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FINAL DELIVERABLE

Title	Stormwater Wetland for Webster City, Iowa
Completed By	Benjamin Palazzolo, Carly Wagner, Nathan Haas
Date Completed	December 2018
UI Department	Civil and Environmental Engineering
Course Name	CEE:4850:0001 Senior Design
Instructor	Paul Hanley
Community Partners	Webster City, IA

This project was supported by the Provost's Office of Outreach and Engagement at the University of Iowa. The Office of Outreach and Engagement partners with rural and urban communities across the state to develop projects that university students and faculty complete through research and coursework. Through supporting these projects, the Office of Outreach and Engagement pursues a dual mission of enhancing quality of life in Iowa while transforming teaching and learning at the University of Iowa.

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Stormwater Wetland for Webster City, Iowa

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Report Submitted To:

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City of Webster City, Iowa

Civil and Environmental Engineering

College of Engineering

The University of Iowa

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Section I Executive Summary

This is a design report for a Constructed Wetland for the town of Webster City, IA. Webster City is in central Iowa and has a population a little over 8,000. The city is looking into different alternatives for storm water management, like a constructed wetland. The wetland will improve the water quality that will drain into the Boone River. This will improve the condition of the River which is an important part of the Webster City community. The city wanted the constructed wetland to slow down storm water, allow pollutants to settle, uptake pollutants, be a habitat that can support wildlife and be a recreational/educational area for residents. All of the previously stated criteria were incorporated into the Wetland final design so that it has a positive impact on the residents, habitat and water quality of the area.

HPW Engineering (HPW), a team of three senior civil engineering students at the University of Iowa in the senior design course, created a design matrix to determine which location provided the best return on investment for the wetland. HPW Engineering's team consist of a project manager, Nathan Haas and two team members Carly Wagner, and Ben Palazzolo. The team's abundant experiences from other projects, as well as their education, makes them uniquely qualified to design this project. The main contact for Webster City is the Environmental/Safety/GIS Coordinator, Brian Stroner.

There were multiple locations that were evaluated for the Constructed Wetland along the Boone River. The potential project locations were located on the North, East and South sides of Webster City. The current water treatment plant location at the Southeast was also a possibility if it is relocated prior to the wetland construction. Factors such as proximity to the river, current land use, current storm water and sanitary sewer locations, and topography were all be analyzed to determine which area was the best site for the constructed wetland.

From the design matrix the Bank Street site had the highest rating (28). This location was used for the design of the wetland. Upon selecting the site, watershed and drainage analysis was conducted in order to determine the sizing needed for the wetland. The drainage area was calculated to be 110 acres and had a Water Quality Volume (WQv) of 26,766 ft^3. This number was used to determine the size of the forebay, low marsh, high marsh, and deep pool zones. The entire amount of water runoff from a 100-year storm was used to size the emergency spillway.

The design had to overcome various constraints and challenges such as limited space available, very flat land, high water table, environmental considerations and a limited budget. The final design incorporated aspects to address all of these factors. The final design selected was a wetland consisting of one forebay with a meandering channel to a deep pool with an outlet structure and emergency spillway. Figure 1 shows a 3D rendering of the final design. This design allows for adequate pollution remediation, reduces cost and provides a water velocity within Iowa DNR design standards.

The total cost of the project is estimated at $500,000 dollars. The largest contribution to the price is the excavation and removal of current soil. With the area being extremely flat, the wetland must be dug down to provide adequate elevation differences and slopes in order for the wetland to work effectively. Construction costs are calculated in Section VII.

Figure 1: 3D rendering of the final wetland design.

<u>Section II</u> Organization Qualifications and Experience

1. **Name of Organization**

   HPW Engineering

2. **Organization Location and Contact Information**

   HPW Engineering is located at the Seamans Center in Iowa City, Iowa. The main contact and project manager will be Nathan Haas. He can be reached via email: nathan-d-haas@uiowa.edu or by phone: 815-980-3064.

3. **Organization and Design team Description**

   HPW Engineering (HPW) is a team of senior University of Iowa students in the capstone design class. Each member of HPW has a unique specialty that compliments the other members. Nathan Haas is HPW's project manager. Haas' specialty is transportation and he was the design lead for the design of the path around the wetland and the construction phasing. The second team member was Carly Wagner and her specialty is in environmental engineering with an emphasis on water resources. She led the work on the hydraulic analysis and sizing calculations. The third and final team member was Ben Palazzolo was his specialty is water resources. He led the work on the landscape and vegetation design and assisted with the hydraulic analysis.

<u>Section III</u> Design Services

1. Project Scope

   The scope of this project was to design an alternative method for stormwater management for a portion of the City of Webster City, Iowa. The desired stormwater management practice was a constructed wetland on one or more of four city owned sites. Each site proposed by the client was evaluated and given a recommendation for future projects. HPW prioritized each site and designed the wetland with the highest priority. The final design is able to slow down stormwater, allow pollutants to settle, uptake pollutants, and is an inviting habitat that can support wildlife. Furthermore, the City of Webster City wanted there to be educational kiosks about the constructed wetland and tied into the existing trail system. The constructed wetland also includes a monitoring plan. The project required a site location, sizing of wetland and outlet structure, vegetation identified, and a monitoring plan to be developed. Wetland banking was also researched for additional funding for this project and future projects.

The site design was completed in Civil 3D. The final drawings include plan views, cross section views, and 3D renderings. The plans were completed by following EPA and Iowa DNR guidelines. The design addressed site selection, permits, regulations, structures, flow control, hydrology, substrates, maintenance, and a monitoring plan.

2. Work Plan

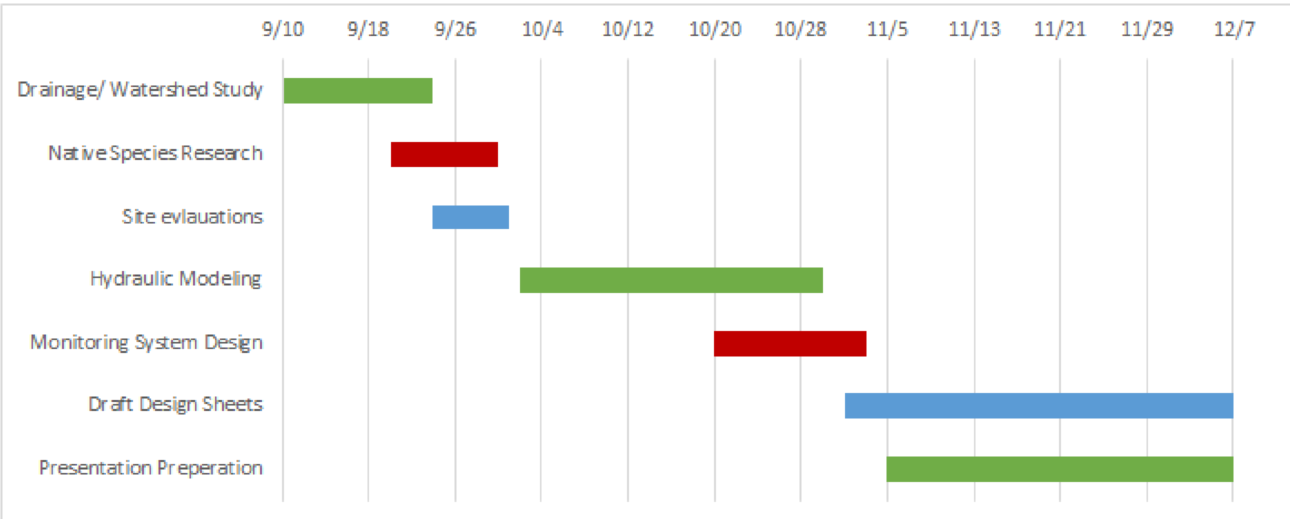


Figure 2. Work flow chart for project.

Figure 2 highlights the main tasks that were completed and whom was leading the completion of said task. Project Manager, Nathan Haas led the tasks in blue. Carly Wagner led the tasks in green, and Benjamin Palazzolo led the tasks in red.

Section IV Constraints, Challenges and Impacts

1. **Constraints**

Constraints for this project include space, environmental considerations and time. Webster city wanted to use land they already owned to complete this project. This limited the project to a few areas of a specific size which reduced options for the project. Being a constructed wetland means there are many laws and regulations that must be followed for the project to be compliant, such as removing set levels of pollutants from the water before it enters in to the Boone River. These regulations are set by the Iowa DNR (Department of Natural Resources) and the EPA (Environmental Protection Agency). There was also a time constrain, all final designs must be submitted by December 7th, 2018.

2. **Challenges**

The initial challenge was determining which site should be used for the constructed wetland. With analysis and the use of a design matrix, HPW was able to choose the best site. More information about the alternatives and final selection can be seen in Section V. Specific challenges to our site were property boundaries, the grade of existing land, and the water table. The property boundaries for the site constricted the shape for the final wetland design. In order to overcome this challenge, HPW chose a design with an inlet deep pool and outlet deep pool connected by one meandering channel. The existing ground level and grade was also a challenge. The area is quite flat, so the design needed to require a lot of cut in order to achieve the regulated sizes and slopes for the wetland. Being right next to the river also is a challenge because the water table level is high. For the water level to not negatively affect the wetland, the forebay and deep pool must be lined with an impervious bentonite clay layer.

3. **Societal Impact within the Community and/or State of Iowa**

   The societal impacts to Webster City from this constructed wetland will be largely positive. It will provide a park type area for residents to use, naturally remove pollutants before it enters the Boone river, educate residents about sustainable and environmentally friendly practices, improve land value around the wetland and provide a desirable habitat for plants and aquatic life. The negative effects will be minimal and will mainly occur during times of construction. Trees will need to be cut down which could force out some animals who currently reside there. Also, rains during construction could erode the soil and deposit it into the Boone River. Erosion control practices such as silt fences are outlined on Sheet 12 will be used to minimize this risk.

Section V Alternative Solutions That Were Considered

There were originally four site alternatives for this project. The first site alternative is in Nokomis Park next to softball and baseball fields. The second site alternative is located south of Bank Street by the City's tree sanctuary. The third site alternative is located next to Lyon's Creek. The final site alternative is on the waste water treatment plant property. The waste water treatment plant is still there but the City will be moving the plant in the near future.

Table 1 displays a decision matrix for the four site locations for possible constructed wetlands in Webster City. The 6 criteria categories were selected based off feedback from Webster City and what HPW thought was important when designing a wetland. Webster City was very adamant about wanting a location that had good public perception, close to trails and parks, and close to the Boone River. HPW thought an adequate location needed sufficient storm water supply, a large drainage area, and minimal initial site preparation and costs. Each location was given a value based on how it compared to the other sites. Each criterion was ranked on a scale from 1 to 5 with 5 being the best score and 1 being the worst score. After totaling up a total for each alternative, Site 2: Bank Street was identified as the preferred site location with a high score of 28.

Table 1. Decision Matrix for four different site locations in Webster City.

Criteria	Site 1: Nokomis Park	Site 2: Bank Street	Site 3: Lyon's Creek	Site 4: Water Treatment Plant
Influence on Public Land	1	5	5	5
Sufficient Storm Water Supply	3	5	3	1
Close to trails/parks	5	4	4	3
Close to Boone River	5	5	4	5
Drainage Area Size	4	5	3	5
Site Preparation and Costs	3	4	3	3
Total	**21**	**28**	**22**	**22**

HPW determined the alternative's scores based off the following reasoning. The Nokomis Park location will get the most negative public perception because people associate wetlands with mosquitos. This site is used for recreational purposes, so people will not want mosquitos around. The rest of the sites are in locations that are not near very public recreational areas. The Nokomis Park location has some storm sewer water supply close by but none that runs directly to the site. Furthermore, the site drains away from the area where the constructed wetland would go. The Bank Street site has five storm sewer lines running directly into the site. The Lyon's Creek site has a storm sewer that runs parallel to the site. To access this water, a connection would have to be built. The water treatment plant has no storm sewer running to this site. This site would require a pump which is very expensive. The Nokomis Park is located right by a park and trail while the Bank Street and Lyon's Creek sites are close to a trail but need to be connected. The water treatment plant is the farthest from a trail and public space. All locations are close to Boone River but the Lyon's Creek site drains to a creek before it goes into the river. The Nokomis Park has a decent sized drainage area. The Bank Street and the water treatment plant sites have the largest drainage areas and the Lyon's Creek site has the smallest drainage area. The Nokomis Park site's preparation would include a lot of grading and getting approval by the community. The Bank Street site would not need much site preparation but will require the city to obtain the land which could be costly. The Lyon's Creek site would need a lot of cleanup of old car parts and tires because of the previous owners. The water treatment plant needs a water source and removal of any part of the plant left.

Three of the alternatives received similar scores but Table 1 shows that the Bank Street site location received the highest score of 28. HPW recommends developing on this location first, and then when more funding comes along, designing for the other locations starting with the Lyon's Creek location or the water treatment plant location and ending with the Nokomis Park location. HPW also advises the city to build a wetland at the water treatment plant as part of the demolition phase. This will help reduce costs for that site and reduce the amount of preparation work needed.

After determining which site was best suited for the project, three design alternatives were created for that site. Alternative 1, shown in Figure 3, consists of one forebay, one meandering channel, and one deep pool at the outlet structure. This alternative will be the most cost effective because it will require the least amount of Bentonite Clay, least amount of grading and excavation, and requires the least amount of new trail to be added. One downside of this design is that having only one channel means it is more likely to fill with sediments. The design of this alternative has a velocity that limits the possibility of this happening.

Figure 3. Alternative 1

Alternative 2 contains one forebay, two meandering channels with water permanently in them, and one outlet structure. This alternative is shown in Figure 4. Alternative 2 will be aesthetically pleasing because it will have constant running water. However, more Bentonite Clay will need to be installed, which will require more money. Furthermore, having two channels so close to each other would increase the likelihood of erosion in the meandering curves. Another concern of have two separate meanders is the flow velocity of the water will be lower which means sediments will build up and block the meanders more frequently. This will result in extra maintained costs as they will need to be cleaned more frequently.

Figure 4. Alternative 2

Alternative 3, shown in Figure 5, is made up of one forebay, to meandering channels, two deep pools, and two outlet structures with their exit pipes joining together. This is a more unique alternative than the other two. Each deep pool will be smaller in this alternative. However, with multiple deep pools and outlet structures, this alternative will have a higher construction cost. Alternative 3 will also require more land surface.

Figure 5. Alternative 3.

For each design alternative, HPW explored using one large inlet structure verse two smaller inlet structures. HPW ultimately decided to design two smaller inlet structures to reduce cost. Furthermore, each design alternative's outlet pipe will try to be connected to the existing pipe if the existing pipe's quality and size is sufficient.

To choose a preferred alternative, HPW presented all three alternatives to the Client to make the final decision. After further analysis, the Client decided to go with the recommended alternative, Alternative 1.

Section VI Final Design Details

Forebay

The Forebay is the pre-treatment initial pool where the storm water pipes flow into, most of the sedimentation occurs here. To size the forebay HPW first found the total water quality volume for the area. To do this, the total drainage area and impervious percentage was found. Then using the first 1.25" of rain in a storm, specified by the Iowa Storm water Management Manual (ISWMM) Chapter 8, the total water quality volume was determined to be 26776 ft3. Ten percent of the total water quality volume can be stored in the forebay. Therefore, the forebay's volume should be at least 2678 ft3. According to ISWMM Chapter 8, the maximum depth for the forebay is 4 feet. North Carolina Storm Water Design Manual(NC) recommends having a deeper depth at the inlet of the forebay and a shallower depth at the outlet of the forebay. Using this information, the inlet of the forebay's depth will be 4 feet and the outlet depth will be 3 feet. The diameter of this permanent pool will be 34 feet. There are two storm sewer pipes that will lead into the forebay. Each pipe will have an apron shaped end cap. The base of the lowest inlet pipe will be two feet above the bottom of the forebay. The bottom of the pipe is at 1003 so the inlet of the bottom of the forebay will be 1001, the outlet will be 1002, and the surface will be 1005. See Appendix 10 Forebay Design for detailed design calculations and Design Sheet A for the site plan drawing.

Low Marsh

The low marsh is connects the forebay to the final deep pool and is a meandering stream channel. This further filters our finer particles through the use of vegetation. The low marsh was designed to have a minimum of a 3:1 ratio for the sinuosity. This ratio was required by ISWMM Chapter 8. The linear length from forebay to deep pool is 200 feet and the meandering length is 840 feet. WIN TR-55 was used to determine a peak flow of 28 cfs for the first 1.25" of rainfall during a 10 year 24-hour storm event. This information was used in HydroCAD to size the trapezoidal channel. According to ISWMM Chapter 8, the maximum velocity of this channel is 10 ft/s. With these constraints the channel's dimensions were calculated to be a depth of 2 feet, a bottom with of 1.5 feet, a side slope of 6:1 and a top width of 19 feet. Additionally, according to NC the low marsh and high marsh areas should hold around 40 percent of the total water quality. The total volume for the low and high marsh areas will be 0.34 acre-feet. The low marsh volume will be 0.5 acre-feet. The low marsh bottom elevation will be 1005 and the top will be 1006.5. See Appendix B Low Marsh Design for detailed design calculations and Design Sheet 10 for the site plan drawing.

High Marsh

The high marsh is a continuation of the low marsh channel. In higher water events, the water level will rise past the low marsh and fill into the high marsh. The high marsh is lined with the same vegetation as the low marsh zone to help filter out the finer particles in the water. ISWMM Chapter 8 required a 6 to 1 elevation increase and a maximum of 0.5-foot depth for the high marsh. The bottom elevation is be 1006.5 and the top will be

1007. The total volume for the high marsh is 0.12 acre-feet. See Appendix C High Marsh Design for detailed design calculations and Design Sheet 10 for the site plan drawing.

Deep Pool

The deep pool is the final collecting location for the water. Water flows from the forebay to the deep pool via the low/high marsh zones and slowly drains from the deep pool through the outlet structure into the river. NC recommends the outlet deep pool be 15 percent of the water quality volume; therefore, the volume is calculated to be 0.14 acre-feet. ISWMM states that the maximum depth for a deep pool is 3 feet. With these standards the pool diameter is 51 feet and the surface area is 2015 square feet. See Appendix D Deep Pool Design for detailed design calculations and Design Sheet 10 for the plan drawing.

Outlet Structure

The outlet structure is located in the deep pool and carries the final treated water from the wetland and deposits it in the river. The outlet structure was designed to handle the peak discharge of a 10-year, 24-hour rainfall event as required by ISWMM chapter 8. WinTR-55 was used to determine a peak flow of 165 cfs. To meet that flow rate, the outlet pipe will have a diameter of 42 inches and the overflow weir will be 2 feet tall and 21 feet wide. Due to the size and location of the current storm sewer pipe, it will not be feasible to repurpose the storm sewer pipe for this wetland. Our client stated during our preliminary on-site visit, that they were very satisfied with the outlet structure that was designed for a nearby wetland, so the structure design mimic what the client currently has at another wetland. The outlet pipe and overflow weir sizes were calculated using WinTR-55. Also included in the outlet design is an intake within the permanent pool to maintain the permanent pool elevation and erosion stone in front of the outlets structure with over flow inlets, to allow for extended detention to be drained at a faster rate in the event of water elevations that are close to the overflow weir. See Appendix E Outlet Structure Design for detailed design calculations and Design Sheet 10 for the site plan drawing

Extended Detention

The extended detention area is a large flat area around the high marsh and deep pools. This area is in case of high rain events. It will fill with water and prevent the surrounding area from flooding. Based off NC's recommendation of having the temporary inundation zone be a minimum of 35 to 45 percent of the water quality volume, HPW decided to dedicate 45 percent of the volume to this zone. The inundation zone includes the extended detention, freeboard, and overflow bank. This requires a volume of 0.42 acre-feet. The extended detention will be flat at an elevation of 1007 and have a volume of 0.23 acre-feet. See Appendix F Extended Detention Design for detailed design calculations and Design Sheet 10 for the site plan drawing.

Overflow Bank and Freeboard

The overflow bank and freeboard is the sloped edges between the wetland and existing grade of the land. This surrounds the entire wetland and during high rain events stores water so it can safely travel through the emergency spillway into the river. Due to the elevation of the inlet pipe, the elevations throughout the wetland are significantly lower than the current surface elevation. In order to minimize the area of the wetland, the top elevation of the wetland will be the current surface elevation. This will not only remove the need to build a berm around the wetland, but it will also decrease the total footprint of the wetland, allowing for the entire design to be located on property that is owned by the client. The freeboard will be used to connect the extended detention to the overflow bank. With the elevation of the extended detention basin being 1007 feet and the elevation of the overflow bank being 1014 feet, the total freeboard for the wetland will be 7 feet. Chapter 8 of ISWMM requires that the maximum slope of the freeboard be no steeper than a H:V ratio of 4:1. This will result in the freeboard being 7 feet tall and a minimum of 28 feet wide around the wetland. See Appendix G Overflow Bank and Freeboard Design for detailed design calculations and Design Sheets 10 for the site plan drawing.

Emergency Spillway

The emergency spillway is designed to safely funnel water away from wetland in extremely high rain events to prevent damage to the wetland and prevent flooding of the surrounding area. The emergency spillway was designed to allow for the peak flow of the 100-year, 24-hour rainfall event with a factor of safety of 1.5, which was recommended in Chapter 8 of ISWMM. With the plan of having the top of the wetland be at the current ground elevation, the emergency spillway channel was designed as a rectangular weir with a depth of 3 feet. There is a 3 foot elevation difference between the top of the outlet structure inlet and the top of the overflow bank. Using HydroCAD, the recommended width of the spillway is 35 feet wide. See Appendix H Emergency Spillway Design for detailed design calculations and Design Sheet 10 for the site plan drawing.

Vegetation and Aquatic Life

No aquatic life will be directly introduced to the wetland. Once the wetland is constructed, it will be a habitat that aquatic life will migrate to naturally. Bat houses also be installed and will be placed in the surrounding trees. Bat houses will also provide a habitat for bats, including the Indiana Bat which is endangered in this area. Underwater plants (sweetflag, a pond weed) will be seeded in the permanent pool, and the low marsh that is not next to the forebay. Above water plants (cattails and bullrush) will be planted in the high marsh and the low marsh surrounding the forebay. To prevent the geese population from inhabiting the area, Big Bluestem is recommended in the extended detention. It is recommended that this tall grass is cut often near any potential trail and annually to define the boundaries of the wetland. See Design Sheet 10 for the vegetation plan drawing.

Connecting Trail

Currently a trail runs along the length of the river. This trail is used for biking, jogging, walking, and many other activities by the residents of Webster City. With the wetland being close to the trail, HPW wanted to capitalize on it. HPW designed the trail to run around the outside of the wetland. Along this trail will be benches and information kiosks for the users to learn more about the constructed wetland and its purpose. Due to the design of the emergency spillway it is more cost effective to reroute the trail around the wetland. See Design Sheets 7, 8, and 9 for the trail cross-sections drawing.

Storm Water Pollution Prevention Plan

A Storm Water Pollution Prevention Plan (SWPPP) is required for this project because more than one acre of soil is being disturbed. The SWPPP reports will be filled out by the site inspector once a week and will be submitted to the IDOT. Erosion control is needed to help stabilize the soil so vegetation will be able to grow. For erosion control, silt fences will be used. Furthermore, silt fences will be placed in the low marsh channel to help stabilize the channel during construction. Silt fences were chosen because they are cheaper than other methods. See Design Sheet 12 for the SWPPP plan.

Monitoring System

The accumulation of sediment at the forebay should be measured every six months. Monitoring should occur at a time when the water surface elevation matches the permanent pool elevation. Monitoring will consist of a manual measurement of the current depth of the forebay at the inlet. There is a 2 foot difference from the bottom of the inlet pipe to the bottom of the forebay at the deepest point. Dredging is recommended when sediment accumulates half of a foot below either inlet. This will allow the client time to plan for dredging the forebay before sediment can begin to settle in the inlet pipe. It is also recommended that the pH of the wetland effluent be measured every six months using test strips.

Education

As previously stated, wetland informational kiosks and benches will be placed along the trail of the wetland. These kiosks will provide information about why the wetland was constructed, how it works and its benefits. It will also provide information about the plants used and aquatic life that will use the wetland.

Wetland Banking

The City of Webster City may qualify for compensation from this wetland mitigation project. This program is run by the Corps of Engineers and awards wetland developers “credits”. Then developers that are disturbing existing wetlands can buy these “credits”. The overall goal is to provide no net loss in wetlands. This program would allow Webster City to be paid for their addition of this wetland or could keep these “credits” and save for another project that might disturb an existing wetland. However, since this project is already being funded, it might not qualify. According to Heath Delzell from the IDNR, “Federal funding cannot be used for the creation of the mitigation bank, however state funding could, depending on the funding. Some state funding sources actually come from the federal government with the intention of the state administering them. Other state funding sources come directly from state taxes. An in-depth review of the specific proposed funding sources would need to occur in order to determine whether or not the resultant wetland would be eligible for a bank. This process would occur during the planning discussions with the US Army Corps.” Therefore, HPW recommends the City of Webster City contact the Corps of Engineers before beginning to verify any funding limitations. Furthermore, if the City of Webster City qualifies for credits, the construction phase will be monitored by the Corps of Engineers and may take longer and the wetland monitoring will have to meet additional requirments.

Recommendations

HPW has several recommendations for the construction of the wetland that were not within the scope of HPW’s work. Due to the high-water table in the project location it is recommended to begin construction during the dry season, when groundwater is the lowest, or during the winter months. This will reduce the chance of hitting groundwater during construction.

In the event total funds are not available for the project the new trail route can be completed on a future date. If this option is taken the emergency spillway should not be graded completely out to the river, as this would remove part of the trail without an alternative. While the old route is still in place it will flood during extreme water events, the frequency of this will be less than it is currently because of the wetland.

Permits

There are two permits required for this project. The first permit is the Corps 404 permit and governed by section 404 of the Clean Water Act. The second permit is the Iowa DNR Flood Plain permit. There is a Joint Application that combines both permits and can be found on the IDNR website.

<u>Section VII</u> Engineer's Cost Estimate

Table 2: Total Project Cost Estimation.

Item No.	Bid Item	Unit	Qty.	Unit Price	Cost	Source
1	Clearing and Grubbing	AC	4	$ 750.00	$ 3,000.00	Idot
2	Topsoil, On-site	CY	1600	$ 7.75	$ 12,400.00	Idot
3	Excavation	CY	20000	$ 7.75	$ 155,000.00	Idot
4	Reventment Mats	SY	315	$ 25.00	$ 7,875.00	Idot
6	Bentonite Pool Clay Lining	SF	2835	$ 1.15	$ 3,260.25	www.homeadvisor.com
8	Storm Sewer, Trenched, RCP, 42" Dia	LF	180	$ 250.00	$ 45,000.00	Idot
9	Removal of Storm Sewer, 24" Dia	LF	520	$ 19.00	$ 9,880.00	RSM
10	Removal of Storm Sewer, 30" Dia	LF	700	$ 19.00	$ 13,300.00	RSM
11	Pipe Apron, 24" Dia.	EA	1	$ 500.00	$ 500.00	Idot
12	Pipe Apron, 30" Dia.	EA	1	$ 780.00	$ 780.00	Idot
13	Manhole	EA	1	$ 3,200.00	$ 3,200.00	Idot
14	Intake SW-509	EA	1	$ 6,600.00	$ 6,600.00	Idot
15	Removal of Shared Use Path, PCC	SY	730	$ 15.00	$ 10,950.00	Idot
16	Shared Use Path, PCC, 6" Thickness	SY	1350	$ 60.00	$ 81,000.00	Idot
17	Gravel Path 4"	SY	255	$ 7.75	$ 1,976.25	Idot
18	Hydraulic Seeding, Seeding, Fertilizing, and Mulching, Temporary Erosion Control Mixture	AC	0.3	$ 1,400.00	$ 420.00	RSM
19	Hydraulic Seeding, Seeding, Fertilizing, and Mulching, Type 1, Permanent Lawn Mixture	AC	1.5	$ 1,400.00	$ 2,100.00	RSM
20	Silt Fence	LF	650	$ 2.00	$ 1,300.00	Idot
21	Silt Fence or Silt Fence Ditch Check, Removal of Sediment	LF	650	$ 0.75	$ 487.50	Idot
22	Construction Survey	LS	1	$ 2,000.00	$ 2,000.00	Idot
23	Mobilization	LS	1	$ 3,000.00	$ 3,000.00	RSM
24	Bench	EA	1	$ 250.00	$ 250.00	RSM
25	Kiosk	EA	4	$ 200.00	$ 800.00	ParkWarehouse.com
26	Bat house	EA	2	$ 16.25	$ 32.50	Walmart
	Construction Subtotal				$ 365,111.50	
	10% Contingencies				$ 36,511.15	
	20% Engineering and Administration				$ 73,022.30	
	Total Project Cost				$ 474,644.95	
	FINAL COST:				**$500,000**	

Appendix A – Forebay Design Calculations

Total Water Quality Volume (WQv)

$$WQv = Qa * \frac{1\,ft}{12\,in} * A(acres) * \frac{43560\,SF}{1\,acre}$$

Total Drainage Area (A) = 109.5 acres

Qa = RV * P = 0.05387 * 1.25 = 0.067

P = 1.25”

RV = 0.05+0.009*(I) = 0.05+0.009*0.43 = 0.05387

Impervious % (I) = 0.43

Table A.1. Land use table calculating impervious percentage and total CN. Soil type C used.

Land Use	**CN**	**Ac (%)**
grass (fair)	79	0.18
paved	98	0.24
residential (1 ac)	79	0.12
Residential (2 ac)	77	0.45
Impervious %		**43.26%**
Total CN	**83**	

$$WQv = 0.067 * \frac{1\,ft}{12\,in} * (109.5) * \frac{43560\,SF}{1\,acre} = \boldsymbol{26766\,ft^3}$$

Forebay sizing

Pre-treatment techniques only need to be able to hold 10% of the total water quality volume.

Forebay volume = 0.1 * WQv = 0.1 * 26766 = 2677 ft^3

Table A.2. Surface area of the forebay at different depths. The maximum depth of a forebay can be 4 feet.

Depth ft	Surface Area s
1	2677
2	1338
3	892
4	669

North Carolina recommended to have a deeper bottom at the intake and a shallower bottom at the outlet of the forebay. HDR decided to have a 4 foot depth at the intake and a 3 foot depth at the outtake. However as a factor of safety the 3 foot depth area will be used.

$$Area = \frac{\pi}{4} * D^2$$

$$D = \sqrt{\frac{A * 4}{\pi}} = \sqrt{\frac{892 * 4}{\pi}} = \mathbf{34\ ft}$$

Table A.3. Summary of Forebay Sizing.

Forebay		
Volume	2732	CF
Depth	3	FT
Surface Area	911	SF
Diameter	34	FT

Forebay Elevations

The Client gave information that at the road the north storm sewer’s top of pipe is 8.5’ below the manhole lid and is 30” in diameter. Also, the south storm sewer’s top of pipe is 8’ below the manhole lid and is 24” in diameter. With this information, HPW assumed that the bottom of the largest pipe would be 11 feet below grade. The bottom of the pipe needs to be at least 2 feet above the bottom of the forebay bottom to reduce sediment buildup at the pipe. The existing elevation where the inlet pipes and forebay is 1014. Therefore, the bottom of the pipe elevation is 1003, so the bottom of the forebay elevation is 1001 and the top of the forebay elevation is 1005.

Appendix B– Low Marsh Design Calculations

Water Quality Volume Addressed by Wetland

Total WQv – ForebayWQv = WQv’ addressed by wetland

WQv’ = 266766 – 2677 = 24089 ft^3

Multiply by a factor of safety of 1.5

WQv’ = 24089*1.5 = **40148 ft^3 = 0.92 acres**

According to NC at least 40% of WQv’ should be shallow water zone, which include low marsh and high marsh zones. ISWMM says sinuosity has to be at least 3.

Flow Rate of First 1.25” of 10 year 24-hour Rain Event

From ISWMM Chapter 2, interpolation was used to solve for the time it took for 1.25”.

$$t = \frac{1.70 - 1.20 inch}{60 - 30\ min} = \frac{1.70 - 1.25\ inch}{60 - x\ min} = \ 16.5\ mins$$

Then

$$Q = \frac{WQv}{t} = \frac{26872.97}{(16.5min * 60s/min)} = \ 28\ cfs$$

Channel Dimensions

Input values into HydroCAD, shown in Figure C.1, to get a channel that will hold this flow rate. Engineering toolbox provided an n value of 0.05 for this type of channel and side slopes of 6. ISWMM requires a velocity of less than 10 feet per second. The depth is 1.5 feet, the bottom width is 1 foot and the top width is 19 feet.

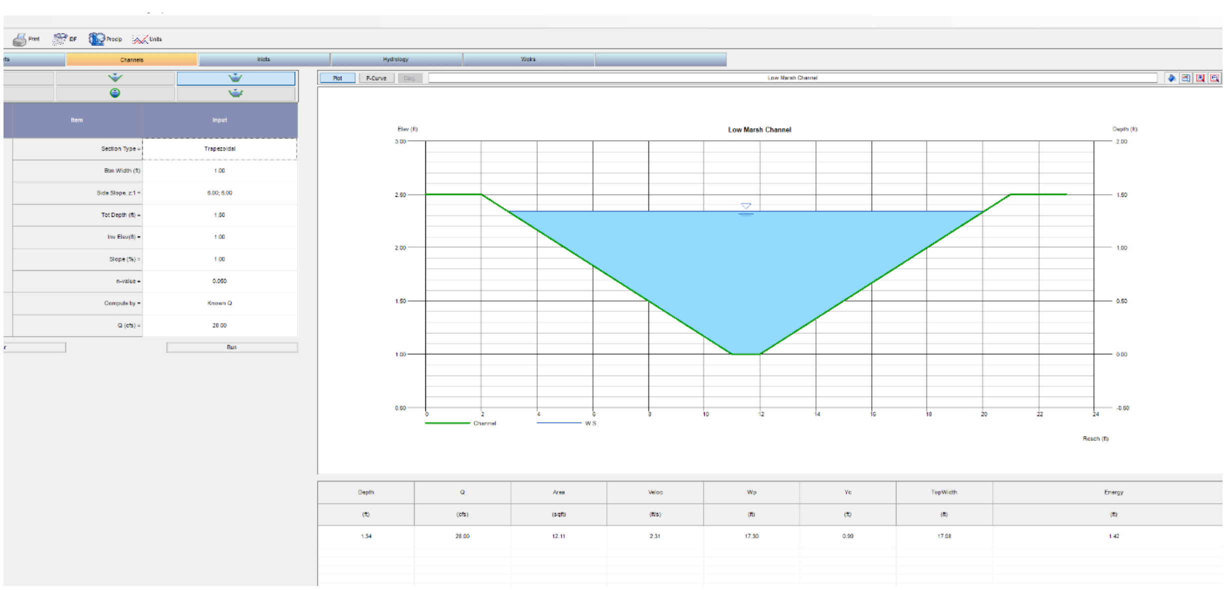


Figure B.1. HydroCAD inputs and outputs for low marsh channel.

Low Marsh Volume

$$V = A * L = 15 * 840 = \frac{12000\ cf}{43560\ ac} = \mathbf{0.29\ ac - ft}$$

Low Marsh Elevation

ISWMM Chapter 8's standard for the depth of a low marsh zones is a maximum of 1.5 feet from the permanent pool surface elevation. Therefore the bottom elevation of the low marsh channel is 1005 and the top is 1006.5.

Appendix C – High Marsh Design Calculations

High Marsh Volume

The remaining volume needed for the shallow water zone is:

$$V = 0.92(0.4) - 0.29 = \mathbf{0.078\ ac - ft}$$

Therefore, the high marsh volume needs to be a minimum of 0.078 acre-feet. ISWMM Chapter 8 has a maximum depth of 0.5 feet. The surface are of the high marsh is

$$SA = \frac{0.078\ ac - ft}{0.5\ ft} = \mathbf{0.16\ ac}$$

High Marsh Elevation

ISWMM Chapter 8's standard for the depth of a high marsh zones is a maximum of 0.5 feet from the low marsh surface and have a 6 to 1 side slope. Therefore the bottom elevation of the high marsh channel is 1006.5 and the top is 1007.

Appendix D – Deep Pool Design Calculations

Deep Pool Volume

NC recommends non-forebay deep pools make up around 15 percent of the WQv.

$$V = 0.15 * 0.92 = \mathbf{0.138\ ac - ft = \ 6025\ cf}$$

Deep Pool Sizing

ISWMM Chapter 8 says that the non-forebay deep pool can have a maximum depth of 3 feet. With this depth and volume the surface area is

$$SA = \frac{6025\ cf}{3\ ft} = \ \mathbf{2015\ sf}$$

This gives a pool diameter of

$$D = \sqrt{\frac{A * 4}{\pi}} = \sqrt{\frac{2015 * 4}{\pi}} = \mathbf{51\ ft}$$

Table D.1. Summary of Deep Pool Sizing.

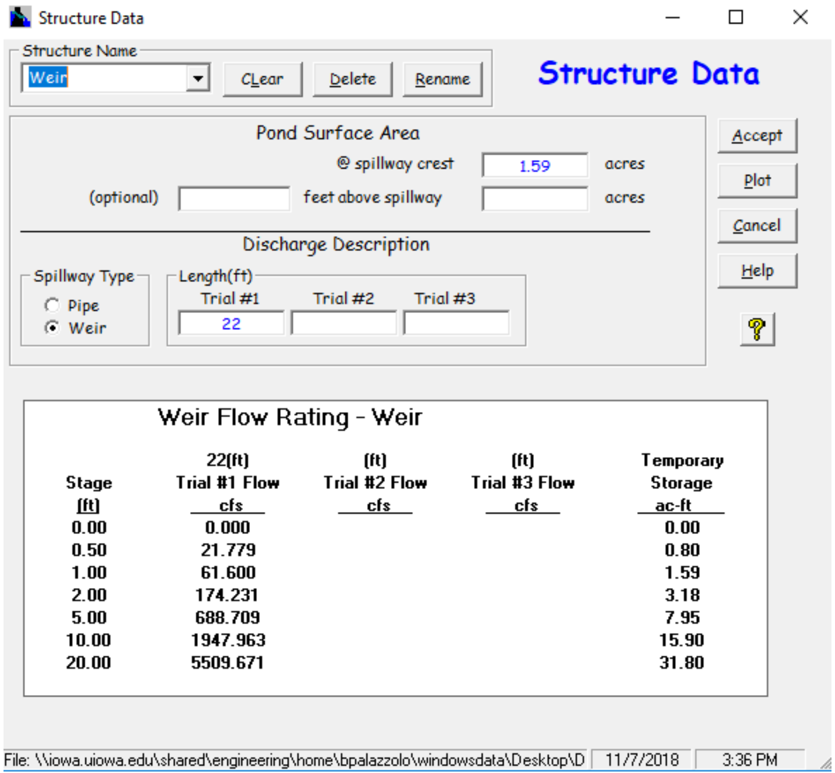
Outlet Pool		
Volume	6128	CF
Depth	3	FT
Surface Area	2043	SF
Pool Diameter	51	FT

Deep Pool Elevation

The deep pool will have the same surface elevation as the forebay at 1005. The bottom of the deep pool's elevation is 1002.

Appendix E– Outlet Structure Design Calculations

Using WinTR-55, the 10-year, 24-hour storm was calculated and using the structure analysis, the required width and height of the overflow weir was calculated. Below is the WinTR-55 output, where 22 feet was selected because the flow rating was the nearest size to matching the 10-year, 24-hour storm peak flow rate.



Stage (ft)	22(ft) Trial #1 Flow cfs	(ft) Trial #2 Flow cfs	(ft) Trial #3 Flow cfs	Temporary Storage ac-ft
0.00	0.000			0.00
0.50	21.779			0.80
1.00	61.600			1.59
2.00	174.231			3.18
5.00	688.709			7.95
10.00	1947.963			15.90
20.00	5509.671			31.80

Figure E.1. A screenshot of WinTR-55 calculations for determining necessary overflow weir size.

Using WinTR-55, the same discharge was used to find the required outlet pipe diameter. Below is the WinTR-55 output, where a 42-inch diameter pipe was selected because the pipe flow rating was greater than or equal to the overflow weir flow rate.

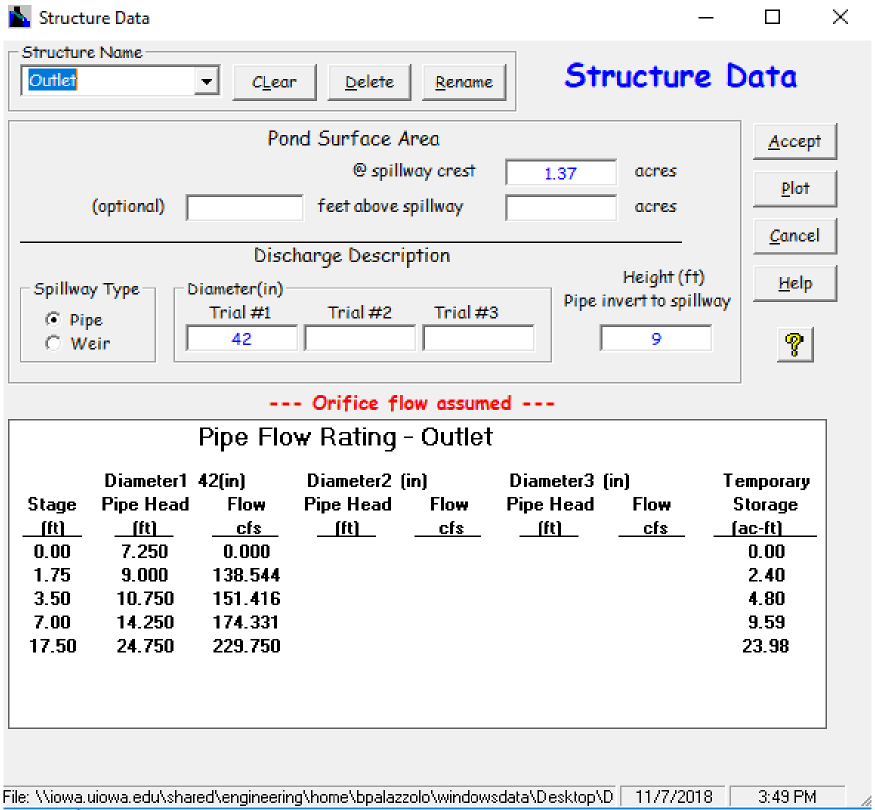


Figure E.2. A screenshot of WinTR-55 calculations for determining necessary outlet pipe diameter.

Appendix F – Extended Detention Design Calculations

Based on the North Carolina Department of Environmental Quality Storm Water Design Manual, the extended detention basin volume must be at least 45% of the water quality volume.

$40148ft^3*.45 = \mathbf{18067ft^3}$

After designing the wetland, the total volume of the extended detention basin was calculated in Civil3D as $214282ft^3$, greater than the required volume. The volume was calculated through Civil3D by measuring the area of each contour and multiplying by the contour interval. Below is a table of the Extended Detention from the top of the permanent pool to the bottom of the emergency spillway.

Table F.1. Detention volume by wetland elevation.

Elevation (ft)	Volume (ft^3)
1007	48844
1008	50094
1009	55820
1010	59524
Sum	214282

Appendix G – Freeboard Design Calculations

The freeboard height was dependent on the change of elevation of the extended detention basin to the current surface area due. The slope of the freeboard was dictated by ISWMM chapter 8 as 4:1 H:V. The area within the freeboard of the final design was calculated in Civil3D. The freeboard begins at the top of the permanent pool and ends at the top of the overflow bank.

Width of freeboard = 4ft/ft*7ft = **28 ft wide**

Appendix H – Emergency Spillway Design Calculations

Using results from WinTR-55, the peak flow for a 100-year, 24-hour storm with a factor of safety of 1.5 was calculated to be 470 cfs. The emergency spillway cannot have a volume faster than 10 feet per second. Using HydroCAD, the peak flow rate, and a maximum spillway height of 3 feet, the required width of the emergency spillway was 35 feet. The maximum spillway height was found as 3 feet because the elevation of the overflow bank is 1014 feet and the top of the overflow weir is 1011 feet, a difference of 3 feet.

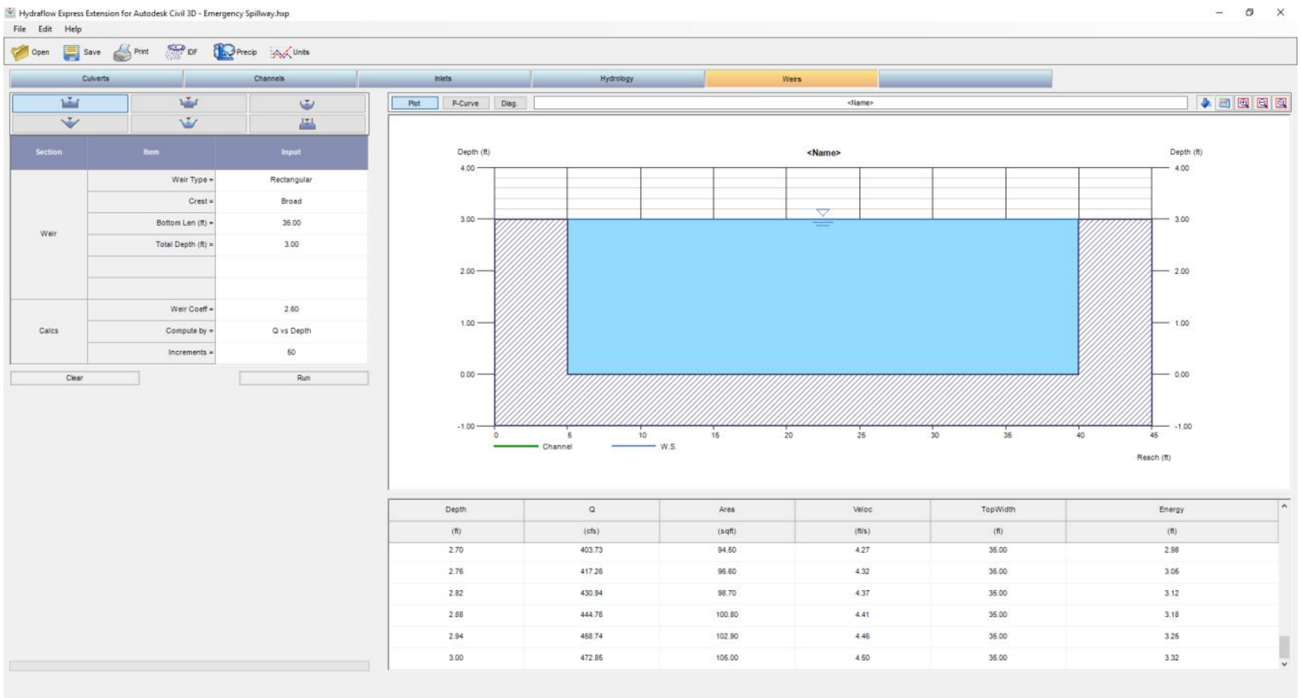


Figure H.1. HydroCAD screen shot of Emergency Spillway.

Appendix I – WinTR-55 results

Throughout the appendix, the 1-year, 10-year, and 100-year, 24-hour peak runoffs were used in making calculations, below are results from WinTR-55 that derived the peak flow rates.

```
                              Webster City
                          Hamilton County, Iowa

                     Hydrograph Peak/Peak Time Table

 Sub-Area       Peak Flow and Peak Time (hr) by Rainfall Return Period
 or Reach      10-Yr    100-Yr      1-Yr
Identifier     (cfs)     (cfs)     (cfs)
             (hr)      (hr)      (hr)
----------------------------------------------------------------------------------
SUBAREAS
DA 1          164.70    313.63     70.92
            12.45     12.47     12.51


REACHES

OUTLET        164.70    313.63     70.92
```

Figure I.1. WinTR55 output table of peak flow rates.

Appendix J – References

1. Iowa Department of Natural Resources (2009, October 28). ISWMM Design Standards Chapter 2 – Unified Sizing Criteria. Retrieved from http://www.iowadnr.gov/Environmental-Protection/Water-Quality/NPDES-Storm-Water/Storm-Water-Manual
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