Pollutant Loading Analysis For Stormwater Retrofitting in Melbourne Beach, Florida

By: Gordon England, P.E.
Creech Engineers, Inc.
4450 W. Eau Gallie Blvd, #232
Melbourne, Fl. 32932

Introduction

At Gemini Elementary School in Melbourne Beach, Florida, there has been a history of repeated flooding on the school grounds and in properties adjacent to the school. In 1999 Creech Engineers, Inc. (CEI) was chosen by Brevard County Stormwater Utility to design drainage improvements to alleviate these flooding conditions, as well as to provide for stormwater treatment within this 20.06 hectare drainage basin. The project was divided into two phases. Phase 1 improvements were made in order to accelerate initial flood control measures for homes downstream of the school. Phase 2 involved the design of more extensive flood and water quality control measures along Oak Street for further protection of school property and roadway flooding at nearby church property. This paper highlights the political challenges of retrofitting stormwater systems in developed areas, as well as demonstrates a methodology for performing a nonpoint source pollutant loading analysis.

Existing Conditions

Gemini Elementary School is located on a 8.02 hectare, triangular shaped property along the south side of Oak Street, a two lane collector road in Melbourne Beach, about one half mile from the Atlantic Ocean. See Exhibit 1. Residential properties lie downstream of the school, along its southeast and southwest borders. 8.51 hectare Doug Flutie Park is on the north side of Oak Street. A soccer club uses the park and school grounds on a daily basis. There was no stormwater system at the park, along Oak Street, or on the school site. Stormwater flowed southward off Doug Flutie Park, across Oak Street, through the school site, and into the yards and homes south of the school. These yards, and the roads downstream of them, are very flat and only a few feet above sea level. Once water stages high enough in the yards, it gradually sheetflows down the adjacent roads a few hundred yards to the Indian River. The affected homeowners naturally blamed the school for allowing the school’s water to flood them.

West of the school, a few hundred yards along Oak Street, was a low point in the road where water ponded and flooded the road and an adjacent churchyard. Due to a thin clay lens at 26 cm deep causing a perched water table, water stood in the road for several days after even a nominal rainfall. This drainage basin was almost completely built out, with no easy path for developing outfalls to relieve flooding.

This section of the Indian River is a Class 2 water body, with a Shellfish Harvesting classification bringing intense scrutiny from the St. Johns River Water Management District. Corp of Engineers permitting is required for new outfalls in the area due to seagrasses near the shoreline.

The park, the school, and Oak Street lie in unincorporated Brevard County. The church, and properties west of the school are in Melbourne Beach. Being a collector road, all of the utility companies have major transmission lines in the road right-of-way.

As can be seen, this challenging project involved Brevard County, Melbourne Beach, the School Board, Brevard County Parks and Recreation Department, Brevard County Road and Bridge Department, Brevard County Stormwater Utility, a church, three different Homeowners Associations, a soccer club, the Water Management District, the Corp of Engineers, and several utility companies. Stakeholder involvement and partnerships were going to be critical to weave a solution through the many players involved.

Proposed Improvements

The first priority was to alleviate flooding in the homes adjacent to the school. As an interim measure, a berm was designed and constructed by County personnel along the south property lines of the school, with a swale behind the berm directing water to the southernmost point of the school property. At that location, an inlet and 18” outfall pipe were constructed in a utility easement through two heavily landscaped and fenced yards, to Pompano Street, where it was tied into an existing storm drain pipe.

A short time later, heavy rains overflowed the berms and swales and flooded homes adjacent to the school again. CEI was engaged at that point to provide more effective drainage improvements.

Fortunately, Gemini Elementary School had a significant area of vacant land on their site. The school entered into agreements with Brevard County allowing the construction of three dry retention ponds totaling 2.95 hectare to reduce flows leaving the school site, as well as provide stormwater treatment where none existed. These dry ponds were wound around several soccer and baseball fields. The soccer field’s locations had to remain in place due to previous agreements with the school and Parks and Recreation Dept. The ponds were only 26-40 cm (12”- 18”) deep and sodded, allowing the soccer teams to use the pond areas as practice fields when dry. When the ponds were excavated, the confining clay layer was removed to allow for infiltration though the beach sand at the site. Construction was scheduled during the summer when school was out.

A control structure was designed at the outfall pipe location to provide protection for a 25 year storm. The temporary connection to the existing downstream pipe had overloaded the downstream system in a heavy rain event, so a new outfall to the Indian River was designed through a park adjacent to the River. The park was owned by a Homeowners

Association, which reluctantly gave a drainage easement through the park. The County agreed to make several improvements to the park and its boat ramp in exchange for the easement. The Corp of Engineers was concerned that the new outfall pipe discharges would impact the nearby seagrasses, so the new discharge pipe was not permitted to be constructed in the Indian River. A bubbleup box was designed ten feet back from the shoreline and rock riprap was placed between the bubbleup box and the mean high water line to prevent erosion. As mitigation for disturbing the shoreline, spartina and other plants were planted among the rocks to further buffer the shoreline from the stormwater discharges.

This first phase of improvements was finished in September 2000 at a cost of $124,000. The improvements implemented proved successful in preventing any flooding of adjacent homes in several large rainfalls in 2001.

The second phase of the project addressed stormwater quantity and quality concerns along 1650 meters of Oak Street, from A1A to Cherry Street. To provide further flood protection at Gemini Elementary School, retention swales were designed along both sides of Oak Street and 625 meters of storm drain pipe was designed to intercept runoff and prevent it from crossing the road onto school property. The piping also provided an outfall for the low spot in the road by the church.

This new pipe system discharged into a residential canal system, which was used by many of the adjacent residents for boating to the Indian River Lagoon (Bay). These canals were very politically sensitive since they were in need of dredging and the Town of Melbourne Beach does not dredge canals. The residents were concerned that the new stormwater system would lead to further sedimentation of the canals. The first alternative for treatment was to use land at the church site for a pond for the road runoff. The church was willing to donate the land where their septic tank fields were located if the County would provide a sewer connection. This scenario was designed, but when it came time for the church to give easements to the County, they balked and it was back to the drawing board.

St. Johns River Water Management District, (District), criteria requires stormwater treatment for improvements which a) increase discharge rates b) which increase pollutant loadings, or c) which increase impervious areas. With this project, no new increased impervious areas were proposed, but there would be additional water flowing to the residential canal from the extension of the pipe system to the flood prone areas. These new flows create the potential for increased pollutant loadings to the canal. Normal design methods would have used treatment ponds to offset these potential impacts. Due to lack of available land for ponds, alternative treatment methods were proposed for this project. The District will consider alternative treatment methods if it can be demonstrated that all other possible alternatives have been exhausted. It would not be possible politically to use more school or park area for treatment ponds. For this project, CEI showed that the only alternatives were to tear down houses for ponds, or use alternate treatment technologies.

The treatment strategy involved maximizing treatment methods within the project basin with alternative BMPs, as well as retrofitting two adjacent watersheds as additional mitigation. A total of 1.67 acre feet of retention storage was provided in Phase 2 in the roadside swales and small ponds. This was equivalent to 0.032 inches of retention from the drainage areas flowing to the retention areas.

A treatment train along Oak Street was designed by using 9 Grated Inlet Skimmer Boxes, from Suntree Technologies, Inc., in the new inlets to trap debris entering the inlets, constructing berms to slow runoff from the ball fields, and installing one baffle box at the downstream end of the new pipe system along Oak Street. Baffle Boxes are in-line stormwater treatment devices which trap sediment, trash, and debris. They have been used by Brevard County successfully for the last 9 years. In offsite Basin 4, which only had one existing baffle box to provide sediment removal, 16 Curb Inlet Skimmer Boxes were installed in all of the existing inlets to provide nutrient removal by trapping grass clippings, leaves, and yard debris. Nutrients were a concern in the canals since the nutrients promote algae blooms, which in turn increase muck build up in the canals. In offsite drainage Basin 5, there are 3 existing pipes which discharge directly to the canals. Three baffle boxes and 6 curb inlet skimmer boxes were designed to provide sediment and nutrient treatment for this drainage basin. Brevard County Stormwater Utility will implement this project and be responsible for all maintenance of the improvements. The baffle boxes will be inspected twice a year and cleaned as needed. The inlet traps will be cleaned twice a year. Brevard County has a vacuum truck dedicated to cleaning stormwater BMPs.

Using numerous BMPs used on this project provided a high degree of treatment for the new piping system along Oak Street, and provided treatment for two offsite basins where little treatment existed. The retrofitting of the offsite areas was, in effect, mitigation for the new discharges to the canal. See Exhibit 1 for a map of the improvements.

Calculations

In Phase 1 of the project, the dry ponds and outfall pipes were modeled hydraulically using the Interconnected Pond Routing program. Since the dry ponds in the Phase 2 project area were too small to provide effective attenuation, the predevelopment and post development runoff calculations were made using Hydraflow and the rational method. The only available storm drain pipe for Phase 2 was a 36” pipe in offsite Basin 4. The new piping along Oak Street was connected to the existing 36” pipe, and the piping downstream of the connection was upgraded to a 42” pipe. The pipes were designed for a 25 year storm. Basins 1,2, and 3 were a much longer distance from the outfall than Basin 4. As a result of different times of concentration, the peak flows from Basin 4 passed sooner than Basins 1,2, and 3, giving only a slight increase in peak discharge, despite adding 12.25 hectares to the area flowing to the existing outfall.

The potential for increased pollutant loadings in the canal system was a concern of local residents. These canals had a history of dredging operations every 8-10 years, and the residents did not want to increase the frequency of costly dredging. The main pollutants of concern leading to muck deposition in the canals were Total Suspended Solids (TSS), Total Nitrogen (TN), and Total Phosphorus (TP). Sediment build up at the end of the pipes was common. Nutrient loadings from grass clippings, leaves, and fertilizers leads to algae blooms and low dissolved oxygen in the canals, which in turn leads to muck build up from the eutrophication process. Most of the material dredged from residential canals is typically muck.

To address this concern, a pollutant loading analysis of the existing and proposed stormwater discharges was performed. In the existing conditions, the only stormwater treatment for the canal system was a baffle box along Cherry Street for offsite Basin 4 of 24.24 hectares. There were a total of 7 outfall pipes discharging into the canal system.

In the first phase of this project stormwater treatment was provided for 8.02 hectares of the school grounds with 3 dry detention ponds. The discharge from these ponds was to the Indian River, rather than the canal system, so these pollutant loads were not included in the pollutant load analysis for the canal outfall.

The existing pollutant load to the canal only came from the drainage Basins 4 and 5, totaling 31.2 hectares. The runoff from Oak Street did not drain to the canal in existing conditions, only in the post development conditions.

The strategy for the pollutant analysis was to calculate the pollutant loads in the existing conditions, and then calculate the pollutant loads after the new pipes were added to the system and offsite areas retrofitted for stormwater treatment. The pollutants used in this analysis were TSS, TP, and TN.

Each drainage basin was categorized by land use. Areal, annual, mass loading rates from "Stormwater Loading Rate Parameters for Central and South Florida", Harper, 1994, were multiplied by each basin’s area to give existing and potential annual pollutant loadings. See Table 1.

The next step was to calculate the pollutant removal rates for the different BMPs. Individual BMP removal efficiencies were take from “A Guide for BMP Selection in Urban Developed Areas”, EWRI, 2000. What was challenging with this analysis was the use of multiple BMPs in series for the treatment train. Each BMP receives cleaner and cleaner water as the water moves down the train. At each BMP, the removal efficiency for each constituent was multiplied by the remaining percentage of the initial loading to give a weighted, cumulative, removal efficiency for each constituent. See Table 2. These calculated removal efficiencies were then multiplied by the total calculated pollutant loads to give the reduced pollutant loadings after the BMPs were installed. See Table 3. Table 4 shows that the total loads to the canal were reduced as a result of the retrofitting of onsite and offsite basins.

The pollutant loading analysis below demonstrates that as a result of the numerous BMPs proposed, the total pollutant loadings entering the canals after project completion will actually be significantly reduced from the existing pollutant loadings entering the canals. The key to overall pollutant reduction is to provide additional treatment in offsite drainage basins. This will result in a net benefit of reduced pollutants entering the canals and a reduction of the severe flooding often seen along Oak Street.

Table 1
Existing Pollutant Loading

Basin	Area (acres)	Land Use	Loading Rate* (kg/ac - year)			Potential Pollutant Loading (kg - year)		
			TSS	Total Phosphorus	Total Nitrogen	TSS	Total Phosphorus	Total Nitrogen
2A	9.23	Recreational	7.6	0.046	1.07	70.15	0.425	9.876
2B	1.15	Recreational	7.6	0.046	1.07	8.74	0.053	1.231
2C	0.77	Recreational	7.6	0.046	1.07	5.85	0.035	0.824
2D	1.45	Recreational	7.6	0.046	1.07	11.02	0.067	1.552
2E	2.63	Recreational	7.6	0.046	1.07	19.99	0.121	2.814
2F	1.97	Recreational	7.6	0.046	1.07	14.97	0.091	2.108
2G	0.75	Recreational	7.6	0.046	1.07	5.70	0.035	0.803
2H	1.29	Recreational	7.6	0.046	1.07	9.80	0.059	1.380
2I	0.08	Recreational	7.6	0.046	1.07	0.61	0.004	0.086
2J	0.8	Recreational	7.6	0.046	1.07	6.08	0.037	0.856
2K	0.57	Recreational	7.6	0.046	1.07	4.33	0.026	0.610
2L	0.34	Recreational	7.6	0.046	1.07	2.58	0.016	0.364
3A	2.19	Single Family	56.1	0.594	4.68	122.86	1.301	10.249
3B	3.02	Single Family	56.1	0.594	4.68	169.42	1.794	14.134
3C	4.02	Low Intensity Commercial	343	0.65	5.18	1378.86	2.613	20.824
Subtotal	**30.26**					**1830.97**	**6.68**	**67.71**
4**	59.9	Single Family	56.1	0.594	4.68	672.00	24.910	280.332
5A	5.9	Single Family	56.1	0.594	4.68	330.99	3.505	27.612
5B	8.62	Single Family	56.1	0.594	4.68	483.58	5.120	40.342
5C	2.68	Single Family	56.1	0.594	4.68	150.35	1.592	12.542
Subtotal	**77.1**					**1636.92**	**35.13**	**360.83**
Totals	**107.36**					**3467.89**	**41.80**	**428.54**

* From "Stormwater Loading Rate Parameters for Central and South Florida", 1994. Harper

** Basin 4 has an existing baffle box providing treatment.

Basins 4 and 5 are the existing pollutant loadings to the canals.

Table 2
BMP Pollutant Removals

BMP POLLUTANT REMOVAL TABLE*			
BMP	**BMP Removal Efficiency**		
Type	**(%)**		
	TSS	**TP**	**TN**
Dry Pond	85	61	91
Swale	80	45	25
Baffle Box	80	30	0
Inlet Trap (grated)	73**	79**	79**
Inlet Trap (curb)	2***	11***	10***
Swale + Inlet Trap (g) + Baffle Box	98.9	91.9	84.2
Dry Pond + Inlet Trap (g) + Baffle Box	99.2	94.3	98.1
Inlet Trap (c)+ Baffle Box	84	37.7	10
Inlet Trap (g)+ Baffle Box	81.1	85.3	79

Multiple BMP Pollutant Removal Calculations

Swale + Inlet Trap (g) + Baffle Box

TSS – 100x0.8 + (100-80)x0.73 + (100-80-14.6)x0.8 = 98.9% Removal
TP - 100x0.45 + (100-45)x.79 + (100-45-43.45) = 91.9% Removal
TN - 100x.25 + (100-25)x.79 = 84.2% Removal

Dry Pond + Inlet Trap (g) + Baffle Box

TSS – 100x0.85 + (100-85)x0.73 + (100-85-10.95)x0.8 = 99.2% Removal
TP - 100x0.61 + (100-61)x0.79 + (100-61-30.8)x.3 = 94.3**% Removal**
TN - 100x.91 + (100-91)x.79 = 98.1% Removal

Inlet Trap (c) + Baffle Box

TSS - 100-x0.2 + (100-20)x0.8 = 84% Removal
TP - 100x0.11 + (100-11)x.3= 37.7% Removal
TN - 100x.10 = 10% Removal

Inlet Trap (g) + Baffle Box

TSS - 100x0.73 + (100-73)x0.30 = **81.1% Removal**
TP - 100x0.79 + (100-79)x0.3 = **85.3% Removal**
TN - 100x.79 = **79% Removal**

All removal values are from "Guide For Best Management Practice

** From Creech Engineers study "Pollutant Removal Testing For a Suntree Technologies Grate Inlet Skimmer Box", 2001

***From visual observation by Brevard County staff

Table 3
Proposed Pollutant Loading

Basin	BMP Type	BMP Removal Efficiency From New BMPs (%)			Pollutant Load Reduction From BMPs (kg/year)			Proposed Pollutant Loading (kg/year)		
		TSS	TP	TN	TSS	TP	TN	TSS	TP	TN
2A	swale + inlet trap (g) + baffle box	98.9	91.9	84.2	69.38	0.39	8.32	0.77	0.03	1.56
2B	swale+ inlet trap (g) + baffle box	98.9	91.9	84.2	8.64	0.05	1.04	0.10	0.00	0.19
2C	dry pond + inlet trap (g) + baffle box	99.2	94.3	98.1	5.81	0.03	0.81	0.05	0.00	0.02
2D	dry pond + inlet trap (g) + baffle box	99.2	94.3	98.1	10.93	0.06	1.52	0.09	0.00	0.03
2E	dry pond + inlet trap (g) + baffle box	99.2	94.3	98.1	19.83	0.11	2.76	0.16	0.01	0.05
2F	swale + inlet trap (g) + baffle box	98.9	91.9	84.2	14.81	0.08	1.77	0.16	0.01	0.33
2G	dry pond + inlet trap (g) + baffle box	99.2	94.3	98.1	5.65	0.03	0.79	0.05	0.00	0.02
2H	dry pond + inlet trap (g) + baffle box	99.2	94.3	98.1	9.73	0.06	1.35	0.08	0.00	0.03
2I	swale + inlet trap (g) + baffle box	98.9	91.9	84.2	0.60	0.00	0.07	0.01	0.00	0.01
2J	inlet trap (g) + baffle box	81.1	85.3	79	4.93	0.03	0.68	1.15	0.01	0.18
2K	inlet trap (g) + baffle box	81.1	85.3	79	3.51	0.02	0.48	0.82	0.00	0.13
2L	inlet trap (g) + baffle box	81.1	85.3	79	2.10	0.01	0.29	0.49	0.00	0.08
3A	inlet trap (g) + baffle box	81.1	85.3	79	99.64	1.11	8.10	23.22	0.19	2.15
3B	inlet trap (g) + baffle box	81.1	85.3	79	137.40	1.53	11.17	32.02	0.26	2.97
3C	dry pond + inlet trap (g) + baffle box	99.2	94.3	98.1	1367.83	2.46	20.43	11.03	0.15	0.40
4	inlet trap (g) + baffle box	81.1	85.3	79	544.99	21.25	221.46	127.01	3.66	58.87
5A	inlet trap (c) + baffle box	84	37	10	278.03	1.30	2.76	52.96	2.21	24.85
5B	inlet trap (c) + baffle box	84	37	10	406.21	1.89	4.03	77.37	3.23	36.31
5C	inlet trap (c) + baffle box	84	37	10	126.29	0.59	1.25	24.06	1.00	11.29
			Total		**3116.31**	**31.0**	**289.08**	**351.60**	**10.76**	**139.47**

Table 4
Net Pollutant Removals

	TSS (kg/yr)	**TP (kg/yr)**	**TN(kg/yr)**
Predevelopment	1636.92	35.13	360.83
Postdevelopment	351.60	10.76	139.47
Net Reduction	1285.32 (79%)	24.37 (69%)	221.36 (61%)

Summary

The days of solving flooding problems in communities with simple ditch and pipe solutions have disappeared. Environmental concerns now dictate that stormwater treatment techniques be integrated into these flood relief projects. By adding water quality components to water quantity projects, communities can help achieve pollution remediation goals being established for NPDES, TMDL, and PLRG programs.

Retrofitting existing stormwater systems to provide water quality treatment is more complicated, expensive, and time consuming than traditional stormwater designs for new development. The scarcity of available land and numerous existing utilities in older built out areas will tax an engineer's imagination to provide innovative BMPs in these locations. An carefully planned treatment train was designed consisting of swales, ponds, berms, baffle boxes, and inlet traps to provide overall stormwater pollution reduction.

In order to address stormwater pollution concerns, treatment mitigation was designed in offsite drainage basins. The pollutant loadings and removals were calculated using a simple but effective spreadsheet analysis incorporating the latest in BMP efficiency studies. While complicated stormwater modeling software can be used for pollutant analysis, this type of modeling is more cost effective on large basin studies than small basins and individual projects. The pollutant removal calculations showed an annual net reduction of 79% for TSS, 37% for Total Phosphorus, and 24% for Total Nitrogen in the Oak Street basin despite the creation of a new stormdrain system for a landlocked area.

As this project demonstrates, there are typically numerous stakeholders that need to be brought into the project early in the process and kept in the process throughout the life of the project. Many meetings were held with city, county, and state officials, homeowners associations, schools, soccer clubs, churches, and utility companies. All it takes is one uncooperative stakeholder to set back or kill a project, as was demonstrated with the church backing out of the land acquisition process after many verbal indications of approval. Using creative partnerships with other entities and agencies allowed the development of a unique strategy to solve flooding at several locations in the project area.

References

ASCE - "Guide For Best Management Practice Selection in Urban Developed Areas", 2001

Gordon England, P.E. "Pollutant Removal Testing For a Suntree Technologies Grate Inlet Skimmer Box", 2001

Harvey Harper, Ph. D, P.E., "Stormwater Loading Rate Parameters for Central and South Florida", 1994


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OAK STREET
PROPOSED IMPROVEMENTS

Exhibit 1