Harvesting Stormwater for Reuse Augmentation: A Regional Collaborative Approach in Osceola County

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Figure 1. Location of Proposed Water Storage Facility Site Preliminary Water Storage Facility Configuration and Siting

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A preliminary evaluation was performed for City of Kissimmee, City of St. Cloud, Osceola County, and Toho Water Authority (stakeholders) by CDM Smith to determine the feasibility of constructing an earthen, aboveground water storage facility on a 450-acre site. The western portion of the site consists of an existing depressional area that is bound on the east and west by urban ditches and is the area being considered for the water storage facility.

The purpose of the storage facility is to harvest and store stormwater from urban ditches and canals for reuse augmentation and to provide nutrient reduction through treatment of surface waters in support of existing regulatory requirements. As shown in Figure 1, the proposed site is located northeast of Lake Tohopekaliga (Toho) in Osceola County, and has historically been used for sod and dairy farming. Surface water flows from East Lake Toho (via the C-31 Canal) and three urban tributaries (East City Ditch, Mill Slough, and Judge Farms Ditch) were considered in the evaluation of alternative supplemental water supply sources for reuse augmentation.

Using surface water as a supplemental source to reclaimed water is consistent with Florida policy on using the lowest acceptable quality water source for irrigation. This conservation practice preserves higher quality groundwater for drinking water purposes. Therefore, the intent for this alternative water supply evaluation is to increase the quantity of reuse to the maximum extent practicable in order to offset using potable groundwater for irrigation. This will help extend the supply of groundwater for potable purposes for both Toho Water Authority and the City of St. Cloud Utilities (the intended recipients of the supplied water). Managing the conjunctive use of these sources will result in improved water availability and reliability. An additional benefit of this project to the City of Kissimmee, City of St. Cloud, Osceola County, and other upstream jurisdictions is a water quality retrofit to impaired waters.

This preliminary feasibility analysis included data collection and analysis; field reconnaissance for hydrologic and environmental conditions; continuous modeling of flows in three urban tributaries (East City Ditch, Mill Slough, and Judge Farms Ditch); surface water storage facility site screening analysis; preparation of site configuration layouts; conceptual feasibility analysis; and preparation of estimates of probable conceptual capital costs.

The evaluation was completed by CDM Smith using existing and available information (topography, land use, and environmental conditions), coupled with modeling tools. During this preliminary analysis, continuous modeling of stormwater flows for the three urban tributaries was completed to estimate the availability of stormwater for alternative water supply. Stormwater flows and volumes were predicted using the U.S. Environmental Protection Agency (EPA) Stormwater Management Model (SWMM), representing the channels and their tributary area based on a 20-year (1990-2010) period of recording daily rainfall values.

Based on feedback from the stakeholders, the site environmental assessment, existing surrounding land use, and a proposed softball complex (181 acres) in the eastern part of the site, two potential water storage facility configurations were identified in the western part of the site. A minimal and a complete perimeter berm were evaluated for this study. It should be noted that the water table is at or above the bottom of the storage facility under existing conditions; therefore, dredging of the basin would not yield additional live storage. Additionally, since this site lies within an historic lake bed, the native soils are likely not suitable for berm construction.

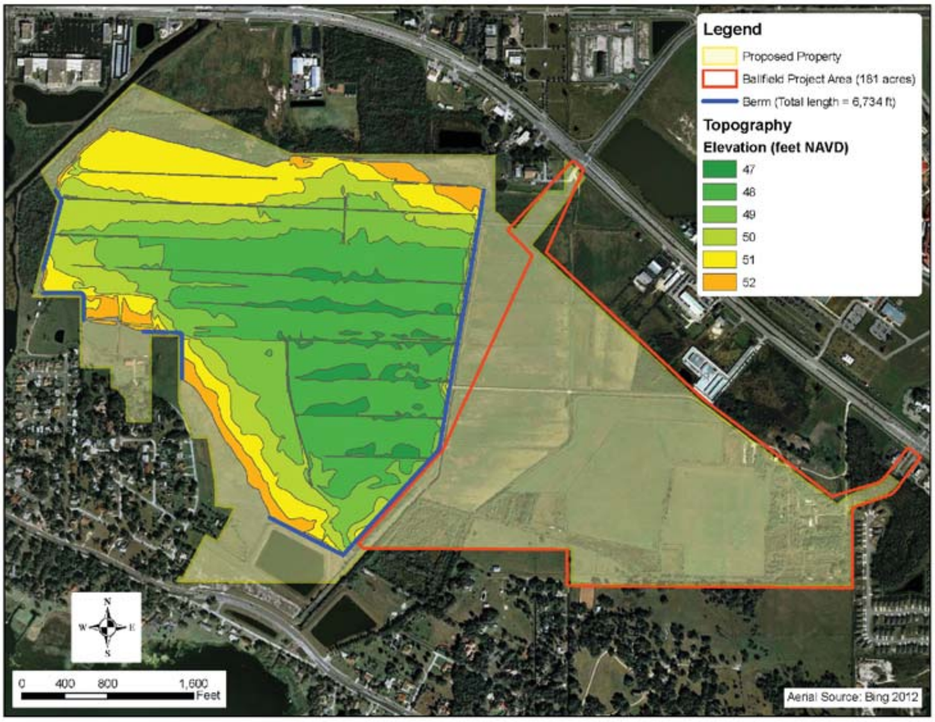

Figure 2. Minimal Berm Option

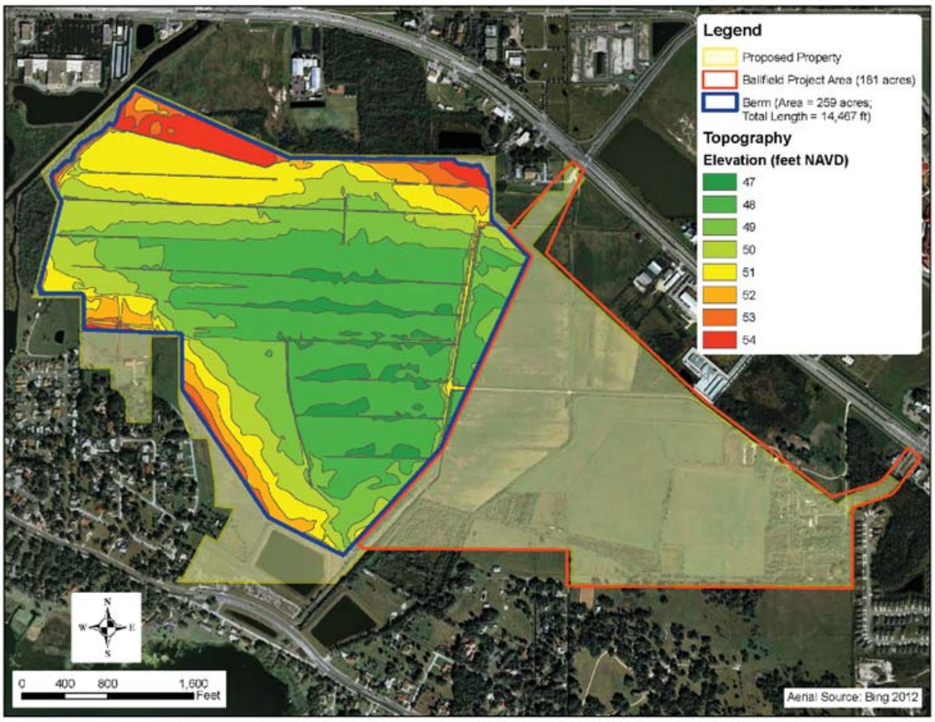

Figure 3. Perimeter Berm Option

The minimal berm option (Figure 2) consists of a 228-acre storage facility footprint with minimal perimeter berms west of Judge Farms Ditch and selected low areas around the remaining perimeter of the site, thereby using the existing topography to contain the stored surface water. For this alternative, fill would have to be placed along 6,730 ft of existing berm along the west side of Judge Farms Ditch to raise the top of the berm elevation along the ditch to 52 ft North American Vertical Datum (NAVD) to prevent comingling of the stored water with water in the ditch, and to fill in low areas around the perimeter of the storage facility footprint to an elevation of 52 ft NAVD to prevent stored water from flowing off-site. This alternative will provide for up to 754 acre-ft (246 mil gal) of live storage between the bottom of the storage facility (48 ft NAVD) and an elevation of 52 ft NAVD. The

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effective storage (from the bottom of the storage facility to the maximum operating water depth) is 335 acre-ft (109 mil gal).

The perimeter berm option (Figure 3) consists of a 259-acre storage facility footprint with more extensive and higher berms around the majority of the perimeter of the proposed storage facility. The eastern limit of the proposed storage facility crosses Judge Farms Ditch. The top of berm elevation would be 54 ft NAVD and provide for up to 1,305 acre-ft (425 mil gal) of live storage between the bottom of the storage facility (48 ft NAVD) and the top of berm. The effective storage is 805 acre-ft (262 mil gal).

Tributary Yield Analysis

In order to determine the flows and stages that would occur in the three urban tributaries that will, over time, contribute surface water to the proposed water storage facility, a hydrologic and hydraulic (H/H) model of the channels and their contributing subcatchments was developed. The output of the H/H model constitutes a major component of the water budget and systems model described. Stormwater flows and volumes were predicted using the EPA SWMM representing the channels and their tributary area based upon the 20-year period of record of daily rainfall values. Figure 4 shows the flow frequency analysis for the three urban tributaries based on the output of the continuous simulation model.

As shown in Figure 4, the mean daily flow through East City Ditch is approximately 11 cu ft per second (cfs). The flow distribution is heavily skewed on both extremes, with the flow frequency analysis demonstrating that more than 70 percent of modeled daily observations are less than 2 cfs; the mean daily flow is similarly influenced on the upper end by rare extreme rainfall events producing modeled flows as high as 575 cfs. The mean daily flow for Mill Slough through the model period is 24 cfs, with approximately 75 percent of modeled observations less than 5 cfs. Having a very small upstream contributing area as compared to East City Ditch and Mill Slough, the flows through the Judge Farms Ditch are predicted to be much smaller than those of the other tributaries. The modeled daily average flow is 0.7 cfs, with more than 70 percent of modeled observations less than 0.1 cfs.

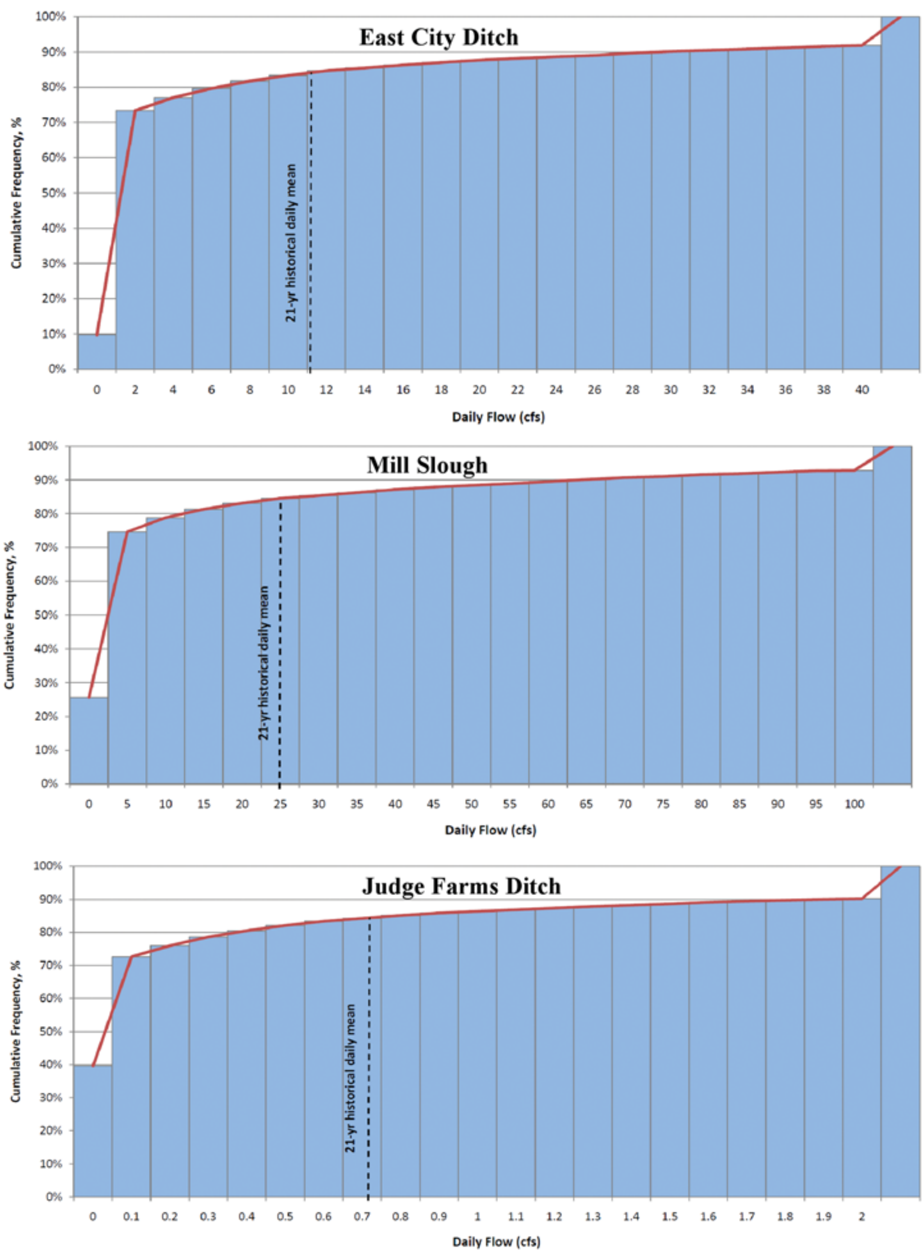

Figure 4. Flow Frequency Duration Curves

Systems Model and Evaluation

A dynamic systems model, using STELLA® (Systems Thinking Experimental Learning Laboratory with Animation) software, was used to: integrate daily climatologic data with results from the surface water runoff and routing model (SWMM), along with supplemental flows from East Lake Toho (C-31 Canal); develop a sitewide water budget; size component elements of the water storage facility, including water levels and pumping capacities; and predict systemwide performance using metrics of water capture, continuity of system hydration, and reliability of supply. While it has been used to address numerous water resources planning issues in Florida and throughout the United States, it was used specifically during this evaluation to integrate data from the National Oceanic and Atmospheric Administration, St. Johns River Water Management District, and U.S. Geological Survey databases to quantify rainfall and evaporation along with output from other models, such as runoff and groundwater seepage to evaluate the dynamic interactions of the system.

The analysis conceptually quantifies flows for this area using historical data, published information, and model-estimated

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flows. The governing equation for this analysis is as follows:

(Equation 1)

$$\Sigma \text{Inflows} = \Sigma \text{Outflows} + \Delta \text{Storage} / \Delta \text{Time}$$

As shown in Figure 5, the inflow terms for the water storage facility control volume consisted of the following:

- Rainfall
- Pumping from three tributaries
- Pumping from East Lake Toho (the C-31 Canal upstream of the S-59 structure)

Also shown in Figure 5 are the outflow terms for the water storage facility control volume, which consisted of the following:

- Evaporation
- Releases from water storage facility for reuse augmentation (water supply) to the City of St. Cloud and Toho Water Authority
- Overflow from water storage facility to Lake Toho (emergency conditions)
- Groundwater seepage

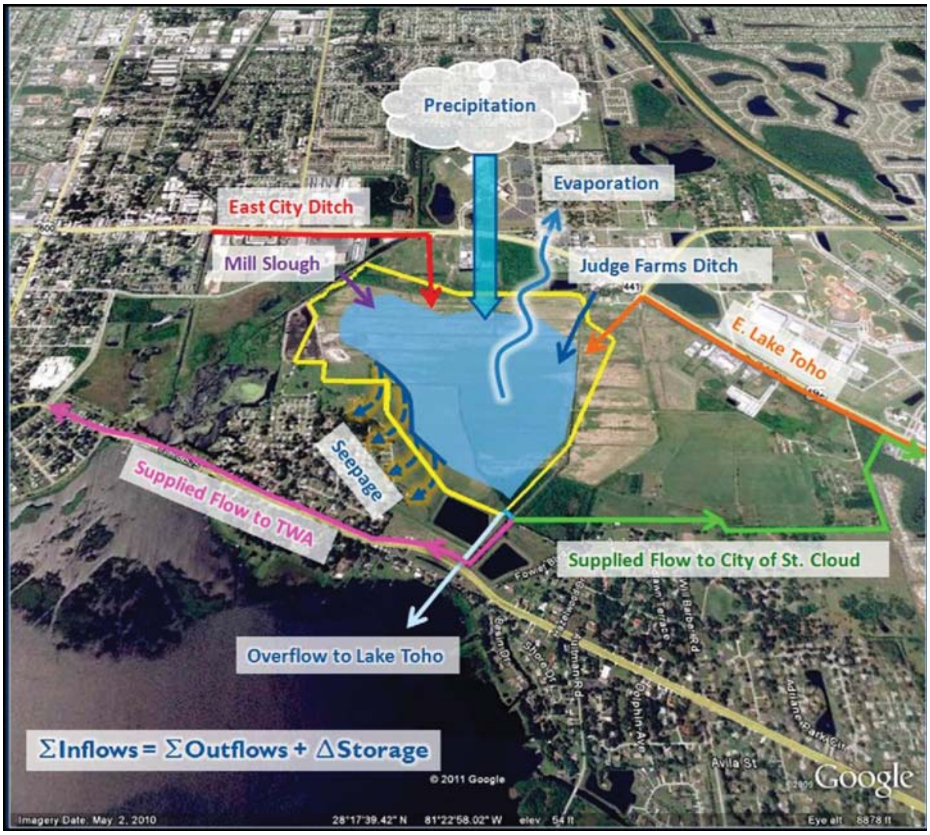

Figure 5. Water Budget Inflows and Outflows

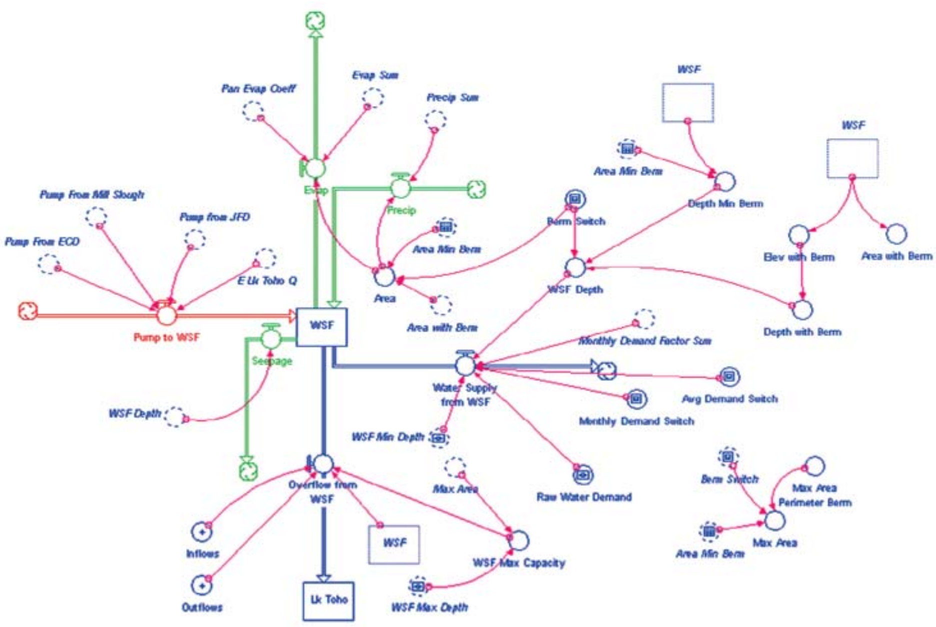

Figure 6. Systems Model Structure

The conceptual water storage facility is represented in the systems model as a storage basin that receives inflows pumped from the three tributaries, inflow pumped from East Lake Toho, and direct rainfall (Figure 6). The system loses water to free-surface evaporation and groundwater seepage. Two additional outflows from the water storage facility consist of water supply releases and a discharge for emergency overflows to Lake Toho. The annual average demand for the reuse supply ranged from 10 to 30 mgd and was discretized into monthly values using seasonally-varying demand fractions specific to the net irrigation requirement for pasture grass in Osceola County (USDA, 1982).

The systems model was used to evaluate and compare two alternative configurations for the conceptual water storage facility (minimal berm and perimeter berm options). During the evaluation, several combinations of operating water depths, pump capacities, and storage facility footprints were evaluated in an effort to converge on the combinations that appeared most likely to effectively and reliably supply the available water. As part of this evaluation, a sensitivity analysis was performed to determine the optimum water level in the water storage facility that would serve as a "trigger" for initiating flows from each of the four water supply sources.

As shown in Table 1, the reliability of the supply for the minimal berm option ranges from 87 percent (30 mgd) to 92 percent (10 mgd), since there are some limited occurrences when supply is not sufficient to meet highest peak demands, such as in April and May. The amount of inflow that the tributaries can contribute is limited since they are low flow "flashy" systems. Inflows from East Lake Toho are needed to meet the vast majority of the demand. Without augmentation from East Lake Toho (Table 2), this option would be able to reliably supply an annual average flow of 1 mgd approximately 90 percent of the time, while a higher flow of 3 mgd can be supplied approximately 69 percent of the time.

The reliability of the supply for the perimeter berm option (Table 1) ranges from 90 percent (30 mgd) to 95 percent (10 mgd), since there are some limited occurrences when supply is not sufficient to meet highest peak reuse (irrigation) demands, such as occurs in May. Again, the amount of inflow that the tributaries can contribute is limited since they are low flow "flashy" systems and inflows from East Lake Toho are needed to meet the vast majority of the demand. However, because the available storage is greater in this option due to the higher berms, the residence times are larger, and hence, inflows from East Lake Toho are initiated less often. These greater residence times will result in higher pollutant reduction benefits than for the minimal berm option. Without augmentation from East Lake Toho (Table 2), this option would be able to reliably supply an annual average flow of 1 mgd approximately 100 percent of the time, while a higher flow of 5 mgd can be supplied approximately 77 percent of the time.

Pollutant Load Analysis

The primary driver for this project is the development of an alternative water supply for reuse augmentation; however, there is also a treatment and nutrient attenuation benefit. The total nitrogen (TN) and total phosphorus (TP) load removals associated with a water storage facility at the proposed property were quantified for the two storage configurations. To calculate the load reduction, two scenarios were considered based on the potential future use of the site and possible phasing of implementation. The first scenario considered the proposed storage facility for wet detention purposes only (i.e., storage and treatment of surface water from the three tributaries), while the second scenario considered the facility at its optimal desired use (storage and treatment of surface waters for water supply purposes with augmentation from East Lake Toho).

As raw water demand increases within each berm option, the amount of nutrient removal is also increased, as there is a lesser probability of the water being released to Lake Toho. Similar to the wet detention scenario, the perimeter berm option provides more volume and, therefore, greater storage for alternative uses. The perimeter berm option results in a greater nutrient load removal compared to the minimal berm option.

A comparison of the two scenarios (wet detention versus water storage) also demonstrates the added nutrient load removal benefit of using the treated surface water for alternative uses. Under the wet detention scenario, the TN load removal ranges from 29,400 to 30,600 lbs/yr, whereas TP removal ranges from 5,600 to 6,200 lbs/yr. Under the water storage facility option, TN load removal ranges from 58,700 to 71,300 lbs/yr, whereas TP removal ranges from 6,300 to 7,700 lbs/yr. In the case of TN removal, the water storage facility scenario at a minimum doubles the load removal; the TP removal is increased from 8 to 24 percent over the wet detention scenario.

Table 1. Systems Model Results Summary (Tributary and East Lake Toho Inflows)

Systems Model Components		*Water Storage Facility Scenarios*					
		Minimal Berm[1]			*Perimeter Berm*[2]		
Raw Water Demand		*10 Mgd*	*20*	*30*	*10*	*20*	*30*
Average Inflows (mgd)	Rainfall	0.6	0.6	0.6	0.9	0.9	0.9
	Pump from East City Ditch	1.0	1.1	1.1	1.4	1.5	1.5
	Pump from Mill Slough	1.9	2.1	2.2	2.7	2.9	3.0
	Pump from Judge Farms Ditch	0.2	0.2	0.2	0.2	0.3	0.3
	Pump from East Lake Toho	7.8	15.9	24.1	5.4	13.0	20.8
	Total Inflows	11.5	20.0	28.3	10.6	18.6	26.4
Average Outflows (mgd)	Evaporation	0.6	0.6	0.6	0.8	0.8	0.8
	Seepage[3]	0.1	0.1	0.1	0.3	0.2	0.2
	Water Supply Releases	8.7	16.5	24.1	9.2	17.4	25.3
	Emergency Overflow	2.1	2.7	3.5	0.4	0.2	0.2
	Total Outflows	11.5	20.0	28.3	10.6	18.6	26.4
Average Residence Time (days)		26.4	23.2	22.1	69.4	57.0	52.7
Percent of Time Water Demand Supplied		92.0	88.7	86.7	95.0	92.0	90.0
Percent of Time Below Minimum Depth		7.3	10.2	12.0	4.5	7.3	9.1
Percent of Time Overflow		21.3	20.0	19.5	3.7	1.8	1.5
Percent Flows Withdrawn from East City Ditch		21.4	23.2	24.1	28.2	30.0	30.4
Percent Flows Withdrawn from Mill Slough		19.5	21.3	22.1	26.2	28.0	28.4
Percent Flows Withdrawn from Judge Farms Ditch		12.6	14.2	14.8	17.8	19.3	19.7
Percent Flows Withdrawn from East Lake Toho		78.4	79.7	80.3	53.9	65.2	69.3

Notes:
[1] Water storage facility trigger depths were set at 2 ft for the tributaries and East Lake Toho withdrawals.
[2] Water storage facility trigger depths were set at 4 ft for the tributaries and 3 feet for East Lake Toho withdrawals.
[3] Seepage primarily consists of horizontal flow in the perimeter berms. Vertical seepage is limited due to high water table conditions (47-48 ft NAVD) and relatively low reservoir head (50 or 52 ft NAVD).

Conceptual estimates of capital costs were prepared for a combined end-use of the facility (stormwater treatment and reuse augmentation), as well as for each end-use individually (Tables 3 through 5); the water supply options varied by water demand (10 mgd to 30 mgd) and by berm configuration (minimal and full perimeter). Pumping and transmission costs were evaluated for conveying raw water from the four water supply sources to the storage facility, and from the facility to the recipients of the supplied water.

As directed by the stakeholders, the available supply from the water storage facility was evaluated as divided equally between the City of St. Cloud and Toho Water Authority. Two alternative transmission routes—an east route and a west route—

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Table 2. Systems Model Results Summary (Tributary Inflows Only)

Systems Model Components		Water Storage Facility Scenarios							
		Minimal Berm[1]			Perimeter Berm[2]				
Raw Water Demand		1 mgd	2	3 mgd	1 mgd	2 mgd	3 mgd	4	5
Average	Rainfall	0.6	0.6	0.6	1.0	1.0	0.9	0.9	0.9
	Pump from East City Ditch	0.9	1.0	1.1	0.9	1.1	1.2	1.3	1.4
	Pump from Mill Slough	1.7	1.9	2.1	1.8	2.1	2.3	2.5	2.6
	Pump from Judge Farms Ditch	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.2
(mgd)	*Total Inflows*	3.4	3.7	3.9	3.8	4.3	4.6	4.9	5.1
Average	Evaporation	0.6	0.6	0.6	0.9	0.9	0.8	0.8	0.8
	Seepage	0.1	0.1	0.1	0.3	0.3	0.3	0.2	0.2
	Water Supply Releases	0.9	1.5	1.9	1.0	1.9	2.6	3.1	3.6
	Emergency Overflow	1.8	1.5	1.3	1.6	1.3	1.0	0.7	0.6
(mgd)	*Total Outflows*	3.4	3.7	3.9	3.8	4.3	4.6	4.9	5.1
Average Residence Time (days)		77.4	67.4	65.3	168.4	126.7	102.7	88.8	84.3
Percent of Time Water Demand Supplied		89.5	77.8	69.0	99.6	96.2	90.2	84.0	76.6
Percent of Time Below Minimum Depth		9.7	20.9	29.0	0.3	3.4	8.9	14.8	21.7
Percent of Time Overflow		13.0	11.0	9.5	12.0	9.1	7.0	5.5	4.2
Percent Flows Withdrawn from East City Ditch		19.3	21.1	22.6	20.0	22.8	24.8	26.5	27.7
Percent Flows Withdrawn from Mill Slough		17.4	19.1	20.5	18.1	20.7	22.8	24.4	25.6
Percent Flows Withdrawn from Judge Farms Ditch		11.4	12.5	13.5	11.9	13.7	15.2	16.5	17.3

Notes:
[1]Water storage facility trigger depths were set at 2 ft for the tributary withdrawals.
[2]Water storage facility trigger depths were set at 4 ft for the tributary withdrawals.

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were considered for distributing water to the City of St. Cloud Lakeshore Stormwater Augmentation Facility site and to the Toho Water Authority's South Bermuda Water Reclamation Facility, respectively. Estimates of capital costs ranged from $11.5 million to $103 million, depending on end-use of the facility and the selected berm configuration.

Conclusions

A preliminary feasibility analysis of an aboveground earthen water storage facility to store and treat surface water harvested from East Lake Toho (via the C-31 Canal) and three urban tributaries was considered in the evaluation of alternative supplemental water supply sources for reuse augmentation. Not only would this facility provide flow equalization storage for supplemental reuse water, but it would also provide treatment and nutrient attenuation benefits for impaired surface waters that are tributaries to Lake Toho, which is part of the headwaters for the Everglades. There is a wide range of capital costs for the water storage facility depending on the selected alternative. The cost-effectiveness of this water storage facility, and a decision to move forward with this project, are still being considered by the various stakeholders.

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Tables 3, 4, and 5 are located on page 34.

Table 3. Summary of Conceptual Capital Costs (Combined Stormwater Treatment and Reuse Augmentation)

Raw Water Demand	10 mgd			20 mgd			30 mgd		
Minimal Berm									
Subtotal of Construction Cost ($ Millions)[1]	$34.0M			$52.5M			$65.9M		
Adjustments to Capital Cost from Construction Cost ($ Millions)[2,3]	*35 Percent* $11.9M	*45 Percent* $15.3M	*55 Percent* $18.7M	*35 Percent* $18.4M	*45 Percent* $23.7M	*55 Percent* $28.9M	*35 Percent* $23.1M	*45 Percent* $29.7M	*55 Percent* $36.2M
Total Capital Cost ($ Millions)[4]	$45.9M	$49.3M	$52.7M	$70.9M	$76.2M	$81.5M	$89.0M	$95.6M	$102.2M
Perimeter Berm									
Subtotal of Construction Cost ($ Millions)[1]	$34.5M			$53.1M			$66.4M		
Adjustments to Capital Cost from Construction Cost ($ Millions)[2,3]	*35 Percent* $12.1M	*45 Percent* $15.5M	*55 Percent* $19.0M	*35 Percent* $18.5M	*45 Percent* $23.9M	*55 Percent* $29.2M	*35 Percent* $23.2M	*45 Percent* $29.9M	*55 Percent* $36.5M
Total Capital Cost ($ Millions)[4]	$46.6M	$50.0M	$53.5M	$71.6M	$76.9M	$82.3M	$89.7M	$96.3M	$103.0M

Notes:

[1] Conceptual construction costs include pumps for East City Ditch, Mill Slough, Judge Farms Ditch, East Lake Toho, and high service pump station; water storage facility; conveyance from East City Ditch, Judge Farms Ditch, and East Lake Toho to water storage facility; conveyance to City of St. Cloud and TWA connection points.

[2] Adjustments from construction cost to capital cost consist of: mobilization/demobilization and contingency (20 percent); non-construction capital cost consisting of planning, engineering, design, and construction services (15 percent).

[3] Adjustments from construction cost to capital cost consist of: mobilization/demobilization (5 percent); contingency (20 or 30 percent); non-construction capital cost consisting of planning, engineering, design, and construction services (20 percent).

[4] Costs do not include estimates for water treatment, operations and maintenance (O&M), proposed Judge Farms Property acquisition, potential wetlands mitigation, dredging of sediments/vegetation, or hazardous material/soil remediation.

Table 4. Summary of Conceptual Capital Costs (Stormwater Treatment)

	Minimal Berm			Perimeter Berm		
Subtotal of Construction Cost ($ Millions)[1]	$8.5M			$9.0M		
Adjustments to Capital Cost from Construction Cost ($ Millions)[2,3]	*35 percent* $3.0M	*45 percent* $3.8M	*55 percent* $4.7M	*35 percent* $3.2M	*45 percent* $4.1M	*55 percent* $5.0M
Total Capital Cost ($ Millions)[4]	$11.5M	$12.3M	$13.2M	$12.2M	$13.1M	$14.0M

Notes:

[1] Conceptual construction costs include pumps for East City Ditch, Mill Slough, and Judge Farms Ditch; water storage facility; and conveyance from East City Ditch and Judge Farms Ditch to water storage facility.

[2] Adjustments from construction cost to capital cost consist of: mobilization/demobilization and contingency (20 percent); non-construction capital cost consisting of planning, engineering, design, and construction services (15 percent).

[3] Adjustments from construction cost to capital cost consist of: mobilization/demobilization (5 percent); contingency (20 or 30 percent); non-construction capital cost consisting of planning, engineering, design, and construction services (20 percent).

[4] Costs do not include estimates for water treatment, O&M, proposed property acquisition, potential wetlands mitigation, dredging of sediments/vegetation, or hazardous material/soil remediation.

Table 5. Summary of Conceptual Capital Costs (Reuse Augmentation)

Raw Water Demand	10 mgd			20 mgd			30 mgd		
Minimal Berm									
Subtotal of Construction Cost ($ Millions)[1]	$25.9M			$44.4M			$57.8M		
Adjustments to Capital Cost from Construction Cost ($ Millions)[2,3]	*35 Percent* $9.0M	*45 Percent* $11.6M	*55 Percent* $14.2M	*35 Percent* $15.6M	*45 Percent* $20.0M	*55 Percent* $24.4M	*35 Percent* $20.2M	*45 Percent* $26.0M	*55 Percent* $31.8M
Total Capital Cost ($ Millions)[4]	$34.9M	$37.5M	$40.1M	$60.0M	$64.4M	$68.9M	$78.0M	$83.8M	$89.6M
Perimeter Berm									
Subtotal of Construction Cost ($ Millions)[1]	$26.4M			$44.9M			$58.3M		
Adjustments to Capital Cost from Construction Cost ($ Millions)[2,3]	*35 Percent* $9.2M	*45 Percent* $11.9M	*55 Percent* $14.5M	*35 Percent* $15.7M	*45 Percent* $20.2M	*55 Percent* $24.7M	*35 Percent* $20.4M	*45 Percent* $26.2M	*55 Percent* $32.1M
Total Capital Cost ($ Millions)[4]	$35.6M	$38.2M	$40.9M	$60.6M	$65.1M	$69.6M	$78.7M	$84.5M	$90.4M

Notes:

[1] Conceptual construction costs include pumps for East Lake Toho and high service pump station; water storage facility; conveyance from East Lake Toho to water storage facility; and conveyance from water storage facility to City of St. Cloud and TWA connection points. Individual cost components summarized in Table 18.

[2] Adjustments from construction cost to capital cost consist of: mobilization/demobilization and contingency (20 percent); non-construction capital cost consisting of planning, engineering, design, and construction services (15 percent).

[3] Adjustments from construction cost to capital cost consist of: mobilization/demobilization (5 percent); contingency (20 or 30 percent); non-construction capital cost consisting of planning, engineering, design, and construction services (20 percent).

[3] Costs do not include estimates for water treatment, O&M, proposed Judge Farms Property acquisition, potential wetlands mitigation, dredging of sediments/vegetation, or hazardous material/soil remediation.