Natural Resources and Environmental Sciences Capstone Seminar

Turf Management & Water Conservation:

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Brought to you by:
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Suggested methods for an environmentally green course

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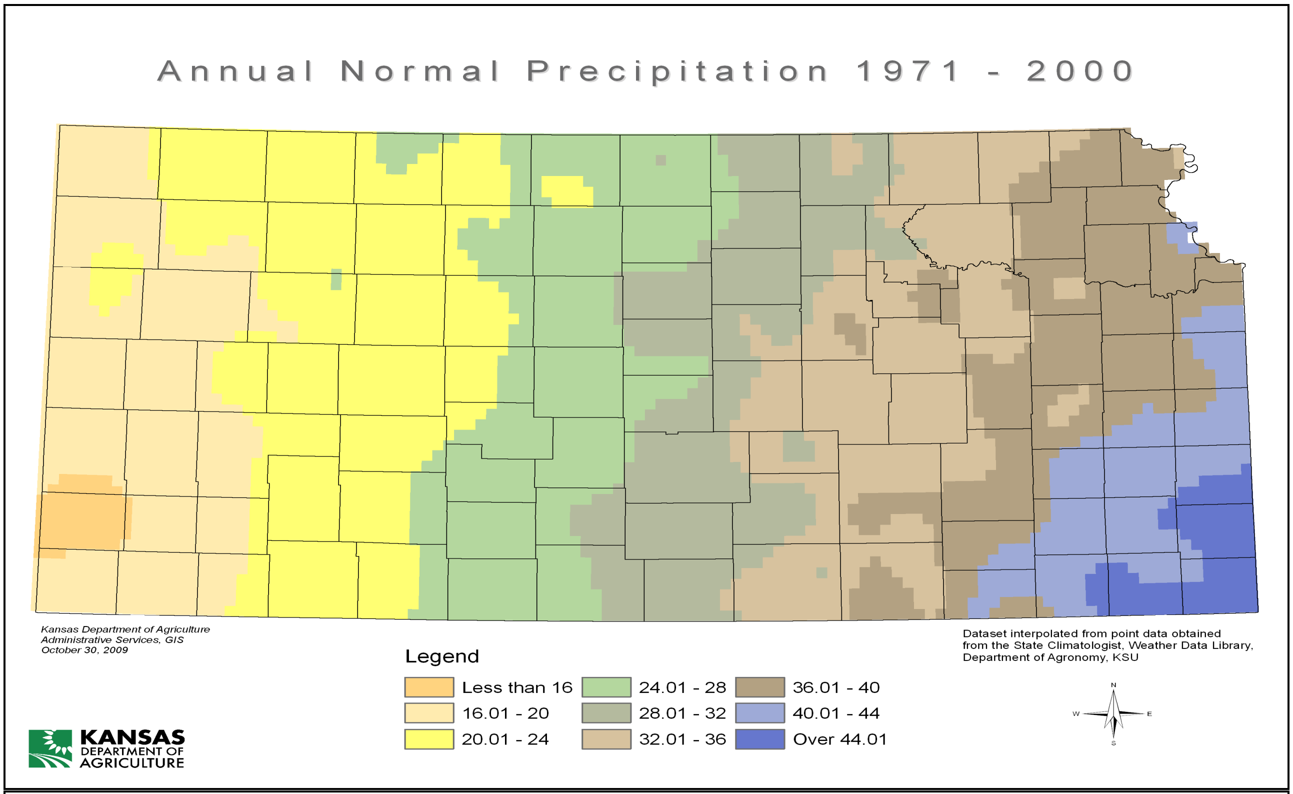
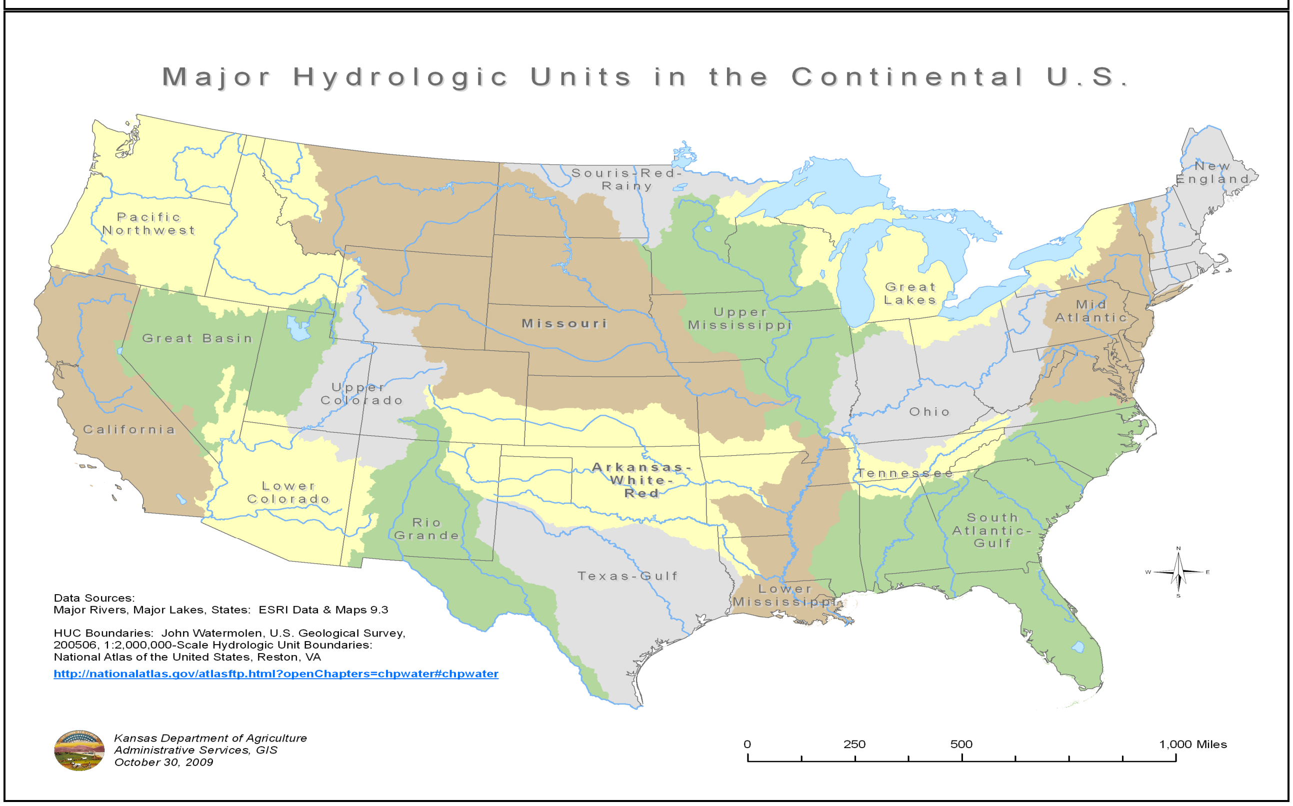

Annual Normal Precipitation 1971 - 2000
Kansas Department of Agriculture
Administrative Services, GIS
October 30, 2009
Legend
Less than 16
16.01 - 20
20.01 - 24
24.01 - 28
28.01 - 32
32.01 - 36
36.01 - 40
40.01 - 44
Over 44.01
Dataset interpolated from point data obtained from the State Climatologist, Weather Data Library, Department of Agronomy, KSU
KANSAS DEPARTMENT OF AGRICULTURE


Major Hydrologic Units in the Continental U.S.
Pacific Northwest
Souris-Red-Rainy
Missouri
Upper Mississippi
Great Lakes
New England
Mid Atlantic
Great Basin
Upper Colorado
California
Lower Colorado
Rio Grande
Arkansas-White-Red
Ohio
Tennessee
South Atlantic-Gulf
Texas-Gulf
Lower Mississippi
Data Sources:
Major Rivers, Major Lakes, States: ESRI Data & Maps 9.3
HUC Boundaries: John Watermolen, U.S. Geological Survey, 200506, 1:2,000,000-Scale Hydrologic Unit Boundaries: National Atlas of the United States, Reston, VA
http://nationalatlas.gov/atlasftp.html?openChapters=chpwater#chpwater
Kansas Department of Agriculture
Administrative Services, GIS
October 30, 2009
0
250
500
1,000 Miles

INTRODUCTION

Kansas is an atypical state for many reasons: for our concerns we will focus on it's being home to an anomalous precipitation pattern. This is due in large part to the shadow cast by the Rocky Mountains, and the 100th meridian that traverses the state, marking a vast change in precipitation levels. Both variables join together in leading to the over-pumping of the Ogallala Aquifer and drought periods that are being dealt with in southwestern portion of the state.

In contrast to a drier west, eastern Kansas is home to a sufficient amount of annual rainfall in addition to being located within the floodplain of the Kansas and Big Blue rivers. With ample water resources available for irrigation, it comes as no surprise that the city of Manhattan is home to two nationally renowned golf courses –Manhattan Country Club and Colbert Hills- each of which are notorious for the greenness of their respective turfs.

Figure 1 lists the ten highest water consumers for the city of Manhattan. From this figure we were able to determine that both golf courses are in fact in the top five listed as high consumers, and therefore most in need of suggestions regarding new and more efficient methods of conservation.

Figure 1: Top ten consumers of Manhattan City Water

Month	Class	Type	Name	Consumption	Billing
8	R	WA	KSU DIV OF FAC #1	45767	55,049.73
2	R	WA	KSU DIV OF FAC #1	37720	45,393.33
8	B	IR	GOLF GENERATIONS INC	6158	7,518.93
8	B	IR	COUNTRY CLUB	3550	4,389.33
2	B	WA	REDBUD ESTATES	3039	3,776.13
8	B	WA	KSU DIVISION OF FACILITIES	2678	3,342.93
2	B	WA	KSU DIVISION OF FACILITIES	2577	3,182.61
8	B	WA	ARC DBA/ COLONIAL GARDENS 1429	2563	3,204.93
2	B	WA	ARC DBA/ COLONIAL GARDENS 1429	2558	3,160.08
8	B	WA	REDBUD ESTATES	2393	3,000.93

The insight we wish to provide these establishments with lies in the area of water conservation. Despite the previously mentioned positive aspects in terms of groundwater availability, it would be foolish to expect any natural resource to last forever. With each of the golf courses in Manhattan being two of the largest potable water consumers in the city, it would be beneficial to everyone involved to take a serious look at how to decrease their water use; particularly by means of recycling the facilities grey water by pumping it to the Manhattan Waste Water Treatment Plant, drilling another well, implementing a storm-water retention pond, and capping the existing lagoon in order to prevent evaporation.

ON-SITE GREY WATER RECYCLING

For the purpose of clarification, grey water is considered discharge from the bathtub or shower, bathroom sink, clothes washing machine, and the dishwasher. It is important to dispose of black and grey sewage water separately because the less chemical breakdown that occurs before disposal the more it will contribute to bacterial growth later on (Brandes). Therefore, separately disposing of grey water from other water waste provides the opportunity to recycle and use it for non-potable purposes; particularly for the irrigation of golf courses. Figure 1 provides an image of the City of Manhattan's current wastewater treatment plant, where all municipal water is treated, whether grey water, waste water, or otherwise, and eventually suitable for drinking.

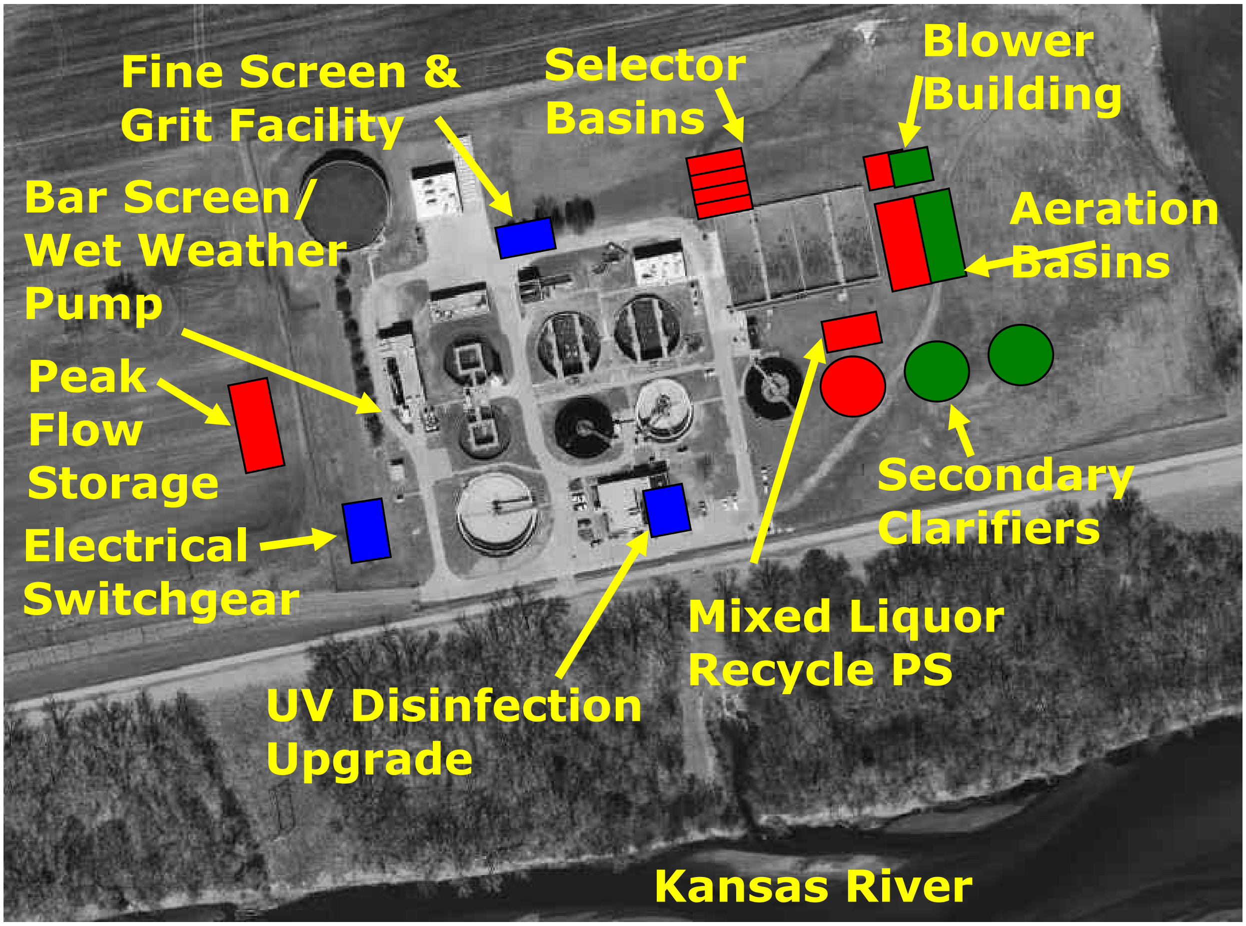


Figure 1: City of Manhattan Wastewater Treatment Plant

As previously noted, two of the largest users of potable drinking water in the city of Manhattan are Colbert Hills Golf Course and Manhattan Country Club. While using grey water to irrigate the golf courses in Manhattan would cut down on their use of water that could be used for drinking, the effects on the soil need to be considered. It is of the utmost importance that the quality of the soil does not deteriorate as a result of the use of grey water. The grasses need to remain fertile so they remain green and profitable to the owners of the course, which is why it will be important to explore the effects of using grey water as an irrigation source before implementing any of the recommended courses of action.

While the amount of contaminants is less substantial than in black water, the use of grey water will still provide certain issues. In a case study that focused on the composition of grey water originating from bathroom wastewater sources, particular attention was paid to the composition of the organic matter, particulates, fatty alcohols, amino acids, and certain metal concentrations. The water was found to have high levels of cadmium and nickel that would be unfit to meet the criteria for water suitable to put on agricultural lands. If used on soil those soils would eventually become Class 3: Polluted Soils by standards in this country (Eriksson and Eilerson).

In addition to concerns regarding chemical elements within the grey water, the oxygen utilization rate shows that the composition of the organic matter contains higher amounts of hydrolysable organic matter than municipal supplies (Eriksson and Eilerson). A separate study also found it to be difficult when removing contaminates to make the water safe enough for drinking. The effective use of aerobic reverse osmosis treated recycled water was tested by looking at the fate of nine organic contaminants. By using large water column tests for a 12 month period, researchers recorded how well contaminants known to have negative effects on water quality were able to persist in the system.

It was found that the anaerobic conditions provided an effective environment for denitrification, and rapid degradation of the endocrine disrupting compounds, and iodipamide. Unfortunately, pharmaceuticals, disinfection by-products and iohexol did not degrade rapidly. There were also minor increases in some metalloid concentrations which were the result of pyrite oxidation, mineral dissolution or pH induced metal desorption (Patterson, et al).

The method for decontaminating sewage water is often times through ultraviolet exposure, but unfortunately there are limitations. The technique did not meet water reuse standards that were implemented through the regulations from the state government. The reason why the water did not pass the test was because of the presence of particles ranging from <1 to ≥2000 micrometers in size. The effectiveness of the UV disinfections was found to decrease as particle size increased.

To make the UV disinfection more effective, measures will have to be taken to settle out particles and filter out the larger forms of particle associated coliform (Winward). What we have concluded to be of the most importance before suggesting the use of grey water irrigation is that in order to maintain the quality turf that presently makes up the course and conserve water simultaneously, it must be ensured that the water is cleaned by adhering to stringent guidelines before it is used as an irrigation source. This, as shown through the various referenced case studies, is necessary since the use of grey water has the capability of becoming detrimental to the soil quality.

PUMPING WATER FROM MANHATTAN WWTP

Pumping water from either the Manhattan WTP or WWTP

One of the options we considered to reduce the dependency of these sites on treated city water was to pipe treated water from the waste water treatment plant (WWTP) or untreated water coming directly from city wells to the water treatment plant to the country club and Colbert Hills golf course. Doing this required the following:

1. **Determining irrigation requirements**
2. **Estimating the piping requirements run water from each source**

3. **Sizing a pump to meet the irrigation requirements**
4. **Calculating total cost of the installation**
5. **Drawbacks to running water from the two sites**

Determining irrigation requirements

Since the golf season runs from early March to November, these months were used to consider when irrigation would be required. To determine this, we first found how much precipitation occurs in Manhattan, KS per month. For this, we used 30-year average values for Manhattan KS, available from WeatherReports.com. Next, it was necessary to determine how much water a golf green in this climate could use per month. This was determined by using potential evapotranspiration (PET) values for Manhattan, KS collected from the Konza research station. Figure 1 shows these two values.

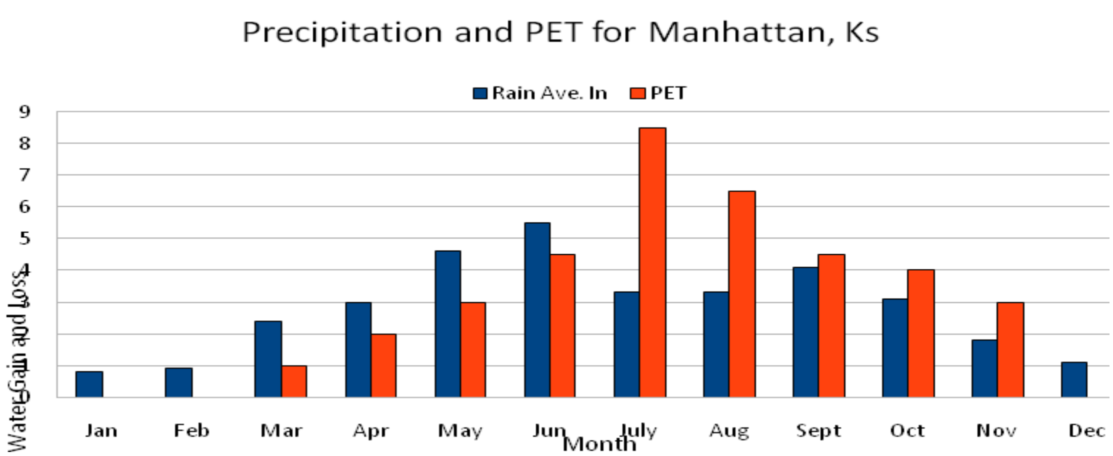


Figure 1. Precipitation and PET values for Manhattan, KS

When PET surpasses precipitation, water will be needed for the green. Assuming a one inch application per irrigation, the number of irrigations per week and then be decided. Using the area of each green, volumes for irrigation were determined. Table 1 shows areas, and volumes for the Colbert Hills and Manhattan Country Club greens.

Colbert Hills									
Month	**Rain Ave. In**	**PET**	**Deficit/Surplus**	**Type Req In/Wk**	**Turf Acre**	**Volume ft^3**		**Ave Daily Ft^3**	**Max Daily Gallons**
Jan	0.8	0	0.8	0	315				
Feb	0.9	0	0.9	0	315				
Mar	2.4	1	1.4	0.1	315				
Apr	3	2	1	0.4	315				
May	4.6	3	1.6	1	315				
Jun	5.5	4.5	1	1	315				
July	3.3	8.5	-5.2	5.2	315	**5945940**	**<-whole area**	**2972970**	**← 2 per week**
Aug	3.3	6.5	-3.2	3.2	315				**So - 2.6 in per irr.**
Sept	4.1	4.5	-0.4	0.4	315				
Oct	3.1	4	-0.9	0.9	315				
Nov	1.8	3	-1.2	1.2	315				
Dec	1.1	0	1.1	0	315				
SUM:	33.9	37	-3.1						**2 per week**

	Total Volume (gal)	Holes	Volume per Hole	Time of Irrigation (hrs)	GPM	Diameter (in)
Manhattan CC	2172192	18	120677.3333	4	101	6
Colbert Hills	8553006	18	475167	5	317	10

Table 1

Piping Requirements

By splitting the irrigated plots into each of the 18 holes, we reduce the amount of water we need to pump at one time. Using the continuity equation, Q=AV where Q=flow rate, A=area, and V=safe operating velocity, table 2 below shows the calculated diameter of pipe required to bring water to each site.

Colbert Hills						
Q=VA					**Volume ft^3**	10.5
A=pi*(D/2)^2	**D=2*sqrt(A/pi)**	1143450		**Colbert Hills**		
				Pipe Dimensions:		

Volume:	63525	Ft^3			Diameter	10	inches
Time:	5	hrs			Length		
Flow:	12705	Ft^3/hr	**gpm**	**Start**	**End**	**Length of Piping**	
	3.53	Ft^3/s	316.78	WTP	Colbert Hills	29000	ft
Safe Velocity:	6	ft/s	316.78	WWTP	Colbert Hills	48000	ft
Area:	0.59	ft					
Diameter:	0.87	ft					
	10.38	inches					
Diameter to buy:	10	inches					
	10						
			Cost of Piping:	**QC Supply**			
	Start	**End**	**Length of Piping (ft)**	**Price/ft for 10"x10' PVC**	**price/ft**	**Total Price (dollars):**	
	WTP	Colbert Hills	29000	54.53	5.45	158137	
	WWTP	Colbert Hills	48000	54.53	5.45	261744	
	Start	**End**	**Total Price of Pipe:**				
	WTP	Colbert Hills	$158,137				
	WWTP	Colbert Hills	$261,744				

MANHATTAN COUNTRY CLUB (MCC)							
Q=VA							
A=pi*(D/2)^2	**D=2*sqrt(A/pi)**	290400					
Volume:	16133.33333	Ft^3					
Time:	4	hrs					
Flow:	4033.333333	Ft^3/hr		**Start**	**End**	**Length of Piping**	
	1.12037037	ft^3/s		WTP	MCC	8000	ft
Safe Velocity:	6	ft/s	100.5644444	WWTP	MCC	27000	ft
Area:	0.186728395	ft					
Diameter	0.487596326	ft.					
	5.851155917	In.					
Diameter to buy	6	In.					

Table 2: Diameter of irrigation piping

Using the online community GIS map available on the WTP website, we calculated average lengths of piping needed by following existing water mains. Table 3 shows the different routes and how much length would be required for each option.

		Cost of Piping:	**QC Supply**		
Start	**End**	**Length of Piping (ft)**	**Price/ft for 10"x10' PVC**	**price/ft**	**Total Price (dollars):**
WTP	Colbert Hills	29000	54.53	5.45	158137
WWTP	Colbert Hills	48000	54.53	5.45	261744

Start	**End**	**Total Price of Pipe:**
WTP	Colbert Hills	$158,137
WWTP	Colbert Hills	$261,744

Table 3: Pipe lengths required

Pump Sizing

The size of the pump is determined by two main factors: 1.) Flow rate and 2.) Head loss. Flow rate was defined in the previous section, but to calculate head loss, we need elevation changes and friction loss. Table 4 shows elevation differences found by referring to the online WTP GIS map.

Hf1 (ft)	**length WTP-CH**	**Length**	**Diameter**
Hf2 (ft)	**length WWTP-CH**	29000	10
		48000	10
Flow, gpm:	13.65		

Start	**End**	**Elevation Change (ft)**
WTP	Colbert Hills	200
WWTP	Colbert Hills	250
WTP	Manhattan CC	50
WWTP	Manhattan CC	100

Table 4. Change in elevations

Friction losses were found by using the Hazen-Williams equation gives that:

$$h_L = \frac{10.67 L Q^{1.852}}{C^{1.852} D^{4.87}}$$

hf=head loss in pipe from friction, (ft)
L=Length of pipe, (ft)
Q=Flow rate in the pipe, (gpm)
C=H-W friction coefficient, in this case 150
D=Inside diameter of pipe, (in)

Using this, the head requirement for the pump was found using the energy equation:

$$Hp=H2-H1$$

Hp=Head of pump
H2=Elevation head at end
H1=Elevation head at start
The calculated values are shown in table 5 were found.

Height at Start (H1)	**Height at End (H2)**	**Friction loss (Hf) (Hazen-Williams)**	**Head of Pump (Hp)**	
1000	1200	13.64619058	-213.6461906	
950	1200	22.5867982	-272.5867982	
		Size pump for:	**250**	**ft of Head**

Table 5. Head losses

Cost of Instillation

From the lengths and diameters calculations and from prices available at QC Supply, total pipe costs were determined. Based on the flow and head loss data, we can find pumps to meet these values. Using prices found from pipebiz.com, average prices for such pumps are given in Table 6.

		Cost of Piping:	QC Supply		
Start	End	Length of Piping (ft)	Price/ft for 6'x10' Pvc	price/ft	**Total Price (dollars):**
WTP	Colbert Hills	8000	34.61	3.461	27688
WWTP	Colbert Hills	27000	34.61	3.461	93447

Start	End	**Total Price of Pipe:**
WTP	MCC	$27,688
WWTP	MCC	$93,447

Start	**End**	**Total Price of Pipe:**	**Price of Pump:**	**Total:**
WTP	Colbert Hills	$158,137	$2,000	$160,137
WWTP	Colbert Hills	$261,744	$2,000	$263,744
WTP	MCC	$27,688	$750	$29,688
WWTP	MCC	$93,447	$1,000	$95,447

Table 6. Cost of installation

Excluded from these total cost are miscellaneous fittings, labor, and operation costs. Viewing this in terms of monetary savings, Table 7 compares each sites annual expenditure on water with the cost of this instillation and gives a return period on when they would see benefits from implementing such a system.

Start	**End**	**Current Yearly Bill**	**Cost of Installation**	**Years to Benefit**
WTP	Colbert Hills	$4,389	$160,137	36
WWTP	Colbert Hills	$7,519	$263,744	35
WTP	**MCC**	**$4,389**	**$29,688**	**7**
WWTP	MCC	$7,519	$95,447	13

Table 7. Turnaround of installation investment

From this we can see that the option of running untreated well water directly from the Water Treatment Plant to the Manhattan Country Club offers the quickest turnaround in investment, there will of course be pump operation costs on top of this each year, but by not having to pay for the treatment of the water, a great deal of money and resources will be saved.

Drawbacks

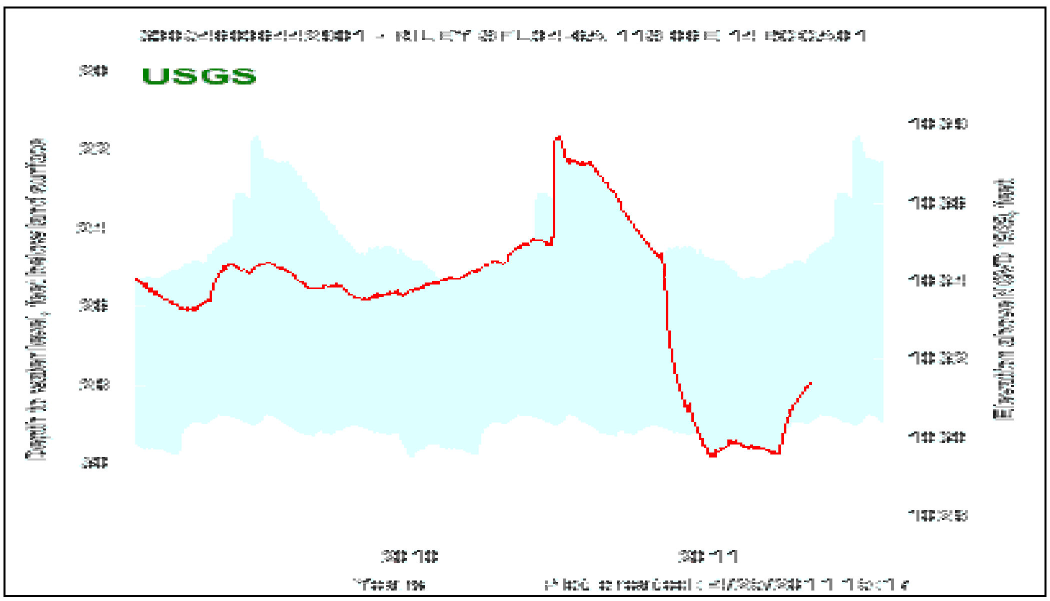
As was mentioned in the Grey Water Reuse section, running water with high nutrient contents through water lines can lead to bacterial growth and algae build up. In order to prevent this from clogging up the irrigation system, routine flushings may necessary. Flushing involves running chlorinated water through the lines to kill off bacteria, sometimes at higher pressure than what the lines regularly flow at. While this should not be a problem with water coming from the wells, lines with water from the Waste Water Treatment plant may have to be serviced this way periodically.

WELL DRILLING

The Manhattan area lies within the Flint Hills eco-region and is home to the greatest reserves of water in Riley County. Located within a valley, it is bordered by several rivers and Tuttle Creek Reservoir to the north- each of which contribute to the city's high water table. Because of its location, and unlike other cities that line the Kansas River, Manhattan has the ability to extract its water from wells rather than the river itself.

Each golf course has a significant amount of water available beneath the surface of their properties, so a more cost effective method for irrigation would be to drill and construct more wells rather than spending excess money transporting treated municipal water. Colbert Hills is the largest consumer of the two and has the most potential for successful drilling of a well because of its being located above a relatively high water table, though each course is in an excellent position to focus on conserving water through the various methods we aim to suggest.

The mechanics of drilling a well are rather simple and involve a process that follows few guidelines. First you must fill out the necessary paperwork in order to properly and legally establish a right to the water, and then a state-certified inspection agent will survey the land for the most suitable area which is generally the low lands. The vast majority of well companies in Kansas drill wells for agricultural purposes which have an output higher than needed for watering a golf course.



The above graph was taken from the USGS site and its analysis of water table levels in Riley county Kansas for 2010-2011. The current water table beneath much of the city is less than 28 ft below the surface. The average depth of wells drilled in other parts of Kansas is over 70 ft below the ground surface. To drill a well in the Manhattan area would be easier and more cost effective compared to other drilling sites in Kansas.

According to The Kansas Department of Health and Environment, the average starting cost of a well (drilling, installation and initial electricity used) is roughly 10,000 dollars, though it is dependent upon on how deep of drilling is required and what type of surface is being drilled through. Riley County rests on top of a significant layer of bedrock limestone, although because of the raised water table the well would likely not have to be drilled very deep. Within a decade or so, the money saved by implementation of the well will cover the initial costs of drilling.

There are several areas that would be suitable for drilling on Colbert Hills, though logistically an ideal location would be next to the existing irrigation lagoon, which would reduce pumping costs. This location will also ensure that for safety and aesthetic concerns, the well will placed in an area that is densely vegetated, a safe distance away from the playing greens, and still within a close enough distance to maximize both the use of the lagoon and well; allowing the course to maximize conservation efforts while maintaining a professional and player-friendly course.

Drilling a well for irrigation purposes would be an environmentally sound pursuit in undertaking the large scale task of irrigating two nationally known golf courses. This would not only save money for the respective courses, but the construction of a well in addition to implementing greywater recycling methods will also aid in lowering the cost to the city of Manhattan for chemically treating potable water being used for irrigation.

CAPPING THE LAGOON

While drilling a well and recycling grey water are viable methods in reducing the environmental impacts of irrigation in golf courses, the redirection of water may be an expensive undertaking. Taking into consideration that the golf courses may be unwilling to alter the schematics of their current irrigation system, we are also suggesting a relatively simpler approach to conserving water that is also rather cost-effective: reducing the evapotranspiration losses from the irrigation reservoirs on the golf courses.

There are two approaches that can be taken with capping their reservoirs: The first is to purchase a mechanical device that stretches across the water's surface and will re-direct sunlight and block wind evaporation. These types of products are very effective (from 80-90% reduction in evaporation), but they are quite expensive and rather unsightly. These products cost on average $10 per square foot, and also take away from the aesthetics of the golf course. Taking aesthetics and the higher cost into account, we have come to the conclusion that a mechanical cap would not be in the best interest of the course.

The second option is a chemical cap. There are two main kinds of products on the market, and both liquid and solid versions do basically the same thing. They are designed to spread out on top of the water to create an extremely thin film on top of the water that shields the water from the elements and making it more resistant to evapotranspiration. The liquid solutions are intended for smaller bodies of water (swimming pools), while the solid solutions were designed for use with larger bodies of water (ponds, lakes, golf course water hazards/irrigation ponds). Since the solid product was designed for golf courses and the liquid was not meant to be used on larger bodies of water, we have determined that the solid chemical cap would be a better fit.

In order to best portray the potential benefits of water conservation methods to Colbert Hills in particular, it would be beneficial to put a dollar value on the amount of water that is being lost to evapotranspiration daily as well as the incentives behind preventing evaporation from their irrigation reservoir.

According to Aquatain Products of Victoria, Australia, a one-acre body of water will lose on average 8,500 gallons of water per day to evapotranspiration (this will vary based on temperatures and wind conditions). Businesses in Manhattan, Kansas are charged $2.39 for every unit of water that they use (1 unit = 750 gallons of water). Colbert Hills has an 8-acre irrigation reservoir and a 4-acre water hazard. With this information, it is suggested that they are losing roughly $324 a day due to evaporation.

Throughout our research, various other golf courses have expressed their happiness with the results of using a solid chemical cap on their irrigation reservoirs. One of the more popular (and also the most cost-effective) products is called WaterSavr, which is made by a company called Flexible Solutions. WaterSavr is designed for one pound of powder per acre to be applied every two days. The powder can be applied with a simple flour sifter on the upwind side of the reservoir, and it will naturally disperse itself evenly over the rest of the water's surface. The product costs $5 per pound, and is shipped in 50-pound bags.

As stated earlier, for every acre or water, an average of 8,500 gallons of water are lost to evaporation every day. WaterSavr is advertised to reduce evaporation by 35% on average. This would save 2,975 gallons of water per acre daily, which is a savings of roughly $9.50/acre/day. Since a pound of product needs to be applied per acre every two days, and a pound costs $5, we can estimate a total savings of $7 per acre per day by using WaterSavr. With 12 acres on their course, Colbert Hills can save roughly $84 a day by using this product.

Important considerations with the use of chemicals on-site are the potential impacts to the environment. This product is made entirely out of food-grade materials, and will completely bio-degrade in three days. Flexible Solutions has done several tests that have determined that because the film that covers the top of the water is so thin and degrades so quickly, it is not used as a food source, which equates to no risk of biomagnifications of any kind. In conclusion, we have determined that by using a chemical cap on their irrigation reservoir, Colbert Hills can save an estimated $7 per acre per day on water, as well as help in reducing the amount of water being consumed.

STORM WATER RETENTION

In addition to protecting an existing water body from the elements, we are also suggesting that the golf courses take into consideration the idea of building a storm water-retention pond/rain garden and using the elements to their advantage. To cut down on water costs and perhaps even up the membership count, a storm-water retention pond is an excellent way to take advantage of the weather provided by the geographic location of Manhattan, as well as getting the community involved and raising awareness of greywater use and water conservation.

Because the annual average rainfall for Manhattan is 34.80 inches, storm water management is within the realm of possibilities for these two courses. Construction of a pond will not only add to the aesthetics of the golf courses, it will provide additional water storage needed to prevent the turfs from drying out during warmer seasons. The rain-garden sketch below, provided by Kansas State University, shows what a simple rain-garden looks like and also provides information about important design considerations.

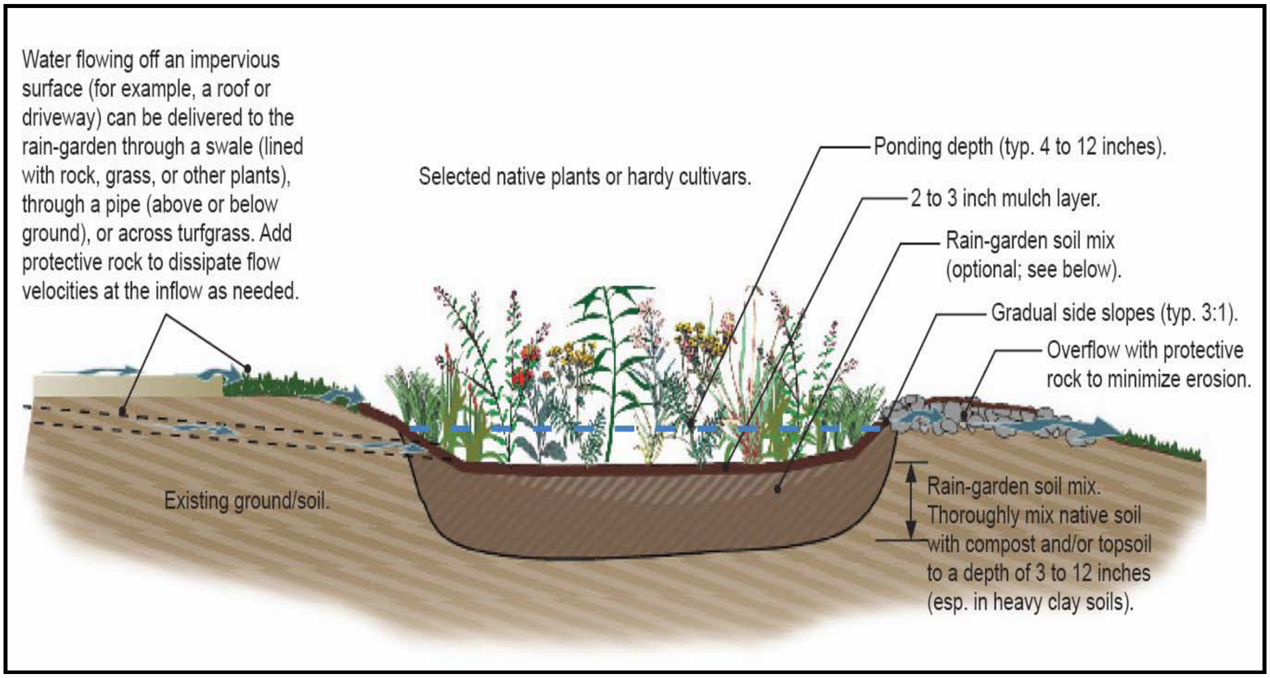


Figure 1. Rain Garden Cross Section

Because of the necessary hilly topography needed to capture the highest amount of flow, a recommendation for Colbert Hills particularly, would be made to place the pond north of the greens on the back nine holes of the course. Since an aquatic habitat will likely attract animals, it would be wise to place the pond a safe distance from the playing areas as to keep any potential wildlife from appearing where they may not be welcome.

Placing the pond at the bottom of a hill will allow water and gravity to run their respective courses and deposit the storm runoff into the pond. Because of the amount of water that can potentially be flowing during peak weather events, erosion control will be crucial in ensuring that the pond is being utilized to its full potential and doesn't become simply a sink for pollutants. A suggestion made in a Kansas State University case study of the campus stormwater collection program, is to line the bed of the pond with medium to coarse sized gravel to aid in slowing down the erosive force of water entering and leaving the pond area.

Combined with lining the bed of the pond, deep rooted plants used for bank stabilization will help to substantially lower the amount of possible water and wind erosion. This will maximize the benefits of the storm water pond, allowing it to flourish as an eco-friendly rain garden that is likely to attract members. Overtime this additional water body will provide water storage, a natural habitat for plants and animals, and an aesthetic advantage over other golf courses.

A suggested course of action would include placing the plants along the edges of the pond while leaving ample area for water to escape during high flow events, and also creating a small sort of plant-based buffer on the downslope side of the pond that receives the most incoming flow and runoff, as illustrated by Figure 2. 'In recent years, rain-gardens and other "best management practices" (BMPs for short) have been designed and implemented in an attempt to slow, hold, filter and infiltrate storm water as near as possible to the places where rain and other forms of precipitation fall to the earth. Rain-gardens are a solution that can be readily adapted to capture and infiltrate storm water on nearly every property, no matter the type of soils or slopes.' (KSU's International Student Center (ISC) Rain-Garden).

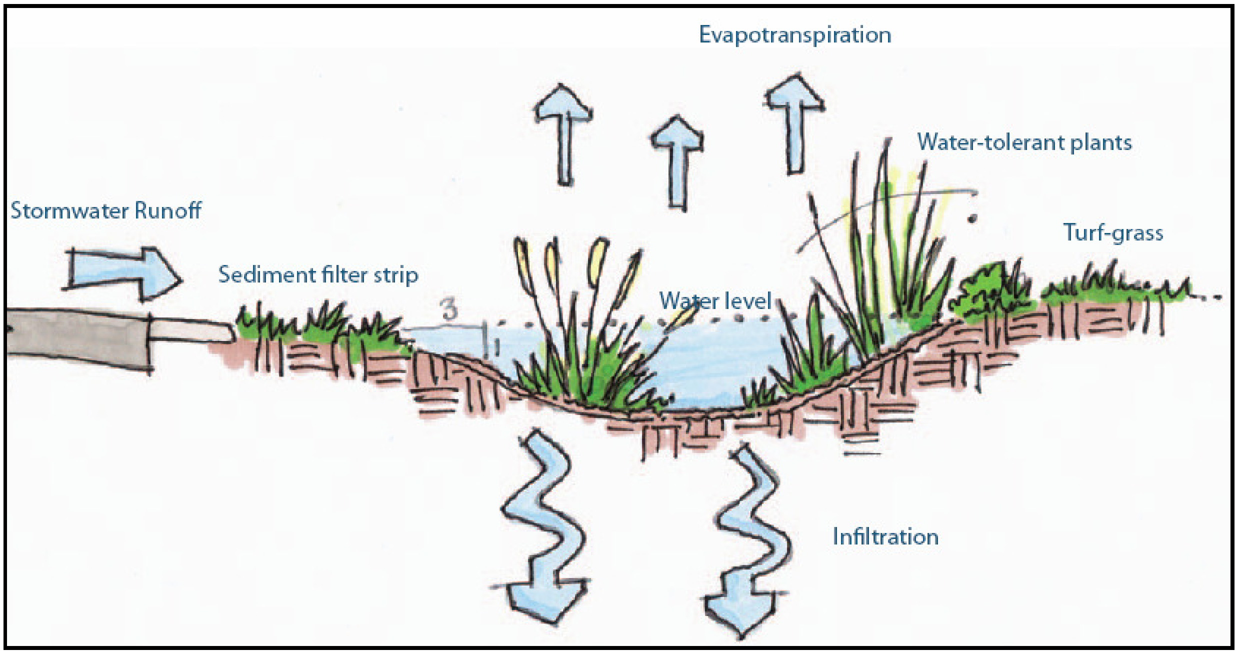


Figure 2. Rain Garden sketch

Since runoff is very likely to include pollutants and other suspended solids, the buffer will provide a natural barrier to these and other fine-grained particles that are picked up by the force of the moving water, and slow their deposition in the pond. Along with ling the bed and planting a buffer, another important aspect in determining the pond's location is its distance from the course. This is important for various reasons such as the amount of runoff, what it is likely to be carrying, and where it will deposit, though perhaps most importantly to reduce the chance of overflow being spilled onto the turf in the event of an extreme weather or otherwise high flow event.

In an effort to reduce the amount of trial and error while implementing a new form of irrigation, and to reduce any possible damage to the above and below surface bodies of water, the Florida golf course referred to in the previously mention case study has provided a suggested list of best management practices. The following should be considered when implementing and maintaining the newly designed course:

DESIGN AND CONSTRUCTION BMPS

• Locate the course so that critical wildlife habitat is conserved and the development does not adversely affect viable, occupied wildlife habitat on the site.

• Identify regional wildlife corridors and configure the course to maintain and/or enhance native habitat to facilitate the use of these corridors. Any existing or proposed crossings of wildlife corridors associated with golf course operations and maintenance should be minimized, and unavoidable crossings should be designed to accommodate wildlife movement.

• Design the course to minimize the need to alter or remove existing native landscapes. The routing should identify the areas that provide opportunities for restoration.

• Design the course to retain as much natural vegetation as possible and to enhance existing vegetation through the supplemental planting of native trees, shrubs, and herbaceous vegetation next to long fairways and in out-of-play areas, and along watercourses supporting fish and other water-dependent species.

• Design out-of-play areas to retain or restore existing native vegetation where possible. Nuisance and invasive exotic plants should be removed and replaced with native species that are adapted to that particular site.

• Retain a qualified golf course superintendent/project manager early in the design and construction process to integrate sustainable maintenance practices in the development, maintenance, and operation of the course.

• Use only qualified contractors who are experienced in the special requirements of golf course construction.

• Develop and implement strategies to effectively control sediment, minimize the loss of topsoil, protect water resources, and reduce disruption to wildlife, plant species, and designed environmental resource areas.

• Schedule construction and turf establishment to allow for the most efficient progress of the work, while optimizing environmental conservation and resource management.

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While enjoying the benefits of the positive financial and environmental responses to conserving water, the golf course has an opportunity to gain community attention and support by allowing the use of the pond and garden for educational programs revolving around the conservation methods in use, or even starting an Adopt-A-Pond program similar to the one in the previously mentioned Florida case studies, allowing community members to get involved and help to actively manage the pond.

CONCLUSION

In closing, the information provided within this report has the capability to drastically alter the dependency of Manhattan golf courses on city water for irrigation that currently exists. The amount of drinking water that is being used on an annual basis to simply water the turf at both Manhattan Country Club and Colbert Hills is deleterious and must be decreased. Despite having current access to copious amounts of surface and ground water, the future generations living in Manhattan will be the ones to suffer if water use is not decreased. Rather than continue wasting a precious resource, we hope that the ideas suggested can be taken into consideration, and appropriate changes can be made for ensuring proper regulations of future water use by each golf course.

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