SECTION 3

FLOODING ASSESSMENT

CITY OF COCOA BEACH, FLORIDA
STORMWATER MASTER PLAN

PARSONS ENGINEERING SCIENCE, INC.

OCTOBER 2001

SECTION 3
FLOODING ASSESSMENT

The incidence of flooding is the most obvious effect of stormwater runoff. It also carries with it the most definable liability for a stormwater utility from a management standpoint. From a Master Plan standpoint, it is important to properly identify current deficiencies within the stormwater management system. These deficiencies can arise not only from lacking or undersized facilities, but also through the deterioration of infrastructure that would, in its original condition, have performed acceptably. Once identified and quantified, these deficiencies can then be addressed through a Capital Improvement Program (CIP) with structural, procedural, and/or maintenance related actions.

This section of the Master Plan details efforts to identify flooding and infrastructure related problems and quantify their causes. Included is a discussion of current problems based on record review, interviews with relevant personnel, and data provided by the City. Following problem discussion, details regarding the Level of Service (LOS) criteria used to evaluate the performance of the stormwater management system are provided. A hydrologic/hydraulic model was developed to simulate the design storm response of key portions of the stormwater management system. The key components of this model are discussed along with the results. The final portion of this section summarized the model results in the context of the defined LOS criteria to identify specific areas of the stormwater management system that warrant further investigation. This further investigation generally consists of the implementation of structural or maintenance related BMPs under the proposed CIP.

3.1 EXISTING FLOODING AND INFRASTRUCTURE PROBLEMS

This section identifies and classifies the City of Cocoa Beach's existing flooding and major infrastructure related problems. The purpose of his exercise was to identify currently known problem areas on which to focus the hydraulic flood assessment modeling. The problem assessment was initiated with a review of maps identifying flood prone areas documented by the City. Staff at Florida Department of Transportation (FDOT), Brevard County, and St. Johns River Water Management District were contacted regarding any additional documentation regarding flooding problem areas within the City. Extensive field investigations were performed throughout the City. Field investigations allowed verification of the information obtained from the sources described above as well as identification of additional flooding problems not previously noted. All flooding information obtained from the City, FDOT, Brevard County, SJRWMD, and field investigations are incorporated herein.

The Existing Flooding Problem Classification Matrix (Table 3.1) and Flood Prone Area Map (Figure 3.1) summarize the problems identified. The classification matrix describes the problem locations and likely causes, and comments on the effects of system integrity.

TABLE 3.1
EXISTING FLOODING PROBLEM CLASSIFICATION SUMMARY
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

Problem Identification	Problem Location	Infrastructure Associated with Problem Area	Problem Description	Probable Problem Type Classification			Means of Addressing Problem
				Inadequate Existing Infrastructure	Lack of Infrastructure	Maintenance Issues	
A1	Approximately 700' length along Ocean Beach Blvd.; includes the intersection of Harding Avenue, Barlow Avenue, and Young Avenue,	SAI003, SAI004	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model; potential flooding from County contribution
A2	Intersection of A1A and Shepard Drive and west of the intersection along Shepard Drive; also includes intersection of A1A and Meade Avenue	SAI029, SAI030	Nuisance flooding, standing water		X		Confirm and address problem with hydrologic/hydraulic model, evaluate application of BMPs to address problem
B1	Approximately 2100' along Ocean Beach Blvd.; includes intersection of California Avenue, E. Alachua Lane, E. Leon Lane, E. Pasco Lane, E. Osceola Lane, E. Park Lane, E. Gadsen Lane, E. Suwannee Lane, E. Volusia Lane, and E. Columbia Lane	SAI014, SAI015, SAI016, SBI001, SBI002, SBI003, SBI004, SBI005, SBI006, SBI007, SBI008, SBI009, SBI010, SBI011, SBI012, SBI013, SBI014	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
B2	Approximately 800' along North Banana River Blvd.; includes the intersection of W. Suwannee Lane (Barrello Lane), W. Volusia Lane, and Angelo Lane	SBI047, SBI049, SBI209, SBI211, SBI212, SBI213, SBIS14, SBI306, SBI307	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
C1	Approximately 1000' along Ocean Beach Blvd.; includes intersection of Hernando Lane, Marion Lane, Brevard Lane, and Palm Lane	SCI007, SCI008, SCI009, SCI010, SCI011, SCI015	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
C2	Intersection of Ocean Beach Blvd. and Wakula Lane	SCI001, SCI002	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
C3	Approximately 800' along South Banana River Blvd.; includes intersection of Street Lucie Lane	SCI055, SCI058, SCI060, SCI062, SCI063	Nuisance flooding, standing water	X	X		Confirm and address problem with hydrologic/hydraulic model; evaluate application of BMPs to address problem
DE1	Approximately 1300' along A1A; includes intersection of South Banana River Blvd. and Bimini Road	SDI018, SDI021, SDI023, SDI024, SDI025, SDI026, SDI028, SDI029, SEI001, SEI212	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
E1	Intersection of South Banana River Blvd. and Banana River Blvd.	SEI109, SEI110, SEI111, SEI112, SEI204	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
E2	Intersection of A1A and Bahama Blvd. and west of the intersection along Bahama Blvd.	SEI004, SEI407, SEI504, SEI505	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
E3	Intersection of A1A and Antigua Drive	SEI006, SEI507	Nuisance flooding, standing water		X		Confirm and address problem with hydrologic/hydraulic model, evaluate application of BMPs to address problem
E4-A	Swale area between houses between Antigua Drive and June Drive	SEI042	Nuisance flooding, fences and structures impeding swale flow	X		X	Confirm and address problem with hydrologic/hydraulic model, evaluate optionsfor improving swale flow, increase storage capacity
E4-B	Swale area between houses between June Drive and Esther Drive	SEI045, SEI046, SEI048	Nuisance flooding, fences and structures impeding swale flow	X		X	Confirm and address problem with hydrologic/hydraulic model, evaluate optionsfor improving swale flow, increase storage capacity
E5	Swale area between houses between Holiday Lane and Samar Road	SEI055, SEI059W	Nuisance flooding, fences and structures impeding swale flow	X		X	Confirm and address problem with hydrologic/hydraulic model, evaluate optionsfor improving swale flow, increase storage capacity
E6	Approximately 1000' along A1A; extends northward from the intersection of Cocoa Isles Blvd.	SEI020, SEI021, SEI022, SEI023, SEI024, SEI025, SEI025A	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
E7	Approximately 1000' between Samar and A1A, behind Econolodge, Denny's, and vacant lot	No inlets	Nuisance flooding in yards behind businesses		X		Evaluate application of BMPs to address problem

TABLE 3.1
EXISTING FLOODING PROBLEM CLASSIFICATION SUMMARY
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

Problem Identification	Problem Location	Infrastructure Associated with Problem Area	Problem Description	Probable Problem Type Classification			Means of Addressing Problem
				Inadequate Existing Infrastructure	Lack of Infrastructure	Maintenance Issues	
F1	Intersection of North Orlando Avenue and 2nd Street North	SFI027, SFI034, SFI035, SFI041, SFI042	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
F2	Approximately 1100' along A1A; includes intersection of 2nd Street North and 1st Street North	SFI008, SFI009, SFI010, SFI011, SFI017, SFI018, SFI019, SGI103, SGI105	Nuisance flooding, standing water	X	X		Confirm and address problem with hydrologic/hydraulic model; evaluate application of BMPs to address problem
F3	Residents to the west of Cedar Avenue between 2nd Street North and 1st Street N	SFI065, SFI066, SFI416	Nuisance flooding, standing water, grading			X	Confirm and address problem with hydrologic/hydraulic model, increase swale storage capacity; low property elevations contribute to flooding problem
F4	Residents to the west of Lookout Point AptSouth; located south of 1st Street North and west of Cedar Avenue	No inlets	Un-managed stormwater from apts. causing flooding at residents to west		X		Evaluate application of BMPs to address problem
F5	Along Minutemen Cswy. between the intersection of Crystal River Drive and Danube River Drive	SFI508, SGI901, SGI902	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
G1	Intersection of North Brevard Avenue and the alley north of Minutemen Cswy.	SGI116, SGI119, SGI121	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
G2	Approximately 1100' along A1A; includes the intersection of Minutemen Cswy. and 1st Street South	SGI001, SGI002, SGI005, SGI006, SGI101, SGI102, SGI124, SGI139	Nuisance flooding, standing water	X	X		Confirm and address problem with hydrologic/hydraulic model; evaluate application of BMPs to address problem
G3	Approximately 900' along A1A; includes intersection of 3rd Street South	No inlets	Nuisance flooding, standing water		X		Evaluate application of BMPs to address problem
G4	Approximately 700' along Riverview Lane	SGI406, SGI407	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
G5	Approximately 1600' along 4th Street South; includes intersection of Greenswood Lane, Riverview Lane, Westview Lane, Yachthaven Drive, and Yawl Drive	SGI412, SGI413, SGI515, SGI516, SGI708, SGI709, SGI710	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
G6	Approximately 600' along Yawl Drive	SGI703, SGI704	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
G7	Extends from the intersection of 4th Street South and Sloop Drive to the terminus of Sloop Drive	SGI706	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
G8	Extends from the point Yawl Drive turns west to the terminus of Yawl Drive	SGI701, SGI703, SGI704	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
H1	Along A1A at the intersection of 8th Street South	No inlets	Nuisance flooding, standing water		X		Evaluate application of BMPs to address problem
H2	Along 11th Street South at the intersection of Brevard Avenue	SHI048, SHI049, SHI050, SHI051, SHM052	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
H3	Approximately 1800' along A1A; includes intersection of 11th Street South, 12th Street South, and 13th Street South	No inlets	Nuisance flooding, standing water		X		Evaluate application of BMPs to address problem; potential flooding from County contribution
H4	Along 13th Street South at the intersection of South Orlando Avenue	No inlets	Nuisance flooding, standing water		X		Evaluate application of BMPs to address problem; potential flooding from County contribution
H5	Approximately 1300' along A1A; includes intersection of 14th Street South, 15th Street South, and 16th Street South	No inlets	Nuisance flooding, standing water		X		Evaluate application of BMPs to address problem; potential flooding from County contribution
H6	Approximately 500' along South Orlando Avenue; includes intersection of 16th Street South and Indian Village Trail	No inlets	Nuisance flooding, standing water		X		Evaluate application of BMPs to address problem; potential flooding from County contribution

TABLE 3.1
EXISTING FLOODING PROBLEM CLASSIFICATION SUMMARY
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

Problem Identification	Problem Location	Infrastructure Associated with Problem Area	Problem Description	Probable Problem Type Classification			Means of Addressing Problem
				Inadequate Existing Infrastructure	Lack of Infrastructure	Maintenance Issues	
I1	Approximately 850' along Minutemen Cswy.; near the point where Minutemen Cswy. turns northwest	SII105, SII106	Nuisance flooding, standing water	X	X		Confirm and address problem with hydrologic/hydraulic model; evaluate application of BMPs to address problem
I2	Intersection of Country Club Road and Minutemen Cswy.	SII401, SII402, SII403, SII404	Nuisance flooding, standing water	X			Confirm and address problem with hydrologic/hydraulic model
I3	North and South of Fairway Road behind houses along golf course	SII301, SII302, SII303, SII306, SII307	Nuisance flooding, golf course grading	X			Confirm and address problem with hydrologic/hydraulic model
I4	Along Willowgreen Drive	SII501	Nuisance flooding, constricted pipe (12-inch HDPE pipe in outfall end)			X	Provide required maintenance/repairs; evaluate application of infrastructure upgrades

Notes:
Refer to Flood Prone Area Figure for problem identification and physical location
NA - Not applicable

The flooding problems have been categorized into three problem types:

Inadequate Existing Infrastructure: Inadequate infrastructure refers to flooding problems that can be attributed to under sized or improperly placed infrastructure based on the current level of development. This could also be a problem caused by otherwise functional infrastructure deteriorating to a point beyond what normal maintenance could correct. Corrective actions for this problem can include structural modifications to increase conveyance capacity, add new capacity, or divert flow where capacity may be available.

Lack of Infrastructure: Lack of infrastructure problems are simply a result of infrastructure not being present to address stormwater runoff properly. This can occur in older portions of the City where current code requirements did not exist, or in areas where gradual development has overburdened natural conveyance features. This can also result in areas where stormwater management features are present, but not placed at proper locations or too widely spaced. Corrective actions for these types of problems are generally the same as for the Inadequate Existing Infrastructure case. This type of problem could also be a function of major paving and/or curbing issues.

Maintenance Issues: Problems identified as maintenance issues would typically be resolved through the implementation of a maintenance/repair measures under the City's current schedule. These include minor, manhole repair, curbing/paving repair/patching, sediment removal, swale re-grading, etc.

Table 3.1 and Figure 3.1 provide a first cut at a focused problem analysis. Many of these locations may be nuisance in nature, with little more than aesthetic problems. These problems could include long standing water what promotes mosquito reproduction pavement staining. Left un-addressed, these small problems can develop into significant pavement degradation issues that are beyond what would be considered nuisance and would become major maintenance and/or structural problems. In many cases, routine maintenance may be sufficient to address and/or a wait and see approach may be warranted to address the problems. In contrast, other areas may indicate a current deficiency or conditions that may soon contribute to a deficiency that would warrant specific corrective action. Final opinions on what problems will warrant further action are provided in Section 3.6 following the discussion of the model results and LOS assessment.

The City of Cocoa Beach has approximately 21 miles of storm sewer piping. Of this, approximately 2 miles is corrugated metal pipe (CMP). The remainder is primarily reinforced concrete pipe (RCP). Other localized runs of various materials also exist, including small runs of plastic (HDPE), PVC, clay, and others. The RCP is in general in fairly good shape overall. The CMP, however, is nearing the end of its service life. The City's Stormwater Utility has undertaken a replacement program for the CMP. As of May 2001, approximately ¾ miles of CMP has been replaced or retrofitted, with the remaining 1-¼ still to be addressed by a target date of approximately 2008.

3.2 LEVEL OF SERVICE GOALS

3.2.1 OVERVIEW

A level of service (LOS) is a measure to which some engineered control can be classified as to its relative ability to function as designed. In the realm of stormwater flooding assessment, a LOS is typically tied to the depth of flooding a stormwater facility or

land use experiences for a particular design storm event. The storm events are typically applied in terms of the frequency/duration (e.g.10-year/24-hour) of the rainfall event. The LOS generally consists of a defined alphanumerical scale to which the degree of flooding can be compared. A modeled situation in which no flooding is indicated would be graded out at the highest or best LOS, whereas instances of flooding would be assigned to an increasingly lower LOS proportional to the degree of flooding. The LOS evaluation allows for a prioritization of flooding problems from which to establish planning goals for corrective action. The LOS criteria used in this Master Plan is discussed below. The results of the LOS analysis with respect to the hydrodynamic model evaluation of the stormwater management system are discussed in Section 3.5.

3.2.2 LOS Development

A site-specific LOS ranking was developed for the City of Cocoa Beach under this Master Plan. This LOS criterion was used in conjunction with the hydrologic/hydraulic model (see Section 3.3) to assess the current performance of the City's stormwater management systems. For each modeled point of concern (catch basin inlet, swale, pond, etc.), a warning elevation was assigned representing the point at which undesirable staging of water takes place that either causes safety concerns or causes property damage. The resulting LOS is a function of the type of facility and the regulatory criteria that governs its operation. The regulatory criteria were based on current City development regulations and SJRWMD stormwater facility minimum performance criteria.

A flood level designation ranging from A-F in descending order was assigned for buildings, roadways, yards/open space, retention/detention facilities, and swales and storm sewers, where applicable. The designations are based on situations of no flooding (stages less than the assigned warning elevation) and flooding scaled in three-inch depth increments. The situations are further organized depending on the modeled storm event. The end result is an assigned LOS based not only on specific depth of flooding but also on applicable regulatory criteria.

The LOS matrix utilized is shown on Table 3-2. The evaluation was based on three categories: properties, roadways, and stormwater facilities. Each roadway in the City was designated as one of the following four types in order to evaluate each individually on their specific LOS criteria: evacuation (100-year), arterial (25-year), collector (10-year), or neighborhood (2.5-year). Exhibit 3A provides a City map depicting each road and their corresponding functional classifications with respect to the LOS criteria. Note that this functional classification is specific only to this Stormwater Master Plan and is not intended to be representative of traffic volume capacity.

TABLE 3-2
FLOOD PROTECTION LEVEL OF SERVICE OBJECTIVES
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

TYPE OF FACILITY		LEVEL OF SERVICE	MAXIMUM DEPTH OF FLOODING			
			Mean Annual	10-YEAR	25-YEAR	100-YEAR
I. **PROPERTIES**	**BUILDINGS** From Floorslab (100-year Criteria)	A	NONE	NONE	NONE	NONE
		B	NONE	NONE	NONE	< 3 inches
		C	NONE	NONE	< 3 inches	< 6 inches
		D	NONE	< 3 inches	< 6 inches	< 9 inches
		E	< 3 inches	< 6 inches	< 9 inches	< 12 inches
		F	< 6 inches	< 9 inches	< 12 inches	< 15 inches
	YARDS, OPEN SPACE (Mean Annual Criteria)	A	NONE	< 3 inches	< 6 inches	< 12 inches
		B	< 3 inches	< 6 inches	< 9 inches	< 15 inches
		C	< 6 inches	< 9 inches	< 12 inches	< 18 inches
		D	< 9 inches	< 12 inches	< 15 inches	< 21 inches
		E	< 12 inches	< 15 inches	< 18 inches	< 24 inches
		F	< 15 inches	< 18 inches	< 21 inches	< 27 inches
II. **ROADWAYS** **From Crown of Travel Lane**	**1. EVACUATION** (100-year Criteria)	A	NONE	NONE	NONE	NONE
		B	NONE	NONE	NONE	< 3 inches
		C	NONE	NONE	< 3 inches	< 6 inches
		D	NONE	< 3 inches	< 6 inches	< 9 inches
		E	< 3 inches	< 6 inches	< 9 inches	< 12 inches
		F	< 6 inches	< 9 inches	< 12 inches	< 15 inches
	2. ARTERIAL (25-year Criteria)	A	NONE	NONE	NONE	< 3 inches
		B	NONE	NONE	< 3 inches	< 6 inches
		C	NONE	< 3 inches	< 6 inches	< 9 inches
		D	< 3 inches	< 6 inches	< 9 inches	< 12 inches
		E	< 6 inches	< 9 inches	< 12 inches	< 15 inches
		F	< 9 inches	< 12 inches	< 15 inches	< 18 inches
	3. COLLECTOR (10-year Criteria)	A	NONE	NONE	< 3 inches	< 6 inches
		B	NONE	< 3 inches	< 6 inches	< 9 inches
		C	< 3 inches	< 6 inches	< 9 inches	< 12 inches
		D	< 6 inches	< 9 inches	< 12 inches	< 15 inches
		E	< 9 inches	< 12 inches	< 15 inches	< 18 inches
		F	< 12 inches	< 15 inches	< 18 inches	< 21 inches
	4. RESIDENTIAL (Mean Annual Criteria)	A	NONE	< 3 inches	< 6 inches	< 9 inches
		B	< 3 inches	< 6 inches	< 9 inches	< 12 inches
		C	< 6 inches	< 9 inches	< 12 inches	< 15 inches
		D	< 9 inches	< 12 inches	< 15 inches	< 18 inches
		E	< 12 inches	< 15 inches	< 18 inches	< 21 inches
		F	< 15 inches	< 18 inches	< 21 inches	< 24 inches
III. **STORMWATER FACILITIES**	**RETENTION/DETENTION FACILITIES** From Top of Bank (25-year Criteria)	A	NONE	NONE	NONE	< 3 inches
		B	NONE	NONE	< 3 inches	< 6 inches
		C	NONE	< 3 inches	< 6 inches	< 9 inches
		D	< 3 inches	< 6 inches	< 9 inches	< 12 inches
		E	< 6 inches	< 9 inches	< 12 inches	< 15 inches
		F	< 9 inches	< 12 inches	< 15 inches	< 18 inches
	SWALES AND STORM SEWERS SEWERS From Top of Bank / Ground Surface (10-year Criteria)	A	NONE	NONE	NONE	< 6 inches
		B	NONE	NONE	< 3 inches	< 9 inches
		C	NONE	< 3 inches	< 6 inches	< 12 inches
		D	< 3 inches	< 6 inches	< 9 inches	< 15 inches
		E	< 6 inches	< 9 inches	< 12 inches	< 18 inches
		F	< 9 inches	< 12 inches	< 15 inches	< 21 inches

Notes:

The hydrologic/hydraulic model will be used to identify/confirm areas that do not meet the flooding LOS objectives.
SJRWMD, 100-year Buildings, 25-year Structure
City of Cocoa Beach, 100-year Building, 10-year Structure, 10-year Roadway

3.2.3 Warning Elevation Development Methodology

The basis for the evaluation of flooding conditions throughout the City are the Mean Annual, 10-year, 25-year, and 100-year return period, 24-hour duration design storm events. These storm events are discussed in detail in Section 2. The methodology used to assess the flooding levels of service provided within the Cocoa Beach basin drainage system was to examine the city-wide survey and compare the model stage results of the design storm events to land surface elevations at selected points throughout the basin. Survey data and/or as-built construction plans were also utilized in this effort when available.

The first step of this process was to examine the topographic maps to select the appropriate locations for this comparison. This was generally accomplished by proceeding along the hydraulic network and examining the areas of development that were hydraulically connected to each of the individual model junctions. Within the areas of hydraulic connection, individual locations of development were demarcated and a set of three elevations recorded. The first elevation that was determined was used to represent "significant street flooding" at that location. This term has an element of subjectivity in its definition, which Parsons ES interpreted to mean the elevation at which a significant portion (generally 10%) of the areal extent of the streets within the area would have some depth of water up to the crown of the road. Thus, a small, isolated low spot in a road profile would not necessarily define the point of "significant street flooding" in a given area. The road crown was used as the basis of assessment because the spot elevations from the Pine Design Survey are usually located at the center of the road alignment.

The second elevation required for the LOS analysis was used to represent "major residential yard flooding". Again, determination of this elevation required subjective judgment in examination of the aerial topographic maps. Where possible, the yard elevations were assessed by topographic contours and spot elevations on the maps. In lieu of this, an elevation of approximately 0.5 feet higher than the street elevation was used as a reasonable estimate. The final elevation recorded was the most difficult to interpret since the aerial topographic maps provided no means of determining an elevation for "significant structure flooding". The general rule of thumb used to estimate this elevation was to assume an elevation a minimum of either 0.5 feet above the yard flooding elevation or 1.0 feet above the street flooding elevation. Often cases point elevations were available in the immediate vicinity of the structure, in which case elevations of 0.5-1′ above the point elevations (depending on structure type) were used.

Due to the degree of uncertainty in the derivation of these elevations, it is emphasized that the assessment of the flooding LOS provided within the basin and the identification of problem areas herein is only cursory. Where critical deficiencies are identified, assessment results should be supplemented with further investigations in the form of field surveys of streets and residential floor slab elevations to confirm the existence and/or magnitude of LOS deficiencies and flooding problems.

3.3 HYDROLOGICAL AND HYDRODYNAMIC MODEL

To assess the current ability of the stormwater management system to manage stormwater runoff, a conceptualized hydrological and hydrodynamic model was developed. This model consists of a theoretical representation of the stormwater management system that focuses on key points of concern. Within the realm of a Master Plan, there is not

sufficient time and resources to model every detail of a system, particularly when dealing with highly urbanized municipalities such as Cocoa Beach. Rather attempts are made to accurately represent critical areas to sufficient detail to allow accurate performance evaluation to be performed.

In general, the City's stormwater management system is made up of surface runoff to manholes with storm sewer pipe routing to outfall discharging into the Banana River. In additional, there are several significant swales and depressional areas that are relevant to model. In general, the model representation was focused on the main storm sewer trunk lines and the larger diameter (>24") minor pipe runs and/or storm sewers that accommodate areas in excess of approximately 5 acres. Additional areas not falling in the above categories were also modeled if they were specifically associated with one of the problem areas identified in Section 3.1.

Appendix 3A includes a detailed discussion of the various aspects of the conceptualized model including the specific model used, model representation setup issues, calculation specifics, data requirements, boundary conditions, and calibration. Also, included are the results of model calibration based on available storm event data.

3.4 HYDRAULIC ASSESSMENT COVERAGE AND RESULTS

The hydraulic assessment focused on the main trunk lines storm sewer pipe networks throughout the City. The modeling was generally limited to multi-pipe runs with diameters in excess of 24 inches and included specific areas where flooding problems had been previously identified (Section 3.1). The stormwater management system was modeled on a design performance basis, assuming all components were operating per intention. This may not reflect actual conditions where unknown flow constrictions may exist (internal sedimentation, minor pipe failures or constriction, etc.). Detailed inspection of each modeled structure was not performed due to time and economic constraints.

The portions of the stormwater management system that were assessed by the model are shown by basin on the model node diagrams included as Appendix 3B. Each node name reflects an "S" at the beginning for stormwater structure, the basin name by letter, a 3 digit numerical identifier, then the structure type. Structure types included "I" for inlet, "M" for manhole, "F" for flume, "W" for swale, or "O" for outfall (i.e., SB112M would be stormwater manhole #112 in basin B). In the cases where a single node represents several structures, the name represents the primary manhole through which flow travels. Other location specific names were used where necessary to represent less common structural elements of storage areas. Links in the model were simply named according to the nodes they connect (i.e., LB111I112M would be the pipe link between nodes SB111I and SB112M.

The model was run on each of these networks for the Mean Annual, 10-Year, 25-Year, and 100-Year 24-Hour duration storm events to evaluate LOS. The model results for subbasin runoff, node peak stages/surcharge elevations, and link peak flow rate and velocity are included by basin in the model data supplement to this report section. A by-subbasin summary of the hydraulic grade lines for the modeled areas for each storm event is provided in Appendix 3C. The interpretation of these results with consideration to the LOS criteria is discussed in the section 3.6.

3.5 FLOODING LOS ASSESSMENT

The node peak stage results were entered into a spreadsheet incorporating the flooding LOS criteria. This allowed LOS to be evaluated on a location-to-location basis to determine areas warranting some type of corrective action. The results of this evaluation are shown by basin in the tables in Appendix 3D. All in all, the vast majority of the stormwater management system (90%+ of nodes modeled) was considered to meet the LOS A classification.

Included, as Table 3.3 is a summary of all locations indicating a LOS of B or below. Those locations designated with LOS of "B" are considered areas warranting some long-term observation for indications of flooding, but are not considered to warrant further assessment or corrective action at this time. **Unless otherwise identified as a flooding problem area, this LOS classification may indicate a point in the system which is functioning at a borderline acceptable case, or possibly comparable to a LOS of A given the inherent approximations in modeling. If problems develop in the future with regard to these locations, an assessment should be made as to whether it may be a maintenance related issue of whether a change in hydraulic conditions has occurred.**

Also, summarized on Table 3.3 are those locations with LOS of "C" or below. These model node locations are further qualified with the approximate amount of peak stage reduction required to meet an LOS of B. Most of these locations have only 0.1-0.2 feet of surcharge stage as the difference between a more acceptable level of service of B or A. Given the conceptual approximations and estimations used in the model representation of the real-world stormwater management system, this difference is considered within the range of error in the model. Unless otherwise identified as a flooding problem area, these areas do not warrant further assessment. Surcharges in the range of approximately 0.5′ and above are flagged on the table and are generally considered to warrant attention and evaluation for possible corrective action if they correspond to areas with identified flooding occurrence.

Table 3.4 provides an abbreviated reiteration of Table 3.1 with notes as to the evaluation of the various flood prone areas evaluated with the flood model. Included in the table are areas that exhibited a LOS warranting further assessment that were not previously identified as problem areas. These locations were added to the table following the same alphanumerical identification style and shaded for contrast. Based on the foregoing, the locations that are considered to warrant further attention are called out as such.

Several areas were identified by City staff as flood prone areas that were not confirmed as problems with the model. These areas were visually inspected for obvious signs of drainage problems. The incidence of flooding at these locations may be a result of non-visible conditions requiring some maintenance such as sediment/debris removal or some minor structural failures. Where appropriate, general recommendations have been made for these areas. The problems associated with the internal swales in Basin E (problem areas E4-A, E4-B, and E5) warrant additional discussion, as presented in the next subsection.

TABLE 3.3
FLOODING RESULTS SUMMARY - LOCATIONS WITH LOS OF B, C, D, E, F
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

MODEL NODE	FLOOD FEATURE	LOS CRITERIA	LOS					Stage Reduction to LOS B*	Stage Reduction to LOS A*
			B	C	D	E	F		
SA015I	Beach Boulevard	Arterial	-	-	-	-	X	1.3	1.3
	Alachua Lane	Residential	-	-	-	X	-	0.6	0.9
	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.2
SA016I	Ridgewood Avenue	Arterial	-	-	X	-	-	0.2	0.2
	California Avenue	Residential	X	-	-	-	-	0.0	0.2
	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.2
SA025I	Ridgewood Avenue	Arterial	-	X	-	-	-	0.2	0.2
SB002I	Beach Boulevard	Arterial	X	-	-	-	-	0.0	0.1
SB402I	520	Evacuation	X	-	-	-	-	0.0	0.1
SB408I	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SC122I	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SC125M	Belt Road	Arterial	-	-	X	-	-	0.4	0.4
	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.3
SD022M	A1A	Evacuation	X	-	-	-	-	0.0	0.1
SD033M	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SE041I	June Lane	Residential	X	-	-	-	-	0.0	0.1
	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SE109I	Banana River Boulevard	Collector	-	-	X	-	-	0.5	0.6
SF024I	N. Orlando Avenue	Evacuation	-	-	X	-	-	0.2	0.3
SF032I	N. Orlando Avenue	Evacuation	X	-	-	-	-	0.0	0.1
	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SF049M	N. Brevard Avenue	Arterial	X	-	-	-	-	0.0	0.1
SF050M	N. Brevard Avenue	Arterial	-	-	X	-	-	0.3	0.4
	N. 2nd Street	Residential	X	-	-	-	-	0.0	0.2
	Open Space	Yards/Open Space	-	X	-	-	-	0.1	0.3
SF057I	Woodland Avenue	Collector	-	X	-	-	-	0.2	0.2
	Open Space	Yards/Open Space	-	X	-	-	-	0.2	0.5
SF065I	Buildings	Buildings	X	-	-	-	-	0.0	0.1
	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SF304I	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.3
SF311I	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.2
SF413I	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SG002I	S. 1st Street	Collector	-	-	X	-	-	0.4	0.5
	N. Orlando Avenue	Evacuation	-	-	-	-	X	0.9	1.0
	Open Space	Yards/Open Space	-	-	-	X	-	0.6	0.9
SG007I	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SG009I	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SG041I	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SG056M	Buildings	Buildings	X	-	-	-	-	0.0	0.2
	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.2
SG059I	S. 4th Street	Residential	X	-	-	-	-	0.0	0.3
	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.2

TABLE 3.3
FLOODING RESULTS SUMMARY - LOCATIONS WITH LOS OF B, C, D, E, F
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

MODEL NODE	FLOOD FEATURE	LOS CRITERIA	LOS B	LOS C	LOS D	LOS E	LOS F	Stage Reduction to LOS B*	Stage Reduction to LOS A*
SG068M	N. Brevard Avenue	Arterial	X	-	-	-	-	0.0	0.1
	S. 4th Street	Residential	X	-	-	-	-	0.0	0.3
SG076M	**N. Brevard Avenue**	**Arterial**	-	-	-	X	-	***0.7***	***0.8***
	Buildings	Buildings	X	-	-	-	-	0.0	0.1
	S. 2nd Street	Residential	-	-	X	-	-	***0.5***	***0.7***
	Open Space	Yards/Open Space	-	-	X	-	-	0.4	***0.7***
SG077I	N. Brevard Avenue	Arterial	-	-	X	-	-	***0.5***	***0.6***
	S. 2nd Street	Residential	X	-	-	-	-	0.0	0.2
	Open Space	Yards/Open Space	-	X	-	-	-	0.2	0.4
SG102I	Atlantic Avenue	Evacuation	-	-	-	-	X	0.5	0.5
	Minutemen Causeway	Evacuation	-	-	-	-	X	***0.7***	***0.7***
	Open Space	Yards/Open Space	-	X	-	-	-	0.2	0.4
SG115I	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.2
SG407I	Riverview Lnae	Residential	X	-	-	-	-	0.0	0.3
SG706I	Sloop Drive	Residential	X	-	-	-	-	0.0	0.2
SG902I	Minutemen Causeway	Evacuation	-	-	X	-	-	***0.5***	***0.7***
	Danube River Drive	Residential	X	-	-	-	-	0.0	0.2
SH014I	N. Orlando Avenue	Evacuation	X	-	-	-	-	0.0	0.1
	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.3
SH052M	**N. Brevard Avenue**	**Arterial**	-	-	-	X	-	***0.6***	***0.7***
	S. 11th Street	Residential	X	-	-	-	-	0.0	0.2
	Yards	Yards/Open Space	X	-	-	-	-	0.0	0.2
SH056M	N. Brevard Avenue	Arterial	X	-	-	-	-	0.0	0.1
SH064M	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.2
SI411I	Country Club Road	Residential	X	-	-	-	-	0.0	0.1
	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.1
SI506I	Country Club Road	Residential	X	-	-	-	-	0.0	0.1
SI205M	Open Space	Yards/Open Space	X	-	-	-	-	0.0	0.2

* BOLD/ITALIC VALUES INDICATE VALUE EQUAL TO OR GREATER THAN 0.5'.
SHADING INDICATES LOS OF C, D, E, OR F

- LOS F
- LOS E
- LOS D
- LOS C

3.5.1 Basin E Internal Swale Problem Areas Discussion

The internal residential swales in Basin E between Antigua and June (problem area E4-A), June and Esther (problem are E4-B), and Holiday and Samar (problem area E5) were noted as problem areas due to reported slow drainage and standing water encroaching homes. The natural swales graded between the house rows at these locations are drained with drop inlets to the storm sewer manhole along the nearby streets. Over time, these swale features have become filled in to a certain degree through natural erosion and yard and landscaping modifications made residents. Many of the swale areas have property fences in addition to backyard storage sheds and other small structures. Although the inlets were observed during field reconnaissance to be in relatively good structural shape and free of obstructions, the aforementioned conditions would tend to inhibit efficient flow to the inlets. . The situation is exasperated by the relatively high water table in this area that inhibits the infiltration of the stormwater runoff. Typical conditions are shown in the following photos.

View of typical back yard at inlet. Note fence obstruction and vegetation (behind fence).	View of small structure obstruction and fencing near inlet.

The flood modeling representation of these areas was set up with stage storage areas representing the swale areas interpreted from the Pine design survey mapping. The drop inlets were modeled as weir/orifices using the available stormline data for the draining conditions to account for submerged inlet situations. Due to the predominance of surface obstructions, approximations were made in the stage storage relationships to account for reduced volume available for storage. Some consideration was also made to the constriction in flow line with modifications made to flow roughness coefficients in the model.

The model results did represent an acceptable LOS "A" for each of these locations with regard to stage level. Staging of water in the swale features was observed, however, this is acceptable to a certain degree in residential areas under large volume storm events. Another note to the modeling results is that the flood duration (which is not necessarily reflected in the LOS assessment methodology) approaches two days in some storm event cases. This can in effect be considered an unacceptable condition given the approximations used in the modeling and the resident reports of standing water encroachment.

Based on the foregoing, **further action appears warranted for this area. The functional performance of the inlet/piping structures should be confirmed. Considerations can also be given to evaluating measures to alleviate the flow impediments in the residents back yards such as fence pass-throughs or**

localized grading to reestablish preferential flow path line to the inlets. Lastly, the installation of additional inlets and piping to the existing system may be considered as a last resort.

3.6 FLOOD ASSESSMENT SUMMARY

Based on the discussions and results presented in this section, the overall flood management LOS of the City of Cocoa Beach is good with its current stormwater management system. This is exemplified by the vast majority of the system meeting a LOS of A (acceptable) or B (conditionally acceptable). This LOS evaluation is based on hydrological/hydraulic modeling that is considered to be reasonably accurate and conservative.

As discussed in Section 3.5, numerous specific points of concern exist where flooding potential has been identified or is suspected. Based on this assessment, the locations that were carried forward for further evaluation are summarized in Table 3-4. These areas were further evaluated under the context of the BMP Evaluation (Section 5) and CIP (Section 6) sections of the Master Plan report for possible corrective action.

Based on repeated reports of slow drainage and standing water encroaching homes, a detailed evaluation of the Basin E internal swales was conducted as presented in Section 3.5.1. Results of the evaluation indicate that **further action appears warranted for this area. The functional performance of the inlet/piping structures should be confirmed. Considerations can also be given to evaluating measures to alleviate the flow impediments in the residents back yards such as fence pass-throughs or localized grading to reestablish preferential flow path line to the inlets. Lastly, the installation of additional inlets and piping to the existing system may be considered as a last resort.**

The flooding problems identified in Cocoa Beach are generally associated with areas or reported nuisance flooding and long-standing water. In addition, several areas were identified through the modeling as having the potential for concern based on the LOS criteria. These areas are generally functioning at a borderline or slightly below borderline LOS, as such a costly flooding-focused assessment of most of these locations does not appear warranted at present. Rather, the BMP Evaluation for flooding purposes detailed in Section 5 focused on the potentials for the identified projects to improve the conditions at these areas to the extent that they may no longer be a concern. The consideration of the possible runoff volume reduction potential of the identified BMPs was used in this evaluation.

The implementation of a CIP (Section 6) that targets the TAPLRG discussed in the Water Quality Assessment (Section 4) is predicted to approach a ~30% reduction in runoff volume as a conservative estimate. This is based on the reliance of a widespread implementation of infiltration and retention focused BMPs (exfiltration, swales, etc.) to reduce runoff quantities. **These BMPs in upstream areas would aid in reducing the runoff to the downstream portions of the storm sewer system, reducing peak volume and flow. BMPs in the downstream portion may alleviate some of the tailwater influence and reduce hydraulic heads.** Based on this and the predominance of near borderline LOS with the majority of flooding problem areas, a deferred problem solution approach may be appropriate.

As many of the BMPs are implemented to address the water quality problems, **re-evaluation of these marginal flooding areas can be preformed on a site by site**

basis to determine if additional engineered controls are necessary. Many of the areas may not present further problems that would warrant study, which would represent a cost savings to the City. **If problems persist, focused small area studies could be performed incorporating the new BMPs to address the lingering flood issues. The hydraulic model developed for this Master Plan could be utilized as a tool for these studies thereby saving effort. Additionally, in areas where curb ponding chronically occurs for several hours following storm events possibly leading to road deterioration, it is recommended that a grading survey be conducted to reestablish the drainage path.**

Table 3-5 reiterates the problem areas carried forward, with final recommendations provided addressing each area. In general, recommendations are made for further addressing flooding issues if they persist beyond the CIP BMP project implementation.

TABLE 3-5
FLOODING PROBLEM AREA BMP EVALUATION
STORMWATER MASTER PLAN CITY OF COCOA BEACH, FLORIDA

Problem ID	Problem Location	Problem Description	Lowest LOS in Area	Recommendation
A3	Model Node SA025I - Ridgewood Avenue	Modeling indicates possible deficiency	C	No action at present, not identified as historical problem, runoff volume reducing BMPs (median swales/exfiltration) to be implemented upstream at SA015I/SA016I
B1	Ocean Beach Blvd.from California Ave.to E. Columbia La.	Nuisance flooding, standing water, supported by modeling	F	Recommend evaluating effectiveness of runoff volume reducing BMPs (median swales/exfiltration) to be implemented upstream at this area to reduce hydraulic loading, re-evaluate after BMP implementation
C4	Model Node SC125M - Belt Road	Modeling indicates possible deficiency	C	No action at present, not identified as historical problem, borderline LOS, FDOT roadway
E1	Intersection of S. Banana River Blvd. and Banana River Blvd.	Nuisance flooding, standing water, supported by modeling	D	Recommend evaluating effectiveness of runoff volume reducing BMPs (median swales) to be implemented upstream at this area to reduce hydraulic loading in concert with existing private retention, re-evaluate after BMP implementation
E4A/B, E5	Internal swale areas in Basin E	Nuisance flooding, fences and structures impeding swale flow	A	Modeling indicates acceptable LOS for flood stage, but model indicates long duration standing water. Drainage path inhibited due to structures and other obstructions. Evaluate for maintenance and/or grading improvements, possible structural upgrades and/or BMP implementation.
E7	Between Samar and A1A	Nuisance flooding in yards behind businesses	n/a	Recommend evaluating effectiveness of runoff volume reducing BMPs (swales) to be implemented at this area to attenuate and better route hydraulic loadings, re-evaluate after BMP implementation
F4	Lookout Point Apts.1st St. N. and Cedar Ave.	Stormwater from apts. causing flooding at residents to west	n/a	Evaluate code enforcement or other action to coerce property owner into compliance.
F5	Minutemen Cswy. Between Crystal River Dr. and Danube River Dr.	Nuisance flooding, standing water, supported by modeling	D	Recommend evaluating effectiveness of runoff volume reducing BMPs (roadside swales) to be implemented at this area to reduce hydraulic loading, re-evaluate after BMP implementation
F6	Model Node SF024I - N. Orlando Ave.	Modeling indicates possible deficiency	D	No action at present, not identified as historical problem, borderline LOS, runoff volume reducing BMPs Recommend evaluating effectiveness of runoff reducing BMPs to be implemented (swales/exfiltration), FDOT roadway
F7	Model Node SF057I Woodland, Yard/Open Space	Modeling indicates possible deficiency	C	No action at present, not identified as historical problem, borderline LOS, upstream BMPs (swales/exfiltration) Recommend evaluating effectiveness of runoff reducing BMPs to be implemented for upstream areas along A1A
F8	Model Node SF050M - N. Brevard, N. 2nd St, Yard/Open Space	Modeling indicates possible deficiency	D	No action at present, not identified as historical problem, borderline LOS, upstream BMPs (swales/exfiltration) Recommend evaluating effectiveness of runoff reducing BMPs to be implemented for upstream areas along A1A
G2	A1A at Minutemen Cswy. and 1st St. S.	Nuisance flooding, standing water, supported by modeling	F	Recommend evaluating effectiveness of runoff volume reducing BMPs (exfiltration/roadside swales) to be implemented at this area to reduce hydraulic loading, FDOT roadway, re-evaluate after BMP implementation
G3	A1A near 3rd St. S.	Nuisance flooding, standing water	n/a	Recommend evaluating effectiveness of runoff volume reducing BMPs (exfiltration/roadside swales) to be implemented at this area to reduce hydraulic loading, FDOT roadway, re-evaluate after BMP implementation
G9	Model Node SG059I - S. 4th St.	Modeling indicates possible deficiency	C	No action at present, not identified as historical problem, borderline LOS, runoff volume reducing BMPs Recommend evaluating effectiveness of runoff reducing BMPs to be implemented for downstream areas
G10 / G11	Model Nodes SG077I / SG076M - N. Brevard, S. 2nd St, Yard/Open Space	Modeling indicates possible deficiency	D	No action at present, not identified as historical problem, borderline LOS, upstream BMPs (swales/exfiltration) Recommend evaluating effectiveness of runoff reducing BMPs to be implemented for upstream areas along A1A and Brevard Ave.
H1	A1A and 8th St. S.	Nuisance flooding, standing water	n/a	Recommend evaluating effectiveness of runoff volume reducing BMPs (exfiltration/roadside swales) to be implemented at this area to reduce hydraulic loading, FDOT roadway, re-evaluate after BMP implementation
H2	11th St. S. and Brevard Ave.	Nuisance flooding, standing water, supported by modeling	E	Recommend evaluating effectiveness of runoff volume reducing BMPs (exfiltration/roadside swales) to be implemented at this area to reduce hydraulic loading, re-evaluate after BMP implementation
H3	A1A and 11th St. S., 12th St. S., and 13th St. S.	Nuisance flooding, standing water	n/a	Recommend evaluating effectiveness of runoff volume reducing BMPs (exfiltration/roadside swales) to be implemented at this area to reduce hydraulic loading, FDOT roadway, re-evaluate after BMP implementation
H4	13th St. S. and S. Orlando Ave.	Nuisance flooding, standing water	n/a	Recommend evaluating effectiveness of runoff volume reducing BMPs (exfiltration/roadside swales) to be implemented at this area to reduce hydraulic loading, FDOT roadway, re-evaluate after BMP implementation
H5	A1A and 14th St. S., 15th St. S., and 16th St. S.	Nuisance flooding, standing water	n/a	Recommend evaluating effectiveness of runoff volume reducing BMPs (exfiltration/roadside swales) to be implemented at this area to reduce hydraulic loading, FDOT roadway, re-evaluate after BMP implementation
H6	S. Orlando Ave. and 16th St. S. and Indian Village Trail	Nuisance flooding, standing water	n/a	Recommend evaluating effectiveness of runoff volume reducing BMPs (exfiltration/roadside swales) to be implemented at this area to reduce hydraulic loading, FDOT roadway, re-evaluate after BMP implementation

Notes:
Refer to Flood Prone Area Figure for problem identification and physical location
NA - Not applicable

EXHIBIT 3A

ROAD FUNCTIONAL CLASSIFICATIONS FOR FLOODING LOS ASSESSMENT STORMWATER MASTER PLAN CITY OF COCOA BEACH, FLORIDA

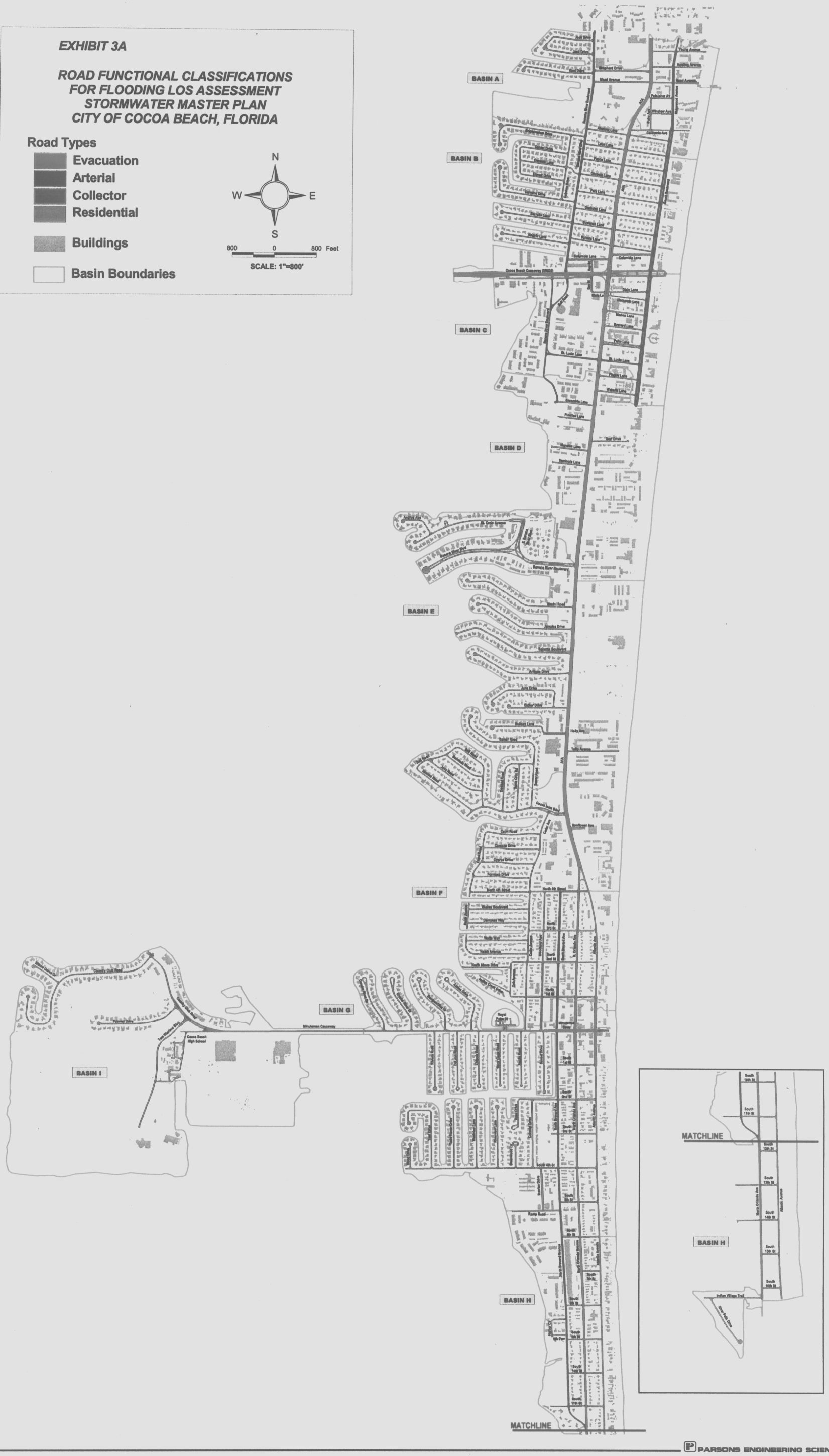
Road Types

- Evacuation
- Arterial
- Collector
- Residential
- Buildings
- Basin Boundaries

N
W E
S

800 0 800 Feet

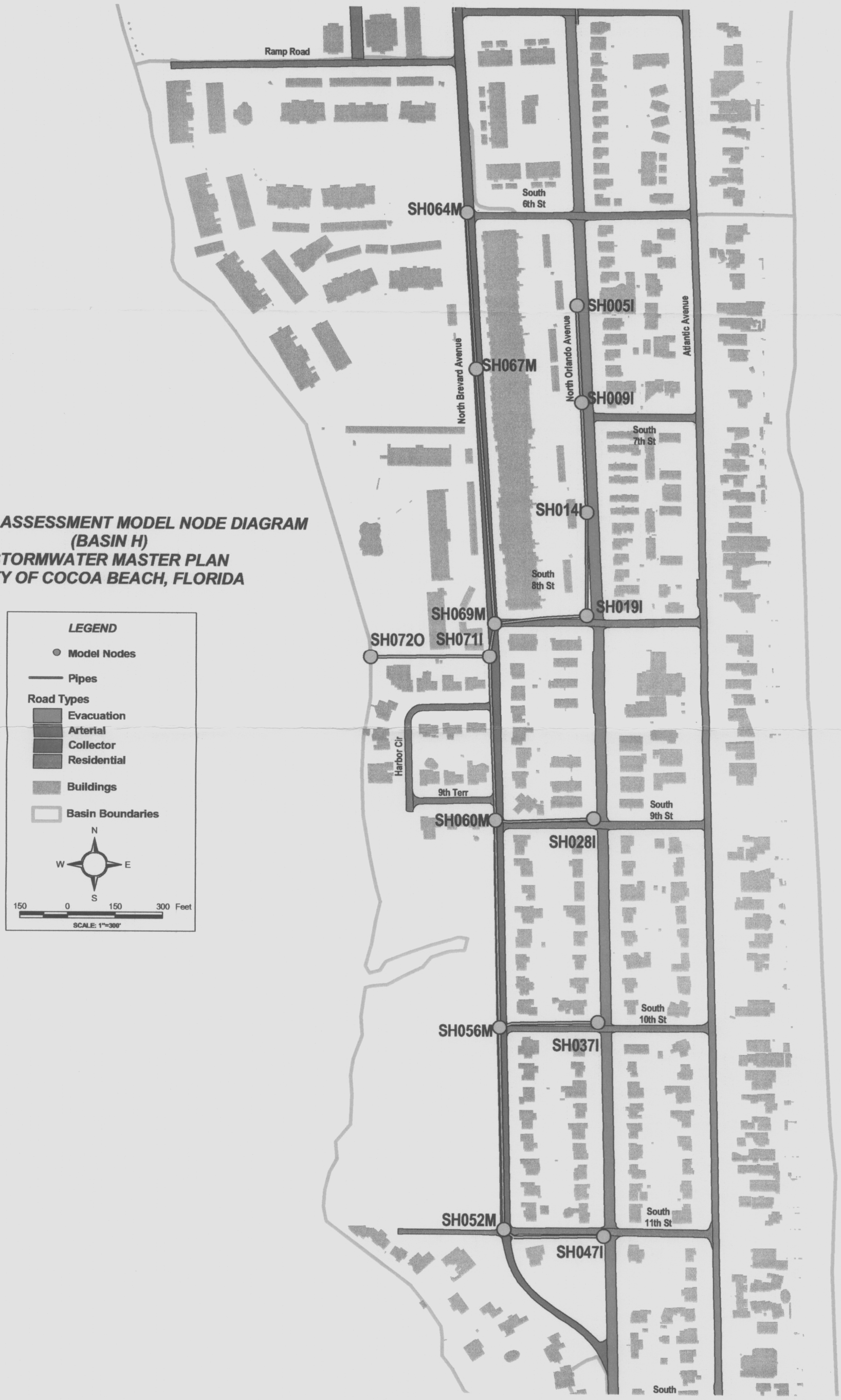
SCALE: 1"=800'



PARSONS ENGINEERING SCIENCE, INC.

FLOODING ASSESSMENT MODEL NODE DIAGRAM (BASIN I)
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

PARSONS ENGINEERING SCIENCE, INC.



FLOODING ASSESSMENT MODEL NODE DIAGRAM
(BASIN H)
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

LEGEND

- Model Nodes
- Pipes

Road Types

- Evacuation
- Arterial
- Collector
- Residential

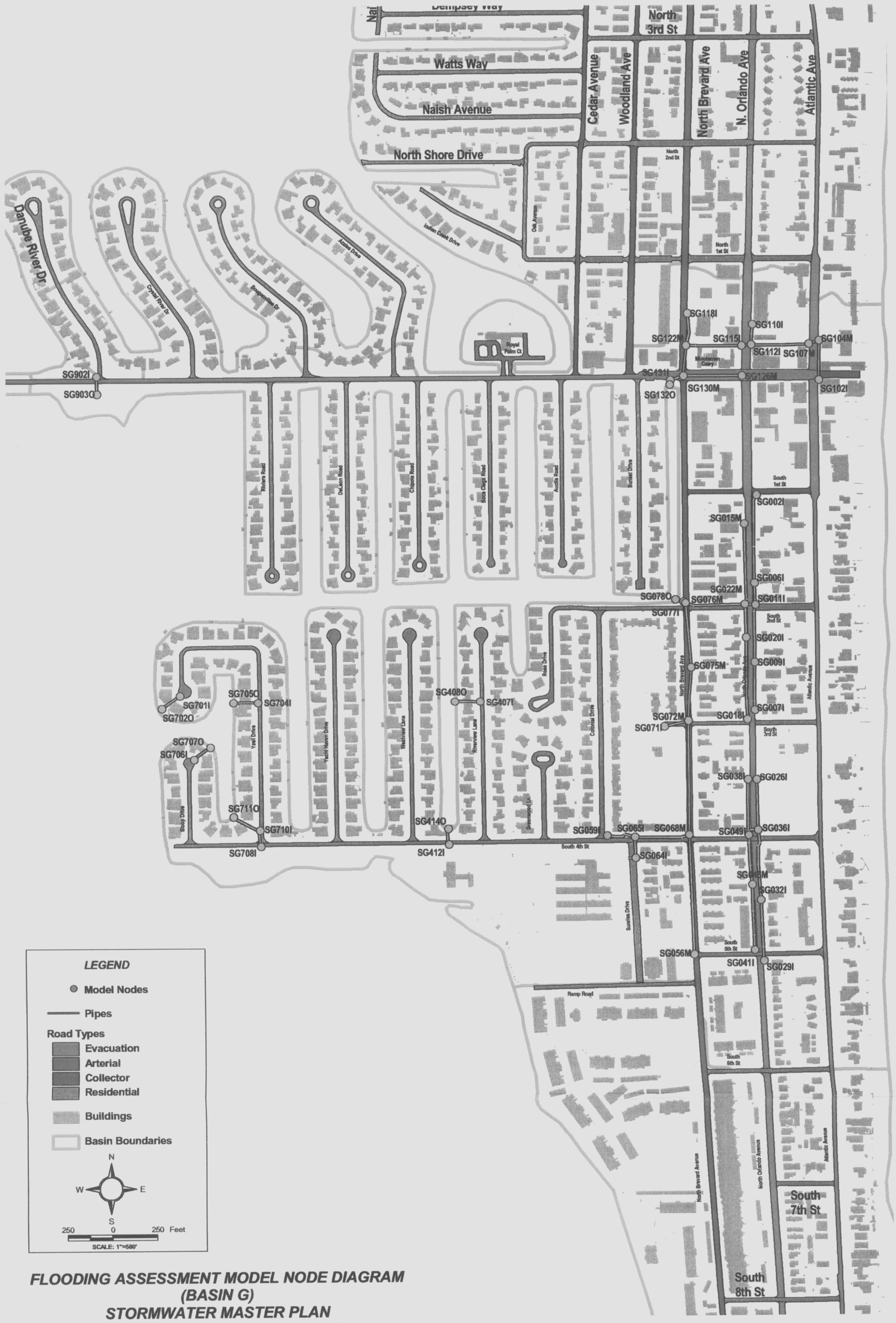
- Buildings
- Basin Boundaries

N
W E
S

150 0 150 300 Feet

SCALE: 1"=300'

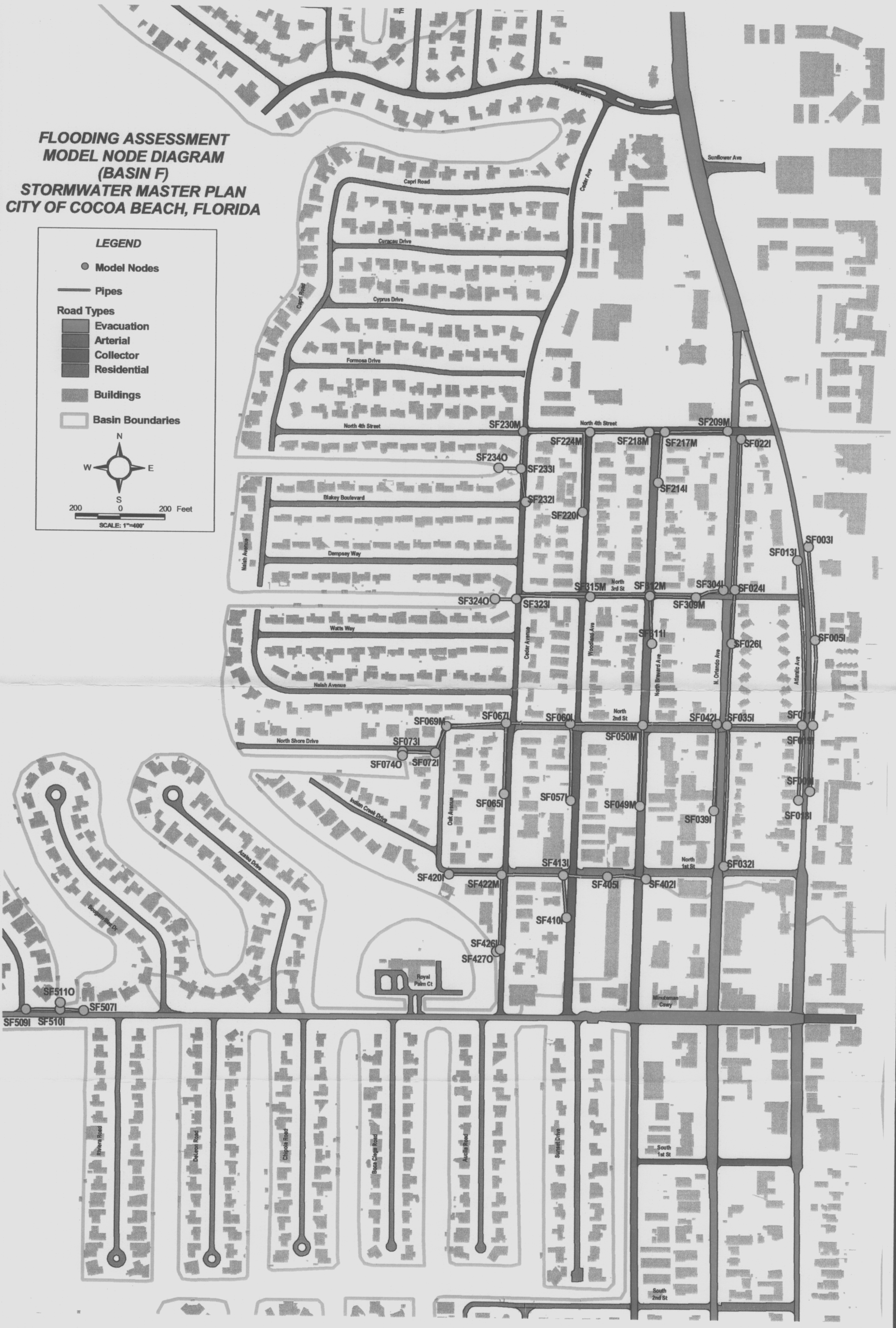
PARSONS ENGINEERING SCIENCE, INC.



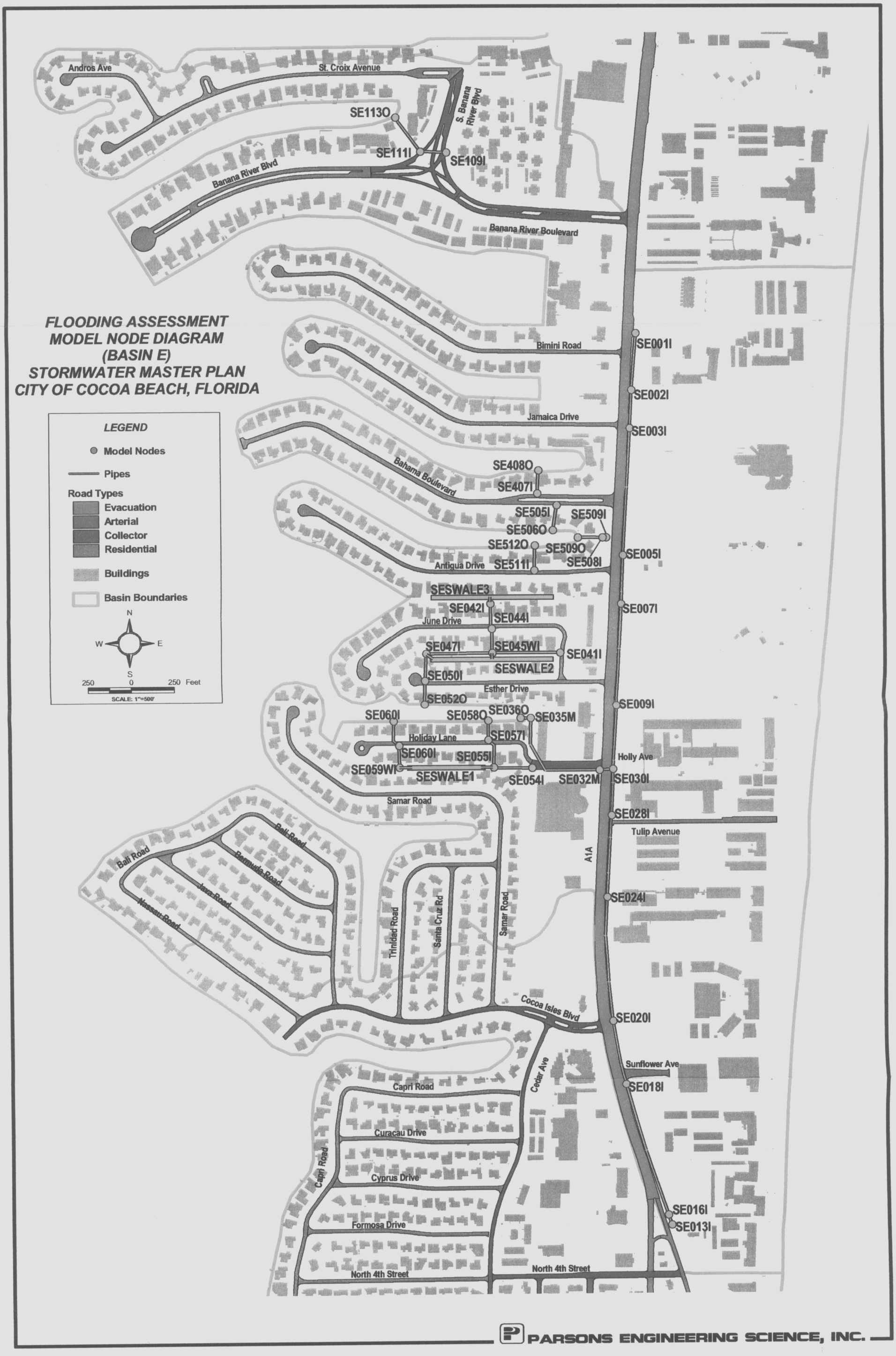
FLOODING ASSESSMENT MODEL NODE DIAGRAM
(BASIN G)
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

PARSONS ENGINEERING SCIENCE, INC.

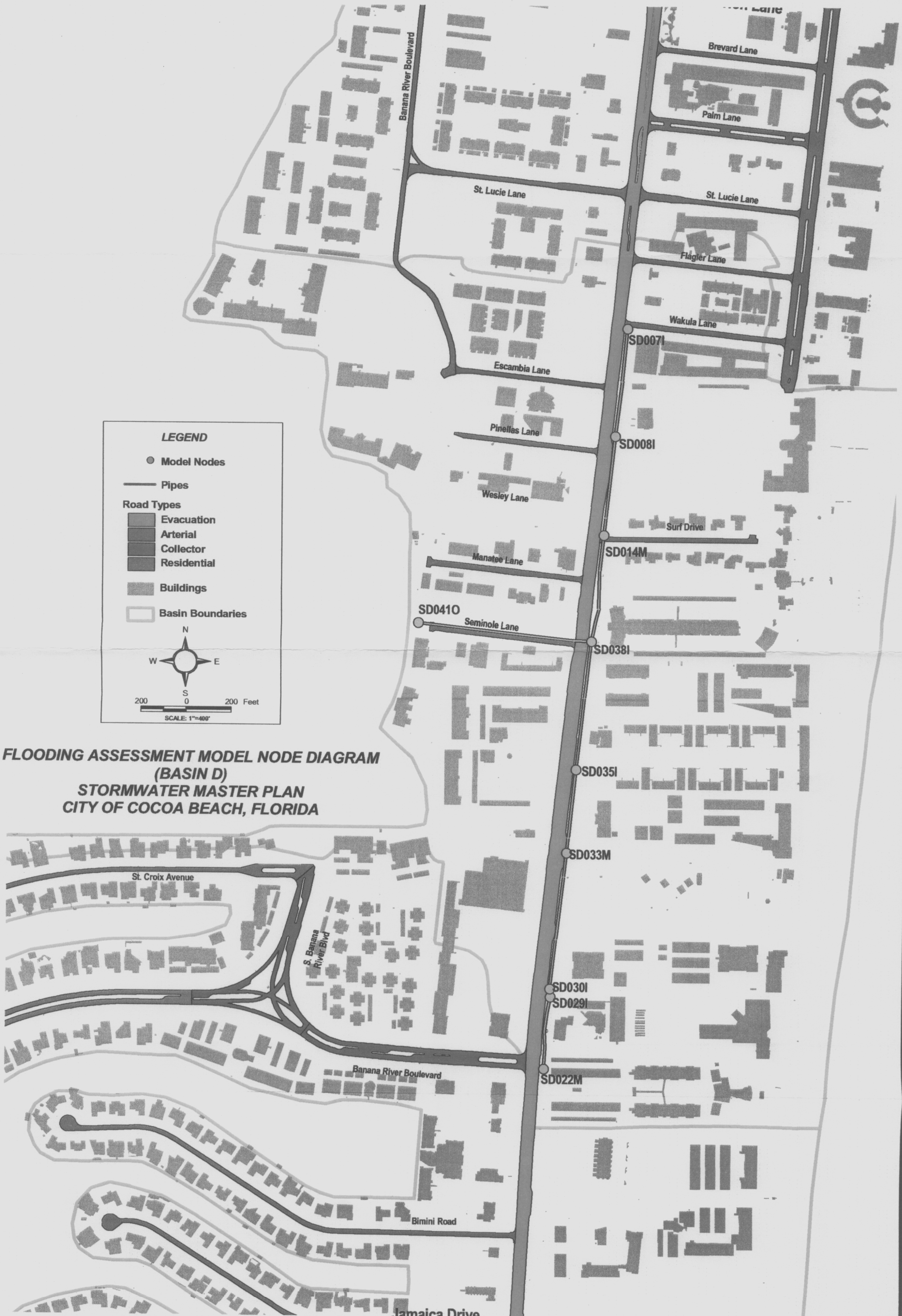
FLOODING ASSESSMENT MODEL NODE DIAGRAM (BASIN F) STORMWATER MASTER PLAN CITY OF COCOA BEACH, FLORIDA



PARSONS ENGINEERING SCIENCE, INC.



PARSONS ENGINEERING SCIENCE, INC.



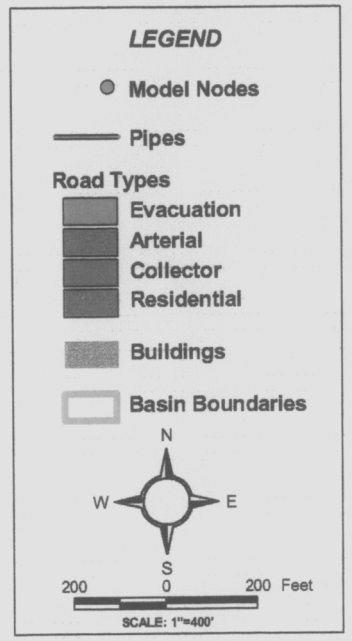
FLOODING ASSESSMENT MODEL NODE DIAGRAM
(BASIN D)
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

PARSONS ENGINEERING SCIENCE, INC.

FLOODING ASSESSMENT MODEL NODE DIAGRAM (BASIN C)
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA

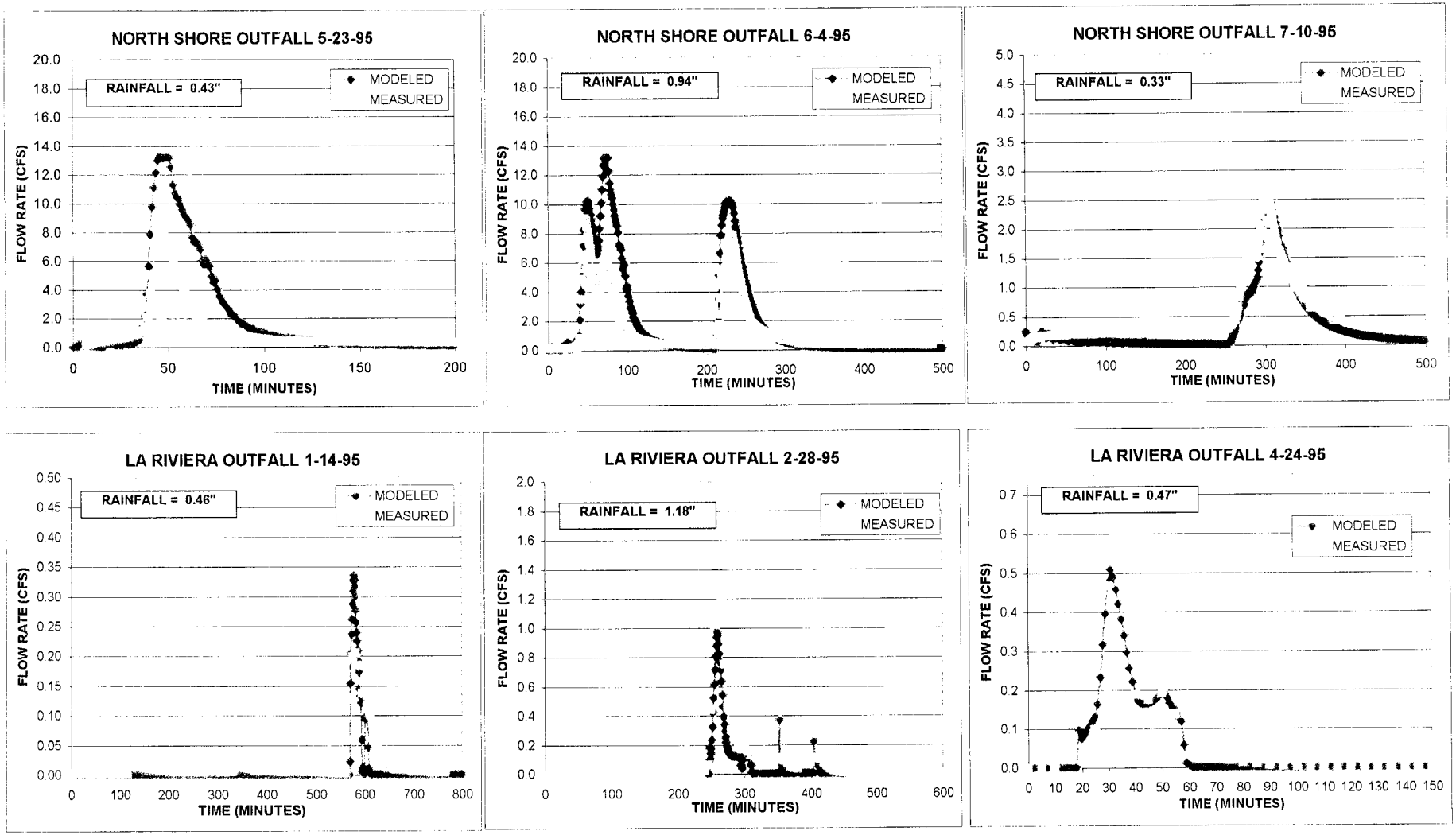
PARSONS ENGINEERING SCIENCE, INC.

FLOODING ASSESSMENT
MODEL NODE DIAGRAM (BASIN B)
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA



PARSONS ENGINEERING SCIENCE, INC.

FIGURE 3A
MODEL CALIBRATION RESULTS
STORMWATER MASTER PLAN
CITY OF COCOA BEACH, FLORIDA



APPENDIX 3A
FLOODING MODEL DETAILS

3A.1 MODEL DESCRIPTION

For this study, watershed hydrodynamics were modeled with the Visual SWMM component of CAiCE Software, Inc.'s Visual Hydro software. Visual SWMM is a graphical user's environment that acts as a pre- and post-processor for the EPA's Storm Water Management Model (SWMM). The program uses a modified SWMM version 4.4 program code that utilizes the SWMM RUNOFF block for hydrology and runoff calculations and the SWMM EXTRAN block for hydraulic routing. Background information on the model is presented in the sections below.

A node/link abstraction of the City of Cocoa Beach's drainage system was input into the model to allow the assessment of flooding potential and LOS conditions under discrete storm events. Nodes represent discrete points in space, whereas links are used to connect the nodes. Nodes and links can represent actual components of the system or theoretical processes (e.g., floodplain storage nodes, groundwater seepage links, etc.). Stormwater enters the link/node system at a terminal or intermediate node, and is routed from node to node within links. For this Master Plan, nodes were generally used to represent catch basin inlets, junction manholes, outfalls, and storage areas such as ponds, depressional areas, or shallow graded swales. Links were generally used to model storm sewer pipes, discrete overland flow paths, and weirs.

SWMM simulates real storm events on the basis of rainfall (hyetograph) and other meteorological inputs and systems (characterization, catchment, conveyance, storage/treatment) to predict outcomes in the form of quantity and quality values. Since study objectives may be directed toward both complete temporal and spatial detail as well as to gross effects (such as total pounds of pollutant discharged in a given storm), it is essential to have both time series output, i.e., hydrographs and "pollutographs" (concentrations versus time) and daily, monthly, annual and total simulation summaries (for continuous simulation) available for review.

The program is constructed in the form of "blocks". The RUNOFF Block generates surface and subsurface runoff based on arbitrary rainfall hyetographs, antecedent conditions, land use, and topography. The RUNOFF, TRANSPORT and Extended TRANSPORT (EXTRAN) blocks route flows through the drainage system. Very sophisticated hydraulic routing may be performed with EXTRAN. Pollutant routing is available in the RUNOFF and TRANSPORT blocks. Quality constituents for simulation may be arbitrarily chosen for any of the blocks. The EXTRAN Block is the only block that does not simulate water quality. The TRANSPORT and EXTRAN blocks may all use input and provide output to any block, including themselves. The RUNOFF block uses input from no other computational block but may receive input from RAIN and TEMP blocks for meteorological input. Continuous simulation relies upon precipitation input using long-term data available on from the National Weather Service (NWS) National Climatic Data Center in the United States. The RAIN block processes rainfall data for input into the RUNOFF block. A synoptic statistical analysis may also be performed on rainfall data. In a similar manner, the TEMP block processes long-term temperature data for input into the RUNOFF Block.

The input data requirements for SWMM may be extensive. Most of the data reduction is straight forward (e.g., tabulation of slopes, lengths, diameters, etc., of the sewer system). SWMM is flexible enough to allow different modeling approaches to the same area and a specific, individual modeling decision upstream in the catchment will have little effect on the predicted results at the outfall. A lumped approach may often be used for preliminary modeling in which catchment properties are aggregated and only minimal data is needed. The model is flexible in that only portions of the overall model (e.g., one block) need be run at any one time.

The Visual SWMM software package includes many enhancements to the original SWMM 4.0 code. These include the EXTRAN option for ponded water at nodes to optionally be returned to the main system, a greatly enhanced stability in the EXTRAN solution of conduit flows and junction depths, expansion/contraction losses due to changes in cross sectional area are simulated in conduits, entrance/exit losses at junctions are simulated in conduits, irregular shaped closed conduits are allowed, user defined weir exponents are allowed, transition to equivalent conduits when a weir surcharge was modified for increased stability, the number of pollutants has been increased to 20 for all modules, the number of land uses has been increased to 10 for all modules, the utilities (Rainfall, Temperature, Wind, Statistics, etc.) are incorporated within the overall interface, infiltration methods and parameters are now catchment dependent, all modules can route flows through all conduit types, the SCS method of hydrograph generation is now provided, and an EMC (Event Mean Concentration) method is now available for pollutant generation.

The EXTRAN block of SWMM was used to route stormwater through the storm sewer network and determine flow capacity and hydraulic grade line information. EXTRAN is a hydraulic flow routing model for both open channel and closed conduits in dendritic and looped networks. EXTRAN receives hydrograph input at specific nodal locations by interface file from an upstream block (e.g., the RUNOFF block) and/or by direct user input. The model performs dynamic routing of stormwater and sanitary flows throughout the major storm drainage system to the outfall points of the receiving water system. Since the flow in sewers is usually non-uniform, turbulent, and subject to backwater and surcharge, a model is required that simulates all of the terms in the one dimensional dynamic flow equation. EXTRAN will simulate branched or looped networks, backwater due to tidal or non-tidal conditions, free-surface flow, pressure or surcharge flow, flow reversals, flow transfer by weirs, orifices and pumping facilities, and pond or lake storage. Types of channels that can be simulated include circular, rectangular, horseshoe, eggshape, baskethandle pipes, trapezoidal, parabolic, natural (irregular) channels, circular and rectangular orifices, and arbitrary closed conduit shapes. Simulation output takes the form of water surface elevations and discharge at selected network locations.

This version of EXTRAN is a combination of implicit and explicit finite difference formulations for solving the nodal continuity equation, combined conduit momentum and continuity equation, and the boundary conditions of the solved network. The nodal continuity equation is solved explicitly based on the last time step and value of the last iteration's nodal depth and surface area. The boundary conditions are solved based on the last iteration value of flow in the outfall conduits. The flow in conduits is solved implicitly using the full dynamic flow equation. The kinematic wave flow is solved iteratively using the value of the last iteration's upstream conduit cross sectional area and hydraulic radius.

EXTRAN uses the link-node description of the storm sewer network or system. This description in EXTRAN facilitates both the finite difference representation of the physical prototype and the mathematical solution of the gradually varied unsteady flow (St. Venant)

equations that form the mathematical basis of the model. The conduit system is idealized as a series of links or conduits that are connected at nodes or junctions. Links and nodes have well-defined properties which, taken together, permit representation of the entire pipe network. Moreover, the link-node concept is very useful in representing flow control devices. Links transmit flow from node to node. The primary dependent variable in the links is the discharge, Q, which is calculated at the center of the conduit. Properties associated with the links are roughness, length, cross-sectional area, hydraulic radius, conduit depth, and surface width. Velocity, hydraulic radius, and the cross-sectional area of flow, or depth, are variable in the link and computed at the upstream and downstream ends of the conduit. The cross sectional area, surface width, and hydraulic radius are functions of the instantaneous depth of flow at the upstream and downstream ends of the conduit. The solution uses the average flow in each link during one iteration to calculate the cross sectional area, surface width, and hydraulic radius.

3A.2 DATA SOURCES

The following data sources were relied upon during the development of the hydrological and hydrodynamic model:

- City of Cocoa Beach Stormwater Utility's land use map, aerial photographs, stormwater atlas drawings, and stormline data spreadsheets;
- Pine Design City of Cocoa Beach Survey;
- Selected GIS shape file coverages from SJRWMD;
- FDOT roadway plans;
- Private development construction and as-built plans;
- Precipitation data from NOAA for the Melbourne Regional Airport station: Cooperative Identification Number 85612;
- Evaporation data from NOAA for the Vero Beach 4 W station: Cooperative Identification Number 89219.

This data was reviewed for general accuracy and applicability for application in the model effort. No effort was made to independently verify the accuracy of this data. Where specific data was incomplete or ambiguous, reasonable assumptions were made to fill in data gaps. This was particularly needed in the case of the stormline data spreadsheets provided by the City, which summarized pipe and manhole invert elevations and sizes. Where isolated cases of missing information were encountered (i.e., missing inverts, ground elevations, etc.) average values were used based on upstream and downstream data and/or direct field inspection. These approximations are not considered to impact the overall confidence of the model give the level of detail incorporated. Subsequent to the completion of the Master Plan, the City should consider efforts towards filling in the data gaps in the stormline data and confirm key invert and ground elevations.

3A.3 RUNOFF SIMULATION

The RUNOFF block of the Visual SWMM was used to model the hydrologic cycle. The model is hydrodynamic – certain input and most output varies with time. The model accounted for major elements of the cycle including precipitation, evaporation, infiltration, overland runoff of excess precipitation, and surface and subsurface storage. The model

was set up to calculate gross annual runoff volumes by sub-basin. The following hydrologic inputs for each sub-basin were required:

- Drainage Basin Area,
- Width of Overland Flow,
- Average Ground Slope,
- Percent Imperviousness,
- Infiltration Rates,
- Depression Storage Volume,
- Roughness Coefficients for Pervious and Impervious Surfaces,
- Rainfall Depths,
- Evaporation Depths.

The remainder of this section describes the methodologies used to estimate these parameters. A summary of these parameters by subbasin and/or model node/link is provided in the model data supplement to this section.

3A.3.1 Runoff Calculation Method

To calculate stormwater runoff volumes from overland flow, the kinematic wave method of the Visual SWMM program was used. The kinematic wave method for overland flow applies only the kinematic wave component of the St. Venant shallow flow equations for momentum and continuity. The subbasins are modeled as idealized rectangular areas with the slope of the subbasin perpendicular to the width. The kinematic wave procedures apply infiltration losses to the pervious percentage of the subarea, as defined by the % impervious data item. The only loss applied to the impervious component is via the depression storage defined for the impervious area. Additional depression loss (defined with infiltration information) was also applied to the pervious component. The parameters used in this method are described individually below.

3A.3.2 Drainage Basin Area

The selection of points, which govern delineation of basins and sub-basins, is strategic. Basins are delineated with respect to source of surface water outfalls. The basins were divided into nodal sub-basins with respect to hydrologic-control and pollutant-loading points. Three major sources of information were used to generate the watershed, basin, and subbasin delineations. The Pine Design City survey showed natural and some developed topographic relief and overland flow direction within the watershed. Construction and grading documents for developments and roadways were also relied upon in some cases to determine the effect major development has had on the natural drainage. Finally, site visits were done to verify and refine delineations. Subbasin delineations were digitized into the existing GIS project of the watershed boundary, where drainage areas were determined for each sub-basin by querying the system for area. For modeling simplification, many subbasins throughout the watershed boundary were aggregated into model node-specific subbasins representing roadway intersections, important structural elements, and/or other areas of particular interest. The areal coverage of these was later refined as appeared necessary.

3A.3.3 Impervious Area

The model uses a subbasin specific *percent impervious* value to represent the portion of the subbasin that is impervious. The impervious areas must be hydraulically (directly) connected to the drainage system. The percent impervious data is used to split the subarea into respective impervious and pervious components. The infiltration calculations are only applied to pervious component. The only losses applied to impervious component are depression storage losses (discussed below).

Impervious areas such as rooftops and pavement, which are directly connected to the subbasin outfall without intermediate flow over a pervious surface, are segregated from pervious area and impervious area that must flow over pervious area to reach the sub-basin outfall. As discussed in Section 2, DCIA estimates of imperviousness based on land uses throughout the City were determined. The DCIA area estimates were then adjusted on a case-by-case basis according to visual inspection of aerial photographs, construction and grading documents, and site visits.

3A.3.4 Infiltration

Runoff from pervious surfaces within the watershed is a function of the infiltration capacity of soils within the basin. Stormwater that infiltrates into the soil is lost in the model and is not available for runoff. Stormwater that does not infiltrate is available for routing throughout the City as surface water runoff. As discussed in Section 2, hydrologic soil groups are used to estimate infiltration rates. Runoff potential and infiltration rates are inversely related; as runoff increases, infiltration rates decrease. Therefore, soils classified as A have a low runoff potential with high infiltration rates, while C and D soils have a higher potential for runoff and lower infiltration values.

For the pervious areas in the watershed, the *Horton soil infiltration method* was used to represent the time-varying infiltration of stormwater into the soil column. This method reflects that if the amount of rainfall exceeds a soil's infiltration capacity, then infiltration will tend to decrease exponentially. During a rainfall event, infiltration rate for each soil type varies from a maximum value to an asymptotic, minimum value. If the antecedent dry period that occurs prior to the next storm is long enough, the model will regenerate the infiltration rate back to its peak value; otherwise, it will compensate for the percent of saturation remaining in the soil. Horton's model is empirical and is perhaps the best known of the infiltration equations.

Horton gives infiltration capacity as a function of time as:

$$\mathbf{Fp = Fc + (Fo - Fc) \cdot e^{-kt}}$$

Where:
- Fp = infiltration capacity into soil, ft/sec
- Fc = minimum or ultimate value of Fp, ft/sec
- Fo = maximum or initial value of Fp, ft/sec
- t = time from beginning of storm, sec
- k = decay coefficient, 1/sec

This equation describes the familiar exponential decay of infiltration capacity evident during heavy storms. However, the program uses the integrated form to avoid an unwanted reduction in infiltration capacity during periods of light rainfall. In addition, a parameter to

regenerate infiltration capacity is required for continuous simulation. The maximum or initial infiltration capacity depends primarily on soil type, initial moisture content and surface vegetation conditions. For single event simulation the initial moisture content is important. The minimum or ultimate value of infiltration capacity is essentially the saturated hydraulic conductivity, or "permeability", of soils. The rate of decrease of infiltration capacity is independent of initial moisture content, and is represented as percent of decline of decay rate infiltration capacity towards a limiting value after 1 hour. Most reported values are in the range 3-6 /hr (0.00083-0.00167 /sec).

Based on the site soil characteristics, the following infiltration parameter values were used in the model:

Soil Group	Horton Max Infiltration Rate (in/hr)	Horton Min Infiltration Rate (in/hr)	Decay Coefficient (1/sec)
A	8	0.45	0.001
B	6	0.30	0.001
C	4	0.15	0.001
D	3	0.05	0.001

3A.3.5 Subbasin Slope

The average slope of the subbasin should reflect the average along the pathway of overland flow to inlet locations. For simple geometry, the calculation is simply the elevation difference divided by the length of flow. For more complex shapes, several overland flow paths may be delineated, their slopes determined, and a weighted slope computed using a path-length weighted average. Alternatively, it may be sufficient to simulate the hydrological dominant slope for the conditions being simulated.

Slopes of overland flow were determined for each subbasin from the Pine Design City survey and construction and grading documents. In uniform sub-basins with limited variation in topography, the slope can be determined by calculating the difference in the high and low elevations along the flow path divided by the flow length. For most cases, it was assumed that the direction of overland flow was perpendicular to the sub-basin width.

3A.3.6 Subbasin Width

The kinematic wave runoff method represents sub-basins with corresponding areas, widths, and slopes as rectangular planes used to route the surface water runoff. The width of the theoretically rectangular sub-basin is equivalent to a value that lies between the length of the dominant flow paths within the sub-basin and twice this length. If overland flow is visualized as running down-slope off an idealized rectangular catchment, then the width of the subbasin is the physical width of overland flow. Since real subbasins will not be rectangular with properties of symmetry and uniformity other procedures are required. The subbasin width is a key calibration parameter, one of the few that can significantly alter the hydrograph shape, rather than just runoff volume. A good estimate for the width is the area of the subbasin divided by the average path length of overland flow. For rainfall durations less than the time of concentration, increasing the width increases the flow peak and decreases time to peak. For rainfall durations greater than the time of concentration, the peak flow is affected only marginally. The time of concentration is reduced slightly for larger widths. Irregularly shaped catchments with drainage channels off-centre can be handled different methods including the use of skew factors.

Visual inspection and quantitative measurement of subbasin shape and topography shown on the Pine Design City survey as well as construction and grading plans were used to determine widths of overland flow. For regularly shaped, homogeneous watersheds, the subbasin width was estimated as the subbasin area divided by the estimated flow length and later refined on a case-by-case basis as deemed necessary.

3A.3.7 Roughness

Values of Manning's roughness coefficient are not as well known for overland flow as for channel flow because of the considerable variability in ground cover, transitions between laminar and turbulent flow, very small depths, etc. Estimates of Manning's roughness are given in various reference materials. For the Master plan model effort. Manning's roughness coefficients for overland flow were estimated using literature values, experience, and visual observation. Within the watershed boundary, a value of 0.014 was used to represent impervious areas with asphalt or concrete paving. To describe the pervious areas, a value representative of grass surfaces of 0.2 was used.

3A.3.8 Depression Storage

Depression storage represents the volume of water available for infiltration and/or evaporation from impervious and pervious surface areas. The depression volume must first be exceeded before surface water runoff can commence. Depression Storage is the volume that must be filled prior to the occurrence of runoff. It represents the loss or "initial abstraction" caused by such phenomena as surface ponding, surface wetting, interception and evaporation. Depression storage may be treated as a calibration parameter, particularly to adjust runoff volumes. Separate depression stores are required for pervious and impervious areas.

Due to a lack of infiltration capacity, the depression storage on impervious areas is only subject to evaporation. Typically, a regression equation is used to estimate impervious depression storage in basins that do not have stormwater management facilities as a function of sub-basin slope. One common equation is as follows (Kidd, 1978):

$$\mathbf{D_p = 0.0303\ S^{-0.49}} \qquad \text{(correlation coefficient = 0.85)}$$

Where: D_p = depression storage (in)
S = catchment slope (%).

This equation was used to determine impervious depression storage for each model node and then averaged to obtain a global, mean value of 0.05 inches used to describe imperviousness throughout the City.

Both infiltration and evaporation can recover the volume of water stored as depression storage on a pervious area. An interception loss is used to describe this quantity according to the type of surface vegetation available. Based on review of reference material, a value of 0.10 inches was used to describe the pervious depression storage in the model.

3A.3.9 Rainfall

Rainfall data is the single most important group of hydrological data required by SWMM. A hyetograph of rainfall intensities versus time is required for the period of the simulation. For single event simulation, the data is usually entered for a gauge directly as a

synthetic design storm. For continuous simulation, an historical rainfall sequence is normally used. Each subbasin references a single rain gauge. The data for each rain gauge may be input manually or defined to come from an external interface file. It is allowable to use a combination of manually entered rain gauges and some to be read in from an external interface file. Spatial variability in rainfall is handled by assigning different rainfall gauges to different subbasins. Storm motion may significantly affect hydrographs at the catchment outlet.

For the purposes of the flooding assessment model, discrete storm event were used to simulate the response of the stormwater management system. Indian River Lagoon specific storm distributions were chosen from a review of SJRWMD reference materials. The selected storm events for simulation were the 24-hour duration storms for the mean annual, 10-year, 25-year, and 100-year return periods. These storm distributions were discussed in detail in Section 2.

3A.3.10 Evaporation

Evaporation is used to renew surface depression storage and is also subtracted from rainfall at each time step. It has very little effect on single event simulation (ie. less than a week long), but is important for continuous simulation. Evaporation does not affect regeneration of infiltration capacity. The evaporation input to the RUNOFF block also acts as an upper bound for evapo-transpiration losses from groundwater and soil moisture. Evaporation also occurs from open channels, and storage areas (ie., natural channels, ponds). Due to the short-term nature of the discrete time storm analysis used in the flooding assessment model hydraulic model, time varying evaporation data was not utilized rather a default value of 0.1 inch per day was used.

3A.4 EQUIVALENT CONDUITS AND HEAD LOSSES

An equivalent pipe is the computational substitution of an actual element of the drainage system by an imaginary conduit that is hydraulically identical to the element it replaces (except for volume). Usually, an equivalent pipe is used when it is suspected that a numerical instability will be caused by the element of the drainage system being replaced in the computation. Weirs and short conduits are known at times to require short time steps and thus may occasionally be replaced by an equivalent pipe. EXTRAN has the ability to modify model links to apply an equivalent conduit automatically, subject to user control. Orifices are automatically converted to equivalent pipes by EXTRAN. Other instances where equivalent pipes can be used include situation where more than one pipe of differing properties or diameter in series is being represented in the model with a single pipe.

The equivalent pipe substitution used by EXTRAN involves the following steps. First the flow equation for the element in question is set equal to the flow equation for an "equivalent pipe", which makes the head losses in the element and its equivalent pipe the same. The length of the equivalent pipe is computed using the numerical stability equation, and a Manning's 'n' is computed based on the equal head loss requirement. The desired equivalent pipe length is either no shorter than one quarter or 1/5 of the length of the longest pipe in the system, or large enough to give a delta time step within the range indicated above. The program can also be forced to use and equivalent conduit based on a used specified time step interval.

System head losses are accommodated within the model in different ways. These head losses typically include manhole/pipe entrance and exit losses along with other typical losses

seen in storm sewer systems such as bend and contraction/expansion losses. The losses can be applied on a global basis by specifying a default head loss values based on structure, and/or location specific head loss terms can be applied to account for unique circumstances (i.e., control valves, diversions, etc.).

3A.5 BOUNDARY CONDITIONS

The stormwater management systems in the City ultimately all discharge to the Banana River. This provides a natural boundary conditions on which to base the modeling. Lagoon elevations vary quite widely depending on seasonal variations and precipitation. In general, elevations fall between approximately –0.5 and 1.5 feet mean sea level, and have been known to vary 2-3 feet. As such, a constant elevation of 0.5 feet was chosen as a conservative boundary elevation. This was used in all cases for consistency. Although, the actual elevation may vary over a 24-hour storm event, this effect was considered negligible given the resolution in accuracy of the model.

3A.6 MODEL CALIBRATION

Model calibration refers to the adjustment of model input parameters within reasonable limitations so that output agrees with a set of measured data. The ability to replicate real world data with the model increases the degree of reliability that is assigned to the model results and the to the confidence on which the conclusions area based. A reasonable range of values for the adjustment of model parameters is typically established through literature review. Adjustments outside reasonable ranges are made only if unusual hydrologic or hydraulic conditions exist. Primary data requirements for model calibration usually consist of measured stage and flow data.

Although the simulation of many of the urban runoff processes found in SWMM is physically based, the concept is limited in practice because the input data and the numerical methods are not accurate enough for many real applications. Furthermore, many computational procedures within the model are based upon limited data themselves and highly empirical, especially surface quality predictions. Calibration and verification data are usually in the form of measured flows and concentrations at outfalls or combined sewer overflow locations. SWMM has sufficient parameters that may be "adjusted," particularly in the RUNOFF Block, such that calibrating the model against measured data is usually readily accomplished. Quantity (hydrograph) predictions are often "within the ball park" on the first try, given decent rainfall, area and imperviousness data.

Model estimates of actual conditions vary in accuracy. Open channel hydraulics such as canals, creeks, and other waterways is often very difficult and cost prohibitive to model without very intensive, discreet data on cross-sections, slopes, and cover types, etc. In modeling stormwater systems that rely primarily on these drainage features, it is critical to have adequate real world stage and flow data from which to compare and calibrate the open channel flow conditions. In the case of Cocoa Beach, the primary component of the stormwater management system is storm sewers. The stage and flow equations governing closes conduit hydraulics are more easily definable as compared to open channel flow. As a result, a higher degree of risibility can be assigned to predictions of flow characteristics within a storm sewer system as compared to a primarily open channel system. Although calibration is important in both cases, a higher degree of accuracy can be expected with storm sewer modeling when a lack of sufficient calibration data exists.

In the case of Cocoa Beach, real time flow data was available at two locations, the North Shore outfall in Basin F (a major trunk line discharging through outfall SF074O) and the La Riviera outfall in G (a minor one-pipe system in a residential area discharging through outfall SG603O). Rainfall data from several storm events in 1995 was available to compare with the modeled representations of these networks. The storm events were simulated in the model with the results compared to the actual flow data recorded from these locations. The results are shown on Figure 3A.

The results indicate a reasonable replication of measured data. Hydrographs shapes are similar, but with some obvious variation in volume. The differences in volume are likely do to some base flow present at the time of the storm measurement possible from previous storm events or groundwater, which were not taken into account. Peak flow predictions are similar within reasonable error given the low storm depths and flow rates. The North Shore results exhibit some overestimation of peak flow rates particularly as the storm depth increases. This data would indicate the model representations as being predictively conservative, which should be taken into account when interpreting the results.

3A.7 MODEL ERROR

The model calculations make successive approximations to the final answer in an iterative fashion until the conditions of the flow equations are met within a specified tolerance. For the purposes of the Master Plan, a default head tolerance of 0.001 feet was used an initial target for successful calculations during a given time step. An overall continuity error of less than 1% was also targeted through the model runs. Where difficulty existed in meeting these criteria, time step adjustments and other calculation parameter tweaking were performed in an attempt to limit continuity error. In virtually all cases, continuity error was less than 5% on the whole. With respect to overall model performance, this would generally represent less than 0.1' of fluctuation in hydraulic grade prediction.