Estero Bay Watershed Assessment

Volume D: Management Options

- Draft Report -

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July 1999

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FOREWARD

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1.0 INTRODUCTION

This report, "Management Options for the Estero Bay Watershed," forms Volume D of a series of reports developed for the South Florida Water Management District's (SFWMD) Estero Bay and Watershed Assessment Plan. Reports in the Estero Bay and Watershed Assessment Plan series are listed below.

- Volume A. Literature Survey of the Estero Bay Watershed
- Volume B. Characterization Report
- Volume C. Basin Prioritization Report
- Volume D. Management Options Report
- Volume E. Monitoring Report
- Volume F. Estero Bay Resources Plan

1.1 BACKGROUND

Estero Bay has long been recognized as one of Florida's significant natural resources. The Bay was designated as the State's first Aquatic Preserve. The Bay's watershed also has a long history of both pre-Columbian and modern settlement and agriculture. The area in and around the Estero Bay watershed has undergone dramatic increases in the rate of residential and commercial development as well as population growth during the past 15 years. As a result, a series of initiatives has been proposed to balance development and environmental interests in the region. These initiatives are listed below and are discussed at length in other volumes of this report

- Arnold Committee,
- Estero Bay Agency on Bay Management,
- Charlotte Harbor National Estuary Program,
- Corps of Engineers Environmental Impact Statement, and the
- South Lee County Watershed Plan.

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1.2 STUDY AREA CHARACTERISTICS

This report describes and analyzes management options for Florida's Estero Bay Watershed . The watershed includes a portion of Lee County south of the Caloosahatchee River, parts of northeastern Collier County, and a small area of Hendry County (Figure 1-1). A substantial portion of the northern watershed area is within the City of Ft. Myers. Other population centers in the watershed are Bonita Springs and the City of Ft. Myers Beach.

The Estero Bay watershed includes all of Estero Bay, most of which lies within the Estero Bay Aquatic Preserve, and the adjacent barrier islands. Hendry Creek, Mullock Creek, the Estero River, areas of Corkscrew Swamp, Flint Pen Strand, Spring Creek, and the Imperial River are major surface water features in the watershed. Hendry Creek, Mullock Creek, Estero River, Spring Creek, and the Imperial River experience some degree of tidal influenced. The portion of the Estero River east of U.S. 41 is a slow conveyance system and is considered a recharge area along with the Imperial River east of I-75 (SWFRPC, 1995). Local drainage canals tend to provide some regional flood protection during wet periods, but also lead to over-drainage during dry periods.

The Estero Bay Watershed is divided into the nine secondary basins for the purpose of this report. These basins are listed below.

- Estero River
- Spring Creek
- Hendry Creek
- Mullock Creek
- Six-Mile Cypress Slough
- Ten-Mile Canal
- Cow Creek
- Imperial River
- Barrier Islands

Cow, Hendry, and Mullock creeks are coastal basins that flow into north Estero Bay. Six-Mile Cypress Slough and Ten Mile Canal do not have direct discharges to the bay, but they are important sources for Mullock Creek, which flows directly into the bay. The Estero River and Spring Creek flow into Estero Bay in the central and southern potions of the bay. The Barrier Islands Basin contains the coastal barrier-islands, along the western length of Estero Bay.

The Estero Bay Watershed encompasses a total of 192,468 acres. The Imperial River, Estero River, and Six-Mile Cypress Slough basins each make up between 35,000 and 54,000 acres and together make up almost 70% of the watershed. Cow Creek, Ten-Mile Canal, Hendry Creek, Spring Creek, and Barrier Islands basins are much smaller, each making up no more than 8% of the entire watershed. The areas of all subbasins are given in Table 1-1.

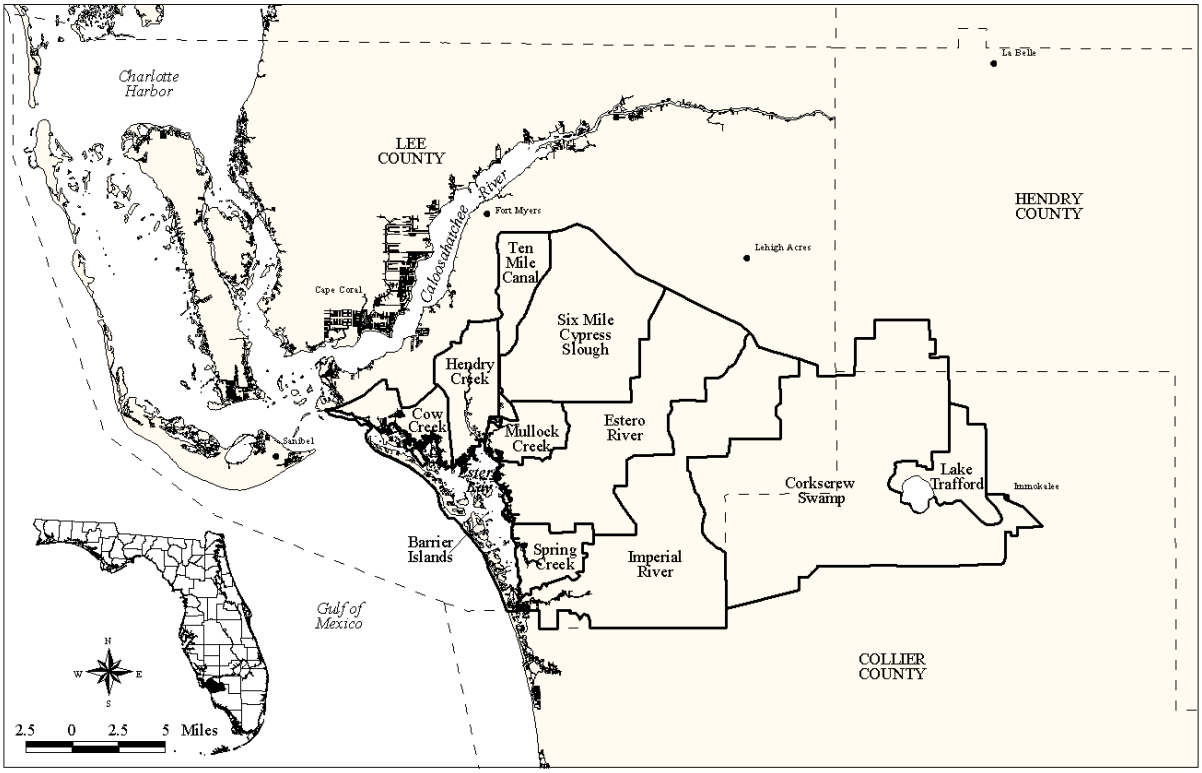


Figure 1-1. The Estero Bay watershed and associated secondary basins.

Table 1-1. Acres and percentage of watershed for the nine secondary basins in the Estero Bay Watershed.		
SECONDARY BASIN	**ACRES**	**PERCENT**
Ten-Mile Canal	8,717	5%
Six-Mile Cypress Slough	35,027	18%
Mullock Creek	6,995	4%
Estero River	45,381	24%
Imperial River	53,664	28%
Cow Creek	7,985	4%
Hendry Creek	11,623	6%
Spring Creek	7,350	4%
Barrier Islands	15,726	8%
Total	**192,468**	

For purposes of this report's analyses, tertiary basins are defined as the watersheds of canals and natural channels that are directly tributary to the nine secondary basins. Figure 1-2 shows the locations and identifying numbers for all of the secondary and tertiary basins within the study area. A total of sixty-two tertiary basins were identified, ranging in size from 38 to about 41,600 acres.

1.3 WATERSHED PROBLEMS

There are several documented, predicted, and perceived problems in the Estero Bay watershed. The problems are primarily related to: 1.) conversion of natural habitats to agricultural, commercial, and residential land uses; 2.) the construction of canals, ditches, and road beds; and

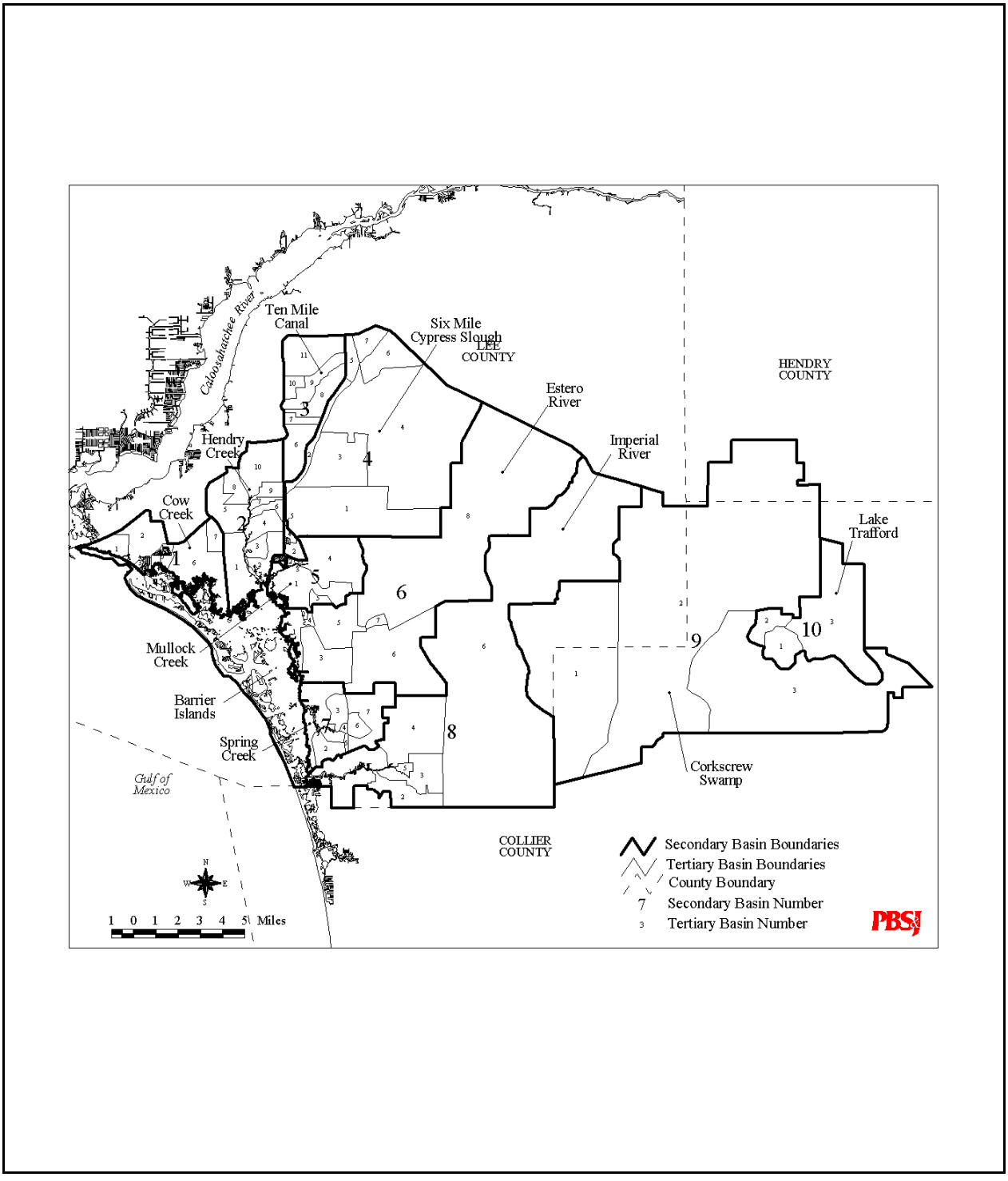


Figure 1-2. Secondary and tertiary basins within the Estero Bay watershed.

3.) filling, dredging, and draining of wetlands waterbodies that occur in association with the previous two factors. The watershed problems include:

- increased watershed size,
- increased freshwater inflows,
- increased nutrient and total suspended solids loading
- lowered water tables
- altered wetland and aquatic hydroperiods
- loss of wetland, upland, and aquatic habitats
- downstream flooding

Increased watershed size

The constituent basins of the Estero Bay watershed were delineated as early as 1962 (Smalley, Welford, and Nalven, 1962). Even in 1962, these constituents had been altered from their pre-development condition by canals and roadbeds. The size of the effective watershed for Estero Bay has increased since pre-development and presumed 1962 conditions as a result of several factors. Prominent among these factors are constrictions or blocks in historic flowways that formerly allowed water from the watershed's eastern basins to flow south through Collier County.

Increased freshwater inflows

Residential, commercial, and agricultural development have changed and will continue to change the natural landscape within the study area. These changes have and will result in changes in the physical manner in which runoff responds to rainfall. Replacement of wetlands and forests with impervious surfaces, like asphalt pavement, rooftops, and concrete sidewalks, produces increased runoff rates from the land surface. Likewise, ditching and pumping increase runoff rates from agricultural areas. These increases have the potential to produce both an increase in the total freshwater discharges to the estuary and increase the magnitude of individual discharge events. On-site and regional stormwater management systems have been and continue to be constructed within the study area in an effort to ameliorate the impacts of these changes to the land surface. Insufficient data are available to determine the effect of both development and existing stormwater management practices on freshwater discharges.

Increased nutrient and total suspended solids loading

Increases in nutrient and total suspended solids loads is a frequent concern in watersheds undergoing significant urban and agricultural development. Implementing "best management practices" in new development is a frequent solution. However best management practices

minimize but do not necessarily eliminate the effect of new development on the watershed. The cumulative effects of several new development projects or the effects of new and old development combined, may degrade downstream waterbodies and estuaries.

Lowered water tables

The construction of canals and channelization of existing waterways has lowered the surficial water table in many portions of the study area. Tabb et al. (1976) describe the pre-development watersheds immediately south of Estero as areas where evaporation exceeds transpiration in many years and drought-conditions are averted by storage of water in shallow, sand filled basins during wet years. Tabb et al. describe a scenario in which canals breach these shallow basins and dissipate water reserves. This shallow-basin characterization applies to much of the Estero Bay watershed. It is because the watershed is a series of shallow basins, that the watershed size has been significantly increased by seemingly minor alterations in topography and conveyance.

Water table declines have been purported causes for excessive wildfires (Tabb et al., 1976), melaleuca (*Melalueaca quinquenervia*) invasion patterns (Myers, 1983), and salinity intrusions in aquifers. Duever et al. (1978) suggested water-table declines might exacerbate winter freeze-damage after observing regional, frost-damage patterns that mirrored regional, water table-decline patterns.

Altered wetland hydroperiods

Ditching, filling, road beds, and urban and agricultural development have altered the hydroperiod of many of the wetlands in the study area. Most wetlands have been excessively drained, though a few may be over-hydrated. Duever et al. (1978) documented the negative effects of over-hydration. They found decreases in cypress growth as a result of excessive, prolonged flooding caused by berms in Corkscrew Swamp.

Loss of wetland, upland, and aquatic habitats

A large amount of upland and wetland habitat in the watershed has been converted to agricultural, residential, and commercial uses. Conversion appears to be continuing at equal or increasing rates. This habitat loss has the potential to effect several regionally or globally threatened or endangered species including the Florida panther (*Felis concolor coryi*), Florida black bear (*Ursus americanus floridanus*), red cockaded woodpecker (*Picoides borealis*), Big Cypress fox squirrel (*Sciurus niger avicennia*), wood stork (*Mycteria americana*), Southeastern American kestrel (*Falco sparverius paulus*), and Florida sandhill crane (*Grus canadensis pratensis*).

Downstream flooding

The 1995 wet season produced severe flooding in Bonita Springs located in the downstream reaches of the Imperial River subbasin. This flooding was particularly notable given that high flows were not documented in the adjacent, Estero River subbasin (Johnson Engineering Inc. et al., 1995). The South Lee County Watershed Study (Johnson Engineering Inc. et al., 1998) was conducted in response to this flooding. This flooding has been attributed to development in historic floodplains, land use changes, flowway constrictions, sub-basin reconfiguration, and agricultural pumping practices (Johnson Engineering Inc. et al., 1998).

1.4 MANAGEMENT OPTIONS

There are several management options available to address the problems identified in the Estero Bay watershed. These options can be divided into two categories, "corrective" and "conservation." Corrective options are management tools that serve to correct problems that may already exist. Conservation options are tools to prevent future problems that may result as the area of developed land in the watershed increases.

Corrective Options

- Require Greater Stormwater Attenuation and Treatment
- Designate Nutrient Sensitive Basins and Permit According to Sensitivity
- Require Demonstrated Concurrency with Loads Reduction
- Construct Regional Treatment Facilities at Strategic, Downstream Basin-Nodes

Conservation Options

- Require Buffer Areas around Tributaries
- Require Upland Buffers/Components for Wetlands
- Preserve and/or Restore Regional Flowways (hydrologic and habitat corridors)
- Transfer Development Rights from Sensitive Areas
- Require Demonstrated Net-Benefits to Listed Species Recovery

1.4.1 Corrective Options

Corrective options are primarily designed to address existing or expected water quality issues.

Require Greater Stormwater Attenuation and Treatment

Requiring more stormwater attenuation and treatment would necessitate rule changes for state permitting agencies (SFWMD and DEP). This option is largely preventive, but partially corrective. The option is preventive when natural land covers are converted to other land uses. The option is corrective when a developed land use (agriculture or mining for example) is converted to another land use providing the original land use contributed to runoff and loading problems.

Nutrient Sensitive Basins - Designate and Permit Accordingly

Under this management option, other management options (like greater attenuation and treatment, demonstrated concurrency with loads reduction) would be implemented in the basins with the highest potential for or highest identified nutrient loading. This report identifies basins with the highest potential for nutrient loadings. This management option would involve specifically designating nutrient-sensitive subbasins. This designation can be made based on the

potential nutrient loadings detailed in this report, or based on nutrient loadings calculated from data that will be collected in future monitoring efforts.

Require Demonstrated Concurrency with Loads Reduction

This option would require that new activities demonstrate contributions to reductions in hydrologic, nutrient, and total suspended solids loadings to Estero Bay. Implementing this option may be hindered by a lack of data on the effectiveness of various treatment methods and techniques within the Estero Bay watershed

Construct Regional Treatment Facilities at Strategic, Downstream Basin-nodes

This is both a corrective and a preventive measure and should be implemented as such. The priority subbasins identified in this report are candidates for treatment facilities intended to serve as corrective measures. Subbasins with large areas of undeveloped land that are not in conservation are candidates for future treatment facilities to prevent future loading problems. The locations for future facilities should be identified and secured before they become prime development lands.

1.4.2 Conservation Options

Conservation options are designed to prevent future problems with water quality and habitat, but the options may also correct some existing problems.

Require Substantial Buffer Areas around Tributaries

Placing buffer zones around tributaries offers the opportunity to protect both the ecological integrity of the tributaries and downstream water bodies. Buffers would help preserve both the habitat quality and water quality of the tributaries and Estero Bay.

Require Significant Upland Buffers/Components for Wetlands

Jurisdictional wetland-boundaries are frequently artificial or legal boundaries that do not necessarily represent the edges of ecological systems. Jurisdictional boundaries are determined by the effect of flooding and the resulting, anaerobic conditions on vegetation and soils. As a result, significant ecological processes or functions inherent to the Estero Bay watershed are only partially represented or contained within the wetland jurisdictional boundaries. Upland buffers for wetlands can affect wildlife habitat values, hydrologic functions, and water quality within the watershed.

Preserve and/or Restore Regional Flowways (hydrologic and habitat corridors)

This option is closely related to the tributaries-buffer option. This option proposes to extend the buffer concept upstream to the wetland location of tributary water-flow origin. Landscape level connections like flowways were identified as early as 1975 by Brown (1975, 1976). The importance of such connections was also emphasized by the actions and reports of the Arnold Committee and the Agency on Bay Management. Flowways in the Estero Bay watershed include water courses such as streams and rivers as well as connected wetlands in slough and marsh systems. These connected wetland systems were once "river-of-trees" analogs of the "river-of-grass" concept popularized for the eastern Everglades. Ditching, fill placement, and channelization have disrupted many of the historic flow patterns, but the basic flowway behavior remains in many places.

Flowway protection has the potential to provide both hydrologic protection as well as habitat protection. Habitat protection in the form of habitat connectivity is particular important. It helps maintain ecosystem functions that are expressed by ecosystems operating as whole units, but not by isolated, parts or sub-units of ecosystems.

Transfer Development Rights from Sensitive Areas

Under this alternative, development rights in sensitive areas would be exchanged for the right to increase development densities in less sensitive areas. There are several methods by which this could be accomplished, some of which are already in place. The initial emphasis of this option would be to implement transfers as a preferred alternative to sensitive area conversions or impacts within the watershed.

Require Demonstrated Concurrency with Listed Species Recovery

This option would require a project demonstrate consistency with recovery of listed species whose habitats fell within or adjacent to the project's boundaries. The concept is similar to demonstrated concurrency with reduction of nutrient and other loads. This would differ from current standards in that instead of proving that it would not impact species, a project would need to demonstrate that it did not impact the recovery of listed species. While seemingly semantic, the change is quite significant. The scope of compensatory-mitigation that contributes to the recovery of listed species can be quite different than the scope of mitigation that results solely in "no net impact" to listed species.

This option is not necessarily a blanket, preservation initiative. Requiring demonstrated concurrency with listed species recovery would discourage excessive efforts to preserve isolated habitat fragments that have lost the ability to contribute to species recovery. Mitigation for impacts to such habitat fragments would still be required, but the mitigation would be directed

towards efforts that would aid in long-term species recovery rather that short-term preservation of isolated individuals.

2.0 PRIORITIZATION OF BASINS

One objective of the Estero Bay Watershed Study, of which this volume is a part, was to assign priority to watershed tertiary basins in terms of the basins' potential to contribute to problems in the watershed and Estero Bay proper. The Basin Prioritization Report (Volume C of this series) evaluates and ranks the watershed tertiary basins. The following is a discussion of basin prioritization as it relates to the choice of watershed management options and the locations where these management tools should be implemented.

2.1 BASIN PRIORITIZATION OBJECTIVES

The Water Management District has identified several, key evaluation-criteria for prioritizing impacts within and management strategies for the Estero Bay Watershed. These key criteria are:

- urban runoff discharge,
- agricultural runoff discharge,
- total suspended solids (TSS) loading,
- total nitrogen loading,
- total phosphorus loading, and
- wastewater and industrial discharge.

An objective of the Estero Bay Watershed Study was to estimate values for each of these criteria in sub-units of the watershed. Each secondary basin within the Estero Bay watershed contains several sub-basins or tertiary basins. The Basin Prioritization Report addresses the criteria above by evaluating and ranking the watershed tertiary basins according to their potential as sources of:

- excess freshwater discharge (hydraulic loading or runoff),
- nutrient loading (total nitrogen and total phosphorous), and
- sediment loading (total suspended solids).

Values for an additional criterion, "wetland area at risk," were also estimated for each the tertiary

basin. Rapid growth and urbanization create the potential for not only changes in runoff and nutrient and sediment loading, but also for wetland losses through filling, excavation, drainage, and other alterations.

The emphasis of the basin-prioritization task was on screening, and the loading and wetland area at risk estimates were designed to be unbiased, relative-values that could support valid comparisons of secondary and tertiary basins. These relative values for each criterion were not developed to provide absolute estimates of discharge and loadings to the bay. Absolute estimates are part of a task to be undertaken by the modeling effort that will follow the Estero Bay and Watershed Assessment. The relative rankings were created to determine which tertiary basins are of high concern or high priority with respect to each criterion.

The basin-prioritization study delineated nine secondary-basins within the watershed. Figures 1-1 and 1-2 are maps showing the locations and identifying numbers of these secondary basins. The study also delineated sixty-two tertiary basins within these secondary basins.

Relative rankings of the tertiary basins are divided into three groups, with the top 25% of the basins (the basins with the highest potential loadings per unit area or largest areas of wetlands at risk) designated as **high impact**, or priority, basins. The middle 50% of the basins are designated as **medium impact** basins, and the lowest 25% are designated as **low impact** basins.

2.2 URBAN RUNOFF DISCHARGE

Urban development has changed the landscape within the study area, resulting changes to the physical manner in which runoff responds to rainfall. Replacement of wetlands and forests with impervious surfaces, like as asphalt pavement, rooftops, and concrete sidewalks, increase runoff rates from the land surface. This will contribute to excessive freshwater-discharges to the estuary observed during periods of high rainfall. Stormwater management systems (specific to individual projects) have been constructed and continue to be constructed within the study area in an effort to ameliorate the impacts of these changes to the land surface. In this study's ranking effort, these stormwater management systems were assumed to be uniformly distributed among the tertiary basins. In reality, stormwater management systems are probably less prevalent in older urban-development areas.

The Basin Prioritization Report assigned relative ranks to tertiary basins according to each basins's estimated total-annual urban-runoff discharge (summed across months). Table 2-1 lists area-weighted relative-ranks for urban-runoff discharge.

Unweighted rankings provide important information about runoff budgets for the watershed. However runoff and loading per unit area are more important than total runoff and loading when evaluating management options. "Per unit area" values convey information on intensity of runoff or

loading that is important the choice and siting of management options.

The area-weighted rankings of the tertiary basins within the Estero Bay Watershed show that three of the top five basins are in the Hendry Creek secondary basin (tertiary basins 6, 9, and 10) . Other highly ranked basins include tertiary basin 4 in the Mullock Creek secondary basin and tertiary basins 4 and 1 in the Ten-Mile Canal secondary basin.

The results of the weighted analysis indicate that priority basins for urban-runoff discharge are predominately in the Ten-Mile Canal and Hendry Creek secondary basins. The Imperial River, Cow Creek, and Mullock Creek secondary basins also contain priority tertiary basins. The Ten-Mile Canal secondary basin discharges into the Mullock Creek secondary basin, and the Mullock Creek and Hendry Creek secondary basins share a common outfall- location is Estero Bay. Taken as a unit, this complex of basins discharging into Estero Bay through Mullock Creek is the is the most important priority basin (in terms of urban runoff) in the watershed.

Table 2-1. Relative ranks of the top 25% of the tertiary basins within the Estero Bay Watershed for area-weighted urban runoff discharge.

Secondary Basin	Tertiary Basin (TB)	Area (acres)	% Urban Land Use	% Agricultural Land Use	Area-weighted Urban Runoff (acre-feet/yr)/acre	Rank
Hendry Creek	6	449	63	7	1.76872	1
Mullock Creek	4	3596	81	7	1.70483	2
Ten-Mile Canal	4	153	67	0	1.63033	3
Hendry Creek	10	2459	59	0	1.53293	4
Hendry Creek	9	517	67	0	1.47858	5
Ten-Mile Canal	1	129	67	0	1.40605	6
Cow Creek	2	1864	61	0	1.31074	7
Hendry Creek	8	863	66	7	1.28883	8
Imperial River	1	3464	61	0	1.2763	9
Estero River	4	124	64	0	1.23072	10
Cow Creek	4	132	74	0	1.16561	11
Ten-Mile Canal	7	404	47	0	1.06851	12
Ten-Mile Canal	9	1266	53	24	1.03585	13
Imperial River	5	202	63	0	1.0033	14
Imperial River	3	1988	58	7	0.97173	15
Ten-Mile Canal	11	2569	42	12	0.89831	16

2.3 AGRICULTURAL RUNOFF DISCHARGE

Agricultural development also changes the natural landscape that preceded it. Like urban development, agricultural development has changed the way the watershed's hydrologic system responds to rainfall. Replacement of rangeland, forests, and wetlands with relatively-open pastureland and well-drained citrus and vegetable croplands leads to increased runoff- rates from the land surface. Like those for urban impervious land surfaces, these increased runoff rates contribute to excessive freshwater-discharges to the estuary during periods of high rainfall.

The Basin Prioritization Report evaluated tertiary basins in terms of their potential to generate agricultural runoff. The tertiary basins were assigned relative ranks according to estimated, total-annual agricultural runoff discharge. Table 2-2 presents the area-weighted relative ranks for agricultural runoff discharge.

When basins are not weighted by their areas, the top ranked Estero Bay Watershed tertiary basins for agricultural runoff include three basins located in the eastern portion of the watershed. These basins, Imperial River -6, Estero River - 8, and Six-Mile Cypress Slough -4, are larger than 18,000 acres and have more than 20% of their land is used for agricultural purposes.

The area-weighted rankings for two of the top three tertiary basins within the Estero Bay Watershed in the unweighted rankings are also in the top 25% of the tertiary basins in the area-weighted rankings. Imperial River - 6 and Estero River - 8 are ranked fourth and fifth, respectively, in the area-weighted rankings of agricultural runoff. Ten-Mile Canal - 8 and Six-Mile Cypress Slough -5, first and second in the area-weighted rankings, both have runoff of more than 0.5 acre-feet/yr/acre.

2.4 TOTAL SUSPENDED SOLIDS LOADING

Agricultural and urban development have likely led to increased suspended solids loading to the Estero Bay estuary. Increased suspended solids loading can increase turbidity and muck deposition in the estuary. The Basin Prioritization study estimates total suspended solids (TSS) loading for each tertiary basin

The tertiary basins were assigned relative ranks according to estimated total annual total suspended solids loading. Table 2-3 shows the area-weighted relative ranks for total suspended solids loading in tertiary basins.

Table 2-2. Relative ranks of the top 25% of the tertiary basins within the Estero Bay Watershed for area-weighted agricultural runoff discharge.

Secondary Basin	Tertiary Basin	Area (acres)	% Urban Land Use	% Agricultural Land Use	Area-weighted Agricultural Runoff (acre-feet/yr)/acre	Rank
Ten-Mile Canal	8	1441	11	42	0.60592	1
Six-Mile Cypress Slough	5	653	14	29	0.51273	2
Imperial River	4	4695	30	37	0.4629	3
Imperial River	6	41568	3	25	0.37922	4
Estero River	8	27647	16	27	0.37194	5
Estero River	6	7467	15	27	0.33781	6
Ten-Mile Canal	6	1728	44	28	0.33523	7
Six-Mile Cypress Slough	6	1968	13	27	0.33106	8
Ten-Mile Canal	9	1266	53	24	0.32244	9
Six-Mile Cypress Slough	4	18354	20	23	0.29188	10
Estero River	7	248	46	24	0.28643	11
Hendry Creek	5	1874	27	29	0.28084	12
Estero River	5	2460	41	17	0.23157	13
Six-Mile Cypress Slough	1	8345	29	15	0.20212	14
Estero River	3	2699	14	15	0.18168	15
Ten-Mile Canal	11	2569	42	12	0.17701	16

The three, highest-ranked basins in the unweighted ranking, Imperial River - 6, Estero River - 8, and Six-Mile Cypress Slough - 4, are also the three highest-ranked (unweighted) tertiary basins with respect to agricultural runoff discharge, and two of the top three ranked (unweighted) basins with respect to urban runoff discharge. These rankings reflect the size of these three basins, and illustrate why weighted rankings are used for basin prioritization.

The area-weighted rankings of the tertiary basins within the Estero Bay watershed show that four of the top six ranked tertiary basins in the area-weighted rankings of TSS loadings are within the Hendry Creek Basin, with the remaining two in the top six within the Ten-Mile Canal Basin. The Ten-Mile Canal Basin contains six of the sixteen tertiary basins in the top 25% of the ranked basins. Over 80% of the priority tertiary basins for total suspended solids loading discharge into Estero Bay through Mullock Creek, Hendry Creek, or the Imperial River.

Table 2-3. Relative ranks of the top 25% of the tertiary basins within the Estero Bay Watershed for area-weighted TSS loading.

Secondary Basin	Tertiary Basin	Area (acres)	% Urban Land Use	% Agricultural Land Use	Area-weighted TSS Load (lbs/yr)	Rank
Hendry Creek	6	449	63	7	369.751	1
Hendry Creek	10	2459	59	0	320.463	2
Ten-Mile Canal	7	404	47	0	272.914	3
Ten-Mile Canal	11	2569	42	12	248.316	4
Hendry Creek	8	863	66	7	222.68	5
Hendry Creek	9	517	67	0	219.408	6
Spring Creek	6	545	40	0	215.518	7
Ten-Mile Canal	4	153	67	0	214.992	8
Mullock Creek	4	3596	81	7	207.975	9
Ten-Mile Canal	10	473	26	0	192.86	10
Ten-Mile Canal	9	1266	53	24	183.581	11
Cow Creek	2	1864	61	0	182.725	12
Imperial River	1	3464	61	0	177.331	13
Ten-Mile Canal	5	88	22	0	164.678	14
Imperial River	2	1738	49	2	153.97	15
Estero River	2	72	0	0	150.162	16

2.5 TOTAL NITROGEN LOADING

Nitrogen loadings to Estero Bay have probably been affected by agricultural and urban development within the watershed. Changes in land use in the watershed have likely led to increased nitrogen loading to the estuary. Increased nitrogen loading to the estuary, in combination with potential increases in phosphorus loading (described below), can produce eutrophication within the estuary. The Basin Prioritization Report ranked tertiary basins in terms of their potential to contribute nitrogen to Estero Bay. The Prioritization Report analysis provided the area-weighted, priority basins ranking given in Table 2-4.

Table 2-4. Relative ranks of the top 25% of the tertiary basins within the Estero Bay Watershed for area-weighted total annual nitrogen loading.

Secondary Basin	Tertiary Basin	Area (acres)	% Urban Land Use	% Agricultural Land Use	Area-weighted Total Nitrogen Load (lbs/yr)/acre	Rank
Ten-Mile Canal	11	2569	42	12	13.0457	1
Hendry Creek	9	517	67	0	12.0308	2
Hendry Creek	10	2459	59	0	11.7398	3
Hendry Creek	8	863	66	7	11.5284	4
Mullock Creek	4	3596	81	7	11.513	5
Spring Creek	6	545	40	0	11.3219	6
Mullock Creek	5	290	53	0	11.0111	7
Ten-Mile Canal	7	404	47	0	10.6779	8
Imperial River	4	4695	30	37	10.5598	9
Six-Mile Cypress Slough	5	653	14	29	10.3357	10
Estero River	2	72	0	0	10.2914	11
Ten-Mile Canal	10	473	26	0	10.2542	12
Ten-Mile Canal	4	153	67	0	10.0608	13
Imperial River	1	3464	61	0	10.0056	14
Hendry Creek	6	449	63	7	10.0011	15
Hendry Creek	5	1874	27	29	9.7186	16

The area-weighted rankings of the tertiary basins within the Estero Bay Watershed show that the top-ranked tertiary basin is Ten-Mile Canal - 11. Three of the top four high priority tertiary basins are in the Hendry Creek Basin. Fifteen of the sixteen high priority tertiary basins have total-nitrogen loads greater than 10 lb/yr/acre. Fourteen of the sixteen priority tertiary basins for nitrogen loading discharge into Estero Bay through Hendry Creek, Mullock Creek, or the Imperial River.

2.6 TOTAL PHOSPHOROUS LOADING

Total phosphorus (TP) loading is another factor that has probably been affected by changes in land use and cover in the Estero Bay watershed. As with nitrogen loading, the conversion of wetlands and forest to urban and agricultural uses increases the potential for phosphorus loading to Estero Bay.

This increased loading can increase eutrophication within the estuary. Total- phosphorous loading per unit area is typically higher for urban and agricultural land uses when compared with to wetlands and other natural land-covers.

Table 2-6 gives the area-weighted relative ranks for annual total nitrogen loading calculated in the Basin Prioritization Report. The area-weighted rankings of the tertiary basins within the Estero Bay Watershed indicate the top-ranked tertiary basin is Cow Creek - 7. This is the only tertiary basin with the Cow Creek Basin in the high priority group. Ten-Mile Canal - 11 is ranked second for area-weighted total phosphorus loading. All of the top 25% of the tertiary basin have total phosphorous loads greater than 2 lb/yr/acre. As with other rankings, the majority of the priority basins discharge through Mullock Creek, Hendry Creek, or the Imperial River.

2.7 POINT SOURCE DISCHARGES

The number of point source discharges within the a secondary basin tends to be related to basin size. There are generally more point source discharges in the larger secondary basins. Over 60% of the known point source discharges are located in tertiary basins that discharge through Mullock Creek-Hendry Creek outfall or the Imperial River. Table 2.7 lists the number of point source discharges documented in each secondary basin. A more detailed discussion and listing of point source discharges is provided in the Watershed Characterization Report (Volume A of this series).

Table 2-6. Relative ranks of the top 25% of the tertiary basins within the Estero Bay Watershed for area-weighted total annual phosphorus loading.

Secondary Basin	Tertiary Basin	Area (acres)	% Urban Land Use	% Agricultural Land Use	Area-weighted Total Phosphorus Load (lbs/yr)/acre	Rank
Cow Creek	7	621	78	4	3.54578	1
Ten-Mile Canal	11	2569	42	12	2.68013	2
Spring Creek	6	545	40	0	2.6564	3
Six-Mile Cypress Slough	5	653	14	29	2.63303	4
Hendry Creek	5	1874	27	29	2.60596	5
Spring Creek	5	88	91	0	2.51201	6
Imperial River	4	4695	30	37	2.49547	7
Mullock Creek	5	290	53	0	2.47242	8
Estero River	7	248	46	24	2.44086	9
Ten-Mile Canal	8	1441	11	42	2.41656	10
Hendry Creek	8	863	66	7	2.38358	11

Spring Creek	3	768	69	0	2.31095	12
Ten-Mile Canal	9	1266	53	24	2.25442	13
Spring Creek	2	868	63	0	2.20255	14
Ten-Mile Canal	6	1728	44	28	2.16375	15
Spring Creek	4	77	46	0	2.02751	16

Table 2.7. Number of domestic and industrial point sources within each secondary basin.

Secondary Basin	Number of Point Sources
Imperial River	33
Estero River	14
Six-Mile Cypress Slough	12
Barrier Islands	11
Hendry Creek	10
Cow Creek	10
Spring Creek	8
Mullock Creek	7
Ten-Mile Canal	7

2.8 OVERALL BASIN PRIORITIZATION BY AGGREGATED CRITERIA

The final product of the basin prioritization effort, was to rank tertiary basins according to aggregates of the individual criteria. This process identified the basins expected to contribute the highest levels of freshwater and pollutant loads to the Estero Bay estuary. The basins were first aggregated according to three important criteria representing the potential for excessive freshwater discharge, total suspended loads, and nutrient loads. Each tertiary basin was then assigned an overall rank based on these three important types of potential impacts to the estuary. In the final step, the top 25% of the basins in terms of this overall rank were identified as priority basins.

The ranks for the important classes of criteria were assigned by combining the freshwater and pollutant load estimates developed for the individual criteria and re-ranking the basins with respect to these aggregated estimates described below.

- Total runoff discharge was computed as the sum of the estimated absolute agricultural runoff discharge and urban runoff discharge, and

- Nutrient loading priorities were computed as the arithmetic mean of the total-nitrogen load rank and the total-phosphorous load rank.

In the overall basin-prioritization, each tertiary basin was assigned an overall rank based on loading impacts. The object of this overall ranking was to identify the areas that should be considered first when developing management options.

The three types of loading (nutrient, total suspended solids, and runoff (freshwater)) are correlated, and they can be attributed to particular anthropogenic activities within the watershed. Excessive freshwater runoff, sediment loads, and nutrient loads all are exacerbated by the creation of impervious surfaces, draining of wetlands, channelization, and clearing of forest and wetland vegetation. As shown in the previous sections, the tertiary basins having the highest runoff discharges are also likely to have the highest sediment and nutrient loads.

Although the geographic distributions of the three classes of impacts are similar, they still respond differently to specific, land-use practices. Land-use specific sediment-loading rates can vary independently from runoff rates depending upon the degree of soil disturbance from tillage, livestock compacting of soils, removal of vegetative cover, and other factors. Land-use specific, nutrient loading-rates can vary independently from runoff rates according to the degree of grove and cropland fertilization, animal waste production, urban and horticulture fertilization, and other factors.

The tertiary basins of the study area were analyzed with a three dimensional model of freshwater runoff discharge, TSS loads, and nutrient loads, and the overall rank calculated as the mean of the ranks of the three criteria. The tertiary basins within the highest quarter were classified as the highest priority tertiary basins within the Estero Bay Watershed.

The area-weighted, overall-rankings of the tertiary basins within the Estero Bay Watershed are listed in Table 2-8. These rankings place Hendry Creek - 10 as the highest priority basin. Three other tertiary basins in the Hendry Creek basin are in the top six ranked tertiary basins. These are tertiary basins 6, 8, and 9. Ten-Mile Canal - 11 is also within the top six ranked tertiary basin, as is Mullock Creek - 4.

As with the individual rankings, the majority of the priority basins in the overall ranking (fourteen of sixteen) discharge through Mullock Creek-Hendry Creek outfall or the Imperial River. These secondary basins contain the majority of tertiary basins in terms of both number and area (Table 2.9). The prioritization efforts strongly suggests that the Mullock Creek basin complex (Mullock Creek, Hendry Creek, Ten-Mile Canal, and Six-Mile Cypress Slough subbasins) and Imperial River basin should be the primary locations for loading-related management efforts.

2.9 WETLANDS AT RISK

Wetland areas within the Estero Bay Watershed are subjected to the effects of rapid growth and urbanization within the region. These factors create both the potential for changes in runoff and nutrient and sediment loading, and increase the potential for wetland losses. These losses include both the spatial loss of wetlands as well as the ecological degradation of wetland habitats that are not eliminated. The Basin Prioritization Report identified wetlands at risk as wetlands that were

valuable habitat but were not protected as public lands or as preserves within approved, large-scale development scenarios like developments of regional impact.

Table 2-10 lists the sixteen tertiary basins with the largest area of wetlands at risk. The results were not area-weighted because the factor in question, wetlands at risk, was only evaluated in terms of spatial parameters. Results indicate that the largest tertiary basins contain the greatest acreages of wetland areas at risk (Table 2-10), with four of the top five high-priority basins containing more than 15,000 acres, and the top five high-priority basins contain a total of more than 34,000 acres of wetland areas at risk. The majority of this acreage, more than 20,000 acres, is found in the Imperial River - 6 tertiary basin.

Of the five highest-ranked tertiary basins with respect to wetland area at risk, all are also un-weighted analysis, priority basins with respect to total annual phosphorus loading and total annual nitrogen loading, and all but one are also priority basins with respect to total suspended solids loading, urban-runoff discharge, and agricultural runoff discharge.

Table 2-8. Relative ranks of the top 25% of the tertiary basins within the Estero Bay Watershed for area-weighted overall rank.

Secondary Basin	Tertiary Basin	Area (acres)	Area-Weighted Total Runoff Rank	Area-Weighted TN&TP Loading Rank	Area-Weighted TSS Loading Rank	Area-Weighted Overall Rank
Hendry Creek	10	2459	4	10.5	2	5.50
Hendry Creek	8	863	7	7.5	5	6.50
Ten-Mile Canal	11	2569	14	1.5	4	6.50
Mullock Creek	4	3596	2	12.0	9	7.67
Hendry Creek	6	449	1	23.5	1	8.50
Hendry Creek	9	517	5	14.5	6	8.50
Ten-Mile Canal	4	153	3	18.5	8	9.83
Ten-Mile Canal	9	1266	8	17.0	11	12.00
Ten-Mile Canal	7	404	15	20.5	3	12.83
Imperial River	1	3464	10	22.5	13	15.17
Ten-Mile Canal	6	1728	13	18.5	17	16.17

Spring Creek	6	545	38	4.5	7	16.50
Mullock Creek	5	290	25	7.5	20	17.50
Six-Mile Cypress Slough	5	653	20	7.0	28	18.33
Cow Creek	2	1864	9	34.5	12	18.50
Imperial River	2	1738	24	18.5	15	19.17

Table 2.9. Area of priority basins and percent of total, priority-basin area within each of the secondary basins.

Secondary basin	Priority tertiary basins within secondary basin	Area of priority tertiary basins (acres)	Percent of summed, priority-basin area
Ten-Mile Canal	5	6120	27%
Imperial River	2	5202	23%
Hendry Creek	4	4288	19%
Mullock Creek	2	3886	17%
Cow Creek	1	1864	8%
Six-Mile Cypress Slough	1	653	3%
Spring Creek	1	545	2%
Estero River	0	0	0%
Barrier Islands	0	0	0%

Table 2-10. Relative ranks of the top 25% of the tertiary basins within the Estero Bay Watershed for wetland area at risk.

Secondary Basin	Tertiary Basin	Area (acres)	% Urban Land Use	% Agricultural Land Use	Wetland Area at Risk (acre)	Rank
Imperial River	6	41568	3	25	20403	1
Barrier Islands	1	15726	13	0	4362	2
Estero River	8	27647	16	27	3970	3
Estero River	6	7467	15	27	2765	4
Six-Mile Cypress Slough	4	18354	20	23	2631	5
Cow Creek	6	3906	2	0	2363	6
Hendry Creek	1	2469	5	0	1605	7
Mullock Creek	1	2973	18	6	971	8
Estero River	1	1278	0	0	898	9
Hendry Creek	2	1139	25	0	601	10

Table 2-10. Relative ranks of the top 25% of the tertiary basins within the Estero Bay Watershed for wetland area at risk.

Secondary Basin	Tertiary Basin	Area (acres)	% Urban Land Use	% Agricultural Land Use	Wetland Area at Risk (acre)	Rank
Six-Mile Cypress Slough	2	934	23	3	572	11
Ten-Mile Canal	9	1266	53	24	537	12
Spring Creek	1	2527	35	<1	507	13
Cow Creek	1	810	7	0	504	14
Ten-Mile Canal	8	1441	11	42	417	15
Imperial River	4	4695	30	37	403	16

3.0 PRIORITY TERTIARY BASINS

This chapter describes and discusses the eight highest priority tertiary basins in the Estero Bay watershed. This proioritization is based on nutrient, runoff, and total suspended solids loading. These priority basins for loading are:

!	Hendry Creek	10
!	Hendry Creek	8
!	Ten-Mile Canal	11
!	Mullock Creek	4
!	Hendry Creek	6
!	Hendry Creek	9
!	Ten-Mile Canal	4
!	Ten-Mile Canal	9

The ranks listed below are not area-weighted. Area weighted ranks for these basins are listed in Chapter 2.

3.1 HENDRY CREEK - 10 TERTIARY BASIN

Location: This basin is situated on the northern edge of the Hendry Creek basin, straddling U.S. 41. The Hendry Creek - 10 basin is northwest of Six Mile Cypress slough and forms the western shore of the Ten Mile Canal for much of the canal's length.

Land Use: This basin is predominated by urban residential and commercial land uses. It does contain one large area of public land, Lakes Park, a county park.

Soils: HSG D soils are most common (1957.2 acres), followed by C (280.2 acres).

Hydrologic Features: This basin is dominated by the Ten Mile Canal which forms the basin's eastern boundary. The borrow-pit lakes in Lakes Park are another important hydrologic feature.

Un-weighted Ranks: Total Discharge = 4.0 Nutrient Load = 11.0
TSS Load = 2 Wetland Risk = 14.0

Table 3.1 Land use in the Hendry Creek - 10 tertiary basin.		
Land Use/Land Cover Type	**Area (acres)**	**Percent Coverage**
Urban	1,637	66.6
Cropland/Pasture	27	1.1
Citrus	0	0.0
Wetland	30	1.2
Forested Upland	722	29.4
Water	42	1.7

3.2 HENDRY CREEK - 8 TERTIARY BASIN

Location: The Hendry Creek -8 subbasin is situated along the northwestern boundary of the Hendry Creek secondary basin. This tertiary basin includes the northwestern tributaries of Hendry Creek

Land Use: The land use in this basin is dominated by residential and commercial uses. There is also a significant area of golf courses associated with the residential developments.

Soils: HSG D soils are most common (729.5 acres), followed by C (115.4 acres).

Hydrologic Features: The tributaries of Hendry Creek dominate the hyrologic features in this subbasin. The upper reaches of some tributaries are channelized. Borrow pits and stormwater ponds are also prevalent in this basin.

Un-weighted Ranks: Total Discharge = 7.0 Nutrient Load = 7.5
TSS Load = 5 Wetland Risk = 47.5

Table 3.2. Land use in the Hendry Creek - 8 tertiary basin.		
Land Use/Land Cover Type	**Area (acres)**	**Percent Coverage**
Urban	570	66.1
Cropland/Pasture	59	6.8
Citrus	0	0.0
Wetland	41	4.7
Forested Upland	168	19.4
Water	25	2.9

3.3 TEN-MILE CANAL - 11 TERTIARY BASIN

Location: The Ten-Mile Canal - 11 tertiary basin is located in the northern-most portion of the Ten-Mile subbasin, north of Colonial Boulevard.

Land Use: This subbasin still retains a significant amount of open space in the form of undeveloped uplands, wetlands, and pasture or fallow agricultural lands. This subbasin is rapidly developing though

Soils: HSG D soils are most common (2,526.8 acres).

Hydrologic Features: Other than wetlands, this subbasin contains few hydrologic features. There are some ditches, borrow pits, and stormwater ponds, but surface water features are not dominant aspects of this subbasin.

Un-weighted Ranks: Total Discharge = 14.0 Nutrient Load = 1.5
TSS Load =4 Wetland Risk = 23.0

Table 3.3. Land use in the Ten-Mile Canal -11 tertiary basin.		
Land Use/Land Cover Type	**Area (acres)**	**Percent Coverage**
Urban	1,104	43.0
Cropland/Pasture	307	11.9
Citrus	0	0.0
Wetland	260	10.1
Forested Upland	808	31.5
Water	90	3.5

3.4 MULLOCK CREEK - 4 TERTIARY BASIN

Location: This tertiary basin encompasses San Carlos Park. The basin is located east of U.S. 41 and west of I-75, in the northern corner of the Mullock Creek basin.

Land Use: The San Carlos Park residential developments occupy almost all of this subbasin. Small areas of agricultural lands, wetlands, and forested uplands occur on the edges of San Carlos Park. The residential development includes an area of golf courses.

Soils: HSG D soils are most common (2,947.4 acres), followed by C, A and B (331.0 acres, 161.3, and 6.7, respectively).

Hydrologic Features: This subbasin has few surface water features. A canal system conveys water to headwaters of Mullock Creek. There are a small number of borrow pits and stormwater ponds that are incorporated into the development as amenities.

Un-weighted Ranks: Total Discharge = 2.0 Nutrient Load = 12.5
TSS Load = 9 Wetland Risk = 50.0

Table 3.4. Land use in the Mullock Creek - 4 tertiary basin.		
Land Use/Land Cover Type	**Area (acres)**	**Percent Coverage**
Urban	3,042	84.6
Cropland/Pasture	251	7.0
Citrus	0	0.0
Wetland	55	1.5
Forested Upland	224	6.2
Water	24	0.7

3.5 HENDRY CREEK - 6 TERTIARY BASIN

Location: The Hendry Creek - 6 basin is a small watershed-unit that encompasses the East Fork of Hendry Creek. The basin includes both banks of the creek and a heavily developed area on the east side of U.S. 41.

Land Use: The basin's western portion is dominated by moderate density residential subdivisions**.** The basin's eastern half, east of U.S. 41 is dominated by dense residential and commercial development. These areas have a high proportion of impervious surfaces and fairly limited stormwater facilities. The wetlands in this basin are primarily associated with Hendry Creek

Soils: HSG D soils are most common (439.1 acres).

Hydrologic Features: The East Fork of Hendry Creek is the dominant hydrologic feature. East of U.S. 41, there are also several drainage canals and a small number of borrow pits that serve stormwater functions.

Un-weighted Ranks: Total Discharge = 1.0 Nutrient Load =24.0
TSS Load = 1 Wetland Risk = 41.0

Table 3.5. Land cover in the Hendry Creek - 6 tertiary basin.		
Land Use/Land Cover Type	**Area (acres)**	**Percent Coverage**
Urban	294	65.4
Cropland/Pasture	30	6.7
Citrus	0	0.0
Wetland	83	18.5
Forested Upland	33	7.4
Water	9	2.0

3.6 HENDRY CREEK - 9 TERTIARY BASIN

Location: This is a small subbasin located just north of Hendry Creek and east of Lakes Park.

Land Use: This subbasin is predominantly urban, though it contains isolated areas of forested uplands. There is a significant amount of commercial land use within this subbasin

Soils: HSG D soils are most common (488.6 acres), followed by C (21.6 acres).

Hydrologic Features: A large borrow-pit used for stormwater and a small number of isolated wetlands are the only hydrologic features in the subbasin.

Un-weighted Ranks: Total Discharge = 5.0 Nutrient Load = 15.0
TSS Load = 6 Wetland Risk = 61.5

Table 3.6. Land cover in the Hendry Creek - 9 tertiary basin.		
Land Use/Land Cover Type	**Area (acres)**	**Percent Coverage**
Urban	346	66.9
Cropland/Pasture	0	0.0
Citrus	0	0.0
Wetland	2	0.5
Forested Upland	153	29.6
Water	15	3.0

3.7 TEN-MILE CANAL - 4 TERTIARY BASIN

Location: The Ten-Mile Canal - 4 tertiary basin is another very small subbasin. Is it located near the outfall of the Ten-Mile canal. The subbasin lies between the canal (to the west) and U.S. 41 to the east.

Land Use: The subbasin is dominated by a dense, mobile home development and commercial land uses along U.S. 41.

Soils: HSG D soils are most common (91.8 acres), followed by C (55.1 acres).

Hydrologic Features: The Ten-mile canal forms this subbasin's western border and dominates the subbasin's hydrologic features and hydrology.

Un-weighted Ranks: Total Discharge = 3.0 Nutrient Load = 19.0
TSS Load = 8 Wetland Risk = 61.5

Table 3.7. Land cover in the Ten-Mile Canal - 4 tertiary basin.		
Land Use/Land Cover Type	**Area (acres)**	**Percent Coverage**
Urban	106	69.4
Cropland/Pasture	21	13.5
Citrus	0	0.0
Wetland	16	10.5
Forested Upland	2	1.4
Water	8	5.2

3.8 TEN-MILE CANAL - 9 TERTIARY BASIN

Location: This subbasin is located on the south side of Colonial Boulevard, north of the Six-Mile Cypress Slough.

Land Use: The northeastern side of this basin is predominantly pasture and cropland, and the southwest side is predominantly residential and commercial developments or units. This subbasin continues to undergo land conversion for development.

Soils: HSG D soils are most common (1264.2 acres).

Hydrologic Features: Medium-sized borrow pits and the Ten-Mile Canal (along the basin's western border) dominate the hydrologic features in this subbasin.

Un-Weighted Ranks: Total Discharge = 8.0 Nutrient Load = 17.5
TSS Load = 11 Wetland Risk = 17.5

Table 3.8. Land cover in the Ten-Mile Canal - 9 tertiary basin.		
Land Use/Land Cover Type	**Area (acres)**	**Percent Coverage**
Urban	668	52.8
Cropland/Pasture	327	25.8
Citrus	0	0.0
Wetland	168	13.2
Forested Upland	85	6.7
Water	18	1.4

4.0 MANAGEMENT OPTIONS

This chapter presents a discussion of certain management approaches or tools, that could be implemented alone, or in combination, to achieve the nutrient loading, runoff, or wetland protection goals in the Estero Bay watershed. These are listed below.

- Require Greater Stormwater Attenuation and Treatment
- Designate Nutrient Sensitive Basins and Permit Accordingly
- Require Demonstrated Concurrency with Loads Reduction
- Construct Regional Treatment Facilities at Strategic, Basin-Nodes
- Require Buffer Areas around Tributaries
- Require Upland Buffers/Components for Wetlands
- Promote Best Management Practices (BMPs)
- Preserve and/or Restore Regional Flowways (hydrologic and habitat corridors)
- Transfer Development Rights from Sensitive Areas
- Require Demonstrated Concurrence With Listed Species Recovery

Options related to nutrient and sediment loading and runoff or hydrologic loading are described and evaluated in Table 4-1. These are primarily corrective actions. Options related to wetlands at risk are described and evaluated in Table 4-2. These are primarily conservation actions. There is some overlap between the corrective and conservation groups.

In addition to being divided into corrective and conservation, the options can be further classified as having the following components:

A.) Corrective
- Permitting practices
- Structural and active treatment
- Best management practices
- Monitoring

B.) Conservation
- Restoration
- Preservation
- Compensation

“Permitting practices” refers to establishing permitting practices, codes, and / or regulations that correct existing loading and runoff problems or prevent future loading, runoff, and wetland-loss problems. “Structural and active treatment”is construction of regional, water treatment and

Table 4.1 Management options for water quality and runoff problems in the Estero Bay watershed.

Management Option	Issues Addressed	Mode of Operation	Constraints to Implementing	Potential Benefits
Require greater stormwater attenuation and treatment for private developments	Nutrient and sediment loading, runoff	Treatment improves stormwater quality, attenuation limits runoff	Cost, land requirements	Decreased loadings from stormwater
Designate nutrient sensitive basins and permit accordingly	Nutrient loading	Additional treatment in priority basins	Cost of additional treatment	Decreased nutrient loadings
Require demonstrated concurrency with loads reduction	Nutrient and sediment loading, runoff (hyrdologic loading)	Appropriate treatment and attenuation by new or modified projects	Cost of additional treatment	Decreased loadings from stormwater
Increase level of reuse for landscape irrigation	Urban water supply	Reuse reduces additional water use and nutrient loading	Reuse distribution systems, public acceptance	Reduces demands on aquifers and nutrient loading
Increase stormwater runoff storage near coast (regional treatment facilities)	Hydrologic alteration	Surface water is stored and gradually released	Cost, land requirements	Ensures stable, natural freshwater inflows for coastal estuary.
Provide for sheet flow of surface water past roads and utility corridors	Flooding, runoff rates, hydrologic loading	Improves surface water flow patterns and rates	Cost, regulatory/ enforcement	Improved surface water flow regime
7) Re-establish hydrologic connection for mined areas	Shell and fill mining	Increases areas that contribute stormwater runoff to estuary	Physical, cost	Improve freshwater inflows to estuary
Identify and correct significant and unnecessary inter-basin transfers	Inter-basin transfer of water	Route surface water and ground-water to natural outfalls	Cost, land requirements	Improved freshwater inflow characteristics, decreased flooding

Table 4.1. Continued.

Management Option	Issues Addressed	Mode of Operation	Constraints to Implementing	Potential Benefits
Determine and achieve appropriate flows and levels for freshwater systems	Hydrologic loading	Determine optimal range, timing, and levels surface water, and groundwater systems	Cost, technical analysis	Re-establishing acceptable freshwater inflow rates to estuary
Provide treatment for runoff from developed, public lands	Nutrient and hydrologic loading	Treatment improves stormwater quality from roads, other public lands	Financial, location (land requirements in specific locations)	Decreased loadings from stormwater
Require vegetated buffers for tributaries, wetlands, and waterbodies	Stormwater runoff; more natural land cover	Buffers will filter runoff prior to entering wetlands	Regulatory (rules not in place), cost (land not available for development)	Decreased pollutant loadings from stormwater
Promote Florida Yards & Neighbor. measures for source reduction for residences, businesses, and public property	Stormwater Runoff	Reducing irrigation, fertilization and pesticide application. decreases loadings from urban lands**.**	Lack of public knowledge	Decreased nutrient and contaminant loadings from residential areas
Increase level of reuse for landscape irrigation	Stormwater runoff	Reuse reduces landscape nutrient loading needs	Reuse distribution system, social (public acceptance)	Decreases fertilizer contribution to nutrient loading
Extend sanitary sewer to coastal areas now served by septic tanks	contamination of Groundwater and surface water supplied by ground water	Removing wastewater effluent from coastal areas reduces chances of water quality impacts	Cost, public acceptance	Reduced nutrient and contaminant loading from septic tanks
Promote the use of agricultural BMPs and development of soil conservation plans	Stormwater runoff; Uplands and wetlands to agriculture	BMPs provide water quality treatment to agricultural. runoff	Cost, farmers' acceptance or regulatory and enforcement	Reduced nutrient and contaminant loads, and enhanced freshwater flow rates from agricultural lands

Table 4.1. Continued.

Management Option	Issues Addressed	Mode of Operation	Constraints to Implementing	Potential Benefits
Reduce extent of paved surfaces	Stormwater runoff; Wetland and upland to urban land use	Reduced pavement reduces runoff quantity and improves quality	Cost, regulatory/ enforcement	Improved surface water quality from urban runoff
Promote compact urban growth	Wetland and upland to urban land use; Stormwater runoff	Minimizing urban sprawl reduces spatial extent of impact	Regulatory, public acceptance	Reduced extent of water quality impacts
Develop program to monitor septic tank operation and efficiency	Uplands to urban land use	Improved monitoring will reduce potential for impacts from septic tanks	Cost, public acceptance	Improvements in septic tank operations and efficiency
Ensure that current monitoring of waste water treatment plant effluent disposal is adequate	Point source discharges	Monitoring should be adequate to indicate water quality problems	Cost, plant operators' acceptance	Reduced water quality impacts from waste water treatment plant
Coordinate water quality monitoring programs		Coordinated monitoring will better characterize surface and groundwater	Cost	Better understanding of trends in water quality in basin

Table 4-2. Management options to address wetlands at risk in the Estero Bay watershed.

Management Option	Issues Addressed	Mode of Operation	Constraints to Implementing	Potential Benefits
Require Upland Buffers/Components for Wetlands	Wetlands at risk, nutrient loading	Protect wetlands from direct impact, preserve important uplands to protect wetlands from indirect impact	Regulations not in place; loss of land use and decreases in land value	Wetland and habitat preservation, nutrient load reduction
Preserve and/or Restore Regional Flowways (hydrologic and habitat corridors)	Wetlands at risk, nutrient loading, flooding	Protect wetlands; preserve habitat connectivity	Cost of land, unwilling sellers	Wetland preservation, flood control
Transfer Development Rights from Sensitive Areas	Wetlands at risk, nutrient loading, flooding	Preserve at-risk habitats from direct and indirect impacts	Existing regulations and codes may prohibit dense development; existing infrastructure may not support dense development	Habitat preservation; prevent increased nutrient loads and runoff
Require Buffer Areas around Tributaries	Wetlands at risk, nutrient loading, flooding	Protect wetlands; preserve habitat connectivity	Regulations not in place; loss of developable land	Wetland and waterbody protection, nutrient and sediment filtering
Require Demonstrated Concurrence With Listed Species Recovery	Wetlands at risk	Prevent direct and indirect impacts to wetlands without full compensation	Regulations not in place; loss of developable land; decreased land values	Wetland and habitat protection and improvement; listed species recovery

attenuation facilities. An option with "best management practice" components would include implementing procedures at the individual homeowner, business, and project level that would aid in nutrient, sediment, and runoff load reductions. "Restoration" and "preservation" would involve restoring or preserving flowways and wetlands at risk. Preservation might consist of actual purchase of sensitive areas, purchase of development rights, or placing a conservation easement over sensitive zones. A management option with a "compensation" component includes either compensation for habitat or loading impacts (e.g. compensatory mitigation) or compensation for the loss of land value or loss of potential use for uplands (e.g. transferred

development rights).

4.1. REGIONAL, SURFACEWATER TREATMENT FACILITIES

Regional water treatment facilities are an important management option for the Mullock Creek Subbasin-Complex and the Imperial River subbasin. These regional treatment and attenuation facilities would generally be large, surfacewater-management areas. The facilities would be above-ground, surface-water reservoirs created by berms and levees and supplied with water by pumps, canals, pipes, and or spillways. Properly located treatment facilities could:

- attenuate nutrient and sediment loadings,
- attenuate freshwater loading,
- provide water supply source (for urban and agricultural users),
- provide habitat,
- increase flood protection (depending on location in watershed),
- create recreation opportunities (fishing, bird watching, etc.),
- provide regional, climatic benefits (frost protection, increased evapotranspiration),
- water conservation, and
- aquifer recharge.

Regional treatment facilities should treat and attenuate large volumes of water while assuring that flood control flows are not impeded. As such treatment facilities will need to be large, and siting and approval of the facilities will more difficult and controversial than for smaller facilities. Considerations important in siting and construction of a treatment facility are described below.

- The site is large enough to provide required, water-storage volume.

- The site would is at near the outfall of a subbasin or subbasin complex so that the facility can treat the majority of the pollutant and runoff load generated by the subbasin.

- The site is adjacent to, or near, an existing primary-canal or watercourse (to maximize management flexibility and minimize water transmission costs (e.g., pumps, pipes, new canals, etc.)).

- The site is at low elevation to maximize storage capacity, minimize costs associated with the construction of water transmission infrastructure, and prevent the facility from flooding or raising the water tables adjacent property.

- The is owned by a willing seller.
- In order to minimize impacts and regulatory constraints, the site has few or no valuable wetland or upland habitats and no protected plant or animal species.
- The site is distant from heavily-developed urban areas, so as to minimize socioeconomic impacts (though some facilities could provide complimentary land uses like lake view, recreation, buffer preserves that increase the value of adjacent properties).
- The property's value for urban or agricultural development is limited or impaired.

Though the purpose of regional treatment facilities is to restore or improve natural hydrologic regimes and nutrient and sediment loading characteristics, adverse environmental impacts associated with facility construction will need to be avoided, minimized, and mitigated. Avoidance and mitigation will be complicated by the fact that many parcels with the fewest environmental constraints have already undergone or been targeted for development. The flexibility of Federal, State, and local regulatory programs is often limited when benefits accrue in a different habitat or to a different species than that being impacted (e.g. freshwater wetlands being dredged in order to improve estuarine water-quality for example). Therefore, environmental sensitivity should be an important factor when siting facilities.

Land parcels available for treatment facility siting will be a factor in determining the type of facility that is constructed. Because of the region's high water tables, above-ground surfacewater reservoirs may be required. If constructed in uplands, such reservoirs would be created excavation and construction of external and internal levees and berms. Such a facility would also require infrastructure (like pumps and conveyance and control structures) to transport and manage water flows. The facility would require the ability to store, transfer and/or release variable volumes of water efficiently and rapidly. Upland sites offer the benefit of additional storage in excavated areas. In wetland sites, the water table is frequently at the surface and this additional storage is not present even after excavation.

4.2 DEMONSTRATING CONCURRENCE WITH LOAD REDUCTIONS

Demonstrating concurrence with load reductions would require that projects contribute to reducing loadings within the watershed. An important provision of this option would be the requirement that new projects treat problem runoff that enters their sites in the existing condition rather than routing this runoff through or around the sites. The cost of this option would accrue primarily to private

interests.

4.3 GREATER TREATMENT AND ATTENUATION

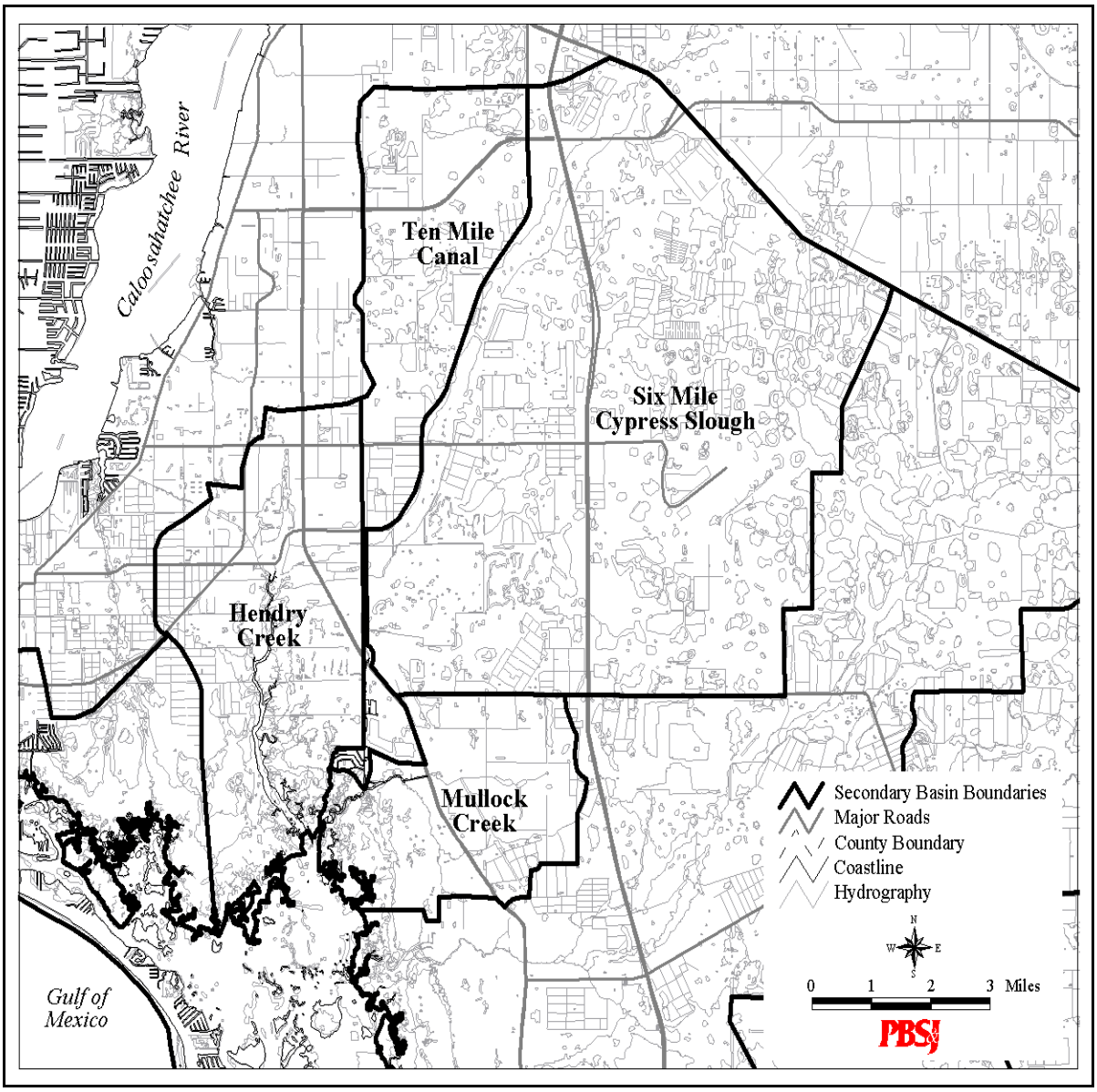
This option would require greater treatment and attenuation of runoff generated by new or substantially modified land development and infrastructure (roads, etc.) projects. Greater treatment could occur through a variety of stormwater-treatment technologies, best management practices that decrease nutrient runoff, or a combination of the two. Implementing this option would require that existing rules and regulatory practices be modified. The majority of the cost associated with this option be born by private landholders, though public facility and infrastructure projects would bear a proportionate amount of the cost.

4.4 MULLOCK CREEK SUBBASIN-COMPLEX

The Mullock Creek Subbbasin-Complex (including the Mullock Creek, Ten-Mile Canal, Hendry Creek, and Six-Mile Cypress Slough subbasins) is dominated by the Ten-Mile canal and Six Mile Cypress Slough waterways (Figure 4.1). All four secondary basins in this complex eventually discharge into Estero Bay through the otufall shared by Mullock Creek and Hendry Creek. The Ten-Mile Canal also discharges through Mullock Creek. The ideal treatment facility location in this basin-complex will be far enough downstream to treat the maximum amount of water, far enough upstream to avoid impacting the wetlands surrounding Estero Bay, and large enough to attenuate the large volumes of flow that will be experienced at a downstream site.

Three management options for the subbasin complex are evaluated in Table 4.1. This table and those that follow, list scores for management options according to several criteria. The regional treatment facility is predicted to have very good nutrient, sediment, and runoff attenuation, but the option is also expected to be expensive. The lower portions of the basin-complex (Figure 4.2) are heavily developed, and large tracts of open land are limited. If the regional treatment facility option is implemented it will probably take the form of several smaller facilities (rather than a few large facilities) in order to meet the limitations of available land. There are several borrow pits in the lower subbasin-complex that could serve as treatment sites, but several are already used for project specific-stormwater attenuation and treatment. The Lakes Park borrow pits in the Hendry Creek subbasin are a suitable site for a treatment facility. Such a facility might not be compatible with the park's current recreational uses.

The other two options, requiring project concurrence with load reduction goals and increasing runoff treatment and attenuation for new development projects are limited by the fact that so much of the lower basin-complex is already developed. Though some retro-fitting is possible



when long-term development plans are revised or infrastructure is maintained, treatment options are limited by the amount of open land. These two options are much less costly (in terms of public expenditures), but they will likely meet some opposition from owners of undeveloped property.

Figure 4.1. The Mullock Creek Subbasin-Complex composed of the Hendry Creek, Mullock Creek, Ten-Mile Canal, and Six-Mile Cypress subbasins.

Table 4.1. A comparison and evaluation of three Mullock Creek Subbasin-Complex, corrective management-options.			
Criterion	**Option 1** **Regional Treatment Facilities**	**Option 2** **Require Concurrency with Load Reduction**	**Option 3** **Require Greater Stormwater Attenuation and Treatment**
Nutrient Load Reduction	222	2	2
TSS Load Reduction	222	2	2
Hydrologic Load Reduction	22	2	2
Flood protection	⊃	2	**2/0**
Habitat	**0**	**0**	**0**
Permitting	**0 /⊃**	**0**	**0**
Sociopolitical	**0 /⊃**	**0 /⊃**	**0 /⊃**
Public Cost	⊃ ⊃	**0 /⊃**	**0 /⊃**
Private Sector Cost	**0**	⊃	⊃
Ease of Implementation	⊃	2 / ⊃	2 / ⊃

2 2 2 2 = better
0 = neutral or equal positive and negative
⊃ ⊃ ⊃ ⊃ = poor
2/ 0 /⊃, 2/ 0, 0 /⊃ = mixed

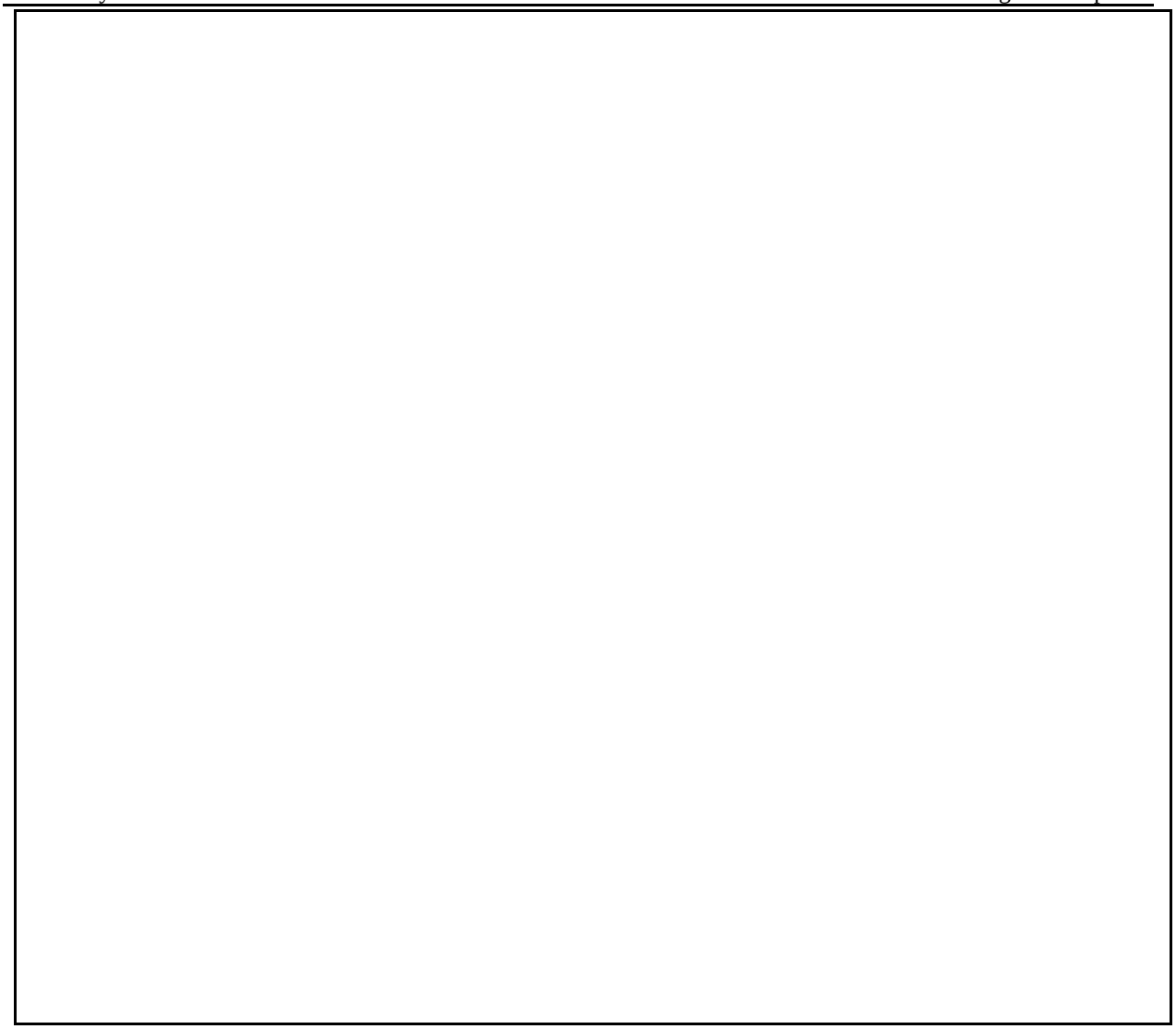


Figure 4.2. The downstream areas of the Mullock Creek Subbasin-Complex.

4.5 IMPERIAL RIVER SUBBASIN

The Imperial River subbasin is a large, watershed-feature that discharges through a small corridor, the Imperial River (Figure 4.3). Areas surrounding the Imperial River were the site of severe flooding in 1995. Much of this flooding has been attributed to an increase in the contributing basin size and runoff-budget and constrictions within the outfall corridor (Johnson Engineering Inc. et al., 1998). The Federally-sponsored Southern CREW critical project is proposed to improve flooding problems in this area.

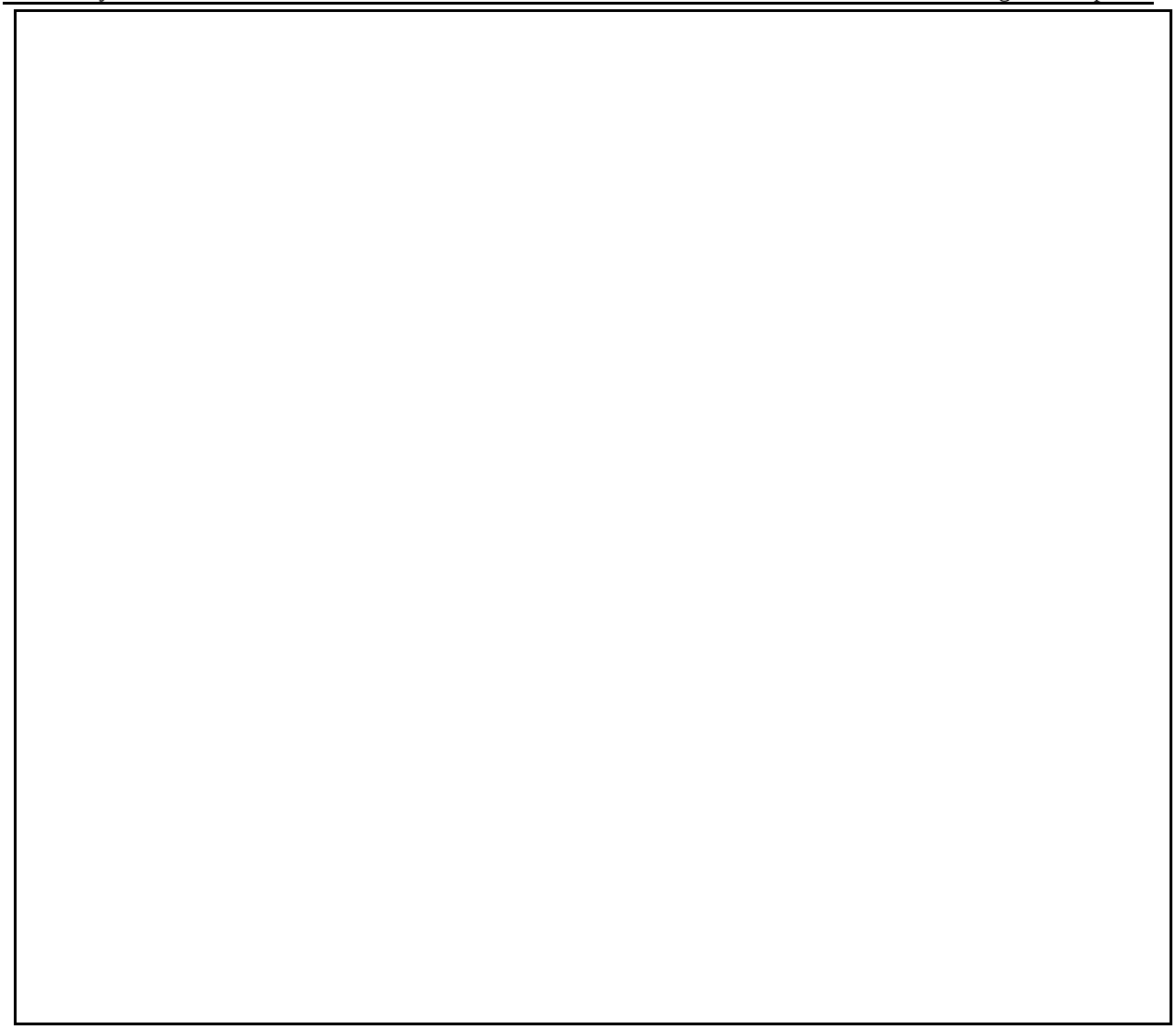
Table 4.2 evaluates three management options for the Imperial River Basin. These options are:

- Regional treatment facilities,
- Restoring historic flowways, and
- Requiring greater stormwater attenuation and treatment.

There is more land available for treatment facilities in this basin than in the Mullock Creek Subbasin-Complex, but the tertiary basin farthest downstream in the Imperial basin is heavily developed with a limited amount of open land. This tertiary basin is also a high priority basin. Two other high priority basins, located immediately upstream of basin have substantial areas of open and fallow agricultural land that are suitable for treatment facilities. Large portions of these tertiary basins are included in the Southern CREW critical project as well.

The option of restoring historic flowways is somewhat constrained by the large number of property owners with small parcels in the historic flowways. It should be possible to create a flowway system that functions more like the historic condition than the current flow patterns. This restoration should improve habitat quality in the area, although the restoration is unlikely to reach its maximum potential for flood control and nutrient attenuation. In the absence of constructed, active, regional treatment facilities, these goals can probably be reached only at the expense of the wetlands in the restoration area. Maximum attenuation and treatment could be achieved by treating the eastern Imperial River subbasin's regional wetland system as a large treatment facility. The potential that this use could adversely affect wetland hydroperiods will make permit approval for such a proposal very difficult and costly.

Requiring greater treatment and attenuation of stormwater in this area appears to be a good option. The flooding problems in the subbasin may have already made greater attenuation a necessity. This



option will likely be resisted by some owners of undeveloped property and encouraged buy property owners in flood-prone areas. Most of the cost for implementing this option will fall on the private sector, but public infrastructure and facilities projects will also bear a portion of the cost.

Figure 4.3. The downstream portions of the Imperial River Subbasin.

Table 4.2. A comparison and evaluation of three Imperial River Subbasin, corrective management-options.

Criterion	Option 1 Regional Treatment Facilities	Option 2 Restore historic flowways	Option 3 Require Greater Stormwater Attenuation and Treatment
Nutrient Load Reduction	222	**2/0**	22
TSS Load Reduction	222	**2/0**	22
Hydrologic Load Reduction	222	**2**2	22
Flood protection	⊃	22	**2/0**
Habitat	**0**	22	**0**
Permitting	⊃	**0**	**0**
Sociopolitical	**0 /**⊃	2/ **0 /**⊃	**0 /**⊃
Public Cost	⊃ ⊃	**0 /**⊃	**0 /**⊃
Private Cost	**0**	**0**	⊃ / ⊃ ⊃
Ease of Implementation	⊃ ⊃	**0**	**2 / 0**

2 2 2 2 = better
0 = neutral or equal positive and negative
⊃ ⊃ ⊃ ⊃ = poor
2/ 0 /⊃, 2/ 0, 0 /⊃ = mixed

4.6 WETLANDS AT RISK

Three options for addressing wetlands at risk in the Estero Bay watershed are evaluated in Table 4.3. These options are:

- Requiring upland buffers and upland-preserve components for wetlands,

! Transferring development rights from sensitive areas in and around wetlands, and

! Requiring the projects in listed species habitat demonstrate concurrency with (or contribute to) listed species recovery.

Table 4.3. A comparison and evaluation of three, conservation management-options.

Criterion	Option 1 Upland Buffers/Components for Wetlands	Option 2 Transfer Development Rights from Sensitive Areas	Option 3 Require Demonstrated Concurrency with Listed Species Recovery
Nutrient Load Reduction	**2/0**	**2/0**	**2/0**
TSS Load Reduction	**2/0**	**2/0**	**2/0**
Hydrologic Load Reduction	**2/0**	**2/0**	**0**
Flood Protection	2	2	**0**
Habitat	22	22	2222
Permitting	2	2	2
Sociopolitical	**0**	22	**2/0**
Public Cost	**0**	⊃	**0**
Private Cost	⊃	**0/**⊃	⊃ ⊃
Ease of Implementation	⊃	2/ **0** /⊃	⊃ ⊃

2 2 2 2 = better
0 = neutral or equal positive and negative
⊃ ⊃ ⊃ ⊃ = poor
2/ 0 /⊃, 2/ 0, 0 /⊃ = mixed

Some form of spatial or physical buffer is a requirement for most development permits. This option would require a significantly larger buffer of undeveloped habitat around wetlands. These buffers would serve to:

! Protect wetland interiors from urban and agricultural land uses,

- Decrease negative ecological edge effects,
- Preserve the upland-wetland ecotone and resulting, positive, ecological edge effect,
- filter some runoff, and
- provide both habitat and habitat corridors.

The Estero Bay watershed is a mosaic of uplands and wetlands. Because of the large number of wetlands in the landscape, requiring substantially larger, upland buffers for wetlands could notably reduce the amount of developable land on many pieces of property. While nature preserves are frequently marketed as development amenities, loss of development land will likely meet strong opposition from many property owners.

Transferring development rights from sensitive areas could be implemented as an effort onto itself or in combination with either of the two other conservation options evaluated here or one of several loading-reduction efforts. Transferring development rights will most likely result in increased development densities elsewhere in Lee County. Infrastructure limitations may constrain development where these increased densities will occur. Furthermore, market demand for both particular locations and specific development densities will determine if development-rights transfers are perceived as benefits or burdens by stakeholders. Development-rights transfers still offer the opportunity to improve the perception of other management options, however.

Requiring that projects in or adjacent to listed species habitats demonstrate contributions to listed species recovery may be the most controversial of the three options. Proving concurrence with listed species recovery may also require that significant areas of otherwise developable land be set aside for conservation. While it is possible that net losses in habitat area or acreage can be compensated for by habitat enhancement, it is more difficult to prove that a net loss in habitat acreage contributes to the recovery of a listed species. Losses of development land will create significant opposition to this management option. This management option will discourage excessive efforts to preserve isolated habitat fragments that no longer benefit listed species recovery (as opposed to short-term support of isolated individuals). This should provide some compensation for losses in development land.

4.7 SUMMARY

When Estero Bay watershed tertiary basins are ranked according to a suite of water quality-related factors, it become apparent that the majority of the priority basins (fourteen of sixteen) discharge to the Bay through either Mullock Creek-Hendry Creek outfall or the Imperial River. These secondary basins also contain the majority of tertiary basins in terms of both number and area. These factors indicate that the Mullock Creek basin-complex (Mullock Creek, Hendry Creek, Ten-Mile Canal, and Six-Mile Cypress Slough subbasins) and Imperial River basin should be the primary locations for loading-related management efforts.

The most effective water treatment and attenuation efforts will involve a combination of techniques ranging from best management practices implemented by individual homeowners to the construction of regional treatment facilities. Scarcity and cost of suitable land for publicly constructed treatment facilities will be major constraints in implementing this management option. Cost and the loss of otherwise developable land will be the major constraints to implementing more stringent water treatment and attenuation requirements for individual, development and infrastructure projects. Cost and the loss of otherwise developable land will also be major constraints to reducing future impacts and degradation to wetland habitats outside of conservation areas.

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