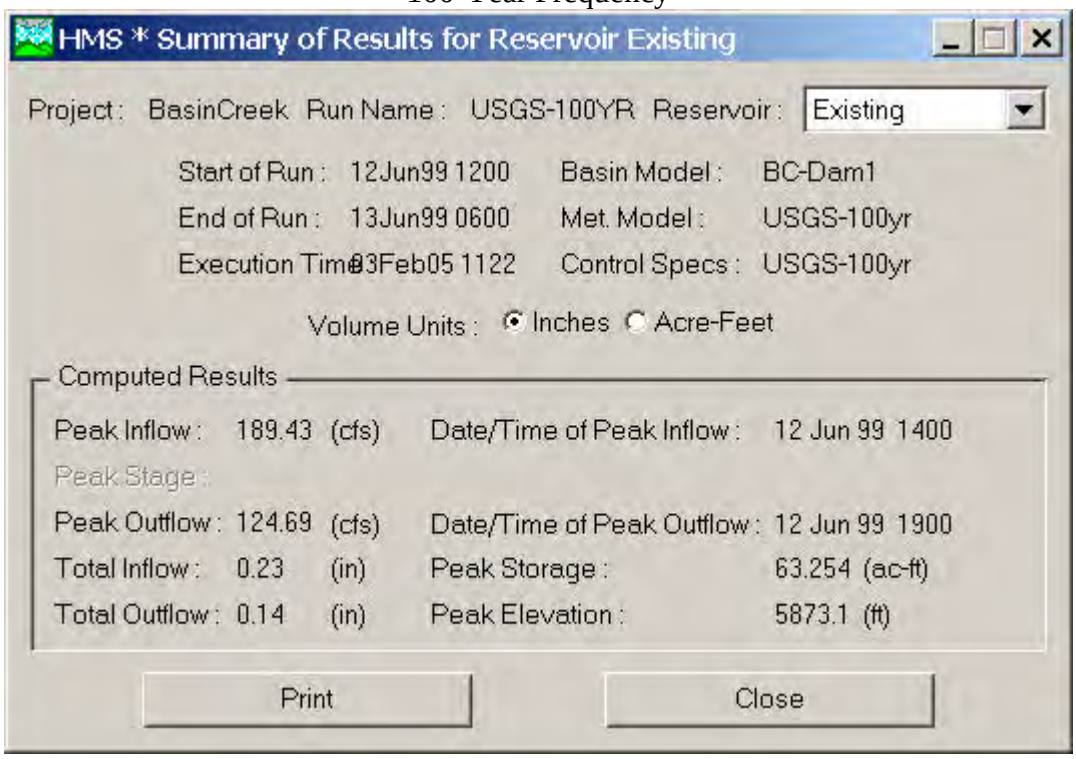
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	141.60	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1415	
Peak Stage:					
Peak Outflow:	83.550	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 2015	
Total Inflow:	0.18	(in)	Peak Storage:	59.897	(ac-ft)
Total Outflow:	0.09	(in)	Peak Elevation:	5873.1	(ft)

Print Close

100-Year Frequency



HMS * Summary of Results for Reservoir Existing

Project: BasinCreek Run Name: USGS-100YR Reservoir: Existing

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-100yr
Execution Time: 03Feb05 1122 Control Specs: USGS-100yr

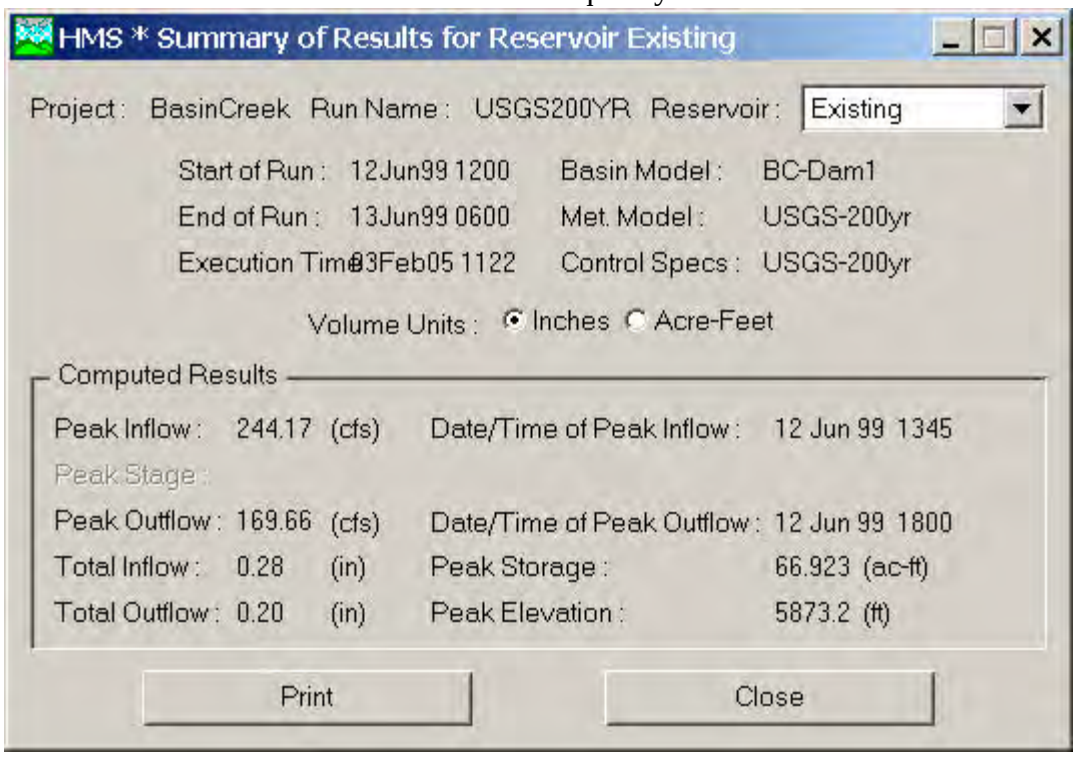
Volume Units: Inches Acre-Feet

Computed Results

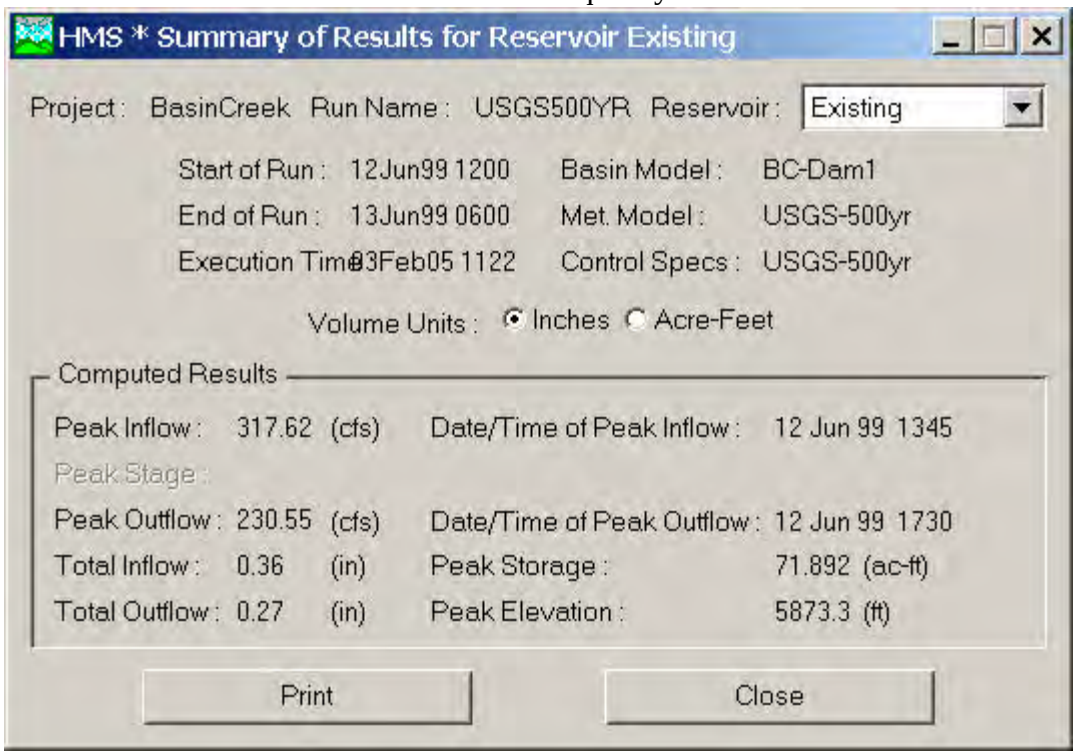
Peak Inflow:	189.43	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1400	
Peak Stage:					
Peak Outflow:	124.69	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1900	
Total Inflow:	0.23	(in)	Peak Storage:	63.254	(ac-ft)
Total Outflow:	0.14	(in)	Peak Elevation:	5873.1	(ft)

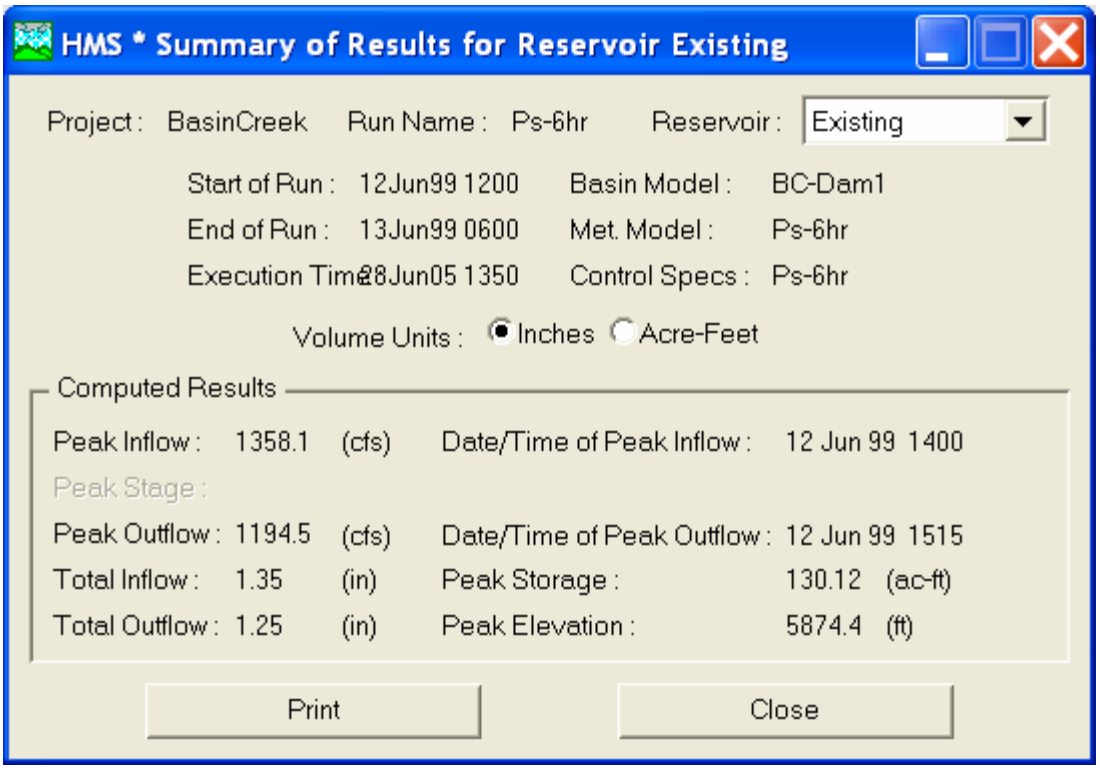
Print Close

200-Year Frequency

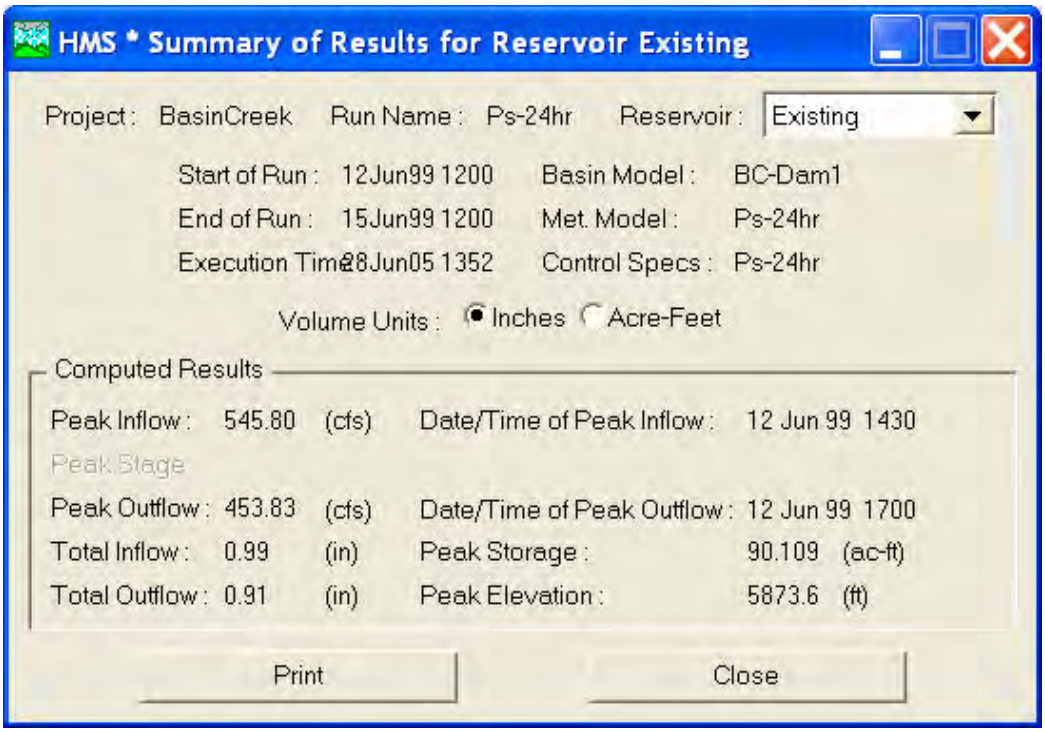


500-Year Frequency

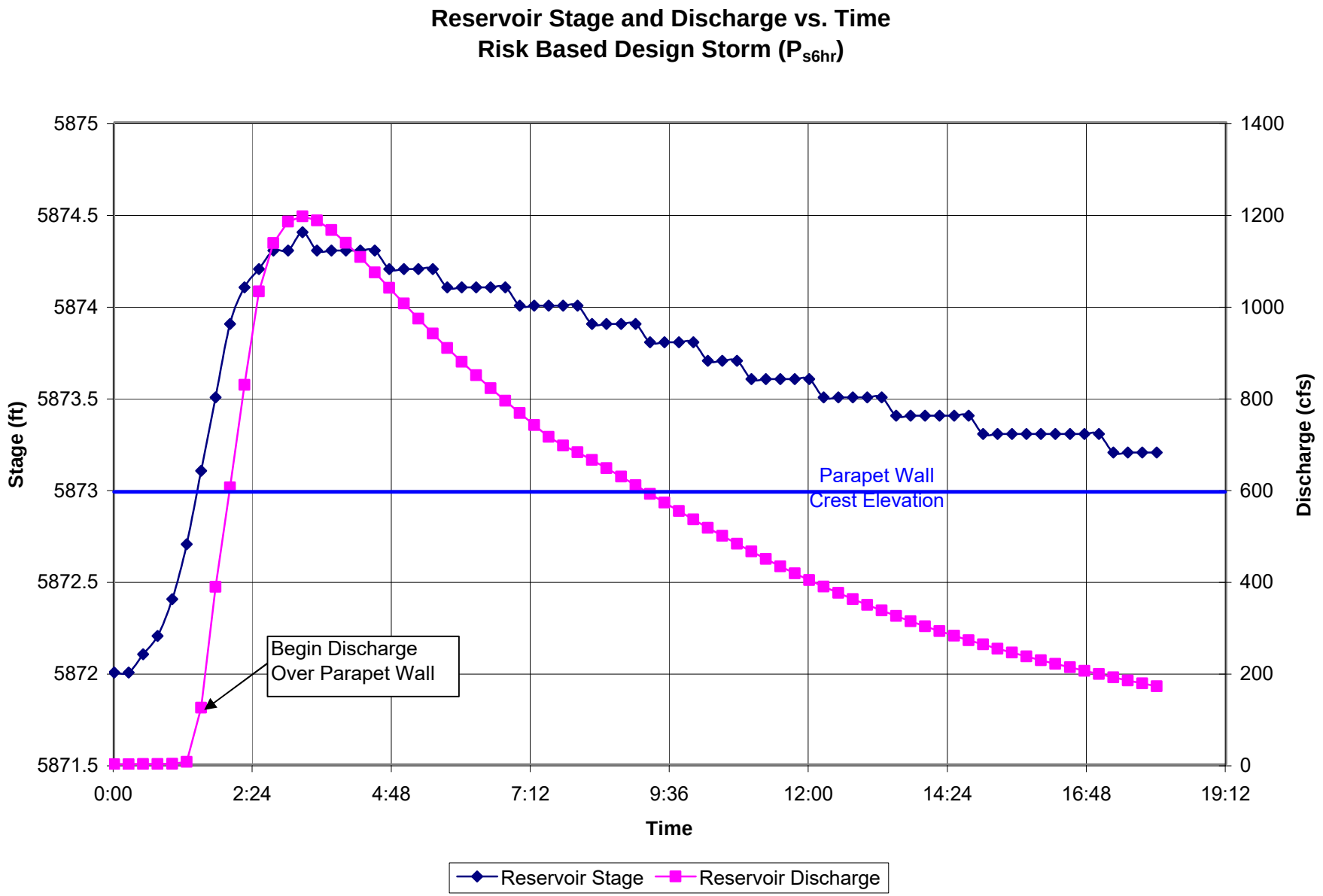




Basin Creek Dam
USGS Unit Hydrograph
Risk Based Analysis
6-hour Storm



Basin Creek Dam
USGS Unit Hydrograph
Risk Based Analysis
24-hour Storm



P:\15\M424117\H&H\HMS\Results\
Stage-Discharge.xls

APPENDIX E1

ALTERNATE SPILLWAY HYDRAULICS

Spillway Discharge Calculations - 5 x 8 ft Alternate Spillway

Weir Flow

$$Q = CLH^{\frac{3}{2}}$$

C	Discharge Coefficient
L	Width of Weir (ft)
H	Head (ft)

Orifice Flow

$$Q = CA\sqrt{2gH}$$

C	Discharge Coefficient
A	Area of Orifice (ft^2)
H	Head (ft)
g	Acceleration of Gravity (32.2 ft/s^2)

Discharge Coeff. =	3.33	Sharp Crested Weir	Normally accepted value.
	2.63	Broad Crested Weir	Most conservative acceptable value.
	0.6	Orifice	Normally accepted value.

Crest Elev. =	Dam	5873.00	ft
	Spillway	5867.00	ft
	Overflow	5871.60	ft

Crest Length =	Dam	252	ft	= 5874
		274	ft	> 5874
	Spillway	8.00	ft	
	Overflow	2.84	ft	

Orifice Center Elev. =	Spillway	5870	ft
	Overflow	5872.10	ft

Orifice Height =	Spillway	6.00	ft
	Overflow	1	ft

No. of Contracions =	2

Orifice Area =	Spillway	48.00	ft^2
	Overflow	2.84	ft^2

$$L_{eff} = L - [(0.1)(No.Contractions)(H)]$$

Stage (ft)	Area (ac)	?Volume (ac-ft)	Storage (ac-ft)	Spillway Q (cfs)	Overflow Q (cfs)	Crest Q (cfs)	Total Q (cfs)
5867.00	44	0	0	0	0	0	0
5868.00	46	45	45	0	0	0	0
5869.00	48	47	92	0	0	0	0
5870.00	52	50	141	0	0	0	0
5871.00	55	53	195	0	0	0	0
5871.60	55	33	228	0	0	0	0
5872.00	55	22	250	0	2	0	2
5872.36	55	20	269	6	5	0	10
5872.50	55	8	277	9	6	0	15
5872.60	55	6	283	240	7	0	247
5872.70	55	6	288	246	8	0	253
5872.86	55	9	297	255	12	0	267
5872.87	55	0	297	255	12	0	267
5873.00	55	7	305	263	13	0	276
5874.00	55	55	360	462	19	662	1,143
5875.00	56	56	416	517	23	2,041	2,581
5876.00	56	56	472	566	27	3,750	4,343
5877.00	56	56	528	611	30	5,773	6,415
5878.00	57	56	584	654	33	8,068	8,755
5879.00	57	57	641	693	36	10,606	11,335
5880.00	57	57	698	731	38	13,365	14,134
5881.00	57	57	755	767	41	16,329	17,136
5882.00	58	57	812	801	43	19,484	20,328
5883.00	58	58	870	833	45	22,820	23,699
5884.00	58	58	928	865	47	26,328	27,240
5885.00	58	58	986	895	49	29,998	30,942

Spillway Discharge Calculations - 5 x 9 ft Alternate Spillway

Weir Flow

$$Q = CLH^{\frac{3}{2}}$$

C	Discharge Coefficient
L	Width of Weir (ft)
H	Head (ft)

Orifice Flow

$$Q = CA\sqrt{2gH}$$

C	Discharge Coefficient
A	Area of Orifice (ft^2)
H	Head (ft)
g	Acceleration of Gravity (32.2 ft/s^2)

Discharge Coeff. =	3.33	Sharp Crested Weir	Normally accepted value.
	2.63	Broad Crested Weir	Most conservative acceptable value.
	0.6	Orifice	Normally accepted value.

Crest Elev. =	Dam	5873.00	ft
	Spillway	5867.00	ft
	Overflow	5871.60	ft

Crest Length =	Dam	252	ft	= 5874
		274	ft	> 5874
	Spillway	9.00	ft	
	Overflow	2.84	ft	

Orifice Center Elev. =	Spillway	5870	ft
	Overflow	5872.10	ft

Orifice Height =	Spillway	6.00	ft
	Overflow	1	ft

No. of Contracions =	2

Orifice Area =	Spillway	54.00	ft^2
	Overflow	2.84	ft^2

$$L_{eff} = L - [(0.1)(No.Contractions)(H)]$$

Stage (ft)	Area (ac)	?Volume (ac-ft)	Storage (ac-ft)	Spillway Q (cfs)	Overflow Q (cfs)	Crest Q (cfs)	Total Q (cfs)
5867.00	44	0	0	0	0	0	0
5868.00	46	45	45	0	0	0	0
5869.00	48	47	92	0	0	0	0
5870.00	52	50	141	0	0	0	0
5871.00	55	53	195	0	0	0	0
5871.60	55	33	228	0	0	0	0
5872.00	55	22	250	0	0	0	0
5872.36	55	20	269	6	1	0	7
5872.50	55	8	277	10	1	0	12
5872.60	55	6	283	275	1	0	276
5872.70	55	6	288	281	2	0	283
5872.86	55	9	297	292	12	0	304
5872.87	55	0	297	292	12	0	304
5873.00	55	7	305	301	13	0	314
5874.00	55	55	360	520	19	662	1,201
5875.00	56	56	416	581	23	2,041	2,646
5876.00	56	56	472	637	27	3,750	4,414
5877.00	56	56	528	688	30	5,773	6,491
5878.00	57	56	584	735	33	8,068	8,837
5879.00	57	57	641	780	36	10,606	11,422
5880.00	57	57	698	822	38	13,365	14,226
5881.00	57	57	755	862	41	16,329	17,232
5882.00	58	57	812	901	43	19,484	20,428
5883.00	58	58	870	937	45	22,820	23,803
5884.00	58	58	928	973	47	26,328	27,348
5885.00	58	58	986	1,007	49	29,998	31,054

Spillway Discharge Calculations - 5 x 10 ft Alternate Spillway

Weir Flow

$$Q = CLH^{\frac{3}{2}}$$

C	Discharge Coefficient
L	Width of Weir (ft)
H	Head (ft)

Orifice Flow

$$Q = CA\sqrt{2gH}$$

C	Discharge Coefficient
A	Area of Orifice (ft^2)
H	Head (ft)
g	Acceleration of Gravity (32.2 ft/s^2)

Discharge Coeff. =	3.33	Sharp Crested Weir	Normally accepted value.
	2.63	Broad Crested Weir	Most conservative acceptable value.
	0.6	Orifice	Normally accepted value.

Crest Elev. =	Dam	5873.00	ft
	Spillway	5867.00	ft
	Overflow	5871.60	ft

Crest Length =	Dam	252	ft	= 5874
		274	ft	> 5874
	Spillway	10.00	ft	
	Overflow	2.84	ft	

Orifice Center Elev. =	Spillway	5870	ft
	Overflow	5872.10	ft

Orifice Height =	Spillway	6.00	ft
	Overflow	1	ft

No. of Contracions =	2

Orifice Area =	Spillway	60.00	ft^2
	Overflow	2.84	ft^2

$$L_{eff} = L - [(0.1)(No.Contractions)(H)]$$

Stage (ft)	Area (ac)	?Volume (ac-ft)	Storage (ac-ft)	Spillway Q (cfs)	Overflow Q (cfs)	Crest Q (cfs)	Total Q (cfs)
5867.00	44	0	0	0	0	0	0
5868.00	46	45	45	0	0	0	0
5869.00	48	47	92	0	0	0	0
5870.00	52	50	141	0	0	0	0
5871.00	55	53	195	0	0	0	0
5871.60	55	33	228	0	0	0	0
5872.00	55	22	250	0	0	0	0
5872.36	55	20	269	7	1	0	8
5872.50	55	8	277	12	1	0	13
5872.60	55	6	283	309	1	0	311
5872.70	55	6	288	317	2	0	319
5872.86	55	9	297	329	12	0	341
5872.87	55	0	297	330	12	0	342
5873.00	55	7	305	340	13	0	353
5874.00	55	55	360	578	19	662	1,259
5875.00	56	56	416	646	23	2,041	2,710
5876.00	56	56	472	708	27	3,750	4,484
5877.00	56	56	528	764	30	5,773	6,568
5878.00	57	56	584	817	33	8,068	8,919
5879.00	57	57	641	867	36	10,606	11,509
5880.00	57	57	698	914	38	13,365	14,317
5881.00	57	57	755	958	41	16,329	17,328
5882.00	58	57	812	1001	43	19,484	20,528
5883.00	58	58	870	1042	45	22,820	23,907
5884.00	58	58	928	1081	47	26,328	27,456
5885.00	58	58	986	1119	49	29,998	31,166

Spillway Discharge Calculations - 3.5 x 8 ft Alternate Spillway

Weir Flow

$$Q = CLH^{\frac{3}{2}}$$

C	Discharge Coefficient
L	Width of Weir (ft)
H	Head (ft)

Orifice Flow

$$Q = CA\sqrt{2gH}$$

C	Discharge Coefficient
A	Area of Orifice (ft^2)
H	Head (ft)
g	Acceleration of Gravity (32.2 ft/s^2)

Discharge Coeff. =	3.33	Sharp Crested Weir	Normally accepted value.
	2.63	Broad Crested Weir	Most conservative acceptable value.
	0.6	Orifice	Normally accepted value.

Crest Elev. =	Dam	5873.00	ft
	Spillway	5868.50	ft
	Overflow	5871.60	ft

Crest Length =	Dam	252	ft	= 5874
		274	ft	> 5874
	Spillway	8.00	ft	
	Overflow	2.84	ft	

Orifice Center Elev. =	Spillway	5870.75	ft
	Overflow	5872.10	ft

Orifice Height =	Spillway	4.50	ft
	Overflow	1	ft

No. of Contracions =	2

Orifice Area =	Spillway	36.00	ft^2
	Overflow	2.84	ft^2

$$L_{eff} = L - [(0.1)(No.Contractions)(H)]$$

Stage (ft)	Area (ac)	?Volume (ac-ft)	Storage (ac-ft)	Spillway Q (cfs)	Overflow Q (cfs)	Crest Q (cfs)	Total Q (cfs)
5867.00	44	0	0	0	0	0	0
5868.00	46	45	45	0	0	0	0
5869.00	48	47	92	0	0	0	0
5870.00	52	50	141	0	0	0	0
5871.00	55	53	195	0	0	0	0
5871.60	55	33	228	0	0	0	0
5872.00	55	22	250	0	0	0	0
5872.36	55	20	269	6	1	0	6
5872.50	55	8	277	9	1	0	10
5872.60	55	6	283	157	1	0	158
5872.70	55	6	288	162	2	0	164
5872.86	55	9	297	171	12	0	183
5872.87	55	0	297	171	12	0	183
5873.00	55	7	305	178	13	0	191
5874.00	55	55	360	312	19	662	993
5875.00	56	56	416	357	23	2,041	2,422
5876.00	56	56	472	397	27	3,750	4,174
5877.00	56	56	528	433	30	5,773	6,237
5878.00	57	56	584	467	33	8,068	8,568
5879.00	57	57	641	498	36	10,606	11,140
5880.00	57	57	698	527	38	13,365	13,931
5881.00	57	57	755	555	41	16,329	16,925
5882.00	58	57	812	581	43	19,484	20,109
5883.00	58	58	870	607	45	22,820	23,472
5884.00	58	58	928	631	47	26,328	27,006
5885.00	58	58	986	654	49	29,998	30,702

Spillway Discharge Calculations - 3.5 x 9 ft Alternate Spillway

Weir Flow

$$Q = CLH^{\frac{3}{2}}$$

C	Discharge Coefficient
L	Width of Weir (ft)
H	Head (ft)

Orifice Flow

$$Q = CA\sqrt{2gH}$$

C	Discharge Coefficient
A	Area of Orifice (ft^2)
H	Head (ft)
g	Acceleration of Gravity (32.2 ft/s^2)

Discharge Coeff. =	3.33	Sharp Crested Weir	Normally accepted value.
	2.63	Broad Crested Weir	Most conservative acceptable value.
	0.6	Orifice	Normally accepted value.

Crest Elev. =	Dam	5873.00	ft
	Spillway	5868.50	ft
	Overflow	5871.60	ft

Crest Length =	Dam	252	ft	= 5874
		274	ft	> 5874
	Spillway	9.00	ft	
	Overflow	2.84	ft	

Orifice Center Elev. =	Spillway	5870.75	ft
	Overflow	5872.10	ft

Orifice Height =	Spillway	4.50	ft
	Overflow	1	ft

No. of Contracions =	2

Orifice Area =	Spillway	40.50	ft^2
	Overflow	2.84	ft^2

$$L_{eff} = L - [(0.1)(No.Contractions)(H)]$$

Stage (ft)	Area (ac)	?Volume (ac-ft)	Storage (ac-ft)	Spillway Q (cfs)	Overflow Q (cfs)	Crest Q (cfs)	Total Q (cfs)
5867.00	44	0	0	0	0	0	0
5868.00	46	45	45	0	0	0	0
5869.00	48	47	92	0	0	0	0
5870.00	52	50	141	0	0	0	0
5871.00	55	53	195	0	0	0	0
5871.60	55	33	228	0	0	0	0
5872.00	55	22	250	0	0	0	0
5872.36	55	20	269	6	1	0	7
5872.50	55	8	277	10	1	0	12
5872.60	55	6	283	179	1	0	180
5872.70	55	6	288	185	2	0	187
5872.86	55	9	297	195	12	0	207
5872.87	55	0	297	195	12	0	207
5873.00	55	7	305	203	13	0	216
5874.00	55	55	360	352	19	662	1,032
5875.00	56	56	416	402	23	2,041	2,466
5876.00	56	56	472	447	27	3,750	4,224
5877.00	56	56	528	488	30	5,773	6,291
5878.00	57	56	584	525	33	8,068	8,627
5879.00	57	57	641	560	36	10,606	11,202
5880.00	57	57	698	593	38	13,365	13,997
5881.00	57	57	755	624	41	16,329	16,994
5882.00	58	57	812	654	43	19,484	20,182
5883.00	58	58	870	683	45	22,820	23,548
5884.00	58	58	928	710	47	26,328	27,085
5885.00	58	58	986	736	49	29,998	30,783

Spillway Discharge Calculations - 3.5 x 10 ft Alternate Spillway

Weir Flow

$$Q = CLH^{\frac{3}{2}}$$

C	Discharge Coefficient
L	Width of Weir (ft)
H	Head (ft)

Orifice Flow

$$Q = CA\sqrt{2gH}$$

C	Discharge Coefficient
A	Area of Orifice (ft^2)
H	Head (ft)
g	Acceleration of Gravity (32.2 ft/s^2)

Discharge Coeff. =	3.33	Sharp Crested Weir	Normally accepted value.
	2.63	Broad Crested Weir	Most conservative acceptable value.
	0.6	Orifice	Normally accepted value.

Crest Elev. =	Dam	5873.00	ft
	Spillway	5868.50	ft
	Overflow	5871.60	ft

Crest Length =	Dam	252	ft	= 5874
		274	ft	> 5874
	Spillway	10.00	ft	
	Overflow	2.84	ft	

Orifice Center Elev. =	Spillway	5870.75	ft
	Overflow	5872.10	ft

Orifice Height =	Spillway	4.50	ft
	Overflow	1	ft

No. of Contracions =	2

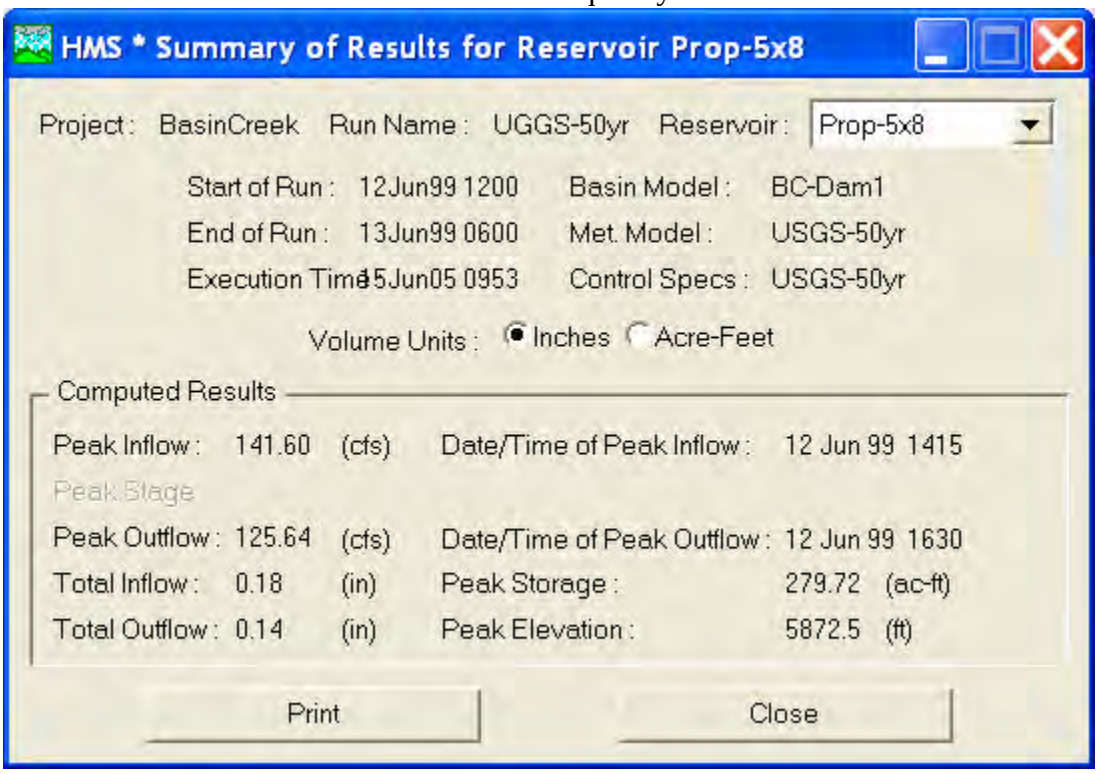
Orifice Area =	Spillway	45.00	ft^2
	Overflow	2.84	ft^2

$$L_{eff} = L - [(0.1)(No.Contractions)(H)]$$

Stage (ft)	Area (ac)	?Volume (ac-ft)	Storage (ac-ft)	Spillway Q (cfs)	Overflow Q (cfs)	Crest Q (cfs)	Total Q (cfs)
5867.00	44	0	0	0	0	0	0
5868.00	46	45	45	0	0	0	0
5869.00	48	47	92	0	0	0	0
5870.00	52	50	141	0	0	0	0
5871.00	55	53	195	0	0	0	0
5871.60	55	33	228	0	0	0	0
5872.00	55	22	250	0	0	0	0
5872.36	55	20	269	7	1	0	8
5872.50	55	8	277	12	1	0	13
5872.60	55	6	283	200	1	0	202
5872.70	55	6	288	207	2	0	209
5872.86	55	9	297	219	12	0	230
5872.87	55	0	297	219	12	0	231
5873.00	55	7	305	228	13	0	241
5874.00	55	55	360	391	19	662	1,072
5875.00	56	56	416	447	23	2,041	2,511
5876.00	56	56	472	496	27	3,750	4,273
5877.00	56	56	528	542	30	5,773	6,345
5878.00	57	56	584	583	33	8,068	8,685
5879.00	57	57	641	622	36	10,606	11,264
5880.00	57	57	698	659	38	13,365	14,062
5881.00	57	57	755	694	41	16,329	17,063
5882.00	58	57	812	727	43	19,484	20,254
5883.00	58	58	870	758	45	22,820	23,624
5884.00	58	58	928	789	47	26,328	27,164
5885.00	58	58	986	818	49	29,998	30,865

Alternate 5 x 8 ft. Spillway Routing

50-Year Frequency



HMS * Summary of Results for Reservoir Prop-5x8

Project: BasinCreek Run Name: UGGS-50yr Reservoir: Prop-5x8

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-50yr
Execution Time: 15Jun05 0953 Control Specs: USGS-50yr

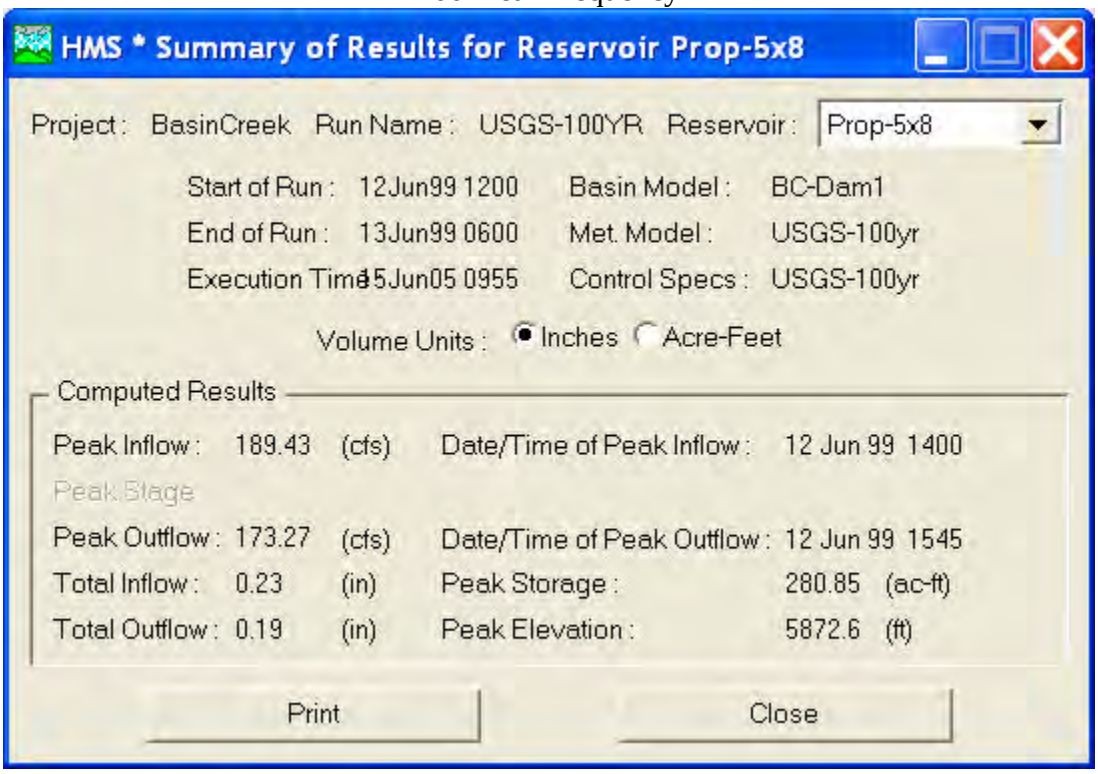
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	141.60	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1415	
Peak Stage					
Peak Outflow:	125.64	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1630	
Total Inflow:	0.18	(in)	Peak Storage:	279.72	(ac-ft)
Total Outflow:	0.14	(in)	Peak Elevation:	5872.5	(ft)

Print Close

100-Year Frequency



HMS * Summary of Results for Reservoir Prop-5x8

Project: BasinCreek Run Name: USGS-100YR Reservoir: Prop-5x8

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-100yr
Execution Time: 15Jun05 0955 Control Specs: USGS-100yr

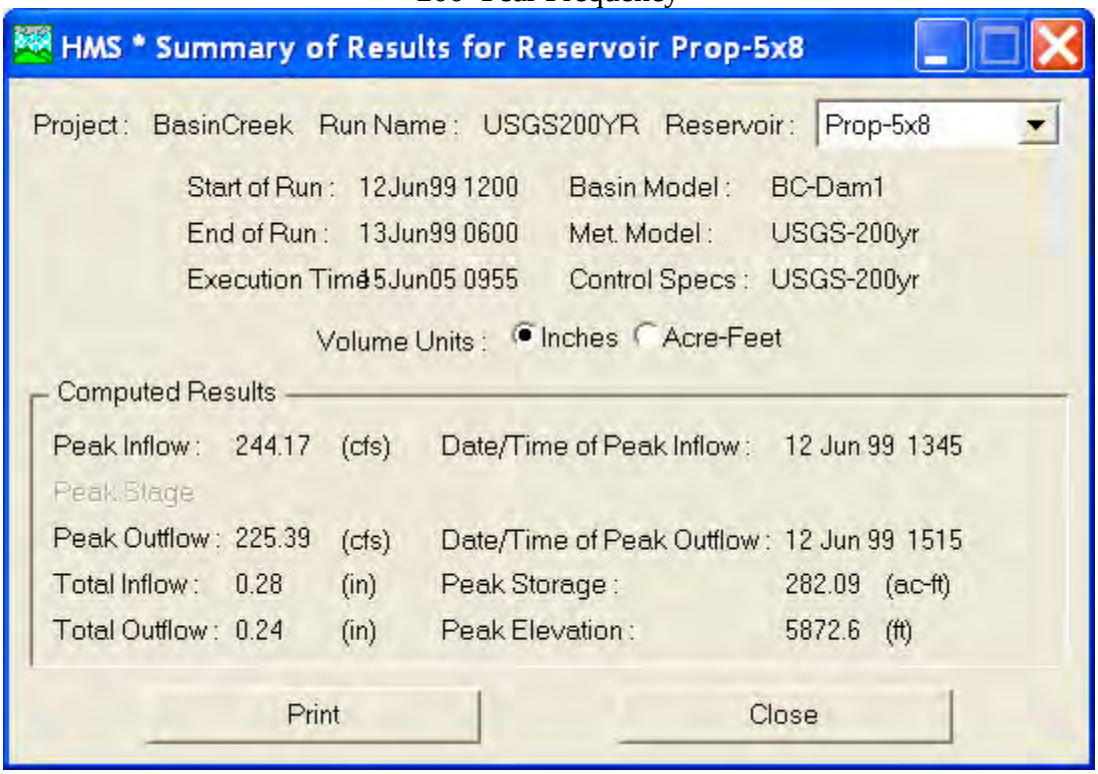
Volume Units: Inches Acre-Feet

Computed Results

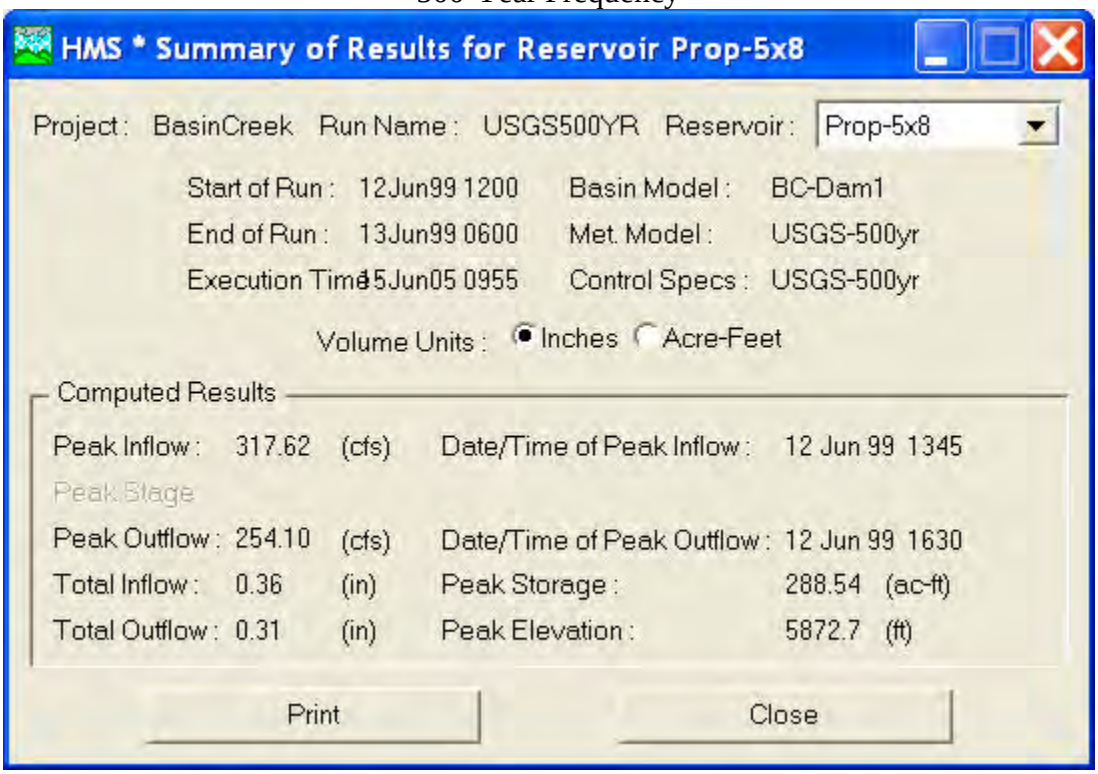
Peak Inflow:	189.43	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1400	
Peak Stage					
Peak Outflow:	173.27	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1545	
Total Inflow:	0.23	(in)	Peak Storage:	280.85	(ac-ft)
Total Outflow:	0.19	(in)	Peak Elevation:	5872.6	(ft)

Print Close

200-Year Frequency

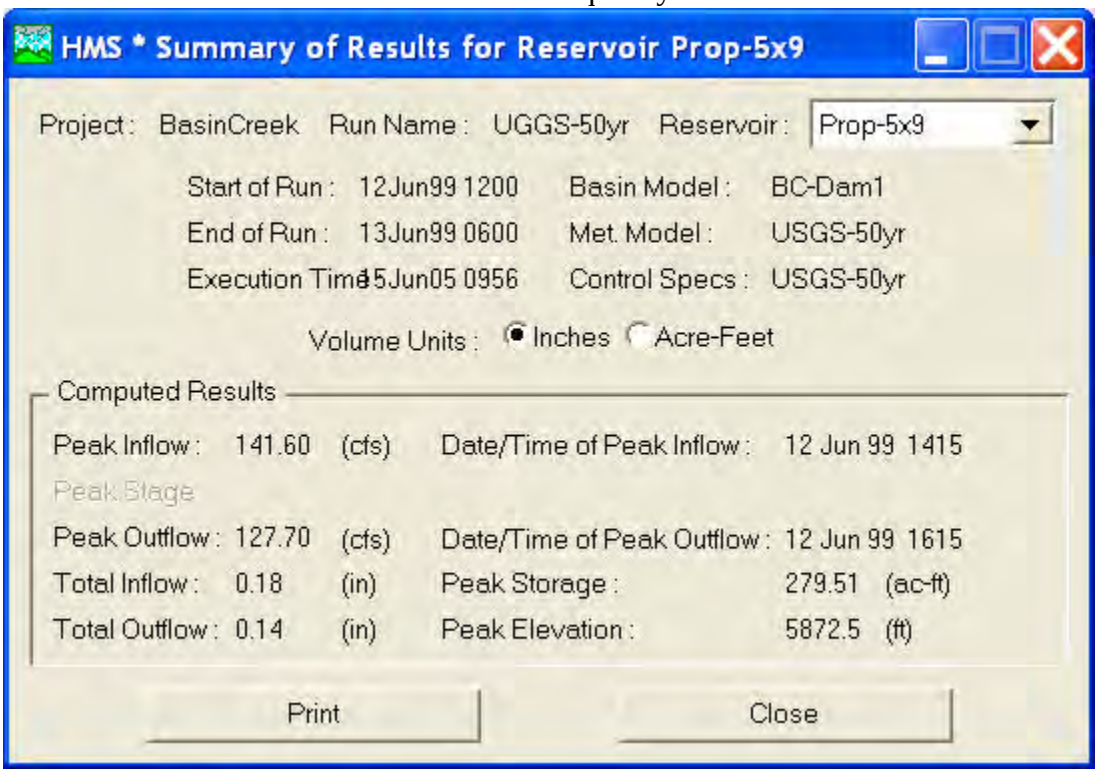


500-Year Frequency



Alternate 5 x 9 ft. Spillway Routing

50-Year Frequency



HMS * Summary of Results for Reservoir Prop-5x9

Project: BasinCreek Run Name: UGGS-50yr Reservoir: Prop-5x9

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-50yr
Execution Time: 15Jun05 0956 Control Specs: USGS-50yr

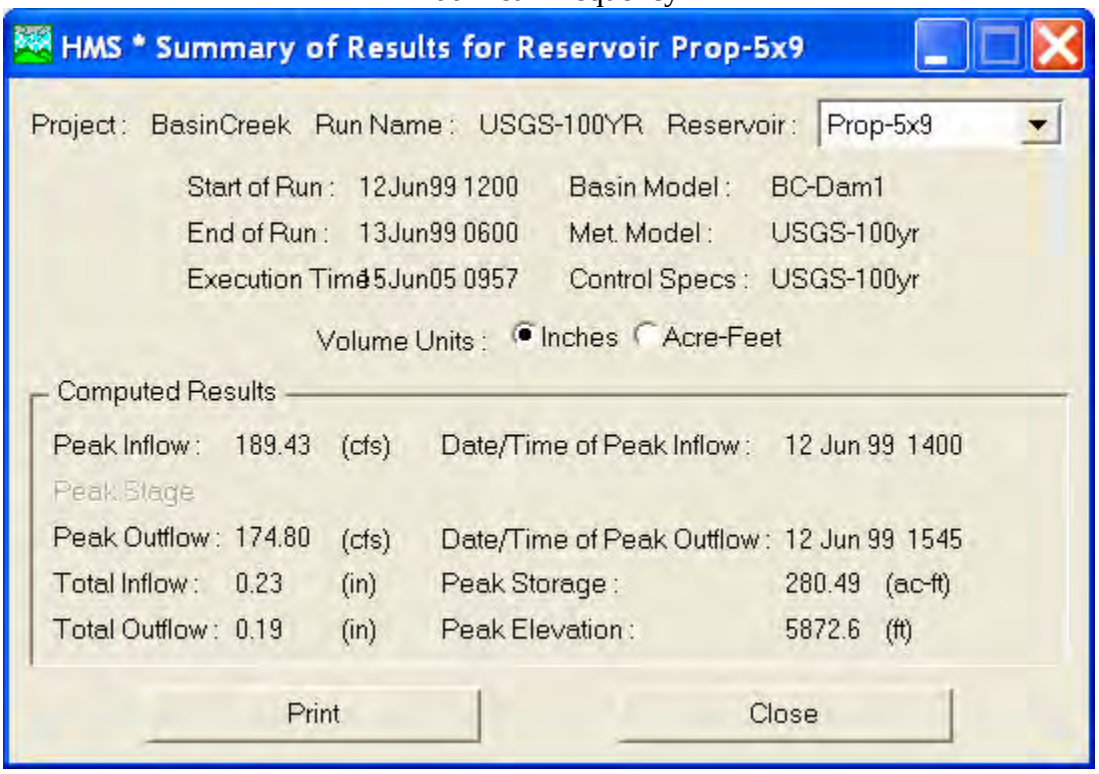
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	141.60	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1415	
Peak Stage					
Peak Outflow:	127.70	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1615	
Total Inflow:	0.18	(in)	Peak Storage:	279.51	(ac-ft)
Total Outflow:	0.14	(in)	Peak Elevation:	5872.5	(ft)

Print Close

100-Year Frequency



HMS * Summary of Results for Reservoir Prop-5x9

Project: BasinCreek Run Name: USGS-100YR Reservoir: Prop-5x9

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-100yr
Execution Time: 15Jun05 0957 Control Specs: USGS-100yr

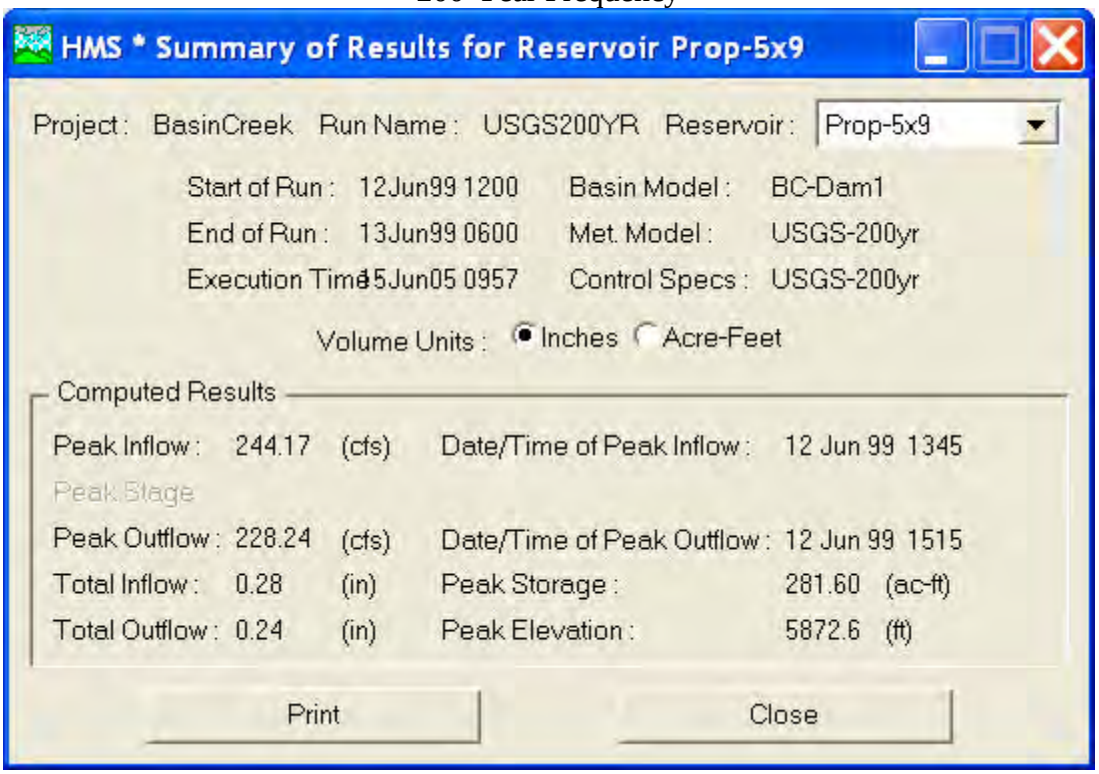
Volume Units: Inches Acre-Feet

Computed Results

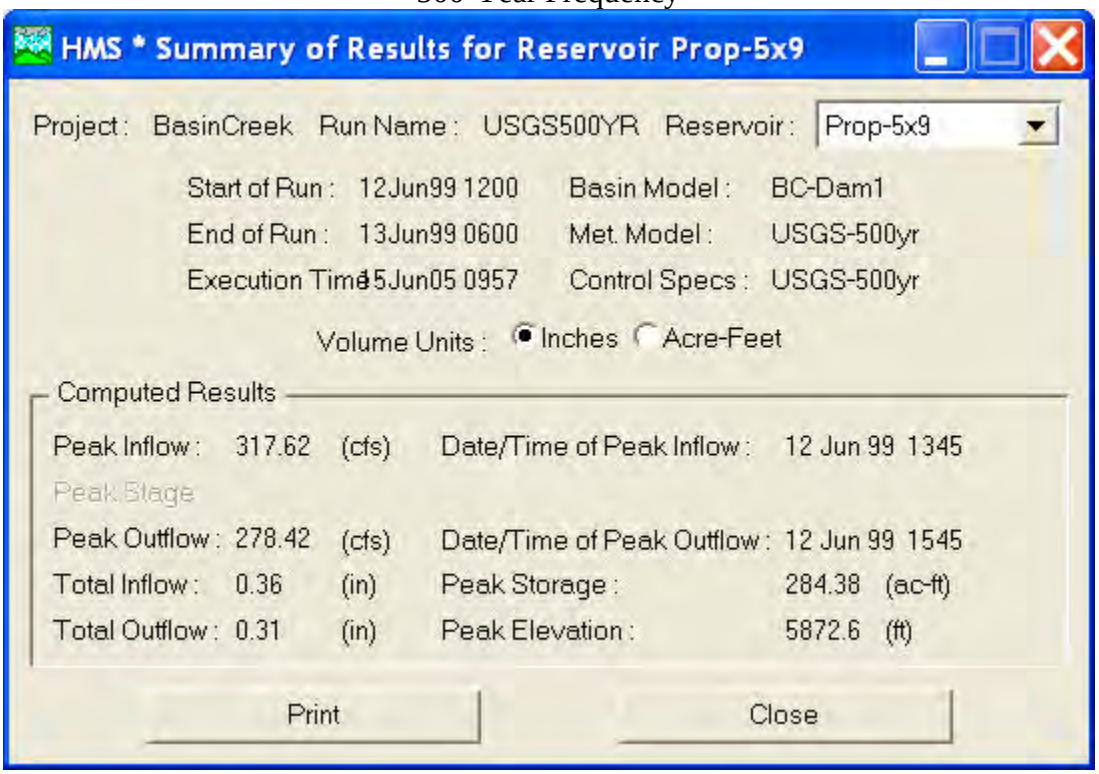
Peak Inflow:	189.43	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1400	
Peak Stage					
Peak Outflow:	174.80	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1545	
Total Inflow:	0.23	(in)	Peak Storage:	280.49	(ac-ft)
Total Outflow:	0.19	(in)	Peak Elevation:	5872.6	(ft)

Print Close

200-Year Frequency

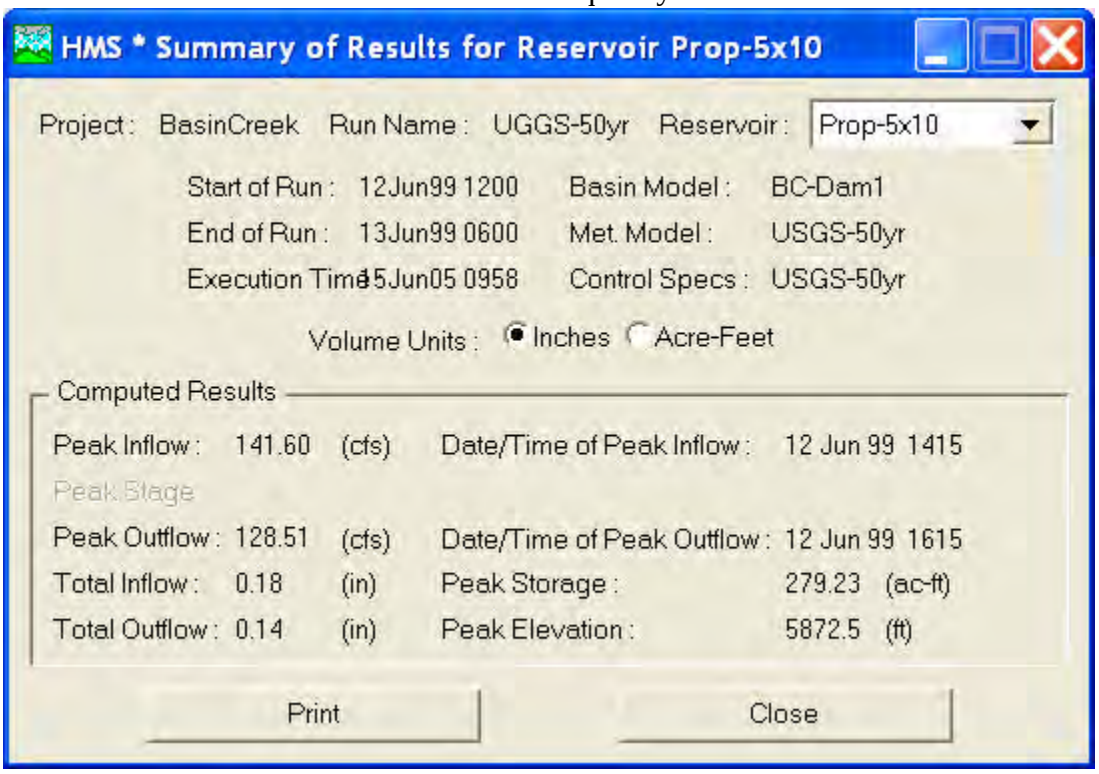


500-Year Frequency



Alternate 5 x 10 ft. Spillway Routing

50-Year Frequency


HMS * Summary of Results for Reservoir Prop-5x10

Project: BasinCreek Run Name: UGGS-50yr Reservoir: Prop-5x10

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-50yr
Execution Time: 15Jun05 0958 Control Specs: USGS-50yr

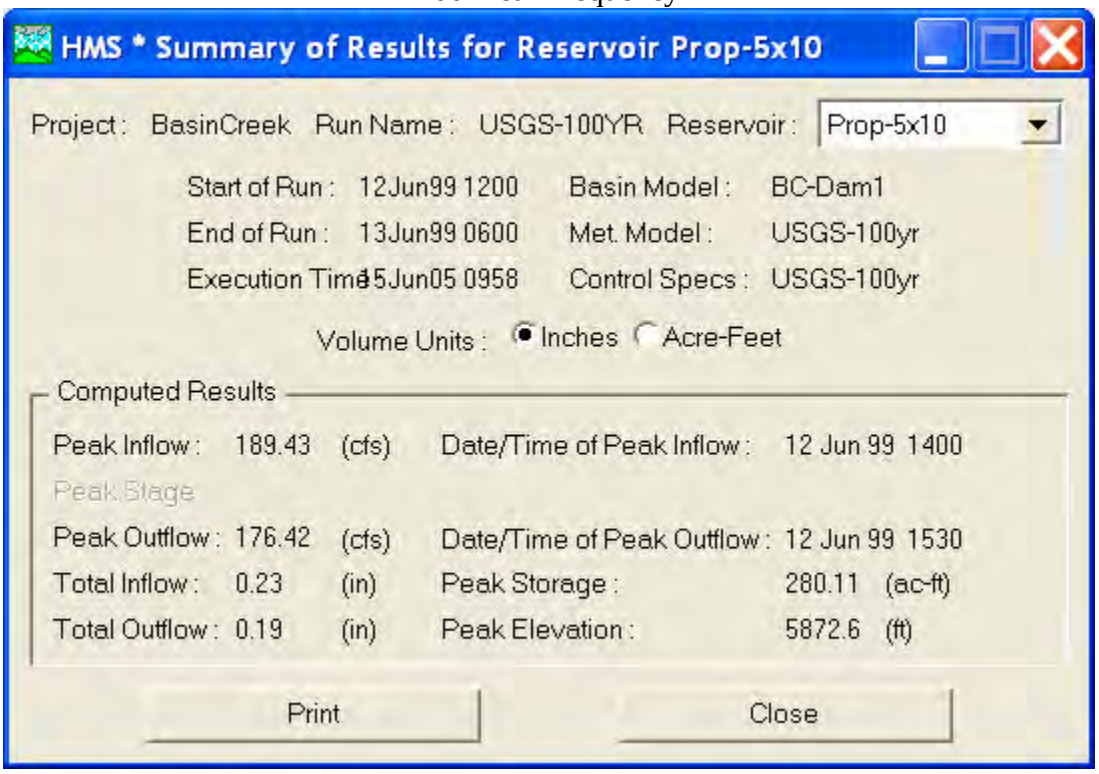
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow: 141.60 (cfs) Date/Time of Peak Inflow: 12 Jun 99 1415
Peak Stage
Peak Outflow: 128.51 (cfs) Date/Time of Peak Outflow: 12 Jun 99 1615
Total Inflow: 0.18 (in) Peak Storage: 279.23 (ac-ft)
Total Outflow: 0.14 (in) Peak Elevation: 5872.5 (ft)

Print Close

100-Year Frequency


HMS * Summary of Results for Reservoir Prop-5x10

Project: BasinCreek Run Name: USGS-100YR Reservoir: Prop-5x10

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-100yr
Execution Time: 15Jun05 0958 Control Specs: USGS-100yr

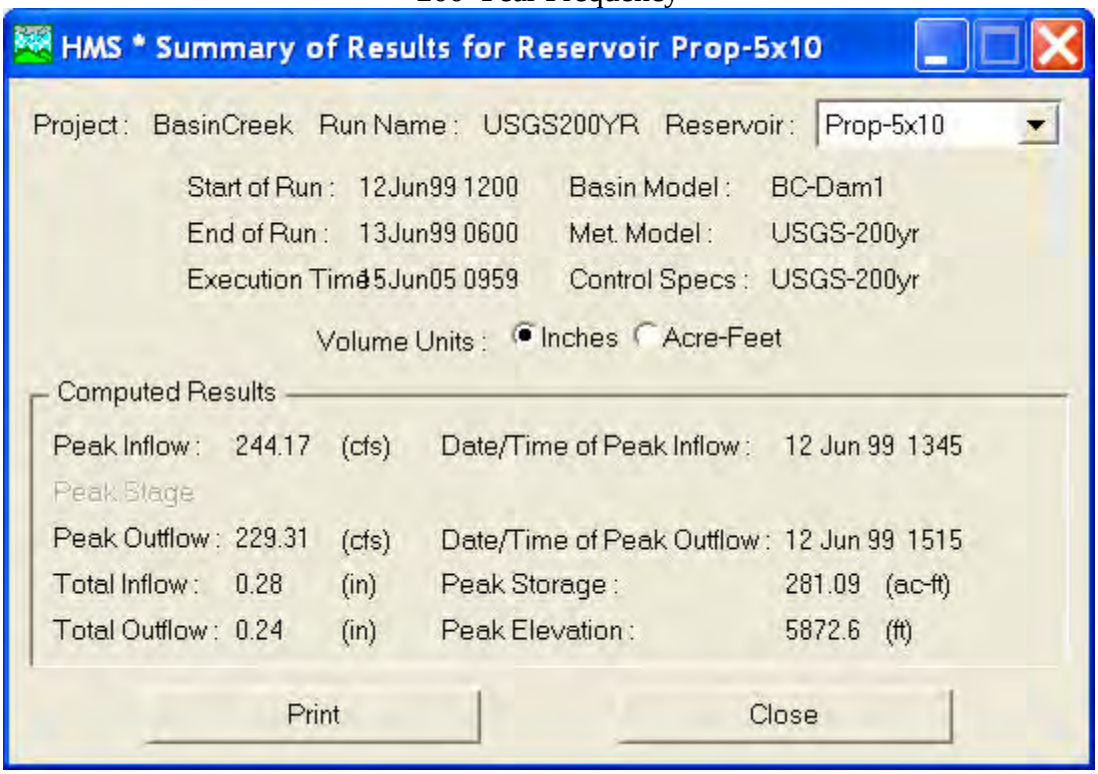
Volume Units: Inches Acre-Feet

Computed Results

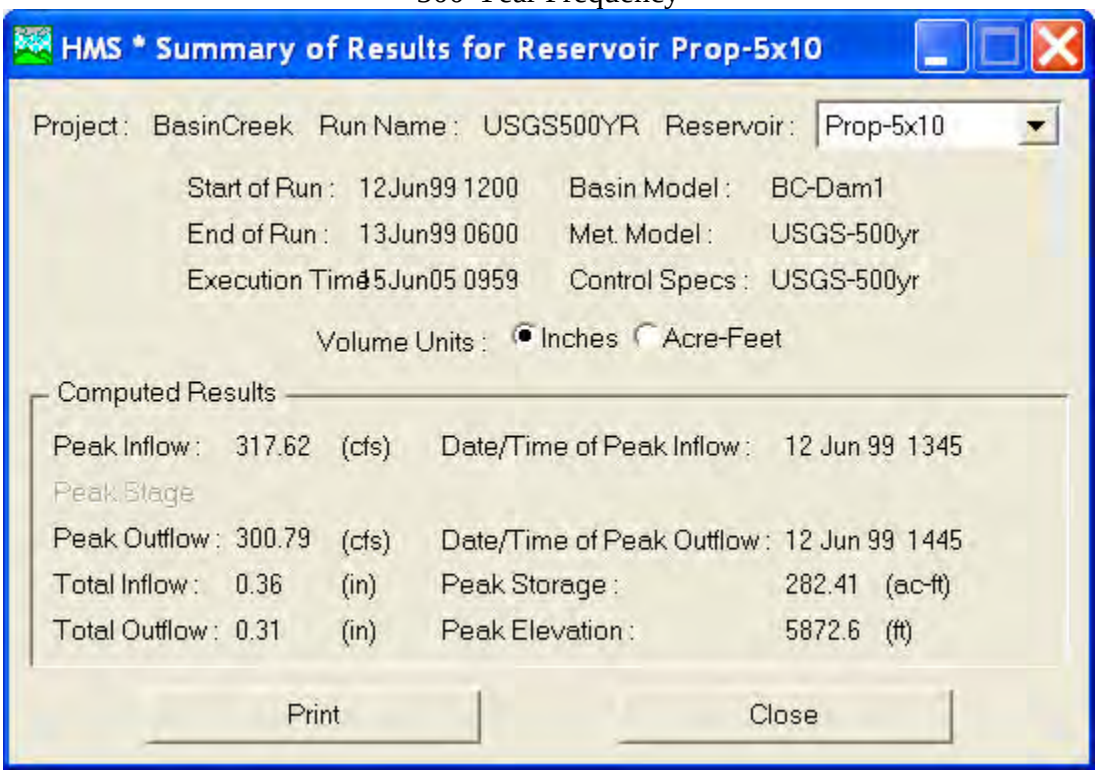
Peak Inflow: 189.43 (cfs) Date/Time of Peak Inflow: 12 Jun 99 1400
Peak Stage
Peak Outflow: 176.42 (cfs) Date/Time of Peak Outflow: 12 Jun 99 1530
Total Inflow: 0.23 (in) Peak Storage: 280.11 (ac-ft)
Total Outflow: 0.19 (in) Peak Elevation: 5872.6 (ft)

Print Close

200-Year Frequency

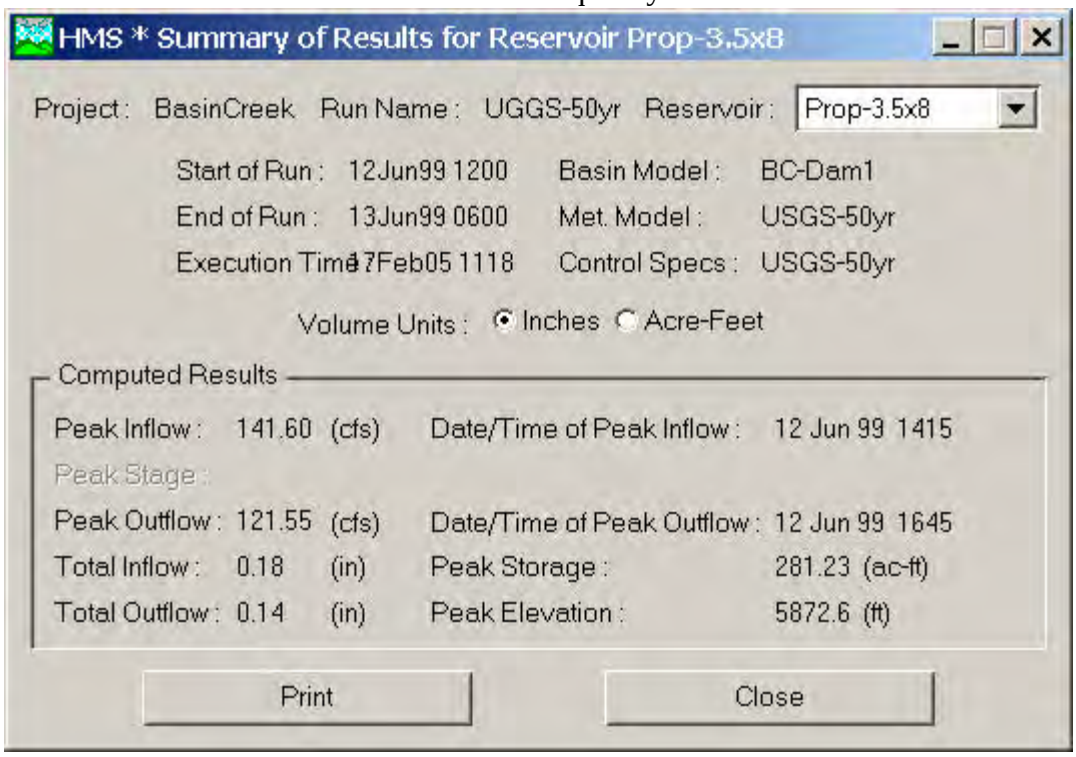


500-Year Frequency



Alternate 3.5 x 8 ft. Spillway Routing

50-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x8

Project: BasinCreek Run Name: UGGS-50yr Reservoir: Prop-3.5x8

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-50yr
Execution Time: 7Feb05 1118 Control Specs: USGS-50yr

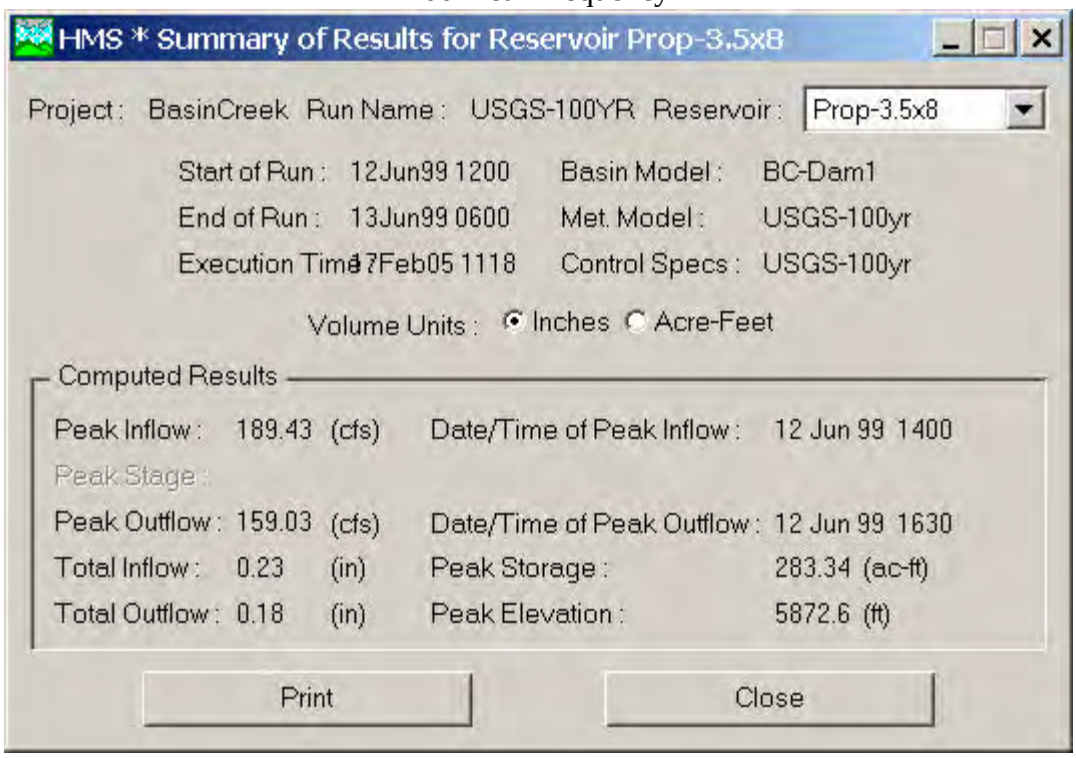
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	141.60	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1415	
Peak Stage:					
Peak Outflow:	121.55	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1645	
Total Inflow:	0.18	(in)	Peak Storage:	281.23	(ac-ft)
Total Outflow:	0.14	(in)	Peak Elevation:	5872.6	(ft)

Print Close

100-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x8

Project: BasinCreek Run Name: USGS-100YR Reservoir: Prop-3.5x8

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-100yr
Execution Time: 7Feb05 1118 Control Specs: USGS-100yr

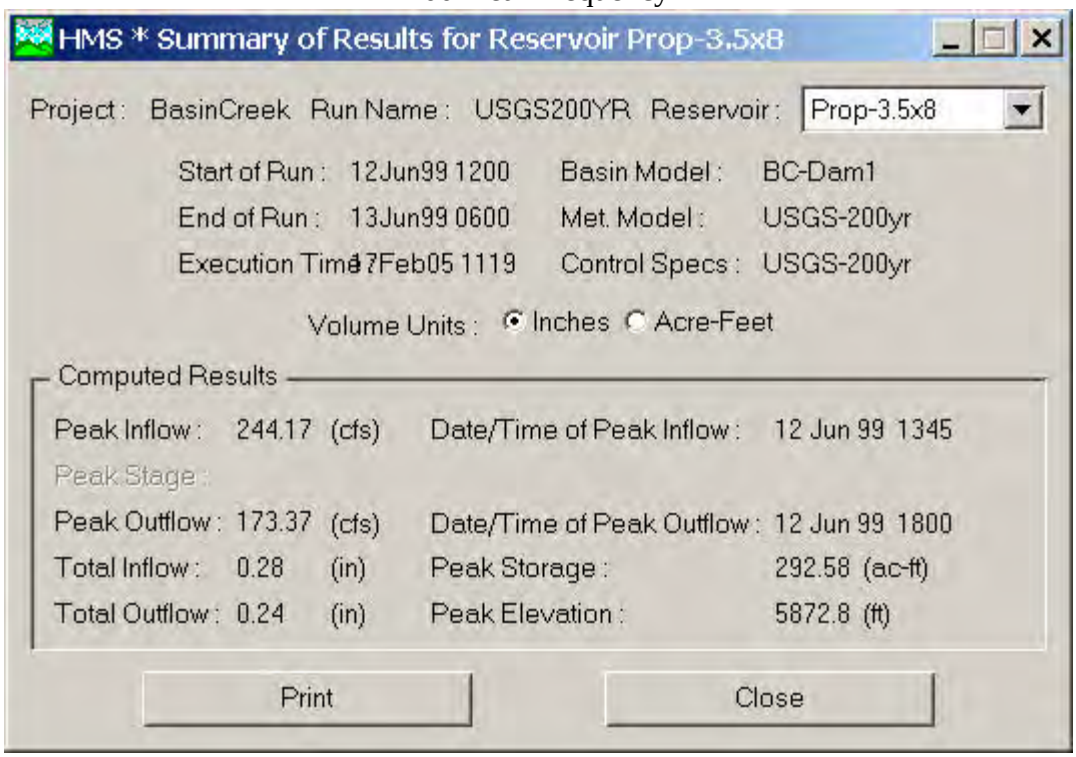
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	189.43	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1400	
Peak Stage:					
Peak Outflow:	159.03	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1630	
Total Inflow:	0.23	(in)	Peak Storage:	283.34	(ac-ft)
Total Outflow:	0.18	(in)	Peak Elevation:	5872.6	(ft)

Print Close

200-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x8

Project: BasinCreek Run Name: USGS200YR Reservoir: Prop-3.5x8

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-200yr
Execution Time: 17Feb05 1119 Control Specs: USGS-200yr

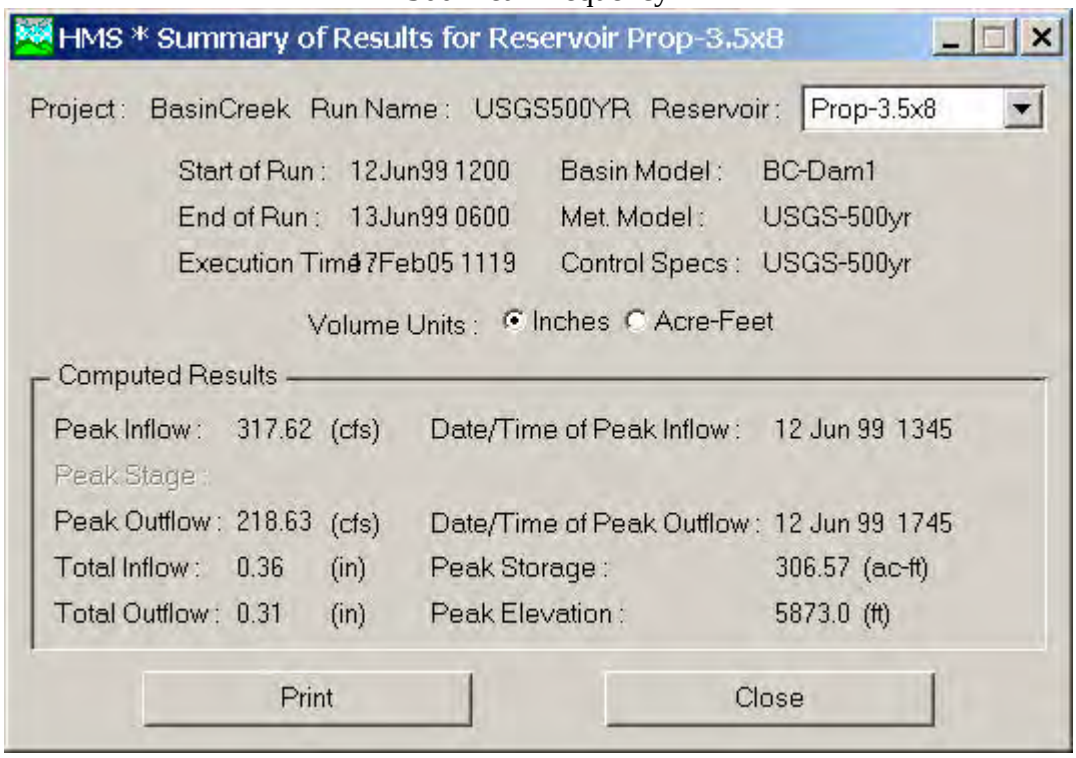
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	244.17	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1345	
Peak Stage:					
Peak Outflow:	173.37	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1800	
Total Inflow:	0.28	(in)	Peak Storage:	292.58	(ac-ft)
Total Outflow:	0.24	(in)	Peak Elevation:	5872.8	(ft)

Print Close

500-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x8

Project: BasinCreek Run Name: USGS500YR Reservoir: Prop-3.5x8

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-500yr
Execution Time: 17Feb05 1119 Control Specs: USGS-500yr

Volume Units: Inches Acre-Feet

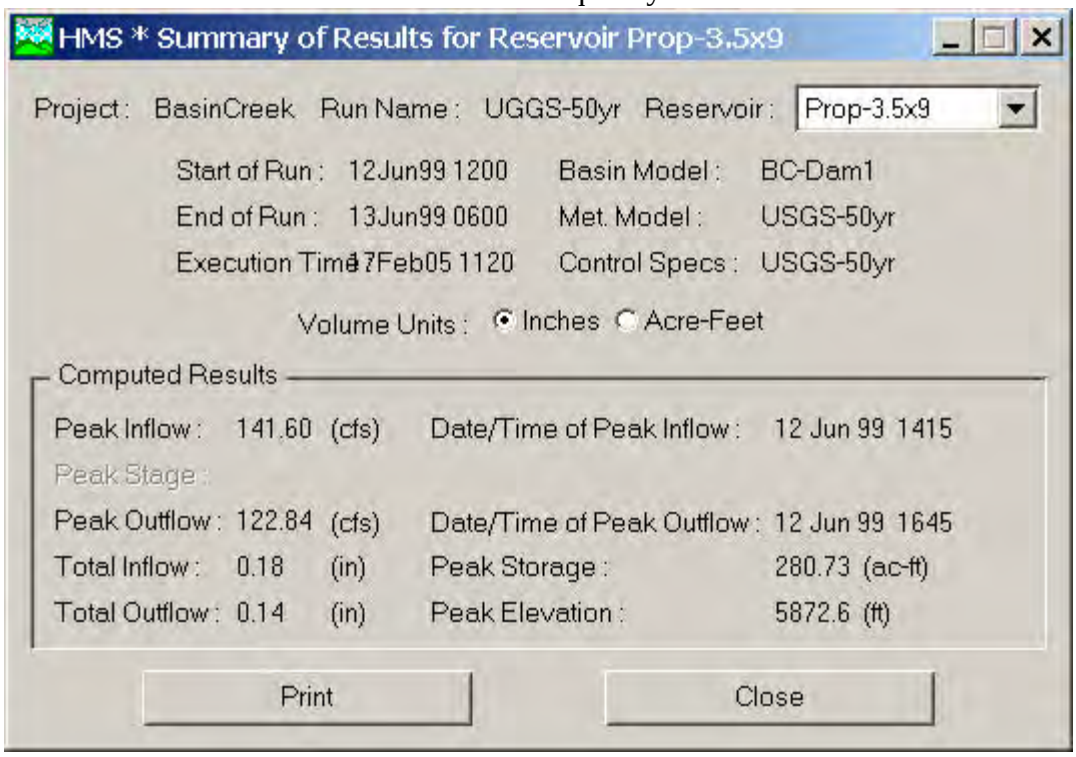
Computed Results

Peak Inflow:	317.62	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1345	
Peak Stage:					
Peak Outflow:	218.63	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1745	
Total Inflow:	0.36	(in)	Peak Storage:	306.57	(ac-ft)
Total Outflow:	0.31	(in)	Peak Elevation:	5873.0	(ft)

Print Close

Alternate 3.5 x 9 ft. Spillway Routing

50-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x9

Project: BasinCreek Run Name: UGGS-50yr Reservoir: Prop-3.5x9

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-50yr
Execution Time: 7Feb05 1120 Control Specs: USGS-50yr

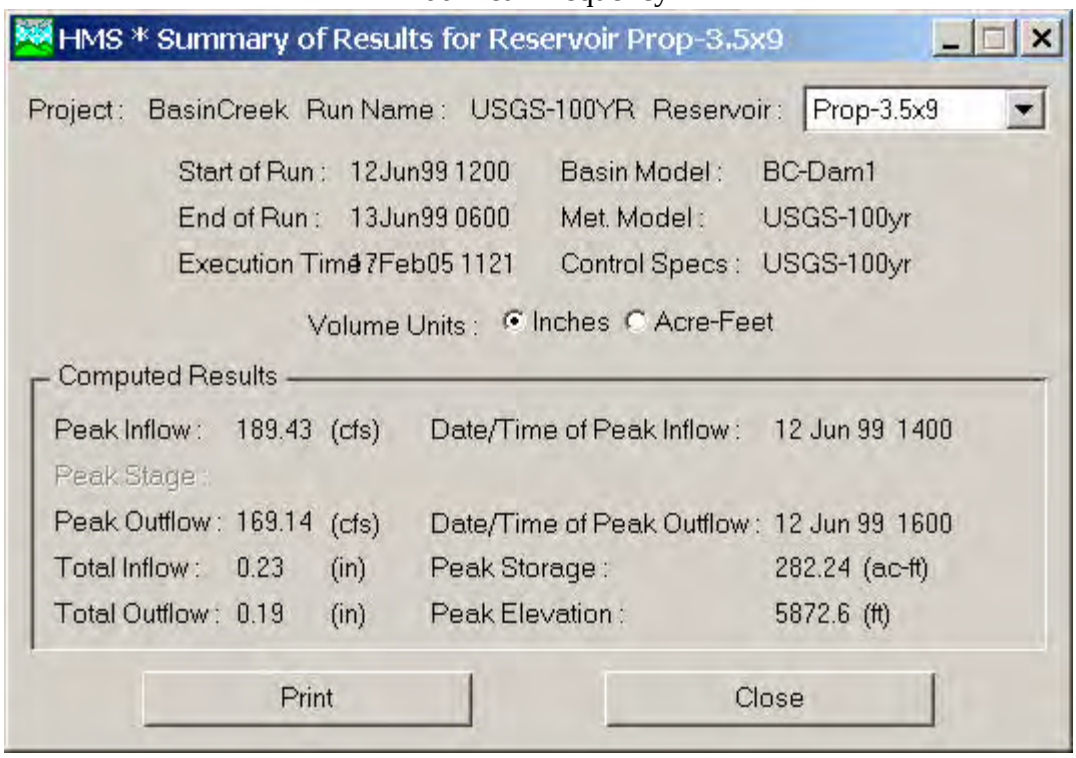
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	141.60	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1415	
Peak Stage:					
Peak Outflow:	122.84	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1645	
Total Inflow:	0.18	(in)	Peak Storage:	280.73	(ac-ft)
Total Outflow:	0.14	(in)	Peak Elevation:	5872.6	(ft)

Print Close

100-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x9

Project: BasinCreek Run Name: USGS-100YR Reservoir: Prop-3.5x9

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-100yr
Execution Time: 7Feb05 1121 Control Specs: USGS-100yr

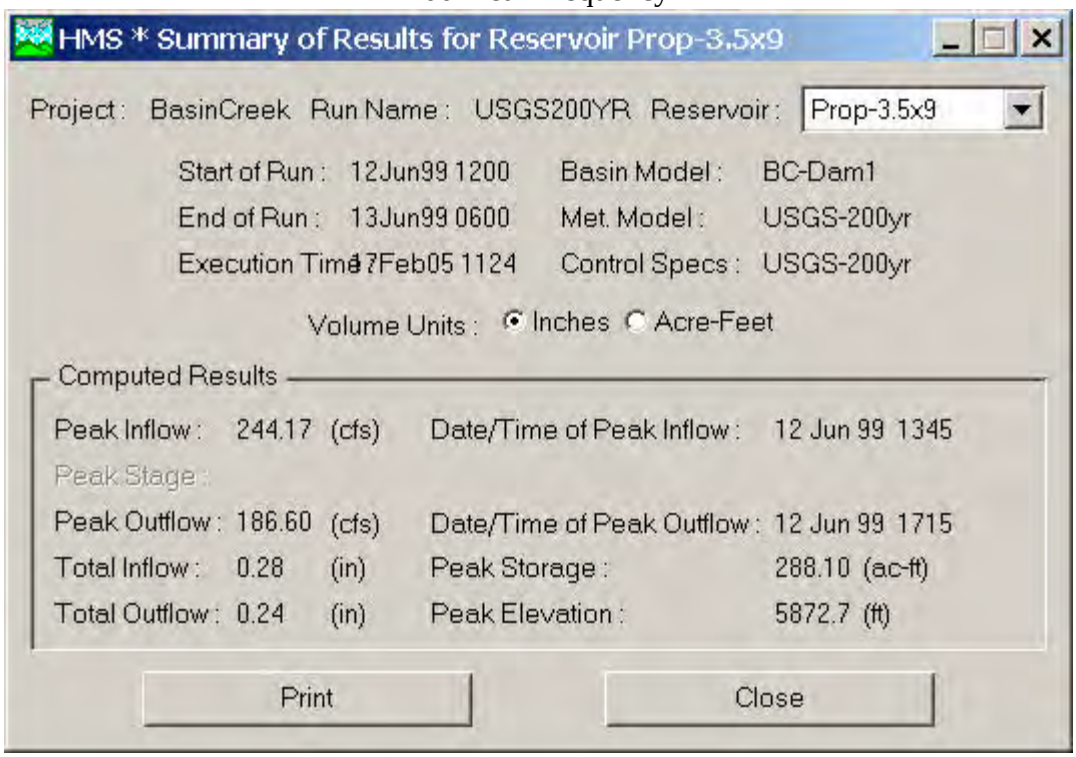
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	189.43	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1400	
Peak Stage:					
Peak Outflow:	169.14	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1600	
Total Inflow:	0.23	(in)	Peak Storage:	282.24	(ac-ft)
Total Outflow:	0.19	(in)	Peak Elevation:	5872.6	(ft)

Print Close

200-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x9

Project: BasinCreek Run Name: USGS200YR Reservoir: Prop-3.5x9

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-200yr
Execution Time: 17Feb05 1124 Control Specs: USGS-200yr

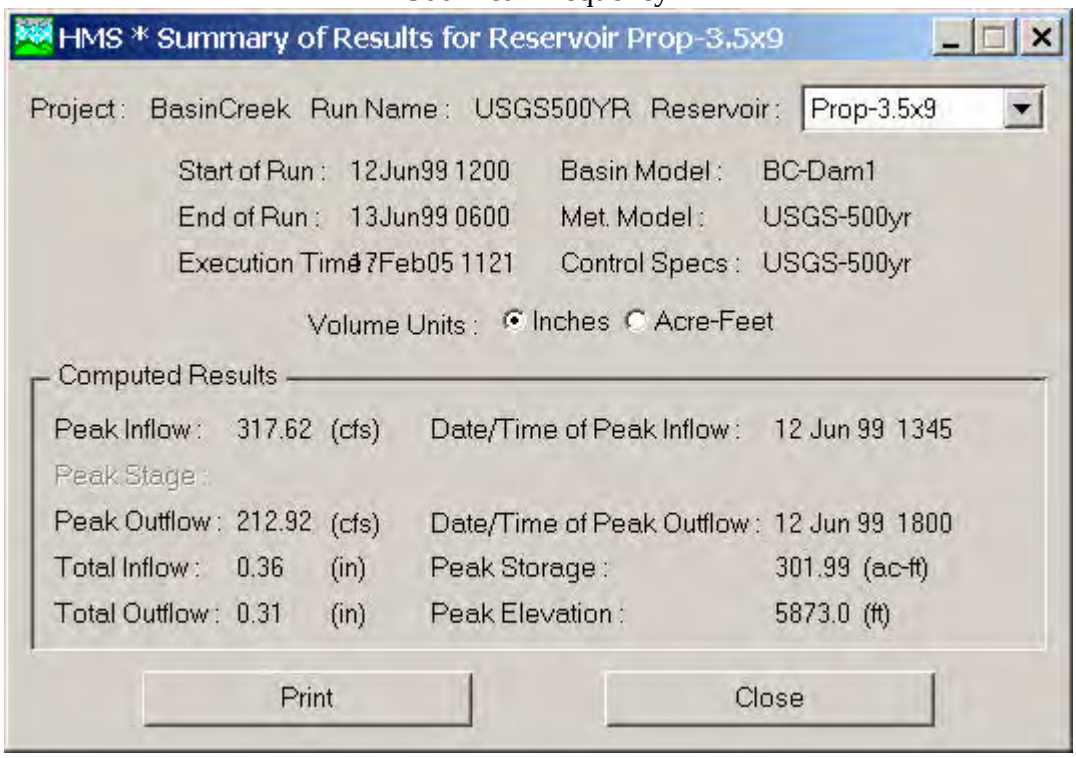
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	244.17	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1345	
Peak Stage:					
Peak Outflow:	186.60	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1715	
Total Inflow:	0.28	(in)	Peak Storage:	288.10	(ac-ft)
Total Outflow:	0.24	(in)	Peak Elevation:	5872.7	(ft)

Print Close

500-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x9

Project: BasinCreek Run Name: USGS500YR Reservoir: Prop-3.5x9

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-500yr
Execution Time: 17Feb05 1121 Control Specs: USGS-500yr

Volume Units: Inches Acre-Feet

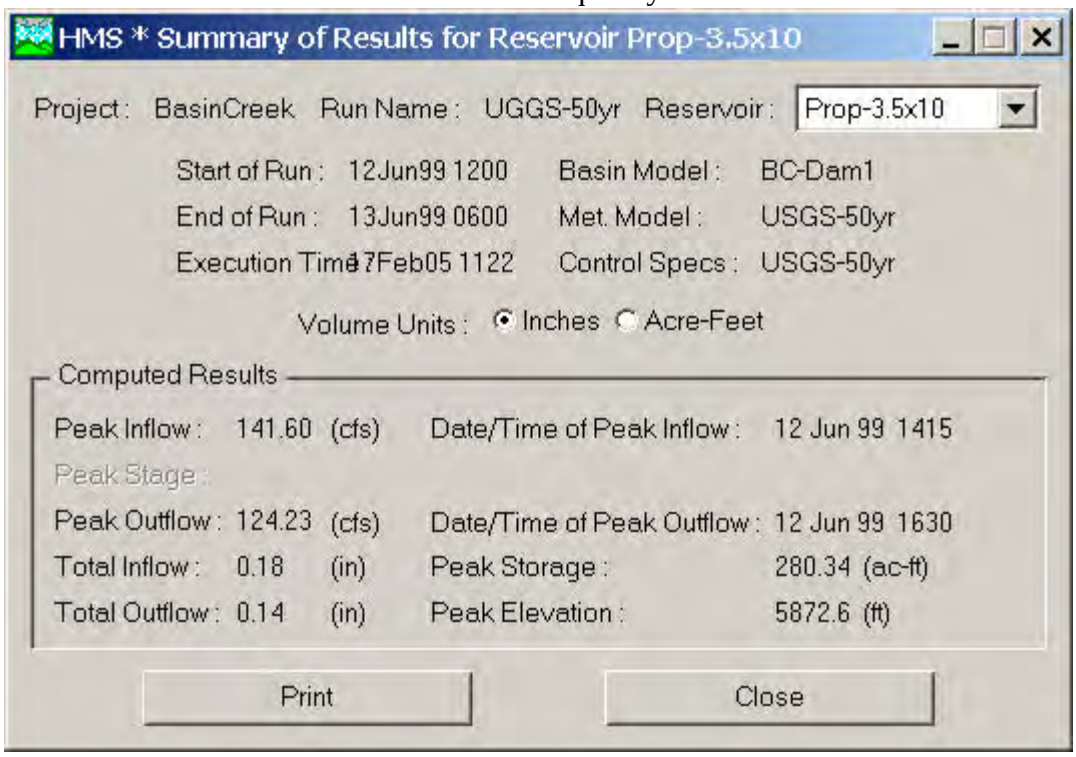
Computed Results

Peak Inflow:	317.62	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1345	
Peak Stage:					
Peak Outflow:	212.92	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1800	
Total Inflow:	0.36	(in)	Peak Storage:	301.99	(ac-ft)
Total Outflow:	0.31	(in)	Peak Elevation:	5873.0	(ft)

Print Close

Alternate 3.5 x 10 ft. Spillway Routing

50-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x10

Project: BasinCreek Run Name: UGGS-50yr Reservoir: Prop-3.5x10

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-50yr
Execution Time: 7Feb05 1122 Control Specs: USGS-50yr

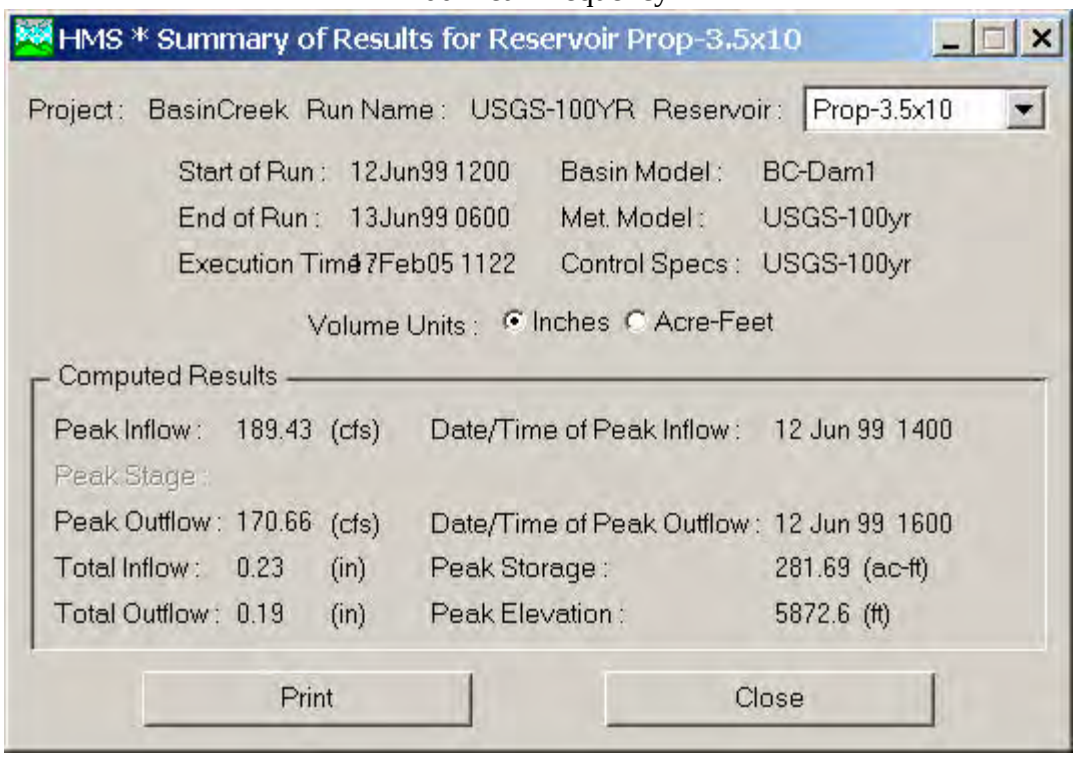
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	141.60	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1415	
Peak Stage:					
Peak Outflow:	124.23	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1630	
Total Inflow:	0.18	(in)	Peak Storage:	280.34	(ac-ft)
Total Outflow:	0.14	(in)	Peak Elevation:	5872.6	(ft)

Print Close

100-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x10

Project: BasinCreek Run Name: USGS-100YR Reservoir: Prop-3.5x10

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-100yr
Execution Time: 7Feb05 1122 Control Specs: USGS-100yr

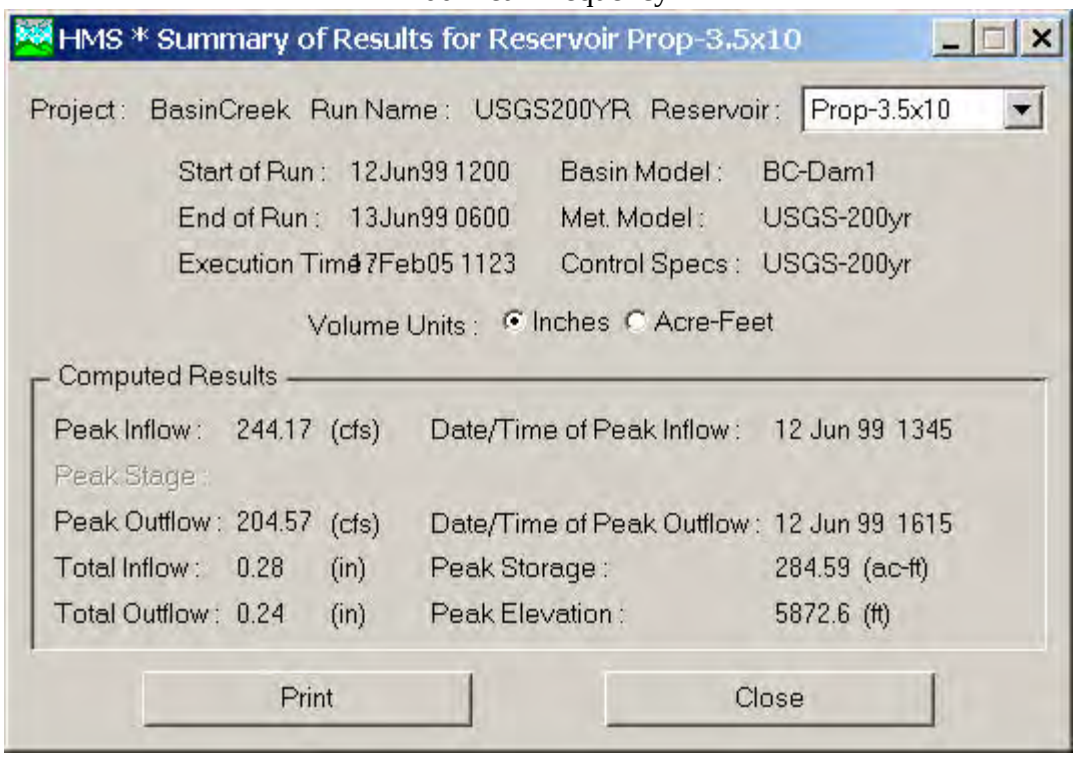
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	189.43	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1400	
Peak Stage:					
Peak Outflow:	170.66	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1600	
Total Inflow:	0.23	(in)	Peak Storage:	281.69	(ac-ft)
Total Outflow:	0.19	(in)	Peak Elevation:	5872.6	(ft)

Print Close

200-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x10

Project: BasinCreek Run Name: USGS200YR Reservoir: Prop-3.5x10

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-200yr
Execution Time: 17Feb05 1123 Control Specs: USGS-200yr

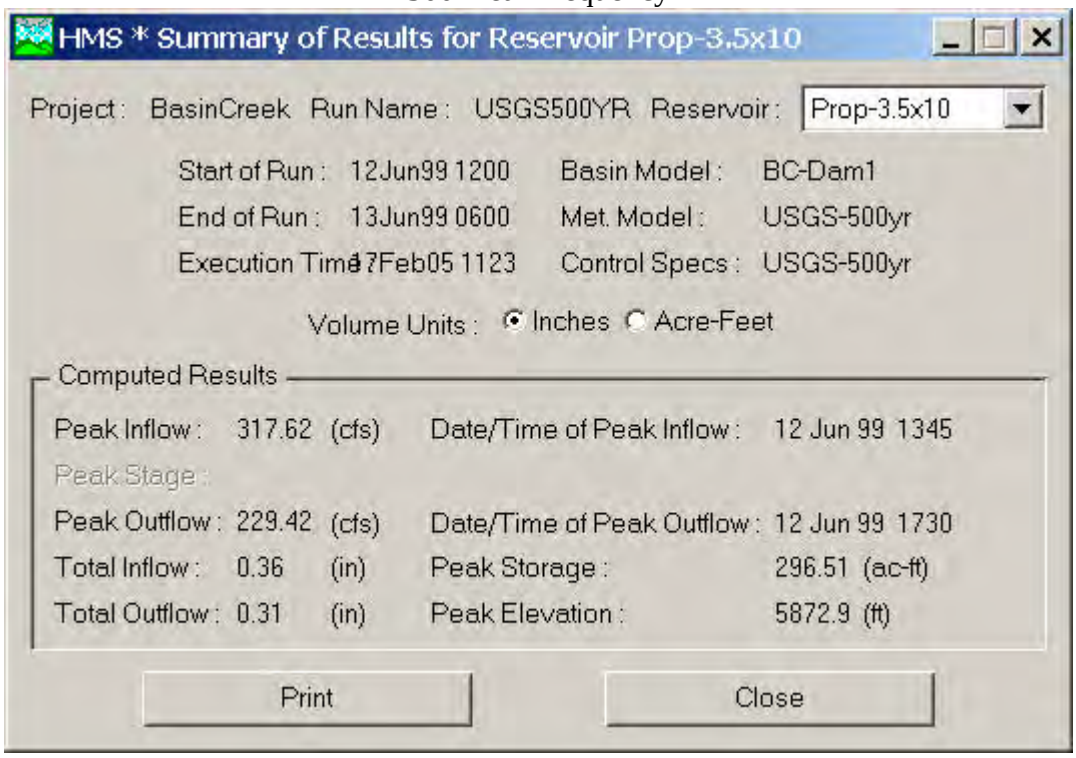
Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	244.17	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1345	
Peak Stage:					
Peak Outflow:	204.57	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1615	
Total Inflow:	0.28	(in)	Peak Storage:	284.59	(ac-ft)
Total Outflow:	0.24	(in)	Peak Elevation:	5872.6	(ft)

Print Close

500-Year Frequency



HMS * Summary of Results for Reservoir Prop-3.5x10

Project: BasinCreek Run Name: USGS500YR Reservoir: Prop-3.5x10

Start of Run: 12Jun99 1200 Basin Model: BC-Dam1
End of Run: 13Jun99 0600 Met. Model: USGS-500yr
Execution Time: 17Feb05 1123 Control Specs: USGS-500yr

Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	317.62	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1345	
Peak Stage:					
Peak Outflow:	229.42	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1730	
Total Inflow:	0.36	(in)	Peak Storage:	296.51	(ac-ft)
Total Outflow:	0.31	(in)	Peak Elevation:	5872.9	(ft)

Print Close

APPENDIX F1

SITE PHOTOS

Overall view of dam and reservoir from right abutment.

Upstream face of dam. White buoys suspend the bubbler system used for de-icing in winter months. Auxiliary overflow shown at right side.

View of auxiliary overflow from top of right abutment.

Low section of parapet wall at right abutment, east of auxiliary overflow.

Right abutment showing auxiliary overflow and box culvert
bringing in Fish Creek Diversion water.

Existing outlet works control valve. (Seized open)

Existing spillway. Elevation controlled with stop-logs.

Drop in spillway from crest control to spillway channel.

Spillway drop. Reservoir spilling Spring 2005.

Spillway channel.

End of spillway. Spilling Spring 2005.

Spillway outflow into Basin Creek. Spilling Spring 2005.

Spillway outflow into Basin Creek.

MAXIM
TECHNOLOGIES
A DIVISION OF TETRA TECH, INC.

RECEIVED
JUL 18 2005
D.N.R.C.

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July 11, 2005

Ms. Michele Lemieux, P.E.
Montana DNRC
Dam Safety Program
P.O. Box 201601
1424 9th Avenue
Helena, MT 59620-1601

Re: Dam Safety Peer Review
Basin Creek Dam No. 1 Hydrologic and Hydraulic Study June 2005

Dear Michele,

This letter summarizes comments of an engineering peer review conducted by Maxim Technologies (Maxim) for the above-referenced study. The study was presented in a report prepared by HKM Engineering titled *Basin Creek Dam No. 1 Hydrologic and Hydraulic Study, June 2005*, prepared for the Butte-Silver Bow Public Works Department. Maxim's review consisted of an office evaluation of the report based on information provided by the Dam Safety Program and limited knowledge of the subject dam/spillway and downstream area. Comments are organized to address specific sections of the report.

Peer Review Comments

1. In Chapter 3.0, Flood Frequency, three methods for estimating flood flows with frequencies from 2- to 500-years were used. The first is the regression equation method based on basin characteristics of Water Resources Investigation Report 03-4308 (WRIR 03-4308). The second method is also from WRIR 03-4308 and involves transferring flood peaks from gaged sites on the same stream to the ungaged site of interest. The gaged sites used in the analysis have a drainage area that differs from the drainage area at Basin Creek Dam No. 1 by too much – the method is not applicable. The third method is a method that HKM may have come up with themselves in which they select a local subset of stream gages whose drainage areas bracket the drainage area of the Basin Creek Dam No. 1 and form a simple linear regression between the basin characteristics of the subset of gages and their known floods of various recurrence intervals. This process basically repeats the process of WRIR 03-4308 except that it lacks the large data set and rigorous checks that WRIR-03-4308 used. In effect, this third method should be considered an experimental, unverified method at best. HKM selected the predicted flood peaks from this third method. The only saving grace in doing so is that the selected flood peaks are slightly more conservative than flood peaks using the well established first method (regressions based on basin characteristics). One additional step that the authors should have considered that would have added better information to their analysis would have been to compute flood peaks based on channel characteristics and then combine the estimated flood peaks based on the regression equations for basin characteristics and channel characteristics using weights suggested in WRIR 03-4308.

2. In Chapter 4.4, Risk Based Design Precipitation, and Appendix C5, the PMP 6-hour precipitation depth (as presented in Table 4.3-1) was 7.2 inches. The PMP_{6hr} value (used to calculate design precipitation depth P_{s6hr}) was 6.23 inches. The 6.23 inches value was calculated in the report as the adjusted 1-hour PMP value, prior to application of temporal adjustment factors presented in Table 4.3-1, resulting in the corrected depth of 7.2 inches. If the calculations in Appendix C5 are corrected for a PMP_{6hr} depth of 7.2 inches, the factor d_{6hr} becomes 0.30 and P_{s6hr} becomes 4.46 inches, instead of 4.27 inches presented in the report.

3. Also in Chapter 4.4, Risk Based Design Precipitation, and Appendix C2, the 6-hour design storm hyetographs indicate ordering of precipitation depth increments from highest at the first time increment to lowest at the last time increment. Such an ordering of precipitation increments results in runoff that is the least conservative of all possible hyetograph scenarios. It is suggested that time-to-peak precipitation be selected for at least the median probability (0.5 exceedance) for storms in Region 1 of Montana, as defined in Table 19 of *USGS Water-Resources Investigations Report 98-4100, Characteristics of Extreme Storms in Montana and Methods for Constructing Synthetic Storm Hyetographs.*

4. In Chapter 5.0, Spillway Hydraulics, no HEC-HMS input data was provided. Maxim could not verify the study HEC-HMS output and an independent HEC-HMS analysis by Maxim was not conducted.

5. In Chapter 5.1.1, Estimated Risk & Spillway Compliance, Maxim did not have access to the most recent dam stability analysis (URS, 2005). The HKM study summarizes interpretations of the stability report and concludes that it is unclear if the dam meets Montana Dam Safety criteria for stability during overtopping. The Montana Dam Safety Program will need to assess if the dam can withstand overtopping without failure and the depth of overtopping that is acceptable.

6. In Chapter 5.2, Spillway Alternates, and Appendix E1, spillway stage-discharge data for the preferred alternative (5-ft by 9-ft spillway opening) is based on operation of an Obermeyer Spillway Crest Gate (details not provided in the report) that has a sill elevation 5867.0 (Appendix E1) and a top elevation of 5872.0. The gate is modeled to be normally closed in the full up position during normal operation of the reservoir because of the wishes of Butte-Silver Bow to maintain as much storage capacity as possible. Based on the tables provided in Appendix E1, once the reservoir stage reaches elevation 5872.5 (0.5 feet over the gate and 0.5 feet below the dam crest elevation of 5873.0), the gate is lowered to provide additional flow capacity. If benefit is to be derived from the crest gate, an operation plan and system should be developed that triggers opening the gate at a specified reservoir stage. If the dam does not have a 24-hour tender on site, gate automation or an alarm system is recommended.

If you have any questions about our review of the report, please feel free to contact me or Gary Fischer.

Sincerely,
***MAXIM* Technologies**

Larry Cawlfield, P.E.
Senior Project Engineer

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www.hkminc.com

August 16, 2005
P:\15\M424117\H&H\H&H Review Comments Response.doc

Montana DNRC
Dam Safety Program
Attn: Michele Lemieux
P.O. Box 201601
1424 9th Avenue
Helena, MT 59620-1601

RE: Basin Creek Dam No. 1 Hydrologic & Hydraulic Study Review Comments

Ms. Lemieux,

Thank you for your assistance in the permitting process for the Basin Creek Reservoir Improvements project. As you are aware, construction for the above referenced project is scheduled to begin in early September, and I wanted to finalize the Hydrologic and Hydraulic Study report before construction begins. As we have previously discussed, none of Mr. Cawlfield's comments had an affect on either the conclusions of the Hydrologic and Hydraulic Study report or the proposed design. However, Mr. Cawlfield did identify some errors in HKM's hydrologic analysis. Below are the responses to each of Mr. Cawlfield's review comments as outlined in his July 11, 2005 peer review letter.

1. I am aware that the ratio of the tributary area to Basin Creek at Basin Creek Reservoir to the tributary area of Blacktail Creek at Butte is outside the data set from which the Gage Translation method exponents were developed. However, it is a method that is easily used and provides a useful comparison to the other methods that were applied to the project site. The third hydrological method that I employed is called the Regional Regression method (identified as the Local Regression method in the report to avoid confusion with the USGS Regional Regression Equations), which is a widely used method. There is an excellent description of this procedure in Chapter 7, Section 7.13 of the MDT Drainage Manual. HKM has employed this method on many past projects that have been reviewed and approved by the DNRC. As the gage sites used in the Local Regression method are for streams with basin characteristics that are reasonably similar to Basin Creek, i.e. small, high mountain basins, it is believed that a smaller data set that better approximates the system for which we are seeking to predict flood magnitudes may be more appropriate than a larger data set that encompasses significantly larger river systems with different basin characteristics. The flood magnitudes, basin areas, average basin elevation, and average annual precipitation values used for each gaged site in the Local Regression method are unaltered, published values from the USGS publication WRIR 03-4308.

2. There was an error in the determination of the six hour risk based precipitation. When the 1-hour PMP is temporally adjusted, and the adjusted value used in the appropriate equations, the correct P_{s6hr} precipitation is 4.46 inches.

BILLINGS, MONTANA 406.656.6399 | BOZEMAN, MONTANA 406.586.8834 | BUTTE LABORATORY 406.494.1502 | MILES CITY, MONTANA 406.232.6666 | SHERIDAN, WYOMING 307.672.9006 | HELENA, MONTANA 406.442.0370

3. The risk based design storm hyetographs (P_{s6hr} and P_{s24hr}) developed for the June report were based on the 0.2 exceedance probability cumulative depth duration relationships described by Table 13 of WRIR 98-4100. The time ordering of the hyetograph ordinates for the 18-hour storm (P_{s6hr}) was similar to macro-pattern 1, and the 72 hour storm was similar to macro-patterns 5 and 6. However, after revisiting WRIR 98-4100 again, I concur that the hyetograph development should more strictly adhere to the procedures described in WRIR 98-4100. The intent of this project is not to design a spillway that will pass the inflow hydrograph resulting from the design precipitation as described by the 1999 Technical Decisions, but to predict the hydraulic loading on the spillway/dam as a result of the required design event. Consequently, the 0.5 exceedance probability for both the rainfall depth vs duration and the time-to-peak is believed to provide better assessment of how the system will function under such an extreme storm event, rather tan the 0.2 exceedance probability used in the Hydrologic and Hydraulic Study. Below is a summary of the revised rainfall-runoff response modeling and the hydrograph routing analyses. Included as an attachment to this letter are supporting calculations and hyetograph plots.

Revision to Table 5.1-1: Inflow Hydrograph Reservoir Routing Summary (Existing Spillway Configuration)

Precipitation	Unit Hydrograph	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Stage (ft)
P_{s6hr}*	USGS	1,497	1,306	5,874.4
P_{s6hr}**	USGS	1,096	930	5,874.2
P_{s24hr}*	USGS	626	594	5,873.8
P_{s24hr}**	USGS	299	271	5,873.4

*Hyetograph ordinates are based on a 0.2 exceedance probability and a 0.5 exceedance probability for time to peak.
**Hyetograph ordinates are based on a 0.5 exceedance probability and a 0.5 exceedance probability for time to peak.

Supplemental Table: Inflow Hydrograph Reservoir Routing Summary (Proposed Spillway Configuration)

Precipitation	Unit Hydrograph	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Stage (ft)
P_{s6hr}**	USGS	1,096	919	5,873.9
P_{s24hr}**	USGS	299	215	5,873.0

**Hyetograph ordinates are based on a 0.5 exceedance probability and a 0.5 exceedance probability for time to peak.

As can be seen in the above two tables, the 24-hour independent storm duration (72-hour total duration) using the 0.5 exceedance probability for both the hyetograph ordinates and the time to peak appears to predict an unreasonably low inflow hydrograph peak, when

compared to the flood magnitudes presented in Table 3.1-1 of the Hydrologic and Hydraulic Study. The 6-hour independent storm is the controlling event.

4. A CD containing the HEC-HMS files is included with this submittal.

5. HKM is still coordinating additional stability investigative efforts; we will continue to keep the DNRC informed as we move forward with this issue.

6. I am aware that the hydraulic modeling demonstrating passage of the 500 year flood hydrograph, without overtopping the parapet wall, relies on an instantaneous opening of the proposed spillway crest gate when the reservoir stage reaches elevation 5,872.5 ft. I also concur that, without automation, it is unlikely that the new gate will be opened in time to prevent overtopping from occurring. I have specified a gate control panel that will accept programmable logic commands, and BSB does intend to coordinate automation control between the ultrasonic lake level device (also being installed as part of this project) and the spillway crest gate.

Thank you for your thorough review, and I look forward to working with you as this project enters the construction phase. If you have additional questions, or would like additional documentation, please don't hesitate to call me at your convenience.

Sincerely,
HKM Engineering Inc.

Russell C. Reed, P.E.
Project Manager

Cc: File
Jean Pentecost, P.E., BSB

Attachments: Revised Risk Based Design Precipitation
Region 1 Storm Characteristics
Dimensionless Storm Depth Duration Tables
6-Hour, 0.5 exceedance probability hyetograph (table)
6-Hour independent storm duration hyetograph (graph)
24-Hour, 0.5 exceedance probability hyetograph (table)
24-Hour independent storm duration hyetograph (graph)
HEC-HMS Output Summary Tables

$P_S = P_{5000}\,(10^{rd})$ $\qquad r = -0.304 + 0.435 \log(LOL)$

P_S = SPILLWAY DESIGN PRECIP. $\qquad d = \log(PMP) - \log(P_{5000})$

P_{5000} = 5,000 YEAR PRECIP.

LOL = LOSS OF LIFE

PMP = PROB. MAX. PRECIP.

$P_{5000} = q(F_{5000})\,P_{24MAX}$

FROM REGIONAL ANALYSIS OF ANNUAL PRECIPITATION MAXIMA IN MONTANA

$F_{5000} = 1 - \frac{1}{5000} = 0.9998$ $\qquad F_{5000}$ = 5,000 YEAR EXCEEDANCE PROBABILITY

$q(F_{5000}) = \xi + \alpha(\{1-(-\log F)^{K}\}/K)$ $\qquad \xi, \alpha, \& K$ ARE PARAMETERS OF THE GENERALIZED EXTREME VALUE (GEV) DISTRIBUTION

FROM TABLE 9 (PAGE 17) FOR REGION 1

	6 HRS	24 HRS
ξ	0.830	0.839
α	0.242	0.258
K	-0.114	-0.047

$q(F_{5000})_{24HR} = 3.87$

$q(F_{5000})_{6HR} = 4.87$

FROM TABLE 11 (PAGE 27)

MAP = MEAN ANNUAL PRECIP.
LAT = LATITUDE (DECIMAL) − 40
LONG = LONGITUDE (DECIMAL) − 100

$P_{max6} = 0.60 + (0.0067\,MAP)$

$P_{max24} = 1.0 + (0.078\,LAT) - (0.059\,LONG) + (0.025\,MAP)$

$P_{max6} = 0.60 + (0.0067(20.9)) = 0.74\,IN$

LATITUDE = 45.8167
LONGITUDE = 112.5147

$P_{max24} = 1.0 + (0.078(5.8167)) - (0.059(12.5147)) + 0.025(20.9) = 1.24\,IN$

$P_{5000_{6HR}} = 4.87(0.74 IN) = 3.60 IN$

$P_{5000_{24HR}} = 3.87(1.24 IN) = 4.80 IN$

$P_S = P_{5000}(10^{rd})$

$r = -0.304 + 0.435 \log(LOL)$
$= -0.304 + 0.435 \log(26)$ — 26 LOL FM DNRC CORRESPONDENCE DATED JAN 26, 2005
$= 0.31$

$d = \log(PMP) - \log(P_{5000})$

$PMP_{24HR} = 20.60 IN$ (10 mi² INDEX PMP W/ 1.0 AREA FACTOR),

$PMP_{6HR} = 7.20 IN$ (1 mi² INDEX PMP ADJUSTED FOR AREA, ELEVATION, & TIME)

$d_{24HR} = \log(20.60) - \log(4.80) = 0.63$

$d_{6HR} = \log(7.16) - \log(3.60) = 0.30$

$P_{S_{6HR}} = 3.60(10^{(0.31)(0.30)}) = 4.46 IN$

$P_{S_{24HR}} = 4.80(10^{(0.31)(0.77)}) = 7.53 IN$

CURRENT RISK FACTOR: $RF = \frac{RI_{SW}}{LOL}$

RI_{SW} = FLOOD RECURRENCE THAT THE SPILLWAY CAN PASS

$\frac{RI_{SW}}{LOL} = \frac{2}{26} = 0.08 < 100$ ∴ SPILLWAY WORK IS RQ'D

HOWEVER, FAILURE DOES NOT OCCUR FROM OVERTOPPING @ THE TWO YEAR FLOOD.

Characteristics of Extreme Storms in Montana and Methods for Constructing Synthetic Storm Hyetographs; WRIR 98-4100

Project: Basin Creek Reservoir Improvements

Homogeneous Region No.: Region 1

Region 1 Macro-Pattern Characteristics (from Figure 5)

2-Hour Storms: ~75% of storms are macro-pattern 1
6-Hour Storms: 60% of storms are macro-pattern 1
24-Hour Storms: 34% of storms are macro-pattern 3

Macro-Pattern 1: 123 storm with continuous precipitation and one precipitation peak
Macro-Pattern 3: 123 storm with intermittent precipitation, 2 breaks, and 3 precipitation peaks

Region 1 High Intensity Storm Patterns (from Tables 2 & 3)

2-Hour Storms: 100% of 2-hr duration storms in WRIR 98-4100 were characterized by the 123 high intensity pattern

6-Hour Storms: 50% of storms are a 321 storm intensity pattern
25% of storms are a 213 storm intensity pattern

24-Hour Storms: 29% of storms are a 123 storm intensity pattern
29% of storms are a 321 storm intensity pattern

Time-to-peak precipitation for Region 1 storms:

Exceedance Probability	Storm Duration Time-to-Peak (Hours)		
	2-Hour	6-Hour	24-Hour
0.5	0.167	3	17
0.2	0.75	7.5	40

Note: Because the Basin Creek Reservoir spillway can not be designed to pass the design storm as defined by the 1999 Spillway Committee Technical Decisions, use the 0.5 exceedance probability to analyze the performance of the proposed spillway configuration under the median probability storm precipitation pattern and resulting inflow hydrograph.

From Table 13 of WRIR 98-4100:
Dimensionless depths for various durations and exceedance probabilities, Region 1, Montana

From Montana Spillway Standards Committee Tchnical Decisions, May 1999, the $P_{s6\text{-}hr}$ = N/A in

2-Hour Independent Duration 0.5-hour kernel duration, Exceedance probability = 0.5									
Cumulateive Incremental Duration, hours	Cumulative Dimension-less Depth	Depth-area adjustment factor	Cumulative adjusted dimension-less depth	Increment al time, hours	Incremental dimension-less depth	Number of 5-min. time periods per incremental time	Dimension-less depth per 5-min. period	Depth per 5 min. period, inch	Total precipitaiton depth, inches
0	0			0	0	0	0	0	0
0.0833	0.270	0.9	0.243	0.0833	0.243	1	0.2430	#VALUE!	#VALUE!
0.167	0.441	0.9	0.397	0.0837	0.154	1	0.1539	#VALUE!	#VALUE!
0.25	0.573	0.9	0.516	0.083	0.119	1	0.1188	#VALUE!	#VALUE!
0.50	0.768	0.9	0.691	0.25	0.176	3	0.0585	#VALUE!	#VALUE!
0.75	0.849	0.92	0.781	0.25	0.090	3	0.0300	#VALUE!	#VALUE!
1.0	0.902	0.94	0.848	0.25	0.067	3	0.0223	#VALUE!	#VALUE!
1.5	0.967	0.94	0.909	0.5	0.061	6	0.0102	#VALUE!	#VALUE!
2	1.000	0.95	0.950	0.5	0.041	6	0.0068	#VALUE!	#VALUE!
3	1.032	0.97	1.001	1	0.051	12	0.0043	#VALUE!	#VALUE!
4	1.041	0.97	1.010	1	0.009	12	0.0007	#VALUE!	#VALUE!
5	1.041	0.97	1.010	1	0.000	12	0.0000	#VALUE!	#VALUE!
6	1.041	0.98	1.020	1	0.010	12	0.0009	#VALUE!	#VALUE!

From Montana Spillway Standards Committee Tchnical Decisions, May 1999, the $P_{s6\text{-}hr}$ = 4.46 in

6-Hour Independent Duration 2-hour kernel duration, Exceedance probability = 0.5									
Cumulateive Incremental Duration, hours	Cumulative Dimension-less Depth	Depth-area adjustment factor	Cumulative adjusted dimension-less depth	Increment al time, hours	Incremental dimension-less depth	Number of 0.25-hour time periods per incremental time	Dimension-less depth per 0.25-hour period	Depth per 0.25-hour period, inch	Total precipitaiton depth, inches
0	0		0.000	0	0	0	0	0.0000	0.0000
0.25	0.199	0.90	0.179	0.25	0.179	1	0.1791	0.7988	0.7988
0.5	0.283	0.90	0.255	0.25	0.076	1	0.0756	0.3372	1.1360
0.75	0.356	0.92	0.328	0.25	0.073	1	0.0728	0.3248	1.4607
1	0.428	0.94	0.402	0.25	0.075	1	0.0748	0.3336	1.7943
2	0.604	0.95	0.574	1	0.171	4	0.0429	0.1912	2.5591
3	0.735	0.97	0.713	1	0.139	4	0.0348	0.1552	3.1798
6	1.000	0.98	0.980	3	0.267	12	0.0223	0.0993	4.3708
9	1.086	0.98	1.064	3	0.084	12	0.0070	0.0313	4.7467
12	1.131	0.98	1.108	3	0.044	12	0.0037	0.0164	4.9434
15	1.162	0.98	1.139	3	0.030	12	0.0025	0.0113	5.0789
18	1.182	0.98	1.158	3	0.020	12	0.0016	0.0073	5.1663

From Montana Spillway Standards Committee Tchnical Decisions, May 1999, the $P_{s24\text{-}hr}$ = 7.53 in

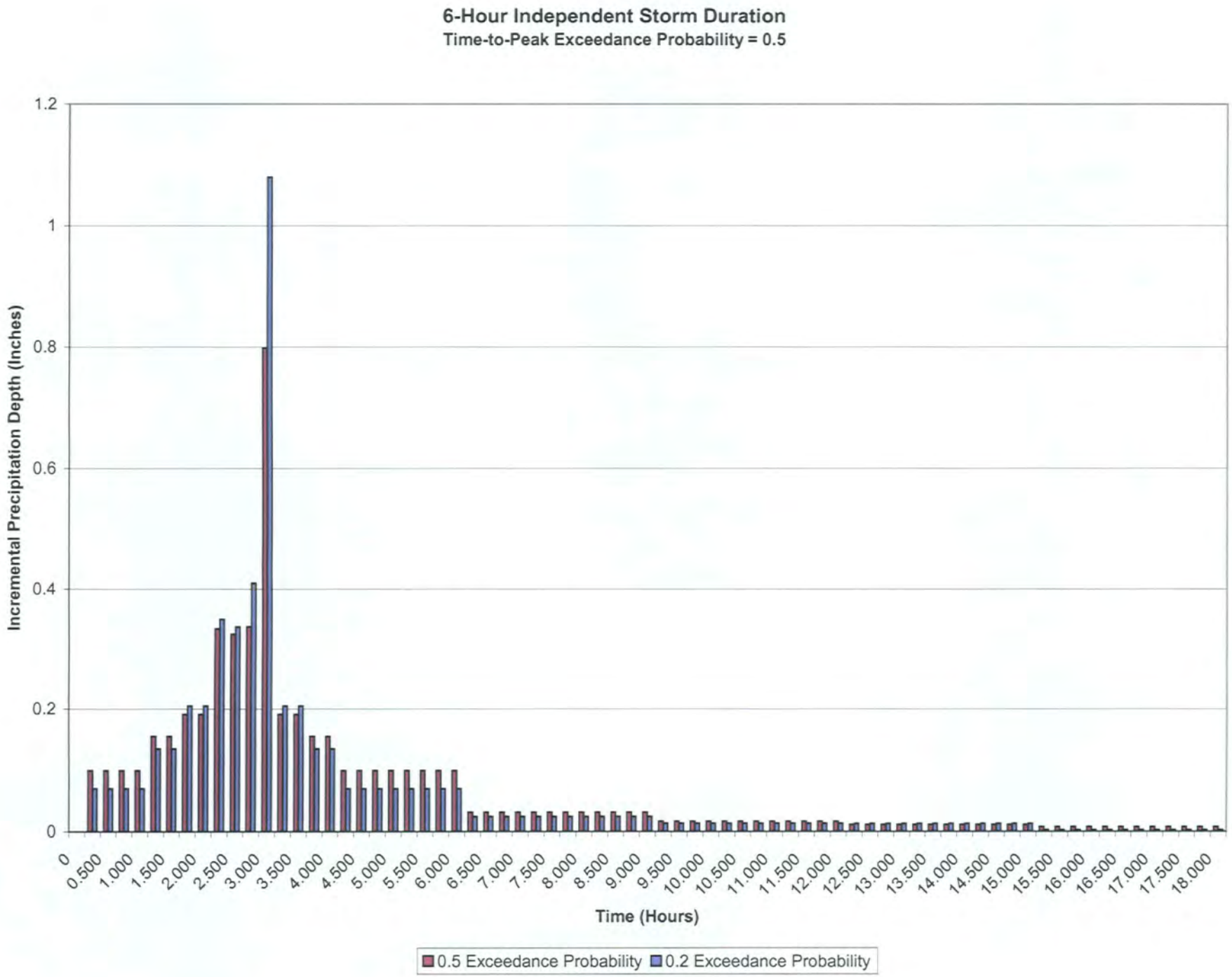
24-Hour Independent Duration 6-hour kernel duration, Exceedance probability = 0.5									
Cumulateive Incremental Duration, hours	Cumulative Dimension-less Depth	Depth-area adjustment factor	Cumulative adjusted dimension-less depth	Increment al time, hours	Incremental dimension-less depth	Number of 0.25-hour time periods per incremental time	Dimension-less depth per 0.25-hour period	Depth per 0.25-hour period, inch	Total precipitaiton depth, inches
0	0		0.000	0	0	0	0	0	0
1	0.14	0.94	0.132	1	0.132	4	0.0329	0.2477	0.9909
2	0.222	0.95	0.211	1	0.079	4	0.0198	0.1493	1.5881
3	0.301	0.97	0.292	1	0.081	4	0.0203	0.1526	2.1985
6	0.437	0.98	0.428	3	0.136	12	0.0114	0.0855	3.2248
9	0.550	0.98	0.539	3	0.111	12	0.0092	0.0695	4.0587
12	0.655	0.98	0.642	3	0.103	12	0.0086	0.0646	4.8335
18	0.865	0.98	0.848	6	0.208	24	0.0086	0.0646	6.3832
24	1.000	0.99	0.990	6	0.142	24	0.0059	0.0446	7.4547
36	1.073	1.00	1.073	12	0.083	48	0.0017	0.0130	8.0797
48	1.117	1.00	1.117	12	0.044	48	0.0009	0.0069	8.4110
60	1.160	1.00	1.160	12	0.043	48	0.0009	0.0067	8.7348
72	1.200	1.00	1.200	12	0.040	48	0.0008	0.0063	9.0360

6-Hour 0.5 exceedance probability hyetograph with a 0.5 exceedance probability time-to-peak

Time-to-peak = 3 Hours
Macro-pattern = 1
High-intensity storm pattern = 321

	Time (hours)	Δ Precip (inches)		Time (hours)	Δ Precip (inches)		Time (hours)	Δ Precip (inches)
Trisector 1	0	0	Trisector 2	6.250	0.0313	Trisector 3	12.250	0.0113
	0.250	0.0993		6.500	0.0313		12.500	0.0113
	0.500	0.0993		6.750	0.0313		12.750	0.0113
	0.750	0.0993		7.000	0.0313		13.000	0.0113
	1.000	0.0993		7.250	0.0313		13.250	0.0113
	1.250	0.1552		7.500	0.0313		13.500	0.0113
	1.500	0.1552		7.750	0.0313		13.750	0.0113
	1.750	0.1912		8.000	0.0313		14.000	0.0113
	2.000	0.1912		8.250	0.0313		14.250	0.0113
	2.250	0.3336		8.500	0.0313		14.500	0.0113
	2.500	0.3248		8.750	0.0313		14.750	0.0113
	2.750	0.3372		9.000	0.0313		15.000	0.0113
	3.000	0.7988		9.250	0.0164		15.250	0.0073
	3.250	0.1912		9.500	0.0164		15.500	0.0073
	3.500	0.1912		9.750	0.0164		15.750	0.0073
	3.750	0.1552		10.000	0.0164		16.000	0.0073
	4.000	0.1552		10.250	0.0164		16.250	0.0073
	4.250	0.0993		10.500	0.0164		16.500	0.0073
	4.500	0.0993		10.750	0.0164		16.750	0.0073
	4.750	0.0993		11.000	0.0164		17.000	0.0073
	5.000	0.0993		11.250	0.0164		17.250	0.0073
	5.250	0.0993		11.500	0.0164		17.500	0.0073
	5.500	0.0993		11.750	0.0164		17.750	0.0073
	5.750	0.0993		12.000	0.0164		18.000	0.0073
	6.000	0.0993						

Precipitation in 1st Trisector =	4.3708	Inches
Precipitation in 2nd Trisector =	0.5726	Inches
Precipitation in 3rd Trisector =	0.2229	Inches
Total Precipitation =	5.1663	Inches

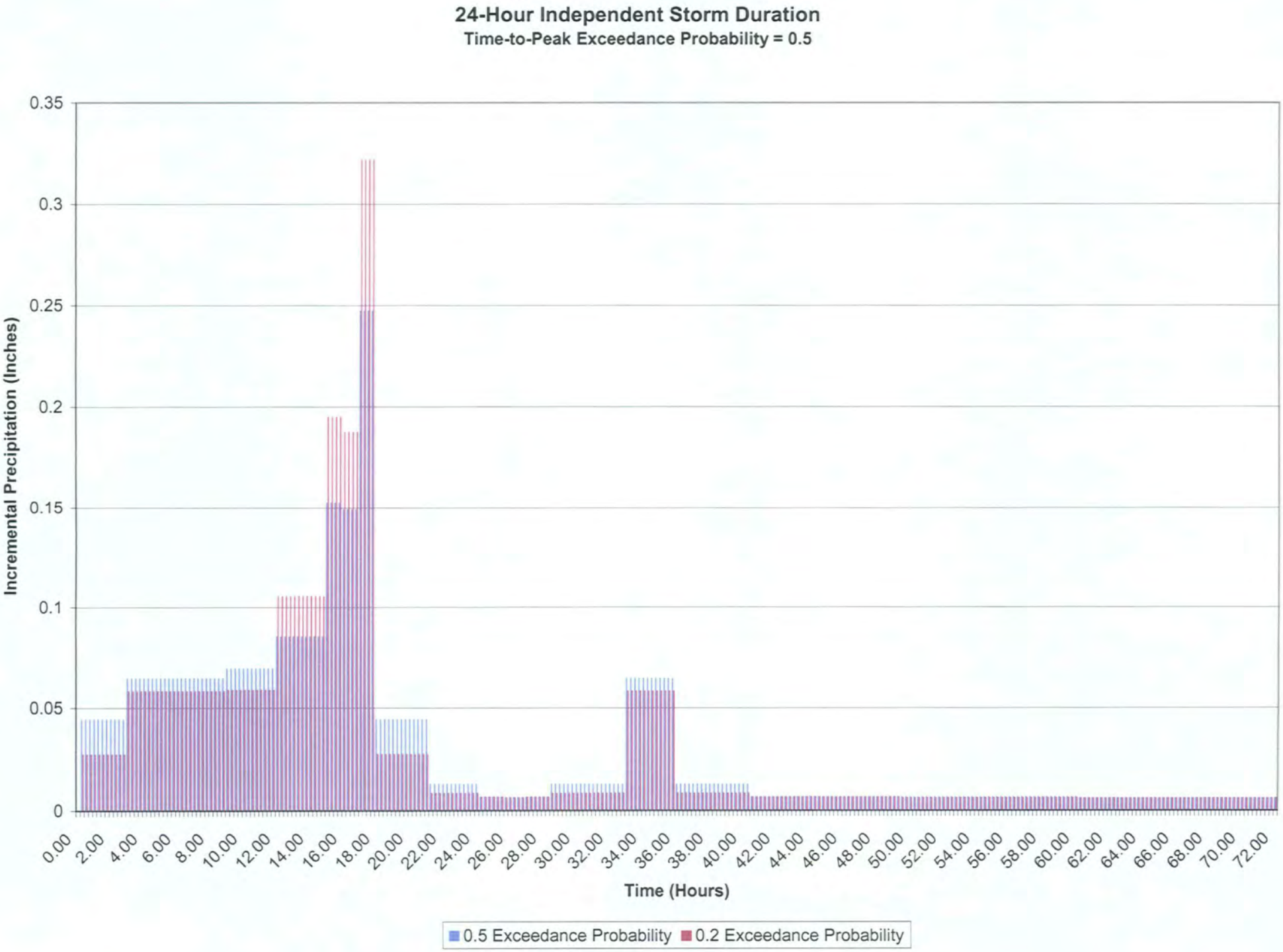

6-Hour Independent Storm Duration
Time-to-Peak Exceedance Probability = 0.5
Incremental Precipitation Depth (Inches)
1.2
1
0.8
0.6
0.4
0.2
0
0
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000
6.500
7.000
7.500
8.000
8.500
9.000
9.500
10.000
10.500
11.000
11.500
12.000
12.500
13.000
13.500
14.000
14.500
15.000
15.500
16.000
16.500
17.000
17.500
18.000
Time (Hours)
0.5 Exceedance Probability
0.2 Exceedance Probability

24-Hour 0.5 exceedance probability hyetograph with a
0.5 exceedance probability time-to-peak

Time-to-peak = 17 Hours
Macro-pattern = 1
High-intensity storm pattern = 321

	Time (hours)	Δ Precip (inches)		Time (hours)	Δ Precip (inches)		Time (hours)	Δ Precip (inches)
	0.00	0		24.25	0.0069		48.25	0.0069
	0.25	0.0446		24.50	0.0069		48.50	0.0069
	0.50	0.0446		24.75	0.0069		48.75	0.0069
	0.75	0.0446		25.00	0.0069		49.00	0.0069
	1.00	0.0446		25.25	0.0069		49.25	0.0069
	1.25	0.0446		25.50	0.0069		49.50	0.0067
	1.50	0.0446		25.75	0.0067		49.75	0.0067
	1.75	0.0446		26.00	0.0067		50.00	0.0067
	2.00	0.0446		26.25	0.0067		50.25	0.0067
	2.25	0.0446		26.50	0.0067		50.50	0.0067
	2.50	0.0446		26.75	0.0067		50.75	0.0067
	2.75	0.0446		27.00	0.0069		51.00	0.0067
	3.00	0.0646		27.25	0.0069		51.25	0.0067
	3.25	0.0646		27.50	0.0069		51.50	0.0067
	3.50	0.0646		27.75	0.0069		51.75	0.0067
	3.75	0.0646		28.00	0.0069		52.00	0.0067
	4.00	0.0646		28.25	0.0069		52.25	0.0067
	4.25	0.0646		28.50	0.0130		52.50	0.0067
	4.50	0.0646		28.75	0.0130		52.75	0.0067
	4.75	0.0646		29.00	0.0130		53.00	0.0067
	5.00	0.0646		29.25	0.0130		53.25	0.0067
	5.25	0.0646		29.50	0.0130		53.50	0.0067
	5.50	0.0646		29.75	0.0130		53.75	0.0067
	5.75	0.0646		30.00	0.0130		54.00	0.0067
	6.00	0.0646		30.25	0.0130		54.25	0.0067
	6.25	0.0646		30.50	0.0130		54.50	0.0067
	6.50	0.0646		30.75	0.0130		54.75	0.0067
	6.75	0.0646		31.00	0.0130		55.00	0.0067
	7.00	0.0646		31.25	0.0130		55.25	0.0067
	7.25	0.0646		31.50	0.0130		55.50	0.0067
	7.50	0.0646		31.75	0.0130		55.75	0.0067
	7.75	0.0646		32.00	0.0130		56.00	0.0067
	8.00	0.0646		32.25	0.0130		56.25	0.0067
	8.25	0.0646		32.50	0.0130		56.50	0.0067
	8.50	0.0646		32.75	0.0130		56.75	0.0067
	8.75	0.0646		33.00	0.0646		57.00	0.0067
	9.00	0.0695		33.25	0.0646		57.25	0.0067
	9.25	0.0695		33.50	0.0646		57.50	0.0067
	9.50	0.0695		33.75	0.0646		57.75	0.0067
	9.75	0.0695		34.00	0.0646		58.00	0.0067
	10.00	0.0695		34.25	0.0646		58.25	0.0067
	10.25	0.0695		34.50	0.0646		58.50	0.0067
	10.50	0.0695		34.75	0.0646		58.75	0.0067
	10.75	0.0695		35.00	0.0646		59.00	0.0067
	11.00	0.0695		35.25	0.0646		59.25	0.0067
	11.25	0.0695		35.50	0.0646		59.50	0.0067
	11.50	0.0695		35.75	0.0646		59.75	0.0067
	11.75	0.0695	Trisector 2	36.00	0.0130	Trisector 3	60.00	0.0067
Trisector 1	12.00	0.0855		36.25	0.0130		60.25	0.0063
	12.25	0.0855		36.50	0.0130		60.50	0.0063
	12.50	0.0855		36.75	0.0130		60.75	0.0063
	12.75	0.0855		37.00	0.0130		61.00	0.0063
	13.00	0.0855		37.25	0.0130		61.25	0.0063
	13.25	0.0855		37.50	0.0130		61.50	0.0063
	13.50	0.0855		37.75	0.0130		61.75	0.0063
	13.75	0.0855		38.00	0.0130		62.00	0.0063
	14.00	0.0855		38.25	0.0130		62.25	0.0063
	14.25	0.0855		38.50	0.0130		62.50	0.0063
	14.50	0.0855		38.75	0.0130		62.75	0.0063
	14.75	0.0855		39.00	0.0130		63.00	0.0063
	15.00	0.1528		39.25	0.0130		63.25	0.0063
	15.25	0.1528		39.50	0.0130		63.50	0.0063
	15.50	0.1528		39.75	0.0130		63.75	0.0063
	15.75	0.1528		40.00	0.0130		64.00	0.0063
	16.00	0.1493		40.25	0.0130		64.25	0.0063
	16.25	0.1493		40.50	0.0069		64.50	0.0063
	16.50	0.1493		40.75	0.0069		64.75	0.0063
	16.75	0.1493		41.00	0.0069		65.00	0.0063
	17.00	0.2477		41.25	0.0069		65.25	0.0063
	17.25	0.2477		41.50	0.0069		65.50	0.0063
	17.50	0.2477		41.75	0.0069		65.75	0.0063
	17.75	0.2477		42.00	0.0069		66.00	0.0063
	18.00	0.0446		42.25	0.0069		66.25	0.0063
	18.25	0.0446		42.50	0.0069		66.50	0.0063
	18.50	0.0446		42.75	0.0069		66.75	0.0063
	18.75	0.0446		43.00	0.0069		67.00	0.0063
	19.00	0.0446		43.25	0.0069		67.25	0.0063
	19.25	0.0446		43.50	0.0069		67.50	0.0063
	19.50	0.0446		43.75	0.0069		67.75	0.0063
	19.75	0.0446		44.00	0.0069		68.00	0.0063
	20.00	0.0446		44.25	0.0069		68.25	0.0063
	20.25	0.0446		44.50	0.0069		68.50	0.0063
	20.50	0.0446		44.75	0.0069		68.75	0.0063
	20.75	0.0446		45.00	0.0069		69.00	0.0063
	21.00	0.0446		45.25	0.0069		69.25	0.0063
	21.25	0.0130		45.50	0.0069		69.50	0.0063
	21.50	0.0130		45.75	0.0069		69.75	0.0063
	21.75	0.0130		46.00	0.0069		70.00	0.0063
	22.00	0.0130		46.25	0.0069		70.25	0.0063
	22.25	0.0130		46.50	0.0069		70.50	0.0063
	22.50	0.0130		46.75	0.0069		70.75	0.0063
	22.75	0.0130		47.00	0.0069		71.00	0.0063
	23.00	0.0130		47.25	0.0069		71.25	0.0063
	23.25	0.0130		47.50	0.0069		71.50	0.0063
	23.50	0.0130		47.75	0.0069		71.75	0.0063
	23.75	0.0130		48.00	0.0069		72.00	0.0063
	24.00	0.0130						

Precipitation in 1st Trisector = 6.8361 Inches
Precipitation in 2nd Trisector = 1.5741 Inches
Precipitation in 3rd Trisector = 0.6258 Inches
Total Precipitation = 9.0360 Inches


24-Hour Independent Storm Duration
Time-to-Peak Exceedance Probability = 0.5
Incremental Precipitation (Inches)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
26.00
28.00
30.00
32.00
34.00
36.00
38.00
40.00
42.00
44.00
46.00
48.00
50.00
52.00
54.00
56.00
58.00
60.00
62.00
64.00
66.00
68.00
70.00
72.00
Time (Hours)
0.5 Exceedance Probability
0.2 Exceedance Probability

Basin Creek Reservoir Improvements

HEC-HMS Output Summary Tables – Revised per July 11, 2005 Peer Review Letter

18 Hour total storm duration: 0.2 EP hyetograph & 0.5 EP time to peak

HMS * Summary of Results for Reservoir Existing

Project: Russ-Test Run Name: 18-hr Storm 0.2 EP Reservoir: Existing

Start of Run:	12Jun99 1200	Basin Model:	BC-Dam1
End of Run:	13Jun99 0600	Met. Model:	18-hr Storm 0.2 EP
Execution Time	16Aug05 1126	Control Specs:	Ps18-Hour Storm Dur

Volume Units: (•) Inches ( ) Acre-Feet

Computed Results

Peak Inflow:	1496.7	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1630	
Peak Stage:					
Peak Outflow:	1305.8	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1730	
Total Inflow:	1.36	(in)	Peak Storage:	134.57	(ac-ft)
Total Outflow:	1.25	(in)	Peak Elevation:	5874.4	(ft)

Print Close

18 Hour total storm duration: 0.5 EP hyetograph & time to peak

HMS * Summary of Results for Reservoir Existing

Project: Russ-Test Run Name: Ps18hr Reservoir: Existing

Start of Run:	12Jun99 1200	Basin Model:	BC-Dam1
End of Run:	13Jun99 0600	Met. Model:	Ps18-hr Total Dur
Execution Time	16Aug05 1127	Control Specs:	Ps18-Hour Storm Dur

Volume Units: (•) Inches ( ) Acre-Feet

Computed Results

Peak Inflow:	1095.6	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1630	
Peak Stage:					
Peak Outflow:	930.29	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1745	
Total Inflow:	1.04	(in)	Peak Storage:	119.55	(ac-ft)
Total Outflow:	0.94	(in)	Peak Elevation:	5874.2	(ft)

Print Close

72 Hour total storm duration: 0.2 EP hyetograph & 0.5 EP time to peak

HMS * Summary of Results for Reservoir Existing

Project: Russ-Test Run Name: Ps24-hr 0.2 EP Reservoir: Existing

Start of Run:	12Jun99 1200	Basin Model:	BC-Dam1
End of Run:	15Jun99 1200	Met. Model:	Ps24 0.2 EP
Execution Time	16Aug05 1131	Control Specs:	Ps72-hr Ttl Dur

Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	625.74	(cfs)	Date/Time of Peak Inflow:	13 Jun 99 0700	
Peak Stage:					
Peak Outflow:	539.83	(cfs)	Date/Time of Peak Outflow:	13 Jun 99 0800	
Total Inflow:	0.95	(in)	Peak Storage:	97.126	(ac-ft)
Total Outflow:	0.87	(in)	Peak Elevation:	5873.8	(ft)

Print Close

72 Hour total storm duration: 0.5 EP hyetograph & time to peak

HMS * Summary of Results for Reservoir Existing

Project: Russ-Test Run Name: Ps72-hr Ttl Dur Reservoir: Existing

Start of Run:	12Jun99 1200	Basin Model:	BC-Dam1
End of Run:	15Jun99 1200	Met. Model:	Ps72-hour Total Dur
Execution Time	16Aug05 1133	Control Specs:	Ps72-hr Ttl Dur

Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	299.48	(cfs)	Date/Time of Peak Inflow:	13 Jun 99 0645	
Peak Stage:					
Peak Outflow:	271.10	(cfs)	Date/Time of Peak Outflow:	13 Jun 99 0800	
Total Inflow:	0.69	(in)	Peak Storage:	75.200	(ac-ft)
Total Outflow:	0.60	(in)	Peak Elevation:	5873.4	(ft)

Print Close

18 Hour total storm duration: 0.5 EP hyetograph & time to peak

HMS * Summary of Results for Reservoir Prop-3.5x9

Project: Russ-Test Run Name: Ps18hr Reservoir: Prop-3.5x9

Start of Run:	12Jun99 1200	Basin Model:	BC-Dam1
End of Run:	13Jun99 0600	Met. Model:	Ps18-hr Total Dur
Execution Time	16Aug05 1115	Control Specs:	Ps18-Hour Storm Dur

Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	1095.6	(cfs)	Date/Time of Peak Inflow:	12 Jun 99 1630	
Peak Stage:					
Peak Outflow:	919.80	(cfs)	Date/Time of Peak Outflow:	12 Jun 99 1800	
Total Inflow:	1.04	(in)	Peak Storage:	352.40	(ac-ft)
Total Outflow:	0.96	(in)	Peak Elevation:	5873.9	(ft)

Print Close

72 Hour total storm duration: 0.5 EP hyetograph & time to peak

HMS * Summary of Results for Reservoir Prop-3.5x9

Project: Russ-Test Run Name: Ps72-hr Ttl Dur Reservoir: Prop-3.5x9

Start of Run:	12Jun99 1200	Basin Model:	BC-Dam1
End of Run:	15Jun99 1200	Met. Model:	Ps72-hour Total Dur
Execution Time	16Aug05 1122	Control Specs:	Ps72-hr Ttl Dur

Volume Units: Inches Acre-Feet

Computed Results

Peak Inflow:	299.48	(cfs)	Date/Time of Peak Inflow:	13 Jun 99 0645	
Peak Stage:					
Peak Outflow:	215.38	(cfs)	Date/Time of Peak Outflow:	13 Jun 99 1000	
Total Inflow:	0.69	(in)	Peak Storage:	303.93	(ac-ft)
Total Outflow:	0.64	(in)	Peak Elevation:	5873.0	(ft)

Print Close

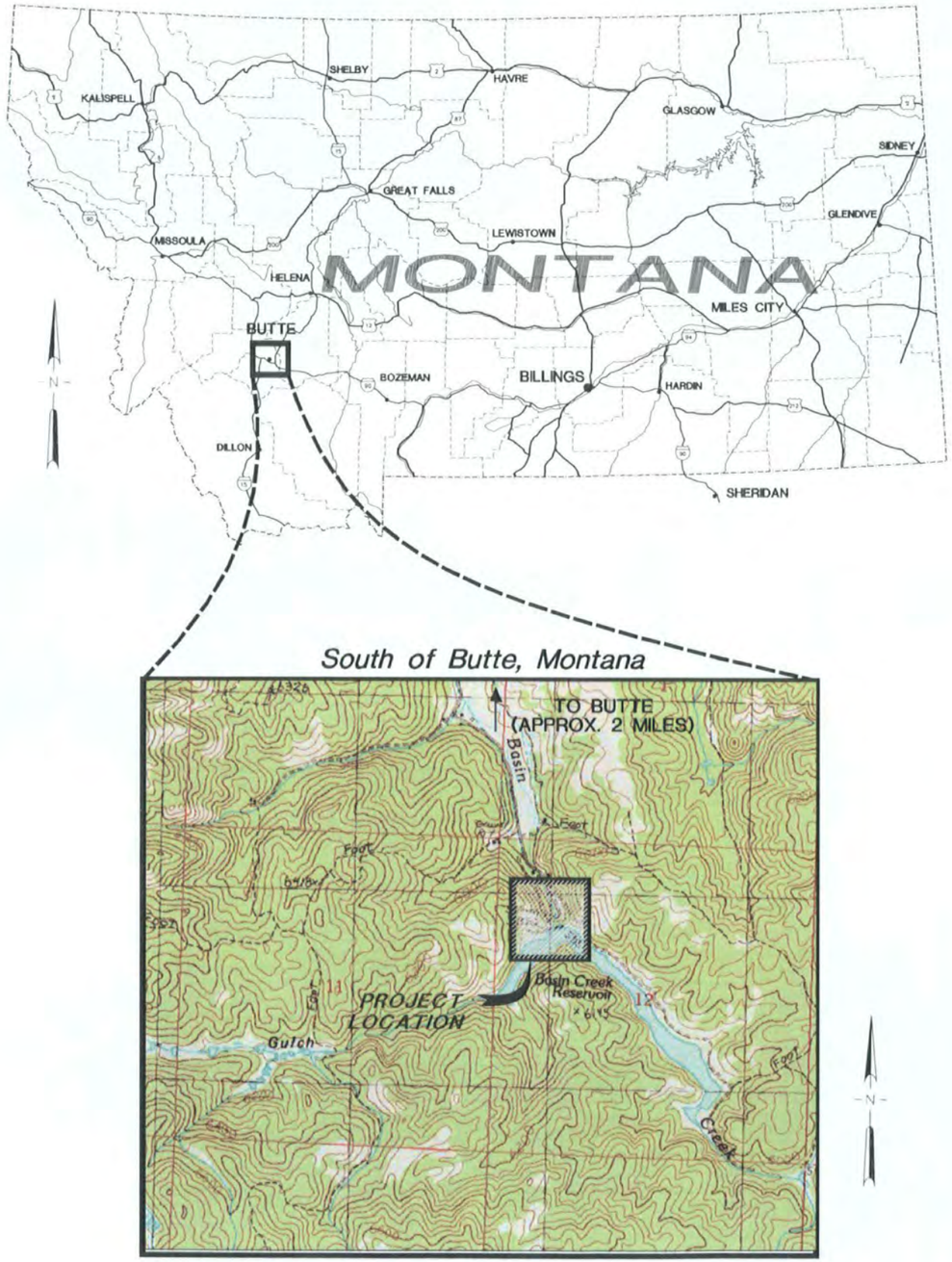
APPENDIX P

Historic Basin Creek Dam Photos

BASIN CREEK DAM. JUNE 11, 1893.

APPENDIX Q

Miscellaneous Dam Historic and Record Drawings



LOCATION MAP

NOT TO SCALE

Construction Drawings for BASIN CREEK RESERVOIR IMPROVEMENTS

BUTTE - SILVER BOW (BSB), MONTANA

PREPARED FOR:
BUTTE - SILVER BOW PUBLIC WORKS DEPARTMENT

FUNDED BY:
NATURAL RESOURCE DAMAGE PROGRAM

PREPARED BY:

HKM Engineering Inc.
1015 S. Montana St.
P.O. Box 3588
Butte, MT 59702
(406) 723-8213
FAX (406) 723-8328

PROJECT NO. 15M424.117

MONTANA RUSSELL CHRISTIAN REED 15740PE LICENSED PROFESSIONAL ENGINEER

RUSSELL C. REED 15740 P.E.
Project Manager
HKM ENGINEERING Inc.

JULY 2005

RECORD DRAWING
SEPTEMBER 2006

Sheet No.
G-1R

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LEGEND

- 5870 = EXISTING GROUND CONTOURS
- = EXISTING CONCRETE
- OHP = EXISTING OVERHEAD POWER
- PWR = EXISTING UNDERGROUND POWER
- x = EXISTING FENCE
- CP-16 = SURVEY CONTROL POINT

PIPING LEGEND

- LARGER PIPING (4" AND OVER)
- FLANGED CONNECTION
- BUTTERFLY VALVE
- GATE VALVE

SHEET INDEX

SHT. NO.	TITLE
G-1R	COVER SHEET
G-2R	SHEET INDEX, LEGEND, & ABBREVIATIONS
G-3R	PROJECT OVERVIEW
G-4R	EXISTING SITE CONDITIONS
G-5R	SITE PLAN AND SHEET REFERENCES
S-1R	GENERAL STRUCTURAL NOTES AND STANDARD DETAILS
S-2R	SPILLWAY PLAN VIEW DEMOLITION DETAILS
S-3R	SPILLWAY STRUCTURE PLAN AND PROFILE
S-4R	SPILLWAY STRUCTURE PLAN
S-5R	SPILLWAY STRUCTURE SECTIONS
S-6R	SPILLWAY STRUCTURE DEMOLITION AND SECTIONS
S-7R	STAIRCASE PLAN, PROFILE AND DETAILS
S-8R	STAIRCASE SECTIONS AND DETAILS
XS-1R	SPILLWAY CROSS SECTIONS STATIONS 1+20 TO 1+60
XS-2R	SPILLWAY CROSS SECTIONS STATIONS 1+65 TO 2+00
M-1R	MECHANICAL BUILDING PLAN, ELEVATIONS AND DETAILS
M-2R	MECHANICAL BUILDING LAYOUT
M-3R	MECHANICAL BUILDING SECTIONS AND MATERIALS DESCRIPTION
M-4R	AIR LINE DETAILS DAM PENETRATION
M-5R	FACE OF DAM CONDUIT LAYOUT AND DETAILS
M-6R	EXISTING DAM SECTION AND DEMOLITION
M-7R	INTAKE SECTIONS AND DETAILS
M-8R	OUTLET WORKS DEMOLITION DETAILS AND LIMITS
M-9R	NEW PIPING PLAN
M-10R	MISCELLANEOUS DETAILS
E-1	MECHANICAL BUILDING LIGHTING & POWER PLANS
E-2	ELECTRICAL ONE-LINE DIAGRAM
E-3	ELECTRICAL SCHEDULES AND LEGEND

ABBREVIATIONS

ASS'Y	ASSEMBLY	N.T.S.	NOT TO SCALE
AVV	AIR/VACUUM VALVE	O.C.	ON CENTER
BM	BENCH MARK	PCP	PLANT CONTROL PANEL
BTM	BOTTOM	PE	PLAIN END
BFV	BUTTERFLY VALVE	PSI	POUNDS PER SQUARE INCH
CONC.	CONCRETE	PVC	POLYVINYL CHLORIDE PIPE
D.I.P.	DUCTILE IRON PIPE	PWR	UNDER GROUND POWER
DIA.	DIAMETER	RED'R	REDUCER
E	EASTING	R/W	RIGHT OF WAY
ELEV.	ELEVATION	REST.	RESTORATION
EXIST.	EXISTING	RT	RIGHT
FLG.	FLANGE	SCH	SCHEDULE
FT	FEET	SP	SLUDGE PUMP
GAL	GALLON	SR	SHORT RADIUS
GPD	GALLONS PER DAY	SURF.	SURFACE
GPH	GALLONS PER HOUR	TEL	UNDER GROUND TELEPHONE
GPM	GALLONS PER MINUTE	TYP.	TYPICAL
G.S.P.	GALVENIZED STEEL PIPE	V	VOLT
HP	HORSEPOWER	W	WATER
LF	LINEAL FEET	W/	WITH
LR	LONG RADIUS	W.S.	WELDED STEEL
MCC	MOTOR CONTROL CENTER	WTP	WATER TREATMENT PLANT
N	NORTHING	X-ING	CROSSING
NPT	NATIONAL PIPE THREAD		

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SHEET INDEX, LEGEND, AND ABBREVIATIONS

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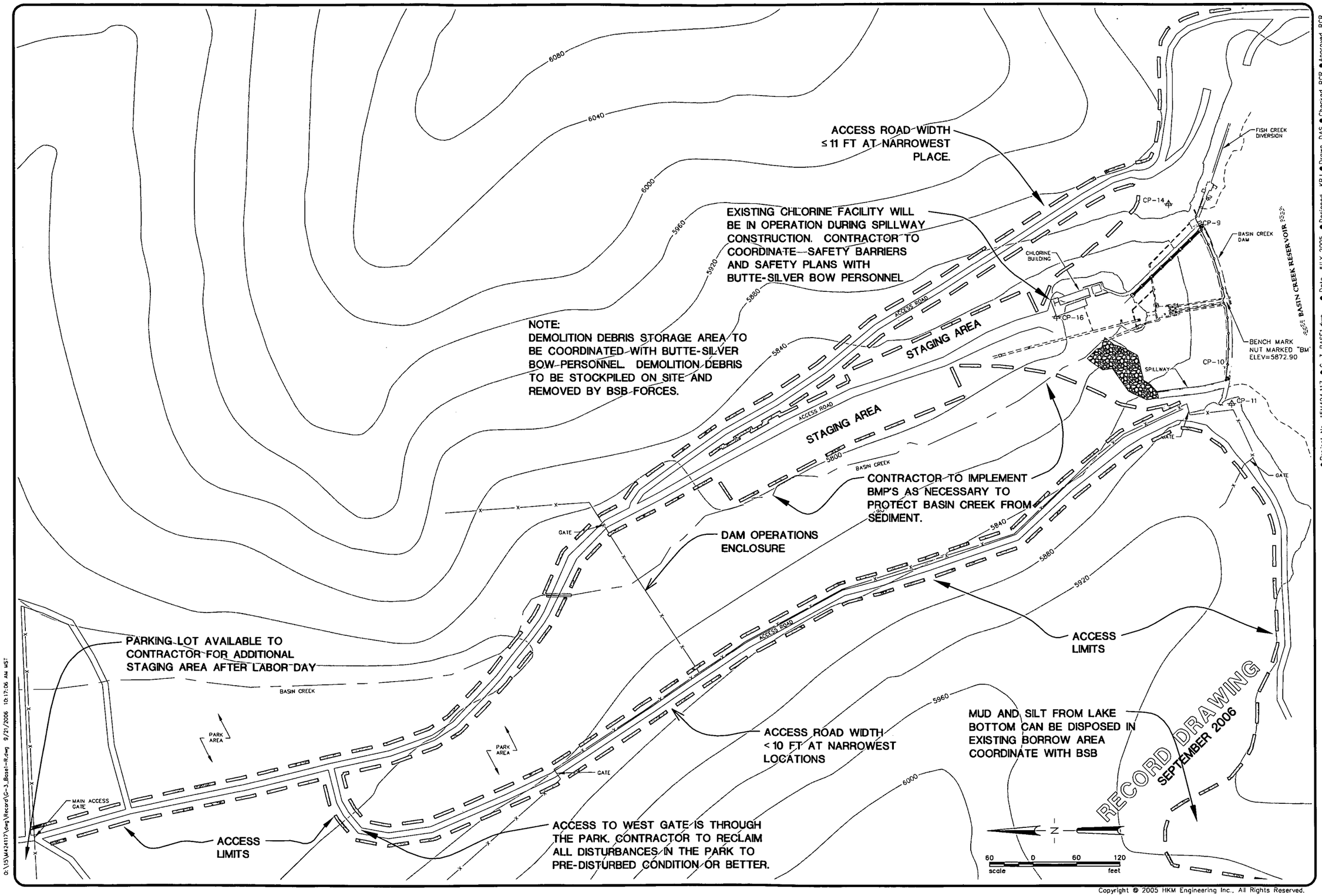

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

PROJECT OVERVIEW

• Project No. 15M424.117 • C-3_BASE1.dwg • Date JULY 2005 • Designed KRJ • Drawn DAS • Checked RCR • Approved RCR

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HKM SURVEY CONTROL POINTS

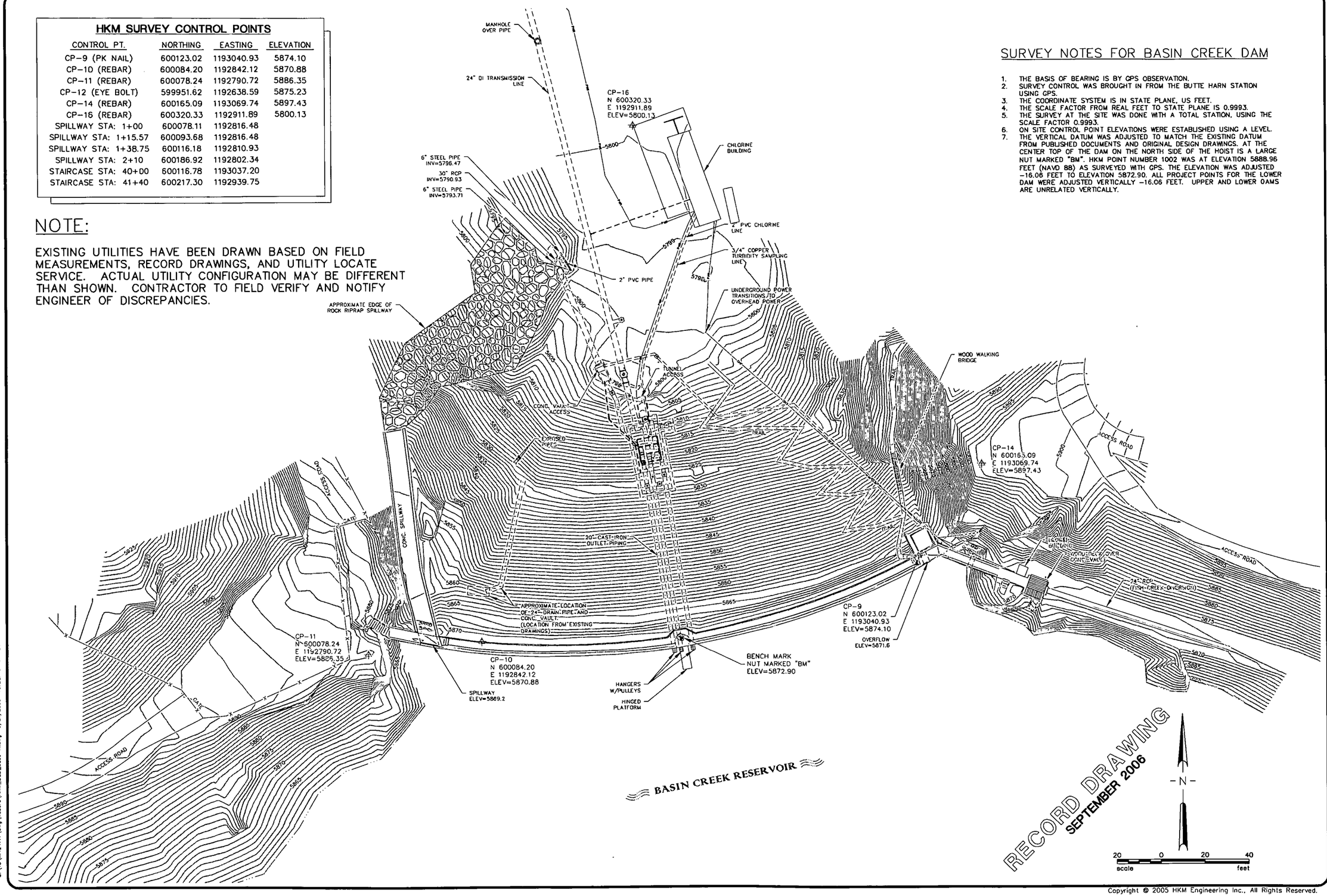
CONTROL PT.	NORTHING	EASTING	ELEVATION
CP-9 (PK NAIL)	600123.02	1193040.93	5874.10
CP-10 (REBAR)	600084.20	1192842.12	5870.88
CP-11 (REBAR)	600078.24	1192790.72	5886.35
CP-12 (EYE BOLT)	599951.62	1192638.59	5875.23
CP-14 (REBAR)	600165.09	1193069.74	5897.43
CP-16 (REBAR)	600320.33	1192911.89	5800.13
SPILLWAY STA: 1+00	600078.11	1192816.48	
SPILLWAY STA: 1+15.57	600093.68	1192816.48	
SPILLWAY STA: 1+38.75	600116.18	1192810.93	
SPILLWAY STA: 2+10	600186.92	1192802.34	
STAIRCASE STA: 40+00	600116.78	1193037.20	
STAIRCASE STA: 41+40	600217.30	1192939.75	

NOTE:

EXISTING UTILITIES HAVE BEEN DRAWN BASED ON FIELD MEASUREMENTS, RECORD DRAWINGS, AND UTILITY LOCATE SERVICE. ACTUAL UTILITY CONFIGURATION MAY BE DIFFERENT THAN SHOWN. CONTRACTOR TO FIELD VERIFY AND NOTIFY ENGINEER OF DISCREPANCIES.

SURVEY NOTES FOR BASIN CREEK DAM

1. THE BASIS OF BEARING IS BY GPS OBSERVATION.
2. SURVEY CONTROL WAS BROUGHT IN FROM THE BUTTE HARN STATION USING GPS.
3. THE COORDINATE SYSTEM IS IN STATE PLANE, US FEET.
4. THE SCALE FACTOR FROM REAL FEET TO STATE PLANE IS 0.9993.
5. THE SURVEY AT THE SITE WAS DONE WITH A TOTAL STATION, USING THE SCALE FACTOR 0.9993.
6. ON SITE CONTROL POINT ELEVATIONS WERE ESTABLISHED USING A LEVEL.
7. THE VERTICAL DATUM WAS ADJUSTED TO MATCH THE EXISTING DATUM FROM PUBLISHED DOCUMENTS AND ORIGINAL DESIGN DRAWINGS. AT THE CENTER TOP OF THE DAM ON THE NORTH SIDE OF THE HOIST IS A LARGE NUT MARKED "BM". HKM POINT NUMBER 1002 WAS AT ELEVATION 5888.96 FEET (NAVD 88) AS SURVEYED WITH GPS. THE ELEVATION WAS ADJUSTED -16.06 FEET TO ELEVATION 5872.90. ALL PROJECT POINTS FOR THE LOWER DAM WERE ADJUSTED VERTICALLY -16.06 FEET. UPPER AND LOWER DAMS ARE UNRELATED VERTICALLY.



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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

EXISTING SITE CONDITIONS

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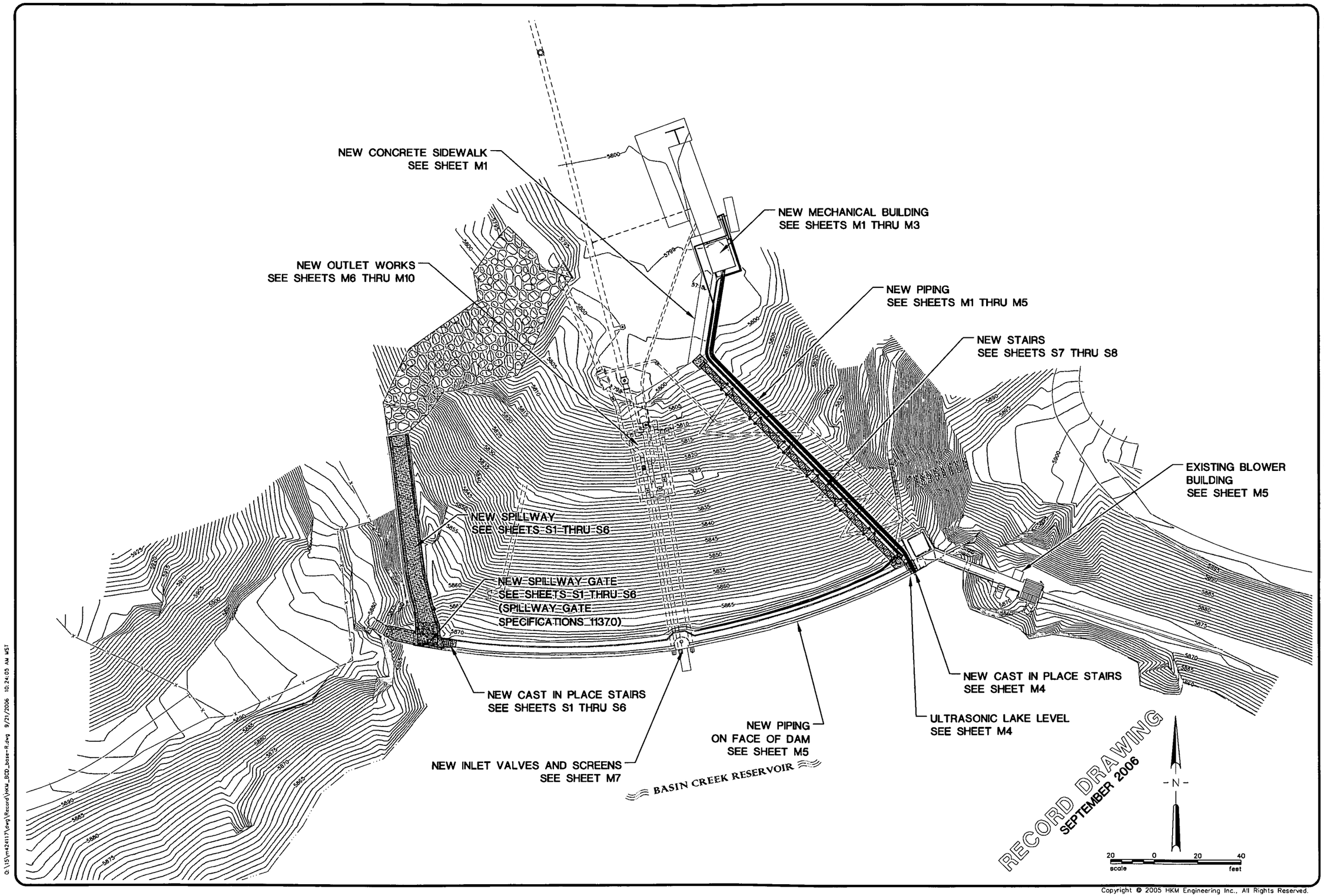

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SITE PLAN AND SHEET REFERENCES

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GENERAL STRUCTURAL NOTES

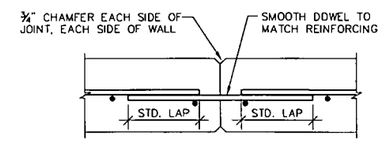
1. APPLICABLE SPECIFICATIONS AND CODES
   CONSTRUCTION AND DESIGN SHALL BE IN ACCORDANCE WITH THE AMERICAN CONCRETE INSTITUTE SPECIFICATIONS AND THE REQUIREMENTS NOTED AS FOLLOWS.
2. CONSTRUCTION LOADS
   PROVIDE TEMPORARY BRACING, SHORING OR OTHER SUPPLEMENTAL SUPPORT DURING CONSTRUCTION AS NECESSARY TO PROTECT THE STRUCTURES FROM EXCESSIVE CONSTRUCTION LOADS.
3. CONCRETE
   a. CONCRETE CONSTRUCTION SHALL CONFORM TO THE AMERICAN CONCRETE INSTITUTE BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE (ACI 318).
   b. DETAILING, FABRICATION AND PLACEMENT OF REINFORCEMENT SHALL CONFORM TO DETAILS AND DETAILING OF CONCRETE REINFORCEMENT (ACI 315).
   c. MATERIALS
      i. STRUCTURAL CAST-IN-PLACE CONCRETE ----- f'c = 4,000 PSI
      ii. REINFORCING BARS ---------- ASTM A615, GRADE 60
   d. ALL BENT REINFORCING BARS SHALL BE SHOP FABRICATED ONLY. REBENDING OR WELDING OF REINFORCEMENT SHALL NOT BE PERMITTED UNLESS AUTHORIZED BY ENGINEER.
   e. END HOOKS IN REINFORCING BARS, SHOWN ON THE DRAWINGS BUT NOT DIMENSIONED, SHALL CONFORM TO ACI 318.
   f. CONCRETE COVER OVER REINFORCEMENT SHALL BE 2" CLEAR, EXCEPT CONCRETE PLACED AGAINST AND PERMENENTLY IN CONTACT WITH EARTH SHALL BE 3" CLEAR.
   g. REINFORCEMENT SPLICES NOT PERMITTED EXCEPT AS DETAILED OR AUTHORIZED BY ENGINEER. LAP REINFORCING BARS THE FOLLOWING MINIMUMS AT ALL SPLICES, CORNERS AND INTERSECTIONS, UNLESS OTHERWISE INDICATED. TOP BARS ARE HORIZONTAL BARS WITH MORE THAN 12" OF CONCRETE CAST BELOW THE BAR.

BAR SIZE	REG. BARS	TOP BARS
#3	1'-3"	1'-7"
#4	1'-7"	2'-1"
#5	2'-0"	2'-7"
#6	2'-5"	3'-1"
#7	3'-6"	4'-6"
#8	4'-0"	5'-2"
#9	4'-6"	5'-10"
#10	5'-1"	6'-7"

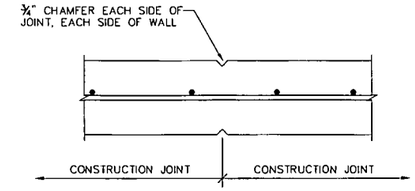
   h. STAGGER ADJACENT REINFORCEMENT LAP SPLICES IN WALLS 18" MINIMUM.
   i. PROVIDE BAR SUPPORTS TO PROPERLY SECURE AND SUPPORT REINFORCING BARS AT POSITIONS SHOWN ON THE DRAWINGS. IN ADDITION TO NORMAL ACCESSORIES PROVIDE #5 STANDEES AT 36" O.C. TO SUPPORT TOP REINFORCEMENT IN BASE SLABS, AND #3 U OR Z SHAPE SPACERS AT 72" O.C. EACH WAY IN WALLS WITH TWO CURTAINS OF REINFORCEMENT.
   j. DOWELS, PIPES AND OTHER INSTALLED MATERIALS AND ACCESSORIES SHALL BE HELD SECURELY IN POSITION DURING CONCRETE PLACEMENT.
   k. REINFORCING BARS AND ACCESSORIES SHALL NOT BE IN CONTACT WITH ANY PIPE, PIPE FLANGE OR METAL PART EMBEDDED IN CONCRETE. PROVIDE 2" CLEARANCE IN ALL CASES UNLESS OTHERWISE INDICATED. NO EMBEDDED ITEM SHALL BE SUSPENDED FROM, SUPPORTED BY, OR BRACED IN PLACE FROM THE STRUCTURAL REINFORCEMENT.
   l. LOCATE CONSTRUCTION JOINTS AT 15'-0" O.C. , WHERE SHOWN ON THE DRAWINGS OR AS AUTHORIZED BY ENGINEER. SLABS, JOISTS AND BEAMS SHALL NOT HAVE JOINTS IN A HORIZONTAL PLANE EXCEPT WHERE DETAILED ON DRAWINGS.
   m. THOROUGHLY CLEAN BY SANDBLASTING ALL BONDED CONSTRUCTION JOINTS PRIOR TO PLACING CONCRETE IN ADJACENT POUR.
   n. BEGIN SPACING OF BARS WHICH PARALLEL CONSTRUCTION AND EXPANSION JOINTS 2" CLEAR FROM EACH SIDE OF JOINT.
   o. UNLESS OTHERWISE SHOWN, PLACE 2-#5 (1 EACH FACE) WITH 2'-0" PROJECTIONS AROUND ALL OPENINGS IN CONCRETE WALLS OR SLABS.
   p. PROVIDE AN ADDITIONAL 100 LINEAL FEET OF #5 REINFORCING BARS FOR USE AS DIRECTED DURING CONSTRUCTION.
   q. CHAMFER ALL EXPOSED CONCRETE EDGES 3/4", UNLESS OTHERWISE INDICATED.
4. STRUCTURAL STEEL
   a. STRUCTURAL STEEL CONSTRUCTION SHALL CONFORM TO THE AMERICAN INSTITUTE OF STEEL CONSTRUCTION SPECIFICATION FOR THE DESIGN, FABRICATION AND ERECTION OF STRUCTURAL STEEL FOR BUILDINGS.
   b. ALL WELDING SHALL CONFORM TO AMERICAN WELDING SOCIETY STRUCTURAL WELDING CODE-STEEL (AWS D1.1), AND SHALL BE PERFORMED BY WELDERS QUALIFIED BY THE APPROPRIATE AWS TEST FOR THE WELDING PERFORMED.
   c. ALL EXPOSED STEEL SHALL HAVE A HOT-DIP ZINC COATING IN ACCORDANCE WITH ASTM A123.
   d. ADHESIVE ANCHORS SHALL BE HILTI HVA ADHESIVE ANCHORS WITH HAS 316 SS RODS OR APPROVED EQUAL.
5. EXISTING CONSTRUCTION
   a. DIMENSIONS, ELEVATIONS AND DETAILS OF EXISTING CONSTRUCTION HAVE BEEN OBTAINED FROM FIELD INVESTIGATIONS AND AS-CONSTRUCTED DOCUMENTS. THE CONTRACTOR SHALL VERIFY ALL EXISTING CONDITIONS NECESSARY TO PROPERLY COORDINATE NEW AND EXISTING CONSTRUCTION, AND SHALL NOTIFY THE ENGINEER OF ALL VARIATIONS IN THE DETAILS, DIMENSIONS AND ELEVATIONS OF EXISTING CONSTRUCTION WITH THAT SHOWN ON THE DRAWINGS.
   b. CLEAN AND PREPARE ALL EXISTING SURFACES WHICH WILL BE IN CONTACT WITH NEW CONSTRUCTION AS INDICATED AND AS ACCEPTABLE TO ENGINEER. APPLY BONDING COMPOUND TO ALL EXISTING CONCRETE SURFACES WHICH WILL BE IN CONTACT WITH NEW CONCRETE IMMEDIATLEY PRIOR TO PLACEMENT.
   c. PROTECT EXISTING MATERIALS FROM DAMAGE DURING CONSTRUCTION.
   d. FURNISH AND INSTALL TEMPORARY SHORING OR BRACING AS NECESSARY TO PROVIDE SUPPORT AND STABILITY FOR EXISTING WALLS AND FRAMING DURING DEMOLITION AND CONSTRUCTION.

GENERAL STRUCTURAL ABBREVIATIONS

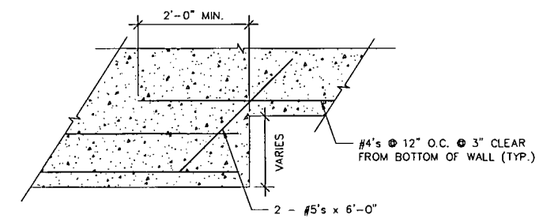
O.C.	ON CENTER
T.O.C.	TOP OF CONCRETE
T.O.F.	TOP OF FOOTING
T.O.S.	TOP OF SLAB
T.O.W.	TOP OF WALL
STD.	STANDARD
TYP.	TYPICAL
MIN.	MINIMUM
SIM.	SIMILAR
REINF.	REINFORCEMENT
SPA.	SPACES
EA.	EACH
EL.	ELEVATION
CLR.	CLEAR



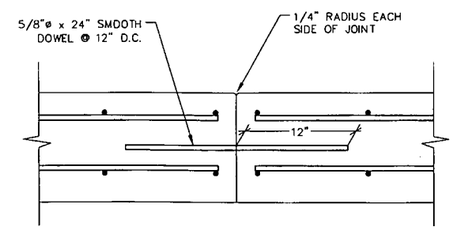
1 / S-1 DETAIL
TYPICAL SPILLWAY WALL CONSTRUCTION JOINT
NOT TO SCALE



2 / S-2 DETAIL
TYPICAL SPILLWAY WALL CONTROL JOINT
NOT TO SCALE

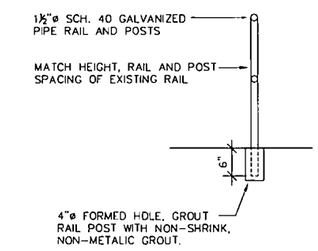


3 / S-1 DETAIL
TYPICAL STEP IN WALL
NOT TO SCALE



NOTE:
FLOOR JOINTS SHALL BE CONSTRUCTED ACROSS THE SPILLWAY AT 15-FOOT SPACING TO MATCH THE SPILLWAY WALL JOINTS.

5 / S-1 DETAIL
TYPICAL SPILLWAY FLOOR CONSTRUCTION JOINT
NOT TO SCALE



4 / S-1 DETAIL
TYPICAL PIPE RAILING
NOT TO SCALE

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

GENERAL STRUCTURAL NOTES AND STANDARD DETAILS

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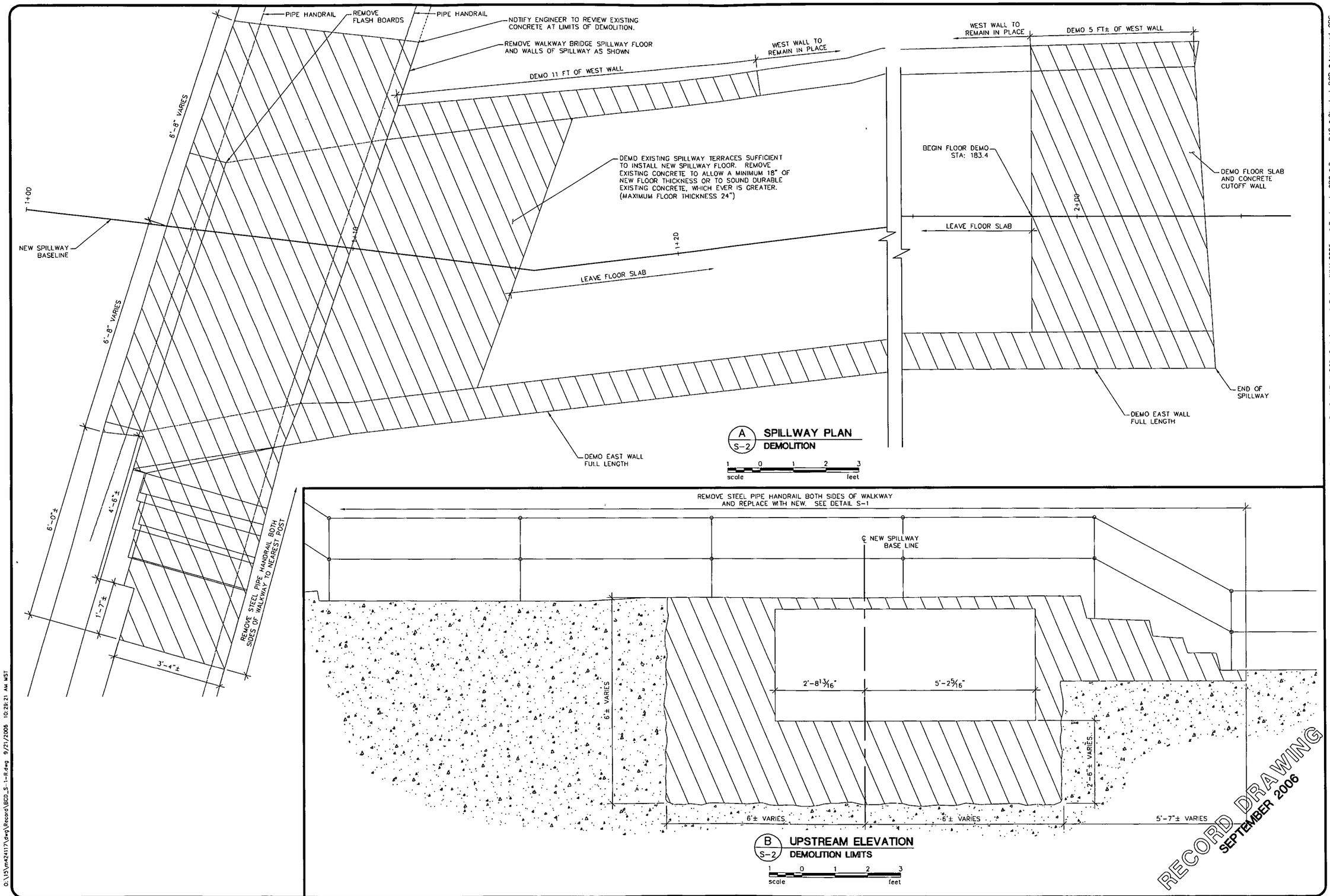

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY PLAN VIEW DEMOLITION DETAILS

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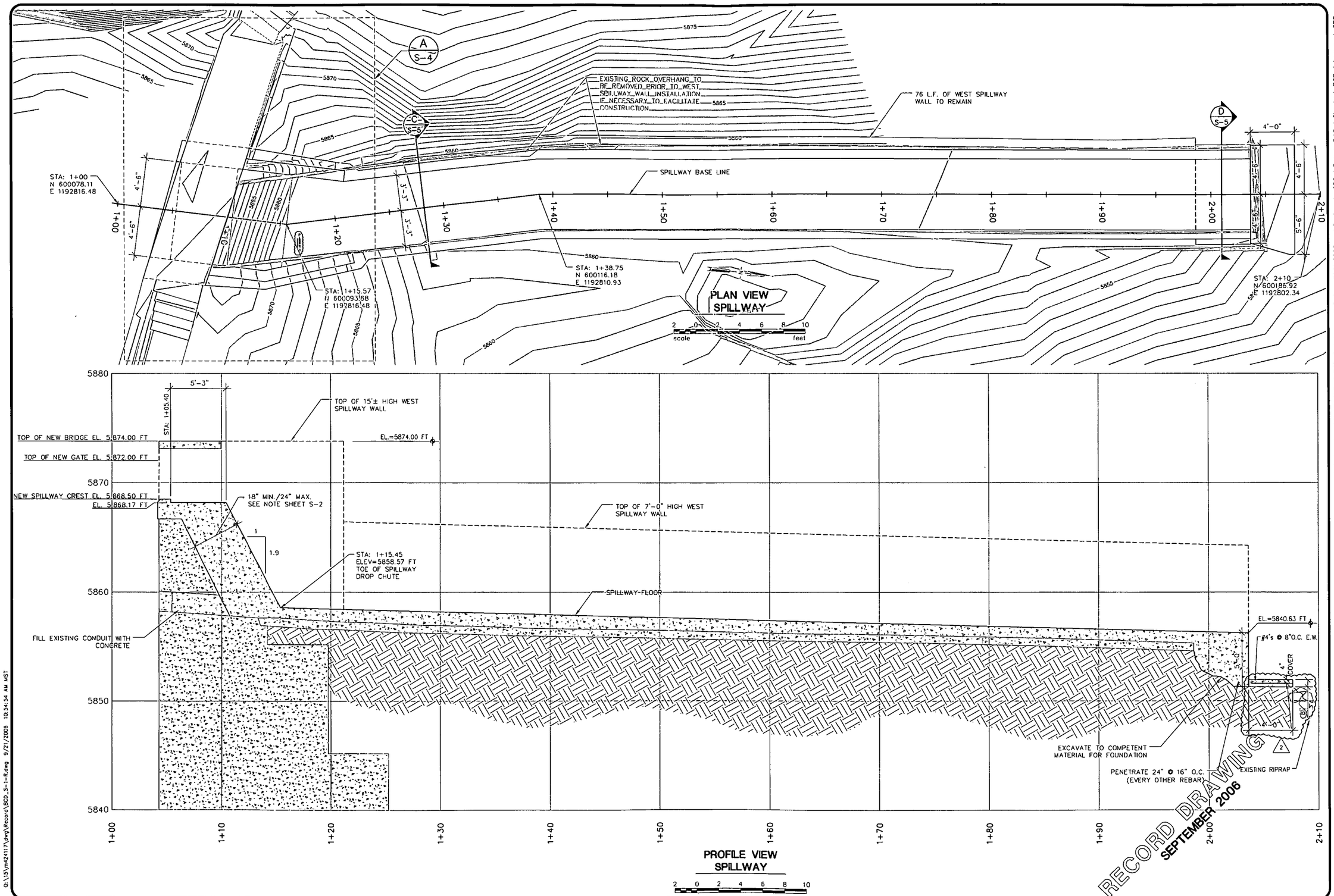

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE PLAN AND PROFILE

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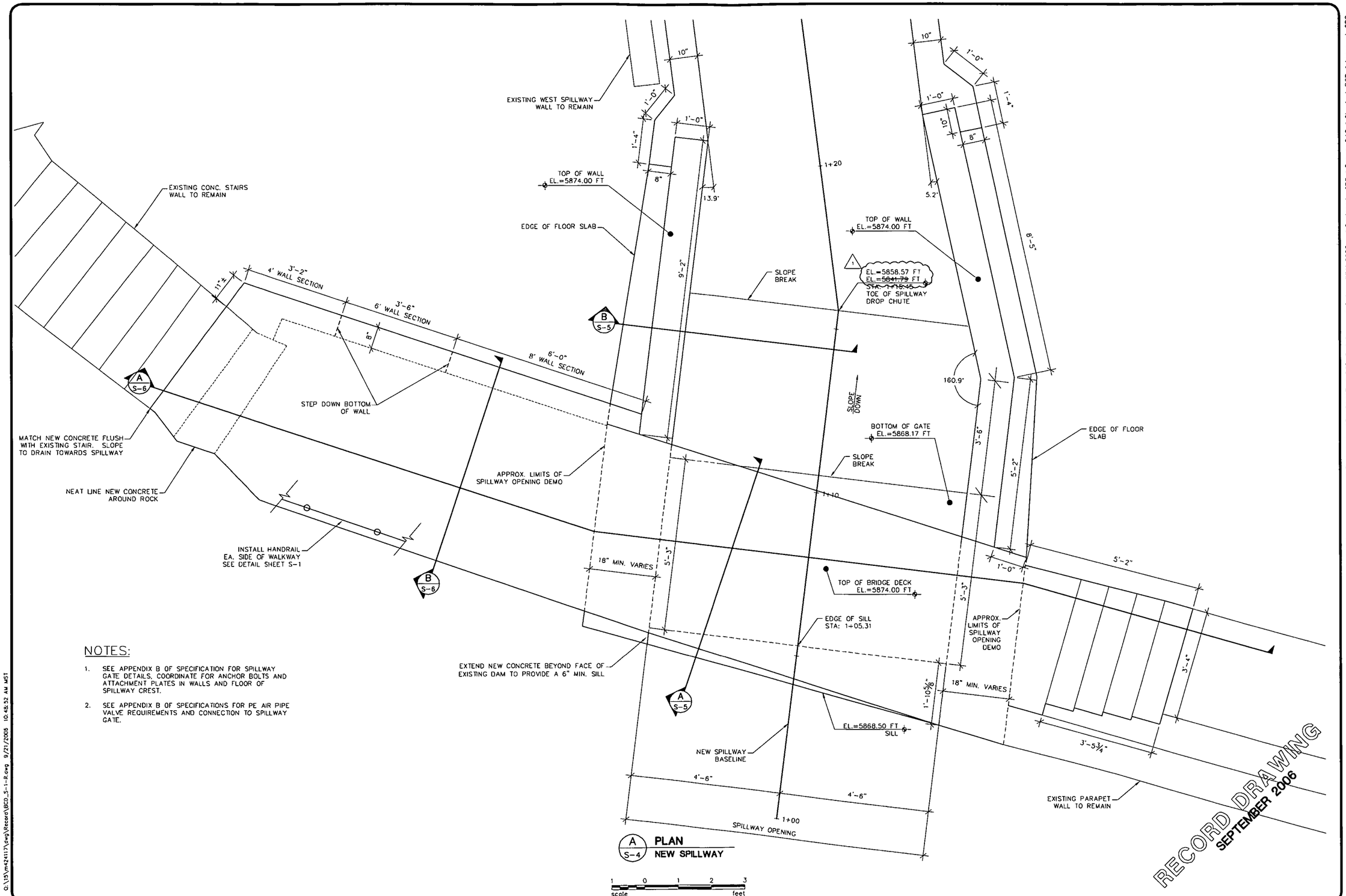

NOTES:

1. SEE APPENDIX B OF SPECIFICATION FOR SPILLWAY GATE DETAILS, COORDINATE FOR ANCHOR BOLTS AND ATTACHMENT PLATES IN WALLS AND FLOOR OF SPILLWAY CREST.
2. SEE APPENDIX B OF SPECIFICATIONS FOR PE AIR PIPE VALVE REQUIREMENTS AND CONNECTION TO SPILLWAY GATE.

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE PLAN

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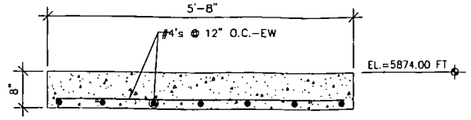
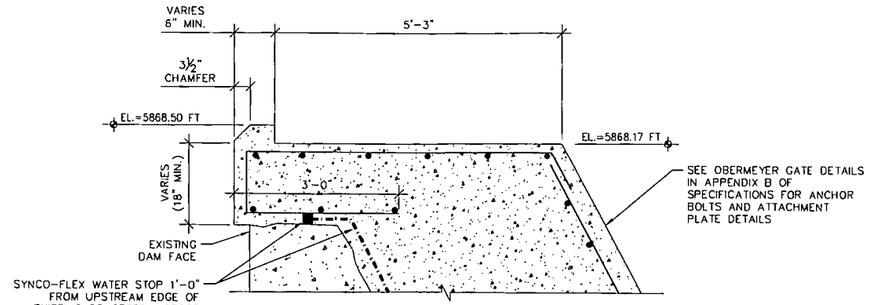
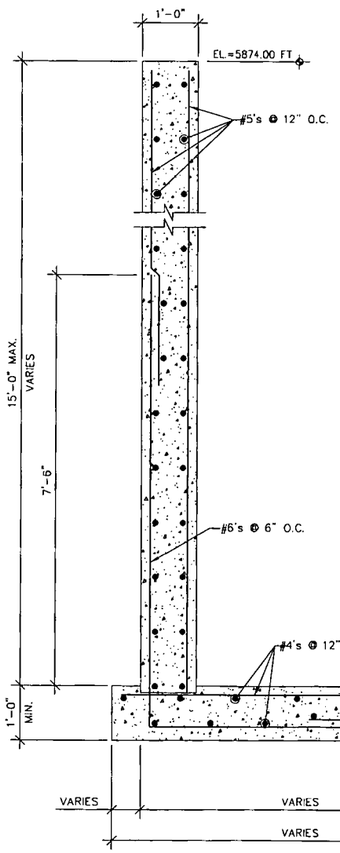




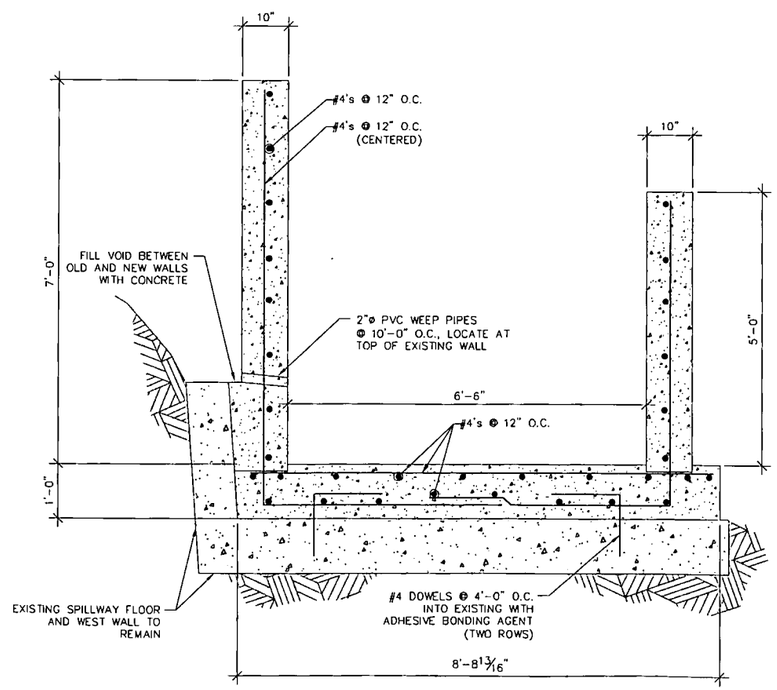
A / S-5 **SECTION**
BRIDGE

1 0 1 2 3
scale feet



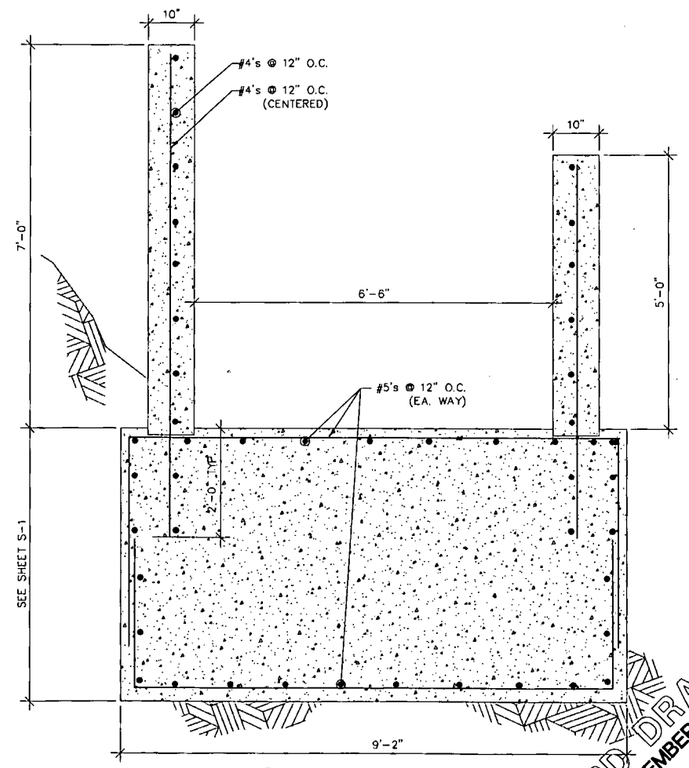
B / S-5 **SECTION**
SPILLWAY - STA: 1+29 TO STA: 1+20.9

1 0 1 2 3
scale feet



C / S-5 **SECTION**
TYPICAL SPILLWAY - STA: 1+20.9 TO STA: 1+98.6

1 0 1 2 3
scale feet



D / S-5 **SECTION**
TYPICAL SPILLWAY - STA: 1+98.6 TO STA: 2+03.6

1 0 1 2 3
scale feet

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE SECTIONS

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• Project No. 15M424.117 • BCD_S-1.dwg • Date JULY 2005 • Designed CRS • Drawn DAS • Checked RCR • Approved CRS

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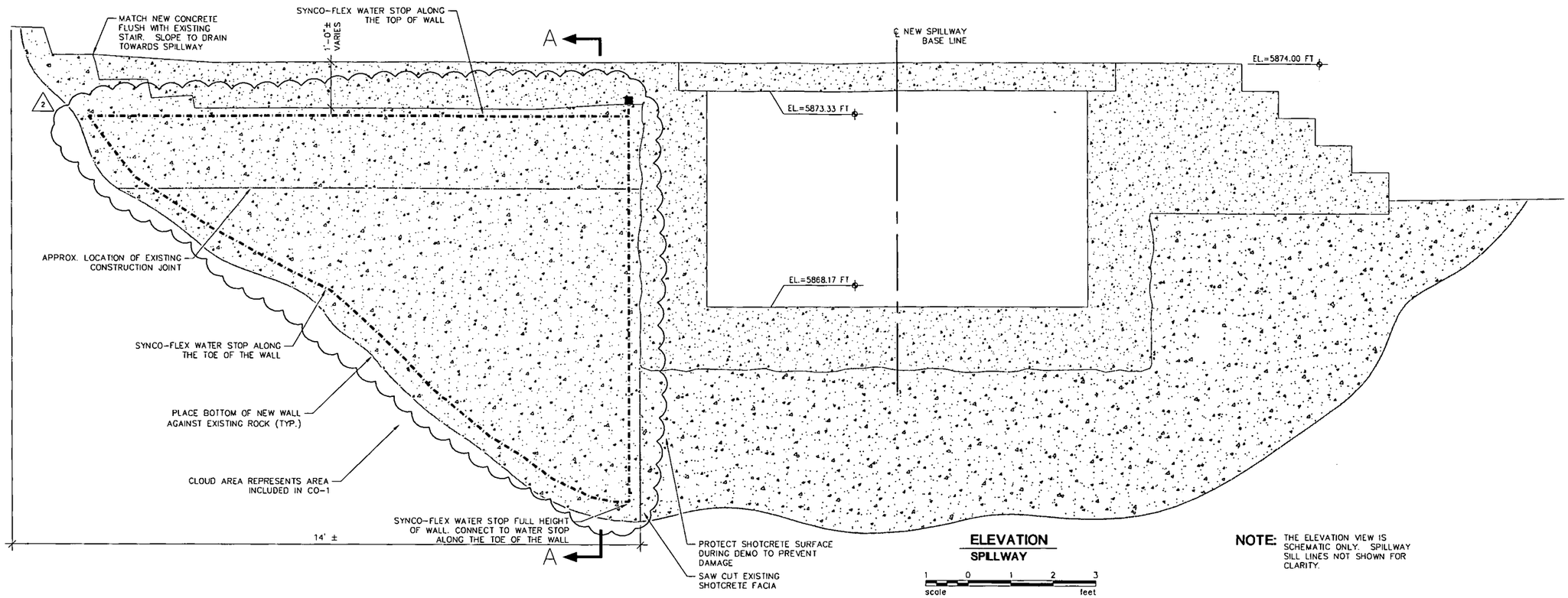
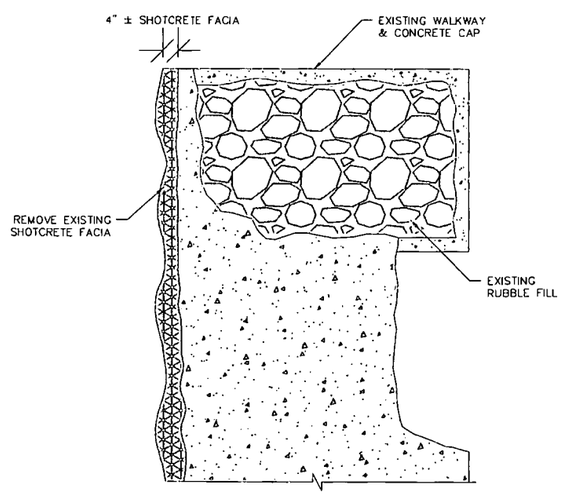
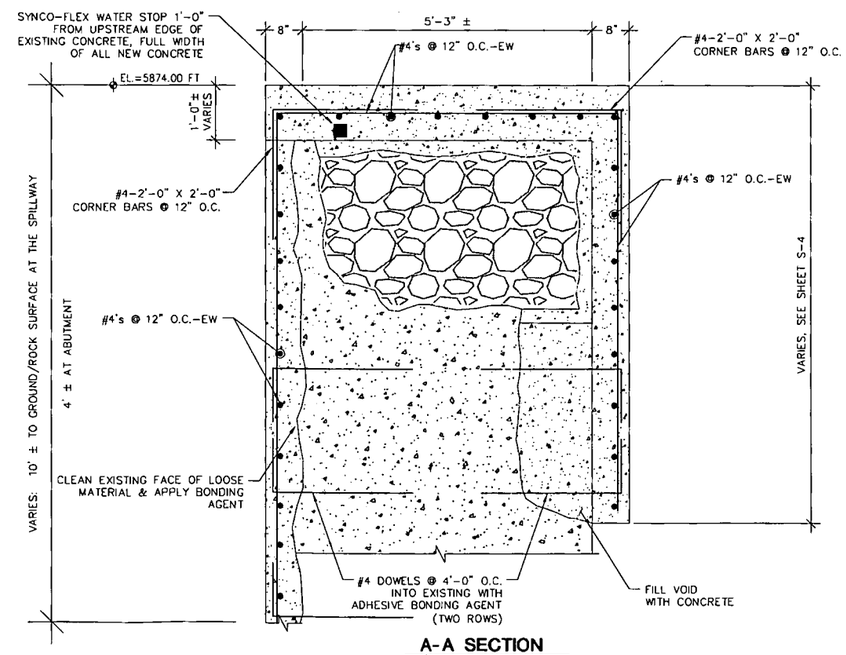


ELEVATION
SPILLWAY

NOTE: THE ELEVATION VIEW IS SCHEMATIC ONLY. SPILLWAY SILL LINES NOT SHOWN FOR CLARITY.



A-A SECTION
WALKWAY - EXISTING & DEMO



A-A SECTION
WALKWAY - NEW

RECORD DRAWING
SEPTEMBER 2006

No.	Revision	By	Date
2	REC. INFO	RCR	9/21/06
1	CO-1	RCR	9/26/05

WARNING
0 ½ 1
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY STRUCTURE DEMOLITION AND SECTIONS

• Project No. 15M424.117 • BCD_S-1.dwg • Date SEP. 2005 • Designed RCR • Drawn RCR • Checked RCR • Approved CRS

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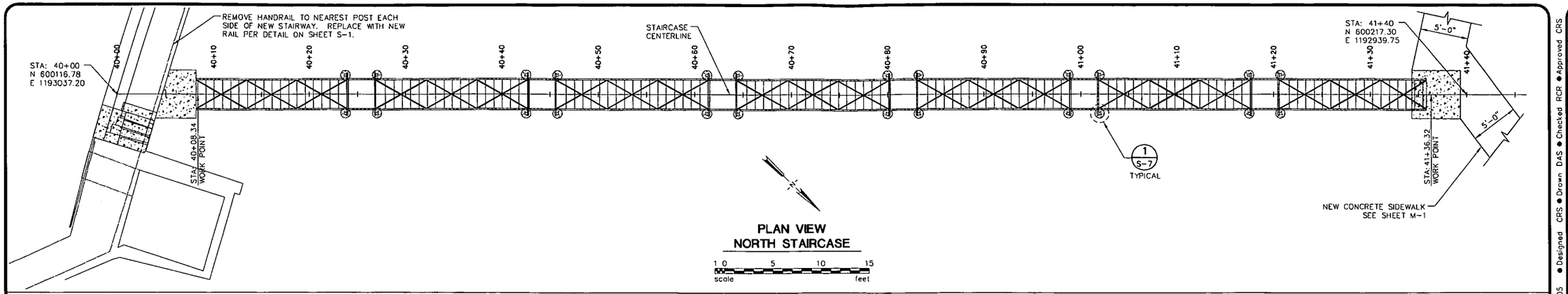
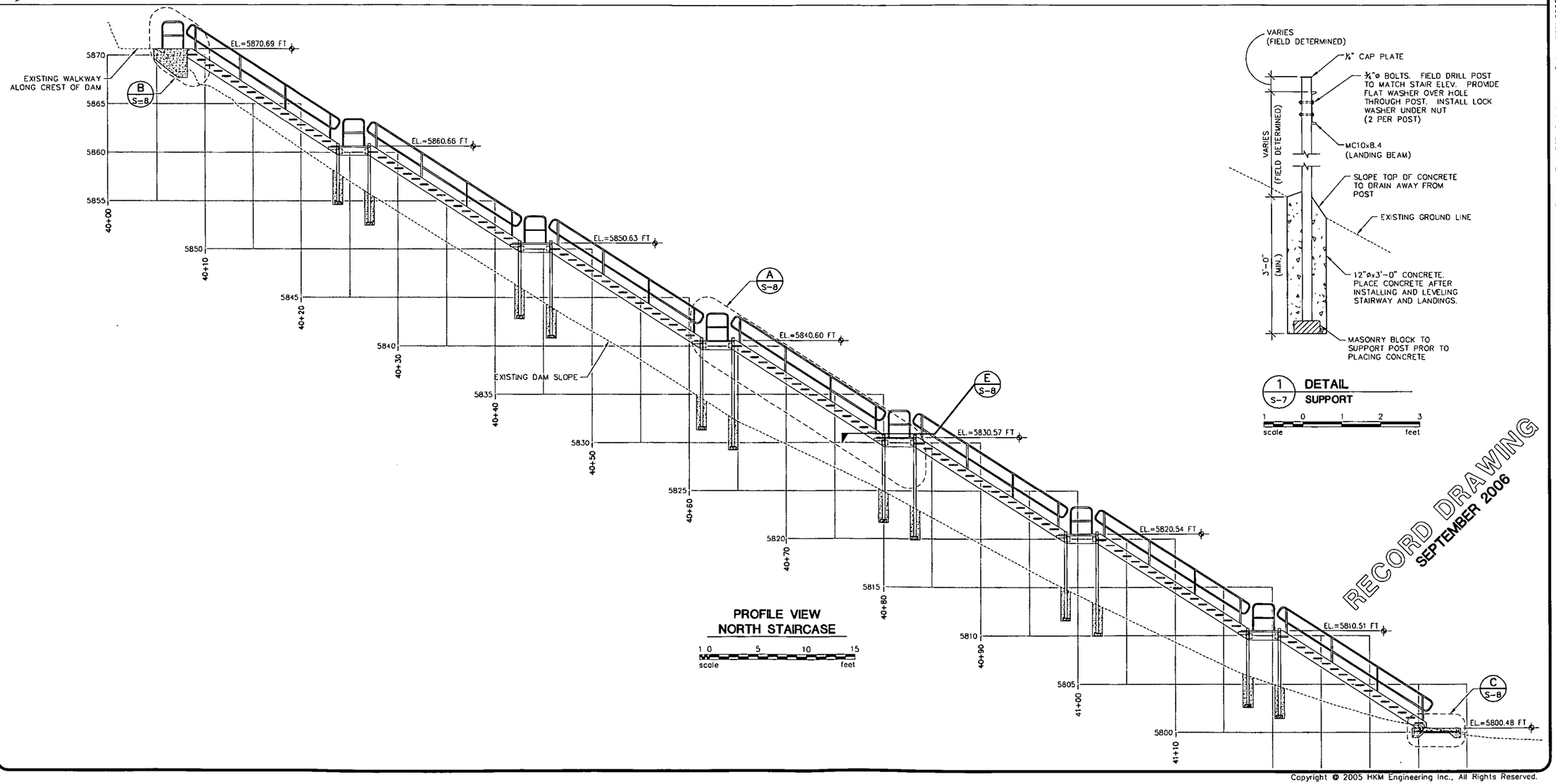


PLAN VIEW
NORTH STAIRCASE

1 0 5 10 15
scale feet



PROFILE VIEW
NORTH STAIRCASE

1 0 5 10 15
scale feet

1 S-7 **DETAIL**
SUPPORT

1 0 1 2 3
scale feet

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/05

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½
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

STAIRCASE PLAN, PROFILE AND DETAILS

MONTANA PROFESSIONAL ENGINEER
CARY R. SIMONICH
4312 E
EXPIRES 12/31/2006

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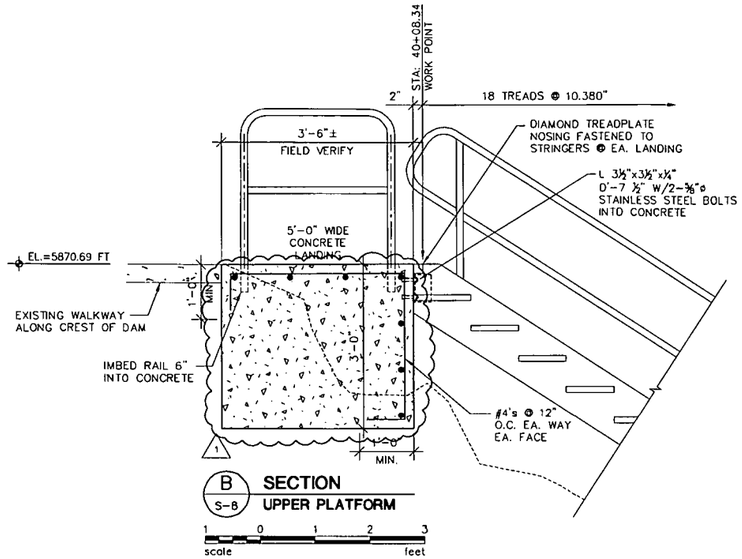

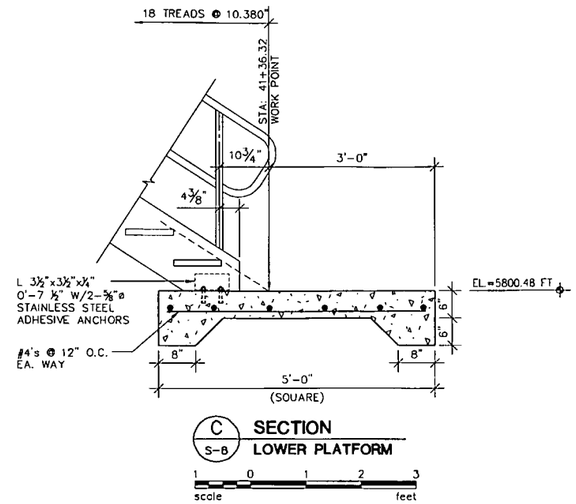

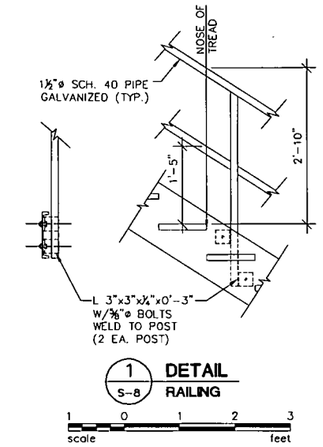

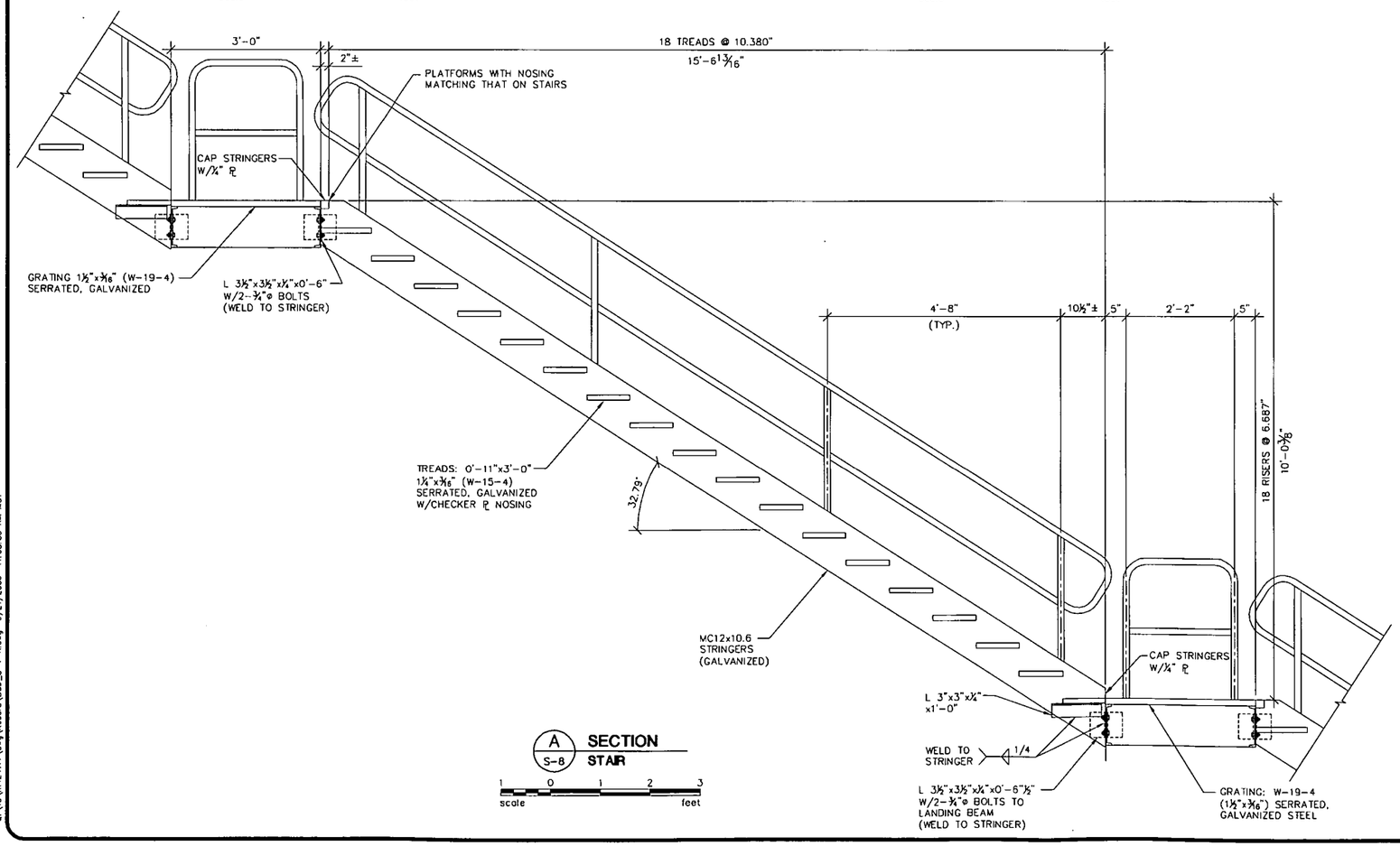

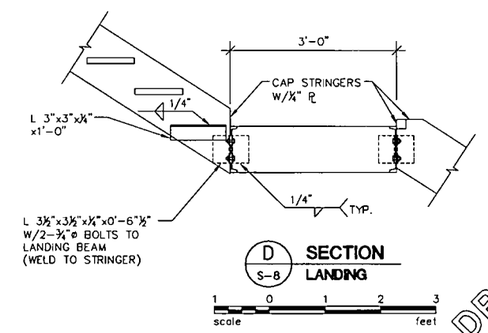

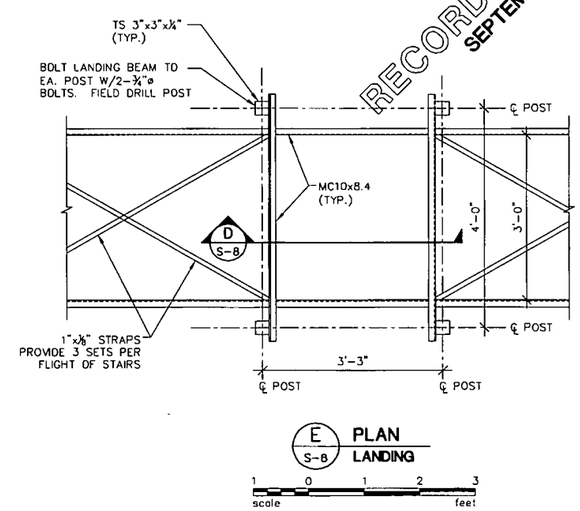

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No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

STAIRCASE SECTIONS AND DETAILS

● Project No. 15M424.117 ● BCD_S-1.dwg ● Date JULY 2005 ● Designed CRS ● Drawn DAS ● Checked RCR ● Approved CRS

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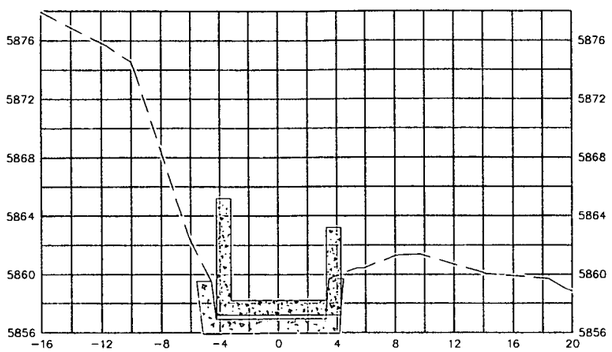

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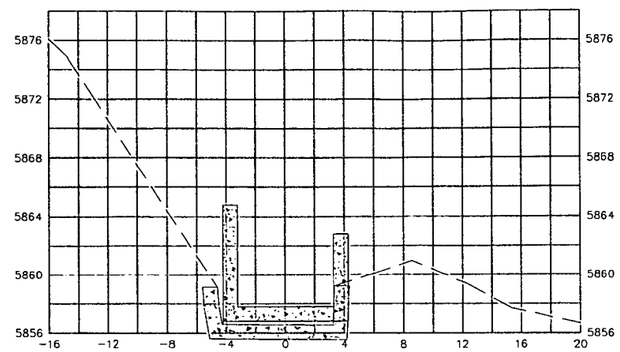

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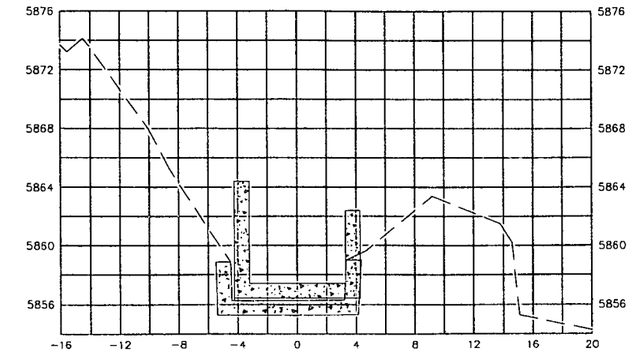

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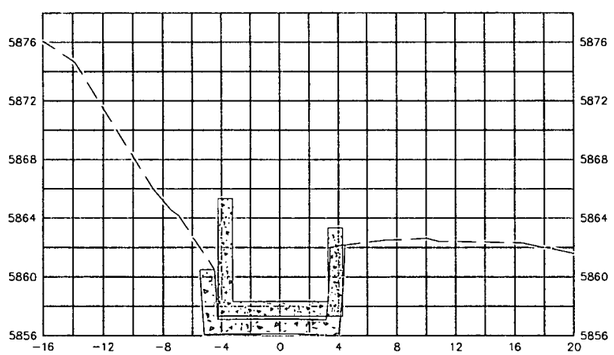

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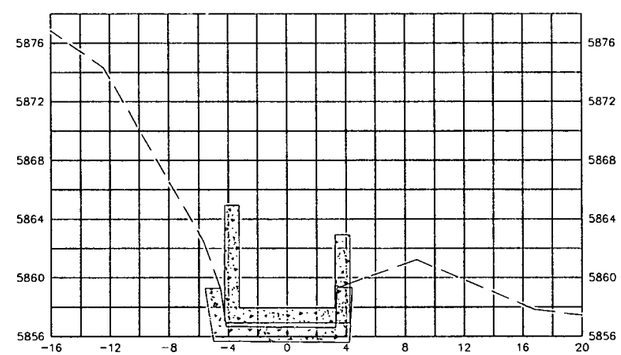

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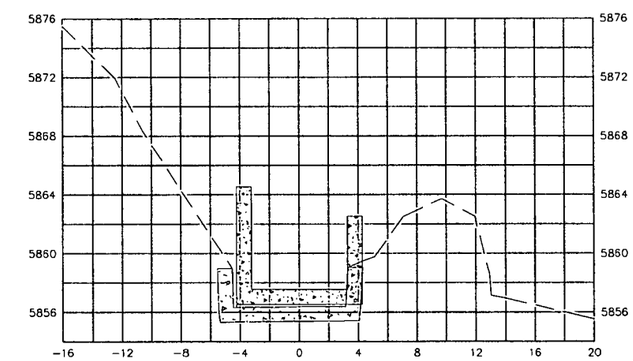

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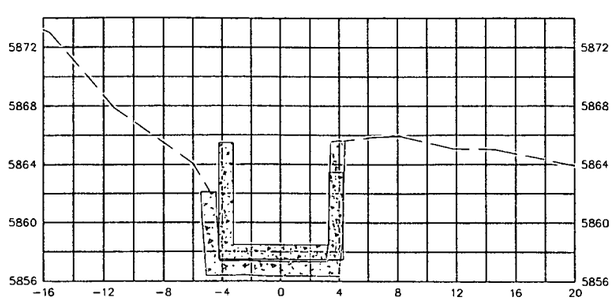

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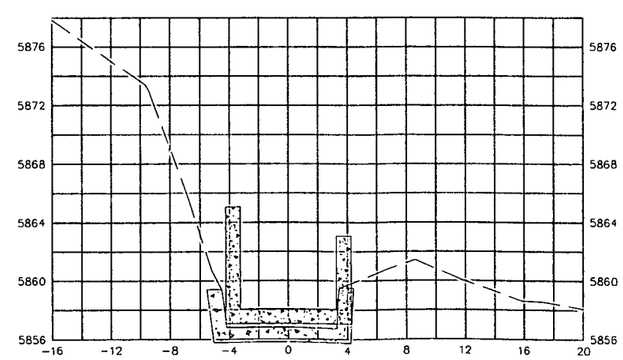

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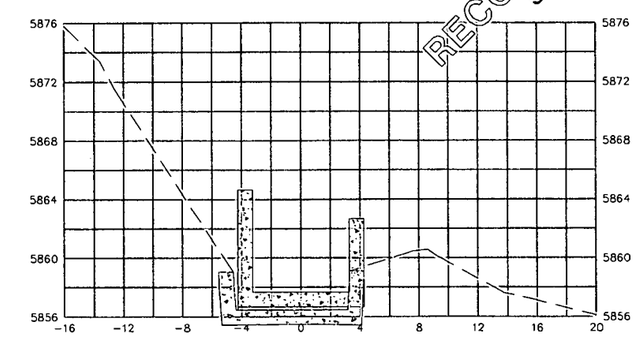

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1	REC. INFO	RCR	9/21/06

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY CROSS SECTIONS
STATIONS 1+20 TO 1+60

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Sheet No.
XS-1R

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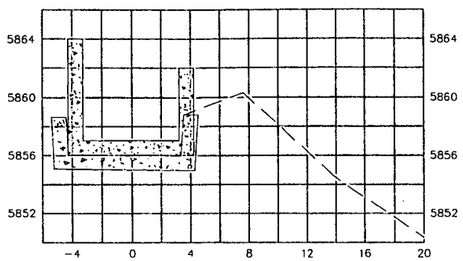
1+75



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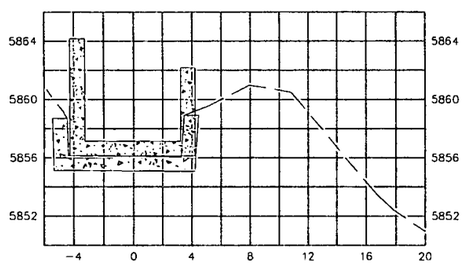

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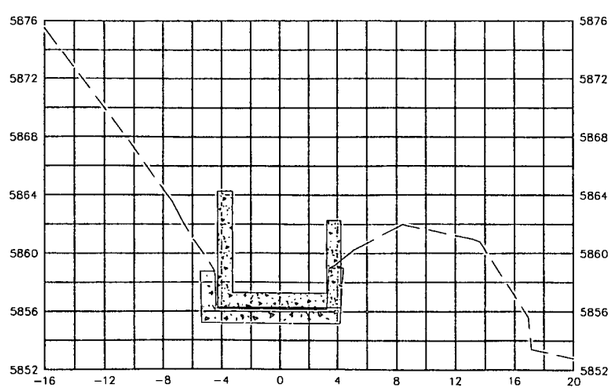

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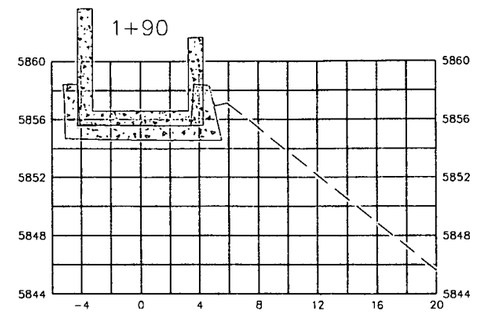

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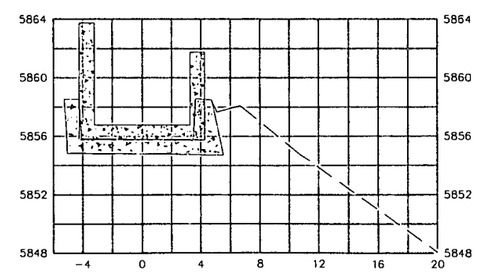

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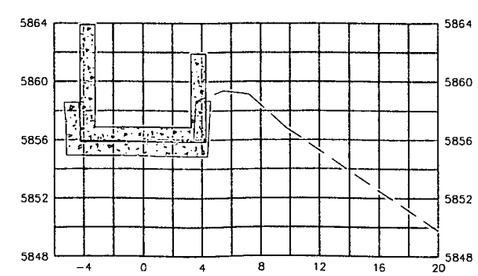

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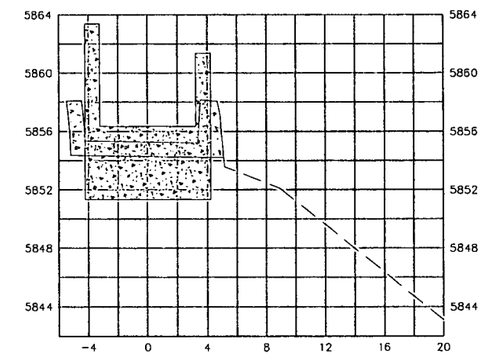

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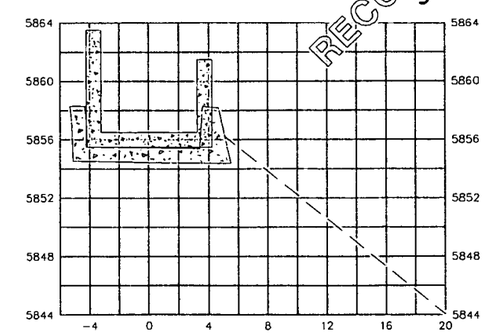

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SEPTEMBER 2006

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

SPILLWAY CROSS SECTIONS
STATIONS 1+65 TO 2+00

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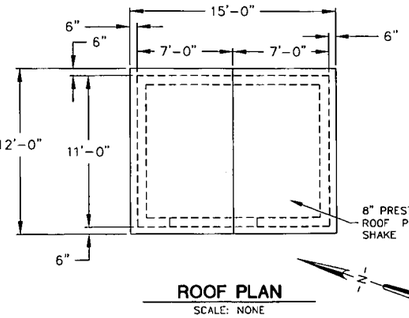
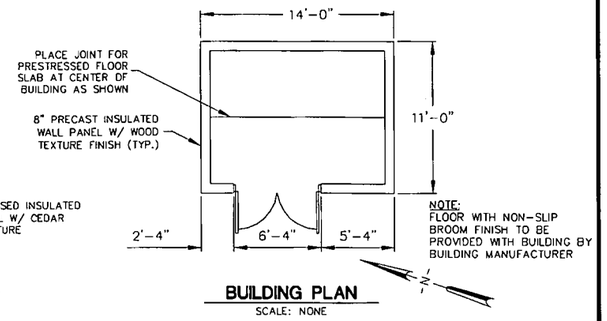
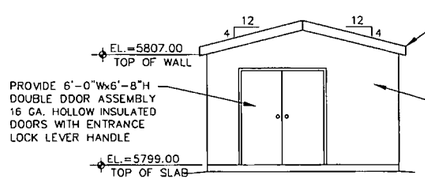


ROOF PLAN
SCALE: NONE



BUILDING PLAN
SCALE: NONE



WEST ELEVATION
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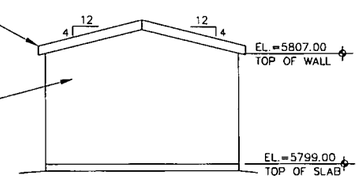

EAST ELEVATION
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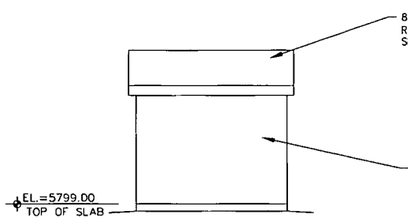

NORTH ELEVATION
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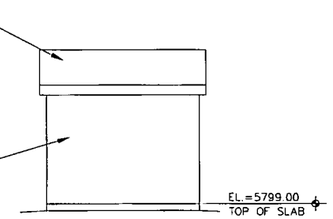
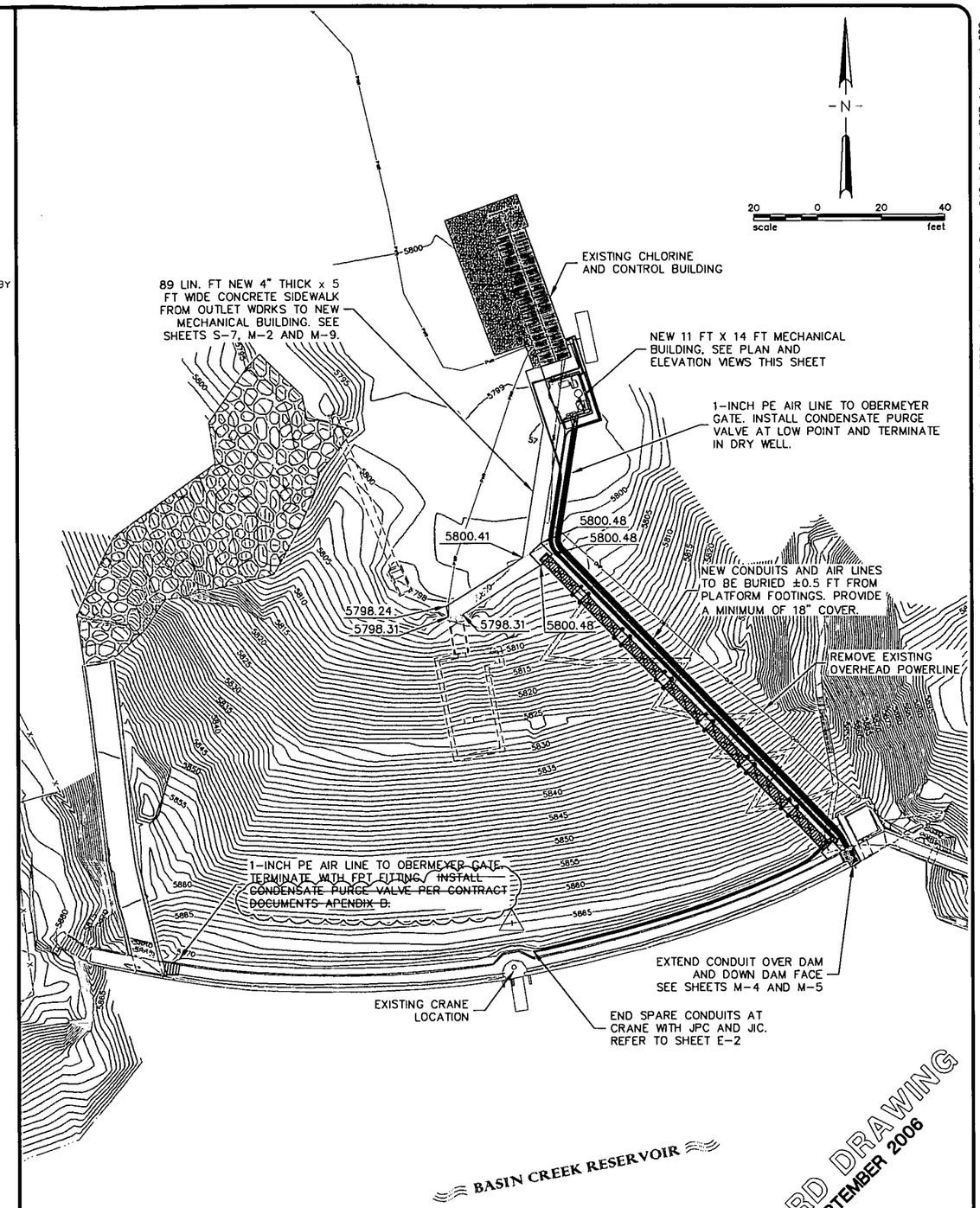


SOUTH ELEVATION
SCALE: NONE

NOTES:

1. SEE SECTION 13126 OF THE SPECIFICATIONS FOR BUILDING REQUIREMENTS.
2. SET BUILDING LEVEL AND TO PROPER ELEVATION. BSB WILL PROVIDE FILL MATERIAL TO ELEVATION OF BASE COURSE MATERIAL.
3. SET BUILDING ON PREPARED BASE. PROVIDE 1'-0" LAYER OF ¾" MINUS CRUSHED BASE COURSE PER MPWSS SECTION 02235 OR APPROVED EQUAL.
4. COMPACT BASE MATERIAL TO 95% MAX. DRY DENSITY PER ASTM D698.



SITE PLAN

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1	REC. INFO	RCR	9/21/06

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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

MECHANICAL BUILDING
PLAN, ELEVATIONS AND DETAILS

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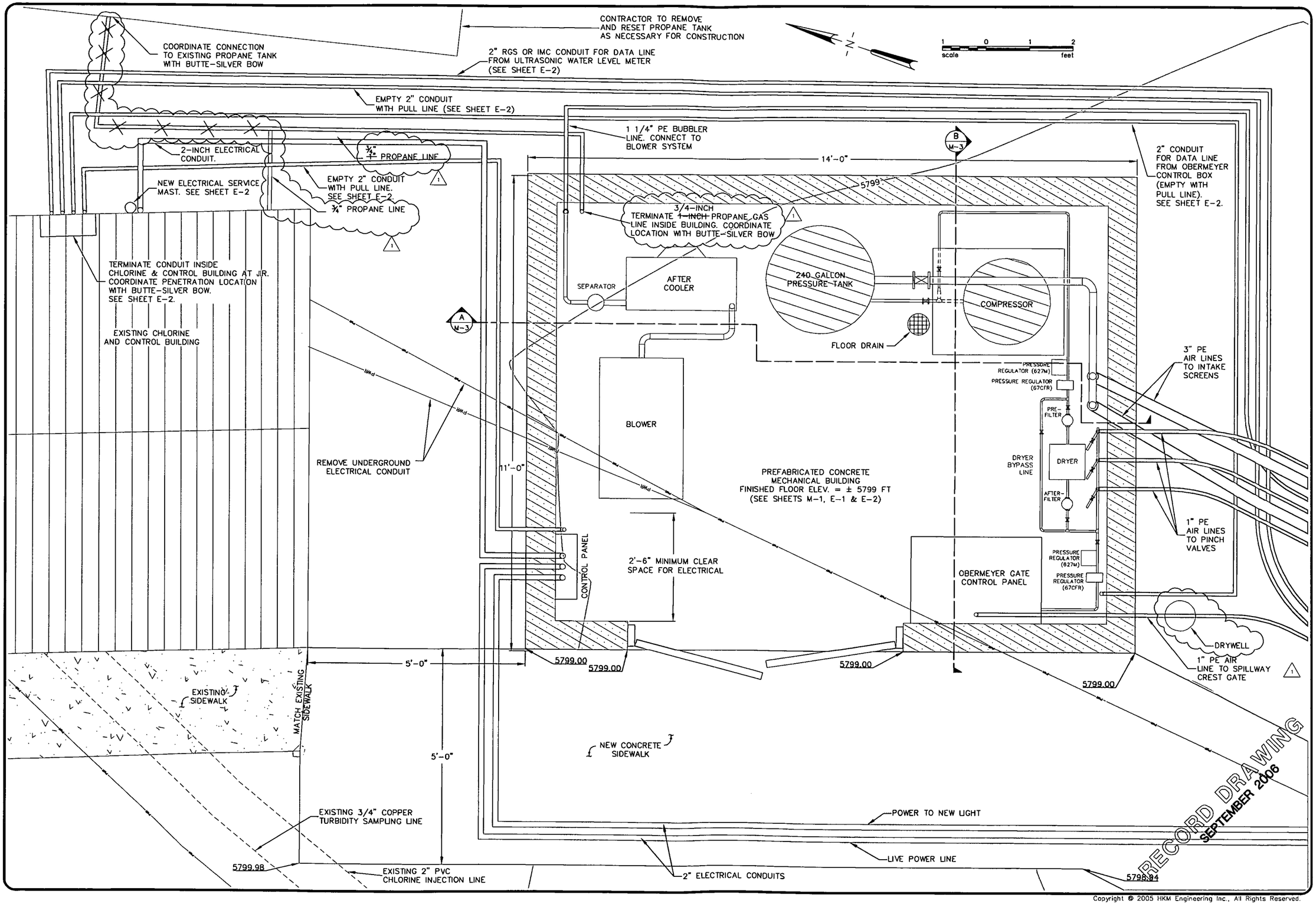

No.	Revision	By	Date
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

MECHANICAL BUILDING LAYOUT

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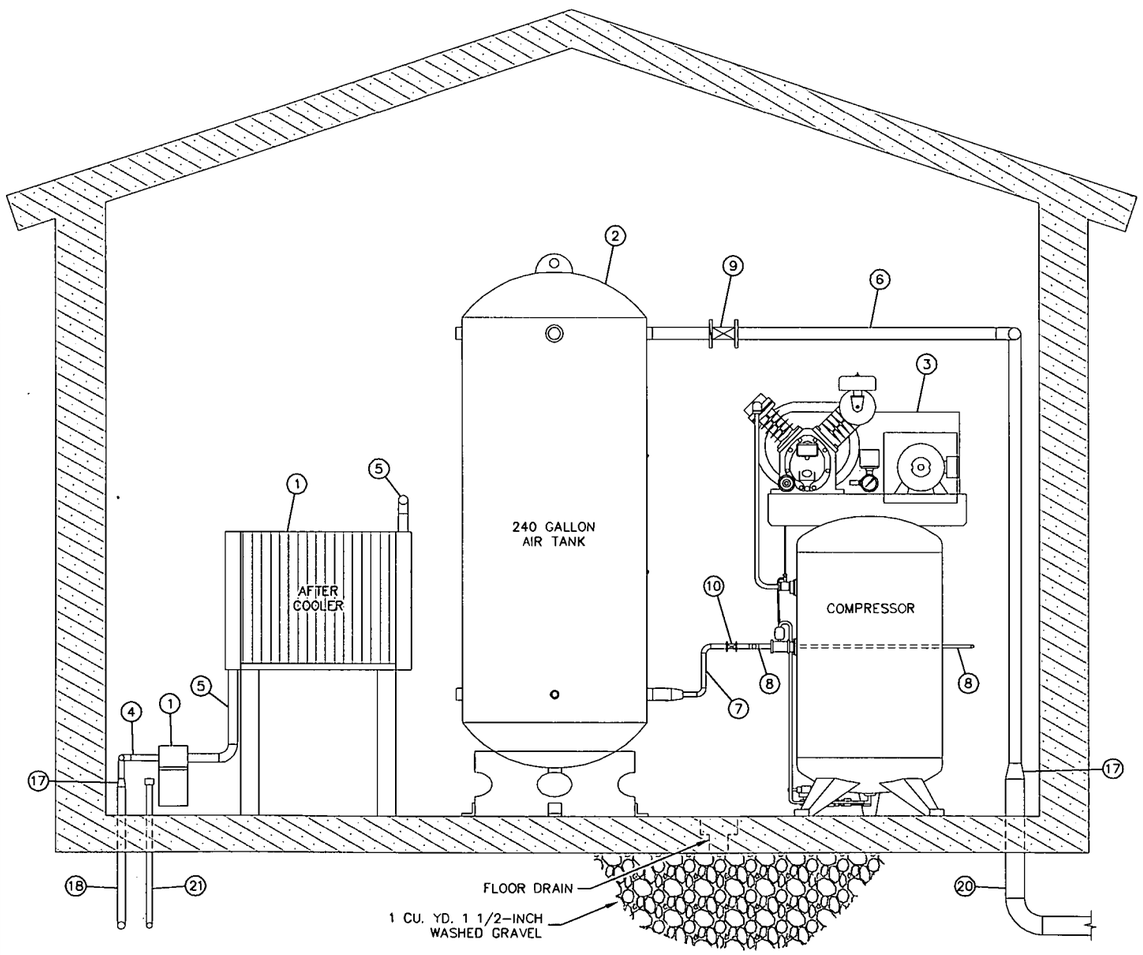
CONSTRUCTION NOTES:

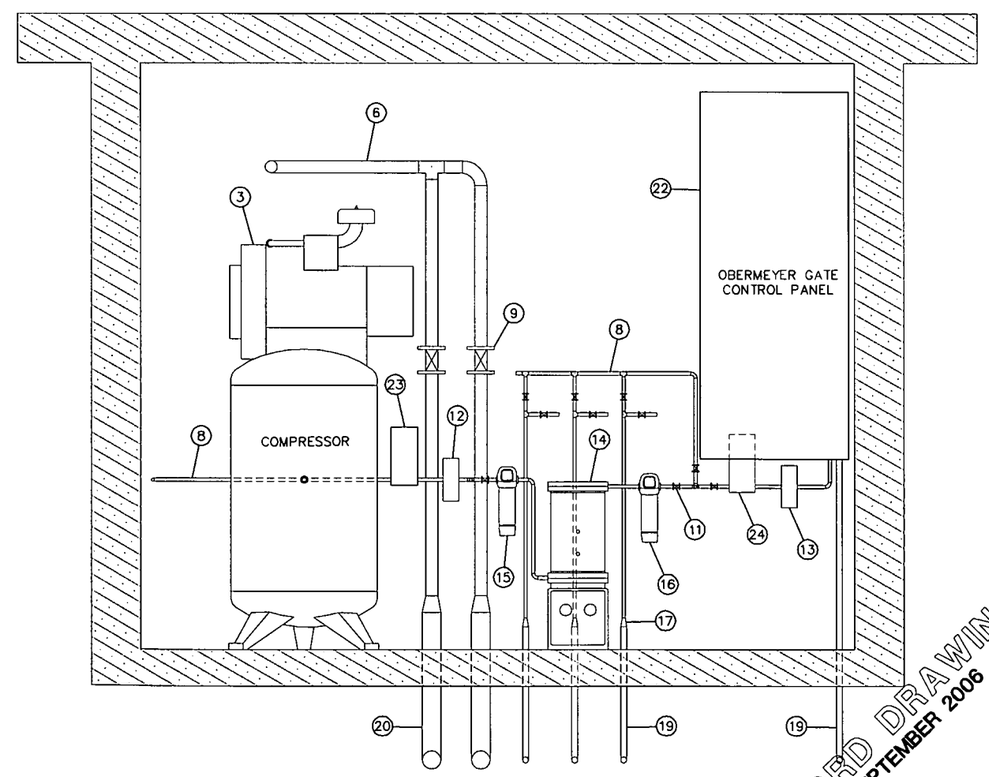
1. SECURE PIPING TO WALL WITH UNISTRUT AND CONCRETE EXPANSION ANCHORS.
2. SUPPORT PIPE WITH FLOOR SUPPORTS IN AREAS WHERE WALL SUPPORT IS NOT FEASIBLE.
3. PLUMB CONDENSATE DRAINS TO FLOOR DRAIN WITH FLEXIBLE TUBING.



A / M-3 **SECTION**
COMPRESSOR AND BLOWER SYSTEMS
SCALE : 1" = 1'

MATERIALS DESCRIPTION

NO.	QUANTITY	DESCRIPTION
1	1	BLOWER SYSTEM COMPONENTS – AFTER COOLER AND SEPARATOR
2	1	240 GALLON AIR TANK
3	1	COMPRESSOR
4	–	1-INCH SCH. 40 GALVANIZED STEEL PIPE AND FITTINGS
5	–	1 1/2-INCH SCH. 40 GALVANIZED STEEL PIPE AND FITTINGS
6	–	2-INCH SCH. 40 GALVANIZED STEEL PIPE AND FITTINGS
7	–	3/4-INCH SCH. 40 GALVANIZED STEEL PIPE FITTINGS
8	–	1/2-INCH SCH. 40 GALVANIZED STEEL PIPE FITTINGS
9	3	2-INCH NYLON SEATED LOCKING BALL VALVE
10	1	3/4-INCH NYLON SEATED LOCKING BALL VALVE
11	11	1/2-INCH NYLON SEATED LOCKING BALL VALVE
12	1	FISHER 67CFR SERIES FILTER REGULATOR WITH PRESSURE GAGE (INLET PRES. = 175 PSI, OUTLET PRES. = 65 PSI)
13	1	FISHER 67CFR SERIES FILTER REGULATOR WITH PRESSURE GAGE (INLET PRES. = 65 PSI, OUTLET PRES. = 30 PSI)
14	1	AIR DRYER
15	1	AIR DRYER PRE-FILTER
16	1	AIR DRYER AFTER-FILTER
17	–	VARIOUS SIZES GALVANIZED STEEL REDUCER AND TRANSITION FITTING TO HDPE PIPE
18	–	1 1/4-INCH PE PIPE
19	–	1-INCH PE PIPE
20	–	3-INCH PE PIPE
21	–	1-INCH PROPANE GAS LINE
22	1	OBERMEYER GATE CONTROL PANEL
23	1	FISHER 627M PRES. REDUCING REGULATOR WITH 1/2" x 3/4" x 1/2" TRANSITION FITTINGS (70 PSI SET PRESSURE)
24	1	FISHER 627M PRES. REDUCING REGULATOR WITH 1/2" x 3/4" x 1/2" TRANSITION FITTINGS (35 PSI SET PRESSURE)



B / M-3 **SECTION**
AIR LINE MANIFOLD
SCALE : 1" = 1'

NOTE: DRYER BYPASS LINE NOT SHOWN FOR CLARITY.

RECORD DRAWING
SEPTEMBER 2006

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

● Project No. 15M424.117 ● BCD_mechanical.dwg ● Date JULY 2005 ● Designed SMJ ● Drawn SMJ ● Checked RCR ● Approved RCR

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

MECHANICAL BUILDING SECTIONS AND MATERIALS DESCRIPTION

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Sheet No.
M-3R

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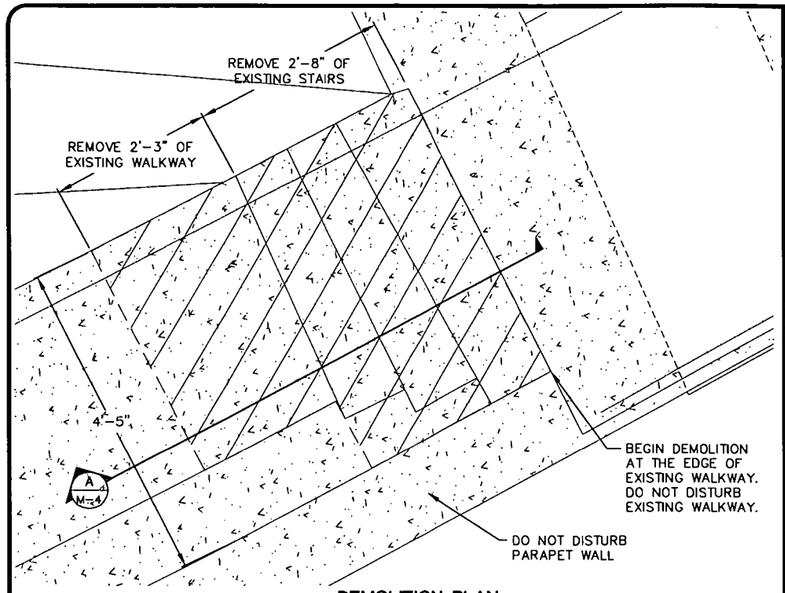
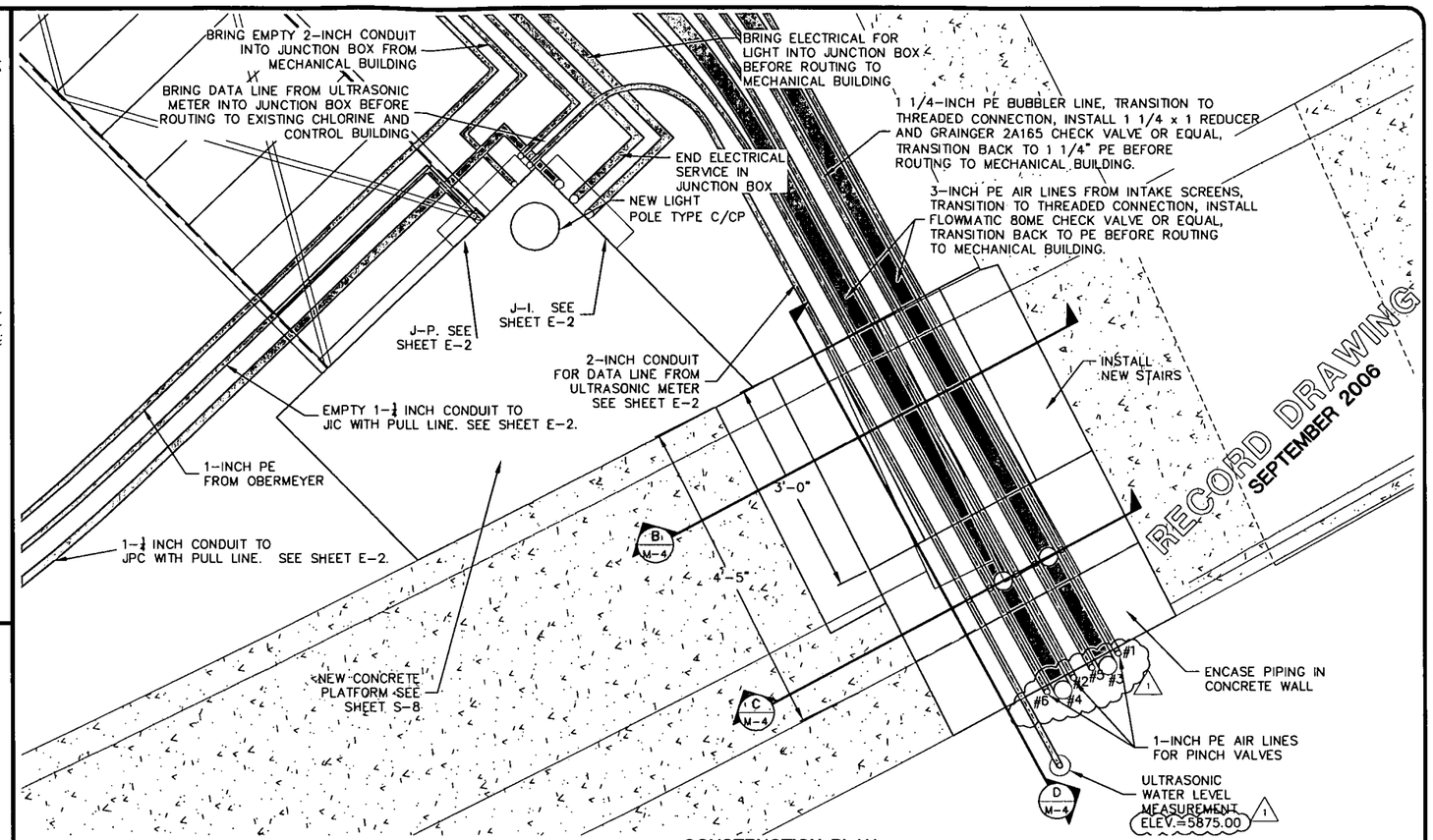
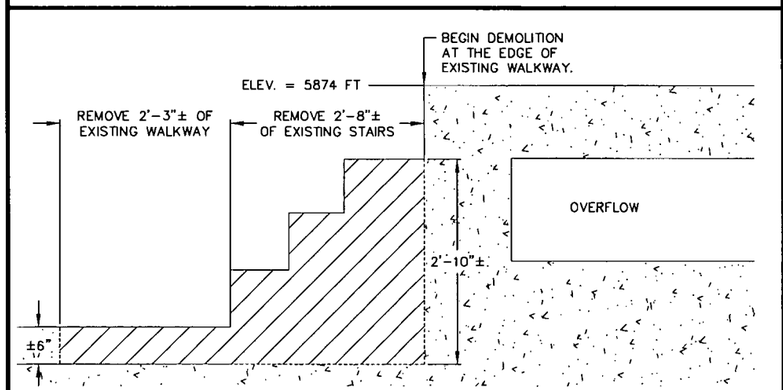


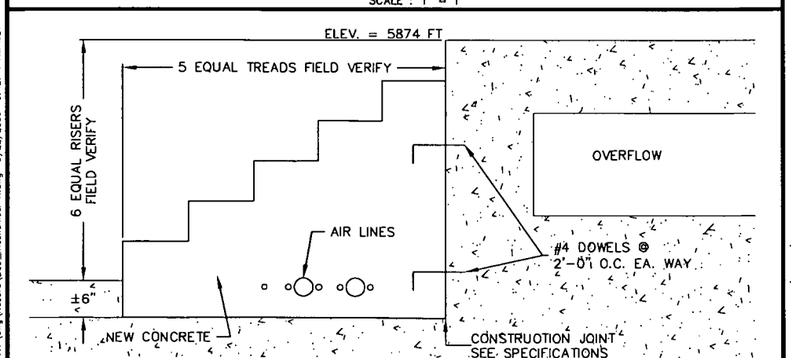
DEMOLITION PLAN
SCALE : 1" = 1'



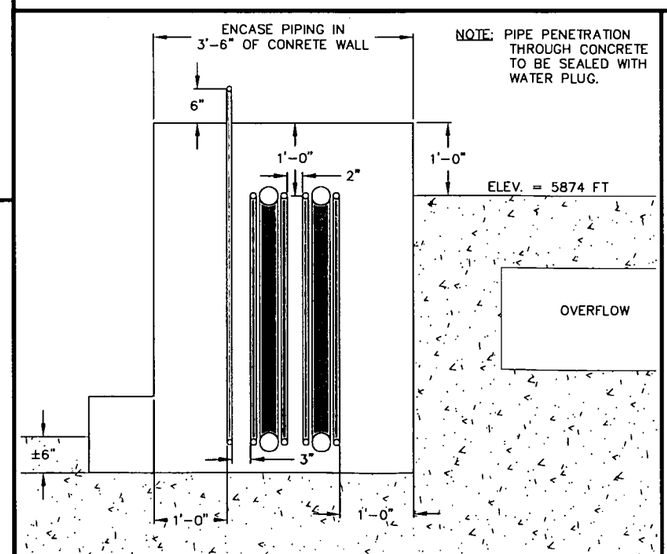
CONSTRUCTION PLAN
SCALE : 1" = 1'



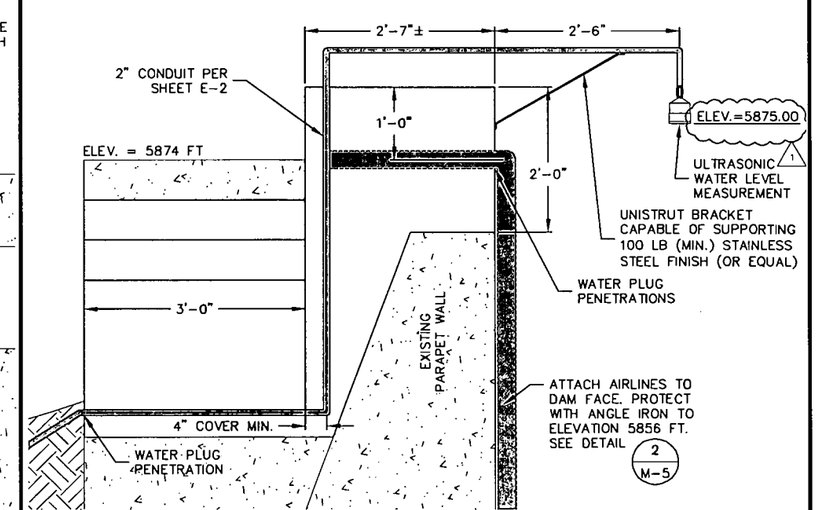
A M-4 SECTION
DEMOLITION
SCALE : 1" = 1'



B M-4 SECTION
NEW STAIR CONSTRUCTION
SCALE : 1" = 1'



C M-4 SECTION
NEW WALL CONSTRUCTION
SCALE : 1" = 1'



D M-4 SECTION
NEW CONDUIT
SCALE : 1" = 1'

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
D 1/2 1
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● Project No. 15M424.117 ● BCD_mechanical.dwg ● Date JULY 2005 ● Designed ??? ● Drawn DAS ● Checked RCR ● Approved RCR

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

AIR LINE DETAILS
DAM PENETRATION

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M-4R

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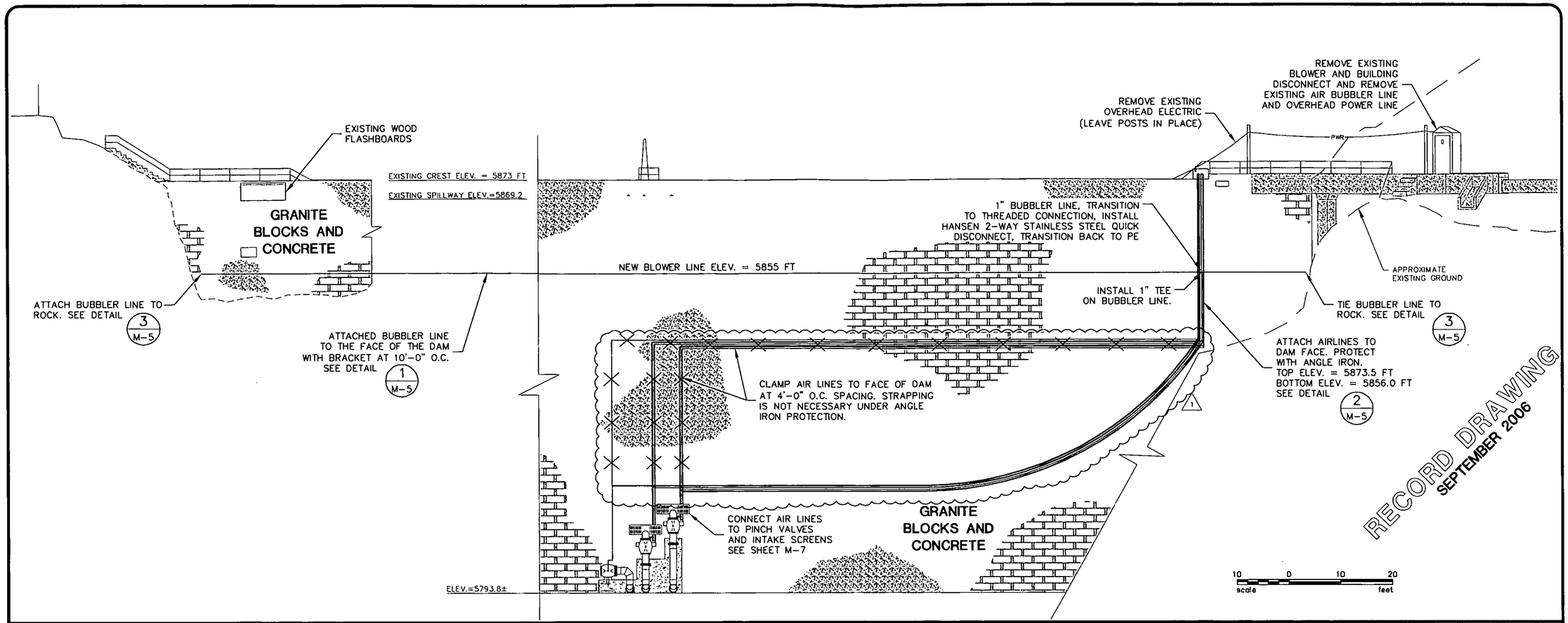
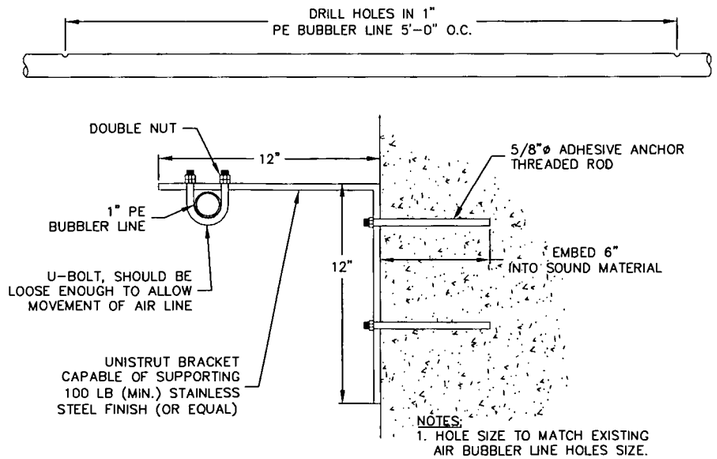
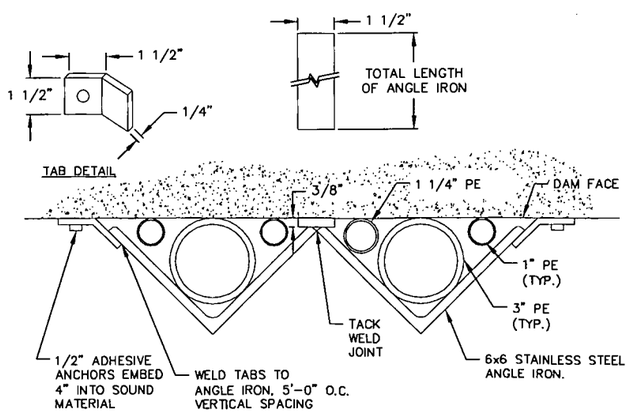


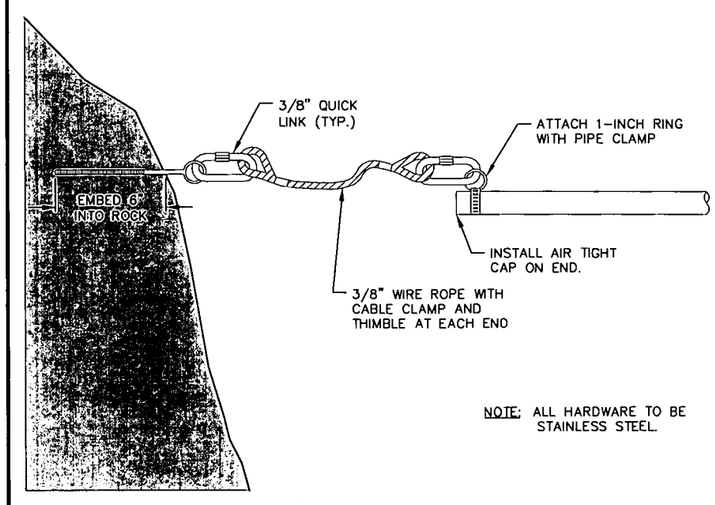


NOTES:
1. HOLE SIZE TO MATCH EXISTING AIR BUBBLER LINE HOLES SIZE.
2. SPACE HDPE SUPPORTS AT 10'-0" O.C.

1/M-5 DETAIL
BUBBLER LINE ATTACHMENT
SCALE : NOT TO SCALE



2/M-5 DETAIL
ANGLE IRON PROTECTION
SCALE : NOT TO SCALE



NOTE: ALL HARDWARE TO BE STAINLESS STEEL.

3/M-5 DETAIL
BUBBLER LINE END
SCALE : NOT TO SCALE

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
D 1/2
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

FACE OF DAM CONDUIT LAYOUT AND DETAILS

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M-5R

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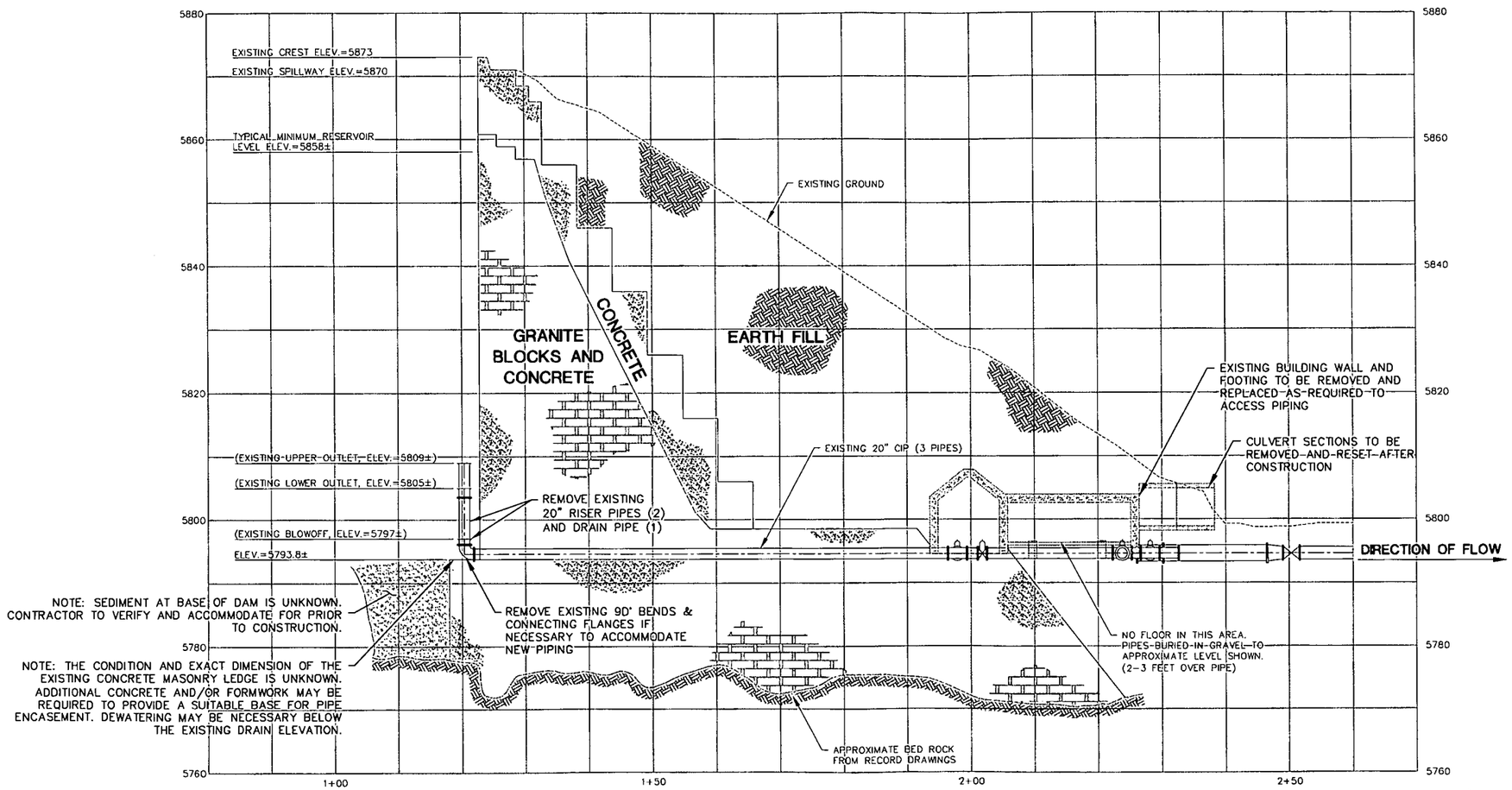

EXISTING RESERVOIR INTAKE SECTION

10 0 10 20
scale feet

RECORD DRAWING
SEPTEMBER 2006

● Project No. 15M424.117 ● EX-2.dwg ● Date JULY 2005 ● Designed KRJ ● Drawn RJA ● Checked PAS ● Approved RCR

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
0 ½ 1
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

EXISTING DAM SECTION AND DEMOLITION

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M-6R

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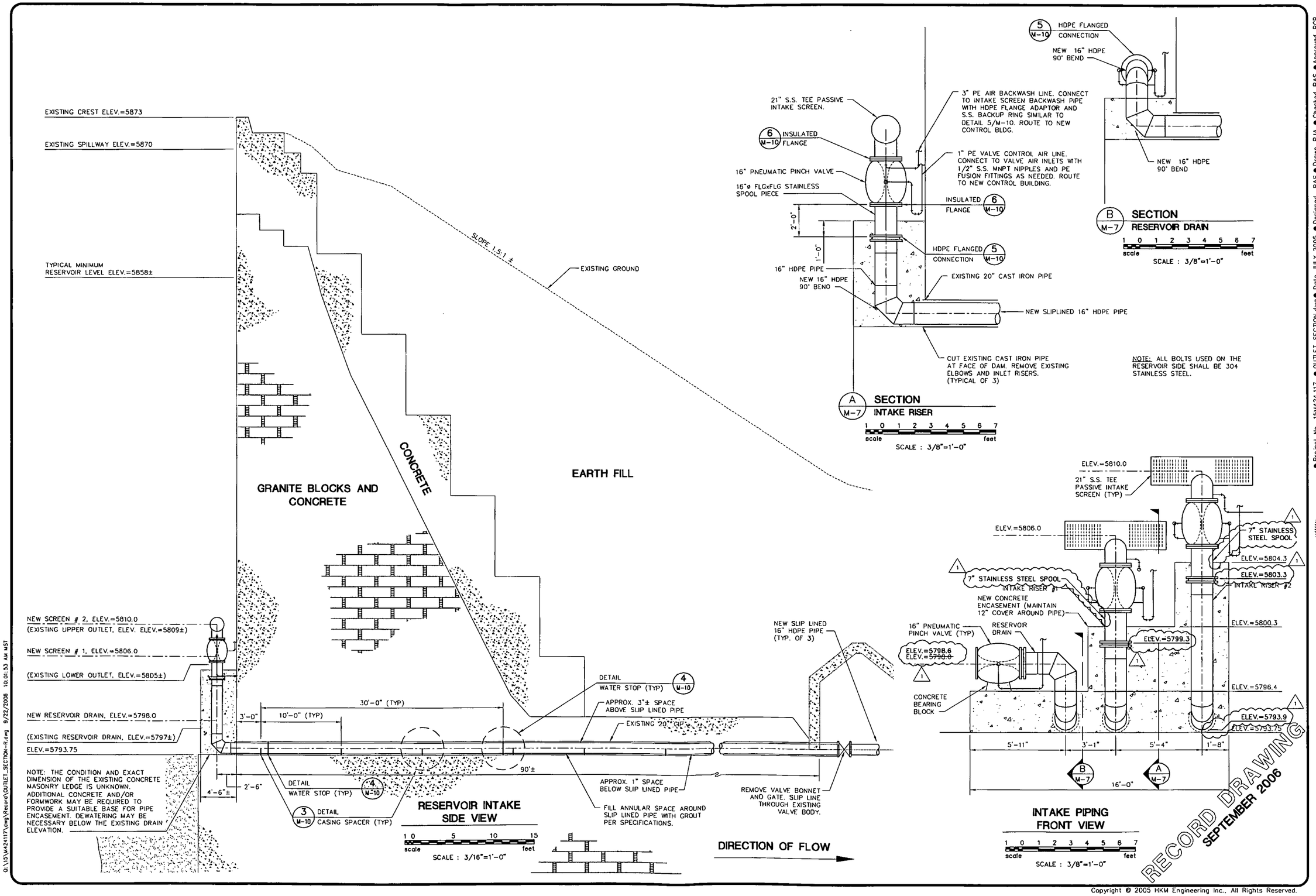

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING 0 ½ 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

INTAKE SECTIONS AND DETAILS

● Project No. 15M424.117 ● OUTLET_SECTION.dwg ● Date JULY 2005 ● Designed PAS ● Drawn RJA ● Checked PAS ● Approved RCR

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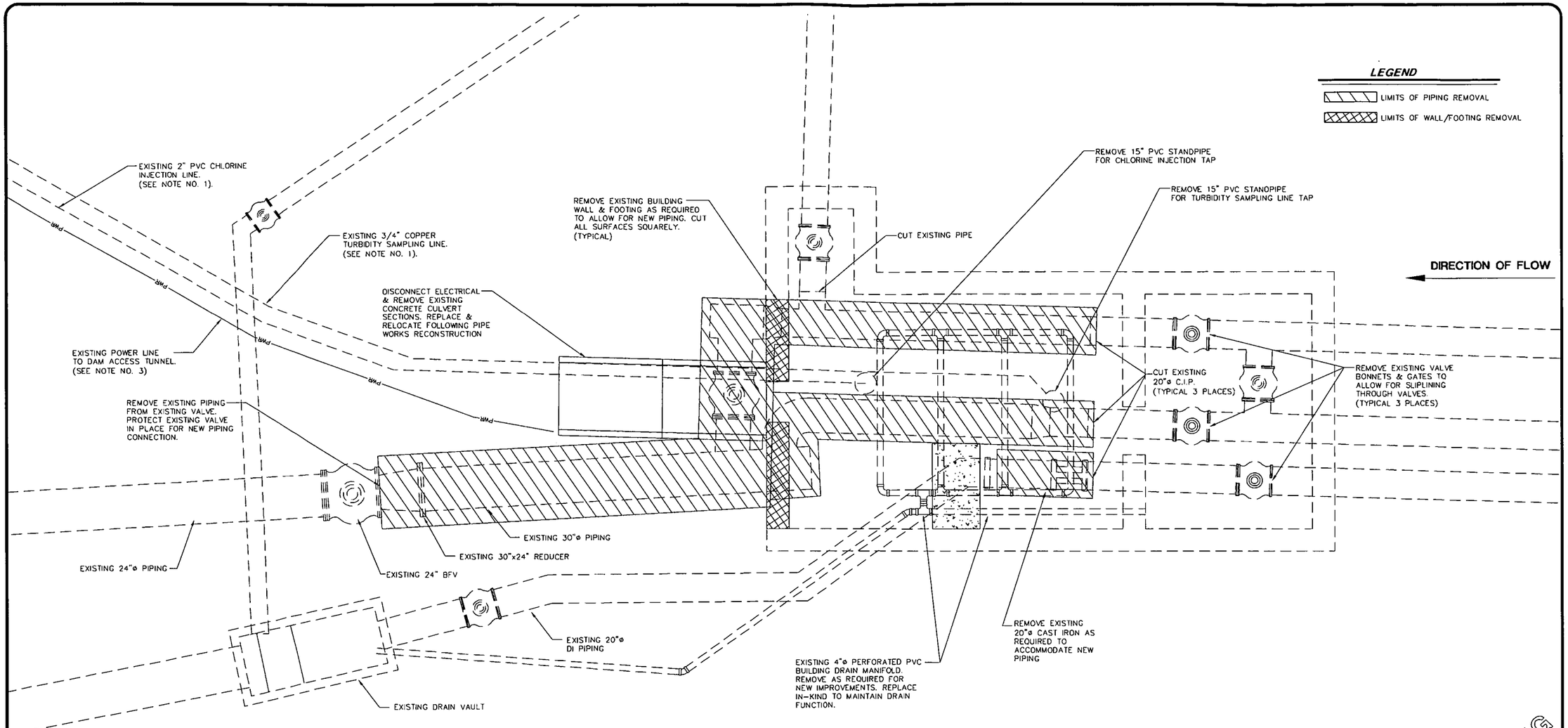

NOTES:

1. REMOVE AND REPLACE AS INDICATED IN THE NEW CONSTRUCTION DRAWINGS. CONTRACTOR TO COORDINATE WITH BUTTE-SILVER BOW PRIOR TO REMOVAL OF EXISTING LINES.

2. EXISTING UTILITIES HAVE BEEN DRAWN BASED ON FIELD MEASUREMENTS, RECORD DRAWINGS, AND UTILITY LOCATE SERVICE. ACTUAL UTILITY CONFIGURATION MAY BE DIFFERENT THAN SHOWN. CONTRACTOR TO FIELD VERIFY AND NOTIFY ENGINEER OF DISCREPANCIES.

3. EXTEND, RELOCATE, OR REROUTE THE EXISTING CIRCUITS AS REQUIRED BY THE CONSTRUCTION. MATCH EXISTING CONDUIT AND CONDUCTOR SIZE AND TYPE FOR ANY REPLACEMENTS. CIRCUIT SPLICES SHALL BE KEPT TO A MINIMUM, AND SHALL BE ACCOMPLISHED ABOVE GRADE WHEREVER POSSIBLE. ANY REQUIRED SPLICES SHALL BE IN JUNCTION BOXES, WITH COPPER COMPRESSION CONNECTORS, AND SHALL BE WATERPROOF.

RECORD DRAWING
SEPTEMBER 2006

3 0 3 6
scale feet

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
0 ½ 1
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● Project No. 15M424.117 ● DEM-1.DWG ● Date JULY 2005 ● Designed KRJ ● Drawn RDH ● Checked RCR ● Approved RCR

BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

OUTLET WORKS
DEMOLITION DETAILS AND LIMITS

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M-8R

D:\15\M424117\dwg\Record\DEM-1-R.dwg 9/22/2006 10:04:54 AM MST

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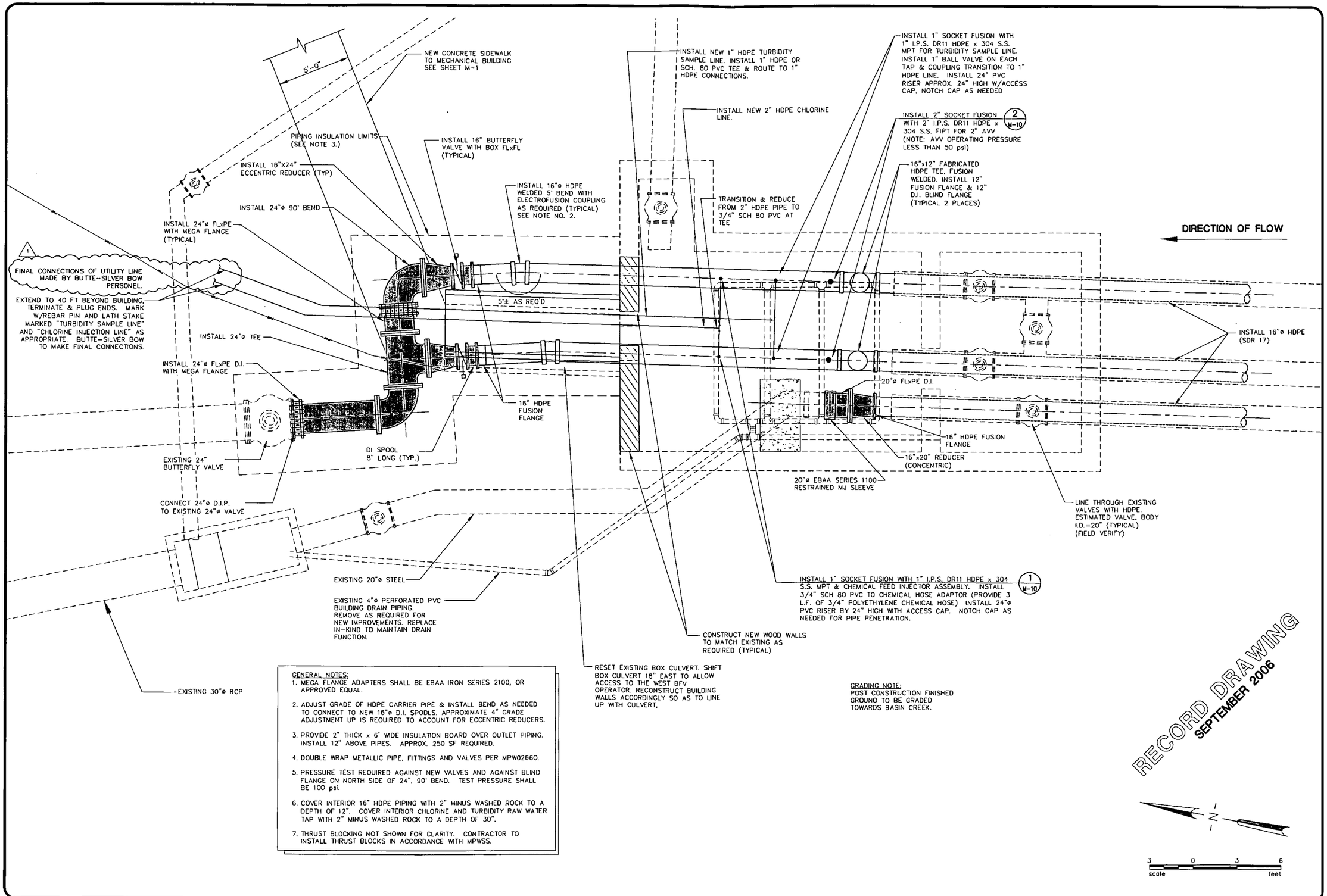

GENERAL NOTES:

1. MEGA FLANGE ADAPTERS SHALL BE EBAA IRON SERIES 2100, OR APPROVED EQUAL.
2. ADJUST GRADE OF HDPE CARRIER PIPE & INSTALL BEND AS NEEDED TO CONNECT TO NEW 16"ø D.I. SPOOLS. APPROXIMATE 4" GRADE ADJUSTMENT UP IS REQUIRED TO ACCOUNT FOR ECCENTRIC REDUCERS.
3. PROVIDE 2" THICK x 6' WIDE INSULATION BOARD OVER OUTLET PIPING. INSTALL 12" ABOVE PIPES. APPROX. 250 SF REQUIRED.
4. DOUBLE WRAP METALLIC PIPE, FITTINGS AND VALVES PER MPW02660.
5. PRESSURE TEST REQUIRED AGAINST NEW VALVES AND AGAINST BLIND FLANGE ON NORTH SIDE OF 24", 90° BEND. TEST PRESSURE SHALL BE 100 psi.
6. COVER INTERIOR 16" HDPE PIPING WITH 2" MINUS WASHED ROCK TO A DEPTH OF 12". COVER INTERIOR CHLORINE AND TURBIDITY RAW WATER TAP WITH 2" MINUS WASHED ROCK TO A DEPTH OF 30".
7. THRUST BLOCKING NOT SHOWN FOR CLARITY. CONTRACTOR TO INSTALL THRUST BLOCKS IN ACCORDANCE WITH MPWSS.

No.	Revision	By	Date
1	REC. INFO	RCR	9/21/06

WARNING
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

NEW PIPING PLAN

• Project No. 15M424.117 • OUTLET_ PIPING PLAN.dwg • Date JULY 2005 • Designed KRJ • Drawn RDH • Checked RCR • Approved RCR

MONTANA REGISTERED PROFESSIONAL ENGINEER
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M-9R

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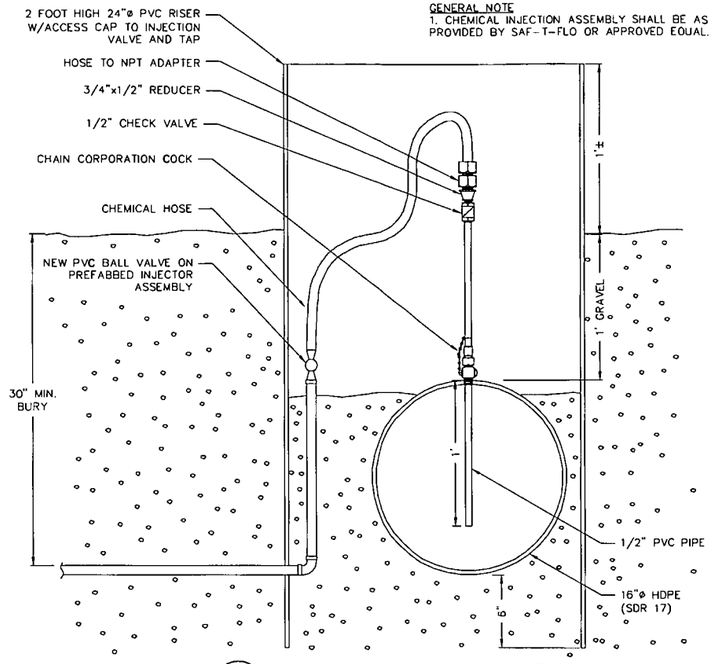
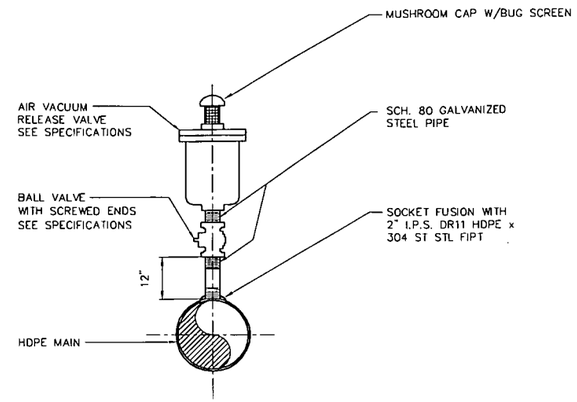
Q:\15\M424117\dwg\Record\OUTLET_PIPING PLAN-R.dwg 9/22/2006 10:08:23 AM MST

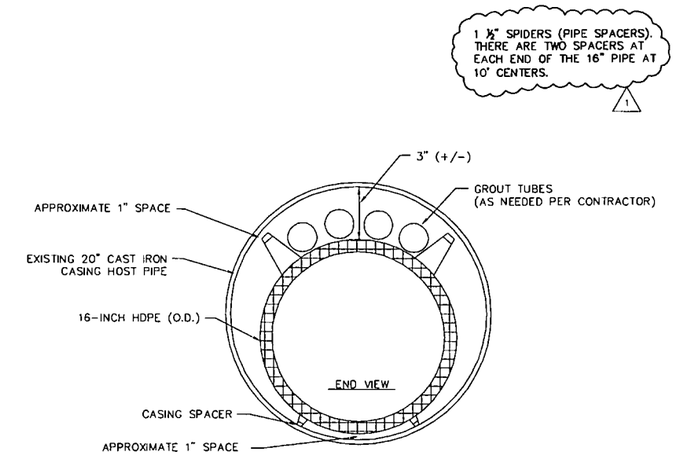
GENERAL NOTE
1. CHEMICAL INJECTION ASSEMBLY SHALL BE AS PROVIDED BY SAF-T-FLO OR APPROVED EQUAL.



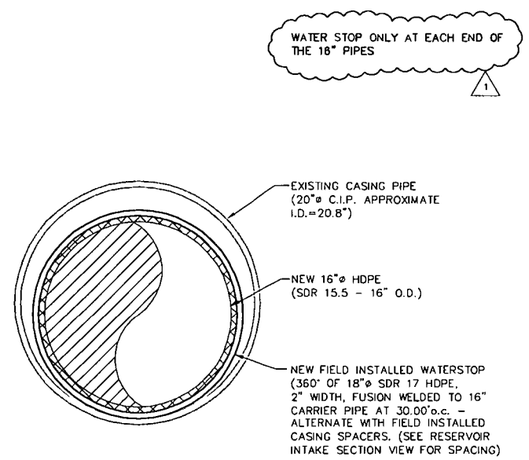
1 M-10 **DETAIL - CHLORINE INJECTOR**
SCALE : NONE



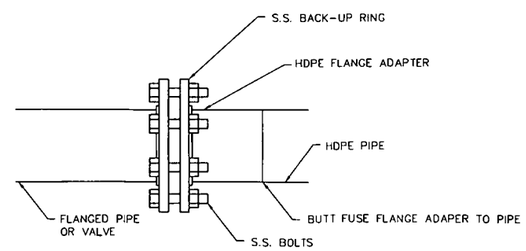
2 M-10 **DETAIL - AIR-VACUUM VALVE**
SCALE : NONE



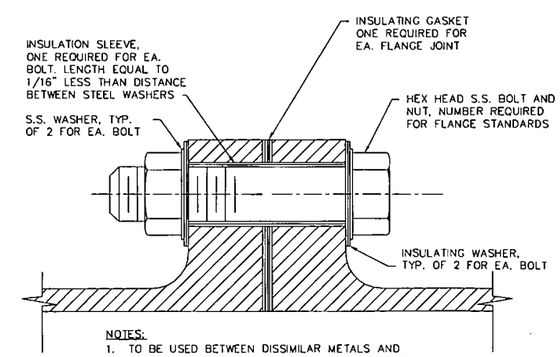
3 M-10 **DETAIL - FIELD INSTALLED CASING SPACER**
SCALE : NONE



4 M-10 **DETAIL - FIELD INSTALLED WATERSTOP**
SCALE : NONE



5 M-10 **DETAIL**
HDPE FLANGED CONNECTION
NOT TO SCALE



NOTES:
1. TO BE USED BETWEEN DISSIMILAR METALS AND BETWEEN NEW AND EXISTING PIPE CONNECTIONS.
2. INSULATING FLANGE SHALL BE COATED WITH MATERIAL COMPATABLE WITH REMAINDER OF PIPE WHERE APPLICABLE.
3. BOLTS AND NUTS SHALL BE STAINLESS STEEL. FOLLOW TORQUE REQUIREMENTS OF GASKET MANUFACTURER.

RECORD DRAWING
SEPTEMBER 2006

6 M-10 **DETAIL**
INSULATING FLANGE
NOT TO SCALE

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1	REC. INFO	RCR	9/21/06

WARNING
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BASIN CREEK RESERVOIR IMPROVEMENTS
BUTTE, MONTANA

MISCELLANEOUS DETAILS

● Project No. 15M424.117 ● D-1 DETAILS.dwg ● Date JULY 2005 ● Designed KRJ ● Drawn RDH ● Checked RCR ● Approved RCR

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M-10R

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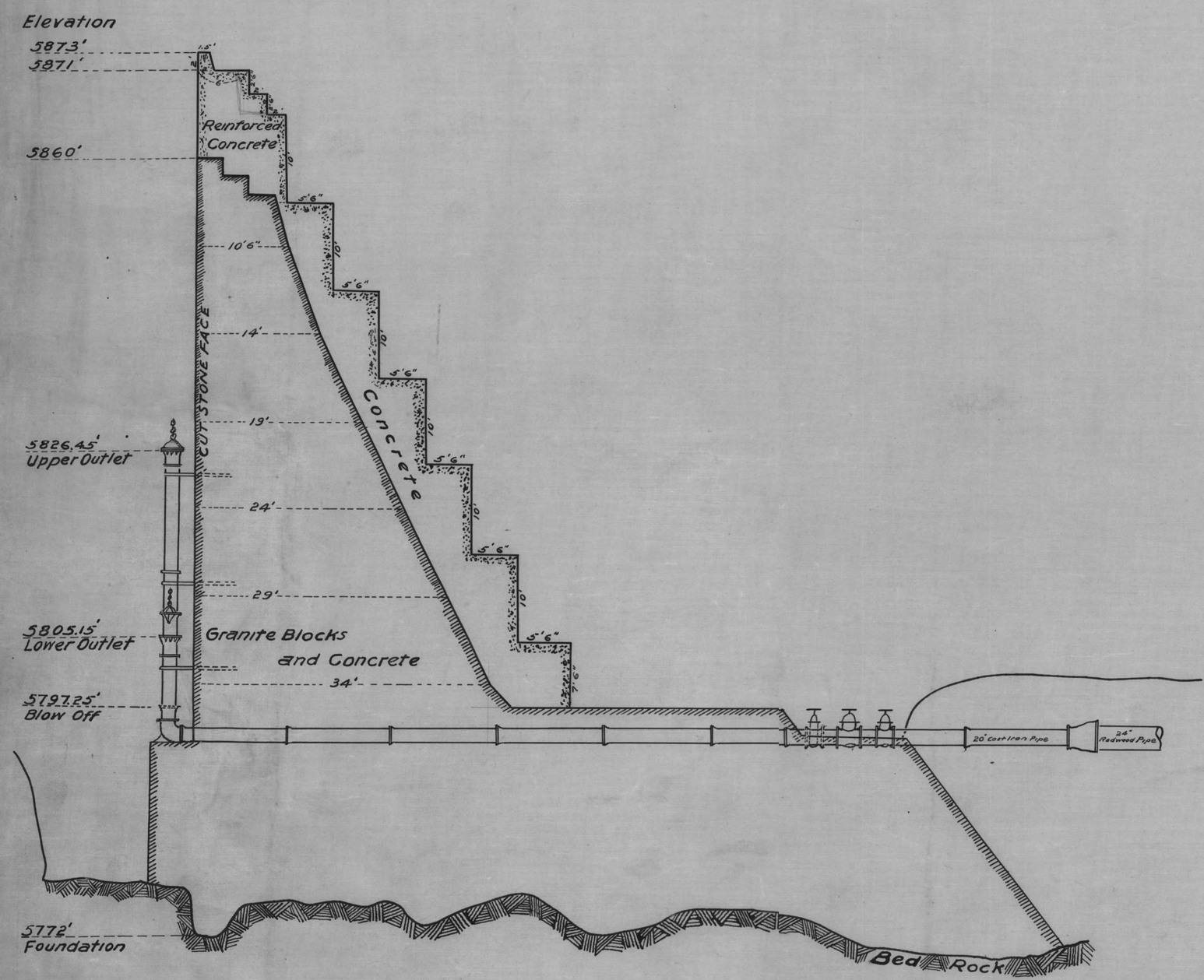
G:\15\M424117\dwg\Record\D-1 DETAILS-R.dwg 9/22/2006 10:14:50 AM MST

Basin Creek Dam No. One
Showing Proposed Concrete Additions
and Earth Fill
Date: 8-3-39 Scale: 1"=10' Drawn by J.B.H.

00377



CROSS SECTION OF BASIN CREEK DAM No. 1
SCALE 10' = 1"

BUTTE WATER COMPANY

K-6-2

00380

Analysis of Stresses in Basin Creek Dam No. 1.

From the resolution of forces in the section shown below it is evident that horizontal thrust due to water pressure and ice action must be taken by the arch and the weight of the dam is more than sufficient to withstand the uplift

Drawn by J.B.H. 1939

Analysis of Arch Stress

Assume Reservoir full to elev. 5873 Radius = 350' & Compressive stress = $\frac{62.5 \times \text{head in ft.} \times \text{radius}}{\text{thickness of dam}}$ = lbs. per sq. ft.

62.5 X Radius (350') = 21875 ft.

Sec. A-A $\frac{21875 \times 25}{2.0}$ = 27,343 lbs. per sq. ft.

Sec. B-B $\frac{21875 \times 25}{5.5}$ = 30,625 " " " "

Sec. C-C $\frac{21875 \times 18}{10.7}$ = 36,800 " " " "

Sec. D-D $\frac{21875 \times 27.5}{15.3}$ = 39,318 " " " "

Sec. E-E $\frac{21875 \times 37.5}{20.5}$ = 40,015 " " " "

Sec. F-F $\frac{21875 \times 47.5}{25.5}$ = 40,748 " " " "

Sec. G-G $\frac{21875 \times 58.4}{30.3}$ = 42,162 " " " "

Sec. H-H $\frac{21875 \times 68.5}{35.2}$ = 42,569 " " " "

Sec. I-I $\frac{21875 \times 76}{42.0}$ = 39,853 " " " "

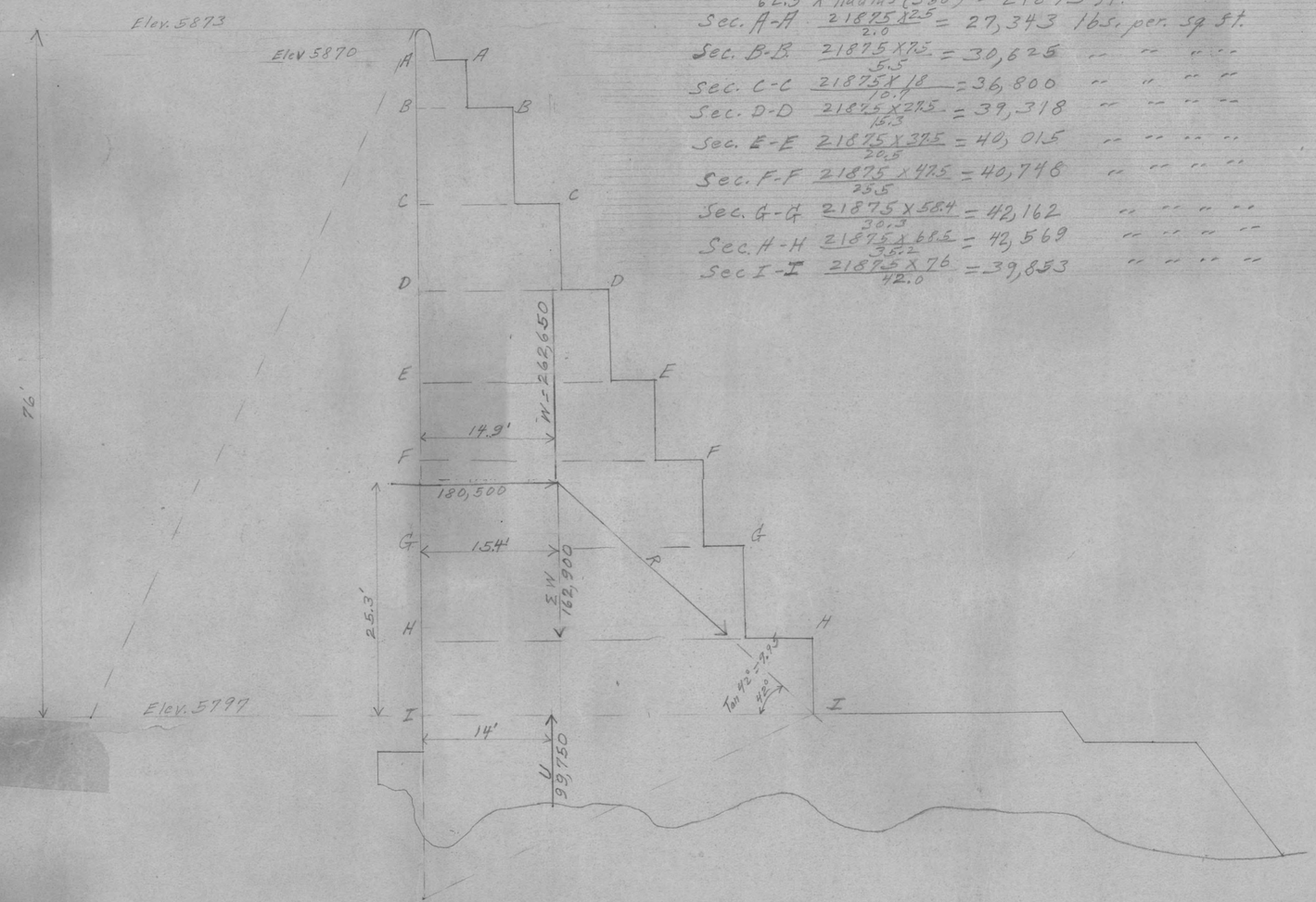
Assume an Ice Pressure on Sec. B-B = 250 lbs per lin. ft. Assuming this pressure to act over a portion of the arch equal to twice the arch thickness + the thickness of the ice:

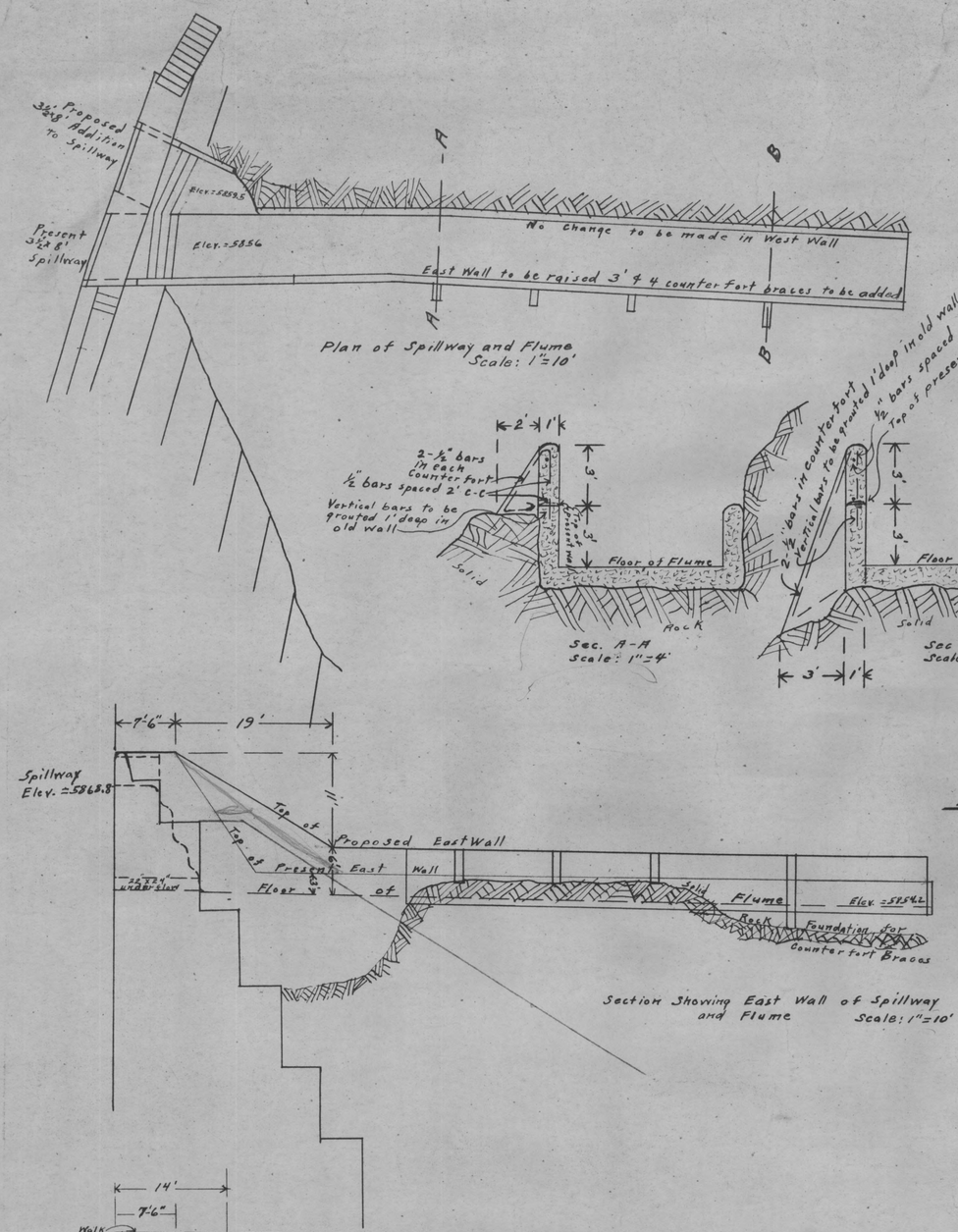
Compressive stress in Sec B-B of the arch due to a sheet of ice 1' thick = $\frac{25{,}000 \times 350}{8.0 \times 16.0}$ = 68,359 lbs. per sq. ft.

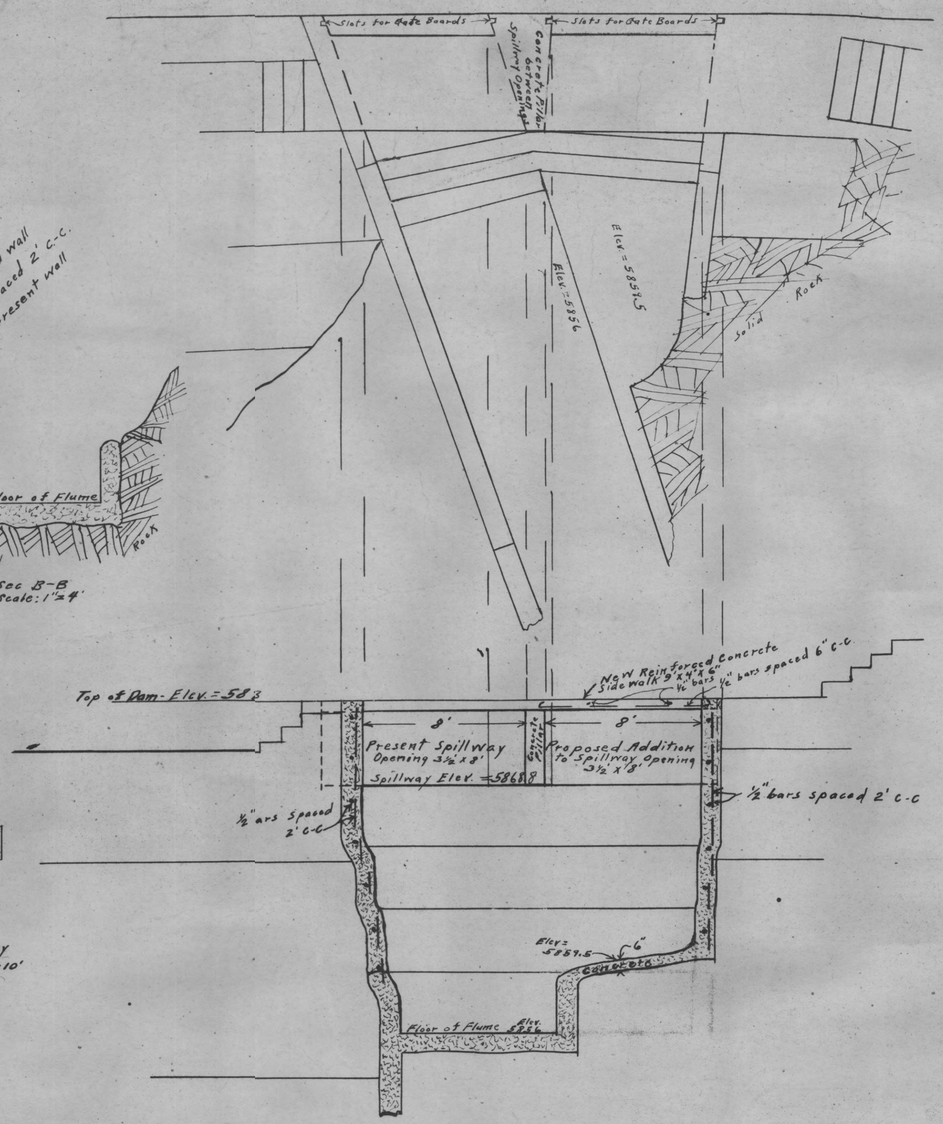
Ice pressure on Sec. C-C = $\frac{25{,}000 \times 350}{13.6 \times 27}$ = 24,929 lbs per sq. ft.

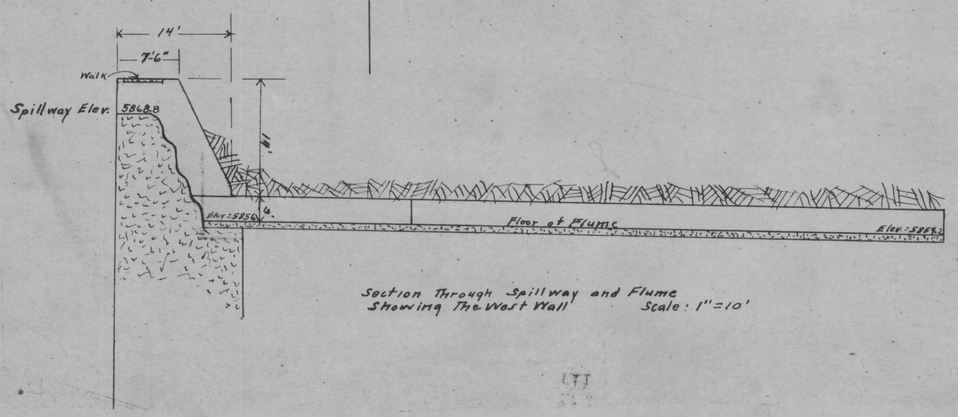
Conclusions.

All stresses within the structure are well within safe limits. Sec. B-B is reinforced with steel hence the apparent high compressive stress due to ice loading is not excessive









Basin Creek Dam No. One
Details of Proposed Changes in Spillway and Flume
Date: 8-1-39 Scales as indicated Drawn by J.B.H.
Note: ½" round deformed reinforcing bars are indicated in these drawings as ½" bars.

00383

K. 17.

Approx Area of Reservoir 16½ A.
" " in Forest 4.7 A
" " on Placer 11.8 A

Plat Showing Location of Basin Reservoir #2.

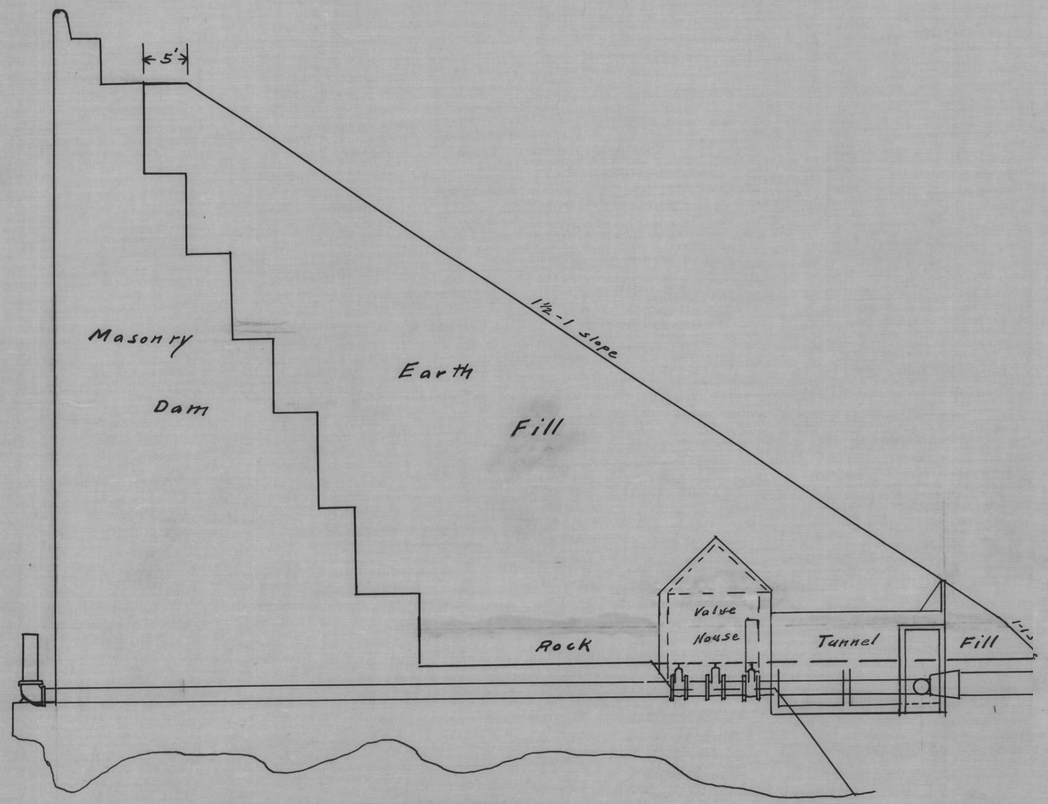
Butte Water Co. July-12-1913.

Scale 1" = 100'

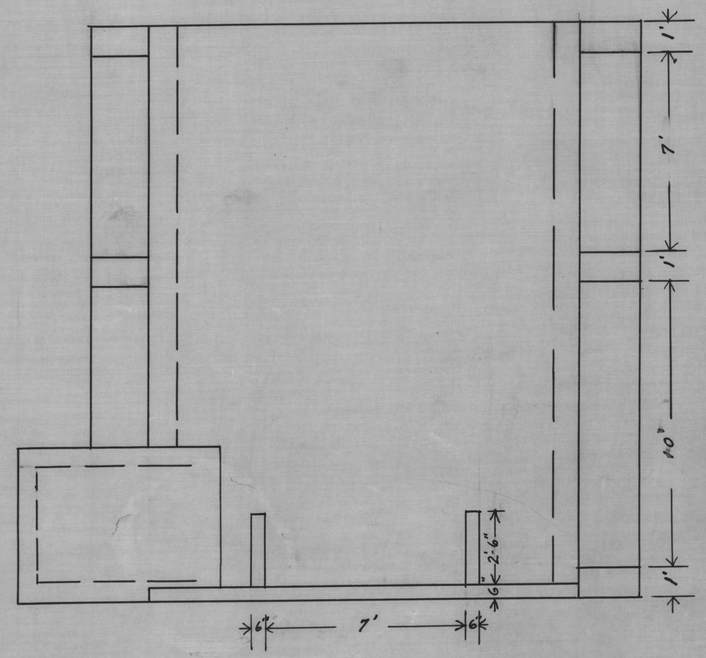
00385

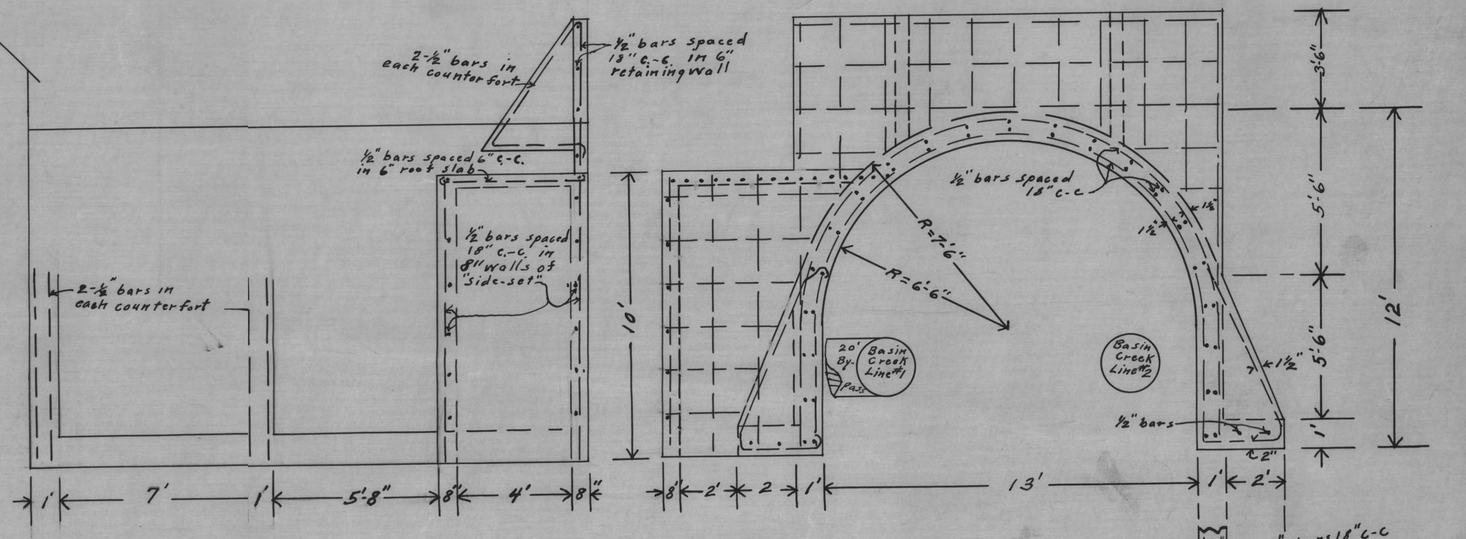
17

K. 17



Basin Creek Dam No. One
Section Through Dam and Fill
Date: 8-2-39. Scale: 1" = 10' Drawn by J.B.H.





Basin Creek Dam No. One
Details of Reinforced Concrete Tunnel
Date: 8-2-39 Not to scale, Work, from dimentions. Drawn by J.B.H.
Note: ½" round deformed reinforcing bars are indicated in these drawings as ½" bars

00402

Loc- April 22nd 1892

Helena Land Dist.

Plat

Frank M. Leonard

CHEROKEE PLACER

Unorganized MD-
Silver Bow County- Montana
143.02 Ac-

500'
Var- 20° East

Surd- May 2nd - 15th 1892
by Nathaniel C. Ray-

Frank M. Leonard

Cherokee Placer

his
Disc.
pit for dam, valued at $3241 00

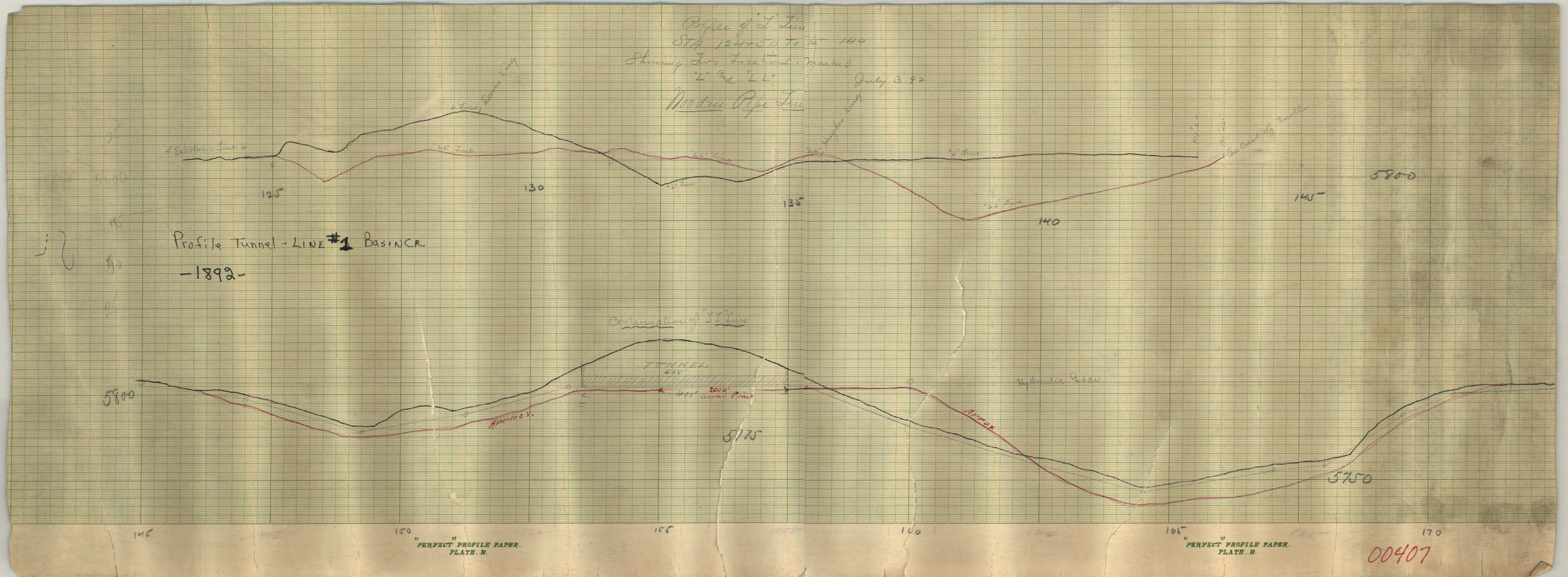
Geo. O. Eaton

July 2nd 1892 Montana

00406

Profile of "L" Line
Sta. 124+50 to Sta. 144
Showing Two Locations, Marked
"L" and "LL"
July 3 '92

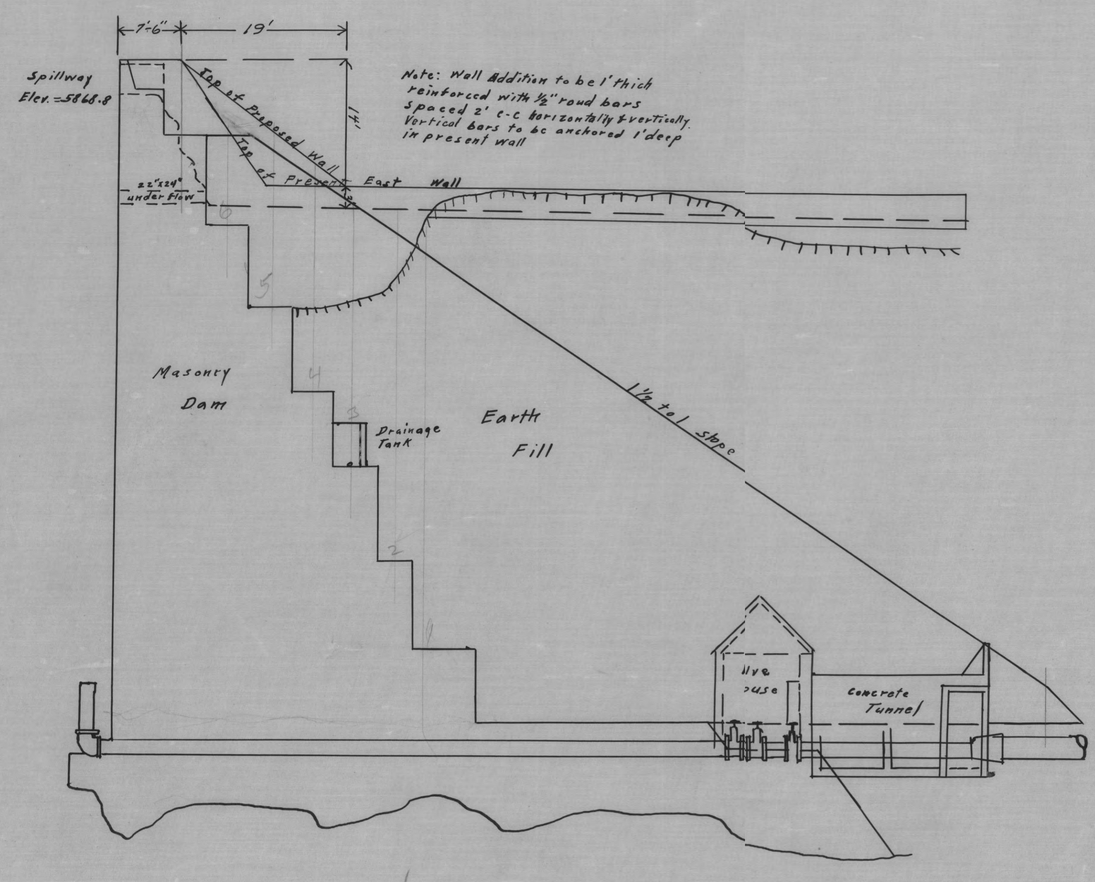
Modoc Pipe Line



"PERFECT" PROFILE PAPER.
PLATE. B.

"PERFECT" PROFILE PAPER.
PLATE. B.

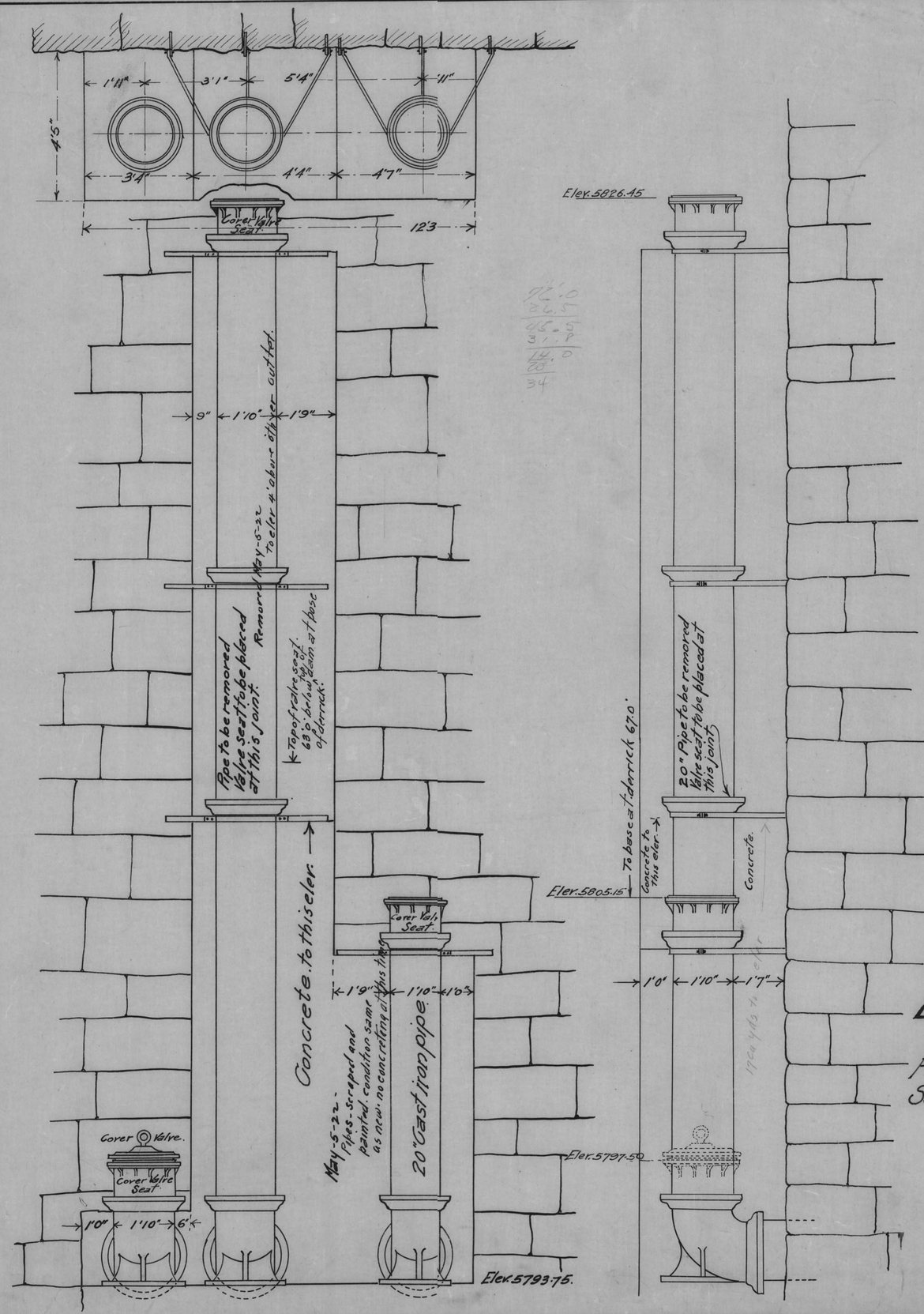
00407



Basin Creek Dam No. One
Details of Proposed Changes in Spillway
Date: 8-28-39 Scale: 1" = 10' Drawn by J.B.H.

Total yardage = 14,483 cu. yds
- Vol of tunnel above ground level 57 " "
- Rock fill 175 " "
Earth fill = 14,251 cu. yds

00417

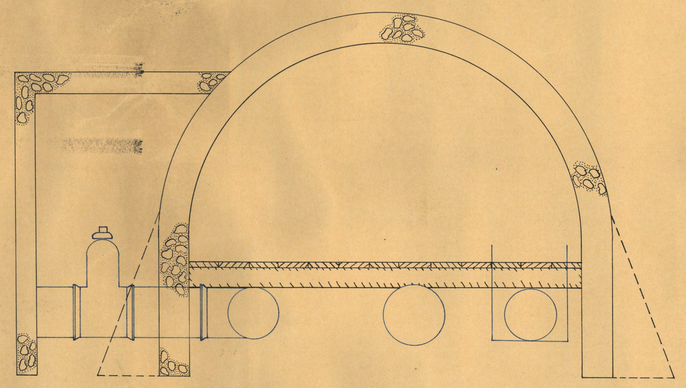


Butte Water Company

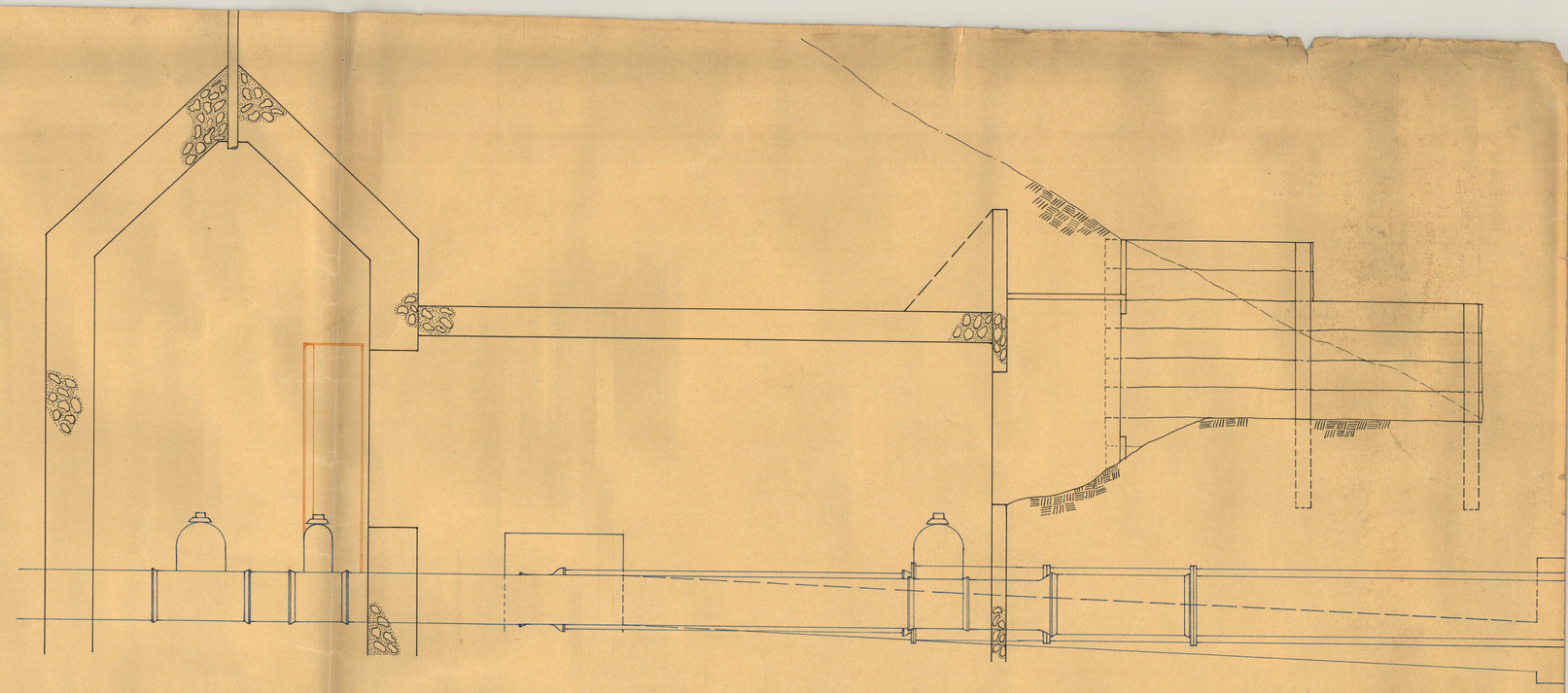
Plan of concrete covering for outlet pipes, Basin Creek Dam.

Scale 1" = 1'

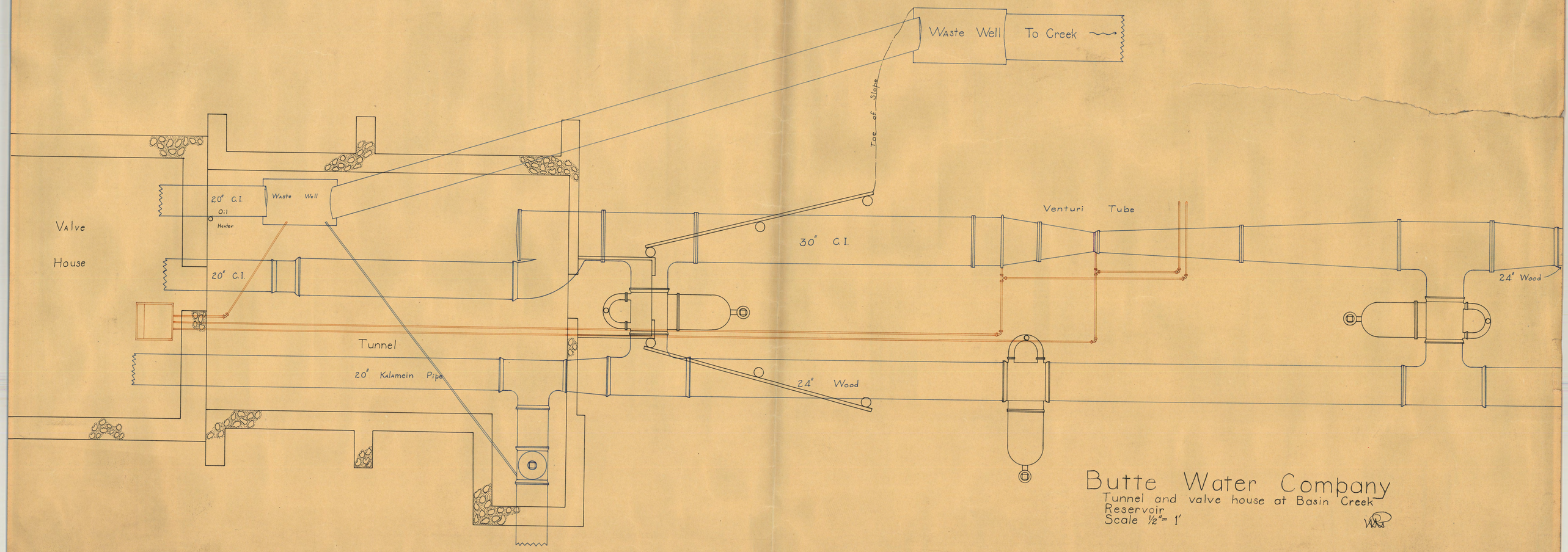
Jan-6-1922.



Cross Section

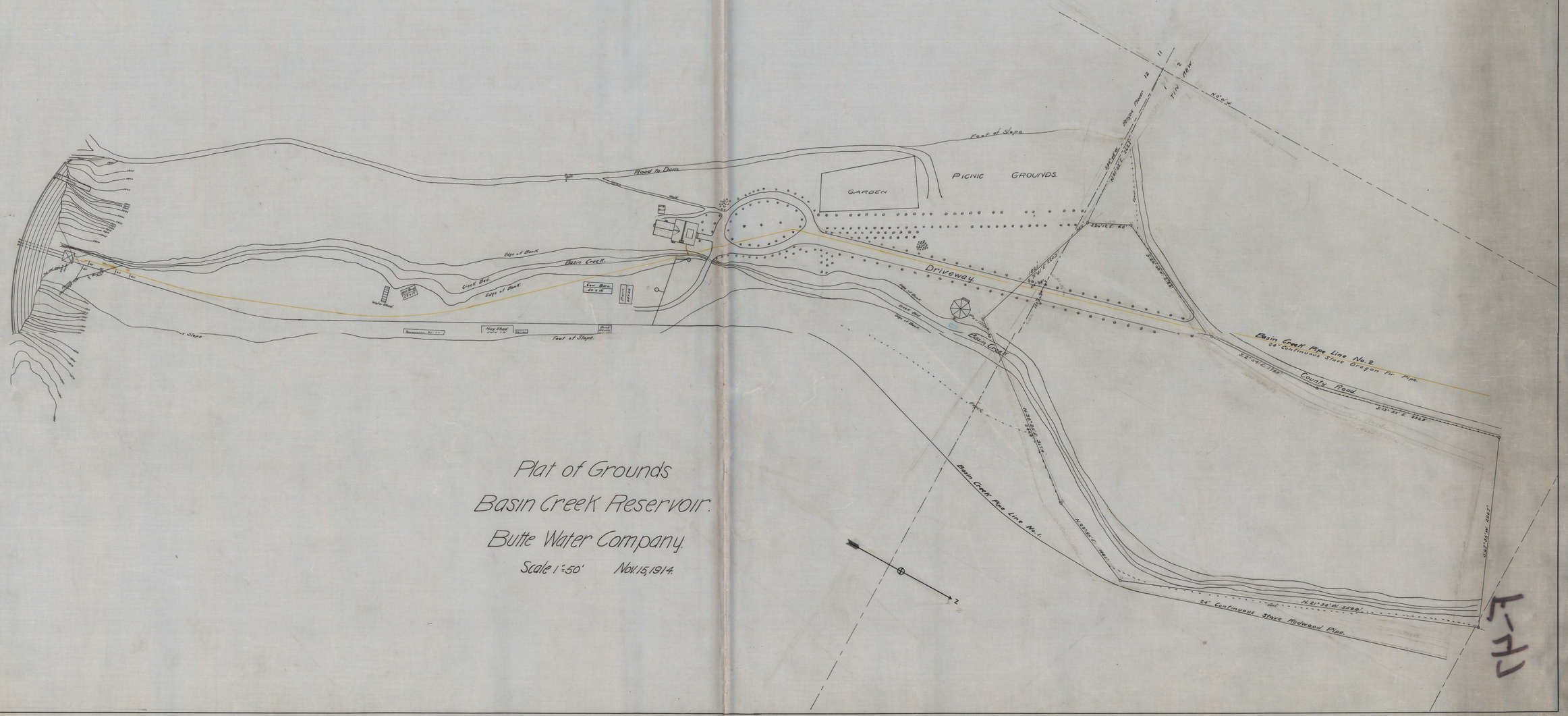


Longitudinal Section



Butte Water Company

Tunnel and valve house at Basin Creek Reservoir
Scale ½" = 1'



Plat of Grounds
Basin Creek Reservoir.
Butte Water Company.
Scale 1" = 50' Nov. 15, 1914.

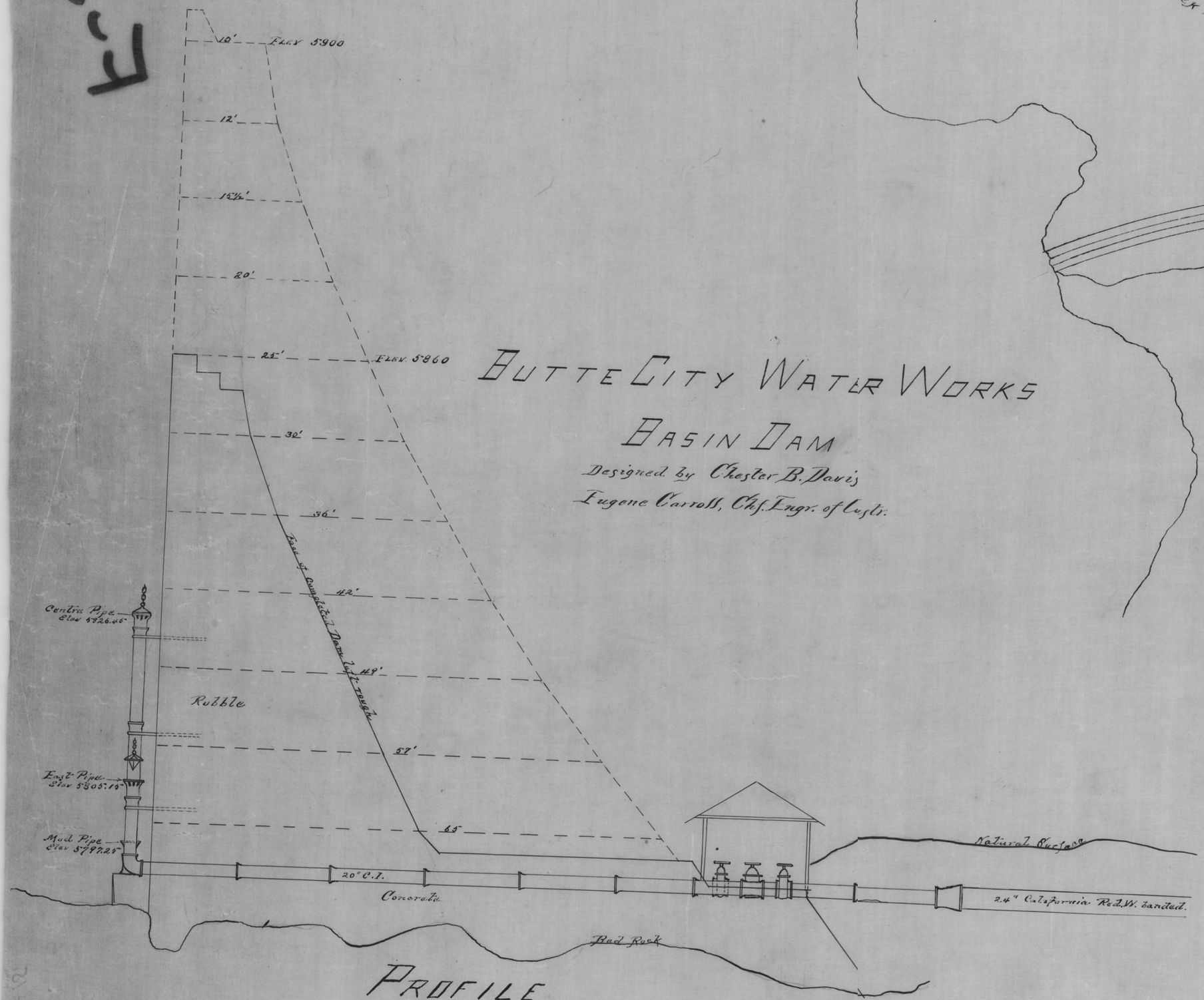
00428

Butte City Water Works

Basin Dam

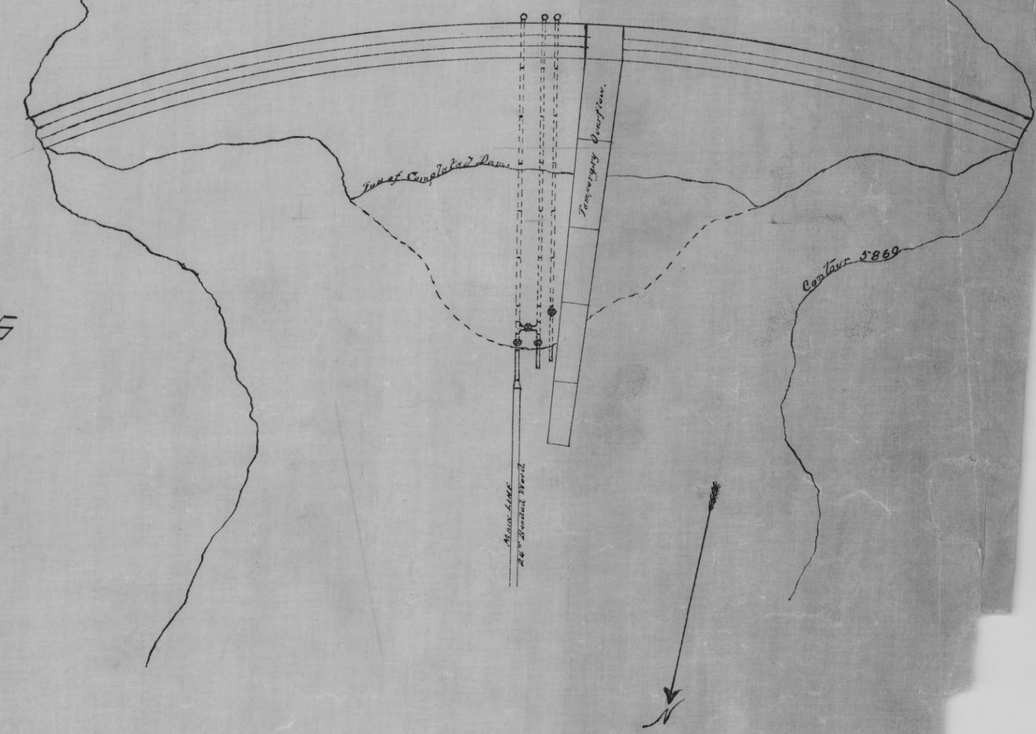
Designed by Chester B. Davis

Eugene Carroll, Chf. Engr. of Cons'tr.



Profile

Solid Lines Dam completed 1895.
Dotted " Profile of Finished Dam.
Scale 1" = 10'
Dec 1895.

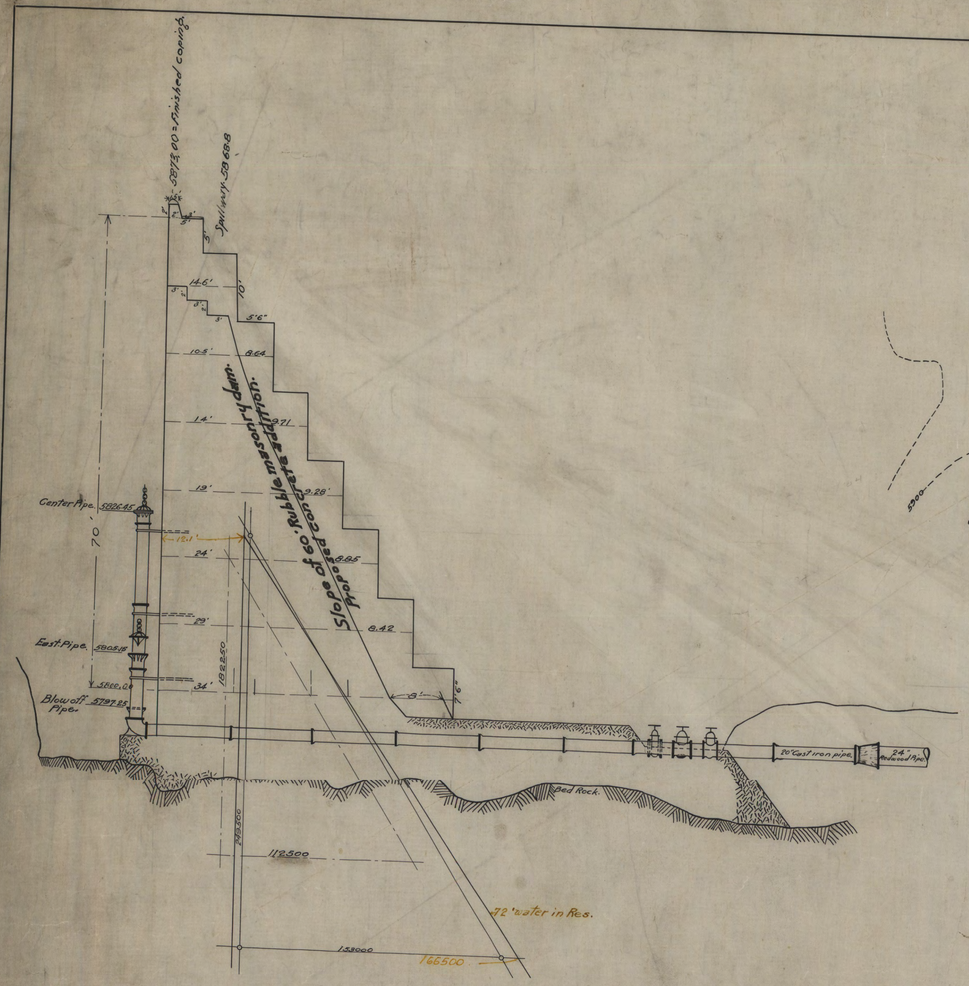


Plan

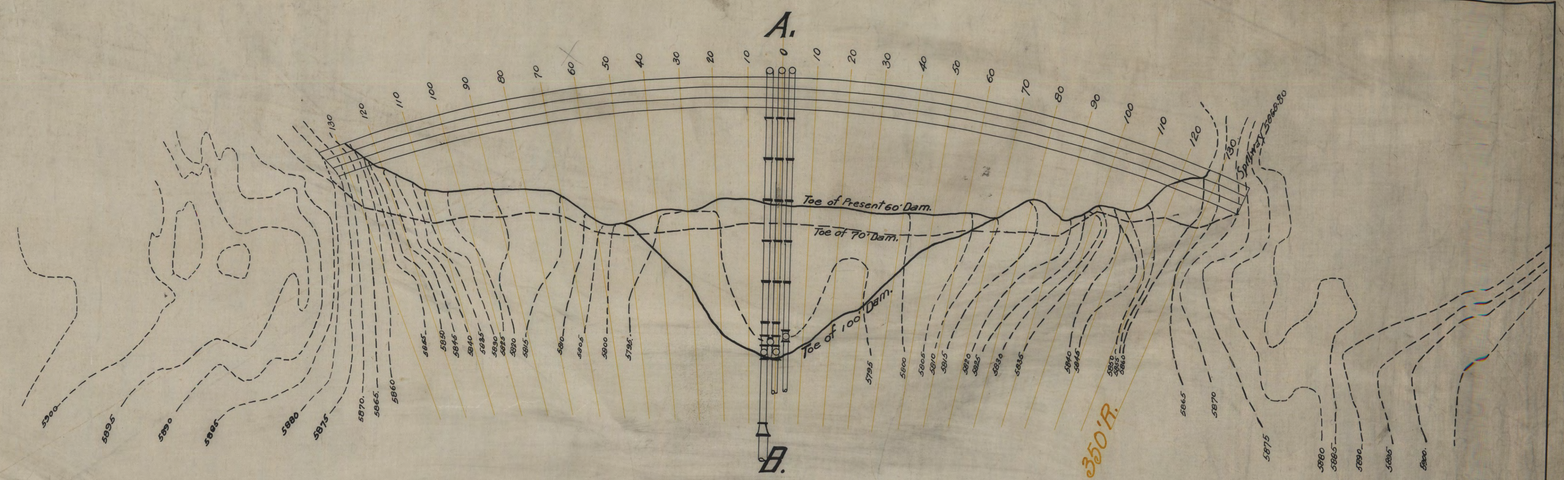
Scale 1" = 30'

Radius of Face 370 ft.

00432



Section A.-B. Scale 1"=10'



Plan of Dam showing 5 ft. contours.

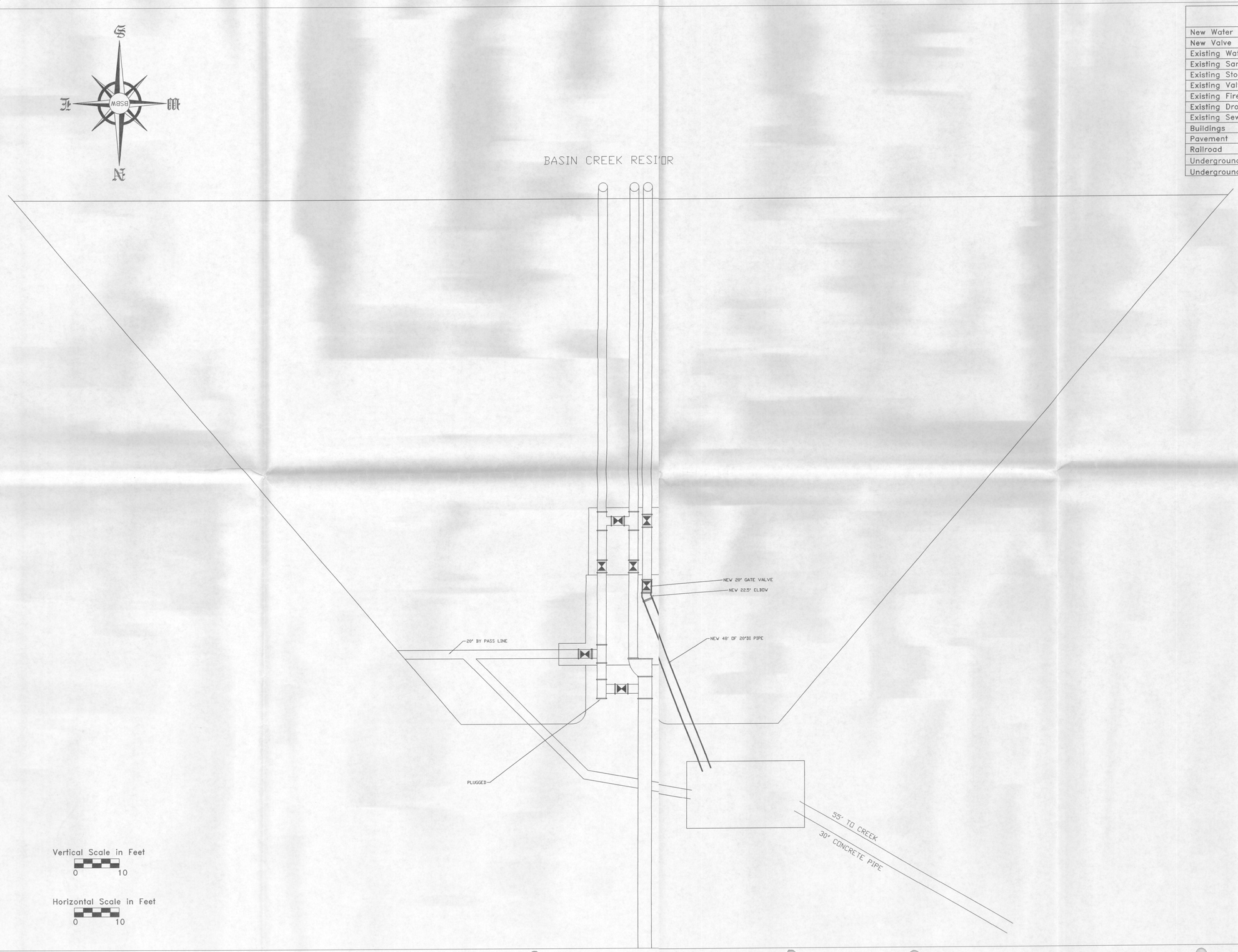
Scale 1"=20'

Basin Creek Dam #1.
Plan and Section showing proposed
Increase in height.
Butte Water Co. Dec. 12, 1912.

J.H.K.

K-6.

00674



Vertical Scale in Feet
0 10

Horizontal Scale in Feet
0 10

Legend

New Water Line	—W—
New Valve	
Existing Water Line	—W—
Existing Sanitary Sewer	—SS—
Existing Storm Drain	—SD—
Existing Valve	
Existing Fire Hydrant	
Existing Drop Inlet	
Existing Sewer Manhole	
Buildings	
Pavement	
Railroad	
Underground Telephone	—Phone—
Underground Gas	—Gas—

City & County of
Butte-Silver Bow
Department of Public Works

MONTANA
DAVID SCHULTZ
10524PE
REGISTERED PROFESSIONAL ENGINEER

BSB99-01-01

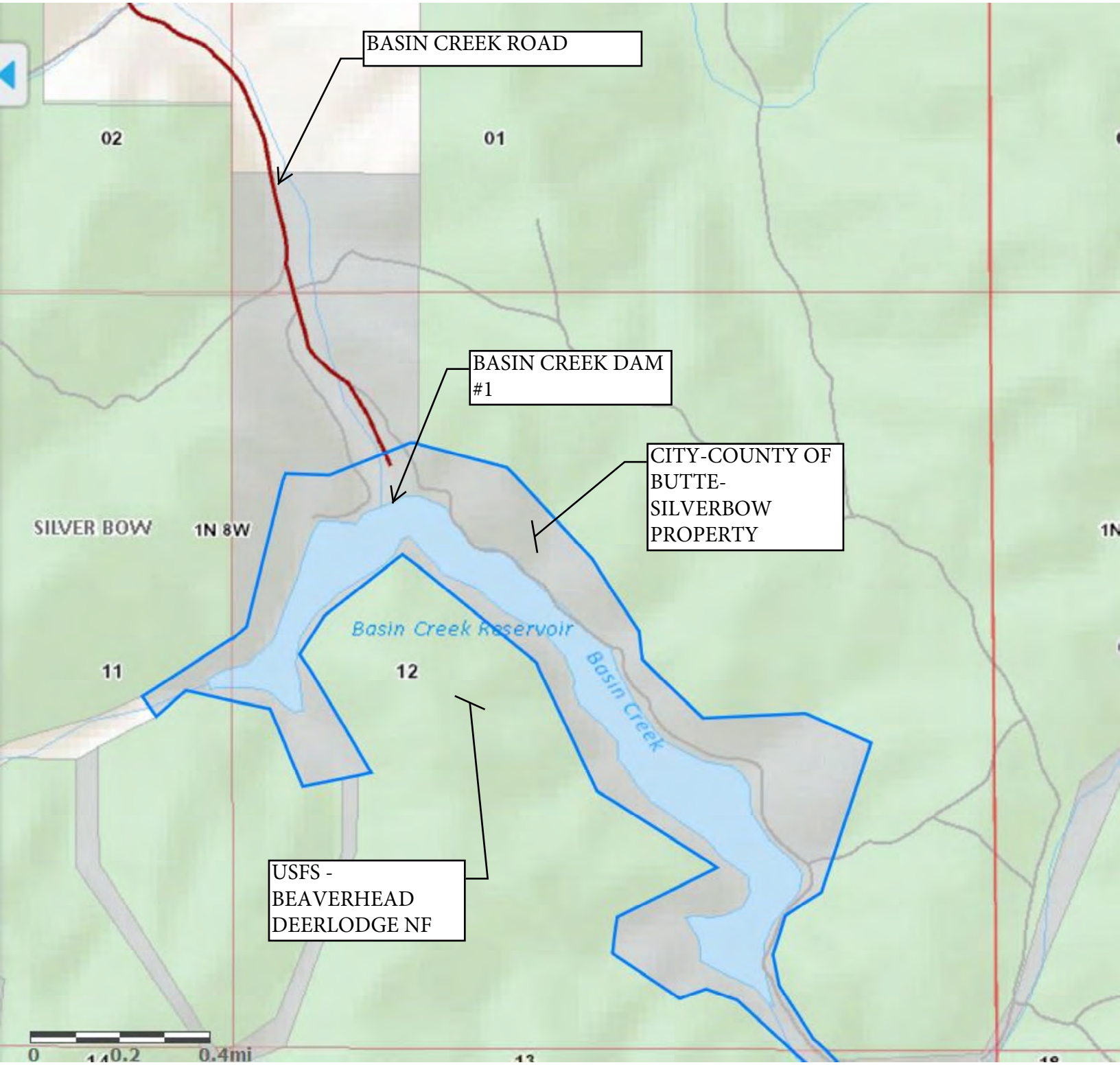
Designed by: Dave Schultz
Kevin Bone Jean Pentecost

Checked by: Dave Schultz
Kevin Bone Jean Pentecost

Drafted by: Kevin Bone
Date: 3/5/99
Scale Horiz. 1"=10'
Scale Vert. 1"=10'
Job: BASIN CREEK RESIVOR
Sheet: 1 of: 1

APPENDIX R

Cadastral Property Map in Dam Vicinity



CADASTRAL MAP OF DAM & RESERVOIR AREA

Source: http://svc.mt.gov/msl/mtcadastral

APPENDIX S

DNRC Correspondence

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

STEVE BULLOCK
GOVERNOR

DIRECTOR'S OFFICE (406) 444-2074
TELEFAX NUMBER (406) 444-2684

STATE OF MONTANA

WATER RESOURCES DIVISION (406) 444-6601
TELEFAX NUMBERS (406) 444-0533 / (406) 444-5918
http://www.dnrc.mt.gov

1424 9TH AVENUE
PO BOX 201601
HELENA, MONTANA 59620-1601

May 4, 2020

Mr. Mark Neary
Butte Silver Bow Public Works
126 W. Granite Street
Butte, MT 59701

Re: Support for Basin Creek #1 Grant Applications

Dear Mr. Neary,

The purpose of this letter is to express our support for your upcoming grant applications to repair the deteriorating concrete on Basin Creek #1. We have concerns about the ability of the dam to safely pass an extreme storm event as required by State dam safety requirements. Should a storm event cause the dam to overtop, the top several feet of the dam could wash away, potentially leading to failure of the dam. It is critical to stabilize the concrete and return the dam to a safe operating condition and full compliance with dam safety standards.

Please note that we are appreciative of your recent efforts to evaluate the structural condition of the concrete. This was important to understand the severity of the situation and options for repair.

We are available to address any questions that arise regarding state dam safety requirements during the grant application process.

Sincerely,

Steve Story, PE, CFM
Water Operations Bureau Chief
Water Resources Division
sestory@mt.gov

c: Jim Keenan, Chief Operator, City-County of Butte Silver Bow
Michele Lemieux, DNRC Dam Safety Program
Brent Zundel, DNRC Bozeman/Helena Regional Office Engineer

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION

STEVE BULLOCK
GOVERNOR

DIRECTOR'S OFFICE (406) 444-2074
TELEFAX NUMBER (406) 444-2684

STATE OF MONTANA

WATER RESOURCES DIVISION (406) 444-6601
TELEFAX NUMBERS (406) 444-0533 / (406) 444-5918
http://www.dnrc.mt.gov

1424 9TH AVENUE
PO BOX 201601
HELENA, MONTANA 59620-1601

Monday, May 4, 2020

Jim Keenan
City-County of Butte-Silver Bow
447 Basin Creek Road
Butte, MT 59701

RE: Basin #1 Operation Permit Conditions

Dear Mr. Keenan,

The purpose of this letter is to acknowledge that Butte Silver Bow (BSB) has met operation permit condition # 1 for Basin Creek #1. The Operation Permit Approval letter dated 12/20/2019 states:

> **Condition 1**: Complete an evaluation of the deteriorated concrete on upper section of dam and report on your findings. **Due Date 9/30/2020.**

Thank you for prompt action in hiring an expert consultant to complete the concrete condition study. I have reviewed the report of this analysis and agree with your consultant's assessment that the deterioration is a dam safety concern. The deterioration limits the ability of the dam to pass the inflow design storm, as required. Should an extreme storm event occur, Basin #1 could be at risk of failure. Thus, it is necessary to revise this condition as follows:

> **Revised Condition 1:** Address deteriorated concrete in dam using one of the recommended approaches discussed in the Basin Creek Dam Structural Assessment (Gannett Fleming, January 2020). Complete repairs to the dam before your current Operation Permit expires (9/29/2024). Failure to make significant progress to address deficiencies at the dam will force DNRC to consider restricting the reservoir operating level.

I understand that you are in the process of evaluating alternatives and pursuing funding options. We are appreciative of your proactive attention to the dam.

Sincerely,

Michele Lemieux

Michele Lemieux, PE
Montana Dam Safety Section Supervisor

C: Mark Neary, BSB Public Works Director
Dan Dennehy, BSB DES
Brent Zundel, DNRC Helena/Bozeman Regional Office Engineer
Steve Story, WOB Bureau Chief

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION

STEVE BULLOCK
GOVERNOR

DIRECTOR'S OFFICE (406) 444-2074
TELEFAX NUMBER (406) 444-2684

STATE OF MONTANA

WATER RESOURCES DIVISION (406) 444-6601
TELEFAX NUMBERS (406) 444-0533 / (406) 444-5918
http://www.dnrc.mt.gov

1424 9TH AVENUE
PO BOX 201601
HELENA, MONTANA 59620-1601

April 8, 2020

Ryan Elliott
Great West Engineering
PO Box 4817
Helena, MT 59604

RE: Basin #1 Rehabilitation – request for comments

Dear Ryan:

I am familiar with the City-County of Butte Silver Bow's plans to rehabilitate Basin #1. The Dam Safety Program has been working with the City closely in the last several months on Basin #1. I am not aware of any adverse environmental impacts from rehabilitation of the dam. Note that failure to complete the project in a reasonable period could have impacts, as we may be forced to implement a reservoir level restriction to reduce the risk of dam failure due to the poor condition of the concrete. A reservoir level restriction could have several adverse impacts.

Since Basin #1 is classified as a high hazard dam, the City-County will be required to obtain a Construction Permit from the Dam Safety Program. We have a detailed design review process in place. As part of this process, we will be involved in all stages of the design to assure appropriate standards are followed.

Please call or email if you need additional information.

Sincerely,

Michele Lemieux, PE
Montana Dam Safety Section Supervisor
mlemieux@mt.gov
406-444-6613

APPENDIX T

Newspaper Articles

Making a splash: Bullock, others to be at Basin Cr plant ceremony

Making a splash: Bullock, others to be at

SHARE THIS
3 comments

Mike Smith
Apr 13, 2017

The new Basin Creek water treatment plant, seen here in February, sits on a 5-acre hillside about 6 miles south of Bert Mooney Airport. Although construction was paid for with money from mine-pollution settlements, annual operating costs of about $650,000 are one reason officials say an increase in water rates is needed.

Walter Hinick, The Montana Standard

After years of planning and construction, Butte's new $30-million Basin Creek water treatment plant goes online next week, and there will be plenty of partners on hand to mark the occasion.

Gov. Steve Bullock will join other state and local officials at an opening ceremony set for 10 a.m. Wednesday outside the new plant tucked in the hills and pines off of Basin Creek Road south of town.

It has been billed as the first ceramic-membrane filter system used to ensure

clean drinking water for a U.S. city, and — in the words of Butte-Si
Chief Executive Dave Palmer — "It's a big deal."

Making a splash: Bullock, others to be at SHARE THIS 3 comments

"It's the last piece of untreated drinking water we have, and we're going to have a ceremony for having the cleanest drinking water in the state of Montana," Palmer said.

"We're going to make a big splash."

One he hopes will get noticed elsewhere, too.

"A lot of people around the state don't want to come to Butte with businesses because they think the drinking water is in poor shape," Palmer said. "Actually, every bit of it is treated now; it meets all the standards, and it's probably the cleanest water in the state."

For decades, water from the Basin Creek Reservoir was some of the best in all of Montana. A little chlorine was added before gravity alone carried it into town, but that was it. No filters and no plant were needed.

But in 2011, for reasons not precisely clear, the water exceeded levels of acceptable disinfection byproducts. For about six months, it had high levels of organic carbons that produce possible carcinogens when treated with chlorine.

Organic carbons soon returned to acceptable levels, and Basin Creek has remained a key source of drinking water in Butte, but there was no turning back.

Bullock and other state officials will be on hand because the state's Natural Resource Damage Program paid for most of the plant with money from mine-pollution settlements.

Harley Harris, program manager for the NRDP, will join Bullock a

Making a splash: Bullock, others to be at

3 comments

will Palmer; Maureen Connor with the Upper Clark Fork River Basin Advisory Council; and Elizabeth Erickson, chairwoman of the Butte Natural Resource Damage Restoration Council. Public Works Director Dave Schultz will be master of ceremonies.

To ensure enough parking at the ceremony, the county will provide bus service from 118 S. Parkmont (parking lot next to the U.S. Army Reserve Building in the Industrial Park). The buses will depart at 9:15 a.m. and 9:45 a.m. Wednesday and return after the event.

3 comments

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Email Address Sign up!

* I understand and agree that registration on or use of this site constitutes agreement to its user agreement and privacy policy.

Big bonus: Basin Creek Reservoir expected to open to recreation next year

Mike Smith
Apr 16, 2017

The dam that created the Basin Creek Reservoir built more than 100 years ago will become part of an ac leading visitors to recreational opportunities within the watershed. Brian Wilkins, left, operations manage county's Water Division, and Public Works Director Dave Schultz are pictured walking across the dam thi

Walter Hinick

Butte already stands to benefit from decades of clean drinking water when the $30-million treatment plant south of town goes online this week, but

there's another big prize — a cherry on top, you might say.

About a year from now, thanks to the treatment plant, the pristine Basin Creek Reservoir, its smaller, higher-up cousin and their surrounding hills and pines should be accessible to everyone.

They will eventually include hikers, bikers, horseback riders, picnickers, and anglers who could cast into a "rather robust, genetically pure westslope cutthroat trout fishery," as Jason Lindstrom, a fisheries biologist with Montana Fish, Wildlife and Parks put it.

"This unique fishery can provide area residents with a quality angling experience, the likes of which has not been available in Butte for several generations," he wrote in a letter supporting public access to the area.

The overall plan is still in its infancy, and there are plenty of partners, spearheaded by the nonprofit George Grant Chapter of Trout Unlimited (GGTU) and Butte-Silver Bow government, with a big hand from Water and Environmental Technologies (W.E.T.) in Butte. Other state agencies and the U.S. Forest Service are on board, too.

There's a lot of work to be done and money to be raised, but the hope is to have walk-in access to the reservoir and surrounding areas by June 2018. Eventually, trails might link with Thompson Park and national forest lands.

"It's a diamond in the rough, and we're going to turn it into a diamond after we're all done," said John Trudnowski, senior engineer for W.E.T. who is playing a big part in the project.

Roy Morris, president of the George Grant chapter, noted that Hyalite Canyon is

part of Bozeman's municipal supply and is also one of Montana's most popular outdoor recreation venues.

"This will be bigger and better than Hyalite," he said.

But he and other supporters know things must be done right to keep the trout thriving and the area beautiful.

"We are all concerned that it doesn't get ruined by being loved to death," Morris said.

GETTING HERE

The Basin Creek reservoirs — a lower one and a smaller one higher up about a 25-minute walk away — were created in the late 1890s to serve as one of Butte's primary sources of drinking water.

Men took granite from a nearby area, chiseled it into giant, square blocks and stacked them side-by-side to form a dam that to this day pools mountain water flowing into Basin Creek. Headwaters to Fish Creek are also diverted across the Continental Divide into the upper reservoir.

Even following more stringent federal requirements in the late 1980s and early 1990s under the Safe Drinking Water Act, Basin Creek was granted a waiver that allowed its water to go unfiltered.

"Butte made the case that Basin Creek water was so pristine and the turbidity so low we didn't need filtration," said Butte-Silver Bow Public Works Director Dave

Schultz.

But that waiver also required that the reservoir be off limits to people so the watershed wasn't harmed.

So while folks could go to Basin Creek Park a short distance from the dam, they weren't allowed in areas surrounding the reservoirs.

In 2011, however, the water exceeded levels of acceptable disinfection byproducts for about six months, and the filtration waiver was revoked, meaning the water had to be treated.

A high-tech, ceramic-membrane treatment plant was funded through mine-pollution settlement money overseen by the state's Natural Resource Damage Program.

About $20 million came from money benefiting the Upper Clark Fork River Basin, and $10 million came from the Butte Natural Resource Damage Program Council (BNRC). That group tacked on a requirement that once the treatment plant was built, the reservoir area would be opened up — though it was always the intent of county officials to do that.

"That's how important it was to them (BNRC)," said Pat Cunneen, an environmental science specialist with the NRDP. "Had they (county officials) not agreed to open up Basin Creek, they probably wouldn't have gotten the $10 million."

The Trout Unlimited chapter is now seeking the first big chunk of funding for the project from the NRDC. Grants are limited to $100,000 for any one project, so that's what GGTU has applied for.

Butte-Silver Bow, which owns the reservoirs and areas closest to them, is contributing time and assistance and is working with GGTU on a plan to provide access without compromising water-system operations.

"We are going to open up a tremendous area for people," Schultz said.

FRAMEWORKS OF THE PLAN

GGTU has estimated "conceptual costs" for improving the area for access and says — roughly — they total about $840,000. They are broken down into more than 30 items, including designs, engineering, fencing, a safe dam walkway, paved trails, benches, picnic tables, and a fishing dock.

Schultz and Brian Wilkins, operations manager for the county's Water Division, took a reporter and photographer from The Montana Standard to the area this week and explained how some key aspects might work.

The downslope of the dam and its associated water-system works would be fenced off from the public, and no motorized vehicles — cars, trucks, four-wheelers, or boats — would be allowed in the reservoir areas. People would walk up on one side from Basin Creek Park.

The plan likely will be done in phases, with some access allowed in the summer of 2018. At some point, people would be allowed to bring their bicycles and

paddleboats, kayaks, and canoes.

There's a cove in the reservoir near the dam called Bear Gulch that could be a good place to launch non-motorized watercraft. Swimming probably won't cause cleanliness problems that can't be eliminated by the treatment plant, Wilkins says, and if further analysis confirms that, Bear Gulch would be a great spot to wade or splash in.

The lower reservoir is bigger than it seems because much of it twists back beyond immediate sight, and there would be trails all around that also reach the upper reservoir, Schultz said.

There is an area just before Basin Creek flows into the top of the lower reservoir that is used to catch and stop sediment. The county removes the sediment periodically, and that area, which creates a barrier preventing trout from moving upstream, must stay intact.

A key part of the plan is to create a passage around it, perhaps via a stair-stepped fish ladder, so the trout can move upstream and spawn in the creek above. Currently they can only move downstream from the upper reservoir.

Cutthroat trout are a great sport fish, in part because they are easy to catch, but

they can't survive with other, more aggressive fish, including brook trout. So they will need more space to spawn to remain a wild, self-sustaining population if fishing is allowed.

Lindstrom said he's confident a bypass can be established, but he and Trudnowski say the precise manner and mechanism must be worked out.

TEAMWORK TOWARD THE BIG VISION

Details about most everything else must be worked out, too, and that effort could get an initial boost if GGTU lands the $100,000 grant.

"Right now, everything has just been ideas we have been discussing back and forth," said Trudnowski, who helped prepare an application proposal for the money. "The purpose of getting the first grant is to get a plan on paper so everyone is on the same page and we can move forward."

The proposal already includes goals and cost estimates and identifies a number of additional funding opportunities, including local, state, and federal grants.

Several people with several entities, including Jocelyn Dodge, who has worked for the U.S. Forest Service in Butte for 26 years, have met to discuss the effort.

"We look at is an opportunity to make connections with our trail system in the area along with potentially Thompson Park," Dodge said.

Cunneen said the effort has been championed for years by BNRC member Emmett Riordan and was an "an amazing project." Among other benefits, it

could create a cohesive habitat for cutthroat trout by connecting several area waterways, including Basin Creek, Moulton Reservoir, Upper Blacktail Creek, German Gulch, and Browns Gulch.

"They are a fairly exotic fish, and you cannot find them in many places," he said.

Before it can be opened up, he said, the Montana Department of Environmental Quality must change its classification that deems it a closed, premier watershed — one of only a few pristine ones in Montana.

Morris gives a lot of credit to W.E.T. co-founder Josh Vincent, who also is a member of the Trout Unlimited chapter, and the environmental firm overall. But there are lots of groups coming together, including nonprofits such as GGTU.

"George Grant likes doing cooperative projects with other conservation groups," Morris said. "We like to get as many groups as involved as we can."

A ceremony is planned Wednesday to mark the opening of the water treatment plant. The access project will take more time to pan out, but Butte-Silver Bow Chief Executive Dave Palmer says it should be worth the wait.

"It's a big bonus," he said.

0 comments

Drink up: Ceremony marks opening of Butte's $30 million water treatment plant

Mike Smith
April 19, 2017

Montana Gov. Steve Bullock addresses a group of some 100 people gathered in front of the Basin Creek Treatment Plant Wednesday morning to officially open the new $30 million drinking water filtration facili

Walter Hinick

Calling it a collaborative commitment to enhancing quality of life, Gov. Steve Bullock joined other state and local officials in a ribbon-cutting ceremony Wednesday for Butte's new $30 million water treatment plant.

"We shouldn't take clean water for granted," Bullock told about 100 people on a deck of the state-of-the-art plant at Basin Creek, about five miles south of Bert Mooney Airport.

Bullock noted that Butte-Silver Bow Chief Executive Dave Palmer, in a Montana

Standard story last week previewing the ceremony, had called the plant "a big deal."

"The drinking water will be some of the cleanest water in the nation and that is a big deal," Bullock said.

The high-tech plant has been billed as the first ceramic-membrane filter system used to ensure clean drinking water for a U.S. city. They are common in Japan and Europe and are known for efficiency and filters that last much longer than those used in conventional plants in the U.S.

Just before Bullock and others cut the ribbon, they put on T-shirts made for the occasion that said, "We have a PhD in H20."

Water from Basin Creek Reservoir was so pristine, a little chlorine was added before gravity carried it into town but no filters were needed.

Federal and state regulators deemed the filter plant necessary in 2011 when, for reasons not precisely clear, the water exceeded acceptable levels of acceptable disinfection byproducts for a short time.

Officials with several groups, businesses and government agencies that played a role in the project were on hand Wednesday. They included representatives for the Natural Resource Damage Program (NRDP) and the Upper Clark Fork River Basin Advisory Council, which combined to pay for the new plant.

The Clark Fork group helped secure about $20 million in mine-pollution settlement money for the plant and the Butte Natural Resource Damage Program Council (BNRC) steered $10 million to the project.

BNRC Chairwoman Elizabeth Erickson said its decision was contentious at the time because one of the group's guiding principles was to focus spending on cleaning up and restoring the Silver Bow Creek channel that runs through central Butte.

But she said one member drove home the point that, "No matter what else we do, if we don't have good drinking water, what else will matter?"

Discussions about a new plant began when Paul Babb was serving his second term as the county's chief executive. He left office in late 2012 but was at Wednesday's ceremony.

"Every form of government got involved in this, as well as the people of Butte. They got behind and supported this," Babb said after the event.

Palmer called it a testament to teamwork.

"There is no reason to go out and buy bottled water anymore," he said. "We have some of the cleanest drinking water in the whole state of Montana."

Bullock's visit came as state lawmakers wind down the 2017 legislative session with no final decision yet on steering tens of millions of dollars toward infrastructure projects in Montana. Infrastructure packages failed to pass in

2013 and 2015 but Bullock is pushing capital projects once again.

"Infrastructure not only creates jobs but sets businesses and families up for the future, so it's important the Legislature get an infrastructure bill to my desk so we will continue to have investments like this for the long-term for our state," Bullock told reporters after the ceremony.

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Mike Smith

Government and Politics Reporter

Mike Smith is a reporter at the Montana Standard with an emphasis on government and politics.

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Apr 16, 2017

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Council recommends $100,000 toward Basin Creek park; $120,000 remains to be spent

Susan Dunlap
Apr 21, 2017

Upper Silver Bow Creek is seen in this file photo from 2014.

Walter Hinick, The Montana Standard

After deciding on how to spend money on 16 community-based grants Thursday — including $100,000 toward the Basin Creek park idea — the Butte Natural Resource Damage Council must now determine what to do with

the $120,000 that is left.

The nine-member, all-volunteer council began with $1 million in 2014 to put toward local projects that are restoration related. The money comes from a state settlement with Atlantic Richfield Co. that was reached in 2008.

The council went into Thursday's meeting with about $600,000 to spend. Pat Cunneen, the council's environmental science specialist, said initially the remaining pot totaled $525,000, but with interest, that sum bumped to about $600,000.

The 16 projects' requests exceeded $900,000 — more than the council had left in the bank. The council whittled the projects to 12 for a total of $479,903. About half of the money being spent in this round goes to Montana Tech professors and students for various cleanup-related studies.

Gov. Steve Bullock has the final say on who gets what and is expected to announce those decisions by this summer.

The council will likely address the leftover cash question at its next meeting, said Natural Resource Damage Council program chief Doug Martin.

Following are the 12 proposals the BNRC is recommending to Bullock:

• George Grant Chapter of Trout Unlimited: $100,000 for preliminary development of a recreational area around Basin Creek near the reservoir. The focus of the funding will go toward building a fishery, reconstructing a channel, designing and installing a fish passage, putting in seeds, and planning and engineering further development. The overall project is expected to cost $840,000.

• Montana Tech professor Robert Pal: $95,747 to build a greenhouse to grow trees for BSB's tree-planting project.

• Tech professor Alysia Cox: $50,306 to look at microbes in Silver Bow Creek and Blacktail Creek to better understand creek sediment.

• Retired hydrogeologist Joe Griffin: $49,700 to create a computer simulation of the aquifer running along upper Silver Bow Creek.

• Watershed Restoration Coalition executive director Ted Dodge: $40,000 to improve Blacktail and Basin Creek's watershed resiliency with beaver mimicry projects.

• Tech professor Chris Gammons: $37,425 to sample Blacktail and Silver Bow Creek beds from Father Sheehan Park to the Interstate 15-90 overpass bridge.

• Tech professor Raja Nagisetty: $35,000 to create a feasibility study for cleanup plans of zinc in Grove Gulch, an intermittent stream south of Butte.

• Butte citizen Crystal Vandermeulen: $29,230 to revegetate a dump site on Montana Street near the courthouse. The funding comes with a contingency that Butte-Silver Bow supplies a match of approximately $10,000 for irrigation water.

• Science Mine board of directors member Lois Podobnik: $19,000 to help create a traveling Science Mine exhibit on Butte cleanup.

• Tech graduate student J. Trilling: $11,170 to look at areas that aren't being reclaimed on the Butte Hill to understand the potential for what could grow at those sites.

• Tech graduate student Joao Nascimento: $4,900 to develop software to track seeds planted by Tech.

• East Middle School eighth-grader Taryn Stratton: $1,278 to $7,425 to install markers on storm drains to heighten community awareness that what enters into a storm drain travels to the creek.

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Susan Dunlap

Environmental and natural resources reporter for the Montana Standard.

Basin Creek plant wins engineering award for teamwork, technology

Mike Smith
Aug 18, 2017

The new Basin Creek water treatment plant has 400 stainless steel tubes, some of them shown here, each containing ceramic membrane filters that capture illness-causing pathogens as water from Basin Creek Reservoir flows through.

Walter Hinick, The Montana Standard

In his 30 years of engineering and work on water facilities, Butte-Silver Bow's Public Works director says the new $30 million Basin Creek Water Treatment Plant stands out.

"Every plant operator in Butte was in the conference room and took part in the design of this plant for over a year," Dave Schultz said Friday. "I have been involved in lots of other plants, and this is the only one that had that much

collaboration."

Engineering News-Record, a weekly publication that provides news, analysis and opinion on the construction industry worldwide, also cited teamwork in giving the Basin Creek plant and Missoula-based HDR Engineering Inc. a Best Project award for 2017.

ENR Mountain States, which focuses on a seven-state region of the U.S., said the Basin Creek plant beat out five other entries for Best Project in the water/environment category.

A panel of nine judges from all areas of the industry—architects, general contractors, green consultants, virtual designers and engineers—selected winners from 105 total entries in all categories in the region this year. HDR Engineering, primary designers of the Basin Creek plant, entered it in the competition.

Mark Shaw, Rocky Mountain bureau chief for ENR, said judges noted "the teamwork and excellence that went into the project."

"Judges also considered the community impact of the project (a big plus for yours) and how well it fulfilled the owner's goals," Shaw wrote in an email to The Montana Standard on Friday. Technology was another factor, he said.

The high-tech plant is the first ceramic-membrane filter system used to ensure clean drinking water for a U.S. city. They're common in Japan and Europe and are known for efficiency and filters that last much longer than those used in conventional plants in the U.S.

Schutz says it is also a "gravity on demand" plant because water from Basin

Creek Reservoir flows into the plant and then into town on gravity alone. That saved the city millions of dollars because a giant storage tank and other equipment wasn't needed.

But Schultz said he's most proud of the teamwork. Bi-weekly design meetings were held for more than a year and input from operators in Butte was incorporated in the plans and added to HDR's experience and expertise, he said.

"The operators had a great deal of say into how that plant was built," he said.

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Mike Smith

Government and Politics Reporter

Mike Smith is a reporter at the Montana Standard with an emphasis on government and politics.

Analysis conducted on crumbling portions of Basin Creek dam

Mike Smith
Nov 30, 2019

Jim Keenan, Butte Water's chief operator, positions a boat at Basin Creek dam on Nov. 23 so Gannett Fleming's professional engineer Aimee Corn can get a close-up look at concrete in the upstream face of the dam. Portions of the concrete are deteriorating and will need repairs.

Courtesy of Butte-Silver Bow

Butte-Silver Bow is paying a Colorado engineering firm $38,283 to do a detailed examination and analysis of crumbling top portions of Basin Creek Dam — deterioration that could lead to overtopping in an extreme storm event.

The water level in Basin Creek Reservoir was lowered last week so an engineer with the firm could get a close look at the top 13 feet of the dam and take core samples of its concrete. The analysis should spell out needed repairs that could be made next year.

The dam is not in imminent danger of failing, officials say, but problems were noted in 2014 and 2019 inspections and Public Works Director Mark Neary told commissioners recently the deterioration has accelerated considerably the past two years.

The county, on advice from Pioneer Technical Services in Butte, wanted repairs designed and approved by a professional engineer with experience in hydraulic structures — in other words, a "dam expert," said Pat Cunneen, senior operations engineer with Butte-Silver Bow.

They got a list of professionals from the state and reached out to Gannett Fleming Inc., a firm based in Greenwood Village, Colo.

The county "wanted to get going before winter set in, so we needed somebody that was available right away," Cunneen said. "Several firms we contacted could not get started this year but when we contacted Gannett Fleming, they stated they could get right to work as soon as we issued them a contract."

Commissioners signed off on the $38,283 contract last week and Aimee Corn, an engineer with Gannett Fleming, was here Nov. 21 and Nov. 22 to inspect the dam.

In preparation for her visit, the water level in the reservoir was lowered to approximately 5,857 feet so the engineer could see the entire top 13 feet of concrete, Cunneen said. Water Division workers put a small boat in the reservoir

so she could get an up-close look at the entire 275-foot width of the upstream concrete face.

"The engineer also looked at the top of the dam and earth was removed from one section of the downstream face so the engineer could look at the concrete on the backside as well," Cunneen said.

County personnel drilled into parts of the concrete to retrieve core samples that have been sent to another company in Boulder, Colo., for lab analysis on the minerals and texture. That should take a month or so.

Gannett Fleming will take that and information collected during their site visit, compile a report, and hopefully deliver it to Butte-Silver Bow by mid-January, Cunneen said. The report will include recommendations for repairs.

The county obtained an $8,000 grant to help pay for the analysis and the balance of $30,283 will come from water ratepayer funds, Cunneen said.

"We plan on using the information from Gannett Fleming's report to apply for future grant funds to help with any repairs that might be needed," Cunneen said.

The deadline for some of those grants is in March, a big reason why the county wanted to get the investigation and recommendations completed right away, he said.

0 comments

EDITOR'S PICK

Off limits: Basin Creek Reservoir still closed, but opening plans taking shape

Mike Smith
Oct 14, 2018

Snow sprays from pines trees at Basin Creek Park this week as county water crews clear out dead trees s won't fall on fencing designed to keep people away from the nearby reservoir.

Mike Smith

Opening Basin Creek Reservoir to the public is at least a year off, probably longer, despite previous auspicious ambitions of letting folks canoe, fish, and picnic the pristine area south of Butte this year.

There's still a long list of things that must be done to make the area safe and usable for people while protecting the westslope cutthroat trout swimming in the reservoir's water. And as of now, there's not enough money to pay for it all.

Off limits: Basin Creek Reservoir still clos 0 comments

Project proponents, led by the George Grant Chapter of Trout Unl putting an initial $100,000 state agency grant to use, and they're getting another $100,000 in county funds to do more.

They need an additional $450,000 to do everything they want to do, which includes securing the dam, putting a boat ramp and fishing dock in, installing restrooms, and clearing trails around the lower and upper reservoirs.

The goal is to provide walk-in access and opportunities for hiking, fishing, biking, horseback riding, canoeing, and other non-motorized uses.

But there's a more pressing problem right now.

People have jumped the gun and are hitting the reservoir in bigger numbers than the occasional teens who have wandered up there for years even though the area is off limits.

Plans to open the reservoir are only possible because of Butte's new $30 million, state-of-the-art water treatment plant. The reservoir is a major source of drinking water for Butte, and the plant's ceramic-membrane system should be able to adequately treat water even when folks are canoeing and fishing in it.

But it's not foolproof, and it seems some are hell-bent on killing a good thing before it's even a thing.

"So far there has been a lot of graffiti on the rocks up there," said Dave Palmer, Butte-Silver Bow's chief executive. "There is trash being left up there. We've even found used diapers in the water."

They've found campfires, too, though so far they have at least been put out.

"There is a lot of downed timber up there that has to be cleaned up because the risk of a fire up there is still very high," Palmer said. "Even the new treatment plant isn't designed to handle a lot of debris getting into the water supply. It would need a separate treatment system for that, and we do not have that."

There have been a few "no trespassing at the reservoir" signs up for a long time, but recently, a giant new sign has been installed right where an overgrown roadway leads up a hill to the dam and reservoir.

This one not only states warnings and state penalties for trespassing and offers rewards for telling on those who do, but it also defines "tampering with a water supply" and spells out its possible consequences.

They include federal penalties of up to 10 years in prison for attempting or threatening to tamper with the water and 20 years for actually doing it. Civil penalties can hit $1 million.

Other steps have been taken to secure the area, and more are planned.

"The biggest thing we are trying to do before we let the public in is protect the water supply," said Roy Morris, director of the nonprofit George Grant chapter. "The second issue is to protect the pure strain of westslope cutthroat trout."

EARLY AMBITIONS AND PROGRESS

Off limits: Basin Creek Reservoir still clos 0 comments

Plans to open the reservoir go back several years.

About $20 million to build the water treatment plant came from money benefiting the Upper Clark Fork River Basin, and $10 million came from the Butte Natural Resource Damage Program Council. The latter group tacked on a requirement that after the plant was built, the reservoir would be opened up.

Like many big projects, it's easy to get ahead of the game. So when the plant came online in April 2017, visions emerged of opening up the reservoir relatively quickly.

Indeed, that's the way The Montana Standard reported it in a story on April 16, 2017.

"There's a lot of work to be done and money to be raised, but the hope is to have walk-in access to the reservoir and surrounding areas by June 2018," the story said.

That time passed three months ago, and it's not close to being open.

"Of course, we were all excited about getting to open this up," Morris said. "As we delved into it, we realized it was much more involved than we realized."

There has been one major development, and it was a key to all plans.

Before it could be opened, the Montana Department of Environmental Quality

had to change the area's classification as a closed, premier watersh
Off limits: Basin Creek Reservoir still clos
0 comments
only a few such places in Montana.

The DEQ did that with enthusiasm last November, noting that prior to the plant, only minimal treatment of water was needed before it was sent to faucets in town.

"Given the current drinking water treatment process, the Department finds that it is no longer necessary to restrict public access to the Basin Creek watershed and hereby rescinds that condition," the DEQ said in a letter to county officials.

With money from an initial $100,000 BNRC grant, steps were recently taken to install new fencing at the base of the reservoir and shore up holes in other sections to help prevent people from sneaking up to the water.

County crews were at the site this week clearing dead trees so they don't fall on the fencing. Money from the initial grant also will be used to complete site evaluations and surveys, obtain necessary permits, complete a master plan, and prepare bid documents.

Project organizers also got a $100,000 grant from the county's Superfund Advisory Redevelopment Trust Authority, or SARTA.

They said the project "dovetails nicely" with SARTA's economic development criteria because it would "support use of undeveloped land, build upon existing infrastructure, provide enhanced recreational opportunities, improve tourism and replace lost recreational opportunities due to historic mining activities."

John Trudnowski, senior engineer for Butte-based Water and Env
Technologies, is leading project efforts and doing much of the work pro bono.

Off limits: Basin Creek Reservoir still clos
0 comments

The whole job, he said, includes 5 to 6 miles of trails and constructing a fish passage that would allow trout to move from the lower to upper reservoirs to spawn. It would all take about $450,000 more on top of the two grants so far.

"We are probably going to take a phase approach," he said. "We can maybe open up the lower reservoir first and then, when we get enough money, build the trails around."

Some of the planning will be done this winter.

Still, he said, "It's going to take a while to get to the point where we can do more groundwork. It could be another two to five years before we get enough money to do everything."

MORE MONEY NEEDED

People can donate money to the George Grant chapter via its website for this and other efforts it backs, but there is potentially a lot more public money available for the project as well.

For one, the state Natural Resource Damage Program is currently updating what's called the Upper Clark Fork River Basin Aquatic and Terrestrial Resources Restoration Plan, and it has called for project ideas.

The NRDP received 23 proposals, including a $252,000 request from Montana

Trout Unlimited — the state chapter — to construct the fish passag
lower and upper Basin Creek reservoirs.

Off limits: Basin Creek Reservoir still clos
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That proposal meets funding criteria as a "new priority tributary watershed," although more evaluation is needed before any award is made. But if funded, it would pay for a major part of the reservoir project.

Also, the BNRC has $1 million from the Butte Area One Restoration Plan that is reserved for recreation projects. It's possible the BNRC could recommend to the governor that some of that money be steered toward Basin Creek.

There are other state and federal grants that can be sought, including some from Montana Fish, Wildlife and Parks and the U.S. Federal Highway Administration Trails Program and federal ADA monies.

The Water Division will continue to oversee equipment and functions related to the water source, but once the area is opened up, the county's Parks Department would be in charge of most recreation aspects.

Parks Director J.P. Gallagher said immediate priorities include clearing dead fall to reduce the possibilities of fires and making the trails and a dock ADA accessible.

But the biggest challenge, he said, is "making sure the water is not compromised."

Off limits: Basin Creek Reservoir still clos SHARE THIS 0 comments

When initial plans are developed, Trudnowski said, the public will get a chance to weigh in, and changes might be made based on the feedback.

CLOSED FOR NOW

Some of the uptick in illegal visitors lately could be tied to a "watchman's house" near the current park entrance being vacant.

The plan was to sell that house and use the proceeds to fix up a more prominent "caretaker's house" at the back of the park, where the road to the reservoir begins. But selling the first house would mean subdividing the property, and doing that would necessitate easements and costly upgrades.

The county now plans to use insurance money and seek a grant to fix up the long-vacant "caretaker's house," and at Palmer's request, commissioners recently rescinded plans to sell the watchman's house.

Officials want to get a county employee to rent the watchman's house, and if not, someone from the general public. That person could at least call police if they saw people wandering up to the reservoir.

"We also encourage neighbors who live along the road to call police if they see suspicious activity," Palmer said. "The park is still open to the public, but the watershed is not."

Sheriff Ed Lester said he plans to meet with county officials and o
proponents this week to discuss additional security steps that could be taken.

Off limits: Basin Creek Reservoir still clos
0 comments

"There is a ton of history associated with the reservoir area," Lester said. "It will be great for the community to have the opportunity to use the area for recreation."

But the area is closed for now, he said, and "we will be meeting with the various entities involved to come up with a plan to minimize vandalism and trespassing issues."

Donating to project

To donate money to the George Grant Chapter of Trout Unlimited, the organization spearheading the opening of Basin Creek Reservoir, go to their website at ggtu.org and click DONATE TO GGTU in the upper right-hand corner of the home page.

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Mike Smith

Government and Politics Reporter

Mike Smith is a reporter at the Montana Standard with an emphasis on government and politics.

Problems accelerating at Basin Creek dam, but failure not imminent

Mike Smith
Oct 6, 2019

The top portion of the Basin Creek Dam south of Butte is deteriorating at a faster rate than past years, which could impact its ability to withstand overtopping in an extreme storm event, officials say.

But Mark Neary, the county's director of Public Works, says there are no concerns about it failing anytime soon. The dam holds water from Basin Creek Reservoir, a major source of drinking water in Butte for decades.

"It's something we're looking at but there's no imminent danger," Neary said.

ow falls on the reservoir near Basin Creek Dam in early October. The concrete above the water has begun to deteriorat l officials are applying for grant funding to fix the structure that was built in the early 1900s.

agan Thompson, The Montana Standard

The county is applying for grant funds that would pay for a detailed examination of

the problem, what it will take to fix it and how much it would cost. Commissioners OK'd the $8,000 grant request this week and money for the actual repairs would be sought next year.

The timetable itself shows it is not an emergency situation, officials say. But the problems are real.

The Basin Creek dam is one of many "high hazard" dams in Montana and all must be inspected every five years by a professional engineer in order to have their operating permits renewed.

A photograph taken around 1915 shows the structure of Basin Creek Dam No. 1. The dam is built with sturdy blocks and the concrete at the top was added after 1913.

Provided Photo

Butte-Silver Bow still does not have a professional engineer on staff, but Neary says it has always contracted out the five-year inspections. Basin Creek was inspected this past July by professional engineers with Pioneer Technical Services and the Montana Department of Natural Resources and Conservation (DNRC).

The 2019 draft report for the Basin Creek dam "describes numerous cracks, spalling, and signs of severe deterioration of the concrete on the upstream face of the dam," Neary wrote in a Sept. 26 letter to commissioners.

"This deterioration was also noted in the 2014 and 2019 Periodic Inspection Reports," the letter said. "However, the rate of deterioration has increased considerably in the past couple of years."

In the report, Neary says, dam safety officials "express concern that the concrete

deterioration appears to be accelerating and this could impact the ability of the dam to withstand overtopping and the top several feet could fail in an extreme storm event."

The water level is currently about 5 to 6 feet below the top of the dam, Neary said.

Jim Keenan, chief operator for Butte's water utility, stands on a small walkway on Basin Creek Dam, Keenan says the top part of the dam is made of concrete and is deteriorating.

Meagan Thompson, The Montana Standard

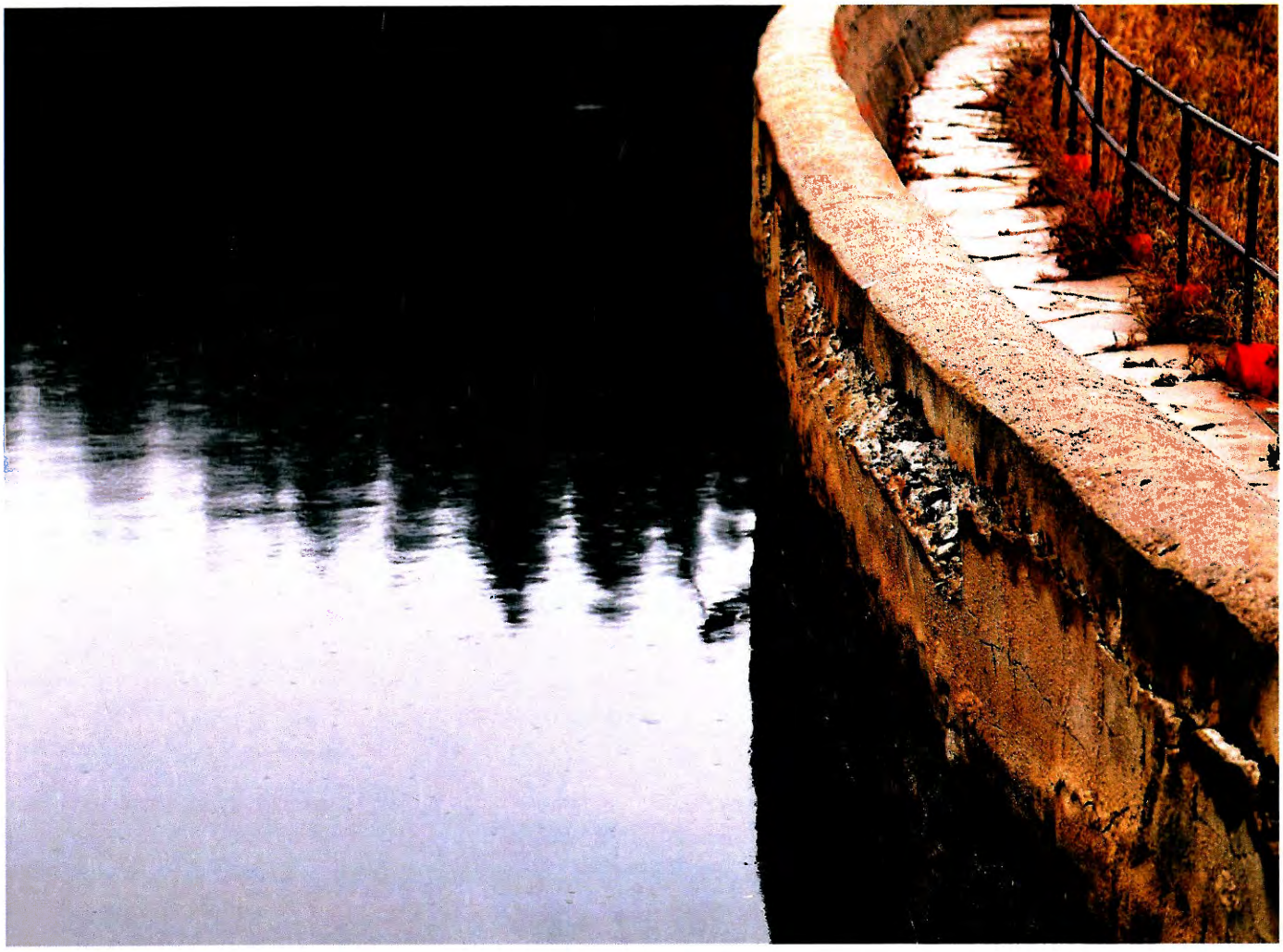
Jim Keenan, chief operator for Butte's water utility, told commissioners this week that most of the dam was constructed with granite in the late 1880s and is solid.

"But then in 1913 they added 13 feet of concrete to the top of the dam," he said. "Well, that top 13 feet is in very bad shape and it is deteriorating pretty quickly."

Because of that, he said, state officials want Butte-Silver Bow to start addressing the problem. That will begin with an analysis by concrete experts, which the initial grant should pay for.

Keenan said if the study is done by November, the county could apply for another grant to help fund technical assistance needed for actual repairs.

"Their concern is the top several feet of that dam could fail in the event of an extreme storm event," he said.



A close look at the crumbling Basin Creek Dam shows concrete erosion. Officials say that although the water line does reach the crumbling portion of the dam, the structure needs to be fixed.

Dan Dennehy, the county's director of emergency management, said the county has action plans in place for all its major dams should they fail but the one for Basin Creek will be updated in the coming weeks.

That will begin with a review of the current plan and latest engineer findings on Oct. 21, he said, and be followed with a full discussion and exercise to update the response plan should there be a breach.

"We will discuss the notification of downstream homeowners, what would happen if the dam is breached, what time frame is needed to get people evacuated, what is the first alert that would go out," Dennehy said.

"There is a plan now but this is a redo with everything updated ... and we will run it through with all our first responders," he said.

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Mike Smith

APPENDIX U

Water Utility Financials

The City-County of
Butte-Silver Bow
State of Montana

Line Item Budget for the Fiscal Year 2019-2020

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Supplemental Information		

Office of Finance and Budget Administration
City-County of Butte-Silver Bow, Montana
Courthouse Room 207
155 West Granite Street
Butte, Montana 59701
(406) 497-6320

August 14, 2019

City-County of Butte-Silver Bow
Council of Commissioners
155 West Granite Street
Butte, MT 59701

The Fiscal Year 2019-2020 Annual Line-item Budget for the City-County of Butte-Silver Bow, Montana (City-County) is hereby submitted as supplementary information to the City-County of Butte-Silver Bow Fiscal Year 2019-2020 Performance Management Budget. This report includes all funds and accounts for the government for which a budget appropriation has been prepared. To the best of my knowledge and belief, the enclosed data is accurate in all material respects. The funds are in balance as demonstrated in the Resource and Requirement Section. During the Fiscal Year 2019-2020 budget process, the City-County continued its efforts to garner input and discussion from the Departments Heads, Council of Commissioners and citizenry prior to the adoption of the final budget. The line-item document details the expenditures by fund, department, function and expenditure category referenced as the object level. It also includes a commentary section that is intended only to give the user a high-level summary of the use of the funds. We encourage all users of this document to reference the Fiscal Year 2019-2020 City-County of Butte-Silver Bow Performance Management Budget.

The City-County of Butte-Silver Bow Fiscal Year 2019-2020 Performance Management Budget has been developed and will assist the departments, administration, and elected officials in assessing goals and objectives. The Performance Budget focuses on long-term financial planning and encourages governments to consider the long-term consequences of actions to ensure that the impacts of budget decisions are understood over a multi-year planning horizon and to assess whether program and service levels can be sustained. There is also a focus on measuring performance to determine what has been accomplished with available government resources. This document is viewable on the City-County of Butte-Silver Bow website.

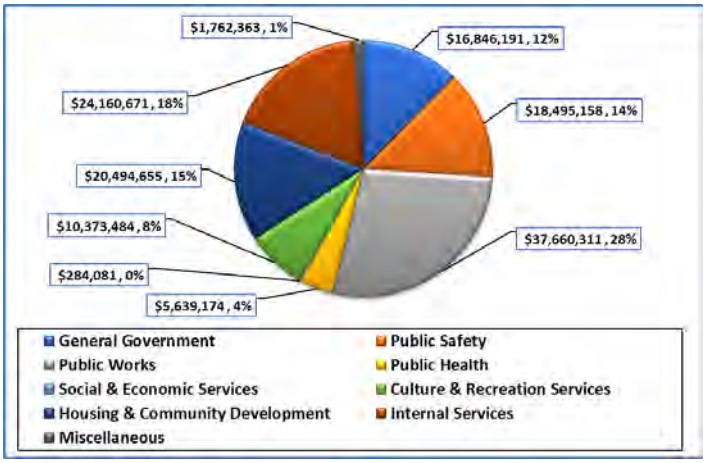
The information below is in summary:

Appropriations

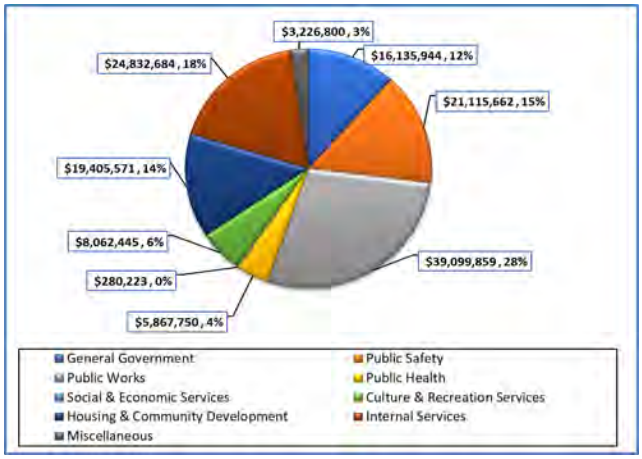
The total appropriation for the City-County of Butte-Silver Bow for fiscal year 2019-2020, including all capital and operating costs, is $138,026,938. The increase is 1.7% when compared to the Fiscal Year 2018-2019 budget of $135,716,088. The charts below show a comparison by function and expenditure classifications between fiscal year 2018-2019 and fiscal year 2019-2020.

Graphs of appropriations by function for all funds of the City-County:

Fiscal Year 2019

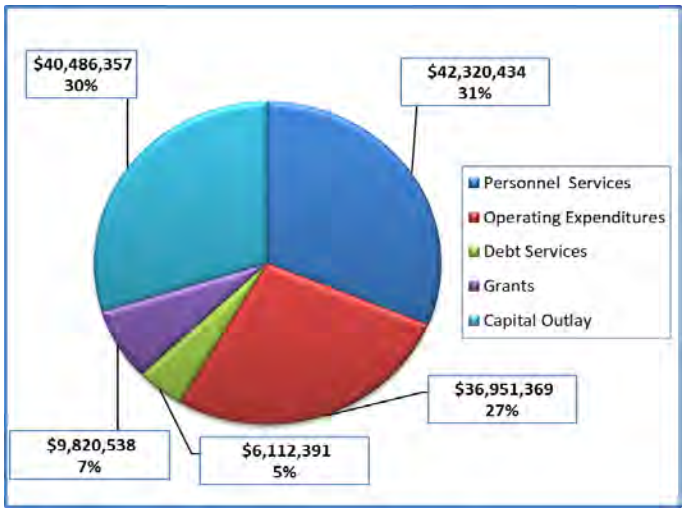


Fiscal Year 2020

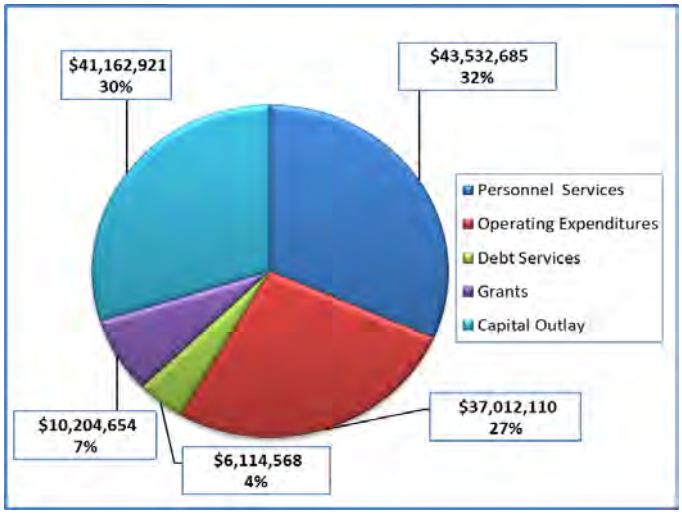


Graphs of total appropriations by expenditure type for all funds of the City-County:

Fiscal Year 2019



Fiscal Year 2020

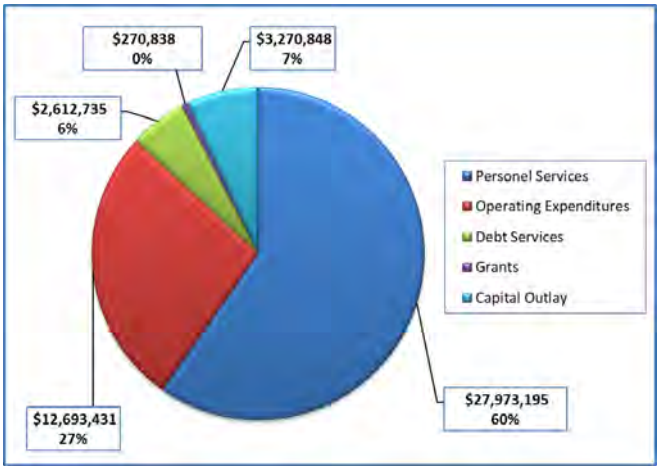


Appropriations for Property Tax-Supported Funds

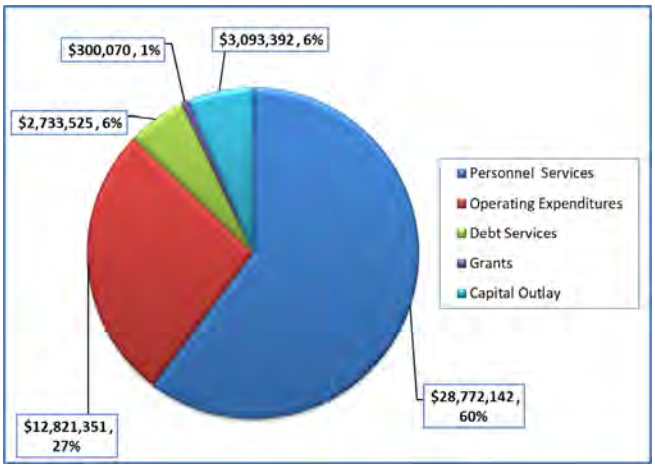
Tax-supported fund appropriations are $48.87 million or 35.27% of the total budget. Property tax revenue is projected be $27.23 million or 55.17% of the revenue needed within these funds. Other revenue sources include the State of Montana Entitlement payments, federal and state grants, and charges for services. In comparison, the fiscal year 2018-2019 budget for tax-supported funds was $47.61 million funded by $25.68 million or 53.94% in property taxes. The tax-supported budgets increased by 2.64% from fiscal year 2018-2019. Personnel services, the charges for salaries and employer provided benefits, represents 60% of the tax-supported budgets in fiscal year 2018-2019 and fiscal year 2019-2020. The graphs exclude intergovernmental operating transfers in the amount of $792,242 for fiscal year 2018-2019 and $1,151,359 for fiscal year 2019-2020.

Graphs of Tax Supported Fund appropriations by expenditure type:

Fiscal Year 2019



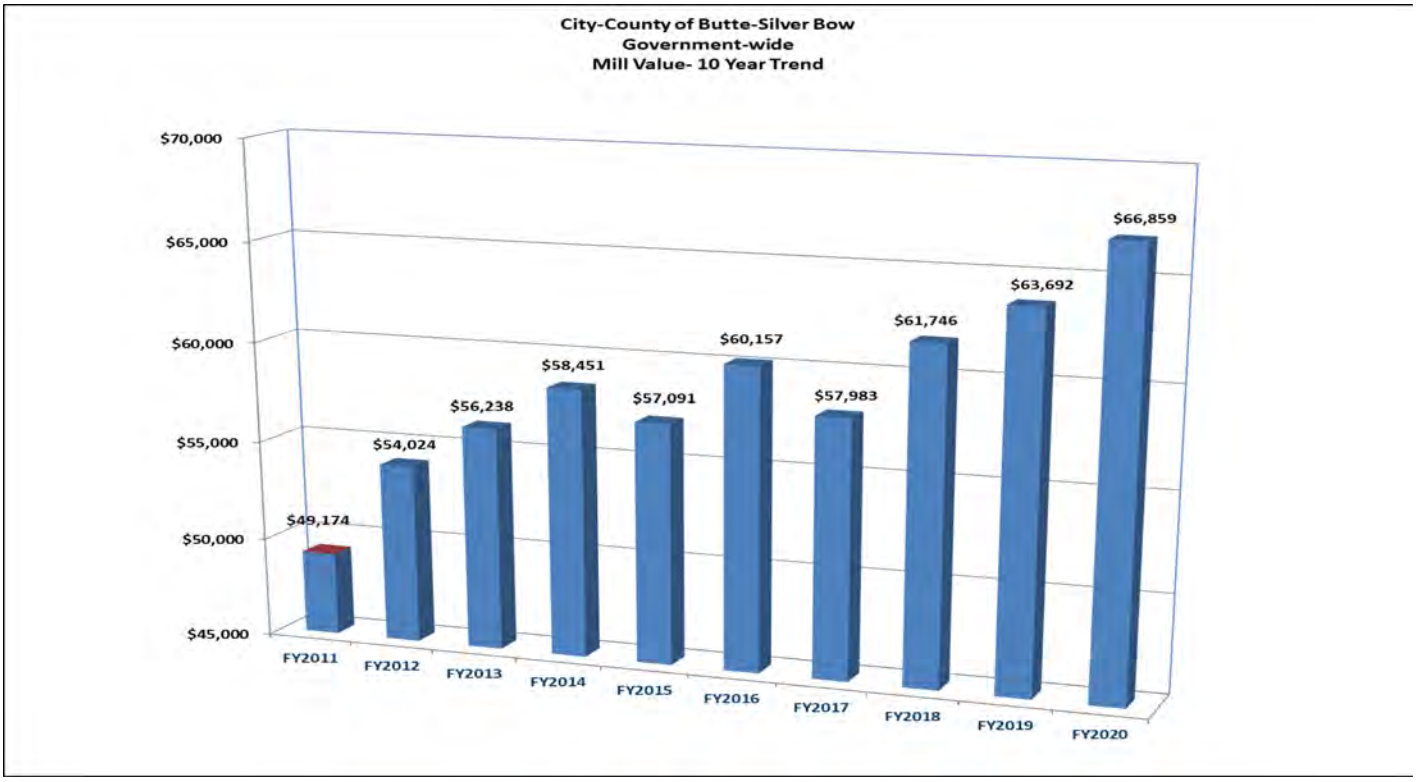
Fiscal Year 2020



Projected Revenue

Property Taxes and Taxable Value

Taxable values are used to develop the mills levied in the tax-supported funds of local governments. The City-County of Butte-Silver Bow's countywide mill value for fiscal year 2019-2020 is $66,859 compared to the mill value of $63,692 for fiscal year 2018-2019. This equates to a 4.97% increase or $3,167 per mill. The following chart illustrates the mill value trend over the past ten years.



The property tax levy was set at 415 mills. This includes 29.85 mills that were voter approved for debt service obligations or economic development activities. The voter approved mills are allocated as follows: 7.41 mills for debt service on the general obligation bond issue for the community pool and 21.45 mills for debt service on the general obligation bond refunding issue. The refunding issues original intent included the Archives building renovation and expansion project, Civic Center renovation, and construction of the new detention center and renovation of Law Enforcement Agency administration building. The budget also contains .99 mills for Economic Development.

The table below shows the property tax comparison for the mills levied by the local government. The comparison is for real property for every $100,000 of market value. The increase in the local government's taxes is approximately 1.22% from the prior year. Over the past eight fiscal years the cumulative local government tax increase has been less than a total of $7.30 (1.37%) per $100,000 in value.

Tax Comparison-Butte-Silver Bow (Local Government)

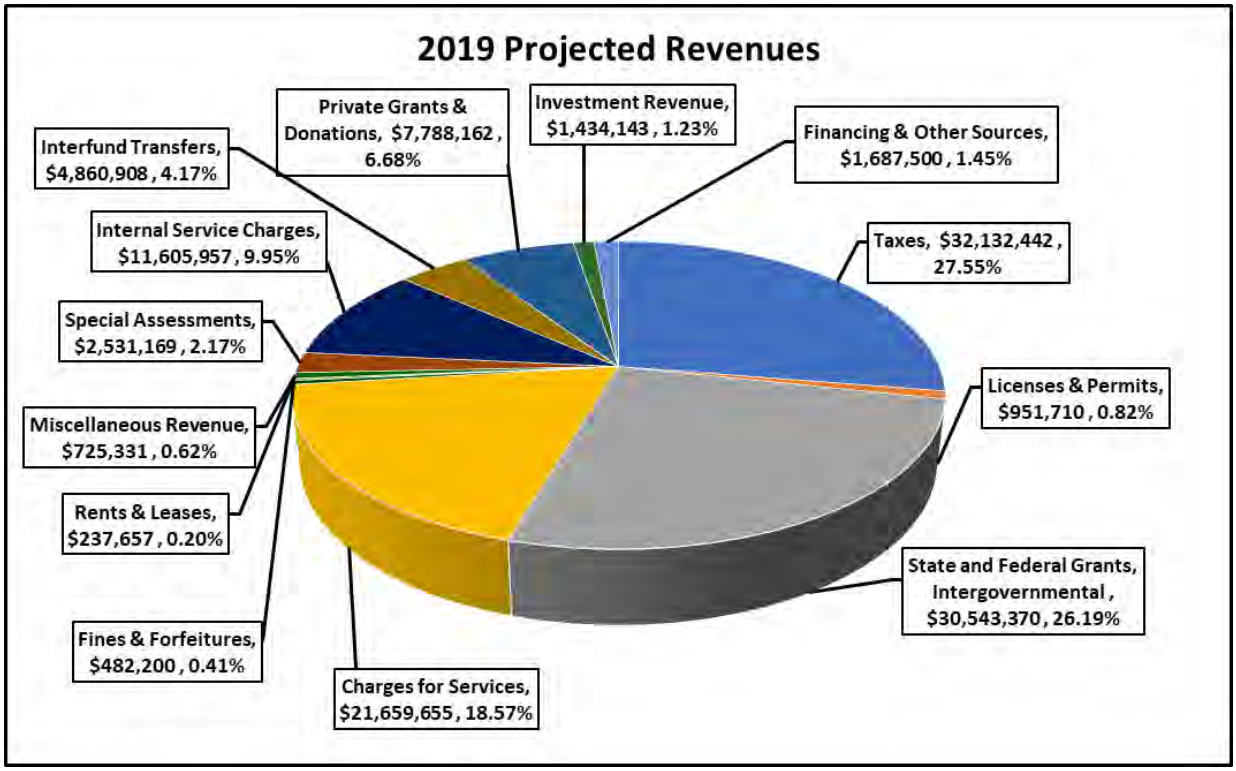
	Fiscal Year 2013	Fiscal Year 2014	Fiscal Year 2015	Fiscal Year 2016	Fiscal Year 2017	Fiscal Year 2018	Fiscal Year 2019	Fiscal Year 2020
Market Value	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000
Homestead Exemption for Tax Year 2014 is 47%; Tax Year 2013 45.50%	$ 44,000	$ 45,500	$ 47,000	$ -	$ -	$ -	$ -	$ -
Market Value less exemption	$ 56,000	$ 54,500	$ 53,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000
Tax Rate	0.0263	0.0254	0.02470	0.01350	0.01350	0.01350	0.01350	0.01350
Taxable Value	$ 1,473	$ 1,384	$ 1,309	$ 1,350	$ 1,350	$ 1,350	$ 1,350	$ 1,350
Mills levied	0.37525	0.37148	0.400000	0.387870	0.396460	0.410210	0.410000	0.415000
Butte-Silver Bow Levied Taxes	$ 553	$ 514	$ 524	$ 524	$ 535	$ 554	$ 554	$ 560
Increase (Decrease) in Taxes		**$ (38.43)**	**$ 9.40**	**$ (0.02)**	**$ 11.60**	**$ 18.56**	**$ (0.28)**	**$ 6.47**
Net Tax Impact over 8 year period								**$ 7.30**

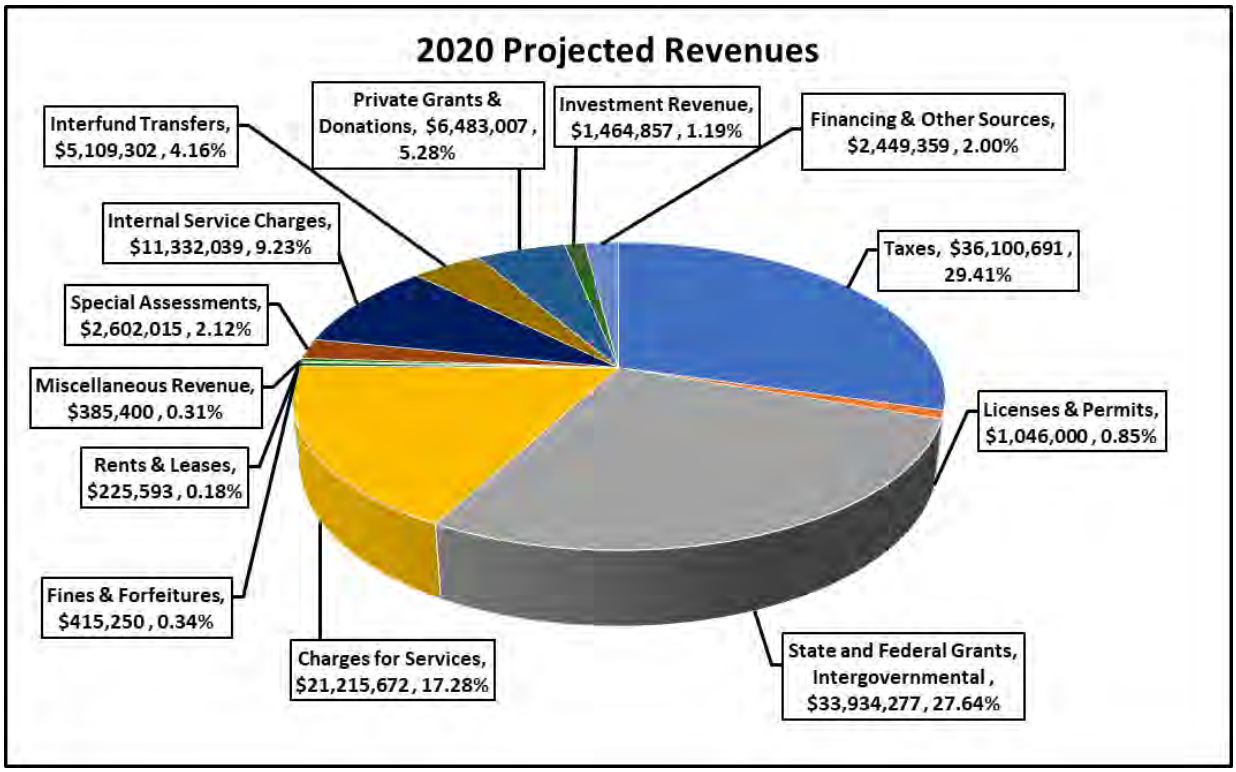
Landfill, Stormwater, Metro Sewer, Water Utility Division User fees and Countywide Road-Street Maintenance Districts

In fiscal year 2019-2020, there were no fee increases in user rates for the Landfill, Stormwater, Metro Sewer or Water Utility Division. In September 2019, the Council of Commissioners adopted Ordinance No. 18-2 which was codified as Chapter 12.18 of the Butte-Silver Bow Municipal Code. This section of municipal code established a single street maintenance district for the boundaries of the city-county. Annually, work-plans are adopted, and rates are set at, at least, 75% of the costs. The district is established, and fees are assessed in accordance with Title 7, Chapter 12, Part 44, of the Montana Code Annotated. In fiscal year 2018-2019, the first year of implementation, the fees were assessed at 75% of the total project cost of the maintenance plan. This amounted to a fee of $72.05 for each parcel of property within Silver Bow County that had a market value $5,000 or greater. For fiscal year 2019-2020, the Council of Commissioners approved funding 87.50% of the annual work-plan. The cost of the fee assessed to each parcel of property will increase to $87.71 for each parcel of property within Silver Bow County with a market value $5,000 or greater.

The other sources of revenue include entitlement fund payments from the State of Montana, federal and state grants which are used for programs such as transit operations, capital improvements, road maintenance and repairs, providing services, district court, and justice court programs. Butte-Silver Bow also anticipates receiving $4.7 million from Atlantic Richfield Company to be used in the Superfund Programs. The City-County of Butte-Silver Bow received an additional grant in the amount of $4.5 million from the Dennis & Phyllis Washington Foundation for the next phase of improvements at the Stodden Park Facilities and Highland's Municipal Golf Course. This grant is fund based on projected cash flows. The City-County anticipates expending $1.65 million of these funds in during the next fiscal year.

The graphs below compare the fiscal year 2018-2019 and fiscal year 2019-2020 revenues by source for all funds:





Summary

The Council of Commissioners, through the adoption of the annual budget, set the reserves at minimum of 16% for the tax-supported funds. The total reserves within the tax-supported funds are projected to be 16.32% ($7,975,040) for fiscal year 2019-2020. Additional reserves consist of those restricted per bond resolutions after the issuance of bonds, restricted funds received for state, federal, or private grants, and donations from other entities for certain purposes.

We encourage the use of the City-County of Butte-Silver Bow Fiscal Year 2019-2020 Performance Management Budget to fully gain an understanding of the strategic planning, multi-year forecasting, capital improvement plans, and economic factors used in assisting with the development of this year's budget.

I want to express my gratitude to all those who helped assemble and balance this budget. This includes Chief Executive Dave Palmer, Department Heads and Elected Officials, the Council of Commissioners, with special acknowledgement to the staff within the Office of Finance and Budget Administration.

Respectfully,

Danette Gleason

Danette Gleason
Finance & Budget Director

City-County of Butte-Silver Bow 2019-2020 Annual Budget - Detail of Expenditures

Fund 5210 **Water Utility Division**
Dept 103 **Public Works**
Activity 4305.40 **Purification & Treatment**

		Actual		2018 - 2019		2019 - 2020		
Obj No	**Description**	**2016-2017**	**2017-2018**	**Budget**	**Actual**	**Request**	**Approved**	
110	Salaries & Wages	742,498	848,967	853,458	853,457	870,077	870,077	2%
115	Salaries & Wages Unclassified Em	0	0	1,500	468	0	0	-100%
120	Salaries & Wages Overtime	44,754	45,276	51,526	42,625	54,479	54,479	6%
122	Salaries & Wages Special Pay	0	0	0	0	1,890	1,890	0%
123	Salaries & Wages Tool Pay	0	0	100	0	100	100	0%
130	Salaries & Wages Longevity	13,633	20,303	24,814	23,574	28,626	28,626	15%
135	Salaries & Wages Clothing Allowa	0	200	2,218	2,217	3,702	3,702	67%
140	Employer Contributions	343,736	401,283	468,200	448,761	460,911	460,911	-2%
190	On behalf payments	855	914	0	0	0	0	0%
210	Office Supplies	5,810	2,491	3,925	1,168	3,925	3,925	0%
220	Operating Supplies	451,882	509,035	576,472	361,782	550,000	550,000	-5%
230	Repair & Maint. Supplies	63,366	65,124	97,592	85,433	117,592	117,592	20%
260	Non capital fixed assets	228,215	18,859	6,100	2,929	9,500	4,500	-26%
310	Postage	6,539	10,425	25,000	2,757	5,000	5,000	-80%
320	Printing- Duplicating-Etc	1,413	1,614	2,800	1,711	2,800	2,800	0%
330	Publicity- Subscr. & Dues	0	249	440	440	500	500	14%
340	Utility Services	355,533	348,787	450,000	367,776	400,000	400,000	-11%
350	Professional Services	57,045	99,687	102,793	87,358	203,000	203,000	97%
360	Repair & Maint. Services	11,214	33,009	45,300	40,114	30,000	30,000	-34%
370	Travel	984	3,417	2,500	863	2,500	2,500	0%
380	Training Services	300	1,075	4,000	1,429	4,000	4,000	0%
390	Other Purchased Services	1,559	1,594	3,707	3,706	22,500	22,500	507%
470	Fabricated Materials	2,490	0	0	0	0	0	0%
530	Rent	11,383	10,178	10,800	10,697	12,000	12,000	11%
531	Equipment rent expense	0	0	12,640	12,640	12,640	12,640	0%
811	Loss on Asset Disposal	0	19,586	0	0	0	0	0%
830	Depreciation	791,347	1,907,896	0	0	0	0	0%
850	Intergovernmental Charges	33,625	33,625	33,625	33,625	33,625	33,625	0%
852	Payroll Charges	4,447	4,949	5,877	4,865	5,761	5,761	-2%
854	Personnel Charges	8,769	9,757	11,582	9,591	11,353	11,353	-2%
920	Buildings	0	0	237,960	73,460	120,000	105,000	-56%
930	Improv other than Bldgs	0	0	205,400	48,015	0	0	-100%
940	Machinery & Equipment	0	0	60,000	34,292	52,500	52,500	-13%
950	Construction in Process	0	0	350,000	24,906	402,814	402,814	15%
Total		**$3,181,396**	**$4,398,298**	**$3,650,329**	**$2,580,660**	**$3,421,795**	**$3,401,795**	**-7%**

Budget Commentary

The Purification and Treatment function of the Water Utility Division became active in November, 1994. This division is responsible for operating and maintaining sources of supply as well as the filtration plants.

Personnel

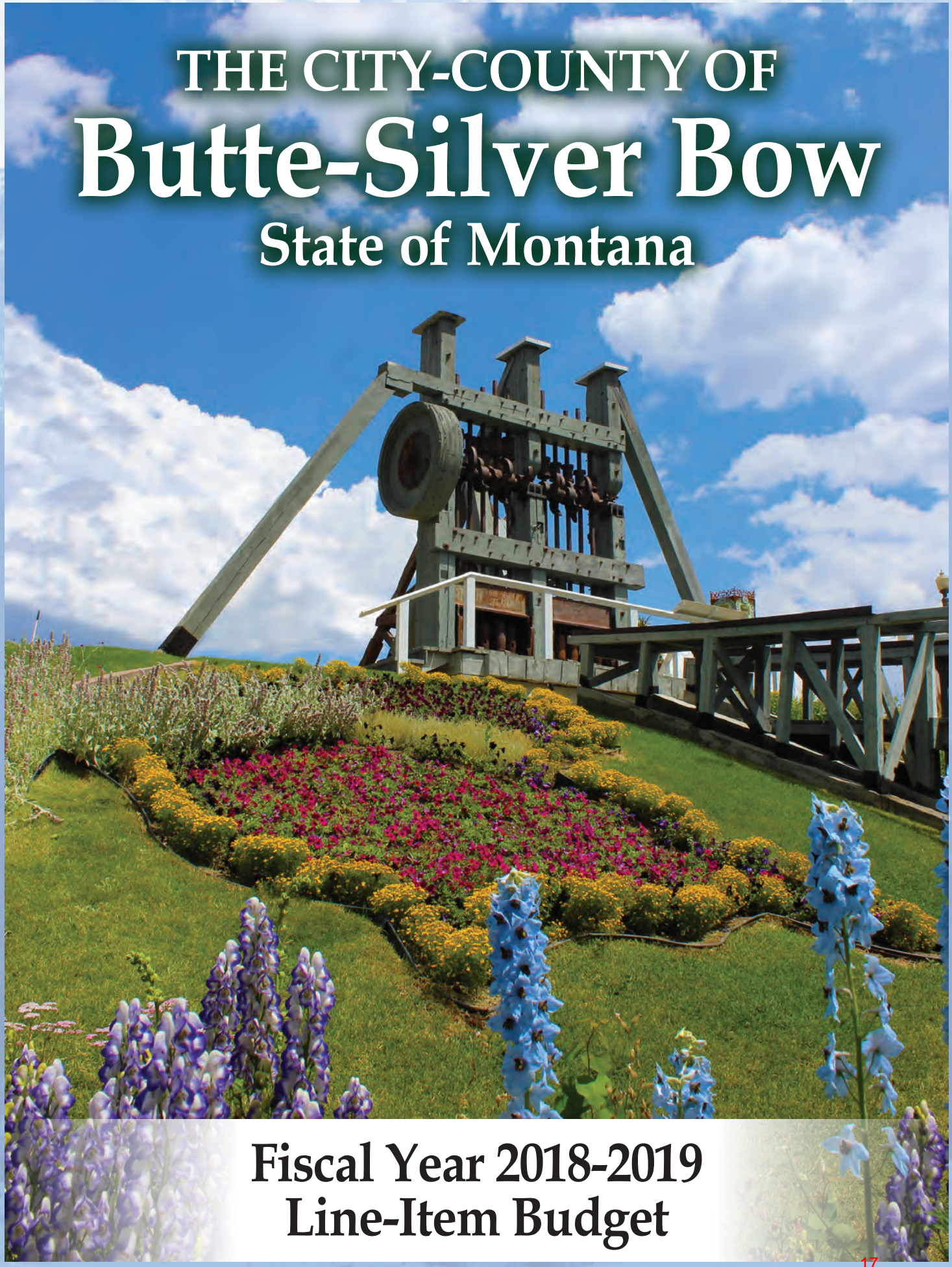
Position Description	Stat	Budgeted Salary
Chief Operator	1	68,850
Electrician	0.9	59,131
Operator	12	701,515
Overtime	1	54,479
Tool Allowance	1	100
Water Treatment Supervisor	1	74,802
Total	16.9	958,876

Fixed Assets

Description	Requested	Approved
Alum Pumps for the Big Hole Treatment Plant	15,000	15,000
Basin Creek Parapet Wall-Carryover from 2019	65,000	65,000
Basin Creek Reservoir fencing	5,000	0
Big Hole Pump House Window replacement	15,000	0
Carryforward-Septics at Basin Creek Caretakers Hous	35,000	35,000
New septic system at Watchman's house	4,500	4,500
NRD Basin Creek WTP Air Dryers	13,800	13,800
NRD Telemetry and Controls	324,014	324,014
Plow attachment for Skid Steer at Basin Creek Treat	7,500	7,500
Replace roof at Moulton Treatment Plant	70,000	70,000
Solar Reservior Mixer; Basin Creek Reservoir	30,000	30,000
Total	584,814	564,814

BSB Public Works Accountant Angie Mullikin confirmed the $65,000 budgeted for FY 2020 is for engineering services associated with the proposed project. Primarily, the Structural Assessment prepared by Gannett-Fleming that is located in the PER, Appendix J.

THE CITY-COUNTY OF
Butte-Silver Bow
State of Montana



Fiscal Year 2018-2019
Line-Item Budget

City-County of Butte-Silver Bow 2018-2019 Annual Budget - Detail of Expenditures

Fund 5210 **Water Utility Division**
Dept 103 **Public Works**
Activity 4305.40 **Purification & Treatment**

		Actual		2017 - 2018		2018 - 2019		
Obj No	**Description**	**2015-2016**	**2016-2017**	**Budget**	**Actual**	**Request**	**Approved**	
110	Salaries & Wages	775,364	742,498	848,968	848,967	850,605	850,605	0%
120	Salaries & Wages Overtime	36,105	44,754	54,241	45,276	54,379	54,379	0%
123	Salaries & Wages Tool Pay	0	0	100	0	100	100	0%
130	Salaries & Wages Longevity	16,488	13,633	20,303	20,303	23,314	23,314	15%
135	Salaries & Wages Clothing Allowa	0	0	200	200	180	180	-10%
140	Employer Contributions	367,521	343,736	424,002	400,442	468,200	468,200	10%
190	On behalf payments	810	855	915	914	0	0	-100%
210	Office Supplies	2,950	5,810	3,925	2,491	3,925	3,925	0%
220	Operating Supplies	345,662	451,882	696,109	509,035	605,000	605,000	-13%
230	Repair & Maint. Supplies	83,097	63,366	97,592	65,124	97,592	97,592	0%
260	Non capital fixed assets	0	228,215	28,723	7,790	1,500	1,500	-95%
310	Postage	187	6,539	11,700	10,425	25,000	25,000	114%
320	Printing- Duplicating-Etc	3,422	1,413	2,800	1,614	2,800	2,800	0%
330	Publicity- Subscr. & Dues	0	0	250	249	250	250	0%
340	Utility Services	294,067	355,533	465,253	347,787	450,000	450,000	-3%
350	Professional Services	42,713	57,045	105,532	99,687	103,000	103,000	-2%
360	Repair & Maint. Services	34,199	11,214	38,188	33,009	25,000	25,000	-35%
370	Travel	819	984	4,000	3,417	2,500	2,500	-38%
380	Training Services	1,050	300	2,405	1,075	4,000	4,000	66%
390	Other Purchased Services	170	1,559	1,595	1,594	1,000	1,000	-37%
470	Fabricated Materials	0	2,490	0	0	0	0	0%
530	Rent	10,252	11,383	10,300	10,178	10,300	10,300	0%
531	Equipment rent expense	0	0	12,533	0	12,640	12,640	1%
830	Depreciation	556,649	791,347	0	0	0	0	0%
850	Intergovernmental Charges	33,625	33,625	33,625	33,625	33,625	33,625	0%
852	Payroll Charges	4,350	4,447	5,761	4,949	5,877	5,877	2%
854	Personnel Charges	8,577	8,769	11,353	9,757	11,582	11,582	2%
920	Buildings	0	0	157,960	0	307,960	237,960	51%
930	Improv other than Bldgs	0	0	35,000	0	945,000	210,000	500%
940	Machinery & Equipment	0	0	0	0	290,000	60,000	0%
950	Construction in Process	0	0	2,369,955	1,317,018	350,000	350,000	-85%
Total		**$2,618,080**	**$3,181,396**	**$5,443,288**	**$3,774,923**	**$4,685,329**	**$3,650,329**	**-33%**

Budget Commentary

The Purification and Treatment function of the Water Utility Division became active in November, 1994. This division is responsible for operating and maintaining sources of supply as well as the filtration plants.

Personnel

Position Description	Stat	Budgeted Salary
Chief Operator	1	66,238
Electrician	0.9	53,683
Operator	12	682,149
Overtime Pay	1	54,379
Tool Allowance - Electrical	1	100
Water Treatment Supervisor	1	72,030
Total	16.9	928,579

Fixed Assets

Description	Requested	Approved
3/4 Ton Pickup	40,000	0
3/4 Ton Pickup	40,000	0
Basin Creek Bypass	50,000	50,000
Basin Creek Parapet Wall	65,000	65,000
Big Hole Water Treatment Plant Roof	80,000	80,000
Carryforward - Septics at Basin Creek Caretakers Ho	35,000	35,000
Carryforward- Improvements at Basin Creek Caretak	157,960	157,960
Fence at the Moulton	35,000	0
Moulton Heaters	40,000	40,000
Moulton Spillway	700,000	0
Moulton Water Treatment Plant Roof	70,000	0
NRD Ground Water Restoration	350,000	350,000
Residual Pumps for Basin Creek	150,000	0
Sand House Improvements	60,000	60,000
Snowmobile Trailer	1,500	1,500
Westside Tank Inlet Mixer	20,000	20,000
Total	1,894,460	859,460

Statements of Revenue, Expenses, and Changes in Fund Net Position

Water Utility Division
Fiscal Years 2017, 2018, and 2019

City-County of Butte-Silver Bow, Montana
Statement of Revenues,
Expenses and Changes in Fund Net Position
Proprietary Funds
For Fiscal Year Ended June 30, 2017

	Business-Type Activities Enterprise Funds					Governmental Activities
	Water Utility Division	**Metro Sewer Division**	**Solid Waste Division**	**Other Enterprise Funds**	**Total**	**Internal Service Funds**
Operating Revenues						
Charges for services	$ 8,602,815	$ 6,588,845	$ 2,774,674	$ 644,904	$ 18,611,238	$ 3,393,419
Rent revenue	-	-	-	184,613	184,613	-
Miscellaneous	7,629	182,593	38,933	13,506	242,661	50,993
Total Operating Revenues	8,610,444	6,771,438	2,813,607	843,023	19,038,512	3,444,412
Operating Expenses						
Personnel services	3,744,400	2,363,809	700,229	220,999	7,029,437	2,202,191
Operation and maintenance	2,717,635	1,807,435	1,765,872	329,855	6,620,797	857,658
Depreciation	3,834,080	2,427,903	352,667	202,919	6,817,569	192,907
Total Operating Expenses	10,296,115	6,599,147	2,818,768	753,773	20,467,803	3,252,756
Operating Income (Loss)	(1,685,671)	172,291	(5,161)	89,250	(1,429,291)	191,656
Non-Operating Revenues (Expenses)						
Interest expense	(66,177)	(698,410)	-	(3,019)	(767,606)	-
Gain (loss) on sale of fixed assets	50,231	95,101	(17,589)	-	127,743	-
Investment earnings	36,546	29,456	34,904	8,560	109,466	275
Increase (decrease) of investments to fair market value	530	(234)	(136)	71	231	54
Intergovernmental	65,036	38,120	9,393	1,061	113,610	63,578
Total Non-Operating Revenues (Expenses)	86,166	(535,967)	26,572	6,673	(416,556)	63,907
Income (Loss) Before Capital Grants & Transfers	(1,599,505)	(363,676)	21,411	95,923	(1,845,847)	255,563
Capital grants	10,548,864	963,295	-	-	11,512,159	-
Transfers in	-	-	-	15,000	15,000	10,000
Transfers out	(311,343)	(380,875)	(166,200)	(10,755)	(869,173)	-
Change in Net Position	8,638,016	218,744	(144,789)	100,168	8,812,139	265,563
Net position, Beginning of year	75,579,076	21,919,936	8,665,011	5,090,483	111,254,506	992,938
Total Net Position, End of Year	$ 84,217,092	$ 22,138,680	$ 8,520,222	$ 5,190,651	$ 120,066,645	$ 1,258,501

See accompanying notes to the basic financial statements

City-County of Butte-Silver Bow, Montana
Statement of Revenues, Expenses and Changes in Fund Net Position
Proprietary Funds
June 30, 2018

	Business-Type Activities Enterprise Funds					Governmental Activities
	Water Utility Division	**Metro Sewer Division**	**Solid Waste Division**	**Total Nonmajor Enterprise Funds**	**Total**	**Internal Service Funds**
OPERATING REVENUES						
Charges for services	$ 9,103,865	$ 6,698,733	$ 2,383,391	$ 693,608	$ 18,879,597	$ 3,697,855
Rent revenue	-	-	-	182,213	182,213	-
Miscellaneous	45,392	22,599	9,607	2,596	80,194	10,248
Total Operating Revenues	9,149,257	6,721,332	2,392,998	878,417	19,142,004	3,708,103
OPERATING EXPENSES						
Personnel services	3,832,447	2,284,317	725,497	313,131	7,155,392	2,243,222
Operation and maintenance	2,437,462	1,700,367	1,776,122	386,495	6,300,446	1,071,343
Depreciation	4,960,821	2,725,654	347,060	124,924	8,158,459	199,822
Total Operating Expenses	11,230,730	6,710,338	2,848,679	824,550	21,614,297	3,514,387
Operating Income (Loss)	(2,081,473)	10,994	(455,681)	53,867	(2,472,293)	193,716
NON-OPERATING REVENUES (EXPENSES)						
Interest expense	(85,925)	(701,327)	-	(3,322)	(790,574)	-
Interest income	79,921	34,918	55,047	15,968	185,854	4,335
Gain (loss) on disposal of capital assets	(432,870)	(5,915)	(7,331)	(1,027,211)	(1,473,327)	(267,249)
Increase (decrease) of investments to fair market valu	(40)	(119)	(400)	(56)	(615)	26
Intergovernmental	59,225	30,631	8,796	1,918	100,570	213,941
Total Non-Operating Revenues (Expenses)	(379,689)	(641,812)	56,112	(1,012,703)	(1,978,092)	(48,947)
Income (Loss) Before Capital Grants & Transfers	(2,461,162)	(630,818)	(399,569)	(958,836)	(4,450,385)	144,769
CAPITAL GRANTS AND TRANSFERS IN (OUT)						
Capital grant income	1,477,801	30,000	-	-	1,507,801	-
Capital grant expense	(94,869)	-	-	-	(94,869)	-
Transfers in	-	-	-	50,000	50,000	81,352
Transfers out	(316,013)	(380,875)	(168,468)	(10,755)	(876,111)	-
Total Capital Grants and Transfers In (Out)	1,066,919	(350,875)	(168,468)	39,245	586,821	81,352
Change in Net Position	(1,394,243)	(981,693)	(568,037)	(919,591)	(3,863,564)	226,121
Net position, Beginning of year	84,217,092	22,138,680	8,520,222	5,190,651	120,066,645	1,258,501
NET POSITION, END OF YEAR	$ 82,822,849	$ 21,156,987	$ 7,952,185	$ 4,271,060	$ 116,203,081	$ 1,484,622

See accompanying notes to the basic financial statements

City-County of Butte-Silver Bow, Montana
Statement of Revenues, Expenses and Changes in Fund Net Position
Proprietary Funds
For Fiscal Year Ended June 30, 2019

	Business-Type Activities Enterprise Funds					Governmental Activities
	Water Utility Division	**Metro Sewer Division**	**Solid Waste Division**	**Total Nonmajor Enterprise Funds**	**Total**	**Internal Service Funds**
OPERATING REVENUES						
Charges for services	$ 9,870,290	$ 6,700,814	$ 2,421,602	$ 691,562	$ 19,684,268	$ 4,055,935
Rent revenue	-	-	-	169,399	169,399	-
Miscellaneous	1,774	12,247	8,736	2,338	25,095	6,348
Total Operating Revenues	9,872,064	6,713,061	2,430,338	863,299	19,878,762	4,062,283
OPERATING EXPENSES						
Personnel services	3,287,181	2,107,697	604,684	351,780	6,351,342	2,454,804
Operation and maintenance	2,414,195	1,737,401	1,750,229	412,402	6,314,227	1,103,762
Depreciation	4,997,915	2,705,848	348,529	119,095	8,171,387	233,191
Total Operating Expenses	10,699,291	6,550,946	2,703,442	883,277	20,836,956	3,791,757
Operating Income (Loss)	(827,227)	162,115	(273,104)	(19,978)	(958,194)	270,526
NON-OPERATING REVENUES (EXPENSES)						
Interest expense	(60,005)	(680,272)	-	(2,478)	(742,755)	-
Interest income	187,152	71,304	86,350	38,879	383,685	23,760
Gain (loss) on disposal of capital assets	-	(7,917)	-	(292)	(8,209)	160,958
Increase (decrease) of investments to fair market value	860	331	215	137	1,543	165
Intergovernmental	67,670	38,830	9,302	2,560	118,362	1,286,246
Total Non-Operating Revenues (Expenses)	195,677	(577,724)	95,867	38,806	(247,374)	1,471,129
Income (Loss) Before Capital Grants & Transfers	(631,550)	(415,609)	(177,237)	18,828	(1,205,568)	1,741,655
CAPITAL GRANTS AND TRANSFERS IN (OUT)						
Capital grant income	215,326	-	-	-	215,326	-
Transfers in	20,000	-	-	50,408	70,408	5,000
Transfers out	(320,684)	(392,302)	(173,760)	(11,500)	(898,246)	-
Total Capital Grants and Transfers In (Out)	(85,358)	(392,302)	(173,760)	38,908	(612,512)	5,000
Change in Net Position	(716,908)	(807,911)	(350,997)	57,736	(1,818,080)	1,746,655
Net position, Beginning of year	82,822,849	21,156,987	7,952,185	4,271,060	116,203,081	1,484,622
NET POSITION, END OF YEAR	$ 82,105,941	$ 20,349,076	$ 7,601,188	$ 4,328,796	$ 114,385,001	$ 3,231,277

See accompanying notes to the basic financial statements

APPENDIX V

Power Consumption Data

Bill History Additional Services
Additional Services Details

Account Number : 100422
Account Name : BUTTE SILVER BOW GOVERNMENT
Premises : FEELY HILL WATER TREATMENT, BUTTE
Service : ELEC DEMAND HANDHELD - Meter DA20764937

Bill Date	Days	Billed Usage	Bill Demand Usage	Charge
5/6/2020	29	1,513.0	4.31	$174.78
4/7/2020	29	1,825.0	4.90	$205.86
3/6/2020	33	2,567.0	6.24	$281.13
2/6/2020	28	1,737.0	5.79	$209.50
1/10/2020	31	1,389.0	4.93	$173.52
1/2/2020	33	833.0	3.59	$113.96
11/22/2019	29	661.0	8.58	$288.14
10/11/2019	27	278.0	8.58	$266.55
9/10/2019	34	42.0	13.70	$696.24
8/9/2019	30	42.0	15.42	$273.19
7/15/2019	29	40.0	13.87	$459.76
6/6/2019	33	427.0	11.72	$288.19
5/7/2019	29	454.0	5.85	$105.44
4/5/2019	29	1,288.0	11.49	$225.55
3/7/2019	28	1,151.0	8.04	$179.01
2/7/2019	32	1,102.0	4.97	$143.49
1/7/2019	31	1,097.0	4.92	$141.23
12/6/2018	33	877.0	3.59	$110.76
11/6/2018	30	541.0	2.20	$70.77
10/4/2018	34	2,857.0	8.58	$312.65
9/7/2018	29	6,293.0	13.70	$624.17
8/6/2018	33	8,241.0	15.42	$788.56
7/6/2018	29	4,139.0	13.87	$468.84
6/6/2018	33	2,113.0	11.72	$289.15
5/7/2018	28	1,296.0	10.67	$214.60
4/5/2018	30	1,403.0	11.49	$231.53
3/6/2018	29	1,255.0	8.04	$184.87
2/6/2018	31	1,300.0	10.54	$214.60
1/5/2018	30	2,647.0	10.54	$319.80
12/5/2017	30	4,784.0	12.05	$500.89
11/7/2017	32	729.0	9.32	$157.60
10/5/2017	29	3,257.0	12.11	$381.77
9/7/2017	29	7,347.0	15.46	$732.16
8/4/2017	33	9,509.0	15.40	$899.13
7/7/2017	29	4,044.0	12.98	$451.09
6/6/2017	30	4,922.0	14.54	$538.65
5/4/2017	31	6,884.0	11.84	$668.34
4/6/2017	29	4,856.0	14.64	$530.79
3/8/2017	14	2,471.0	9.99	$484.19
3/8/2017	15	1,836.0	14.16	$484.19
2/6/2017	29	3,668.0	14.16	$446.43
1/9/2017	34	4,782.0	14.16	$528.82
12/8/2016	30	3,947.0	12.96	$448.31
11/9/2016	31	5,014.0	11.23	$518.21
10/11/2016	30	4,344.0	15.55	$504.56
9/12/2016	29	6,299.0	13.13	$639.75

8/5/2016	33	7,820.0	14.16	$773.91
7/8/2016	29	5,546.0	15.03	$600.82
6/7/2016	30	4,032.0	11.23	$443.42
5/6/2016	32	3,908.0	16.93	$489.02
4/7/2016	30	2,302.0	11.05	$301.77
3/7/2016	29	2,010.0	10.88	$275.96
2/5/2016	32	2,645.0	12.78	$332.79
1/7/2016	29	3,041.0	15.03	$379.89
12/8/2015	30	342.0	3.97	$73.10
11/9/2015	31	22.0	1.38	$23.86
10/8/2015	31	31.0	0.69	$18.15
9/9/2015	29	66.0	0.34	$17.64
8/7/2015	33	8,616.0	16.07	$829.68
7/8/2015	29	6,606.0	15.72	$695.93
6/5/2015	32	4,959.0	11.75	$526.89
5/7/2015	30	3,342.0	9.67	$374.40
4/7/2015	29	4,120.0	10.88	$451.39
3/6/2015	29	4,103.0	13.99	$480.18
2/6/2015	31	2,605.0	10.19	$318.19
1/8/2015	31	2,912.0	10.71	$346.81
12/8/2014	33	992.0	5.18	$135.38
11/6/2014	29	2,055.0	11.75	$275.46
10/8/2014	29	999.0	8.81	$167.58
9/8/2014	32	4,734.0	13.99	$503.51
8/7/2014	31	7,655.0	15.89	$747.52
7/9/2014	28	7,734.0	15.72	$702.28
6/6/2014	33	7,354.0	15.37	$677.76
5/7/2014	30	5,541.0	12.96	$529.56
4/8/2014	29	4,766.0	13.13	$476.70
3/7/2014	31	3,048.0	12.78	$348.22
2/7/2014	29	2,850.0	10.71	$316.05
1/9/2014	31	3,031.0	12.09	$342.94
12/6/2013	61	9,686.0	11.40	$951.77
10/10/2013	35	9,258.0	15.72	$847.16
9/11/2013	28	8,372.0	16.07	$779.45

Bill History Additional Services
Additional Services Details

Account Number : 100431
Account Name : BUTTE SILVER BOW GOVERNMENT
Premises : FEELEY HILL WATER TREATMENT PLANT, BUTTE
Service : ELEC DEMAND HANDHELD - Meter DG28611532

Bill Date	Days	Reading	Billed Usage	Bill Demand Usage	Charge
5/7/2020	29	16378.0	89,280.0	288.00	$10,192.30
4/8/2020	29	16316.0	100,800.0	302.40	$11,259.07
3/9/2020	33	16246.0	125,280.0	345.60	$13,788.24
2/7/2020	28	16159.0	106,560.0	345.60	$12,288.27
1/8/2020	31	16085.0	112,320.0	360.00	$13,005.38
12/6/2019	33	16007.0	118,080.0	345.60	$13,326.40
11/7/2019	29	15925.0	93,600.0	302.40	$10,870.50
10/8/2019	27	15860.0	89,280.0	360.00	$10,782.21
9/10/2019	34	15798.0	174,240.0	388.80	$17,641.23
8/8/2019	30	15677.0	129,600.0	417.60	$14,501.66
7/9/2019	29	15587.0	109,440.0	302.40	$11,694.10
6/7/2019	33	15511.0	73,440.0	273.60	$8,607.68
5/8/2019	29	15460.0	110,880.0	360.00	$12,422.30
4/8/2019	29	15383.0	89,280.0	374.40	$10,756.61
3/8/2019	28	15321.0	92,160.0	360.00	$10,817.77
2/8/2019	32	15257.0	119,520.0	316.80	$12,475.11
1/8/2019	31	15174.0	119,520.0	360.00	$12,840.49
12/7/2018	33	15091.0	105,120.0	331.20	$11,418.92
11/5/2018	30	15018.0	54,720.0	288.00	$7,070.97
10/5/2018	34	14980.0	144,000.0	360.00	$14,675.64
9/10/2018	29	14880.0	148,320.0	417.60	$15,485.74
8/7/2018	33	14777.0	181,440.0	388.80	$17,696.13
7/9/2018	29	14651.0	96,480.0	302.40	$10,558.29
6/7/2018	33	14584.0	76,320.0	273.60	$8,708.95
5/7/2018	28	14531.0	76,320.0	316.80	$9,139.67
4/6/2018	30	14478.0	96,480.0	374.40	$11,323.24
3/7/2018	29	14411.0	100,800.0	360.00	$11,446.43
2/7/2018	31	14341.0	110,880.0	288.00	$11,576.40
1/8/2018	30	14264.0	128,160.0	316.80	$13,198.30
12/6/2017	30	14175.0	155,520.0	360.00	$15,733.80
11/8/2017	32	14067.0	103,680.0	288.00	$10,993.26
10/6/2017	29	13995.0	129,600.0	360.00	$13,685.82
9/8/2017	29	13905.0	177,120.0	374.40	$17,497.99
8/7/2017	33	13782.0	195,840.0	388.80	$19,090.72
7/10/2017	29	13646.0	113,760.0	360.00	$12,438.81
6/7/2017	30	13567.0	133,920.0	374.40	$14,251.01
5/5/2017	31	13474.0	155,520.0	331.20	$15,577.88
4/7/2017	29	13366.0	146,880.0	374.40	$15,155.18
3/9/2017	29	13264.0	158,400.0	302.40	$15,359.31
2/7/2017	29	13154.0	175,680.0	374.40	$17,996.60
1/10/2017	34	13032.0	201,600.0	388.80	$19,944.69
12/6/2016	30	12892.0	133,920.0	331.20	$13,879.89
11/8/2016	31	12799.0	172,800.0	403.20	$17,697.24
10/10/2016	30	12679.0	194,400.0	489.60	$20,226.85
9/9/2016	29	12544.0	181,440.0	388.80	$18,265.94
8/8/2016	33	12418.0	213,120.0	417.60	$21,142.97
7/11/2016	29	12270.0	180,000.0	432.00	$18,678.59

6/8/2016	30	12145.0	109,440.0	302.40	$11,767.35
5/9/2016	32	12069.0	112,320.0	302.40	$12,060.42
4/8/2016	30	11991.0	113,760.0	316.80	$12,299.77
3/8/2016	29	11912.0	123,840.0	288.00	$12,834.84
2/8/2016	32	11826.0	149,760.0	374.40	$15,032.81
1/8/2016	29	11722.0	188,640.0	475.20	$18,745.14
12/9/2015	30	11591.0	203,040.0	403.20	$19,708.21
11/9/2015	31	11450.0	126,720.0	403.20	$13,706.29
10/8/2015	31	11362.0	149,760.0	388.80	$15,362.23
9/9/2015	29	11258.0	187,200.0	417.60	$18,559.00
8/10/2015	33	11128.0	246,240.0	547.20	$24,273.12
7/9/2015	29	10957.0	197,280.0	532.80	$21,103.85
6/8/2015	32	10820.0	129,600.0	288.00	$13,358.89
5/8/2015	30	10730.0	109,440.0	316.80	$11,966.51
4/8/2015	29	10654.0	106,560.0	345.60	$12,040.83
3/9/2015	29	10580.0	131,040.0	345.60	$14,106.82
2/9/2015	31	10489.0	123,840.0	345.60	$13,402.12
1/8/2015	31	10403.0	122,400.0	345.60	$13,228.40
12/8/2014	33	10318.0	141,120.0	360.00	$14,461.16
11/7/2014	29	10220.0	133,920.0	446.40	$14,399.95
10/8/2014	29	10127.0	154,080.0	417.60	$15,710.88
9/9/2014	32	10020.0	175,680.0	417.60	$17,410.47
8/12/2014	31	9898.0	204,480.0	417.60	$19,666.42
7/9/2014	28	9756.0	158,400.0	432.00	$15,222.38
6/6/2014	33	9646.0	151,200.0	403.20	$14,561.53
5/7/2014	30	9541.0	110,880.0	302.40	$10,820.01
4/8/2014	29	9464.0	126,720.0	331.20	$12,271.99
3/7/2014	31	9376.0	139,680.0	345.60	$13,319.01
2/7/2014	29	9279.0	118,080.0	316.80	$11,544.74
1/9/2014	31	9197.0	142,560.0	403.20	$14,205.97
12/6/2013	32	9098.0	146,880.0	345.60	$14,029.75
11/7/2013	29	8996.0	177,120.0	460.80	$17,508.64
10/10/2013	35	8873.0	211,680.0	446.40	$19,975.30
9/11/2013	28	8726.0	192,960.0	446.40	$18,466.88
8/7/2013	30	8592.0	230,400.0	475.00	$21,590.97
7/8/2013	31	8432.0	169,920.0	432.00	$16,656.11
6/7/2013	30	8314.0	141,120.0	418.00	$14,312.68
5/7/2013	29	8216.0	105,120.0	274.00	$10,246.68
4/5/2013	32	8143.0	120,960.0	302.00	$11,672.20
3/7/2013	29	8059.0	116,640.0	317.00	$11,420.54
2/7/2013	28	7978.0	118,080.0	317.00	$11,585.68
1/8/2013	31	7896.0	136,800.0	346.00	$13,103.84
12/6/2012	33	7801.0	141,120.0	374.00	$13,554.32
11/7/2012	29	7703.0	102,240.0	432.00	$11,213.20
10/8/2012	32	7632.0	184,320.0	432.00	$17,103.35
9/10/2012	30	7504.0	211,680.0	590.00	$20,347.50
8/7/2012	30	7357.0	214,560.0	562.00	$20,115.51
7/9/2012	31	7208.0	205,920.0	547.00	$18,980.89
6/7/2012	31	7065.0	139,680.0	418.00	$13,255.18
5/7/2012	32	6968.0	158,400.0	403.00	$14,562.71
4/6/2012	30	6858.0	155,520.0	403.00	$14,373.20
3/7/2012	29	6750.0	158,400.0	432.00	$14,901.60
2/7/2012	32	6640.0	178,560.0	461.00	$16,571.52
1/9/2012	29	6516.0	172,800.0	432.00	$15,976.80
12/6/2011	31	6396.0	167,040.0	432.00	$15,546.14
11/7/2011	31	6280.0	87,840.0	389.00	$9,696.19

10/7/2011	30	6219.0	172,800.0	562.00	$17,247.46
9/8/2011	30	6099.0	205,920.0	504.00	$19,065.43
8/5/2011	32	5956.0	247,680.0	562.00	$22,463.87
7/8/2011	29	5784.0	120,960.0	418.00	$12,277.45
6/7/2011	30	5700.0	165,600.0	475.00	$15,900.09
5/6/2011	31	5585.0	148,320.0	446.00	$14,582.48
4/7/2011	30	5482.0	158,400.0	418.00	$15,128.32
3/7/2011	30	5372.0	169,920.0	461.00	$16,293.91
2/4/2011	32	5254.0	172,800.0	446.00	$16,327.37
1/7/2011	29	5134.0	156,960.0	432.00	$13,861.68
12/7/2010	30	5025.0	162,720.0	432.00	$14,286.27
11/5/2010	31	4912.0	108,000.0	403.00	$10,645.61
10/7/2010	30	4837.0	102,240.0	403.00	$10,112.91
9/8/2010	30	4766.0	133,920.0	446.00	$12,631.02

Bill History Additional Services
Additional Services Details

Account Number : 3116608
Account Name : BUTTE SILVER BOW GOVERNMENT
Premises : 447 BASIN CREEK RD, BUTTE
Service : ELEC DEMAND HANDHELD - Meter DA18501652

Bill Date	Days	Billed Usage	Bill Demand Usage	Charge
5/8/2020	29	45,200.0	180.00	$5,535.68
4/9/2020	33	51,440.0	106.40	$5,229.24
3/10/2020	29	48,080.0	110.40	$5,057.01
2/10/2020	29	48,240.0	108.80	$5,060.93
1/13/2020	33	56,560.0	109.60	$5,778.70
12/9/2019	30	46,400.0	117.60	$5,045.93
11/8/2019	32	48,640.0	104.80	$5,090.86
10/9/2019	28	39,200.0	100.80	$4,135.20
9/12/2019	31	67,680.0	241.60	$7,829.17
8/12/2019	33	101,040.0	220.80	$10,183.17
7/11/2019	29	71,120.0	200.00	$7,639.85
6/10/2019	29	45,360.0	152.00	$5,137.11
5/9/2019	33	53,440.0	193.60	$6,206.71
4/9/2019	29	43,600.0	153.60	$4,956.03
3/11/2019	28	44,800.0	150.40	$5,008.02
2/11/2019	32	54,560.0	103.20	$5,270.48
1/9/2019	31	42,640.0	104.80	$4,350.84
12/7/2018	32	47,440.0	136.00	$5,023.79
11/7/2018	30	45,840.0	174.40	$5,262.15
10/9/2018	33	86,320.0	200.00	$8,647.09
9/11/2018	29	97,040.0	217.60	$9,583.41
8/9/2018	34	109,200.0	277.60	$11,073.49
7/10/2018	29	52,800.0	244.80	$6,562.67
6/11/2018	30	71,600.0	224.80	$7,856.08
5/8/2018	29	60,480.0	170.40	$6,447.48
4/9/2018	32	50,000.0	176.00	$5,694.24
3/8/2018	29	42,480.0	97.60	$4,293.85
2/7/2018	27	39,040.0	127.20	$4,339.01
1/9/2018	34	49,200.0	104.80	$4,904.35
12/7/2017	30	25,600.0	54.40	$2,547.43
11/9/2017	29	34,160.0	104.00	$3,718.75
10/11/2017	33	54,080.0	196.80	$6,183.74
9/12/2017	29	68,880.0	235.20	$7,705.99
8/9/2017	30	80,400.0	240.00	$8,646.27
7/10/2017	32	53,360.0	191.20	$6,061.82
6/8/2017	29	37,280.0	232.80	$5,258.24
5/8/2017	29	29,360.0	244.80	$4,770.12
4/10/2017	29	24,480.0	200.80	$3,921.15
3/10/2017	31	28,880.0	215.20	$4,407.57
2/9/2017	30	29,520.0	132.00	$3,715.08
1/11/2017	33	29,440.0	96.00	$3,294.08
12/8/2016	30	16,160.0	55.20	$1,826.83
11/9/2016	29	11,440.0	46.40	$1,365.80
10/12/2016	25	3,200.0	20.00	$454.63

Bill History Additional Services
Additional Services Details

Account Number : 3377443
Account Name : BUTTE SILVER BOW GOVERNMENT
Premises : 5050 WYNNE AVE, BUTTE
Service : ELEC DEMAND HANDHELD - Meter DG46184849

Bill Date	Days	Billed Usage	Bill Demand Usage	Charge
4/27/2020	30	40,880.0	124.00	$4,585.96
3/26/2020	33	52,000.0	100.00	$5,224.32
2/26/2020	29	41,520.0	100.00	$4,424.51
1/28/2020	33	43,600.0	100.00	$4,605.87
12/30/2019	30	44,240.0	99.20	$4,672.65
11/25/2019	28	44,160.0	96.80	$4,640.40
10/25/2019	29	36,880.0	123.20	$4,294.50
9/26/2019	32	16,400.0	123.20	$2,596.84
8/27/2019	30	41,040.0	130.40	$4,577.67
7/26/2019	32	61,360.0	120.00	$6,033.55
6/26/2019	29	42,560.0	160.80	$5,015.63
5/28/2019	31	24,800.0	100.00	$2,993.44
4/25/2019	32	39,760.0	98.40	$4,115.22
3/27/2019	28	55,920.0	128.00	$5,631.54
2/26/2019	29	28,720.0	71.20	$2,952.36
1/28/2019	34	39,680.0	128.00	$4,371.80
12/31/2018	30	46,800.0	128.00	$4,898.21
11/30/2018	29	44,880.0	127.20	$4,731.84
10/25/2018	33	29,600.0	165.60	$3,928.48
9/26/2018	30	68,240.0	160.80	$6,848.58
8/27/2018	33	52,880.0	166.40	$5,691.90
7/27/2018	30	30,880.0	165.60	$4,024.15
6/27/2018	32	49,440.0	160.80	$5,475.69
5/30/2018	28	60,960.0	164.00	$6,420.64
4/30/2018	30	46,880.0	164.00	$5,320.04
3/29/2018	29	31,280.0	92.00	$3,379.16
2/28/2018	32	33,360.0	71.20	$3,325.04
1/31/2018	30	39,600.0	71.20	$3,820.44
12/27/2017	29	9,840.0	71.20	$1,488.53
11/29/2017	31	8,240.0	69.60	$1,346.89
10/26/2017	29	35,520.0	70.40	$3,484.29
9/27/2017	30	36,320.0	84.80	$3,678.20
8/25/2017	32	45,280.0	84.80	$4,369.24
7/27/2017	30	49,040.0	89.60	$4,708.74
6/28/2017	30	49,920.0	91.20	$4,805.80
5/26/2017	28	7,600.0	52.80	$1,132.19
4/27/2017	32	1,680.0	2.40	$163.28
3/28/2017	29	1,520.0	4.00	$165.43
2/28/2017	30	1,760.0	4.00	$185.95
2/1/2017	32	4,800.0	87.20	$1,254.89
1/17/2017	31	4,560.0	87.20	$1,197.23

Bill History Additional Services
Additional Services Details

Account Number : 2002494
Account Name : BUTTE SILVER BOW GOVERNMENT
Premises : 800 PUMPHOUSE RD, DIVIDE
Service : ELEC DEMAND MV90 - Meter DA07667752

Bill Date	Days	Billed Usage	Bill Demand Usage	Charge
5/14/2020	31	11,015.0	22.00	$1,117.83
4/15/2020	31	13,073.0	198.00	$3,192.47
3/12/2020	29	15,878.0	258.00	$4,041.83
2/13/2020	31	17,021.0	199.00	$3,496.67
1/16/2020	29	15,742.0	223.00	$3,671.58
12/17/2019	31	17,124.0	273.00	$4,331.13
11/14/2019	31	13,531.0	212.00	$3,384.07
10/18/2019	30	97,215.0	436.00	$12,330.99
9/12/2019	31	273,296.0	649.00	$28,086.31
8/16/2019	32	256,453.0	596.00	$26,216.31
7/17/2019	30	12,014.0	25.00	$1,202.95
6/12/2019	31	11,811.0	152.00	$2,549.80
5/15/2019	30	11,485.0	28.00	$1,193.89
4/16/2019	30	16,417.0	73.00	$2,034.53
3/15/2019	28	14,531.0	28.00	$1,414.40
2/15/2019	32	40,636.0	303.00	$6,265.90
1/14/2019	30	17,645.0	198.00	$3,360.78
12/14/2018	29	16,106.0	206.00	$3,297.76
11/16/2018	32	11,735.0	211.00	$3,005.63
10/17/2018	31	56,191.0	289.00	$7,204.57
9/13/2018	31	185,320.0	489.00	$19,061.49
8/14/2018	31	267,053.0	507.00	$25,371.08
7/13/2018	29	19,440.0	1,105.00	$12,436.57
6/14/2018	32	12,745.0	226.00	$3,237.43
5/16/2018	28	10,928.0	343.00	$4,249.37
4/17/2018	31	30,529.0	741.00	$9,723.42
3/13/2018	28	40,463.0	232.00	$5,473.25
2/15/2018	32	94,846.0	407.00	$11,486.07
1/16/2018	30	85,449.0	455.00	$11,246.35
12/19/2017	32	226,558.0	433.00	$22,019.66
11/16/2017	31	179,194.0	466.00	$18,669.26
10/16/2017	29	140,447.0	473.00	$15,679.84
9/14/2017	31	355,655.0	629.00	$33,917.12
8/16/2017	32	349,631.0	610.00	$33,236.56
7/14/2017	28	161,244.0	442.00	$16,942.80

6/16/2017	33	147,156.0	328.00	$14,786.16
5/17/2017	30	204,144.0	455.00	$20,624.67
4/18/2017	31	207,483.0	942.00	$25,612.03
3/16/2017	28	254,626.0	515.00	$24,961.31
2/15/2017	31	286,153.0	489.00	$27,853.62
1/19/2017	29	251,934.0	490.00	$25,059.35
12/20/2016	32	228,956.0	510.00	$23,216.08
11/23/2016	30	231,472.0	552.00	$23,807.74
10/18/2016	29	343,368.0	811.00	$35,225.53
9/23/2016	33	445,417.0	828.00	$43,613.76
8/22/2016	30	409,123.0	771.00	$40,262.60
7/20/2016	31	306,082.0	705.00	$31,438.32
6/22/2016	31	166,015.0	422.00	$17,486.66
5/16/2016	29	134,722.0	416.00	$14,947.35
4/20/2016	32	148,366.0	955.00	$21,145.77
3/22/2016	28	130,885.0	252.00	$13,077.26
2/23/2016	31	164,430.0	419.00	$16,820.56
1/26/2016	31	279,302.0	521.00	$26,136.53
12/29/2015	31	306,928.0	461.00	$28,182.13
11/18/2015	29	206,463.0	436.00	$20,283.83
10/27/2015	32	210,856.0	503.00	$21,219.14
9/21/2015	31	347,674.0	687.00	$33,638.28
8/26/2015	31	357,364.0	691.00	$34,300.57
7/21/2015	30	355,701.0	802.00	$36,177.63
6/24/2015	30	152,311.0	432.00	$16,553.35
5/20/2015	30	141,976.0	267.00	$14,183.25
4/23/2015	32	156,815.0	883.00	$21,179.48
3/19/2015	28	155,640.0	449.00	$17,100.51
2/18/2015	29	143,811.0	248.00	$14,169.39
1/21/2015	32	163,590.0	294.00	$16,138.33
12/23/2014	31	165,315.0	306.00	$16,130.87
11/25/2014	30	189,114.0	434.00	$18,491.68
10/27/2014	31	290,636.0	714.00	$28,924.83
9/22/2014	30	228,833.0	573.00	$22,931.46
8/26/2014	32	348,384.0	612.00	$32,561.63
7/18/2014	30	192,573.0	477.00	$18,397.91
6/23/2014	29	171,526.0	433.00	$16,250.23
5/21/2014	32	127,220.0	261.00	$11,592.57
4/21/2014	31	162,588.0	740.00	$18,648.52
3/19/2014	28	151,907.0	440.00	$15,085.97
2/19/2014	31	190,028.0	321.00	$16,797.00
1/21/2014	31	174,574.0	322.00	$15,778.94
12/23/2013	29	197,068.0	400.00	$18,216.76
11/18/2013	32	296,220.0	583.00	$27,438.61
10/23/2013	30	416,054.0	754.00	$38,112.37
9/25/2013	30	407,612.0	815.00	$37,887.89
8/28/2013	32	503,754.0	839.00	$45,287.20

7/22/2013	29	305,209.0	748.00	$29,665.20
6/26/2013	32	220,155.0	484.00	$20,838.53
5/23/2013	30	157,260.0	318.00	$14,467.09
4/19/2013	30	143,558.0	275.00	$13,074.58
3/21/2013	28	159,552.0	454.00	$15,841.23
2/19/2013	32	179,380.0	291.00	$15,794.17
1/24/2013	31	191,754.0	470.00	$18,264.21
12/19/2012	28	167,762.0	454.00	$16,226.74
11/26/2012	33	176,619.0	508.00	$17,254.75
10/22/2012	30	278,853.0	640.00	$25,747.84
9/20/2012	31	432,984.0	815.00	$38,179.36
8/21/2012	31	418,679.0	820.00	$36,860.73
7/25/2012	29	342,812.0	768.00	$30,484.21
6/19/2012	32	213,539.0	506.00	$19,078.61
5/21/2012	19	86,006.0	422.00	$21,692.95
5/21/2012	19	170,700.0	447.00	$21,692.95
4/6/2012	30	260,700.0	759.00	$24,835.76
3/7/2012	29	66,000.0	1,035.00	$13,876.56
2/7/2012	28	6,600.0	336.00	$3,479.53
1/9/2012	6	-	-	$1.82

Craig Erickson

Subject: FW: Updated Power Consumption Data and Proposed Change to Appendices
Attachments: BSB Meter-kWh analysis GW-PER 05252020.xlsx

From: Keenan, Jim <jkeenan@bsb.mt.gov>
Sent: Monday, May 25, 2020 8:47 AM
To: Jeremiah Theys <jtheys@greatwesteng.com>; Ryan Elliott <relliott@greatwesteng.com>; Craig Erickson <cerickson@greatwesteng.com>
Subject: Re: Updated Power Consumption Data and Proposed Change to Appendices

Hello again,

After thinking about it for a second, I went back and deleted the data for the old Big Hole Pump Station since the start up of the new pump station. Any power consumption at the old pump station that has occurred since the start up of the new pump station has not been related to water delivery.

Thanks,

Jim Keenan
Desk: (406) 497-6596
Mobile: (406) 475-4541

From: Keenan, Jim
Sent: Monday, May 25, 2020 8:39 AM
To: Jeremiah Theys <jtheys@greatwesteng.com>; Ryan Elliott <relliott@greatwesteng.com>; Craig Erickson <cerickson@greatwesteng.com>
Subject: Updated Power Consumption Data and Proposed Change to Appendices

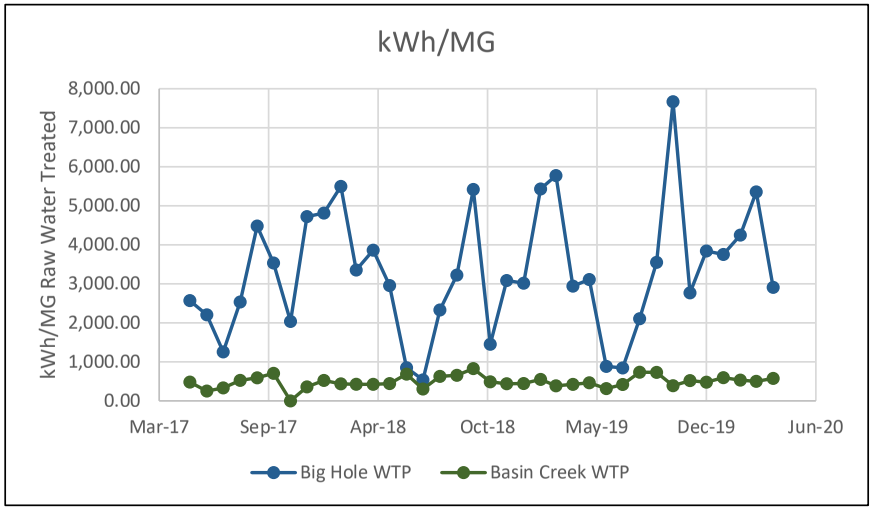
Hello,

I've added the data for the Old Pump station and missing data for one of the meters at the Feeley plant. I only had data through July 2019, but it looks like we are using around 2000 kWh/month there. I did a quick calculation on average total power consumption reduction since the Basin Creek Plant and Southside Pump station were brought online. It looks like we are averaging around a 1,200,000 kWh reduction per year since Jun-17. According to a quick Google search, that's enough power savings to run nearly 120 MT households each year.

I think it would be better to include the attached in a separate Power Consumption Data appendix rather than under Financial Data. I think the information on the amount of the total monthly bills may be considered confidential. If you think it's important to have those numbers in the report, I can find out if it's okay.

Also, I forgot to add information on the number of employees as requested in the original draft. We have 14 operators and one electrician on our crew. We operate the three treatment plants and the associated facilities as well as the industrial water system.

	kWh/MG BHWTP	kWh/MG BCWTP	kWH/MG BCWTP + SSPS	
May-20	#DIV/0!	#DIV/0!	#DIV/0!	
Apr-20	2,909.18	576.94	1160.16	
Mar-20	5,356.08	501.30	934.20	
Feb-20	4,248.93	533.30	1015.30	
Jan-20	3,752.96	595.58	1061.43	
Dec-19	3,841.23	479.48	935.81	
Nov-19	2,768.68	520.48	915.12	
Oct-19	7,666.83	389.45	552.38	
Sep-19	3,550.78	731.64	1175.30	
Aug-19	2,105.76	735.37	1181.94	
Jul-19	844.11	420.80	672.62	
Jun-19	883.64	315.34	487.75	
May-19	3,110.29	464.13	809.45	
Apr-19	2,941.33	424.13	968.11	
Mar-19	5,774.05	387.17	635.37	
Feb-19	5,431.39	551.26	952.17	
Jan-19	3,016.45	446.04	935.59	
Dec-18	3,084.11	440.04	856.34	
Nov-18	1,451.20	488.77	804.38	
Oct-18	5,418.08	827.45	1481.60	
Sep-18	3,223.40	656.46	1014.19	
Aug-18	2,329.70	628.57	806.31	
Jul-18	538.18	304.36	589.36	
Jun-18	849.60	686.15	1270.33	
May-18	2,956.00	443.69	787.60	
Apr-18	3,862.13	424.31	689.77	
Mar-18	3,353.05	426.12	760.76	
Feb-18	5,496.51	436.79	879.85	
Jan-18	4,813.93	524.82	629.78	
Dec-17	4,723.01	359.92	475.77	
Nov-17	2,036.09	#DIV/0!	#DIV/0!	BCWTP down for const/mods
Oct-17	3,534.16	706.49	1180.97	
Sep-17	4,481.30	591.48	980.30	
Aug-17	2,535.64	525.69	846.34	
Jul-17	1,255.92	333.37	645.26	
Jun-17	2,205.80	252.55	304.04	
May-17	2,570.84	482.43	510.04	



kWh/MG	Average May-17 thru Apr-20	
BHWTP	BCWTP	
3,303.34	503.20	

2909.178	576.9403
5356.078	501.2981
4248.932	533.298
3752.964	595.5816
3841.225	479.4775
2768.682	520.4811
7666.829	389.4452
3550.78	731.644
2105.759	735.3658
844.1057	420.801
883.6432	315.3394
3110.287	464.1306
2941.33	424.1328
5774.054	387.1681
5431.391	551.2559
3016.45	446.0391
3084.11	440.0416
1451.198	488.7671

APPENDIX W

Letters of Support

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

STEVE BULLOCK
GOVERNOR

DIRECTOR'S OFFICE (406) 444-2074
TELEFAX NUMBER (406) 444-2684

STATE OF MONTANA

WATER RESOURCES DIVISION (406) 444-6601
TELEFAX NUMBERS (406) 444-0533 / (406) 444-5918
http://www.dnrc.mt.gov

1424 9TH AVENUE
PO BOX 201601
HELENA, MONTANA 59620-1601

May 4, 2020

Mr. Mark Neary
Butte Silver Bow Public Works
126 W. Granite Street
Butte, MT 59701

Re: Support for Basin Creek #1 Grant Applications

Dear Mr. Neary,

The purpose of this letter is to express our support for your upcoming grant applications to repair the deteriorating concrete on Basin Creek #1. We have concerns about the ability of the dam to safely pass an extreme storm event as required by State dam safety requirements. Should a storm event cause the dam to overtop, the top several feet of the dam could wash away, potentially leading to failure of the dam. It is critical to stabilize the concrete and return the dam to a safe operating condition and full compliance with dam safety standards.

Please note that we are appreciative of your recent efforts to evaluate the structural condition of the concrete. This was important to understand the severity of the situation and options for repair.

We are available to address any questions that arise regarding state dam safety requirements during the grant application process.

Sincerely,

Steve Story, PE, CFM
Water Operations Bureau Chief
Water Resources Division
sestory@mt.gov

c: Jim Keenan, Chief Operator, City-County of Butte Silver Bow
Michele Lemieux, DNRC Dam Safety Program
Brent Zundel, DNRC Bozeman/Helena Regional Office Engineer

STATE WATER PROJECTS BUREAU (406) 444-6646
WATER MANAGEMENT BUREAU (406) 444-6637
WATER OPERATIONS BUREAU (406) 444-0860
WATER RIGHTS BUREAU (406) 444-6610

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION

STEVE BULLOCK
GOVERNOR

DIRECTOR'S OFFICE (406) 444-2074
TELEFAX NUMBER (406) 444-2684

STATE OF MONTANA

WATER RESOURCES DIVISION (406) 444-6601
TELEFAX NUMBERS (406) 444-0533 / (406) 444-5918
http://www.dnrc.mt.gov

1424 9TH AVENUE
PO BOX 201601
HELENA, MONTANA 59620-1601

Monday, May 4, 2020

Jim Keenan
City-County of Butte-Silver Bow
447 Basin Creek Road
Butte, MT 59701

RE: Basin #1 Operation Permit Conditions

Dear Mr. Keenan,

The purpose of this letter is to acknowledge that Butte Silver Bow (BSB) has met operation permit condition # 1 for Basin Creek #1. The Operation Permit Approval letter dated 12/20/2019 states:

> **Condition 1**: Complete an evaluation of the deteriorated concrete on upper section of dam and report on your findings. **Due Date 9/30/2020.**

Thank you for prompt action in hiring an expert consultant to complete the concrete condition study. I have reviewed the report of this analysis and agree with your consultant's assessment that the deterioration is a dam safety concern. The deterioration limits the ability of the dam to pass the inflow design storm, as required. Should an extreme storm event occur, Basin #1 could be at risk of failure. Thus, it is necessary to revise this condition as follows:

> **Revised Condition 1:** Address deteriorated concrete in dam using one of the recommended approaches discussed in the Basin Creek Dam Structural Assessment (Gannett Fleming, January 2020). Complete repairs to the dam before your current Operation Permit expires (9/29/2024). Failure to make significant progress to address deficiencies at the dam will force DNRC to consider restricting the reservoir operating level.

I understand that you are in the process of evaluating alternatives and pursuing funding options. We are appreciative of your proactive attention to the dam.

Sincerely,

Michele Lemieux

Michele Lemieux, PE
Montana Dam Safety Section Supervisor

C: Mark Neary, BSB Public Works Director
Dan Dennehy, BSB DES
Brent Zundel, DNRC Helena/Bozeman Regional Office Engineer
Steve Story, WOB Bureau Chief

STATE WATER PROJECTS BUREAU (406) 444-6646
WATER MANAGEMENT BUREAU (406) 444-6637
WATER OPERATIONS BUREAU (406) 444-0860
WATER RIGHTS BUREAU (406) 444-6610

BUTTE-SILVER BOW OFFICE OF EMERGENCY MANAGEMENT

Dan Dennehy
Director of Emergency Management

Emergency Preparedness. . .it's everyone's responsibility!

May 21, 2020

Jim Keenan, Chief Operator
The City-County of Butte-Silver Bow
Water Treatment Plant
447 Basin Creek Road
Butte, Montana 59701

RE: Basin Creek Dam #1 Rehabilitation Project

To Whom it May Concern:

The Butte-Silver Bow Office of Emergency Management is supporting the Butte-Silver Bow Department of Public Works Water Utility Division application for the rehabilitation project of Basin Creek Dam #1.

The rehabilitation project will provide much need improvements to Basin Creek Dam #1. The Basin Creek Dam #1 is a high hazard dam. During a recent inspection (August 2019), it was discovered that the dam has "numerous cracks, spalling, and signs of severe deterioration of the concrete on the upstream face of the dam". Additionally, a Dam Breach Analysis and Inundation Mapping report completed in November 2019 indicates that downstream property owners have approximately 30 minutes to move out of harms way if there was a major breach of the Basin Creek Dam.

The rehabilitation project for Basin Creek Dam #1 will stabilize and address the deficiencies that currently exist at the dam. Additionally, the proposed project will protect lives, property and our primary source of drinking water, I support the proposed project.

If you have any questions regarding this project, please contact me.

Dan Dennehy, Director
Butte-Silver Bow Office of Emergency Management

(406) 497-6295 • CELL: (406) 490-5802 • FAX: (406) 497-6294 • ddennehy@bsb.mt.gov • 155 W. Granite • Butte, MT 59701

DEPARTMENT OF JUSTICE
NATURAL RESOURCE DAMAGE PROGRAM

TIM FOX
ATTORNEY GENERAL

1720 9TH AVENUE

STATE OF MONTANA

(406) 444-0205 (OFFICE)
(406) 444-0236 (FAX)

PO BOX 201425
HELENA, MONTANA 59620-1425

May 27, 2020

To Whom it May Concern:

The Natural Resource Damage Program (NRDP) understands that Butte-Silver Bow (BSB) has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. State of Montana natural resource damage settlement funds funded the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam. NRDP supports Butte Silver Bows (BSB) request for funding repairs to Basin Creek Dam #1 to ensure this source of water supply is secure.

It is understood that unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. This reduced the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet would not only reduce the amount of available water, but also reduces the driving force that provides gravity flow through the new treatment plant. If the volume of finished water coming from the Basin Creek Water Treatment Plant is significantly reduced BSB must make up the difference from the Big Hole River nearly 22 miles from Butte. The Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

NRDP sincerely urges you to consider Butte-Silver Bow's funding request to repair the Basin Creek Dam. The proposed project will ensure the City of Butte can fully utilize the most ecological and economically water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Douglas H. Martin
Restoration Program Chief
Montana DOJ / Natural Resource Damage Program

Jeffrey L. Miller
Director of Fire Services
Butte-Silver Bow Fire Department
120 South Idaho St.
Butte, MT 59701
(406) 497-6483

May 27, 2020

To Whom it May Concern:

It is my understanding that the City and County of Butte-Silver Bow has applied to your organization for grant funding which would be used to rehabilitate the top portion of the Basin Creek Dam Number 1. As a critical user of the water which is supplied to Butte from the Basin Creek Dam Number 1, I urge you to give serious consideration to this funding request. Water for fire protection is supplied to the Southern end of our municipal area from Basin Creek Dam Number 1.

I have been informed that unless the critical repairs are made to the top portion of the dam, Butte-Silver Bow would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. This will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow of water through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, Butte-Silver Bow would need to resort to pumping and treating water from the Big Hole River, located nearly 22 miles from Butte. As you may know, the Big Hole River is an important agriculture resource and a very popular recreational stream for folks in Southwestern Montana, and it struggles to fulfill all that is asked of it during the late summer and early fall.

Thank you for your consideration of this request. If approved, the funding will ensure that the citizens of Butte-Silver Bow can fully utilize its most ecological and economically friendly water source for Butte, while lessening the impacts to the Big Hole River.

Sincerely,

Jeffrey L. Miller
Director of Fire Services

22 May 2020

Dan Olsen
1066 Standby Creek Rd
Butte, MT 59701

To Whom It May Concern:

I would like to provide this letter in support of Butte-Silver Bow applying to you agency for grant funds to repair the historical Basin Creek Dam #1. I've walked across the top of the dam recently and at that time I noticed the upper concrete structure of the dam was in the poor condition.

My house is about 2 miles downstream from the dam in the Basin Creek drainage. When we moved onto our property, one of the 24" wooden water mains from the dam runs through our property and provided water to our home. I am also the B-SB commissioner for that District, so the safety of the dam directly affects my neighbors and all the citizens living in that drainage. I am also the Chair of the B-SB Public Works Committee which oversees the B-SB public water supply system.

One of the first official events that I attended after being appointed in 2017 as Commissioner was the ribbon cutting for the new Basin Creek Water Treatment plant which is served by the Basin Creek Dam #1 water. I think it is important to capture and process as much water as possible through this plant provided by the Basin Creek Reservoir behind the dam. Without this needed repair, it will significantly reduce the storage capacity of the Reservoir, decrease the head pressure providing the gravity feed to plant and thus waste some of the substantial investments that B-SB has made to this water supply system.

As I've been told by the B-SB water engineers, this water plant provides one of the lowest cost supplies that B-SB has for its public water system.

I strongly support B-SB in applying for this grant to maintain our critical public water supply that the Basin Creek Reservoir, Basin Creek Dam #1 and Basin Creek Water Treatment Plant. I also believe that it is critical that this structure be repaired to provide the highest level of safety for the citizens who live below this dam. Thank you for providing B-SB an opportunity to apply for this very generous grant submission.

Sincerely,
Dan Olsen
B-SB Commissioner District #5

Big Hole Watershed Committee
Post Office Box 21
Divide, Montana 59727
(406) 960-4855
pmarques@bhwc.org
www.bhwc.org

Steering Committee
Randy Smith- Chair
Rancher - Middle Big Hole
Jim Hagenbarth- Vice Chair
Rancher - Middle Big Hole
Roy Morris- Secretary
George Grant Trout Unlimited
Steve Luebeck- Treasurer
Sportsmen
Governing Board
Dave Ashcraft
Rancher- Lower Big Hole
Sierra Harris
The Nature Conservancy
Peter Frick
Rancher- Upper Big Hole
Jim Dennehy
Butte-Silver Bow Water Dept.
Eric Thorsen
Fishing Guide
John Jackson
Beaverhead County
Hans Humbert
Rancher- Upper Big Hole
Liz Jones
Rancher- Middle Big Hole
Mark Kambich
Rancher- Middle Big Hole
Brian Wheeler
Big Hole River Foundation
Erik Kalsta
Rancher- Lower Big Hole
Dean Peterson
Rancher- Upper Big Hole
Phil Ralston
Rancher- Middle Big Hole
John Reinhardt
Rancher- Middle Big Hole
Bill Kemph
Fishing Guide
Paul Cleary
Resident
Andy Suenram
Resident and Sportsman
Mark Raffetty
Rancher- Lower Big Hole
Ray Weaver
Rancher- Upper Big Hole

To whom it may concern,

The Big Hole Watershed Committee strongly supports efforts by Butte-Silver Bow County to improve water storage capacity in the Basin Creek Reservoir. With this letter, I would like to represent the opinion of our 22-member board of directors that we enthusiastically support project proposals by water managers for the city of Butte to increasingly supply its users from water originating in the Basin Creek watershed.

This proposal, to replace the aging concrete in the upper 11 feet of the upstream face of the dam, would substantially increase the reservoir's storage capacity and consequently reduce Butte's reliance on water it pumps from the Big Hole River, 22 miles away. This approach would maximize the use of the most cost-effective water source for the city while reducing costs to pump and treat Big Hole River water. With the funding of this project, the residents of Butte would benefit by getting more world-class water from its new treatment facility while decreasing overall maintenance costs of their water system.

The Big Hole Watershed Committee, and all the water users of the Big Hole River would benefit from this project because decreased consumption from Butte would mean more water in our free-flowing river, particularly during the critical late summer season. Our group, now in its 25th year, will continue to operate our model Drought Management Plan, under which irrigators voluntarily give up their water rights at defined river stages and the guide community selflessly follows fishing restrictions to ease pressure on that resource during periods of high river temperatures.

This project will help us maintain river flows and keep temperatures down, benefitting the resources of our watershed and the livelihoods of the people who depend on the Big Hole River. Thank you for your attention to this matter and feel free to contact me for further information.

Sincerely,

5/26/2020

Pedro Marques
Executive Director
Big Hole Watershed Committee

George Grant Trout Unlimited
PO Box 563
Butte, MT 59703
Cold Clean Fishable Water

May 28, 2020

To Whom it May Concern:

The George Grant Chapter of Trout Unlimited (GGTU) understands that Butte-Silver Bow (BSB) has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, GGTU urges you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana and it struggles to fulfill all that is asked of it during late summer and early fall.

The George Grant Chapter of Trout Unlimited represents 214 engaged, concerned, and environmentally active members. The Big Hole River is a prime focus for our Chapter's mission: To Conserve, Protect, and Restore Cold Water Fisheries and Their Watersheds in Southwest Montana. Any extra amount of water we can keep in the Big Hole River will help the fish and habitat and this is in direct line with our mission. Repairs to Basin Creek Dam #1 will accomplish these goals; therefore, GGTU is in support of this project.

GGTU sincerely urges you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Sincerely,

Forrest C. Jay

Forrest C. Jay – Vice President
George Grant TU
PO Box 563
Butte, MT 59703
president@ggtu.org

Office of the Chancellor
MONTANA TECHNOLOGICAL UNIVERSITY

1300 West Park Street
Butte, Montana 59701
(406) 496-4129
Fax (406) 496-4387
Chancellor@mtech.edu
www.mtech.edu

May 26, 2020

To Whom It May Concern:

I am writing in support on behalf of Montana Technological University to support the request from Butte-Silver Bow County for grant funds to help repair the top portion of the Basin Creek Dam. The reservoir behind the dam is the source of the highest quality water for the city of Butte. The problem is that the top 11 feet of the dam is made of concrete, is more than 100 years old, and needs to be repaired.

Montana Technological University enrolls about 2,500 students on our campus in Butte. We have three dormitory buildings, with capacity to house 416 students on campus, along with a 60-unit apartment complex about 1 mile away. Faculty, students, staff, and visitors on our campus depend on Butte Silver Bow municipal water, with one of its major and highest-quality sources being the Basin Creek Reservoir.

Without the proposed repairs to the top portion of the dam, the County would probably be required to reduce the depth of the reservoir to a level below the concrete portion of the dam. Such a change will cut the storage capacity of the reservoir by about half—from nearly 1,000 acre-feet to less than 460 acre-feet. The lowered water level would also reduce the pressure driving the gravity flow through the nearby new, high-technology $30-million Basin Creek Water Treatment Plant. This drop in pressure would significantly reduce the volume of finished water produced. To make up the difference, the county would have to pump and treat water from the Big Hole River, nearly 22 miles from Butte and located on the other side of the Continental Divide. The Big Hole River is an important agricultural and recreational resource for Southwest Montana. Very low flows during late summer and early fall, moreover, cause its temperature to rise, which threatens fisheries and limits irrigation available to the farms and ranches that need it especially during the hot weather.

On behalf of the University and its 2,500 users of the high-quality Basin Creek water, I urge you to consider favorably the funding request for the dam-repair project from Butte-Silver Bow County. The proposed project is well planned, achievable, and cost effective. Its completion will ensure that Butte can fully utilize its most ecological and economically friendly water source, while minimizing impacts to the Big Hole River. Thank you for this funding opportunity.

Sincerely,

Les P. Cook

May 27, 2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Sincerely,

ROBERT PAL
Assoc. Prof., Director of Restoration
MontanaTech

Biological Sciences
1300 West Park St
Butte, Montana 59701
EMAIL: rpal@mtech.edu
OFFICE PHONE: (406) 496-4725
https://www.mtech.edu/clsps/biology/robert-pal.html

BUTTE LOCAL DEVELOPMENT CORPORATION

5/25/2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

As Butte's lead economic development organization, access to clean water is critical to our ability to support our existing businesses and recruit new businesses to our community. The need for clean water supports our residents and workforce, as well as provides important resources to our large employers. Ensuring that this project moves forward is incredibly important for all aspects of Butte and the future that our community deserves.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Joseph J Willauer

65 E. Broadway, Thornton Building, 5th Floor | Butte, Montana 59701 | 406.723.4349 | bldc.net

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THE CITY-COUNTY OF
Butte-Silver Bow

Community and Economic Development
Kristen Rosa, Economic Development Coordinator
Ph: 406-497-6470 E-Mail: krosa@bsb.mt.gov

May 26, 2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte at greater expense.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Sincerely,

Kristen Rosa

Kristen Rosa
Butte-Silver Bow TIFID Administrator
406-497-6470

22 May 2020

To Whom it May Concern:

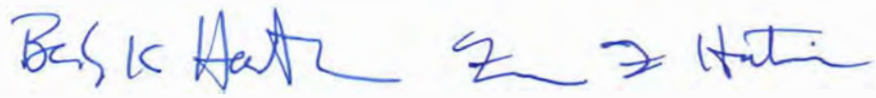
We strongly support Butte-Silver Bow County's proposal requesting funding to help repair the top portion of the Basin Creek Dam. Due to a new, very high-tech water treatment facility, the ~1,000-acre-feet reservoir behind the dam is the source of the highest quality water for the city of Butte. Because the top 11 feet of the dam is made of concrete placed more than 100 years ago, it needs desperately to be repaired.

Although our household water comes from a well, and we live just outside the area served by Butte Silver Bow's municipal water supply, Beverly works at Montana Tech, Fred volunteers at the Science Mine, and we care about the community and often visit friends and business establishments served by Butte's excellent municipal water. The Basin Creek water is of a purity and potability that rivals that of the best water systems in the country, which we and our neighbors appreciate.

If the concrete portion of the dam cannot be repaired soon, it will likely be necessary to reduce the reservoir's water depth substantially, lowering the capacity of the reservoir by about half—to below 460 acre-feet—dramatically cutting the quantity of water that can be provided. Where will the county get the water to fill this gap? It will need to turn to the Big Hole River, on the other side of the Continental Divide and located nearly 22 miles away. Infrastructure and water rights are in place to use this water, but it will need to be pumped and piped quite a distance. Plus its quality does not compete with the water from Basin Creek and its water treatment facility. Moreover, the Big Hole River serves critical regional agricultural and recreational needs. Already it suffers extremely low flows during late summer and early fall, which raise its temperature, threaten fisheries, and restrict irrigation flows to the farms and ranches that need it especially during August and September, when the weather is hot and dry and crops and livestock are approaching the harvest stage.

Please act favorably on this grant request. We appreciate the funding opportunity you provide for projects like this that are vital to their communities. Thank you.

Sincerely,



Beverly K. Hartline, Ph.D. and Frederick F. Hartline, Ph.D.

340 Telluride Ridge · Butte, MT 59701

5/26/20

To Whom it May Concern:

I understand that the top portion of Basin Creek Dam #1 is in need of repair and that Butte-Silver Bow has applied to your agency for grant funds to repair the Dam. As a user of the finished water supplied to Butte from Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. Many local ranches, small businesses, residents, non-residents, and wildlife species rely on the water flowing down the Big Hole River. As you know, the Big Hole River annually struggles to fulfill all that is asked of it during late summer and early fall.

My family owns a small business which relies on the Big Hole River and also uses the finished water that is supplied to Butte from the Basin Creek Water Treatment Plant. I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River and to those who depend on it.

Thank you for your time,

Caleb Gillis

May 21, 2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. The Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Northey Tretheway
3448 Wharton
Butte, MT 59701

May 22, 2020

To Whom it May Concern:

Butte-Silver Bow County has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will decrease the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the lowered elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the flowrate of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Sincerely,

Butch Gerbrandt, P. E.
412 West Broadway
Butte, MT 59701

May 26, 2020

To Whom it May Concern:

I understand that Butte-Silver Bow (BSB) has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced.

To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Kayla Lappin, Butte Citizen

May 27, 2020

To Whom it May Concern:

It is my understanding that Butte-Silver Bow has applied to your Agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte's municipal water system from the recently completed $30 million Basin Creek Water Treatment Plant, which is just downstream of the dam, I urge you to consider funding these critical repairs.

The residents of Butte have already invested a significant amount of their available financial resources into this water source, and it is a critical and prized element of Butte's municipal water system. My monthly municipal water bill has increased substantially over the years in order to generate funding to repair Butte dilapidated water system. I have never complained but as a recent retiree I am unsure if I can pay much more.

Without repair to the top portion of the dam, Butte-Silver Bow will be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. As a result, a significant amount of snow melt will be lost and not available during critical summer months.

Additionally, the decreased elevation of water in the reservoir will reduce gravity flow through the Basin Creek Water Treatment Plant and the volume of finished water will be significantly reduced. To make up the difference, Butte-Silver Bow will need to pump and treat water from the Big Hole River nearly 22 miles from Butte.

As you know, the Big Hole River is an important recreational and agricultural resource for Southwest Montana, and the river struggles to fulfill all that is asked of it during late summer and early fall. The Community would prefer to use the Basin Creek Water Source over drawing water from the Big Hole River.

Please consider Butte-Silver Bow's request for funding of repairs to the Basin Creek Reservoir. The proposed project will ensure Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

This is a good project that makes sense on many levels.

Thank you in advance for your consideration.

Regards,

Larry Curran
6 Bittersweet Dr.
Butte, Montana 59701

5/22/2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

John Moodry

Mile High Conservation District

Supervisor

May 26, 2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Loren Burmeister
3420 Quincy St.
Butte, MT 59701

May 26, 2020

Shanna Adams, P.E.
406.546.1483
Shanna.adams@hdrinc.com
465 E. Galena Street, Butte, MT 59701

Subject: Basin Creek Dam #1

To Whom it May Concern:

The purpose of this letter is to express my support for the grant application for repairs to Basin Creek Dam #1.

As a professional engineer working for Butte Silver Bow (BSB), I've had the opportunity to review the plans and studies associated with Basin Creek Dam #1, and it is imperative that repairs to the dam are initiated soon.

The dam was originally built in the 1890's and it has done a remarkably good job of providing a clean, safe drinking water source for the Butte community since then. However, in recent years the upper concrete portion of the dam has shown signs of severe deterioration including cracks, surface voids, and spalling, and the rate of deterioration has increased considerably over the past couple of years.

Repairing Basin Creek Dam #1 is timely and critical for the following reasons;

- In 2017, Butte Silver Bow completed construction of the Basin Creek Drinking Water Treatment Plant and the Southside Pump Station. These improvements allow BSB to maximize the use of water stored by the Basin Creek Dam #1. As a result, BSB has been able to meet nearly 60% of the City's municipal water needs from the Basin Creek supply, vastly reducing energy consumption and costs associated with using water from the Big Hole River Water Treatment Plant and pumping station, located on the other side of the Continental Divide approximately 26 miles south of Butte. Without repairs to Basin Creek Dam #1, BSB would be forced to reduce the amount of stored water available for the Basin Creek Plant.

- By maximizing the use of water from Basin Creek, BSB is able to minimize the amount of water needed from the Big Hole River. Instream flows in the Big Hole River have substantial economic value for irrigators, fisheries, recreation, tourism, and local economies.

- If repairs are not made to the Basin Creek Dam #1, the dam will continue to deteriorate threatening the entire Basin Creek water supply.

- As part of the Basin Creek Drinking Water Treatment Plant project, BSB agreed to evaluate recreation opportunities at Basin Creek Reservoir. These may include a walking trail, mountain biking, fishing, and non-motorized boating on the reservoir. Repairs to the dam are critical if any future recreational opportunities are to be realized.

Kind regards,

Shanna Adams, P.E.

Project Manager
HDR Engineering, Inc.

27-May-2020

To Whom it May Concern:

I am a citizen in butte and a hydrogeologist with 15 years of experience working on Butte water issues in the Summit Valley, the headwaters of the Columbia River Drainage Basin. I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I strongly support this project and urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Nicholas J. Tucci

1034 Caledonia St.
Butte, MT 59701

ntucci@haleyaldrich.com
(406) 465-5727

May 28, 2020

Subject: Basin Creek Dam Rehabilitation

Dear Sir/Madam:

Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As local business and user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to fund the critical repairs needed for this integral part of Butte's water system infrastructure.

Unless repairs are made, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

For the last 10 years, I have also chaired the Butte Natural Resource Damage Council. In preparing the Butte Area One Plan for allocation of the scarce restoration dollars, the council carefully evaluated many critical projects within the area that needed funded. Nothing is more critical to a community than clean drinking water and as such we dedicated $10 million dollars to the upgrade to the Basin Creek Water Treatment Plant. It is critical to the continuing operation of this plant that this rehabilitation project is completed. Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water, while minimizing impacts to the Big Hole River.

Sincerely,

Elizabeth Erickson

Water & Environmental TECHNOLOGIES

Elizabeth M Erickson

Principal/Founder/Hydrogeologist

P: (406) 723-1523

C: (406) 490-3135

waterenvtech.com

May 27, 2020

To Whom it May Concern:

I am aware that Butte-Silver Bow City-County (BSB) has applied for grant funds from your agency to repair the top portion of Basin Creek Dam #1. I would like to take this opportunity to urge you to seriously consider funding repairs to Basin Creek Dam for the following reasons.

The recently completed $30 million Basin Creek Water Treatment Plant lies just downstream of the dam. Unless these repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. This will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. Also, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River which is 22 miles from Butte. As you know, the Big Hole River is an important recreational, agricultural, and ecological resource for multiple communities in Southwest Montana. Currently, the river struggles to meet the demands on it during parts of the year.

If the Basin Creek Dam #1 ever were to fail, it could destroy or damage critical infrastructure. As stated above, the water treatment plant is located just below the dam. Bert Mooney Airport is also located in the floodplain, seven miles below the dam. Here, Basin Creek runs through airport property and into a 1,000-foot-long culvert underneath a runway. Further downstream, Basin Creek runs along and then, under Interstate 90 through another small diameter culvert.

Further downstream, Basin Creek's water flows into or directly adjacent to multiple active Superfund remedies which would also be impacted by dam failure. These include but are not limited to:

- Restored (and soon to be restored) sections of Blacktail and Silver Bow Creeks;
- Active Butte Priority Soils Operable Unit sites (Diggins East and Northside Tailings);
- The Butte treatment Lagoons, which clean shall groundwater contaminated by historic mining and smelting activities before it enters Silver Bow Cr.;
- Durant Canyon Fish Barrier, a small dam constructed to keep non-native fish out of Upper Silver Bow Creek;
- And finally, the Warm Springs Ponds Operable Unit, a settling ponds and lime treatment facility. These ponds are formed by large earthen berms and were constructed to treat/settle out metals from Silver Bow Creek waters with the addition of lime from a treatment facility before it is released into the Clark Fork River.

I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure BSB can fully utilize its most ecologically and economically friendly water source for Butte, while minimizing impacts to the Big Hole River. Additionally, in the case of potential dam failure, it will protect critical infrastructure, Superfund remedies, and both public/private properties along the watercourse.

Regards,

Matt Vincent,

Local business owner (Rampart Solutions) and former BSB Chief Executive

05/22/20

Dear Sir/Madam,

As Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1, I want to take the opportunity to express my support. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I respectfully, encourage you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet.

In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte.

The Big Hole River is an iconic recreational destination and important agricultural resource for all of us who live in Southwest Montana. It now already struggles to meet these expectations during late summer and early fall.

Therefore, your consideration of this funding request would be immensely appreciated. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Yours Truly,

Patrick Beretta

Parish Priest

Butte, MT

5/22/2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

For these reasons, the citizens of Butte have been fortunate to have this resource and the capable people that operate our water treatment and distribution facilities.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Bob Lazzari

2939 Burke Lane

Butte Montana 59701

May 26, 2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

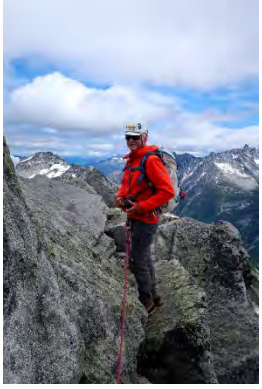
Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Lee Whitney

Lee Whitney
3151 Quincy
Butte, MT 59701



David Williams
2731 Princeton St.
Butte, MT 59701

May 21, 2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

I believe these repairs are important from the standpoint of operational considerations for the most efficient operation of the reservoir and the recently completed Basin Creek Water Treatment plant. As noted above, considerable NRD funds were allocated by the BNRC, I've which I'm a member, for the completion of the Basin Creek Water Treatment plant so it's important to make the best possible use of the Basin Creek watershed and associated treatment plant in supplying high quality water to the community. This has the added benefit of reducing the need for pumping and treating water from the already stressed Big Hole River.

While I believe that these repairs/upgrades are important from an operational standpoint, I believe, more importantly, they are absolutely critical from the perspective of Climate Change.

I've presented extensively on Climate Change and the Mining Industry (references by request if needed) and a critical factor for essentially all infrastructure is the predicted increase in storm intensity. This increase has been well documented in the past National Climate Assessment reports. This article in today's New York Times discusses exactly what I've been preaching to the Mining Industry for several years (https://www.nytimes.com/2020/05/21/climate/dam-failure-michigan-climate-change.html?action=click&module=News&pgtype=Homepage). Repairs to the dam should include considerations for anticipated/modeled change in precipitation intensity and should also look to the Michigan events for "lessons learned".

Additionally, Climate Change will only add to the seasonal stress on the Big Hole River and its associated fisheries. Anything that can be done to maintain late season flows will help keep river temperatures most suitable for supporting this critical fishery.

Please feel free to contact me if you have any questions in regards to Climate Change issues.

I urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize the recently completed Basin Creek Water Treatment plant while minimizing impacts to the Big Hole River.

Thank you for your consideration
Stay Safe!

David Williams

Geologist (retired, U. S. Department of Interior)

May 27, 2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Dr. Alysia Cox

1026 Caledonia St.

Butte, MT 59701

HOLY TRINITY ORTHODOX CHRISTIAN CHURCH

The Rev. Fr. Russell Radoicich, Parish Priest
2100 Continental Drive, Butte, Montana 59701 • Office Tel & Fax: (406) 723-7889
Serbian Patriarchate
rradoici@yahoo.com

May 22, 2020

To Whom it May Concern,

With regards to the grant funds applied for by Butte-Silver Bow for Basin Creek Dam #1.

I urge you to seriously consider funding the repairs.

Water is a critical resource. Clean Water even more so. Any investment in water is a good long-term investment. The investment in 1913 (the year the current concrete was poured) was a Very Worthy Investment as well.

Other states have "Wished" they could have granted such an investment when they had the chance to upgrade infrastructure.

As we go through a Global Climate Swing, and as Butte area grows, this Grant will be "Dimes Well Spent" to secure the Health and Prosperity of the Public now and into the future in an Ecologically Efficient way.

As the representative of a large group of people living in the area, I urge you to give Top consideration to this Funding Request.

Sincerely

Father Russell Radoicich
Parish Priest.

May 27, 2020

To Whom it May Concern:

I understand that Butte-Silver Bow (BSB) has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a FORTUNATE user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall. So while doable, it does not make economical, recreational, or agricultural sense.

Therefore, I sincerely urge you to consider BSB's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

William (Bill) Henne, PE, CFM

05/26/2020

Paul and Ann Antonioli
829 W Broadway St
Butte, MT 59701

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Ann Antonioli

Paul and Ann Antonioli

May 27, 2020

Sister Mary Jo McDonald

438 West Porphyry

To Whom it May Concern:

I am Sister Mary Jo, and have been active in social justice issues here in Butte for the past 40 years with special attention on those who struggle to simply survive. Butte's a city with a significant number of families and senior citizens who live below the poverty level. The opportunity for our community to receive this grant will serve these individuals well as our water rates are already higher than many other communities in Montana. I strongly support this request for a grant that will help water rates to remain steady with no increase.

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

This grant would be a win, win for the citizens of Butte and the environment.

Sincerely yours,

Sister Mary Jo McDonald

County Superintendent of Schools

Butte-Silver Bow Courthouse
155 W. Granite • Butte, Montana 59701
Phone (406) 497-6215

May 22, 2020

Re: Support for Grant to Fund Repairs to Basin Creek Dam

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed $30 million Basin Creek Water Treatment Plant, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

This is important for our community to grow and for the rural areas in our county to survive. I speak from an educational standpoint, please assist in giving future generations a better environment to work with. Time is of the essence.

Regards,

Cathy F. Maloney

Cathy F. Maloney, County Superintendent of Schools

May 22, 2020

To Whom it May Concern:

I understand that Butte-Silver Bow has applied to your agency for grant funds to repair the top portion of Basin Creek Dam #1. As a user of the finished water supplied to Butte from the recently completed **$30 million Basin Creek Water Treatment Plant that operates via gravity flow**, just downstream of the dam, I urge you to seriously consider funding repairs to Basin Creek Dam #1.

Unless repairs are made to the top portion of the dam, BSB would likely be forced to reduce the maximum operating level in the reservoir to an elevation below the concrete portion of the dam. That will reduce the storage capacity of the reservoir from nearly 1,000 acre-feet to less than 460 acre-feet. In addition, the decreased elevation of water in the reservoir would reduce the driving force that provides gravity flow through the treatment plant, so the volume of finished water coming from the Basin Creek Water Treatment Plant would be significantly reduced. To make up the difference, BSB would have to pump and treat water from the Big Hole River nearly 22 miles from Butte. As you know, the Big Hole River is an important recreational and agricultural resource for folks in Southwest Montana, and it struggles to fulfill all that is asked of it during late summer and early fall.

Therefore, I sincerely urge you to consider Butte-Silver Bow's funding request. The proposed project will ensure the City of Butte can fully utilize its most ecological and economically friendly water source for Butte, while minimizing impacts to the Big Hole River.

Regards,

Katherine R. Zodrow

Butte Resident

From: Amy Chadwick
To: Craig Erickson
Subject: Fwd: Inquiry about benefit of Basin Creek Dam to WSCT
Date: Tuesday, May 26, 2020 2:46:59 PM

Fyi
Amy Chadwick

Begin forwarded message:

> **From:** "Uerling, Caleb" <Caleb.Uerling@mt.gov>
> **Date:** May 26, 2020 at 2:34:45 PM MDT
> **To:** Amy Chadwick <achadwick@greatwesteng.com>
> **Subject: Re: Inquiry about benefit of Basin Creek Dam to WSCT**

Amy,

Sorry for the late response. We have pretty good WCT genetics in Silverbow Creek above the barrier we constructed below German Gulch, so from a genetics standpoint it's somewhat redundant, but it is a pure population above the Basin Cr Reservoir. From a native species standpoint it is a beneficial barrier because there are non-native brook trout below the dam and no brook trout above the dam. I would recommend the dam continue to be operated as a barrier to protect against brook trout invasion. Maintaining the level of the reservoir would be a benefit to the WCT population in the reservoir simply from a population size standpoint. The lower the reservoir depth the less habitat there will be in the reservoir for the WCT. If the water level were to be lowered the reservoir would likely support fewer WCT. Depending on how much it was lowered it may also impact the reservoirs ability to over-winter fish. However, it would likely have to be lowered fairly substantially to impact the ability to overwinter fish.

The only upgrades that I can think of to add benefits from a fisheries standpoint would be how the dam is operated from a flow perspective for the downstream fisheries. I'm not exactly sure what this would look like because I don't know specifically how they operate the dam now and what might be possible. Generally though there are times of the year when the fishery downstream is impacted by low flows. For instance, the channel immediately below the reservoir is mostly dry right now, if that section could be re-watered and utilized by fish that would

be a big benefits. There are also issues with low flows further down in the system later in the year, so added water at that time could be really beneficial. I would have to understand how much water they have and are using and when they are using it to better understand if there is an opportunity to operate the dam differently to benefit fish downstream. It's possible that letting some water by at a few strategic times could be really beneficial for the downstream fishery.

Let me know if you have further questions or clarifications.

Caleb Uerling

Fisheries Biologist - Upper Clark Fork

Fisheries Division

Montana Fish, Wildlife & Parks

Ph: (406) 493-2694

FWPTaglineEmailLockupSm

From: Amy Chadwick <achadwick@greatwesteng.com>
Sent: Tuesday, May 19, 2020 2:22 PM
To: Uerling, Caleb
Cc: Lindstrom, Jason; Craig Erickson
Subject: [EXTERNAL] Inquiry about benefit of Basin Creek Dam to WSCT

Hi Caleb,

We are working on a TSEP grant application for repairs to the Basin Creek Dam. What I would like to know is, do you see the dam as a beneficial barrier to maintain the pure westslope cutthroat population? DO you see any other

environmental benefits of the dam or maintaining the reservoir level?

And, is there anything you can think of that could be incorporated into dam maintenance/upgrade to benefit the WSCT population?

Just to let you know, your response may be incorporated into the communication record for the grant application.

Thanks!

Amy Chadwick

Ecologist I Project Manager

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