AN ANALYSIS OF STORMWATER INPUTS TO THE APALACHICOLA BAY

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EXECUTIVE SUMMARY

Apalachicola Bay is responsible for approximately 90% of Florida's oyster harvest and a significant portion of the blue crab and shrimp harvests. It also provides nursery areas for finfish, crabs, and shrimp. The bay has been designated an Outstanding Florida Water, a State Aquatic Preserve, and an International Biosphere Reserve. Nonpoint source pollution from urban areas and increasing development represents one of the water quality concerns in Apalachicola Bay, and potentially may be more devastating than more distant or regional sources of pollution originating upstream in the riverine watershed. An unprecedented, local-state-interstate-federal effort is now underway to protect and restore the resources of the Apalachicola Bay. Missing in this effort, however, is a detailed nonpoint source control strategy for the urbanized communities, including the cities of Apalachicola and Carabelle and the unincorporated communities of Eastpoint, St. George Island, and Lanark Village.

As part of an overall management strategy for Apalachicola Bay, the Northwest Florida Water Management District has examined the impacts of urban stormwater runoff on the bay by monitoring and characterizing the quality and quantity of runoff from the communities, and has applied a computer simulation model to evaluate the stormwater status of the City of Apalachicola. Central to this project was the incorporation of improved stormwater management practices as an integral component of the ongoing comprehensive effort to protect and restore the environmental and economic resources associated with Apalachicola Bay. The study provides guidance and information necessary to develop and implement an integrated nonpoint source management plan for the City of Apalachicola, as well as other municipal areas along the bay.

This study has identified several stormwater-related problem areas. Coliform contamination throughout the bay, originating from the Apalachicola River and from the communities located on the bay appears to be a real and dangerous threat to the seafood industry and local economy of the area. Sources appear to be both human and nonhuman in origin. The bay is closed to oyster harvesting during periods of high coliform counts, resulting in loss of income to the local seafood industry. This concern deserves immediate attention. With the exceptions of coliforms and of discharges from economically depressed urban areas, most of the municipal areas sampled indicated that pollutant levels were generally low. However, increased levels of typical stormwater contaminants such as turbidity, total suspended solids, coliforms, nutrients, and some metals including copper, zinc and lead, are indicated with increased levels of development. The cumulative impacts of these increases are a primary concern. Serious flooding problems within the City of Apalachicola are due to clogged, undersized, and deteriorating conveyance systems and a lack of rate controls. While cleaning and repair of existing pipes could offer some level of immediate relief, even under ideal conditions the system remains undersized to carry anticipated flows. The study also suggests a number of solutions, which, if properly focused, could have an immediate improvement in water quality. Both structural and nonstructural solutions should be considered to address these problems, including urban renewal programs, comprehensive stormwater management plans, drainage basin investigations and retrofits, and stringent use of best management practices, including those used during constructions activities.

INTRODUCTION

Nonpoint source pollution from urban areas represents a serious threat to water quality in Apalachicola Bay. In particular, the impacts of urban areas, and discharges from municipal stormwater drainage systems have the potential to be far more devastating than the more distant or regional sources of pollution originating upstream in the riverine watershed. This threat is increasing, as the area is becoming the focus of growing development interests. The degradation of water quality, as has occurred in many Gulf Coast estuaries, would severely degrade the unique and highly productive natural or estuarine resources associated with Apalachicola Bay and adversely impact the region's economy, which is directly dependent upon the bay's productivity. The bay produces approximately 90% of the state's oyster harvest and a significant portion of the state's blue crab and penaeid shrimp harvests. It also provides important nursery areas for finfish, crabs, and shrimp. Additionally, because most of these species spend only a portion of their lives in the bay and because the vast majority of commercially important species are estuarine dependent, the productivity of the bay may be reflected in dock yields throughout the Gulf of Mexico. The situation is further complicated by the existence of the Apalachicola-Chattahoochee-Flint River Compact, which authorizes the States of Florida, Alabama, and Georgia to negotiate a water allocation formula for the river basin. The resulting allocation formula will reduce freshwater flows to the bay, which will in turn affect such factors as bay salinity and nutrient levels. An unprecedented effort by a combination of State, federal, and local agencies is now underway to protect and restore the resources of Apalachicola Bay. Missing in this effort, however, has been a detailed nonpoint source control strategy for the urbanized communities, including the cities of Apalachicola and Carabelle and the unincorporated communities of Eastpoint, St. George Island, and Lanark Village.

The City of Apalachicola's storm drainage network, much like other coastal communities in northwest Florida, is considered antiquated and inadequate, unable to meet current stormwater management and treatment standards. According to the city's comprehensive plan, the existing system is characterized by deterioration, undersized piping, sedimentation from eroding ditches, overgrown conveyances, direct infiltration into the wastewater sewer collection system (which has resulted in secondary wastewater overflow during sustained storms), and a number of direct, untreated outfalls into the estuary. Results of such conditions include the potential for degraded water quality and increased flood hazard potential. While it was generally accepted that the city is in need of stormwater management system improvements, the data and analysis required for their development in a cost effective and efficient manner have previously been unavailable. The seriousness of stormwater-related water quality and flooding problems had not been adequately quantified, and primary problem locations were open to speculation. Sources of pollutants found in the bay, such as coliform bacteria, are also unknown and may be primarily locally derived. This information must be developed before decisions and the need for retrofit of stormwater facilities can be evaluated.

This report includes a description of the data collected and analysis of Apalachicola Bay area urban stormwater systems. Most of the data in this report are presented in the form of summary tables and GIS data overlays to depict problem areas.

Objectives

As part of an overall water quality management strategy for Apalachicola Bay, the Northwest Florida Water Management District (NWFWMD) proposed to examine urban stormwater runoff entering the bay, and to identify potential problem areas. Specifically, the NWFWMD proposed to monitor and characterize the quality and quantity of stormwater runoff from urbanized coastal communities. It was also proposed to design a computer simulation model to evaluate the stormwater status of the largest community on the bay, the City of Apalachicola. Model results and monitoring data were used to analyze pollutant loading impacts, evaluate the capacity of system conveyances, determine the potential for flood hazards, and consider the potential for stormwater improvements. Central to this project was the incorporation of improved stormwater management practices as one of the many components of ongoing efforts to protect and restore the environmental and economic resources associated with Apalachicola Bay.

A directed effort was initiated to ensure the future health of Apalachicola Bay's environment and the vitality of the region's natural resource-based economy. The bay and surrounding waters have been recognized as a resource of state, federal, and international importance. The bay has been designated an Outstanding Florida Water, a State Aquatic Preserve, and an International Biosphere Reserve. It includes the Apalachicola Bay National Estuarine Research Reserve and is adjacent to St. Vincent National Wildlife Refuge. Additionally, state and federal agencies, as well as the NWFWMD, have made an extensive investment in acquiring and protecting lands in the watershed, and local governments have implemented comprehensive planning efforts. The foregoing management efforts, however, lacked a detailed analysis of existing stormwater runoff problems and an evaluation of future stormwater management requirements. As development intensifies in the area, the threat increases that stormwater runoff will precipitate the same kind of ecological deterioration that has impacted virtually every other estuarine system of comparable size in the state of Florida.

Proposed Solution

The NWFWMD proposed to monitor stormwater quality and quantify pollutant loading from urbanized areas along Apalachicola Bay. The District further proposed to complete a detailed analysis of the City of Apalachicola as a model test site to demonstrate the problems of urban stormwater runoff under existing conditions as provided for in existing land use maps. Part of this analysis included development of a simulation model to provide temporal and spatial characterization of stormwater runoff from the city of Apalachicola and an assessment of resulting flood hazards and water quality impacts on adjacent surface waters. The study provides the information necessary to begin to develop and implement an integrated nonpoint source management program for the study area. Implementation of such a plan would help to protect and potentially improve water and sediment quality for municipal areas around the bay; address potential flood hazards; and provide an integral component of the state, federal, and local effort which is being implemented to protect and restore the environmental and economic resources associated with Apalachicola Bay and the surrounding waters.

The project was comprised of three major components.

1. *Stormwater runoff monitoring*. Stormwater quality and quantity data were collected for the cities of Apalachicola and Carabelle and the unincorporated communities of Eastpoint, and Lanark Village. The information generated by the monitoring effort was entered into a database and used to identify the extent and magnitude of local nonpoint source pollution from stormwater runoff.

2. *Data analysis*. Analysis was conducted to identify specific water quality parameters of concern, and to accurately quantify the local contribution of pollutant loading to the estuarine system. Laboratory analysis included: tests of bacterial contaminants that may affect the quality of seafood; suspended sediments; and other contaminants of concern that were suspected to be transported in stormwater.

3. *Detailed stormwater modeling and analysis for the City of Apalachicola*. This component included modeling of stormwater quantity and pollutant loading, quantification of nonpoint source problems and potential impacts, evaluation of existing nonpoint source controls and drainage system capacities, and recommendation of a general strategy for future stormwater planning and nonpoint source control. Additional City of Apalachicola data required to facilitate any modeling effort included existing and future land uses, long-term rainfall, soils, and assessment of the existing storm drainage network.

The data collection and analysis effort provided the information to develop an "existing condition" stormwater loading model for the City of Apalachicola, as well as for future application of similar models for other urbanized areas. Stormwater quantity and quality data were collected for each of the urbanized areas identified along Apalachicola Bay, including the cities of Apalachicola and Carabelle and the unincorporated communities of Eastpoint and Lanark Village. Data collected for the City of Apalachicola were used in an initial model simulation effort. Additional data collected for Apalachicola included existing and future land use, topography, storm drainage and treatment system data, soils, observed or known pollution sources, and historic rainfall data.

A stormwater quality and quantity simulation model was developed for the City of Apalachicola, utilizing the Storm Water Management Model (SWMM) developed by the U.S. Environmental Protection Agency (EPA). For this study the model serves several purposes, including quantification of stormwater volumes; evaluation of the storm sewer system capacity as related to water quality, soil erosion and flooding problems; analysis of discharge locations (flow path); and refinement of the runoff portion of pollutant loading rate estimates. The model was calibrated using the short-term monitoring data obtained as part of this project. Long-term and spatially distributed stormwater flows and pollutant loading were simulated using existing land uses, as delineated in the local government comprehensive plan. This final report was prepared by characterizing stormwater runoff impacts on conveyance system capacity, potential flood hazards within the city, and potential water quality impacts on adjacent surface waters.

The model used long-term meteorological inputs, including rain, evaporation, and antecedent conditions; physical parameters, including land use, impervious surfaces, and topography; and drainage system parameters, including catchment, conveyance, storage, and treatment. The model is capable of continuously simulating storm events and will spatially and temporally project water quantity and quality variables, including hydrologic flow and a variety of water quality parameters.

Study Area

The study area for this project encompassed five northwest Florida municipal areas located along the coast of Franklin County. The primary focus was to have been on the cities of Apalachicola and Carabelle and the communities of Eastpoint, Lanark Village, and St. George Island. These were primary areas of interest because of their potential contribution of municipal nonpoint stormwater discharges into Apalachicola Bay and surrounding waters. On St. George Island, the opportunities to sample stormwater proved to be extremely limited, as there are only a few defined channels and no storm sewers. Drainage is predominantly sheet flow, and infiltrates rapidly into highly permeable sands. After several visits to St. George Island to locate a suitable monitoring station, this site was eliminated as a potential area for sampling discharges to Apalachicola Bay. With two stations in Apalachicola, a total of five monitoring sites were selected, as shown in Figure 1.

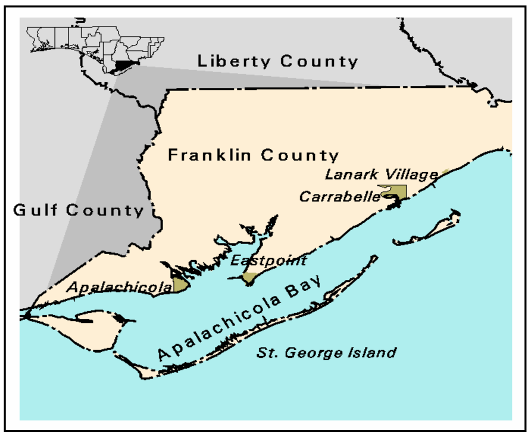
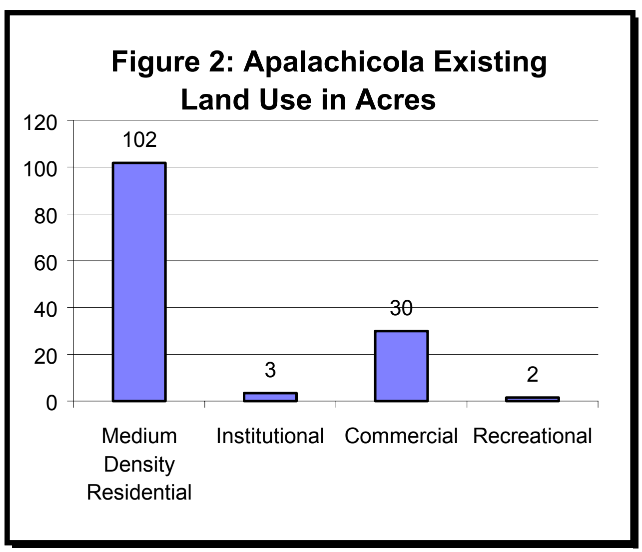


Figure 1: Area Site Map

The City of Apalachicola is a predominantly (approximately 75%) medium density residential community, with contributions from commercial sites and minor contributions from institutional and recreational areas, as shown in Figures 2 and 3. The watersheds are very flat, averaging 0.012 ft/ft, and soils are highly permeable. Most of the City was divided into drainage subbasins for modeling purposes, also depicted in Figure 3 (following page).

Within the city there are several storm sewer outfalls, two of which were used as stormwater monitoring sites for this study. The two outfalls also dictated the study area modeled, since funding did not allow modeling of the entire city proper. Subbasins 1 through 38 were chosen from the "downtown" area, comprising approximately 17% of the city.



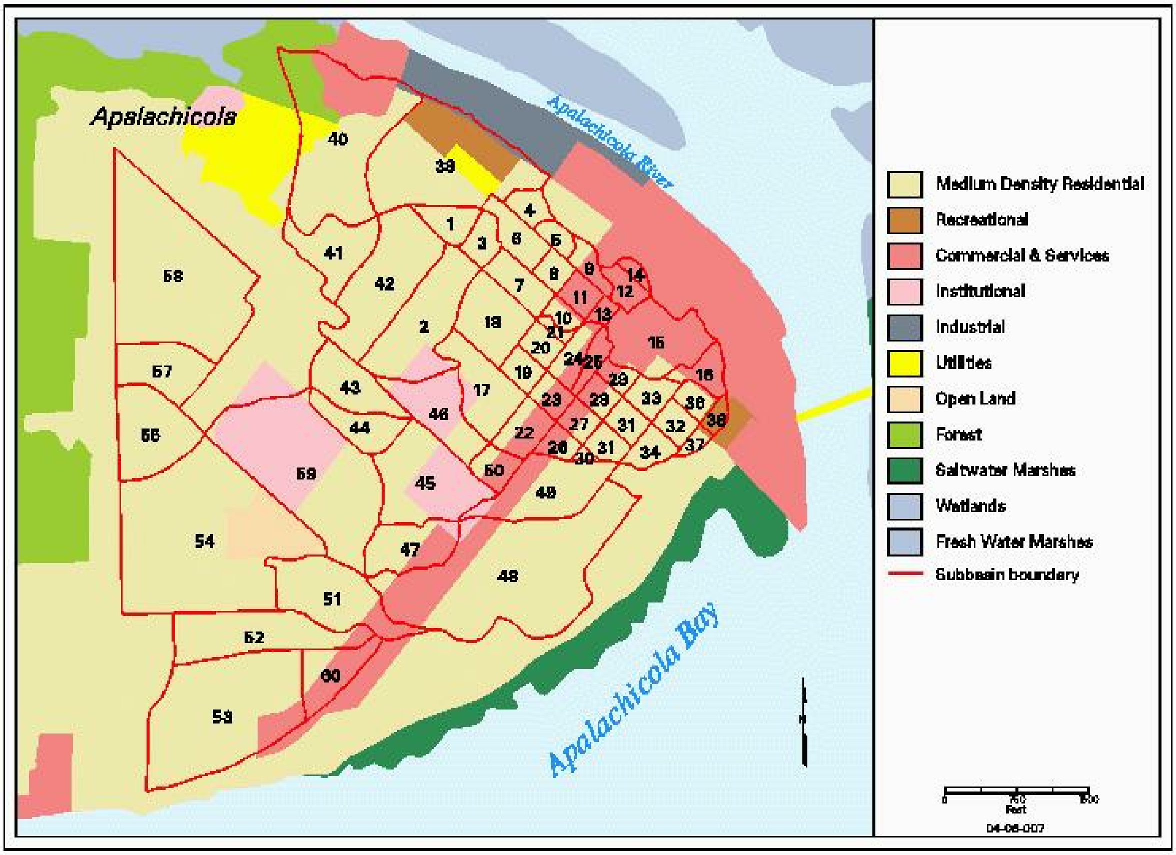
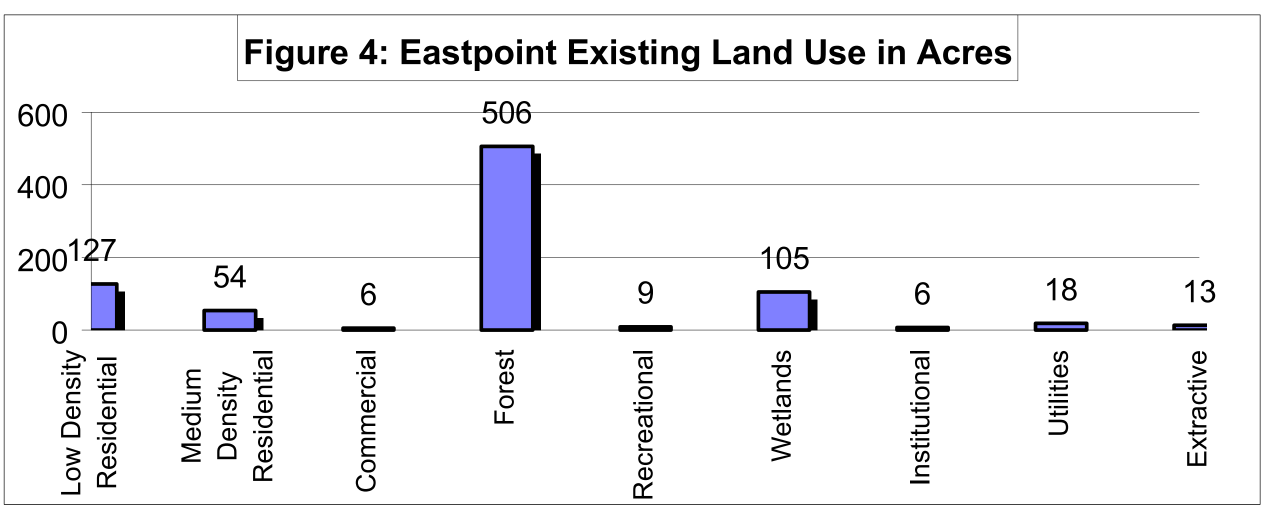


Figure 3: Existing Land Use Categories

The community of Eastpoint is a typical low to medium density residential area in the sections that are developed. The majority of the area (72%), however, is either forested or wetlands. (See Figure 4) The entire Indian Creek watershed comprises 13 individual subbasins covering approximately 877 acres, as depicted in Figure 5 (following page). Due to the location of the sampling site, only 9 of the 13 subbasins, covering 740 acres, contribute runoff for sampling purposes. Land use in the area sampled is primarily forested, although low and medium density residential, institutional and utilities occur.



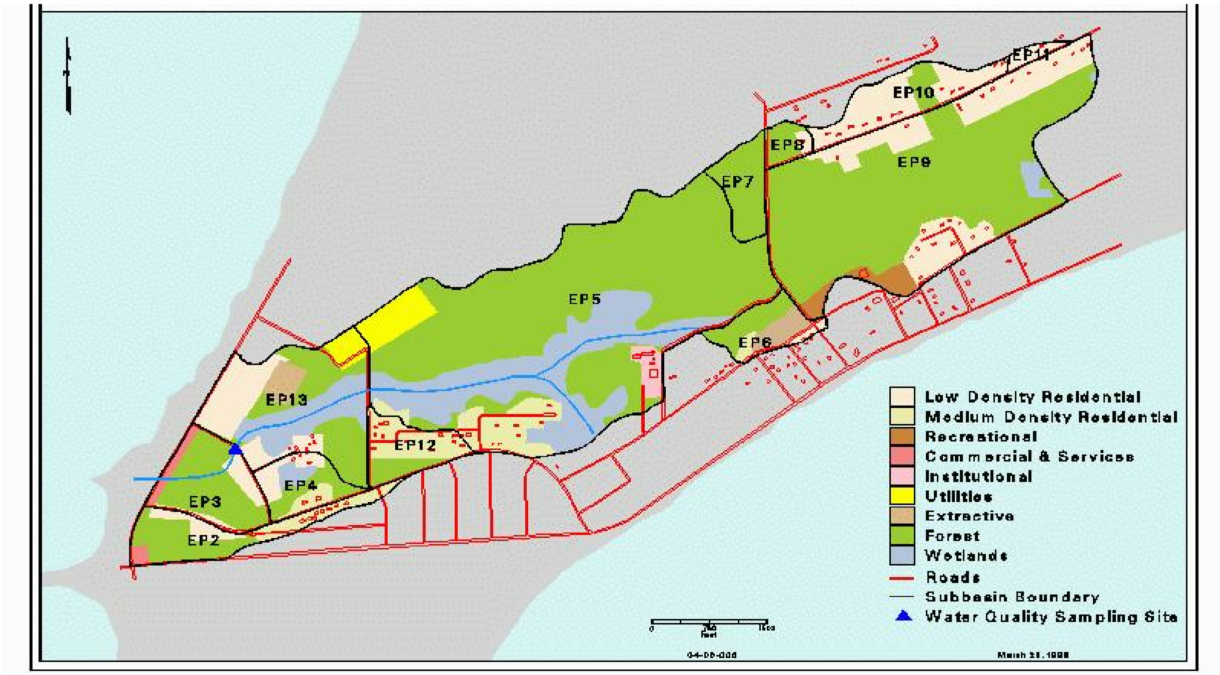


Figure 5: Eastpoint Land Use and Basin Subdivision

The town of Carabelle is generally a low to medium density residential community, whose land uses are shown in Figure 6. A large part of the community's residential section is drained by a single channel that trends southwest through the sample area and discharges into St. George Sound. The sample site selected for this area (Sample Station S524) is located along this channel on private property adjacent to Osbourne Street. The area sampled comprises four individual subbasins covering approximately 641 acres, primarily forest and wetland areas as depicted in Figure 7 (following page). Low and medium density residential and institutional areas also contribute runoff. Figures 6 and 7 indicate existing land use categories and subbasin delineation surrounding the area.

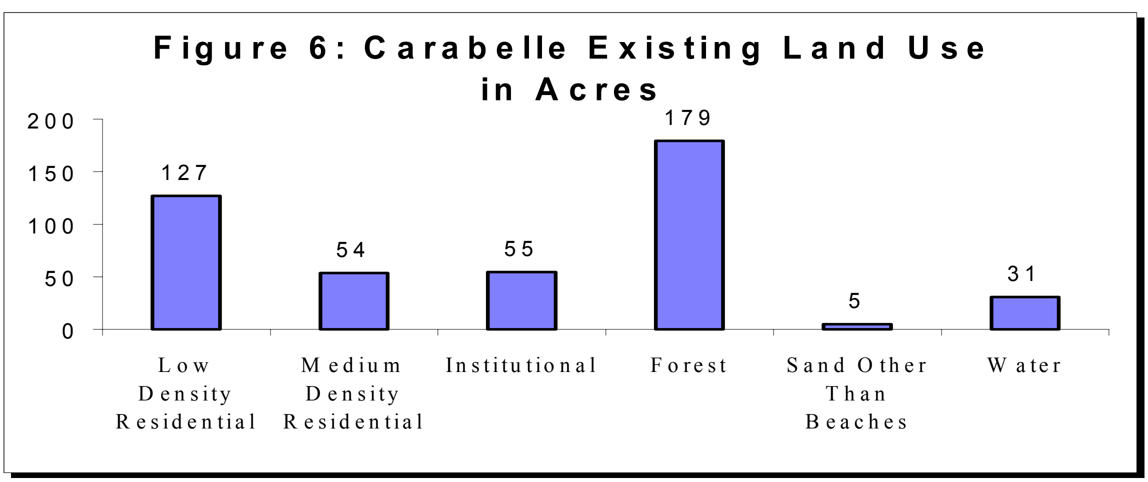


Figure 6: Carabelle Existing Land Use in Acres

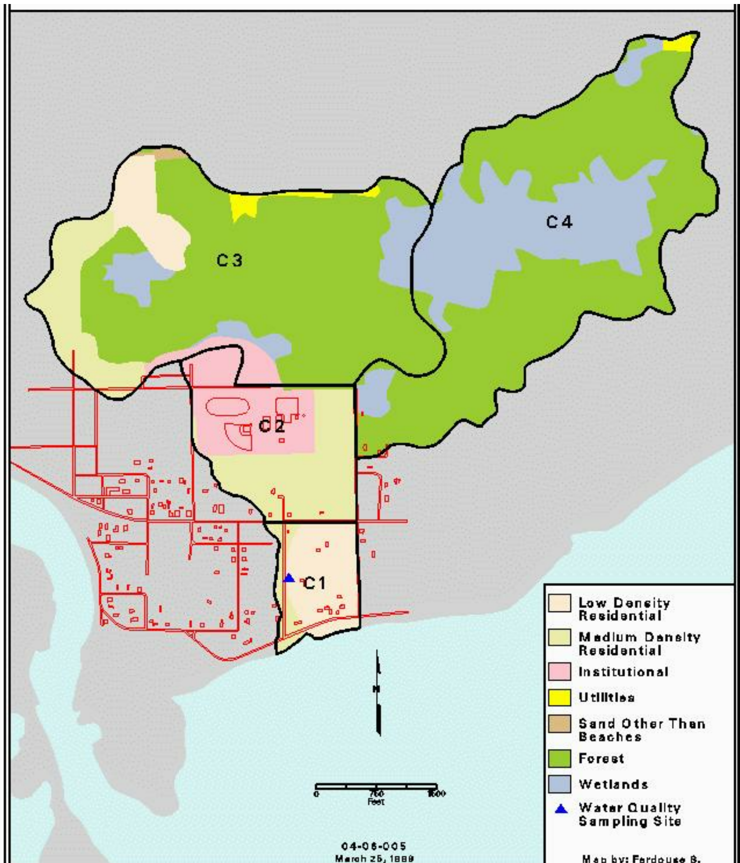
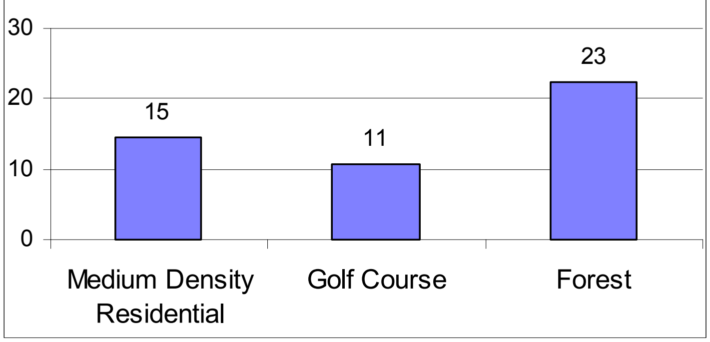


Figure 7: Carabelle Existing Land Use

The Lanark Village retirement community is also a medium density residential development, whose existing land uses are depicted in Figure 8. The study area comprises a single basin covering 50 acres, as shown in Figure 9. The surface drainage system in this area is predominately grassed swales with one small groundwater fed pond that contributes discharge to the swale system. The main grassed swale runs south, then east along Heffernan Street and Highway 98. The channel crosses under Highway 98 approximately 200 feet east of Heffernan Street through a 36-inch culvert and discharges directly into the bay at this location.

Figure 8: Lanark Village Existing Land Use in Acres



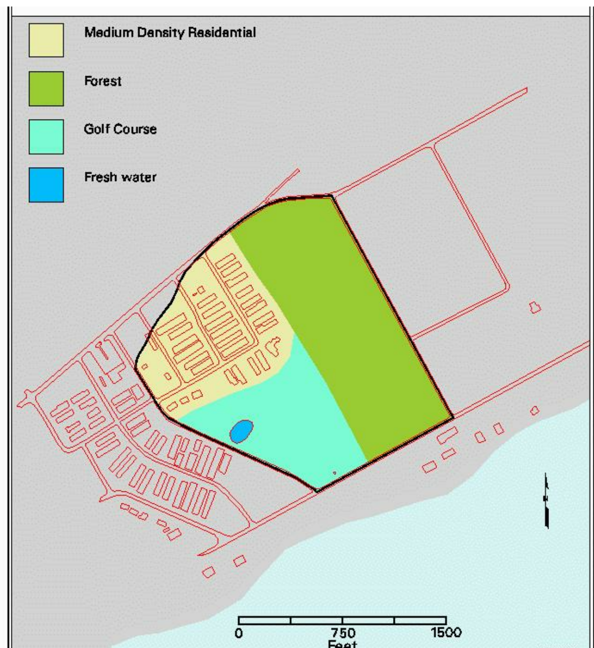


Figure 9: Lanark Village Existing Land Use

There has been a near total lack of sampling data on the quality of stormwater discharges from municipal areas into Apalachicola Bay. As discussed in the Surface Water Improvement and Management (SWIM) Program Franklin County Nonpoint Source Assessment (1993), nonpoint source pollution from urban areas represents one of the most serious threats to water quality in Apalachicola Bay. This threat is increasing as development interest in the area grows. The degradation of water quality as has occurred in many estuary systems, may severely impact the unique and highly productive environmental resources associated with Apalachicola Bay. One of the greatest concerns is a potential for adverse human health effects that are directly related to the consumption of contaminated seafood and linked to nonpoint sources. This could adversely impact the region's economy, which is directly dependent upon those resources.

There are many sources of stormwater pollutants present in any drainage basin, and the effects of these pollutants often interact and overlap. Because of this, it is difficult to attribute the pollutants measured at a particular location within a drainage basin to a specific source within the drainage area. Research efforts in recent years have identified at least seven major sources of stormwater pollutants that may typically be found within the study area. These major sources are:

Street Pavement – The components of road surface degradation are frequently common constituents of urban runoff. The largest component of street pavement is the aggregate material itself, with asphalt binder, fillers, and substances applied to the surface contributing smaller quantities. Studies conducted by researchers in Europe have indicated that as much as 0.05 - 0.10 inch of pavement surface is worn away from the roadway each year. The amount contributed to runoff will depend upon the age and type of the surface, the average daily traffic loading, and the climate of the area.

Motor vehicles – Motor vehicles contribute a wide variety of contaminants to runoff. Common constituents include fuels, lubricants, particles from tires and brake linings, exhaust emissions that settle onto the roadway surface, and corrosion products. Although the actual quantity of material generated by the operation and maintenance of motor vehicles is relatively small, the pollution potential is significant due to the number of vehicles on the road. In addition, many of the materials described are toxic to aquatic life. Motor vehicles have been found to be the principle contributor of asbestos and many heavy metals, such as copper, lead and zinc. Historically, leaded gasoline has resulted in increased concentrations of lead in lake and estuary bottom sediments, which may be re-entrained into the water column. Not all of the pollutants generated by motor vehicles during rain events originate with the vehicle itself. A large portion of the pollutant loading in runoff consists of organics, nutrients, and suspended solids which have become attached to the vehicle surface or underside and are washed onto the roadway surface by the action of the rain or street runoff.

Atmospheric Fallout – Atmospheric fallout originates as air pollution, such as dust or particles from industrial processes and land clearing operations, acid particles and heavy metals from fossil fuel power plants, and dust emissions from automobiles and planes. A large portion of the atmospheric fallout settles on the land surface, to become entrained into the runoff flow during storm events. Another significant fraction of atmospheric fallout consists of smaller particles, along with pollutants such as nitrogen and sulfur oxides, which become entrained into the rainfall prior to reaching the land surface. In some areas, atmospheric loading of heavy metals and nutrients generated by direct rainfall exceed contributions generated from the land surface.

Vegetation – Vegetative matter, or detritus, is an important source of organic and nutrient pollutant in urban stormwater. Organic matter such as leaves, grass, and other plant materials that fall or become deposited in urban areas can easily become part of stormwater flows. Recent studies have suggested that nutrients, particularly phosphorus, are released rapidly from plant matter after entering water. Excess vegetation may also choke drainage systems and interfere with the proper function of these systems if not properly handled, causing a maintenance problem.

Land surface – Land use within a drainage basin, both present and future, is a primary factor in determining the characteristics of stormwater runoff generated within that basin. The type of ground cover found in the drainage basin, as well as the amount of vehicular and pedestrian traffic, is a function of land use and will have a direct effect on the quality of runoff generated within that area.

Litter – Litter consists of various kinds of discarded material, such as food containers, packaging material, and animal droppings. Although most types of litter may not constitute significant sources of pollution, it is highly visible and can be aesthetically unpleasant when discharged into a receiving waterbody. It can also be an indicator of land use, and can aggravate clogging of underground storm sewers. In some cases, animal droppings have been shown to be a major contributor of both nutrients and bacterial contamination in stormwater runoff. Apalachicola Bay receives a significant impact of detritus from its floodplain, which is used and required for part of the bay's secondary production.

Construction Sites – Erosion of soil from land disturbed from construction activities is a highly visible source of suspended matter in stormwater runoff. Soil erosion is a major source of stormwater solids for both urban and suburban areas. Included in this category are unpaved dirt or sand roads, which can contribute tons of sediment to the bay every year.

Road Maintenance Chemicals – Chemicals such as fertilizers, insecticides and herbicides are used for maintenance of roadside areas. Although the quantities used are generally small, the enrichment and toxic effects of these materials often makes them significant in a runoff flow.

Although many different constituents can be found in urban runoff, the consistent presence of certain pollutants leads them to be "standard pollutants characterizing urban runoff." These pollutants include suspended solids (sediment), nutrients, metals, oxygen demanding substances, oils, greases and hydrocarbons, and pathogens. Pollutants considered during this study include:

Arsenic is widely distributed in waters of the United States in low concentrations ranging from a trace to approximately 1100 *u*g/l in surface waters with isolated instances of higher concentrations in well waters. Human exposure to arsenic sufficient to cause severe toxicosis usually occurs through ingestion of contaminated food or drink.

Cadmium's industrial uses are in electroplating, in pigment manufacture, and as a plasticizer, chiefly in polyvinylchloride. Cadmium occurs in zinc ores and is an important byproduct in the metallurgy of zinc. Even though only traces are likely to be found in natural waters, cadmium can be introduced in amounts significant from a health standpoint by disposal of industrial wastewaters. The major route of cadmium absorption in the human body is through the gastrointestinal tract with major effects likely to be on the kidney. Health effects can be both acute, resulting from overexposure at a high concentration, and chronic since cadmium tends to accumulate in the liver and renal cortex. The Nationwide Urban Runoff Program (NURP) (U.S.EPA, 1983) determined that on a national basis, freshwater chronic exceedance occurred in 48 percent of samples.

Chromium is amphoteric and can exist in water in several different valence states. Natural waters contain only traces of chromium since it is held in rocks in essentially insoluble forms of trivalent chromium. Under strongly oxidizing conditions, it can be converted to the hexavalent state and occur as chromate anions CrO_4^-, which are usually the result of pollution from industrial wastes. Acute systemic poisoning can result from high exposures to hexavalent chromium; the trivalent form is relatively innocuous. The chronic adverse health effects are respiratory and dermatologic.

Copper is recognized as an essential element for both plants and animals, and is a component of several enzymes that perform important physiologic functions. The Nationwide Urban Runoff Program (NURP) (U.S.EPA, 1983) determined that on a national basis, freshwater acute criteria were exceeded by concentrations in 47 percent of the samples, and chronic exceedances in 82 percent.

Iron is present in most water supplies, because iron is common in igneous rock and is found in trace amounts in practically all sediments and sedimentary rock. The iron content of water is important because small amounts seriously affect water's usefulness for some domestic and industrial purposes. Iron in water stains plumbing fixtures, stains clothes during laundering, encrusts well screens, and clogs pipes. Some industrial plant processes cannot tolerate more than 0.1 *u*g/l of iron. Most water problems that result from high iron content are associated with the sudden change from ferrous (dissolved) to ferric (semisolid) iron. Ferric oxides and oxyhydroxides come out of solution and coat surrounding surfaces. These coatings are precipitated from solution during aeration and also occur as rust on metal surfaces exposed to the atmosphere.

Lead content in surface waters is only 1 - 10 *u*g/l. Acute lead poisoning is extremely rare. The main chronic adverse effects of lead poisoning are produced in the hemapoietic system, central and peripheral nervous systems, and kidneys. Experimental data strongly indicate that among human populations the fetus and young child, particularly under 3 years of age, are at increased risk due to lead. The Nationwide Urban Runoff Program (NURP) (U.S.EPA, 1983) determined that on a national basis, freshwater acute criteria were exceeded by concentrations in 23 percent of the samples, and chronic exceedances in 94 percent.

Zinc is an essential trace element in human and animal nutrition. The Nationwide Urban Runoff Program (NURP) (U.S.EPA, 1983) determined that on a national basis, freshwater chronic exceedances occurred in 77 percent of samples.

Fecal coliform and *Fecal Streptococci* bacteria indicate the possible presence of pathogenic organisms. The correlation between coliforms and human pathogens in natural waters is not, however, absolute since these bacteria can originate from both the feces of humans and other warm-blooded animals. Coliforms from the intestinal tract of a human cannot readily and reliably be distinguished from those of animals.

The *dissolved oxygen* standard establishes lower limits to protect propagation of fish and other aquatic life, enhance recreation and reduce the possibility of odors resulting from decomposition of organic matter, and maintain a suitable quality for water treatment. The primary pollutant associated with depletion of dissolved oxygen is carbonaceous Biochemical Oxygen Demand (BOD), although it is also affected by both the temperature and the salinity or conductivity of the water. In addition, sedimentation of suspended solids can cause a buildup of decomposing organic matter in sediments, and dissolved ammonia can contribute to oxygen depletion by nitrification. Fish vary in their oxygen requirements according to species, age, activity, temperature, and nutritional state. In general, the minimum dissolved-oxygen level needed to support a diverse population of fish is 5 mg/l for Class III streams, 4 mg/l for estuaries.

The *pH* of surface waters is specified for protection of fish life and to control undesirable chemical reactions, such as the dissolution of metal ions in acidic waters. Many substances increase in toxicity with changes in pH. For example, the ammonium ion is shifted to the much more poisonous form of un-ionized ammonia as the pH of water rises above neutrality. Natural waters usually have pH values in the range of 4.0 to 9.0. Most are slightly basic, with pH values higher than 7.0, because of the natural presence of carbonates and alkaline metals and soils in the water, particularly in the Apalachicola estuary.

Phosphate-phosphorus and o*rtho-phosphorous* are forms of dissolved phosphorus directly available for uptake by algae and other plants, and are the most common and important forms of the phosphorous contaminant compounds contaminating surface waters. They are key nutrients stimulating excessive plant growth – both weeds and algae – in lakes, estuaries, and slow-moving rivers. Cultural eutrophication is the accelerated fertilization of surface waters arising from phosphate pollution associated with discharge of wastewaters, and agricultural and rural drainage.

Suspended solids interfere with the transmission of light and can settle out of suspension, covering a streambed or lake bottom. Turbid water interferes with recreational use and aesthetic enjoyment. Excess suspended solids adversely affect fish by reducing their growth rate and resistance to disease, preventing the successful development of fish eggs and larvae, and reducing the amount of food available. Settleable solids covering the bottom damage invertebrate populations, smother seagrass beds, and fill gravel spawning beds. Sediment is the largest contributor by volume to nonpoint source pollution in the United States, and is generated primarily through erosion processes during rain events. Erosion results from rainfall and runoff when soil and other particles are removed from the land surface and transported into conveyance systems and water bodies. Suspended solids are naturally high in the Apalachicola river and bay system. Although erosion is a natural process, and particularly so in the Apalachicola system, it is frequently exacerbated by the activities of man, in both urban and rural environments. Nonpoint sources of suspended solids contribute 95% of the average daily loading of sediments to receiving waters in the U.S.

Monitoring and Water Quality Sampling Activities

During the course of this investigation, District staff met with local and state officials in the Apalachicola Bay area to discuss the project and begin identifying stormwater problems in the area. Through these discussions it was decided to form the Apalachicola Urban Stormwater Technical Advisory Committee, consisting of local officials and state offices involved with the nonpoint pollution problems in the area. The Apalachicola National Estuarine Research Reserve, the Bureau of Marine Resource Regulation and Development, the Department of Environmental Protection, the University of Florida, Franklin County, the City of Apalachicola, the Department of Community Affairs, the US Fish and Wildlife Service, and the National Resource Conservation Service all participated in the formation of the committee. The committee served as an information sharing and coordination mechanism for the Apalachicola Bay area. Topics of the periodic meetings included discussion of the problem areas in the Apalachicola Bay region, relating to water quality, and the location of the stormwater sampling sites and the sampling parameter selection. One of the major concerns voiced was the potential impacts of nonpoint upland sources on the seafood industry. It was pointed out that this is a concern shared with the Food and Drug Administration at the federal level, the leading agency involved in regulating this industry.

The monitoring activities were designed to provide data to characterize the quality and quantity of surface water run-off from selected sub-basins in the Apalachicola Bay watershed. The data collection effort included the measurement of channel stage discharge, rainfall, and the collection of water quality samples at low flow conditions (baseflow) and during storm events. The data collected provides both non-point source water quality parameter concentrations and loads contributed by the monitored sub-basins.

The type of monitoring equipment used for this study require well defined surface water conveyance such as open drainage channels or culverts for successful operation. Initially, monitoring was planned at six representative municipal or residential sub-basins where the highest density of development existed in Apalachicola, Eastpoint, St. George Island, Carrabelle and Lanark Village.

The St. George Island monitoring station was eliminated as a candidate site due to the lack of well defined drainage conveyance that would provide the suitable conditions for operation of a monitoring station and collection of water quality samples. Drainage on St. George Island is primarily sheet flow run-off that rapidly infiltrates into highly permeable sands.

The sampling sites that were selected are described on the following pages.

Monitoring Stations

- Station S526 is located in the southeast corner of Apalachicola in Battery Park, shown in Figure 10. Battery Park is located near the mouth of the Apalachicola River where it empties into Apalachicola Bay. The station is located on an inlet structure of a 34-inch diameter concrete storm drainage pipe that drains to the east into the Apalachicola River,. Land use within the sub-basin is approximately half residential and half commercial, with a small contribution from Battery Park (recreational) at the end of the conveyance system. The stormwater conveyance systems in this area are predominately grassed swales and vegetated ditches terminating at storm sewer drop inlet structures. The area sampled comprises a watershed area covering approximately 126 acres, as shown in Figure 11.

Figure 10: Battery Park Collection Station

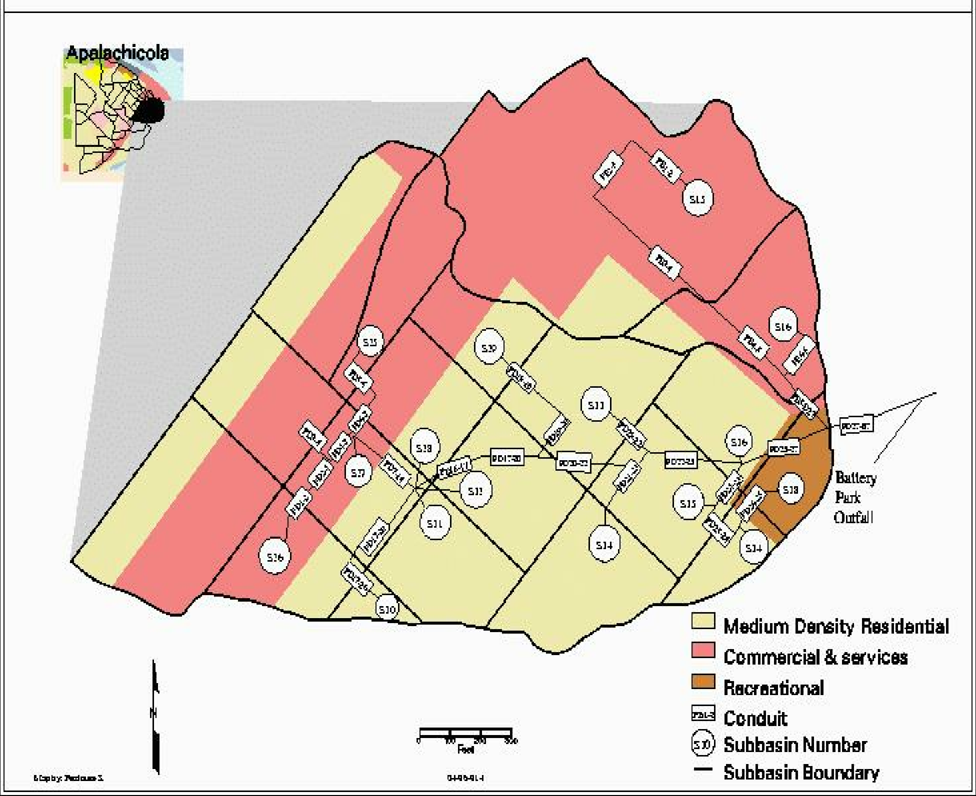


Figure 11: Battery Park Watershed

- Station S527 is located in northeast corner of the intersection of Avenue I and 4th Street. The station is located on a concrete headwall structure at the outlet of two 36-inch concrete drainage pipes, as shown in Figure 12. The major overland stormwater conveyance in this area is a vegetated ditch running east along the south side of Avenue J, terminating at a storm sewer drop inlet structure at the intersection of Avenue J and 7th Street. The ditch is irregular in cross section and is fragmented by numerous driveway culverts, some of which are partially blocked by debris or damaged outlet ends. Land use in the area sampled is primarily medium density residential, with some contributions from commercial sites. The ditch is irregular in cross section and is fragmented by numerous driveway culverts, some of which are partially blocked by debris or damaged ends. The area sampled covers a watershed area of about 51 acres, as depicted in Figure 13.

Figure 12: Avenue I Collection Station

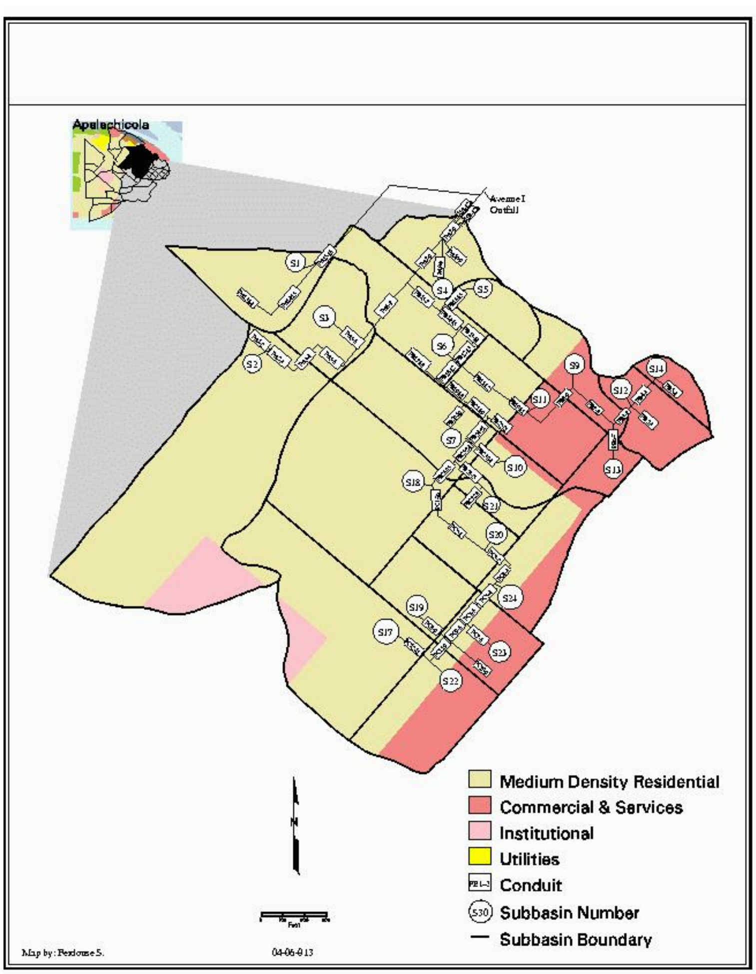


Figure 13: Avenue I Watershed

Station S525 is located on Indian Creek at the intersection with Hickory Dip Road (paved), approximately one block north of the Sportsman Lodge and Old Ferry Road in Eastpoint. The monitoring equipment was located on the east side of the channel about forty feet upstream (north) of two 30-inch diameter corrugated metal culverts under Hickory Dip Road, and is shown in Figure 14. The culverts were repaired after sustaining damage from Hurricane Opal and stabilized with granite rock. The portion of the Indian Creek watershed upstream of the monitoring station includes nine sub-basins covering 740 acres. Drainage from this area is predominately sheet flow into a low vegetated wet corridor that conveys water southwest into East Bay. The entire Indian Creek watershed that discharges into East Bay covers approximately 877 acres, and was shown previously in Figure 5.

Figure 14: Eastpoint Sampling Station

Figure 15: Carrabelle Sampling Station

Figure 16: Lanark Village Sampling Station

- Station S524 is located on a small stream in the coastal community of Carrabelle. The station is located on the east side of Carrabelle adjacent to Osbourne Street, on private property. The monitoring station is located approximately 1000 feet upstream from the discharge point where the channel empties into St. George Sound. A photograph of the sampling station is shown as Figure 15. The small tannic colored stream is a meandering channel with a sandy bottom. There is limited vegetation in the channel in the vicinity of the monitoring station. The primary types of land use in this drainage area include medium to low density residential, silviculture and natural land use. The contributing area for the monitoring station is approximately 641 acres, and was previously shown in Figure 7.

- Station S523 is located on a grass swale drainage channel adjacent the Lanark Village retirement community. The station is on the upstream side (north side) of a 36-inch culvert that flows under U.S. 98 and directly into St. George Sound, as shown in Figure 16. The sub-basin for this monitoring station is approximately 50 acres in size and is predominately medium density residential land use as previously shown in Figure 9. The primary conveyance is grass swale ditches along the side of the roadways in the community. One small pond that receives groundwater inflow discharges into the ditch upstream of the monitoring station. A drainage ditch along the side of U.S. 98 that drains towards the west contributes runoff to the monitoring station site.

Stage and Rainfall Data Acquisition

Automated digital data collection equipment was installed at the five monitoring sites. The automated data collection equipment used on the project was a Data Acquisition System (DAS) that has the capability to process and record a variety of environmental data and send output signals to auxiliary equipment to control water quality sample collection. The data is stored internally by the DAS in digital format and is retrieved from the field by portable computers. The types of automated digital data collected for this study include water level (stage), discharge data and rainfall data. The digital data were recorded in the DAS on a ten minute time interval. The data recording time interval utilized at a station is, in part, determined by the size and response characteristics of the watershed and the type of data analyses required. All five monitoring stations collected stage and discharge data. The stage data were recorded using pressure transducer water level sensors that convert the pressure of the water column over the sensor into a stage level measurement in hundredths of a foot resolution.

Two stations (Battery Park - S526 and Indian Creek - S525) had tipping bucket sensors to measure continuous rainfall data. This type of sensor uses a calibrated see-saw bucket mechanism to record rainfall data in increments of one hundredth of an inch. In addition, rainfall data from a Florida Forest Service Tower in Carrabelle were obtained for the study.

Discharge Data Acquisition

The discharge data were calculated and stored in the DAS using a non-linear conversion function to translate the stage levels to corresponding discharge rates. The non-linear function uses a rating table developed by a hydrologist to convert stage levels to discharge values for stage level variations as small as one hundredth of a foot. The discharge data were then stored in the DAS along with the stage and rainfall data for retrieval or use by another programming function in the DAS. The non-linear conversion table was produced from the stage/discharge rating developed for each station.

The stage discharge ratings were developed using conventional open channel discharge measurements supplemented with calculated discharge values using Manning's equation for stage levels outside the empirically measured range. A series of seven to twelve conventional channel discharge measurements were completed at each station over as wide a range of stage levels as possible. The monitored sites were surveyed to determine channel slope and channel or drainage pipe geometry to provide the information required to calculate discharges using Manning's equation.

Water Quality Sample Collection

Water quality samples were collected at dry weather conditions (baseflow) and during storm events to characterize the concentration and the quantity of pollutants in the stormwater runoff. A Quality Assurance Project Plan (QAPP Number 8905636) was submitted and approved by the

Florida Department of Environmental Protection's (FDEP) Quality Assurance Section. All water quality sample collection was conducted in accordance with the Project QAPP and FDEP's and the District's standard operating procedures.

The FDEP Central Laboratory analyzed chemistry samples on this project, and the FDEP Shellfish Environmental Assessment Facility in Apalachicola analyzed microbiological samples. Samples were collected by District staff in sample containers provided by the laboratories and all sample collection and preservation protocols described in the QAPP were followed for sample collection activities.

Two dry weather (baseflow) samples and a minimum of three storm event samples were planned for the project. Baseflow samples were analyzed for the physical, nutrient, heavy metal and biological constituents listed in Table 1. In addition to the laboratory parameters, field parameters were measured for dry weather samples. Dry weather samples were collected by grab sample method in a well mixed flowing portion of the drainage channel.

Table 1: Water Quality Parameters

Laboratory Parameters

Physical Analytes	**Metal Analytes**
Turbidity	Aluminum
Alkalinity	Arsenic
Total suspended solids	Cadmium
	Calcium
	Chromium
Nutrient Analytes	Copper
Total Phosphorus	Iron
Ortho-Phosphorus	Lead
Nitrate-Nitrite	Magnesium
Total Kjeldahl Nitrogen	Nickel
Ammonia Nitrogen	Zinc
Biological Analytes	
Total coliform	
Fecal coliform	
Fecal streptococci	

Field Parameters

Dissolved Oxygen
pH
Specific Conductance
Salinity
Temperature
Secchi Depth

Stormwater samples were collected using an automatic sample collection instrument that collects and preserves the samples on ice until they could be retrieved. The sample collection method used was the flow-weighted composite method. This method combines a series of individual and discrete sample aliquots of equal volume, taken at equal increments of flow, into a single collection container. This resulted in a composite sample that is proportional to the flow for the entire rain storm event.

The DAS is used as the primary controlling device for collecting flow-weighted samples. The criteria for setting up the automatic samplers in advance of an event was a National Weather Service forecast of greater than 50% probability of rainfall. The sample event set-up consisted of: installing a fresh battery on the auto-sampler, checking the equipment for proper operation, replacing the intake tubing, icing the sampler and setting the stage threshold value. The stage threshold value was set to the water level at which storm water discharge begins at each site. The stage threshold value varied depending on antecedent conditions at each station, but was typically set 0.05 feet to 0.10 feet above the existing water level when the station was set up.

Run-off characteristics were analyzed for each station to determine the flow rate accumulations that would result in a flow weighted composite sample representative of the entire rainfall event. The targeted range of total accumulated rainfall for sampling events ranged from 0.50 inches to 3.00 inches. The flow limit value that initiated the collection of an individual sample was adjusted to allow the collection of between nine and thirty individual sample aliquots for each composite storm sample.

Two base flow samples were collected on June 25 and September 25, 1996. A total of five storm events were sampled, in varying combinations between the five stations, during the period of September 29, 1996 and February 14, 1997. Table 2 shows the distribution of captured storms.

Table 2: Date of Storm Capture by Site

Station Number	**Station Name**	9/29/96	12/19/96	1/9/97	1/25/97	2/14/97
S523	Lanark Village	X	X		X	X
S524	Carrabelle	X	X	X	X	
S525	Eastpoint	X	X	X	X	
S526	Battery Park	X		X		X
S527	Avenue I	X		X		X

Water Quality Analysis

As mentioned earlier, two base flow samples were collected from all five sampling sites. Laboratory results from these two events, sorted by station and parameter, are presented on the following two pages, in Table 3.

Table 3: Base Flow Water Quality Sampling Results

Parameter/ Storet Code/ units	**Station Number**	**Minimum**	**Maximum**	**Average**
Dissolved Oxygen	S523	6.1	7.1	6.6
299	S524	4.3	4.5	4.4
mg/l	S525	3.8	4.9	4.35
	S526	4.9	6	5.45
	S527	1.7	2.2	1.95
pH	S523	7.21	7.49	7.35
400	S524	4.21	5.24	4.725
pH Units	S525	5.21	6.93	6.07
	S526	7.01	7.43	7.22
	S527	7.1	7.27	7.185
Specific Conductance	S523	151	162	156.5
94	S524	101	195	148
*u*mho/cm	S525	109	165	137
	S526	800	980	890
	S527	500	1620	1060
Temperature	S523	27	29.9	28.45
10	S524	22.6	25.1	23.85
degrees Celcius	S525	23.1	27.1	25.1
	S526	26.2	26.3	26.25
	S527	25.1	25.2	25.15
Depth	S523	0.15	0.25	0.2
	S524	0.2	0.3	0.25
meters	S525	0.1	0.35	0.225
	S526	0.2	0.5	0.35
	S527	0.3	0.4	0.35
Turbidity	S523	0.25	0.35	0.3
76	S524	1.7	1.8	1.75
(NTU)	S525	1.7	7.2	4.45
	S526	1.4	2.2	1.8
	S527	2.4	2.9	2.65
Total Suspended Solids	S523	2	2	2
530	S524	2	5	3.5
(mg/L)	S525	2	15	8.5
	S526	2	6	4
	S527	2	3	2.5
Coliforms, Total	S523	130	920	525
31501	S524	49	920	484.5
(colonies/100 ml)	S525	1600	1700	1650
	S526	1600	1700	1650
	S527	1600	1600	1600

Table 3, Continued: Base Flow Water Quality Sampling Results

Coliforms, Fecal 31616 (colonies/100 ml)	S523 S524 S525 S526 S527	17 33 49 350 540	220 350 920 920 1600	118.5 191.5 484.5 635 1070
Streptococci, Fecal 31673 (colonies/100 ml)	S523 S524 S525 S526 S527	2 2 2 6 2	130 2 1600 1600 1600	66 2 801 803 801
Ammonia Nitrogen, as N 610 (mg N/L)	S523 S524 S525 S526 S527	0.01 0.17 0.043 0.19 0.078	0.032 0.39 0.06 0.4 0.4	0.021 0.28 0.0515 0.295 0.239
Total Kjeldahl Nitrogen, as N 625 (mg N/L)	S523 S524 S525 S526 S527	0.3 1.1 0.79 0.73 0.74	0.35 1.3 1.3 1.6 1.5	0.325 1.2 1.045 1.165 1.12
Nitrate+Nitrite, as N 630 (mg N/L)	S523 S524 S525 S526 S527	0.028 0.034 0.025 0.12 0.083	0.056 0.034 0.027 0.15 0.16	0.042 0.034 0.026 0.135 0.1215
Phosphorous, Total as P 665 (mg P/L)	S523 S524 S525 S526 S527	0.019 0.024 0.051 0.065 0.073	0.023 0.083 0.15 0.17 0.18	0.021 0.0535 0.1005 0.1175 0.1265
Orthophosphate, as P 671 (mg P/L)	S523 S524 S525 S526 S527	0.006 0.014 0.048 0.057 0.063	0.015 0.041 0.05 0.072 0.11	0.0105 0.0275 0.049 0.0645 0.0865
Magnesium 927 (mg/L)	S523 S524 S525 S526 S527	1.67 1.13 1.43 25 8.92	1.67 2.03 2.4 36.7 31.6	1.67 1.58 1.915 30.85 20.26
Zinc 1092 (ug/L)	S523 S524 S525 S526 S527	5 10 8 8 20	10 10 30 53 38	7.5 10 19 30.5 29

Lanark Village (Station S523) base flow sampling showed overall good water quality, with little apparent impact from development. There was one instance of elevated total coliforms (920 colonies/100 ml), which may or may not be attributable to man-made sources, as elevated coliforms are not uncommon even in pristine basins. The Lanark Village drainage basin has well-developed best management practices, including wide, shallow grassed swales and a wet detention system, which appear to be reducing the amount of contaminants released to the bay.

Carrabelle (Station S524) base flow sampling also indicated overall good water quality. Dissolved oxygen was depressed slightly below 5 mg/l (Class III Water Quality Standards, F.A.C.), and a consistently low pH accompanied this. Coliform counts were highly variable, and were elevated in one instance.

Eastpoint (Station S525) base flow sampling indicated consistently depressed dissolved oxygen level. It also had the highest base flow turbidity of all the sites surveyed. Total and fecal coliform colony counts and fecal streptococci colony counts were also consistently elevated. Although not a constituent of concern, this site also exhibited the highest dissolved iron content, more than twice that of the next highest site level. This waterway is a "blackwater" type of system, which is typically high in iron.

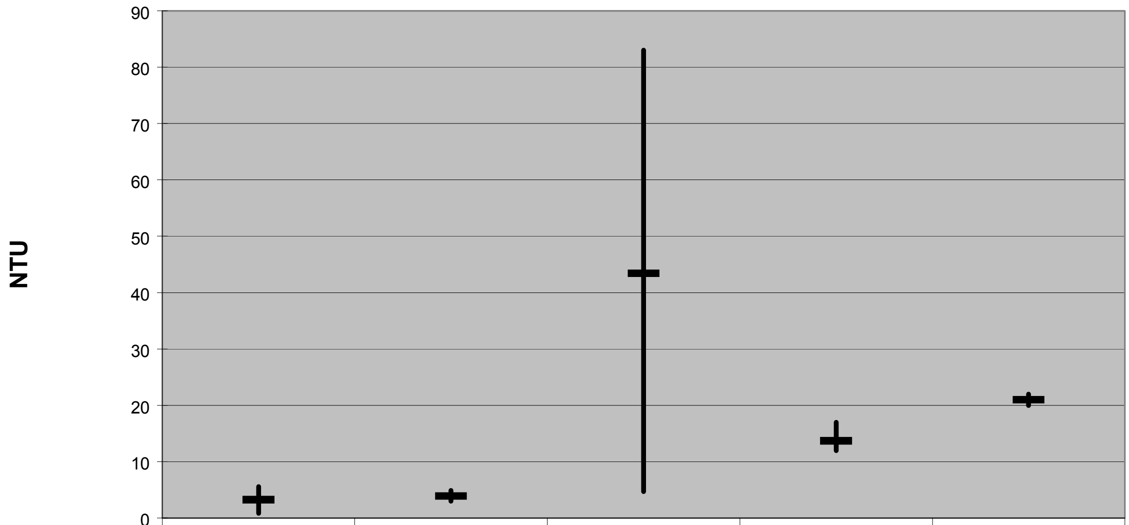
Apalachicola, southeast corner of Battery Park (S526), base flow sampling indicated significant bacteriological contamination, as total and fecal coliforms and fecal streptococci were all consistently elevated. Magnesium and zinc levels were also elevated.

Apalachicola, northwest corner of Avenue I and 4th Street (S527), showed the highest concentrations of contaminants in the base flow samples of any of the sites surveyed. Dissolved oxygen was consistently impaired, averaging less than 2 mg/l. Specific conductance was markedly elevated, which may indicate the site's tidal influence. Total and fecal coliform colony counts were consistently elevated, as were fecal streptococci colony counts. Nutrients in the base flow, including ammonia-nitrogen, total Kjendahl nitrogen, nitrate+nitrite, phosphorus and orthophosphate, were also markedly elevated. This combination of results could be indicative of sewage contamination, through cross connections or illicit connections.

With the exception of the contamination noted at the Avenue I site in Apalachicola (S527), base flow water quality at the sampling sites was generally good. There were isolated instances of dissolved oxygen depression and bacterial contamination noted, but the only site currently needing more investigation into base flows was S527.

The results of storm flows sampled at the sites were generally variable. Figures 17 through 26 indicate the mean concentrations of various contaminants found in the storm flows, and also indicate the maximum and minimum levels. Appendix B provides statistical tables for storm flows. Figures 27 through 34 depict average change in storm flows over base flows.

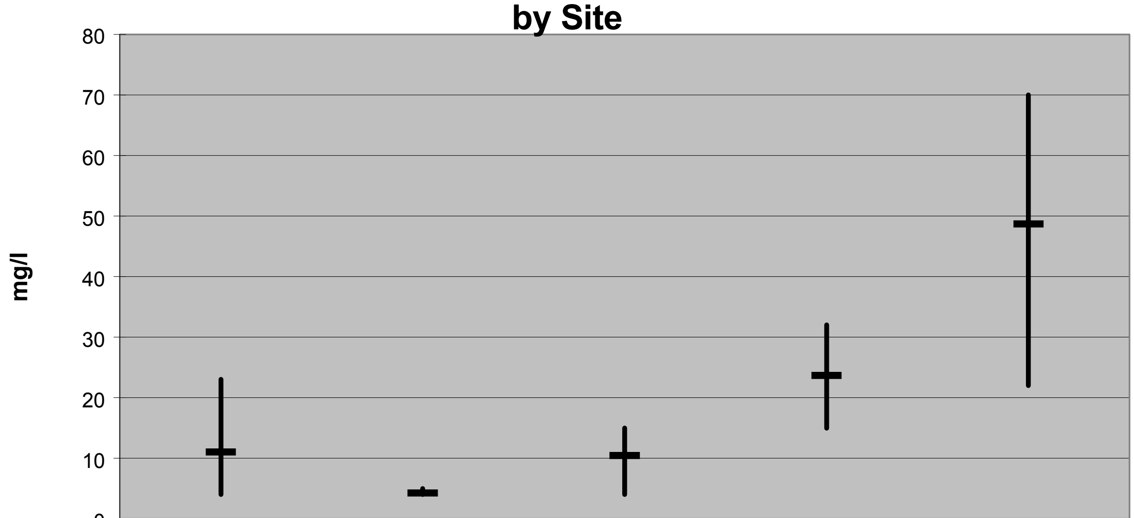
Figure 17: Storm Flow Turbidity Ranges by Site



	S523	S524	S525	S526	S527
Maximum	5.60	4.90	83.00	17.00	22.00
Minimum	0.85	3.00	4.70	12.00	20.00
Mean	3.2	3.9	43.4	13.7	21.0

Site Number

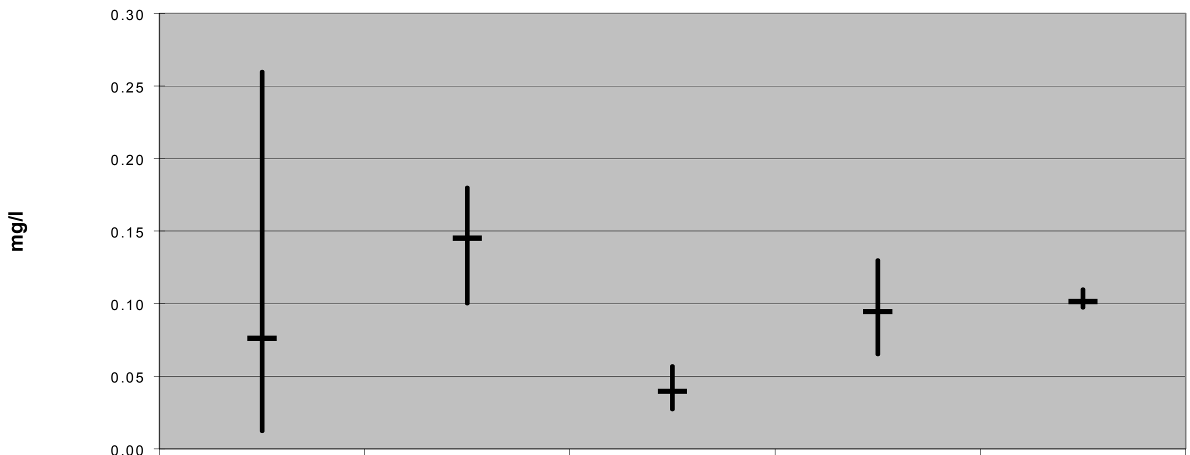
Figure 18: Storm Flow Total Suspended Solid Ranges by Site



	S523	S524	S525	S526	S527
Maximum	23.00	5.00	15.00	32.00	70.00
Minimum	4.00	4.00	4.00	15.00	22.00
Mean	11	4	10	24	49

Site Number

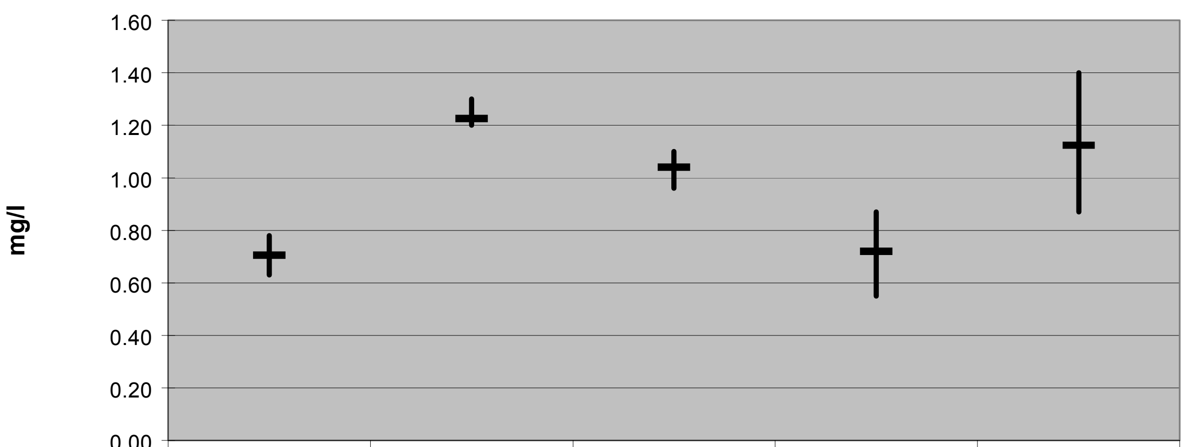
Figure 19: Storm Flow Ammonia Nitrogen Ranges by Site



	S523	S524	S525	S526	S527
Maximum	0.26	0.18	0.06	0.13	0.11
Minimum	0.01	0.10	0.03	0.07	0.10
– Mean	0.08	0.15	0.04	0.09	0.10

Site Number

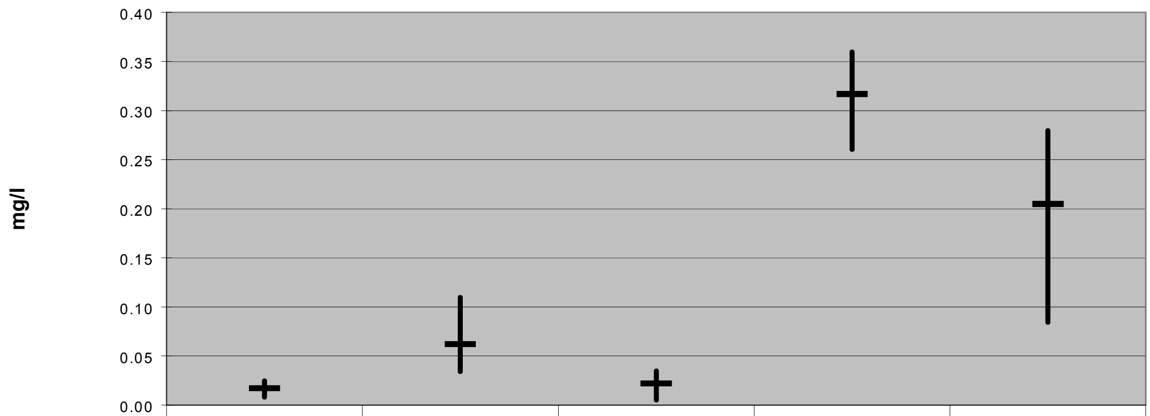
Figure 20: Storm Flow Total Kjeldahl Nitrogen Ranges by Site



	S523	S524	S525	S526	S527
Maximum	0.78	1.30	1.10	0.87	1.40
Minimum	0.63	1.20	0.96	0.55	0.87
– Mean	0.71	1.23	1.04	0.72	1.12

Site Number

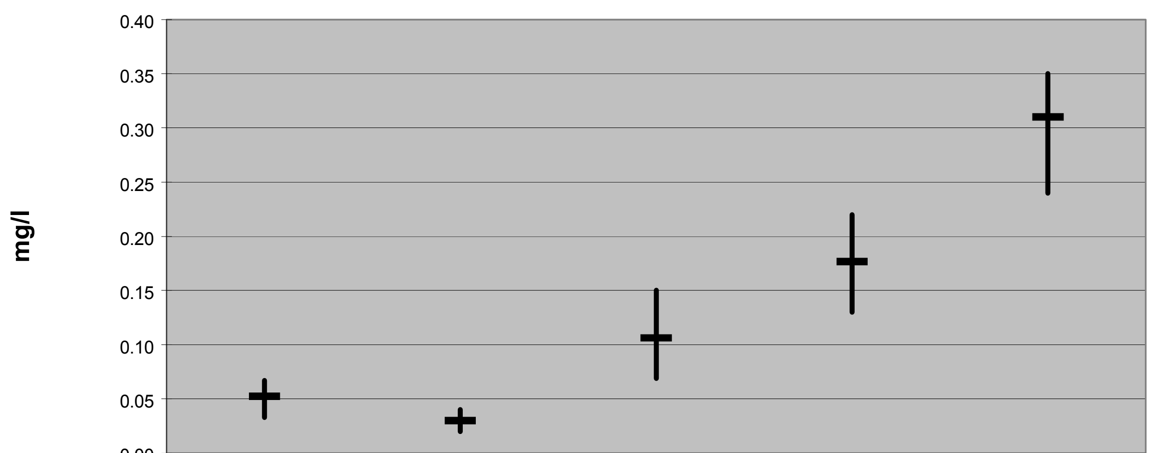
Figure 21: Storm Flow Nitrate+Nitrite Ranges by Site



	S523	S524	S525	S526	S527
Maximum	0.03	0.11	0.04	0.36	0.28
Minimum	0.01	0.03	0.01	0.26	0.08
– Mean	0.02	0.06	0.02	0.32	0.20

Site Number

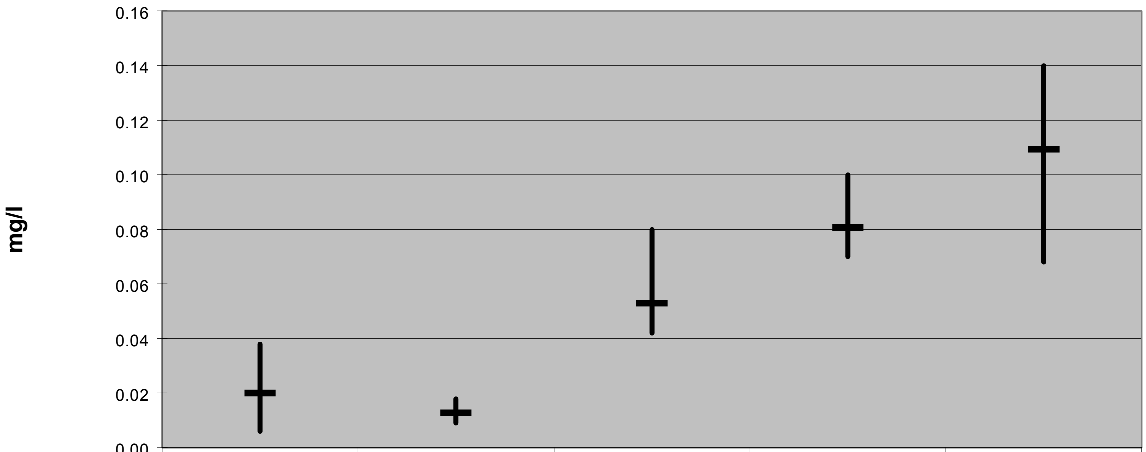
Figure 22: Storm Flow Total Phosphorus Ranges by Site



	S523	S524	S525	S526	S527
Maximum	0.07	0.04	0.15	0.22	0.35
Minimum	0.03	0.02	0.07	0.13	0.24
– Mean	0.05	0.03	0.11	0.18	0.31

Site Number

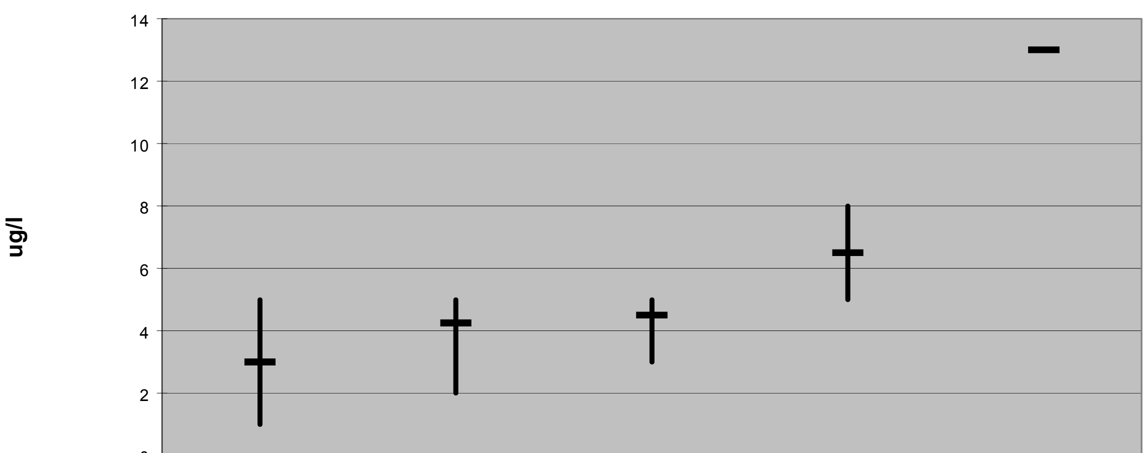
Figure 23: Storm Flow Orthophosphate Ranges by Site



	S523	S524	S525	S526	S527
Maximum	0.04	0.02	0.08	0.10	0.14
Minimum	0.01	0.01	0.04	0.07	0.07
Mean	0.02	0.01	0.05	0.08	0.11

Site Number

Figure 24: Storm Flow Copper Ranges by Site



	S523	S524	S525	S526	S527
Maximum	5	5	5	8	13
Minimum	1	2	3	5	13
Mean	3	4	5	7	13

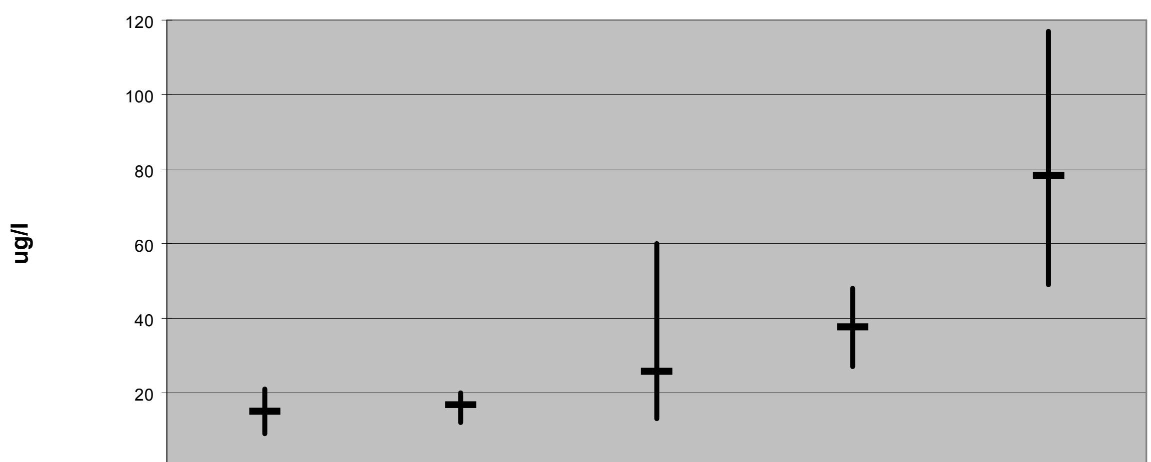
Sire Number

Figure 25: Storm Flow Lead Ranges by Site

	S523	S524	S525	S526	S527
Maximum	0	0	0	26	27
Minimum	0	0	0	20	13
Mean	0	0	0	23	20

Site Number

Figure 26: Storm Flow Zinc Ranges by Site



	S523	S524	S525	S526	S527
Maximum	21	20	60	48	117
Minimum	9	12	13	27	49
Mean	15	17	26	38	78

Site Number

Figure 27: Average Increase in Turbidity During Storm Events

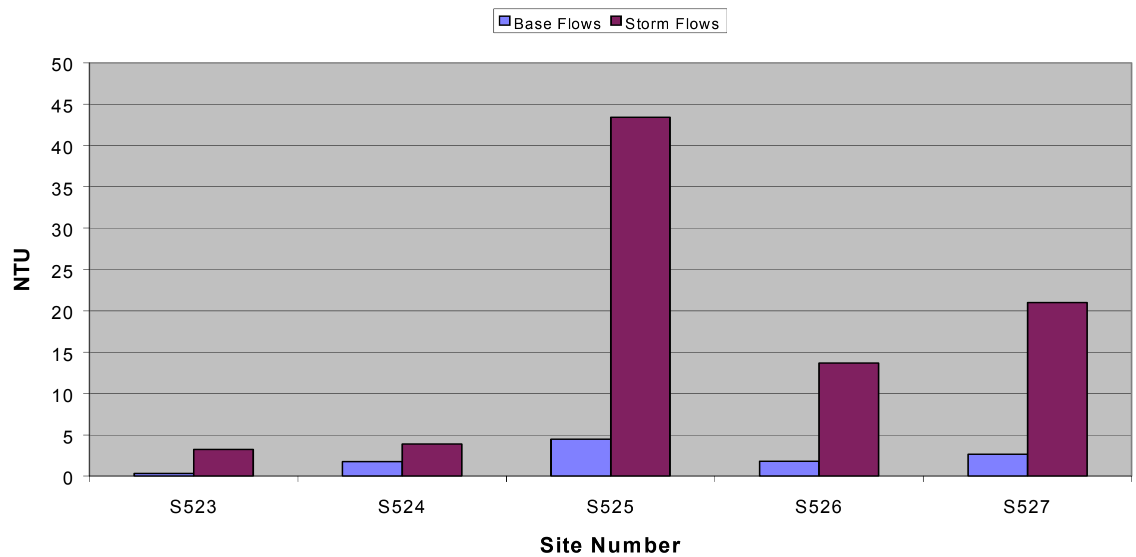


Figure 28: Average Increase in Total Suspended Solids During Storm Events

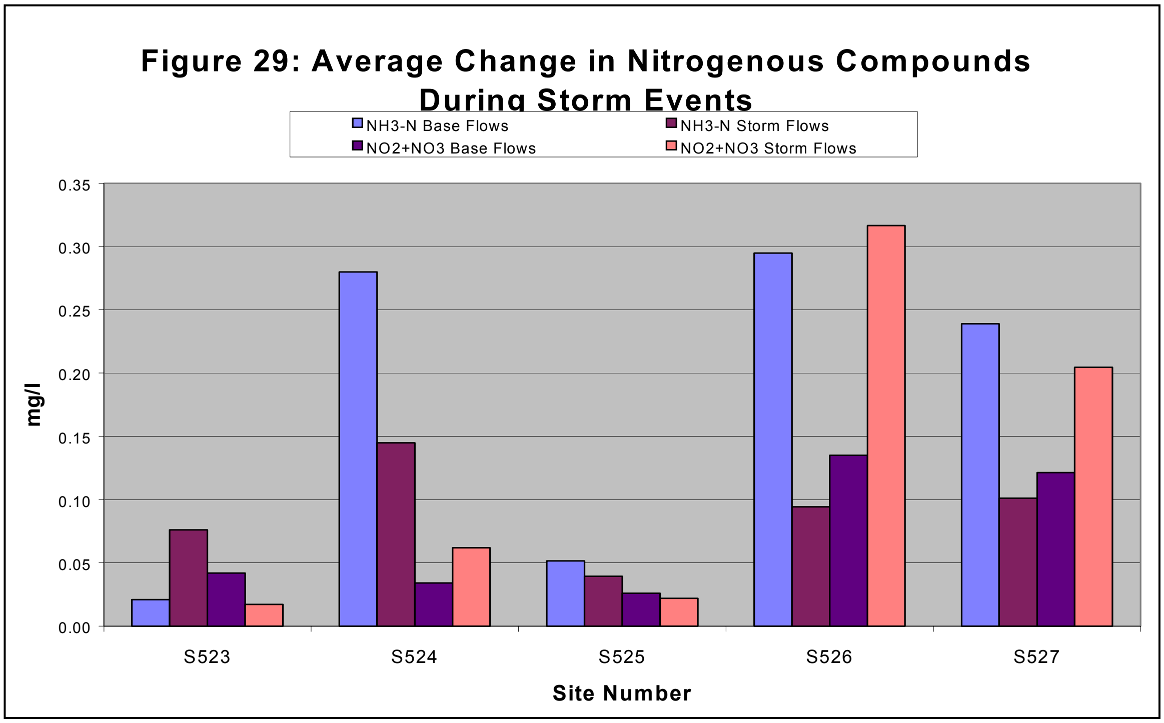


Figure 29: Average Change in Nitrogenous Compounds During Storm Events
NH3-N Base Flows
NH3-N Storm Flows
NO2+NO3 Base Flows
NO2+NO3 Storm Flows
mg/l
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
S523
S524
S525
S526
S527
Site Number

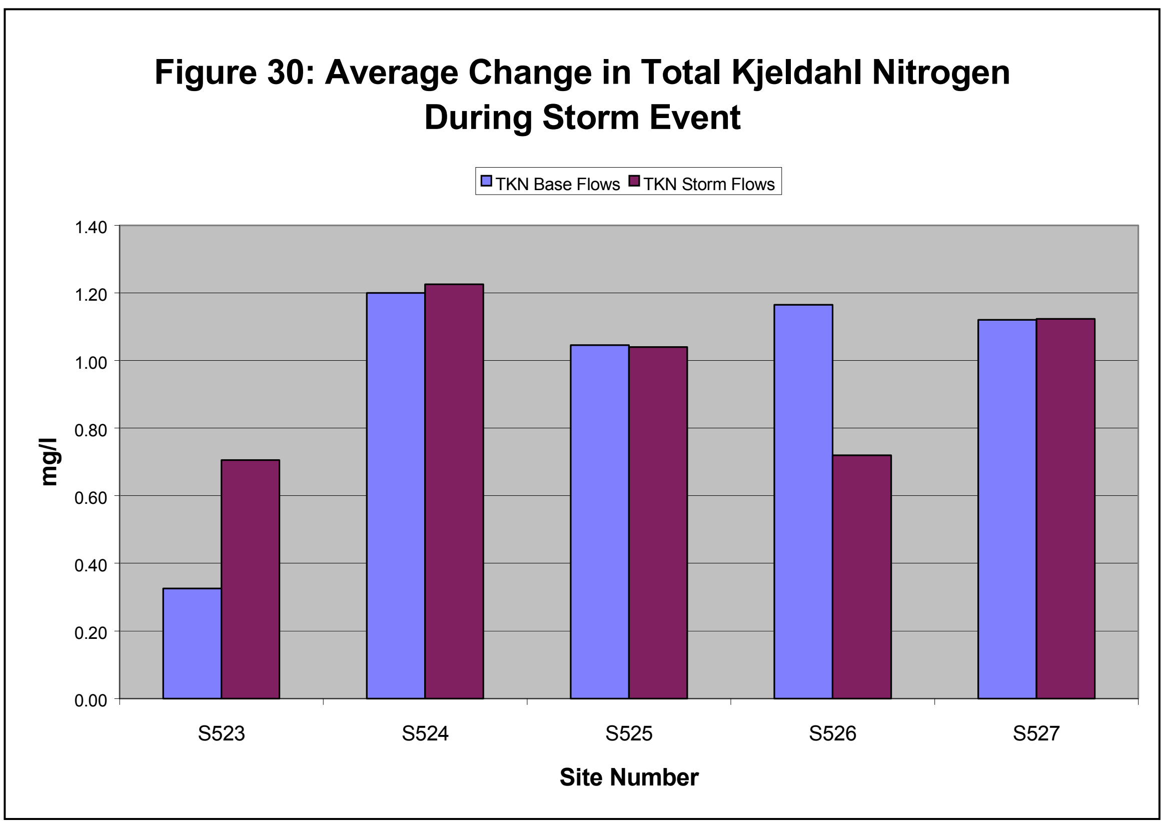


Figure 30: Average Change in Total Kjeldahl Nitrogen During Storm Event
TKN Base Flows
TKN Storm Flows
mg/l
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
S523
S524
S525
S526
S527
Site Number

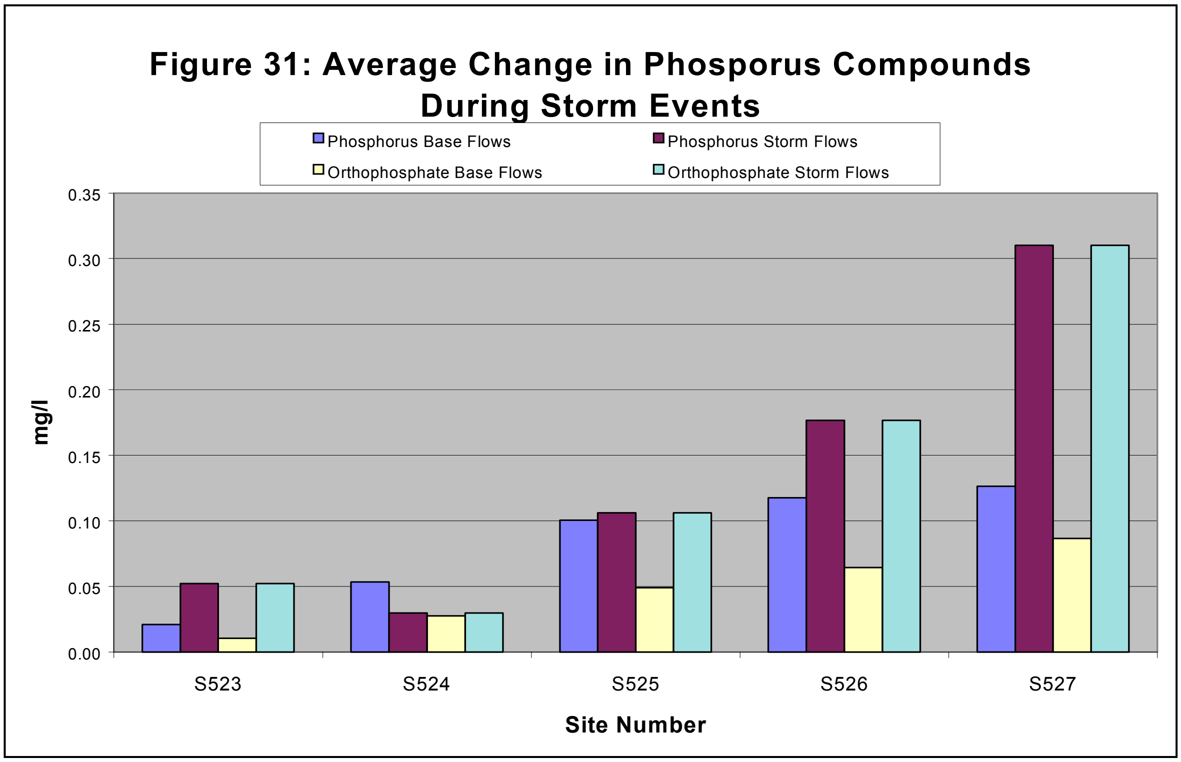


Figure 31: Average Change in Phosporus Compounds During Storm Events
Phosphorus Base Flows
Phosphorus Storm Flows
Orthophosphate Base Flows
Orthophosphate Storm Flows
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
mg/l
S523
S524
S525
S526
S527
Site Number

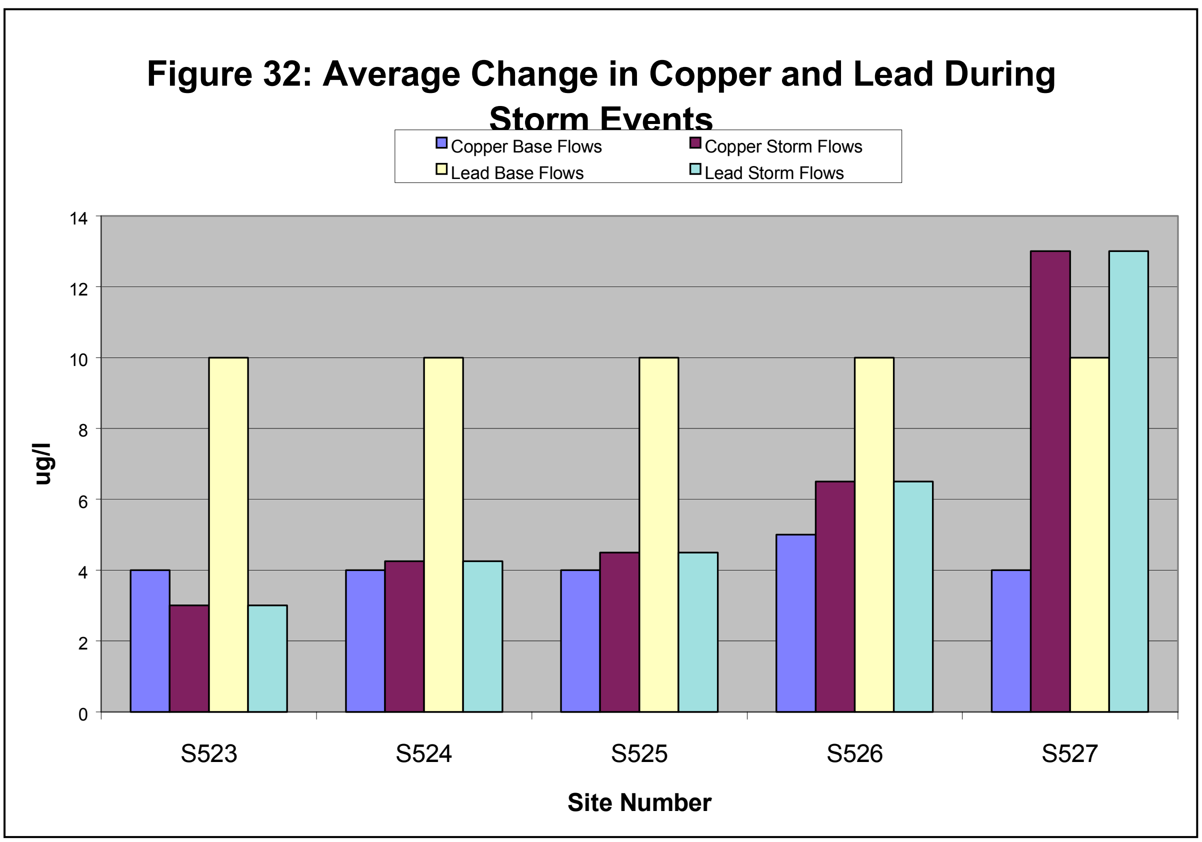


Figure 32: Average Change in Copper and Lead During Storm Events
Copper Base Flows
Copper Storm Flows
Lead Base Flows
Lead Storm Flows
14
12
10
8
6
4
2
0
ug/l
S523
S524
S525
S526
S527
Site Number

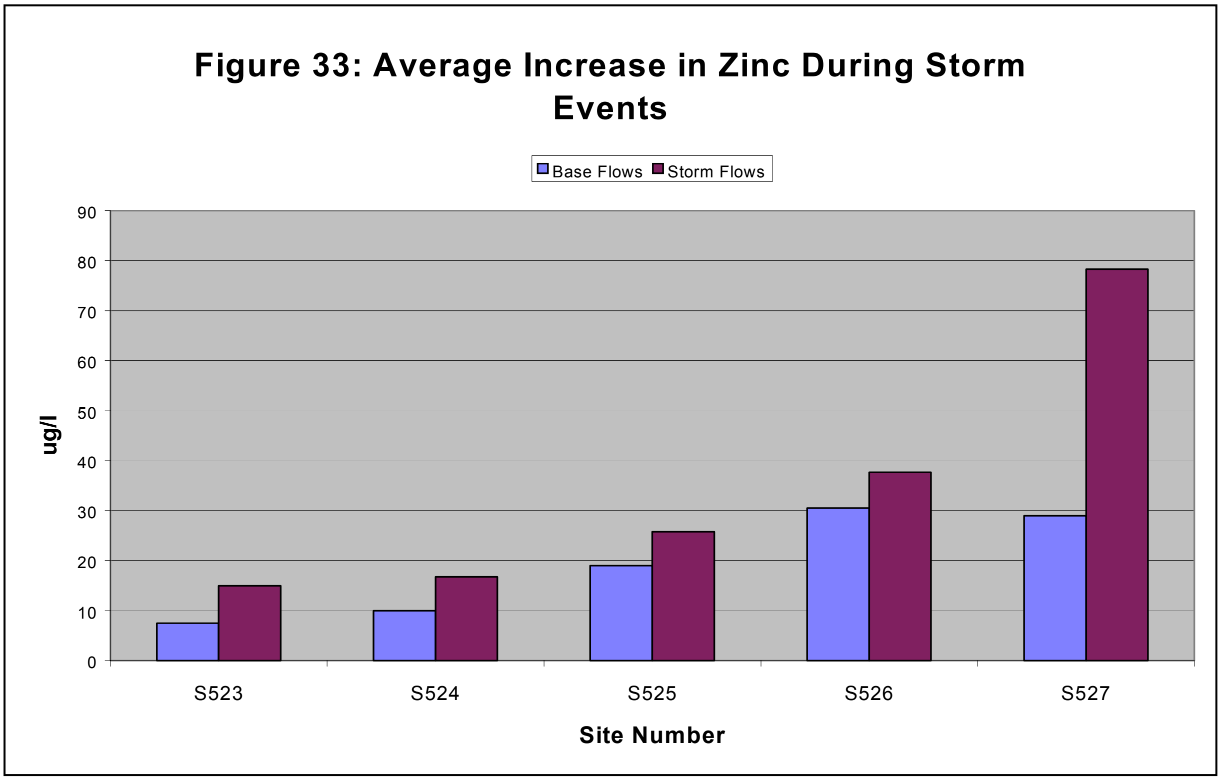


Figure 33: Average Increase in Zinc During Storm Events
Base Flows
Storm Flows
90
80
70
60
50
40
30
20
10
0
ug/l
S523
S524
S525
S526
S527
Site Number

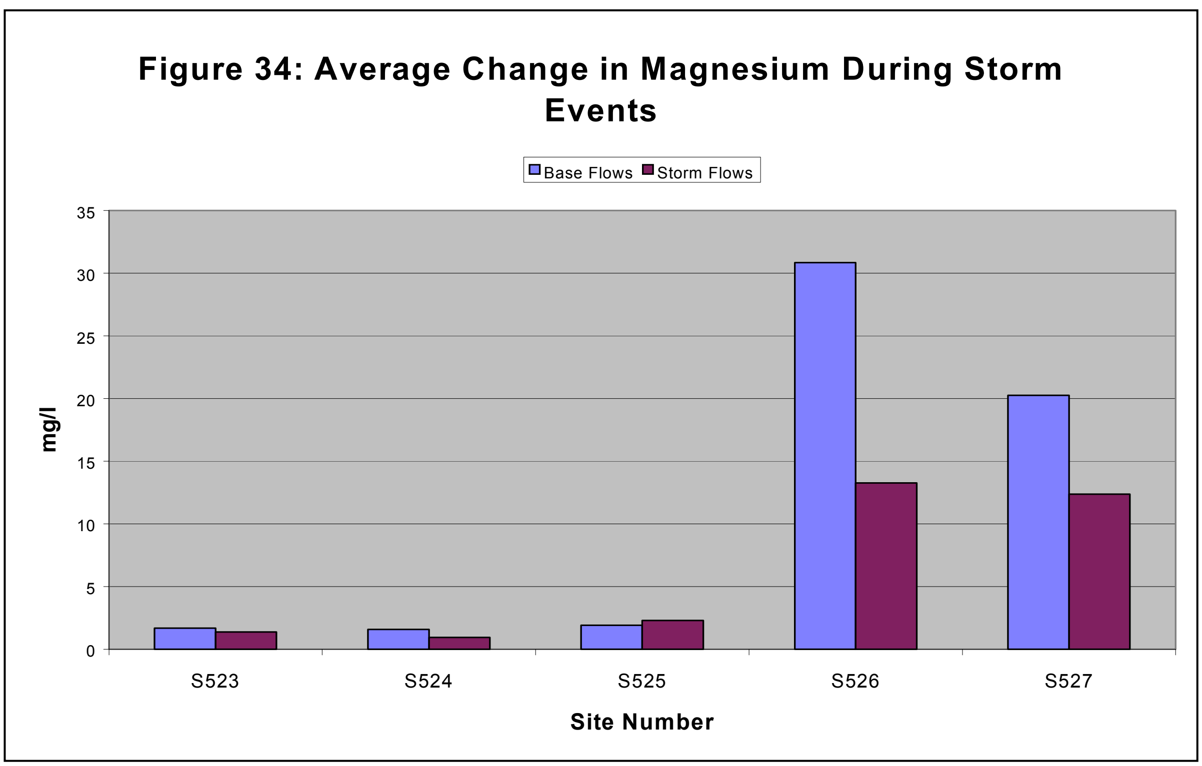


Figure 34: Average Change in Magnesium During Storm Events
Base Flows
Storm Flows
35
30
25
20
15
10
5
0
mg/l
S523
S524
S525
S526
S527
Site Number

Lanark Village (Station S523) storm flows show little effect from development. Most constituents were relatively low and consistent, although ammonia nitrogen was highly variable, reaching at various times both the maximum and minimum values noted in all five sites (see Figure 19). Comparison of storm flows to base flows indicated moderate increases in contamination, with an average five-fold increase in total suspended solids accompanying a slight increase in turbidity over base flow averages. Only slight changes in other constituents were noted.

Carrabelle (Station S524) storm flows also showed only minor changes from base flows. While the levels of contaminants measured at this station were higher than the previous one, levels were relatively unchanged in reaction to storm events. Nutrients generally decreased over base flow averages during storm events, possibly due to dilution, while zinc showed a slight increase over base flow averages.

Eastpoint (Station S525) storm flow turbidities were elevated and highly variable, the most widely so of all stations sampled, reaching levels of almost ten times those of the base flows. Recent repairs and earth works in the basin, as well as contributions from dirt roads, all might account for the elevated storm flow turbidities. Total Kjeldahl Nitrogen was also consistently elevated in the storm flow, again higher than the other four sampling sites. Other nutrients, including ammonia-nitrogen, nitrate+nitrite, total phosphorus and orthophosphate were present in consistently low amounts. Zinc was also present in varying amounts.

Apalachicola, southeast corner of Battery Park (S526) storm flows tended to exacerbate problems noted previously in the discussions of base flow contamination levels. Increased levels of turbidity, total suspended solids, nitrate+nitrite, phosphorus, and lead were documented. It is of interest to note that little variability in the elevations was documented.

The second sampling site in Apalachicola, at the northwest corner of Avenue I and 4th Street (S527), also showed impairments to water quality, both in the previously discussed base flow and in storm flows. Turbidity was consistently elevated, and total suspended solids were both the highest and most variable of all sites tested. Nutrients were elevated, with total phosphorus and orthophosphate the highest measured of all sites. Copper was also markedly elevated over base flows, with lead, magnesium and zinc also present. This area of the city may be considered to be economically depressed, with deteriorating infrastructure. The results of this sampling are consistent with this observation.

Overall, it would appear that the largest nonpoint source pollutant problems identified are turbidity, total suspended solids, coliforms, nutrients and some metals, including copper, zinc and lead. All sites surveyed showed no effect from cadmium, chromium, or nickel. The apparent problems are consistent with the group of contaminants known as stormwater pollutants, and are also consistent with impacts due to development, economic depression, and deteriorating infrastructures.

Investigations Into Coliform Bacteria

Coliform bacteria, as typified by *Escherichia coli* (*E. coli*) and fecal streptococci (enterococci), have for decades been used as indicator organisms. An indicator organism is a microorganism whose presence is evidence that water has been polluted with the feces of humans or other warm-blooded animals. The coliform group of bacteria, commonly used as an indicator, is defined as aerobic and facultative anaerobic, nonspore forming, Gram-stain negative rods that ferment lactose with gas production within 48 hours of incubation at 35^{o}C. Coliforms reside in the intestinal tract, and are excreted in large numbers in feces, averaging about 50 million coliforms per gram. Pathogenic bacteria and viruses causing enteric diseases in humans originate from fecal discharges of diseased persons. Pathogenic bacteria, however, are normally present at very low levels, and are expensive and difficult to isolate and identify. Isolation of disease causing organisms is further complicated by their low survival rate in the ambient environment. Coliform bacteria, on the other hand, have a relatively high survival rate in the ambient environment and are easily and inexpensively identified with a minimum of laboratory equipment. Consequently, water contaminated by fecal pollution is identified as being potentially dangerous by the presence of coliform bacteria.

Elevated coliform counts frequently close the Bay to shellfish harvesting. Levels increase in the Bay during local rainfall and when the Apalachicola River rises. It is assumed that rainfall transports bacteria from the land into the river, and that the river transports bacteria to the Bay. The high coliform counts observed in the base flows of the selected sites led NWFWMD to investigate the distribution and sources of coliform bacteria entering the bay. Long-term fecal coliform data collected from specific sites within the Apalachicola Bay shellfish harvesting area were obtained from the FDEP Division of Marine Resources. In addition to coliform data, the files also contained corresponding data on local rainfall and river stages. These data were plotted onto a map of the Bay utilizing the District's GIS system. Figure 35 depicts average coliform count isoconcentration lines within the Apalachicola Bay, developed using the same techniques

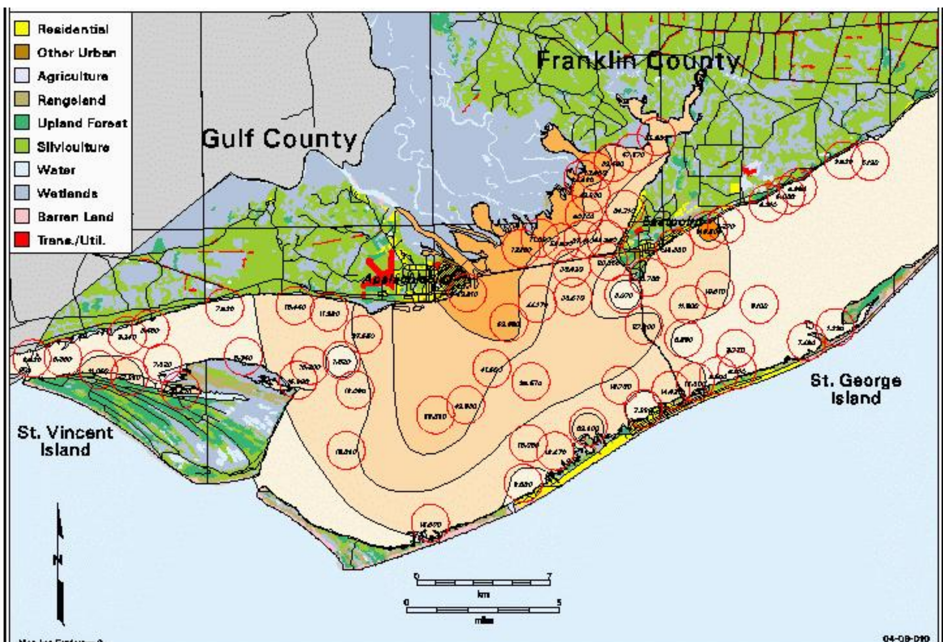


Figure 35: Distribution of Coliform Concentrations

used to depict contamination plumes in groundwater contamination analysis. Higher average concentrations are indicated in the figure by darker colors; conversely, lower average concentrations are indicated by lighter colors. The figure suggests that the source of coliform contamination is closely associated to the Apalachicola River inflow. Local nonpoint discharges adjacent to the bay at Apalachicola, Eastpoint and St. George Island also appear to contribute to the coliform contamination within the bay. This observation seems consistent with the land-based sampling efforts previously described. A statistical summary of the long-term fecal coliform data from the Apalachicola Bay shellfish harvesting areas collected from January 1979 through December 1995 is located as a table in Appendix C. The number of samples taken was highly variable, ranging from single samples taken in some areas to several hundred in others. The sampling results were highly variable as well, with means ranging from less than one to thousands of colonies measured in samples from a single site.

In late fall of 1996, FDEP initiated a water quality study to identify sources of fecal coliform bacteria. Fecal coliform levels were monitored by FDEP at selected locations in the Apalachicola River and its tributaries from the Chipola River cutoff south, beginning in November 1996 and ending in March 1998. River and tributary samples were collected on dates selected to coincide as closely as possible with sampling done by FDEP's Shellfish Environmental Assessment Section in Apalachicola Bay. A total of 11 coordinated river and bay sampling excursions were conducted during the study period. Elevated levels of fecal coliform were observed throughout the study area. Observed levels varied widely by location and time of year, with no single location or suite of locations having elevated levels during each sampling event. The most frequent high coliform levels were found in the upper reaches of tributaries in the immediate vicinity of the City of Apalachicola, including Breakaway Canal, Poorhouse Creek, and Scipio Creek. Brothers River and Jackson River above and below Huckleberry Creek also demonstrated frequently elevated coliform levels.

All tributaries demonstrated high coliform levels periodically during the study. In the Chipola, Brothers, and Jackson Rivers, levels at or above 200 MPN/100 ml at tributary mouths were observed in February 1997 and 1998, and in May 1997 in the Chipola River. At the mouths of smaller tributaries in the upper portion of the study area, such as Kennedy, Brushy, Scott, Owl and Smith Creeks, levels at or above 200 MPN/100 ml also occurred in February 1997 and 1998, and in May 1997 at Kennedy Creek. A similar pattern was observed at smaller tributary mouths from Jackson River south, including Grassy, Poorhouse, and Scipio Creeks and Breakaway Canal, with very high February coliforms in both 1997 and 1998. However, high coliform levels in May 1997, as noted for both the Chipola River and Kennedy Creek in the upper portion of the study area, were not evident at any tributaries in the lower portion of the study area.

Frequent high coliform levels, with less clear seasonal patterns, were observed at sites in the upper reaches of the tributaries, including Brothers River in January 1997, February 1998, and March 1998; at Jackson River and Huckleberry Creek in February, May, and August 1997 and January and February 1998; at Breakaway Canal in November 1996, February and August 1997, and February 1998; at Scipio Creek in November 1996, February, May, and August 1997, and February 1998.

Fecal coliform levels in the mainstem of the river varied considerably by time of year, and generally showed a pattern of either being low to moderate and stable throughout the study area, declining from upriver to downriver, or increasing from upriver to downriver. Consistently low river coliform levels were found throughout the study area in November 1996 and August 1997, accompanied by a very low river flow. Moderate coliform levels were found in the river in December 1997 and January 1998, accompanied by a moderate to high river stage, which increased by about four feet between December 16, 1997 and January 20, 1998.

Results of the FDEP study indicate that sources of fecal coliform are widespread throughout the lower portion of the Apalachicola River drainage basin. It seems clear that a comprehensive approach to source identification and reduction is needed. This approach will require that the cumulative impacts of multiple sources be understood and dealt with effectively. Elevated levels of fecal coliforms were observed in several tributaries that drain watersheds with very little human development, suggesting non-human sources. The study suggested that the most prudent approach would be to identify human sources of coliform contamination, and implement strategies to address these sources. (Marx, 1998)

One of the main characteristics of an indicator organism, such as coliform bacteria, is that it must be present at a higher concentration than the pathogens it infers. For this reason, methods that can discriminate the source of coliforms may have greater predictive and useful value, compared to developing multiple tests that must target specific pathogens. It would be useful to identify the source of fecal pollution during regular water analysis, so that potential remediation efforts can be more focused and effective. Several attempts have been made to develop methods that differentiate sources of fecal pollution, including the use of fecal streptococci. Initially, the ratio of fecal coliform to fecal streptococci was used as an indicator of fecal source. A ratio of four or greater was considered to indicate a human source, while a ratio of 0.7 or less indicated an animal source. This ratio has since proven unreliable, and the method has been abandoned. Other methods under consideration or under development include DNA fingerprinting, *Cryptosporidium* oocyst viability assays in cell cultures, and microbial source tracking.

It has been reported (Tamplin, 1997) that discriminate analysis of multiple antibiotic resistance (MAR) and ribotype profiles of *E. coli* could differentiate human and nonhuman sources of fecal pollution, and permit an estimation of the proportion from each source. These applications were initially limited to human versus nonhuman, and not a specific nonhuman species, although work is proceeding on differentiation of non-human species. MAR differentiates *E. coli* from different sources using antibiotics commonly associated with human and animal therapy, as well as animal feed. Human origin isolates are typically more resistant to antibiotics than nonhuman origin isolates. Examples of single antibiotics which differentiate human and nonhuman *E. coli* at a P value less than 0.05 (two-sided binomial test) are ampicillin, chlortetracycline, kanamycin, nalidixic acid, neomycin, oxytetracycline, streptomycin, sulfathiazole and tetracycline. The results of the research indicate that the MAR profile of *E. coli* is associated with source. MAR profiles of *E. coli* isolated directly from human and animal feces showed high similarity with MAR profiles of human and nonhuman sources. Importantly, discriminate analysis of MAR profiles showed that 82% of human isolates were correctly classified.

Samples were collected by standard methods, labeled and placed on ice inside coolers, and transported to the laboratory by overnight courier. Because the number of bacteria per sample is less critical than the actual types of bacteria isolated, the traditional six-hour holding time associated with coliform sampling may be expanded. Sample preparation and bacteriological tests for isolation of *E. coli* were performed using established procedures. A predetermined water volume, based on an initial measurement of the *E. coli* Most Probable Number (MPN), was filtered through a 0.2 *u*m pore sized filter. Filters were placed on MacConkey agar, incubated at 35^{o}C for 18 hours, and all lactose-fermenting *E. coli* were screened for presumptive identification. Presumptive *E. coli* isolates were confirmed by standard biochemical tests (Indole, Methyl red, Voges-Proskaur and Citrate).

MAR were performed by established procedures using selected antibiotics typically associated with animal feed and/or clinical treatments. Concentrations of antibiotics used include: 10 *u*g/ml ampicillin, 25 *u*g/ml chlortetracycline, 75 U/ml penicillin G, and 500 *u*g/ml sulfathiazole. Aliquots of stock solutions were added to tempered Mueller-Hinton agar, mixed, poured into petri dishes and stored at 5^{0}C for no longer than two weeks. *E. coli* isolates were grown in 96 well plates containing Tryptic Soy Broth at 35^{o}C for four to six hours, replica-plated onto antibiotic containing agar and control plates without antibiotic, and incubated at 35^{o}C for 18 hours. *Pseudomonas aeruginosa* ATCC 27853 and *Staphylococcus aureus* ATCC 25923 were used as positive (resistant to all antibiotics except for sulfathiazole; *E. coli* ATCC 25922 or *Klebsiella Pneumoniae* ATCC 13883 was used as positive control for sulfathiazole) and negative (sensitive to all antibiotics tested) controls, respectively. Isolates were recorded as resistant to an antibiotic if growth, measured with a metric ruler, was indistinguishable from that on the control plate without antibiotic; more than 10 to 15% reduced growth was recorded as a sensitive reaction to the antibiotic, although growth was normally reduced greater than 90%.

The District contracted with Dr. Tamplin to perform MAR analysis on samples collected from the river and bay. Funding permitted only a limited number of samples to be analyzed, and it was decided to sample in and near likely coliform sources in the bay, during both a low and a high flow period. Additional sampling was performed on the Apalachicola River, beginning at the base of the Jim Woodruff Dam and proceeding south, sampling above and below major tributaries and communities.

The sampling sites were chosen with the intent to gather a "snapshot" of the distribution of coliforms and an estimation of their origins. Site descriptions are presented in Table 4. Sites C1, C2, and C3 were chosen to evaluate potential runoff from Eastpoint vicinity, as the results of sampling presented earlier in this report indicated elevated total and fecal coliform counts. C4 was chosen due to its proximity with the oyster beds, while C5 was chosen for its proximity to a developed portion of St. George Island. C6 was located to sample the background runoff entering East Bay from an undeveloped area, and C7 is proximate to both the Eastpoint sewage treatment plant outfall and the Sportsman Lodge Motel and Marina. C8 was chosen to represent an undeveloped portion of the Apalachicola River discharge, and C9 again represented the oyster beds. C10, C11, and C12 sampled developed portions of St. George Island, where four "package" sewage treatment plants are located, and C13, C14, and C15 represent "clear" portions of the Bay. St. Vincent's Island is uninhabited, so C16 was expected to display non-human origin bacteria. Sites C17 through C22 sampled runoff and discharge from the City of

Apalachicola, proximate to a number of marinas, landfills, stormwater outfalls, and sewage disposal sites. Site C23 sampled Huckleberry Creek at its confluence with Jackson River, to evaluate the effects of the City of Apalachicola sewage treatment plant discharge into it. Finally, Site C24 sampled the Apalachicola River upstream of the confluence of Jackson River.

Table 4: Coliform Sampling Sites in Apalachicola Bay

Station Number	Description
C1	St. George Sound at Highway 65
C2	Off patrol station at Porters Bar
C3	Mouth of jetties and channel marker
C4	Over oyster beds, by 5 pole wooden structure
C5	East Hole off Church Street
C6	East Bay near the data log station
C7	East Point Causeway anchor
C8	East Bay River
C9	East of the causeway
C10	St. George Island, third channel west
C11	Plantation East
C12	Nick's Hole
C13	Turn buoy
C14	Little St. George, Marshall House between docks
C15	Dry Bar near data log station
C16	Big Bayou
C17	Mouth of 2 Mile Channel
C18	2 Mile Channel, Mile Marker 12
C19	Between TM marker and west bank
C20	by Number 4 channel mark out from marina
C21	Scipio boat basin
C22	Scipio Creek north of boat basin
C23	mouth of Huckleberry Creek
C24	Apalachicola River, mile marker 6.6

On April 27 and 28, 1999 the District conducted its first "snapshot" sample of the bay, at the sites previously described. The river flow during this period was uncharacteristically low, and was dropping due to an ongoing drought situation, contrary to typical historical seasonal flow. River flow, as measured at the Chattahoochee gage, was 7030 cubic feet per second (cfs) on April 27, and 6950 cfs on April 28. April is typically one of the rivers high flow months. Samples were collected by standard methods over the two-day period, and shipped on ice to the University of Florida Food Safety Laboratory each evening via overnight mail. For each sample where *E. coli* was isolated, ten strains were identified to allow a ratio of human source to nonhuman source to be calculated. The results of the sampling and analyses are presented numerically in Table 5, and graphically in Figure 36. Figure 36 also provides an indication of the distribution of the identification of source among the ten strains isolated, by utilizing pie charts where coliforms were isolated. It should be noted that the nature of the tests allows for instances where even below the detection limit of less than two Most Probable Number per 100 milliliter of sample (<2 MPN/100 mL), it is still possible to isolate bacterial colonies. This allows isolation of strains to differentiate even when the MPN is reported to be below the detection limit.

Table 5: Discriminate Analysis of MAR Profiles
(Apalachicola Bay Samples Taken April 27 and 28, 1999)

Sample Site	MPN/100 mL	Source of Pollution	Probability of Correct Identification	Number of Strains Isolated
C1	<2	NA	NA	NA
C2	<2	NA	NA	NA
C3	<2	NA	NA	NA
C4	<2	NA	NA	NA
C5	<2	NA	NA	NA
C6	<2	NH	0.98	H(0), NH(10), ND(0)
C7	<2	NA	NA	NA
C8	23	NH	0.98	H(0), NH(10), ND(0)
C9	<2	NA	NA	NA
C10	<2	NA	NA	NA
C11	<2	NA	NA	NA
C12	2	ND	<0.95	H(0), NH(0), ND(10)
C13	<2	NA	NA	NA
C14	<2	NA	NA	NA
C15	<2	NA	NA	NA
C16	<2	NH	0.98	H(0), NH(10), ND(0)
C17	13	NH	0.95	H(0), NH(8), ND(2)
C18	10	NH/H	0.98/0.99	H(3), NH(2), ND(5)
C19	31	NH/H	0.98/0.99	H(1), NH(9), ND(0)
C20	13	NH	0.98	H(0), NH(9), ND(1)
C21	130	NH	0.98	H(0), NH(8), ND(2)
C22	170	NH	0.98	H(0), NH(10), ND(0)
C23	8	NH	0.98	H(0), NH(10), ND(0)
C24	5	NH	0.98	H(0), NH(10), ND(0)

H = Human Source Pollution
NH = Non-human Source Pollution
NA = Not Available
ND = Not Determined

Due perhaps in part to the low river flow, sufficient coliforms were not isolated from half the sites sampled (C1 through C5, C7, C9 through C11, and C13 through C15) to allow MAR testing (MPN less than two). These sites were, for the most part, either within the main body of the Bay or along St. George Island. With only a few exceptions, the remaining sites, taken from the

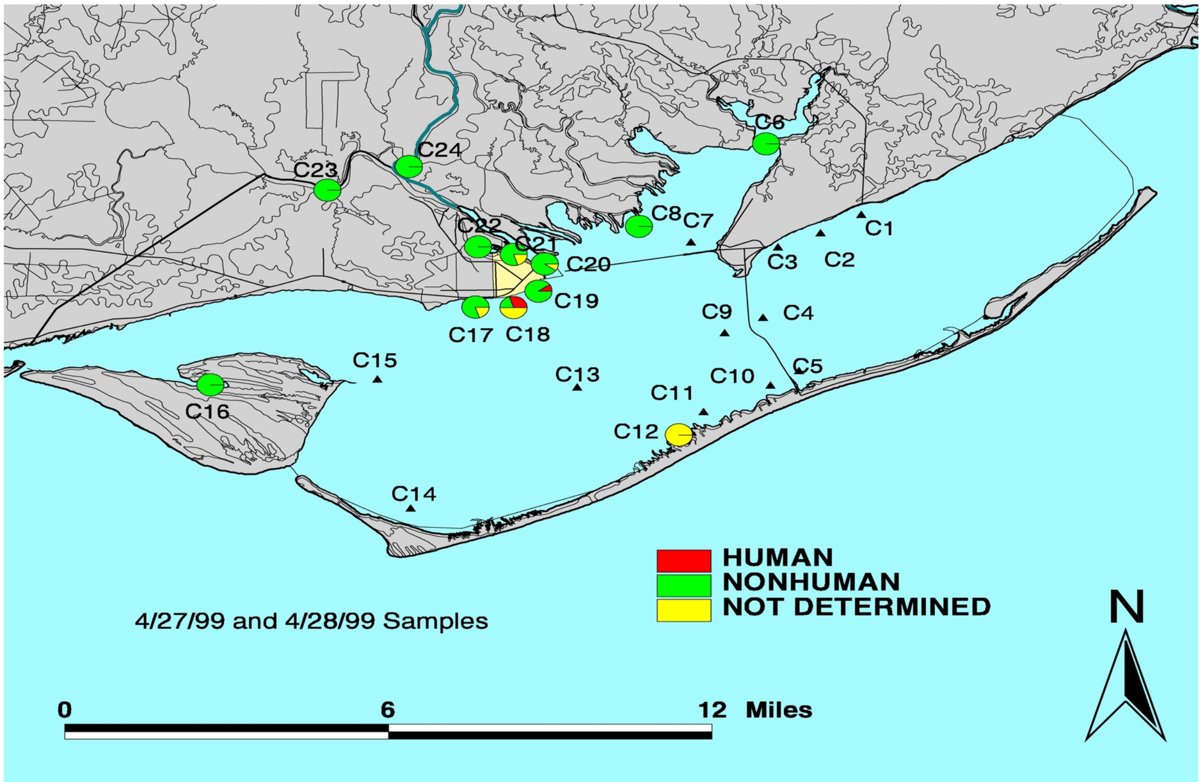


Figure 36: Results of April MAR Coliform Sampling

Apalachicola River, East Bay and St. Vincent Island, returned low coliform counts, of nonhuman and indeterminate sources. Two of the notable exceptions, Site C18 (2-Mile Channel at Mile Marker 12), and Site C19 (between TM marker and west bank), both indicated mixed human/nonhuman sources. Three human origin strains were isolated from Site C18, accompanied by two strains of nonhuman origin, while one human origin strain was isolated from Site C19, accompanied by nine nonhuman origin strains. Of those sites where coliforms could be isolated, all, with the exception of C8 (East Bay River) and C24 (Apalachicola River, mile marker 6.6) were associated with fishing or marina activities or with the sewage treatment plant discharging into Huckleberry Creek. It is of interest to note that in this sampling run, approximately 17% of the strains of *E. coli* sampled could not be differentiated.

On June 29 and 30, 1999 the District conducted its second "snapshot" sample of the bay. The river stage during the period sampled was higher than the previous sampling event in April, and was increasing, although typically and historically June is not a high river flow month. Again, the current drought situation is likely a cause. River flow, again measured at the Chattahoochee gage, was 12,700 cfs on June 29 and 14,100 cfs on June 30. Samples were again collected by standard methods over the two-day period, and shipped on ice to the University of Florida Food Safety Laboratory each evening via overnight mail. For each sample where *E. coli* was isolated, ten strains were identified to allow a ratio of human source to nonhuman source to be calculated. The results of the sampling and analyses are presented numerically in Table 6, and graphically in

Figure 37. Figure 37 also provides an indication of the distribution of the identification of source among the ten strains isolated, by utilizing pie charts where coliforms were isolated.

Table 6: Discriminate Analysis of MAR Profiles
(Apalachicola Bay Samples Taken June 29 and 30, 1999)

Sample Site	MPN/100 mL	Source of Pollution	Probability of Correct Identification	Number of Strains Isolated
C1	<2	NA	NA	NA
C2	<2	H	0.99	H(9), NH(0), ND(1)
C3	2	ND	<0.95	H(0), NH(0), ND(10)
C4	<2	NA	NA	NA
C5	<2	NA	NA	NA
C6	5	H	0.99	H(4), NH(0), ND(6)
C7	4	H	0.99	H(4), NH(0), ND(6)
C8	7	H	0.99	H(1), NH(0), ND(9)
C9	2	ND	<0.95	H(0), NH(0), ND(10)
C10	8	NH/H	0.98/0.99	H(5), NH(1), ND(4)
C11	2	NH	0.98	H(0), NH(10), ND(0)
C12	<2	ND	<0.95	H(0), NH(0), ND(10)
C13	<2	NA	NA	NA
C14	<2	NA	NA	NA
C15	<2	NA	NA	NA
C16	5	H	0.99	H(9), NH(0), ND(1)
C17	2	ND	<0.95	H(0), NH(0), ND(10)
C18	5	NH	0.98	H(0), NH(2), ND(8)
C19	33	NH/H	0.98/0.99	H(2), NH(1), ND(7)
C20	13	H	0.99	H(1), NH(0), ND(10)
C21	130	H	0.99	H(1), NH(0), ND(9)
C22	79	NH/H	0.98/0.99	H(2), NH(1), ND(7)
C23	8	NH/H	0.98/0.99	H(1), NH(1), ND(8)
C24	8	NH/H	0.98/0.99	H(1), NH(1), ND(8)

H = Human Source Pollution
N = Non-human Source Pollution
NA = Not Available
ND = Not Determined

This sampling event, taken during a higher river flow than the previous one, presents a different picture of the river and bay. Only six sites, again within the body of the bay, failed to produce sufficient coliforms for MAR analysis. The river sites all returned strains from both human and nonhuman sources, as did two of the Eastpoint sites and one of the St. George Island sites. Surprisingly, both the East Bay and the St. Vincent Island sites returned human origin strains, the St. Vincent Island site strongly so with nine out of ten strains isolated being of human origin. Oddly, this site gave the strongest reading of any site for human origins. Only one site sampled,

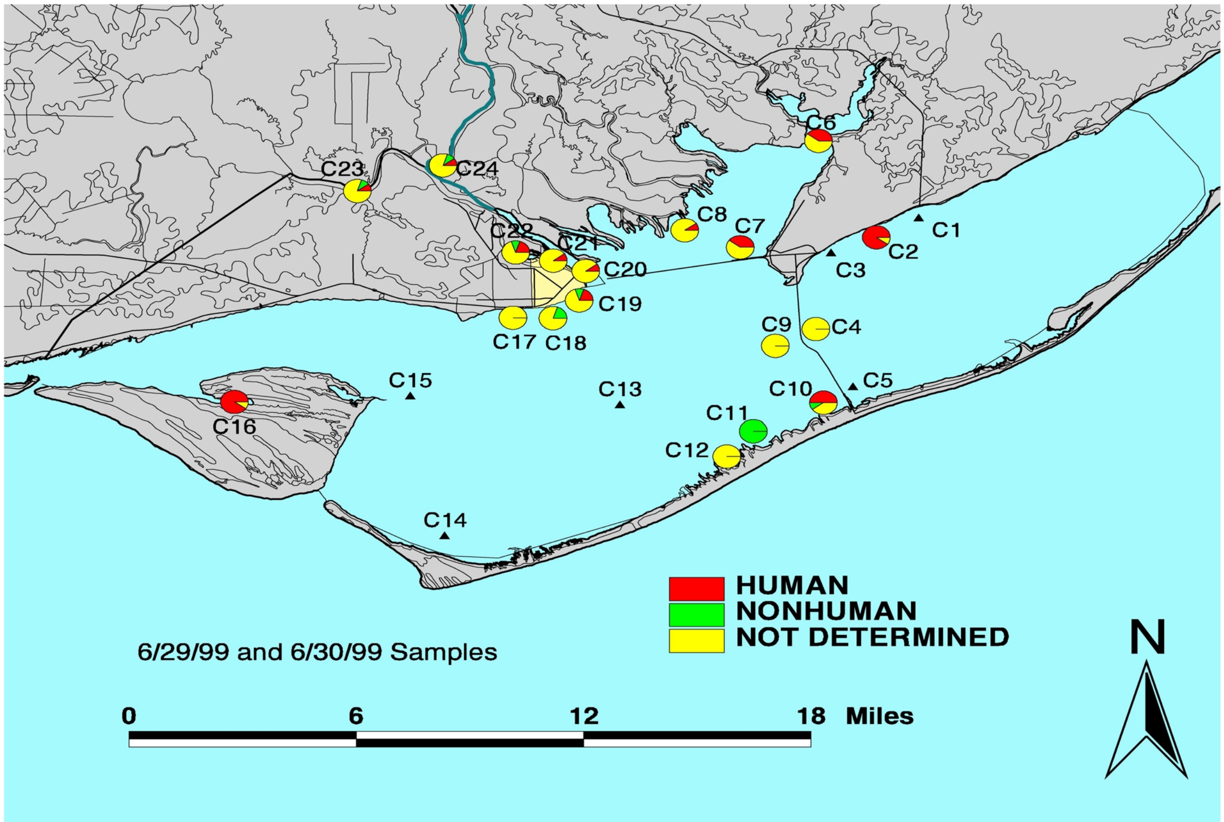


Figure 37: Results of June MAR Coliform Sampling

Site C11 (Plantation East on St. George Island), returned strains exclusively nonhuman in origin, although the low number of strains isolated suggests limited human involvement. It should be noted, however, that the indeterminate strains isolated throughout the sampling area might well be of either human or nonhuman origin. The greater number of sites where coliforms were isolated (although the MPN's were lower) may lend credence to the theory that the river is a source of coliform bacteria to the Bay. The results also suggest that stormwater runoff and/or sewer or septic tank overflows during wet periods may be a significant source of human origin coliforms. From this sampling run, approximately 69% of the strains isolated could not be differentiated.

To complete the limited discriminate coliform sampling events scheduled by the District, a screen of the Apalachicola River was needed. Accordingly, on September 28 and 29, 1999 the District sampled the length of the river. River flow at the time of this sampling was again low and dropping, measured at the Chattahoochee gage as 6090 cfs on September 28 and 6000 cfs on September 29 (provisional data at the time of this writing). Table 7 presents descriptions of the sample sites. The goal in choosing the sites was to gather information above and below major tributary inflows and settlements, where coliform bacteria might be introduced into the mainstem of the river. Sampling began at the base of the Jim Woodruff Dam and proceeded south to the bay. In addition to the river samples, the river/bay interface sampling sites and those adjoining the City of Apalachicola previously described were included, as were two sites bracketing Eastpoint. Results of the sampling event are presented numerically in Table 8, and graphically in Figure 38.

Table 7: Coliform Sampling Sites on the Apalachicola River

Station Number	Description
R1	Near Jim Woodruff Dam Outfall, upstream of US 90
R2	Above Flat Creek, above I-10
R3	Below Flat Creek, above I-10
R4	Above Graves Creek (Thomas Mill and Wilson Mill Tributaries)
R5	Below Graves Creek (Thomas Mill and Wilson Mill Tributaries)
R6	Below Stafford Creek
R7	Above Sutton Creek
R8	Below Sutton Creek
R9	Above Iamonia Lake
R10	Below Florida River (above cutoff)
R11	Dead Lake at County Road 22 Bridge
R12	Below Chipola River inflow
R13	Above Brothers River
R14	Below Brothers River
R15	Apalachicola River, mile marker 6.6 (C24 above)
R16	Mouth of Huckleberry Creek (C23 above)
R17	Scipio Creek, North of boat basin (C22 above)
R18	Scipio Creek boat basin (C21 above)
R19	Apalachicola River, by No. 4 channel marker (C20 above)
R20	Apalachicola Bay, between TM marker and west bank (C19 above)
R21	2 Mile Channel mile marker 12 (C18 above)
R22	Mouth of 2 Mile Channel (C17 above)
R23	Bay, East Point Causeway anchor (C7 above)
R24	Bay near Eastpoint, mouth of jetties and channel marker (C3 above)

Table 8: Discriminate Analysis of MAR Profiles
(Apalachicola River and Bay Samples Taken September 28 and 29, 1999)

Sample Site	MPN/100 mL	Source of Pollution	Probability of Correct Identification	Number of Strains Isolated
R1	2	H/NH	0.99/0.98	H(3), NH(7), ND(0)
R2	2	NH	0.98	H(0), NH(1), ND(9)
R3	2	NH	0.98	H(0), NH(10), ND(0)
R4	17	NH	0.98	H(0), NH(4), ND(6)
R5	22	NH	0.98	H(0), NH(2), ND(8)
R6	33	H/NH	0.99/0.98	H(1), NH(5), ND(4)
R7	79	NH	0.98	H(0), NH(6), ND(4)
R8	33	NH	0.98	H(0), NH(6), ND(4)
R9	170	ND	<0.95	H(0), NH(0), ND(10)
R10	17	ND	<0.95	H(0), NH(0), ND(10)
R11	23	ND	<0.95	H(0), NH(0), ND(10)
R12	23	ND	<0.95	H(0), NH(0), ND(10)
R13	23	ND	<0.95	H(0), NH(0), ND(10)
R14	49	ND	<0.95	H(0), NH(0), ND(10)
R15	23	ND	<0.95	H(0), NH(0), ND(10)
R16	49	ND	<0.95	H(0), NH(0), ND(10)
R17	49	ND	<0.95	H(0), NH(0), ND(10)
R18	350	H	0.99	H(2), NH(0), ND(8)
R19	23	ND	<0.95	H(0), NH(0), ND(10)
R20	33	ND	<0.95	H(0), NH(0), ND(10)
R21	13	ND	<0.95	H(0), NH(0), ND(10)
R22	31	ND	<0.95	H(0), NH(0), ND(10)
R23	NA	NA	NA	NA
R24	350	H	0.99	H(1), NH(0), ND(9)

H = Human Source Pollution
N = Non-human Source Pollution
NA = Not Available
ND = Not Determined

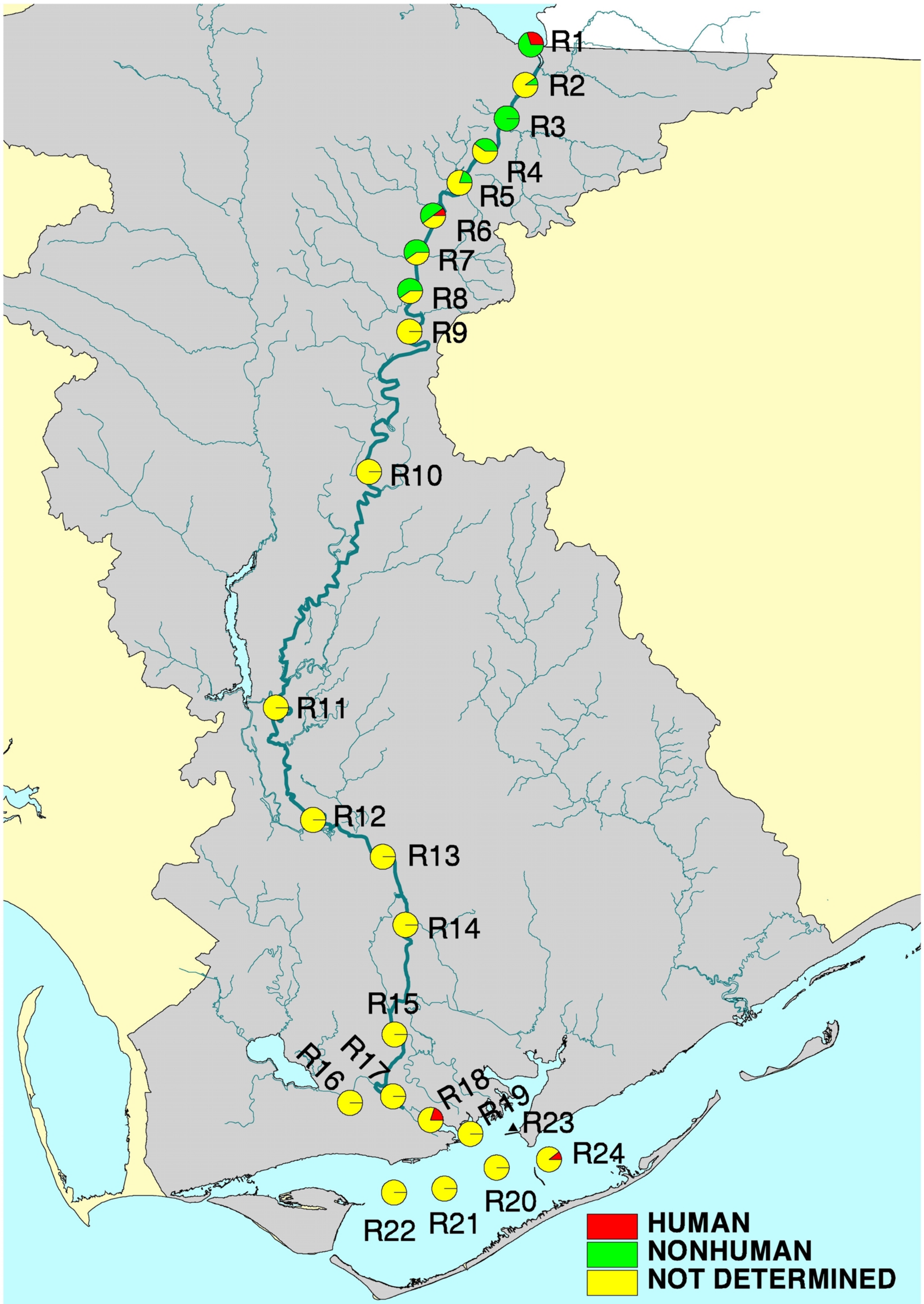


Figure 38: Results of September MAR Coliform Sampling

Site R1 at the base of the Jim Woodruff dam outfall returned a low count (MPN of two) of coliform strains of mixed human (three strains) and nonhuman (seven strains) origin. This suggests that Lake Seminole may be a limited source of human contamination, possibly through boaters, marinas, or septic tanks. Discharges from the town of Chattahoochee may also contribute. The MPN does not increase downriver, indicating that during this time the Flat Creek inflow had little effect. The MAR analysis, however, did not return strains from human sources. Above Flat Creek, only one "certain" (with a probability of 98%) nonhuman source strain was isolated. Below Flat Creek, however, every strain isolates was "certainly" nonhuman in origin. The indeterminate strains may be of either human or nonhuman origin, indicating a very limited human involvement. Therefore, little significance should be placed on this observation.

Samples taken above and below the entry of Graves Creek, which drains both Thomas Mill and Wilson Mill tributaries, also returned strains identified as having nonhuman origins. It is noteworthy, however, that the coliform MPN increased from Flat Creek to Graves Creek, and increased again below the confluence, suggesting the creek may be a source of coliforms. Stafford Creek is possibly a source of human origin coliforms, as one strain was isolated below its confluence. Coliforms are introduced into the mainstem of the river between Stafford Creek and Sutton Creek, as the MPN increased significantly, all apparently of nonhuman origin. The MPN dropped below Sutton Creek, while still returning nonhuman origin strains.

Sampling down the remainder of the river to the bay did not isolate strains that could be differentiated as originating from human or nonhuman sources. Therefore, no clear conclusions could be drawn concerning sources in this region. In fact, over 79% of the strains of *E. coli* isolated were indeterminate. With the exception of the sample taken above Iamonia Lake, the MPN's were all relatively low and consistent, with the exception of a few elevated (relatively so) values. The Scipio Creek boat basin, for example, returned a coliform MPN of 350, of human origin. The June 29 and 30 sampling event also returned strains of human origin. It would appear (based, of course, on only two sampling events) that there are significant sources of human waste contamination within the boat basin. One other source of human contamination was isolated off East Point, at the mouth of the jetties and channel marker. Again, the results of this sampling event point to boating activities and sewage treatment plants.

While the results of these sampling events and the discrimination of sources are interesting, they are obviously far too limited to draw concrete conclusions. It is clear, however, that human fecal contamination is present, both in the river and in the bay, which comes as no surprise. The study presented here suggests that likely sources to the Bay include stormwater runoff from both Apalachicola and Eastpoint, the City of Apalachicola sewage treatment plant discharge to Huckleberry Creek and treatment plants on St. George Island, and from the lower section of the Apalachicola River. Human source coliforms were also isolated from East Bay and St. Vincent Island, which warrants further investigation. The St. Vincent Island findings also indicates the need for further testing of the MAR procedure, as the island is uninhabited and therefore is not expected to be a source of human origin coliforms. Possible river sources suggested by this study include water released from Lake Seminole and Stafford Creek. The Scipio Creek boat basin also appears to be a hot spot. These results agree with suspected or observed sources of contamination. It should be noted that these river sources were "identified" with a single screen of the river, which unfortunately resulted in a significant number of strains that could not be differentiated. There may be other sources of human contamination that were not identified by this limited screen. Despite the shortcomings inherent to such a limited sampling base, it would appear that there may be some merit to the method. However, with over half the strains of *E. coli* isolated (61.4%) indeterminate as to source, further testing will be needed to insure the test is conveying expected results.

MODEL DEVELOPMENT AND FLOW ANALYSIS

Computer simulation models capable of replicating the runoff quantity and quality processes are typically used for comprehensive analysis of stormwater management systems. Once calibrated and verified, they provide an opportunity to estimate the hydraulic, hydrologic and water quality responses of the basin for both short- and long-term precipitation data, and the effect of proposed pollution abatement procedures. These models are also used to assist in determining water quality problems, quantify storm volumes, estimate pollutant and hydraulic loading to watersheds, and for detailed designs of pollution and flood control. The limitations of this study confined the modeling effort to two selected watershed basins in the City of Apalachicola. The model used for this study was the Environmental Protection Agency (EPA). Stormwater Management Model (SWMM) (Huber and Dickinson, 1988). This model was initially developed for the EPA by the University of Florida, Metcalf and Eddy, Inc., and Water Resources Engineers, Inc. XP-SWMM, developed by XP-Software, is a commercial version of the EPA SWMM model.

The version of the XP-SWMM (version 2) utilized in this study can simulate every aspect of urban drainage, from routing drainage design, to sophisticated hydraulic analysis, to non-point source runoff quality studies, using both single-event and long-term continuous simulation. Water quality can also be simulated and the output from continuous simulation can be analyzed statistically. XP-SWMM's positive features compared to other stormwater models are summarized as:

- the model's reputation and accessibility
- inclusion of a graphical user interface for model construction
- flexibility and accuracy to represent the runoff and flow routing features in the basin
- ability to perform continuous long-term and single-event simulation
- capability to simulate water quality
- capability to simulate non steady state system hydraulics.

In accordance with the scope of the project, the stormwater model was applied only to two selected drainage basins within the City of Apalachicola, although stormwater was monitored for water quality in other municipal areas of the study area. The model was applied to quantify runoff and pollutant loading to evaluate existing nonpoint source controls and drainage system capacities. Of particular interest in this study was the ability to use the model to quantify pollutant loading when only a limited number of stations and storm samples are available.

The City of Apalachicola basins selected for this study are well suited for simulation with the XP-SWMM model. Most of the components of the hydrologic processes occurring in the basin can readily be obtained to use in the model, such as rainfall, evaporation, surface runoff, flow through conduits, open channels and ponds, base-flow and water quality in terms of pollutant concentrations and total loads. The basic model components include the physical characteristics of the basin such as topography, soil types, land use characteristics, and climate characteristics such as evaporation, temperature and precipitation, and were also readily obtained.

<u>Watershed Characteristics</u>

The City of Apalachicola is a medium density urban residential community. Two drainage basins, routing stormwater to outfalls at Avenue-I and Battery Park, were chosen to represent the City. These watersheds are very flat, with slopes ranging from 0.001 feet per feet (ft/ft) to 0.045 ft/ft, with an average slope of 0.012 ft/ft. The soils are highly permeable, with a saturated hydraulic conductivity of 6.0 inches/hour. Stormwater is predominantly conveyed by overland flow through grassed swales and vegetated ditches into manholes located in each subbasin, then through a storm sewer system consisting of 68 pipes and two natural channels. A reconnaissance survey of the study area indicated that most of these storm sewers were clogged with sand, grass and debris, causing stormwater overflows. To identify potential flooding problems and to quantify storm volumes and pollutant loading to the Bay, the stormwater systems were modeled as though they were clean systems. This assumption allowed an evaluation of the maximum capacity of the system and illustrated the need for repairs.

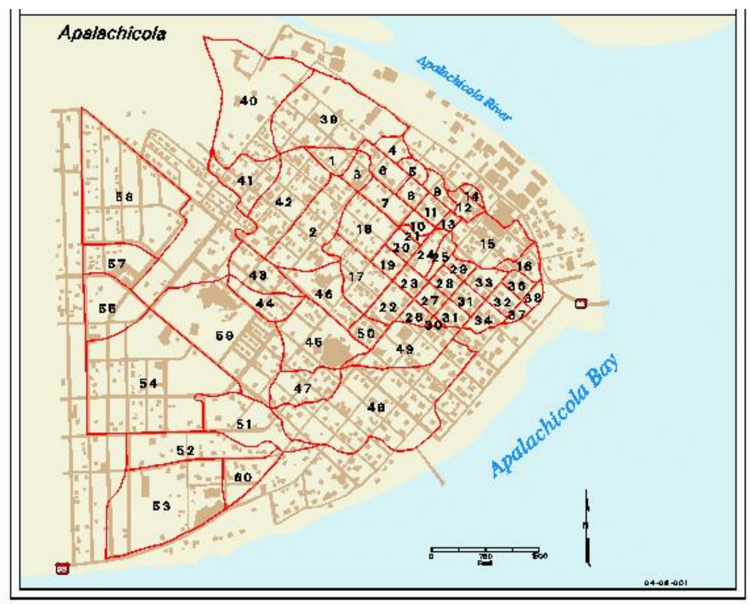


Figure 39: Subbasin Delineation

The first step in the construction of the hydrologic model consisted of dividing the study area into watersheds. For the purpose of this study, two watershed areas were selected to represent the City of Apalachicola. Major watershed delineations were based upon the topography of the study area, utilizing 2-ft contour maps. Each watershed was divided into subbasins as shown in Figure 39, according to storm sewer collector lines. Division into subbasins also assisted in identifying different land uses and problem spots. The surface area for the Avenue-I watershed is approximately 126 acres, and the Battery Park watershed is approximately 51 acres. The Avenue-I outfall watershed was subdivided into 22 subbasins (subbasins 1 through 14, and 17 through 24). The Battery Park watershed was subdivided into 16 subbasins (subbasins 15, 16 and 25 through 38).

<u>Climate</u>

The City of Apalachicola's climate is typical of the Gulf Coast, with high humidity, hot summers and mild winters. The Southeast Regional Climate Center's records for the periods of 1961-90 indicated an average temperature of 68° F. Table 9 provides the average monthly minimum, average monthly maximum and monthly average temperatures from 1961 to 1990 for the City of Apalachicola.

Table 9 –Average Temperatures for the City of Apalachicola. (1961-90)

	Avg Min (F)	Avg Max (F)	Avg Temp (F)
January	43.9	60.5	52.2
February	46.1	62.9	54.5
March	52.6	68.6	60.6
April	59.2	75.6	67.4
May	66.0	82.1	74.1
June	72.2	87.3	79.8
July	74.3	88.5	81.4
August	74.2	88.5	81.3
Septemer	71.4	85.9	78.6
October	61.4	78.9	70.2
November	53.1	70.7	61.9
December	46.8	63.9	55.4
Annual Avg	60.1	76.1	68.1

Temperature is an important factor in estimating the evaporation component of the total precipitation in the basin. Temperature variations are directly related to evaporation patterns over the study area. Table 10 lists the pan evaporation values used in the model to simulate evaporation.

Table 10 -- Average Monthly Evaporation

Evaporation (Inches)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Monthly Avg.	1.8	2.4	3.6	4.5	5.1	5.4	5.1	4.8	4.5	3.6	2.4	1.8	45.0

The total average annual precipitation for the City of Apalachicola was approximately 55 inches during the years 1961-90. The highest average rainfall occurred during the months of July, August and September, with an average precipitation of 7.5 inches for these three months. April and May had the lowest average monthly precipitation of 2.7 inches. Table 11 summarizes the average monthly precipitation at Station 080211 for the period of 1961-90. The missing data for this period was about 0.05 percent.

Table 11 --Average Monthly Rainfall (Inches) for the City of Apalachicola. (Station ID Number 080211)

Rain (Inches)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Monthly Avg.	3.90	3.79	4.25	2.72	2.67	4.55	7.35	7.50	7.54	3.40	3.20	4.08	54.96

Soils

The soil types within the basin influence the amount and rate of stormwater runoff from a watershed. Water losses due to infiltration are important in the overall water budget of the study area, and must be accurately estimated. Infiltration loses in the SWMM model can be computed with a choice of two traditional methods: Horton's or Green-Ampt formulation. In this study, the Green-Ampt method was chosen, because its parameters (saturated hydraulic conductivity, suction and initial moisture deficit) are more physically based than those in Horton's formula, and can be easily obtained through available soil surveys. (U.S. Department of Agriculture, Soil Conservation Service, 1994)

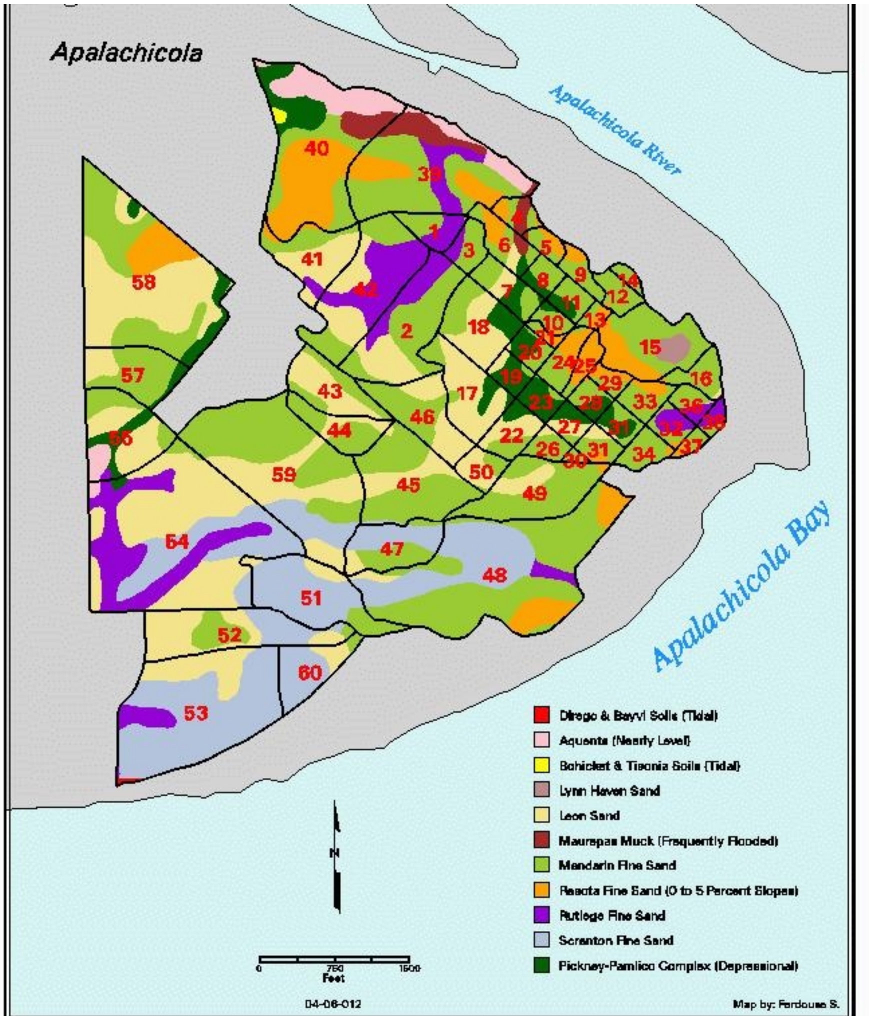


Figure 40: Soil Classes

According to the Soil Conservation Service, eleven general soil types characterize the City of Apalachicola study area. As shown in Figure 40, the most dominant soil types are Leon Sand, Mandrain Fine Sand, Resota Fine Sand, Rutlege Fine Sand and Scranto Fine Sand. The permeability for these soils ranges from 3 to 15 inches/hour. Other significant soil types in this area are Dirego & Bayvi Soils, Aquents, Bohicket & Tisonia Soils, Lynn Haven Sand, and Pickney-Pamlico Complex. Physical characteristics of these soil types are available from SCS surveys. Descriptions of these soils are provided in Appendix D.

Model Development

As previously discussed, the SWMM model is primarily an urban runoff simulation model, designed to simulate the runoff of a drainage basin for any prescribed rainfall pattern. For demonstration and planning purposes, the tasks faced in this project were to calibrate the model and determine the long-term distribution of stormwater flows in urban portions of the study area, namely two drainage basins within the City of Apalachicola. Local short-term data from the Northwest Florida Water Management District gauge stations were used to calibrate the model. A 31-year rainfall record from the City of Apalachicola Municipal Airport statement was used as a long-term data set in order to investigate the long-term distribution of stormwater flows.

Surface Runoff

Surface runoff was simulated using the Runoff Block of the SWMM model. The runoff parameters utilized in the runoff block simulation were estimated as follows:

Area -- The area (in acres) for each subbasin was obtained utilizing the basin map developed by the District's Geographic Information System (GIS) system, overlaid by the subbasin boundary map digitized from the 2-ft contour map of the City of Apalachicola.

Percent Impervious Area -- This parameter was obtained by overlaying an impervious area map on the subbasin map using the District's GIS system. See Figure 41. The SWMM model requires the value of percent impervious area to be calculated using directly connected impervious areas only. This value of imperviousness is always less than the value calculated using both directly and indirectly connected impervious areas. The values used for percent impervious utilized in the model were obtained from the total impervious areas in the basin in order to overcome one of the limitations of the SWMM model in running the long-term precipitation record, which is a tendency to underestimate the long-term runoff volumes from subbasins.

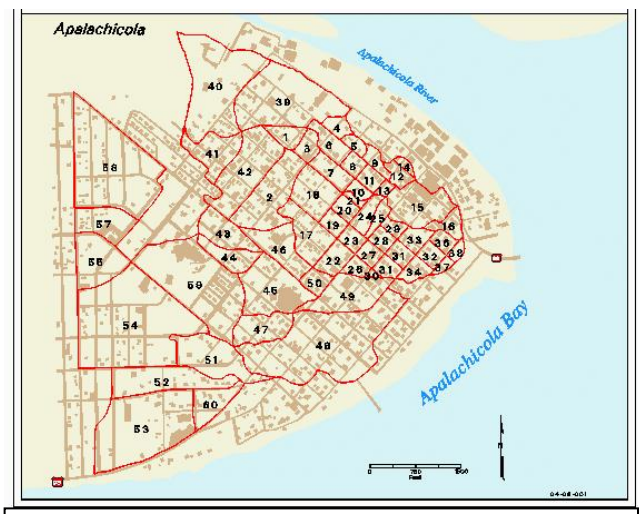


Figure 41: Impervious Surfaces in Apalachicola

Slope – As with impervious area, average slope values were obtained using the District's GIS system on a slope map generated with the GIS. The elevations to generate this map were obtained from a 2-foot contour map of the basin.

Manning's n for Pervious Area -- This parameter is generally not of major significance in calibration of the model. It was estimated from literature values, land cover maps and vegetation characteristics.

Depression Storage in Pervious and Impervious Areas -- These parameters depend on the type of land cover in the subbasin. They represent the volume of rainfall trapped in depressions and surfaces of the ground for impervious areas, and for pervious areas the volume of water captured by ground vegetation cover. They were estimated following the guidelines in the SWMM model user's manual (Huber and Dickinson, 1988).

Soil's Capillary Suction, Saturated Hydraulic Conductivity and Initial Moisture Deficit -- These three parameters are used in the Green-Ampt formula to compute infiltration in a particular subbasin. For each subbasin in the runoff model, the average value for each of these parameters was obtained by overlaying the county's Soil Survey map (U.S. Department of Agriculture, Soil Conservation Service, 1994) on the subbasin delineation map. For a subbasin with more than one soil type, the average value of each parameter was obtained utilizing a weighted average.

The values obtained for the above parameters, and the lengths, diameters and slopes of the sewers and channels obtained by field survey, are provided in Appendix E. The physical characteristics of the conduits making up the storm sewer/channel network are provided in Appendix F. The storm sewer/channel network for each of the watersheds was overlaid on the land use maps using the District's GIS system, and are presented in Figures 42 and 43.

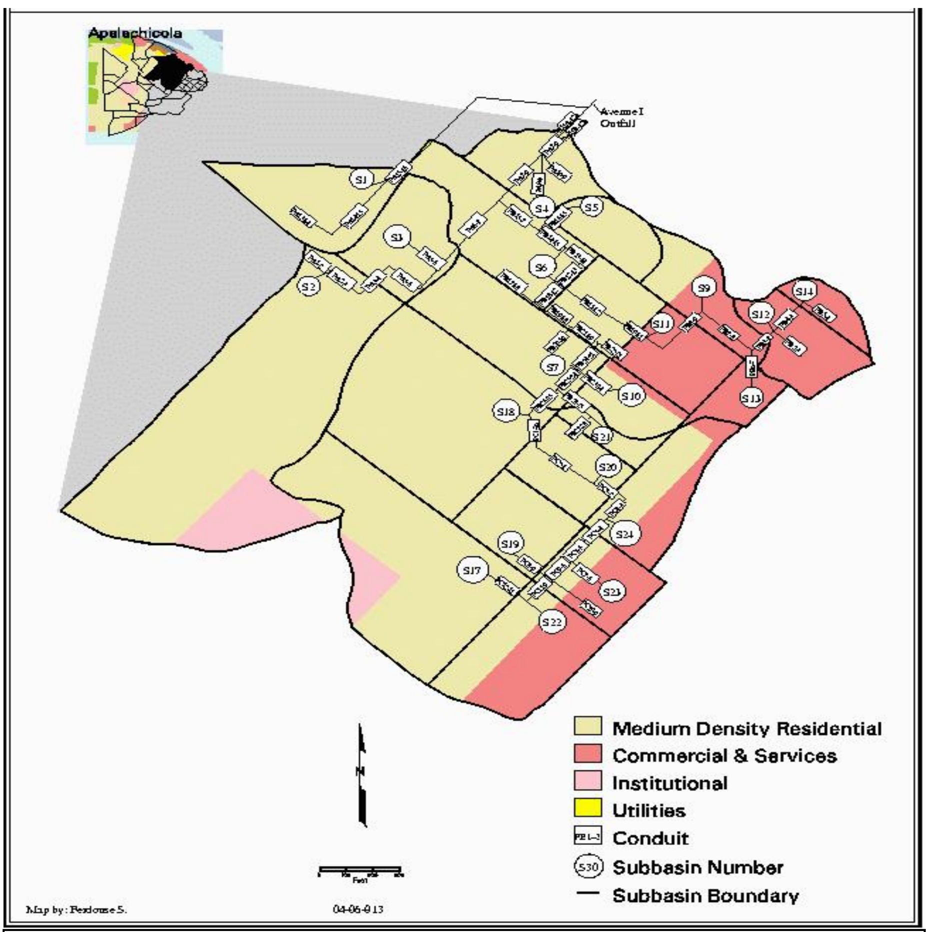


Figure 42: SWMM Model Diagram Superimposed Onto the Avenue I Watershed

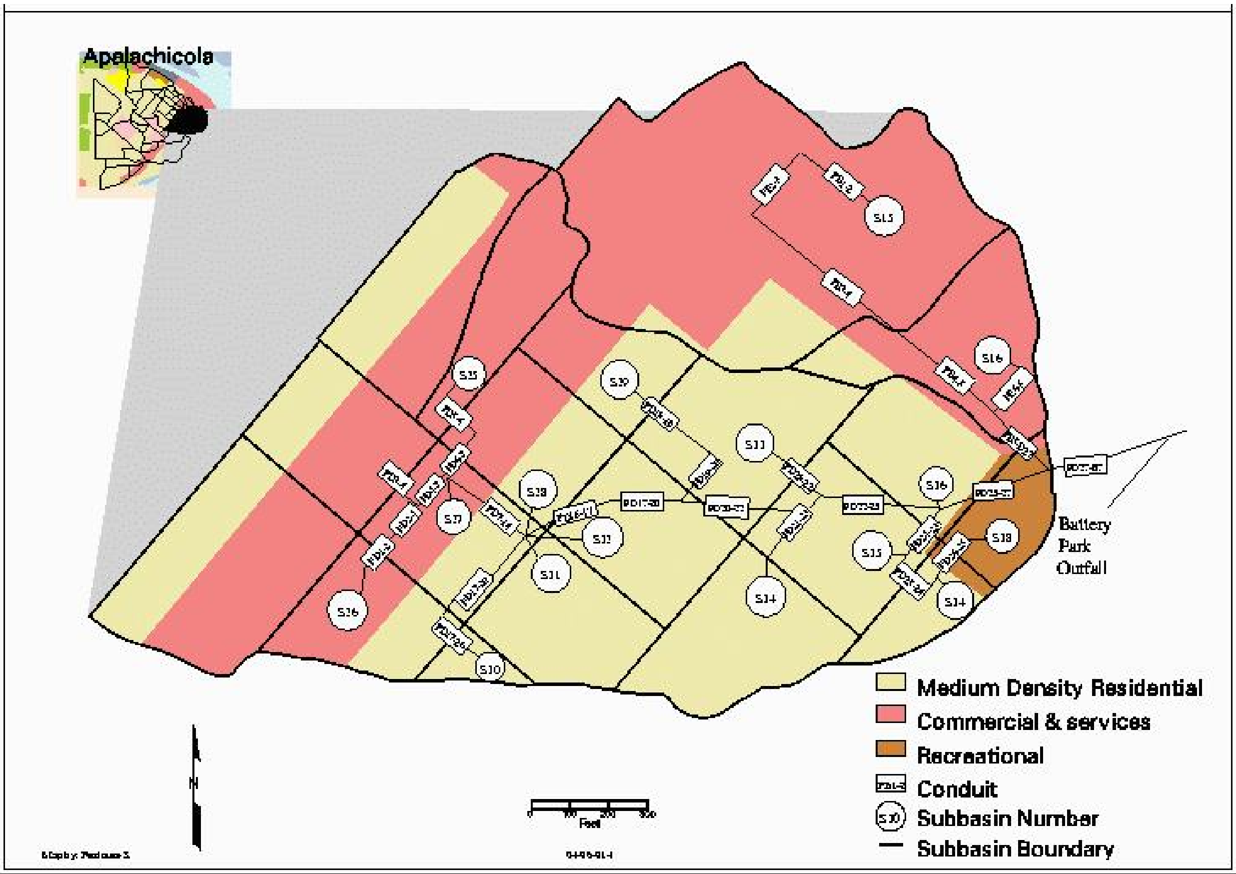


Figure 43: SWMM Model Diagram Superimposed Onto the Battery Park Watershed

Flow Routing
Most of the flooding problems in the City of Apalachicola are associated with storm sewer surcharge, due to inadequate conveyance capacity and to clogging of storm sewers with sand and vegetation. The TRANSPORT block of the SWMM model, although capable of routing the flows accurately through the storm system cannot, due to its limitations, be used in determining surcharge and other dynamic conditions that may occur in real life situations. Some of these dynamic flow conditions are flow reversals, backwater flow and looped sewer connections. For this reason, the EXTRAN routing module was chosen to simulate surcharge and backwater conditions in the City of Apalachicola study watershed.

The EXTRAN routing model is also capable of reading hydrographs generated by the RUNOFF block. However, the main drawback of using a dynamic routing model such as EXTRAN is the computational effort required to achieve stable solutions. Instability of the solution is characterized by oscillating hydrographs and large continuity errors. Stability in the solution depends on factors such as length of the shortest pipes, size of the conduits, and length of the simulation time step. When instabilities arise during the solution, the simulated time interval must be reduced until stability is reached again. This may employ a computational time step of a few seconds for highly unstable situations. Routing capabilities of the EXTRAN model include flow routing through pipes, manholes, weirs, orifices, pumps, storage basins, outfall structures, tidal or flap gates and natural channels. Histories of flow discharges, velocities, and water surface elevations can be simulated at selected nodes (manholes) or conduits.

The EXTRAN routing block uses a link-node representation of the storm sewer/channel system. This discrete representation of the system is necessary to numerically solve the gradually varied unsteady flow equations that form the mathematical basis of the model. The discretized storm sewer/channel system is idealized as a series of sewer reaches or links connected together by nodes or manholes. Each link transmits flow from node to node which are treated as storage elements. Inflows, such as inlet hydrographs generated in the RUNOFF block, and outflows take place at the nodes. The resulting routed flows and water surface elevations can be printed or plotted at any junction, pipe or outfall node for a selected period or for the entire simulation.

Model Calibration

The calibration of the RUNOFF/EXTRAN model for the two watersheds consisted of matching observed and simulated stage elevations at the Avenue-I and Battery Park outfalls. The model could not be calibrated directly to flow, as the rating curves developed for these two outfalls were affected by tidal influences from the bay. The bay was used as a boundary condition in order to remove the tidal influence data from the model. The tidal data was obtained from a tide gauge station in Apalachicola Bay near the St. George Island causeway, which measures at ten-minute intervals. There was no significant lag in tidal data from this station to the modeled site. It was also observed that wind direction and differences in atmospheric pressure that occurred during storm events influenced the data measured. The stage elevations were measured at both of these outfalls with automated data collection equipment, also at ten-minute intervals. The continuous rainfall data from the Battery Park (S526) rain gauge station was used to calculate the simulated stage from the SWMM model. The rainfall data was recorded in increments of one hundredth of an inch at ten-minute intervals. Since the model was not calibrated to directly to discharge, the model parameters were also compared to those of similar watersheds. Subbasin width, depression storage and the NGVD correction factor were the parameters adjusted to calibrate the model. Of these three, the model appeared to be most sensitive to subbasin width.

The period of November 30, 1996 to December 4, 1996 was chosen as a calibration period. During this time interval, there was a distinct storm with a total rainfall of 1.57 inches. The calibration hydrographs are shown in Figures 44 and 45. The results show an excellent fit between the observed and simulated water elevations for the Avenue-I watershed; however, they indicate a small difference in the peak discharge for the Battery Park watershed. The model predicted that this storm produced 153,000 cubic feet of runoff at the Avenue I outfall, and 92,200 cubic feet at the Battery Park outfall.

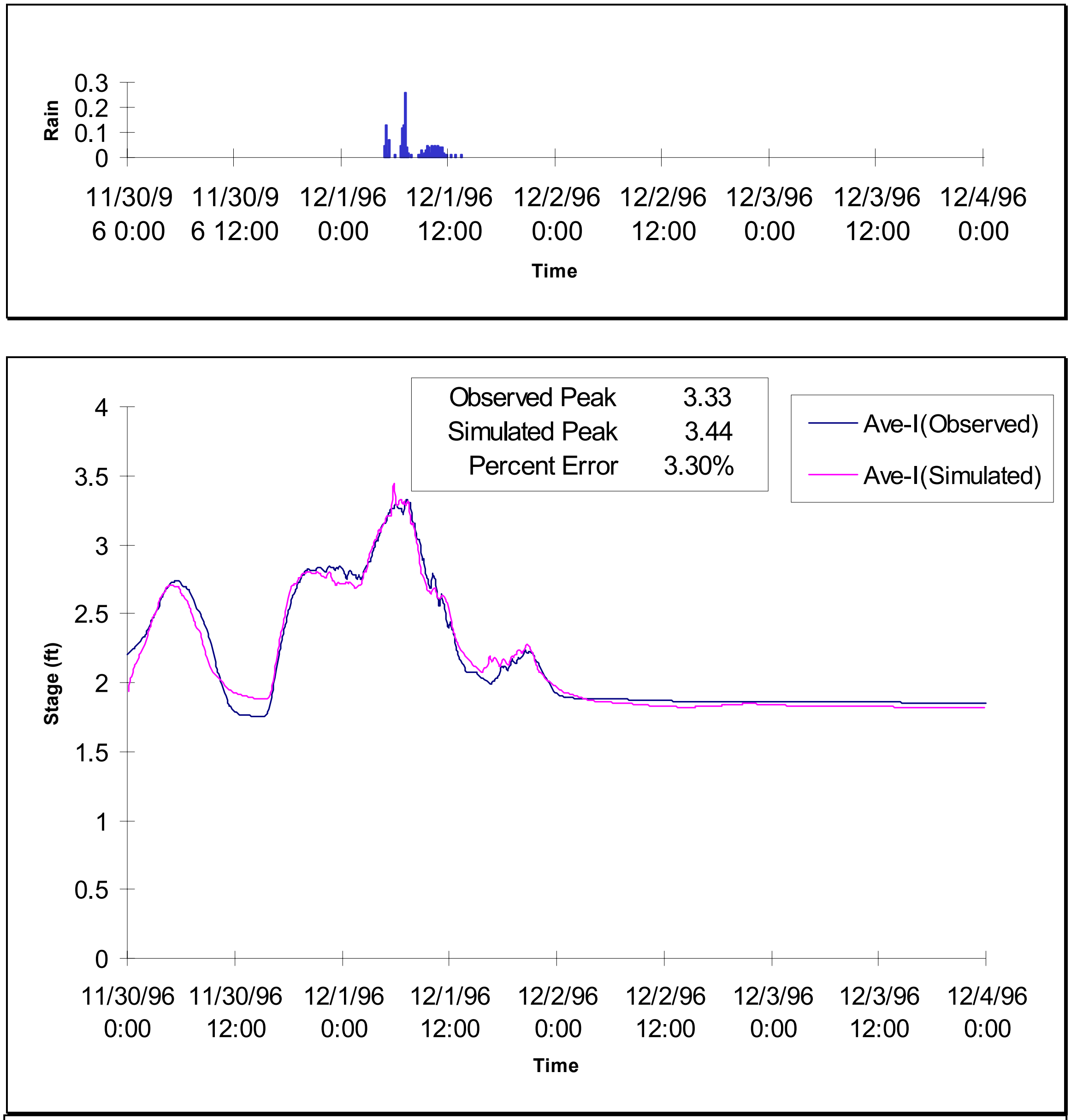
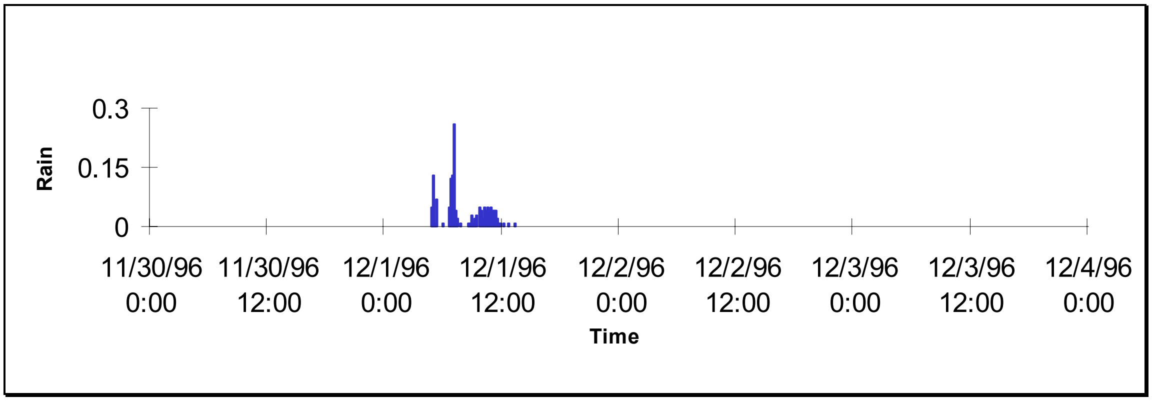


Figure 44 -- Calibration Chart for Avenue-I



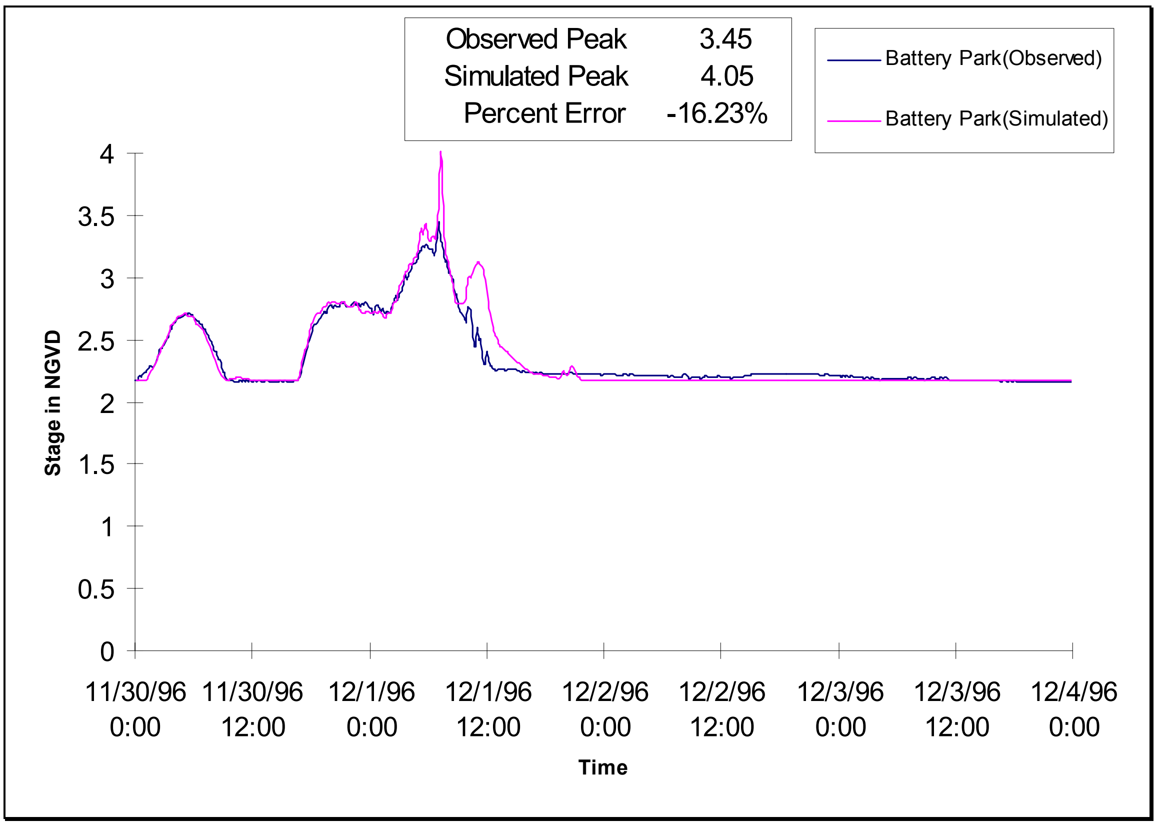


Figure 45 -- Calibration Hydrograph for Battery Park

Long Term Simulation Results

Accurate identification of stormwater quality related problems and economic design of stormwater treatment facilities in urban areas can depend on the knowledge of the long-term response of the basin. Standard engineering methods based on synthetic design storms to route peak discharges through a system provide very little information concerning storm volumes. Long-term continuous simulation, on the other hand, can provide useful information for the placement and design of cost effective runoff controls. This section describes the methodology used to estimate runoff volumes from each subbasin of the two watersheds, and an estimation of annual pollutant loadings from the city into Apalachicola Bay.

The model was used in conjunction with the long-term data to estimate annual runoff from each subbasin of the Avenue-I and Battery Park watersheds. For this purpose, the RUNOFF block of the model was simulated for 31 years of hourly rainfall data, recorded at the Apalachicola Municipal Airport for the period of 1962 to 1992. From these precipitation data, the RUNOFF block produced yearly runoff from each subbasin. Average runoff and average volumes for all the subbasins were estimated and the results are presented in Appendix G.

Average annual runoff volumes were used to estimate annual pollutant loadings from the subbasins. The pollutants estimated include: total suspended solids, total Kjeldahl nitrogen, nitrate+nitrite, phosphorus, orthophosphate, magnesium, and zinc. The concentrations of these pollutants were measured from the storm samples collected at the Avenue-I and Battery Park outlets. The average annual pollutants were estimated using the average concentration and average annual runoff, and the results are presented in Appendix H.

Synthetic Storm Simulation Results

A number of synthetic design storms were routed through the model to study flooding in the study area. Because there was no specific information available regarding the location and length of flooding in the city, no critical storms were identified. Instead, the term “critical storm” was defined for this study in terms of length of flooding at a selected number of junctions where street flooding is known to occur. One- and three-hour duration storms with return periods of 5, 10, 25, and 50 years were input into the RUNOFF block of the SWMM model, then routed through the EXTRAN block. Table 12 provides the rainfall amounts and intensities for these storms. The 25-year 24-hour storm (a synthetic storm of 24-hour duration with a return period of 25 years) is widely used as a “standard” design storm for public works stormwater drainage structures.

The simulation results indicate that the present stormwater system in Apalachicola, even making the assumption of a clean system in modeling the study area, is inadequate to meet the demands of street and storm sewer flooding. A synthetic storm of one-hour duration and five-year return period (1.4 inches of rainfall) surcharged 31 junctions in the Avenue-I watershed, and 19 junctions in the Battery Park watershed. Another synthetic storm of 24-hour duration and 25-year return period (10.2 inches of rainfall) surcharged 25 junctions in the Avenue-I watershed, and 10 junctions in the Battery Park watershed. Because the Apalachicola system is old, and characterized by undersized piping, sedimentation of sand, and vegetation, the actual flooding problem can reasonably be expected to be greater than the simulated results. The peak flows generated by the synthetic storms at the Avenue-I and Battery Park outfalls are shown in Table 12. The surcharged and flooded times at different junctions for each of the design storms are provided in Appendix I.

Table 12. Peak Flows at Selected Apalachicola Locations in Cubic Feet per Second (cfs) Existing Conditions

Storm Event		Ave - I	Battery Park
Return Period Duration	Total Rainfall(Inches)	**Outfall** (cfs)	**Outfall** (cfs)
5YR-1HR	1.400	50.90	42.50
5YR-3HR	4.000	64.10	47.00
10YR-1HR	1.545	56.40	42.50
10YR-3HR	4.500	67.60	48.80
25YR-1HR	1.794	63.90	45.80
25YR-3HR	5.300	72.80	51.20
25YR-24HR	10.181	38.73	27.66
50YR-1HR	1.993	72.00	47.70
50YR-3HR	5.700	75.20	51.20

The stormwater model analysis presented here could easily be expanded to evaluate alternatives to alleviate the problems identified. Possible alternatives to alleviate flooding could include increased storage to serve a dual purpose of water quality and quantity treatment, as well as rerouting and resizing dilapidated and eroding conveyances. These results merely identify the suspected locations of flooding, and suggest the magnitude of the problem. Additional sampling and modeling efforts would be required to verify the model predictions with observations of street flooding, and to apply the model for possible solutions to these problems. It is quite possible that a stormwater storage and treatment facility located within Subbasin 2 would alleviate the problem.

CONCLUSIONS AND RECOMMENDATIONS

The rural communities of Lanark Village and Carabelle are representative of medium density residential communities. Under current conditions, based on the water quality results presented in this report, storm drainage discharges from these two basins do not appear to present a significant threat to receiving waters. The Carabelle drainage basin base flow indicated occasional depressed dissolved oxygen levels and moderate increases in nutrients such as ammonia nitrogen, total Kjeldahl nitrogen, and nitrate/nitrite, possibly indicative of sewage contamination, perhaps from leaking and poorly maintained septic tanks or aging treatment systems, cross connections, or illicit connections. Without future development, these basins would have continued to cause little impact, assuming that current rules requiring adequate stormwater and erosion control practices were followed. Based solely on the water quality data in this report, a plan to address aging septic tanks or sewage treatment plants may be needed, as well as a plan to locate and eliminate illicit discharges and connections. Future development and other alterations of current land use in Lanark Village will, if not carefully planned and executed, cause future water quality problems. Carrabelle, however, is currently undergoing serious development pressures, and little control is being exercised to implement stormwater controls. It is generally accepted that with increasing levels of development, water quality often suffers, and the data presented in this report generally substantiates this assumption. The less developed areas of Lanark Village and Carabelle displayed a lower pollutant loading than the more developed City of Apalachicola, suggesting that increased development often results in increased pollutant loading from nonpoint sources.

The unincorporated community of Eastpoint is a typical low to medium density residential area. Despite having a lower residential density level than either Lanark Village or Carabelle, the Eastpoint drainage basin showed greater impacts to water quality attributable to development than either of the other two basins. Elevated total and fecal coliforms, and nutrients such as ammonia nitrogen, total Kjeldahl nitrogen, nitrate/nitrite, phosphorus and orthophosphate, as well as depressed dissolved oxygen in the base flow is suggestive of contamination by sewage, possibly from leaking and poorly maintained septic tanks or a sewage treatment plant, cross connections, or illicit connections. Baskerville-Donovan and CH2M-Hill (1992) suggested that other sources of fecal contamination from the Eastpoint area included dog pens, chicken coops and pigs along the main channel. Due to the large natural areas in Eastpoint, it has been demonstrated that the coliform contamination is from both human and animal origin. Strains of *E. coli* from both sources were isolated during the MAR sampling and testing detailed earlier in this report. Increases in turbidity, suspended solids, copper, and zinc were observed during storm sampling events. The elevated turbidity and suspended solids during storm events are typically indicative of poor construction, dirt roads, or other erosion control practices. To address future growth, reevaluation and possible expansion of Eastpoint's existing Stormwater Management Master Plan (1992) should be undertaken, which might include consideration for preservation of wetland areas, adoption of best management practices, and regional stormwater management facilities for the 877-acre drainage basin. Further efforts are needed to identify and address possible septic tank or sewer line problems, as well as illicit connections. An examination of the functionality of a sewage treatment plant sprayfield located on the north side of the watershed is also recommended, as well as investigations of a sand mine immediately above of the sampling site. For stormwater management planning and design, Eastpoint may need to consider a stormwater utility for future growth in these developing watersheds. Expansion of the Baskerville-Donovan and CH2M-Hill 1992 HYMO (US Department of Agriculture) model into that developed for the City of Apalachicola as part of this study would be extremely beneficial and is highly recommended, as the previous model used a regional equation to estimate time peaking time, and was not specific to the Eastpoint drainage basins.

The City of Apalachicola is a medium to high-density residential community, which includes several industries. There are several storm sewer outfalls within the city, two of which were used as water quality monitoring sites for this study. The storm drainage network is considered to be antiquated and unable to meet current stormwater management and treatment standards. This is not surprising, as most of the infrastructure was planned and constructed prior to the onset of stormwater quality rules, and rate controls have only recently been a consideration to designs. According to the city's local government Comprehensive Plan, the existing system has deteriorated and is undersized. Sedimentation from eroding ditches and overgrown or filled culverts also plagues the system. Direct infiltration into the municipal wastewater collection system has resulted in secondary wastewater overflows into receiving waters during sustained storms, as treatment systems are hydraulically overloaded.

Most of the stormwater outfalls in the City discharge untreated stormwater directly into the bay. This condition has resulted in degraded water quality and increased flood hazard potential, which will only increase in severity as time progresses and the system continues to degrade. Impacts to base flow are evidenced by depressed dissolved oxygen concentrations, increased specific conductance, elevated total and fecal coliform and fecal streptococci colony counts, and increased nutrient levels, such as ammonia nitrogen, total Kjeldahl nitrogen, nitrate/nitrite, phosphorus, and orthophosphate. The problem is exacerbated by storm events, which produce marked increases in turbidity, total suspended solids, copper, lead, and zinc, as well as further increases in selected nutrients such as nitrate/nitrite, phosphorus, and orthophosphate.

As part of this study, NWFWMD developed a computer model to simulate stormwater quantity and pollutant loading for the "downtown" area of Apalachicola. This area corresponds to subbasins 1 through 38, or approximately 17% of the delineated subbasins identified as part of this study. Based on the results from the model and storm event monitoring, this area of the city contributes an annual average according to projections and calculations, 2458 pounds of suspended solids, 6.6 pounds of ammonia nitrogen, 56.6 pounds of Kjeldahl nitrogen, 13.5 pounds of nitrate/nitrite, 13.2 pounds of phosphorus, and 5.5 pounds of orthophosphate to the estuary. As an example to place these annual load estimates in the proper perspective, the estimated load of dissolved inorganic nitrogen at the mouth of the Apalachicola River is about 1.5×10^4 kilograms per day.

Analysis of discharge by subbasin also suggested some interesting concepts. Subbasin 2 is 18.3 acres in size, approximately ten percent of the modeled study area. It is approximately 86.9% medium density residential and 13.1% institutional, based on current land use maps. Calculations based on the estimate of discharge per subbasin suggests that Subbasin 2 may contribute an aggregate average of approximately half of the total annual pollutant load, based on an analysis of six selected pollutants (total suspended solids, total Kjeldahl nitrogen, phosphorous, copper, lead and zinc). The estimates of pollutant load per subbasin were calculated using samples at one site for each watershed. All subbasins within a watershed were given the same concentration; thus, calculated loading was a function entirely of the estimated discharge from each subbasin, which limits the reliability of the analysis. Clearly, additional investigation is needed to fully investigate the discharges from this subbasin and others like it.

Deteriorating neighborhoods and crumbling infrastructure all contribute to the stormwater contamination problem from the City. Percentage of impervious surface, lack of ground covers, omission of erosion controls during and after construction, and inappropriate land uses all contribute to the annual pollution load. As previously mentioned, Subbasin 2 may contribute an inordinate share of the annual average pollutant load from the City to the bay. This basin is categorized as an economically depressed area, with decaying, substandard housing and crumbling infrastructure. Subbasins 39, 41 and 42 were not included in the model development, but are adjacent to Subbasin 2 and similar in characterization. It is reasonable to assume that the discharges from these basins would be similar in nature to that of Subbasin 2, and may also contribute large amounts of stormwater contamination to the Bay. Explorations into potentially available funding sources for urban renewal as a nonstructural type of control measure, along with drainage basin retrofits in these areas could help to alleviate a large percentage of the total annual pollutant loading entering the Apalachicola Bay from the City.

The computer model previously referenced also simulated stormwater volumes and return frequencies for the City of Apalachicola, and modeled the stormwater management system's response to a variety of real and synthesized storms. As mentioned, the model simulated the city's stormwater management system as though the pipes, swales and ditches were clean and unobstructed. The model predicted that, even with this optimizing assumption, a rainfall of only 1.4 inches was sufficient to cause flooding in the majority of manhole junctions, demonstrating the magnitude of the system undersizing issue. The flooding problem is exacerbated by the current condition of the system. According to the city's Comprehensive Plan, the system is clogged with sedimentation and vegetation, which further reduces its carrying capacity. Additionally, the surcharging of the conveyance system can cause excessive pressure on old, brittle pipe walls, which ultimately may lead to collapse of the pipes and further sedimentation and aggravation of the problem.

Future stormwater management programs initiated for the City should include water quality considerations, repair and expansion of the system, additional investigation into the suspected sewage contamination of the streams via cross connections or illicit connections, and retrofitting drainage basins. The SWMM model of Apalachicola developed for this project is capable of being expanded and enhanced to include subbasins not previously modeled, and can be a valuable tool to assist in the development of these management efforts. A program to address the clogging of storm sewers with sand and vegetation could realize some level of immediate relief for flooding and pollution problems, although the system would remain undersized to carry anticipated flows.

The SWMM model has been developed with a number of capabilities for future analyses. It is a powerful evaluation and design tool to quantify loading to the bay from local municipal sources. It would be highly beneficial to apply these modeling techniques for the communities of Eastpoint, Lanark Village, and Carrabelle, as well as areas that may continue to develop or in need of repair in the vicinity of Apalachicola. These models more completely categorize the discharges from the drainage basins and identify and prioritize potential problem areas prior to making large expenditures to retrofit these areas with stormwater controls. Time, effort and resources can be saved by identification and characterization of problems prior to the implementation of structural and nonstructural improvements to the stormwater management system.

With regard to SWIM program managers and other state and local resource managers, the following actions are immediately recommended:

1. Additional investigation into upland sources of sewage and other sources of coliform contamination, and further testing of the MAR techniques to finalize their usefulness in identifying sources.

2. Assist the Cities of Apalachicola and Eastpoint in finding funds for urban renewal programs, waterfront revitalization attempts, and in the development of stormwater retrofit plans.

3. Identify, map and field verify possible sources of sewage contamination entering the stormwater management systems of all communities through illicit connections, cross connections, and sewage overflows.

4. Based on the loading data and techniques presented herein, efforts should be made to evaluate future cumulative impacts of development throughout the Bay area.

5. Investigation into upstream riverine anthropogenic inputs into the study area.

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Appendix A

Study Area Land Use by Subbasin

Apalachicola Study Area Existing Land Use

Subbasin	Total area (acres)	Land Use Type	Area (acres)	Percent of Subbasin
1	4.1	Medium Density Residential	4.1	100
2	18.3	Medium Density Residential Institutional	15.9 2.4	87 13
3	3.4	Medium Density Residential	3.4	100
4	2.9	Medium Density Residential	2.9	100
5	2.1	Medium Density Residential	2.1	100
6	5.1	Medium Density Residential	5.1	100
7	5.2	Medium Density Residential	5.2	100
8	2.6	Medium Density Residential	2.6	100
9	2.7	Medium Density Residential Commercial	1.1 1.6	41 59
10	1.9	Medium Density Residential Commercial	1.6 0.3	84 16
11	2.8	Commercial	2.8	100
12	2.9	Commercial	2.9	100
13	1.3	Commercial	1.3	100
14	1.1	Commercial	1.1	100
15	3.6	Medium Density Residential Commercial	1.2 2.4	33 67
16	3.6	Medium Density Residential Commercial	0.4 3.2	11 89
17	10.8	Medium Density Residential Institutional	9.8 1.0	91 9
18	10.5	Medium Density Residential	10.5	100
19	2.9	Medium Density Residential	2.9	100
20	2.8	Medium Density Residential	2.8	100
21	1.0	Medium Density Residential	1.0	100
22	5.0	Medium Density Residential Commercial	2.0 3.0	40 60
23	2.8	Medium Density Residential Commercial	1.0 1.8	36 64
24	3.8	Medium Density Residential Commercial	2.1 1.7	55 45
25	2.5	Commercial	2.5	100
26	2.5	Medium Density Residential Commercial	0.9 1.6	36 64
27	2.7	Medium Density Residential Commercial	1.2 1.5	44 56
28	2.6	Medium Density Residential Commercial	1.2 1.4	46 54

29	1.9	Medium Density Residential Commercial	1.1 0.8	58 42
30	0.5	Medium Density Residential	0.5	100
31	2.7	Medium Density Residential	2.7	100
32	2.9	Medium Density Residential	2.9	100
33	3.6	Medium Density Residential	3.6	100
34	3.4	Medium Density Residential	3.4	100
35	2.9	Medium Density Residential	2.9	100
36	2.5	Medium Density Residential	2.5	100
37	1.2	Medium Density Residential	1.2	100
38	1.5	Recreational	1.5	100

Carabelle Study Area Existing Land Use

Subbasin	**Total area** (acres)	**Land Use Type**	**Area** (acres)
C1	34.5	**Low Density Residential** **Medium Density Residential**	15.0 19.5
C2	78.3	**Medium Density Residential** **Institutional** **Forest**	14.9 54.6 8.8
C3	257.7	**Low Density Residential** **Medium Density Residential** **Forest** **Sand Other Than Beaches** **Water**	32.8 18.9 170.4 5.0 30.6

Eastpoint Study Area Existing Land Use

Subbasin	**Total area** (acres)	**Land Use Type**	**Area** (acres)
EP2	33.5	Low Density Residential Medium Density Residential Commercial Forest	4.9 9.4 1.7 17.5
EP3	39.5	Low Density Residential Commercial Forest	6.8 3.8 28.8
EP4	22.0	Low Density Residential Medium Density Residential Forest Wetlands	6.3 3.9 8.7 3.1

EP5	321.7	Medium Density Residential Institutional Utilities Forest Wetlands	21.9 5.8 12.3 205.3 76.4
EP6	20.9	Low Density Residential Medium Density Residential Extractive Forest	1.6 1.9 7.1 10.3
EP7	19.5	Forest	19.5
EP8	8.5	Low Density Residential Forest	1.5 7.0
EP9	228.2	Low Density Residential Recreational Forest Wetlands	49.2 8.9 166.6 3.5
EP10	34.2	Low Density Residential Forest	28.4 5.8
EP11	4.0	Low Density Residential	4.0
EP12	23.5	Medium Density Residential Forest	16.4 7.1
EP13	86.4	Low Density Residential Extractive Utilities Forest Wetlands	24.3 5.6 5.3 29.4 21.8

Lanark Village Study Area Existing Land Use

Subbasin	**Total area** (acres)	**Land Use Type**	**Area** (acres)
LV1	48.3	Medium Density Residential Golf Course Forest	14.6 10.6 22.5

Appendix B

Storm Flow Statistics

Storm Flow Statistics

Parameter/ Storet Code/ units	Station Number	Number of Samples	Minimum	Maximum	Average	Median	Standard Deviation
Turbidity	S523	4	0.85	5.6	3.24	3.25	2.15
76	S524	4	3	4.9	3.90	3.85	1.04
(NTU)	S525	4	4.7	83	43.43	43.00	32.23
	S526	3	12	17	13.67	12.00	2.89
	S527	3	20	22	21.00	21.00	1.00
Total Suspended Solids	S523	4	4	23	11.00	8.50	8.29
530	S524	4	4	5	4.25	4.00	0.50
(mg/L)	S525	4	4	15	10.40	11.30	4.81
	S526	3	15	32	23.67	24.00	8.50
	S527	3	22	70	48.67	54.00	24.44
Ammonia Nitrogen	S523	4	0.01	0.26	0.07	0.01	0.12
610	S524	5	0.10	0.18	0.15	0.17	0.03
(mg N/L)	S525	5	0.03	0.06	0.04	0.04	0.01
	S526	4	0.07	0.19	0.12	0.11	0.05
	S527	4	0.08	0.11	0.10	0.10	0.01
Total Kjeldahl Nitrogen	S523	5	0.35	0.78	0.63	0.70	0.17
625	S524	5	1.20	1.30	1.24	1.20	0.05
(mg N/L)	S525	5	0.96	1.30	1.09	1.10	0.13
	S526	4	0.55	0.87	0.72	0.74	0.13
	S527	4	0.74	1.40	1.03	0.99	0.29
Nitrate+Nitrite	S523	5	0.01	0.06	0.03	0.02	0.02
630	S524	5	0.03	0.11	0.06	0.04	0.03
(mg N/L)	S525	5	0.01	0.04	0.02	0.03	0.01
	S526	4	0.15	0.36	0.28	0.30	0.09
	S527	4	0.08	0.28	0.19	0.21	0.09
Total Phosphorous	S523	5	0.02	0.07	0.05	0.05	0.02
665	S524	5	0.02	0.04	0.03	0.03	0.01
(mg P/L)	S525	5	0.05	0.15	0.10	0.10	0.04
	S526	4	0.07	0.22	0.15	0.16	0.07
	S527	4	0.07	0.35	0.25	0.29	0.13
Orthophosphate	S523	5	0.01	0.04	0.02	0.02	0.01
671	S524	5	0.01	0.02	0.01	0.01	0.00
(mg P/L)	S525	5	0.04	0.08	0.05	0.05	0.02
	S526	4	0.06	0.10	0.07	0.07	0.02
	S527	4	0.06	0.14	0.10	0.09	0.04
Magnesium	S523	3	1.21	1.67	1.39	1.28	0.25
927	S524	5	0.81	1.13	0.93	0.92	0.12
(mg/L)	S525	5	1.83	2.92	2.29	2.22	0.41
	S526	4	4.81	25.00	13.26	11.62	8.87
	S527	4	4.48	31.60	12.38	6.71	12.96
Zinc	S523	4	5.00	21.00	11.25	9.50	6.85
1092	S524	4	12.00	20.00	16.75	17.50	3.40
(ug/L)	S525	5	8.00	60.00	22.20	14.00	21.34
	S526	4	8.00	48.00	30.25	32.50	17.13
	S527	4	38.00	117.00	68.25	59.00	34.94

APPENDIX C – LONG TERM FECAL COLIFORM DATA

The following is a statistical summary of the long-term fecal coliform data in the Apalachicola Bay shellfish harvesting area received from the Department of Environmental Protection.

SUMMARY OF LONG TERM FECAL COLIFORM DATA IN THE APALACHICOLA BAY SHELLFISH HARVESTING AREA JANUARY, 1979 THROUGH DECEMBER, 1995					
Station ID Number	**Num. of Samples**	**Mean** (MPN/100ML)	**Minimum Value**	**Maximum Value**	**Std. Deviation**
53	2	1	1	1	N/A
70	427	9	1	220	21.98
72	212	10	1	540	40.40
73	1	1	1	1	N/A
74	98	7	1	170	23.87
75	103	4	1	79	11.66
76	88	4	1	79	10.40
77	24	4	1	49	9.87
79	21	6	1	79	17.09
80	427	7	1	170	17.23
81	418	8	1	240	20.74
82	304	7	1	220	21.31
83	301	12	1	540	44.44
84	36	5	1	70	14.11
85	28	3	1	33	6.51
86	25	2	1	13	2.54
87	6	1	1	2	0.52
90	12	144	1	1700	490.17
100	490	16	1	920	66.42
109	1	540	540	540	N/A
140	530	16	1	350	35.59
150	197	12	1	240	25.34
151	196	11	1	350	31.49
152	203	9	1	110	17.66
153	155	8	1	79	13.91
155	30	4	1	49	9.10
160	534	17	1	1600	74.84
162	291	19	1	240	38.46
163	172	14	1	350	36.72
190	238	53	1	1700	142.28
200	8	4	1	17	5.84
210	1	79	79	79	N/A
221	445	46	1	1700	134.96
222	1	11	11	11	N/A
223	1	11	11	11	N/A
224	130	37	1	350	58.78
225	133	35	1	350	57.09
230	212	57	1	1700	167.99
231	120	59	1	1600	157.63
232	119	74	1	1700	181.23
233	127	85	1	1700	234.50
234	154	50	1	540	90.19
235	135	48	1	920	123.99
240	460	44	1	920	79.43

SUMMARY OF LONG TERM FECAL COLIFORM DATA IN THE APALACHICOLA BAY SHELLFISH HARVESTING AREA JANUARY, 1979 THROUGH DECEMBER, 1995 (continued)					
Station ID Number	**Num. of Samples**	**Mean** (MPN/100ML)	**Minimum Value**	**Maximum Value**	**Std. Deviation**
242	130	72	1	1700	165.42
244	88	38	1	220	49.74
246	89	37	1	540	75.71
250	389	71	1	1700	155.30
251	1	49	49	49	N/A
252	1	13	13	13	N/A
253	100	64	2	540	85.43
254	134	73	1	1700	164.78
255	103	59	1	1700	179.08
257	95	60	1	540	98.83
259	92	55	1	540	93.06
260	590	29	1	540	50.90
265	7	7	1	33	11.51
270	277	69	1	1600	122.33
272	153	57	1	540	75.80
275	5	33	1	130	55.18
280	598	63	1	1700	123.08
281	2	90	70	110	28.28
285	17	18	1	79	25.70
289	1	23	23	23	N/A
295	15	38	1	240	66.98
320	331	42	1	350	59.08
321	333	15	1	180	27.00
322	41	50	1	350	73.08
323	353	9	1	350	26.54
325	39	60	1	540	103.17
330	2	23	23	23	0.00
340	549	12	1	350	27.81
341	560	28	1	1600	86.20
342	461	15	1	350	36.79
343	443	8	1	350	21.18
344	239	10	1	130	18.08
345	47	34	1	350	65.66
346	210	8	1	240	22.10
349	10	19	1	94	30.21
350	468	5	1	170	13.49
351	194	5	1	110	12.34
352	477	18	1	350	44.55
353	536	8	1	240	18.81
354	154	20	1	540	53.17
355	47	11	1	240	34.97
356	47	8	1	49	11.78
359	108	3	1	49	6.47
360	240	6	1	130	15.04
370	6	7	1	33	12.83

SUMMARY OF LONG TERM FECAL COLIFORM DATA IN THE APALACHICOLA BAY SHELLFISH HARVESTING AREA JANUARY, 1979 THROUGH DECEMBER, 1995 (continued)					
Station ID Number	**Num. of Samples**	**Mean** (MPN/100ML)	**Minimum Value**	**Maximum Value**	**Std. Deviation**
371	552	16	1	220	27.33
372	539	17	1	920	53.14
373	242	18	1	540	46.48
374	346	13	1	240	26.16
375	10	16	1	110	34.01
380	494	28	1	1700	96.54
390	236	19	1	170	32.07
400	14	5	1	33	9.75
410	473	20	1	920	61.25
482	1	8	8	8	N/A
578	143	7	1	110	14.15

APPENDIX D -- Study Area Soils Index

Types and Descriptions

(**3**) Beaches. Beaches consist of narrow strips of nearly level land areas along the Gulf of Mexico and adjacent bays. These soils are covered daily with saltwater at high tides. Beaches are used intensively for recreation. Homes and commercial buildings have been built on the fringes of beaches in many places. Beaches are not suitable for homesite development, however, because of frequent tidal flooding.

(**4**) Dirego and Bayvi soils, tidal. These very poorly drained, nearly level soils are in gulf coast tidal marshes and in estuarine marshes along the lower reaches of the Apalachicola River. In areas where these soils occur they are comprised of approximately 50 percent Dirego soil and 40 percent Bayvi soil with slopes less than 1 percent. These soils have a water table at or near the surface throughout the year and are flooded daily by normal high tides. Permeability is rapid. In most areas the natural vegetation consists of black needlerush, marshhay cordgrass, and smooth cordgrass. These soils are unsuitable for development.

(**5**) Aquents, nearly level. These are poorly drained and somewhat poorly drained soils are in low landscape positions adjacent to rivers, coastal bays, marshes, and in shallow excavated areas. Slopes range from 0 to 2 percent. These soils formed in recent fill of variable composition. They generally contain fragments of brick, oyster shells, woody material, and assorted human artifacts. A seasonal high water table is generally within a depth of 20 inches throughout the year, but it may be slightly above the surface during periods of unseasonably high rainfall. Onsite investigation is needed to determine the suitability of the soils for most land uses.

(**7**) Bohicket and Tisonia soils, tidal. These very poorly drained, nearly level soils are in gulf coast tidal marshes and in estuarine marshes along the lower reaches of the Apalachicola River. In areas where these soils occur they are comprised of approximately 45 percent Bohicket soil and 40 percent Tisonia soil with slopes less than 1 percent. These soils have a water table at or near the surface throughout the year and are flooded daily by normal high tides. The available water capacity is high. Permeability is very slow. In most areas the natural vegetation consists of black needlerush, marshhay cordgrass, and smooth cordgrass. These soils are unsuitable for development.

(**8**) Ridgewood Sand, 0 to 5 percent slopes. This somewhat poorly drained, nearly level or gently sloping soil is on slightly convex knolls in the uplands and in the flatwoods. Slopes range from 0 to 5 percent. The Ridgewood soil has a seasonal high water table at a depth of 24 to 42 inches for 2 to 4 months in most years. The water table is at a depth of 15 to 24 inches for less than 3 weeks in some years. The available water capacity is low in the surface layer and very low or low in the rest of the profile. Permeability is rapid. This soil is only moderately suited to homesite development because of the seasonal wetness and the occasional droughtiness. It is only moderately suited to use as a site for small commercial buildings because of the wetness. Because of the rapid permeability, areas for onsite waste disposal should be carefully selected to prevent contamination of ground water. Homes should not be clustered together, and the waste disposal site should not be located adjacent to any body of water.

(**10**) Corolla sand, 0 to 5 percent slopes. This somewhat poorly drained, nearly level or gently sloping soil is on flats and small dunes and in swales on large dunes along the gulf coast beaches. Slopes range from 0 to 5 percent but are generally less than 3 percent. The Corolla soil has a seasonal high water table at a depth of 18 to 36 inches for 3 to 6 months in most years. Flooding can occur during severe coastal storm. The available water capacity is low. Permeability is very rapid. The soil is poorly suited to use as a site for homes, small commercial buildings, sewage lagoons, and sanitary landfills. It is moderately suited to use as a site for local roads and streets. The major limitations are seasonal droughtiness and wetness, the hazard of flooding, and the very rapid permeability.

(11) Dorovan-Pamlico complex, depressional. These very poorly drained, nearly level soils are in depressions and poorly defined drainage ways . In areas where these soils occur they are comprised of approximately 55 percent Dorovan soil and 30 percent Pamlico soil with slopes ranging from 0 to 2 percent. These soils have a seasonal high water table ponded on the surface or within a depth of 24 inches for 3 to 6 months in most years. The available water capacity is and the permeability ranges from moderate to rapid. These soils are unsuitable for development.

(15) Ortega fine sand, 0 to 5 percent slopes. This moderately well drained, nearly level or gently sloping soil is on side slopes or in concave areas in the sandy uplands. Slopes range from 0 to 5 percent. This soil has a seasonal high water table at a depth of 60 to 72 inches for as long as 6 months in most years. The available water capacity is low in the surface layer and very low in the underlying material. Permeability is rapid. This soil is well suited to use as a site for homes, small commercial buildings, and local streets. It is poorly suited to sewage lagoons and landfills because of seepage. Homes should not be clustered together, and the waste disposal site should not be located adjacent to any body of water.

(**19**) Kureb fine sand, 3 to 8 percent slopes. This excessively drained, gently sloping or sloping soil is on convex coastal ridges and remnant dunes. Slopes range from 3 to 8 percent. This soil does not have a seasonal high water table within a depth of 72 inches. The available water capacity is very low. Permeability is very rapid. This soil is well suited to use as a site for homes, small commercial buildings, and local streets. It is poorly suited to sewage lagoons and landfills because of seepage. Homes should not be clustered together, and the waste disposal site should not be located adjacent to any body of water.

(20) Lynn Haven sand. This poorly drained, nearly level soil is in broad, very slightly depressional areas in the flatwoods. Slopes range from 0 to 2 percent. Lynn Haven soil has a seasonal high water table within a depth of 12 inches for 4 to 6 months each year and within a depth of 30 inches for the rest of the year. The available water capacity is low in the surface layer, moderate or high in the subsoil, and very low in the substratum. Permeability is moderate or moderately rapid in the subsoil and rapid or very rapid in the rest of the profile. This soil is poorly suited to development because of the wetness.

(22) Leon sand. This poorly drained, nearly level soil is in broad areas in the flatwoods and on knolls or low ridges in titi bogs. Slopes range from 0 to 2 percent. Leon soil has a seasonal high water table within a depth of 6 to 12 inches for 4 months in most years. The water table recedes to a depth of more than 40 inches during dry periods The available water capacity is very low in the surface and subsurface layers and low in the subsoil. Permeability is rapid in the surface and subsurface layers and moderate or moderately rapid in the subsoil. This soil is poorly suited to development because of the wetness.

(23) Maurepas muck, frequently flooded.. This very poorly drained, nearly level, organic soil is in slightly brackish swamps and marshes. Slopes are generally less than 1 percent. Maurepas soil has a high water table 12 inches above the surface to a depth of 6 inches throughout the year. The water table fluctuates with the rising and falling tide. The available water capacity is very high. Permeability is rapid. This soil is not suited to development because of the high water table, a lack of drainage outlets, and the low strength of the soil.

(24) Mandarin fine sand. This somewhat poorly drained, nearly level soil is on low coastal ridges and knolls in the flatwoods. Slopes range from 0 to 3 percent. Mandarin soil has a seasonal high water table at a depth of 18 to 36 inches for 3 to 6 months in most years. The available water capacity is very low in the surface and subsurface layers and moderate in the subsoil. Permeability is rapid in the surface and subsurface layers and moderate in the subsoil. This soil is only moderately suited to homesite, small commercial, and road development because of the seasonal wetness and the occasional droughtiness. Because of the rapid permeability, areas for onsite waste disposal should be carefully selected to prevent contamination of ground water. Homes should not be clustered together, and the waste disposal site should not be located adjacent to any body of water.

(**26**) Duckston sand, occasionally flooded. This somewhat poorly drained, nearly level soil is on level flats adjacent to coastal dunes and marshes and in low swales between dunes. Slopes range from 0 to 2 percent. Duckston soil has a high water table within a depth of 12 inches throughout most years. The water table may fluctuate with the rising and falling tide. Flooding is likely during periods of heavy rainfall in combination with high tides or during strong coastal storms. The available water capacity is very low. Permeability is very rapid. This soil is poorly suited to use as a site for homes, small commercial, and road development.

(29) Resota fine sand, 0 to 5 percent slopes. This moderately well drained, nearly level or gently sloping soil is on coastal ridges and remnant dunes. Slopes range from 0 to 5 percent. The Resota soil has a seasonal high water table at a depth of 40 to 60 inches for as long as 6 months in most years. The water table is below a depth of 60 inches during dry periods. The available water capacity is very low. Permeability is very rapid. The soil is well suited to use as a site for homes, small commercial buildings, and local roads and streets. It is poorly suited to sewage lagoons and landfills. Because of the very rapid permeability, areas for onsite waste disposal should be carefully selected to prevent contamination of ground water. Homes should not be clustered together, and the waste disposal site should not be located adjacent to any body of water.

(30) Rutlege loamy fine sand, depressional. This very poorly drained, nearly level soil is in depressions. Slopes are generally less than 2 percent. The Rutlege soil has a seasonal high water table ponded on the surface or within a depth of 24 inches 3 to 6 months in most years. The available water capacity is low. Permeability is rapid. This soil is poorly suited to local roads and streets and is generally unsuited to use as a site for small commercial buildings because of the seasonal high water table.

(31) Rutlege fine sand. This very poorly drained, nearly level soil is on broad low-lying flats and on narrow flats adjacent to streams. Slopes range from 0 to 2 percent. The

Rutlege soil has a seasonal high water table at or slightly above the surface for 3 to 6 months in most years. The water table is within a depth of 20 inches during the rest of most years. The available water capacity is low. Permeability is rapid. This soil is poorly suited to use as a site for homes, local roads and streets and is generally unsuited to use as a site for small commercial buildings because of the seasonal high water table.

(33) Scranton fine sand. This very poorly drained, nearly level soil is in broad areas in the flatwoods. Slopes range from 0 to 2 percent. The Scranton soil has a seasonal high water table at a depth of 6 to 18 inches for 3 to 6 months in most years.. The available water capacity is low. Permeability is rapid. This soil is poorly suited to use as a site for homes, local roads and streets and is generally unsuited to use as a site for small commercial buildings because of the seasonal high water table.

(36) Pickney-Pamlico complex, depressional. These very poorly drained, nearly level soils are in depressions, freshwater swamps, and poorly defined drainageways. In areas where these soils occur they are comprised of approximately 45 percent Pickney soil and 40 percent Pamlico soil with slopes generally less than 1 percent. These soils have a seasonal high water table within a depth of 18 inches for as much as 5 months each year. The water table is generally within a depth of less than 6 inches for the rest of most years. The available water capacity ranges from very low to very high in the Pamlico soil and from very low to moderate in the Pickney soil. Permeability ranges from moderate to rapid in both soils These soils are unsuitable for development.

(38) Meadowbrook sand. This poorly drained, nearly level soil is in the flatwoods. Slopes range from 0 to 2 percent. The Meadowbrook soil has a seasonal high water table at a depth of 12 inches for 3 to 6 months in most years.. The available water capacity is low or very low in the surface and subsurface layers and moderate in the subsoil. Permeability is rapid in the surface and subsurface layers and moderately slow in the subsoil. This soil is poorly suited to use as a site for homes, local roads and streets and is generally unsuited to use as a site for small commercial buildings because of the wetness.

(39) Scranton sand, slough. This very poorly drained, nearly level soil is in broad sloughs. Slopes are generally less than 2 percent. The Scranton soil has a seasonal high water table within a depth of 6 inches for 3 to 6 months in most years. The water table is within a depth of 30 inches for the rest of most years, but recedes to a depth of more than 30 inches during extended dry periods. After periods of heavy rainfall, the surface is covered by shallow, slow moving water for as long as 3 weeks. The available water capacity is low. Permeability is rapid. This soil is poorly suited to use as a site for homes, local roads and streets and is generally unsuited to use as a site for small commercial buildings because of the wetness.

(41) Pamlico-Pickney complex, frequently flooded. These very poorly drained, nearly level soils are on flood plains along rivers and major streams . In areas where these soils occur they are comprised of approximately 45 percent Pickney soil and 55 percent Pamlico soil with slopes generally less than 1 percent. These soils have a seasonal high water table at or above the surface for much of the year. They are flooded during periods of heavy rainfall, mainly from December to April. The available water capacity is very high in the organic layers and very low to moderate in the mineral layers. Permeability is rapid or moderately rapid. These soils are unsuitable for development because of the seasonal high water table.

(48) Udorthents, nearly level. These somewhat poorly drained to moderately well drained soils are on high, nearly level deposits of dredge spoil. Slopes generally range from 0 to 3 percent. These soils have a seasonal high water table at a depth of 20 to 60 inches for 3 months or longer during most years. Other soil properties are so variable that they cannot be determined without onsite investigation. The suitability of this soil for development must be determined by onsite investigation.

Appendix E – Runoff Parameters Used in the SWIM Models

SWMM RUNOFF PARAMETERS FOR THE CITY OF APALACHICOLA STUDY AREA											
Subbasin No.	**W**	**A**	**PI**	**S**	**n_i**	**n_p**	**d_I**	**d_p**	**Su**	**Ks**	**IMD**
1	208.00	4.066	26.488	0.006	0.20	0.013	0.035	0.10	4.0	6.0	0.34
2	528.00	18.183	23.978	0.002	0.20	0.013	0.035	0.10	4.0	6.0	0.34
3	409.00	3.183	28.976	0.005	0.20	0.013	0.035	0.10	4.0	6.0	0.34
4	426.00	2.860	16.329	0.045	0.20	0.013	0.035	0.10	4.0	6.0	0.34
5	250.00	2.099	22.153	0.026	0.20	0.013	0.035	0.10	4.0	6.0	0.34
6	319.00	5.127	23.093	0.014	0.20	0.013	0.035	0.10	4.0	6.0	0.34
7	309.00	5.155	18.642	0.022	0.20	0.013	0.035	0.10	4.0	6.0	0.34
8	338.00	2.566	26.228	0.020	0.20	0.013	0.035	0.10	4.0	6.0	0.34
9	342.00	3.211	29.897	0.011	0.20	0.013	0.035	0.10	4.0	6.0	0.34
10	200.00	1.958	13.432	0.013	0.20	0.013	0.035	0.10	4.0	6.0	0.34
11	260.00	2.875	27.722	0.015	0.20	0.013	0.035	0.10	4.0	6.0	0.34
12	280.00	2.246	36.376	0.017	0.20	0.013	0.035	0.10	4.0	6.0	0.34
13	207.00	1.430	30.699	0.034	0.20	0.013	0.035	0.10	4.0	6.0	0.34
14	160.00	1.152	32.205	0.008	0.20	0.013	0.035	0.10	4.0	6.0	0.34
15	988.40	13.614	41.083	0.013	0.20	0.013	0.035	0.10	4.0	6.0	0.34
16	355.90	3.677	32.200	0.006	0.20	0.013	0.035	0.10	4.0	6.0	0.34
17	466.75	10.715	23.565	0.007	0.20	0.013	0.035	0.10	4.0	6.0	0.34
18	571.80	10.501	17.332	0.011	0.20	0.013	0.035	0.10	4.0	6.0	0.34
19	300.00	2.893	21.120	0.013	0.20	0.013	0.035	0.10	4.0	6.0	0.34
20	300.00	2.806	19.066	0.005	0.20	0.013	0.035	0.10	4.0	6.0	0.34
21	121.50	0.976	27.869	0.004	0.20	0.013	0.035	0.10	4.0	6.0	0.34
22	369.75	5.093	30.964	0.017	0.20	0.013	0.035	0.10	4.0	6.0	0.34
23	300.00	2.888	31.891	0.001	0.20	0.013	0.035	0.10	4.0	6.0	0.34
24	239.27	3.845	16.697	0.011	0.20	0.013	0.035	0.10	4.0	6.0	0.34
25	142.40	2.452	23.695	0.014	0.20	0.013	0.035	0.10	4.0	6.0	0.34
26	266.37	2.446	27.105	0.019	0.20	0.013	0.035	0.10	4.0	6.0	0.34
27	254.80	2.632	29.597	0.013	0.20	0.013	0.035	0.10	4.0	6.0	0.34
28	267.40	2.762	20.927	0.010	0.20	0.013	0.035	0.10	4.0	6.0	0.34
29	218.20	2.004	23.902	0.015	0.20	0.013	0.035	0.10	4.0	6.0	0.34
30	153.60	0.529	34.594	0.010	0.20	0.013	0.035	0.10	4.0	6.0	0.34
31	332.02	2.744	25.255	0.022	0.20	0.013	0.035	0.10	4.0	6.0	0.34
32	272.30	2.813	26.271	0.002	0.20	0.013	0.035	0.10	4.0	6.0	0.34
33	513.14	3.534	20.855	0.023	0.20	0.013	0.035	0.10	4.0	6.0	0.34
34	293.25	3.366	26.708	0.012	0.20	0.013	0.035	0.10	4.0	6.0	0.34
35	320.17	2.940	21.837	0.020	0.20	0.013	0.035	0.10	4.0	6.0	0.34
36	314.50	2.527	34.230	0.014	0.20	0.013	0.035	0.10	4.0	6.0	0.34
37	157.40	1.265	26.482	0.023	0.20	0.013	0.035	0.10	4.0	6.0	0.34
38	182.20	1.464	14.071	0.012	0.20	0.013	0.035	0.10	4.0	6.0	0.34

W = subbasin width (feet)
A = subbasin area (acres)
PI = percent imperviousness (acres/acres)
S = average basin slope
n_I = Manning's n for impervious areas (feet)
n_p = Manning's n for pervious areas
d_I = depression storage in impervious areas (feet)
d_p = depression storage in pervious areas (feet)
Su = capillary suction (inches)
Ks = saturated hydraulic conductivity (in/hr)
IMD = initial moisture deficit

Appendix F – Physical Characteristics of Conduits in the Apalachicola Study Area

Physical Characteristics of Conduits				
conduit type = circular pipe				
Conduit No.	**Length (feet)**	**Diameter (feet)**	**Slope (ft/ft)**	**Manning's n**
PA2-3	110	1.5	0.360	0.015
PA3-4	230	4.0	0.360	0.015
PA4-6	120	4.0	0.360	0.015
PA6-7	400	4.0	1.325	0.015
PA7-9	300	4.0	0.0	0.015
PA9-11	100	4.0	0.0	0.015
PBA15-7	200	3.5	0.0	0.015
PA8-9	200	1.0	0.435	0.015
PA15-16	700	2.0	0.780	0.015
PB16-15	100	1.0	0.100	0.015
PB14-15	120	3.5	0.0	0.015
PB13-14	100	3.5	0.0	0.015
PB12-13	100	3.5	0.135	0.015
PB18-12	100	3.5	0.135	0.015
PB19-18	130	3.0	0.308	0.015
PB10-11	100	1.5	0.610	0.015
PB11-12	250	1.5	0.702	0.015
PB21-19	100	3.0	0.490	0.015
PB8-9	100	1.0	0.670	0.015
PB7-8	100	1.0	0.670	0.015
PB3-7	100	1.0	0.670	0.015
PB4-3	200	1.0	0.670	0.015
PB24-21	100	2.0	0.173	0.015
PB23-24	100	1.0	0.100	0.015
PB25-24	200	2.0	0.173	0.015
PB28-25	100	1.0	0.100	0.015
PB26-25	100	2.0	0.173	0.015
PB6-7	150	1.0	0.100	0.015
PC12-11	100	1.0	0.100	0.015
PC11-9	100	2.0	0.100	0.015
PC8-9	100	1.0	0.100	0.015
PC9-6	100	2.0	0.150	0.015
PC7-5	100	2.0	0.158	0.015
PC5-4	100	2.0	0.158	0.015
PC4-3	100	2.0	0.158	0.015
PC3-2	100	2.0	0.158	0.015
PC2-1	260	2.0	0.292	0.015
PC1-B26	150	2.0	0.913	0.015
PC7-6	60	1.0	0.100	0.015
PA11A-12A	50	3.0	0.0	0.015
PA11A-12B	50	3.0	0.0	0.015

Physical Characteristics of Conduits				
conduit type = circular pipe				
Conduit No.	**Length (feet)**	**Diameter (feet)**	**Slope (ft/ft)**	**Manning's n**
PA2-3	110	1.5	0.360	0.015
PA3-4	230	4.0	0.360	0.015
PA4-6	120	4.0	0.360	0.015
PA6-7	400	4.0	1.325	0.015
PA7-9	300	4.0	0.0	0.015
PA9-11	100	4.0	0.0	0.015
PBA15-7	200	3.5	0.0	0.015
PA8-9	200	1.0	0.435	0.015
PA15-16	700	2.0	0.780	0.015
PB16-15	100	1.0	0.100	0.015
PB14-15	120	3.5	0.0	0.015
PB13-14	100	3.5	0.0	0.015
PB12-13	100	3.5	0.135	0.015
PB18-12	100	3.5	0.135	0.015
PB19-18	130	3.0	0.308	0.015
PB10-11	100	1.5	0.610	0.015
PB11-12	250	1.5	0.702	0.015
PB21-19	100	3.0	0.490	0.015
PB8-9	100	1.0	0.670	0.015
PB7-8	100	1.0	0.670	0.015
PB3-7	100	1.0	0.670	0.015
PB4-3	200	1.0	0.670	0.015
PB24-21	100	2.0	0.173	0.015
PB23-24	100	1.0	0.100	0.015
PB25-24	200	2.0	0.173	0.015
PB28-25	100	1.0	0.100	0.015
PB26-25	100	2.0	0.173	0.015
PB6-7	150	1.0	0.100	0.015
PC12-11	100	1.0	0.100	0.015
PC11-9	100	2.0	0.100	0.015
PC8-9	100	1.0	0.100	0.015
PC9-6	100	2.0	0.150	0.015
PC7-5	100	2.0	0.158	0.015
PC5-4	100	2.0	0.158	0.015
PC4-3	100	2.0	0.158	0.015
PC3-2	100	2.0	0.158	0.015
PC2-1	260	2.0	0.292	0.015
PC1-B26	150	2.0	0.913	0.015
PC7-6	60	1.0	0.100	0.015
PA11A-12A	50	3.0	0.0	0.015
PA11A-12B	50	3.0	0.0	0.015

Appendix G – Average Runoff and Volume by Subbasin

Average Runoff and Average Volume (1962 - 1992)				
Sub-Basin	Area (Acres)	Percent Impervious	Average Runoff (Inches)	Average Runoff Volume (cubic feet)
1	4.1	26.5	1.62	23,945
2	18.2	24.0	5.94	392,071
3	3.2	29.0	1.56	18,037
4	2.9	16.3	0.95	9,831
5	2.1	22.2	0.84	6,433
6	5.1	23.1	2.01	15,344
7	5.2	18.6	1.83	13,919
8	2.6	26.2	1.15	8,727
9	3.2	29.9	1.52	11,586
10	2.0	13.4	0.60	4,538
11	2.9	27.7	1.30	9,915
12	2.2	36.4	1.23	9,392
13	1.4	30.7	0.70	5,369
14	1.2	32.2	0.57	4,378
15	13.6	41.1	14.29	10,8914
16	3.7	32.2	3.35	25,526
17	10.7	23.6	3.94	29,994
18	10.5	17.3	3.42	26,052
19	2.9	21.1	1.12	8,520
20	2.8	19.1	0.99	7,555
21	1.0	27.9	0.42	3,227
22	5.1	31.0	2.44	18,569
23	2.9	31.9	1.28	9,756
24	3.9	16.7	1.20	9,114
25	2.5	23.7	1.84	14,000
26	2.4	27.1	2.10	15,966
27	2.6	29.6	2.13	16,208
28, 31, 32	8.3	24.2	6.40	48,790
29	2.0	23.9	1.58	12,068
30	0.5	34.6	0.53	4,073
33	3.5	20.9	2.59	19,736
34	3.4	26.7	2.79	21,228
35	2.9	21.8	2.21	16,865
36	2.5	34.2	2.51	19,099
37	1.3	26.5	1.07	8,180
38	1.5	14.1	0.79	6,029

APPENDIX H -- Average Annual Pollutant Loadings

Average annual pollutants estimated using the average concentration and average annual runoff.

Total Suspended Solids						
Sub-basin	Average Runoff Volume		Average Concentration (mg/L)	Land Use Type	Average Load per Year	
	(cu.ft.)	% of Total			(lbs.)	% of Total
1	23,945	2.4%	48.67	MDR	72.7	3.0%
2	39,2071	39.9%	48.67	MDR, I	1190	48.4%
3	18,037	1.8%	48.67	MDR	54.7	2.2%
4	9,831	1.0%	48.67	MDR	29.8	1.2%
5	6,433	0.7%	48.67	MDR	19.5	0.8%
6	15,344	1.6%	48.67	MDR	46.6	1.9%
7	13,919	1.4%	48.67	MDR	42.2	1.7%
8	8,727	0.9%	48.67	MDR	26.5	1.1%
9	11,586	1.2%	48.67	MDR, C	35.2	1.4%
10	4,538	0.5%	48.67	MDR, C	13.7	0.6%
11	9,915	1.0%	48.67	C	30.1	1.2%
12	9,392	1.0%	48.67	C	28.5	1.2%
13	5,369	0.5%	48.67	C	16.3	0.7%
14	4,378	0.4%	48.67	C	13.3	0.5%
15	10,8914	11.1%	23.67	MDR, C	160.8	6.5%
16	25,526	2.6%	23.67	MDR, C	37.6	1.5%
17	29,994	3.1%	48.67	MDR, I	91.0	3.7%
18	26,052	2.7%	48.67	MDR	79.1	3.2%
19	8,520	0.9%	48.67	MDR	25.9	1.1%
20	7,555	0.8%	48.67	MDR	22.9	0.9%
21	3,227	0.3%	48.67	MDR	9.8	0.4%
22	18,569	1.9%	48.67	MDR, C	56.4	2.3%
23	9,756	1.0%	48.67	MDR, C	29.6	1.2%
24	9,114	0.9%	48.67	MDR, C	27.7	1.1%
25	14,000	1.4%	23.67	C	20.7	0.8%
26	15,966	1.6%	23.67	MDR, C	23.6	1.0%
27	16,208	1.6%	23.67	MDR, C	23.9	1.0%
28, 31, 32	48,790	5.0%	23.67	MDR, C	72.0	2.9%
29	12,068	1.2%	23.67	MDR, C	17.8	0.7%
30	4,073	0.4%	23.67	MDR	6.0	0.2%
33	19,736	2.0%	23.67	MDR	29.1	1.2%
34	21,228	2.2%	23.67	MDR	31.3	1.3%
35	16,865	1.7%	23.67	MDR	24.9	1.0%
36	19,099	1.9%	23.67	MDR	28.2	1.1%
37	8,180	0.8%	23.67	MDR	12.1	0.5%
38	6,029	0.6%	23.67	R	8.9	0.4%
TOTAL	982,952				2,458.5	

LEGEND: MDR - Medium Density Residential; R - Recreational; C - Commercial; I - Institutional

Total Kjeldahl Nitrogen, as N						
Sub-basin	Average Runoff Volume		Average Concentration (mg/L)	Land Use Type	Average Load per Year	
	(cu.ft.)	% of Total			(lbs.)	% of Total
1	23,945	2.4%	1.03	MDR	1.5	2.7%
2	392,071	39.9%	1.03	MDR, I	25.2	44.5%
3	18,037	1.8%	1.03	MDR	1.2	2.0%
4	9,831	1.0%	1.03	MDR	0.6	1.1%
5	6,433	0.7%	1.03	MDR	0.4	0.7%
6	15,344	1.6%	1.03	MDR	1.0	1.7%
7	13,919	1.4%	1.03	MDR	0.9	1.6%
8	8,727	0.9%	1.03	MDR	0.6	1.0%
9	11,586	1.2%	1.03	MDR, C	0.7	1.3%
10	4,538	0.5%	1.03	MDR, C	0.3	0.5%
11	9,915	1.0%	1.03	C	0.6	1.1%
12	9,392	1.0%	1.03	C	0.6	1.1%
13	5,369	0.5%	1.03	C	0.3	0.6%
14	4,378	0.4%	1.03	C	0.3	0.5%
15	108,914	11.1%	0.72	MDR, C	4.9	8.6%
16	25,526	2.6%	0.72	MDR, C	1.1	2.0%
17	29,994	3.1%	1.03	MDR, I	1.9	3.4%
18	26,052	2.7%	1.03	MDR	1.7	3.0%
19	8,520	0.9%	1.03	MDR	0.5	1.0%
20	7,555	0.8%	1.03	MDR	0.5	0.9%
21	3,227	0.3%	1.03	MDR	0.2	0.4%
22	18,569	1.9%	1.03	MDR, C	1.2	2.1%
23	9,756	1.0%	1.03	MDR, C	0.6	1.1%
24	9,114	0.9%	1.03	MDR, C	0.6	1.0%
25	14,000	1.4%	0.72	C	0.6	1.1%
26	15,966	1.6%	0.72	MDR, C	0.7	1.3%
27	16,208	1.6%	0.72	MDR, C	0.7	1.3%
28, 31, 32	48,790	5.0%	0.72	MDR, C	2.2	3.9%
29	12,068	1.2%	0.72	MDR, C	0.5	1.0%
30	4,073	0.4%	0.72	MDR	0.2	0.3%
33	19,736	2.0%	0.72	MDR	0.9	1.6%
34	21,228	2.2%	0.72	MDR	1.0	1.7%
35	16,865	1.7%	0.72	MDR	0.8	1.3%
36	19,099	1.9%	0.72	MDR	0.9	1.5%
37	8,180	0.8%	0.72	MDR	0.4	0.6%
38	6,029	0.6%	0.72	R	0.3	0.5%
TOTAL	982,952				56.6	

LEGEND: MDR – Medium Density Residential; R - Recreational; C - Commercial; I - Institutional

Nitrate + Nitrite, as N						
Sub-basin	Average Runoff Volume		Average Concentration (mg N/L)	Land Use Type	Average Load per Year	
	Volume (cu.ft.)	% of Total			per Year (lbs.)	% of Total
1	23,945	2.4%	0.19	MDR	0.3	2.1%
2	392,071	39.9%	0.19	MDR, I	4.6	34.3%
3	18,037	1.8%	0.19	MDR	0.2	1.6%
4	9,831	1.0%	0.19	MDR	0.1	0.9%
5	6,433	0.7%	0.19	MDR	0.1	0.6%
6	15,344	1.6%	0.19	MDR	0.2	1.3%
7	13,919	1.4%	0.19	MDR	0.2	1.2%
8	8,727	0.9%	0.19	MDR	0.1	0.8%
9	11,586	1.2%	0.19	MDR, C	0.1	1.0%
10	4,538	0.5%	0.19	MDR, C	0.1	0.4%
11	9,915	1.0%	0.19	C	0.1	0.9%
12	9,392	1.0%	0.19	C	0.1	0.8%
13	5,369	0.5%	0.19	C	0.1	0.5%
14	4,378	0.4%	0.19	C	0.1	0.4%
15	108,914	11.1%	0.28	MDR, C	1.9	14.0%
16	25,526	2.6%	0.28	MDR, C	0.4	3.3%
17	29,994	3.1%	0.19	MDR, I	0.4	2.6%
18	26,052	2.7%	0.19	MDR	0.3	2.3%
19	8,520	0.9%	0.19	MDR	0.1	0.7%
20	7,555	0.8%	0.19	MDR	0.1	0.7%
21	3,227	0.3%	0.19	MDR	0.04	0.3%
22	18,569	1.9%	0.19	MDR, C	0.2	1.6%
23	9,756	1.0%	0.19	MDR, C	0.1	0.9%
24	9,114	0.9%	0.19	MDR, C	0.1	0.8%
25	14,000	1.4%	0.28	C	0.2	1.8%
26	15,966	1.6%	0.28	MDR, C	0.3	2.1%
27	16,208	1.6%	0.28	MDR, C	0.3	2.1%
28, 31, 32	48,790	5.0%	0.28	MDR, C	0.9	6.3%
29	12,068	1.2%	0.28	MDR, C	0.2	1.6%
30	4,073	0.4%	0.28	MDR	0.1	0.5%
33	19,736	2.0%	0.28	MDR	0.3	2.5%
34	21,228	2.2%	0.28	MDR	0.4	2.7%
35	16,865	1.7%	0.28	MDR	0.3	2.2%
36	19,099	1.9%	0.28	MDR	0.3	2.5%
37	8,180	0.8%	0.28	MDR	0.1	1.1%
38	6,029	0.6%	0.28	R	0.1	0.8%
TOTAL	982,952				13.5	

LEGEND: MDR - Medium Density Residential; R - Recreational; C - Commercial; I - Institutional

Phosphorus, Total as P						
Sub-basin	Average Runoff Volume		Average Concentration (mg P/L)	Land Use Type	Average Load per Year	
	(cu.ft.)	% of Total			(lbs.)	% of Total
1	23,945	2.4%	0.25	MDR	0.4	2.8%
2	392,071	39.9%	0.25	MDR, I	6.1	46.2%
3	18,037	1.8%	0.25	MDR	0.3	2.1%
4	9,831	1.0%	0.25	MDR	0.2	1.2%
5	6,433	0.7%	0.25	MDR	0.1	0.8%
6	15,344	1.6%	0.25	MDR	0.2	1.8%
7	13,919	1.4%	0.25	MDR	0.2	1.6%
8	8,727	0.9%	0.25	MDR	0.1	1.0%
9	11,586	1.2%	0.25	MDR, C	0.2	1.4%
10	4,538	0.5%	0.25	MDR, C	0.1	0.5%
11	9,915	1.0%	0.25	C	0.2	1.2%
12	9,392	1.0%	0.25	C	0.1	1.1%
13	5,369	0.5%	0.25	C	0.1	0.6%
14	4,378	0.4%	0.25	C	0.1	0.5%
15	108,914	11.1%	0.15	MDR, C	1.0	7.7%
16	25,526	2.6%	0.15	MDR, C	0.2	1.8%
17	29,994	3.1%	0.25	MDR, I	0.5	3.5%
18	26,052	2.7%	0.25	MDR	0.4	3.1%
19	8,520	0.9%	0.25	MDR	0.1	1.0%
20	7,555	0.8%	0.25	MDR	0.1	0.9%
21	3,227	0.3%	0.25	MDR	0.05	0.4%
22	18,569	1.9%	0.25	MDR, C	0.3	2.2%
23	9,756	1.0%	0.25	MDR, C	0.2	1.2%
24	9,114	0.9%	0.25	MDR, C	0.1	1.1%
25	14,000	1.4%	0.15	C	0.1	1.0%
26	15,966	1.6%	0.15	MDR, C	0.1	1.1%
27	16,208	1.6%	0.15	MDR, C	0.2	1.1%
28, 31, 32	48,790	5.0%	0.15	MDR, C	0.5	3.5%
29	12,068	1.2%	0.15	MDR, C	0.1	0.9%
30	4,073	0.4%	0.15	MDR	0.04	0.3%
33	19,736	2.0%	0.15	MDR	0.2	1.4%
34	21,228	2.2%	0.15	MDR	0.2	1.5%
35	16,865	1.7%	0.15	MDR	0.2	1.2%
36	19,099	1.9%	0.15	MDR	0.2	1.4%
37	8,180	0.8%	0.15	MDR	0.1	0.6%
38	6,029	0.6%	0.15	R	0.1	0.4%
TOTAL	982,952				13.2	

LEGEND: MDR - Medium Density Residential; R - Recreational; C - Commercial; I - Institutional

Orthophosphate, as P						
Sub-basin	Average Runoff Volume		Average Concentration (mg P/L)	Land Use Type	Average Load per Year	
	(cu.ft.)	% of Total			(lbs.)	% of Total
1	23,945	2.4%	0.10	MDR	0.1	2.7%
2	39,2071	39.9%	0.10	MDR, I	2.4	44.5%
3	18,037	1.8%	0.10	MDR	0.1	2.0%
4	9,831	1.0%	0.10	MDR	0.1	1.1%
5	6,433	0.7%	0.10	MDR	0.04	0.7%
6	15,344	1.6%	0.10	MDR	0.1	1.7%
7	13,919	1.4%	0.10	MDR	0.1	1.6%
8	8,727	0.9%	0.10	MDR	0.05	1.0%
9	11,586	1.2%	0.10	MDR, C	0.1	1.3%
10	4,538	0.5%	0.10	MDR, C	0.02	0.5%
11	9,915	1.0%	0.10	C	0.1	1.1%
12	9,392	1.0%	0.10	C	0.06	1.1%
13	5,369	0.5%	0.10	C	0.03	0.6%
14	4,378	0.4%	0.10	C	0.03	0.5%
15	10,8914	11.1%	0.07	MDR, C	0.5	8.6%
16	25,526	2.6%	0.07	MDR, C	0.1	2.0%
17	29,994	3.1%	0.10	MDR, I	0.2	3.4%
18	26,052	2.7%	0.10	MDR	0.2	3.0%
19	8,520	0.9%	0.10	MDR	0.05	1.0%
20	7,555	0.8%	0.10	MDR	0.05	0.9%
21	3,227	0.3%	0.10	MDR	0.02	0.4%
22	18,569	1.9%	0.10	MDR, C	0.1	2.1%
23	9,756	1.0%	0.10	MDR, C	0.1	1.1%
24	9,114	0.9%	0.10	MDR, C	0.06	1.0%
25	14,000	1.4%	0.07	C	0.06	1.1%
26	15,966	1.6%	0.07	MDR, C	0.07	1.3%
27	16,208	1.6%	0.07	MDR, C	0.07	1.3%
28, 31, 32	48,790	5.0%	0.07	MDR, C	0.2	3.9%
29	12,068	1.2%	0.07	MDR, C	0.05	1.0%
30	4,073	0.4%	0.07	MDR	0.02	0.3%
33	19,736	2.0%	0.07	MDR	0.09	1.6%
34	21,228	2.2%	0.07	MDR	0.09	1.7%
35	16,865	1.7%	0.07	MDR	0.07	1.3%
36	19,099	1.9%	0.07	MDR	0.08	1.5%
37	8,180	0.8%	0.07	MDR	0.03	0.6%
38	6,029	0.6%	0.07	R	0.03	0.5%
TOTAL	982,952				5.5	

LEGEND: MDR - Medium Density Residential; R - Recreational; C - Commercial; I - Institutional

Magnesium						
Sub-basin	Average Runoff Volume		Average Concentration (mg/L)	Land Use Type	Average Load per Year	
	(cu.ft.)	% of Total			(lbs.)	% of Total
1	23,945	2.4%	12.38	MDR	18.5	2.4%
2	392,071	39.9%	12.38	MDR, I	302.7	38.9%
3	18,037	1.8%	12.38	MDR	13.9	1.8%
4	9,831	1.0%	12.38	MDR	7.6	1.0%
5	6,433	0.7%	12.38	MDR	5.0	0.6%
6	15,344	1.6%	12.38	MDR	11.8	1.5%
7	13,919	1.4%	12.38	MDR	10.7	1.4%
8	8,727	0.9%	12.38	MDR	6.7	0.9%
9	11,586	1.2%	12.38	MDR, C	8.9	1.2%
10	4,538	0.5%	12.38	MDR, C	3.5	0.5%
11	9,915	1.0%	12.38	C	7.7	1.0%
12	9,392	1.0%	12.38	C	7.3	0.9%
13	5,369	0.5%	12.38	C	4.1	0.5%
14	4,378	0.4%	12.38	C	3.4	0.4%
15	108,914	11.1%	13.26	MDR, C	90.1	11.6%
16	25,526	2.6%	13.26	MDR, C	21.1	2.7%
17	29,994	3.1%	12.38	MDR, I	23.2	3.0%
18	26,052	2.7%	12.38	MDR	20.1	2.6%
19	8,520	0.9%	12.38	MDR	6.6	0.8%
20	7,555	0.8%	12.38	MDR	5.8	0.8%
21	3,227	0.3%	12.38	MDR	2.5	0.3%
22	18,569	1.9%	12.38	MDR, C	14.3	1.8%
23	9,756	1.0%	12.38	MDR, C	7.5	1.0%
24	9,114	0.9%	12.38	MDR, C	7.0	0.9%
25	14,000	1.4%	13.26	C	11.6	1.5%
26	15,966	1.6%	13.26	MDR, C	13.2	1.7%
27	16,208	1.6%	13.26	MDR, C	13.4	1.7%
28, 31, 32	48,790	5.0%	13.26	MDR, C	40.3	5.2%
29	12,068	1.2%	13.26	MDR, C	10.0	1.3%
30	4,073	0.4%	13.26	MDR	3.4	0.4%
33	19,736	2.0%	13.26	MDR	16.3	2.1%
34	21,228	2.2%	13.26	MDR	17.6	2.3%
35	16,865	1.7%	13.26	MDR	13.9	1.8%
36	19,099	1.9%	13.26	MDR	15.8	2.0%
37	8,180	0.8%	13.26	MDR	6.8	0.9%
38	6,029	0.6%	13.26	R	5.0	0.6%
TOTAL	982,952				777.3	

LEGEND: MDR - Medium Density Residential; R - Recreational; C - Commercial; I - Institutional

Zinc						
Sub-basin	Average Runoff Volume		Average Concentration (ug/L)	Land Use Type	Average Load per Year	
	(cu.ft.)	% of Total			(lbs.)	% of Total
1	23,945	2.4%	68.25	MDR	0.010	3.0%
2	392,071	39.9%	68.25	MDR, I	0.167	49.3%
3	18,037	1.8%	68.25	MDR	0.008	2.3%
4	9,831	1.0%	68.25	MDR	0.004	1.2%
5	6,433	0.7%	68.25	MDR	0.003	0.8%
6	15,344	1.6%	68.25	MDR	0.006	1.9%
7	13,919	1.4%	68.25	MDR	0.006	1.7%
8	8,727	0.9%	68.25	MDR	0.004	1.1%
9	11,586	1.2%	68.25	MDR, C	0.005	1.5%
10	4,538	0.5%	68.25	MDR, C	0.002	0.6%
11	9,915	1.0%	68.25	C	0.004	1.2%
12	9,392	1.0%	68.25	C	0.004	1.2%
13	5,369	0.5%	68.25	C	0.002	0.7%
14	4,378	0.4%	68.25	C	0.002	0.6%
15	108,914	11.1%	30.25	MDR, C	0.020	6.1%
16	25,526	2.6%	30.25	MDR, C	0.005	1.4%
17	29,994	3.1%	68.25	MDR, I	0.013	3.8%
18	26,052	2.7%	68.25	MDR	0.011	3.3%
19	8,520	0.9%	68.25	MDR	0.004	1.1%
20	7,555	0.8%	68.25	MDR	0.003	0.9%
21	3,227	0.3%	68.25	MDR	0.001	0.4%
22	18,569	1.9%	68.25	MDR, C	0.008	2.3%
23	9,756	1.0%	68.25	MDR, C	0.004	1.2%
24	9,114	0.9%	68.25	MDR, C	0.004	1.1%
25	14,000	1.4%	30.25	C	0.003	0.8%
26	15,966	1.6%	30.25	MDR, C	0.003	0.9%
27	16,208	1.6%	30.25	MDR, C	0.003	0.9%
28, 31, 32	48,790	5.0%	30.25	MDR, C	0.009	2.7%
29	12,068	1.2%	30.25	MDR, C	0.002	0.7%
30	4,073	0.4%	30.25	MDR	0.001	0.2%
33	19,736	2.0%	30.25	MDR	0.004	1.1%
34	21,228	2.2%	30.25	MDR	0.004	1.2%
35	16,865	1.7%	30.25	MDR	0.003	0.9%
36	19,099	1.9%	30.25	MDR	0.004	1.1%
37	8,180	0.8%	30.25	MDR	0.002	0.5%
38	6,029	0.6%	30.25	R	0.001	0.3%
TOTAL	982,952				0.339	

LEGEND: MDR - Medium Density Residential; R - Recreational; C - Commercial; I - Institutional

APPENDIX I –SURCHARGED AND FLOODED TIMES FOR DESIGN STORMS

Surcharged and flooded times at different junctions for each design storm.

Junction Surcharge and Flooding Times for 5yr1hr Synthetic Storm		
Junction Name	**Surcharged Time (minutes)**	**Flooded Time (minutes)**
MHA2 SB2	15.63	0.00
MHA3	0.00	0.00
MHA4	0.00	0.00
MHA6 SB3	0.00	0.00
MHA7	0.00	0.00
MHA9	0.00	0.00
MHA11	0.00	0.00
MHA12	0.00	0.00
MHB15	1.33	0.00
MHA8 SB4	29.40	0.00
MHA15 SB1	0.00	0.00
MHA16	0.00	0.00
MHB16 SB5	41.63	0.00
MHB14 SB6	2.70	0.00
MHB13 SB8	3.33	0.00
MHB12	2.68	0.00
MHB18	1.63	0.00
MHB19	3.87	0.00
MHB10 SB11	0.00	0.00
MHB11	17.30	0.00
MHB21	0.00	0.00
MHB9	0.00	28.78
MHB8 SB9	42.80	0.83
MHB7	38.42	1.40
MHB3 SB12	21.18	6.73
MHB4 SB14	14.20	9.20
MHB24 SB7	21.63	0.00
MHB23 SB10	42.75	0.00
MHB25	24.28	0.00
MHB28 SB21	42.72	0.00
MHB26 SB18	24.95	0.00
MHB6 SB13	33.85	6.25
MHC12 SB17	42.20	16.13
MHC11 SB22	15.77	5.70
MHC9	15.88	3.05
MHC8 SB19	30.78	6.58
MHC6	16.17	2.83
MHC5	16.10	2.75
MHC4 SB24	16.02	2.67
MHC3	15.50	0.60
MHC2 SB20	14.92	0.20
MHC1	15.50	0.00
MHC7 SB23	37.22	7.08
MHE4 SB15	43.35	17.80
MHE6 SB16	40.78	0.00
MHD27	0.00	0.00
MHE7	0.00	0.00

Junction Name	Surcharged Time (minutes)	Flooded Time (minutes)
MHE8	0.00	0.00
MHE9	0.00	0.00
MHD1 SB26	10.90	3.22
MHD2	5.53	0.23
MHD4	5.90	0.37
MHD7 SB27	4.87	0.00
MHD6	6.58	0.17
MHD5 SB25	7.50	3.55
MHD14	9.03	0.00
MHD12	0.00	0.00
MHD13 SB30	0.00	0.00
MHD16	9.27	0.00
MHD17	9.67	0.00
MHD20	0.00	0.00
MHD18 SB29	28.42	0.00
MHD19	33.70	0.00
MHD22	0.00	0.00
MHD21 SB34	31.70	0.00
MHD23 SB36	0.00	0.00
MHD26 SB38	38.40	1.37
MHD25 SB37	39.40	0.33
MHD24 SB35	39.68	0.00
MHE5	40.87	0.00
MHD28 SB33	31.83	0.00

Junction Surcharge and Flooding Time for 5yr3hr Synthetic Storm		
Junction Name	**Surcharged Time (minutes)**	**Flooded Time (minutes)**
MHA2 SB2	46.75	26.58
MHA3	0.00	0.00
MHA4	0.00	0.00
MHA6 SB3	0.00	0.00
MHA7	0.00	0.00
MHA9	0.00	0.00
MHA11	0.00	0.00
MHA12	0.00	0.00
MHB15	28.93	0.00
MHA8 SB4	62.95	0.00
MHA15 SB1	0.00	0.00
MHA16	0.00	0.00
MHB16 SB5	137.12	0.00
MHB14 SB6	30.80	0.00
MHB13 SB8	31.90	0.00
MHB12	30.88	0.00
MHB18	29.65	0.00
MHB19	32.52	0.00
MHB10 SB11	22.22	0.00
MHB11	47.90	0.00
MHB21	27.22	0.00
MHB9	0.00	63.20
MHB8 SB9	123.08	0.00
MHB7	77.42	0.00
MHB3 SB12	58.35	36.25
MHB4 SB14	45.95	38.58
MHB24 SB7	53.85	0.00
MHB23 SB10	95.85	0.00
MHB25	57.55	0.00
MHB28 SB21	96.47	0.00
MHB26 SB18	58.55	0.00
MHB6 SB13	70.35	33.58
MHC12 SB17	89.37	47.20
MHC11 SB22	46.50	32.65
MHC9	46.70	22.18
MHC8 SB19	69.13	34.70
MHC6	47.12	21.67
MHC5	46.93	18.65
MHC4 SB24	46.63	21.32
MHC3	45.87	0.00
MHC2 SB20	45.40	0.00
MHC1	46.95	0.00
MHC7 SB23	75.78	34.80
MHE4 SB15	93.60	49.05
MHE6 SB16	81.10	0.00
MHD27	0.00	0.00
MHE7	0.00	0.00

Junction Name	Surcharged Time (minutes)	Flooded Time (minutes)
MHE8	0.00	0.00
MHE9	0.00	0.00
MHD1 SB26	37.45	25.33
MHD2	29.93	0.00
MHD4	30.47	0.00
MHD7 SB27	28.55	0.00
MHD6	31.03	0.00
MHD5 SB25	31.93	25.82
MHD14	34.47	0.00
MHD12	0.00	0.00
MHD13 SB30	0.00	0.00
MHD16	34.95	0.00
MHD17	35.52	0.00
MHD20	0.00	0.00
MHD18 SB29	65.35	0.00
MHD19	74.25	0.00
MHD22	0.00	0.00
MHD21 SB34	69.22	0.00
MHD23 SB36	9.20	0.00
MHD26 SB38	75.02	16.70
MHD25 SB37	80.70	0.00
MHD24 SB35	87.27	0.00
MHE5	86.08	0.00
MHD28 SB33	68.60	0.00

Junction Surcharge and Flooding Times for 10yr1hr Synthetic Storm		
Junction Name	**Surcharged Time (minutes)**	**Flooded Time (minutes)**
MHA2 SB2	17.12	1.47
MHA3	0.00	0.00
MHA4	0.00	0.00
MHA6 SB3	0.00	0.00
MHA7	0.00	0.00
MHA9	0.00	0.00
MHA11	0.00	0.00
MHA12	0.00	0.00
MHB15	3.67	0.00
MHA8 SB4	32.32	0.00
MHA15 SB1	0.00	0.00
MHA16	0.00	0.00
MHB16 SB5	42.70	0.00
MHB14 SB6	4.73	0.00
MHB13 SB8	5.67	0.00
MHB12	4.85	0.00
MHB18	4.07	0.00
MHB19	6.27	0.00
MHB10 SB11	0.00	0.00
MHB11	19.68	0.00
MHB21	2.93	0.00
MHB9	0.00	33.87
MHB8 SB9	43.83	1.95
MHB7	40.08	2.53
MHB3 SB12	24.38	7.37
MHB4 SB14	15.38	10.93
MHB24 SB7	23.80	0.00
MHB23 SB10	43.88	0.00
MHB25	26.62	0.00
MHB28 SB21	43.92	0.00
MHB26 SB18	27.33	0.00
MHB6 SB13	37.95	6.80
MHC12 SB17	44.05	17.15
MHC11 SB22	16.90	6.38
MHC9	17.02	4.18
MHC8 SB19	35.67	8.07
MHC6	17.37	4.02
MHC5	17.30	3.93
MHC4 SB24	17.20	3.85
MHC3	16.65	2.02
MHC2 SB20	16.12	1.85
MHC1	16.92	0.00
MHC7 SB23	41.05	9.08
MHE4 SB15	44.52	18.93

Junction Name	Surcharged Time (minutes)	Flooded Time (minutes)
MHE6 SB16	41.90	0.00
MHD27	0.00	0.00
MHE7	0.00	0.00
MHE8	0.00	0.00
MHE9	0.00	0.00
MHD1 SB26	12.27	4.28
MHD2	6.60	0.15
MHD4	7.07	0.70
MHD7 SB27	5.83	0.00
MHD6	7.78	0.50
MHD5 SB25	8.62	4.58
MHD14	10.52	0.00
MHD12	0.25	0.00
MHD13 SB30	1.23	0.00
MHD16	10.82	0.00
MHD17	11.22	0.00
MHD20	0.00	0.00
MHD18 SB29	31.28	0.00
MHD19	37.58	0.00
MHD22	0.00	0.00
MHD21 SB34	35.10	1.65
MHD23 SB36	0.00	0.00
MHD26 SB38	39.78	2.75
MHD25 SB37	40.20	1.45
MHD24 SB35	40.63	0.00
MHE5	41.98	0.00
MHD28 SB33	34.90	0.00

Junction Surcharge and Flooding Times for 10yr3hr Synthetic Storm		
Junction Name	**Surcharged Time (minutes)**	**Flooded Time (minutes)**
MHA2 SB2	49.35	29.68
MHA3	0.00	0.00
MHA4	0.00	0.00
MHA6 SB3	0.00	0.00
MHA7	0.00	0.00
MHA9	0.00	0.00
MHA11	0.00	0.00
MHA12	0.00	0.00
MHB15	31.38	0.00
MHA8 SB4	67.17	0.00
MHA15 SB1	0.00	0.00
MHA16	0.00	0.00
MHB16 SB5	139.93	0.00
MHB14 SB6	33.18	0.00
MHB13 SB8	34.27	0.00
MHB12	33.20	0.00
MHB18	31.98	0.00
MHB19	35.10	0.00
MHB10 SB11	26.38	0.00
MHB11	51.58	0.00
MHB21	29.78	0.00
MHB9	0.00	69.80
MHB8 SB9	130.87	0.00
MHB7	86.17	0.00
MHB3 SB12	63.10	37.98
MHB4 SB14	49.22	42.28
MHB24 SB7	57.60	0.00
MHB23 SB10	104.63	0.00
MHB25	61.48	0.00
MHB28 SB21	105.52	0.00
MHB26 SB18	62.98	0.00
MHB6 SB13	77.05	35.48
MHC12 SB17	99.90	49.77
MHC11 SB22	49.52	34.68
MHC9	49.72	25.52
MHC8 SB19	74.97	36.85
MHC6	50.22	25.02
MHC5	49.97	14.10
MHC4 SB24	49.65	24.75
MHC3	49.00	2.02
MHC2 SB20	48.53	0.62
MHC1	50.40	0.00
MHC7 SB23	83.50	37.38
MHE4 SB15	102.38	53.58
MHE6 SB16	87.18	0.00
MHD27	15.67	0.00
MHE7	0.00	0.00

Junction Name	Surcharged Time (minutes)	Flooded Time (minutes)
MHE8	0.00	0.00
MHE9	0.00	0.00
MHD1 SB26	39.90	27.97
MHD2	32.12	2.83
MHD4	32.62	16.20
MHD7 SB27	30.88	0.00
MHD6	33.20	16.47
MHD5 SB25	34.18	28.37
MHD14	37.00	0.00
MHD12	0.00	0.00
MHD13 SB30	21.33	0.00
MHD16	37.50	0.00
MHD17	38.03	0.00
MHD20	14.80	0.00
MHD18 SB29	66.02	0.00
MHD19	73.57	0.00
MHD22	12.97	0.00
MHD21 SB34	71.05	19.35
MHD23 SB36	20.12	0.00
MHD26 SB38	79.22	23.05
MHD25 SB37	85.42	0.07
MHD24 SB35	92.22	0.00
MHE5	93.65	0.00
MHD28 SB33	69.92	0.00

Junction Surcharge and Flooding Times for 25yr1hr Synthetic Storm		
Junction Name	**Surcharged Time (minutes)**	**Flooded Time (minutes)**
MHA2 SB2	20.87	4.92
MHA3	0.00	0.00
MHA4	0.00	0.00
MHA6 SB3	0.00	0.00
MHA7	0.00	0.00
MHA9	0.00	0.00
MHA11	0.00	0.00
MHA12	0.00	0.00
MHB15	5.73	0.00
MHA8 SB4	36.25	0.00
MHA15 SB1	0.00	0.00
MHA16	0.00	0.00
MHB16 SB5	44.23	0.00
MHB14 SB6	7.60	0.00
MHB13 SB8	8.73	0.00
MHB12	7.67	0.00
MHB18	6.45	0.00
MHB19	9.27	0.00
MHB10 SB11	2.53	0.00
MHB11	23.22	0.00
MHB21	4.70	0.00
MHB9	0.00	36.53
MHB8 SB9	45.45	3.50
MHB7	42.53	4.02
MHB3 SB12	29.65	9.58
MHB4 SB14	17.40	13.63
MHB24 SB7	27.58	0.00
MHB23 SB10	45.53	0.00
MHB25	30.82	0.00
MHB28 SB21	45.55	0.00
MHB26 SB18	31.67	1.55
MHB6 SB13	40.90	7.65
MHC12 SB17	46.92	19.20
MHC11 SB22	19.42	7.47
MHC9	19.62	5.45
MHC8 SB19	41.95	10.92
MHC6	20.10	5.42
MHC5	19.98	5.30
MHC4 SB24	19.85	5.28
MHC3	19.12	3.80
MHC2 SB20	18.42	3.65
MHC1	20.07	1.58
MHC7 SB23	44.00	11.57
MHE4 SB15	46.72	22.70
MHE6 SB16	43.55	0.00
MHD27	0.00	0.00
MHE7	0.00	0.00

Junction Name	Surcharged Time (minutes)	Flooded Time (minutes)
MHE8	0.00	0.00
MHE9	0.00	0.00
MHD1 SB26	14.47	5.50
MHD2	8.45	0.80
MHD4	9.02	3.48
MHD7 SB27	7.35	0.00
MHD6	9.82	3.15
MHD5 SB25	10.55	5.90
MHD14	12.85	0.00
MHD12	1.08	0.00
MHD13 SB30	1.67	0.03
MHD16	13.17	0.00
MHD17	13.58	0.00
MHD20	0.00	0.00
MHD18 SB29	36.92	0.00
MHD19	41.47	0.00
MHD22	0.00	0.00
MHD21 SB34	41.83	3.63
MHD23 SB36	0.00	0.00
MHD26 SB38	41.45	4.37
MHD25 SB37	41.87	3.33
MHD24 SB35	42.30	0.00
MHE5	43.65	0.00
MHD28 SB33	41.03	0.00

Junction Surcharge and Flooding Time for 25yr3hr Synthetic Storm		
Junction Name	**Surcharged Time (minutes)**	**Flooded Time (minutes)**
MHA2 SB2	53.98	33.32
MHA3	0.00	0.00
MHA4	0.00	0.00
MHA6 SB3	0.00	0.00
MHA7	0.00	0.00
MHA9	0.00	0.00
MHA11	0.00	0.00
MHA12	0.00	0.00
MHB15	34.48	0.00
MHA8 SB4	74.42	0.00
MHA15 SB1	0.00	0.00
MHA16	0.00	0.00
MHB16 SB5	143.77	0.00
MHB14 SB6	36.65	0.00
MHB13 SB8	38.22	0.00
MHB12	36.77	0.00
MHB18	35.12	0.00
MHB19	39.20	0.00
MHB10 SB11	30.33	0.00
MHB11	56.48	0.00
MHB21	32.93	0.00
MHB9	0.00	82.12
MHB8 SB9	139.12	21.85
MHB7	99.13	22.62
MHB3 SB12	70.75	42.37
MHB4 SB14	55.82	46.85
MHB24 SB7	63.63	0.00
MHB23 SB10	116.47	0.00
MHB25	68.50	0.00
MHB28 SB21	116.98	0.00
MHB26 SB18	70.00	0.28
MHB6 SB13	89.98	37.78
MHC12 SB17	111.08	56.50
MHC11 SB22	54.37	37.28
MHC9	54.58	29.57
MHC8 SB19	86.23	41.77
MHC6	55.07	29.13
MHC5	54.87	14.93
MHC4 SB24	54.70	28.85
MHC3	54.22	24.22
MHC2 SB20	53.72	24.15
MHC1	55.85	0.40
MHC7 SB23	97.27	42.10
MHE4 SB15	114.08	60.50
MHE6 SB16	99.47	0.00
MHD27	23.22	0.00
MHE7	16.97	0.00

Junction Name	Surcharged Time (minutes)	Flooded Time (minutes)
MHE8	0.00	0.00
MHE9	0.00	0.00
MHD1 SB26	43.53	31.13
MHD2	35.20	4.50
MHD4	35.90	24.53
MHD7 SB27	33.75	0.00
MHD6	36.57	24.28
MHD5 SB25	37.48	31.50
MHD14	40.80	0.00
MHD12	19.33	0.00
MHD13 SB30	25.57	0.00
MHD16	41.33	0.00
MHD17	41.97	0.00
MHD20	22.93	0.00
MHD18 SB29	73.58	0.00
MHD19	83.03	0.00
MHD22	22.37	0.00
MHD21 SB34	79.38	25.32
MHD23 SB36	25.60	0.00
MHD26 SB38	89.17	27.08
MHD25 SB37	96.30	24.35
MHD24 SB35	103.80	0.00
MHE5	105.68	0.00
MHD28 SB33	78.25	0.00

Junction Surcharge and Flooding times for 25yr24hr Synthetic Storm		
Junction Name	**Surcharged Time (minutes)**	**Flooded Time (minutes)**
MHA2 SB2	72.58	0
MHA3	0	0
MHA4	0	0
MHA6 SB3	0	0
MHA7	0	0
MHA9	0	0
MHA11	0	0
MHA12	0	0
MHB15	0	0
MHA8 SB4	161	0
MHA15 SB1	0	0
MHA16	0	0
MHB16 SB5	1102.58	0
MHB14 SB6	0	0
MHB13 SB8	0	0
MHB12	0	0
MHB18	0	0
MHB19	0	0
MHB10 SB11	0	0
MHB11	43.8	0
MHB21	0	0
MHB9	0	210.6
MHB8 SB9	442.92	0
MHB7	234.3	0
MHB3 SB12	178.53	0
MHB4 SB14	102.27	38.33
MHB24 SB7	124.38	0
MHB23 SB10	271.58	0
MHB25	141.87	0
MHB28 SB21	276.98	0
MHB26 SB18	146.98	0
MHB6 SB13	221.2	0
MHC12 SB17	249.87	91.17
MHC11 SB22	87.32	0
MHC9	87.78	0
MHC8 SB19	204.77	0
MHC6	89.12	0
MHC5	88.5	0
MHC4 SB24	87.72	0
MHC3	84.72	0
MHC2 SB20	81.35	0

Junction Name	Surcharged Time (minutes)	Flooded Time (minutes)
MHC1	91.8	0
MHC7 SB23	221.37	0
MHE4 SB15	263.77	119.65
MHE6 SB16	234.62	0
MHD27	0	0
MHE7	0	0
MHE8	0	0
MHE9	0	0
MHD1 SB26	0	0
MHD2	0	0
MHD4	0	0
MHD7 SB27	0	0
MHD6	0	0
MHD5 SB25	0	0
MHD14	0	0
MHD12	0	0
MHD13 SB30	0	0
MHD16	0	0
MHD17	0	0
MHD20	0	0
MHD18 SB29	202.03	0
MHD19	231.05	0
MHD22	0	0
MHD21 SB34	208.47	0
MHD23 SB36	0	0
MHD26 SB38	222.68	0
MHD25 SB37	239.5	0
MHD24 SB35	266.43	0
MHE5	248.25	0
MHD28 SB33	209.28	0

Junction Surcharge and Flooding Times for 50yr1hr Synthetic Storm		
Junction Name	**Surcharged Time (minutes)**	**Flooded Time (minutes)**
MHA2 SB2	24.47	7.72
MHA3	0	0
MHA4	0	0
MHA6 SB3	0	0
MHA7	0.4	0
MHA9	0	0
MHA11	0	0
MHA12	0	0
MHB15	8.37	0
MHA8 SB4	38.65	0
MHA15 SB1	0	0
MHA16	0	0
MHB16 SB5	45.05	0
MHB14 SB6	10.63	0
MHB13 SB8	11.95	0
MHB12	10.7	0
MHB18	8.98	0
MHB19	12.5	0
MHB10 SB11	6.1	0
MHB11	27.33	0
MHB21	6.48	0
MHB9	0	36.57
MHB8 SB9	46.57	4.82
MHB7	43.23	5.3
MHB3 SB12	36.47	13.57
MHB4 SB14	20.88	16.5
MHB24 SB7	32.32	0
MHB23 SB10	46.77	0
MHB25	36.05	0
MHB28 SB21	46.75	1.33
MHB26 SB18	37.08	3.3
MHB6 SB13	41.67	9.25
MHC12 SB17	48.52	23.8
MHC11 SB22	23.37	9.62
MHC9	23.62	6.97
MHC8 SB19	43.9	13.82
MHC6	24.18	6.83
MHC5	24	6.8
MHC4 SB24	23.77	6.78
MHC3	22.92	5.4
MHC2 SB20	22.15	5.28
MHC1	24.67	2.37
MHC7 SB23	45.77	14.28
MHE4 SB15	48.27	27.13
MHE6 SB16	44.67	0.00
MHD27	0.00	0.00
MHE7	0.00	0.00

Junction Name	Surcharged Time (minutes)	Flooded Time (minutes)
MHE8	0.00	0.00
MHE9	0.00	0.00
MHD1 SB26	16.07	6.33
MHD2	10.02	0.98
MHD4	10.67	4.77
MHD7 SB27	8.73	0.00
MHD6	11.45	4.57
MHD5 SB25	12.12	6.72
MHD14	14.52	0.00
MHD12	1.38	0.00
MHD13 SB30	3.83	0.28
MHD16	14.83	0.00
MHD17	15.27	0.00
MHD20	1.35	0.00
MHD18 SB29	42.10	1.27
MHD19	42.83	0.00
MHD22	0.00	0.00
MHD21 SB34	43.08	4.88
MHD23 SB36	2.95	0.00
MHD26 SB38	42.62	5.33
MHD25 SB37	43.00	4.47
MHD24 SB35	43.42	0.13
MHE5	45.00	0.00
MHD28 SB33	42.32	0.00

Junction Surcharge and Flooding times for 50yr3hr Synthetic Storm		
Junction Name	**Surcharged Time (minutes)**	**Flooded Time (minutes)**
MHA2 SB2	56.62	34.70
MHA3	0.00	0.00
MHA4	0.00	0.00
MHA6 SB3	0.00	0.00
MHA7	13.57	0.00
MHA9	0.00	0.00
MHA11	0.00	0.00
MHA12	0.00	0.00
MHB15	35.98	0.00
MHA8 SB4	78.20	0.00
MHA15 SB1	0.00	0.00
MHA16	0.00	0.00
MHB16 SB5	145.53	0.00
MHB14 SB6	38.63	0.00
MHB13 SB8	40.33	0.00
MHB12	38.72	0.00
MHB18	36.90	0.00
MHB19	41.23	0.00
MHB10 SB11	32.07	0.00
MHB11	58.70	0.00
MHB21	34.22	0.00
MHB9	0.00	88.38
MHB8 SB9	140.90	23.90
MHB7	104.65	24.63
MHB3 SB12	75.17	44.90
MHB4 SB14	58.90	49.48
MHB24 SB7	66.80	0.00
MHB23 SB10	121.92	0.00
MHB25	71.80	0.00
MHB28 SB21	122.58	0.00
MHB26 SB18	73.32	21.18
MHB6 SB13	96.00	38.77
MHC12 SB17	115.57	59.55
MHC11 SB22	56.87	38.78
MHC9	57.08	30.92
MHC8 SB19	92.45	43.92
MHC6	57.57	30.60
MHC5	57.40	15.18
MHC4 SB24	57.37	30.43
MHC3	56.85	26.15
MHC2 SB20	56.23	26.08
MHC1	58.57	20.30
MHC7 SB23	103.12	44.20
MHE4 SB15	114.08	60.50
MHE6 SB16	99.47	0.00
MHD27	23.22	0.00
MHE7	16.97	0.00

Junction Name	Surcharged Time (minutes)	Flooded Time (minutes)
MHE8	0.00	0.00
MHE9	0.00	0.00
MHD1 SB26	43.53	31.13
MHD2	35.20	4.50
MHD4	35.90	24.53
MHD7 SB27	33.75	0.00
MHD6	36.57	24.28
MHD5 SB25	37.48	31.50
MHD14	40.80	0.00
MHD12	19.33	0.00
MHD13 SB30	25.57	0.00
MHD16	41.33	0.00
MHD17	41.97	0.00
MHD20	22.93	0.00
MHD18 SB29	73.58	0.00
MHD19	83.03	0.00
MHD22	22.37	0.00
MHD21 SB34	79.38	25.32
MHD23 SB36	25.60	0.00
MHD26 SB38	89.17	27.08
MHD25 SB37	96.30	24.35
MHD24 SB35	103.80	0.00
MHE5	105.68	0.00
MHD28 SB33	78.25	0.00