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Towards Smart Cities: Retrofit of Urban Infrastructure for Sustainable Operation

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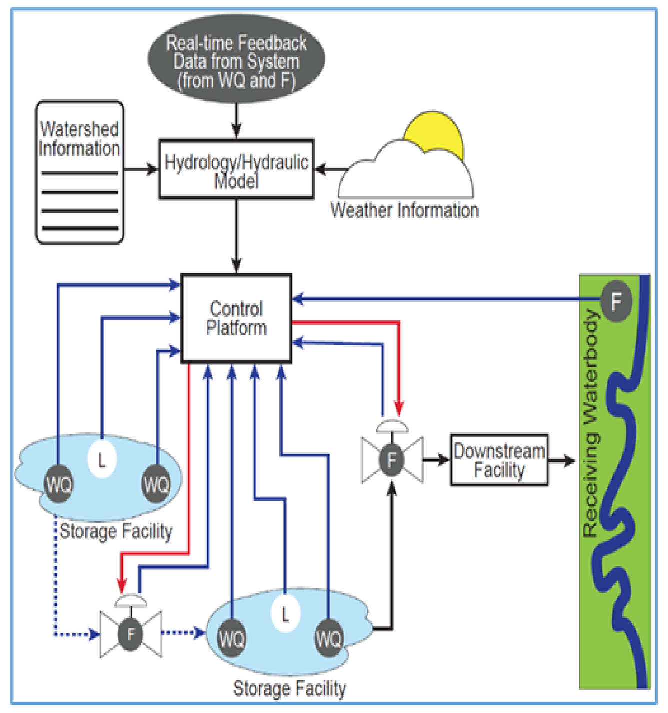
Abstract

Stress on natural resources in urban areas has been increasing continuously in proportion to increasing urban density. Managing water resources through an ecotechnological approach is important for stormwater management and water pollution mitigation. Retrofitting existing infrastructure by well-established Green Infrastructure (GI) combined with emerging technological advancements in informational system can provide a sustainable solution for managing urban water resources. In such effort, our research is exploring application of GI retrofit integrated with upgrade of ponds with remote sensing and artificial intelligence support systems for their optimized operation.

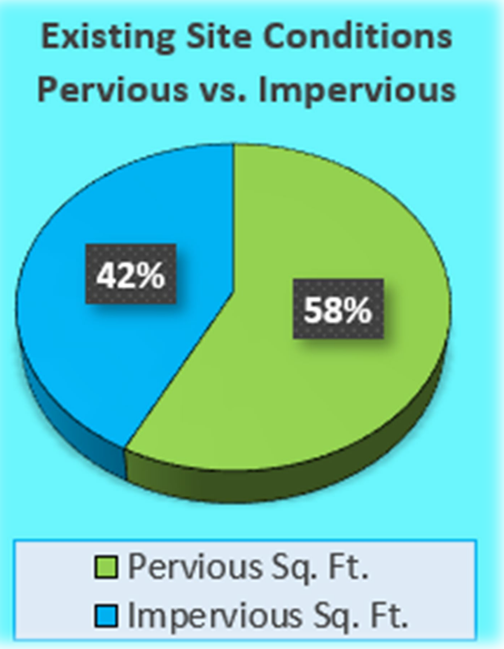
Background and Objectives

By Implementing technologies commonly used in hydrology, flood routing, weather forecasting, and water quality, this project aims to provide a model for tracking and predicting the changing conditions of the watershed found at Warner Park and the Zoo. By changing Ponds 2 and 3 from dry detention basins to naturalized basins, contaminants from the parking lots and roadway will be decreased allowing the water to be used for irrigation. In addition to the environmental improvements, the retrofit will be representative of features that complement the Zoo experience including native species planting to create an ecosystem that supports wildlife such as bees, insects, and birds.

Objective 1: Demonstration of real-time water level and water quality metering network within existing drainage infrastructure for combined sewer overflow and downstream inundation prevention.
Objective 2: Provide opportunity for rainwater harvest for onsite use towards achieving sustainability for water resources.
Objective 3: Sustainable technology implementation for social, economic, and environmental benefits.



Schematic of SmaRT Control System (F, WG, L are flow, water quality, and level sensors, respectively)



SmaRT Weather Station and Pond Control

Legend
1) Pond 1 underground detention and existing bioretention areas
2) Pond 2 existing configuration
3) Pond 3 existing configuration
4) Proposed parking lot with porous asphalt, tree canopy, and depressed islands
5) Pond 2 converted to naturalized basin with sitting area
6) Pond 2 outlet control location with SmaRT Technology
7) Pond 3 Converted to Naturalized basin with benches, picnic tables
8) Pond 3 outlet control to the combined sewer system by SmaRT Technology

SWMM PySWMM Analysis

The Environmental Protection Agency's (EPA) Storm Water Management Model (SWMM) implemented with the Python program PySWMM, clearly demonstrates the reduction of storm water discharge from the system through adaptive pond depth controls. SWMM and PySWMM archive this in the model simulation due to a series of pumps at the end of each of the three ponds controlling the outflows and depths. The pumps receive outflow conditions based on future storm precipitation data along with minimum or maximum pond depth limits. The data present in the graphs and tables shows the ponds during a heavy rainfall event with one showing existing conditions of free flow and the other using variable controlled pumps. The pumps release water prior to a heavy rainfall event to store water, reducing discharge during the heavy rainfall event.

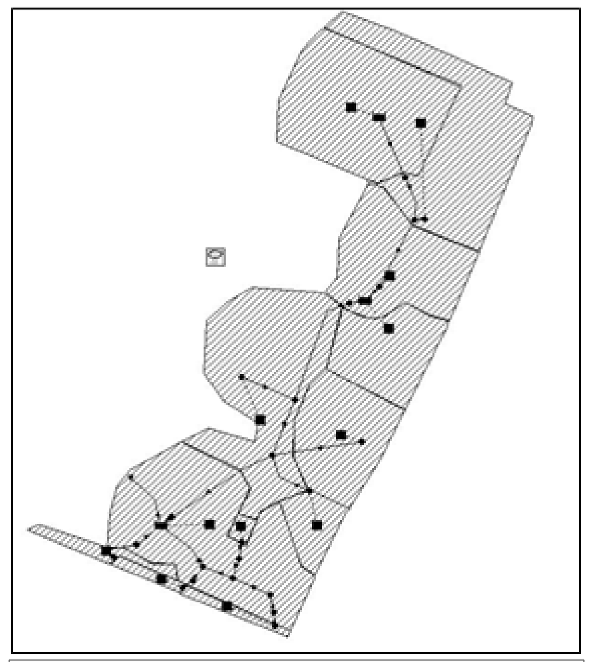


Illustration of SWMM Existing Condition Model for Study Area

Existing Condition Model Peak Flows (CFS)	
1 Year Event	
Pond 1	3.89
Pond 2	9.77
Pond 3	17.6
2 Year Event	
Pond 1	4.72
Pond 2	11.45
Pond 3	22.08
25 Year Event	
Pond 1	7.16
Pond 2	16.62
Pond 3	37.63
100 Year Event	
Pond 1	8.27
Pond 2	20.46
Pond 3	45.87

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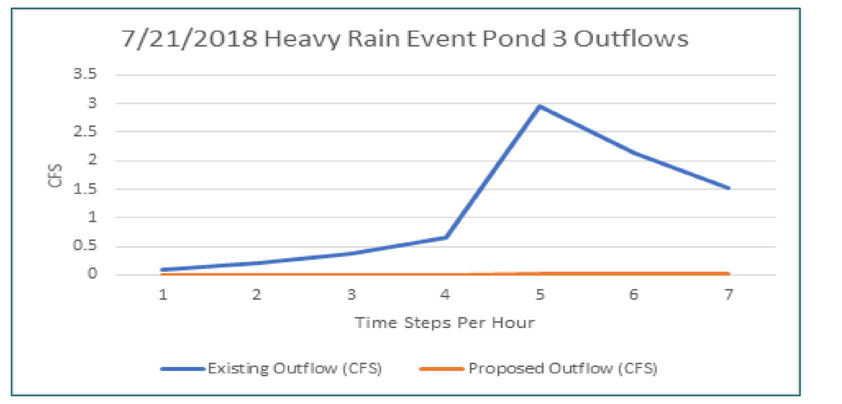
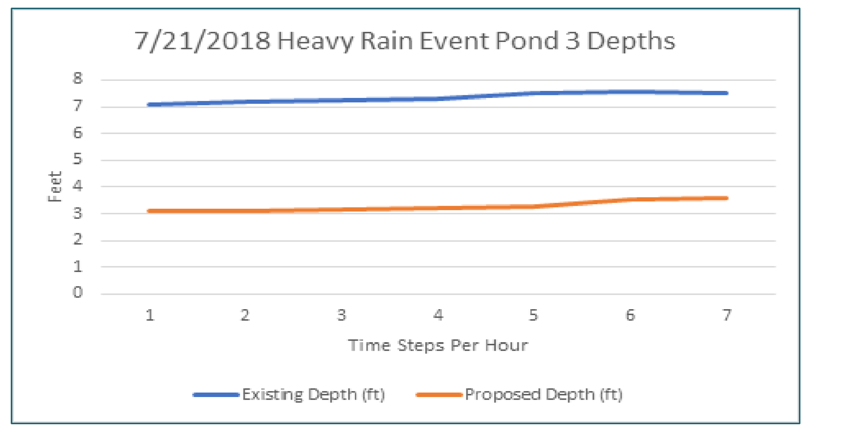
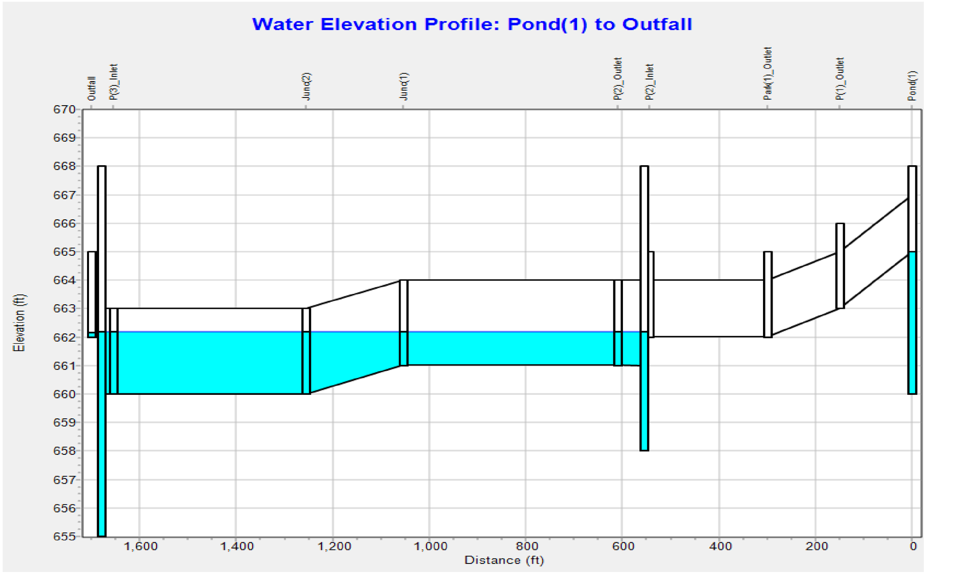
RAIN EVENT IN PROGRESS AT: 2016-04-06 23:00:01
Percent Complete: 0.05%
2016-04-07 00:00:01
2016-04-06 00:00:01
2021-03-20 23:00:00
5.039408181337508e-07
0.38748670281151787
3.7398404018029305
8.327319481791822e-10
0.193772156056219З
1.1097606012310197
26
RAIN EVENT STOPPED AT: 2016-04-07 00:00:01
Percent Complete: 0.06%
RESTART
2016-04-07 00:00:02
2016-04-07 00:00:01
2021-03-20 23:00:00
4.999999482758705
4.999954804254822
7.999930606207985
0.029999994827586203
3.109795712984379
10.40887600047642
```

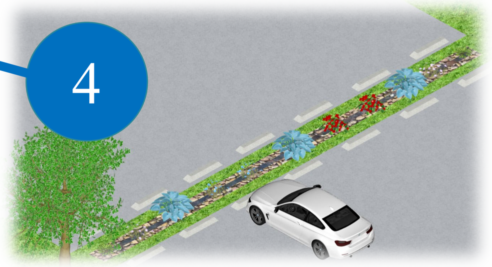
PySWMM results showing a Heavy Rainfall Event with Date in Run along with Depth of Ponds (Pond 1 to Pond 3) and Outflows (Pond 1 to Pond 3) Numbers Displayed are in Feet and CFS

Heavy Rain Event Comparison for Pond 3 in Existing and Proposed Models				
Prec. (in)	Exist. Outflow (CFS)	Exist. Depth (ft)	Prop. Outflow (CFS)	Prop. Depth (ft)
Date: 4/7/2016				
0.042	0.36	7.22	0.007	3.18
0.299	0.69	7.28	0.007	3.18
0.218	0.69	7.28	0.007	3.25
0.001	0.56	7.25	0.01	3.54
0	0.49	7.25	0.01	3.38
Date: 5/21/2017				
0.233	0.69	7.28	0.007	3.25
0.336	0.92	7.32	0.007	3.25
0.099	0.89	7.32	0.007	3.28
0.049	0.75	7.28	0.013	3.41
0.031	0.66	7.28	0.013	3.44
0.016	0.56	7.25	0.013	3.48
0.006	0.46	7.22	0.013	3.51
0	0.39	7.22	0.013	3.51
Date: 7/21/2018				
0.05	0.1	7.12	0.0	3.08
0.24	0.2	7.15	0.0	3.08
0.091	0.36	7.22	0.003	3.15
0.26	0.66	7.28	0.007	3.18
0.78	2.95	7.51	0.007	3.28
0.01	2.13	7.58	0.013	3.51
0	1.51	7.48	0.013	3.58









SmaRT Weather Station and Pond Control

Conclusion

SmaRT Control technology can improve the ability of stormwater controls to reduce runoff and combat sprawling urban nonpoint source pollution in addition to maximizing stormwater reuse. Green Infrastructure (GI), most prominently, bioswales and underground cisterns assist in reducing the pollution and expanding the reusability of stormwater through retention of clean water and discharging or absorption of pollutants. As multiple systems incur the base cost for each one, having a scalable platform and building further systems on top of it avoids incurring a considerable number of multiple base costs. Working with the Chattanooga Zoo opens new opportunities to help the local community to learn and grow as well as providing firsthand experience on how the ponds and surrounding areas respond to the changes implemented. Data aggregation combines spatial and temporal information into one report to construct a full view of the urban stormwater management. Temporal variables include data from past weather and forecasts, and flood modeling. Amassing historical and real-time data, stormwater management is compiled within large quantities and collected from various sources and modalities. The future of this project brings further research and development and with it, comes a better understanding of how the watershed behaves and reacts to adjustments within. This allows us to better calibrate our model to a near perfect digital representation of the existing site leading to more accurate predictions.

Acknowledgements

The City of Chattanooga Water Resources Department helped us with site selection and took time to help us with understanding the complex storm water management design for this location. Tennessee American reviewed our plans and Hamilton County GIS for providing some GIS Data to use in our analysis. A mention to TDEC for help answering questions regarding weather forecast models.

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