RESTORING THE ROOKERY BAY ESTUARY

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Rookery Bay National Estuarine Research Reserve

Henderson Creek Watershed Engineering Research Project

Task 4.2.3 – Final Technical Memorandum

Model Simulation of Belle Meade Agricultural Area Conversion

Prepared for Rookery Bay National Estuarine Research Reserve
June 2, 2015

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Funding for this project was provided to the Rookery Bay National Estuarine Research Reserve in 2011-2015 by the National Estuarine Research Reserve System's (NERRS) Science Collaborative which is a cooperative agreement between the National Oceanic and Atmospheric Administration (NOAA) and the University of New Hampshire under NOAA grant NA09NOS4190153. The NERRS Science Collaborative puts Reserve-based science to work for coastal communities by engaging the people who need the science in the research process—from problem definition and project design through implementation of the research and use of its results in coastal decisions. For more information about this project please visit www.rookerybay.org/restoreRB or contact Principal Investigator Tabitha Whalen Stadler at the Rookery Bay National Estuarine Research Reserve in Naples, Florida at 239-530-5940.

Certification

Not valid unless stamped or embossed with Engineer's Seal, signed and dated in contrasting color ink.

This report titled *Henderson Creek Watershed Engineering Research Project Task 4.2.3 – Final Technical Memorandum, Model Simulation of Belle Meade Agricultural Area Conversion* was prepared under the responsible charge of John E. Loper, P.E.

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6/19/2015

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Executive Summary

This memo contains details of **Task 4.2,** of the Henderson Creek Watershed Engineering Research Project (HCWERP).

The HCWERP includes several interrelated modeling tasks with the major objectives of gaining a better understanding of the volume and timing of freshwater deliveries to the Rookery Bay Estuary. Prior to the Future Scenario model two models were developed under **Tasks 2.3** and **2.4** respectively, these models are known as and referred to here as the:

- Existing Conditions Local Scale Model (LSM)
- Historical Conditions Natural Systems Model (NSM)

The Existing-LSM was developed with a refined model domain covering 167 square miles, at a grid-cell size of 375-ft and provides results for the analysis of the watershed under Existing Conditions (2002 – 2012). The NSM provides results for the analysis of the watershed in a pre-development or Historical Conditions for comparison against conditions as they are today.

In this current effort, the local-scale model was used to simulate two Future Scenarios within the study area. Important aspects of the model setup, including saturated zone layering and parameters, rainfall and potential evapotranspiration, and soils parameters were held constant between all models in order to provide scientifically defensible comparisons between Existing, Historical and Future Scenario Conditions. Care was taken to ensure that differences in model inputs and outputs between the two models are solely attributable to anthropogenic changes in the watershed.

To maintain uniform simulation periods between all models listed herein, the simulation period is defined as 2002 through 2012. The overall simulated cumulative freshwater deliveries to Rookery Bay were similar between Existing and Historical Conditions. However, a geographic flow re-distribution was evident in the Existing Conditions, and has been attributed to anthropogenic activities in the watershed (i.e., U.S. Highway 41 canal, and other ditching and draining practices).

This task (**Task 4.2.3**) presents results of two Future Scenario simulations whereby a spreader canal and three flow-ways have been built and the entire Belle Meade agricultural area converted to urban development. The two Future Scenario model configurations simulate the impacts of maximum allowable runoff (0.15 cfs/acre and 0.04 cfs/acre) from the conceptual development. The simulated land use changes associated with these Future Scenarios are consistent with the transfer of development rights, as specified by Collier County. The spreader canal shown in **Figure ES-1** is an east west canal at the north boundary of the area to be converted. It facilitates water deliveries through each control structure on the north/south oriented flow-ways. The flow-ways are thought to improve the current condition or restore the historical conveyance from north of the Belle Meade agricultural area to the canal. The modeling work quantifies the effects on hydrology and hydraulics resulting from the land use conversion, and proposed flow-ways. The starting point was the Existing-LSM model, developed and documented in **Task 2.7 – Interim Hydrodynamic Modelling Report**. The results of the Future Scenario models were compared with the results of the Existing Conditions-LSM and Historical Conditions-LSM to assess the effectiveness of the Future Scenario. The Future Scenario models were developed by making the appropriate revisions to the Existing Conditions LSM. Modeling work associated with this study was completed primarily with MIKE SHE v.2011 Sp-7.

The scenarios simulated the potential conversion of the Belle Meade Agricultural Area to urban development. This effort required changing the topography and land use-related parameters in the MIKE SHE / MIKE-11 model and to develop assumed conceptual stormwater routing, storage, and water control features. MIKE SHE/MIKE-11 parameters that were changed specifically for the Belle Meade Agricultural Area are:

- Vegetation and impervious land cover (refer to Figure ES.1)
- Topography
- Irrigation command areas (including irrigation rates)
- Overland Manning's Roughness Coefficient
- Detention Storage
- Separated Flow Areas
- Channel network

The physical conversion from agriculture to urban land use was simulated using information from published Collier County best management practices and other standards such as the South Florida Water Management District or Collier County specified detention storage, and maximum allowable runoff for each area (i.e., cubic feet per second per square mile [CSM]) required by development regulations. Topographic changes associated with conversion to urban land use were assumed to be consistent with other developments near the subject area. This scenario also simulated three flow-ways through the developed areas to route offsite sheet flow from the north of the current agricultural area southward towards U.S. Highway 41. This scenario does not aim to provide a design level analysis from the land use conversion, but rather answer the broader scale question:

> *"How would the assumed differences in land use affect runoff to Rookery Bay in terms of the quantity and timing of flows?"*

The Future Scenario simulations showed that:

- The two Future Scenario configurations would contribute about 4% to 5% more freshwater to Rookery Bay Estuary for the 0.04 cfs/acre and 0.15 cfs/acre configurations respectively.
- The additional flows are attributed to the opening up of the flow-ways allowing water to flow in the historical flow pattern.
- An assessment of surface water levels, overland flow depths and groundwater levels did not show any detrimental effects. However, it should be noted that the model did not simulate flood conditions associated with large storms (e.g., 100 year event).
- U.S. Highway 41 outfall swale No. 2 (**Fig. ES.1**) generates larger freshwater input to the Rookery Bay Estuary, when compared to Existing Conditions. This is likely due to the additional water routed through the proposed flow-ways upstream of U.S. Highway 41.
- As stated in previous technical memoranda (**Task 2.7 – Hydrodynamic Modeling Report**), the overall volume of flow to Rookery Bay under Existing and Historical Conditions was very similar. A comparison of the cumulative freshwater inflow volumes, showed that simulated flows were 0.5 percent higher for Existing Conditions when compared to Historical Conditions. This flow

difference is negligible and in essence shows no difference between the cumulative freshwater inputs to the Rookery Bay Estuary. The primary issue along the coast line was a shift in the sources of freshwater deliveries to the coast. Channelization and other factors in the watershed provided a geographic redistribution of flow along the coastline when compared to Historical conditions.

- Restoring the historical flow path to U.S. Highway 41 and allowing some of this water to be diverted to rehydrate wetlands, was accomplished by the current Future Scenario modeling effort.
- Flows through some coastal transects were improved, insofar as the model predicted some shift towards a more historical flow regime, but further investigation of the potential to improve the geographic distribution of flow to Rookery Bay, other alternatives may be warranted.

Figure ES. 2 presents the locations of all analysis points used for this study.

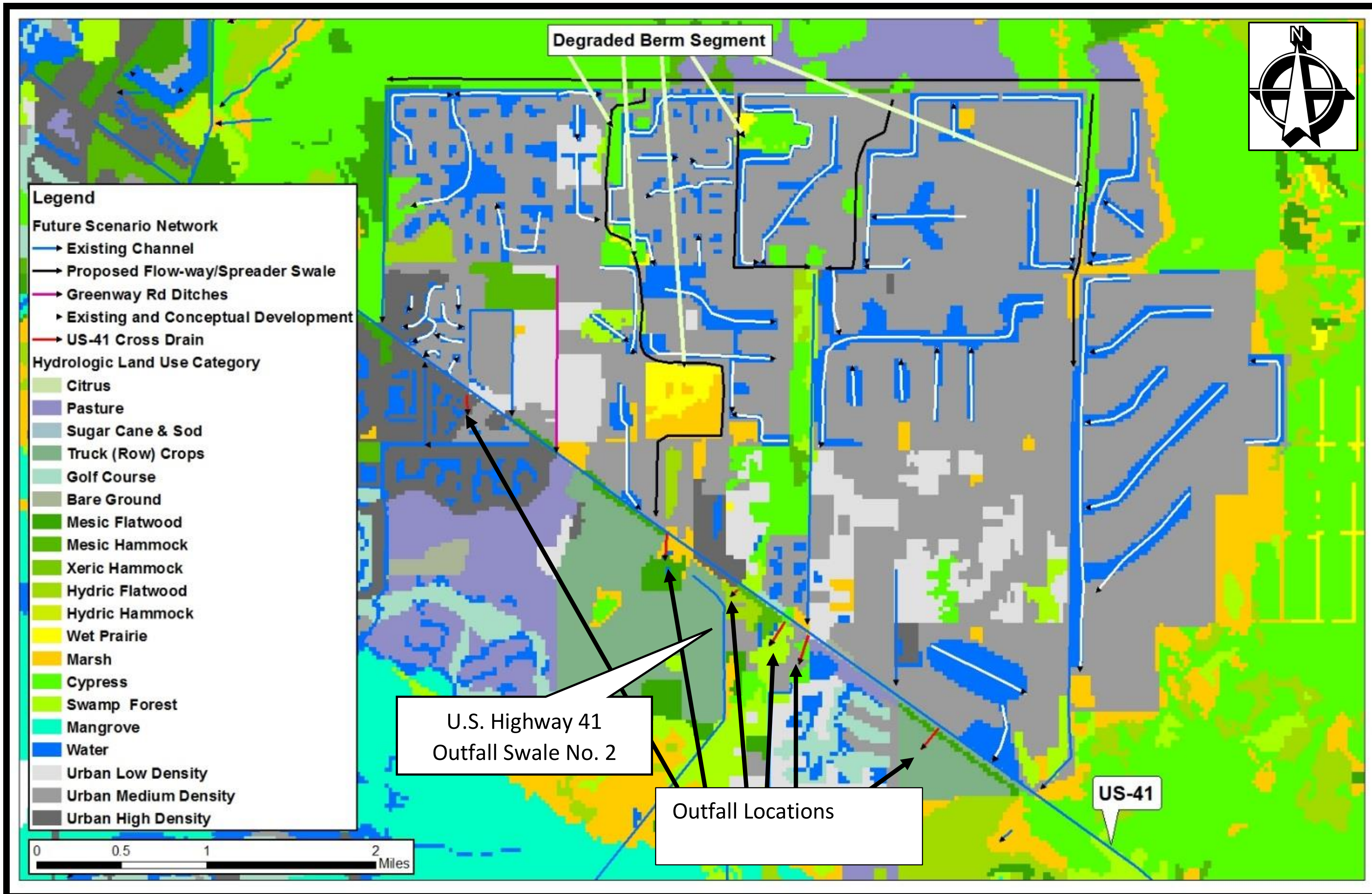

Figure ES. 1. Belle Meade Agricultural Area Future Scenario Land Use Map

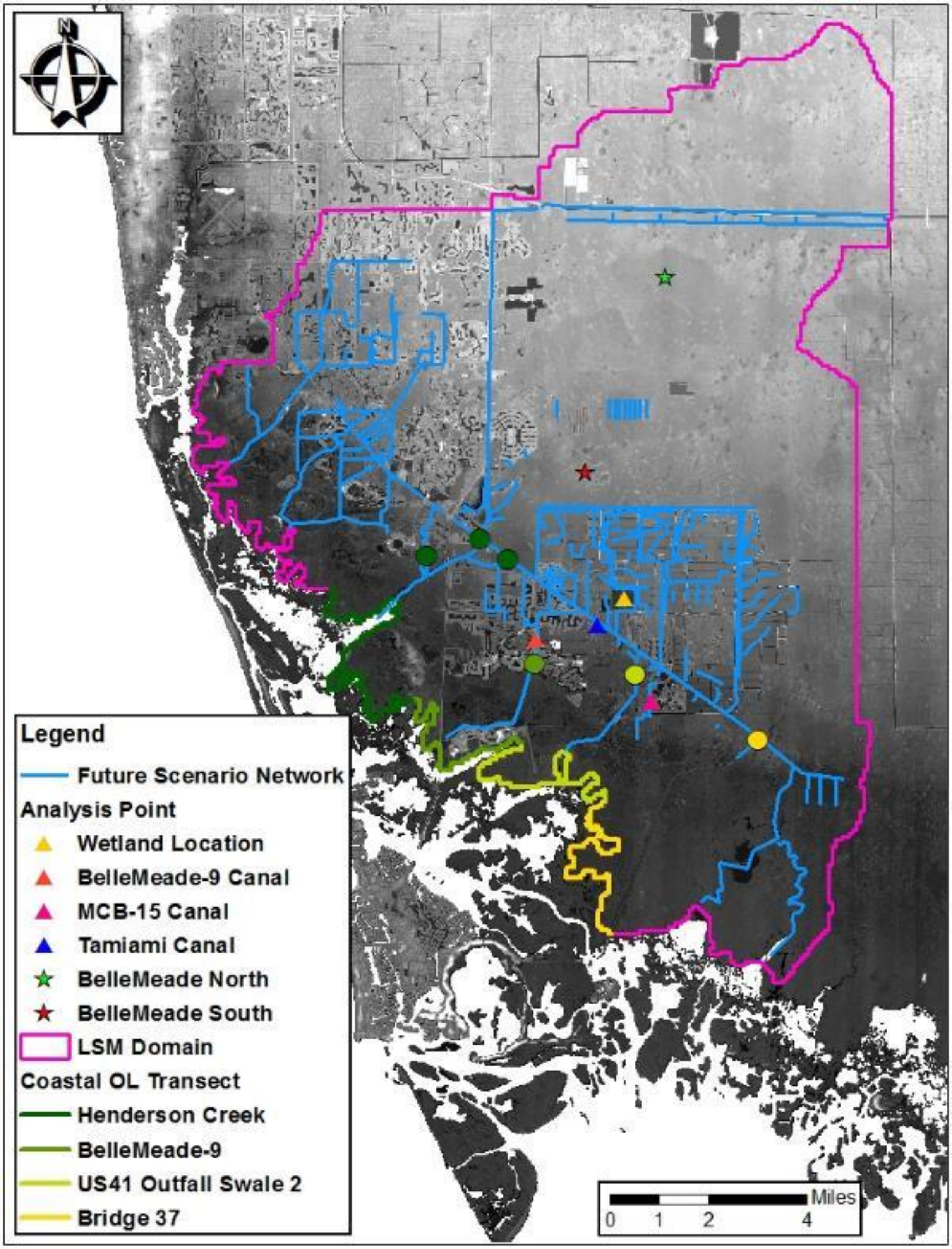

Figure ES. 2. Analysis Locations Within The LSM Domain

1.0 Introduction

This memo contains details of **Task 4.2,** development of the Future Scenario model, of the Henderson Creek Watershed Engineering Research Project (HCWERP). The HCWERP includes several interrelated modeling tasks with the major objectives of gaining a better understanding of the volume and timing of freshwater deliveries to the Rookery Bay Estuary. Prior to the Future Scenario models, two models were developed under **Tasks 2.3** and **2.4** respectively, these models are known as and referred to here as the:

- Existing Conditions Local Scale Model (LSM)
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The Existing-LSM was developed with a refined model domain covering 167 square miles, at a grid-cell size of 375-feet and provides results for the analysis of the watershed under Existing Conditions (2002 – 2012). The NSM provides results for the analysis of the watershed in a pre-development or Historical Conditions for comparison against conditions as they are today.

In this current effort, the local-scale model was used to simulate two configurations of a Future Scenario within the study area. Differences in each conceptual Future Scenario model are discussed in the appropriate section of this technical memorandum. Important aspects of the model setup, including saturated zone layering and parameters, rainfall and potential evapotranspiration, and soils parameters were held constant between all models in order to provide scientifically defensible comparisons between Existing, Historical and Future Scenario Conditions. Care was taken to ensure that differences in model inputs and outputs between the two models are solely attributable to anthropogenic changes in the watershed.

To maintain uniform simulation periods between all models listed herein, the simulation period is defined as 2002 through 2012. The overall simulated cumulative freshwater deliveries to Rookery Bay were similar between Existing and Historical Conditions. However, a geographic flow re-distribution was evident in the Existing Conditions, and has been attributed to anthropogenic activities in the watershed (i.e., U.S. Highway 41 canal, and other ditching and draining practices).

This study follows a Phase I study that assessed an operational scenario on the weirs on the HENDTAMI and TAMIHEND structures on Henderson Creek. This current study is Phase II in which the conversion of the Belle Meade Agricultural Area to urban development is being assessed. Hereafter, this alternative Phase II is referred to as "Future Scenario" based on the Collier County transfer of development rights program, where the Belle Meade Agricultural area is defined as receiving lands and is documented in the Collier County Growth Management Plan-Future Land Use Element (Collier County, 1997). **Figure 1** presents the location of the Future Scenario development within the LSM Domain.

Under contract to Rookery Bay National Estuarine Research Reserve (RBNERR), Taylor Engineering was tasked to perform scientific and engineering services to develop a photographic interpretation of aerial photographs for biologic signatures and to perform hydrologic modeling for the Future Scenario. This memorandum presents the results of Task 4, the hydrologic modeling, the scope of which is described in Section 2 below.

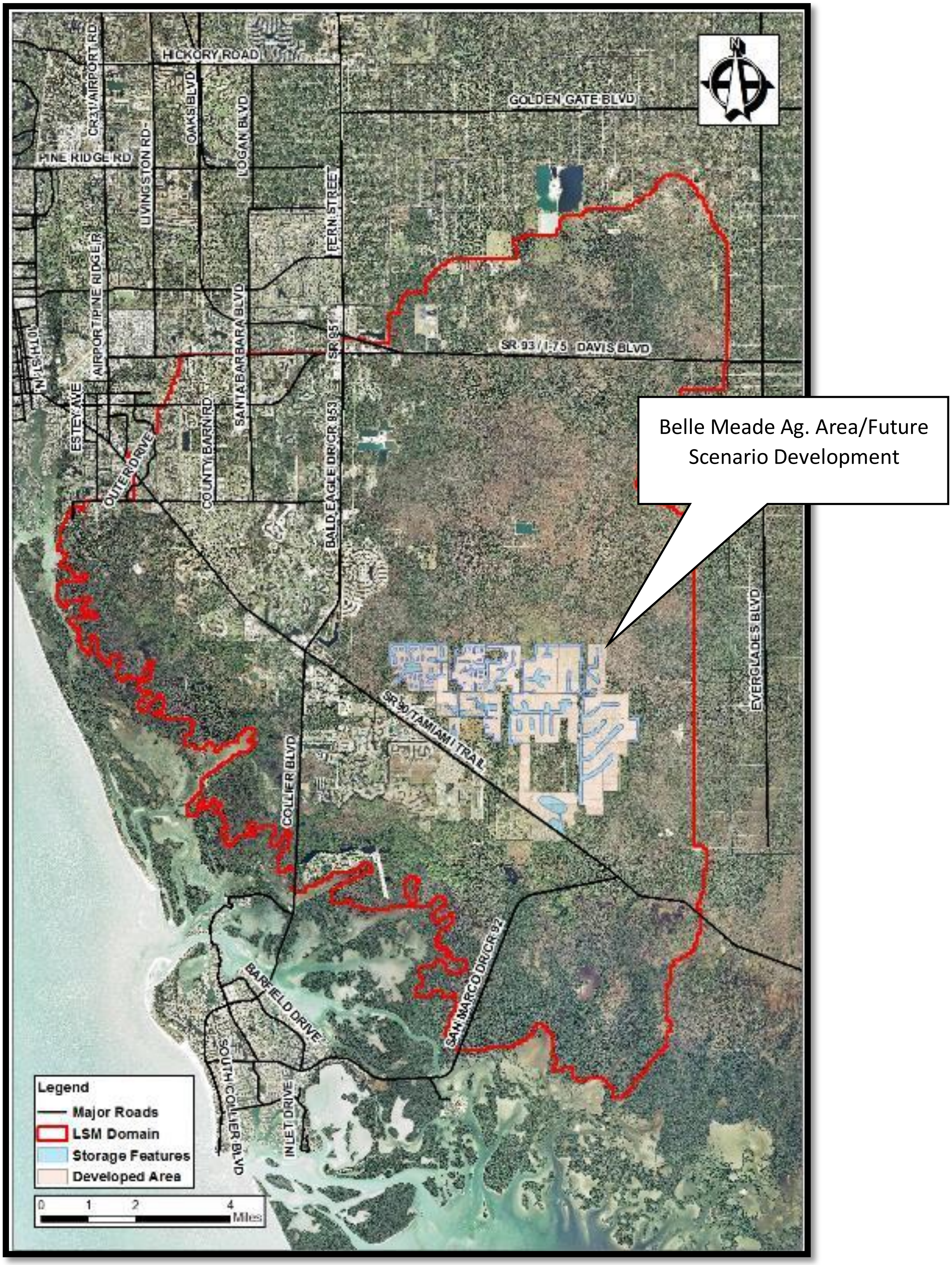

Figure 1. Model Domain and Future Scenario Location Map

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2.0 Purpose and Scope

The potential conversion of the Belle Meade Agricultural Area (to urban development (see **Fig. 1** for location)was modeled starting from the MIKE SHE/MIKE-11 model previously developed under Phase I, Task 2 and making the appropriate revisions. The hydrologic modeling (Task 4) addresses the following items shown in the scope of services:

- Field Reconnaissance
- Belle Meade Agricultural Area Conversion
- Technical Memorandum Outline
- Draft Technical Memorandum
- Final Technical Memorandum

The field reconnaissance and technical memoranda outline are documented as separate technical memoranda, whereas this memorandum is the Final Technical Memorandum which includes the Belle Meade Agricultural Area Conversion.

2.1 Belle Meade Agricultural Area Conversion

This scenario simulated the potential conversion of the Belle Meade Agricultural Area to urban development. This effort required changing the topography and land use-related parameters in the MIKE SHE / MIKE-11 model and to develop assumed conceptual stormwater routing, storage, and water control features. MIKE SHE/MIKE-11 parameters that were changed specifically for the Belle Meade Agricultural Area are:

- Vegetation and impervious land cover
- Topography
- Irrigation command areas (including irrigation rates)
- Overland Manning's Roughness Coefficient
- Detention Storage
- Separated Flow Areas
- Channel network

The physical conversion from agriculture to urban land use was simulated using information from published Collier County best management practices and other standards such as the South Florida Water Management District (SFWMD) or Collier County specified detention storage, and maximum allowable runoff for each area (i.e., cubic feet per second per square mile [CSM]) required by development regulations. Topographic changes associated with conversion to urban land use were assumed to be consistent with other developments near the subject area. This scenario also simulated three flow-ways through the developed areas to route offsite sheet flow from the north of the current agricultural area southward towards U.S. Highway 41. This scenario does not aim to provide a design level analysis from the land use conversion, but rather answer the broader scale question:

> *"How would the assumed differences in land use affect runoff to Rookery Bay in terms of the quantity and timing of flows?"*

This task included periodic coordination with RBNERR and the Consultant Team via emails and phone calls. In addition, a visit was made to RBNERR's office to have direct dialogue with the RBNERR Project Manager on December 17, 2014.

3.0 Data Review

Various sources of data were reviewed to develop an enhanced understanding of the project area with specific attention paid to details which would influence future development. Specific sources of data reviewed were:

- Belle Meade Stormwater Management Master Plan (SWMMP) (Parsons, 2006)
- FEMA flood Insurance study (both the report and GIS format)
- SFWMD Environmental Resource Permits (ERPs) for developments near the project location
- Collier County Future Land Use Map
- Collier County development ordinances specifically related to stormwater runoff
- FDOT drainage design documents (U.S. Highway 41)
- Topographic Data Including LiDAR

The Belle Meade SWMM provided guidance for the flow-way design included as part of the modeling efforts in **Task 4.2**. The flow-ways' alignment and control structures from the Belle Meade SWMM were utilized within the MIKE SHE/MIKE-11 model developed for this task. **Figure 3.1** presents Belle Meade flow-ways conceptual alignments including cross-section and control structure design elements. Conceptual plans from the Belle Meade SWMMP were reviewed and digitized in GIS. These were overlaid on aerial photographs and vegetative cover to determine feasible flow-way alignments.

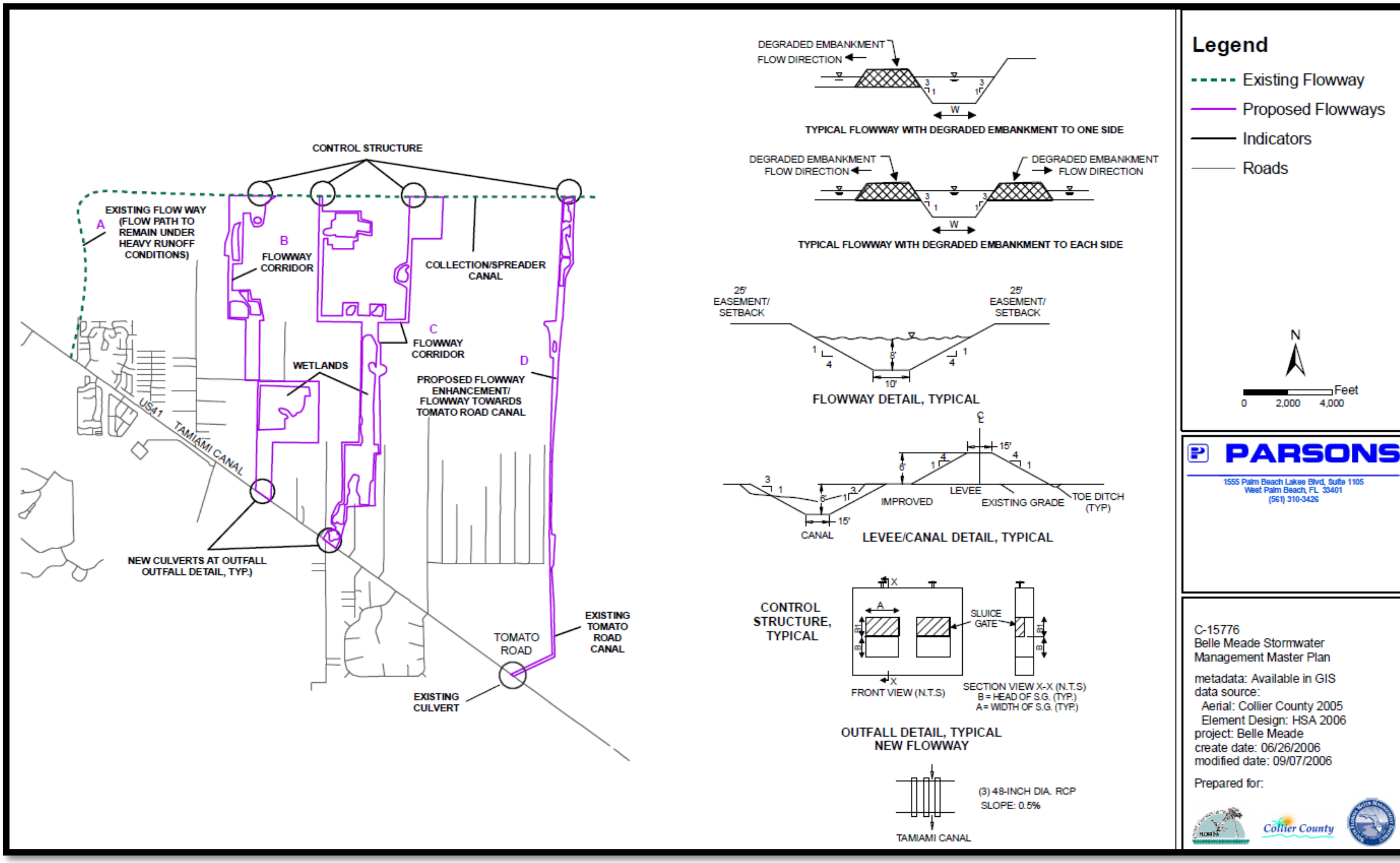

Figure 3. 1. Flow-way alignment. Source: Parsons (2006).

The FEMA Flood Insurance Study (FIS: 12021CV000B, revised May 16, 2012) documents and digital files were reviewed to determine the base flood elevation (BFE) of the area to be converted. The digital files were available in GIS format. These files included coastal transects which were used to create a surface (TIN) of the area to enable a calculation of the average BFE. This data provided the appropriate minimum elevation that the land surface would need to be built up to, so that housing finished floor elevations would be above the FEMA BFE. This BFE, in conjunction with a recent SFWMD ERP, was used to set the land surface elevation for the entire conceptual development.

Recent SFWMD ERPs, including available plans, were reviewed and will be described in subsequent sections of this memorandum. It should be noted that these documents and plans were reviewed to provide a basis for the conceptual design for the remaining areas of the Belle Meade Agricultural Area not yet developed. For example, the Naples Reserve development (SFWMD ERP # 11-00090-S-02) is currently being constructed and provided an example for the rest of the conceptual development. A complete discussion of the conceptual topography is presented in **Section 4.1.3**.

The Collier County Future Land Use Map was obtained and reviewed to ensure that the projected land uses were incorporated into the Future Scenario model as a conceptual development.

When using the land for agriculture or developing the land for residential development a maximum allowable runoff rate is generally accepted by the water management district regulations and/or County ordinance.

The following excerpt from the Stormwater Management Sub-element of the Collier County Growth Management Plan provides allowable off-site discharge rates for all areas within the county (Collier County, 1997).

(I)(II) **Policy 6.3:**
Allowable off-site discharge rates shall be computed using a storm event of 3 day duration and 25 year return frequency. The allowable off-site discharge rates are as follows:

a.	Airport Road North Sub-Basin (North of Vanderbilt Beach Road)	0.04 cfs/acre
b.	Airport Road South Sub-basin (South of Vanderbilt Beach Road)	0.06 cfs/acre
c.	Cocohatchee Canal Basin	0.04 cfs/acre
d.	Lely Canal Basin	0.06 cfs/acre
e.	Harvey Basin	0.055 cfs/acre
f.	Wiggins Pass Basin	0.13 cfs/acre
g.	All other areas	0.15 cfs/acre

Please note, these allowable offsite discharge rates include amendments (Ordinance: 2000-27 and 2007-11) to Collier County Ordinance 90-10.

The allowable off-site discharge rate utilized for all conceptual developments within the Belle Meade Agricultural Area have been restricted to 0.15 cfs/acre and 0.04 cfs/acre. Thus, all conceptual control structures were developed based upon this criteria. It is assumed that the entire area will be developed in a phased manner with multiple land owners and developers creating unique subdivisions with differing areas. For example, parcel A may be 100 acres in size, thus using the allowable off-site discharge of 15-cfs (100 acres x 0.15 cfs/acre) as specified by Collier County Ordinance 90-10. The updated model utilizes a maximum allowable runoff rate of 0.04 cfs/acre, due to projected revisions to Collier County Ordinance 90-10, thus limiting the runoff rates within the Henderson Creek watershed.

Recent FDOT hydraulic reports and design documents filed as part of SFWMD ERPs were reviewed in conjunction with field reconnaissance and verification performed on 10/31/2014 and 12/17/2014 and described in **Section 4.2.4**. Specific segments along U.S. Highway 41 are being widened or have plans to be widened in the near future. These plans are near or adjacent to the project area and were deemed necessary to investigate any potential effects these culverts may have on the drainage along U.S. Highway 41 and from the conceptual development into the future. **Figure 3.2** presents the major bridges and associated canals along the U.S. Highway 41 canal from C.R. 951 to Greenway Road (SFWMD Permit No.: 11-03368-P). **Figure 3.3** presents the SFWMD Permit 11-01368-P project location associated with existing and proposed culverts along U.S. Highway-41 from Greenway Road to Six L's Farm Road (SFWMD Permit No.: 11-01368-P), where both permits contain information on culverts (cross-drains) within the project area. An in depth map detailing the simulated location of all proposed culverts is presented in **Section 4.2.1.** Plan information associated with the aforementioned ERPs are available online at the SFWMD e-permitting website.

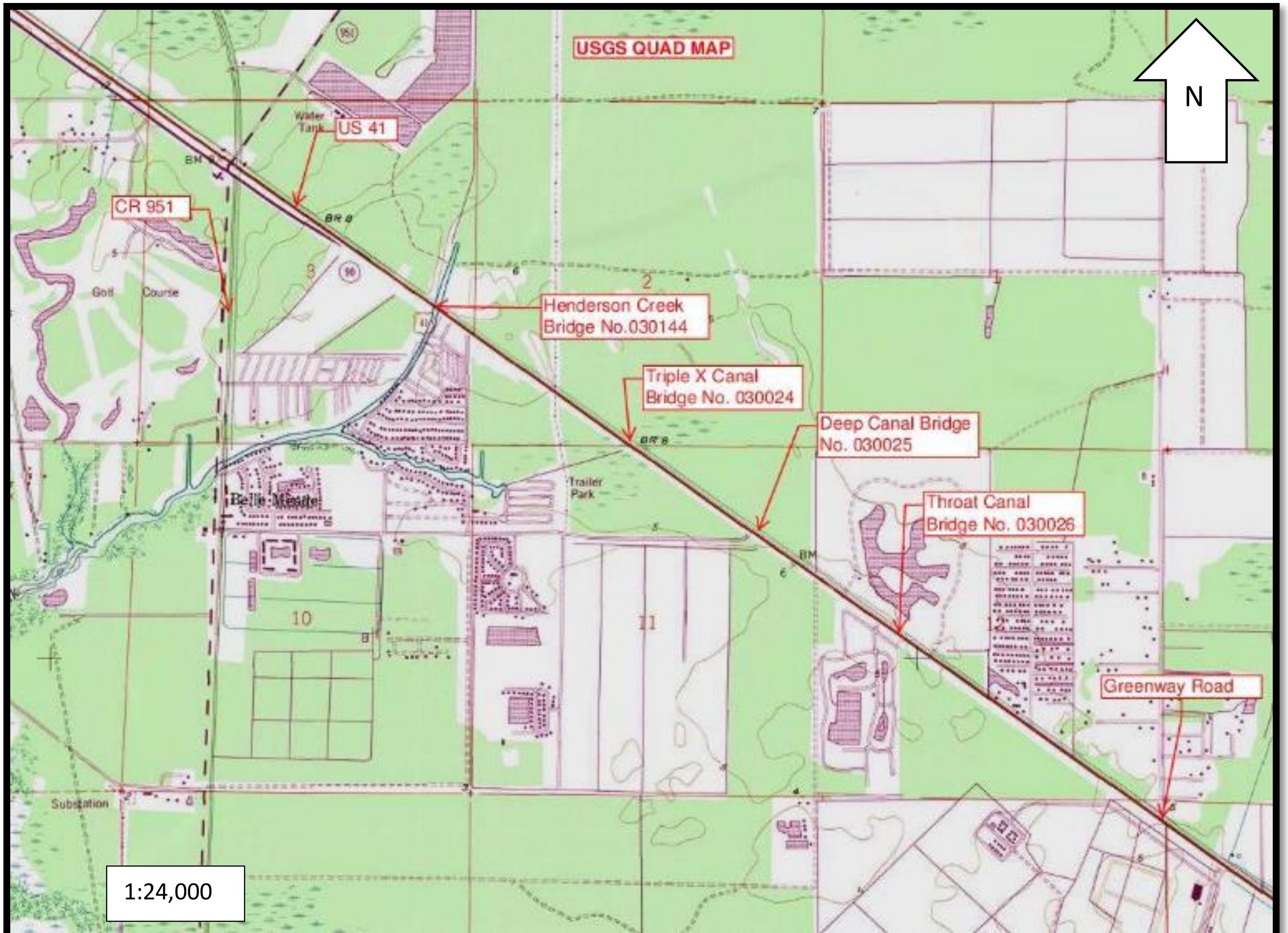

Figure 3. 2. Canal and Culvert Locations: After SFWMD Permit: 11-03368-P

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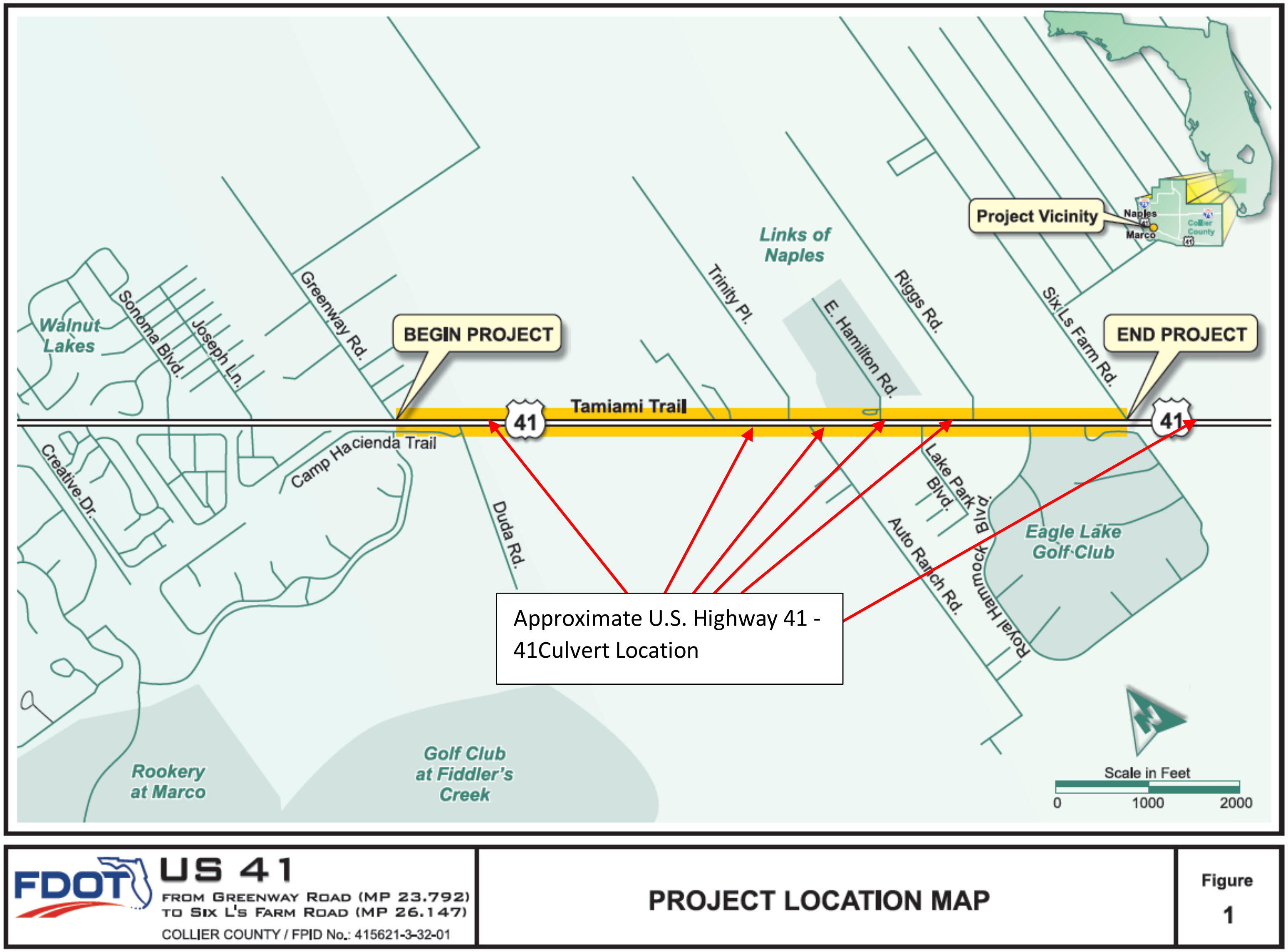

Figure 3. 3. Project Location Source: Modified from SFWMD Permit: 11-01368-P

4.0 Methodology

This section documents the methods and rationale behind assumptions and changes made to the MIKE SHE/MIKE-11 Existing Conditions model developed to predict the Future Scenario. Each component of the model where changes were made is described and justified based on available data or professional judgment. It is important to note that all MIKE SHE/MIKE-11 files associated with the following sections were updated only in the area of conceptual development. That is, all areas within the model domain outside of the conceptual development boundary remain equivalent to Existing Conditions.

4.1 MIKE SHE Updates and Revisions

The following sub-sections detail the revisions and updates within MIKE SHE as part of the model development for the Future Scenario. Revisions in the model reflect changes from agriculture to urban land use, and construction of flow-ways for the Future Scenario.

4.1.1 Vegetation

Vegetative land use coverage was developed based on an assumption from the Collier County Future Land Use Map which shows the entire Belle Meade Agricultural Area north of U.S. Highway 41 as receiving lands eligible for development. In conjunction with reviewing the land use map, other areas within the model domain were reviewed for development density. Development density is a parameter that defines how the physical properties of the land cover are represented within the model.

For the current study, it was assumed that the conversion from agriculture to urban land would be done in a manner that coincides with a medium density residential land use attribute within the MIKE SHE model. It is important to note that several model parameters (paved runoff coefficient, irrigation command area, irrigation rate, Overland Manning's Roughness Coefficient, and detention storage) are a function of the vegetative class within the model framework.

Figure 4.1 presents the Existing and Future Conditions Scenarios, conceptual land use represented by the conversion from agriculture to urban land and associated storage features within the Belle Meade Agricultural Area. **Figure 4.1** and **Table 4.1** show comparison of Existing and Future Scenario land use.

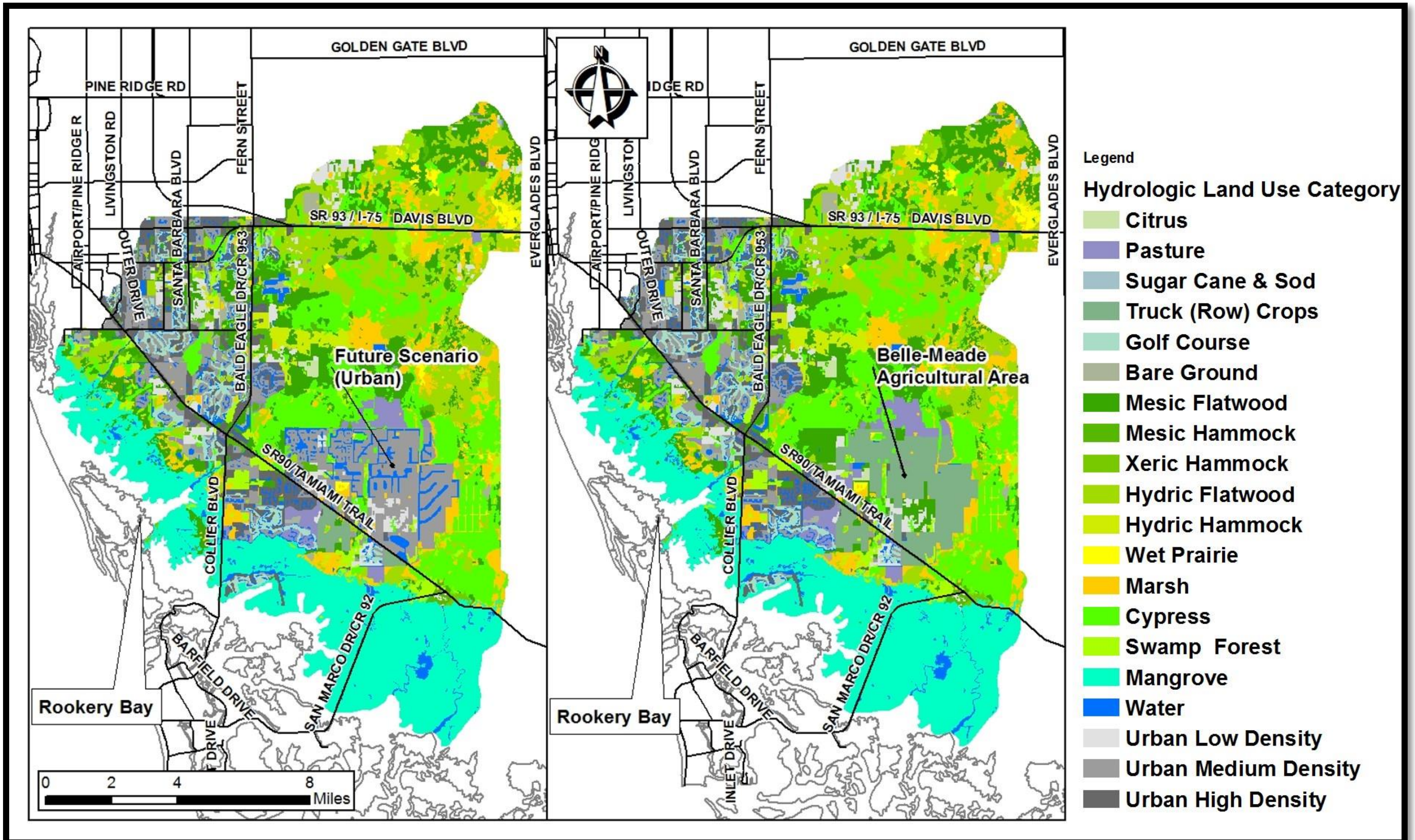

Figure 4. 1. Existing (right) vs Future Scenario (left) Land Use Comparison

Table 4. 1. Existing vs Future Scenario Land Use Comparison

Land Use Category	Percentage of Watershed		Difference (Future Scenario - Existing)
	Existing	Future Scenario	
Citrus	0.19%	0.14%	-0.1%
Pasture	2.07%	1.61%	-0.5%
Sugar Cane & Sod	0.01%	0.01%	0.0%
Truck (Row) Crops	5.57%	0.71%	-4.9%
Golf Course	2.83%	2.78%	0.0%
Bare Ground	0.97%	0.95%	0.0%
Mesic Flatwood	11.98%	10.77%	-1.2%
Mesic Hammock	1.08%	1.09%	0.0%
Xeric Hammock	0.20%	0.19%	0.0%
Hydric Flatwood	12.37%	12.37%	0.0%
Hydric Hammock	1.31%	1.31%	0.0%
Wet Prairie	0.87%	0.87%	0.0%
Marsh	7.38%	7.37%	0.0%
Cypress	13.76%	13.74%	0.0%
Swamp Forest	2.77%	2.76%	0.0%
Mangrove	19.57%	19.57%	0.0%
Water	3.50%	4.83%	1.3%
Urban Low Density	2.84%	2.82%	0.0%
Urban Medium Density	4.85%	10.23%	5.4%
Urban High Density	5.89%	5.89%	0.0%

As presented in **Figure 4.1** and **Table 4.1** the land use in the Future Scenario would change significantly from Existing to Future Scenario Conditions, specifically related to Truck Crops and Urban Medium Density. There would be a 5.4 percent and 1.3 percent increase in Urban Medium Density and Water respectively. Land use modifications would result in the loss of Truck Crops, Pasture, Mesic Flatwood and Citrus (4.9%, 0.5%, 1.2% and 0.1%, respectively) from Existing Conditions.

4.1.2 Impervious Land Cover

The directly connected impervious land cover is represented in MIKE SHE by the paved runoff coefficient (PRC) and is a reflection of the land use described in **Section 4.1.1**. The PRC defined in the Future Scenario model has been set to 0.15, which accounts for about 15% of the land cover converted to directly connected impervious surface (roads, parking lots, and the portions of roofs that drain directly to a paved surface or storm drain) features associated with development. The overall residential density of these conceptual developments was modeled as medium density. Medium density residential is defined by the Florida Department of Transportation as two to five dwelling units per acre (FDOT,1999)

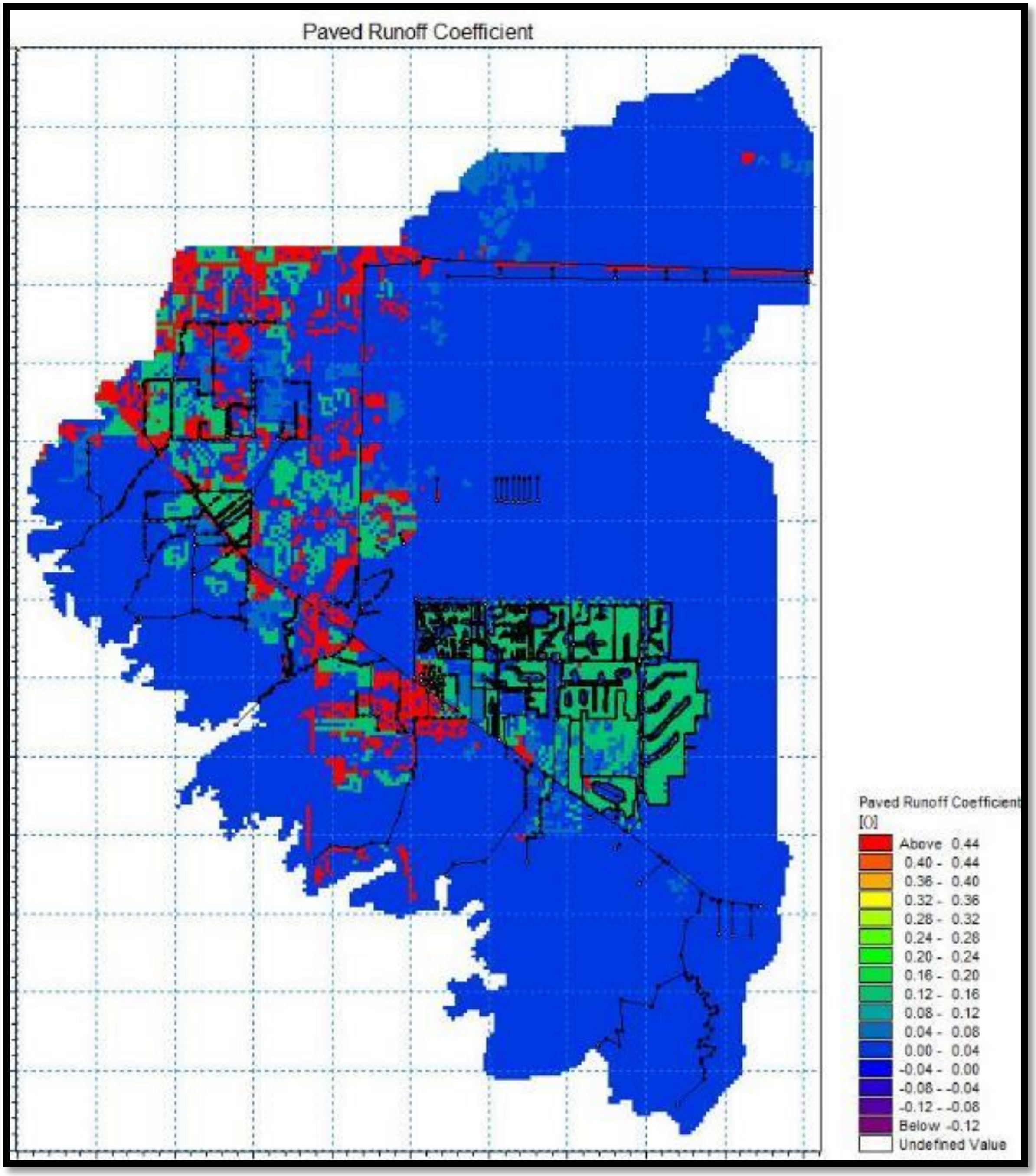

Figure 4. 2. Future Scenario MIKE SHE Paved Runoff Coefficient.

4.1.3 Topography

In reviewing FEMA Flood Insurance Study 12021CV000B and associated GIS and digital files (DFIRM), it was noted that the average base flood elevation (BFE) within the northern portion of the Belle Meade Agricultural Area was 7.5 feet-NAVD88. Using the FEMA BFE information and the Naples Reserve (SFWMD ERP # 11-00090-S-02) plans, where the engineers' recommended minimum finished floor elevation ranged from 8.6 to 8.8 feet-NAVD88, an average land surface value of 9 feet-NAVD88 was set across the conceptual developments within the land area to be converted. **Figure 4.3** presents the topography for the entire model domain, where it can be seen that the only area of change is the area associated with the conceptual development. This area is shown in yellow as a large homogenous region within the development at the previously specified elevation of 9 feet-NAVD88. Please note, the lakes within the Belle Meade Agricultural Area are represented within the MIKE-11 network as cross-sections. The topography presented in **Figure 4.4** represents only the land surface, not the lake bathymetry. Refer to **Section 4.2.3** for a description of the lake bathymetry.

The elevations developed as part of the Future Scenario model are reasonable assumptions based on ERP and FEMA flood study review. In addition, recent developments in the area have similar land surface elevations (Winding Cypress, Naples Reserve). It is important to remember that this study is not a flood study, nor is it a design level analysis, but does consider the physical attributes of the surrounding area including a realistic conceptualization of the potential land surface elevation.

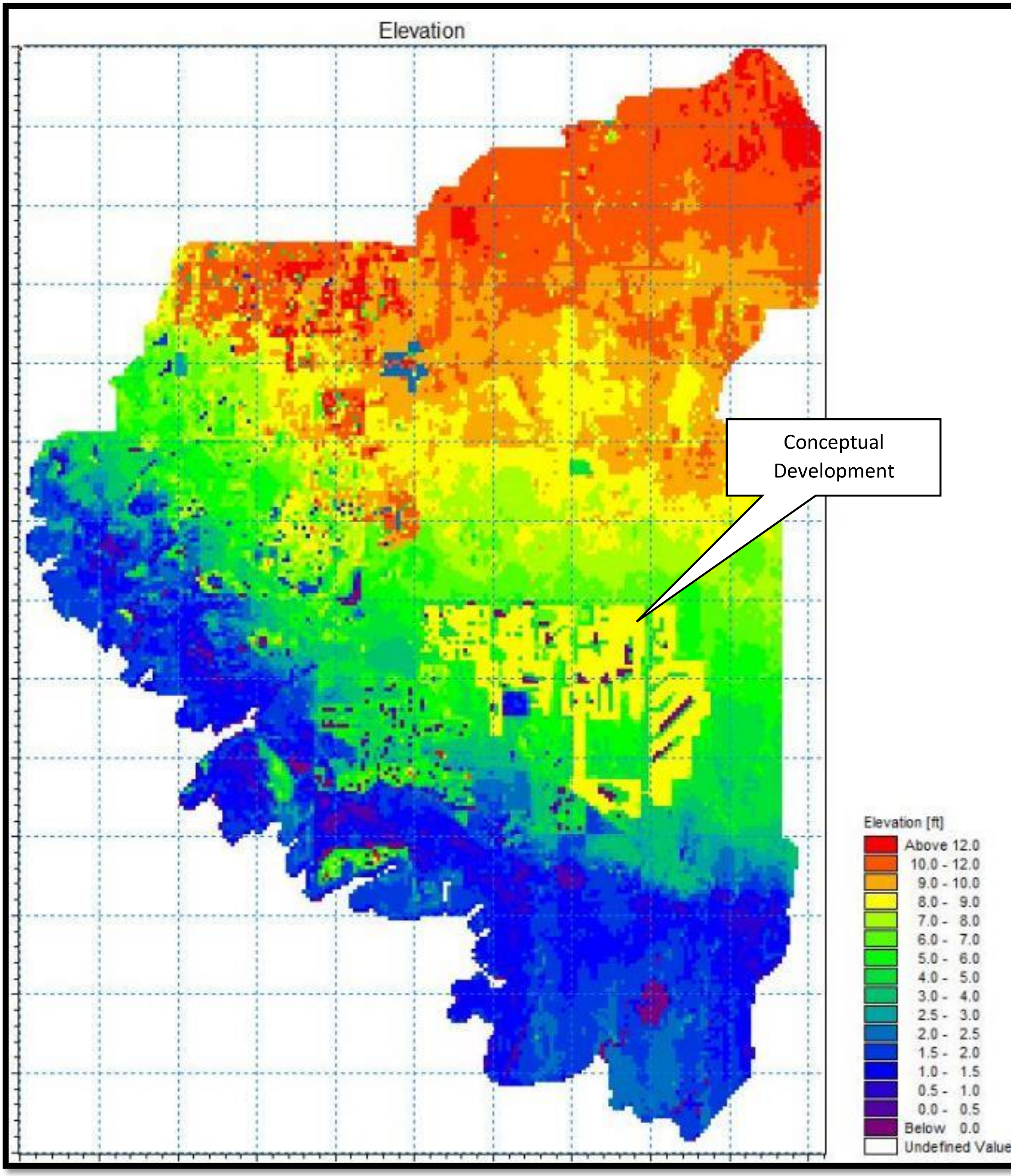

Figure 4. 3. Future Scenario MIKE SHE Conceptual Topography.

4.1.4 Irrigation Command Areas

Figure 4.4 presents the Future Scenario irrigation command areas (ICA). ICA, define where irrigation will be applied within the model domain. The ICAs were updated based upon the conceptual land use changes, except that the proposed stormwater management system (lakes) for each development was not receiving irrigation. Allowance was also made for the fact that approximately 30% (green areas) of the area was irrigable to account for some areas being covered with houses.

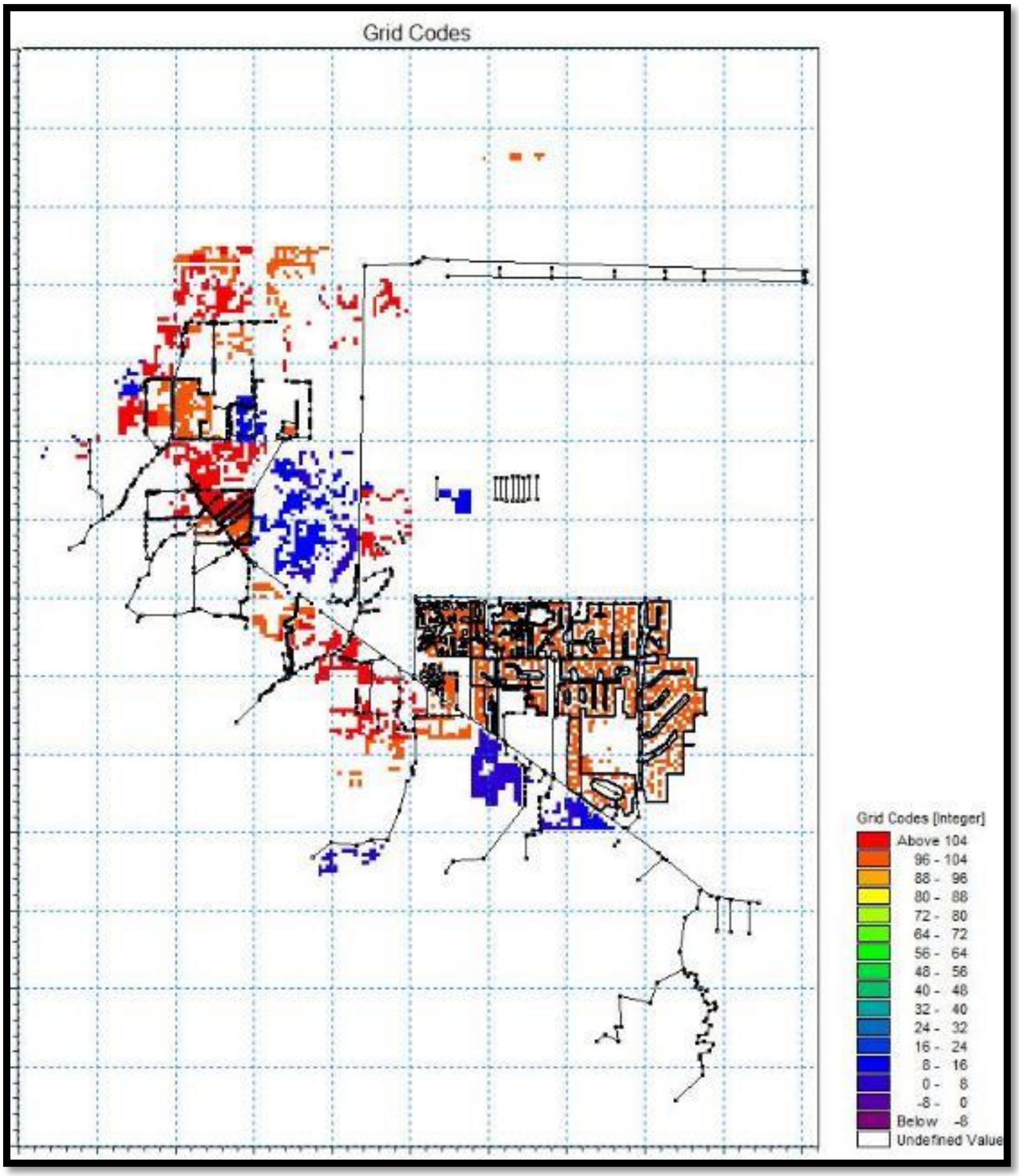

Figure 4.4. Future Scenario MIKE SHE Irrigation Command Areas

4.1.5 Irrigation Rates

Irrigation rates were revised based upon the land use changes and have been attributed based on other developments within the study area comprised of similar land use type. The main difference is that the irrigation rate has been decreased by an order of magnitude to be consistent with the previous modeling effort difference between urban and agricultural area. **Table 4.2** presents the maximum irrigation rates used for the Existing Conditions and Future Scenario models.

Under Existing Conditions, the Belle Meade Agricultural Area was divided into three irrigation command areas obtaining water from various depths below land surface. One obtained water from 16-feet below land surface, another from 48-feet below land surface while the third obtained water from 80-feet below land surface. These depths have not been altered for the Future Scenario model, rather a reduction in maximum rates as discussed previously. Discussions with a member of the project team indicate that the conceptual development will likely continue to use the existing sources of water within the site.

Table 4. 2. Maximum Irrigation Rate Comparison

Simulation	Maximum Irrigation Rate (cfs)
Existing Conditions	0.25
Future Scenario	0.023

4.1.6 Overland Manning's Roughness Coefficient

Figure 4.5 presents the Future Scenario Overland Manning's Roughness Coefficient (OL Manning's' M). The OL-Manning's M was unchanged for most portions of the model domain. The only area where OL-Manning's M was changed lies within the area of the conceptual development where agricultural land was converted to urban land use. Wetland land use categories within the area of conceptual development remained unchanged. The agricultural area was changed from an M value of 5.88 to 8.33 $m^{1/3}$/sec. This decrease in roughness of the land surface is because the hydraulic characteristics are of a smoother surface with lower friction consistent with an urban area.

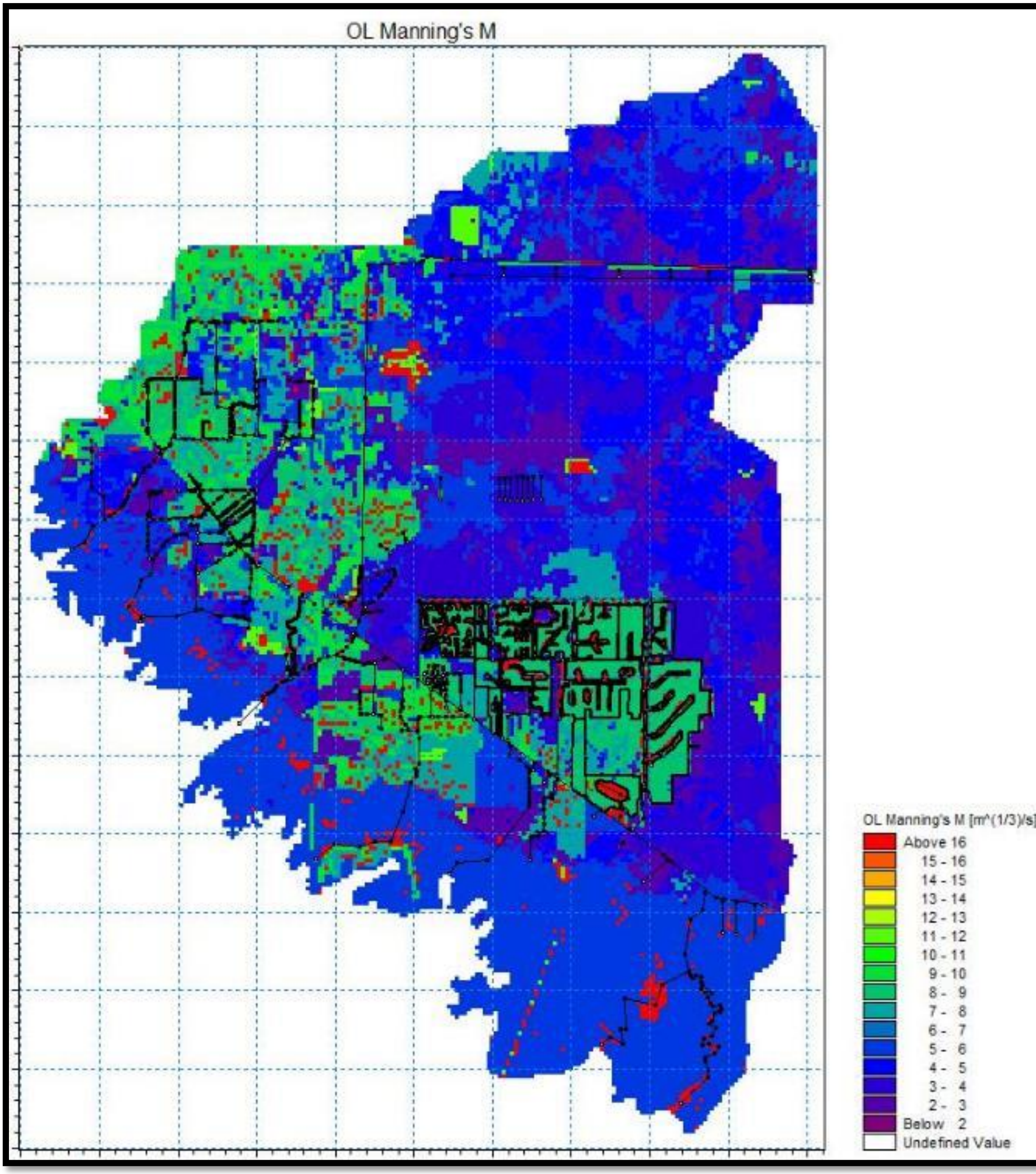

Figure 4.5 Future Scenario MIKE SHE Manning's M

4.1.7 Separated Flow Areas

Figure 4.6 presents the Future Scenario separated flow areas. Separated flow areas were largely left unchanged. However, there was an area on the eastern portion of the Belle Meade Agricultural Area that needed to be added to account for proposed development within the area. This change was made to ensure the entire area was being represented as a single separated flow area. This means that water is not allowed to enter the system from the overland flow plane or MIKE-11 network, unless the MIKE-11 network contains a connection from the surrounding separated flow areas. In essence, it represents a berm around the entire conceptual development, with a channel being the only allowance for water to move from one area to another.

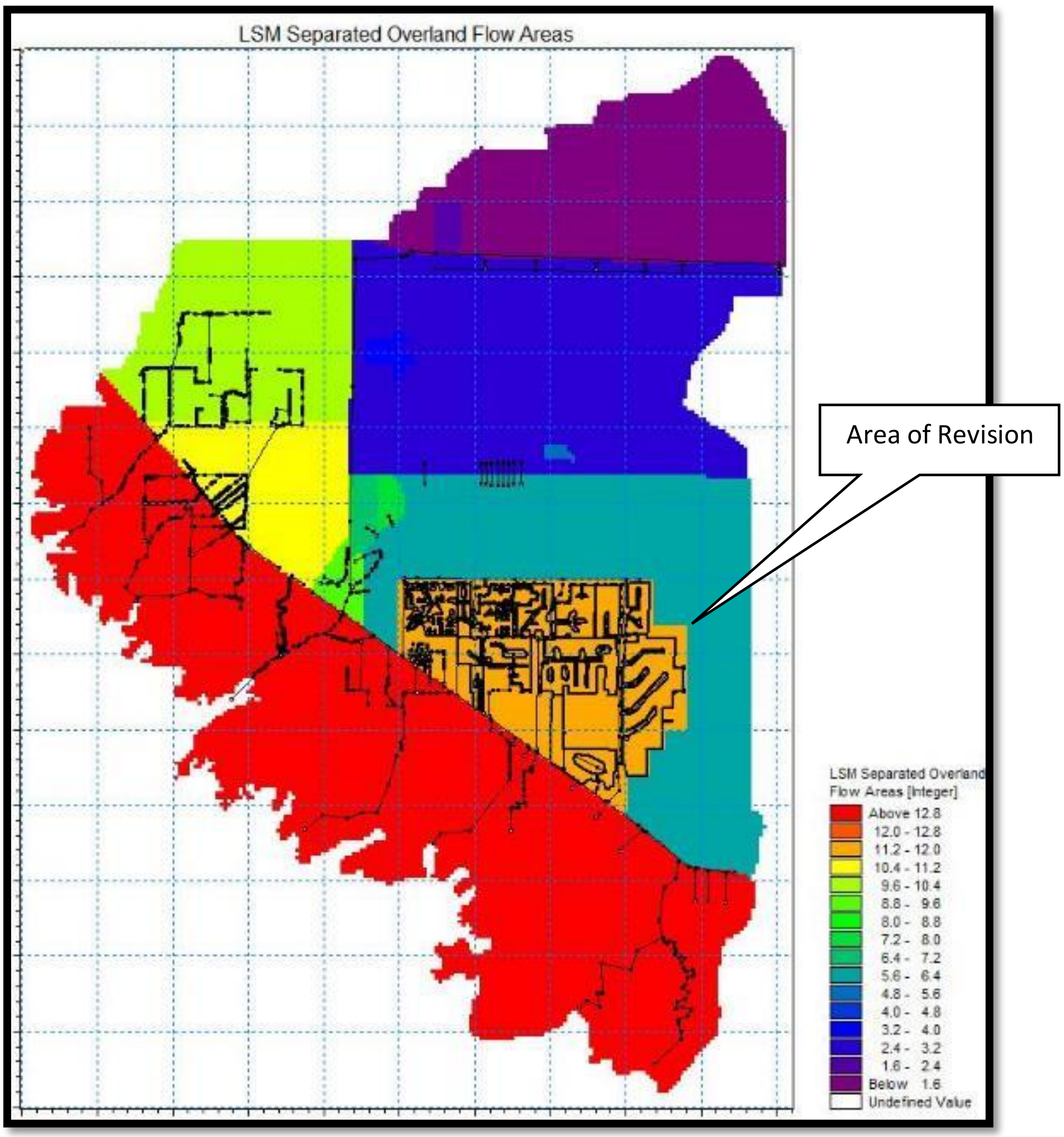

Figure 4.6. Future Scenario MIKE SHE Separated Flow Areas

4.1.8 Detention Storage

Figure 4.7 presents the Future Scenario detention storage. The detention storage parameter is also a function of land use, and has been revised based upon the conceptual land use changes described in **Section 4.1.1**. Within the model, it provides a storage depth for each associated grid cell to account for micro-topography on the land surface. The previous detention storage depth for the agricultural land use was 0.25 inch and is now 0.1 inch to represent the development. This value corresponds with the detention storage depth associated with similar land use classifications within the model domain. However, it should be noted that all detentions systems (ponds) are not included in detention storage as they are modeled explicitly.

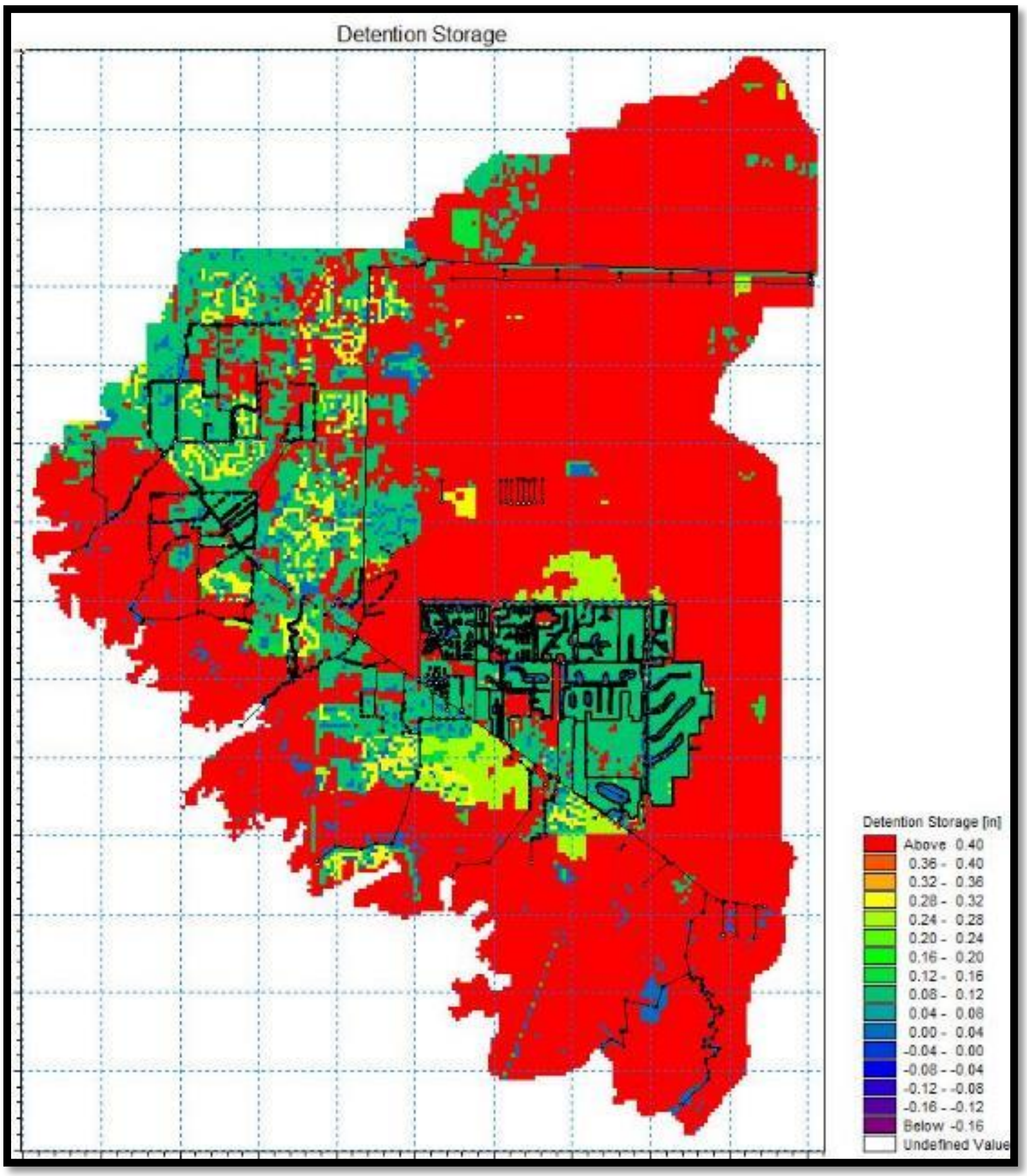

Figure 4.7. Future Scenario MIKE SHE Detention Storage.

4.2 MIKE-11 Revisions

MIKE-11 parameters that were updated/refined include:

- Mike-11 stream network (proposed channels/flow-ways were added)
- Cross-sections associated with proposed network changes
- Control structures associated with proposed network changes
- Manning's n (1/M) for proposed network changes
- Culverts under U.S. Highway 41

4.2.1 Surface Water Network

The MIKE-11 surface water network was revised to account for the hydraulic connections of the conceptual development within the Belle Meade Agricultural Area. Lakes and control structures were added to account for the runoff associated with the land use changes and hydraulic connections that have been proposed. Control structures were sized and vertical control was based upon ERP review of the most recent developments and available data in the area as described in the following sections.

The Belle Meade SWMMP as described and presented in **Section 3.0** provided information on flow-way alignment as well as a spreader canal along the northern portion of the conceptual development. The spreader canal serves two purposes:

1. To intercept water (overland flow and groundwater)
2. To distribute the captured water from the Belle Meade area between the proposed flow-ways

Figure 3.1 presents the flow-way design from the Belle Meade SWMMP and shows the spreader canal linking into an existing flow-way on the western border of the conceptual development. This existing flow-way is a ditch labeled within MIKE-11 network as "BELLEMEADE-2," and connects with the U.S. Highway 41 canal and has been left within the model unchanged from Existing Conditions. BELLEMEADE-2 provides an outfall under large runoff conditions (Parsons, 2006).

Figure 4.8 presents the MIKE-11 network representing the conceptual development and proposed spreader swale and flow-way channel alignments. To account for the changes in hydraulic routing represented by the spreader swale, flow-ways and conceptual development, 49 channel branches were added to the MIKE-11 network. Additionally, **Figure 4.8** presents the areal extent of the conceptual branches developed for the Future Scenario MIKE-11 network, overlying the Future Scenario land use showing the alignment of the proposed flow-ways and spreader canal, storage areas associated with the conceptual development, and the existing channel network. Further additions of the MIKE-11 network included:

- 13 weirs representing outfall control structures within the conceptual development and a fixed control from the spreader swale to BELLEMEADE-2 to prevent over drainage of the surrounding wetlands
- Four operable control structures providing seasonal control at the upstream end of each proposed flow-way
- Two weirs to control diversion of water from flow-ways into adjacent wetland areas

- Nine culverts as per the Belle Meade SWMM to allow for water to pass from each flow-way into the U.S. Highway 41 canal and allow for roadway crossings as necessary

See **Section 4.1.3** for a discussion of the conceptual topography which details the land surface elevation of the conceptual development represented within this model. The storage features associated with the conceptual development have been incorporated based upon the lake depths from the Naples Reserve ERP described in **Section 4.2.3**, at a depth of approximately -15 feet-NAVD88. Other permits and aerial photo review of developments in the area were reviewed to maintain consistency with urban land use features in the study area. Examination of other developments in the study area show that as a general rule of thumb, surface water management lakes comprise about 20-25% of the land area. While this general rule holds true and was shown in permit files reviewed (e.g., Walnut Lakes, SFWMD ERP # 11-02131-P, and Winding Cypress), the Naples Reserve development incorporated higher levels of stormwater detention. Thirty three percent (33%) of the Naples Reserve area was surface water storage and the remaining 67% was for roadways, lots, greenspaces, etc. Other developments such as Walnut Lakes and Winding Cypress had approximately 20% of the area as surface water storage and the remaining 80% for roadways, roadways, lots, greenspaces, etc. Walnut Lakes and Winding Cypress are consistent with a general rule of thumb to use about 20% of the land area for surface water storage. Therefore, 20% was adopted for this Belle Meade Agricultural Area conversion study.

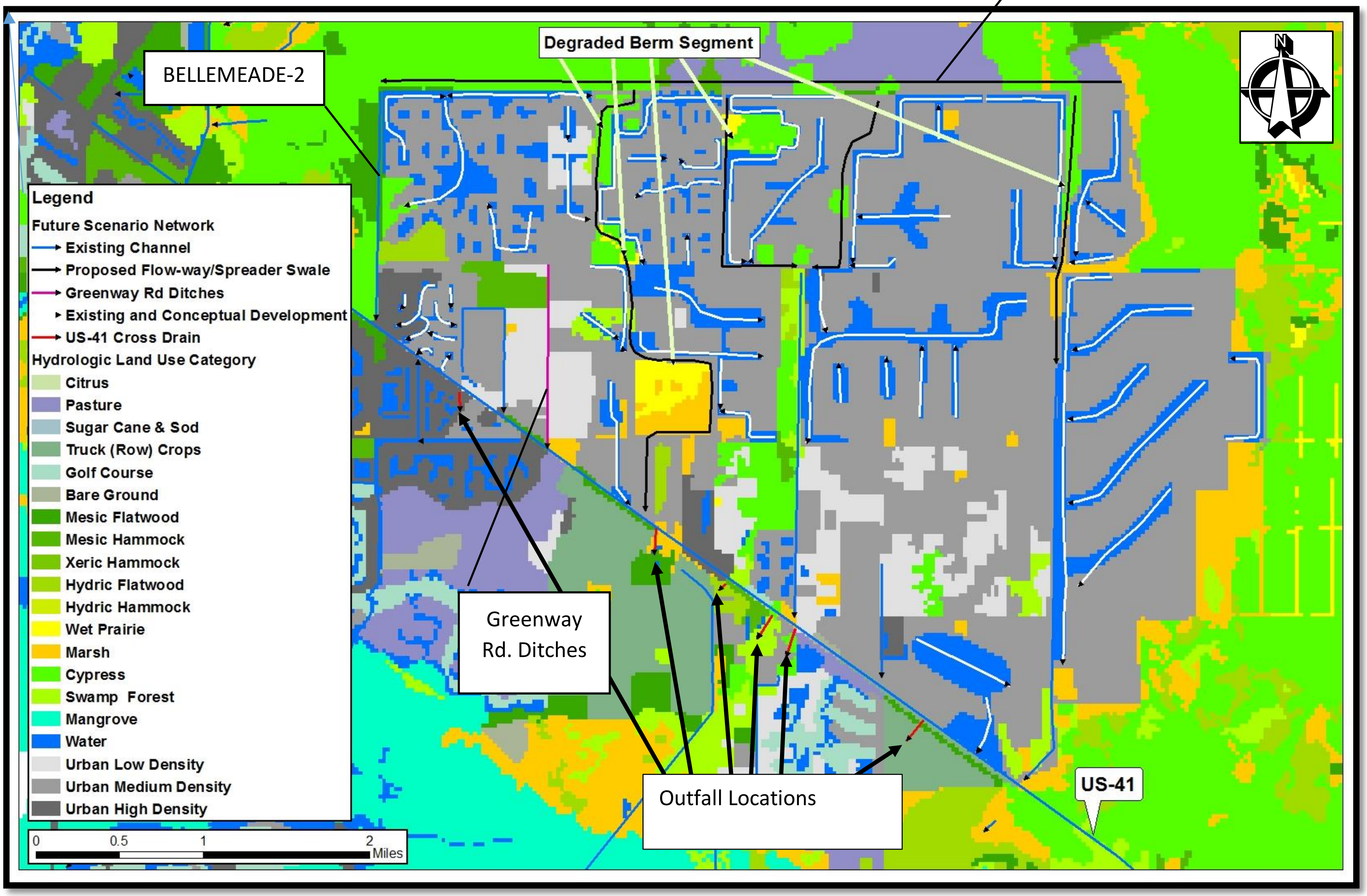

Figure 4.8. MIKE-11 Network Including Conceptual Flow-ways, Development and Storage Features.

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4.2.2 Proposed Flow-ways

The proposed flow-ways were represented based on information from the Belle Meade SWMMP, in conjunction with aerial photograph and LiDAR interpretation. The flow-way alignment and cross-section design was based upon the data presented in the SWMMP and presented in **Figure 3.1.** Control structures were sized based upon the simulated flows previously determined in the Belle Meade SWMMP (Parsons, 2006) and operational criteria was based upon relevant permits in the area specifying the seasonal high water elevation. From this seasonal high water table data, the invert of each control structure was set to 4.5 feet NAVD-88. Both wet season and dry season gate operations allow each gate to open 1 foot, with only the upstream water level triggering the seasonal controls.

Flow-way cross-sections were interpreted and developed from the plans presented in **Figure 3.1** (Parsons, 2006). Where the majority of the flow-way cross-sections have a berm on either side to protect the surrounding land from flooding, details are given for the berm to be degraded at locations along flow-ways. Several cross-sections have a degraded berm on one or both sides to allow water to spill onto the overland flow plain into adjacent wetland areas. Segments where the berm has been degraded within the cross-sections are presented in **Figure 4.8**., as shown each segment is associated with a wetland land use category. The berms were degraded in these areas to provide an overflow into these wetlands for potential rehydration and stormwater attenuation. While this study does not aim to provide design level analysis of the stormwater attenuation, it is a known fact that water diverted to a low-lying area can provide a significant level of attenuation as well as benefits to wetlands. An analysis of the impacts to overland flow depths near a selected area of berm degradation is in **Section 5.1**, which provided insight on the hydroperiod within this wetland area.

4.2.3 Future Scenario Development

A major component of this project is the projected Future Scenario where the entire Belle Meade Agricultural Area is converted to urban development. Specifically, how the stormwater component of runoff would be affected if the maximum allowable runoff rate was reduced from 0.15 cfs/acre to 0.04 cfs/acre. While two models were developed under this task, the only parameter revised between each model was the size of the conceptual control structures. This change allowed for an analysis between the maximum allowable runoff rates of 0.15 and 0.04 cfs/acre. In order to accomplish this conceptual conversion, several developments in the area were reviewed to maintain consistency with the area practice.

Three urban areas (developments) were specifically reviewed as part of this project, the following list presents the developments reviewed from SFWMD ERPs and water use permits:

- Naples Reserve (added to Future Scenario)
- Walnut Lakes (also known as Reflection Lakes added to Future Scenario)
- Winding Cypress (from Existing Conditions simulation)

Both the Naples Reserve and Reflection Lakes developments lie within the boundary of the agricultural area, with work presently (December 2014) being conducted within the Naples Reserve. Thus, specific attention was paid to these developments as fitting within the framework of common practices within Collier County.

Storage features associated with the Naples Reserve and Reflection Lakes developments were incorporated and represented spatially as per the ERP plan documents, but simplified for numerical stability and model run times. Lake depths were standardized across the site at an elevation of approximately -15 feet-NAVD88 as per the dewatering permits.

Although this work is not for a flood study, allowance had to be made so that the control structures would not deviate from either 0.15 cfs/acre or 0.04 cfs/acre for the 25 year flood event. This was accomplished by conducting HEC-RAS modeling to determine the flood flows for each of 12 parcels contributing to the flow-ways. Input data included watershed size, curve number, hydraulic slopes and lengths, flow, and rainfall for a 25-year three-day event based on SFWMD distribution. Having determined the flood flows, a stand-alone MIKE-11 model was constructed to design the structures to incorporate the flood flows. The structures were then placed in the overall MIKE SHE/MIKE-11 model for the Future Scenario. Control structures for the aforementioned developments have been added to the model as specified in the ERP documents.

4.2.4 U.S. Highway 41 Culverts

Figures 4.9 and 4.10 present example photographs that were obtained from a recent field verification of existing and newly installed cross-drains under U.S. Highway 41**. Figure 4.9** presents a downstream view of the Existing Conditions culverts which are three 4 feet high x 10 feet wide boxes. **Figure 4.10** presents an upstream view of the newly aligned and constructed culverts which consist of three boxes each 5 feet high x 11 feet wide. Neither the Collier County nor the Existing-LSM models contained these existing or newly constructed culverts. The only conveyance features in the aforementioned models were the canals and cross-sections representing the canals at the culvert locations (See **Figure 3.3**). Because of the size of the culverts and the comparatively small simulated flows for the ten year simulation period, flows were not restricted by the culverts.

The model developed for the Future Scenario has incorporated all proposed cross-drains from CR-951 to Six L's Farm Road based on SFWMD ERPs 11-03368-P and 11-01368-P. As for the Collier County and the Existing-LSM models, based on the size of the existing culverts and simulated flows, the flows would not have been restricted by the culverts. However, the proposed culverts detailed in the aforementioned SFWMD permit files were added to this Future Scenario model as an update in case the model is later used for flood studies with higher flow rates where the culverts may become restrictive. As shown in **Figures 4.9** and **4.10**, some additional culverts are being constructed just downstream of the existing culverts to accommodate the widening of U.S. Highway 41 with the addition of roadway lanes. The cross sectional area for new culverts is greater than the existing culverts. Consequently, the new culverts would not create any additional flow restrictions but were included in the model to further the reliability of the model into the future. **Figure 4.11** presents the location of all culverts under U.S. Highway 41 revised or added as part of this Future Scenario model.

Model limitations/sensitivity to culverts under US-41: In order to assess placement of culverts that were not in the Existing Condition model, a simulation was run, where the only differences to the model were hydraulic features upstream of the US-41 canal, with all cross-drains (culverts under US-41) removed. When cross drains were removed the hydraulics reverted to that of the Existing Condition model where the culverts were not explicitly simulated. Instead, branch connections were included to convey water south of US-41.

Figure 4.9. Existing Cross-Drain under U.S. Highway 41 at Throat Canal

Figure 4.10. Current Construction of Cross-Drain under U.S. Highway 41 at Throat Canal.

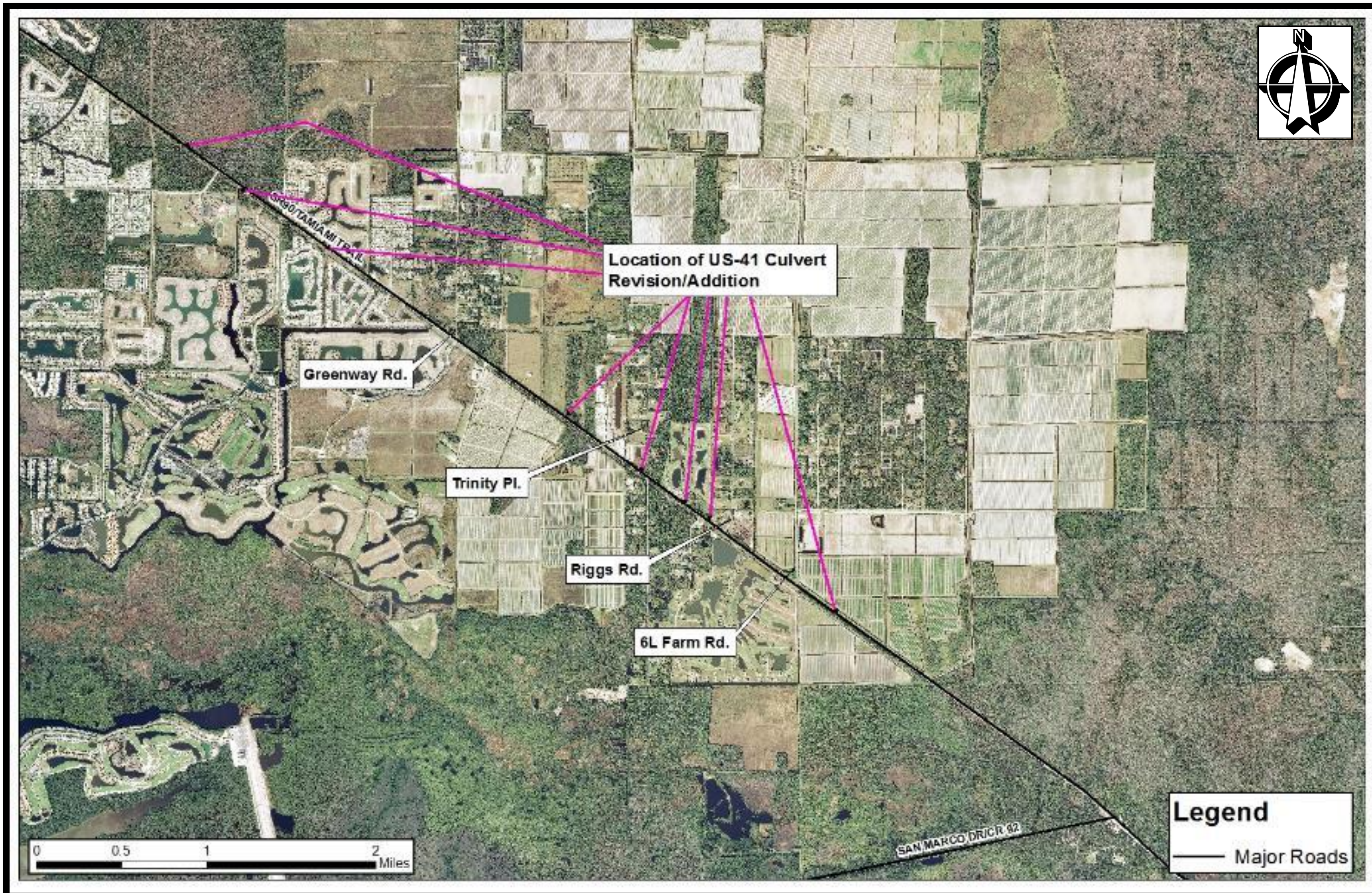

Figure 4.11. Locations of Culvert Revision/Addition along U.S. Highway 41.

4.2.5 Greenway Road Ditches

The ditches along Greenway Road (east and west) have been added to the MIKE-11 network as part of this Future Scenario. This addition was made at the request of the project advisor. These ditches have been noted as major drainage (conveyance) routes from areas within the Belle Meade Agricultural Area. These ditches were not added retroactively to the Existing-LSM or Collier County Existing Conditions (CC-ECM) models. As such, no reliable comparisons can be made at this location between Future and Existing conditions. However, the water associated with these ditches was previously simulated and accounted for as overland flow, within the separated flow area representing the Belle Meade Agricultural Area and conceptual development. Ditch invert and outfall culvert dimensions were obtained from SFWMD ERP: 11-03048-P. Each ditch side (east/west) is represented within MIKE-11 as a single channel, with cross-sections accounting for each side of the road as well as the road invert along the channel. **Figure 4.8** presents the location of the Greenway Road ditches (shown in pink) within the MIKE-11 network, while **Figure 4.12** presents a representative cross-section as defined within MIKE-11.

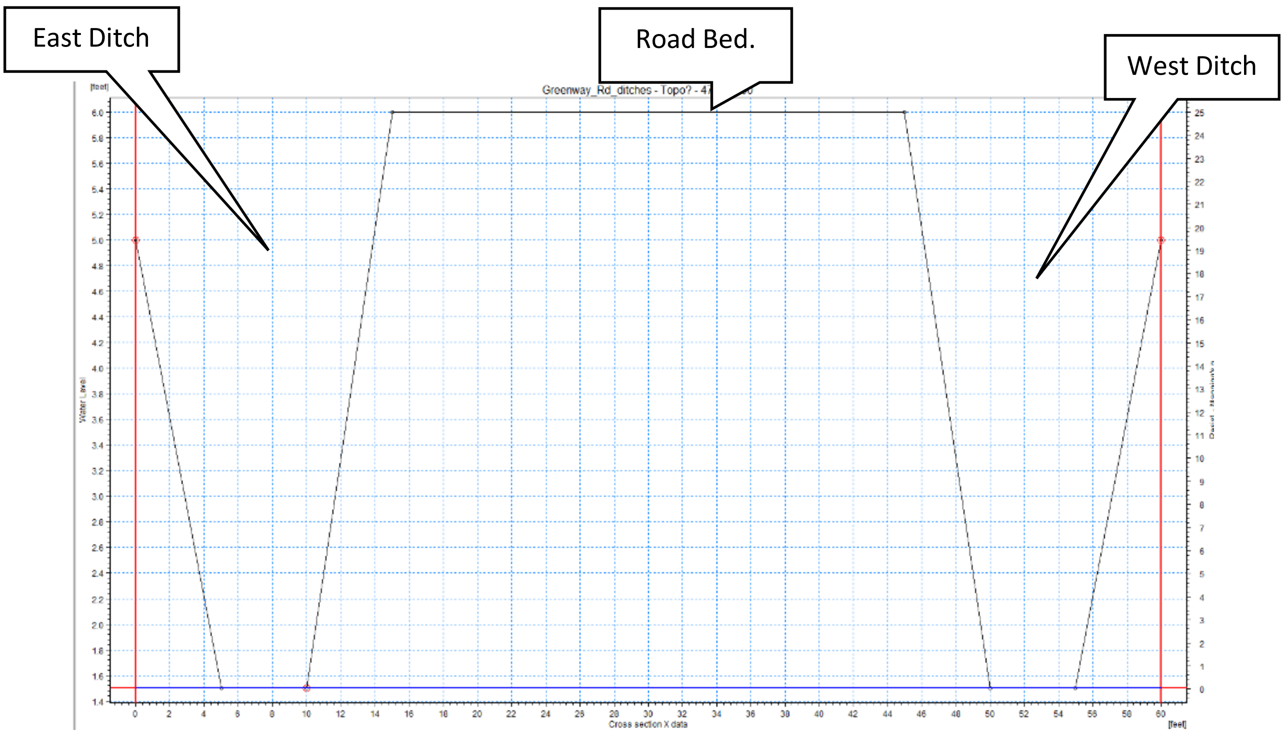

Figure 4.12. Representative MIKE-11 Cross-section along Greenway Road.

5.0 Results and Discussion

Simulation results were processed, reviewed and compared against Existing and Historical Conditions results (MIKE SHE/MIKE-11), where relevant transects are presented as a subset of those presented in the ***Task 2.7 – Interim Hydrodynamic Modeling Report***. **Figure 5.1** presents coastal transects used to assess the differences simulated from the Future Scenario to Existing and Historical Conditions. Results are discussed in a manner that reflects an understanding of how the land use changes and flow-way inclusion may have affected flows to each transect. Changes were assessed by comparisons of:

- Discharge
- Overland flow depth
- Groundwater levels

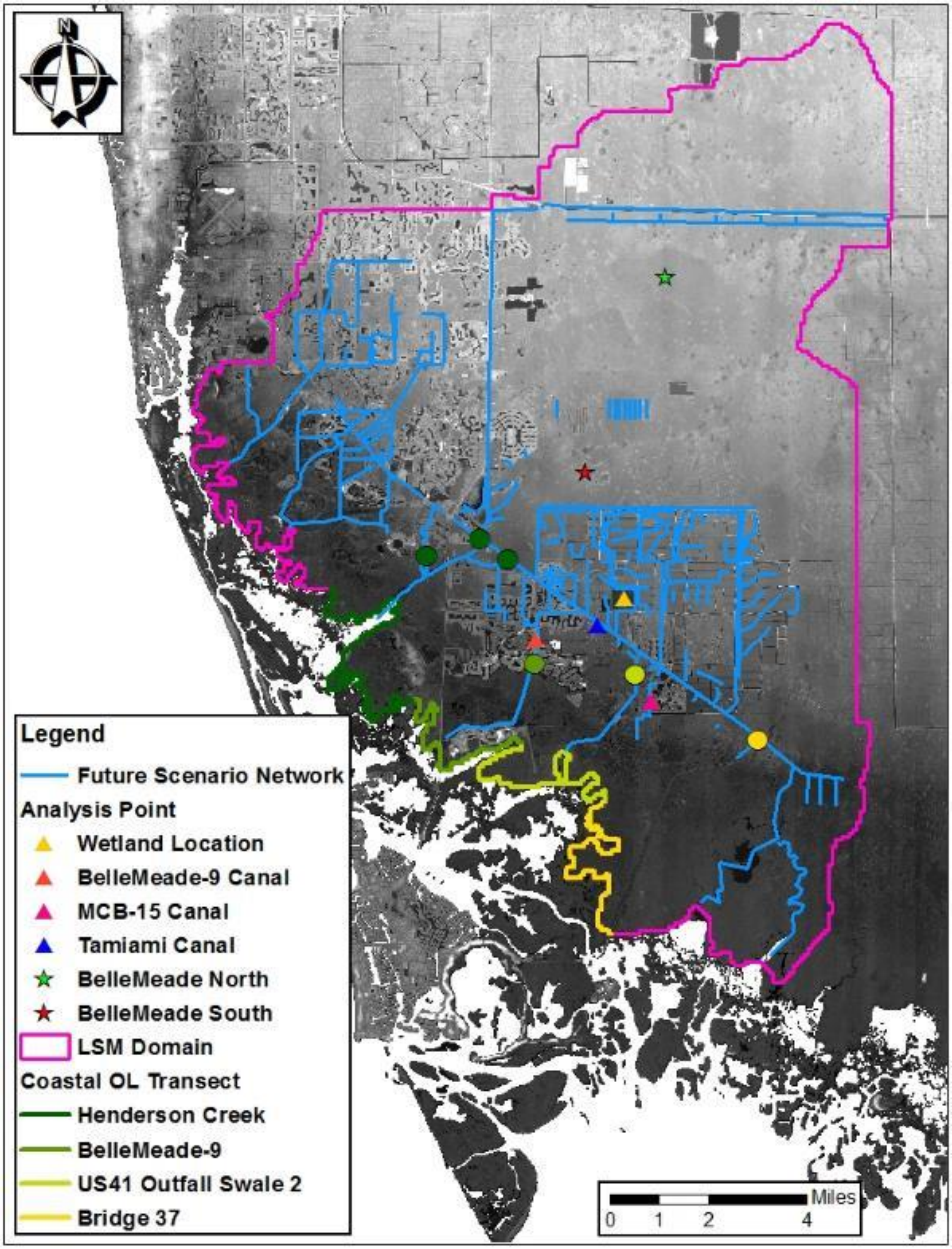

Figure 5.1. Coastal Transect and Result Analysis Locations.

5.1 MIKE SHE Results

Figure 5.1 presents coastal transects used to assess the potential simulated differences from each configuration of the Future Scenario (0.15 cfs/ac and 0.04 cfs/ac) to Existing and Historical Conditions. Each segment accounts for the total flow (MIKE SHE Overland and MIKE-11) delivered to Rookery Bay. The selected transects south of the current project area were the same transects used in ***Task 2.7 – Interim Hydrodynamic Modeling Report***. The following list presents the relevant transects to be evaluated as part of this project:

- Henderson Creek
- BelleMeade-9
- U.S. Highway 41 Outfall Swale 2
- Bridge 37

Table 5.1. Coastal Transect Average Annual Flow (cfs)

Coastal Transect	Existing (cfs)	Historical (cfs)	Future Scenario (cfs) (0.15 cfs/acre)	Future Scenario (cfs) (0.04 cfs/acre)	%-Diff. Exis vs Future Scenario (0.15 cfs/acre)	%-Diff. Exis vs Future Scenario (0.04 cfs/acre)
Henderson Creek	18.10	17.85	17.05	17.07	-5.82%	-5.72%
BelleMeade-9	8.05	9.91	8.82	8.93	9.59%	10.86%
US41OutfallSwale2	4.46	3.75	6.70	6.28	50.08%	40.73%
Bridge37	0.69	5.48	0.91	0.81	30.92%	16.40%
Total Coastal	53.89	53.62	56.39	56.00	4.65%	3.91%

Table 5.1 presents the average annual flow through each coastal transect shown in **Figure 5.1**, in addition to the cumulative flow through the model domain into Rookery Bay. The only transect with less flow to the coast is the Henderson Creek location. This is likely due to the addition of the proposed flow-ways within the conceptual development of the future scenario model. The new flow ways would accept a portion of the sheet flow that now makes its way to the Henderson Creek Canal.

It should be noted that the largest increase (50%) when comparing Existing Conditions to Future occurs at the U.S. Highway 41 Outfall Swale 2, and is likely due to the proximity of the flow-way and conceptual development outfalls to the U.S. Highway 41 canal. The Future Scenario cumulative coastal flow on an average annual basis, shows an increase over Existing Conditions of approximately 2.5 cfs (56.39 minus 53.89) or 4.65% and 2.1 cfs (56.00 minus 53.89) or 3.91% for the 0.15 cfs/acre and 0.04 cfs/acre configurations respectively. The Future Scenario simulation where maximum allowable runoff was reduced to 0.04 cfs/acre delivered the same amount of flow to Rookery Bay from a volumetric comparison where on average the reduced maximum allowable runoff from each parcel reduced the average coastal flow by 0.39 cfs or 0.69%.

5.1.1 Henderson Creek Coastal Transect Results

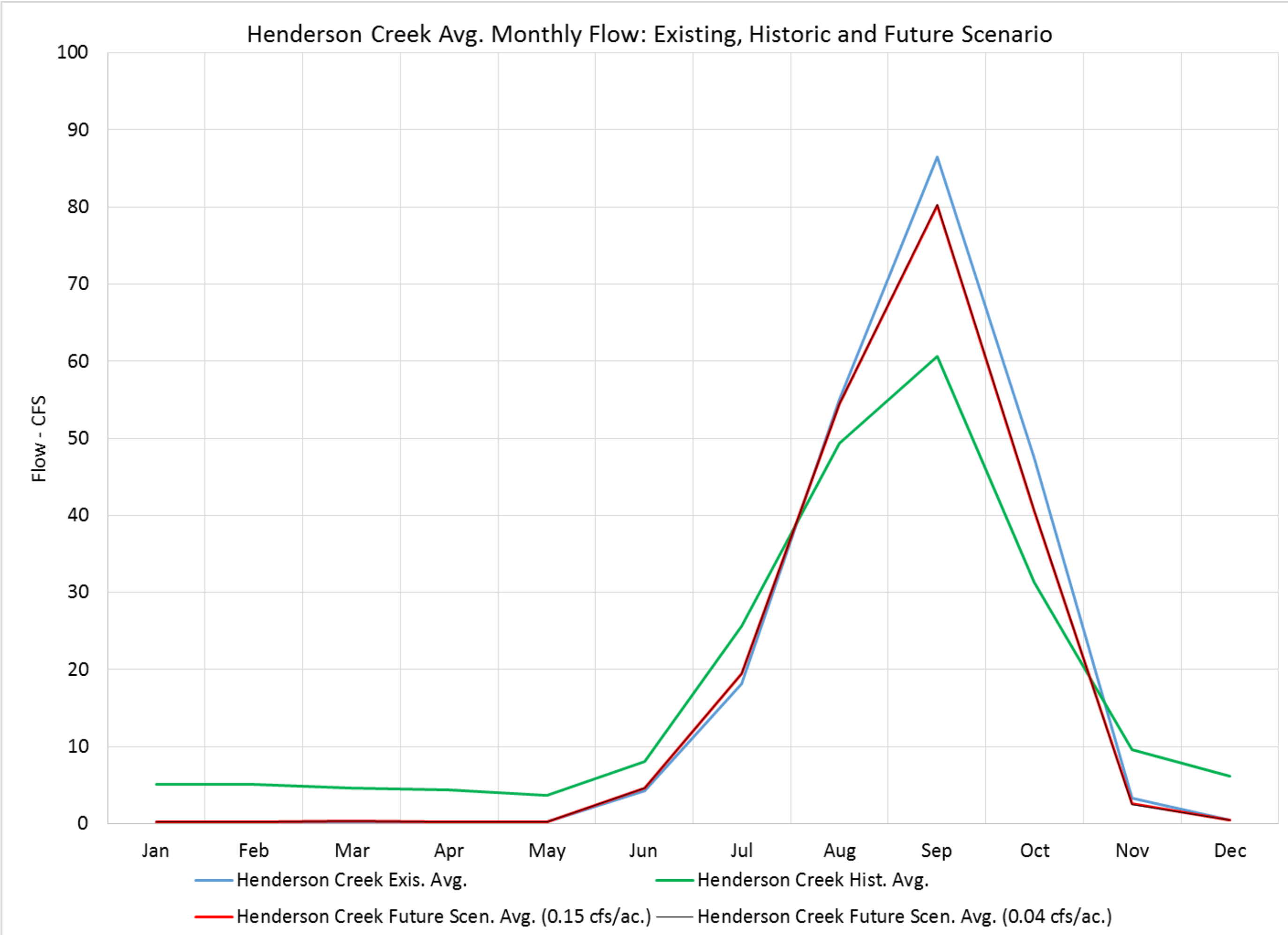

Figure 5.2. Henderson Creek Average Monthly Flows

Figure 5.2 presents the average monthly flow for the Henderson Creek coastal transect to Rookery Bay. As shown, the Future Scenario flows (both 0.15 and 0.04 cfs/acre configurations) are reduced in the wet season by about 5-cfs when comparing with the Existing Conditions. This is likely due to the addition of the spreader swale and flow-ways. The flow-ways are allowing the water to flow through the development, whereas under Existing Conditions, water would reach the berm protecting the farm fields and be diverted east or west around the agricultural fields.

5.1.2 BelleMeade-9 Coastal Transect Results

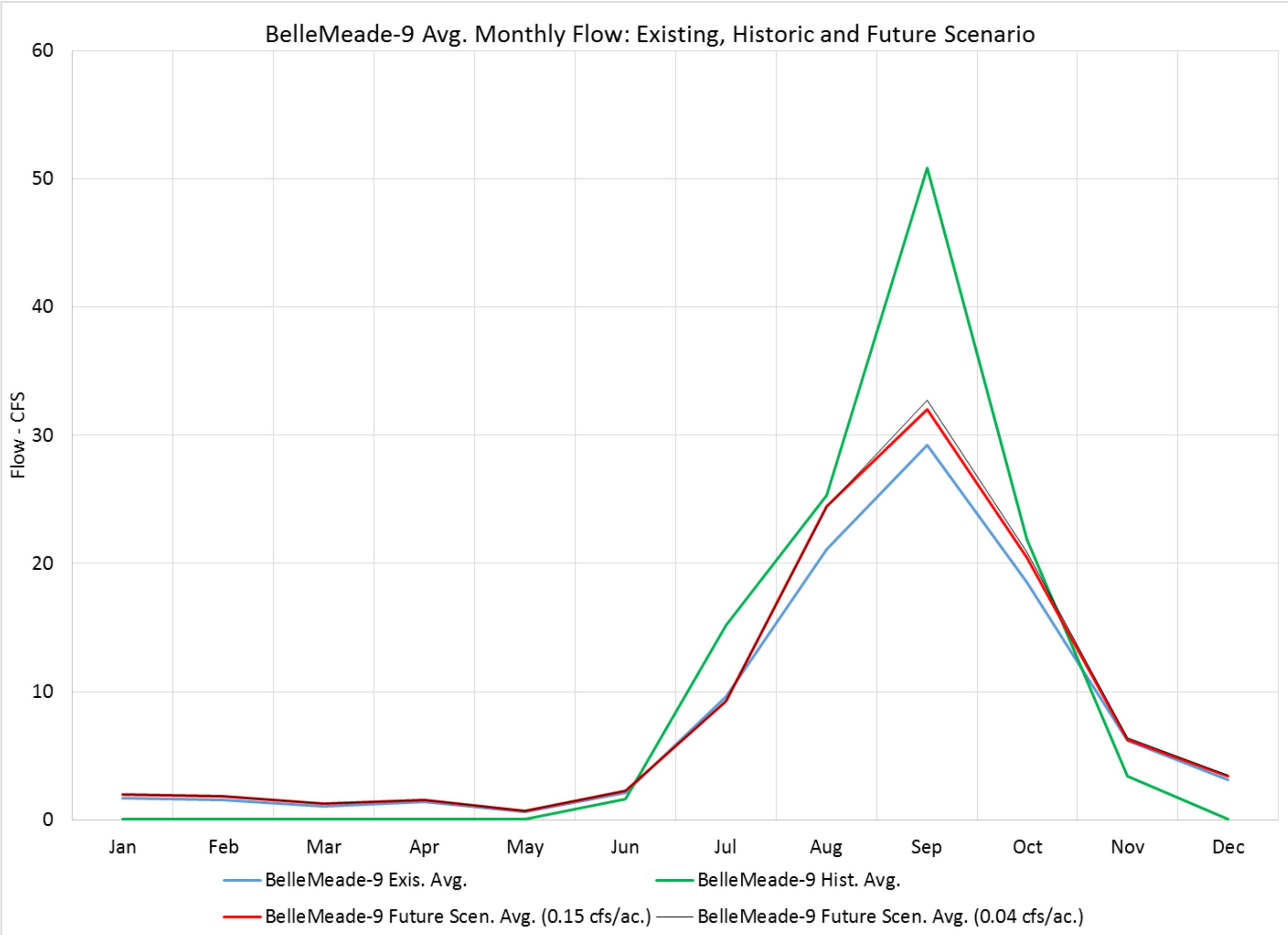

Figure 5. 3 BelleMeade-9 Average Monthly Flows

Figure 5.3 presents the average monthly flow for the BelleMeade-9 coastal transect to Rookery Bay. As shown, the Future Scenario (both 0.15 and 0.04 cfs/acre configurations)wet season flows show a slight increase which is trending in a positive direction when evaluating success in terms of restoring Historical Condition flows. No seasonal controls have been placed within the U.S. Highway 41 canal, resulting in insignificant change in dry season flows. The U.S Highway-41 canal ultimately flows towards the coast transmitting flow to Rookery Bay.

5.1.3 U.S. Highway 41 Outfall Swale 2 Coastal Transect Results

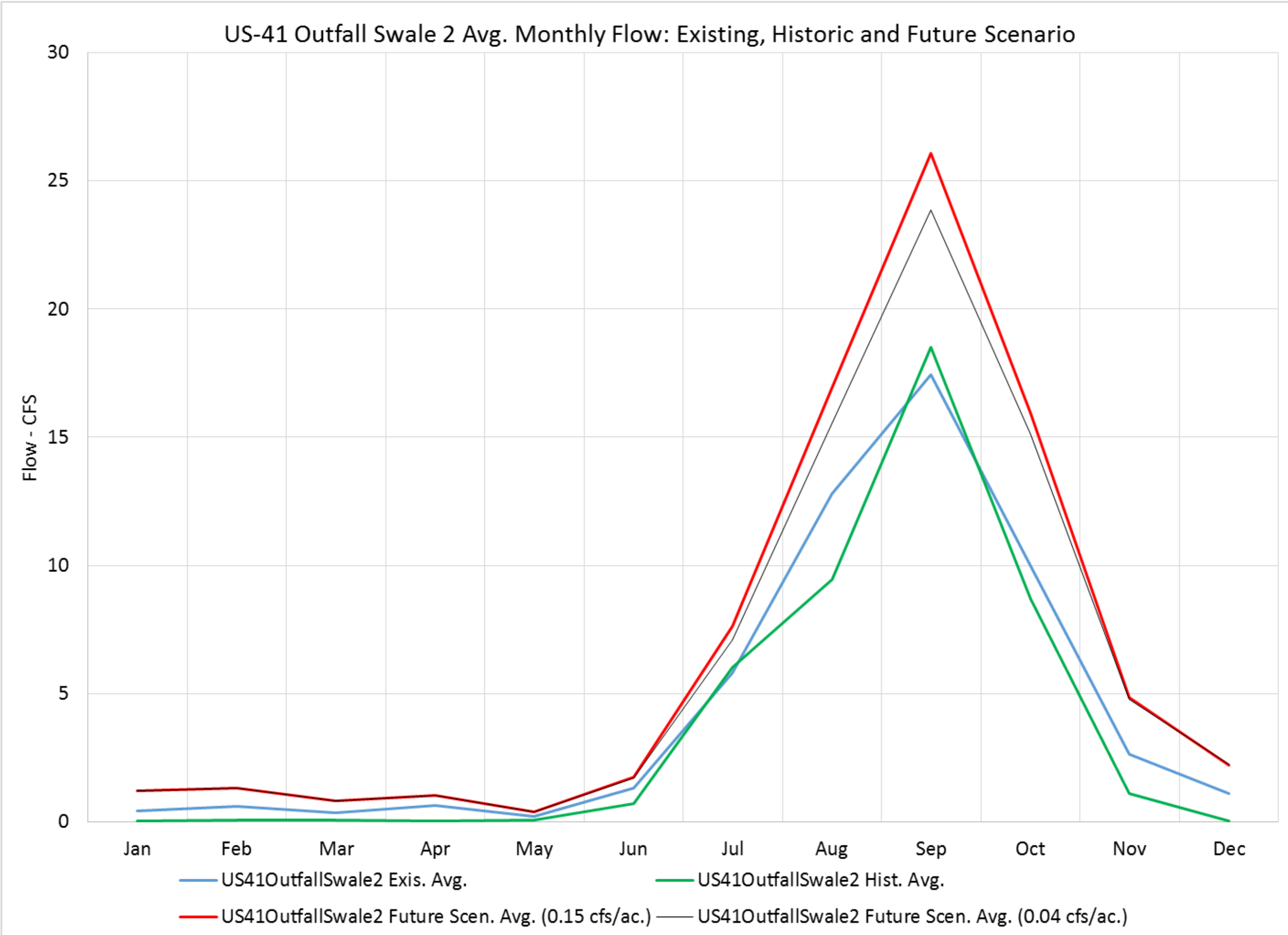

Figure 5. 4. *U.S. Highway 41 Outfall Swale No. 2 Average Monthly Flows*

Figure 5.4 presents the average monthly flow for the U.S. Highway 41 Outfall Swale 2 coastal transect to Rookery Bay. Under both future conditions configurations, the flows from this transect are significantly higher in the wet season when compared to Existing Conditions. The reduced maximum allowable runoff configuration of the Future Scenario shows slightly less water flowing through the swale, which is logical as more water is detained within the conceptual ponds (smaller weir, less out flow) Dry season flows show a slight increase on average which leads to an annual increase of freshwater flows into Rookery Bay, about 50% higher than Existing Conditions. Additionally, flows are higher than Historical Conditions, and as previously mentioned is likely due to the number of outfalls into U.S. Highway 41 providing additional freshwater inflow to this transect.

5.1.4 Bridge 37 Coastal Transect Results

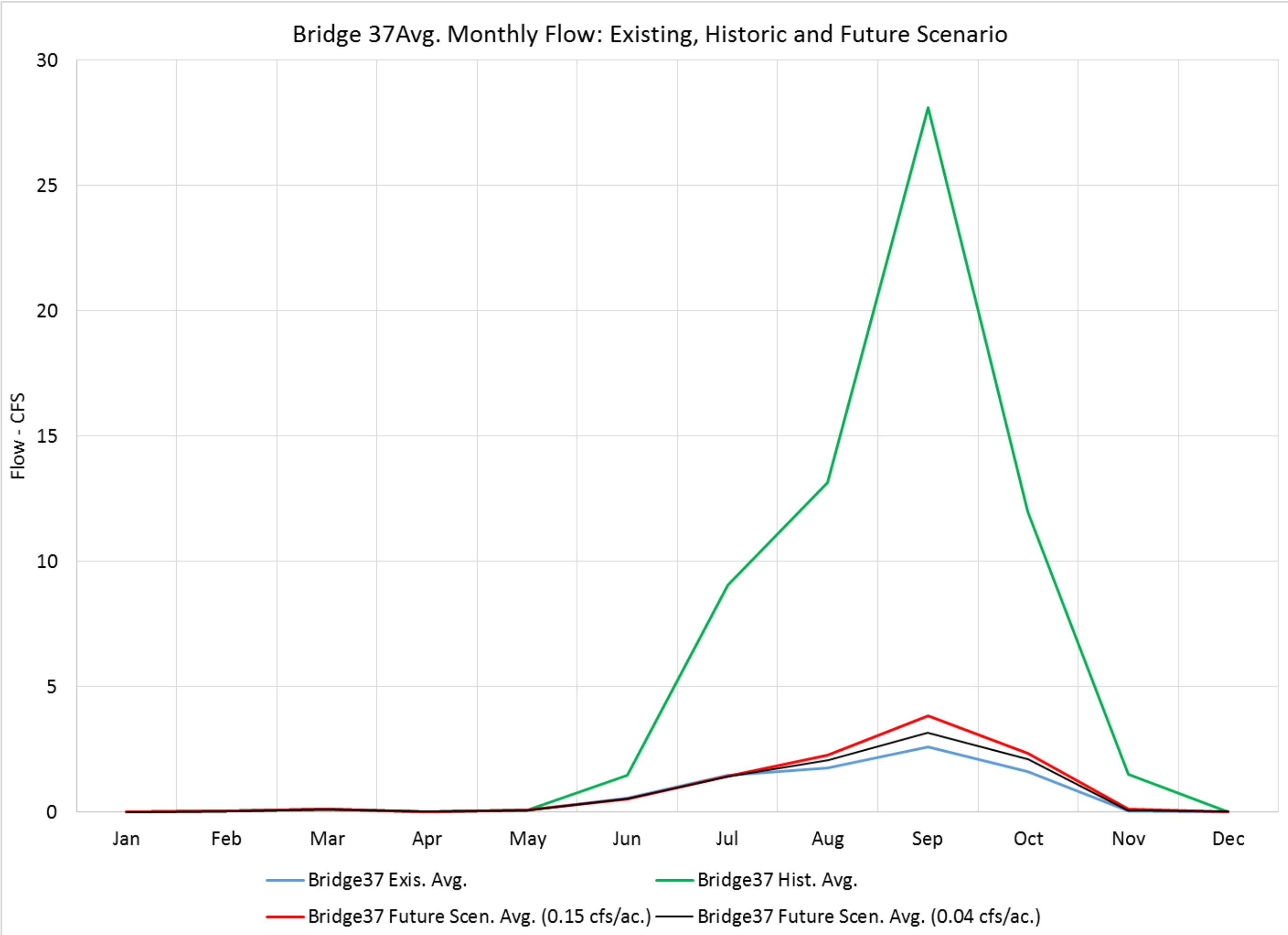

Figure 5. 5. Bridge 37 Average Monthly Flows

Figure 5.5 presents the average monthly flow for the Bridge 37 coastal transect to Rookery Bay. Under future conditions, the flows from this transect are higher in the wet season when compared to Existing Conditions, while dry season flows would remain largely unchanged. Bridge 37 would have significantly less flow under future and Existing Conditions when compared to the Historical Condition flows. Similar to the aforementioned US 41 Outfall Swale results, slightly less water would flow through the Bridge 37 transect, under the 0.04 cfs/acre configuration, for similar reasons. However, it should be noted that there are slight improvements in coastal transect flows when comparing the Future Scenario flows to historical. This improvement in coastal transect flows is attributed to the flow-way connections upstream of U.S. Highway 41 allowing water to flow through the development and into the canal, which then distributes the flows to the aforementioned transect.

5.1.5 Cumulative Freshwater Inflow to Rookery Bay Coastal Transect Results

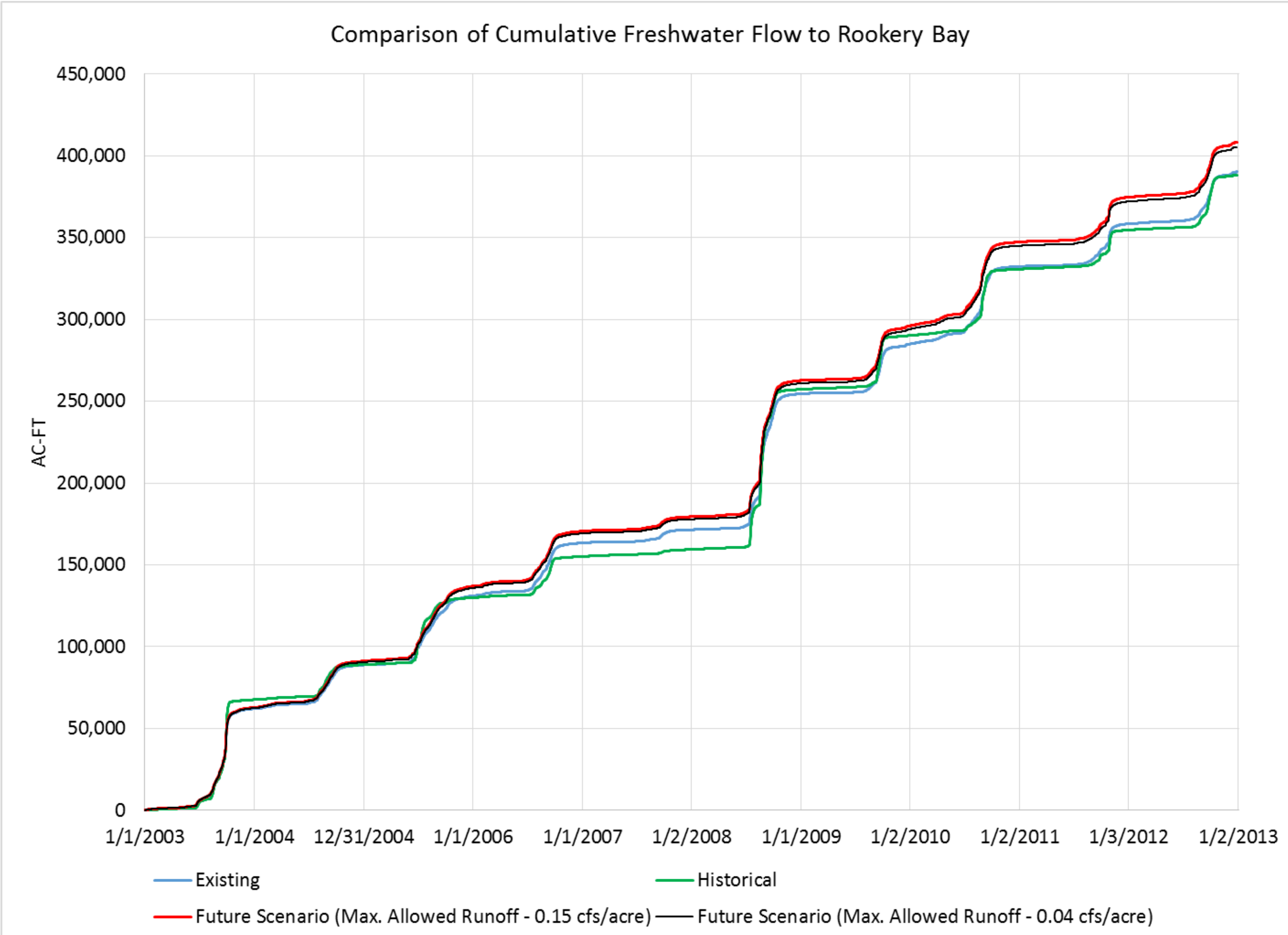

Figure 5. 6. Cumulative Freshwater Inflow Flow Comparison

Figure 5.6 presents the cumulative freshwater inflows to the Rookery Bay Estuary. As evidenced the 0.15 cfs/acre and 0.04 cfs/acre Future Scenarios would contribute about 5% and 4% respectively, more water than both Existing and Historical Conditions. This is not surprising, as under this scenario, no water control structures would be added to regulate the flow of water from north of U.S. Highway 41 to south. While there are seasonal controls for water entering the proposed flow-ways, this control only facilitates the prevention of over-draining the Belle Meade flow-way. In other words, with the exception of the Henderson Creek transect, water is not being stored, nor does a seasonal regulation schedule exist for any of the coastal transects analyzed as part of this study. In order to maximize the full potential of the watershed to deliver water in a manner similar to Historical Conditions, other infrastructure will need to be investigated.

5.1.6 Belle Meade Analysis Locations: Overland Flow and Groundwater Results

In addition to coastal transects, both comparison points within the Belle Meade flow-way (refer to **Figure 5.1** for locations) were compared in the following manner:

- Time series plots of daily depths of overland water
- Depth-duration of overland water depth
- Stage-duration of water table aquifer elevation relative to ground surface elevation

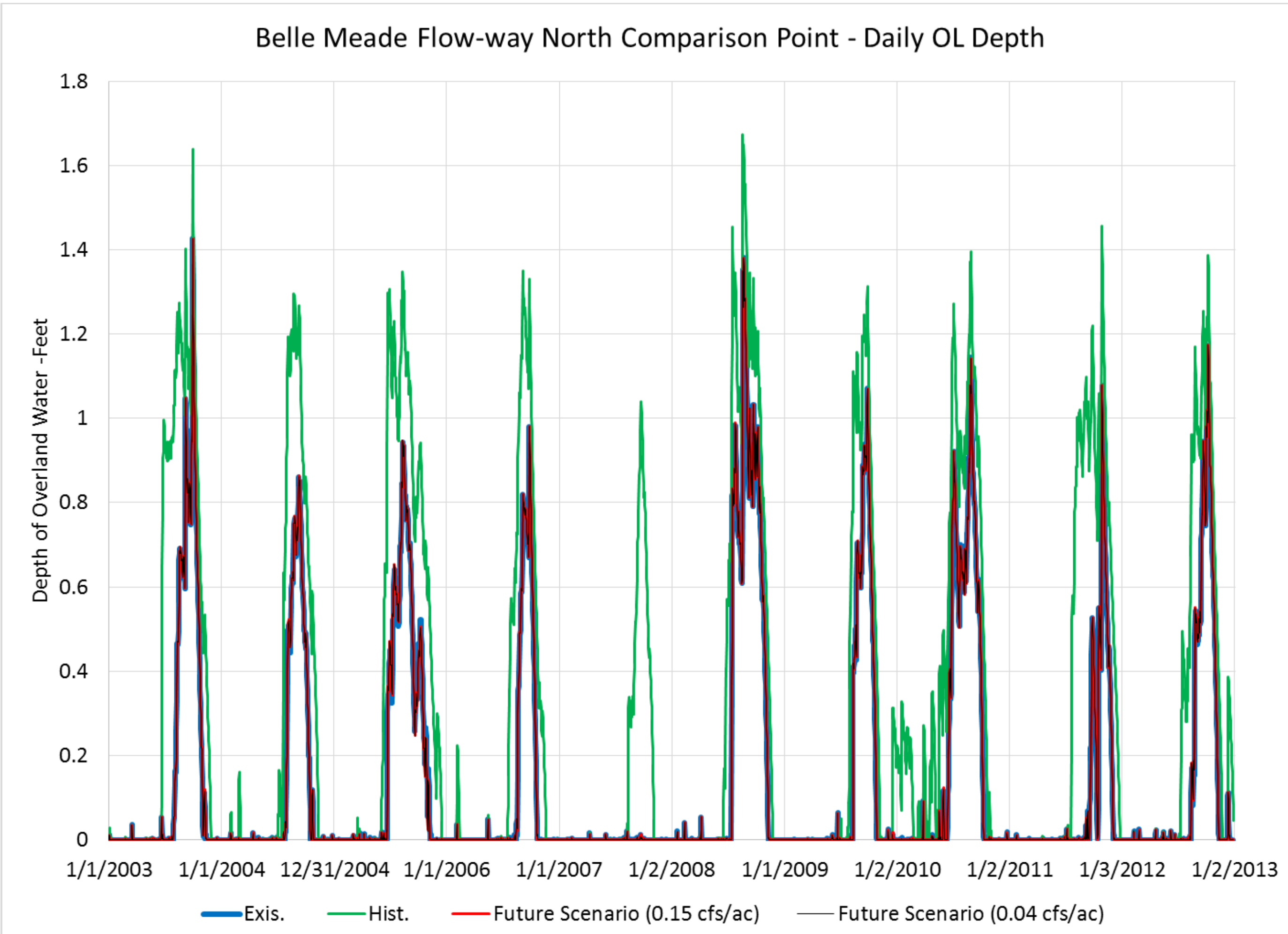

Figure 5. 7. Daily OL Water Depth Comparison: Belle Meade North Location.

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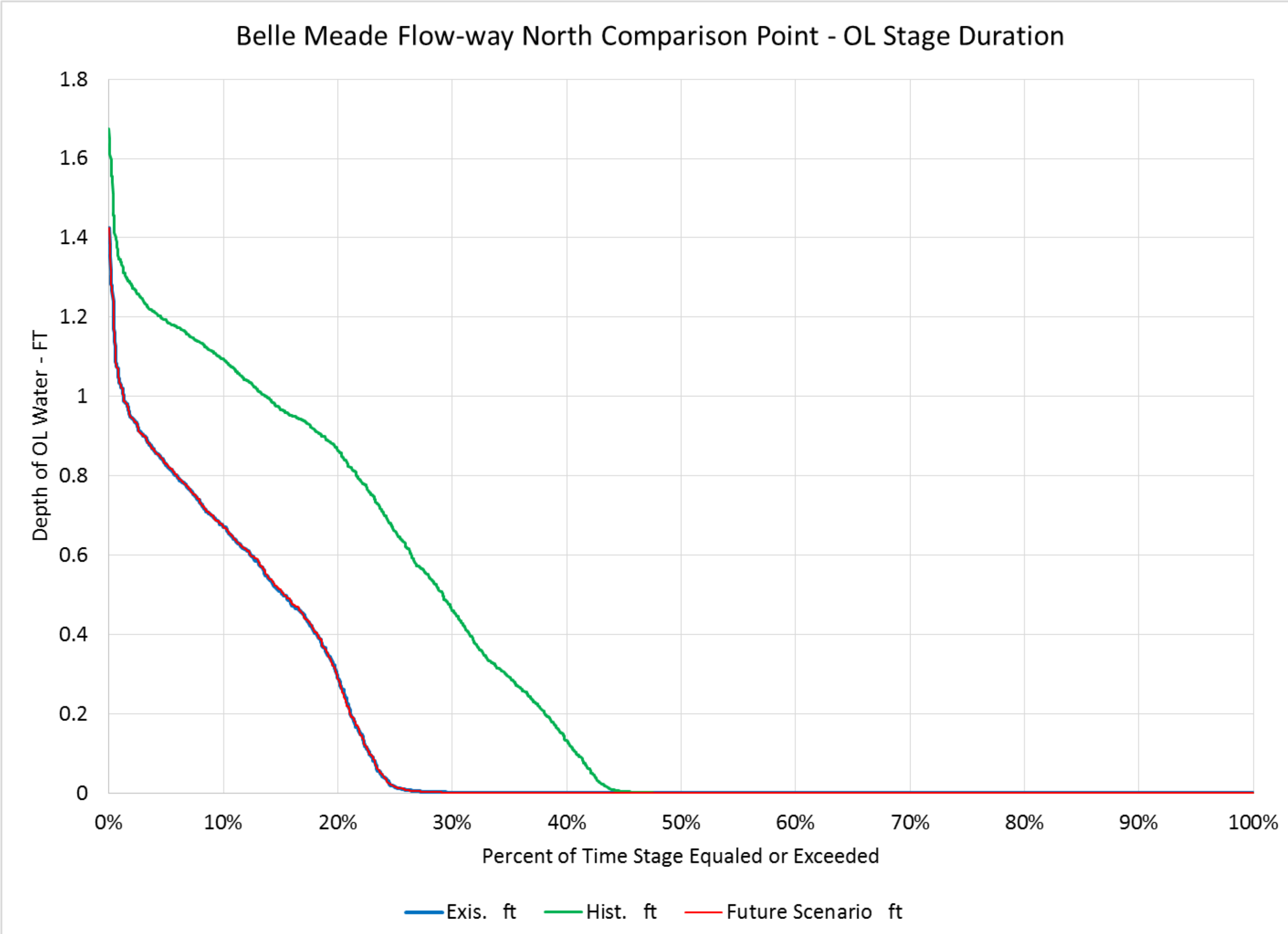

Figure 5. 8. OL Water Depth Duration Comparison: Belle Meade North Location.

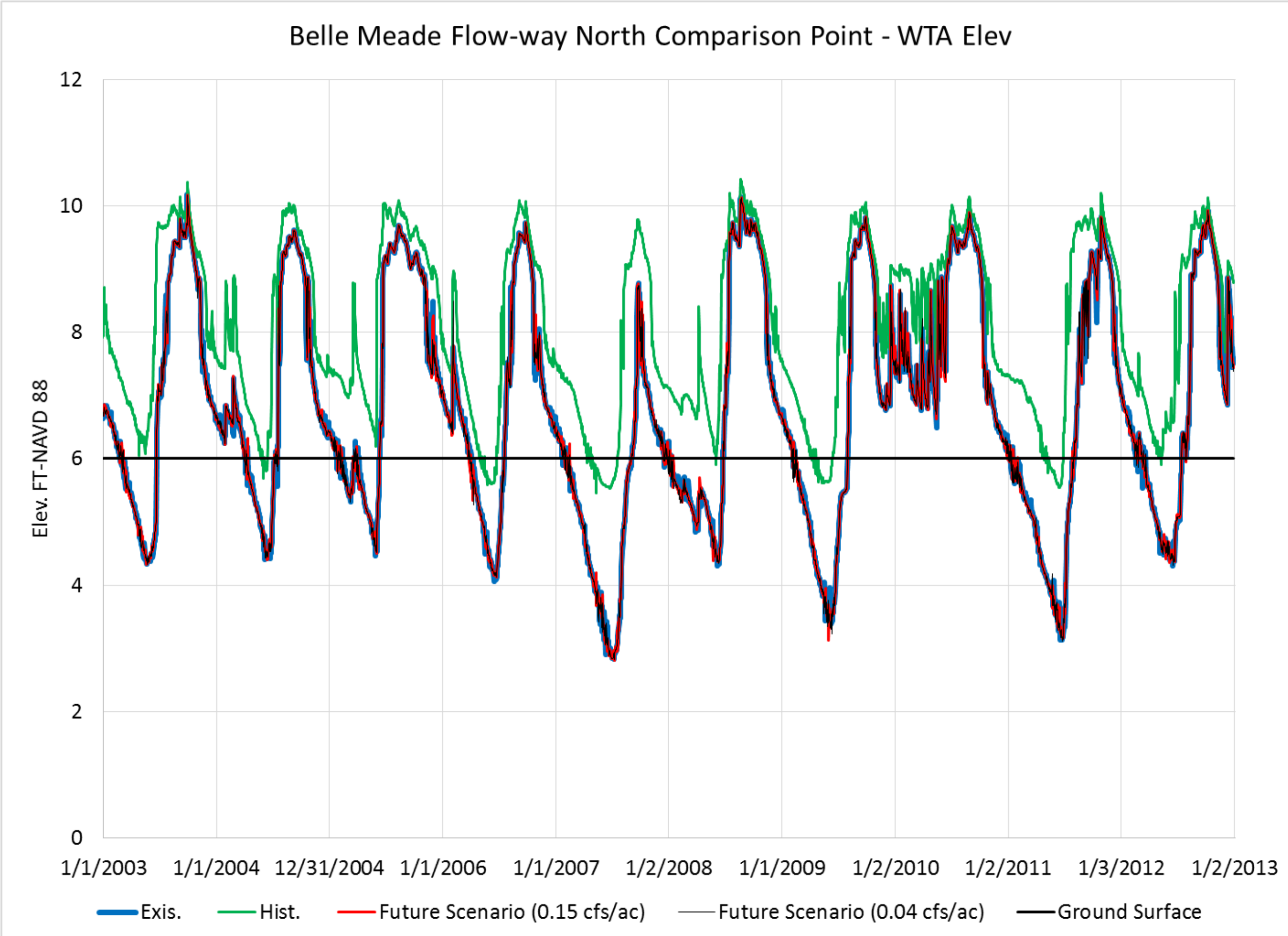

Figure 5. 9. Daily Groundwater Elevation Comparison: Belle Meade North Location.

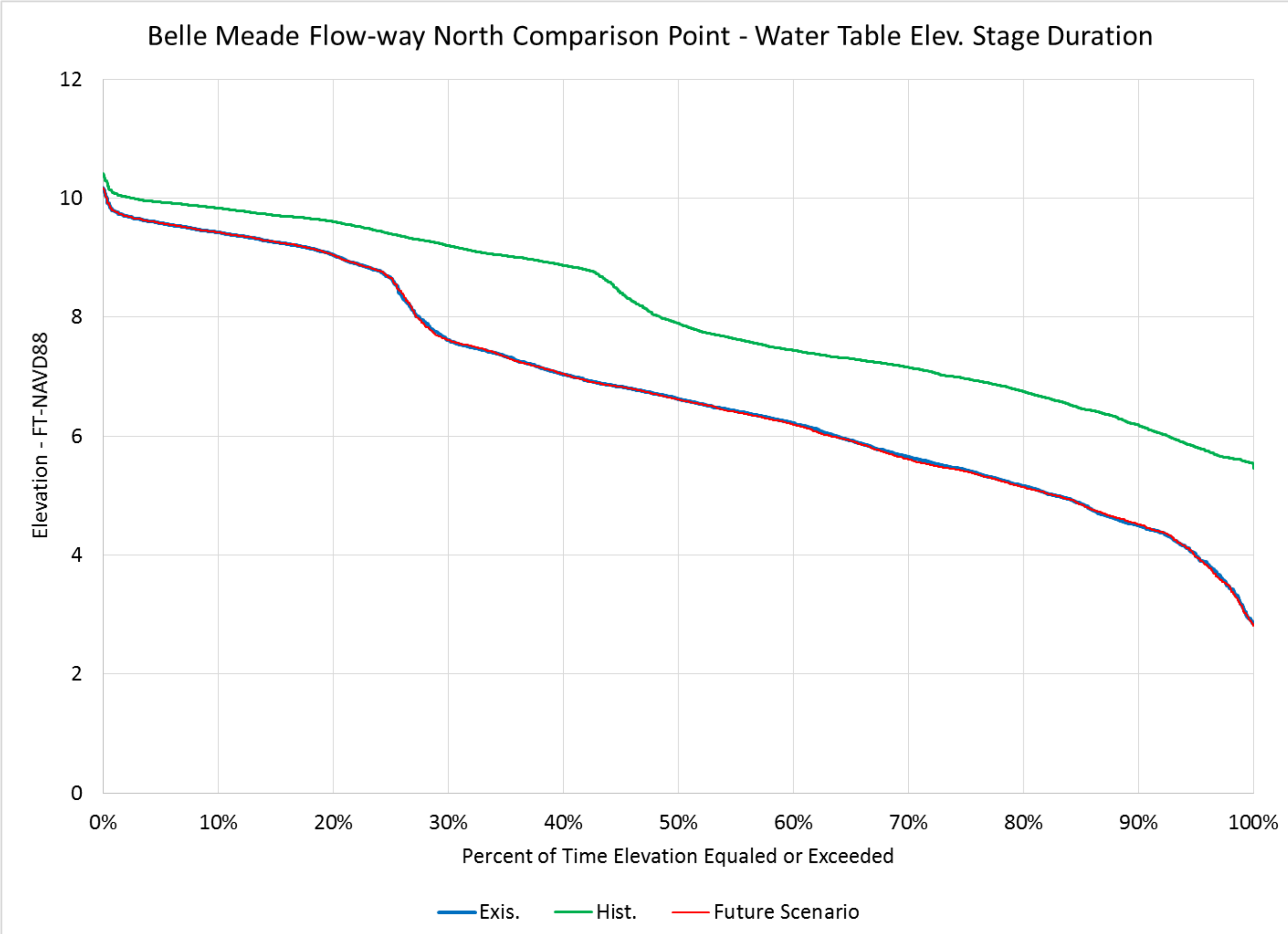

Figure 5. 10. Groundwater Elevation Duration Comparison: Belle Meade North Location.

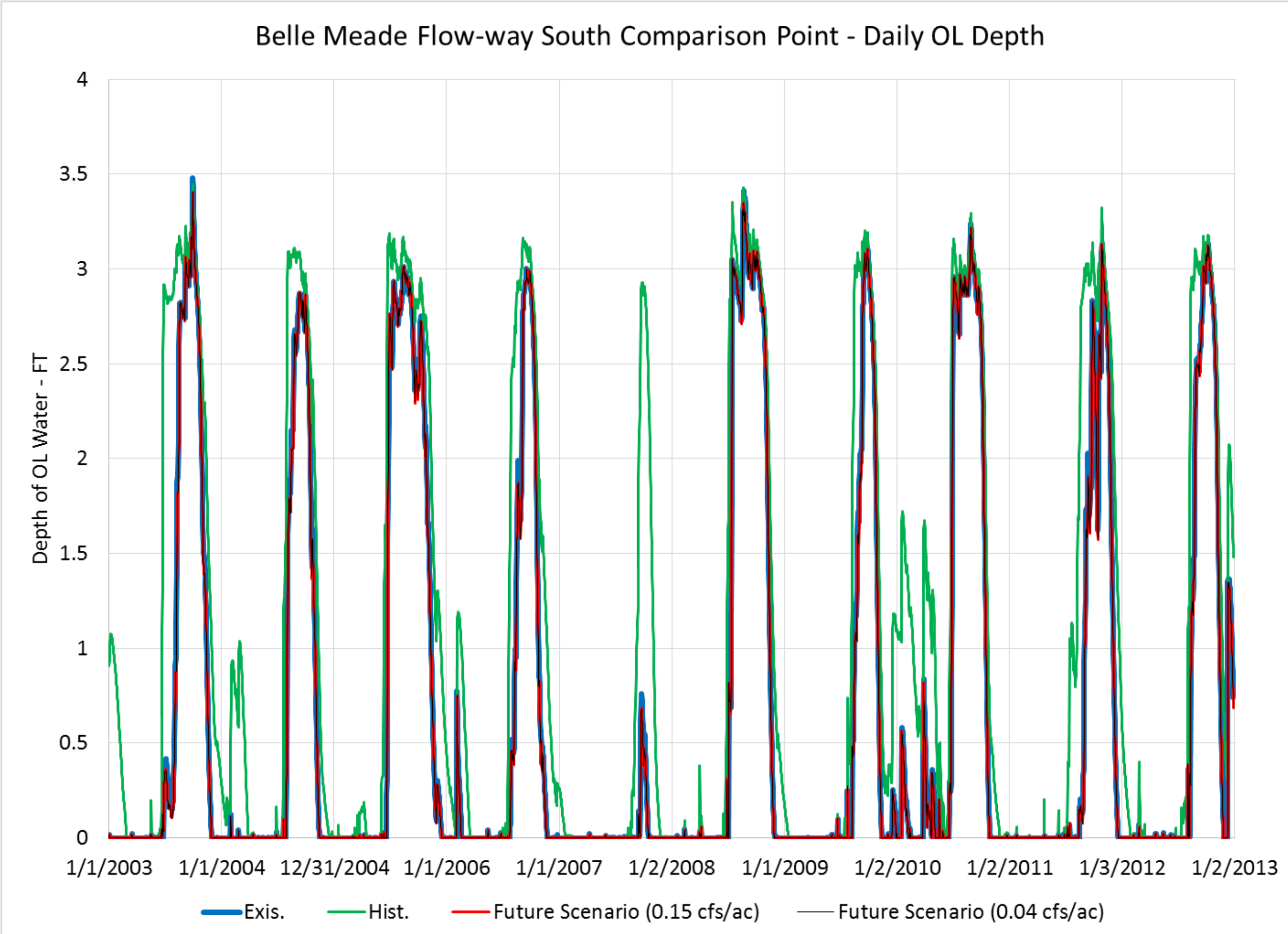

Figure 5. 11. Daily OL Water Depth Comparison: Belle Meade South Location.

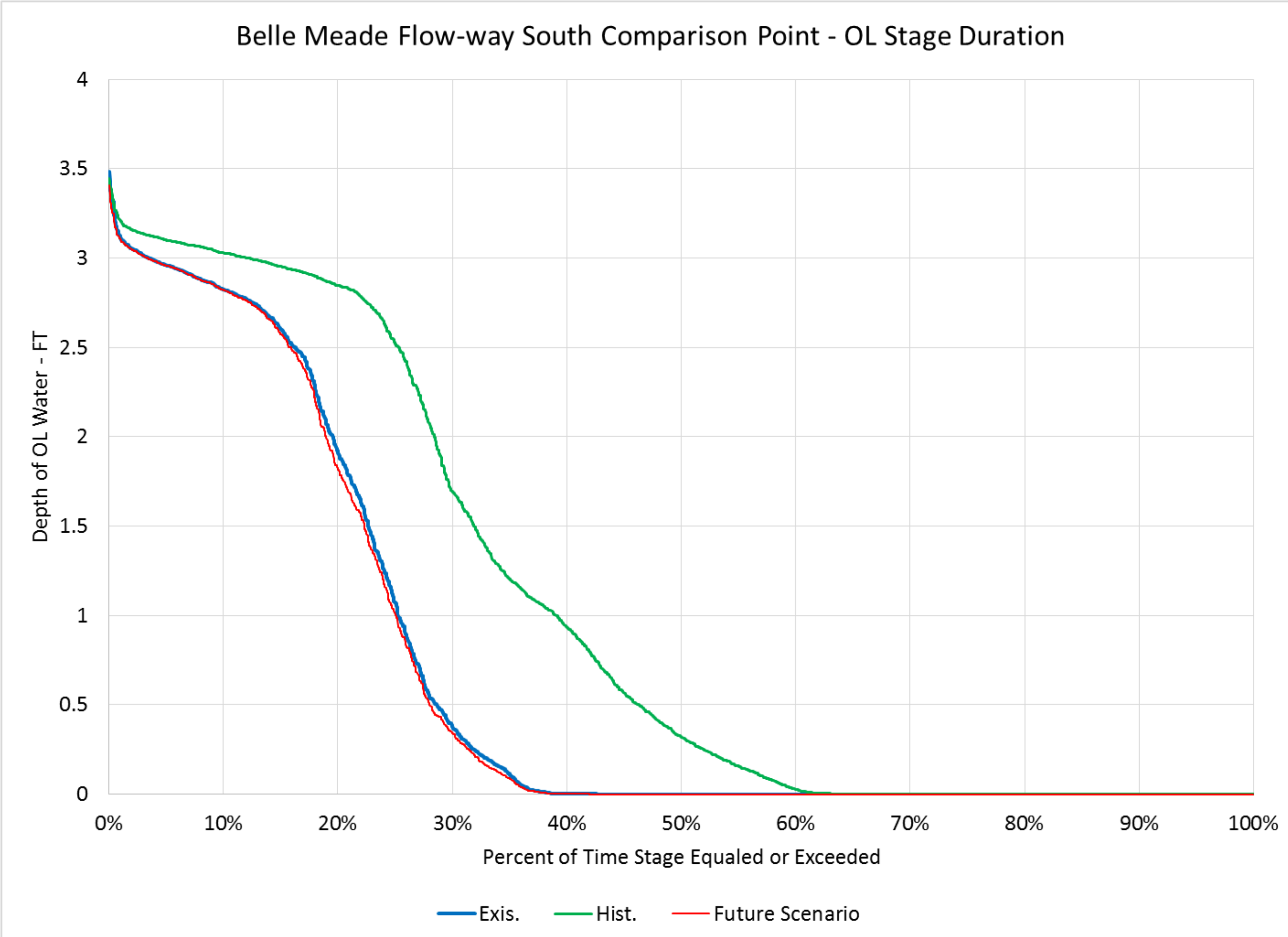

Figure 5. 12. OL Water Depth Duration Comparison: Belle Meade South Location.

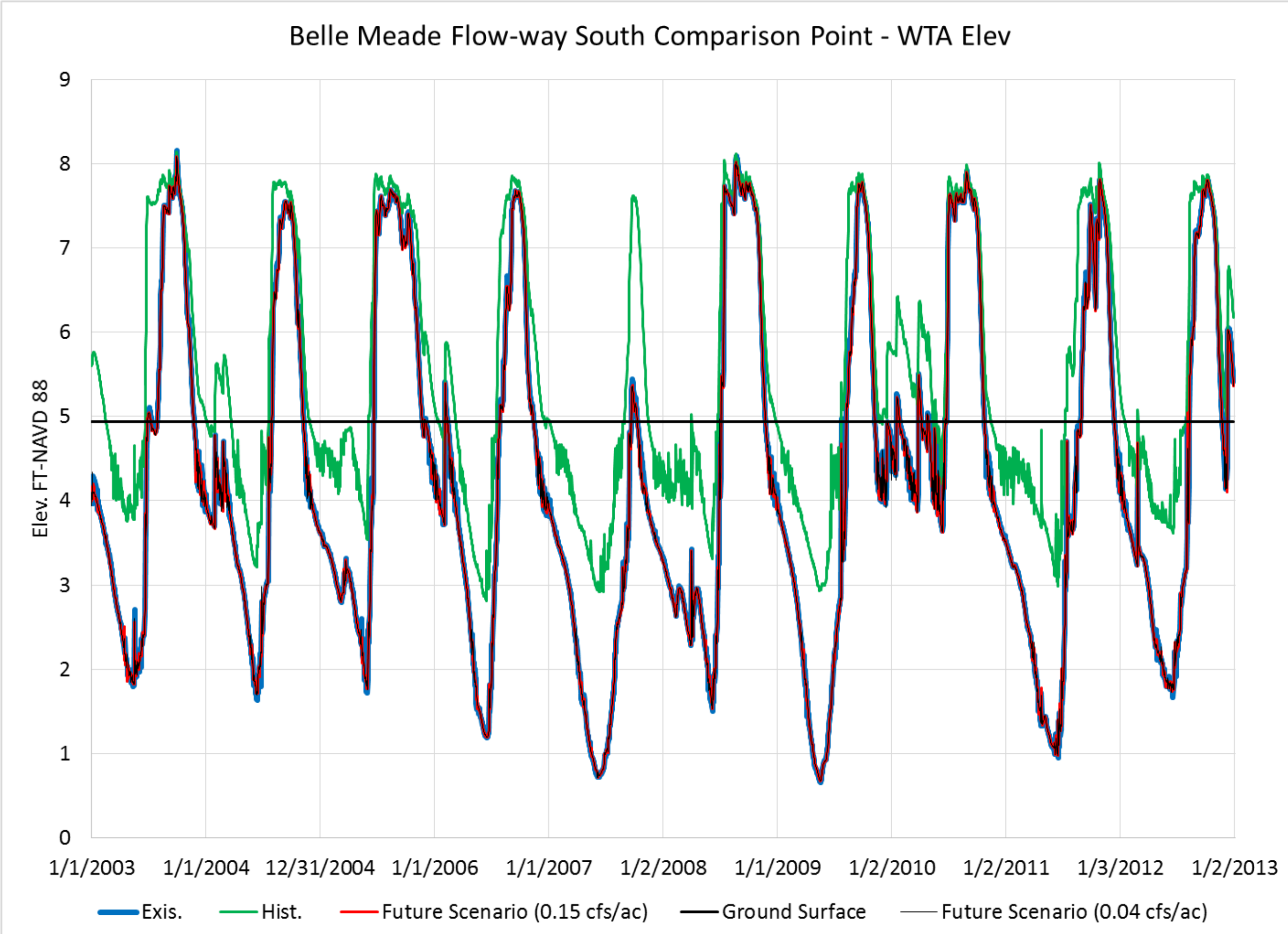

Figure 5. 13. Daily Groundwater Elevation Comparison: Belle Meade South Location.

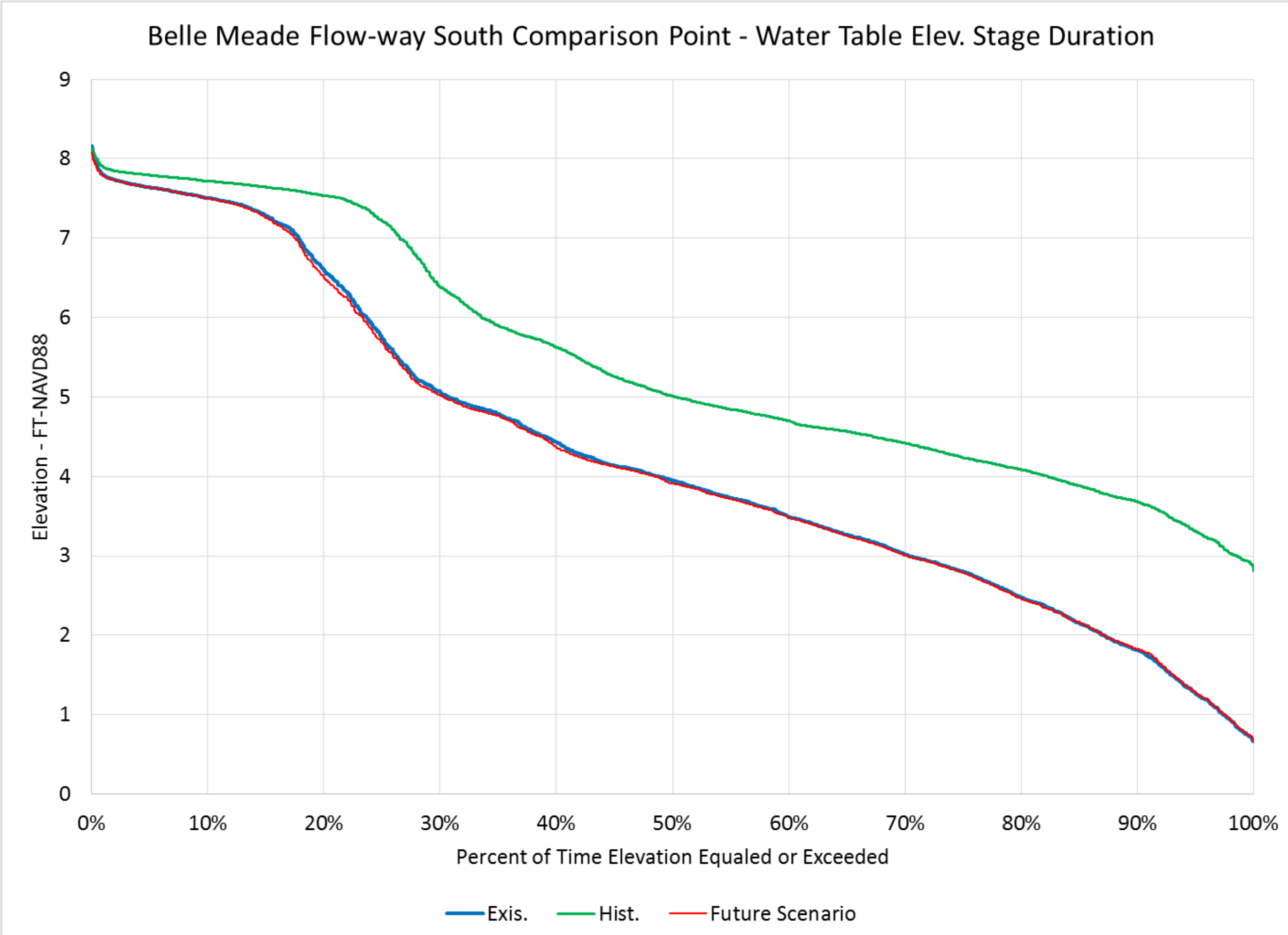

Figure 5. 14. Groundwater Elevation Duration Comparison: Belle Meade South Location.

Examination of **Figures 5.7** to **5.14** shows that neither configuration of the Future Scenario impacts groundwater elevations nor overland water depths within the Belle Meade flow-way. That is to say, the land use and hydraulic changes associated with the Future Scenario simulation do not project over distances large enough to cause significant changes at the two comparison points. Daily comparisons between Future Scenario simulations (0.15 cfs/acre vs 0.04 cfs/acre) show that there would be no changes with respect to groundwater elevations and overland water depths. As such, no additional duration comparisons were made for the Future Scenario simulation with conceptual structures limiting runoff to 0.04 cfs/acre

5.1.7 Future Conditions Wetland Analysis Location

The following analysis was conducted for the selected wetland location (orange triangle shown in **Figure 5.1)** within the project area**.** Assessments have been made by comparing Existing and Future Scenario time series plots of daily OL water depth and OL depth duration. **Figure 5.15a** presents a zoomed in view of the analysis locations within the Belle Meade Agricultural Area (wetlands outlined in gray and analysis location shown at blue triangle). **Figure 5.15b** shows that the water depths would increase by about 0.3 to 0.8 feet, depending on the season, as well as having a slow recession limb to the dry season for both configurations of the Future Scenario simulation.

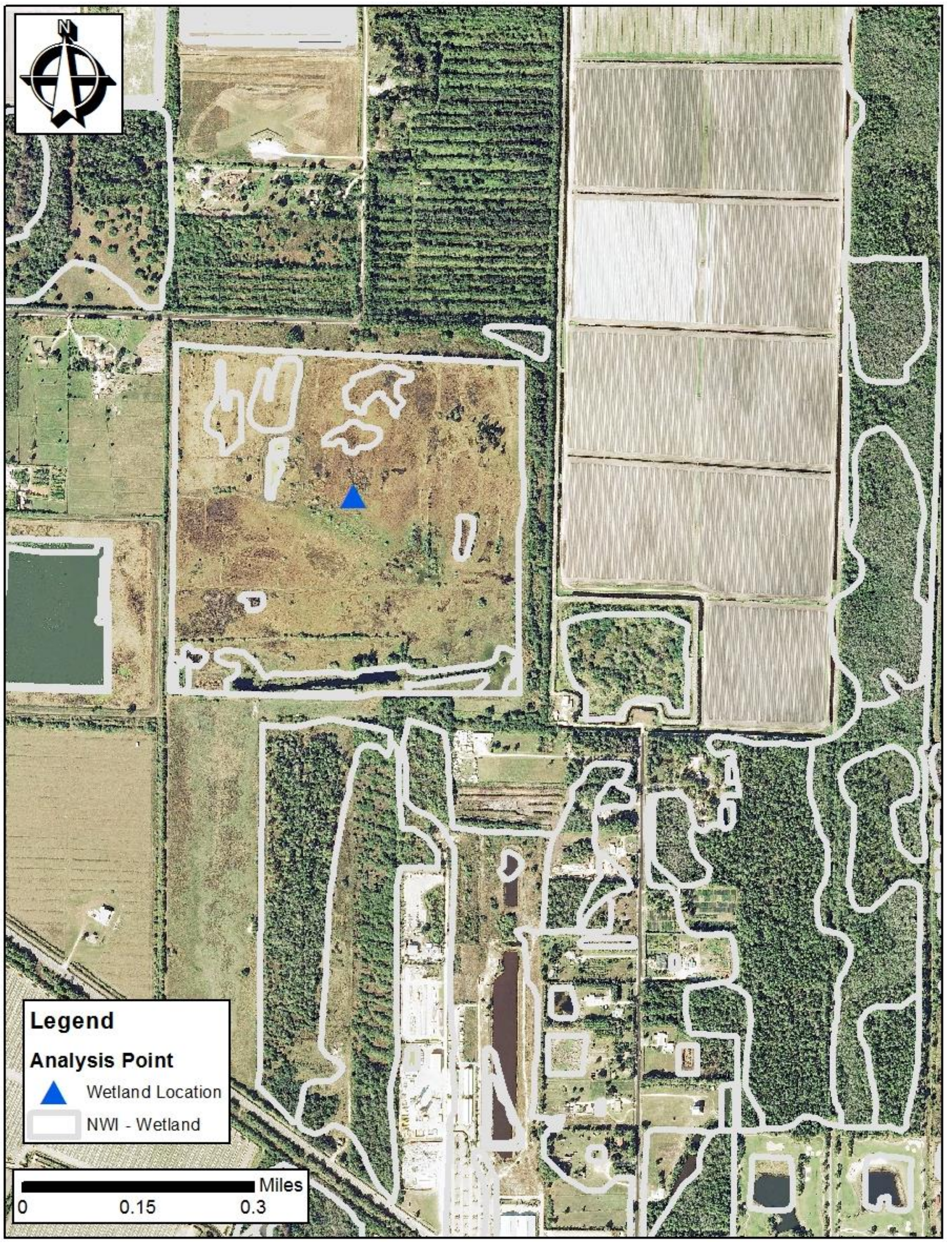

Figure 5. 15a. Zoomed in View of Analysis Locations Within the Belle Meade Agricultural Area

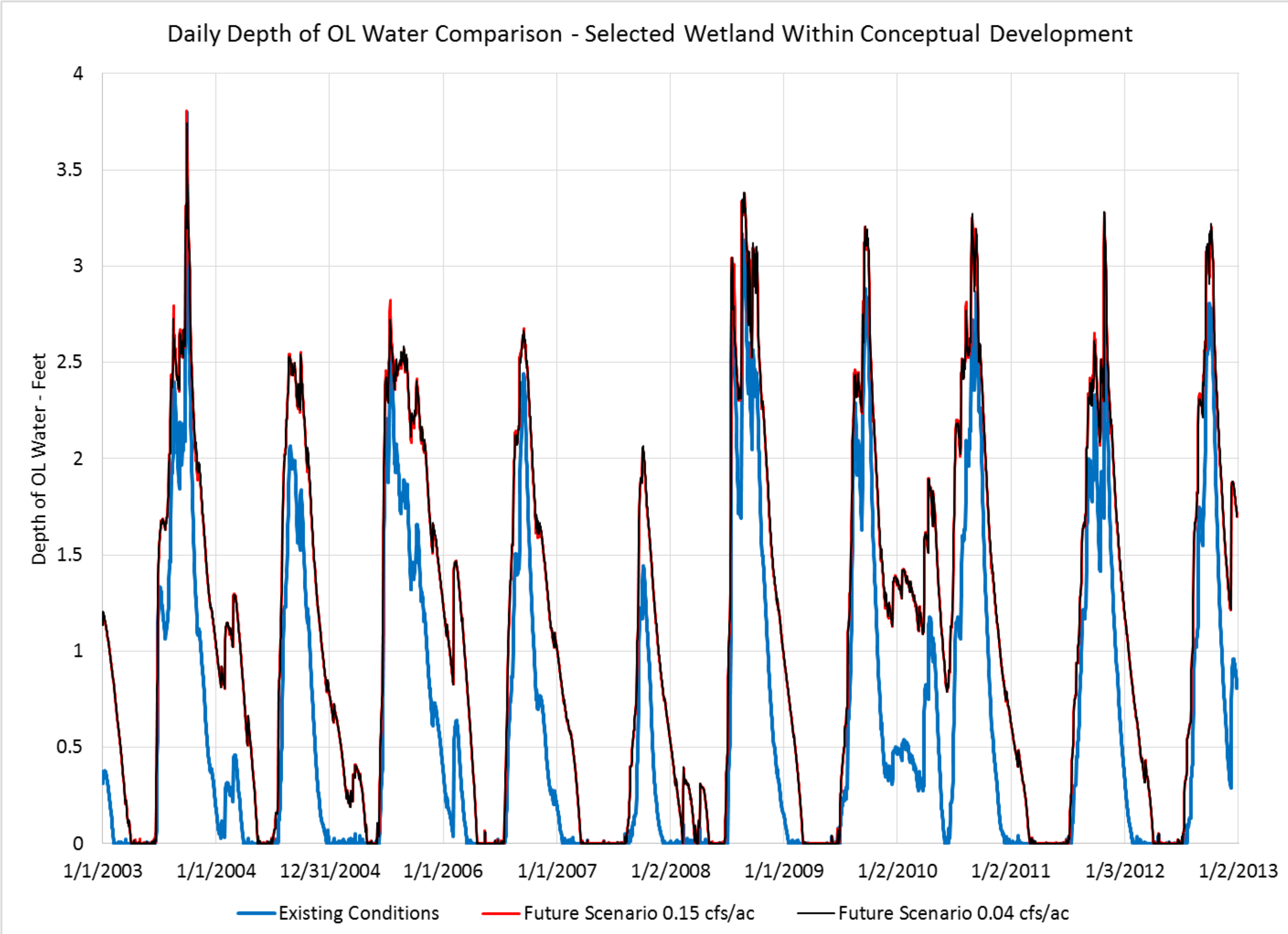

Figure 5. 15b. Daily OL Water Depth Comparison: Wetland Location within Conceptual Development.

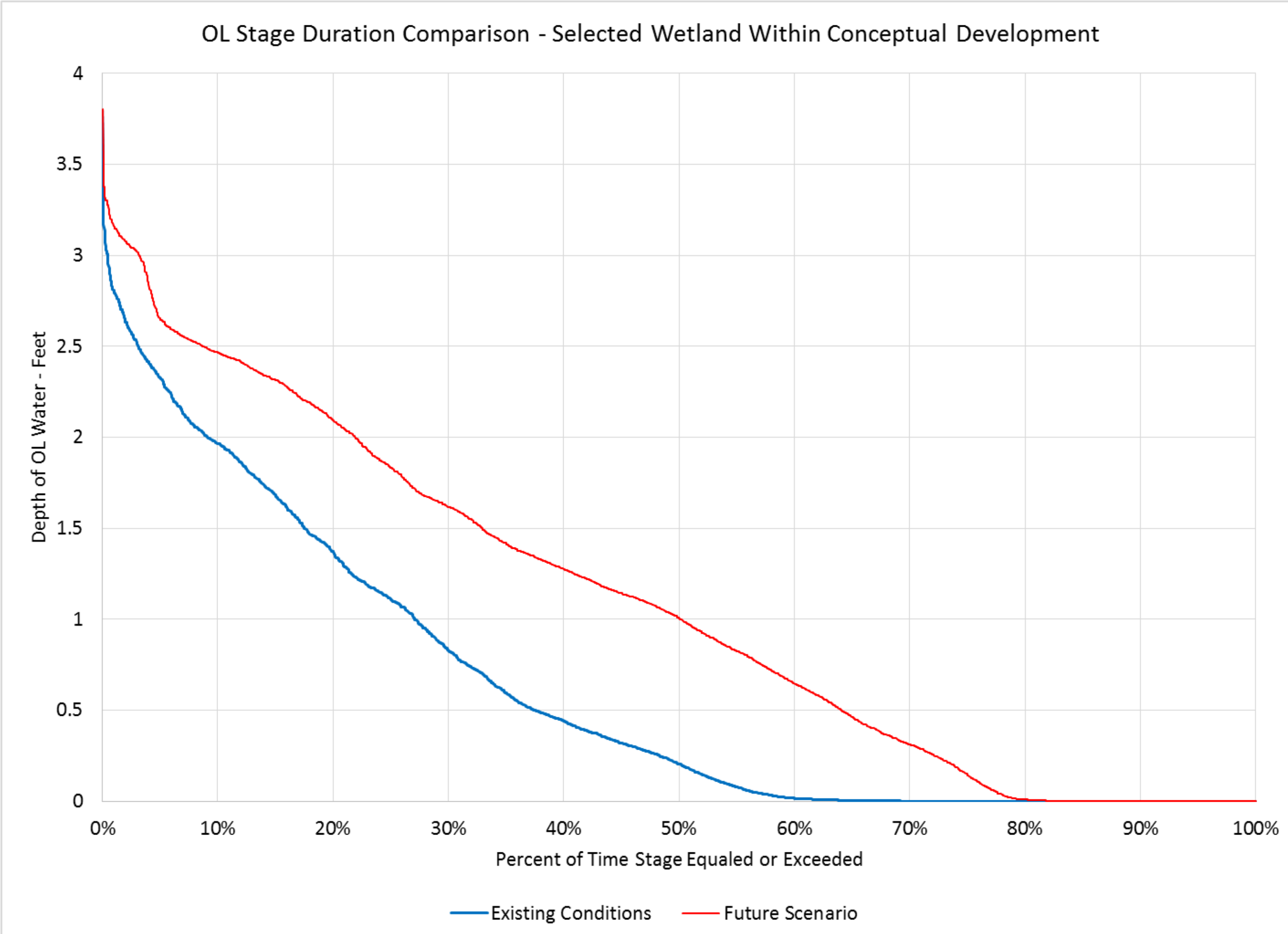

Figure 5. 16. OL Stage Duration Comparison: Wetland Location within Conceptual Development.

Figure 5.16 presents the stage duration curve of OL water depths at the wetland location within the conceptual development. Stage duration plots were not recomputed for the updated (0.04 cfs/acre) Future Scenario simulation, as there are no evident differences between the Future Scenario simulations. As shown in the time series plot presented in **Figure 5.15b**, both Future Scenario simulation configurations allow for an increase in the duration of inundation as well as a sustained water depth that is higher than Existing Conditions. These results are directly related to the cross-section and control structure additions within the proposed flow-way.

5.2 MIKE-11 Stage Results

The following MIKE-11 results are provided to compare stages along U.S. Highway 41 and at selected outfall locations to provide insight to potential changes associated with the proposed future land use and flow-way additions. From **Figure 5.1**, the following MIKE-11 channel locations are presented to assess the potential impacts due to the land use, and hydraulic revisions associated with this Future Scenario model.

5.2.1 BelleMeade-9 Surface Water Stage Evaluation

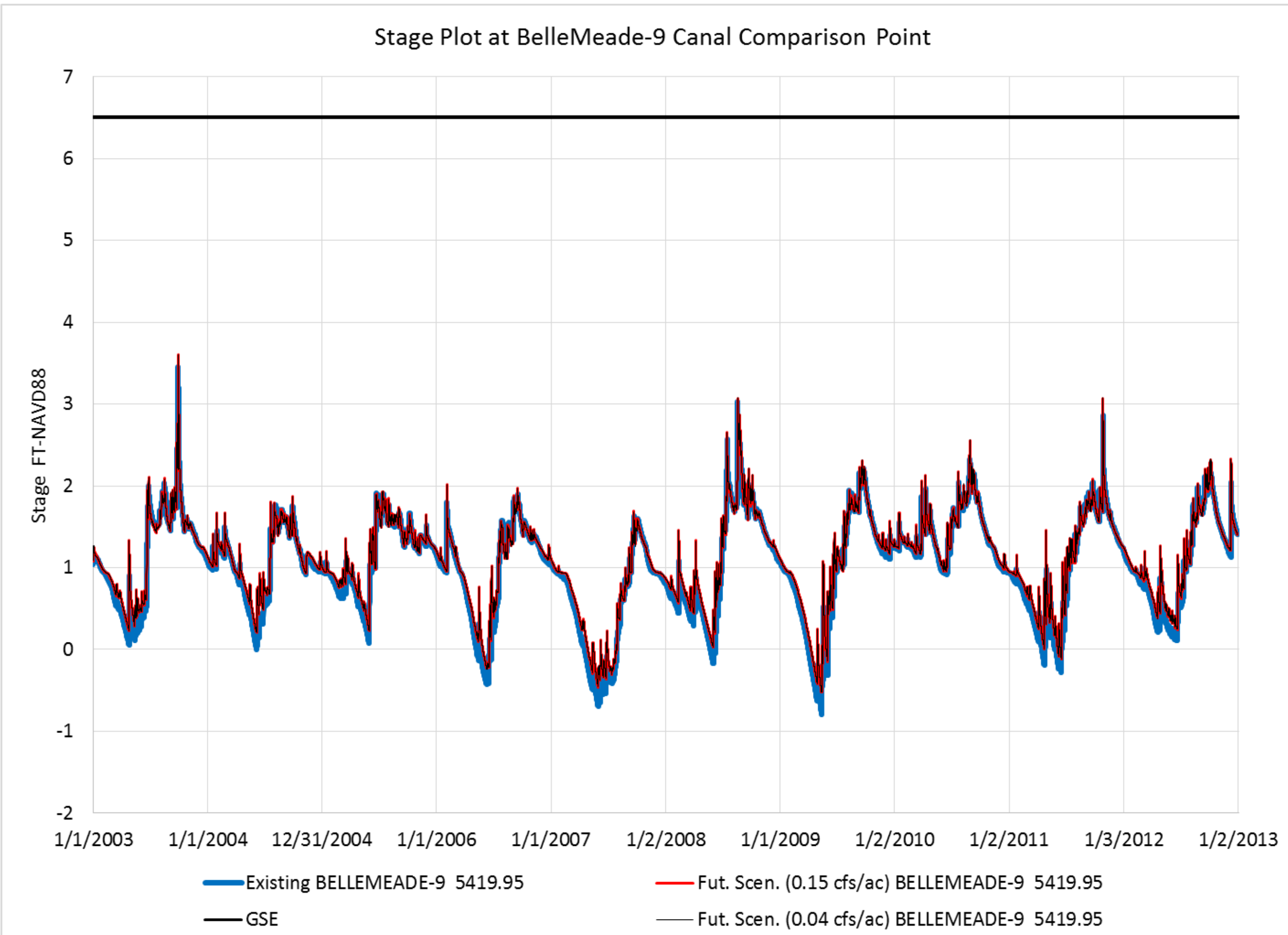

Figure 5.17. MIKE-11 Time series Stage BelleMeade-9 Canal.

As evidenced in **Figure 5.17**, stages in the BelleMeade-9 canal remain similar to Existing Conditions with slight increases in water levels during the peak of each wet season over the simulation period. Dry season stages show a slight increase, likely associated with the addition of the proposed flow-ways. Assessment of this time series shows that stages would not overtop the banks (GSE) of the cross-section, thus no flooding of adjacent lands is anticipated.

5.2.2 Tamiami Canal Surface Water Stage Evaluation

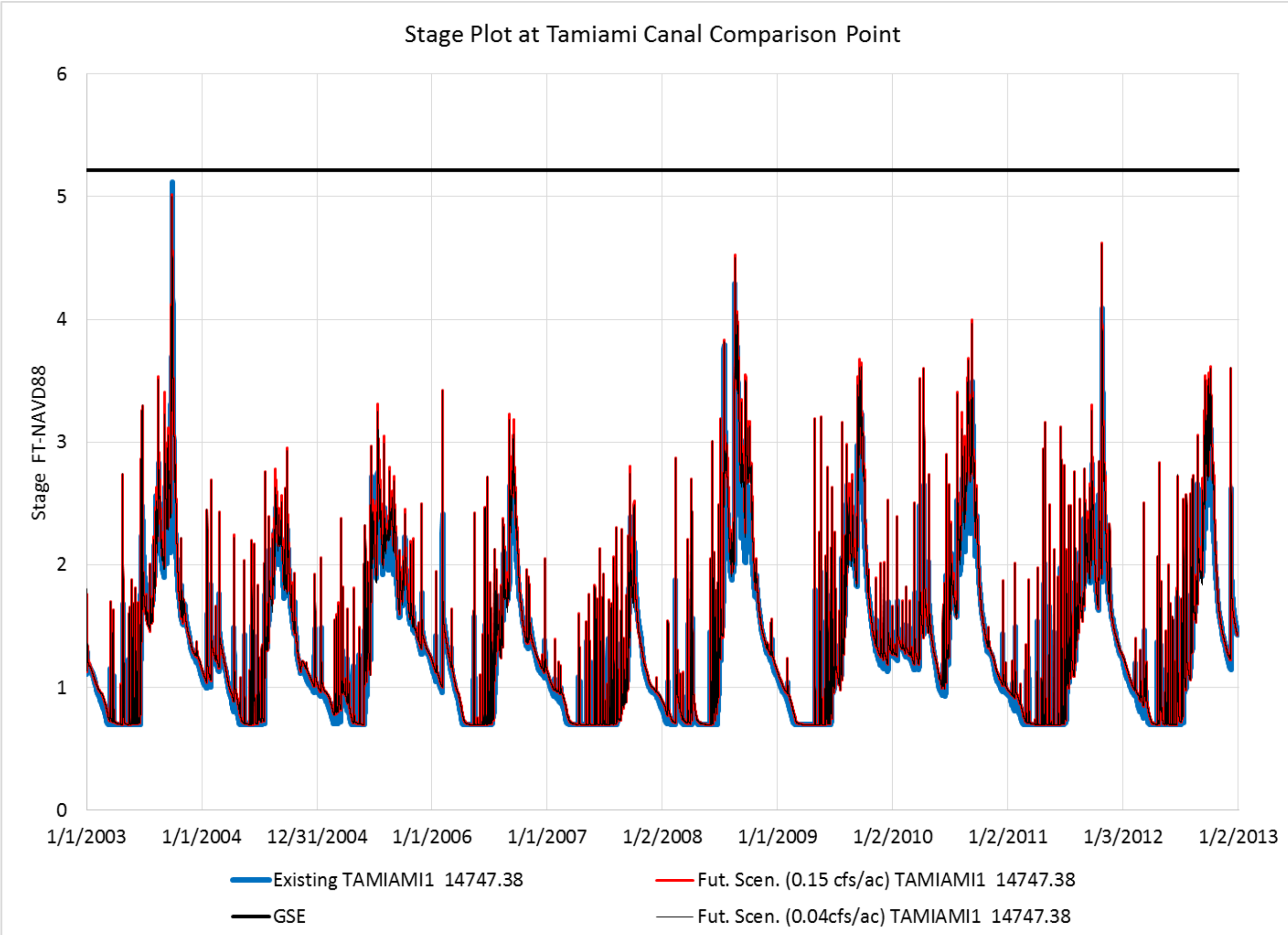

Figure 5. 18. MIKE-11 Time Series Stage Tamiami Canal.

Figure 5.18 presents the time series plot of stages at the Tamiami Canal over the simulation period, and shows that stages would be slightly increased in the wet season, and remain slightly higher in the dry season. Additionally, **Figure 5.18** shows no overbank flooding from the canal network. While there does appear to be a maximum water level that approaches the left levee bank of the cross-section, this levee bank is associated with the naturally lower ground elevation on the north side of U.S. Highway 41 and does not represent cause for concern at this time.

5.2.3 MCB-15 Canal Surface Water Stage Evaluation

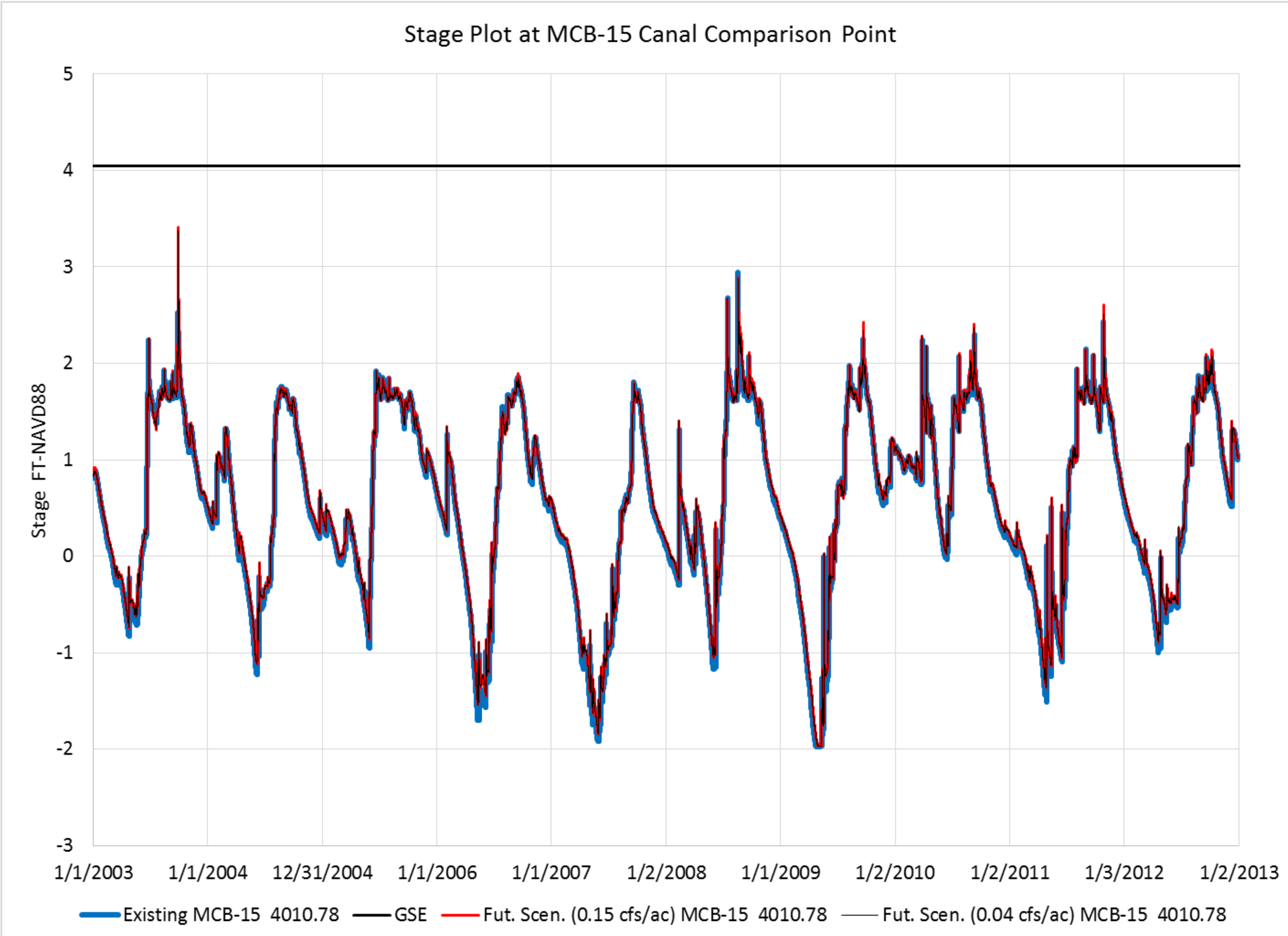

Figure 5.19. MIKE-11 Time Series Stage MCB-15 Canal.

Figure 5.19 presents the time series plot of stages at the MCB-15 Canal over the simulation period. It shows that stages are increased in the wet season with the largest increase in the 2003 wet season, while stages would remain slightly higher in the dry season. Additionally, **Figure 5.19** shows no overbank flooding from the canal network.

The MIKE-11 results presented in **Section 5.2** show that the neither configuration of the Future Scenario model would lead to an increase in stages downstream of the conceptual development and flow-way revisions. While stages do not appear to be over topping the cross-sections at this time, additional work should be performed along each downstream canal where the conceptual development and flow-ways are represented. This work should be done in conjunction with a design level study of the development and flow-ways, as this analysis presents a purely conceptual view of potential Future Scenarios.

Additionally the maximum stage within each conceptual parcel was assessed between the Future Scenario simulations. As would be expected, simulated stages within the conceptual parcels increased due to the reduced control structure sizes. This increase in stage did not lead to unacceptable stages within the development, as no water breached the lake banks. In other words, the increases in maximum stage within each conceptual storage area (lake) did not create overland flooding for the assessed period of 2003 through 2012. Table 5.2 presents the average and maximum stage differences within the conceptual development, where comparisons were made between the 0.15 cfs/acre and 0.04 cfs/acre simulations. Differences in stage were calculated by subtracting the stages from the 0.15 cfs/acre configuration from the 0.04 cfs/acre, configuration, where an increase in stage as shown below is a positive value.

Table 5. 2. Statistical Stage Differences Within The Future Scenario Conceptual Development.

Statistic Analyzed	Difference in stage (feet)
Average	0.24
Maximum	0.66

6.0 Conclusions

Two configurations of a Future Scenario model were developed to simulate the conversion of agricultural land (Belle Meade conversion) to medium density residential land use. The updated configuration includes a reduced maximum allowable runoff rate of 0.04 cfs/acre. This additional simulation was conducted in order to assess how the potential land use conversion may affect flows to Rookery Bay should Collier County pass an Ordinance that calls for reduced peak runoff rates in the Henderson Creek Watershed. Additionally, flow through proposed flow-ways was assessed. Flow-ways are proposed to provide a more direct north-south connection to the U.S. Highway 41 canal to more closely approximate Historical Condition flows when compared to the Existing Conditions. The Belle Meade conversion and flow-way modeling included changing the following Existing Condition MIKE SHE/MIKE-11 parameters to represent the Future Scenario:

- Vegetation and impervious land cover
- Topography
- Irrigation command areas (including irrigation rates)
- Overland Manning's Roughness Coefficient
- Detention storage
- Separated flow areas
- Channel network

The conclusions are as follows:

- Overall, each Future Scenario configuration would contribute about 5% (0.15 cfs/acre) and 4% (0.04 cfs/acre) respectively more freshwater to the Rookery Bay Estuary.
- While there are slight differences in the cumulative freshwater flows into Rookery Bay, the actual difference between Future Scenarios of 1% is relatively insignificant with respect to the overall volume of water delivered to Rookery Bay through each transect.

- Flow at the Henderson Creek coastal transect would experience a reduction in flow. These reduced flows are attributed to re-routing the water south through the proposed flow-ways.
- Reduction in the wet season peak flow is in the right direction, meaning under Historical Conditions, Henderson Creek on average experienced less flow in the peak of the wet season.
- The BelleMeade-9 coastal transect showed increased freshwater inputs, that better reflected the historical wet season flows. These additional flows are attributed to the proposed flow-ways delivering water to the US-41 canal.
- The Bridge 37 coastal transect showed increased freshwater inputs that better reflected the historical wet season flows. These additional flows are attributed to the proposed flow-ways delivering water to the US-41 canal.
- Increased flows are attributed to the combination of opening up the flow-ways allowing water to flow in the historical flow pattern. Additionally a shift in the water budget within the Belle Meade agricultural area showed that there was less ET and more runoff simulated for the Future Scenario as compared to Existing Conditions. These outcomes are not surprising due to the land use and hydraulic network changes associated with the Future Scenario.
- MIKE-11 stages are not seen as an issue at the time of the conceptual model development. However, care should be taken and surveys should be completed along all outfall canals, if ever a design level development with flow-ways should be installed. It should also be noted that the model did not simulate flood conditions associated with large storms (e.g., 100 year event)
- A comparison of the Future Scenario simulation (with and without revised US-41 culverts) showed negligible flow differences for the 10-year simulation period of the model. This led to the conclusion that the culverts under U.S. Highway 41 are not the prominent factor in controlling delivery of fresh water to the Rookery Bay Estuary. Rather the primary factor is the land use change and other hydraulic changes upstream of U.S. Highway 41.
- U.S. Highway 41 Outfall Swale No. 2 generates larger freshwater input to Rookery Bay, when compared to Existing and Historical Conditions. This is likely due to the additional water routed through the proposed flow-ways upstream of U.S. Highway 41
- As stated in previous technical memoranda (**Task 2.7 – Hydrodynamic Modeling Report**), the overall volume of flow to Rookery Bay under Existing and Historical Conditions is very similar. A comparison of the cumulative freshwater inflow volumes, showed that simulated flows were 0.5 percent higher for Existing Conditions when compared to Historical Conditions. This flow difference is negligible and in essence shows no difference between the cumulative freshwater inputs to the Rookery Bay Estuary. The primary issue along the coast line was a shift in the sources of freshwater deliveries to the coast. Channelization and other factors in the watershed provided a geographic redistribution of flow along the coastline when compared to Historical Conditions.
- Restoring the historical flow path to U.S. Highway 41 and allowing some of this water to be diverted to rehydrate wetlands was accomplished by the current modeling effort.
- Flows through some coastal transects were improved, insofar as the model predicted some shift towards a more historical flow regime, but further investigation of the potential to improve the geographic distribution of flow to Rookery Bay, other alternatives may be warranted.
- Additional work is necessary to evaluate other alternatives that may provide more water to the Belle Meade flow way, allow this water to flow in a historical pathway, and then redistribute

these flows along the U.S. Highway-41 canal and provide water level control to distribute these flows at the right locations.

7.0 References

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