Stormwater Facility Improvement Program

City of Key West

June 2010

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Summary

The purpose of this report is to summarize stormwater management efforts in the City of Key West since 1989, when stormwater deficiencies were identified as part of long range planning efforts, including updates to the City's Comprehensive Plan. Since that time, the City has conducted a series of stormwater system studies and implemented progressive improvements to address water quality concerns as well as localized flooding. The majority of the city was developed before modern stormwater management systems were required and the historic collection systems discharged untreated water into surface waters. These antiquated systems were cross contaminated by leaking underground sewer lines. Further, the gravity collection systems were not always successful in the many low lying areas of the city, where localized flooding has historically been a problem.

Over the last fifteen years the City of Key West has transformed its approach to stormwater management practices and policies. These efforts began with creation of a stormwater department, initiation of maintenance and rehabilitation of the existing system and inventory of existing systems. In 2002 the City created a stormwater utility to fund future programs. The City then embarked on a long term capital program to repair the system and construct new improvements. Throughout the process the City has updated studies, conducted modeling and also modified implementation through permitting programs, most importantly the NPDES MS4 process.

An interagency review conducted by the Florida Keys National Marine Sanctuary Water Quality Protection Program Steering Committee in 2002 not only found that the City's stormwater management plan was consistent with long range planning documents, including the Comprehensive Plan and stormwater management studies, but also commended the City for its strong commitment to water quality programs. The interagency review recommended four actions, all of which were addressed within three years by the City, mostly through the implementation of the MS4 NPDES program.

Certain inherent design constraints continue to impact the City's ability to manage flooding and treat stormwater in many low lying areas. Because gravity wells don't work when groundwater is close to the surface, the city's approach has been to capture water upstream of floodprone areas. This policy approach (which is technically described as the limited Driving Force/Salinity Differential effect on gravity wells) was implemented in 2005 in the City planning and design process. This assured that gravity wells would be placed at elevations high enough so that there was sufficient pressure to make the flow into the gravity well effective.

Modeling has been widely used in Key West stormwater design and all of the priority flood zones currently identified (and for which the City is responsible) have been modeled. As of the latest modeling report 40 additional flood sites have been identified.

A 1997 sewer Consent Order required the City to eliminate and avoid future conflicts between the sewer and stormwater system. In 2000, Helena Solo-Gabriela, Ph.D. from the University of Miami confirmed that there is a direct correlation between sewer and

stormwater systems and nearshore water contamination. In order to avoid potential cross contamination, the Utilities Department adopted a conflict avoidance policy by selecting wells over other stormwater options. Incremental cost comparisons between wells and pipe collections system show that wells are more cost effective than pipe systems for all but the very short pipe runs. Even short pipe runs get more expensive than a gravity well with even one in-ground utility conflict.

Nearshore water quality has been a high priority since the health advisories effectively closed nearly all Key West beaches in 1999. The City committed to retrofitting stormwater outfalls with pollution control, implementing Best Management Practices (BMPs) and diverting water away from outfalls where possible (wells). Key West diverts water away from outfalls because current pollution control devices do a poor job of biological and nutrient removal.

DNA testing confirmed that stormwater has other sources of contamination. The University of Miami analysis linked stormwater outfalls to nearshore water quality contamination even after City sewer lines were totally replaced. Best Management Practices (BMPs) include pollution control devices for the wells (gravity and pump assist). As a result every site selection is based on a combination of factors related to improvement of quality of life, protection of property, and water quality.

Through steady implementation of stormwater management improvements, the city has continued to improve flood protection and water quality associated with its drainage system. Further improvements are required, and additional modeling is recommended to facilitate improvements design. An updated stormwater master plan is an option for consideration since initial planning documents are now between ten and twenty years old.

History of Stormwater Management in Key West

Existing Stormwater System

The City has 63 outfalls and associated collection systems under its control. There are other private property outfalls and approximately 40 Navy outfalls that the City does not have direct responsibility for and will not be discussed herein. The City systems are a combination of systems designed to standards (at the time they were constructed) and systems that were substandard when constructed. Many of these substandard systems appear to have been built by developers. Other substandard systems appear to have been built by City Staff with whatever pipe and materials were available at hand. None of these outfall collection systems were designed with pollution control required by today's standards. There are a number of manmade and natural drainage systems that also serve the City.

History of Existing Wells

Prior to the 1980's stormwater gravity injection wells were not prevalent. At this time the City has ninety two (92) stormwater gravity injection wells in-place and twenty-seven (27) wells under construction. The oldest operational City well located on Margaret Street

between Virginia and Catherine Streets (not included below) was constructed prior to 1970s. The history of this well is sketchy at best. Twelve (12) of the wells were built as part of City development of Mallory Square, Key West Bight Parking Lots, Police and Fire Facility Parking Lot, and the Southernmost Point. Twenty (20) Wells were built by City Engineering Department in flood zones identified in the 1994 KCA Report. One (1) was built in a flood zone identified in the 2001 Long Range Plan. The remaining sixteen (16) wells built by the Engineering Department began addressing standing water problems not identified in the KCA Report or the Long Range Plan. A total of forty-nine (49) stormwater gravity injection wells were installed by the City's Engineering Department (not including the old Margaret Street well).

The Utilities Department has constructed thirty-nine-two (39) stormwater gravity wells and 3 stormwater pump assisted wells (2 at Simonton / Front Street and 1 at Patricia / Ashby). Twenty-nine (29) of the forty-two (42) wells were sited at locations called out in modeling reports discussed below. Two (2) modeling report locations (#77 and #91) were moved upstream to higher elevations during the design process because the original sites were too low (see driving force discussion in design criteria below). The model called for double wells at one intersection downstream of #85. The second well was moved to this site to intercept the stormwater before it created staging downstream. Well #53 was placed at location with staging problems as identified by modeling. Five (5) more wells were placed upstream of known flood problems as verified by modeling. Two (2) were placed in FZ 6. One (1) was placed upstream of FZ 8. One (1) was installed for water quality purposes to divert flow from an outfall near beaches.

Table 1. Existing Gravity Wells - Engineering

	EXISTING WELLS Engineering SITE LOCATION	City Development	2001 KW Long Range Plan	1994 KCA FZ	Other
1	Caroline and Margaret	x			
2	Public Service/Fire Station	x			
3	Public Service/Fire Station	x			
4	Public Service/Fire Station	x			
5	Conch Farm/Greene and Elizabeth	x			
6	Mallory Square	x			
7	Mallory Square	x			
8	Mallory Square	x			
9	Mallory Square	x			
10	Mallory Square	x			
11	Mallory Square	x			
12	Whitehead and South	x			
13	Thomas sand Catherine			In FZ 2	
14	White Street Pump Assist			In FZ 4	
15	White Street Pump Assist			In FZ 4	
16	Josephine Street s. of Blanch				FP
17	Laird and Leon			In FZ 5	
18	Venetia and Dennis		In FZ 13		
19	Rose and Ashby			In FZ 5	
20	Atlantic and Ashby			In FZ 5	
21	Atlantic and Leon			In FZ 5	
22	Reynolds and Von Phister				FP
23	Donald and 19th				**FP**
24	Donald and 17th				**FP**
25	Donald and 17th Terrace				**FP**
26	Rose and Thompson			In FZ 5	
27	Patricia and Steven				FP
28	Laird and Florida			In FZ 4	
29	Ashby and Laird			In FZ 5	
30	Reynolds and South				FP
31	Blanche and George			In FZ 5	
32	Venetia and George			In FZ 5	
33	Leon and South				FP
34	Windsor and Olivia			In FZ 1	
35	Laird and Thompson			In FZ 5	
36	Virginia and Margaret			In FZ 3	
37	Southard and Margaret			In FZ 1	
38	Angela and Margaret			In FZ 1	
39	Catherine and Margaret			In FZ 3	
40	Seidenberg and 3rd Avenue				FP
41	Catherine and Varela				FP
42	Patricia and Ashby			In FZ 5	
43	Patricia and George			In FZ 5	
44	Blanche and Josephine				FP
45	#1 Smathers Beach				FP
46	#2 Smathers Beach				FP
47	#3 Smathers Beach				FP
48	#4 Smathers Beach				FP
49	#5 Smathers Beach				FP
92	Margaret Street (between Catherine St & Virginia St)			In FZ 3	

Table 2. Existing Gravity and Pump Assist Wells - Utilities

EXISTING WELLS (continued)

	Utilities	1994 KCA Rpt	2001 KW Long Range Plan	Wells Models Recommended: CH2MHILL Mdl Rpt 02	CDM Mdl Rpt 03	Parsons Mdl Rpt 03	Parsons Mdl Rpt 06	Other
50	Simonton #1 Pump Assist		In FZ 12	x				
51	Simonton #2 Pump Assist		In FZ 12	x				
52	Patricia and Ashby Pump Assist	In FZ 5		x				
53	Olivia Street and Emma Street						FPN	
54	Amelia Street and Whitehead street	In FZ 2				x		
55	Howe Street and Virginia Street					x		
56	Truman Avenue and Thomas Street							x
57	Louisa Street and Simonton Street					x		
58	Simonton Street and South Street					x		
59	Angela Street and Simonton Street					x		
60	Caroline Street and Whitehead					x		
61	Green Street and Whitehead			UpSFPN				
62	Caroline Street and Simonton Street		UpSFZ 9		UpSFPN			
63	Varela Street and Virginia Street					x		
64	Catherine Street and White Street	UpSFZ 8						
65	Virginia Street and White Street					UpSFPN		
66	Fleming Street and White Street	In FZ 6				x		
67	Southard Street and White Street	UpSFZ 6				x		
68	Angela Street and White Street	UpSFZ 6				x		
69	Fleming Street and Frances Street	UpSFZ 6				x		
70	Angela Street and Ashe Street					x		
71	Eaton Street and White Street	In FZ 6						
72	Eaton Street and Frances Street	In FZ 6						
73	Frances Street and Petronia Street				x			
74	Grinnell Street and Johnson Street					x		
75	Grinnell Street and Von Phister Street					x		
76	Johnson Street and Whalton Street	UpSFZ 8				x		
77	George Street and Washington Street	UpSFZ 8				Moved Elev		
78	Ashby Street and Washington Street	UpSFZ 8					x	
79	Thompson Street and Washington street	UpSFZ 8					x	
80	Tropical Street and Seminary Street	UpSFZ 8					x	
81	Tropical Street and South Street	UpSFZ 8					x	
82	Pearl Street and Duncan Street	UpSFZ 8					x	
83	Pearl Street and United Street	UpSFZ 8					x	
84	Florida Street and United Street	UpSFZ 8					x	
85	Washington Street and Whalton Street					Moved Dbl		
86	Von Phister Street and Whalton Street					x		
87	Albury Street and Pearl Avenue					x		
88	Olivia Street and Pearl Avenue						UpSFPN	
89	Pine Street and Pearl Avenue						UpSFPN	
90	Windsor Lane and Passover Lane (Cemetery)	In FZ 1				x		
91	Florida Street and Petronia Street					Moved Elev		

In addition, the Utilities Department restored flow to seven (7) critical drainage flow ways (canals/ditches) and provided for the associated environmental mitigation. These flow ways directly serve more than fourteen essential stormwater collection system outfalls.

Planning Efforts

In 1989 the City began evaluating its stormwater drainage system in support of the City Comprehensive Planning efforts. CH2M HILL was tasked to begin the process of drainage structure identification through field investigation. However, plans did not exist in City records for much of the drainage system. The completed the Drainage Investigation Report was completed in 1989 (Attachment 1). As required by Comprehensive Plan Policy 4-2.1d.1 KCA preformed the 1994 Stormwater Runoff Study (Attachment 2) that identified and mapped existing flood problems as of the date of the report. The report included aerial mapping using surveyed ground controls. Some surveying was included in the scope of work. Eight (8) flood areas were identified and ranked by severity. The number of structures and cost to address these problems was estimated. The next Phases were identified to include modeling and design as funds became available.

June 2001, the City created a Long Range Stormwater Utility Plan (Attachment 3) that identified seven additional flood zones (FZ) for a total of 15 FZs. The plan further documented existing systems and identified capital projects and funding requirements. The plan incorporated policies set out in the White Paper and discussed University of Miami Water Quality Analysis that was the basis for the policy related to diverting water from outfalls.

Document Review

The CH2M HILL 1989 Drainage Investigation Report began the process of evaluating existing stormwater infrastructure. Because only limited plans were available for the review, the collection systems were located on a preliminary basis, and permitting meetings were held. At the time FDER (now FDEP), SFWMD and ACOE recommended the City avoid increased discharge to wetlands. They also cautioned against rerouting stormwater to wetlands. The agencies suggested drilling holes in the bottom of inlets as flood reduction measure. They also recommended that turbidity be avoided. The report went on to recommend aerial mapping, surveying and topographic mapping. A system by system assessment of the drainage problems would be required. The report pointed out that a drainage area and system study could proceed on a drainage area basis; this process would allow the City to deal with the most severe problems first.

The aerial mapping was conducted as part of the 1994 KCA study to the specifications recommended. The structure by structure survey could not be done until the cleaning was complete as discussed above. In 1995 a cleaning contract was implemented and the system was located and documented. As the Sewer Collection System replacement was designed between 1995 and 2000 detailed surveying was conducted that captured detailed stormwater system information (i.e., pipe inverts, grate elevations etc.). The Sewer rehabilitation took priority over stormwater due to health reasons. Section 1.3 (pg 2) of the

1994 KCA confirms that the aerial mapping was done. The Utilities Department adopted a drainage system by drainage system approach to allow use of the City's limited resources to deal with the most severe problems first, as recommended in the report.

In 1994 KCA completed a Stormwater Runoff Study that identified 8 major flood locations and the associated severity. The study provided the planning and design tools recommended in the 1989 CH2M HILL report. The report recommended design minimum criteria for stormwater infrastructure. The City and the Utilities Department has met or exceeded these guidelines. Design Criteria discussed below highlights areas critical to effective stormwater management in Key West. Section 8.1 Conclusions (pg. 61) outlines factors that contributed to flood problems at the time of the study and are summarized as follows:

- Existing storm drain inlets do not have sufficient capacity to collect the stormwater runoff
- Inlets are not placed along the drainage path but only low areas
- Storm drain inlets get blocked by yard debris and trash
- Storm drain are clogged with debris
- Outfalls have been destroyed, blocked, or do not exist for some storm drain systems
- High water table and high tidal elevations

To address flooding and provide stormwater treatment the Study Section 8.2 - Recommendations (pg. 62) provides the following:

1. Implement a city-wide maintenance program that would provide scheduled cleaning of the existing and/or any proposed storm drain system.
2. Implement a street sweeping program to keep the streets clean of yard debris and trash that would eventually block inlets and pipes.
3. Install flap gates or similar devices on outfalls that discharge into the Atlantic Ocean or the Gulf of Mexico. This would help prevent tidal waters from entering the storm drainage system and flooding roadways.
4. The existing storm drainage system should be inventoried and mapped. This would include documenting the type, size, location, elevation, and condition of all inlets, manholes, pipes and outfalls. To accomplish this all structures filled with dirt and debris would need to be cleaned. This could be completed on each flooding location as they are chosen for improvements.
5. Model the existing storm drain system associated with each flood location and determine which improvements are necessary to alleviate the flooding problems and provide as much stormwater treatment as possible.

6. Drainage easements should be purchased for any existing or future outfalls. The Kamien subdivision would be a good example where the purchase of private land would improve the drainage in the area. The outfall at the end of Thompson Street [should have been Ashby Street] is blocked and needs cleaning. If the City owned the property Southeast of Atlantic Boulevard, they could keep the outfall clean and also use this property to provide a retention pond for stormwater treatment. Other areas will be identified in subsequent phases.

In Spring 1995, OMI was hired to maintain the stormwater collection system as recommended by KCA Section 8.2.1 as discussed above. Street sweeping and right-of-way cleaning programs were implemented as recommended in KCA 8.2.2. City Engineering Staff installed 8 tide valves on collection systems severely influenced negatively by tides, as per KCA Section 8.2.3. To implement the recommendations of Section 8.2.4, pipes were cleaned, necessary spot repairs were made and flow ways were restored. The stormwater system was inventoried and mapped. Detailed survey information was gathered as sewer projects were surveyed and designed. A stormwater topographical map was updated with spot elevations and stormwater collection system information (imbedded in a CAD file). Modeling (discussed below) of 14 of the 15 flood zones were completed between 2002 and 2006, as recommended in Section 8.2.5. The Berg property and Kitsos property, on the south side of the Atlantic Boulevard were purchased, as recommended by KCA 8.2.6.

The City's 2001 Long Range Stormwater Utility Plan identified 7 additional Flood Zones (FZ) for a total 15 FZs in need of stormwater improvements. The plan identified 118 projects to be considered. 63 of these projects have been completed or will be completed at the conclusion of the current construction projects. These projects include 3 pump assist wells and 9 pollution control structures on outfalls.

The plan recommended the following:

- Establish a stormwater utility and fund to a level of $2 million per year.
- Adopt NPDES (MS4) guidelines
- Create and enforce water quality criteria.
- Implement a quality maintenance program
- Require stormwater treatment and retain age on all construction sites greater than 1 acre.

The City implemented the Stormwater Utility beginning FY 2003 (October 2002). The City currently collects approximately $2 million per year from the utility. In 2005 the City received its 1st MS4/NPDES permit. As part of the MS4 program the City has implemented a water quality component to all projects undertaken. The City has doubled its stormwater maintenance efforts in recent years. The Stormwater Utility also provided Stormwater training and certification to Key West Building Officials and Code Compliance Officers. The Building Department implemented a program that ties proper completion of the applicant's

stormwater plan to the issuance of the Certificate of Occupancy. This program includes enforcing containment of construction runoff.

The City of Key West Water Quality Improvement Program (White Paper, Attachment 4) describes the City's accomplishment in rebuilding 46 miles on mainline sewers and 27 miles of laterals between 1999 and 2002. The paper went on to outline City water quality goals/policies as it relates to stormwater and identify projects intended to achieve those goals. The City committed to divert runoff from Outstanding Florida Waters (OFW) to injection wells. Diverting water to injection wells was intended to keep sewer and stormwater pipes from being close to one another in the streets, which reduces the risk of nearshore water contamination. The City also committed to retrofitting outfalls with pollution control structures. These policies were the based on University of Miami, Ph.D. Helena Solo-Gabriele's extensive analysis nearshore water contamination and its correlation to stormwater outfalls. As discussed above these policies were incorporated in the 2001 Long Range Stormwater Plan.

In a letter dated March 22, 2002, City of Key West Mayor Jimmy Weekley (Attachment 5) requested that the Florida Keys Marine Sanctuary Water Quality Protection Program steering committee appoint a technical review committee for the purpose of reviewing the City of Key West's Long Range Stormwater Utility Plan. He further requested a resolution endorsing the Plan. The technical review committee issued a review report on March 18, 2003 (Attachment 6).

> FDCA found the plan consistent with the City's Comprehensive Plan including Policy 9-1.4.3 - Master Drainage Plan (see Comprehensive Plan below). However, the Panel recommended development of Best Management Practices (BMPs) with clear measurable goals and objectives for control and treatment of stormwater. Pollution prevention should be a focus of the BMPs. They recommended the continuation of the City's sewer lateral testing program. The Panel also recommended designation under the MS4 program and apply for a NPDES general permit under the MS4 program.

On April 3, 2003 FKNMS Water Quality Protection Program Steering Committee approved the Key West Stormwater Plan (Attachment 7) by resolution. Based on the committee's recommendation FDEP designated Key West a Phase II MS4 City under the Federal Clean Water Act. As part of the MS4 application the City developed clear measurable goals and objectives for control and treatment of stormwater. Pollution prevention was a focus of the BMPs. The City developed its stormwater pollution prevention plan and received its first NPDES/MS4 permit February 2005.

The Comprehensive Plan Goals, Objectives, and Policies address stormwater issues as follows:

- **Policy 4-1.1.2 Compliance with the Level of Service Standards (LOS).** This section requires that all new public facilities (or alteration of) shall be compatible with the adopted LOS for that facility.

- **Policy 4-1.2.1 Capital Improvement Schedule.** Provides for the annual evaluation and ranking of capital improvement projects for inclusion in the five year schedule.

- **Policy 4-1.2.2 Public Facility Evaluation Criteria.** The projects shall be ranked based on the need for the project to protect health and safety, and the legal commitment to provide facilities and services.

- **Objective 4-2.1d Plan and coordinate surface water management services to meet existing and future surface water management needs, including preparation of an engineered stormwater management plan and ensure plan implementation.** To maximize existing surface water facilities and address problems identified in the FY 1993 Data and Analysis drainage supplement this objective required the City to commence an engineered stormwater management plan to identify short and long term stormwater management needs. The master plan shall include an inventory of natural and structural drainage systems existing, assess related drainage problems and recommend capital projects to address the problem.

- **Policy 4-2.1d.1 Stormwater Management Plan.** An engineered stormwater management plan (study) shall be completed by FY 1994 and a capital improvement program implemented with funding for the drainage improvements recommended in the adopted master drainage plan. The study shall address major drainage improvement needs.

- **Policy 4-2.1d.2 Improvement of flow at the Riviera Canal and Salt Run.**

    1. The scheduled Master Drainage Plan shall include a study of all streets which direct runoff to Riviera canal and recommend drainage improvements to reduce non point source pollutants that impact Riviera canal.

- **Goal 4-3 Provide adequate drainage.** Provide drainage to protect against flooding and prevent receiving water degradation.

- **Objective 4-3.1 Protect Natural Drainage Features.** The City shall undertake a master drainage plan that shall recommend measures to protect natural drainage features including capital projects (new and retrofits) that avoid degrading these receiving waters with urban runoff. The program shall include periodic investigation of on-site systems to assure continued compliance.

- **Policy 4-3.1.2 Provide adequate onsite retention and ground water recharge while directing the surplus to receiving water in a manner which prevents imbalance to their ecosystems.** The City shall enforce the LOS in Policy 4-1.1.1. The stormwater management plan shall recommend measures to protect water quality, slow runoff and enhance percolation. The measures shall be adopted by ordinance.

- **Policy 4-3.1.4. Coordinate Watershed Management Plans and policies with appropriate public agencies.**

- **Policy 4-3.1.7. Implement stormwater management plan.** Implement the plan with a funding mechanism.
- **Objective 6-1.2 Water Quality and Quantity.** The City shall complete the improvements in the Public Facilities Element Goals, Objectives, and Policies Table IV-1 including the Deep Injection Well (for sewer disposal). The 1994 master drainage plan was the only capital project included in Table IV-I for stormwater.
- **Policy 9-1.4.3 Master Drainage Plan.** Needed drainage improvements through 2010 shall be identified in the drainage improvement plan.
- **Policy 9-1.5.1 Resolving Concurrency Issues.**
- **Policy 9-1.6.1 Level of Service Standards.** For Drainage LOS the most restrictive of the requirements apply. Post development runoff shall not exceed pre development for a 25 year, 24 hour storm. The development must treat and retain the 1st inch of stormwater for water quality. Additional requirements apply if discharges are to OFW. Stormwater facilities must be designed to not degrade the receiving waters below minimum conditions as defined in F.A.C.

The City of Key West Comprehensive Plan committed to completing an engineered stormwater management plan by FY 1994. This plan was referred to as stormwater management plan (Objective 4-2.1d, Policy 4-2.1d.1, Policy 4-3.1.2) and master drainage plan (Policy 4-2.1d.1, Policy 4-2.1d.2.1, Objective 4-3.1, Policy 9-1.4.3, Objective 6-1.2 Table IV-I pg. 3) interchangeably. Table IV-I pg.3 of Objective 6-1.2 (Attachment 8) shows funding in FY1993 in the Gas Tax Fund for the Master Drainage Plan. As outlined above the Comprehensive Plan defined what was to be included in the engineered stormwater management plan. The 1994 KCA Stormwater Runoff Study was the engineered stormwater plan or master drainage plan referred to in the Comprehensive Plan.

As discussed above the FDCA found the 2001 Long Range Stormwater Plan, the 1994 Stormwater Runoff Study and supporting documentation consistent with Comprehensive Plan; however, they expressed concern that the City's plan did not have enough detail relating to nutrient removal, several shallow injection wells exist without treatment proposed and several outfalls that discharge into surrounding OFW without treatment proposed. The outfalls draining into the OFW include North and South Roosevelt Boulevard. DCA recommended that these outfalls be given priority for water quality retrofit or outfall removal.

The Land Development Regulations (LDRs) govern development and redevelopment of private property. They also apply when the City or most other local governments act as the developer. Proper application of the LDRs is critical to Concurrency Management and the associated need for public stormwater facilities. A summary of the LDRs stormwater issues can be found in Attachment 9.

On June 5, 2001, the Stormwater Utility Ordinance No. 01-06 (Attachment 10) created the stormwater Utility and associated user fee. The Ordinance provided for the establishment

regulations necessary to implement the utility. It grants the power necessary to administer all operational, regulatory, capital, planning and financial aspects of the utility.

The Ordinance provides the method of calculation for the bills. It defines the Stormwater Management System as the existing stormwater management of the City and improvements thereto...to be operated to...conserve water, control discharges, collect, convey, store, absorb, inhibit, treat, use or reuse water to prevent or reduce flooding, over-drain, environmental degradation and water pollution or otherwise affect the quality and quantity of discharge from such systems.

On June 18, 2002, Ordinance No. 02-16 (Attachment 11) amended Chapter 74 of Code of Ordinance prior to implementation of the Utility. The primary purpose of the amendment was to establish credits related to level service including opt out provisions for those properties that can demonstrate that they do not contribute runoff to City-owned or maintained stormwater facilities. The amendment also created a Senior Citizen discount.

Creation of a Utilities Department and Subsequent Establishment of a Stormwater Utility

Prior to 1995, failure to maintain the stormwater collection system resulted in pipes and inlets full of silt and storm debris that prevented surveying of the collection system, identification of the pipe size and evaluation existing stormwater infrastructure. A Utilities Department, funded by gas taxes, was created and a Utilities Director appointed in FY1995 in part to implement the KCA recommendations and move forward with stormwater management in Key West. In 1995 an ongoing cleaning contract was implemented, the stormwater collection systems was inventoried (including pipe sizes) and mapped (not surveyed). Stormwater flow was restored in areas that had collection systems and altering inlets was not considered further.

To secure funds to move the stormwater management to a higher level of activity, the City enacted Ordinance 01-06 established a Stormwater Utility (later amended by Ordinance 02-16) as discussed above. The Ordinance was based on a May 2001 Stormwater User Charge Feasibility Study by Black & Veatch. Events of 9/11 lead to a one year delay in implementing the user fee charge. Billing began in FY 2003.

The first Key West stormwater design project that included modeling was task in May 2001 and modeled four major drainage basins. In the summer of 2002 the completed planning effort for Pump Assisted Well Scope of Work included nine (9) Technical Memorandums (TM) that addressed the following issues:

- Estimation of Drainage Well Capacities for both gravity and pump assisted wells. The TM identified Salinity Density Differential at low elevations as a design constraint for Key West gravity wells.
- Stormwater Pollution Reduction through Mechanical Separation Techniques selected the structural pollution control BMP for pump assist wells. An evaluation of

Stormwater Disinfection Alternatives feasibility and cost effectiveness was also completed. A TM also quantified the First Flush Discharge.

- Drainage Basin Characteristics were identified. Hydrologic & Hydraulic Analysis (modeling) of Drainage System were completed at Patricia/Ashby Streets, White Street/Atlantic Blvd, Duval Street/South Street, and Duval Street/Front Street

The design project was completed for four pressurized well locations and the project was bid. Only two (2) of the four pump assisted wells were constructed due to funding constraints. A third pump assisted well location is currently under construction.

Both CDM and PED/Parsons were tasked to do design and modeling for 60 potential gravity well sites. These modeling reports were issued in 2003. Additional modeling efforts were tasked in 2003 and completed in 2006 by Parsons.

Flooding and Standing Water Problems

The 1994 KCA Drainage Report and 2001 Long Range Stormwater Utility Plan identified 15 flood zones (FZ) as discussed previously. The Utilities Department began modeling stormwater basins using a basin by basin approach recommended in the KCA report as part of the design selection process. Basin delineation was refined as part of the modeling effort. Subsequent modeling efforts have identified 40 additional flood problem nodes/locations not already included in a flood zone. Attachment 12 a & b is an updated Stormwater Utility Map that documents these flood location and stormwater infrastructure. The City has recently received updated hurricane planning maps from the State with aerial laser survey (LiDAR) generated contours overlaying new aerial photographs. These GIS maps provide detailed topographical information that will help refine future modeling efforts and will eventually become the new base maps for the utility. It is important to note that although most areas of the City has had some stormwater modeling completed; however, some areas have not been modeled yet.

Utilities Department Site Selection

Site selection is based in part on identifying flood problems beginning with the 1994 KCA Drainage Report, 2001 Long Range Stormwater Utility Plan and subsequent modeling and design efforts. A review of the reasoning for the selection of the most recent gravity wells under construction is provided in this section. Detailed hydrologic modeling (like ICPR, which was used by some consultants) is an effective and powerful tool for large and small areas when paired with sound judgment of the design engineer; however, similar results can be achieved using the simpler Rational Method (see below) for the design of smaller basins/sub-basins. Designers using the Rational Method had access to the previous modeling reports during the design efforts.

It is important to note that the Nearshore Water Quality has been a HIGH priority since the health advisories effectively closed nearly all Key West beaches in 1999. Under the Federal Clean Water Act the EPA (thru FDEP) can require a very costly Total Maximum Daily Load

(TMDL) program aimed at protecting our near shore waters from stormwater and other discharges. The program would have a significant impact on local government's ability to issue building permits. The City, County and the State have participated in preparing the Florida Keys Reasonable Assurance Document (FKRAD). EPA's approvals of this document will allow local governments to avoid implementing the TMDL program. The FKRAD identified actions taken and to be taken by each local community to protect our nearshore waters. For example the City committed to retrofitting stormwater outfalls with pollution control, implementing Best Management Practices (BMPs) and diverting water away from outfalls where possible (wells).

Stormwater studies typically examine the volume of stormwater runoff and the quality of the stormwater separately. Even the water management district rules address them separately. The normal approach to estimate water quality is to estimate the amount of runoff, size to pass the flow rates, then address water quality by adding treatment boxes, wells, or ponds (in areas with space). The water quality is normally estimated by taking the flow rate (volume) and multiplying it by an average concentration. The average concentration is often based on literature values or on a few local water quality samples. This approach approximates pollutant loading since concentrations can vary a lot because of different factors like time between storms, amount of build-up of sediment (or trash) in any given basin, size of storm, and seasons (periods of high pollen).

Treatment devices are designed to capture and treat the first part of the storm, often called the first flush. This treatment volume is normally about 0.5 to 2.5 inches of runoff in the water management district rules. There are roughly about 120 or so storm events per year in Florida but only about 70 to 90 of them are big enough to generate runoff and about 80 percent of the storms are less than 1-inch in volume. Therefore, when the City of Key West intercepts stormwater in its wells, many of the storms can be captured completely without discharge to the nearshore waters (if all of the water reaches them at a slow enough flow rate). This means that bacteria and turbidity reaching the shoreline is also reduced too. Some nutrients, like nitrogen, may eventually make its way to the ocean through the marl but it is much later and diluted with groundwater. Because of the variability in stormwater concentrations, the rules normally require higher volumes of stormwater to be treated, especially in commercial areas. However, some technologies capture and remove the stormwater from the surface, like the gravity wells, and these are considered more effective than detention alone. The volume to be captured is lower (typically in the 0.5-inch range) in the rules than for stormwater ponds, for example. However, a lower regulatory volume does not mean that the City should not capture as much stormwater as possible to protect its beaches and nearshore waters. Furthermore, the state is in the process of increasing the strictness related to water quality in a new statewide stormwater rule under development for 2011 implementation.

Key West tries to divert stormwater away from outfalls because current pollution control devices do a poor job of biological and nutrient removal. The University of Miami analysis linked stormwater outfalls to nearshore water quality contamination even after City sewer lines were totally replaced. BMPs include pollution control devices for the wells (gravity and

pump assist). As a result every site selection is based on a combination of factors related to improvement of quality of life, protection of property, and water quality.

The City of Key West Comprehensive Plan requires the City to base its capital planning efforts on the following:

- The projects shall be ranked based on the need for the project to protect health and safety, and the legal commitment to provide facilities and services (Policy 4-1.2.2).
- Plan and coordinate surface water management services to meet existing and future surface water management needs (Objective 4-2.1d).
- Provide drainage to protect against flooding and prevent receiving water degradation (Goal 4-3).
- Protect Natural Drainage Features including capital projects (new and retrofits) that avoid degrading these receiving waters with urban runoff (Objective 4-3.1).
- Provide adequate onsite retention and ground water recharge while directing the surplus to receiving water in a manner which prevents imbalance to their ecosystems (Policy 4-3.1.2).

Protection of surface waters from degradation caused by stormwater runoff is an essential part of the evaluation of sites.

Review of Projects Under Construction

Table 3 lists the well projects currently under construction and how they relate to the planning efforts to date. Five (5) of the total thirty-three (33) sites are pollution control structures for outfalls. Twenty-three (23) well/pump station sites of the thirty-three (33) total sites directly or indirectly reduce flow to outfalls (see Attachment 12 a & b).

Modeling studies recommended sixteen (16) of the sites under construction as shown on Attachment 12 a & b. An additional modeled well site was moved upstream to a location also upstream of FZ #1 and FZ #9 during the design site selection process due to the lower elevation at the originally proposed site. Two (2) modeled well sites were moved upstream to capture stormwater before it gets to the lower intersection in locations where the modeling results recommended two wells. Seven (7) well sites were placed upstream of locations identified by the model studies that have water staging/flooding problems. Two (2) additional sites were placed upstream of KCA FZ #1.

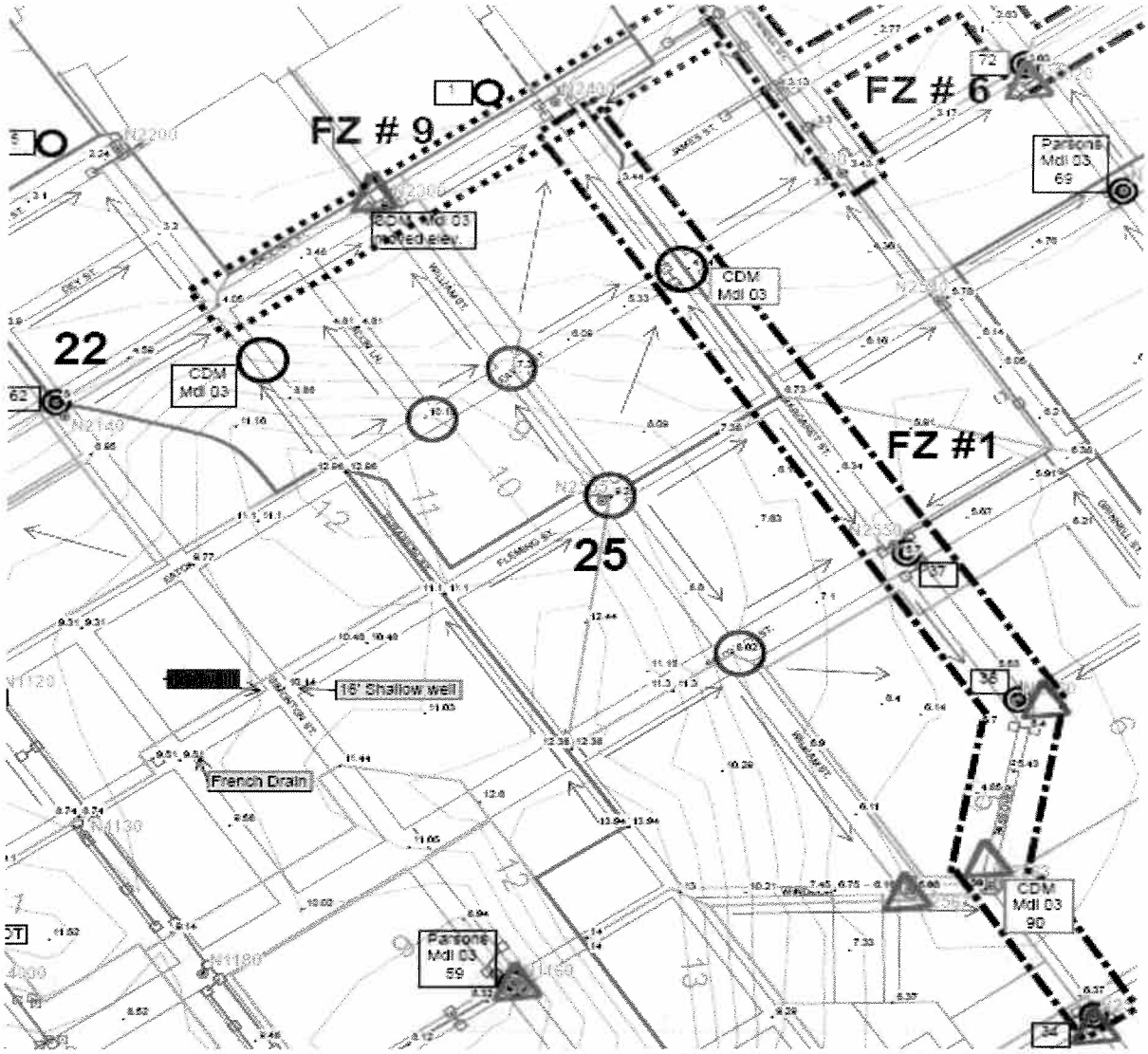
Flood Zone #1 and FZ #9 are heavily influence by the higher, upstream Drainage Basins 22 and 25. Runoff from Basin 22 flows to the North end of FZ #1 and towards the Caroline Street corridor (FZ #9) that has stormwater staging problems confirmed by the CDM 2003 model report. Runoff from Basin 25 flows to FZ #1 and to a lesser extent towards the FZ # 9 (via the Southard/Grinnell Streets stormwater collection system). Five (5) new wells help protect FZ #1 and the Caroline Street Corridor (FZ # 9) and the Key West Bight nearshore waters by intercepting the stormwater before it flows into these flood prone areas (Figure 1).

Table 3. *List of Well Projects Currently Under Construction*

	WELLS & PUMP STATION UNDER CONSTRUCTION	Wells Models Recommended						
		CH2MHILL 2002	Parsons 2003	Parsons 2006	CDM 2003	KCA 1994	Long Range Utility Plan 2001	Outfall Flow Reduction
1	Angela St. & Pearl St.			UpSFPN				OFR
2	Pearl St. & Newton St. (from Fl/Pearl)			Moved double				OFR
3	Virginia St. & Florida St.			UpSFPN				OFR
4	Southard St.& Frances St.		UpSFPN					
5	Emma St.& Truman Avenue		x					OFR
6	Florida & Newton Streets		x	x				OFR
7	Washington &William St.		x	x				
8	Margaret St. & Eaton St.			UpSFPN	x	In FZ1	UpSFZ9	OFR
9	2nd Ave. & Stapes Ave.				x			
10	Caroline St. & Elizabeth St.				x		UpSFZ9	OFR
11	Harriett Ave. & 15th St.				x			OFR
12	Von Phister St. & George St..				x	UpSFZ8		OFR
13	Von Phister St. & Ashby St				x	UpSFZ8		OFR
14	William St. & Catherine St./Louisa St.			x		UpSFZ3,8		OFR
15	Royal St. & Catherine St.			x		In FZ3 UpSFZ8		OFR
16	Watson St. & Catherine St.		UpSFPN			UpSFZ3,8		OFR
17	Grinnell St. & Catherine St.			UpSFPN		UpSFZ3,8		OFR
18	Packer St. & Catherine St.			x		In FZ3 UpSFZ8		OFR
19	Windsor Lane & Virginia St (from Truman/Windsor)			Moved double		In FZ3 UpSFZ8		OFR
20	William St. & Fleming St.					UpSFZ1	UpSFZ9	OFR
21	William St. & Southard St.					UpSFZ1		OFR
22	Eaton St. & Pecan Lane			UpSFPN		UpSFZ1	UpSFZ9	OFR
23	William St. & Eaton St. (from Caroline/Wm.)		Moved Elev.	UpSFPN		UpSFZ1	UpSFZ9	OFR
24	Caroline St. & Anne St.			UpSFPN			UpSFZ12	OFR
25	United St. & Simonton St.		x					
26	United St. & Whitehead St.		x					OFR
27	Catherine St. & Whitehead St.		x					
28	White Street Pump Assist	x				In FZ4		OFR
29	4th St. & North Roosevelt Blvd. (Pollution Control)	N/A						
33	1st St. & North Roosevelt Blvd. (Pollution Control)	N/A						
31	11th St. & Riviera Dr. (Pollution Control)	N/A						
32	15th St. & Riviera Dr. (Pollution Control)	N/A						
33	18th St. & Sunrise Dr. (Pollution Control)	N/A						

FZ means flood zone per 1994 KCA Report
UpS means upstream of a FZ or FPN
FPN means flood problem node (location)
OFR means outfall flow reduction

Figure 1. *A Portion of the KCA Flood Zone #1 and Flood Zone #9*



Drainage Basin 28 stretches from Simonton Street to George Street (see Figure 2 below). Stormwater flows from the higher landscape West of White Street into the lower reaches. The 5-year, 10-year and 25-year 24-hour storms would produce approximately 7.8 million gallons, 9.3 million gallons and 12.4 million gallons of stormwater, respectively, West of White Street. Most of this stormwater ends up in FZ #3 and FZ #8 which are located in Basin 28. Two (2) of the wells are upstream of FZ # 8 and were recommended by the 2003 CDM model. Six of the wells in Basin 28 are designed to significantly reduce stormwater that is staging in FZ #3 on Margaret Street which then spills over to Varela Street (Figure 3). These wells also reduce flow to FZ #8 as not all stormwater staging in the streets (Catherine Street in particular) will flow toward FZ #3. These wells are necessary because of the undersize 10-inch diameter clay line on Catherine Street. This will remove peak flow through the pipe of 2.25 cfs or about 1,000 gpm from the Jose Marti outfall (Figure 3). Under full pipe conditions this pipe could carry only 1.44 million gallons per day of the flows shown above.

Figure 2. *Basin 28 Flood Zones 3, 8 and 14*

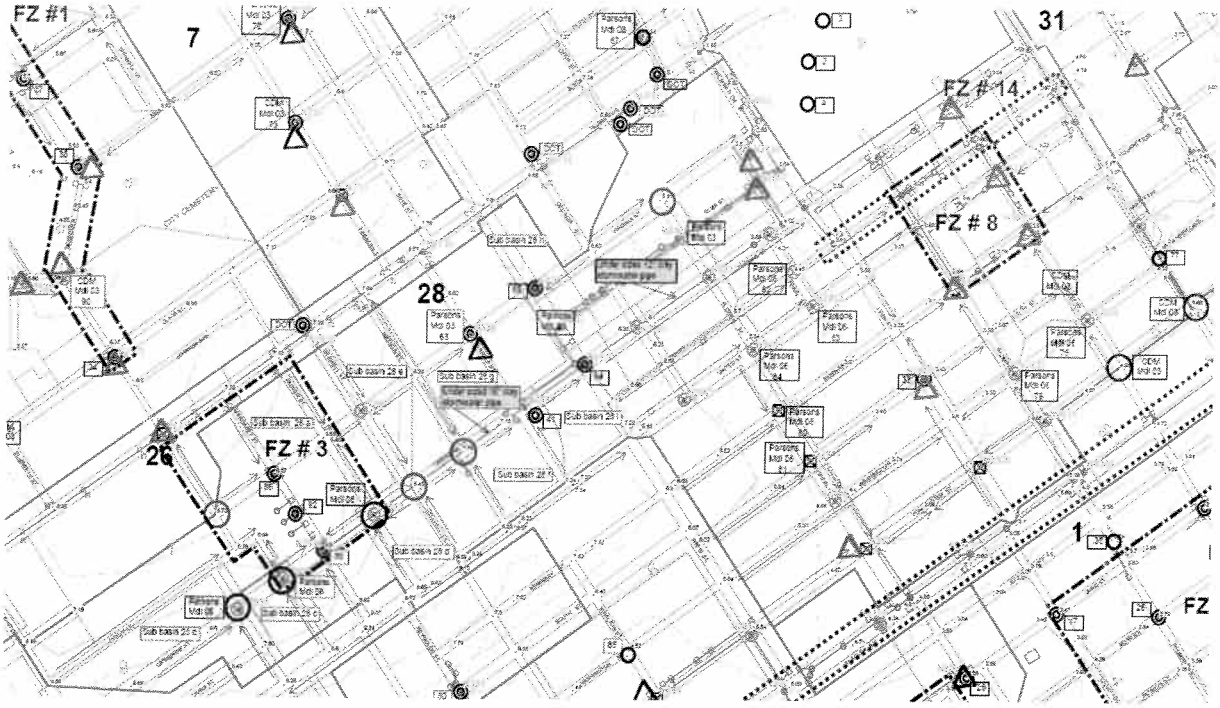


Figure 3. *Closeup View of FZ #3*

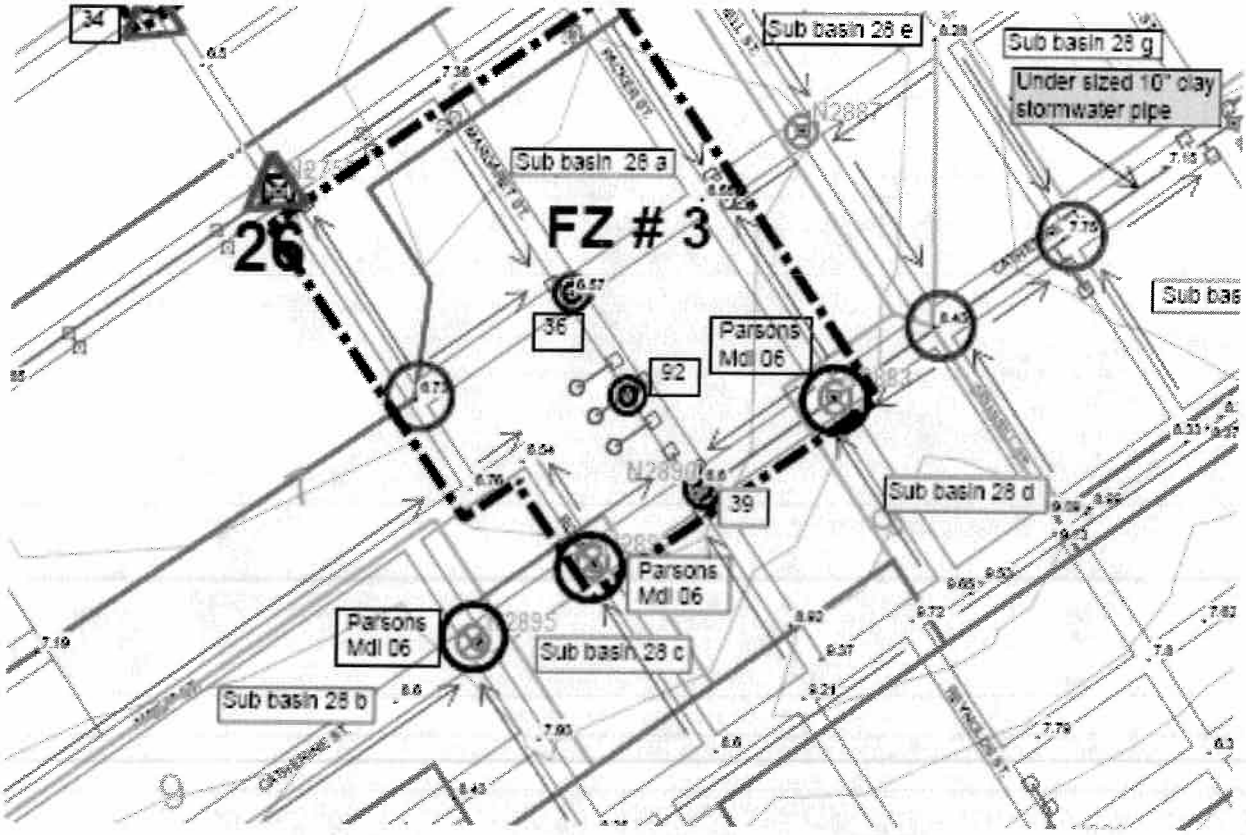


Table 4. *Estimated Flow Capacity of Existing Pipes*

Peak Flow through Clay Pipe
10-inch clay => 2.25 cfs or about 1,000 gpm
12-inch clay => 3.7 cfs or about 1,650 gpm
15-inch clay => 6.6 cfs or about 3,000 gpm

The west end of Stormwater Basin 28 is served by a 10-inch diameter stormwater collection system starting at Catherine/Margaret Streets and going East down Catherine Street. At White Street the pipe size increases to 12-inch diameter. The maximum flow of the 10-inch system is 1,000 gpm and increases to 1,650 gpm for the 12-inch line at White Street.

The 3-year, 10-minute storm exceeds the pipe capacity of this undersized stormwater pipe line by more than 18 times (Table 2). Sheet flow and flow through the pipe from FZ #3 go downstream to impact subbasin 28g (Varela St.).

Table 5. *Rational Method Estimate of Peak Runoff Rates at Gravity Wells VI*

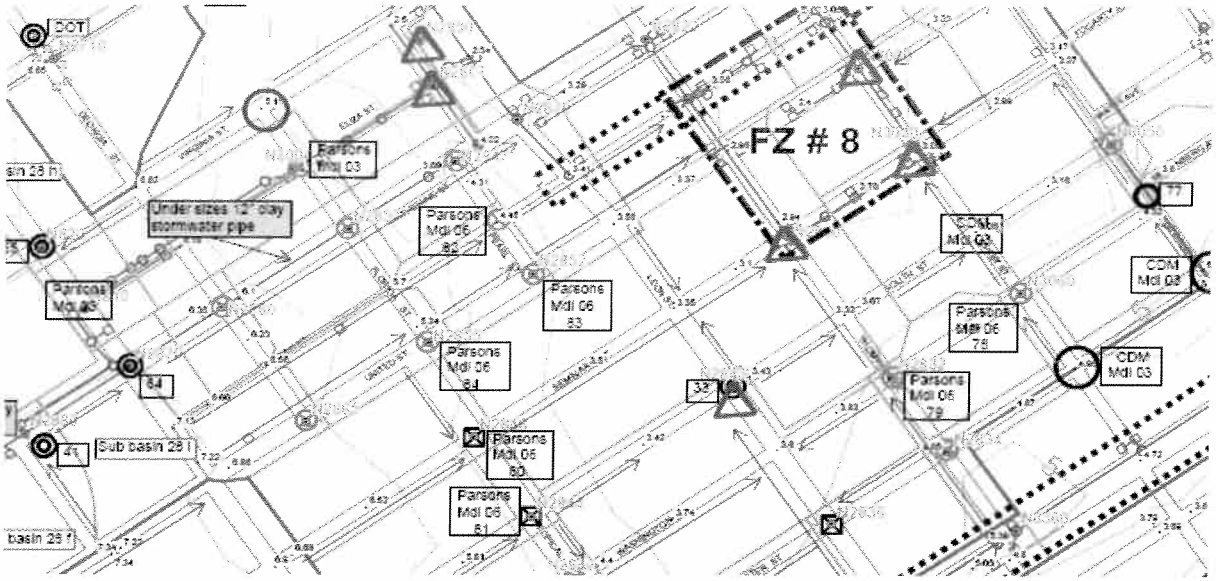
Peak Flow Rates 3 year 10 min Storm (5.6 inches per hour)	
Catherine & Williams	= 7.86 CFS
Catherine & Royal	= 5.09 CFS
Catherine & Packer	= 6.80 CFS
Catherine & Grinnell	= 7.31 CFS
Catherine & Watson	= 8.47 CFS
Catherine & Margret	= 6.0 CFS (assumed)
Total = 41.53 CFS (18,638 gpm)	

1 cf/s x 7.48 g/cf x 60 s/min □ 1 cfs = 448.83 gpm

The flow not intercepted by the stormwater collection system continues via sheet flow down the streets to FZ #8 (United/Ashby). From this brief review it is apparent why chronic flooding takes place at FZ #8 from even minimal storms.

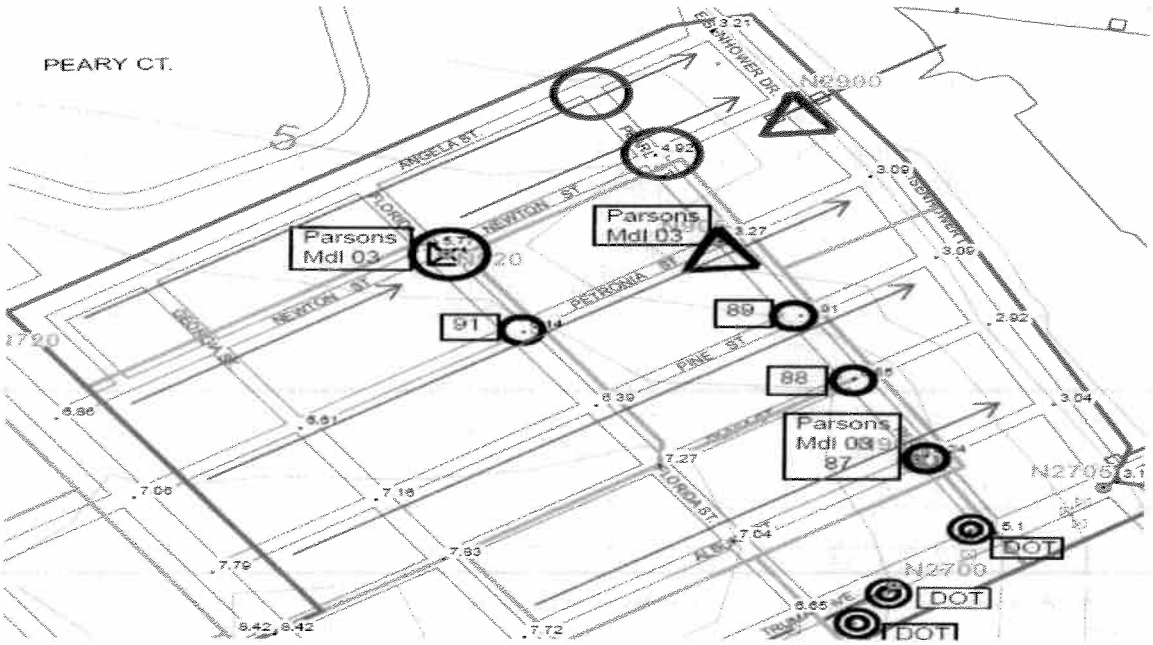
The well at Florida and Virginia Streets is upstream of the flood problem at Pearl and Virginia Streets (Figure 4). This well helps protect that residential area and Jose Marti Drive. Runoff ultimately would stage and then flow to Garrison Bight through Jose Marti Pond. Stormwater staging at Jose Marti Drive has impeded access to HOB Middle School and flooded cars parked in the area.

Figure 4. *Close-up View of Streets Leading to FZ #8*



Eisenhower is an additional flood location confirmed by modeling. Stormwater flows downhill from White Street at elevations near 7-ft to elevations below 3-ft, causing staging on Eisenhower. Wells on Pearl/Angela Streets and Pearl/Newton Streets help reduce the staging problems confirmed by the 2006 Parsons Model Report (Figure 5). Wells previously installed on Pearl Street and on Florida Street in the Meadows significantly reduce flooding problems on Eisenhower Drive and stormwater flow to Garrison Bight. Prior to recent drainage improvements this flooding spilled onto Eisenhower Drive and Truman Avenue impeding emergency response through that intersection.

Figure 5. *Stormwater Wells near Eisenhower Drive and Pearl Street*

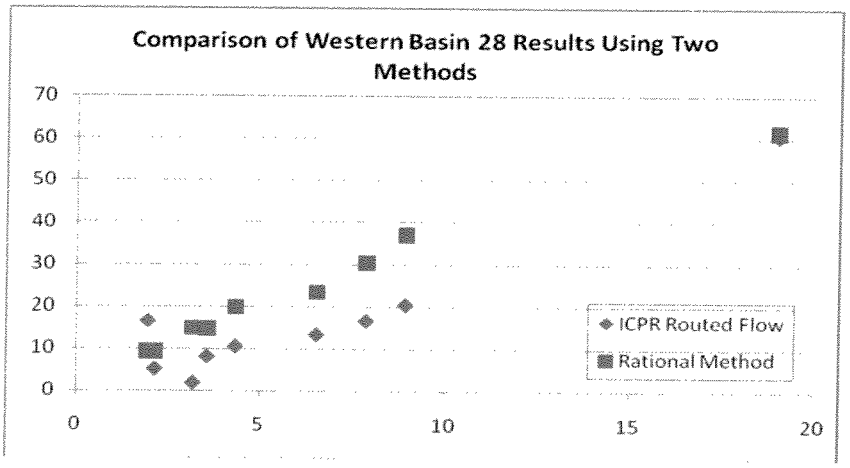


As discussed above, the wells at Caroline/Ann Street, Pearl/Florida Street, Pearl/Newton Street, Pearl/Angela Street, Southard/Francis, Eaton/Pecan Street, the three wells on Williams west of FZ #1, and three of the six wells in the Catherine Street area of Basin 28 West of White Street were designed by using the Rational Method which is discussed further below.

Computational Method Comparison

The 1994 KCA Report suggests that the Rational Method is an acceptable approach for areas less than 600 acres. It is more commonly used today in areas less than 100 acres with uniform characteristics. The Rational Method typically has similar results to the ICPR model when used for intersection design within a range of plus or minus 15%. As confirmed by the comparison for Basin 28 (a) thru (i) the Rational Method will tend to show slightly higher flows for most sites because it cannot route overflow downstream or account for ponding.

Figure 6. *Comparison of Peak Flow Results between Parsons (2006) and Gravity Well VI (2010) for Each Intersection*



The City standard well design uses a 24-inch diameter casing installed to a depth of 60-feet below ground and an injection zone of 60-feet below the casing or a total well depth of 120-feet. Based on approved construction techniques the open hole is 22-inch in diameter. The estimated capacity of these wells in Key West is based on the landscape (most often the street) elevation. The higher above sea level a top of well casing is placed the greater the well capacity. Since the groundwater in the Keys are tied so closely to the ocean, Mean High Water (MHW), Mean High High Water (MHHW) and elevation above sea level must be considered because fresh water floats on top of saltwater (salinity differential Figure 7). It takes 1.6-feet of standing water above the saltwater in the casing to overcome friction loss and salinity differential to force the stormwater down the well (driving force). Water needs to pond up to achieve the kind of design flows needed. Consequently, landscape elevations below about elevation 4 will not be adequately drained by gravity wells under high tidal conditions. Figure 8 illustrates the capacity of gravity wells in Key West using the recommended design criteria (next section). For elevations less than 4-feet (National Geodetic Vertical Datum of 1929, NGVD29), the flow down a gravity well is low to negligible.

Figure 7. *Gravity Well Diagrams*

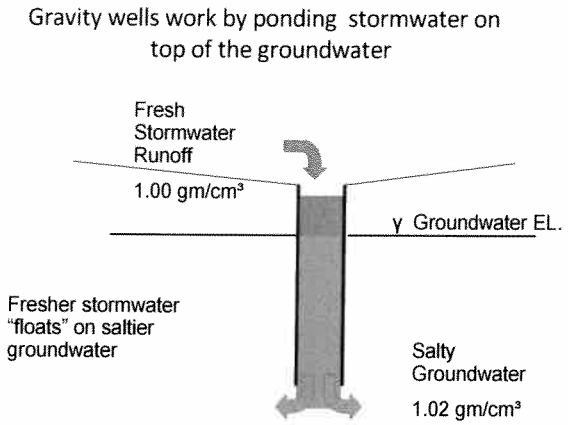
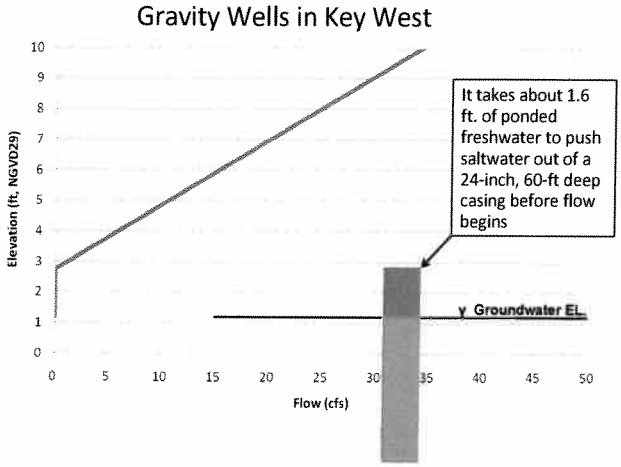


Figure 8. *Capacity of Gravity Wells Used as a Basis of Design in Key West*



Wells are often placed at the bottom of a drainage basin (i.e., the lowest elevation in an area). If elevations are high enough, a well will prevent prolonged standing water problems. However, because of rain intensity in our sub-tropic environment this will rarely prevent stormwater staging completely (Table 6). Wells can also be placed in the flow paths leading to the bottom of the basin to intercept water before it reaches the bottom. Because of our inability to effectively deal with the water at the bottom of many basins consideration must be given to all flow paths.

Table 6. *Key West 10-Minute Intensity Data used in the Rational Method*

Return Period	Intensity (in/hr)
2 year	5.2
3 year	5.6
5 year	6.1
10 year	6.6
25 year	7.3
100 year	8.4

During the design of the gravity wells, the Rational Method was applied because each well primarily serves a small contributing area. The drainage area used to predict the peak flow rates entering an intersection was limited to upstream streets and front yards. This is the contributing area that will reach the site quickest in the intense 10-minute peak storm interval. The result is a smaller drainage area that will drain to the site in a 24-hour period; however, because the approach uses peak flow intensities RM gives a conservative design margin for safety. The current gravity well designs based on the RM provide excess peak flow capacity for a 3-, 5-, 25-, 50- and 100-year 10-minute storms (Table 7). From Table 4, it can be verified that the gravity well capacity at low elevations (Figure 8) cannot be adequate to serve these intersections except maybe for the very small area contributing to Caroline and Ann Streets. Fortunately, these intersections are at elevations much higher than elevation 4, except for Caroline and Ann Streets.

Table 7. *Estimated Peak Runoff Rates at the Gravity Well VI Project Intersections for Various Design Storms*

Gravity Well VI Peak Flow Rates

Assumptions:

Peak rates based on land adjacent to streets leading to design intersection

Rational Method applied to estimate peak flow rates

			Peak Runoff Rate to Wells					
Name	Site #	Drainage Area	3-year	5-year	10-year	25-year	100-year	Estimated New Gravity Well Capacity[1]
		(acres)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
Caroline-Ann	1	0.71	3.6	3.9	4.2	4.7	5.4	5.5
Eaton-Peacon	2	0.64	9.1	3.5	3.8	4.2	4.8	29.0
Eaton-William	3	1.25	6.3	6.9	7.4	8.2	9.5	18.9
Fleming-William	4	1.55	7.8	8.5	9.2	10.2	11.7	25.8
Southard-William	5	1.29	6.5	7.1	7.7	8.5	9.8	24.7
Virginia-Windsor	6	1.87	9.4	10.3	11.1	12.3	14.1	16.6
Catherine-Royal	7	1.01	5.1	5.5	6.0	6.6	7.6	17.8
Catherine-Packer	8	1.35	6.8	7.4	8.0	8.9	10.2	20.5
Catherine-Grinnel	9	1.45	7.3	8.0	8.6	9.5	11.0	23.5
Catherine-Watson	10	1.68	8.5	9.2	10.0	11.0	12.7	20.2

[1] Capacity based on ponding up to the top of grate at drainage well.

Localized Facilities versus Larger Piped Networks

The higher gravity well capacity at higher elevations gives the City more flexibility with mini collection systems located at individual intersections as part of its stormwater management plan. It is possible to install inlets and piping connected to a single well that extend to one or more blocks. However, constructability issues must also be considered. Phone and electric duct banks, overhead utilities, water lines, fuel lines, sewer lines and tree roots all must be avoided or moved out of the way if a larger pipe network is installed. Longer pipe runs increase the number of conflicts encountered and increase the overall construction cost for the pipe network option. An example of this trade off using actual bid prices from a recent well project demonstrates that only very short pipe runs are cost effective. Table 8 contains typical costs for underground facilities. It is important to note that even one additional conflict structure, concrete encasement because of proximity to a water/sewer line, or water line relocate could quickly eliminate any potential savings.

Eaton Street/ Peacon Lane is an example of where constructability becomes an overriding consideration. Currently stormwater runs down Peacon Lane to Caroline Street. An expanded drainage system along Eaton Street has to consider that an 18-inch water main, 8-inch water main, 6-inch water main retired, 4-inch water line, 2-inch water line retired, 8-inch sewer line, and an AT&T cable duct bank are in the street right-of-way. There is very little room for new pipes. FDEP requires 10-feet horizontal or 18-inch vertical separation between water and sewer lines/stormwater lines. When these separations cannot be maintained, the sewers must have an extra concrete encasement or conflict structures installed which greatly increases construction cost. Adding a stormwater pipeline from Peacon Lane to Williams Street on Eaton Street instead of an injection well at the intersection with limited piping would run a high risk of increased construction cost just due to conflicts. In addition, installing block-long pipelines will close down even more stretches of streets during construction, causing more disruption and limiting parking.

Modeling and Master Planning

In 2001 the Utilities Department began modeling stormwater basins using a basin by basin approach recommended in the KCA report as part of the design selection process. Modeling reports included CH2M HILL 2002 (various TMs), Parsons 2003, Parsons 2006, and CDM 2003 Reports . Modeling 14 of the 15 flood zones were completed between 2002 and 2006 (FZ #7 is County owned). These modeling efforts have identified 40 additional flood problem locations not already included in a flood zone. Most areas of the City have modeling completed; however, some areas have not been modeled yet.

The City has recently received LiDAR aerial maps from the State. The LiDAR maps provide detailed topographical maps that will help refine future modeling efforts and will eventually become the new base maps. Detailed modeling enhanced by LiDAR aerials will provide staging information not previously available for many of the relatively flat areas of Key West not yet modeled. All areas of the City should be modeled as part of any future stormwater master planning efforts.

Table 8. *Cost Estimates for Underground Facilities*

DESCRIPTION OF WORK	UNIT	UNIT PRICE	Pipe vs. Well Box Cost Difference LF 135	LF 150	LF 180	LF 200	LF 210	LF 230	LF 300	LF 335	LF 400	LF 410	LF 430
TRENCH EXCAVATION, BACKFILL, STORM PIPE SHEET C-17													
18" HDPE STORM PIPE													
4' TO 6' DEEP	LF	$284											
6' TO 8' DEEP	LF	$279	$37 665	$41 850	$50 220	$55 800	$58 590	$64 170	$83 700	$93 465	$111 600	$114 390	$119 970
8' TO 10' DEEP	LF	$298											
24" HDPE STORM PIPE													
4' TO 6' DEEP	LF	$348											
6' TO 8' DEEP	LF	$365	see above										
8' TO 10' DEEP	LF	$366											
10' TO 12' DEEP	LF	$376											
6" PVC WATER PIPE													
4' TO 6' DEEP	LF	$518											
8" PVC WATER PIPE													
4' TO 6' DEEP	LF	$187											
12" PVC WATER PIPE													
4' TO 6' DEEP	LF	$235											
CATCH BASINS, INLETS & MANHOLES													
BOX P / INLET 5	EA	$3 100											
BOX P / INLET 6	EA	$2 875											
BOX P / INLET 9	EA	$6 500											
BOX J / INLET G	EA	$3 200	$3 200	$3.200	$3 200	$3 200	$3.200	$3.200	$3 200	$3 200	$3 200	$3 200	$3 200
BOX P / INLET MH	EA	$3.400											
BOX J / INLET F	EA	$3.670											
OFFSET STORMWATER INLET	EA	$5 700											
TRIPPLE CHAMBER BAFFLE BOX W/ INJ WELL	EA	$50 000	-$50 000	-$50 000	-$50 000	-$50 000	-$50 000	-$50 000	-$50 000	-$50 000	-$50 000	-$50 000	-$50 000
WELL TESTING	EA	$1 800	-$1.800	-$1 800	-$1 800	-$1 800	-$1 800	-$1 800	-$1 800	-$1 800	-$1 800	-$1 800	-$1 800
DEWATERING PER INTERSECTION	EA	$1 800											
FLORIDA TRENCH SAFETY ACT COMPLIANCE	LF	$1											
PAVEMENT													
PAVEMENT RESTORATION @ CURB	SY	$65											
PAVEMENT RESTORATION @ TRENCH	SY	$42	$2 835	$3.150	$3 780	$4 200	$4 410	$4 830	$6 300	$7 035	$8 400	$8 610	$9 030
WATERLINE VALVES													
6" GATE VALVES	EA	$1 100											
8" GATE VALVES	EA	$1.400											
12" GATE VALVES	EA	$2.400											
WATERLINE TAPPING SLEEVE ASSEMBLY													
12 "	EA	$7 700											
8 "	EA	$6 100											
6 "	EA	$5.400											
CONTINGENCY ALLOWANCE	LS	$200 000											
PERMITS: CKW ROW & FDEP WATERMAIN RELOCATES $9,800.00													
			-$8,100	-$3,600	$5,400	$11,400	$14,400	$20,400	$41,400	$51,900	$71,400	$74,400	$80,400

Modeling is an effective tool especially for larger areas; however, the protection of surface waters from degradation caused by stormwater runoff is an essential component of site evaluations. Standards set solely on flood staging (road overtopping) do not adequately address City goals of protecting Nearshore Water (Receiving Waters). Comprehensive Plan Goal 4-3 requires the City to provide drainage to protect against flooding and prevent receiving water degradation. Objective 4-3.1 requires the City to protect Natural Drainage Features including capital projects (new and retrofits) that avoid degrading these receiving waters with urban runoff.

It is important to note that there are no legal requirements to perform a stormwater master plan other than the Comprehensive Plan related studies already completed. However, substantial gains have been made in the City's stormwater capital plans in specific areas over the past ten years. As we look to the future of stormwater management in Key West, a comprehensive stormwater master plan that addresses drainage issues and water quality issues will be an important tool.

Conclusions

The City's approach to stormwater management has been based on a series of studies, modeling, best management practices, and intensive construction of stormwater improvement devices. While these measures have been successful, the proposed improvements are not complete and the city faces years of further improvements. While the program is based on sound foundations, it may be time to advance stormwater planning through updated master planning efforts.