BIG CYPRESS BASIN WATERSHED MANAGEMENT PLAN

Corkscrew Canal Improvement Plan

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BIG CYPRESS BASIN
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ACRONYMS AND INTIALISMS

BCB	Big Cypress Basin
BCBWMP	Big Cypress Basin Watershed Management Plan
CREW	Corkscrew Regional Ecosystem Watershed
DHI	Danish Hydraulic Institute
HEC RAS	Hydrologic Engineering Center River Analysis System
H&H	Hydrologic and Hydraulic
NGVD	National Geodatic Vertical Datum
SFWMD	South Florida Water Management District
UNET	Unsteady Network Hydraulic model

EXECUTIVE SUMMARY

The Corkscrew Canal and its tributaries drain approximately 7,600 acres in Collier County, Florida. This canal network is a part of the Big Cypress Basin's (BCB) primary canal system. The main branch of the canal is approximately six miles long and connects the Corkscrew Swamp with the Cocohatchee and Cypress Canals. The canal presently does not have adequate conveyance capacity to provide the level of service for flood protection. The residential area north of Immokalee Road has been subjected to chronic flooding. The BCB five-year plan has identified the Corkscrew Canal improvement as a priority capital improvement project. A comprehensive flood control, water supply, and environmental quality protection plan has been formulated in this report.

Hydrologic assessment of the canal basin and hydraulic evaluation of the conveyance capacity of the canal was conducted by using the regional models developed as a part of the Big Cypress Basin Watershed Management Plan (BCBWMP). Recently, an integrated and interactive Hydrologic and Hydraulic (H&H) evaluation of the Big Cypress Basin (BCB) water resources system was done using Danish Hydraulic Institute’s (DHI’s) MIKE SHE-MIKE 11 surface water-groundwater modeling system. Achievement of the desired level of flood protection and general water management functions of the existing condition and alternative improvement scenarios were simulated for the design storm event. The assessment of the existing condition for flood hydrology indicating peak discharges range from 63 cubic feet per second at the north end of the canal to 627 cubic feet per second at the south end (confluence with Cypress Canal). The northern segment of the canal (upstream of the Cocohatchee Canal) does not satisfy the flood control requirement for 25-year 3-day storm event. Inadequate conveyance capacity of the canal is largely contributed by six grossly undersized culverts and small canal sizes. Peak discharges in the improved canal range from 64 cubic feet per second at the north end, to 651 cubic feet per second at the south end. The proposed improvements are designed to convey these larger discharges without causing canal over

bank flooding. The proposed improvement plan includes the following modification of the Corkscrew Canal.

- Enlarge the canal cross section reaches north of Cypress Canal.
- Remove 6 culvert crossings (33rd, 35th, 37th, 39th, 41st, and 43rd Avenues).
- Replace 43rd Avenue circular culvert by a two 10 ft (width) by 8 ft (height) box culvert.
- Construct 25-ft single span bridges and associated access roads at 33rd, 35th, 37th, 39th, and 41st Avenues.
- Construct two 10 ft by 8 ft water control structure (sluice gates) at 43rd Avenue.
- Landscape the canal bank and right of way.

The Corkscrew Canal improvements will be carried out in three phases. These are: Phase I – Replacement of Culverts and Gated Water Control Structure, Phase II – Excavation between Upstream end and Cocohatchee Canal, and Phase III – Excavation between Cocohatchee and Cypress Canal. A preliminary cost estimate of the proposed improvement plan is approximately $1,273,980, $671,000, and $495,000 for phases I, II, and III respectively. The information in this report will be used for final engineering design and other project activities, which include environmental permitting, real estate needs assessment and acquisition, preparation of construction plans, and development of operation schedule of the water control structures.

INTRODUCTION

1.1 BACKGROUND AND WATER MANAGEMENT PROBLEMS

The Corkscrew Canal and its side ditches comprise a dendritic network of poorly drained canals that provides an interbasin transfer of water from the northeastern part of the Corkscrew-Cocohatchee basin to the Golden Gate Canal basin. Virtually uncontrolled flows through these canals have led to over drainage of portions of the Bird Rookery Swamp ecosystem and a loss of dry season surface and shallow aquifer storage. The Bird Rookery Swamp is located immediately south and west of Corkscrew Swamp Sanctuary. This is a part of the Corkscrew Regional Ecosystem Watershed (CREW) project, which covers more than 55,000 acres in Lee and Collier Counties (CREW Management Planning Team, 1992).

The flood control capability of the Corkscrew Canal is also limited as was evident during the recent wet seasons of 1991, 1992, 1995, and 2001. Figures 1a through 1f illustrate the magnitude of flooding (along the northern reaches of the canal) that occurred during a tropical storm event in 2001. This canal system was adopted as the "works of the Basin" effective FY 1994. The two water control structures were constructed in cooperation with Collier County by utilizing wetlands mitigation funds from the Livingston Road construction project. Some preliminary drainage improvement works in the secondary canals were also coordinated with the Collier County Stormwater Management Department.

The project for Corkscrew Canal improvement is included in the proposed budget for construction in Fiscal Year 2004. The project will be performed in two phases. The Phase I improvements will involve replacement of six existing undersized culvert crossings and relocated by any utility crossings identified. The Phase II improvements will involve modification of the channel. A priori H&H analysis is needed for attaining the goals of the project effectively. This analysis will be based on the BCB Watershed Management Plan H&H model developed earlier by Dames & Moore (1998) and DHI

Figure 1a. Flooding from Corkscrew Canal on 43rd Ave., 2001

Figure 1b. Flooding from Corkscrew Canal on Wilson Blvd., 2001

Figure 1c. Flooding from Corkscrew Canal on Wilson Blvd., 2001

Figure 1d. Flooding from Corkscrew Canal at Intersection of 41st Ave NW & 9th St. NW, 2001

Figure 1e. Flooding from Corkscrew Canal on Wilson Blvd., 2001

Figure 1f. Flooding from Corkscrew Canal at Intersection of Wilson Blvd. & 39th St., 2001

(2002). Based on the earlier H&H analyses, the present study will address improvement scenario for the development of an economically and environmentally sound improvement plan. For Corkscrew Canal, improvements include construction/modification of water control structures, enlarging the canal cross section, and modifying and replacing undersized culvert crossings. The channel improvements for the Corkscrew Canal will be made to an approximately 6-mile reach between the westerly terminus of 47th Ave SE and the Cypress Canal. These improvements will provide the required flood protection after future development plans are implemented.

1.2 BASIN PHYSICAL FEATURES

The Corkscrew Canal is located in the north-central portion of Collier County. The canal is in the Golden Gate basin as shown in Figure 2. The canal system in the Golden Gate basin primarily serves to drain the lands for residential development in the area known as Golden Gate Estates. The total basin area is approximately 120 square miles with primary land uses consisting of agriculture, rural and urban residential, and commercial. The Golden Gate Canal basin consists of nine drainage subbasins, as shown in Figure 2. It is bounded by the Corkscrew-Cocohatchee basin to the north, the Gordon River Extension basin to the west, the District VI basin to the south, the Henderson Creek basin to the southeast, and the Faka Union Canal basin to the east. The flow in the Corkscrew Canal is generally toward south and drains an approximately 12 square mile basin. It flows downward to Cypress Canal, which in turn flows to the Golden Gate Main Canal. The Golden Gate Main Canal is the largest canal in the Golden Gate basin. Presently, seven water control structures in the Golden Gate Main Canal provide a controlled step-down of the water level to prevent over drainage of the interior lands. In addition, many canals of its tributary network, namely Golden Gate side branch, Cypress, Harvey, I-75, Corkscrew, CR 951, and Airport Road Canals, also have operable water control structures.

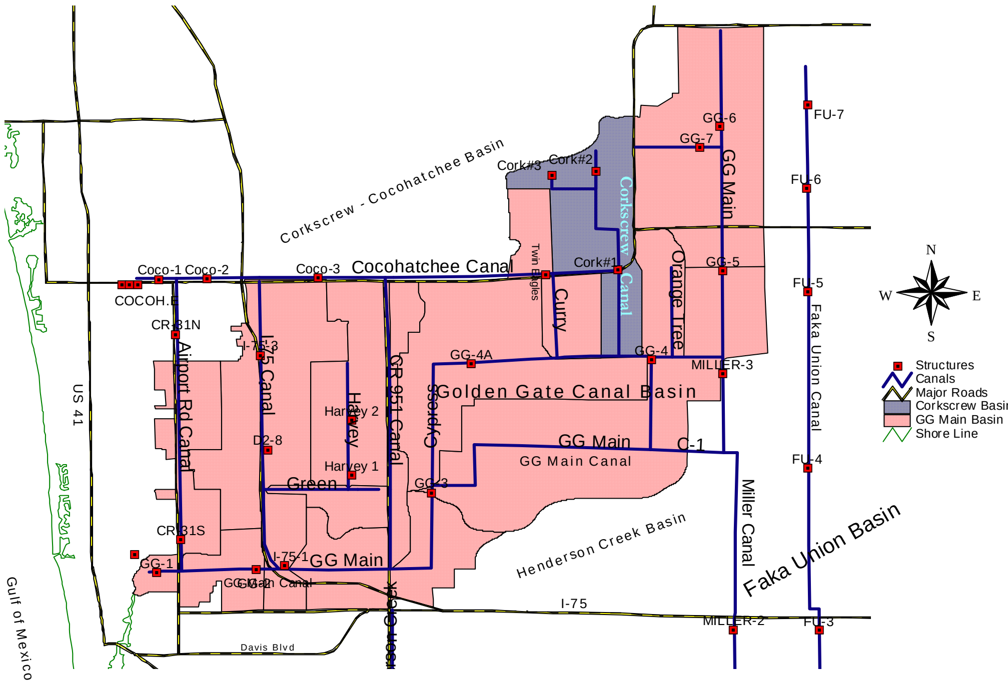


Figure 2. Corkscrew Canal subbasin in Golden Gate Canal Basin.

In spite of the low-relief terrain of the Golden Gate Canal basin, natural surface drainage is controlled by the topography. The Immokalee Rise provides the high point for the basin where drainage begins to flow towards the southwest, across the Southwestern Slope, and then flows in a more southerly and then westerly direction towards the Naples Bay. Ground elevations range from approximately 23 feet National Geodatic Vertical Datum (NGVD) of 1929, in the northeastern end, to nearly 6 feet NGVD near GG-1. Other meteorological and hydrologic features of the Basin are described in the Big Cypress Basin Watershed Management Plan (BCBWMP) (Dames & Moore, 1998).

2 H&H MODELING FOR THE CORKSCREW CANAL IMPROVEMENTS

2.1 MODELING METHODOLOGY

The H&H assessment for the Corkscrew Canal improvements were carried out using the H&H models developed as a part of the BCB Integrated Surface Water-Groundwater Modeling efforts. DHI developed the BCB Integrated Surface Water-Groundwater Model to assess the impact of various water management strategies. The integrated and the interactive Surface Water-Groundwater Model include MIKE SHE and MIKE 11 modeling codes developed by DHI. The overland flow and groundwater system is modeled using MIKE SHE, which is an integrated, distributed hydrological model that encompasses all major components of the hydrologic cycle including overland flow, unsaturated flow, and groundwater flow. The channel flow is modeled using dynamic river hydraulics model MIKE 11 developed by DHI. The hydrologic model MIKE SHE is dynamically connected to the hydraulic channel routing model MIKE 11. The modeling methodologies focused on representing H&H components to simulate flood levels, peak flows, and wetland hydroperiods in the watersheds. The H&H components included in the models are summarized as follows:

- Overland sheet flow and depression storage
- Infiltration and storage in the unsaturated zone
- Groundwater flow, storage and potential heads
- Open channel flow and water levels
- Evapotranspiration losses
- Effects of drainage
- Effects of irrigation water allocation
- Dynamic exchange between unsaturated zone-groundwater (recharge)

A schematic representation of the complete water resources system that is represented by MIKE SHE-MIKE 11 interaction model is shown in Figure 3.

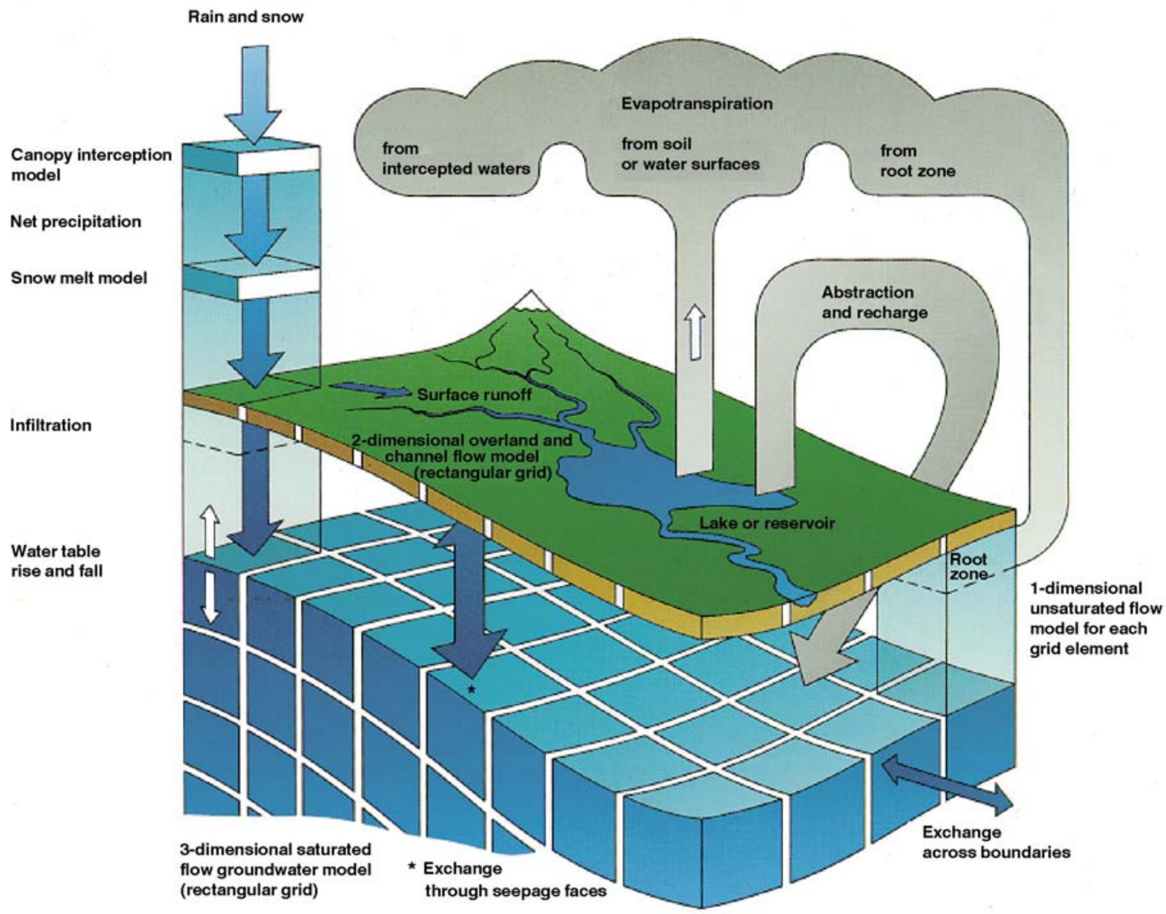


Figure 3. A general configuration of an interactive groundwater-surface water model.

To simulate all the processes using one modeling system, the combined MIKE SHE-MIKE 11 modeling codes were selected by DHI. Various flow modules of MIKE SHE were employed to describe flow within the entire land based part of the hydrologic cycle. All the components of MIKE SHE are described by DHI (2002). MIKE 11 dynamically receives the overland flows from MIKE SHE into the channels for routing in both spatial and temporal directions. In developing the MIKE SHE/MIKE 11 integrated model, all the available data from the previously developed BCB H&H model by Dames & Moore (1998) were incorporated. The updated data based on new survey in 2002 were also incorporated into the model.

2.2 HYDROLOGIC MODEL

The overland flow component of MIKE SHE model represented the rainfall-runoff processes including the unsaturated zone and the interaction between groundwater and surface water. The BCB overland flow model was set up to simulate both surface runoff and groundwater influence for drainage areas located in the BCB. The GIS coverage including topographic data of the BCB area was used to develop the conceptual model for the overland flow to be simulated using MIKE SHE. The topographic coverage of the BCB area describes the overland flow processes in MIKE SHE. The MIKE SHE generated overland flows acted as distributed sources for the MIKE 11 channel routing model. The topographic map used in the MIKE SHE model is shown in Figures 4a and 4b.

In MIKE SHE model, the surface runoff occurs when water starts ponding on the surface. The ponding may occur due to insufficient infiltration capacity of the underlying soil, proximity of the groundwater table near the ground surface, or existence of drainage flows from low-lying areas. The overland flow in MIKE SHE uses a 2-D kinematic wave approximation for computing hydrologic components, which depend on the ground surface slope, surface roughness, and detention storage. All these parameters are described in detail in the report prepared by DHI (2002).

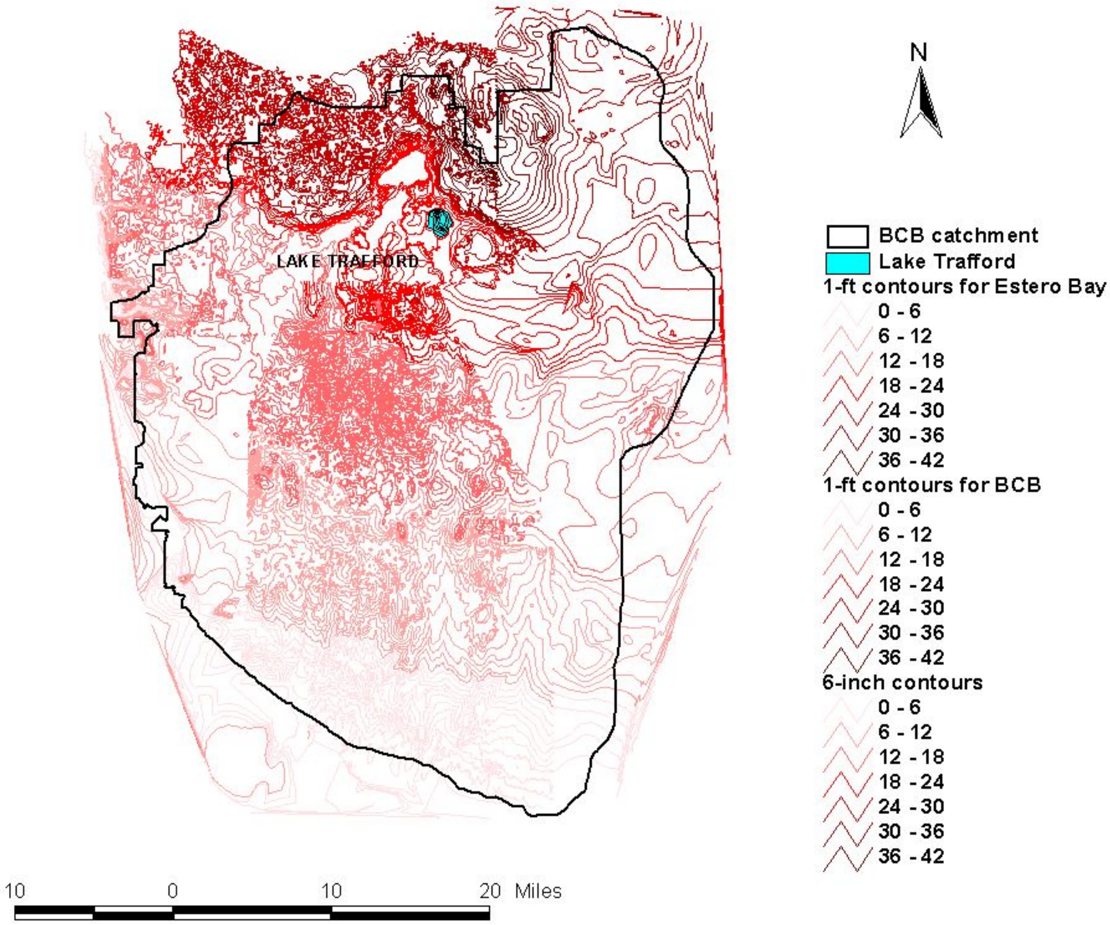


Figure 4a. Combined 6-inch and 1-ft surface elevations contours in the BCB watershed (excl. spot elevations in Corkscrew swamp).

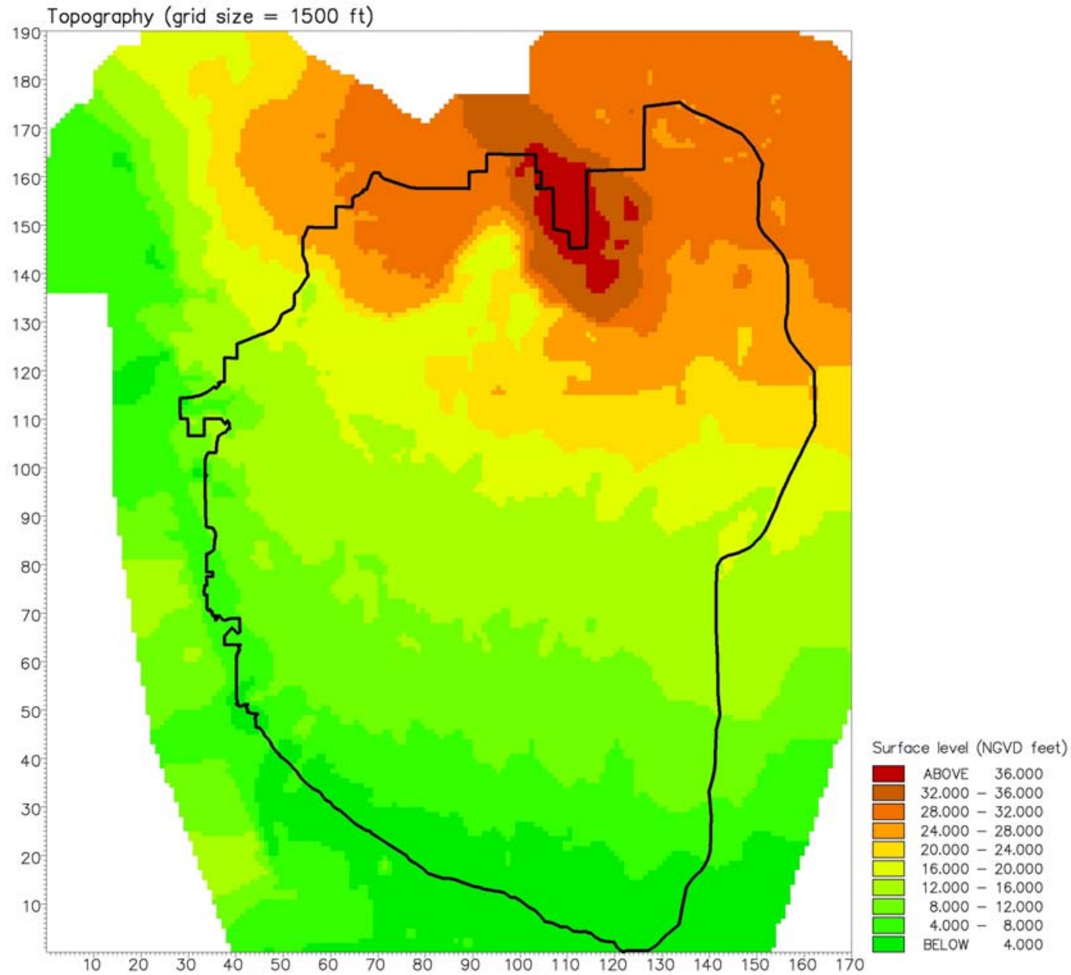


Figure 4b. Interpolated topography (feet) using a discretization of 1500 ft (457.2 m).

Rainfall on the west coast of Florida is typically dominated by local weather phenomena, which also applies for the BCB. Rainfall data collected at different stations from different sources were organized by DHI for entry into the model. A spatially distributed rainfall pattern was developed using Theissen polygon as shown in Figure 5. Evapotranspiration from the land surface consists of evaporation directly from the soil and the soil-vegetation surface, as well as transpiration through plant leaves. A record of actual pan evaporation data for the full simulation period from 1990 to 1999 was analyzed and the data were incorporated into the MIKE SHE model. Land use maps based on aerial photographs and field inventories were used as well for setting up an appropriate evapotranspiration module in MIKE SHE. The land use distribution map used in the MIKE SHE model is shown in Figure 6. Various vegetation specific parameters such as Leaf Area Index, root depth, crop coefficient, etc. are described in the report prepared by DHI (2002).

2.3 UNSATURATED ZONE MODEL

The unsaturated zone extends from the ground surface to the groundwater table. The depth is dynamic and varies throughout the year with groundwater fluctuations and rainfall. During periods of the year, the unsaturated zone may occasionally disappear in depression areas where the water table rises above ground, e.g. in floodplain areas. Unsaturated flow in MIKE SHE is computed based on a simplified Richard's equation and infiltration rates thus depend on a number of soil parameters such as hydraulic conductivity of the soil, soil retention, residual soil moisture, and water content at field capacity. The model computes infiltration rates and soil moisture, which in turn affects evapotranspiration losses from the root zone and irrigation demands. Input for the model consists of soil property parameters and a soil column distribution map. The soil parameters in MIKE SHE are specified in a database and a number of soil profiles are set up using soil types from the database. The MIKE SHE soil distribution map is shown in Figure 7. Various soil physical parameters entered into the unsaturated zone database are given in Table 1. All the input data entered into the model are described in greater detail in the report prepared by DHI (2002).

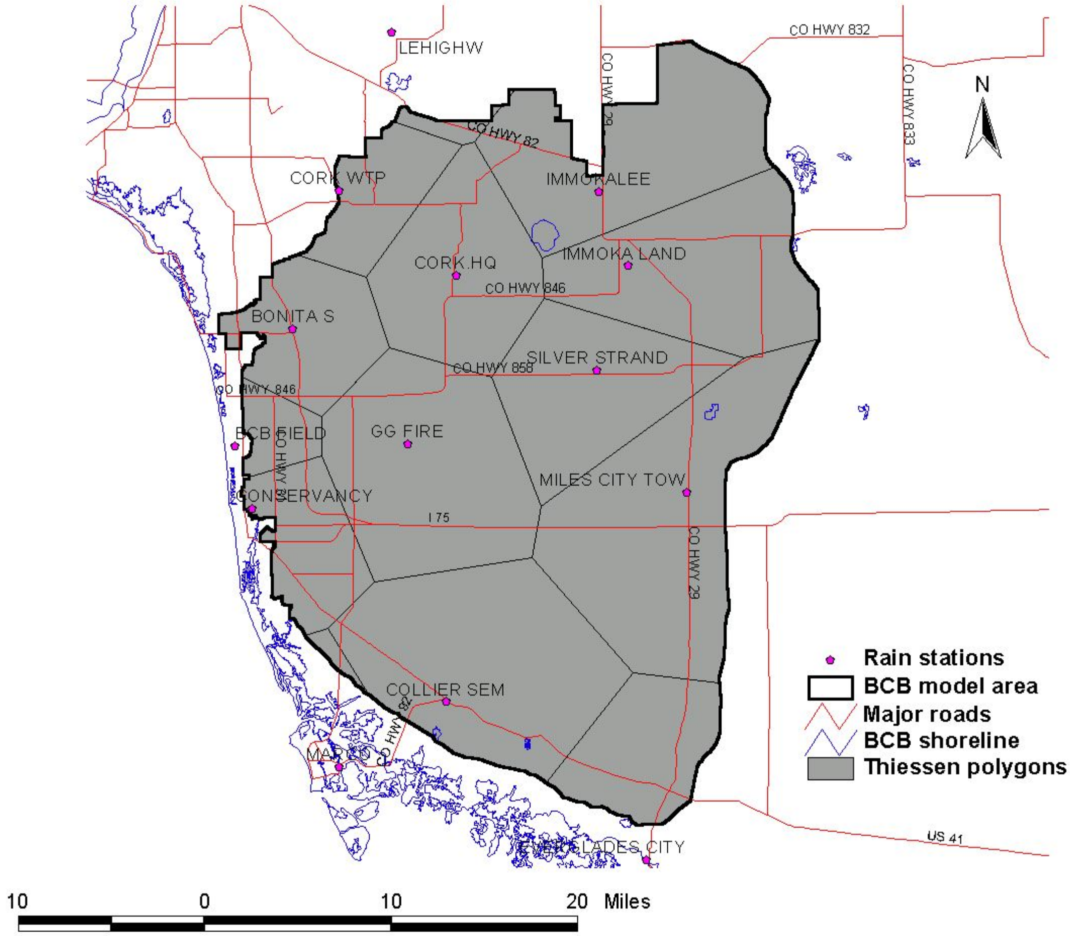


Figure 5. Rainfall distribution using Thiessen Polygons.

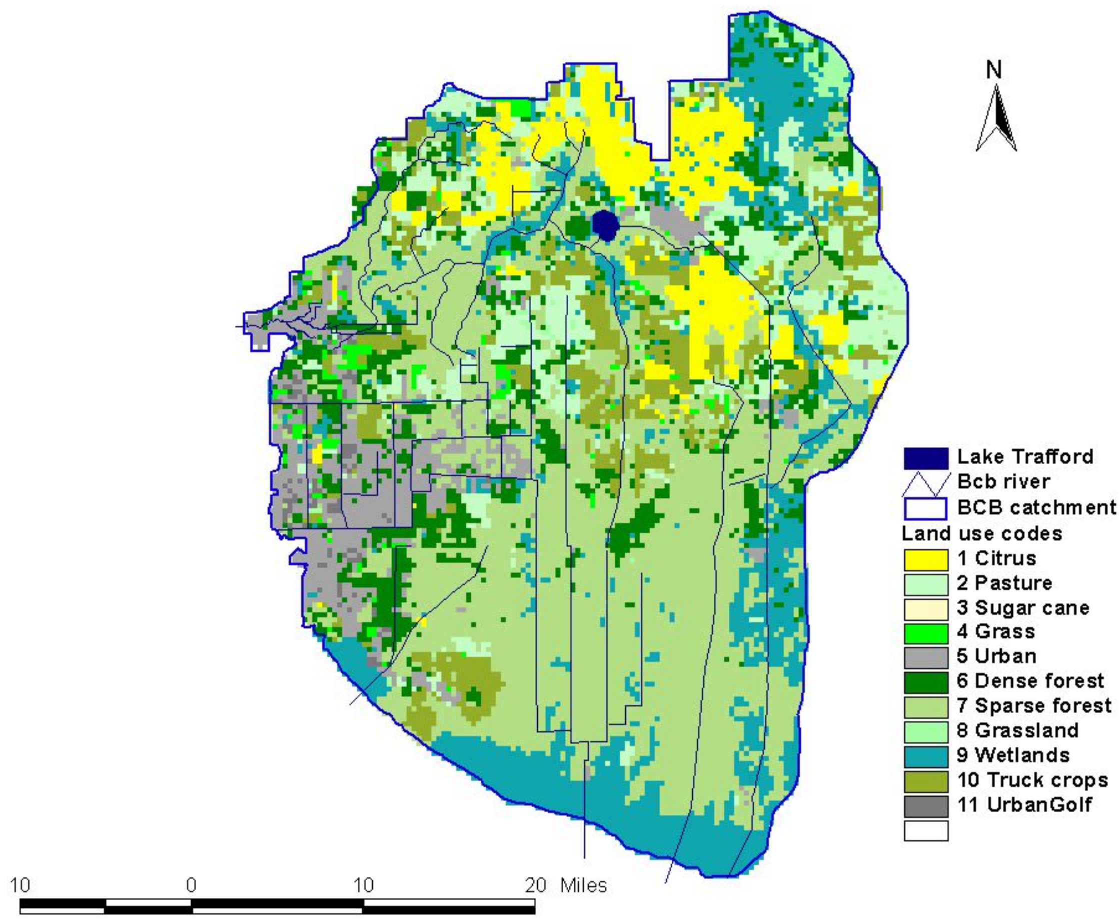


Figure 6. MIKE SHE land use distribution map (1500 ft grid).

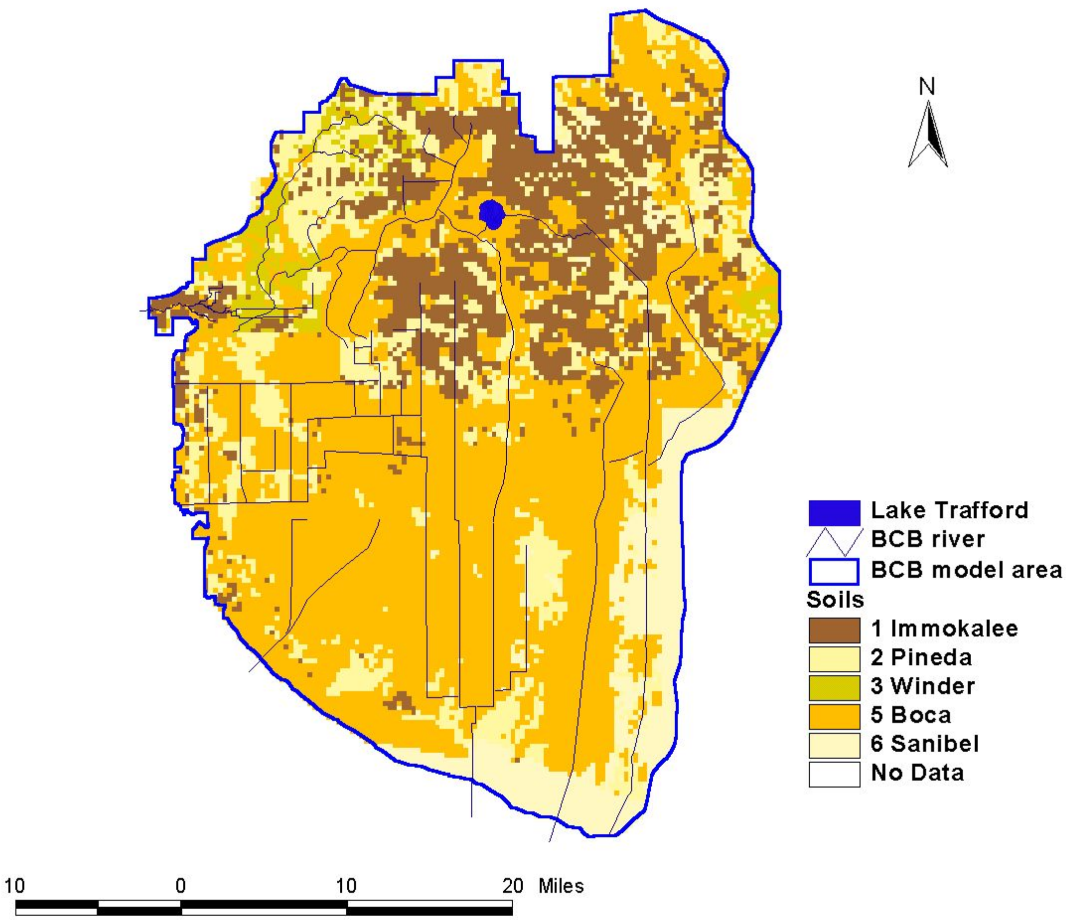


Figure 7. MIKE SHE soil distribution map (1500 ft grid).

Table 1. Soil physical parameters entered into the unsaturated zone database.

Profile No. and Landscape Type	Soil Type and Depth	Saturated Hydraulic Conductivity K_s [m/s]	Saturated Water Content Θ_s [%]	Water Content at Field Capacity Θ_{fc} [%]	Water Content at Wilting Point Θ_w [%]	Residual Water Content Θ_r [%]
(1) Flatwoods	Immokalee A1 (0.0-0.1 m)	2.0e-4	0.42	0.079	0.03	0.01
	Immokalee AE (0.1-0.23 m)	1.1e-4	0.42	0.095	0.057	0.031
	Immokalee E1 (0.23-0.41 m)	8.6e-5	0.39	0.084	0.025	0.015
	Immokalee E2 (0.41-0.91 m)	1.0e-4	0.38	0.074	0.017	0.01
	Immokalee Bh2 (0.91-1.4 m)	6.1e-6	0.38	0.225	0.07	0.043
	Immokalee Bw/Bh (1.4-23 m)	7.5e-5	0.38	0.112	0.033	0.02
(2) Slough	Pineda E (0.0-0.13 m)	8.0e-5	0.464	0.085	0.033	0.02
	Pineda Bw1 (0.13-0.33 m)	8.0e-5	0.449	0.085	0.023	0.02
	Pineda Bw2 (0.33-0.58 m)	6.4e-5	0.422	0.095	0.009	0.01
	Pineda E1 (0.58-0.91 m)	5.3e-5	0.408	0.076	0.012	0.02
	Pineda Btg/E (0.91-1.37 m)	3.1e-7	0.351	0.31	0.11	0.1
	Pineda Cg (1.37-22 m)	1.1e-6	0.380	0.347	0.162	0.1
(3)Depression	Winder A1 (0.0-0.08 m)	3.6e-5	0.374	0.175	0.024	0.014
	Winder E (0.08-0.33 m)	5.7e-5	0.37	0.092	0.008	0.004
	Winder Btg (0.33-0.58 m)	7.4e-6	0.43	0.395	0.153	0.101
	Winder C1 (0.58-0.89 m)	4.1e-6	0.332	0.225	0.038	0.021
	Winder C3 (0.89-21.7 m)	1.9e-6	0.355	0.303	0.107	0.062
(5) Rock	Boca A (0.0-0.08 m)	1.1e-4	0.487	0.088	0.04	0.029
	Boca E1 (0.08-0.23 m)	9.7e-5	0.46	0.080	0.034	0.023
	Boca E2 (0.23-0.36 m)	8.0e-5	0.408	0.064	0.024	0.015
	Boca Bw (0.36-0.64 m)	5.4e-5	0.396	0.071	0.009	0.006
	Boca Btg (0.64-22.64 m)	8.3e-7	0.347	0.031	0.122	0.071
(6) Marsh	Okeelanta Oa1 (0.0-0.50 m)	2.0e.5	0.55	0.715	0.197	0.2
	Okeelanta A1 (0.5-0.55 m)	9.4e-5	0.51	0.370	0.025	0.01
	Okeelanta C1 (0.55-0.66 m)	1.4e-4	0.37	0.069	0.013	0.01
	Okeelanta C2 (0.66-21.7 m)	1.1e-4	0.38	0.062	0.011	0.01

2.4 HYDRAULIC ROUTING MODEL

Channel flows in the watershed are described by a one-dimensional fully hydrodynamic river/flood model MIKE 11, which couples dynamically to the integrated hydrologic MIKE SHE model. All surface flowways can, in principle, be accounted for by the model, including main rivers, channels, irrigation canals and floodplains and various loops - except surface runoff, which is handled by the MIKE SHE overland flow component. Floodplains are often characterized by two-dimensional flow, which can be described artificially in the model by using link channels, thereby creating flowways that only exist during flood situations.

Input for the model consists of the channel network (which is crucial in describing the channels and floodplains adequately), and surveyed cross-sections as well as appropriate boundary conditions consistent with actual surface boundaries and bed resistance. Moreover, regulatory structures such as culverts, weirs, and control gates that may significantly alter or modify channelized flows, and stages are specified as input to the model. Finally, the channels exchange water with the underlying aquifer. This may either be described entirely by the aquifer material properties or by a channel lining leakage coefficient as specified in MIKE 11.

The major flow ways in the Big Cypress Basin consist of a number of flood plains and an intricate system of manmade channels. The major flow ways in the BCB are shown in Figure 8. The main channels defined in Figure 8 were all included in the model, coming to a total of 28 MIKE 11 branches. Moreover, a number of floodplains or sloughs were defined in MIKE 11, in total 14 branches. The final MIKE 11 branch system is presented in Figure 9. The conveyance and storage capacity of the channel system is described by the cross-sectional geometry of the channel branches. Cross-sections are preferably entered into the model at regular intervals of approximately 600-

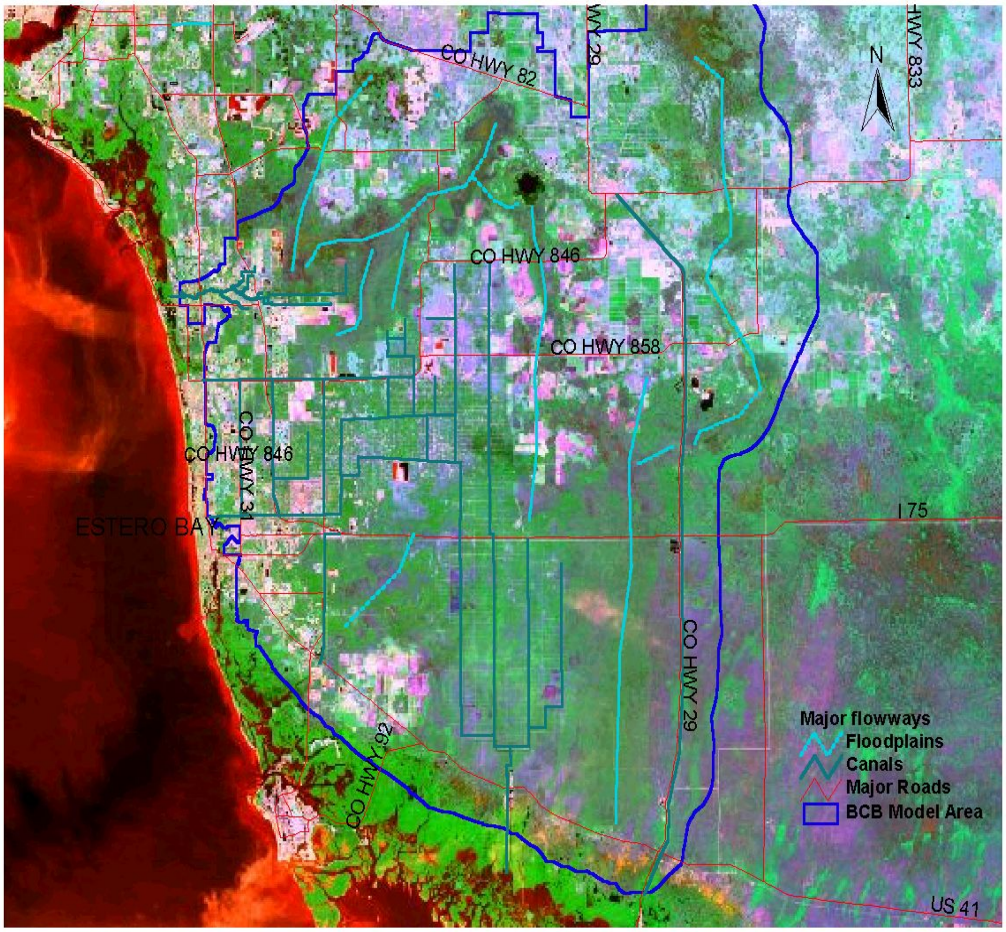


Figure 8. Major flowways in the BCB watershed.

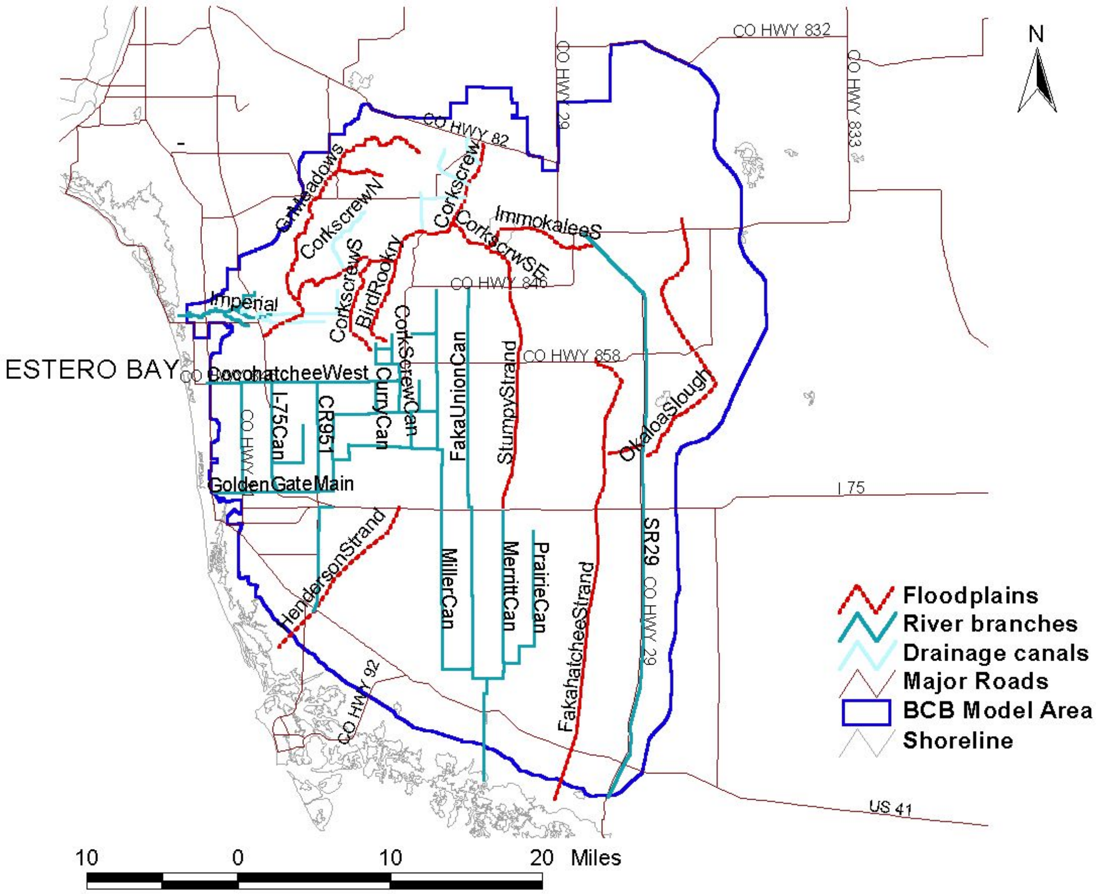


Figure 9. MIKE 11 channel network for the BCB watershed.

1600 ft (200 - 500 m) if available and as a minimum at up and downstream ends of each channel branch. Surveyed channel cross-sections with limited extent of the flood plains for the entire BCB channel system were available in an existing Unsteady Network Hydraulic model (UNET) model (U.S. Army Corps of Engineers, 1996) set up by Dames & Moore (1998). The cross-sections were converted to MIKE 11 format and imported directly into the model.

The BCB channel system is characterized by an intricate network of channels with a large number of control structures, culverts and bridges. In total 38 control structures are located in the BCB major canal system as outlined in Figure 10. In total, five different types of control structures are found in the BCB channel system: fixed crest weirs with underflow gates, movable crest weirs, fixed crest weirs with V-notches, fixed crest weirs with steel sheets and amil gate weirs. The structures generally prevent over-drainage from the watershed and minimize tidal effects as well as saltwater intrusion in the canals. The dimensions and operation of the control structures are described in the operation manual, BCB (2000 a), and a pamphlet with operating water elevations, BCB (2000 b). Based on this information, the MIKE11 structure module was used for setting up the structure operation in the model and, since the module is very flexible, the gates are operated close to the description in the operation manual.

2.5 GROUNDWATER MODEL

Groundwater flow and potential heads are computed using a 3-D finite-difference groundwater model. A conceptual geological model representing the major layers including aquitards and aquifers was initially set up for the watershed to adequately represent flows in the groundwater system. A number of soil parameters e.g. hydraulic conductivity and storage coefficients, are specified and appropriate boundary conditions are set up. The delineation of boundary conditions is essential for obtaining a correct water balance for the groundwater basin. Moreover, water allocation from groundwater wells will affect the water balance significantly and impact groundwater levels locally.

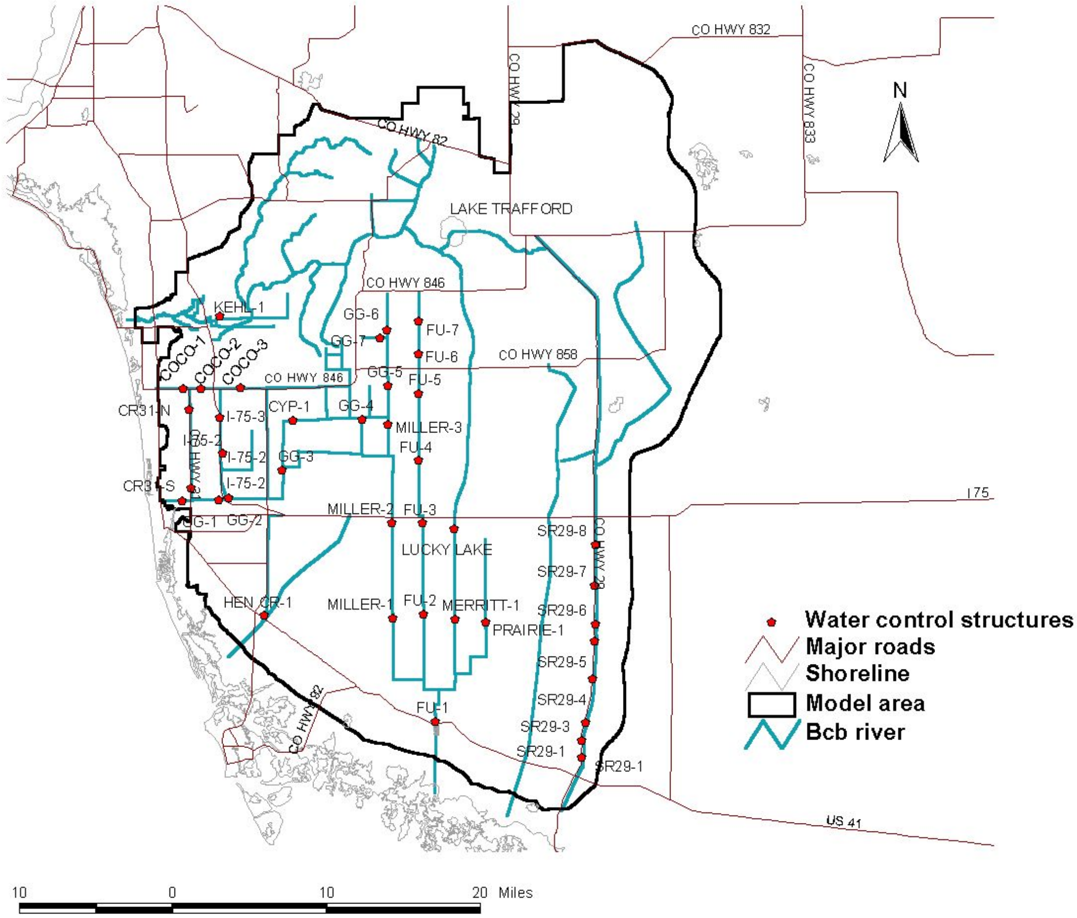


Figure 10. Control structures in the BCB model (1995 conditions).

Similarly groundwater drainage will affect water levels and the dynamics of groundwater levels primarily in the shallow aquifers.

The surficial and intermediate aquifer system in the BCB watershed is represented by a number of aquifers and aquitards in a conceptual geological model. The subsurface system is divided into the following aquifers:

- Water Table aquifer
- Lower Tamiami aquifer
- Sandstone aquifer
- Mid Hawthorn aquifer

The listed aquifers are assumed to account for the exchange with the river and canal network and to constitute the major source of groundwater in the model area. The deeper Floridian aquifer system is not considered to be recharged or add to the water available in the overlying aquifer systems. According to geological surveys in the area, negligible exchange occurs between the Mid Hawthorn and the underlying Floridian aquifer. A profile of the geological model in MIKE SHE is represented in Figure 11.

The shallow water table aquifer exists in the entire watershed with a fairly small thickness of approximately 25 ft (8 m) in the coastal region extending to a thickness of approximately 145 ft (44 m) north east of the Corkscrew and Camp Keais Strand areas in the Lake Trafford area (see Figure 12). The combined Tamiami/Sandstone aquifer reaches a thickness of approximately 300 ft (91 m) in the middle of the watershed. The mapped thickness of the aquifer in Figure 13 reveals a rather steep discontinuity where the different geological formations (available from the MODFLOW model) from Lee County and Collier County meet. The aquitard separating the two upper aquifers exists in

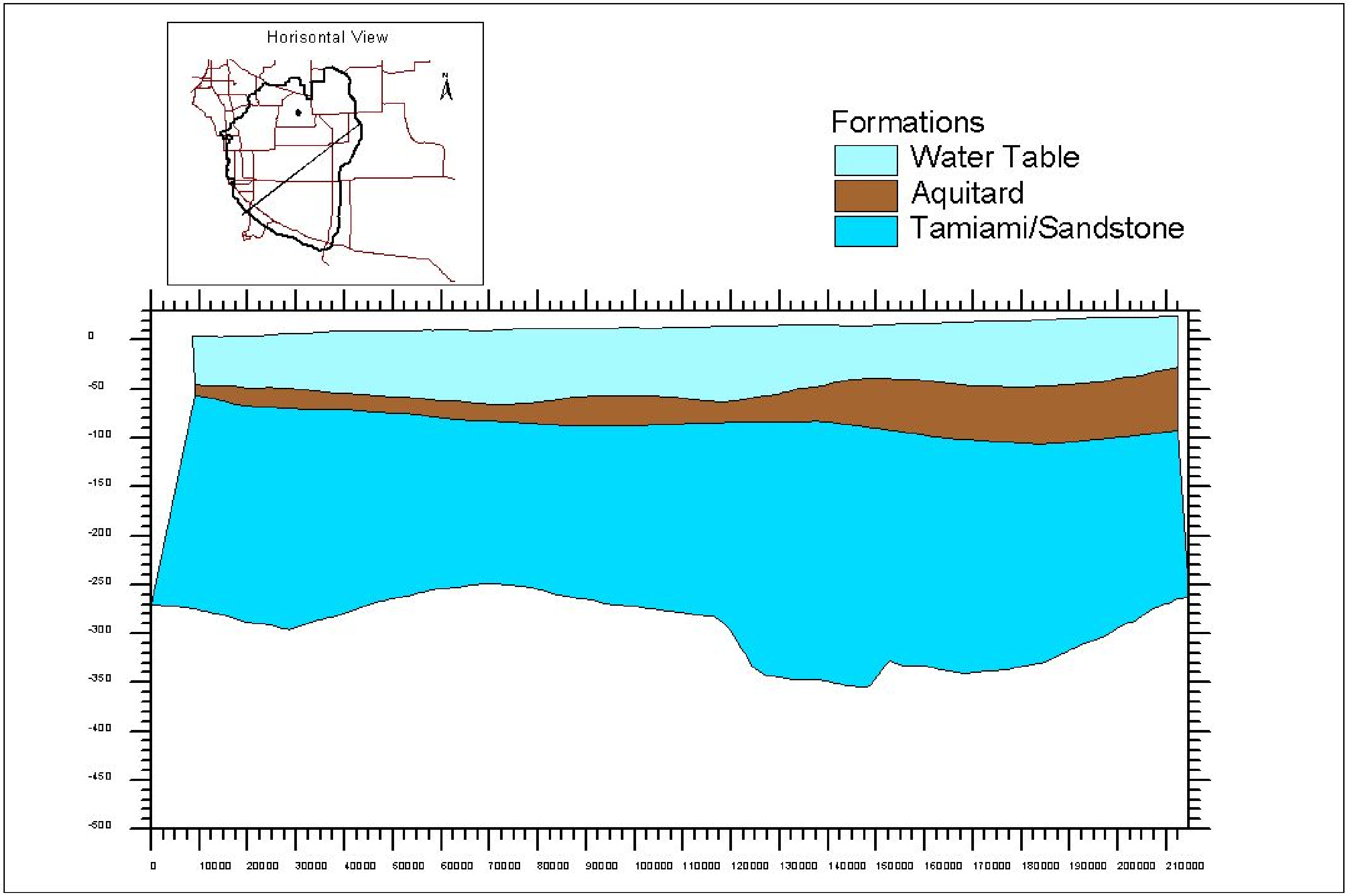


Figure 11**.** West-East cross-sectional geological profile in the Big Cypress Basin (elevation in feet).

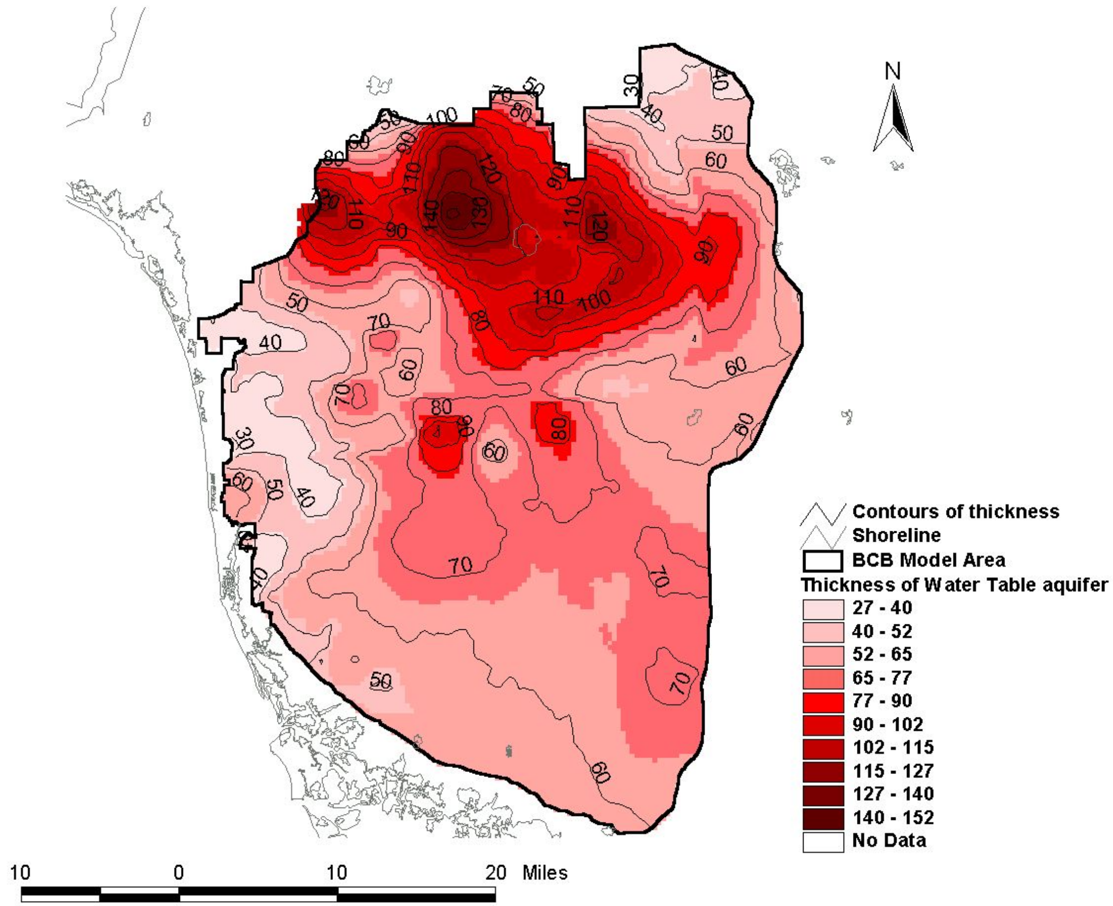


Figure 12. Thickness in feet of the Water Table aquifer in a 1500 ft (457.2 m) grid.

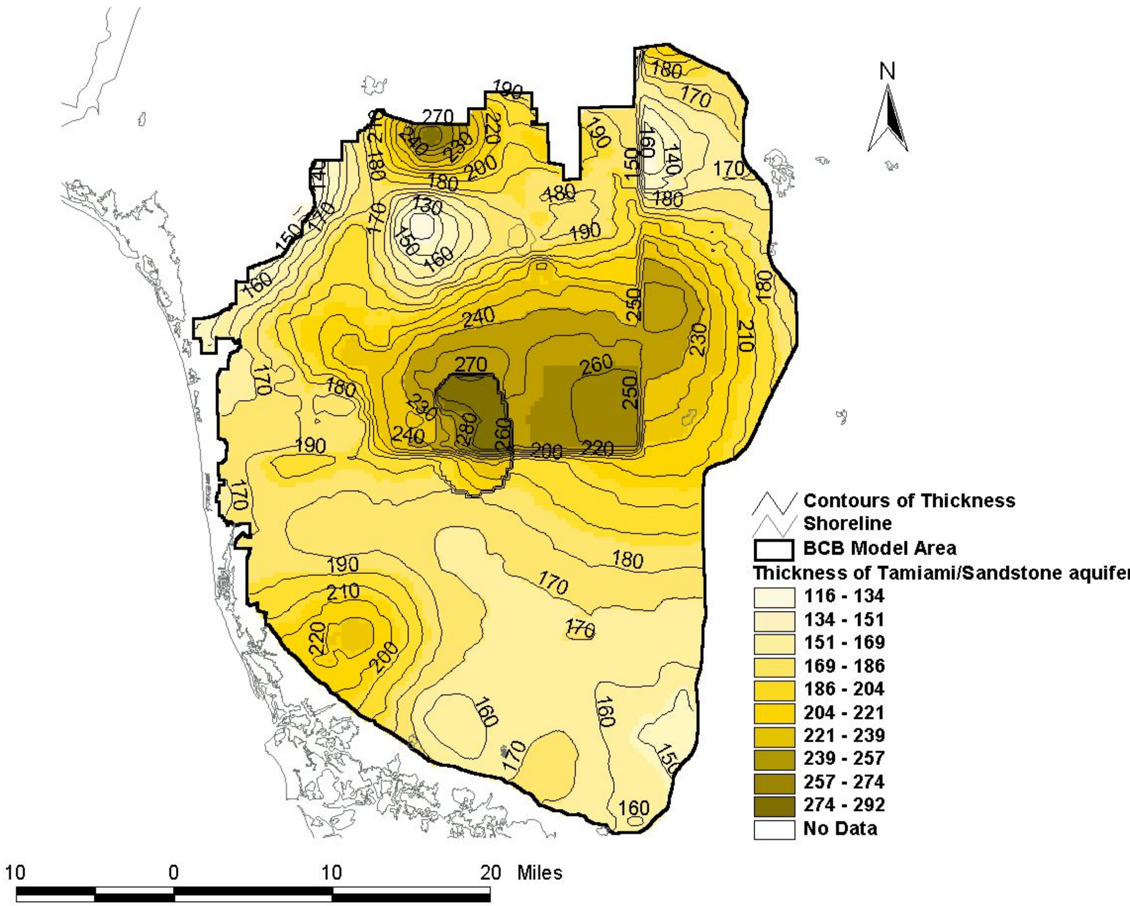


Figure 13. Thickness in feet of the combined Lower Tamiami/Sandstone aquifer in a 1500 ft (457.2 m) grid.

this area whereas in the northern areas the water table aquifer is in direct contact with the Sandstone/Hawthorn aquifer.

Soil properties were available in the existing Estero Bay model and the MODFLOW model for Collier County. Initially, the horizontal hydraulic conductivities from the two models were merged and interpolated to the BCB grid. As for the vertical conductivities, these were assessed based on the values used in the Estero Bay model and the leakage coefficients from MODFLOW. Uniform values for the storage coefficients were taken from the MODFLOW model and thus a specific yield of 0.2 was used for the surficial aquifer and the storage coefficient was set at $1 \cdot 10^{-5}$ m^{-1} for the combined lower Tamiami and Sandstone aquifers multiplied by the aquifer thickness. The final soil properties were determined through calibration of the model. The boundary conditions and different model parameters are described in detail in the report prepared by DHI (2002).

2.6 CALIBRATION

The integrated surface water-groundwater management model for BCB is calibrated and validated so that the model represents actual H&H conditions prevalent in the domain. A well calibrated and validated model ensures better performance in evaluating scenarios associated with different water resources management projects. The performance of this type of integrated model will depend on a number of factors as follows:

- Model conceptualization
- Quantity and quality of input data
- Model parameters
- Accuracy, availability and distribution of field observations
- Mathematical/numerical model application

The model conceptualization and other factors involved in analyzing the performance of the model were described in the DHI's report (2002). The conceptual model for the BCB area was developed by analyzing hydrologic data. The items of basin hydrologic data were incorporated in MIKE SHE as given in Table 2. The channel hydraulic characteristics were incorporated in MIKE 11 model. The model was calibrated and validated for a period from 1990-1995 including a number of dry and wet years. The model was mainly calibrated for the period from 1990-1992 and validated against observations from 1993-1995 to demonstrate that the calibrated model was capable of reproducing field data measured outside the calibration period. A number of key calibration parameters were identified for the model. The parameters adjusted during calibration and their ranges are given in Table 3.

The main calibration data comprise river flows and stages at a number of gauging stations and a number of monitored groundwater levels in both the shallow and deep aquifers. Stream flows have been recorded for the simulation period from 1990-95 at four stations located at the outlets of the main rivers and canals. The stage and discharge station locations are outlined in Figure 14. Groundwater observations consist of 38 records of monitored potential head in the watershed. The wells generally cover most of the watershed and as such constitute a good basis for the calibration. The well locations are presented in Figure 15.

The rigorous calibration and validation for both surface water and groundwater system in the BCB area are illustrated in the modeling report (DHI, 2002). The comparisons of observed data and simulated results at different locations in the channels are given in figures in Appendix A. The graphs illustrating observed and model simulated groundwater levels are given as well in Appendix A.

Table 2. List of model input and parameters for MIKE SHE.

Model Component	Model Input	Model Parameters
MIKE SHE SZ Saturated zone flow	Geological model (lithological information Boundary conditions Drainage depth (drain maps) Wells and withdrawal rate	$K_{h,}$ Horizontal hydraulic conductivity $K_{v,}$ Vertical hydraulic conductivity S, confined storage coefficient S , unconfined storage coefficient Drainage time constant
MIKE SHE UZ Unsaturated zone flow	Map of characteristic soil types Hydraulic Conductivity Curves Retention curves	Ks, saturated hydraulic conductivity Θs Saturated water content Θ_{res} Residual water content Θ_{eff} Effective saturation water content pFc, Capillary pressure at field capacity pFw, Capillary pressure at wilting point n, Exponent of hydraulic conductivity curve
MIKE SHE ET Evapotranspiration	Time series of vegetation Leaf Area Index Time series of vegetation root depth	C_1, C_2, C_3 : Empirical parameters C_{int} : Interception parameter A_{root} :Root mass parameter Kc : Crop coefficient
MIKE SHE OC Overland and river/canal flow (MIKE11)	Topographical map Boundary conditions Digitized river/canal network River/canal cross sections	M, Overland Manning no. D , Detention storage L, leakage coefficient M, River/canal Manning no.
MIKE SHE IRR Irrigation module	Irrigated areas Irr. sources (pumps/canals/reservoirs) Distribution method (sheet, sprinkler, drip) Source capacity	Eact/Epot, crop water stress factor (target ratio between actual and potential evapotranspiration rates) Well threshold

Table 3. Primary parameters adjusted during calibration.

Model Component	Calibration Parameters	Parameter Range
MIKE SHE SZ – Saturated zone flow	K_v: Vertical hydraulic conductivity (m/s) K_H/K_v Drainage time constant (s^{-1}) Drain depth (m) Boundary conditions (-)	$1 \cdot 10^{-8}$- $1 \cdot 10^{-6}$ $10\text{-}10^{6}$ 0.00001 - 0.001 0-1.25 0/2
MIKE SHE OC – Overland and river/canal flow (MIKE11)	M, Overland Manning no. $m^{1/3}/s$ D , Detention storage (m) L, leakage coefficient (s^{-1}) River M/Canal Manning no. ($m^{1/3}/s$) Floodplains M ($m^{1/3}/s$)	1-10 0.01 m (0.03 ft) $1 \cdot 10^{-4}$ – $1 \cdot 10^{-7}$ 10-30 2-10
MIKE SHE ET – Evapotranspiration module	Kc, Crop coefficient Aroot, Root distribution Root depth	0.25-1.0 0.25-0.75 0.3-1.8

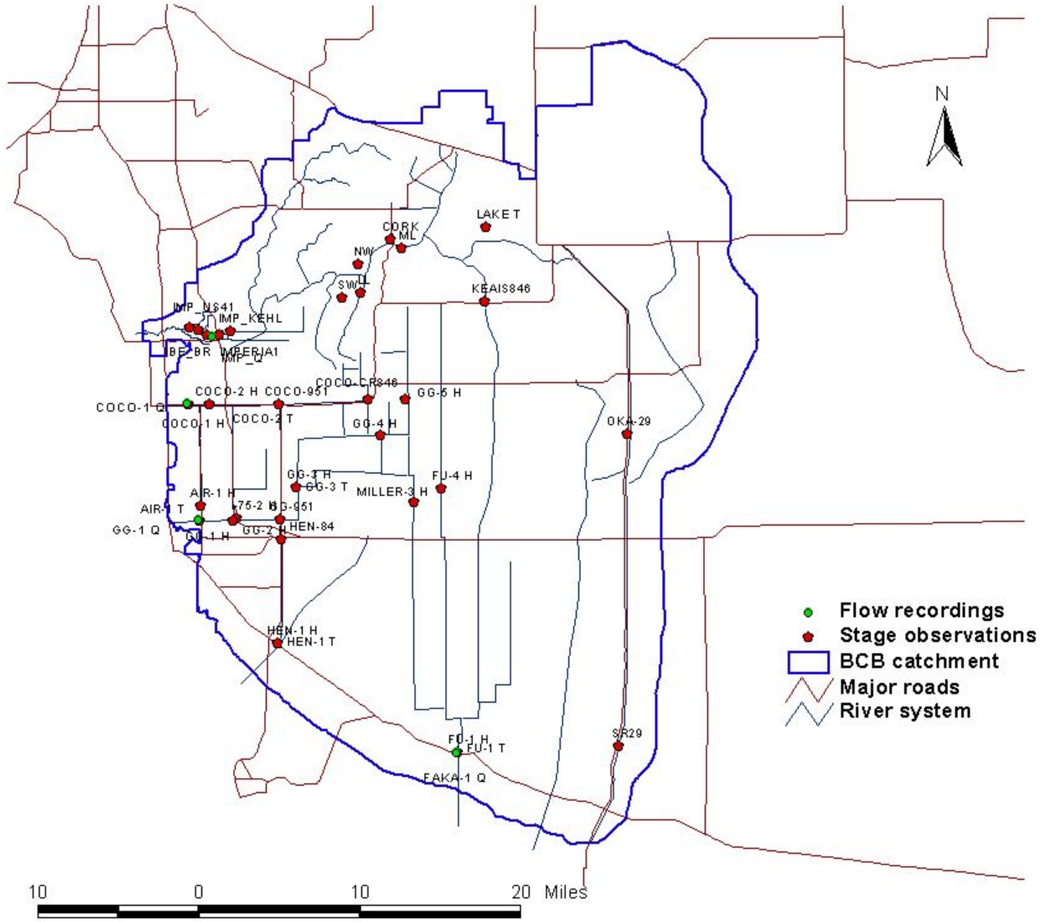


Figure 14. Locations of flow and stage observations for 1990-95.

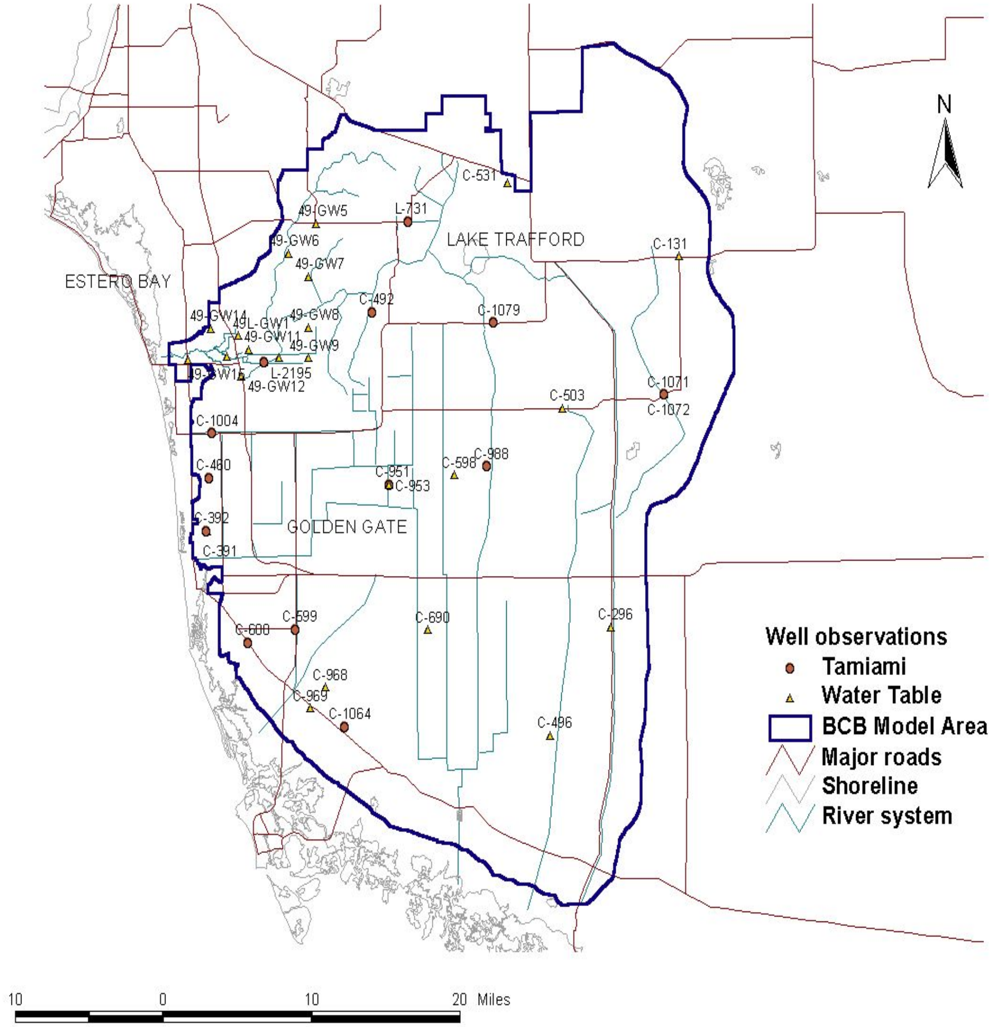


Figure 15. Groundwater well observations for 1990-1995 in the Big Cypress Basin watershed

3 DESIGN STORM SIMULATIONS

3.1 DESIGN STORM EVENT

The design storm used for the Corkscrew Canal improvements is a 25-year, 3-day event. Intensity-duration-frequency distribution of the design rainfall event was obtained from the South Florida Water Management District (SFWMD) Permit Information Manual Volume V (1999). A 25-year, 3-day rainfall magnitude of 11 inches was used for the design storm simulation. The distribution of rainfall over a 3-day period is shown in Figure 16.

The calibrated model was run for the design storm event. In the MIKE SHE-MIKE 11 model, the unsaturated zone module cannot be initialized with given antecedent soil moisture conditions and consequently the rainfall event data was placed in the existing rainfall records from August 1 to August 3, 1995. The soil moisture content at this time can be assumed close to the saturation due to the rainfall occurring in June and July and the simulation may as such be considered a worst-case scenario.

3.2 CHANNEL FLOW MODELING

The calibrated interactive MIKE SHE-MIKE 11 model was used to simulate the existing canal condition. Hydraulic design of channel improvements, culvert replacement, and water control structures was a two step process. The first step utilized the "channel improvement" option of the Corps of Engineers' Hydrologic Engineering Center River Analysis System (HEC RAS) program (U.S. Army Corps of Engineers, 1997) for designing the improved channel based on target invert elevation, slope, and bottom width. The second step utilized the integrated model to investigate the performance of the configuration of the canal in an unsteady state condition. The modified channel geometry data are organized and reformatted for entry into the MIKE

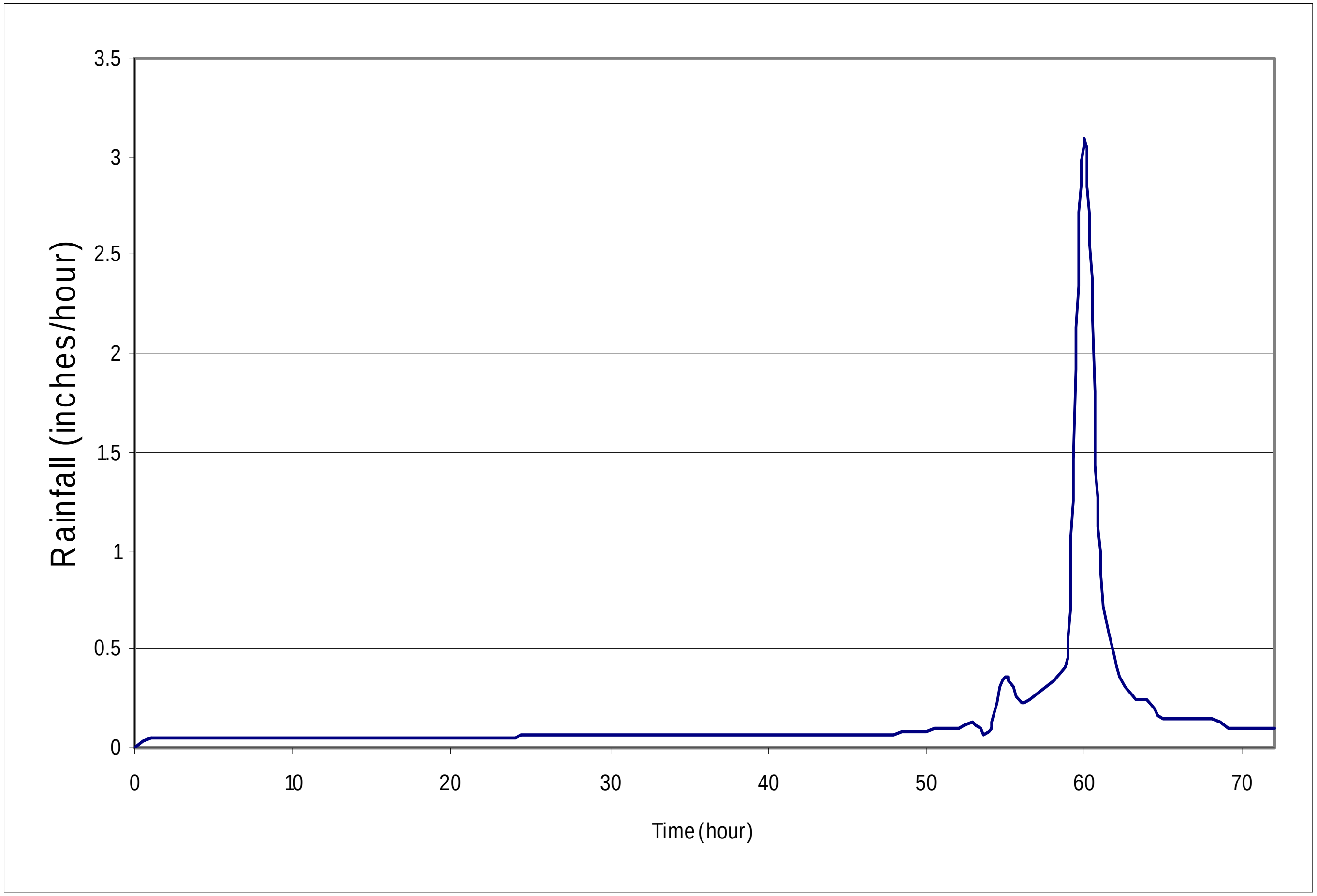


Figure 16. Distribution of 25-year 3-day rainfall.

11 model. The channel flows and stages are then simulated with the modified geometry to compare the performance against the existing condition in terms of the water resources and environmental system management.

3.2.1 HYDRAULIC PERFORMANCE OF EXISTING CANAL

The calibrated unsteady state integrated model for BCB was used to simulate the existing canal condition. The existing canal crossing structures are summarized in Table 4. The canal network with the existing Corkscrew Canal was simulated using MIKE SHE-MIKE 11 for the aforementioned 25-year, 3-day design storm event.

The Corkscrew Canal Flood profile for the 25-year storm runoff under existing conditions simulated by MIKE 11 model is presented in Figure 17.   The water surface profile indicates that the 25-year stages in the upper reaches of the canal do not stay within the banks. Several sections of the canal do not meet the criteria of maintaining 1.5 feet of freeboard under the design, 25-year flood conditions. The criteria for bridge and culvert crossings on the Corkscrew Canal are summarized in the SFWMD Permit Information Manual, Volume V (1999). All the existing structures noted in Table 4 do not meet District criteria for the use of works of the District. The head losses through the undersized culverts contribute significantly to the flooding shown in Figure 17. Head losses at these crossing locations are illustrated in Table 4.

3.2.2 IMPROVEMENT SCENARIO

The Corkscrew canal improvement scenario was first evaluated using U. S. Army Corps of Engineers HEC RAS model. The cutting and improvement option of HEC RAS model was used to modify the geometry with calculation for the amount of excavation needed for the canal. The modified geometry was reformatted from HEC RAS for entry into the MIKE 11 model. The integrated MIKE SHE-MIKE 11 modeling system is then

Table 4. Existing Corkscrew Canal Crossings

Model (MIKE 11) Station (Chainage, m)	Approximate Miles North of Cypress Canal	Name	Structure	Invert Elevation (in feet)		Existing Head Loss (ft)
				Upstream	Downstream	
6551	2.14	Sluice Gate	Two 9 ft (span) by 9 ft (rise)	4.23	4.23	0.21
6551	2.14	Immokalee Road	Two 9 ft (span) by 9 ft (rise) Box Culvert	4.38	4.07	0.21
3914	3.6	33rd Avenue	Two 48-inch RCP	7.85	7.85	0.43
3322	3.85	35th Avenue	Two 48-inch RCP	9.0	9.18	0.27
2939	4.09	37th Avenue	Two 48-inch RCP	9.81	8.85	0.26
2547	4.34	39th Avenue	Two 48-inch RCP	9.25	9.22	0.44
2148	4.52	41st Avenue	Two 48-inch RCP	9.07	9.03	0.50
1780	4.57	43rd Avenue	Two 48-inch RCP	10.28	9.69	0.07

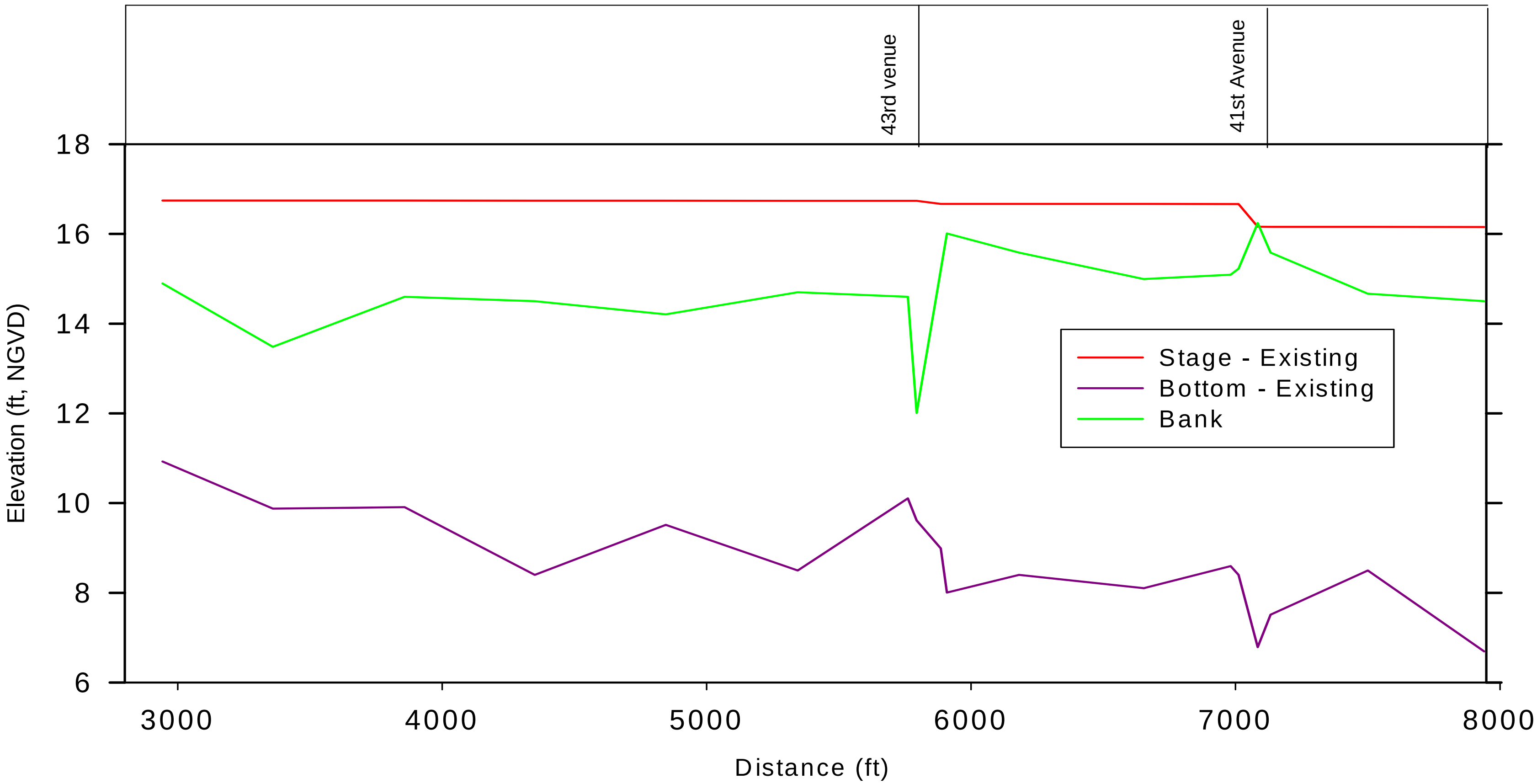


Figure 17a. Corkscrew Canal simulated water surface profile for existing condition.

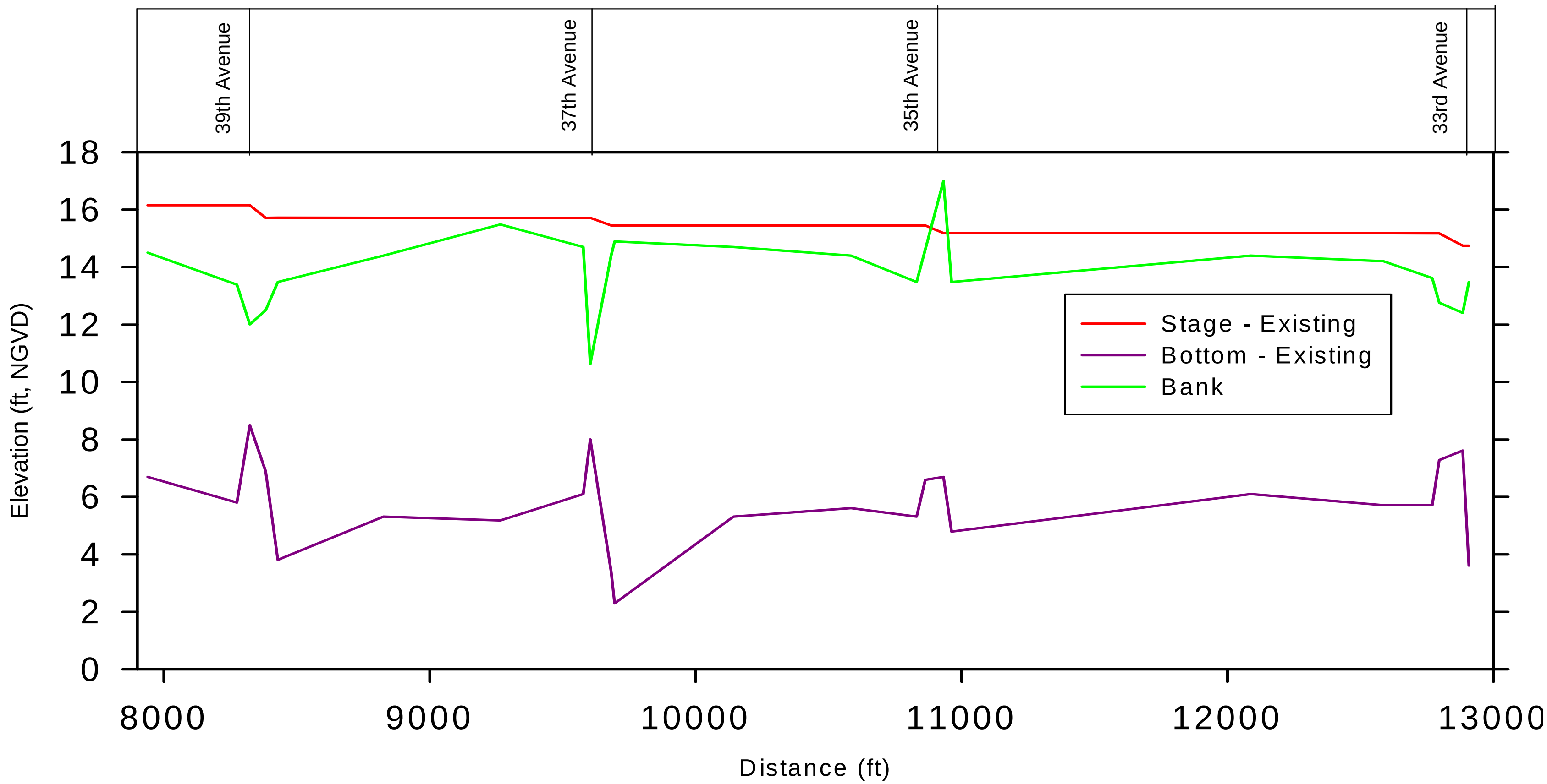


Figure 17b. Corkscrew Canal simulated water surface profile for existing condition.

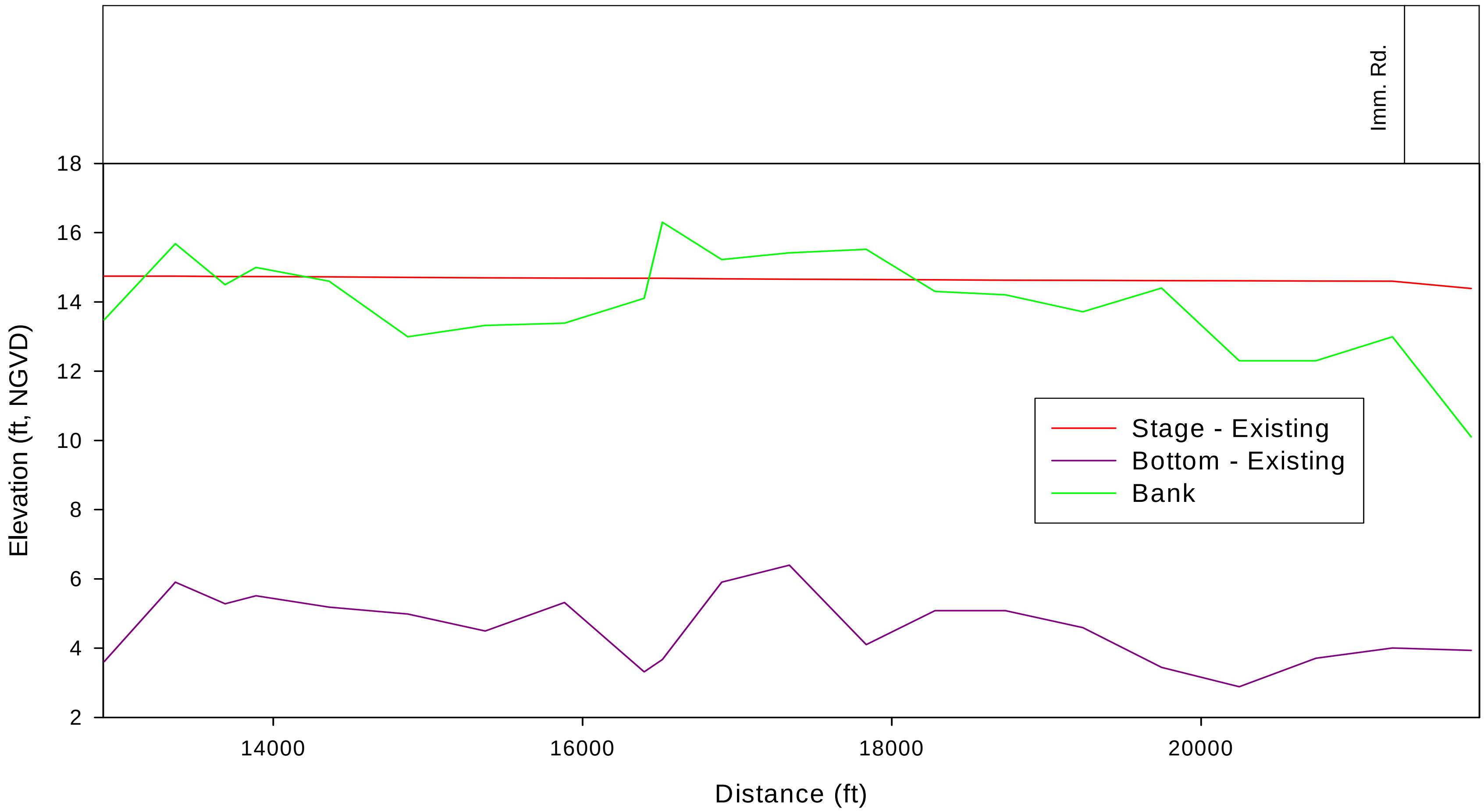


Figure 17c. Corkscrew Canal simulated water surface profile for existing condition.

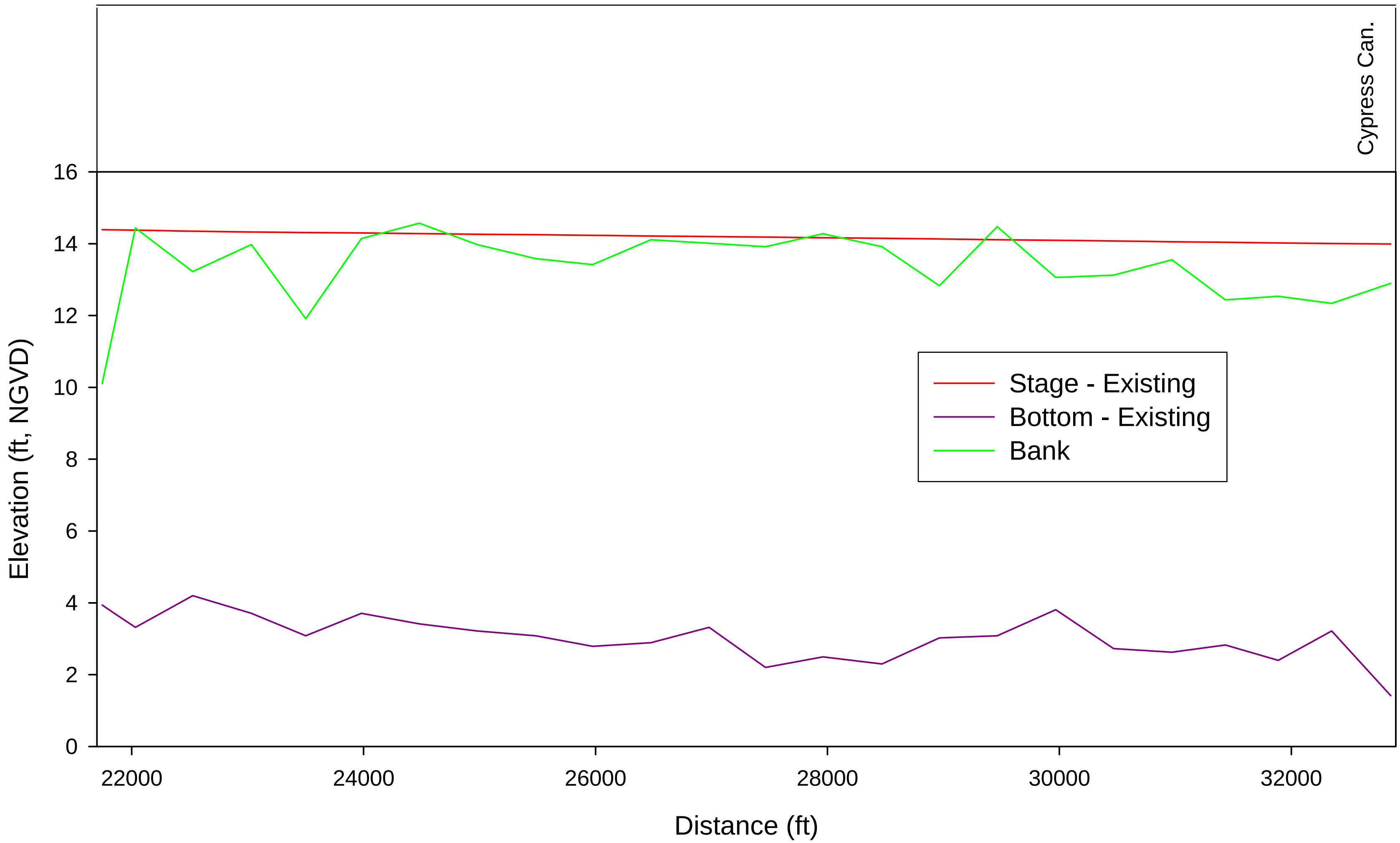


Figure 17d. Corkscrew Canal simulated water surface profile for existing condition.

run for hydraulic evaluation of the modified canal including structural improvements. The existing and proposed cross sections at a few locations are shown in Figure 18.

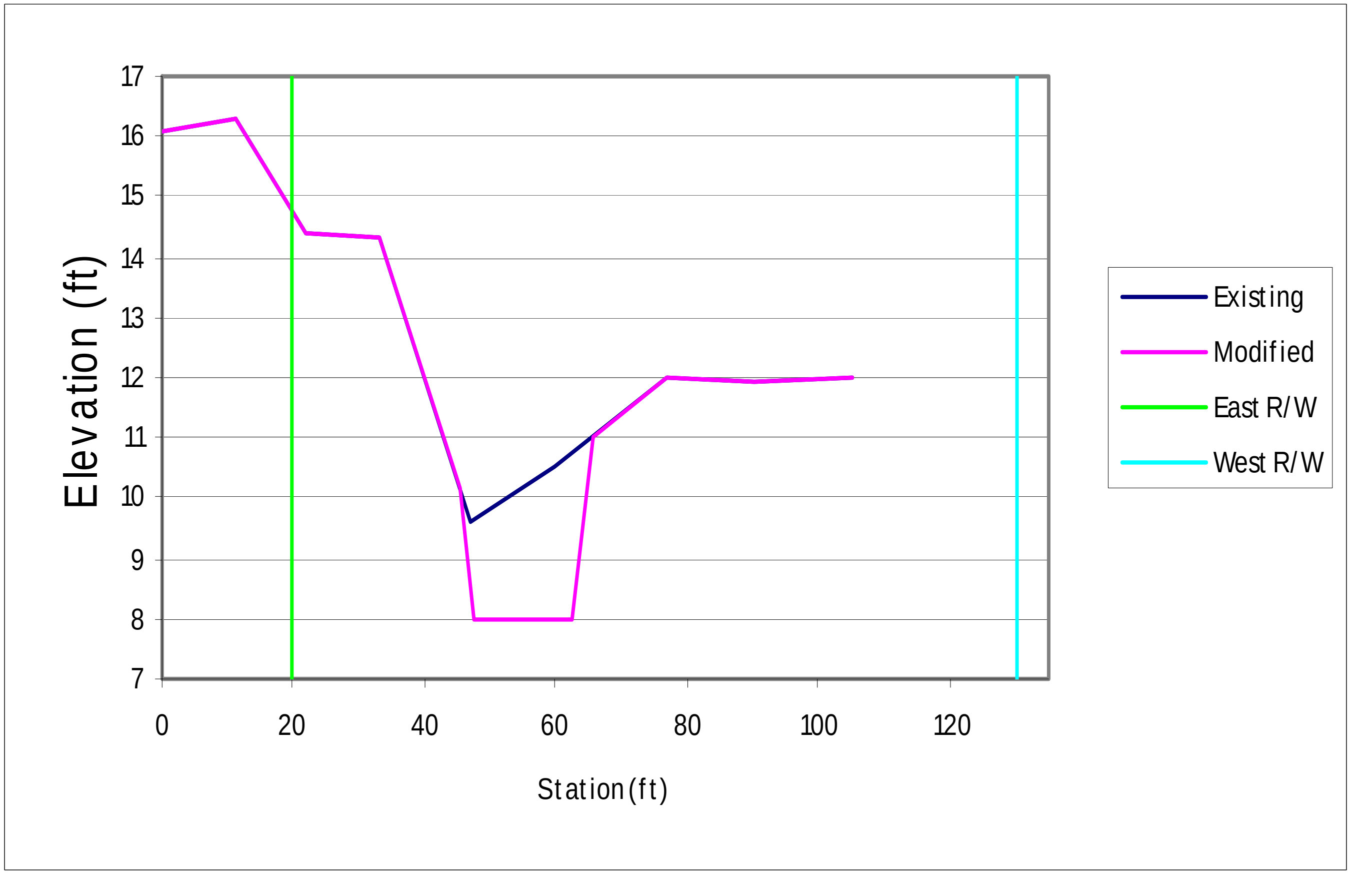


Figure 18a. A typical Corkscrew Canal section upstream of 43rd Avenue.

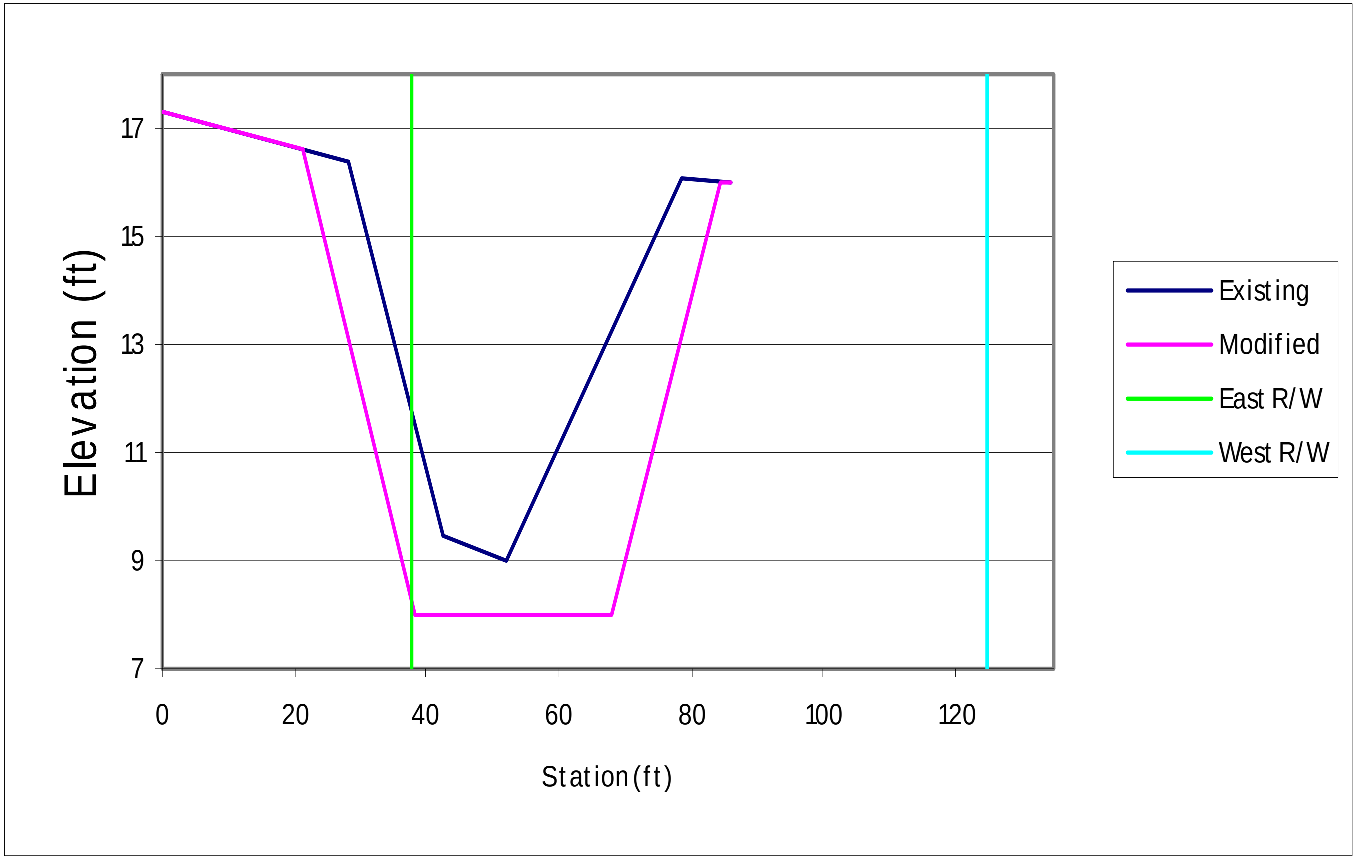


Figure 18b. A typical Corkscrew Canal section just downstream of 43rd Avenue.

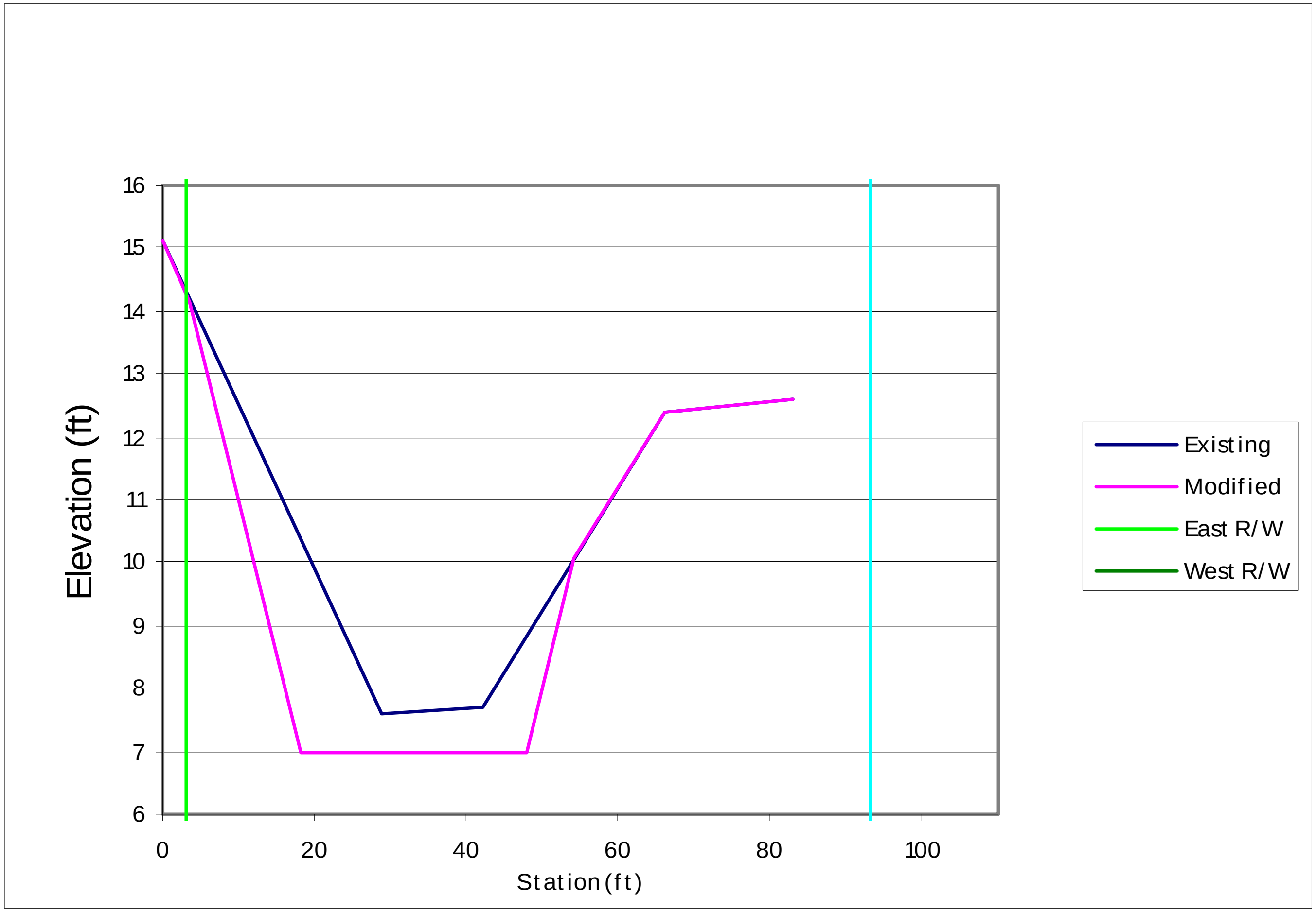


Figure 18c. A typical Corkscrew Canal section just downstream of 33rd Avenue.

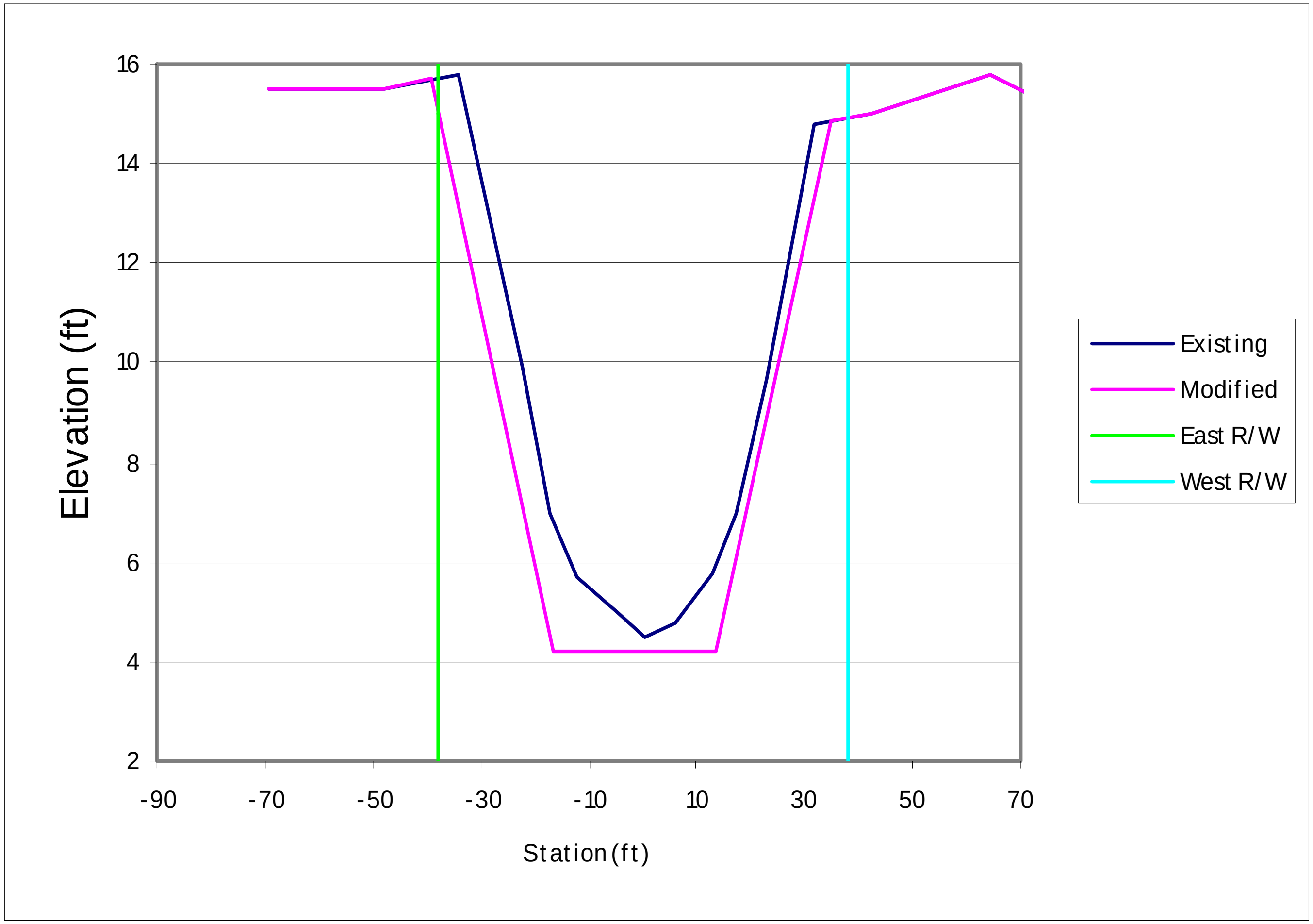


Figure 18d. A typical Corkscrew Canal section just downstream of 33rd Avenue.

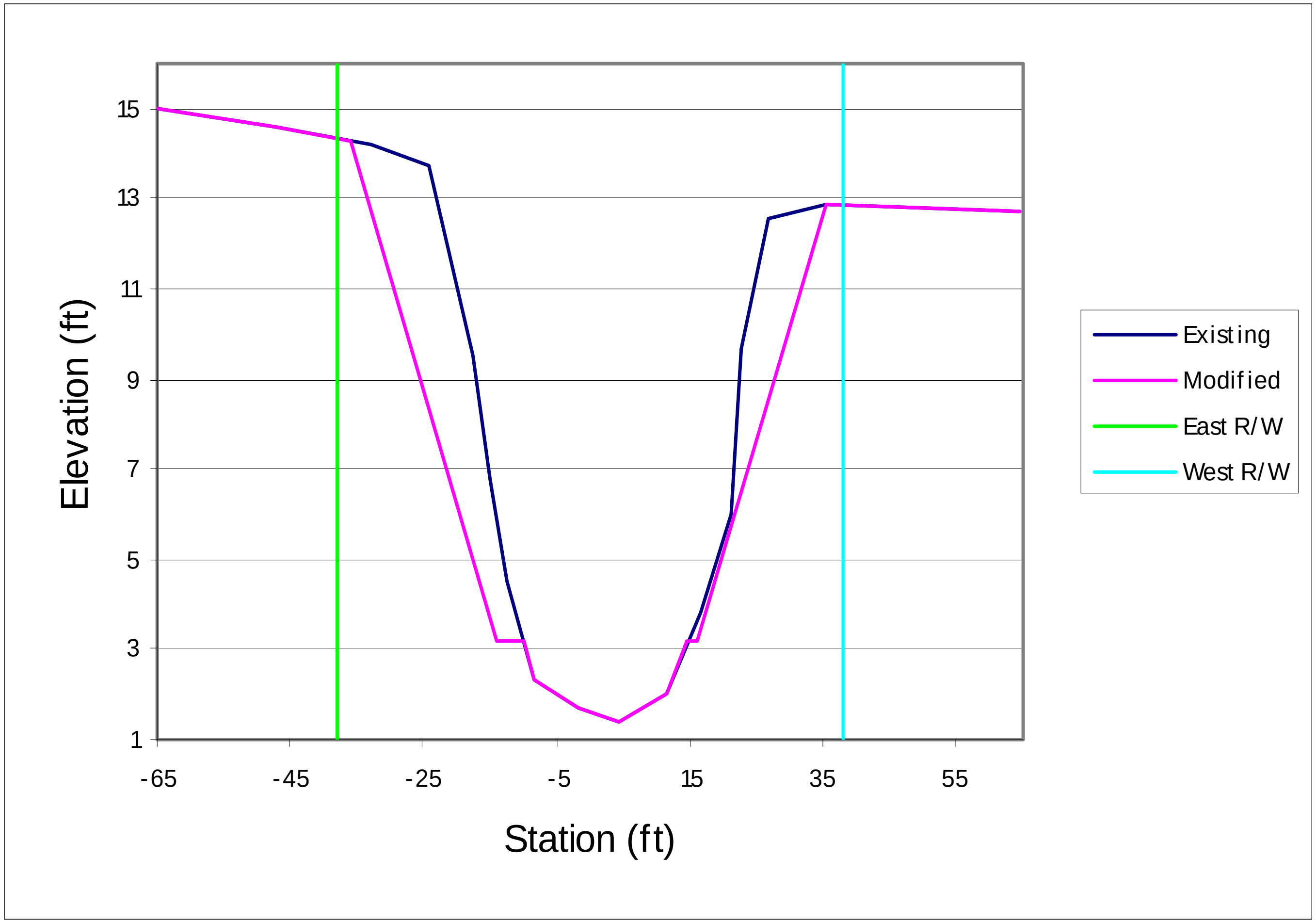


Figure 18e. A typical cross section just downstream of 39th Avenue.

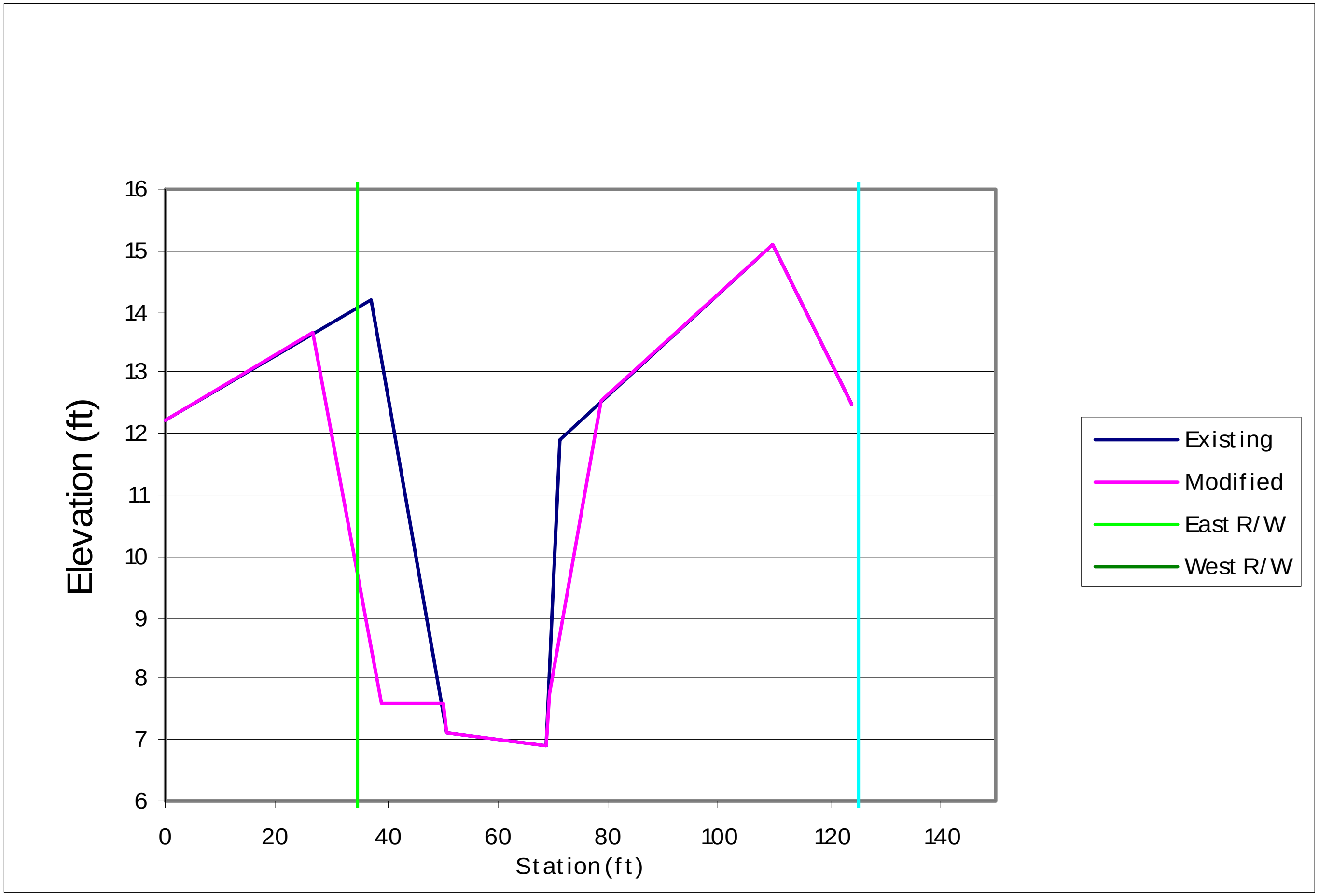


Figure 18f. A typical cross section just upstream of Cypress Canal.

More cross sections illustrating the existing and proposed conditions are given in Appendix B.

Hydraulic analyses are performed using the MIKE SHE-MIKE 11 model for different scenario of canal modifications at the hydraulically deficient reaches of the Corkscrew Canal to assess the most efficient 25-year peak flow conveyance enhancement at minimal excavation and cost for the project reach. The channel excavation scenario is based on a bottom slope of 0.5 foot per mile. The modified channel cross section has a bottom width of 15 feet with a side slope of 1:1 (horizontal:vertical) from 43rd Avenue to the upstream end of the canal. From 43rd Avenue to the downstream end of the canal (confluence with Cypress Canal), the modified canal includes a bottom width of 30 ft, bottom slope of 0.5 ft per mile, and a side slope of 2:1 (horizontal:vertical). The proposed culvert replacements include replacing the 43rd Avenue culvert by a double-barrel 10 ft by 8 ft gated box culvert and replacing 41st Avenue, 39th Avenue, 37th Avenue, 35th Avenue, and 33rd Avenue culverts by 25-ft single span bridges to maximize the conveyance capacity.

The proposed changes in canal cross section configurations, with respect to the existing conditions, are summarized in Table 5. The flow areas of the water control structures for the existing and modified conditions are summarized in Table 6. The proposed canal configurations were found to be the most effective way to provide the design conveyance for the hydraulically deficient reaches of Corkscrew Canal. The general configurations of the modified culvert at 43rd Avenue and the 25 ft. single span bridges at 41st Avenue, 39th Avenue, 37th Avenue, 35th Avenue and 33rd Avenue are shown in Appendix C. The enlarged Corkscrew Canal cross sections and structural improvements outlined in Table 5 and in Figure 18 were incorporated into the MIKE 11 model described earlier.

Table 5. Summary of Corkscrew Canal cross sections.

Location	Model (MIKE 11) Section	Miles North of Cypress Canal	Existing Conditions		Proposed Conditions	
			Bottom Width (ft)	Bottom Elevation (ft)	Bottom Width (ft)	Bottom Elevation (ft)
Confluence with Cypress Canal	10014	0	20	1.4	30	1.4
Immokalee Road downstream	6551	2.15	13	4.5	30	4.23
33rd Avenue downstream	3914	3.61	13	7.65	30	7
35th Avenue downstream	3322	3.86	25	5	30	5
37th Avenue downstream	2939	4.1	12	3.4	30	3.4
39th Avenue downstream	2547	4.35	14	7	30	7
41st Avenue downstream	2148	4.53	11.5	6.8	30	6.8
43rd Avenue downstream	1780	4.58	15	9.25	30	8
43rd Avenue upstream	1780	4.58	5	9.6	15	8
47th Avenue downstream	1024	5.05	7	9.9	30	8.23

Table 6. Summary of proposed canal crossing and water control structures on Corkscrew Canal.

Model Section	Miles North of Cypress Canal (miles)	Description	Existing		Proposed	
			Culvert	Flow area (ft^2)	Bridge/Water Control Structure	Flow area (ft^2)
33rd Avenue	3.6	Replace by a 25-ft span bridge	Two 48-inch RCP	25.1	Single Span	250
35th Avenue	3.85	Replace by a 25-ft span bridge	Two 48-inch RCP	25.1	Single Span	260
37th Avenue	4.09	Replace by a 25-ft span bridge	Two 48-inch RCP	25.1	Single Span	240
39th Avenue	4.34	Replace by a 25-ft span bridge	Two 48-inch RCP	25.1	Single Span	236
41st Avenue	4.52	Replace by a 25-ft span bridge	Two 48-inch RCP	25.1	Single Span	230
43rd Avenue	4.57	Replace by a two 10 ft by 8 ft box culverts	Two 48-inch RCP	25.1	Single Span	160
43rd Avenue	4.57	Install two 10 ft by 8 ft water control structure	-		Sluice gate	160

The hydraulic performance was simulated for a 3-day, 25-year design storm. The dynamically simulated stage and flow hydrographs at different locations for the existing and improved Corkscrew Canal conditions are illustrated in Figures 19 and 20 respectively. A summary of the simulated flows and stages is also presented in Table 7. The simulated peak water surface profiles for the existing and modified conditions for Corkscrew Canal, Cocohatchee East Canal and Cypress Canal are illustrated in Figures 21 through 23. The modified canal with structural improvements enhances the conveyance capacity of the canal causing a lower stage and a higher flow rate in the reaches upstream of 33rd Avenue. This will reduce the overbank flooding prevalent in the area. The changes in stages are not significant in the downstream reaches of the Corkscrew Canal. Similar insignificant changes are observed in the other adjacent canals due to the improvements in the Corkscrew Canal.

3.3 GROUNDWATER FLOW SIMULATION

The calibrated BCB MIKE SHE-MIKE 11 model was used to simulate the groundwater flow in the aquifer conceptualized based on the existing data and Collier County MODFLOW model. Information on the existing aquifer conditions was provided from different sources. The existing Estero Bay model (Christierson, 2001) contains bottom elevations and hydrogeologic properties for the water table aquifer, the lower Tamiami aquifer, and the Sandstone/Mid Hawthorn aquifer in the northern part of the BCB model area. This information was originally extracted from the existing calibrated regional SFWMD MODFLOW model for Lee County. The existing physically based conceptual model data were organized and entered into the MIKE SHE model. The proposed channel geometry configuration was incorporated in the MIKE 11 model. The existing and the proposed conditions were then simulated to investigate the aquifer response in terms of the water resources and environmental system management.

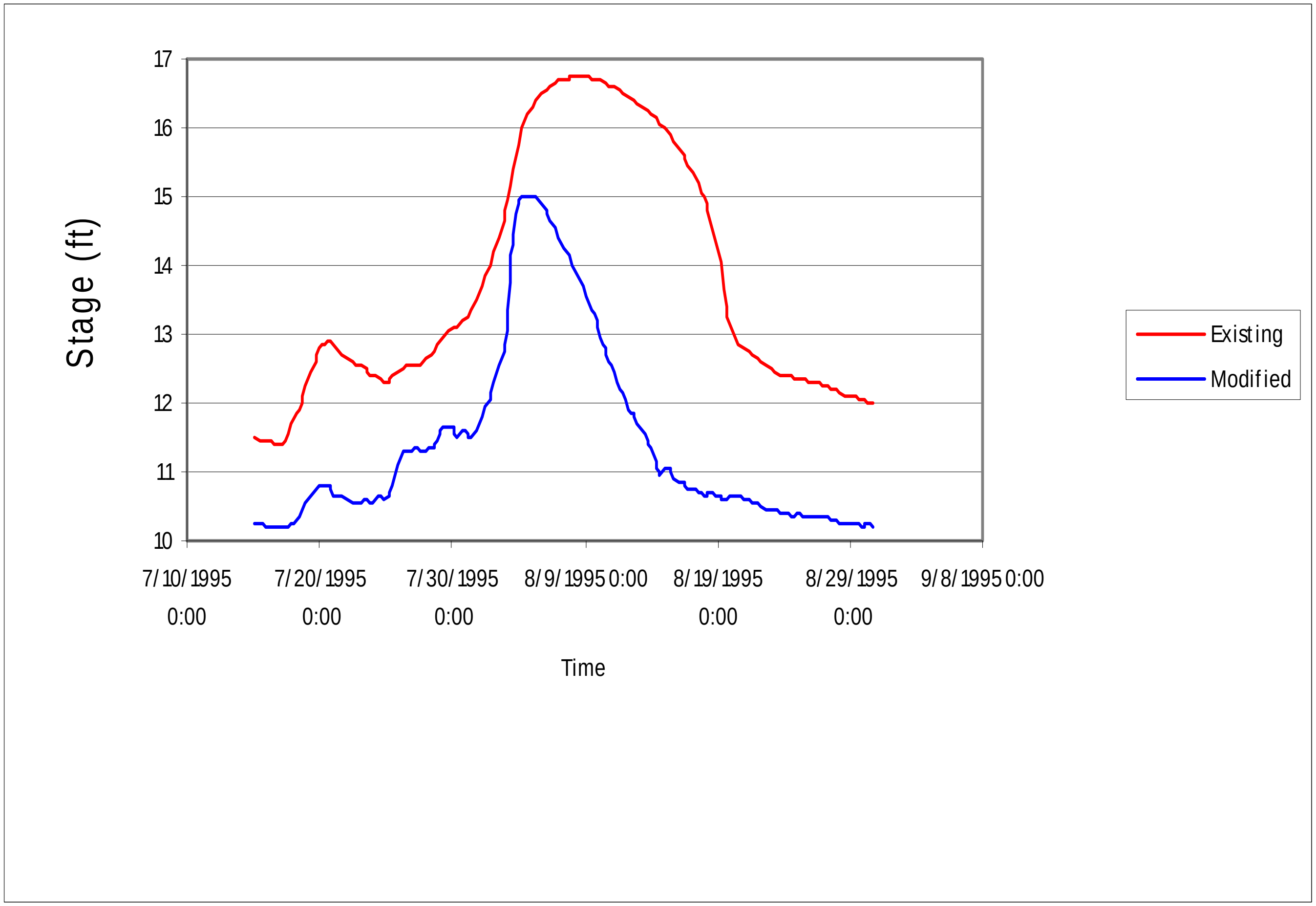


Figure 19a. Variations of stages in Corkscrew Canal at 43rd Avenue.

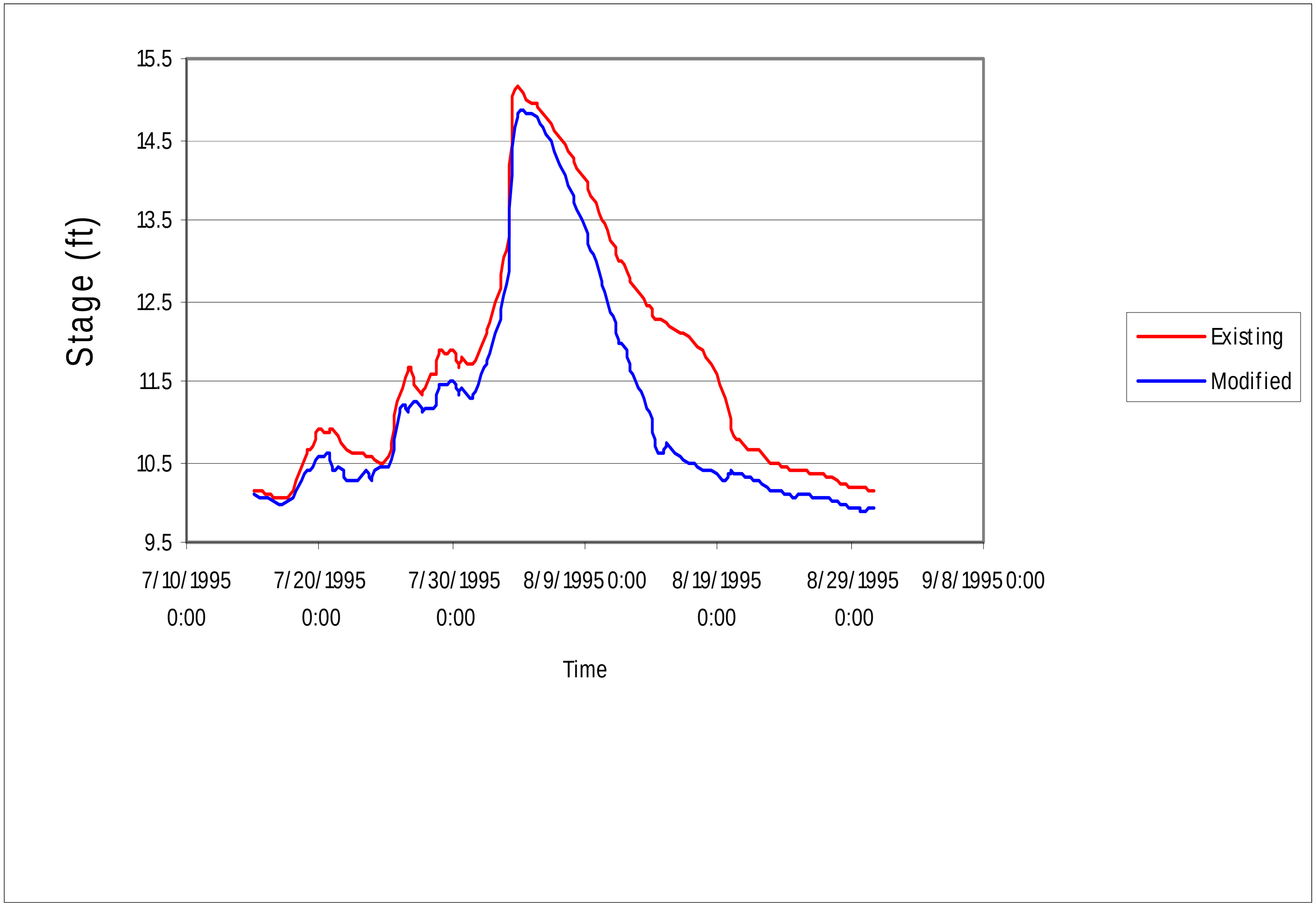


Figure 19b. Variations of stages in Corkscrew Canal at 33rd Avenue.

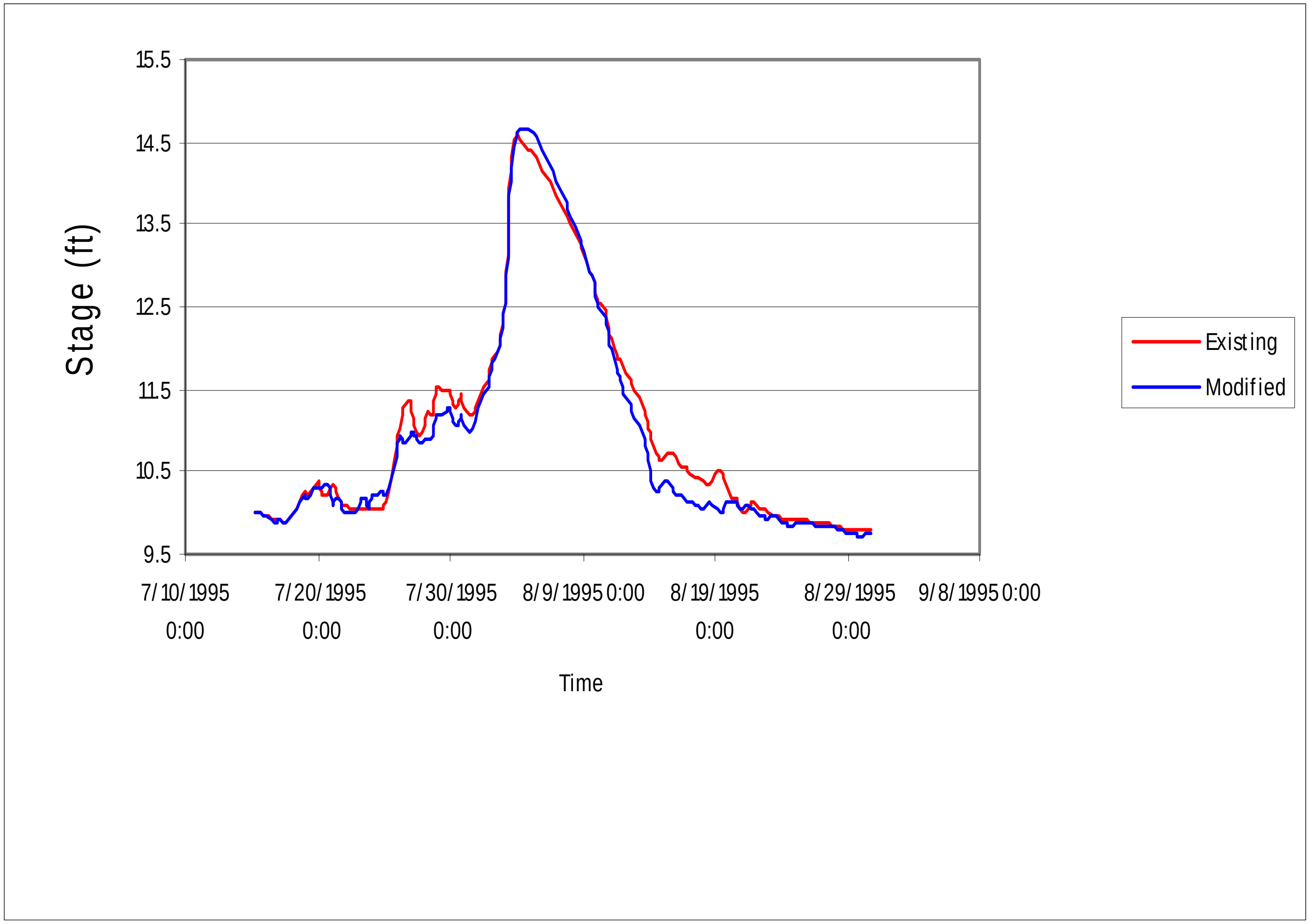


Figure 19c. Variations of stages in Corkscrew Canal at the confluence with Cocohatchee Canal.

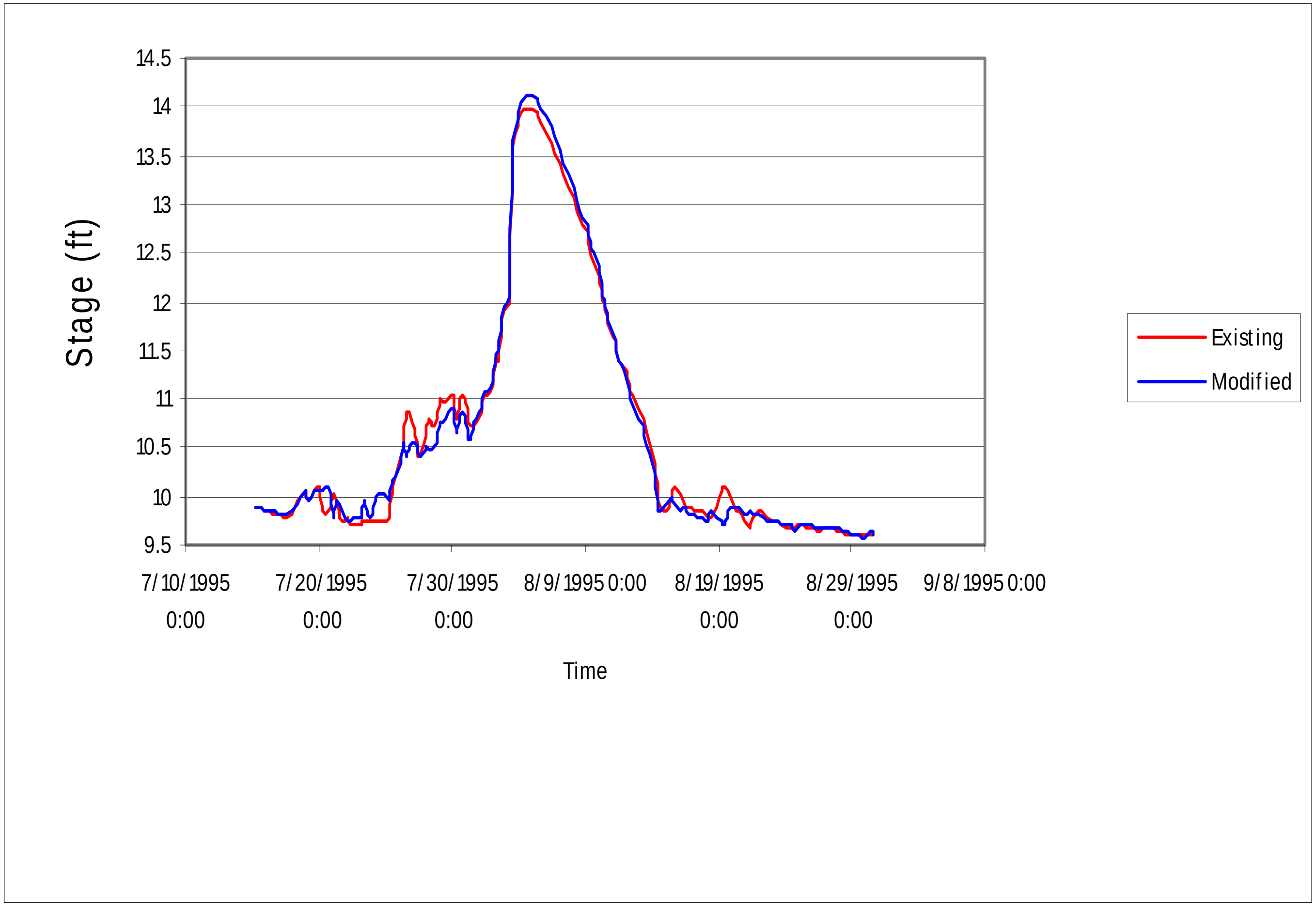


Figure 19d. Variations of stages in Corkscrew Canal at the confluence with Cypress Canal.

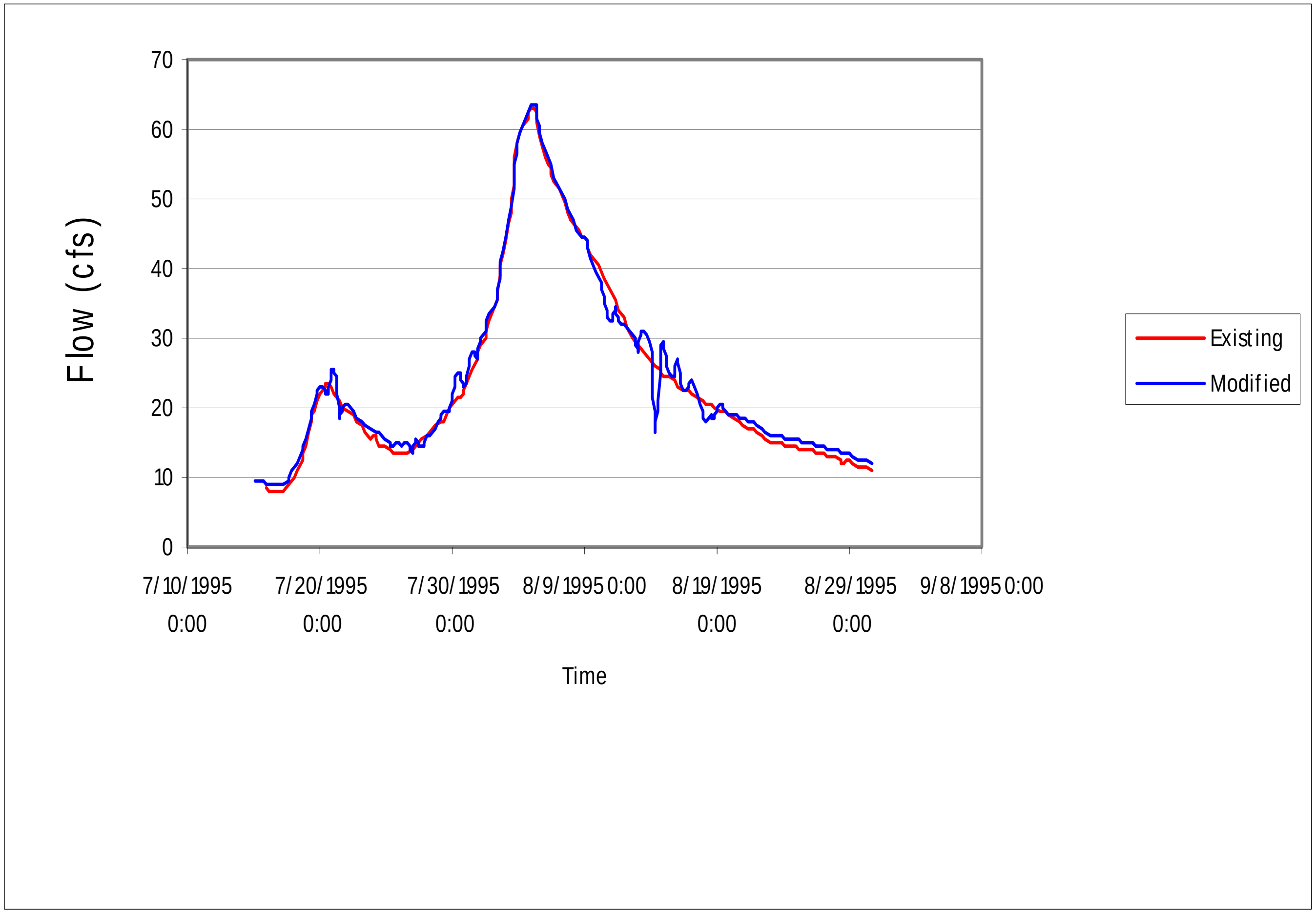


Figure 20a. Variations of flows in Corkscrew Canal at 43rd Avenue.

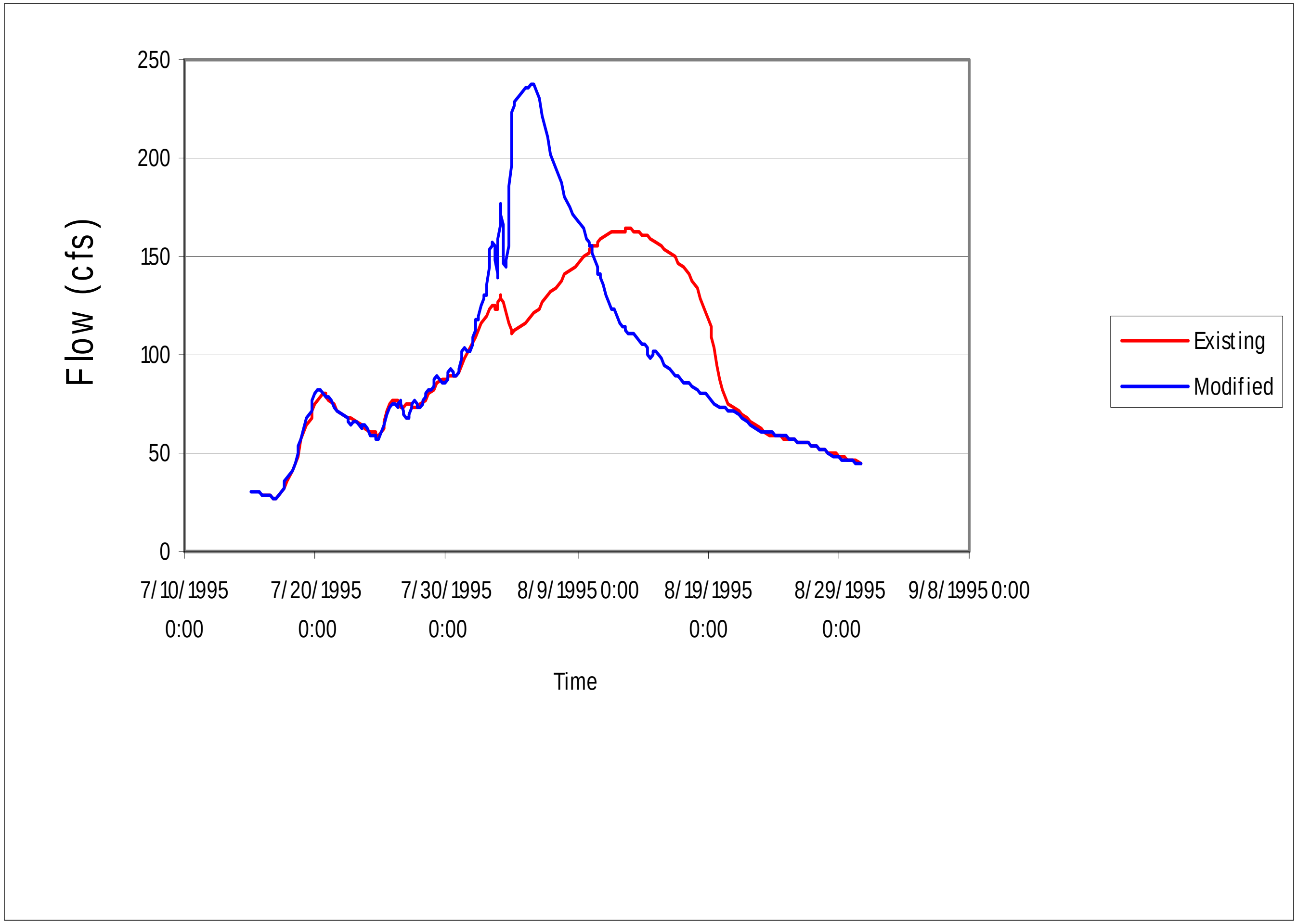


Figure 20b. Variations of flows in Corkscrew Canal at 33rd Avenue.

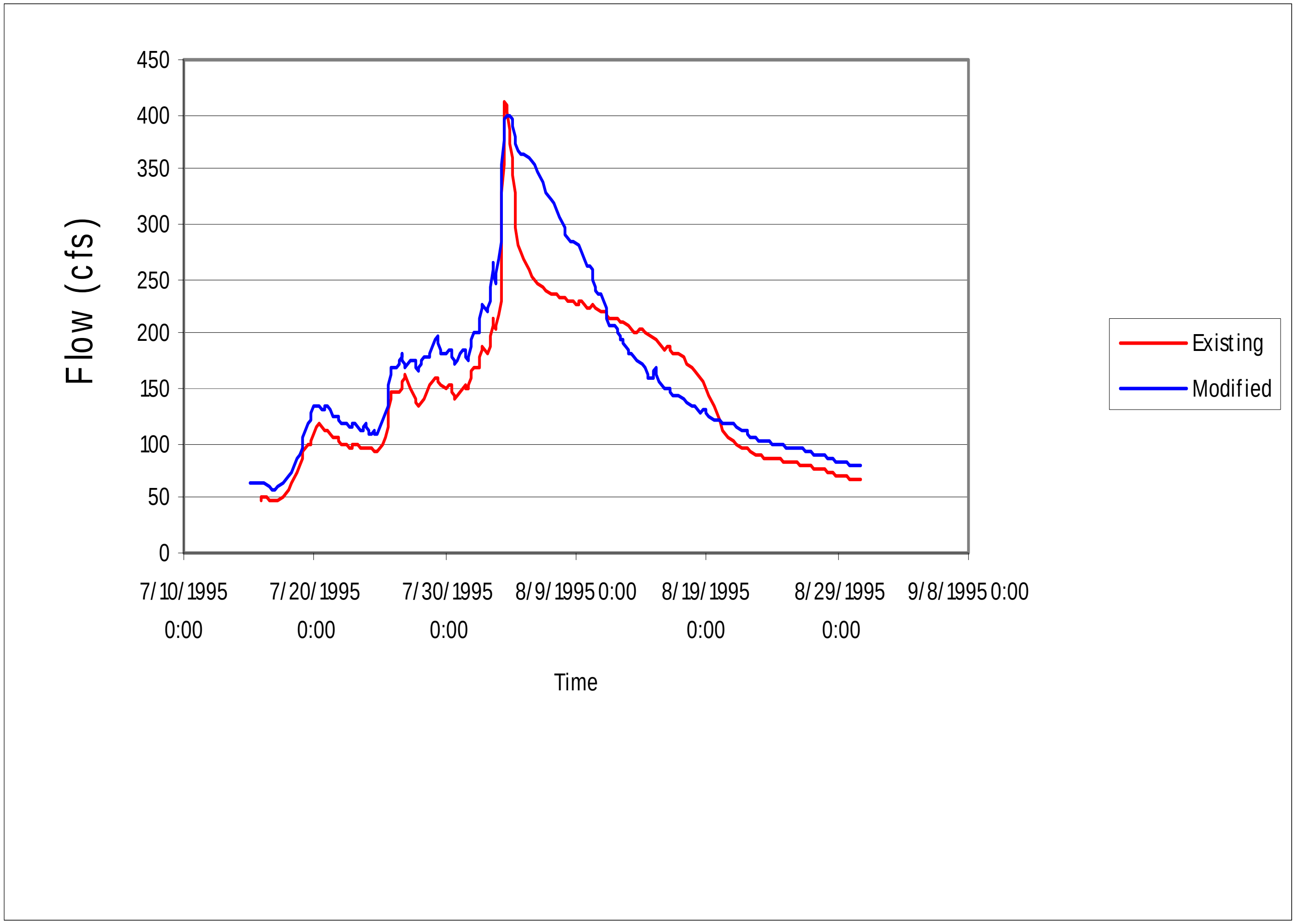


Figure 20c. Variations of flows in Corkscrew Canal at the confluence with Cocohatchee Canal.

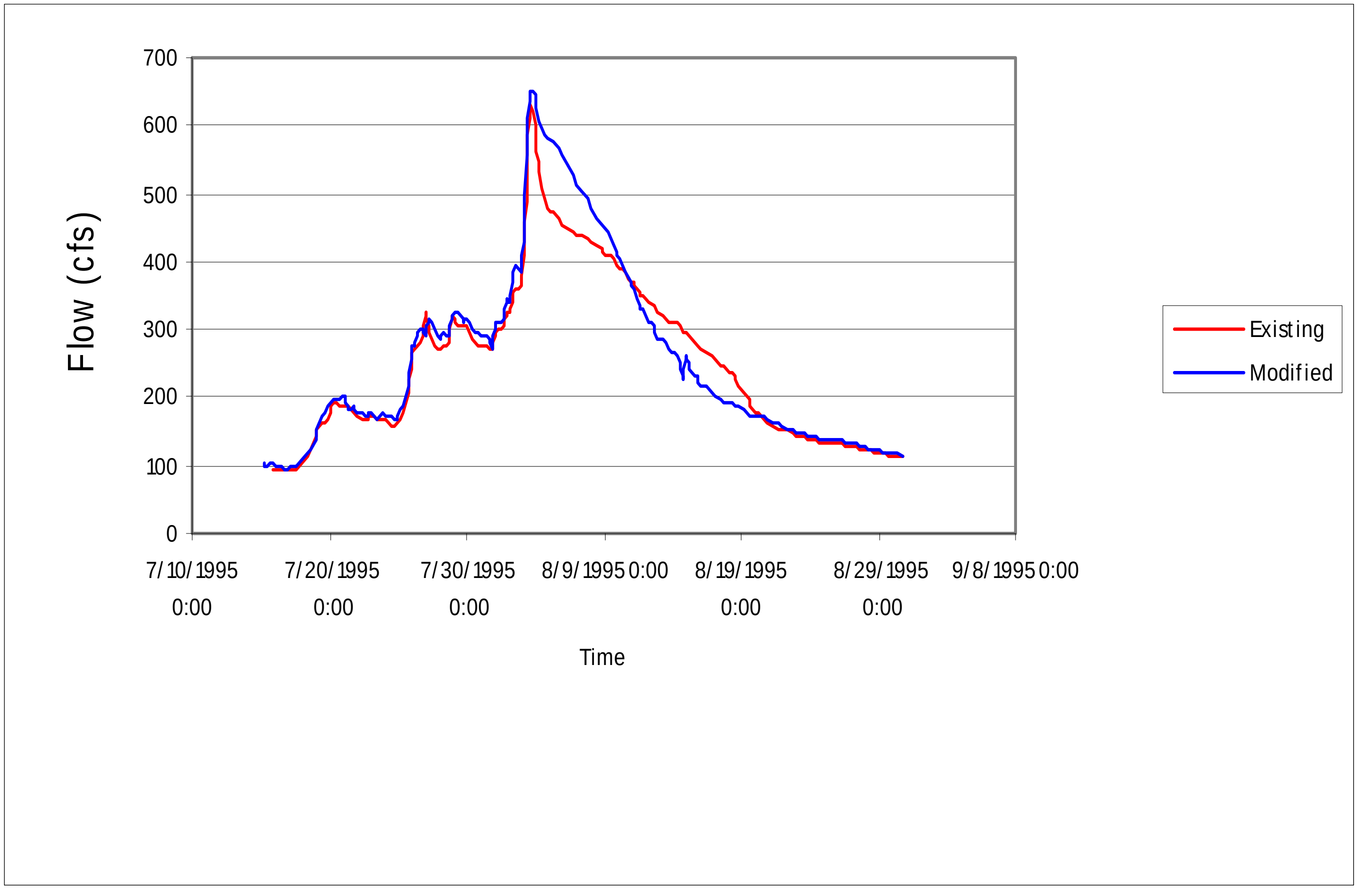


Figure 20d. Variations of flows in Corkscrew Canal at the confluence with Cypress Canal.

Table 7. Summary of integrated flow modeling results.

Location	Existing condition		Modified condition	
	Flow (cfs)	Stage (ft)	Flow (cfs)	Stage (ft)
43rd Avenue	63	16.7	64	15.0
33rd Avenue	164	15.2	238	14.8
Confluence of Corkscrew with Cocohatchee Canal	409	14.6	399	14.6
Confluence of Corkscrew with Cypress Canal	627	14.0	651	14.1

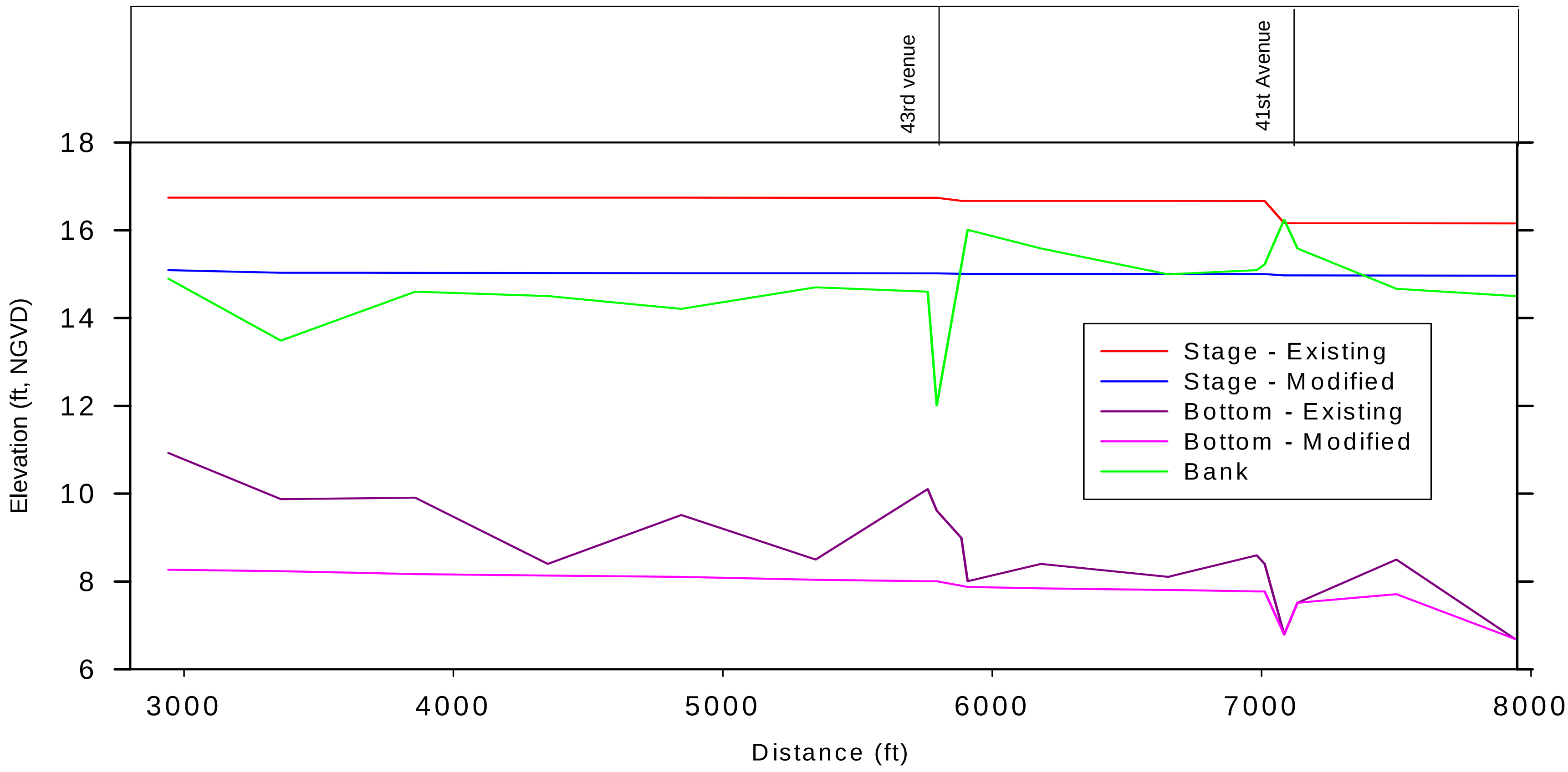


Figure 21a. Corkscrew Canal simulated water surface profiles.

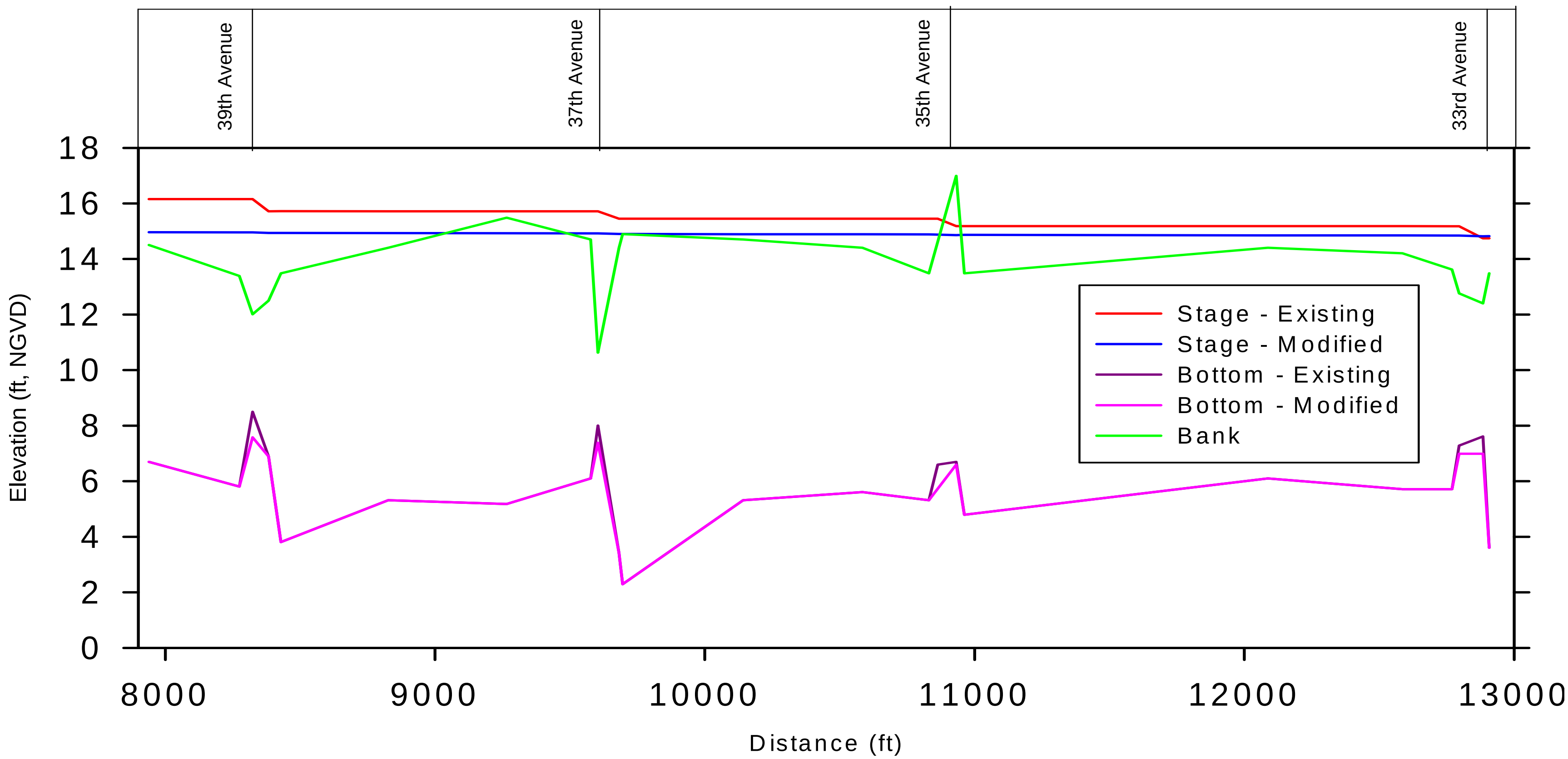


Figure 21b. Corkscrew Canal simulated water surface profiles.

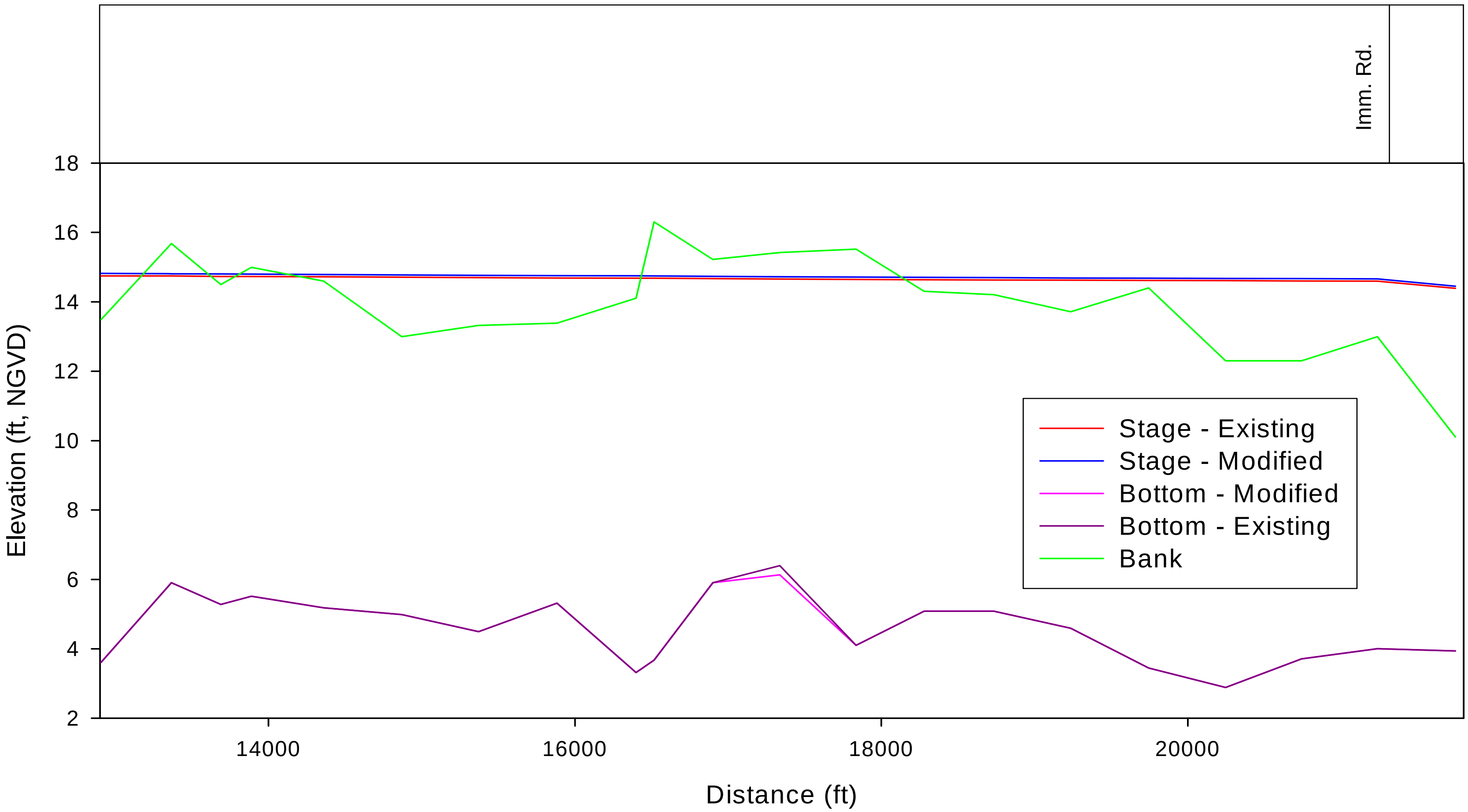


Figure 21c. Corkscrew Canal simulated water surface profiles.

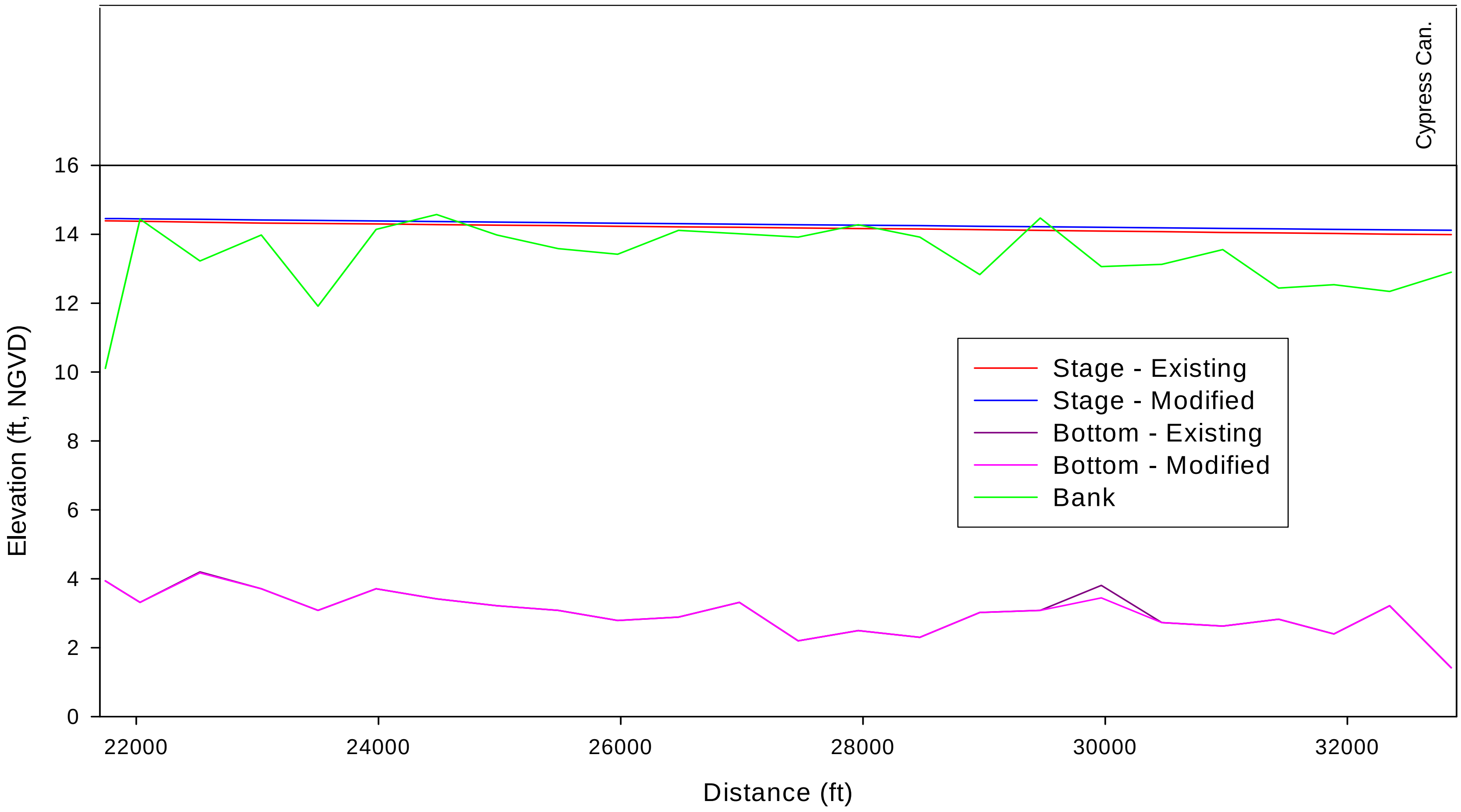


Figure 21d. Corkscrew Canal simulated water surface profiles.

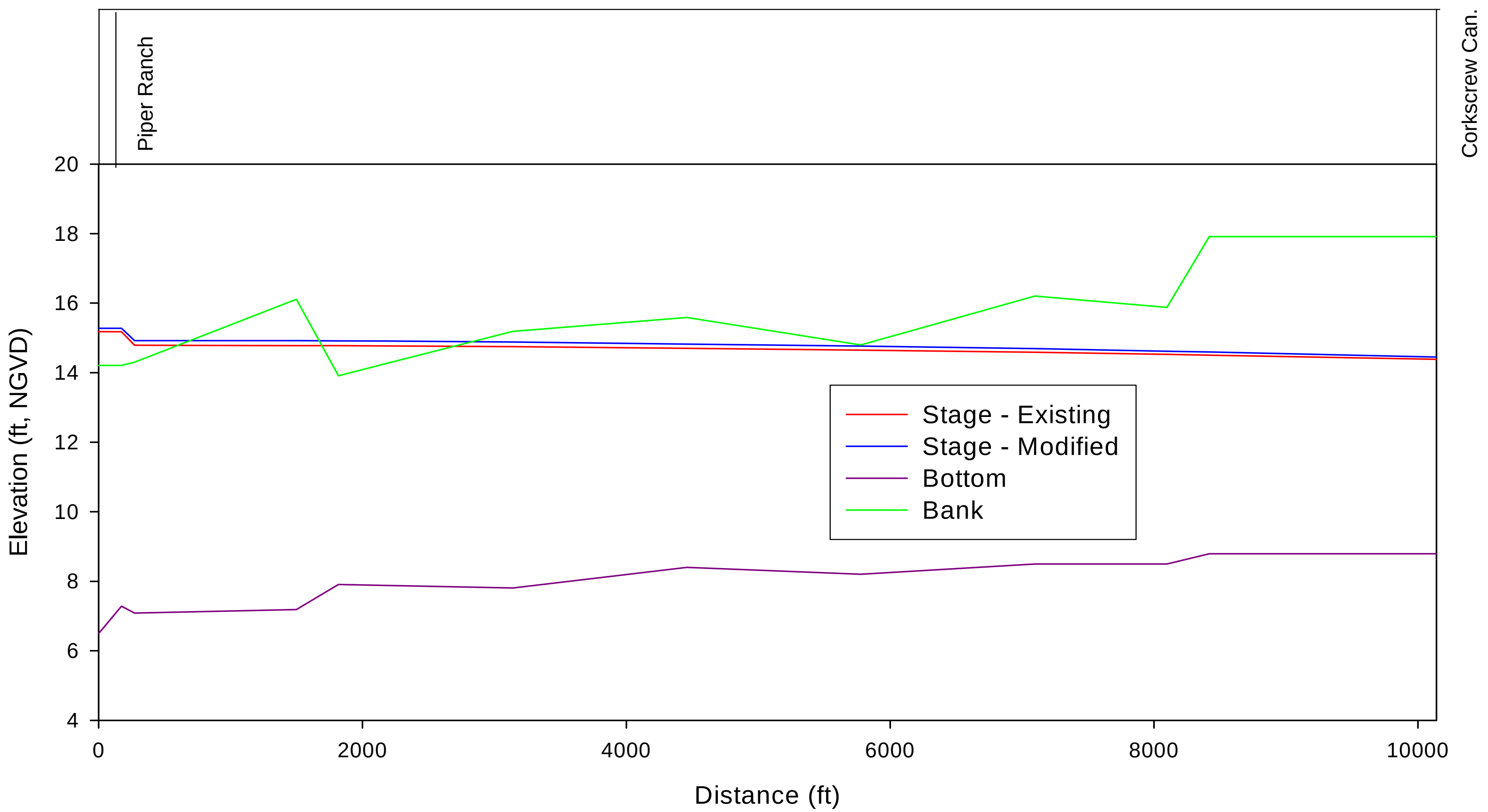


Figure 22. Cocohatchee (East) Canal simulated water surface profiles.

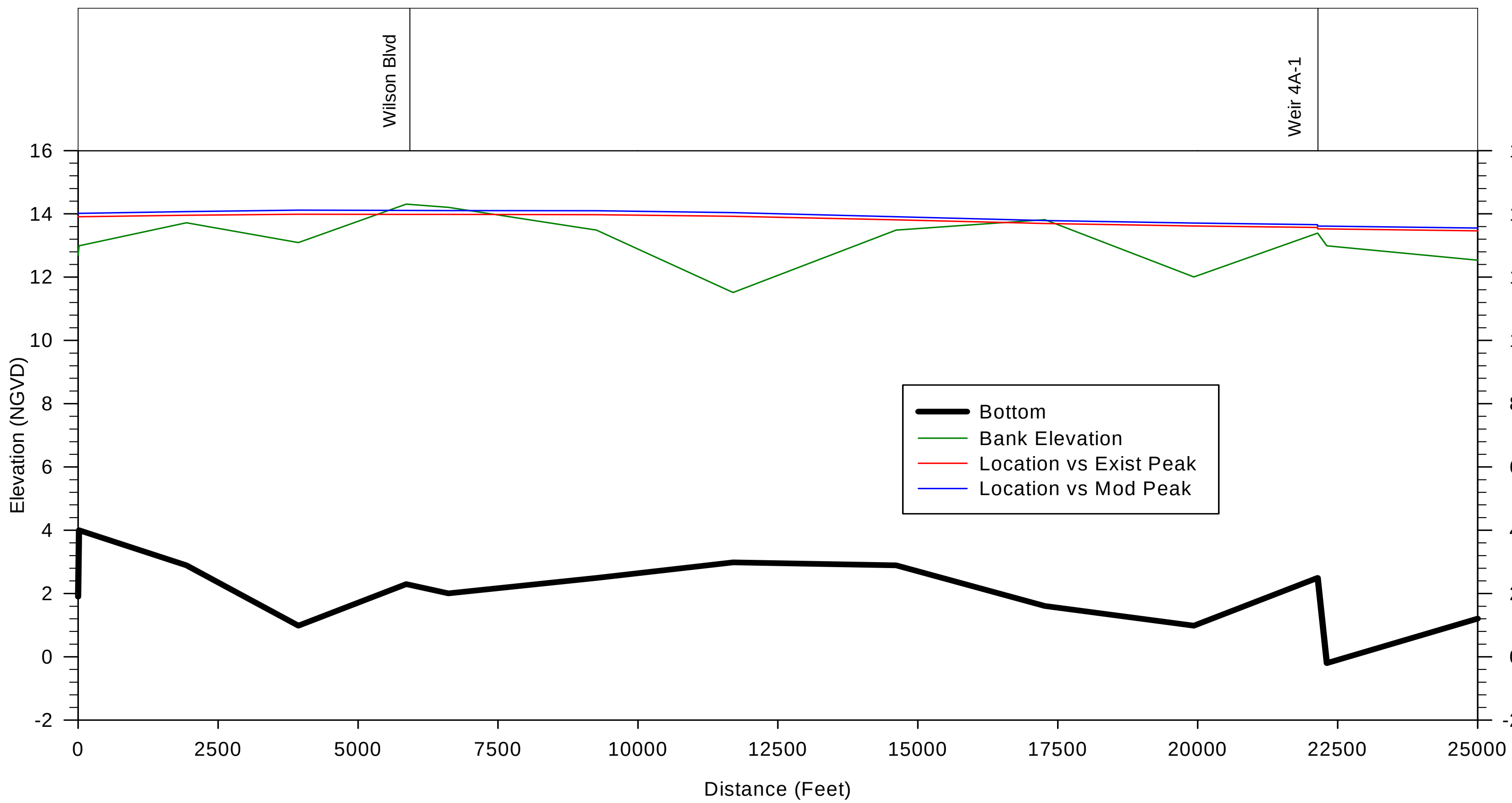


Figure 23a. Cypress Canal simulated water surface profiles.

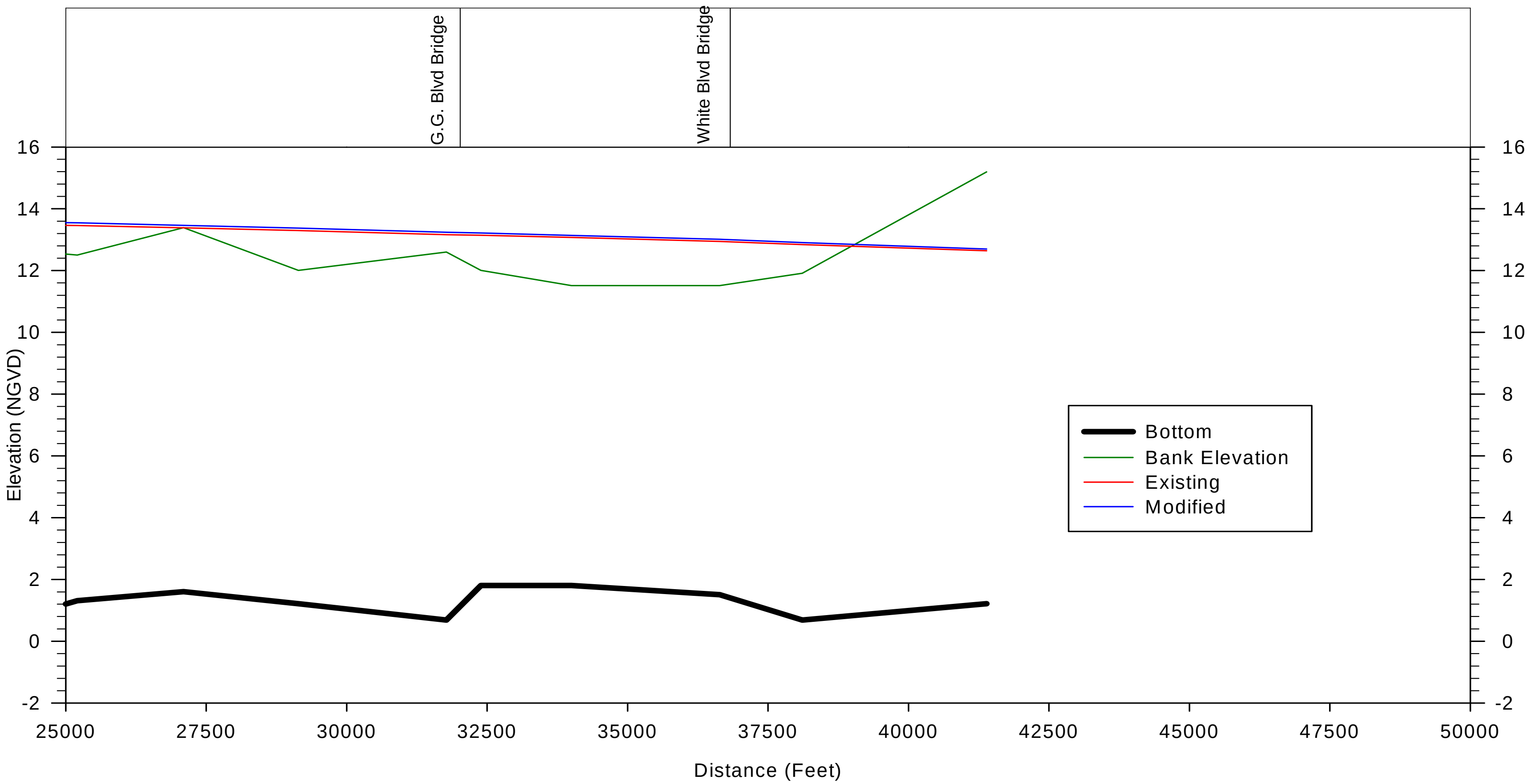


Figure 23b. Cypress Canal simulated water surface profiles

3.3.1 GROUNDWATER SIMULATION FOR EXISTING CONDITION

The existing aquifer conditions for BCB were simulated using the calibrated unsteady state integrated model. The BCB groundwater flow field was represented in the model for simulating design storms after calibration. The variations of peak hydraulic heads for the existing conditions at different locations along the Corkscrew Canal are investigated. The spatial variations of average hydraulic heads of the water table aquifer simulated by the MIKE SHE-MIKE 11 modelling system are plotted as shown in Figure 24. The groundwater levels vary from 12 ft to 17 ft in the area around the Corkscrew Canal. The overall groundwater flow occurs from north to southwest direction.

3.3.2 GROUNDWATER SIMULATION FOR IMPROVEMENT SCENARIO

The integrated MIKE SHE-MIKE 11 model simulated the aquifer conditions for the Corkscrew Canal improvement. The effects of water level change in the Corkscrew Canal are visualized by comparing the aquifer hydraulic heads for both the existing and the proposed canal improvement conditions. The temporal effects are examined as well by comparing the time-varying variations of groundwater levels.

Figure 25 shows the groundwater hydraulic head contours with the improved Corkscrew Canal condition. The groundwater flow directions are not changed due to the proposed improvements in the Corkscrew Canal. The time-history of groundwater levels are compared for different locations as shown in Figure 26. The model runs were done for the existing and modified conditions to investigate the changes in groundwater levels for an average year (1994). The changes in average groundwater levels due to canal improvements and structural modifications in the average year are depicted in Figure 27. The results indicate an overall gain in groundwater storage due to the operations of the

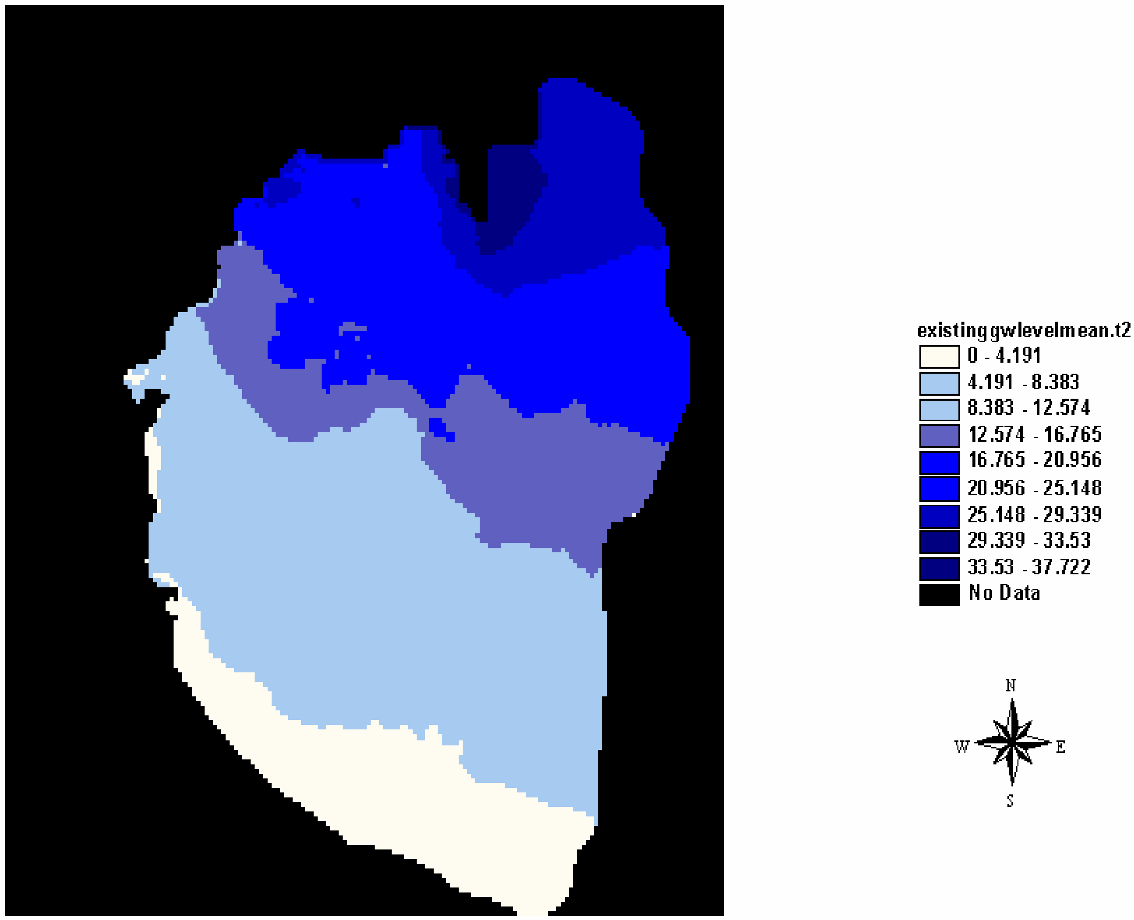


Figure 24 Simulated Average Groundwater Levels for the Existing Condition.

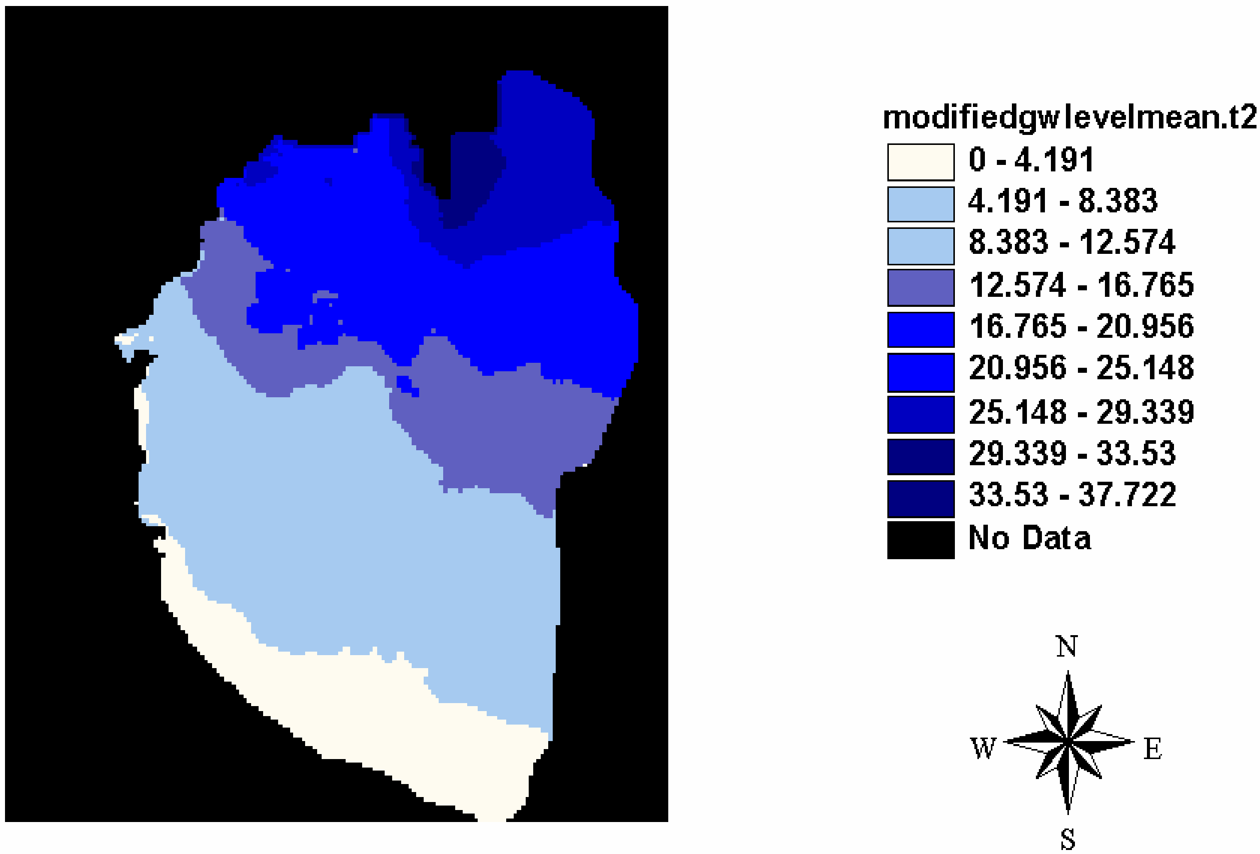


Figure 25 Simulated Average Groundwater Levels for the Modified Condition.

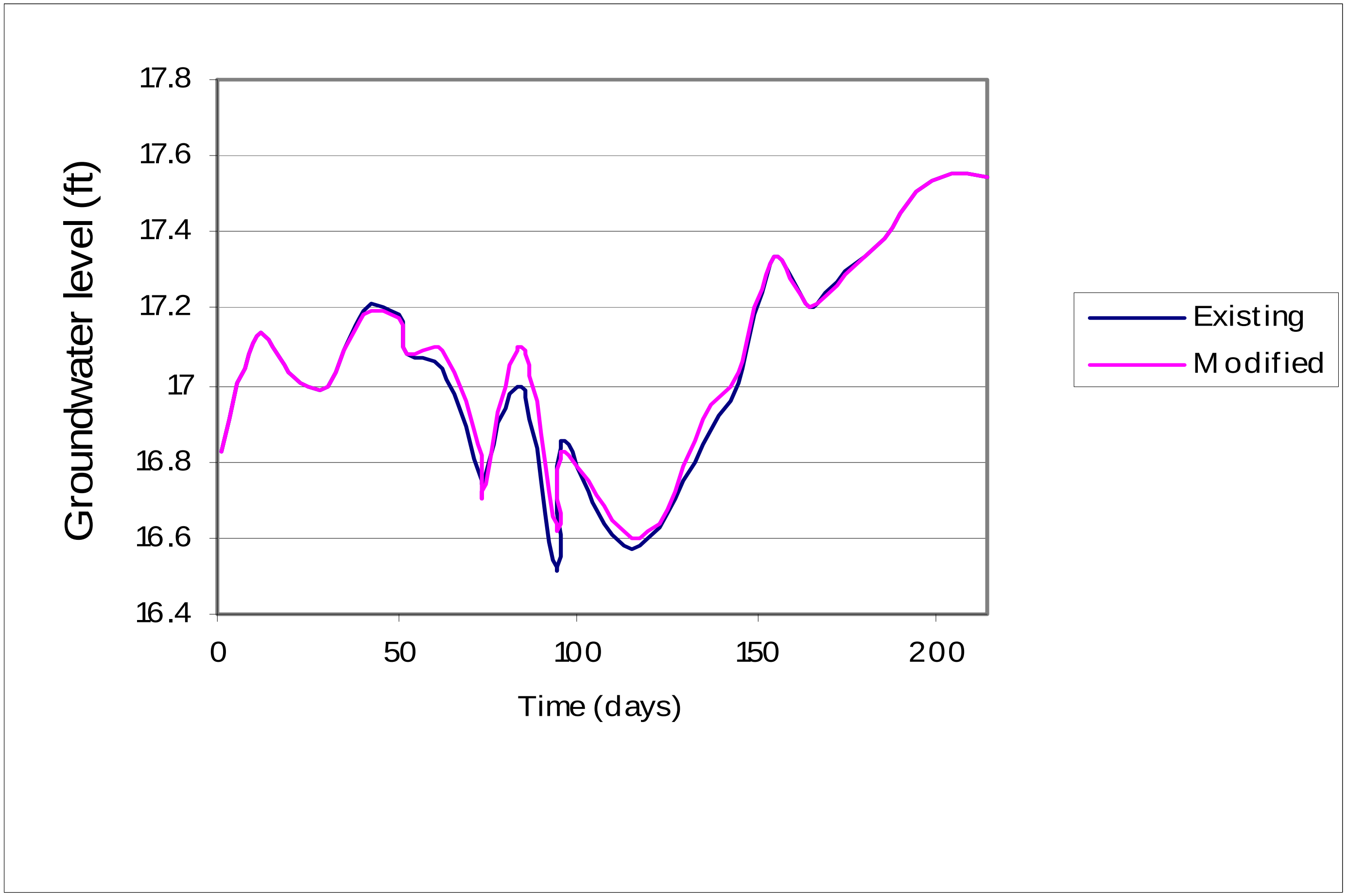


Figure 26a. Variations of groundwater levels at the upstream end of the Corkscrew Canal.

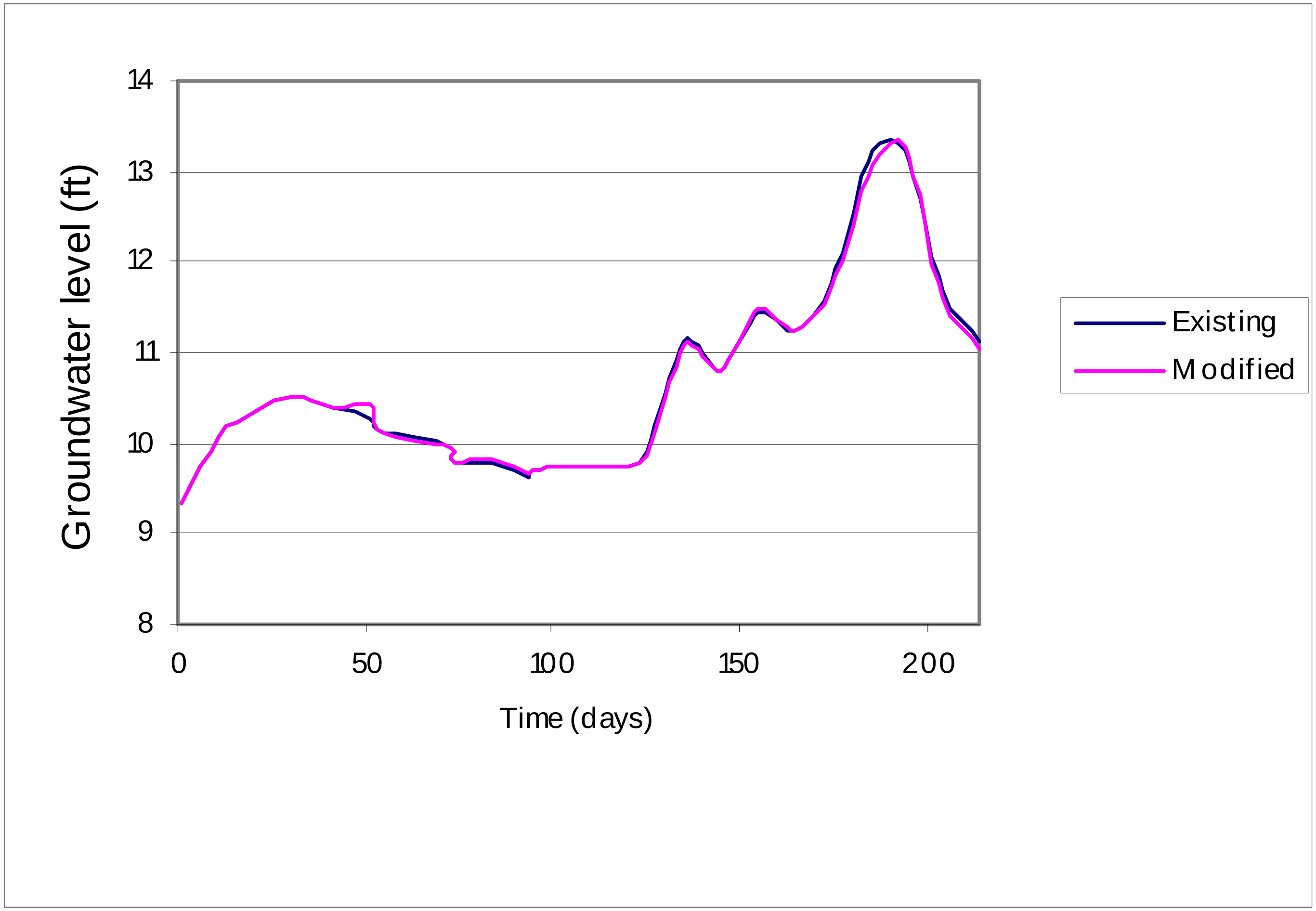


Figure 26b. Variations of groundwater levels at the confluence with Cocohatchee Canal.

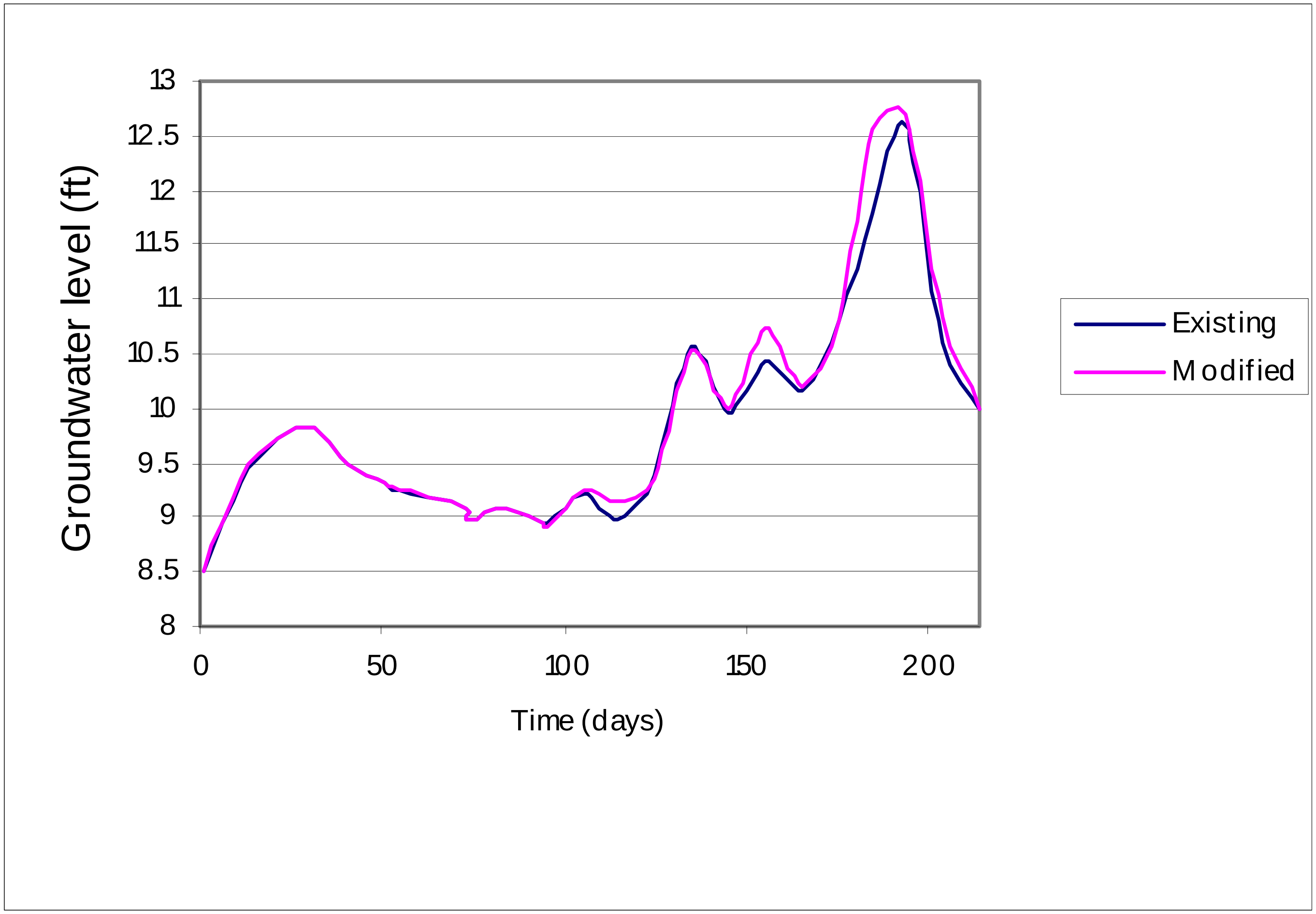
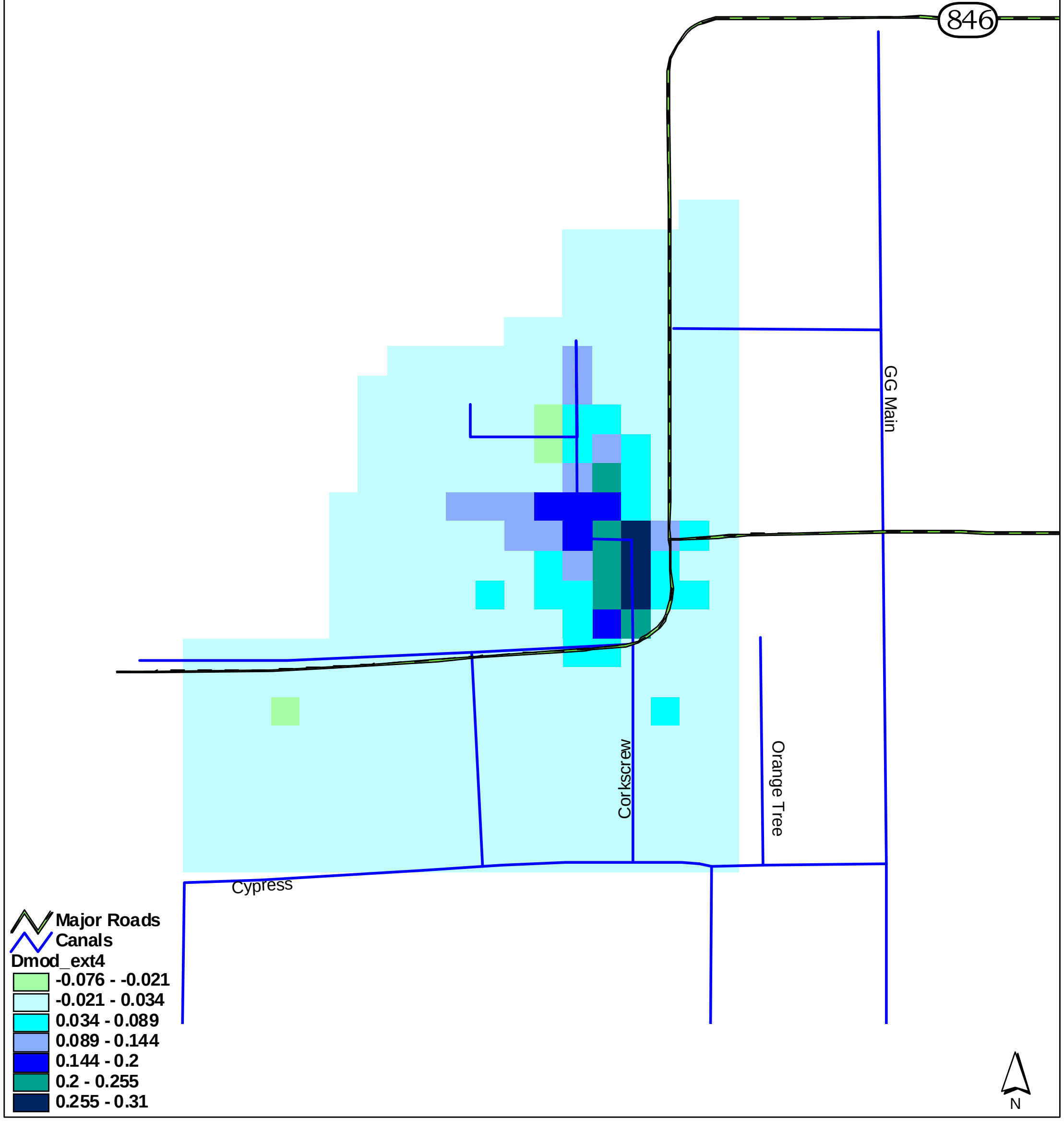


Figure 26c. Variations of groundwater levels at the confluence with Cypress Canal.

Figure 27

Changes in groundwater levels due to canal improvements and structure modifications in an average year (1994)



water control structures at 43rd Avenue and Immokalee Road. The gates at 43rd Avenue and at Immokalee Road are operated based on the wet and dry season criteria (Table 8). This helped maintain water level in the canal at desired levels which in turn ensured no significant change in groundwater levels.

Table 8. Operating water levels for water control structures.

Structure	Season	Operating Water Level (ft NGVD)	
		Open	Close
43rd Avenue	Dry	12.5	11.5
	Wet	11.5	10
Confluence with Cocohatchee	Dry	12.5	11
	Wet	11	9

4 RECOMMENDED PLAN

The findings of the integrated and interactive H&H modeling for the Corkscrew Canal improvements are used as the basis for identifying different components of the recommended plan. The recommended plan includes:

- Channel enlargement in a 6 mile reach
- Replacement of culverts by 25-ft single span bridges
- Construction of a gated culvert at 43rd Avenue

The hydraulic design data for canal crossings and water control structures for the project are summarized in Table 9. The responsible entities for funding, design, and construction of facilities in connection with the Corkscrew Canal improvements are listed in Table 10.

4.1 CHANNEL IMPROVEMENT

Channel improvements include excavation from the upstream end of the canal on the north to the confluence with the Cypress Canal on the south for a distance of 6 miles. The proposed bottom width is 15 ft with side slope 1:1 for the reach of the canal north of 43rd Avenue (invert elevation 8 ft). For the reach between 43rd Avenue and Cocohatchee Canal, the proposed width is 30 ft with a side slope of 2:1 and a bottom slope of 0.5 foot per mile. The same criteria are used for the cutting and improvement for the reach south of Cocohatchee Canal (invert elevation 4.23).

The total volume excavation various segments of the canal computed using HEC RAS model is estimated to be 77,400 cubic yards. However, the volume to be excavated may be different since the section of the canal north of 33rd Avenue will need to be realigned to fit the limits of canal row.

Table 9. Corkscrew Canal Crossings/Structures Hydraulic Design Data.

Structure Location	**Invert elevation (feet)**	**Design water surface (feet)**	**Minimum low cord elev. (feet)**	**Minimum height of opening (feet)**	**Minimum width of opening (feet)**
33rd Avenue	7	14.8	17	2.2	25
35th Avenue	6.6	14.89	17	2.11	25
37th Avenue	7.38	14.92	17	2.08	25
39th Avenue	7.58	14.96	17	2.04	25
41st Avenue	7.77	15	17	2	25
43rd Avenue	8	15	17	2	20

Table 10. Responsible entities for Corkscrew Canal improvements.

	Approximate		Responsibility Entity			Include in
Facility	Station	Owner	Funding	Design	Construction	C-11423?
Enlarge/excavate canal – 5.7 linear miles	0+00 - 106+00	SFWMD/BCB	BCB	BCB	BCB	Y
Landscaping on right of way – 5.7 linear miles		SFWMD/BCB	BCB	BCB	BCB	Y
Replace 33rd Avenue Culvert		Collier County	BCB	BCB	County	Y
Replace 35rd Avenue Culvert		Collier County	BCB	BCB	County	Y
Replace 37rd Avenue Culvert		Collier County	BCB	BCB	County	Y
Replace 39rd Avenue Culvert		Collier County	BCB	BCB	County	Y
Replace 41st Avenue Culvert		Collier County	BCB	BCB	County	Y
Replace 43rd Avenue Culvert		Collier County	BCB	BCB	County	Y
Install two 10 ft by 8 ft water control structure		BCB	BCB	BCB	County	Y

4.2 REPLACEMENT OF CULVERTS

Based on the findings of the integrated H&H evaluation, it was revealed that the enlargement and improvement of the channel without replacement of any of the existing culvert crossings would not be adequate to enhance the drainage and mitigate flooding. An optimized approach was adopted to improve hydraulic performance of the structures in Corkscrew Canal. The approach includes replacing the existing culverts north of Cocohatchee Canal by 25-ft single span bridges to get higher conveyance capacities. The 43rd Avenue circular culvert will be replaced by a two 10 ft (width) by 8 ft (height) box culverts for the same purpose. The recommended plan for replacement of culverts is as follows:

- Replace 33rd Avenue two 48 inch RCP culvert by a 25-ft single span bridge
- Replace 35th Avenue two 48 inch RCP culvert by a 25-ft single span bridge
- Replace 37th Avenue two 48 inch RCP culvert by a 25-ft single span bridge
- Replace 39th Avenue two 48 inch RCP culvert by a 25-ft single span bridge
- Replace 41st Avenue two 48 inch RCP culvert by a 25-ft single span bridge
- Replace two 48-inch RCP culverts on 43rd Avenue by a double-barrel 10 ft by 8 ft gated box culvert.

A typical cross-section of the replacement bridges and the gated culvert are illustrated in Appendix C.

4.3 WATER CONTROL STRUCTURES

To reduce dry season over drainage from the Corkscrew Canal basin, there are water control structures at 43rd Avenue and at the confluence with the Cocohatchee Canal. The water control structure at 43rd Avenue will be modified to regulate flows through a double-barrel 10 ft by 8 ft box culvert. A control structure with two gates (each 10 ft by 8 ft) will be constructed at 43rd Avenue. Additionally, the present gated culvert at CR 846 is being retrofitted as a part of four-lane improvement of Immokalee Road.

4.4 COST ESTIMATE

A preliminary cost estimate for the Corkscrew Canal improvements for phases I, II, and II are given in Tables 11, 12, and 13. These costs are based on historical similar work and will be updated after detailed design work is complete.

Table 11. Preliminary cost for Corkscrew Canal improvement in Phase I

Description	Quantity	Unit	Unit Price	Amount
GENERAL				
Mob/Demob	1	LS	$40,000.00	$40,000.00
SITE WORK				
43rd Avenue				
Set turbidity Barrier & Silt Fence	1	LS	$5,000.00	$5,000.00
Relocate utilities	1	LS	$10,000.00	$10,000.00
Drive Temporary Sheet Pile	3200	SF	$18.00	$57,600.00
Excavation	2000	CY	$6.00	$12,000.00
Concrete	300	CY	$500.00	$150,000.00
Rip Rap	125	CY	$110.00	$13,750.00
Roadway Base Course	350	CY	$10.00	$3,500.00
Asphalt	350	SY	$4.00	$1,400.00
Guardrail	260	LF	$15.00	$3,900.00
Type 4 end anchorage	4	ea	$100.00	$400.00
Gates	2	ea	$7,500.00	$15,000.00
Staff gage	2	ea	$800.00	$1,600.00
Demo Culverts	1	LS	$10,000.00	$10,000.00
Remove turbidity Barrier & Silt Fence	1	LS	$3,000.00	$3,000.00
				$0.00
41st Avenue Bridge				$0.00
Set turbidity Barrier & Silt Fence	1	LS	$1,000.00	$1,000.00
Relocate utilities	1	LS	$10,000.00	$10,000.00
Demo Culverts	1	LS	$10,000.00	$10,000.00
Excavation	2000	CY	$6.00	$12,000.00
Permanent Sheet Pile w/ Concrete Cap	125	LF	$150.00	$18,750.00
Backfill	300	CY	$6.00	$1,800.00
Bridge Deck	600	SF	$110.00	$66,000.00
Rip Rap	100	CY	$150.00	$15,000.00
Roadway Base Course	350	CY	$10.00	$3,500.00
Asphalt	350	SY	$4.00	$1,400.00
Guardrail	260	LF	$15.00	$3,900.00
Type 4 end anchorage	4	ea	$100.00	$400.00
Remove turbidity Barrier & Silt Fence	1	LS	$3,000.00	$3,000.00
				$0.00
39th Avenue Bridge				$0.00
Set turbidity Barrier & Silt Fence	1	LS	$1,000.00	$1,000.00
Relocate utilities	1	LS	$10,000.00	$10,000.00
Demo Culverts	1	LS	$10,000.00	$10,000.00
Excavation	2000	CY	$6.00	$12,000.00
Permanent Sheet Pile w/ Concrete Cap	120	LF	$150.00	$18,000.00
Backfill	300	CY	$6.00	$1,800.00
Bridge Deck	600	SF	$110.00	$66,000.00

Rip Rap	125	CY	$150.00	$18,750.00
Roadway Base Course	350	CY	$10.00	$3,500.00
Table 10. Preliminary cost for Corkscrew Canal improvement in Phase I (continued)				
Asphalt	350	SY	$4.00	$1,400.00
Guardrail	260	LF	$15.00	$3,900.00
Type 4 end anchorage	4	ea	$100.00	$400.00
Remove turbidity Barrier & Silt Fence	1	LS	$3,000.00	$3,000.00
37th Avenue Bridge				$0.00
Set turbidity Barrier & Silt Fence	1	LS	$1,000.00	$1,000.00
Relocate utilities	1	LS	$10,000.00	$10,000.00
Demo Culverts	1	LS	$10,000.00	$10,000.00
Excavation	2000	CY	$6.00	$12,000.00
Permanent Sheet Pile w/ Concrete Cap	120	LF	$150.00	$18,000.00
Backfill	300	CY	$6.00	$1,800.00
Bridge Deck	600	SF	$110.00	$66,000.00
Rip Rap	125	CY	$150.00	$15,000.00
Roadway Base Course	350	CY	$10.00	$3,500.00
Asphalt	350	SY	$4.00	$1,400.00
Guardrail	260	LF	$15.00	$3,900.00
Type 4 end anchorage	4	ea	$100.00	$400.00
Remove turbidity Barrier & Silt Fence	1	LS	$3,000.00	$3,000.00
35th Avenue Bridge				$0.00
Set turbidity Barrier & Silt Fence	1	LS	$1,000.00	$1,000.00
Relocate utilities	1	LS	$10,000.00	$10,000.00
Demo Culverts	1	LS	$10,000.00	$10,000.00
Excavation	2000	CY	$6.00	$12,000.00
Permanent Sheet Pile w/ Concrete Cap	120	LF	$150.00	$18,000.00
Backfill	300	CY	$6.00	$1,800.00
Bridge Deck	600	SF	$110.00	$66,000.00
Rip Rap	125	CY	$150.00	$15,000.00
Roadway Base Course	350	CY	$10.00	$3,500.00
Asphalt	350	SY	$4.00	$1,400.00
Guardrail	260	LF	$15.00	$3,900.00
Type 4 end anchorage	4	ea	$100.00	$400.00
Remove turbidity Barrier & Silt Fence	1	LS	$3,000.00	$3,000.00
33rd Avenue Bridge				$0.00
Set turbidity Barrier & Silt Fence	1	LS	$1,000.00	$1,000.00
Relocate utilities	1	LS	$10,000.00	$10,000.00
Demo Culverts	1	LS	$10,000.00	$10,000.00
Excavation	2000	CY	$6.00	$12,000.00
Permanent Sheet Pile w/ Concrete Cap	120	LF	$150.00	$18,000.00
Backfill	300	CY	$6.00	$1,800.00
Bridge Deck	600	SF	$110.00	$66,000.00
Rip Rap	125	CY	$150.00	$15,000.00
Roadway Base Course	350	CY	$10.00	$3,500.00

Asphalt	350	SY	$4.00	$1,400.00
Guardrail	260	LF	$15.00	$3,900.00
Type 4 end anchorage	4	ea	$100.00	$400.00
Remove turbidity Barrier & Silt Fence	1	LS	$3,000.00	$3,000.00
Table 10. Preliminary cost for Corkscrew Canal improvement in Phase I (continued)				
Subtotal				$1,061,650.00
Contingency 20% of subtotal				$212,330.00
Total Cost				**$1,273,980.00**

Table 12. Preliminary cost for Corkscrew Canal improvement in Phase II

Description	Quantity	Unit	Unit Price	Amount
Excavation/shaping	44500	CY	LS	$550,000.00
Clearing and grubbing			LS	$35,000.00
Grassing and landscaping			LS	$25,000.00
Subtotal				$610,000.00
Contingency				$61,000.00
Total Cost				**$671,000.00**

Table 13. Preliminary cost for Corkscrew Canal improvement in Phase III

Description	Quantity	Unit	Unit Price	Amount*
Excavation/shaping	32900	CY	LS	$410,000.00
Clearing and grubbing			LS	$25,000.00
Grassing and landscaping			LS	$15,000.00
Subtotal				$450,000.00
Contingency (10%)				$45,000.00
Total Cost				**$495,000.00**
* The cost is based on conceptual plan. The total cost may				
Increase/decrease as the plans progress into final development.				

5 SUMMARY AND CONCLUSIONS

The optimized configuration for cutting and improvement includes excavation and replacement of existing structures. The proposed improvement plan will control floods during wet season while it will retain water during dry season. The gated hydraulic structures at 43rd Avenue and Immokalee Road will be operated manually to control floods at peak rainfall events during wet season. In the dry season, the gates will be closed for retaining water in the canal. This will ensure lateral recharge to the groundwater system. Also, the high elevations of water in the canal during dry season will prevent loss due to seepage from the water table aquifer. The operating control elevations (water surface elevations) for the wet and dry seasons are set as follows:

43rd Avenue:

In wet season gates open at 11.5 ft and close at 10 ft

In dry season, gates open at 12.5 ft and close at 11.5 ft

Immokalee Road (Confluence with Cocohatchee Canal)

In wet season gates open at 11 ft and close at 9 ft

In dry season, gates open at 12.5 ft and close at 11 ft

The above gate operating criteria have been established to ensure improvements in groundwater storage.

6 REFERENCES

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APPENDIX A- CALIBRATION RESULTS

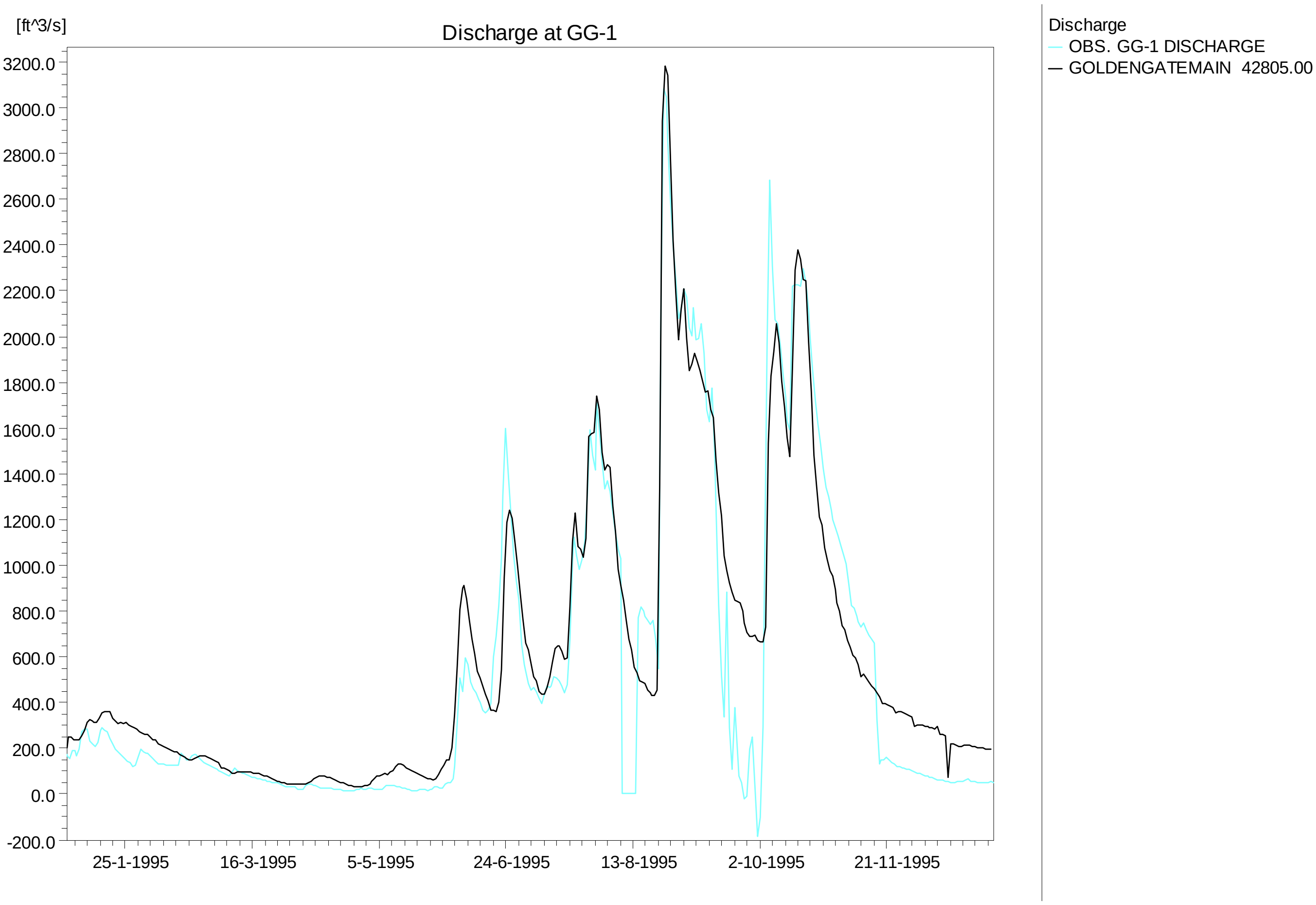


Figure A-1. Simulated and observed stream flows in Golden Gate Canal at weir GG-1 (chainage 42805) in 1995.

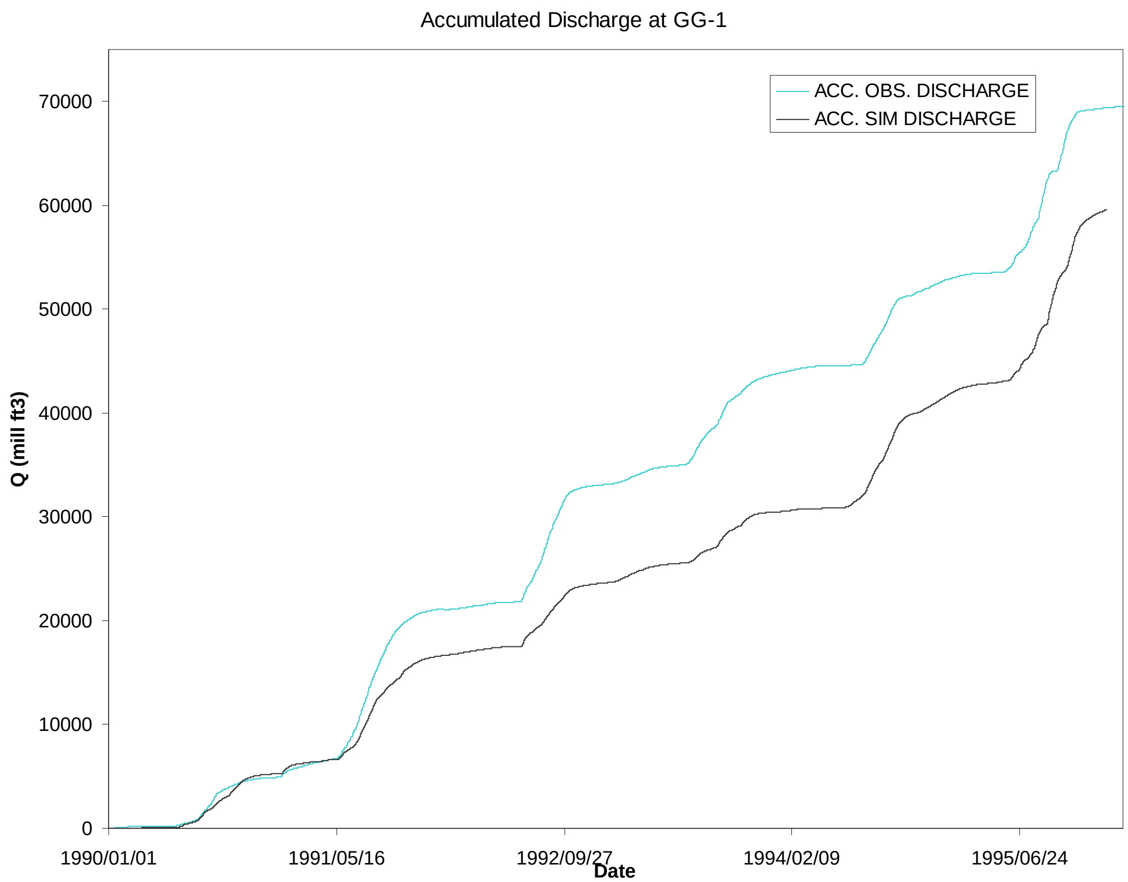


Figure A-2. Accumulated simulated and observed flow in Golden Gate Main Canal at GG-1 in mill. cubic feet from 1990-95.

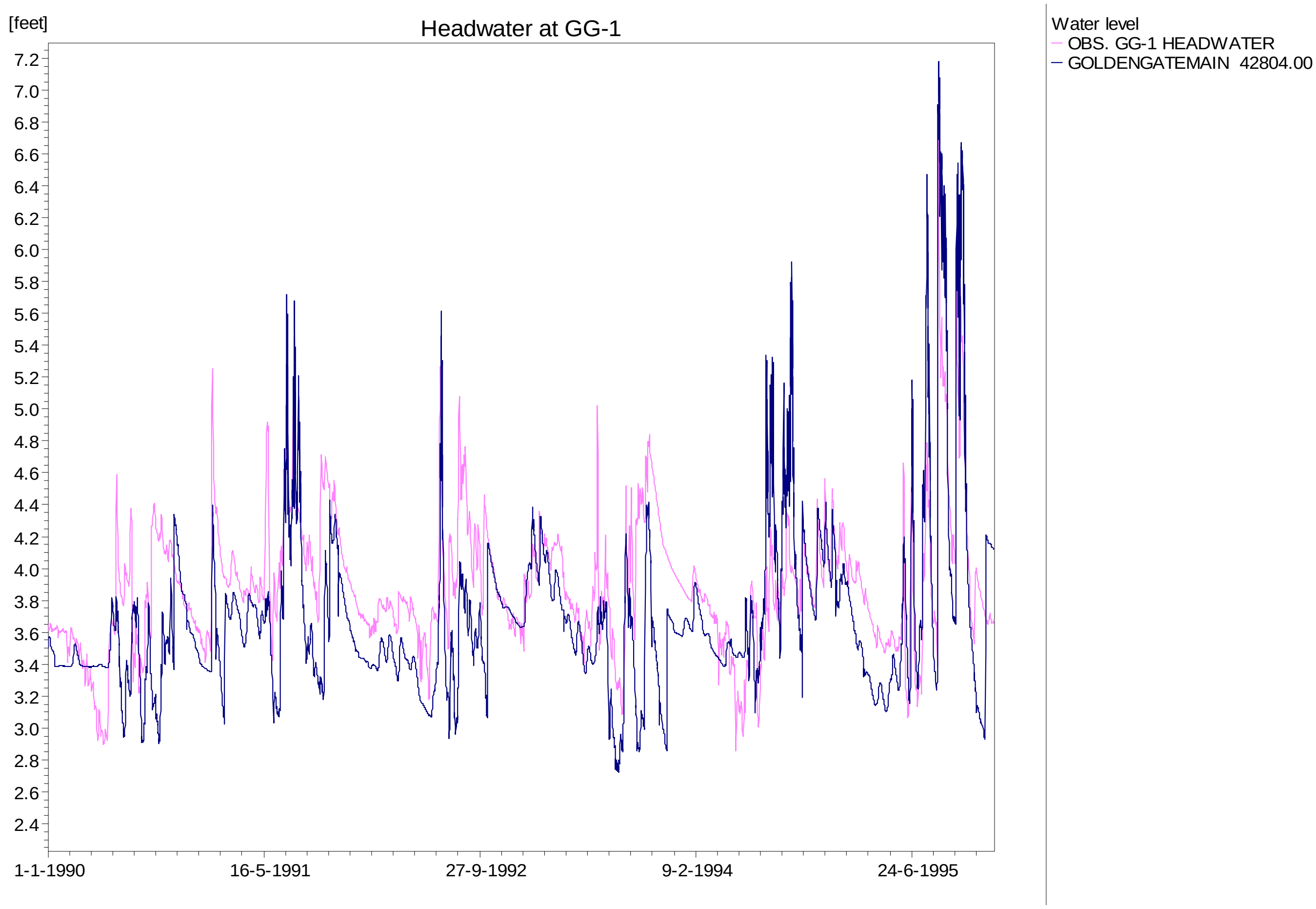


Figure A-3. Simulated and observed headwater in Golden Gate Main Canal at weir GG-1 (chainage 42804) in cfs from 1990-95.

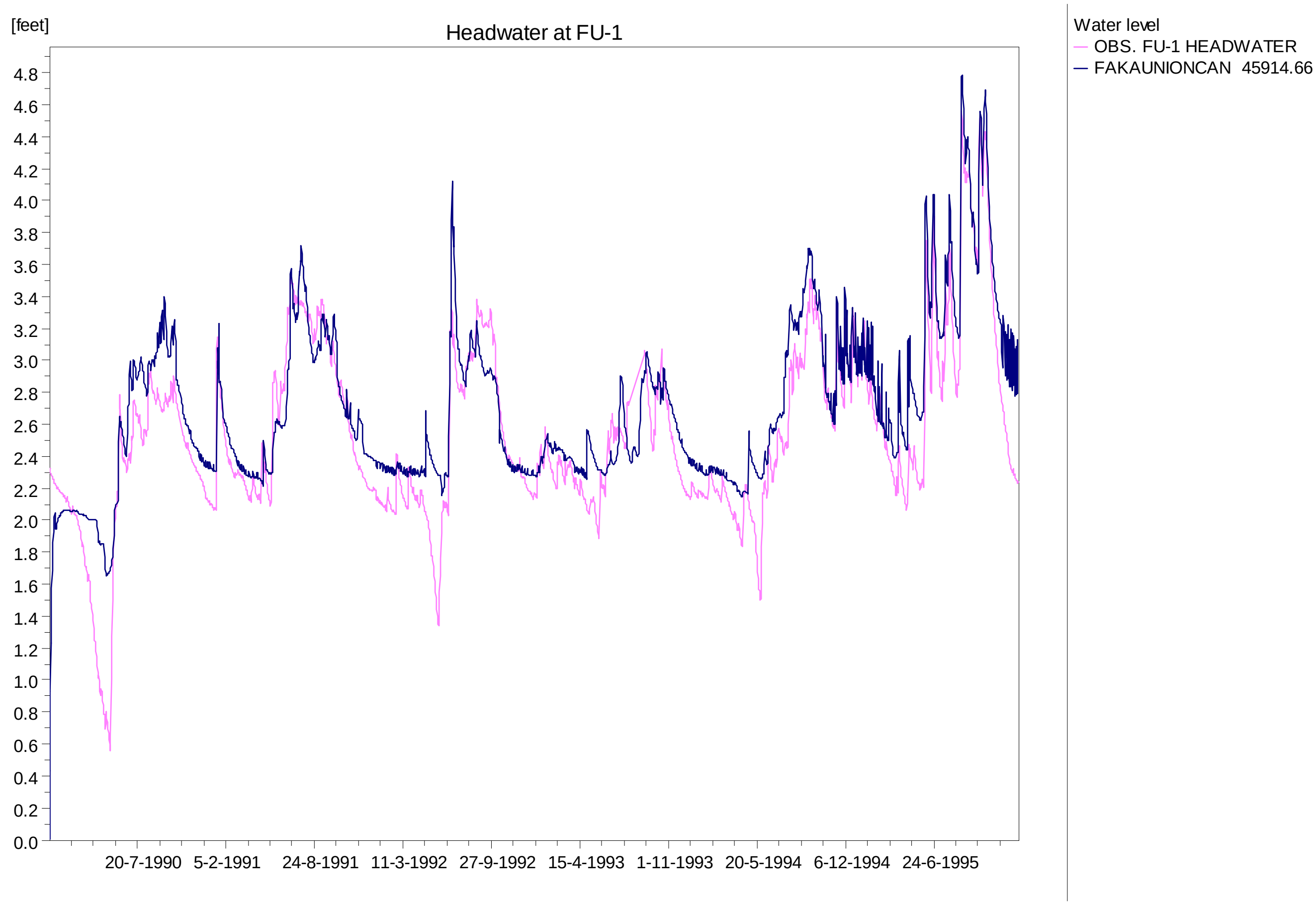


Figure A-4. Simulated and observed headwater in Faka Union Canal at weir FU-1 (chainage 45992) in cfs from 1990-95.

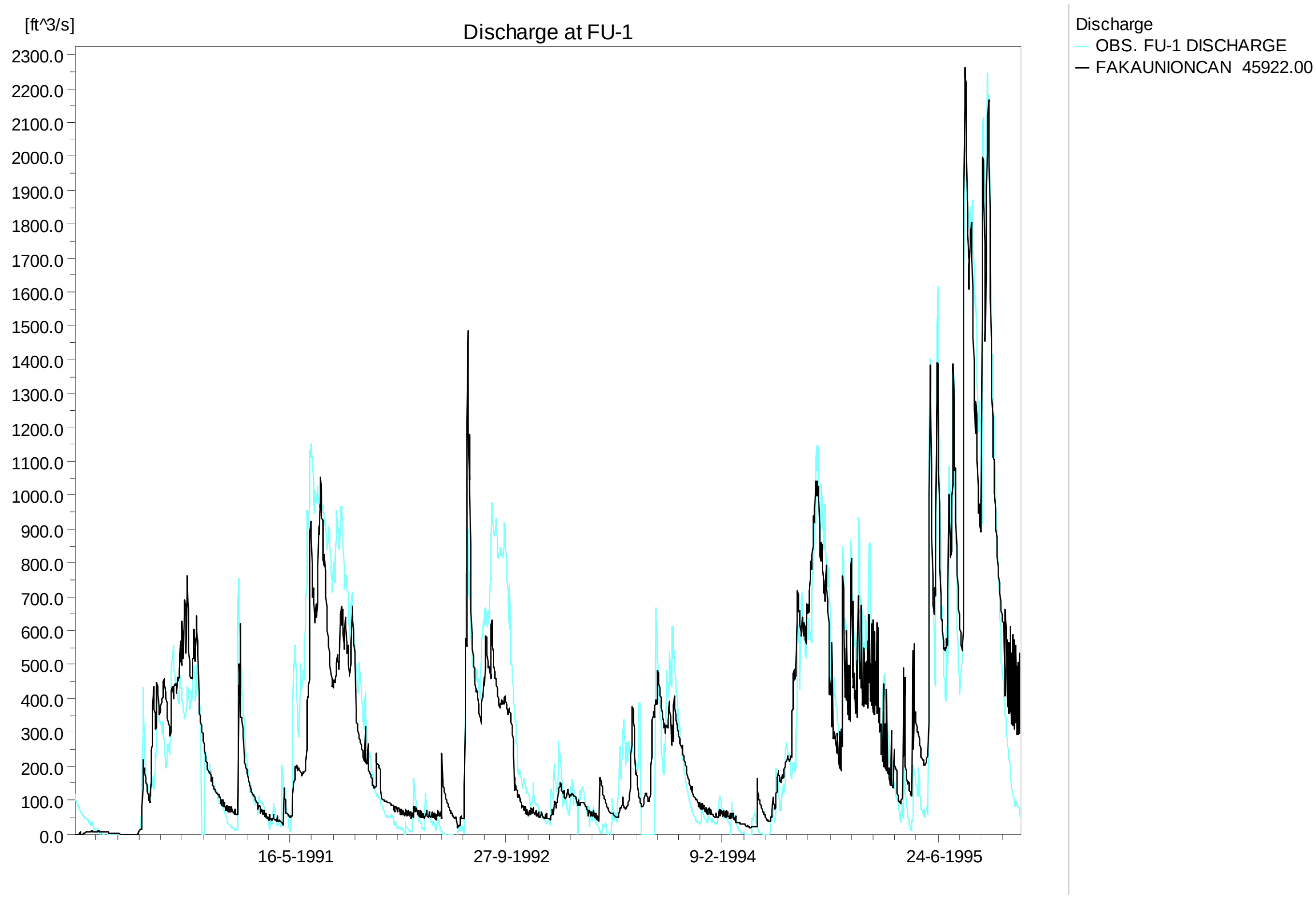


Figure A-5. Simulated and observed river flows in Faka Union Canal at weir FU-1 (chainage 45992) in cfs from 1990-95.

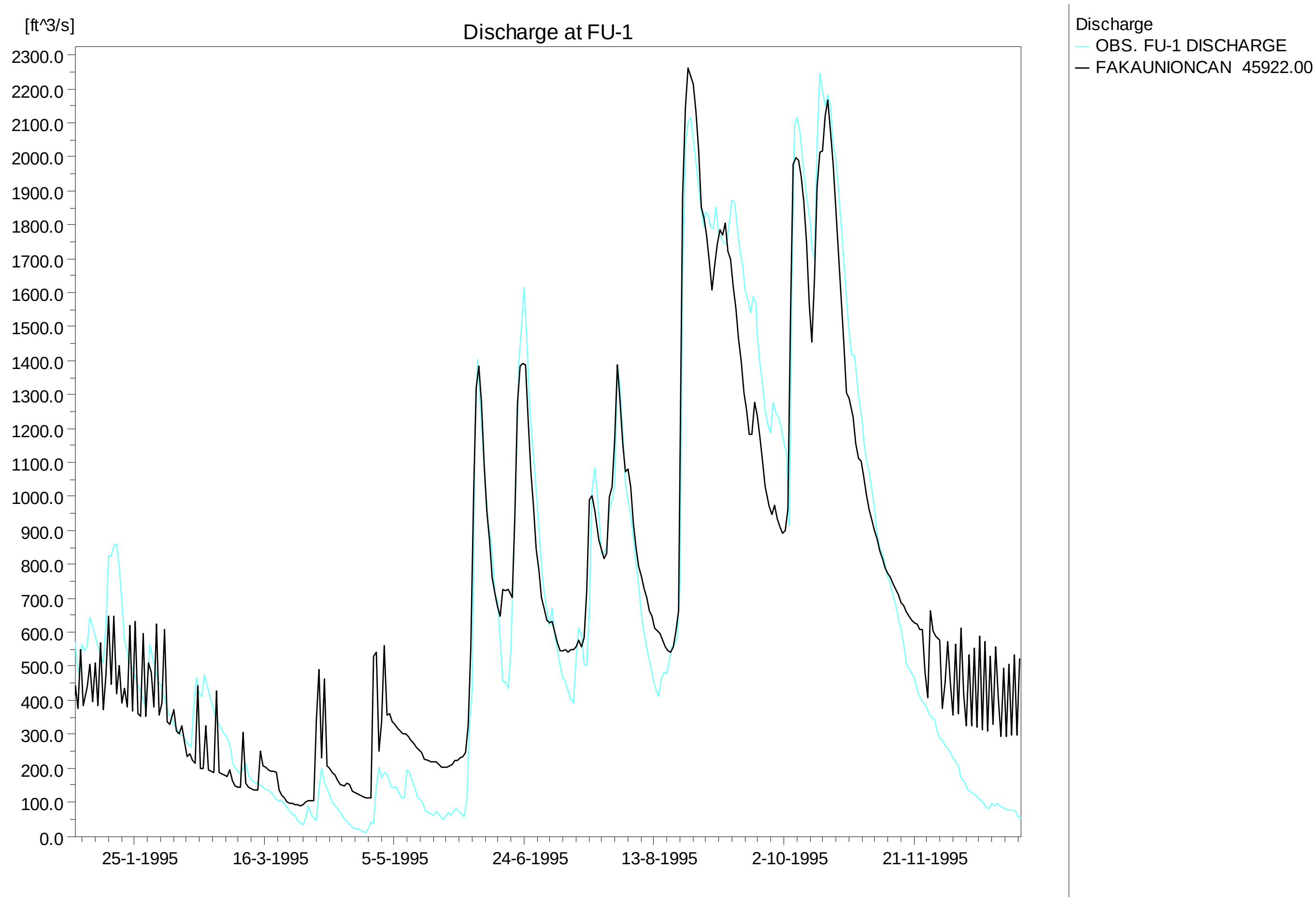


Figure A-6. Simulated and observed river flows in Faka Union Canal at weir FU-1 (chainage 45992) in 1995.

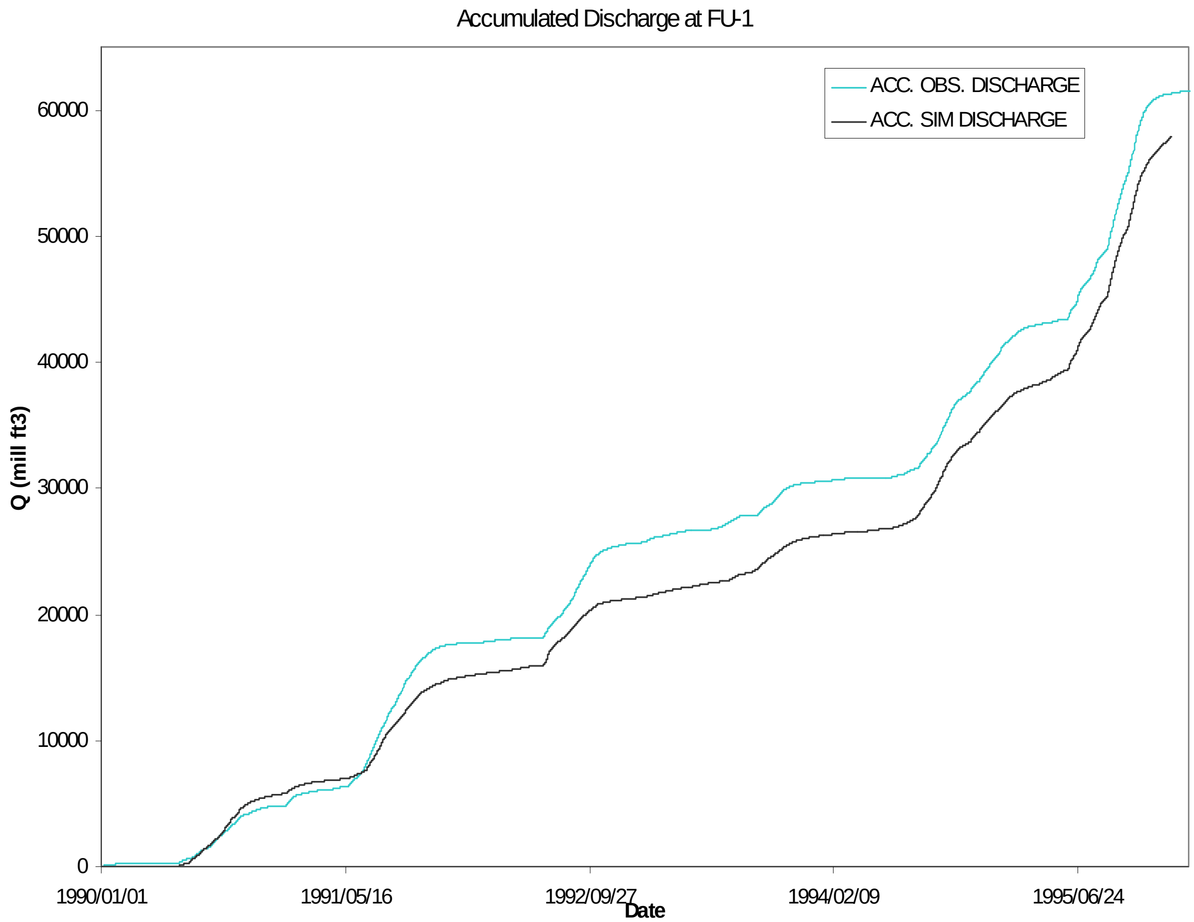


Figure A-7. Accumulated simulated and observed flow in Faka Union Canal at FU-1 in mill. cubic feet from 1990-95.

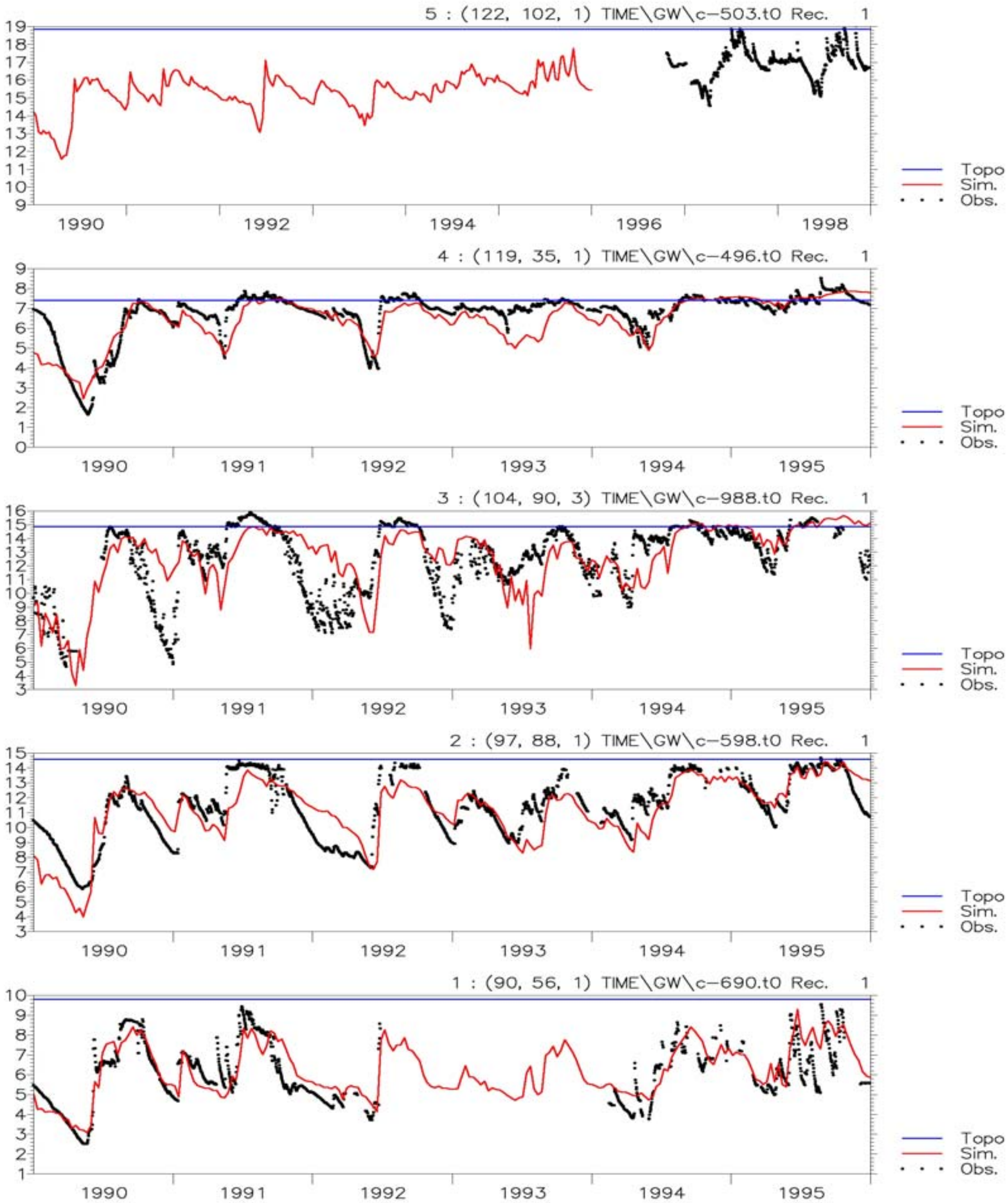


Figure A-8. Simulated and observed groundwater levels in the Faka Union Canal sub-catchment

APPENDIX B – EXISTING AND MODIFIED CROSS SECTIONS

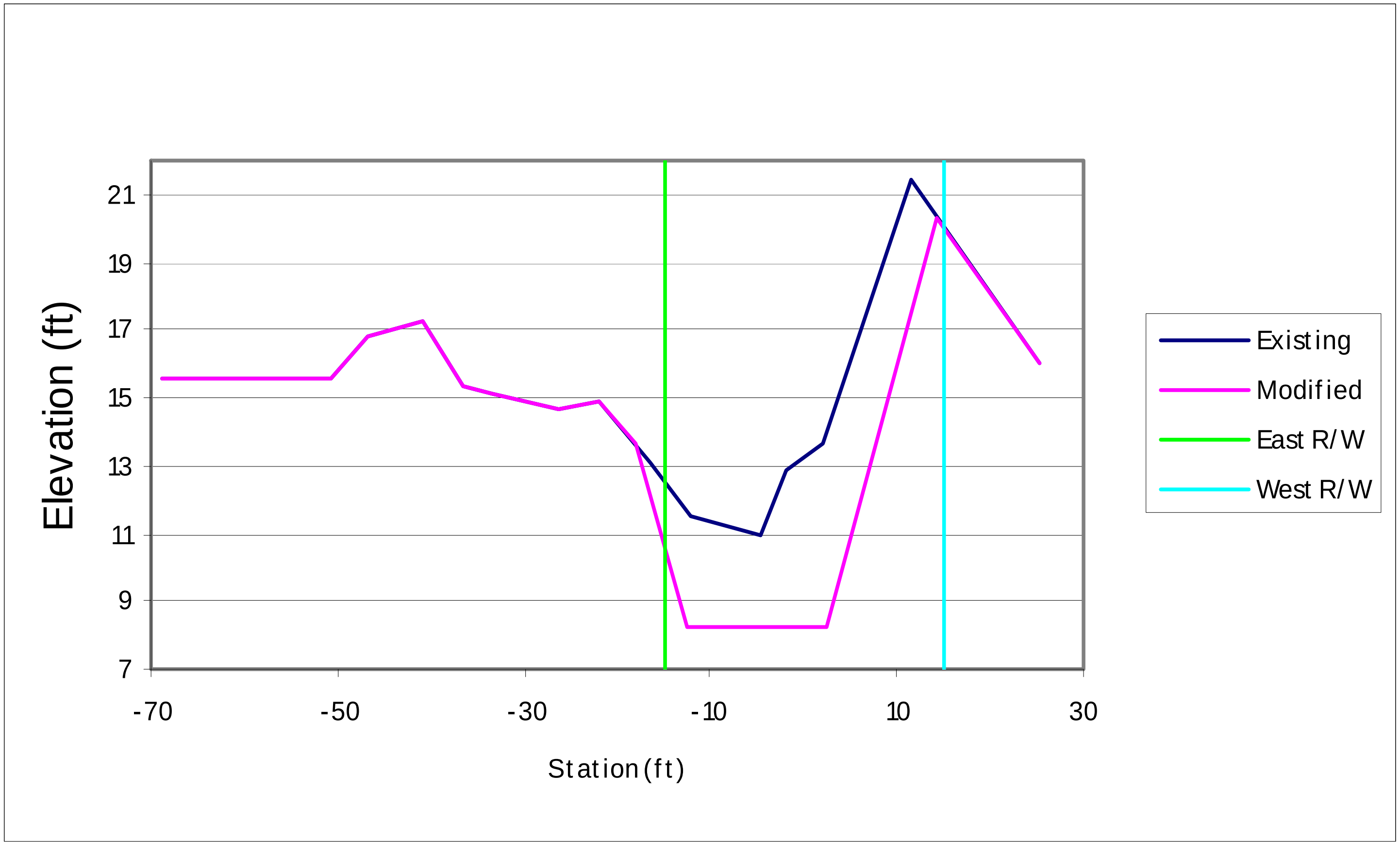


Figure B-1. Corkscrew Canal cross section upstream of 47th avenue.

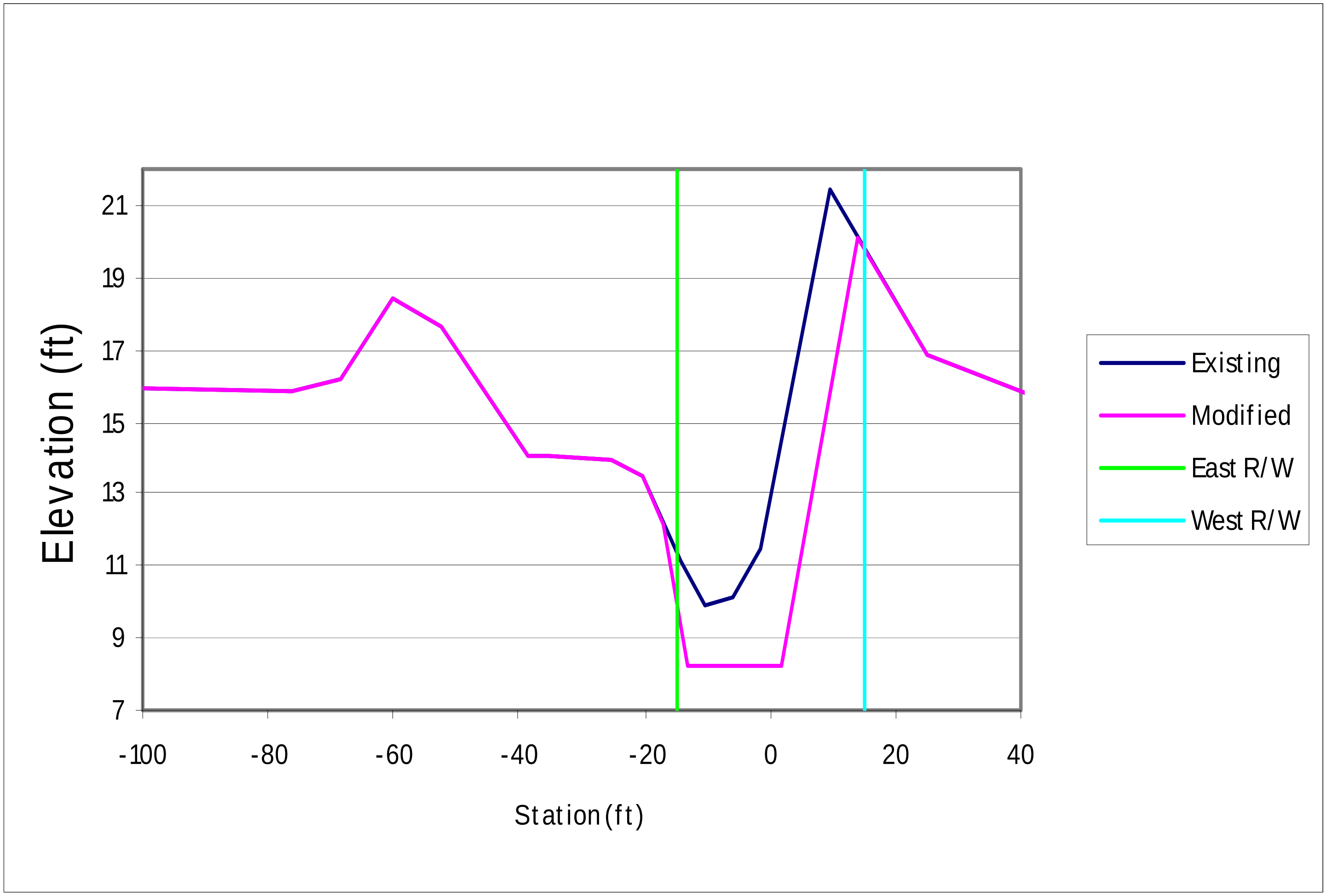


Figure B-2. Corkscrew Canal cross section between 47th and 45th avenues.

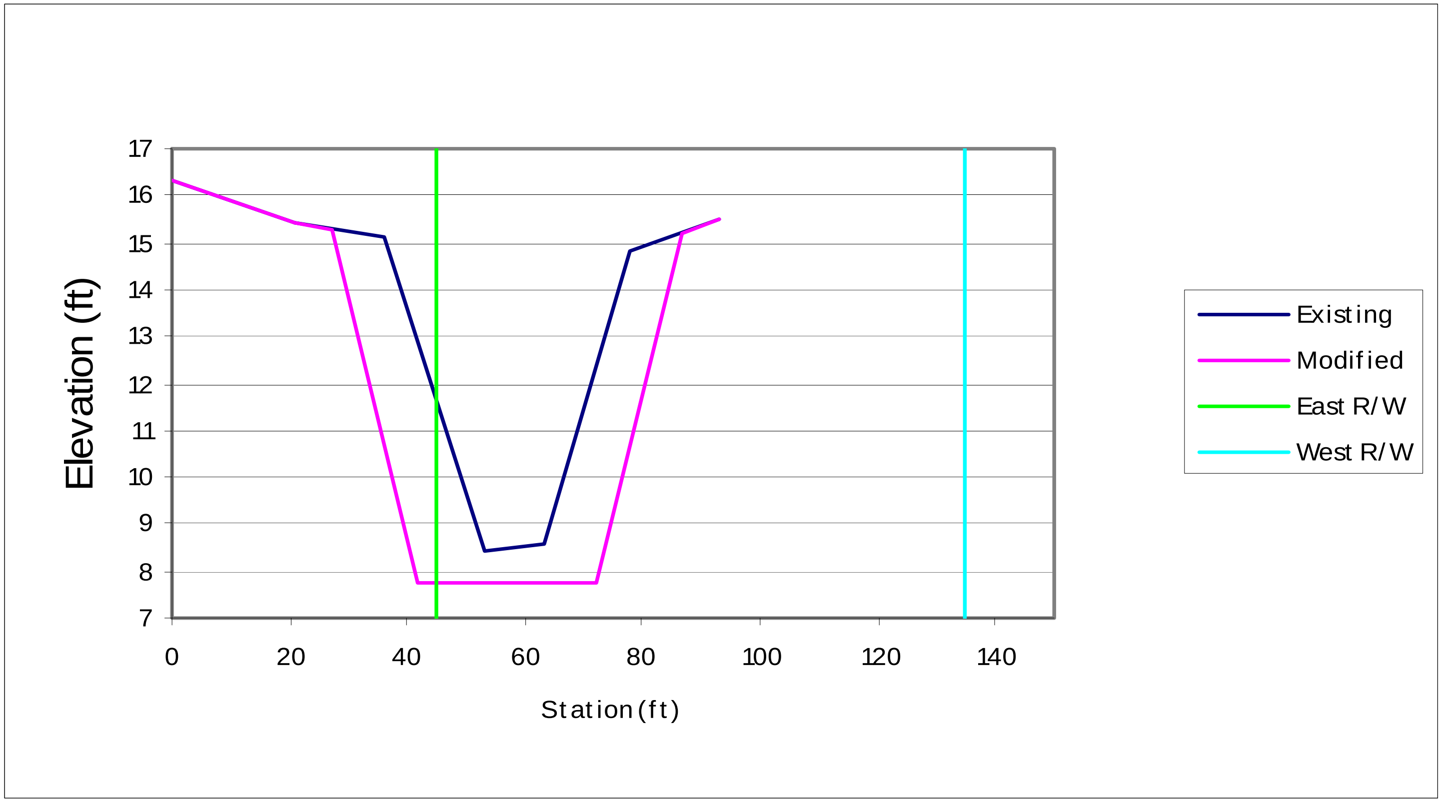


Figure B-3. Corkscrew Canal cross section just upstream of 41st avenue.

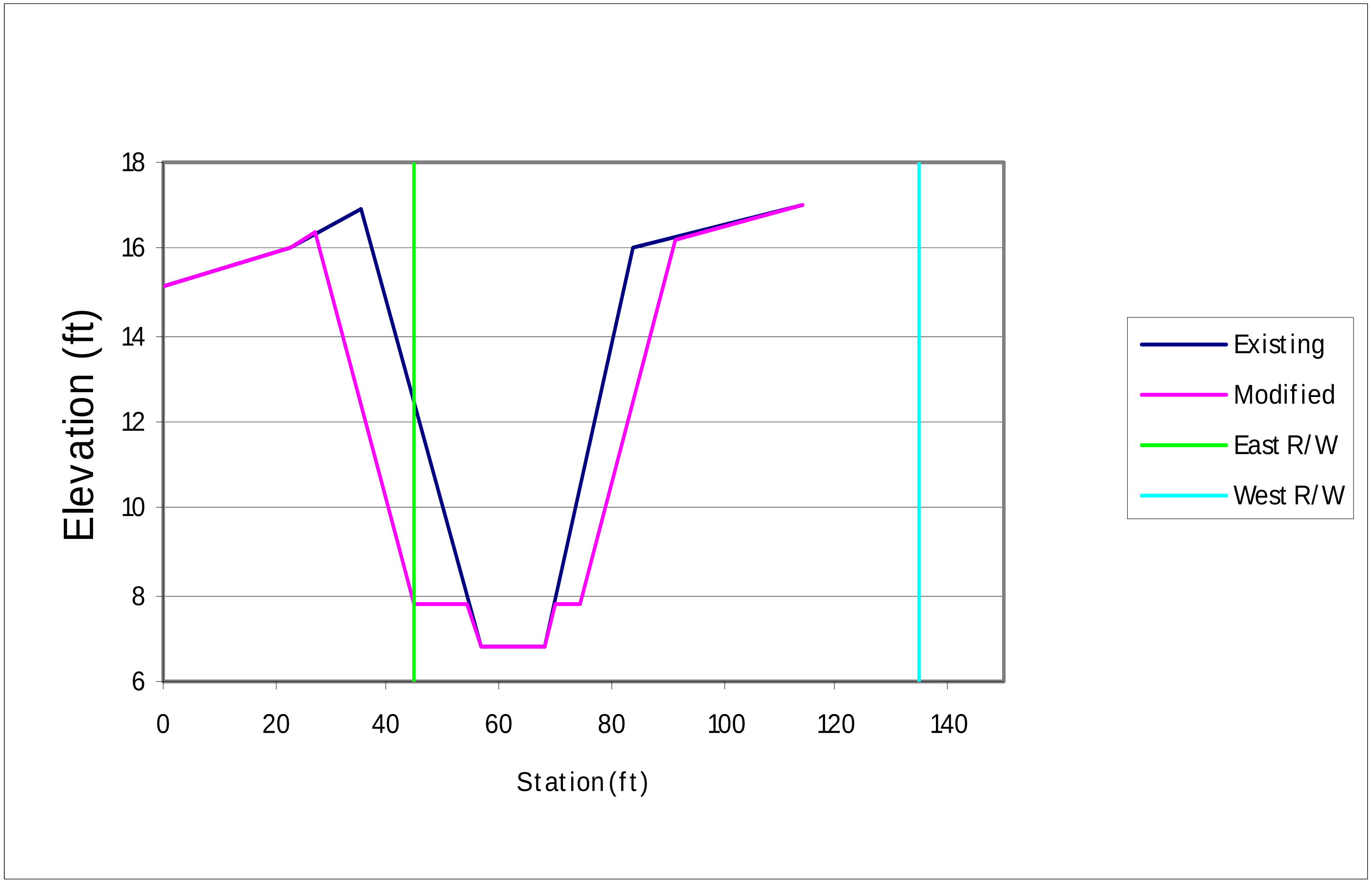


Figure B-4. Corkscrew Canal cross section just downstream of 41st avenue.

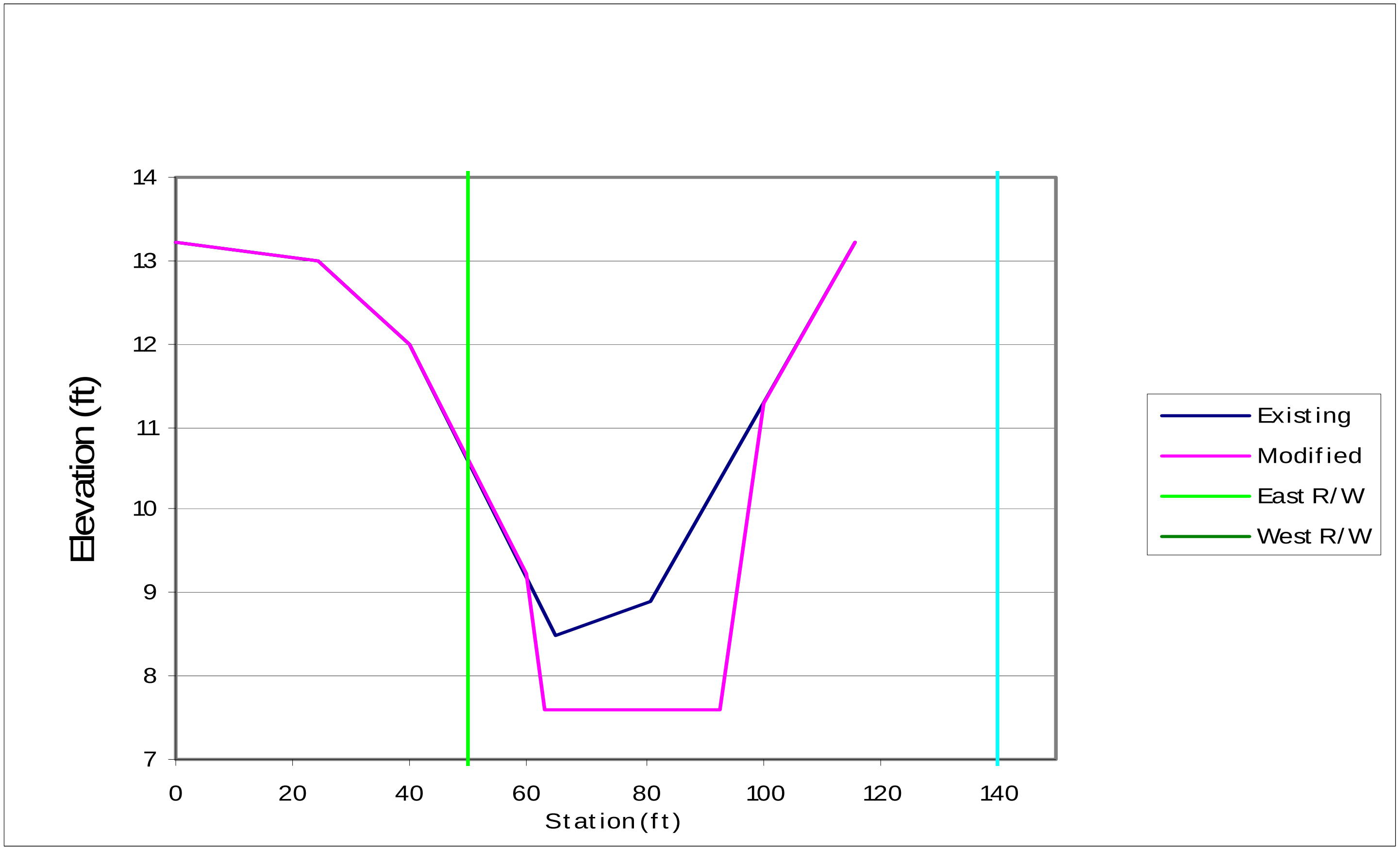


Figure B-5. Corkscrew Canal cross section just upstream of 39th avenue.

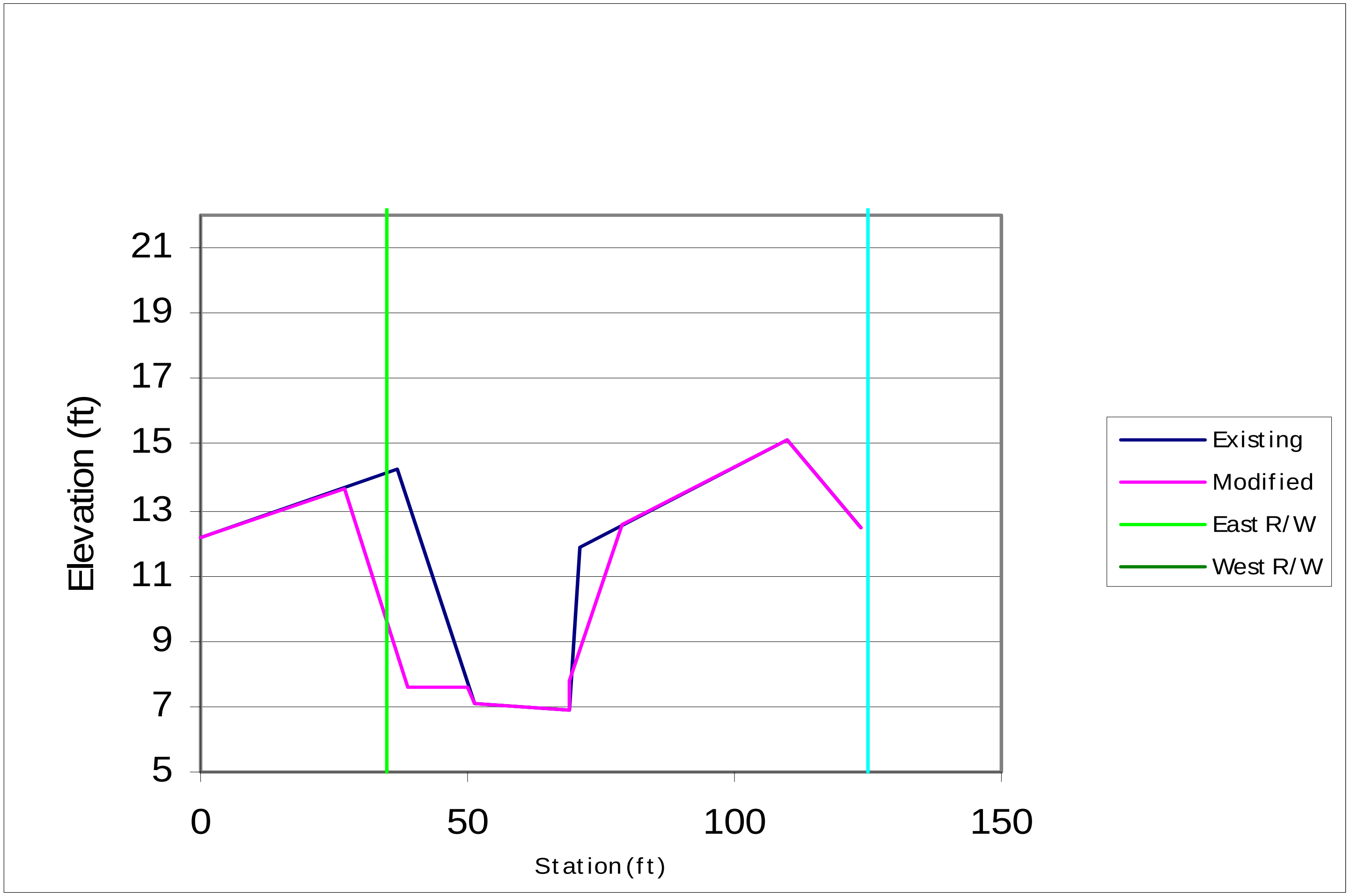


Figure B-6. Corkscrew Canal cross section just downstream of 39th avenue.

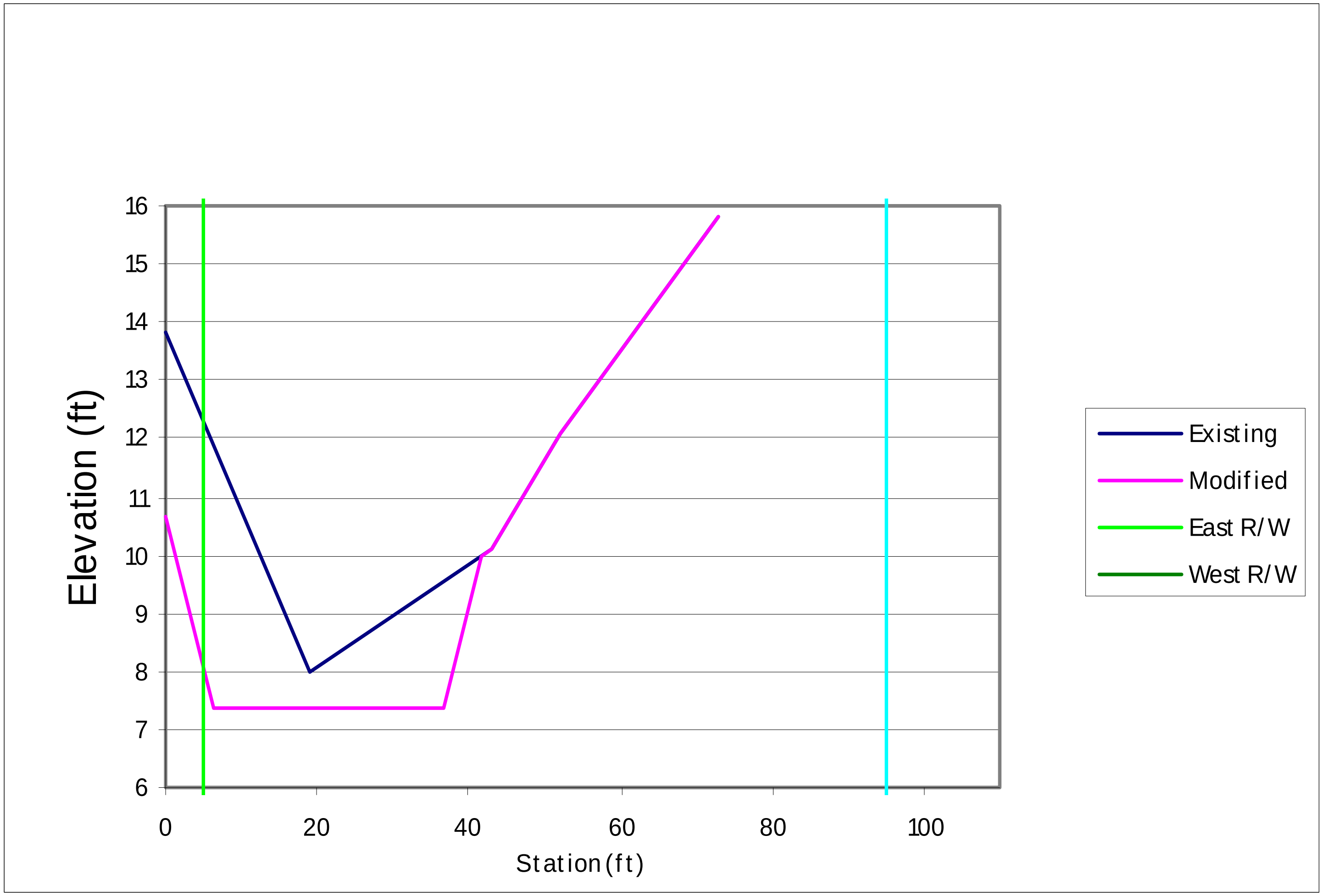


Figure B-7. Corkscrew Canal cross section just upstream of 37th avenue.

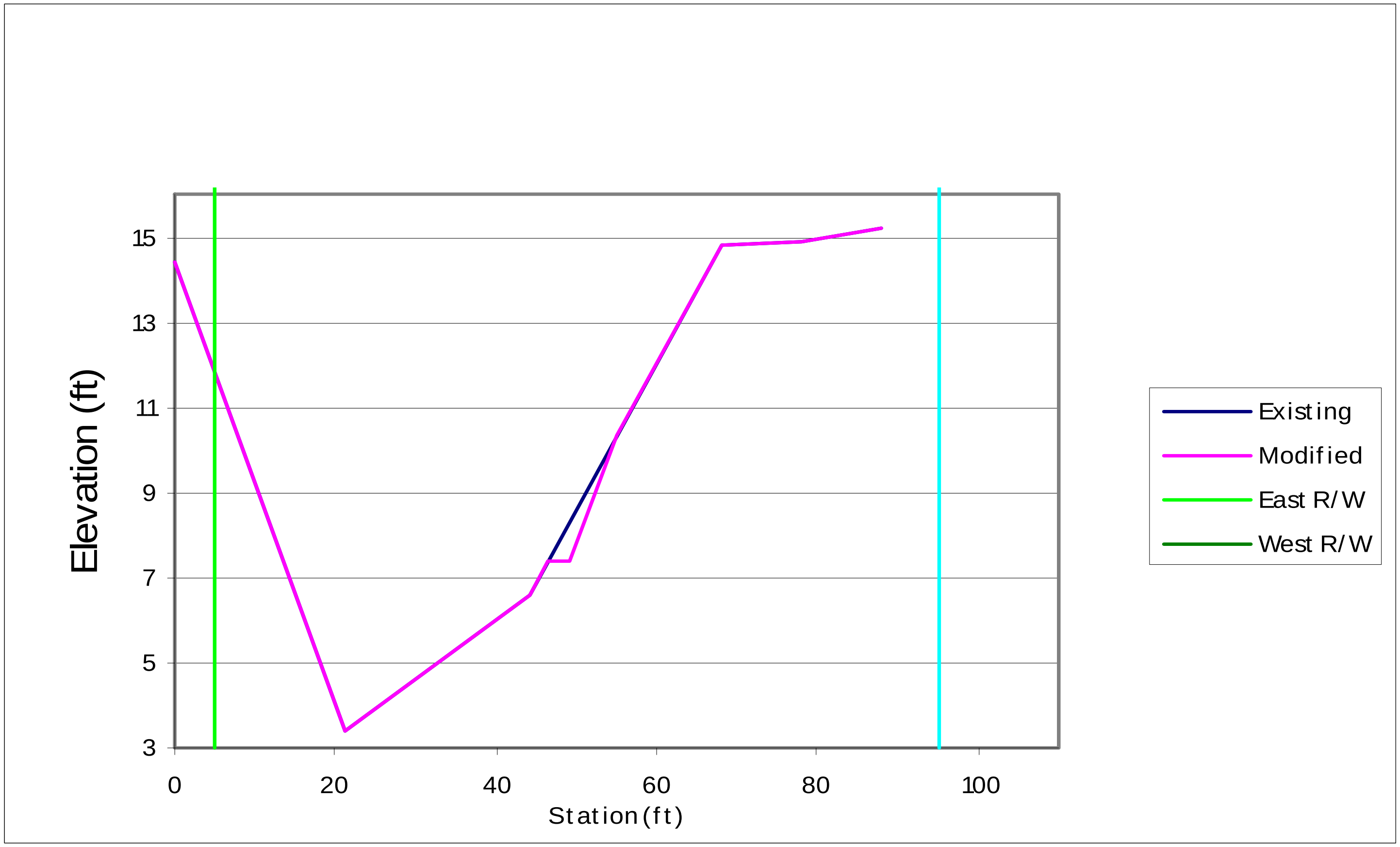


Figure B-8. Corkscrew Canal cross section just downstream of 37th avenue.

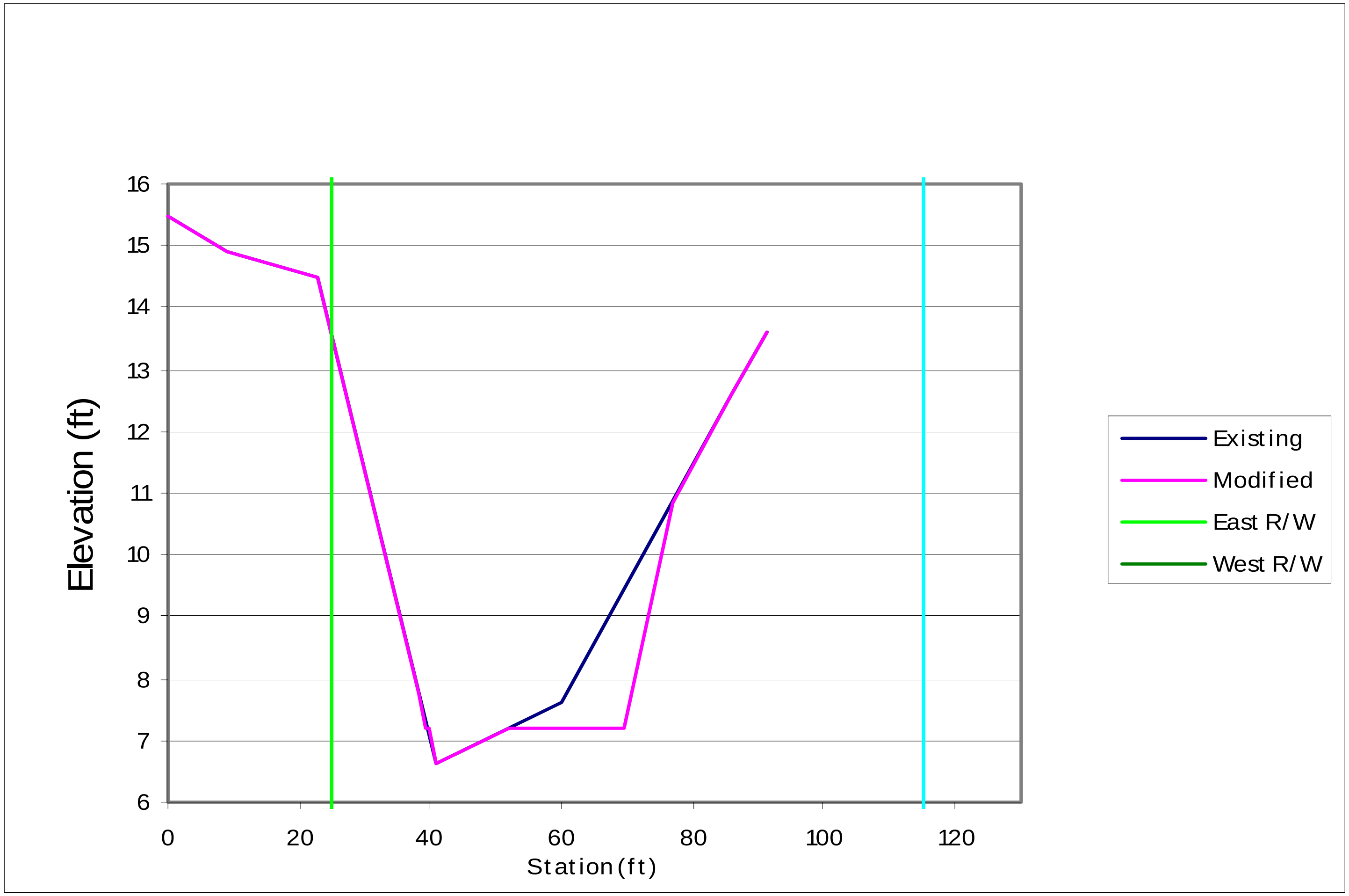


Figure B-9. Corkscrew Canal cross section just upstream of 35th avenue.

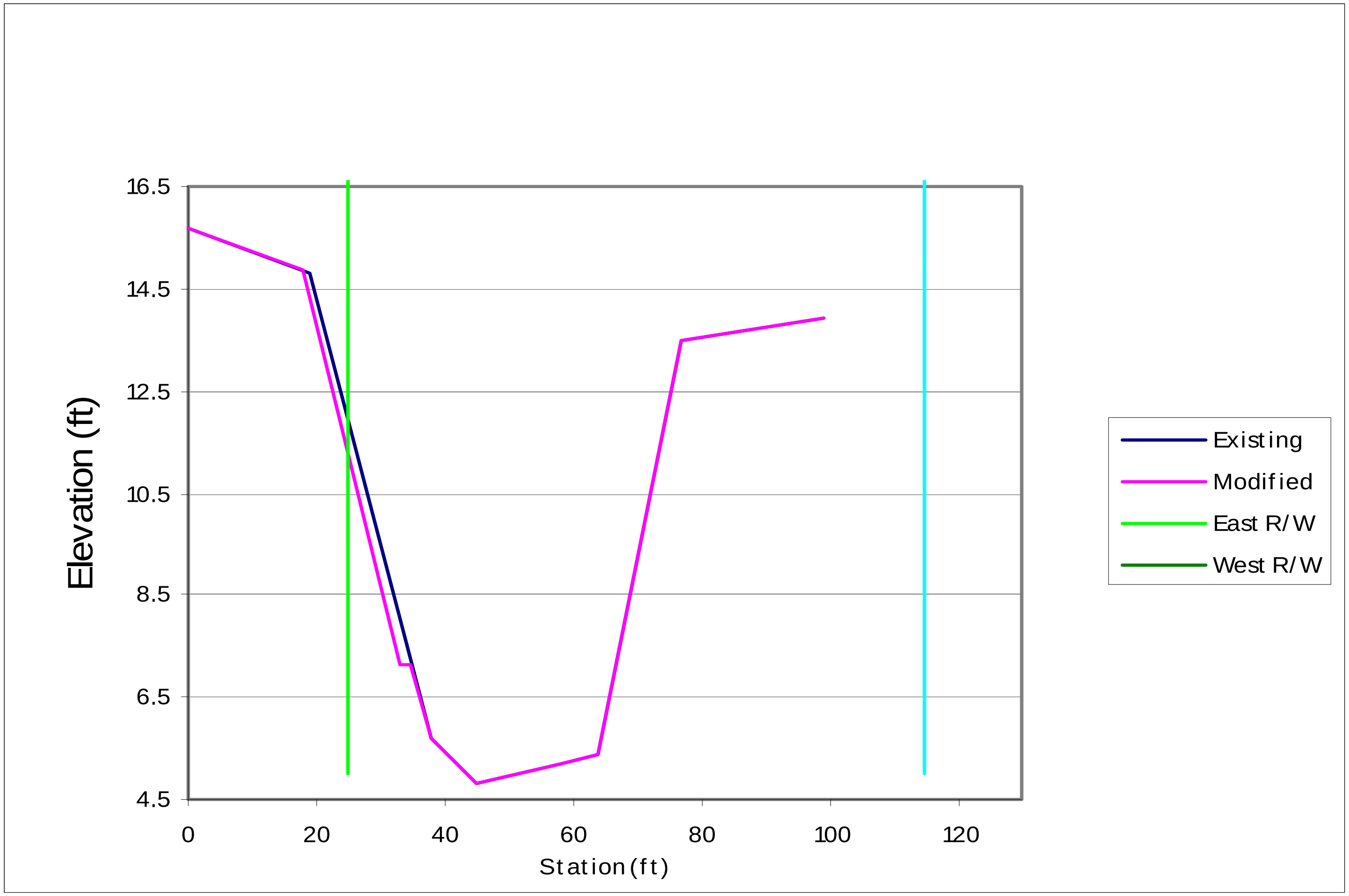


Figure B-10. Corkscrew Canal cross section just downstream of 35th avenue.

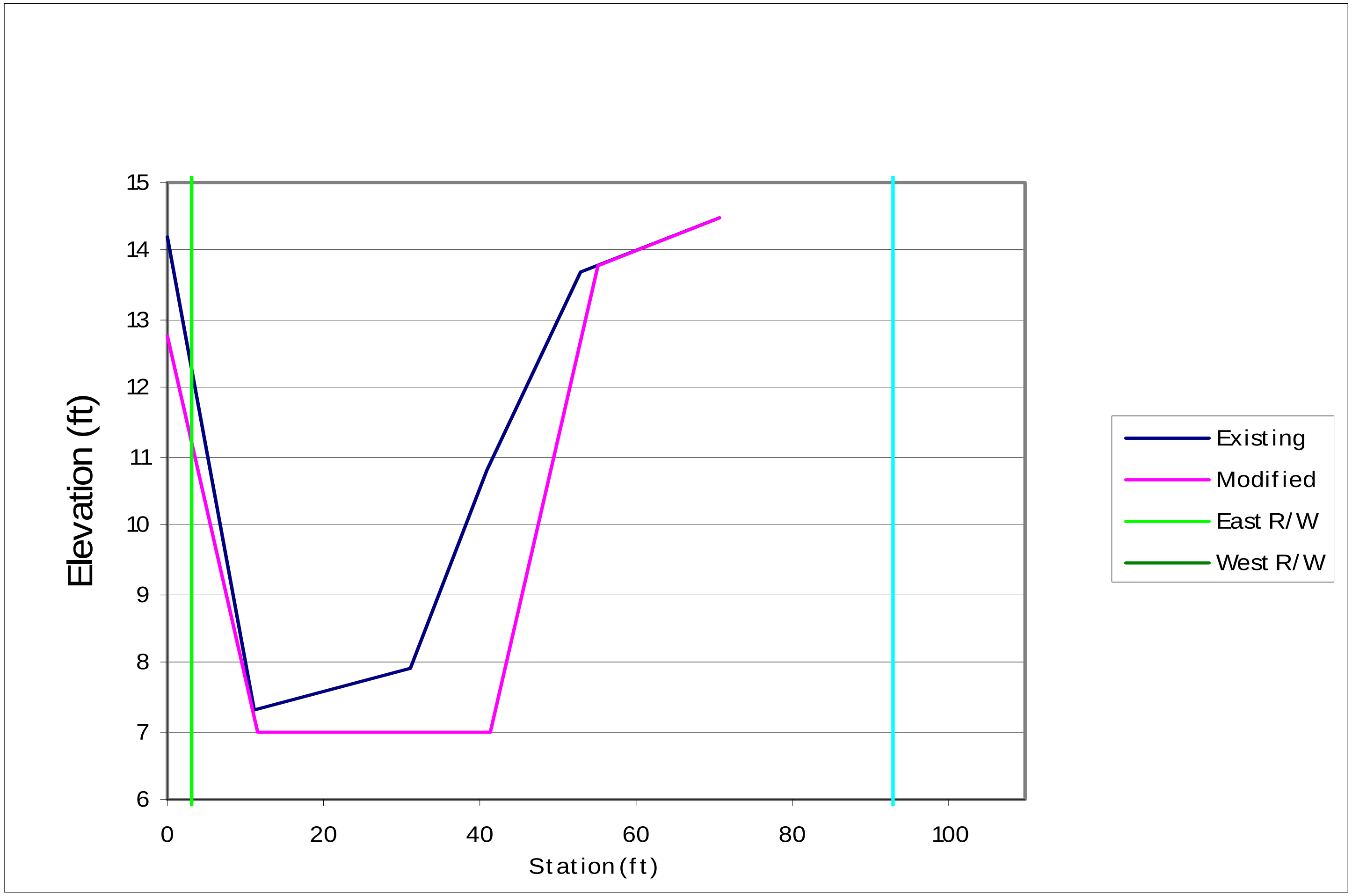


Figure B-11. Corkscrew Canal cross section just upstream of 33rd avenue.

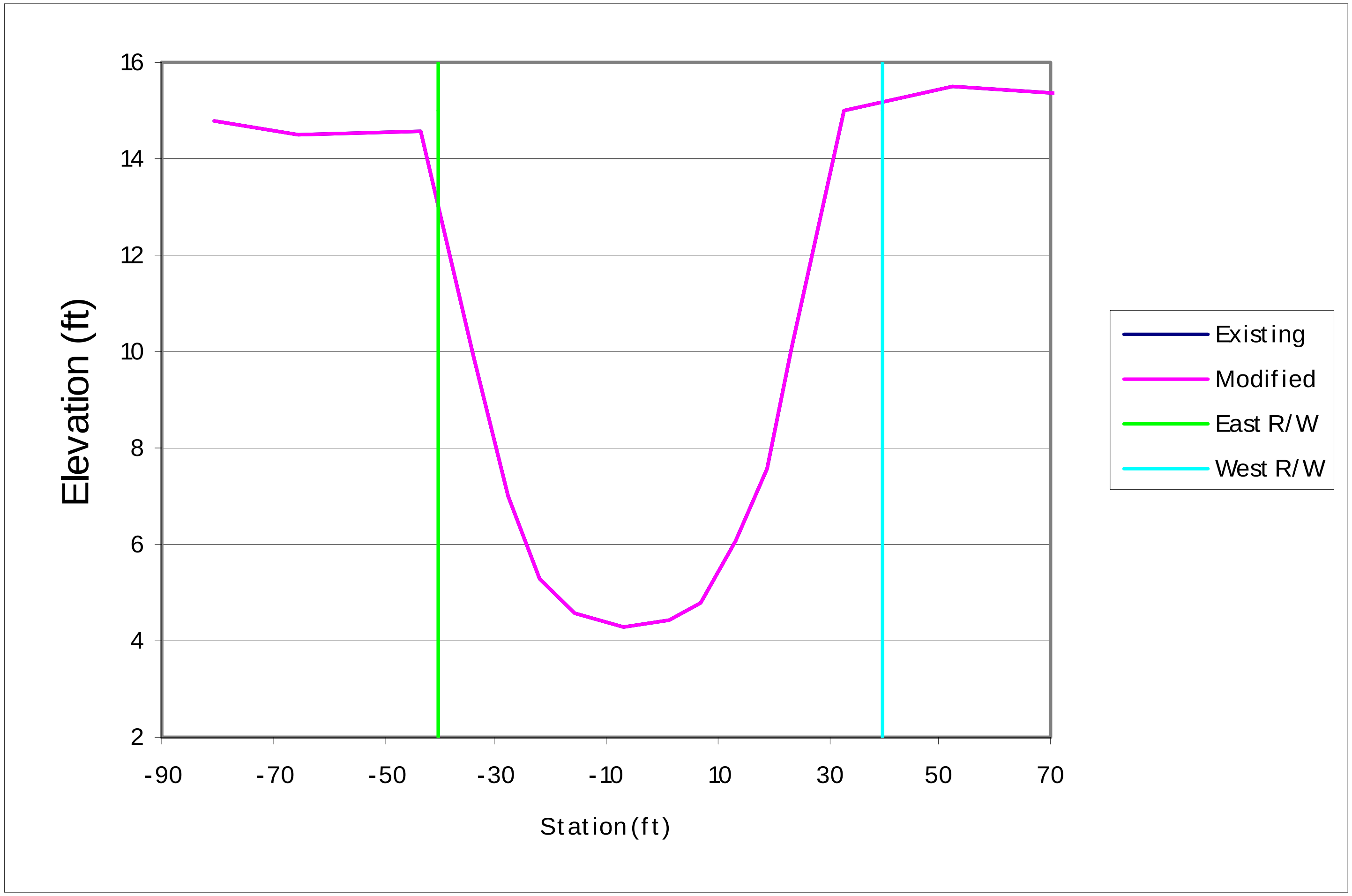


Figure B-12. Corkscrew Canal cross section just upstream of Immokalee Road.

APPENDIX C – MODIFIED CULVERT AND BRIDGE CONFIGURATIONS

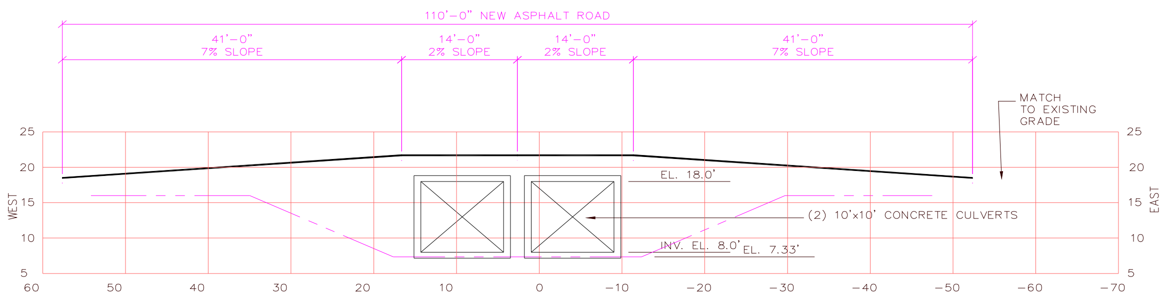
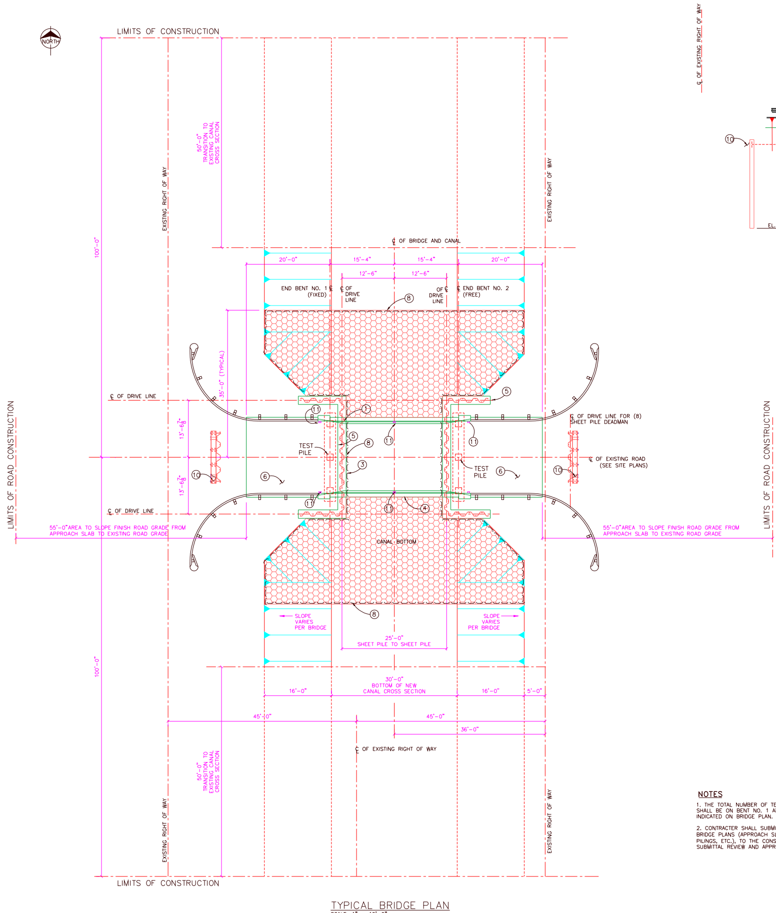
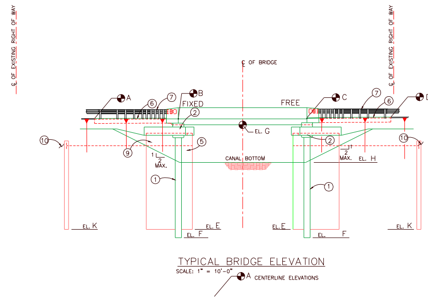


Figure C-1. Gated box culvert at 43rd Avenue.





NOTES

1. THE TOTAL NUMBER OF TEST PILES ARE TWO (2). ONE SHALL BE ON BENT NO. 1 AND ONE ON BENT NO. 2 AS INDICATED ON BRIDGE PLAN.

2. CONTRACTER SHALL SUBMIT SIGNED AND SEALED COMPLETE BRIDGE PLANS (APPROACH SLAB, DECK RAILINGS, BENTS, PILINGS, ETC.), TO THE CONSTRUCTION ENGINEER. FOR SUBMITTAL REVIEW AND APPROVAL.

ELEVATION TABLE IN – FT NGVD 29

BRIDGE SITE LOCATION	A	B	C	D	E	F	G	H	K
41 AVE. N.W.	18.3	18.7	18.7	18.3	–3.0	–10.0	17.0	7.8	–3.0
39 AVE. N.W.	18.3	18.7	18.7	18.3	–3.0	–10.0	17.0	7.6	–3.0
37 AVE. N.W.	18.3	18.7	18.7	18.3	–8.0	–10.0	17.0	7.4	–3.0
35 AVE. N.W.	18.3	18.7	18.7	18.3	–8.0	–10.0	17.0	6.6	–3.0
33 AVE. N.W.	18.3	18.7	18.7	18.3	–8.0	–10.0	17.0	7.0	–3.0

KEY NOTES

1. 18" SQUARE CONCRETE PILE 3 REQUIRED/BENT; SEE FDOT INDEX 600
2. BENT: 3'-0" DEEP FOR END BENT (BENTS 1 & 2); SEE SHEET 14 OF 17.
3. PRECAST, PRESTRESSED CONCRETE DECK SLABS; TO BE DETERMINED BY CONTRACTOR
4. CONCRETE BARRIER; SEE SHEETS 6 AND FDOT INDEX 700
5. SHEET PILES WITH CONCRETE CAP
6. CONCRETE APPROACH SLAB SEE FDOT INDEX 900
7. GUARD RAIL, SHALL CONFORM TO FDOT INDEX 400 (REFER TO DETAILS P AND J)
8. RIP RAP (UNDER BRIDGE)
9. SELECT FILL UNDER APPROACH SLAB AND END BENTS
10. SHEET PILE DEAD MEN
11. REFLECTIVE BARRIER MARKER (WHITE) INSTALLED IN ACCORDANCE WITH D.O.T. INDEX NO. 410 AND CONFORM TO SECTION 993-5 OF THE F.D.O.T. SPECIFICATIONS.

Figure C-2. A typical bridge cross section.