Warner Park Pond Project

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Abstract

Students of the NRES Capstone course were charged with the task of developing a design plan for the Warner Park pond, a storm water detention basin in the Miller Ranch neighborhood of Manhattan, Kansas. The objectives of the design are to: maintain the pond function as a storm water basin by creating a wetland buffer to help reduce erosion and algae bloom, design a wetland shelf on the south side of the pond which has the highest level of silting and erosion, adopt an aesthetic feature on the north and west side that provides residence and visitors a place to enjoy the pond and it's natural features, and create cohesiveness between neighboring Warner Park and the drainage pond along the south and east side. This plan was designed to serve the objectives of the neighborhood residents and to provide a low-cost maintenance solution for the City of Manhattan.

Introduction/Context

The residents of Miller Ranch, a neighborhood on the south west side of Manhattan, Kansas, approached the Manhattan Parks and Recreation Advisory Board about their neighborhood storm water retention basin in the summer of 2014. A presentation was given to the advisory board concerning the current state of the pond and action items that Miller Ranch residents would like the city to consider. Since that time, the Warner Park pond has been on the agenda of two additional city meetings. No decisions concerning the design of the pond have been made. It is the intent of the NRES project design team to propose a concept for the Warner Park pond that is in the best interest of the City of Manhattan and Miller Ranch residents alike.

Critical Issues

Residents of the Miller Ranch Neighborhood have become increasingly concerned with the state of the Warner Park pond, a residential stormwater detention pond bordering the backyards of four neighborhood homeowners. Many homeowners believe the current state of the pond is of a failed condition – one that fosters insects and algae due to stagnant water conditions and in which sedimentation from erosion has resulted in marsh-like conditions. The homeowners are concerned with the health, safety and aesthetic appeal of the current pond condition, which if restored to its former beauty, could result in a community space for residents. Part of the current pond condition, the homeowners believe, is due to a lack of continual maintenance by the city. The four neighboring homeowners have taken it upon themselves to mow the perimeter of the pond on the north and west sides, and clean debris and trash from the area. The homeowners request the city to send maintenance crews more frequently than the current annual basis, and wish to see

the pond dredged of sedimentation, large storm debris removed, and erosion of inlet tubes controlled through tree removal and placing rock along the channel.

The homeowners are also personally seeking ways to eliminate algae from the pond. There is an annual bloom of algae that correlates to use of fertilizers in the spring by homeowners in the upper area of the watershed. The eutrophication is not necessarily hazardous to the pond as long as there is not an acute overabundance of the algae. Excess amounts could cause hypoxia, or oxygen depletion, and create dead zones in the pond which would kill off the plant and animal life.

The City of Manhattan offers an opposing view on the condition of the stormwater pond. From a functional perspective, the city argues that the stormwater pond is serving its intended purpose – that of stormwater detention – and has no desire to spend Stormwater budget dollars on improvements to the area. The city notes that the pond was the neighborhood developer's infrastructure that they later chose not to maintain. The pond was then left in the hands of the city, who argues they would not have constructed the basin to begin with. Erosion and unwanted pond infill is not a major issue and no construction projects are located nearby, so little soil will reach the pond. Additionally, the city argues that the Miller Ranch Homeowners Association lacks consensus on the future of the pond, which hinders the decision making process of the city.
If a change to the pond is to be made, the city notes that its two main objectives are:

1. A design plan that is easy to maintain
2. A plan that fosters public education and outreach for Wildcat Creek.

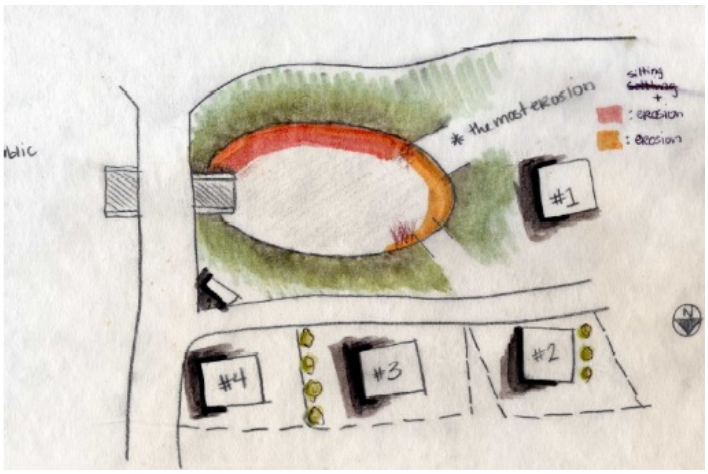
Methods

The process of developing a new approach to the design of the Warner Park pond involved research of relevant literature and personal interviews with homeowners and the City of Manhattan. Literature regarding wetlands, wetland shelves, stormwater runoff and low impact designs led to a plan to adapt what is already present at the project site. Funding of the project was a contributing factor to the design decision, and resulted in a two-phase project outlook. The first phase will establish a limited number of wetland plants as well as hydrophilic tree species. These will serve to provide further infiltration and add to the consumption of algal producing nutrients. The second phase will contribute to site aesthetics and involve limestone seating areas and the creation of a park-like space.

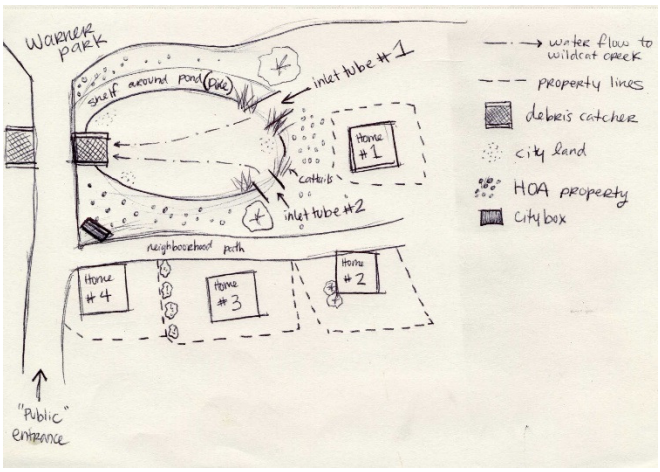
During our interviews with the city, it was discovered that the Public Works branch is not interested in funding this project as there are no current issues impairing the pond's function. The pond is able to manage the rain events in Manhattan, and an emergency spillway serves to reduce water level in extreme cases. If the City decides to make a change to the pond itself they would like to create a dry basin as it is a cost effective solution. The homeowners, however, would like to see the pond retained, as adults and children enjoy the aquatic habitat and community space it creates. The following Proposal A was developed upon this knowledge, and if a funding source is made available, will be sourced from the Parks and Recreation Department within the City of Manhattan.

Proposal A – Wetland Shelf

Concept



Drawing 1



Drawing 2

Drawing 3

Once the interview process was completed, project programming begin. Project programing offers an organized and descriptive set of requests presented by the homeowners and City of Manhattan. One overarching request made by both parties is low maintenance and cost effective. Therefore, this was the main goal for Proposal A and Proposal B. However, the homeowners also requested a space to view aquatic habitat and provide a space to have community interaction. Due to the additional requests, Proposal A was created. The above drawings (1-3) illustrate the purposed plan. Drawing 1 and Drawing 2 are plan views of the site. Indicating the relationship to neighboring Warner Park and nearby residents (Drawing 1). Drawing 1 is a rendered plan indicating where the most erosion and silting takes place around the pond. Drawing 2 is a diagram explaining connectivity between neighboring Warner Park along with four residents. The third drawing is a rendered perspective illustrating a few aesthetic features such as a limestone bench, cattails near the inlet tubes, four trees, wetland shelf (red-orange color), and debris catcher along the north side. This perspective provides a three dimensional view of the site providing further explanation of Proposal A. One main difference between Proposal A and Proposal B is the wetland shelf. The additional sections that follow expand on this feature through application, budget, and maintenance.

Wetland features

The Warner Park pond is a small pond in a watershed that has sediment accumulation, algae and mosquito issues. In order to remediate some of these problems, establishing a hydrophilic vegetative ecosystem and an environment that fosters mosquito eating insects will create a more pleasing area. The wetland needs to be self-sustaining in order for the city to consider approving improvement funding. As such, there are many crucial aspects that come into play during the design of a wetland shelf. Each of these aspects, if not done correctly, can potentially cause more problems in the long run. The Warner Park pond has the opportunity to be a highly attractive and aesthetically pleasing area; however, if it is overrun with mosquitoes and people will likely not spend their afternoons and evenings there. The following section will cover flooding, suggested plant species, mowing practices, predators as a controlling feature, and animal species to reduce the mosquito population.

Flooding: One of the issues occurring within the Warner Park pond is an abnormal amount of flooding. It will be difficult and costly to increase the depth of the pond. Instead, the design proposes planting hydrophilic species higher up in the watershed. Although the amount of hundred year floods cannot be controlled, planting hydrophilic vegetative species around the pond may help to absorb some of the excess water that can happen during these events. The Pawpaw tree, *Asimina Triloba*, is a hydrophilic species that could be planted a few dozen yards from the pond to help use some of the water that would normally runoff into the pond. Also, a Willow tree, preferably one that would grow to be over 15 feet could be planted at the water's edge. This would create pleasant shade over the pond for animal life as well as a place for people to sit and relax on a hot summer's day.

Plant Species: Introducing new plant life to the pond will create a habitat for not only fish but also other wildlife. When creating a self-sustaining pond it is important to have a variety of plant types. The types of aquatic vegetation necessary include: emergent, rooted floating, submerged and free floating. An emergent plant is one that grows along the shoreline. Using species such as Cattails, which are already present in the pond, Bulrushes and Common Reed, dragonflies can be attracted. One of the staples of the dragonfly and dragonfly larvae's diet includes mosquitoes. "A single dragonfly can eat 30 to hundreds of mosquitoes per day" (Zielinski). Rooted floating species, including water lilies, are more aesthetically pleasing than other types of plant species. This pond has some turbidity to it so an overabundance of water lilies should not become an issue. "Clear water allows these lilies to send up stems and leaves from a greater depth" (Lynch 2). Turbidity will also help the pond in this regard. Additionally, submerged plants are great for attracting birds and wildlife. "Submerged plants are critical to a well-structured fish assemblage" (Lynch 1). Submerged plants create a great habitat for fish to be protected from predators as well as a place to be protected from the sun. The last type of plant that is present in most ponds are free floating aquatic species. Free floating species take their nutrients directly from the pond. This prevents the development of algae by taking away the algae's source of food.

Mowing Practices: In order to lower the mosquito population, implementing a mowing practice will be helpful. Mowing removes the mosquitos' habitat as long as the mowing

does not create ruts. Ruts create places that can harbor mosquitos so it is essential to mow when the area is not damp from precipitation. Along with mowing, it is important to make sure there is not seepage out of the pond. Seepage creates stagnant water and a perfect habitat for mosquitoes to lay their eggs.

Animal Species: Top feeding minnows, mosquito fish and swallows are species that are great for the reduction of mosquitos. Mosquito fish are relatively cheap to buy and can help reduce the amount of mosquitos by eating the larvae out of the pond. Mosquito fish generally run $1.25 each when buying a dozen. On Carolina.com, it is $14.25 for 12 mosquito fish. To stock a pond the size of Warner Park it would be less than $200. Minnows are very cheap to purchase through online sources as well. From Smith Creek Fish Farm it is $85.00 for 1,000 minnows.

In order to attract swallows there needs to be water, shelter and nesting sites. Birds can also offer an attraction for people of the area. According to the Nature Travel Network, birding is the 15th most popular recreational activity. By not planting an excess amount of trees, a nice habitat for swallows is created. They are a species that rarely stops flying and prefer open spaces. The nearby Warner Park creates an attractive setting for this genus. In the trees that are available, it is a good idea to put up birdhouses, as this type of bird is apt to use birdhouses as nesting sites.

Through welcoming new species of plants and animals we can economically create an aesthetically pleasing area for residents of Miller Ranch and park visitors to spend their time. Although some ideas, including dredging and increasing the depth of the pond are out of the question at this moment in time due to funding, there are solutions that can potentially create an area that will not flood as frequently and be more pleasant to relax in. By adding shaded areas and bringing in species that feed on mosquitos, it will be more welcoming to the passerby. The Warner Park pond has a lot of potential, and with improved wetland features, could become an appealing recreation space.

Watershed

The pond is roughly 500,000 ft^3 (10.72 acre-ft) in volume with a 48 in concrete pipe draining the pond to the north. The pond can drain quickly. It would need to drain at a rate of 5.7 cubic feet per second (cfs) in order to empty within 24 hours. The maximum allowable rate is 131.66 cfs for a 100-year storm (Manhattan, 1995). The actual maximum rate is in excess of 100 cfs. This pond can easily handle most rain events in Manhattan. The largest storm event in Manhattan since 2006 was 4.12 in. This is a volume of 22.61 acre-ft, over twice the volume of the storage basin. However, this occurred over a period of 24 hours, so the basin had plenty of time to release the rainwater before it flooded. **Table 1** summarizes the largest rainfall events each year since 2006 (NOAA, 2014). A more detailed summary of rainfall events can be found in **Appendix 1**.

Year	Largest	Date
2006	2.05	08/28/14
2007	4.12	05/07/14
2008	3.60	08/10/14
2009	3.25	04/27/14
2010	1.86	07/05/14
2011	2.76	06/02/14
2012	2.36	08/25/14
2013	2.08	07/30/14
2014	2.67	06/10/14

Table 1. Summary of Rainfall Events

This plan will have little effect on flooding issues, since it does not significantly change the pond volume or the pipe size.

Policy/Maintenance

"For ponds, the annual cost of routine maintenance is typically estimated at about 3 to 5 percent of the construction cost" (EPA, 2014). As such, policy and maintenance plans should be formed at the design outset of any stormwater wetland in order to keep the infrastructure in proper working order long term. These maintenance concerns include:

Clogging and Pipe Repair: Stormwater wetlands are designed to hold water for short periods of time, allowing the majority of flow to continue through a drawdown hole. These pipes are susceptible to clogging by plant debris and trash, which can change water levels and negatively affect desired plant species. Clogged pipes can also cause flooding by preventing the stormwater wetland from retaining additional runoff. Damaged pipes can also lead to embankment failure and leaking of the main spillway through erosion of the bank from the interior. Inlet and outlet pipes should be inspected regularly and after large rainfalls exceeding 2 inches (Hunt).

Maintaining the Permanent Pool: Aquatic habitat, water quality, and visual appeal are dependent upon the water depth of the stormwater wetland. If too deep, the basin cannot hold runoff or serve wetland functions, and if too shallow, mosquito habitat is more likely. Proper water circulation is also necessary to prevent algae buildup due to an excess in nutrients.

Vegetation Management: Wetland plant species are established around the perimeter of the pond and can easily be overrun with invasive species. Plants such as cattails can crowd out more desirable plants and limit wetland diversity. Cattails are not easily removed, and should be limited before a large colonization begins. One method of removing invasive cattails is by the aquatic formulation of the herbicide glyphosate, used by wiping the tip of the cattail fronds (Hunt). Additionally, Miller Ranch values the aesthetics of the turf grass on the upper slopes of the open space surrounding the stormwater wetland, using the

space for recreational purposes. The mowing of this grass is seasonal, and should be done every 1 to 3 weeks as needed.

Dredging: Dredging of stormwater wetlands is needed when sedimentation compromises the functionality of the stormwater wetland design. Sedimentation can cause clogging of the inlets and outlets and decrease the stormwater volume. Dredging can be costly to the city and is not needed often.

Sidewalks and Access: The Warner Park stormwater wetland is used by a number of individuals, and as such, should have key access points for facility inspection by the city and use by homeowners. There is currently sidewalk access for pedestrians, but accommodation for maintenance trucks, emergency repairs, and other future major repairs should be provided (Hoyt and Brown).

Annual inspection of mechanical components: All mechanical components of the stormwater wetland should be inspected on an annual basis at least. This includes gates, hatches, and valves, the failure of which could cause clogging and access issues.

Nuisance issues: The Warner Park stormwater wetland is currently a location of beaver habitat. Beavers can lead to ineffective stormwater detention designs by changing the water levels of the wetland and altering vegetative habitat. Beavers will remove trees and shrubs surrounding the stormwater wetland to build its lodge and dam. If beavers become a nuisance issue, a professional beaver trapper should be contacted (Hunt).

City and HOA understanding: The City of Manhattan owns and is responsible for maintaining the Warner Park watershed pond. Miller Ranch homeowners, however, have for the recent past taken it upon themselves to mow and clear debris from the surrounding area. It is in the best interest of the city and Miller Ranch to devise a clear agreement as to the responsibilities of maintenance and the appropriation of funds, should such become available. This will ensure each party does its duty to upkeep the functionality and aesthetic purposes of the neighborhood open space.

If a stormwater wetland design is funded by the city, then the city must monitor the establishment of new plant species until there is little danger of losing the plantings, thereby making the design ineffective. Once the new design is established, the city should inspect all components of the stormwater wetland on an annual basis. The appendix offers additional information on annual maintenance plans for both wet and dry ponds.

Budget

Manhattan Parks and Recreation Services has resources that can be utilized to implement the wetland shelf improvements to the Warner Park Pond. Implementation is feasible in two phases. Phase 1 will focus solely on implementing vegetation and aquatic life, while

Phase 2 will address seating and additional components to make the pond an inviting community feature. See the appendix for limestone seating designs available in Manhattan, Kansas.

Wet Pond 2-YR Phasing and Maintenance Budget Summary				
Item	Unit Price	Quantity		Total
Feeding Minnows	$ 0.09	1000	$	85.00
Mosquito Fish	$ 1.19	12	$	14.25
Pawpaw Tree	$ 37.00	1	$	37.00
Willow Tree	$ 12.00	1	$	12.00
Water Lilies	$ 25.00	10	$	250.00
Submerged Plants	$ 18.00	20	$	360.00
Floating Pond Plants	$ 6.00	10	$	60.00
3 Months Mowing ($/sf)	$ 0.02	21780	$	1,306.80
Limestone Benches	$ 450.00	4	$	1,800.00
		Total:	$	3,825.80

Transforming the Warner Park Pond into wetland shelf area results in less maintenance for the City to fund and yields a lower annual cost.

Implications to the Community and City

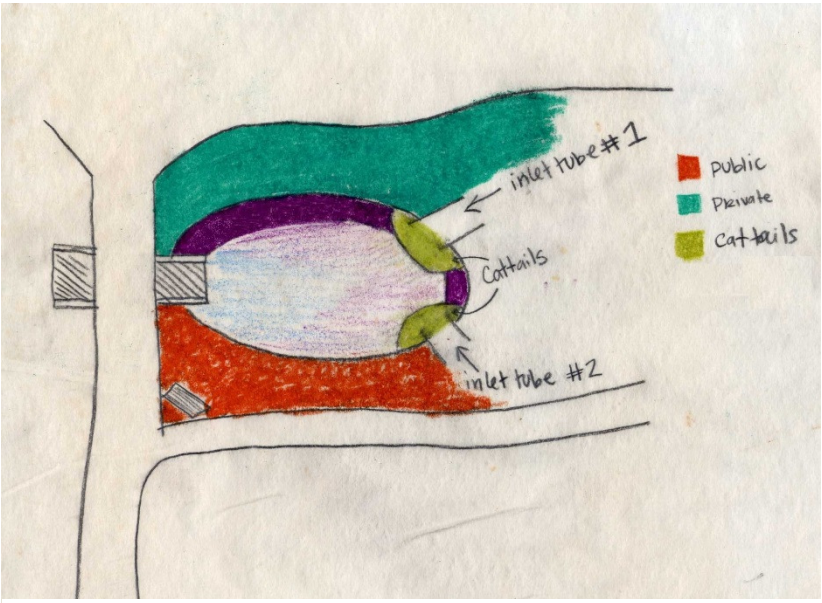
Well-designed spaces should use transition areas and focus on connectivity. The current design of the storm water basin lacks a connection to Warner Park. The design team's proposal is to create a connection between both segments. The pond and Warner Park are both public spaces, the park being a well-known area, and our goal is to heighten interest to this existing pond by creating a park like space surrounding the pond itself.

After speaking with Mr. Wheeler, a neighboring resident to the storm water basin near Warner Park, he would like to see the pond stay intact. One study suggests that "pond front" property can increase the selling price of new properties by about 10 percent (USEPA, 1995).

According to Mr. Wheeler and other community members, the pond is used during track meets, as a community gathering point, for fishing, frog catching, and as a relaxing oasis. Therefore, maintaining the features of the pond for the local community is crucial to the families surrounding this amenity. Creating an aesthetically pleasing experience around the pond will not only benefit the visiting community members, but will also benefit the neighboring homeowners.

Proposal B – Dry Basin

Concept



Drawing 4

Proposal B takes a different approach. Unlike Proposal A which caters to the requests of the homeowners; Proposal B caters to the requests made by the City of Manhattan during the conducted interview process. This interview presented a set of conflicting views. Similar to the homeowners, the City also wanted a low maintenance and cost effective plan. However, the City was unwilling to spend money to create aesthetic features on the site. As a result, creating a dry basin was the only acceptable route. Drawing 4 above illustrates in plan the site and the relationship between public and private spaces. The public space is the main area in which all users will occupy at any given time. With this in mind, not utilizing this space means a loss of cost effectiveness which is called "dead space." Dead space is defined, as space that is not in use or does not have a designated purpose. Not utilizing this dead space means a loss in property value for the neighboring residents. Along with disregarding the requests made by the local homeowners to design an area that offers views of the pond and providing a community like atmosphere for those to use the pond. Additional sections below will expand on the dry basin concept; and providing a further explanation of the basin along with downfalls of adopting this specific proposal.

Watershed

Converting the pond to a dry basin would reduce peak flow and decrease erosion and downstream sedimentation. Flood control would be nearly identical, since the new floor would be at the same elevation as the current pond surface, resulting in very little storage volume loss.

Budget

Retrofitting the pond into a dry basin has a high initial cost to implement. Sediment Removal Solutions estimates mechanically dredging a pond costs $75,000/acre on average. Dredging is an important component to the design life of the pond, however, this task can be postponed and incorporated into the City's stormwater budget at a later date. A feasible alternative for the City to investigate could use high-volume suction pumps, as described on the Sediment Removal Solutions website, which costs nearly 75% less than mechanical dredging (Sediment Solutions, 2012).

The following dredging and mowing estimates are based on 0.5 acres, with grading based on 0.75 acres.

Dry Pond Retrofit and Maintenance Budget Summary			
Item	Unit Price	Quantity	Total
Hydraulic Dredging ($/ac)	$ 18,750.00	0.5	$ 9,375.00
Grading ($/sf)	$ 2.80	32670	$ 91,476.00
3 Months Mowing ($/sf)	$ 0.02	21780	$ 1,306.80
15" RCP Class IV ($/LF)	$ 19.30	60	$ 1,158.00
48" RCP Removal ($/LF)	$ 12.00	62	$ 744.00
15" RCP Installation ($/LF)	$ 39.25	62	$ 2,433.50
		Total:	$ 106,493.30

Implications to the Community and City

Benefits of repurposing the pond to a dry basin are: a reduction in mosquitoes, fewer frogs, limiting of algae blooms, odor reduction, less maintenance cost, and a decrease in peak flow discharge. A negative of repurposing the pond to a dry basin is that, although the water is removed from the basin, this will not completely remove the problem of algae. Algae have the ability to become dormant within soil. Therefore, once Manhattan experiences another large storm, the algae that went dormant at the pond floor could regain life and be deposited down-stream.

From a reselling standpoint, maintaining the basin as a pond is the main reason most homeowners purchased the home itself. As a result, repurposing the pond to a dry basin could deter families from purchasing the homes surrounding the basin in the future.

"Perceived value (i.e., the value estimated by residents of a community) of homes was increased by about 15 to 25 percent when located near a wet pond" and "dry ponds can actually detract from the perceived value of homes adjacent to a dry pond by between 3 and 10 percent" (Emmerling-Dinovo, 1995).

Converting the pond into a dry basin would therefore result in a potential decrease of $140,960 in value for the four adjacent properties. NOTE: the 2014 appraisals for the four

adjacent properties summed to $1,409,600—found on the Riley County Community GIS site http://gis.rileycountyks.gov/website/rileyco/viewer.htm.

Team Recommendations

It is the recommendation of the student design team for the City of Manhattan to implement Proposal A – "Wetland Shelf" as a design solution for the Warner Park storm water detention basin. This aesthetically pleasing option would support appropriate levels of storm water runoff for the area, while simultaneously filtering excess nutrients and controlling algae blooms. By this, the storm water pond can be managed for multiple uses – maintaining ecosystem habitats, a passive recreational area, an amenity for public appreciation, and a functional system for reducing the impact of storm water flows to downstream Wildcat Creek. Through small budget allowances over multiple years, the City of Manhattan can affectively fund the project while continuing low yearly maintenance requirements.

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Appendix

Table 1: Summary of Rainfall Events in Manhattan, Kansas

Year	Month	Total	Largest	Year	Month	Total	Largest
2006	Jan	0.44	0.25	2011	Jan	0.61	0.31
	Feb	0.00	0.00		Feb	0.50	0.28
	Mar	2.06	0.50		Mar	1.58	0.58
	Apr	2.83	1.49		Apr	3.17	1.22
	May	1.35	0.57		May	4.64	1.39
	Jun	1.72	0.41		Jun	4.24	1.76
	Jul	3.01	1.28		Jul	2.69	1.25
	Aug	8.19	2.05		Aug	2.91	1.14
	Sep	2.09	0.77		Sep	1.35	0.72
	Oct	2.09	1.24		Oct	2.24	0.95
	Nov	0.04	0.02		Nov	4.09	1.95
	Dec	1.27	0.61		Dec	3.61	1.37
2007	Jan	0.61	0.27	2012	Jan	0.03	0.02
	Feb	0.85	0.62		Feb	1.87	1.53
	Mar	3.92	2.04		Mar	2.17	0.63
	Apr	2.44	0.81		Apr	2.51	1.39
	May	12.39	4.12		May	1.34	0.97
	Jun	2.70	1.14		Jun	3.85	1.98
	Jul	4.86	2.16		Jul	1.00	0.42
	Aug	0.58	0.47		Aug	5.04	2.36
	Sep	2.35	1.39		Sep	2.52	1.64
	Oct	2.80	1.48		Oct	0.51	0.21
	Nov	0.10	0.09		Nov	0.74	0.54
	Dec	0.72	0.37		Dec	0.39	0.14
2008	Jan	0.14	0.11	2013	Jan	0.69	0.27
	Feb	1.10	0.50		Feb	1.03	0.59
	Mar	2.61	1.63		Mar	1.07	0.47
	Apr	1.32	0.79		Apr	3.27	1.51
	May	4.22	2.46		May	3.55	0.70
	Jun	9.47	3.46		Jun	3.17	0.97
	Jul	2.94	1.39		Jul	4.33	2.08
	Aug	4.04	3.60		Aug	4.10	1.87
	Sep	5.28	2.57		Sep	3.10	1.05
	Oct	2.08	0.74		Oct	3.74	0.97
	Nov	0.94	0.30		Nov	0.54	0.48
	Dec	0.42	0.21		Dec	0.60	0.51
2009	Jan	0.01	0.01	2014	Jan	0.31	0.11
	Feb	0.56	0.43		Feb	1.20	0.77
	Mar	2.47	1.39		Mar	0.54	0.33
	Apr	5.65	3.08		Apr	2.70	0.89
	May	0.48	0.13		May	2.15	1.08
	Jun	8.13	2.28		Jun	6.83	2.66
	Jul	5.08	2.48		Jul	0.91	0.40
	Aug	4.50	1.24		Aug	3.39	1.18
	Sep	2.70	1.18		Sep	1.28	0.42
	Oct	2.29	1.34		Oct	2.45	1.00
	Nov	2.09	0.81		Nov		
	Dec	0.67	0.50		Dec		
2010	Jan	0.08	0.03				
	Feb	0.08	0.03				
	Mar	1.41	0.54				
	Apr	2.48	1.61				
	May	2.48	0.68				
	Jun	6.59	1.77				
	Jul	4.17	1.86				
	Aug	1.88	1.54				
	Sep	3.43	1.35				
	Oct	1.37	0.93				
	Nov	1.86	1.69				
	Dec	0.03	0.02				

(NOAA, 2014)

Table 2: Typical Maintenance Activities for Wet Ponds

Activity	Schedule
• If wetland components are included, inspect for invasive vegetation.	Semi-annual inspection
• Inspect for damage. • Note signs of hydrocarbon build-up, and deal with appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational.	Annual inspection
• Repair undercut or eroded areas.	As needed maintenance
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Monthly maintenance
• Manage and harvest wetland plants.	Annual maintenance (if needed)
• Remove sediment from the forebay.	5- to 7-year maintenance
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly or the pond becomes eutrophic.	20-to 50-year maintenance

Watershed Management Institute (WMI). 1997. *Operation, Maintenance, and Management of Stormwater Management Systems*. Prepared for U.S. Environmental Protection Agency, Office of Water. Washington, DC.

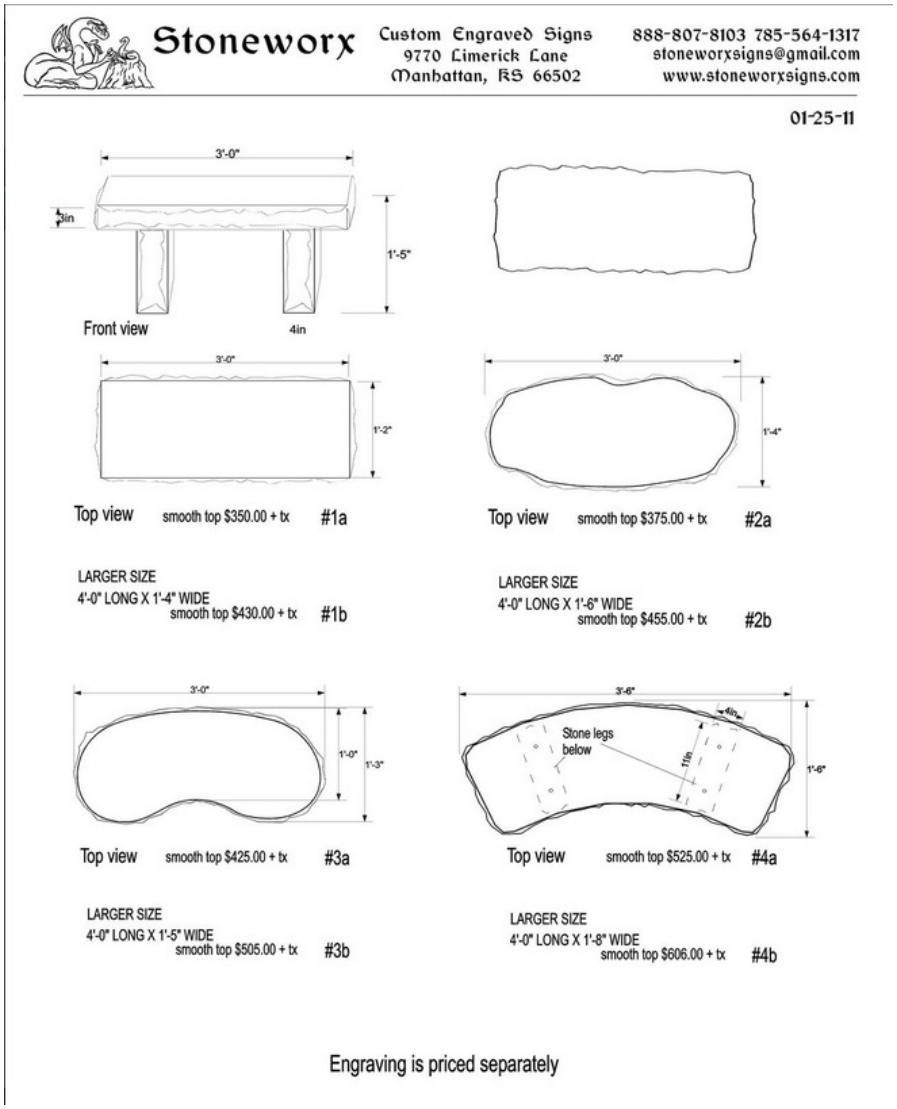
Table 3: Typical Maintenance Activities for Dry Ponds

Activity	Schedule
• Note erosion of pond banks or bottom	Semiannual inspection
• Inspect for damage to the embankment • Monitor for sediment accumulation in the facility and forebay • Examine to ensure that inlet and outlet devices are free of debris and operational	Annual inspection
• Repair undercut or eroded areas • Mow side slopes • Manage pesticide and nutrients • Remove litter and debris	Standard maintenance

• Seed or sod to restore dead or damaged ground cover	Annual maintenance (as needed)
• Remove sediment from the forebay	5- to 7-year maintenance
• Monitor sediment accumulations, and remove sediment when the pond volume has been reduced by 25 percent	25- to 50-year maintenance

Watershed Management Institute (WMI). 1997. *Operation, Maintenance, and Management of Stormwater Management Systems*. Prepared for U.S. Environmental Protection Agency, Office of Water. Washington, DC.

Figure 1: Limestone Seating Designs



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