Lower Yellowstone Project
Fish Screening and Sediment Sluicing
Preliminary Design Report

February 2008

FINAL REPORT

US Army Corps of Engineers ®
Omaha District

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TABLE OF CONTENTS

CONTENTS

FIGURES

TABLES

Lower Yellowstone Project
Fish Screening and Sediment Sluicing
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EXECUTIVE SUMMARY

The Bureau of Reclamation's Lower Yellowstone Project and its impacts on the fishery of the Lower Yellowstone River have been the subject of many studies by state and federal resource agencies. These studies indicated that the unscreened intake structure entrains large numbers of fish into the canal system with the diversion flow, and that the diversion dam itself is a barrier to upstream migration of many fish species, including the endangered pallid sturgeon. The natural condition of the Yellowstone River and its status as historical habitat to pallid sturgeon affords it unique opportunities that could contribute to assisting with the recovery of that species and developing a better understanding of its behavior and habitat preferences. The U.S. Fish and Wildlife Service even emphasized the importance of the Yellowstone River to pallid sturgeon recovery in both their <u>1993 Recovery Plan for the Pallid Sturgeon</u> and <u>2003 Amended Biological Opinion for the Missouri River Master Manual</u>. The Lower Yellowstone Project is critical to that effort because of its strategic location, ~75-miles upstream from the Yellowstone-Missouri River confluence and ~165-miles downstream from the next irrigation diversion dam.

During 2005 the Bureau of Reclamation and the Corps of Engineers agreed to collaborate and form a partnership with the U.S. Fish and Wildlife Service, the State of Montana Department of Fish, Wildlife and Parks, and The Nature Conservancy of Montana. The partnership was formalized with the signing of a Memorandum of Understanding in July 2005. Subsequent to signing the MOU, Bureau of Reclamation contracted with the Omaha District during 2006 to conduct a Preliminary (10%) Design Analysis and develop detailed cost estimates for the most promising alternatives. U.S. Fish and Wildlife Service facilitated the assembly of a panel of pallid sturgeon and fish passage experts to review the Preliminary Design Analysis during August 2006. The panel made several recommendations regarding design considerations to be addressed as the project moved forward. The three most prominent recommendations were to include a trash rack on the river side of the existing headwall structure to protect adult fish (esp. pallid sturgeon) from being entrained into the canal and from ever reaching the v-shaped screen; evaluate a removable on-river screening structure as an alternative to the in-canal v-shaped screen; and evaluate the need and size of a potential sluiceway to help manage sediment deposition in front of the headworks gate structure. This document presents the results of the Preliminary Design Analysis for the in-channel screen and sluice alternatives.

This Preliminary Design Analysis involved a multi-discipline team that completed the following tasks:

- *Fisheries – Reviewed the comments provided by the panel and served an advisory role to the design team.*
- *Hydraulics & Geomorphology – Reviewed hydraulic performance data from screen vendor and performed preliminary design analysis of the three alternative sluice designs to determine size of alternative features, evaluate hydraulic feasibility, and identify design concerns.*

- *Geotechnical – Performed geotechnical evaluation, prepared drawings, and identified construction and operation and maintenance concerns.*
- *Engineering Design – Performed structural computations and prepared drawings for each alternative.*
- *Cost Engineering – Developed cost estimates of each alternative.*

Conclusion

The purpose of this study was to evaluate additional alternatives and design features related to addressing the entrainment piece of the overall project at a comparable level of detail (10% design) to the Preliminary Design Analysis which was conducted during 2006. This analysis included an updated cost estimate, and a preliminary evaluation of alternative performance with respect to successful fish entrainment protection. This study presents only the preliminary design data and cost estimates and is not intended to be a decision document or make recommendations on a final course of action. A summary of the detailed cost estimates that were developed for the on-channel fish screen alternative and the three sluice alternatives is presented in the following table.

Summarized Cost Estimates for Alternatives

Alternatives	*Estimated Cost [$ millions]*
On-Channel Fish Screen Facility	*19.63*
New Headworks Structure and Canal Section	*7.51*
Removable, Rotating Drum Screens	*10.75*
Utilities and Controls	*0.61*
Concrete Bollards for Ice Protection	*0.18*
Water Management	*0.58*
Sluice Structure Alternatives	
In-Channel through Dam & Ramp	*15.25*
Left Bank Conduit through Existing Headworks Structure	*11.09*
Left Bank Open Channel through Existing Headworks Structure	*1.25*

PRELIMINARY FISH SCREEN DESIGN

An in-channel fish screen along the left bank of the Yellowstone River was proposed as an alternative to address the fish entrainment issues during the Biological Review Panel review of the Lower Yellowstone Project Fish Passage and Screening Preliminary Design Report. This panel of pallid sturgeon and fish passage experts was assembled during 2006 to provide an independent review of the preliminary design alternatives and assist the team with identification of performance criteria for the project.

New Headworks with Cylindrical Fish Screens. The preliminary design of the in-channel fish screen identified that fourteen (14) identical screens would be required to meet the diversion capacity of the existing canal. To be conservative on the design and preliminary cost estimates the team decided that a new headworks structure and canal inlet would best accommodate these screens versus retrofitting these screens to an expansion of the existing headworks. The new headworks structure was located upstream of the existing structure (Figure 1). The new headworks structure would require a new inlet to the canal and a transition section over to match up with the existing canal. A cylindrical fish screen would be installed on the river side of the gated headworks. The screens are mounted on a rail to allow raising during the non-irrigation season to prevent damage, primarily from ice flows and jams during the winter and early spring. Details of the new headworks and fish screen are described in the following sections.

Cylindrical Screens. The preliminary fish screen concept design and hydraulics were provided by a manufacturer representative, Mr. Darryll Hayes, of Intake Screens, Inc (dhayes@intakescreensinc.com). Illustration concepts are shown in Figure 2. A summary of fish screen design parameters that apply to the Intake project are as follows:

- Fourteen individual units with an assumed 100 cubic feet per second per unit;
- Each individual until would be a 72-inch diameter cylindrical unit with two screen cylinders (one on each end) each 84 inches long (net 264 sq. ft. of screen area per unit);
- The screen is constructed of #69 wedge wire (width of 0.069 inches) and a slot opening of 0.068 inches which produces a 50% open area.
- Screen approach velocity is 0.4 ft/sec over the screen area (i.e. a slot velocity of 0.8 ft/sec) which meets fisheries criteria proposed for this project.
- Each unit would include a slide gate behind the screen unit to help regulate flow imbalance and allow a single unit to be taken out of service for maintenance or repair;
- The screens would slide (or roll) on a recessed track to allow raising the screens out of the river when the canal is not operating to prevent damage from large debris and ice.
- The portal where the screen connects to the headworks structure was assumed to be a 6-foot square opening with a coarse trashrack to block debris during periods when the screen was in the raised position.

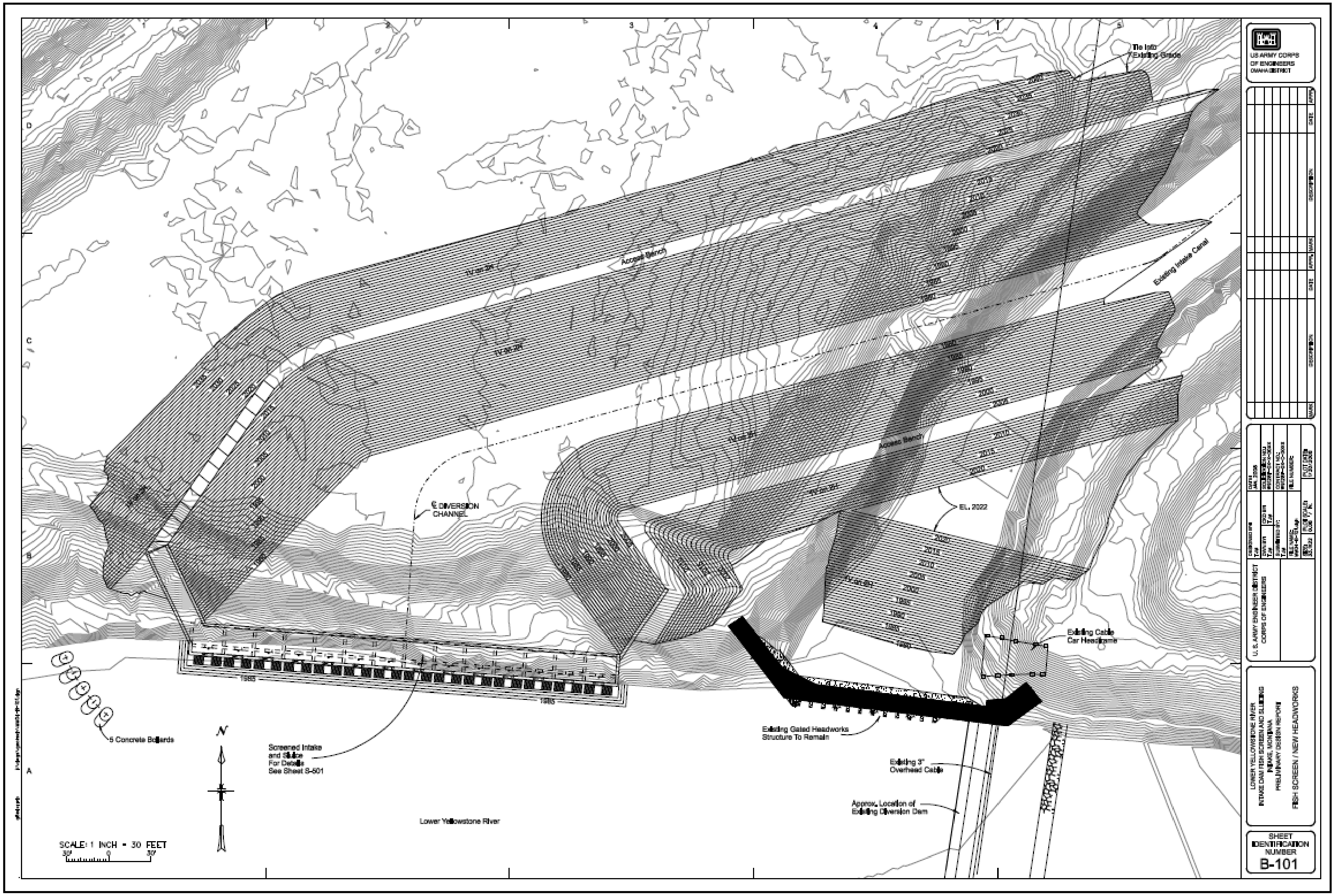

Figure 1. Fish Screen New Headworks and Canal Inlet Site Plan

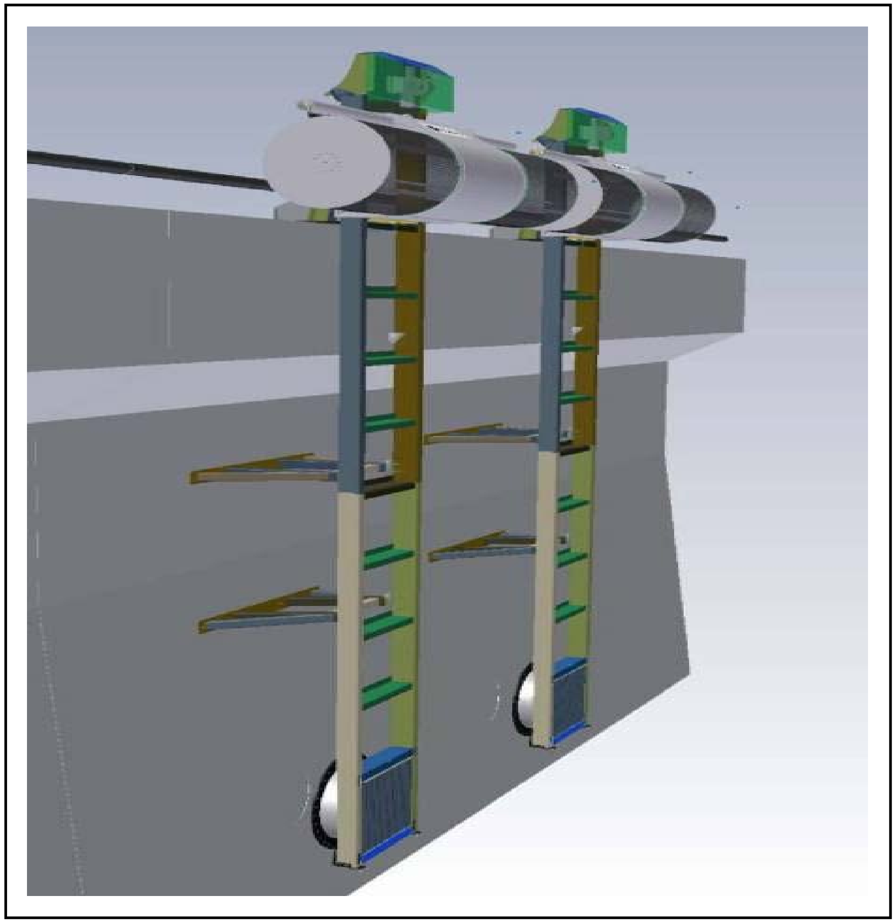

Figure 2. Concept Cylindrical Screens (raised position)

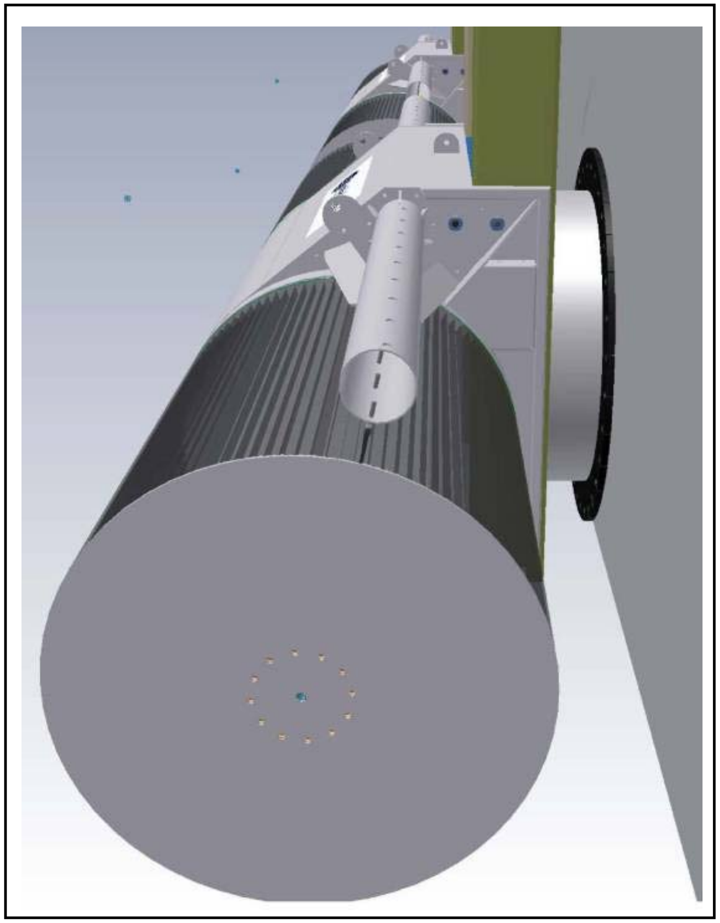

Figure 3. Concept Cylindrical Screens (side view)

Ice Protection. A preliminary design for ice protection was developed consisting of a series of concrete bollards upstream of the new headworks structure to help deflect ice out into the center portion of the channel. The need for ice protection will be evaluated during the final design.

Detailed Construction Cost Estimate. As part of this design analysis a detailed engineering construction cost estimate was developed which estimated the cost of the fish screen structure and associated facilities at $19.63 million (Table 1). The preliminary cost estimate includes a 25% contingency, 5% escalation, 9% for engineering and design, and 6% for construction supervision and administration.

Table 1. Detailed Construction Cost Estimate for In-Channel Screen Alternative

Features	Estimated Cost [$ millions]
On-Channel Fish Screen Facility	19.63
New Headworks Structure and Canal Section	7.51
Removable, Rotating Drum Screens	10.75
Utilities and Controls	0.61
Concrete Bollards for Ice Protection	0.18
Water Management	0.58

Real Estate. The detailed cost estimate does not include the cost for any real estate rights-of-way required for the construction of the project. The preliminary design includes a new inlet section for the canal which may require additional real estate. The preliminary alignment would require approximately four acres of additional real estate which is currently privately owned.

Construction Considerations. The preliminary design incorporates the construction of a new headworks structure with the in-channel screen alternative. Since a new structure would be constructed upstream from the existing headworks the canal could remain operational throughout construction. The construction of the headworks on the bank would require a cofferdam to control water at the site, but even with a cofferdam it is still likely that the existing facility could remain operational during construction. Excavated soils from the construction of the headworks and canal inlet would be stockpiled for use as filling in the existing canal and during construction of the rock ramp. It may be possible to expand the existing headworks for the project which could save costs, but maintaining canal diversions during construction could be a challenge.

Operation and Maintenance Considerations. The detailed cost estimate does not include the cost for operations and maintenance of the facility. The removable screens proposed are relatively simple in design and removal of these screens during non-irrigation season should dramatically increase their life expectancy. In addition, since each screen is a separate element they could be removed individually for repair or maintenance without shutting down water delivery to the canal. For the concrete headworks structure, maintenance should be lower than for the existing structure due to age and deterioration of the existing structure.

PRELIMINARY SLUICEWAY DESIGN

This section of the report is dedicated to presenting the preliminary design information for a sluiceway to allow sediment flushing from in front of the diversion headworks structure. The design team and biological review panel have expressed some concern that sediment maintenance with either of the screen alternatives may be a concern and utilization of a sluiceway was identified as a potential means to address that concern. Numerous irrigation diversion structures throughout the West include sediment sluiceways to help manage sediment deposition. The goal of the sluiceway design is to maintain sufficient velocity in front of the headworks structure to mobilize any deposited sediments and carry them downstream of the diversion dam.

Since no detailed sediment data was available for the preliminary design, the target sediment size was assumed to be coarse gravel which requires a minimum velocity of six (6) feet per second. Due to the length of the new headworks structure a training wall parallel to the headworks structure would help concentrate velocities and was assumed to be necessary for a sluiceway to be effective. Sediment and physical modeling during the final design will further refine the need for a training wall. The preliminary design of the sluiceway involved three alternatives: an in-channel sluiceway through the diversion dam and proposed rock ramp; a left abutment closed conduit sluiceway utilizing the existing headworks as the control structure; and a left abutment open channel sluiceway utilizing the existing headworks as the control structure.

In-Channel Sluiceway. The sluiceway gate structure is located just downstream from the new headworks screening structure approximately 250 feet upstream from the existing diversion dam. The in-channel sluice invert was set at 1981.58 ft as controlled by invert elevation of the toe of the rock ramp (approximately 1980.0 ft) and providing sufficient slope to maintain the required velocities. The top of the gate housing would extend to the same elevation as the new headworks structure and would be connected by a walkway to provide access the gate operators. The sluiceway would utilize four 8-foot wide by 6-foot tall flat, vertical lift gates. The sluiceway downstream from the gates would consist of two covered conduits 20.5 feet wide by 10 feet high extending approximately 2,050 feet downstream to the toe of the rock ramp (slope 0.077% or 4.1 feet per mile). Figure 4 illustrates the layout of the proposed in-channel sluiceway.

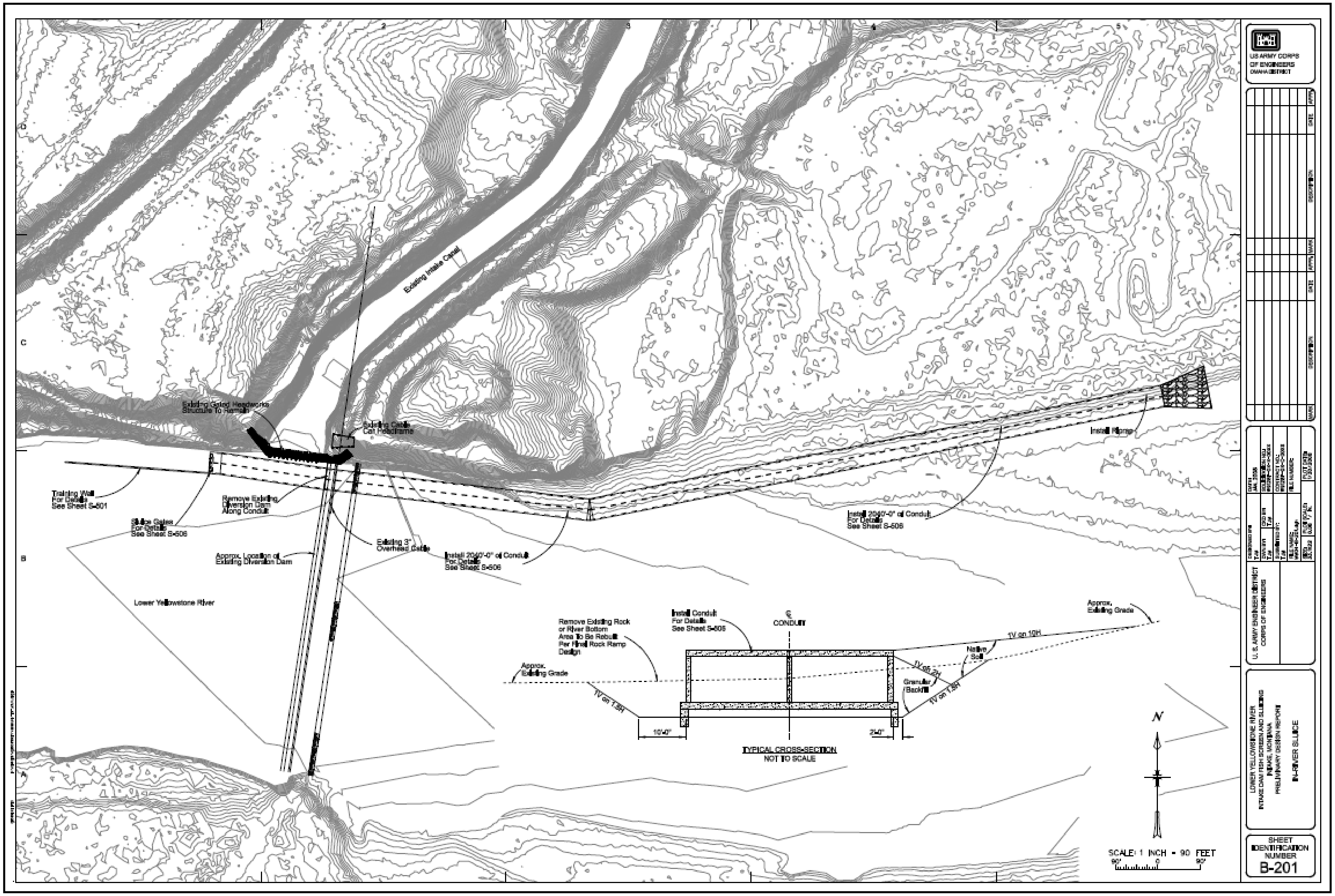

Figure 4. In-Channel Sluiceway Site Plan

Abutment Closed Conduit Sluiceway. The abutment sluiceway concept builds upon the constructive re-use of the existing headworks structure as the gate structure for the sluiceway which would then run along the left bank of the river until it reaches the toe of the proposed rock ramp. The invert of the existing gates is already set at 1983.58 ft and the outlet invert elevation was set at the elevation of the toe of the rock ramp (approximately 1980.0 ft). The sluiceway would utilize four 8-foot wide by 8-foot tall flat, box culverts. The sluiceway downstream from the gates would consist of four 8-foot by 8-foot box culverts extending approximately 1,900 feet downstream to the toe of the rock ramp (slope 0.19% or 9.9 feet per mile). Figure 5 illustrates the layout of the proposed abutment closed conduit sluiceway.

Abutment Open Channel Sluiceway. This abutment sluiceway concept again re-uses the existing headworks structure as the gate structure for the sluiceway which would then run along the left bank of the river until it reaches the toe of the proposed rock ramp. The invert of the existing gates is already set at 1983.58 ft and the outlet invert elevation was set at the elevation of the toe of the rock ramp (approximately 1980.0 ft). Instead of a closed box culvert conduit, this sluiceway would utilize trapezoidal open channel. The sluiceway downstream from the gates would consist of a trapezoidal channel with a 30-foot bottom width and 1.5:1 side slopes. The channel would extend approximately 1,900 feet downstream to the toe of the rock ramp (slope 0.19% or 9.9 feet per mile). Figure 6 illustrates the layout of the proposed abutment open channel sluiceway.

Sluiceway Design Considerations. The sluiceway design is preliminary and based on limited analysis with several design constraints that require further evaluation. Safety is a concern with the possible requirement to limit public access. Sluice seasonal operation duration and maximum flow was not evaluated. Operation of the sluiceway during the irrigation season and possible impact to flows on the rock ramp was not evaluated. The conceptual analysis indicates that it is possible to implement a sluice. Further sediment transport analysis will determine the final sluiceway size, flow requirements, and effectiveness for the final design.

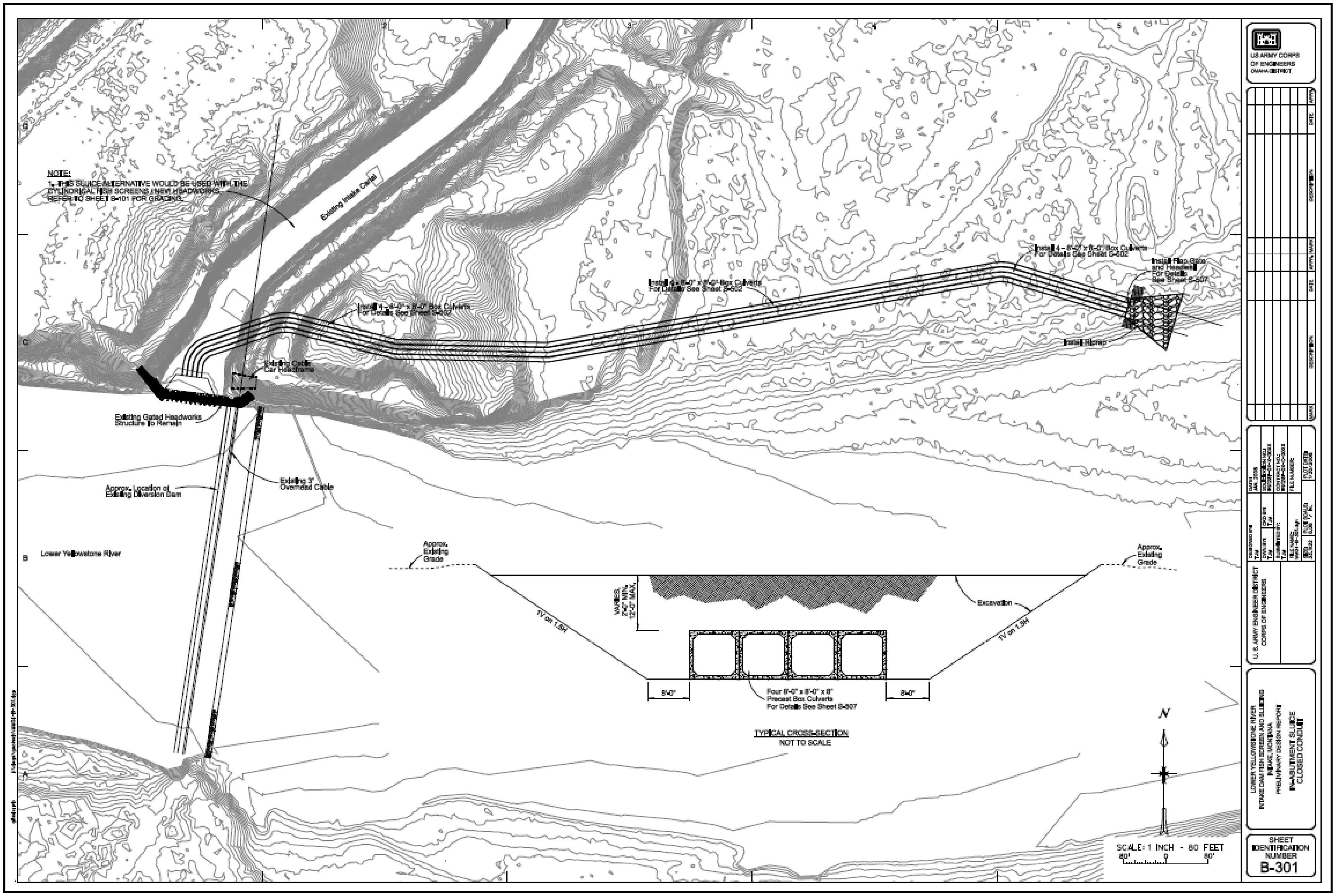

Figure 5. Abutment Closed Conduit Sluiceway Site Plan

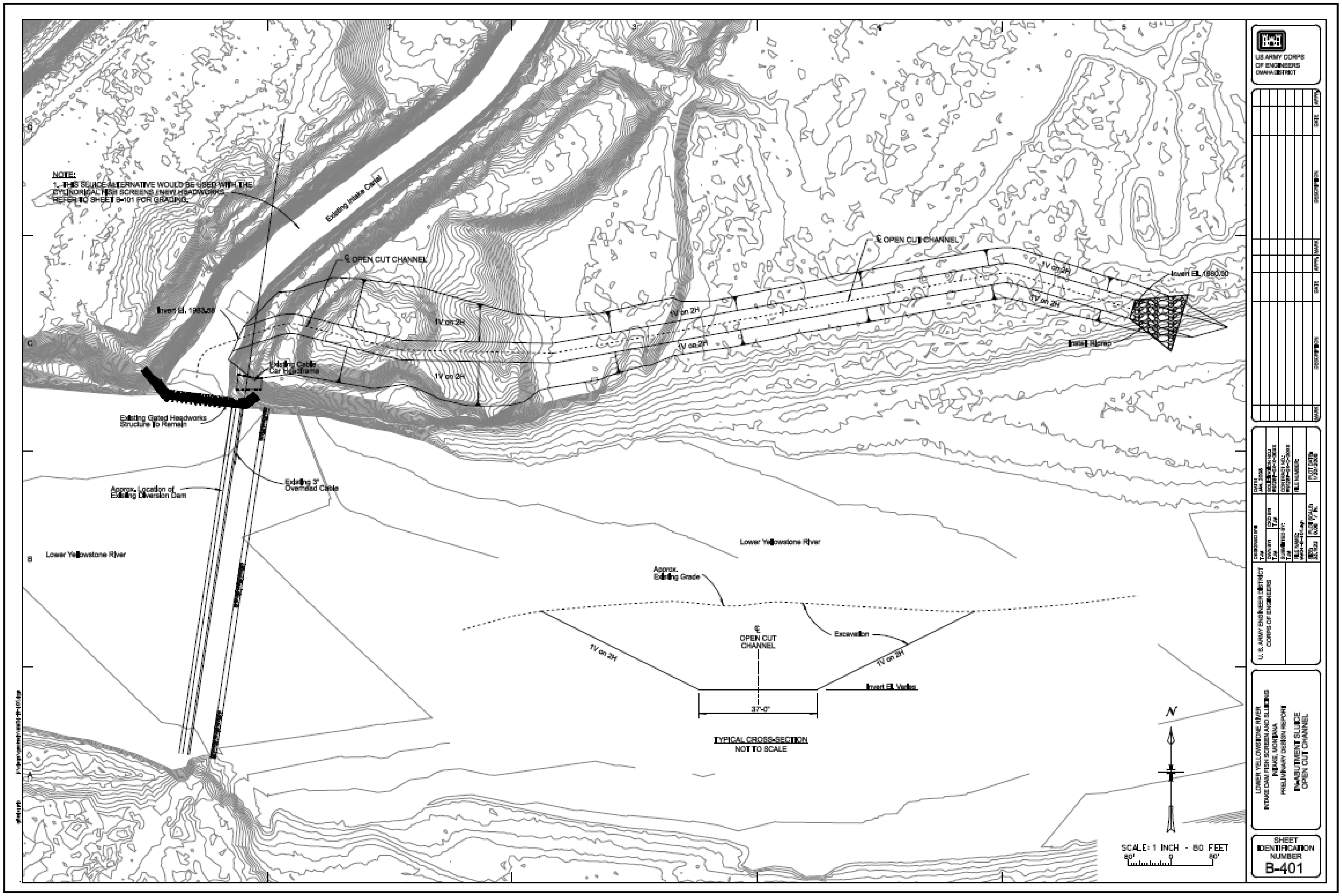

Figure 6. Abutment Open Channel Sluiceway Site Plan

Detailed Construction Cost Estimate. As part of this design analysis a detailed engineering construction cost estimate was developed for the three sluiceway alternatives which are presented in Table 2. The preliminary cost estimate includes a 25% contingency, 5% escalation, 9% for engineering and design, and 6% for construction supervision and administration.

Table 2. Detailed Construction Cost Estimates for Sluiceway Alternatives

Alternatives	Estimated Cost [$ millions]
Sluice Structure Alternatives	
In-Channel through Dam & Ramp	15.25
Left Bank Conduit through Existing Headworks Structure	11.09
Left Bank Open Channel through Existing Headworks Structure	1.25

Real Estate. The detailed cost estimate does not include the cost for any real estate rights-of-way required for the construction of the project. The preliminary design for the abutment sluiceway alternatives would cross through the existing campground and park area operated by Montana Department of Fish, Wildlife, and Parks. The land appears to all be public, but impacts to the park and boat ramp would need further evaluation and a mitigation plan would need to be developed. Impacts to the park might be able to be minimized if the sluiceway is routed behind the park or utilizes a buried conduit instead of an open channel, however a close conduit is much more costly than and open channel.

Construction Considerations. The preliminary design for the in-channel sluiceway would require a cofferdam to control water, but likely would be constructed in conjunction with the new diversion dam and rock ramp utilizing the same cofferdam. The training wall parallel to the headworks would also require construction of a cofferdam. Depending on the final size and orientation of the training wall construction may or may not impact canal operations during construction. The in-channel sluiceway construction would also need to be concurrent or prior to the construction of the rock ramp since the ramp would cover some parts of the sluiceway.

Operation and Maintenance Considerations. The detailed cost estimate does not include the cost for operations and maintenance of the facility. The closed conduit sluiceways may require some periodic maintenance and inspections due to the structural concrete, but maintenance should be minimal. The open channel sluiceway would require some vegetation maintenance and possible repair of erosion or sloughing, but it would be typical of the existing maintenance occurring for the canal itself. The in-channel sluiceway consists of a new gate structure which would require manual operations during periods when sluicing would occur. The abutment sluiceway alternatives would require continued use of the existing headworks to operate the gates.

Appendix A
Hydraulics

FINAL REPORT

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US Army Corps of Engineers
Omaha District

Hydraulic Analysis
Intake Diversion Dam, Yellowstone River
Table of Contents

List of Tables

List of Figures

1. INTRODUCTION.

Alternative hydraulic analysis was performed at a conceptual level to examine alternative feasibility and refine cost estimates. Future detailed design analysis is required to further define project features and thoroughly evaluate alternative feasibility. Preliminary design of a sediment sluice was performed. However, future detailed design is required to further evaluate sluice feasibility and operation requirements.

1.1 ALTERNATIVES

Hydraulic analysis was conducted for a total of four alternatives. These alternatives are illustrated in Figure 1.

- New Headworks with Cylindrical Fish Screen
- In River Sluice
- In Abutment Sluice Closed Conduit
- In Abutment Sluice Open Conduit

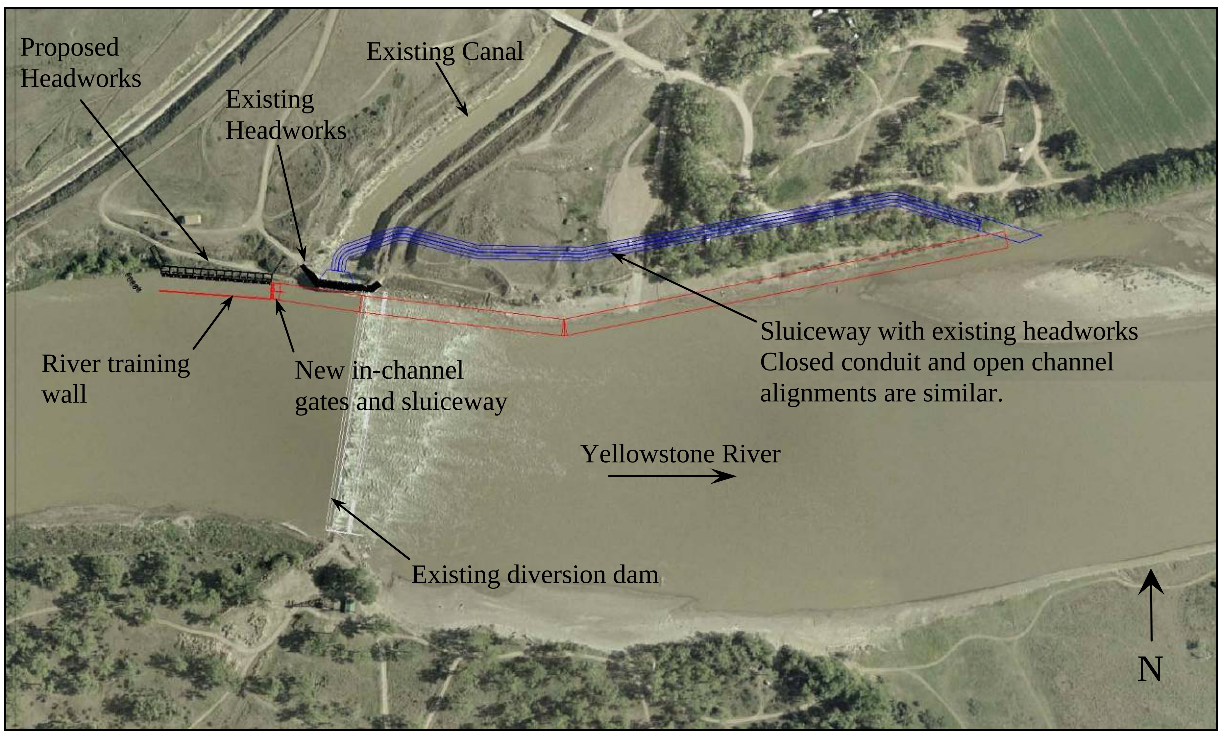


Figure 1. Sediment sluiceway design options at the intake dam.

1.2 CANAL OPERATION

The irrigation district reports that they typically open the gates by May 1, and they are occasionally open by April 15. The first call for water typically occurs by May 10. Approximately a maximum of 1400 cfs is diverted with all 11 of the gates open in the existing headworks. The canal operates through September of each year.

1.3 NEW SURVEY

Lidar topographic data of the site was available that was previously collected for the Yellowstone River Corridor Study. However, the Lidar topography didn't include any below water elevations with the minimum elevation near the waters edge elevation. In 2007, the Montana USGS collected survey data in the vicinity of the dam to evaluate Yellowstone River bed topography. Limited bank surveys were also collected. All survey data was combined into a single terrain model for use with this study. The survey data uses the following coordinate system:

Horizontal: Montana State Plane NAD 83
Vertical: NAVD 1988

The new survey was examined to determine river bottom elevation and possible sediment information. Sediment deposition immediately riverward of the structure has not been a problem with the current headworks. The most recent survey data riverward and upstream of the existing headworks show elevations as low as 1976.0 ft, which is several feet below the invert elevation of the intakes. The nearest survey data is approximately 130 ft from the headworks, so it is not possible to determine the extent that a scour hole has development near the intakes. Figure 2 shows the extent of the current survey data near the diversion dam and a .tin representing elevations interpolated from the survey data. The large void is where the dam is located and conditions were too turbulent to survey.

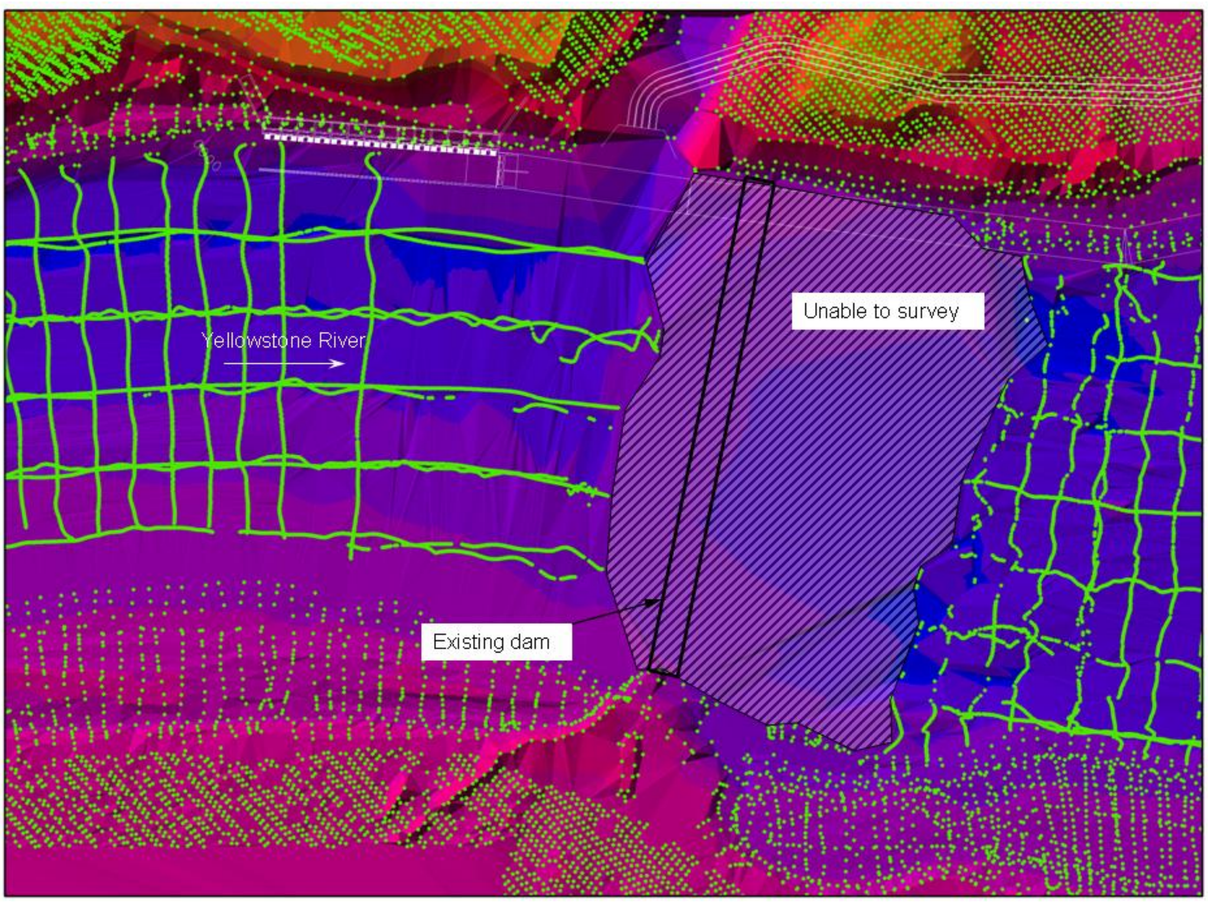


Figure 2. Survey data collected in 2007 near the intake dam.

1.4 PAST STUDIES

This study has a narrow hydraulic scope that relies on previous evaluations. Numerous past studies have been performed to evaluate many different alternatives for providing fish passage at the Intake Diversion Dam. A few of the recent studies with additional information include the *Intake Diversion Dam, Yellowstone River, Montana, Fish Protection and Passage Concept Study Report* (Bureau of Reclamation, 2000), the *Lower Yellowstone River Intake Dam Fish Passage Alternatives Analysis* (USACE, 2002), the *Intake Diversion Dam, Fish Protection and Passage Concept Study Report II* (Bureau of Reclamation, 2004), the *Draft Biological Assessment: Future Operation of the Lower Yellowstone Project with Proposed Conservation Measures* (Bureau of Reclamation, 2005), and *Lower Yellowstone Project Fish Passage and Screening, Preliminary Design Report, Intake Diversion Dam July 2006* (USACE, 2006).

1.5 YELLOWSTONE RIVER HYDROLOGY

Yellowstone River flow values were extracted from the previous USACE study and are tabulated in Table 1 for convenience. Flow frequency and flow duration analysis considered both the Sydney and Glendive gage record and examined the impact of Yellowtail Dam on results. Refer to the previous study (USACE, 2006, Hydrology Appendix B) for a complete discussion of analysis methods and results. Significant values used in this analysis are shown in Table 1.

Table 1. Yellowstone River Hydrologic Design Data

Instantaneous Annual Peak Flow (cfs)[1]	100-Year	160,200	
	10-Year	104,900	
	2-Year	60,400	
Monthly Flow Duration (Percent Time Flow is Equaled or Exceeded)[2]	May	July	September
20%	23,300	30,300	9,710
50%	14,800	17,100	6,660
90%	7,560	5,730	3,600

1 USACE, 2006, Hydrology Appendix B, Table 4.
2 USACE, 2006, Hydrology Appendix B, Table 3.

2. NEW HEADWORKS WITH CYLINDRICAL FISH SCREEN.

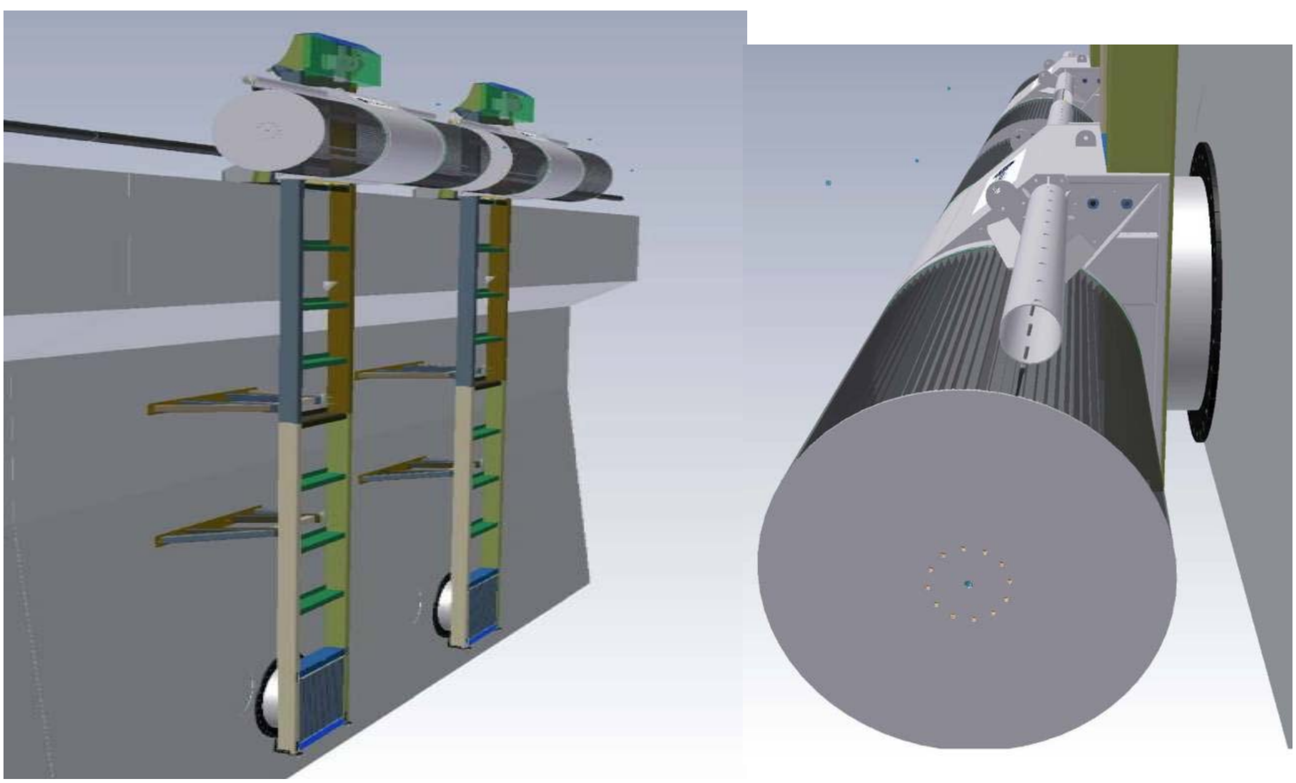
This alternative consists of constructing a new headworks upstream of the existing structure. A cylindrical fish screen would be installed on the river side of the gated headworks. The screens are mounted on a rail to allow raising during the non-irrigation season to prevent damage. Details of the new headworks and fish screen are described in the following sections.

2.1 CYLINDRICAL FISH SCREEN.

Fish screen hydraulics were provided by a manufacturer representative, Mr. Darryl Hayes, of Intake Screens, Inc (dhayes@intakescreensinc.com). Illustration concepts are shown in Figure 1. A summary of fish screen design parameters that apply to the Intake project are as follows:

- Fourteen separate units with an assumed 100 cfs per unit with flow roughly equal to all units.
- Each unit would include a slide gate behind the screen unit to help regulate flow imbalance and allow closure. Each unit may be operated separately if one unit is clogged or undergoing repair.

- The proposed screen is a 72 inch diameter unit with two screen cylinders each 84 inches long. That translates to 264 square feet of screen surface area for each complete screen unit.
- The screen consists of a #69 wedgewire (width of 0.069 inches) and a slot opening of 0.068 inches. This results in a 50% open area. A 50% open area is typical for slots down to about 1.75 mm. If slot size is desired to be less, the open area will decrease because the wire size is generally wider than the slot.
- The assumed screen approach velocity is 0.4 ft/sec over the screen area (i.e. a slot velocity of 0.8 ft/sec). This is the general fisheries criteria used in the western states for most fish. If the water was especially dirty or desired to screen for smaller fish (i.e larval, or weak swimmers), the approach velocity would be lower and more screens would therefore be required. A slot velocity of 0.5 ft/sec is desirable to really minimize headloss, but many installations have velocity up to 0.8 ft/sec with no real issues. Debris will clog the screen faster as the slot velocity is increased. Brush cleaning intervals are increased if the slot velocity is higher.
- It is possible to install water level differential sensors for the screen. If a set value is triggered, for instance 2 inches across the screen surface, the sensor will trigger an additional cleaning cycle.
- The screens can be raised when the canal is not operating to prevent damage from large flood debris and ice. In addition, a plate could be placed upstream of the screen raising track to deflect ice flows. The track may also be recessed a depth of about 12 to 15 inches for a screen of this size.
- Head loss also occurs through the collection pipes and downstream gate if flow velocities are high. Manufacturer design guidance is to keep the maximum flow velocity in the screen unit less than about 5 ft/sec. At Intake, this would mean keeping the suction pipe inside each screen cylinder sized at 42-inches and the pipe connection to intake greater than 5 foot diameter for the design flow of 100 cfs.
- The portal downstream of the screen collection pipe was assumed to be a 6 foot square opening. This opening would have a coarse trashrack for periods when the screen was in the raised position.



Raised Screens Screen Side View

Figure 3. Fish Screen Concept Illustrations.

2.2 NEW HEADWORKS.

The new headworks would be constructed upstream of the existing structure. Hydraulic computations or a detailed design of the new headworks was not conducted for this alternative. The existing headgate structure has 11 5-ft diameter slide gates. Based on information supplied by the manufacturer, the fish screen requires 14 cylindrical openings to achieve the canal diversion capacity of 1400 cfs. Therefore, the requirement for fish screen open area controls the diversion capability, not the downstream slide gate. The new headworks control gates would be constructed at a similar elevation as the existing gate invert elevation of 1981.5 feet. Each of the fourteen fish screen openings would require a downstream slide gate to regulate flow diversion and allow closure. The total length of the headworks structure is 307 feet. A series of concrete bollards is proposed on the upstream end of the headworks to serve as an ice and debris deflector. Refer to the structural drawings for additional details.

Diversion Capacity

The HEC-RAS hydraulic analysis model developed for the previous analysis (USACE, 2006) was used to verify diversion capacity. The RAS model computations determined a water surface elevation of 1990.0 upstream of the Intake dam at a Yellowstone River flow of 4000 cfs. With a six foot diameter screen, it is desirable to maintain at least 1 foot of water depth above the top of screen. This results in an elevation of 1983 for the screen invert. Current plans are to maintain a screen invert elevation of less than 1982. All screen and headworks flow components will be sized to limit headloss through the screen to less than 1 foot. Therefore, 1400 cfs diversion capacity at minimal Yellowstone River flow is feasible.

Headworks Top Elevation

Previous HEC-RAS model computations determined a 100-year flow elevation of 2002.2 at the existing headworks. The opposite bank floodplain elevation varies from 2000 to 2002 which is slightly less than the 100-year elevation. This information was used to develop a recommended elevation of 2006 for the top of structure. The recommended elevation is 3.8 ft above the 100-yr and a minimum of 4 ft above the opposite bank maximum floodplain elevation. For ice flows that have up to a 4 foot maximum thickness, the proposed elevation should be sufficient to prevent unwanted flood damage.

3. SEDIMENT SLUICE ALTERNATIVES.

Concerns have been raised by the design team that minimal amounts of sediment will be able to pass through the proposed fish screen structure. Low velocities in the vicinity of the proposed headworks could cause deposition to occur. Numerous irrigation diversions managed by the USBR have sediment sluiceways installed. The goal of each alternative is to pass sediment from upstream of the diversion dam to downstream. In this case, the sediment will return to the river at the base of the rock ramp. Each alternative evaluated must maintain a velocity adjacent to the proposed gates and in the sluiceway fast enough to entrain any sediment that has deposited in the vicinity of the headworks. The design velocity was determined to be 6.0 ft/sec. This is the minimum velocity required to move coarse gravel (Schwab, et al., 1993 p. 269). Coarse gravel was considered the target sediment size to transport.

Four alternatives were evaluated for use as a sluiceway. The first alternative was vertical lift gates positioned perpendicular to the bank line on the downstream end of the proposed headworks, with a sluiceway parallel to the bank. This would require building the sluiceway through the existing dam. The second and third alternatives evaluated using the existing headworks as the sluice gates. One option with the existing headworks is to use concrete culverts to route sediment through the bank and return it to the river. The second option with the existing headworks is to use an open channel as a sluiceway to return the sediment to the river.

For all sluiceway alternatives, a training wall upstream of Intake Dam is required to maintain flow velocity in the vicinity of the gate and maximize sluice capability. The goal of the sluiceway is to move material from in front of the proposed headworks. The training wall will prevent expansion of the flow area contributing to the gate structure and thus increase velocity in this area when the sluice is operated. Future design is required to evaluate the design length, width, and elevation of the training wall. The current wall top elevation is 1986.00 ft, which is approximately five feet above the bed of the river. The alignment of the wall is approximately 40 ft from the riverward side of the intake screen for the length of the headworks. This distance was selected by visually analyzing the depression maintained adjacent to the existing headworks. Rather than a concrete wall, it may also be possible to use a linear riprap structure.

3.1 New Sluice Gate Option

Selection of Gate Invert Elevation and Location

The invert elevation of the proposed intake structure is 1981.58 ft. The gate invert of the sluice must be no greater than this to allow movement of bed material past the intake. A scour hole exists in front of the existing intake gates. The most recent digital terrain model (dtm) was analyzed to determine the depth and extent of this scour. Elevations from the dtm indicate that elevations in front of the existing gates are as low as approximately 1977.0 ft. The invert elevation of the sluice gates are set at 1981.58 ft. Ideally, the invert elevation of the sluice should be set lower than that of the intake structure to prevent sediment from depositing adjacent to the screens. However, this elevation is limited by the downstream ramp elevation of 1980.0 ft. Gate and sluice invert elevations less than this would be flat or slope upstream.

The proposed new intake structure begins approximately 250 ft upstream from the dam crest. The proposed location for the sluice gates is just downstream of the new intake structure and are placed perpendicular to the bank line. The walkway to access the operators could attach to the walkway for the headworks.

Gate Selection

Radial, or tainter, gates are commonly used for sediment sluiceways in irrigation diversion dams. Advantages of tainter gates are reduced friction during movement since the hydrostatic forces are focused on the trunnions around which the gate pivots. Tainter gates typically have lower maintenance costs than vertical lift gates. Ice and flood debris impacts to gates at the Intake, MT site would be severe. To keep the top of the gate above the 100 year elevation, the top elevation would require a gate size of approximately 20x30 ft. The structure above the gate with the lifting mechanisms would be very large.

If it was acceptable for water and debris to flow over the tainter gate a smaller gate could be selected. In this case, two gates 11x18 feet would be required. The top of the gate would be approximately two feet higher than the proposed top of the new rock ramp (1989. ft). Due to repetitive damage concerns, the design assumed that that ice and debris are not allowed to flow over the tops of the gates. Smaller tainter gates are therefore not feasible.

Flat vertical lift gates were also evaluated. The primary goal of the gates is to transport bed material from in front of the intake structure, so a large size is not necessary. The concrete gate housing extends above the 100 yr water surface elevation. The top of the structure housing the lifting mechanisms and walkway is at elevation 2006 ft, and is integrated into the walkway over the intakes. The top of structure elevation prevents flood damage to the gates and lifting mechanisms.

HEC-RAS Model
Sediment sluice feasibility was evaluated with the previously constructed HEC-RAS model (USACE, 2006, App. C). The model was not updated to include the new survey data. The sediment sluice option was evaluated with the split flow option within HEC-RAS. A rectangular reach with n=.012 was added to simulate a concrete sluiceway. Three design flows were identified to evaluate the flow and velocity in the sluice with different gate sizes. The flows used within the model were the average monthly flows for May equaled or exceeded 20, 50, and 80% of the time. These flows were 23,300, 14,800, and 9770 cfs, respectively (USACE, 2006, App. B Table 3). These flows were selected as representative of discharge when Yellowstone River sluice operations may occur. For purposes of the model, the entrance of the sluiceway started adjacent to the proposed intake structure. The sluice gates were positioned approximately 250 ft upstream of the crest of the rock ramp.

Four gate sizes were evaluated; these were (width x height) 5x4 ft, 5x5 ft, 8x6 ft, and 8x8 ft. Six gates were evaluated using the five foot wide gates and four were evaluated using the eight foot wide gates. The split flow analysis was used to estimate the amount of flow moving through the sluiceway and the velocities. The preliminary results of the split flow modeling are shown in Table 2. The lowest velocity in the sluiceway is the limiting factor for movement of sediment adjacent to the proposed headworks. For all gate sizes evaluated, the lowest velocity was the first cross-section immediately upstream of the sluice gates.

Table 2. Intake Dam sluice design flows and velocities near proposed headworks

# gates	gate size (w x h)	Q total = 9770 cfs		Q total = 14800 cfs		Q total = 23300 cfs	
		Q sluice (cfs)	min velocity (ft/sec)	Q sluice (cfs)	min velocity (ft/sec)	Q sluice (cfs)	min velocity (ft/sec)
6	5x4	1874	5.6	1963	5.3	1979	4.7
6	5x5	2034	6.2	2230	6.2	2322	5.6
4	8x6	2204	6.6	2456	6.7	2688	6.2
4	8x8	2400	7.7	2674	7.9	3050	7.9

The selected sluice uses four gates that are each 8 foot wide by 6 foot in height. With this gate size, velocities upstream of the sluice gates ranged from 6.2 to 6.4 ft/sec. Velocities downstream of the gates in the sluice ranged from 8 to 10 ft/sec. This size was selected because velocities were above the design velocity for all flows.

Downstream Sluiceway
To maintain the slope of 0.50%, the rock ramp will have a length of approximately 1800 ft. The downstream end of the sluiceway is located at the base of the rock ramp. The total length of the sluiceway is approximately 2050 ft since the gates are 250 ft upstream of the diversion. The slope of the sluiceway is therefore approximately .077% (4.1 ft/mi). This appears to be about the same as the existing Yellowstone River slope. The HEC-RAS model was further refined by placing dividers between the gates for the entire length of the sluiceway. The sluiceway will likely be covered for safety reasons and to prevent Yellowstone River water traveling on the ramp and outside the sluiceway from entering the sluiceway. The water surface elevation in the sluiceway and in the Yellowstone River at the equivalent station is shown in Table 3. The total flow in this table (river and sluice) is 23,300 cfs. This would likely limit the rock ramp effectiveness during periods of low flow. In addition, entering river flow could disrupt sediment transport within the sluiceway.

Table 3. Intake Dam sluice design water surface elevation in the sluice and adjacent river with a total flow of 23300 cfs.

Yellowstone cross-section	Yellowstone Water Surface Elev.	Sluice cross-section	Sluice Water Surface Elev.
28564	1993.7	2340	1994.2
28278	1993.6	2050	1994.2
27725	1991.2	1491	1990.8
27164	1989.8	932	1990.0
26601	1989.5	373	1989.2
26227	1989.4	0	1988.5

For the conceptual analysis, the downstream sluiceway was assumed to be a constant width for the entire length. The sluiceway downstream of the gates may be designed narrower than the sluice area upstream of the gates. This would increase the velocities and possibly ensure sediment is transported through the sluice more efficiently. Key design considerations include the amount of constriction that can occur before flow through the gates is affected, the transition from the gates into the sluiceway, and the downstream outlet configuration

The recommended sluice would consist of the following:

Number of Boxes: 2
Conduit Size: 20.5 ft wide x 10 ft high (inside dimensions)
Conduit Length: 2,050 ft from the sluice gates to the base of the rock ramp
Invert Slope: .077% (4.1 ft/mi)

Design summary details are as follows:

- The previously constructed HEC-RAS model was not updated to include current survey information. The accuracy of the model was assumed appropriate for the conceptual analysis.
- Detailed evaluation is required to determine bed and suspended sediment load and design details of the sluice.
- A HEC-RAS model determined that maintaining a flow velocity of 6 ft/sec within the sluice is feasible.
- Sluice operation time and duration was not evaluated.
- A sluiceway through the existing dam uses four gates that are each 8 feet wide by 6 feet in height.
- The downstream sluiceway within the river was assumed to be covered. This is necessary for safety reasons and to prevent flow transfer from the Yellowstone River.
- The upstream sluiceway training wall requires further evaluation to determine optimum wall height, length, and distance from the headworks structure.
- The downstream sluiceway requires additional evaluation. It is likely that some convergence of the sluiceway is possible without inhibiting the sediment transport.
- The conceptual analysis indicates that it is possible to implement a sluice . Further analysis may determine that operational constraints and Yellowstone River sediment load may severely limit sluice effectiveness.
- This option would require building the sluiceway through the existing dam. There may be issues with partial dam removal and constructability.

3.2 USE OF THE EXISTING HEADWORKS AS A SLUICEWAY

Covered Conduit

The invert elevation of the existing gates is 1983.58 ft. The invert elevation of a closed conduit used for the sluiceway is set at the same elevation. The invert elevation of the downstream outlet is set at 1980.0 ft to correspond with the rock ramp. Modeling was conducted with HEC-RAS to estimate how much flow could be transported with box culverts of various sizes, from 5x5 ft to 12x12 ft. The length was estimated to be 1900 ft, to allow for transitions to and from the river. The slope of the sluiceway with this alternative is 0.19% (9.9 ft/mi). The material was assumed to be finished concrete with n=0.015. The flow was modeled as an open channel so the results are equivalent for a partially full closed conduit or open channel. The amount of flow conveyed for each culvert size, the number of culverts required, and the diameter of an equivalent round pipe are shown in Table 4. The equivalent diameter for a round pipe carrying the same flow was determined using the procedure found in EM 1110-2-1602 (p. 2-9).

The recommended conduit would consist of the following:

Number of Boxes: 4
Conduit Size: 8 ft x 8 ft
Conduit Length: 1,860 ft
Invert Slope: 0.19% (9.9 ft/mi)

Table 4. Culvert sizes and flow for sluiceway through the existing headworks.

Box culvert size (ft)	Q_{pipe} (cfs)	# culverts required	Flow depth (ft)	Average velocity (ft/sec)	R (ft)	Round pipe equivalent diameter (ft)
5x5	150	11	4.9	6.1	1.7	7
7x7	375	5	6.7	7.7	2.3	10
8x8	500	4	7.5	8.3	2.6	11
10x10	950	2	9.8	9.7	3.3	14
12x12	1600	1	12.1	11.0	4.0	16

Open Conduit

The geometry for an open channel would consist of a flat bottom ditch with a trapezoidal cross-section. A concrete lined channel may be required to maintain sediment transport through the section. Use of concrete avoids increasing roughness, maintains higher flow velocity, and reduces maintenance for vegetation and bank stability. Using the larger culverts, the flow depth is much greater than the height of the existing gates which are five feet. Construction of a flat bottom open channel may be preferable to provide the required flow area. The channel could be relatively easily constructed wider to allow the same flow with a shallower depth. The open channel would consist of the following:

Bottom Width: 30 ft
Side Slope: 1.5:1
Length: 1,860 ft
Invert Slope: 0.19% (9.9 ft/mi)

For the above geometry, the design flow depth is 5.2 ft and the velocity is 7 ft/sec.

Design summary details for options using the existing headworks as a sluice are as follows:

- Under current conditions, sediment deposition is not occurring in the first few miles of the canal. It is inferred that sediment can be entrained and passed through the existing headworks.
- HEC-RAS modeling was used to estimate the velocity through conduits used as sluiceways.
- Further analysis is required to determine if a gate is required on the downstream end of each sluice option. A gate may be required to prevent river water from entering the sluiceway during non-sluicing operations. It may also be beneficial for maintenance access. The gate selected would likely be a hand operated vertical lift gate.
- Further analysis is required to evaluate if the entire flow of 1400 cfs is required to entrain sediment and move it from in front of the proposed headworks. If less than this flow is necessary, smaller or fewer conduits could be used. This would substantially reduce construction costs.
- Additional analysis is required to evaluate if the sluiceway can be designed using an open channel rather than a closed conduit. The analysis should evaluate lining required for the open channel to maintain sediment transport.
- The conceptual analysis indicates that it is possible to implement a sluice . Further analysis may determine that operational constraints and Yellowstone River sediment load may severely limit sluice effectiveness.

3.3 SLUICE OUTLET RIPRAP PROTECTION

Riprap stone is placed at the outlet of the both sluice options to reduce the energy of water exiting the sluiceway. The stone was size using the Ishbash equation for turbulent flow as stated in the procedure outlined in the Hydraulic Design Criteria (USACE 1987). The D_{50} was estimated to be 1.5 ft, and the D_{100} was estimated to be 3.0 ft. The thickness of the stone is 4.4 ft and extends 100 ft downstream of the sluice outlet. At the downstream end, the width of the stone is 50% greater than the width at the sluice.

3.4 SLUICE GATE OPERATIONAL CONSIDERATIONS

The amount of flow used by the sluice will impact diversion capacity. Sluiceway operation will consider Yellowstone River flow elevation and diversion needs. Some limited operation during high flows may be beneficial to limit sediment accumulation in front of the headworks. Sediment sluicing during low flow periods may not be feasible due to low head and irrigation needs. Sediment will likely accumulate throughout the year, then will be removed during sluicing operations primarily in the spring before irrigation begins. Sluicing could also occur in the fall after irrigation but before winter ice conditions if flow levels permit.

Additional considerations for sluicing operations:

- Estimate the length of time the sluice gates must be open to move the accumulated sediment.
- Determine preferred sluice operation with respect to Yellowstone River flow, incoming sediment load, and irrigation canal diversion.

3.5 ALTERNATE SEDIMENT REMOVAL STRATEGIES

A rock dike upstream of the proposed headworks and revetment parallel to the headworks may prevent sediment accumulation in front of the headworks. This concept is similar to an ‘L-head’ dike often employed on rivers to alter the sediment deposition pattern, especially for bed load material. Primarily fine grained material would likely deposit behind the rock structure.

Other sediment removal devices such as a siphon or vortex weir should also be investigated. Siphoning could be used to remove the fine grained material from the vicinity of the fish screens. The available hydraulic head and sediment outlet may limit the feasibility of other sediment removal options.

4. REFERENCES

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Appendix B
Geotechnical

FINAL REPORT

Lower Yellowstone Project

Fish Screening and Sediment Sluicing

Preliminary Design Report

February 2008

US Army Corps
of Engineers ®
Omaha District

Geotechnical

1. Geology and Soils. The following geology and soils information presented in paragraphs 1.1. and 1.2. was obtained from the Bureau of Reclamations Concept Study Report II.

1.1. General. The Intake Diversion Dam, here after referred to as Intake Dam, is situated along the northeast Bank of the Cedar Creek Anticline, a major structural feature in southeastern Montana. Cretaceous strata, exposed along the axis of this northwest-southeast trending (northwest plunging) anticline, dip gently to the northeast and are overlain by Paleocene sedimentary strata of the Fort Union Formation in the Intake area. Here, the Yellowstone River has incised an approximately 2-mile-wide channel into the surrounding upland. The Fort Union Formation constitutes bedrock in the area and consists of an alternating sequence of clay shales, siltstones, sandstones, lignitic shales and lignite. Because of the terrestrial-type deposition, the beds interfinger and grade both laterally and vertically. The stratigraphic section varies from location to location and correlation between points is unpredictable. Permeability of the various strata varies greatly due to the varying degree of compaction and cementation. The high erodibility of Fort Union material on steep, unprotected slopes gives rise to badland type topography along the walls of the Yellowstone River valley.

Weathered bedrock is soft and has soil properties. Unweathered bedrock materials have both rock- and soil-like characteristics. Exceptions are lenticular bodies of moderately cemented, moderately hard sandstone locally present within the Fort Union. Also, thicker lignite beds have burned back from their outcrops and overlying shales have been baked and fused to form moderately hard material locally referred to as clinker. These vary in both thickness and lateral extent. Beds of variable thickness of lignitic shale to lignite occur throughout the Fort Union Formation.

Several terrace levels, cut into the Fort Union Formation and overlain with gravel, are recognized along the valley. These range in age from Pleistocene to Holocene (recent) and occur from 14 to as high as 420 feet above the present river level. The younger terraces which range from 14 to 90 feet above the river underlie most of the Intake Dam area. The gravel terrace occurring in the floodplain is generally blanketed with fine-grained soils.

1.2. Construction Areas. The fish screen structure, located within the Main Canal, will be founded on bedrock of the Fort Union Formation. The fish bypass, extending to the downstream end of the screen to the Yellowstone River downstream of the Intake Dam, a distance of approximately 700 feet, will be excavated in bedrock of the Fort Union Formation. Overburden is up to about 55 feet thick above the bypass invert.

Surficial deposits consisting of alluvial, colluvial, eolian and terrace deposits of Quaternary age generally mantle the bedrock and occur along the upper portion of the canal prism. Surficial deposits consisting of material excavated from the canal and placed

in waste banks is present on both sides of the canal. Also, fill material has been placed along the river bank downstream of the Intake Dam to provide slope protection. Depending on the direction of the bypass alignment, the slope protection material may be encountered at the bypass outlet. Surficial deposits will have no significant design or construction considerations for the fish screen and, depending on designs and construction methods, no to minor considerations for the fish bypass.
Shales, siltstones, uncemented sandstones, lignitic shales and lignite of the Fort Union Formation generally are rippable with modern equipment and excavated by common methods. Cemented sandstones and concretions within the Fort Union can not be ripped and, if encountered, may require drilling and blasting to remove from excavations. It should be anticipated bedrock will bulk about 27 percent if excavated and dumped. It will probably bulk 10 to 15 percent after being excavated and compacted.

The siltstones, uncemented sandstones, lignitic shale and lignite are all quite erodible. However, the shales and cemented sandstones will retard (but not eliminate) erosion. There is a potential of encountering methane gas within the lignific shales and lignite beds.

Stability of bedrock materials within the fish barrier and bypass excavations is not expected to be a significant problem. Shallow excavations in bedrock will be stable on 1/2:l slopes. Permanent excavations should be laid back on 1:1 slopes.

Bedrock materials below the weathered zone (upper 5 to 10 feet) likely will have sufficient bearing capacity to support the fish barrier and bypass pipeline. However, lignitic shales and lignite are fractured, soft, low in density and readily air slake. If these materials are encountered within the excavations, they should be overexcavated and replaced with compacted backfill to preclude problems with deformation. Also, shales exposed within the excavations will likely air slake rapidly and freshly exposed surfaces should be protected before being covered with concrete or compacted backfill.

Groundwater is believed to be tributary to the Yellowstone River with the water table occurring at or above the river. Perched groundwater may occur in surficial deposits just above the bedrock contact and also in sandstone units and fractured lignite beds within the bedrock.

The shales and siltstones are generally impervious. The sandstones are semi-pervious and will weep water. The lignite beds are fractured, low in density and semipervious to pervious. Lignite beds encountered within the screen or bypass excavations should be expected to pass water rapidly.

The dam across the center section and right abutment is founded on Quaternary alluvial deposits. Alluvial deposits are shown to extend across the floodplain (Torrey and Kohout, 1956) and mapped by McKenna, et al (1994) to vary between 20 and 50 feet thick in the vicinity of the Intake Dam. However, a small, isolated exposure of bedrock of the Fort Union Formation appears to outcrop locally along the right (south) bank of the river downstream of the dam.

Preconstruction drill hole information indicate alluvial deposits within the area of the present river channel consist of sand and gravel. Although not noted on the logs, cobble-size material is also present within the coarse-grained materials. These coarse-grained soils are continuous across the floodplain but, outside the river channel, including the right abutment, are overlain with fine-grained soils (silts and clays).

Fill material was placed on the right abutment to divert river flows around and support the right abutment concrete wall. These materials consist of a varying percentage of boulders and cobbles in a matrix of fine- and coarse-grained soils. The dimensions and configuration of the fill material is uncertain but maximum thickness is believed to be about 20 feet adjacent to the right abutment concrete wall based on design drawings.

The right abutment fill material may contain boulders up to 3 feet maximum size. Drill hole data suggest the bedrock surface occurs at approximate elevation 1960 feet along the fishway and bedrock is not expected to be encountered. The coarse-grained alluvial deposits are rounded and consist of sand, gravel, and cobbles, up to about 6-inch-maximum size with lesser amounts of cohesive and cohesionless fines. These materials are stable on 2-1/2:1 slopes. The fine-grained alluvial deposits and fill material are stable an 2:l slopes if seepage is not occurring. If seepage occurs in these materials, remedial measures may be required to prevent internal erosion and slope instability including flattening the cut slopes.

2. Construction of Alternatives. Paragraphs 2.1. and 2.2. deal with the construction specifics of the two alternatives studied.

2.1. New Headworks with Cylindrical Fish Screens Alternative.

The fish screen/headworks alternative is described in detail in the Hydraulics appendix. A plan view of this alternative is shown on Sheet B-101. The major feature is the headworks gate structure and the cylindrical fish screen. The gate structure will require pile foundations because of it's location relative to the river bed and the pressure placed upon the soil. Dewatering with sumps and well points will be needed. This will done in conjunction with an earthen cofferdam.

The initial idea for this alternative was to lengthen the existing gate structure to accommodate all of the gates required for flow and screening of fish. It was decided by the team to use a new structure due to the known construction procedures and numerous alterations needed for the existing structure. The fish screens dimensions would require the flow opening locations to be altered. This would involve significant drilling, cutting, removal and placing of concrete, in addition to the new concrete extension. The new structure was sited to the West of the existing structure along and parallel with the river bank. This involves the excavation of the existing bank area to tie-in to the existing irrigation ditch grading. Some of the excess excavated material would be placed in the existing irrigation ditch to the gate structure to act as a block. The remainder of the material would be used for cofferdam construction or in the rock ramp (see earlier report). The gate structure will be installed with cylindrical fish screens that allow irrigation flows to pass but not larvae fish, these are discussed in more detail in the main report.

The channel cross section varies in bottom width, from full width at the gate structure exit to the existing irrigation ditch bottom width at the tie-in. Both sides of the excavation accommodate a bench for access from the high bank to the new gate structure. The sides are 1 vertical on 2 horizontal. A 12" layer of riprap and bedding would be used at the exit of the gate structure to protect against erosion.

The channel excavation will be a mixture of soil and stone, and soft weathered (easily rippable) bedrock. The material would be excavated and hauled using scrapers, and excavated with backhoes, and loaded on trucks and hauled to the disposal site.

This would require the construction of a riprap protected/earthen cofferdam. The cofferdam would be constructed to close-off water of the Yellowstone River and allow for the structure to be located as close as possible to the river.

This alternative would be combined with the rock ramp alternative from an earlier 10% report.

2.2. In-River Sluice Alternative.

The In-River Sluice alternative is described in detail in the Hydraulics appendix. A plan view of this alternative is shown on Sheet B-201. This alternative is a concrete structure which includes a gate control structure, inlet training wall, and a covered conduit downstream of the gated structure. The Structural appendix provides details on the dimensions and design. This alternative as designed is intended to be used with the new headworks and cylindrical fish screens alternative. There is some duplication of cost in the cofferdams.

This structure was sited as close to the left bank as possible; this would allow for the removal of sediment from the front of the irrigation gate structure. Excavation is required to prepare for construction of the structure. Excavation of the portion upstream of the Diversion Dam is minor, most of the excavation will be downstream of the Diversion Dam along the left bank. A portion of the existing Diversion Dam planking, timbers and rock would be removed in the area where the closed conduit penetrates the dam. The large rock downstream of the dam, placed in past years by the irrigation district, will be removed and excavation to progress. The excavation side slopes would be 1 vertical on 1.5 horizontal. The concrete structures would require forming and concrete pumping.

The cofferdam would be a U-shaped structure to completely isolate the construction area. The cofferdam will consist of two sections, one upstream of the Diversion Dam and another downstream of the Diversion Dam. The portion downstream of the Diversion

Dam and parallel with the flow would require the removal of some existing riprap to minimize seepage into the construction area. The cofferdam riprap will be reused for backfilling of the covered conduit on the ramp side. It is assumed some of the earthen material will not be recovered completely due to the moisture content and will wash into the river. Pumps would be utilized to minimize water in the construction area.

***This alternative is of maximum extent and would not be acceptable if the V-fish screen is selected; this alternative would have to be redesigned with the gate structure located at the Diversion Dam and the training wall would shorten* (everything else is unchanged), *thus a less expensive alternative*.** Either of these alternatives would be combined with the rock ramp alternative from an earlier 10% report.

2.2. In-Abutment Sluice Closed Conduit Alternative. The In-Abutment Closed Conduit Sluice alternative is described in detail in the Hydraulics appendix. A plan view of this alternative is shown on Sheet B-301. This alternative is a concrete closed conduit conveyance structure which includes utilizing the existing irrigation gate control structure, and a new slanted wall connection between the two. The Structural appendix provides details on the dimensions and design. There is some duplication of cost in the cofferdams.

Excavation of the abutment soils and rock would be required for construction of the structure. The excavation side slopes would be 1 vertical on 1.5 horizontal and space on each side of the closed conduit was included. The structure would be backfilled, covered with soil, and compacted, but limited to cover as discussed in the Structural appendix. Therefore, a majority of the excavated material will be wasted and used in the rock ramp (see earlier report).

This would require the construction of a riprap protected/earthen cofferdam at the downstream end. The cofferdam would be constructed to close-off water of the Yellowstone River and allow for the structure to be located as close as possible to the river.

This alternative as designed is intended to be used with the new headworks and cylindrical fish screens alternative.

2.3. In-Abutment Sluice Open-Cut Alternative. This alternative is a variation of the In-Abutment Closed Conduit Sluice alternative is described in the Hydraulics appendix. A plan view of this alternative is shown on Sheet B-401. This alternative is an excavated channel which includes utilizing the existing irrigation gate control structure and a short section of existing irrigation ditch between the two. Discussions with the irrigation district and the Hydraulics discipline resulted in the determination that the existing irrigation ditch does not experience sediment deposition in the first few miles, therefore this option became a viable alternative.

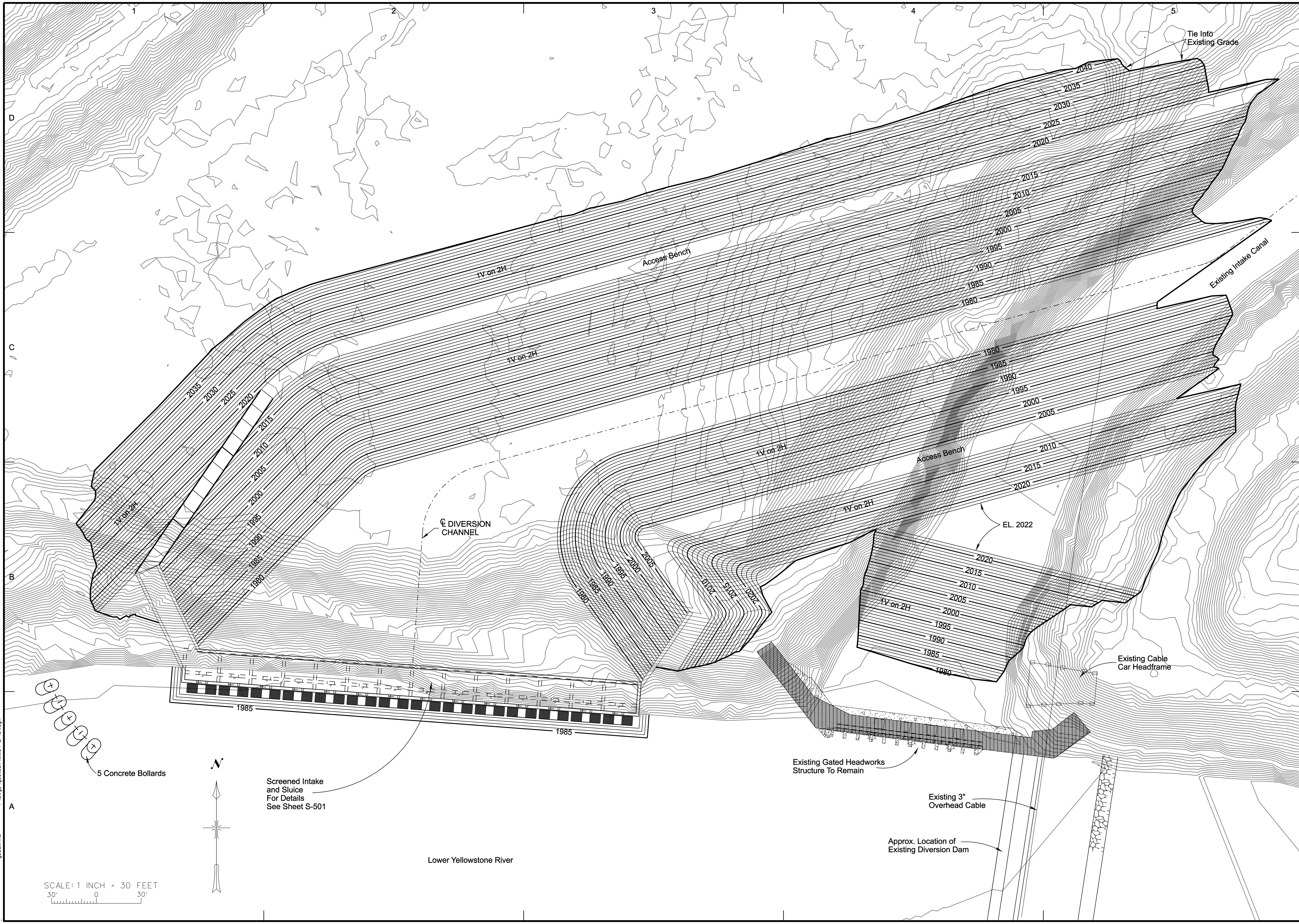
Excavation of the abutment soils and rock would be required for construction of the alternative. The permanent excavated cross section would be side slopes of 1 vertical on

2 horizontal and a bottom width equal to the closed conduit width (approx. 37’). The alignment of the channel is the same centerline as the closed conduit alternative. Therefore, a majority of the excavated material will be wasted and used in the rock ramp (see earlier report).

This alternative may or may not require the construction of a riprap protected/earthen cofferdam at the downstream end. The cofferdam would be constructed to close-off water of the Yellowstone River. If a cofferdam is not used, the constructor would complete the channel as close to the river as safety will allow, and either excavate with larger equipment or let the sluice clear the channel to the river when operated.

This alternative as designed is intended to be used with the new headworks and cylindrical fish screens alternative.

3. Future Studies. A soil investigation will be required for all project structures prior to initiated final designs. The irrigation district quarry site will be investigated and mapped by a geologist to confirm the production potential.



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US ARMY CORPS
OF ENGINEERS
OMAHA DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

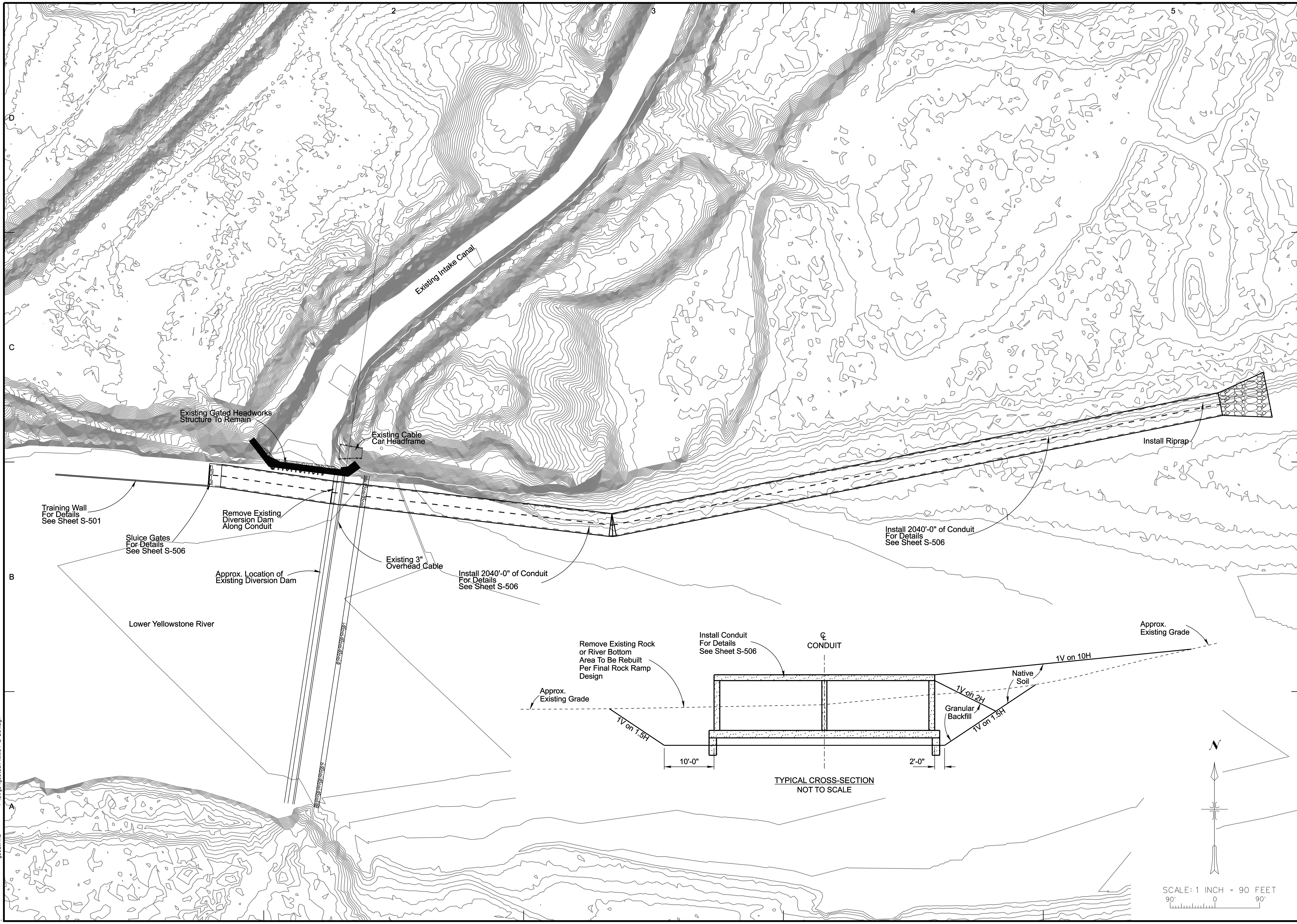
U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

DESIGNED BY: TJM
DATE: JAN. 2008
DWN BY: TJM
CKD BY: TJM
SOLICITATION NO.: W9128F-0X-X-00XX
SUBMITTED BY: TJM
CONTRACT NO.: W9128F-0X-C-00XX
FILE NAME: MM04-B-101.dgn
FILE NUMBER:
SIZE: 33.1X22
PLOT SCALE: 0.08 ' / IN.
PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT

FISH SCREEN / NEW HEADWORKS

SHEET
IDENTIFICATION
NUMBER
B-101



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SIZE: 33.1X22
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DATE: JAN. 2008
SOLICITATION NO.: W9128F-0X-X-00XX
CONTRACT NO.: W9128F-0X-C-00XX
FILE NUMBER:
PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT

IN-RIVER SLUICE

SHEET IDENTIFICATION NUMBER
B-201

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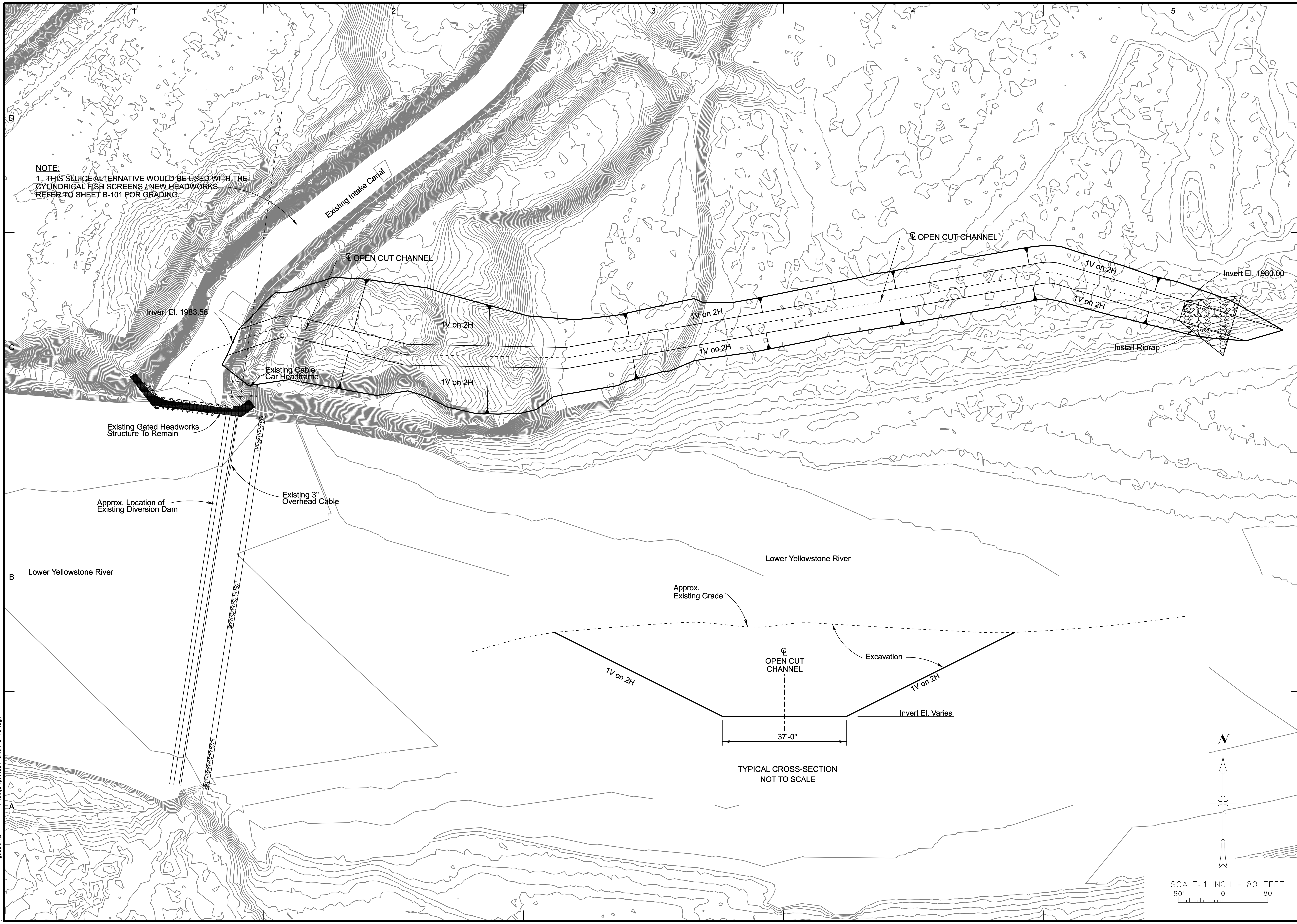
NOTE:
1. THIS SLUICE ALTERNATIVE WOULD BE USED WITH THE CYLINDRICAL FISH SCREENS / NEW HEADWORKS. REFER TO SHEET B-101 FOR GRADING.
Existing Intake Canal
Install 4 - 8'-0" x 8'-0" Box Culverts For Details See Sheet S-502
Install 4 - 8'-0" x 8'-0" Box Culverts For Details See Sheet S-502
Install 4 - 8'-0" x 8'-0" Box Culverts For Details See Sheet S-502
Install Flap Gate and Headwall For Details See Sheet S-507
Install Riprap
Existing Cable Car Headframe
Existing Gated Headworks Structure To Remain
Existing 3" Overhead Cable
Approx. Location of Existing Diversion Dam
Lower Yellowstone River
Approx. Existing Grade
Approx. Existing Grade
VARIES, 2'-0" MIN. 12'-0" MAX.
Excavation
1V on 1.5H
1V on 1.5H
8'-0"
8'-0"
Four 8'-0" x 8'-0" x 8" Precast Box Culverts For Details See Sheet S-507
TYPICAL CROSS-SECTION
NOT TO SCALE
N
SCALE: 1 INCH = 80 FEET
80' 0 80'
1
2
3
4
5
D
C
B
A
US ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
MARK
DESCRIPTION
DATE
APPR.
MARK
DESCRIPTION
DATE
APPR.
DESIGNED BY: TJM
DWN BY: TJM
CKD BY: TJM
SUBMITTED BY: TJM
FILE NAME: MM04-B-301.dgn
SIZE: 33.1X22
PLOT SCALE: 0.08 '/ IN.
DATE: JAN. 2008
SOLICITATION NO.: W9128F-0X-X-00XX
CONTRACT NO.: W9128F-0X-C-00XX
FILE NUMBER:
PLOT DATE: 1/30/2008
U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT
IN-ABUTMENT SLUICE
CLOSED CONDUIT
SHEET IDENTIFICATION NUMBER
B-301



US ARMY CORPS OF ENGINEERS
OMAHA DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

DESIGNED BY: T JM		DATE: JAN. 2008
DWN BY: T JM	CKD BY: T JM	SOLICITATION NO.: W9128F-0X-X-00XX
SUBMITTED BY: T JM		CONTRACT NO.: W9128F-0X-C-00XX
FILE NAME: MM04-B-401.dgn		FILE NUMBER:
SIZE: 33.1X22	PLOT SCALE: 0.08 ' / IN.	PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT

IN-ABUTMENT SLUICE OPEN CUT CHANNEL

SHEET IDENTIFICATION NUMBER
B-401

Appendix C
Engineering Design

FINAL REPORT

Lower Yellowstone Project

Fish Screening and Sediment Sluicing

Preliminary Design Report

February 2008

US Army Corps
of Engineers ®
Omaha District

STRUCTURAL

1.1 DESIGN CRITERIA

The following references were used in preparing the structural design:

American Concrete Institute (ACI) Publications

ACI 318-05 Building Code Requirements for Structural Concrete (2005)

Corps of Engineers, Engineer Manuals

EM 1110-2-1612 Ice Engineering (2002)

EM 1110-2-2104 Strength Design for Reinforced Concrete Hydraulic Structures (1992) and Change 1 (2003)

EM 1110-2-2502 Retaining and Flood Walls (1989)

EM 1110-2-2902 Conduits, Culverts and Pipes (1998)

EM 1110-2-2906 Design of Pile Foundations (1991)

1.2 DESIGN LOADS

1.2.1 Ice Loads

Ice loads on the sluice training wall were calculated in accordance with EM 1110-2-1612 assuming an ice sheet thickness of 22 inches, and ice sheet compressive strength of 100 psi due to partial breakup of the ice sheet in the approach to the sluiceway. Ice loads on the bollards must be calculated for final design of the bollards.

1.2.2 Seismic Loads

At the project site, the maximum considered earthquake (MCE) short-period spectral acceleration is Ss = 0.12g, and one-second spectral acceleration is S1 = 0.035g. For these accelerations, seismic loads usually do not control design of structures. Therefore, seismic loads were not calculated for this preliminary design, but must be checked for final design of these structures.

1.2.3 Assumed Foundation Design Parameters

Design frost depth = 3.5 feet below finish grade;

Allowable excess soil bearing pressure = 2,000 psf;

Active and Passive lateral earth pressures coefficients were calculated using a strength mobilization factor = 2/3 to account for rigidity of structures not allowing development of full active or passive pressures.

Cohesionless fill internal friction angle = 25 degrees.

Steel piles were assumed to be end-bearing on competent rock.

1.3 STRUCTURAL MATERIALS

Concrete, ACI 318, f'c = 4,000 psi at 28 days;

Concrete Reinforcement, deformed bars conforming to ASTM A 615 Grade 60;

Structural Steel, ASTM A 36;

Reinforced Concrete Pipe (RCP), ASTM C 76, Class to be determined for earth pressures encountered.

Precast reinforced concrete box culverts, ASTM C 789 (AASHTO HS20 truck load with minimum of 2 feet of cover).

1.4 DESCRIPTION OF STRUCTURES

1.4.1 SCREENED INTAKE

The screened intake structure is shown on drawings S-501, S-503 and S-504. This reinforced concrete structure is founded on steel H-piles. It is designed to retain the water on the river side up to it’s top elevation of 2006.00 FMSL. Fourteen cylindrical intake screens can be placed on the river side on vertical tracks. The screens can be raised out of water during winter months to prevent damage from river ice. The tracks are recessed for protection from ice loading. A wetwell with electrically operated Hydro Gate Heavy Duty cast iron sluice gates (Series HG-560) is provided behind the screens to control water diverted to the canal. Access is provided to the top deck by a concrete slab bridge on the north wingwall.

1.4.2 SLUICE (IN CHANNEL ALTERNATIVE)

This sluice alternative is shown on drawings S-501 and S-506. A training wall upstream of the sluice is shown on drawings S-501 and S-505. The sluice is a cast-in-place reinforced double barrel box culvert. Concrete foundation keys are cast below the bottom slab to provide resistance against sliding due to fill placed against the structure on the land side only. Four 6’ x 8’ electrically operated Hydro Gate Heavy Duty cast iron sluice gates (Series HG-560) are provided at the upstream end.

1.4.3 SLUICE (IN EMBANKMENT ALTERNATIVE)

This sluice alternative is shown on drawings S-502 and S-507. The sluice consists of four 8’ x 8’ predcast box culverts. The precast culverts are designed for an AASHTO HS20 truck wheel load, with minimum and maximum earth covers depths of 2 feet and 12 feet respectively. A cast-in-place alternative should be investigated for final design because cast-in-place could be designed for cover depth greater than 12 feet, and could be formed to follow the curves shown. The sluice upstream end is uncontrolled because the gates on the existing headwall would be used to control flow. Either Hydro Gate Flexible or Heavy Duty flapgates are provided on the downstream end.

1.4.4 BOLLARDS

The bollards are shown on drawings S-501 and S-505. The bollards are founded on steel H-piles designed to resist ice forces on the bollards.

1.5 ELECTRICAL

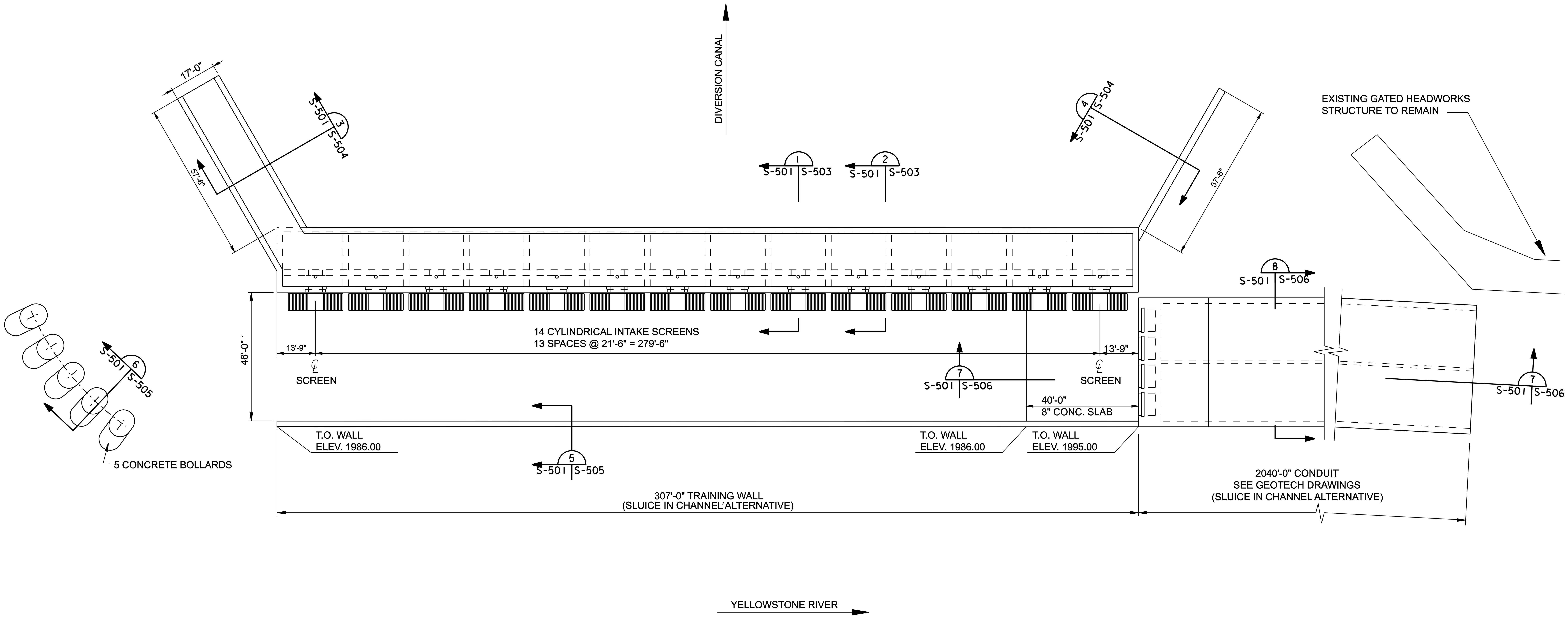
The electrical utility for the Lower Yellowstone Fish Passage – Intake Diversion Dam was identified as Montana Dakota Utilities (MDU) in Glendive, Montana. Steve Merrill was designated as the point of contact steve.merrill@mdu.com (406) 359-3100 (406-359-3122 electrical) for MDU. Location maps were sent to Steve Merrill of MDU by Joe Chamberlain of USACE-Omaha on January 11th, 2008. The load for the fish screen was identified by Joe Chamberlain of USACE-Omaha as being 3 phase, 25 kVA. The following costs were identified:

MDU has existing single phase primary lines within 200 feet of the existing irrigation intake. MDU currently has an existing low voltage service to lighting at the intake structure. Costs would be approximately $12,000-15,000 for MDU’s upgrade of facilities to accommodate a three phase load.

MDU also has an existing 3 phase underground primary power line in the vicinity of the site. This existing power line serves an irrigation pump. MDU can provide electrical service for three phase power from this site. A very rough estimate of this construction cost is $30,000. Actual measurements for the power line extension are required to obtain a more accurate cost. This line is served from a substation that is energized only seasonally as needed for the farmers irrigation.

MDU would provide electrical service to the meter point only. The Corps of Engineers contractor would provide the meter base, breakers and downstream wiring. The Corps of Engineers contract would also provide power for the fish screen units and gates.

The Electrical Composite Site Plan is shown on Sheet ES-100, and the Electrical Line Diagram is shown on Sheet EP-601.



SCREENED INTAKE AND SLUICE - PLAN

20' 10' 0 20'

SCALE: 1" = 20'-0"

NOTES:

1

US ARMY CORPS
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OMAHA DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

DESIGNED BY: L.E.P.
DWN BY: L.E.P.
CKD BY:
SUBMITTED BY: B.N.H.
FILE NAME: MM04-S-501.DGN
SIZE: 33.1X22
PLOT SCALE: 0.08 ft / IN.
DATE: JAN. 2008
SOLICITATION NO.: W9128F-0X-X-00XX
CONTRACT NO.: W9128F-0X-C-00XX
FILE NUMBER: X
PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT

SCREENED INTAKE
AND SLUICE

SHEET
IDENTIFICATION
NUMBER
S-501

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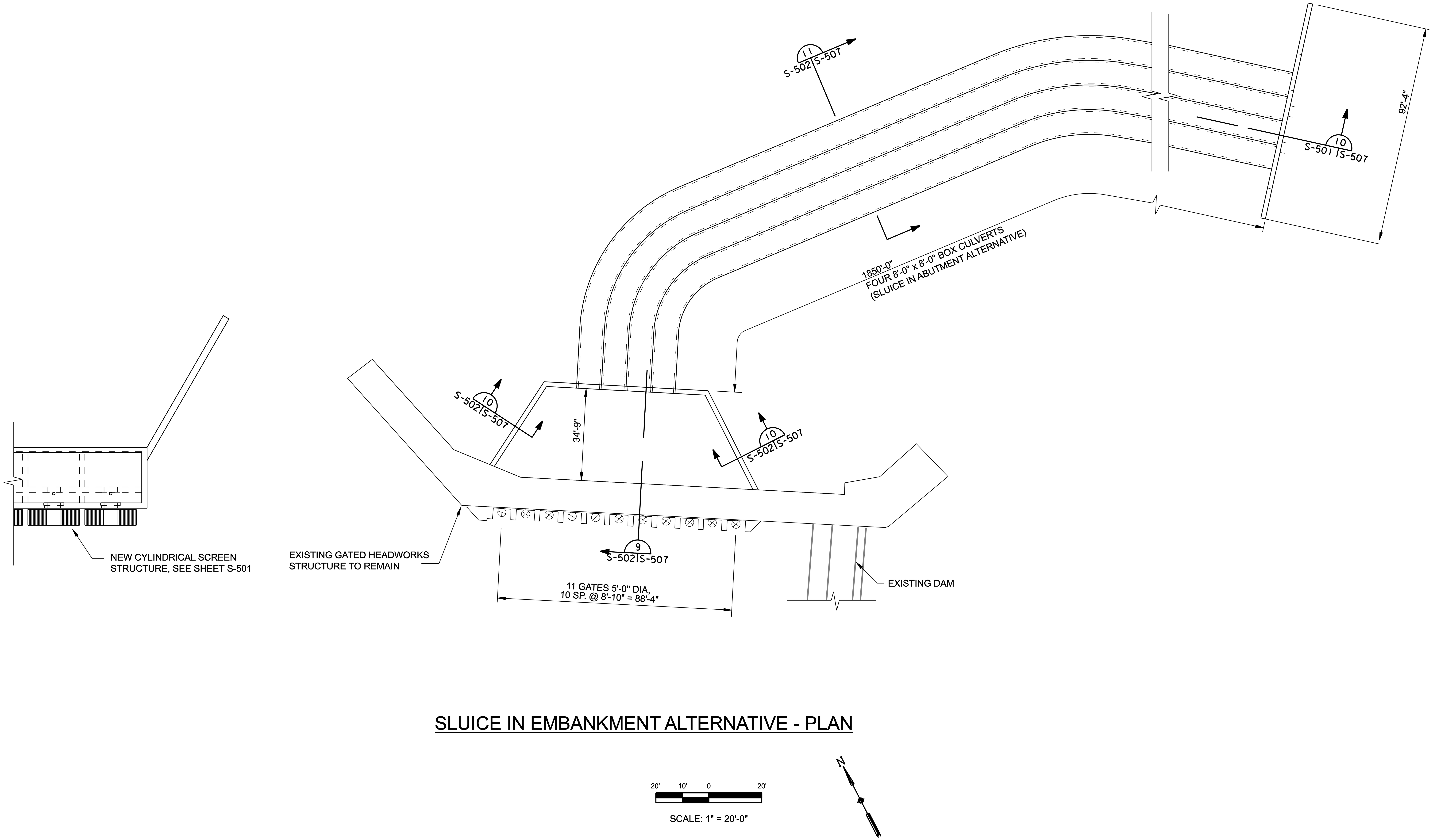
g6edrrmb



SLUICE IN EMBANKMENT ALTERNATIVE - PLAN

SCALE: 1" = 20'-0"

NOTES:

1

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SUBMITTED BY: B.N.H.
FILE NAME: MM04-S-502.DGN
SIZE: 33.1X22
PLOT SCALE: 0.08 ft / in.
DATE: JAN. 2008
SOLICITATION NO.: W912BF-0X-X-00XX
CONTRACT NO.: W912BF-0X-C-00XX
FILE NUMBER: X
PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT
SLUICE IN EMBANKMENT ALTERNATIVE

SHEET IDENTIFICATION NUMBER
S-502

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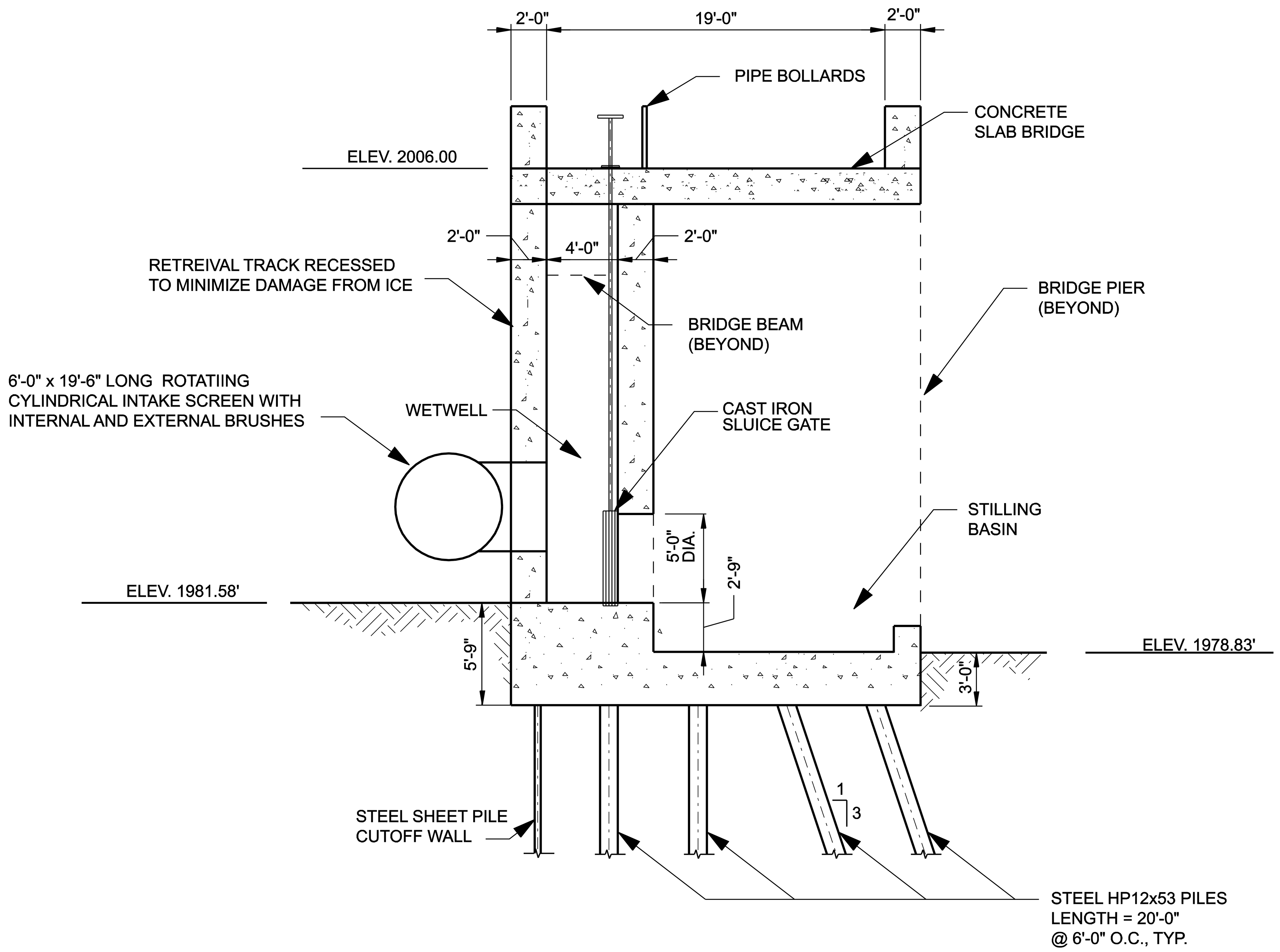
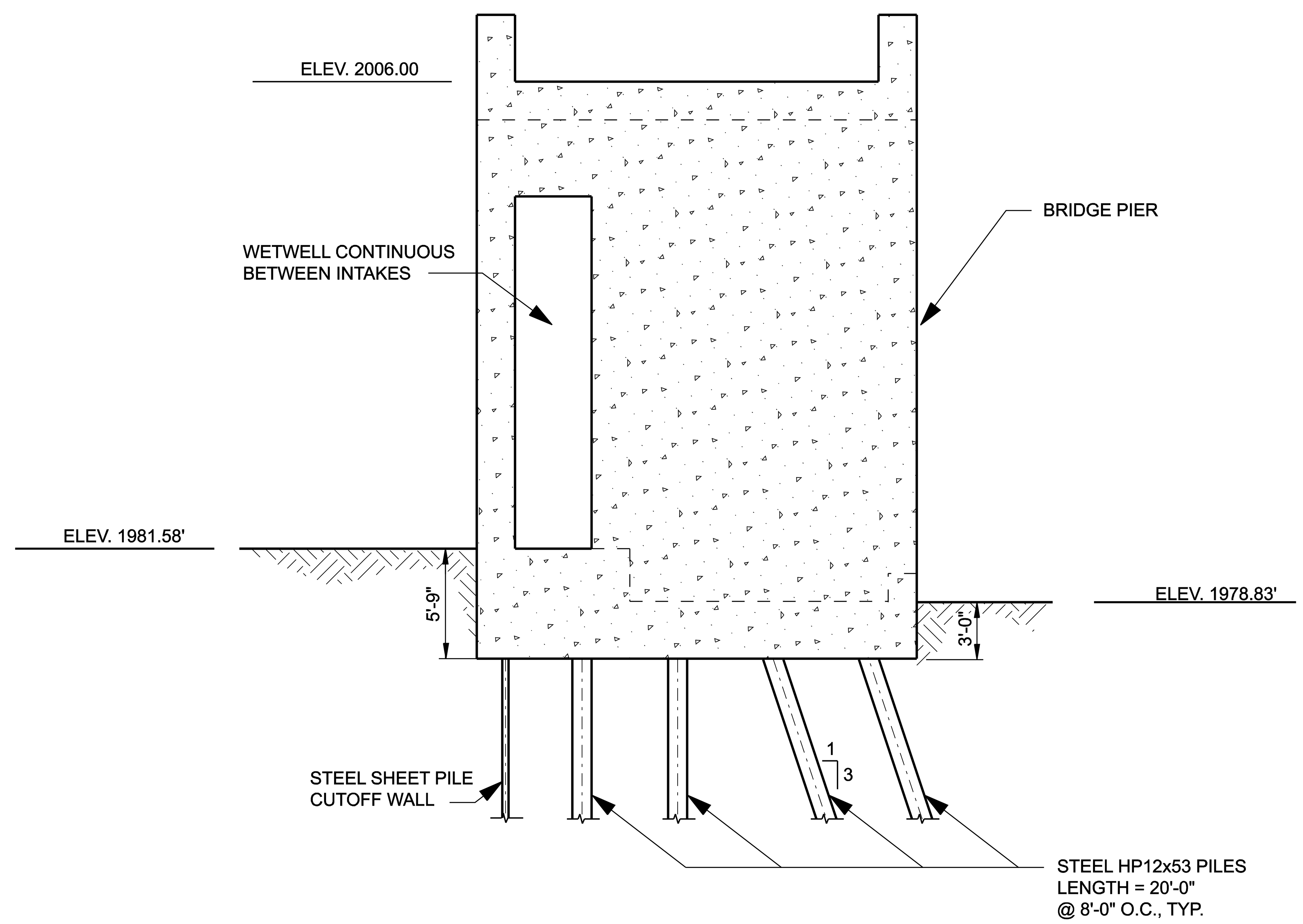


SECTION AT INTAKE

SECTION 1 S-501 S-503

8' 4' 0 8'

SCALE: 3/16" = 1'-0"



SECTION AT BRIDGE PIER

SECTION 2 S-501 S-503

8' 4' 0 8'

SCALE: 3/16" = 1'-0"

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MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
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DWN BY: L.E.P.	CKD BY:	SOLICITATION NO.: W9128F-0X-X-00XX
SUBMITTED BY: B.N.H.		CONTRACT NO.: W9128F-0X-C-00XX
FILE NAME: MM04-S-503.DGN		FILE NUMBER: X
SIZE: 33.1X22	PLOT SCALE: 0:1 ft:in / IN.	PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT
SECTIONS AND DETAILS

SHEET IDENTIFICATION NUMBER
S-503

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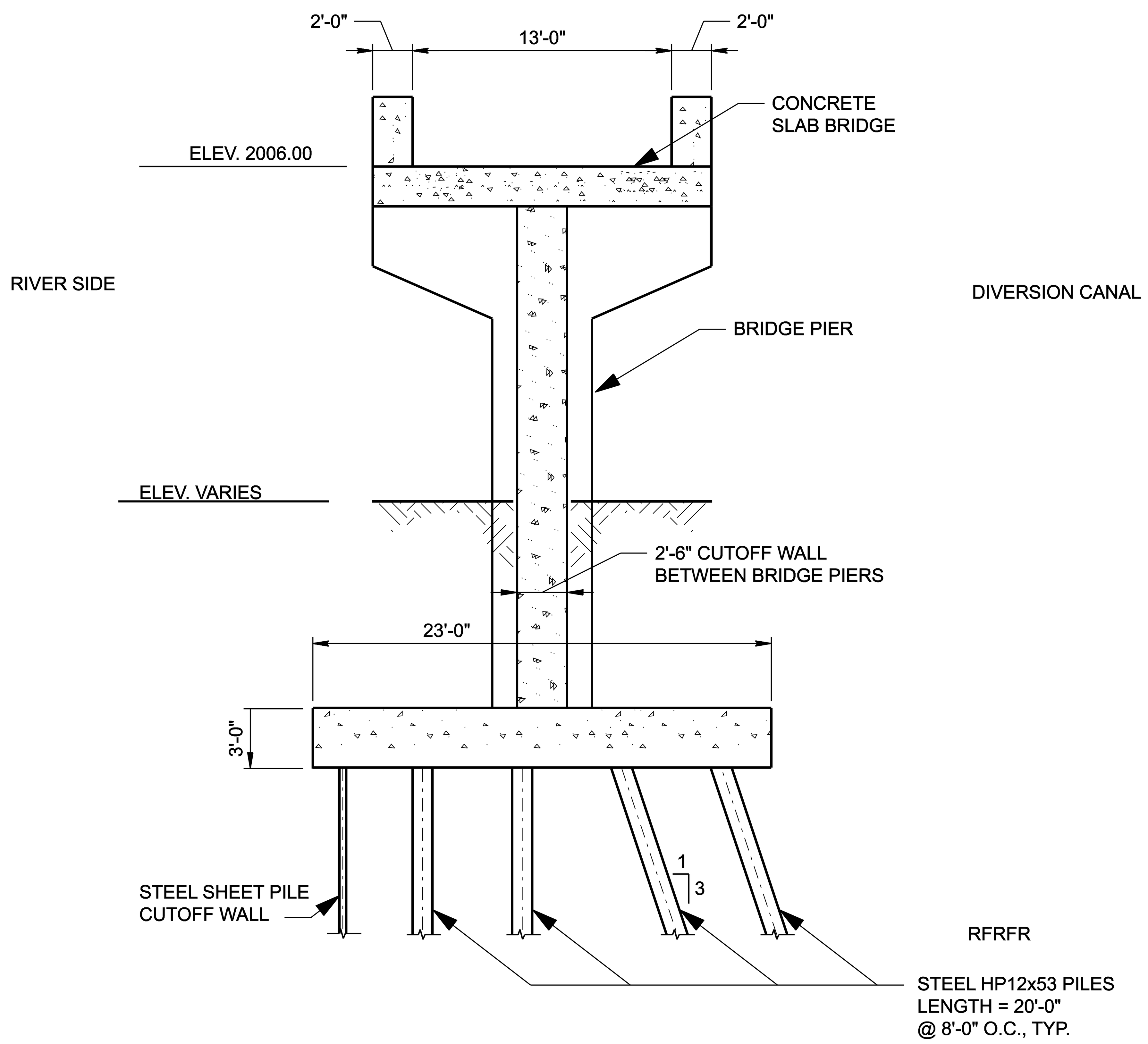
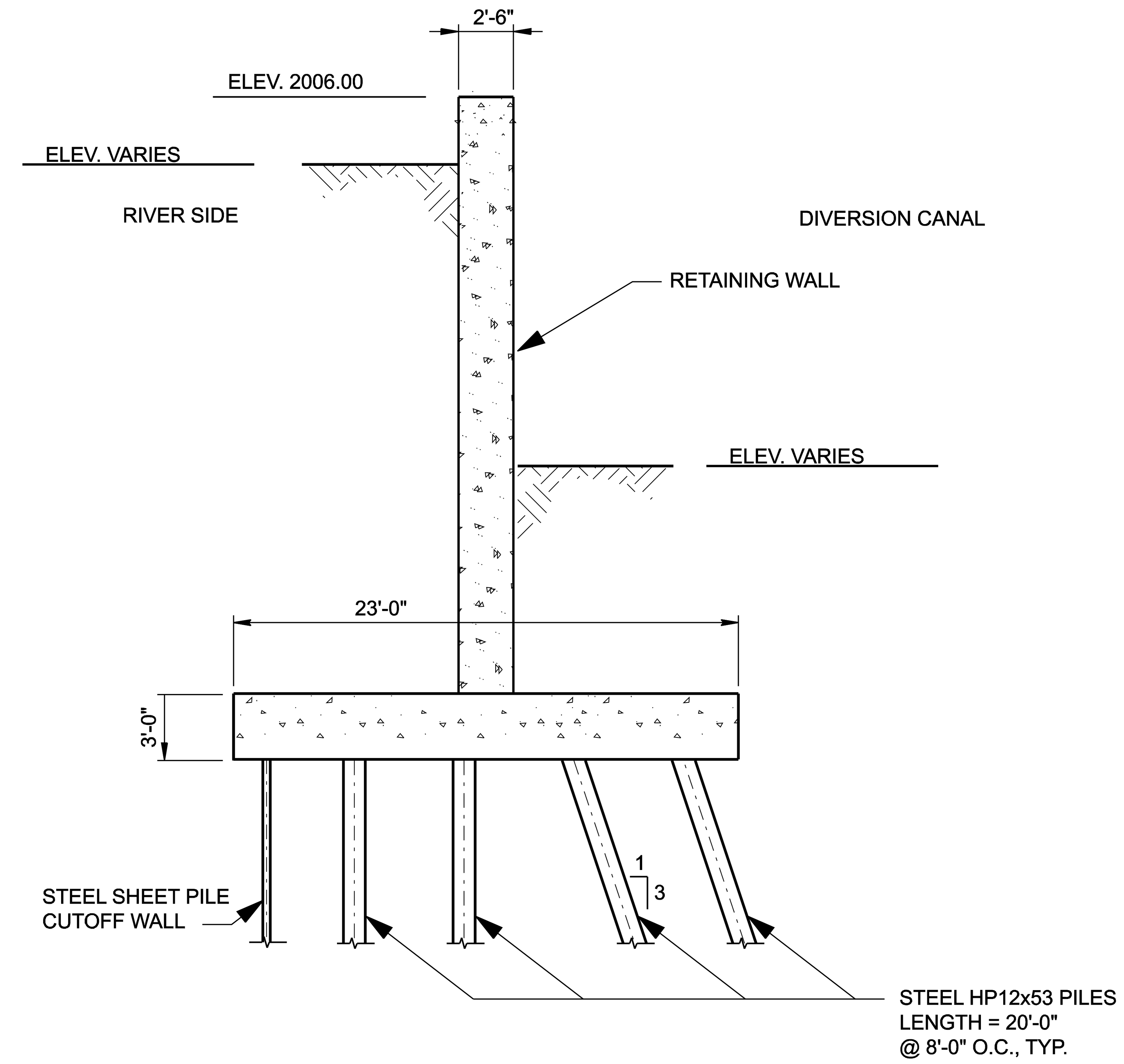


SECTION AT ACCESS BRIDGE

SECTION 3 S-501 S-504

8' 4' 0 8'

SCALE: 3/16" = 1'-0"



SECTION AT WINGWALL

SECTION 4 S-501 S-504

8' 4' 0 8'

SCALE: 3/16" = 1'-0"

US ARMY CORPS OF ENGINEERS
OMAHA DISTRICT

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U. S. ARMY ENGINEER DISTRICT
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DWN BY: L.E.P.
CKD BY:
SUBMITTED BY: B.N.H.
FILE NAME: MM04-S-504.DGN
SIZE: 33.1X22
PLOT SCALE: 0.1 ft/in / IN.
DATE: JAN. 2008
SOLICITATION NO.: W912BF-0X-X-00XX
CONTRACT NO.: W912BF-0X-C-00XX
FILE NUMBER: X
PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT

SECTIONS AND DETAILS

SHEET IDENTIFICATION NUMBER
S-504

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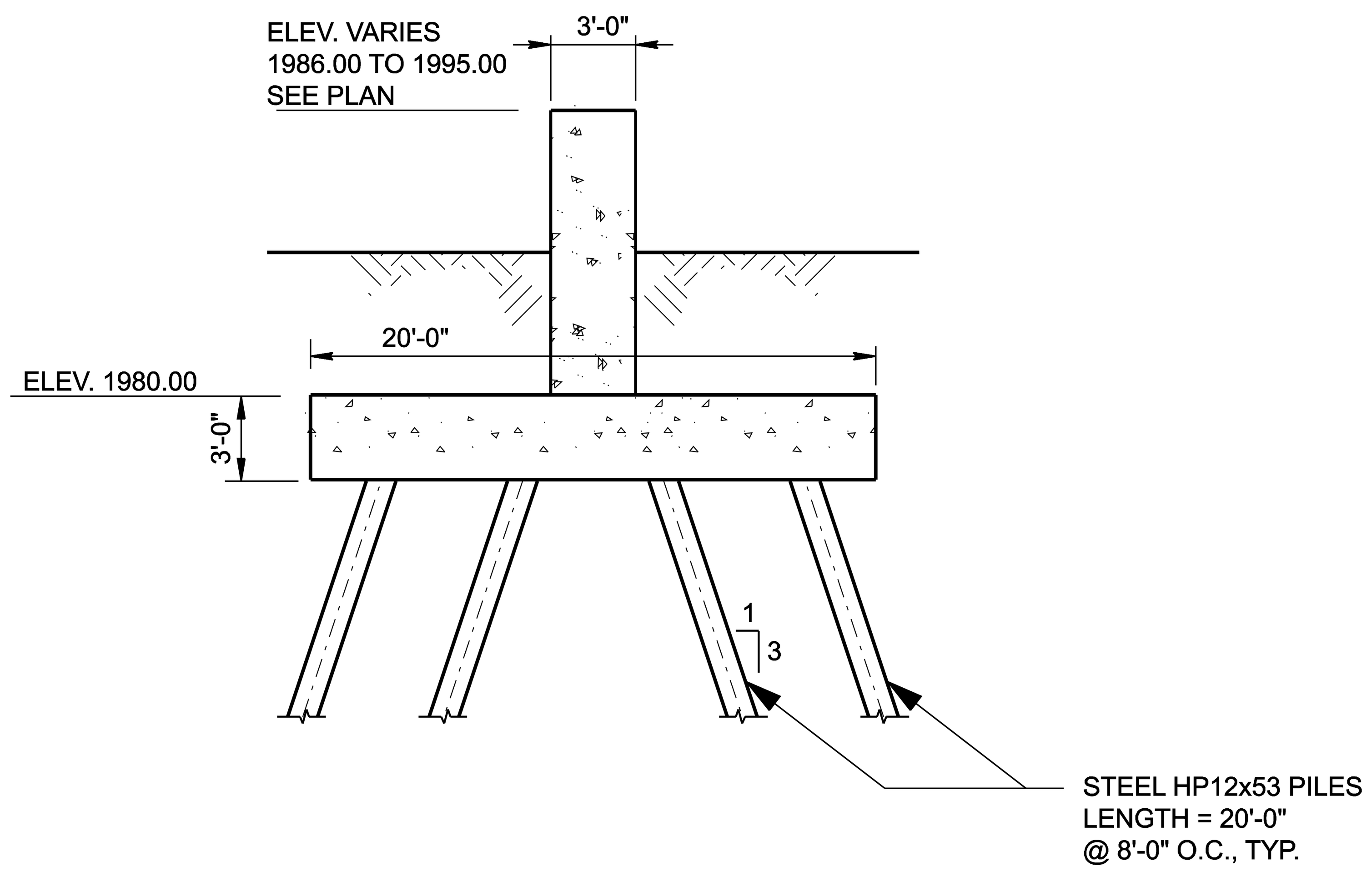
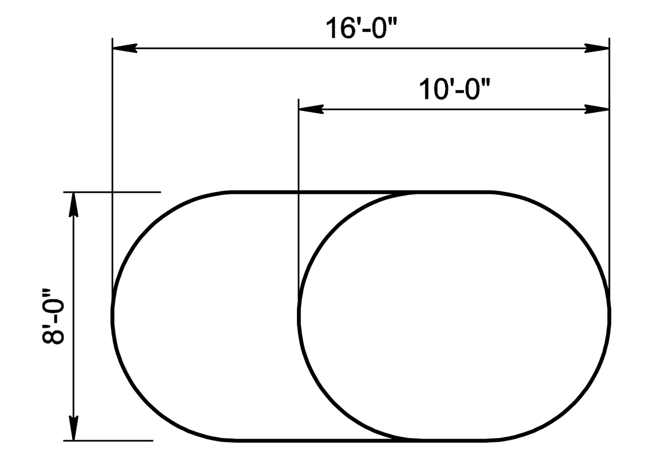
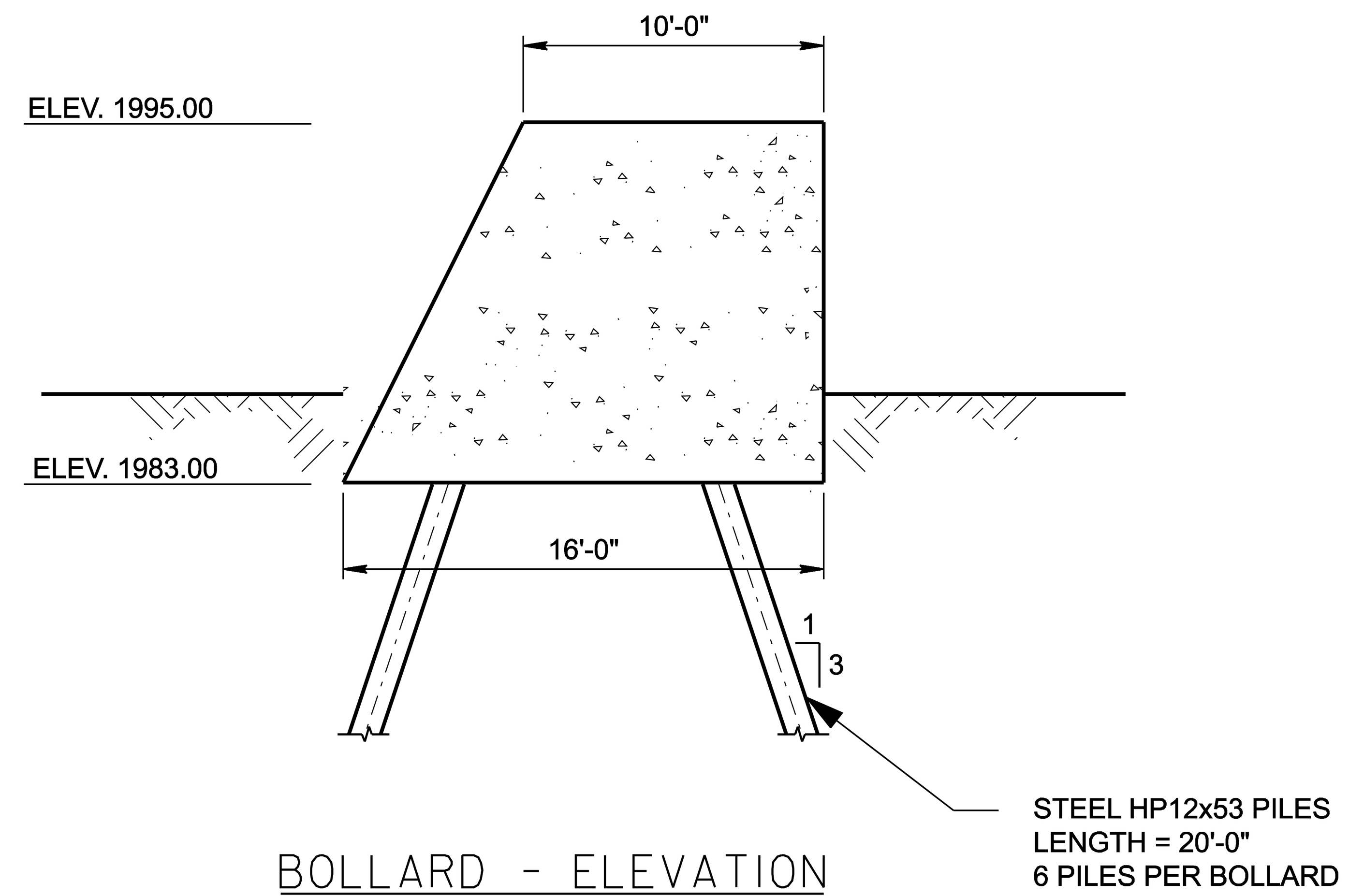


SECTION 5
S-501 S-505

SCALE: 3/16" = 1'-0"



BOLLARD - PLAN



BOLLARD - ELEVATION

SECTION 6
S-501 S-505

SCALE: 3/16" = 1'-0"

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OMAHA DISTRICT

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DWN BY: L.E.P. | CKD BY: | SOLICITATION NO.: W9128F-0X-X-00XX
SUBMITTED BY: B.N.H. | CONTRACT NO.: W9128F-0X-C-00XX
FILE NAME: MM04-S-505.DGN | FILE NUMBER: X
SIZE: 33.1X22 | PLOT SCALE: 0.1 ft/in / IN. | PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT
SECTIONS AND DETAILS

SHEET
IDENTIFICATION
NUMBER
S-505

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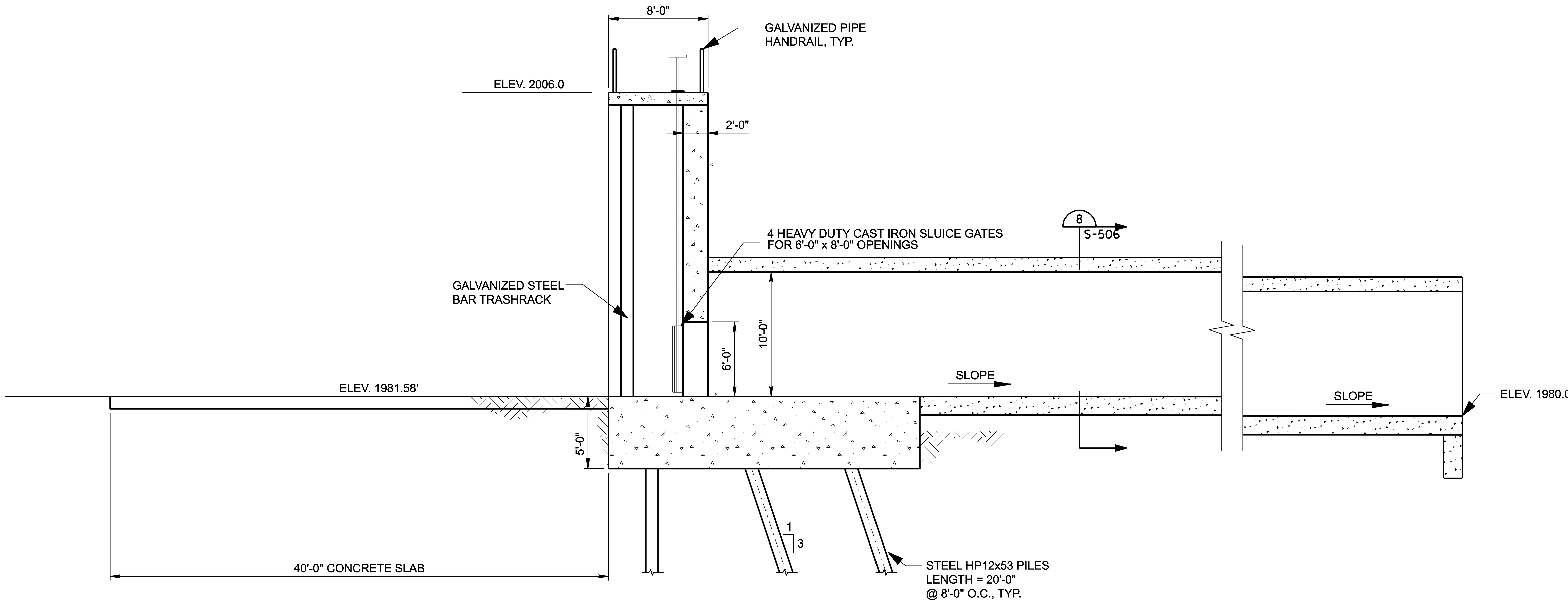
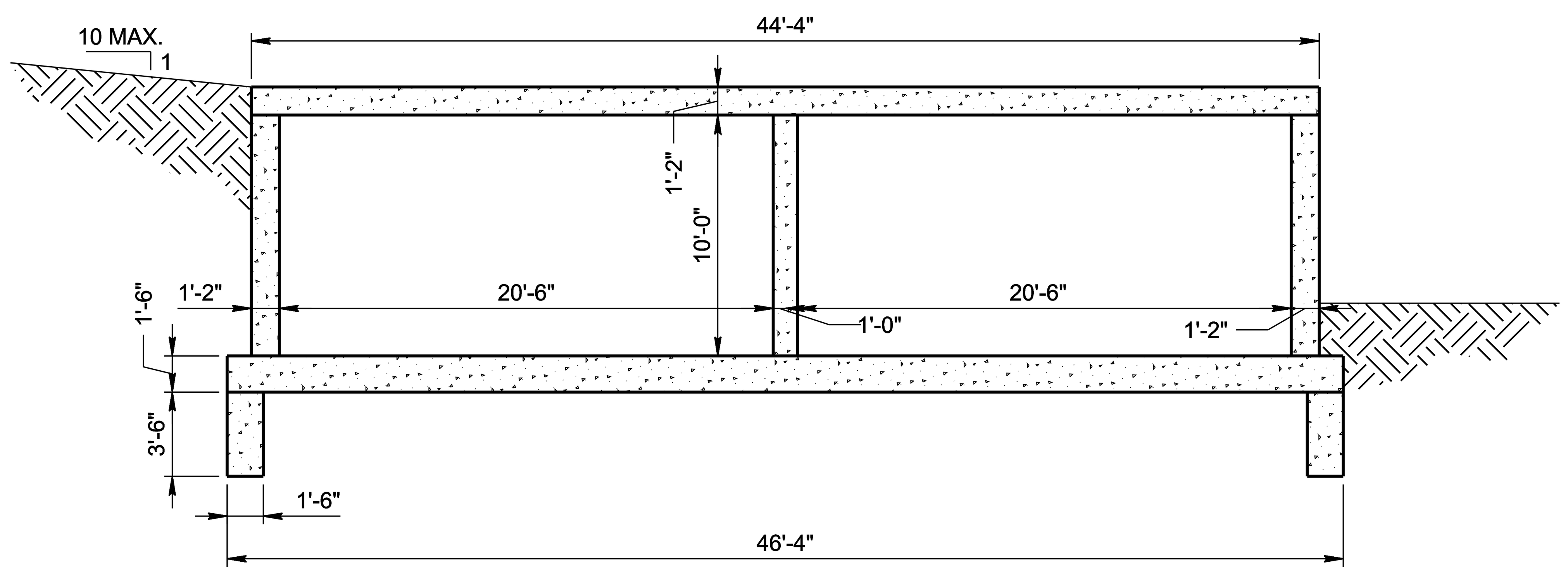


SECTION 7
S-501 | S-506

8' 4' 0 8'

SCALE: 3/16" = 1'-0"



SECTION 8
S-501 | S-506

8' 4' 0 8'

SCALE: 3/16" = 1'-0"

US ARMY CORPS OF ENGINEERS
OMAHA DISTRICT

MARK	DESCRIPTION	DATE	APPR.

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LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT
SECTIONS AND DETAILS

SHEET IDENTIFICATION NUMBER
S-506

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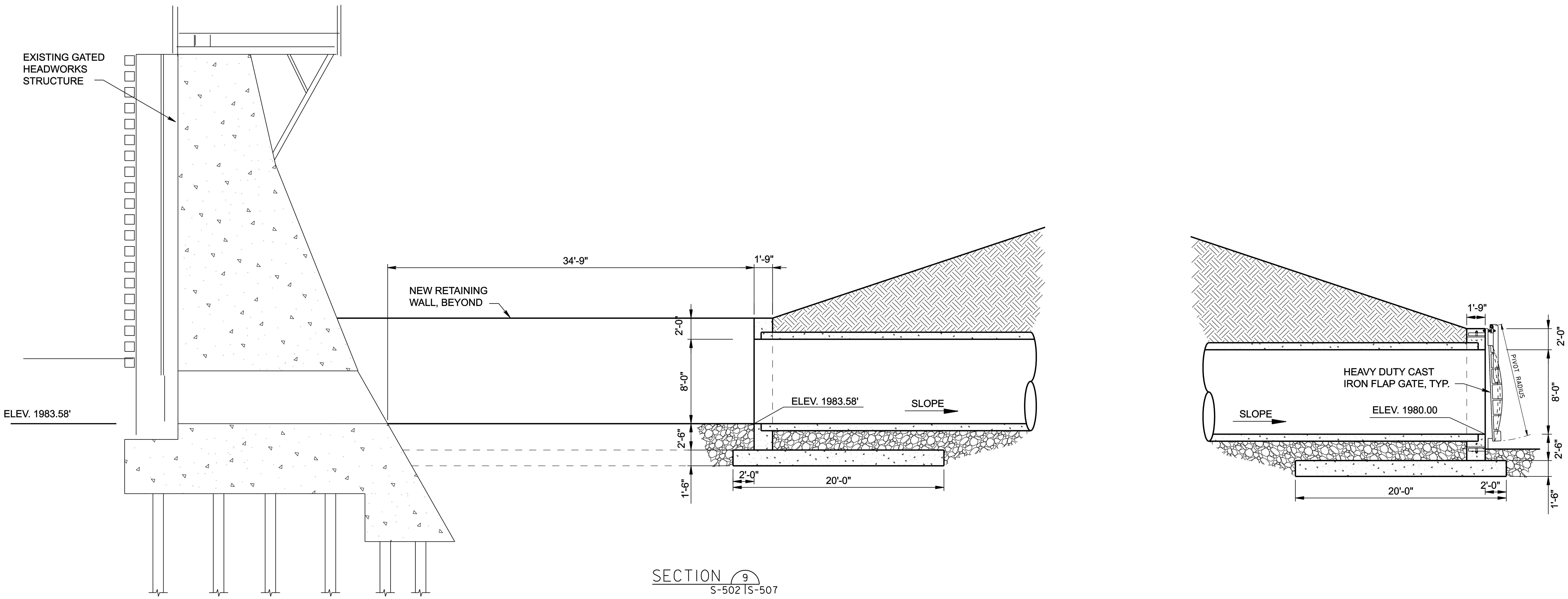
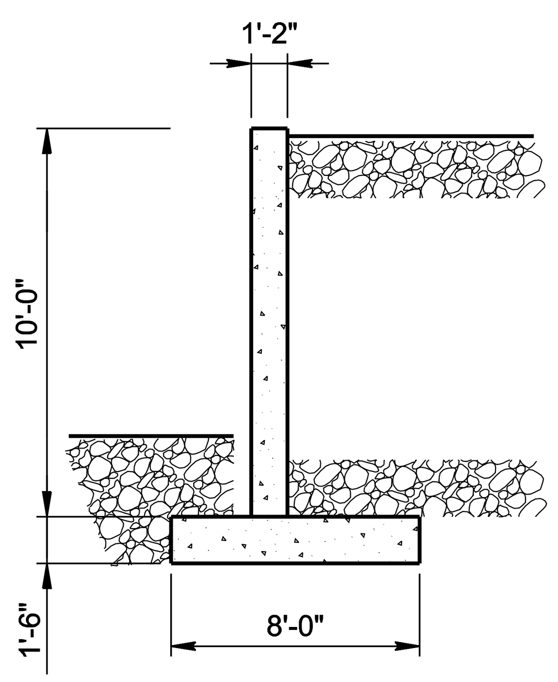


SECTION 9
S-502 S-507

8' 4' 0 8'

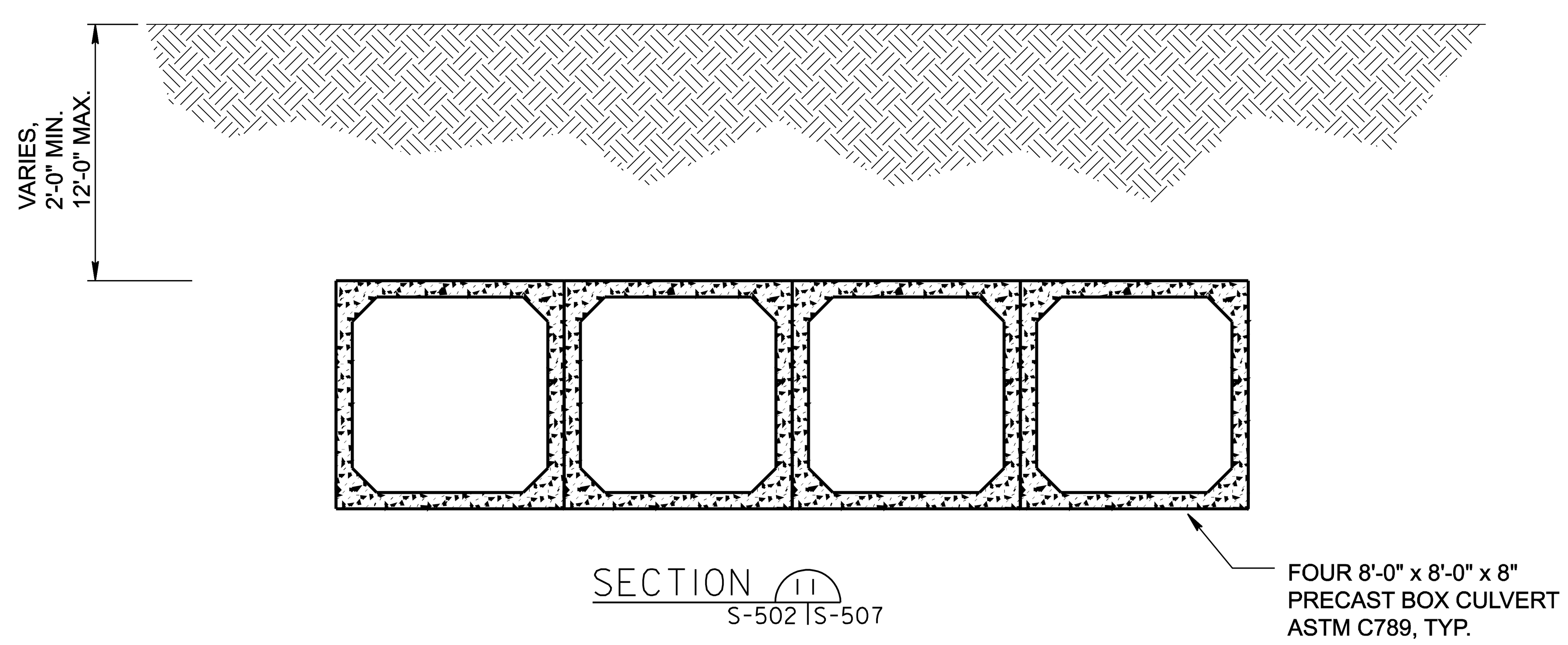
SCALE: 3/16" = 1'-0"



SECTION 10
S-502 S-507

8' 4' 0 8'

SCALE: 3/16" = 1'-0"



SECTION 11
S-502 S-507

8' 4' 0 8'

SCALE: 3/16" = 1'-0"

US ARMY CORPS OF ENGINEERS
OMAHA DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS

DESIGNED BY: L.E.P.
DWN BY: L.E.P.
CKD BY:
SUBMITTED BY: B.N.H.
FILE NAME: MM04-S-507.DGN
SIZE: 33.1X22
PLOT SCALE: 0.1 ft/in / IN.
DATE: JAN. 2008
SOLICITATION NO.: W912BF-0X-X-00XX
CONTRACT NO.: W912BF-0X-C-00XX
FILE NUMBER: X
PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT
SECTIONS AND DETAILS

SHEET IDENTIFICATION NUMBER
S-507

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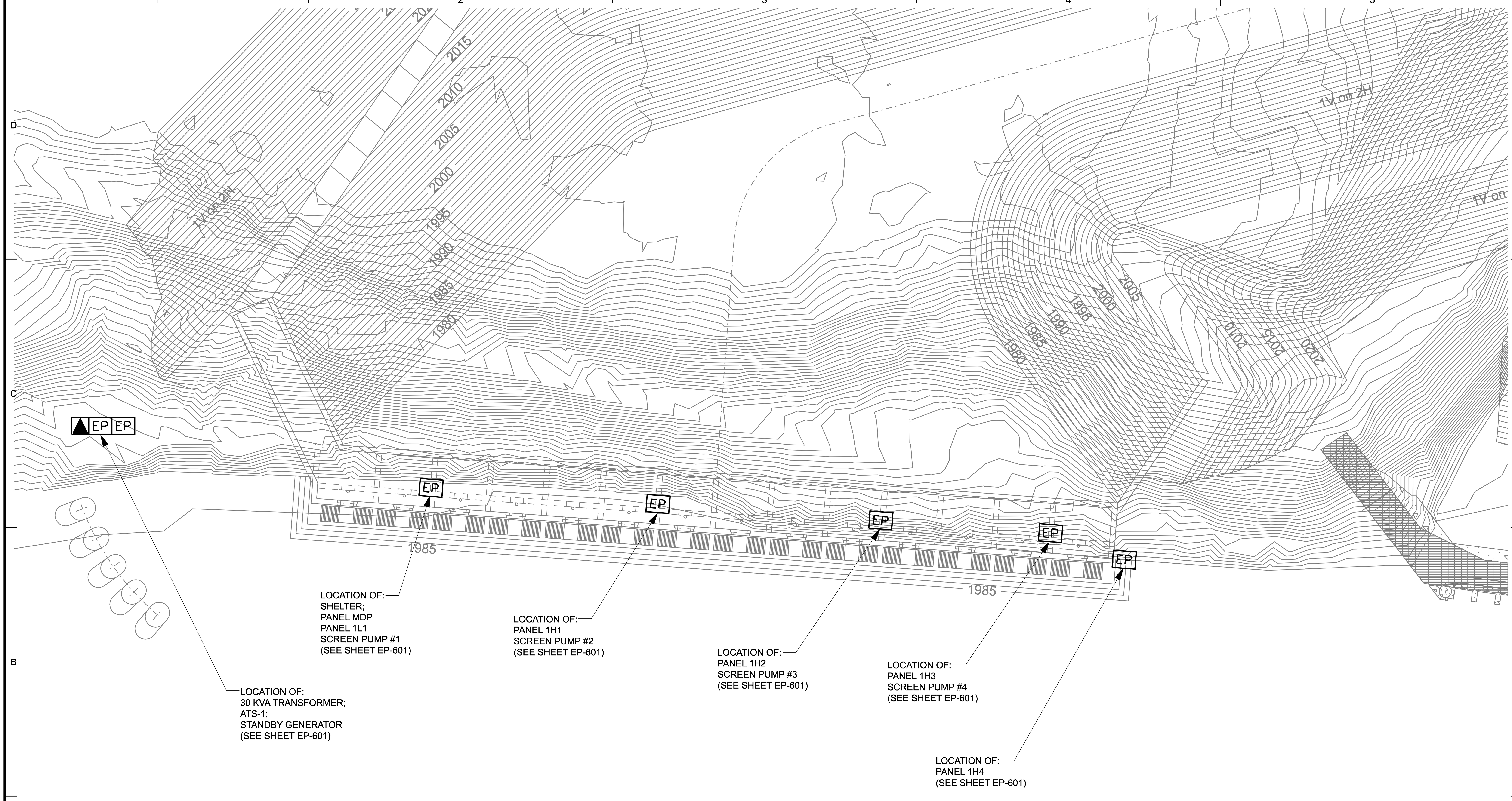

N

ELECTRICAL COMPOSITE SITE PLAN

20' 10' 0 20'

SCALE: 1" = 20'-0"

US ARMY CORPS OF ENGINEERS
OMAHA DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

DESIGNED BY: JOE E. CHAMBERLAIN
DWN BY: J.E.C.
CKD BY: R.J.B.
SUBMITTED BY: RUSSELL J. BROICH
FILE NAME: MM04-ES-100.dgn
SIZE: 33.1X22
PLOT SCALE: 0.08 ft / in.
DATE: JAN. 2008
SOLICITATION NO.: W9128F-0X-X-00XX
CONTRACT NO.: W9128F-0X-C-00XX
FILE NUMBER:
PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT

ELECTRICAL COMPOSITE SITE PLAN

SHEET IDENTIFICATION NUMBER
ES-100

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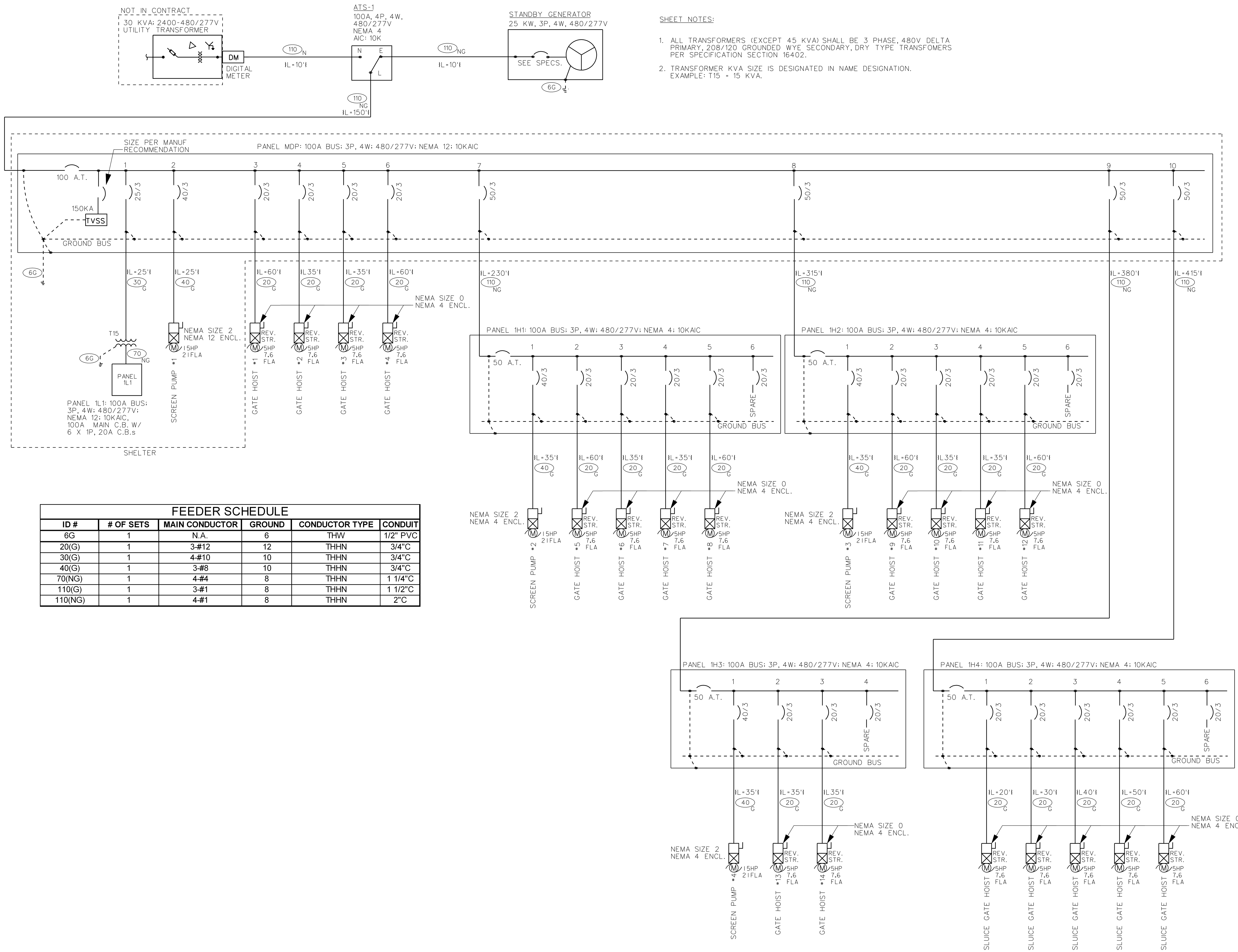
g6edxrmb



SHEET NOTES:

1. ALL TRANSFORMERS (EXCEPT 45 KVA) SHALL BE 3 PHASE, 480V DELTA PRIMARY, 208/120 GROUNDED WYE SECONDARY, DRY TYPE TRANSFOMERS PER SPECIFICATION SECTION 16402.
2. TRANSFORMER KVA SIZE IS DESIGNATED IN NAME DESIGNATION. EXAMPLE: T15 = 15 KVA.

FEEDER SCHEDULE					
ID #	# OF SETS	MAIN CONDUCTOR	GROUND	CONDUCTOR TYPE	CONDUIT
6G	1	N.A.	6	THW	1/2" PVC
20(G)	1	3-#12	12	THHN	3/4"C
30(G)	1	4-#10	10	THHN	3/4"C
40(G)	1	3-#8	10	THHN	3/4"C
70(NG)	1	4-#4	8	THHN	1 1/4"C
110(G)	1	3-#1	8	THHN	1 1/2"C
110(NG)	1	4-#1	8	THHN	2"C

US ARMY CORPS OF ENGINEERS
OMAHA DISTRICT

MARK | DATE | DESCRIPTION | APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

DESIGNED BY: JOE E. CHAMBERLAIN
DWN BY: J.E.C.
CKD BY: R.J.B.
SUBMITTED BY: RUSSELL J. BROICH
FILE NAME: MM04-EP-601.dgn
SIZE: 33.1X22
PLOT SCALE: 0:1 ft:in / IN.
DATE: JAN. 2008
SOLICITATION NO.: W9128F-0X-X-00XX
CONTRACT NO.: W9128F-0X-C-00XX
FILE NUMBER:
PLOT DATE: 1/30/2008

LOWER YELLOWSTONE RIVER
INTAKE DAM FISH SCREEN AND SLUICING
INTAKE, MONTANA
PRELIMINARY DESIGN REPORT

ELECTRICAL ONE LINE DIAGRAM

SHEET IDENTIFICATION NUMBER
EP-601

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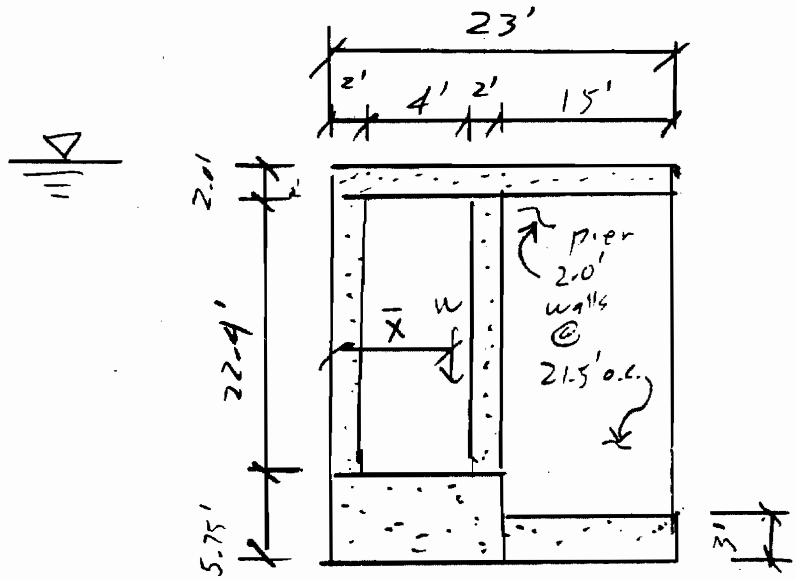
g6edrrmb

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT Intake Dam	SHEET NO. 1	OF 10
ITEM Intake Screen Structure	BY LEP	DATE Jan 08
	CHKD. BY	DATE

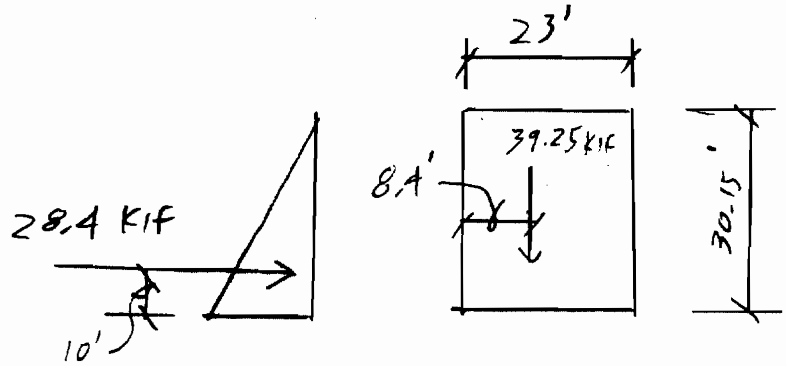


	w_i (klf)	x_i (ft)
Front wall	$2(22.4)(0.15) = 6.72$	1.0
Gate Way	$2(22.4)(0.15) = 6.72$	4.5
Pier Walls	$\frac{2(25.15)(15)(0.15)}{21.5} = 5.26$	15.5
Gate Slab	$5.75(8.0)(0.15) = 6.90$	4.0
Stilling Basin Slab	$3.0(15.0)(0.15) = 6.75$	15.5
Top Slab	$2.0(23.0)(0.15) = 6.90$	11.5

$$\Sigma w_i = 39.25 \text{ klf}$$

$$\bar{x} = \frac{\Sigma w_i x_i}{\Sigma w_i} = \frac{330.1}{39.25} = 8.40 \text{ ft.}$$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Intake Dam		SHEET NO. 2	OF 10
ITEM Intake Screen Structure		BY LEP	DATE Jan 08
		CHKD. BY	DATE

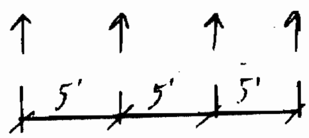


Try row of 4 piles @ 8' o.c.

$P = 39.25(8) = 314^k$

$M = 8\left[28.4(10) - 39.25\left(\frac{23}{2} - 8.4\right)\right]$

$M = 1298^{k\cdot ft}$



$\Sigma d^2 = 2(2.5)^2 + 2(7.5)^2 = 125\ ft^2$

$$\frac{P}{A} \pm \frac{Mc}{I} = \frac{314}{4} \pm \frac{1298(7.5)}{125} = 78.5^k \pm 77.9^k$$

$\left(\text{Vertical} = \begin{matrix} -0.6^k \text{ tension} \\ 156^k \text{ compr.} \end{matrix}\right)$

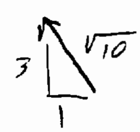
HP 12×53 Grade 50

Unbr. length	P_{allow}
≈0	460^k
10'	405^k
20'	276^k

battered piles for horiz.

$H = 28.4\left(\frac{8\ ft^2}{2 \text{ battered piles}}\right)$

$H = 114^k/\text{pile}$



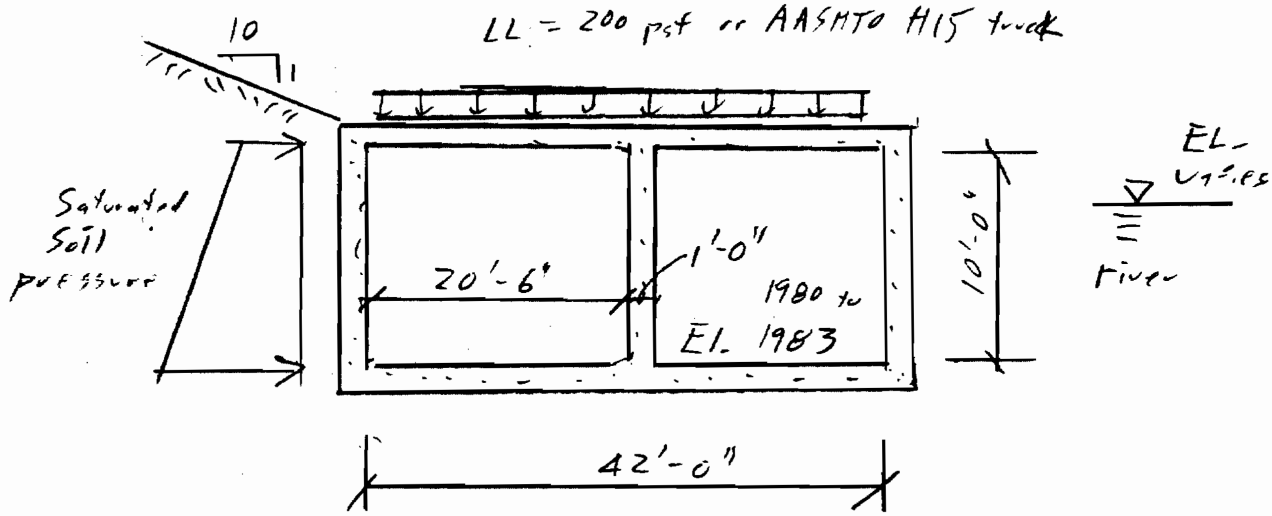
Additional

$P = 114\sqrt{10} = 360^k$

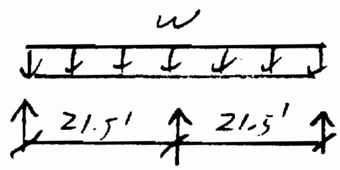
$360 + 156 = 516^k$

Reduce spacing to $\frac{405}{516}(8) = 6.2$ say 6' o.c.

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Intake Dam		SHEET NO. 3	OF 10
ITEM Sluiceway in channel		BY LEP	DATE Jan 00
		CHKD. BY	DATE



Top slab live load:



$$V_L = \frac{5}{8} wL = \frac{5}{8}(200)(21.5) = 2688 \text{ plf}$$

$$M_L = 0.125\, wL^2 = 0.125(0.200)(21.5)^2 = 11.56 \text{ k-ft/ft.}$$

If 12" slab

$$V_D = \frac{5}{8}(150)(21.5) = 2016 \text{ plf}$$

$$M_D = 0.125(0.15)(21.5)^2 = 8.67 \text{ k-ft/ft}$$

$$V_u = 1.2(2016) + 1.6(2688) = 6720 \text{ plf}$$

$$d = 12 - 3 - \frac{1.0}{2} = 8.5 \text{ in}$$

$$\phi V_c = 0.75(2)\sqrt{4000}(12)(8.5) = 9676 \text{ plf} > V_u \text{ OK}$$

$$M_u = 1.2(8.67) + 1.6(11.56) = 28.9 \text{ k-ft/ft}$$

Hydraulic factor $M_{uf} = 1.3(28.9) = 37.6$ k-ft/ft

$$\text{Req } R_n = \frac{M_u}{\phi b d^2} = \frac{37.6(12{,}000)}{0.9(12)(8.5)^2} = 577 \text{ psi} \Rightarrow \text{req } \rho = 0.01063 \le 0.37\rho_{bal} \text{ OK}$$

$$\text{Req } A_s = 0.01063(12)(8.5) = 1.08 \text{ in}^2/\text{ft} \Rightarrow \#8 @ 8"$$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Intake Dam		SHEET NO. 4	OF 10
ITEM Sluiceway in channel		BY LEP	DATE Jan 08
		CHKD. BY	DATE

AASHTO H15 truck load

Reinf perpendicular to traffic

$$M_L = 0.8\left(\frac{S+2}{32}\right)P_{15} = 0.8\left(\frac{21.5+2}{32}\right)12 = 7.05 \text{ k-ft/ft}$$

Reinf. parallel to traffic

$$M_L = 0.8(0.75)(0.9\,S) = 0.8(0.75)(0.9)(21.5) = 11.61 \text{ k-ft/ft}$$

cont. H15

$$M_{uf} = 1.3\left[1.2(8.67) + 1.6(11.61)\right] = 37.6 \text{ k-ft/ft} \quad (\text{same as } 7200\text{ psf})$$

Active Earth Pressure on conduit wall

Assume granular fill $\phi = 25$ deg (conserv.)

Strength mobilization factor (approximates at-rest condition)

$$\phi_d = \tan^{-1}\left(\tfrac{2}{3}\tan\phi\right) = 17.27 \text{ deg.}$$

level fill $K_a = \tan^2\left(45 - \frac{\phi_d}{2}\right) = 0.54$

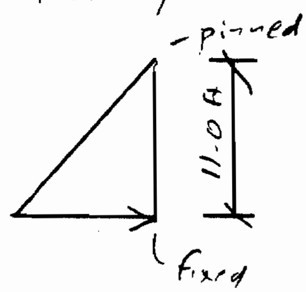
Sloped fill $\beta = \tan^{-1}\left(\frac{1}{10}\right) = 5.71$ deg

$$K_a = \frac{\cos^2\phi}{\left[1 + \sqrt{\frac{\sin\phi\sin(\phi-\beta)}{\cos\beta}}\right]^2} = 0.59$$

Saturated soil $\gamma_s = 120$ pcf

Equiv. fluid pressure $= 0.59(120 - 62.4) + 62.4 = 96$ pcf

conservative



$11(96) = 1056$

$V_{max} = 4624$ plf

$M_{max} = 8280$ ft·lb/ft

OMAHA DISTRICT	COMPUTATION SHEET		CORPS OF ENGINEERS
PROJECT Intake Dam		SHEET NO. 5	OF 10
ITEM Sluiceway in channel		BY LEP	DATE Jan 08
		CHKD. BY	DATE

Conduit ext. wall (cont.)

$V_u = 1.6(4624) = 7400$ plf

try 12" wall w/ $d = 8.5$"

$\phi V_c = 0.75(2)\sqrt{4000}(12)(8.5) = 9676 > V_u$ ok

$M_u = 1.3\left[1.6(8+28)\right] = 17.2$ k-ft/ft

↑ HF

Req $R_n = \frac{M_u}{\phi b d^2} = \frac{17.2(12000)}{0.9(12)(8.5)^2} = 265 \Rightarrow$ req $\rho = 0.00460$

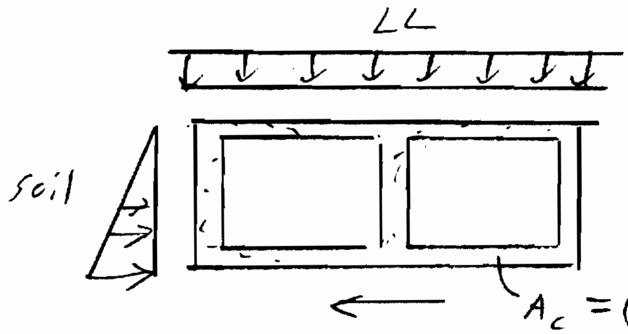
$= 0.17\rho_{bal}$

ok

Req $A_s = 0.00460(12)(8.5) = 0.47$ in²/ft

$\Rightarrow$ #5 @ 8" o.c.

At final design, check unbalanced loads



$\Rightarrow$ increase to 14" top and ext. walls for moment at corners

$A_c = (44.33)(12.33) - 2(16)(20.5)$

$= 136.6$ ft²

bouyant wt. $= 136.6(150 - 62.4) = 11{,}970$ plf

Sliding F.S. $= \frac{[\tan(25)](11970)}{\frac{1}{2}(1056)(11)} = 0.96 < 1.5$ NG

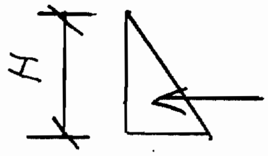
provide shear keys below bottom slab

Req FS $= 1.5 = \frac{5580 + \text{Passive}}{5808} \Rightarrow$ Passive $= 3130$ plf

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Intake Dam		SHEET NO. 6	OF 10
ITEM Sluice way in channel		BY LEP	DATE Jan 08
		CHKD. BY	DATE

$$K_p = \tan^2\left(45 + \frac{17.27}{2}\right) = 1.85$$

Shear key



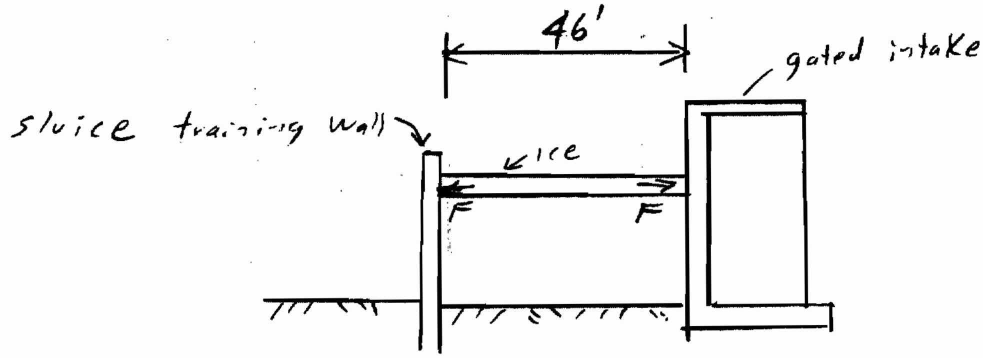
$$\frac{1}{2}(1.85)(120-62.4)H^2 = 3130 \text{ plf}$$

$$H = 7.7 \text{ ft}$$

If two keys $\frac{1}{2}(1.85)(120-62.4)H^2 = \frac{3130}{2}$

$$H = 5.4 \text{ ft}$$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Intake Dam		SHEET NO. 7	OF 10
ITEM Ice Forces		BY LED	DATE Jan 08
		CHKD. BY	DATE



Ref: EM 1110-2-1612 ICE ENGINEERING

Ice sheet thickness $h = \alpha\sqrt{AFDD}$ [Eq. 2-10]

$\alpha = 0.4$ [Table 2-2]

max $AFDD = 3000$ [CRREL Report Fig. 1]

$h = 0.4\sqrt{3000} = 22$ inches $= 1.83$ ft.

Buckling Strength of ice sheet

$$\frac{F}{B} = \alpha \gamma_w L^2 \quad \text{[Eq. 6-16]}$$

$\alpha = 2.0$ (conserv. assumed fixed at ends)

$\gamma_w = 62.4\ \text{lb/ft}^3$

$$L = \sqrt[4]{\frac{E h^3}{12\gamma_w}}$$

$$L = \sqrt[4]{\frac{(300{,}000\ \text{lb/in}^2)(144\ \text{in}^2/\text{ft}^2)(1.83\ \text{ft})^3}{12(62.4\ \text{lb/ft}^3)}} = 24.3\ \text{ft}$$

< 46 ft

$\Rightarrow$ can buckle

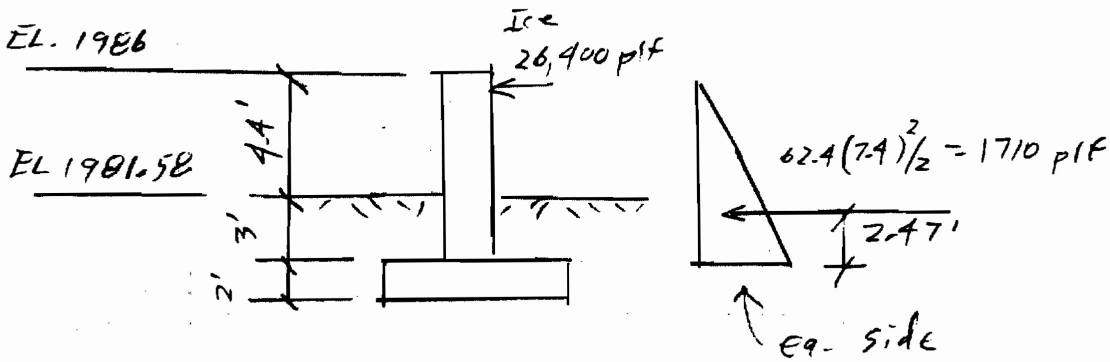
$$\frac{F}{B} = 2.0(62.4\ \text{lb/ft}^3)(24.3\ \text{ft})^2 = 74{,}200\ \text{lb/ft}$$

Crushing Strength of ice sheet

$$\frac{F_c}{w} = p\,h = (100\ \text{lb/in}^2)(22\ \text{in})(12\ \text{in/ft}) = 26{,}400\ \text{lb/ft}$$

$\Rightarrow$ Force limited by crushing strength $= 26{,}400$ lb/ft

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Intake Dam		SHEET NO. 8	OF 10
ITEM Sluice Training Wall		BY LEP	DATE Jun 08
		CHKD. BY	DATE



$V_u = 1.6(26,400) = 42,240$ plf

$\phi V_c = 0.75(2)\sqrt{4000}(12)d$ (3" cover)

⇒ Req $d = 37.1''$, try 36" wall, $d = 32.5$ in

add shear friction reinf.

$M = 7.4(26.4) = 195.3$

$M_u = 1.3(1.6)(195.3) = 406$ k-ft/ft

$R_n = \frac{M_u}{\phi b d^2} = \frac{406(12,000)}{0.9(12)(32.5)^2} = 427 \Rightarrow$ req. $\rho = 0.00764$
$= 27\% \rho_{bal}$ ok

that $\rho_{max} = 0.375\rho_{bal} = 0.01070$

$A_s = 0.00764(12)(32.5) = 3.0$ in²/ft

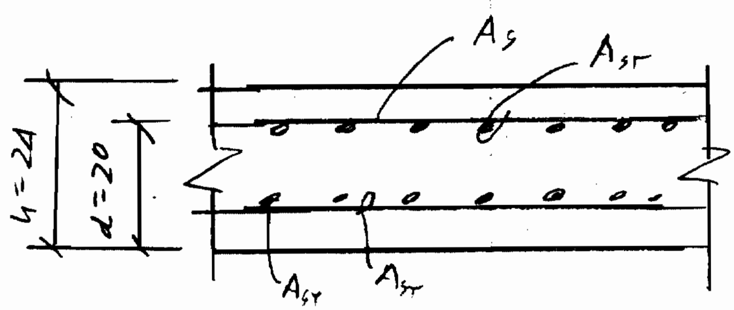
try 2 layers #9 @ 8" o.c.

$A_s = 2(1.00)\left(\frac{12}{8}\right) = 3.00$

$\phi M_n = 0.9(3.00)(60)\left[32.5 - \frac{4.41}{2}\right]\frac{1}{12} = 408 > M_u$

ok

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Intake Dam		SHEET NO. 9	OF 10
ITEM Typ. reinf. per Civil Works Criteria		BY LEP	DATE Jan 08
		CHKD. BY	DATE



Assume $\rho = 0.25\,\rho_{bal} = 0.00713$

$$A_s = 0.00713(12)(20) = 1.71 \text{ in}^2/\text{ft}$$

Assume $A_{ST} = \left(\dfrac{0.0028}{2 \text{ faces}}\right)(24)(12) = 0.40 \text{ in}^2/\text{ft. ea. face}$

per 10'×10'

$$A_{concr.} = \frac{10(10)(2)}{27} = 7.41 \text{ CY}$$

$$A_s + A_{sT} = 1.71(10)(10\times12) + 3(0.40)(10)(10\times12) = 3492 \text{ in}^3$$

$$\frac{3492 \text{ in}^3}{(12 \text{ in/ft})^3}(490 \text{ lb/ft}^3) = 990 \text{ lb}$$

$$\frac{990 \text{ lb}}{7.41 \text{ CY}} = 134 \text{ lb/CY}$$

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Intake Dam		SHEET NO. 10	OF 10
ITEM Bollards		BY LEP	DATE Jan 08
		CHKD. BY	DATE

Ice sheet thickness = 22 in (prev. calcs.)

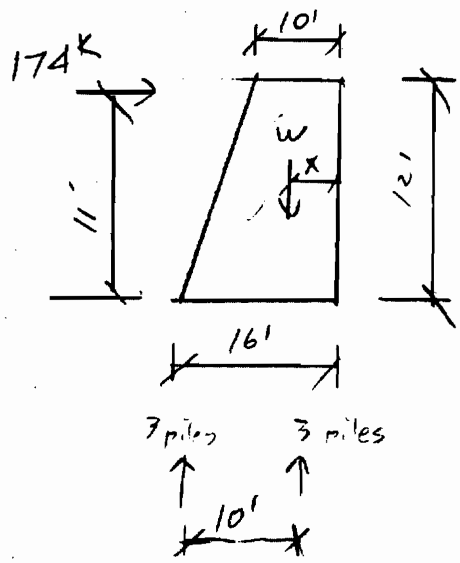
Ice compressive strength = 110 psi (CREL report, Springtime ice run)

AASHTO 2002

Crushing $F_c = C_n \, t \, p \, w$

$F_c = 0.75(22 \text{ in})(110 \text{ lb/in}^2)(8 \times 12 \text{ in}) / (1000 \text{ lb/k})$

$F_c = 174^k$



$W = 162^k$

$x = 6.6$ ft.

$M = 174(11) + 162\left[\frac{16}{2} - 6.6\right)$

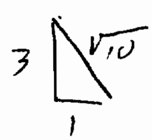
$M = 2140$

$\Sigma A d^2 = 6(5)^2 = 150 \text{ ft}^2$

$\frac{P}{A} \pm \frac{Mc}{I} = \frac{162}{6} \pm \frac{2140(5)}{150} = 27 \pm 71$

$\left[\text{vertical load} = \begin{matrix} 44^k \text{ tension} \\ 98^k \text{ compr.} \end{matrix}\right]$

horizontal load $= \frac{174}{3} = 58^k$ per battered pile



added $P = 58\sqrt{10} = 183^k$

$P_{max} = 98 + 183 = 281^k < 405^k$ ok

Appendix D
Cost

FINAL REPORT

Lower Yellowstone Project

Fish Screening and Sediment Sluicing

Preliminary Design Report

February 2008

US Army Corps of Engineers ®
Omaha District

CI12403 Intake Structure

Estimated by	CENWO-ED-C
Designed by	CENWO
Prepared by	Hightower
Preparation Date	1/11/2008
Effective Date of Pricing	1/11/2008
Estimated Construction Time	365 Days

Owner Markups used to get cost from Contract Cost to Project Cost

Escalation = 5%
Contingency = 25%
E & D = 9%
S & A = 6%

Description	ContractCost	ProjectCost
Intake Structure	**31,135,095.22**	**47,215,204.34**
Headwork Outlet	**12,944,410.56**	**19,629,713.20**
Sluice in Channel Alternative	**10,058,202.06**	**15,252,886.24**
Concrete Pipe Sluice Alternative	**7,310,342.75**	**11,085,860.65**
In-Abutment Open Cut Alternative	**822,139.84**	**1,246,744.24**

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	Quantity	UOM	ContractCost	ProjectCost
Level 2			**31,135,095.22**	**47,215,204.34**
Headwork Outlet	**1.0000**	**EA**	**12,944,410.56**	**19,629,713.20**
Earthwork	**1.0000**	**EA**	**1,008,586.70**	**1,529,483.90**
Diversion of Water	**1.0000**	**EA**	**380,063.93**	**576,352.70**
Gated Intake Structure	**1.0000**	**EA**	**11,037,333.32**	**16,737,702.08**
Concrete Bollards	**5.0000**	**EA**	**116,069.62**	**176,015.22**
Electrical	**1.0000**	**EA**	**232,090.23**	**351,956.13**
MDU Electrical Cost	**1.0000**	**EA**	**170,266.77**	**258,203.17**
Sluice in Channel Alternative	**1.0000**	**EA**	**10,058,202.06**	**15,252,886.24**
Upstream Wall - Section 5/S5.05	**307.0000**	**LF**	**533,812.74**	**809,507.00**
Gate Structure - Section 7/S5.06	**1.0000**	**EA**	**1,023,364.45**	**1,551,893.81**
Conduit - Section 8/S5.06	**1.0000**	**EA**	**7,398,820.36**	**11,220,033.63**
Diversion of Water	**1.0000**	**EA**	**1,048,002.47**	**1,589,256.45**
Place Riprap	**1,550.0000**	**TON**	**44,704.66**	**67,792.94**
Place Bedding	**265.0000**	**TON**	**6,877.92**	**10,430.10**
Geotextile Filter	**640.0000**	**SY**	**2,619.47**	**3,972.32**
Concrete Pipe Sluice Alternative	**1.0000**	**EA**	**7,310,342.75**	**11,085,860.65**
Section 10/S5.07	**1.0000**	**EA**	**81,371.41**	**123,396.70**
Section 9/S5.07	**1.0000**	**EA**	**5,866,975.19**	**8,897,047.87**
Earthwork	**1.0000**	**EA**	**1,195,855.48**	**1,813,469.99**
Diversion of Water	**1.0000**	**EA**	**122,091.60**	**185,147.33**
Place Riprap	**1,260.0000**	**TON**	**36,340.56**	**55,109.10**
Place Bedding	**215.0000**	**TON**	**5,580.20**	**8,462.16**
Geotextile Filter	**520.0000**	**SY**	**2,128.32**	**3,227.51**
In-Abutment Open Cut Alternative	**1.0000**	**EA**	**822,139.84**	**1,246,744.24**
Earthwork	**1.0000**	**EA**	**778,090.77**	**1,179,945.47**
Place Riprap	**1,260.0000**	**TON**	**36,340.56**	**55,109.10**
Place Bedding	**215.0000**	**TON**	**5,580.20**	**8,462.16**
Geotextile Filter	**520.0000**	**SY**	**2,128.32**	**3,227.51**

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	Quantity	UOM	ContractCost	ProjectCost
Level 3			31,135,095.22	47,215,204.34
Headwork Outlet	1.0000	EA	12,944,410.56	19,629,713.20
Earthwork	1.0000	EA	1,008,586.70	1,529,483.90
Excavation	204,100.0000	CY	855,463.72	1,297,278.65
Backfill and Compaction	40,000.0000	CY	153,122.98	232,205.25
Diversion of Water	1.0000	EA	380,063.93	576,352.70
Construct Cofferdam	1,900.0000	CY	36,584.49	55,479.01
Dewatering	1.0000	EA	333,629.82	505,937.12
Remove Cofferdam	1,900.0000	CY	9,849.61	14,936.57
Gated Intake Structure	1.0000	EA	11,037,333.32	16,737,702.08
Intake Structure	1.0000	EA	10,480,642.92	15,893,501.96
Access Bridge	1.0000	EA	319,019.33	483,780.85
Wingwall	1.0000	EA	237,671.08	360,419.27
Concrete Bollards	5.0000	EA	116,069.62	176,015.22
Earthwork	1.0000	EA	620.41	940.83
Steel HP 12x53 Piles	30.0000	EA	25,246.39	38,285.20
Concrete Bollard	5.0000	EA	90,202.81	136,789.18
Electrical	1.0000	EA	232,090.23	351,956.13
Digital Meter	1.0000	EA	976.54	1,480.88
Automatic Transfer Switch	1.0000	EA	10,533.78	15,974.08
Standby Generator	1.0000	EA	44,150.73	66,952.93
Main Distribution Panel	1.0000	EA	7,852.37	11,907.83
Panels	4.0000	EA	11,694.33	17,734.01
Fish Screen Main Disconnect Switch	14.0000	EA	881.46	1,336.70
Fish Screen Controllers	14.0000	EA	42,213.59	64,015.32
Fish Screen Hoist	14.0000	EA	42,213.59	64,015.32
Fish Screen Intake Gate Hoist Controllers	14.0000	EA	42,213.59	64,015.32
Sluice Gate Main Disconnect Switch	1.0000	EA	1,066.29	1,616.99
Screen Pumps	4.0000	EA	18,902.73	28,665.28
Feeder Lines	1.0000	EA	9,391.23	14,241.45
MDU Electrical Cost	1.0000	EA	170,266.77	258,203.17
Sluice in Channel Alternative	1.0000	EA	10,058,202.06	15,252,886.24
Upstream Wall - Section 5/S5.05	307.0000	LF	533,812.74	809,507.00
Earthwork	1.0000	EA	33,007.50	50,054.63
Steel HP 12x53 Piles	152.0000	EA	127,915.04	193,978.36
Bottom Slab	1.0000	EA	257,460.12	390,428.62
Concrete Wall	1.0000	EA	115,430.08	175,045.39
Gate Structure - Section 7/S5.06	1.0000	EA	1,023,364.45	1,551,893.81
Earthwork	1.0000	EA	13,709.56	20,790.04
40'-0" Concrete Slab	1.0000	EA	24,983.96	37,887.24
Steel HP 12x53 Piles	18.0000	EA	15,147.83	22,971.12
Concrete Foundation	1.0000	EA	79,603.25	120,715.35

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	Quantity	UOM	ContractCost	ProjectCost
Downstream Wall	1.0000	EA	33,624.58	50,990.42
Bridge Pier	1.0000	EA	20,273.90	30,744.60
End Walls	1.0000	EA	30,027.68	45,535.85
Concrete Slab Bridge	1.0000	EA	7,591.81	11,512.69
Sluice Gate & Frame	4.0000	EA	666,881.31	1,011,300.50
Handrailing	1.0000	EA	4,651.03	7,053.12
Galvinized Steel Bar Trash Rack	4.0000	EA	110,277.85	167,232.23
Electrical	1.0000	EA	16,591.68	25,160.66
Conduit - Section 8/S5.06	1.0000	EA	7,398,820.36	11,220,033.63
Earthwork	1.0000	EA	430,593.77	652,979.30
Grade Beams	1.0000	EA	552,365.09	837,640.94
Bottom Slab	1.0000	EA	1,890,833.33	2,867,377.83
Sidewalls	1.0000	EA	1,397,347.28	2,119,024.75
Middle Wall	1.0000	EA	655,403.47	993,894.78
Top Slab	1.0000	EA	2,258,812.87	3,425,405.02
Place Bedding	8,300.0000	TON	213,464.56	323,711.00
Diversion of Water	1.0000	EA	1,048,002.47	1,589,256.45
Construct Cofferdam	22,000.0000	CY	373,776.91	566,818.67
Dewatering	1.0000	EA	564,707.55	856,357.82
Remove Cofferdam	22,000.0000	CY	109,518.01	166,079.96
Place Riprap	1,550.0000	TON	44,704.66	67,792.94
Placement	1,550.0000	TON	13,426.03	20,360.06
Material - Riprap	1,550.0000	TON	31,278.64	47,432.88
Place Bedding	265.0000	TON	6,877.92	10,430.10
Placement	265.0000	TON	1,530.28	2,320.61
Material - Bedding	265.0000	TON	5,347.64	8,109.49
Geotextile Filter	640.0000	SY	2,619.47	3,972.32
Concrete Pipe Sluice Alternative	1.0000	EA	7,310,342.75	11,085,860.65
Section 10/S5.07	1.0000	EA	81,371.41	123,396.70
Footing	1.0000	EA	40,022.64	60,692.83
Retaining Wall	1.0000	EA	41,348.78	62,703.87
Section 9/S5.07	1.0000	EA	5,866,975.19	8,897,047.87
Retaining Wall	1.0000	EA	76,746.10	116,382.58
Concrete Box Culverts	1.0000	EA	5,438,604.45	8,247,439.70
Heavy Duty Cast Iron Flap Gate	4.0000	EA	351,624.64	533,225.59
Earthwork	1.0000	EA	1,195,855.48	1,813,469.99
Clear Area	3.5000	ACR	1,194.73	1,811.77
Topsoil Stripping	1,700.0000	CY	6,521.51	9,889.63
Topsoil Replacement	1,700.0000	CY	6,360.67	9,645.72
Excavation	180,000.0000	CY	759,493.24	1,151,743.02
Backfill and Compaction	84,000.0000	CY	417,925.55	633,768.42
Seeding and Mulching	3.5000	ACR	4,359.76	6,611.42

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	Quantity	UOM	ContractCost	ProjectCost
Diversion of Water	**1.0000**	**EA**	**122,091.60**	**185,147.33**
Construct Cofferdam	**1,900.0000**	**CY**	**36,584.49**	**55,479.01**
Dewatering	**1.0000**	**EA**	**72,931.99**	**110,598.63**
Remove Cofferdam	**1,900.0000**	**CY**	**12,575.11**	**19,069.68**
Place Riprap	**1,260.0000**	**TON**	**36,340.56**	**55,109.10**
Placement	**1,260.0000**	**TON**	**10,914.06**	**16,550.76**
Material - Riprap	**1,260.0000**	**TON**	**25,426.50**	**38,558.34**
Place Bedding	**215.0000**	**TON**	**5,580.20**	**8,462.16**
Placement	**215.0000**	**TON**	**1,241.55**	**1,882.76**
Material - Bedding	**215.0000**	**TON**	**4,338.65**	**6,579.40**
Geotextile Filter	**520.0000**	**SY**	**2,128.32**	**3,227.51**
In-Abutment Open Cut Alternative	**1.0000**	**EA**	**822,139.84**	**1,246,744.24**
Earthwork	**1.0000**	**EA**	**778,090.77**	**1,179,945.47**
Clear Area	**3.5000**	**ACR**	**1,194.73**	**1,811.77**
Topsoil Stripping	**1,700.0000**	**CY**	**6,521.51**	**9,889.63**
Topsoil Replacement	**1,700.0000**	**CY**	**6,521.51**	**9,889.63**
Excavation	**180,000.0000**	**CY**	**759,493.24**	**1,151,743.02**
Seeding and Mulching	**3.5000**	**ACR**	**4,359.76**	**6,611.42**
Place Riprap	**1,260.0000**	**TON**	**36,340.56**	**55,109.10**
Placement	**1,260.0000**	**TON**	**10,914.06**	**16,550.76**
Material - Riprap	**1,260.0000**	**TON**	**25,426.50**	**38,558.34**
Place Bedding	**215.0000**	**TON**	**5,580.20**	**8,462.16**
Placement	**215.0000**	**TON**	**1,241.55**	**1,882.76**
Material - Bedding	**215.0000**	**TON**	**4,338.65**	**6,579.40**
Geotextile Filter	**520.0000**	**SY**	**2,128.32**	**3,227.51**

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	UOM	Quantity	ContractCost	ProjectCost
Level 4			31,135,095.22	47,215,204.34
Headwork Outlet	EA	1.0000	12,944,410.56	19,629,713.20
Earthwork	EA	1.0000	1,008,586.70	1,529,483.90
Excavation	CY	204,100.0000	855,463.72	1,297,278.65
Excavate and Haul Soil	CY	61,100.0000	220,504.22	334,386.37
Excavate and Haul Rock	CY	103,000.0000	497,480.40	754,410.38
Excavate Soil - Use For Backfill	CY	40,000.0000	137,479.10	208,481.90
Backfill and Compaction	CY	40,000.0000	153,122.98	232,205.25
Backfill & Compact - Compaction Factor 1.2	CY	48,000.0000	153,122.98	232,205.25
Diversion of Water	EA	1.0000	380,063.93	576,352.70
Construct Cofferdam	CY	1,900.0000	36,584.49	55,479.01
Excavate and Haul Soil	CY	1,900.0000	7,008.94	10,628.80
Spread/Combact Embankment	CY	1,900.0000	10,252.54	15,547.60
Place Riprap	TON	400.0000	11,536.69	17,494.95
Place Bedding	TON	300.0000	7,786.32	11,807.66
Dewatering	EA	1.0000	333,629.82	505,937.12
Surface Pump	DAY	150.0000	212,097.18	321,637.41
Dewatering Wells (Placement)	EA	2.0000	6,383.02	9,679.62
Dewatering Wells (Removal)	EA	2.0000	1,374.51	2,084.39
Well Maintenance	DAY	150.0000	113,775.11	172,535.69
Remove Cofferdam	CY	1,900.0000	9,849.61	14,936.57
Gated Intake Structure	EA	1.0000	11,037,333.32	16,737,702.08
Intake Structure	EA	1.0000	10,480,642.92	15,893,501.96
Steel HP 12x53 Piles	EA	152.0000	127,915.04	193,978.36
Steel Sheet Pile Cutoff Wall	SF	6,140.0000	273,740.56	415,117.29
Bottom Slab	EA	1.0000	414,342.11	628,334.27
Sidewalls	EA	1.0000	296,917.20	450,263.80
Wetwell Wall	EA	1.0000	295,134.78	447,560.83
Bridge Pier	EA	1.0000	254,565.31	386,038.75
End Walls	EA	1.0000	45,809.24	69,467.99
Concrete Slab Bridge	EA	1.0000	257,381.03	390,308.67
Edge Walls on Bridge	EA	1.0000	98,535.45	149,425.32
Sluice Gate & Frame	EA	14.0000	1,258,454.97	1,908,399.76
Pipe Bollards	EA	28.0000	19,956.93	30,263.93
Handrailing	EA	1.0000	39,673.29	60,163.06
Rotating Cylindrial Intake Screen	EA	14.0000	7,088,142.49	10,748,902.28
Place Riprap	TON	211.0000	6,010.98	9,115.42
Place Bedding	TON	158.0000	4,063.54	6,162.21
Access Bridge	EA	1.0000	319,019.33	483,780.85
Steel HP 12x53 Piles	EA	28.0000	23,563.30	35,732.86
Steel Sheet Pile Cutoff Wall	SF	1,520.0000	67,766.39	102,765.19
Bottom Slab	EA	1.0000	62,225.75	94,363.02

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	UOM	Quantity	ContractCost	ProjectCost
Cutoff Wall	EA	1.0000	73,197.32	111,000.99
Bridge Pier	EA	1.0000	24,897.27	37,755.78
Concrete Slab Bridge	EA	1.0000	37,931.55	57,521.77
Edge Walls on Bridge	EA	1.0000	21,092.03	31,985.28
Handrailing	EA	1.0000	8,345.72	12,655.97
Wingwall	EA	1.0000	237,671.08	360,419.27
Steel HP 12x53 Piles	EA	28.0000	23,563.30	35,732.86
Steel Sheet Pile Cutoff Wall	SF	1,520.0000	67,766.39	102,765.19
Concrete Foundation Slab	EA	1.0000	62,225.75	94,363.02
Retaining Wall	EA	1.0000	84,115.64	127,558.21
Concrete Bollards	EA	5.0000	116,069.62	176,015.22
Earthwork	EA	1.0000	620.41	940.83
Steel HP 12x53 Piles	EA	30.0000	25,246.39	38,285.20
Concrete Bollard	EA	5.0000	90,202.81	136,789.18
Place Forms	SF	2,100.0000	24,846.80	37,679.23
Place Rebars	LB	27,300.0000	26,521.07	40,218.21
Place Concrete	CY	210.0000	35,031.88	53,124.53
Remove Forms	SF	2,100.0000	3,803.07	5,767.21
Electrical	EA	1.0000	232,090.23	351,956.13
Digital Meter	EA	1.0000	976.54	1,480.88
Automatic Transfer Switch	EA	1.0000	10,533.78	15,974.08
Standby Generator	EA	1.0000	44,150.73	66,952.93
Main Distribution Panel	EA	1.0000	7,852.37	11,907.83
Panels	EA	4.0000	11,694.33	17,734.01
Fish Screen Main Disconnect Switch	EA	14.0000	881.46	1,336.70
Fish Screen Controllers	EA	14.0000	42,213.59	64,015.32
Fish Screen Hoist	EA	14.0000	42,213.59	64,015.32
Fish Screen Intake Gate Hoist Controllers	EA	14.0000	42,213.59	64,015.32
Sluice Gate Main Disconnect Switch	EA	1.0000	1,066.29	1,616.99
Screen Pumps	EA	4.0000	18,902.73	28,665.28
Feeder Lines	EA	1.0000	9,391.23	14,241.45
Line 110 (NG)	LF	150.0000	4,523.10	6,859.11
Line 30 (G)	LF	10.0000	124.59	188.94
Screen Pump	EA	1.0000	506.55	768.17
Gate Hoist	EA	1.0000	4,236.99	6,425.23
MDU Electrical Cost	EA	1.0000	170,266.77	258,203.17
Sluice in Channel Alternative	EA	1.0000	10,058,202.06	15,252,886.24
Upstream Wall - Section 5/S5.05	LF	307.0000	533,812.74	809,507.00
Earthwork	EA	1.0000	33,007.50	50,054.63
Excavation	CY	4,650.0000	24,051.95	36,473.88
Backfill and Compaction	CY	1,800.0000	8,955.55	13,580.75
Steel HP 12x53 Piles	EA	152.0000	127,915.04	193,978.36

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	UOM	Quantity	ContractCost	ProjectCost
Bottom Slab	EA	1.0000	257,460.12	390,428.62
Place Forms	SF	1,962.0000	13,831.97	20,975.66
Place Rebars	LB	93,080.0000	104,021.23	157,744.29
Place Concrete	CY	716.0000	136,645.96	207,218.48
Remove Forms	SF	1,962.0000	2,960.96	4,490.19
Concrete Wall	EA	1.0000	115,430.08	175,045.39
Place Forms	SF	4,044.0000	32,327.45	49,023.37
Place Rebars	LB	31,590.0000	30,688.67	46,538.22
Place Concrete	CY	231.0000	45,090.33	68,377.80
Remove Forms	SF	4,044.0000	7,323.62	11,106.00
Gate Structure - Section 7/S5.06	EA	1.0000	1,023,364.45	1,551,893.81
Earthwork	EA	1.0000	13,709.56	20,790.04
Excavation	CY	1,000.0000	4,754.02	7,209.29
Backfill and Compaction	CY	1,800.0000	8,955.55	13,580.75
40'-0" Concrete Slab	EA	1.0000	24,983.96	37,887.24
Place Forms	SF	170.0000	1,198.49	1,817.46
Place Rebars	LB	9,100.0000	10,169.67	15,421.93
Place Concrete	CY	70.0000	13,359.24	20,258.79
Remove Forms	SF	170.0000	256.56	389.06
Steel HP 12x53 Piles	EA	18.0000	15,147.83	22,971.12
Concrete Foundation	EA	1.0000	79,603.25	120,715.35
Place Forms	SF	700.0000	4,934.95	7,483.67
Place Rebars	LB	28,470.0000	31,816.55	48,248.60
Place Concrete	CY	219.0000	41,795.34	63,381.07
Remove Forms	SF	700.0000	1,056.41	1,602.00
Downstream Wall	EA	1.0000	33,624.58	50,990.42
Place Forms	SF	1,626.0000	12,998.13	19,711.18
Place Rebars	LB	7,150.0000	6,946.00	10,533.34
Place Concrete	CY	55.0000	10,735.79	16,280.43
Remove Forms	SF	1,626.0000	2,944.66	4,465.47
Bridge Pier	EA	1.0000	20,273.90	30,744.60
Place Forms	SF	987.0000	7,890.01	11,964.90
Place Rebars	LB	4,277.0000	4,154.97	6,300.85
Place Concrete	CY	33.0000	6,441.48	9,768.26
Remove Forms	SF	987.0000	1,787.44	2,710.59
End Walls	EA	1.0000	30,027.68	45,535.85
Place Forms	SF	1,128.0000	9,017.15	13,674.17
Place Rebars	LB	7,670.0000	7,451.16	11,299.40
Place Concrete	CY	59.0000	11,516.58	17,464.46
Remove Forms	SF	1,128.0000	2,042.79	3,097.82
Concrete Slab Bridge	EA	1.0000	7,591.81	11,512.69
Place Elevated Forms	SF	222.0000	1,934.04	2,932.91

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	UOM	Quantity	ContractCost	ProjectCost
Place Edge Forms	SF	106.0000	738.81	1,120.38
Place Rebars	LB	1,820.0000	1,789.46	2,713.65
Place Concrete	CY	14.0000	2,679.85	4,063.89
Remove Elevated Forms	SF	222.0000	283.49	429.90
Remove Edge Forms	SF	106.0000	166.14	251.95
Sluice Gate & Frame	EA	4.0000	666,881.31	1,011,300.50
Handrailing	EA	1.0000	4,651.03	7,053.12
Galvinized Steel Bar Trash Rack	EA	4.0000	110,277.85	167,232.23
Electrical	EA	1.0000	16,591.68	25,160.66
Panels	EA	1.0000	2,923.58	4,433.50
Sluice Gate Hoist Controllers	EA	4.0000	12,061.02	18,290.09
Feeder Lines	EA	1.0000	1,607.07	2,437.06
Conduit - Section 8/S5.06	EA	1.0000	7,398,820.36	11,220,033.63
Earthwork	EA	1.0000	430,593.77	652,979.30
Excavation	CY	45,700.0000	256,413.51	388,841.48
Backfill and Compaction	CY	7,450.0000	34,837.24	52,829.37
Backfill and Compaction Select Fill	CY	7,450.0000	139,343.01	211,308.45
Grade Beams	EA	1.0000	552,365.09	837,640.94
Place Forms	SF	28,952.0000	231,440.25	350,970.47
Place Rebars	LB	108,603.0000	105,504.32	159,993.35
Place Concrete	CY	835.0000	162,988.87	247,166.51
Remove Forms	SF	28,952.0000	52,431.64	79,510.62
Bottom Slab	EA	1.0000	1,890,833.33	2,867,377.83
Place Forms	SF	6,140.0000	43,286.59	65,642.49
Place Rebars	LB	710,970.0000	794,542.04	1,204,893.20
Place Concrete	CY	5,469.0000	1,043,738.49	1,582,790.28
Remove Forms	SF	6,140.0000	9,266.21	14,051.86
Sidewalls	EA	1.0000	1,397,347.28	2,119,024.75
Place Forms	SF	81,627.0000	652,520.50	989,522.87
Place Rebars	LB	241,410.0000	234,522.05	355,643.90
Place Concrete	CY	1,857.0000	362,479.44	549,686.48
Remove Forms	SF	81,627.0000	147,825.29	224,171.50
Middle Wall	EA	1.0000	655,403.47	993,894.78
Place Forms	SF	40,813.0000	326,256.25	494,755.37
Place Rebars	LB	103,194.0000	100,249.65	152,024.84
Place Concrete	CY	794.0000	154,985.82	235,030.19
Remove Forms	SF	40,813.0000	73,911.74	112,084.38
Top Slab	EA	1.0000	2,258,812.87	3,425,405.02
Place Elevated Forms	SF	90,463.0000	788,105.59	1,195,132.57
Place Edge Forms	SF	4,827.0000	33,643.86	51,019.65
Place Rebars	LB	535,080.0000	526,102.06	797,814.04
Place Concrete	CY	4,116.0000	787,876.36	1,194,784.95

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	UOM	Quantity	ContractCost	ProjectCost
Remove Elevated Forms	SF	90,463.0000	115,519.14	175,180.45
Remove Edge Forms	SF	4,827.0000	7,565.87	11,473.35
Place Bedding	TON	8,300.0000	213,464.56	323,711.00
Placement	TON	8,300.0000	45,972.51	69,715.58
Material - Bedding	TON	8,300.0000	167,492.05	253,995.41
Diversion of Water	EA	1.0000	1,048,002.47	1,589,256.45
Construct Cofferdam	CY	22,000.0000	373,776.91	566,818.67
Excavate and Haul Soil	CY	22,000.0000	81,156.18	123,070.31
Spread/Combact Embankment	CY	22,000.0000	118,713.67	180,024.83
Place Riprap	TON	3,600.0000	103,830.18	157,454.57
Place Bedding	TON	2,700.0000	70,076.88	106,268.96
Dewatering	EA	1.0000	564,707.55	856,357.82
Surface Pump	DAY	150.0000	427,659.83	648,530.10
Dewatering Wells (Placement)	EA	6.0000	19,149.07	29,038.85
Dewatering Wells (Removal)	EA	6.0000	4,123.53	6,253.18
Well Maintenance	DAY	150.0000	113,775.11	172,535.69
Remove Cofferdam	CY	22,000.0000	109,518.01	166,079.96
Place Riprap	TON	1,550.0000	44,704.66	67,792.94
Placement	TON	1,550.0000	13,426.03	20,360.06
Material - Riprap	TON	1,550.0000	31,278.64	47,432.88
Place Bedding	TON	265.0000	6,877.92	10,430.10
Placement	TON	265.0000	1,530.28	2,320.61
Material - Bedding	TON	265.0000	5,347.64	8,109.49
Geotextile Filter	SY	640.0000	2,619.47	3,972.32
Concrete Pipe Sluice Alternative	EA	1.0000	7,310,342.75	11,085,860.65
Section 10/S5.07	EA	1.0000	81,371.41	123,396.70
Footing	EA	1.0000	40,022.64	60,692.83
Place Forms	SF	474.0000	3,341.67	5,067.51
Place Rebars	LB	13,910.0000	15,545.07	23,573.52
Place Concrete	CY	107.0000	20,420.56	30,967.01
Remove Forms	SF	474.0000	715.34	1,084.78
Retaining Wall	EA	1.0000	41,348.78	62,703.87
Place Forms	SF	2,381.0000	19,033.55	28,863.66
Place Rebars	LB	7,280.0000	7,072.29	10,724.86
Place Concrete	CY	56.0000	10,930.99	16,576.44
Remove Forms	SF	2,381.0000	4,311.96	6,538.92
Section 9/S5.07	EA	1.0000	5,866,975.19	8,897,047.87
Retaining Wall	EA	1.0000	76,746.10	116,382.58
Footing	EA	1.0000	39,186.17	59,424.35
Retaining Wall	EA	1.0000	37,559.93	56,958.23
Concrete Box Culverts	EA	1.0000	5,438,604.45	8,247,439.70
Bottom Slab	EA	1.0000	605,029.25	917,504.16

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	UOM	Quantity	ContractCost	ProjectCost
Walls	EA	1.0000	3,667,606.93	5,561,788.38
Top Slab	EA	1.0000	1,165,968.27	1,768,147.16
Heavy Duty Cast Iron Flap Gate	EA	4.0000	351,624.64	533,225.59
Earthwork	EA	1.0000	1,195,855.48	1,813,469.99
Clear Area	ACR	3.5000	1,194.73	1,811.77
Topsoil Stripping	CY	1,700.0000	6,521.51	9,889.63
Topsoil Replacement	CY	1,700.0000	6,360.67	9,645.72
Excavation	CY	180,000.0000	759,493.24	1,151,743.02
Excavate and Haul Rock	CY	90,000.0000	434,691.61	659,193.53
Excavate Soil - Use For Backfill	CY	84,000.0000	303,148.18	459,712.85
Excavate and Haul Soil	CY	6,000.0000	21,653.44	32,836.63
Backfill and Compaction	CY	84,000.0000	417,925.55	633,768.42
Backfill & Compact - Compaction Factor 1.2	CY	100,800.0000	417,925.55	633,768.42
Seeding and Mulching	ACR	3.5000	4,359.76	6,611.42
Diversion of Water	EA	1.0000	122,091.60	185,147.33
Construct Cofferdam	CY	1,900.0000	36,584.49	55,479.01
Excavate and Haul Soil	CY	1,900.0000	7,008.94	10,628.80
Spread/Combact Embankment	CY	1,900.0000	10,252.54	15,547.60
Place Riprap	TON	400.0000	11,536.69	17,494.95
Place Bedding	TON	300.0000	7,786.32	11,807.66
Dewatering	EA	1.0000	72,931.99	110,598.63
Surface Pump	DAY	30.0000	42,419.44	64,327.48
Dewatering Wells (Placement)	EA	2.0000	6,383.02	9,679.62
Dewatering Wells (Removal)	EA	2.0000	1,374.51	2,084.39
Well Maintenance	DAY	30.0000	22,755.02	34,507.14
Remove Cofferdam	CY	1,900.0000	12,575.11	19,069.68
Place Riprap	TON	1,260.0000	36,340.56	55,109.10
Placement	TON	1,260.0000	10,914.06	16,550.76
Material - Riprap	TON	1,260.0000	25,426.50	38,558.34
Place Bedding	TON	215.0000	5,580.20	8,462.16
Placement	TON	215.0000	1,241.55	1,882.76
Material - Bedding	TON	215.0000	4,338.65	6,579.40
Geotextile Filter	SY	520.0000	2,128.32	3,227.51
In-Abutment Open Cut Alternative	EA	1.0000	822,139.84	1,246,744.24
Earthwork	EA	1.0000	778,090.77	1,179,945.47
Clear Area	ACR	3.5000	1,194.73	1,811.77
Topsoil Stripping	CY	1,700.0000	6,521.51	9,889.63
Topsoil Replacement	CY	1,700.0000	6,521.51	9,889.63
Excavation	CY	180,000.0000	759,493.24	1,151,743.02
Excavate and Haul Rock	CY	90,000.0000	434,691.61	659,193.53
Excavate and Haul Soil	CY	90,000.0000	324,801.63	492,549.49
Seeding and Mulching	ACR	3.5000	4,359.76	6,611.42

Labor ID: LB06NatFD EQ ID: EP03R04 Currency in US dollars TRACES MII Version 2.2

Description	UOM	Quantity	ContractCost	ProjectCost
Place Riprap	**TON**	**1,260.0000**	**36,340.56**	**55,109.10**
Placement	**TON**	**1,260.0000**	**10,914.06**	**16,550.76**
Material - Riprap	**TON**	**1,260.0000**	**25,426.50**	**38,558.34**
Place Bedding	**TON**	**215.0000**	**5,580.20**	**8,462.16**
Placement	**TON**	**215.0000**	**1,241.55**	**1,882.76**
Material - Bedding	**TON**	**215.0000**	**4,338.65**	**6,579.40**
Geotextile Filter	**SY**	**520.0000**	**2,128.32**	**3,227.51**

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