Coon Rapids Dam Fish Barrier and Improvements Preliminary Design

Minnesota Department of Natural Resources
St. Paul, Minnesota

FINAL
February 17, 2011

Stanley Consultants INC

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I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

Signature: Martin J. Weber Typed or Printed Name: Martin Weber, P.E.

Date: 2011.02.17 Reg. No: 20419

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

Signature: Bill Holman Typed or Printed Name: Bill Holman, P.E.

Date: 2011.02.17 Reg. No: 24427

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Executive Summary

The primary goal of this preliminary design effort was to identify the improvement measures required to meet the Minnesota Department of Natural Resources' objectives for the Coon Rapids Dam which primarily consists of preventing the migration of invasive fish species for decades to come.

The most practical and economic method to impede the upstream migration of invasive fish was determined to be a physical barrier that utilizes the natural fall and velocity of water over the existing spillway. The existing Dam and existing upstream pool level operating procedure would serve as an effective barrier approximately 89.1 percent of the time[1]. An improved dam structure coupled with a modified upstream pool level operating procedure that maintains the summer recreational pool year-round would serve as an effective barrier approximately 99.9 percent of the time. Preliminary design of improvements necessary to provide an improved invasive fish barrier and to prolong the overall life of the Dam was completed. Major improvements include replacement of the main spillway inflatable gate system and implementation of downstream scour protection measures. The estimated capital cost for improvements totals $16.9 million (2011).

It is recommended that the proposed dam improvements and modified pool operating procedure be considered by State and Federal agencies as part of an overall plan for control of invasive fish species migration into the waters of the State of Minnesota including the Upper Mississippi River Watershed.

[1] Statistical percent of time based on 79 years of historic river flow data, excluding effects of periodic ice jams.

Section 1

Conclusions and Recommendations

1.1 Conclusions

The primary goal of this preliminary design effort was to identify the improvement measures required to meet long term (50-year) objectives for the Coon Rapids Dam. These objectives include:

- Prevention of upstream migration of invasive fish,
- Protecting the Dam against downstream scour,
- Providing long-term solution to main spillway gate system,
- Maintain existing spillway capacity,
- Maintain key recreational features,
- Maintain pool levels such that shoreline properties are not adversely impacted, and
- Maintain feasibility for future hydropower development.

The most practical and economic method to impede upstream migration of invasive fish was determined to be a physical barrier that utilizes the natural fall and velocity of water over the spillway to prevent migration. A modified dam and modified operating procedure would be a significant contribution to impeding passage of invasive fish passage. However it should be noted that fish passage may still be possible under very high river flow conditions and abnormally high tailwater conditions resulting from downstream ice jams.

Preliminary design of improvements necessary to provide an improved invasive fish barrier and to prolong the overall life of the Dam was completed. Improvements that were identified contribute to achievement of the long term objectives of the Dam with the exception of the maintenance of upstream pool levels. The invasive fish barrier analysis concluded that modifying the existing pool operation (i.e. maintaining the summer recreation pool year-round) greatly improves the barrier effectiveness of the Dam. Continued development of the modified pool operation scenario was therefore deemed prudent and its associated results are presented here.

The preliminary design served as the basis for development of initial capital costs to construct dam improvements. In addition annual operation, maintenance, and equipment replacements costs were developed for the subsequent 50-year period. Annual costs are presented in Section 5. Capital costs and other comparative results are presented in Table 1-1 below.

Table 1-1 Comparative Results

		Barrier Effectiveness[1]		Dam Improvements	
Gate System	Winter Pool Level	#Days[2]	Barrier Effectiveness[3]	Expected Dam Life (years)	Capital Cost[4] (million)
Existing	Drawdown	3,153	89.1	3±	$0
	830.1	211	99.2	5±	$0
New	Drawdown	3,127	89.2	50±	$16.6
	830.1	36	99.9	50±	$16.9
	829.1	78	99.7	50±	$16.9
	828.1	211	99.3	50±	$16.9
	827.1	629	97.8	50±	$16.9

[1] Excludes periodic tailwater ice jam effects.
[2] Indicates number of days the dam would have been passable in 79-year period of record.
[3] Indicates percent of days the dam would have been impassable in 79-year period of record.
[4] Cost base is year 2011.

1.2 Recommendations

It is recommended that the proposed Dam improvements and modified pool operating procedure be considered by State and Federal agencies as part of an overall plan for control of invasive fish species migration into the waters of the State of Minnesota including the Upper Mississippi River Watershed.

Section 2

Introduction

2.1 Background

Three Rivers Park District (District) currently owns and operates the Coon Rapids Dam (Dam), located on the Mississippi River in Brooklyn Park and Anoka, Minnesota. The Minnesota Department of Natural Resources (DNR) has identified the Dam as a potential barrier that could limit upstream migration of the group of invasive fish species known as "Asian carp". In the 2008 legislative session, the DNR received funding to evaluate measures that could be taken to prevent upstream migration of Asian carp, specifically to "*predesign, design, renovate, or construct an adequate barrier in the Mississippi River to prevent aquatic invasive species from migrating up river*". The DNR as well as other State and Federal agencies desire a long term invasive species barrier; therefore, dam improvements to enhance the Dam's effectiveness as a fish barrier, including a long term solution to the Dam's structural integrity, would be implemented.

Coon Rapids Dam also functions as a barrier to fish species formerly only native below St. Anthony Falls, but that now occupy the reach between the Dam and the Falls because navigation locks at St. Anthony have allowed them to bypass the former barrier. There are 119 native fish species found in the Mississippi River Watershed downstream of St. Anthony Falls, but only 65 native species have been found upstream of the falls. Invasion of some native species into the Upper Mississippi Watershed and especially systems like Lake Mille Lacs could significantly alter these ecosystems.

Three Rivers Park District agreed to solicit a scope of services and fee proposal from Stanley Consultants to prepare a recommended preliminary design with cost estimate. It was agreed that the District and DNR would provide oversight and review of the work. It was further agreed that the DNR would provide technical advisement in the development of a single design concept that may incorporate a combination of physical and behavioral invasive fish barrier technologies to be taken through preliminary design.

The Coon Rapids Dam Commission was established by the 2010 State Legislature to "*study options and make recommendations for the future of the Coon Rapids Dam, including its suitable public uses, governance, operation, and maintenance and financing of the Dam and its operations. The commission shall consider economic, environmental, ecological, and other pertinent factors*". This report is not directly related to the work of the Commission; however, the subject matter has been shared with and discussed by the Commission. The DNR intends to share this final report with the Commission as background for its deliberations and recommendations.

2.2 Objective

The overall objective of this report is to evaluate the Coon Rapids Dam for its effectiveness to act as an invasive fish barrier, to prepare conceptual designs for measures required to improve the Dam's effectiveness as a fish barrier, prepare conceptual designs to extend the life of the Dam for fifty years, and to estimate costs required to implement the improvements.

Primary design objectives for the Dam included the following.

- Provide a barrier that prevents upstream migration of invasive fish species to the extent practical.
- Create a solution that adequately controls and/or resists downstream scour action of the river.
- Incorporate a long-term plan of action for repair and/or replacement of the main spillway crest gate system (inflatable gates).
- Incorporate a long-term plan and include improvements that will preserve the Dam's structural integrity for a minimum of 50 years.
- Maintain existing spillway capacity of the Dam.
- Maintain recreational aspects of the structure, including the upstream impoundment (pool) and pedestrian river crossing (bridge).
- Maintain the elevation of the upstream impoundment (pool) such that shoreline properties are not adversely impacted.
- Not inhibit possible future development of a hydroelectric power facility at the Dam.

As the invasive fish barrier analysis unfolded, it became apparent that not all of the above objectives would be achievable. As described in detail in Section 3, modifying the existing pool operation greatly improves the barrier effectiveness of the Dam and it was therefore decided to continue development of the modified pool operation alternative throughout preliminary design.

Section 3

Invasive Fish Barrier Effectiveness

3.1 Overview

3.1.1 Invasive Fish Species

The DNR [1] has indicated that the spread of invasive species, particularly Asian carp, is a major concern of the DNR. "Asian carp" are defined by the DNR [2] as any one of four species native to Asia that have since been introduced into the United States. Species include black, bighead, grass, and silver carp. As reported by the Asian Carp Working Group (ACWG) [2]:

> *"Natural resources managers are concerned that Asian carps have the potential to cause extensive and irreversible changes to the aquatic environment, particularly those that have been extensively altered and are severely impacted by on-going physical and chemical stressors, thereby jeopardizing the long-term sustainability of native aquatic species, particularly to imperiled, threatened, and endangered species."*

Specific potential adverse effects of Asian carp reported by the ACWG [2] are summarized in Table 3-1 below:

Table 3-1 Potential Adverse Effects of Asian Carp

Impact	Species: Black	Bighead	Grass	Silver
Feed on Plankton [1]		✓		✓
Feed on Mussels/Snails	✓			
Dietary Overlap	✓	✓		✓
Alter Food Web Interactions		✓		✓
Commercial Fishery		✓		✓
Nonnative Pathogen Introduction	✓	✓	✓	✓
Habitat (Vegetation) Alteration			✓	
Water Quality			✓	
Human Safety				✓

[1] Plankton is primary food source for mussels, larval fish & several adult fishes.

The DNR [3] reports that although specific data is lacking as to the abilities of Asian carp, calculations based upon body size and leaping ability would put Asian carp in roughly the same category as Pacific salmonids with respect to burst and sustained swimming speeds. Given this, it is estimated that Asian carp have burst and sustained swimming speeds of 23 and 17 feet per second respectively.

Spawning and migratory habits of Asian carp were reported by the ACWG [2]. In general all four species tend to spawn and/or migrate upstream during periods of high river flows typically occurring in spring and early summer.

3.1.2 Potential Barrier Systems

At the onset of this effort, several potential fish barrier systems were discussed with respect to their effectiveness and feasibility for long term operation at Coon Rapids Dam. Such systems include those featuring electric current, acoustics, lights/strobe lights, and air bubbles. During the meeting held on August 26, 2010 (see Appendix D), Stanley Consultants, the DNR, and the District agreed to dismiss such "behavioral" barriers from further consideration due to their shortcomings which include:

- Barrier would need to be effective over entire length of spillway (~1000 feet)
- Barrier could be damaged or impeded by:
  - high river flows,
  - water level fluctuations,
  - ice jams/floes, and
  - cold climate
- Barrier would be difficult to operate and maintain

A physical barrier suspended from the bridge above the Dam was also considered. The system would be modular and portable such that it would only be installed during times when migration is possible, e.g. during high river flows. The barrier may be fabricated with heavy plastic grid that would allow water and air movement but prevent passage of a solid object. This option was also dismissed due to concerns over potential damage from ice and floating debris, significant operation/maintenance needs to remain effective, and reductions in walkway/bridge aesthetics and functionality.

Other potential migration/introduction preventive measures and barrier sites in Minnesota have been evaluated by FISHPRO [4] and the DNR [5]. Evaluation of other measures or barrier sites is beyond the scope of this report.

3.1.3 Selected Barrier System

The vast majority of water passing the Coon Rapids Dam flows over the main spillway. Less amounts of water flow over/through the ancillary discharge facilities associated with the old powerhouse structure. For a fish to make its way from the Dam's tailwater (downstream of Dam) to the pool (upstream of Dam), it must swim and/or leap up or through one of these discharge facilities. The Dam currently provides "natural" impediments to this movement including differential water elevation or "head" and water velocity. These impediments must be overcome by strong swimming and/or leaping ability.

3.1.4 Overview of Analysis

The effectiveness of Coon Rapids Dam as an invasive fish barrier was quantified through development of a detailed hydraulic model of the spillway. Modeling was performed over a range of river flows representing what has been recorded historically as well as existing and proposed spillway geometries. The output of the model was a water surface and velocity profile along the length of the spillway for a given flow and spillway geometry. Typically, the water surface and velocity profile shows a portion of the spillway that would be impassable to fish due to the high velocity associated flow accelerating down the spillway. Fish passage was evaluated by determining if the fish could physically jump over the impassable portion of the spillway and swim upstream to safety.

3.2 Input Parameters

3.2.1 River Flow

The United States Geological Survey (USGS) maintains a streamflow gage just downstream of the Dam near the Highway 610 Bridge [6]. Daily discharge has been recorded at this gage since 1931 providing a 79 year flow record at the Dam. At this point on the Mississippi River, the watershed area is approximately 19,100 square miles. The flow regime is not flashy, but historically flows have varied from approximately 1,000 cubic feet per second (cfs) to 90,000 cfs. Given the historic range of flows, hydraulic modeling was performed for river flows ranging from 10,000 cfs to 90,000 cfs in 10,000 cfs increments. A flow duration curve is shown on Figure 3-1. Table 3-2 and Figure 3-2 show the flood frequency characteristics for the Mississippi River at the Dam as reported by FEMA [7] and as independently determined by Stanley Consultants using the Log Pearson Type III Distribution.

Table 3-2 Flood Frequency for Mississippi River at Coon Rapids Dam

	Discharge, cfs	
Return Period (year)	FEMA	Stanley
1		7,000
2		30,400
5		45,300
10	50,200	54,400
25		65,000
50	74,800	72,300
100	85,500	79,000
500	113,000	

3.2.2 Tailwater

The relationship between river flow and tailwater elevation at Coon Rapids Dam has been well established. Between 2005 and 2007, the District staff made sixty-six tailwater measurements at the Dam. Using these measurements a relationship was developed between river flow and tailwater and a regression equation developed to estimate tailwater elevations over the range of river flows. A graph of the relationship between flow and tailwater is shown on Figure 3-3.

3.2.3 Dam Operation

Coon Rapids Dam is operated in compliance with a DNR Permit that requires maintenance and transition between a "summer" and "winter" pool which each have their own operating conditions. During winter operation, all gates are completely lowered and the pool level varies with river flow. "Winter" begins each year on November 1. During summer operation, gates are operated as necessary to maintain a constant pool elevation of 830.1. "Summer" begins each year on May 1 as long as the river flow is 20,000 cfs or less. If the river flow is greater than 20,000 cfs winter operation continues until the river flow falls below this threshold. This summer operation "delay" is consistent with the original DNR operating permit which states, *"As soon as practical after the spring run-off of the succeeding year, tainter gates shall be closed and the reservoir level returned to the normal reservoir elevation…"* A copy of the DNR operating permit is provided in Appendix E.

3.2.3.1 Existing Condition. During summer pool the pool elevation of 830.1 is maintained through adjustment of the inflatable gates and steel control gate. The five spillway gates (four inflatable, one steel) and various available settings allow for 31 separate gate configurations that are used to maintain the constant pool. The steel control gate has a variable setting so its crest can be set anywhere within its range of motion. The four inflatable gates can be fully inflated (crest elevation 830.1), fully deflated (crest elevation 822.5), or partially inflated (crest elevation ~828.1). When flows exceed roughly 10,000 cfs at least one of the inflatable gates is fully deflated.

During winter operation all gates are fully lowered to the Dam crest elevation of 822.5 and streamflow is passed over the spillway in an uncontrolled manner. The winter pool elevation is variable and dictated by the amount of water passing over the spillway.

3.2.3.2 Proposed Condition. In terms of fish passage, the major deficiency with the existing gate system is that even during summer operation; at least one of the gates is fully down for flows above 10,000 cfs. This creates a "weak link" in the Dam since there is a segment of the Dam that does not have the barrier feature created by a fully or partially raised gate. It was determined that a crest gate system featuring gates with full range of motion and where all gates are raised and lowered in tandem would provide an improved barrier. This "crest" gate configuration was analyzed as the proposed condition.

For the proposed condition the existing steel control gate would remain and a new crest gate system would replace the four inflatable gates. The new crest gates would consist of hinged, steel crest gates actuated either by pressurized hydraulic fluid or by compressed air. The new gates would be operated in tandem and have variable crest elevation settings ranging from fully open to fully closed. The new crest gate system would utilize the existing bridge piers to accommodate the new gates so the effective crest length of the Dam would remain essentially the same[1].

The new gate system's variable crest setting also creates the possibility of providing a constant winter pool, where the effective crest elevation (i.e. gate setting) is raised above the 822.5 elevation. Maintaining raised gates throughout the year would increase barrier effectiveness from the existing operating regime. Because a change in existing dam operation would require consideration outside the scope of this report a series of winter pool elevations from 830.1 to 827.1 was evaluated.

3.2.4 Spillway Hydraulics

The concrete portion of Coon Rapids Dam spillway has an ogee shape. In both the existing and proposed condition, the spillway gates sit just downstream of the crest, so when they are fully deflated or down, the spillway's crest elevation is 822.5. From the crest, the spillway has a steep pitch down to the toe of the spillway. Water passing over the spillway accelerates as it falls, achieving supercritical (fast) velocities which transitions to a subcritical (slow) velocity at some point downstream of the Dam. This transition is distinguished by an abrupt and turbulent decrease in velocity and increase in flow depth called a *hydraulic jump* which can cause significant scour to the river channel if left unprotected.

Scour protection for Coon Rapids Dam is provided by two separate systems, each covering roughly half of the structure. On the Hennepin side the spillway flows into a deep concrete "stilling basin" that forces the hydraulic jump to occur closer to the Dam, thus decreasing the necessary length of scour protection. Both observations and analysis have found that the stilling basin keeps the hydraulic jump submerged, near the toe of the spillway, for the range of historical flow conditions at the Dam.

[1] The hydraulic crest gate system may result in some loss of spillway capacity due to the addition of hydraulic cylinder pedestals to existing piers.

On the Anoka side, the spillway flows across a series of more shallow concrete aprons that were intended to armor the river channel and contain the hydraulic jump within the protected area. Although the length of aprons is adequate, over time, these apron features have been undermined and portions have collapsed and subsequently been repaired.

For fish passage, the apron provides a more effective barrier since the hydraulic jump is located further downstream and the high water velocities leading to the jump would not be passable by a fish. Because the stilling basin contains the hydraulic jump closer to spillway, the lower velocity water is closer to the pool, making the physical jump distance required for passage less than that for the apron. However, once river flows approach about 60,000 cfs (~17-year flood per Figure 3-2), the apron hydraulic jump becomes submerged and its effectiveness as a fish barrier is the same as the stilling basin.

Spillway hydraulics were analyzed for both the existing and proposed condition. For the existing condition, the stilling basin (Hennepin side) and apron (Anoka side) spillway geometries were considered. Proposed Dam improvements include replacing the existing apron spillway with a stilling basin across the full length of the dam. Hydraulic analysis for the proposed condition therefore, considered only stilling basin geometry for spillway conditions.

3.3 Field Observations

Stanley Consultants conducted seven field observations of flow conditions at Coon Rapids Dam during the fall of 2010 for river flows ranging from 10,500 cfs to 16,500 cfs. The objective of the observations was to provide field measurements of downstream flow conditions for comparison with computed downstream flow conditions. The main feature being investigated was the presence and location of a hydraulic jump on the downstream stilling basin and apron. The USBR publication, *Hydraulic Design of Stilling Basins and Energy Dissipators* [8] provides a series of equations for predicting the presence and location of a hydraulic jump downstream of a spillway so it was a physical feature that could be field measured, predicted through computation, and then compared for verification of the hydraulic analysis.

The three key parameters that define hydraulic jump prediction are flow, velocity and downstream flow depth. Flow on this segment of the spillway was estimated using the river flow provided by the USGS flow gage [6] which was distributed over the spillway using the gate settings which were provided by the District. Velocity was estimated using a USBR empirical formula for estimating velocity at the toe of ogee spillways. Downstream flow depth was computed using the tailwater elevation estimated from the river flow, tailwater relationship discussed in Section 3.2.2.

On the stilling basin (Hennepin) side, no hydraulic jump was observed during any of the site visits, meaning the jump was always “submerged”. On the apron (Anoka) side, a hydraulic jump was observed and its location measured during each visit.

During the evaluation of potential Dam improvements, a hydraulic analysis of the existing stilling basin was performed to confirm that it provided adequate energy dissipation over the range of historic river flows. The analysis found that the hydraulic jump on the stilling basin would be submerged over the range of river flow conditions. This was verified by the field observations where the water surface downstream of the spillway was generally flat which would indicate that the tailwater elevation was high enough that the downstream flow depth submerged the hydraulic jump. Hydraulic calculation tables for the stilling basin can be found in the stilling basin computation section of Appendix F.

The existing apron elevation is 809.6, which is ten feet higher than the elevation of the stilling basin. The USBR [8] has developed a set of equations for estimating the location and flow parameters associated with a hydraulic jump but the downstream water surface (e.g. tailwater elevation) has to be at a minimum depth above the channel bottom (e.g. apron) for the jump to occur. This means that if the tailwater elevation was too low, the hydraulic jump would not occur on the flat apron but further downstream on the sloped apron where the channel bottom was lower and the minimum downstream depth was met.

Initially it was thought that the hydraulic jump would be contained on the apron for flows in the 10,500 cfs to 16,500 cfs range. However once the observations were taken and the detailed analysis was developed, both methods found the hydraulic jump to occur near the end of the apron where the channel bottom drops by four feet to the sloped apron. In all seven cases measured/analyzed, the tailwater depth was not high enough on the apron to force a hydraulic jump, but the four foot drop to the sloped apron met the minimum downstream depth. The added depth combined with the energy dissipation of a sudden drop in channel bottom likely forced the hydraulic jump at the end of the flat apron.

Further analysis was performed to estimate at what river flows the hydraulic jump would be contained on the flat apron. Given the current inflatable gate operating scheme, the analysis predicted the hydraulic jump would be contained on the flat apron for river flows ranging from 21,000 to 27,000 cfs. At 21,000 cfs the tailwater reaches the minimum depth needed for the USBR hydraulic jump relationships to be applicable on the flat apron. At 27,000 cfs the inflatable gate is lowered from partially to fully lowered and the USBR relationships are no longer applicable for the flat apron because the tailwater depth is now too low relative to the significant increase in flow depth. At river flows above 27,000 cfs, the analysis predicted the hydraulic jump to occur at or downstream of the end of the flat apron. The analysis demonstrates that flow conditions on the apron are not conducive to fish passage due to the high velocities on the flat apron for most flows. However, the analysis also demonstrates that the existing apron does not provide adequate energy dissipation and the turbulent hydraulic jump frequently occurs on the non-pile supported sloped apron which is vulnerable to damage by high velocity flows. So replacing the apron with a stilling basin would make conditions for fish passage consistent across the entire length of the spillway (i.e. losing velocity barrier provided by flat apron) but would contain the hydraulic jump and reduce risk of downstream scour. Field observation reports and calculation tables are provided in Appendix F.

3.4 HEC-RAS Model

A U.S. Army Corps of Engineers' HEC-RAS hydraulic analysis software model was developed to analyze flow over the main spillway for river flows ranging from 10,000 cfs to 90,000 cfs. Several spillway/gate geometries were created to analyze the series of summer/winter pool, existing/proposed conditions discussed previously.

HEC-RAS is a cross-section based hydraulic analysis program. The spillway/gate geometries were created in HEC-RAS by providing cross-sections of the given spillway profile spaced in 1-foot increments. The spillway was considered uniform (no piers) and the sides were vertical. The width of the cross-sections was set by the effective length of the stilling basin or apron portion of the spillway crest. Flow over the spillway was then set by proportioning the total river flow (10,000-90,000 cfs) into what would be flowing over the given portion of the spillway.

The HEC-RAS model extended just downstream of the end of the apron and stilling basin. To represent flow conditions downstream of the model a tailwater elevation for each flow condition was provided as a downstream water surface starting point for the model.

During the existing summer pool condition, when flows reach 10,000 cfs at least one of the inflatable gates is down and during winter pool all the inflatable gates are down, so the existing condition geometry was represented in HEC-RAS with gates down for all flow conditions. For the proposed condition, gate settings were established for pool elevations of 830.1, 829.1, 828.1, and 827.1 over the range of flow conditions. The shape and elevation of each gate setting was incorporated into the HEC-RAS spillway profile so the gate was essentially part of the spillway shape. When flows reached a point where the gates were fully down (e.g. 60,000 cfs for 830.1; 50,000 cfs for 829.1; 40,000 cfs for 828.1; and 30,000 cfs for 827.1) the gates down stilling basin profile developed in the existing condition was used to represent the proposed condition.

The output of the HEC-RAS model used for the evaluation is the profile of water flowing over the spillway/gates and into the downstream stilling basin or apron. Key modeling results included water surface elevation, flow depth and velocity along the spillway and into the stilling basin or apron, and the location of the hydraulic jump in the stilling basin or on the apron. The HEC-RAS derived water surface profile over the spillway was checked against the hydraulic jump location and submergence predicted by the equations developed by the USBR in their publication, *Hydraulic Design of Stilling Basins and Energy Dissipators* [8] and the results matched closely.

A copy of the HEC-RAS model is included on a CD in Appendix F.

3.5 Old Powerhouse Ancillary Discharge Features

3.5.1 Old Powerhouse Turbine Pit, Log Sluice and Fish Ladder

In 1975 the *Repair and Modification of the Coon Rapids Dam Project* [9] included repairs to the Dam, modifications to powerhouse features for public accessibility and to take inactive powerhouse structures out of operation. The powerhouse turbine pit, log sluice, and fish ladder were taken out of operation. These modified structures were reviewed for invasive fish passage potential.

During the 1975 project four out of five turbine water passages were capped. The uncapped passage was modified to include a headwall with a trashrack on the upstream end that created an overflow weir at Elevation 825.2. A ten foot wide, eight inch tall orifice slot was installed at invert Elevation 814.2 to discharge to the downstream draft tube. For passage, the downstream water elevation would need to be up to the invert of the orifice slot, the fish would swim through the slot and into the concrete inlet structure. The fish would need to swim/jump up the inlet structure and through the trashrack to make passage upstream. The trashrack has approximately one-inch clear openings between bars so only a small fish could pass through. For a fish to get from the orifice slot to the headwall, water would need to be backed up approximately eleven feet deep inside the inlet. Fish passage through the turbine pit is considered to be low risk but would be evaluated during the detailed design phase with closure of the opening considered if passage was possible.

The fish ladder and log sluice are located adjacent to each other and originally provided narrow spillways that allowed passage of fish from downstream to upstream and logs from upstream to downstream of the Dam. During the 1975 project the fish ladder was filled with concrete rubble and capped with concrete slabs. The log sluice has an upstream overflow weir (crest) elevation of 829.2 and the fish ladder has an upstream overflow weir (crest) elevation of 829.6. To allow passage, both structures would need sufficient flow depth at velocities below 25 feet per second. The modified fish ladder consists of a series of concrete slabs with cascading drops and the log sluice consists of a sloped concrete channel. With less than one foot between the summer pool elevation and crest elevations of the two spillways a shallow quickly moving flow would be typical for both. Fish passage through the modified fish ladder and log sluice is considered to be low risk but would be evaluated during the detailed design phase with raising the overflow weir elevation considered if passage was possible.

3.5.2 Old Powerhouse Spillway

The 1975 project also included repairs to the old powerhouse auxiliary spillway. This spillway was analyzed for invasive fish barrier effectiveness. The auxiliary spillway is a steep concrete ogee spillway with a flip bucket at the bottom that discharges onto a series of flat concrete aprons and then is discharged into the main river channel. The crest elevation of this spillway is approximately 828.8 ft so it is 5.3 feet higher than the main spillway crest. The auxiliary spillway sits on a concrete apron with an elevation of approximately 809.3 feet. The flip bucket at the end of the spillway set approximately three feet above the apron. The flip bucket has a round concave shape and its purpose is to propel the high velocity flow partially upwards and away from the spillway. The result is that the highly turbulent (scouring) area is separated from the spillway so the spillway structure is at less risk for damage. Flip bucket hydraulics are very turbulent and complex. So for fish passage analysis, a conservative simplification was made and hydraulics at the auxiliary spillway was essentially ignored. Over the range of flow conditions the auxiliary spillway crest elevation was compared to the downstream tailwater elevation and its location/distance from the crest. This vertical/horizontal separation of crest and tailwater allowed fish passage to be analyzed at the structure. The computation table is provided in Appendix F.

3.6 Invasive Fish Jumping Parameters

During the majority of river flow conditions, the high velocity of water flowing over the main spillway prevents fish from swimming up the spillway. For a fish to get from the downstream to upstream side of Dam it would have to leap from a low velocity (swimmable) area downstream of the spillway, over the high velocity (un-swimmable) segment of the spillway, and land in the low velocity (swimmable) area on the upstream end of the spillway. Invasive fish jumping parameters were provided by the DNR [3]. Asian Carp have been known to swim at speeds of up to 23 feet per second (fps) and jump upwards of ten feet vertically. To date, the DNR has reported that more detailed analysis/characterization of their jumping abilities and tendencies has not been published. Given the absence of available data, a swim speed of 25 fps (rounded up from 23 fps) was used as the basis of the invasive fish jumping parameters.

An invasive "design" fish was incorporated into the barrier effectiveness analysis by using a common ballistic trajectory equation to represent the parabolic path of a fish leap. The two parameters used in developing this trajectory are launch velocity and launch angle. The launch velocity was set at 25 fps. Initially, several launch angles were evaluated but a launch angle of 60 degrees was found to provide the most effective jump for the spillway conditions, and was therefore used throughout the analysis. The 25 fps launch velocity was checked against the reported jump height of 10 feet and did yield a maximum height (in the trajectory) of close to 10 feet.

The fish is assumed to be able to progress upstream either by swimming (if water velocity is less than 25 fps) or by leaping upstream to a point where water velocity is less than 25 fps and swimming up the remainder of the spillway. For the new gate system, if the fish landed on the spillway and the water velocity was less than 25 fps, it was assumed to swim up the spillway to the gate and then leap again at a reduced velocity (25fps minus water velocity) in an attempt to jump over the gate. A schematic of the fish jump for the gates down and proposed crest gate condition is shown on Figure 3-4.

3.7 Results

The invasive fish barrier effectiveness analysis was comprised of establishing water surface profiles on the spillway for a range of river flows and then "testing" each river flow to determine if the "design" fish could make its way upstream. Once the "passable" river flow was determined, historic streamflow data was used to determine how many days "impassable" river flows had occurred over the period of record of streamflow data. For example, assume the impassable river flow was determined to be 30,000 cfs. Over the 79 years of record, a total of 629 days (out of the total 28,854 days) recorded streamflow of 30,000 cfs or more. Therefore the barrier efficiency is computed to be:

Efficiency = (28,854 – 629) ÷ 28,854 = 97.9%.

3.7.1 Assumptions/Exclusions

Assumptions/Exclusions made in the course of analysis included:

- Spillway Shape: Uniform (constant width, no piers) with vertical sides. This is a simplification but likely has little impact on the analysis results.
- Water Depth: No minimum depth of water necessary for fish to swim and for fish to accelerate toward the water surface to facilitate leap. This is a conservative exclusion.
- Water Density: The fish is assumed to leap at the point where the hydraulic jump occurs. At this point in the water profile, large amounts of air will have been entrained into the water column, reducing the density of the water and reducing the swimming and leaping ability of the fish. This is a conservative exclusion.

- Control Gate: The control gate was excluded from the detailed fish barrier analysis. For the existing condition at flows above 10,000 cfs, the crest elevation of the control gate is always higher than the crest elevation of the inflatable gates so fish passage is always controlled by the inflatable gates. For the proposed condition, the control gate is assumed to raise and lower in tandem with the new crest gates so conditions for fish passage are the same for the control gate as for the crest gates. This means that exclusion of the control gate has no impact on the analysis results.
- Backwater Effects due to Ice: In 2005 and 2010, ice jams formed downstream of the Dam and backed water up to the spillway. Dam operators indicate that these events happen at approximate five year intervals. These are winter events and water temperatures are low, but such events could provide opportunities for fish passage. Photographs of the 2005 and 2010 ice jams are included in Appendix A. Ice jams were excluded from the analysis. This is an un-conservative exclusion.
- Migratory Tendencies: For the purposes of the analysis it is assumed that the invasive fish have the same swimming/jumping ability and would attempt passage above the Dam all year round. It is unknown whether cooler water temperatures during the winter would have any influence on invasive fish activity or migratory tendencies during winter months. This is a conservative exclusion.

3.7.2 Main Spillway

For the Main Spillway, the invasive fish barrier effectiveness was evaluated using the spillway flow profile developed in HEC-RAS and locating the jumping trajectory of the invasive "design" fish on the flow profile to determine if passage was possible. HEC-RAS provided a flow and velocity profile along the length of the spillway for a given spillway geometry/gate setting and river flow (10,000 cfs to 90,000 cfs in 10,000 cfs increments). The launch point where the fish left the water surface was set at the downstream end of the hydraulic jump which could easily be identified on each of the HEC-RAS profiles.

Table 3-3 on the following page provides a summary of the fish barrier effectiveness for the existing inflatable gate system during summer operating condition when the pool elevation is maintained at 830.1 feet. The table shows the individual gate position for each flow condition, its discharge, location relative to the apron or stilling basin, and whether the flow condition at the gate creates an effective barrier.

Table 3-3 Existing Gate System, Pool 830.1 (Summer Operating Condition)

River Discharge (cfs)	Gate Configuration	Gate	Gate Position	Gate Discharge (cfs)	Apron/ Basin	Effective Barrier?
10,000	17	#1	Partial	1,050	Apron	Yes
		#2	Partial	500	Basin[1]	Yes
		#3	Down	5,340	Basin	Yes
		#4	Partial	1,050	Basin	Yes
20,000	19	#1	Partial	1,050	Apron	Yes
		#2	Down	10,470	Basin[1]	Yes
		#3	Down	5,340	Basin	Yes
		#4	Partial	1,050	Basin	Yes
30,000	22	#1	Down	22,010	Apron	Yes
		#2	Partial	500	Basin[1]	Yes
		#3	Down	5,340	Basin	Yes
		#4	Partial	1,050	Basin	Yes
40,000	27	#1	Partial	1,050	Apron	Yes
		#2	Down	10,470	Basin[1]	No
		#3	Down	5,340	Basin	No
		#4	Down	22,010	Basin	No
50,000	28	#1	Down	22,010	Apron	Yes
		#2	Partial	500	Basin[1]	Yes
		#3	Partial	260	Basin	Yes
		#4	Down	22,010	Basin	No
60,000	30	#1	Down	22,010	Apron	Yes
		#2	Down	10,470	Basin[1]	No
		#3	Partial	260	Basin	Yes
		#4	Down	22,010	Basin	No
70,000	31	#1	Down	22,900	Apron	No
		#2	Down	10,890	Basin[1]	No
		#3	Down	5,560	Basin	No
		#4	Down	22,900	Basin	No
80,000	31	#1	Down	26,160	Apron	No
		#2	Down	12,440	Basin[1]	No
		#3	Down	6,350	Basin	No
		#4	Down	26,160	Basin	No
90,000	31	#1	Down	29,420	Apron	No
		#2	Down	13,990	Basin[1]	No
		#3	Down	7,140	Basin	No
		#4	Down	29,420	Basin	No

[1] Gate 2 spills into both apron & stilling basin. Basin assumed for conservatism.

The analysis shows that the existing gate system during summer pool is an effective barrier up to 30,000 cfs. Flows at or above 40,000 provide conditions where passage is possible for the invasive "design" fish.

Table 3-4 provides a summary of the fish barrier effectiveness for the existing inflatable gate system during winter operating condition when the gates are down. The table presents the basin side flow condition and shows the distance from the invasive "design" fish leaping point to the Dam crest, the water velocity and depth at the landing point, its discharge, and whether the flow condition on the spillway creates an effective barrier.

Table 3-4 Existing Gate System, Gates Down (Winter Operating Condition)

River Discharge (cfs)	Fish Leap Point at Hydraulic Jump, Distance from Dam Crest (ft)	Fish Leap Landing Point		Effective Barrier?
		Water Velocity (ft/s)	Water Depth (ft)	
10,000	29	21	0.5	No
20,000	29	21	1	No
30,000	29	21	1.5	No
40,000	28	21	2	No
50,000	27	20	2.6	No
60,000	26	20	3.2	No
70,000	25	19	3.9	No
80,000	23	18	4.7	No
90,000	23	18	5.3	No

The analysis shows that when all gates are down, the Dam is not an effective invasive fish barrier for any flows between 10,000 cfs and 90,000 cfs. The invasive "design" fish jumps from a point between 23 and 29 feet from the Dam crest. The fish is not able to clear the crest, but is able to jump to a point on the crest where the velocity is less than the 25 fps swimming velocity, so it is assumed the fish can swim up the remaining length of spillway.

Table 3-5 provides a summary of the fish barrier effectiveness for the proposed crest gate system for several pool elevations. The table presents gate setting and barrier effectiveness for a given river discharge and pool elevation.

Table 3-5 Proposed Gate System, Pool Elevations 830.1-827.1

River Discharge (cfs)	830.1 Pool		829.1 Pool		828.1 Pool		827.1 Pool	
	Gate Setting (ft)	Effective Barrier?	Gate Setting (ft)	Effective Barrier?	Gate Setting (ft)	Effective Barrier?	Gate Setting (ft)	Effective Barrier?
10,000	828	Yes	827	Yes	826	Yes	825	Yes
20,000	826.7	Yes	825.7	Yes	824.7	Yes	823.7	Yes
30,000	825.7	Yes	824.7	Yes	823.7	Yes	822.7	No
40,000	824.7	Yes	823.7	Yes	822.7	No	822.5	No
50,000	823.9	Yes	822.9	No	822.5	No	822.5	No
60,000	823.1	No	822.5	No	822.5	No	822.5	No
70,000	822.5	No	822.5	No	822.5	No	822.5	No
80,000	822.5	No	822.5	No	822.5	No	822.5	No
90,000	822.5	No	822.5	No	822.5	No	822.5	No

The analysis shows that the proposed gate system is an effective invasive fish barrier for current summer pool operating conditions (Pool at elevation 830.1 feet) up to 50,000 cfs. Flows at or above 60,000 provide conditions where passage is possible for the invasive "design" fish. As the set pool elevation is decreased, passage becomes possible at lower flows. For each foot the pool elevation is lowered, the flow where passage becomes possible decreases by approximately 10,000 cfs.

Plots of the spillway flow and velocity profiles with the fish jump trajectory for all studied flow conditions are provided in Appendix F.

To relate invasive fish barrier effectiveness to historical flows, the river discharge frequency was established using the daily flow record. The results are shown on Table 3-6.

Table 3-6 River Discharge Frequency

River Discharge (cfs)	No. of Events in 79-Year Period of Record			Mean No. of Days per Event			Percentage of Time During Period of Record (%)		
	Annual	Summer	Winter	Annual	Summer	Winter	Annual	Summer	Winter
10,000	306	199	146	24	21	21	25.3	29.5	21.3
20,000	133	65	68	16	12	21	7.5	5.4	9.6
30,000	52	19	33	12	8	14	2.2	1.1	3.2
40,000	23	5	18	9	5	10	0.7	0.2	1.3
50,000	9	--	9	9	--	9	0.3	--	0.5
60,000	6	--	6	6	--	6	0.1	--	0.2
70,000	3	--	3	4	--	4	0.05	--	0.09
80,000	1	--	1	4	--	4	0.014	--	0.027
90,000	1	--	1	1	--	1	0.003	--	0.007

The river discharge frequency was then correlated to the barrier effectiveness to quantify the effectiveness of each gate/operation configuration for the 79-year flow record. The results are summarized in Table 3-7.

Table 3-7 Invasive Fish Barrier Effectiveness

		Barrier Effectiveness[1]					
		Annual		Summer		Winter	
Gate System	Winter Pool Level	#Days[2]	% Effective[3]	#Days[2]	% Effective[3]	#Days[2]	% Effective[3]
Existing	Drawdown	3,153	89.1	26	99.8	3,127	78.7
	830.1	211	99.2	26	99.8	185	98.7
New	Drawdown	3,127	89.2	0	100	3,127	78.7
	830.1	36	99.9	0	100	36	99.8
	829.1	78	99.7	0	100	78	99.5
	828.1	211	99.3	26	99.8	185	98.7
	827.1	629	97.8	156	98.9	473	96.8

[1] Excludes periodic tailwater ice jam effects.

[2] Indicates number of days the dam would have been passable in 71-year period of record.

[3] Indicates percentage of days that dam would have been impassable in 71-year period of record.

The analysis found that no gate configuration provided a 100% effective barrier. The most effective barrier was the proposed crest gates with the pool maintained at 830.1 all year long. Current winter pool operation provides the greatest opportunity for fish passage with both the existing Dam and new gates (gates down at crest) providing a roughly 80% effective fish barrier during winter operating conditions. As shown in Table 3-7, if gates are raised during winter months the barrier effectiveness increases. However, even with a year-long 830.1 pool elevation, gates would be all the way down (same as current winter operation) when flows exceeded roughly 65,000 cfs for both existing and proposed conditions.

3.7.3 Old Powerhouse Spillway

For the Old Powerhouse Spillway a vertical and horizontal distance from the tailwater location to the spillway crest was established for the range of river flows. The invasive "design" fish was assumed to jump from the tailwater at a point roughly one foot downstream from where the spillway met the tailwater. If the fish jump trajectory could clear the vertical and horizontal distance from tailwater to crest for that flow, passage was assumed possible. Computations are provided in Appendix F. Results are summarized in Table 3-8.

Table 3-8 Powerhouse Spillway Invasive Fish Barrier Effectiveness

River Discharge (cfs)	Effective Barrier?
10,000	Y
20,000	Y
30,000	Y
40,000	Y
50,000	Y
60,000	Y
70,000	N
80,000	N
90,000	N

The analysis shows that the powerhouse spillway is an effective invasive fish barrier for river flows up to 60,000 cfs. Flows at or above 70,000 cfs provide conditions where passage is possible for the invasive "design" fish. The powerhouse spillway is less vulnerable to fish passage than the Dam spillway and has invasive fish barrier effectiveness greater than 99.9%.

Section 4

Dam Improvements

4.1 Current Condition of Dam

4.1.1 General

The current condition of the Dam was documented by Stanley Consultants during its five year inspection report, commissioned by the District. The inspection, performed in October of 2009, resulted in the following recommended actions:

- Control Gate: Replace missing bolts, repair supporting grout pads, sandblast and paint, and replace seals.
- Gate Control System: Replace data logger.
- Old Powerhouse Pedestrian Bridges: Sandblast and paint supporting steel.
- Concrete: Monitor and repair spalled concrete and cracking in various locations.
- Main Spillway: Re-surface spillway exposed aggregate.
- Main Spillway Bridge: Clean and protect anchor bolts, seal joint and cracks in deck, repair handrail system, monitor concrete condition, monitor pipe supports.
- Asphalt: Repair and seal problem areas.
- Modular Retaining Wall: Repair damaged areas on south abutment.
- Sheetpile Wall (on south bank of Dunn Island): Monitor and replace if necessary.

4.1.2 Energy Dissipation

A scour hole was discovered during a sounding program in 2005. The scour had formed downstream of Gate 1 and had resulted in failure of a significant portion of the sloping and horizontal slab-on-grade aprons and had begun undermining the pile-supported apron.

Repairs completed in 2006 included isolation of the failed area with steel sheet piling, grouting of the void under the pile supported apron, and placement of riprap in the scour hole.

Soundings performed in 2008 and 2009 revealed a second scour hole forming downstream of Gate 2. A subsequent underwater inspection completed on October 20, 2009, identified two areas of concern: 1) An undermined area beneath a retaining wall separating concrete aprons at two elevations downstream of the control gate; and 2) a large area of failed sloped and horizontal slab-on-grade apron downstream of Gate 2. The undermined retaining wall does not pose a threat to the stability or integrity of the Dam or stilling basin, but should be monitored for change during future inspections. The apron failure is similar to the failure discovered in 2005 and repaired in 2006 and there was concern that scour had progressed under the pile-supported apron. An underwater acoustic imaging program was conducted to document the condition of the downstream apron and stilling basin and to estimate the lateral extent of the apron failure identified downstream of Gate 2. In addition, the acoustic imaging was utilized to determine if the scour had progressed under the pile supported apron, adversely impacting the structural integrity of the Dam structure. The acoustic imaging of the apron identified areas with multiple stages of structural deterioration. In several locations, complete destruction of the Dam apron was observed. It was also determined that the sheet pile wall at the downstream end of the pile supported apron was not undermined but had been exposed. The full 2009 underwater acoustic imaging report is included in the 5-Year Inspection Report Document [10].

A recommendation was made to raise Gate 2 in order to reduce future scour and then to repeat the acoustic imaging program after high spring flows to determine if the apron failure had progressed and if the pile supported apron had been undermined. An acoustic imaging program completed in April of 2010 did not indicate additional deterioration or undermining of the sloping or pile supported horizontal apron. The scour hole downstream of Gate 2 had filled with sediment as a result of flows being diverted around the area. The filling of the scour hole with sediment was confirmed by a diver during the acoustic imaging program. Details of the 2010 Acoustic Imaging Program can be found in the AMI Sector Scan Report [11]. A comparison of the 2009 and 2010 acoustic images is provided as Figure 4-1 in Appendix C.

The failed apron section downstream of Gate 2 had not been repaired at of the time of this report. Gate 2 will remain inflated and the area will continue to be monitored, with acoustic imaging being completed after major flow events.

4.1.3 Inflatable Gates

Since their installation in 1997 there have been problems with the inflatable gates. The manufacturer of the gates, Sumitomo Electric Corporation (SEI) stood behind their product and made many extensive and expensive repairs to the gates. After six failures in four years, SEI agreed to completely replace the inflatable gates with gates having a modified design. The second set of inflatable gates was installed and went into service in 2001. Since the new inflatable gates were installed in 2001, repairs requiring use of closure panels have been required six times and each of the last three years (2008 through 2010). In addition, Gate 3 has periodically experienced excessive loss of air pressure, the cause of which has not yet been determined.

Inflatable gate repairs requiring use of the closure panels is expensive, due mostly to the measures needed to provide adequate access to the problem area (see Photograph 21). The typical cost for inflatable gate repairs is approximately $180,000, 50 percent of which has been paid by SEI as part of their warranty agreement. The inflatable gate warranty expires in the fall of 2011.

It is evident that the remaining service life of the inflatable gates is limited. With continued periodic repairs the gates may last another ten years. Without continued repairs the gates would likely last only two to three years.

4.1.4 Control Gate

The control gate is due for a periodic maintenance program as documented by the 5-Year Inspection report [10]. The maintenance program should include the following:

- Removal of existing paint system to bare steel and new paint system.
- Seal replacement.
- Addition of nappe breakers[1].
- Hydraulic cylinder rehabilitation.
- Repairs as required for concrete, anchor bolts, etc.

4.2 Recommended Improvements

4.2.1 General

The DNR, as well as other state and federal resource agencies, desire a long term invasive species barrier; therefore, Dam improvements to enhance its effectiveness as a fish barrier, including a long term solution to the Dam's structural integrity, would be implemented.

With one exception, all of the long-term dam objectives listed in Section 1 would be met with the proposed improvements described in the subsequent paragraphs. The exception is *"Maintenance of the elevation of the upstream pool such that shoreline properties are not adversely impacted."* As the invasive fish barrier analysis unfolded, it became apparent that modifying the existing pool operation (i.e. maintaining the summer recreation pool year-round) greatly improved the barrier effectiveness of the Dam. It was therefore decided to continue development of the modified pool operation alternative throughout preliminary design.

4.2.2 Energy Dissipation

Energy dissipation improvements recommended to meet the long term objectives for the Dam are as follows:

[1] Nappe breakers are elements added to gate crest to reduce gate vibrations caused by water passing over the gate.

4.2.2.1 Existing Apron System. Over time, the existing apron system has been undermined and portions have collapsed. The apron system has served its useful life and can no longer be relied upon to provide scour protection for the north side of the main spillway.

Stanley Consultants evaluated several alternatives to improve the apron system to provide adequate scour protection for the next 50 years. Alternative 1 would include restoration of the apron system in the form of complete in-kind reconstruction. Alternative 2 would include installation of a sheet pile cutoff to isolate the upstream pile support portion of the apron from the unsupported downstream portion. Alternative 3 would include reconstructing the north side into a conventional stilling basin.

Alternative 1 was dismissed due to its expense and unreliable longevity. Alternative 2 would initially cost less than Alternative 1 but would require frequent monitoring and maintenance in the form of riprap placement downstream of the sheet pile cutoff. Alternative 2 was therefore dismissed because it again does not provide a long term solution to the scour issue.

Alternative 3 was selected as the most prudent solution since it provides a long term solution to the scour issue using modern dam design standards. Exhibit 04 presents an overall view of the proposed improvements. As shown on Exhibit 11, the stilling basin would reflect a United States Bureau of Reclamation (USBR) Type III design which features concrete chute blocks, baffle piers, and end sill constructed on the stilling basin floor. This stilling basin configuration was developed and tested by the USBR and has been installed in many spillway projects providing an extensive record of successful performance. The USBR Type III stilling basin provides more efficient energy dissipation than the Dam's existing stilling basin so its floor elevation would be four feet higher and its length would be fifteen feet shorter than the existing stilling basin.

The stilling basin would be supported by a grid of new steel H-piles. Additional scour protection would be provided by a steel sheet pile cutoff wall driven along the downstream face of the stilling basin, and placement of a riprap armoring system downstream of the stilling basin.

The work area would be isolated from the river by constructing a cellular sheet pile cofferdam, shown in sectional view on Exhibit 07. Construction of the cofferdam would require removal of a portion of the existing concrete apron and timber piles to facilitate pile driving (see Exhibit 09). Removed concrete rubble would be used to fill existing scour holes. The remaining (downstream) portion of the existing apron would be left in place.

4.2.2.2 Existing Stilling Basin. The existing stilling basin (shown on Exhibit 07) located on the Hennepin County side of the main spillway has been in service for approximately 100 years and has served its purpose well over that time. Recent inspections indicate that the stilling basin is in good condition and hydraulic computations indicate that the basin configuration is adequate according to modern USBR established design criteria. Therefore, recommended actions for the stilling basin are limited to those necessary to extend its life for 50 years and include the following (see Exhibit 10):

- Isolate the stilling basin to allow for comprehensive inspection and damage assessment. Complete dewatering is not deemed necessary for this assessment and in fact may result in damage to the structure stemming from uplift forces.
- Areas requiring repairs would be dewatered locally, using fabricated steel box structures. Measures would likely consist of crack repairs, concrete overlays, and foundation grouting.
- Drive steel sheet pile cutoff wall on downstream side of stilling basin.
- Place riprap armoring system downstream of stilling basin.

4.2.3 Inflatable Gates

It is apparent from the previous discussions that the inflatable gates will require replacement before the end of their original anticipated service life.

4.2.3.1 Gate Type. As indicated in the previous "barrier evaluation" memo [12], top-discharging crest gates have been identified as having the potential to increase the effectiveness of Coon Rapids Dam as an invasive fish barrier. Crest gates would consist of hinged steel crest gates, actuated either by pressurized hydraulic fluid or by compressed air. New gates would have variable crest elevations, ranging from fully open to fully closed. Crest gates are preferred over tainter gates for the replacement. Crest gates pass water over the top and are much less likely to be affected by ice and debris than tainter gates which rise up to pass flow between the bottom of the gate and the spillway crest. Crest gates would also be less expensive since they would be easier to retrofit onto the existing dam, requiring less modification to the existing piers, bridge, and air piping infrastructure. Note that the existing control gate at Coon Rapids Dam is a hydraulic crest gate and has worked well since its installation in 1996. Note also that the gates that were replaced during the 1996 rehabilitation project were tainter gates which were problematic from an operations and maintenance standpoint.

4.2.3.2 Gate Actuation. Two basic types of actuation (lifting/lowering mechanism) are available for crest gates, hydraulic and pneumatic (air). Hydraulic actuation features hydraulic cylinders that are mounted to the top of each end of a gate section. Gates are raised or lowered by varying the pressure in the hydraulic cylinder. The cylinders are fed by hydraulic fluid through piping that originates at a hydraulic power unit (HPU) that features pumps, valves and controls. The HPU is usually housed within a climate controlled building. Gate abutment plates can be provided with electric heating systems to allow winter operation. Exhibit 12 illustrates work required for installation of hydraulic crest gates. A brochure outlining the specifics of a hydraulic gate system as offered by Rodney Hunt Company, Orange, Massachusetts is provided in Appendix E.

Pneumatic actuation features air bladders located immediately downstream of a gate section. Gates are raised or lowered by varying the air pressure in the bladder. The bladders are fed by air through piping that originates at air compressors and a control unit that is again normally housed within a climate controlled building. Gate abutment plates can be provided with electric heating systems to allow winter operation. Exhibit 11 illustrates work required for installation of pneumatic crest gates. A brochure outlining the specifics of a pneumatic gate system as offered by Obermeyer Hydro, Fort Collins, Colorado is provided in Appendix E.

A summary of the relative pros and cons of the two gate actuation systems (with respect to retrofitting onto Coon Rapids Dam) is as follows:

Table 4-1 Gate Actuation Pros & Cons

	Actuation Type	
Parameter	Hydraulic	Pneumatic
Pool Level Control	+	+
Robustness	+	-
Cold Climate	-	+
Maintenance	-	+
Service Life	+	+
Retrofit Work Required	-	+
Loss of Spillway Capacity	-	+

Costs to procure and install the two types of crest gates are similar and it is recommended that both systems be included as options in the eventual bidding documents. By doing so, comprehensive cost and function evaluations can be performed and the better system selected for implementation.

4.2.3.3 Construction Activities. The following construction activities would be required to replace the inflatable gates with crest gates:

- Construct upstream cofferdam and causeway using combination of steel sheet pile and earth embankment (see Exhibit 07). This method was used successfully during the 1996 reconstruction project.
- Removal of existing gate system including bladders and mounting hardware.
- Demolition of existing crest concrete to facilitate gate mounting hardware and air piping (pneumatic system only). Demolition of existing concrete “fillets” in eight locations.
- Concrete crest construction and embedment of gate supports and piping system (pneumatic gate). Re-surfacing of crest concrete for longevity.
- Modification of existing piers to receive abutment plates, heating systems, piping, and electrical conduit. Addition of concrete to fill five hollow piers.
- Addition of hydraulic cylinder mounting platforms to existing piers (hydraulic system only).

- Addition of piping and electrical conduit beneath bridge.
- Control Building modifications including new control system, new air compressors (pneumatic system), new HPU's (hydraulic system), and ancillary systems.

4.2.4 Control Gate

Recommended repairs to the hydraulic control gate include application of a new paint system, seal replacement, bolt replacement, hydraulic cylinder rehabilitation, and foundation grout repairs. Stanley Consultants prepared construction documents for rehabilitation of the control gate (in conjunction with inflatable gate repairs) in 2008. Rehabilitation was to include painting, seal replacement, bolt replacement, and installation of nappe breakers. Bids for control gate rehabilitation came in high and therefore the control gate work was reduced to bolt replacement only.

4.2.5 Ice Suppression System

If the decision is made to maintain the recreation pool level (830.1) year-round, it is recommended that the main spillway be fitted with an ice suppression system in addition to the gate side seal heating system described earlier. The ice suppression system would prevent formation of ice against the face of a gate leaf. The recommended system consists of an air bubbler system due to its proven effectiveness on similar structures and its economy.

Air bubbler systems suppress ice formation by carrying deeper, warmer water to the surface to keep water just above the freezing point. This is accomplished by releasing air bubbles at the bottom of the water column, immediately upstream of the gates. Two (redundant) air compressors would be used to supply air to perforated piping located along the Dam near the base of the gates. The air pressure would be sufficient to overcome the hydrostatic pressure and the friction losses in the supply and diffuser lines, and yet provide a pressure differential at the orifice to drive the air out at the desired rate. The air compressors would be housed within the existing control building.

4.2.6 Closure Panel Improvement

The existing closure panel system was designed as a retrofit to the existing Dam. The proposed Dam improvements project provides an opportunity to improve the closure panel system. Proposed improvements would include the following:

- Addition of closure panel seat. During rehabilitation of the Dam crest, a concrete seat for the closure panels would be constructed at the upstream face of Dam, so that the closure panels would seat directly on the structure, rather than primarily hang from the bridge deck. This would facilitate the installation of panels and improve the water sealing condition.
- Panel Modifications. Panels would be modified to fit the closure panel seats, and the waterstop arrangement to be modified to provide a more water-tight condition.

4.2.7 Other Repairs and Improvements

It is recommended that the following additional repair and restoration activities be undertaken as part of the overall rehabilitation project. By doing so, cost savings (mobilization, access, permitting, management & administration) would be realized.

- Pedestrian bridge painting.
- Handrail repair or replacement.
- Miscellaneous minor repairs recommended in 5-year inspection report.

4.2.8 Construction Sequencing

It is anticipated that rehabilitation measures could be completed over two construction seasons. Stage 1 (see Exhibit 04) would include construction of the new north stilling basin and replacement of the north gate system (Gates 1 and 2). Stage 2 (see Exhibit 05) would include inspection and repair of the south stilling basin and replacement of the south gate system (Gates 3 and 4). It is not anticipated that extensive repairs are required for the existing stilling basin, but if necessary Stage 2 would be modified to allow dewatered access to the downstream side of the southern portion of the main spillway as shown on Exhibit 06.

As shown on Exhibit 03, access to the Stage 1 work area would be provided by roadways and a causeway constructed downstream of the old powerhouse area and on Dunn Island. A staging area would be set aside on the east end of the existing Anoka County parking lot.

As shown on Exhibit 02, access to the Stage 2 work area would be provided by access roads and staging areas located near the south abutment.

4.2.9 Cofferdam Design

The proposed construction activities along the existing apron portion of the Dam (Stage 1) which include the construction of a new stilling basin, removal and replacement of inflatable gates, and the driving of downstream scour protection sheet pile, require both the upstream and downstream portions of the Dam to be dewatered prior to construction to allow work to be conducted in the dry. Sheet pile cofferdams would be driven both upstream and downstream of the Dam. This is shown in detail on Exhibit 04 and Exhibit 07. The upstream cofferdam would act as a seepage cutoff and would also allow for the gate work to be completed in dry conditions by allowing construction access to the Dam from the upstream side. During Stage 1 construction, all river flow would be directed through the Hennepin County portion of the main spillway (Spans 7 through 10). Although this would be a contractor designed element, a preliminary design of the system was completed.

It is recommended that all gates would be lowered to draw down the upstream pool during construction and therefore, for preliminary design and cost estimating purposes this was assumed. The main reason for this is the risk associated with the scour protection construction activities taking place on the downstream side of the Dam. During installation of the new stilling basin on the Anoka side of the Dam, the work area will be dewatered to facilitate construction. Water pressure from the upstream pool will cause seepage to occur beneath the Dam and enter into the work area. A higher upstream pool will increase the pressure on the underlying soils and increase the seepage gradient, thus, increasing the potential for a catastrophic excavation blowout, dam undermining failure, or dam uplift failure. Such a failure occurred in 1918 (see Engineering News Record article [13] included in Appendix E). Less significant reasons to draw down the pool during construction include decreased construction costs resulting from reduced cofferdam height, depth and robustness, as well as reduced dewatering volume requirements.

Upstream sheet pile would be driven roughly parallel to the Dam on a 40 ft offset working outward, starting from the Anoka shoreline. Sheet pile should be driven approximately 5 feet into the dense glacial till stratum. As the contractor progresses out into the river, fill would be pushed out between the cofferdam and the concrete dam to serve as both a counterforce against high headwater and also an access platform/surface. The upstream sheet pile would be tied into the existing Dam near Pier 7. The upstream cofferdam preliminary design was completed assuming the 2-year dry season (August through February) high headwater elevation with one foot of freeboard (top of cofferdam set to Elevation 827.3). It was assumed that Stage 1 dewatering would be achieved using a line of deep wells running parallel to the upstream cofferdam at the top of the earthen berm.

The downstream Stage 1 cofferdam system would include driving the permanent scour protection line of sheet pile at the proposed stilling basin sill elevation and bracing against another row of sheets driven 20 ft downstream (See Exhibits 04 and 07). Fill would be placed between the two rows of braced sheets to add stability to the temporary structure. The permanent sheets would be driven and left to elevation 813.4 (2-year dry season tailwater elevation). Following construction of the new stilling basin, the outer row of sheet pile would be removed and the inner row (permanent) would be cut to its final elevation flush with the top of the sill. The downstream dual wall braced system would tie into a center contractor fabricated cofferdam structure which would tie into the downstream portion of the Dam near Pier 6 using a fabricated (sloped) end section. Downstream access would be gained using an access causeway running along the shoreline. All sheet pile wall structural analyses, as well as causeway slope stability analysis, is provided in the Geotechnical Section of Appendix F.

For Stage 2 construction, upstream cofferdam would be constructed using the same methods described for Stage 1 above, however, sheet pile would extend from Hennepin shoreline and would tie in near Pier 5 (See Exhibit 05). River flows would be directed through Spans 1 through 4. The Stage 2 upstream cofferdam was also analyzed with water to the 2-year dry season high headwater elevation (827.3).

The Stage 2 downstream cofferdam system would depend on the results of the comprehensive underwater inspection of the existing stilling basin. If damage is minor and repairs can be made locally, small sections of the basin would be isolated and dewatered individually (See Exhibit 05). If the inspection yields the recommendation that more intensive repairs are required, a full downstream cofferdam system would be constructed similar to Stage 1 (See Stage 3 – "If Necessary" Exhibit 06). If the full downstream cofferdam is required, the inner downstream sheet pile would be driven adjacent to the sill of the existing stilling basin. Similar to Stage 1, an outer row of sheets would be driven 20 ft downstream and braced back to the inner row and fill would be placed between the rows. Following construction, the inner row of sheets would be left in place to serve as the permanent scour protection. It is recommended that all downstream sheet pile be driven with adequate embedment into the dense glacial till stratum. All sheet pile wall structural analyses for Stage 2 cofferdams are provided in the Geotechnical Section of Appendix F.

4.3 Hydroelectric Power Development

Hydroelectric power development is discussed in detail in Section 8.1.4. If and when developed, a hydroelectric power plant would be located on the Hennepin County side of the river, on the landward side of the control building. The improvement measures discussed in this section would not inhibit future development of hydroelectric power. Under current upstream pool level operating conditions, approximately 34 million kilowatt-hours of electricity would be generated by the plant annually. If the decision is made to modify the current Dam operating procedure (i.e. maintain current summer recreational pool year-round), generation would increase to approximately 44 million kilowatt-hours per year.

Section 5

Construction & Operation Costs

5.1 General

For the Coon Rapids Dam Fish Barrier and Improvements Preliminary Design, both a capital construction cost estimate and lifecycle (operation) cost estimate were created. Methodology and assumptions used will be discussed in the sections below.

5.2 Capital Construction Cost Estimate

Material, labor, and equipment unit prices were based upon recent cost estimates and/or bid results from similar projects completed for regional government agencies. To a lesser extent, construction pricing was based upon construction cost data published my Means [14, 15, 16]. Major equipment (crest gates, gate actuation systems and gate control systems) budgetary pricing was obtained from nationally known manufacturers. Costs include construction, cofferdams and dewatering, final design and engineering, surveying, additional geotechnical investigations and permitting. A ten percent (10%) factor was applied to construction costs (excluding gate system procurement) to account for underdeveloped design details. A fifteen percent (15%) contingency was added to the subtotal including the underdeveloped design details. A five percent (5%) engineering, administration, and permitting cost was added to the overall bottom line. A detailed breakdown of Stanley Consultants' opinion of probable cost is provided in Table 5-1 below. The complete opinion of probable cost and cost assumptions are provided as Figures 5-1a and 5-1b respectively in Appendix C.

Table 5-1 Summary of Capital Construction Costs

Item	2011 Cost (in millions)
Site Preparation/General	$4.1
Scour Mitigation	$3.3
New Gate System	$6.6
Dam/Other Repairs	$2.1
Engineering/Administration	$0.8
Total	$16.9

The following specific assumptions were made when computing the project quantities and associated unit prices:

- Mobilization/Demobilization equal to 5% of construction cost.
- Sediment and erosion control equal to 1% of construction cost.
- Construction surveying equal to 0.5% of construction cost.
- Engineering and administration (Contractor) equal to 3% of construction cost.
- Pneumatic gate option assumed. Costs for procurement, installation, and controls based on Waverly Dam – Waverly, IA Project. Similar gate size was used and price was extrapolated for increased dam length.
- Handrail rehabilitation option assumed. Costs based on quote from BOE Ornamental Iron Inc.
- Pedestrian bridge painting costs based on 2009 gate repair bids.
- Control gate rehabilitation costs based on 2008 bids from Lunda, Kraemer, and Lametti.
- Rubble from apron demolition used to fill scour holes.

For additional notes and assumptions, refer to the Figure 5-1b.

5.3 Operation (Life Cycle) Cost Estimate

In addition to “one-time” capital costs described in Section 5.2, a long-term cash flow analysis was also determined. The desired project life of 50 years was assumed for the analysis period. In order to remove unknowns related to inflation and discount rates, the cash flow analysis shows costs in terms of 2011 dollars only. Debt service to cover the initial capital cost of improvements is excluded from the cash flow analysis. Following describes items included in the cash flow analysis:

1. General Operations:
    a. Utilities: Electricity and natural gas service to control building and exterior lighting. Utility rates based on recent billings. Usage based on past usage plus anticipated increases in electrical load due to air bubbler system and gate side-seal heaters.

b. Manpower: Labor costs for day-to-day Dam operations, supervision and administration. Costs based on recent District data.

c. Annual Gate Inspections.

2. Repairs and Rehabilitation:

a. Consultant Inspection Services. Engineering consultant services including 5-year inspections, river sounding programs at five year intervals, and underwater inspections at ten year intervals. Costs based on actual recent billings.

b. Control Gate Maintenance. Rehabilitation of hydraulic cylinders at ten year intervals. Costs based on actual recent billings.

c. Control Gate Repair. Installation of closure panels/access-way, gate painting, seal replacement, and miscellaneous other work. Interval is 20-years and costs are based on 2008 bids.

d. Control Gate Replacement. Installation of closure panels/access-way, and complete gate replacement at 40-year intervals. Costs based on vendor quotes and recent closure panel/access work.

e. Crest Gate Maintenance. Estimated costs for miscellaneous maintenance work required at ten year intervals.

f. Crest Gate Repair. Installation of closure panels/access-way, complete replacement of bladders, and miscellaneous work. Interval is 20 years and costs based on vendor quotes.

g. Crest Gate Replacement. Installation of closure panels/access-way and complete gate replacement at 40-year intervals. Costs based on vendor quotes and recent closure panel/access work.

h. Control Building - General. Periodic replacement of minor electrical and mechanical components. Costs based on Asset Management and Maintenance Plan (AMMP).

i. Control Building – Standby Generator. Replacement of standby natural generator at 30 year intervals. Costs based on AMMP.

j. Pedestrian Bridge Painting. Estimated costs for painting of supporting steel for two pedestrian bridges in old powerhouse area. Interval is 20 years.

k. Handrail Replacement. Complete replacement of handrail/guardrail system at 20-year intervals. Costs based on quotes received in 2008.

l. Miscellaneous Repairs. Estimated costs related to concrete elements, riprap replacement, pavement restoration, modular retaining walls, etc. Interval is 20 years.

The complete cash flow analysis is included as Figure 5-2 in Appendix C. A summary is provided in Table 5-2 below.

Table 5-2 50-Year Life Cycle Cost Summary

	2011 Cost	
Item	Total Life Cycle	Annual
General Operations	$5,850,000	$117,000
Repairs/Rehabilitation	$10,270,000	$205,000
Total	$16,120,000	$322,000

5.4 Limitations

All cost estimates presented in this report are Stanley Consultants' opinions of probable project, construction, and operation and maintenance costs. Cost estimates are made on the basis of Stanley Consultants' experience and best judgment. Stanley Consultants has no control over cost of labor, materials, equipment, contractor's methods, or bidding and market conditions. Therefore, Stanley Consultants does not guarantee the proposals, bids, or actual construction costs will not vary from estimates of project costs, construction, and/or operation and maintenance costs presented.

Section 6

Schedule

The anticipated project development schedule for the Dam improvements documented in this report is shown on the Gantt chart of Figure 6-1 in Appendix C. This schedule begins with the current preliminary design by Stanley Consultants and ends with completion of construction. The schedule was developed presuming that project development would begin in 2011 with regulatory agency action, legislative action, gate system procurement, and final design of Dam improvements. Stage 1 construction would begin in 2012, following bidding and award of the general construction contract. Stage 2 construction would take place during the construction season of 2013.

Section 7

Regulatory Issues

7.1 Public Waters Permit

In Minnesota, the process to permit new construction in water bodies is to submit an application for Minnesota Local/State/Federal Water/Wetland Projects. Completed applications are submitted to the Local Government Unit (LGU), Department of Natural Resources, and the U.S. Army Corps of Engineers (Corps). For Coon Rapids Dam, it is understood that the LGU is the Six Cities Watershed Management Organization but it is recommended that the Hennepin Conservation District and Anoka Soil & Water Conservation District also be provided with the application. The Minnesota Pollution Control Agency would be notified by the Corps if state water quality certification is required from the MPCA. Authority of these governmental units is provided by the following:

- Local Government Unit Approval Pursuant to Minnesota Wetlands Conservation Act (WCA)
- Minnesota Department of Natural Resources Permit to Work in Public Waters (Minnesota Statute103G.245)
- Department of the Army Permit (33 CFR 325)

Contents of the "joint permit" application include a general project description, location, owner information, description of public water impacted, project alternatives, and adjoining property owners. An Environmental Assessment Worksheet (EAW) may also be required.

7.2 DNR Dam Safety Permit

Since construction would result in alteration of an existing regulated dam, a dam safety permit would be required from the DNR. It is anticipated that the dam safety permit process would be sought in conjunction with the Minnesota Local/State/Federal Water/Wetland Project process described previously. Additional supporting documentation would be required including hydraulic, structural, and geotechnical design computations.

7.3 DNR Operating Permit

7.3.1 General

If the decision is made to modify the current dam operating procedure (i.e. maintain current recreational pool year-round), a revision to the DNR operating permit would be required. Again, this application process would likely coincide with the Minnesota Local/State/Federal Water/Wetland Project process, but the operational change may require a public involvement process. This process would include published announcements, public access to application documents, and public hearings.

7.3.2 Control Over Lands

As stated above, if the decision is made to modify the current dam operating procedure, a revision to the DNR operating permit would be required. Modified operation would not require acquisition of additional lands affected by the Dam impoundment since no change to the upper pool limit would be proposed. Regardless, the District may have to prove that it has the necessary flowage easements. Alternatively, perpetual flowage easements may exist in accordance with Minnesota Statute 103G.551.

If necessary, proof of land control would likely involve conformance and consolidation of the original flowage easements. The history of acquired flowage easements is as follows: In 1969, the District (then Hennepin County Park Reserve District) received a Quit Claim Deed from Northern States Power (NSP) for the Coon Rapids Dam and other lands lying within Hennepin and Anoka Counties. Included in this deed, which was filed for public record December 31, 1969 as Document No. 3812910 Abstract Property, and Document No. 1801615 Torrens Property, were numerous flowage easement rights that had been deeded to NSP from preceding power companies that had owned the Dam. The flowage easement rights that the District obtained from NSP were initially created beginning in the early 1900’s. These were blanket easements obtained on large parcels of land that bordered on the Mississippi River. As these large parcels have become subdivided over the years, the flowage easements have become components of each individual title.

7.3.3 Floodplain Issues

Since 1969, the Dam has been operated with the gates fully lowered during the winter then raised again after spring floods have receded. If the operating procedure is modified, the DNR Floodplain Management Unit would likely require verification that the new operating procedure would not adversely affect flood elevations upstream of the Dam. Verification would come in the form of backwater analyses utilizing the established river floodplain model, e.g. HEC-2 or HEC-RAS.

7.4 Wetlands Permit

Additional permit requirements are in place for construction projects involving impacts to protected wetlands. According to the National Wetlands Inventory published by the U.S. Fish & Wildlife Service, wetlands that may be impacted by construction would include the Mississippi

River itself. Additional landward wetlands may be temporarily impacted, depending upon the access route to the river.

Final design should include measures to minimize disturbance to receiving waters and minimize potential for erosion and sedimentation entering the river. Regulatory agencies will have the opportunity to comment on wetland impacts and proposed construction measures as part of their review of the Public Waters Permit application. Impacts to the river wetlands will be temporary and unavoidable and therefore it is not anticipated that any wetland mitigation (other than construction BMP's) will be required in conjunction with the construction project.

7.5 NPDES Permit

The U.S. Environmental Protection Agency's (EPA) Clean Water Act requires compliance with the National Pollution Discharge Elimination System (NPDES). NPDES requirements are regulated on the State level by the Minnesota Pollution Control Agency (MPCA). Construction projects that will disturb one or more acres of land require an NPDES Construction Stormwater Permit. The area of disturbance for the Coon Rapids Dam construction project would exceed one acre; therefore a construction stormwater permit would be required. The NPDES process requires development and implementation of a Storm Water Pollution Prevention Plan (SWPPP) and submittal of a construction stormwater permit application. It is anticipated that a "general permit" (MNR100001) (as opposed to an individual permit) can be obtained for the project. As such, the permit application must be submitted seven days in advance of construction or two days if the on-line form is used. Upon completion of the project and establishment of cover over all disturbed areas, a Notification of Termination form must be submitted to the MPCA.

It is recommended that the SWPPP be prepared coincidently with technical plans and specifications and that the SWPPP and NPDES permit be incorporated into the eventual contract documents.

7.6 Building Permit

The need for a building permit from the cities of Brooklyn Park or Coon Rapids would be investigated as part of final design.

7.7 Historic Issues

The Minnesota State Historic Preservation Office (SHPO) should be consulted to determine if any additional research, including field surveys, may be necessary to adequately assess the area's potential to contain historic properties. It is not anticipated that additional studies would be required since in 1994 (as part of the major dam rehabilitation) a determination of National Register eligibility was prepared for Coon Rapids Dam [17]. The report concluded that the dam was not eligible.

Section 8

Background Information

8.1 Dam

8.1.1 Setting and Description

Coon Rapids Dam is located on the Mississippi River within the Minnesota counties of Hennepin and Anoka. The Dam and impoundment are bordered by the cities of Brooklyn Park, Champlin, Coon Rapids, and Anoka. Land use immediately adjacent to the Dam includes the Coon Rapids Dam Regional Park which is owned and operated by the Three Rivers Park District and Anoka County Parks Department. Land use adjacent to the impoundment are largely single family/low density residential housing and to a lesser extent, conservancy/parkland.

The Dam is located in the Twin Cities sub-watershed (Hydrologic Unit Code 7010206) of the Upper Mississippi River watershed. The sub-watershed stretches from Elk River to Hastings for a length of approximately 70 mi. Drainage areas for the watershed and sub-watershed are 20,100 and 1085 square miles, respectively. The Twin Cities sub-watershed has approximately 646 miles of streams, 414 miles of which are perennial.

The Coon Rapids Dam was originally constructed in the early 1910's and included an overflow spillway section, powerhouse, and auxiliary spillway facilities. A plan of the Project is shown on Figure 8-1. Photograph 1 shows a downstream aerial view of the Dam. In 1969, ownership of the Dam and powerhouse was transferred from Northern States Power Company to the Suburban Hennepin Regional Park District (now Three Rivers Park District). In the 1990's and 2001 the Dam, including the spillway gate system, walkway, and portions of the old powerhouse area, underwent a major rehabilitation. The following paragraphs describe the Dam in its present state.

South Abutment Area: As originally constructed, a 75-foot long earth dike provided the transition from natural ground to the main spillway. The dike includes a concrete core wall and sheetpile cutoff wall. The area presently includes an approach ramp connecting a parking area to the main spillway bridge.

The main Dam consists of a reinforced concrete spillway, control gate and four inflatable gates. The mass concrete spillway is ogee shaped with a crest elevation of 822.5 feet and is founded on a grid of 12 inch diameter timber piles.

Water passing over spillways accelerates as it falls, commonly achieving supercritical (fast) velocities which transition to subcritical (slow) velocities at some point downstream of the Dam. This transition is distinguished by an abrupt and turbulent decrease in velocity and increase in flow depth called a hydraulic jump. Left unprotected, river channels will experience scour due to supercritical flows and the violent hydraulic jump. Scour protection for the main spillway is provided by two separate systems, each covering roughly half of the structure. The north side of the Dam features shallow concrete aprons that were intended to armor the river channel and contain the hydraulic jump within the protected area. The south side of the Dam features a deep concrete "stilling basin" that forces the hydraulic jump to occur closer to the Dam, thus decreasing the necessary length of protection.

The main Dam has maximum structural heights of 23.2 feet (top of concrete sill to top of stilling basin) and 30.8 feet (top of adjustable gates to top of stilling basin). With the exception of surface overlays and miscellaneous repairs, the spillway and stilling basin remain essentially as originally constructed. Sectional views of the original main spillway are shown on Figure 8-2. The main Dam spillway crest was resurfaced in 1995. The control gate is a 103 foot long steel gate mounted on the main spillway crest (Elevation 822.5) with a maximum hydraulic height of 7.6 feet. The gate is hinged on its bottom and operated by hydraulic cylinders mounted on concrete piers located at either end. The control gate system was installed in 1995. Figure 8-3 shows profile and sectional views of the control gate. The four inflatable gates have clear spans of 315 feet (Gate 1), 150 feet (Gate 2), 75 feet (Gate 3), and 315 feet (Gate 4). Each inflatable gate has a maximum hydraulic height of 7.6 feet and is constructed of a multi-layered, woven rubber material. The inflatable gates are mounted to the main spillway crest (Elevation 822.5) and to concrete piers on either end. The inflatable gates were replaced in 2001. Figure 8-4 shows a cross sectional view of the inflatable gate spillway and piping system. Spanning the entire main spillway is a bicycle/pedestrian bridge with a crown elevation of 841.1 and low chord elevation of approximately 835.7. The bridge was constructed in 1995/1996. The bridge is shown on Figure 8-4. The main spillway is shown on Photographs 2 through 5.

The Control Building, located near the south abutment of the Dam, houses the Dam's control and monitoring equipment. Constructed of reinforced concrete, the structure has a width parallel to the Dam axis of 18 feet and a length of 70.5 feet. The Control Building is founded on the Dam spillway and on a 2-foot thick concrete slab that rests directly on the former stilling basin slab. The control building, shown on Figure 8-5 and Photograph 6, was constructed in 1995.

The north abutment of the main Dam is located on Dunn Island and links the main spillway with the auxiliary spillway area. Components of this area are described below. A view of the Anoka abutment area is shown on Photograph 11.

Approach Ramp: Asphalt surfaced roadway originating at the old powerhouse access bridge and terminating on top of the main Dam. Modular block retaining walls provide grade transitions for portions of both sides of the ramp.

Retaining Dam: Mass concrete, non-overflow structure approximately 170 feet in length with a top elevation of 835. Completed as part of original construction, the retaining dam provides the transition between the main spillway and the auxiliary spillway. The structure is now nearly completely buried.

- Auxiliary Spillway Area: The auxiliary spillway area has an overall length of 66.5 feet and resides between Dunn Island and the old powerhouse. Its components are shown on Photograph 10 and include the following:
  - Auxiliary Spillway: Concrete ogee spillway with crest elevation of 829.1 and clear length of 40 feet. The auxiliary spillway was rehabilitated in 1996.
  - Log Sluice/Fish Ladder: Original construction included a log sluice and a fish ladder. These facilities were combined to form a scenic waterfall with an overflow weir elevation of 829.5 and clear length of approximately 21.5 feet. The log sluice/fish ladder was rehabilitated in 1996.
- Old Powerhouse Area: The old powerhouse is a reinforced concrete structure approximately 280 feet long by 60 feet wide. At one time, the powerhouse contained five vertical Francis turbine - generator units. The units were removed in 1966, and subsequently the powerhouse was converted into a recreation/observation area. Originally the generator floor (El. 828.3), the powerhouse deck provides access to the Dam, auxiliary spillway area, and the downstream fishing bridge. The old powerhouse area was rehabilitated in 1996. Photographs 7 through 9 show the old powerhouse area.
- North Embankment: The north embankment extends north from the old powerhouse approximately 450 feet to where it meets natural ground. The earthen embankment was rehabilitated in 1996 to have a top width of 8 feet and side slopes of 2.5 to 1. Top elevations of the embankment range from 836.5 to 840. The north embankment was rehabilitated in 1996.

In 2001, the District fabricated an emergency gate closure system. This is a system of steel cofferdam panels with heavy rubber seals on their edges. The panels are placed on the upstream side of the Dam, side-by-side, to divert the flow so that inspections or repairs can be made to the gates. The panels are placed from the main pedestrian walkway by a crane. The bottom of the cofferdam panels bear against the upstream edge of the Dam and the top of the panels bear against the upstream edge of the walkway. Each of the panels is 20-feet tall and approximately 10-feet wide. A total of 54 of the panels are of a single type. There are also 6 other types of panels with different dimensions to accommodate the different lengths of crest gates. There are a total of 69 panels and they are stored near the Dam next to the XCEL Energy substation. There are enough of the panels to close off the two shorter inflatable gates plus one of the long ones or to close off both of the long ones at the same time. The gate closure system was designed to allow repairs to be made to the Dam with the reservoir up. If the panels need to be placed during the time that the reservoir is up, the reservoir should be lowered for the placement of the panels and then raised after the panels are in place. However, experience has shown that working behind the panels with the reservoir up, greatly increases the amount of leakage through the panels.

8.1.2 History

The Coon Rapids Dam was built by Northern States Power Company in 1913-1914 to utilize the Mississippi River for electric power generation. The original main spillway structure included 28 tainter gates which controlled the reservoir elevation. For economic reasons, Northern States Power Company discontinued power generation activities at the site in 1966. Since that time the primary use of the reservoir has been recreation.

In 1969, the Dam, along with 225 acres of adjoining property, was donated to the District (then Suburban Hennepin Regional Park District). In 1975, The District undertook the development of the Coon Rapids Dam Regional Park, which included necessary structural repairs to the Dam, construction of a pedestrian walkway with viewing platforms along the entire length of the main spillway, entrance roads and parking areas, visitor center/maintenance buildings, fishing areas, picnic areas, and trail development on both sides of the river, and public boat launching area on the Anoka County side of the park. The District operated the Coon Rapids Dam Regional Park on both sides of the river until 1991, when Anoka County took over the operations on the east side through joint agreement with the District. The operation of the Dam itself has remained the responsibility of the District.

In the years after the major repairs were made to the Dam in 1975, its structural integrity deteriorated dramatically. The Dam presents a very harsh environment for construction materials, especially those concrete surfaces that are exposed to hundreds, or perhaps thousands, of freeze-thaw cycles over the years. In December 1992, the pedestrian walkway was closed due to concerns about its condition. A structural evaluation was made in 1993, which pointed out certain items in need of immediate repair or replacement. In late 1993, the District held a series of public meetings in an effort to learn if there was support for repairing this structure, or should the Dam be removed from the Mississippi River. The Park District learned that there was great support from the public, as well as local and state officials, for saving and rehabilitating the structure.

Plans and specifications were prepared, permits were applied for and received and in June 1995, construction began on a major rehabilitation project. The project budget was $6.2 million, and was funded through the Minnesota Department of Natural Resources Dam Safety Program and matching funds from the Metropolitan Council. Included in the project were the removal of the existing control gate system, including the gates, intermediate piers, and operator's bridge, and the installation of a new system of control gates and a new pedestrian bicycle bridge. Also included were miscellaneous repairs to the powerhouse and earth dike area on the Anoka Side. This was a two-year construction project with the work on the Hennepin County side taking place in 1995, and the work on the Anoka County side taking place in 1996. All of the work was completed in the spring of 1997. The reconstructed Dam has quite a different look from the original Coon Rapids Dam. The 28-tainter gates were replaced with five crest gates – the type where the water flows over the top of the gate. One of these is a steel control gate and the other four are inflatable crest gates.

8.1.3 Operations and Maintenance

The operating permit issued to District by the Minnesota Department of Natural Resources requires that the reservoir be held at a specified elevation during the open water months (summer) and lowered approximately 7-1/2 feet to its free-flow elevation over the spillway during the winter. The original permit issued in 1969 was permissive in nature thus *allowing* the district to perform the winter drawdown to decrease the potential for ice damage to the tainter gates. The subsequent permit (issued in 1995) made the winter drawdown a permanent operational requirement. Both permits are included in Appendix E.

Per DNR requirements, the District maintains an *Operations and Maintenance (O&M) Plan* for the Dam. The Plan includes the following general topics: objectives & policies; operating procedures; description of mechanical & electrical equipment; surveillance procedures; maintenance procedures; monitoring procedures; safety features; and operator training. Requirements for District and independent consultant periodic inspection are documented in the District's *Dam Inspection Program* which is appended to the O&M Plan. Also per DNR Requirements, the District maintains an *Emergency Action Plan* (EAP) for the Dam. The EAP is intended to provide operating, notification, and response procedures to be followed in the event of an emergency or unusual situation relating to the Coon Rapids Dam. The District instituted an *Asset Maintenance & Management Program* (AMMP) for the Dam in 2006. The AMMP includes a comprehensive inventory of all civil/structural, mechanical, and electrical features of the Dam and among other data, their dates of installation; life expectancy; and repair & replacement costs.

The Dam structure is maintained along with the West Coon Rapids Dam Regional Park amenities by District maintenance employees, with the primary responsibility for the Dam assigned to a crew chief/specialist position. Seven-day per week coverage is provided through the assignment of back up crew chief/specialist duties to qualified District maintenance employees from other park units. Approximately 400 hours/annually of staff time are spent monitoring and maintaining the non-recreational components of the Coon Rapids Dam.

8.1.4 Hydroelectric Power Development

Generation of hydropower at the Coon Rapids Dam site was ceased in 1966 when Northern States Power decommissioned its plant located on the Anoka County side of the river. Since the original plant was shut down, numerous attempts with varying levels of effort have been undertaken to re-develop hydropower at the site.

As most recently conceived, the Coon Rapids Dam Hydroelectric Project would be a low head, run-of-river facility featuring two identical horizontal pit-type Kaplan units. A Kaplan turbine is an axial flow machine with adjustable blades and adjustable wicket gates. The "pit type" designation refers to the water passage design in which the generator and speed increaser are located in a pit and the water flows around the pit to the turbine. Rated capacity of each unit would be nominally 4000 kW. Each turbine would have a minimum hydraulic capacity of approximately 600 cfs and maximum hydraulic capacity of approximately 3000 cfs. The Project control system would allow unattended operation. The system would monitor upstream pool elevation and keep the elevation within prescribed limits by controlling the hydro plant turbine blade angles, wicket gates openings, and the existing control gate. The control system would notify plant operators of equipment malfunction or other problems with the plant. The powerhouse would be a reinforced concrete structure with structural steel supported metal deck roof. The powerhouse would be founded on glacial till and would be connected to the existing gate control building on the Hennepin County side of the river.

8.2 Streamflow Data

Daily streamflow data for Coon Rapids Dam is available via a USGS streamflow gage located just downstream of the Dam near the Highway 610 Bridge [6]. Historical flow values used in computations were all derived from the gage record. Discussions of gage and streamflow characteristics are provided in Section 3.

In 2009, the St. Paul District Corps of Engineers (Corps) [18] completed its evaluation of alternative operating plans for headwaters reservoirs including Cass Lake, Lake Winnibigoshish, Leech Lake, Pokegama Lake, Sandy Lake, Cross Lake, and Gull Lake; for the purpose of balancing benefits relating to tribal trust, flood risk, environment, water quality, water supply, recreation, navigation, hydroelectric power, and other public interests. The Corps concluded that, *"Overall, the Final Plan would have a negligible or a minor beneficial effect on the human environment in the project area when compared to projected future conditions under the existing operating plan. This is because the Final Plan is so similar to the current plan that projected future conditions under each plan are expected to be so similar that they are nearly indistinguishable."*

Since the ROPE study recommendations are expected to have indistinguishable effects to streamflow, no adjustments to historic streamflow data utilized for this report are warranted.

8.3 Geology and Soils

8.3.1 Basin Geology

The operating permit issued to District geology of the upper Mississippi Basin and the Coon Rapids Dam site has been discussed in the project's National Dam Safety Program Report [19]. The following information is an excerpt from said report:

"This area of the Mississippi River Basin is in the Central Lowland - Western Lake Section and is just upstream from the mouth of the Minnesota River. The general topography is rolling to hilly and is formed by the many terminal moraines that exist in the Minneapolis-St. Paul region. Bedrock of the Ordovician system outcrops in the river bluffs (i.e., downstream of the Dam) and the basin contains a system of pre-glacial channels filled with glacio-fluvial deposits. The glacial materials originate from both the Keewatin and Labradorean centers."

8.3.2 Site Geology

The following discussion of the surface geology was also excerpted from the Dam Inspection Report [19]:

"The Minnesota G. S. Bulletin 37 describes the surface geology of the uplands to be a glacial sand plain consisting of glacial river sand and sand dunes with lakes and swamps formed by buried ice blocks and shallow basins eroded by wind. These deposits were formed during the retreat of the Grantsburg sublobe of the Des Moines lobe during the Wisconsin glaciation."

The geologic map entitled "Surficial Geology of Hennepin County" [20] shows the surficial soils in the vicinity of the river to consist predominately of sandy Holocene flood plain alluvium.

The bedrock underlying the glacio-fluvial deposits is the Jordan Sandstone (Late Cambrian). A geologic map of the Twin Cities [21] indicates the top of the Jordan Sandstone to be located between elevation 700 feet and 750 feet in the vicinity of the Dam. This would place the top of bedrock at 50 feet to 100 feet below the base of the Dam.

8.3.3 Soil Descriptions

The soil survey maps for Hennepin and Anoka Counties [22, 23] indicate that the near surface soils encountered along the flanks of the Mississippi, both upstream and downstream of the project, consist predominately of glacial outwash sands and gravels with variable amounts of silt. Lesser deposits of alluvial and glacial till soils are also indicated in the soil survey maps.

Thirteen core borings were taken by Soil Exploration Company in February and June of 1973. The logs and locations of the core borings are contained in engineering reports by Barr Engineering [24]. The core borings advanced in the area of the powerhouse encountered 20 feet to 50 feet of soft clayey and silty alluvium overlying sandy alluvium. The sandy alluvium was underlain by silty sand and clayey sand glacial till.

The core borings advanced along the spillway structure indicated variable soil conditions between the south (Hennepin) and north (Anoka) abutments of the structure. Under the north end of the spillway, the core borings encountered approximately 25 feet of coarse, sandy, alluvial deposits overlying up to 10 feet of fine, silt and clay, alluvial deposits. These alluvial deposits were underlain by a glacial till consisting of silty sand and gravel. These alluvial soils, as well as the alluvial deposits encountered under the powerhouse appear to have filled a pre-glacial river channel that had been cut in the underlying till.

Core borings advanced towards the center of the Dam indicated as much as 30 feet of coarse, sandy alluvium overlying the glacial till soils. At the south end of the spillway, the core borings indicated as little as 10 feet of sandy alluvium overlying the glacial till soils. The top elevation of the glacial till soils ranged from 770 feet at the powerhouse, to 780 feet under the north end of the spillway to 810 feet at the south end of the spillway. The soil profile along the Dam is shown on Figure 8-6 in Appendix C (from [24]).

8.4 Field Observations

Stanley Consultants conducted seven field observations in the fall of 2010. The primary purpose of the field observations was to observe and measure the location of the hydraulic jump on the downstream stilling basin and concrete apron over a range of river flows. Field collected data is included in the Hydraulic Computation Section of Appendix F. A discussion of field observations and analysis of the hydraulic jump is provided in Section 3.

8.5 Meetings and Correspondence

The fish barrier and improvement preliminary design process included communications and information exchanges with the District and DNR. Communications came in the form of telephone conversations, e-mails, written correspondence and face-to-face meetings. Copies of pertinent correspondence are included in Appendix D. A summary is provided below:

- August 26, 2010 – Project Kickoff Meeting.
- October 21, 2010 – Progress Meeting
- November 8, 2010 – Progress Meeting.
- December 15, 2010 – Barrier Evaluation Memo issued.
- December 28, 2010 – Dam Improvement Memo issued.

Section 9

References

1. Minnesota Department of Natural Resources letter to Three Rivers Park District, subject: *Importance of the Coon Rapids Dam as barrier to the spread of Asian Carp*, February 12, 2010.

2. Asian Carp Working Group, *Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (submitted to the Aquatic Nuisance Species Task Force), November 2007.

3. Minnesota Department of Natural Resources, "Importance of Coon Rapids Dam as a Barrier to Spread of Asian Carp", October 18, 2010.

4. FISHPRO Consulting Engineers & Scientists, "Feasibility Study to Limit the Invasion of Asian Carp into the Upper Mississippi River Basin", March 15, 2004.

5. Minnesota Department of Natural Resources, *Preventing the Introduction of Asian Carp into Minnesota*, November 1, 2007.

6. United States Geological Survey, *USGS Gage 05288500 – Mississippi River near Anoka*, MN, (http://waterdata.usgs.gov/nwis/nwisman/?site_no=05288500&agency_cd=USGS), 2010.

7. Federal Emergency Management Agency, "Flood Insurance Study – Hennepin County, Minnesota – All Jurisdictions", September 2, 2004.

8. United States Bureau of Reclamation, Hydraulic Design of Stilling Basins and Energy Dissipators, EM 25, 1958.

9. Barr Engineering Co., *Plans and Specifications for Repair and Modification of the Coon Rapids Dam*, prepared for Hennepin County Park Reserve District, April 1975.

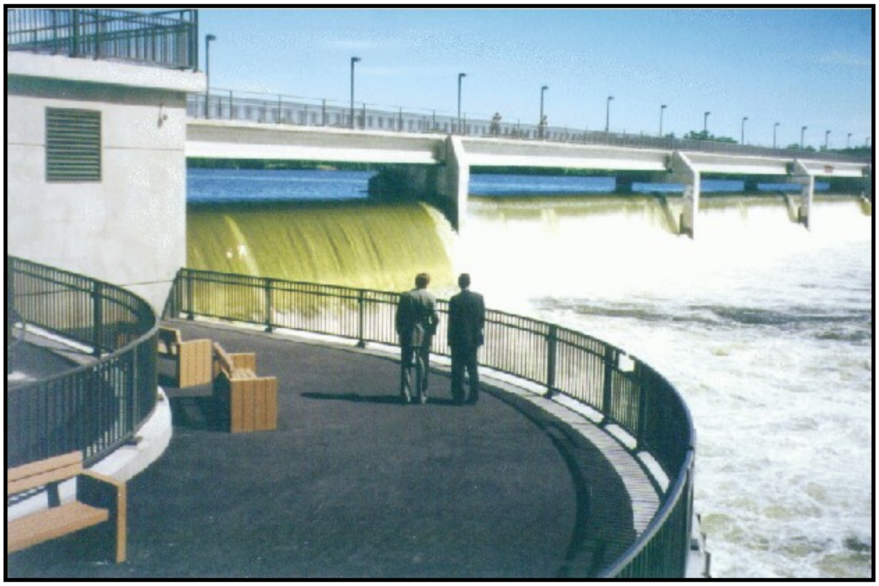
10. Stanley Consultants, Inc. "5-Year Inspection Report - Coon Rapids Dam – Final Draft", July 2010.

11. AMI Consulting Engineers, P.A. “Coon Rapids Dam Structural Inspection – Underwater Sector Scan Imaging – Coon Rapids, MN”, Prepared for Stanley Consultants, July 2010.
12. Stanley Consultants, Inc., “Coon Rapids Dam Fish Barrier and Improvements Preliminary Design – Barrier Evaluation Memo”, December 15, 2010.
13. H.M Byllesby & Co, Engineering News Record – Vol. 81 - No. 4, *“Repair Washout Under Dam by Sheet Pile Cutoff Embedded in Concrete”*, July 25, 1918.
14. RS Means, *“Mechanical Cost Data”*, 34th Annual Edition. 2011.
15. RS Means, “*Heavy Construction Cost Data”* 22nd Annual Edition. 2008.
16. RS Means, *“Site Work & Landscape Cost Data”* 27th Annual Edition. 2008.
17. Roise, Charlene K. (Hess, Roise and Company), “Determination of National Register Eligibility – Coon Rapids Dam, Mississippi River, Hennepin and Anoka Counties, Minnesota”, 1994.
18. U.S. Army Corps of Engineers, St. Paul District, “Mississippi River Headwaters Reservoir Operating Plan Evaluation (ROPE) – Upper Mississippi River Headwater, Bemidji to St. Paul, Minnesota – Final Integrated Reservoir Operating Plan Evaluation and Environmental Impact Statement”, September 2009.
19. U.S. Army Corps of Engineers, St. Paul District, “Mississippi river – Coon Rapids Dam, Hennepin County, Inventory No. 507, National Dam Safety Program Inspection Report”, October 1978.
20. Meyer, Gary N. & Hobb, Howard C (University of Minnesota/Minnesota Geological Survey), *“Surficial Geology of Hennepin County”* (map), 1989.
21. Mosler, John H. & Tipping, Robert G. (University of Minnesota/Minnesota Geological Survey), *“Bedrock Geology and Structure of the Seven-County Twin Cities Metropolitan Area, Minnesota”*, 2000.
22. United States Department of Agriculture/Natural Resources Conservation Service, *“Soil Survey of Hennepin County, Minnesota”*.
23. United States Department of Agriculture/Natural Resources Conservation Service, *“Soil Survey of Anoka County, Minnesota”*, 1977.
24. Barr Engineering Company, “Preliminary Report on Repairs and Improvements to the Coon Rapids Dam”, 1973.

Appendix A

Photographs

Photograph 1
Downstream Aerial View of Coon Rapids Dam



Photograph 2
Main Spillway (background) Fishing Platform and Gate Control Building (foreground)

Photograph 3
Main Spillway Inflatable Gate, Bridge Girders, and Bridge Pier

Photograph 4
Downstream View of Main Spillway, Inflatable Gate, and Bridge

Photograph 5
Downstream View of Main Spillway

Photograph 6
Gate Control Building

Photograph 7
Old Powerhouse Deck Area

Photograph 8
Upstream View of Old Powerhouse

Photograph 9
Downstream View of Old Powerhouse/Fishing Area

Photograph 10
Downstream View of Ancillary Spillway Area

Photograph 11
Looking Downstream from Anoka Abutment

Photograph 12
Xcel Energy Substation

Photograph 13
Three Rivers Park District Visitors Center

Photograph 14
Anoka County Visitors Center & Parking Area

Photograph 15
CR Dam Regional Park Paved Trail

Photograph 16
Typical Shoreline Residential Property

Photograph 17
Typical Shoreline Vacant Property

Photograph 18
2005 Ice Jam Effects during Low River Flow

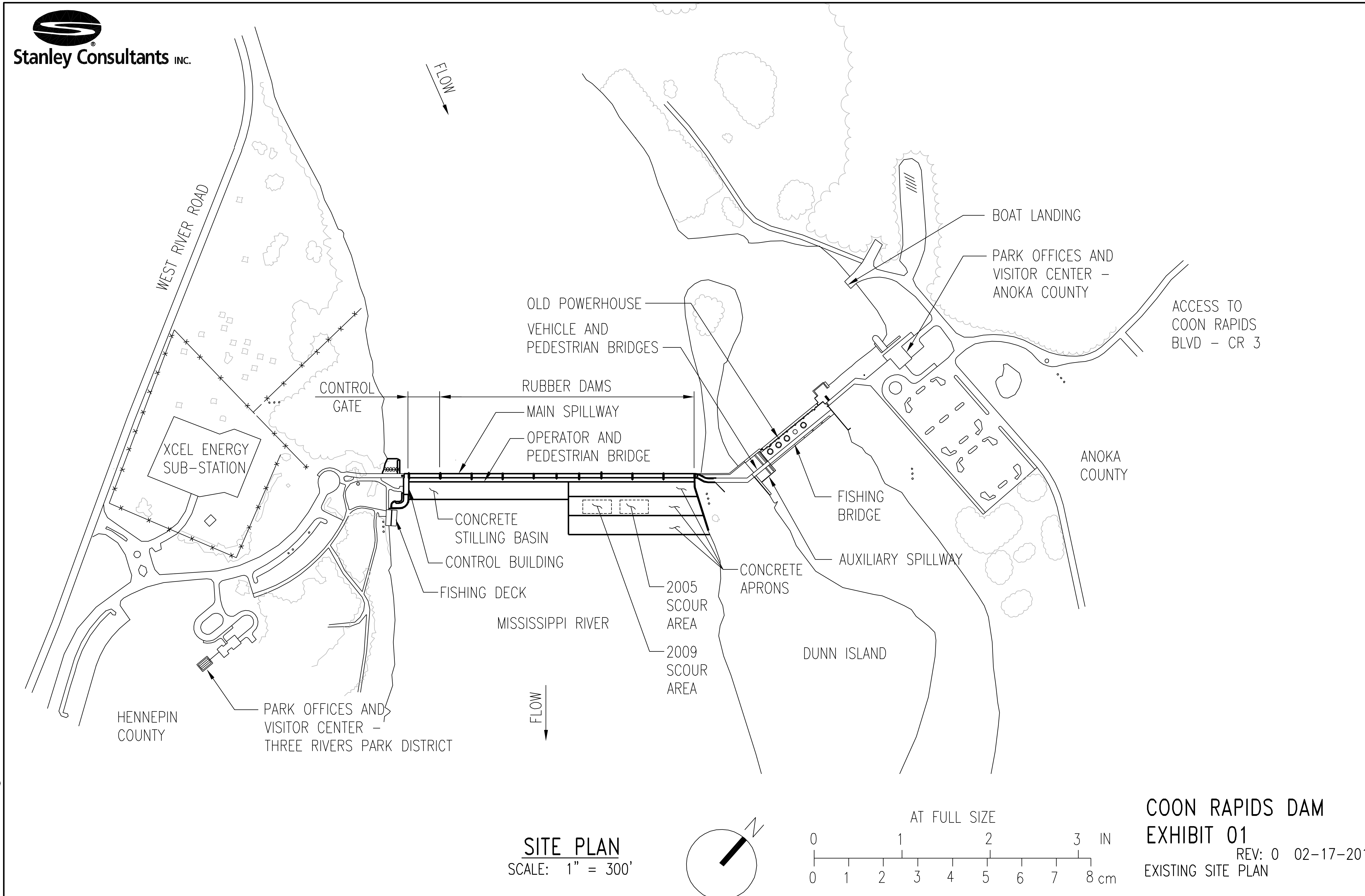
Photograph 19
2010 Ice Jam Effects during Low River Flow

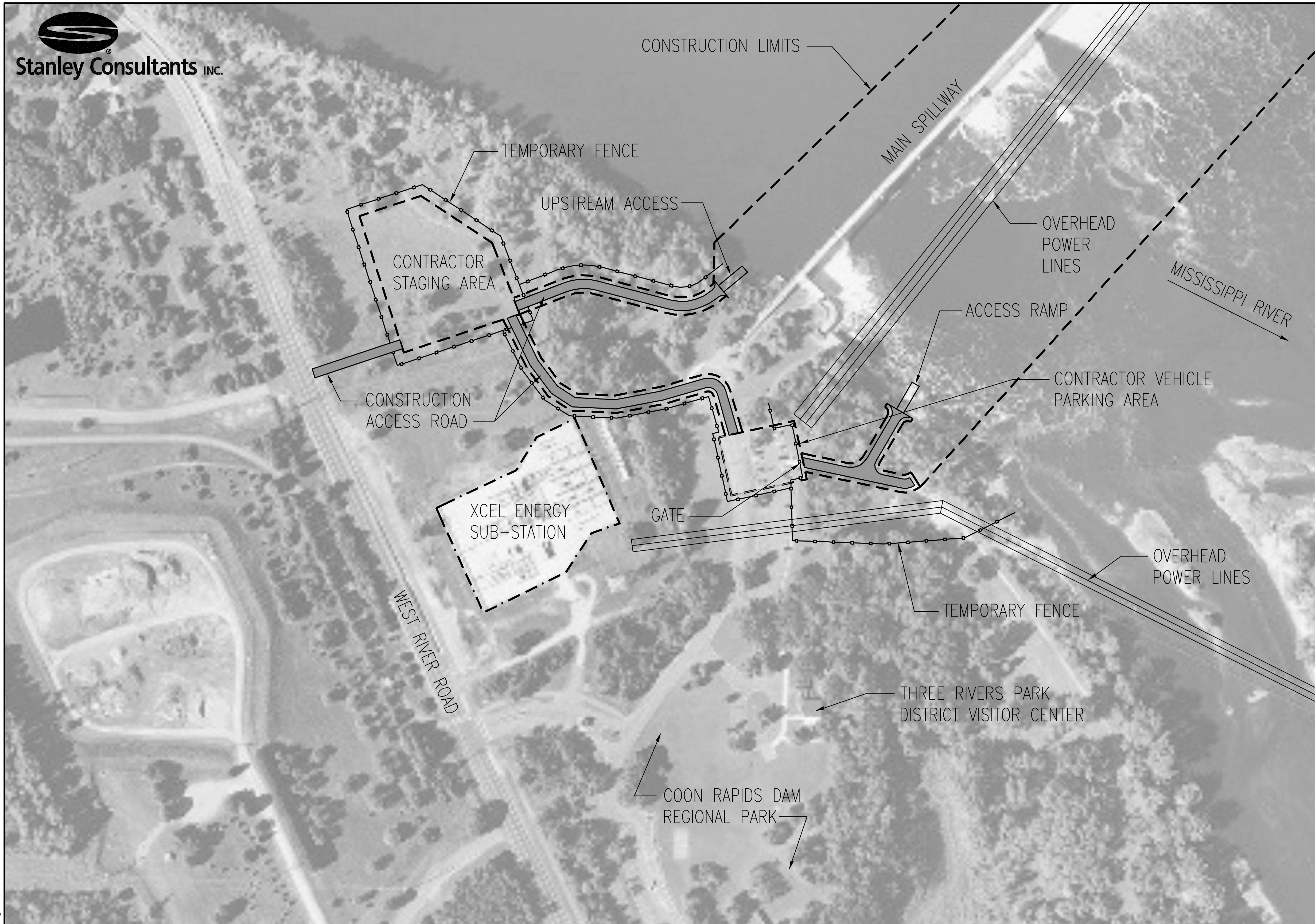
Photograph 20
Hydraulic Jump on Apron Portion of Dam

Photograph 21
Inflatable Gate Repair Operation

Appendix B

Exhibits


Stanley Consultants INC.
FLOW
WEST RIVER ROAD
BOAT LANDING
PARK OFFICES AND VISITOR CENTER – ANOKA COUNTY
ACCESS TO COON RAPIDS BLVD – CR 3
OLD POWERHOUSE
VEHICLE AND PEDESTRIAN BRIDGES
CONTROL GATE
RUBBER DAMS
MAIN SPILLWAY
OPERATOR AND PEDESTRIAN BRIDGE
XCEL ENERGY SUB-STATION
ANOKA COUNTY
FISHING BRIDGE
CONCRETE STILLING BASIN
CONTROL BUILDING
AUXILIARY SPILLWAY
CONCRETE APRONS
FISHING DECK
2005 SCOUR AREA
MISSISSIPPI RIVER
2009 SCOUR AREA
DUNN ISLAND
HENNEPIN COUNTY
PARK OFFICES AND VISITOR CENTER – THREE RIVERS PARK DISTRICT
FLOW
SITE PLAN
SCALE: 1" = 300'
N
AT FULL SIZE
0 1 2 3 IN
0 1 2 3 4 5 6 7 8 cm
COON RAPIDS DAM
EXHIBIT 01
REV: 0 02-17-2011
EXISTING SITE PLAN



CADD B2-R3 © STANLEY CONSULTANTS Plot Date:2/16/2011 11:32:52 AM CADD File: EX-02.dwg

SITE PLAN

SCALE: 1" = 200'

N

AT FULL SIZE

0 1 2 3 IN

0 1 2 3 4 5 6 7 8 cm

COON RAPIDS DAM EXHIBIT 02

REV: 0 02-17-2011

CONSTRUCTION ACCESS PLAN – HENNEPIN COUNTY SIDE

NOTE:

ALTERNATE CONSTRUCTION ACCESS COULD BE PROVIDED FROM UPSTREAM OF DAM.

© STANLEY CONSULTANTS Plot Date:2/16/2011 11:33:01 AM CADD File: EX-03.dwg

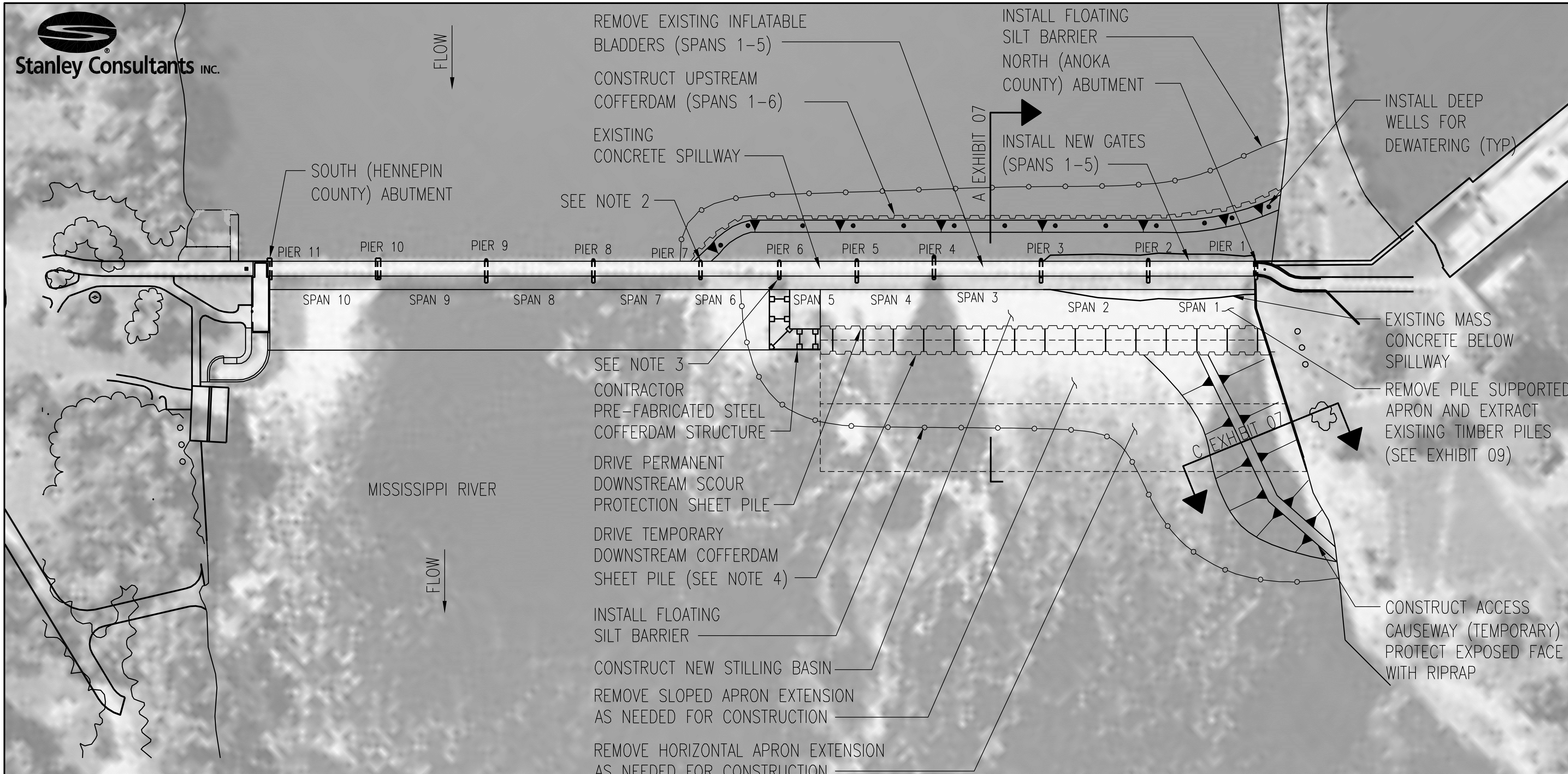
CADD B2-R3

SITE PLAN
SCALE: 1" = 200'

N

AT FULL SIZE
0 1 2 3 IN
0 1 2 3 4 5 6 7 8 cm

COON RAPIDS DAM
EXHIBIT 03
REV: 0 02-17-2011
CONSTRUCTION ACCESS PLAN – ANOKA COUNTY SIDE



NOTES:

1. DIRECT RIVER FLOW THROUGH SPANS 6 THROUGH 10 FOR STAGE 1 WORK.
2. TIE IN UPSTREAM SHEET PILE NEAR PIER 7.
3. TIE IN CENTER COFFERDAM STRUCTURE TO CONCRETE SPILLWAY NEAR PIER 6, USING FABRICATED END SECTION. CONNECT TO DOWNSTREAM COFFERDAM SHEET PILE.
4. DRIVE SHEETS FOR USE AS DOWNSTREAM COFFERDAM. REMOVE FOLLOWING STAGE 1 CONSTRUCTION.
5. USE RUBBLE FROM APRON REMOVAL TO FILL EXISTING SCOUR HOLES. FILL REMAINING VOIDS WITH RIPRAP TO MIN EL.795

SITE PLAN
SCALE: 1" = 100'

N

AT FULL SIZE
0 1 2 3 IN
0 1 2 3 4 5 6 7 8 cm

COON RAPIDS DAM
EXHIBIT 04
REV: 0 02-17-2011
CONSTRUCTION STAGING PLAN - STAGE 1

Plot Date:2/16/2011 11:38:29 AM CADD File: EX-04.dwg

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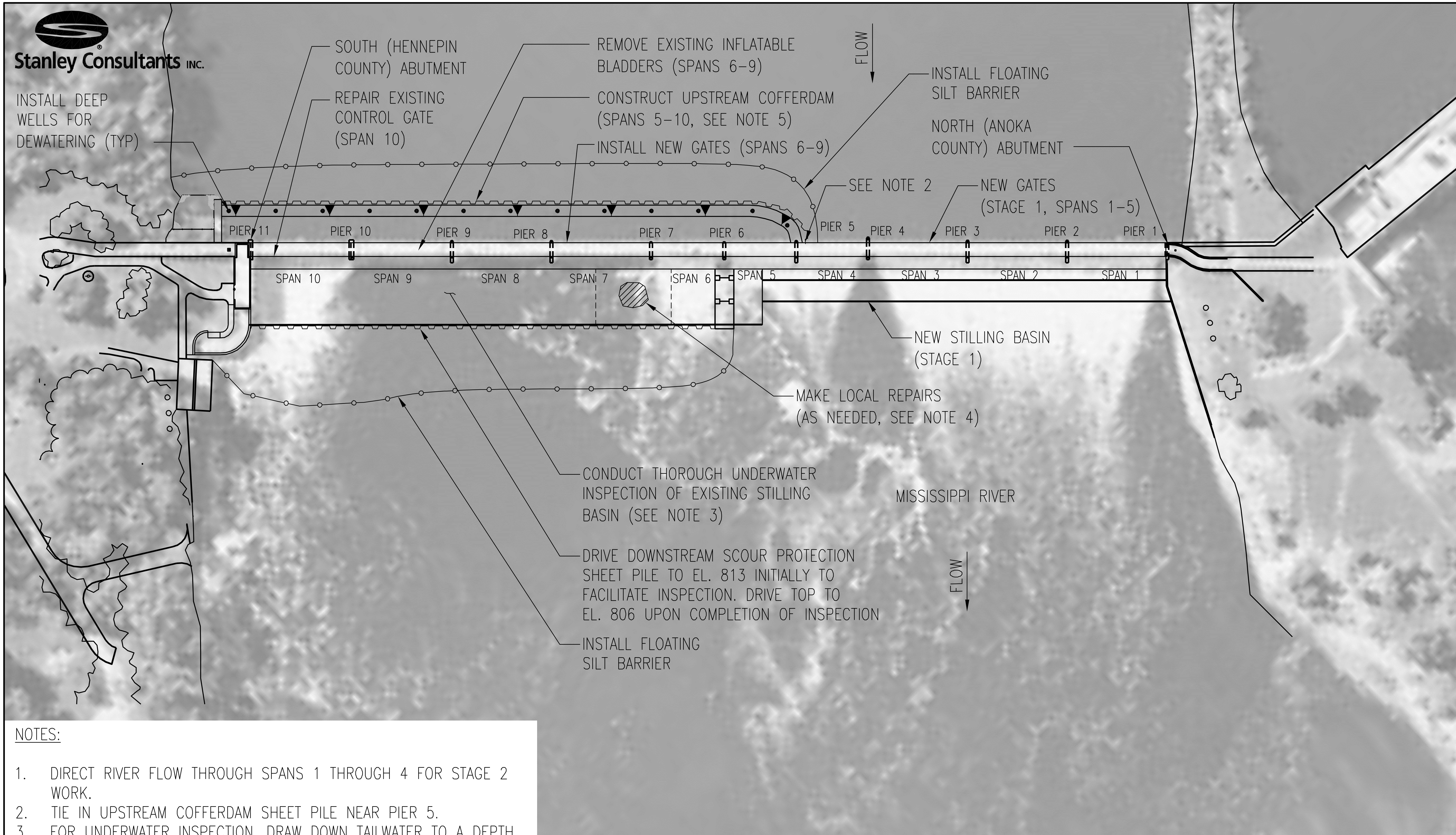
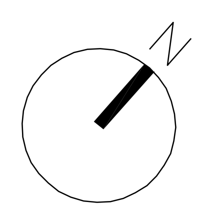


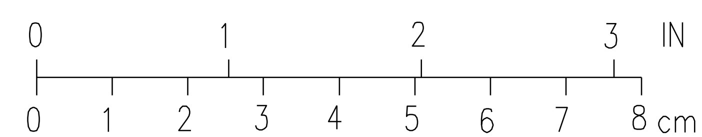
NOTES:

1. DIRECT RIVER FLOW THROUGH SPANS 1 THROUGH 4 FOR STAGE 2 WORK.
2. TIE IN UPSTREAM COFFERDAM SHEET PILE NEAR PIER 5.
3. FOR UNDERWATER INSPECTION, DRAW DOWN TAILWATER TO A DEPTH WHERE COMPREHENSIVE AND ACCURATE INSPECTION CAN BE MADE.
4. MAKE REPAIRS BY ISOLATING DAMAGED AREA WITH BOX STRUCTURE AND DEWATERING.
5. FOR UPSTREAM COFFERDAM, EXTRACT AND RE-USE SHEET PILE FROM STAGE 1 UPSTREAM COFFERDAM. BACKFILL WITH EARTH TO ESTABLISH DRIVING SURFACE.

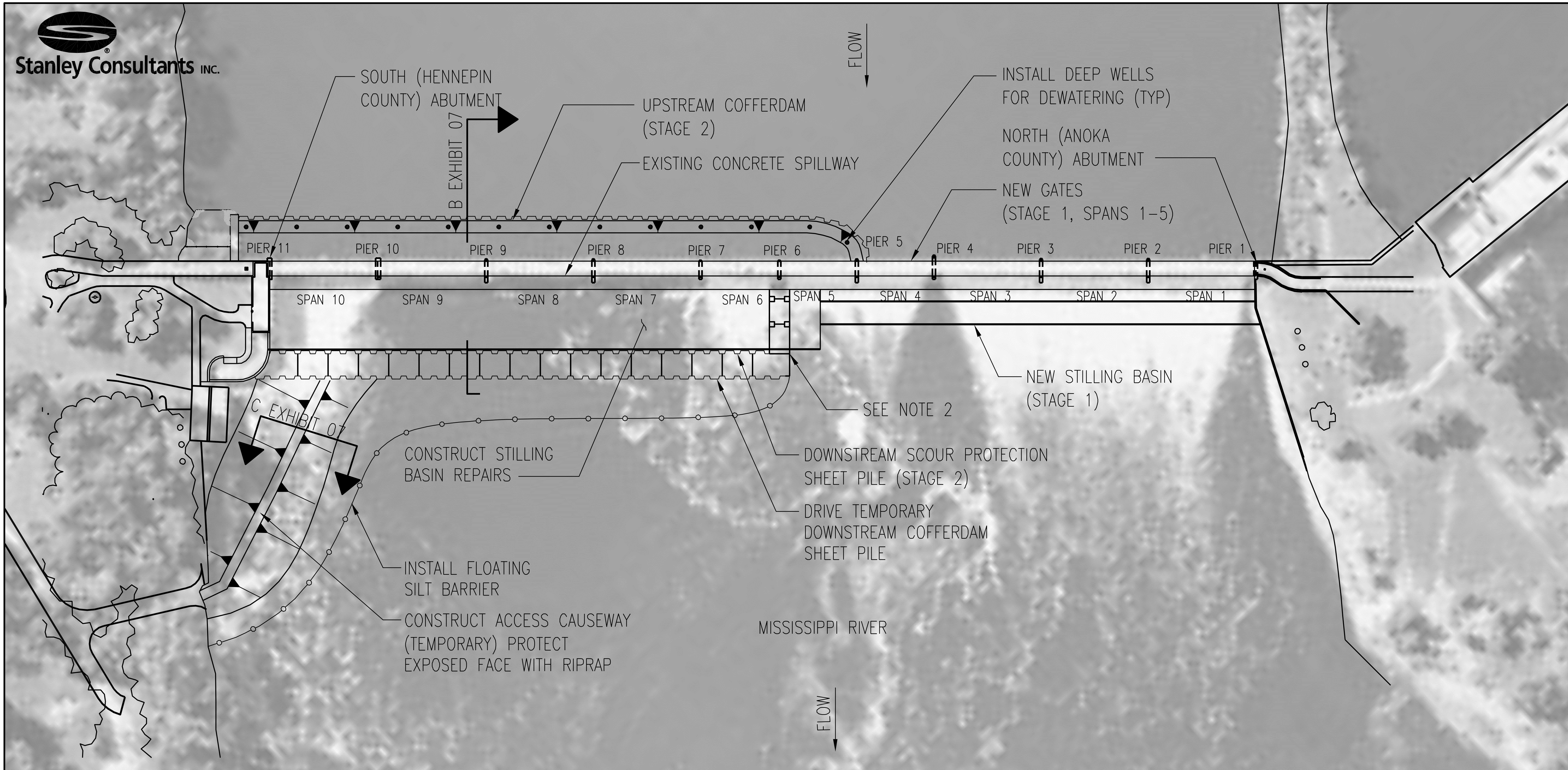
SITE PLAN
SCALE: 1" = 100'



AT FULL SIZE



COON RAPIDS DAM
EXHIBIT 05
REV: 0 02-17-2011
CONSTRUCTION STAGING PLAN - STAGE 2



Plot Date:2/16/2011 11:33:35 AM CADD File: EX-06.dwg

NOTES:

1. THIS DRAWING DEPICTS A CONCEPTUAL LAYOUT FOR A DOWNSTREAM COFFERDAM THAT WOULD BE NECESSARY IF SIGNIFICANT REPAIRS ARE IDENTIFIED DURING THE STAGE 2 INSPECTION OF THE EXISTING STILLING BASIN. THE ACTUAL CONFIGURATION OF THE COFFERDAM WOULD BE MODIFIED TO DEWATER THE REQUIRED WORK AREA. LESS SIGNIFICANT REPAIRS WOULD BE FACILITATED USING LOCALIZED DEWATERING STRUCTURES ONLY.
2. TIE IN DOWNSTREAM COFFERDAM SHEET PILE TO CENTER CLOSURE STRUCTURE.

SITE PLAN

SCALE: 1" = 100'

N

AT FULL SIZE

0 1 2 3 IN

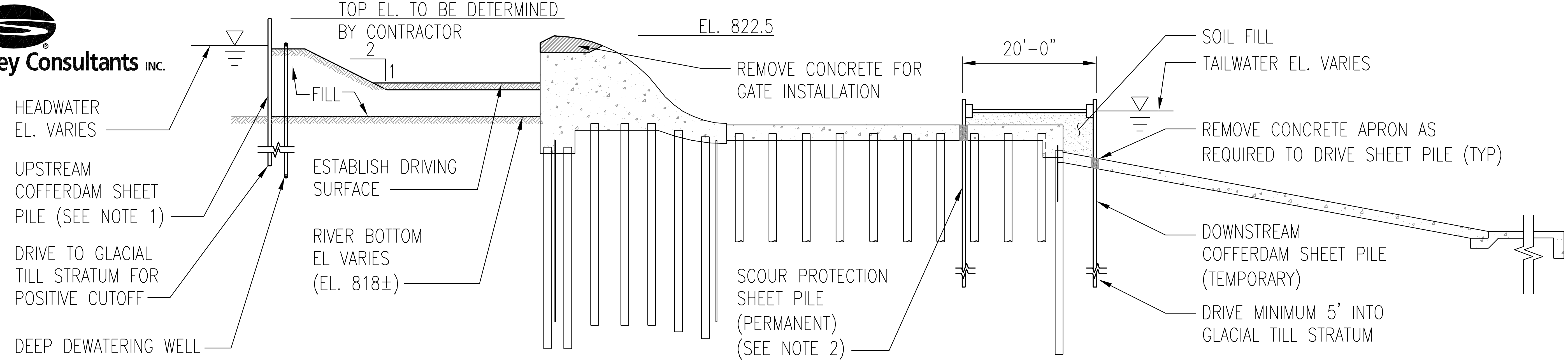
0 1 2 3 4 5 6 7 8 cm

COON RAPIDS DAM
EXHIBIT 06

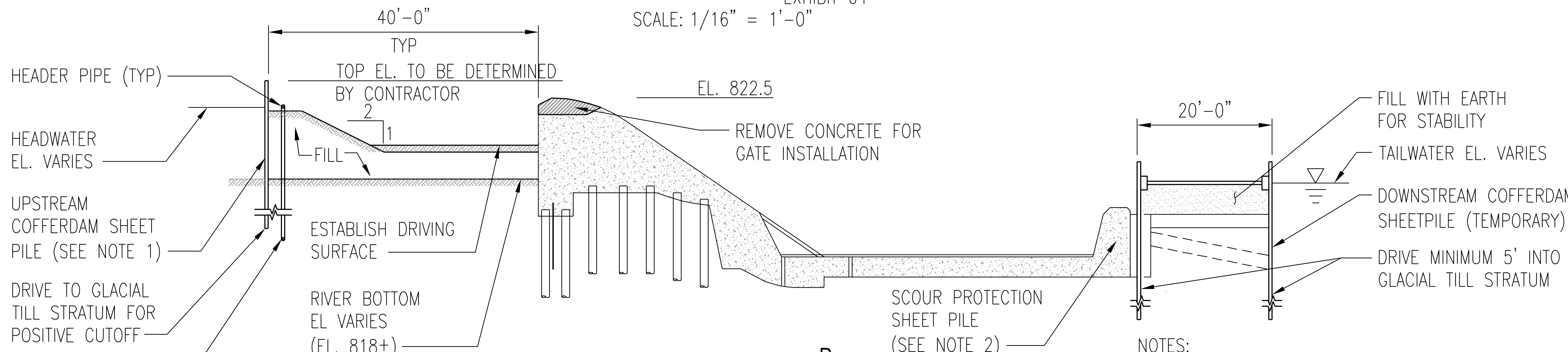
REV: 0 02-17-2011

CONSTRUCTION STAGING PLAN – STAGE 3 (IF NECESSARY)

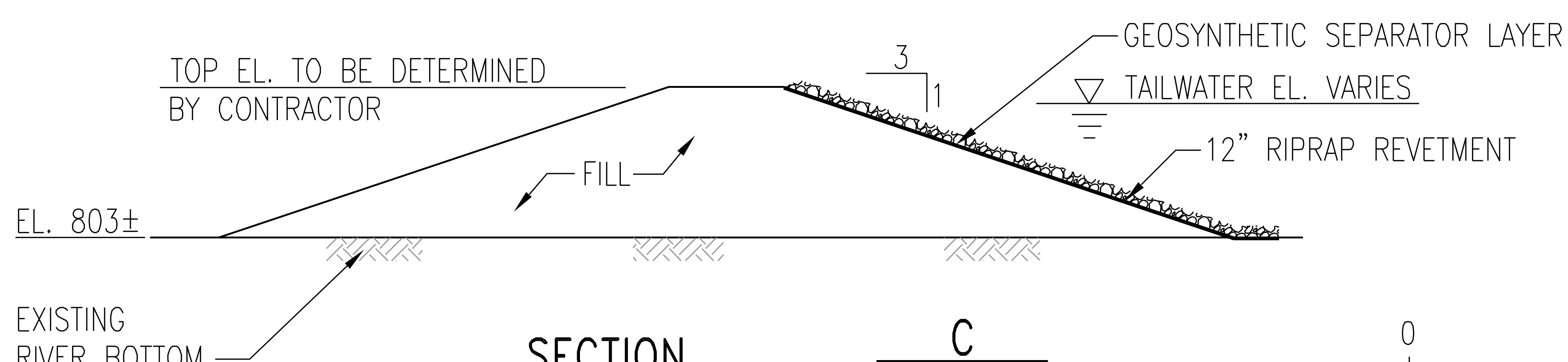
Stanley Consultants INC.



SECTION A
EXHIBIT 04
SCALE: 1/16" = 1'-0"



SECTION B
EXHIBIT 06
SCALE: 1/16" = 1'-0"



SECTION C
EXHIBIT 04
EXHIBIT 06
SCALE: 1/16" = 1'-0"

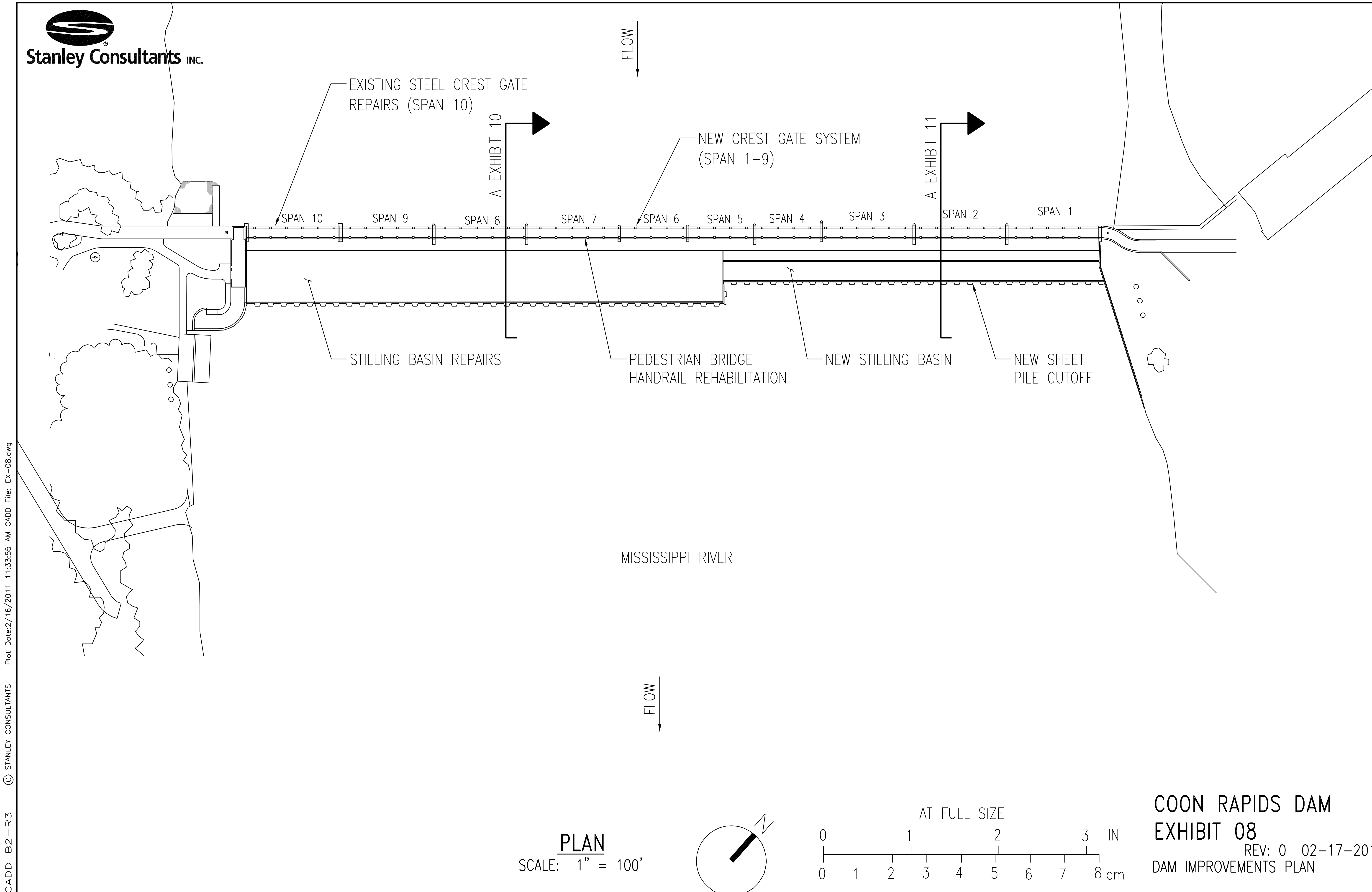
NOTES:

1. UPSTREAM AND DOWNSTREAM COFFERDAM ELEVATIONS TO BE SET BY CONTRACTOR BASED ON ASSESSMENT OF ACCEPTABLE RISK.
2. AFTER NEW STILLING BASIN IS CONSTRUCTED, CUT OR DRIVE SHEETS TO TOP ELEVATION OF 806.0 (SECTION A) AND 809.0 (SECTION B)
3. REMOVE AND SALVAGE DOWNSTREAM COFFERDAM SHEET PILE AFTER CONSTRUCTION.

AT FULL SIZE
0 1 2 3 IN
0 1 2 3 4 5 6 7 8 cm

COON RAPIDS DAM
EXHIBIT 07
REV: 0 02-17-2011
COFFERDAM SECTIONS AND DETAILS

CADD B2-R3 © STANLEY CONSULTANTS Plot Date:2/16/2011 11:33:51 AM CADD File: EX-07.dwg



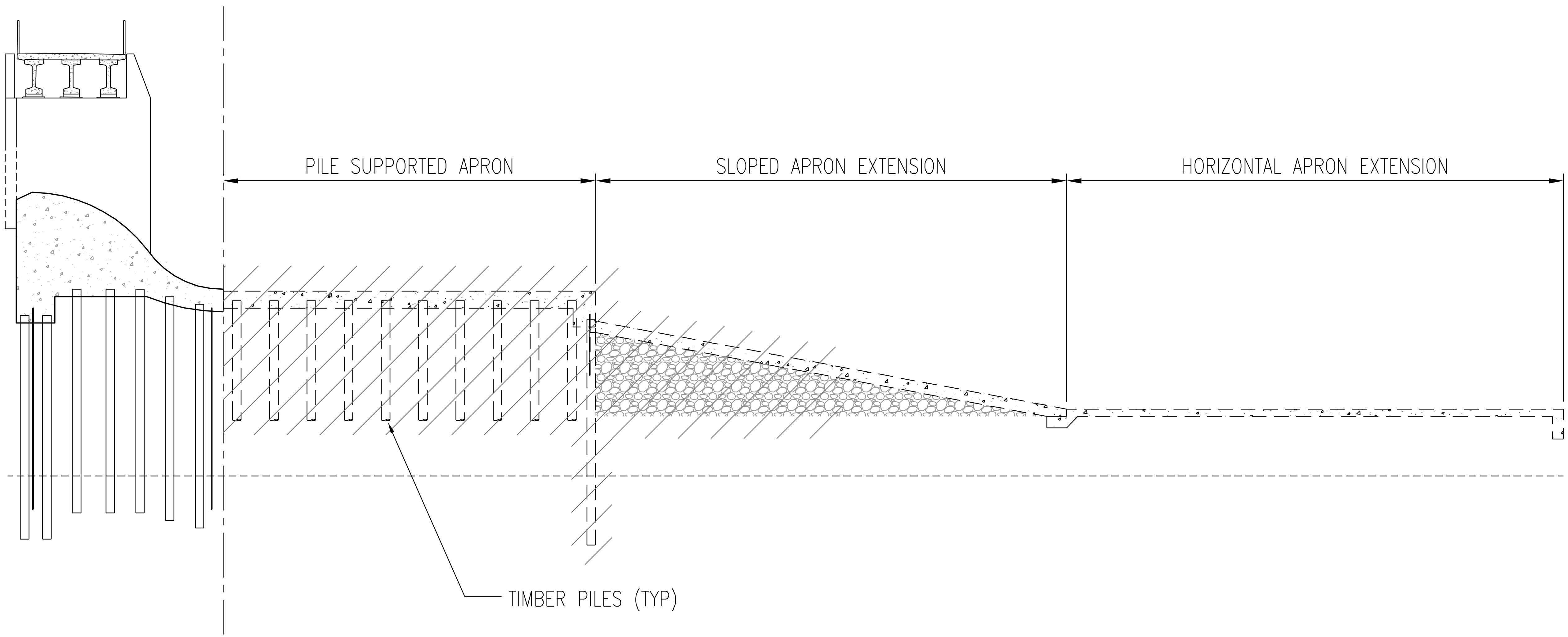
PLAN
SCALE: 1" = 100'

COON RAPIDS DAM
EXHIBIT 08
REV: 0 02-17-2011
DAM IMPROVEMENTS PLAN

Stanley Consultants INC.

NOTES:

1. REMOVE HORIZONTAL PILE-SUPPORTED APRON.
2. REMOVE EXISTING TIMBER PILES.
3. REMOVE SLOPED APRON EXTENSION AS NEEDED FOR SCOUR PROTECTION AND COFFERDAM INSTALLATION.
4. USE RUBBLE FROM DEMOLISHED APRONS TO FILL LARGE SCOUR HOLES TO MINIMUM EL. 795.



SECTION A / EXHIBIT 04
SCALE: 1/16" = 1'-0"

AT FULL SIZE
0 1 2 3 IN
0 1 2 3 4 5 6 7 8 cm

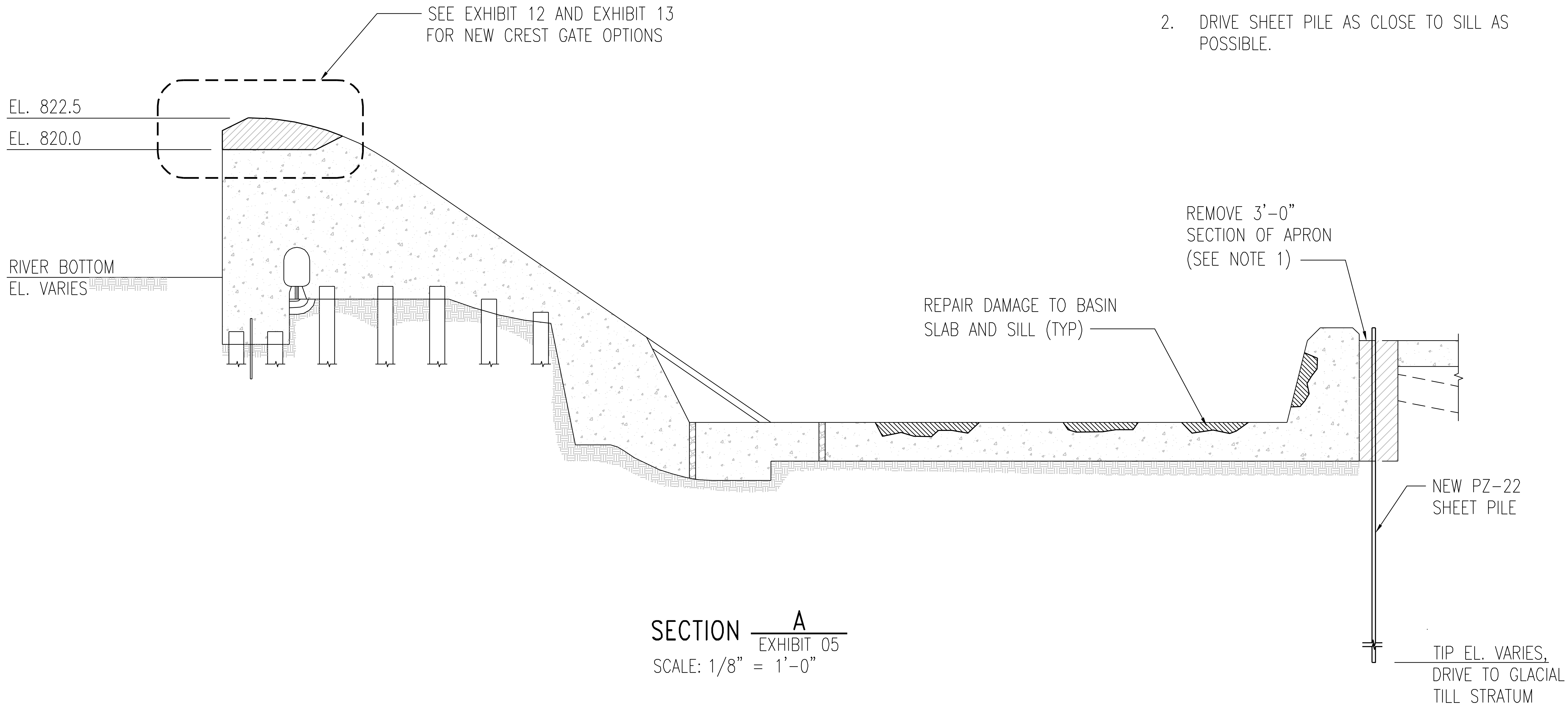
COON RAPIDS DAM
EXHIBIT 09
REV: 0 02-17-2011
APRON DEMOLITION SECTION

Stanley Consultants INC.

NOTES:

1. REMOVE CONCRETE APRON TO DRIVE NEW SCOUR CUTOFF SHEET PILE. BACKFILL WITH CONCRETE.

2. DRIVE SHEET PILE AS CLOSE TO SILL AS POSSIBLE.



SECTION $\frac{A}{\text{EXHIBIT 05}}$

SCALE: 1/8" = 1'-0"

AT FULL SIZE

0 1 2 3 IN

0 1 2 3 4 5 6 7 8 cm

COON RAPIDS DAM

EXHIBIT 10

REV: 0 02-17-2011

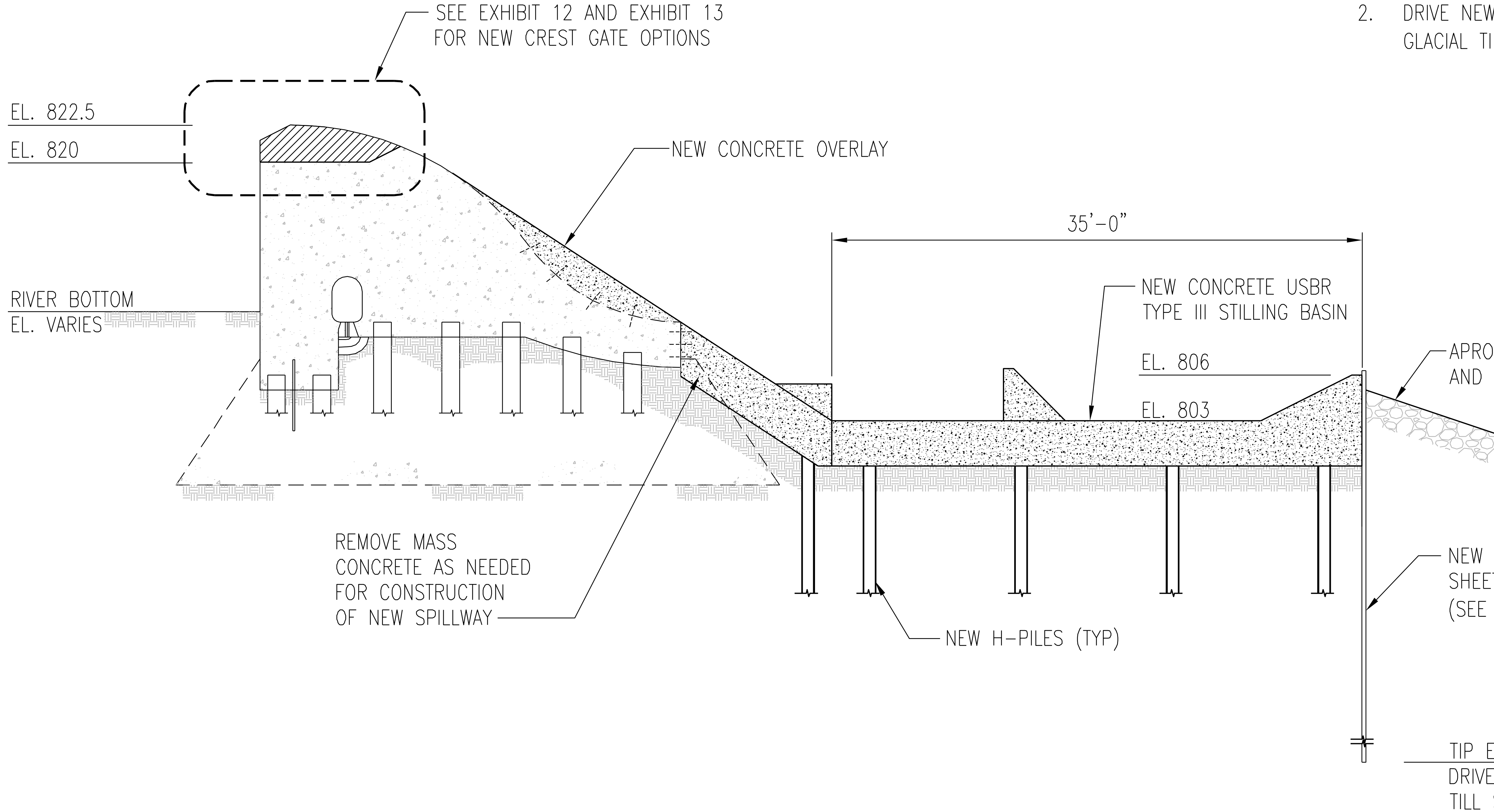
STILLING BASIN REPAIRS – HENNEPIN COUNTY SIDE

Stanley Consultants INC.

NOTES:

1. DRIVE DOWNSTREAM SHEET PILE FIRST AND USE AS FORM FOR SILL POUR.

2. DRIVE NEW HP 10x42 STEEL H-PILES TO GLACIAL TILL. SPACE 10' EACH WAY.



SECTION A / EXHIBIT 08

SCALE: 1/8" = 1'-0"

AT FULL SIZE

0 1 2 3 IN

0 1 2 3 4 5 6 7 8 cm

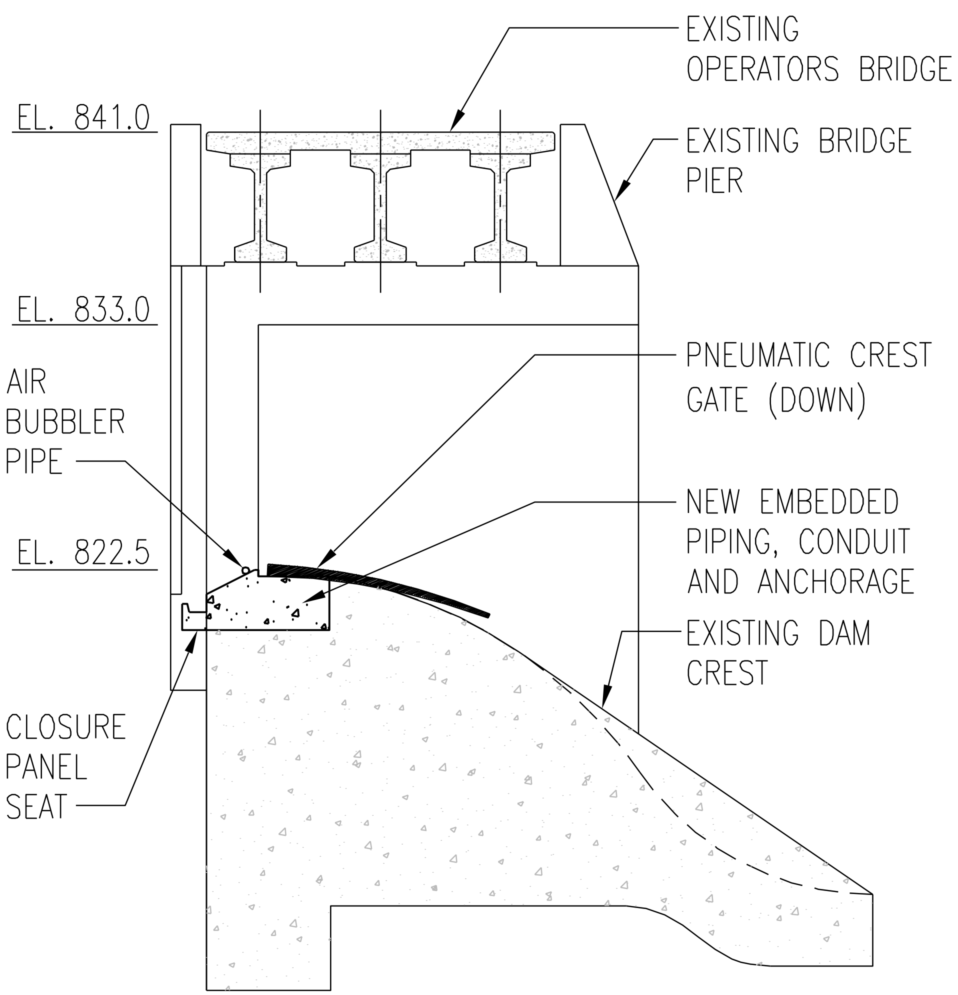
COON RAPIDS DAM
EXHIBIT 11

REV: 0 02-17-2011

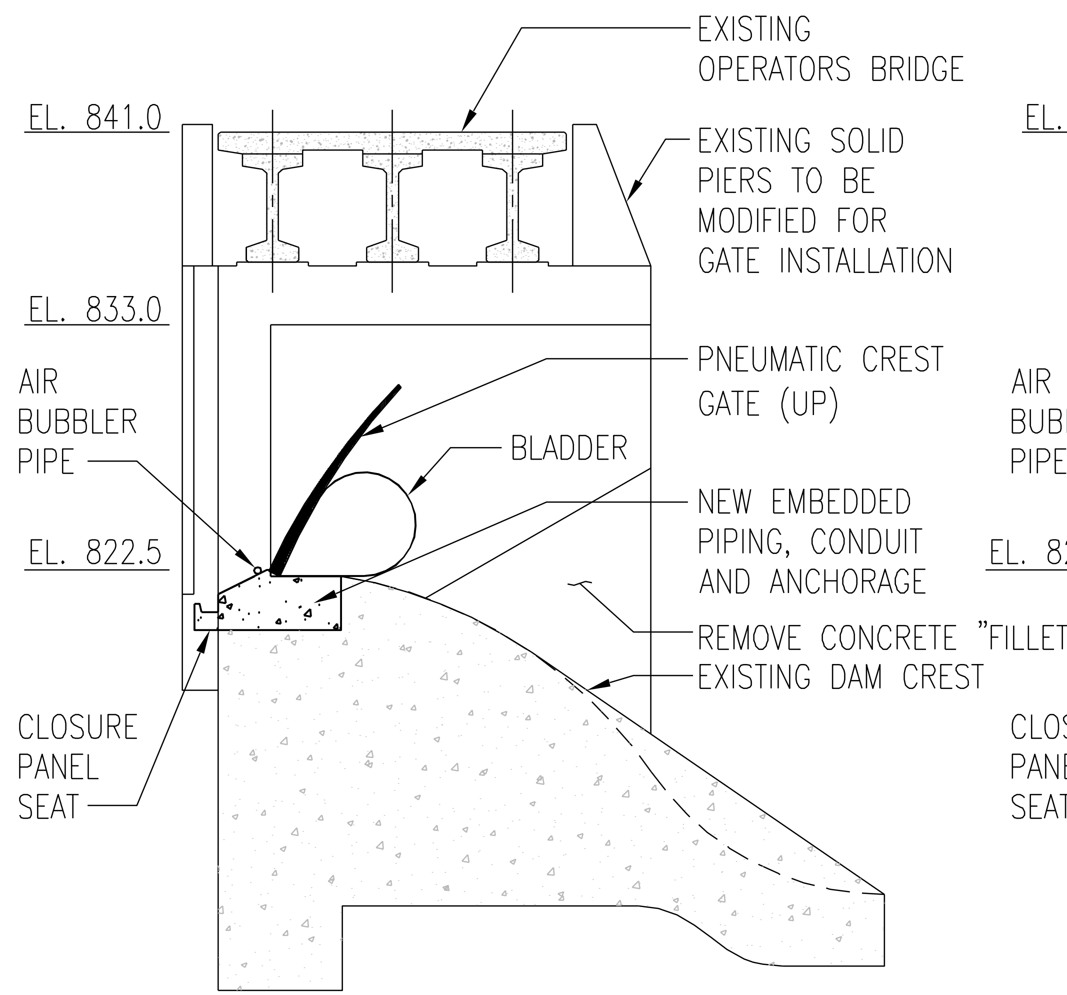
NEW STILLING BASIN – ANOKA COUNTY SIDE

CADD B2-R3 © STANLEY CONSULTANTS Plot Date:2/16/2011 11:34:10 AM CADD File: EX-11.dwg

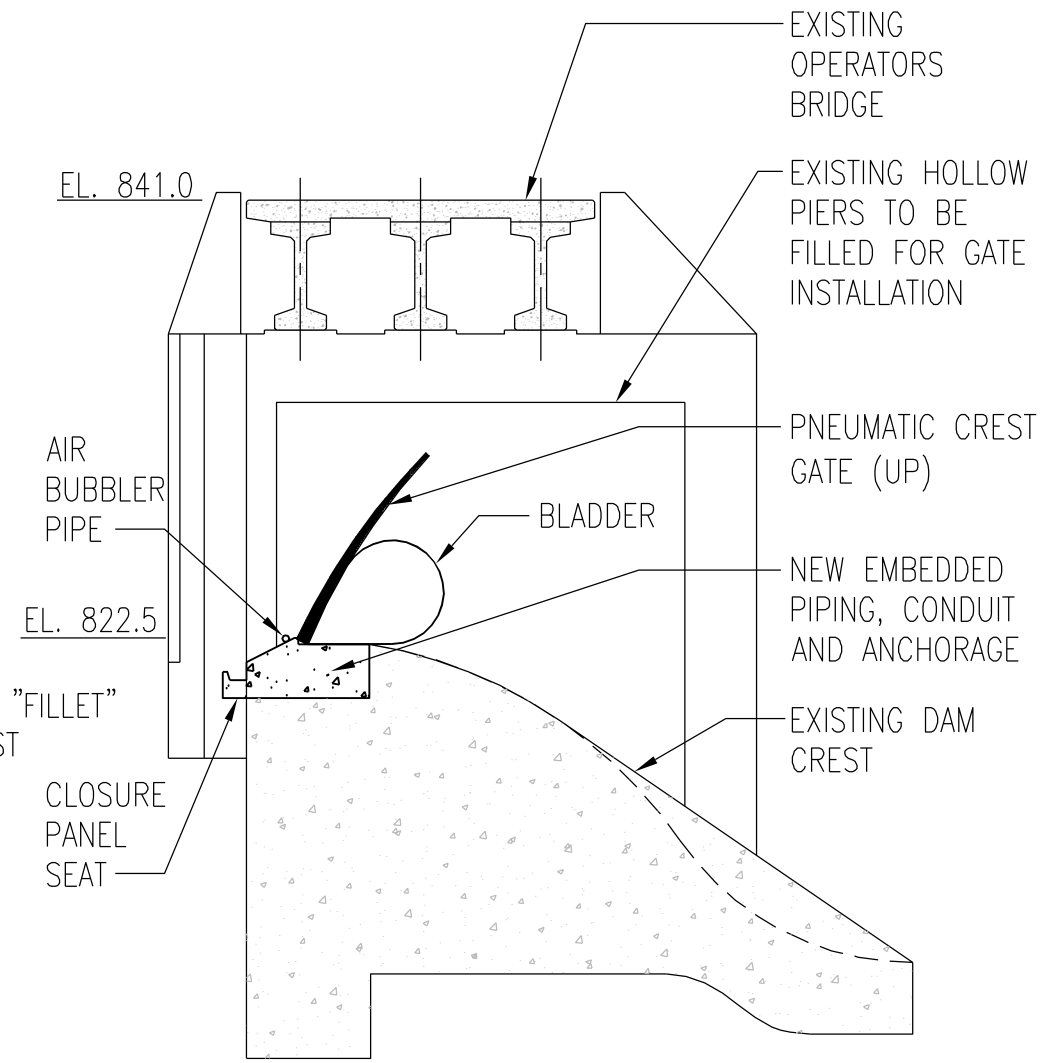
Stanley Consultants INC.



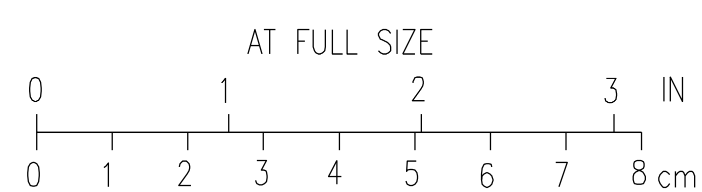
GATE IN DOWN POSITION
SCALE: 1/8" = 1'-0"



GATE IN UP POSITION (AT SOLID PIERS)
SCALE: 1/8" = 1'-0"

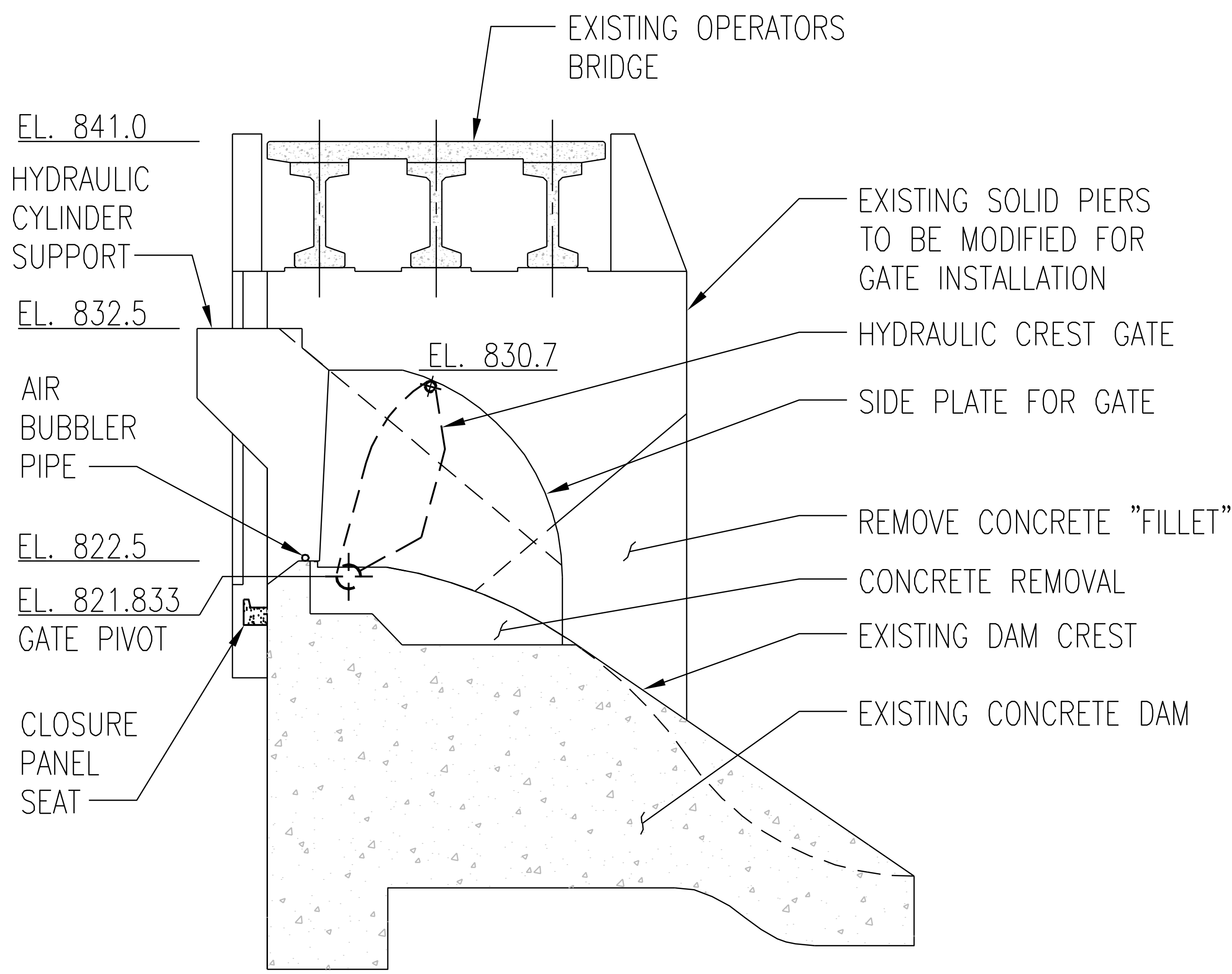


GATE IN UP POSITION (AT HOLLOW PIERS)
SCALE: 1/8" = 1'-0"

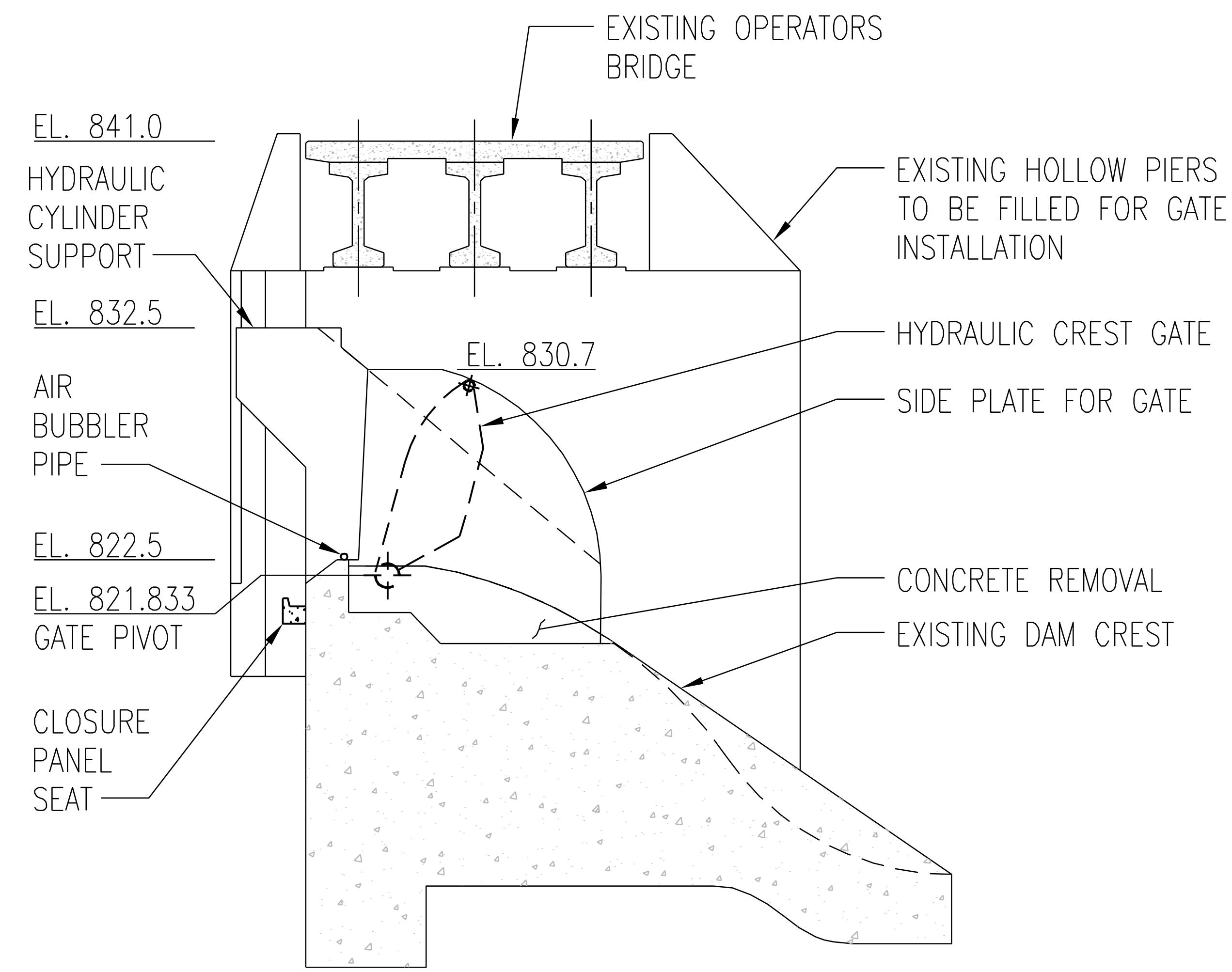


COON RAPIDS DAM
EXHIBIT 12
REV: 0 02-17-2011
PNEUMATIC GATE WORK

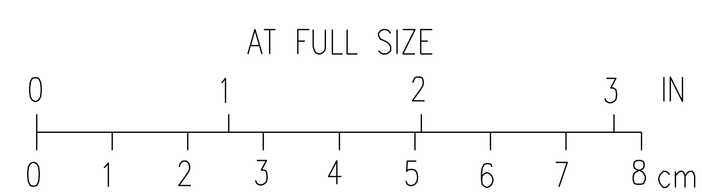
Stanley Consultants INC.



GATE SECTION AT SOLID PIERS
SCALE: 1/8" = 1'-0"



GATE SECTION AT HOLLOW PIERS
SCALE: 1/8" = 1'-0"



COON RAPIDS DAM
EXHIBIT 13
REV: 0 02-17-2011
HYDRAULIC GATE WORK

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Appendix C

Figures

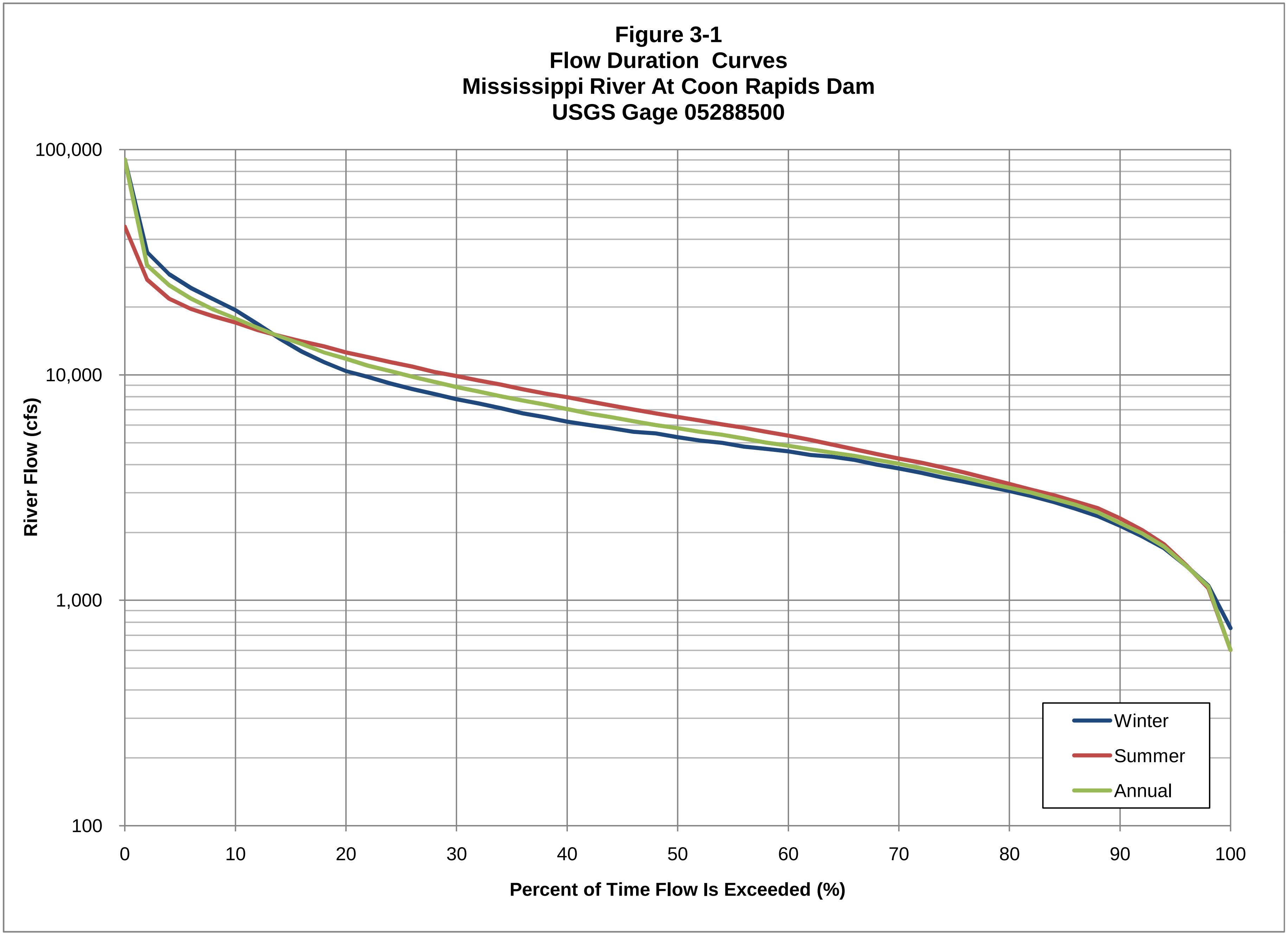


Figure 3-1
Flow Duration Curves
Mississippi River At Coon Rapids Dam
USGS Gage 05288500
100,000
10,000
1,000
100
River Flow (cfs)
0
10
20
30
40
50
60
70
80
90
100
Percent of Time Flow Is Exceeded (%)
Winter
Summer
Annual

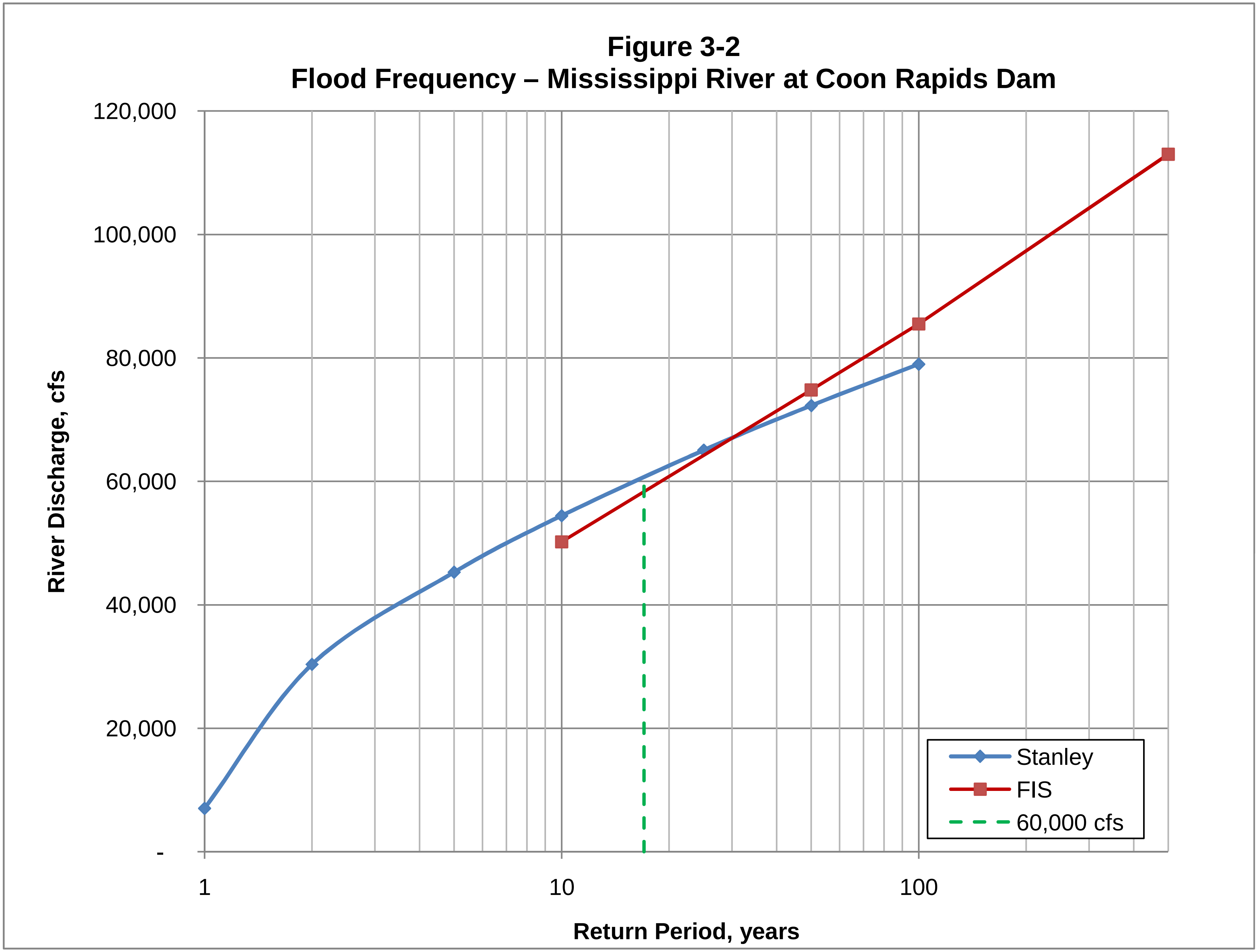


Figure 3-2
Flood Frequency – Mississippi River at Coon Rapids Dam
River Discharge, cfs
120,000
100,000
80,000
60,000
40,000
20,000
-
1
10
100
Return Period, years
Stanley
FIS
60,000 cfs

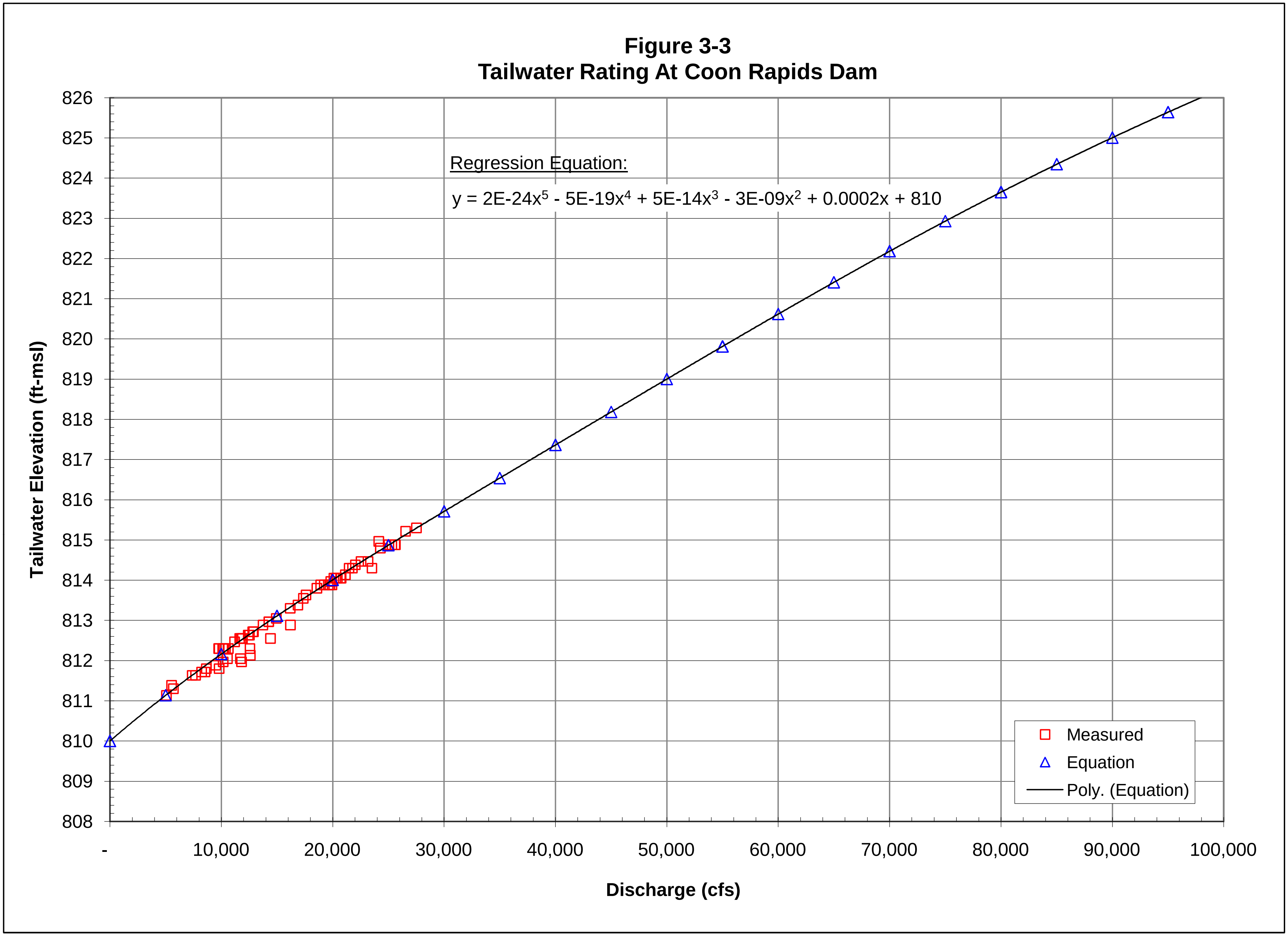
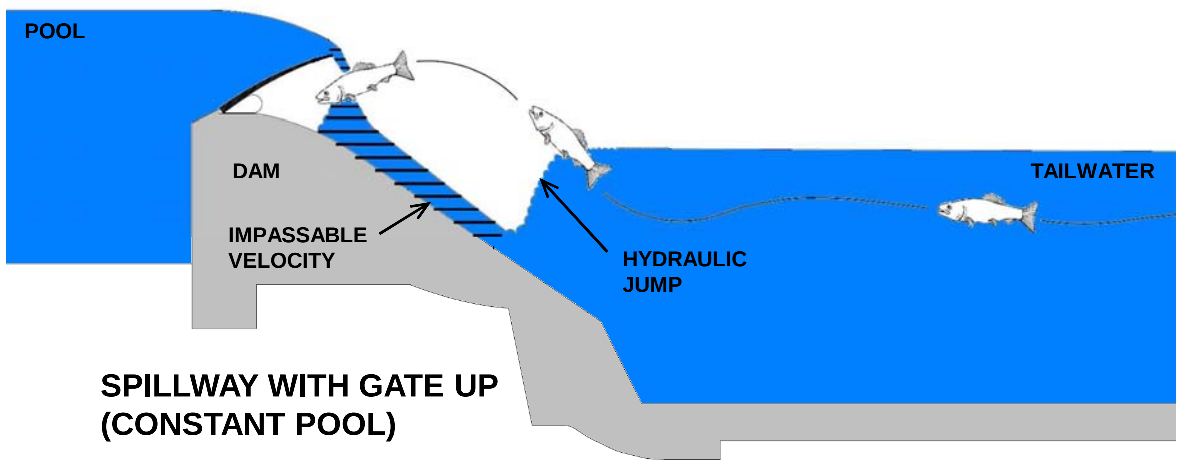
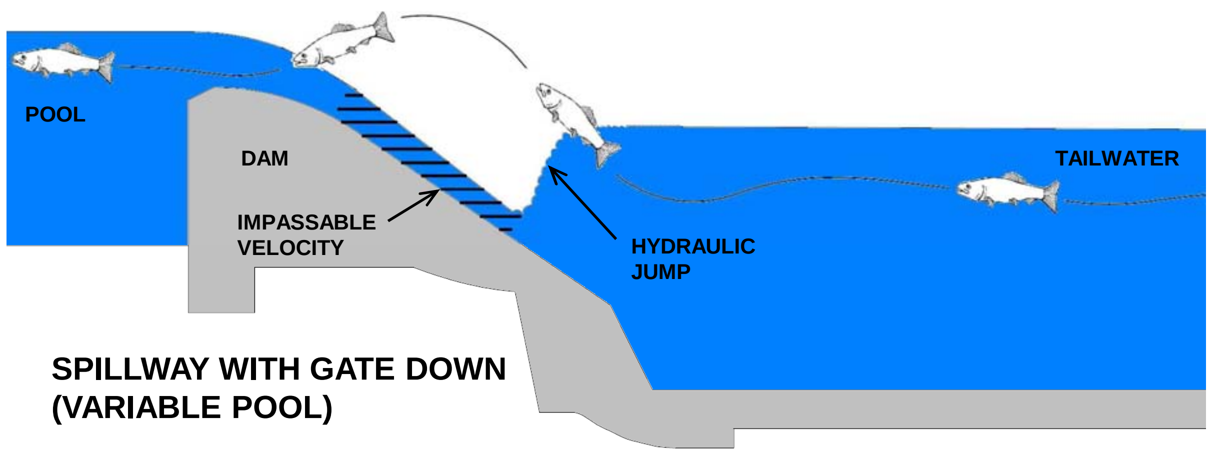


Figure 3-3
Tailwater Rating At Coon Rapids Dam
Regression Equation:
y = 2E-24x5 - 5E-19x4 + 5E-14x3 - 3E-09x2 + 0.0002x + 810
Tailwater Elevation (ft-msl)
826
825
824
823
822
821
820
819
818
817
816
815
814
813
812
811
810
809
808
-
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
Discharge (cfs)
Measured
Equation
Poly. (Equation)

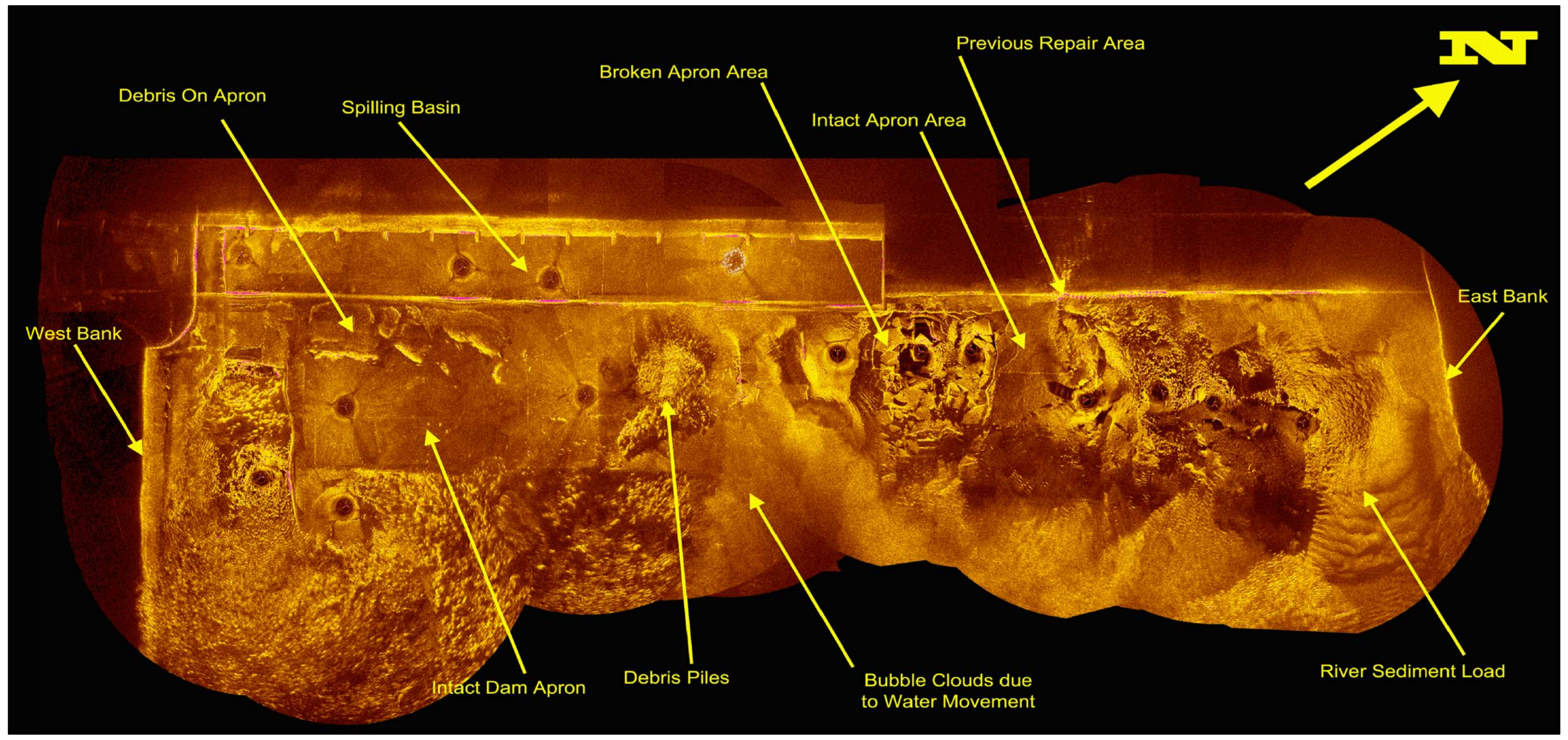


SPILLWAY WITH GATE UP
(CONSTANT POOL)



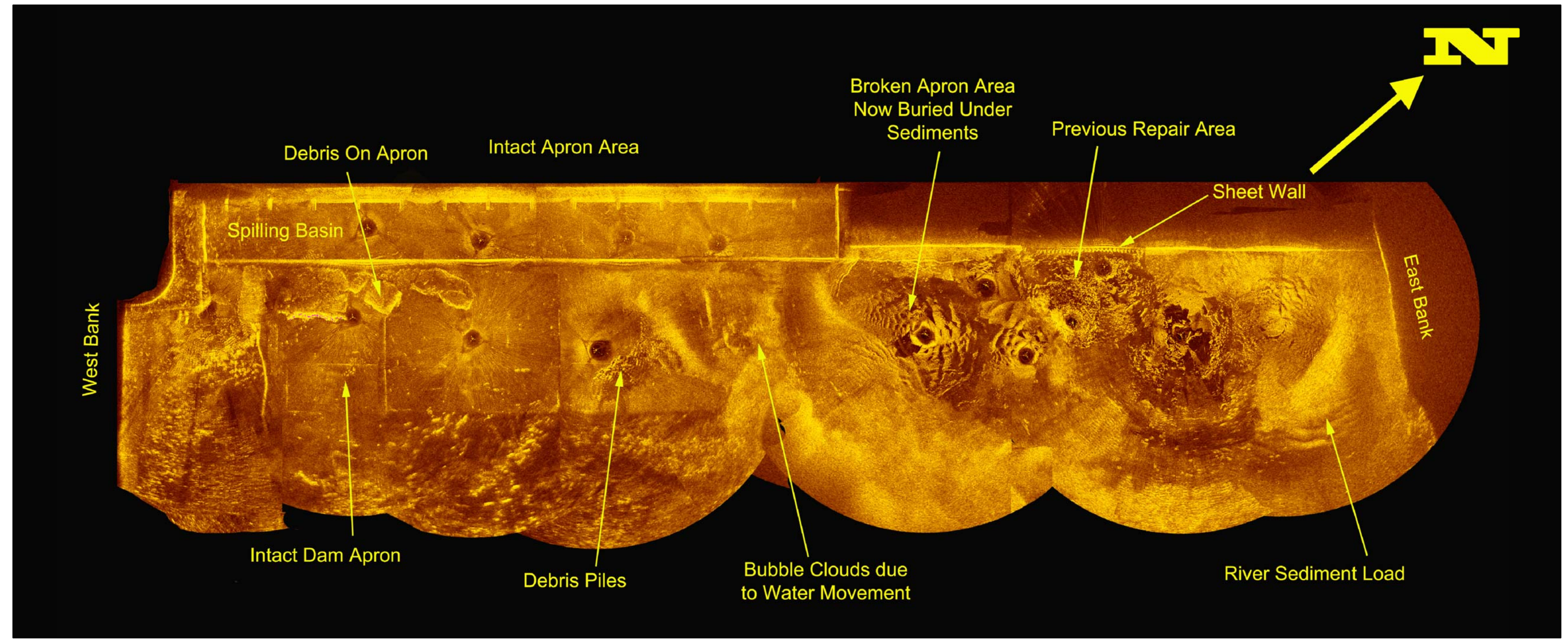
SPILLWAY WITH GATE DOWN
(VARIABLE POOL)

FIGURE 3-4
FISH JUMP SCHEMATIC



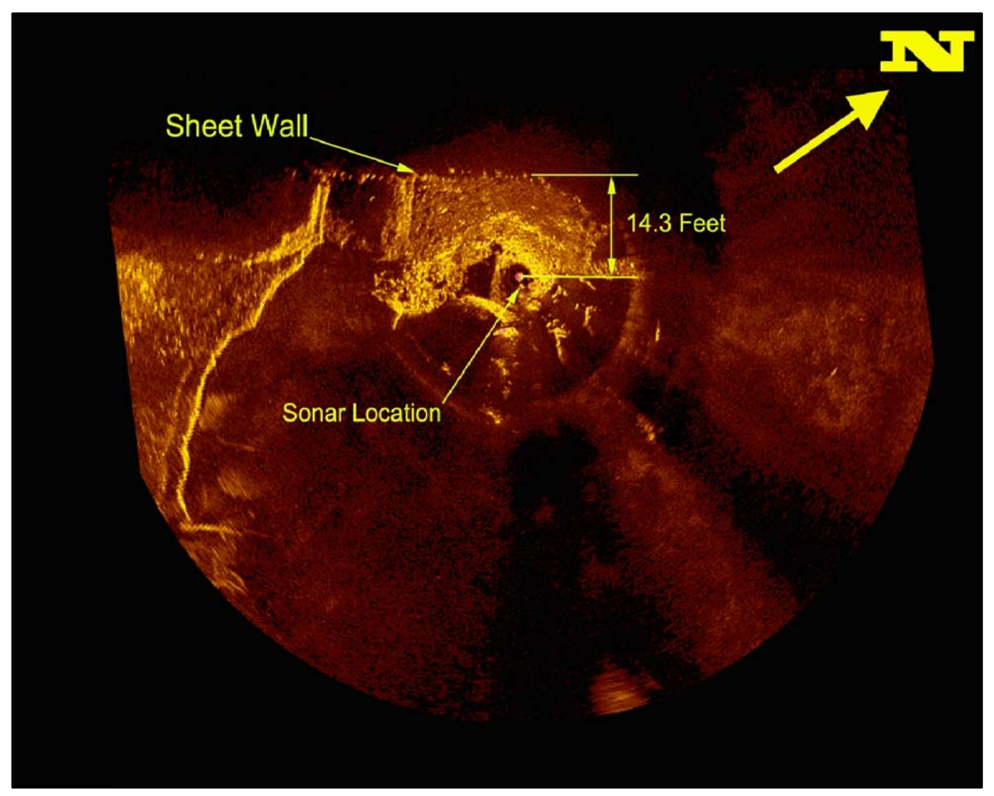
Dam Apron
Plan View- November 2009
1 / S1.0

0 50 100 200

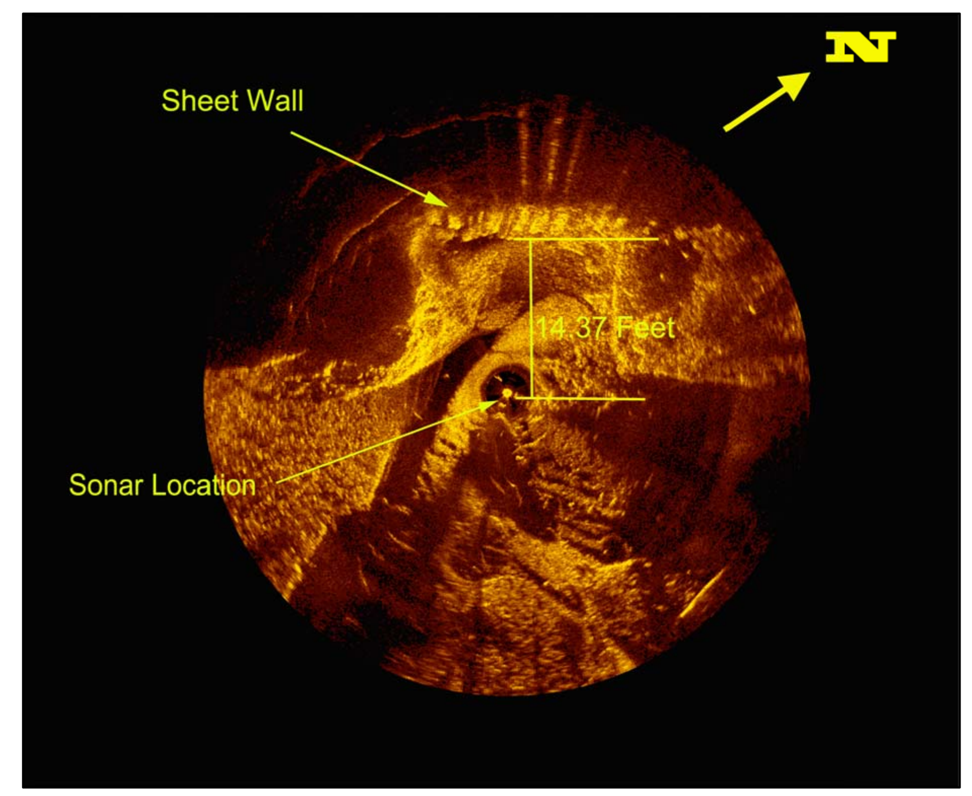


Dam Apron
Plan View- April 2010
2 / S1.0

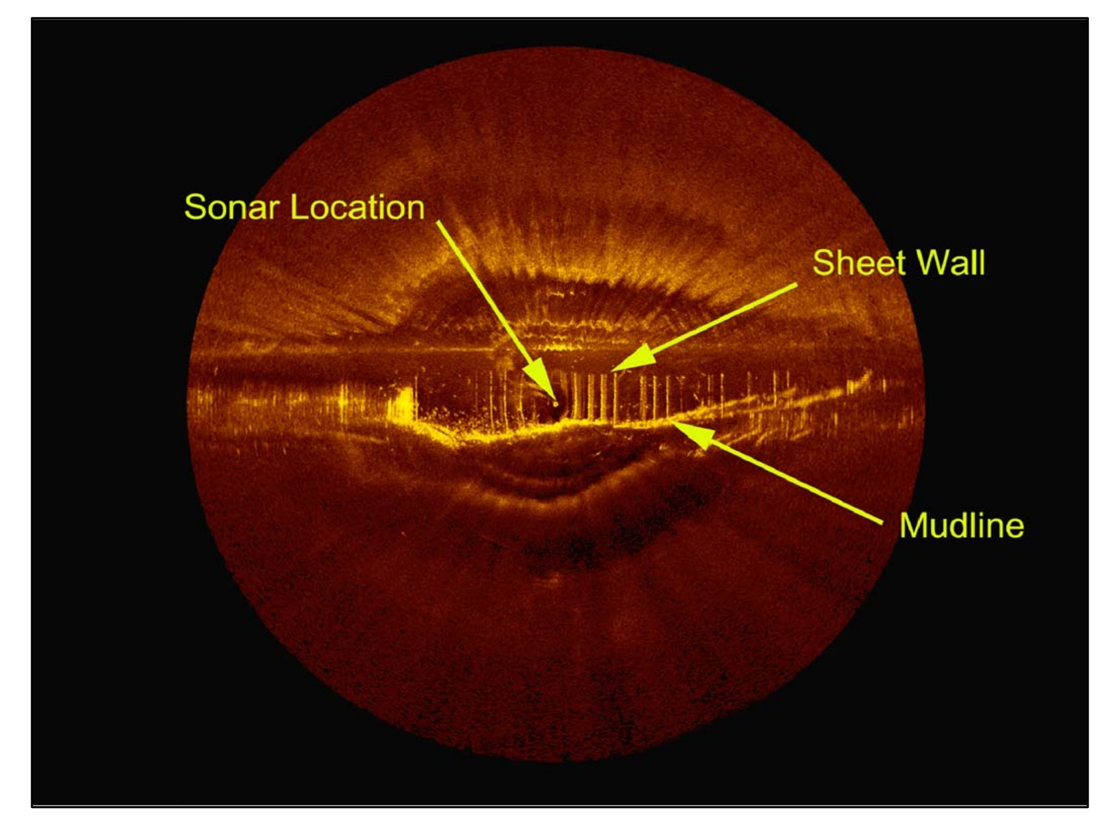
0 50 100 200



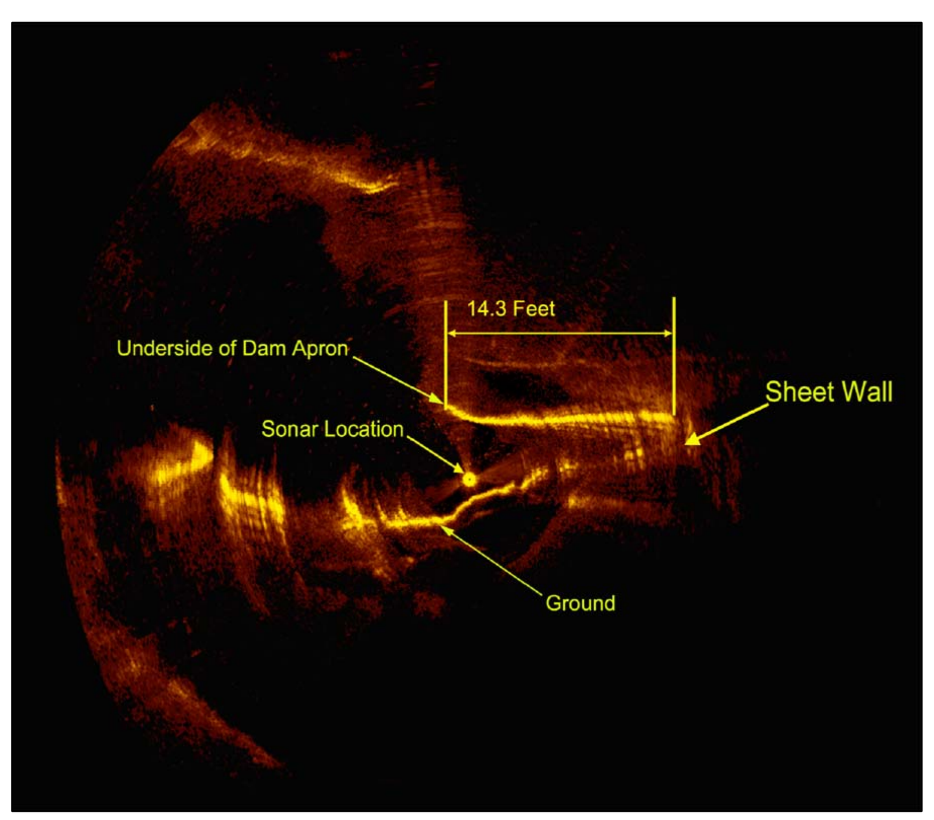
Damaged Area
Plan View- November 2009
3 / S1.0



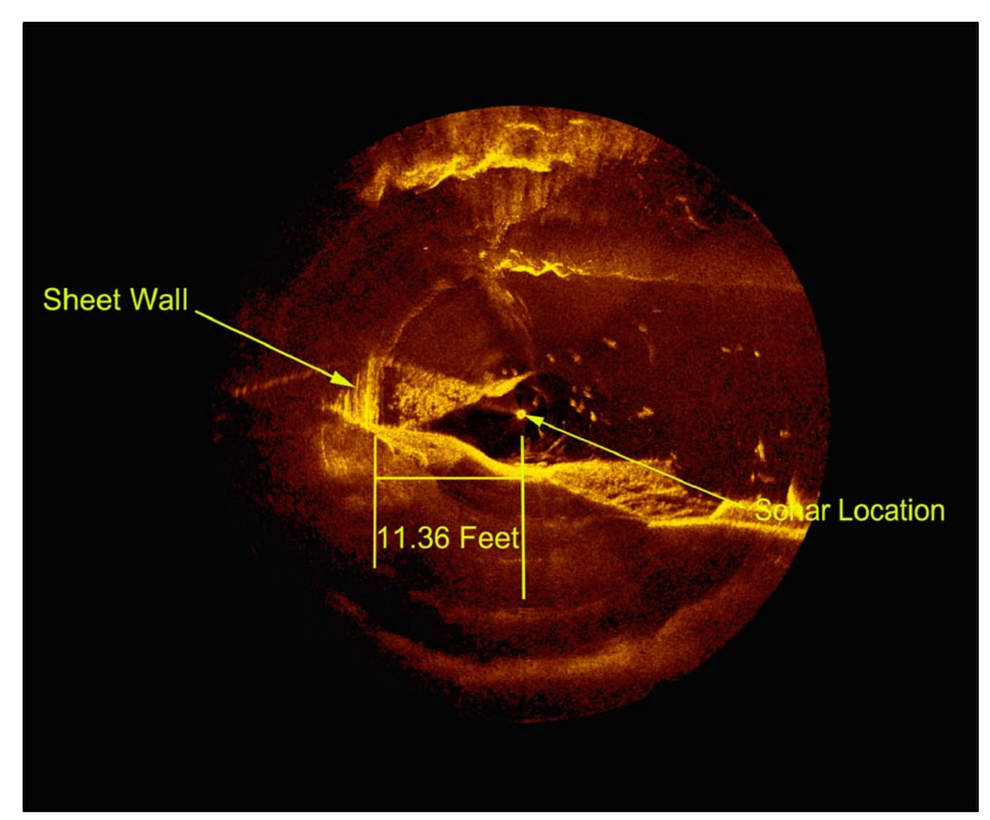
Damaged Area
Plan View- April 2010
4 / S1.0



Sheet Pile Repair
Elevation View- April 2010
7 / S1.0



Damaged Area
Section View- November 2009
5 / S1.0



Dam Apron
Section View- April 2010
6 / S1.0

AMI
CONSULTING ENGINEERS P.A.
1 East 1st Street Suite 403
Duluth, MN 55802
PH 218.727.1206 Fax 218.727.3961

NAUTILUS MARINE GROUP

REV. BY: | DESCRIPTION | REV: | DATE:

Stanley Consultants, Inc.
Coon Rapids Dam
Apron Inspection
Coon Rapids, Minnesota

Sector Scan Imagery
Comparison Scans
November 2009 to April 2010

JOB No: 101057
DATE: 5-06-10
DRAWN BY: SAJ
DESIGNED BY:

SHEET:
S1.0

FIGURE 5-1a - OPINION OF PROBABLE COST

ITEM NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT COST	EXTENSION	SUBTOTALS
100	***General***					
101	Mobilization/Demobilization	LS	1	$ 408,000	$ 408,000	
102	Sediment and Erosion Control	LS	1	$ 82,000	$ 82,000	
103	Construction Surveying	LS	1	$ 41,000	$ 41,000	
104	Engineering and Administration (Contractor)	LS	1	$ 245,000	$ 245,000	
105	Independent Testing Firm	LS	1	$ 82,000	$ 82,000	
						$ 858,000
200	***Site Preparation/Site Access - Anoka Side***					
201	Access Road Preparation	ACRE	1.5	$ 2,000	$ 3,000	
202	Temporary Gravel Road	SY	2500	$ 8	$ 20,000	
203	Road Fill (Cofferdam Fill)	CY	2850	$ 25	$ 71,250	
204	Culvert	LF	100	$ 275	$ 27,500	
205	Access Ramp	EACH	1	$ 5,000	$ 5,000	
						$ 126,750
300	***Site Preparation/Site Access - Hennepin Side***					
301	Clearing and Grubbing	ACRE	3	$ 4,000	$ 12,000	
302	Access Road Preparation	ACRE	2	$ 3,000	$ 6,000	
303	Temporary Gravel Road	SY	1000	$ 8	$ 8,000	
304	Access Ramp	EACH	1	$ 5,000	$ 5,000	
						$ 31,000
400	***Cofferdam/Dewatering Operations***					
401	Contractor Fabricated Cofferdam Structure (Center)	LS	1	$ 75,000	$ 75,000	
402	Granular Fill	CY	833	$ 25	$ 20,833	
403	Cellular Cofferdam Fill	CY	3259	$ 25	$ 81,481	
404	Earthen Cofferdam Fill (1:3 Slopes, 10' high, 10' crown)	CY	3704	$ 12	$ 44,444	
405	PZ-22 Sheet Pile (Downstream Cofferdam)	SF	14200	$ 22	$ 312,400	
406	PZ-22 Sheet Pile (Upstream Cofferdam - Stage 1)	SF	25200	$ 22	$ 554,400	
407	PZ-22 Sheet Pile (Upstream Cofferdam - Stage 2)	SF	8800	$ 22	$ 193,600	
408	Upstream Cofferdam Fill	CY	10000	$ 25	$ 250,000	
409	Riprap for Scour Holes	CY	2955	$ 60	$ 177,315	
410	Riprap for Cofferdam Stabilization	CY	356	$ 60	$ 21,333	
411	Dewatering Operations	LS	1	$ 500,000	$ 500,000	
						$ 2,230,807
500	***Downstream Scour Protection Improvements***					
501	Pilot Trough	LF	990	$ 200	$ 198,000	
502	Remove Concrete Apron for Pile Driving	CY	111	$ 150	$ 16,667	
503	PZ-27 Steel Sheet Pile (Downstream Sill Cutoff)	SF	23000	$ 42	$ 966,000	
504	Torch-Cut Downstream Sill Cutoff	EA	667	$ 40	$ 26,680	
505	Connect to Existing Sheet Pile	EA	2	$ 7,000	$ 14,000	
						$ 1,221,347
600	***New Stilling Basin (Anoka Side)***					
601	Demolish and Remove Existing Concrete Apron	CY	2039	$ 80	$ 163,081	
602	Timber Pile Removal	VLF	13500	$ 5	$ 67,500	
603	Excavation	CY	5200	$ 10	$ 52,000	
604	Pile Installation	VLF	3762.5	$ 28	$ 105,350	
	Reinforced Concrete					
605	Spillway Extension	CY	890	$ 300	$ 267,000	
606	Basin Floor	CY	1750	$ 300	$ 525,000	
607	End Sill	CY	175	$ 300	$ 52,500	
608	Concrete Baffles	CY	96	$ 300	$ 28,800	
609	Downstream Riprap	CY	370	$ 60	$ 22,222	
						$ 1,283,454
700	***Stilling Basin Improvements (Hennepin Side)***					
	Reinforced Concrete					
701	Basin Floor Repairs	LS	1	$ 60,000	$ 60,000	
702	End Sill Repairs	LS	1	$ 40,000	$ 40,000	
704	Downstream Riprap	CY	370	$ 60	$ 22,222	
						$ 122,222
800	***Gate System Procurement (Pneumatic)***					
801	Gate System	LS	1	$ 3,700,000	$ 3,700,000	
						$ 3,700,000
900	***Gate System Installation (Pneumatic)***					
901	Downstream Concrete Fillet Removal & Restoration	CY	52	$ 130	$ 6,760	
902	Concrete Fill for Hollow Piers	CY	117	$ 500	$ 58,333	
903	Concrete Removal for Gate Piping/Anchorage	CY	433	$ 200	$ 86,600	
904	Concrete Fill for Gate Piping/Anchorage	CY	433	$ 400	$ 173,200	
905	Gate System Installation	FT	860	$ 250	$ 215,000	
906	Gate System Piping (Air & Electrical)	FT	860	$ 240	$ 206,400	
907	Abutment Plates and Misc.	EACH	18	$ 7,500	$ 135,000	
908	Install Embedded Parts	FT	860	$ 220	$ 189,200	
909	Control Building Preparation	LS	1	$ 20,000	$ 20,000	
910	Control Building Mechanical Work	LS	1	$ 66,000	$ 66,000	
911	Control Building Electrical Work	LS	1	$ 100,000	$ 100,000	
912	Gate System Testing	FT	860	$ 50	$ 43,000	
913	Gate Support System for Bladder Repair	EACH	86	$ 500	$ 43,000	
914	Existing Gate System Removal	EACH	8	$ 2,500	$ 20,000	
915	Existing air piping removal	LS	1	$ 30,000	$ 30,000	
						$ 1,392,493
1000	***Ice Suppression System***					
1001	Air Compressor	EA	2	$ 2,500	$ 5,000	
1002	Air Bubbling Piping - Carbon Steel Pipe	FT	900	$ 41	$ 36,900	
1003	Air Bubbling Piping - HDPE Pipe	FT	2600	$ 3	$ 7,800	
1004	Welding HDPE Pipe	EA	130	$ 23	$ 2,990	
1005	Electrical System	LS	1	$ 10,000	$ 10,000	
1006	Temperature Sensing System	LS	1	$ 30,000	$ 30,000	
						$ 92,690
1100	***Control Gate Rehabilitation***					
1101	Disassemble, Clean & Inspect Gate	LS	1	$ 11,000	$ 11,000	
1102	Rehabilitate Gate	LS	1	$ 51,000	$ 51,000	
1103	Nappe Breakers	LS	1	$ 12,000	$ 12,000	
1104	Paint Gate	LS	1	$ 87,000	$ 87,000	
1105	Rehabilitate Cylinders	LS	1	$ 38,000	$ 38,000	
1106	Re-install Gate/Test Gate	LS	1	$ 17,000	$ 17,000	
						$ 216,000
1200	***Pedestrian Bridge Painting***					
1201	Administration & Engineering	JOB	1	$ 15,700	$ 15,700	
1202	Mobilization	JOB	1	$ 5,100	$ 5,100	
1203	Demobilization	JOB	1	$ 18,900	$ 18,900	
1204	Access - Upper Bridge	JOB	1	$ 20,600	$ 20,600	
1205	Access - Lower Bridge	JOB	1	$ 13,800	$ 13,800	
1206	Prepare for Painting	JOB	1	$ 16,076	$ 16,076	
1207	Welding (Optional)	LB	100	$ 10	$ 1,000	
1208	Steel Fab (Optional)	LB	500	$ 5	$ 2,500	
1209	Paint Upper Bridge	JOB	1	$ 4,519	$ 4,519	
1210	Paint Lower Bridge	JOB	1	$ 10,038	$ 10,038	
						$ 108,233
1300	**Handrail Repair/Replacement**					
1301	Rehabilitation Option	LS	1	$ 500,000	$ 500,000	
						$ 500,000
1400	***Miscellaneous Repairs and Improvements***					
1401	Embankments	LS	1	$ 10,000	$ 10,000	
1402	Bridge Concrete	LS	1	$ 20,000	$ 20,000	
1403	Old Powerhouse Concrete	LS	1	$ 50,000	$ 50,000	
1404	Retaining Walls	LS	1	$ 200,000	$ 200,000	
1405	Miscellaneous Steel	LS	1	$ 20,000	$ 20,000	
1406	Foundation Grouting	LS	1	$ 300,000	$ 300,000	
						$ 600,000
1500	***Miscellaneous***					
1501	Crane Barge	MON	8	$ 8,000	$ 64,000	
1502	Runner Barge	MON	8	$ 5,000	$ 40,000	
1503	Diving Team	DAY	20	$ 5,000	$ 100,000	
1504	Geotechnical Investigations	LS	1	$ 25,000	$ 25,000	
						$ 229,000
				SUBTOTAL	$ 12,711,997	$ 12,711,997

UNDERDEVELOPED DESIGN DETAILS	$ 1,271,200	10%
SUBTOTAL	$ 13,983,196	
CONSTRUCTION CONTINGENCY	$ 2,097,479	15%
SUBTOTAL	$ 16,080,676	
ENGINEERING, ADMIN, PERMITTING	$ 804,034	5%
TOTAL	**$ 16,900,000**	

FIGURE 5-1b - OPINION OF PROBABLE COST ASSUMPTIONS

ITEM NO.	ITEM DESCRIPTION	UNIT	NOTES
100	***General***		
101	Mobilization/Demobilization	LS	5% of construction cost (excluding major equipment).
102	Sediment and Erosion Control	LS	1% of construction cost (excluding major equipment).
103	Construction Surveying	LS	0.5% of construction cost (excluding major equipment).
104	Engineering and Administration (Contractor)	LS	3% of construction cost (excluding major equipment).
105	Independent Testing Firm	LS	1% of construction cost (excluding major equipment).
200	***Site Preparation/Site Access - Anoka Side***		
201	Access Road Preparation	ACRE	Clear debris/obstructions from old access road.
202	Temporary Gravel Road	SY	6" thick - Haul, place, compact, remove. Assume material is available near dam site.
203	Road Fill (Cofferdam Fill)	CY	Haul, place, compact, remove. Cofferdam placed north of Dunn Island for access to north end of dam. Assume material is available near dam site.
204	Culvert	LF	2 - 8' x 3' Box Culverts side by side
205	Access Ramp	EACH	Construct and dress up access ramp inside of dewatered cofferdam for Stage
300	***Site Preparation/Site Access - Hennepin Side***		
301	Clearing and Grubbing	ACRE	Includes roads, parking areas, and contractor laydown areas.
302	Access Road Preparation	ACRE	Rough grading of access road.
303	Temporary Gravel Road	SY	6" of 3" minus or similar for dry diving surface.
304	Access Ramp	EACH	Ramp to dewatered side of cofferdam.
400	***Cofferdam/Dewatering Operations***		
401	Contractor Fabricated Cofferdam Structure (Center)	LS	Install and Remove. For center span of cofferdam. (Approx 100 ft). Includes move after Stage 1 of construction.
402	Granular Fill	CY	Install and remove. Fill for cellular center span cofferdam structure. Assume material on site. New London - 2009.
403	Cellular Cofferdam Fill	CY	Fill between cellular and contractor fabricated cofferdam structures (temporary). New London - 2009.
404	Earthen Cofferdam Fill (1:3 Slopes, 10' high, 10' crown)	CY	Anoka side access causeway.
405	PZ-22 Sheet Pile (Downstream Cofferdam)	SF	Varying length with till stratum. Install, remove, and salvage. Use same pile for Stage 2 after Stage 1 complete. New London - 2009.
406	PZ-22 Sheet Pile (Upstream Cofferdam - Stage 1)	SF	Drive sheets upstream of concrete spillway and connect horizontally. New London - 2009.
407	PZ-22 Sheet Pile (Upstream Cofferdam - Stage 2)	SF	Drive sheets upstream of concrete spillway and connect horizontally. New London - 2009.
408	Upstream Cofferdam Fill	CY	New London - 2009.
409	Riprap for Scour Holes	CY	Use rubble from apron first. Fill existing scour holes and voids to elevation 795. Match elevation of horizontal apron section. New London - 2009.
410	Riprap for Cofferdam Stabilization	CY	Place riprap on riverside access causeway structure to help with erosion. New London - 2009.
411	Dewatering Operations	LS	New London - 2009.
500	***Downstream Scour Protection Improvements***		
501	Pilot Trough	LF	Lametti - 2005.
502	Remove Concrete Apron for Pile Driving	CY	Jackhammer out existing concrete so that new scour protection apron sheet pile can be driven adjacent to sill.
503	PZ-27 Steel Sheet Pile (Downstream Sill Cutoff)	SF	Assume sheet pile tip elevations based on anticipated elevation of hard till. Assume 5 ft of embedment into till stratum). New London - 2009.
504	Torch-Cut Downstream Sill Cutoff	EA	Cut after it is used as a cofferdam. New London - 2009.
505	Connect to Existing Sheet Pile	EA	Connect to apron repair job completed in 2005.
600	***New Stilling Basin (Anoka Side)***		
601	Demolish and Remove Existing Concrete Apron	CY	Use as fill for large scour holes. Do not haul off site.
602	Timber Pile Removal	VLF	Approx 900 piles. 15' max length. May have high salvage value.
603	Excavation	CY	Excavate from Btm of Apron (El. ~808) to Btm of Stilling (El. ~800)
604	Pile Installation	VLF	HP10x42 Steel H-Piles, Spaced 10' EW, average of 25 ft long.
	Reinforced Concrete		
605	Spillway Extension	CY	Mass concrete, vertical on backside and 1.5:1 slope down to floor of stilling basin. New London - 2009.
606	Basin Floor	CY	3 ' thick, 51' long, 430' wide. New London - 2009.
607	End Sill	CY	3' thick, 6' tall, 430' wide. New London - 2009.
608	Concrete Baffles	CY	2' high x 2' high x 430' long x 0.5 (of spillway). New London - 2009.
609	Downstream Riprap	CY	Assumes 4' high by 10 ft base triangular wedge across 500 ft of basin.
700	***Stilling Basin Improvements (Hennepin Side)***		
	Reinforced Concrete		
701	Basin Floor Repairs	LS	
702	End Sill Repairs	LS	
704	Downstream Riprap	CY	Assumes 4' high by 10 ft base triangular wedge across 500 ft of basin.
800	***Gate System Procurement (Pneumatic)***		
801	Gate System	LS	2009 Obermeyer quote.
900	***Gate System Installation (Pneumatic)***		
901	Downstream Concrete Fillet Removal & Restoration	CY	8 locations, Waverly $130/cy
902	Concrete Fill for Hollow Piers	CY	5 piers. New London - 2009.
903	Concrete Removal for Gate Piping/Anchorage	CY	Total dam length 900', 2'x5' removal
904	Concrete Fill for Gate Piping/Anchorage	CY	With anchor bars and reinforcing
905	Gate System Installation	FT	Waverly - 2010.
906	Gate System Piping (Air & Electrical)	FT	Waverly - 2010.
907	Abutment Plates and Misc.	EACH	Waverly - 2010.
908	Install Embedded Parts	FT	Waverly - 2010.
909	Control Building Preparation	LS	
910	Control Building Mechanical Work	LS	Waverly - 2010.
911	Control Building Electrical Work	LS	Waverly - 2010.
912	Gate System Testing	FT	Waverly - 2010.
913	Gate Support System for Bladder Repair	EACH	Hanging cable from operator bridge, 86 supports
914	Existing Gate System Removal	EACH	8 locations
915	Existing air piping removal	LS	
1000	***Ice Suppression System***		
1001	Air Compressor	EA	Controlled for 1000 ft, 600 ft working simultaneously. 3" pipe, max delivery dist 1200 ft, pipe submerged 10 ft, air rate 16 cfm (2 gal/sec) for each comp. 2 ind systems.
1002	Air Bubbling Piping - Carbon Steel Pipe	FT	3" pipe embedded portion and exposed to air - galvernized steel pipe. Schedule 40. Welded.
1003	Air Bubbling Piping - HDPE Pipe	FT	3" pipe with 1/8" orifices at 2 ft spacing (total 600 holes). Underwater - HDPE pipe, plus couplings.
1004	Welding HDPE Pipe	EA	Welding labor per joint. Straight pipe.
1005	Electrical System	LS	Conduit, connectors, control system.
1006	Temperature Sensing System	LS	Automatically start bubbling system when temperature drops to preset temperature. Automatically control air flow rate based on water temperatures.
1100	***Control Gate Rehabilitation***		
1101	Disassemble, Clean & Inspect Gate	LS	2008 Bids - Lunda, Kraemer, Lametti.
1102	Rehabilitate Gate	LS	2008 Bids - Lunda, Kraemer, Lametti.
1103	Nappe Breakers	LS	2008 Bids - Lunda, Kraemer, Lametti.
1104	Paint Gate	LS	2008 Bids - Lunda, Kraemer, Lametti.
1105	Rehabilitate Cylinders	LS	2008 Bids - Lunda, Kraemer, Lametti.
1106	Re-install Gate/Test Gate	LS	2008 Bids - Lunda, Kraemer, Lametti.
1200	***Pedestrian Bridge Painting***		
1201	Administration & Engineering	JOB	Average of 2009 gate repair bids: Item 1.
1202	Mobilization	JOB	Average of 2009 gate repair bids: Item 2.
1203	Demobilization	JOB	67% x average of 2009 gate repair bids: Items 3 + 12.
1204	Access - Upper Bridge	JOB	60% x average of 2009 gate repair bids: Items 7 + 8 + 9.
1205	Access - Lower Bridge	JOB	40% x average of 2009 gate repair bids: Items 7 + 8 + 9.
1206	Prepare for Painting	JOB	160 manhours @ average labor cost from 2009 gate repair.
1207	Welding (Optional)	LB	2009 gate repair bid.
1208	Steel Fab (Optional)	LB	2009 gate repair bid.
1209	Paint Upper Bridge	JOB	40 manhours + $500 materials.
1210	Paint Lower Bridge	JOB	80 manhours + $2000 materials.
1300	**Handrail Repair/Replacement**		
1301	Rehabilitation Option	LS	From 2008 Handrail Report.
1400	***Miscellaneous Repairs and Improvements***		
1401	Embankments	LS	Per 5-Year inspection Report.
1402	Bridge Concrete	LS	Per 5-Year inspection Report.
1403	Old Powerhouse Concrete	LS	Per 5-Year inspection Report.
1404	Retaining Walls	LS	Estimate - to be verified during construction inspections.
1405	Miscellaneous Steel	LS	Per 5-Year inspection Report.
1406	Foundation Grouting	LS	Estimate - to be verified during construction inspections.
1500	***Miscellaneous***		
1501	Crane Barge	MON	Assume 6 month construction duration.
1502	Runner Barge	MON	Assume 6 month construction duration.
1503	Diving Team	DAY	Inspection of existing stilling basin, etc.
1504	Geotechnical Investigations	LS	Necessary for final design/construction.

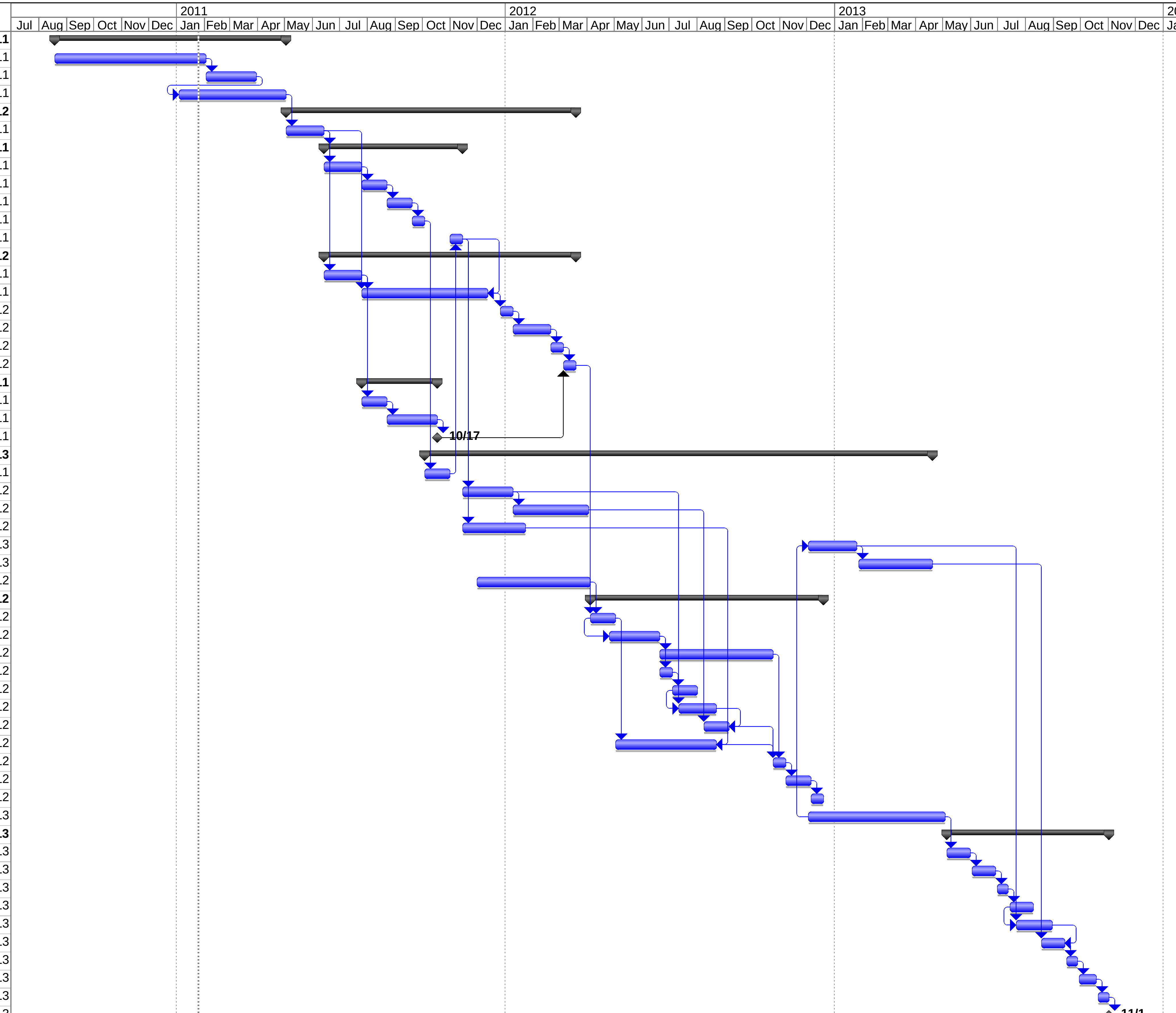
FIGURE 5-2. LIFE CYCLE CASH FLOW

Cost in 2011 Dollars

Year		General Operations		Inspections				Control Gate			Crest Gates			Control Building		Other			
Calendar	Delta	Utilities ($)	Manpower ($)	Gates ($)	5-Year ($)	Soundings ($)	Underwater ($)	Maintenance ($)	Repair ($)	Replace ($)	Maintenance ($)	Repair ($)	Replace ($)	General ($)	Replace Generator ($)	Paint Ped Bridges ($)	Replace Handrail ($)	Miscellaneous Repairs ($)	Total Annual Cost ($)
2013	0																		
2014	1	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2015	2	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2016	3	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2017	4	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2018	5	$ 30,000	$ 87,000	$ 5,000	$ 23,000	$ 7,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 23,000	$ -	$ -	$ -	$ -	$ 175,000
2019	6	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2020	7	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2021	8	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2022	9	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2023	10	$ 30,000	$ 87,000	$ 5,000	$ 23,000	$ 7,000	$ 11,000	$ 37,000	$ -	$ -	$ 92,000	$ -	$ -	$ 23,000	$ -	$ -	$ -	$ -	$ 315,000
2024	11	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2025	12	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2026	13	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2027	14	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 84,000	$ -	$ -	$ -	$ 206,000
2028	15	$ 30,000	$ 87,000	$ 5,000	$ 23,000	$ 7,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 23,000	$ -	$ -	$ -	$ -	$ 175,000
2029	16	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2030	17	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2031	18	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2032	19	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2033	20	$ 30,000	$ 87,000	$ 5,000	$ 23,000	$ 7,000	$ 11,000	$ 37,000	$ 229,000	$ -	$ 92,000	$ 1,098,000	$ -	$ 23,000	$ -	$ 101,000	$ 824,000	$ 183,000	$ 2,750,000
2034	21	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2035	22	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2036	23	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2037	24	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2038	25	$ 30,000	$ 87,000	$ 5,000	$ 23,000	$ 7,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 23,000	$ -	$ -	$ -	$ -	$ 175,000
2039	26	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2040	27	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2041	28	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2042	29	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2043	30	$ 30,000	$ 87,000	$ 5,000	$ 23,000	$ 7,000	$ 11,000	$ 37,000	$ -	$ -	$ 92,000	$ -	$ -	$ 23,000	$ -	$ -	$ -	$ -	$ 315,000
2044	31	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2045	32	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2046	33	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2047	34	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2048	35	$ 30,000	$ 87,000	$ 5,000	$ 23,000	$ 7,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 23,000	$ -	$ -	$ -	$ -	$ 175,000
2049	36	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2050	37	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2051	38	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2052	39	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2053	40	$ 30,000	$ 87,000	$ 5,000	$ 23,000	$ 7,000	$ 11,000	$ 37,000	$ 229,000	$ 458,000	$ 92,000	$ 1,098,000	$ 4,118,000	$ 23,000	$ -	$ 101,000	$ -	$ 183,000	$ 6,502,000
2054	41	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2055	42	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2056	43	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2057	44	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 84,000	$ -	$ -	$ -	$ 206,000
2058	45	$ 30,000	$ 87,000	$ 5,000	$ 23,000	$ 7,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 23,000	$ -	$ -	$ -	$ -	$ 175,000
2059	46	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2060	47	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2061	48	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2062	49	$ 30,000	$ 87,000	$ 5,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 122,000
2063	50	$ 30,000	$ 87,000	$ 5,000	$ 23,000	$ 7,000	$ 11,000	$ 37,000	$ -	$ -	$ 92,000	$ -	$ -	$ 23,000	$ -	$ -	$ -	$ -	$ 315,000
	Total	$ 1,500,000	$ 4,350,000	$ 250,000	$ 230,000	$ 70,000	$ 55,000	$ 185,000	$ 458,000	$ 458,000	$ 460,000	$ 2,196,000	$ 4,118,000	$ 230,000	$ 168,000	$ 202,000	$ 824,000	$ 366,000	$ 16,120,000

COON RAPIDS DAM FISH BARRIER & IMPROVEMENTS
FIGURE 6-1. PROJECT DEVELOPMENT SCHEDULE

ID		Task Name	Duration	Start	Finish
1		**Study & Funding**	**183 days**	**Thu 8/19/10**	**Tue 5/3/11**
2		Evaluation Study	6 mons	Thu 8/19/10	Wed 2/2/11
3		Agency Evaluation	8 wks	Thu 2/3/11	Wed 3/30/11
4		Legislative Action	119 edays	Tue 1/4/11	Tue 5/3/11
5		**Engineering**	**230 days**	**Tue 5/3/11**	**Mon 3/19/12**
6		Bid/Award Contract	6 wks	Tue 5/3/11	Mon 6/13/11
7		**Gate Procurement**	**110 days**	**Tue 6/14/11**	**Mon 11/14/11**
8		Bidding Docs	6 wks	Tue 6/14/11	Mon 7/25/11
9		Bid Period	4 wks	Tue 7/26/11	Mon 8/22/11
10		Evaluation	4 wks	Tue 8/23/11	Mon 9/19/11
11		Award	2 wks	Tue 9/20/11	Mon 10/3/11
12		Shop Dwg Review	2 wks	Tue 11/1/11	Mon 11/14/11
13		**General Construction**	**200 days**	**Tue 6/14/11**	**Mon 3/19/12**
14		Geotechnial Investigations	6 wks	Tue 6/14/11	Mon 7/25/11
15		Final Design	20 wks	Tue 7/26/11	Mon 12/12/11
16		Bidding Documents	2 wks	Tue 12/27/11	Mon 1/9/12
17		Bid Period	6 wks	Tue 1/10/12	Mon 2/20/12
18		Evaluation	2 wks	Tue 2/21/12	Mon 3/5/12
19		Award	2 wks	Tue 3/6/12	Mon 3/19/12
20		**Permitting**	**60 days**	**Tue 7/26/11**	**Mon 10/17/11**
21		Prepare Applications	4 wks	Tue 7/26/11	Mon 8/22/11
22		Agency Review	8 wks	Tue 8/23/11	Mon 10/17/11
23		Permits Received	0 days	Mon 10/17/11	Mon 10/17/11
24		**Gate Procurement**	**404 days**	**Tue 10/4/11**	**Fri 4/19/13**
25		Shop Drawings	4 wks	Tue 10/4/11	Mon 10/31/11
26		Stage 1 Embeds	8 wks	Tue 11/15/11	Mon 1/9/12
27		Stage 1 Gates/Bladders	12 wks	Tue 1/10/12	Mon 4/2/12
28		Control Equipment	10 wks	Tue 11/15/11	Mon 1/23/12
29		Stage 2 Embeds	8 wks	Mon 12/3/12	Fri 1/25/13
30		Stage 2 Gates/Bladders	12 wks	Mon 1/28/13	Fri 4/19/13
31		**Winter/Spring Delay**	**18 wks**	**Thu 12/1/11**	**Wed 4/4/12**
32		**Stage 1 Construction**	**185 days**	**Thu 4/5/12**	**Wed 12/19/12**
33		Mobilization	4 wks	Thu 4/5/12	Wed 5/2/12
34		Cofferdams/Dewatering	8 wks	Thu 4/26/12	Wed 6/20/12
35		Stlling Basin	18 wks	Thu 6/21/12	Wed 10/24/12
36		Gate Removal	2 wks	Thu 6/21/12	Wed 7/4/12
37		Concrete Demolition	4 wks	Thu 7/5/12	Wed 8/1/12
38		Crest Embeds/Concrete	6 wks	Thu 7/12/12	Wed 8/22/12
39		Install Gate System	4 wks	Thu 8/9/12	Wed 9/5/12
40		Control Bld/System	16 wks	Thu 5/3/12	Wed 8/22/12
41		Test/Commission Gates	2 wks	Thu 10/25/12	Wed 11/7/12
42		Remove Cofferdams	4 wks	Thu 11/8/12	Wed 12/5/12
43		Demobilize	2 wks	Thu 12/6/12	Wed 12/19/12
44		**Winter/Spring Delay**	**22 wks**	**Mon 12/3/12**	**Fri 5/3/13**
45		**Stage 2 Construction**	**130 days**	**Mon 5/6/13**	**Fri 11/1/13**
46		Mobilization	4 wks	Mon 5/6/13	Fri 5/31/13
47		Cofferdams/Dewatering	4 wks	Mon 6/3/13	Fri 6/28/13
48		Gate Removal	2 wks	Mon 7/1/13	Fri 7/12/13
49		Concrete Demolition	4 wks	Mon 7/15/13	Fri 8/9/13
50		Crest Embeds/Concrete	6 wks	Mon 7/22/13	Fri 8/30/13
51		Install Gate System	4 wks	Mon 8/19/13	Fri 9/13/13
52		Test/Commission Gates	2 wks	Mon 9/16/13	Fri 9/27/13
53		Remove Cofferdams	3 wks	Mon 9/30/13	Fri 10/18/13
54		Demobilize	2 wks	Mon 10/21/13	Fri 11/1/13
55		**Project Complete**	**0 days**	**Fri 11/1/13**	**Fri 11/1/13**



Stanley Consultants

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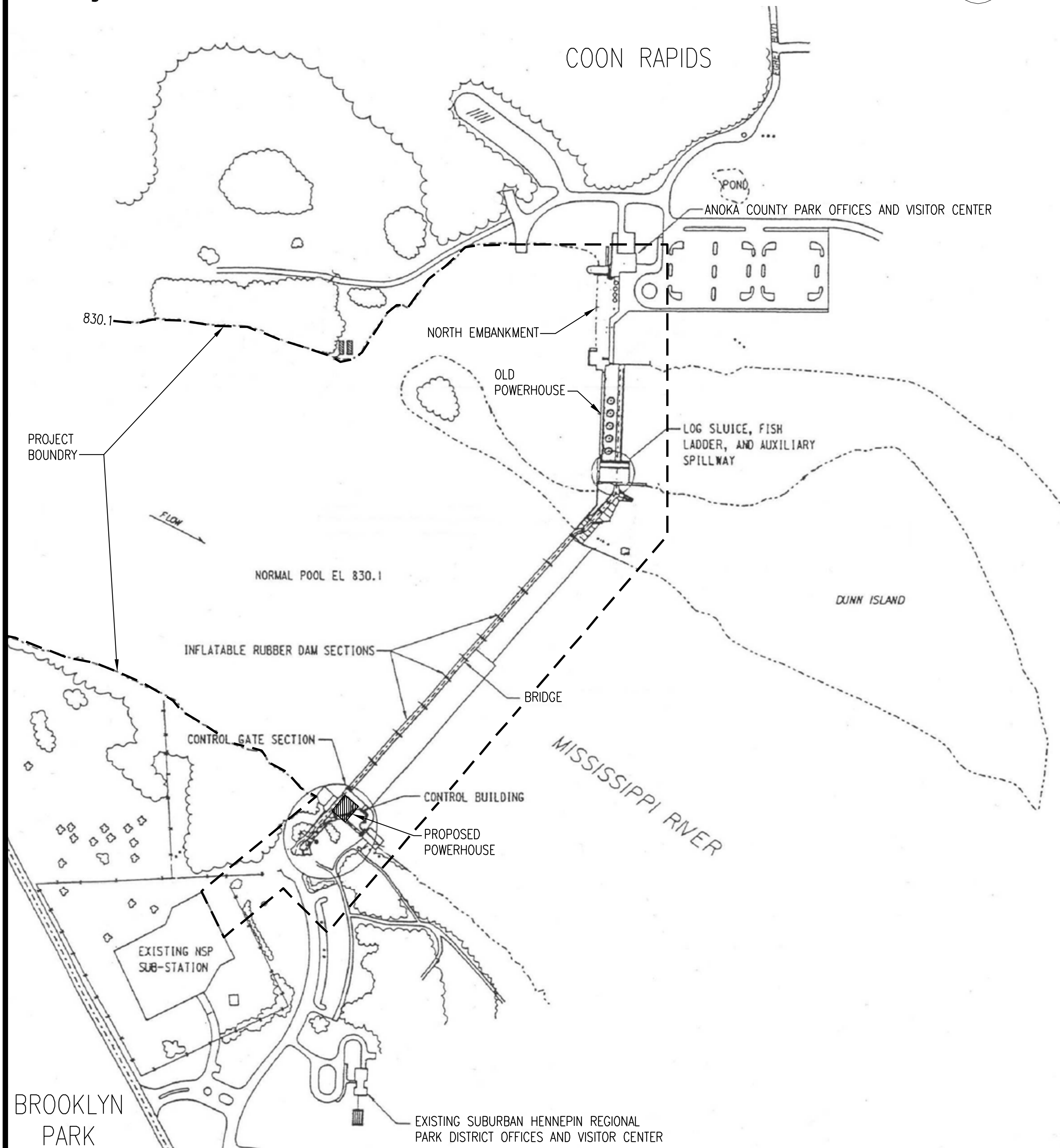
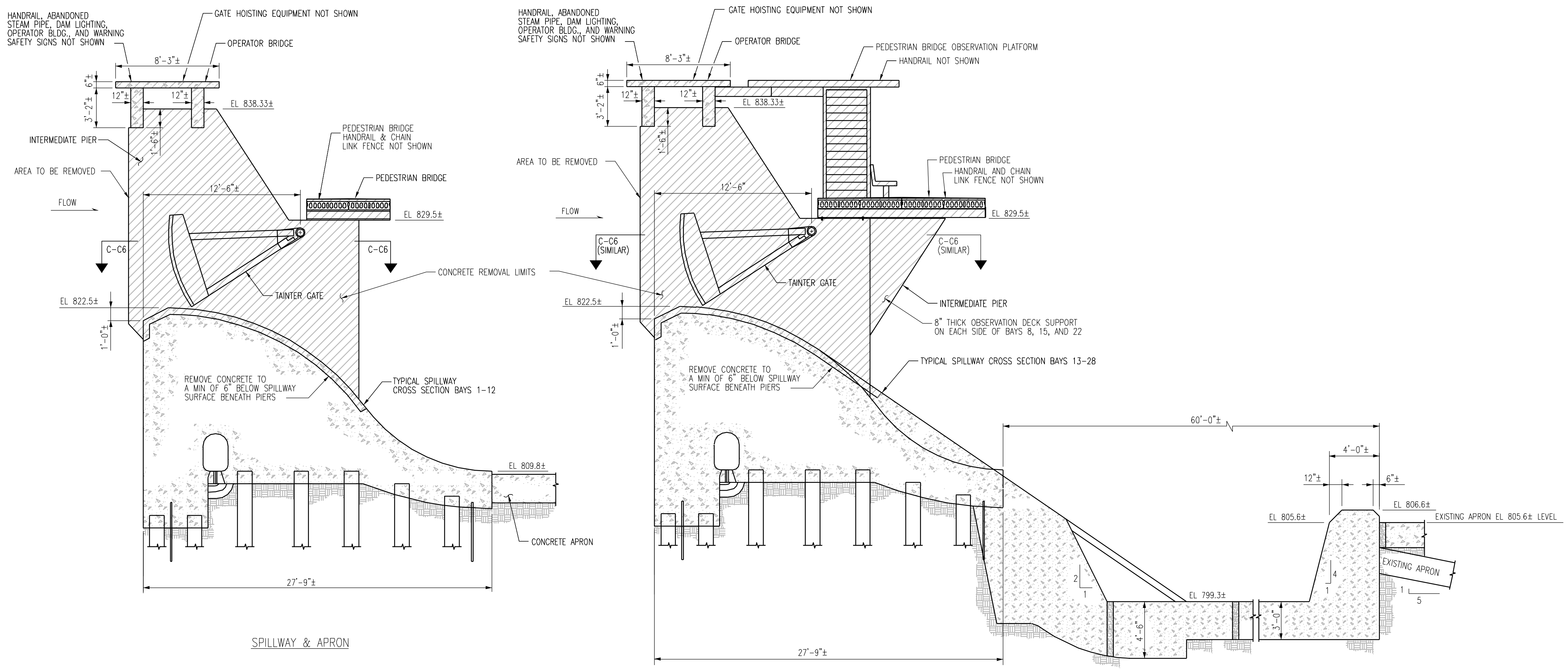


COON RAPIDS DAM FISH BARRIER AND IMPROVEMENTS PRELIMINARY DESIGN

SITE PLAN

FIGURE 8-1



SPILLWAY & APRON

SPILLWAY & STILLING BASIN

NOTE:
CROSS-HATCHED AREAS DEPICT FORMER PIERS AND BRIDGES.

COON RAPIDS DAM FISH BARRIER AND IMPROVEMENTS PRELIMINARY DESIGN
MAIN DAM SECTIONS
FIGURE 8-2

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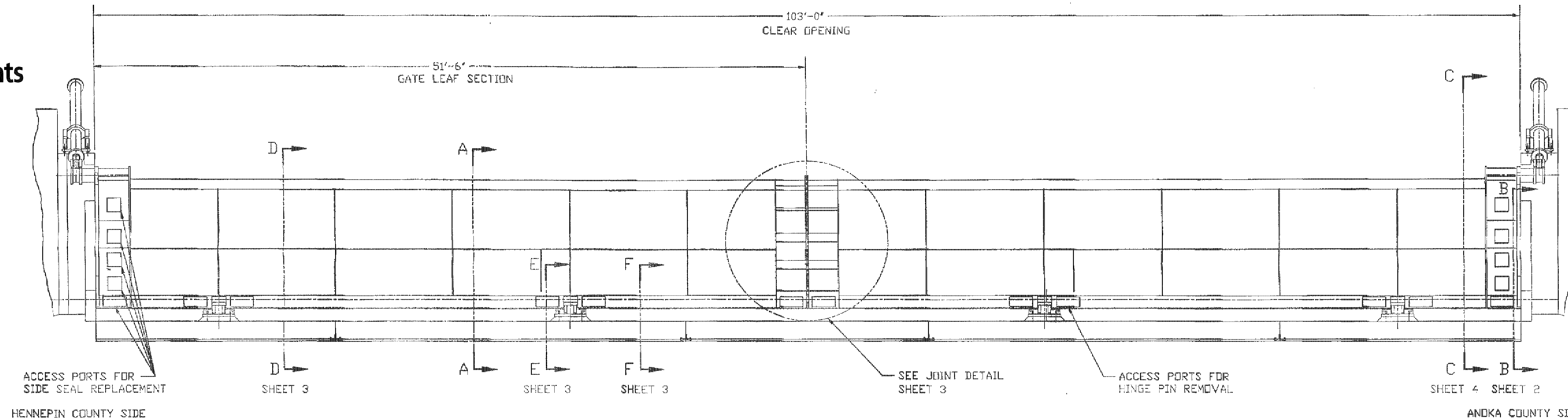
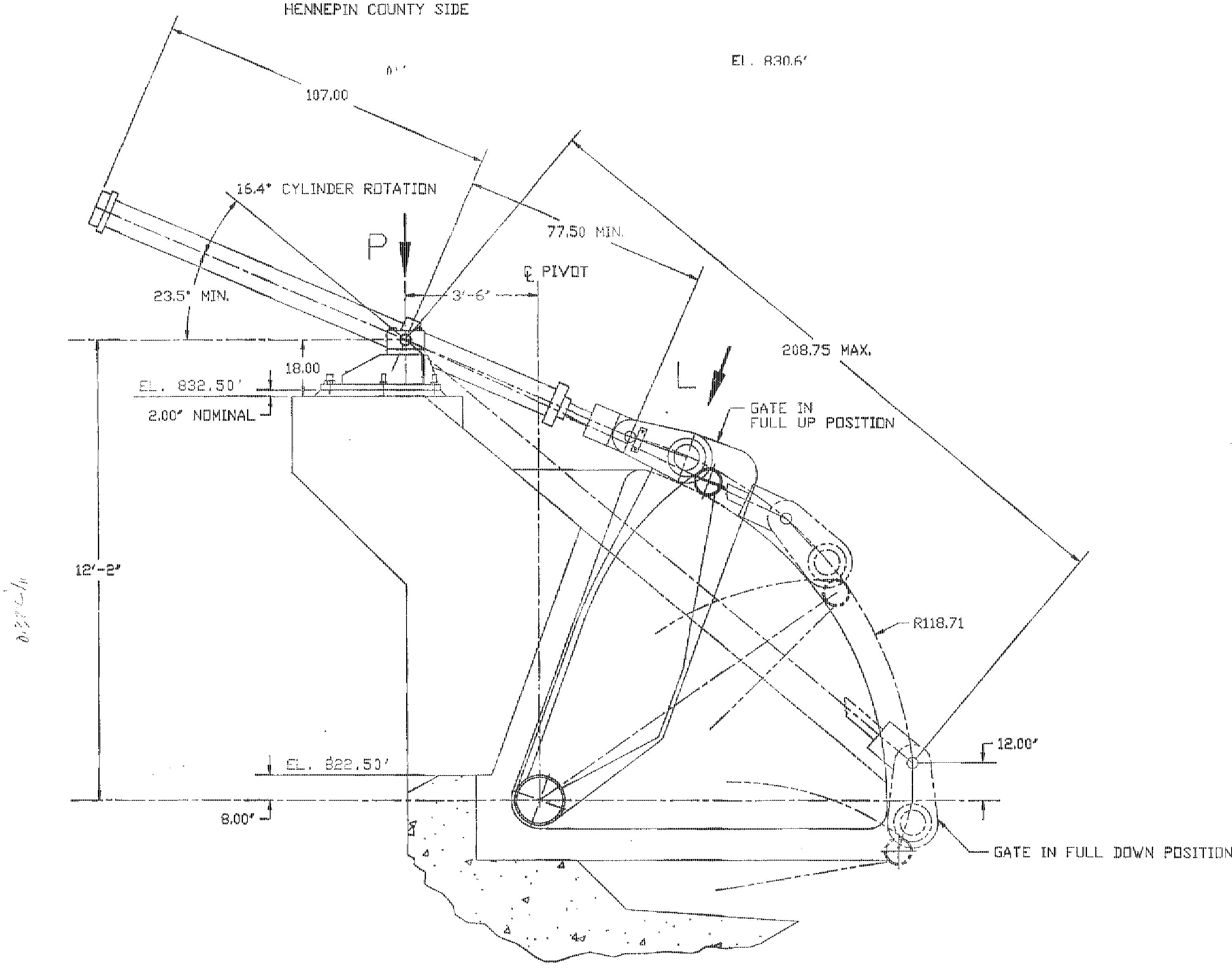
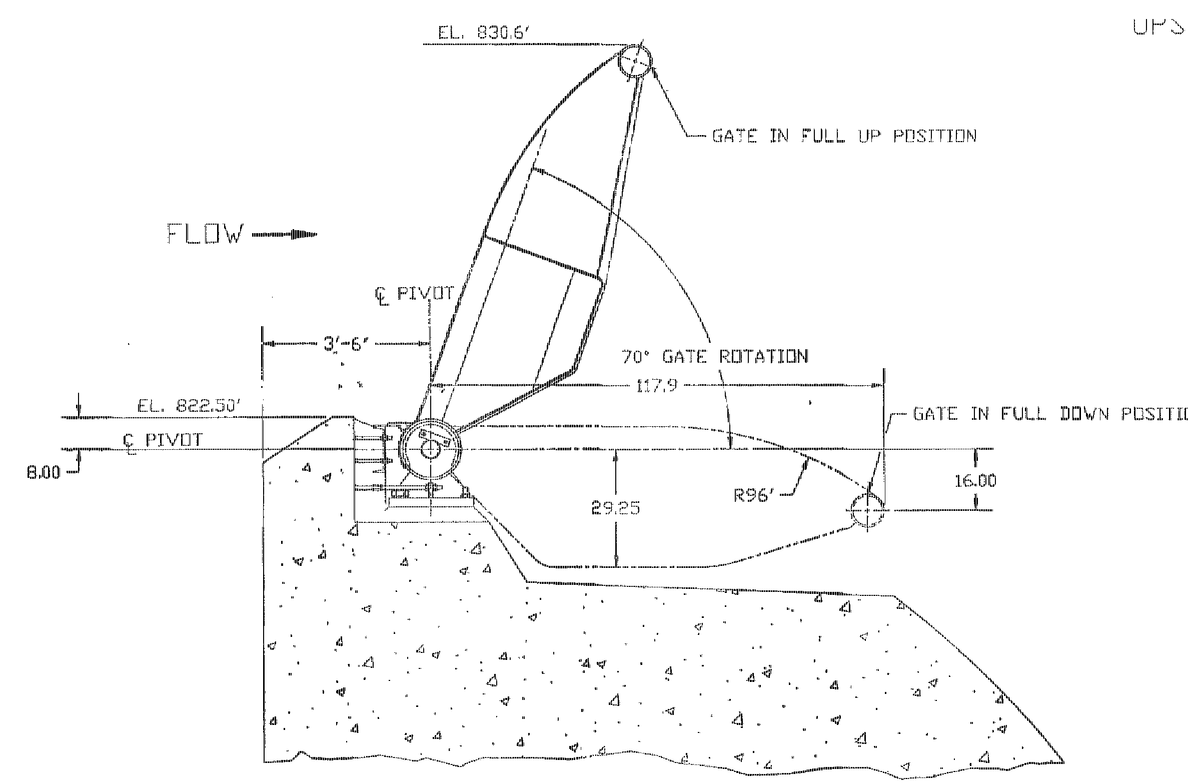


VIEW LOOKING UPSTREAM



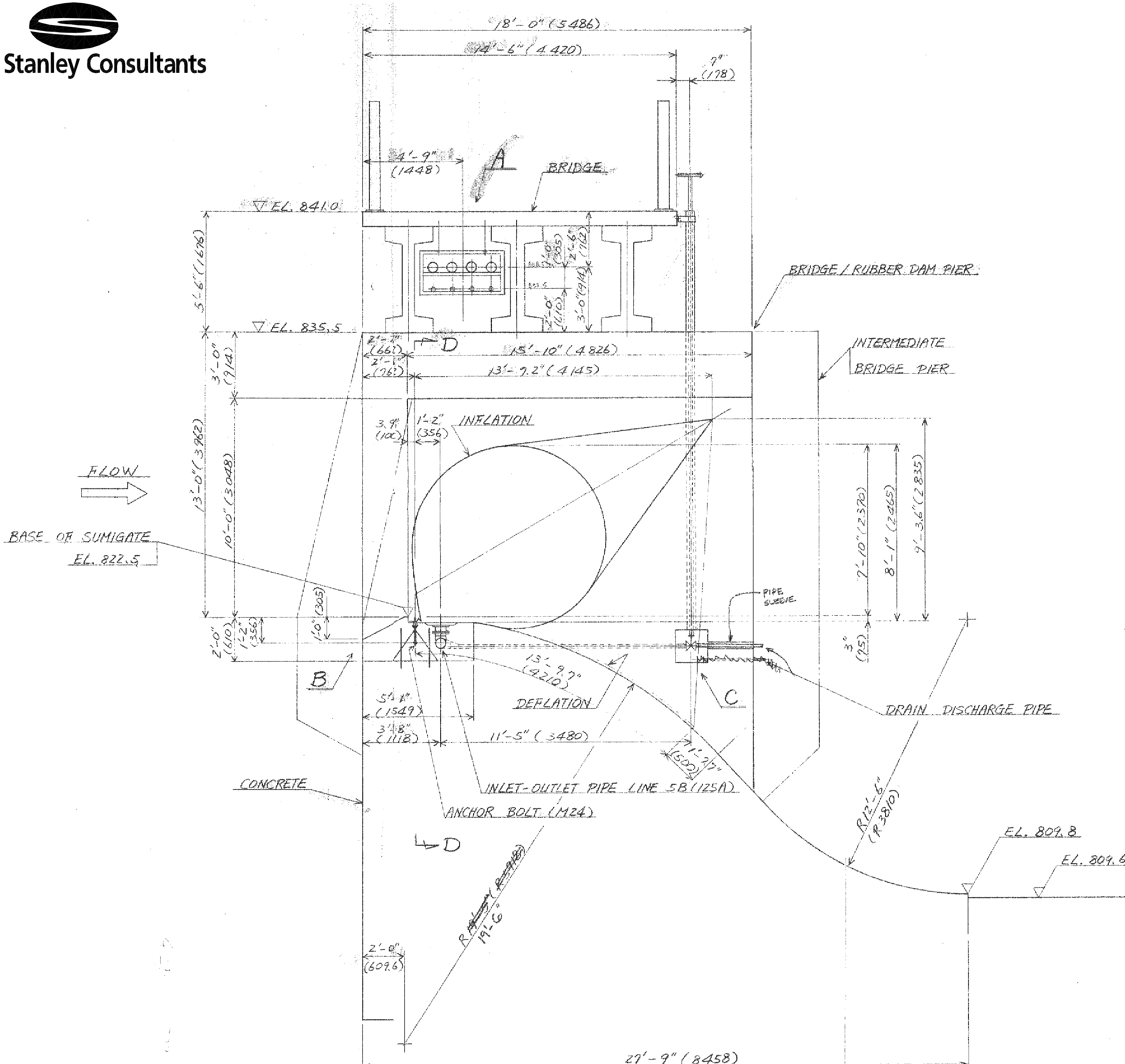
SECTION C-C
(SHEET 1)

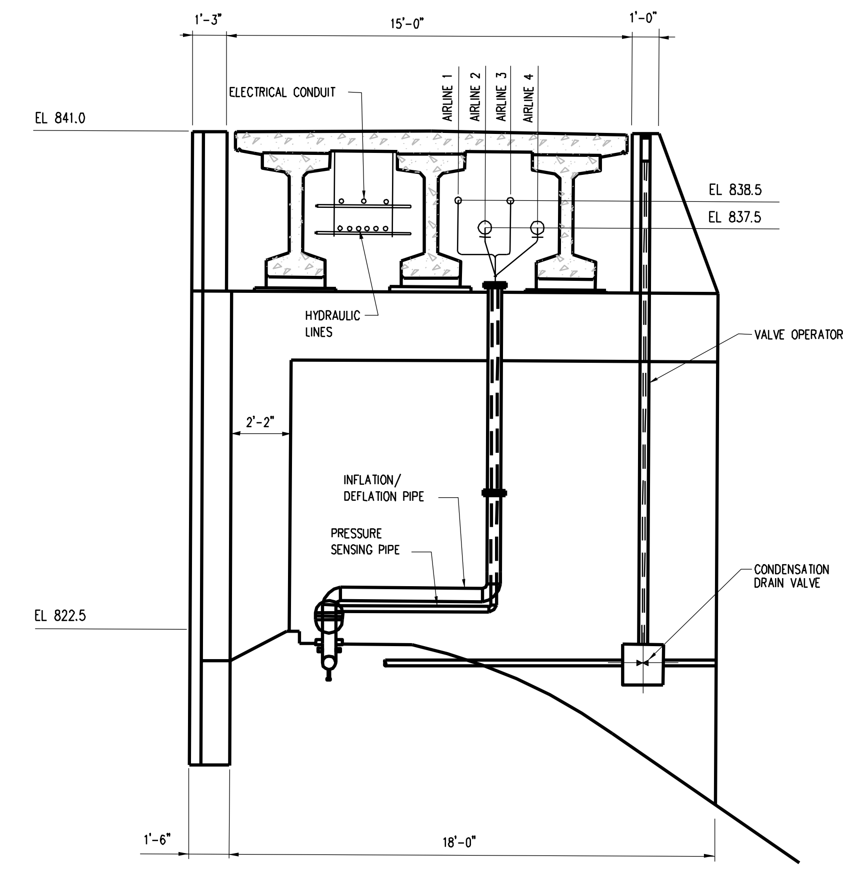


SECTION A-A
TYPICAL CROSS SECTION

COON RAPIDS DAM FISH BARRIER AND IMPROVEMENTS PRELIMINARY DESIGN
CONTROL GATE SECTIONS
FIGURE 8-3

Stanley Consultants

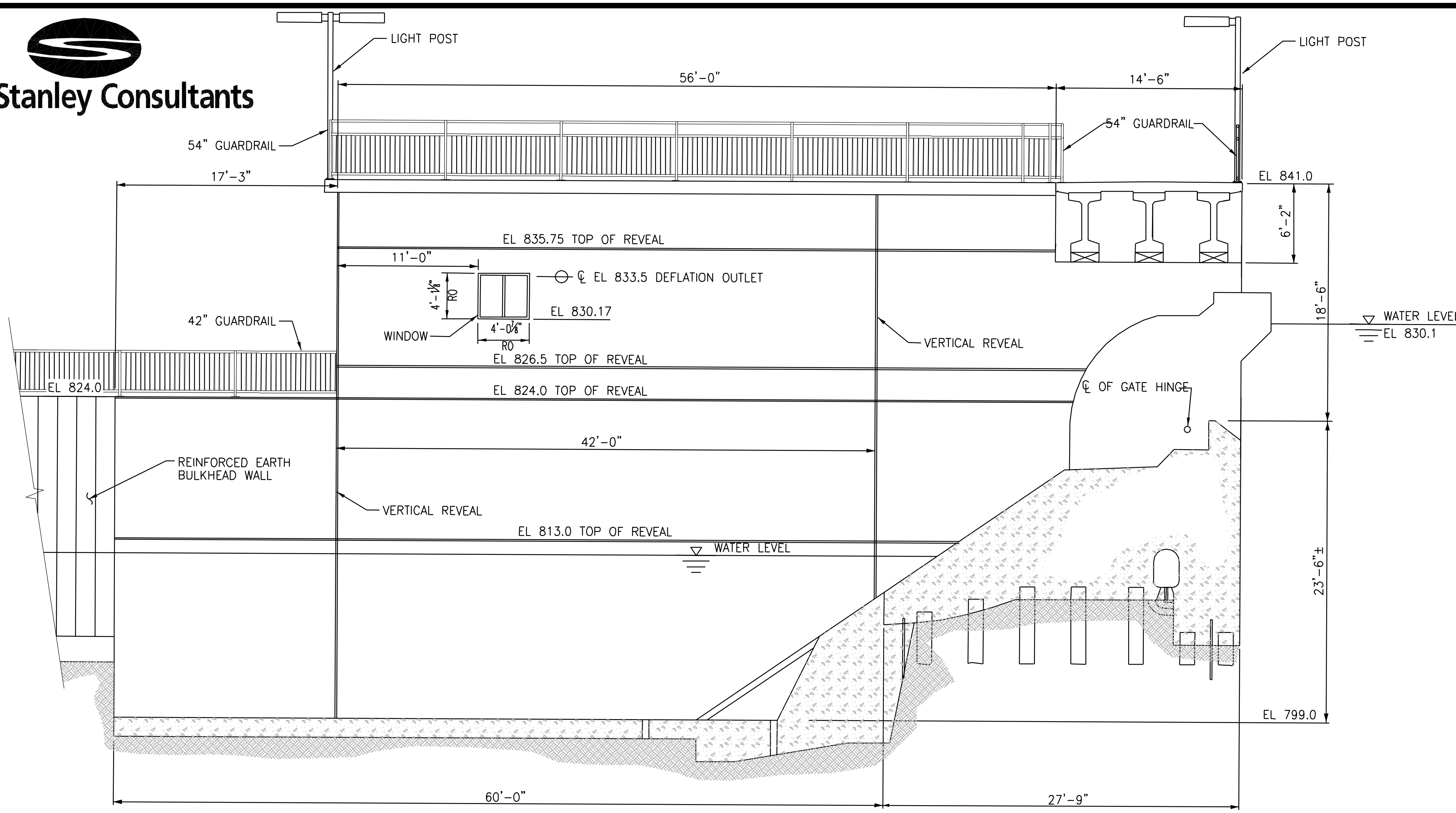




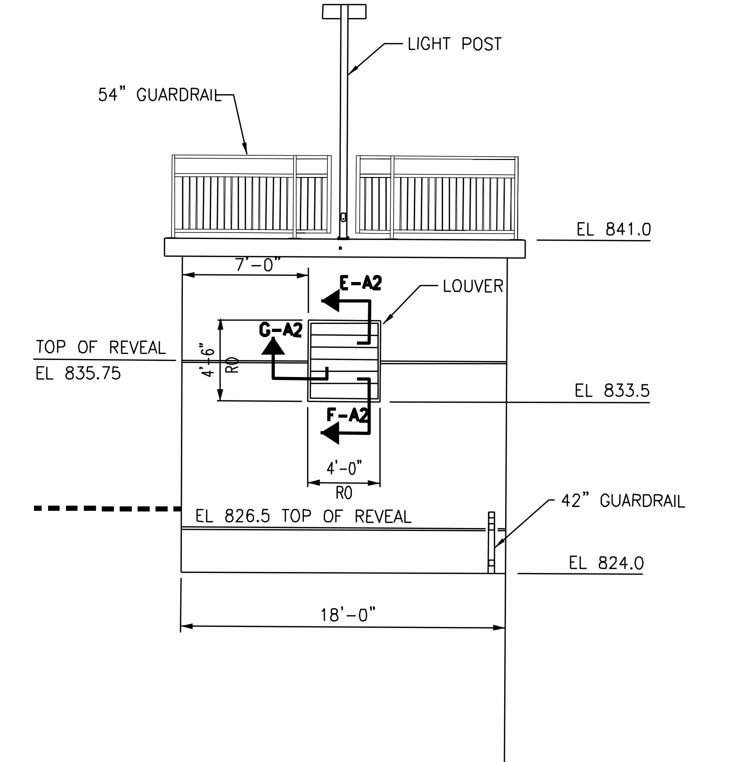
BRIDGE, PIERS & PIPING
SCALE: 3/8" = 1'-0"

COON RAPIDS DAM FISH BARRIER AND IMPROVEMENTS PRELIMINARY DESIGN
INFLATABLE GATE & BRIDGE CROSS SECTIONS
FIGURE 8-4

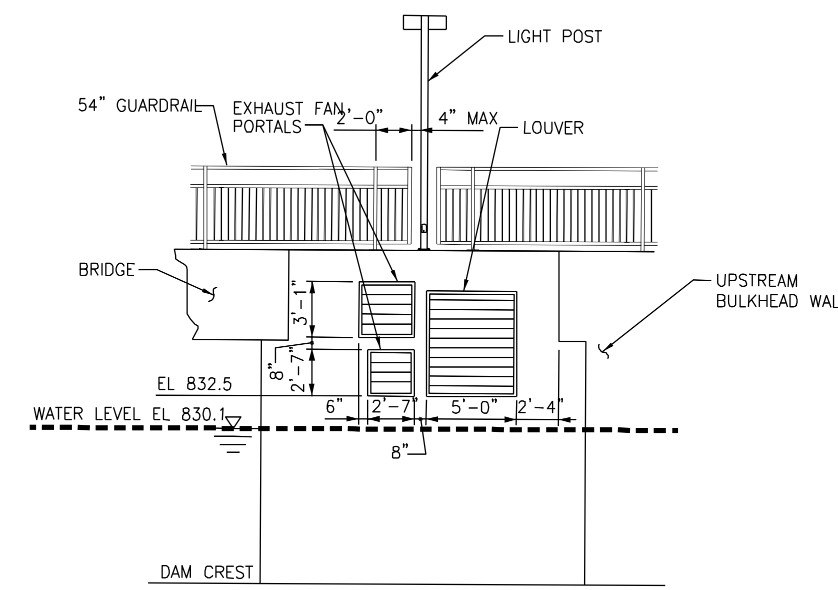
Stanley Consultants



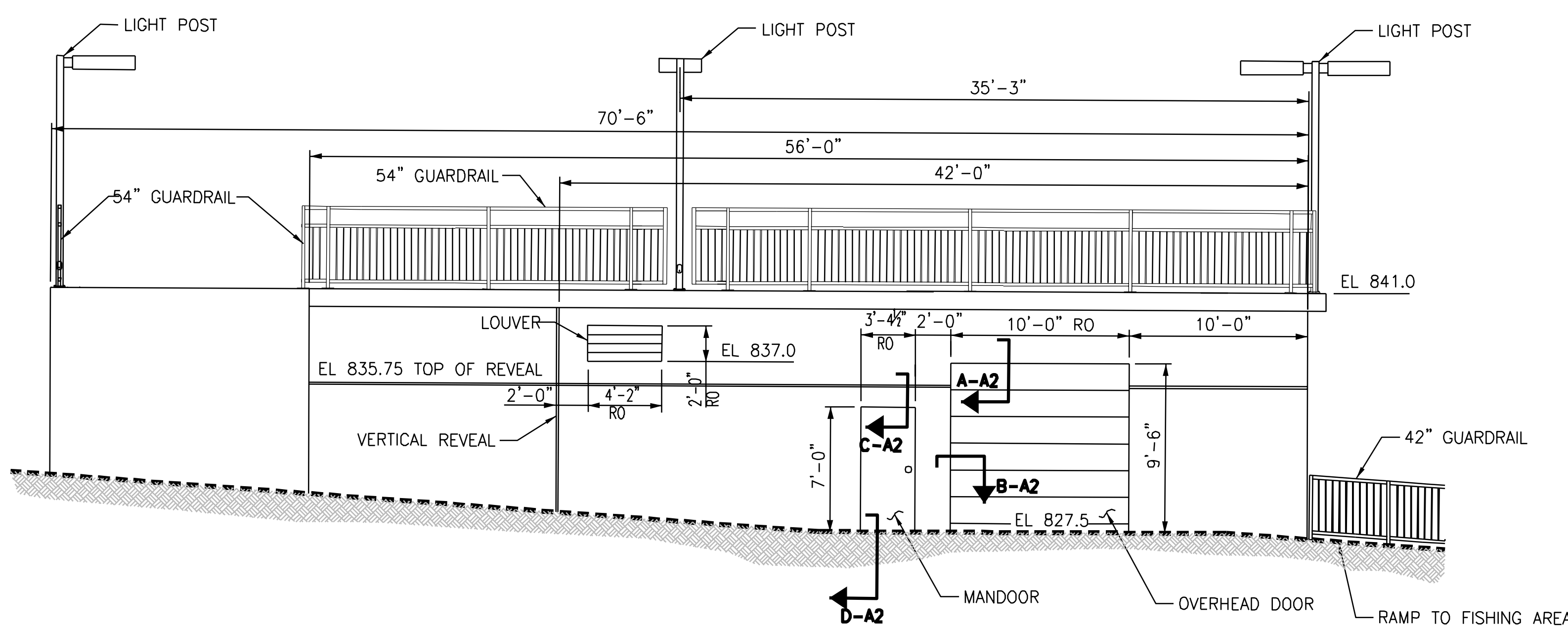
NORTH ELEVATION
SCALE: 3/16" = 1'-0"



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



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



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

COON RAPIDS DAM FISH BARRIER AND IMPROVEMENTS PRELIMINARY DESIGN

GATE CONTROL BUILDING ELEVATIONS

FIGURE 8-5

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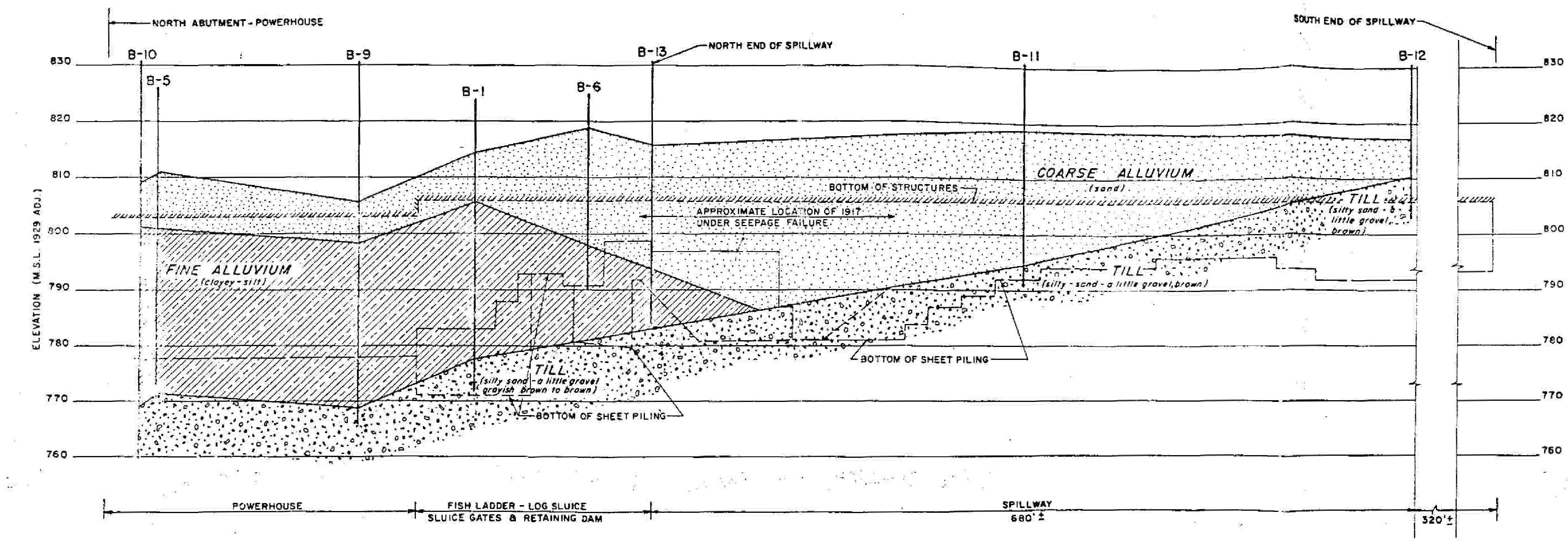

KEY

— — —	DENOTES BOTTOM OF ORIGINAL SHEET PILING
– – – –	DENOTES BOTTOM OF SHEET PILING INSTALLED DURING REPAIRS
//////	DENOTES BOTTOM OF CONCRETE STRUCTURES
B-6	DENOTES APPROXIMATE BORING LOCATIONS
SCALE	HORIZ. 1" = 100' VERT. 1" = 20'

NOTE: SOIL BORINGS AND SOILS CLASSIFICATION BY SOIL EXPLORATION CO.

COON RAPIDS DAM FISH BARRIER AND IMPROVEMENTS PRELIMINARY DESIGN

SOIL PROFILE

FIGURE 8-6

Appendix D

Correspondence

Stanley Consultants INC.

MEETING NOTES (REV 2)

Date: August 26, 2010

Place: Stanley – Minneapolis

Project/Purpose: Coon Rapids Dam – Evaluation Kickoff Meeting

Attendees: Margie Walz, TRPD
Amy Gurski, TRPD
Jason Boyle, DNR
Brian Nerbonne, DNR
Jay Rendall, DNR
Martin Weber, Stanley
Craig Johnson, Stanley
Bill Holman, Stanley

Notes By: Stanley

The following meeting notes set forth our understanding of the discussions and decisions made at this meeting. If no objections, questions, additions, or comments are received within 5 working days from issuance of the meeting notes, we will assume that our understandings are correct. We are proceeding based on the contents of these meeting notes.

Purpose of the meeting was to kick off the Coon Rapids Dam Fish Barrier and Improvements Preliminary Design project. The following discussions took place, not necessarily in the order listed:

1. Roles and Responsibilities:
   a. DNR
      i. Jason Boyle is main contact and responsible for dam safety issues.
      ii. Jay Rendall and Brian Nerbonne will jointly handle all fisheries issues.
   b. Three Rivers Park District (District)
      i. Margie Walz Margie Walz is responsible for operational/maintenance related issues and communications with Park District Superintendent for coordination with the Coon Rapids Dam Commission.
      ii. Amy Gurski will serve as the Project Manager for the Park District in the administration of Stanley's contract, and will be responsible for technical/engineering issues.

2. Dam Background
   a. M. Weber discussed the existing dam components and functions and presented drawings and photos of the components. **M. Weber to provide DNR with Barr Engineering drawings showing old powerhouse area discharge facilities with elevations converted to current datum.**
   b. M. Weber indicated that Stanley has a comprehensive file of the dam including drawings from various construction projects, hydraulic data, hydrologic data, etc.; and that DNR is welcome to all this information.
   c. M. Weber discussed inflatable dams and past maintenance issues.
   d. B. Holman discussed recent downstream scour issues as well as completed and possible future mitigation measures.

3. Study Objectives. The group discussed the major study objectives which include:
    a. Single recommended fish barrier.
    b. Permanent (50-year) fix for scour issues.
    c. Evaluation of inflatable gate system including life of existing system and recommended replacement system.
    d. Recommendations to improve structural integrity of dam to provide 50-year life.
    e. Improvements must maintain existing spillway capacity.
    f. Improvements must maintain recreational benefits of dam. Park District's key feature is the bridge that connects the two regional parks.
    g. Improvements must maintain the historic impoundment.
    h. Improvements must not prohibit future development of hydroelectric power.

4. Preferred Fish Barrier Concept
    a. Fish Species (DNR lead discussion)
        i. Asian carp include four species:
            1. Bighead carp. Feeds on plankton and very strong (can jump up to ten feet).
            2. Silver carp. Feeds on plankton and very strong (can jump up to ten feet).
            3. Black carp. Feeds on mollusks and not as strong as bighead or silver.
            4. Grass carp. Feeds on aquatic plants and not as strong as bighead or silver.
        ii. Other invasive species include snakehead and goby.
        iii. Zebra mussels are not to be considered.
    b. Barriers
        i. DNR discussed various barrier concepts including lights, electrical, sound, and physical barriers.
        ii. DNR prefers to use physical barrier due to the width (1000 feet) of the dam's main spillway and due to simplicity of operation. Other "behavioral" barriers would not work well at the dam unless they would be used only periodically and at a confined portion of the waterway.
        iii. Barrier needs to be effective in preventing migration of native species (not currently found upstream of dam) also.
        iv. Barrier effectiveness cannot reasonably be 100 percent. Barrier should limit migration to the fullest extent practical.
        v. General plan for other river systems is to promote passage in river sections that are bounded by upstream and downstream barriers.
        vi. Depending on hydraulics of existing dam, additional measures could be implemented during periods that dam is "exposed" to fish migration.
        vii. Barrier might require changes to dam's existing dam operation.
        viii. Consideration must be given to less tangible phenomena such as air-entrained water and ability of fish to circumvent barrier (e.g. gate is down, creating high velocity water but fish approaches dam in quieter adjacent water then jumps past).
    c. Fish Characteristics.
        i. USGS has good "fish ability" data (sustained swimming velocity, burst velocity, jumping ability).
        ii. Fish are normally more active in summer than in winter.
        iii. DNR to perform additional research and provide design data to Stanley.
    d. Alternate Location. Group discussed potential barrier at St. Anthony falls, which was the natural barrier for thousands of years. Issues with this location include the existing lock, Xcel hydroelectric plant, U of M hydraulics laboratory and steam plant, and potential whitewater rafting course. Study is not to include evaluation of this site.

5. Scour Mitigation Concepts. M. Weber discussed scour mitigation methods that would be considered, including sheetpile cutoff walls, deep stilling basin, and other standard design basins (to control location of hydraulic jump).

6. Study/Report Requirements
    a. Conceptual Designs
    b. Cost Estimates/Cash Flow
    c. Audience/Presentations
        i. Scope includes four meetings/presentations to CRD Commission.
        ii. Report needs to be technical in nature but also be readable (at least executive summary) by the layman.
        iii. **Margie Walz to will coordinate schedule/topics of meetings/briefs for Park District Administration or CRD Commission.**
    d. Schedule.
        i. Recommended measures, cost estimates, and life cycle economics is due before end of 2010.
        ii. Final report is due in early 2011.
        iii. CRD Commission report is due to State legislature on March 1, 2011.
        iv. DNR (in cooperation with Stanley) to select preferred barrier on or about September 13, 2010.

7. Moving Forward
    a. Stanley to proceed with scour mitigation alternatives.
    b. Stanley to provide summary of existing dam hydraulic characteristics to DNR by September 2:
        i. Headwater, tailwater, and discharge duration relationships by season.
        ii. Water depth and velocity at key locations downstream of the dam, corresponding to seasonal duration values.
    c. DNR to review hydraulic data, coordinate additional studies with Stanley, and provide criteria for physical fish barrier design.

Stanley Consultants INC.

MEETING NOTES

Date: October 21, 2010

Place: Teleconference

Project/Purpose: Coon Rapids Dam Evaluation – Fish Barrier

Attendees: Amy Gurski, Three Rivers Park District
Jason Boyle, DNR
Luke Skinner, DNR
Brian Nerbonne, DNR
Martin Weber, Stanley
Andrew Judd, Stanley

Notes By: Stanley

The following meeting notes set forth our understanding of the discussions and decisions made at this meeting. If no objections, questions, additions, or comments are received within 5 working days from issuance of the meeting notes, we will assume that our understandings are correct. We are proceeding based on the contents of these meeting notes.

Purpose of the meeting was to discuss the preliminary conclusions provided by DNR on the adequacy of the Coon Rapids Dam (CRD) to act as a fish barrier. DNR's preliminary conclusions (October 15, 2010 e-mail) are attached. The following discussions took place, not necessarily in the order listed:

1. DNR Preliminary Evaluation:
   a. DNR clarified that the preliminary conclusion that the CRD is not an effective fish barrier was based on an evaluation of the dam with its current spillway gates and their operational capabilities.
   b. Group agreed that another evaluation should be done that considers an alternative gate system. The alternative system would be a "crest gate" type system that maintains a desired pool level through a variable crest elevation (similar to the existing control gate). With such a system, river discharges could be passed with a constant head across the entire spillway, which as opposed to the existing inflatable gate system would not result in "windows of opportunity" for upstream fish migration though individual lowered gates.
2. Fish Passage Criteria
   a. Differential head of 8-feet was agreed upon as criterion to prevent upstream fish passage for Asian carp.
   b. Other factors including water air entrainment, water velocity, and water depth are at this point considered less critical and will be considered in subsequent evaluations.
   c. No seasonal migration limitations are to be considered. Asian carp tend to become active during high river flows, whatever time of year they might occur.
3. Behavioral Barriers
   a. Behavioral barriers (bubblers, electrical, etc.) would likely only be practical for relatively confined channels. Use of this type of barrier would not be practical at CRD unless critical portion of river flow can somehow be confined.
4. Action Items
   a. Stanley to perform the "crest gate" evaluation to determine the CRD's barrier effectiveness and distribute results to DNR and District.
   b. DNR (Brian Nerbonne) to further research water depth and its effect on fish jumping

ability.

Distribution:

Attendees
Margie Walls, Three Rivers Park District
Jay Rendall, DNR

Date: November 8, 2010

Place: Stanley – Minneapolis

Project/Purpose: Coon Rapids Dam – Evaluation Progress Meeting

Attendees: Margie Walz, TRPD
Amy Gurski, TRPD
Jason Boyle, DNR (via telephone)
Brian Nerbonne, DNR
Martin Weber, Stanley
Craig Johnson, Stanley
Andrew Judd, Stanley

Notes By: Stanley

Purpose of the meeting was to discuss progress on the Coon Rapids Dam Fish Barrier and Improvements Preliminary Design project. The following discussions took place, not necessarily in the order listed:

1. Hydraulic Analysis
   a. Stanley presented the latest hydraulic analysis that is a refinement of previous analyses that only took into account differential head across dam and water velocity at take-off point. Latest analysis includes the following:
      i. Addition of crest gates to spillway crest to allow full range of gate operation.
      ii. Hydraulic jump characteristics of spillway, stilling basin, and downstream apron as previously computed.
      iii. Computation of water surface profile and water velocities from pool to gate to spillway to stilling basin/apron.
      iv. Theoretical (parabolic) profile of leaping fish taking into account take-off velocity, angle, and starting point.
         1. Take-off starting point defined as one-foot downstream of apron water-jet to level tailwater interface or the point where tailwater velocity is less than assumed take-off velocity.
         2. Take-off velocity assumed to be 25 feet per second (fps).
      v. Delineation of "barrier zone" on spillway where fish cannot sustain upstream movement. Limiting factor is water velocity where fish lands after initial leap.
   b. Group agreed that the latest analysis is more representative of actual conditions and fish abilities necessary for upstream migration.
   c. Following analysis limitations remain:
      i. Limited information on actual ability of target species (Asian carp) exists locally, regionally or nationally.
      ii. Model species (salmonid) is known to have burst velocity of 25 fps (sustainable for ten seconds) but the swimming ability after an initial leap is not known.

iii. Analysis does not take into account the "net" velocity at take-off, i.e. capable velocity minus water velocity.
iv. Analysis needs to be refined to better model water profile over crest/spillway.
v. Analysis does not take into account the decreased density of water at the take-off point. Density is decreased due to air content resulting from turbulence. Analogy is motor-boat in dam "roller" that cannot escape due to ineffectiveness of propeller.
vi. Analysis does not take into account effects of ice dams.
vii. Analysis does not take into account piers and the potential for fish to hide/rest in areas downstream of piers.

2. Other Barrier Concepts
   a. As discussed in previous meetings, other barrier types (bubblers, acoustic, light, electric, etc.) have been proposed but few have been proven. The feasibility of such barriers is limited by the width of channel over which they need to be effective. The width of the Coon Rapids Dam does not lend itself to barriers other than physical (water velocity & head).
   b. An additional barrier that could be retrofitted onto Coon Rapids Dam could consist of a physical barrier suspended from the bridge above the dam. Such a barrier would be "hinged" to allow water to pass downstream but physically prevent any upstream movement. The system would be modular and portable such that it would only be installed during times (high river flows) when migration is possible.
   c. If it determined that Coon Rapids Dam cannot be modified to act as an effective barrier, other potential measures (beyond scope of this study) may include:
      i. Closure of Upper St. Anthony Fall Lock (would require federal legislation).
      ii. Allow migration past Coon Rapids Dam up to St. Cloud Dam. Evaluate/modify St. Cloud and Rum River dams to prevent migration.

3. Other Issues
   a. Asian carp are known to presently exist in Lake Pepin. Barrier concepts and schedules must consider the anticipated speed at which they may migrate up to the barrier.

4. **Moving Forward/Action Items**:
   a. Brian Nerbonne to provide Stanley with link to Chinese technical paper that may shed more light on Asian carp abilities.
   b. Stanley to more accurately model the water surface profile across the crest/gate/spillway.
   c. Stanley to report the theoretical effectiveness of the dam to act as a barrier using historic streamflow data.
   d. Stanley to model crest gate system vs. existing inflatable gate system to determine barrier efficiency improvement that could be realized with the former.
   e. Stanley to further investigate "suspended barrier" concept.

Distribution:

Attendees
Jay Rendall, DNR

Minnesota Department of Natural Resources
500 Lafayette Road • St. Paul, MN • 55155-40

February 12, 2010

REC'D FEB 16 2010

Cris Gears, Superintendent
Three Rivers Park District
3000 Xenium Lane North
Plymouth, MN 55441

Subject: Importance of the Coon Rapids dam as barrier to the spread of Asian Carp

Dear Mr. Gears,

After our meeting January 6, 2010 and in response to your request for a department position Ecological Resources and Fisheries staff have reviewed this issue and provided the following information.

Preventing the spread of invasive species is a major concern for the Department of Natural Resources (DNR). Asian carp are of particular concern to Minnesota, because they are naturally moving up the Mississippi River. Several Asian carp were caught last year in Pool 5 near Winona.

Limiting the migration of Asian carp into the lower reaches of the Mississippi River in Minnesota is inherently difficult, due to the size of the river and the upstream spread of the fish. Nevertheless, there is an opportunity to prevent Asian carp from invading the upper portions of the Mississippi River. St. Anthony Falls, on the Mississippi River in Minneapolis, was an effective, natural fish barrier for about 10,000 years. Historically, there were 123 fish species known to be present below the falls, but only 64 species upstream of it. In the early 1960s, a lock system was constructed at St. Anthony Falls to allow upstream navigation, thereby eliminating the fish barrier.

The Coon Rapids Dam now acts as a de-facto barrier to upstream migration of fish that were formerly blocked by St. Anthony Falls. Although the DNR is generally in favor of removing dams for multiple reasons, maintaining the Coon Rapids Dam provides a unique opportunity to prevent the spread of Asian carp and other invasive species to the upper Mississippi River system and maintain the unique differences in the natural fish communities that formerly existed above and below St. Anthony Falls.

As a result, the DNR believes it is important to maintain the integrity of the Coon Rapids Dam as a fish barrier and is committed to helping Three Rivers Park District accomplish that.

Please feel free to contact me if you have questions or would like more information.

Sincerely,
DNR Waters

Kent Lokkesmoe

Kent Lokkesmoe
Director

c: Dirk Peterson, Regional Fisheries Supervisor
Steve Hirsch, Director, Ecological Resources
Jason Boyle, State Dam Safety Engineer

From: Nerbonne, Brian A (DNR) [mailto:Brian.Nerbonne@state.mn.us]
Sent: Friday, October 15, 2010 4:06 PM
To: Weber, Martin
Cc: Lokkesmoe, Kent M (DNR); Peterson, Dirk L (DNR); Rendall, Jay J (DNR); Boyle, Jason (DNR); Homuth, Dale (DNR); Skinner, Luke C (DNR)
Subject: Coon Radids Dam as Fish Barrier

Martin,

As part of the contract that DNR has with Three Rivers Park District to evaluate repairs to the Coon Rapids Dam, I have been researching criteria that the Stanley Group can use to assess the potential of the dam as a fish barrier. I apologize that our research and internal coordination did not allow us to respond sooner.

My general conclusion is that for <u>native</u> Mississippi River species the dam is a decent barrier, but far from impassable. Native fish behaviorally do not leap to overcome obstacles such as dams, and are only able to achieve moderate swimming speeds. However, there have been 2 years within the last 30 in which the dam has been theoretically passable for non-jumping species such as are found in the Mississippi, ranging from 4 to 6 days for each occurrence. These periods occurred during high flows when the head of the dam is overcome by the flood stage of the river, and the return interval on such an event is approximately 25 years. Thus far the dam seems to have been sufficient to prevent upstream movement of species such as flathead catfish and white bass, but in the fullness of time there is a good chance that the dam as currently constructed and operated will not be an effective enough barrier to prevent upstream movement of even native species.

The dam is even less of a barrier for the various Asian carp (bighead, silver, black, and grass carp) that are especially important to prevent from migrating upstream. All 4 Asian carp species are impressive swimmers. Although data from the literature is lacking on specific swimming performance for these species, calculations based on body size as well as leaping ability place the Asian carp as roughly equivalent to Pacific salmonids in their burst and sustained swimming speeds. Asian carp are estimated to be able to swim at up to 23 feet per second for short bursts, and 17 feet per second for several minutes. Velocity at the dam during high flows where the dam head is washed out by high water would not stop upstream migration.

In addition, silver carp are notorious for their tremendous leaping ability. The behavior of the Asian carp species during migration is not well understood, specifically whether they will attempt to overcome waterfall barriers such as occurs at Coon Rapids dam by leaping over the falls. Until strong evidence proves otherwise, I believe the safest assumption is that leaping ability must be considered in any fish barrier analysis. Silver carp have been documented to leap up to 10 feet in the air, and if one takes the most conservative assumption and simply uses that value as what is required to block upstream movement, the dam could be passable as frequently as every year during high water periods. A slightly less conservative value might be to assume that greater forward momentum would be required when leaping the dam, meaning that perhaps a vertical drop of greater than 8 feet may be impassable. Using this value, the dam may still be passable every other year under the current operating plan. There is uncertainty about whether a lower dam head might also be a barrier because Asian carp behavior, but based on my best judgment an elevation of at least 8 feet must be maintained to have relative certainty that fish will not leap over it. It should go without saying that the lower the elevation, the greater the risk.

The Stanley Group has been contracted to consider changes to either the operating plan, the dam configuration, or both to address the ability of fish to pass during high flows. Changes to the operation plan appear to have little benefit based on my assessment of velocity and head at the dam during higher flows. The dam has inflatable gates that can raise the head of the pool, but an unblocked control segment of the dam maintains the lower crest elevation. Also, the inflatable gates are not intended to have flow pass over them. I believe that park district does not have the option to keep the gates inflated at all flows, because they will not withstand such conditions. Reconfiguration of the dam to increase the head difference may be possible if the inflatable gates are replaced.

Hopefully these criteria are enough assess the dam as currently configured and operated, as well as to assess possible changes. Please feel free to contact me for clarification, or for further guidance.

Brian Nerbonne
Stream Habitat Specialist
Minnesota Department of Natural Resources
1200 Warner Rd.
St. Paul, MN 55106
(651)259-5786
brian.nerbonne@state.mn.us

COON RAPIDS DAM

Fish Barrier and Improvements Preliminary Design

Status Report – Coon Rapids Dam Commission
January 11, 2011

Stanley Consultants INC.

Coon Rapids Dam
Fish Barrier and Improvements Preliminary Design

Status Report Agenda:

1. Invasive Fish Barrier Effectiveness
2. Condition of Dam
3. Improvements & Costs

Stanley Consultants INC.

Coon Rapids Dam
Fish Barrier and Improvements Preliminary Design

1. **Invasive Fish Barrier Effectiveness**
2. Condition of Dam
3. Improvements & Costs

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1. Invasive Fish Barrier Effectiveness

"Asian carp have the potential to cause extensive and irreversible changes to the aquatic environment, thereby jeopardizing the long-term sustainability of native aquatic species, including threatened and endangered species" (MN DNR)

"Asian carp" include black carp, bighead carp, grass carp, & silver carp.

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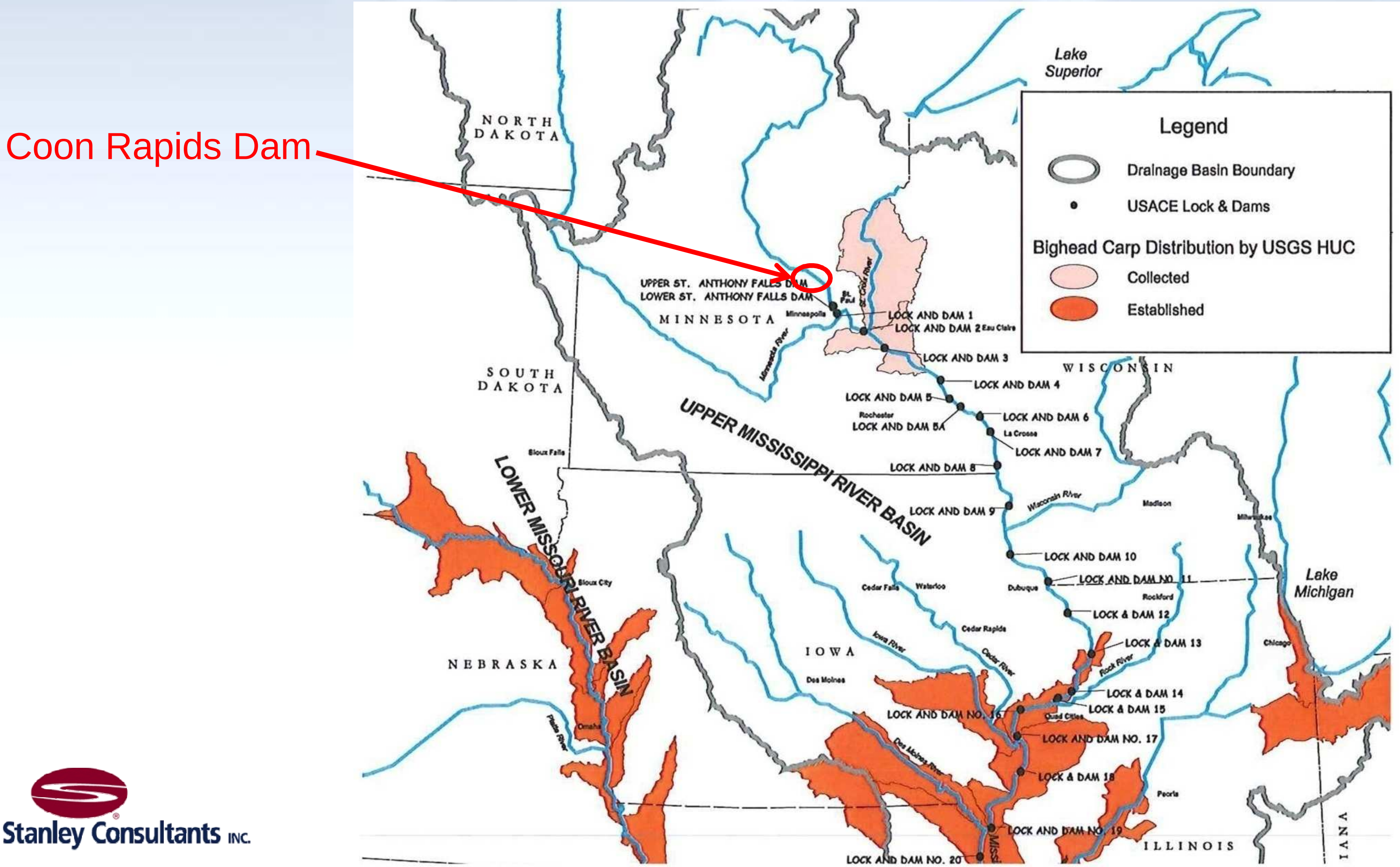
1. Invasive Fish Barrier Effectiveness

Distribution of bighead carp (FISHPRO, 2004):



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1. Invasive Fish Barrier Effectiveness

Capabilities:
- 25 feet per second burst velocity
- 10-foot leaping ability

Tendencies:
- No seasonal migration habits
- Migrate during high river flows

Potential Affected Waters:
- Upper Mississippi
- Lake Mille Lacs

Detrimental Effects:
- Jeopardize native fish species
- Hazard to boaters/water skiers

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1. Invasive Fish Barrier Effectiveness

Barrier & Deterrent Alternatives:

Behavioral:

- Strobe lights
- Air bubble curtains
- Acoustics
- Electrical barriers
- Hydrodynamic Louvers

Physical:

- Screens
- Curtains
- **Vertical drops***
- **Water velocity barriers***

*** Deemed practical & feasible at Coon Rapids Dam - other alternatives dismissed due to width of waterway, high river flows, water level fluctuations, & climate/ice.**

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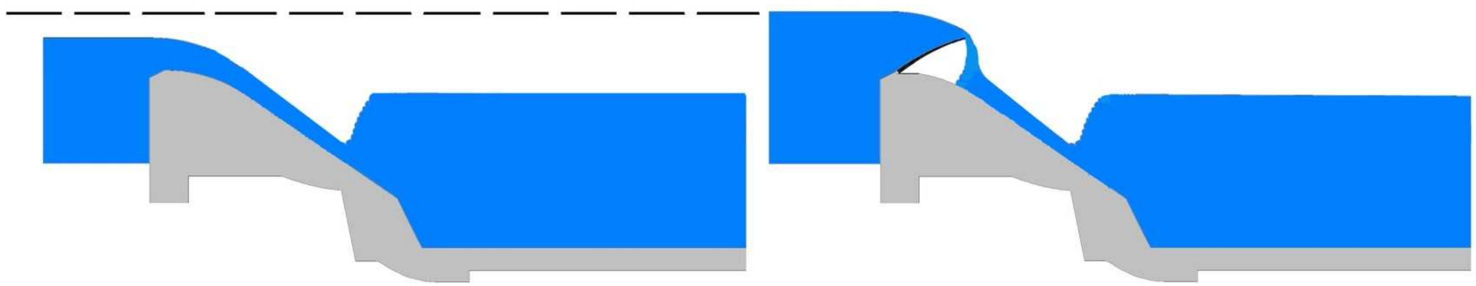
1. Invasive Fish Barrier Effectiveness

Evaluation of Coon Rapids Dam:

- Spillway hydraulics (vertical drop & water velocity)
- Historic river flows (79 years)
- Existing gates & operation
- New gates & modified operation*

*Modified operation: maintain recreational (summer) pool level year-round



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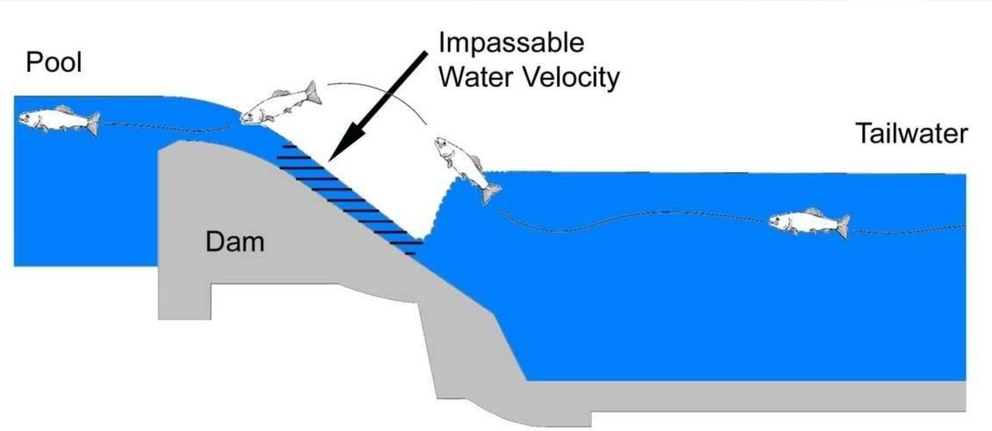
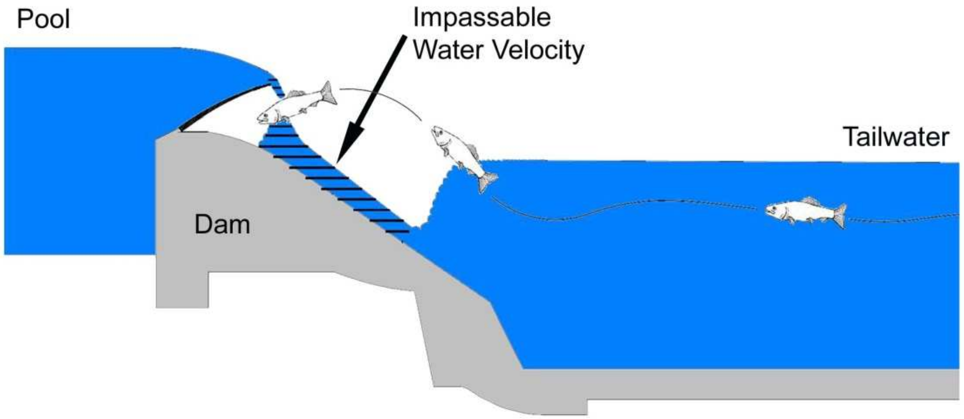
Evaluation of Coon Rapids Dam:

- Fish must swim and/or leap its way from tailwater to pool





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1. Invasive Fish Barrier Effectiveness

Results

Gates	Operation	Barrier Effectiveness	Expected Life (years)
Existing	Current	89% (marginal)	3±
	Modified	99% (effective)	5±
New	Current	89% (marginal)	50±
	Modified	99.9% (effective)	50±

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Coon Rapids Dam
Fish Barrier and Improvements Preliminary Design

1. Invasive Fish Barrier Effectiveness
2. **Condition of Dam**
3. Improvements & Costs

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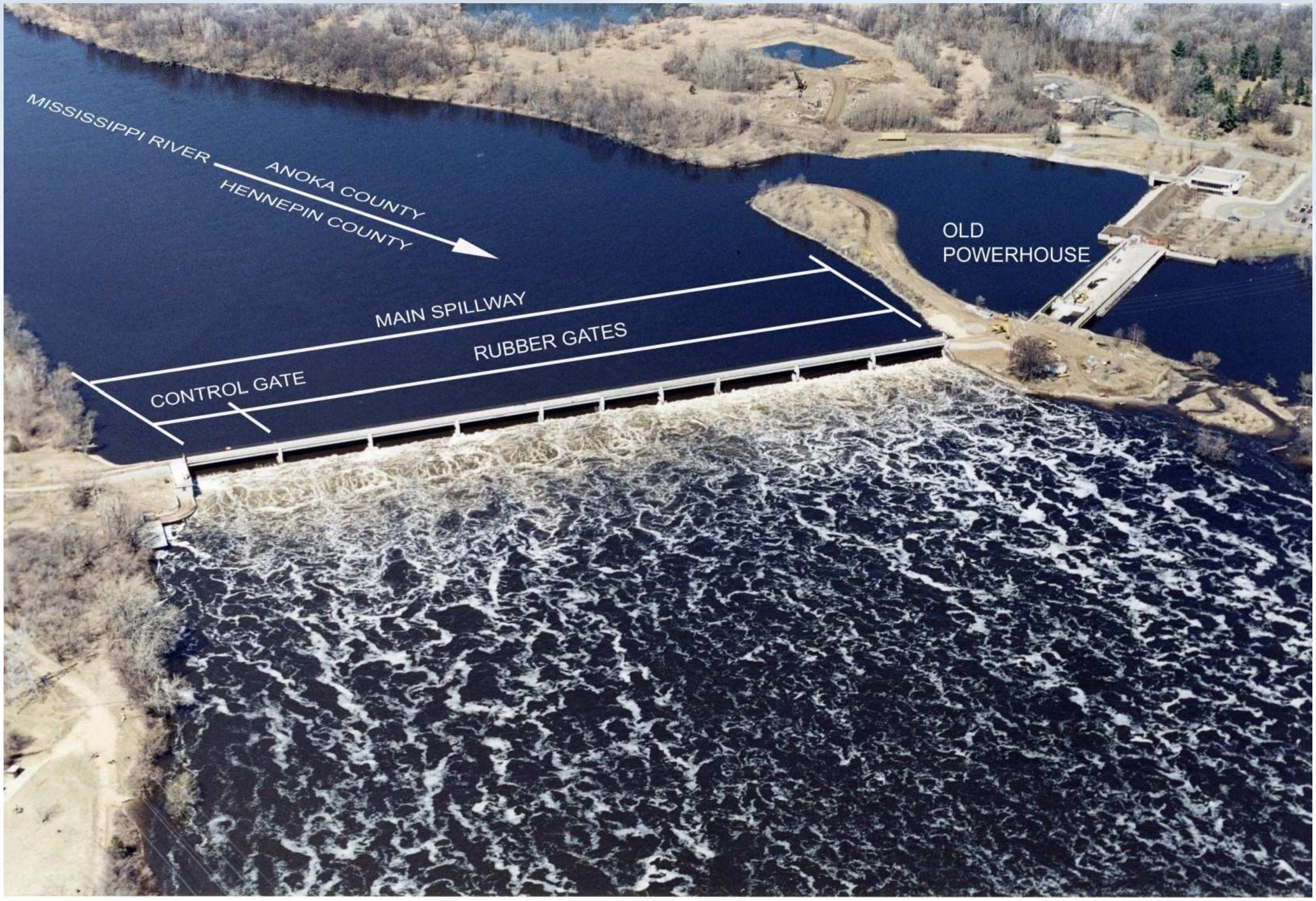
Coon Rapids Dam Today



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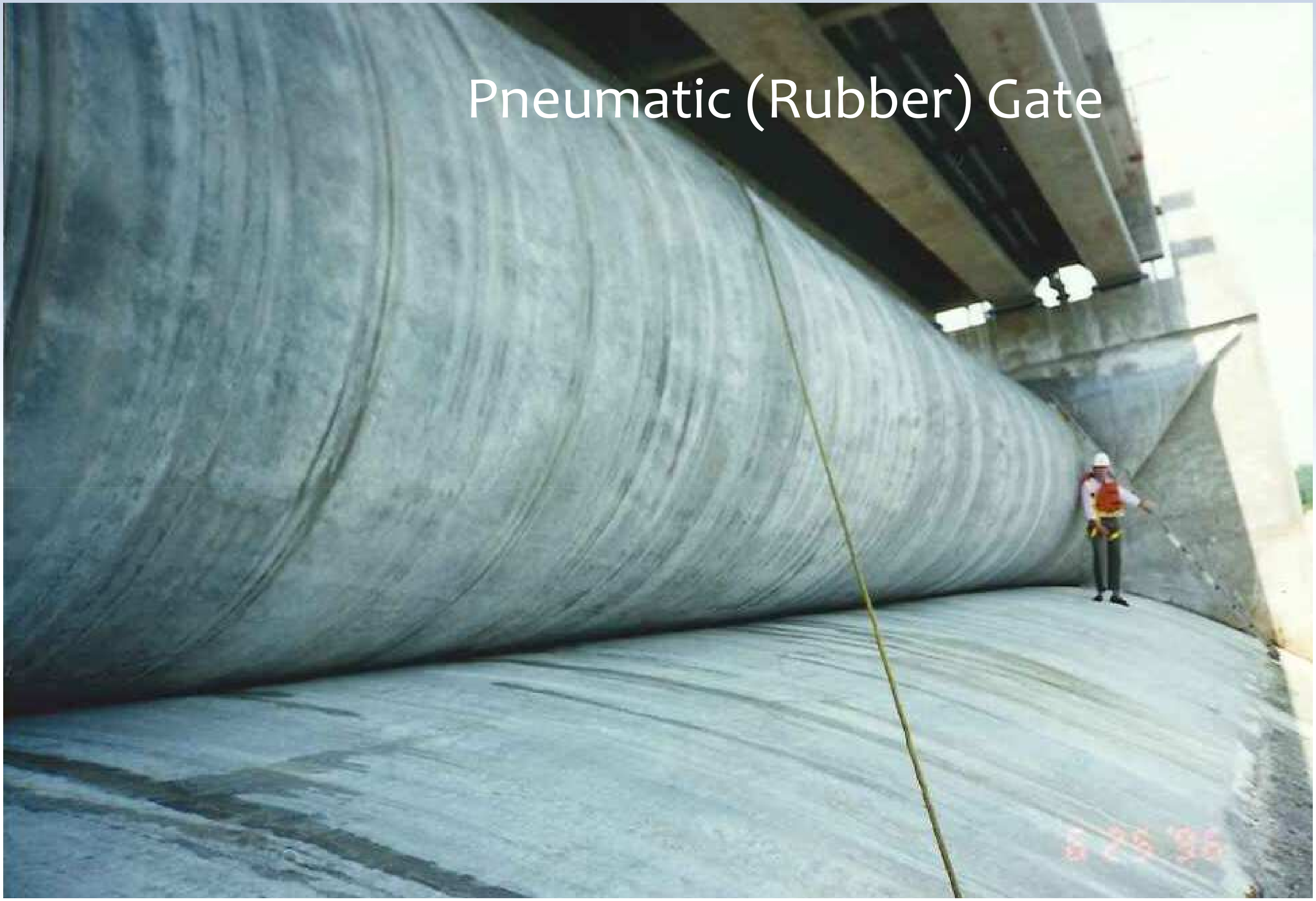
2. Condition of Dam



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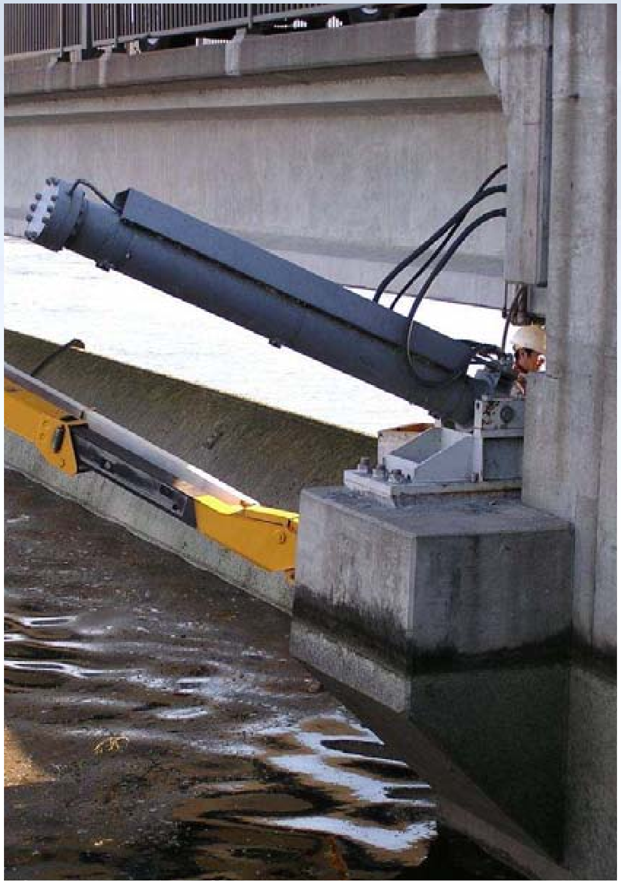
2. Condition of Dam



Control Gate

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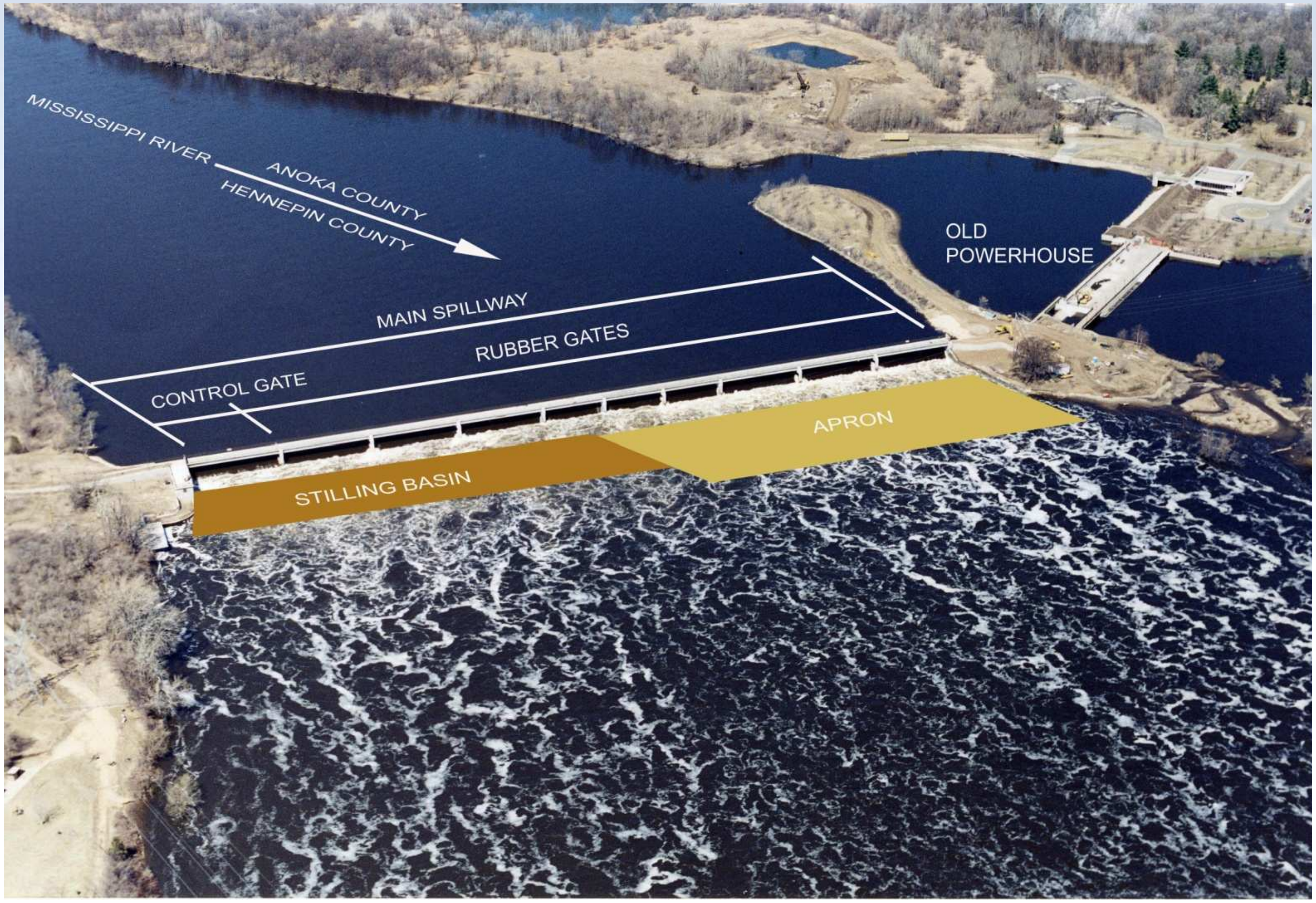
2. Condition of Dam



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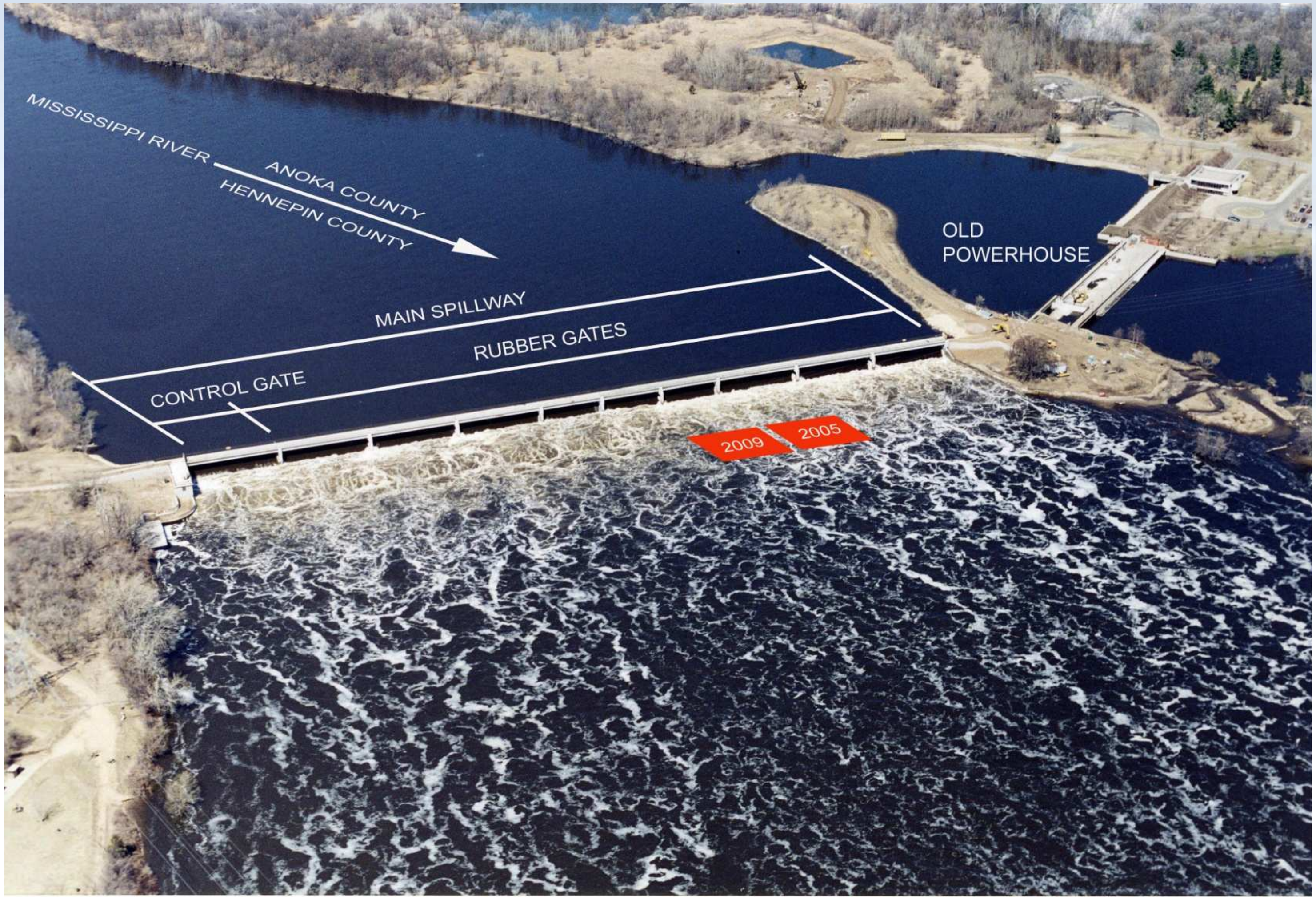
2. Condition of Dam

Apron Scour



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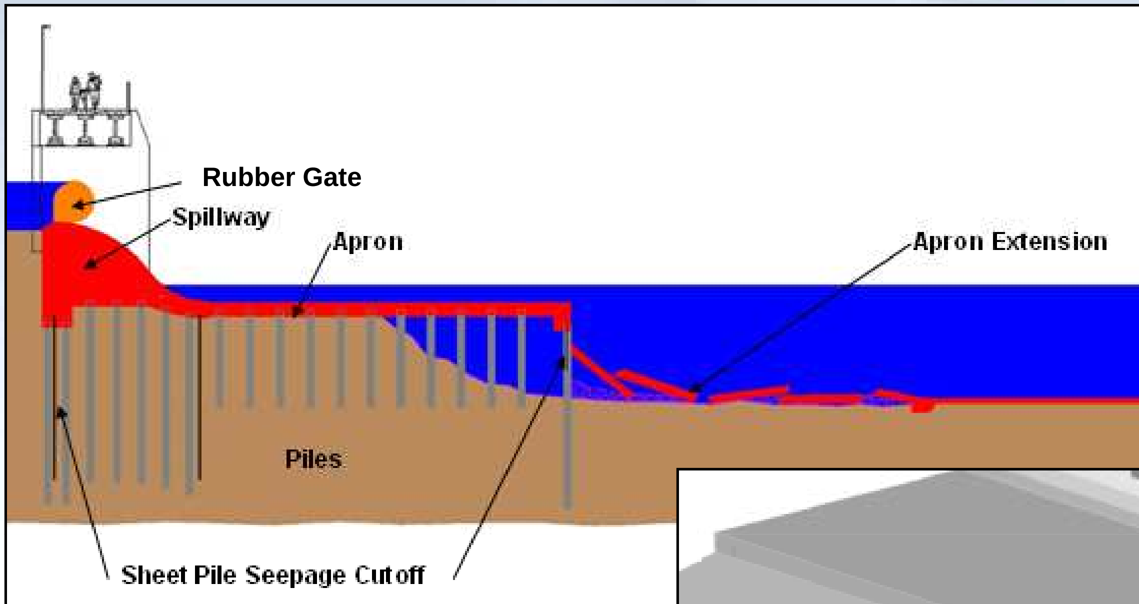
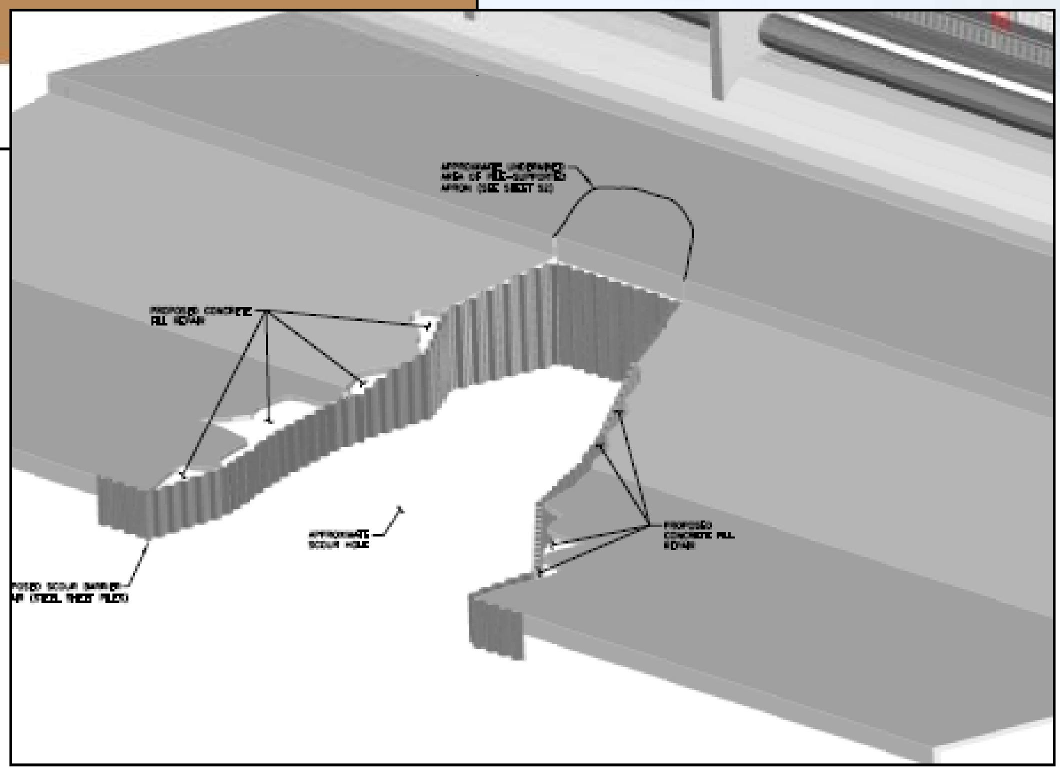
2. Condition of Dam

Apron Scour





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Rubber Gates

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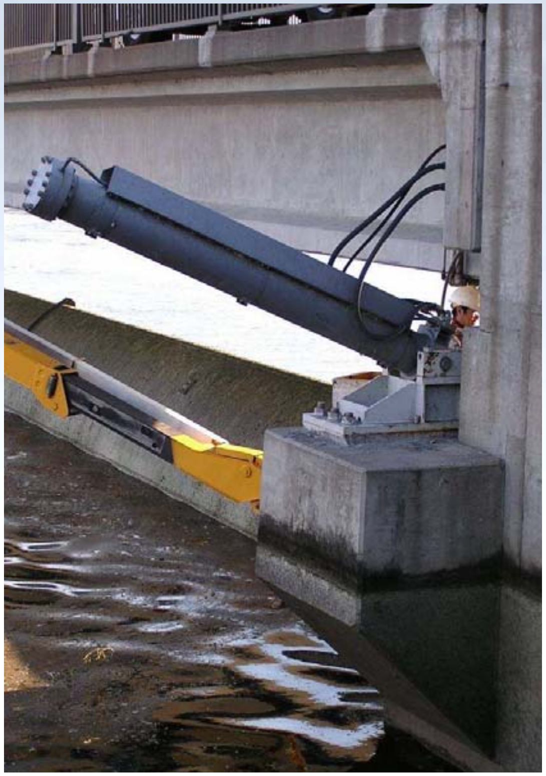
Control Gate Maintenance



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Coon Rapids Dam
Fish Barrier and Improvements Preliminary Design

1. Invasive Fish Barrier Effectiveness
2. Condition of Dam

3. Improvements & Costs

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3. Improvements & Costs

Major Improvements Required to Provide 50-Year Life*:

- Replace Rubber Gates
- Mitigate Downstream Scour

* - Hydropower potential not diminished by proposed improvements
- Other minor repairs/improvements included in cost estimate

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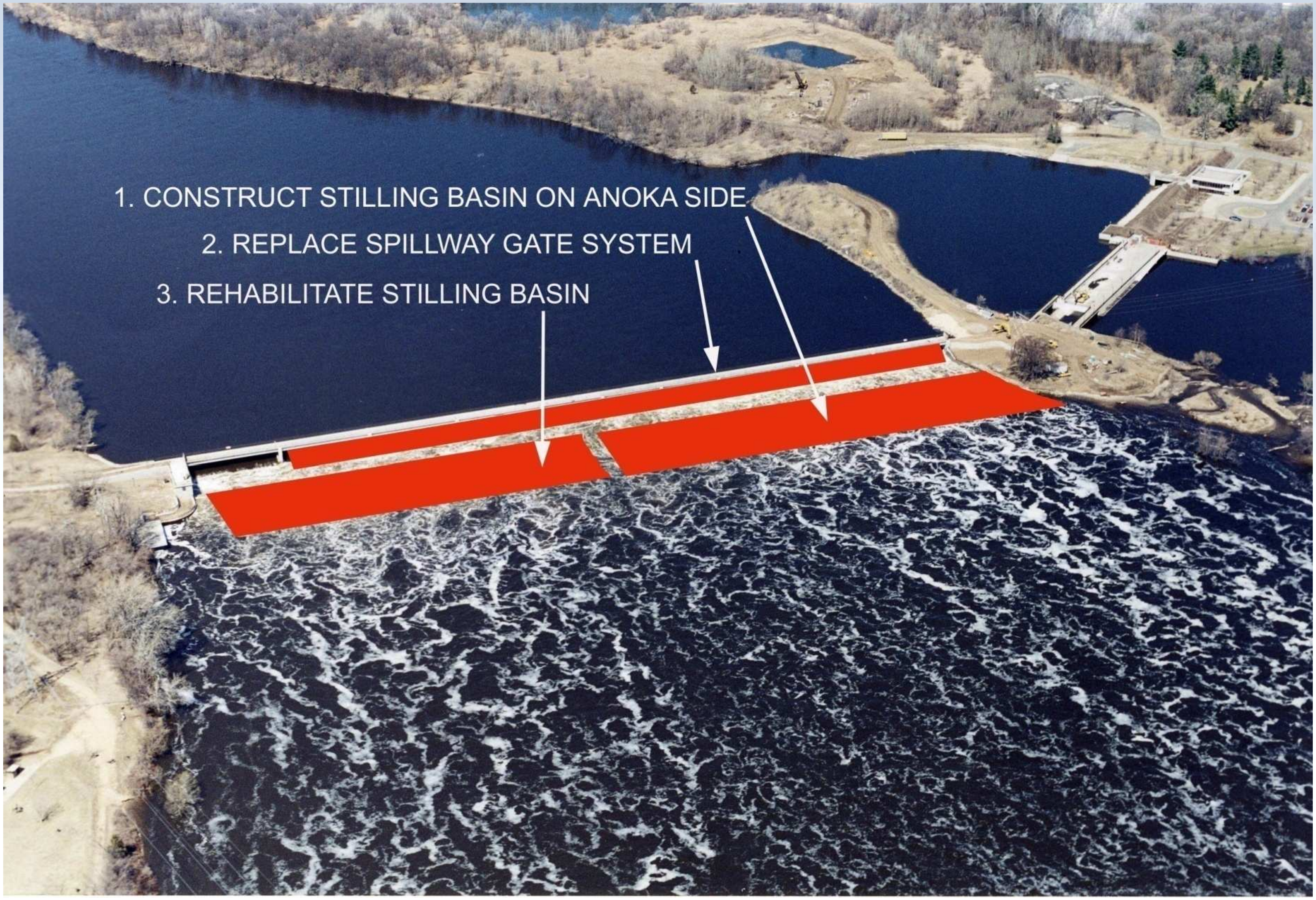
3. Improvements & Costs

Stanley Consultants INC.

3. Improvements & Costs

Stanley Consultants INC.

3. Improvements & Costs



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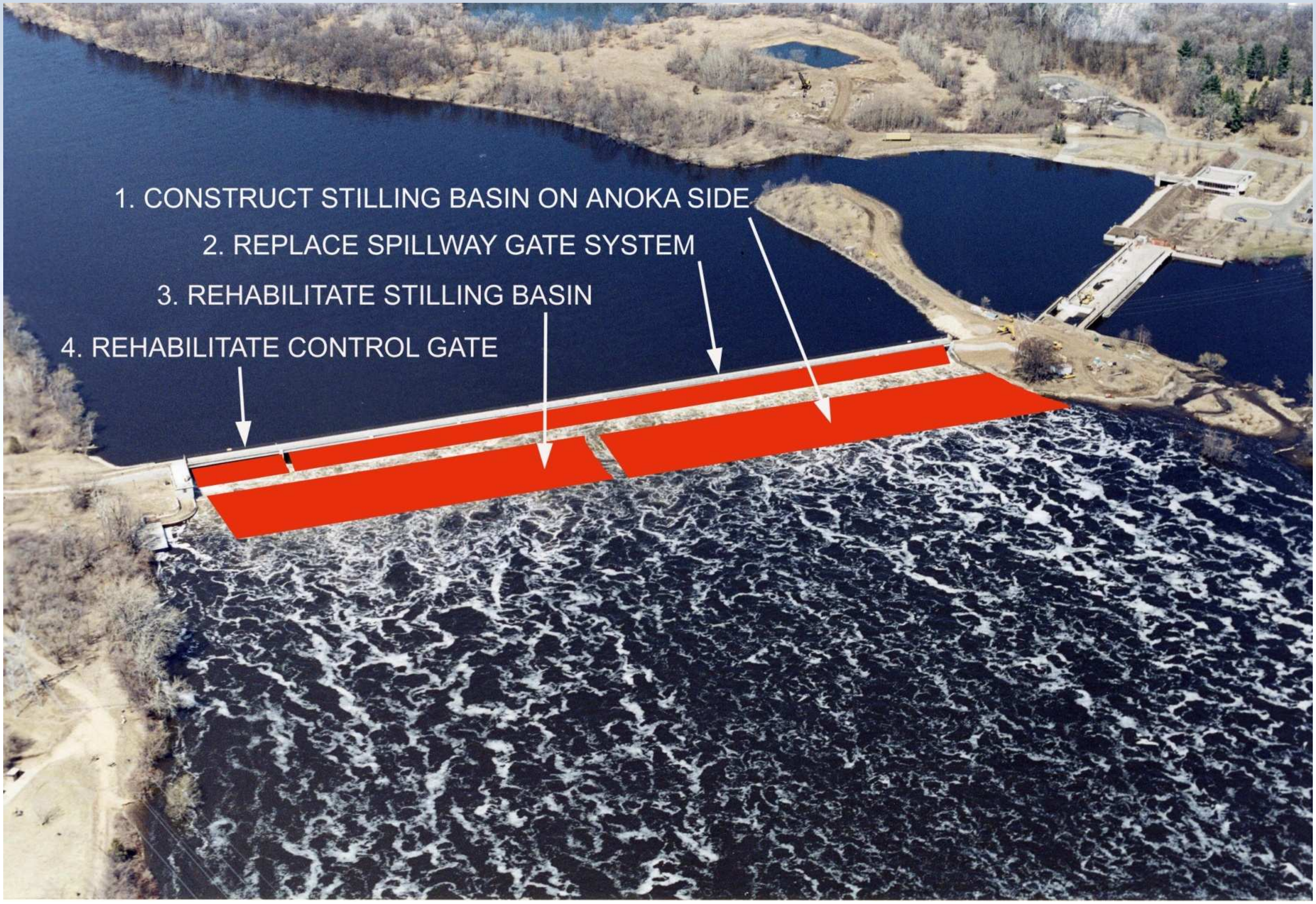
3. Improvements & Costs



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3. Improvements & Costs

Replacement Gate System:

- Pneumatic or hydraulic crest gate

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Opinion of Probable Construction Cost*

Item	Cost (millions)
Site Prep/General	$4.0
Scour Mitigation	$3.3
New Gate System	$6.4
Other Repairs	$1.5
Engineering/Permitting/CM	$0.8
Total	**$16.0**

* Excludes operations and maintenance costs over 50-year life.

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3. Improvements & Costs

Development Schedule (assuming 2011 start):

- Funding, Final Design, Permitting & Gate System Procurement: 2011
- Stage 1 Construction: 2012 (May – December)
- Stage 2 Construction: 2013 (May – November)

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Conclusions:

Comparative Results

Gates	Operation	Barrier Effectiveness	Expected Life (years)	Capital Cost* ($million)
Existing	Current	89% (marginal)	3±	$0
	Modified	99% (effective)	5±	$0
New	Current	89% (marginal)	50±	$16
	Modified	99.9% (effective)	50±	$16

Stanley Consultants INC.

Coon Rapids Dam
Fish Barrier and Improvements Preliminary Design

Thank You.

Stanley Consultants INC.

Appendix E

Background Information

1969 DNR Permit

STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
ST. PAUL, MINNESOTA 55101

P.A. 68-1474
Amended

In the matter of the application of Northern States Power Company for a permit to lower, below the level of usual operation, the level of the reservoir created by its Coon Rapids Hydro Generating Plant dam on the Mississippi River, located in Section 27, Township 31 north, Range 24 west, Anoka County;

AMENDED PERMIT

Pursuant to Minnesota Statutes, Chapter 105, and on the basis of statements and information contained in the permit application, submitted plans, and recorded measurements and data resumé submitted by the applicant, all of which are made a part hereof by reference;

A hearing on said application is hereby waived, and permission is hereby granted to:

1. Commence gradual drawdown of the level of the reservoir by means of opening the tainter gates of the dam, on or about October 25; said drawdown to proceed until the tainter gates are fully opened thereby allowing free overflow at the spillway crest elevation of 823.2 Sea Level Datum. 1912 ADJ
2. As soon as practicable after the spring run-off of the succeeding year, tainter gates shall be closed and the reservoir level returned to the normal reservoir elevation of 830.5 Sea Level Datum in order to provide for boating and recreation. 1912 ADJ

This permit is granted subject to the following GENERAL AND SPECIAL PROVISIONS:

GENERAL PROVISIONS

1. This permit is permissive only and shall not release the permittee from any liability or obligation imposed by Minnesota Statutes, Federal Law or local ordinances relating thereto and shall remain in force subject to all conditions and limitations now or hereafter imposed by law.

2. This permit is not assignable except with the written consent of the Commissioner of Conservation.

3. This permit may be terminated by the Commissioner of Conservation, without notice, at any time he deems it necessary for the conservation of water resources of the state; or in the interest of public health and welfare, or for violation of any of the provisions of this permit, unless otherwise provided in the Special Provisions.

SPECIAL PROVISIONS

I. In all cases where the doing by the permittee of anything authorized by this permit shall involve the taking, using, or damaging of any property, rights or interests of any other person or persons, or of any publicly owned lands or improvements thereon or interests therein, the permittee, before proceeding therewith, shall obtain the written consent of all persons, agencies, or authorities concerned, and shall acquire all property, rights and interests necessary therefor.

II. This permit is permissive only. No liability shall be imposed upon or incurred by the State of Minnesota or any of its officers, agents or employees, officially or personally, on account of the granting hereof or on account of any damage to any person or property resulting from any act or omission of the permittee or any of its agents, employees, or contractors relating to any matter hereunder. This permit shall not be construed as estopping or limiting any legal claims or right of action of any person other than the state against the permittee, its agents, employees, or contractors, for any damage or injury resulting from any such act or omission, or as estopping or limiting any legal claim or right of action of the state against the permittee, its agents, employees, or contractors for violation of or failure to comply with the provisions of the permit or applicable provisions of law.

III. The permittee shall record reservoir water elevations by means of measurements or gage readings taken at the hydro plant site. These measurements shall be recorded a minimum of once each day at commencement of drawdown until such time as the reservoir level has stabilized or until the tainter gates are fully open, and shall be reported thereafter to the Director. Thereafter, measurements shall be recorded a minimum of twice each month throughout the winter season, and submitted annually to the Director. Prior to October 1 of each succeeding year, the permittee shall submit a resumé of data recorded during the above period together with any other pertinent data relating to the mode of operation authorized herein.

Dated at St. Paul, Minnesota, this 27th day of October, 1969.

STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION

BY: Eugene R. Gere
Eugene R. Gere, Director of Waters,
Soils and Minerals

WOP:rw

cc: U.S. Corps of Engineers
P.O. & Custom House
180 E. Kellogg Boulevard
St. Paul, Minnesota 55101

1995 DNR Permit

NA-02733-06
Rev. 6/94

MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
Division of Waters

PROTECTED WATERS PERMIT

P.A. Number
95-6052

Pursuant to Minnesota Statutes, Chapter 103G, and on the basis of statements and information contained in the permit application, letters, maps, and plans submitted by the applicant and other supporting data, all of which are made a part hereof by reference, **PERMISSION IS HEREBY GRANTED** to the applicant to perform the work as authorized below:

Protected Water: Mississippi River	County: Hennepin and Anoka
Name of Permittee: Suburban Hennepin Regional Park District	Telephone Number (include Area Code): (612) 559-6762
Address (No. & Street, RFD, Box No., City, State, Zip Code): 12615 County Road 9, Minneapolis, MN 55441	
Authorized Work: Conduct major repairs and modifications to the Coon Rapids Dam. The work may include: constructing cofferdams and temporary access roads in the river, streamflow diversion, reservoir level changes, concrete demolition, gate removals, walkway removal, operator bridge removal, spillway modifications, new steel and rubber gates, new walkway, new gate controls, new piers, new abutment walls, embankment repairs, placing riprap, new railings and fencing, and miscellaneous concrete repairs.	
Purpose of Permit: Improve safety, structural integrity, and operational efficiency of the dam.	Expiration Date of Permit: December 31, 1997
Property Described as: NE¼ Sec 2, T119N, R21W in the City of Brooklyn Park, Hennepin County SE¼ Sec 27, T31N, R24W in City of Coon Rapids, Anoka County	

This permit is granted **subject to** the following **GENERAL** and **SPECIAL PROVISIONS:**

GENERAL PROVISIONS

1. The **permittee** is not released from any rules, regulations, requirements, or standards of any applicable federal, state or local agencies; including, but not limited to, the U.S. Army Corps of Engineers, Board of Water and Soil Resources, MN Pollution Control Agency, watershed districts, water management organizations, county, city and township zoning. This permit does not release the **permittee** of any permit requirement of the St. Paul District, U.S. Army Corps of Engineers, Army Corps of Engineers Centre, 190 Fifth Street East, St. Paul, MN 55101-1638.

2. This permit is not assignable by the **permittee** except with the written consent of the Commissioner of Natural Resources.

3. The **permittee** shall notify the Area Hydrologist at least five days in advance of the commencement of the work authorized hereunder and notify him/her of its completion within five days. The Notice of Permit issued by the Commissioner shall be kept securely posted in a conspicuous place at the site of operations.

4. The **permittee** shall make no changes, without written permission previously obtained from the Commissioner of Natural Resources, in the dimensions, capacity, or location of any items of work authorized hereunder.

5. The **permittee** shall grant access to the site at all reasonable times during and after construction to authorized representatives of the Commissioner of Natural Resources for inspection of the work authorized hereunder.

6. This permit may be terminated by the Commissioner of Natural Resources at any time deemed necessary for the conservation of water resources of the state, or in the interest of public health and welfare, or for violation of any of the provisions or applicable law of this permit, unless otherwise provided in the Special Provisions.

7. Construction work authorized under this permit shall be completed on or before the date specified above. The **permittee** may request an extension of time to complete the project, stating the reason thereof, upon written request to the Commissioner of Natural Resources.

8. In all cases where the **permittee** by performing the work authorized by this permit shall involve the taking, using, or damaging of any property rights or interests of any person or persons, or of any publicly owned lands or improvements thereon or interests therein, the **permittee**, before proceeding, shall obtain the written consent of all persons, agencies, or author-

9. This permit is permissive only. No liab y shall be imposed by the State of Minnes or any of its officers, agents or employees, officially or personally, on account of the granting hereof or on account of any damage to any person or property resulting from any act or omission of the **permittee** or any of its agents, employees, or contractors. This permit shall not be construed as estopping or limiting any legal claims or right of action of any person other than the state against the **permittee**, its agents, employees, or contractors, for any damage or injury resulting from any such act or omission, or as estopping or limiting any legal claim or right of action of the state against the **permittee**, its agents, employees, or contractors for violation of or failure to comply with the permit or applicable provisions of law.

10. Any extension of the surface of protected waters from work authorized by this permit shall become protected waters and left open and unobstructed for use by the public.

11. Where the work authorized by this permit involves the draining or filling of wetlands not subject to DNR protected water permit jurisdiction, the **permittee** shall not initiate any work under this permit until the **permittee** has obtained official approva ne responsible local government unit as required by the Minnesota Wetland Conservation Act of 1991.

SPECIAL PROVISIONS

SEE ATTACHED SPECIAL PROVISIONS.

SPECIAL PROVISIONS

1. COMPLIANCE WITH OTHER LAWS:

Permittee shall comply with all rules, regulations, requirements, or standards of any applicable federal, state, or local agencies, including, but not limited to the U.S. Army Corps of Engineers, Board of Water and Soil Resources, MN Pollution Control Agency, watershed districts, water management organizations, county, city, and township zoning. Particularly, local controls governing floodplain standards must be followed.

2. PLANS, SPECIFICATIONS, DESIGN REPORT:

Permittee shall submit the design report, plans and specifications to the Division of Waters for approval at least three weeks prior to sending the project out for construction bids. The specifications for construction bidding shall include a copy of this permit. The plans shall include a plan and profile of the existing dam that shows all relevant elevations and dimensions.

3. OPERATION AND MAINTENANCE PLAN:

This permit does not authorize any change in the existing normal pool elevation of 830.5 during summer or in the spillway crest of 823.2 during winter. Permittee shall develop a documented operation and maintenance plan for the dam, and submit copies to the Division of Waters for approval prior to the structure being placed in operation. The plan shall include objectives and policies for water level and water quality management and shall describe operating procedures for typical flow conditions, high flow and flood conditions, low flood conditions including instream flow protection, drawdowns, and other proposed reservoir releases. The plan shall include a bench mark and headwater and tailwater elevation gages. The plan shall include provisions for periodic review and update by the DNR, PCA, USCOE and other appropriate federal, state and local agencies. The permittee shall keep complete records of headwater elevation, tailwater elevation, gate settings, and maintenance and repairs conducted on the dam. The plan shall also include provisions for safety features such as railings, fencing, signs and buoys to alert and protect the public and users of the dam and reservoir.

4. CONSTRUCTION REPORT:

Within 60 days following the completion of construction, the permittee shall submit a Construction Report to the Division of Waters, including a statement of the professional engineer in charge of construction inspection that the dam was completed in accordance with the approved designs, plans and specifications. The report shall also include a construction summary, quality control tests and summary, as-built drawings with changes clearly marked, final cost summary, listing of contractors, bench mark information and descriptive photographic record of major construction stages.

5. COFFERDAMS\TEMPORARY FILLS:

Cofferdams or fills for access shall be placed and removed in a manner that prevents erosion or release of sediment. Granular sand may be used provided it is protected from erosion by rock and impervious membranes. A before and after survey of streambed contours must be provided to show that all materials are removed and the original streambed conditions are restored. The cofferdams should be built prior to raising pool to the summer 830.5 elevation. This should hold true for both years of the project.

6. EROSION PROTECTION:

Erosion control measures must be designed for the site and maintained throughout the project. Stock piles of sand or dirt within 100 feet of the river should also be protected from eroding into the river.

All exposed soils resulting from the project should be seeded and mulched or sodded within 72 hours of completion of work for that phase of the project. Exposed soils on slopes of greater that 10 percent should utilize sodding and staking or wood fiber blankets and seeding.

Intakes of siphon pipes must be screened to prevent passage of sediment downstream. Siphon outlets should discharge over the dam apron to limit scour.

7. DEBRIS\CONCRETE RUBBLE\SPOIL\HAZARDOUS MATERIALS:

These materials shall be prevented from entering the protected water or wetland during construction. Upon completion of the project these materials shall be disposed offsite in a location and manner approved by the appropriate governmental authority. All materials from demolition of existing structure, construction debris, and cofferdam material must be removed to restore the stream bed to original cross-section. A temporary barrier shall be constructed on the spillway to prevent construction materials or rubble from falling into the tailwater area. Fuel handling facilities should be located away from the river and should be conducted at a location where spills will be contained or directed away from the river.

8. BARRIER TO MIGRATION:

The existing dam is an important barrier to upstream migration of exotic species. Throughout the project extreme care and consideration must be given to assure the dam acts, without interruption, as a fish barrier. Equipment and materials used for cofferdams must not be moved from downstream to upstream of the dam. If this must occur, inspection and cleaning of equipment for zebra mussels must be completed. The outlet of siphon pipes must be kept above water to avoid fish or zebra mussel migration.

9. EMERGENCY WORK, UNFORESEEN CONDITIONS:

If the permittee finds at any time during construction or operation that immediate alterations to the approved plans and specifications are required, or emergency drawdowns are necessary, the alterations or drawdowns may be started, but the permittee shall promptly notify the Division of Waters of such requirements. If the alterations are to remain permanent project features, the permittee shall, within 60 days from installation, revise the plans and specifications and submit the revisions to the Director of the Division of Waters for approval.

10. QUALITY CONTROL:

The permittee, in cooperation with the designer, shall be responsible for inspection and quality control to ensure the work is completed according to the approved design, plans and specifications.

11. INSPECTIONS BY PERMITTEE:

The permittee shall have the dam inspected every five years by a qualified registered engineer. A written report shall be made for each inspection describing the conditions found and listing needed corrective actions with a time frame to complete each action. A copy of the report shall be sent to the Director of the Division of Waters.

12. CONSTRUCTION PROCEDURES AND SCHEDULE:

The permittee shall take necessary precautions to minimize adverse environmental impacts resulting from construction activities. Details of diversions, dewatering, water level and streamflow manipulations, cofferdams, fills, and construction scheduling shall be submitted to the Division of Waters for approval before the start of construction. Updated work schedules and progress reports should be submitted every 6 months.

13. COORDINATION:

The permittee shall ensure that the contractor has received and thoroughly understands all provisions of this permit. Permittee shall inform the Division of Waters of preconstruction meetings with contractors.

14. EFFECTIVE DATE:

This permit shall become effective on the date it is signed by the Director of the Division of Waters, Minnesota Department of Natural Resources. Enclosed with this permit is a Notice of Permit Card. The work authorized herein shall not be commenced until the Notice of Permit Card and a copy of this permit have been clearly posted at or near the construction site.

Executed in St. Paul, Minnesota
this 11th of January, 1995

COMMISSIONER OF NATURAL RESOURCES

BY: Kent Lokkesmoe
Kent Lokkesmoe, Director
Division of Waters

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

500 LAFAYETTE ROAD • ST. PAUL, MINNESOTA • 55155-4032

DNR INFORMATION
(612) 296-6157

February 22, 1995

Suburban Hennepin Regional Park District
c/o Mr. Timothy Marr
12615 County Road 9
Minneapolis, MN 55441

Dear Mr. Marr:

RE: COON RAPIDS DAM, PERMIT 95-6052

This is to provide clarification of the intent of some provisions of this permit that was issued on January 11, 1995.

* Special Provision #2 requires DNR approval of the final plans and specifications. You submitted the plans on February 13, 1995 and we should have the review completed by March 1, 1995.

* Special Provision #3 requires the existing operation and maintenance plan to be updated and submitted for approval. This special provision will govern the operation of the dam <u>after</u> the proposed construction is completed and not during the construction. Pool levels of 830.5 during the summer and 823.2 during the winter will still be used <u>after</u> construction is completed. The new gate system will necessitate more operational details in the updated plan.

* <u>Pool level during construction</u> is addressed in the permit's scope of work, in Special Provision #5 and in Special Provision #12. The "authorized work" in the permit cover sheet allows for the possibility of reservoir level changes <u>during</u> construction. Special Provision #12 requires submittal for approval of details of any proposed reservoir level changes <u>during</u> construction. You have now submitted this information and are requesting the winter level of 823.2 throughout the construction period. We are now reviewing this request and will make a decision by early March. Special Provision #5 requires cofferdams to be installed when the pool is at winter level and is not intended to require a 830.5 summer pool during construction.

Pneumatic Gate Brochure

OBERMEYER HYDRO, INC.

P.O. Box 668 Fort Collins, Colorado 80522 USA
Tel 970-568-9844 Fax 970-568-9845
Email: hydro@obermeyerhydro.com www.obermeyerhydro.com

Thank you for your interest in Obermeyer Spillway Gates. Obermeyer gates offer an economical and technologically superior method of spillway control. Some of the features include:

1. Obermeyer Spillway Gates conform to almost any spillway shape without costly changes to the existing spillway profile.

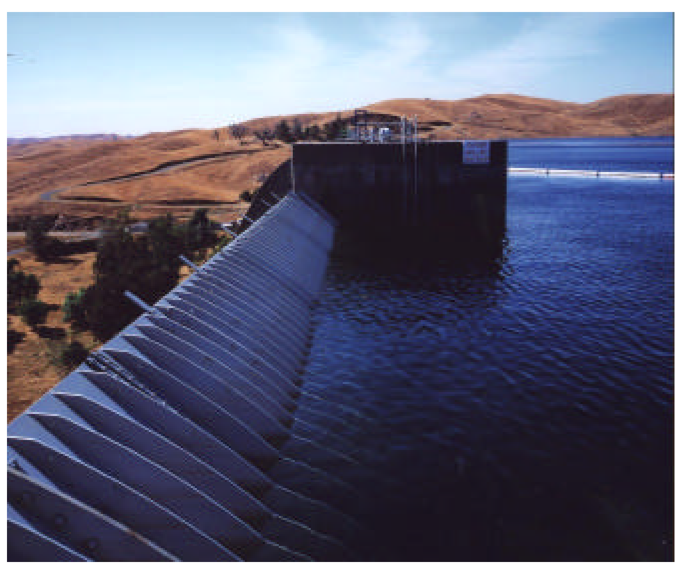
2. The rugged steel gate panels overhang the reinforced air bladders in all positions. The gate panels protect the air bladders from damage due to ice, logs, or other debris.

3. The Obermeyer Spillway Gates are very controllable. Our gates can be set at an infinite number of positions between fully raised and fully lowered. Our standard pneumatic controller provides accurate upstream pond control, and discharges water appropriately to maintain upstream pond elevation through a full range of flow conditions.

4. Obermeyer Spillway Gates use no high precision parts or bearings. This allows for easy installation and long service life.

5. Obermeyer Spillway Gates use clean, dry, compressed air for actuation. No hydraulic fluid or other contaminates are used.

6. The modular design of Obermeyer Spillway Gates creates a very safe operating system. For large gate systems, each air bladder is isolated from the other by means of a check valve. If one air bladder becomes damaged, the rest of the gate system will not deflate through the damaged section.

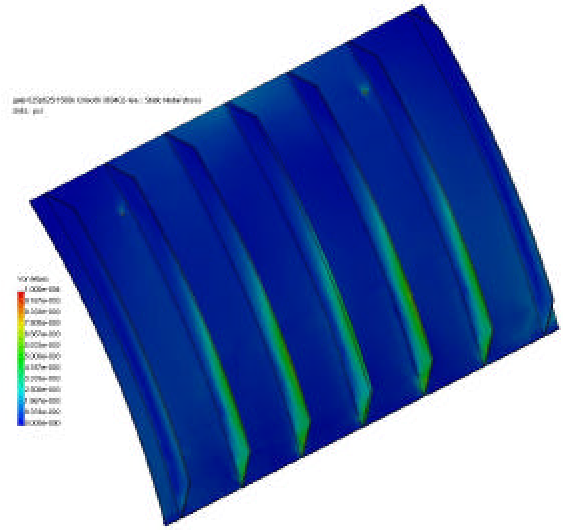


7. The modular design of Obermeyer Spillway Gates simplifies installation and maintenance. The use of individual air bladders and gate panels minimizes the lifting capacity required for installation. This saves significant time and money by reducing the size of equipment and manpower needed to install the system.

Obermeyer Spillway Gates are manufactured under license under one or more of the following patents:
U.S. PATENT 4,780,024 • U.S. PATENT 5,092,707 • U.S. PATENT 5,538,360 • U.S. PATENT 5,642,963
U.S. PATENT 5,709,502 • U.S. PATENT 5,713,699 • OTHER U.S. AND FOREIGN PATENTS PENDING

8. Obermeyer Spillway Gates are very vandal and damage resistant. From the upstream side, steel panels protect the air bladders in all positions. Damage due to ice, trees, or other debris is nearly impossible from the upstream side. The air bladders are reinforced by multiple plies of polyester of aramid tire fabric. The use of these types of fabrics, in combination with generous thickness of rubber, creates a very bullet and vandal resistant air bladder.

9. Obermeyer Hydro utilizes state of the art engineering and software packages to insure that each gate system design will be safe and reliable. Gate panels and other steel components are designed using the latest finite element analysis programs.



We hope this package answers the questions you have regarding Obermeyer Spillway Gates. If you have any other questions, please don't hesitate to contact our head office by phone or email. If you desire a site-specific price quote, please refer Page 4, Site Specific Details, which lists questions asked by our applications engineers when designing a project.

Once again, we appreciate your interest in Obermeyer Spillway Gates and we look forward to hearing more about your project.

Sincerely,
Rob Eckman
Vice President
Obermeyer Hydro, Inc.

P.O. Box 668
Fort Collins, CO 80522
PH: 970-568-9844
FX: 970-568-9845
hydro@obermeyerhydro.com
http://www.obermeyerhydro.com

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Introduction

Obermeyer Spillway Gates are most simply described as a row of steel gate panels supported on their downstream side by inflatable air bladders. By controlling the pressure in the bladders, the pond elevation maintained by the gates can be infinitely adjusted within the system control range (full inflation to full deflation) and accurately maintained at user-selected set points.

Obermeyer Spillway Gates are patented bottom hinged spillway gates with many unique attributes that include:

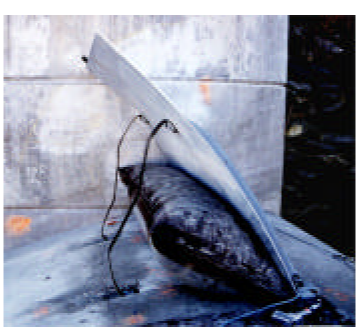
- Accurate automatic pond level control even under power failure conditions.
- Modular design simplifies installation and maintenance.
- Unlike torque tube type spillway gates, Obermeyer gates are supported for their entire width by an
  inflatable air bladder, resulting in simple foundation requirements and a cost effective, efficient gate structure.
- Thin profile efficiently passes flood flows, ice, and debris.
- Unlike rubber dams, the steel gate panels overhang the air bladder in all positions, protecting the bladder from floating logs, debris, ice, etc.
- No intermediate piers are required.
- Obermeyer Spillway Gates are a great investment due to increased revenue, decreased maintenance, and low cost of installation.

These features are the result of combining rugged steel gate panels with a resilient pneumatic support system.

The Spillway Gates are attached to the foundation structure by anchor bolts which are secured with epoxy or non-shrink cement grout as design dictates. The required number of air bladders are clamped over the anchor bolts and connected to the air supply pipes. When the air bladder hinge flaps are fastened to the gate panels, the installation of the strong, durable and resilient crest gate system is complete.

View of Gate from Downstream

The individual steel gate panels and air bladders are fabricated in widths of five or 10 feet, (1.5 meters or 3 meters for metric installations) for systems up to 6.5 (2 meters) high. Systems higher than 6.5 feet (2 meters) use various standard width air bladders such that the height/length ratio is less than approximately 1.0.



The gaps between adjacent panels are spanned by reinforced interpanel seals clamped to adjacent gate panel edges. At each abutment, a robust, low-friction lip seal is affixed to the gate panel edge. This seal moves along the abutment plate, keeping abutment plate seepage to a minimum. For installation in cold climates the abutment plates are provided with heaters to prevent ice formation. Alternatively, rubber seals may be fixed to the abutments or piers which engage when raised.

Hydraulic Performance

Obermeyer Spillway Gates provide excellent controllability over a full range of flow rates, water elevations and gate positions.

All gates operating on the same air supply line maintain a uniform crest height. This is because any differential lowering of a gate panel relative to others on the same air supply manifold causes said gate panel to develop more contact area with its respective air bladder than other gate panels. The extra contact area produces a restoring moment that returns said gate panel to the same position as the others.

Vibration due to von Karman vortex shedding does not occur with Obermeyer spillway gates. The shape of the system when raised or partially raised causes flow separation to occur only at the downstream edge of the gate panels. This favorable condition also occurs when the system is operating in a submerged or high tailwater condition; in contrast, rubber dams which due to their rounded shape can vibrate destructively as the line of flow separation moves cyclically back and forth across the rounded surface of the inflated structure.

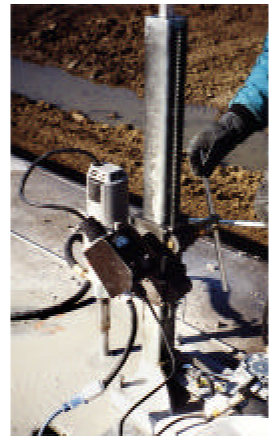
Obermeyer Spillway Gates provide very repeatable positioning relative to inflation pressure and headwater level and can be used to precisely measure the flow, as well as control flow.

Obermeyer Spillway Gates can be operated continuously over a full range of gate positions, headwater elevations and tailwater elevations and may be installed within siphon spillways subject to extreme water velocities.

Obermeyer Spillway Gates are manufactured under license under one or more of the following patents:
U.S. PATENT 4,780,024 • U.S. PATENT 5,092,707 • U.S. PATENT 5,538,360 • U.S. PATENT 5,642,963
U.S. PATENT 5,709,502 • U.S. PATENT 5,713,699 • OTHER U.S. AND FOREIGN PATENTS PENDING

Installation

Installation of Obermeyer Spillway Gates is quick and easy. For systems up to approximately 4 meters high, the air bladders are secured to the spillway with a row of anchor bolts. For system heights above 4 meters, an embedded clamp is used to secure the gate system to the spillway. The anchor bolts may be embedded in a new spillway or may be secured in holes drilled into an existing spillway. The air supply lines, which connect to each individual air bladder, can be embedded or grouted into a saw slot in the spillway. Surface mounted air supply lines may also be used. A typical installation sequence is as follows:



Drilling of Anchor Bolt Holes

1. Place anchor bolts
2. Install air supply lines
3. Install abutment plates, if used
4. Place air bladders over anchor bolts
5. Secure air bladders to spillway with clamp bars
6. Connect air supply lines to underside of air bladders
7. Attach steel gate panels to each air bladder
8. Attach interpanel seals
9. Attach restraining straps if used
10. Attach nappe breakers
11. Adjust and grout abutment plates or install J seals
12. Install compressor, drier and controls
13. Start up system

Installation of Gate Panels

Start of Installation – Installing Gate Panel – Completed Gate

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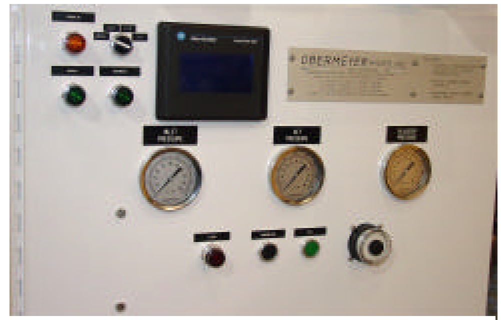
U.S. PATENT 5,709,502 • U.S. PATENT 5,713,699 • OTHER U.S. AND FOREIGN PATENTS PENDING

Types of Control Systems

Obermeyer Spillway Gates are supplied with control systems in accordance with customer requirements. Each control system includes a controlled source of compressed air and a means for controlled venting of air from the air bladders. All automatic systems also include provision for local manual control. Each system includes an air compressor, a receiver tank, and required control valves. Most systems, especially those subject to freezing conditions, include air driers.



Control System with Touch Panel

Pneumatic Water Level Control

The most basic control system uses an all-pneumatic water level controller to automatically regulate air bladder pressure in inverse proportion to upstream water level. This system requires no electrical power to accurately maintain a constant upstream pool elevation over a full range of gate positions and spillway flow rates. This controller is ideally suited to hydroelectric projects where a turbine load rejection is often associated with loss of electrical power. This control system is also ideal for safety critical flood control projects where flood conditions and extended loss of electrical power often occur simultaneously. A bubbler line senses upstream water level. The minute amount of air required for the bubbler system is supplied from the air receiver with the air stored within the air bladders connected as a backup supply.

Programmable Controllers

In many applications, it is desirable to control Obermeyer Spillway Gates with a Programmable Controller. A Programmable Controller is ideal for complex schemes such as maintaining precise environmentally mandated spillway flows under varying head pond elevation at hydroelectric peaking plants. Pre-existing programmable controllers at numerous hydroelectric plants have been used to control Obermeyer Spillway Gates, thus reducing the overall cost of the gate installation. Conversely, at new projects, an Obermeyer supplied Programmable Controller can also serve other control requirements not related to the spillway gates. Programmable Controller based systems can be provided with Pneumatic Water Level Controllers as a mechanical backup.

Solar Powered Controls

Obermeyer Spillway Gates can be supplied with solar powered compressors and control systems. Obermeyer Spillway Gates are well suited to solar powered operation because no large electric motors are required even on quite large gate installations. Solar powered systems normally use 12-volt solar panels, battery and compressor. A programmable controller with optional radio modem operates the compressor or vent valves in accordance with water level readings or remote control signals.

Safety Critical Applications

For relatively small gate installations on large rivers, it is usual to operate all of the air bladders on the same pipe or pressure manifold. For large gate installations on narrow populated river channels, check valves are used on each air bladder to insure that damage to any one air bladder cannot release air from any of the other air bladders. This feature is an important safety advantage of Obermeyer Spillway Gates over rubber dams.

Independent Operation of Groups of Gates

At many projects it is desirable to control various sections of the spillway independently. This can be accomplished by simply providing separate pipes to each independent section. No intermediate piers are required. Applications for this scheme include:

- Releasing floating debris from near a power plant intake.
- Concentrating flows to discharge upstream sediment.
- Minimizing tailwater elevation by releasing excess flow away from the power plant.
- Providing fishway attraction water in the precise amounts and locations needed.
- Diverting flows to allow inspection access to the raised portion of a gate system.

Flow Measurement and Control

Obermeyer Spillway Gates respond to changes in headwater elevation and internal air pressure in a precise and repeatable manner. For any particular gate installation, the flow rate and gate crest elevation can be calculated on the basis of the measured up stream pond elevation and the controlled air bladder pressure. Flow rates for submerged installations, i.e., installations with high tailwater, can be calculated on the basis of upstream and downstream levels and air bladder pressure.

Gate Panels

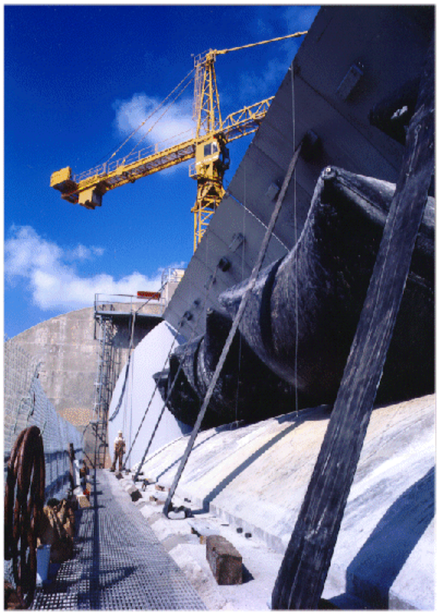
Gate panels are made from high strength steel plate that is epoxy coated or galvanized in accordance with customer preference. Stainless steel gate panels may be supplied on request. Gate panels for systems less than 1 meter high are made from a flat plate that is bent to conform to the spillway shape when in the lowered position. A small amount of additional curvature of the gate panel profile is provided to allow space for the deflated air bladder when the gate panels are fully lowered. Gate panels for systems higher than 1 meter are provided with stiffening ribs running parallel to the direction of flow. The ribs provide strength without obstruction of flow. A high degree of torsional rigidity is not required because of the uniform support of the gate panels by the air bladders. For the same design stress level, the gate panels are much lighter, less costly and less restrictive to water flow compared to gate panels for hydraulically or mechanically operated gates.

Gate panels are provided with a row of threaded studs near the pivot edge to which the hinge flap is clamped. Similar threaded studs are provided at the right and left edges of each gate panel for sealing to the adjacent gate panels or to the abutments.

The outermost ribs on each gate panel are provided with lifting holes. The upper/downstream edge of each gate panel features holes or studs for the attachment of nappe breakers. For installations that utilize restraining straps, holes or studs are provided for attaching the restraining straps to each gate panel.

The upstream/lower edge of each gate panel features a smooth rounded surface for transferring a reaction load to the air bladder and hinge flap.

Air Bladders



Air bladders are designed and manufactured by methods similar to those used in the manufacture of automotive tires. A butyl rubber inner liner provides excellent air retention characteristics. A intermediate layer of high tensile strength rubber compounds containing multiple plies of polyester or arimid tire cord reinforcement, e.g. DuPont KEVLAR ® fiber, provide the mechanical strength needed to contain the internal pressure. A cover compound utilizing aging and ozone resistant polymers such as EPDM is used to protect the bladder from wear and weathering.

Air bladders for systems of less than 2 meters in height incorporate integral hinge flaps to which the gate panels are attached. Systems higher than 2 meters utilize separate hinge flaps which utilize the same high strength tire cord construction as the inflatable portion of the air bladders. No mechanical hinges are used.

Comparison Chart

Obermeyer Spillway Gates vs. Rubber Dams

Advantages of Obermeyer Spillway Gates:	*Disadvantages of Rubber Dams:*
Precise control of upstream elevation over a full range of headwater elevations and gate positions	*The inflatable membrane is exposed directly to ice and debris*
Unlimited spans can be installed without intermediate piers	*Allowable overtopping is limited by vortex shedding induced by vibration*
Steel panels provide robust protection from debris damage	*Replacement at an entire span is required if damage cannot be repaired*
Vertical abutments provide maximum discharge capacity and reduced civil costs	*Discharge along crest is non-uniform when partially inflated*
Modular design reduces maximum required crane capacity	
Modular design allows change out of any damaged components without requiring whole system replacement. This dramatically reduces life cycle cost and limits any downtime	
Check valve isolation of individual air bladders maximizes public safety by dramatically limiting unintended flows which could result from air loss	
Obermeyer Spillway Gates can provide precise flow data and flow control	

Site Specific Details Questionnaire

The following information should be supplied to Obermeyer Hydro, Inc. to facilitate the design of a Spillway Gate System:

1. Is the proposed gate installation on an existing dam or a proposed dam?

   What is the proposed: Length? ______________________________

   Height? ______________________________

   Fixed crest elevation? ______________________________

   Top of Gate elevation? ______________________________

   Tailwater Rating Curve? ______________________________

   Upstream streambed elevation? ______________________________

   Downstream streambed elevation? ______________________________

2. If this is a new dam, is it founded on bedrock or sand, gravel, clay, etc.?

3. What existing features such as piers, abutments, intakes, exist?

4. What is the desired function and purpose of the proposed gate structure?

5. Local Regulations, such as national electrical codes:

6. Anticipated debris flow:

7. Climate description including minimum and maximum temperature and humidity. Ice conditions if applicable.

8. Control System functions required? Automatic upstream level control, diversion flow control, etc.

9. Control system power source, 1 phase, 3 phase, solar, etc.?

10. Required inflation and deflation time of bladders:

Hydraulic Gate Brochure

Rodney Hunt

A ZURN *Company*

Bascule® and Pelican® Gates

Crest

Gates

Hinged Crest Gates

- Precise Flow and Level Control
- Fully Functional in Ice Conditions
- Proven Performance
- One Source: Design, Build, Actuate
- Long Life, Low Maintenance

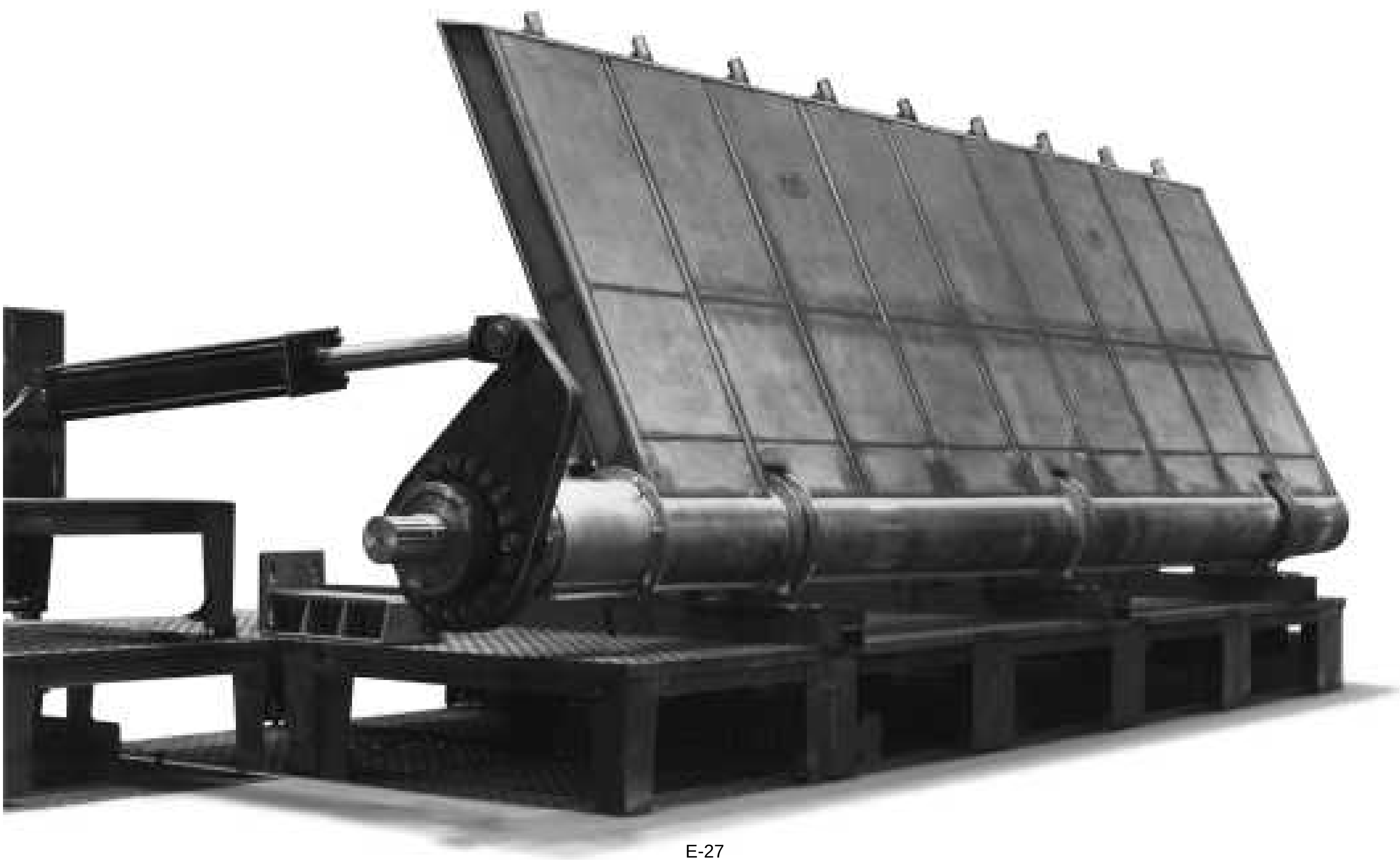
Bascule® and Pelican® gates for spillway applications

In 1990 Rodney Hunt Company acquired all product lines of AC Valve, including Bascule and Pelican technologies. The established reputation of Rodney Hunt as a designer and manufacturer of hinged crest gates, coupled with acquired Allis-Chalmers' gate technology, offers you the technical and manufacturing expertise for the most effective solution for flow control in spillway applications.

Hinged crest gates have an established reputation for long life, trouble-free service, and low maintenance for a wide range of flow control applications.

They have been used for flow, or water-level control in municipal water systems; dams for flood control, hydroelectric or recreational use; as well as a variety of industrial water supply applications.

Below: *A 25' x 8' Bascule Crest Gate with hydraulic cylinder actuator for Lane City, Texas.*



Hinged Crest Gates:

Reliable, safe, low maintenance, long service life... in virtually any spillway flow control application.

Accurate Level Control

• Level sensing devices provide automatic control of predetermined pond levels,

• In flood control installations, gates can be lowered to increase flood handling capacity.

Ice/Debris Handling Capability

• In the event of ice or debris buildup, the gate would be lowered allowing the debris or ice to flow over the gate, and raised when the overload is past.

Ice may be easily broken up and skimmed off by alternately lowering and raising the gate.

Flow Control for Hydroelectric Installations

• Higher heads may be provided for more generating capacity.

• Flood protection

• Spillway control

Cost-Effectiveness

• Freeboard is reduced to a minimum.

• Spillway size and project civil cost can be reduced by adding crest control.

Rodney Hunt Capability of Complete Package

• Rodney Hunt hinged crest gate experience

•Hydraulic actuation design/manufacture

A 65' x 10' high crest gate on the Snoqualmie River in North Bend, Washington. Hydraulic system consists of two top-mounted hydraulic cylinders (2000 psi).

Bascule and Pelican Gate Design Features

Hinged crest gates are mounted on the crest of a dam and are hinged along the invert. There are several types of hinged crest gates, but they all lower to open, and raise to close. All hinged crest gates are of fabricated steel construction, and have either a straight or a curved shape, sometimes to fit the shape of the crest when the gate is in the lowered position.

Bascule Gate

The standard Bascule Gate is normally a flat plate design that is reinforced with vertical and horizontal members and is fitted with a single torque tube across the invert. Side seal plates are mounted in the abutments and resilient seals attach to the sides of the movable disc to seal against the side plates. There is a seal across the hinge or the invert of the gate in the form of a bulb or J-type seal.

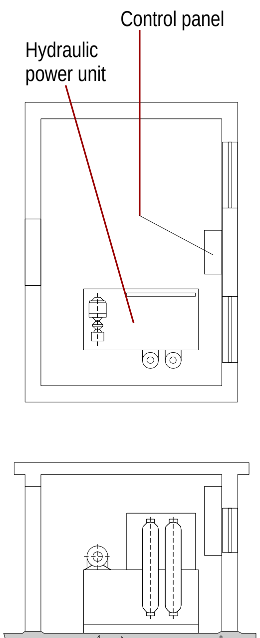
The torque tube of the Bascule Gate is supported by bearings along the invert edge of the gate. One end of the torque tube extends through the side wall into an operating space in the abutment. A stuffing box around the torque tube prevents leakage into the operating space. A hydraulic cylinder or an electric motor-driven actuator is attached to the arm of the gate with a stem, and as the actuator raises and lowers the arm, the gate is likewise raised and lowered.

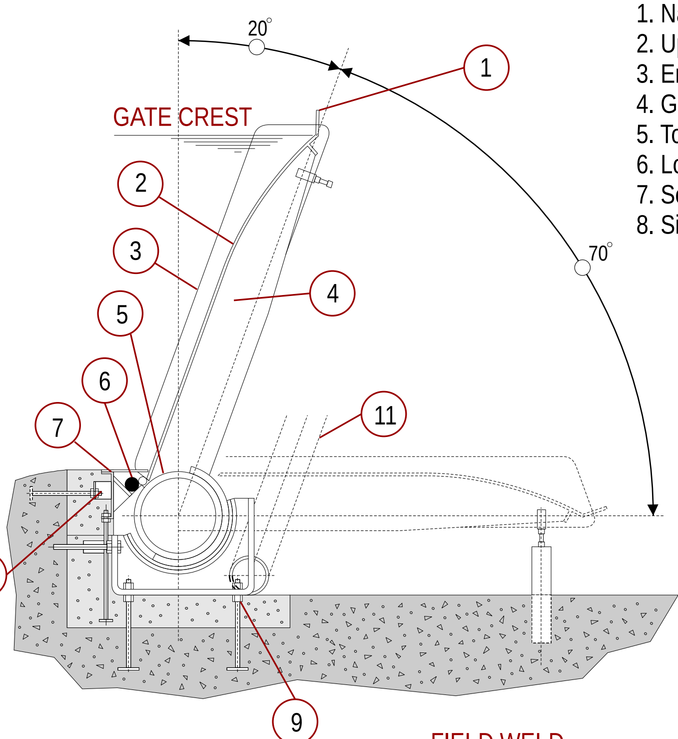
The Bascule Gate, or torque tube style crest gate, is normally limited to approximately 10 feet high. This size limitation depends on several factors, including the type of actuation, the location of the gate, the application, and head.

Basic Construction

Standard Bascule Gate

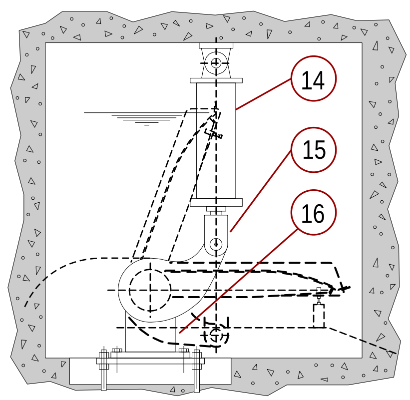
The drawings presented here show a standard Bascule Gate, and typical construction arrangement.

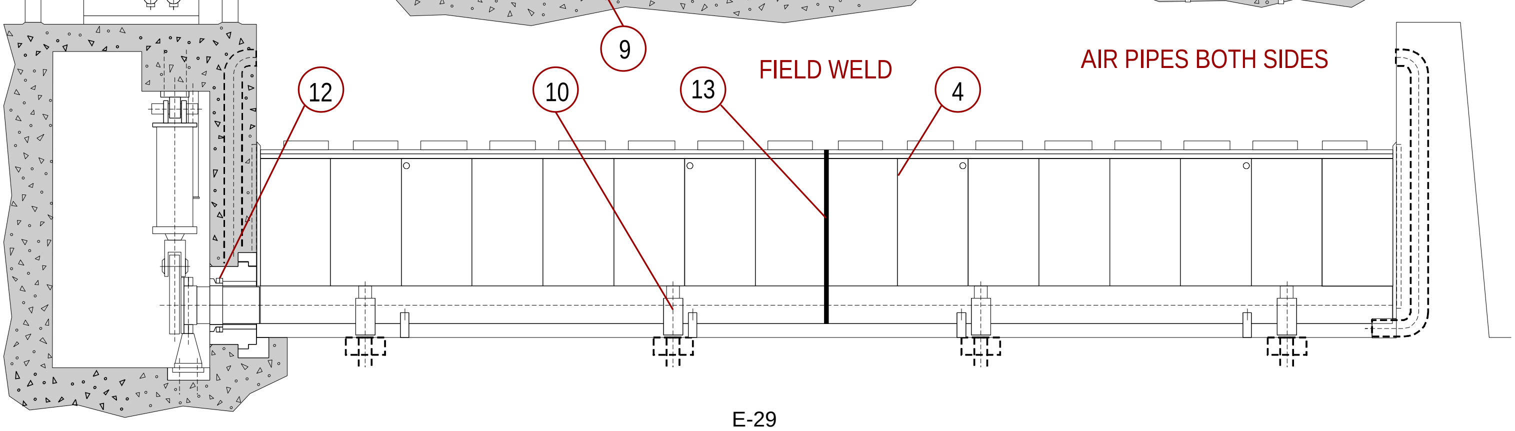




PARTS IDENTIFICATION

1. Napp breaker
2. Upstream skin plate
3. End plate
4. Gate rib
5. Torque tube
6. Longitudinal rubber seal
7. Seal cover plate
8. Sill beam
9. Anchor bolt
10. Intermediate bearing
11. Air admission pipe
12. Packing box
13. Field joint rib
14. Cylinder operator
15. Lever
16. Main bearing





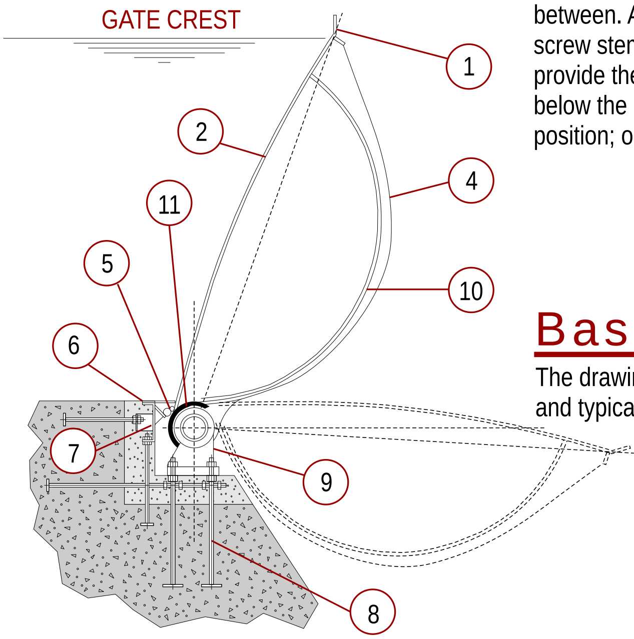
Pelican Gate

The standard Pelican Gate consists of two curved plates with internal braces and vertical ribs forming a strong closed shell structure. ' Another primary difference between the Pelican Gate and Bascule Gate is that the Pelican Gate is supported by a number of separate hinges (instead of a torque tube), which are attached to the concrete at the invert. A matching pair of hinge plates are welded to the bottom of the gate, and a stainless steel pin passes through these plates (and the trunnion) to complete the "hinge" configuration.

The Pelican Gate can be operated in a number of different ways. The gate can be raised or lowered by one or more cylinders either at the ends of the spillway or at intermediate points in between. Although crest gates can be operated by screw stem or cable drum, hydraulic cylinders provide the flexibility of being mounted either below the gate, pushing the gate "up" to the closed position; or mounted above the gate, pulling the gate "up" to the closed position.

As with the Bascule gate, side seal plates are mounted in the abutments and resilient seals attach to the sides of the disc to seal against the side plates. There is also a seal across the hinge or invert of the gate in the form of a bulb or J-type seal.

The Pelican Gate, with hydraulic cylinders mounted beneath the gate, can be fabricated in greater lengths. A drop in downstream elevation is required for mounting the hydraulic cylinders, and to lower the gate below the crest.



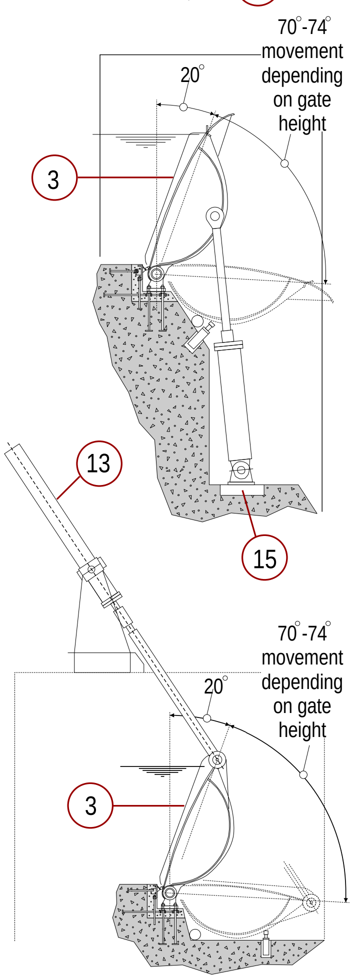
Basic Construction

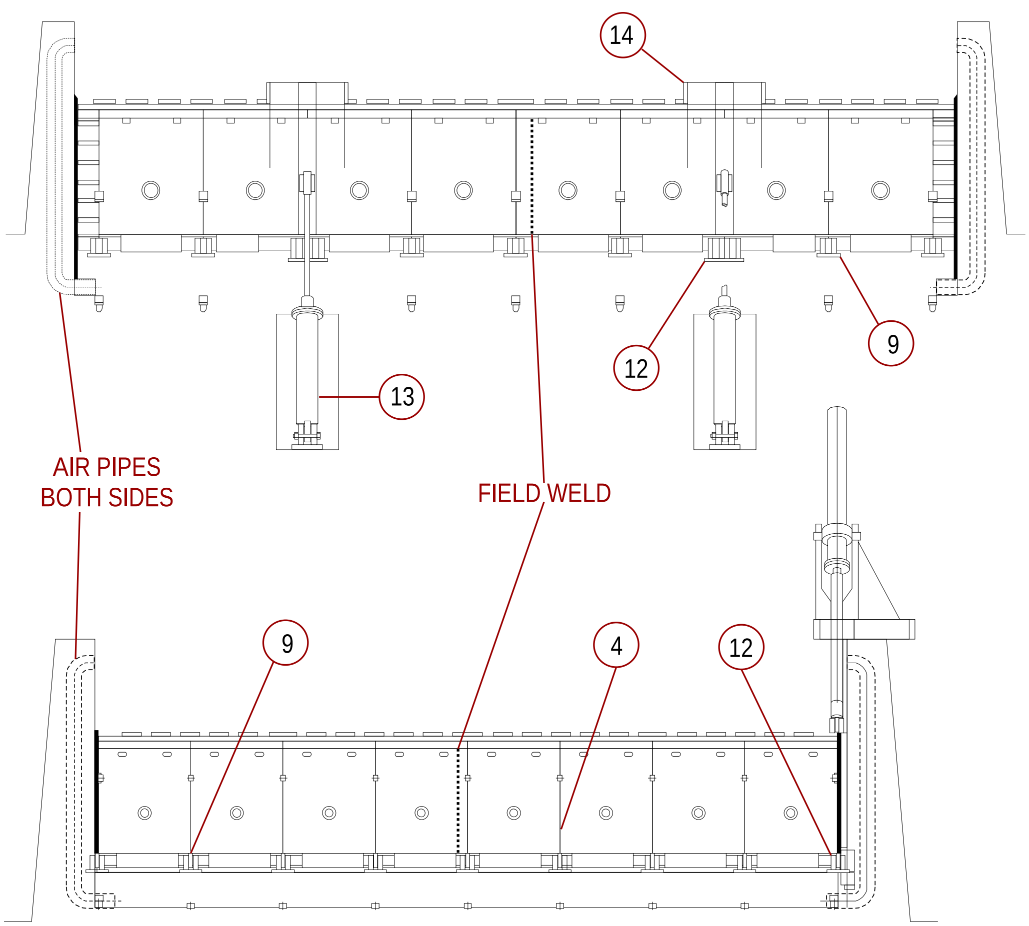
Pelican Gate

The drawings presented here show a standard Pelican Gate, and typical construction arrangement.

PARTS IDENTIFICATION

1. Napp breaker
2. Upstream skin plate
3. End plate
4. Gate rib
5. Longitudinal rubber seal
6. Seal cover plate
7. Sill beam
8. Anchor bolt
9. Intermediate bearing
10. Downstream skin plate
11. Seal contact surface (tube)
12. Main bearing
13. Cylinder operator
14. Cylinder hood
15. Cylinder base plate





Hinged Crest Gate Specification

1. SCOPE

This specification covers the design, manufacture and supply of the hinged crest gate system.

The system shall include the gate leaf, hinges and brackets, sealing system, anchorages, hydraulic cylinders, cylinder supports, seal heaters, air vent piping (when necessary, water level sensors, hydraulic power unit, automatic controller, local control panel, gate position indicators, transportation to the site, drawings, installation procedures, and Operation & Maintenance manuals.

2. DESCRIPTION OF OPERATION

A. Automatic

The operating system shall automatically monitor the upstream water level and position the gate leaf to maintain a constant level under varying flow conditions.

B. Manual

Provisions shall be made to raise or lower the gate via manually actuated controls located on the local control panel.

3. GENERAL DESCRIPTION OF GATE

The gate shall be of the Bascule or Pelican type and arranged to lower to open. Each gate shall have a clear waterway opening of_______ft. The effective height of the leaf in the raised position shall be ______ft.

When in the fully raised position the leaf shall lean downstream approximately 20°. The gate will rotate approximately 75° from the fully raised to the fully lowered position.

This 147' x 5' high Pelican Gate- shown here on the factory floor- is destined for the south fork of the Zumbro River in Rochester, Minnesota.

4. DESIGN REQUIREMENTS

A. The gate hoisting system shall have sufficient thrust capacity to raise the leaf from the fully lowered position to the fully raised position when the upstream water level is _____ft. above the fixed crest.
B. The gate shall be structurally designed to withstand the worst combination of static and dynamic loadings at any position with the upstream water surface at a fixed level of elevation_____ . When subjected to the flood head it shall be possible to lower the leaf from the fully raised position to the fully lowered position by manually opening bypass valving at the hydraulic power unit.

5. GATE COMPONENTS

A. Leaf
The gate leaf for Pelican gates shall consist of curved upstream and downstream skin plates and flat vertical diaphragm plates arranged to form a rigid cellular type construction. For Bascule gates, the leaf shall consist of a flat plate and vertical diaphragm plates. The curved plates shall be pressure vessel quality conforming to ASTM A516, class 60 or 70. The remainder of the leaf structure will be ASTM A36 structural steel. A curved Type 304 stainless steel surface shall be provided directly above the gate hinges to mate with the horizontal J-seals. The top edge of the upstream skin plate shall form a discharge lip of a design to minimize flow induced vibrations.
B. Bearings
The standard Bascule gate will be supported by a series of intermediate saddle bearings with self-lubricating graphite plug bushings. The torque tube will extend into the operating chamber through a suitable packing box.
The Pelican gate leaf shall rotate on pin type hinges. The hinge pins shall be Type 304 stainless steel and fixed to the gate leaf. The pins will rotate in permanently lubricated bronze bushings which shall be retained in fabricated or cast steel bearing brackets. The brackets shall be anchored to the concrete structure in a manner to allow adjustment in all three planes during erection of the leaf sections.
C. Seal Support Members
The side seals shall be designed to seal in all leaf positions. The J-seal shall be attached to the ends of the leaf. The side seals shall be fluoro-carbon clad neoprene. The seal attachments shall allow for replacement of the seal without removal of the leaf. The side seal plates shall consist of a stainless steel plate with seal reinforcing on the backside.
D. Erection and Maintenance Supports.
Erection struts and associated brackets shall be provided to support the leaf in the full up position with the operator detached from the leaf.
E. Leaf Supports
When the leaf is in the fully lowered position the weight of the leaf shall be supported by adjustable gate stops contacting pads on the downstream surface of the spillway.
F. Air Vent Piping
It shall be the responsibility of the gate manufacturer to determine the necessity of air vent piping and to determine the size, location and shape of the air vent piping system. The air vent piping shall be galvanized steel or equivalent and have protective screens on both the inlets and outlets.

6. ELECTRICAL CONTROL and HYDRAULIC POWER SYSTEM

It shall be the responsibility of the gate manufacturer to design, manufacture, test and supply a complete control and hydraulic operating system to meet the performance requirements of the owner.

7. MANUFACTURE

The gates and associated components shall be fabricated in sections that are convenient for shipment and field erection: All major components shall have lifting ears, eyes and/or lugs arranged to facilitate handling during site offloading and erection.
All welding and welding procedures and qualifications, and welder qualifications shall be in accordance with the most recent revision of AWSD1.1.
Each gate leaf shall be completely assembled in the manufacturer's facility. The gate pivot bores shall be sighted to assure correct alignment of the centers. Each hinge bracket shall be assembled to the leaf at its respective location and the bracket rotated through its full range of operating swing. All mating parts shall be trial fitted. During shop assembly the gates shall be checked for dimensions for tolerances, accuracy of alignment and squareness. An operational test of the hydraulic and electric control system shall be made to demonstrate proper functioning of the system, including functioning and sequencing of all control and alarm devices. The hydraulic cylinder shall be hydrostatically tested in the cylinder manufacturer's facility, at a pressure of 150% of the hydraulic power unit design pressure.

8. PAINTING

The gate disc and all exposed steel surfaces shall be blasted to SSPC SP-6.

Prime: One (1) coat of Amerlock
4000 at 5.0 mils thick
Finish: One (1) coat of Amerlock
400 at 5.0 mils thick

1918 Engineering News Record Article

Repair Washout Under Dam by Sheet Pile Cutoff Embedded in Concrete

Hole in Cutoff Wall and Deep Erosion of River Bed Contribute to Accident—Closure to Coon Rapids Dam Made Rapidly Behind Steel Sheet-Pile and Timber Crib Cofferdam in Reservoir

PREPARED BY THE STAFF OF H. M. BYLLESBY & CO., CHICAGO

A WASHOUT through the pile foundation of the Coon Rapids dam in the Mississippi River, 11 miles above Minneapolis, occurred on Sept. 1, 1917. By energetic work in planning and carrying out the repairs rapidly in spite of difficulties, the power plant was put in operation again on Feb. 24. The break was due primarily to a gap in a steel cutoff wall beneath the face of the dam. The leakage saturated the material under the dam and caused a large cavity. Erosion beyond the toe of the apron below the dam contributed to the accident by forming a deep hole and thus increasing

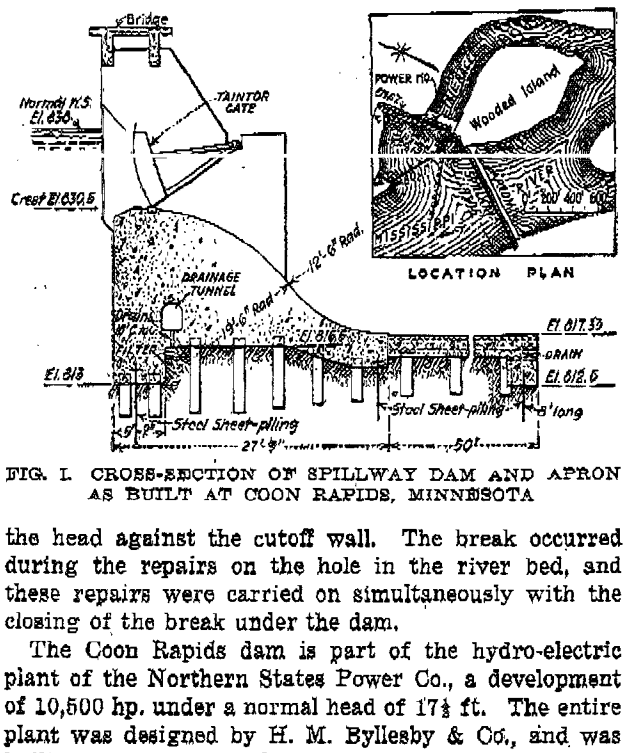


FIG. 1. CROSS-SECTION OF SPILLWAY DAM AND APRON AS BUILT AT COON RAPIDS, MINNESOTA

the head against the cutoff wall. The break occurred during the repairs on the hole in the river bed, and these repairs were carried on simultaneously with the closing of the break under the dam.

The Coon Rapids dam is part of the hydro-electric plant of the Northern States Power Co., a development of 10,500 hp. under a normal head of 17½ ft. The entire plant was designed by H. M. Byllesby & Co., and was built by day labor under their direction as engineers and managers for the power company. It was completed early in 1914. The repair work also was planned and carried out by the Byllesby company. When plans for repairing the dam were under consideration this company called into consultation J. G. Giaver, Chicago, and Francis C. Shenehon, Minneapolis.

The concrete spillway dam, under which the blowout occurred, is of the gravity type, with a height of about 21 ft. and a base width of 27 ft. 9 in., as shown in the cross-section, Fig. 2. It is built on a glacial drift formation. The south bank, to a height of about 20 ft. above low water, is a so-called hardpan, but is really only a mixture of sand, gravel and clay, very hard and dense in places, though easily crumbled in the fingers when broken off in small pieces. It is practically impervious to any head created by the dam. This hardpan has a decided dip to the north, and after passing below the river bed is overlaid by a deposit of clay containing a considerable percentage of very fine sand. The clay deposit, extending in general from the river bed down to the hardpan, is interspersed with pockets of sand of varying degrees of fineness. Near the head of the island at the north end of the spillway it is overlaid by a deposit of boulders and sand. The accident occurred in this vicinity.

Wood piles were so driven as to insure a safe bearing value of 10 tons per pile. Cutoff walls of steel sheeting were placed under the heel and the toe of the dam; the sheeting was driven to such a depth as to penetrate at least 5 ft. into material that would be impervious under the head developed at the dam. This depth was determined by test borings; the maximum length of the steel piles was 25 ft. A 50-ft. concrete apron beyond the toe of the dam is also carried on wood piles, and has a toe wall with a line of 8-ft. steel sheeting to prevent scour from cutting back under the apron.

The dam with its gates and other works was described in *Engineering Record* of Jan. 17, 1914, p. 77, and in *Engineering News* of July 16, 1914, p. 118.

Locating the plant at the head of an island (see key plan in Fig. 1) gave a 1000-ft. spillway across the south channel and a 255-ft. power house across the north channel; the total length between abutments is about 2000 ft. Formerly the north channel, being the deeper of the two, carried probably more than half of the flow during floods, but since the works were built practically the entire flood-flow goes over the spillway into the shallow south channel. This condition was a factor in the erosion which took place below the dam. It was assumed that with the high velocity in the south channel, due to its greatly increased discharge, there would be some scouring until the river reëstablished a permanent condition of flow.

The history of the case is as follows: In January, 1914, the dam and the power house substructure were completed and the gates were then closed. The spring flood, which was not of large proportions, carried over the spillway a quantity of logs. Soundings made after the flood showed that considerable erosion had taken place, but not near the apron; it was deemed safe to await further developments.

The spring flood of 1915, considered to have been the maximum for this part of the river, amounted to more than 60,000 cu.ft. per second. Soundings made in the fall showed that irregular scouring had proceeded along the entire length of the spillway. The condition was such as to make it necessary to carry out protective work before the next flood. For this purpose rock-filled timber cribs about 24 ft. wide, with their tops below the top of the apron, were sunk against the toe of the apron for something more than half the length of the spillway section.

Soundings made in the winter of 1916-17 showed that the cribbing had been damaged considerably. The erosion also had extended so that protective work of a more extensive character was rendered necessary. After a contour map of the river bottom had been made from soundings, and studying the situation, it was decided that during the following summer a cofferdam should be built around the hole to admit of pumping out the water and placing a concrete floor or paving. Arrangements were made to carry out this work after the high water of 1917.

The spring flood of 1917 carried large quantities of logs and heavy ice over the spillway, so that although dam of rock-filled timber cribs faced with wood sheeting driven by hand, so as to obstruct the flow of water under the dam and thereby retard or stop the erosion. In the meantime the ends of the break were covered with brush and sand bags to prevent it from widening.

As this temporary work progressed, materials were ordered for a more substantial cofferdam in the reservoir, the construction of which was commenced with steel sheet piling on hand in Minneapolis. Additional piling was rushed from Buffalo and Louisville, so that the floating driver was not delayed for lack of material. This cofferdam was about 350 ft. long, with its face about 150 ft. upstream of the dam. It consisted of steel sheeting driven to a penetration of about 30 ft. and supported by rock-filled cribs 16 and 24 ft. wide. The earth cofferdam around the scoured hole below

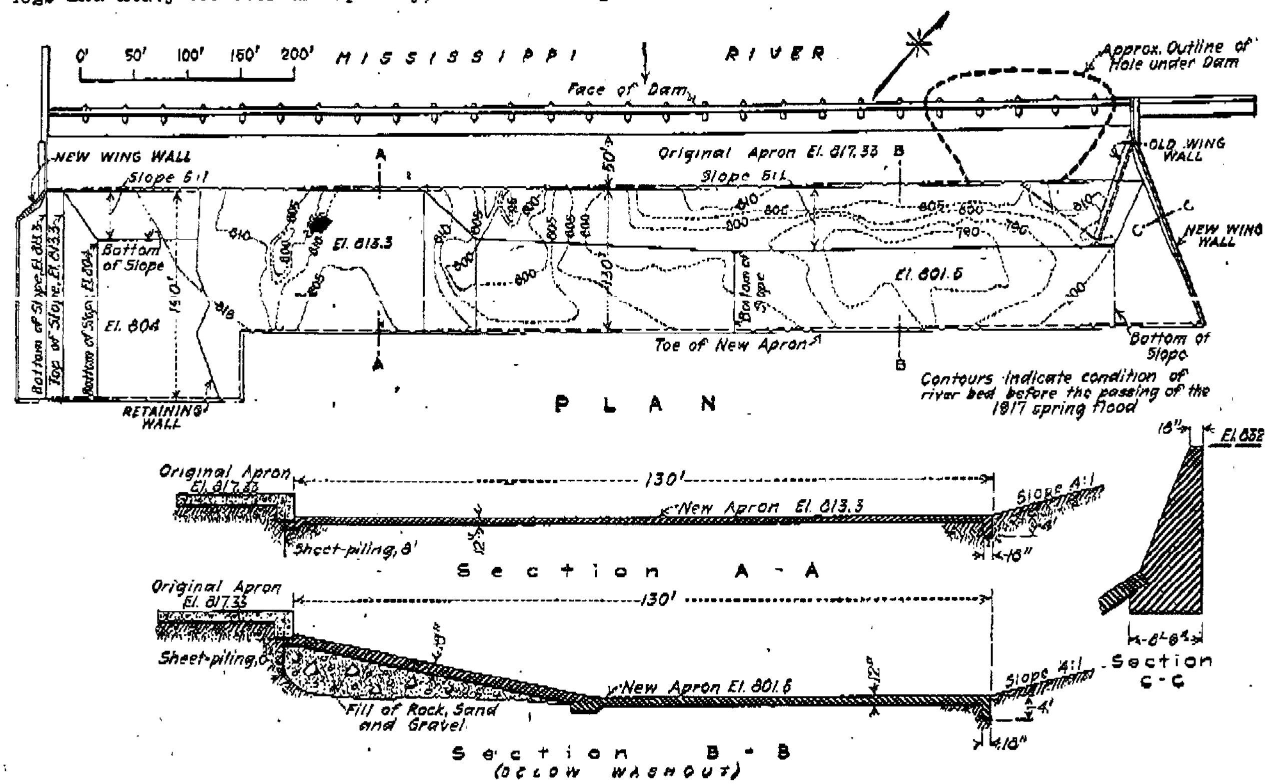


FIG 2. FIVE BAYS OF DAM UNDERMINED BY WASHOUT—NEW APRON BUILT OVER SCOURED-OUT AREA

the flood was not nearly so great as that of 1915 it caused probably more scouring than any previous flood.

Construction of the cofferdam was commenced in June. An area below the apron two-thirds of the length of the dam was inclosed. Owing to the low stage of the river only an earth embankment 3 to 5 ft. in height was required to keep out the backwater. On Aug. 11, 1917, the hole was unwatered, and on Aug. 31 all was ready for filling it with concrete the next day.

No leakage or even seepage had been observed as coming from under the dam. At 2 a. m. on Sept. 1, however, the watchman noticed that the water in the hole was gaining on his pumps. He reported this immediately to the superintendent through the operator at the power house, but the flow developed so rapidly that the hole was filled with water before anything could be done to stop it except to open the sluice gates and thus hasten the lowering of the pond level.

Steps were taken immediately to build a rough coffer- the dam was repaired where it had been breached by the washout, and it served its purpose until the completion of the repairs.

During the period of repair the river flow was taken care of through the wheels and the sluice gates. Provision was made for raising those portions of the cofferdam not already up to 3 ft. above the crest of the dam, in the event that high water should be reported from upstream stations.

When the cofferdam was pumped out it was discovered that a hole about 200 ft. long had been eroded under the concrete dam. This hole was about 26 ft. deep at the center and sloped up to the base of the dam at each end. The foundation piles were not undermined, so that they sustained the load, and no portion of the dam was lost or seriously damaged. There was no settlement or sign of distress. The two lines of steel sheeting under the dam were not damaged, but they were undermined at the break by the washout. Two 54-ft. sections of the apron collapsed, as the shorter foundation piles and sheeting under the apron were undermined.

In the original construction of the dam, the sheeting and foundation piling in the portion where the washout occurred were driven from the ice before the cofferdam was built. The steel sheeting was driven first. Considerable difficulty was experienced on account of boulders and old logging cribs. There was some apprehension that these obstructions might split the webs of the piles or pull the interlocks apart, but nothing of the kind was discovered.

Examination of the sheeting exposed by the erosion, however, revealed the fact that when one of the bearing piles was driven it had been set on top of a steel pile and, while the former was badly split, it had nevertheless carried the head of the steel pile to the bottom of the adjacent piles, thus leaving a slot partially filled by the wooden pile. When the excavation was made for bedding the heads of the steel piles in concrete this opening should have been discovered and a new pile driven to close the opening, but if it was noticed by the inspector it was covered up without the defect being remedied. This opening through the cutoff wall is considered the cause of the accident, beyond doubt.

Three Plans for Work Were Considered

Three plans for the repair work were considered, though two of these differed only in detail. As the driving of additional piling under the dam seemed impracticable, and as the original steel cutoff wall had been undermined at the break, the main points to be determined were the bearing value of the clay and the possibility of constructing a new cutoff wall or waterstop which would tie in with the original cutoff wall beyond the limits of the break.

Plan A was to fill the hole under the dam with 1:3:6 concrete, and face this on the upstream side with 1:2:4 concrete, incasing the heads of the steel piles of a new cutoff wall to be driven about 5 ft. upstream from the face of the dam. Plan B was practically the same, except that the concrete was to be of a very lean mixture, approximating the adjacent hardpan in rigidity though not in density.

Plan C provided for a reinforced-concrete mat under the dam, extending from the downstream side of the original cutoff wall a sufficient distance beyond the toe to distribute the pressures properly. Cross-walls resting on this mat would support the undermined portion of the dam. After cutting out the two upstream rows of bearing piles a reinforced-concrete cutoff wall would be built in line with the original cutoff, bearing against the upstream ends of the cross walls and carried down to bond into the hardpan. The spaces between the walls were then to be filled with sand and the apron was to be restored in its original form.

Objections to Plans A and B were the increase of weight and the difficulty of bonding the new cutoff wall with the old so as to make it continuous and of equal effectiveness. The original steel cutoff is more than 2 ft. in from the face of the concrete, and as the new steel could not be driven closer to the dam than about 12 in. there would have been a gap of at least 2 ft. between the two rows of sheeting. By the removal of part of the bridge and the cutting of a slot from the crest to the base of the dam it would have been possible to turn the new line of sheeting perpendicular to the axis of the dam and drive it up to the old sheeting. But no junction with the old sheeting would have been possible, nor would there have been any assurance of contact between the two lines. This difficulty would be eliminated in Plan C because of the new cutoff wall being in the same plane as the old one, so that it would only be necessary to extend the concrete wall sufficiently to bond over the edge of the old steel sheeting.

Leakage of the cofferdam proved to be the deciding factor. Although the amount of the inflow was not serious, the water was difficult to collect and pump, and that which was not controlled seeped through the ground inside of the cofferdam and flowed into the deep part of the hole. This made excavation difficult and of questionable benefit, because any disturbance of the clay in the presence of water quickly turned it into mud. Under these conditions it was deemed too hazardous to attempt to make a deep trench excavation for the cutoff wall as required by Plan C. Plan A was therefore adopted.

Reconstruction Carried Out in Very Cold Weather

The new cutoff wall driven according to this plan was 175 ft. long. The sheet piles varied in length and were driven into the hardpan.

On account of the close spacing of the bearing piles under the dam, placing the concrete was very difficult, except in the lower part, where it could be spouted. As it was desired to get the concrete packed in so solidly against the base of the original structure as to avoid the necessity of grouting, the pneumatic method of mixing and placing was adopted. This method was not as satisfactory as had been anticipated, due largely to the adverse conditions and to the occasional necessity of operating the mixer with inexperienced help. Some difficulty was caused by the concrete clogging in the discharge pipe. This probably could have been reduced materially had it been possible to keep a trained man at the mixer. Some segregation of the materials occurred as the concrete was deposited, probably due to the difficulty of proper manipulation at the outlet of the discharge pipe on account of the interference of the bearing piles. Wear of the discharge pipe was another trouble. There was no way of ascertaining easily the amount of wear, and blowouts had a way of occurring at inopportune times. Notwithstanding the difficulties, good work was done, and it was considered that pneumatic placing was the only method practicable in the circumstances.

Most of the concrete under the dam was placed during weather that was near or considerably below zero. The space where the concrete was to be placed was inclosed by hanging tarpaulins from the original structure, all materials were heated, and salamanders were used when necessary to prevent frost getting into the concrete.

Junction between old and new cutoff walls at the south end was effected by excavating a well between the end of the new sheeting and the face of the old sheeting, down to the bottom of the former. A section of the old sheeting about 2 ft. wide was then cut out with a blow torch and sufficient excavation was made behind the sheeting to get a good bond. Finally, the well was filled with concrete placed solid against the undisturbed earth. As the cutting and excavating proved to be difficult the method was changed when the junction at the north end was made. An angle iron was tap-bolted to the web of one of the piles in the old sheeting and the outstanding leg was embedded in the concrete. The latter method was much more easily carried out and resulted in more satisfactory work.

The toe of the new concrete under the dam was extended 10 ft. beyond the toe of the original structure, and in this 10-ft. width three lines of bearing piles were driven.

After the work under the dam was completed a fill was made on the downstream side to level up the eroded bed, and the apron at the two collapsed sections was rebuilt as in the original structure. Where erosion at the toe of the apron had taken place to a depth of 10 ft. or more, a fill with slope of 1 on 5 was so made that the concrete pavement laid on this slope bonded in under the toe wall of the original apron, as shown.

The river-bed protection was extended about 135 ft. beyond the original apron, or to about the limits of the deep erosion. In placing this protection only such grading was done as was necessary to eliminate abrupt changes of section. A new wing wall was built, flaring away from the dam so as to allow the free escape of the tail water.

Full reservoir head has been maintained since the repairs were completed, without any indication of further trouble, and it is thought that if additional erosion takes place in the river bed it will not be of such a nature as to require further protective work.

Machinery Ordered for One Purpose Cannot Be Tested for Another

Court of Claims Decides That Dry Dock Contractor Can Recover When Use for Which Engines Were Intended Is Changed

By William B. King

of King & King, Attorneys-at-Law, Washington, D. C.

In a decision handed down by the United States Court of Claims Apr. 29, it was decided that machinery ordered for one purpose by a contractor on a naval drydock cannot be subjected to a test with reference to a different service from that covered by the original contract.

The case was that of the trustee in bankruptcy for the Scofield Co. against the United States Government, arising out of the contract made by that company on Mar. 9, 1903, for completing the dry dock at the Philadelphia Navy Yard. The principal question arose over the rejection of the three main engines furnished by the contractor and purchased by the Government, and the purchase in their place of more powerful and expensive engines. The three original engines were sold practically for junk, and after crediting the price obtained by the sale the cost of the three new engines was charged to the contractor.

The three engines originally furnished were found on final test to have a speed regulation which did not come up to the requirements of the specifications. The contractor, as well as the subcontractor, the maker of the engines, endeavored to bring them within the specification requirements. While this work was in progress the contracting company became financially involved and the Government took over the completion of the dock and the machinery.

The Government then made a contract with the Providence Engineering Works to alter the three engines to bring them within the specifications. One engine was to be altered, and if it were satisfactory $8400 was to be paid for altering all three. It was agreed that if the alteration of the first engine was unsatisfactory, it was to be returned to its original condition and nothing was to be paid for the work done.

The first engine was altered, and failed to meet the test. It came so near it, however, that the Providence Works asserted that by further slight alteration it could be brought within the specifications. The Government, however, paid the Providence Works a proportionate part of the agreed price for the alterations, rejected all three engines and sold them at a small price. Three larger engines were then purchased and charged to the contractor.

While the original contract was solely for a dry dock and machinery to operate it, the tests of the engines were conducted with reference to their capacity to operate not only the dry dock but a central station which would furnish heat and light for the entire yard, and power for all the shops in the yard. The court held that no such requirement could be made, and that the contractor had complied with all his obligations when he furnished engines capable of operating the machinery and dry dock. Therefore, it credited the contractor with the price of the new engines, and held that from this there must be deducted the price which it would have cost the Government to have the Providence Engineering Works alter the old engines to bring them within the specification requirements. Subject to this credit of $8400 the contractor recovered from the United States the increased cost of the new engines.

The case was presented for the contractor by the writer and Russell H. Robbins, of New York, while Philip G. Walker appeared for the Government with Assistant Attorney General Houston Thompson.

Culvert Maintenance Cheaper Than Upkeep of Bridge Floor

Repair on the road surface has been found to be the most expensive item in the maintenance of canal highway crossings in the South San Joaquin Irrigation District of California. As a result, culverts which can be jacked beneath paved surfaces without disturbing the roadway are considered to be very much cheaper than small bridges or culverts of the type which involve the removal of the highway surfacing. Large pipes therefore are used in place of the old type bridge-culvert whenever feasible. By using two or more pipes in parallel, ditches of comparatively large capacity have been provided for at crossings. Corrugated iron pipes as large as 48 in. diameter are now being successfully jacked under highways. A description of the method of jacking appeared in *Engineering News-Record* of June 27, p. 1236.

Available Dam Information

Available Dam Information

The following bibliography presents a list of known information relating to Coon Rapids Dam. Section 9 lists documents specifically referenced in this report.

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3. Barr Engineering Co., Preliminary Report on Repairs and Improvements to the Coon Rapids Dam: Phase I – Powerhouse and Appurtenant Structures, prepared for Hennepin County Park Reserve District, March 1973.
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5. Department of the Interior, United States Geological Survey, *Coon Rapids Pool Hydrographic Study*, July 1974.
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51. Stanley Consultants, Inc., *Coon Rapids Dam – Inflatable Gate Inspection Memo*, prepared for Three Rivers Park District, April 16, 2010.

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Appendix F

Computations

Hydraulic Computations

Computed by: A. Judd
Checked by: N. VANG
Approved by: M. Weber

Description:

Analyze hydraulic conditions for fish passage at Coon Rapids Dam Spillway

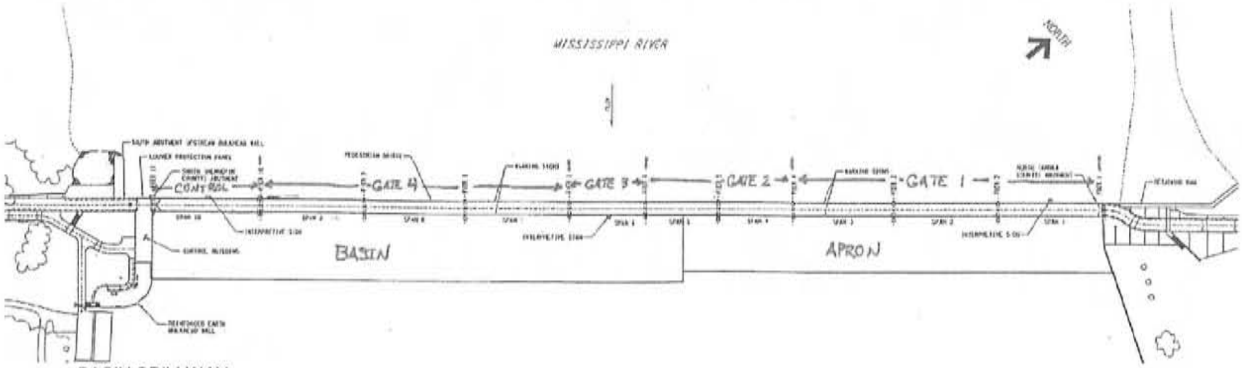
Reference:

(1) USBR, *Hydraulic Design of Stilling Basins and Energy Dissipators*, EM 25, 1958.
(2) Chow, *Open-Channel Hydraulics*, 1958.
(3) USACE, HEC-RAS River Analysis System, 2010.

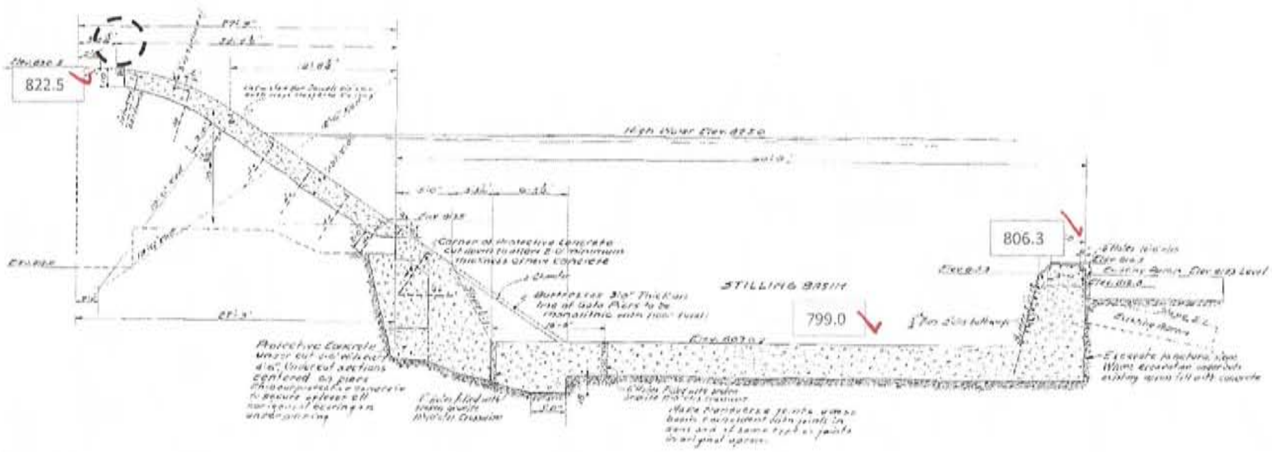
Analysis:

Coon Rapids spillway has a variety of flow conditions depending on gate and bag settings with the objective being to keep the normal pool at 830.1 during the summer. Bags and gates are lowered in the winter to 822.5. This analysis estimates hydraulic conditions of the spillway for a range of flows. Under summer and winter conditions for existing and proposed (new gates) conditions.

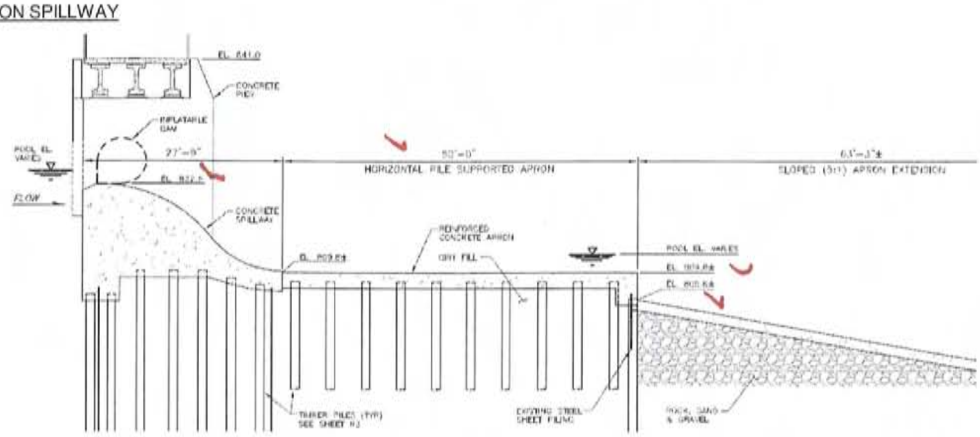
Coon Rapids Dam has 2 Spillway Geometries. Control, Gate 3, and Gate 4 are on the Basin Spillway and Gates 1 and 2 are on the Apron Spillway.



BASIN SPILLWAY



APRON SPILLWAY



Hydraulic Computations

River Flow Conditions

Computed by: A. Judd
Checked by: N. VANG
Approved by: M. Weber

STEP 1 Define range of possible river flow conditions at spillway

Previous analysis has reviewed range of discharge at the dam

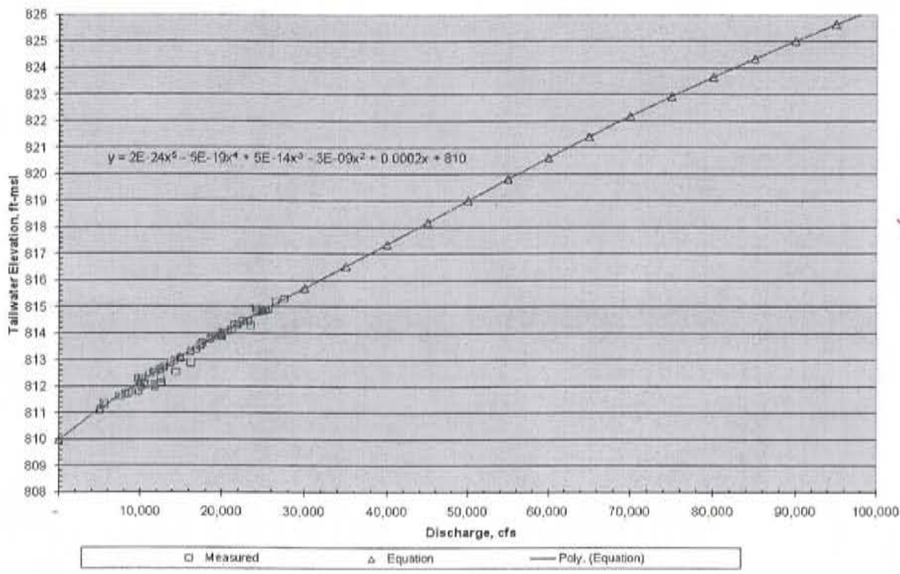
Return Period (yr)	Flood Discharge for given Time Period													
	Jan (cfs)	Feb (cfs)	Mar (cfs)	Apr (cfs)	May (cfs)	Jun (cfs)	Jul (cfs)	Aug (cfs)	Sep (cfs)	Oct (cfs)	Nov (cfs)	Dec (cfs)	Annual (cfs)	Aug - Feb (cfs)	Mar - Apr (cfs)
1	970	1,170	1,960	4,260	4,440	2,760	1,380	1,310	1,260	1,270	1,420	1,260	6,560	2,080	6,380
2	4,840	4,510	12,170	22,700	19,710	15,790	10,760	6,630	6,440	7,030	7,290	5,820	29,650	11,110	29,240
5	7,090	7,090	21,640	37,990	30,620	25,410	19,790	11,640	11,310	13,120	12,060	8,960	44,430	18,680	44,130
10	8,340	8,910	28,730	48,820	37,790	31,620	26,480	15,540	15,090	18,200	15,400	10,960	53,400	24,090	53,270
25	9,660	11,310	38,380	62,950	46,630	39,050	35,450	21,090	20,440	25,820	19,730	13,350	63,730	31,190	63,860
50	10,490	13,160	45,950	73,640	52,990	44,260	42,350	25,630	24,800	32,380	22,990	15,020	70,710	36,600	71,070
100	11,200	15,040	53,760	84,370	59,120	49,160	49,330	30,490	29,460	39,690	26,240	16,590	77,130	42,050	77,740

Essentially flows range from 1,000-90,000 cfs

Higher flows are more conducive to fish passage due to the reduced difference between headwater and tailwater, so analysis focused on flows in 10K increments from 10,000 to 90,000

Number of Days Exceeding Given Discharge								
7,308	2,170	629	211	78	36	13	4	1
10,000 (cfs)	20,000 (cfs)	30,000 (cfs)	40,000 (cfs)	50,000 (cfs)	60,000 (cfs)	70,000 (cfs)	80,000 (cfs)	90,000 (cfs)

Tailwater has also been measured/analyzed at the dam so the tailwater can be defined for any River Flow



Hydraulic Computations

HEC-RAS Model

Computed by: A. Judd
Checked by: N. VANG
Approved by: M. Weber

STEP 2 Create HEC-RAS Model of Spillway

3 spillways were analyzed in HEC-RAS
- Apron Spillway
- Basin Spillway
- Gate Spillway (using basin configuration)

Geometries were established using spillway profiles with HEC-RAS cross-sections at 1' spacing along length of spillway

Flows analyzed were 10,000 - 90,000 cfs in 10,000 cfs increments

Upstream pool scenarios analyzed were
-Existing Apron and Basin
  +Summer Pool 830.1
  +Winter Pool - pool variable, crest at 822.5
-New Gate System
  +830.1 Pool
  +829.1 Pool
  +828.1 Pool
  +827.1 Pool

Various combination of geometries/flows/pools were analyzed by creating flow profiles of potential scenarios

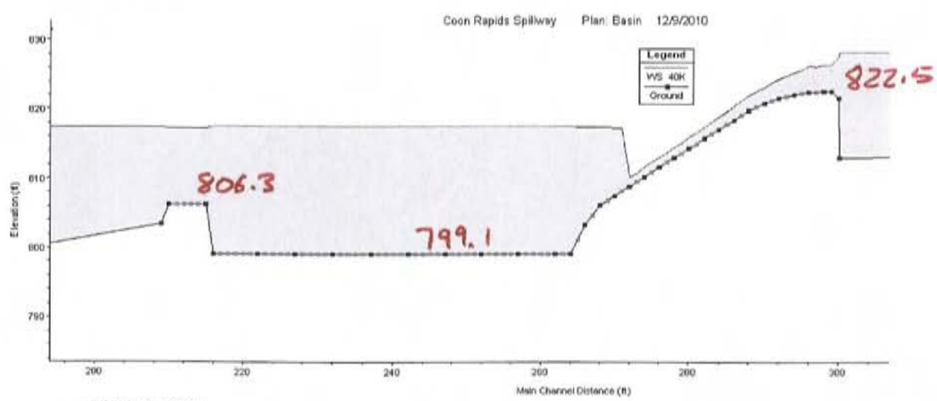
Something to note with the existing rubber dam is that even with Summer Pool per the O&M Manual, for any flow above 10,000 cfs, atleast one of the gates is fully deflated. So to analyze, the flow through the deflated gate segment was computed and then the tailwater adjusted for total river flow, and the flow/tailwater run for the basin geometry with a crest elevation of 822.5.

For proposed gates, the gate setting for given flow was determined using the weir equation
(Q = 3.4 * Length * H^(3/2)) with a head (H) that produced the desired pool elevation
Cd

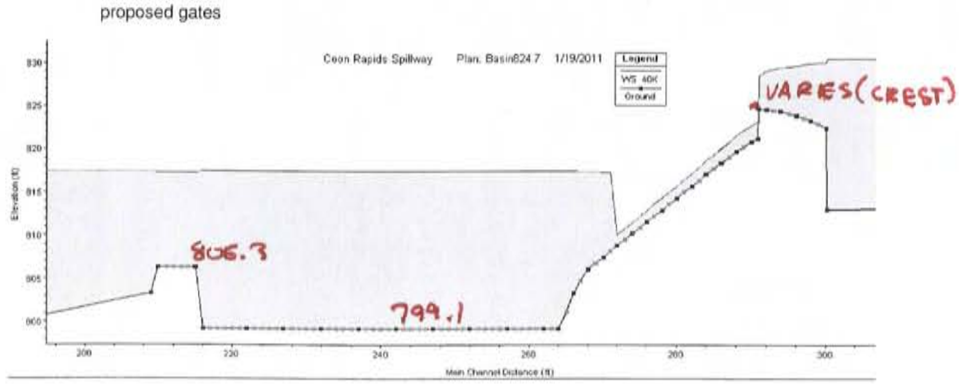
Q (cfs)	Upstream Pool Elev.			
	830.10	829.10	828.10	827.10
	Gate setting			
60000	823.10			
50000	823.90	822.90		
40000	824.70	823.70	822.70	
30000	825.70	824.70	823.70	822.70
20000	826.70	825.70	824.70	823.70
10000	828.00	827.00	826.00	825.00

Gates are considered flush with existing spillway for flows above 60K for Pool 830.1, 50K for Pool 829.1, etc. so the existing spillway analysis applies

Example of results
existing dam



proposed gates

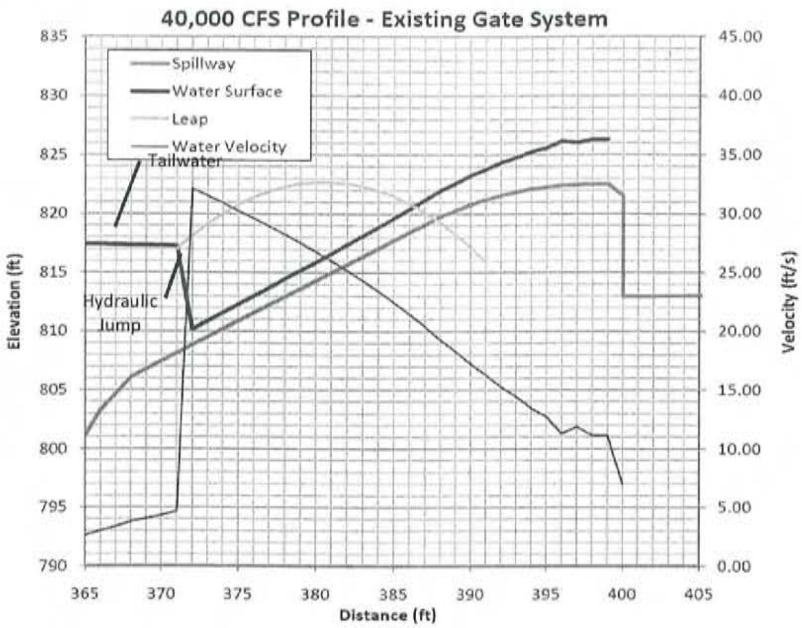


Hydraulic Computations

Flow/Fish Jump Profiles

Computed by: A. Judd
Checked by: N. VANG
Approved by: M. Weber

STEP 3 Plot Water Surface and Velocity for series of flow scenarios and analyze fish passage



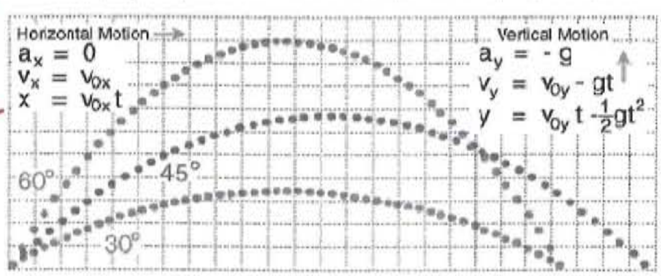
Flow/Gate scenarios are described as

Existing Gate System - concrete spillway with gates down, represents existing and proposed with all gates down
Existing Gate (open) - existing system where segment of rubber dam is totally down (per O&M manual), discharging large portion of flow
New Gate System - proposed gate system, operating at Summer Pool Elevation of 830.1
New Gate System 829.1,828.1,827.1 Pool - proposed gate system, operating at reduced Pool Elevation.

The fish was assumed to jump from point where the hydraulic jump met the tailwater
The fish swimming/jumping speed was assumed to be 25 ft/sec (provided by MnDNR)

From that a leap trajectory could be calculated for a given launch point, velocity and angle

$t = \frac{x}{V_x}$



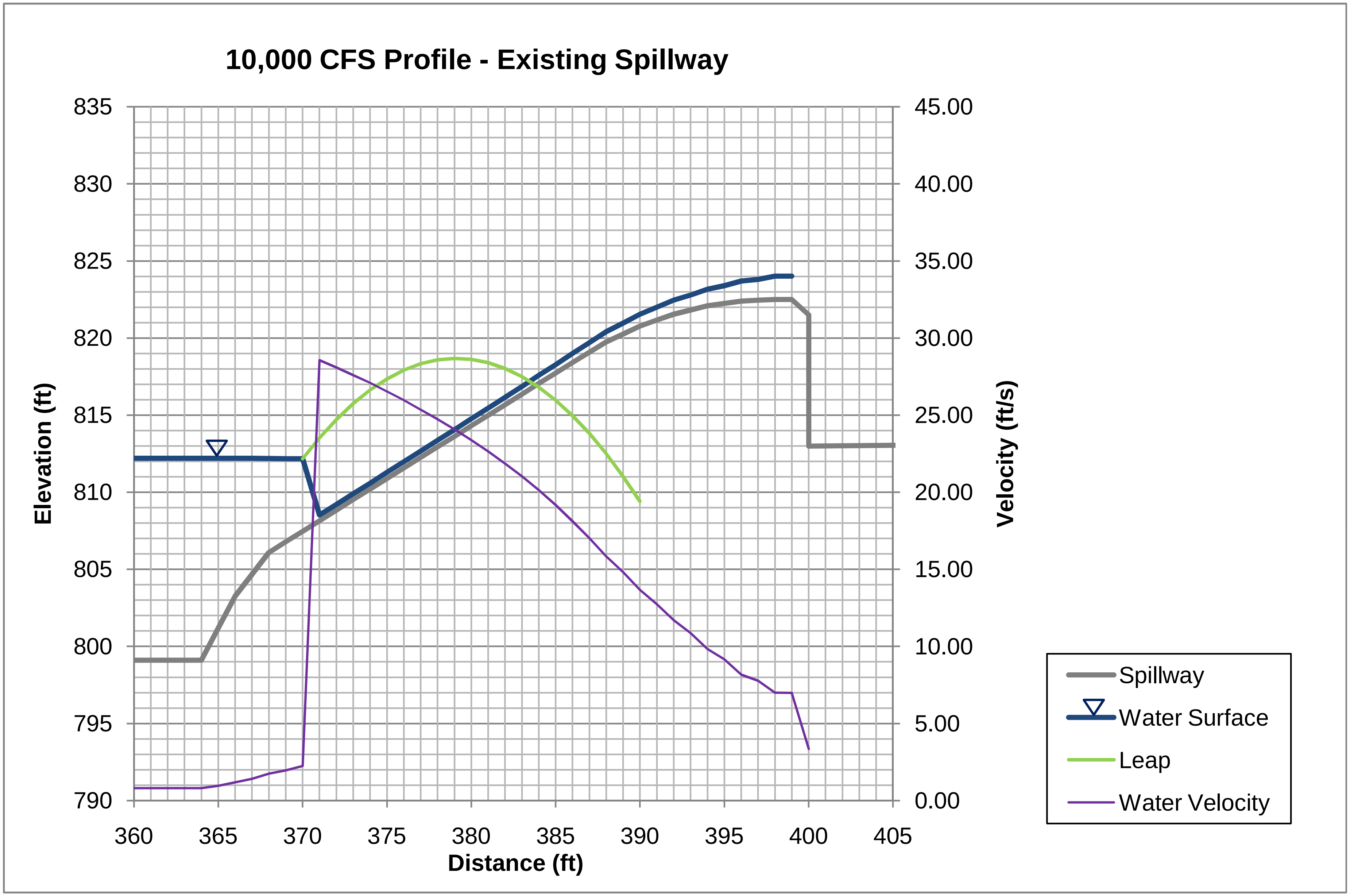
$\therefore y = V_y \frac{x}{V_x} - \frac{1}{2} g \left(\frac{x}{V_x}\right)^2$

$g = 32.2 \text{ ft/s}^2$

The criteria for fish passage is defined by where the fish lands, if it lands at a point on the spillway where the velocity is less than 25 ft/s, then it is assumed the fish can swim upstream and over the spillway. If the velocity is greater than 25 ft/s then the fish is assumed to be washed downstream.

For gates, in some cases the fish lands where the flow is less than 25 ft/s, but then it must swim upstream to the base of the gate and jump over the gate. The velocity of the second jump was assumed to be 25 ft/s - flow velocity on spillway at base of gate.

Results of the analysis can be found in the series of plots that are attached


10,000 CFS Profile - Existing Spillway
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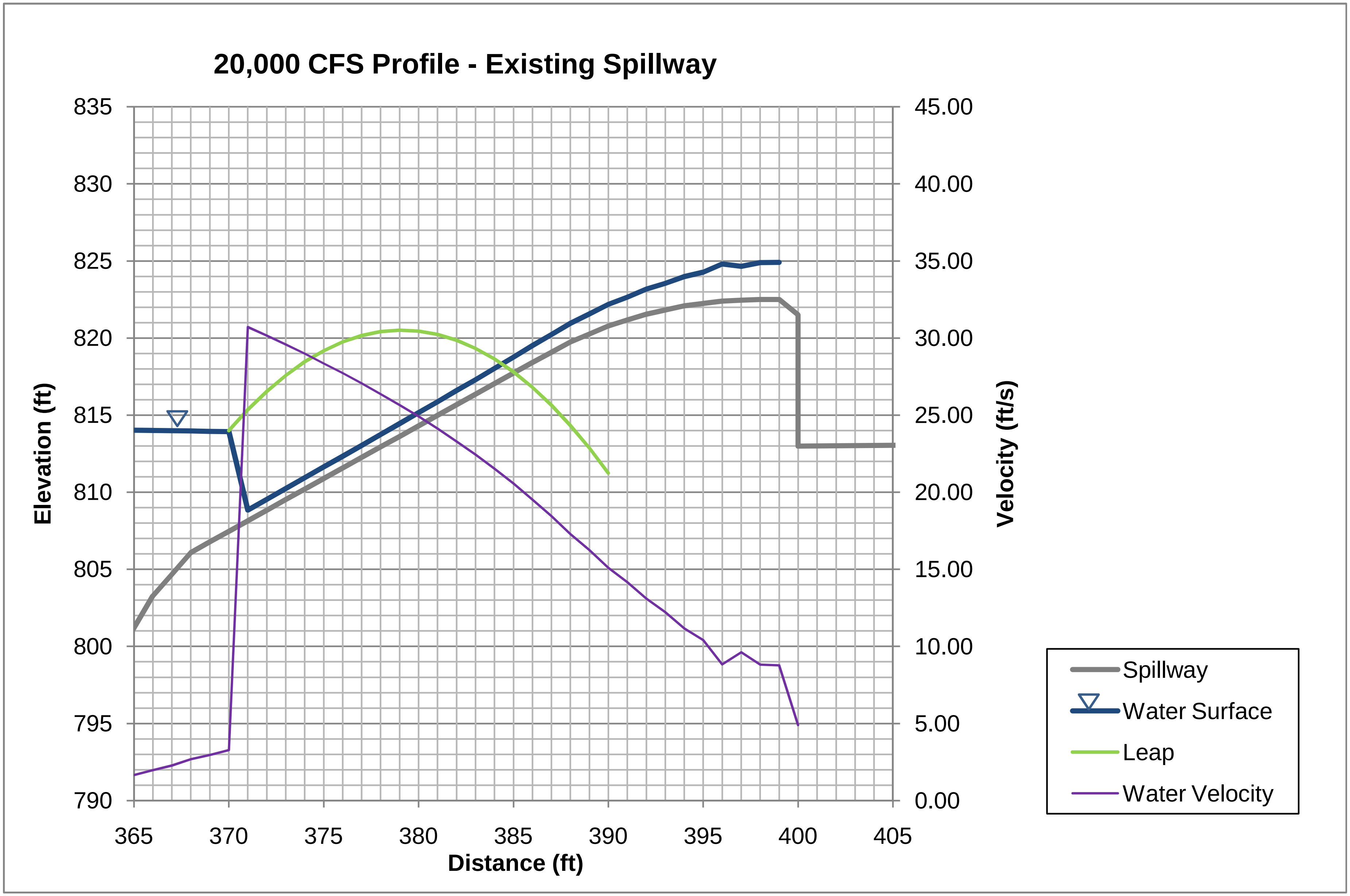
Elevation (ft)
Velocity (ft/s)
Distance (ft)
Spillway
Water Surface
Leap
Water Velocity


20,000 CFS Profile - Existing Spillway
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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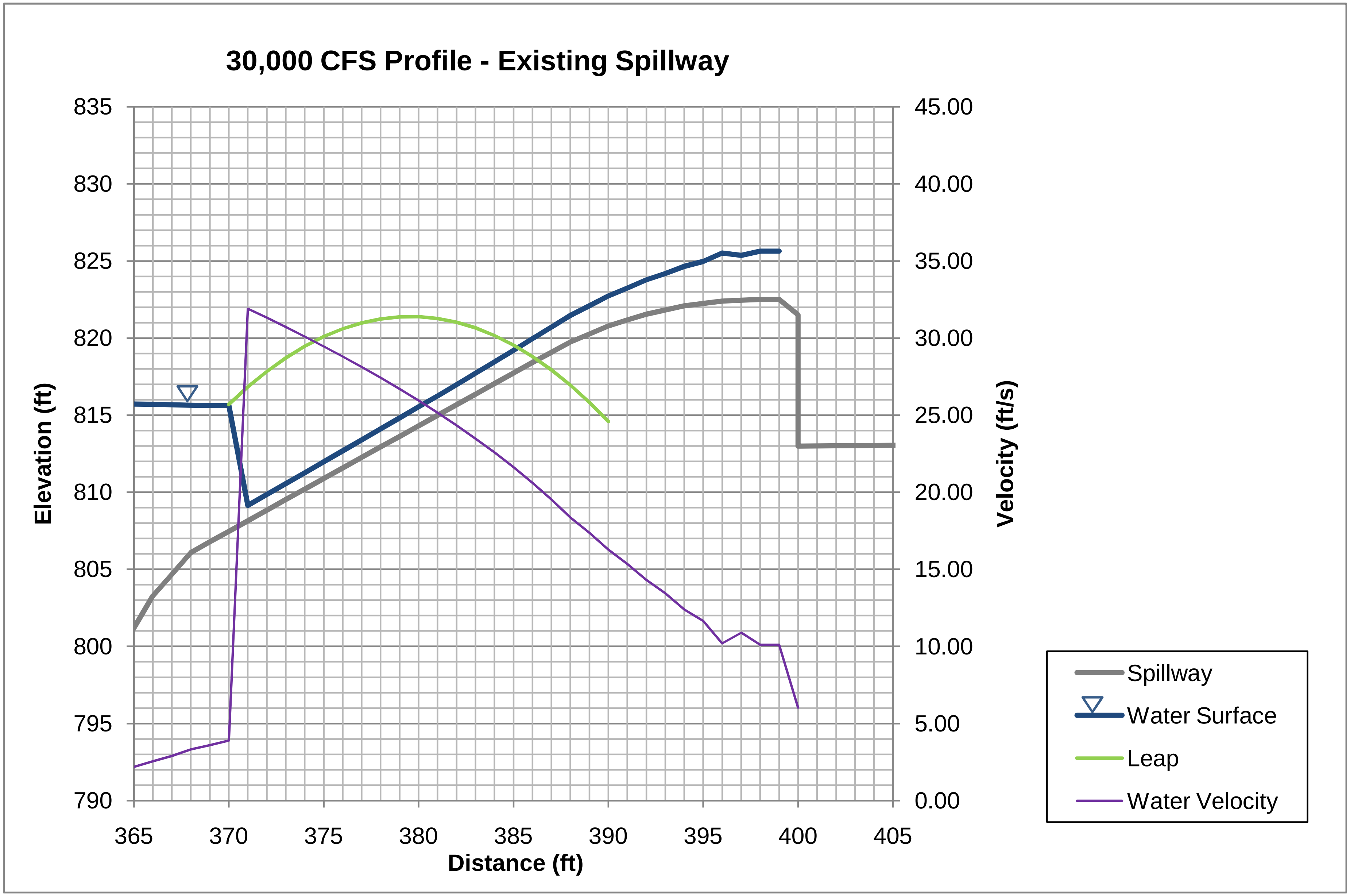
Spillway
Water Surface
Leap
Water Velocity



30,000 CFS Profile - Existing Spillway
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Elevation (ft)
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Distance (ft)
Spillway
Water Surface
Leap
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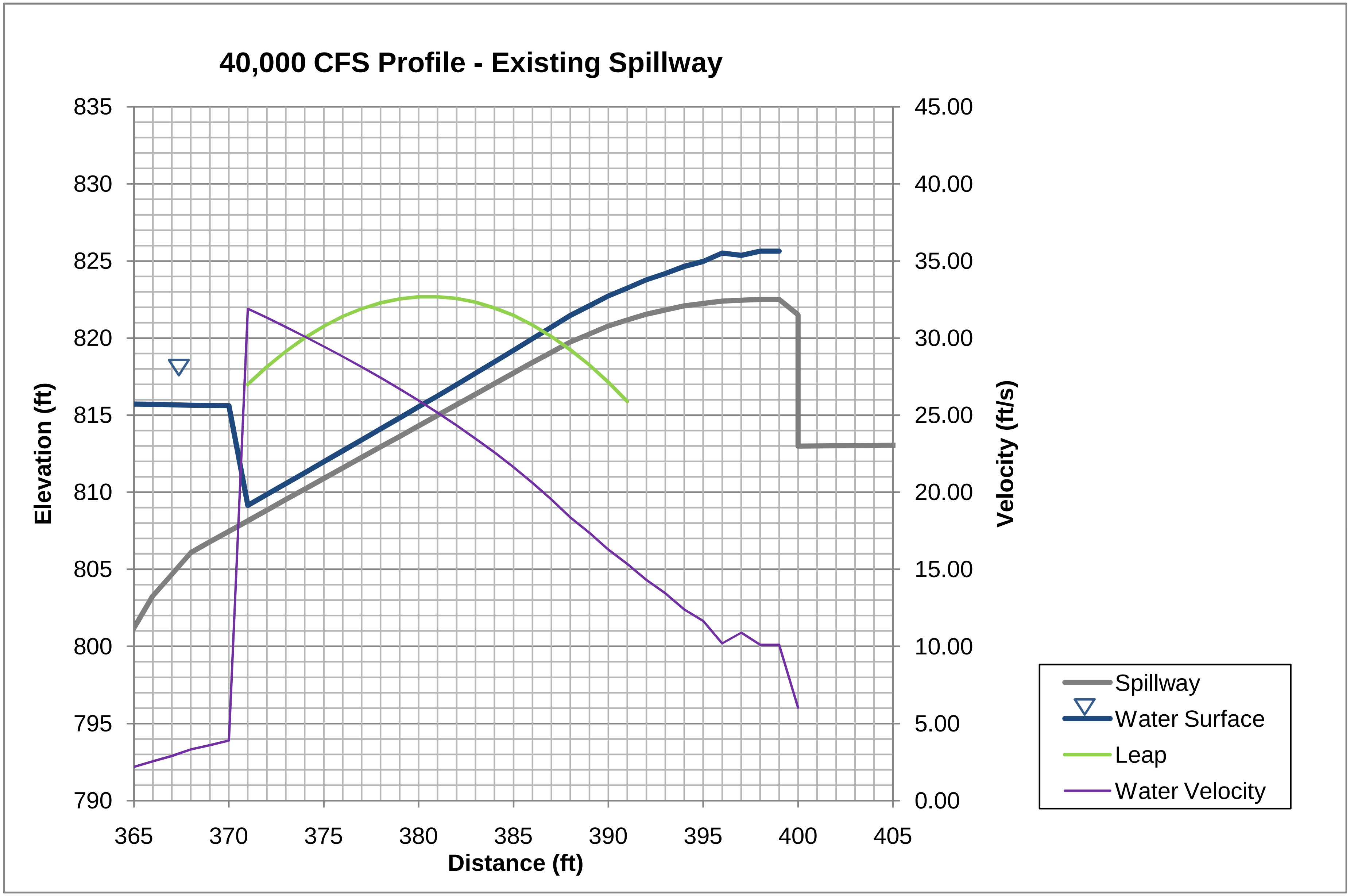

40,000 CFS Profile - Existing Spillway
Elevation (ft)
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Distance (ft)
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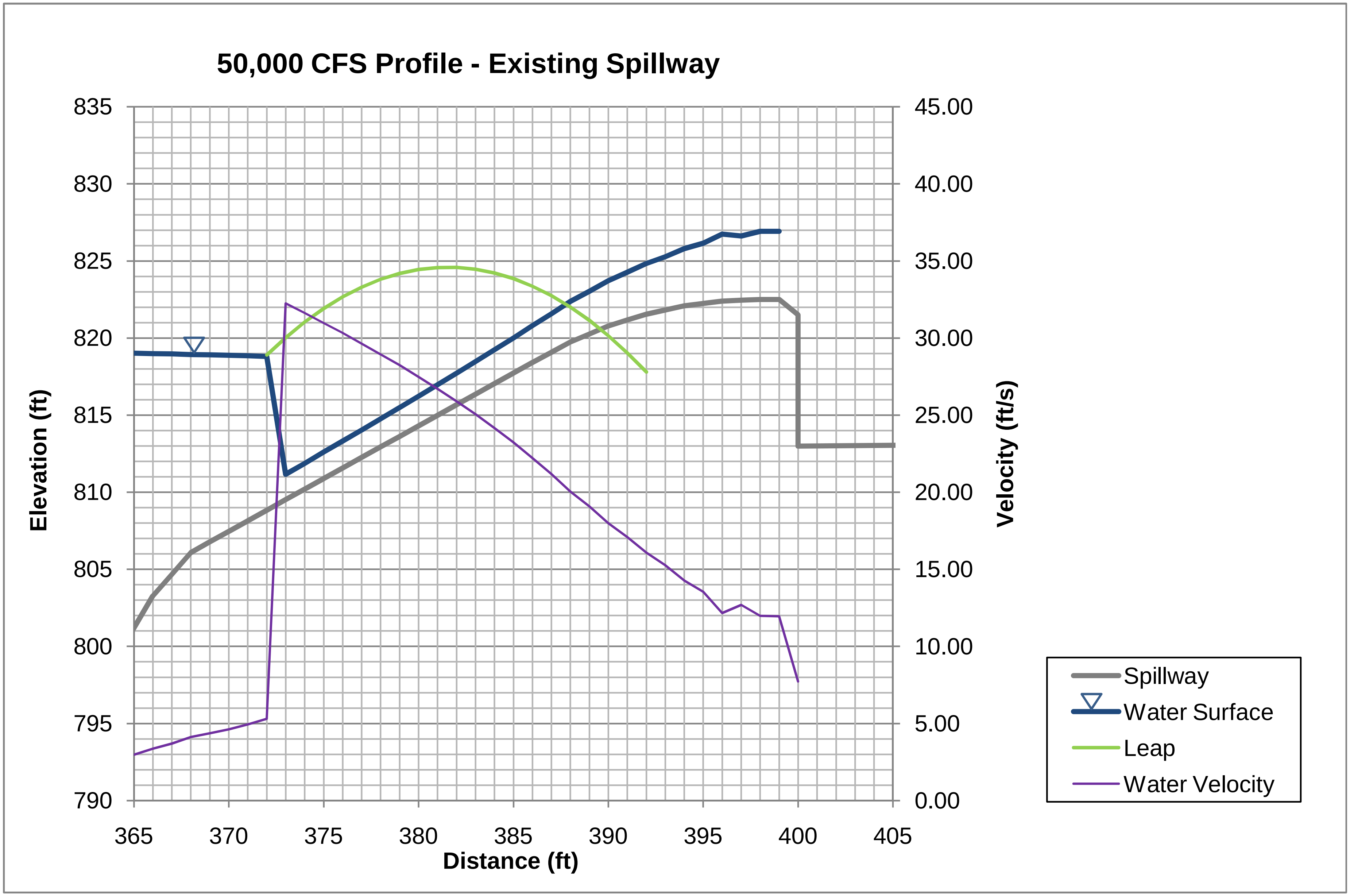
Spillway
Water Surface
Leap
Water Velocity


50,000 CFS Profile - Existing Spillway
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Elevation (ft)
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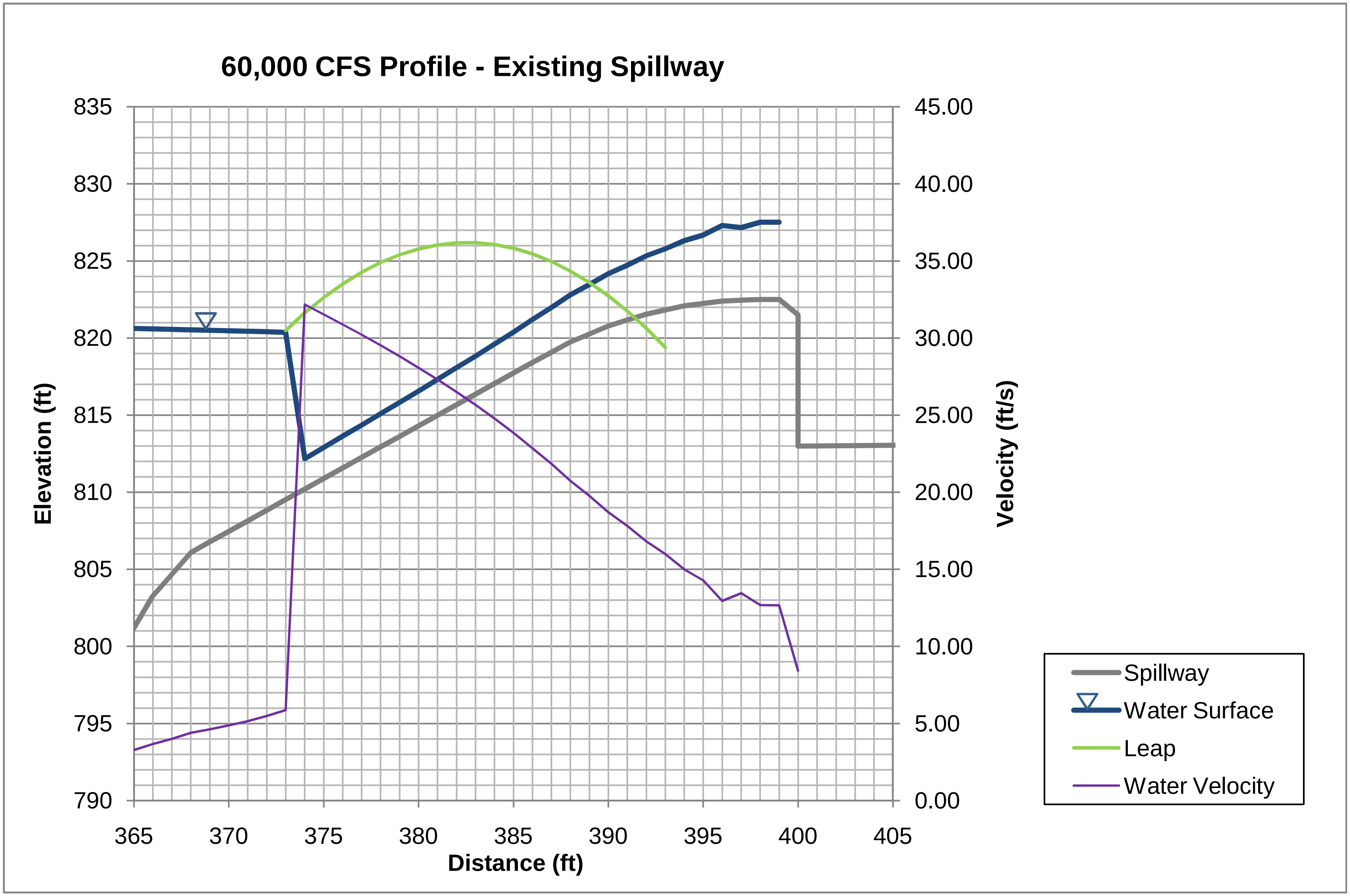
Distance (ft)
Spillway
Water Surface
Leap
Water Velocity



60,000 CFS Profile - Existing Spillway
Elevation (ft)
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Distance (ft)
Spillway
Water Surface
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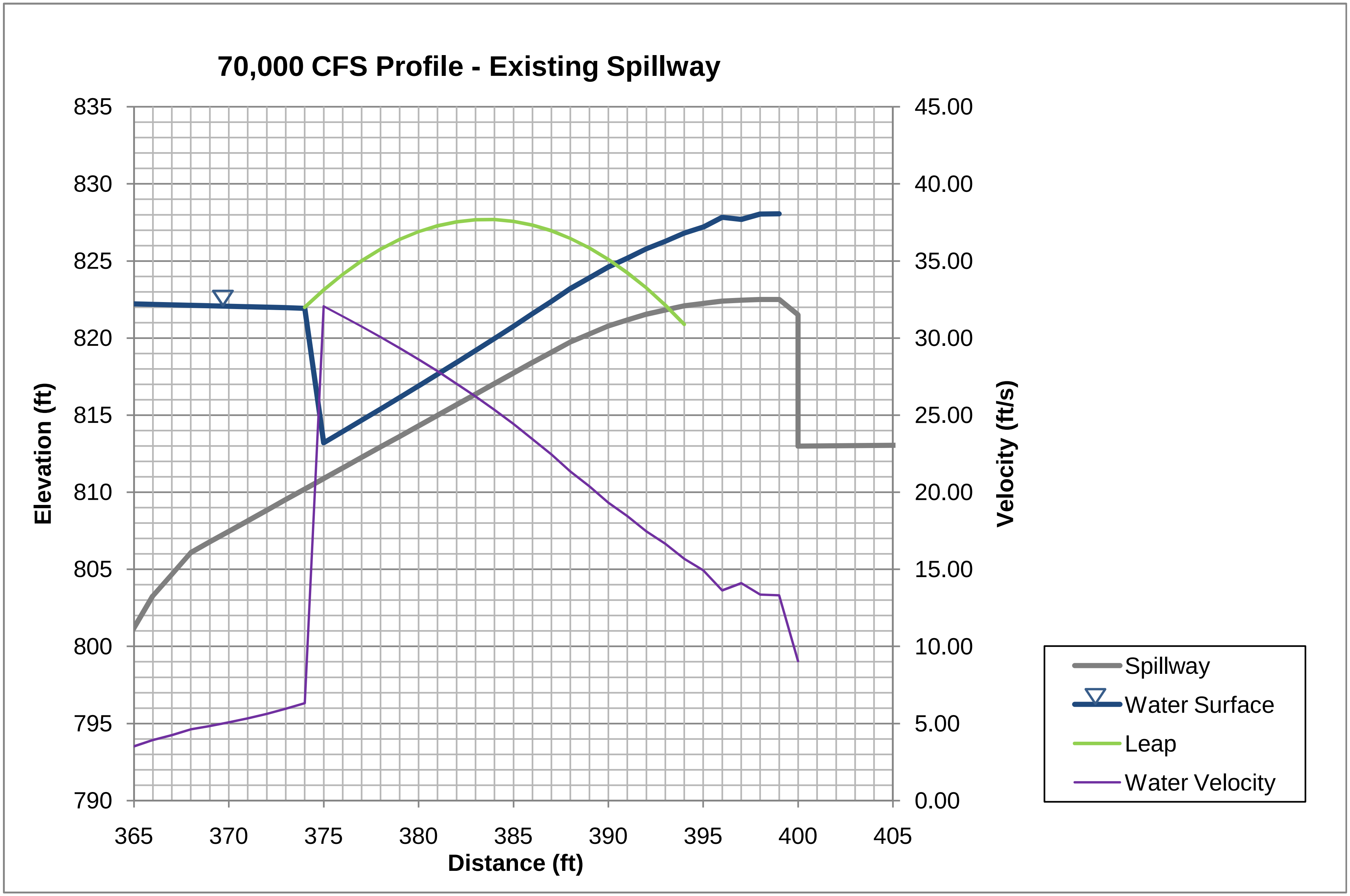
Water Velocity



70,000 CFS Profile - Existing Spillway
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Distance (ft)
Spillway
Water Surface
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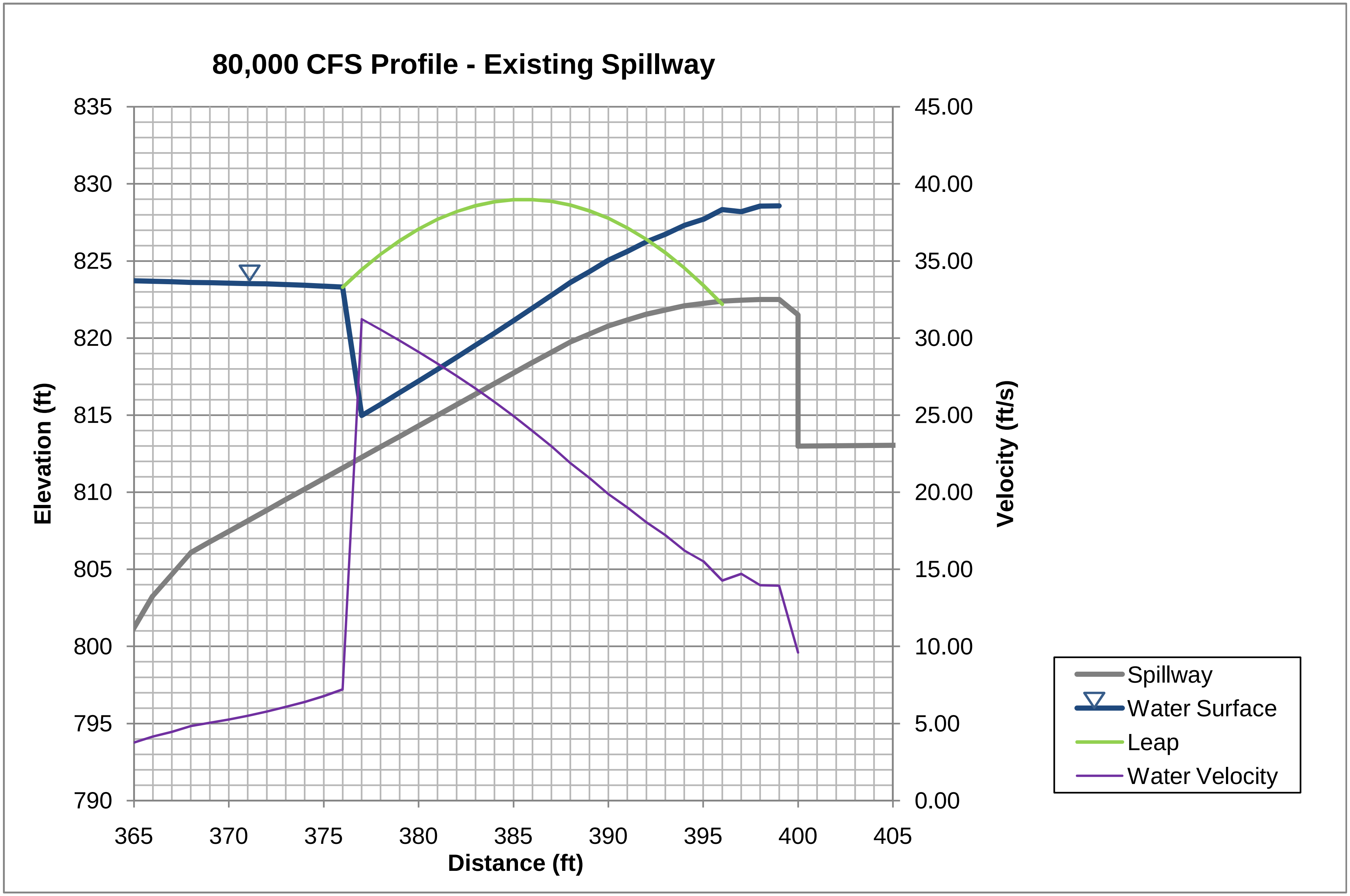
Water Velocity



80,000 CFS Profile - Existing Spillway
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Distance (ft)
Spillway
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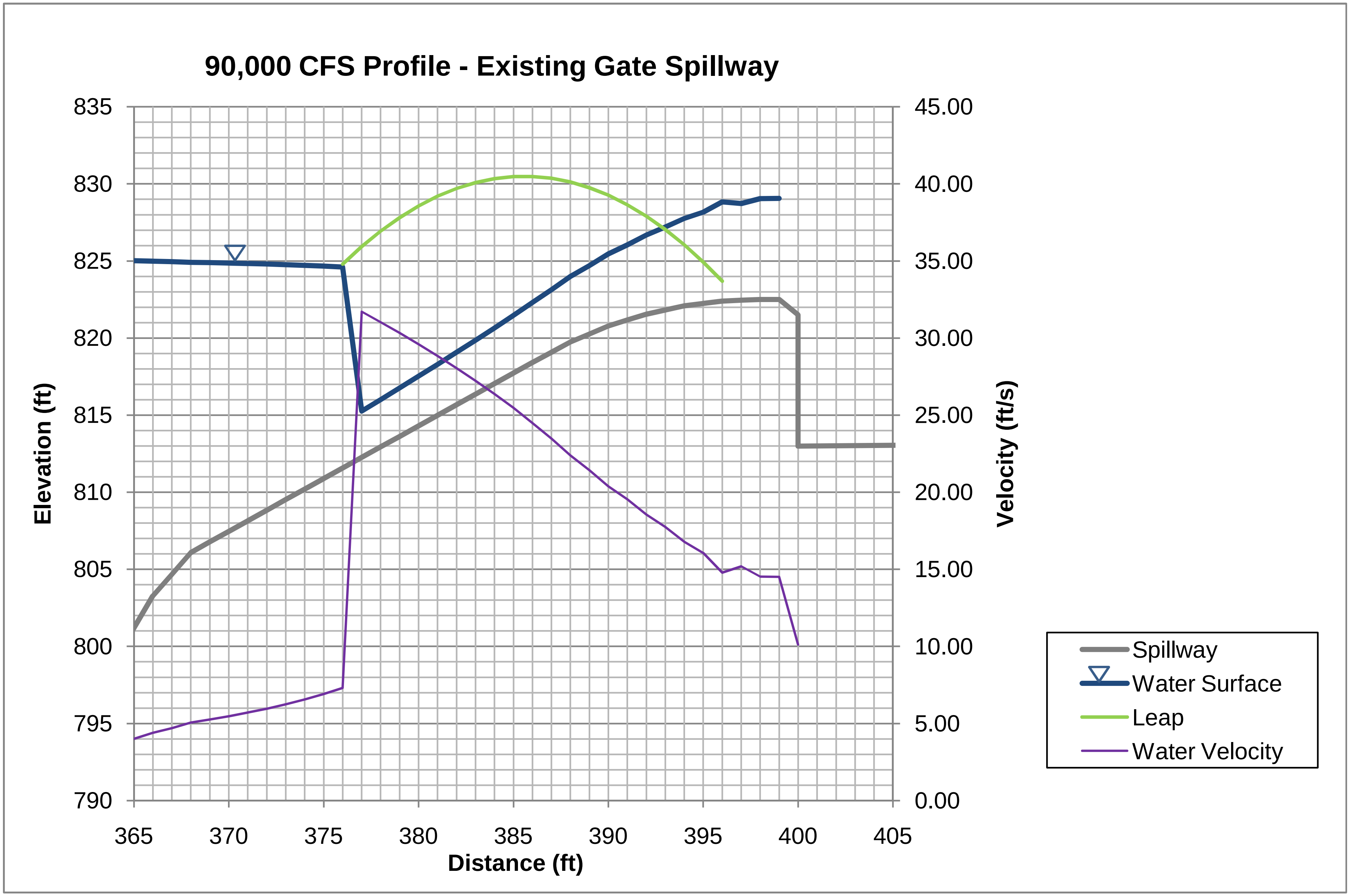

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Spillway
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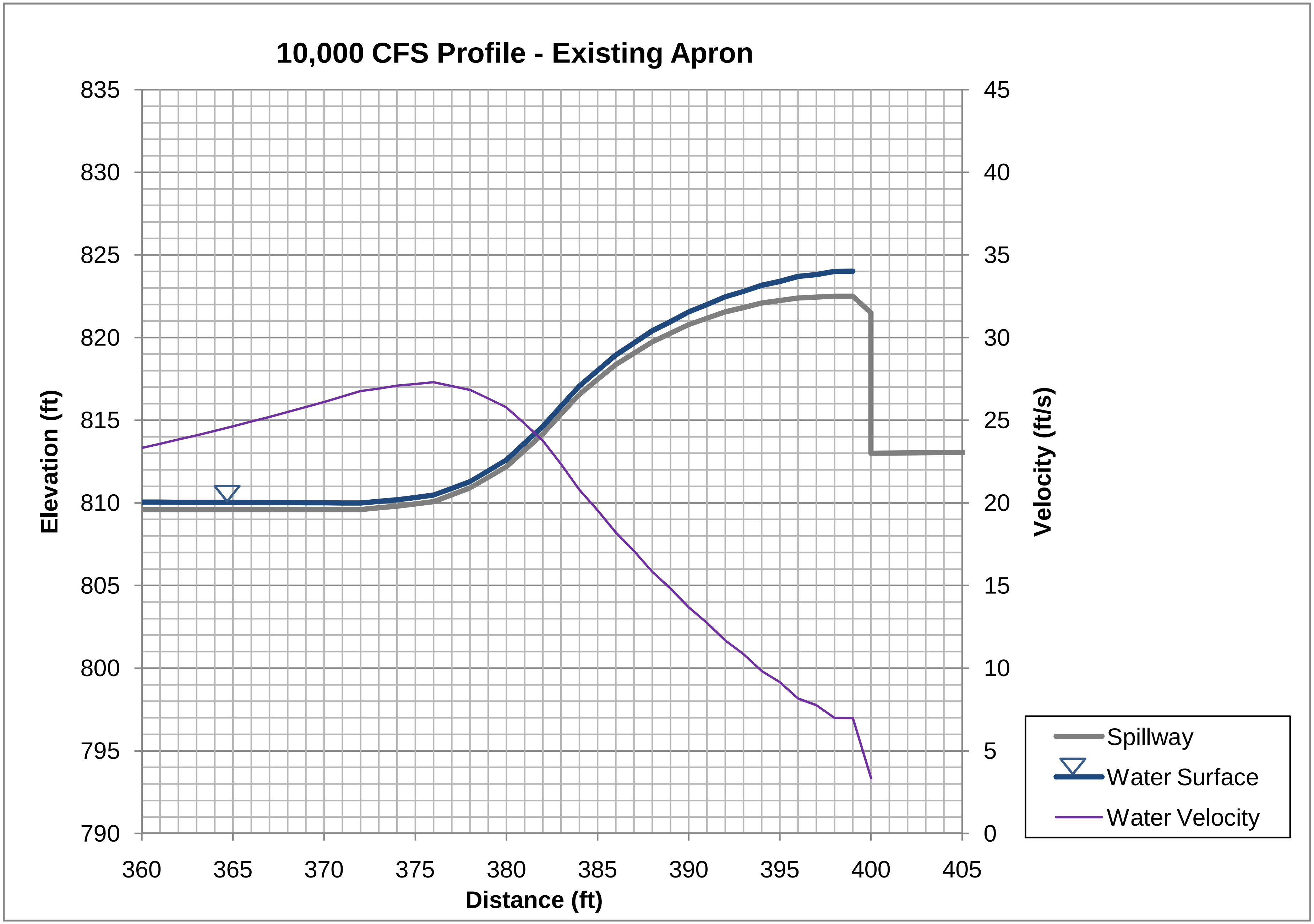
Leap
Water Velocity



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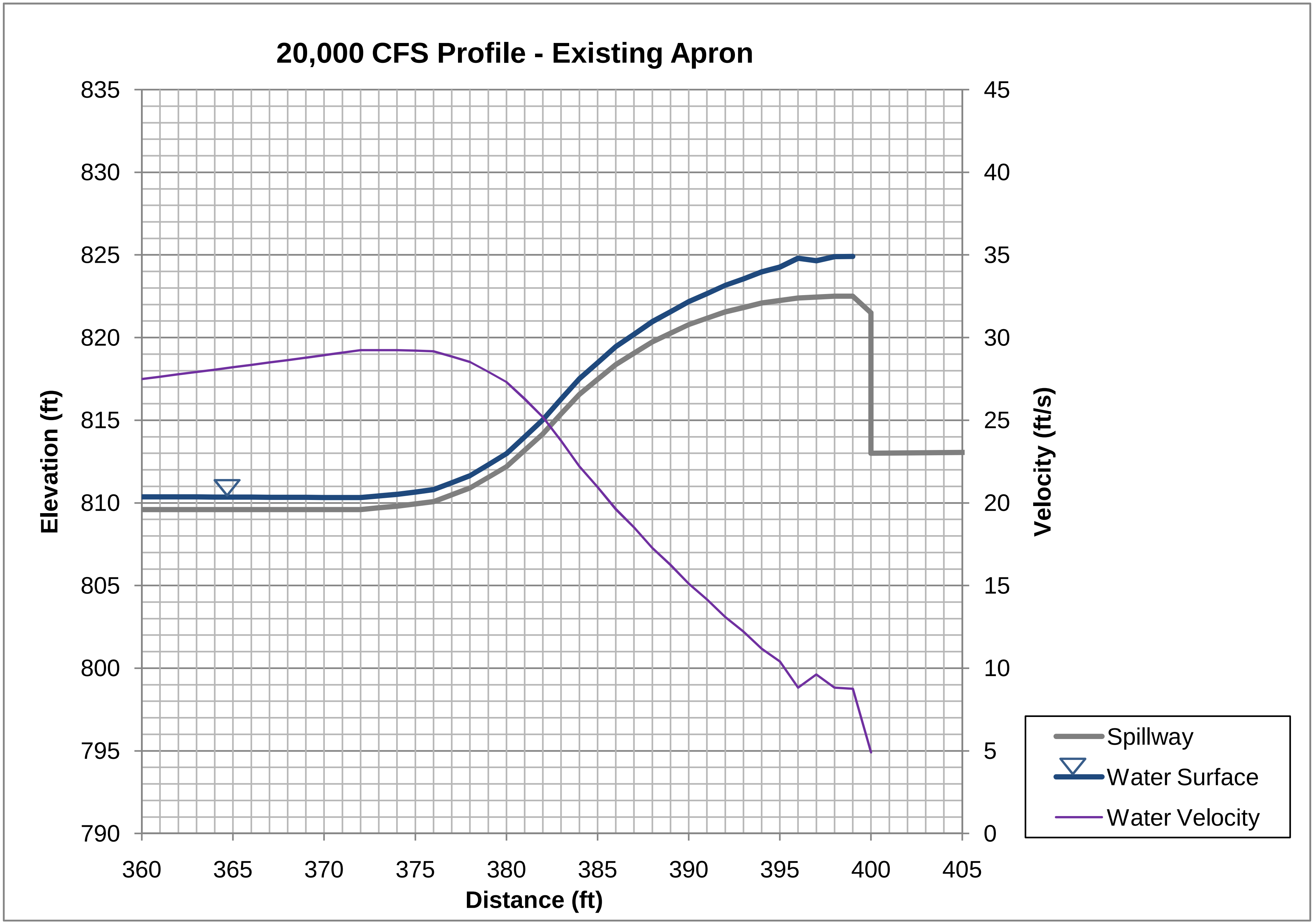
20,000 CFS Profile - Existing Apron
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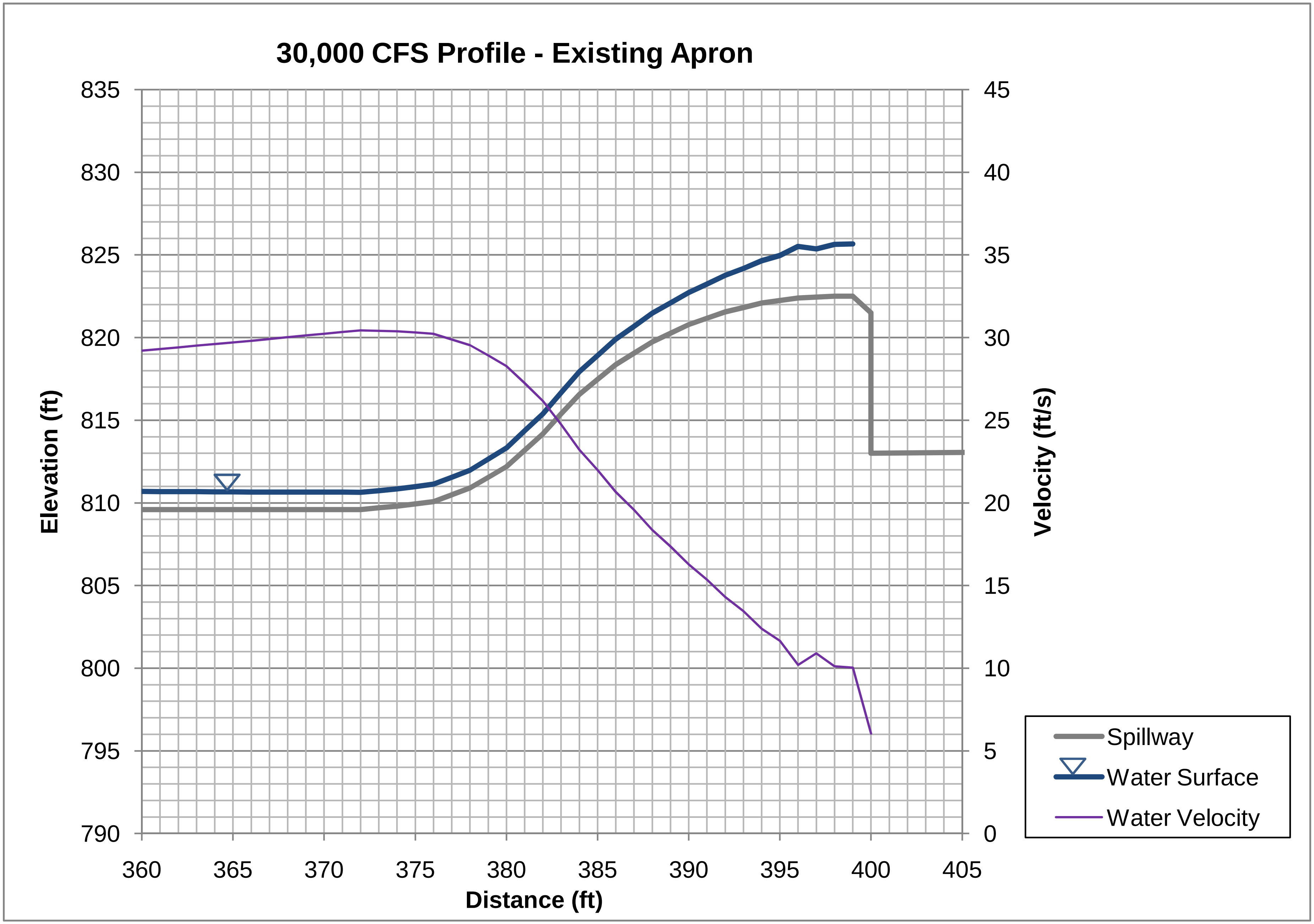

30,000 CFS Profile - Existing Apron
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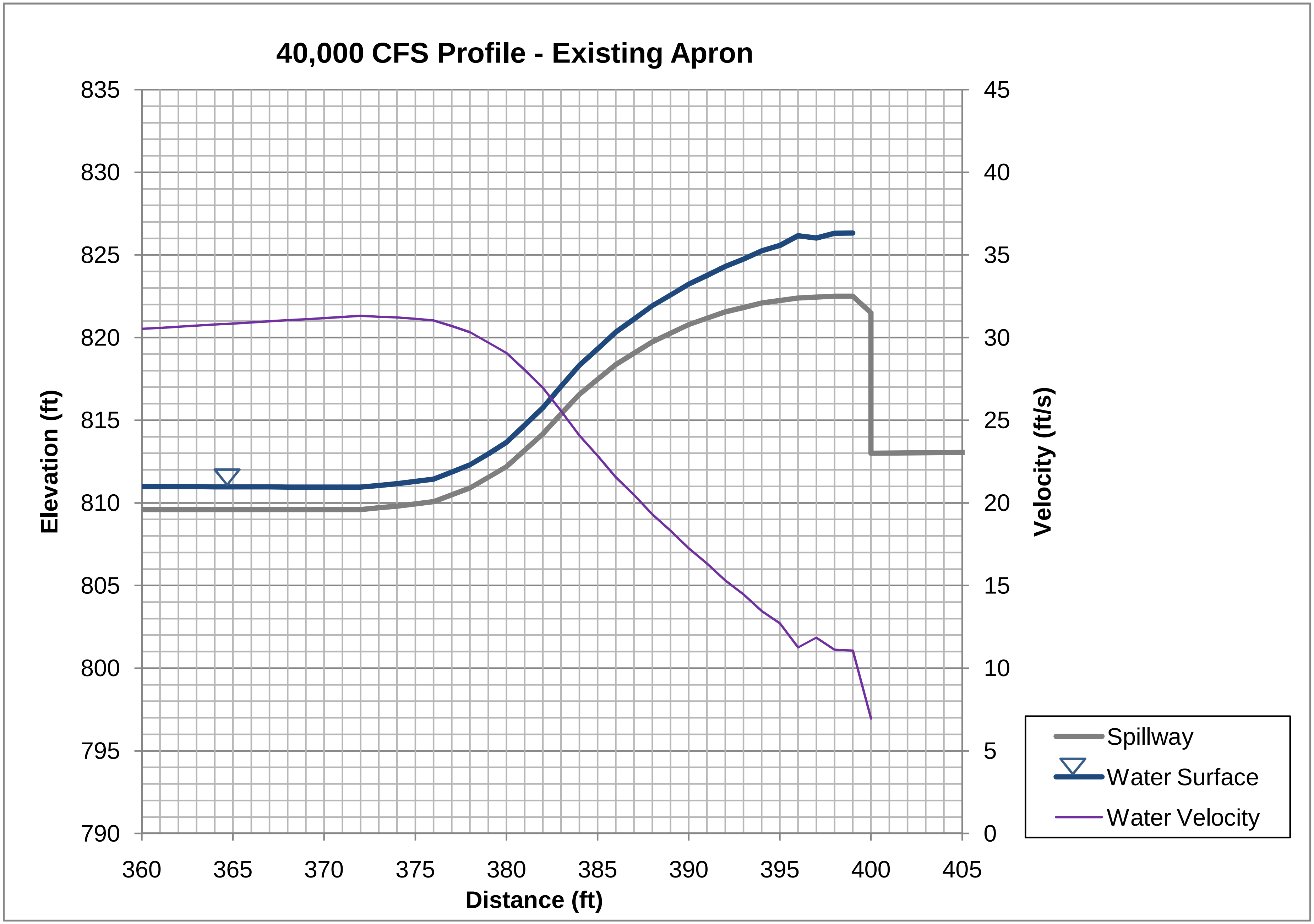
Water Velocity



40,000 CFS Profile - Existing Apron
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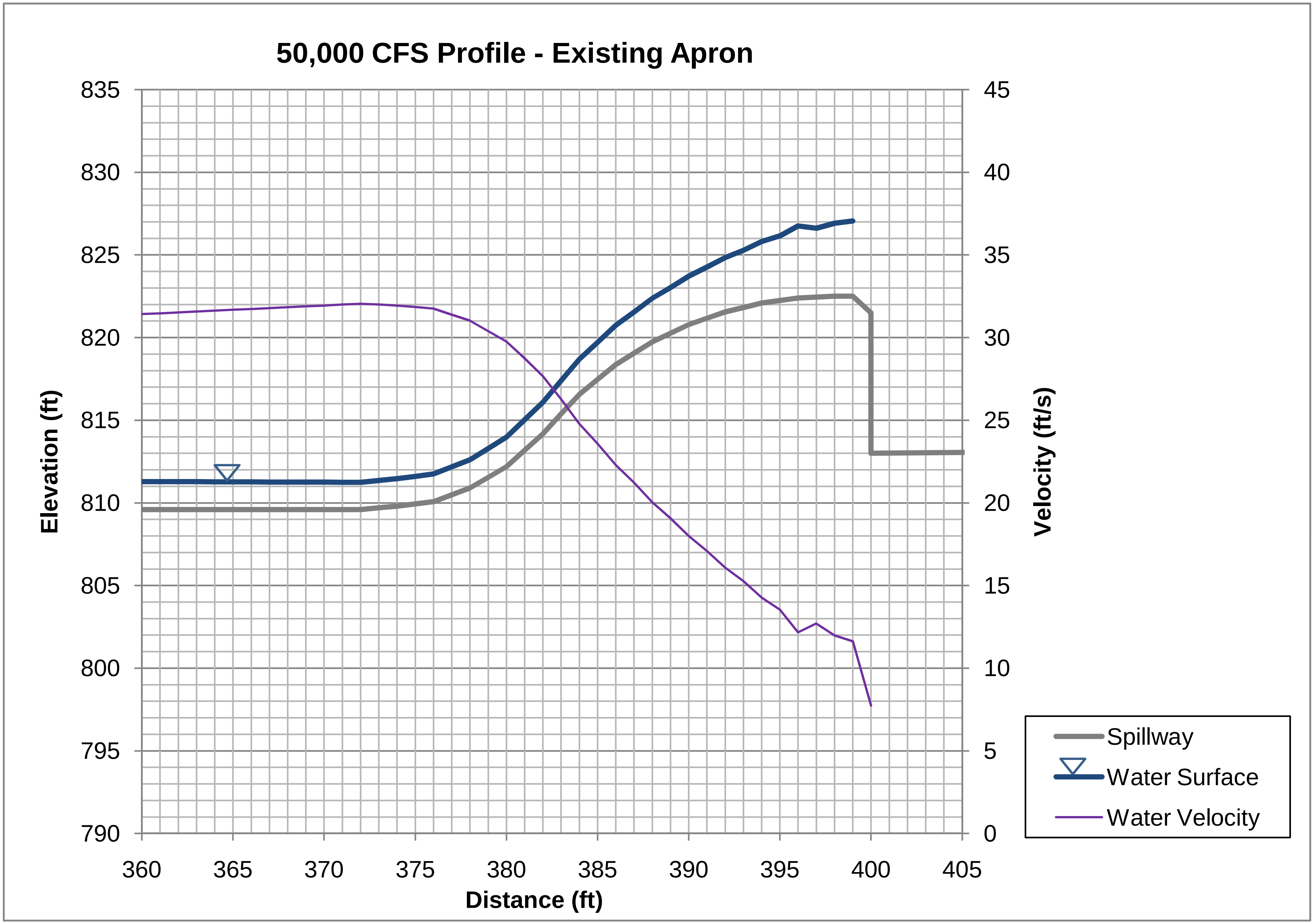
Distance (ft)
Spillway
Water Surface
Water Velocity



50,000 CFS Profile - Existing Apron
Elevation (ft)
Velocity (ft/s)
Distance (ft)
835
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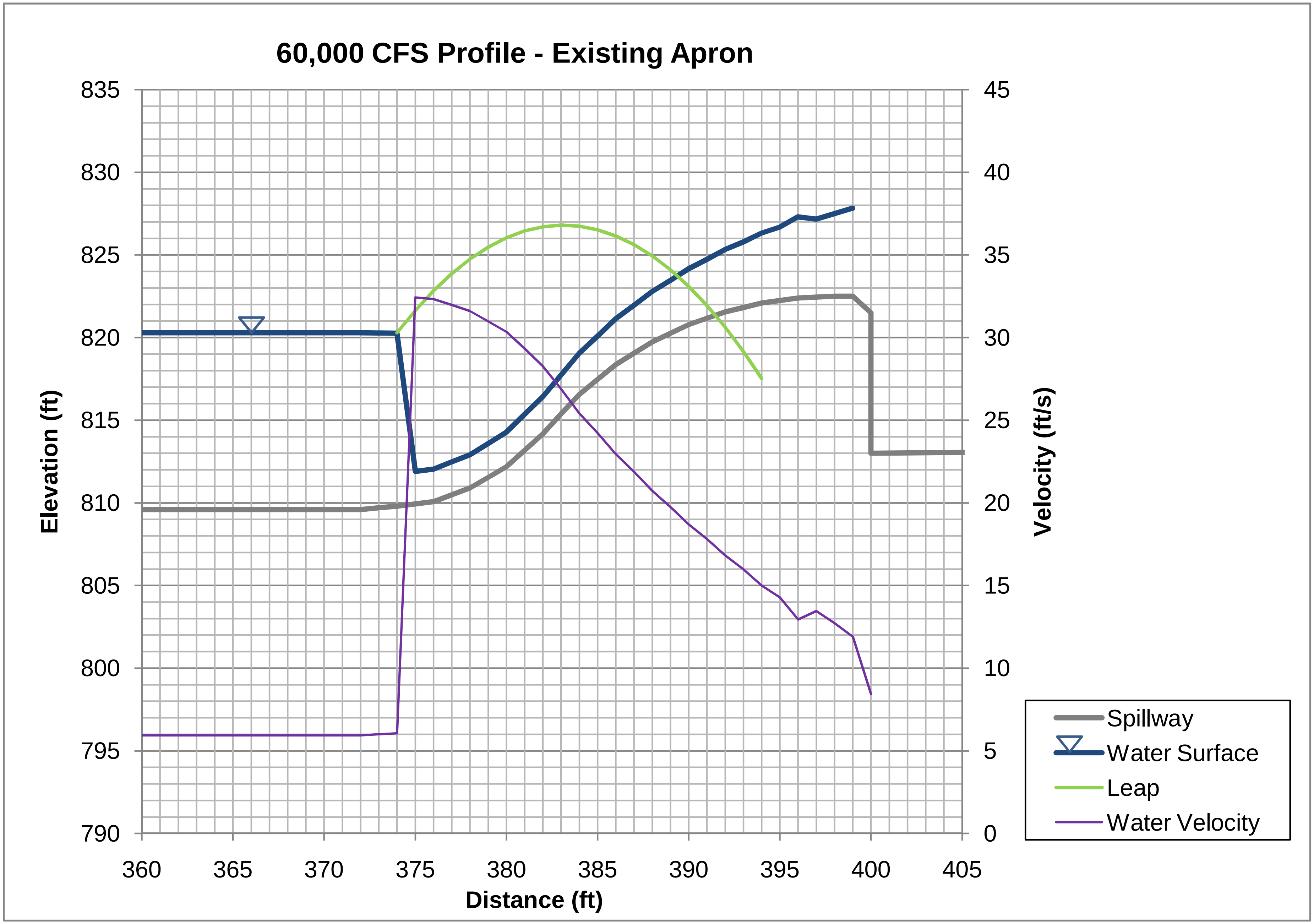
Spillway
Water Surface
Water Velocity


60,000 CFS Profile - Existing Apron
Elevation (ft)
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825
820
815
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805
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795
790
Velocity (ft/s)
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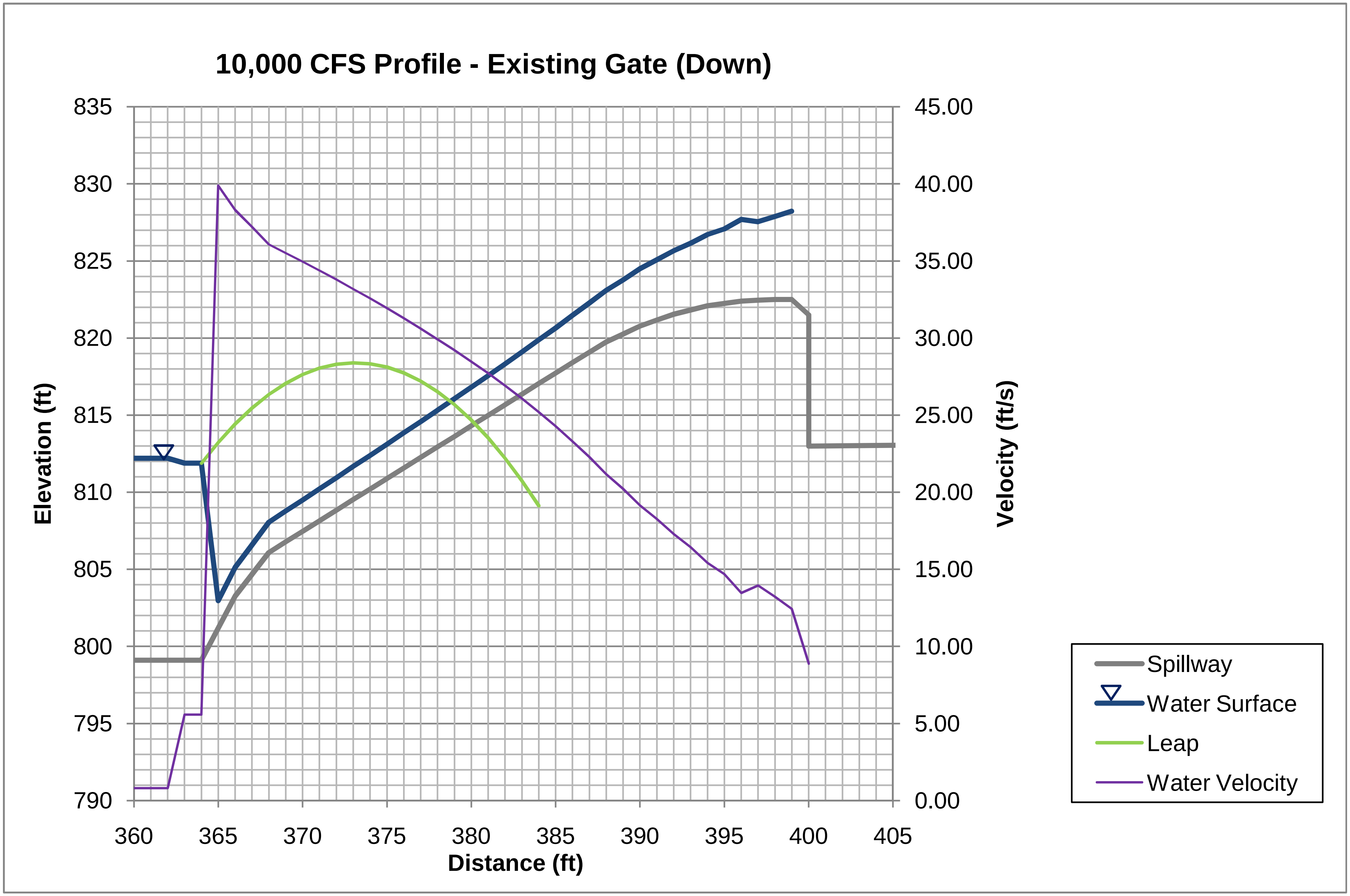
Distance (ft)
Spillway
Water Surface
Leap
Water Velocity


10,000 CFS Profile - Existing Gate (Down)
Elevation (ft)
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820
815
810
805
800
795
790
Velocity (ft/s)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
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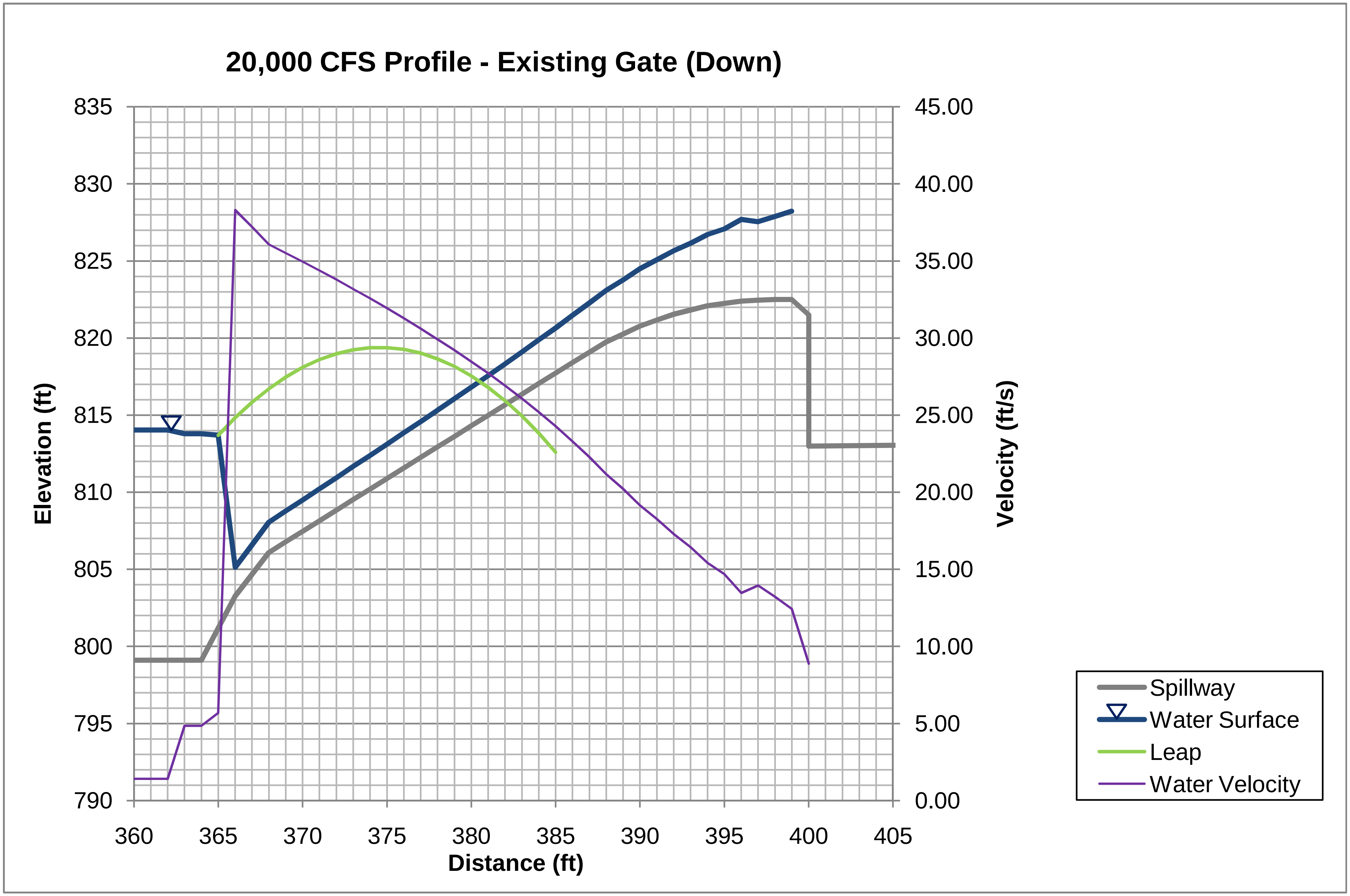
Distance (ft)
Spillway
Water Surface
Leap
Water Velocity



20,000 CFS Profile - Existing Gate (Down)
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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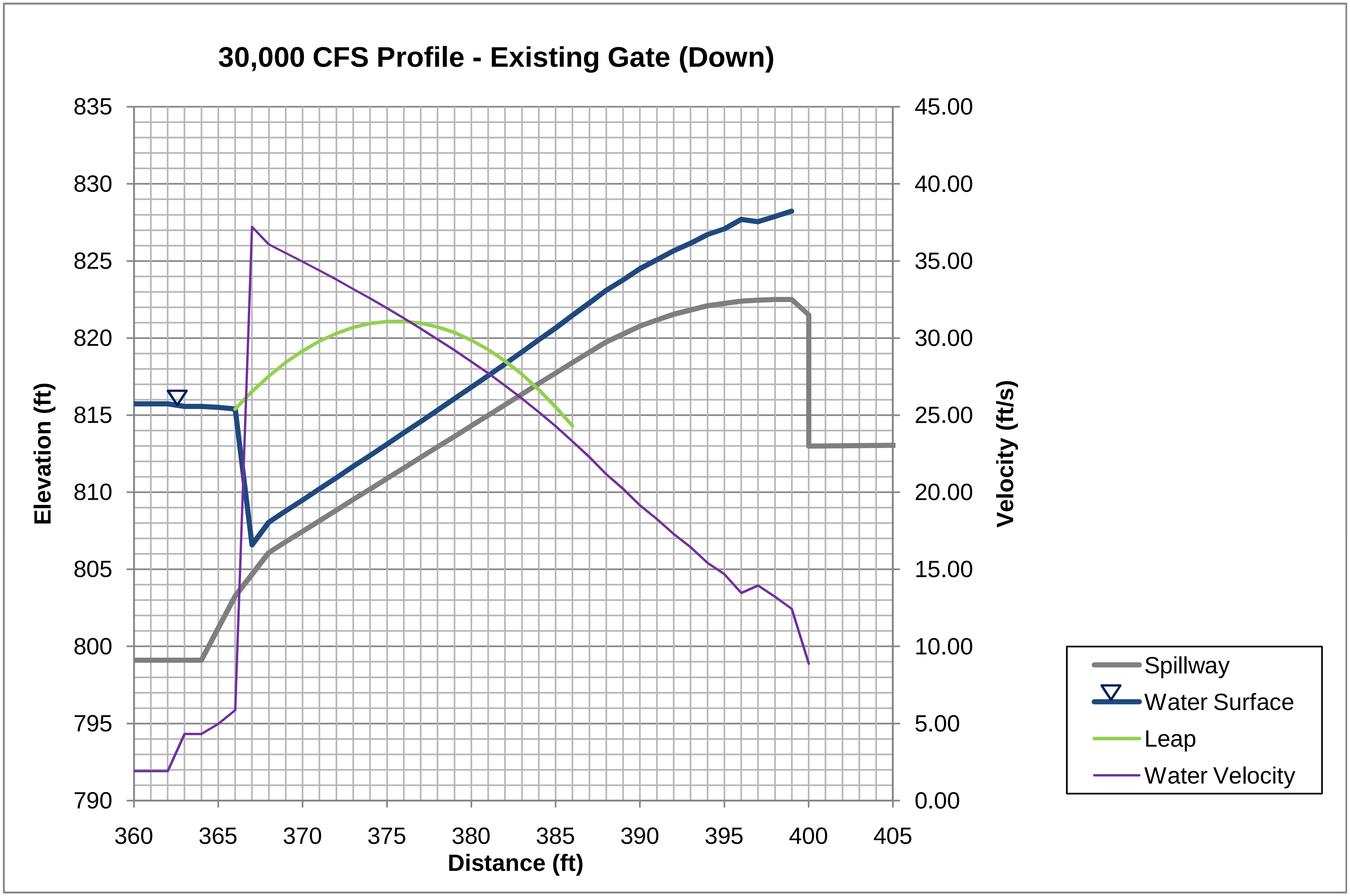
Spillway
Water Surface
Leap
Water Velocity



30,000 CFS Profile - Existing Gate (Down)
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Velocity (ft/s)
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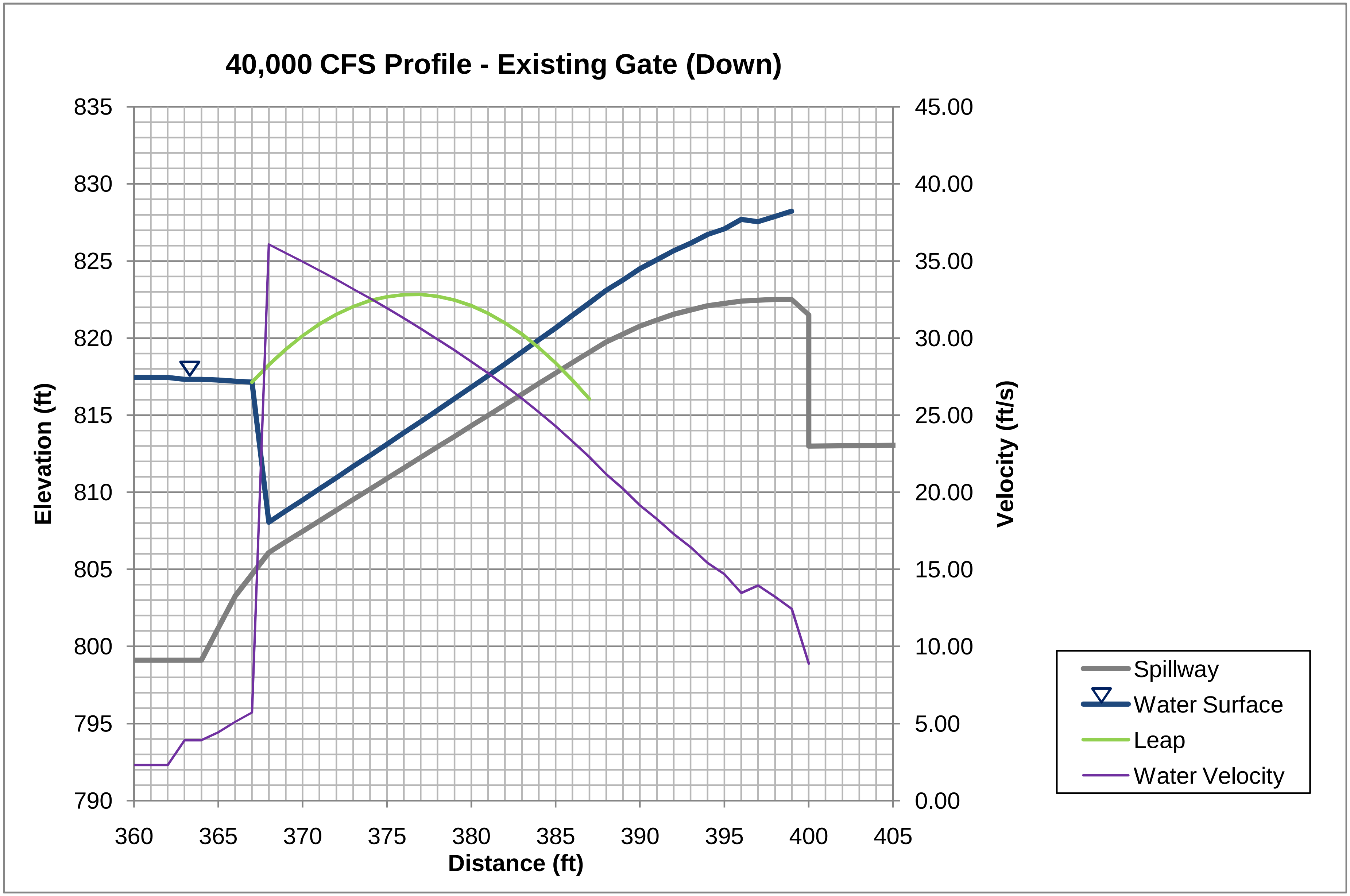
Distance (ft)
Spillway
Water Surface
Leap
Water Velocity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Elevation (ft)
Velocity (ft/s)
Distance (ft)
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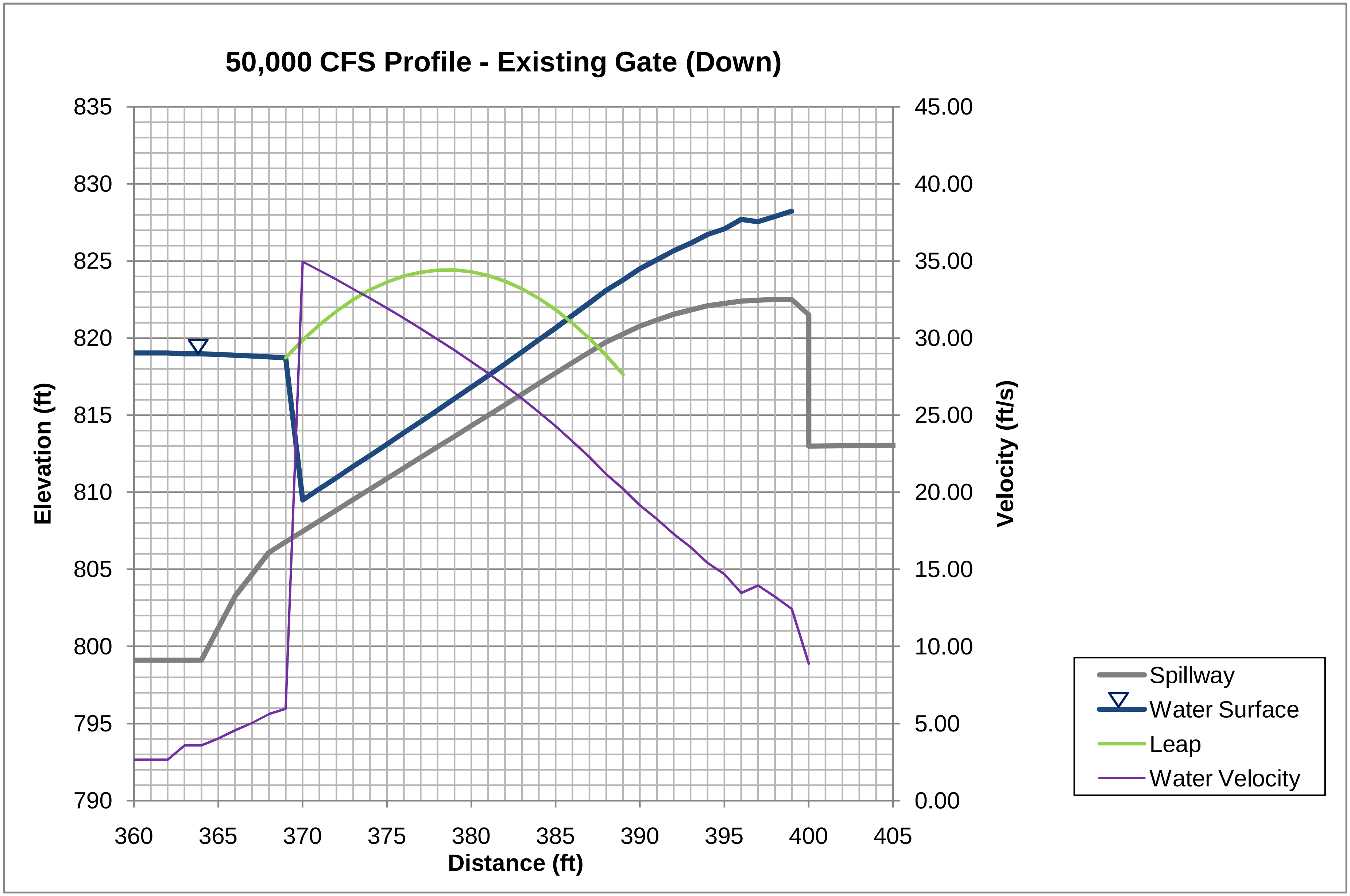
Spillway
Water Surface
Leap
Water Velocity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Elevation (ft)
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Velocity (ft/s)
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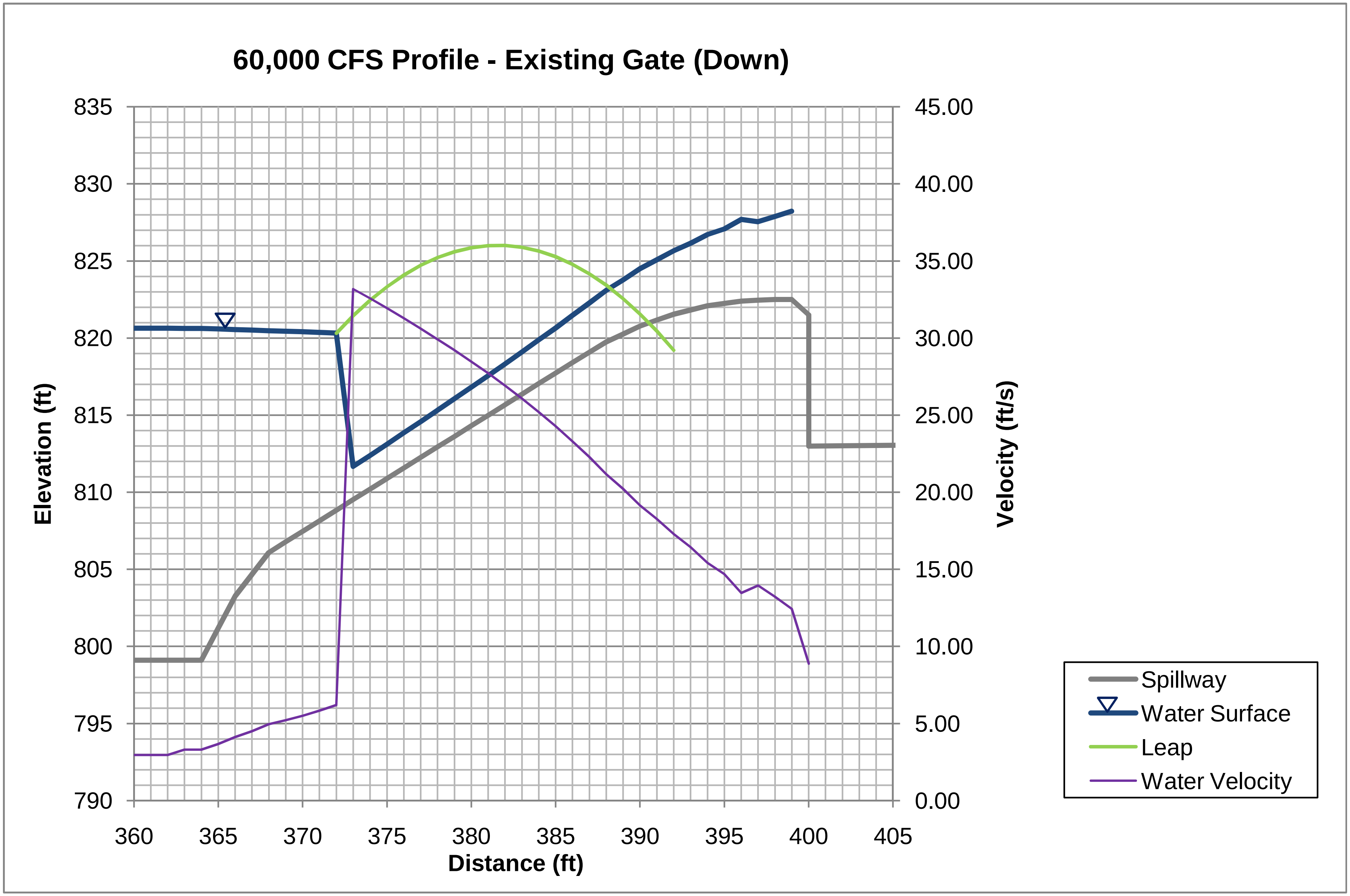
Distance (ft)
Spillway
Water Surface
Leap
Water Velocity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Elevation (ft)
Velocity (ft/s)
Distance (ft)
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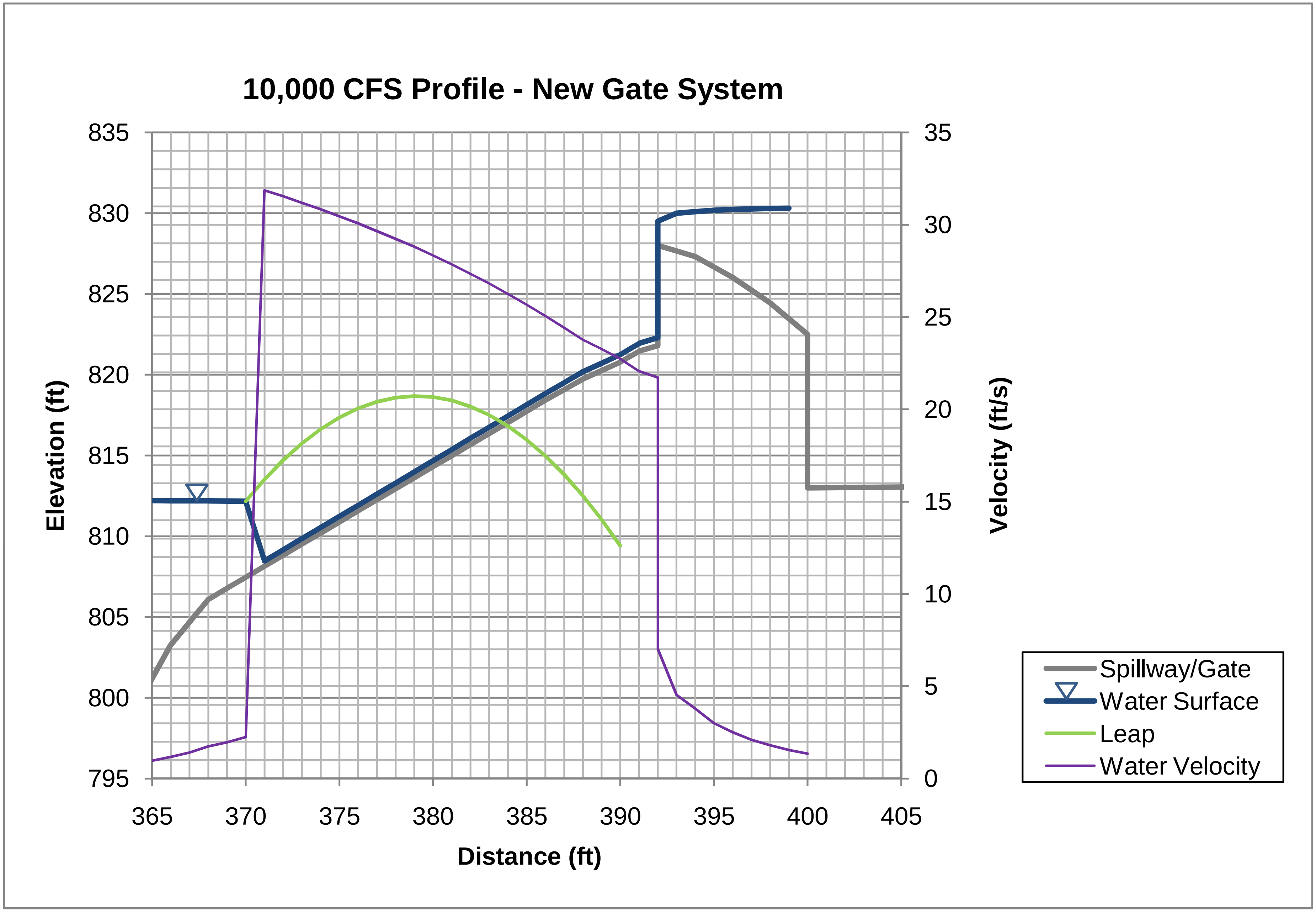
Spillway
Water Surface
Leap
Water Velocity


10,000 CFS Profile - New Gate System
Elevation (ft)
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Velocity (ft/s)
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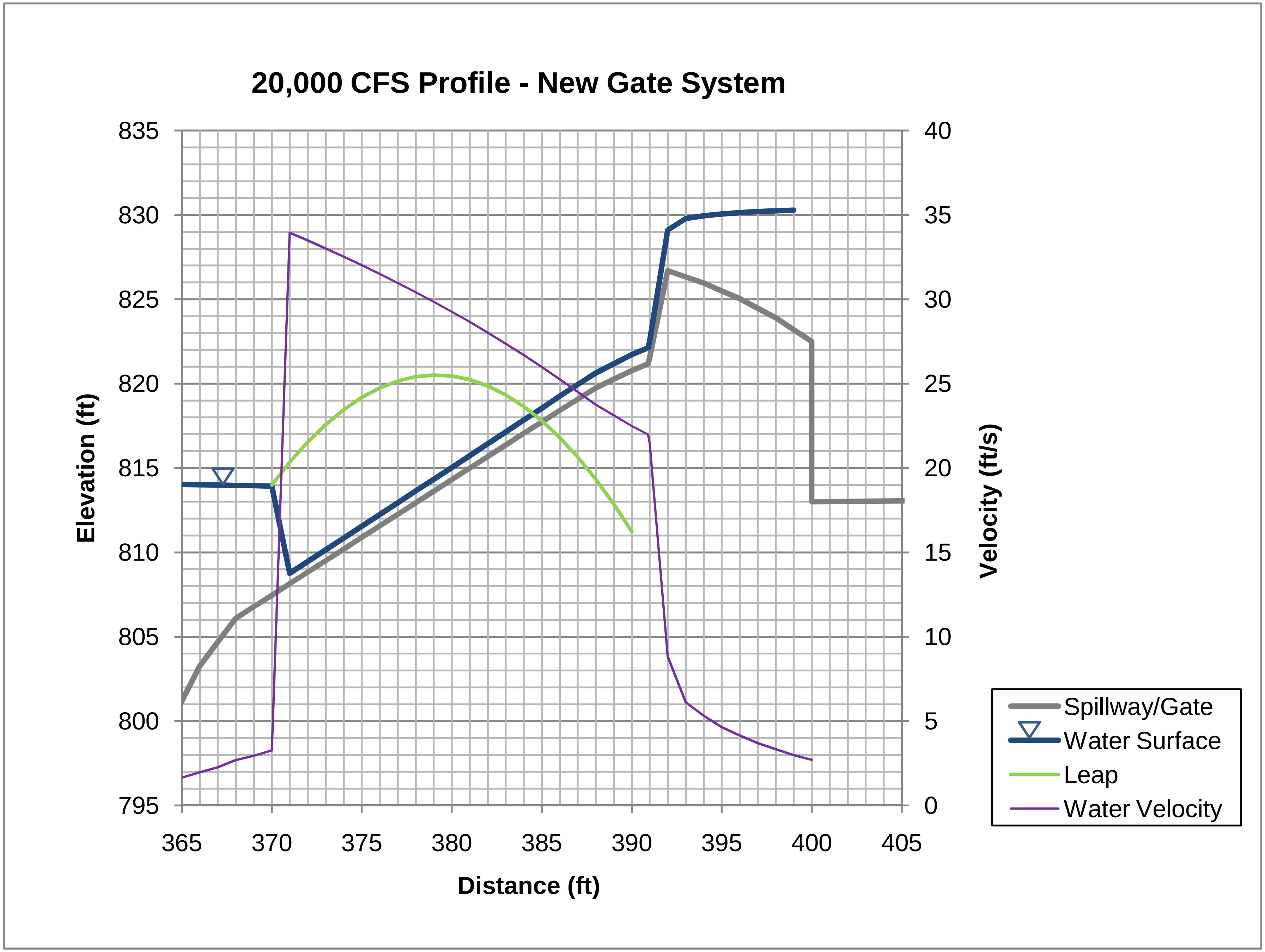
Distance (ft)
Spillway/Gate
Water Surface
Leap
Water Velocity



20,000 CFS Profile - New Gate System
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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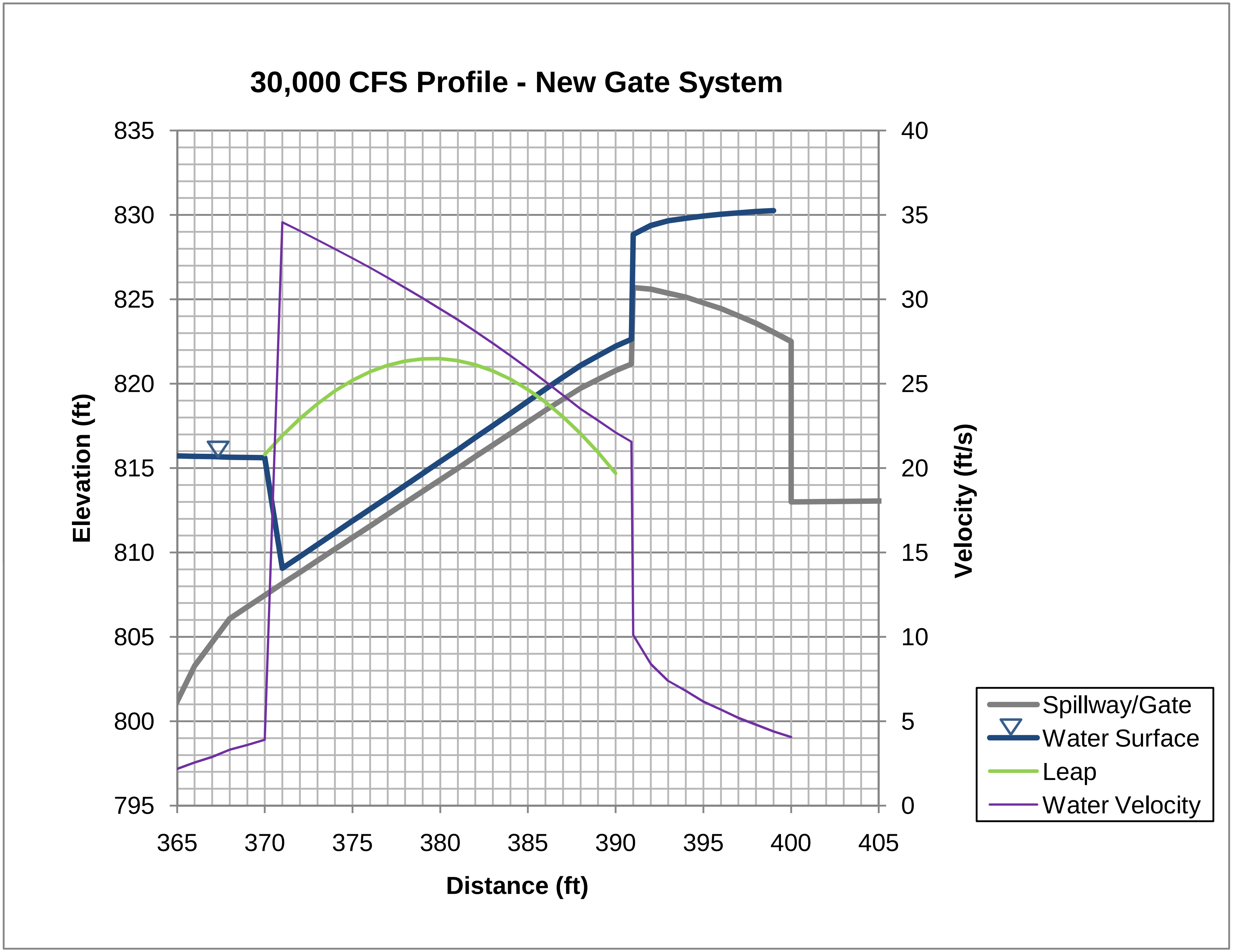
Spillway/Gate
Water Surface
Leap
Water Velocity


30,000 CFS Profile - New Gate System
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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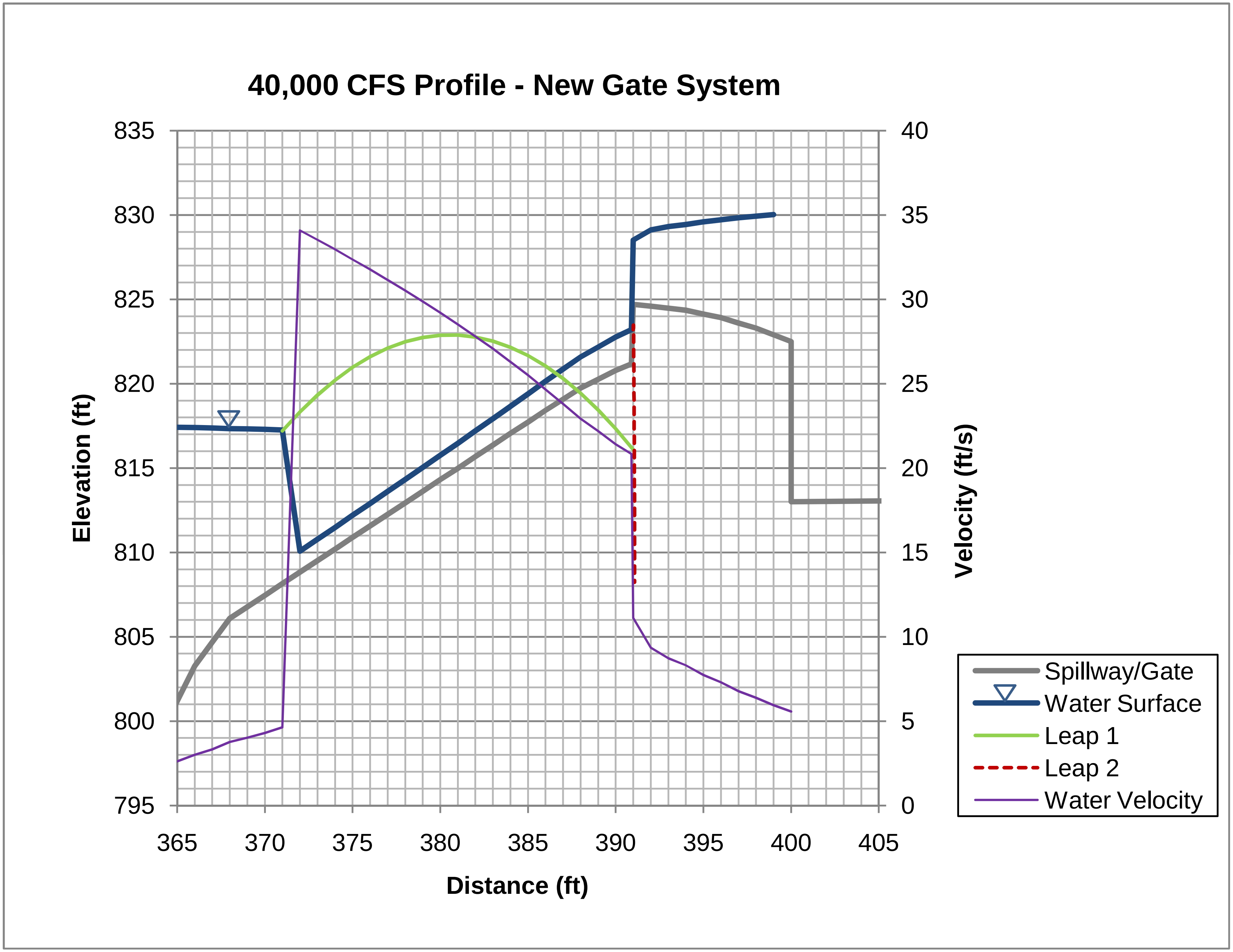
Spillway/Gate
Water Surface
Leap
Water Velocity



40,000 CFS Profile - New Gate System
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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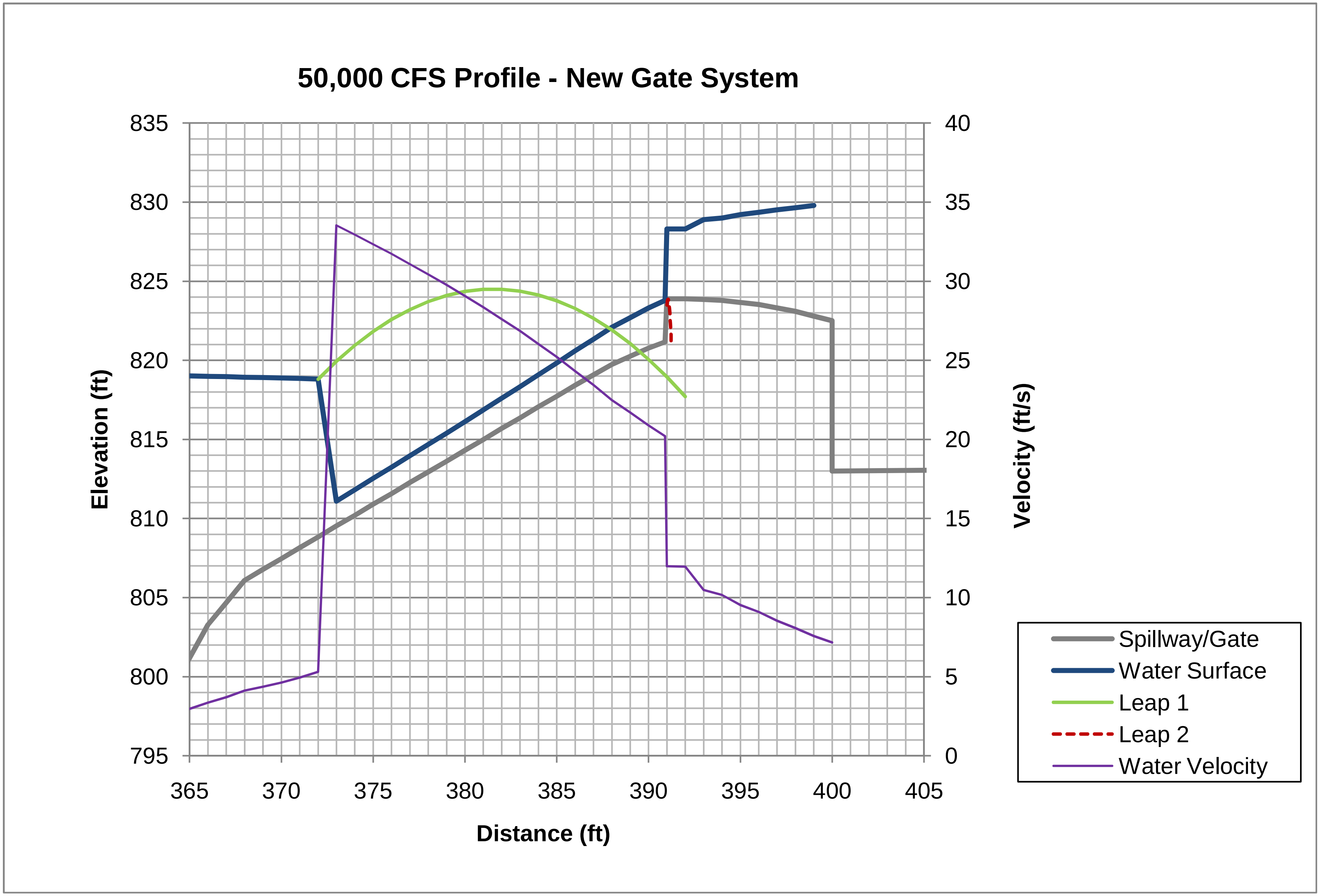
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity


50,000 CFS Profile - New Gate System
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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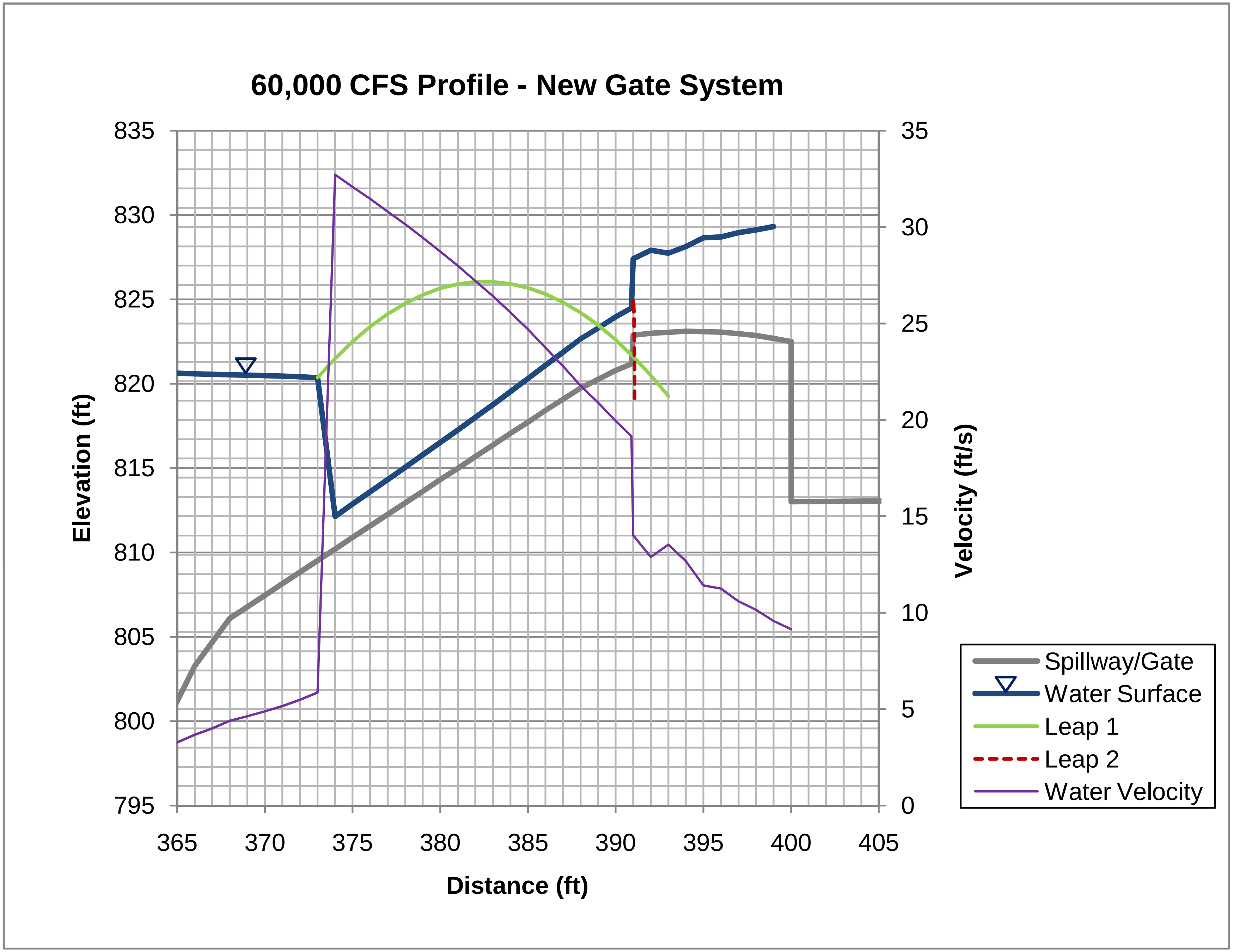
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity



60,000 CFS Profile - New Gate System
Elevation (ft)
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Velocity (ft/s)
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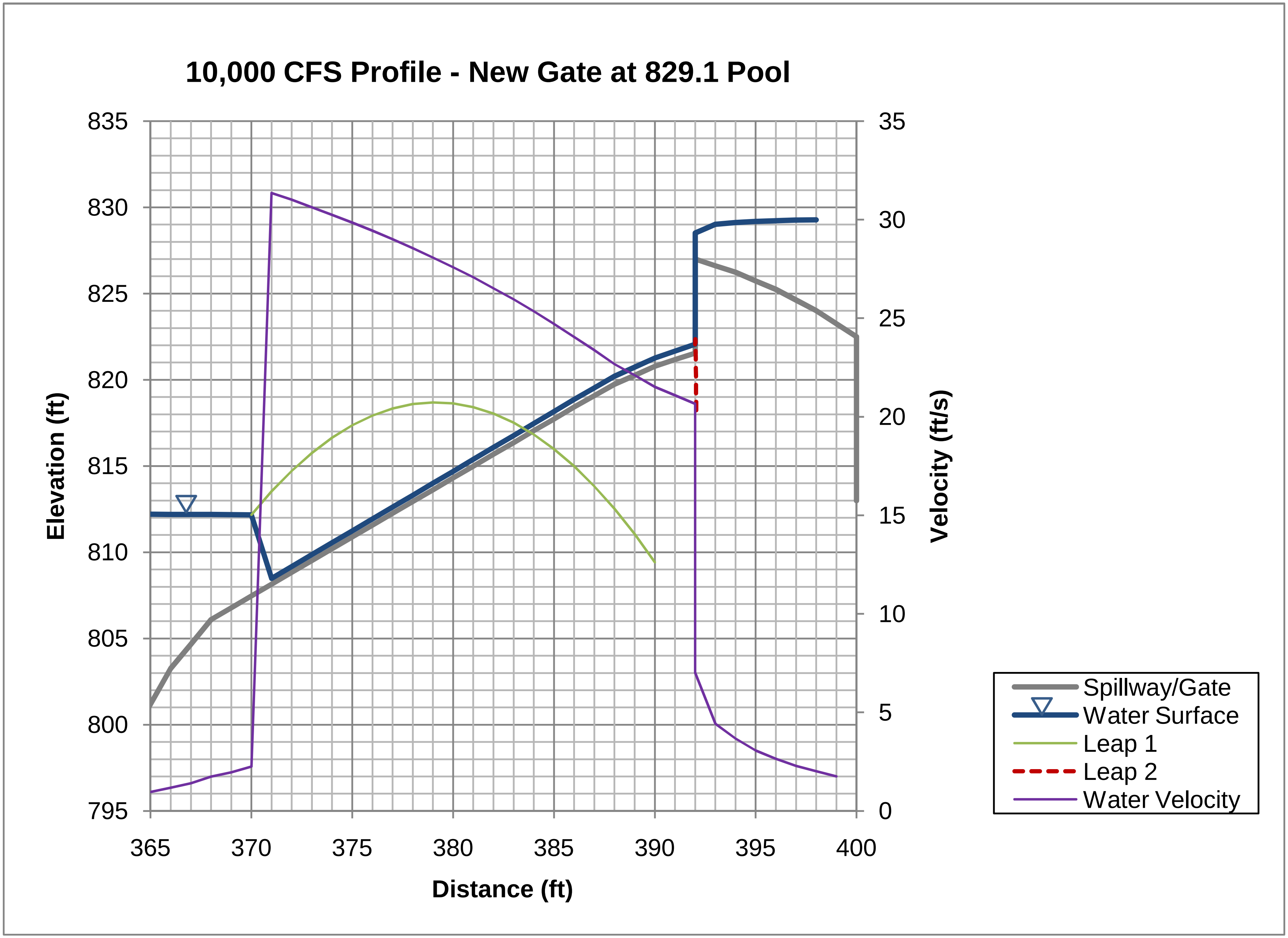
Distance (ft)
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity


10,000 CFS Profile - New Gate at 829.1 Pool
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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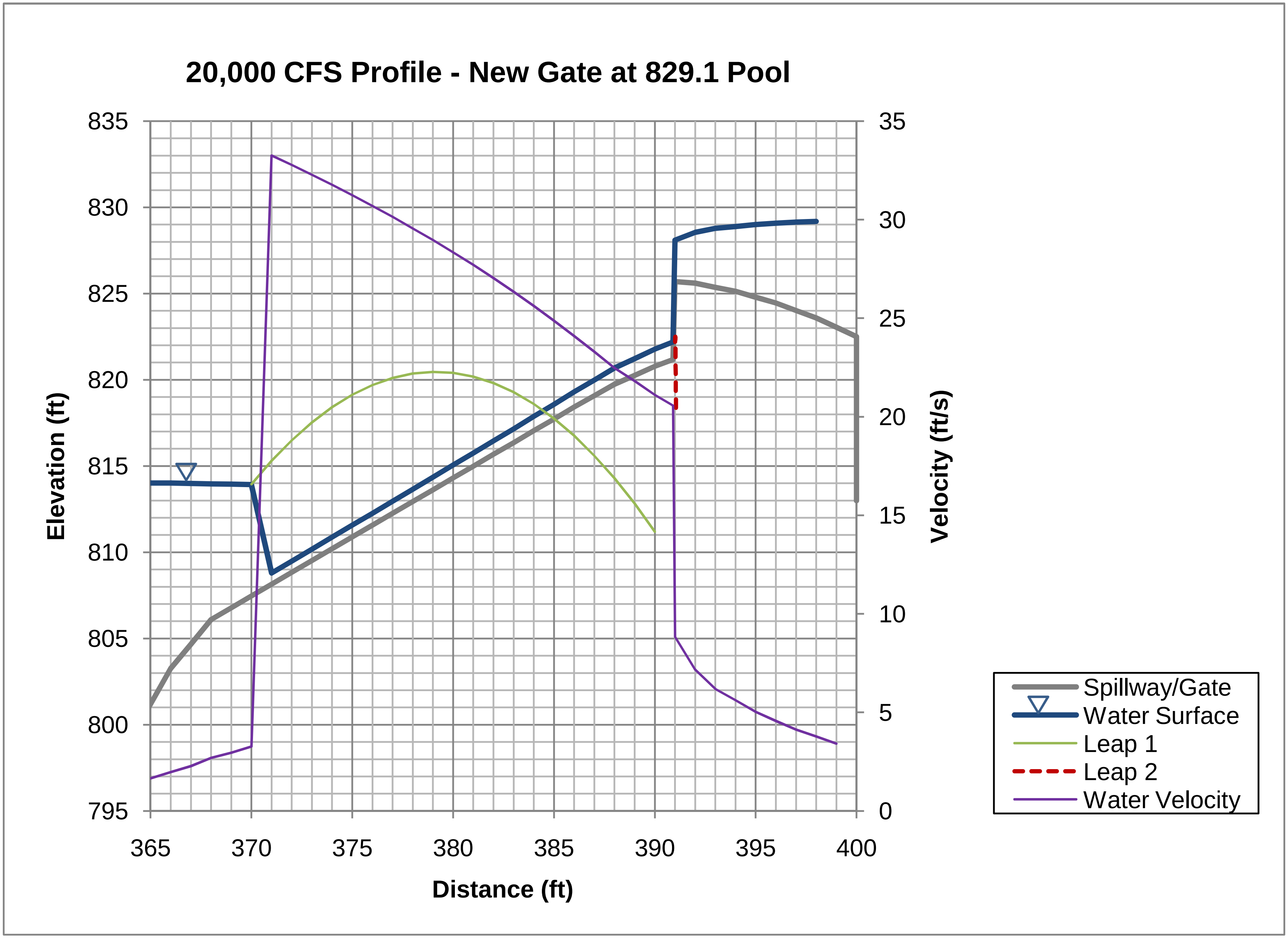
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity



20,000 CFS Profile - New Gate at 829.1 Pool
Elevation (ft)
835
830
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795
Velocity (ft/s)
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395
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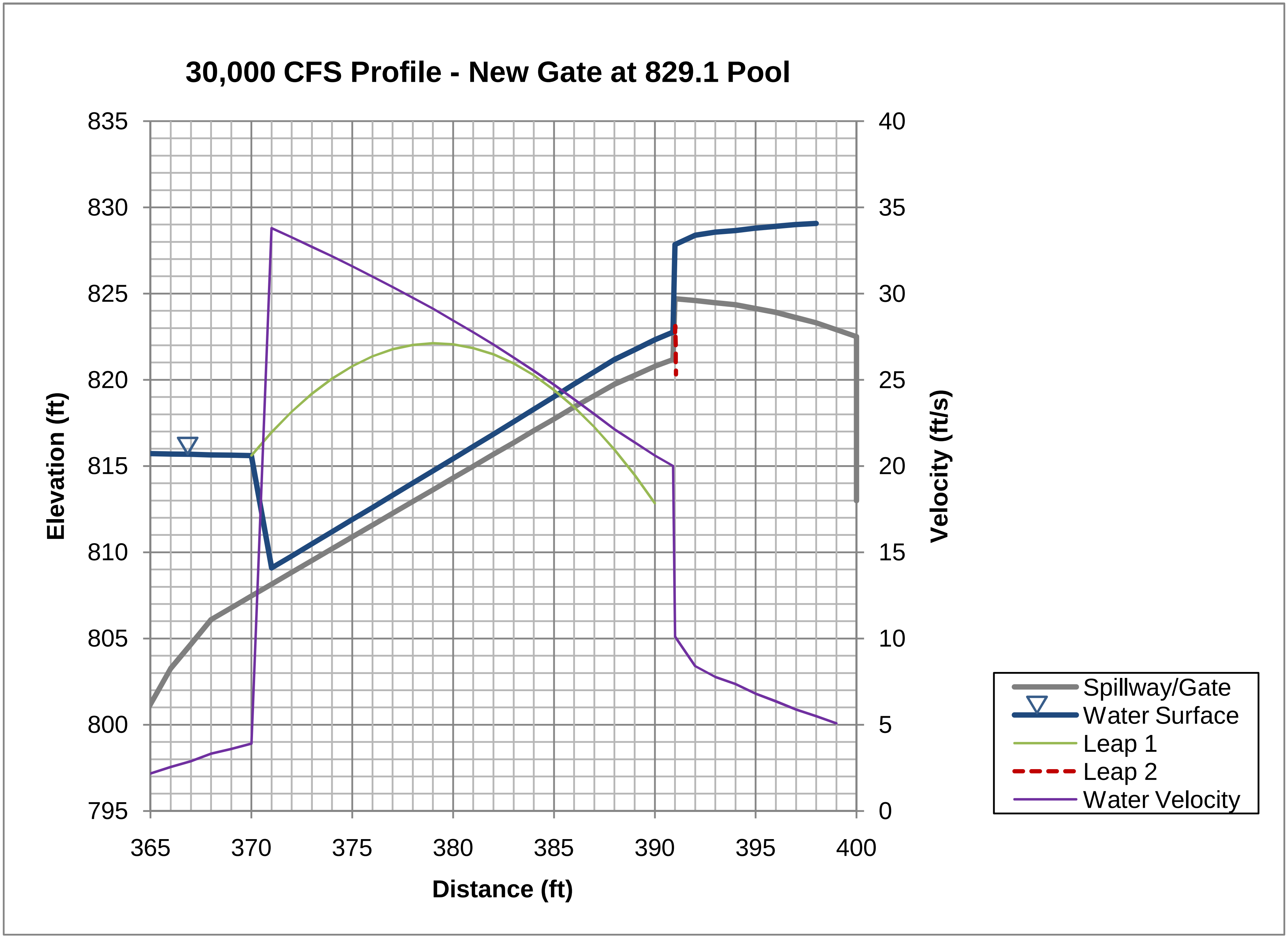
Distance (ft)
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity



30,000 CFS Profile - New Gate at 829.1 Pool
Elevation (ft)
Velocity (ft/s)
Distance (ft)
835
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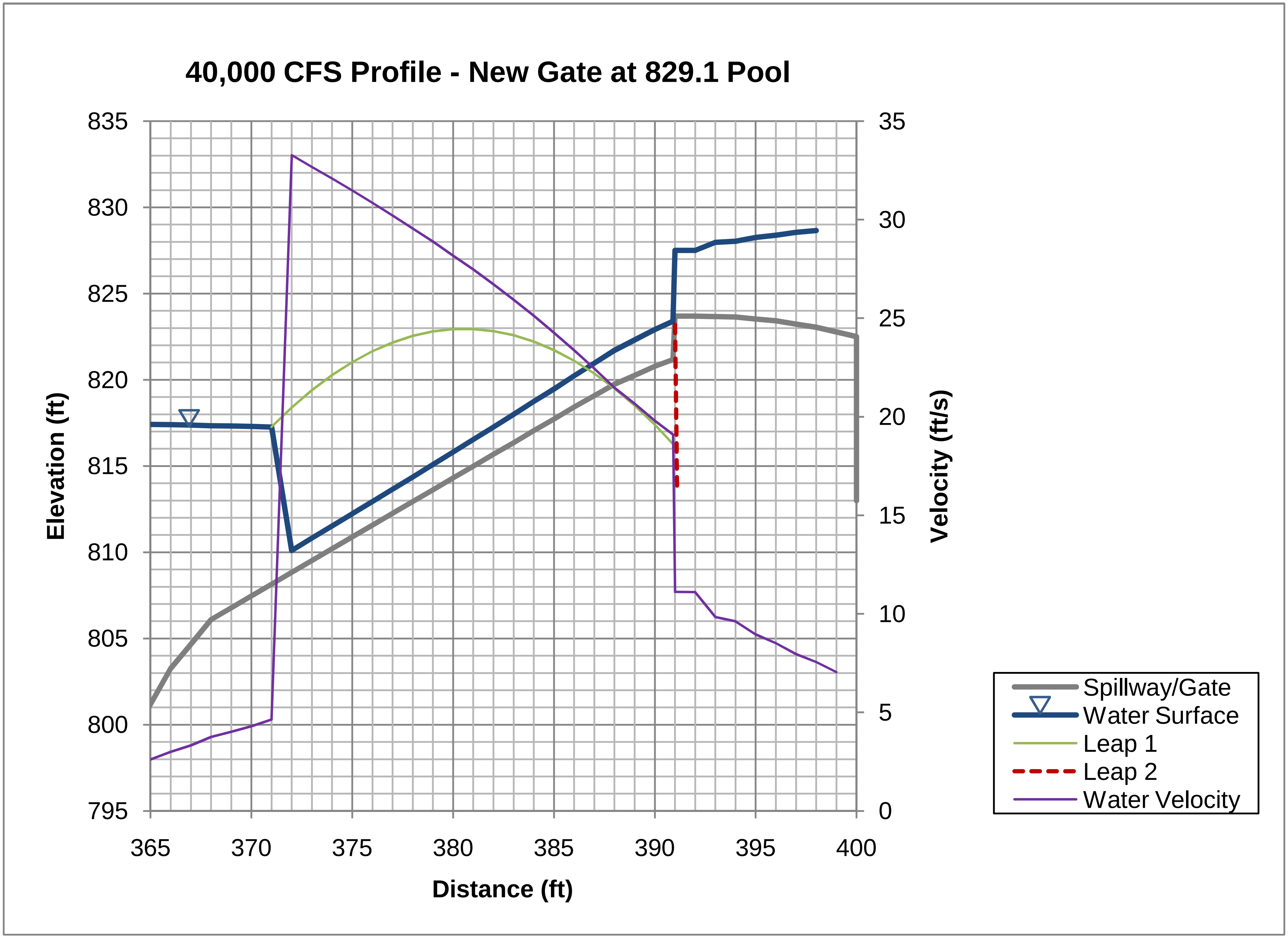
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity


40,000 CFS Profile - New Gate at 829.1 Pool
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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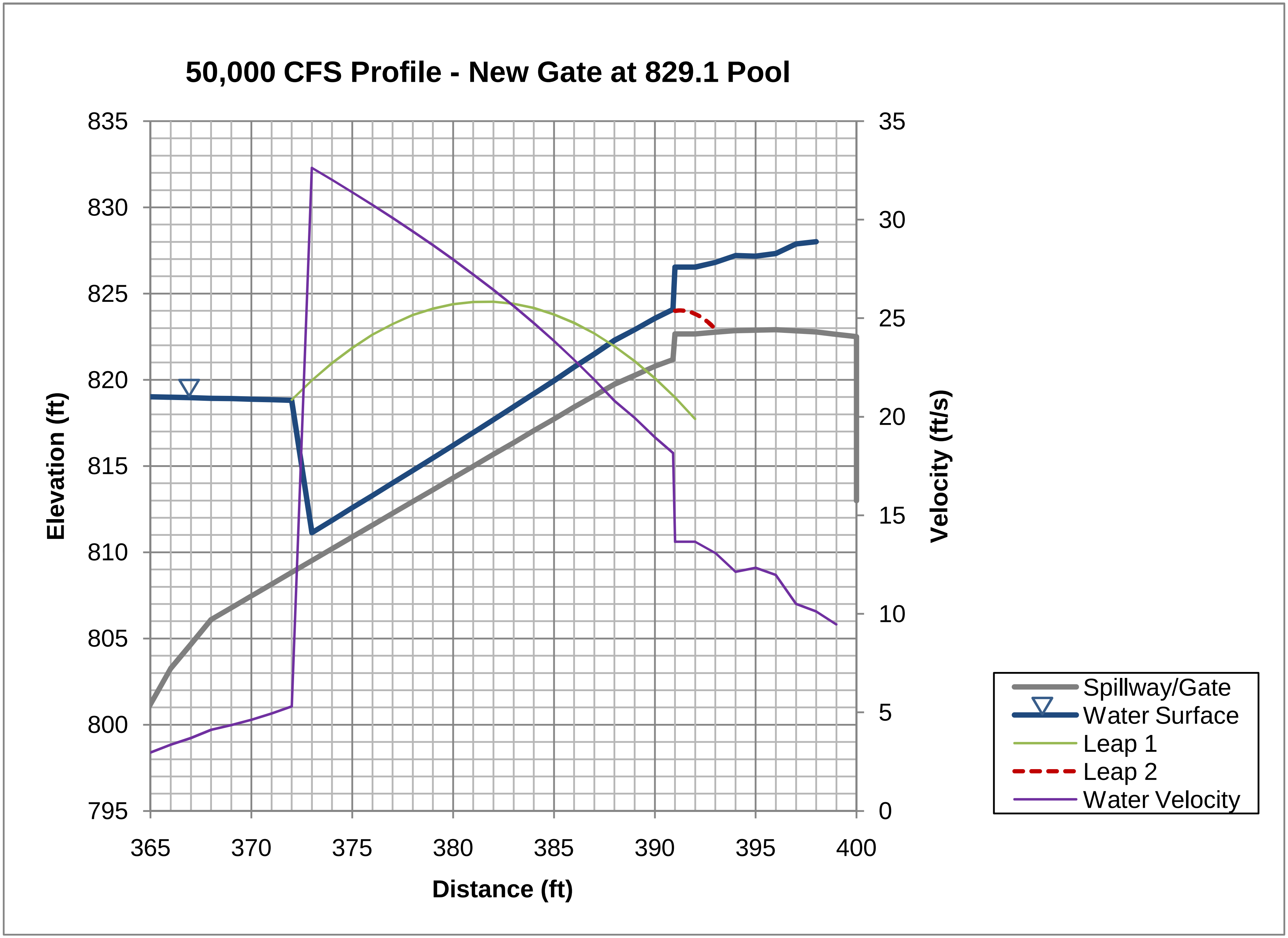
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity



50,000 CFS Profile - New Gate at 829.1 Pool
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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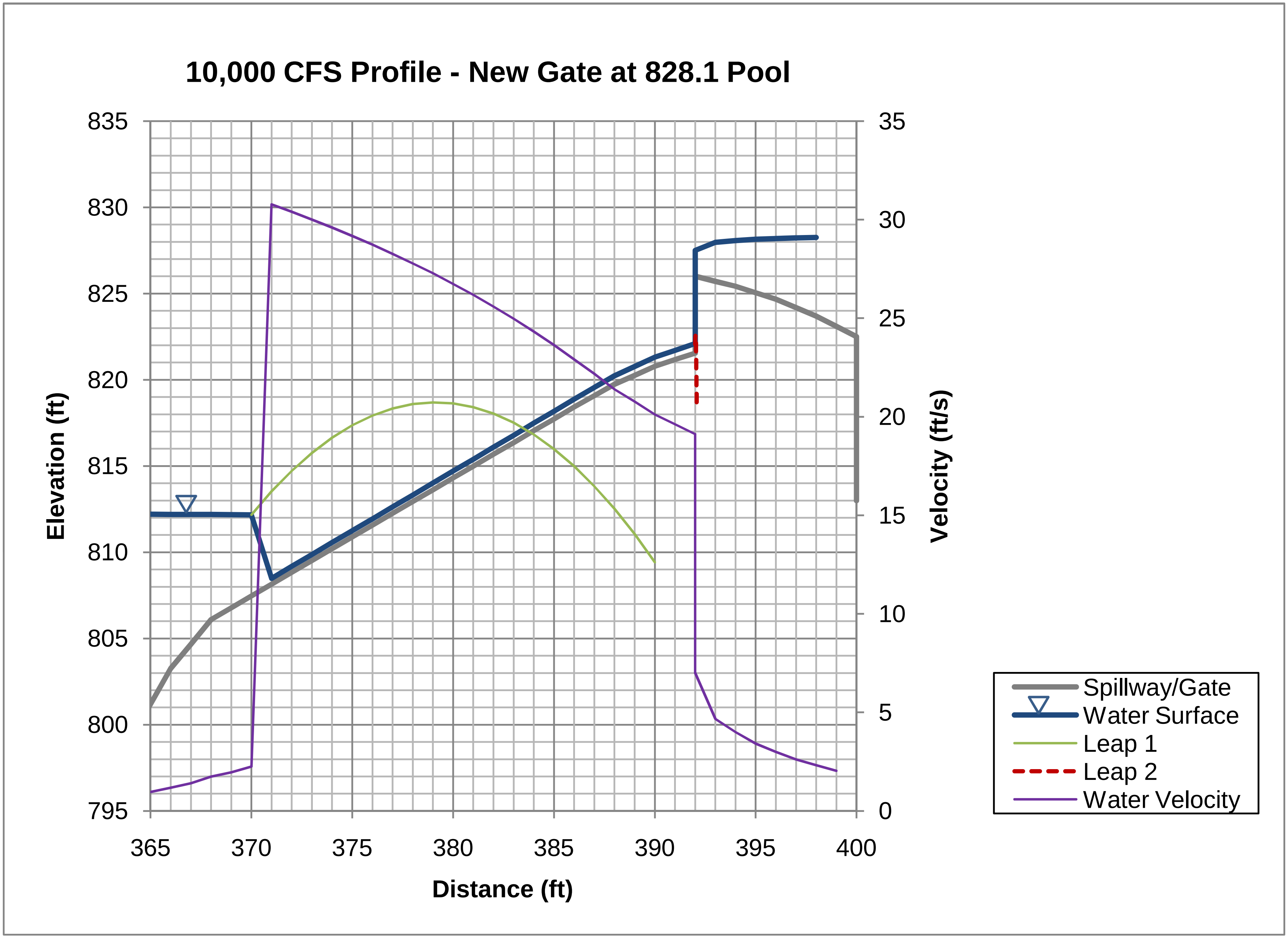
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity


10,000 CFS Profile - New Gate at 828.1 Pool
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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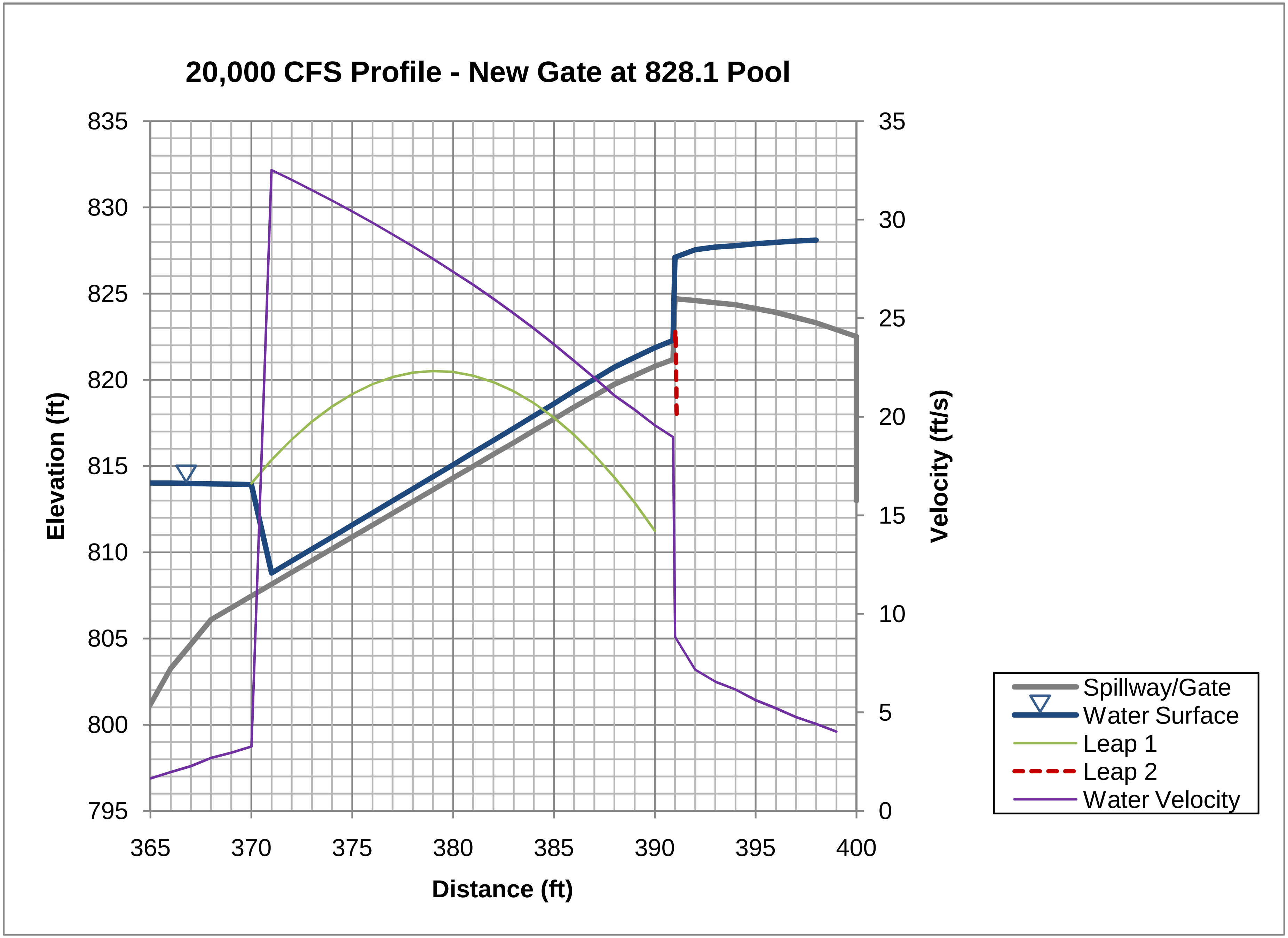
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity



20,000 CFS Profile - New Gate at 828.1 Pool
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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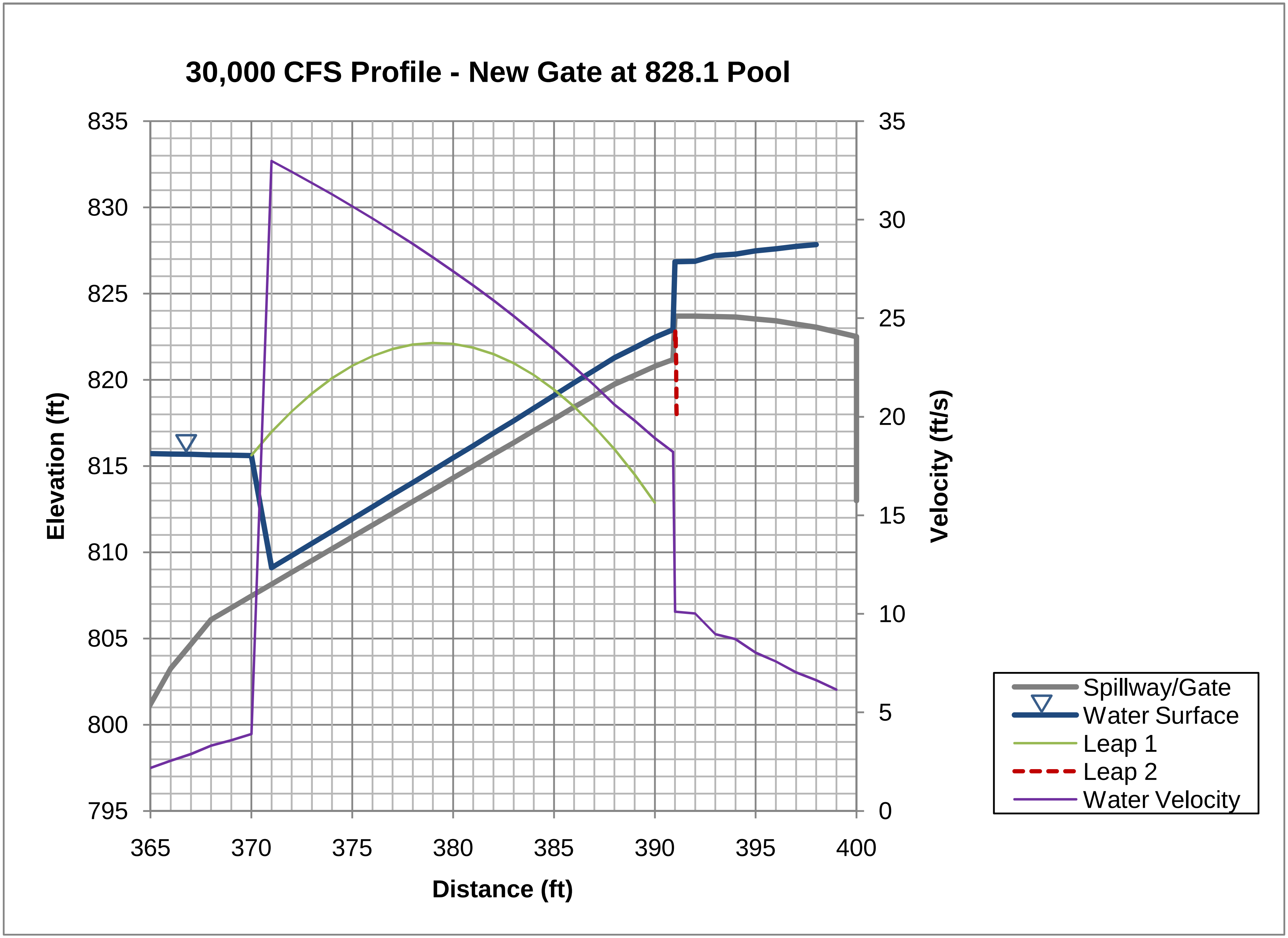
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity



30,000 CFS Profile - New Gate at 828.1 Pool
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Velocity (ft/s)
Distance (ft)
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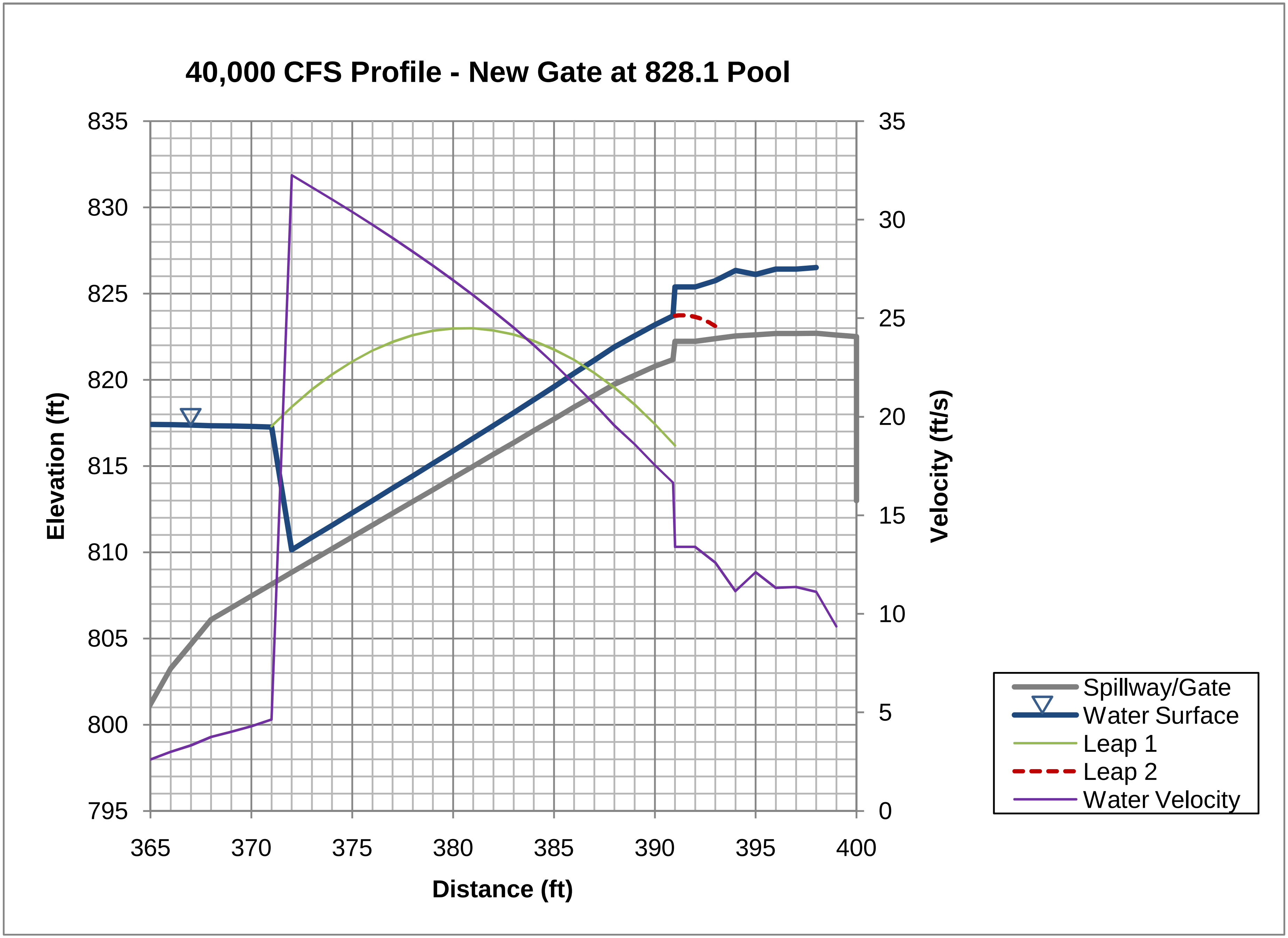
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity


40,000 CFS Profile - New Gate at 828.1 Pool
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Velocity (ft/s)
Distance (ft)
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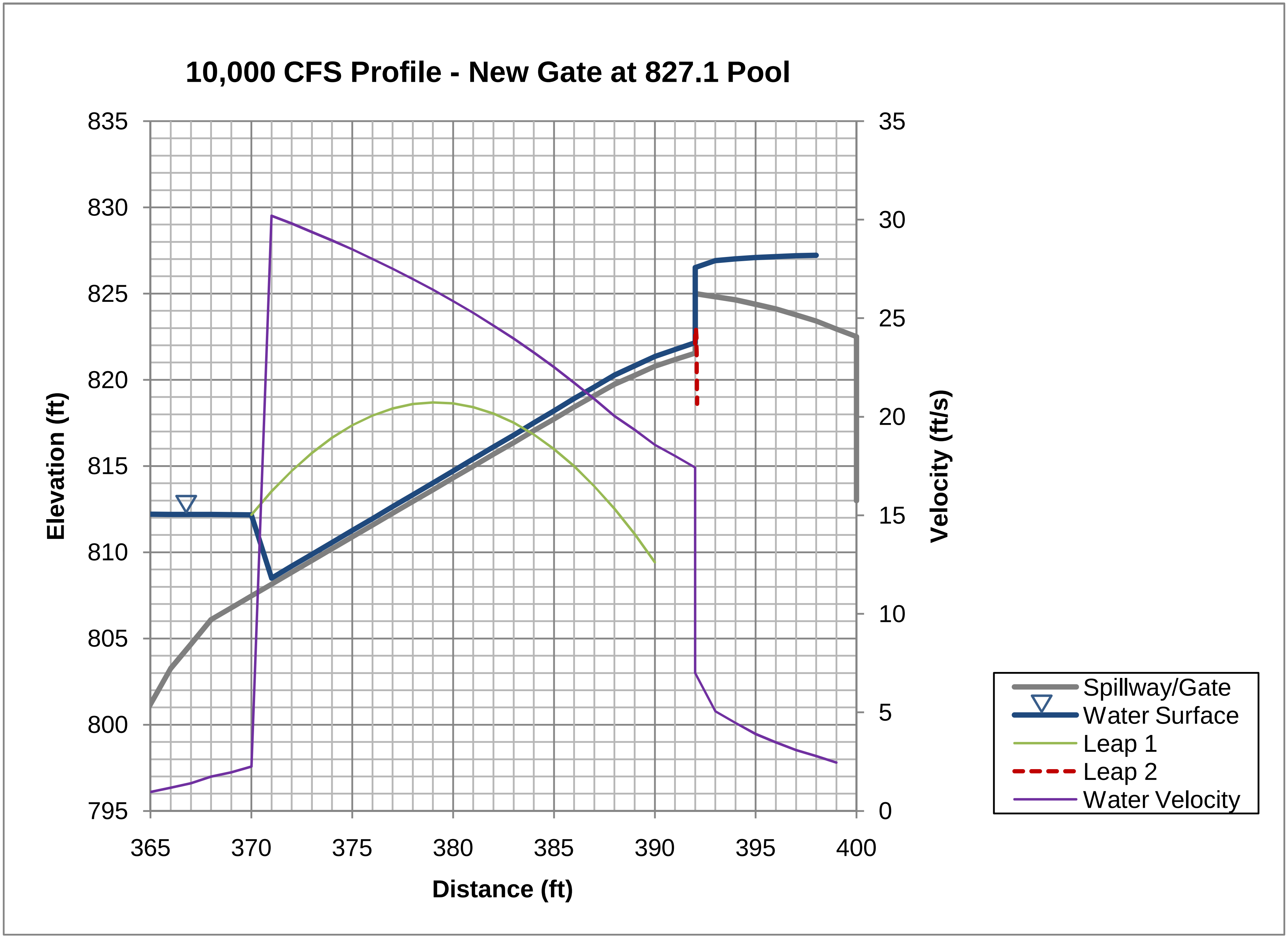
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity



10,000 CFS Profile - New Gate at 827.1 Pool
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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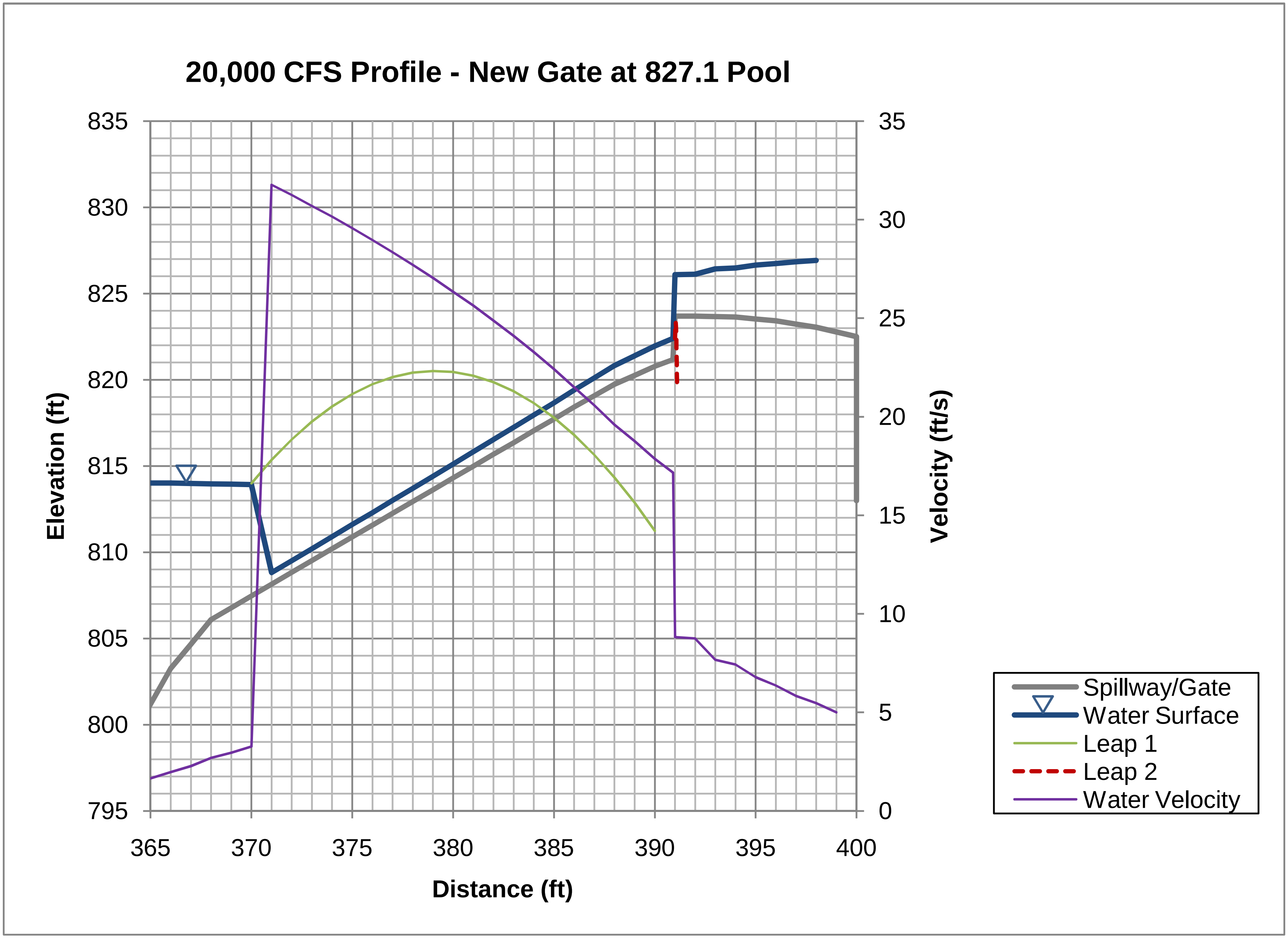
400
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity


20,000 CFS Profile - New Gate at 827.1 Pool
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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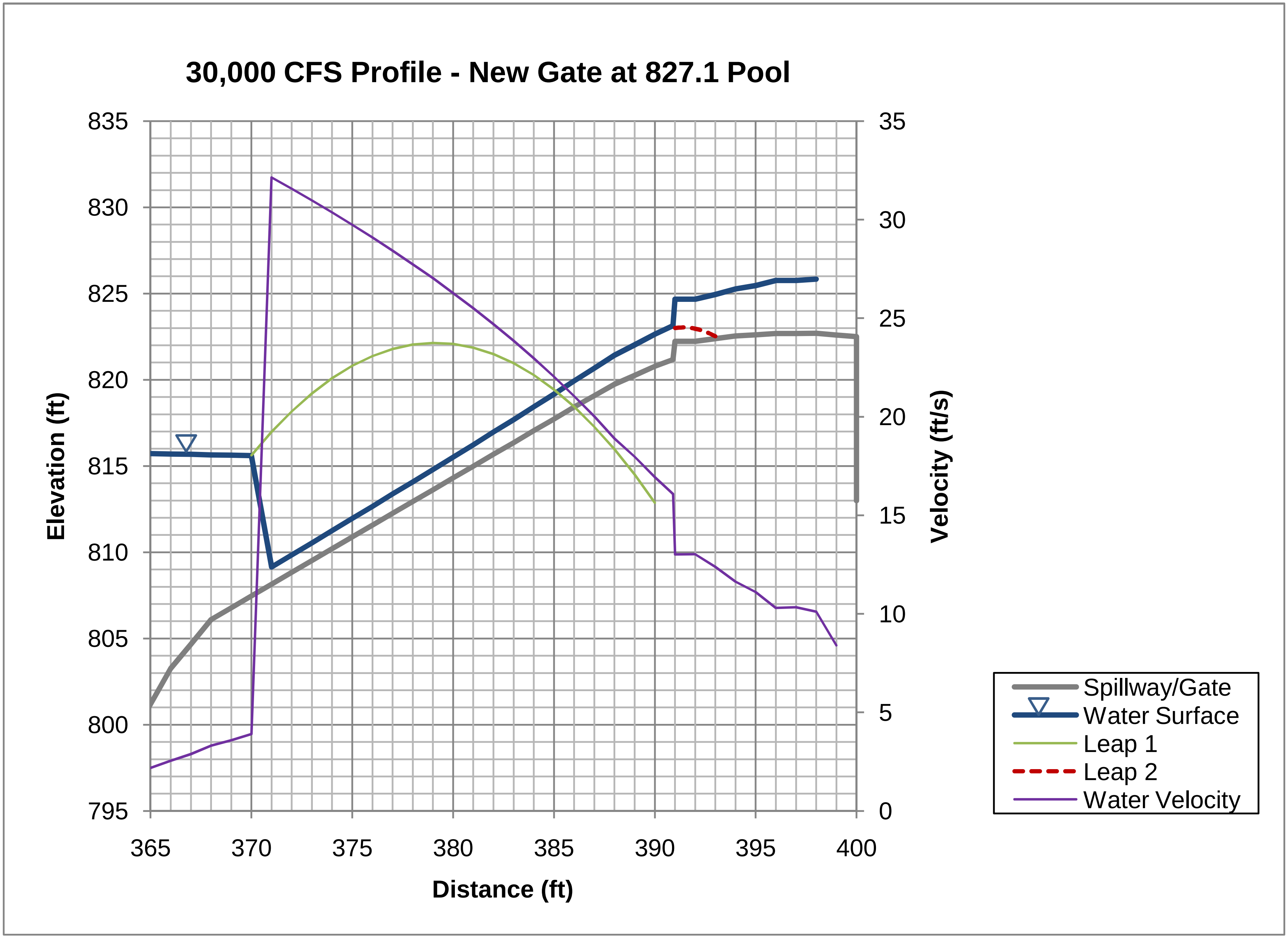
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity



30,000 CFS Profile - New Gate at 827.1 Pool
Elevation (ft)
Velocity (ft/s)
Distance (ft)
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395
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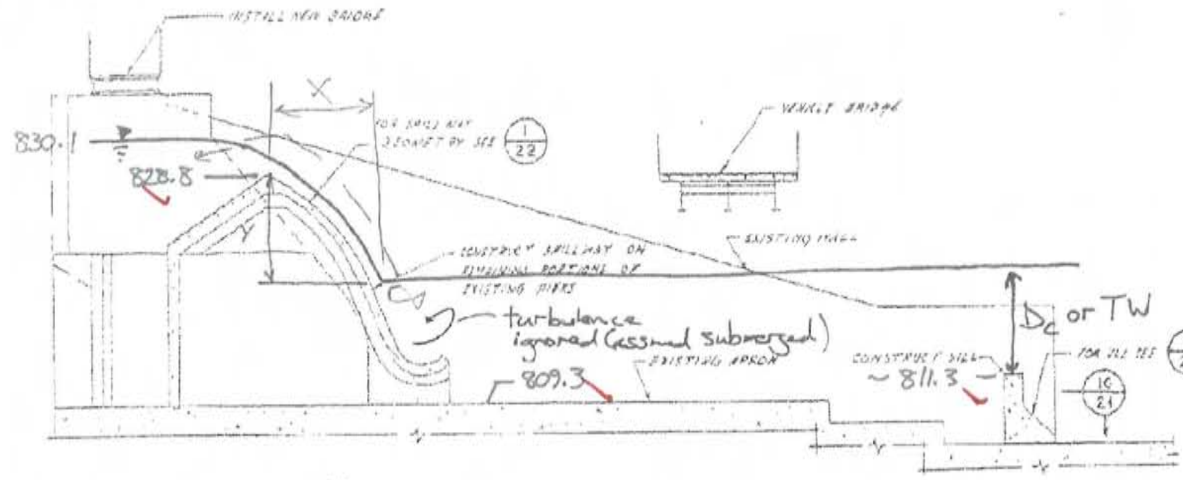
Spillway/Gate
Water Surface
Leap 1
Leap 2
Water Velocity

Hydraulic Computations

Powerhouse Auxiliary Spillway

Computed by: A. Judd
Checked by: N. VANG
Approved by: M. Weber

STEP 4 Analyze fish passage at powerhouse spillway



SECTION: SLUICEWAY MODIFICATION
SCALE 1/8"=1'-0"

Analysis focused on comparison of headwater vs tailwater, tailwater was either critical depth of flow over sill or actual river tailwater

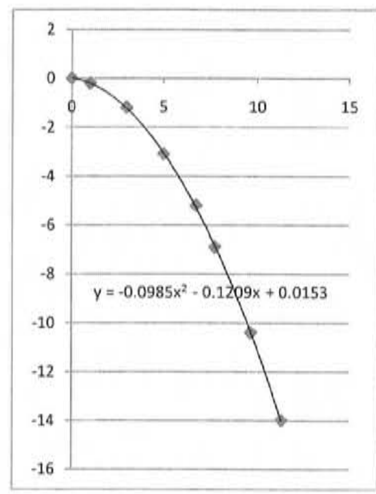
The turbulence associated with the flip bucket was ignored which is a very conservative assumption but allows for a quicker analysis of fish jump at the spillway

Tailwater elevation and its location on the spillway surface (relative to crest) were computed, then using fish jump criteria the X,Y of the fish's jump trajectory was computed. If given X, the fish could clear Y, then passage was assumed.

The Calculation table is attached

Spillway Geometry

X	Y
0	0
1	-0.2
3	-1.2
5	-3.1
6.75	-5.2
7.75	-6.9
9.67	-10.4
11.34	-14



THREE RIVERS PARK DISTRICT
COON RAPIDS FISH PASSAGE
AUXILIARY SPILLWAY HYDRAULICS
STANLEY CONSULTANTS, INC.
12-Jan-11

This calculation analyzes whether a fish can jump from the tailwater over the crest of the auxiliary spillway.
Turbulence at the flip bucket is not considered.

Cd = 3.4
Crest Elevation = 828.8 ft-msl
Sill Elevation = 811.3 ft-msl

Fish Jump Criteria			
Fish Launch Velocity =	25 ft/sec	vx =	12.5
Fish Launch Angle =	60 °	vy =	21.7

Time (%)	Flow (cfs)	HWEL (ft-msl)	TWEL (ft-msl)	Head on Crest (ft)	Aux Spwy q (ft^2/s)	Crit Depth at Sill (ft)	Adj TW Elev (ft-msl)	HW-TW Diff (ft)	Vert Sep Y Crest-TW Diff (ft)	Horiz Sep X TW Dist. From Crest (horiz) (ft)	Given X, and Vx,Vy, solve for Y using trajectory eqn Jump Y Fish Jump Height for above criteria (ft)	**Passage Possible?**
0.01	90,000	831.72	825.0	2.9	17.0	2.1	825.0	6.7	3.8	7.7	7.2	Y
0.01	89,000	831.65	824.9	2.9	16.4	2.0	824.9	6.8	3.9	7.7	7.2	Y
0.01	88,000	831.59	824.7	2.8	15.8	2.0	824.7	6.8	4.1	7.8	7.2	Y
0.01	87,000	831.52	824.6	2.7	15.2	1.9	824.6	6.9	4.2	7.8	7.2	Y
0.01	86,000	831.45	824.5	2.6	14.7	1.9	824.5	7.0	4.3	7.9	7.3	Y
0.01	85,000	831.38	824.3	2.6	14.1	1.8	824.3	7.0	4.5	7.9	7.3	Y
0.01	84,000	831.31	824.2	2.5	13.5	1.8	824.2	7.1	4.6	8.0	7.3	Y
0.01	83,000	831.24	824.1	2.4	12.9	1.7	824.1	7.2	4.7	8.0	7.3	Y
0.01	82,000	831.17	823.9	2.4	12.4	1.7	823.9	7.2	4.9	8.1	7.3	Y
0.01	81,000	831.10	823.8	2.3	11.8	1.6	823.8	7.3	5.0	8.1	7.3	Y
0.01	80,000	831.03	823.7	2.2	11.3	1.6	823.7	7.4	5.1	8.2	7.3	Y
0.01	79,000	830.96	823.5	2.2	10.8	1.5	823.5	7.4	5.3	8.2	7.3	Y
0.01	78,000	830.88	823.4	2.1	10.2	1.5	823.4	7.5	5.4	8.3	7.3	Y
0.01	77,000	830.81	823.2	2.0	9.7	1.4	823.2	7.6	5.6	8.3	7.3	Y
0.01	76,000	830.74	823.1	1.9	9.2	1.4	823.1	7.7	5.7	8.4	7.3	Y
0.01	75,000	830.67	822.9	1.9	8.7	1.3	822.9	7.7	5.9	8.4	7.3	Y
0.01	74,000	830.59	822.8	1.8	8.2	1.3	822.8	7.8	6.0	8.5	7.3	Y
0.01	73,000	830.52	822.6	1.7	7.7	1.2	822.6	7.9	6.2	8.5	7.3	Y
0.01	72,000	830.45	822.5	1.6	7.2	1.2	822.5	8.0	6.3	8.6	7.3	Y
0.01	71,000	830.37	822.3	1.6	6.7	1.1	822.3	8.0	6.5	8.6	7.3	Y
0.01	70,000	830.30	822.2	1.5	6.2	1.1	822.2	8.1	6.6	8.7	7.3	Y
0.02	69,000	830.23	822.0	1.4	5.8	1.0	822.0	8.2	6.8	8.7	7.3	Y
0.03	68,000	830.15	821.9	1.4	5.3	1.0	821.9	8.3	6.9	8.8	7.3	Y
0.04	67,000	830.10	821.7	1.3	5.0	0.9	821.7	8.4	7.1	8.7	7.3	Y
0.05	66,000	830.10	821.6	1.3	5.0	0.9	821.6	8.5	7.2	8.8	7.3	Y
0.05	65,000	830.10	821.4	1.3	5.0	0.9	821.4	8.7	7.4	8.9	7.3	N
0.06	64,000	830.10	821.3	1.3	5.0	0.9	821.3	8.8	7.5	9.0	7.2	N
0.09	63,000	830.10	821.1	1.3	5.0	0.9	821.1	9.0	7.7	9.1	7.2	N
0.10	62,000	830.10	820.9	1.3	5.0	0.9	820.9	9.2	7.9	9.2	7.2	N
0.12	61,000	830.10	820.8	1.3	5.0	0.9	820.8	9.3	8.0	9.3	7.2	N
0.14	60,000	830.10	820.6	1.3	5.0	0.9	820.6	9.5	8.2	9.4	7.2	N
0.16	59,000	830.10	820.5	1.3	5.0	0.9	820.5	9.6	8.3	9.5	7.1	N
0.17	58,000	830.10	820.3	1.3	5.0	0.9	820.3	9.8	8.5	9.6	7.1	N
0.18	57,000	830.10	820.1	1.3	5.0	0.9	820.1	10.0	8.7	9.6	7.1	N
0.20	56,000	830.10	820.0	1.3	5.0	0.9	820.0	10.1	8.8	9.7	7.1	N
0.22	55,000	830.10	819.8	1.3	5.0	0.9	819.8	10.3	9.0	9.8	7.1	N
0.23	54,000	830.10	819.7	1.3	5.0	0.9	819.7	10.4	9.1	9.9	7.0	N
0.23	53,000	830.10	819.5	1.3	5.0	0.9	819.5	10.6	9.3	10.0	7.0	N
0.25	52,000	830.10	819.3	1.3	5.0	0.9	819.3	10.8	9.5	10.1	7.0	N
0.25	51,000	830.10	819.2	1.3	5.0	0.9	819.2	10.9	9.6	10.2	6.9	N
0.28	50,000	830.10	819.0	1.3	5.0	0.9	819.0	11.1	9.8	10.2	6.9	N
0.33	49,000	830.10	818.8	1.3	5.0	0.9	818.8	11.3	10.0	10.3	6.9	N
0.37	48,000	830.10	818.7	1.3	5.0	0.9	818.7	11.4	10.1	10.4	6.9	N
0.41	47,000	830.10	818.5	1.3	5.0	0.9	818.5	11.6	10.3	10.5	6.8	N
0.47	46,000	830.10	818.3	1.3	5.0	0.9	818.3	11.8	10.5	10.6	6.8	N
0.53	45,000	830.10	818.2	1.3	5.0	0.9	818.2	11.9	10.6	10.6	6.8	N
0.59	44,000	830.10	818.0	1.3	5.0	0.9	818.0	12.1	10.8	10.7	6.7	N
0.68	43,000	830.10	817.9	1.3	5.0	0.9	817.9	12.2	10.9	10.8	6.7	N
0.74	42,000	830.10	817.7	1.3	5.0	0.9	817.7	12.4	11.1	10.9	6.6	N
0.80	41,000	830.10	817.5	1.3	5.0	0.9	817.5	12.6	11.3	11.0	6.6	N
0.90	40,000	830.10	817.4	1.3	5.0	0.9	817.4	12.7	11.4	11.0	6.6	N
0.97	39,000	830.10	817.2	1.3	5.0	0.9	817.2	12.9	11.6	11.1	6.5	N
1.05	38,000	830.10	817.0	1.3	5.0	0.9	817.0	13.1	11.8	11.2	6.5	N
1.12	37,000	830.10	816.9	1.3	5.0	0.9	816.9	13.2	11.9	11.3	6.4	N
1.21	36,000	830.10	816.7	1.3	5.0	0.9	816.7	13.4	12.1	11.3	6.4	N
1.39	35,000	830.10	816.5	1.3	5.0	0.9	816.5	13.6	12.3	11.4	6.3	N
1.55	34,000	830.10	816.4	1.3	5.0	0.9	816.4	13.7	12.4	11.5	6.3	N
1.76	33,000	830.10	816.2	1.3	5.0	0.9	816.2	13.9	12.6	11.6	6.2	N
1.93	32,000	830.10	816.0	1.3	5.0	0.9	816.0	14.1	12.8	11.6	6.2	N
2.11	31,000	830.10	815.9	1.3	5.0	0.9	815.9	14.2	12.9	11.7	6.1	N
2.35	30,000	830.10	815.7	1.3	5.0	0.9	815.7	14.4	13.1	11.8	6.1	N
2.56	29,000	830.10	815.5	1.3	5.0	0.9	815.5	14.6	13.3	11.9	6.0	N
2.86	28,000	830.10	815.4	1.3	5.0	0.9	815.4	14.7	13.4	11.9	6.0	N
3.11	27,000	830.10	815.2	1.3	5.0	0.9	815.2	14.9	13.6	12.0	5.9	N
3.60	26,000	830.10	815.0	1.3	5.0	0.9	815.0	15.1	13.8	12.1	5.9	N
4.01	25,000	830.10	814.9	1.3	5.0	0.9	814.9	15.2	13.9	12.2	5.8	N
4.46	24,000	830.10	814.7	1.3	5.0	0.9	814.7	15.4	14.1	12.2	5.8	N
5.24	23,000	830.10	814.5	1.3	5.0	0.9	814.5	15.6	14.3	12.3	5.7	N
6.04	22,000	830.10	814.4	1.3	5.0	0.9	814.4	15.7	14.4	12.4	5.6	N
6.92	21,000	830.10	814.2	1.3	5.0	0.9	814.2	15.9	14.6	12.4	5.6	N
8.06	20,000	830.10	814.0	1.3	5.0	0.9	814.0	16.1	14.8	12.5	5.5	N
9.68	19,000	830.10	813.8	1.3	5.0	0.9	813.8	16.3	15.0	12.6	5.4	N
11.23	18,000	830.10	813.7	1.3	5.0	0.9	813.7	16.4	15.1	12.7	5.4	N
13.06	17,000	830.10	813.5	1.3	5.0	0.9	813.5	16.6	15.3	12.7	5.4	N
14.76	16,000	830.10	813.3	1.3	5.0	0.9	813.3	16.8	15.5	12.8	5.3	N
16.88	15,000	830.10	813.1	1.3	5.0	0.9	813.1	17.0	15.7	12.9	5.2	N
19.15	14,000	830.10	812.9	1.3	5.0	0.9	812.9	17.2	15.9	13.0	5.1	N
21.37	13,000	830.10	812.7	1.3	5.0	0.9	812.7	17.4	16.1	13.0	5.1	N
24.14	12,000	830.10	812.5	1.3	5.0	0.9	812.5	17.6	16.3	13.1	5.0	N
27.12	11,000	830.10	812.4	1.3	5.0	0.9	812.4	17.7	16.4	13.2	4.9	N
31.05	10,000	830.10	812.2	1.3	5.0	0.9	812.2	17.9	16.6	13.2	4.9	N
36.34	9,000	830.10	812.0	1.3	5.0	0.9	812.2	17.9	16.6	13.2	4.9	N
43.24	8,000	830.10	811.8	1.3	5.0	0.9	812.2	17.9	16.6	13.2	4.9	N
50.90	7,000	830.10	811.6	1.3	5.0	0.9	812.2	17.9	16.6	13.2	4.9	N
59.45	6,000	830.10	811.3	1.3	5.0	0.9	812.2	17.9	16.6	13.2	4.9	N
69.17	5,000	830.10	811.1	1.3	5.0	0.9	812.2	17.9	16.6	13.2	4.9	N
80.40	4,000	830.10	810.9	1.3	5.0	0.9	812.2	17.9	16.6	13.2	4.9	N
91.28	3,000	830.10	810.7	1.3	5.0	0.9	812.2	17.9	16.6	13.2	4.9	N
98.23	2,000	830.10	810.5	1.3	5.0	0.9	812.2	17.9	16.6	13.2	4.9	N
99.93	1,000	830.10	810.2	1.3	5.0	0.9	812.2	17.9	16.6	13.2	4.9	N

Hydraulic Computations

Stilling Basin Calculations

Computed by: A. Judd
Checked by: N. VANG
Approved by: M. Weber

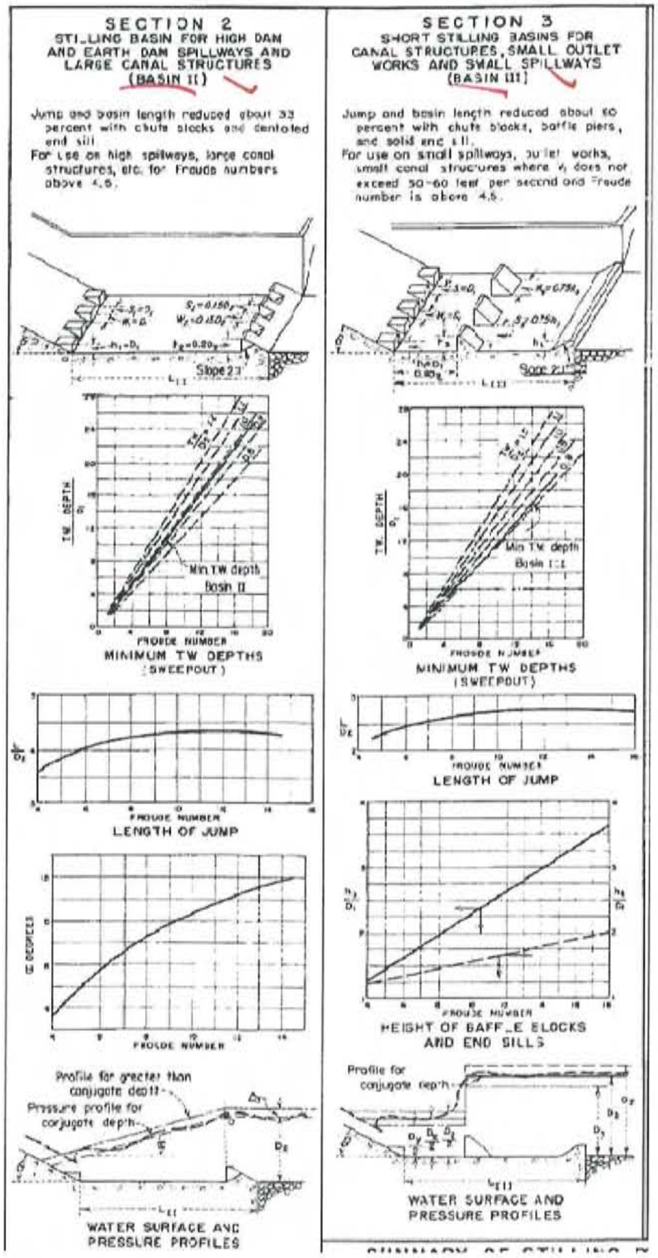
Step 5 Review adequacy of existing stilling basin geometry and design stilling basin geometry to replace apron

Proposed dam improvements will also include replacement of the existing apron with a stilling basin
The existing basin side of the dam will be left in place, with small repairs performed as necessary

Two computation were done on the basins
- -Adequacy of existing stilling basin over range of flow conditions (10K - 90K)
- -Sizing of new stilling basin to replace apron using range of flow conditions (10K -90K)

Due to the sill at the end, the existing basin was assumed to function as a USBR Type II basin
For economy/efficiency it was decided to use the USBR Type III basin to replace the apron segment
Calculation tables are attached

From Ref 1



THREE RIVERS PARK DISTRICT
COON RAPIDS DAM FISH PASSAGE EVALUATON
PRELIMINARY HYDRAULIC RESULTS - EXISTING DAM
STANLEY CONSULTANTS, INC.
20-Sep-10

This Calculation looks at the adequacy of the existing stilling basin, if the hydraulic jump is submerged or "on apron" it is considered contained and the stilling basin is adequate

Gate Settings		
Position	Abbrev	Crest El.
Partial	P	828.1
Up	U	830.1
Down	D	822.5

Cd = 3.4

Manipulate these cells to adjust stilling basin geometry

SPILLWAY RATING - SUMMER

submerged = tailwater is higher than jump so jump is submerged
on apron = jump is predicted to occur on apron
off apron = jump is predicted to occur off apron
recedes = tailwater is less than 0.9 of the jump height enough so jump recedes downstream
0.9

Bottom Elev, ft-msl >> 799.0
Stilling Basin Length, ft >> 51.0

Formulas used to compute hydraulic parameters are from
USBR's Hydraulic Design of Stilling Basins and Energy Dissipators for the TYPE II Basin

			Gate Setting			Gate Setting			q (discharge/ft of width)			Velocity at Toe of Spillway			Depth of Flow at Toe of Spillway			Froude #			Hydraulic Jump Height			Jump Length			Jump Condition/Location			Velocity at Toe			Depth at Toe			Height (Dam Crest-Tailwater)		
Flow	HWEL	TWEL	Up	Partial	Down	Up	Partial	Down	Up	Partial	Down	Gate 1	Gate 2	Gate 3	Gate 1	Gate 2	Gate 3	Gate 1	Gate 2	Gate 3	Gate 1	Gate 2	Gate 3	Gate 1	Gate 2	Gate 3	Gate 1	Gate 2	Gate 3	Gate 1	Gate 2	Gate 3	Gate 1	Gate 2	Gate 3	Gate 1	Gate 2	Gate 3
(cfs)	(ft-msl)	(ft-msl)	(position)	(position)	(position)	(ft-msl)	(ft-msl)	(ft-msl)	(ft^2/s)	(ft^2/s)	(ft^2/s)	(ft/s)	(ft/s)	(ft/s)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/s)	(ft/s)	(ft/s)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
90,000	831.72	825.0	U	P	D	830.10	828.10	822.50	7	23	95	45.33	44.62	42.55	0.16	0.53	2.24	20.28	10.85	5.01	4.37	7.80	14.79	14.36	34.25	56.57	submerged	submerged	submerged	0.27	0.90	3.66	26.01	26.01	26.01	5.09	3.09	(2.51)
89,000	831.65	824.9	U	P	D	830.10	828.10	822.50	7	23	94	45.31	44.59	42.52	0.15	0.51	2.21	20.93	10.99	5.04	4.24	7.69	14.70	23.86	33.79	56.32	submerged	submerged	submerged	0.25	0.88	3.64	25.88	25.88	25.88	5.22	3.22	(2.38)
88,000	831.59	824.7	U	P	D	830.10	828.10	822.50	6	22	93	45.28	44.57	42.50	0.14	0.50	2.19	21.64	11.15	5.06	4.10	7.58	14.62	22.88	33.31	56.07	submerged	submerged	submerged	0.24	0.86	3.62	25.74	25.74	25.74	5.36	3.36	(2.24)
87,000	831.52	824.6	U	P	D	830.10	828.10	822.50	6	21	92	45.26	44.54	42.47	0.13	0.48	2.17	22.40	11.30	5.08	3.95	7.47	14.54	21.89	32.83	55.81	submerged	submerged	submerged	0.22	0.84	3.59	25.61	25.61	25.61	5.49	3.49	(2.11)
86,000	831.45	824.5	U	P	D	830.10	828.10	822.50	5	21	91	45.24	44.52	42.44	0.12	0.47	2.14	23.24	11.47	5.11	3.81	7.36	14.45	20.87	32.33	55.55	submerged	submerged	submerged	0.21	0.82	3.57	25.48	25.48	25.48	5.62	3.62	(1.98)
85,000	831.38	824.3	U	P	D	830.10	828.10	822.50	5	20	90	45.21	44.49	42.42	0.11	0.45	2.12	24.16	11.64	5.13	3.66	7.25	14.37	19.84	31.83	55.30	submerged	submerged	submerged	0.19	0.80	3.55	25.34	25.34	25.34	5.76	3.76	(1.84)
84,000	831.31	824.2	U	P	D	830.10	828.10	822.50	5	20	89	45.19	44.47	42.39	0.10	0.44	2.10	25.18	11.82	5.16	3.51	7.13	14.29	18.78	31.31	55.03	submerged	submerged	submerged	0.18	0.78	3.53	25.21	25.21	25.21	5.89	3.89	(1.71)
83,000	831.24	824.1	U	P	D	830.10	828.10	822.50	4	19	88	45.16	44.44	42.36	0.09	0.43	2.07	26.31	12.01	5.19	3.36	7.01	14.20	17.70	30.78	54.77	submerged	submerged	submerged	0.16	0.75	3.50	25.07	25.07	25.07	6.03	4.03	(1.57)
82,000	831.17	823.9	U	P	D	830.10	828.10	822.50	4	18	87	45.14	44.42	42.34	0.08	0.41	2.05	27.58	12.20	5.21	3.20	6.90	14.12	16.60	30.24	54.51	submerged	submerged	submerged	0.15	0.73	3.48	24.93	24.93	24.93	6.17	4.17	(1.43)
81,000	831.10	823.8	U	P	D	830.10	828.10	822.50	3	18	86	45.11	44.39	42.31	0.08	0.40	2.03	29.01	12.41	5.24	3.04	6.78	14.03	15.47	29.69	54.24	submerged	submerged	submerged	0.14	0.71	3.46	24.79	24.79	24.79	6.31	4.31	(1.29)
80,000	831.03	823.7	U	P	D	830.10	828.10	822.50	3	17	85	45.09	44.37	42.28	0.07	0.38	2.00	30.63	12.62	5.27	2.88	6.66	13.94	14.31	29.12	53.97	submerged	submerged	submerged	0.12	0.69	3.43	24.65	24.65	24.65	6.45	4.45	(1.15)
79,000	830.96	823.5	U	P	D	830.10	828.10	822.50	3	16	84	45.06	44.34	42.26	0.06	0.37	1.98	32.49	12.85	5.29	2.71	6.54	13.86	13.12	28.54	53.70	submerged	submerged	submerged	0.11	0.67	3.41	24.51	24.51	24.51	6.59	4.59	(1.01)
78,000	830.88	823.4	U	P	D	830.10	828.10	822.50	2	16	83	45.03	44.31	42.23	0.05	0.36	1.95	34.66	13.08	5.32	2.54	6.42	13.77	11.89	27.94	53.43	submerged	submerged	submerged	0.10	0.65	3.39	24.37	24.37	24.37	6.73	4.73	(0.87)
77,000	830.81	823.2	U	P	D	830.10	828.10	822.50	2	15	81	45.01	44.29	42.20	0.05	0.34	1.93	37.22	13.33	5.35	2.37	6.29	13.68	10.62	27.32	53.16	submerged	submerged	submerged	0.08	0.63	3.36	24.22	24.22	24.22	6.88	4.88	(0.72)
76,000	830.74	823.1	U	P	D	830.10	828.10	822.50	2	15	80	44.98	44.26	42.18	0.04	0.33	1.91	40.29	13.59	5.38	2.19	6.17	13.59	9.32	26.69	52.88	submerged	submerged	submerged	0.07	0.61	3.34	24.08	24.08	24.08	7.02	5.02	(0.58)
75,000	830.67	822.9	U	P	D	830.10	828.10	822.50	1	14	79	44.96	44.23	42.15	0.03	0.32	1.88	44.05	13.86	5.41	2.00	6.04	13.50	7.96	26.03	52.60	submerged	submerged	submerged	0.06	0.58	3.32	23.93	23.93	23.93	7.17	5.17	(0.43)
74,000	830.59	822.8	U	P	D	830.10	828.10	822.50	1	13	78	44.93	44.21	42.12	0.03	0.30	1.86	48.78	14.15	5.44	1.80	5.92	13.41	6.54	25.36	52.32	submerged	submerged	submerged	0.05	0.56	3.29	23.78	23.78	23.78	7.32	5.32	(0.28)
73,000	830.52	822.6	U	P	D	830.10	828.10	822.50	1	13	77	44.90	44.18	42.09	0.02	0.29	1.84	54.94	14.46	5.48	1.60	5.79	13.32	5.06	24.66	52.04	submerged	submerged	submerged	0.04	0.54	3.27	23.63	23.63	23.63	7.47	5.47	(0.13)
72,000	830.45	822.5	U	P	D	830.10	828.10	822.50	1	12	76	44.88	44.15	42.06	0.02	0.28	1.81	63.36	14.78	5.51	1.39	5.66	13.23	3.50	23.94	51.76	submerged	submerged	submerged	0.03	0.52	3.24	23.48	23.48	23.48	7.62	5.62	0.02
71,000	830.37	822.3	U	P	D	830.10	828.10	822.50	0	12	75	44.85	44.13	42.04	0.01	0.26	1.79	75.67	15.13	5.54	1.16	5.52	13.14	1.84	23.18	51.47	submerged	submerged	submerged	0.02	0.50	3.22	23.33	23.33	23.33	7.77	5.77	0.17
70,000	830.30	822.2	U	P	D	830.10	828.10	822.50	0	11	74	44.83	44.10	42.01	0.01	0.25	1.76	95.71	15.49	5.57	0.92	5.39	13.05	0.04	22.40	51.18	submerged	submerged	submerged	0.01	0.48	3.20	23.18	23.18	23.18	7.92	5.92	0.32
69,000	830.23	822.0	U	P	D	830.10	828.10	822.50	0	11	73	44.80	44.07	41.98	0.00	0.24	1.74	135.44	15.88	5.61	0.65	5.25	12.96	(1.96)	21.59	50.89	submerged	submerged	submerged	0.01	0.46	3.17	23.03	23.03	23.03	8.07	6.07	0.47
68,000	830.15	821.9	U	P	D	830.10	828.10	822.50	0	10	72	44.77	44.05	41.95	0.00	0.23	1.72	265.82	16.30	5.64	0.33	5.12	12.86	(4.33)	20.74	50.59	submerged	submerged	submerged	0.00	0.44	3.15	22.87	22.87	22.87	8.23	6.23	0.63
67,000	830.10	821.7	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.42	3.14	-	22.72	22.72	31.10	6.38	0.78
66,000	830.10	821.6	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.43	3.16	-	22.56	22.56	31.10	6.54	0.94
65,000	830.10	821.4	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.43	3.18	-	22.41	22.41	31.10	6.69	1.09
64,000	830.10	821.3	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.43	3.20	-	22.25	22.25	31.10	6.85	1.25
63,000	830.10	821.1	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.44	3.22	-	22.09	22.09	31.10	7.01	1.41
62,000	830.10	820.9	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.44	3.25	-	21.94	21.94	31.10	7.16	1.56
61,000	830.10	820.8	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.44	3.27	-	21.78	21.78	31.10	7.32	1.72
60,000	830.10	820.6	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.44	3.30	-	21.62	21.62	31.10	7.48	1.88
59,000	830.10	820.5	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.45	3.32	-	21.46	21.46	31.10	7.64	2.04
58,000	830.10	820.3	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.45	3.34	-	21.30	21.30	31.10	7.80	2.20
57,000	830.10	820.1	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.45	3.37	-	21.14	21.14	31.10	7.96	2.36
56,000	830.10	820.0	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.46	3.40	-	20.98	20.98	31.10	8.12	2.52
55,000	830.10	819.8	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.46	3.42	-	20.81	20.81	31.10	8.29	2.69
54,000	830.10	819.7	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.47	3.45	-	20.65	20.65	31.10	8.45	2.85
53,000	830.10	819.5	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.47	3.48	-	20.49	20.49	31.10	8.61	3.01
52,000	830.10	819.3	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.47	3.50	-	20.33	20.33	31.10	8.77	3.17
51,000	830.10	819.2	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.48	3.53	-	20.16	20.16	31.10	8.94	3.34
50,000	830.10	819.0	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.48	3.56	-	20.00	20.00	31.10	9.10	3.50
49,000	830.10	818.8	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.48	3.59	-	19.84	19.84	31.10	9.26	3.66
48,000	830.10	818.7	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.49	3.62	-	19.67	19.67	31.10	9.43	3.83
47,000	830.10	818.5	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.49	3.65	-	19.51	19.51	31.10	9.59	3.99
46,000	830.10	818.3	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.50	3.68	-	19.35	19.35	31.10	9.75	4.15
45,000	830.10	818.2	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.50	3.71	-	19.18	19.18	31.10	9.92	4.32
44,000	830.10	818.0	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.51	3.75	-	19.02	19.02	31.10	10.08	4.48
43,000	830.10	817.9	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.51	3.78	-	18.86	18.86	31.10	10.24	4.64
42,000	830.10	817.7	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.51	3.81	-	18.69	18.69	31.10	10.41	4.81
41,000	830.10	817.5	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.52	3.85	-	18.53	18.53	31.10	10.57	4.97
40,000	830.10	817.4	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.52	3.88	-	18.36	18.36	31.10	10.74	5.14
39,000	830.10	817.2	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.53	3.91	-	18.20	18.20	31.10	10.90	5.30
38,000	830.10	817.0	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.53	3.95	-	18.03	18.03	31.10	11.07	5.47
37,000	830.10	816.9	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.54	3.99	-	17.87	17.87	31.10	11.23	5.63
36,000	830.10	816.7	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.54	4.02	-	17.70	17.70	31.10	11.40	5.80
35,000	830.10	816.5	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.55	4.06	-	17.54	17.54	31.10	11.56	5.96
34,000	830.10	816.4	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.55	4.10	-	17.37	17.37	31.10	11.73	6.13
33,000	830.10	816.2	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.56	4.14	-	17.21	17.21	31.10	11.89	6.29
32,000	830.10	816.0	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.56	4.18	-	17.04	17.04	31.10	12.06	6.46
31,000	830.10	815.9	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.57	4.22	-	16.88	16.88	31.10	12.22	6.62
30,000	830.10	815.7	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.58	4.26	-	16.71	16.71	31.10	12.39	6.79
29,000	830.10	815.5	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.58	4.31	-	16.54	16.54	31.10	12.56	6.96
28,000	830.10	815.4	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.59	4.35	-	16.37	16.37	31.10	12.73	7.13
27,000	830.10	815.2	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.59	4.40	-	16.21	16.21	31.10	12.89	7.29
26,000	830.10	815.0	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.60	4.44	-	16.04	16.04	31.10	13.06	7.46
25,000	830.10	814.9	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.61	4.49	-	15.87	15.87	31.10	13.23	7.63
24,000	830.10	814.7	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.61	4.54	-	15.70	15.70	31.10	13.40	7.80
23,000	830.10	814.5	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.62	4.59	-	15.53	15.53	31.10	13.57	7.97
22,000	830.10	814.4	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.63	4.64	-	15.36	15.36	31.10	13.74	8.14
21,000	830.10	814.2	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.63	4.69	-	15.18	15.18	31.10	13.92	8.32
20,000	830.10	814.0	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.64	4.75	-	15.01	15.01	31.10	14.09	8.49
19,000	830.10	813.8	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.65	4.80	-	14.83	14.83	31.10	14.27	8.67
18,000	830.10	813.7	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.66	4.86	-	14.65	14.65	31.10	14.45	8.85
17,000	830.10	813.5	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.66	4.92	-	14.48	14.48	31.10	14.62	9.02
16,000	830.10	813.3	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.67	4.98	-	14.29	14.29	31.10	14.81	9.21
15,000	830.10	813.1	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.68	5.05	-	14.11	14.11	31.10	14.99	9.39
14,000	830.10	812.9	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.69	5.12	-	13.93	13.93	31.10	15.17	9.57
13,000	830.10	812.7	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.70	5.18	-	13.74	13.74	31.10	15.36	9.76
12,000	830.10	812.5	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.71	5.26	-	13.55	13.55	31.10	15.55	9.95
11,000	830.10	812.4	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.72	5.33	-	13.36	13.36	31.10	15.74	10.14
10,000	830.10	812.2	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.73	5.41	-	13.16	13.16	31.10	15.94	10.34
9,000	830.10	812.0	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	submerged	-	0.74	5.49	-	12.96	12.96	31.10	16.14	10.54
8,000	830.10	811.8	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	on apron	-	0.75	41.93	-	12.76	1.70	31.10	16.34	21.80
7,000	830.10	811.6	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	on apron	-	0.77	41.93	-	12.56	1.70	31.10	16.54	21.80
6,000	830.10	811.3	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	on apron	-	0.78	41.93	-	12.35	1.70	31.10	16.75	21.80
5,000	830.10	811.1	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	on apron	-	0.79	41.93	-	12.14	1.70	31.10	16.96	21.80
4,000	830.10	810.9	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	on apron	-	0.81	41.93	-	11.92	1.70	31.10	17.18	21.80
3,000	830.10	810.7	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	on apron	-	0.82	41.93	-	11.70	1.70	31.10	17.40	21.80
2,000	830.10	810.5	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	recedes	-	0.84	41.93	-	11.47	1.70	31.10	17.63	21.80
1,000	830.10	810.2	U	P	D	830.10	828.10	822.50	-	10	71	-	44.03	41.93	-	0.22	1.70	-	16.60	5.67	-	5.02	12.80	-	20.14	50.39	-	submerged	recedes	-	0.86	41.93	-	11.24	1.70	31.10	17.86	21.80

			Basin
Spillway Length =	945 ft	Bottom Elev >>	799.0
Cd =	3.4	Stilling Basin Length >>	51.0
Crest Elevation =	822.5 ft-msl		

SPILLWAY RATING - WINTER

Time (%)	Flow (cfs)	HWEL (ft-msl)	TWEL (ft-msl)	q (ft^2/s)	Velocity at Toe (ft/s)	Flow Depth (ft)	Froude # (ft)	Jump Height (ft)	Jump Length (ft)	Jump Location	Revised Velocity (ft/s)	Crest-TW Difference (ft)	Tailwater Depth (ft)
0	69,100	830.23	822.0	73.1	42.0	1.7	5.6	13.0	50.9	submerged	3.2	0.5	23.0
2	25,400	826.47	814.9	26.9	40.5	0.7	8.8	7.9	34.0	submerged	1.7	7.6	15.9
4	20,500	825.94	814.1	21.7	40.3	0.5	9.7	7.1	30.9	submerged	1.4	8.4	15.1
6	17,400	825.58	813.5	18.4	40.2	0.5	10.5	6.6	28.7	submerged	1.3	9.0	14.5
8	15,000	825.29	813.1	15.9	40.0	0.4	11.2	6.1	26.7	submerged	1.1	9.4	14.1
10	12,800	825.01	812.7	13.5	39.9	0.3	12.1	5.6	24.7	submerged	1.0	9.8	13.7
12	11,900	824.89	812.5	12.6	39.9	0.3	12.5	5.4	23.8	submerged	0.9	10.0	13.5
14	11,100	824.79	812.4	11.7	39.8	0.3	12.9	5.2	22.9	submerged	0.9	10.1	13.4
16	10,500	824.70	812.3	11.1	39.8	0.3	13.3	5.1	22.2	submerged	0.8	10.2	13.3
18	10,100	824.65	812.2	10.7	39.8	0.3	13.5	5.0	21.7	submerged	0.8	10.3	13.2
20	9,690	824.59	812.1	10.3	39.8	0.3	13.8	4.9	21.1	submerged	0.8	10.4	13.1
22	9,310	824.53	812.0	9.9	39.7	0.2	14.1	4.8	20.6	submerged	0.8	10.5	13.0
24	8,990	824.49	812.0	9.5	39.7	0.2	14.3	4.7	20.2	submerged	0.7	10.5	13.0
26	8,680	824.44	811.9	9.2	39.7	0.2	14.5	4.6	19.8	submerged	0.7	10.6	12.9
28	8,450	824.41	811.9	8.9	39.7	0.2	14.7	4.6	19.4	submerged	0.7	10.6	12.9
30	8,250	824.38	811.8	8.7	39.7	0.2	14.9	4.5	19.1	submerged	0.7	10.7	12.8
32	8,020	824.34	811.8	8.5	39.7	0.2	15.1	4.5	18.8	submerged	0.7	10.7	12.8
34	7,780	824.30	811.7	8.2	39.6	0.2	15.3	4.4	18.4	submerged	0.6	10.8	12.7
36	7,560	824.27	811.7	8.0	39.6	0.2	15.5	4.3	18.0	submerged	0.6	10.8	12.7
38	7,340	824.23	811.6	7.8	39.6	0.2	15.8	4.3	17.6	submerged	0.6	10.9	12.6
40	7,130	824.20	811.6	7.5	39.6	0.2	16.0	4.2	17.3	submerged	0.6	10.9	12.6
42	6,900	824.16	811.5	7.3	39.6	0.2	16.2	4.1	16.8	submerged	0.6	11.0	12.5
44	6,700	824.13	811.5	7.1	39.6	0.2	16.5	4.1	16.5	submerged	0.6	11.0	12.5
46	6,510	824.10	811.5	6.9	39.6	0.2	16.7	4.0	16.1	submerged	0.6	11.0	12.5
48	6,300	824.07	811.4	6.7	39.5	0.2	17.0	4.0	15.7	submerged	0.5	11.1	12.4
50	6,130	824.04	811.4	6.5	39.5	0.2	17.2	3.9	15.3	submerged	0.5	11.1	12.4
52	5,950	824.01	811.3	6.3	39.5	0.2	17.4	3.9	14.9	submerged	0.5	11.2	12.3
54	5,790	823.98	811.3	6.1	39.5	0.2	17.7	3.8	14.6	submerged	0.5	11.2	12.3
56	5,650	823.96	811.3	6.0	39.5	0.2	17.9	3.8	14.3	submerged	0.5	11.2	12.3
58	5,500	823.93	811.2	5.8	39.5	0.1	18.1	3.7	13.9	submerged	0.5	11.3	12.2
60	5,350	823.90	811.2	5.7	39.5	0.1	18.4	3.7	13.6	submerged	0.5	11.3	12.2
62	5,190	823.88	811.2	5.5	39.5	0.1	18.6	3.6	13.2	submerged	0.5	11.3	12.2
64	5,010	823.84	811.1	5.3	39.5	0.1	19.0	3.5	12.7	submerged	0.4	11.4	12.1
66	4,890	823.82	811.1	5.2	39.4	0.1	19.2	3.5	12.4	submerged	0.4	11.4	12.1
68	4,780	823.80	811.1	5.1	39.4	0.1	19.4	3.5	12.1	submerged	0.4	11.4	12.1
70	4,650	823.78	811.1	4.9	39.4	0.1	19.7	3.4	11.7	submerged	0.4	11.4	12.1
72	4,500	823.75	811.0	4.8	39.4	0.1	20.0	3.4	11.3	submerged	0.4	11.5	12.0
74	4,390	823.73	811.0	4.6	39.4	0.1	20.2	3.3	10.9	submerged	0.4	11.5	12.0
76	4,220	823.70	811.0	4.5	39.4	0.1	20.6	3.2	10.4	submerged	0.4	11.5	12.0
78	4,040	823.66	810.9	4.3	39.4	0.1	21.1	3.2	9.8	submerged	0.4	11.6	11.9
80	3,880	823.63	810.9	4.1	39.4	0.1	21.5	3.1	9.2	submerged	0.3	11.6	11.9
82	3,730	823.60	810.9	3.9	39.4	0.1	21.9	3.1	8.7	submerged	0.3	11.6	11.9
84	3,550	823.57	810.8	3.8	39.3	0.1	22.4	3.0	8.0	submerged	0.3	11.7	11.8
86	3,390	823.54	810.8	3.6	39.3	0.1	22.9	2.9	7.3	submerged	0.3	11.7	11.8
88	3,200	823.50	810.7	3.4	39.3	0.1	23.6	2.8	6.5	submerged	0.3	11.8	11.7
90	3,060	823.47	810.7	3.2	39.3	0.1	24.1	2.8	5.9	submerged	0.3	11.8	11.7
92	2,930	823.44	810.7	3.1	39.3	0.1	24.6	2.7	5.2	submerged	0.3	11.8	11.7
94	2,770	823.41	810.6	2.9	39.3	0.1	25.3	2.6	4.4	submerged	0.3	11.9	11.6
96	2,570	823.36	810.6	2.7	39.3	0.1	26.3	2.5	3.3	submerged	0.2	11.9	11.6
98	2,290	823.30	810.5	2.4	39.2	0.1	27.8	2.4	1.5	submerged	0.2	12.0	11.5
100	1,310	823.05	810.3	1.4	39.1	0.0	36.6	1.8	0.0	submerged	0.1	12.2	11.3

THREE RIVERS PARK DISTRICT
COON RAPIDS DAM FISH PASSAGE EVALUATON
PRELIMINARY HYDRAULIC RESULTS - PROPOSED DAM WITH PNEUMATIC GATES
STANLEY CONSULTANTS, INC.
21-Oct-10

USER ENTERED

This Calculation looks at the sizing of the proposed stilling basin, different lenghts and basin bottom elevations were analyzed to determine what the shortest highest basin was that kept the hydraulic jump submerged.

Spillway Length = 945 ft
Cd = 3.4
Crest Elevation = 822.5 ft-msl

Computed Stilling Basin Block/Sill Geometry

Basin Bottom Elev:	803 ft-msl	Basin Length:	35 ft		
Chute Block Height :	2.4 ft	Baffle Block Height:	3.4 ft	Sill Height:	3.0 ft
Chute Block Width:	2.4 ft	Baffle Block Width:	2.5 ft		
Chute Block Spacing:	2.4 ft	Baffle Block Spacing:	2.5 ft		

Formulas used to compute hydraulic parameters are from USBR's Hydraulic Design of Stilling Basins and Energy Dissipators for the TYPE III Basin

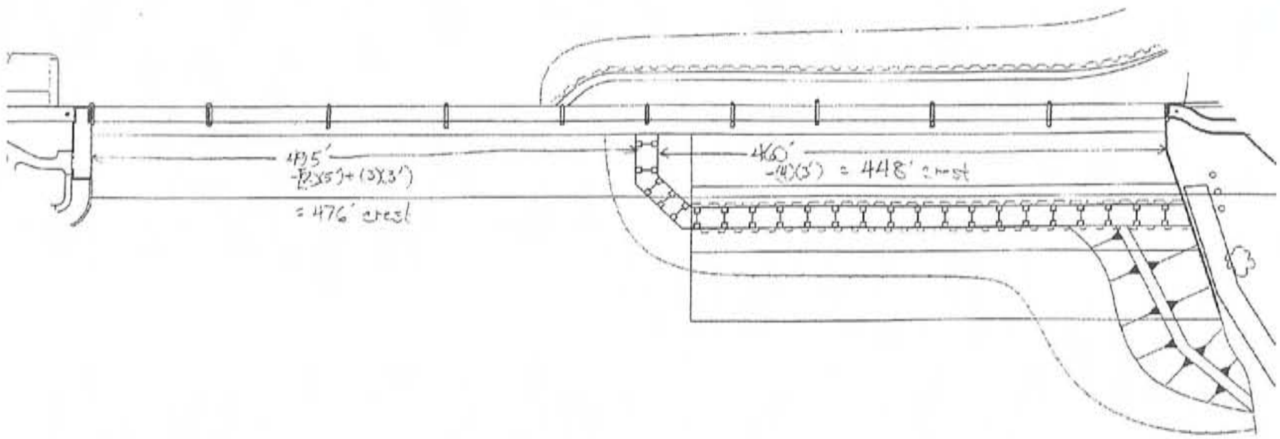
SPILLWAY RATING - NEW GATES	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	20
Time	Flow	HWEL	TWEL	Gate Setting	Flow Check	Head	q	Approach Velocity	Critical Depth	Critical Velocity	Velocity at Toe	Flow Depth at Toe (d1)	Froude # at Toe	Hyd Jump Height	Hyd Jump Length	h3 (baffle coeff)	h4 (sill coeff)	Jump Condition	Revised Velocity
(%)	(cfs)	(ft-msl)	(ft-msl)	(ft-msl)	(cfs)	(ft)	(ft^2/s)	(ft/s)	(ft)	(ft/s)	(ft/s)	(ft)	(ft)	(ft)	(ft)				(ft/s)
0.01	90,000	831.72	825.0	822.5	90,000	9.22	95	10.33	6.56	14.53	39.4	2.4	4.5	14.1	31.7	3.4	3.0	submerged	4.3
0.01	89,000	831.65	824.9	822.5	89,000	9.15	94	10.29	6.51	14.47	39.4	2.4	4.5	14.0	31.6	3.3	3.0	submerged	4.3
0.01	88,000	831.59	824.7	822.5	88,000	9.09	93	10.25	6.46	14.42	39.3	2.4	4.5	13.9	31.5	3.3	3.0	submerged	4.3
0.01	87,000	831.52	824.6	822.5	87,000	9.02	92	10.21	6.41	14.37	39.3	2.3	4.5	13.9	31.3	3.3	2.9	submerged	4.3
0.01	86,000	831.45	824.5	822.5	86,000	8.95	91	10.17	6.36	14.31	39.3	2.3	4.5	13.8	31.2	3.2	2.9	submerged	4.2
0.01	85,000	831.38	824.3	822.5	85,000	8.88	90	10.13	6.31	14.25	39.3	2.3	4.6	13.7	31.0	3.2	2.9	submerged	4.2
0.01	84,000	831.31	824.2	822.5	84,000	8.81	89	10.09	6.26	14.20	39.2	2.3	4.6	13.6	30.9	3.2	2.8	submerged	4.2
0.01	83,000	831.24	824.1	822.5	83,000	8.74	88	10.05	6.21	14.14	39.2	2.2	4.6	13.5	30.8	3.2	2.8	submerged	4.2
0.01	82,000	831.17	823.9	822.5	82,000	8.67	87	10.01	6.16	14.08	39.2	2.2	4.6	13.5	30.6	3.1	2.8	submerged	4.1
0.01	81,000	831.10	823.8	822.5	81,000	8.60	86	9.97	6.11	14.03	39.1	2.2	4.7	13.4	30.5	3.1	2.8	submerged	4.1
0.01	80,000	831.03	823.7	822.5	80,000	8.53	85	9.93	6.06	13.97	39.1	2.2	4.7	13.3	30.3	3.1	2.7	submerged	4.1
0.01	79,000	830.96	823.5	822.5	79,000	8.46	84	9.89	6.01	13.91	39.1	2.1	4.7	13.2	30.2	3.1	2.7	submerged	4.1
0.01	78,000	830.88	823.4	822.5	78,000	8.38	83	9.84	5.96	13.85	39.1	2.1	4.7	13.1	30.0	3.0	2.7	submerged	4.1
0.01	77,000	830.81	823.2	822.5	77,000	8.31	81	9.80	5.91	13.79	39.0	2.1	4.8	13.0	29.9	3.0	2.6	submerged	4.0
0.01	76,000	830.74	823.1	822.5	76,000	8.24	80	9.76	5.86	13.73	39.0	2.1	4.8	13.0	29.7	3.0	2.6	submerged	4.0
0.01	75,000	830.67	822.9	822.5	75,000	8.17	79	9.72	5.80	13.67	39.0	2.0	4.8	12.9	29.6	2.9	2.6	submerged	4.0
0.01	74,000	830.59	822.8	822.5	74,000	8.09	78	9.67	5.75	13.61	38.9	2.0	4.8	12.8	29.4	2.9	2.6	submerged	4.0
0.01	73,000	830.52	822.6	822.5	73,000	8.02	77	9.63	5.70	13.55	38.9	2.0	4.9	12.7	29.3	2.9	2.5	submerged	3.9
0.01	72,000	830.45	822.5	822.5	72,000	7.95	76	9.59	5.65	13.49	38.9	2.0	4.9	12.6	29.1	2.9	2.5	submerged	3.9
0.01	71,000	830.37	822.3	822.5	71,000	7.87	75	9.54	5.60	13.42	38.9	1.9	4.9	12.5	29.0	2.8	2.5	submerged	3.9
0.01	70,000	830.30	822.2	822.5	70,000	7.80	74	9.50	5.54	13.36	38.8	1.9	5.0	12.4	28.8	2.8	2.4	submerged	3.9
0.02	69,000	830.23	822.0	822.5	69,000	7.73	73	9.45	5.49	13.30	38.8	1.9	5.0	12.4	28.6	2.8	2.4	submerged	3.8
0.03	68,000	830.15	821.9	822.5	68,000	7.65	72	9.40	5.44	13.23	38.8	1.9	5.0	12.3	28.5	2.8	2.4	submerged	3.8
0.04	67,000	830.10	821.7	822.5	67,000	7.58	71	9.36	5.38	13.17	38.7	1.8	5.0	12.2	28.3	2.7	2.3	submerged	3.8
0.05	66,000	830.10	821.6	822.6	66,000	7.50	70	9.31	5.33	13.10	38.8	1.8	5.1	12.1	28.2	2.7	2.3	submerged	3.8
0.05	65,000	830.10	821.4	822.7	65,000	7.42	69	9.26	5.28	13.04	38.8	1.8	5.1	12.0	28.1	2.7	2.3	submerged	3.7
0.06	64,000	830.10	821.3	822.8	64,000	7.35	68	9.22	5.22	12.97	38.8	1.7	5.2	11.9	28.0	2.6	2.2	submerged	3.7
0.09	63,000	830.10	821.1	822.8	63,000	7.27	67	9.17	5.17	12.90	38.9	1.7	5.2	11.9	27.9	2.6	2.2	submerged	3.7
0.10	62,000	830.10	820.9	822.9	62,000	7.19	66	9.12	5.11	12.83	38.9	1.7	5.3	11.8	27.7	2.6	2.2	submerged	3.7
0.12	61,000	830.10	820.8	823.0	61,000	7.12	65	9.07	5.06	12.76	38.9	1.7	5.3	11.7	27.6	2.5	2.1	submerged	3.6
0.14	60,000	830.10	820.6	823.1	60,000	7.04	63	9.02	5.00	12.69	39.0	1.6	5.4	11.6	27.5	2.5	2.1	submerged	3.6
0.16	59,000	830.10	820.5	823.1	59,000	6.96	62	8.97	4.95	12.62	39.0	1.6	5.4	11.5	27.4	2.5	2.1	submerged	3.6
0.17	58,000	830.10	820.3	823.2	58,000	6.88	61	8.92	4.89	12.55	39.0	1.6	5.5	11.4	27.2	2.5	2.1	submerged	3.5
0.18	57,000	830.10	820.1	823.3	57,000	6.80	60	8.87	4.83	12.48	39.1	1.5	5.5	11.4	27.1	2.4	2.0	submerged	3.5
0.20	56,000	830.10	820.0	823.4	56,000	6.72	59	8.82	4.78	12.40	39.1	1.5	5.6	11.3	27.0	2.4	2.0	submerged	3.5
0.22	55,000	830.10	819.8	823.5	55,000	6.64	58	8.76	4.72	12.33	39.1	1.5	5.7	11.2	26.8	2.4	2.0	submerged	3.5
0.23	54,000	830.10	819.7	823.5	54,000	6.56	57	8.71	4.66	12.25	39.2	1.5	5.7	11.1	26.7	2.3	1.9	submerged	3.4
0.23	53,000	830.10	819.5	823.6	53,000	6.48	56	8.66	4.61	12.18	39.2	1.4	5.8	11.0	26.6	2.3	1.9	submerged	3.4
0.25	52,000	830.10	819.3	823.7	52,000	6.40	55	8.60	4.55	12.10	39.2	1.4	5.8	10.9	26.4	2.3	1.9	submerged	3.4
0.25	51,000	830.10	819.2	823.8	51,000	6.32	54	8.54	4.49	12.02	39.3	1.4	5.9	10.8	26.3	2.2	1.8	submerged	3.3
0.28	50,000	830.10	819.0	823.9	50,000	6.23	53	8.49	4.43	11.94	39.3	1.3	6.0	10.7	26.1	2.2	1.8	submerged	3.3
0.33	49,000	830.10	818.8	824.0	49,000	6.15	52	8.43	4.37	11.86	39.3	1.3	6.0	10.6	26.0	2.2	1.8	submerged	3.3
0.37	48,000	830.10	818.7	824.0	48,000	6.07	51	8.37	4.31	11.78	39.4	1.3	6.1	10.5	25.8	2.2	1.7	submerged	3.2
0.41	47,000	830.10	818.5	824.1	47,000	5.98	50	8.32	4.25	11.70	39.4	1.3	6.2	10.4	25.6	2.1	1.7	submerged	3.2
0.47	46,000	830.10	818.3	824.2	46,000	5.90	49	8.26	4.19	11.62	39.4	1.2	6.3	10.3	25.5	2.1	1.7	submerged	3.2
0.53	45,000	830.10	818.2	824.3	45,000	5.81	48	8.20	4.13	11.53	39.5	1.2	6.3	10.2	25.3	2.1	1.6	submerged	3.1
0.59	44,000	830.10	818.0	824.4	44,000	5.72	47	8.13	4.07	11.45	39.5	1.2	6.4	10.1	25.2	2.0	1.6	submerged	3.1
0.68	43,000	830.10	817.9	824.5	43,000	5.64	46	8.07	4.01	11.36	39.5	1.2	6.5	10.0	25.0	2.0	1.6	submerged	3.1
0.74	42,000	830.10	817.7	824.6	42,000	5.55	44	8.01	3.94	11.27	39.6	1.1	6.6	9.9	24.8	2.0	1.5	submerged	3.0
0.80	41,000	830.10	817.5	824.6	41,000	5.46	43	7.95	3.88	11.18	39.6	1.1	6.7	9.8	24.6	1.9	1.5	submerged	3.0
0.90	40,000	830.10	817.4	824.7	40,000	5.37	42	7.88	3.82	11.09	39.7	1.1	6.8	9.7	24.4	1.9	1.5	submerged	2.9
0.97	39,000	830.10	817.2	824.8	39,000	5.28	41	7.81	3.75	10.99	39.7	1.0	6.9	9.6	24.2	1.9	1.4	submerged	2.9
1.05	38,000	830.10	817.0	824.9	38,000	5.19	40	7.75	3.69	10.90	39.7	1.0	7.0	9.5	24.1	1.8	1.4	submerged	2.9
1.12	37,000	830.10	816.9	825.0	37,000	5.10	39	7.68	3.62	10.80	39.8	1.0	7.1	9.4	23.9	1.8	1.4	submerged	2.8
1.21	36,000	830.10	816.7	825.1	36,000	5.01	38	7.61	3.56	10.70	39.8	1.0	7.2	9.2	23.7	1.8	1.3	submerged	2.8
1.39	35,000	830.10	816.5	825.2	35,000	4.91	37	7.54	3.49	10.60	39.8	0.9	7.3	9.1	23.4	1.7	1.3	submerged	2.7
1.55	34,000	830.10	816.4	825.3	34,000	4.82	36	7.46	3.43	10.50	39.9	0.9	7.4	9.0	23.2	1.7	1.3	submerged	2.7
1.76	33,000	830.10	816.2	825.4	33,000	4.73	35	7.39	3.36	10.40	39.9	0.9	7.5	8.9	23.0	1.7	1.2	submerged	2.6
1.93	32,000	830.10	816.0	825.5	32,000	4.63	34	7.32	3.29	10.29	40.0	0.8	7.6	8.8	22.8	1.6	1.2	submerged	2.6
2.11	31,000	830.10	815.9	825.6	31,000	4.53	33	7.24	3.22	10.18	40.0	0.8	7.8	8.6	22.5	1.6	1.2	submerged	2.5
2.35	30,000	830.10	815.7	825.7	30,000	4.43	32	7.16	3.15	10.07	40.0	0.8	7.9	8.5	22.3	1.6	1.1	submerged	2.5
2.56	29,000	830.10	815.5	825.8	29,000	4.34	31	7.08	3.08	9.96	40.1	0.8	8.1	8.4	22.1	1.5	1.1	submerged	2.4
2.86	28,000	830.10	815.4	825.9	28,000	4.23	30	7.00	3.01	9.84	40.1	0.7	8.2	8.2	21.8	1.5	1.1	submerged	2.4
3.11	27,000	830.10	815.2	826.0	27,000	4.13	29	6.91	2.94	9.73	40.2	0.7	8.4	8.1	21.5	1.5	1.0	submerged	2.3
3.60	26,000	830.10	815.0	826.1	26,000	4.03	28	6.83	2.86	9.60	40.2	0.7	8.6	8.0	21.2	1.4	1.0	submerged	2.3
4.01	25,000	830.10	814.9	826.2	25,000	3.93	26	6.74	2.79	9.48	40.2	0.7	8.7	7.8	21.0	1.4	1.0	submerged	2.2
4.46	24,000	830.10	814.7	826.3	24,000	3.82	25	6.65	2.72	9.35	40.3	0.6	8.9	7.7	20.7	1.4	0.9	submerged	2.2
5.24	23,000	830.10	814.5	826.4	23,000	3.71	24	6.55	2.64	9.22	40.3	0.6	9.1	7.5	20.3	1.3	0.9	submerged	2.1
6.04	22,000	830.10	814.4	826.5	22,000	3.61	23	6.46	2.56	9.08	40.4	0.6	9.4	7.4	20.0	1.3	0.9	submerged	2.1
6.92	21,000	830.10	814.2	826.6	21,000	3.50	22	6.36	2.48	8.94	40.4	0.5	9.6	7.2	19.7	1.2	0.8	submerged	2.0
8.06	20,000	830.10	814.0	826.7	20,000	3.38	21	6.25	2.40	8.80	40.5	0.5	9.9	7.0	19.3	1.2	0.8	submerged	1.9
9.68	19,000	830.10	813.8	826.8	19,000	3.27	20	6.15	2.32	8.65	40.5	0.5	10.1	6.9	18.9	1.2	0.8	submerged	1.9
11.23	18,000	830.10	813.7	826.9	18,000	3.15	19	6.04	2.24	8.50	40.5	0.5	10.4	6.7	18.5	1.1	0.7	submerged	1.8
13.06	17,000	830.10	813.5	827.1	17,000	3.04	18	5.92	2.16	8.34	40.6	0.4	10.7	6.5	18.1	1.1	0.7	submerged	1.7
14.76	16,000	830.10	813.3	827.2	16,000	2.92	17	5.81	2.07	8.17	40.6	0.4	11.1	6.3	17.7	1.0	0.7	submerged	1.6
16.88	15,000	830.10	813.1	827.3	15,000	2.79	16	5.68	1.99	8.00	40.7	0.4	11.5	6.1	17.2	1.0	0.6	submerged	1.6
19.15	14,000	830.10	812.9	827.4	14,000	2.67	15	5.55	1.90	7.81	40.7	0.4	11.9	5.9	16.7	1.0	0.6	submerged	1.5
21.37	13,000	830.10	812.7	827.6	13,000	2.54	14	5.42	1.80	7.62	40.8	0.3	12.4	5.7	16.1	0.9	0.6	submerged	1.4
24.14	12,000	830.10	812.5	827.7	12,000	2.41	13	5.28	1.71	7.42	40.8	0.3	12.9	5.5	15.5	0.9	0.5	submerged	1.3
27.12	11,000	830.10	812.4	827.8	11,000	2.27	12	5.12	1.61	7.21	40.9	0.3	13.5	5.3	14.8	0.8	0.5	submerged	1.2
31.05	10,000	830.10	812.2	828.0	10,000	2.13	11	4.96	1.52	6.98	40.9	0.3	14.2	5.1	14.1	0.8	0.5	submerged	1.2
36.34	9,000	830.10	812.0	828.1	9,000	1.99	10	4.79	1.41	6.74	41.0	0.2	15.0	4.8	13.2	0.7	0.4	submerged	1.1
43.24	8,000	830.10	811.8	828.3	8,000	1.84	8	4.61	1.31	6.48	41.1	0.2	15.9	4.5	12.3	0.7	0.4	submerged	1.0
50.90	7,000	830.10	811.6	828.4	7,000	1.68	7	4.41	1.19	6.20	41.1	0.2	17.1	4.3	11.2	0.6	0.4	submerged	0.9
59.45	6,000	830.10	811.3	828.6	6,000	1.52	6	4.19	1.08	5.89	41.2	0.2	18.5	4.0	9.9	0.6	0.3	submerged	0.8
69.17	5,000	830.10	811.1	828.8	5,000	1.34	5	3.94	0.95	5.54	41.3	0.1	20.3	3.6	8.3	0.5	0.3	submerged	0.7
80.40	4,000	830.10	810.9	828.9	4,000	1.16	4	3.66	0.82	5.15	41.3	0.1	22.8	3.2	6.2	0.5	0.2	submerged	0.5
91.28	3,000	830.10	810.7	829.1	3,000	0.96	3	3.32	0.68	4.68	41.4	0.1	26.4	2.8	3.3	0.4	0.2	submerged	0.4
98.23	2,000	830.10	810.5	829.4	2,000	0.73	2	2.90	0.52	4.08	41.5	0.1	32.4	2.3	-1.4	0.3	0.1	submerged	0.3
99.93	1,000	830.10	810.2	829.6	1,000	0.46	1	2.30	0.33	3.24	41.6	0.0	46.0	1.6	-11.2	0.2	0.1	submerged	0.1

Hydraulic Computations

Flow Bypass During Construction

Computed by: A. Judd
Checked by: N. VANG
Approved by: M. [illegible]

Step 6 Review flow bypass during construction



Preliminary staging was developed for the dam improvement analysis and is comprised of two stages. The spillway length will be reduced by approximately 1/2 during construction. It is assumed that the crest will be at 822.5 during construction and construction will be undertaken during lower flow season (Aug-Feb). An effective spillway length of 430' was used in the computation. The calculation table is attached.

THREE RIVERS PARK DISTRICT
COON RAPIDS DAM GATE REPAIRS
CONSTRUCTION STAGING HYDRAULICS
STANLEY CONSULTANTS, INC.
21-Oct-10

This calculation computes headwater for a given flow with a reduced spillway length due to construction over ~1/2 of the spillway. Tailwater is determined by the established River flow/Tailwater relationship.

Spillway Length =	430	ft
Cd =	3.4	
Crest Elevation =	822.5	ft-msl

1	2	3	4	5
SPILLWAY RATING - NEW GATES			Gate	Flow
Time	Flow	HWEL	TWEL	Setting	Check

Time (%)	Flow (cfs)	HWEL (ft-msl)	TWEL (ft-msl)	Gate Setting (ft-msl)	Flow Check (cfs)
99.93	1,000	823.28	810.2	822.5	1,000
98.23	2,000	823.73	810.5	822.5	2,000
91.28	3,000	824.11	810.7	822.5	3,000
80.40	4,000	824.46	810.9	822.5	4,000
69.17	5,000	824.77	811.1	822.5	5,000
59.45	6,000	825.06	811.3	822.5	6,000
50.90	7,000	825.34	811.6	822.5	7,000
43.24	8,000	825.61	811.8	822.5	8,000
36.34	9,000	825.86	812.0	822.5	9,000
31.05	10,000	826.10	812.2	822.5	10,000
27.12	11,000	826.34	812.4	822.5	11,000
24.14	12,000	826.57	812.5	822.5	12,000
21.37	13,000	826.79	812.7	822.5	13,000
19.15	14,000	827.01	812.9	822.5	14,000
16.88	15,000	827.22	813.1	822.5	15,000
14.76	16,000	827.43	813.3	822.5	16,000
13.06	17,000	827.63	813.5	822.5	17,000
11.23	18,000	827.83	813.7	822.5	18,000
9.68	19,000	828.03	813.8	822.5	19,000
8.06	20,000	828.22	814.0	822.5	20,000
6.92	21,000	828.41	814.2	822.5	21,000
6.04	22,000	828.60	814.4	822.5	22,000
5.24	23,000	828.78	814.5	822.5	23,000
4.46	24,000	828.96	814.7	822.5	24,000
4.01	25,000	829.14	814.9	822.5	25,000
3.60	26,000	829.31	815.0	822.5	26,000
3.11	27,000	829.49	815.2	822.5	27,000
2.86	28,000	829.66	815.4	822.5	28,000
2.56	29,000	829.83	815.5	822.5	29,000
2.35	30,000	830.00	815.7	822.5	30,000
2.11	31,000	830.16	815.9	822.5	31,000
1.93	32,000	830.32	816.0	822.5	32,000
1.76	33,000	830.49	816.2	822.5	33,000
1.55	34,000	830.65	816.4	822.5	34,000
1.39	35,000	830.81	816.5	822.5	35,000
1.21	36,000	830.96	816.7	822.5	36,000
1.12	37,000	831.12	816.9	822.5	37,000
1.05	38,000	831.27	817.0	822.5	38,000
0.97	39,000	831.43	817.2	822.5	39,000
0.90	40,000	831.58	817.4	822.5	40,000
0.80	41,000	831.73	817.5	822.5	41,000
0.74	42,000	831.88	817.7	822.5	42,000
0.68	43,000	832.03	817.9	822.5	43,000
0.59	44,000	832.18	818.0	822.5	44,000
0.53	45,000	832.32	818.2	822.5	45,000
0.47	46,000	832.47	818.3	822.5	46,000
0.41	47,000	832.61	818.5	822.5	47,000
0.37	48,000	832.75	818.7	822.5	48,000
0.33	49,000	832.90	818.8	822.5	49,000
0.28	50,000	833.04	819.0	822.5	50,000
0.25	51,000	833.18	819.2	822.5	51,000
0.25	52,000	833.32	819.3	822.5	52,000
0.23	53,000	833.45	819.5	822.5	53,000
0.23	54,000	833.59	819.7	822.5	54,000
0.22	55,000	833.73	819.8	822.5	55,000
0.20	56,000	833.86	820.0	822.5	56,000
0.18	57,000	834.00	820.1	822.5	57,000
0.17	58,000	834.13	820.3	822.5	58,000
0.16	59,000	834.27	820.5	822.5	59,000
0.14	60,000	834.40	820.6	822.5	60,000
0.12	61,000	834.53	820.8	822.5	61,000
0.10	62,000	834.66	820.9	822.5	62,000
0.09	63,000	834.79	821.1	822.5	63,000
0.06	64,000	834.92	821.3	822.5	64,000
0.05	65,000	835.05	821.4	822.5	65,000
0.05	66,000	835.18	821.6	822.5	66,000
0.04	67,000	835.31	821.7	822.5	67,000
0.03	68,000	835.43	821.9	822.5	68,000
0.02	69,000	835.56	822.0	822.5	69,000
0.01	70,000	835.69	822.2	822.5	70,000

Return	River Flow		Headwater Elev.		Tailwater Elev.	
Period (yr)	Annual (cfs)	Aug - Feb (cfs)	Annual (ft-msl)	Aug - Feb (ft-msl)	Annual (ft-msl)	Aug - Feb (ft-msl)
1	6,560	2,080	825.1	823.7	811.5	810.5
2	29,650	11,110	829.8	826.3	815.7	812.4
5	44,430	18,680	832.2	827.8	818.1	813.8
10	53,400	24,090	833.5	829.0	819.6	814.7
25	63,730	31,190	834.8	830.2	821.2	815.9
50	70,710	36,600	835.7	831.0	822.3	816.8
100	77,130	42,050	836.6	831.9	823.2	817.7

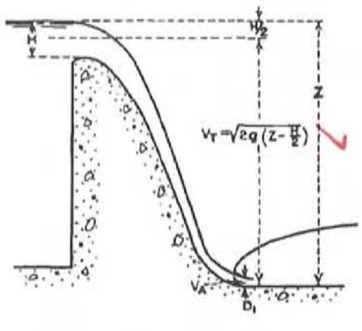
Hydraulic Computations

Hydraulic Jump Measurement/Prediction

Computed by: A. Judd
Checked by: N. VANG
Approved by: M. Weber

Step 7 Estimate hydraulic jump location for spillway apron

The figure below is from Ref 1 and was used to estimate the velocity at the toe
The equation was developed for steeper spillway slope than Coon Rapids but with Coon Rapids Dam's "relatively" small Z the relationship is assumed to provide a order of magnitude estimate of velocity at toe.



Once the theoretical velocity at the toe is estimated, hydraulic parameters can be computed using relationships established by Ref 1

$$D_1 = \frac{Q}{V_1 * W}$$ where W = width of spillway

$$F_1=\frac{V_1}{\sqrt{gD_1}}$$

$$\frac{D_2}{D_1}=1/2\ (\sqrt{1+8F_1^2}-1)$$

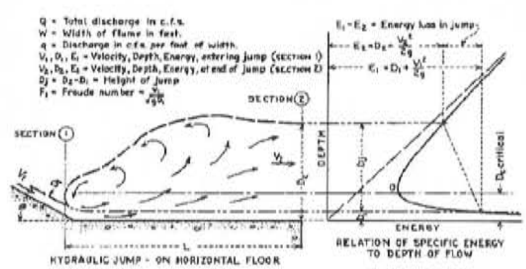
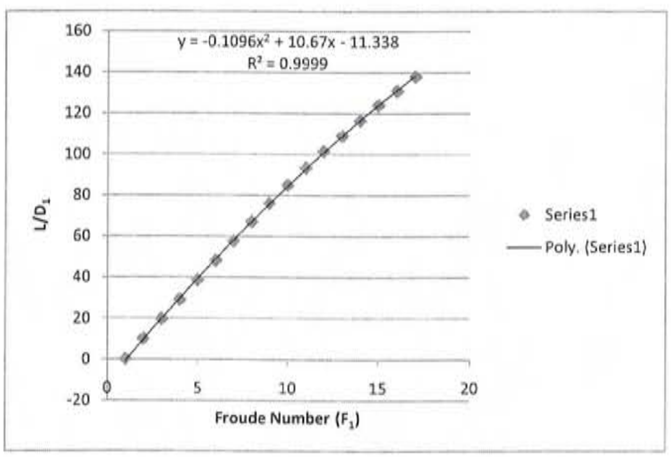


Figure 4.—*Definition of symbols (Basin I).*

Discharge over the spillway is assumed to be supercritical at the toe followed by a hydraulic jump on the downstream apron, with D_2 being the flow depth following the hydraulic jump

Using an empirical relationship from Ref 1 the length of apron from the toe to the end of the hydraulic jump can be estimated.



X	Y
1	0
2	10
3	19.5
4	29
5	38.5
6	48
7	57.5
8	67
9	76
10	85
11	93.5
12	101.5
13	109
14	116.5
15	124
16	131
17	138

Observations of the hydraulic jump were conducted by measuring the location of the hydraulic jump relative to the downstream end of pier 1. River flows were obtained from the USGS gage and gate settings were obtained from Three Rivers Park District. Inspection forms are attached.

THREE RIVERS PARK DISTRICT
COON RAPIDS DAM FISH PASSAGE EVALUATON
FIELD INVESTIGATION HYDRAULIC RESULTS - HYDRAULIC JUMP PREDICTION/MEASUREMENT
STANLEY CONSULTANTS, INC.
21-Jan-11

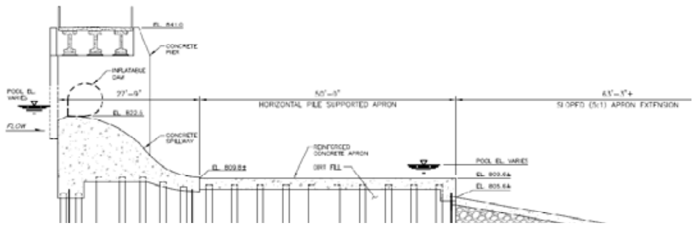
FIELD DATA

				Length >>	***105***		***309***	***147***	***75***	***309***	Hydraulic Jump	
	USGS			Control	Flow Passing Over Gate						Measured	Adjusted
Date	Discharge (cfs)	Pool Elevation (ft)	Tailwater Elevation (ft)	Gate setting (%)	Control Gate (cfs)	Difference	Gate 1 (cfs)	Gate 2[1] (cfs)	Gate 3 (cfs)	Gate 4 (cfs)	Length (ft)	Length (ft)
9/16/2010	10500	830.1	812.3	40.34	2373	8127	3624	0	880	3624	66.2	53.4
9/21/2010	12200	830.1	812.6	40.08	2394	9806	4373	0	1061	4373	60.3	47.8
9/24/2010	14000	830.1	812.9	42.25	2220	11780	5253	0	1275	5253	67.7	54.8
9/28/2010	15200	830.1	813.1	45.09	1993	13207.2	5889	0	1429	5889	66.7	53.9
9/30/2010	16500	830.1	813.4	40.57	2354	14145.6	6307	0	1531	6307	64.7	52.0
10/6/2010	15300	830.1	813.2	44.73	2022	13278.4	5921	0	1437	5921	66.2	53.4
10/8/2010	13100	830.1	812.8	46.43	1886	11214.4	5000	0	1214	5000	67.2	54.3

[1]Gate 2 fully inflated. No water passage allowed.

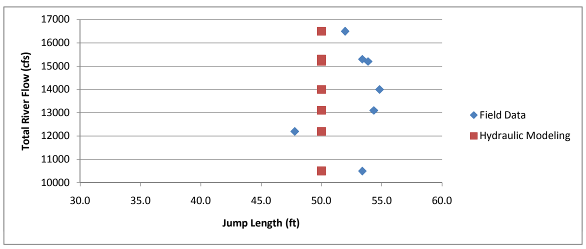
gate releasing flow onto apron

HYDRAULIC MODELING



Apron Elevation at Gate 1 809.6 Sloped Apron Elevation = 805.6

Gate 1 Hydraulic Parameters									
Gate 1 Setting (ft)	q (ft^2/s)	Toe Velocity (ft/s)	Flow Depth D_1 (ft)	Froude Number	Min D_2 for jump(ft)	TW Depth on Apron (ft)	TW Depth at Sloped Apron (ft)	Jump Length (ft)	Jump Difference (ft)
827.82	11.7	35.3	0.33	10.8	4.9	2.7	6.7	50.0	3.4
827.51	14.2	35.2	0.40	9.8	5.4	3.0	7.0	50.0	-2.2
827.17	17.0	35.0	0.49	8.9	5.8	3.3	7.3	50.0	4.8
826.94	19.1	34.9	0.55	8.3	6.2	3.5	7.5	50.0	3.9
826.79	20.4	34.8	0.59	8.0	6.4	3.8	7.8	50.0	2.0
826.93	19.2	34.9	0.55	8.3	6.2	3.6	7.6	50.0	3.4
827.27	16.2	35.1	0.46	9.1	5.7	3.2	7.2	50.0	4.3



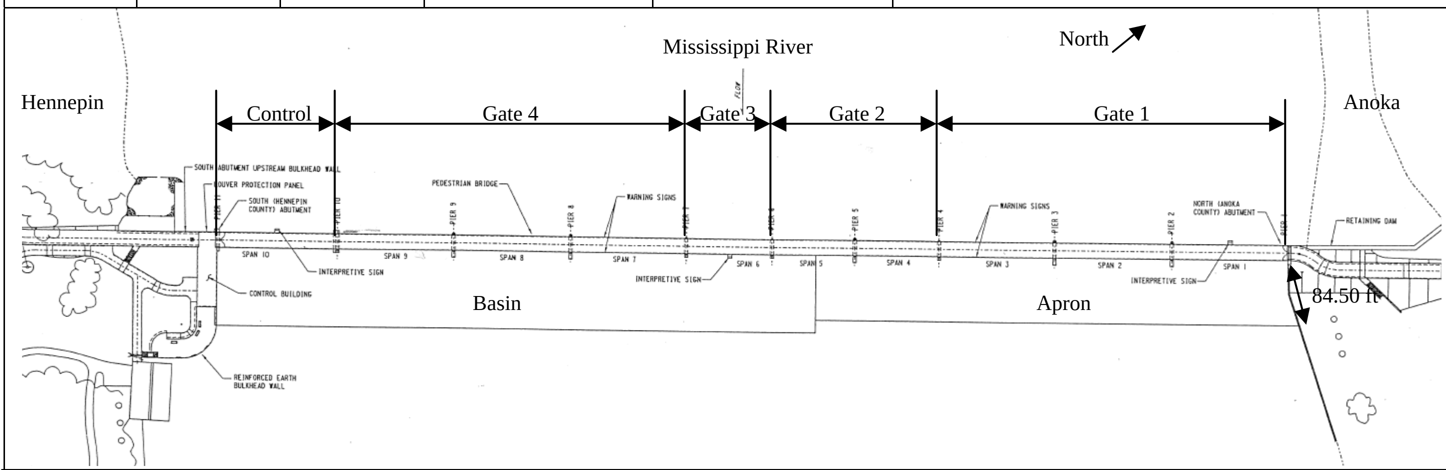
U = 830.1
At what flows would jump be contained on the Apron for Gate 1 P = 828.1
D = 822.5

Flow (cfs)	HWEL (ft-msl)	TWEL (ft-msl)	Setting U,P,D	Elevation (ft-msl)	Flow (cfs)	q (ft^2/s)	Toe Velocity (ft/s)	Flow Depth D_1 (ft)	Froude Number	Min D_2 (ft)	TW Depth Apron (ft)	TW Depth Sloped (ft)	Jump L (ft)
65,000	830.10	821.4	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	11.8	15.8	62.6
64,000	830.10	821.3	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	11.7	15.7	62.6
63,000	830.10	821.1	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	11.5	15.5	62.6
62,000	830.10	820.9	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	11.3	15.3	62.6
61,000	830.10	820.8	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	11.2	15.2	62.6
60,000	830.10	820.6	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	11.0	15.0	62.6
59,000	830.10	820.5	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	10.9	14.9	50.0
58,000	830.10	820.3	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	10.7	14.7	50.0
57,000	830.10	820.1	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	10.5	14.5	50.0
56,000	830.10	820.0	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	10.4	14.4	50.0
55,000	830.10	819.8	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	10.2	14.2	50.0
54,000	830.10	819.7	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	10.1	14.1	50.0
53,000	830.10	819.5	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	9.9	13.9	50.0
52,000	830.10	819.3	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	9.7	13.7	50.0
51,000	830.10	819.2	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	9.6	13.6	50.0
50,000	830.10	819.0	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	9.4	13.4	50.0
49,000	830.10	818.8	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	9.2	13.2	50.0
48,000	830.10	818.7	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	9.1	13.1	50.0
47,000	830.10	818.5	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	8.9	12.9	50.0
46,000	830.10	818.3	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	8.7	12.7	50.0
45,000	830.10	818.2	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	8.6	12.6	50.0
44,000	830.10	818.0	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	8.4	12.4	50.0
43,000	830.10	817.9	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	8.3	12.3	50.0
42,000	830.10	817.7	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	8.1	12.1	50.0
41,000	830.10	817.5	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	7.9	11.9	50.0
40,000	830.10	817.4	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	7.8	11.8	50.0
39,000	830.10	817.2	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	7.6	11.6	50.0
38,000	830.10	817.0	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	7.4	11.4	50.0
37,000	830.10	816.9	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	7.3	11.3	50.0
36,000	830.10	816.7	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	7.1	11.1	50.0
35,000	830.10	816.5	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	6.9	10.9	50.0
34,000	830.10	816.4	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	6.8	10.8	50.0
33,000	830.10	816.2	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	6.6	10.6	50.0
32,000	830.10	816.0	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	6.4	10.4	50.0
31,000	830.10	815.9	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	6.3	10.3	50.0
30,000	830.10	815.7	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	6.1	10.1	50.0
29,000	830.10	815.5	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	5.9	9.9	50.0
28,000	830.10	815.4	D	822.5	22,012	71.24	32.8	2.17	3.9	11.0	5.8	9.8	50.0
27,000	830.10	815.2	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	5.6	9.6	27.4
26,000	830.10	815.0	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	5.4	9.4	27.4
25,000	830.10	814.9	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	5.3	9.3	27.4
24,000	830.10	814.7	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	5.1	9.1	27.4
23,000	830.10	814.5	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	4.9	8.9	27.4
22,000	830.10	814.4	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	4.8	8.8	27.4
21,000	830.10	814.2	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	4.6	8.6	27.4
20,000	830.10	814.0	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	4.4	8.4	50.0
19,000	830.10	813.8	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	4.2	8.2	50.0
18,000	830.10	813.7	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	4.1	8.1	50.0
17,000	830.10	813.5	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	3.9	7.9	50.0
16,000	830.10	813.3	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	3.7	7.7	50.0
15,000	830.10	813.1	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	3.5	7.5	50.0
14,000	830.10	812.9	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	3.3	7.3	50.0
13,000	830.10	812.7	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	3.1	7.1	50.0
12,000	830.10	812.5	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	2.9	6.9	50.0
11,000	830.10	812.4	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	2.8	6.8	50.0
10,000	830.10	812.2	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	2.6	6.6	50.0
9,000	830.10	812.0	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	2.4	6.4	50.0
8,000	830.10	811.8	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	2.2	6.2	50.0
7,000	830.10	811.6	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	2.0	6.0	50.0
6,000	830.10	811.3	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	1.7	5.7	50.0
5,000	830.10	811.1	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	1.5	5.5	50.0
4,000	830.10	810.9	P	828.1	2,972	9.62	35.4	0.27	12.0	4.5	1.3	5.3	50.0

COON RAPIDS DAM EVALUATION
FIELD OBSERVATIONS
INSPECTION FORM

<table>
<tr><td>Inspectors:
Nelson Vang, Andrew Judd, Luke Karels</td><td>Date:
09/16/2010</td><td>Pool Elevation:
830.1</td></tr>
<tr><td>Weather:
Overcast, chilly, rained day before.</td><td>Time:
10:00 AM – 12:00 PM</td><td>USGS River Discharge:
10,460 cfs</td></tr>
</table>

<table>
<tr><th colspan="2">Gate Config: 14</th><th>Side</th><th>Tailwater Reading</th><th>Jump Location</th><th>Notes</th></tr>
<tr><td>Gate 1</td><td>Partial</td><td rowspan="3">Anoka</td><td rowspan="3"></td><td rowspan="3">66’-2”</td><td rowspan="5">Measurement was taken from end of fence post at the dam wall to the location of jump. Note: The distance of 6 fence posts from the dam wall is about 51.5 ft.</td></tr>
<tr><td>Gate 2</td><td>Full</td></tr>
<tr><td>Gate 3</td><td>Partial</td></tr>
<tr><td>Gate 4</td><td>Partial</td><td rowspan="2">Hennepin</td><td rowspan="2">11’-11”</td><td rowspan="2">Submerged</td></tr>
<tr><td>Control</td><td>40.34%</td></tr>
</table>



COON RAPIDS DAM EVALUATION
FIELD OBSERVATIONS
INSPECTION FORM

<table>
<tr><td>Inspectors:
Nelson Vang</td><td>Date:
09/21/2010</td><td>Pool Elevation:
830.1</td></tr>
<tr><td>Weather:
Sunny w/ little breeze, had stormed overnight</td><td>Time:
8:30 AM – 9:30 AM</td><td>USGS River Discharge:
12,200 cfs</td></tr>
</table>

<table>
<tr><th colspan="2">Gate Config: 14</th><th>Side</th><th>Tailwater Reading</th><th>Jump Location</th><th>Notes</th></tr>
<tr><td>Gate 1</td><td>Partial</td><td rowspan="3">Anoka</td><td rowspan="3">12’-7”</td><td rowspan="3">60’-4”</td><td rowspan="5">Jump location seemed to have moved back (towards dam) compared to last observation. Tailwater reading on Anoka side was taken from 7th fence post. Note: The measure tape ran along slanted wall, not completely vertical (Anoka side, tailwater reading). There has been a huge amount of rainfall overnight. Photo 1 taken from fence post 7. Keep consistent from here on.</td></tr>
<tr><td>Gate 2</td><td>Full</td></tr>
<tr><td>Gate 3</td><td>Partial</td></tr>
<tr><td>Gate 4</td><td>Partial</td><td rowspan="2">Hennepin</td><td rowspan="2">11’-8”</td><td rowspan="2">Submerged</td></tr>
<tr><td>Control</td><td>40.08%</td></tr>
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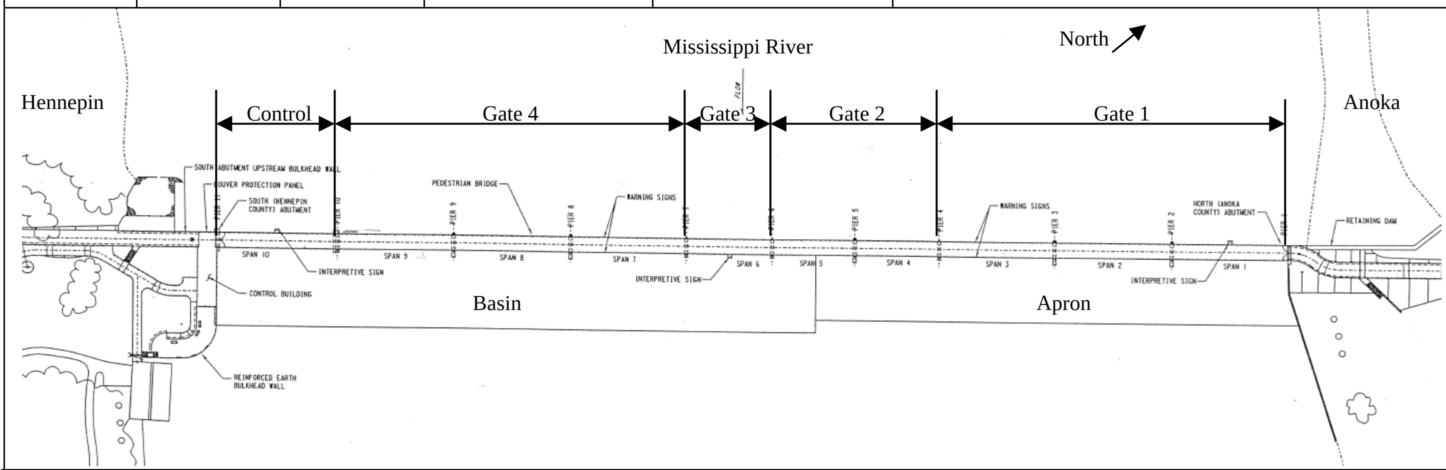
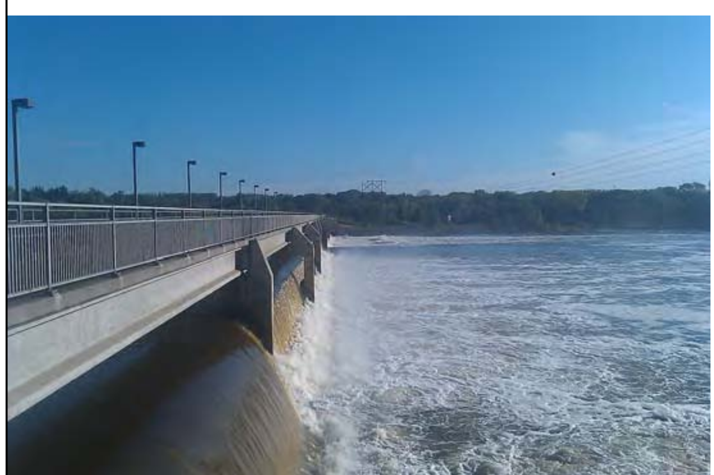
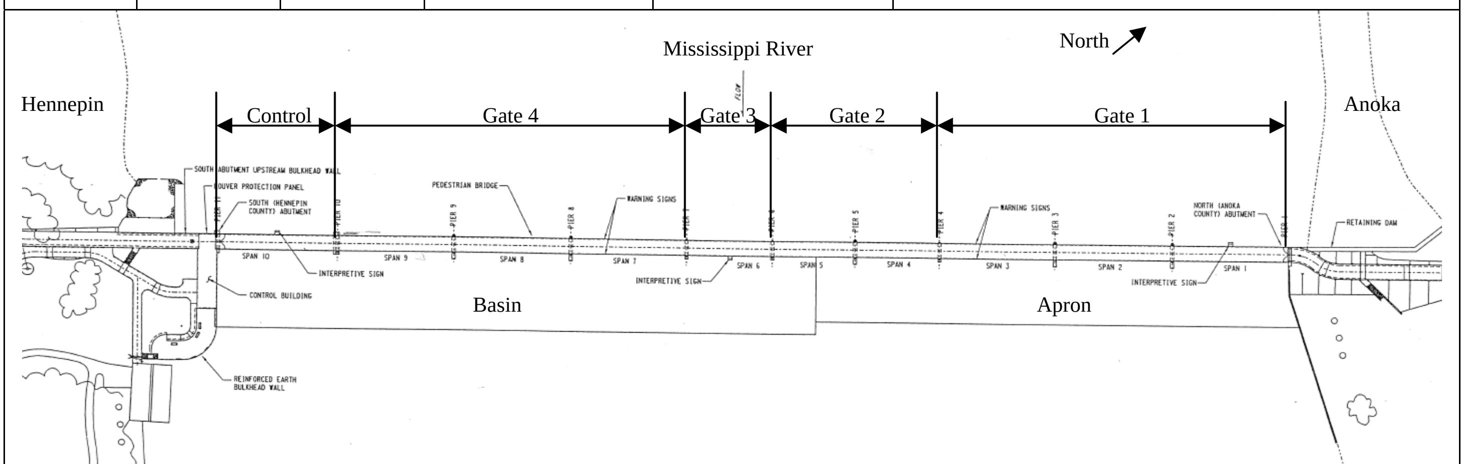




COON RAPIDS DAM EVALUATION
FIELD OBSERVATIONS
INSPECTION FORM

Inspectors:	Date:	Pool Elevation:
Nelson Vang	09/24/2010	830.1
Weather:	**Time:**	**USGS River Discharge:**
Cold, windy, had rained all day before, very cloudy	9:00 AM – 10:00 AM	13,920 cfs

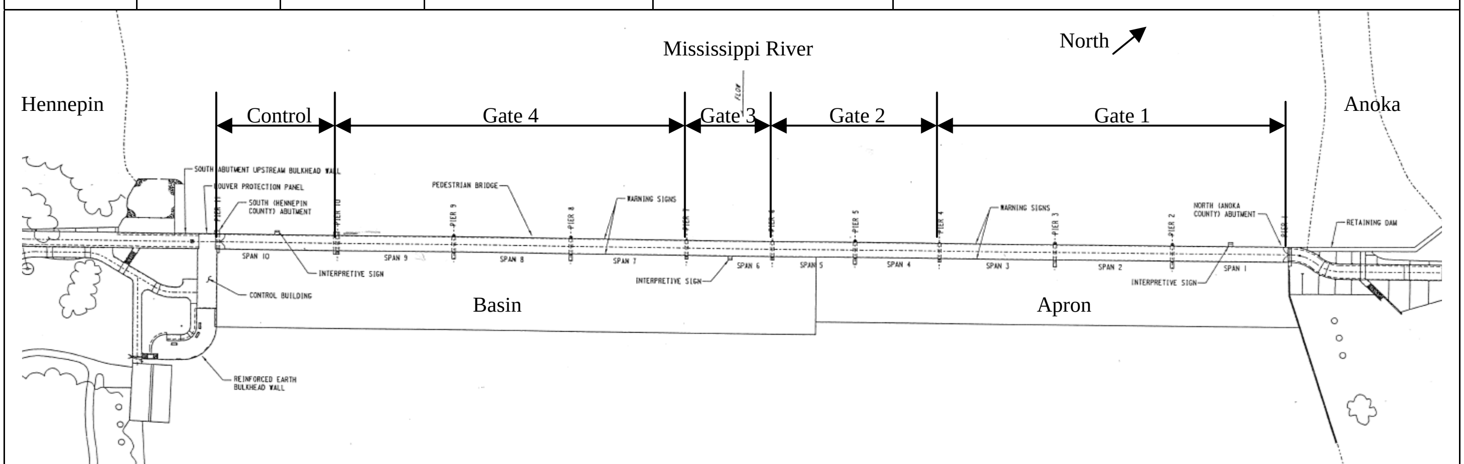
Gate Config: 14		Side	Tailwater Reading	Jump Location	Notes
Gate 1	Partial	Anoka	12’-4”	67’-8”	Rushing water over dam due to high winds. It had rained ALL day before. Gate 2 was fully inflated, but water was rushing over. Water on apron side was running very fast. High misting and lots of turbulence. Hydraulic jump was noticeably higher at jump location.
Gate 2	Full				
Gate 3	Partial				
Gate 4	Partial	Hennepin	11’-7”	Submerged	
Control	42.25%				

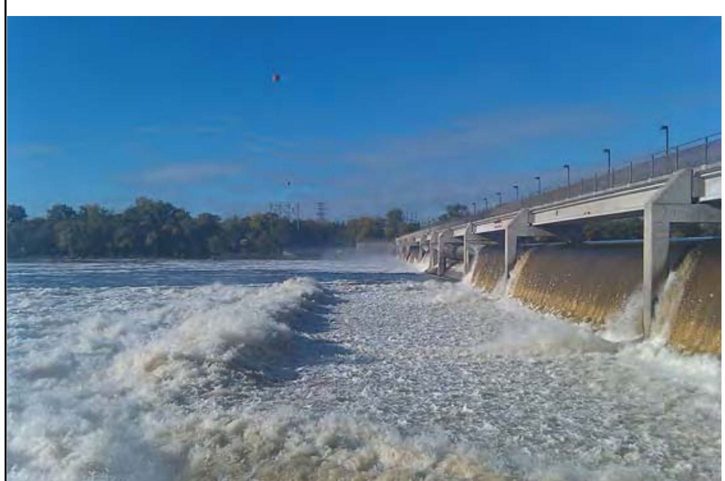


COON RAPIDS DAM EVALUATION
FIELD OBSERVATIONS
INSPECTION FORM

Inspectors: Nelson Vang	Date: 09/28/2010	Pool Elevation: 830.1
Weather: Sunny, calm breeze, cool	Time: 9:00 AM – 10:00 AM	USGS River Discharge: 15,200 cfs

Gate Config: 14		Side	Tailwater Reading	Jump Location	Notes
Gate 1	Partial	Anoka	12’-4”	66’-8”	Flooding of Minnesota River and Mississippi River this week downstream in St. Paul. Hydraulic jump location seemed to have retreated towards dam a bit on Apron side. Heavy current.
Gate 2	Full				
Gate 3	Partial				
Gate 4	Partial	Hennepin	11’-4”	Submerged	
Control	45.09%				

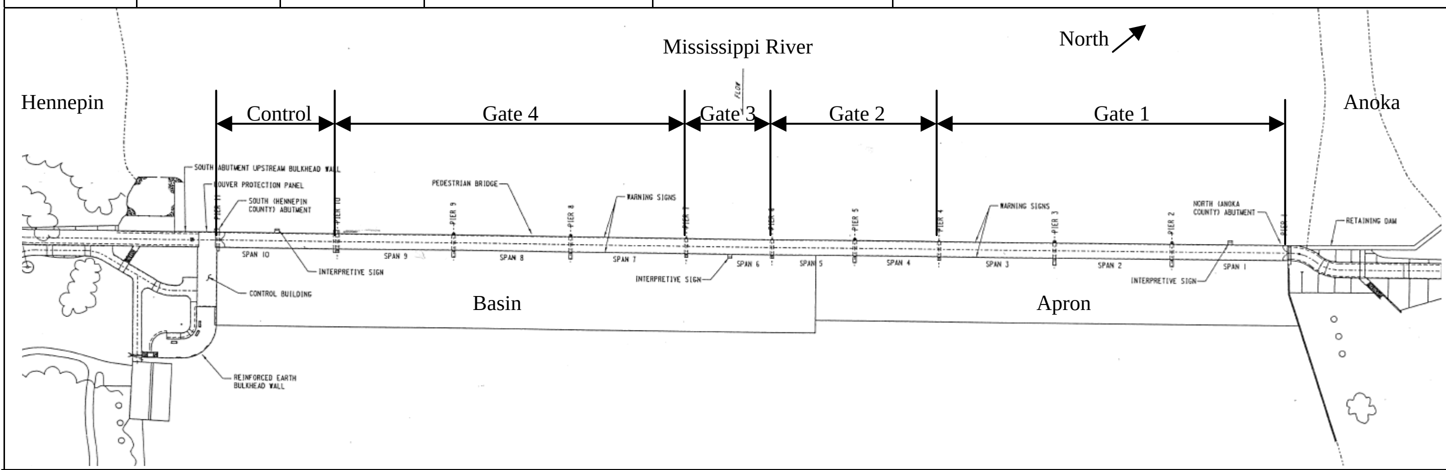




COON RAPIDS DAM EVALUATION
FIELD OBSERVATIONS
INSPECTION FORM

Inspectors: Nelson Vang	Date: 09/30/2010	Pool Elevation: 830.1
Weather: Sunny, warm day, breezy	Time: 2:00 PM – 3:00 PM	USGS River Discharge: 16,500 cfs

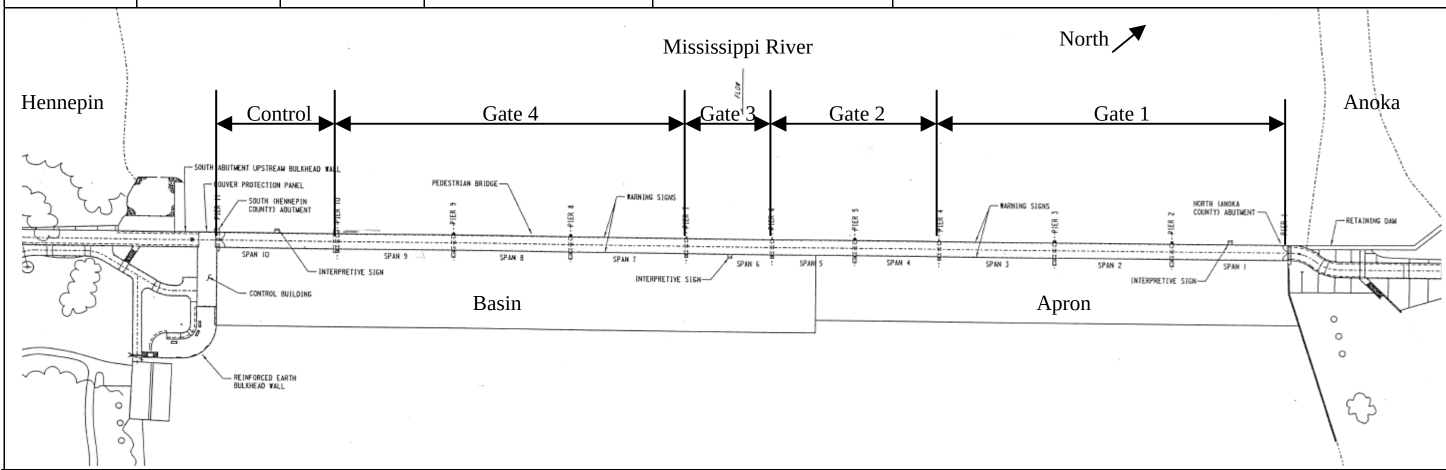
Gate Config: 14		Side	Tailwater Reading	Jump Location	Notes
Gate 1	Partial	Anoka	12’-10”	64’-8”	
Gate 2	Full				
Gate 3	Partial				
Gate 4	Partial	Hennepin	11’-2”	Submerged	
Control	40.57%				

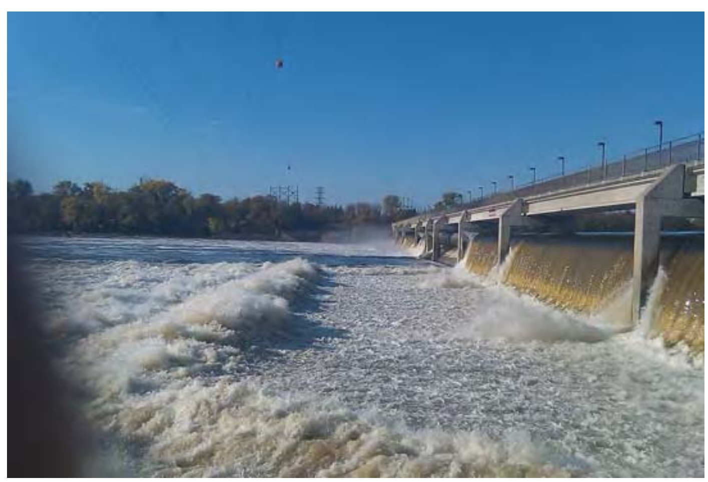


COON RAPIDS DAM EVALUATION
FIELD OBSERVATIONS
INSPECTION FORM

Inspectors: Nelson Vang	Date: 10/06/2010	Pool Elevation: 830.1
Weather: Sunny, breezy, cool	Time: 9:30 AM – 10:30 AM	USGS River Discharge: 15,280

Gate Config: 14		Side	Tailwater Reading	Jump Location	Notes
Gate 1	Partial	Anoka	12’-10”	66’-2”	Floods in Minnesota River and Mississippi River downstream are lowering. Max flow occurred on Saturday, Oct 2 to about 17,000 cfs and has been descending since. An extra measurement taken from bridge on Span 2; tape measure was rolled down to the water (from top of bridge), where the weight was dragged to approx where jump was. The distance was recorded: 71’-4”.
Gate 2	Full				
Gate 3	Partial				
Gate 4	Partial	Hennepin	11’-2”	Submerged	
Control	44.73%				





COON RAPIDS DAM EVALUATION
FIELD OBSERVATIONS
INSPECTION FORM

Inspectors: Nelson Vang	Date: 10/08/2010	Pool Elevation: 830.1
Weather: Sunny, calm wind, warm	Time: 8:30 AM – 9:30 AM	USGS River Discharge: 13,100

<table>
<tr><th colspan="2">Gate Config: 14</th><th>Side</th><th>Tailwater Reading</th><th>Jump Location</th><th>Notes</th></tr>
<tr><td>Gate 1</td><td>Partial</td><td rowspan="3">Anoka</td><td rowspan="3">12’-10”</td><td rowspan="3">67’-2”</td><td rowspan="5">Top of bridge jump location: 71’-10”</td></tr>
<tr><td>Gate 2</td><td>Full</td></tr>
<tr><td>Gate 3</td><td>Partial</td></tr>
<tr><td>Gate 4</td><td>Partial</td><td rowspan="2">Hennepin</td><td rowspan="2">11’-8”</td><td rowspan="2">Submerged</td></tr>
<tr><td>Control</td><td>46.43%</td></tr>
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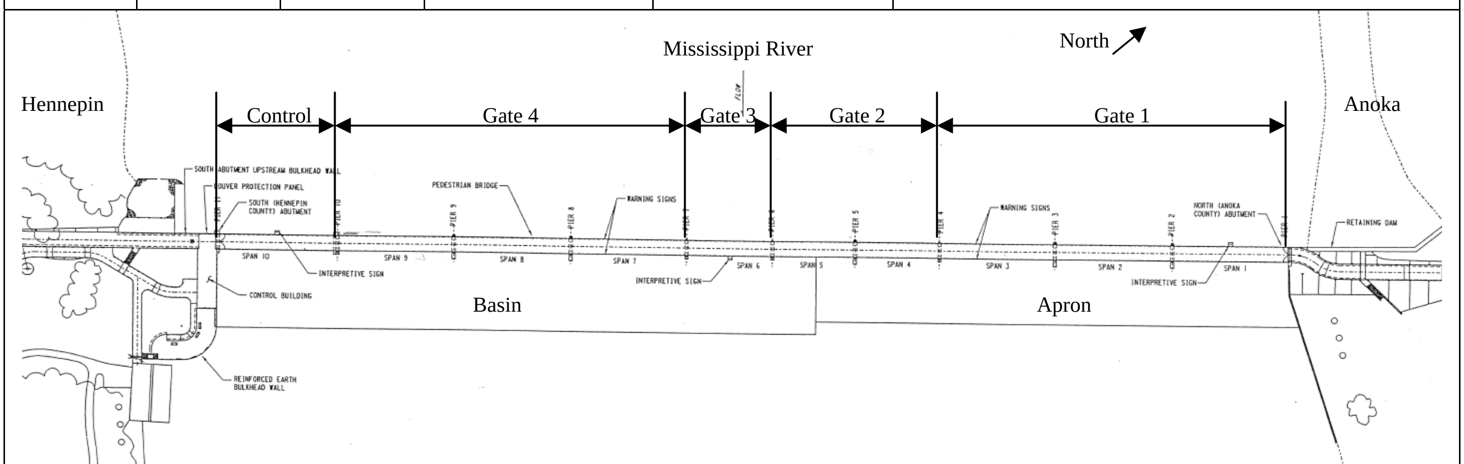
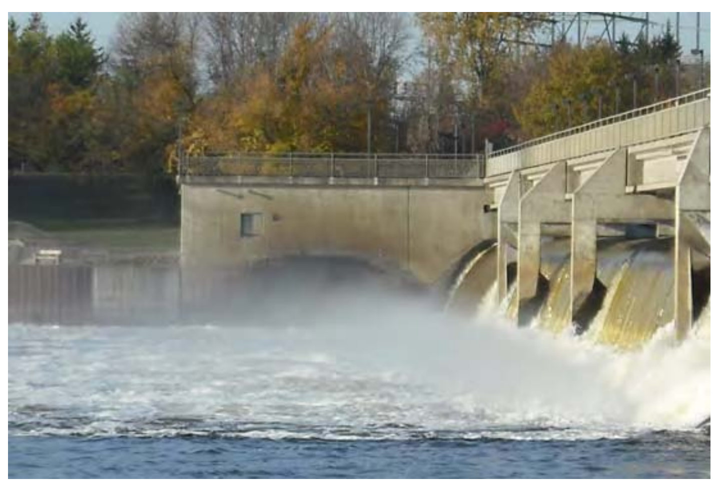




Geotechnical Computations

Sheet Pile Cofferdam Structural Analysis

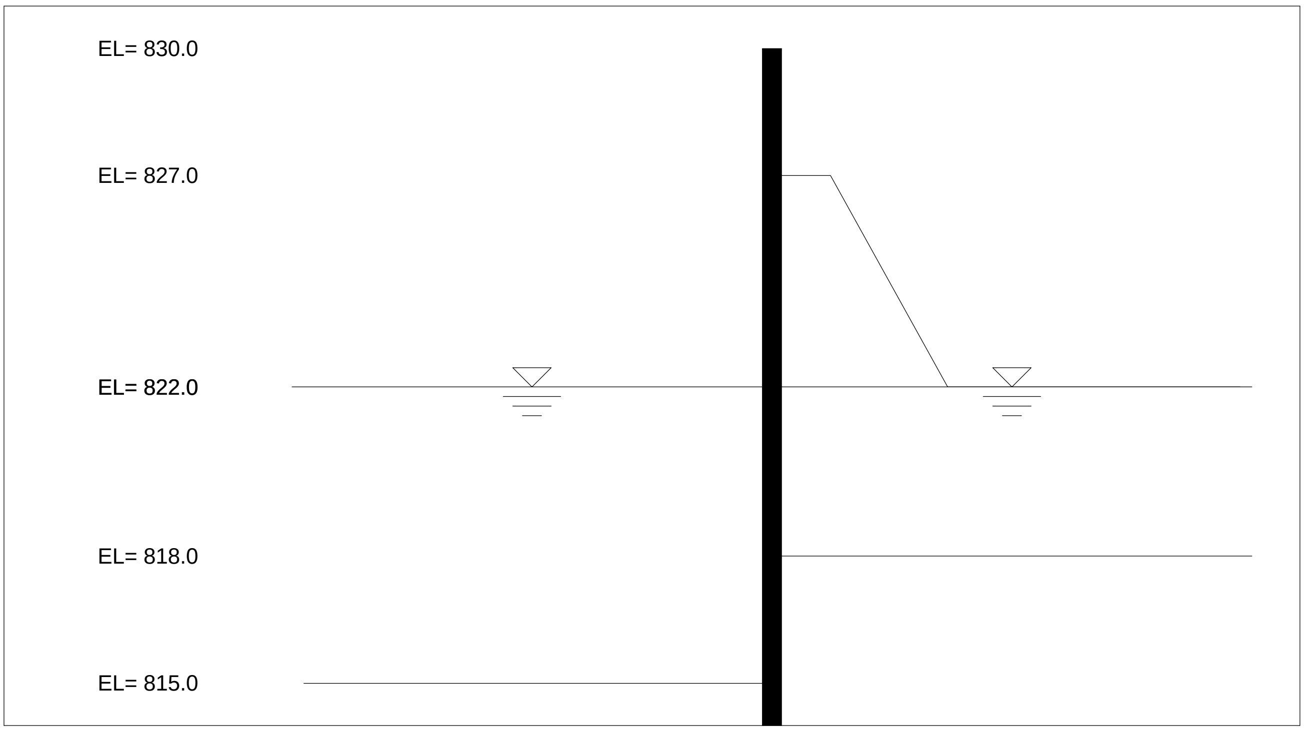
Case 1

Upstream Cofferdam – Upstream Deflection

Anoka Side

'COON RAPIDS DAM

'UPSTREAM COFFERDAM ANALYSIS



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'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   830
SURFACE RIGHTSIDE   4    0    827
                  5    827
                  15    822
                  40    822
SURFACE LEFTSIDE   2    0    815
                  40    815
SOIL RIGHTSIDE  STRENGTHS   2
   120    120    27    0    0    0    818   0
   125    125    30    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   125    125    30    0    0    0
WATER ELEVATIONS   62.4    822    822
VERTICAL STRIP  RIGHTSIDE   2    0    5    100
                     15    40    200
FINISHED
```

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 10:27:28

```
                    ****************
                    *  INPUT DATA  *
                    ****************

    I.--HEADING
   'COON RAPIDS DAM
   'UPSTREAM COFFERDAM ANALYSIS
   'ANOKA SIDE - ALLUVIAL SANDS

   II.--CONTROL
      CANTILEVER WALL DESIGN
      FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
      FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

  III.--WALL DATA
      ELEVATION AT TOP OF WALL    = 830.00 FT.

   IV.--SURFACE POINT DATA

        IV.A.--RIGHTSIDE
           DIST. FROM     ELEVATION
           WALL (FT)        (FT)
                0.00       827.00
                5.00       827.00
               15.00       822.00
               40.00       822.00

        IV.B.--LEFTSIDE
           DIST. FROM     ELEVATION
           WALL (FT)        (FT)
                0.00       815.00
               40.00       815.00

    V.--SOIL LAYER DATA

       V.A.--RIGHTSIDE
           LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
           LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH- ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH- ESION (PSF)	<--BOTTOM--> ELEV. (FT)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	<-SAFETY-> <-FACTOR-> PASS.
120.00	120.00	27.00	0.00	0.00	0.00	818.00	0.00	DEF	DEF
125.00	125.00	30.00	0.00	0.00	0.00			DEF	DEF

```
       V.B.--LEFTSIDE
           LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
           LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH- ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH- ESION (PSF)	<--BOTTOM--> ELEV. (FT)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	<-SAFETY-> <-FACTOR-> PASS.
125.00	125.00	30.00	0.00	0.00	0.00			DEF	DEF

```
   VI.--WATER DATA
      UNIT WEIGHT         = 62.40 (PCF)
      RIGHTSIDE ELEVATION = 822.00 (FT)
```

```
        LEFTSIDE ELEVATION  = 822.00 (FT)
        NO SEEPAGE

    VII.--VERTICAL SURCHARGE LOADS

        VII.A.--VERTICAL LINE LOADS
             NONE

        VII.B.--VERTICAL UNIFORM LOADS
                  NONE

        VII.C.--VERTICAL STRIP LOADS

             VII.C.1.--RIGHTSIDE
             <-DIST. FROM WALL->
               START       END      STRIP LOAD
                (FT)       (FT)        (PSF)
                0.00       5.00       100.00
               15.00      40.00       200.00

             VII.C.2.--LEFTSIDE
                  NONE

        VII.D.--VERTICAL RAMP LOADS
             NONE

        VII.E.--VERTICAL TRIANGULAR LOADS
             NONE

        VII.F.--VERTICAL VARIABLE LOADS
             NONE

   VIII.--HORIZONTAL LOADS
        NONE
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                         TIME: 10:27:32

                          **************************
                          *    SOIL PRESSURES FOR    *
                          * CANTILEVER WALL DESIGN *
                          **************************

    I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'ANOKA SIDE - ALLUVIAL SANDS

   II.--SOIL PRESSURES

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.
```

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)
830.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
829.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
828.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
827.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
826.0	0.0	0.0	0.0	82.6	280.1	82.6	280.1*
825.0	0.0	0.0	0.0	127.7	372.8	127.7	372.8*
824.0	0.0	0.0	0.0	172.7	506.5	172.7	506.5*
823.0	0.0	0.0	0.0	217.8	649.7	217.8	649.7*
822.0	0.0	0.0	0.0	257.0	704.1	257.0	704.1*
821.0	0.0	0.0	0.0	284.4	708.5	284.4	708.5
820.0	0.0	0.0	0.0	306.1	773.7	306.1	773.7
819.0	0.0	0.0	0.0	323.6	890.3	323.6	890.3
818.0	0.0	0.0	0.0	311.0	1123.1	311.0	1123.1
817.0	0.0	0.0	0.0	293.8	1322.6	293.8	1322.6
816.0	0.0	0.0	0.0	304.0	1401.6	304.0	1401.6
815.0	0.0	0.0	0.0	318.1	1488.5	318.1	1488.5
814.0	0.0	132.8	20.8	197.5	1565.6	330.3	1586.4
813.0	0.0	265.6	41.7	76.9	1647.5	342.5	1689.2
812.4	0.0	350.2	55.0	0.0	1699.7	350.2	1754.7
812.0	0.0	398.4	62.5	-43.8	1729.4	354.6	1791.9
811.0	0.0	531.2	83.4	-164.4	1833.2	366.8	1916.6
810.0	0.0	664.0	104.2	-283.9	1943.4	380.1	2047.6
809.0	0.0	796.8	125.1	-402.2	2045.0	394.6	2170.1
808.0	0.0	929.6	145.9	-521.4	2158.5	408.2	2304.4
807.0	0.0	1062.4	166.8	-641.3	2257.2	421.1	2424.0
806.0	0.0	1195.2	187.6	-759.4	2357.4	435.8	2545.1
805.0	0.0	1328.0	208.5	-877.5	2471.4	450.6	2679.9
804.0	0.0	1460.8	229.3	-996.8	2585.4	464.0	2814.8
803.0	0.0	1593.6	250.2	-1116.1	2673.8	477.5	2924.0
802.0	0.0	1726.4	271.0	-1235.5	2668.7	491.0	2939.7
801.0	0.0	1859.2	291.9	-1354.8	2666.8	504.4	2958.7
800.0	0.0	1992.0	312.7	-1474.1	2744.8	517.9	3057.5
799.0	0.0	2124.8	333.6	-1593.5	2836.2	531.4	3169.8
798.0	0.0	2257.6	354.4	-1712.8	2943.5	544.8	3297.9
797.0	0.0	2390.4	375.3	-1832.2	3061.9	558.3	3437.2
796.0	0.0	2523.2	396.1	-1951.5	3155.4	571.8	3551.5
795.0	0.0	2656.0	417.0	-2070.8	3238.9	585.2	3655.9
794.0	0.0	2788.9	437.8	-2190.2	3346.0	598.7	3783.8
793.0	0.0	2921.7	458.7	-2309.5	3461.9	612.2	3920.5
792.0	0.0	3054.5	479.5	-2428.8	3577.7	625.6	4057.2
791.0	0.0	3187.3	500.4	-2548.2	3693.5	639.1	4193.9
790.0	0.0	3320.1	521.2	-2667.5	3779.6	652.5	4300.9
789.0	0.0	3452.9	542.1	-2765.3	3864.6	687.5	4406.7
788.0	0.0	3585.7	562.9	-2840.7	3978.4	745.0	4541.3
787.0	0.0	3718.5	583.8	-2933.9	4092.4	784.5	4676.2
786.0	0.0	3851.3	604.6	-3046.0	4206.4	805.3	4811.0
785.0	0.0	3984.1	625.5	-3158.1	4320.4	826.0	4945.8
784.0	0.0	4116.9	646.3	-3270.2	4434.3	846.7	5080.7
783.0	0.0	4249.7	667.2	-3382.3	4548.3	867.4	5215.5
782.0	0.0	4382.5	688.0	-3494.4	4657.9	888.1	5345.9
781.0	0.0	4515.3	708.9	-3606.5	4746.3	908.8	5455.2
780.0	0.0	4648.1	729.7	-3718.6	4838.7	929.5	5568.4
779.0	0.0	4780.9	750.6	-3830.6	4951.4	950.2	5702.0
778.0	0.0	4913.7	771.4	-3942.7	5064.2	971.0	5835.6
777.0	0.0	5046.5	792.3	-4054.8	5176.9	991.7	5969.2
776.0	0.0	5179.3	813.1	-4166.6	5289.7	1012.7	6102.8
775.0	0.0	5312.1	834.0	-4275.2	5402.4	1036.9	6236.4
774.0	0.0	5444.9	854.8	-4384.2	5515.2	1060.7	6370.0

773.0	0.0	5577.7	875.7	-4496.1	5627.9	1081.6	6503.6
772.0	0.0	5710.5	896.5	-4608.1	5740.7	1102.4	6637.2
771.0	0.0	5843.3	917.4	-4720.0	5853.4	1123.3	6770.8
770.0	0.0	5976.1	938.2	-4832.0	5966.2	1144.1	6904.4
769.0	0.0	6108.9	959.1	-4943.9	6078.9	1165.0	7038.0

* STANDARD WEDGE SOLUTION DOES NOT EXIST FOR INDICATED PRESSURE
FOR THIS ELEVATION.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 10:28:14

```
****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING

'COON RAPIDS DAM

'UPSTREAM COFFERDAM ANALYSIS

'ANOKA SIDE - ALLUVIAL SANDS

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

*****WARNING: STANDARD WEDGE SOLUTION DOES NOT EXIST
AT ALL ELEVATIONS. SEE COMPLETE OUTPUT.

```
WALL BOTTOM ELEV. (FT)     :      794.81
      PENETRATION (FT)     :       20.19

MAX. BEND. MOMENT (LB-FT)  :  3.7943E+04
      AT ELEVATION (FT)    :      804.98

MAX. SCALED DEFL. (LB-IN^3):  2.1818E+10
      AT ELEVATION (FT)    :      830.00
```

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF
ELLASTICITY IN PSI TIMES PILE MOMENT
OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 10:28:14

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****************************
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```
* COMPLETE OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS

II.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
830.00	0.0000E+00	0.	2.1818E+10	0.00
829.00	3.4925E-09	0.	2.0874E+10	0.00
828.00	3.4925E-09	0.	1.9929E+10	0.00
827.00	3.4925E-09	0.	1.8984E+10	0.00
826.00	1.3767E+01	41.	1.8039E+10	82.60
825.00	1.0388E+02	146.	1.7095E+10	127.66
824.00	3.2164E+02	297.	1.6150E+10	172.71
823.00	7.1212E+02	492.	1.5206E+10	217.77
822.00	1.3194E+03	729.	1.4264E+10	256.96
821.00	2.1817E+03	1000.	1.3323E+10	284.45
820.00	3.3274E+03	1295.	1.2387E+10	306.07
819.00	4.7786E+03	1610.	1.1456E+10	323.56
818.00	6.5482E+03	1927.	1.0534E+10	310.97
817.00	8.6281E+03	2230.	9.6228E+09	293.85
816.00	1.1006E+04	2529.	8.7267E+09	304.01
815.00	1.3689E+04	2840.	7.8497E+09	318.11
814.00	1.6668E+04	3097.	6.9964E+09	197.49
813.00	1.9844E+04	3235.	6.1719E+09	76.86
812.36	2.1915E+04	3259.	5.6641E+09	0.00
812.00	2.3097E+04	3251.	5.3817E+09	-43.77
811.00	2.6306E+04	3147.	4.6314E+09	-164.40
810.00	2.9351E+04	2923.	3.9265E+09	-283.87
809.00	3.2113E+04	2580.	3.2724E+09	-402.17
808.00	3.4472E+04	2118.	2.6736E+09	-521.43
807.00	3.6309E+04	1537.	2.1344E+09	-641.28
806.00	3.7506E+04	836.	1.6578E+09	-759.39
805.00	3.7943E+04	18.	1.2459E+09	-877.46
804.00	3.7502E+04	-919.	8.9941E+08	-996.79
803.00	3.6065E+04	-1976.	6.1761E+08	-1116.13
802.00	3.3511E+04	-3151.	3.9796E+08	-1235.47
801.00	2.9722E+04	-4447.	2.3605E+08	-1354.81
800.46	2.7117E+04	-5196.	1.7033E+08	-1419.32
800.00	2.4594E+04	-5761.	1.2530E+08	-1038.87
799.00	1.8451E+04	-6386.	5.6894E+07	-210.64
798.00	1.2098E+04	-6182.	2.0346E+07	617.59
797.00	6.3627E+03	-5151.	4.7920E+06	1445.82
796.00	2.0731E+03	-3291.	4.4125E+05	2274.05
795.00	5.7524E+01	-602.	2.9899E+02	3102.27
794.81	0.0000E+00	0.	0.0000E+00	3259.15

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

```
                 <-------------SOIL PRESSURES-------------->
      WATER      <----LEFTSIDE----->      <---RIGHTSIDE---->
```

ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
830.00	0.	0.	0.	0.	0.
829.00	0.	0.	0.	0.	0.
828.00	0.	0.	0.	0.	0.
827.00	0.	0.	0.	0.	0.
826.00	0.	0.	0.	83.*	280.
825.00	0.	0.	0.	128.*	373.
824.00	0.	0.	0.	173.*	507.
823.00	0.	0.	0.	218.*	650.
822.00	0.	0.	0.	257.*	704.
821.00	0.	0.	0.	284.	708.
820.00	0.	0.	0.	306.	774.
819.00	0.	0.	0.	324.	890.
818.00	0.	0.	0.	311.	1123.
817.00	0.	0.	0.	294.	1323.
816.00	0.	0.	0.	304.	1402.
815.00	0.	0.	0.	318.	1489.
814.00	0.	133.	21.	330.	1586.
813.00	0.	266.	42.	342.	1689.
812.36	0.	350.	55.	350.	1755.
812.00	0.	398.	63.	355.	1792.
811.00	0.	531.	83.	367.	1917.
810.00	0.	664.	104.	380.	2048.
809.00	0.	797.	125.	395.	2170.
808.00	0.	930.	146.	408.	2304.
807.00	0.	1062.	167.	421.	2424.
806.00	0.	1195.	188.	436.	2545.
805.00	0.	1328.	208.	451.	2680.
804.00	0.	1461.	229.	464.	2815.
803.00	0.	1594.	250.	477.	2924.
802.00	0.	1726.	271.	491.	2940.
801.00	0.	1859.	292.	504.	2959.
800.46	0.	1931.	303.	512.	3012.
800.00	0.	1992.	313.	518.	3058.
799.00	0.	2125.	334.	531.	3170.
798.00	0.	2258.	354.	545.	3298.
797.00	0.	2390.	375.	558.	3437.
796.00	0.	2523.	396.	572.	3552.
795.00	0.	2656.	417.	585.	3656.
794.81	0.	2789.	438.	599.	3784.
793.00	0.	2922.	459.	612.	3921.

* STANDARD WEDGE SOLUTION DOES NOT EXIST FOR INDICATED PRESSURE AT THIS ELEVATION.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 1

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam on the Anoka side of Coon Rapids Dam. On Anoka side (existing apron side), alluvial sands are present do elevaton 775. Potential failure occuring from downstream to upstream during low headwater case (CASE 1).

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 3.79 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 2.18\, 10^{10} lbf \cdot in^3$

Required Penetraion: 20.19

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3 \quad I_{PZ} := 184.20 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 15.06 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi \quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_35} = 4.081 \cdot in$

Conclusion

A PZ 27 (or equivalent) is adequate.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 1

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $kpf := \frac{k}{ft}$ $ksf := \frac{k}{ft^2}$ $ksi := \frac{k}{in^2}$ $kcf := \frac{k}{ft^3}$ $ppf := \frac{lbf}{ft}$ $psf := \frac{lbf}{ft^2}$ $psi := \frac{lbf}{in^2}$ $pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\gamma_{water} := 62.4 \cdot pcf$ $\gamma_{conc} := 150 \cdot pcf$ $f_c := 4 \cdot ksi$ $f_y := 60 \cdot ksi$ $F_y := 50 \cdot ksi$ $E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam on the Anoka side of Coon Rapids Dam. On Anoka side (existing apron side), alluvial sands are present do elevaton 775. Potential failure occuring from downstream to upstream during low headwater case (CASE 1).

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 22 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 3.79 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 2.18\, 10^{10} lbf \cdot in^3$

Required Penetraion: 20.19

Section Design

Using a PZ 22

$S_{PZ} := 18.1 in^3$ $I_{PZ} := 84.38 in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 25.127 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $f_b = 25 \cdot ksi$ $f_b < \sigma_b$ Strength NOT sufficient. Use a PZ 27.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_35} = 8.909 \cdot in$

Conclusion

A PZ 27 (or equivalent) is adequate.

Sheet Pile Cofferdam Structural Analysis

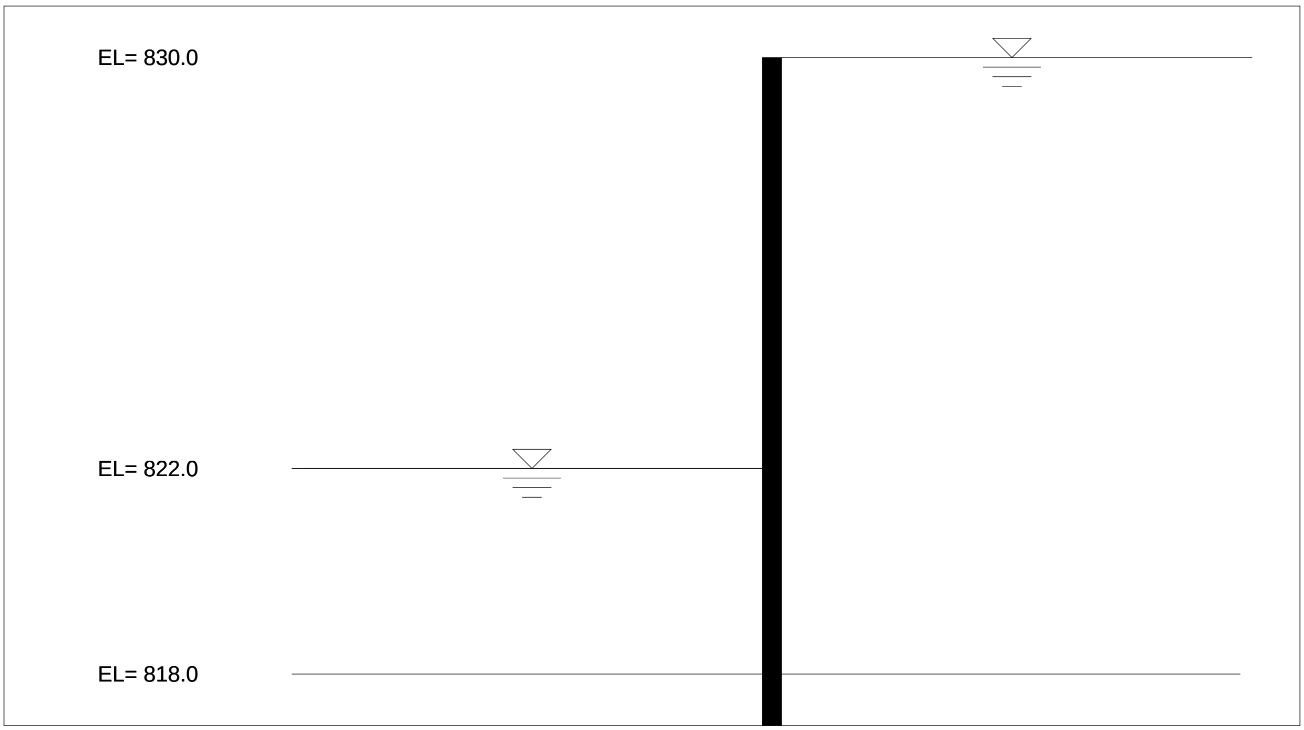
Case 2

Upstream Cofferdam – Downstream Deflection

Anoka Side

'COON RAPIDS DAM

'UPSTREAM COFFERDAM ANALYSIS



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'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'REVERSE CASE - FAILURE TOWARD DOWNSTREAM - WATER TO EL. 830
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   830
SURFACE RIGHTSIDE   2    0    818
                  40    818
SURFACE LEFTSIDE   2    0    822
                  40    822
SOIL RIGHTSIDE  STRENGTHS   1
   125    125    30    0    0    0
SOIL LEFTSIDE  STRENGTHS   2
   120    120    27    0    0    0    818   0
   125    125    30    0    0    0
WATER ELEVATIONS   62.4    830    822
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                       TIME: 10:55:17

                            ****************
                            *  INPUT DATA  *
                            ****************

     I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'ANOKA SIDE - ALLUVIAL SANDS
    'REVERSE CASE - FAILURE TOWARD DOWNSTREAM - WATER TO EL. 830

    II.--CONTROL
       CANTILEVER WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

   III.--WALL DATA
       ELEVATION AT TOP OF WALL    = 830.00 FT.

    IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00       818.00
                40.00       818.00

         IV.B.--LEFTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00       822.00
                40.00       822.00

     V.--SOIL LAYER DATA

        V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

              ANGLE OF         ANGLE OF                         <-SAFETY->
 SAT.   MOIST  INTERNAL  COH-    WALL    ADH-    <--BOTTOM-->   <-FACTOR->
 WGHT.  WGHT.  FRICTION  ESION FRICTION  ESION   ELEV.  SLOPE   ACT. PASS.
 (PCF)  (PCF)   (DEG)    (PSF)  (DEG)    (PSF)   (FT)  (FT/FT)
125.00 125.00   30.00    0.00    0.00    0.00                    DEF  DEF

        V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

              ANGLE OF         ANGLE OF                         <-SAFETY->
 SAT.   MOIST  INTERNAL  COH-    WALL    ADH-    <--BOTTOM-->   <-FACTOR->
 WGHT.  WGHT.  FRICTION  ESION FRICTION  ESION   ELEV.  SLOPE   ACT. PASS.
 (PCF)  (PCF)   (DEG)    (PSF)  (DEG)    (PSF)   (FT)  (FT/FT)
120.00 120.00   27.00    0.00    0.00    0.00  818.00   0.00     DEF  DEF
125.00 125.00   30.00    0.00    0.00    0.00                    DEF  DEF

    VI.--WATER DATA
       UNIT WEIGHT          = 62.40 (PCF)
       RIGHTSIDE ELEVATION = 830.00 (FT)
       LEFTSIDE ELEVATION  = 822.00 (FT)
```

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 20-JANUARY-2011 TIME: 10:55:19

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**************************
*    SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
**************************
```

I.--HEADING
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'REVERSE CASE - FAILURE TOWARD DOWNSTREAM - WATER TO EL. 830

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
830.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
829.0	62.4	0.0	0.0	62.4	62.4	0.0	0.0
828.0	124.8	0.0	0.0	124.8	124.8	0.0	0.0
827.0	187.2	0.0	0.0	187.2	187.2	0.0	0.0
826.0	249.6	0.0	0.0	249.6	249.6	0.0	0.0
825.0	312.0	0.0	0.0	312.0	312.0	0.0	0.0
824.0	374.4	0.0	0.0	374.4	374.4	0.0	0.0
823.0	436.8	0.0	0.0	436.8	436.8	0.0	0.0
822.0	499.2	0.0	0.0	499.2	499.2	0.0	0.0
821.0	499.2	112.2	21.6	387.0	477.6	0.0	0.0
820.0	499.2	224.5	43.3	274.7	455.9	0.0	0.0
819.0	499.2	336.7	64.9	162.5	434.3	0.0	0.0
818.0	499.2	474.0	81.4	25.2	417.8	0.0	0.0
817.8	499.2	503.3	84.6	0.0	441.0	4.1	26.4
817.0	499.2	621.6	97.6	-101.5	534.4	20.8	132.8
816.0	499.2	754.4	118.4	-213.5	646.4	41.7	265.6
815.0	499.2	887.2	139.3	-325.4	758.3	62.5	398.4
814.0	499.2	1020.0	160.1	-437.4	870.3	83.4	531.2
813.0	499.2	1152.8	181.0	-549.3	982.2	104.2	664.0
812.0	499.2	1285.6	201.8	-661.3	1094.2	125.1	796.8
811.0	499.2	1418.4	222.7	-773.3	1206.1	145.9	929.6

810.0	499.2	1551.2	243.5	-885.2	1318.1	166.8	1062.4
809.0	499.2	1684.0	264.4	-997.2	1430.0	187.6	1195.2
808.0	499.2	1816.8	285.2	-1109.1	1542.0	208.5	1328.0
807.0	499.2	1949.6	306.1	-1221.1	1653.9	229.3	1460.8
806.0	499.2	2082.4	326.9	-1333.0	1765.9	250.2	1593.6
805.0	499.2	2215.2	347.8	-1445.0	1877.8	271.0	1726.4
804.0	499.2	2348.0	368.6	-1556.9	1989.8	291.9	1859.2
803.0	499.2	2480.8	389.5	-1668.9	2101.8	312.7	1992.0
802.0	499.2	2613.6	410.3	-1780.8	2213.7	333.6	2124.8
801.0	499.2	2746.4	431.2	-1892.8	2325.7	354.4	2257.6
800.0	499.2	2879.2	452.0	-2004.7	2437.6	375.3	2390.4
799.0	499.2	3012.0	472.9	-2116.7	2549.6	396.1	2523.2
798.0	499.2	3144.8	493.7	-2228.6	2661.5	417.0	2656.0
797.0	499.2	3277.6	514.6	-2340.6	2773.5	437.8	2788.9
796.0	499.2	3410.4	535.4	-2452.5	2885.4	458.7	2921.7
795.0	499.2	3543.2	556.3	-2564.5	2997.4	479.5	3054.5
794.0	499.2	3676.0	577.1	-2676.4	3109.3	500.4	3187.3
793.0	499.2	3808.8	598.0	-2788.4	3221.3	521.2	3320.1
792.0	499.2	3941.6	618.8	-2900.4	3333.2	542.1	3452.9
791.0	499.2	4074.4	639.7	-3012.3	3445.2	562.9	3585.7
790.0	499.2	4207.2	660.5	-3124.3	3557.1	583.8	3718.5
789.0	499.2	4340.1	681.4	-3236.2	3669.1	604.6	3851.3
788.0	499.2	4472.9	702.2	-3348.2	3781.0	625.5	3984.1
787.0	499.2	4605.7	723.1	-3460.1	3893.0	646.3	4116.9
786.0	499.2	4738.5	743.9	-3572.1	4005.0	667.2	4249.7
785.0	499.2	4871.3	764.8	-3684.0	4116.9	688.0	4382.5
784.0	499.2	5004.1	785.6	-3796.0	4228.9	708.9	4515.3
783.0	499.2	5136.9	806.5	-3907.9	4340.8	729.7	4648.1
782.0	499.2	5269.7	827.3	-4019.9	4452.8	750.6	4780.9
781.0	499.2	5402.5	848.2	-4131.8	4564.7	771.4	4913.7

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 10:55:19

```
****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING

'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'REVERSE CASE - FAILURE TOWARD DOWNSTREAM - WATER TO EL. 830

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

WALL BOTTOM ELEV. (FT) : 800.31
PENETRATION (FT) : 17.69

```
MAX. BEND. MOMENT (LB-FT)  :  3.1702E+04
      AT ELEVATION (FT)    :      810.48

MAX. SCALED DEFL. (LB-IN^3):  1.3243E+10
      AT ELEVATION (FT)    :      830.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELLASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                          TIME: 10:55:19

                        ****************************
                        * COMPLETE OF RESULTS FOR  *
                        *  CANTILEVER WALL DESIGN  *
                        ****************************
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I.--HEADING
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'REVERSE CASE - FAILURE TOWARD DOWNSTREAM - WATER TO EL. 830

II.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
830.00	0.0000E+00	0.	1.3243E+10	0.00
829.00	1.0400E+01	31.	1.2511E+10	62.40
828.00	8.3200E+01	125.	1.1779E+10	124.80
827.00	2.8080E+02	281.	1.1048E+10	187.20
826.00	6.6560E+02	499.	1.0316E+10	249.60
825.00	1.3000E+03	780.	9.5865E+09	312.00
824.00	2.2464E+03	1123.	8.8587E+09	374.40
823.00	3.5672E+03	1529.	8.1350E+09	436.80
822.00	5.3248E+03	1997.	7.4174E+09	499.20
821.00	7.5525E+03	2440.	6.7091E+09	386.96
820.00	1.0167E+04	2771.	6.0140E+09	274.72
819.00	1.3057E+04	2989.	5.3364E+09	162.48
818.00	1.6104E+04	3083.	4.6814E+09	25.19
817.80	1.6717E+04	3086.	4.5544E+09	0.00
817.00	1.9179E+04	3045.	4.0543E+09	-101.53
816.00	2.2154E+04	2887.	3.4602E+09	-213.49
815.00	2.4916E+04	2618.	2.9045E+09	-325.44
814.00	2.7353E+04	2237.	2.3917E+09	-437.39
813.00	2.9352E+04	1743.	1.9261E+09	-549.34
812.00	3.0802E+04	1138.	1.5112E+09	-661.30
811.00	3.1591E+04	421.	1.1494E+09	-773.25
810.00	3.1606E+04	-409.	8.4212E+08	-885.20
809.00	3.0736E+04	-1350.	5.8930E+08	-997.16
808.00	2.8869E+04	-2403.	3.8945E+08	-1109.11
807.00	2.5893E+04	-3568.	2.3933E+08	-1221.06
806.82	2.5238E+04	-3787.	2.1742E+08	-1241.02
806.00	2.1758E+04	-4618.	1.3377E+08	-781.48

805.00	1.6842E+04	-5120.	6.5703E+07	-222.21
804.00	1.1704E+04	-5063.	2.6706E+07	337.05
803.00	6.9029E+03	-4446.	7.9818E+06	896.32
802.00	2.9981E+03	-3270.	1.3152E+06	1455.58
801.00	5.4892E+02	-1535.	3.9032E+04	2014.85
800.31	0.0000E+00	0.	0.0000E+00	2403.45

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
830.00	0.	0.	0.	0.	0.
829.00	62.	0.	0.	0.	0.
828.00	125.	0.	0.	0.	0.
827.00	187.	0.	0.	0.	0.
826.00	250.	0.	0.	0.	0.
825.00	312.	0.	0.	0.	0.
824.00	374.	0.	0.	0.	0.
823.00	437.	0.	0.	0.	0.
822.00	499.	0.	0.	0.	0.
821.00	499.	112.	22.	0.	0.
820.00	499.	224.	43.	0.	0.
819.00	499.	337.	65.	0.	0.
818.00	499.	474.	81.	0.	0.
817.80	499.	503.	85.	4.	26.
817.00	499.	622.	98.	21.	133.
816.00	499.	754.	118.	42.	266.
815.00	499.	887.	139.	63.	398.
814.00	499.	1020.	160.	83.	531.
813.00	499.	1153.	181.	104.	664.
812.00	499.	1286.	202.	125.	797.
811.00	499.	1418.	223.	146.	930.
810.00	499.	1551.	244.	167.	1062.
809.00	499.	1684.	264.	188.	1195.
808.00	499.	1817.	285.	208.	1328.
807.00	499.	1950.	306.	229.	1461.
806.82	499.	1973.	310.	233.	1485.
806.00	499.	2082.	327.	250.	1594.
805.00	499.	2215.	348.	271.	1726.
804.00	499.	2348.	369.	292.	1859.
803.00	499.	2481.	389.	313.	1992.
802.00	499.	2614.	410.	334.	2125.
801.00	499.	2746.	431.	354.	2258.
800.31	499.	2879.	452.	375.	2390.
799.00	499.	3012.	473.	396.	2523.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 2

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam on the Anoka side of Coon Rapids Dam. On Anoka side (existing apron side), alluvial sands are present do elevaton 775. Potential failure occuring from upstream to downstream during high headwater case (CASE 2). Backfill not yet piled - construction case.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 3.17 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.32\, 10^{10} lbf \cdot in^3$

Required Penetration: 17.69 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3 \quad I_{PZ} := 184.20 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 12.596 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi \quad$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_35} = 2.471 \cdot in$

Conclusion

A PZ 27 (or equivalent) is adequate.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 2

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam on the Anoka side of Coon Rapids Dam. On Anoka side (existing apron side), alluvial sands are present do elevaton 775. Potential failure occuring from upstream to downstream during high headwater case (CASE 2). Backfill not yet piled - construction case.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 22 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 3.17 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.32\, 10^{10} lbf \cdot in^3$

Required Penetration: 17.69 ft

Section Design

Using a PZ 22

$S_{PZ} := 18.1 in^3 \quad I_{PZ} := 84.38 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 21.017 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi \quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_35} = 5.394 \cdot in$

Conclusion

A PZ 22 (or equivalent) is adequate.

Sheet Pile Cofferdam Structural Analysis

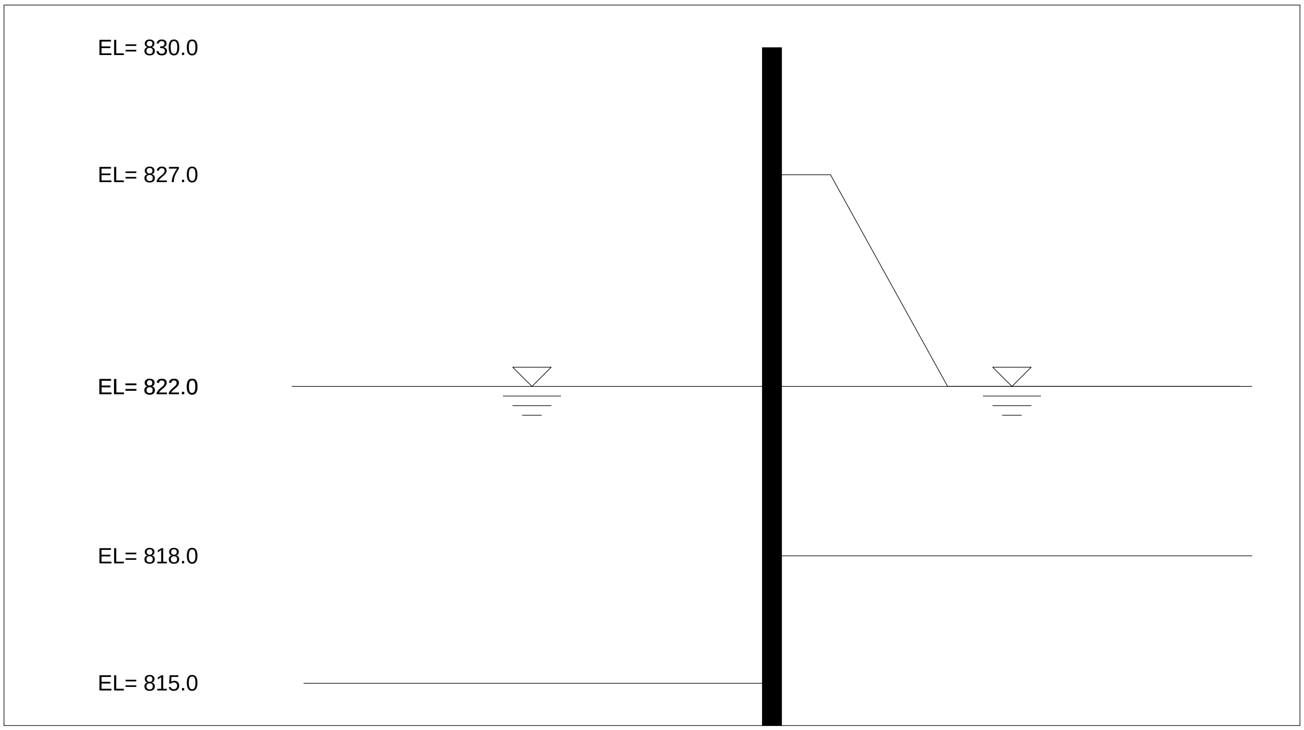
Case 3

Upstream Cofferdam – Upstream Deflection

Hennepin Side

'COON RAPIDS DAM

'UPSTREAM COFFERDAM ANALYSIS



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'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   830
SURFACE RIGHTSIDE   4    0    827
                  5    827
                  15    822
                  40    822
SURFACE LEFTSIDE   2    0    815
                  40    815
SOIL RIGHTSIDE  STRENGTHS   2
   120    120    27    0    0    0    818   0
   135    135    38    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   135    135    38    0    0    0
WATER ELEVATIONS   62.4    822    822
VERTICAL STRIP  RIGHTSIDE   2    0    5    100
                     15    40    200
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                        TIME: 10:57:29

                            ****************
                            *  INPUT DATA  *
                            ****************

      I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL

     II.--CONTROL
        CANTILEVER WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

    III.--WALL DATA
        ELEVATION AT TOP OF WALL    = 830.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       827.00
                  5.00       827.00
                 15.00       822.00
                 40.00       822.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       815.00
                 40.00       815.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                ANGLE OF          ANGLE OF                            <-SAFETY->
 SAT.    MOIST  INTERNAL  COH-      WALL     ADH-    <--BOTTOM-->    <-FACTOR->
WGHT.    WGHT.  FRICTION  ESION   FRICTION   ESION    ELEV.  SLOPE   ACT. PASS.
(PCF)    (PCF)    (DEG)   (PSF)     (DEG)    (PSF)    (FT)  (FT/FT)
120.00  120.00    27.00    0.00      0.00     0.00   818.00   0.00    DEF  DEF
135.00  135.00    38.00    0.00      0.00     0.00                    DEF  DEF

         V.B.--LEFTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                ANGLE OF          ANGLE OF                            <-SAFETY->
 SAT.    MOIST  INTERNAL  COH-      WALL     ADH-    <--BOTTOM-->    <-FACTOR->
WGHT.    WGHT.  FRICTION  ESION   FRICTION   ESION    ELEV.  SLOPE   ACT. PASS.
(PCF)    (PCF)    (DEG)   (PSF)     (DEG)    (PSF)    (FT)  (FT/FT)
135.00  135.00    38.00    0.00      0.00     0.00                    DEF  DEF

     VI.--WATER DATA
        UNIT WEIGHT          = 62.40 (PCF)
        RIGHTSIDE ELEVATION = 822.00 (FT)
```

```
     LEFTSIDE ELEVATION  = 822.00 (FT)
     NO SEEPAGE

 VII.--VERTICAL SURCHARGE LOADS

     VII.A.--VERTICAL LINE LOADS
          NONE

     VII.B.--VERTICAL UNIFORM LOADS
               NONE

     VII.C.--VERTICAL STRIP LOADS

          VII.C.1.--RIGHTSIDE
          <-DIST. FROM WALL->
            START      END      STRIP LOAD
             (FT)      (FT)        (PSF)
             0.00      5.00       100.00
            15.00     40.00       200.00

          VII.C.2.--LEFTSIDE
               NONE

     VII.D.--VERTICAL RAMP LOADS
          NONE

     VII.E.--VERTICAL TRIANGULAR LOADS
          NONE

     VII.F.--VERTICAL VARIABLE LOADS
          NONE

VIII.--HORIZONTAL LOADS
     NONE
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                        TIME: 10:57:31

                          **************************
                          *    SOIL PRESSURES FOR   *
                          * CANTILEVER WALL DESIGN *
                          **************************

    I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL

   II.--SOIL PRESSURES

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.
```

ELEV. (FT)	NET WATER (PSF)	LEFTSIDE PASSIVE (PSF)	LEFTSIDE ACTIVE (PSF)	NET (SOIL + WATER) ACTIVE (PSF)	NET (SOIL + WATER) PASSIVE (PSF)	RIGHTSIDE ACTIVE (PSF)	RIGHTSIDE PASSIVE (PSF)
830.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
829.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
828.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
827.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
826.0	0.0	0.0	0.0	82.6	280.1	82.6	280.1*
825.0	0.0	0.0	0.0	127.7	372.8	127.7	372.8*
824.0	0.0	0.0	0.0	172.7	506.5	172.7	506.5*
823.0	0.0	0.0	0.0	217.8	649.7	217.8	649.7*
822.0	0.0	0.0	0.0	257.0	704.1	257.0	704.1*
821.0	0.0	0.0	0.0	284.4	708.5	284.4	708.5
820.0	0.0	0.0	0.0	306.1	773.7	306.1	773.7
819.0	0.0	0.0	0.0	323.6	890.3	323.6	890.3
818.0	0.0	0.0	0.0	266.7	1446.3	266.7	1446.3
817.0	0.0	0.0	0.0	207.9	1942.8	207.9	1942.8
816.0	0.0	0.0	0.0	217.0	2000.9	217.0	2000.9
815.0	0.0	0.0	0.0	227.1	2080.7	227.1	2080.7
814.0	0.0	197.3	17.2	42.8	2148.3	240.1	2165.5
813.8	0.0	242.9	21.2	0.0	2166.9	242.9	2188.2
813.0	0.0	394.5	34.5	-142.5	2228.9	252.1	2263.4
812.0	0.0	591.8	51.7	-330.1	2346.2	261.7	2397.9
811.0	0.0	789.1	69.0	-517.8	2535.0	271.3	2604.0
810.0	0.0	986.4	86.2	-705.5	2741.2	280.9	2827.4
809.0	0.0	1183.6	103.5	-893.1	2903.9	290.5	3007.4
808.0	0.0	1380.9	120.7	-1080.8	3063.9	300.1	3184.6
807.0	0.0	1578.2	138.0	-1267.1	3245.2	311.1	3383.2
806.0	0.0	1775.5	155.2	-1447.6	3427.8	327.8	3583.1
805.0	0.0	1972.7	172.5	-1628.0	3610.4	344.7	3782.9
804.0	0.0	2170.0	189.7	-1812.6	3776.8	357.4	3966.5
803.0	0.0	2367.3	207.0	-1997.2	3900.3	370.1	4107.3
802.0	0.0	2564.5	224.2	-2181.8	3929.0	382.8	4153.2
801.0	0.0	2761.8	241.5	-2366.4	4002.1	395.4	4243.6
800.0	0.0	2959.1	258.7	-2551.0	4162.1	408.1	4420.8
799.0	0.0	3156.4	276.0	-2735.6	4273.6	420.8	4549.6
798.0	0.0	3353.6	293.2	-2920.2	4410.9	433.5	4704.2
797.0	0.0	3550.9	310.5	-3104.8	4596.7	446.1	4907.1
796.0	0.0	3748.2	327.7	-3289.3	4782.4	458.8	5110.1
795.0	0.0	3945.4	345.0	-3473.9	4955.1	471.5	5300.1
794.0	0.0	4142.7	362.2	-3658.5	5097.4	484.2	5459.6
793.0	0.0	4340.0	379.5	-3843.1	5251.1	496.9	5630.6
792.0	0.0	4537.3	396.7	-4027.7	5433.7	509.5	5830.4
791.0	0.0	4734.5	414.0	-4212.3	5616.3	522.2	6030.3
790.0	0.0	4931.8	431.2	-4396.9	5798.9	534.9	6230.2
789.0	0.0	5129.1	448.5	-4581.5	5981.5	547.6	6430.0
788.0	0.0	5326.4	465.7	-4766.1	6164.1	560.2	6629.9
787.0	0.0	5523.6	483.0	-4911.1	6346.7	612.5	6829.7
786.0	0.0	5720.9	500.2	-5058.2	6529.3	662.7	7029.6
785.0	0.0	5918.2	517.5	-5244.6	6688.6	673.6	7206.1
784.0	0.0	6115.4	534.7	-5426.1	6835.9	689.4	7370.6
783.0	0.0	6312.7	552.0	-5605.6	7005.5	707.1	7557.5
782.0	0.0	6510.0	569.2	-5787.4	7186.3	722.6	7755.5
781.0	0.0	6707.3	586.5	-5967.9	7367.0	739.3	7953.5
780.0	0.0	6904.5	603.7	-6146.8	7547.7	757.7	8151.5
779.0	0.0	7101.8	621.0	-6326.8	7728.5	775.0	8349.4
778.0	0.0	7299.1	638.2	-6506.8	7909.2	792.2	8547.4
777.0	0.0	7496.3	655.5	-6686.9	8089.9	809.5	8745.4
776.0	0.0	7693.6	672.7	-6866.9	8270.6	826.7	8943.4
775.0	0.0	7890.9	690.0	-7046.9	8451.4	844.0	9141.4
774.0	0.0	8088.2	707.2	-7226.9	8632.1	861.2	9339.3

773.0	0.0	8285.4	724.5	-7406.9	8812.8	878.5	9537.3
772.0	0.0	8482.7	741.7	-7587.0	8993.6	895.7	9735.3
771.0	0.0	8680.0	759.0	-7767.0	9174.3	913.0	9933.3
770.0	0.0	8877.3	776.2	-7947.0	9355.0	930.2	10131.2
769.0	0.0	9074.5	793.5	-8127.0	9535.7	947.5	10329.2

* STANDARD WEDGE SOLUTION DOES NOT EXIST FOR INDICATED PRESSURE FOR THIS ELEVATION.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 20-JANUARY-2011 TIME: 10:57:32

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****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

*****WARNING: STANDARD WEDGE SOLUTION DOES NOT EXIST AT ALL ELEVATIONS. SEE COMPLETE OUTPUT.

```
WALL BOTTOM ELEV. (FT)     :      800.63
      PENETRATION (FT)     :       14.37

MAX. BEND. MOMENT (LB-FT)  :  2.6339E+04
      AT ELEVATION (FT)    :      808.38

MAX. SCALED DEFL. (LB-IN^3):  1.0377E+10
      AT ELEVATION (FT)    :      830.00
```

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 20-JANUARY-2011 TIME: 10:57:32

****

* COMPLETE OF RESULTS FOR *
* CANTILEVER WALL DESIGN *
****

I.--HEADING
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL

II.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
830.00	0.0000E+00	0.	1.0377E+10	0.00
829.00	1.0477E-09	0.	9.8543E+09	0.00
828.00	1.0477E-09	0.	9.3315E+09	0.00
827.00	1.0477E-09	0.	8.8088E+09	0.00
826.00	1.3767E+01	41.	8.2860E+09	82.60
825.00	1.0388E+02	146.	7.7633E+09	127.66
824.00	3.2164E+02	297.	7.2407E+09	172.71
823.00	7.1212E+02	492.	6.7188E+09	217.77
822.00	1.3194E+03	729.	6.1981E+09	256.96
821.00	2.1817E+03	1000.	5.6797E+09	284.45
820.00	3.3274E+03	1295.	5.1652E+09	306.07
819.00	4.7786E+03	1610.	4.6564E+09	323.56
818.00	6.5409E+03	1905.	4.1559E+09	266.70
817.00	8.5696E+03	2142.	3.6668E+09	207.93
816.00	1.0817E+04	2355.	3.1925E+09	217.01
815.00	1.3283E+04	2577.	2.7370E+09	227.11
814.00	1.5942E+04	2712.	2.3044E+09	42.83
813.77	1.6570E+04	2717.	2.2081E+09	0.00
813.00	1.8645E+04	2662.	1.8994E+09	-142.46
812.00	2.1205E+04	2426.	1.5265E+09	-330.13
811.00	2.3434E+04	2002.	1.1903E+09	-517.80
810.00	2.5146E+04	1390.	8.9449E+08	-705.48
809.00	2.6152E+04	591.	6.4202E+08	-893.15
808.00	2.6265E+04	-396.	4.3462E+08	-1080.82
807.00	2.5298E+04	-1570.	2.7245E+08	-1267.12
806.00	2.3064E+04	-2927.	1.5381E+08	-1447.64
805.00	1.9383E+04	-4465.	7.4819E+07	-1627.99
804.74	1.8147E+04	-4901.	5.9849E+07	-1676.69
804.00	1.4178E+04	-5757.	2.9090E+07	-648.68
803.00	8.3290E+03	-5708.	7.7658E+06	747.69
802.00	3.2280E+03	-4262.	9.4229E+05	2144.05
801.00	2.7107E+02	-1419.	5.5373E+03	3540.41
800.63	0.0000E+00	0.	0.0000E+00	4061.86

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
		<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	WATER PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
830.00	0.	0.	0.	0.	0.
829.00	0.	0.	0.	0.	0.
828.00	0.	0.	0.	0.	0.
827.00	0.	0.	0.	0.	0.

826.00	0.	0.	0.	83.*	280.
825.00	0.	0.	0.	128.*	373.
824.00	0.	0.	0.	173.*	507.
823.00	0.	0.	0.	218.*	650.
822.00	0.	0.	0.	257.*	704.
821.00	0.	0.	0.	284.	708.
820.00	0.	0.	0.	306.	774.
819.00	0.	0.	0.	324.	890.
818.00	0.	0.	0.	267.	1446.
817.00	0.	0.	0.	208.	1943.
816.00	0.	0.	0.	217.	2001.
815.00	0.	0.	0.	227.	2081.
814.00	0.	197.	17.	240.	2166.
813.77	0.	243.	21.	243.	2188.
813.00	0.	395.	34.	252.	2263.
812.00	0.	592.	52.	262.	2398.
811.00	0.	789.	69.	271.	2604.
810.00	0.	986.	86.	281.	2827.
809.00	0.	1184.	103.	290.	3007.
808.00	0.	1381.	121.	300.	3185.
807.00	0.	1578.	138.	311.	3383.
806.00	0.	1775.	155.	328.	3583.
805.00	0.	1973.	172.	345.	3783.
804.74	0.	2025.	177.	348.	3831.
804.00	0.	2170.	190.	357.	3967.
803.00	0.	2367.	207.	370.	4107.
802.00	0.	2565.	224.	383.	4153.
801.00	0.	2762.	241.	395.	4244.
800.63	0.	2959.	259.	408.	4421.
799.00	0.	3156.	276.	421.	4550.

* STANDARD WEDGE SOLUTION DOES NOT EXIST FOR INDICATED PRESSURE AT THIS ELEVATION.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 3

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $\quad kpf := \frac{k}{ft}$ $\quad ksf := \frac{k}{ft^2}$ $\quad ksi := \frac{k}{in^2}$ $\quad kcf := \frac{k}{ft^3}$ $\quad ppf := \frac{lbf}{ft}$ $\quad psf := \frac{lbf}{ft^2}$ $\quad psi := \frac{lbf}{in^2}$ $\quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\quad \gamma_{water} := 62.4 \cdot pcf$ $\quad \gamma_{conc} := 150 \cdot pcf$ $\quad f_c := 4 \cdot ksi$ $\quad f_y := 60 \cdot ksi$ $\quad F_y := 50 \cdot ksi$ $\quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $\quad cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $\quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam on the Anoka side of Coon Rapids Dam. On Hennepin side (existing stilling basin side), alluvial sands are present do elevaton 775. Potential failure occuring from downstream to upstream during low headwater case (CASE 3).

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 2.63 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.04\,10^{10} lbf \cdot in^3$

Required Embedment: 14.37 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3$ $\quad I_{PZ} := 184.20 in^4$ $\quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\quad \sigma_b = 10.45 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $\quad f_b = 25 \cdot ksi$ $\quad$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\quad \delta_{PZ\_35} = 1.947 \cdot in$

Conclusion

A PZ 27 (or equivalent) is adequate.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 3

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam on the Anoka side of Coon Rapids Dam. On Hennepin side (existing stilling basin side), alluvial sands are present do elevaton 775. Potential failure occuring from downstream to upstream during low headwater case (CASE 3).

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 22 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 2.63 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.04\, 10^{10} lbf \cdot in^3$

Required Embedment: 14.37 ft

Section Design

Using a PZ 22

$S_{PZ} := 18.1 in^3 \quad I_{PZ} := 84.38 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 17.436 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi \quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_35} = 4.25 \cdot in$

Conclusion

A PZ 22 (or equivalent) is adequate.

Sheet Pile Cofferdam Structural Analysis

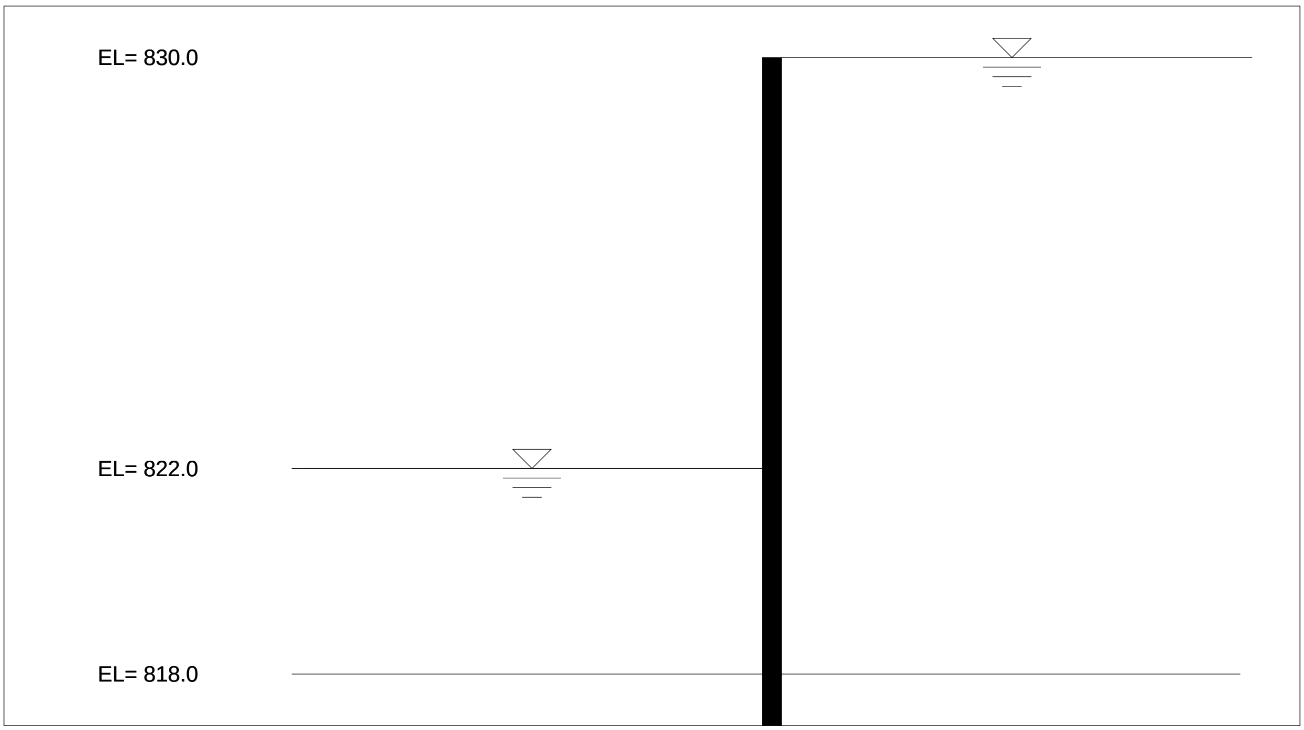
Case 4

Upstream Cofferdam – Downstream Deflection

Hennepin Side

'COON RAPIDS DAM

'UPSTREAM COFFERDAM ANALYSIS



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'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'REVERSE CASE - FAILURE TOWARD DOWNSTREAM - WATER TO EL. 830
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   830
SURFACE RIGHTSIDE   2    0    818
                  40    818
SURFACE LEFTSIDE   2    0    822
                  40    822
SOIL RIGHTSIDE  STRENGTHS   1
   135    135    38    0    0    0
SOIL LEFTSIDE  STRENGTHS   2
   120    120    27    0    0    0    818   0
   135    135    38    0    0    0
WATER ELEVATIONS   62.4    830    822
FINISHED
```

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 11:00:59

****
* INPUT DATA *
****

I.--HEADING
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'REVERSE CASE - FAILURE TOWARD DOWNSTREAM - WATER TO EL. 830

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

III.--WALL DATA
ELEVATION AT TOP OF WALL = 830.00 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	818.00
40.00	818.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	822.00
40.00	822.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH- ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH- ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
135.00	135.00	38.00	0.00	0.00	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH- ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH- ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
120.00	120.00	27.00	0.00	0.00	0.00	818.00	0.00	DEF	DEF
135.00	135.00	38.00	0.00	0.00	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 830.00 (FT)
LEFTSIDE ELEVATION = 822.00 (FT)

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 20-JANUARY-2011 TIME: 11:01:01

****
* SOIL PRESSURES FOR *
* CANTILEVER WALL DESIGN *
****

I.--HEADING
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'REVERSE CASE - FAILURE TOWARD DOWNSTREAM - WATER TO EL. 830

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
830.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
829.0	62.4	0.0	0.0	62.4	62.4	0.0	0.0
828.0	124.8	0.0	0.0	124.8	124.8	0.0	0.0
827.0	187.2	0.0	0.0	187.2	187.2	0.0	0.0
826.0	249.6	0.0	0.0	249.6	249.6	0.0	0.0
825.0	312.0	0.0	0.0	312.0	312.0	0.0	0.0
824.0	374.4	0.0	0.0	374.4	374.4	0.0	0.0
823.0	436.8	0.0	0.0	436.8	436.8	0.0	0.0
822.0	499.2	0.0	0.0	499.2	499.2	0.0	0.0
821.0	499.2	112.2	21.6	387.0	477.6	0.0	0.0
820.0	499.2	224.5	43.3	274.7	455.9	0.0	0.0
819.0	499.2	336.7	64.9	162.5	434.3	0.0	0.0
818.0	499.2	560.8	68.9	-61.6	430.3	0.0	0.0
817.0	499.2	826.4	70.9	-309.9	625.5	17.2	197.3
816.0	499.2	1022.7	88.7	-489.0	805.0	34.5	394.5
815.0	499.2	1219.0	106.3	-668.0	984.7	51.7	591.8
814.0	499.2	1415.1	123.7	-846.9	1164.5	69.0	789.1
813.0	499.2	1612.4	141.0	-1027.0	1344.6	86.2	986.4
812.0	499.2	1809.7	158.2	-1207.0	1524.6	103.5	1183.6
811.0	499.2	2007.0	175.5	-1387.0	1704.6	120.7	1380.9
810.0	499.2	2204.2	192.7	-1567.0	1884.6	138.0	1578.2

809.0	499.2	2401.5	210.0	-1747.1	2064.7	155.2	1775.5
808.0	499.2	2598.8	227.2	-1927.1	2244.7	172.5	1972.7
807.0	499.2	2796.0	244.5	-2107.1	2424.7	189.7	2170.0
806.0	499.2	2993.3	261.7	-2287.1	2604.7	207.0	2367.3
805.0	499.2	3190.6	279.0	-2467.2	2784.8	224.2	2564.5
804.0	499.2	3387.9	296.2	-2647.2	2964.8	241.5	2761.8
803.0	499.2	3585.1	313.5	-2827.2	3144.8	258.7	2959.1
802.0	499.2	3782.4	330.7	-3007.2	3324.8	276.0	3156.4
801.0	499.2	3979.7	348.0	-3187.2	3504.8	293.2	3353.6
800.0	499.2	4177.0	365.2	-3367.3	3684.9	310.5	3550.9
799.0	499.2	4374.2	382.5	-3547.3	3864.9	327.7	3748.2
798.0	499.2	4571.5	399.7	-3727.3	4044.9	345.0	3945.4
797.0	499.2	4768.8	417.0	-3907.3	4224.9	362.2	4142.7
796.0	499.2	4966.0	434.2	-4087.4	4405.0	379.5	4340.0
795.0	499.2	5163.3	451.5	-4267.4	4585.0	396.7	4537.3
794.0	499.2	5360.6	468.7	-4447.4	4765.0	414.0	4734.5
793.0	499.2	5557.9	486.0	-4627.4	4945.0	431.2	4931.8
792.0	499.2	5755.1	503.2	-4807.4	5125.1	448.5	5129.1
791.0	499.2	5952.4	520.5	-4987.5	5305.1	465.7	5326.4
790.0	499.2	6149.7	537.7	-5167.5	5485.1	483.0	5523.6
789.0	499.2	6346.9	555.0	-5347.5	5665.1	500.2	5720.9
788.0	499.2	6544.2	572.2	-5527.5	5845.1	517.5	5918.2
787.0	499.2	6741.5	589.5	-5707.6	6025.2	534.7	6115.4
786.0	499.2	6938.8	606.7	-5887.6	6205.2	552.0	6312.7
785.0	499.2	7136.0	624.0	-6067.6	6385.2	569.2	6510.0
784.0	499.2	7333.3	641.2	-6247.6	6565.2	586.5	6707.3
783.0	499.2	7530.6	658.5	-6427.7	6745.3	603.7	6904.5
782.0	499.2	7727.9	675.7	-6607.7	6925.3	621.0	7101.8
781.0	499.2	7925.1	693.0	-6787.7	7105.3	638.2	7299.1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 11:01:02

```
****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'REVERSE CASE - FAILURE TOWARD DOWNSTREAM - WATER TO EL. 830

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

```
WALL BOTTOM ELEV. (FT)     :      804.51
      PENETRATION (FT)     :       13.49
```

```
MAX. BEND. MOMENT (LB-FT)  :  2.6100E+04
      AT ELEVATION (FT)    :      812.83

MAX. SCALED DEFL. (LB-IN^3):  7.8603E+09
      AT ELEVATION (FT)    :      830.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELLASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
```

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 11:01:02

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****************************
* COMPLETE OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'REVERSE CASE - FAILURE TOWARD DOWNSTREAM - WATER TO EL. 830

II.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
830.00	0.0000E+00	0.	7.8603E+09	0.00
829.00	1.0400E+01	31.	7.3658E+09	62.40
828.00	8.3200E+01	125.	6.8713E+09	124.80
827.00	2.8080E+02	281.	6.3770E+09	187.20
826.00	6.6560E+02	499.	5.8832E+09	249.60
825.00	1.3000E+03	780.	5.3906E+09	312.00
824.00	2.2464E+03	1123.	4.9003E+09	374.40
823.00	3.5672E+03	1529.	4.4139E+09	436.80
822.00	5.3248E+03	1997.	3.9337E+09	499.20
821.00	7.5525E+03	2440.	3.4629E+09	386.96
820.00	1.0167E+04	2771.	3.0051E+09	274.72
819.00	1.3057E+04	2989.	2.5649E+09	162.48
818.00	1.6090E+04	3040.	2.1473E+09	-61.63
817.00	1.9057E+04	2854.	1.7575E+09	-309.94
816.00	2.1726E+04	2454.	1.4006E+09	-489.02
815.00	2.3907E+04	1876.	1.0812E+09	-668.04
814.00	2.5419E+04	1118.	8.0295E+08	-846.95
813.00	2.6084E+04	182.	5.6853E+08	-1026.97
812.00	2.5722E+04	-935.	3.7904E+08	-1206.99
811.00	2.4153E+04	-2232.	2.3382E+08	-1387.01
810.05	2.1370E+04	-3636.	1.3416E+08	-1558.54
810.00	2.1197E+04	-3708.	1.3013E+08	-1520.76
809.00	1.6861E+04	-4829.	6.2867E+07	-720.12
808.00	1.1806E+04	-5149.	2.4635E+07	80.53
807.00	6.8310E+03	-4668.	6.8160E+06	881.17
806.00	2.7373E+03	-3386.	9.2756E+05	1681.81
805.00	3.2533E+02	-1304.	1.1324E+04	2482.46
804.51	0.0000E+00	0.	0.0000E+00	2872.44

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
830.00	0.	0.	0.	0.	0.
829.00	62.	0.	0.	0.	0.
828.00	125.	0.	0.	0.	0.
827.00	187.	0.	0.	0.	0.
826.00	250.	0.	0.	0.	0.
825.00	312.	0.	0.	0.	0.
824.00	374.	0.	0.	0.	0.
823.00	437.	0.	0.	0.	0.
822.00	499.	0.	0.	0.	0.
821.00	499.	112.	22.	0.	0.
820.00	499.	224.	43.	0.	0.
819.00	499.	337.	65.	0.	0.
818.00	499.	561.	69.	0.	0.
817.00	499.	826.	71.	17.	197.
816.00	499.	1023.	89.	34.	395.
815.00	499.	1219.	106.	52.	592.
814.00	499.	1415.	124.	69.	789.
813.00	499.	1612.	141.	86.	986.
812.00	499.	1810.	158.	103.	1184.
811.00	499.	2007.	175.	121.	1381.
810.05	499.	2195.	192.	137.	1569.
810.00	499.	2204.	193.	138.	1578.
809.00	499.	2402.	210.	155.	1775.
808.00	499.	2599.	227.	172.	1973.
807.00	499.	2796.	244.	190.	2170.
806.00	499.	2993.	262.	207.	2367.
805.00	499.	3191.	279.	224.	2565.
804.51	499.	3388.	296.	241.	2762.
803.00	499.	3585.	313.	259.	2959.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 4

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $kpf := \frac{k}{ft}$ $ksf := \frac{k}{ft^2}$ $ksi := \frac{k}{in^2}$ $kcf := \frac{k}{ft^3}$ $ppf := \frac{lbf}{ft}$ $psf := \frac{lbf}{ft^2}$ $psi := \frac{lbf}{in^2}$ $pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\gamma_{water} := 62.4 \cdot pcf$ $\gamma_{conc} := 150 \cdot pcf$ $f_c := 4 \cdot ksi$ $f_y := 60 \cdot ksi$ $F_y := 50 \cdot ksi$ $E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam on the Anoka side of Coon Rapids Dam. On Henneipn side (existing Stilling Basin side), all glacial till is present. Potential failure occuring from upstream to downstream during high headwater case (CASE 4). Backfill not yet piled - construction case.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 2.6 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 3.69\, 10^9 lbf \cdot in^3$

Required Penetration: 13.5 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3$ $I_{PZ} := 184.20 in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 10.331 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $f_b = 25 \cdot ksi$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_35} = 0.691 \cdot in$

Conclusion

A PZ 27 (or equivalent) is adequate.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 4

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $\quad kpf := \frac{k}{ft}$ $\quad ksf := \frac{k}{ft^2}$ $\quad ksi := \frac{k}{in^2}$ $\quad kcf := \frac{k}{ft^3}$ $\quad ppf := \frac{lbf}{ft}$ $\quad psf := \frac{lbf}{ft^2}$ $\quad psi := \frac{lbf}{in^2}$ $\quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\quad \gamma_{water} := 62.4 \cdot pcf$ $\quad \gamma_{conc} := 150 \cdot pcf$ $\quad f_c := 4 \cdot ksi$ $\quad f_y := 60 \cdot ksi$ $\quad F_y := 50 \cdot ksi$ $\quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $\quad cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $\quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam on the Anoka side of Coon Rapids Dam. On Henneipn side (existing Stilling Basin side), all glacial till is present. Potential failure occuring from upstream to downstream during high headwater case (CASE 4). Backfill not yet piled - construction case.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 22 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 2.6 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 3.69\ 10^9 lbf \cdot in^3$

Required Penetration: 13.5 ft

Section Design

Using a PZ 22

$S_{PZ} := 18.1 in^3$ $\quad I_{PZ} := 84.38 in^4$ $\quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\quad \sigma_b = 17.238 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $\quad f_b = 25 \cdot ksi$ $\quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\quad \delta_{PZ\_35} = 1.508 \cdot in$

Conclusion

A PZ 22 (or equivalent) is adequate.

Sheet Pile Cofferdam Structural Analysis

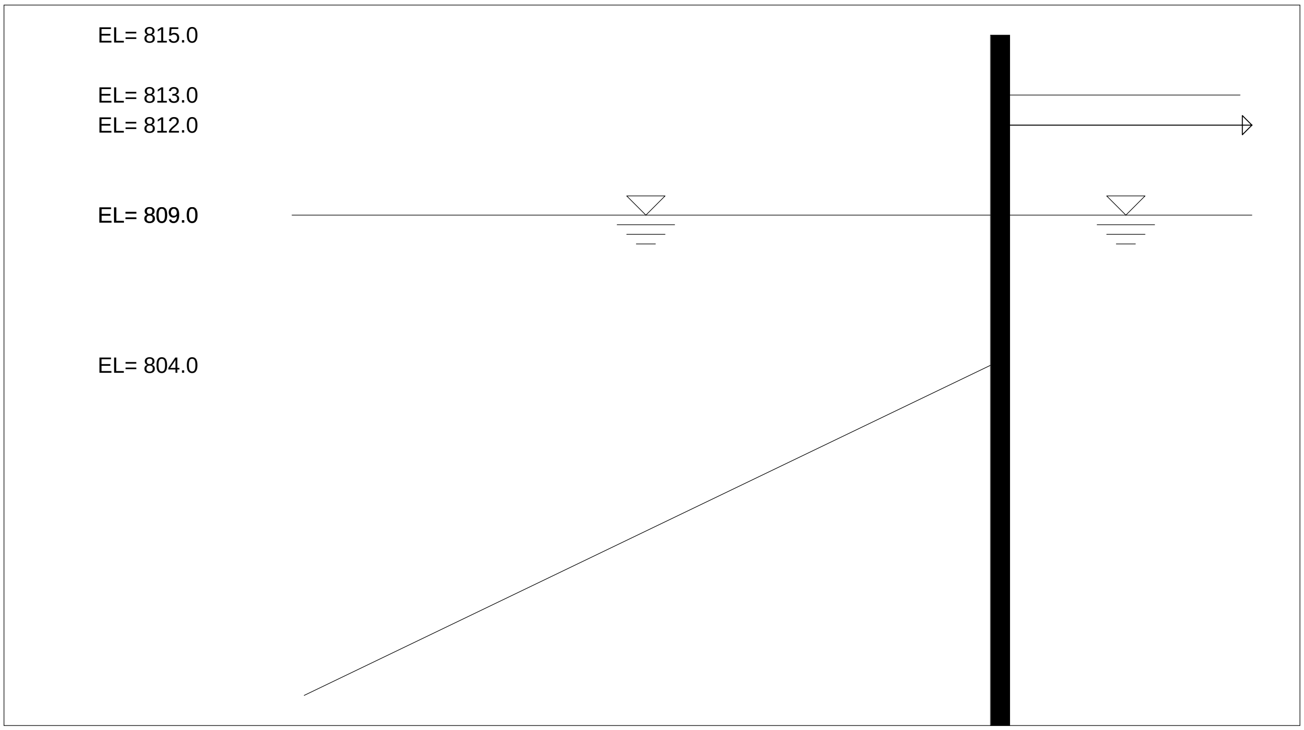
Case 5

Downstream Cofferdam – Outer Sheet

Anoka Side – Low Tailwater

'COON RAPIDS DAM

'DOWNSTEAM COFFERDAM ANALYSIS



```
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SAND
'OUTER SHEET PILE - LOW TAILWATER - EL. 809
CONTROL  ANCHORED  DESIGN  1.00  1.50
WALL   815    812
SURFACE RIGHTSIDE   2    0    813
                  20    813
SURFACE LEFTSIDE   2    0    804
                  58    793
SOIL RIGHTSIDE  STRENGTHS   1
   125    125    30    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   125    125    30    0    0    0
WATER ELEVATIONS   62.4    809    809
VERTICAL STRIP  RIGHTSIDE   1    0    20    100
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                      TIME: 12:52:09

                           ****************
                           *  INPUT DATA  *
                           ****************

      I.--HEADING
     'COON RAPIDS DAM
     'DOWNSTEAM COFFERDAM ANALYSIS
     'ANOKA SIDE - ALLUVIAL SANDS
     'OUTER SHEET PILE - LOW TAILWATER - EL. 809

     II.--CONTROL
        ANCHORED WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

    III.--WALL DATA
        ELEVATION AT TOP OF WALL    = 815.00 FT.
        ELEVATION AT ANCHOR         = 812.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       813.00
                 20.00       813.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       804.00
                 58.00       793.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

               ANGLE OF         ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-     <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION    ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)    (FT)  (FT/FT)
125.00  125.00    30.00    0.00     0.00    0.00                   DEF  DEF

         V.B.--LEFTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

               ANGLE OF         ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-     <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION    ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)    (FT)  (FT/FT)
125.00  125.00    30.00    0.00     0.00    0.00                   DEF  DEF

     VI.--WATER DATA
        UNIT WEIGHT          = 62.40 (PCF)
        RIGHTSIDE ELEVATION = 809.00 (FT)
        LEFTSIDE ELEVATION  = 809.00 (FT)
```

```
     NO SEEPAGE

 VII.--VERTICAL SURCHARGE LOADS

     VII.A.--VERTICAL LINE LOADS
          NONE

     VII.B.--VERTICAL UNIFORM LOADS
               NONE

     VII.C.--VERTICAL STRIP LOADS

          VII.C.1.--RIGHTSIDE
          <-DIST. FROM WALL->
            START      END      STRIP LOAD
             (FT)      (FT)        (PSF)
             0.00      20.00       100.00

          VII.C.2.--LEFTSIDE
               NONE

     VII.D.--VERTICAL RAMP LOADS
          NONE

     VII.E.--VERTICAL TRIANGULAR LOADS
          NONE

     VII.F.--VERTICAL VARIABLE LOADS
          NONE

VIII.--HORIZONTAL LOADS
     NONE
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                       TIME: 12:52:11

                          **************************
                          *    SOIL PRESSURES FOR   *
                          *   ANCHORED WALL DESIGN  *
                          **************************

 I.--HEADING
  'COON RAPIDS DAM
  'DOWNSTEAM COFFERDAM ANALYSIS
  'ANOKA SIDE - ALLUVIAL SANDS
  'OUTER SHEET PILE - LOW TAILWATER - EL. 809

II.--SOIL PRESSURES

     RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

     LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.
```

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)
815.0	0.0	0.0	0.0	0.0	0.0	0.0
814.0	0.0	0.0	0.0	0.0	0.0	0.0
813.0	0.0	0.0	0.0	0.0	0.0	0.0
812.0	0.0	0.0	0.0	74.9	74.9	477.3
811.0	0.0	0.0	0.0	116.6	116.6	742.5
810.0	0.0	0.0	0.0	158.2	158.2	1007.7
809.0	0.0	0.0	0.0	194.6	194.6	1239.8
808.0	0.0	0.0	0.0	220.7	220.7	1405.7
807.0	0.0	0.0	0.0	241.5	241.5	1538.5
806.0	0.0	0.0	0.0	262.4	262.4	1671.3
805.0	0.0	0.0	0.0	283.2	283.2	1804.1
804.0	0.0	0.0	0.0	304.1	304.1	1936.9
803.0	0.0	98.5	18.9	226.5	324.9	2069.7
802.0	0.0	196.9	37.8	148.9	345.8	2202.5
801.0	0.0	295.4	56.7	71.3	366.6	2280.8
800.1	0.0	385.8	74.0	0.0	385.8	2319.9
800.0	0.0	393.8	75.6	-6.3	387.5	2323.4
799.0	0.0	492.3	94.4	-84.0	408.3	2412.0
798.0	0.0	590.7	113.3	-161.6	429.2	2536.6
797.0	0.0	689.2	132.2	-239.2	450.0	2670.2
796.0	0.0	787.7	151.1	-316.8	470.9	2803.8
795.0	0.0	886.1	170.0	-394.4	491.7	2937.4
794.0	0.0	984.6	188.9	-472.0	512.6	3071.0
793.0	0.0	1083.0	207.8	-549.6	533.4	3202.3
792.0	0.0	1181.5	226.7	-627.2	554.3	3327.4
791.0	0.0	1280.0	245.5	-704.8	575.1	3454.5
790.0	0.0	1378.4	264.4	-782.4	596.0	3587.4
789.0	0.0	1476.9	283.3	-860.0	616.8	3720.3
788.0	0.0	1575.3	302.2	-937.7	637.7	3853.3
787.0	0.0	1673.8	321.1	-1015.3	658.5	3986.2
786.0	0.0	1772.2	340.0	-1092.9	679.4	4119.1
785.0	0.0	1870.7	358.9	-1170.5	700.2	4252.0
784.0	0.0	1969.2	377.8	-1248.1	721.1	4385.0
783.0	0.0	2067.6	396.7	-1325.7	741.9	4517.9
782.0	0.0	2166.1	415.5	-1403.3	762.8	4650.8
781.0	0.0	2264.5	434.4	-1480.9	783.6	4783.8
780.0	0.0	2363.0	453.3	-1558.5	804.5	4916.7
779.0	0.0	2461.5	472.2	-1636.1	825.3	5049.6
778.0	0.0	2559.9	491.1	-1713.7	846.2	5182.5
777.0	0.0	2658.4	510.0	-1806.6	851.7	5315.5
776.0	0.0	2756.8	528.9	-1900.9	855.9	5448.4
775.0	0.0	2855.3	547.8	-1979.9	875.4	5581.3
774.0	0.0	2953.7	566.7	-2057.5	896.3	5714.3
773.0	0.0	3052.2	585.5	-2135.1	917.1	5847.2
772.0	0.0	3150.7	604.4	-2212.7	938.0	5980.1
771.0	0.0	3255.7	623.3	-2296.9	958.8	6113.0
770.0	0.0	3384.2	642.2	-2404.6	979.7	6246.0

DATE: 20-JANUARY-2011 TIME: 12:52:12

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****************************
*  SUMMARY OF RESULTS FOR  *
*   ANCHORED WALL DESIGN   *
****************************
```

I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'OUTER SHEET PILE - LOW TAILWATER - EL. 809

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

METHOD	:	FREE EARTH	FIXED EARTH
WALL BOTTOM ELEVATION (FT)	:	795.30	791.53
PENETRATION (FT)	:	8.70	12.47
MAXIMUM BENDING MOMENT (LB-FT)	:	-5.6529E+03	-4.5572E+03
AT ELEVATION (FT)	:	804.99	805.57
MAXIMUM SCALED DEFLECTION (LB-IN^3)	:	2.5235E+08	1.8187E+08
AT ELEVATION (FT)	:	804.00	805.00
ANCHOR FORCE (LB)	:	1.4145E+03	1.2515E+03

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 20-JANUARY-2011 TIME: 12:52:12

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****************************
* COMPLETE OF RESULTS FOR  *
*   ANCHORED WALL DESIGN   *
*   BY FREE EARTH METHOD   *
****************************
```

I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'OUTER SHEET PILE - LOW TAILWATER - EL. 809

II.--RESULTS (ANCHOR FORCE= 1414. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
815.00	0.0000E+00	0.	-1.5527E+08	0.00

814.00	4.3656E-11	0.	-1.0351E+08	0.00
813.00	0.0000E+00	0.	-5.1756E+07	0.00
812.00+	1.2490E+01	37.	0.0000E+00	74.94
812.00-	1.2490E+01	-1377.	0.0000E+00	74.94
811.00	-1.3201E+03	-1281.	5.1381E+07	116.57
810.00	-2.5361E+03	-1144.	1.0050E+08	158.20
809.00	-3.5948E+03	-967.	1.4525E+08	194.64
808.00	-4.4605E+03	-760.	1.8383E+08	220.69
807.00	-5.1065E+03	-529.	2.1472E+08	241.54
806.00	-5.5109E+03	-277.	2.3683E+08	262.39
805.00	-5.6529E+03	-4.	2.4945E+08	283.24
804.00	-5.5117E+03	290.	2.5235E+08	304.09
803.00	-5.0828E+03	555.	2.4576E+08	226.48
802.00	-4.4274E+03	743.	2.3042E+08	148.87
801.00	-3.6232E+03	853.	2.0746E+08	71.26
800.08	-2.8201E+03	886.	1.8083E+08	0.00
800.00	-2.7477E+03	885.	1.7824E+08	-6.35
799.00	-1.8785E+03	840.	1.4428E+08	-83.96
798.00	-1.0933E+03	717.	1.0705E+08	-161.57
797.00	-4.6971E+02	517.	6.7914E+07	-239.17
796.00	-8.5256E+01	239.	2.7931E+07	-316.78
795.30	0.0000E+00	0.	0.0000E+00	-370.74

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
815.00	0.	0.	0.	0.	0.
814.00	0.	0.	0.	0.	0.
813.00	0.	0.	0.	0.	0.
812.00	0.	0.	0.	75.	477.
811.00	0.	0.	0.	117.	743.
810.00	0.	0.	0.	158.	1008.
809.00	0.	0.	0.	195.	1240.
808.00	0.	0.	0.	221.	1406.
807.00	0.	0.	0.	242.	1538.
806.00	0.	0.	0.	262.	1671.
805.00	0.	0.	0.	283.	1804.
804.00	0.	0.	0.	304.	1937.
803.00	0.	98.	19.	325.	2070.
802.00	0.	197.	38.	346.	2202.
801.00	0.	295.	57.	367.	2281.
800.08	0.	386.	74.	386.	2320.
800.00	0.	394.	76.	387.	2323.
799.00	0.	492.	94.	408.	2412.
798.00	0.	591.	113.	429.	2537.
797.00	0.	689.	132.	450.	2670.
796.00	0.	788.	151.	471.	2804.
795.00	0.	886.	170.	492.	2937.

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****************************
* COMPLETE OF RESULTS FOR  *
*   ANCHORED WALL DESIGN   *
*   BY FIXED EARTH METHOD  *
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I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'OUTER SHEET PILE - LOW TAILWATER - EL. 809

II.--RESULTS (ANCHOR FORCE= 1251. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
815.00	0.0000E+00	0.	-1.1940E+08	0.00
814.00	-2.1828E-11	0.	-7.9601E+07	0.00
813.00	0.0000E+00	0.	-3.9801E+07	0.00
812.00+	1.2490E+01	37.	0.0000E+00	74.94
812.00-	1.2490E+01	-1214.	0.0000E+00	74.94
811.00	-1.1571E+03	-1118.	3.9473E+07	116.57
810.00	-2.2101E+03	-981.	7.6962E+07	158.20
809.00	-3.1058E+03	-804.	1.1066E+08	194.64
808.00	-3.8085E+03	-597.	1.3901E+08	220.69
807.00	-4.2915E+03	-366.	1.6082E+08	241.54
806.00	-4.5329E+03	-114.	1.7524E+08	262.39
805.00	-4.5119E+03	159.	1.8187E+08	283.24
804.00	-4.2076E+03	453.	1.8074E+08	304.09
803.00	-3.6157E+03	718.	1.7239E+08	226.48
802.00	-2.7974E+03	906.	1.5782E+08	148.87
801.00	-1.8301E+03	1016.	1.3844E+08	71.26
800.08	-8.7737E+02	1049.	1.1782E+08	0.00
800.00	-7.9161E+02	1048.	1.1590E+08	-6.35
799.00	2.4055E+02	1003.	9.1998E+07	-83.96
798.00	1.1888E+03	880.	6.8498E+07	-161.57
797.00	1.9754E+03	680.	4.7029E+07	-239.17
796.00	2.5229E+03	402.	2.8939E+07	-316.78
795.00	2.7535E+03	46.	1.5163E+07	-394.39
794.00	2.5898E+03	-387.	6.0886E+06	-472.00
793.00	1.9541E+03	-898.	1.4211E+06	-549.61
792.00	7.6880E+02	-1486.	5.1153E+04	-627.22
791.00	0.0000E+00	-1789.	0.0000E+00	-663.68

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
		<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	WATER PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
815.00	0.	0.	0.	0.	0.
814.00	0.	0.	0.	0.	0.
813.00	0.	0.	0.	0.	0.
812.00	0.	0.	0.	75.	477.
811.00	0.	0.	0.	117.	743.

810.00	0.	0.	0.	158.	1008.
809.00	0.	0.	0.	195.	1240.
808.00	0.	0.	0.	221.	1406.
807.00	0.	0.	0.	242.	1538.
806.00	0.	0.	0.	262.	1671.
805.00	0.	0.	0.	283.	1804.
804.00	0.	0.	0.	304.	1937.
803.00	0.	98.	19.	325.	2070.
802.00	0.	197.	38.	346.	2202.
801.00	0.	295.	57.	367.	2281.
800.08	0.	386.	74.	386.	2320.
800.00	0.	394.	76.	387.	2323.
799.00	0.	492.	94.	408.	2412.
798.00	0.	591.	113.	429.	2537.
797.00	0.	689.	132.	450.	2670.
796.00	0.	788.	151.	471.	2804.
795.00	0.	886.	170.	492.	2937.
794.00	0.	985.	189.	513.	3071.
793.00	0.	1083.	208.	533.	3202.
792.00	0.	1181.	227.	554.	3327.
791.00	0.	1280.	246.	575.	3454.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 12:52:13

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*******************************
* PRELIMINARY DESIGN DATA FOR *
*  FREE EARTH DESIGN IN SAND  *
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I.--HEADING

'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'OUTER SHEET PILE - LOW TAILWATER - EL. 809

II.--DESIGN PARAMETERS

WALL HEIGHT RATIO (ALPHA) =   0.56
ANCHOR HEIGHT RATIO (BETA) =   0.15

SHEET PILE DATA:

SHEET PILE NAME	<SECTION PROPERTIES> (PER FOOT OF WALL) SECTION MODULUS (IN^3)	MOMENT OF INERTIA (IN^4)	ALLOWABLE STRESS (PSI)	MODULUS OF ELLASTICITY (PSI)
PZ40	60.70	490.80	2.40E+04	2.90E+07
PZ38	46.80	280.80	2.40E+04	2.90E+07
PZ35	48.50	361.20	2.40E+04	2.90E+07
PZ32	38.30	220.40	2.40E+04	2.90E+07
PZ27	30.20	184.20	2.40E+04	2.90E+07
PZ22	18.10	84.40	2.40E+04	2.90E+07

PLZ25	32.80	223.25	2.40E+04	2.90E+07
PLZ23	30.20	203.75	2.40E+04	2.90E+07

III.--PRELIMINARY DESIGN DATA

SHEET PILE NAME	LOG(H^4/EI)	ROWE'S MOMENT REDUCTION COEF.	RATIO OF ALLOWABLE MOMENT TO FREE EARTH MOMENT
PZ40	-4.98	1.0 (***)	21.48
PZ38	-4.73	1.0 (***)	16.56
PZ35	-4.84	1.0 (***)	17.16
PZ32	-4.63	1.0 (***)	13.55
PZ27	-4.55	1.0 (***)	10.68
PZ22	-4.21	1.0 (***)	6.40
PLZ25	-4.63	1.0 (***)	11.60
PLZ23	-4.59	1.0 (***)	10.68

*** REDUCTION NOT APPLICABLE DUE TO ALPHA LESS THAN 0.6.

*** REDUCTION NOT APPLICABLE DUE TO RIGHTSIDE SURFACE BELOW TOP OF WALL.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 5

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $\quad kpf := \frac{k}{ft}$ $\quad ksf := \frac{k}{ft^2}$ $\quad ksi := \frac{k}{in^2}$ $\quad kcf := \frac{k}{ft^3}$ $\quad ppf := \frac{lbf}{ft}$ $\quad psf := \frac{lbf}{ft^2}$ $\quad psi := \frac{lbf}{in^2}$ $\quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\quad \gamma_{water} := 62.4 \cdot pcf$ $\quad \gamma_{conc} := 150 \cdot pcf$ $\quad f_c := 4 \cdot ksi$ $\quad f_y := 60 \cdot ksi$ $\quad F_y := 50 \cdot ksi$ $\quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $\quad cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $\quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam outer sheet on the Anoka side of Coon Rapids Dam. Anchor placed at elevation 812.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 5.65 \times 10^3 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 2.50\, 10^8 lbf \cdot in^3$

Required Penetration: 8.70 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3$ $\quad I_{PZ} := 184.20 in^4$ $\quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\quad \sigma_b = 2.245 \cdot ksi$

Allowable Stress: $f_b := 0.5F_y$ $\quad f_b = 25 \cdot ksi$ $\quad$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\quad \delta_{PZ\_35} = 0.047 \cdot in$

Conclusion

A PZ 27 (or equivalent) is adequate.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 5

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam outer sheet on the Anoka side of Coon Rapids Dam. Anchor placed at elevation 812.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 22 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 5.65 \times 10^3 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 2.50\ 10^8 lbf \cdot in^3$

Required Penetration: 8.70 ft

Section Design

Using a PZ 22

$S_{PZ} := 18.1 in^3 \quad I_{PZ} := 84.38 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 3.746 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi \quad$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_35} = 0.102 \cdot in$

Conclusion

A PZ 22 (or equivalent) is adequate.

Sheet Pile Cofferdam Structural Analysis

Case 6

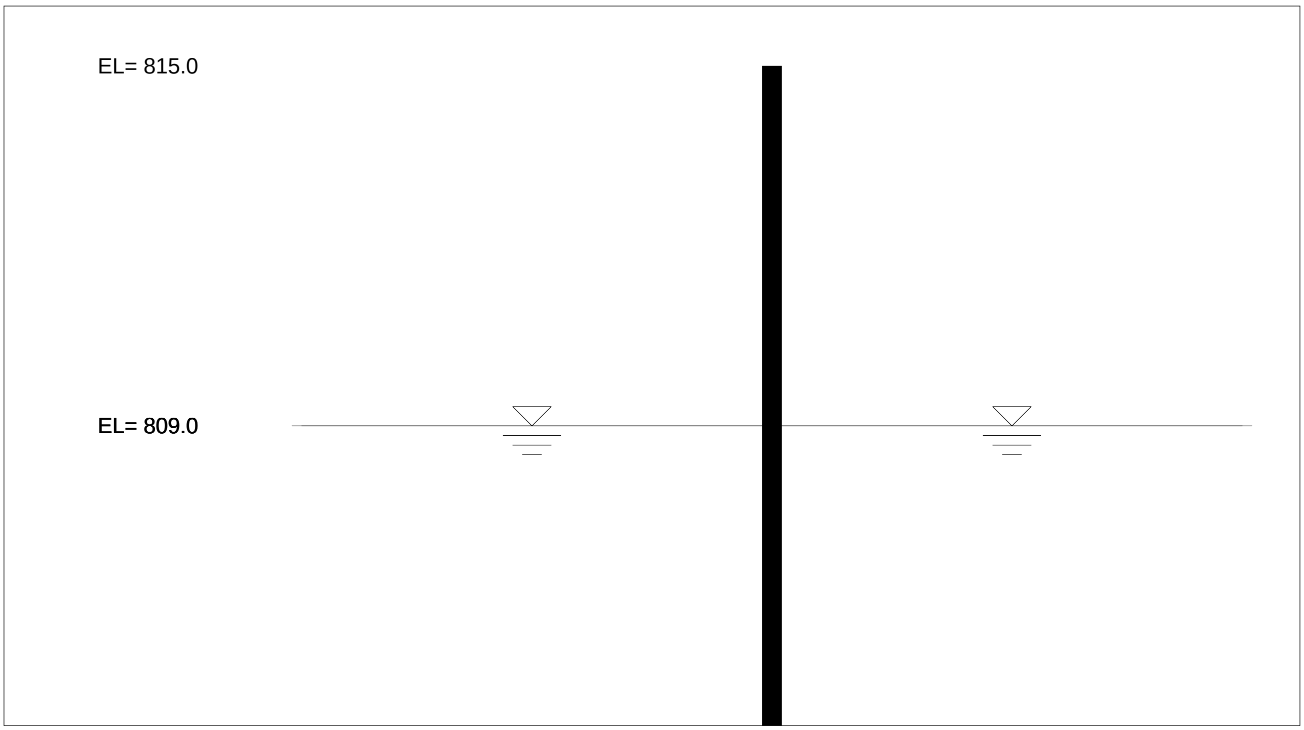
Downstream Cofferdam – Inner Sheet

Anoka Side – Low Tailwater

Counter Force Check

'COON RAPIDS DAM

'DOWNSTEAM COFFERDAM ANALYSIS



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'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'INNER SHEET PILE - LOW TAILWATER - EL. 809 - COUNTER FORCE CHECK
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   815
SURFACE RIGHTSIDE   2    0    809
                  50    809
SURFACE LEFTSIDE   2    0    809
                  50    809
SOIL RIGHTSIDE  STRENGTHS   1
   125    125    30    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   125    125    30    0    0    0
WATER ELEVATIONS   62.4    809    809
HORIZONTAL LINE   1   812   1410
FINISHED
```

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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                       TIME: 13:00:28

                            ****************
                            *  INPUT DATA  *
                            ****************

     I.--HEADING
    'COON RAPIDS DAM
    'DOWNSTEAM COFFERDAM ANALYSIS
    'ANOKA SIDE - ALLUVIAL SANDS
    'INNER SHEET PILE - LOW TAILWATER - EL. 809 - COUNTER FORCE CHECK

    II.--CONTROL
       CANTILEVER WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

   III.--WALL DATA
       ELEVATION AT TOP OF WALL    = 815.00 FT.

    IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00       809.00
                50.00       809.00

         IV.B.--LEFTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00       809.00
                50.00       809.00

     V.--SOIL LAYER DATA

        V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

               ANGLE OF         ANGLE OF                        <-SAFETY->
 SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
(PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
125.00  125.00   30.00    0.00     0.00    0.00                  DEF  DEF

        V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

               ANGLE OF         ANGLE OF                        <-SAFETY->
 SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
(PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
125.00  125.00   30.00    0.00     0.00    0.00                  DEF  DEF

    VI.--WATER DATA
       UNIT WEIGHT          = 62.40 (PCF)
       RIGHTSIDE ELEVATION = 809.00 (FT)
       LEFTSIDE ELEVATION  = 809.00 (FT)
       NO SEEPAGE
```

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS

VIII.A.--HORIZONTAL LINE LOADS

ELEVATION (FT)	LINE LOAD (PLF)
812.00	1410.00

VIII.B.--HORIZONTAL DISTRIBUTED LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 20-JANUARY-2011 TIME: 13:00:30

```
**************************
*    SOIL PRESSURES FOR  *
* CANTILEVER WALL DESIGN *
**************************
```

I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'INNER SHEET PILE - LOW TAILWATER - EL. 809 - COUNTER FORCE CHECK

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

	NET	<---LEFTSIDE--->		<------NET------> (SOIL + WATER)		<--RIGHTSIDE--->	
ELEV. (FT)	WATER (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
815.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
814.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
813.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
812.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
811.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
810.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
809.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
808.0	0.0	132.8	20.8	-112.0	112.0	20.8	132.8
807.0	0.0	265.6	41.7	-223.9	223.9	41.7	265.6
806.0	0.0	398.4	62.5	-335.9	335.9	62.5	398.4
805.0	0.0	531.2	83.4	-447.8	447.8	83.4	531.2
804.0	0.0	664.0	104.2	-559.8	559.8	104.2	664.0
803.0	0.0	796.8	125.1	-671.7	671.7	125.1	796.8
802.0	0.0	929.6	145.9	-783.7	783.7	145.9	929.6
801.0	0.0	1062.4	166.8	-895.6	895.6	166.8	1062.4

800.0	0.0	1195.2	187.6	-1007.6	1007.6	187.6	1195.2
799.0	0.0	1328.0	208.5	-1119.5	1119.5	208.5	1328.0
798.0	0.0	1460.8	229.3	-1231.5	1231.5	229.3	1460.8
797.0	0.0	1593.6	250.2	-1343.4	1343.4	250.2	1593.6
796.0	0.0	1726.4	271.0	-1455.4	1455.4	271.0	1726.4
795.0	0.0	1859.2	291.9	-1567.3	1567.3	291.9	1859.2
794.0	0.0	1992.0	312.7	-1679.3	1679.3	312.7	1992.0
793.0	0.0	2124.8	333.6	-1791.2	1791.2	333.6	2124.8
792.0	0.0	2257.6	354.4	-1903.2	1903.2	354.4	2257.6
791.0	0.0	2390.4	375.3	-2015.1	2015.1	375.3	2390.4
790.0	0.0	2523.2	396.1	-2127.1	2127.1	396.1	2523.2
789.0	0.0	2656.0	417.0	-2239.1	2239.1	417.0	2656.0
788.0	0.0	2788.9	437.8	-2351.0	2351.0	437.8	2788.9
787.0	0.0	2921.7	458.7	-2463.0	2463.0	458.7	2921.7
786.0	0.0	3054.5	479.5	-2574.9	2574.9	479.5	3054.5
785.0	0.0	3187.3	500.4	-2686.9	2686.9	500.4	3187.3
784.0	0.0	3320.1	521.2	-2798.8	2798.8	521.2	3320.1
783.0	0.0	3452.9	542.1	-2910.8	2910.8	542.1	3452.9
782.0	0.0	3585.7	562.9	-3022.7	3022.7	562.9	3585.7
781.0	0.0	3718.5	583.8	-3134.7	3134.7	583.8	3718.5
780.0	0.0	3851.3	604.6	-3246.6	3246.6	604.6	3851.3
779.0	0.0	3984.1	625.5	-3358.6	3358.6	625.5	3984.1
778.0	0.0	4116.9	646.3	-3470.5	3470.5	646.3	4116.9

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 13:00:31

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****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'INNER SHEET PILE - LOW TAILWATER - EL. 809 - COUNTER FORCE CHECK

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

```
WALL BOTTOM ELEV. (FT)     :      797.04
      PENETRATION (FT)     :       11.96

MAX. BEND. MOMENT (LB-FT)  :  8.9478E+03
      AT ELEVATION (FT)    :      803.98

MAX. SCALED DEFL. (LB-IN^3):  1.3606E+09
      AT ELEVATION (FT)    :      815.00
```

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 13:00:31

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*****************************
* COMPLETE OF RESULTS FOR   *
*  CANTILEVER WALL DESIGN   *
*****************************
```

I.--HEADING

'COON RAPIDS DAM

'DOWNSTEAM COFFERDAM ANALYSIS

'ANOKA SIDE - ALLUVIAL SANDS

'INNER SHEET PILE - LOW TAILWATER - EL. 809 - COUNTER FORCE CHECK

II.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
815.00	0.0000E+00	0.	1.3606E+09	0.00
814.00	-1.7462E-10	0.	1.2299E+09	0.00
813.00	-1.7462E-10	0.	1.0991E+09	0.00
812.00+	-1.7462E-10	0.	9.6835E+08	0.00
812.00-	1.7462E-10	1410.	9.6835E+08	0.00
811.00	1.4100E+03	1410.	8.3800E+08	0.00
810.00	2.8200E+03	1410.	7.1008E+08	0.00
809.00	4.2300E+03	1410.	5.8704E+08	0.00
808.00	5.6213E+03	1354.	4.7131E+08	-111.95
807.00	6.9007E+03	1186.	3.6527E+08	-223.91
806.00	7.9562E+03	906.	2.7113E+08	-335.86
805.00	8.6758E+03	514.	1.9068E+08	-447.81
804.00	8.9477E+03	11.	1.2517E+08	-559.76
803.00	8.6597E+03	-605.	7.5031E+07	-671.72
802.00	7.7000E+03	-1333.	3.9763E+07	-783.67
801.97	7.6542E+03	-1360.	3.8808E+07	-787.48
801.00	6.0383E+03	-1919.	1.7693E+07	-370.63
800.00	4.0060E+03	-2074.	6.0049E+06	60.90
799.00	2.0346E+03	-1797.	1.2477E+06	492.42
798.00	5.5563E+02	-1089.	7.7271E+04	923.95
797.04	0.0000E+00	0.	0.0000E+00	1339.21

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
815.00	0.	0.	0.	0.	0.

814.00	0.	0.	0.	0.	0.
813.00	0.	0.	0.	0.	0.
812.00	0.	0.	0.	0.	0.
811.00	0.	0.	0.	0.	0.
810.00	0.	0.	0.	0.	0.
809.00	0.	0.	0.	0.	0.
808.00	0.	133.	21.	21.	133.
807.00	0.	266.	42.	42.	266.
806.00	0.	398.	63.	63.	398.
805.00	0.	531.	83.	83.	531.
804.00	0.	664.	104.	104.	664.
803.00	0.	797.	125.	125.	797.
802.00	0.	930.	146.	146.	930.
801.97	0.	934.	147.	147.	934.
801.00	0.	1062.	167.	167.	1062.
800.00	0.	1195.	188.	188.	1195.
799.00	0.	1328.	208.	208.	1328.
798.00	0.	1461.	229.	229.	1461.
797.04	0.	1594.	250.	250.	1594.
796.00	0.	1726.	271.	271.	1726.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 6

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam inner sheet on the Anoka side of Coon Rapids Dam. Equivalent horizontal line load (anchor force fro Case 5) placed at elevation 812.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 8.95 \times 10^3 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.36\,10^9 lbf \cdot in^3$

Required Penetration: 11.96 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2in^3 \qquad I_{PZ} := 184.20in^4 \qquad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \qquad \sigma_b = 3.556 \cdot ksi$

Allowable Stress: $f_b := 0.5F_y \qquad f_b = 25 \cdot ksi \qquad$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}} \qquad \delta_{PZ\_35} = 0.255 \cdot in$

Conclusion

A PZ 27 (or equivalent) is adequate.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 6

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $kpf := \frac{k}{ft}$ $ksf := \frac{k}{ft^2}$ $ksi := \frac{k}{in^2}$ $kcf := \frac{k}{ft^3}$ $ppf := \frac{lbf}{ft}$ $psf := \frac{lbf}{ft^2}$ $psi := \frac{lbf}{in^2}$ $pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\gamma_{water} := 62.4 \cdot pcf$ $\gamma_{conc} := 150 \cdot pcf$ $f_c := 4 \cdot ksi$ $f_y := 60 \cdot ksi$ $F_y := 50 \cdot ksi$ $E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam inner sheet on the Anoka side of Coon Rapids Dam. Equivalent horizontal line load (anchor force fro Case 5) placed at elevation 812.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 22 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 8.95 \times 10^3 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.36\,10^9 lbf \cdot in^3$

Required Penetration: 11.96 ft

Section Design

Using a PZ 22

$S_{PZ} := 18.1 in^3$ $I_{PZ} := 84.38 in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 5.934 \cdot ksi$

Allowable Stress: $f_b := 0.5F_y$ $f_b = 25 \cdot ksi$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_35} = 0.556 \cdot in$

Conclusion

A PZ 22 (or equivalent) is adequate.

Sheet Pile Cofferdam Structural Analysis

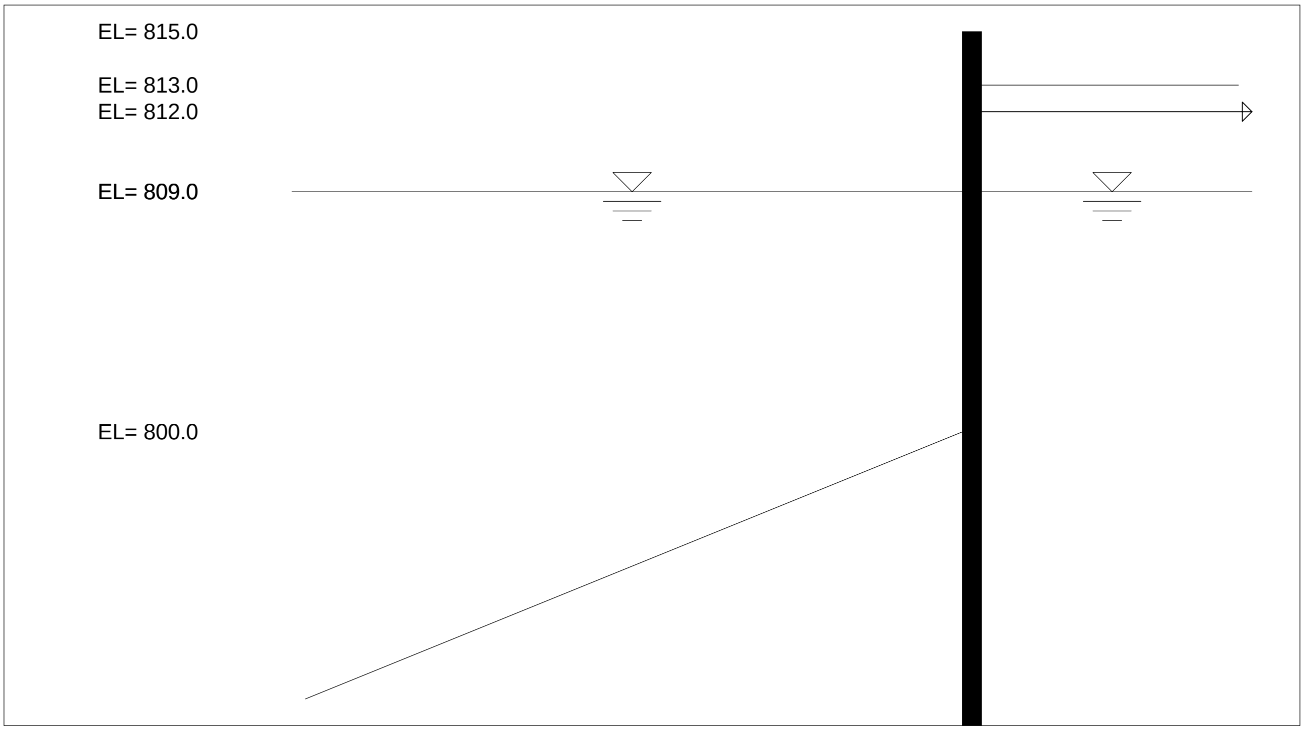
Case 7

Downstream Cofferdam – Outer Sheet

Hennepin Side – Low Tailwater

'COON RAPIDS DAM

'DOWNSTEAM COFFERDAM ANALYSIS



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'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809
CONTROL  ANCHORED  DESIGN  1.00  1.50
WALL   815    812
SURFACE RIGHTSIDE   2    0    813
                  20    813
SURFACE LEFTSIDE   2    0    800
                  50    790
SOIL RIGHTSIDE  STRENGTHS   1
   125    125    30    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   125    125    30    0    0    0
WATER ELEVATIONS   62.4    809    809
VERTICAL STRIP  RIGHTSIDE   1    0    20    100
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                          TIME: 13:25:52

                            ****************
                            *  INPUT DATA  *
                            ****************

      I.--HEADING
     'COON RAPIDS DAM
     'DOWNSTEAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'OUTER SHEET PILE - LOW TAILWATER - EL. 809

     II.--CONTROL
        ANCHORED WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

    III.--WALL DATA
        ELEVATION AT TOP OF WALL    = 815.00 FT.
        ELEVATION AT ANCHOR         = 812.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       813.00
                 20.00       813.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       800.00
                 50.00       790.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

               ANGLE OF          ANGLE OF                         <-SAFETY->
 SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->  <-FACTOR->
WGHT.   WGHT.  FRICTION  ESION  FRICTION   ESION   ELEV.  SLOPE  ACT. PASS.
(PCF)   (PCF)    (DEG)   (PSF)    (DEG)    (PSF)   (FT)  (FT/FT)
125.00  125.00   30.00    0.00     0.00     0.00                  DEF  DEF

         V.B.--LEFTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

               ANGLE OF          ANGLE OF                         <-SAFETY->
 SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->  <-FACTOR->
WGHT.   WGHT.  FRICTION  ESION  FRICTION   ESION   ELEV.  SLOPE  ACT. PASS.
(PCF)   (PCF)    (DEG)   (PSF)    (DEG)    (PSF)   (FT)  (FT/FT)
125.00  125.00   30.00    0.00     0.00     0.00                  DEF  DEF

     VI.--WATER DATA
        UNIT WEIGHT          = 62.40 (PCF)
        RIGHTSIDE ELEVATION = 809.00 (FT)
        LEFTSIDE ELEVATION  = 809.00 (FT)
```

NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

VII.A.--VERTICAL LINE LOADS
NONE

VII.B.--VERTICAL UNIFORM LOADS
NONE

VII.C.--VERTICAL STRIP LOADS

VII.C.1.--RIGHTSIDE

<-DIST. FROM WALL->		
START (FT)	END (FT)	STRIP LOAD (PSF)
0.00	20.00	100.00

VII.C.2.--LEFTSIDE
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 13:25:56

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**************************
*    SOIL PRESSURES FOR  *
*  ANCHORED WALL DESIGN  *
**************************
```

I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)
815.0	0.0	0.0	0.0	0.0	0.0	0.0
814.0	0.0	0.0	0.0	0.0	0.0	0.0
813.0	0.0	0.0	0.0	0.0	0.0	0.0
812.0	0.0	0.0	0.0	74.9	74.9	477.3
811.0	0.0	0.0	0.0	116.6	116.6	742.5
810.0	0.0	0.0	0.0	158.2	158.2	1007.7
809.0	0.0	0.0	0.0	194.6	194.6	1239.8
808.0	0.0	0.0	0.0	220.7	220.7	1405.7
807.0	0.0	0.0	0.0	241.5	241.5	1538.5
806.0	0.0	0.0	0.0	262.4	262.4	1671.3
805.0	0.0	0.0	0.0	283.2	283.2	1804.1
804.0	0.0	0.0	0.0	304.1	304.1	1936.9
803.0	0.0	0.0	0.0	324.9	324.9	2069.7
802.0	0.0	0.0	0.0	345.8	345.8	2202.5
801.0	0.0	0.0	0.0	366.6	366.6	2280.8
800.0	0.0	0.0	0.0	387.5	387.5	2323.4
799.0	0.0	96.7	18.8	311.7	408.3	2412.0
798.0	0.0	193.4	37.6	235.8	429.2	2536.6
797.0	0.0	290.0	56.4	160.0	450.0	2670.2
796.0	0.0	386.7	75.2	84.2	470.9	2803.8
795.0	0.0	483.4	94.0	8.3	491.7	2937.4
794.9	0.0	494.0	96.1	0.0	494.0	2952.2
794.0	0.0	580.1	112.8	-67.5	512.6	3071.0
793.0	0.0	676.7	131.6	-143.3	533.4	3202.3
792.0	0.0	773.4	150.4	-219.1	554.3	3327.4
791.0	0.0	870.1	169.2	-295.0	575.1	3454.5
790.0	0.0	966.8	188.0	-370.8	596.0	3587.4
789.0	0.0	1063.4	206.8	-446.6	616.8	3720.3
788.0	0.0	1160.1	225.6	-522.4	637.7	3853.3
787.0	0.0	1256.8	244.4	-598.3	658.5	3986.2
786.0	0.0	1353.5	263.2	-674.1	679.4	4119.1
785.0	0.0	1450.2	282.0	-749.9	700.2	4252.0
784.0	0.0	1546.8	300.8	-825.8	721.1	4385.0
783.0	0.0	1643.5	319.6	-901.6	741.9	4517.9
782.0	0.0	1740.2	338.4	-977.4	762.8	4650.8
781.0	0.0	1836.9	357.2	-1053.2	783.6	4783.8
780.0	0.0	1933.5	376.0	-1129.1	804.5	4916.7
779.0	0.0	2030.2	394.8	-1204.9	825.3	5049.6
778.0	0.0	2126.9	413.6	-1280.7	846.2	5182.5
777.0	0.0	2223.6	432.4	-1371.8	851.7	5315.5
776.0	0.0	2320.3	451.2	-1464.3	855.9	5448.4
775.0	0.0	2416.9	470.0	-1541.5	875.4	5581.3
774.0	0.0	2513.6	488.7	-1617.3	896.3	5714.3
773.0	0.0	2617.5	507.5	-1700.4	917.1	5847.2
772.0	0.0	2714.7	526.3	-1776.7	938.0	5980.1
771.0	0.0	2812.9	545.1	-1854.1	958.8	6113.0
770.0	0.0	2942.5	563.9	-1962.9	979.7	6246.0
769.0	0.0	3064.9	582.7	-2064.4	1000.5	6378.9
768.0	0.0	3162.2	601.5	-2140.8	1021.4	6511.8
767.0	0.0	3281.5	620.3	-2239.3	1042.2	6644.8
766.0	0.0	3424.2	639.1	-2361.1	1063.1	6777.7
765.0	0.0	3538.7	657.9	-2454.7	1083.9	6910.6
764.0	0.0	3636.2	676.7	-2531.4	1104.8	7043.6
763.0	0.0	3760.2	695.5	-2634.6	1125.6	7176.5
762.0	0.0	3899.5	714.3	-2753.0	1146.5	7309.4
761.0	0.0	4038.8	733.1	-2871.4	1167.3	7442.3
760.0	0.0	4149.2	751.9	-2961.0	1188.2	7575.3
759.0	0.0	4248.0	770.7	-3039.0	1209.0	7705.3
758.0	0.0	4374.3	789.5	-3144.4	1229.9	7834.5

757.0	0.0	4511.0	808.3	-3260.3	1250.7	7966.5
756.0	0.0	4647.7	827.1	-3376.1	1271.6	8099.3
755.0	0.0	4784.4	845.9	-3492.0	1292.4	8232.1
754.0	0.0	4920.3	864.7	-3607.0	1313.3	8364.9

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                       TIME: 13:25:57

                        ****************************
                        *   SUMMARY OF RESULTS FOR  *
                        *    ANCHORED WALL DESIGN   *
                        ****************************

    I.--HEADING
     'COON RAPIDS DAM
     'DOWNSTEAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'OUTER SHEET PILE - LOW TAILWATER - EL. 809

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   METHOD                             :     FREE EARTH         FIXED EARTH

   WALL BOTTOM ELEVATION (FT)         :         788.31              783.05
         PENETRATION (FT)              :         11.69               16.95

   MAXIMUM BENDING MOMENT (LB-FT)     :    -1.4498E+04         -1.1545E+04
         AT ELEVATION (FT)            :         801.77              802.66

   MAXIMUM SCALED DEFLECTION (LB-IN^3):     1.3136E+09          9.3727E+08
         AT ELEVATION (FT)            :         801.00              801.00

   ANCHOR FORCE (LB)                  :     2.4337E+03          2.1321E+03

            NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                   ELLASTICITY IN PSI TIMES PILE MOMENT
                   OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                   IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                       TIME: 13:25:57

                        ****************************
                        * COMPLETE OF RESULTS FOR  *
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*   ANCHORED WALL DESIGN   *
*   BY FREE EARTH METHOD   *
****************************
```

I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809

II.--RESULTS (ANCHOR FORCE= 2434. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
815.00	0.0000E+00	0.	-5.6340E+08	0.00
814.00	8.7311E-11	0.	-3.7560E+08	0.00
813.00	0.0000E+00	0.	-1.8780E+08	0.00
812.00+	1.2490E+01	37.	0.0000E+00	74.94
812.00-	1.2490E+01	-2396.	0.0000E+00	74.94
811.00	-2.3393E+03	-2300.	1.8713E+08	116.57
810.00	-4.5746E+03	-2163.	3.7023E+08	158.20
809.00	-6.6525E+03	-1987.	5.4546E+08	194.64
808.00	-8.5375E+03	-1779.	7.0921E+08	220.69
807.00	-1.0203E+04	-1548.	8.5825E+08	241.54
806.00	-1.1626E+04	-1296.	9.8968E+08	262.39
805.00	-1.2788E+04	-1023.	1.1011E+09	283.24
804.00	-1.3666E+04	-729.	1.1904E+09	304.09
803.00	-1.4240E+04	-415.	1.2562E+09	324.94
802.00	-1.4489E+04	-80.	1.2974E+09	345.79
801.00	-1.4392E+04	277.	1.3136E+09	366.64
800.00	-1.3928E+04	654.	1.3050E+09	387.48
799.00	-1.3094E+04	1003.	1.2723E+09	311.66
798.00	-1.1947E+04	1277.	1.2171E+09	235.83
797.00	-1.0565E+04	1475.	1.1413E+09	160.00
796.00	-9.0227E+03	1597.	1.0473E+09	84.18
795.00	-7.3962E+03	1643.	9.3768E+08	8.35
794.89	-7.2153E+03	1644.	9.2477E+08	0.00
794.00	-5.7614E+03	1614.	8.1527E+08	-67.48
793.00	-4.1941E+03	1508.	6.8291E+08	-143.31
792.00	-2.7701E+03	1327.	5.4327E+08	-219.13
791.00	-1.5652E+03	1070.	3.9882E+08	-294.96
790.00	-6.5530E+02	737.	2.5162E+08	-370.79
789.00	-1.1617E+02	328.	1.0323E+08	-446.62
788.31	0.0000E+00	0.	0.0000E+00	-499.28

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF
ELLASTICITY IN PSI TIMES PILE MOMENT
OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
		<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	WATER PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
815.00	0.	0.	0.	0.	0.
814.00	0.	0.	0.	0.	0.
813.00	0.	0.	0.	0.	0.
812.00	0.	0.	0.	75.	477.
811.00	0.	0.	0.	117.	743.
810.00	0.	0.	0.	158.	1008.

809.00	0.	0.	0.	195.	1240.
808.00	0.	0.	0.	221.	1406.
807.00	0.	0.	0.	242.	1538.
806.00	0.	0.	0.	262.	1671.
805.00	0.	0.	0.	283.	1804.
804.00	0.	0.	0.	304.	1937.
803.00	0.	0.	0.	325.	2070.
802.00	0.	0.	0.	346.	2202.
801.00	0.	0.	0.	367.	2281.
800.00	0.	0.	0.	387.	2323.
799.00	0.	97.	19.	408.	2412.
798.00	0.	193.	38.	429.	2537.
797.00	0.	290.	56.	450.	2670.
796.00	0.	387.	75.	471.	2804.
795.00	0.	483.	94.	492.	2937.
794.89	0.	494.	96.	494.	2952.
794.00	0.	580.	113.	513.	3071.
793.00	0.	677.	132.	533.	3202.
792.00	0.	773.	150.	554.	3327.
791.00	0.	870.	169.	575.	3454.
790.00	0.	967.	188.	596.	3587.
789.00	0.	1063.	207.	617.	3720.
788.00	0.	1160.	226.	638.	3853.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 20-JANUARY-2011 TIME: 13:25:57

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****************************
* COMPLETE OF RESULTS FOR  *
*   ANCHORED WALL DESIGN   *
*   BY FIXED EARTH METHOD  *
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I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809

II.--RESULTS (ANCHOR FORCE= 2132. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
815.00	0.0000E+00	0.	-4.2924E+08	0.00
814.00	0.0000E+00	0.	-2.8616E+08	0.00
813.00	0.0000E+00	0.	-1.4308E+08	0.00
812.00+	1.2490E+01	37.	0.0000E+00	74.94
812.00-	1.2490E+01	-2095.	0.0000E+00	74.94
811.00	-2.0377E+03	-1999.	1.4250E+08	116.57
810.00	-3.9713E+03	-1861.	2.8149E+08	158.20
809.00	-5.7476E+03	-1685.	4.1364E+08	194.64
808.00	-7.3310E+03	-1477.	5.3589E+08	220.69
807.00	-8.6946E+03	-1246.	6.4550E+08	241.54
806.00	-9.8166E+03	-994.	7.4013E+08	262.39
805.00	-1.0676E+04	-721.	8.1783E+08	283.24
804.00	-1.1253E+04	-428.	8.7712E+08	304.09
803.00	-1.1525E+04	-113.	9.1701E+08	324.94

802.00	-1.1472E+04	222.	9.3703E+08	345.79
801.00	-1.1074E+04	578.	9.3727E+08	366.64
800.00	-1.0309E+04	955.	9.1844E+08	387.48
799.00	-9.1725E+03	1305.	8.8184E+08	311.66
798.00	-7.7244E+03	1579.	8.2944E+08	235.83
797.00	-6.0405E+03	1777.	7.6373E+08	160.00
796.00	-4.1966E+03	1899.	6.8760E+08	84.18
795.00	-2.2685E+03	1945.	6.0423E+08	8.35
794.89	-2.0544E+03	1945.	5.9475E+08	0.00
794.00	-3.3209E+02	1915.	5.1694E+08	-67.48
793.00	1.5369E+03	1810.	4.2907E+08	-143.31
792.00	3.2625E+03	1629.	3.4383E+08	-219.13
791.00	4.7690E+03	1372.	2.6420E+08	-294.96
790.00	5.9806E+03	1039.	1.9277E+08	-370.79
789.00	6.8213E+03	630.	1.3162E+08	-446.62
788.00	7.2154E+03	146.	8.2190E+07	-522.44
787.00	7.0871E+03	-415.	4.5155E+07	-598.27
786.00	6.3606E+03	-1051.	2.0281E+07	-674.10
785.00	4.9599E+03	-1763.	6.3001E+06	-749.93
784.00	2.8093E+03	-2551.	7.8220E+05	-825.75
783.00	0.0000E+00	-3370.	0.0000E+00	-897.84

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
815.00	0.	0.	0.	0.	0.
814.00	0.	0.	0.	0.	0.
813.00	0.	0.	0.	0.	0.
812.00	0.	0.	0.	75.	477.
811.00	0.	0.	0.	117.	743.
810.00	0.	0.	0.	158.	1008.
809.00	0.	0.	0.	195.	1240.
808.00	0.	0.	0.	221.	1406.
807.00	0.	0.	0.	242.	1538.
806.00	0.	0.	0.	262.	1671.
805.00	0.	0.	0.	283.	1804.
804.00	0.	0.	0.	304.	1937.
803.00	0.	0.	0.	325.	2070.
802.00	0.	0.	0.	346.	2202.
801.00	0.	0.	0.	367.	2281.
800.00	0.	0.	0.	387.	2323.
799.00	0.	97.	19.	408.	2412.
798.00	0.	193.	38.	429.	2537.
797.00	0.	290.	56.	450.	2670.
796.00	0.	387.	75.	471.	2804.
795.00	0.	483.	94.	492.	2937.
794.89	0.	494.	96.	494.	2952.
794.00	0.	580.	113.	513.	3071.
793.00	0.	677.	132.	533.	3202.
792.00	0.	773.	150.	554.	3327.
791.00	0.	870.	169.	575.	3454.
790.00	0.	967.	188.	596.	3587.
789.00	0.	1063.	207.	617.	3720.
788.00	0.	1160.	226.	638.	3853.
787.00	0.	1257.	244.	659.	3986.

786.00	0.	1353.	263.	679.	4119.
785.00	0.	1450.	282.	700.	4252.
784.00	0.	1547.	301.	721.	4385.
783.00	0.	1644.	320.	742.	4518.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 20-JANUARY-2011 TIME: 13:25:59

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********************************
* PRELIMINARY DESIGN DATA FOR *
*  FREE EARTH DESIGN IN SAND  *
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I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809

II.--DESIGN PARAMETERS

WALL HEIGHT RATIO (ALPHA) = 0.56
ANCHOR HEIGHT RATIO (BETA) = 0.11

SHEET PILE DATA:

SHEET PILE NAME	<SECTION PROPERTIES> (PER FOOT OF WALL) SECTION MODULUS (IN^3)	MOMENT OF INERTIA (IN^4)	ALLOWABLE STRESS (PSI)	MODULUS OF ELLASTICITY (PSI)
PZ40	60.70	490.80	2.40E+04	2.90E+07
PZ38	46.80	280.80	2.40E+04	2.90E+07
PZ35	48.50	361.20	2.40E+04	2.90E+07
PZ32	38.30	220.40	2.40E+04	2.90E+07
PZ27	30.20	184.20	2.40E+04	2.90E+07
PZ22	18.10	84.40	2.40E+04	2.90E+07
PLZ25	32.80	223.25	2.40E+04	2.90E+07
PLZ23	30.20	203.75	2.40E+04	2.90E+07

III.--PRELIMINARY DESIGN DATA

SHEET PILE NAME	LOG(H^4/EI)	ROWE'S MOMENT REDUCTION COEF.	RATIO OF ALLOWABLE MOMENT TO FREE EARTH MOMENT
PZ40	-4.45	1.0 (***)	8.37
PZ38	-4.21	1.0 (***)	6.46
PZ35	-4.31	1.0 (***)	6.69
PZ32	-4.10	1.0 (***)	5.28
PZ27	-4.02	1.0 (***)	4.17
PZ22	-3.68	1.0 (***)	2.50
PLZ25	-4.11	1.0 (***)	4.52
PLZ23	-4.07	1.0 (***)	4.17

```
*** REDUCTION NOT APPLICABLE DUE TO ALPHA LESS THAN 0.6.

*** REDUCTION NOT APPLICABLE DUE TO RIGHTSIDE SURFACE
    BELOW TOP OF WALL.
```

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 7

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam outer sheet on the Hennepin side of Coon Rapids Dam. Anchor placed at elevation 812.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 1.45 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.31\ 10^9 lbf \cdot in^3$

Required Penetration: 11.69 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2in^3 \quad I_{PZ} := 184.20in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 5.762 \cdot ksi$

Allowable Stress: $f_b := 0.5F_y \quad f_b = 25 \cdot ksi \quad$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_35} = 0.245 \cdot in$

Conclusion

A PZ 27 (or equivalent) is adequate.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 7

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $\quad kpf := \frac{k}{ft}$ $\quad ksf := \frac{k}{ft^2}$ $\quad ksi := \frac{k}{in^2}$ $\quad kcf := \frac{k}{ft^3}$ $\quad ppf := \frac{lbf}{ft}$ $\quad psf := \frac{lbf}{ft^2}$ $\quad psi := \frac{lbf}{in^2}$ $\quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\quad \gamma_{water} := 62.4 \cdot pcf$ $\quad \gamma_{conc} := 150 \cdot pcf$ $\quad f_c := 4 \cdot ksi$ $\quad f_y := 60 \cdot ksi$ $\quad F_y := 50 \cdot ksi$ $\quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $\quad cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $\quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam outer sheet on the Hennepin side of Coon Rapids Dam. Anchor placed at elevation 812.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 22 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 1.45 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.31\, 10^9 lbf \cdot in^3$

Required Penetration: 11.69 ft

Section Design

Using a PZ 22

$S_{PZ} := 18.1 in^3$ $\quad I_{PZ} := 84.38 in^4$ $\quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\quad \sigma_b = 9.613 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $\quad f_b = 25 \cdot ksi$ $\quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\quad \delta_{PZ\_35} = 0.535 \cdot in$

Conclusion

A PZ 22 (or equivalent) is adequate.

Sheet Pile Cofferdam Structural Analysis

Case 8

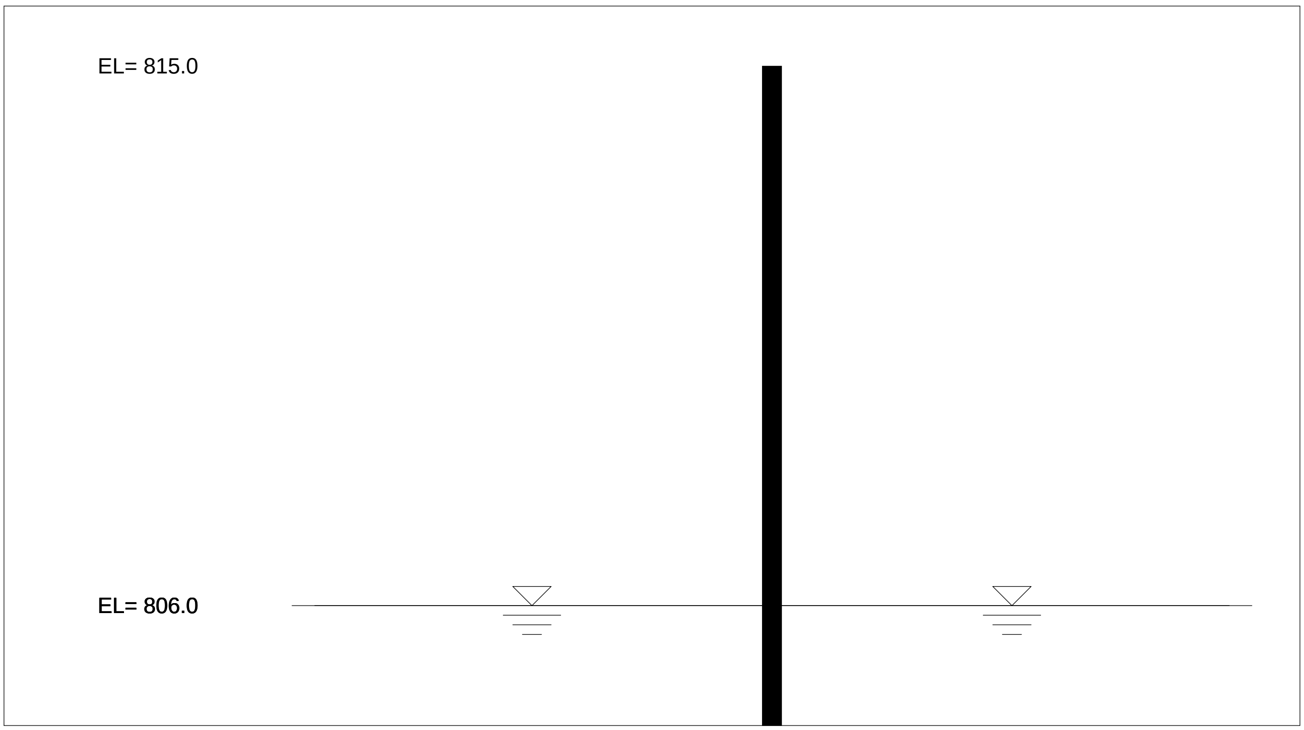
Downstream Cofferdam – Inner Sheet

Hennepin Side – Low Tailwater

Counter Force Check

'COON RAPIDS DAM

'DOWNSTEAM COFFERDAM ANALYSIS



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'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEIPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809 - COUNTER FORCE CHECK
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   815
SURFACE RIGHTSIDE   2    0    806
                  20    806
SURFACE LEFTSIDE   2    0    806
                  20    806
SOIL RIGHTSIDE  STRENGTHS   1
   125    125    30    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   125    125    30    0    0    0
WATER ELEVATIONS   62.4    806    806
HORIZONTAL LINE   1   812   2430
FINISHED
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 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
 DATE: 20-JANUARY-2011                                       TIME: 13:23:07

                             ****************
                             *  INPUT DATA  *
                             ****************

      I.--HEADING
     'COON RAPIDS DAM
     'DOWNSTEAM COFFERDAM ANALYSIS
     'HENNEIPIN SIDE - GLACIAL TILL
     'OUTER SHEET PILE - LOW TAILWATER - EL. 809 - COUNTER FORCE CHECK

     II.--CONTROL
        CANTILEVER WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

    III.--WALL DATA
        ELEVATION AT TOP OF WALL    = 815.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00        806.00
                 20.00        806.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00        806.00
                 20.00        806.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

               ANGLE OF          ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
125.00  125.00    30.00    0.00     0.00    0.00                  DEF  DEF

         V.B.--LEFTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

               ANGLE OF          ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
125.00  125.00    30.00    0.00     0.00    0.00                  DEF  DEF

     VI.--WATER DATA
        UNIT WEIGHT          = 62.40 (PCF)
        RIGHTSIDE ELEVATION = 806.00 (FT)
        LEFTSIDE ELEVATION  = 806.00 (FT)
        NO SEEPAGE
```

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS

VIII.A.--HORIZONTAL LINE LOADS

ELEVATION (FT)	LINE LOAD (PLF)
812.00	2430.00

VIII.B.--HORIZONTAL DISTRIBUTED LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 20-JANUARY-2011 TIME: 13:23:14

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**************************
*   SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
**************************
```

I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEIPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809 - COUNTER FORCE CHECK

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

	NET	<---LEFTSIDE--->		<------NET------> (SOIL + WATER)		<--RIGHTSIDE--->	
ELEV. (FT)	WATER (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
815.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
814.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
813.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
812.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
811.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
810.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
809.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
808.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
807.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
806.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
805.0	0.0	132.8	20.8	-112.0	112.0	20.8	132.8
804.0	0.0	265.6	41.7	-223.9	223.9	41.7	265.6
803.0	0.0	398.4	62.5	-335.9	335.9	62.5	398.4
802.0	0.0	531.2	83.4	-447.8	447.8	83.4	531.2
801.0	0.0	664.0	104.2	-559.8	559.8	104.2	664.0

800.0	0.0	796.8	125.1	-671.7	671.7	125.1	796.8
799.0	0.0	929.6	145.9	-783.7	783.7	145.9	929.6
798.0	0.0	1062.4	166.8	-895.6	895.6	166.8	1062.4
797.0	0.0	1195.2	187.6	-1007.6	1007.6	187.6	1195.2
796.0	0.0	1328.0	208.5	-1119.5	1119.5	208.5	1328.0
795.0	0.0	1460.8	229.3	-1231.5	1231.5	229.3	1460.8
794.0	0.0	1593.6	250.2	-1343.4	1343.4	250.2	1593.6
793.0	0.0	1726.4	271.0	-1455.4	1455.4	271.0	1726.4
792.0	0.0	1859.2	291.9	-1567.3	1567.3	291.9	1859.2
791.0	0.0	1992.0	312.7	-1679.3	1679.3	312.7	1992.0
790.0	0.0	2124.8	333.6	-1791.2	1791.2	333.6	2124.8
789.0	0.0	2257.6	354.4	-1903.2	1903.2	354.4	2257.6
788.0	0.0	2390.4	375.3	-2015.1	2015.1	375.3	2390.4
787.0	0.0	2523.2	396.1	-2127.1	2127.1	396.1	2523.2
786.0	0.0	2656.0	417.0	-2239.1	2239.1	417.0	2656.0
785.0	0.0	2788.9	437.8	-2351.0	2351.0	437.8	2788.9
784.0	0.0	2921.7	458.7	-2463.0	2463.0	458.7	2921.7
783.0	0.0	3054.5	479.5	-2574.9	2574.9	479.5	3054.5
782.0	0.0	3187.3	500.4	-2686.9	2686.9	500.4	3187.3
781.0	0.0	3320.1	521.2	-2798.8	2798.8	521.2	3320.1
780.0	0.0	3452.9	542.1	-2910.8	2910.8	542.1	3452.9
779.0	0.0	3585.7	562.9	-3022.7	3022.7	562.9	3585.7
778.0	0.0	3718.5	583.8	-3134.7	3134.7	583.8	3718.5
777.0	0.0	3851.3	604.6	-3246.6	3246.6	604.6	3851.3
776.0	0.0	3984.1	625.5	-3358.6	3358.6	625.5	3984.1
775.0	0.0	4116.9	646.3	-3470.5	3470.5	646.3	4116.9

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                          TIME: 13:23:14

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************

    I.--HEADING
     'COON RAPIDS DAM
     'DOWNSTEAM COFFERDAM ANALYSIS
     'HENNEIPIN SIDE - GLACIAL TILL
     'OUTER SHEET PILE - LOW TAILWATER - EL. 809 - COUNTER FORCE CHECK

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      789.42
         PENETRATION (FT)     :       16.58

   MAX. BEND. MOMENT (LB-FT)  :  2.5254E+04
         AT ELEVATION (FT)    :      799.41
```

MAX. SCALED DEFL. (LB-IN^3): 7.9648E+09
AT ELEVATION (FT) : 815.00

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 13:23:14

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****************************
* COMPLETE OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
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I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEIPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809 - COUNTER FORCE CHECK

II.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
815.00	0.0000E+00	0.	7.9648E+09	0.00
814.00	1.0477E-09	0.	7.4124E+09	0.00
813.00	1.0477E-09	0.	6.8601E+09	0.00
812.00+	1.0477E-09	0.	6.3077E+09	0.00
812.00-	-1.0477E-09	2430.	6.3077E+09	0.00
811.00	2.4300E+03	2430.	5.7561E+09	0.00
810.00	4.8600E+03	2430.	5.2086E+09	0.00
809.00	7.2900E+03	2430.	4.6696E+09	0.00
808.00	9.7200E+03	2430.	4.1431E+09	0.00
807.00	1.2150E+04	2430.	3.6335E+09	0.00
806.00	1.4580E+04	2430.	3.1448E+09	0.00
805.00	1.6991E+04	2374.	2.6814E+09	-111.95
804.00	1.9291E+04	2206.	2.2472E+09	-223.91
803.00	2.1366E+04	1926.	1.8464E+09	-335.86
802.00	2.3106E+04	1534.	1.4825E+09	-447.81
801.00	2.4398E+04	1031.	1.1584E+09	-559.76
800.00	2.5130E+04	415.	8.7639E+08	-671.72
799.00	2.5190E+04	-313.	6.3772E+08	-783.67
798.00	2.4467E+04	-1152.	4.4245E+08	-895.62
797.00	2.2848E+04	-2104.	2.8934E+08	-1007.57
796.40	2.1406E+04	-2726.	2.1686E+08	-1074.49
796.00	2.0227E+04	-3125.	1.7556E+08	-905.56
795.00	1.6720E+04	-3820.	9.6609E+07	-485.68
794.00	1.2727E+04	-4096.	4.6476E+07	-65.80
793.00	8.6676E+03	-3952.	1.8324E+07	354.08
792.00	4.9628E+03	-3388.	5.2018E+06	773.96
791.00	2.0320E+03	-2404.	7.6650E+05	1193.84
790.00	2.9500E+02	-1000.	1.4375E+04	1613.72
789.42	0.0000E+00	0.	0.0000E+00	1855.79

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF

ELLASTICITY IN PSI TIMES PILE MOMENT
OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
815.00	0.	0.	0.	0.	0.
814.00	0.	0.	0.	0.	0.
813.00	0.	0.	0.	0.	0.
812.00	0.	0.	0.	0.	0.
811.00	0.	0.	0.	0.	0.
810.00	0.	0.	0.	0.	0.
809.00	0.	0.	0.	0.	0.
808.00	0.	0.	0.	0.	0.
807.00	0.	0.	0.	0.	0.
806.00	0.	0.	0.	0.	0.
805.00	0.	133.	21.	21.	133.
804.00	0.	266.	42.	42.	266.
803.00	0.	398.	63.	63.	398.
802.00	0.	531.	83.	83.	531.
801.00	0.	664.	104.	104.	664.
800.00	0.	797.	125.	125.	797.
799.00	0.	930.	146.	146.	930.
798.00	0.	1062.	167.	167.	1062.
797.00	0.	1195.	188.	188.	1195.
796.40	0.	1275.	200.	200.	1275.
796.00	0.	1328.	208.	208.	1328.
795.00	0.	1461.	229.	229.	1461.
794.00	0.	1594.	250.	250.	1594.
793.00	0.	1726.	271.	271.	1726.
792.00	0.	1859.	292.	292.	1859.
791.00	0.	1992.	313.	313.	1992.
790.00	0.	2125.	334.	334.	2125.
789.42	0.	2258.	354.	354.	2258.
788.00	0.	2390.	375.	375.	2390.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 8

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam inner sheet on the Hennepin side of Coon Rapids Dam. Equivalent horizontal line load (anchor force fro Case 7) placed at elevation 812.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 2.53 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 7.96\ 10^9 lbf \cdot in^3$

Required Penetration: 16.58 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3 \quad I_{PZ} := 184.20 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 10.053 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi \quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_35} = 1.49 \cdot in$

Conclusion

A PZ 27 (or equivalent) is adequate.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 8

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $\quad kpf := \frac{k}{ft}$ $\quad ksf := \frac{k}{ft^2}$ $\quad ksi := \frac{k}{in^2}$ $\quad kcf := \frac{k}{ft^3}$ $\quad ppf := \frac{lbf}{ft}$ $\quad psf := \frac{lbf}{ft^2}$ $\quad psi := \frac{lbf}{in^2}$ $\quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\quad \gamma_{water} := 62.4 \cdot pcf$ $\quad \gamma_{conc} := 150 \cdot pcf$ $\quad f_c := 4 \cdot ksi$ $\quad f_y := 60 \cdot ksi$ $\quad F_y := 50 \cdot ksi$ $\quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $\quad cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $\quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam inner sheet on the Hennepin side of Coon Rapids Dam. Equivalent horizontal line load (anchor force fro Case 7) placed at elevation 812.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 22 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 2.53 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 7.96\, 10^9 lbf \cdot in^3$

Required Penetration: 16.58 ft

Section Design

Using a PZ 22

$S_{PZ} := 18.1 in^3$ $\quad I_{PZ} := 84.38 in^4$ $\quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\quad \sigma_b = 16.773 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $\quad f_b = 25 \cdot ksi$ $\quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\quad \delta_{PZ\_35} = 3.253 \cdot in$

Conclusion

A PZ 22 (or equivalent) is adequate.

Sheet Pile Cofferdam Structural Analysis

Case 9

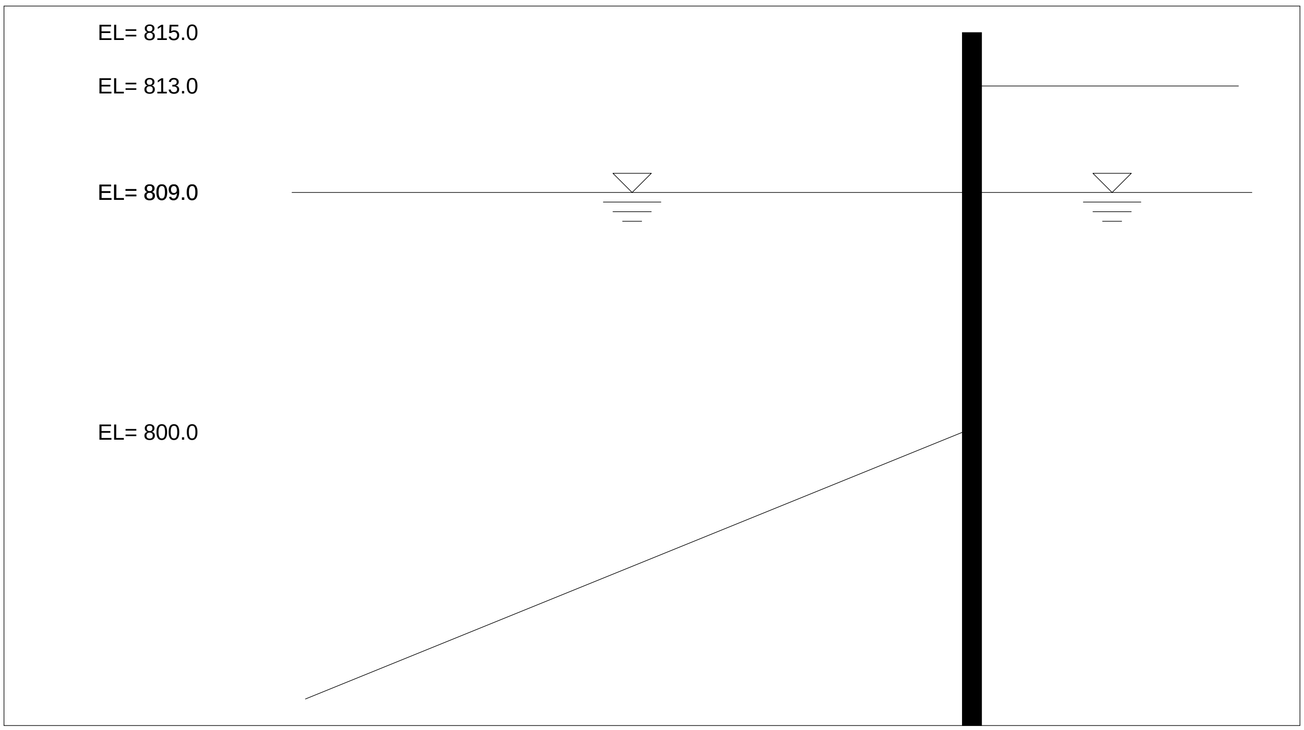
Downstream Cofferdam – Outer Sheet

Hennepin Side – Low Tailwater

No Strut Check

'COON RAPIDS DAM

'DOWNSTEAM COFFERDAM ANALYSIS



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'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809  - NO STRUT CHECK
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   815
SURFACE RIGHTSIDE   2    0    813
                  20    813
SURFACE LEFTSIDE   2    0    800
                  50    790
SOIL RIGHTSIDE  STRENGTHS   1
   125    125    30    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   125    125    30    0    0    0
WATER ELEVATIONS   62.4    809    809
VERTICAL STRIP  RIGHTSIDE   1    0    20    100
FINISHED
```

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 20-JANUARY-2011 TIME: 13:49:52

****
* INPUT DATA *
****

I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809 - NO STRUT CHECK

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

III.--WALL DATA
ELEVATION AT TOP OF WALL = 815.00 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	813.00
20.00	813.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	800.00
50.00	790.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	<-SAFETY-> <-FACTOR-> PASS.
125.00	125.00	30.00	0.00	0.00	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	<-SAFETY-> <-FACTOR-> PASS.
125.00	125.00	30.00	0.00	0.00	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 809.00 (FT)
LEFTSIDE ELEVATION = 809.00 (FT)
NO SEEPAGE

```
VII.--VERTICAL SURCHARGE LOADS

    VII.A.--VERTICAL LINE LOADS
         NONE

    VII.B.--VERTICAL UNIFORM LOADS
              NONE

    VII.C.--VERTICAL STRIP LOADS

         VII.C.1.--RIGHTSIDE
         <-DIST. FROM WALL->
           START       END      STRIP LOAD
            (FT)       (FT)        (PSF)
            0.00      20.00       100.00

         VII.C.2.--LEFTSIDE
              NONE

    VII.D.--VERTICAL RAMP LOADS
         NONE

    VII.E.--VERTICAL TRIANGULAR LOADS
         NONE

    VII.F.--VERTICAL VARIABLE LOADS
         NONE

VIII.--HORIZONTAL LOADS
     NONE
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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                         TIME: 13:49:55

                          **************************
                          *   SOIL PRESSURES FOR   *
                          * CANTILEVER WALL DESIGN *
                          **************************

    I.--HEADING
     'COON RAPIDS DAM
     'DOWNSTEAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'OUTER SHEET PILE - LOW TAILWATER - EL. 809  - NO STRUT CHECK

   II.--SOIL PRESSURES

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                   <------NET------>
```

	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
815.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
814.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
813.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
812.0	0.0	0.0	0.0	74.9	477.3	74.9	477.3
811.0	0.0	0.0	0.0	116.6	742.5	116.6	742.5
810.0	0.0	0.0	0.0	158.2	1007.7	158.2	1007.7
809.0	0.0	0.0	0.0	194.6	1239.8	194.6	1239.8
808.0	0.0	0.0	0.0	220.7	1405.7	220.7	1405.7
807.0	0.0	0.0	0.0	241.5	1538.5	241.5	1538.5
806.0	0.0	0.0	0.0	262.4	1671.3	262.4	1671.3
805.0	0.0	0.0	0.0	283.2	1804.1	283.2	1804.1
804.0	0.0	0.0	0.0	304.1	1936.9	304.1	1936.9
803.0	0.0	0.0	0.0	324.9	2069.7	324.9	2069.7
802.0	0.0	0.0	0.0	345.8	2202.5	345.8	2202.5
801.0	0.0	0.0	0.0	366.6	2280.8	366.6	2280.8
800.0	0.0	0.0	0.0	387.5	2323.4	387.5	2323.4
799.0	0.0	96.7	18.8	311.7	2393.2	408.3	2412.0
798.0	0.0	193.4	37.6	235.8	2499.1	429.2	2536.6
797.0	0.0	290.0	56.4	160.0	2613.9	450.0	2670.2
796.0	0.0	386.7	75.2	84.2	2728.7	470.9	2803.8
795.0	0.0	483.4	94.0	8.3	2843.5	491.7	2937.4
794.9	0.0	494.0	96.1	0.0	2856.1	494.0	2952.2
794.0	0.0	580.1	112.8	-67.5	2958.3	512.6	3071.0
793.0	0.0	676.7	131.6	-143.3	3070.7	533.4	3202.3
792.0	0.0	773.4	150.4	-219.1	3177.0	554.3	3327.4
791.0	0.0	870.1	169.2	-295.0	3285.3	575.1	3454.5
790.0	0.0	966.8	188.0	-370.8	3399.4	596.0	3587.4
789.0	0.0	1063.4	206.8	-446.6	3513.5	616.8	3720.3
788.0	0.0	1160.1	225.6	-522.4	3627.7	637.7	3853.3
787.0	0.0	1256.8	244.4	-598.3	3741.8	658.5	3986.2
786.0	0.0	1353.5	263.2	-674.1	3855.9	679.4	4119.1
785.0	0.0	1450.2	282.0	-749.9	3970.1	700.2	4252.0
784.0	0.0	1546.8	300.8	-825.8	4084.2	721.1	4385.0
783.0	0.0	1643.5	319.6	-901.6	4198.3	741.9	4517.9
782.0	0.0	1740.2	338.4	-977.4	4312.5	762.8	4650.8
781.0	0.0	1836.9	357.2	-1053.2	4426.6	783.6	4783.8
780.0	0.0	1933.5	376.0	-1129.1	4540.7	804.5	4916.7
779.0	0.0	2030.2	394.8	-1204.9	4654.9	825.3	5049.6
778.0	0.0	2126.9	413.6	-1280.7	4769.0	846.2	5182.5
777.0	0.0	2223.6	432.4	-1371.8	4883.1	851.7	5315.5
776.0	0.0	2320.3	451.2	-1464.3	4997.2	855.9	5448.4
775.0	0.0	2416.9	470.0	-1541.5	5111.4	875.4	5581.3
774.0	0.0	2513.6	488.7	-1617.3	5225.5	896.3	5714.3
773.0	0.0	2617.5	507.5	-1700.4	5339.6	917.1	5847.2
772.0	0.0	2714.7	526.3	-1776.7	5453.8	938.0	5980.1
771.0	0.0	2812.9	545.1	-1854.1	5567.9	958.8	6113.0
770.0	0.0	2942.5	563.9	-1962.9	5682.0	979.7	6246.0
769.0	0.0	3064.9	582.7	-2064.4	5796.2	1000.5	6378.9
768.0	0.0	3162.2	601.5	-2140.8	5910.3	1021.4	6511.8
767.0	0.0	3281.5	620.3	-2239.3	6024.4	1042.2	6644.8
766.0	0.0	3424.2	639.1	-2361.1	6138.6	1063.1	6777.7
765.0	0.0	3538.7	657.9	-2454.7	6252.7	1083.9	6910.6
764.0	0.0	3636.2	676.7	-2531.4	6366.8	1104.8	7043.6
763.0	0.0	3760.2	695.5	-2634.6	6481.0	1125.6	7176.5
762.0	0.0	3899.5	714.3	-2753.0	6595.1	1146.5	7309.4
761.0	0.0	4038.8	733.1	-2871.4	6709.2	1167.3	7442.3
760.0	0.0	4149.2	751.9	-2961.0	6823.3	1188.2	7575.3
759.0	0.0	4248.0	770.7	-3039.0	6934.6	1209.0	7705.3
758.0	0.0	4374.3	789.5	-3144.4	7045.0	1229.9	7834.5
757.0	0.0	4511.0	808.3	-3260.3	7158.1	1250.7	7966.5

756.0	0.0	4647.7	827.1	-3376.1	7272.1	1271.6	8099.3
755.0	0.0	4784.4	845.9	-3492.0	7386.1	1292.4	8232.1
754.0	0.0	4920.3	864.7	-3607.0	7500.1	1313.3	8364.9

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                          TIME: 13:49:55

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************

    I.--HEADING
     'COON RAPIDS DAM
     'DOWNSTEAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'OUTER SHEET PILE - LOW TAILWATER - EL. 809  - NO STRUT CHECK

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      772.07
         PENETRATION (FT)     :       27.93

   MAX. BEND. MOMENT (LB-FT)  :  6.2615E+04
         AT ELEVATION (FT)    :      784.52

   MAX. SCALED DEFL. (LB-IN^3):  5.7593E+10
         AT ELEVATION (FT)    :      815.00

             NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                    ELLASTICITY IN PSI TIMES PILE MOMENT
                    OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                    IN INCHES.


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                          TIME: 13:49:55

                       ****************************
                       * COMPLETE OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************

     I.--HEADING
     'COON RAPIDS DAM
```

'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'OUTER SHEET PILE - LOW TAILWATER - EL. 809 - NO STRUT CHECK

II.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
815.00	0.0000E+00	0.	5.7593E+10	0.00
814.00	1.1176E-08	0.	5.5529E+10	0.00
813.00	1.1176E-08	0.	5.3464E+10	0.00
812.00	1.2490E+01	37.	5.1400E+10	74.94
811.00	9.4368E+01	133.	4.9336E+10	116.57
810.00	2.9282E+02	271.	4.7272E+10	158.20
809.00	6.4861E+02	447.	4.5209E+10	194.64
808.00	1.1973E+03	655.	4.3147E+10	220.69
807.00	1.9658E+03	886.	4.1087E+10	241.54
806.00	2.9759E+03	1138.	3.9030E+10	262.39
805.00	4.2483E+03	1411.	3.6979E+10	283.24
804.00	5.8040E+03	1704.	3.4935E+10	304.09
803.00	7.6638E+03	2019.	3.2901E+10	324.94
802.00	9.8485E+03	2354.	3.0880E+10	345.79
801.00	1.2379E+04	2710.	2.8876E+10	366.64
800.00	1.5276E+04	3087.	2.6894E+10	387.48
799.00	1.8545E+04	3437.	2.4938E+10	311.66
798.00	2.2125E+04	3711.	2.3015E+10	235.83
797.00	2.5941E+04	3909.	2.1129E+10	160.00
796.00	2.9917E+04	4031.	1.9289E+10	84.18
795.00	3.3977E+04	4077.	1.7500E+10	8.35
794.89	3.4426E+04	4077.	1.7306E+10	0.00
794.00	3.8045E+04	4047.	1.5770E+10	-67.48
793.00	4.2046E+04	3942.	1.4105E+10	-143.31
792.00	4.5904E+04	3761.	1.2513E+10	-219.13
791.00	4.9543E+04	3504.	1.1001E+10	-294.96
790.00	5.2886E+04	3171.	9.5740E+09	-370.79
789.00	5.5859E+04	2762.	8.2384E+09	-446.62
788.00	5.8385E+04	2278.	6.9993E+09	-522.44
787.00	6.0389E+04	1717.	5.8610E+09	-598.27
786.00	6.1795E+04	1081.	4.8270E+09	-674.10
785.00	6.2526E+04	369.	3.8996E+09	-749.93
784.00	6.2508E+04	-419.	3.0802E+09	-825.75
783.00	6.1663E+04	-1282.	2.3687E+09	-901.58
782.00	5.9917E+04	-2222.	1.7636E+09	-977.41
781.00	5.7194E+04	-3237.	1.2618E+09	-1053.24
780.00	5.3418E+04	-4328.	8.5882E+08	-1129.06
779.00	4.8512E+04	-5495.	5.4794E+08	-1204.89
778.00	4.2402E+04	-6738.	3.2072E+08	-1280.72
777.00	3.5008E+04	-8064.	1.6658E+08	-1371.85
776.45	3.0390E+04	-8828.	1.0870E+08	-1422.42
776.00	2.6268E+04	-9312.	7.2734E+07	-713.07
775.00	1.6860E+04	-9243.	2.4180E+07	852.28
774.00	8.3042E+03	-7608.	4.8826E+06	2417.63
773.00	2.1662E+03	-4407.	2.8299E+05	3982.98
772.07	0.0000E+00	0.	0.0000E+00	5446.34

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELLASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
815.00	0.	0.	0.	0.	0.
814.00	0.	0.	0.	0.	0.
813.00	0.	0.	0.	0.	0.
812.00	0.	0.	0.	75.	477.
811.00	0.	0.	0.	117.	743.
810.00	0.	0.	0.	158.	1008.
809.00	0.	0.	0.	195.	1240.
808.00	0.	0.	0.	221.	1406.
807.00	0.	0.	0.	242.	1538.
806.00	0.	0.	0.	262.	1671.
805.00	0.	0.	0.	283.	1804.
804.00	0.	0.	0.	304.	1937.
803.00	0.	0.	0.	325.	2070.
802.00	0.	0.	0.	346.	2202.
801.00	0.	0.	0.	367.	2281.
800.00	0.	0.	0.	387.	2323.
799.00	0.	97.	19.	408.	2412.
798.00	0.	193.	38.	429.	2537.
797.00	0.	290.	56.	450.	2670.
796.00	0.	387.	75.	471.	2804.
795.00	0.	483.	94.	492.	2937.
794.89	0.	494.	96.	494.	2952.
794.00	0.	580.	113.	513.	3071.
793.00	0.	677.	132.	533.	3202.
792.00	0.	773.	150.	554.	3327.
791.00	0.	870.	169.	575.	3454.
790.00	0.	967.	188.	596.	3587.
789.00	0.	1063.	207.	617.	3720.
788.00	0.	1160.	226.	638.	3853.
787.00	0.	1257.	244.	659.	3986.
786.00	0.	1353.	263.	679.	4119.
785.00	0.	1450.	282.	700.	4252.
784.00	0.	1547.	301.	721.	4385.
783.00	0.	1644.	320.	742.	4518.
782.00	0.	1740.	338.	763.	4651.
781.00	0.	1837.	357.	784.	4784.
780.00	0.	1934.	376.	804.	4917.
779.00	0.	2030.	395.	825.	5050.
778.00	0.	2127.	414.	846.	5183.
777.00	0.	2224.	432.	852.	5315.
776.45	0.	2276.	443.	854.	5388.
776.00	0.	2320.	451.	856.	5448.
775.00	0.	2417.	470.	875.	5581.
774.00	0.	2514.	489.	896.	5714.
773.00	0.	2617.	508.	917.	5847.
772.07	0.	2715.	526.	938.	5980.
771.00	0.	2813.	545.	959.	6113.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 9

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $\quad kpf := \frac{k}{ft}$ $\quad ksf := \frac{k}{ft^2}$ $\quad ksi := \frac{k}{in^2}$ $\quad kcf := \frac{k}{ft^3}$ $\quad ppf := \frac{lbf}{ft}$ $\quad psf := \frac{lbf}{ft^2}$ $\quad psi := \frac{lbf}{in^2}$ $\quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\quad \gamma_{water} := 62.4 \cdot pcf$ $\quad \gamma_{conc} := 150 \cdot pcf$ $\quad f_c := 4 \cdot ksi$ $\quad f_y := 60 \cdot ksi$ $\quad F_y := 50 \cdot ksi$ $\quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $\quad cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $\quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam outer sheet on the Hennepin side of Coon Rapids Dam. NO ANCHOR CHECK.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 6.26 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 5.76\,10^{10} lbf \cdot in^3$

Required Penetration: 27.93 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2in^3$ $\quad I_{PZ} := 184.20in^4$ $\quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\quad \sigma_b = 24.874 \cdot ksi$

Allowable Stress: $f_b := 0.5F_y$ $\quad f_b = 25 \cdot ksi$ $\quad$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\quad \delta_{PZ\_35} = 10.783 \cdot in$ $\quad$ Excessive Deflection without struts.

Conclusion

A PZ 27 (or equivalent) is adequate with struts.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 9

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam outer sheet on the Hennepin side of Coon Rapids Dam. NO ANCHOR CHECK.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 22 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 6.26 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 5.76\,10^{10} lbf \cdot in^3$

Required Penetration: 27.93 ft

Section Design

Using a PZ 22

$S_{PZ} := 18.1 in^3 \quad I_{PZ} := 84.38 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 41.503 \cdot ksi$

Allowable Stress: $f_b := 0.5F_y \quad f_b = 25 \cdot ksi$ $\quad f_b < \sigma_b$ Strength NOT sufficient. Use a PZ 27.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_35} = 23.539 \cdot in$ Excessive Deflection without struts.

Conclusion

A PZ 27 (or equivalent) is adequate with struts.

Sheet Pile Cofferdam Structural Analysis

Case 10

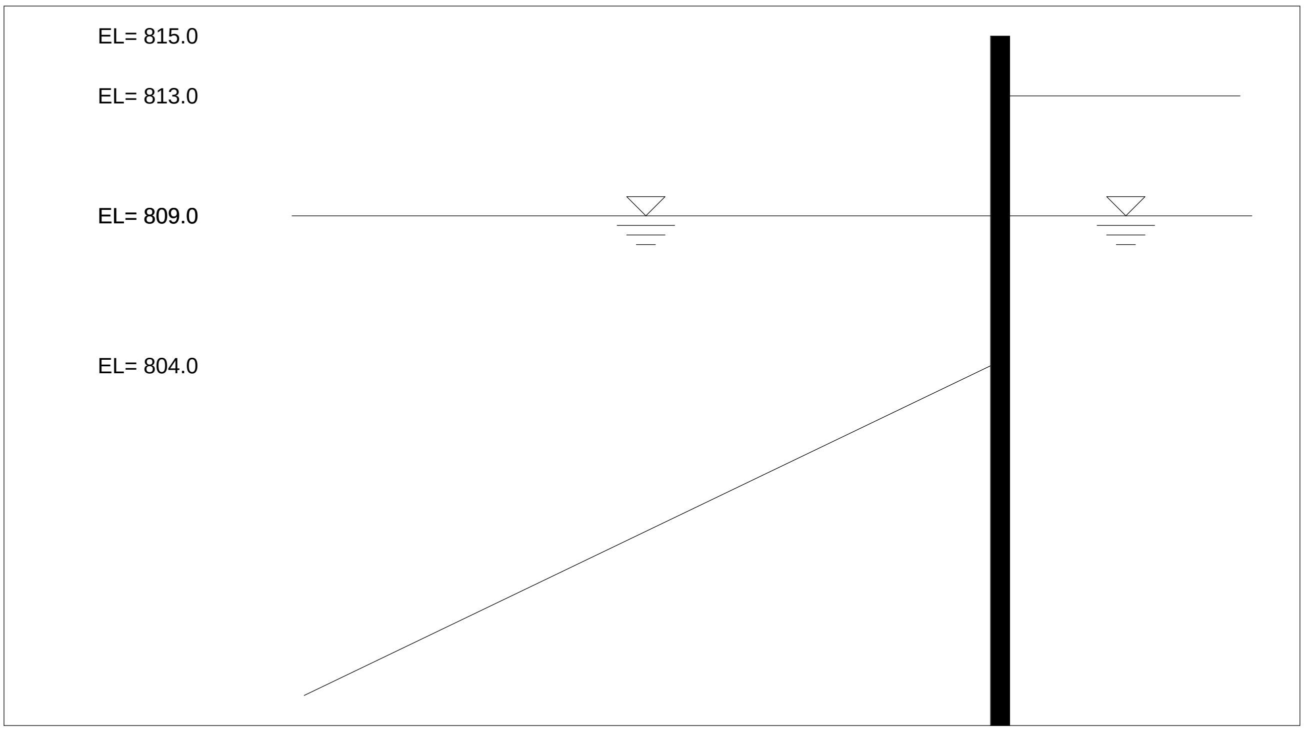
Downstream Cofferdam – Outer Sheet

Anoka Side – Low Tailwater

No Strut Check

'COON RAPIDS DAM

'DOWNSTEAM COFFERDAM ANALYSIS



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'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SAND
'OUTER SHEET PILE - LOW TAILWATER - EL. 809  - NO STRUT CHECK
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   815
SURFACE RIGHTSIDE   2    0    813
                  20    813
SURFACE LEFTSIDE   2    0    804
                  58    793
SOIL RIGHTSIDE  STRENGTHS   1
   125    125    30    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   125    125    30    0    0    0
WATER ELEVATIONS   62.4    809    809
VERTICAL STRIP  RIGHTSIDE   1    0    20    100
FINISHED
```

```
 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
 DATE: 20-JANUARY-2011                                        TIME: 13:50:26

                              ****************
                              *  INPUT DATA  *
                              ****************

       I.--HEADING
      'COON RAPIDS DAM
      'DOWNSTEAM COFFERDAM ANALYSIS
      'ANOKA SIDE - ALLUVIAL SAND
      'OUTER SHEET PILE - LOW TAILWATER - EL. 809  - NO STRUT CHECK

      II.--CONTROL
         CANTILEVER WALL DESIGN
         FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
         FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

     III.--WALL DATA
         ELEVATION AT TOP OF WALL    = 815.00 FT.

      IV.--SURFACE POINT DATA

           IV.A.--RIGHTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)        (FT)
                   0.00        813.00
                  20.00        813.00

           IV.B.--LEFTSIDE
              DIST. FROM     ELEVATION
              WALL (FT)        (FT)
                   0.00        804.00
                  58.00        793.00

       V.--SOIL LAYER DATA

          V.A.--RIGHTSIDE
              LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
              LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                ANGLE OF          ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->   <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION   FRICTION  ESION   ELEV.  SLOPE   ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)     (DEG)   (PSF)   (FT)  (FT/FT)
125.00  125.00    30.00    0.00     0.00     0.00                   DEF  DEF

          V.B.--LEFTSIDE
              LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
              LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                ANGLE OF          ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->   <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION   FRICTION  ESION   ELEV.  SLOPE   ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)     (DEG)   (PSF)   (FT)  (FT/FT)
125.00  125.00    30.00    0.00     0.00     0.00                   DEF  DEF

      VI.--WATER DATA
         UNIT WEIGHT          = 62.40 (PCF)
         RIGHTSIDE ELEVATION = 809.00 (FT)
         LEFTSIDE ELEVATION  = 809.00 (FT)
         NO SEEPAGE
```

```
     VII.--VERTICAL SURCHARGE LOADS

         VII.A.--VERTICAL LINE LOADS
              NONE

         VII.B.--VERTICAL UNIFORM LOADS
                   NONE

         VII.C.--VERTICAL STRIP LOADS

              VII.C.1.--RIGHTSIDE
              <-DIST. FROM WALL->
                START       END      STRIP LOAD
                 (FT)       (FT)        (PSF)
                 0.00      20.00       100.00

              VII.C.2.--LEFTSIDE
                   NONE

         VII.D.--VERTICAL RAMP LOADS
              NONE

         VII.E.--VERTICAL TRIANGULAR LOADS
              NONE

         VII.F.--VERTICAL VARIABLE LOADS
              NONE

    VIII.--HORIZONTAL LOADS
         NONE
```

```
 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
 DATE: 20-JANUARY-2011                                         TIME: 13:50:29

                           **************************
                           *    SOIL PRESSURES FOR   *
                           * CANTILEVER WALL DESIGN *
                           **************************

     I.--HEADING
      'COON RAPIDS DAM
      'DOWNSTEAM COFFERDAM ANALYSIS
      'ANOKA SIDE - ALLUVIAL SAND
      'OUTER SHEET PILE - LOW TAILWATER - EL. 809  - NO STRUT CHECK

    II.--SOIL PRESSURES

         RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

         LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                    <------NET------>
```

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	(SOIL + WATER) ACTIVE (PSF)	PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)
815.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
814.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
813.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
812.0	0.0	0.0	0.0	74.9	477.3	74.9	477.3
811.0	0.0	0.0	0.0	116.6	742.5	116.6	742.5
810.0	0.0	0.0	0.0	158.2	1007.7	158.2	1007.7
809.0	0.0	0.0	0.0	194.6	1239.8	194.6	1239.8
808.0	0.0	0.0	0.0	220.7	1405.7	220.7	1405.7
807.0	0.0	0.0	0.0	241.5	1538.5	241.5	1538.5
806.0	0.0	0.0	0.0	262.4	1671.3	262.4	1671.3
805.0	0.0	0.0	0.0	283.2	1804.1	283.2	1804.1
804.0	0.0	0.0	0.0	304.1	1936.9	304.1	1936.9
803.0	0.0	98.5	18.9	226.5	2050.8	324.9	2069.7
802.0	0.0	196.9	37.8	148.9	2164.7	345.8	2202.5
801.0	0.0	295.4	56.7	71.3	2224.1	366.6	2280.8
800.1	0.0	385.8	74.0	0.0	2245.9	385.8	2319.9
800.0	0.0	393.8	75.6	-6.3	2247.8	387.5	2323.4
799.0	0.0	492.3	94.4	-84.0	2317.5	408.3	2412.0
798.0	0.0	590.7	113.3	-161.6	2423.3	429.2	2536.6
797.0	0.0	689.2	132.2	-239.2	2538.0	450.0	2670.2
796.0	0.0	787.7	151.1	-316.8	2652.7	470.9	2803.8
795.0	0.0	886.1	170.0	-394.4	2767.4	491.7	2937.4
794.0	0.0	984.6	188.9	-472.0	2882.2	512.6	3071.0
793.0	0.0	1083.0	207.8	-549.6	2994.5	533.4	3202.3
792.0	0.0	1181.5	226.7	-627.2	3100.7	554.3	3327.4
791.0	0.0	1280.0	245.5	-704.8	3208.9	575.1	3454.5
790.0	0.0	1378.4	264.4	-782.4	3323.0	596.0	3587.4
789.0	0.0	1476.9	283.3	-860.0	3437.0	616.8	3720.3
788.0	0.0	1575.3	302.2	-937.7	3551.0	637.7	3853.3
787.0	0.0	1673.8	321.1	-1015.3	3665.1	658.5	3986.2
786.0	0.0	1772.2	340.0	-1092.9	3779.1	679.4	4119.1
785.0	0.0	1870.7	358.9	-1170.5	3893.2	700.2	4252.0
784.0	0.0	1969.2	377.8	-1248.1	4007.2	721.1	4385.0
783.0	0.0	2067.6	396.7	-1325.7	4121.2	741.9	4517.9
782.0	0.0	2166.1	415.5	-1403.3	4235.3	762.8	4650.8
781.0	0.0	2264.5	434.4	-1480.9	4349.3	783.6	4783.8
780.0	0.0	2363.0	453.3	-1558.5	4463.4	804.5	4916.7
779.0	0.0	2461.5	472.2	-1636.1	4577.4	825.3	5049.6
778.0	0.0	2559.9	491.1	-1713.7	4691.4	846.2	5182.5
777.0	0.0	2658.4	510.0	-1806.6	4805.5	851.7	5315.5
776.0	0.0	2756.8	528.9	-1900.9	4919.5	855.9	5448.4
775.0	0.0	2855.3	547.8	-1979.9	5033.6	875.4	5581.3
774.0	0.0	2953.7	566.7	-2057.5	5147.6	896.3	5714.3
773.0	0.0	3052.2	585.5	-2135.1	5261.6	917.1	5847.2
772.0	0.0	3150.7	604.4	-2212.7	5375.7	938.0	5980.1
771.0	0.0	3255.7	623.3	-2296.9	5489.7	958.8	6113.0
770.0	0.0	3384.2	642.2	-2404.6	5603.8	979.7	6246.0

```
****************************
*   SUMMARY OF RESULTS FOR  *
*   CANTILEVER WALL DESIGN  *
****************************

  I.--HEADING
   'COON RAPIDS DAM
   'DOWNSTEAM COFFERDAM ANALYSIS
   'ANOKA SIDE - ALLUVIAL SAND
   'OUTER SHEET PILE - LOW TAILWATER - EL. 809  - NO STRUT CHECK

 II.--SUMMARY

      RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

      LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

 WALL BOTTOM ELEV. (FT)     :      783.19
       PENETRATION (FT)     :       20.81

 MAX. BEND. MOMENT (LB-FT)  :  2.5842E+04
       AT ELEVATION (FT)    :      792.38

 MAX. SCALED DEFL. (LB-IN^3):  1.2990E+10
       AT ELEVATION (FT)    :      815.00

            NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                   ELLASTICITY IN PSI TIMES PILE MOMENT
                   OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                   IN INCHES.


PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 20-JANUARY-2011                                        TIME: 13:50:31

****************************
* COMPLETE OF RESULTS FOR   *
*   CANTILEVER WALL DESIGN  *
****************************

   I.--HEADING
   'COON RAPIDS DAM
   'DOWNSTEAM COFFERDAM ANALYSIS
   'ANOKA SIDE - ALLUVIAL SAND
   'OUTER SHEET PILE - LOW TAILWATER - EL. 809  - NO STRUT CHECK

  II.--RESULTS
```

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
815.00	0.0000E+00	0.	1.2990E+10	0.00
814.00	2.0955E-09	0.	1.2365E+10	0.00
813.00	2.0955E-09	0.	1.1739E+10	0.00
812.00	1.2490E+01	37.	1.1114E+10	74.94
811.00	9.4368E+01	133.	1.0488E+10	116.57
810.00	2.9282E+02	271.	9.8630E+09	158.20
809.00	6.4861E+02	447.	9.2383E+09	194.64

808.00	1.1973E+03	655.	8.6148E+09	220.69
807.00	1.9658E+03	886.	7.9933E+09	241.54
806.00	2.9759E+03	1138.	7.3753E+09	262.39
805.00	4.2483E+03	1411.	6.7625E+09	283.24
804.00	5.8040E+03	1704.	6.1570E+09	304.09
803.00	7.6474E+03	1970.	5.5616E+09	226.48
802.00	9.7172E+03	2157.	4.9795E+09	148.87
801.00	1.1936E+04	2267.	4.4142E+09	71.26
800.08	1.4038E+04	2300.	3.9132E+09	0.00
800.00	1.4226E+04	2300.	3.8695E+09	-6.35
799.00	1.6509E+04	2255.	3.3494E+09	-83.96
798.00	1.8709E+04	2132.	2.8578E+09	-161.57
797.00	2.0747E+04	1931.	2.3985E+09	-239.17
796.00	2.2546E+04	1653.	1.9750E+09	-316.78
795.00	2.4028E+04	1298.	1.5905E+09	-394.39
794.00	2.5116E+04	865.	1.2474E+09	-472.00
793.00	2.5732E+04	354.	9.4760E+08	-549.61
792.00	2.5798E+04	-235.	6.9223E+08	-627.22
791.00	2.5237E+04	-901.	4.8134E+08	-704.83
790.00	2.3971E+04	-1644.	3.1397E+08	-782.43
789.00	2.1923E+04	-2465.	1.8790E+08	-860.04
788.00	1.9014E+04	-3364.	9.9589E+07	-937.65
787.00	1.5168E+04	-4341.	4.4000E+07	-1015.26
786.43	1.2526E+04	-4932.	2.4472E+07	-1059.51
786.00	1.0329E+04	-5241.	1.4477E+07	-375.85
785.00	5.1654E+03	-4821.	2.7488E+06	1214.53
784.00	1.2164E+03	-2812.	1.2164E+05	2804.91
783.19	0.0000E+00	0.	0.0000E+00	4100.07

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF
ELLASTICITY IN PSI TIMES PILE MOMENT
OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
815.00	0.	0.	0.	0.	0.
814.00	0.	0.	0.	0.	0.
813.00	0.	0.	0.	0.	0.
812.00	0.	0.	0.	75.	477.
811.00	0.	0.	0.	117.	743.
810.00	0.	0.	0.	158.	1008.
809.00	0.	0.	0.	195.	1240.
808.00	0.	0.	0.	221.	1406.
807.00	0.	0.	0.	242.	1538.
806.00	0.	0.	0.	262.	1671.
805.00	0.	0.	0.	283.	1804.
804.00	0.	0.	0.	304.	1937.
803.00	0.	98.	19.	325.	2070.
802.00	0.	197.	38.	346.	2202.
801.00	0.	295.	57.	367.	2281.
800.08	0.	386.	74.	386.	2320.
800.00	0.	394.	76.	387.	2323.
799.00	0.	492.	94.	408.	2412.
798.00	0.	591.	113.	429.	2537.
797.00	0.	689.	132.	450.	2670.
796.00	0.	788.	151.	471.	2804.
795.00	0.	886.	170.	492.	2937.
794.00	0.	985.	189.	513.	3071.

793.00	0.	1083.	208.	533.	3202.
792.00	0.	1181.	227.	554.	3327.
791.00	0.	1280.	246.	575.	3454.
790.00	0.	1378.	264.	596.	3587.
789.00	0.	1477.	283.	617.	3720.
788.00	0.	1575.	302.	638.	3853.
787.00	0.	1674.	321.	659.	3986.
786.43	0.	1730.	332.	670.	4062.
786.00	0.	1772.	340.	679.	4119.
785.00	0.	1871.	359.	700.	4252.
784.00	0.	1969.	378.	721.	4385.
783.19	0.	2068.	397.	742.	4518.
782.00	0.	2166.	416.	763.	4651.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 10

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $\quad kpf := \frac{k}{ft}$ $\quad ksf := \frac{k}{ft^2}$ $\quad ksi := \frac{k}{in^2}$ $\quad kcf := \frac{k}{ft^3}$ $\quad ppf := \frac{lbf}{ft}$ $\quad psf := \frac{lbf}{ft^2}$ $\quad psi := \frac{lbf}{in^2}$ $\quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\quad \gamma_{water} := 62.4 \cdot pcf$ $\quad \gamma_{conc} := 150 \cdot pcf$ $\quad f_c := 4 \cdot ksi$ $\quad f_y := 60 \cdot ksi$ $\quad F_y := 50 \cdot ksi$ $\quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $\quad cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $\quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam outer sheet on the Anoka side of Coon Rapids Dam. NO ANCHOR CHECK.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 2.58 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.30\ 10^{10} lbf \cdot in^3$

Required Penetration: 20.81 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3$ $\quad I_{PZ} := 184.20 in^4$ $\quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\quad \sigma_b = 10.252 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $\quad f_b = 25 \cdot ksi$ $\quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\quad \delta_{PZ\_35} = 2.434 \cdot in$ Excessive deflection without struts.

Conclusion

A PZ 27 (or equivalent) is adequate with struts.

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 10

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf$ $kpf := \frac{k}{ft}$ $ksf := \frac{k}{ft^2}$ $ksi := \frac{k}{in^2}$ $kcf := \frac{k}{ft^3}$ $ppf := \frac{lbf}{ft}$ $psf := \frac{lbf}{ft^2}$ $psi := \frac{lbf}{in^2}$ $pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\gamma_{water} := 62.4 \cdot pcf$ $\gamma_{conc} := 150 \cdot pcf$ $f_c := 4 \cdot ksi$ $f_y := 60 \cdot ksi$ $F_y := 50 \cdot ksi$ $E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam outer sheet on the Anoka side of Coon Rapids Dam. NO ANCHOR CHECK.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 22 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 2.58 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.30\, 10^{10} lbf \cdot in^3$

Required Penetration: 20.81 ft

Section Design

Using a PZ 22

$S_{PZ} := 18.1 in^3$ $I_{PZ} := 84.38 in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 17.105 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $f_b = 25 \cdot ksi$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_35} = 5.313 \cdot in$ Excessive deflection without struts.

Conclusion

A PZ 22 (or equivalent) is adequate with struts.

Stanley Consultants INC

Project No. 23082 Page No.

Subject CRD

CWALSHT Cofferdam analysis

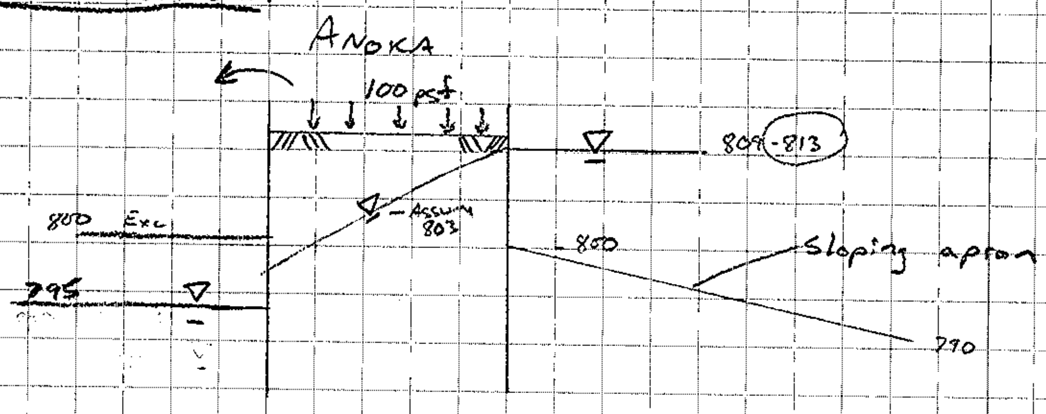
Computed by JRJ Date 2-1-11

Checked by [signature] Date 2·10·11

Approved by Date

Sheet No. of

Downstream Cofferdam

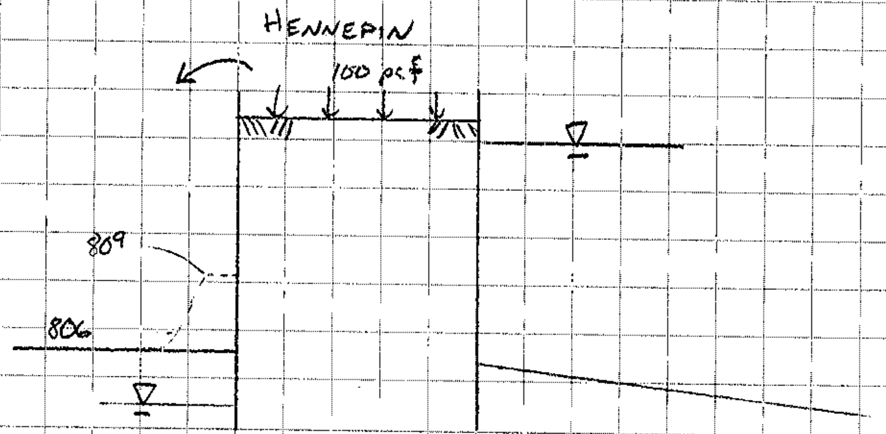


f_b = 0.56 Fy for PZ 27

δ = 10"

Pile Length = 25'

→ struts to reduce δ
-not req'd for stability



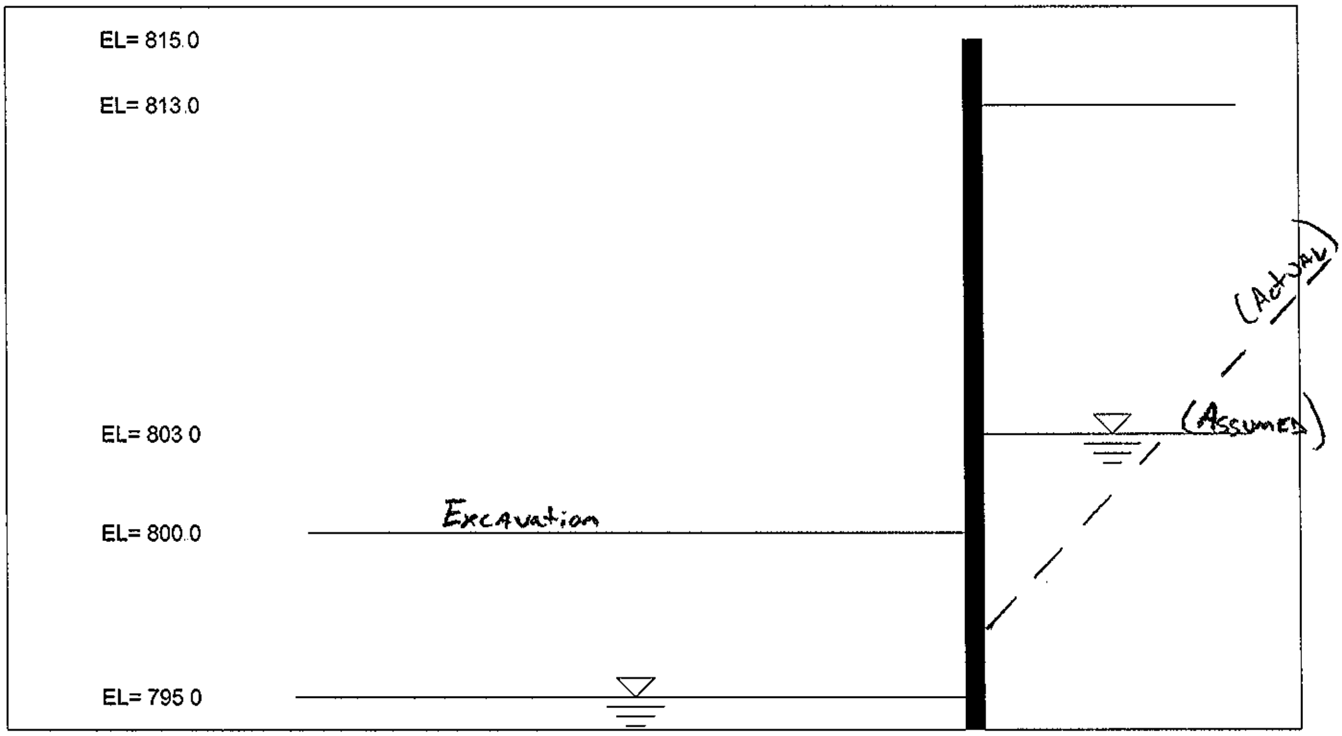
* Anoka side is worst-case (6' deeper Excavation)

SC 3004 R4 898

Anoka SIDE
Interior sheet

'COON RAPIDS DAM

'DOWNSTEAM COFFERDAM ANALYSIS



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'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'INNER SHEET PILE - HIGH TAILWATER - EL. 813  - NO STRUT CHECK
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   815
SURFACE RIGHTSIDE   2    0    813
                  20    813
SURFACE LEFTSIDE   2    0    800
                  50    800
SOIL RIGHTSIDE  STRENGTHS   1
   125    125    30    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   125    125    30    0    0    0
WATER ELEVATIONS   62.4    803    795
VERTICAL STRIP  RIGHTSIDE   1    0    20    100
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
DATE: 1-FEBRUARY-2011                                           TIME: 8:09:25

                            ****************
                            *  INPUT DATA  *
                            ****************

      I.--HEADING
     'COON RAPIDS DAM
     'DOWNSTEAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'INNER SHEET PILE - HIGH TAILWATER - EL. 813  - NO STRUT CHECK

     II.--CONTROL
        CANTILEVER WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

    III.--WALL DATA
        ELEVATION AT TOP OF WALL    = 815.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)         (FT)
                  0.00        813.00
                 20.00        813.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)         (FT)
                  0.00        800.00
                 50.00        800.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

               ANGLE OF          ANGLE OF                           <-SAFETY->
 SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->  <-FACTOR->
WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION    ELEV.  SLOPE  ACT. PASS.
(PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)    (FT)  (FT/FT)
125.00  125.00   30.00    0.00     0.00    0.00                   DEF   DEF

         V.B.--LEFTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

               ANGLE OF          ANGLE OF                           <-SAFETY->
 SAT.   MOIST  INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->  <-FACTOR->
WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION    ELEV.  SLOPE  ACT. PASS.
(PCF)   (PCF)    (DEG)   (PSF)    (DEG)   (PSF)    (FT)  (FT/FT)
125.00  125.00   30.00    0.00     0.00    0.00                   DEF   DEF

     VI.--WATER DATA
        UNIT WEIGHT          = 62.40 (PCF)
        RIGHTSIDE ELEVATION = 803.00 (FT)
        LEFTSIDE ELEVATION  = 795.00 (FT)
        NO SEEPAGE

    VII.--VERTICAL SURCHARGE LOADS

        VII.A.--VERTICAL LINE LOADS
             NONE

        VII.B.--VERTICAL UNIFORM LOADS
                  NONE

        VII.C.--VERTICAL STRIP LOADS

             VII.C.1.--RIGHTSIDE
             <-DIST. FROM WALL->
               START       END      STRIP LOAD
                (FT)       (FT)        (PSF)
                0.00      20.00       100.00
```

VII.C.2.--LEFTSIDE
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 1-FEBRUARY-2011 TIME: 8:09:29

****
* SOIL PRESSURES FOR *
* CANTILEVER WALL DESIGN *
****

I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'INNER SHEET PILE - HIGH TAILWATER - EL. 813 - NO STRUT CHECK

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

				<------NET------>			
	NET	<---LEFTSIDE--->		(SOIL + WATER)		<--RIGHTSIDE--->	
ELEV.	WATER	PASSIVE	ACTIVE	ACTIVE	PASSIVE	ACTIVE	PASSIVE
(FT)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)	(PSF)
815.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
814.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
813.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
812.0	0.0	0.0	0.0	74.9	477.3	74.9	477.3
811.0	0.0	0.0	0.0	116.6	742.5	116.6	742.5
810.0	0.0	0.0	0.0	158.2	1007.7	158.2	1007.7
809.0	0.0	0.0	0.0	199.8	1272.9	199.8	1272.9
808.0	0.0	0.0	0.0	241.5	1538.0	241.5	1538.0
807.0	0.0	0.0	0.0	283.1	1803.2	283.1	1803.2
806.0	0.0	0.0	0.0	324.7	2068.4	324.7	2068.4
805.0	0.0	0.0	0.0	366.4	2333.6	366.4	2333.6
804.0	0.0	0.0	0.0	408.0	2598.8	408.0	2598.8
803.0	0.0	0.0	0.0	444.4	2830.9	444.4	2830.9
802.0	62.4	0.0	0.0	532.9	3059.2	470.5	2996.8
801.0	124.8	0.0	0.0	616.1	3223.1	491.3	3098.3
800.0	187.2	0.0	0.0	699.4	3321.5	512.2	3134.3
799.0	249.6	265.2	41.6	517.5	3410.0	533.0	3202.1
798.0	312.0	530.4	83.3	335.5	3564.4	553.9	3335.7
797.0	374.4	795.5	124.9	153.6	3718.8	574.7	3469.3
796.2	427.1	1019.4	160.0	0.0	3848.4	592.3	3581.4
796.0	436.8	1060.7	166.5	-28.3	3872.4	595.6	3602.1
795.0	499.2	1292.8	203.0	-177.2	4022.4	616.4	3726.2
794.0	499.2	1458.7	229.0	-322.2	4120.9	637.3	3850.7
793.0	499.2	1591.5	249.9	-434.2	4233.0	658.1	3983.6
792.0	499.2	1724.3	270.7	-546.1	4345.0	679.0	4116.6
791.0	499.2	1857.1	291.6	-658.1	4457.1	699.8	4249.5
790.0	499.2	1989.9	312.4	-770.0	4569.2	720.7	4382.4
789.0	499.2	2122.7	333.3	-882.0	4681.3	741.5	4515.3
788.0	499.2	2255.5	354.1	-993.9	4793.4	762.4	4648.3

787.0	499.2	2388.3	375.0	-1105.9	4905.4	783.2	4781.2
786.0	499.2	2521.1	395.8	-1217.8	5017.5	804.1	4914.1
785.0	499.2	2653.9	416.7	-1329.8	5129.6	824.9	5047.1
784.0	499.2	2786.7	437.5	-1441.8	5241.7	845.8	5180.0
783.0	499.2	2919.5	458.4	-1553.7	5353.8	866.6	5312.9
782.0	499.2	3052.3	479.2	-1665.7	5465.8	887.5	5445.9
781.0	499.2	3185.1	500.1	-1777.6	5577.9	908.3	5578.8
780.0	499.2	3317.9	520.9	-1889.6	5690.0	929.2	5711.7
779.0	499.2	3450.7	541.8	-2001.5	5802.1	950.0	5844.6
778.0	499.2	3583.5	562.6	-2113.5	5914.2	970.9	5977.6
777.0	499.2	3716.3	583.5	-2240.7	6026.2	976.4	6110.5
776.0	499.2	3849.2	604.3	-2369.3	6138.3	980.6	6243.4
775.0	499.2	3982.0	625.2	-2482.6	6250.4	1000.1	6376.4
774.0	499.2	4114.8	646.0	-2594.6	6362.5	1021.0	6509.3
773.0	499.2	4247.6	666.9	-2706.5	6474.6	1041.8	6642.2
772.0	499.2	4380.4	687.7	-2818.5	6586.6	1062.7	6775.1
771.0	499.2	4513.2	708.6	-2930.4	6698.7	1083.5	6908.1
770.0	499.2	4646.0	729.4	-3042.4	6810.8	1104.4	7041.0
769.0	499.2	4778.8	750.3	-3154.3	6922.9	1125.2	7173.9
768.0	499.2	4911.6	771.1	-3266.3	7035.0	1146.1	7306.9
767.0	499.2	5044.4	792.0	-3378.3	7147.0	1166.9	7439.8
766.0	499.2	5177.2	812.8	-3490.2	7259.1	1187.8	7572.7
765.0	499.2	5310.0	833.7	-3602.2	7371.2	1208.6	7705.7
764.0	499.2	5442.8	854.5	-3714.1	7482.0	1229.5	7837.3
763.0	499.2	5575.6	875.4	-3826.1	7590.3	1250.3	7966.4
762.0	499.2	5708.4	896.2	-3938.0	7699.7	1271.2	8096.7
761.0	499.2	5841.2	917.1	-4050.0	7811.7	1292.0	8229.5
760.0	499.2	5974.0	937.9	-4161.9	7923.6	1312.9	8362.3
759.0	499.2	6106.8	958.8	-4273.9	8035.6	1333.7	8495.1
758.0	499.2	6239.6	979.6	-4385.8	8147.5	1354.6	8627.9
757.0	499.2	6372.4	1000.5	-4497.8	8259.5	1375.4	8760.7
756.0	499.2	6505.2	1021.3	-4609.7	8371.4	1396.3	8893.5
755.0	499.2	6638.0	1042.2	-4721.7	8483.4	1417.1	9026.3
754.0	499.2	6770.8	1063.0	-4833.6	8595.3	1438.0	9159.1

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 1-FEBRUARY-2011                                            TIME: 8:09:29

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************

    I.--HEADING
     'COON RAPIDS DAM
     'DOWNSTEAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'INNER SHEET PILE - HIGH TAILWATER - EL. 813  - NO STRUT CHECK

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      775.42
         PENETRATION (FT)     :       24.58

   MAX. BEND. MOMENT (LB-FT)  :  7.0255E+04
         AT ELEVATION (FT)    :      786.90

   MAX. SCALED DEFL. (LB-IN^3):  5.3135E+10
         AT ELEVATION (FT)    :      815.00

             NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                    ELLASTICITY IN PSI TIMES PILE MOMENT
                    OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                    IN INCHES.
```

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 1-FEBRUARY-2011 TIME: 8:09:29

****
* COMPLETE OF RESULTS FOR *
* CANTILEVER WALL DESIGN *
****

I.--HEADING
'COON RAPIDS DAM
'DOWNSTEAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'INNER SHEET PILE - HIGH TAILWATER - EL. 813 - NO STRUT CHECK

II.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
815.00	0.0000E+00	0.	5.3135E+10	0.00
814.00	8.3819E-09	0.	5.1091E+10	0.00
813.00	8.3819E-09	0.	4.9047E+10	0.00
812.00	1.2490E+01	37.	4.7003E+10	74.94
811.00	9.4368E+01	133.	4.4959E+10	116.57
810.00	2.9282E+02	271.	4.2915E+10	158.20
809.00	6.4947E+02	450.	4.0871E+10	199.84
808.00	1.2060E+03	670.	3.8829E+10	241.47
807.00	2.0039E+03	933.	3.6789E+10	283.10
806.00	3.0850E+03	1236.	3.4753E+10	324.74
805.00	4.4908E+03	1582.	3.2721E+10	366.37
804.00	6.2630E+03	1969.	3.0698E+10	408.00
803.00	8.4423E+03	2395.	2.8685E+10	444.44
802.00	1.1075E+04	2884.	2.6687E+10	532.88
801.00	1.4239E+04	3459.	2.4709E+10	616.13
800.00	1.8020E+04	4116.	2.2755E+10	699.38
799.00	2.2455E+04	4725.	2.0832E+10	517.45
798.00	2.7409E+04	5151.	1.8948E+10	335.52
797.00	3.2697E+04	5396.	1.7112E+10	153.59
796.16	3.7289E+04	5461.	1.5605E+10	0.00
796.00	3.8140E+04	5458.	1.5332E+10	-28.34
795.00	4.3559E+04	5356.	1.3618E+10	-177.18
794.00	4.8802E+04	5106.	1.1979E+10	-322.22
793.00	5.3728E+04	4728.	1.0424E+10	-434.18
792.00	5.8220E+04	4238.	8.9627E+09	-546.13
791.00	6.2166E+04	3636.	7.6016E+09	-658.08
790.00	6.5454E+04	2921.	6.3477E+09	-770.03
789.00	6.7972E+04	2095.	5.2068E+09	-881.99
788.00	6.9608E+04	1158.	4.1833E+09	-993.94
787.00	7.0250E+04	108.	3.2799E+09	-1105.89
786.00	6.9786E+04	-1054.	2.4977E+09	-1217.85
785.00	6.8104E+04	-2328.	1.8359E+09	-1329.80
784.00	6.5092E+04	-3714.	1.2917E+09	-1441.75
783.00	6.0639E+04	-5212.	8.5967E+08	-1553.70
782.00	5.4632E+04	-6821.	5.3224E+08	-1665.66
781.00	4.6959E+04	-8543.	2.9896E+08	-1777.61
780.12	3.8697E+04	-10158.	1.6058E+08	-1876.60
780.00	3.7509E+04	-10364.	1.4658E+08	-1677.39
779.00	2.6593E+04	-11181.	5.8790E+07	43.31
778.00	1.5720E+04	-10278.	1.6955E+07	1764.02
777.00	6.6113E+03	-7653.	2.5390E+06	3484.72
776.00	9.8722E+02	-3308.	4.8894E+04	5205.43
775.42	0.0000E+00	0.	0.0000E+00	6203.32

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF
ELLASTICITY IN PSI TIMES PILE MOMENT
OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
		<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	WATER PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)

815.00	0.	0.	0.	0.	0.
814.00	0.	0.	0.	0.	0.
813.00	0.	0.	0.	0.	0.
812.00	0.	0.	0.	75.	477.
811.00	0.	0.	0.	117.	743.
810.00	0.	0.	0.	158.	1008.
809.00	0.	0.	0.	200.	1273.
808.00	0.	0.	0.	241.	1538.
807.00	0.	0.	0.	283.	1803.
806.00	0.	0.	0.	325.	2068.
805.00	0.	0.	0.	366.	2334.
804.00	0.	0.	0.	408.	2599.
803.00	0.	0.	0.	444.	2831.
802.00	62.	0.	0.	470.	2997.
801.00	125.	0.	0.	491.	3098.
800.00	187.	0.	0.	512.	3134.
799.00	250.	265.	42.	533.	3202.
798.00	312.	530.	83.	554.	3336.
797.00	374.	796.	125.	575.	3469.
796.16	427.	1019.	160.	592.	3581.
796.00	437.	1061.	167.	596.	3602.
795.00	499.	1293.	203.	616.	3726.
794.00	499.	1459.	229.	637.	3851.
793.00	499.	1592.	250.	658.	3984.
792.00	499.	1724.	271.	679.	4117.
791.00	499.	1857.	292.	700.	4249.
790.00	499.	1990.	312.	721.	4382.
789.00	499.	2123.	333.	742.	4515.
788.00	499.	2256.	354.	762.	4648.
787.00	499.	2388.	375.	783.	4781.
786.00	499.	2521.	396.	804.	4914.
785.00	499.	2654.	417.	825.	5047.
784.00	499.	2787.	438.	846.	5180.
783.00	499.	2920.	458.	867.	5313.
782.00	499.	3052.	479.	887.	5446.
781.00	499.	3185.	500.	908.	5579.
780.12	499.	3303.	518.	927.	5696.
780.00	499.	3318.	521.	929.	5712.
779.00	499.	3451.	542.	950.	5845.
778.00	499.	3584.	563.	971.	5978.
777.00	499.	3716.	583.	976.	6110.
776.00	499.	3849.	604.	981.	6243.
775.42	499.	3982.	625.	1000.	6376.
774.00	499.	4115.	646.	1021.	6509.

Sheet Pile Cofferdam Structural Analysis

Miscellaneous Computations

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 11

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the downstream sheetpile cofferdam outer sheet on the Anoka side of Coon Rapids Dam. NO ANCHOR CHECK.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 7.03 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 5.31\, 10^{10} lbf \cdot in^3$

Required Penetration: 24.58 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3 \quad I_{PZ} := 184.20 in^4 \quad E = 29000 \cdot ksi$

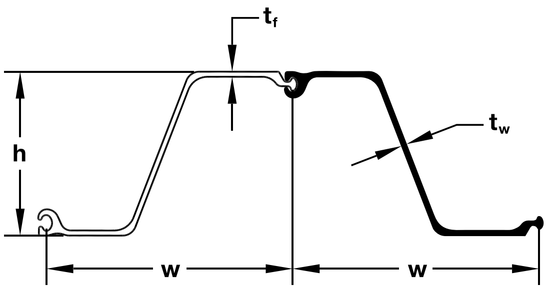
Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 27.934 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi$ $\quad f_b < \sigma_b \quad \sigma_b = 0.56Fy$ ===> OK.

Deflection: $\delta_{PZ\_35} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_35} = 9.94 \cdot in$ Excessive deflection without struts, but not req'd for strength.

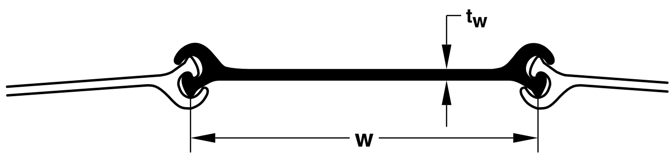
Conclusion

A PZ 27 (or equivalent) is adequate with struts.



PZ

SECTION	Width (w) in (mm)	Height (h) in (mm)	THICKNESS Flange (t_f) in (mm)	THICKNESS Wall (t_w) in (mm)	Cross Sectional Area in²/ft (cm²/m)	WEIGHT Pile lb/ft (kg/m)	WEIGHT Wall lb/ft² (kg/m²)	SECTION MODULUS Elastic in³/ft (cm³/m)	SECTION MODULUS Plastic in³/ft (cm³/m)	Moment of Inertia in⁴/ft (cm⁴/m)	COATING AREA Both Sides ft²/ft of single (m²/m)	COATING AREA Wall Surface ft²/ft² of wall (m²/m²)
PZ 22	22.0 (559)	9.0 (229)	0.375 (9.50)	0.375 (9.50)	6.47 (136.9)	40.3 (60.0)	22.0 (107.4)	18.1 (973)	21.79 (1171.4)	84.38 (11500)	4.48 (1.37)	1.22 (1.22)
PZ 27	18.0 (457)	12.0 (305)	0.375 (9.50)	0.375 (9.50)	7.94 (168.1)	40.5 (60.3)	27.0 (131.8)	30.2 (1620)	36.49 (1961.9)	184.20 (25200)	4.48 (1.37)	1.49 (1.49)
PZ 35	22.6 (575)	14.9 (378)	0.600 (15.21)	0.500 (12.67)	10.29 (217.8)	66.0 (98.2)	35.0 (170.9)	48.5 (2608)	57.17 (3073.5)	361.22 (49300)	5.37 (1.64)	1.42 (1.42)
PZ 40	19.7 (500)	16.1 (409)	0.600 (15.21)	0.500 (12.67)	11.77 (249.1)	65.6 (97.6)	40.0 (195.3)	60.7 (3263)	71.92 (3866.7)	490.85 (67000)	5.37 (1.64)	1.64 (1.64)



PS

SECTION	Width (w) in (mm)	Web (t_w) in (mm)	Maximum Interlock Strength k/in (kN/m)	Minimum Cell Diameter* ft (m)	Cross Sectional Area in²/ft (cm²/m)	WEIGHT Pile lb/ft (kg/m)	WEIGHT Wall lb/ft² (kg/m²)	Elastic Section Modulus in³/sheet (cm³/sheet)	Moment of Inertia in⁴/sheet (cm⁴/sheet)	COATING AREA Both Sides ft²/ft of single (m²/m)	COATING AREA Wall Surface ft²/ft² of wall (m²/m²)
PS 27.5	19.69 (500)	0.4 (10.2)	24 (4800)	30 (9.14)	8.09 (171.2)	45.1 (67.1)	27.5 (134.3)	3.3 (54)	5.3 (221)	3.65 (1.11)	1.11 (1.11)
PS 31	19.69 (500)	0.5 (12.7)	24 (4800)	30 (9.14)	9.12 (193.0)	50.9 (75.7)	31.0 (151.4)	3.3 (54)	5.3 (221)	3.65 (1.11)	1.11 (1.11)

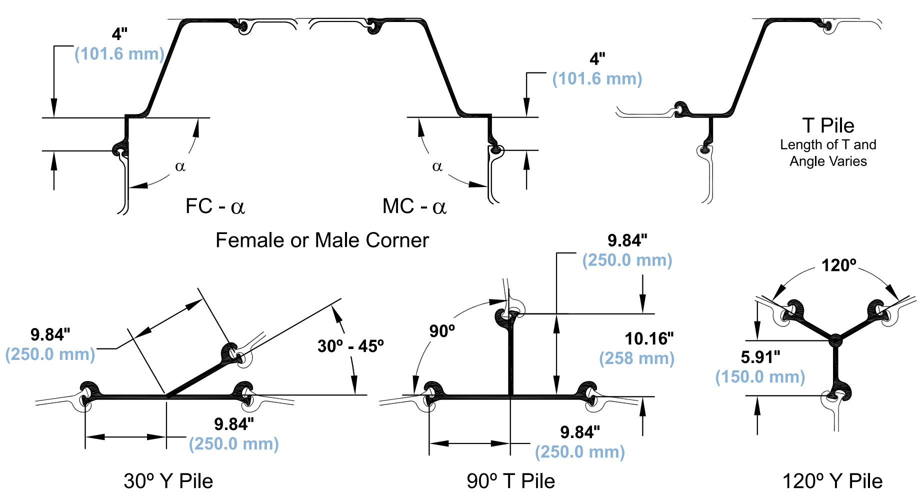
* Minimum cell diameter cannot be guaranteed for piles over 65 feet (19.81 m) in length.
* Minimum cell diameter cannot be guaranteed if piles are spliced.
* 58 Piles are needed to make a 30 foot diameter cell.

PZ/PS

PZ/PS Hot Rolled Steel Sheet Piling

Available Steel Grades								
PZ's			PS's					
ASTM	YIELD STRENGTH		ASTM	YIELD STRENGTH		INTERLOCK STRENGTH		
	(ksi)	(MPa)		(ksi)	(MPa)	(k/in)	(kN/m)	
A 328	39	270	A 328	39	270	16	2800	
A 572 Grade 50	50	345	A 572 Grade 50	50	345	20	3500	
A 572 Grade 60	60	415	A 572 Grade 60	60	415	24	4200	
A 572 Grade 65	65	450	A 572 Grade 65	65	450	24	4200	
A 588	50	345	A 588	50	345	20	3500	
A 690	50	345	A 690	50	345	20	3500	

Corner and Junction Piles



Delivery Conditions & Tolerances

	ASTM A 6	
Mass	± 2.5%	
Length	+ 5 inches	– 0 inches

Maximum Rolled Lengths*

PZ	85 feet for singles, 70 feet for pairs	(25.9 m, 21.3 m)
PS	65 feet	(19.8 m)

* Longer lengths may be possible upon request.

Stanley Consultants INC.

Computed By:	L. Karels	**Date:**	1/17/2011	**Job No.**	23082 Coon Rapids Dam
Checked By:	J. Jacks	**Date:**	1/17/2011	**Subject**	Design of Downstream Cofferdam Structure
Approved By:		**Date:**			

Sheet No. 1 of 3

Diagrams and Variables, Sliding Stability: ***Notes:***

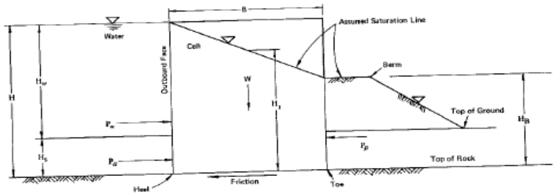


Fig. 69

Driving Forces:

Full water pressure, $P_W = \gamma_W H^2/2$, per foot of wall

Active earth pressure, $P_a = \gamma' K_a H_S^2/2$, per foot of wall

where K_a = active earth pressure coefficient
γ' = submerged unit weight of soil on the outboard side of the cofferdam
γ_W = unit weight of water = 62.4 pounds per cubic foot
H and H_S = height of cofferdam and soil, respectively
H_B = height from toe of cofferdam to top of berm

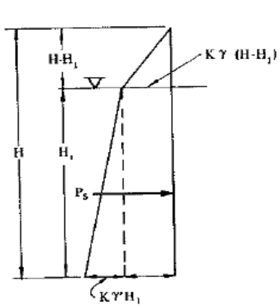
Resisting Forces:

Friction force along bottom of the cell, W tanδ';

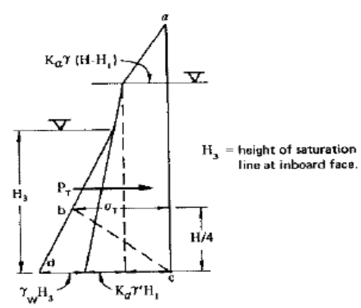
$W \tan\delta' = B[\gamma(H-H_1) + \gamma' H_1] \tan\delta'$

where W = effective weight of cell fill
B = equivalent width of cofferdam
γ = unit weight of cell fill above saturation line
H = total height of cofferdam
H_1 = average height of saturation line
γ' = submerged unit weight of cell fill
tan δ' = coefficient of friction of cell fill on rock, for smooth rock = 0.5
δ' = ϕ-angle of the soil for other types

System:			
Top El	813		
Base El	770		
B	20		
Wet Water	813	2 Yr High Tail Water	
Dry Water	795		
Wet Soil	804		
Dry Soil	795		
Soil:			
Unit Weight	125		
Friction Ang.	28	Fill	
Friction Ang.	30	Foundation	
Water:			
Unit Weight	62.5		
			Radians(45-phi/2)
Ka	0.361033		0.541052068
			Radians(45+phi/2)
Kp	2.769826		1.029744259
γ'	62.5		
H	43		
Hs	34		
Hb	25		
H1	36.33333	(assume 1.5 : 1 sat line)	
H3	29.66667		
Tan(δ')	0.57735	= tan(34)	
W	62.08333	k	
Friction	35.84383	=W*tan(δ')	
Pw(drive)	57.78125	k	
Pa	13.04233	k	
Pw(resist)	19.53125		
Pp	54.09817		
FOS	**1.545717**		



Vertical Plane On Centerline of Cofferdam
(a)



Inboard Sheeting
(b)

Notes: Computation assumes dual (braced) sheet pile cofferdam structure acts as single unit for sliding/overturning. Individual sheet-pile performance investigated using CWALSHT software.

Preliminary Dewatering Computations

Stanley Consultants INC.

Computed by LPK Date 1/17/2011
Checked by J. Jacks Date 2/9/2011
Approved by ______ Date ______

Project No. 23082 Page No. ______
Subject COON RAPIDS DAM STAGE 1 DEWATERING COMP.

Sheet No. ______ of ______

DEWATERING COMPUTATIONS (PRELIMINARY)

STAGE 1: AREA = 450' × 100'

COEFFICIENT OF PERMEABILITY (UPPER)

$K = 25 \text{ gpd/ft}^2$ (ALLUVIAL SANDS - SILTY)

RADIUS OF INFLUENCE: $R = 500$ ft

UPPER FORMATION THICKNESS (820 → 770) = 50 LF

REQUIRED DRAWDOWN (822 → 795) = 27 ft

WELL RADIUS $= \dfrac{4\sqrt{B1 \cdot B2}}{\pi}$ $B1 = 450'/2 = 225'$

$B2 = 100'/2 = 50'$

$= \dfrac{4\sqrt{225 \cdot 50}}{\pi}$

$= 135$ ft

$$Q_{REQ}(\text{GPM}) = \frac{K_1(H^2 - h_w^2)}{458 \ln(R_o/R_w)}$$

$$Q_{REQ} = \frac{25(1875)}{458 \ln\left(\frac{500}{135}\right)} = 78 \text{ gpm}$$

USE MULTIPLE DEEP WELLS (≈ 50' INTERVALS) w/ 1-1/2 HP, 1 Phase, 230 Volt well pump.

SC 3004 R4 898

Slope Stability Analysis

Earthen Cofferdam

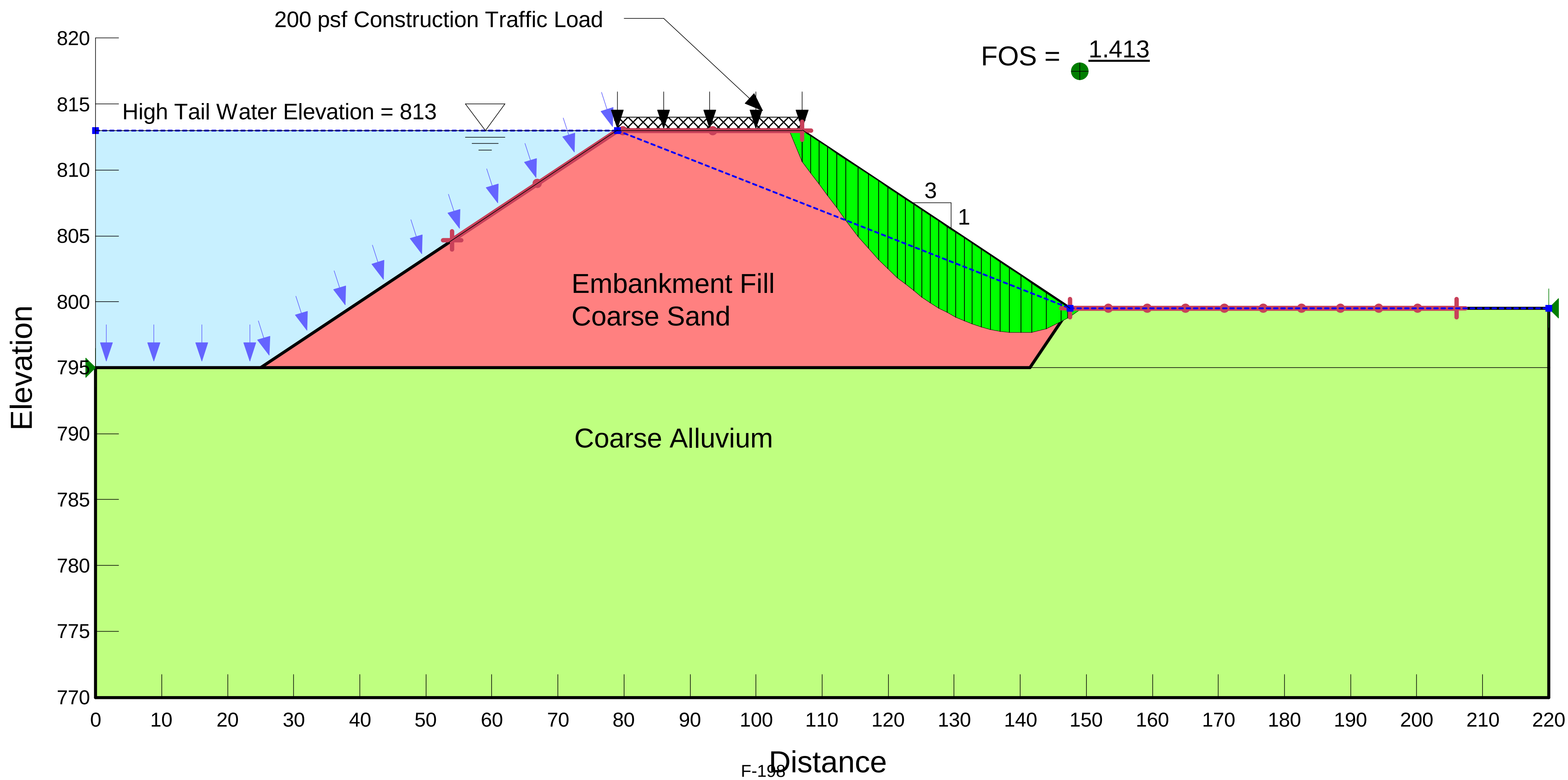
Anoka Side – Alluvial Sands

Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Earthen Cofferdam/ Causeway Stability
Tailwater to Elevation 813 (2 Construction High)

Computed By: L. Karels
Checked By: J. Jacks
File Name: Cofferdam_Slope.gsz
Date: 1/20/2011

Material Information:

Name: Coarse Alluvium   Unit Weight: 125 pcf   Cohesion: 0 psf   Phi: 37 °
Name: Embankment Fill - Coarse Sand   Unit Weight: 120 pcf   Cohesion: 0 psf   Phi: 30 °



COON RAPIDS DAM DOWNSTREAM EARTHEN COFFERDAM

File Information

Title: Coon Rapids Dam Earthen Cofferdam Design
Created By: Karels, Lucas
Revision Number: 24
Last Edited By: Karels, Lucas
Date: 1/20/2011
Time: 11:14:02 AM
File Name: Cofferdam_Slope.gsz
Directory: K:\23082\Active\06-Studies\RepairReport\Draft_Report\03_Appendicies\App_C_Computations\Geotechnical\
Last Solved Date: 1/20/2011
Last Solved Time: 11:14:07 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

795 Base

Kind: SLOPE/W
Method: Spencer
Settings
- Apply Phreatic Correction: No
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

Slip Surface
- Direction of movement: Left to Right
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1

Optimize Critical Slip Surface Location: Yes
Tension Crack
Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Coarse Alluvium

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 37 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Embankment Fill - Coarse Sand

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (54, 804.66667) ft
Left-Zone Right Coordinate: (107, 813) ft
Left-Zone Increment: 4
Right Projection: Range
Right-Zone Left Coordinate: (147.5, 799.5) ft
Right-Zone Right Coordinate: (206, 799.5) ft

Right-Zone Increment: 10
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 795) ft
Right Coordinate: (220, 799.5) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	813
	79	813
	147.5	799.5
	220	799.5

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 200 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	79	814
	107	814

Regions

	Material	Points	Area (ft²)
Region 1	Embankment Fill - Coarse Sand	1,2,3,9,4	1432.125
Region 2	Coarse Alluvium	5,1,4,6,7,8	5500
Region 3	Coarse Alluvium	9,10,6,4	339.75

Points

	X (ft)	Y (ft)
Point 1	25	795
Point 2	79	813
Point 3	107	813
Point 4	141.5	795
Point 5	0	795
Point 6	220	795
Point 7	220	770
Point 8	0	770
Point 9	147.5	799.5
Point 10	220	799.5

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.413	(140.108, 840.354)	22.66666	(105.072, 813)	(149.396, 799.5)
2	500	1.457	(140.108, 840.354)	42.946	(107, 813)	(153.35, 799.5)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	106.02495	811.8275	-259.18198	194.46591	112.27494	0
2	Optimized	106.98895	810.64755	-197.41034	356.50806	205.83003	0
3	Optimized	107.6395	810.21165	-178.20767	228.42541	131.88147	0
4	Optimized	108.91845	809.35475	-140.46805	266.61972	153.93297	0
5	Optimized	110.1974	808.4978	-102.72193	304.82054	175.98822	0
6	Optimiz	111.5302	807.59675	-62.886411	343.23836	198.16876	0

	ed						
7	Optimized	112.9168	806.6516	-20.962931	385.81614	222.75105	0
8	Optimized	114.5116	805.56455	27.257291	437.8811	237.07377	0
9	Optimized	116.19585	804.50775	72.489599	515.55204	255.80222	0
10	Optimized	117.76135	803.62305	108.44244	552.61711	256.44436	0
11	Optimized	119.2555	802.8416	138.82906	607.72766	270.71873	0
12	Optimized	120.6783	802.16335	163.65485	629.31779	268.85062	0
13	Optimized	122.01235	801.578	183.77837	671.30257	281.47223	0
14	Optimized	123.25765	801.0856	199.18409	679.81567	277.49277	0
15	Optimized	124.50295	800.5932	214.59727	688.32877	273.509	0
16	Optimized	125.75335	800.14215	227.36376	717.22526	282.82167	0
17	Optimized	127.00885	799.7325	237.4875	716.34691	276.46961	0
18	Optimized	128.29795	799.34955	245.53322	733.00799	281.44369	0
19	Optimized	129.62065	798.99325	251.49744	723.38639	272.44521	0
20	Optimized	130.8873	798.6894	254.87855	734.20131	276.73713	0
21	Optimized	132.0979	798.438	255.67924	716.34348	265.96462	0
22	Optimized	133.4021	798.206	254.11555	714.64694	265.88792	0
23	Optimized	134.79985	797.99345	250.19008	683.9788	250.44803	0
24	Optimized	136.2158	797.82825	243.08837	674.00544	248.79008	0
25	Optimiz	137.65	797.71035	232.81057	628.76644	228.60523	0

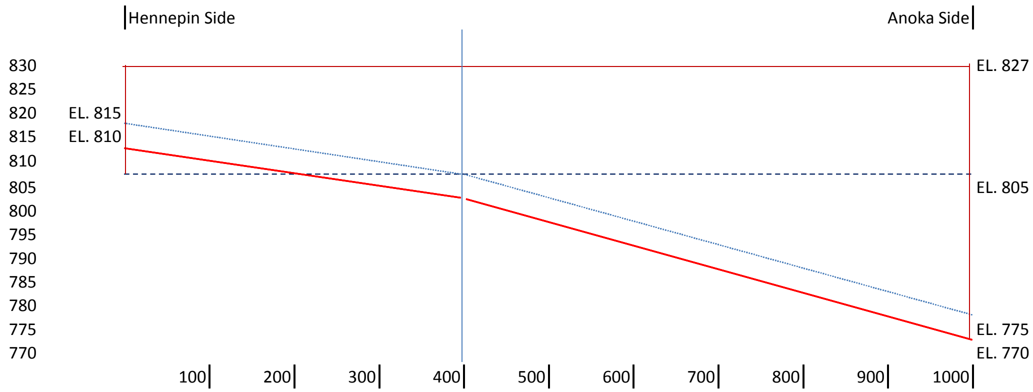
	ed						
26	Optimized	139.22015	797.65195	217.14436	600.60958	221.39374	0
27	Optimized	140.92625	797.653	196.09636	525.49675	190.1794	0
28	Optimized	142.8711	797.7899	163.63063	459.33637	170.72579	0
29	Optimized	145.07055	798.2175	109.90556	327.17586	125.44107	0
30	Optimized	146.6819	798.6411	63.657905	190.09425	95.276616	0
31	Optimized	147.3428	798.82515	44.04344	133.0518	67.072606	0
32	Optimized	148.44795	799.1884	19.442856	57.299828	28.527274	0

Slices of Slip Surface: 500

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	500	107.72715	812.16475	-301.1585	42.664798	24.632533	0
2	500	109.1814	810.57435	-219.8048	127.97185	73.884581	0
3	500	110.63565	809.1328	-147.73394	208.45261	120.35017	0
4	500	112.08995	807.82015	-83.710568	283.87397	163.89471	0
5	500	113.5442	806.6213	-26.788478	354.09498	204.43683	0
6	500	115.04195	805.49455	25.102229	423.92768	230.26198	0
7	500	116.5833	804.43565	72.22272	491.61056	242.13368	0
8	500	118.12465	803.47155	113.42807	551.28506	252.79685	0
9	500	119.66595	802.59495	149.17428	603.23555	262.1524	0
10	500	121.2073	801.7999	179.82797	647.56479	270.04798	0
11	500	122.74865	801.08145	205.70344	684.55067	276.46258	0
12	500	124.28995	800.4354	227.06628	714.26417	281.28383	0
13	500	125.83125	799.8583	244.12107	736.70144	284.39141	0
14	500	127.3726	799.34725	257.05225	751.8811	285.68957	0
15	500	128.91395	798.8998	266.01952	759.83206	285.10281	0
16	500	130.45525	798.5139	271.14405	760.45507	282.50385	0

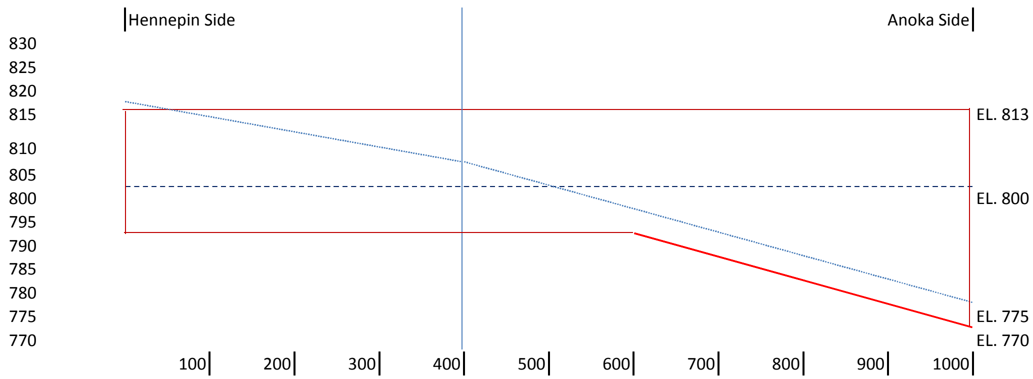
17	500	131.9966	798.18785	272.53649	753.63726	277.76366	0
18	500	133.53795	797.92025	270.27737	739.24757	270.76007	0
19	500	135.07925	797.71005	264.43807	717.00661	261.29057	0
20	500	136.62055	797.5564	255.07667	686.73991	249.22089	0
21	500	138.1619	797.4586	242.22364	648.05987	234.30966	0
22	500	139.70325	797.41635	225.89912	600.57896	216.3215	0
23	500	141.24455	797.4295	206.12659	543.81439	194.96414	0
24	500	142.78585	797.49805	182.89449	477.18335	169.90775	0
25	500	144.3272	797.6223	156.18322	399.96849	140.7495	0
26	500	145.6984	797.77725	129.65464	337.27872	156.45597	0
27	500	146.89945	797.9523	103.96499	263.38181	120.12919	0
28	500	148.23125	798.18935	81.784996	205.04998	92.886826	0
29	500	149.69375	798.4977	62.543573	161.80095	74.7958	0
30	500	151.15625	798.8599	39.944418	106.89463	50.450604	0
31	500	152.61875	799.2773	13.897574	38.585766	18.603887	0

Upstream
Cofferdam



Stage 1	25200 sf	
Stage 2	8800 sf	(If Necessary)
	34000 sf	

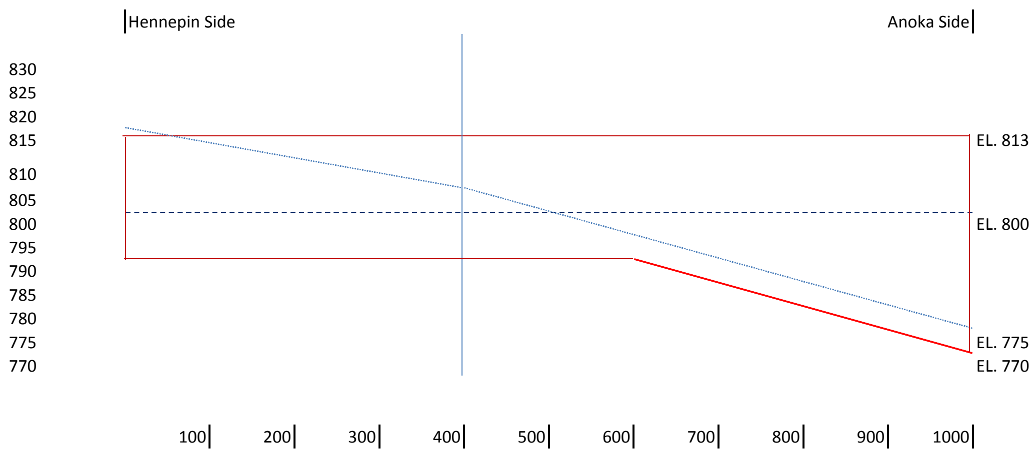
Downstream
Cofferdam



Stage 1	14200 sf	
Stage 2	13800 sf	(If Necessary)

Area = 23000 sf

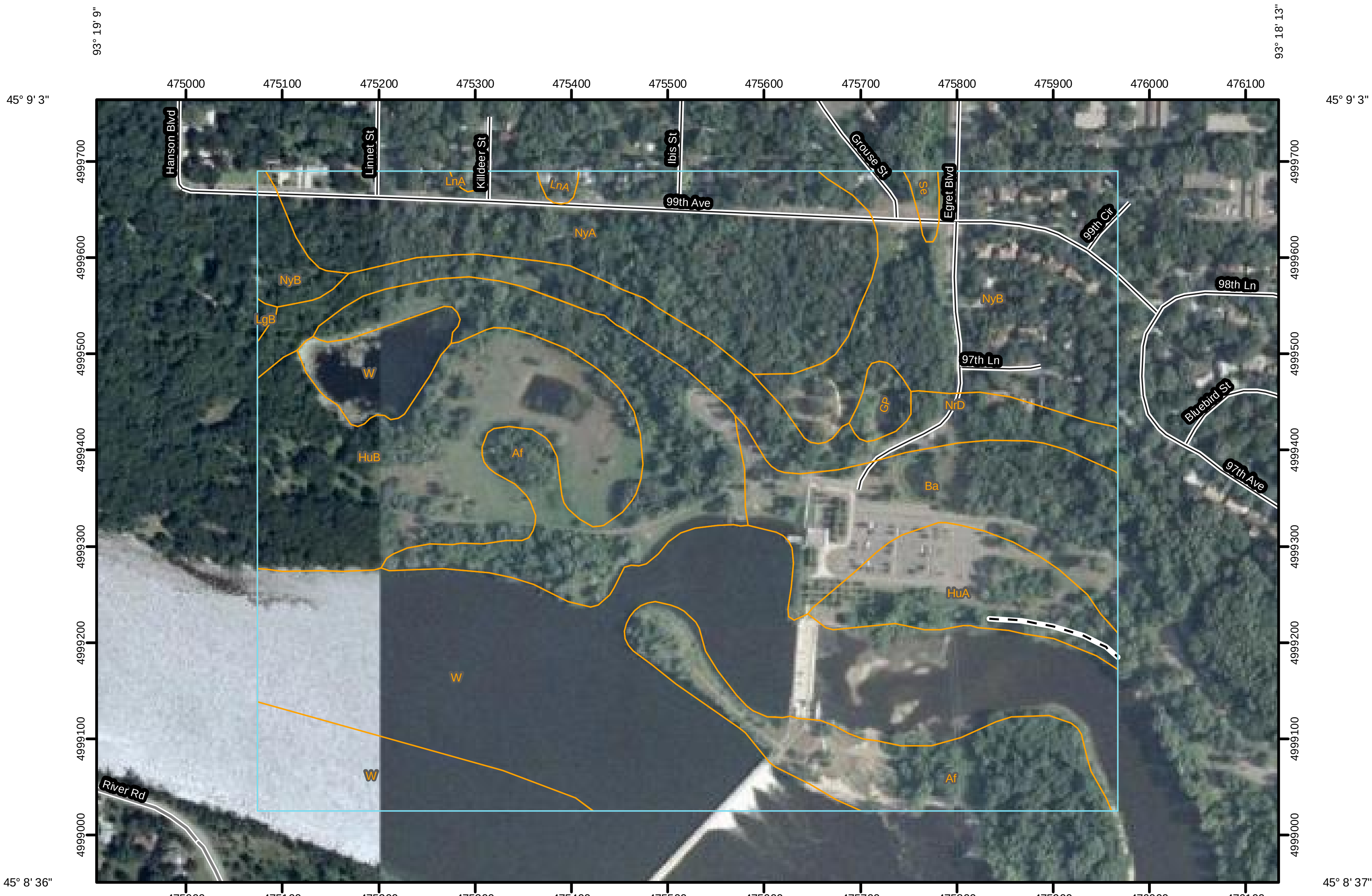
Scour
Protection
(Dowstream
Sill)



Area = 23000 sf

Borrow Material Background Information

Soil Map—Anoka County, Minnesota, and Hennepin County, Minnesota
(Coon Rapids Dam Borrow - Anoka Side)



Map Scale: 1:5,820 if printed on A size (8.5" x 11") sheet.

N

Meters: 0, 50, 100, 200, 300

Feet: 0, 300, 600, 1,200, 1,800

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Units

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Gully

Short Steep Slope

Other

Political Features

Cities

Water Features

Oceans

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

MAP INFORMATION

Map Scale: 1:5,820 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at scales ranging from 1:12,000 to 1:15,840.

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

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 15N NAD83

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

Soil Survey Area: Anoka County, Minnesota
Survey Area Data: Version 8, Dec 14, 2009

Soil Survey Area: Hennepin County, Minnesota
Survey Area Data: Version 7, Aug 2, 2010

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 7/18/2003; 8/7/2003

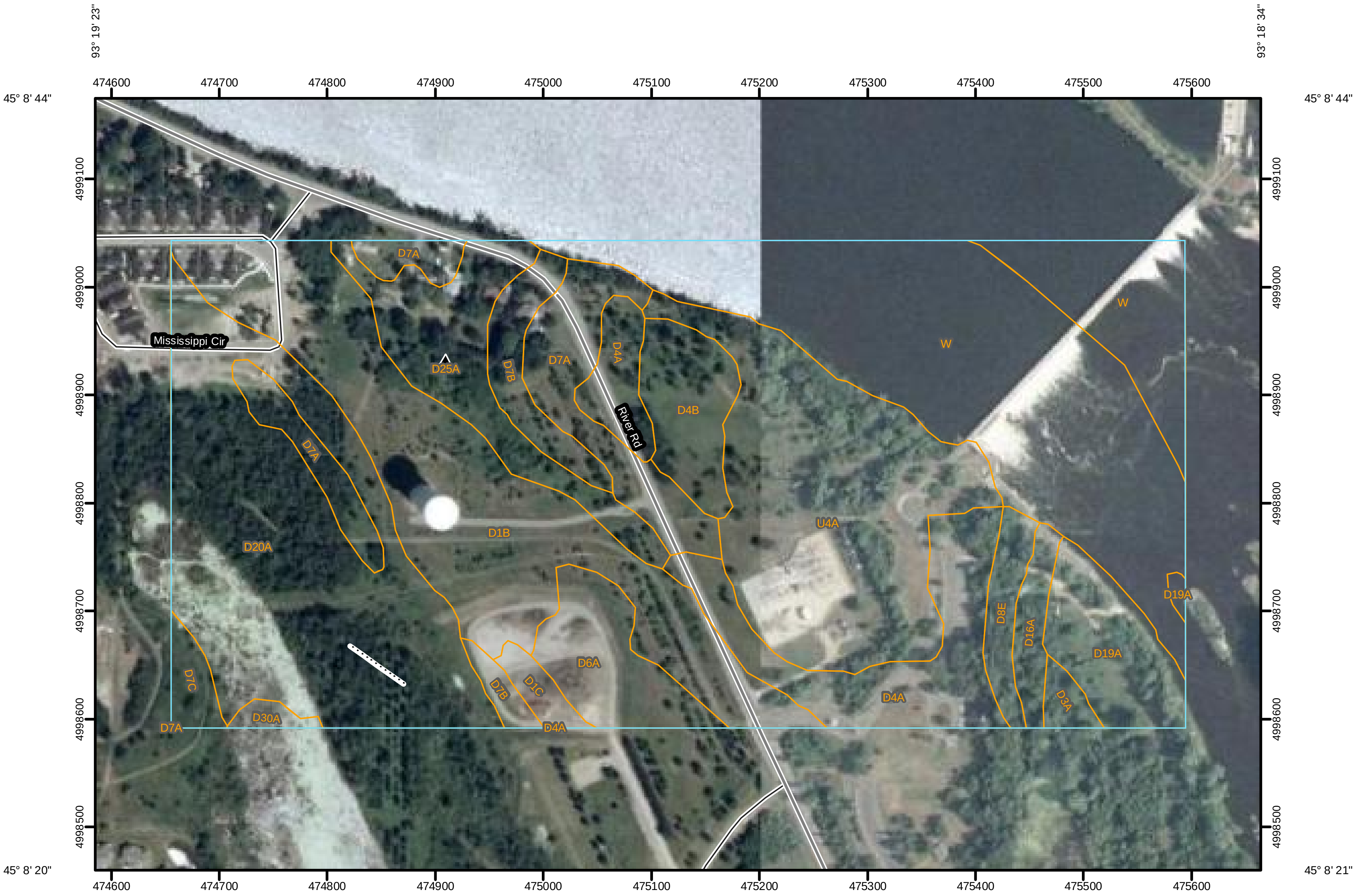
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

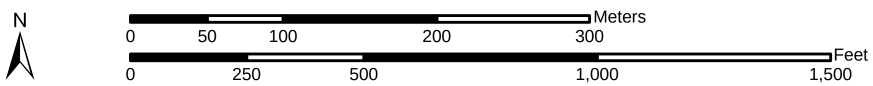
Anoka County, Minnesota (MN003)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Af	Alluvial land, mixed, frequently flooded	21.2	14.4%
Ba	Becker very fine sandy loam	10.4	7.0%
GP	Pits, gravel-Udipsamments complex	0.9	0.6%
HuA	Hubbard coarse sand, 0 to 2 percent slopes	6.1	4.2%
HuB	Hubbard coarse sand, 2 to 6 percent slopes	16.5	11.2%
LgB	Langola loamy sand, 0 to 6 percent slopes	0.1	0.1%
LnA	Lino loamy fine sand, 0 to 4 percent slopes	0.4	0.3%
NrD	Nymore loamy coarse sand, 12 to 25 percent slopes	8.8	6.0%
NyA	Nymore loamy sand, 0 to 2 percent slopes	18.9	12.9%
NyB	Nymore loamy sand, 2 to 6 percent slopes	18.2	12.4%
Se	Seelyeville muck	0.4	0.3%
W	Water	39.5	26.9%
Subtotals for Soil Survey Area		**141.5**	**96.3%**
Totals for Area of Interest		**147.0**	**100.0%**

Hennepin County, Minnesota (MN053)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
W	Water	5.5	3.7%
Subtotals for Soil Survey Area		**5.5**	**3.7%**
Totals for Area of Interest		**147.0**	**100.0%**

Soil Map—Anoka County, Minnesota, and Hennepin County, Minnesota
(Coon Rapids Dam - Hennepin Side)



Map Scale: 1:5,120 if printed on A size (8.5" x 11") sheet.



MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Units

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Gully

Short Steep Slope

Other

Political Features

Cities

Water Features

Oceans

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

MAP INFORMATION

Map Scale: 1:5,120 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at scales ranging from 1:12,000 to 1:15,840.

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

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Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 15N NAD83

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

Soil Survey Area: Anoka County, Minnesota
Survey Area Data: Version 8, Dec 14, 2009

Soil Survey Area: Hennepin County, Minnesota
Survey Area Data: Version 7, Aug 2, 2010

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 7/18/2003; 8/7/2003

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

Map Unit Legend

Anoka County, Minnesota (MN003)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
W	Water	4.3	4.1%
Subtotals for Soil Survey Area		**4.3**	**4.1%**
Totals for Area of Interest		**104.9**	**100.0%**

Hennepin County, Minnesota (MN053)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
D1B	Anoka and Zimmerman soils, terrace, 2 to 6 percent slopes	14.9	14.2%
D1C	Anoka and Zimmerman soils, terrace, 6 to 12 percent slopes	0.7	0.7%
D3A	Elkriver fine sandy loam, 0 to 2 percent slopes, occasionally flooded	0.5	0.5%
D4A	Dorset sandy loam, 0 to 2 percent slopes	7.2	6.9%
D4B	Dorset sandy loam, 2 to 6 percent slopes	2.9	2.8%
D6A	Verndale sandy loam, acid substratum, 0 to 2 percent slopes	3.4	3.2%
D7A	Hubbard loamy sand, 0 to 2 percent slopes	6.2	5.9%
D7B	Hubbard loamy sand, 2 to 6 percent slopes	2.6	2.4%
D7C	Hubbard loamy sand, 6 to 12 percent slopes	0.9	0.8%
D8E	Sandberg loamy coarse sand, 18 to 35 percent slopes	1.4	1.3%
D16A	Seelyeville and Markey soils, ponded, 0 to 1 percent slopes	1.2	1.1%
D19A	Fordum-Winterfield complex, 0 to 2 percent slopes, frequently flooded	3.6	3.4%
D20A	Isan sandy loam, 0 to 2 percent slopes	17.1	16.3%
D25A	Soderville loamy fine sand, terrace, 0 to 3 percent slopes	5.1	4.9%
D30A	Seelyeville and Markey soils, depressional, 0 to 1 percent slopes	0.4	0.4%
U4A	Urban land-Udipsamments (cut and fill land) complex, 0 to 2 percent slopes	13.9	13.3%
W	Water	18.6	17.8%
Subtotals for Soil Survey Area		**100.6**	**95.9%**
Totals for Area of Interest		**104.9**	**100.0%**