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transmittal

date	September 26, 2013	__X__ attached	_____ via regular mail
to	Jim Johannessen (Coastal Geologic Services)	_____ via messenger	_____ via overnight mail

project Swan Lake Engineering Feasibility

items Conceptual Design Memorandum

comments Hi Jim,

Please find attached a revised Conceptual Design Memorandum for the Swan Lake Engineering Feasibility per our discussions. The revisions focus on improved discussion of the lowered alternative concept design and modeling, include text and reference of fish passage assumptions, additional discussion on gate type, revisions and refinements to the cost estimate, and additional text on cost estimate factors. I hope these revisions are acceptable and meet your expectations.

Sincerely,

Louis White

sent by LAW

cc

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memorandum

date September 26, 2013

to Jim Johannessen (Coastal Geologic Services)

from Louis White, PE (CA)

subject Conceptual Design Memorandum for Estuarine Enhancement at Swan Lake

1. Introduction

ESA PWA is assisting Coastal Geologic Services Inc. (CGS) to prepare an engineering feasibility assessment as part of the Swan Lake Restoration Project for the Skagit Fisheries Enhancement Group (SFEG). Specifically, SFEG and Island County (County) seek to improve the habitat of Swan Lake for juvenile salmonid rearing and to improve drainage issues. This memorandum documents and presents the conceptual design approach for enhancing the project site by constructing a tidal connection between Swan Lake and the Strait of Juan de Fuca (the sound).

The work described in this memorandum was completed by Louis White, PE, and Eddie Divita, PE, with oversight by Bob Battalio, PE. The work described in this memorandum builds upon previous studies for the site that describe the existing conditions, including the wave climate, littoral transport, and hydrology (ESA PWA 2013a), and the hydraulic modeling that was performed to evaluate fish passage for various alternatives (ESA PWA 2013b).

1.1. Background

Swan Lake is a back-barrier, closed lagoonal marsh located on the western edge of Whidbey Island, Washington on the Strait of Juan de Fuca (Figure 1). Historically, the site was likely a forested swampland that was converted to agricultural land in the late 19th Century. The site is currently managed as a back-barrier lake that drains through two culverts with flap gates (CGS 2010). The spit of land between the Sound and Swan Lake was developed in the mid 20th Century, and now includes a series of small beach cabins that are located just above the mixed sand and cobble beach (Figure 2). West Beach Road is a county road that is located on the spit and runs along the east side of the existing homes. Several homes and farmland are located around the perimeter of Swan Lake.

The coastal hydrology including waves and tides incident to the site are described in ESA PWA (2013a). The site is exposed to wind waves and swell that propagates from the Pacific Ocean and through the Strait of Juan de Fuca. Littoral transport of sand and cobble materials is predominantly from south to north. The tidal datums at Swan Lake were estimated by CGS using the program VDatum, and verified to within 0.5 ft using water level data collected on site by CGS (Table 1). All of the elevations presented in this memorandum are presented relative to MLLW[1].

TABLE 1
TIDAL DATUMS ESTABLISHED FOR THE SWAN LAKE PROJECT SITE

Tide	Elevation (ft MLLW)
Mean Higher High Water (MHHW)	7.5
Mean High Water (MHW)	6.8
Mean Tide Level (MTL)	4.6
Mean Sea Level (MSL)	4.6
Mean Low Water (MLW)	2.4
North American Vertical Datum of 1988 (NAVD)	0.3
Mean Lower Low Water (MLLW)	0.0

Source: CGS, data from VDatum

1.2. Problem Description

Tidal rearing habitat for juvenile salmonids has been identified as a limiting factor in Chinook recovery in Puget Sound (SRSC & WDFW 2005). The amount of tidal rearing habitat in Puget Sound has declined significantly due to anthropomorphic pressures. Tidal rearing habitat is particularly threatened by development and changes in land use. Restoration of tidal rearing habitat has been identified as a strategic need by the Puget Sound Nearshore Ecosystem Restoration Project (Schlenger et al. 2010). Swan Lake represents a potential site for restoring tidal rearing habitat due to the large area of shallow water area that can be converted from a predominantly static reservoir-drainage to a more dynamic tidal embayment.

The purpose of this study is to evaluate the feasibility of establishing a sustainable tidal connection to Swan Lake, and to develop a conceptual design that can be used to generate wider interest in implementation and lay the groundwork for detailed design and environmental review. Previous analyses were completed to evaluate the feasibility of potential alternatives, including an open channel and culvert alternatives.

In addition to improving rearing habitat quality and access, the conceptual design is based on the following additional considerations:

- reducing maintenance requirements for the culvert system;
- efficiently draining the lake for water level management;
- minimizing impacts to private property and other infrastructure.

1.3. Fish Passage Assumptions

Fish passage guidelines are fairly developed for fluvial systems, but are not clearly defined for tidal water bodies (see ESA PWA 2013b for discussion). Recently published design guidelines for water crossings in Washington provide improved guidance for evaluation of the fish passage criteria and analysis methods (Barnard et al. 2013).

[1] MLLW refers to mean lower low water, a tidal datum that is the average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch.

For the current study, we assumed that juvenile salmonids move with the mass of water, moving upstream with the flood tide and downstream with the ebb tide (Barnard et al. 2013). Therefore, meeting set velocity criteria through culverts is not the primary concern in establishing juvenile fish passage through culverts in tidal systems. Furthermore, Barnard et al. (2013) suggest that systems restored to full tidal action provide optimal fish passage and create better rearing habitat than systems that are restored to partial or muted tidal action using fish friendly tide gates. Although research shows that gated systems provide rearing habitat that is less optimal than ungated sloughs, restoring a tidal connection to Swan Lake will improve rearing habitat and would allow juvenile fish to move through the gates. The following conceptual alternative should be reviewed by fish biologists to evaluate the level of fish passage that may result from implementation of the project.

2. Goals and Objectives

This section presents a discussion on the goals and objectives for the project.

2.1. Project Goals

The overarching goal of this project is to improve the hydrologic and ecological function of Swan Lake to a more natural back-barrier coastal lagoon condition. The project must allow for the responsible hydrologic management of the lagoon while encouraging the healthy ecological function of the lagoon. The project aims to achieve these goals through the implementation of technically feasible and cost effective improvements that will withstand the test of time.

2.2. Objectives

The following are the major objectives that were identified by the project team and are intended to support the project goals. Other objectives of the project, or modifications to these, may be developed during the course of subsequent studies.

1. Create a tidal connection between Swan Lake and the Strait of Juan de Fuca using a natural channel or culvert system.
2. Increase the amount of suitable rearing habitat by juvenile salmonids in Swan Lake.
3. Improve the access to the rearing habitat in Swan Lake by juvenile salmonids.
4. Maintain the maximum water surface elevations in Swan Lake to be less than or equal to 6 ft MLLW.
5. Maintain minimum depth of 2 ft in Swan Lake at all times.
6. Minimize ongoing maintenance requirements for fully functional lagoon.
7. Minimize impacts to littoral drift and coastal access and recreation.
8. Minimize impacts to private property.
9. Develop plans that adhere to the regulatory agency guidelines.

3. Alternatives

This section presents the conceptual alternatives that were developed to meet the goals and objectives described above. We considered two main conceptual alternatives: an open channel alternative and a suite of culvert alternatives. The culvert alternative includes several variations of culvert geometries, sizes, and elevations. These alternatives are described below with a brief summary of their anticipated performance and conformance with design objectives.

3.1. Previously Identified and Evaluated Alternatives

Two major alternative approaches were described and evaluated in ESA PWA (2013b): open channel and culvert alternatives. Extensive hydraulic modeling and evaluation of the local hydrologic and littoral systems were used to develop the alternatives and identify the most promising approach. The sections below summarize the findings of this previous work.

3.1.1. Open Channel Alternative

An open channel tidal connection alternative was initially developed as a possible alternative (see Figure 27, ESA PWA 2013b). This alternative would connect Swan Lake to the Sound through a drainage outlet type of open channel over the beach berm at the northern end of the lake. This alternative was identified as a high risk approach due to its potential for closure after large swell events. The beach berm is expected to build upwards due to wave action, and over time may constrain the function of the proposed outlet channel. The analysis also revealed that the open channel alternative is likely to perch the water levels above the tidal elevations, and therefore may impact private property and infrastructure, including nearby septic drain fields. Based on these concerns the project team decided to remove this alternative from consideration.

3.1.2. Culvert Alternatives

Several culvert designs were simulated to evaluate the hydraulics of the culvert alternatives, including the impacts on the water levels in Swan Lake and the velocities through the culverts. This initial analysis of the culvert alternatives did not consider the use of self-regulating tide gates (SRTs), and therefore the tidal water levels in Swan Lake are unconstrained. This initial analysis was used to evaluate the culvert sizing and elevations within the tide frame as related to fish passage requirements. The culvert alternatives that we analyzed are summarized in Table 2.

A refined culvert approach was developed as a possible alternative for further development (see Figure 26, ESA PWA 2013b). This alternative included three 8-ft tall by 10-ft wide box culverts that run approximately along the alignment of the existing culverts through the County easement, with an open box or vault located in the County easement in the vicinity of the existing vault. Gates could be included and placed on the culverts in the vault. An invert elevation of +2 ft MLLW was assumed for this alternative, with the soffit elevation at +10 ft MLLW. This culvert geometry was found to provide a free water surface for most tidal water levels, which may be beneficial for fish passage. However, the culverts would significantly higher than the beach face, and may act as a barrier to littoral transport and beach recreation. Similar to the open channel alternative, water levels within Swan Lake would be unconstrained, resulting in water levels that may flood and impact private property and infrastructure.

TABLE 2
SUMMARY OF CULVERT ALTERNATIVES ANALYZED PREVIOUSLY

Number of Culverts	Culvert Size (ft) (height x width)	Invert Elevation (ft MLLW)
1	4 x 6	-10
2	4 x 6	-10
4	4 x 6	-10
6	4 x 6	-10
8	4 x 6	-10
4	8 x 12	0
4	10 x 16	0
1	10 x 20	0
2	10 x 20	0
4	10 x 20	0
6	10 x 20	0
8	10 x 20	0
3	8 x 10	2

4. Preferred Alternative

The preferred alternative for the project was identified by project stakeholders as the refined culvert alternative with the addition of self regulating tide gates. This alternative was developed further and is described in the sections below, including a general description of the alternative and construction considerations, as well as additional modeling that was performed to assess the performance of the alternative.

4.1. General Description: Culvert with Self-Regulating Tide Gates

The preferred alternative is based on the refined culvert alternative described above, except that the effective culvert dimensions are 4-ft tall by 10-ft wide, and would run through the beach berm and under West Beach Road in two reaches – the "beach-side" reach and the "lake-side" reach – connected by a large vault that would house self-regulating tide gates (Figure 3). The proposed design assumes an invert elevation of +0 ft MLLW for the beach-side reach and an invert elevation of +2 ft MLLW for the lake-side reach. The reasoning for the difference in elevations is to provide the desired water level ranges in the lake, but also to minimize impacts to the beach, including longshore littoral transport of sand and beach access and recreation.

The conceptual design of the culverts assume that they would be constructed of pre-cast or cast-in-place reinforced concrete boxes, with 2-ft thick walls and floors, and a 1-ft thick roof (Figure 4). The culvert structure would be supported by a series of piles spaced 6-ft laterally and reinforced concrete pile caps every 10-ft longitudinally. The Structural elements of this alternative are subject to change and would require design and review by a licensed structural engineer.

The water-side outlet of the new culverts will need to be designed to minimize the impacts to the beach and to also discourage sediment from building up in the entrance. The beach-side outlet of the culvert is shown in Figure 3 to have culvert face that slopes landward at a 5:1 (H:V) slope. Fish screens, which are similar to standard trash racks, will likely be needed to keep cobble, wood, and other debris from entering the culvert but also allow fish to traverse the culvert entrance. The fish screen concept and materials needs to be developed further at the next level of design. A scour apron and low-profile jetty would be constructed of rock rip rap to protect the culvert outlet from wave and current induced scour in front of the structure and along the sides, as well as discouraging the longshore sediment transport from depositing sand and cobble directly in front of the culvert outlet. Existing rock rip rap located at the outlet of the existing culverts could be salvaged and reused at the outlet of the new culverts. Additional rock material may need to be imported to the site depending on recommendations of the scour protection to be developed further at the next stage of design. The rip rap would wrap around the ends of the culvert to mitigate impacts caused by “end effects” of the structure jutting out into the surf zone. Further analysis will be needed to evaluate the structure’s effects on the wave reflections and the likely increased wave runup adjacent to the location of the new culverts.

A vault would be located in the County easement on the west side of West Beach Road between the residential properties, near the existing culvert vault. The vault would comprise a deep and open basin that connects the beach-side reach of culverts to the lake-side reach of culverts. A series of self regulating tide gates (SRTs) would be located in the vault on the lake-side set of culverts. Several options for gates are available, and additional discussion on gates is presented in Section 5 below.

The preferred alternative would require the demolition and reconstruction of the West Beach Road, as well as temporary traffic control during the construction period. Construction would likely be completed in reaches, and should be phased so as to minimize impacts on traffic to the extent possible.

Water management will be important during construction and would likely require local dewatering of groundwater in the trench as well as bypassing drainage flows from Swan Lake to the Sound. Pumps may be used to dewater the trench, and discharged to approved and permitted location. Best management practices would be required to achieve regulatory compliance with any waters discharged locally. Bypassing of flows from Swan Lake to the Sound could be achieved by using the existing culverts for part of the construction period, but an appropriate and cost-effective system for maintaining the drainage during construction should be identified during subsequent phases of design.

4.2. Updated Modeling for Preferred Alternative

We used the Delft3d hydrodynamic model to estimate flows through the proposed culverts at Swan Lake. The model set-up and configuration is described in ESA PWA (2013b). The current investigation analyzes hydraulic conditions at the site for preferred conceptual design alternative. The design alternative under consideration consists of three 10ft-wide by 4ft-high culverts connecting the lake to the sound located along the alignment shown in Figure 3. However, due to limitations of the hydrodynamic model we simulated the culvert invert at elevation +2 ft MLLW for both the beach-side and lake-side reaches. We assumed that the hydraulic connectivity is dominated by the lake-side reach of the culvert that has an invert elevation of +2 ft MLLW, and that the difference in the flows through the beach-side culvert would be negligible for beach-side invert elevations of +2 ft MLLW and 0 ft MLLW. This is discussed briefly below. The results presented in this memorandum represent a conceptual-level analysis and it is understood that the final dimensions and elevations of the culverts may change as the design is refined.

We ran the model for the updated preferred design to evaluate the flows through the culverts and the resulting water level in the lake as controlled by a full spring-neap tidal cycle. The results of the Delft3d model were processed to evaluate the relative submergence of the culvert outlet based on the simulated water levels, and also to estimate the velocities that can be anticipated from the culvert configuration described above. The results in general suggest that the alternative can achieve the goals and objectives of the project by creating a fish passable connection and providing a system that improves habitat within the lake while managing the water levels. The modeling results are described further below.

4.2.1. Culvert Outfall Submergence

The culvert invert elevation affects the frequency of submergence of the culvert outfall. A culvert located at a lower elevation is more likely to experience submerged, pressure driven flow conditions while a higher culvert will be more likely to be partially submerged and experience free-surface flow. There is some concern that a culvert located at a relatively higher elevation may have undesirable impacts on sediment transport and recreational access along the beach. However, the frequency of submergence may also have implications for fish passage, and these results should be reviewed by qualified fish biologist to assess the actual degree that the culverts are fish-passable.

We estimated the percent occurrence of a fully submerged outfall, partially submerged outfall, and dry outfall based on the tidal record for a tranquil 14-day spring-neap cycle by comparing the water surface elevation to the invert elevation of culverts at 0 ft MLLW and +2 ft MLLW. This analysis does not consider the affect of storm-surge or wave run-up on water levels. Based on the recorded water levels within the sound and considering 4-ft tall culverts with beach-side invert elevation of 0 ft MLLW and the lake-side invert elevation of +2 ft MLLW, we found that the outfalls are expected to be fully submerged 64% of the time, partially submerged 28% of the time, and dry approximately 8% of the time. We also considered the case of the both beach-side and lake side culvert outlets at +2 ft MLLW. A culvert outfall located at this elevation is expected to be fully submerged 40% of the time, partially submerged 40% of the time, and a dry less than 20% of the time. Table 3 tabulates these findings.

TABLE 3
SUMMARY OF PERCENT OCCURRENCE OF CULVERT SUBMERGENCE FOR TWO OUTFALL INVERT ELEVATIONS

Outfall Invert Elevation[1]	Fully Submerged Outfall[2]	Partially Submerged Outfall[3]	Dry Outfall[4]
+2 ft MLLW	40%	40%	20%
0 ft MLLW	64%	28%	8%

[1]Assumes a 4-ft tall culvert; [2]WSE in Sound above culvert soffit; [3]WSE in Sound below culvert soffit and above culvert invert; [4]WSE in Sound below culvert invert

4.2.2. Tide Gate Hydrodynamics

The proposed project design includes self-regulating tide gates which are intended to block flow through the culverts when water levels on the lake-side of the culverts exceed an elevation threshold. Based on discussions with CGS, we chose a maximum tidal inundation elevation of +6 ft MLLW. This elevation provides 1 ft of freeboard between the maximum tidal inundation elevation and the maximum allowable water surface elevation of +7 ft MLLW, which was determined by CGS based on potential for precipitation and fluvial contributions to the lake and potential impacts to private property. The tide gate threshold elevation may change in later phases of design. The goal of this analysis is to determine the frequency of various flow regimes through the proposed culverts during normal tidal conditions. We investigated the frequency of outflow, inflow, and closed tide gates and estimated the expected occurrence of low flow velocities through the culverts.

We used the Delft3D model to simulate tidal flows through the culverts and to predict the resulting water levels inside of the lagoon. We modeled a 2-week tidal cycle representing typical conditions at the project site. This analysis does not consider the affects of storm surge or wave run-up on water levels or flows through the culverts. The tide gate operation is represented in the model by clamping water levels within the lake, preventing the water levels in the lake from exceeding elevation 6 ft MLLW. This provides an improved representation of the water levels within the lake and the inflows and outflows through the culverts during open tide gate conditions. The flow velocities within the culverts during closed tide gate conditions were corrected in post-processing.

Figure 5 shows a time-series of the water surface elevations in the Sound and within Swan Lake. The figure also highlights the periods where the culverts experience unrestricted inflows into the lake, unrestricted outflows from the lake, or closed tide gate conditions. Figure 6 shows the percent exceedance curve for flow velocities through the culverts. Table 4 tabulates the percent occurrence of unrestricted inflows, unrestricted outflows and closed tide gate conditions. Table 4 also presents the percent occurrence of fish-passable low velocity inflows and outflows for threshold velocities of 2 feet per second (fps) and 1 fps.

TABLE 4
SUMMARY OF PERCENT OCCURRENCE OF TIDE GATE OPERATIONS AND THRESHOLD VELOCITIES

Flow Condition	Total % Occurrence (Any Velocity)	% Occurrence Velocity <2 fps	% Occurrence Velocity <1 fps
Unrestricted Inflow	30%	15%	8%
Unrestricted Outflow	50%	25%	8%
Closed Tide Gates	20%	N/A	N/A

4.3. Outstanding Issues

Outstanding issues regarding the preferred alternative that should be addressed during subsequent phases of design include:

- Type of self-regulating tide gates to use (see discussion below in Section 5);
- Tradeoffs between fish passage and littoral barrier issues related to elevation / size of culvert outlet on beach side;
- Evaluate potential for sediment buildup at culvert outlet and other possible maintenance needs;
- Evaluate impacts of project on wave runup elevations adjacent to culvert.

5. Tide Gate Approaches

Several tide gate alternatives are available for use that would likely comply with the project objectives. Below we have included a summary of several types of tide gates that we have used or reviewed for a number of projects. The following discussions begins to describe the configuration and use of a traditional flap gates, which is consistent with the existing conditions at the site, and then describes several options for self-regulating tide gates that may be considered for use in the project. The intent of this section is to describe different types of gates that could facilitate the project to meet the goals and objectives. The gate selection should occur during the next stage of design as the culvert concept is improved and refined.

5.1. Traditional Flap Gates

A flap gate is a type of tide gate with a heavy hinged door which is configured to close automatically under its own weight, preventing backflow through the culvert (Figure 7, top panel). Hydrostatic forces will cause the gate to open when the upstream water level exceeds the downstream water level, allowing water to drain through the culvert until the water levels on both sides of the gate reach equilibrium. Flap gates are commonly installed with trash racks in order to reduce the risk of debris becoming wedged in the opening and preventing the gate from closing properly. Flap gates are often installed with ropes or chains which allow an operator to prop open the gate manually if tidal flushing is desired. A manually opened flap gate will function similarly to an un-gated culvert, allowing unrestricted flows in both directions for temporarily improved for fish passage and tidal flushing. Manually opened flap gates do not offer protection against tidal flooding; consequently active monitoring of the flap gate is necessary during manual operation. Flap gates can be installed with either vertical (side) or horizontal (top) hinges. Gates with vertical hinges are less likely to trap floating debris but must be built to withstand greater structural loads.

In general, flap gates are simple to operate, relatively low cost, and low maintenance, but they do not allow for upstream fish passage except when being actively operated. Flap gates cause increased hydraulic losses which can significantly reduce conveyance through the gate relative to an un-gated culvert. Flap gates are not likely to be recommended as part of the Swan Lake preferred alternative.

5.2. Self-Regulating Tide Gates (SRTs)

Self-regulating tide gates are flap gates with attached mechanisms which open and close the tide gate based on the water level on the downstream or upstream side of the gate. SRTs typically use a floating buoy system which can be adjusted so that the gate remains open until water levels exceed a selected elevation, at which point the mechanism will cause the gate to close. For SRTs, a portion of the tidal inflows can pass through the gate allowing for tidal flushing and fish passage because the mechanism allows the gate to remain open when water levels are low. At higher water levels, SRTs provide a level of flood protection comparable to a traditional flap gate. SRTs generally contain more moving parts than a traditional flap gate making them more prone to jamming due to debris entrapment. SRTs can be installed in both horizontal and vertical hinge configurations. A SRT gate is likely to be recommended as part of the Swan Lake preferred alternative.

Three variations of SRTs are described below, including a flap gate with mitigator fish-passage device, the horizontal hinge float gate, and the muted tide regulator with vertical hinged gates.

5.2.1. Flap Gate with Mitigator Fish-Passage Device

The mitigator fish passage device can be attached to a horizontal hinge flap gate in order to allow limited tidal inflows and fish passage through the gate (Figure 7, bottom panel). This device uses a float and cam mechanism to prevent the tide gate from fully closing during periods of the flood tide when water levels are below a set threshold elevation. The gate will completely close when the water levels downstream of the gate exceed the threshold elevation, preventing backflow through the culvert. This device is intended to allow juvenile salmonids to travel upstream past the tide gate during portions of the flood tide, while preventing the highest tidal water levels from flowing upstream. A flap gate with a mitigator fish-passage device is more expensive and requires more maintenance than a traditional flap gate but is less expensive than other types of self-regulating tide gates. This type of gate is controlled by the water levels in the Sound, and therefore has less control and accuracy of the resulting lake water levels.

5.2.2. Horizontal Hinge Float-Operated SRT

The Horizontal Hinge SRT design uses a metal gate which swings on a horizontally oriented hinge like a traditional flap gate, except that the opening and closing of the gate is based on the downstream water levels (Figure 8, top panel). The float assembly for the horizontal hinge SRT is similar to the Mitigator Fish-Passage Device and can be located anywhere in the tide range, which allows for increased flexibility in selecting the water level that will trigger the closure of the tide gate. The gate operates similar to a traditional flap gate when the downstream water elevation is below the threshold elevation and when it is lower than the upstream water elevation. As the downstream water level rises during a flood tide, the floats act to keep the gate open and allow water to move upstream through the culvert until the downstream water level reaches a set threshold elevation causing the gate to shut. This type of gate is more expensive than the mitigator fish-passage device gates, but increases the time and size of the opening during flood tides.

5.2.3. Muted Tide Regulator with Vertical Hinged Gates

A muted tide regulator (MTR) with vertical hinged gates is a variation of the SRT design that is controlled by water levels upstream of the gate (Figure 8, bottom panel). This design uses a vertical hinge and a float and lever system to open and close the gate. The system allows a greater amount of tidal exchange and improved fish passage conditions as compared to other types of SRTs by placing the float on the upstream side of the tide gate. The benefits of the MTR system with the vertical hinged gates include the improved accuracy of controlling the water level in the target water body rather than closing based on the downstream water level, and the improved flow conditions from the vertical hinged gates. The vertical orientation of the hinge allows the gate to open more completely compared to a horizontal hinged gate, which decreases the velocities, increases amount of fish passage and reduces the risk of debris entrainment. A vertical hinge SRT requires sturdy hinges and experiences larger stresses relative to comparably sized horizontal hinge SRT.

The muted tide regulator has more moving parts than other types of SRTs, and likely results in higher maintenance requirements. The float assembly for the MTR vertical hinge SRT can be located anywhere in the tide range, allowing for more flexibility in selecting the water level that will trigger the closure of the tide gate. The MTR system is ideal for relatively large system such as Swan Lake, and is a good candidate for including in the preferred conceptual design.

5.3. Automated Canal Gate

The automated canal gate (also known as a sluice gate or slide gate) is mounted in a vertical bracket and can be raised or lowered in order to control flow through the gate (Figure 9). The operation of the gate can be automated through the use of a digital water level gage connected to a motorized lead screw assembly. The height of the opening of the sluice gate can be precisely adjusted to achieve the desired flow through the culvert, and the frequency of opening can be controlled using computerized control software which can simultaneously consider water level on both the upstream and downstream sides of the tide gate. When fully opened the sluice gate places no restriction on flow through the culvert, resulting in maximum conveyance and minimizing debris entrainment. A vertical sliding sluice gate has fewer moving parts than a hinged SRT, reducing the likelihood of damage or failure due to debris entrapment. This type of gate requires electrical power and may need more specialized skills for service and maintenance, but has a high degree of reliability and is likely cost competitive with other approaches. This type of gate should be considered for the preferred conceptual alternative for Swan Lake.

5.4. Maintenance and Redundancy

All of the gates described above will require periodic maintenance to keep the system operating as designed or to fix temporary issues. The current configuration of the flap gates located in the existing vault often is jammed with wood debris and requires County crews to unclog the gates. Installing fish screens at both ends of the culvert may reduce the amount of debris that can enter the culverts from the beach-side and the lake-side, but the cost for each screen is relatively high. Other methods, such as a floating screen, may reduce the amount of floating debris that can enter the culvert on the lake-side. Regardless, subsequent design of the gates and culvert system should incorporate methods to reduce the maintenance issues that are common to the project site.

Redundancy of the system is another important factor that will need to be incorporated into the design at future stages. For example, if an automated canal gate is to be pursued, drainage of the lake will need to occur in the event of a power outage if the gates are closed. Similarly, a method for closing the gate would need to be employed in the event that the gate is open during a power outage. One solution for adding redundancy in these cases would be to include manually operable gates. The method of redundancy should be included at the next stage of design when the desired type of gate is selected.

6. Engineer's Estimate of Construction Costs

The estimated conceptual level construction costs for the preferred alternative are presented in Table 5.

For planning purposes we have provided order of magnitude estimates to allow cost comparison of alternatives. These cost estimates are intended to provide an approximation of total project costs appropriate for the conceptual level of design. These cost estimates are considered to be approximately -30% to +50% accurate, and include a 35% contingency to account for project uncertainties (such as final design, permitting restrictions and bidding climate). These estimates are subject to refinement and revisions as the design is developed in future stages of the project.

This table does not include estimated project costs for permitting, design, monitoring, and ongoing maintenance. Estimated costs are presented in 2013 dollars, and would need to be adjusted to account for price escalation for implementation in future years. This opinion of probable construction cost is based on: ESA PWA's previous experience, bid prices from similar projects, consultation with contractors and suppliers, and R.S Means 2011 Heavy Construction Cost Data edition.

The line items presented in Table 5 include several standard construction line items as well as items specific to the project. The major line items specific to the project control the magnitude of the estimate, and include the new culverts, the new gates, the vault, and the fish screen. Several factors and assumptions affect the cost of each of the line items, including the thickness of concrete walls in the culverts and vault, the extent of steel reinforcing in the concrete, the plan size and depth of the vault, and the number and style of fish screens. We included an allowance of $200,000 per gate, as the size of the gates is very large, and the type of gate is very specialized. Other items in the estimate, including mobilization, water control, and traffic control were estimated as a percentage of the subtotal. Furthermore, the contingency of 35% is typical of estimates for conceptual-level projects, and will move up into the estimate as details of the design progress.

TABLE 5
ENGINEER'S ESTIMATE OF PROBABLE CONSTRUCTION COSTS

Item	Description	Quantity	Unit	Unit Price	Total Cost
1	Mobilization	1	LS	$ 240,000	$ 240,000
2	Demolition & Site Preparation	1	LS	$ 15,000	$ 15,000
3	Water Control & Culvert Bypass	1	LS	$ 80,000	$ 80,000
4	Traffic Control	1	LS	$ 80,000	$ 80,000
5	New 10-ft by 4-ft Culverts	3	EA		$ 1,200,000
5a	*Beach-side Reach*	*3*	*EA*	*$ 250,000*	*$ 750,000*
5b	*Lake-side Reach*	*3*	*EA*	*$ 150,000*	*$ 450,000*
6	SRT Gates (Allow)	3	EA	$ 200,000	$ 600,000
7	Vault	1	LS	$ 400,000	$ 400,000
8	Fish Screens	3	EA	$ 120,000	$ 360,000
9	Dredging	1800	CY	$ 15	$ 27,000
10	Road Reconstruction	2600	SF	$ 6	$ 15,600
11	Planting	250	SY	$ 10	$ 2,500
12	Beach Material Salvage & Reuse	225	CY	$ 20	$ 4,500
	Subtotal				$ 3,024,600
	Contingency	35%			$ 1,058,610
	Total				$ 4,083,210
	Total (Rounded)				**$ 4,090,000**

Strategies for reducing the cost can be developed as the design moves forward. For example, the estimate assumed that the culvert structure was constructed of cast-in-place concrete, which would likely be difficult to complete in the marine environment. Therefore, use of pre-cast sections of box culvert may reduce the total cost of the project. Other items that have high uncertainty is the foundation of the new culverts, including the depth and the number of piles. However, including piles is prudent at this stage of design, and can be modified as the design is refined in the next stages of the project.

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SOURCE: Image from Google Earth

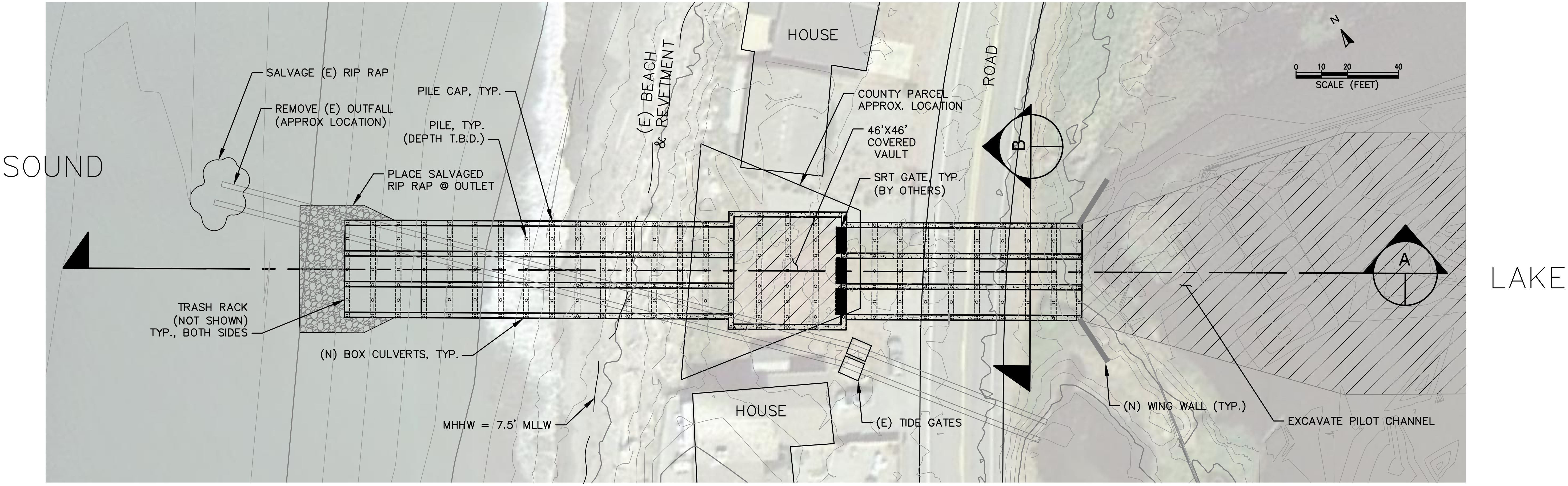
Swan Lake Engineering Feasibility . 120062.00

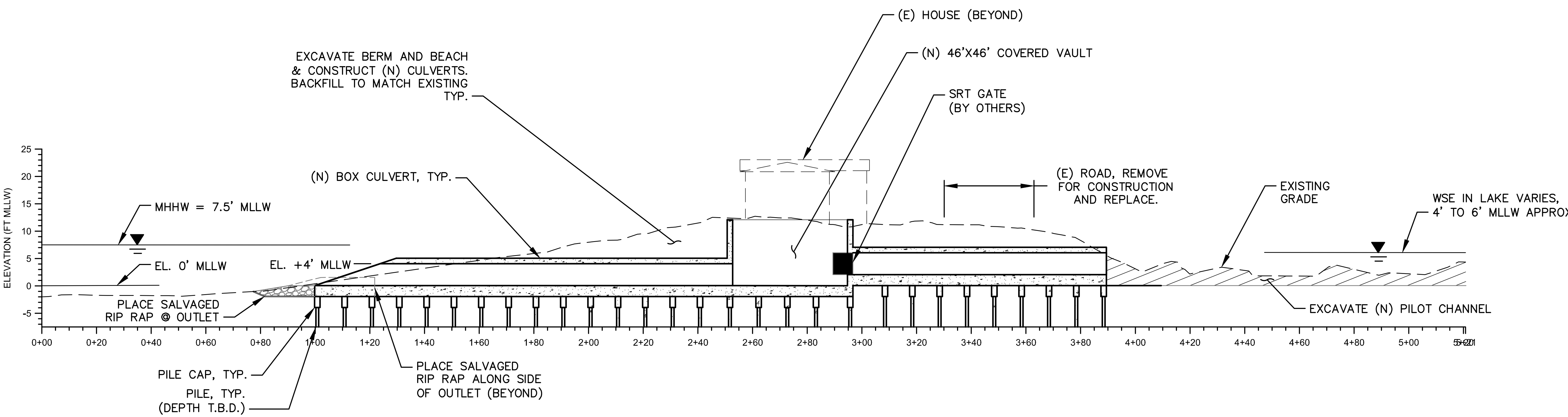
Figure 1

Location Map and geographic setting of the project site

SOURCE: Image from Google Earth

Figure 2
Site Map of Swan Lake showing the location of the existing culvert and profile surveys





A TYPICAL CULVERT PROFILE
HORIZ: 1" = 40'
VERT: 1" = 20'
2X VERT EXAGERATION

Figure 3
Plan and Profile
Lowered Culvert Outlet

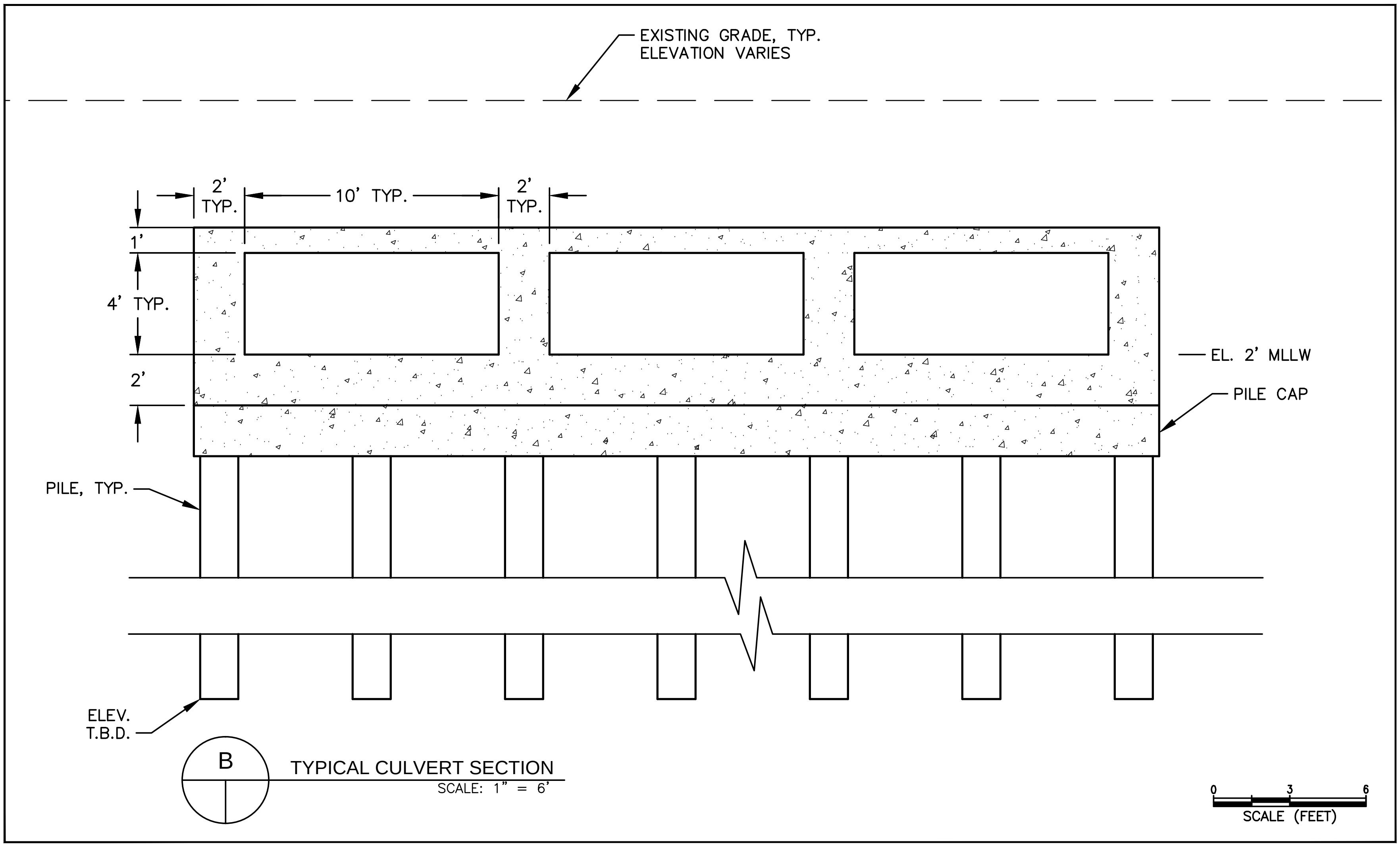


Figure 4

Typical Section
New Culverts

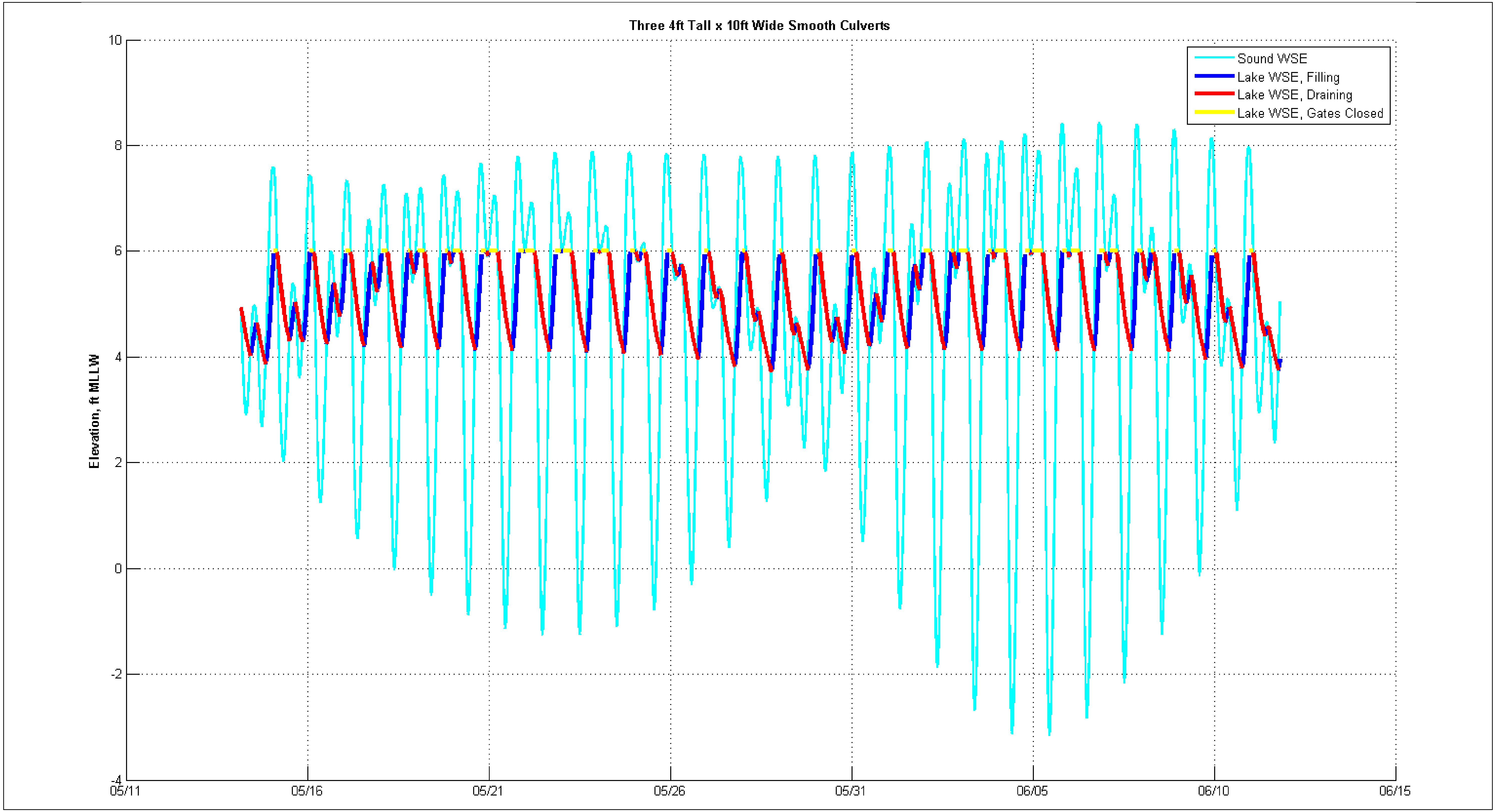


Figure 5
Water Surface Elevations in Sound and Lake
3 x 10’ x 4’ Culverts, Inverts at 2’ MLLW
With Tide Gates at 6’

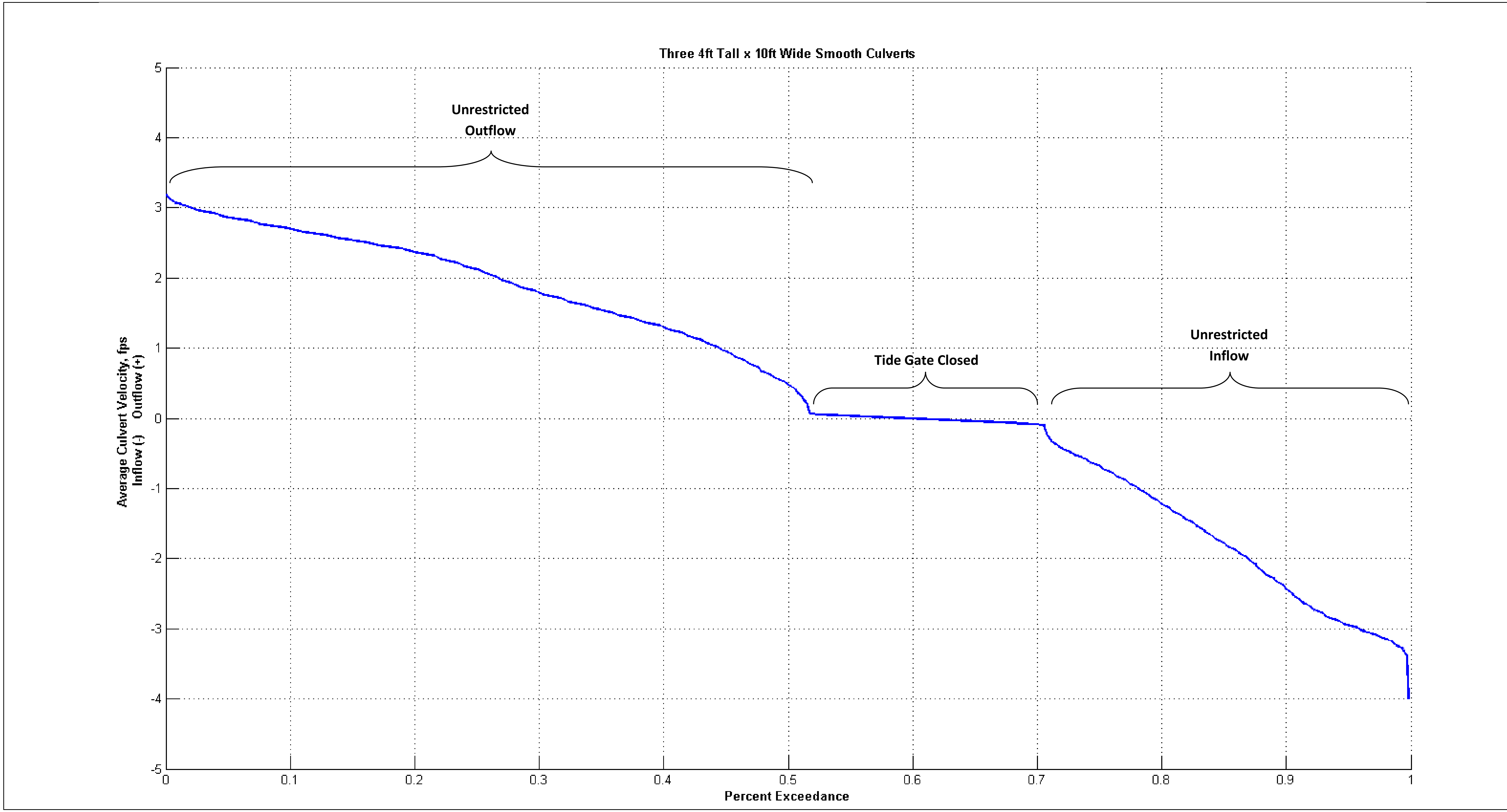
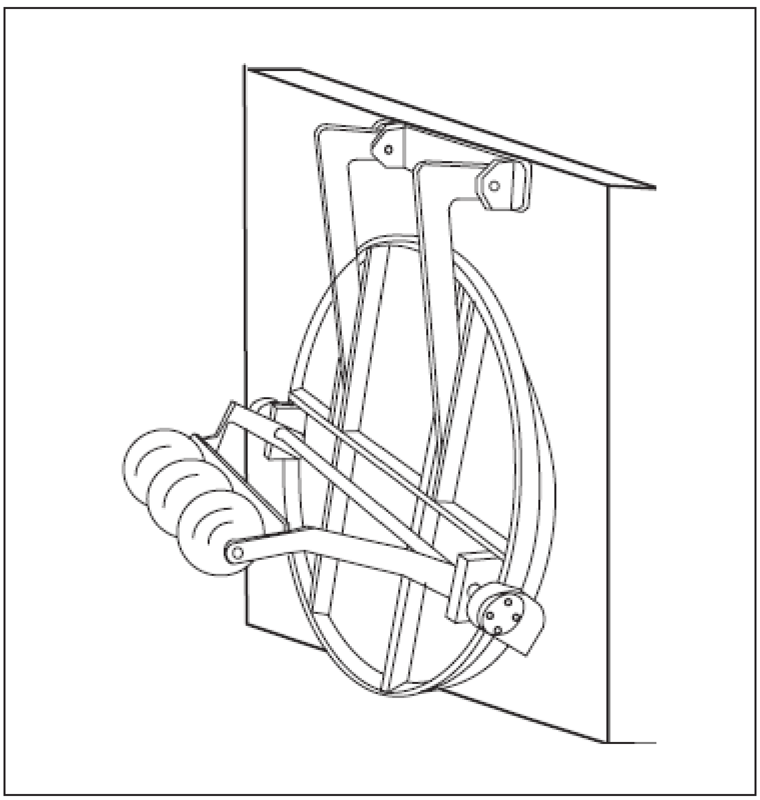


Figure 6
Exceedance Velocities
3 x 10’ x 4’ Culverts, Inverts at 2’ MLLW
With Tide Gates at 6’



Source: Giannico & Sounder, 2005

Note:
Top: Flap gate at Arroyo Grande Lagoon, California
Bottom: Diagram of flap gate with mitigation fish-passage device

Figure 7
Flap Gate and Mitigator Fish-Passage Device

Notes:
Top: Horizontal hinge self-regulating tide gates at Ballona Wetlands, LA, CA
Bottom: Muted tide regulator gates on the Skajit River, Washington

Figure 8
Self Regulating Tide Gates

Note:
Shorebird Marsh, Marin, California

Figure 9
Automated Canal Gate