5-2017

Design of Logan City's Stormwater Conveyance System

Kade Jacob Beck
Utah State University

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DESIGN OF LOGAN CITY'S STORMWATER CONVEYANCE SYSTEM

by

Kade Jacob Beck

Thesis submitted in partial fulfillment of the requirements for the degree

of

DEPARTMENTAL HONORS

in

Civil Engineering in the Department of Civil and Environmental Engineering

Approved:

Thesis/Project Advisor
Dr. Richard C. Peralta

Departmental Honors Advisor
Dr. V. Dean Adams

Honors Program Director
Dr. Kristine Miller

UTAH STATE UNIVERSITY
Logan, UT

Spring 2017
Final Report for the Design of Logan City’s Storm Water Conveyance System

Prepared for
Civil and Environmental Engineering
Senior Design Sequence, Semester 3
CEE 4880, Dr. Peralta
Utah State University

Prepared by
Kade Beck
Megan Gordon
Ryan Weller

Mentored by
Lance E. Houser PE
Dr. Michael C. Johnson PE

26 April 2017
## Team Member Roles

### Table 1. Team Member Roles for 10th West Engineers

<table>
<thead>
<tr>
<th>Function or specialty on team</th>
<th>Last name</th>
<th>First name</th>
</tr>
</thead>
<tbody>
<tr>
<td>External PE Liaison</td>
<td>Beck</td>
<td>Kade</td>
</tr>
<tr>
<td>Faculty Liaison</td>
<td>Weller</td>
<td>Ryan</td>
</tr>
<tr>
<td>Financial Planner</td>
<td>Beck</td>
<td>Kade</td>
</tr>
<tr>
<td>Geotechnical Engineer</td>
<td>Weller</td>
<td>Ryan</td>
</tr>
<tr>
<td>Hydraulic Engineer</td>
<td>Weller</td>
<td>Ryan</td>
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<tr>
<td>Hydrologist</td>
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<td>Kade</td>
</tr>
<tr>
<td>Records Keeper</td>
<td>Gordon</td>
<td>Megan</td>
</tr>
<tr>
<td>Structural Engineer</td>
<td>Gordon</td>
<td>Megan</td>
</tr>
<tr>
<td>Team Leader</td>
<td>Beck</td>
<td>Kade</td>
</tr>
<tr>
<td>Technical Writer</td>
<td>Gordon</td>
<td>Megan</td>
</tr>
</tbody>
</table>
Executive Summary

This report summarizes 10th West Engineers’ (10WE) storm water conveyance design for Logan City. The implementation of the design mitigates flood risk due to storm water discharge, helps improve local water quality, and uses infrastructure that would otherwise be abandoned. The system collects storm water discharged along 1000 West and transports the water to the holding pond located at approximately 2400 West 2200 North, Logan, Utah (see Figure 1).

Logan City is located in northern Utah’s Cache County. As development and redevelopment occur, storm water runoff quantities will decrease due to new regulations. However, Logan City’s storm water system does not extend beyond 1000 West, which causes localized flooding.

This project had three phases. First, 10WE collected data from both Logan City and through field investigations. Second, 10WE designed an efficient system to convey water from existing discharge locations to the holding pond. Third, 10WE completed this final report to submit to Logan City on the proposed storm water conveyance system.

10WE followed several design methods outlined in government manuals. 10WE’s post-construction recommendations for Logan City are: 1) mow banks of each channel annually; 2) conduct a system inspection yearly and after a storm that exceeds the 20-year event to ensure that all channels and diversion structures are operating as designed.

10WE collaborated with the client, Logan City, to ensure the design satisfied all the client’s goals. The client had three goals: design a gravity-fed system, minimize effect on wetlands, and produce an economical design. 10WE collaborated with Cutler Engineering, who designed a treatment process for the storm water, and Westside Drainage Solutions, who designed a drainage system for a farm.
Acknowledgements

I would like to thank Lance Houser PE for his mentorship and supervision during the Senior Design Sequence. I would also like to thank Dr. Michael C. Johnson PE for his assistance with the design and final product. I am grateful for the desire of Dr. Richard C. Peralta PE, F.ASCE, to inspire us to achieve our very best in his course and in all of our endeavors. I am grateful for Ryan Weller and Megan Gordon for their insight and engineering skills.
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Problem Statement

Logan City is located in northern Utah’s Cache County. The average annual rainfall for Cache Valley is between 15 and 20 inches (PRISM 2016). Several times a year, the incomplete storm water system causes flooding, which risks industrial and agricultural lands. The current system collects storm water between 200 West and 1000 West, and discharges the water directly along 1000 West.

Cutler Reservoir, Swift Slough, and the Lower Bear River in Cache Valley do not comply with water quality regulations. The Clean Water Act of 1972 mandates that all municipal separate storm sewer systems (MS4) comply with EPA regulations, expressed as Total Maximum Daily Loads (TMDLs). Logan City’s untreated storm water might contribute to the pollution in these water bodies. The pollution threatens surface water, groundwater, and wildlife in the area.

Logan City plans to implement a new wastewater treatment process. However, the new treatment process is not designed to use the existing polishing ponds. Consequently, Logan City hopes to use these polishing ponds to treat storm water.

The implementation of this design improves storm water management. 10th West Engineers (10WE) had three goals. First, design a system to transport water from the discharge locations to the holding pond. Second, design a system that provides irrigation users access to water during a storm. Third, comply with the goals of the client: design a gravity-fed system, minimize effect on wetlands, and produce an economical design.
Project Description

10WE's objective was to design a storm water conveyance system for the client, Logan City. This design report details a system that collects storm water along 1000 West and transports the water to the holding pond (see Figure 2).

![Figure 2. Aerial Photo of the Area of Interest New Holding Pond](image)

The following project description is divided into four sections: tasks, inter-team cooperation, professional ethics, and design sequence.

Tasks

- Completed a field investigation between 1000 West and 2400 West
- Gathered pertinent data from Logan City, Cutler Engineering, and Westside Drainage Solutions
- Identified locations of surface water rights using ArcGIS
- Identified potential flow paths using TauDEM and ArcGIS
- Created design storm using Storm and Sanitary
- Designed and drafted channels and diversion structures using AutoCAD and Microsoft Office
- Selected optimal flow paths
- Completed the final design report using Microsoft Office

Inter-team Cooperation

Lance Houser, PE, Assistant City Engineer, and client representative, served as the External Professional Engineer (EPE) for three related design projects. 10WE designed a system to transport storm water to the holding pond. Cutler Engineering designed a system to treat this
storm water. Westside Drainage Solutions designed a drainage system for a farm located near 1000 West.

10WE, Cutler Engineering, and Westside Drainage Solutions worked together to obtain and process data. Westside Drainage Solutions conducted a Cone Penetration Test (CPT) to identify soil properties (see Appendix I). Due to budget constraints, 10WE did not conduct further CPT’s in the area of interest to verify soil conditions. However, Westside Drainage Solutions did not provide a unit weight or friction angle for the soil. Therefore, under the direction of the EPE, 10WE assumed a unit weight and friction angle.

The team leaders held meetings to coordinate assignments and deadlines. Additionally, the teams shared meeting minutes via Google Drive to provide each team access to relevant information.

**Professional Ethics**

10WE was committed to using the highest level of professional ethics. Therefore, 10WE complied with the American Society of Civil Engineers (ASCE) Code of Ethics (see Special Summary Documentation).

10WE used industry standard design criteria under the direction of the EPE. 10WE used the Natural Resources Conservation Service (NRCS) manual *Urban Hydrology for Small Watersheds* to create the design storm. 10WE used local design standards for open channel design and the United States Bureau of Reclamation (USBR) manual *Design of Small Canal Structures* for the hydraulic structure design. 10WE followed the American Concrete Institute’s (ACI) design standards for the design of the diversion structures. 10WE complied with additional regulations as needed (see Special Summary Documentation).

10WE used professional conduct in their interactions with the client and mentors. 10WE developed and applied effective methods for overcoming challenges (see Special Summary Documentation). During the design sequence, 10WE met all deadlines they had control over and was punctual to all meetings. Additionally, 10WE communicated professionally within the team, with the external and faculty mentors, and with team leaders from Cutler Engineering and Westside Drainage Solutions. Minutes for meetings conducted since the Interim Report submission are included in Appendix II. Person-hour work reports are included in Appendix III.

**Design Sequence**

The design sequence had three phases: data collection, system design, and a final report. 10WE produced a final Gantt chart that displays the project timeline (see Figure 3). The design phases were divided into five sections: data collection, design storm, topography, design, and final report. Appendix IV contains the proposed, revised, and final Gantt charts.
Data Collection. In May 2016, 10WE completed a field investigation from 1400 North to 2500 North and 200 West to 3200 West (area of interest) (see Figure 4). 10WE drove through the area of interest and identified potential flow paths. 10WE also observed the holding pond, polishing ponds, pump, and outflow from the polishing ponds. The field investigation illustrated the scale of the project and the current conditions in the area of interest.

This field investigation involved driving to, around, and through the area of interest. 10WE mitigated the risks from injury while traveling by wearing seatbelts and obeying all local driving regulations. Photographs from the field investigation are included in Appendix V.

The EPE and Logan City provided essential data for the completion of the design. Data collection began in May 2016. The design process commenced as soon as 10WE received the necessary data.

In addition, 10WE completed field measurements. These measurements established a base flow for various creeks in the area of interest. This process involved taking the water velocity and cross-sectional area measurements in the creeks (see Appendix VI). The creeks measured are lined with fine clay. 10WE carefully evaluated where to take measurements to ensure they did not become trapped in the clay. 10WE completed this investigation in late fall and all team members wore appropriate clothing to diminish the risk of illness.

Design Storm. Logan City’s design storm was outdated due to the effect of land developments. Under the direction of the EPE, 10WE created a new design storm. The creation of the new design storm was not anticipated and delayed the project.
Using information from the NRCS, 10WE identified a hydrologic group for each soil type in the drainage basin. With topographical contours overlaid in ArcGIS, 10WE delineated sub basins and assigned a curve number to each sub basin. 10WE decided to create the design storm in Storm and Sanitary, an Autodesk application. The drainage area data is included in Appendix I. The hydrologic group and surface terrain of the sub basins determined the curve number. By determining the total sheet and pipe flow distance, 10WE calculated a time to concentration for each sub basin. The conveyance system design ensures containment of runoff for a 100-year storm. Using the 100-year storm minimizes the risk of flood damage to the area of interest.

The design was created on November 3, 2016, and approved by the EPE on December 13, 2016. The maximum flow of the 100-year storm is 430 cubic feet per second. Consequently, 10WE eliminated the do nothing alternative because of potential damage from the high flows.

Under the supervision of the EPE, 10WE conducted a groundwater analysis to evaluate whether or not on-site treatment was a viable alternative. 10WE used data from the NRCS to determine a representative hydraulic conductivity (k) in the area of interest. To determine elevation of the water table, 10WE researched average well depths in the area of interest using information from the Utah Division of Water Rights. Using this information, 10WE calculated a groundwater velocity of 0.0064 feet per hour (see Table 2 and Appendix VI).

<table>
<thead>
<tr>
<th>Hydraulic Conductivity k (in/hr)</th>
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<tbody>
<tr>
<td>Differential Head Δh (ft)</td>
<td>207.13</td>
</tr>
<tr>
<td>Length L (ft)</td>
<td>161.00</td>
</tr>
<tr>
<td>Darcy Velocity v (ft./hr.)</td>
<td>0.0064</td>
</tr>
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</table>

Due to the low permeability of the soil, 10WE determined that on-site treatment of storm water would not be possible. Furthermore, 10WE concluded that groundwater in the area would not be significantly affected by the construction and operation of the storm water conveyance system.

**Topography.** To understand the topography of the area of interest, 10WE compiled aerial photographs in ArcGIS (see Figure 4A).
10WE overlaid elevation data on the aerial photographs (see Figure 4B). Using this information, 10WE ran TauDEM over the area of interest. TauDEM analyzed the elevations in the area and displayed natural flow paths for the area (see Figure 4C). The natural flow paths helped 10WE consider the constraints associated with the design.

Canals in the area supply water to owners of water rights. Surface water rights are signified by pink dots in Figure 4D. This social constraint was addressed in the final design. 10WE ensured that all individuals have access to their water rights by designing diversion structures.

Diversion structure design was a health and safety constraint. Obtaining soil data where structures are built was essential for the safety of the structure (see Appendix I). As previously mentioned, 10WE used representative soil data for the design. 10WE ensured structural integrity by designing for the saturated soil conditions. Structural failure may cause flooding damages.

Wetlands in the area of interest were environmental and economic constraints. As defined by the EPA, wetlands improve water quality, provide wildlife habitat, and regulate surface water flow.
(EPA 2016). For these reasons, the design avoided disturbing the wetlands to the extent possible. In addition, the Army Corps of Engineers requires three acres of wetlands be restored for every acre disturbed during construction. This was an economic constraint because the cost of replacing one acre of disturbed wetland is $180,000.

The design of a gravity-operated conveyance system was an economic and constructability constraint. Pumps in the design were outside Logan City’s budget. Therefore, natural flow paths identified by TauDEM enabled 10WE to design a gravity-operated system. 10WE conducted a meeting with the faculty advisor (FA) and the EPE to discuss flow paths. Several potential paths were identified.

The existing pipe transporting water from the holding pond to the polishing ponds does not have the required capacity. Two alternative designs were replacing the existing 48-inch pipe with 60-inch pipe or moving the holding pond. These alternatives were economic constraints that required a cost benefit analysis (Appendix VI). 10WE determined that moving the holding pond is more economical than replacing the existing pipe (see Figure 2).

**Design.** 10WE designed channels and diversion structures for the storm water conveyance system. 10WE used *Design of Small Canal Structures* to design safe and effective structures. A sedimentology specialist may review the design to analyze long-term channel conditions. The channels and diversion structures were constrained by economic, health and safety, and constructability factors.

Economic constraints were a factor in this design. 10WE minimized the size, length, and quantity of hydraulic structures. As the channel length increases, more materials, time, and work are necessary to complete construction. These factors increased the cost of the project. As the size and quantity of diversion structures increased, construction costs also increased.

The health and safety of the public is an important factor to consider. All structures were designed to government standards and with adequate factors of safety. This prevents failure that could risk public health and safety.

Constructability was important to consider. Many constructability factors were related to economic factors. 10WE designed simple and economical channels and diversion structures. 10WE avoided harming wetlands to the extent possible during design. Additionally, saturated soil and slope instability may cause construction equipment to sink or overturn. 10WE considered saturated conditions to ensure the safety of construction workers.

The final channel alignment governed channel design. 10WE designed the channels to avoid wetlands and transport the water to the new holding pond. Mitigating disturbed wetlands is expensive. Therefore, 10WE decided to expand the existing canals to convey the water and avoid the wetlands. 10WE looked at maps of the area to determine what channels could be used to convey the water to the new holding pond location. With the assistance of the EPE, 10WE selected the final channel alignment.
The next step in channel design was to size the existing channels for the 100-year design storm. 10WE used the outflow hydrograph to determine the flow rates for each channel (Figure 5).

![Figure 5. Channel Reaches](image)

10WE used elevation and aerial photography in AutoCAD Civil 3D to plot the existing channels. 10WE created profile plots of the existing ground surface for each channel (Figure 6).

![Figure 6. Profile Plot](image)
Using the profile plots, 10WE determined the channel bed slopes. Each time the flow rate or channel bed slope changed, 10WE designed a unique cross section. Under the direction of the EPE and the FA, 10WE used Manning’s equation to design each cross section. 10WE ensured channel geometry followed standards from Logan City’s *Cache Valley Storm Water Design Standards*. The USBR manual *Design of Small Canal Structures* provided specifications for the freeboard requirements.

Figure 7 shows a map of every cross section. The number and letter for each cross section corresponds to a table displaying the geometry for each cross section. Table 3 contains the geometry of each section on Reach 5(2). Appendix VI contains cross sections and tables for every channel. Detailed calculations for the channel geometry are contained on the flash drive.

![Figure 7. Channel Cross Sections](image)

**Table 3. Reach Summary**

<table>
<thead>
<tr>
<th>Plan View Key</th>
<th>Station</th>
<th>Flow (cfs)</th>
<th>Slope</th>
<th>Base (ft)</th>
<th>Depth (ft)</th>
<th>Side Slope</th>
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<tr>
<td>5(2)A</td>
<td>3036+00</td>
<td>97.79</td>
<td>0.0065</td>
<td>3</td>
<td>3.7</td>
<td>3</td>
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<tr>
<td>5(2)B</td>
<td>3018+37</td>
<td>97.79</td>
<td>0.0006</td>
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<td>5.0</td>
<td>3</td>
</tr>
<tr>
<td>5(2)C</td>
<td>3000+00</td>
<td>97.79</td>
<td>0.0006</td>
<td>f</td>
<td>5.0</td>
<td>3</td>
</tr>
</tbody>
</table>
Using the section lines, 10WE created a plot of the ground surface at every location. 10WE drew cross sections to calculate cut volumes and top scrape areas. 10WE used this data in the economic analysis. Figure 8 shows a section view of station number 3018+37.

![3018+37.05](image)

**Figure 8. Section View**

The bottom axis represents distance in feet from the centerline of the channel. The left and right axes display channel elevation in feet. 10WE created similar section views for every cross section shown in Figure 7. The area between the pink lines represents the soil that must be excavated along the channel. 10WE used the end area method to calculate total cut volumes and scrape areas (Appendix VI).

In the area of interest, there are multiple owners of surface water rights. The owners of surface water rights are legally entitled to have access to the water at any time during the year. 10WE designed two reinforced concrete diversion structures to ensure the owners have access to the water (see Figure 5). 10WE designed the diversion structures under the direction of the EPE in compliance with the ACI Building Code, *Building Code for Requirements for Structural Concrete*. Calculations are shown in Appendix VI. 10WE designed the diversion structures as cantilever retaining walls.

The entire area of interest was assumed to be wetlands for the cost estimate. Local water rights and the layout of the channels governed the location of the diversion structures. Therefore, 10WE did not attempt to avoid wetlands when determining the location of the diversion structures.
10WE began diversion structure design after the width of the channels and flow through the channels were designed. Under the direction of the EPE, twelve-inch diameter head gates were selected to ensure water right owners are provided with three to five cubic feet of water per second. The owners of the water rights will use a Waterman C-10 12-inch Canal Gate, or an equivalent gate, based on specifications provided by the manufacturer (see Appendix I) (Waterman Industries, 2017). 10WE designed a weir to pass the maximum flow to the polishing ponds when the head gate is closed. The top widths of the channel and the existing diversion canal determined the length of the structure (see Figure 9). 10WE designed both diversion structures using the same method. Figures of diversion structure 2 are in Appendix V.

![Figure 9. Structure 1 View BB](image)

Once the initial dimensions of the structures were calculated, 10WE determined the base width of the structure through trial and error. 10WE minimized the size of the structure due to economic constraints. 10WE used the following safety factors for design: 1.5 for overturning, 2 for sliding, and 3 for bearing capacity.

To prevent sliding, 10WE could have increased the width of the structure or added a cutoff wall. Adding a cutoff wall was more economical. Additionally, the cutoff wall controls seepage under the structure (see Figure 10). 10WE assumed the specific weight of the soil was 100 pounds per cubic foot, and the friction angle of the soil was 30 degrees.
The structures will have 1.5 feet of soil on top of the foundation. 10WE designed diversion structure 1 to be embedded in 3 feet of soil on each side and diversion structure 2 to be embedded in 5 feet of soil on each side. Using Google Earth, 10WE calculated the angle required for the design of the diversion structures (see Figure 11).
10WE calculated the necessary amount of reinforcing steel. The design complies with the ACI Building Code minimum area of reinforcing steel for temperature shrinkage. 10WE designed the reinforcing steel to be embedded in three inches of concrete because the structure is in contact with soil and water.

When the diversion structures are constructed, the contractor will need to stabilize the soil to prevent differential settlement. The contractors must excavate the area to a depth of 18 inches and backfill with 12 inches of 3-inch diameter rock. The contractors will continue to consolidate the soil and add rock until the area stabilizes. Once the area stabilizes, the contractors will add 6 inches of crushed, well-graded aggregate with a maximum particle size of ¾-inch. Contractors will compact the area to 95% of standard proctor. Once this has occurred, the contractors may build the diversion structure.

10WE designed riprap to prevent scour on the downstream side of the structure. Scour could undermine the foundation, causing failure. 10WE calculated the plunge velocity of the water and the appropriate gradation of riprap required to prevent scour. The design specifies that the riprap be 24 inches deep and extend 10 feet downstream (see Table 4 and Table 5).

### Table 4. Diversion Structure 1 Riprap

<table>
<thead>
<tr>
<th>Lower Range</th>
<th>Higher Range</th>
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<tbody>
<tr>
<td>ft in lbs</td>
<td>ft in lbs</td>
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<tr>
<td>D&lt;sub&gt;100&lt;/sub&gt;</td>
<td>0.91 10.90 64.76</td>
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</tr>
<tr>
<td>D&lt;sub&gt;15&lt;/sub&gt;</td>
<td>0.49 5.87 10.12</td>
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### Table 5. Diversion Structure 2 Riprap

<table>
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<th>Higher Range</th>
</tr>
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<td>ft in lbs</td>
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<td>D&lt;sub&gt;100&lt;/sub&gt;</td>
<td>1.53 18.31 306.76</td>
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<td>1.21 14.53 153.38</td>
</tr>
<tr>
<td>D&lt;sub&gt;15&lt;/sub&gt;</td>
<td>0.82 9.86 47.93</td>
</tr>
</tbody>
</table>

10WE’s post-construction recommendations for Logan City are: 1) mow banks of each channel annually; 2) conduct a system inspection yearly and after a storm that exceeds the 20-year event to ensure that all channels and diversion structures are operating as designed.
An alternative to this design is to install about 8.6 miles of box culvert instead of expanding the existing canals. The estimated cost of this alternative is $68.3 million dollars. Therefore, 10WE selected the design presented in this report.

**Final Report.** The objective of this project was to deliver this final report to Logan City on the design of a storm water conveyance system. The FA and EPE approved all final designs, construction drawings, and estimated costs before 10WE submitted this final report. Construction of this design is dependent upon approval by Logan City Council. Contractors will review this design report during the bidding process.

**Budget**

10WE incurred travel expenses during the field investigation. These expenses and the estimated cost of the project are outlined below.

**Team Expenses**

Per the Internal Revenue System (IRS 2016), the “standard mileage rates for the use of a car” is reimbursed at 54 cents per mile driven for business purposes. Consequently, the travel reimbursement to date is $24.30 (Appendix VI). However, 10WE is volunteering their time and will not actually be reimbursed by Logan City.

**Estimated Cost**

The total estimated cost of the project is $12.4 million. This cost includes design, materials, excavation, wetland mitigation, relocating pump stations, and purchasing land (Appendix VI). All construction costs were estimated under the direction of the EPE.

**Conclusion**

This design focused on transporting storm water from 1000 West to a holding pond. The water is pumped from the holding pond into the polishing ponds for treatment. The treated water is discharged into Swift Slough. Logan City’s interest in this project highlights the possibility of implementing this design.

The negative environmental impact of untreated storm water affects water bodies downstream of Logan City. Collecting and treating storm water could prevent pollution, which contributes to removing Cutler Reservoir, Swift Slough, and the Lower Bear River from the EPA’s list of impaired waters.

Conveying storm water to the holding ponds and through the polishing ponds has three benefits. First, flood risk is minimized. Second, pollutant discharge is decreased. Third, Logan City uses infrastructure that would otherwise be abandoned.
LOWE cooperated with Cutler Engineering and Westside Drainage Solutions to design a storm water conveyance and treatment system. Together, these teams provided a long-term sustainable solution for Logan City’s storm water management system.
Reflective Writing

My participation in the Civil and Environmental Engineering Design Sequence (CEEDS) was a growing experience for three reasons. First, I learned how the design process works. Second, I gained experience overcoming challenges and delays. Third, I learned from each of my team members and became a better leader because of them.

We began the project by meeting with Lance Houser, the Assistant City Engineer for Logan City. As we met with Lance, we outlined the scope of the project. This experience was valuable because it was an open-ended problem that wasn’t from a textbook. It was up to us to evaluate and analyze what parameters would be important. I enjoyed this because it helped me realize that a thorough understanding of the problem isn’t sufficient. It was necessary for us to understand all of the elements that were connected to the problem and how they influenced the problem. We spent a great deal of time understanding as much as we could about the problem. This helped us create a better solution. I believe that the ability to understand a problem is directly proportional to the ability to develop an effective solution efficiently. In other words, this experience reinforced the fact that it’s difficult to fix something that you don’t know is broke—or how it broke in the first place.

The next phase of the process was to collect data and evaluate alternative designs. This process was helpful because I was able to apply what I had learned about economic analysis and quantify why some alternatives were better than others. It was satisfying to present an alternative to our client with a monetary benefit associated with it.

One of my main contributions to the project was to create a 100-year storm event. This was rewarding because I was able to apply the theory and concepts I learned in CEE 3430 (Hydrology). I was expected to scientifically determine the amount of runoff that would be generated in subdivisions and industrial areas. This was difficult because I had never done this before. Once the design storm was approved, I was extremely satisfied knowing that I succeeded in applying what I had learned in my course. This helped me look forward to applying principles that I understand to solve a variety of problems.

Understanding the design process was helpful because now I have a better idea what to expect in my career. Most of the coursework in the department focuses on covering theory and application. However, I don’t recall ever understanding how it all fit into the big picture. This design process did that for me. It helped to see how technical knowledge is necessary, but not sufficient. Economic, social, and constructability factors constrained the design.

Compiling the design report was the most frustrating part of the project. It was frustrating because I felt that I was expected to perform at a high standard without being provided sufficient tools to help me elevate my performance to meet the expectations. During this process, technical writing help wasn’t provided to assist students in the class. However, I took our design report to technical writers on campus who helped me improve the language mechanics of the report. During these visits, I found myself correcting the report before the technical writers caught errors. This was an extremely rewarding feeling. Although, it wasn’t an easy learning process, I felt that I learned technical writing better than I would have otherwise.
As the team leader, I had the primary responsibility to communicate with the client and External Professional Engineer (EPE). This was often difficult because he was unresponsive. I attempted steadily for 3 months to establish contact and was unsuccessful. This was demotivating and frustrating. Looking back, I realized that I could have leveraged a contract that was signed by our team and the EPE to hold the EPE accountable. I believe that I could have done this in a professional and empathetic way. I understood that the EPE was busy, but I could have prevented a great deal of frustration if I had gone to the EPE’s office and spoken directly about how we as a team were feeling because of his neglect. I think that the ability to express feelings and perspectives openly helps prevent and resolve conflict. I could have done better at developing this ability.

I felt that we used our time wisely throughout the entire course of the project. We focused on creating detailed agendas to help attendees prepare for the meeting. The agendas enabled us to use the time we were together to make decisions and receive feedback. Minimal time was spent updating each other because that was taken care of mainly over email. It was extremely rewarding to complete the final design report on schedule even when our final report file became corrupted. This was rewarding because even though there were many things we couldn’t control, we accomplished everything that we did have control over.

I enjoy coordinating with people. As the team leader, I felt that I learned a lot from each of my team members. I learned to be more thorough and detail oriented in design. I learned to think through problems and analyze each component of a project. I also experienced the creativity and synergy that can come from a group that trusts and values each other’s opinions. I became a better leader because of the strengths of my team members.

For engineering students preparing for their senior design project I would emphasize the importance of initiative. It is essential to meet deadlines. Mentors are busy people and they don’t get paid extra money to assist and supervise you. I would also emphasize that students spend time selecting a team that they can work with and invest in open communication to build trust as a team. This will pay dividends all throughout the design process.

The CEEDS process was helpful because I learned that it is worth every effort to develop a deep understanding of the problem because this is an essential in order to solve the problem. I also learned how to manage setbacks and delays in a project. Finally, I felt that I was able to learn from the skills and abilities of my team members.
Citations


Appendix I: Data
Atterberg Limits Data Sheet
ASTM D4318-10

Project Name: Boudrego Pond
Location: 1405 W 1000 N
Boring No: #1 at CP1
Sample Depth: 12-24 inches

Tested By: Tyson Glover
Checked By: Curtis Brown
Date: 10/4/16

Test Number: 1

Sample Depth: __12-24 inches__

USCS Soil Classification: Fat Clay (CH)

<table>
<thead>
<tr>
<th>TEST</th>
<th>PLASTIC LIMIT</th>
<th>LIQUID LIMIT</th>
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<td>Variable</td>
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<td>Number of Blows</td>
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<td>blows</td>
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<td>Can Number</td>
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<td>---</td>
</tr>
<tr>
<td>Mass of Empty Can</td>
<td>$M_C$</td>
<td>(g)</td>
</tr>
<tr>
<td>Mass Can &amp; Soil (Wet)</td>
<td>$M_{CMS}$</td>
<td>(g)</td>
</tr>
<tr>
<td>Mass Can &amp; Soil (Dry)</td>
<td>$M_{CD0}$</td>
<td>(g)</td>
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<td>Mass of Soil</td>
<td>$M_s$</td>
<td>(g)</td>
</tr>
<tr>
<td>Mass of Water</td>
<td>$M_w$</td>
<td>(g)</td>
</tr>
<tr>
<td>Water Content</td>
<td>w (%)</td>
<td></td>
</tr>
</tbody>
</table>

Liquid Limit (LL or $w_L$) (%): 75
Plastic Limit (PL or $w_p$) (%): 58
Plasticity Index (PI) (%): 17
USCS Classification: CH

PI at "A" Line = 0.73(LL-20)
One Point Liquid Limit Calculation:
$LL = w_n(N25)^{0.12}$

PROEDURE USED

- Wet Preparation Multipoint
- Dry Preparation Multipoint
- Procedure A Multipoint
- Procedure B One-Point

14.333 Atterberg Limits Worksheet Revised 02/13

Figure 12. Atterberg Limits Soil Test 1
Atterberg Limits Data Sheet
ASTM D4318-10

Project Name: Boulston Pond
Location: 1405 W 1000 N
Boring No: #2 at North End
Sample Depth: 12-24 inches

Tested By: Tyson Glover
Date: 10/4/16
Checked By: Curtis Bown
Date: 10/4/16

USCS Soil Classification: Fat Clay (CH)

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<thead>
<tr>
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<td>blows</td>
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<td>%</td>
<td>50.9</td>
<td>53.1</td>
<td>64.6</td>
<td>76.7</td>
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Liquid Limit (LL or wL) (%): 71
Plastic Limit (PL or wP) (%): 52
Plasticity Index (PI) (%): 19
USCS Classification: CH

PI at "A" Line = 0.73(LL-20)
One Point Liquid Limit Calculation:
LL = w_p x(N/25)^0.15

<table>
<thead>
<tr>
<th>PROCEDURE USED</th>
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<tbody>
<tr>
<td>Wet Preparation Multipoint</td>
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<tr>
<td>Dry Preparation Multipoint</td>
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<td>Procedure A Multipoint</td>
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</tr>
<tr>
<td>Procedure B One-Point</td>
<td></td>
</tr>
</tbody>
</table>

y = -27.1ln(x) + 155.6
R^2 = 0.8531

Figure 13. Atterberg Limits Soil Test 2
Drainage Area Characteristics

Table III. Drainage Basin Characteristics

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<th>Basin #</th>
<th>Hydrologic Soil Group Classification</th>
<th>Area (Acres)</th>
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Canal Gate Specifications

C-10 CANAL GATE

This gate is designed for use on canal and pipeline systems which operate at low "heads" and where a moderately priced gate is desired. Typical installations include: farm runoffs, control of industrial wastes, drainage, and for tide control.

Construction is of grey iron with an all-bolted steel frame with 3/8" minimum thickness. The standard stem is of a special leaded steel which resists corrosion. The stem is operated at the structural frame top by a heavy cast-bronze lift nut and a cast iron wheel.

Adjustable cast iron wedge blocks, held securely in place by two machine bolts, assure a dependable seating closure with a practical degree of water tightness. The cast iron seats are machined or ground. A solid rim "easy-grip" handwheel is standard.

Optional materials include: bronze seats; stainless steel structural frame and bolts; stainless steel or brass stems; and special epoxies, coal tar or ASTM galvanized coatings.

When desired, design variation in stem diameter, pitch and thread rotation are available to match existing equipment. Extended stems, special lifts, oil seals, stem guides and limit nuts are a few of the optional items available for use with these gates.

Various sizes and options are available.

Special materials available include: "Ni-Resist" iron castings, stainless steel structural frame and assembly bolts; total galvanizing per ASTM A-123, coal tar, and epoxy coatings.

Recommended Maximum Seating Heads

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<tr>
<th>Size</th>
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<tbody>
<tr>
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<td>23 foot head</td>
</tr>
<tr>
<td>30&quot;</td>
<td>11 foot head</td>
</tr>
<tr>
<td>42&quot;</td>
<td>9 foot head</td>
</tr>
<tr>
<td>54&quot;</td>
<td>6 foot head</td>
</tr>
</tbody>
</table>

Recommended Maximum Unseating Head - 0

Frame Types for Various Installation Requirements

- F: Flatback for headwall mounting
- SB: Spigotback for annular or recirc spiral corrugated pipe
- CIP: For solvent cement mounting over plastic pipe
- C: With galvanized steel tapered setting collar for concrete or asbestos cement pipe
- SA: Spigotback for annular corrugated pipe
- TYPE 4: For mounting in plastic pipe utilizing special two part epoxy

Features 3/8" minimum thickness. Compare to competitor’s gates.

Waterman Model C-10 wedging system offers two point adjustment and larger wedging surfaces for a more positive contact.
CL-10 CANAL GATE

Waterman CL-10 Canal Gates are identical to our model C-10 Gates with the exception of the cast iron cover (slide) which is of a flat plate type construction with ribs reinforcing its face, to withstand the maximum heads as noted for our C-10 gates. This gate cover also features a square bottom design, which allows a more open "clog-free" flow at points of initial opening. The seat being only slightly raised above the cover plate surface helps prevent trash from collecting behind the cover which can cause difficulty in operation.

Available with threaded thrust nut for true NRS application. All parts are interchangeable with our Standard C-10 gate. Available in a variety of sizes.

Part List:

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Qty.</th>
</tr>
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<tbody>
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<td>Frame</td>
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<tr>
<td>2</td>
<td>Cover</td>
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<td>3</td>
<td>Wedge (R.H.)</td>
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<tr>
<td>4</td>
<td>Gate Rod (R.H.)</td>
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<td>5</td>
<td>Headrail</td>
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<td>6</td>
<td>Stem</td>
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<td>7</td>
<td>Handwheel</td>
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<td>8</td>
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<td>9</td>
<td>U-H Nut</td>
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<tr>
<td>10</td>
<td>Wedge Bolt</td>
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<td>11</td>
<td>Wedge Nut</td>
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<tr>
<td>12</td>
<td>Frame Bolt</td>
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<tr>
<td>13</td>
<td>Frame Nut</td>
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<td>Collar Nut</td>
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<td>16</td>
<td>Stop Bolt &amp; Nut</td>
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<tr>
<td>17</td>
<td>Unit Nut (optional)</td>
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* With set screw

**Shown with optional threaded thrust nut for true non-rising stem operation**
C-10 CANAL GATE

PARTS LIST

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Qty</th>
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<td>1</td>
<td>Frame</td>
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<td>Cover</td>
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<tr>
<td>5</td>
<td>Nut Screw</td>
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<tr>
<td>8</td>
<td>Bolt or rivet</td>
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<tr>
<td>9</td>
<td>Lift Collar</td>
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<tr>
<td>10</td>
<td>Handwheel</td>
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<td>11</td>
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<tr>
<td>12</td>
<td>Land Nut</td>
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</table>

BOLT DIA = Q

NOTES
1. TYPE 2 lubricated ball bearing lift used on 45° and larger gates.
2. Applies to swingback gate only. Optional spigot, shown in separate detail.
3. All dimensions are also applicable for model CL-10 & CM-10 gates.
4. Add grout pad thickness in addition to bolt projection.
5. Type 3221 lift used, mounted to dual head rail.

GATE DIMENSIONS IN PRACTICAL
Appendix II: Meeting Minutes
December 13, 2016 Minutes

Tuesday, December 13, 2016; 3:30pm – 5:00pm

Location
UWRL 2nd Floor Conference Room

Meeting Attendees:
Beck, Kade; Houser, Lance; Gordon, Megan; Johnson, Mike; Weller, Ryan

1. 3:55 – Welcome – Lance Houser
2. 3:57 – Follow-up – Mike Johnson
   a. Discussion of Interim Report
3. 4:00 – Discussion – Lance Houser
   a. Channels
      i. Lance and Kade will finalize design storm after the meeting
      ii. Ryan and Lance will size channels over the break
         1. 1ft freeboard required
         2. Vegetated side slope of 2:1 or 3:1
         3. Velocity below 2-3 cfs
         4. Safety factor on flows
         5. Use normal manning’s coefficient and excel
   b. Diversion Structures
      i. 2 diversion structures needed for water rights
      ii. Head gate with fixed orifice \( Q = 0.61 * A_0 * \sqrt{2 * g * \Delta h} \)
      iii. Assume gate will be full open
      iv. Bypass weir at 5 cfs per mentor’s advice
      v. Concrete
         1. 12in thick walls
         2. 2 mats of steel/rebar
         3. Cantilever/retaining wall design
         4. Size footing for no water downstream
         5. Cutoff wall to prevent seepage
         6. Check for overturning
         7. Assume 4000psi concrete
         8. Waterman head gates, use bolt pattern
         9. Use same structures and worse case
      vi. Culverts as needed
   c. Final Drawings
      i. Plan to overview and cross section at key locations
      ii. Standard cross sections
      iii. Locate and define grade breaks
   d. Groundwater
      i. Aquiclude
      ii. Surface water does not penetrate into groundwater
      iii. Signed memo from Lance approving aquiclude assumption
e. Cost
   i. Channels
      1. Assume the channel is filled in to begin with for estimating soil to be removed
      ii. Ryan will work on costs and be given standard bid/estimate sheets
      iii. Material, foundation, excavation, grading, excess material to landfill, mobilization, culverts, wetland, pollution
   f. Final Report
      i. Start around Spring Break

4. 1:00 – Timeline/Procedure – Kade Beck
   a.

5. 4:45 – Task Summary – Megan Gordon
   a.

6. 4:50 – Next Meeting Time – Kade Beck, Lance Houser, Megan Gordon, Ryan Weller
   a. Lance Houser and Ryan Weller will meet Monday, December 19, 2016 at 8am to go over channel sizing
   b. Kade Beck, Lance Houser, and Megan Gordon will meet Tuesday, January 10, 2017 at 3:30pm to work on diversion structures
   c. Both meetings will be held at Logan City
   d. Next meeting with both mentors will be to approve economics

7. 5:00 – Adjournment – Lance Houser
January 20, 2017 Minutes

Friday, January 20, 2017; 9:25am – 10:10am

Location
ASCE Study Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. 9:25 – Welcome – Kade Beck
2. 9:26 – Follow-up and Discussion – Kade Beck, Megan Gordon, Ryan Weller
   a. Bearing Capacity is still needed from the Westside group
   b. Channels
      i. Could not get the file to work and met with ArcGIS specialists for help
      ii. Received new imagery and DEM files, working to import them into Civil 3D
      iii. Will use all existing channels
         1. Kade had excluded two channels in his analysis and we will edit numbers and not redo design storm
      iv. Ryan will meet with Lance this Tuesday if needed, if not Ryan will meet with Lance next Tuesday for final approval
      v. Channels should be done by February 1, 2017
   c. Economics and Resizing Culverts
      i. Kade will wait to begin until channels and diversion structures are finalized
   d. Diversion Structures
      i. Begin making spreadsheet with tentative values
      ii. Lance will put pressure on Westside for bearing capacity
3. 9:37 – Timeline/Procedure – Kade Beck
   a. Progress Report 1
      i. Turn in by February 6, 2017 at 5pm
      ii. Need report back by February 9, 2017 at 5pm
   b. Progress Report 2
      i. Turn in by March 3, 2017 at 5pm
      ii. Need report back by March 9, 2017 at 5pm
   c. Final Report
      i. Turn in by April 17, 2017 at 5pm
      ii. Need report back by April 20, 2017 at 5pm
   d. Meeting with Lance, Mike, and all group members
      i. March 14, 2017 at 3:30pm in the UWRL 2nd Floor Conference Room
4. 10:07 – Task Summary – Megan Gordon
   a. Ryan will work on channel cross sections and slopes
   b. Kade will email Lance and Mike about dates to approve reports and meet
   c. Megan will begin making a spreadsheet for diversion structures
5. 10:08 – Next Meeting Time – Kade Beck
a. Friday, January 27, 2017 at 9:30am in the ASCE Study Room
b. Tuesday, March 14, 2017 at 3:30pm in the UWRL 2nd Floor Conference Room

6. 10:10 – Adjournment – Kade Beck
Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. 9:30 – Welcome – Kade Beck
2. 9:30 – Follow-up
   a. Covered in discussion
3. 9:32 – Discussion – Kade Beck, Ryan Weller
   a. Progress Report 3
      i. We will not revise the Gantt Chart yet, just discuss changes
      ii. Design will be done February 28th
      iii. Team Mentor Meeting
         1. Expectation for final report
         2. Base flows
         3. Culvert and diversion structures
         4. Groundwater concerns
            a. Need technical memo from Lance
   b. Design of channels
      i. Difficulty with spatial references in program
      ii. Finish design by February 10th and have the design be approved by Lance in meeting February 14th
   c. Team leader presentation
      i. Discussed presentation
      ii. Practiced presentation
4. 10:25 – Timeline/Procedure – Kade Beck
   a. Finish design by February 28th
   b. Begin working on the Final Report March 1st
   c. Send progress report to Lance by February 6th at 5pm
5. 10:28 – Task Summary – Megan Gordon
   a. Megan Gordon will write the progress report and have it finished by February 3rd
   b. Ryan Weller will complete the channel design
   c. Kade Beck will complete the team leader presentation and send the progress report to Lance for approval by February 6th at 5pm
   d. Kade and Ryan will review the progress report
6. 10:29 – Next Meeting Time – Kade Beck
   a. Monday, February 6, 2017 at 7:45 am in ENLAB 235 B
7. 10:30 – Adjournment – Kade Beck
March 2, 2017 Minutes

Thursday, March 2, 2017; 3:00 pm-5:00 pm

Location
Lance Houser’s Office

Meeting Attendees:
Beck, Kade; Gordon, Megan; Houser, Lance; Weller, Ryan

1. 3:00 – Welcome – Lance Houser
2. 3:10 – Follow-up – Lance Houser
   a. See Discussion
3. 3:11 – Discussion – Lance Houser
   a. Channels
      i. Limited by the quality of data available
      ii. Channel’s will not show due to the level of detail (5m DEM)
      iii. Cut vs. cut/fill channels
      iv. Excavation numbers sound appropriate
   b. Structures
      i. One wall will be poured
      ii. Pipe width of channel from field investigation
      iii. Sliding FS=2, Overturn FS=1.5
      iv. Frost depth at 30”, have bottom of foundation at 30”
      v. Weir crest at yo+.1ft, 6” freeboard when in use
      vi. Cantilever wall
      vii. 2 steel mats
      viii. Use 1ft sections for typical section in series of independent beams
   c. Cost
      i. Kade was given spreadsheet as basis
      ii. Filled out spreadsheet while discussing, see spreadsheet
      iii. Need rip rap downstream of diversion structures
         1. Ryan given spreadsheet to find gradation of rip rap
      iv. Need total soil excavation amounts
      v. Think of any other potential costs
      vi. Assume entire area is wetland and will be disturbed, $180,000 per acre of wetland destroyed
      vii. Beat $83.2 million
   d. Drawings
      i. Overview and key locations of channel cross sections
      ii. 1:100 scale appropriate for channels
      iii. Draw and send to Lance for red line (Megan and Ryan)
         1. Send by next meeting
   e. Groundwater
      i. Consider to find if it is important
      ii. Find data from the Soil Conservation Service
1. Depth to clay layer, pressure, permeability/hydraulic conductivity  
   iii. DWR well logs drilled near the area of interest for thickness to clay layer  
   iv. NRCS for physical properties and pick worst case  
   v. Darcy’s Law to estimate flow up through channel  

4. 4:40 – Timeline/Procedure – Kade Beck  
   a. By next meeting  
      i. Cost estimate  
      ii. Diversion structures  
      iii. Drawings  

5. 4:45– Task Summary – Lance Houser  
   a. Kade Beck will finish cost estimates and look into groundwater  
   b. Ryan will finish excavation amounts and channel drawings  
   c. Megan will finish diversion structures and drawings  

6. 4:55 – Next Meeting Time – Kade Beck  
   a. March 14, 2017 at 3:30 pm at the UWRL  

7. 5:00 – Adjournment – Lance Houser
March 23, 2017 Minutes

Thursday, March 23, 2017; 4:30pm - 5:05pm

Location
UWRL 2nd Floor Conference Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Houser, Lance; Johnson, Mike; Weller, Ryan

1. 4:50 – Welcome – Kade Beck
2. 4:50 – Follow-up
   a. See Discussion
3. 4:50 – Discussion – Kade Beck
   a. Channels
      i. Sections and tables need additional formatting
      ii. Check style guide after meeting
      iii. Profile is very long
         1. Tabular data with typical representation
         2. State to see complete file on drive in paper
         3. Overview with key that refers to table
   b. Structures
      i. Calculations are good so far
   c. Cost
      i. About $12.4 million
      ii. Cheaper than box and culvert along NW Field Canal
   d. Final Drawings
      i. Update after meeting
   e. Groundwater
      i. K is 0-0.06 in/hr with one location of 0.2 in/hr
         1. Throw out 0.2 in/hr (Lance Houser)
      ii. Well depth to water is 306ft with 20 psi artesian pressure at surface
   f. Presentation
      i. Invited to presentation on April 12th or 14th
      ii. Cover alternatives and design process
   g. Final Report
      i. Assignments have been made
      ii. Incorporate revisions
      iii. Send to Lance by April 19th
4. 5:00 – Timeline/Procedure – Kade Beck
   a. Presentation on April 12th or 14th
   b. Report to Lance by April 19th
5. 5:01 – Task Summary – Megan Gordon
6. 5:02 – Next Meeting Time – Kade Beck
   a. We have finished with meetings with both mentors
7. 5:03 – Adjournment – Kade Beck
March 24, 2017 Minutes

Friday, March 24, 2017; 9:25am - 10:20am

Location
ASCE Study Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. 9:25 – Welcome – Kade Beck
2. 9:25 – Follow-up
   a. See Discussion
3. 9:26 – Discussion – Kade Beck
   a. Updates
      i. Structures
         1. Meeting with Lance March 29th to finish going over calculations
      ii. Drawing
         1. Issues with elevations
         2. Annotate by hand
         3. Will re-snipe profile and work on plan view
            a. Data in table to coordinate with labels on diagrams
      iii. Groundwater
         1. Checked calculations
         2. Report velocity and flow for each one (as example of scale)
         3. Artesian conditions so the water is flowing upward
   b. Presentation
      i. North arrows
      ii. Costs for alternatives
      iii. Edit Gantt Chart to have final and projected on same chart
4. 10:10 – Timeline/Procedure – Kade Beck
   a. Meet Monday, March 27th at 7:30am in the ASCE Study Room
   b. Meet Wednesday, March 29th at 8pm in ENGR 301
   c. Meet Thursday, March 30th at 8pm in ENGR 301
   d. Rough Draft of entire paper completed by April 7th
      i. Kade and Megan will meet on April 7th at 9:30am in the ASCE Study Room to begin editing the paper
   e. Kade will finish editing the Interim Report by April 3rd at 5pm
5. 10:20 – Task Summary – Megan Gordon
   a. Kade
      i. Finish groundwater
      ii. Edit interim report
      iii. Work on slides for presentation
      iv. Work on section for paper
   b. Megan
i. Work on slides for presentation
ii. Work on section for paper
iii. Finish diversion structures
iv. Meet with Lance on March 20th at 3pm
v. Work on final paper

c. Ryan
   i. Update Gantt Chart
   ii. North arrows on pictures in presentation
   iii. Work on slides for presentation
   iv. Work on section for paper

6. **10:20 – Next Meeting Time** – Kade Beck
   a. Monday, March 27th at 7:30am in the ASCE Study Room

7. **10:20 – Adjournment** – Kade Beck
March 27, 2017 Minutes

Monday, March 27, 2017; 7:30pm - 8:20pm

Location
ASCE Study Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. 7:30 – Welcome – Kade Beck
2. 7:30 – Follow-up
   a. Kade checked other well logs in the area of interest and changed the depth to water to an average value
3. 7:52 – Discussion – Kade Beck
   a. Worked on compiling the presentation
   b. Assigned roles for presentation
   c. Conclusion: will discuss realistic expectations if we need to fill more time
4. 8:13 – Timeline/Procedure – Kade Beck
5. 8:15 – Task Summary – Megan Gordon
   a. Everyone will introduce themselves during the presentation
   b. Everyone will practice individually before the meeting on Wednesday
   c. Kade
      i. Overview, on-site treatment, do nothing alternative, design, conclusion
   d. Megan
      i. Objective, scope, site investigation, design, cost, Gantt chart
   e. Ryan
      i. Design, constraints
6. 8:20 – Next Meeting Time – Kade Beck
   a. Wednesday, March 29th at 8pm in ENGR 301
   b. Thursday, March 30th at 8pm in ENGR 106
7. 8:20 – Adjournment – Kade Beck
April 3, 2017 Minutes

Monday, April 3, 2017; 7:45am - 8:20am

Location
ASCE Study Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. 7:45 – Welcome – Kade Beck
2. 7:45 – Follow-up
3. 7:47 – Discussion – Kade Beck
   a. Paper
      i. Executive Summary
         1. Design and post-construction
         2. Methods
         3. Possibly re-write
      ii. Description
         1. Post-constructions
         2. Paragraph about how entire project relates before section on design storm
         3. Alternatives, methods, decisions
         4. Table with all alternatives and costs
      iii. Budget
         1. Revise to final estimate
         2. Take out mileage cost
      iv. Conclusion/References
         1. Add necessary information
      v. Appendices
         1. Add relevant calculations, figures, data, tables
         2. Gantt Chart for only 4880 (Ryan)
         3. Minutes for only this semester in paper, all on drive
         4. Total hours
         5. Re-write constraints to ensure it is not in passive voice
         6. Engineering tools
         7. Government regulations (ACI)
         8. Edit post-design risk
         9. Overcoming challenges
4. 8:15 – Timeline/Procedure – Kade Beck
   a. Rough draft of paper by April 7th at 9:30 am
5. 8:17 – Task Summary – Megan Gordon
   a. Rough draft of paper – all
      i. Include decisions, logic, and alternatives
   b. Kade:
      i. Edit and add to Interim Report as outlined above
ii. Talk to Lance about post-construction

c. Megan:
   i. Box and Culvert alternative
   ii. Finish diversion structure design
   iii. Ask Lance about Box and Culverts
   iv. Minutes for paper and drive

d. Ryan – Gantt Chart

6. **8:19 – Next Meeting Time** – Kade Beck

7. **8:20 – Adjournment** – Kade Beck
April 12, 2017 Minutes

Wednesday, April 12, 2017; 7:20 am - 8:25 am

Location
ASCE Study Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. 7:20 – Welcome: Kade Beck
2. 7:20 – Follow-up
3. 7:20 – Discussion: All
   a. Review respective writing portions
      i. Add North arrows
      ii. Find water rights?
      iii. No alternative table
      iv. Box and Culvert
      v. Add calculations
   b. Discuss submission guideline items left to be done
      i. Formatting appendices
         1. Everyone will add and format their own appendices
      ii. Technical writing review
         1. Kade will take to technical writing lab and complete changes
      iii. Update Lists of Tables and Figures
      iv. Format USB
         1. Everyone will add their own files
      v. Purchase new Binder (maybe new USB?)
         1. Megan will purchase new binder and USB
      vi. Update Special Summary Documentation
         1. Everyone will add code and software used
4. 8:15 – Discuss timeline for remainder of semester- Kade Beck
   a. Have edits done by Friday
   b. Ryan will add his appendices then give to Megan
5. 8:20 – Task Summary- Megan Gordon
   a. Kade:
      i. Take to technical writing lab and incorporate changes
      ii. Ask Lance about Box and Culvert
   b. Ryan:
      i. Ask Dr. Peralta about adding calculations from spreadsheet
      ii. Add appendices
   c. Megan:
      i. Buy USB and binder
      ii. Add appendices
   d. All will review the paper
6. 8:25 – Next Meeting Time – Kade Beck
a. May meet next week
7. 8:25 – Adjournment – Kade Beck
Appendix III: Person-hour work reports
## Team Member Work Record Summary Table

**Table III. Team Member Work Record Summary**

<table>
<thead>
<tr>
<th>Last Name</th>
<th>First Name</th>
<th>Role(s) on Team</th>
<th>Total work hrs for Fall 2016 &amp; Spring 2017 semesters</th>
<th>Signature (by hand is required)</th>
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<td>Beck</td>
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<td>Gordon</td>
<td>Megan</td>
<td>Structural Engineer, Technical Writer, Records Keeper</td>
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<td>Weller</td>
<td>Ryan</td>
<td>Faculty Liaison, Hydraulics and Geotechnical Engineer</td>
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**Individual Team Member Work Logs**

**Team:** 10th West Engineers  
**Individual:** Beck, Kade  
**Hours worked on team project:** (including class attendance)

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| Semester total | 81.25 |

**Certification by Individual**
I declare that I worked at least the number of hours I report above for each week during the semester.

12/7/2016  
Date

**Certification by Team Leader**
I believe that the above-reported hours are accurate.

12/7/2016  
Date
Team: 10th West Engineers  
Individual (last name, first name): Beck, Kade  
Hours worked on team project (including class attendance)  

<table>
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<tr>
<th>Week</th>
<th>Start Day</th>
<th>End Day</th>
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Semester total 48.75

Certification by Individual
I declare that I worked at least the number of hours I report above for each week during the semester.

4/15/2017  
Date

Certification by Team Leader
I believe that the above-reported hours are accurate.

4/15/2017  
Date
**Team:** 10th West Engineers  
**Individual (last name, first name):** Gordon, Megan  
**Hours worked on team project** (including class attendance)

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**Semester total**

55.00

**Certification by Individual**

I declare that I worked at least the number of hours I report above for each week during the semester.

12/6/2016

**Certification by Team Leader**

I believe that the above-reported hours are accurate.

12/6/2016
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Semester total: 75

Certification by Individual
I declare that I worked at least the number of hours I report above for each week during the semester.

15-Apr-17
Date

Certification by Team Leader
I believe that the above-reported hours are accurate.

15-Apr-17
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**Semester total**  
78.25

**Certification by Individual**  
I declare that I worked at least the number of hours I report above for each week during the semester.

12/6/16  
Date

**Certification by Team Leader**  
I believe that the above-reported hours are accurate.

12/6/16  
Date
Team: 10th West Engineers
Individual (last name, first name): Weller, Ryan
(including class attendance)

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Semester total: 73.75

Certification by Individual
I declare that I worked at least the number of hours I report above for each week during the semester.

4/15/2017
Date

Certification by Team Leader
I believe that the above-reported hours are accurate.

4/15/2017
Date
Appendix IV: Gantt Charts
Figure IV1. Final Gantt Chart

Figure IV2. Revised Gantt Chart
Figure IV3. Projected Gantt Chart
Appendix V: Photos
Figure V1. Aerial Photo of Area of Interest Current Conditions

Figure V2. Aerial Photo of Area of Interest New Holding Pond
Figure V3. AGRC, Elevation, TauDEM, Surface Water Rights

Figure V4. Channel Reaches
Figure V5. Profile Plot

Figure V6. Channel Cross Sections
Figure V7. Section View

Figure V8. Structure 1 View BB
Figure V9. Structure 1 View AA

Figure V10. Structure 1 Plan View
Figure V11. Structure 2 View BB

Figure V12. Structure 2 View AA
3.50" 2.75"

#4 Rebar with 6" Spacing
#4 Rebar with 12" Spacing

Figure V13. Structure 2 Plan View

Figure V14. Reach 1 Measurement Location
Figure V15. Reach 2 at Diversion Above Measurement Location

Figure V16. Reach 3 Measurement Location
Figure V17. Reach 4 Measurement Location
Appendix VI: Detailed Calculations
Flow Calculations

Reach 1:
Velocity:

Ping Pong Balls:

\[
\begin{align*}
\text{Time}_{1A} &= 11.8 \text{ s} & \text{Time}_{1B} &= 12.8 \text{ s} & \text{Time}_{1C} &= 11.3 \text{ s} & L_1 &= 16 \text{ ft}
\end{align*}
\]

\[
\begin{align*}
\text{Velocity}_{1A} &= \frac{L_1}{\text{Time}_{1A}} & v_{1A} &= 1.0847 \text{ ft/s}
\end{align*}
\]

\[
\begin{align*}
\text{Velocity}_{1B} &= \frac{L_1}{\text{Time}_{1B}} & v_{1B} &= 1 \text{ ft/s}
\end{align*}
\]

\[
\begin{align*}
\text{Velocity}_{1C} &= \frac{L_1}{\text{Time}_{1C}} & v_{1C} &= 1.1327 \text{ ft/s}
\end{align*}
\]

Cross Sections:

Culvert

\[
\begin{align*}
Y_{1A} &= 16 \text{ in} & Y_{1B} &= 7 \text{ in} & D &= 24 \text{ in}
\end{align*}
\]

\[
\begin{align*}
\theta_{1A} &= \cos^{-1}\left(1 - \frac{Y_{1A}}{D}\right) = 1.9106
\end{align*}
\]

\[
\begin{align*}
\text{Area}_{1A} &= \frac{D^2}{4} \left(\theta_{1A} - \sin(\theta_{1A}) \cos(\theta_{1A})\right) = 2.2249 \text{ ft}^2
\end{align*}
\]

\[
\begin{align*}
\theta_{1B} &= \cos^{-1}\left(1 - \frac{Y_{1B}}{D}\right) = 1.141
\end{align*}
\]

\[
\begin{align*}
\text{Area}_{1B} &= \frac{D^2}{4} \left(\theta_{1B} - \sin(\theta_{1B}) \cos(\theta_{1B})\right) = 0.7622 \text{ ft}^2
\end{align*}
\]

\[
\begin{align*}
\text{Area}_{avgl} &= \frac{\text{Area}_{1A} + \text{Area}_{1B}}{2} = 1.4936 \text{ ft}^2
\end{align*}
\]

Flows:

\[
\begin{align*}
Q_{1A} &= \frac{\text{Area}_{avgl} \times \text{Velocity}_{1A}}{s} = 1.6201 \text{ ft}^3/s
\end{align*}
\]

\[
\begin{align*}
Q_{1B} &= \frac{\text{Area}_{avgl} \times \text{Velocity}_{1B}}{s} = 1.4936 \text{ ft}^3/s
\end{align*}
\]

\[
\begin{align*}
Q_{1C} &= \frac{\text{Area}_{avgl} \times \text{Velocity}_{1C}}{s} = 1.6918 \text{ ft}^3/s
\end{align*}
\]

\[
\begin{align*}
Q_1 &= \frac{Q_{1A} + Q_{1B} + Q_{1C}}{3} = 1.6315 \text{ ft}^3/s
\end{align*}
\]
Reach 2:

Velocity:

Dye:

Plume \( A \) = 60 s + 33 s = 93 s
Plume \( B \) = 60 s + 58 s = 118 s

Plume \( \text{avg} \) \( A \) = \( \frac{L_{2A}}{2} \) = 105.5 s
Plume \( \text{avg} \) \( B \) = \( \frac{L_{2B}}{2} \) = 105.5 s

\( L_{2A} = 100 \text{ ft} \)

Ping Pong Balls:

\( \text{Time} \) \( A \) = 60 s + 44 s = 104 s
\( \text{Time} \) \( B \) = 60 s + 47 s = 107 s

\( \text{Vel} \) \( A \) = \( \frac{L_{2A}}{\text{Time}_{2A}} \) = 0.7692 ft/s
\( \text{Vel} \) \( B \) = \( \frac{L_{2B}}{\text{Time}_{2B}} \) = 0.7692 ft/s

Cross Section:

\( B = 10 \text{ ft} \)
\( Y_{2A} = 6 \text{ in} \)

Triangular cross section

\( \text{Area} \) \( 2A \) = \( \frac{BY_{2A}}{2} \) = 2.5 ft\(^2\)

Flows:

\( Q_{2A} = \text{Area} \) \( 2A \) \( \text{Vel} \) \( A \) = 2.3697 ft\(^3\)/s
\( Q_{2B} = \text{Area} \) \( 2B \) \( \text{Vel} \) \( B \) = 1.9231 ft\(^3\)/s
\( Q_{2C} = \text{Area} \) \( 2C \) \( \text{Vel} \) \( C \) = 1.8692 ft\(^3\)/s

\( Q_2 = \frac{Q_{2A} + Q_{2B} + Q_{2C}}{3} \)

\( Q_2 = 2.054 \text{ ft}^3/s \)
Reach 3:

Velocity:

\[ \text{Plume}\_3A = 60 \text{s} + 1 \text{s} = 61 \text{s} \]
\[ \text{Plume}\_3B = 60 \text{s} + 34 \text{s} = 94 \text{s} \]
\[ \text{Plume}_{\text{avg3}} = \frac{\text{Plume}\_3A + \text{Plume}\_3B}{2} = 77.5 \text{s} \]
\[ \text{Vel}_{3A} = \frac{L_3}{\text{Plume}_{\text{avg3}}} = 0.3355 \text{ ft/s} \]

Cross Section:

\[ Y_{3A} = 4 \text{ in} \]
\[ Y_{3B} = 5 \text{ in} \]
\[ Y_{\text{avg3}} = \frac{Y_{3A} + Y_{3B}}{2} = 4.5 \text{ in} \]
\[ B_{3A} = 6 \text{ ft} \]
\[ B_{3B} = 6 \text{ ft} \]
\[ Y_{\text{avg3}} = \frac{Y_{3A} + Y_{3B}}{2} = 4.5 \text{ in} \]
\[ B_{\text{avg3}} = \frac{B_{3A} + B_{3B}}{2} = 6 \text{ ft} \]
\[ \text{Area}_{3A} = B_{3A} Y_{\text{avg3}} = 2.25 \text{ ft}^2 \]
\[ \text{Area}_{3B} = B_{3B} Y_{\text{avg3}} = 2.25 \text{ ft}^2 \]
\[ \text{Area}_{\text{avg3}} = \frac{\text{Area}_{3A} + \text{Area}_{3B}}{2} = 2.625 \text{ ft}^2 \]

Flows:

\[ Q_3 = \text{Vel}_{3A} \text{ Area}_{\text{avg3}} \]
\[ Q_3 = 0.8806 \text{ ft}^3/\text{s} \]
Reach 4:

Velocity:

\[ \text{Plume}_4^A = 5 \, \text{ft} + 57 \, \text{s} = 357 \, \text{s} \]
\[ \text{Plume}_4^B = 8 \, \text{ft} + 4 \, \text{s} = 484 \, \text{s} \]
\[ \text{Plume}_4^A + \text{Plume}_4^B = 420.5 \, \text{s} \]
\[ \text{Plume}_{avg4}^4 = \frac{420.5 \, \text{s}}{2} \]
\[ \text{Vel}_4 = \frac{L_4}{\text{Plume}_{avg4}} = \frac{50 \, \text{ft}}{0.1189 \, \text{s}} \]

Cross Section:

\[ \text{Area}_4^A = 2.5 \, \text{ft} \]
\[ \text{Area}_4^B = 2.5 \, \text{ft} \]
\[ \text{Area}_4^A = 14 \, \text{ft} \]
\[ \text{Area}_4^B = 14 \, \text{ft} \]
\[ \text{Area}_4^A + \text{Area}_4^B = 35 \, \text{ft}^2 \]
\[ \text{Area}_{avg4} = \frac{35 \, \text{ft}^2}{2} \]

Flows:

\[ Q_4 = \text{Vel}_4 \, \text{Area}_{avg4} \]
\[ Q_4 = 4.161 \, \text{ft}^3 \]
Reach 5:

**Velocity:**

- **Dye:**
  - Plume\(5_A\) = \(60 s + 37 s = 97 s\)
  - Plume\(5_B\) = \(2 \cdot 60 s + 3 s = 123 s\)
  - \(\text{Plume}_{5A} + \text{Plume}_{5B} = 110 s\)
  - \(\text{Plume}_{\text{avg}} = \frac{\text{Plume}_{5A} + \text{Plume}_{5B}}{2}\)
  - \(L_5 = 100 \text{ ft}\)
  - \(V_{\text{avg}} = \frac{L_5}{\text{Plume}_{\text{avg}}} = 0.9091 \text{ ft/s}\)

- **Ping Pong:**
  - Time\(5_A\) = \(60 s + 38 s = 98 s\)
  - Time\(5_B\) = \(60 s + 37 s = 97 s\)
  - \(\text{Vel}_{5B} = \frac{L_5}{\text{Time}_{5A}} = 0.8163 \text{ ft/s}\)
  - \(\text{Vel}_{5C} = \frac{L_5}{\text{Time}_{5B}} = 0.8247 \text{ ft/s}\)

- **Area:**
  - \(B_{5A} = 78 \text{ in}\)
  - \(Y_{5A} = 6 \text{ in}\)
  - Area\(5A = B_{5A} Y_{5A} = 3.25 \text{ ft}^2\)
  - \(B_{5B} = 84 \text{ in}\)
  - \(Y_{5B} = 10 \text{ in}\)
  - Area\(5B = B_{5B} Y_{5B} = 5.8333 \text{ ft}^2\)

  - \(\text{Area}_{\text{avg}} = \frac{\text{Area}_{5A} + \text{Area}_{5B}}{2} = 4.5417 \text{ ft}^2\)

- **Flows:**
  - \(Q_{5A} = \text{Vel}_{5A} \text{ Area}_{\text{avg}} = 4.1288 \text{ ft}^3/s\)
  - \(Q_{5B} = \text{Vel}_{5B} \text{ Area}_{\text{avg}} = 3.7075 \text{ ft}^3/s\)
  - \(Q_{5C} = \text{Vel}_{5C} \text{ Area}_{\text{avg}} = 3.7457 \text{ ft}^3/s\)
  - \(Q_5 = \frac{Q_{5A} + Q_{5B} + Q_{5C}}{3} = 3.9607 \text{ ft}^3/s\)
Channel Design Calculations

Reach 1:

<table>
<thead>
<tr>
<th>Plan View Key</th>
<th>Station</th>
<th>Flow (cfs)</th>
<th>Slope</th>
<th>Base (ft)</th>
<th>Depth (ft)</th>
<th>Side Slope</th>
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<tbody>
<tr>
<td>1A</td>
<td>620+18</td>
<td>18.9</td>
<td>0.0022</td>
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<td>1B</td>
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<td>3</td>
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<td>1C</td>
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<tr>
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<td>4C</td>
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<tbody>
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<td>2500+00</td>
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Reach 5(2):

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<th>Depth (ft)</th>
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<td>3036+00</td>
<td>97.79</td>
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<tr>
<td>5(2)B</td>
<td>3018+37</td>
<td>97.79</td>
<td>0.0006</td>
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<tr>
<td>5(2)C</td>
<td>3000+00</td>
<td>97.79</td>
<td>0.0006</td>
<td>4</td>
<td>5.0</td>
<td>3</td>
</tr>
</tbody>
</table>

![Graph of Reach 5(2) A]  
![Graph of Reach 5(2) B]  
![Graph of Reach 5(2) C]
Diversion Structure Calculations
Channel Dimensions:

\[ b = 3 \text{ ft} \quad m = 3 \quad y_0 = 1.38 \text{ ft} \quad Q = 19.5 \text{ ft}^3/\text{sec} \]
\[ s = 0.009 \quad y_0 = 1.5 \text{ ft} \quad t_w = 18.77 \text{ ft} \quad d_t = 3 \text{ ft} \]
\[ T_w = b \times 2(m + d) = 21 \text{ ft} \quad W_c = 2 \text{ ft} \text{ Width of existing channel} \]

For construction purposes, \( y_0 \) is assumed to be 1.5 ft and total depth is 3 ft.

Head Gate:

\[ D = 1 \text{ ft} \quad \frac{y_0 - 0.5}{h_o} = 0.5 \text{ ft} \]

Orifice will be 6 inches from the bottom. Head is defined as the head at the midpoint of the orifice. Flow is assumed to fill the orifice.

\[ Q_o = 0.7 \cdot A_o \sqrt{2gh} \]
\[ A_o = \frac{b^2}{4} \cdot 0.7854 \text{ ft}^2 \]

\[ Q_o = 0.7 \cdot A_o \sqrt{2gh} = 3.1197 \text{ ft}^3/\text{sec} \]

Weir:

Weir crest will be at \( y_0 \). 1 ft of flow is assumed to be going over the weir. The most conservative assumption will be that the head gate is closed and that the weir will need to pass the entire flow.

\[ Q_w = 3 \cdot L \cdot h_w = 1.5 \quad \frac{L}{Q_w} = \frac{1}{3} \cdot h_w = 5 \text{ ft} \]

\[ Q_w = \frac{Q}{3 \cdot h_w} \]

Since the weir equation is not homogeneous, the values will need to be unitless.

\[ L = \frac{Q_w}{h_w} = 6.5 \text{ ft} \]

Structure:

Assume: \( \Phi = 30 \text{ (deg)} \quad \alpha = 0 \text{ (deg)} \quad k_a = 0.33 \quad Y_{\text{soil}} = 100 \frac{\text{lb}}{\text{ft}^3} \quad c' = 0 \quad \frac{\text{lb}}{\text{ft}^3} \quad k_p = 3 \]

\[ Y_{\text{water}} = 62.4 \frac{\text{lb}}{\text{ft}^3} \quad Y_{\text{concrete}} = 150 \frac{\text{lb}}{\text{ft}^3} \]

\[ V_w = V_{\text{water}} \quad V_c = V_{\text{concrete}} \quad V_s = V_{\text{soil}} \]
Overturning:

Area

\[ A_1 = 3 \text{ ft} \cdot 4 \text{ ft} = 12 \text{ ft}^2 \]
\[ A_2 = 1 \text{ ft} \cdot 5.25 \text{ ft} = 5.25 \text{ ft}^2 \]
\[ A_3 = 1 \text{ ft} \cdot 6 \text{ ft} = 6 \text{ ft}^2 \]
\[ A_4 = 3 \text{ ft} \cdot 1.5 \text{ ft} = 4.5 \text{ ft}^2 \]
\[ A_5 = 2 \text{ ft} \cdot 1.5 \text{ ft} = 3 \text{ ft}^2 \]
\[ A_6 = 8 \text{ in} \cdot 2 \text{ ft} = 1.3333 \text{ ft}^2 \]

Weight

\[ W_1 = A_1 \cdot \gamma_w = 748.8 \frac{\text{lb}}{\text{ft}} \]
\[ W_2 = A_2 \cdot \gamma_w = 787.5 \frac{\text{lb}}{\text{ft}} \]
\[ W_3 = A_3 \cdot \gamma_w = 900 \frac{\text{lb}}{\text{ft}} \]
\[ W_4 = A_4 \cdot \gamma_w = 450 \frac{\text{lb}}{\text{ft}} \]
\[ W_5 = A_5 \cdot \gamma_w = 300 \frac{\text{lb}}{\text{ft}} \]
\[ W_6 = A_6 \cdot \gamma_w = 200 \frac{\text{lb}}{\text{ft}} \]

Moment Arm

\[ MA_1 = 3 \text{ ft} \cdot \frac{3 \text{ ft}}{2} = 4.5 \text{ ft} \]
\[ MA_2 = 2 \text{ ft} \cdot \frac{1 \text{ ft}}{2} = 2.5 \text{ ft} \]
\[ MA_3 = 6 \cdot \frac{\text{ft}}{2} = 3 \text{ ft} \]
\[ MA_4 = 3 \text{ ft} \cdot \frac{3 \text{ ft}}{2} = 4.5 \text{ ft} \]
\[ MA_5 = \frac{2 \text{ ft}}{2} = 1 \text{ ft} \]
\[ MA_6 = 5 \text{ ft} \cdot \frac{1 \text{ ft}}{2} = 5.5 \text{ ft} \]

Moment

\[ M_1 = W_1 \cdot MA_1 = 3369.6 \text{ lb} \]
\[ M_2 = W_2 \cdot MA_2 = 1968.75 \text{ lb} \]
\[ M_3 = W_3 \cdot MA_3 = 2700 \text{ lb} \]
\[ M_4 = W_4 \cdot MA_4 = 2025 \text{ lb} \]
\[ M_5 = W_5 \cdot MA_5 = 300 \text{ lb} \]
\[ M_6 = W_6 \cdot MA_6 = 1100 \text{ lb} \]
\[ M = M_1 + M_2 + M_3 + M_4 + M_5 + M_6 = 11463.35 \text{ lb} \]
\[ P_c = \frac{5}{2} \cdot k_p \cdot h \cdot \frac{\text{cutoff}}{\gamma_w} = 600 \frac{\text{lb}}{\text{ft}} \]
\[ P_h = \frac{5}{2} \cdot k_a \cdot H \cdot \frac{\text{cutoff}}{\gamma_w} = 1031.25 \frac{\text{lb}}{\text{ft}} \]
\[ P_w = \frac{5}{2} (H - 1.25 \text{ ft})^2 \cdot \gamma_w = 780 \frac{\text{lb}}{\text{ft}} \]
Soil forces cancel out

\[ M_d = P_w \frac{H - 1.25 \text{ ft}}{3}, \quad P_c = 2^2 - h_{\text{cutoff}} = 2100 \text{ lb} \]

\[ \text{FS} = \frac{M}{M_d} = 5.4587 > 1.5 \]

Sliding:

Assume vertical weight is uniformly distributed

\[ W = \frac{W}{\text{Width}} = \frac{564.3833 \text{ lb}}{ft^2} \]

\[ W_{\text{cutoff}} = \frac{2 \cdot V}{\text{Width}} \cdot \frac{P - 100 \text{ lb}}{ft^2} \]

\[ F = \frac{w \cdot a}{s \cdot \text{cutoff}} = 286.2465 \frac{\text{lb}}{ft^2} \]

\[ F = \frac{P_w}{s \cdot \text{Width}} = 130 \frac{\text{lb}}{ft^2} \]

\[ \text{FS} = \frac{F}{F_s} = 2.2019 > 2 \]

Resisting Force is also in the banks

\[ W_e = 3 \text{ ft} \quad \text{Width of embedment on each side} \]

\[ D_e = 5.25 \text{ ft} \quad \text{Depth of embedment} \]

\[ p_e = \frac{w \cdot V_a}{a} = \frac{454.7813 \text{ lb}}{ft} \]

\[ F_e = 2.3 \text{ ft} \cdot p_e = 2728.6875 \text{ lb} \quad \text{Total resisting force from the embedment} \]

\[ F_{\text{eperfoot}} = \frac{F_e}{\text{Eper foot}} = 15.6021 \frac{\text{lb}}{ft^2} \]

\[ F_{\text{rn}} = \frac{F}{F_{\text{eperfoot}}} = 301.9286 \frac{\text{lb}}{ft^2} \]

\[ \text{FS}_{sn} = \frac{F_{\text{rn}}}{F_s} = 2.3225 \]

Bearing Capacity:

\[ M_{\text{net}} = M - M_d = 9363.35 \text{ lb} \]

\[ M_{\text{net}} = M \cdot X_{\text{bar}} \quad \text{X}_{\text{bar}} = \frac{M_{\text{net}}}{M} = \frac{h}{2} - X_{\text{bar}} \]
\[
q = \frac{W}{A} \cdot \frac{\text{net} \cdot Y}{1} \left( 1 - \frac{e}{w} \right) \cdot \frac{3}{12} \cdot \frac{3}{12} \cdot \frac{w}{12} \cdot \text{ft}
\]
\[
q_{\text{toe}} = \frac{W}{B} \left( 1 - \frac{6 - e}{B} \right)
\]
\[
q_{\text{heel}} = \frac{W}{B} \left( 1 - \frac{6 - e}{B} \right)
\]
\[
X_{\text{bar}} = \frac{W}{W} = 2.765 \text{ ft}
\]
\[
e = \text{Width} - X_{\text{bar}} = 0.2349 \text{ ft}
\]
\[
q_{\text{toe}} = \frac{W}{\text{Width}} \left( 1 - \frac{6 - e}{\text{Width}} \right) = 696.975 \frac{lb}{ft^2}
\]
\[
q_{\text{heel}} = \frac{W}{\text{Width}} \left( 1 - \frac{6 - e}{\text{Width}} \right) = 431.7917 \frac{lb}{ft^2}
\]
\[
\theta = \tan \left( \frac{F_h}{W} \right) \quad \text{and} \quad \frac{F_h}{p_w + p_h} = 883.125 \frac{lb}{ft}
\]
\[
\phi = \tan \left( \frac{p_h}{W} \right) = 0.2551 \quad \phi = \frac{180}{\pi} = 14.6168 \text{ (deg)}
\]
\[
B^* = \text{Width} - 2e = 5.5301 \text{ ft}
\]
\[
C' = 0 \quad \text{Therefore:}
\]
\[
q_u = 0.5 \cdot q \cdot N \cdot F \cdot F \cdot q_i \cdot 0.5 \cdot \gamma \cdot B^* \cdot N \cdot F \cdot F \cdot y_d \cdot y_c
\]
\[
\gamma = Y_w - Y_s = 37.6 \frac{lb}{ft^3}
\]
\[
D_s = 2.5 \text{ ft} \quad \text{depth of soil}
\]
\[
q = D_s \cdot \gamma = 94 \frac{lb}{ft^2}
\]
\[
\phi = 30, \quad N_s = 30.14 \quad N = 18.4 \quad N = 22.4 \quad Y
\]
\[
F_{yd} = 1 \quad F_{qd} = 1
\]
\[
F_qi = \left( 1 - \frac{\phi}{90} \right) = 0.7016
\]
\[
F_{yi} = \left( 1 - \frac{\phi}{90} \right) = 0.2629
\]
\[
q_u = 0.5 \cdot q \cdot N \cdot F \cdot F \cdot q_i \cdot 0.5 \cdot \gamma \cdot B^* \cdot N \cdot F \cdot F \cdot y_d \cdot y_c = 1825.7569 \frac{lb}{ft^2}
\]
\[
FS_{\text{req}} = \frac{q_u}{q_{\text{heel}}} = 4.2283
\]
Steel:

Flexural:

\[ F = 0.5 \{ \text{ft} \}^2 \cdot \gamma_w = 499.2 \text{ lb/ft} \]

\[ F = 0.5 \cdot k \cdot h \cdot \gamma_s = 103.125 \text{ lb/ft} \text{ Force of soil will cancel} \]

\[ M = F \cdot h = 665.6 \text{ lb} \]

\[ d = h - 3.5 \text{ in} = 8.5 \text{ in} \]

\[ f_c = 4000 \text{ psi} \quad f_y = 60000 \text{ psi} \]

Assume \( \Phi = 0.9 \)

\[ \lambda_{\text{min}} = \frac{b_w \cdot d}{\text{in}} \cdot \frac{\gamma_c}{\text{psi}} \cdot \frac{\text{in}^2}{\text{in}^2} = 0.3226 \text{ in}^2 \]

As \( \lambda_{\text{min}} \) is max of:

\[ \lambda_{\text{min}} = \frac{200 \cdot b_w \cdot d}{\text{in}} \cdot \frac{f_y}{\text{psi}} \cdot \frac{\text{in}^2}{\text{in}^2} = 0.34 \text{ in}^2 \]

\[ \lambda_{\text{min}} = 0.34 \text{ in}^2 \]

\[ a = \frac{A_s \cdot f_y}{0.85 \cdot f_c \cdot b_w} \quad M_n = \frac{M}{\Phi} \quad M_n = \frac{M}{n} \quad M_{n_s} = 739.5556 \text{ lb} \]

\[ M_n = A_s \cdot f_y \left( d - \frac{b}{2} \right) \quad \lambda_{\text{min}} = \frac{a - f_y}{2 \cdot 0.85 \cdot f_c \cdot b_w} \quad M_{n_s} = 4.7619 \cdot 10^{-7} \]

As \( \lambda_{\text{min}} \) governs

\[ \lambda_{\text{a}} = \lambda_{\text{min}} \cdot 0.34 \text{ in}^2 \]

Use 2 no. 4 bars.

\[ d_b = 0.5 \text{ in} \quad A_b = 0.20 \text{ in}^2 \]

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\[ A_b = 2 \cdot A_d \cdot 0.4 \text{ in}^2 \]

Clear Space: \[ \left( \frac{12 \text{ in} - 2 \cdot 3 \text{ in} - 2 \cdot 0.375 \text{ in} - 2 \cdot d_b}{1} \right) = 4.25 \text{ in} > 1 \text{ in} \]

\[ d_c = 12 \text{ in} - 3 \text{ in} - 0.375 \text{ in} = 8.125 \text{ in} \]

\[ \beta_1 = \frac{A_s \cdot \frac{f_y}{0.85 \cdot f'c \cdot b_w}}{A_s} = 0.5882 \text{ in} \]

\[ c = \frac{A_s}{\beta_1} = 0.692 \text{ in} \]

\[ \frac{c}{d_t} = 0.0852 < 0.375 \text{ Therefore } \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s \cdot \frac{f_y}{0.85 \cdot f'c \cdot b_w} \left( d_c - \frac{d}{2} \right) = 14.0956 \text{ ksi in}^2 \text{ ft} \]

\[ \Phi M_n = \frac{10}{3} \frac{\Phi M_n - 10^3}{\text{ ksi in}^2 \text{ ft}} \frac{\text{ lb} \text{ ft}}{\text{ ft}^2} = 14095.5882 \text{ lb} \text{ ft} \]

\[ M_a = M_n \cdot 1 \text{ ft} = 665.6 \text{ lb ft} \]

Shear:

\[ V_{\text{max}} = F_a \cdot F_a = 602.325 \frac{\text{ lb}}{\text{ ft}} \]

\[ \Phi = 0.75 \]

\[ \Phi V_c = \Phi \cdot \frac{f'c}{\text{ psi}} \cdot \frac{b_w \cdot d_t}{\text{ in in}} \text{ lb} = 9240.6622 \text{ lb} \]

\[ \Phi \frac{V_c}{(2)} = 4624.8311 \text{ lb} \]

\[ \frac{4 V_c}{(2)} > V_{\text{max}} \]

\[ \text{No stirrups required} \]

Footing: M positive CCW

\[ q_{\text{toe}} = 696.975 \frac{\text{ lb}}{\text{ ft}^2} \]
\[
q_{\text{heel}} = \frac{431.791}{\text{lb}} \left(\frac{\text{ft}^2}{2}\right)
\]

\[
q_{\text{diff}} = q_{\text{toe}} - q_{\text{heel}} = \frac{265.183}{\text{lb}} \left(\frac{\text{ft}^2}{2}\right)
\]

\[
M_{\text{soilbc}} = \frac{\text{Width}^2}{2} q_{\text{heel}} (1 - \frac{\text{Width}^2}{2}) = 9363.35 \text{ lb}
\]

\[
M_{\text{soiltop}} = \frac{h^2}{2} Y_s k a (\frac{1}{3} h) = \frac{h^2}{2} Y_s k a (\frac{1}{3} h) = 0 \text{ lb}
\]

\[
M_{\text{water}} = \frac{1 \text{ ft}}{3} (h) = 1164.8 \text{ lb}
\]

\[
M_{\text{weight}} = M_\text{w} = -11463.35 \text{ lb}
\]

\[
M_{\text{cutoff}} = \frac{3}{2} h_{\text{cutoff}} Y_s k a = 800 \text{ lb}
\]

\[
M_{\text{at soilbc}} M_{\text{water}} M_{\text{weight}} M_{\text{cutoff}} M_{\text{soiltop}}
\]

Max moment will occur at the toe when moments in one direction are summed

\[
M_{\text{design}} = M_{\text{soilbc}} + M_{\text{weight}} = 11463.35 \text{ lb}
\]

\[
d = h - 3.5 \text{ in} = 8.5 \text{ in}
\]

\[
\beta_1 = 0.85 \quad f_c = 4000 \text{ psi} \quad f_y = 60000 \text{ psi}
\]

assume \( \phi = 0.9 \)

\[
\frac{3}{2} \frac{f_c}{\text{psi}} \frac{b}{\text{in}} \frac{d}{\text{in}} \left(\frac{\text{in}^2}{\text{psi}}\right) = 0.3226 \text{ in}^2
\]

As \( \min \) is max of:

\[
A_{\min} = \frac{200}{f_y} \left(\frac{\text{in}}{\text{psi}}\right) \left(\frac{\text{in}}{\text{in}}\right)^2 = 0.34 \text{ in}^2
\]

\[
A_{\min} = 0.34 \text{ in}^2
\]

\[
A_y = \frac{f_y}{0.85 f_c b_w} = \frac{M_{\text{design}}}{M_{\text{design}} + M_{\text{soiltop}}} = \frac{M_{\text{design}}}{\phi} = 12737.0556 \text{ lb}
\]

\[
M_n = A_y (d - \frac{a}{2})
\]

\[
M_n = A_y \left(\frac{d}{0.85 f_c b_w} - \frac{A_y}{2} \right)
\]

\[
M_n = A_y \left(\frac{d}{0.85 f_c b_w} - \frac{A_y}{2} \right)
\]

\[
M_n = 0
\]

94
\[ A_s = 0.02839293631 \text{ in}^2 \]

\[
A_s = \frac{A_s \cdot f_y}{\text{in}^2 \cdot \text{psi}} \left(\frac{d}{\text{in}} - \frac{A_s \cdot f_y}{\text{psi} \cdot \text{in}^2} \right) - \frac{M}{\text{in} \cdot \text{lb}} = 1699.6528
\]

As \( \min \) governs

\[ A_s = A_{\min} = 0.34 \text{ in}^2 \]

**Use 2 to 4 bars**

\[ d_b = 0.5 \text{ in} \quad A_b = 0.20 \text{ in}^2 \]

\[ A_s = 2 \cdot A_b = 0.4 \text{ in}^2 \]

Clear Space: \[
\left(\frac{12 \text{ in} - 2.3 \text{ in} - 2.375 \text{ in} - 2 \cdot d_b}{1}\right) = 4.25 \text{ in} \quad > 1 \text{ in}
\]

\[ d_t = 12 \text{ in} - 3 \text{ in} - 0.375 \text{ in} - d_b = 8.125 \text{ in} \]

\[ a = \frac{A_s \cdot f_y}{0.85 \cdot f_c \cdot d_w} = 0.5882 \text{ in} \]

\[ c = \frac{a}{d_t} = 0.692 \text{ in} \]

\[ \frac{c}{d_t} = 0.0852 < 0.375 \quad \text{Therefore} \quad \Phi = 0.9 \]

\[ M_n = \Phi A_s \cdot f_y \left(\frac{d_t - 0.5}{2}\right) = 14.0956 \text{ ksi in}^2 \text{ ft} \]

\[ M_n = 10^3 \]

\[ M_n = \frac{14095.5882 \text{ lb}}{\text{ksi in}^2 \text{ ft}} \]

\[ M_{design} = M_{design} = 11463.35 \text{ lb ft} \]

4Mn < Mdesign
Cutoff Wall:

\[
M_{\text{cutoff}} = 800 \text{ lb}
\]

\[
d = w_{\text{cutoff}} = 3.5 \text{ in} = 4.5 \text{ in}
\]

\[
\beta_1 = 0.85 \quad f'c = 4000 \text{ psi} \quad fy = 60000 \text{ psi}
\]

\[
\phi = 0.9
\]

\[
3 \sqrt{\frac{f'c \cdot b \cdot d}{\text{psi} \cdot \text{in}^2}} = 0.1708 \text{ in}^2
\]

\[
\text{As min is max of:}
\]

\[
A_{\text{min}} = \frac{200 \cdot w \cdot d}{\text{psi} \cdot \text{in}^2} = 0.18 \text{ in}^2
\]

\[
A_{\text{min}} = 0.18 \text{ in}^2
\]

\[
\frac{A_s \cdot fy}{0.85 \cdot f'c \cdot bw} = M_{\text{cutoff}} \cdot \phi \cdot n_\phi
\]

\[
M_n = A_s \cdot fy \left( d - \frac{A}{2} \right)
\]

\[
M_n = A_s \cdot fy \left( d - \frac{A}{2} \cdot 0.85 \cdot f'c \cdot bw \right)
\]

\[
A_s = 0.003294267 \text{ in}^2
\]

\[
\frac{A_s \cdot fy}{\text{psi} \cdot \text{in}^2} \left( \frac{1}{d - \frac{A}{2} \cdot 0.85 \cdot f'c \cdot bw} \right) = M \leq 6.1609 \cdot 10^{-5}
\]

As min governs

\[
A_s = A_{\text{min}} = 0.18 \text{ in}^2
\]

Use 1 no 4 bars

\[
d_b = 0.5 \text{ in} \quad A_b = 0.20 \text{ in}^2
\]

\[
A_s = 1 \cdot A_b = 0.2 \text{ in}^2
\]

\[
d_t = 8 \text{ in} - 3 \text{ in} = 0.375 \text{ in} - d_b = 4.125 \text{ in}
\]
\[ a = \frac{0.85 f' c b}{0.83 f' c b_w} = 0.2941 \text{ in} \]

\[ c = \frac{a}{f} = 0.346 \text{ in} \]

\[ \frac{c}{d_t} = 0.0839 < 0.375 \text{ Therefore } \phi = 0.9 \]

\[ Q_n = \phi A_s f_y \left( d_t - \frac{a}{2} \right) = 3.5801 \text{ ksi in}^2 \text{ ft} \]

\[ Q_n \times 10^3 \text{ lb ft} = 3580.1471 \text{ lb ft} \]

\[ M_{\text{cutoff}} = M_{\text{cutoff}} \quad 1 \text{ ft} = 800 \text{ lb ft} \]

\[ \phi M_n < M_{\text{cutoff}} \]

Volume:

\[ L_s = W_e + 2 + 2 \text{ ft} = 29 \text{ ft} \]

\[ \text{Vol} = \text{Width} \times \text{Length} = 13.5154 \text{ yd}^3 \]

Steel (ACI min):

\[ \rho_{\text{min}} = 0.0018 \quad D_t = 8.125 \text{ in} \]

\[ A_s = \rho \cdot b \cdot d_t = 4.125 \text{ in} \]

\[ A_{\text{min}} = \rho_{\text{min}} \cdot w \cdot t \text{ in}^2 \]

\[ A_s = \rho_{\text{min}} \cdot w \cdot d = 0.1755 \text{ in}^2 \text{ Foundation} \]

\[ A_s = \rho_{\text{min}} \cdot w \cdot d = 0.0891 \text{ in}^2 \text{ Cutoff wall} \]

For both, use 1 no 4 bar:

\[ f' = \frac{f_y}{\psi_y} \text{ psi} \]

\[ l_d = \frac{y' t e d_b}{25 \cdot \phi_t} \text{ in} \]

\[ f' = \frac{f_y}{\psi_y} = 60000 \text{ psi} \]

\[ \phi_t = 1.0 \]

\[ f'c = \frac{f' c}{\psi_c} = 4000 \text{ psi} \]

\[ \psi_e = 1.0 \]

\[ d_b = \frac{b}{\text{ in}} = 0.5 \]

\[ l_d = \frac{y' t e d_b}{25 \cdot \phi_t} = 18.9737 \text{ in} \]

\[ l_s = 1.3 \cdot l_d = 24.6658 \]

\[ l_s = 25 \text{ in} \]
Structure 2

Channel Dimensions:

\[ b = 4 \text{ ft} \quad m = 3 \quad y_0 = 2.43 \text{ ft} \quad PB = 1.8 \text{ ft} \quad d_t = 4.23 \text{ ft} \quad Q = 72.74 \frac{\text{ft}^3}{\text{sec}} \]

\[ y_0 = 2.5 \text{ ft} \quad t_w = 23.391 \text{ ft} \quad d_t = 4.5 \text{ ft} \quad g = 32.2 \frac{\text{ft}}{\text{sec}^2} \]

\[ T_w = b + 2 \left( m \cdot d_t \right) = 31 \text{ ft} \quad W_c = 10 \text{ ft} \quad \text{Width of existing channel} \]

For construction purposes, \( y_0 \) is assumed to be 1.5 ft and total depth, is 3 ft.

Head Gate:

\[ D = 1 \text{ ft} \quad h_o = y_o - 0.5 = \frac{D}{2} = 1.5 \text{ ft} \]

\[ Q_o = 0.7 \cdot A_o \cdot \sqrt{2 \cdot g \cdot h} \]

\[ A_o = D^2 \cdot \frac{m}{4} = 0.7854 \text{ ft}^2 \]

\[ Q_o = 0.7 \cdot A_o \cdot \sqrt{2 \cdot g \cdot h_o} = 5.403 \frac{\text{ft}^3}{\text{sec}} \]

Weir:

Weir crest will be at \( y_0 + 1 \text{ ft} \) of flow is assumed to be going over the weir. The most conservative assumption will be that the head gate is closed and that the weir will need to pass the entire flow.

\[ Q_w = 3 \cdot L \cdot h_w = 1.5 \quad L = \frac{Q_w}{3 \cdot h_w} \]

\[ Q_w = \frac{O}{ft^3} \quad h_w = 1 \text{ (ft)} \quad \text{Since the weir equation is not homogeneous, the values will need to be unitless.} \]

\[ L = \frac{Q_w}{3 \cdot h_w} = 24.2467 \text{ ft} \]

Structure:

Assume:

\[ \Phi = 10 \text{ (deg)} \quad \alpha = 0 \text{ (deg)} \quad k = 0.33 \quad Y_{\text{soil}} = 100 \frac{1b}{3 \text{ ft}} \quad c' = 0 \frac{1b}{3 \text{ ft}} \]

\[ Y_{\text{water}} = 62.4 \frac{1b}{3 \text{ ft}} \quad Y_{\text{concrete}} = 150 \frac{1b}{3 \text{ ft}} \quad k_p = 3 \]

\[ Y_w = Y_{\text{water}} \quad Y_c = Y_{\text{concrete}} \quad Y_s = Y_{\text{soil}} \]
Overturning:

Area

\[ A_1 = 6 \text{ ft} \cdot 5 \text{ ft} = 30 \text{ ft}^2 \]
\[ A_2 = 1 \text{ ft} \cdot 6.8 \text{ ft} = 6.8 \text{ ft}^2 \]
\[ A_3 = 1 \text{ ft} \cdot \text{Width} = 9 \text{ ft}^2 \]
\[ A_4 = 6 \text{ ft} \cdot 1.5 \text{ ft} = 9 \text{ ft}^2 \]
\[ A_5 = 2 \text{ ft} \cdot 1.5 \text{ ft} = 3 \text{ ft}^2 \]
\[ A_6 = 8 \text{ in} \cdot h_{\text{cutoff}} = 1.333 \text{ ft}^2 \]

Weight

\[ W_1 = A_1 \cdot \gamma_w = 1872 \text{ lb ft} \]
\[ W_2 = A_2 \cdot \gamma_e = 1020 \text{ lb ft} \]
\[ W_3 = A_3 \cdot \gamma_e = 1350 \text{ lb ft} \]
\[ W_4 = A_4 \cdot \gamma_e = 900 \text{ lb ft} \]
\[ W_5 = A_5 \cdot \gamma_e = 300 \text{ lb ft} \]
\[ W_6 = A_6 \cdot \gamma_e = 200 \text{ lb ft} \]

Moment Arm

\[ M_{A_1} = 3 \text{ ft} + 6 \cdot \frac{6}{2} = 6 \text{ ft} \]
\[ M_{A_2} = 2 \text{ ft} + 1 \cdot \frac{6}{2} = 2.5 \text{ ft} \]
\[ M_3 = \frac{\text{Width}}{2} = 4.5 \text{ ft} \]
\[ M_4 = M_{A_3} = 6 \text{ ft} \]
\[ M_5 = M_{A_5} = 1 \text{ ft} \]
\[ M_6 = 8 \text{ ft} + 1 \cdot \frac{6}{2} = 8.5 \text{ ft} \]

\[ M = W_1 + W_2 + W_3 + W_4 + W_5 + W_6 = 5642 \text{ lb ft} \]

Moment

\[ M_1 = M_{A_1} = 11232 \text{ lb ft} \]
\[ M_2 = W_2 \cdot MA = 2550 \text{ lb ft} \]
\[ M_3 = W_3 \cdot MA = 6075 \text{ lb ft} \]
\[ M_4 = W_4 \cdot MA = 5400 \text{ lb ft} \]
\[ M_5 = W_5 \cdot MA = 300 \text{ lb ft} \]
\[ M_6 = W_6 \cdot MA = 1700 \text{ lb ft} \]
\[ M_p = M_1 + M_2 + M_3 + M_4 + M_5 + M_6 = 27257 \text{ lb ft} \]

\[ p_c = 0.5 \cdot k \cdot h_{\text{cutoff}} \cdot \gamma_e = 600 \text{ lb ft} \]
\[ p_h = 0.5 \cdot k \cdot H^2 \cdot \gamma_e = 103.125 \text{ lb ft} \]

Soil forces cancel out

\[ p_w = 0.5 (H - 1.8 \text{ ft})^2 \cdot \gamma_w = 1123.2 \text{ lb ft} \]
Sliding:

Assume vertical weight is uniformly distributed

\[ W = \frac{W}{\text{Width}} \\ W = \frac{h_{\text{cutoff}} \cdot \gamma_s \cdot 5 \cdot k \cdot \text{Width}}{3} \\ F = k \cdot W + \frac{W}{\text{Width}} = 273.56 \text{ lb/ft}^2 \\ F = \frac{P_w}{\text{Width}} = 124.8 \text{ lb/ft}^2 \\ FS = \frac{F_s}{F} = 2.1918 > 2.0 \\

Resisting Force is also in the banks

\[ W = 5 \text{ ft} \quad \text{Width of embedment on each side} \\
D = 6.8 \text{ ft} \quad \text{Depth of embedment} \\
\]
\[ p_e = 5 \cdot k \cdot D^2 \gamma_s = 762.96 \text{ lb/ft} \\
F_e = 2.3 \text{ ft} \cdot p_e \cdot 4577.76 \text{ lb} = 20,385.4 \text{ lb} \quad \text{Total resisting force from the embedment} \\
F_{\text{eperfoot}} = \frac{F_e}{L_{\text{Width}}} = 9.9733 \text{ lb/ft}^2 \\
F_{\text{perfoot}} = F_e \cdot \frac{F_{\text{eperfoot}}}{283.5133} = 283.5133 \text{ lb/ft}^2 \\
FS = \frac{F_{\text{perfoot}}}{F_s} = 2.2717 > 2.062 \]

Bearing Capacity:

\[ M_{\text{net}} = M_R - M_D = 24004.68 \text{ lb} \\
M_{\text{net}} = W \cdot X_{\text{bar}} \cdot X_{\text{bar}} \cdot \frac{M_{\text{net}}}{W} = \frac{W}{2} \cdot X_{\text{bar}} \\
\]
\[ q_{t,\text{net}} = \frac{W}{A} \left( \frac{W}{L} \right)^{\frac{3}{12}} B \left( \frac{B}{12} \right) \text{ w = 1 ft} \]

\[ X_{\text{bar}} = \frac{W}{3} \cdot \frac{B}{12} \text{ ft} \]

\[ e = \frac{\text{Width}}{2} - X_{\text{bar}} = 0.245 \text{ ft} \]

\[ q_{\text{toe}} = \frac{W}{\text{Width}} \left( \frac{1 - 6e}{\text{Width}} \right) = 729.43 \text{ lb/ft} \]

\[ q_{\text{heel}} = \frac{W}{\text{Width}} \left( \frac{1 - 6e}{\text{Width}} \right) = 524.3 \text{ lb/ft} \]

\[ \phi = \arctan \left( \frac{P_h}{W} \right) \]

\[ \psi = \arctan \left( \frac{P_h}{W} \right) \]

\[ B' = \text{Width} - 2e = 8.5093 \text{ ft} \]

\[ q_u = c' \cdot H \cdot F \cdot F_i \cdot q \cdot N_i \cdot F_q \cdot q_i \cdot 5 \cdot V_i \cdot B' \cdot H \cdot F_i \cdot F_{y,q} \]

\[ C' = 0 \text{ Therefore:} \]

\[ q_u = 0 + q \cdot N_i \cdot F_i \cdot F_q \cdot q_i \cdot 5 \cdot V_i \cdot B' \cdot H \cdot F_i \cdot F_{y,q} \]

\[ y = \frac{q - y'}{q} \]

\[ D_s = 2.4 \text{ ft} \text{ depth of soil} \]

\[ q = D_s \cdot y = 94 \text{ lb/ft} \]

\[ q = 40 \text{ lb/ft} \]

\[ q_i = 1 \]

\[ F_{yd} = 1 \]

\[ F_{y,q} = \left[ 1 - \frac{\psi}{\phi} \right] = 0.7461 \]

\[ F_{y,l} = \left[ 1 - \frac{\psi}{\phi} \right] = 0.3496 \]

\[ q_u = 0 + q \cdot N_i \cdot F_i \cdot F_q \cdot q_i \cdot 5 \cdot V_i \cdot B' \cdot H \cdot F_i \cdot F_{y,q} = 2543.011 \text{ lb/ft} \]

\[ \text{FS} = \frac{q_u}{q_{t,\text{net}}} = 3.4063 > 3.0 \]
Steel:

Flexural:

\[ F_w = 0.5(5 \text{ ft})^2 \times 780 \frac{\text{lb}}{\text{ft}} \]

\[ F_s = 0.5 \times k_a \times 103.125 \text{ ft} \times 10,125 \text{ lb} \times \frac{\text{lb}}{\text{ft}} \]

Forces of soil will cancel

\[ q_{\text{avg}} = \frac{q_{\text{heel}} + q_{\text{toe}}}{2} = 626.889 \frac{\text{lb}}{\text{ft}^2} \]

\[ M = F_s \times \frac{ft}{2} = 1300 \text{ lb} \]

\[ d = h - 3.5 \text{ in} = 6.5 \text{ in} \]

\[ \beta = 0.85 \quad f_{\text{c}} = 4000 \text{ psi} \quad f_y = 60000 \text{ psi} \]

\[ \Phi = 0.9 \]

\[ b_w \times d = 3 \times \frac{f_{\text{c}}}{\text{psi}} \times \frac{b_w}{\text{in}} \times \frac{d}{\text{in}} \times \frac{\text{in}}{\text{in}}^2 = 0.3226 \text{ in}^2 \]

As min is max of:

\[ A_{\text{s min}} = \frac{b_w}{\text{in}} \times \frac{d}{\text{in}} \times \frac{\text{in}}{\text{in}}^2 = 0.34 \text{ in}^2 \]

\[ A_{\text{s min}} = 0.34 \text{ in}^2 \]

\[ A_s \times f_y \]

\[ M_n = 1444.4444 \text{ lb} \]

\[ A_s \times f_y (d - \frac{a}{2}) \]

\[ A_s \times f_y (d - \frac{A_s 	imes f_y}{2 	imes 0.85 	imes f_{\text{c}} 	imes b_w}) \]

\[ A_s \times f_y (d - \frac{A_s 	imes f_y}{2 	imes 0.85 	imes f_{\text{c}} 	imes b_w}) \]

\[ M_n = 424.6521 \text{ lb} \]

As min governs

\[ A_s = A_{\text{s min}} = 0.34 \text{ in}^2 \]
Use 2 no 4 bars.

\[ d_b = 0.5 \text{ in} \quad A_{b} = 0.20 \text{ in}^2 \]

\[ A_s = 2A_{b} = 0.4 \text{ in}^2 \]

Clear Space: \[ \frac{12 \text{ in} - 2 \cdot 3 \text{ in} - 2 \cdot 0.375 \text{ in} - 2 \cdot d_b}{1} = 4.25 \text{ in} > 1 \text{ in} \]

\[ d_t = 12 \text{ in} - 3 \text{ in} - 0.375 \text{ in} - d_b = 8.125 \text{ in} \]

\[ a = \frac{A_{s} \cdot f_y}{0.85 \cdot f'c \cdot b \cdot w} = 0.5882 \text{ in} \]

\[ c = \frac{a}{b_1} = 0.692 \text{ in} \]

\[ \frac{c}{d_t} = 0.0852 < 0.375 \text{ Therefore } \Phi = 0.9 \]

\[ \Phi N_n = \Phi \cdot A_{s} \cdot f_y \left[ d_t - \frac{a}{2} \right] = 14095.5882 \text{ psi in}^2 \text{ ft} \]

\[ \Phi N_n \cdot \frac{lb \text{ ft}}{psi \text{ in}^2 \text{ ft}} = 14095.5882 \text{ lb ft} \]

\[ M = M_a = 1 \text{ ft} \cdot 1300 \text{ lb ft} \]

\[ \Phi M_n < M_a \]

Shear:

\[ V_{\text{max}} = F + F' = 883.125 \text{ lb ft} \]

\[ \Phi V_c = \Phi \cdot 2 \cdot \frac{f'c \cdot b \cdot w}{psi \text{ in} \cdot \text{in} \cdot \text{lb}} \frac{d_t}{lb} = 9249.6622 \text{ lb} \]

\[ \Phi V_C = 4624.8311 \text{ lb} \]

\[ \frac{\Phi V}{2} > V_{\text{max}} \]

No stirrups required.
Footing: M positive CCW

\[ q_{\text{toe}} = \frac{729.4311 \text{ lb}}{\text{ft}^2} \]
\[ q_{\text{heel}} = \frac{524.3467 \text{ lb}}{\text{ft}^2} \]
\[ q_{\text{diff}} = q_{\text{toe}} - q_{\text{heel}} = \frac{205.0844 \text{ lb}}{\text{ft}^2} \]

\[ M_{\text{soilbc}} = \frac{\text{Width}^2}{2} q_{\text{heel}} \left( \frac{\text{Width}}{2.3} \right)^2 \]
\[ q_{\text{diff}} = 24004.68 \text{ lb} \]

\[ M_{\text{soiltop}} = \frac{H^2 \cdot V \cdot k}{2} - \frac{1}{3} \left( \frac{H^2 \cdot V \cdot k}{2} \right)^2 \]
\[ h = 0.1 \text{ in} \]
\[ M_{\text{water}} = W \left( \frac{5 \text{ ft}}{3} \right) = 2080 \text{ lb} \]
\[ M_{\text{weight}} = M = -2757.1 \text{ lb} \]
\[ M_{\text{cutoff}} = \frac{h}{3.5} \cdot \frac{V \cdot k - 2}{3} = 800 \text{ lb} \]

\[ M_{\text{design}} = 1 \left( M_{\text{soilbc}} + M_{\text{water}} + M_{\text{weight}} + M_{\text{cutoff}} + M_{\text{soiltop}} \right) \]

Max moment will occur at the toe when moments in one direction are summed

\[ d = h - 3.5 \text{ in} = 8.5 \text{ in} \]
\[ \beta_1 = 0.85 \quad f'c = 4000 \text{ psi} \quad f_y = 60000 \text{ psi} \]

assume \( \Phi = 0.9 \)

\[ 3 \left( \frac{f'c}{\text{psi}} \cdot \frac{b}{\text{in}} \cdot \frac{d}{\text{in}} \cdot \frac{\text{in}}{\text{psi}} \right)^2 = 0.3226 \text{ in}^2 \]

As min is max of:

\[ A_{\text{min}} \]
\[ \frac{200 \cdot \frac{b}{\text{in}} \cdot \frac{d}{\text{in}}}{\text{in}^2} = 0.34 \text{ in}^2 \]

\[ A_{\text{min}} = 0.34 \text{ in}^2 \]

As

\[ \frac{A \cdot f_y}{0.85 f'c \cdot b_w} \]

\[ M_{\text{design}} = \Phi M_n \]

\[ M_{\text{design}} = \frac{M}{n} = \frac{30283.5556 \text{ lb}}{} \]

\[ M = A_s \cdot f_y \left( d - \frac{a}{2} \right) \]

\[ M = A_s \cdot f_y \left( d - \frac{A_s \cdot f_y}{2 \cdot 0.85 f'c \cdot b_w} \right) \]

\[ A_s = \frac{A \cdot f_y}{2 \cdot 0.85 f'c \cdot b_w} \]
\[
A_s = 0.059746729 in^2
\]

\[
\frac{A_s}{in^2} \cdot \frac{f_y}{psi} \left( \frac{d}{in} \right) = \left( \frac{A_s \cdot f_y}{ps \cdot in^2} \right) = \frac{W}{lb} = 0.0008
\]

As min governs

\[
A_s = A_{min} = 0.34 in^2
\]

Use 2 no 4 bars

\[
d_b = 0.5 in \quad A_b = 0.20 in^2
\]

\[
A_s = 4 \cdot A_b = 0.8 in^2
\]

Clear Space: \[
\frac{12 in - 2.3 in - 2.3 in - .375 in - 4 \cdot d_b}{3} = 1.0833 in > 1 in
\]

\[
d_t = 12 in - 3 in - .375 in - d_b = 8.125 in
\]

\[
a = \frac{A_s \cdot f_y}{0.85 \cdot f'c \cdot b_w} = 1.1765 in
\]

\[
c = \frac{a}{b_1} = 1.3841 in
\]

\[
\frac{c}{d_t} = 0.1703 < 0.375 \quad \text{Therefore} \quad \phi = 0.9
\]

\[
\Phi_n = \phi \cdot A_s \cdot \frac{f_y}{d_t} \cdot \frac{d}{2} = 27.1324 ksi \cdot in^2 \cdot ft
\]

\[
\Phi_n = \frac{4M_n}{ksi \cdot in^2 \cdot ft} = 27132.3529 lb \cdot ft
\]

\[
M_{design} = M_{design} \cdot 1 ft = 27257 lb \cdot ft
\]

\[
\Phi_{Mn} = M_{design}
\]
Cutoff Wall:

\[ M_{\text{cutoff}} = 800 \text{ lb} \]

\[ d = w_{\text{cutoff}} = 3.5 \text{ in} = 4.5 \text{ in} \]

\[ f'c = 4000 \text{ psi} \quad f_y = 60000 \text{ psi} \]

assume \( \phi = 0.9 \)

\[
3 \left( \frac{f'c}{\text{psi}} \right) \frac{b_w}{\text{in}} \frac{d}{\text{in}} \frac{d}{\text{in}} = 0.1708 \text{ in}^2
\]

As \( \text{min} \) is max of:

\[
A_{\text{min}} = \frac{200}{f_y} \frac{d}{\text{in}} \frac{d}{\text{in}} = 0.18 \text{ in}^2
\]

\[ A_{\text{min}} = 0.18 \text{ in}^2 \]

\[
a = \frac{A_s \cdot f_y}{0.85 \cdot f'c \cdot b_w} \cdot \frac{M_{\text{cutoff}}}{\phi \cdot M_n} \quad M_n = \frac{M_{\text{cutoff}}}{\phi} = 888.8889 \text{ lb}
\]

\[
H_n = A_s \cdot f_y \left( d - \frac{A_s \cdot f_y}{2 \cdot 0.85 \cdot f'c \cdot b_w} \right)
\]

\[
A_s = \frac{0.03294267}{\text{in}^2}
\]

As \( \text{min} \) governs:

\[ A_s = A_{\text{min}} = 0.18 \text{ in}^2 \]

Use 1 no 4 bar:

\[ d_b = 0.5 \text{ in} \quad A_b = 0.20 \text{ in}^2 \]

\[ A_s = 1.0 \quad A_b = 0.2 \text{ in}^2 \]

\[ d_t = 8 \text{ in} - 3 \text{ in} = 0.375 \text{ in} - d_b = 4.125 \text{ in} \]

\[
a = \frac{A_s \cdot f_y}{0.85 \cdot f'c \cdot b_w} = 0.2941 \text{ in}
\]
\[ c = \frac{a}{b} = 0.346 \text{in} \]

\[ c = 0.0839 \times 0.375 \text{ Therefore } \Phi = 0.9 \]

\[ \Phi_H = \Phi_{A_s} - \Phi_{d_t} \left( d_t - A_s \right) = 3.5801 \text{ksi in}^2 \text{ ft} \]

\[ \Phi = \frac{4.0}{0.315} \frac{\Phi_H}{l_b ft} = 3580.1471 \text{lb ft} \]

\[ M_{\text{cutoff}} = M \text{ ft} \times 800 \text{ lb ft} \text{ } \Phi_{Mn} < M_{\text{cutoff}} \]

Volume:

\[ V_{\text{vol}} = (L_a - W) + 10 \text{ ft} = 51 \text{ ft} \]

\[ V_{\text{vol}} = \text{Width} \times (H - 1 \text{ ft}) \times L_a \times h \text{ cutoff} \text{ cutoff} \text{ L_a} = 32.363 \text{yd}^3 \]

\[ V_{\text{vol}} = 32.363 \text{yd}^3 \text{ Vol}_1 = 13.5154 \text{yd}^3 \]

\[ V_{\text{vol}} = V_{\text{vol}} + V_{\text{vol}} = 45.878 \text{yd}^3 \]

Steel (ACI min):

\[ \rho_{\text{min}} = 0.0018 \text{ in} \]

\[ d_t = 8.125 \text{ in} \]

\[ A_s = \rho_{\text{min}} \cdot b \cdot d_t = 4.125 \text{ in}^2 \text{ Foundation} \]

\[ A_s = \rho_{\text{min}} \cdot w \cdot d_t = 0.0891 \text{ in}^2 \text{ Cutoff wall} \]

For both, use 1 no 4 bar

\[ f' = \frac{f}{f_{\text{c}} \cdot \psi_e \cdot d} \]

\[ \lambda = 1.0 \]

\[ \Phi = 1.0 \]

\[ d_b = \frac{b}{in} = 0.5 \]

\[ \phi = 1.0 \]

\[ f = \frac{f_y}{25 \cdot \lambda \cdot f_{\text{c}}} \]

\[ d = \frac{18.9737}{25 \cdot \lambda \cdot f_{\text{c}}} \]

\[ L_a = 1.31 \cdot d = 24.6658 \]

\[ L_a = 25 \text{ in} \]
Budget

Travel reimbursement
IRS cost per mile = $0.54/mile
Miles to date = 45 miles
Expected total miles = 90 miles

\[
\text{Current Reimbursement} = \text{Cost per Mile} \times \text{Miles} \\
= \$0.54 \times 45 = \$24.30
\]

Estimated Design Costs

PRELIMINARY ESTIMATE

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>DESCRIPTION</th>
<th>UNIT</th>
<th>QUANTITY</th>
<th>UNIT PRICE</th>
<th>TOTAL PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>Lump Sum</td>
<td>1</td>
<td>-</td>
<td>$618,966.15</td>
</tr>
<tr>
<td>2</td>
<td>Implement SWPPP</td>
<td>Lump Sum</td>
<td>1</td>
<td>-</td>
<td>$618,966.15</td>
</tr>
<tr>
<td>3</td>
<td>Survey</td>
<td>Lump Sum</td>
<td>1</td>
<td>-</td>
<td>$25,000.00</td>
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<tr>
<td>4</td>
<td>Channel Grubbing</td>
<td>Square foot</td>
<td>1447451</td>
<td>$0.30</td>
<td>$434,235.30</td>
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<tr>
<td>5</td>
<td>Channel Excavation</td>
<td>Cubic Yard</td>
<td>134751</td>
<td>$25.00</td>
<td>$3,368,775.00</td>
</tr>
<tr>
<td>6</td>
<td>Install specialty concrete</td>
<td>Cubic Yard</td>
<td>46</td>
<td>$350.00</td>
<td>$16,100.00</td>
</tr>
<tr>
<td>7</td>
<td>Provide Quality Control Testing</td>
<td>Lump Sum</td>
<td>1</td>
<td>$10,000.00</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Install 18-inch stop gate</td>
<td>Each</td>
<td>1</td>
<td>$500.00</td>
<td>$500.00</td>
</tr>
<tr>
<td>9</td>
<td>Install 12-inch diameter rip rap</td>
<td>Cubic Yard</td>
<td>1106</td>
<td>$60.00</td>
<td>$66,360.00</td>
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<tr>
<td>10</td>
<td>Silt Fence</td>
<td>Linear Feet</td>
<td>91060</td>
<td>$1.25</td>
<td>$113,825.00</td>
</tr>
<tr>
<td>11</td>
<td>Wetland Mitigation</td>
<td>Acres</td>
<td>33</td>
<td>$180,000.00</td>
<td>$5,981,202.48</td>
</tr>
</tbody>
</table>

Total
$11,253,930.09

10% ADJUSTMENT (Design and Construction Inspection) $1,125,393.01

25% CONTINGENCY (Unexpected Construction Costs) $2,658,740.98

TOTAL OF BID $12,379,323.10

Cost Benefit Analysis

Alternative 1—Moving the Polishing Pond

Land purchase for new polishing pond
Land needed = 21.71 acres
Land price = $7596 per acre

\[
\text{Land Price} = \text{Land Needed} \times \text{Land Price}
\]
= 21.7 * $7595 = $164,833

Moving the pump station
Estimated cost = $1,000,000

Total Cost
Total Cost = Land Price + Moving the Pump Station
= $164,833 + $1,000,000 = $1,164,833

Alternative 2—Upgrading Existing Pipe

Feet of pipe to be replaced = 6200
Cost of 60” concrete pipe installed per foot = $600
Cost of New Pipe = Feet of Pipe * Cost per Foot
= 6200 * $600 = $3,720,000
Special Summary Documentation
Constraints Consideration Summary

**Health and Safety.** The implementation of this project minimizes flood risk to the agricultural and industrial land. During the construction process, equipment may overturn due to slope instability. 10WE considered the safety of the construction crew during the design process. 10WE used saturated soil conditions for design calculation. 10WE also used government design regulations and adequate factors of safety to ensure the integrity of the structures.

**Constructability.** 10WE designed simple channels and diversion structures. 10WE avoided harming wetlands to the extent possible. In addition, the storm water conveyance system is gravity fed.

**Economic.** There were many economic constraints for this project: gravity-fed system, channel length, hydraulic structures, wetlands, and moving the holding pond and screw pumps.
- The storm water system is gravity-fed due to the cost of installing and maintaining pumps.
- The channel length was minimized due to the increase in cost as the length increases.
- The size and quantity of hydraulic structures were minimized due to the cost increase as the structures grow in both size and quantity.
- The construction avoided wetlands to the extent possible due to the cost of replacing wetlands.
  - The Army Corps of Engineers requires three acres of wetlands be restored for every acre disturbed during construction.
  - The price of replacing one acre of disturbed wetland is $180,000.
- The holding pond and screw pumps were relocated due to economic constraints.
  - 10WE completed a cost benefit analysis to assist in the decision of whether or not to move the holding pond and screw pumps.

**Environmental.** As defined by the EPA, wetlands improve water quality, provide wildlife habitat, and regulate surface water flow. The design avoided disturbing the wetlands to the extent possible.

**Social.** Canals in the area supply water to farmers who own water rights. 10WE ensured all individuals have access to their water rights by designing diversion structures.
Engineering Tools Summary

Table SSD1. 10WE Engineering Tools

<table>
<thead>
<tr>
<th>Software Name</th>
<th>Version</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>ArcGIS</td>
<td>ArcGIS 10.4</td>
<td>Esri</td>
</tr>
<tr>
<td>AutoCAD</td>
<td>AutoCAD 2016</td>
<td>AutoDesk</td>
</tr>
<tr>
<td>Civil3D</td>
<td>Civil3D 2017</td>
<td>AutoDesk</td>
</tr>
<tr>
<td>Google Drive</td>
<td>N/A</td>
<td>Google</td>
</tr>
<tr>
<td>Slide</td>
<td>Slide 6.0</td>
<td>Rocscience</td>
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<tr>
<td>Smathstudio</td>
<td>0.98.6179</td>
<td>Andrey Ivashev</td>
</tr>
<tr>
<td>Storm and Sanitary</td>
<td>Storm and Sanitary 2015</td>
<td>AutoDesk</td>
</tr>
<tr>
<td>TauDEM</td>
<td>5.0</td>
<td>Available from David Tarboton</td>
</tr>
</tbody>
</table>

Government Regulations

Table SSD2. 10WE Government Regulations

<table>
<thead>
<tr>
<th>Organization</th>
<th>Number</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRCS</td>
<td>TR-55</td>
<td>Urban Hydrology for Small Watersheds</td>
</tr>
<tr>
<td>USBR</td>
<td>N/A</td>
<td>Design of Small Canal Structures</td>
</tr>
<tr>
<td>Logan City</td>
<td>N/A</td>
<td>Cache Valley Storm Water Design Standards</td>
</tr>
<tr>
<td>American Concrete Institute</td>
<td>318 &amp; 10-5-4</td>
<td>Building Code for Requirements for Structural Concrete</td>
</tr>
</tbody>
</table>

Professional Responsibility and Conduct Summary

Table SSD3. Professional Standards

<table>
<thead>
<tr>
<th>Organization</th>
<th>Number</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCE</td>
<td>N/A</td>
<td>ASCE Code of Ethics</td>
</tr>
</tbody>
</table>

Risk Considerations

Design process risk considerations. The field investigation risked the health and safety of members of 10WE. The purpose of the field investigation was to gain a better understanding of current conditions in the area of interest. This involved driving and taking velocity and cross-sectional area measurements of canals. The canals of interest are lined with a fine clay. 10WE carefully evaluated where to take measurements to ensure they did not get trapped in the mud. 10WE completed this investigation in late fall and all team members wore appropriate clothing.
to diminish the risk of illness. 10WE mitigated risk while driving to the area of interest by wearing seatbelts and obeying all local driving regulations.

**Post-design process risk considerations.** The implementation of this project minimizes flood risk to the agricultural and industrial land. During the construction process, equipment may overturn due to slope instability. 10WE considered the safety of the construction crew during the design process. 10WE used saturated soil conditions for design calculation.

**Potential Additional Reviewers**

- Lance Houser PE
- Sedimentologist
- Logan City Council
- Construction Contractors

**Methods for Overcoming Challenges**

10WE employed several methods to overcome challenges. 10WE focused on communication, comparative advantage, and planning. By designating a “naysayer” for several meetings, 10WE evaluated many different ideas and methods. 10WE avoided confusion among the team and between the client by using the proper method of communication for each task. 10WE reallocated assignments to increase efficiency. For example, Ryan Weller and Megan Gordon changed roles so that Megan is the primary technical writer and Ryan is the geotechnical engineer. Finally, 10WE used planning as method to communicate and coordinate with the client.
Professional Author Biography

Kade J. Beck majored in Civil Engineering. He is married to Megan Beck and they are the parents of Savannah Mae. Kade served as the Engineering Senator and Senate Pro Tempore during his sophomore year where he initiated a college sponsored career exploration program. Kade was an Engineering Undergraduate Research Fellow and conducted research at the Utah Water Research Laboratory. During this time, Kade chartered and served as the founding member and Chapter President of Utah’s first Student Chapter of the American Water Works Association. Kade is the co-author of several publications on the subject of electromagnetic meter accuracy. He will intern with CH2M during the summer and continue at Utah State University in the fall to complete his master’s degree in Fluid Mechanics and Hydraulics. In his free time Kade enjoys playing games with his wife and spending time on the playground with his daughter. Kade loves being with his family outdoors and enjoys mountain biking and reading.