PMTurkeyCOLPEm Resource

From:	Orthen, Richard [Richard.Orthen@fpl.com]
Sent:	Wednesday, October 17, 2012 1:05 PM
To:	Williamson, Alicia; Matthews, David; Maher, William; Comar, Manny; Stewart, Scott; McCree, Victor
Subject:	FPL Letter L-2012-366 Dated 17OCT12: Groundwater Flow Model Revision 6
Attachments:	L-2012-366 Dated 17OCT12 GW Flow Model Rev 6_reduced.pdf

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555-0001

Re: Florida Power & Light Company
    Proposed Turkey Point Units 6 and 7
    Docket Nos. 52-040 and 52-041
    <u>Groundwater Flow Model Revision 6</u>

References:

1. FPL Letter L-2011-082 to NRC dated February 28, 2011, NRC June 2010 Environmental Audit Submittal of Groundwater Model Development and Analysis: Units 6 & 7 Dewatering and Radial Collector Well Simulations, Revision 1

2. FPL Letter L-2011-098 to NRC dated March 17, 2011, NRC June 2010 Environmental Audit Submittal of Groundwater Flow Model (MODFLOW) Calculation Revision 4 Input/Output Files

The groundwater flow model developed for the Biscayne Aquifer in support of the FPL Turkey Point Units 6 & 7 COL Application has been revised. The purpose of this letter is to provide the Revision 2 Groundwater Model Development and Analysis Report (Enclosure 1) and the associated Revision 6 Groundwater Flow Model for Biscayne Aquifer Calculation Input/Output Files (Enclosure 2). The enclosed information supersedes that provided in the referenced letters. A summary of the revised groundwater flow model is included in the attachment to this letter.

The attachment identifies changes that will be made in a future revision of the Turkey Point Units 6 and 7 Combined License Application (if applicable).

The materials provided on the enclosed optical storage media (OSM) are to assist the NRC staff with their review. As discussed with the NRC, the data provided on the enclosed OSM is not convertible to PDF files. Consequently, the information submitted herein does not comply with the requirements for electronic submission in NRC Guidance Document, "Guidance for Electronic Submissions to the NRC," dated May 27, 2011.

Richard F. Orthen
Principal Licensing Engineer
New Nuclear Projects NNP/JB B3314
Florida Power & Light Company
700 Universe Boulevard
Juno Beach, FL 33408-0420
richard.orthen@nexteraenergy.com
o(561) 691-7512

Subject: FPL Letter L-2012-366 Dated 17OCT12: Groundwater Flow Model Revision 6
Sent Date: 10/17/2012 1:05:29 PM
Received Date: 10/17/2012 1:31:18 PM
From: Orthen, Richard

Created By: Richard.Orthen@fpl.com

Recipients:
"Williamson, Alicia" <Alicia.Williamson@nrc.gov>
Tracking Status: None
"Matthews, David" <David.Matthews@nrc.gov>
Tracking Status: None
"Maher, William" <William.Maher@fpl.com>
Tracking Status: None
"Comar, Manny" <Manny.Comar@nrc.gov>
Tracking Status: None
"Stewart, Scott" <Scott.Stewart@nrc.gov>
Tracking Status: None
"McCree, Victor" <Victor.McCree@nrc.gov>
Tracking Status: None

Post Office: GOXEXVS01.fplu.fpl.com

Files	Size	Date & Time
MESSAGE	2263	10/17/2012 1:31:18 PM
L-2012-366 Dated 17OCT12 GW Flow Model Rev 6_reduced.pdf	4556864	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

October 17, 2012

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555-0001

Re: Florida Power & Light Company
    Proposed Turkey Point Units 6 and 7
    Docket Nos. 52-040 and 52-041
    Groundwater Flow Model Revision 6

References:

1. FPL Letter L-2011-082 to NRC dated February 28, 2011, NRC June 2010 Environmental Audit Submittal of Groundwater Model Development and Analysis: Units 6 & 7 Dewatering and Radial Collector Well Simulations, Revision 1

2. FPL Letter L-2011-098 to NRC dated March 17, 2011, NRC June 2010 Environmental Audit Submittal of Groundwater Flow Model (MODFLOW) Calculation Revision 4 Input/Output Files

The groundwater flow model developed for the Biscayne Aquifer in support of the FPL Turkey Point Units 6 & 7 COL Application has been revised. The purpose of this letter is to provide the Revision 2 Groundwater Model Development and Analysis Report (Enclosure 1) and the associated Revision 6 Groundwater Flow Model for Biscayne Aquifer Calculation Input/Output Files (Enclosure 2). The enclosed information supersedes that provided in the referenced letters. A summary of the revised groundwater flow model is included in the attachment to this letter.

The attachment identifies changes that will be made in a future revision of the Turkey Point Units 6 and 7 Combined License Application (if applicable).

The materials provided on the enclosed optical storage media (OSM) are to assist the NRC staff with their review. As discussed with the NRC, the data provided on the enclosed OSM is not convertible to PDF files. Consequently, the information submitted herein does not comply with the requirements for electronic submission in NRC Guidance Document, "Guidance for Electronic Submissions to the NRC," dated May 27, 2011.

If you have any questions, or need additional information, please contact me at 561-691-7490.

Sincerely,

William Maher
Senior Licensing Director – New Nuclear Projects

WDM/RFO

Attachment: Groundwater Flow Model Revision 6 Summary

Enclosure 1: Groundwater Model Development and Analysis: Units 6 & 7 Dewatering
and Radial Collector Well Simulations (Revision 2) – September 2012

Enclosure 2: Groundwater Flow Model for Biscayne Aquifer Calculation Input/Output
Files (Revision 6) – September 2012 (5 OSM)

cc (w/o Enclosure 2):
PTN 6 & 7 Project Manager, AP1000 Projects Branch 1, USNRC DNRL/NRO
Regional Administrator, Region II, USNRC
Senior Resident Inspector, USNRC, Turkey Point Plant 3 & 4

Revision Discussion

The groundwater flow model developed for the Biscayne Aquifer (Bechtel Power Corporation, 2011) in support of the FPL Turkey Point Units 6 & 7 COL Application has been revised. This revision is the result of updates to the groundwater flow model to correct errors in the model input/output files. The documents affected by this revision are FSAR Appendix 2CC and the Groundwater Model Development and Analysis Report (i.e., *Groundwater Model Development and Analysis: Units 6 & 7 Dewatering and Radial Collector Well Simulations*; updated Revision 2 provided in Enclosure 1). Updates to FSAR Appendix 2CC will be provided in the next scheduled COLA revision in December 2012. The affected section narratives, tables, and figures as the result of these changes are identified in Table 1 for the Groundwater Model Development and Analysis Report and Table 2 for FSAR Appendix 2CC. Lastly, the updated Groundwater Flow Model for Biscayne Aquifer Calculation Input/Output Files (Rev. 006) are provided in Enclosure 2.

The input/output file errors were associated with the conductance calculation for the model perimeter general-head boundary (GHB) cells, which was introduced in the data pre-processing phase. As a result of the error, lateral flow of water into and out of the model boundaries was incorrectly calculated. In addition, it was found that two grid cells in model layer 3 for the RCW simulations had incorrect top and bottom surface elevations. These GHB and grid cell errors, corrected in the Enclosure 2 input/output files, are further described below.

The error in the groundwater flow model files was discovered during preparation of the response to RAI 6354 (EIS 2.3.1-6). This RAI requested information on how the conductance values were determined for certain model boundary condition cells. The preparer of the RAI response identified an inconsistency between the boundary conductance values for the model perimeter GHB cells compared to what was reported. This error was introduced through the use of a MATLAB$^®$ script in pre-processing of the data prior to running MODFLOW.

Data for the numerical grid, boundary conditions, and model parameters are typically entered through the graphical user interface, which in this case is the software package Visual MODFLOW. For the FPL model however, the conductance values were prepared external to Visual MODFLOW using the scripting language MATLAB$^®$. The error was introduced through incorrect model cell row and column spacing values that are used to calculate the GHB cell conductance. The result of this error is that lateral flow of water into and out of the model was incorrectly calculated. In addition, it was found that two grid cells in Model Layer 3 for the RCW simulations had incorrect top and bottom surface elevations.

Additionally, during the review of the groundwater flow model supporting analyses, it was also determined that incorrect RCW approach velocities from the sensitivity cases and Units 6 & 7 excavation construction dewatering rates were reported in FSAR Appendix 2CC and in the groundwater model development and analysis report. Incorrect RCW approach velocities were reported due to a transcription error (the correct modeling simulation files were run, but the values were entered incorrectly into a summary table). Incorrect dewatering rates were reported because they were taken from an earlier set of modeling files that had been superseded.

The updated model shows no changes to the calibration, validation, and groundwater control simulations. For the radial collector well (RCW) simulations, the base case showed no change in the quantity of water originating from Biscayne Bay or from the inland flow to the RCW. The

components of the inland flow each changed by a value of 0.1 percent for the base case; the portion of water originating from the cooling canal system increased from 1.9 to 2.0 percent, and the water originating from regional eastward flow decreased from 0.3 to 0.2 percent as shown in Table 3. There are minor changes to the portion of the water originating from Biscayne Bay, the cooling canal system, and the regional eastward flow for the sensitivity analyses (up to a 0.2 percentage point change from the previously reported values) as shown in Table 3. Additionally, for the base case, there were no changes in the approach velocity calculations and no changes to the drawdown contours for the radial collector wells.

Changes to the RCW approach velocity values are shown in Table 4. As stated there were no changes to the base case. The error to the model boundary GHB conductance values resulted in minor revisions to the reported sensitivity analyses values. However, for the three values identified with an asterisk (*), as shown in Table 4, it was determined that incorrect values had been previously reported.

It was also determined that incorrect Units 6 & 7 construction dewatering rates were reported in FSAR Appendix 2CC and the Groundwater Model Development and Analysis Report. The reported dewatering rates in FSAR Appendix 2CC and the Groundwater Model Development and Analysis Report are 140 gallons per minute (gpm) and 136 gpm for Units 6 & 7, respectively. These reported rates should have been 96 gpm for each unit, a lower rate than what was previously reported.

Revision Impacts Conclusion

The primary model changes are to the RCW origination of water percentages (FSAR Appendix 2CC, Table 2CC-211; Groundwater Model Development and Analysis Report, Table 11) and the RCW approach velocities (FSAR Appendix 2CC, Table 2CC-212; Groundwater Model Development and Analysis Report Table 12). A comparison of the previously reported values and the revised values in Tables 3 and 4 demonstrates that the changes are inconsequential. The revised construction dewatering rates for Units 6 & 7 are 96 gpm for each unit, lower than the values previously reported and therefore do not impact any conclusions in the COLA.

Table 1

Groundwater Model Development and Analysis Report (Rev. 2) Change Description

	Narrative
Executive Summary	Provide reason for Revision 2 (model error and updates).
Section 3.1.1	Clarification to the description of the Interceptor Ditch water level.
Section 3.3.9	Clarification to the description of the simulated RCW lateral lengths and screen locations.
Section 5.1	Update Units 6 & 7 simulated dewatering rates.
Section 5.2	Clarification to the description of the simulated RCW lateral lengths and screen locations.
Section 5.2.1	Updates to the ZoneBudget results for flow into and out of the model in relationship to the origins of water supplying the RCWs.
Section 5.2.3	Updates to the ZoneBudget results for flow into and out of the model in relationship to the origins of water supplying the RCWs, sensitivity analysis.
Section 6.0	Update Units 6 & 7 simulated dewatering rates.
Various	Additional minor editorial and clarification changes.
	Tables
Table 6	Editorial change to table title.
Table 10	Editorial change to table title.
Table 11	Changes to RCW Origin of Water percentages and footnotes (refer to Table 3, below).
Table 12	Changes to RCW Approach Velocity values and footnotes (refer to Table 4, below).
Various	Additional minor editorial and clarification changes.
	Figures
Figure 21	Revision 1 flow diagram had two Post – EPU values, for Revision 2, changed to Pre – EPU values.
Figure 33	Revision 1 included the RCW laterals which should not be shown since figure is for pre-RCWs condition. For Revision 2, removed laterals and added footnote pointing to Figure 55 for location of RCW laterals.
Figures 37 through 44	Contours revised as the result of the corrected GHB conductance.
Figure 45	Revision 1 had a Post – EPU value, for Revision 2, changed to Pre – EPU value. Slight changes to the modeled values and percentages as the result of the corrected GHB conductance.

Table 1

Groundwater Model Development and Analysis Report (Rev. 2) Change Description

Figure 49	Revision 1 showed only one unit, Revision 2 changed to show both units and additional visual refinements.
Figure 50	Edits to figure title since figure represents only Unit 7 and not both units, and added footnote that Unit 6 has similar configuration.
Figure 52	Revised figure with the correct dewatering rates for different grout plug hydraulic conductivity simulations.
Figure 55	Refinements to the figure to more accurately represent lateral pumping nodes (minor changes).
Figure 56	Contours revised as the result of the corrected GHB conductance and changes associated with areas near model boundary, away from RCWs and Units 6 & 7, as a result of the corrected GHB conductance.
Figure 61	Slight Layer 1 area changes as the result of the corrected GHB conductance.
Figure 62	Slight Layer 2 area changes as the result of the corrected GHB conductance.
Figure 65	Added footnote.
Various	Additional minor editorial and clarification changes.

Table 2

FSAR Appendix 2CC Change Description

Narrative	
Section 3.1.1	Provide reason for Appendix revision changes.
Section 3.3.5	Clarification to the description of the Interceptor Ditch water level.
Section 3.3.9	Clarification to the description of the simulated RCW lateral lengths and screen locations.
Section 5.1	Update Units 6 & 7 simulated dewatering rates.
Section 5.2	Clarification to the description of the simulated RCW lateral lengths and screen locations.
Section 5.2.1	Updates to the ZoneBudget results for flow into and out of the model in relationship to the origins of water supplying the RCWs.
Section 5.2.3	Updates to the ZoneBudget results for flow into and out of the model in relationship to the origins of water supplying the RCWs, sensitivity analysis.
Section 6.0	Update Units 6 & 7 simulated dewatering rates.
Various	Additional minor editorial and clarification changes.
Tables	
Table 2CC-206	Editorial change to table title.
Table 2CC-210	Editorial change to table title.
Table 2CC-211	Changes to RCW Origin of Water percentages and footnotes (refer to Table 3, below).
Table 2CC-212	Changes to RCW Approach Velocity values and footnotes (refer to Table 4, below).
Various	Additional minor editorial and clarification changes.
Figures	
Figure 2CC-213	Flow diagram had two Post – EPU values, changed to Pre – EPU values.
Figure 2CC-222	Removed laterals from figure and added footnote pointing to Figure 2CC-242 for location of the RCW laterals.
Figures 2CC-226 through -233	Contours revised as the result of the corrected GHB conductance.
Figure 2CC-234	Flow diagram had a Post – EPU value, changed to Pre – EPU value. Slight changes to the modeled values and percentages as the result of the corrected GHB conductance.
Figure 2CC-237	Revised figure to show both units and additional visual refinement.

Table 2

FSAR Appendix 2CC Change Description

Figure 2CC-238	Edits to figure title since figure represents only Unit 7 and not both units, and added a footnote that Unit 6 has similar configuration.
Figure 2CC-240	Revised figure with the correct dewatering rates for different grout plug hydraulic conductivity simulations.
Figure 2CC-242	Refinement to the figure to more accurately represent lateral pumping nodes (minor changes).
Figure 2CC-243	Contours revised as the result of the corrected GHB conductance. Changes associated with areas near model boundary, away from RCWs and Units 6 & 7, as a result of the corrected GHB conductance.
Figure 2CC-248	Slight area changes as the result of the corrected GHB conductance.
Figure 2CC-249	Slight Layer 2 area changes as the result of the corrected GHB conductance.
Figure 2CC-262	Very minor changes in Layer 2 head distribution.
Figure 2CC-263	Very minor changes in Layer 1 head distribution.
Figure 2CC-264	Very minor changes in Layer 1 head distribution.
Various	Additional minor editorial and clarification changes.

Table 3

FSAR Table 2CC-211 / Groundwater Modeling Report Table 11

Radial Collector Wells – Origin of Water (including sensitivity analysis)

Percent Contribution to Radial Collector Wells

Zone	RCW in Upper Higher Flow Zone (Base Case)	RCW in Key Largo Limestone	Seasonal High Water Level	Seasonal Low Water Level	Double Vertical Hyd. Cond.	Half Vertical Hyd. Cond.	Key Largo All ~~Lower~~ High K (Blue)	Key Largo All ~~Higher~~ Low K (Red)
Biscayne Bay	97.8%	97.8%	98.1%	97.6%	~~99.2~~ **99.1**%	~~95.3~~ **95.4**%	~~97.4~~ **97.6**%	98.5%
Flow from inland	2.2%	2.2%	1.9%	2.4%	~~0.8~~ **0.9**%	~~4.7~~ **4.6**%	~~2.6~~ **2.4**%	1.5%
- Via Cooling Canal System	~~1.9~~ **2.0**%	~~1.9~~ **2.0**%	1.8%	~~2.0~~ **2.1**%	~~0.7~~ **0.8**%	3.2%	~~2.2~~ **2.1**%	~~1.3~~ **1.4**%
- Regional Eastward Flow	~~0.3~~ **0.2**%	~~0.3~~ **0.2**%	0.1%	~~0.4~~ **0.3**%	0.1%	~~1.5~~ **1.4**%	~~0.4~~ **0.3**%	0.2%

Notes: The top two rows contribute to the total flow and sum to 100 percent.

The bottom two rows are components of inland flow. Not all component flows sum to the total inland flow due to rounding.

The terms 'Blue' and 'Red' in the column header refer to the colors shown for the Key Largo hydraulic conductivity distribution shown in FSAR Appendix 2CC Figure 2CC-216 and Groundwater Modeling Report Figure 27.

Each strikethrough table entry is replaced by its adjacent bold red (corrected) entry.

Table 4

FSAR Table 2CC-212 / Groundwater Modeling Report Table 12

Radial Collector Wells – Approach Velocity (including sensitivity analysis)

Approach Velocity (cm/s)

Zone	RCW in Upper Higher Flow Zone (Base Case)	RCW in Key Largo Limestone	Seasonal High Water Level	Seasonal Low Water Level	Double Vertical Hyd. Cond.	Half Vertical Hyd. Cond.	Key Largo All ~~Lower~~ **High K** (Blue)	Key Largo All ~~Higher~~ **Low** K (Red)
Entire RCW Catchment	3.3E-05	3.3E-05	3.2E-05	3.3E-05	~~3.9~~ **3.7**E-05	2.9E-05	3.2E-05	3.5E-05
Immediate RCW Area	5.2E-04	5.2E-04	5.2E-04	5.2E-04	~~5.3~~ **7.3**E-04*	~~5.0~~ **3.5**E-04*	5.2E-04	~~5.2~~ **6.3**E-04*
Average of all RCW Laterals	6.2E-04	~~6.4~~ **6.2**E-04	6.2E-04	6.2E-04	9.2E-04	4.0E-04	6.1E-04	7.7E-04

Notes: The terms 'Blue' and 'Red' in the column header refer to the colors shown for the Key Largo hydraulic conductivity distribution shown in FSAR Appendix 2CC Figure 2CC–216 and Groundwater Modeling Report Figure 27.

Each strikethrough table entry is replaced by its adjacent bold red (corrected) entry.

*Change in value due to transcription error.

References:

Bechtel Power Corporation, 2011. *Groundwater Model Development and Analysis: Units 6 & 7 Dewatering and Radial Collector Well Simulations*, Rev. 1. Available at: http://publicfiles.dep.state.fl.us/Siting/Outgoing/FPL_Turkey_Point/Units_6_7/Completeness/Plant_Associated_Facilities/4th_Round_Completeness/FPL%20Response_4thCompleteness/Groundwater%20Modeling%20Report,%20Rev.%201,%202011/Groundwater_Model_Report-Revision_1_022311_Final.pdf, Accessed on June 12, 2012.

ASSOCIATED ENCLOSURES:

Enclosure 1: Groundwater Model Development and Analysis: Units 6 & 7 Dewatering and
Radial Collector Well Simulations (Rev. 2) – September 2012

Enclosure 2: Groundwater Flow Model for Biscayne Aquifer Calculation Input/Output Files
(Rev. 6) – September 2012 (5 OSM)

The materials provided on the enclosed optical storage media (OSM) are to assist the NRC staff with their review. As discussed with the NRC, the data provided on the enclosed OSM is not convertible to PDF files. Consequently, the information submitted herein does not comply with the requirements for electronic submission in NRC Guidance Document, "Guidance for Electronic Submissions to the NRC," dated May 27, 2011.

Enclosure 1

Turkey Point Nuclear Plant Units 6 and 7
COL Application

GROUNDWATER FLOW MODEL REVISION

**Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations (Revision 2)
September 2012**

FPL Turkey Point Units 6 & 7 Project

GROUNDWATER MODEL DEVELOPMENT AND ANALYSIS:

UNITS 6 & 7 DEWATERING AND RADIAL COLLECTOR WELL SIMULATIONS
Revision 2

Bechtel Power Corporation
September 2012

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

UNITS

cm/s	centimeters per second
ft/day	feet per day
ft^2/day	feet squared per day
ft/s	feet per second
gpm	gallons per minute
in/yr	inches per year
kg/m^3	kilograms per meter cubed

ABBREVIATIONS

ARM	Absolute Residual Mean
bgs	Below Ground Surface
CCS	Cooling Canal System
COLA	Combined License Application
DEM	Digital Elevation Model
DRN	Drain Package (MODFLOW)
epm	Equivalent Porous Media
FPL	Florida Power and Light
GHB	General-Head Boundary Package (MODFLOW)
GMG	Geometric Multigrid (MODFLOW)
HFB	Horizontal Flow Boundary Package (MODFLOW)
IWW	Industrial Wastewater Facility
Kh	Horizontal Hydraulic Conductivity
Kv	Vertical Hydraulic Conductivity
M_d	Mass Balance Discrepancy
MNW	Multi-Node Well Package (MODFLOW)
MODFLOW	Modular Groundwater Flow Model
MRGIS	Marine Resources Geographic Information System
MSE	Mechanically Stabilized Earth (Retaining Wall)
NED	National Elevation Dataset
NAVD 88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NRMS	Normalized Root Mean Square
OCS	Office of Coast Survey
RCW	Radial Collector Well
RMS	Residual Mean Squared
RIV	River Cell Package (MODFLOW)
SCA	Site Certification Application

SEE	Standard Error of the Estimate
SEGS	Southeastern Geological Society
SFWMD	South Florida Water Management District
USGS	United States Geological Survey
WEL	Well Package (MODFLOW)

EXECUTIVE SUMMARY

A groundwater flow model for the Biscayne Aquifer at the Florida Power & Light Company (FPL) Turkey Point site has been developed for Units 6 & 7. The model is a steady-state, constant-density, three-dimensional representation of the surficial aquifer system developed using the numerical code MODFLOW 2000 developed by the U.S. Geological Survey (USGS), as it is implemented in the user-interface software Visual MODFLOW developed by Schlumberger Water Services. The groundwater model serves two purposes. The first is to evaluate groundwater control options for construction of Units 6 & 7. The second is to simulate the feasibility of a radial collector well system to serve as a temporary source of make-up water. The original version of this report (Revision 0, October 2009) was issued in support of the Site Certification Application (SCA) completeness review. Revision 1 (February 2011) of this report documented changes to the groundwater flow model in response to reviews from the South Florida Water Management District (SFWMD) and other state, local, and federal agencies. Changes to the model included modifications to the conceptual model, the numerical model, the calibration and validation runs, the predictive runs, and the sensitivity analyses.

Revision 2 of this report provides updates to the groundwater flow model to (a) correct errors in the groundwater flow model input/output files, (b) update incorrectly reported Units 6 & 7 construction dewatering rates, and (c) update incorrectly reported approach velocities for the sensitivity analyses of the radial collector wells (RCW). Editorial and grammatical changes were also incorporated.

The groundwater flow model hydrostratigraphic layer elevations were developed from geotechnical and geophysical logs for Units 6 & 7, pumping test wells in the Turkey Point Units 6 & 7 plant area and Turkey Point peninsula, pumping wells from the 1975 Turkey Point plant property Upper Floridan Aquifer study, from historical borings and well logs from the Turkey Point plant property, and from logs for wells in the Florida Geological Survey Lithologic database.

Hydraulic conductivity values were based on results from three historical pumping tests in the Biscayne Aquifer on the Turkey Point plant property, regional groundwater models that include the Turkey Point plant property within their domain, recent pumping tests at the plant area and the Turkey Point peninsula, and literature values.

The interaction between surface water and groundwater was simulated by including Biscayne Bay, the cooling canals, L-31E Canal, Card Sound Canal, Florida City Canal, and Model Land Canal (C-107) in the model. Spatially-variable groundwater recharge and evapotranspiration are considered based on land-use classification.

Calibration was approached with a multi-faceted methodology. Initially, the response to three pumping tests (PW-7L, PW-1, and PW-7U) was simulated by adjusting hydraulic conductivities of the various hydrostratigraphic units

comprising the Biscayne Aquifer. The conductance values of the various head-dependent boundary conditions were also primary calibration parameters.

Following the calibration, groundwater flow directions were compared to historical data, and a qualitative comparison of calculated groundwater discharge/recharge between cooling water canals and groundwater beneath Biscayne Bay to results from pre-existing surface water modeling was performed. The groundwater model was then validated by simulating an additional pumping test (PW-6U) and comparing the modeled and observed drawdown values.

The calibrated model was used to simulate construction dewatering for the Unit 6 and Unit 7 nuclear islands. Utilizing cut-off walls and implementing a grout blanket between the base of the excavation and the base of the cut-off walls, construction dewatering rates were reduced to approximately 100 gallons per minute (gpm) for each unit.

Particle tracking and water balance calculations from the proposed radial collector wells at the Turkey Point peninsula in Biscayne Bay indicate that approximately 97.8 percent of the water pumped from the radial collector wells originates in Biscayne Bay. A suite of sensitivity analyses addressing parameter and water level uncertainty indicate that this percentage remains similar for the tested range of variability.

1.0 OBJECTIVE & SCOPE

The objective of this report is to document the development, calibration, and simulation results of a groundwater flow model of the proposed dewatering systems and radial collector well system for the Turkey Point Units 6 & 7 Project at the Turkey Point facility.

A three-dimensional groundwater model was used to simulate steady-state, constant-density groundwater flow in the Biscayne Aquifer to evaluate construction and post-construction activities related to the construction and operation of two new nuclear units (Units 6 & 7).

2.0 AQUIFER DESCRIPTION & AVAILABLE DATA

2.1 Site Overview

Turkey Point plant property is located in Miami-Dade County, Florida, approximately 25 miles south of Miami (Figure 1) and approximately 9 miles southeast of Homestead. It is bordered on the east by Biscayne Bay, on the west by the FPL Everglades Mitigation Bank, and on the northeast by Biscayne National Park. The 5900-acre Industrial Wastewater Facility (IWW) (approximately 2 miles wide and 5 miles long), of which 4370 acres is water (approximately 75 percent), is a predominant feature within the Turkey Point plant property (Figure 2). Just west of the IWW is the L-31E canal, which is part of the regional drainage system.

The Units 6 & 7 plant area covers an area of approximately 218 acres and is situated south of Units 1 through 5 within the IWW. The units occupy a relatively small portion of the Turkey Point plant property. The preconstruction ground surface in the Units 6 & 7 plant area is generally flat, with elevations ranging from –2.4 to 0.8 feet NAVD 88.

Surface waters are a dominant feature of the Turkey Point plant property and surrounding region given that the plant is located between Biscayne Bay and the Everglades. A network of regional canals surround the site boundary and provides drainage for areas west of the Turkey Point plant property. The Units 6 & 7 plant area is within the IWW and is surrounded by cooling canals that return water back to the intake structures for Units 1 through 4.

2.2 Regional Hydrostratigraphy

The hydrostratigraphic framework of Florida consists of a thick sequence of Cenozoic sediments that comprise three main units (Reference 1):

- The surficial aquifer system (containing the Biscayne Aquifer and semi-confining Tamiami Formation).

- The intermediate confining unit, referred to as the Hawthorn Group.

- The Floridan aquifer system.

In southern Florida, the surficial aquifer system consists of the Tamiami, Caloosahatchee, Fort Thompson, and Anastasia Formations; the Key Largo and Miami Limestones; and undifferentiated sediments. The thickness of the surficial aquifer system ranges from approximately 20 feet to 400 feet and is approximately 220 feet under the Units 6 & 7 plant area.

The intermediate confining unit separates the Biscayne aquifer from the underlying Floridan aquifer system. It is characterized regionally by a sequence of relatively low hydraulic conductivity, largely clayey deposits, but it can locally contain transmissive units that act as an aquifer system. The Southeastern Geological Society (SEGS) (Reference 1) define the intermediate confining unit as "all rocks that lie between and collectively retard the exchange of water between the overlying surficial aquifer system and the underlying Floridan aquifer system." This unit is also referred to as the Hawthorn Group, with a thickness of approximately 900 feet in southern Florida.

Beneath the intermediate aquifer system/confining unit is the Floridan aquifer system which underlies all of Florida. The system formally consists of three hydrogeologic units: the Upper Floridan aquifer, the middle confining unit, and the Lower Floridan aquifer. The Upper Floridan aquifer is a major source of potable water in Florida, however, in the southeastern portion of the state (including Miami-Dade County) the water is brackish.

Hydrostratigraphic columns are presented in Figures 3 and 4.

2.3 Biscayne Aquifer

The surficial aquifer system within the Turkey Point plant property does not contain all of the regionally identified units. Those units identified within the plant property as a result of the 1971 (Reference 2), 2008 (Reference 3), and 2009 (Reference 4) subsurface investigations are summarized as:

- Muck – The surface of the site consists of approximately 2 to 6 feet of organic soils called muck. The muck is composed of recent light gray calcareous silts with varying amounts of organic content. This unit does not extend into Biscayne Bay, where exposed rock and sandy material is present in its place.

- Miami Limestone – The Pleistocene Miami Limestone is a white, porous sometimes sandy, fossiliferous, oolitic limestone.

- Upper Higher Flow Zone – At the boundary between the Miami Limestone and Key Largo Limestone is a laterally continuous relatively thin layer of high secondary porosity. The Upper Higher Flow Zone was defined based on a review of geophysical logs and drilling records. The primary identifier was the loss of drilling fluid identified at the boundary of the Key Largo Limestone and Miami Limestone. This observation was also

coincident with an increase in the boring diameter as identified by the caliper logging.

- Key Largo Limestone (interpreted as the Fort Thompson Formation elsewhere) – This is a coralline limestone (fossil coral reef) believed to have formed in a complex of shallow-water, shelf-margin reefs and associated deposits along a topographic break during the last interglacial period.

- Freshwater Limestone – At the base of the Key Largo Limestone is a layer of dark-gray fine-grained limestone, referred to as the Freshwater Limestone. Where present, the limestone is generally two feet or more thick and often possesses a sharp color change from light to dark gray at its base marking the transition from the Key Largo Limestone to the Fort Thompson Formation. It is not laterally continuous across the Turkey Point plant property.

- Fort Thompson Formation – The Pleistocene Fort Thompson Formation directly underlies the Key Largo Limestone. The Fort Thompson Formation is generally a sandy limestone with zones of uncemented sand interbeds, some vugs, and zones of moldic porosity after gastropod and/or bivalve shell molds and casts.

- Lower Higher Flow Zone –At the location of Units 6 & 7, a zone of secondary porosity was evident from the drilling and geophysical logs. This occurred at a depth of approximately 15 feet below the top of the Fort Thompson Formation and was assumed to extend across the model domain. The regional drilling conducted by the U.S. Geological Survey (USGS) (Reference 5) did not identify a laterally persistent layer but rather more isolated zones at varying depths below the Upper Higher Flow Zone. As represented in the model, the Lower Higher Flow Zone represents an aggregation of these observations and is conservative due to the fact it is modeled as laterally extensive.

- Tamiami Formation – The Pliocene Tamiami Formation directly underlies the Fort Thompson Formation. The contact between the Tamiami Formation and the Fort Thompson Formation is an inferred contact picked as the bottom of the last lens of competent limestone encountered. The Tamiami Formation represents a semi-confining unit.

The most permeable portions of the Miami Limestone and Key Largo Limestone are considered to be acting as one hydrogeological unit and designated the "Upper Monitoring Zone." The underlying Fort Thompson is designated the "Lower Monitoring Zone."

The geology is shown in the following cross sections:

- Hydrostratigraphic cross section in the vicinity of the Units 6 & 7 as shown in Figure 5 and Figure 6 (Reference 2).

- Geologic cross section in the vicinity of the Units 6 & 7 as shown in Figure 7 (Reference 6).

- Boring plan and stratigraphic cross sections parallel to and across Units 6 & 7 as shown in Figure 8, Figure 9, and Figure 10 (Reference 7).

- Plan and geologic cross section at the Turkey Point peninsula from exploratory drilling and aquifer testing program as shown in Figure 11 (Reference 4).

The following list summarizes the stratigraphic picks for the top of each stratum identified above from geotechnical boring logs and well logs:

- Stratigraphic picks from geotechnical boring logs for Units 6 & 7 (Reference 3) B-601 to B-639, B-701 to B-739, and B-802 to B-814.

- Stratigraphic picks from boring logs for the 1971 site investigation (Reference 2), L-1 through L-6, and GH-1 through GH-15.

- Stratigraphic picks from Upper Floridan aquifer study pumping wells (Reference 2), GB-1 and GB-2.

- Geotechnical boring logs from the Feasibility Geological Investigation of Potential Plant Site (Reference 7) borings B-1000 through B-1003.

- Additional water well logs available from Florida Geological Survey lithologic database (Reference 8) and the USGS (Reference 9).

- Stratigraphic picks from boring logs for the Turkey Point peninsula (Reference 4) and Units 6 & 7 pumping tests.

In 2010, 14 borings were drilled in and around the Turkey Point plant area as part of the FPL Unit 3 & 4 Uprate Conditions of Certification (Reference 5). Biscayne aquifer monitoring well clusters were subsequently installed at each of the 14 core borings as part of a monitoring plan. The plan was developed and implemented to satisfy Conditions of Certification IX and X of the Turkey Point Units 3 & 4 Uprate Certification (Reference 10). These well clusters were not included in the stratigraphic picks used to develop the model because they were not available at the appropriate time, but downhole logs (caliper and acoustic) performed by the USGS from these borings were qualitatively assessed to confirm zones of secondary porosity.

2.4 Groundwater Levels

During the 2008 subsurface investigation for Units 6 & 7, 22 groundwater monitoring locations were installed within the Units 6 & 7 plant area. Ten observation wells were installed in the Key Largo and Miami Limestone (referred to as the Upper Monitoring Unit) and ten were installed in the Lower Fort Thompson Formation (referred to as the Lower Monitoring Unit). Two

piezometers were installed in the Tamiami Formation, one at each proposed reactor site. The 20 observation wells were installed as 10 well pairs, enabling the determination of the vertical gradient between the upper and lower monitoring units. A description of the field activities and groundwater level data evaluation are presented in Reference 3.

Figure 12 shows the 22 monitoring locations within the Units 6 & 7 plant area. The observation wells are named in three series, which represent the location and screened intervals as described below:

- OW-600 series wells are located in the Unit 6 power block area and include "U," "L," and "D" suffix wells monitoring the Miami Limestone, the lower Fort Thompson Formation, and the upper Tamiami Formation.

- OW-700 series wells are located in the Unit 7 power block area and include "U," "L," and "D" suffix wells monitoring the Miami Limestone, the lower Fort Thompson Formation, and the upper Tamiami Formation.

- OW-800 series wells are located outside of the power block areas and include "U" and "L" suffix wells that monitor the Miami Limestone and the lower Fort Thompson Formation.

The U and L observation wells recorded hourly water level measurements between June 2008 and June 2010, after which point the transducers were removed and monitoring ceased. Comparison of well clusters (U and L wells) show an upward gradient during both high and low tides at all monitored locations.

Two regional historic Biscayne Aquifer potentiometric surface maps are also available. They cover the following months:

- May 1993, Figure 13

- November 1993, Figure 14

2.5 Surface Water

Surface water features around the Turkey Point plant property are shown on Figure 2 and include the following:

- Biscayne Bay – This feature is located east of Units 6 & 7 and is a shallow, subtropical lagoon along the southeastern coast of Florida. Biscayne Bay is a fairly recent geological feature and has been modified and dredged with average depths ranging from 6 feet to 10 feet. Surface water flow into Biscayne Bay is primarily controlled by the system of canals, levees, and control structures maintained by the South Florida Water Management District (SFWMD). The National Oceanic and Atmospheric Administration (NOAA) maintains a tidal water level and meteorological data collection station (#8723214) on Virginia Key in

Biscayne Bay. The station is located on a pier just to the southwest of the causeway that connects Virginia Key to Key Biscayne (Reference 11). Station 8723214 is the closest active station to the study area. The diurnal range, difference in height between mean higher high water and mean lower low water for the station is approximately 2.19 feet (Reference 11).

- Cooling Canal System (CCS) (also referred to as the Industrial Wastewater Facility) – The cooling canals are a closed system and do not directly discharge to adjacent surface water, however, the canals are unlined and hence the water interacts with groundwater.

    — After cooling water passes through the Units 1 through 4 condensers and gains heat, the water is released to the northern end of the 32 westernmost canals. These westernmost canals are approximately 4 feet deep and oriented north-south. The warm water flows toward the southern end of the westernmost canals where it then flows eastward across the southern end of the canals to the seven easternmost canals. These easternmost canals provide the cooling water return, and the circulating pumps are located on the return side, in the northeastern corner of the closed loop system. The pumps in the northeastern corner maintain a head difference of four to five feet relative to the release location. This head difference is the driving force for circulation through the system. Blowdown from Unit 5 also contributes to flow in the CCS.

    — The head differential created by the circulating water pumps is maintained despite or in addition to the tidal fluctuations. The head differential is a maximum at the northern end of the system; the highest head is in the northern end of the westernmost canals and the lowest head is in the northern end of the easternmost canals. The release of warm water to the northern end of the cooling canals means that the water level in the westernmost canals is always higher than the water level in Biscayne Bay. The intake of return water from the easternmost canals by the circulating pumps, means that the water level in the easternmost canals is always lower than that of Biscayne Bay. At the southern end of the system, the influence of the enforced head differential is relatively lower and water levels are approximately equal to the water level in Biscayne Bay/Card Sound.

    — Interceptor Ditch – The Interceptor Ditch was constructed in conjunction with the cooling canals to limit inland movement of the water from the cooling canals in the upper portion of the aquifer. This ditch is about 30 feet wide, 19 feet deep, and has a total length of approximately 29000 feet. The Interceptor Ditch is located about 1000 feet to the southeast of the L-31E canal. Operation of the Interceptor Ditch prevents seepage from the

industrial waste water facility from moving landwards toward the L-31E Canal in the upper portion of the aquifer. The Interceptor Ditch is operated (seasonally) only when required to maintain a seaward hydraulic gradient from L-31E.

- L-31E (SFWMD Salinity Structure) – The L-31E Canal (shown in Figure 2) is a stormwater control structure and also provides a salinity barrier that is designed to help prevent saltwater from moving inland. L-31E was constructed prior to the cooling canals being built.

2.6 Recharge and Evapotranspiration

The net infiltration, or groundwater recharge, accounts for the rate of net gain of the groundwater system resulting from surface infiltration. Recharge to the Biscayne Aquifer is controlled by land use, and in southern Florida the recharge occurs mainly through wetland areas. Figure 15 indicates major land use classifications used by Langevin (Reference 12) for a regional model of the Biscayne Aquifer.

Based on land use and the Turkey Point facility-related surface conditions, three recharge/evapotranspiration zones are considered for the model domain:

- Surface water bodies with continuous head of water, such as Biscayne Bay, the cooling canal system, and regional canals.

- Areas of wetland.

- Buildings and paved areas.

Surface water bodies, buildings, and paved areas in the model are assumed to have zero recharge and zero evapotranspiration. Recharge applied to the wetland areas is determined by using monthly rainfall data from SFWMD Station S20F (Reference 13) located on canal L-31E. Historically, up to four different rainfall data recorders have been used at Station S20F. The NRG recorder (which reports rain gauge data augmented with radar-based rainfall data), is the preferred data source, but is only available for the most recent two years. The TELE (telemetry, i.e., radio network) and OMD (data received from operation/ main, with multiple sources) recorders are considered to be equally reliable secondary sources of data, for years prior to the NRG record. In years when both TELE and OMD data were available, but NRG data were not, the TELE and OMD records were averaged. Finally, the BELF (Belfort rain gauge) recorder data are used prior to 1992, before the other recorders were available. For the calibration/validation models, a value of 42.6 in/yr is used for the wetlands recharge rate. This value is calculated by summing the total rainfall data for the months during which the on-site 2009 pumping tests were conducted (February to May 2009) and then scaling the total to a year, as shown in Table 1. For the predictive runs, the long-term average rainfall for the period of record at Station S20F was used, giving a recharge rate of 46.75 in/yr, as shown in Table 2.

The evapotranspiration rate and extinction depth for the wetland areas is determined using values from Langevin (Reference 12) presented in Table 3. For the calibration/validation, using maximum evapotranspiration from February to May gives an evapotranspiration rate of 54.52 in/yr. For the predictive runs, maximum evapotranspiration for every month is used to calculate an evapotranspiration rate of 59.50 in/yr. For all models, the extinction depth of 0.69 m (2.26 ft) for wetlands is used (Table 3).

2.7 Hydraulic Conductivity

The following sections describe the results from pumping tests and slug tests to evaluate hydraulic conductivity for the Biscayne Aquifer.

2.7.1 Pumping Tests

Pumping tests performed within the footprints of Units 6 & 7 power block are summarized as follows:

- PW-6U (Key Largo Limestone) – This pumping test was performed in March 2009, with the test well pumped at an average rate of 5103 gpm for eight hours. The test well is located in the footprint of the Unit 6 reactor building. The hydraulic conductivity was estimated to be 3.3 cm/s.

- PW-7U (Key Largo Limestone) – This pumping test was performed in February 2009, with the test well pumped at an average rate of 4181 gpm for approximately nine hours. The test well is located in the footprint of the Unit 7 reactor building. The hydraulic conductivity was estimated to be 4.3 cm/s.

- PW-6L (Fort Thompson Formation) – This pumping test was performed in March 2009, with the test well pumped at an average rate of 3342 gpm for eight hours. The test well is located in the footprint of the Unit 6 reactor building. The hydraulic conductivity was estimated to be 0.1 cm/s.

- PW-7L (Fort Thompson Formation) – This pumping test was performed in March 2009, with the test well pumped at an average rate of 3403 gpm for nine hours. The test well is located in the footprint of the Unit 7 reactor building. The hydraulic conductivity was estimated to be 0.2 cm/s.

A pumping test at Turkey Point peninsula to characterize the hydrogeology for a potential radial collector system is summarized as follows (Reference 4):

- PW-1 (Miami Limestone/Cemented Sand/Key Largo Limestone) – This pumping test was performed in April and May 2009, with the test well pumped at an average rate of 7100 gpm for seven days. The hydraulic conductivity of the test zone was estimated to be

between 10.3 cm/s and 17.6 cm/s based on a reported range of transmissivity between 700,000 ft^2/day and 1,200,000 ft^2/day.

On the Turkey Point plant property, aquifer pumping tests in the Biscayne Aquifer have been performed in three test wells (Reference 2). Figure 5 shows locations of test wells GH-11B, GH-14A, and GH-14B. Pumping test results are summarized as follows:

- GH-14A (Miami Limestone) – This pumping test is located to the southeast of L-31E, adjacent to the northwest portion of the cooling canal system. The test was performed in June 1971, with the test well pumped at 1386 gpm for four hours. The hydraulic conductivity was estimated to be 7.9 x 10^{-2} cm/s.

- GH-11B (Key Largo Limestone) – This pumping test is located between Model Land Canal and L-31E. The test was performed in June 1971, with the test well pumped at 1386 gpm for four hours. The hydraulic conductivity was estimated to be 5.1 cm/s.

- GH-14B (Fort Thompson Formation) – This pumping test is located to the southeast of L-31E adjacent to the northwest portion of the cooling canals. The test was performed in June 1971, with the test well pumped at 1386 gpm for two hours. The hydraulic conductivity was estimated to be 1.6 cm/s.

2.7.2 Literature Values

Several investigations of the Biscayne Aquifer have provided estimates for the hydraulic conductivity of various units of the Biscayne Aquifer. All of these studies have been conducted by either the USGS or SFWMD. Presented in Table 4 is a summary of hydraulic conductivity values for the Biscayne Aquifer.

2.8 Water Wells

No water supply wells are located in the Biscayne Aquifer within the plant property. Three production wells (PW-1, PW-2, and PW-4) are located in the Upper Floridan aquifer (Figure 16) and provide process water for Units 1 and 2, and process and cooling tower makeup water for Unit 5. The average production of these wells is approximately 180 million gallons per month.

The Biscayne Aquifer at Turkey Point Units 3 & 4 is also used for disposal of domestic wastewater. A single Class V, Group 3 gravity injection well is used to dispose of up to 35000 gpd of domestic wastewater at the Turkey Point Units 3 & 4 wastewater treatment plant. The well, designated IW-1, is open from 42 to 62 feet bgs and is 8-inches in diameter. Due to the low injection rate (up to 24 gpm) this well is not included in the numerical model.

3.0 MODEL DEVELOPMENT

3.1 Conceptual Hydrogeologic Model

The Biscayne Aquifer is conceptualized as consisting of eight hydrostratigraphic units. The base of the model (bottom of the Tamiami Formation) is designated as a no-flow boundary as leakage through the confining Hawthorn Formation is assumed to be negligible.

Recharge to the Biscayne Aquifer occurs primarily in areas of wetland and along the regional series of canals. Discharge from the Biscayne Aquifer occurs to Biscayne Bay, a portion of the cooling canals, and the regional series of canals. The cooling canals are the dominant stress at the Units 6 & 7 Site. Evapotranspiration is also a dominant stress on the groundwater system.

The model domain was selected to minimize the impact of assumptions regarding boundary conditions at model sides. The boundaries of the model domain were placed where reasonable assumptions regarding local conditions could be made. Figure 17 shows the model domain. The model area extends several miles beyond the plant property and covers a total area of 47500 feet by 37000 feet (about 63 square miles).

The northern and southern model boundaries were extended several miles beyond the plant property, however they do not coincide with any hydrogeologic features. The eastern model boundary extends into Biscayne Bay, and the western boundary was extended beyond the L-31E canal.

3.1.1 Summary of Model Changes and Report Revisions

The initial release of this report (Revision 0, October 2009) documents the groundwater flow model developed for the Biscayne Aquifer at the FPL Turkey Point site for Units 6 & 7. The model is a steady-state, constant-density, three-dimensional representation of the Biscayne Aquifer developed using the numerical code MODFLOW 2000 developed by the USGS, as it is implemented in the user-interface software Visual MODFLOW, developed by Schlumberger Water Services. The groundwater model serves two purposes. The first is to evaluate groundwater control options for construction of Units 6 & 7. The second is to simulate the feasibility of an RCW system to serve as a temporary source of makeup water. The report was issued in support of the Florida Department of Environmental Protection (FDEP) Site Certification Application (SCA).

3.1.1.1 Revision 1

Revision 1 (February 2011) of this report provided changes to the groundwater flow in response to reviews from the SFWMD and other state, federal, and local agencies. Changes to the model included modifications to the conceptual model, the numerical model, the calibration and validation runs, the predictive runs, and the sensitivity analyses.

A comprehensive listing of modifications is detailed below. The majority of these modifications have arisen from comments provided following review of the groundwater model by state, federal, and local agencies. The intention of these changes was to provide a more robust conceptual and numerical model and to incorporate local knowledge of the Biscayne Aquifer from working practitioners. Other additions of and corrections to various site features were made as a part of the model revision and recalibration process.

Conceptual Model

- Identification and incorporation of zones of higher hydraulic conductivity based on review of geological and geophysical data. These zones of higher hydraulic conductivity are associated with secondary porosity. This has resulted in including a zone of higher hydraulic conductivity at the top of the Key Largo Limestone (average elevation of -16.4 feet) and one within the Fort Thompson Formation (average elevation of -52.4 feet).

- Coincident with the refinement of the geology has been a reinterpretation of the geology of Turkey Point peninsula. This reinterpretation incorporated new geophysical data and drilling information.

- The muck layer present throughout Biscayne Bay has been revised based on a literature review of sediment/rock type on the floor of Biscayne Bay. This review identified sandy soils and bare rock (Miami Limestone) that had previously been represented as muck.

- Incorporation of two hydraulic conductivity zones within the Key Largo Limestone based on prior information and model calibration.

- Across the Turkey Point Units 6 & 7 plant area, recharge zones have been delineated to represent post-construction conditions. These updated zones are used for the radial collector well simulations.

- The head drop across the circulating water pumps has been updated to the average value observed over the period of the pumping tests, as opposed to spot measurements, which provided a smaller head drop than observed.

Numerical Model

- The base model used for calibration begins with all layering modifications necessary for construction and post-construction simulations.

- The model layers are laterally continuous across the model domain. Previously, surface water features had been incised into layers, resulting in lateral discontinuity between some cells.

- The boundary condition used to represent Biscayne Bay has been updated from constant-head to general-head to account for resistance to flow to the bay floor.

Calibration and Validation

- Three pumping tests are now used in the model calibration phase; two of these tests were conducted in the Key Largo Limestone and one in the Fort Thompson Formation. In the previous revision of the model, two tests had been simulated.

- The model now includes a validation step, whereby an additional pumping test is simulated following the calibration phase.

- A range for the hydraulic conductivity anisotropy value (horizontal: vertical) of between 8:1 and 15:1 is used for the various hydrogeologic units. These values were determined during calibration and constrained by literature and field observations.

Predictive Runs

Construction

- Construction Groundwater Control: Grouting the rock between the base of the excavation and base of the cut-off walls. Grouting simulated to estimate associated dewatering rates.

Operational

- Radial Collector Well (RCW) System: Upper Higher Flow Zone and bottom of the Key Largo Limestone evaluated for placement of laterals.

- RCW: Flow into the laterals distributed non-linearly along its length to reflect the increase in flow closer to the caisson.

Sensitivity Analyses

Construction

- Construction Groundwater Control: Sensitivity analysis of hydraulic conductivity of grout plug and its effect on seepage rates into the base of the excavations for Units 6 & 7.

Operational

- RCW: Sensitivity analysis on Biscayne Bay general-head conductance to determine the origin of water to the radial collector wells and approach velocities to the bay floor.

- RCW: Sensitivity analysis on Biscayne Bay seasonal high and low water level to determine the origin of water to the radial collector wells and approach velocities to the bay floor.

- RCW: Sensitivity analysis on hydraulic conductivity of the Key Largo Limestone to determine the origin of water to the radial collector wells and approach velocities to the bay floor.

3.1.1.2 Revision 2

Revision 2 of this report provides updates to the groundwater flow model to correct errors in the groundwater flow model input/output files and to update incorrectly reported Units 6 & 7 construction dewatering rates and sensitivity analyses of the RCW approach velocities.

Errors associated with the conductance calculation for the model perimeter general-head boundary (GHB) cells were introduced in the data pre-processing phase. As a result of the errors, lateral flow of water into and out of the model boundaries was incorrectly calculated. It was also found that two grid cells in model layer 3 had incorrect top and bottom surface elevations. These errors have been corrected in Revision 2.

The updated model retains the calibration and validation results of Revision 1.

For the RCW simulations (Section 5.2), the base case showed no change in the quantity of water originating from Biscayne Bay or from the inland flow to the RCW. The components of the inland flow each changed by 0.1 percentage points for the base case; the portion of water originating from the cooling canal system increased from 1.9 to 2.0 percent, and the water originating from regional eastward flow deceased from 0.3 to 0.2 percent. There are minor changes to the portion of the water originating from Biscayne Bay, the cooling canal system, and the regional eastward flow for the sensitivity analyses (up to a 0.2 percentage point change from the previously reported values). There were no changes to the drawdown contours for the RCWs.

There were no changes to the RCW approach velocities for the base case, but the corrections to the model boundary GHB conductance values changed five of the seven sensitivity analysis case results.

It was also determined that incorrect Units 6 & 7 construction dewatering rates were previously reported for the groundwater control simulations. The revised dewatering rates (Section 5.1) are 96 gallons per minute (gpm) for each unit, lower than that previously reported in Revision 1 (140 gpm and 136 gpm for Unit 6 and Unit 7, respectively). The incorrect dewatering rates were the result of data post-processing on an earlier set of modeling files that had been superseded.

Numerical comparisons of the affected Revision 1 and Revision 2 values indicate that the differences are minor (and in the case of groundwater control, result in smaller dewatering rates), and the Revision 1 model conclusions are unchanged.

3.2 Numerical Model

3.2.1 Numerical Code

The conceptual hydrogeologic model is developed into a three-dimensional numerical groundwater model using the code MODFLOW-2000 (Reference 14). MODFLOW solves the three-dimensional groundwater flow equation using a finite-difference method. This code is widely used in the industry since its development by the USGS (Reference 15 and Reference 16).

MODFLOW has a modular structure that allows the incorporation of additional modules and packages to solve other equations that are often needed to handle specific groundwater problems. Over the years several such modules and packages have been added to the original code. MODFLOW-2000 is major revision of the code that expands upon the modularization approach that was originally included in MODFLOW.

The modeling pre-processor Visual MODFLOW (Reference 17) is used to facilitate the development of the FPL Turkey Point Units 6 & 7 groundwater flow model. Visual MODFLOW is developed by Schlumberger Water Services.

3.2.2 Numerical Solver

The geometric multigrid solver (GMG) in Visual MODFLOW produces converged solutions for the model, and is used for all simulations presented. The GMG solver uses two convergence criteria, the head change between successive outer iterations and the residual criterion, which is based on the change between successive inner iterations. The model uses the default values of 0.01 feet for the head change criterion and 0.01 feet for the residual criterion.

3.2.3 Model Grid

Figure 18 shows the model grid and site features for the power block vicinity. At its finest, the model grid spacing is approximately three feet by three feet within the plant area for Units 6 & 7, and expands to 100 feet by 100 feet at the model perimeter. The grid spacing is also refined in the vicinity of the Turkey Point peninsula, to enable simulation of pumping test PW-1 and the radial collector wells. In this area, the grid spacing is reduced to 25 feet by 25 feet.

3.2.4 Model Layers

The model is bounded by the ground surface and bottom of Biscayne Bay on top and the bottom of the Tamiami Formation at the model bottom. A topobathy surface referenced to NAVD 88 was developed for the ground surface topography of the FPL Turkey Point Units 6 & 7 groundwater flow model. A topobathy surface is a surface that combines land elevation and seafloor topography with a uniform vertical datum (Reference 18). Several data sources were reviewed for potential integration into the topobathy surface. The final topobathy surface was developed from the USGS's National Elevation Dataset

(NED) Digital Elevation Models (DEMs) (Reference 19) and NOAA's Office of Coast Survey (OCS) harbor soundings (Reference 20). The selection of the final datasets was based primarily on which two datasets produced the smoothest shoreline transition.

Fourteen model layers are included as follows:

- Model Layer 1 – Onshore organic soils, referred to as Muck and Marl. Offshore sand/sediment and Miami Limestone.

- Model Layers 2/3 – Marine limestone, referred to as the Miami Limestone.

- Model Layer 4 – Marine limestone, referred to as the Upper Higher Flow Zone.

- Model Layer 5/6 – Marine limestone, referred to as the Key Largo Limestone (divided into two areal zones based on prior information).

- Model Layer 7 – Freshwater limestone, referred to as the Freshwater Limestone, and where this is absent the Key Largo Limestone.

- Model Layer 8/9 and 11/12/13 – Marine limestone, referred to as the Fort Thompson Formation.

- Model Layer 10 – Marine limestone, referred to as the Lower Higher Flow Zone.

- Model Layer 14 – Marine limestone or sandstone, referred to as the Tamiami Formation.

Elevations are assigned to each model cell based on the results of the interpolation of stratigraphic picks. Figure 19 and Figure 20 show cross sections of the model with relevant features highlighted.

3.2.5 Boundary Conditions

The model incorporates several types of boundary conditions, including river cells, recharge cells, evapotranspiration cells, general-head cells, horizontal flow barrier cells, and no-flow cells. A brief description of boundary conditions as they are used in the model is provided below:

- River Boundary – (1) Cooling Canal System, (2) L-31E, (3) C-107, (4) Card Sound Canal, and (5) Florida City Canal: The river boundary condition allows leakage into the model or leakage out of the model based on (a) specified surface water elevation in the canal, (b) simulated groundwater elevations in adjoining grid cells, and (c) sediment conductance at the bottom and sides of the canals. River cells are employed in lieu of constant head cells to allow flexibility to adjust the conductance and hence flow to adjoining cells during calibration.

- Recharge Boundary – Model Layer 1: The recharge boundary condition is applied at the ground surface (top of model layer 1) and simulates the

effect of infiltration from precipitation (before evapotranspiration losses). Recharge in the model is only applied to land surfaces (no recharge is applied to surface water features).

- Evapotranspiration Boundary – Model Layer 1: The evapotranspiration boundary condition is applied at the ground surface (top of model layer 1) and simulates the effects of plant transpiration and direct evaporation by removing water from the saturated groundwater regime. Evapotranspiration is applied only over land surfaces in the model.

- General-Head Boundary (GHB):

  o (1) Model Sides: General-head boundary conditions are assigned to the perimeter of all layers. The general-head boundary represents the influence of conditions beyond the model area. Flow through the onshore general-head boundaries is influenced by aquifer recharge in the Everglades area.

  o (2) Biscayne Bay: General-head boundary conditions are assigned to the top of model layer 1 to represent the exchange of water between Biscayne Bay and the underlying aquifer. The specified head in the GHB cell is based on tidal monitoring at Virginia Key. Use of the GHB condition rather than the constant head condition allows for limiting the exchange of water between Biscayne Bay and the underlying aquifer based on the properties of the sea floor sediments.

- Horizontal Flow Barrier Boundary – Mechanically Stabilized Earth (MSE) Retaining Wall and Cut-Off Walls for Units 6 & 7: The horizontal flow barrier boundary is used to simulate the effects of the excavation cut-off walls surrounding the power blocks for Units 6 & 7 for construction dewatering and also the MSE retaining wall surrounding the Units 6 & 7 plant area (excluding the makeup water reservoir). This package was developed to simulate the effects of thin, vertical, low hydraulic conductivity features that restrict the horizontal flow of groundwater.

- No-Flow Boundary – Bottom of Model: The bottom of the model is designated a no-flow boundary because water levels in the Biscayne Aquifer are expected to be negligibly affected by upward leakage through the Lower Tamiami Formation and Hawthorne Group, which is several hundred feet thick and acts as a confining layer.

- No-Flow Boundary – Units 6 & 7 Excavations: The excavations are designated as inactive to flow. Minor seepage will occur through the cut-off walls into the excavations but the quantities will be insignificant.

3.3 Assumptions

The model development includes the assumptions described below.

3.3.1 Equivalent Porous Media

Assumption: The flow regime is simulated using an equivalent porous media (epm).

> Rationale: The effects of small-scale heterogeneities become averaged when used in an analysis of this scale. Preferential higher flow zones identified at the site are relatively thin and are expected to have laminar flow; therefore, they can be represented in the model by assigning higher hydraulic conductivities to these zones using an epm approach (as opposed to conduit flow).

3.3.2 Steady-State Condition

3.3.2.1 Pumping Tests

Assumption: The pumping tests can be modeled by matching the steady-state drawdown values in each observation well rather than a transient simulation matching the entire drawdown curve.

> Rationale: Steady-state conditions from the pumping tests are reached after a very short period of time due to 1) the confined nature of the test zones, and 2) the high hydraulic conductivity of the test zones.

3.3.2.2 Groundwater Flow

Assumption: The cooling canals are assumed to be in steady-state.

> Rationale: Previous modeling of the cooling canals assumed the system was in equilibrium and hence steady state. Figure 21 presents the balance of flows as documented in a previous study. This balance assumes that the existing units are operating at capacity. This assumption is conservative for determination of origins of water to the radial collector wells.

3.3.3 Constant-Density

Assumption: The flow regime is simulated with a constant-density groundwater model.

> Rationale: The primary purpose of this groundwater model is to estimate quantities for excavation dewatering and to evaluate the influence of the radial collector wells. For these two localized areas of interest the pressure influences of density variation are insignificant relative to the hydraulic gradient imposed by pumping.

Assumption: Seawater is used as the reference fluid.

Rationale: For a constant density model, water levels should be normalized to a reference fluid to satisfy the steady-state, constant-density equation. Water levels in the model are normalized to a saline reference density of 1022.4 kg/m^3. The hypersaline water of the cooling canal system and the freshwater of the drainage canals are adjusted to seawater using the following equation:

$$h_r = \frac{\rho_w}{\rho_r} h_w - \frac{\rho_w - \rho_r}{\rho_r} z_w$$

Where:

h_r is the head at the reference density

h_w is the observed head at the natural density

z_w is the water (canal) depth at the natural density

ρ_w is the natural density of the water

ρ_r is the reference density

For the calibration cases where the Biscayne Bay level is -1.05 feet NAVD 88, normalized head values at locations around the cooling canals and stormwater management canals are presented in Table 5.

3.3.4 Hydrostratigraphic Units

Assumption: The Freshwater Limestone is assumed to be absent if the contoured thickness is less than 1.5 feet.

Rationale: It is possible that this layer is laterally continuous and where it is not observed it is due to the method of drilling used. A more likely explanation is that due to the freshwater nature of the deposit it is not laterally continuous and the assumed distribution is a reasonable interpretation. Figure 22 shows the extent of the Freshwater Limestone in the model.

Assumption: The Upper and Lower Higher Flow Zones are assumed to be laterally continuous. The Upper Higher Flow Zone is assumed to be present on top of the Key Largo Limestone over the model domain. The Lower Higher Flow Zone is assumed to be present 15 feet below the top of the Fort Thompson Formation over the model domain.

Rationale: Review of borings logs indicates mud loss at the contact between the Miami Limestone and Key Largo Limestone. Caliper logs also indicate an enlarged boring diameter at this depth. This layer is identified across the site and designated the Upper Higher Flow Zone. At Units 6 & 7, where the majority of borings exist, another higher flow zone is identified at approximately 15 feet below the top of the Fort Thompson Formation. Its laterally continuity across the site is not as obvious as the Upper Higher Flow Zone; however, for the purposes of this model it is assumed to be laterally extensive. Uprate monitoring

borings, drilled as part of FPL Units 3 & 4 Uprate Conditions of Certification (Reference 5) in 2010 confirm these interpretations

Assumption: The Upper and Lower Higher Flow Zones are assumed to have a thickness of one foot.

Rationale: A study conducted by Renken et al. (Reference 21) suggested a thickness of three feet for an aerially extensive zone of higher hydraulic conductivity. Because the transmissivity of the units needs to be preserved during calibration, selecting a smaller thickness for these units will permit a higher hydraulic conductivity, which will facilitate preferential flow and hence be conservative.

Assumption: Hydrostratigraphic units in layer 1 are assumed to be distributed as shown in Figure 23.

Rationale: Layer 1 of the model represents the hydrostratigraphic units located at ground surface on land or on the floor of Biscayne Bay. Muck is known to be present on land (Reference 3); however, this unit does not extend into Biscayne Bay, where exposed rock and sandy material is present in its place. Hydrostratigraphic units in Biscayne Bay were assigned using the Marine Resources Geographic Information System (MRGIS) "Benthic Habitats – South Florida" file (Reference 22). Benthic zones designated as "Continuous Seagrass" were designated as sandy material in layer 1 as loose material is necessary to support seagrass. "Patchy (Discontinuous) Seagrass" and "Hardbottom with seagrass" benthic zones were designated as rock in layer 1.

3.3.5 Boundary Conditions

Assumption: Upward leakage through the Hawthorn Group to the Biscayne Aquifer is assumed to be sufficiently small that it will have negligible effect on flow paths within the Biscayne Aquifer, so the bottom of the Tamiami Formation is assumed to be a no-flow boundary for this model.

Rationale: The Hawthorn Group has a relatively low hydraulic conductivity and is hundreds of feet thick in South Florida.

Assumption: The cooling canals and regional canals can be modeled by the MODFLOW River Package (RIV).

Rationale: The River Package is applicable to surface water bodies that can either contribute water to the groundwater system, or act as groundwater discharge zones, depending on the hydraulic gradient between the surface water body and the groundwater system.

Assumption: Biscayne Bay has a surface water elevation of -1.05 feet NAVD 88 in the model for the model calibration and validation phases.

Rationale: This value is the average of the monthly average surface water elevation between February 2009 and May 2009. This time period is when the pumping tests used for calibration and validation occurred.

Assumption: The head difference between release and intake structures of the cooling canals is assumed to be 4.66 feet.

Rationale: Field monitoring during the period of the pumping tests showed an average head difference of 2.33 feet between the barge canal (Biscayne Bay) and the intake basin. Because the southern end of the cooling canal system is assumed to be equal to the water level in Biscayne Bay, and the head difference assumed to be equal between the intake and release sides, the head difference across the circulating water pumps is therefore twice the difference between the barge canal and intake basin, or 4.66 feet. Additional observations to confirm the field monitoring indicate that the water level on the east or intake side of the cooling canal system is drawn down about three feet lower than the water level on the west or release side of the cooling canal system. Field observations in 2009 also provide a similar number for the head difference.

Assumption: The 4.66 feet head drop between release and intake structures of the cooling canals can be equally distributed between the south flowing cooling canals and the north flowing cooling canals. Based on the surface water elevation for Biscayne Bay, the following water levels are assigned to the intake and release sides for Units 1 through 4:

— Release side of Units 1 though 4 is 1.28 feet NAVD 88.

— Lake Rosetta (intake structure) is -3.38 feet NAVD 88.

Rationale: The flowpath length for the release side and return canals is approximately equal.

Assumption: Water level at the southern end of the cooling canals is assumed to be equal to the water level in Biscayne Bay/Card Sound.

Rationale: Site information indicated that at the southern end of the cooling canal system the water level is approximately equal to the water level in Biscayne Bay/Card Sound.

Assumption: A thickness of 0.1 feet of sediment is assumed to have built up in the cooling canals.

Rationale: Negligible silt build up is assumed to occur due to the scouring action of the water and the flushing as a result of tide changes and the high hydraulic conductivity of the Miami Limestone.

Assumption: Water level in:

> — L-31E is 0.02 feet NAVD 88.

> — Interceptor Ditch is -0.28 feet NAVD 88 at the northern end and remains constant until the point where the water level in L-31E minus the water level in C32 is less than 0.2 foot. At this point, the water level in the Interceptor Ditch reduces linearly to -1.05 feet NAVD 88 at the southern end.

> — Westernmost release side cooling canal is 1.08 feet NAVD 88 at northern end dropping linearly to -1.05 feet NAVD 88 at the southern end.

>> Rationale: Water level in the Interceptor Ditch is maintained (by pumping) at a certain level to induce a seaward hydraulic gradient, ensuring that water from the cooling canals does not move inland in the upper portion of the aquifer. The Interceptor Ditch is operated (seasonally) only when required to maintain a seaward hydraulic gradient.

3.3.6 Hydraulic Conductivities

Assumption: The anisotropy ratio is determined by calibration and limited to a value between 1:1 and 15:1 for all layers (Kh:Kv).

> Rationale: Anisotropy was estimated from Figure 24, which tends to cluster between a value of 1:1 and 10:1. This figure presents the results of a USGS study by Cunningham et al. of horizontal and vertical air permeability measurements on core samples from the Biscayne Aquifer (References 23 and 24). Subsequent work by the same author (Reference 25) indicates similar anisotropy ratios. An upper limit of 15:1 was designated to allow for large-scale features not represented by the core samples.

Assumption: The hydraulic conductivity of material accumulated in the bottom of the cooling canals is assumed to be 1×10^{-5} cm/s.

> Rationale: This represents a standard value for the hydraulic conductivity of silty sand (Reference 26).

3.3.7 Precipitation and Evapotranspiration

Assumption: Groundwater recharge zones are separated into two zones.

> Rationale: Two groundwater recharge zones are used in the model. These zones represent 1) a recharge value of zero applied to: open water and the existing plant area that is paved and impermeable, and 2) wetlands, which have a constant recharge rate. These recharge zones are based on the land use classifications of Langevin as shown in Figure 15 (Reference 12).

Assumption: Evapotranspiration zones are the same as the groundwater recharge zones.

Rationale: Impermeable areas and open water will also have zero evapotranspiration. Wetland areas will have a constant evapotranspiration rate.

3.3.8 Groundwater Control: Dewatering

Assumption: Figure 25 shows the location of the excavation cut-off walls for constructing Units 6 & 7 structures. The elevation of the base of the excavation is -35 feet NAVD 88 and the cut-off wall depth has been revised from -65 to -60 feet NAVD 88. The thickness of the cut-off walls is 3 feet.

Rationale: The cut-off wall depth has been raised to -60 feet NAVD 88 to avoid setting the toe within the Lower Higher Flow Zone. Borings logs at Units 6 & 7 indicate that the Lower Higher Flow Zone occurs at approximately -65 feet NAVD at this location.

Assumption: The walls are assumed to have a hydraulic conductivity of 1×10^{-8} cm/s.

Rationale: The design value for the hydraulic conductivity of the cut-off walls is 8.3×10^{-10} cm/s (Reference 27). A value of 1×10^{-8} cm/s is a conservative estimate that will provide an upper bound on the dewatering rate.

Assumption: Units 6 & 7 are excavated and dewatered sequentially.

Rationale: The construction schedule shows the power block excavations to be excavated sequentially.

Assumption: The rock between the base of the cut-off walls and base of the excavation can be grouted to a hydraulic conductivity of 1×10^{-4} cm/s.

Rationale: A value of 1×10^{-4} cm/s is an industry standard for this type of formation (Reference 28 and 29).

3.3.9 Radial Collector Wells

Assumption: The three western-most radial collector wells and laterals are modeled as operational for plant operations. Figure 26 shows the general location where all four of the radial collector wells will be located.

Rationale: This simulation will provide a conservative estimate of the quantity of water originating from inland due to the proximity of the radial collector wells to land.

<u>Assumption:</u> Operation of the radial collector wells is simulated using the MODFLOW WEL package.

> <u>Rationale:</u> Use of the WEL package is a documented method of simulating horizontal wells (Reference 30). Other methods within MODFLOW of simulating the radial collector wells could include the drain package (DRN) and the multi-node well package (MNW).

<u>Assumption:</u> Operation of the radial collector wells is simulated as steady-state.

> <u>Rationale:</u> The radial collector wells are intended to be operated only when the primary source of makeup water is not available. Simulating the radial collector wells on a steady-state basis provides the maximum drawdown from the wells and is therefore a conservative approach.

<u>Assumption:</u> The laterals are assumed to be less than 700 feet in length with approximately 300 feet of screened casing at the end of the lateral.

> <u>Rationale:</u> A conceptual engineering study (Reference 31) provided an upper estimate of 900 feet for the length of the laterals. This value was adjusted during modeling to remain outside the boundary of the Biscayne National Park. A shorter lateral provides a more conservative estimate. It should also be noted that the layout will go through a formal design process at a later stage.

<u>Assumption:</u> Flow to the radial collector wells is distributed non-linearly along the laterals.

> <u>Rationale:</u> The head difference between the water level in the lateral and outside the lateral is greatest closest to the caisson and smallest at the end of the lateral.

4.0 MODEL CALIBRATION

A multi-faceted approach to calibration was taken that included the following:

- Calibration to pumping tests on the Turkey Point plant property.

- Verification using a pumping test on the Turkey Point plant property.

- Performing a qualitative comparison of calculated groundwater flows to and from the cooling canal system with an analytical water balance (Reference 32).

- Qualitatively comparing model wide groundwater flow directions with published potentiometric surface maps.

4.1 Calibration Measures and Statistics

Several parameters providing different measures of the agreement between simulated and observed drawdown levels were used for the calibration of the model. These parameters are defined in terms of the calibration residuals of the drawdown defined as the difference between calculated and observed drawdown. The calibration residual, R_i at a point i is defined as:

$$R_i = {}^{model}X_i - {}^{obs}X_i \qquad (1)$$

Where:

${}^{model}X_i$ is the calculated drawdown at point i; and

${}^{obs}X_i$ is the observed drawdown at point i.

The residual mean, $\bar{R}$ is a measure of the average residual value and is defined by the equation:

$$\bar{R} = \frac{1}{n}\sum_{i=1}^{n}R_i \qquad (2)$$

Where n is the number of points where calculated and observed values are compared.

The absolute residual mean (ARM), $|\bar{R}|$ is a measure of the average absolute residual value and is defined as:

$$|\bar{R}| = \frac{1}{n}\sum_{i=1}^{n}|R_i| \qquad (3)$$

The Root Mean Squared (RMS) residual is defined by:

$$RMS = \left[\frac{1}{n}\sum_{i=1}^{n}R_i^2\right]^{1/2} \qquad (4)$$

The normalized root mean squared (NRMS) is the RMS divided by the maximum difference in the observed drawdown values. It is given by the following equation:

$$NRMS = \frac{RMS}{{}^{obs}X_{max} - {}^{obs}X_{min}} \qquad (5)$$

A measure of the numerical convergence of each run is the discrepancy between inflows and outflows from the model domain. To satisfy the overall mass balance, this discrepancy should be zero. In practice, however, a mass balance of zero may not be possible. The aim in obtaining a converged numerical solution is to achieve a mass balance discrepancy as small as possible. The numerical mass balance discrepancy, M_d, is calculated using the following equation:

$$M_d = \frac{V_{in} - V_{out}}{\frac{1}{2}(V_{in} + V_{out})} \qquad (6)$$

where

V_{in} is total flow into the model domain; and

V_{out} is total flow out of the model domain.

The final measure of the adequacy of the calibrated model is the discrepancy between the cooling canal system inflows and outflows determined by the groundwater model and the steady-state water balance determined by the site surface water model (Reference 32). Flow values for the groundwater model are determined by assigning flow zones across the discharge and recharge sides of the cooling canal system. Fluxes into and out of these zones are then calculated and compared with the water balance. In a successful calibration, the mass balance discrepancy between the two models will be as small as possible.

4.2 Calibration Criteria

The following criteria for calibration measures and statistics were used for model calibration:

- Root mean squared residual (RMS) < 1 foot;
- Normalized root mean squared residual (NRMS) < 10 percent;
- Absolute residual mean (ARM) < 1 foot;
- Numerical mass balance discrepancy (M_d) < 0.1 percent;
- Physical mass balance in the cooling canal system within an order of magnitude of the water balance from the surface water model.

4.3 Calibration Parameters

The primary calibration parameters were the hydraulic conductivity, and also the conductance for head dependent boundary conditions (cooling canals, regional canals, Biscayne Bay and model sides). These parameters were varied to achieve satisfactory agreement between simulated and observed pumping test drawdowns, regional flow directions, and flow magnitudes.

4.4 Calibration Results

The original intent was to utilize the steady-state drawdown values from pumping tests PW-7L and PW-1 as the calibration data set and then validate the model using an additional pumping test from the suite conducted in the vicinity of the proposed Units 6 & 7 power blocks. Following calibration to the two tests, the validation case was run (pumping test PW-7U) and the results demonstrated that the model could not replicate the drawdown values observed at the end of this test. As a result, the validation data set subsequently became part of the calibration data set and an additional pumping test (PW-6U) was used for model validation. As the model was able to adequately replicate the drawdown values from the PW-6U pumping test, model validation was achieved.

4.4.1 Simulation of Pumping Tests

Parameter estimation was performed using manual optimization, whereby model parameters were changed on a trial-and-error basis until a satisfactory match was observed between observed and modeled drawdowns. The procedure used to calibrate the model to the drawdown data was to run the model to steady state with no wells operating for an assumed set of model parameters. Following this run, the steady-state head at each of the monitoring well locations was noted and used as the initial head for the simulation with the pumps operating. Following the execution of the model with the pumping well operating, the model drawdown at each well was calculated by subtracting the final head from the starting head values. This model-determined drawdown was then compared to the observed drawdown to calculate calibration statistics. Model parameters were then adjusted to match the observed drawdown values, and the process described above was then repeated. In addition to adjusting the hydraulic conductivity of the hydrogeologic units, the conductance of the general-head boundaries was also adjusted to represent changes in the properties of the layers, thereby tying the conductance of all general-head boundary cells to the hydraulic conductivity of the layer that the boundary cell is contained within.

Initially, the model was calibrated to two pumping tests: PW-7L and PW-1. During the calibration process, the hydraulic conductivity of all layers was allowed to vary within a predefined range, which was determined from the literature and site hydrogeologic parameters given in Table 4. Following adequate calibration to these two tests, pumping test PW-7U was simulated with the parameters determined from the prior utilization. This simulation provided a poor match to test PW-7U, and as a result a series of forward runs were conducted where the hydraulic conductivity of the Key Largo Limestone was

varied to improve the match. Following an adequate match to PW-7U, it was observed that PW-1 was unacceptably degraded. It was then concluded that a satisfactory match to both the PW-7U and PW-1 drawdown data could not be achieved by treating the hydraulic conductivity of the Key Largo Limestone as a homogeneous property.

The final phase in calibrating involved holding constant parameters below the Freshwater Limestone from the first optimization and further optimizing to the two tests conducted in the Key Largo Limestone. In order to achieve satisfactory calibration, it was necessary to introduce two hydraulic conductivity zones within the Key Largo Limestone, which were delineated based on two pieces of prior information. The first piece of prior information was an observation from the 2010 drilling program that the upper portion of the Fort Thompson Formation (synonymous here with the Key Largo Limestone) exhibited heterogeneity across the model domain. The second was from the type-curve analysis of pumping tests conducted at the nuclear island (the Units 6 & 7 containment building, shield building, and auxiliary building) and at the Turkey Point peninsula; the tests at the nuclear island consistently demonstrated a lower hydraulic conductivity than the one conducted at the Turkey Point peninsula. The zones were established by drawing a line between PW-1 on the Turkey Point peninsula and the nuclear island, bisecting the line, and then extending another line perpendicular from this point until it intersected the boundaries of the model domain. The two zones are displayed in Figure 27. The strategy behind this approach was to fix the dominant parameters controlling test PW-7L, hence trying to maintain an optimal calibration and then only allowing parameters above the Freshwater Limestone to vary, which provide primary control on the tests in the Key Largo Limestone. It was important to check this final phase of calibration by simulating all tests separately to ensure that well interference from simulating multiple tests at the same time did not affect the results. In addition, following each round of optimization, the starting heads were updated, and the conductance value for each general head boundary cell was updated to reflect the new hydraulic conductivity value in the direction of flow. These steps were necessary because the optimization runs only updated the hydraulic conductivity of the model layers. The final hydraulic conductivity values determined from the model calibration are presented in Table 6 and fall within the limits defined by the literature and site review of hydrogeologic parameters.

4.4.1.1 Pumping Test PW-7L

Calibration to pumping test PW-7L results was performed by simulating the steady-state response to pumping from the Fort Thompson Formation within the footprint of the proposed reactor building for Unit 7. This test was one of four conducted in the first quarter of 2009 to assess the feasibility of construction dewatering. Two tests were conducted within the footprint of each of the reactor buildings for Units 6 & 7, one in the Key Largo Limestone (U or upper test zone), and one in the Fort Thompson Formation (L or lower test zone). The layout of the test (test well and monitoring wells) for this phase of calibration is shown in Figure 28. The notation used for the observation well naming is as follows:

CX-#$ where:

X = Reactor building (6 or 7)

= Number indicating well position

1= approximately 10 feet east of upper zone test well

2= approximately 10 feet north of upper zone test well

3= approximately 25 feet north of upper zone test well

4= approximately 40 feet north of upper zone test well

5= approximately 10 feet east of lower zone test well

$ = Alphabetic character designating the well monitoring zone

A= Miami Limestone

B= Freshwater Limestone

C= Tamiami Formation

D= Key Largo Limestone

E= Fort Thompson Formation

The constant rate test of well PW-7L was conducted in March 2009, with an average discharge rate of 3403 gpm for nine hours.

The rationale for selecting test well PW-7L is:

- The hydrogeological units overlying the Fort Thompson formation and within the footprint of the excavation will be contained by a cut-off wall with the implication that the deeper zone tests are more relevant.

- The PW-7L pumping test data were considered more complete than the PW-6L data.

The refined grid in the area of Unit 7 is presented in Figure 29 along with a close-up showing the test and observation wells in Figure 30. The model interpolates the numerical results calculated at the grid nodes to the input locations of the observation wells. Because water levels in the Fort Thompson Formation stabilized within ten minutes of turning on the pump, the test was simulated by matching the drawdown values at the end of the test only. The rationale for this is that the test had reached steady-state and hence a transient simulation was not necessary.

Results of the pumping test simulation are tabulated in Table 7. This shows simulated and measured drawdown values in each of the monitoring wells that were instrumented. The drawdown response was well matched.

A plot of observed versus simulated drawdown is presented in Figure 31 for all monitored layers. The normalized root mean square for all layers is 7.9 percent,

which is considered acceptable for this model and is within the calibration criteria established in Section 4.2.

4.4.1.2 Pumping Test PW-1

An exploratory drilling and aquifer testing program was performed on the Turkey Point peninsula to assess the hydraulic properties of the Biscayne Aquifer (Reference 4). The aim of the program was to provide data to help determine whether a radial collector well system could be implemented at this location to meet the water-supply requirements for Units 6 & 7.

The pumping well, PW-1 was open across the Key Largo Limestone. Five monitoring wells were installed at radial distances of between 75 feet and 2070 feet of the pumping well. Monitoring wells at all radial distances are screened in the Key Largo Limestone to monitor water levels in the test zone. In the case of the closest monitoring well, the zones immediately above (Miami Limestone) and below (Fort Thompson Formation) the test zone are also monitored. The layout of the test (test well and monitoring wells) is shown in Figure 32. The constant rate test of well PW-1 was conducted in April and May of 2009, with an average discharge rate of 7100 gpm for seven days.

The finite-difference grid in the area of the Turkey Point peninsula and the wells (pumping and observation) is presented in Figure 33. Results of the pumping test simulation are tabulated in Table 8. This shows simulated and measured drawdown values in each of the monitoring wells that were instrumented. The drawdown response was well matched.

A plot of observed versus simulated drawdown is presented in Figure 34 for all monitored layers. The normalized root mean square for all layers is 5.3 percent, which is considered acceptable for this model and is within the calibration criteria established in Section 4.2.

4.4.1.3 Pumping Test PW-7U

Calibration to pumping test PW-7U results was performed by simulating the steady-state response to pumping from the Key Largo Limestone within the footprint of the proposed reactor building for Unit 7. The layout of the test (test well and monitoring wells) for this phase of calibration is shown in Figure 28 and follows the same notation as test PW-7L described in Section 4.4.1.1.

The constant rate test of well PW-7U was conducted in March 2009, with an average discharge rate of 4181 gpm for just under nine hours. As shown in Figure 28, observation wells were constructed in all geologic units of the Biscayne Aquifer to monitor the water level response to pumping.

PW-7U was selected as part of the calibration data following its unsuccessful use to validate the model after calibration to PW-7L and PW-1 alone. The grid refinement presented for PW-7L also covers the same area for PW-7U and is presented in Figure 29 along with a close-up showing the test and observation wells in Figure 35.

Because water levels in the Key Largo Limestone stabilized within ten minutes of initiating pumping, the test was simulated by matching the drawdown values at the end of the test only. The rationale for this is that the test had reached steady-state and hence a transient simulation was not necessary.

Results of the pumping test simulation are tabulated in Table 9, which shows simulated and measured drawdown values in each of the monitoring wells that were instrumented. The drawdown response was well matched with the exception of monitoring well C7-1D, which shows greater drawdown compared to C7-2D, both of which are equidistant from the test well. The difference in drawdown between the observation wells could suggest localized heterogeneity and/or well construction issues or instrument malfunction. Review of the well construction information and both the raw data and processed data files did not indicate any obvious well construction or data collection issues that would cause the difference in drawdown. The difference in drawdown between these two wells is likely attributable to small-scale heterogeneities that are not captured in the model. A plot of observed versus simulated drawdown is presented in Figure 36 for all monitored layers.

The normalized root mean square for all layers is 11.3 percent. Although the NRMS is marginally outside the criterion established in Section 4.2, the RMS, ARM, and M_d are all within limits. This result is considered adequate because the model is also calibrated to two other pumping tests, compared to the regional flow regime, and additionally calibrated to a water balance for the cooling canal system.

4.4.2 Comparison to Regional Flow Regime

For matching of regional flow direction and patterns, simulated groundwater contours and levels were compared to potentiometric surface maps for the Biscayne Aquifer from May and November 1993 (Figure 13 and Figure 14).

The intention of this is to qualitatively capture the overall flow paths and direction. Figure 37 through Figure 44 show the simulated heads for each of the hydrostratigraphic units, indicating a predominant flow direction from west to east, which is in agreement with Figure 13 and Figure 14. Flows are more complex in the vicinity of the cooling canals due to the exchange of water between the canals and groundwater. These nuances are not captured in the larger flow picture shown in Figure 13 and Figure 14.

4.4.3 Comparison with Cooling Canal System

The interaction of groundwater with the surface water comprising the cooling canal system was assessed by comparing model results against estimates obtained from an independent water balance model on a steady-state basis. The water balance model for the cooling canal system (Reference 33) is displayed schematically in Figure 21 (Reference 32). The model accounts for flow from the release side of the cooling canals downward to the groundwater beneath the canal system and flow from underneath Biscayne Bay inward and upward to the

return canals. This figure has been updated to include the simulated flow rates from the groundwater model and is shown in Figure 45. The area outlined in blue shows that part of the surface water model that is replicated in the current groundwater model. The top figure for each parameter (net blowdown and net makeup) represents that from the surface water model while the lower figure is the calculated value from the groundwater model. Values for comparison were determined from the groundwater model by assigning flow zones across the release and return sides of the cooling canal system. Fluxes into and out of these zones were then calculated for comparison with the water balance. A comparison of the values indicates that the groundwater model shows up to 31 percent higher cooling canal system makeup and blowdown values than the surface water. This is considered an acceptable match given that the cooling canal system water balance is a simple analytical model.

4.5 Model Validation

The PW-6U test, conducted in the Key Largo Limestone at the location of the proposed site of the Unit 6 power block, was used for model validation. The test and monitoring well layout is depicted in Figure 46 and uses the same numbering system as described in Section 4.4.1.1.

The constant rate test of well PW-6U used an average discharge rate of 5103 gpm for eight hours. As shown in Figure 46, observation wells were constructed in all geologic units of the Biscayne Aquifer to monitor the water level response to pumping.

Results of the pumping test simulation are tabulated in Table 10. This shows simulated and measured drawdown values in each of the monitoring wells that were instrumented. The drawdown response was well matched.

A plot of observed versus simulated drawdown is presented in Figure 47 for all monitored layers. Although the NRMS of 11.4 percent is marginally outside the criterion established in Section 4.2, the RMS, ARM, and M_d are all within limits. These results are considered acceptable for model validation, considering that PW-6U data are completely independent.

4.6 Conclusions

The model is considered to be calibrated based on the following observations:

- Calibration to pumping tests at PW-7L, PW-1, and PW-7U indicate a good match between observed and modeled drawdown values.

- Matching of regional flow patterns.

- Comparison with an independent cooling canal system water model shows similar flow exchanges between the cooling canals and the groundwater beneath them.

- Validation of the model to pumping test PW-6U indicates a good match between observed and modeled drawdown values.

- Hydraulic conductivity values obtained by model calibration are within the range of values reported in the literature.

5.0 CONSTRUCTION & POST-CONSTRUCTION SIMULATIONS

Predictive simulations are used for two purposes: evaluating groundwater control options during construction of Units 6 & 7, and operation of the radial collector well system and its influence of the existing groundwater regime.

A concrete cut-off wall for construction groundwater dewatering control will be installed around the excavations for Units 6 & 7. It is estimated that the cut-off wall will extend to an elevation of -60 feet NAVD 88 with the base of the excavation at an elevation of -35 feet NAVD 88. The top of the cut-off wall will extend up to an elevation of 2 feet NAVD 88. In addition, the rock between the base of the excavation and the base of the cut-off walls will be grouted. The purpose of modeling the construction dewatering is to estimate discharge rates required to maintain the water table below the base of the excavation.

Radial collector wells will be installed on Turkey Point peninsula in order to provide backup cooling tower makeup water for the proposed AP1000 units at Units 6 & 7 when the primary supply of makeup water is not available. These simulations are performed to determine the origins of water that supply the RCW system, using MODPATH (Reference 34) and ZoneBudget (Reference 35).

5.1 Groundwater Control During Construction

Groundwater flow simulations for dewatering of the power block excavations were performed with the calibrated base model. For these simulations, the muck is left in place in the model. It is likely that during earthworks, the muck will be stripped and replaced with backfill to provide a stable working platform. This simplification is expected to have no impact on the dewatering rates.

Several refinements were made to the base model to represent the excavations:

- The interior of the excavation (ground surface to -35 feet NAVD 88) was defined as inactive to flow.

- The Horizontal Flow Boundary (HFB) package (Reference 36) was used to simulate the cut-off walls from the base of the excavation down to an elevation of -60 feet NAVD 88.

- Constant head cells were added to the layer below the excavation to represent the sump pumps in the base of the excavation used to maintain dry working conditions. The constant head level was set to -35 feet NAVD 88 (the floor of the excavation), and pumping rates were calculated from the simulated inflows to the constant head cells. The grid elevations

of the cells immediately below the base of the excavation were adjusted to provide a uniform, thin layer within which the constant head cells could be placed.

- A new hydraulic conductivity zone was added from the base of the excavation to the base of the cut-off walls to simulate grouting.

- The water level in Biscayne Bay was set to the long-term average of -0.81 feet NAVD 88.

- Water levels in the cooling canal system, L-31E Canal, Card Sound Canal, and the Model Land Canal (C-107) were adjusted based on the long-term average Biscayne Bay water level.

Figure 48 shows the outline of the excavations while Figure 49 illustrates the implementation of the excavation in the model. Figure 49 shows the model grid, excavation walls, and interior dewatering wells. A cross section through the model illustrating the depth of the excavation and cut-off walls is presented in Figure 50

The two excavations were dewatered sequentially to represent the construction schedule. For each unit, the model was run to steady-state, starting with previously derived steady-state heads under no pumping conditions. ZoneBudget was used along with the simulation to determine the quantity of water being extracted from the interior dewatering wells.

To aid in construction-related groundwater control, a 'grout plug' will be formed between the bottom of the excavation and the bottom of the cut-off wall. The rationale behind this methodology is to reduce the hydraulic conductivity by injecting grout into a pattern of holes within the excavation between the bottom of the excavation and the bottom of the cut-off wall. By reducing the hydraulic conductivity of the rock, lower discharge rates are achieved, such that sump pumps in the floor of the excavation rather than active dewatering wells can be used to keep the excavation dry.

Figure 51 shows the proposed methodology whereby grout is injected in a series of "Primary" borings until refusal is achieved. Subsequent borings are then drilled in between the borings of the prior step. Three series of borings are possible after the "Primary" set: a "Secondary," "Tertiary," and "Quarternary" set. Each set is drilled and grout injected until refusal occurs. "Quarternary" borings may not be required at all locations; only where excessive seepage is observed as the excavation progresses.

In the base case, a hydraulic conductivity of 1×10^{-4} cm/s is used for the grouted formations. Discharge rates obtained from this model yield a value of 96 gpm for each unit. A series of runs evaluating different values for the hydraulic conductivity of the grout plug were performed to determine a feasible range of discharge rates that may be achievable with grouting. In addition to the run

described above, values of 1 x 10^{-3} cm/s, 1 x 10^{-5} cm/s, and 1 x 10^{-6} cm/s were simulated. The results are displayed graphically in Figure 52.

5.2 Post-Construction Radial Collector Well Simulation

Groundwater flow simulations for the radial collector wells were performed with the calibrated base model. Several refinements were made to the represent the conditions at the site post-construction:

- Cut-off walls installed during construction (and represented in dewatering simulations) are left in place;

- Concrete fill added within the cut-off walls between an elevation of -35 feet NAVD 88 (base of excavation) and -16 feet NAVD 88 with a hydraulic conductivity of 1 x 10^{-8} cm/s;

- Concrete mud mat for reactor building added within cut-off walls between -16 feet NAVD 88 and -14 feet NAVD 88 with a hydraulic conductivity of 1 x 10^{-8} cm/s;

- Reactor building included as inactive to flow;

- Redefined new zones of recharge at the Units 6 & 7 plant area as represented in Figure 53. The values of recharge for grass and backfill of 2 in/yr and 10 in/yr respectively were selected to represent the land surface and also the relatively lower recharge expected compared to the wetlands which dominates a large majority of the model area;

- Backfill added between reactor building and cut-off walls with a hydraulic conductivity of 0.01 cm/s;

- Muck removed from area in immediate vicinity of reactor buildings (shown in upper half of Figure 25) and replaced with backfill (hydraulic conductivity of 0.01 cm/s);

- The water level in Biscayne Bay was set to the long-term average of -0.81 feet NAVD 88;

- Recharge and evapotranspiration set to long-term average values;

- Water levels in the cooling canal system were shifted to account for the change in Biscayne Bay water level;

- Mechanically Stabilized Earth (MSE) retaining walls, as shown in Figure 54 installed around perimeter of the Turkey Point Units 6 & 7 plant area (excluding the makeup water reservoir) down to 0 feet NAVD 88. The MSE retaining wall is also shown as implemented in the numerical model in Figure 53, which details recharge zones at the Turkey Point Units 6 & 7 plant area.

To simulate the radial collector wells and laterals, other changes were made to the model:

- Four pumping wells were placed on approximately the last 300 feet of each lateral to represent the screened intervals. Flows were distributed along the laterals based on head loss calculations. The flows are as follows: 872 gpm at the end, 881 gpm at 100 feet from the end, 909 gpm at 200 feet from the end, and 956 gpm at 300 feet from the end of the lateral. Total flows are 3618 gpm per lateral or 28,944 gpm per radial collector well (8 laterals per radial collector well x 3618 gpm per lateral). In the model, the pumping wells are placed at approximately 100-foot intervals.

- Three of the four radial collector wells are operational, resulting in a total system pumping rate of 86,832 gpm (3 radial collector wells x 28,944 gpm per radial collector well). To provide a conservative estimate of the source of water from inland areas to the radial collector wells, the three wells closest to the shore were modeled as operational.

- Zones were defined around the model domain to estimate the volume of water coming from land or Biscayne Bay.

- The radial collector wells are pumped from the Upper Higher Flow Zone. An alternate scenario was also modeled in which the radial collector wells are pumped from the Key Largo Limestone.

- The top of the cut-off walls was truncated at the boundary of the Miami Limestone and muck (approximate elevation -4 feet NAVD 88). The actual elevation will be 2 feet NAVD 88, however this simplification is expected to have no affect on the RCW calculations of approach velocity and origin of flow to the RCW.

Figure 55 shows the modeled location of the radial collector wells on the Turkey Point peninsula with the finite-difference grid overlaid and also the location of the pumping wells (light blue) representing the screened portion of the laterals. Figure 56 shows the potentiometric surface after model execution in the Upper Higher Flow Zone. Figure 57 shows the head contours in layer 1. Figure 58 is a section across the most centrally located radial collector well showing groundwater contours for all modeled layers. Figure 59 and Figure 60 show the drawdown in the vicinity of the Turkey Point peninsula in layer 1 and the Upper Higher Flow Zone (pumped zone) respectively. In the alternate case where the radial collector wells are instead placed in the Key Largo Limestone, the water table, groundwater contours, and drawdown plots are virtually identical to those produced when the radial collector wells are pumped from the Upper Higher Flow Zone.

5.2.1 Origins of Water Supplying Radial Collector Wells

To determine the origins of water supplying the radial collector wells a multi-step process is followed. The first step is to place a particle in each boundary condition cell representing a source of water (River, General-Head, and Recharge). Particles are not placed in other cells because the model is steady-state and therefore all water discharging from the RCWs has to originate from a boundary condition. MODPATH is then run in forward tracking mode and the endpoint file reviewed to identify only those particles that end up in the pumping cells representing the RCWs. Once those particles have been identified their starting locations are set up as a separate zone within ZoneBudget for tracking purposes. Following execution of ZoneBudget, the separate fluxes from each of the boundaries (River, General-Head, and Recharge minus Evapotranspiration) are summed and compared to the discharge from the RCW system as a check. For both the base case with the laterals in the Upper Higher Flow Zone and the alternate case with the laterals in the Key Largo Limestone, 99.9 percent of the expected flow to the RCW system is accounted for by the ZoneBudget boundary fluxes. The results presenting the origins of the water to the RCW are presented in Table 11 and broken down into two main components. The first of these is flow from Biscayne Bay, which includes vertical flow down through the Bay floor and lateral flow from the sides of the model in the Bay. The second component is flow from inland, which is further broken down into water originating from the CCS, and that originating from recharge by precipitation.

Figure 61 and Figure 62 present the output for layers 1 and 2 for the base case where the laterals are placed in the Upper Higher Flow Zone. The blue colored clusters on these figures show the starting location of particles that ultimately discharge to the RCW. In the alternate case where the radial collector wells are pumped from the Key Largo Limestone, the flow distribution is the same as the base case, as is shown in Table 11.

The cumulative impacts of the radial collector wells were examined by comparing the difference in flow into and out of the model across the western, northwestern, and southwestern boundary when the radial collector wells are operating at steady-state, versus the steady-state case when no wells are running. Eastward flow is defined as the flow across the western boundary and the flow across the northern boundary from the western edge of the model to L-31E. Flow quantities were determined using ZoneBudget. In both cases, 26 gpm of additional flow into the model domain is induced across the model boundaries as compared to the case with no pumps operating.

5.2.2 Approach Velocity at Bay/Aquifer Interface

Three separate approach velocities through the floor of Biscayne Bay were calculated while simulating the operation of the radial collector wells. Using the Biscayne Bay capture zone identified in Figure 61 and the additional zones identified in Figure 63, three values for the approach velocity were calculated representing the following:

1. Average approach velocity for entire control volume (blue in NE corner of Figure 61);

2. Average approach velocity for immediate area defined by the radial collector wells (green in Figure 63); and

3. Average approach velocity for the laterals (colored zones along laterals in Figure 63).

The volumetric flow rate for each of these zones was calculated using ZoneBudget and then divided by the area of the zone to calculate an approach velocity. The following values were obtained for the three zones for the base case with the radial collector wells pumping from the Upper Higher Flow Zone:

- Entire RCW Catchment: 3.3×10^{-5} cm/s (1.1×10^{-6} ft/s)

- Immediate RCW Area: 5.2×10^{-4} cm/s (1.7×10^{-5} ft/s)

- Average of all RCW Laterals: 6.2×10^{-4} cm/s (2.0×10^{-5} ft/s)

To further illustrate these results, a plot of the Darcy velocities in the top layer of the model showing the spatial variation in approach velocity (ft/day) through the floor of Biscayne Bay is given in Figure 64. Irregularities in the contours of the Darcy velocity are related to the hydraulic conductivity distribution for layer 1 (Figure 23). When the radial collector wells are instead located in the Key Largo Limestone, the approach velocities are only slightly different compared to the base case (see Table 12).

5.2.3 Sensitivity Analysis

A suite of sensitivity analyses was performed on the radial collector well simulations to address parameter and water level uncertainty. The radial collector wells pump from the Upper Higher Flow Zone in all sensitivity runs.

Two sensitivity runs were performed to address the uncertainty in Biscayne Bay water levels. These runs considered that Biscayne Bay water levels vary seasonally. One case was run with Biscayne Bay set at the seasonal high water level, and another case was run with Biscayne Bay set at the seasonal low level. The seasonal extreme values were determined by taking the highest and lowest monthly mean sea level measurements at NOAA's tidal water level and meteorological data collection station (#8723214) on Virginia Key in Biscayne Bay. The seasonal low level of Biscayne Bay is -1.40 feet NAVD 88 while the seasonal high level of Biscayne Bay is 0.09 feet NAVD 88 (Reference 11). Using the equation given in Section 3.3.3, water levels in the cooling canals, L-31E Canal, Card Sound Canal, and Model Land Canal (C-107) were adjusted based on the water level in Biscayne Bay. The areal extent of the GHB cells representing Biscayne Bay was not adjusted for this sensitivity analysis. Results of the seasonal water level runs indicate that either increasing or decreasing the Biscayne Bay water level has no effect on the approach velocities for the RCW.

Increasing the Biscayne Bay water level slightly increases the percent contribution to the radial collector wells from Biscayne Bay, while lowering the Biscayne Bay water level slightly decreases the percent contribution to the radial collector wells. Changing the Biscayne Bay level induces an additional flow into the model domain of 23 gpm for the high water level case and 27 gpm for the low water level case when compared to the case with no pumps operating.

Two additional sensitivity runs were performed to assess the impact of the anisotropy ratio in Biscayne Bay on the radial collector well simulations. In the base model, an anisotropy ratio of 15:1 (Kh:Kv) is used. In the sensitivity runs, the vertical hydraulic conductivity (Kv) is either doubled or halved, producing anisotropy ratios of 7.5:1 or 30:1, respectively. This change is only made offshore to the first three layers of the model, which represent the Miami Limestone (and a small area of sediment in layer one) Results of the anisotropy sensitivity runs indicate that for the RCW laterals and the immediate RCW area, the approach velocities increase as the Kv increases, and decrease as the Kv decreases. Doubling the Kv slightly increases the percent contribution to the radial collector wells from Biscayne Bay, while halving the Kv slightly decreases the percent contribution to the radial collector wells. Changing the anisotropy ratio in Biscayne Bay induces an additional flow into the model domain of 7 gpm for the double Kv case and 82 gpm within the model domain for the half Kv case, when compared to the case with no pumps operating.

A final set of sensitivity runs were performed to evaluate the impact of the hydraulic conductivity of the Key Largo Limestone on the radial collector well simulations. The reason for this additional suite is because the Key Largo Limestone is divided into two zones of hydraulic conductivity based on prior information. These zones were defined to improve the calibration and these sensitivity runs are intended to determine if the difference in hydraulic conductivity between the zones results in any change in the induced flow across the western boundary. The results indicate that an additional 11 gpm of flow is induced across the model boundaries when the horizontal hydraulic conductivity is 5.9 cm/s and 34 gpm when the horizontal hydraulic conductivity is 10 cm/s when compared to the case with no pumps operating.

A compilation of the results for the base case and sensitivity cases can be found in Table 11 for the origin of water to the radial collector wells and Table 12 for the approach velocities of each zone. As was done with the base case, a comparison of the RCW discharge was made with the ZoneBudget boundary fluxes as a check. For these sensitivity cases, between 99.8 and 100.4 percent of the expected flow to the RCW system is accounted for by the ZoneBudget boundary fluxes. For both the base case with the laterals in the Upper Higher Flow Zone and the alternate case with the laterals in the Key Largo Limestone, 99.9 percent of the expected flow to the RCW system is accounted for by the ZoneBudget boundary fluxes. In addition to the tabulated summary a graphical representation of the sensitivity of these parameters to the 0.1 foot drawdown contour is presented in Figures 65, 66, and 67 for the aforementioned cases.

6.0 CONCLUSIONS

A steady-state, constant-density, three-dimensional model was developed to simulate groundwater flow under present conditions at the Turkey Point Units 6 & 7 Site. The model was developed and calibrated using available historic data and data collected in support of the Combined License Application (COLA) and Site Certification Application (SCA).

The calibrated model was used to simulate construction dewatering for the Unit 6 and Unit 7 nuclear islands. Calculated pumping rates to enable dry working conditions are 96 gpm for each excavation, when each unit is constructed separately. These simulations for groundwater control involve injecting grout between the bottom of the excavation and the bottom of the cut-off wall and using sump pumps in the base of the excavation to remove seepage through the grout plug into the excavation.

The model was also used to determine the origin of water supplying the radial collector wells by a combination of particle tracking and evaluating flows through different parts of the model. These simulations indicate that approximately 97.8 percent of the pumped water will originate from Biscayne Bay while the remainder will originate from inland.

7.0 REFERENCES

1.   Southeastern Geological Society (SEGS), 1986. *Hydrogeological Units of Florida*, Special Publication 28, Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition.

2.   Dames & Moore, 1971, *Geohydrologic Conditions Related to the Construction of Cooling Ponds*, Florida Power & Light Company, Steam Generating Station, Turkey Point, Florida, Prepared for Brown and Root, Inc.

3.   MACTEC Engineering and Consulting, 2008. *Final Data Report – Geotechnical Exploration and Testing: Turkey Point COL Project Florida City, Florida, Rev. 2,* October 6, 2008.

4.   HDR Engineering Inc., 2009. *Turkey Point Exploratory Drilling and Aquifer Performance Test Program*. August 19, 2009*.*

5.   JLA Geosciences Inc., 2010. *Geology and Hydrogeology Report for Turkey Point Plant Groundwater, Surface Water & Ecological Monitoring Plan*.

6.   Dames & Moore, 1975, *Florida Aquifer Water Supply Investigation, Turkey Point Area, Dade County, Fl*. Prepared for Florida Power & Light Company.

7.   Enercon Services, Inc. and William Lettis & Associates, Inc. (WLA), 2006. *Feasibility Geological Investigation of Potential New Nuclear Plant Site: FPL Turkey Point Facility*. Submitted to: Florida Power and Light.

8.   Florida Geological Survey, 2008. *Lithologic Database*. Available at: http://www.dep.state.fl.us/geology/gisdatamaps/litholog.htm, accessed September 6, 2008.

9.   Reich, C., Halley, R.B., Hickey, T., and Swarzenski, P., 2006. *Groundwater Characterization and Assessment of Contaminants in Marine Areas of Biscayne National Park* United States Geological Survey (USGS), Technical Report/NPS/NRWRD/NRTR-2006/356. Available at: http://sofia.usgs.gov/publications/reports/bisc_gw_char/Bisc_gw_char.pdf, accessed May 17, 2012.

10.   Florida Power and Light (FPL), 2009. *FPL Turkey Point Power Plant Groundwater, Surface Water, and Ecological Monitoring Plan*. Exhibit B. October 2009. Available at http://publicfiles.dep.state.fl.us/siting/Outgoing/FPL_Turkey_Point/Units_6 _7/Completeness/Plant_Associated_Facilities/2nd_round_Completeness/ FPL_Response_Part_A_Information/Attachments/2nd%20Round%20Atta chments/101409%20Final%20Turkey%20Point%20Monitoring%20Plan.p df, accessed November 10, 2010.

11.   NOAA, 2010. *Tides & Currents Virginia Key, FL #8723214 web page (NOAA)*. Available at: http://tidesandcurrents.noaa.gov/station_info.shtml?stn=8723214%20Virgi nia%20Key,%20FL, accessed October 13, 2010.

12.   Langevin, C.D., 2001. *Simulation of Ground-Water Discharge to Biscayne Bay, Southeastern Florida*, U.S. Geological Survey Water-Resources Investigations Report 00-4251.

13.   South Florida Water Management District (SFWMD), 2010. *South Florida Water Management District DBHYDRO database query, Station S20F*, available at: http://www.sfwmd.gov/dbhydroplsql/show_dbkey_info.date_selection?v_j s_flag=Y&v_db_request_id=2802506&v_parameter_string=&v_dbkey=05 816%2FVN225%2FK8666%2F16692&v_frequency=&v_sdate=19680522 &v_edate=20101025, accessed October 14, 2010.

14.   Harbaugh, Arlen W., Edward R. Banta, Mary C. Hill, and Michael G. McDonald, 2000. *MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*, U.S. Geological Survey Open-File Report 00-92. Available at http://pubs.er.usgs.gov/usgspubs/ofr/ofr200092, accessed September 30, 2008.

15.   McDonald, Michael G., and Arlen W. Harbaugh, 1984. *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model*. U.S. Geological Survey Open-File Report 83-875, 528 p. Available at http://pubs.er.usgs.gov/usgspubs/ofr/ofr83875, accessed September. 29, 2008.

16.   McDonald, Michael G., and Arlen W. Harbaugh, 1988. *Chapter A1 – A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model*. Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 6, Modeling Techniques. Available at http://pubs.er.usgs.gov/usgspubs/twri/twri06A1, accessed September. 29, 2008.

17.   Schlumberger Water Services, 2008. *Visual MODFLOW Professional v.4.3, User's Manual*.

18.   NOAA, 2008. NOAA Coastal Services Center. *Topographic and bathymetric data considerations: datums, datum conversion techniques and data integration, Part II: A Roadmap to a Seamless Topobathy Surface*, National Oceanic and Atmospheric Administration (NOAA), Technical Report NOAA/CSC/20718-PUB.

19.   NOAA, 2010. *VDatum - Online User's Guide*, available at http://vdatum.noaa.gov/docs/usersguide.html, accessed October 13, 2010.

20.   NOAA, 2010. *FME SpatialDirect*, Office of Coast Survey (OCS) Harbor Sounding, available at http://ocs-spatial.ncd.noaa.gov/SpatialDirect/translationServlet?SSFunction=prepareFetch, accessed May 13, 2010.

21.   Renken, R., Cunningham, K., Shapiro, A., Harvey, R., Zygnerski, M., Metge, D., and Wacker, M., 2008. *Pathogen and chemical transport in the karst limestone of the Biscayne aquifer: 1. Revised conceptualization of groundwater flow*, Water Resources Research, Vol. 44.

22.   Fish and Wildlife Research Institute (FWRI), 2010. Marine Resources Geographic Information System (MRGIS) GIS Data, Benthic Habitats – South Florida. Available at: http://ocean.floridamarine.org/mrgis_ims/Description_Layers_Marine.htm, accessed June 25, 2010.

23.   Cunningham, K.J., Carlson, J.L., Wingard, G.L., Robinson, E., and Wacker, M.A., 2004. *Characterization of Aquifer Heterogeneity Using Cyclostratigraphy and Geophysical Methods in the Upper Part of the Karstic Biscayne Aquifer, Southeastern Florida*, Water-Resources Investigations Report 03-4208, U.S. Geological Survey, 2004.

24. Cunningham, K.J., Wacker, M.A., Robinson, E., Dixon, J.F., and Wingard, G.L., 2006. *A Cyclostratigraphic and Borehole-Geophysical Approach to the Development of a Three-Dimensional Conceptual Hydrogeologic Model of the Karstic Biscayne Aquifer, SE Florida*. U.S.G.S. Scientific Investigations Report 2005-5235.

25. Cunningham, K.J., Sukop, M.C., Huang, H., Alvarez, P.F., Curran, H.A., Renken, R.A., and Dixon, J.F., 2009. *Prominence of ichnologically influenced macroporosity in the karst Biscayne aquifer: Stratiform "super-K" zone.* Geological Society of America Bulletin, v. 121, no. 1/2, p. 164-180.

26. Fetter, C.W., 1994. *Applied Hydrogeology*. 3rd Edition, Prentice Hall.

27. Rice, R.W. and Walton, T.C., October 2006 "Design Factors Affecting the Flow of Water through Below-Ground Concrete Vaults", *Journal of Environmental Engineering*, v, 132, no. 10, pp 1346-1354.

28. Warner, J., 2004. *Practical Handbook of Grouting: soil, rock, and structures*. John Wiley and Sons, 700 p.

29. Weaver, K.D. and Bruce, D.A., 2007. *Dam Foundation Grouting, Revised and Expanded Edition*, American Society of Civil Engineers, Subsection 14.2.1 Permeability Criteria.

30. Gamble, B.F. and Stowe, S.M., 2008. "Approaches to Modeling Collector Wells and Horizontal Wells with MODFLOW." *MODFLOW and More 2008: Groundwater and Public Policy*. Conference proceedings, pp 489-493.

31. HDR Engineering Inc., 2009. *Conceptual Engineering Report – March 2009 FPL Turkey Point Units 6 & 7*.

32. Golder Associates, Inc., 2008. *Cooling Canal System Modeling Report*.

33. Golder Associates, Inc., 2008. *Final Report on Florida Power & Light Company. Turkey Point New Nuclear Project Cooling Canal Data and Analysis Report*.

34. Pollock, D.W., 1994. *User's Guide for MODPATH/MODPATH-PLOT, Version 3: A particle tracking post-processing package for MODFLOW, the U. S. Geological Survey finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 94-464*. http://water.usgs.gov/software/MODPATH/code/doc/ofr94464.pdf, Accessed 1/31/2011.

35. Harbaugh, A.W., 1990. *A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular

three-dimensional ground-water flow model: U.S. Geological Survey
Open-File Report 90-392, p. 46.

36. Hsieh, Paul and Freckleton, John, 1993*. Documentation of Computer
Program to Simulate Horizontal-Flow Barriers Using the United States
Geological Survey's Modular Three-Dimensional Finite-Difference
Ground-Water Flow Model*. U.S. Geological Survey Open-File Report 92-
477, 528 p. Available at
http://water.usgs.gov/nrp/gwsoftware/modflow2005/ofr92_477_HFB.pdf ,
accessed May 27, 2009.

37. Krupa, A.J. and M.T. Mullen, 2005. *Literature Review And Assessment
Of Geologic Logs To Determine The Extent Of A Dense Limestone Layer
In The Upper Portion Of The Biscayne Aquifer In The Pennsuco
Wetlands, Miami-Dade County, Florida*.

38. Sonenshein, R.S., 2001. *Methods to Quantify Seepage Beneath Levee
30, Miami-Dade County, Florida*, U.S. Geological Survey Water-
Resources Investigations Report 01-4074.

39. Merritt, M.L., 1996. *Simulation of the Water-Table Altitude in the
Biscayne Aquifer, Southern Dade County, Florida, Water Years 1945-89*,
U.S. Geological Survey Water-Supply Paper 2458.

40. Swain, E.D., Howie, B., and Dixon, J. 1996. *Description and Field
Analysis of a Coupled Ground-Water/Surface-Water Flow Model
(MODFLOW/BRANCH) with Modifications for Structures and Wetlands in
Southern Dade County, Florida*: U.S. Geological Survey Water-
Resources Investigations Report 1996-4118, 71 p.

41. Fish, J.E. and M. Stewart, 1991. *Hydrogeology of the Surficial Aquifer
System, Dade County, Florida*, U.S. Geological Survey Water-Resources
Investigations Report 90-1408.

42. Florida Power & Light, 2011. *Turkey Point Units 6 & 7 Final Safety
Analysis Report, Combined Licensing Application, Rev. 3*.

43. Reese, R., and Richardson, E., 2008. *Synthesis of the Hydrogeologic
Framework of the Floridan Aquifer System and Delineation of a Major
Avon Park Permeable Zone in Central and Southern Florida*, Scientific
Investigations Report 2007-5207, U.S. Geological Survey.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Table 1.
Station S20F Rainfall Data for February to May 2009

2009		Total Precipitation (inches)
Month	Days	VN225
Feb	28	0.34
Mar	31	3.72
Apr	30	0.27
May	31	9.63
Total	120	13.96

Rounded to nearest tenth   14.0

Scaled to Year   42.6   in/yr

Source: Based on Reference 13

Table 2.
Station S20F Annual Rainfall Data

Water Year	Precipitation (inches)				Recorder Selected	Combined Series (inches)
	BELF 5618	OMD 16692	TELE K866	NRG VN225		
1969	67.52				BELF	67.52
1970	40.67				BELF	40.67
1971	32.16				BELF	32.16
1972	54.38				BELF	54.38
1973	40.60				BELF	40.60
1974	35.48				BELF	35.48
1975	43.08				BELF	43.08
1976	43.68				BELF	43.68
1977	43.89				BELF	43.89
1978	38.06				BELF	38.06
1979	33.89				BELF	33.89
1980	41.17				BELF	41.17
1981	45.46				BELF	45.46
1982	46.19				BELF	46.19
1983	59.62				BELF	59.62
1984	36.92				BELF	36.92
1985	37.37				BELF	37.37
1986	38.75				BELF	38.75
1987	41.54				BELF	41.54
1988	73.31				BELF	73.31
1989	46.84				BELF	46.84
1990	39.89				BELF	39.89
1991	40.41				BELF	40.41
1992	46.26	60.38			OMD	60.38
1993	38.59	36.18			OMD	36.18
1994	55.10	60.06			OMD	60.06
1995	74.75	86.11			OMD	86.11
1996	49.55	49.56			OMD	49.56
1997	53.25	49.98			OMD	49.98
1998	48.01	57.41	64.32		OMD/TELE	60.87
1999	36.46	44.62	44.90		OMD/TELE	44.76
2000	38.87	41.23	41.64		OMD/TELE	41.44
2001	57.35	47.41	47.66		OMD/TELE	47.54
2002		48.91	48.48		OMD/TELE	48.70
2003		43.75	43.48		OMD/TELE	43.62
2004		32.60	32.90		OMD/TELE	32.75
2005		47.91	44.98		OMD/TELE	46.45
2006		44.54	44.97		OMD/TELE	44.76
2007		51.14	51.42		OMD/TELE	51.28
2008		44.11	45.47	45.61	NRG	45.61
2009		44.89	44.00	45.86	NRG	45.86

Average **46.75** **in/yr**

Source: Based on Reference 13

Proposed Turkey Point Units 6 and 7
Docket Nos. 52-040 and 52-041
L-2012-366 Enclosure 1 Page 58 of 134

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

FPL Turkey Point Units 6 & 7 Project
Rev. 002
Page 57 of 133

Table 3.
Extinction Depth and Maximum Evapotranspiration Rate

Land-use category	Runoff coefficient	Extinction depth (m)
Urban	0.5	0.3
Agriculture	0.5	0.43
Rangeland	0.2	0.61
Upland forests	0.2	0.7
Water	0	0.183
Wetlands	0	0.69
Barren land	0	0.15
Transportation	0.5	0.3

	January	February	March	April	May	June – October	November	December
Maximum evapotranspiration rate (cm/d)	0.20	0.28	0.36	0.43	0.46	0.53	0.30	0.28

Source: Based on Reference 12

Table 4.
Regional Hydraulic Conductivity Values Based on Onsite Tests and Literature Review

HG Unit	FPL Onsite Tests				Literature Review							
	Kh min	Kh max	Kv min	Kv max	Kh min	Ref	Kh max	Ref	Kv min	Ref	Kv max	Ref
Offshore Sediment												
Onshore Muck			*2.5E-04*	*2.5E-04*	3.5E-05	37	1.8E-02	38	3.5E-04	12	1.8E-03	38
Miami Limestone	*7.9E-02*	*7.9E-02*	5.0E-03	8.0E-03	3.5E-05	37	1.1E+01	39	3.5E-02	38	1.1E+00	40
Upper Higher Flow Zone												
Key Largo	3.3E+00	1.8E+01			1.1E+00	38	3.5E+01	41	1.1E-01	38		
Freshwater Limestone			7.0E-05	3.0E-03	3.5E-05	37	3.5E-04	38	3.5E-05	38	3.0E-03	37
Lower Higher Flow Zone												
Fort Thompson	1.0E-01	1.6E+00			1.8E-01	39	1.1E+01	39	1.8E-02	39	1.1E+00	40
Tamiami Formation			3.0E-02	4.0E-01	3.5E-05	40	7.1E-01	41	3.5E-06	40	7.1E-03	38

Note: Italicized values indicate instances where only one hydraulic conductivity value was available and thus the maximum and minimum values are equal.

Table 5.
Surface Water Levels Corrected to Reference Density

Surface Water Feature	Location	Base of Canal (ft NAVD 88)	Canal Stage (ft NAVD 88)	Water Type	Water Density (kg/m³)	Reference Head (ft NAVD 88)
Interceptor Ditch	CHD of -0.28	-19.2	-0.28	FW	996.70	-0.76
Interceptor Ditch	Start of variable H	-19.2	-0.18	FW	996.70	-0.66
Interceptor Ditch	End of variable H	-19.2	-1.05	FW	996.70	-1.51
L-31E	All	-22.8	0.02	FW	996.70	-0.55
Southern Portion of Grand Canal Outside the CCS	All	-21.2	-1.05	SALINE	1022.40	-1.05
C-106	All	-14	-1.05	SALINE	1022.40	-1.05
E-W Release Canal	H = 1.28	-21.2	1.28	CCS	1048.00	1.84
E-W Release Canal	H = 1.08	-21.2	1.08	CCS	1048.00	1.64
N-S Shallow Canal	H = 1.08	-3.02	1.08	CCS	1048.00	1.18
N-S Shallow Canal	H = -1.05	-3.02	-1.05	CCS	1048.00	-1.00
E-W Collector	All	-21.2	-1.05	CCS	1048.00	-0.55
Grand Canal	Top	-21.2	-3.18	CCS	1048.00	-2.73
Grand Canal	Bottom	-21.2	-1.05	CCS	1048.00	-0.55
E. Return Canal	Top	-19.2	-3.18	CCS	1048.00	-2.78
E. Return Canal	Bottom	-19.2	-1.05	CCS	1048.00	-0.60
Island	SW	-21.2	-3.18	CCS	1048.00	-2.73
Island	NE	-21.2	-3.28	CCS	1048.00	-2.83
Intake Basin	NE Island	-21.2	-3.28	CCS	1048.00	-2.83
Intake Basin	Pumps	-21.2	-3.38	CCS	1048.00	-2.93

FW - Freshwater
CCS - Hypersaline

FW 8	996.7	kg/m³
Ref 8. (Bisc. Bay)	1022.4	kg/m³
CCS 8	1048.0	kg/m³

Table 6.
Model Calibration – Hydraulic Conductivity

HG Unit	Hydraulic Conductivity (cm/s)		Anisotropy Ratio
	Kh	Kv	
Offshore Sediment	3.53E-02	2.4E-03	15:1
Onshore Muck	4.4E-03	4.4E-04	10:1
Miami Limestone	8.8E-02	5.9E-03	15:1
Upper Higher Flow Zone	3.0E+01	3.7E+00	8:1
Key Largo SW	5.9E+00	7.4E-01	8:1
Key Largo NE	1.0E+01	1.3E+00	8:1
Freshwater Limestone	3.4E-05	2.3E-06	15:1
Lower Higher Flow Zone	1.7E+00	1.7E-01	10:1
Fort Thompson	3.3E-01	3.3E-02	10:1
Tamiami Formation	2.8E-04	2.8E-05	10:1

Table 7.
Model Calibration PW-7L - Measured Versus Simulated Drawdowns (at End of Test)

Well	HG Unit	Easting	Northing	DRAWDOWN (ft) Observed	DRAWDOWN (ft) Calculated	R_i (Obs-Calc)	$|R_i|$	$|R_i|^2$
C7-2A	Miami Limestone	875822.2	396944.9	0.31	0.48	-0.18	0.18	0.03
C7-2C	Tamiami Formation	875822.2	396944.9	1.54	1.19	0.35	0.35	0.12
C7-2D	Key Largo Limestone	875817.3	396944.9	0.34	0.49	-0.15	0.15	0.02
C7-2E	Fort Thompson Formation	875817.3	396944.9	3.56	4.44	-0.87	0.87	0.76
C7-3A	Miami Limestone	875822.4	396960.2	0.32	0.48	-0.16	0.16	0.03
C7-3C	Tamiami Formation	875822.4	396960.2	2.91	1.21	1.70	1.70	2.89
C7-3D	Key Largo Limestone	875817.2	396959.9	0.35	0.49	-0.14	0.14	0.02
C7-3E	Fort Thompson Formation	875817.2	396959.9	4.96	6.10	-1.15	1.15	1.32
C7-4A	Miami Limestone	875822.3	396975.2	0.32	0.48	-0.16	0.16	0.03
C7-4C	Tamiami Formation	875822.3	396975.2	2.03	1.22	0.81	0.81	0.66
C7-4E	Fort Thompson Formation	875817.3	396974.3	11.40	9.37	2.03	2.03	4.13
C7-5A	Miami Limestone	875829.5	396984.1	0.32	0.48	-0.16	0.16	0.02
C7-5D	Key Largo Limestone	875828.1	396989.3	0.38	0.48	-0.10	0.10	0.01
C7-5E	Fort Thompson Formation	875828.1	396989.3	12.61	10.85	1.77	1.77	3.12
PW-7L	Fort Thompson Formation	875819.4	396985.1					

	Observed	Calculated			
Difference	12.30	10.37	Number	14	14
Maximum	12.61	10.85	Total	9.72	13.16
Minimum	0.31	0.48	ARM	0.69	
			RMS	0.97	
			NRMS (%)	7.9	
			M_d (%)	0.00	

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Table 8.
Model Calibration PW-1 - Measured Versus Simulated Drawdowns (at End of Test)

Well	HG Unit	Easting	Northing	DRAWDOWN (ft)		Ri (Obs-Calc)	|Ri|	|Ri|^2
				Observed	Calculated			
MW-1A	Miami Limestone	880083.2	401545.1	0.78	0.74	0.04	0.04	0.00
MW-1B	Key Largo Limestone	880083.2	401545.1	0.71	0.78	-0.07	0.07	0.00
MW-1D	Fort Thompson Formation	880083.2	401545.1	0.63	0.63	0.00	0.00	0.00
MW-2B	Key Largo Limestone	880967.2	402023.5	0.19	0.17	0.02	0.02	0.00
MW-3B	Key Largo Limestone	878292.6	401339.6	0.08	0.07	0.01	0.01	0.00
MW-4B	Key Largo Limestone	878331.1	400609.9	0.09	0.06	0.03	0.03	0.00
PW-1	Key Largo Limestone	880146.6	401595.4					

	Observed	Calculated
Difference	0.70	0.72
Maximum	0.78	0.78
Minimum	0.08	0.06

	|Ri|	|Ri|^2
Number	6	6
Total	0.18	0.01
ARM	0.03	
RMS		0.04
NRMS (%)	5.3	
M_d (%)	0.00	

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Table 9.
Model Calibration PW-7U - Measured Versus Simulated Drawdowns (at End of Test)

Well	HG Unit	Easting	Northing	DRAWDOWN (ft) Observed	DRAWDOWN (ft) Calculated	Ri (Obs-Calc)	|Ri|	|Ri|²
C7-1A	Miami Limestone	875829.5	396932.8	0.88	1.03	-0.15	0.15	0.02
C7-1C	Tamiami Formation	875829.5	396932.8	0.42	0.52	-0.10	0.10	0.01
C7-1D	Key Largo Limestone	875829.6	396937.7	2.07	1.50	0.57	0.57	0.33
C7-1E	Fort Thompson Formation	875829.6	396937.7	0.50	0.62	-0.12	0.12	0.01
C7-2A	Miami Limestone	875822.2	396944.9	0.89	1.04	-0.15	0.15	0.02
C7-2C	Tamiami Formation	875822.2	396944.9	0.42	0.52	-0.10	0.10	0.01
C7-2D	Key Largo Limestone	875817.3	396944.9	1.48	1.55	-0.07	0.07	0.01
C7-2E	Fort Thompson Formation	875817.3	396944.9	0.54	0.62	-0.08	0.08	0.01
C7-3A	Miami Limestone	875822.4	396960.2	0.75	1.02	-0.27	0.27	0.07
C7-3C	Tamiami Formation	875822.4	396960.2	0.35	0.52	-0.17	0.17	0.03
C7-3D	Key Largo Limestone	875817.2	396959.9	1.27	1.30	-0.03	0.03	0.00
C7-3E	Fort Thompson Formation	875817.2	396959.9	0.42	0.61	-0.19	0.19	0.04
C7-4A	Miami Limestone	875822.3	396975.2	0.82	1.00	-0.18	0.18	0.03
C7-4C	Tamiami Formation	875822.3	396975.2	0.44	0.52	-0.08	0.08	0.01
C7-4D	Key Largo Limestone	875817.3	396974.3	1.13	1.18	-0.06	0.06	0.00
C7-4E	Fort Thompson Formation	875817.3	396974.3	0.52	0.61	-0.09	0.09	0.01
PW-7U	Key Largo Limestone	875819.3	396935.3					

		Observed	Calculated		|Ri|	|Ri|²
Difference		1.72	1.03	Number	16	16
Maximum		2.07	1.55	Total	2.41	0.60
Minimum		0.35	0.52	ARM	0.15	
				RMS		0.19
				NRMS (%)		11.3
				M_d (%)		0.00

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Table 10.
Model Validation PW-6U - Measured Versus Simulated Drawdowns (at End of Test)

Well	HG Unit	Easting	Northing	DRAWDOWN (ft) Observed	Calculated	Ri (Obs-Calc)	|Ri|	|Ri|^2
C6-1A	Miami Limestone	876678.1	396935.4	1.46	1.37	0.08	0.08	0.01
C6-1C	Tamiami Formation	876678.1	396935.4	0.53	0.53	0.01	0.01	0.00
C6-1D	Key Largo Limestone	876677.9	396940.4	1.66	1.86	-0.20	0.20	0.04
C6-1E	Fort Thompson Formation	876677.9	396940.4	0.57	0.58	-0.01	0.01	0.00
C6-2A	Miami Limestone	876670.8	396947.3	1.34	1.39	-0.05	0.05	0.00
C6-2C	Tamiami Formation	876670.8	396947.3	0.53	0.53	0.00	0.00	0.00
C6-2D	Key Largo Limestone	876665.5	396947.4	2.08	1.95	0.13	0.13	0.02
C6-2E	Fort Thompson Formation	876665.5	396947.4	0.58	0.58	0.00	0.00	0.00
C6-3A	Miami Limestone	876670.5	396962.6	1.09	1.36	-0.27	0.27	0.07
C6-3C	Tamiami Formation	876670.5	396962.6	0.51	0.53	-0.01	0.01	0.00
C6-3D	Key Largo Limestone	876665.7	396962.5	1.30	1.60	-0.30	0.30	0.09
C6-3E	Fort Thompson Formation	876665.7	396962.5	0.50	0.58	-0.07	0.07	0.01
C6-4A	Miami Limestone	876670.9	396978.1	0.98	1.30	-0.32	0.32	0.10
C6-4C	Tamiami Formation	876670.9	396978.1	0.56	0.52	0.04	0.04	0.00
C6-4D	Key Largo Limestone	876666.0	396977.9	1.01	1.43	-0.42	0.42	0.17
C6-4E	Fort Thompson Formation	876666.0	396977.9	0.52	0.57	-0.05	0.05	0.00
PW-6U	Key Largo Limestone	876668.7	396938.0					

	Observed	Calculated				
Difference	1.58	1.43	Number	16	16	
Maximum	2.08	1.95	Total	1.96	0.51	
Minimum	0.50	0.52	ARM	0.12		
			RMS	0.18		
			NRMS (%)	11.4		
			M_d (%)	0.00		

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Table 11.
Radial Collector Wells – Origin of Water (including Sensitivity Analysis)

Zone	RCW in Upper Higher Flow Zone (Base Case)	RCW in Key Largo Limestone	Seasonal High Water Level	Seasonal Low Water Level	Double Vertical Hyd. Cond.	Half Vertical Hyd. Cond.	Key Largo All High K (Blue)	Key Largo All Low K (Red)
			Percent Contribution to Radial Collector Wells					
Biscayne Bay	97.8%	97.8%	98.1%	97.6%	99.1%	95.4%	97.6%	98.5%
Flow from inland	2.2%	2.2%	1.9%	2.4%	0.9%	4.6%	2.4%	1.5%
- Via Cooling Canal System	2.0%	2.0%	1.8%	2.1%	0.8%	3.2%	2.1%	1.4%
- Regional Eastward Flow (Precipitation Recharge)	0.2%	0.2%	0.1%	0.3%	0.1%	1.4%	0.3%	0.2%

Note: The top two rows contribute to the total flow and sum to 100%.
The bottom two rows are components of inland flow. Not all component flows sum to the total inland flow due to rounding
(Blue) and (Red) in final two columns refer to the colors shown for the Key Largo hydraulic conductivity distribution shown in Figure 27.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Table 12.
Radial Collector Wells – Approach Velocity (including Sensitivity Analysis)

Zone	Approach Velocity (cm/s)							
	RCW in Upper Higher Flow Zone (Base Case)	RCW in Key Largo Limestone	Seasonal High Water Level	Seasonal Low Water Level	Double Vertical Hyd. Cond.	Half Vertical Hyd. Cond.	Key Largo All High K (Blue)	Key Largo All Low K (Red)
Entire RCW Catchment	3.3E-05	3.3E-05	3.2E-05	3.3E-05	3.7E-05	2.9E-05	3.2E-05	3.5E-05
Immediate RCW Area	5.2E-04	5.2E-04	5.2E-04	5.2E-04	7.3E-04	3.5E-04	5.2E-04	6.3E-04
Average of all RCW Laterals	6.2E-04	6.2E-04	6.2E-04	6.2E-04	9.2E-04	4.0E-04	6.1E-04	7.7E-04

Note: (Blue) and (Red) in final two columns refer to the colors shown for the Key Largo hydraulic conductivity distribution shown in Figure 27

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 1. Location of Turkey Point Units 6 & 7 and Major Hydrological Features

Source: Reference 42.

Figure 2. Industrial Wastewater Facility, the L-31E Canal, and the Card Sound Canal

Source: Reference 42.

Figure 3. Regional Generalized Hydrostratigraphic Column

Source: Reference 42 (modified from Reference 43)

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations
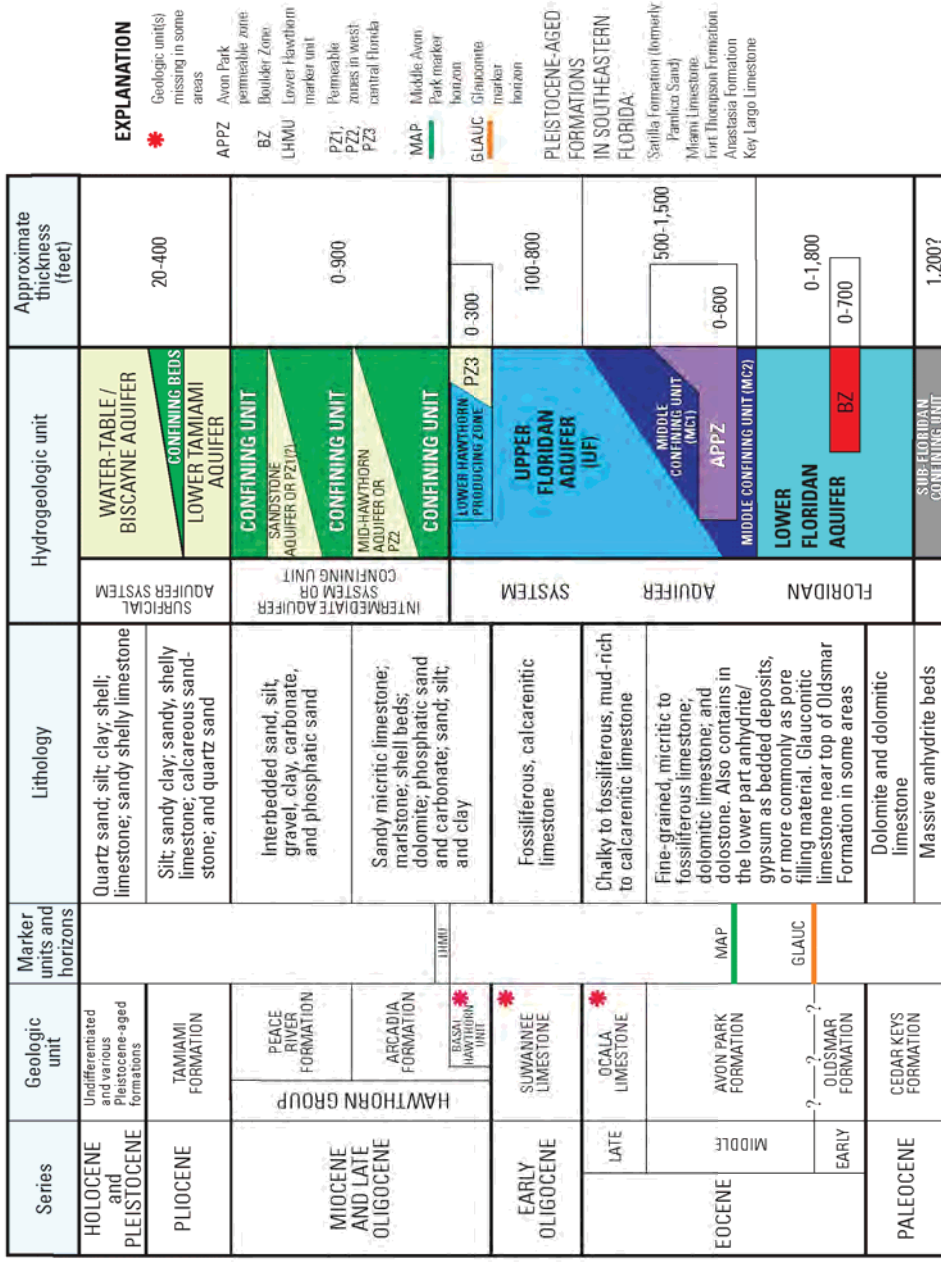
Figure 4. Site Hydrostratigraphic Column

ERATHEM	SYSTEM	SERIES	HYDRO-GEOLOGIC UNIT		STRATIGRAPHIC UNIT	LITHOLOGY	APPROXIMATE TOP ELEVATION (ft NAVD 88)	APPROXIMATE THICKNESS (ft)
CENEZOIC	QUATERNARY	HOLOCENE	Surficial aquifer system		organic muck	organic soil and silt	0	3
		PLEISTOCENE		Biscayne aquifer	Miami Limestone	sandy, oolitic limestone	-3	25
					Key Largo Limestone	well indurated, vuggy, coralline limestone	-28	22
		PLIOCENE			Fort Thompson Formation	poor/well indurated fossiliferous limestone	-50	65
	TERTIARY		Semi-confining unit		Tamiami Formation	sand and silt with calcarenitic limestone	-115	105
		MIOCENE	Intermediate confining unit	Hawthorn Group	Peace River Formation	silty calcareous sand and silt	-220	235
					Arcadia Formation	calcareous wackestone with indurated limestones, sandstone, and sand	-455	>160

formation contact based on natural gamma signature

drilling ended at -616.5 ft

Color represents similar composition (carbonate, clastics, and organics).
Source: Reference 42.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 5. Cross Section Location

Source: Adapted from Reference 2
Note: Best available scan from original document

Figure 6. Hydrostratigraphic Cross Section A-A'
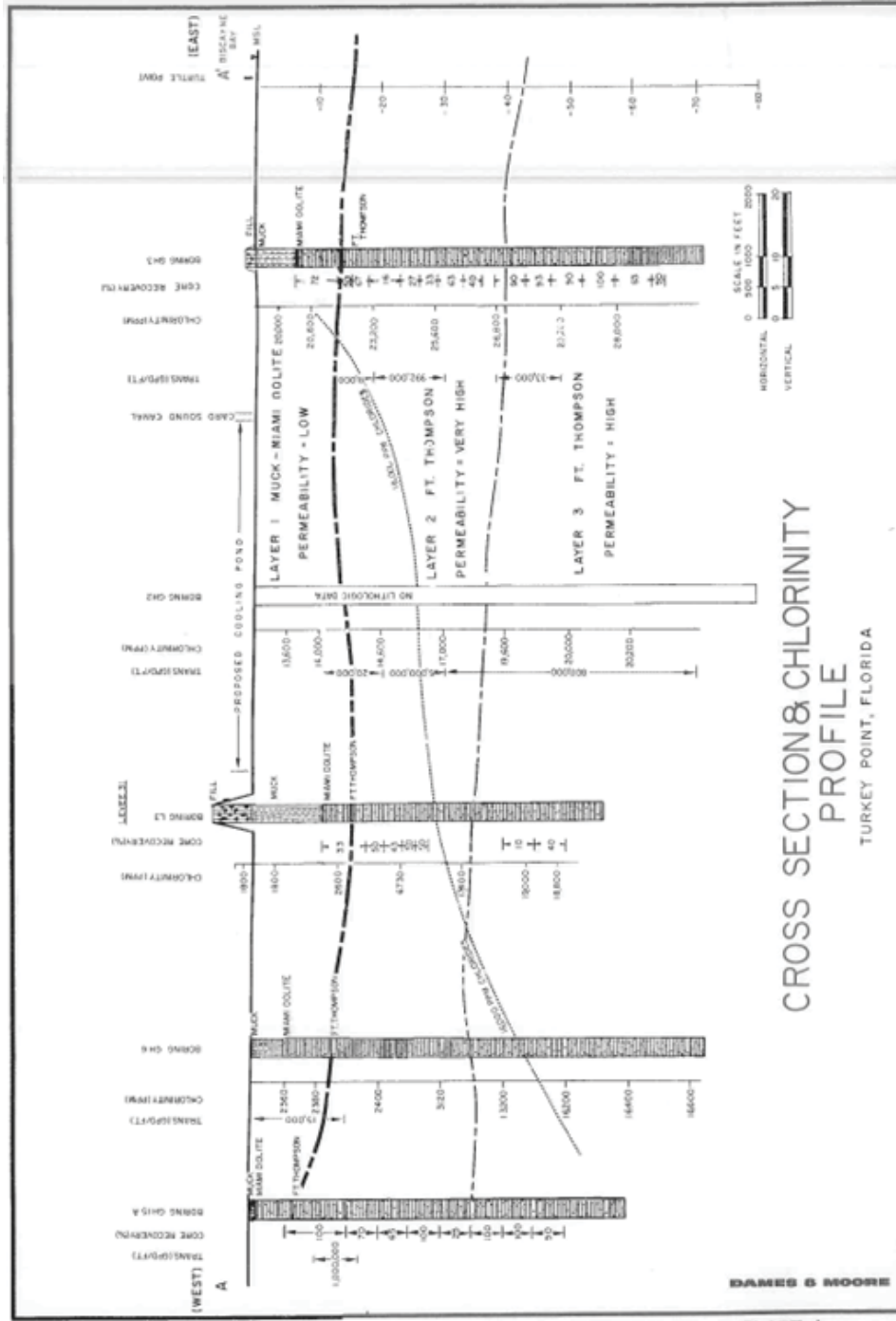
Source: Reference 2
Note: Best available scan from original document

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 7. West–East Cross Section in the Vicinity of the Southern End of the Turkey Point Plant Property

Source: Reference 6
Note: Best available scan from original document

**Figure 8. Feasibility Geological Investigation of Potential Plant Site (2006) -
Boring and Stratigraphic Cross Section Locations**

Source: Reference 7

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 9. Feasibility Geological Investigation of Potential Plant Site (2006) - Stratigraphic Cross Section A-A'
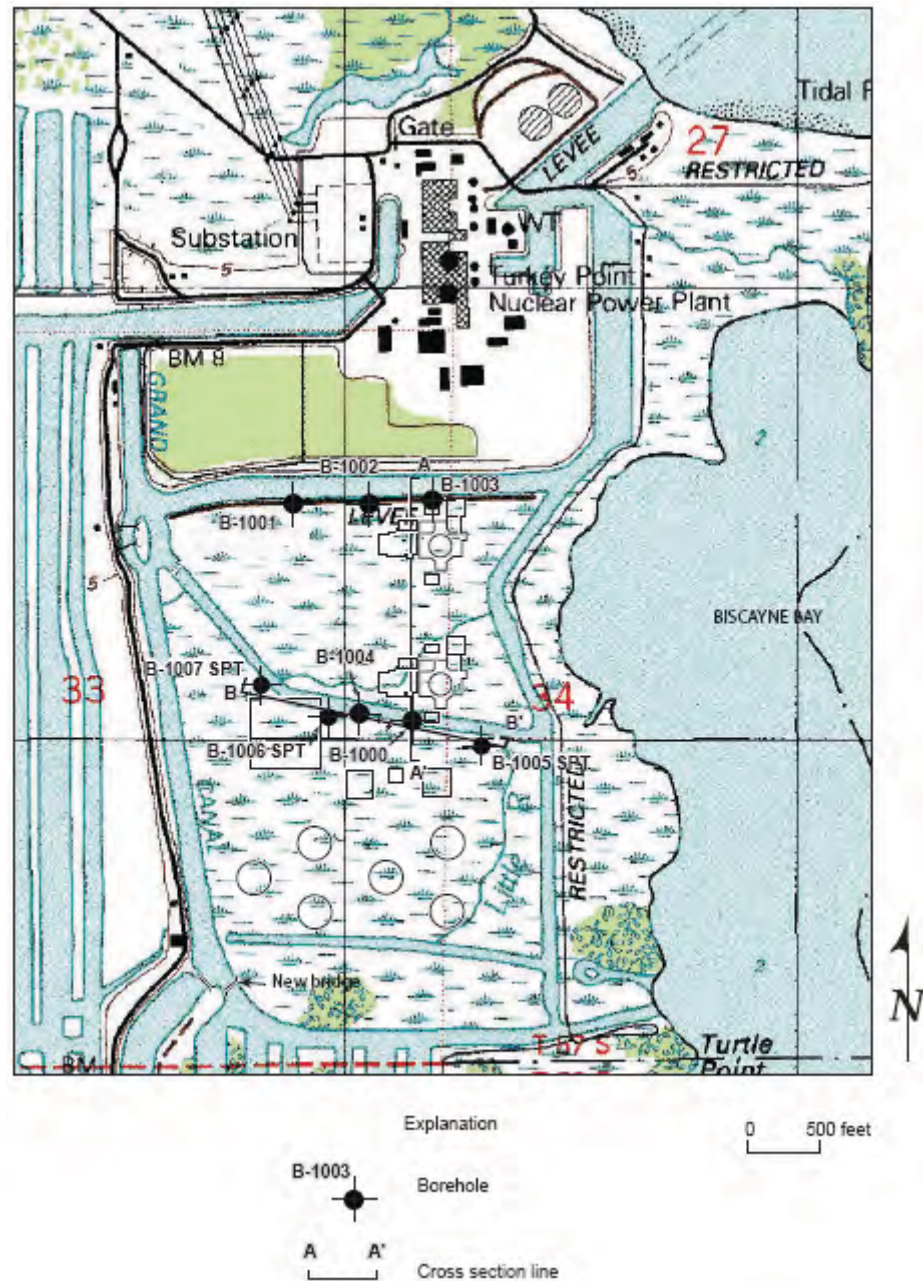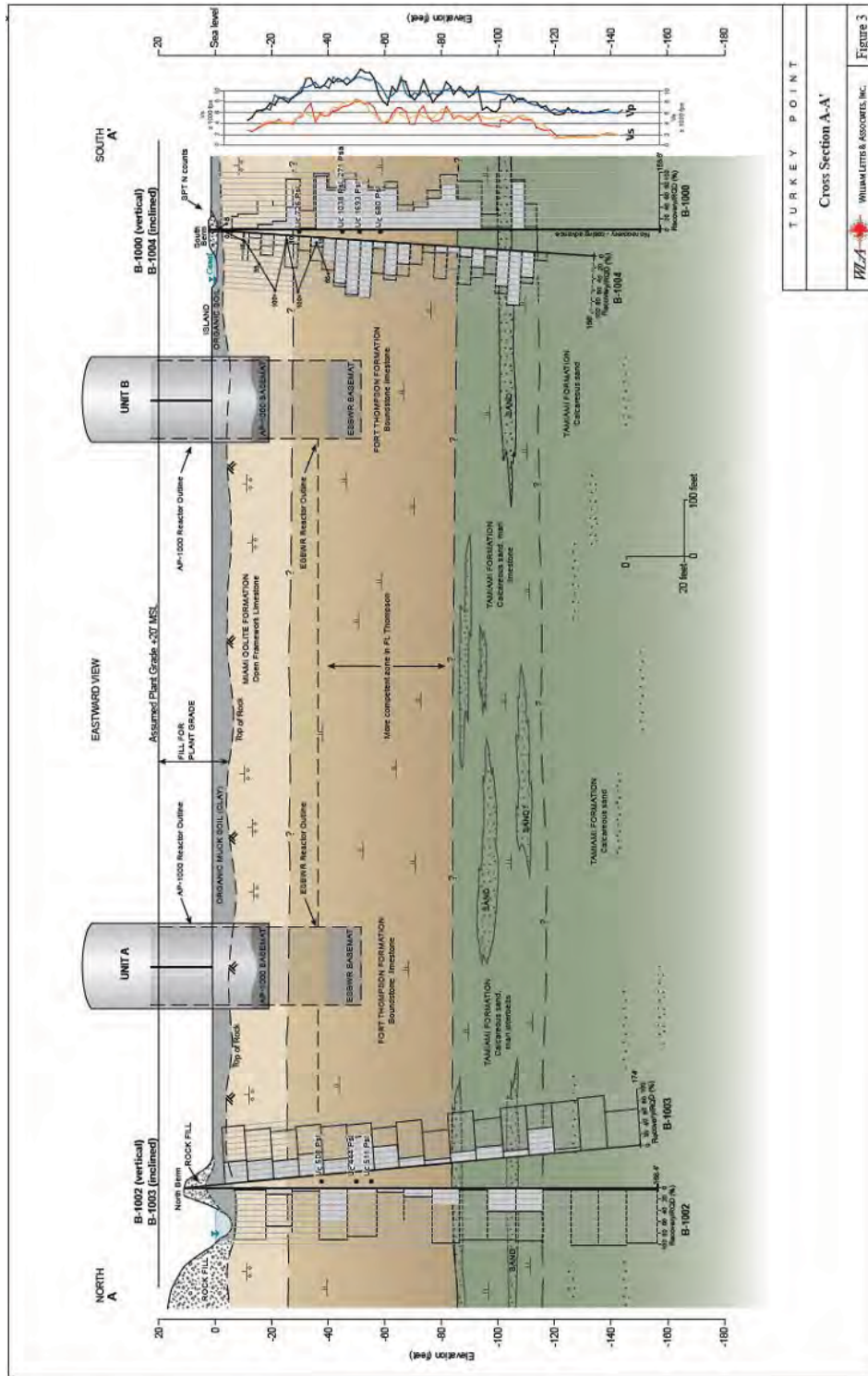
Source: Reference 7

Figure 10. Feasibility Geological Investigation of Potential Plant Site (2006) - Stratigraphic Cross Section B-B'

Source: Reference 7

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 11. Stratigraphic Cross Section from Wells Drilled for Turkey Point Peninsula Aquifer Performance Test
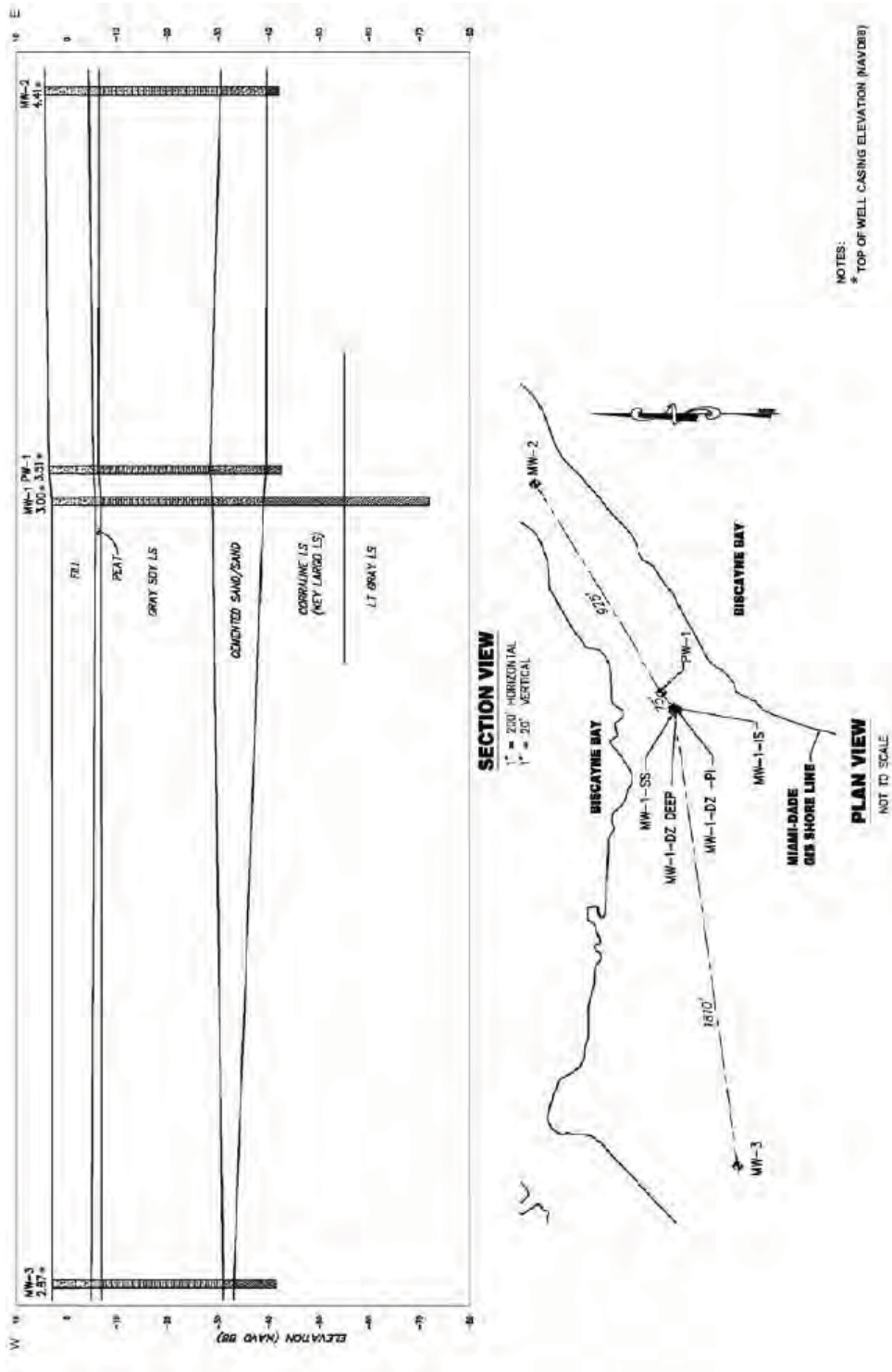
Source: Reference 4

Figure 12. Turkey Point Units 6 & 7 Site Investigation Observation Well Location Plan
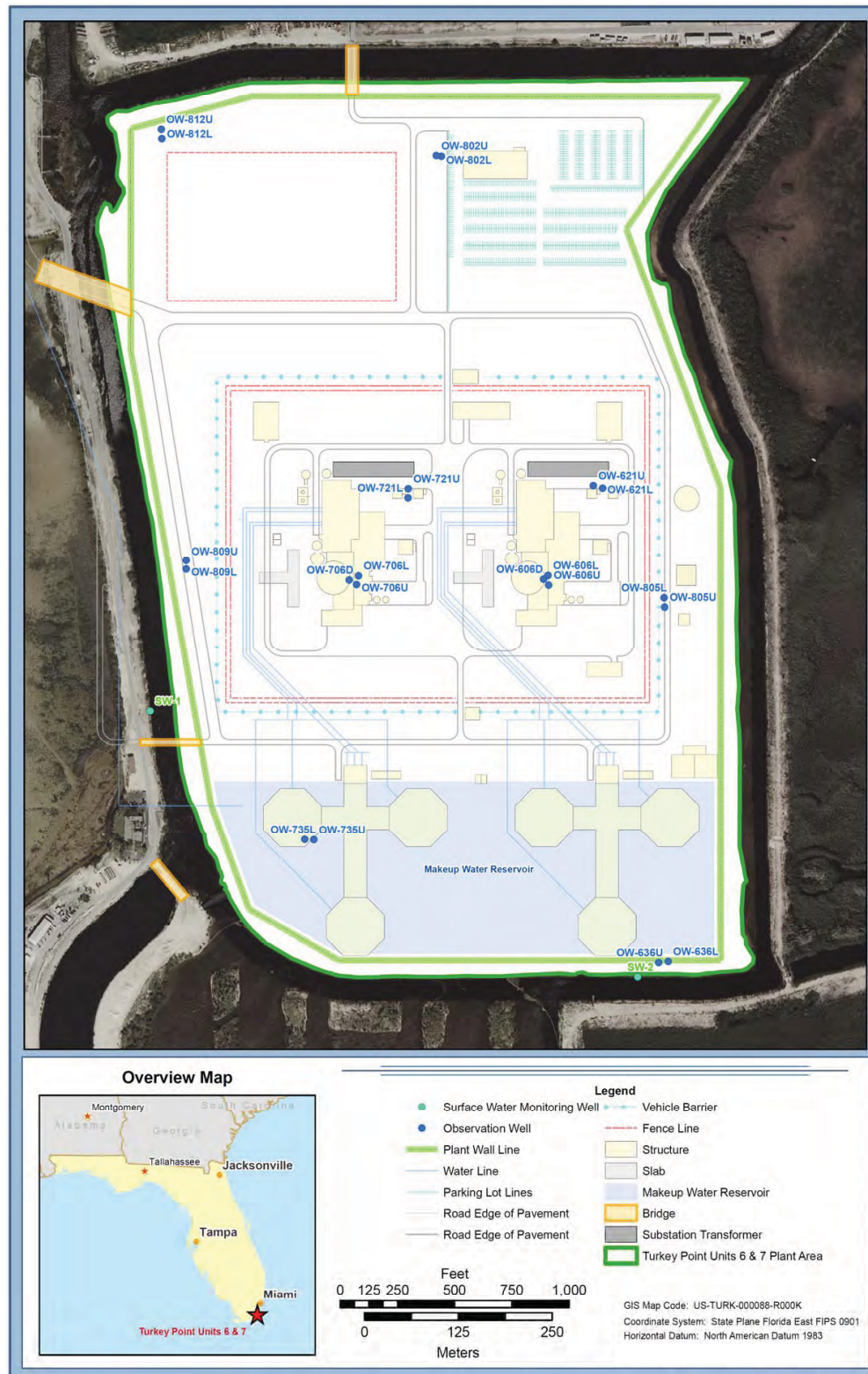
Source: Reference 42.

Figure 13. May 1993 Biscayne Aquifer Potentiometric Surface Map
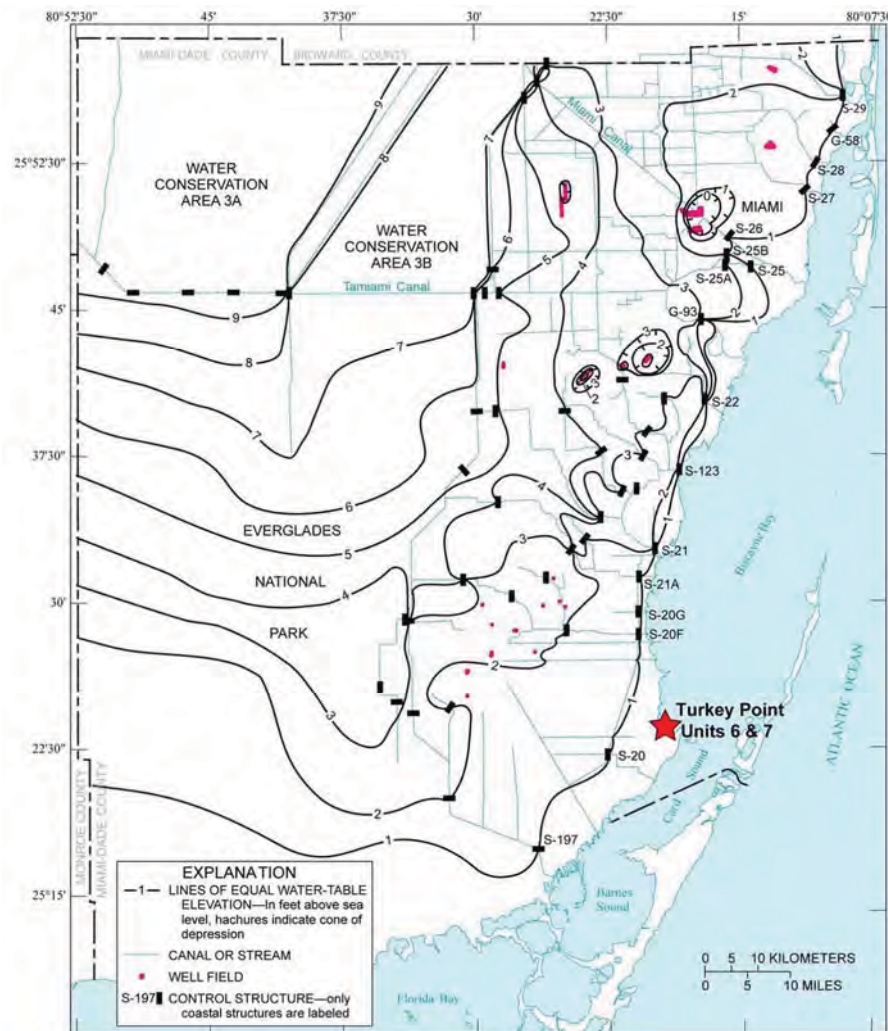
Source: Reference 42 (modified from Reference 12)

**Figure 14. November 1993 Biscayne Aquifer Potentiometric
Surface Map**

Source: Reference 42 (modified from Reference 12)
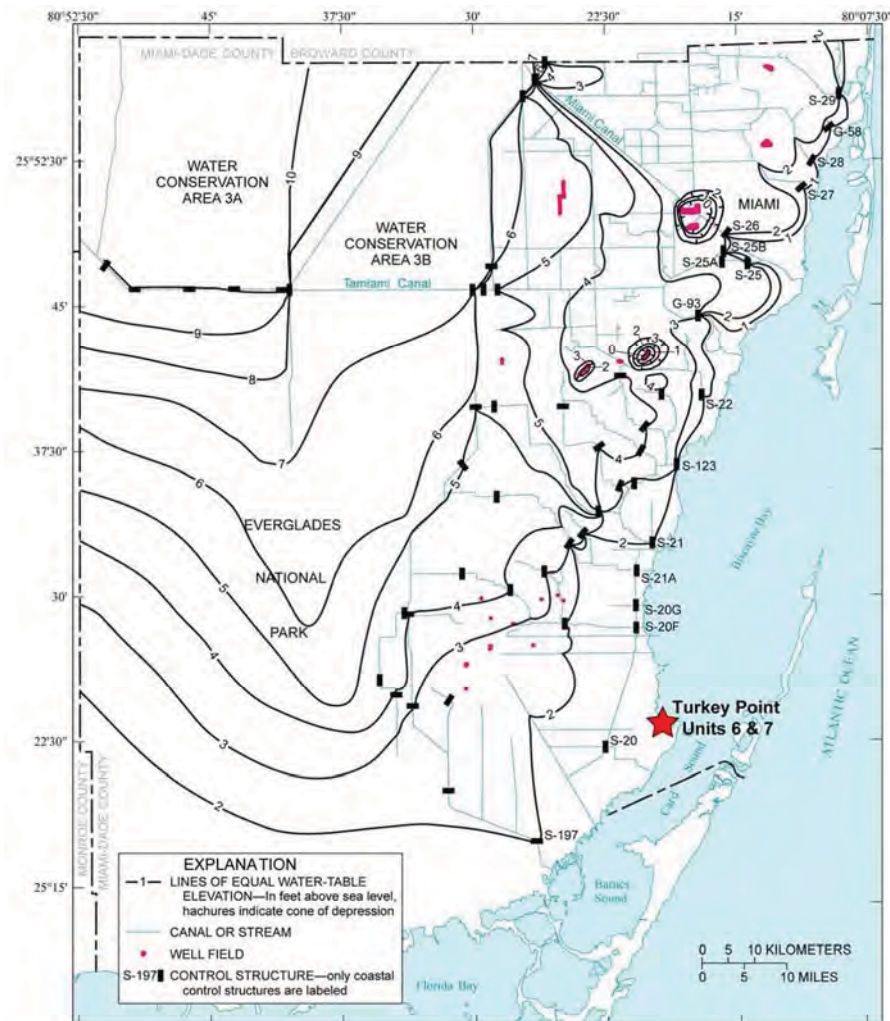
Figure 15. Land Use for Southern Florida
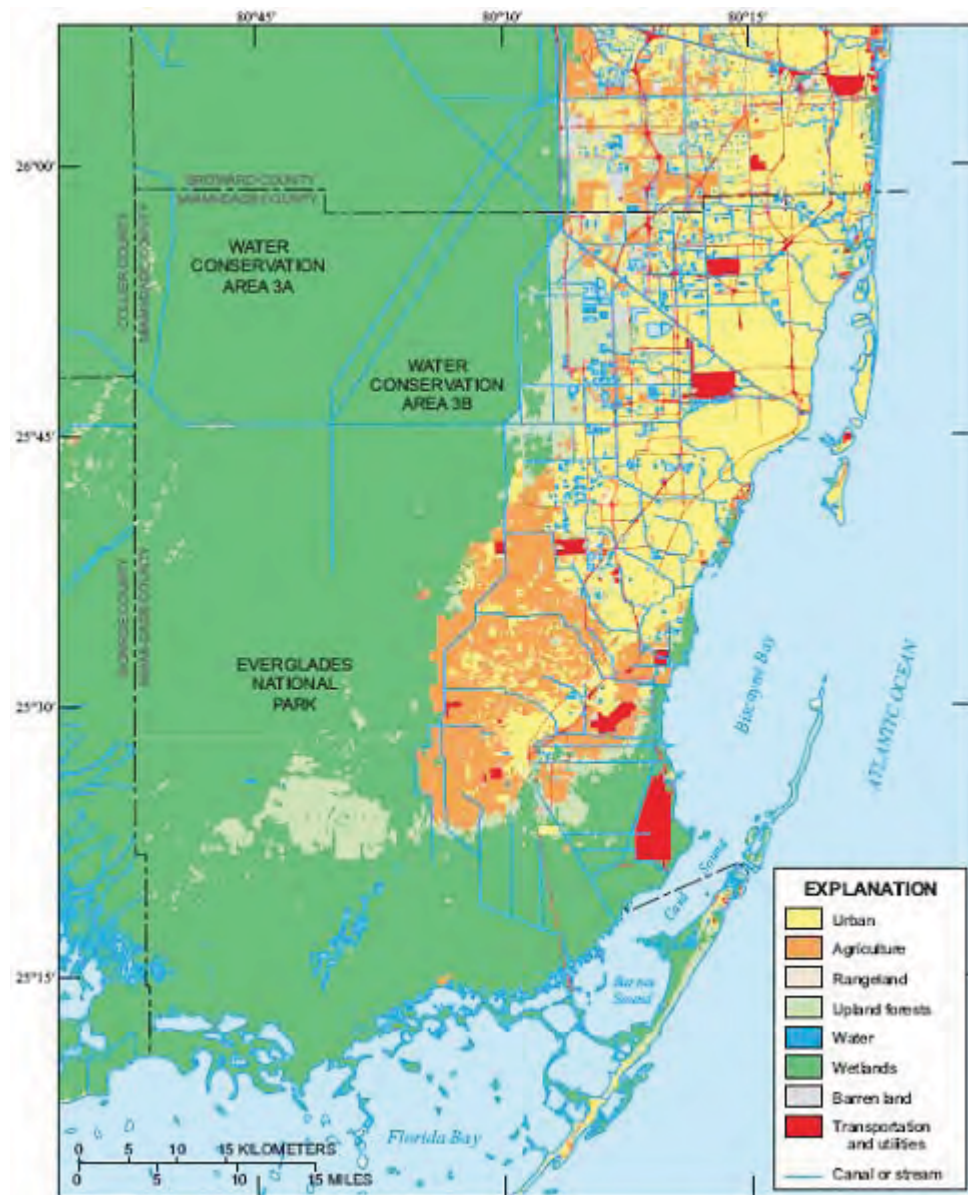
Source: Reference 12

Figure 16. Upper Floridan Aquifer Production Wells for Unit 5

Source: Reference 42

Figure 17. Numerical Model Domain
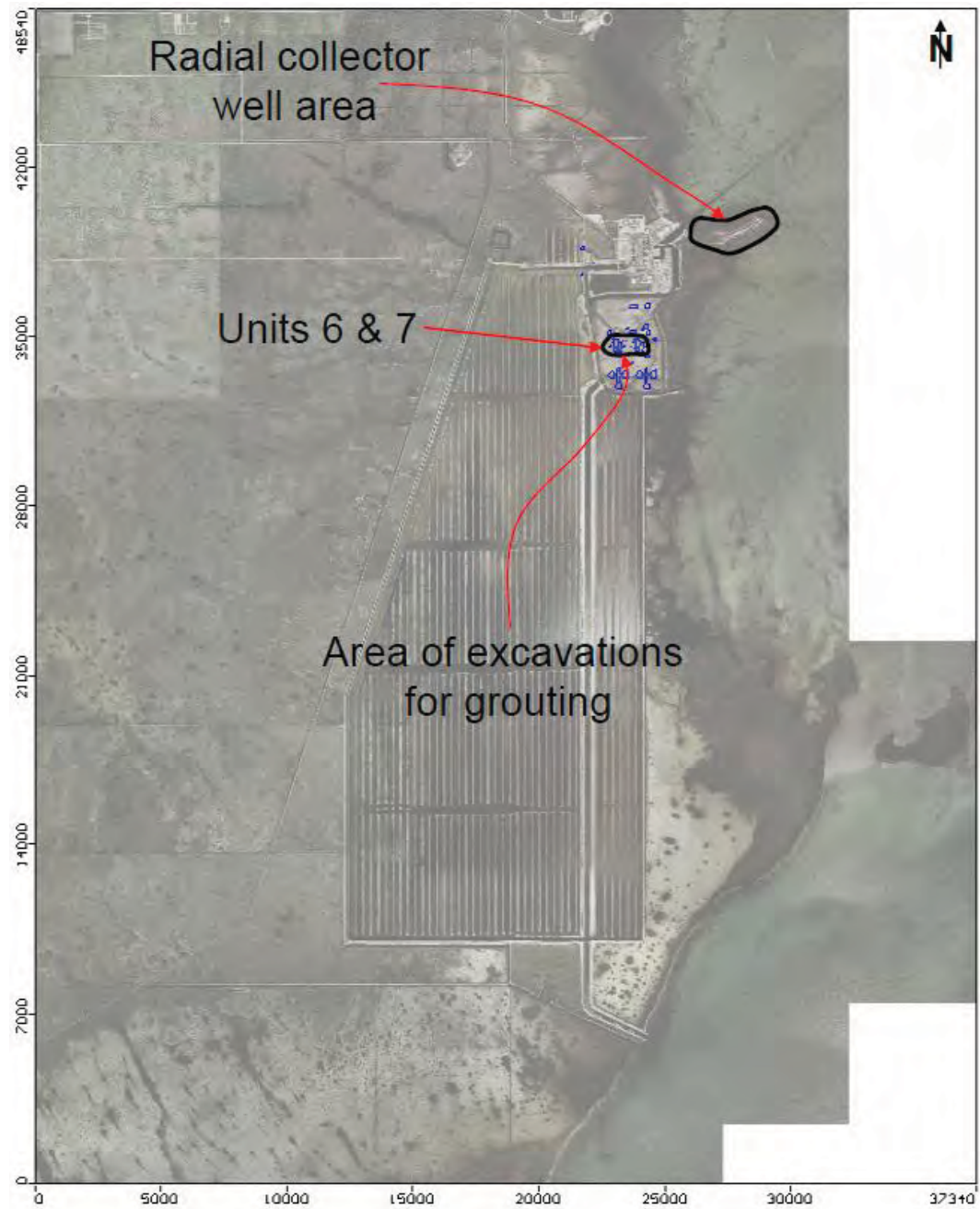
Note: Model domain identified by extents of axes, not extents of image. White portions on right side are where aerial imagery is not available.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 18. Model Grid and Site Features for the Units 6 & 7 Power Block
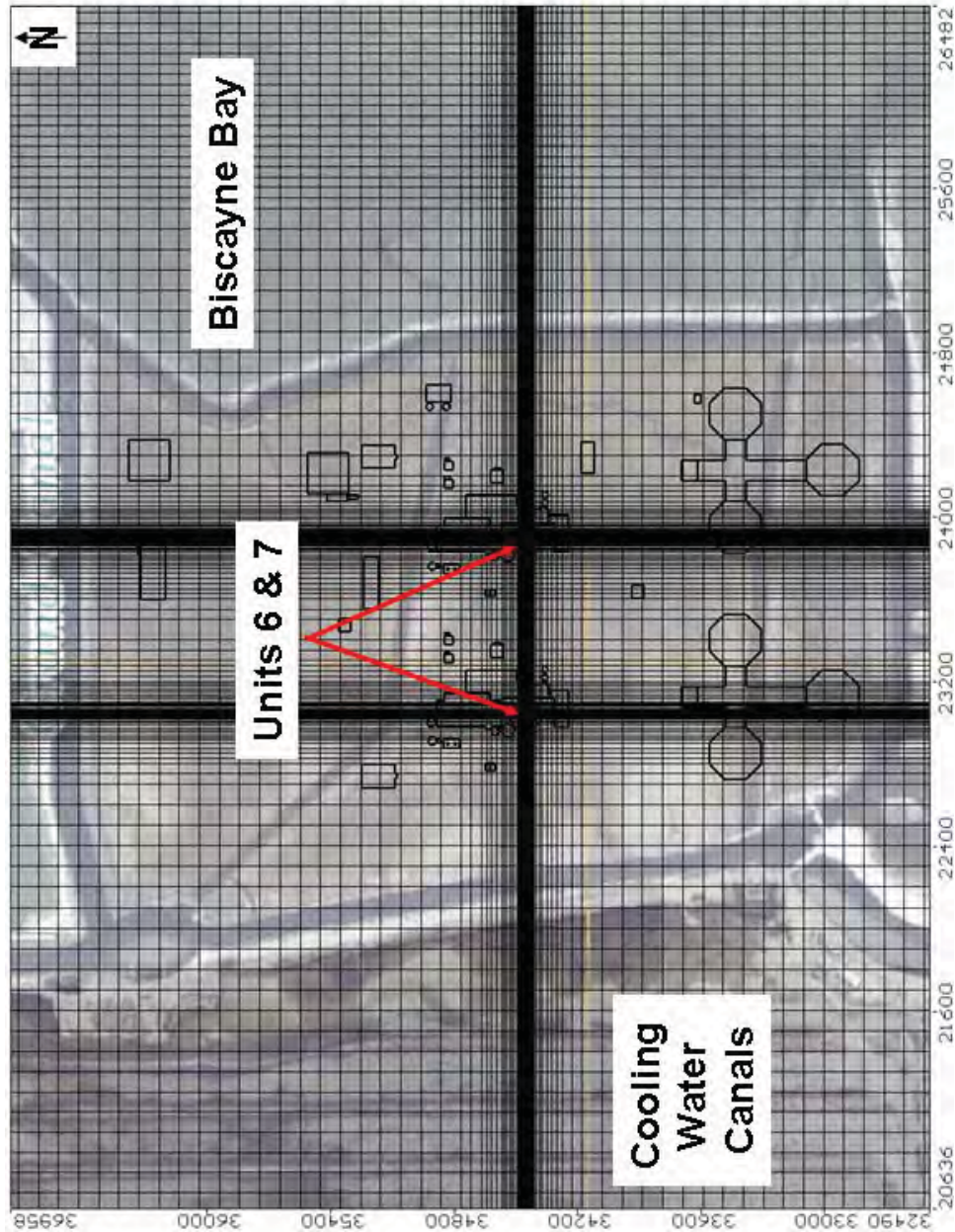
Figure 19. East-West Model Cross Section towards Southern End of the Turkey Point Cooling Canals
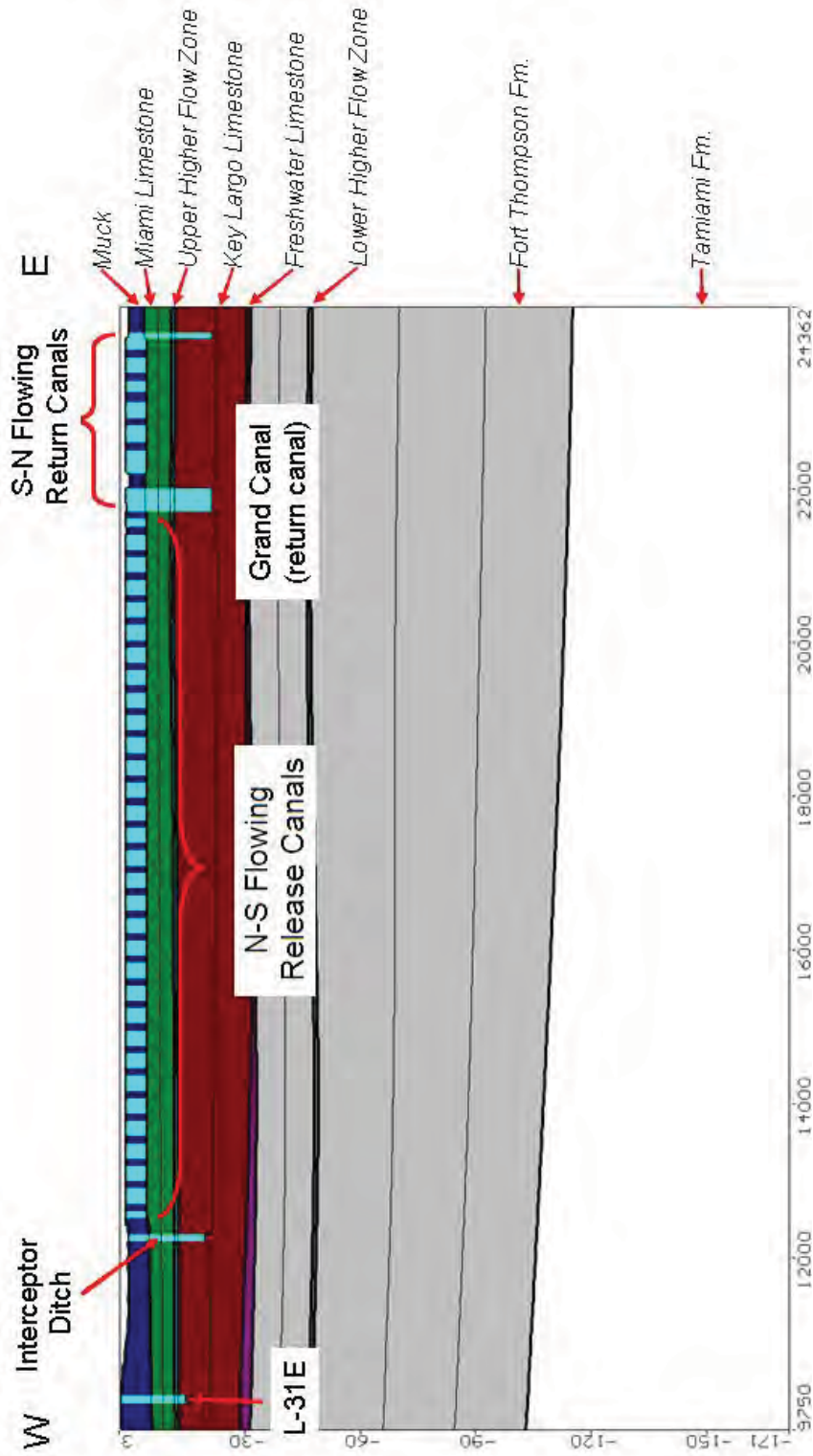
Note: Section along Row 420, vertical exaggeration 50:1

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 20. South-North Model Cross Section along Return Canal of Turkey Point Cooling Canals
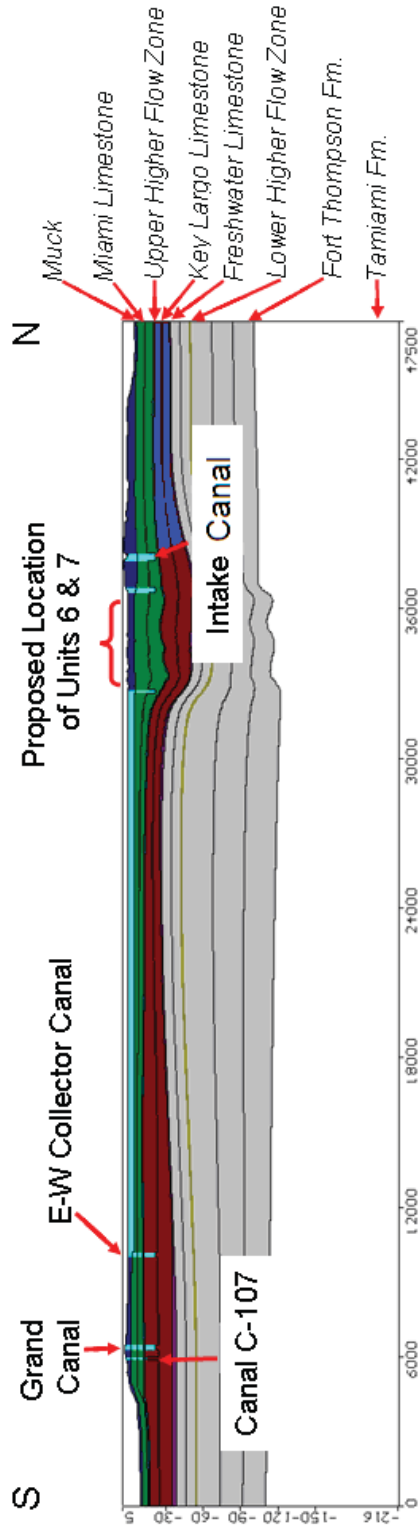
Note: Section along Column 280, vertical exaggeration 50:1.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 21. Cooling Canals Water Balance
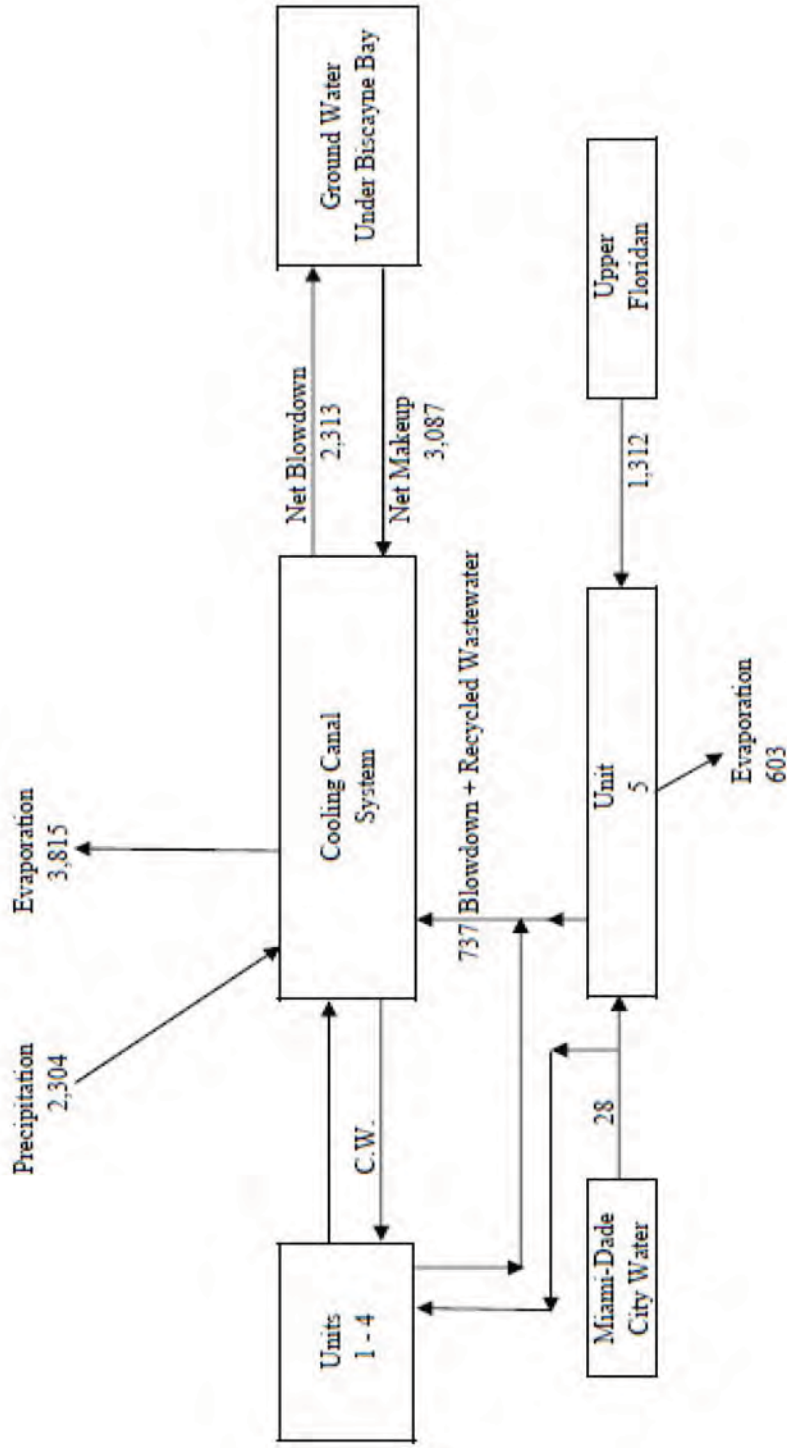
Note: Units in acre-ft/month
Source: Reference 32

Figure 22. Extent of Freshwater Limestone and Key Largo Limestone in Model Layer 7

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations
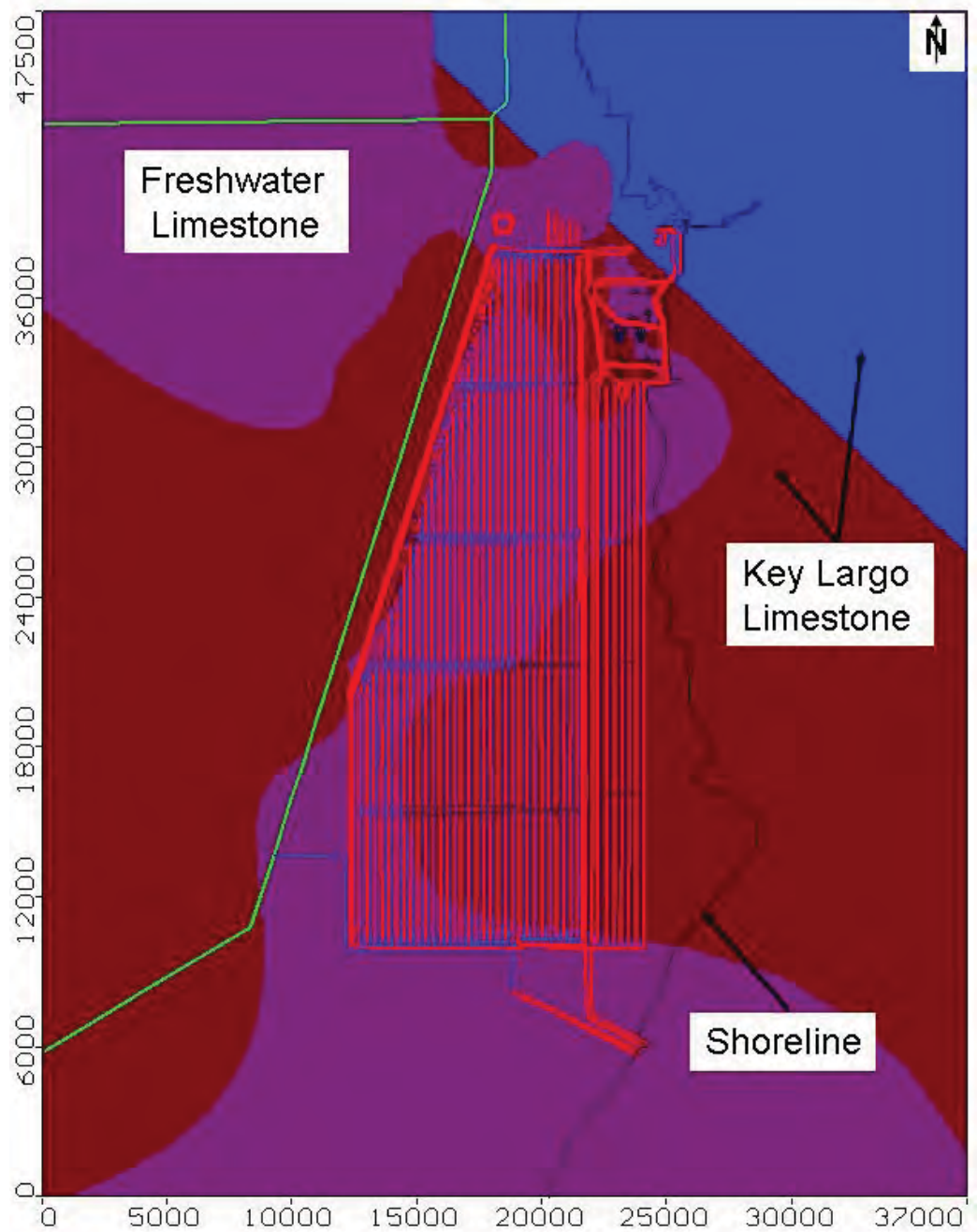
Figure 23. Material Distribution in Biscayne Bay
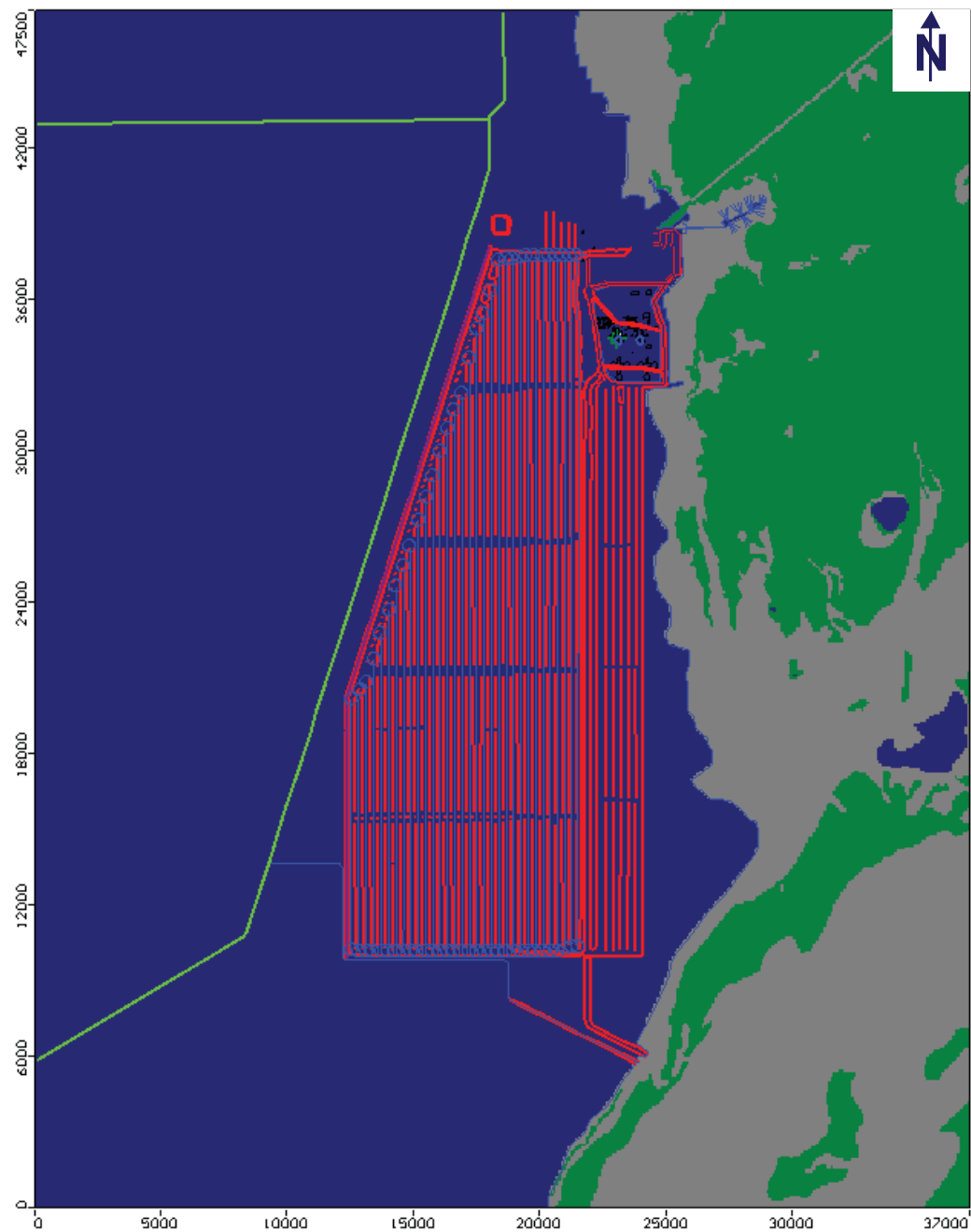
Note: Blue = Muck. Green = Miami Limestone. Grey = Offshore Sediment.

Figure 24. Hydraulic Conductivity Anisotropy Values in the Different Formations
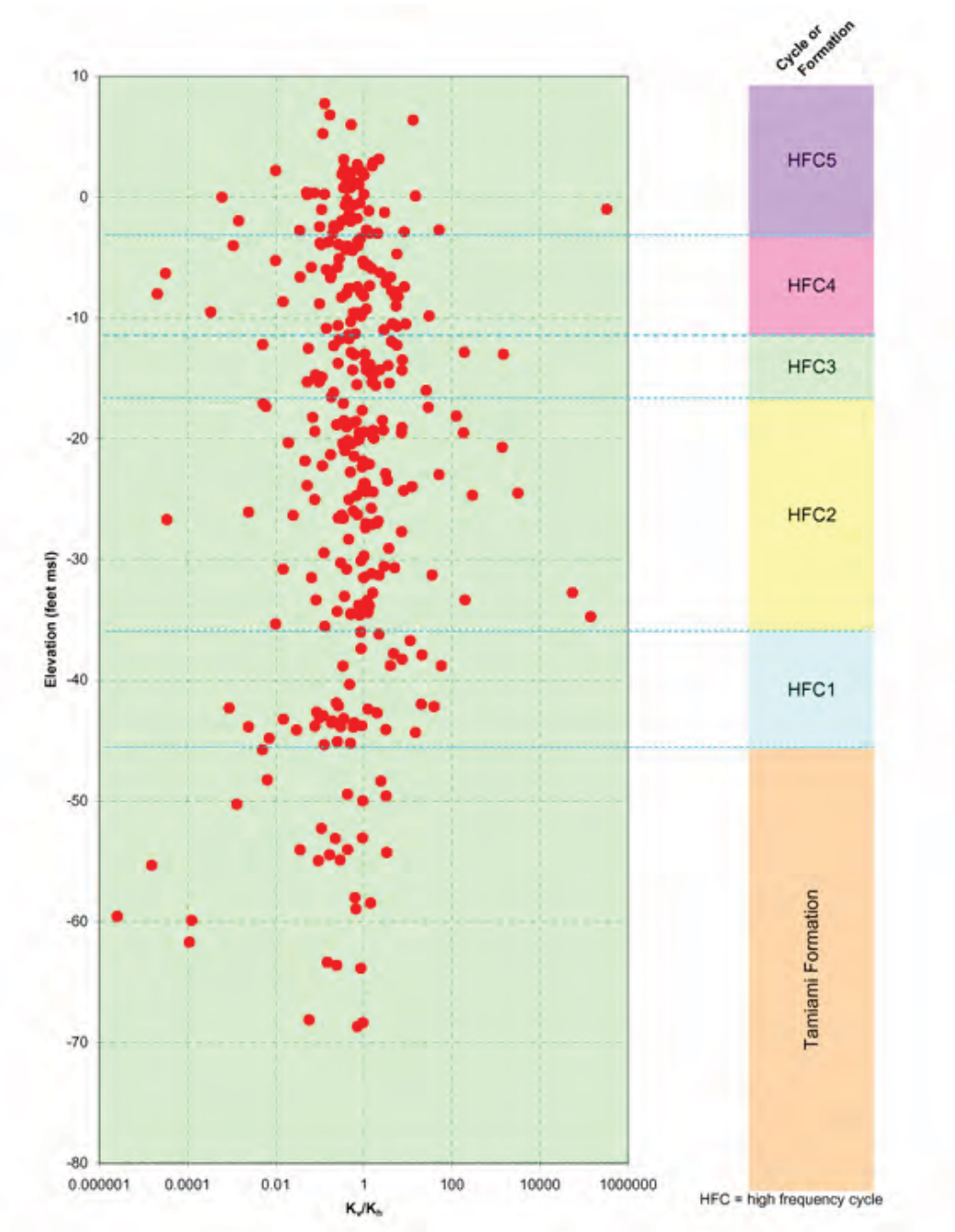
Source: Reference 42 (data from Reference 23 & 24).

Figure 25. Plan and Cross-Section of Units 6 & 7 Excavations
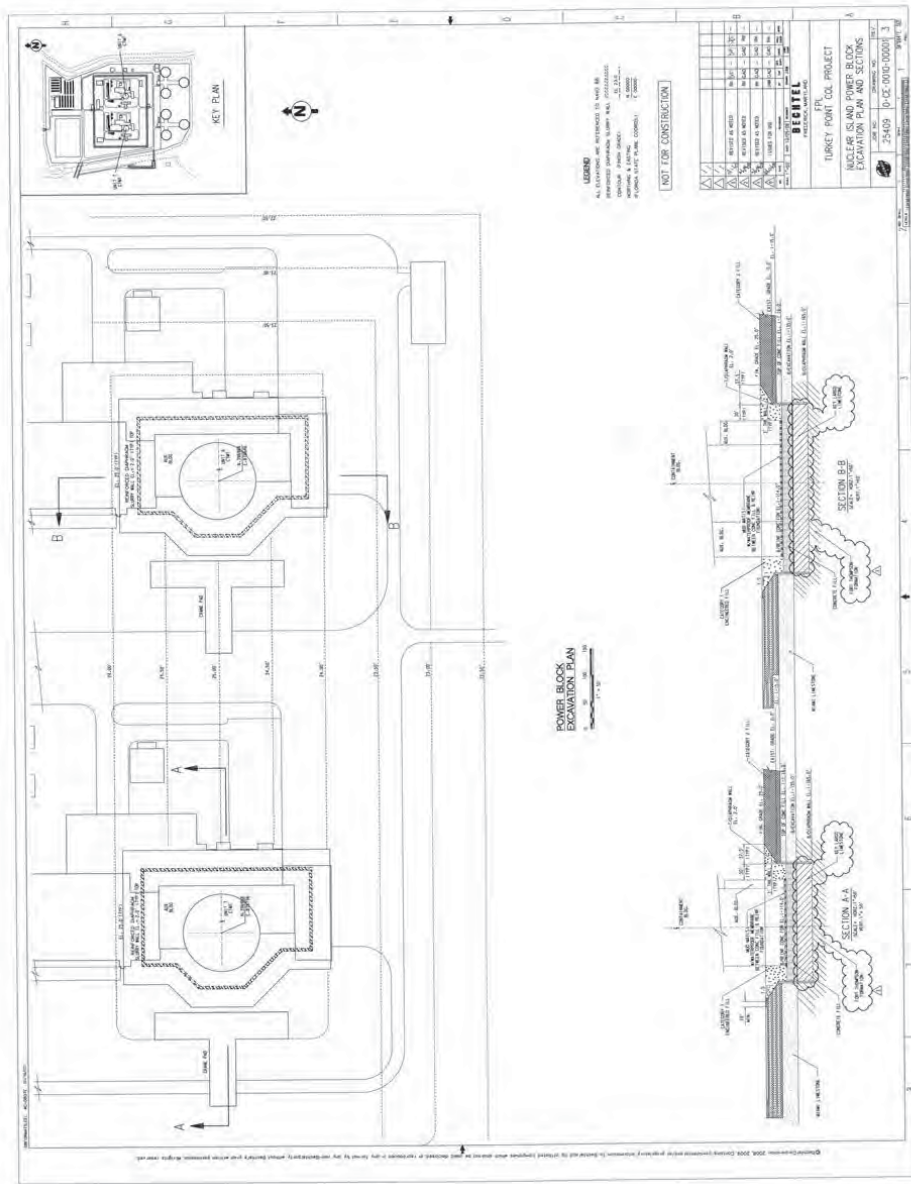
Figure 26. Planned Area of Radial Collector Well Caissons Relative to Plant Site Area

Source: Reference 42.

**Figure 27. Model Calibration – Delineation of Hydraulic Conductivity Zones
in the Key Largo Limestone**

Legend: Dark Red = Key Largo Limestone Southwest. Blue = Key Largo Limestone Northeast.
Green Lines = SFWMD Canals.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 28. Model Calibration – Layout of Pumping Well and Observation Well Clusters for Pumping Tests PW-7L and PW-7U

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations
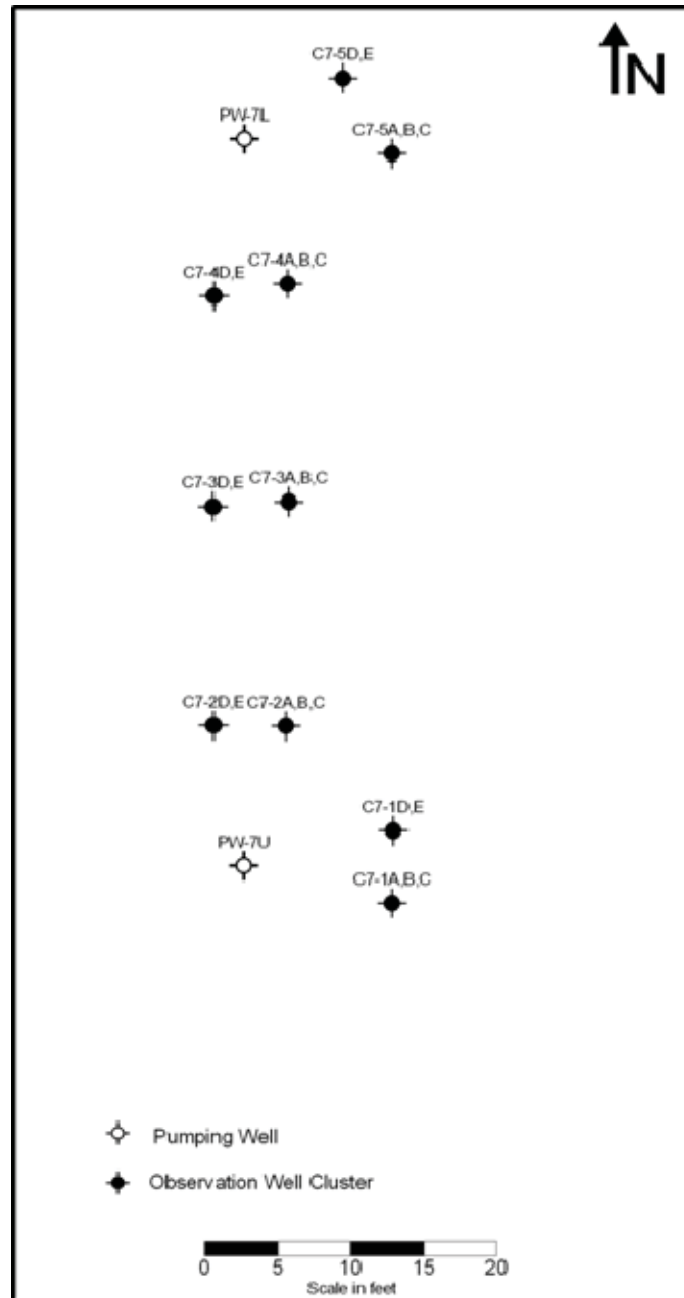
Figure 29. Grid Refinement in Vicinity of Unit 7 Reactor Footprint
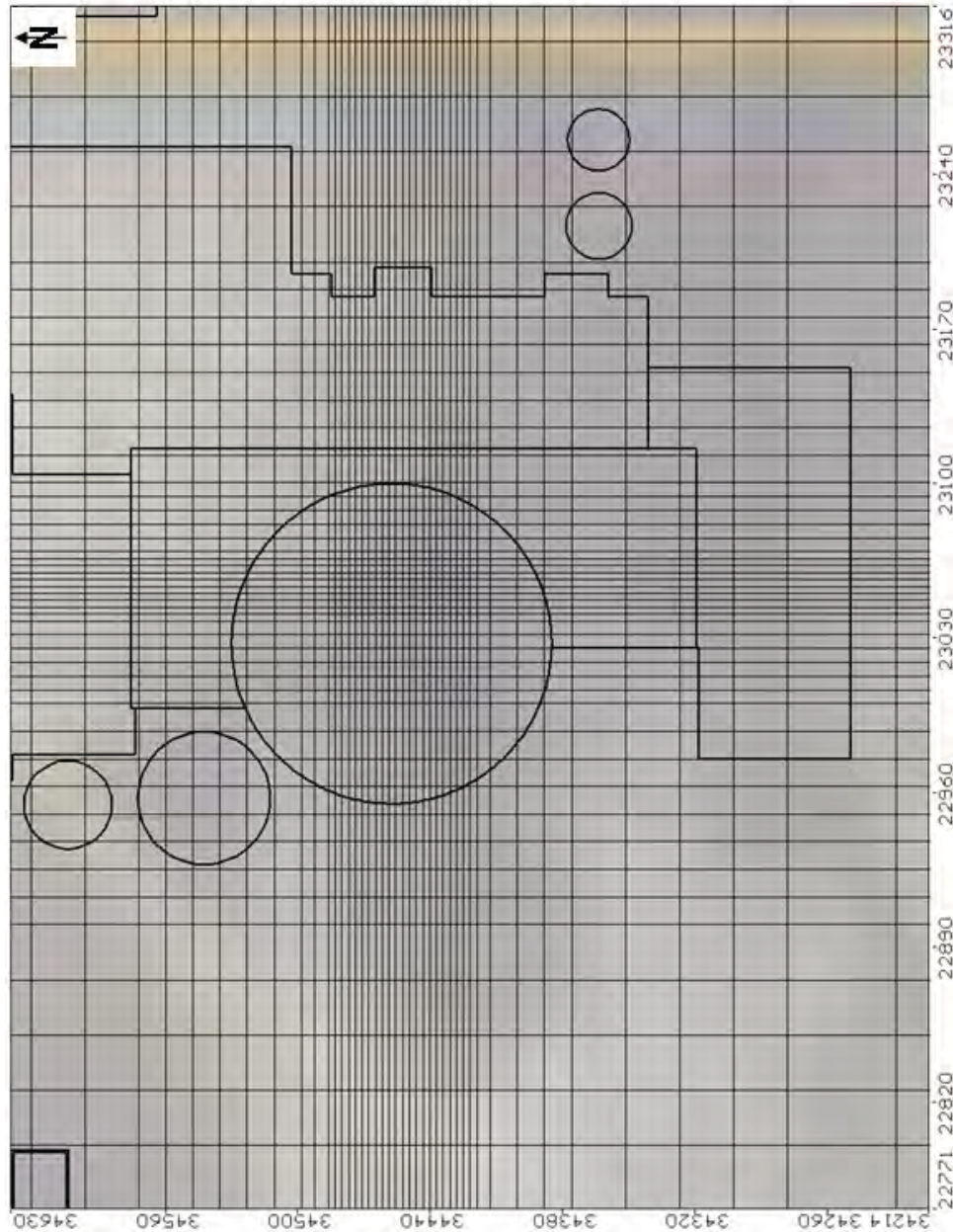
Note: Black lines represent Unit 7 reactor building and associated structures.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 30. Test Well PW-7L and Related Observation Wells
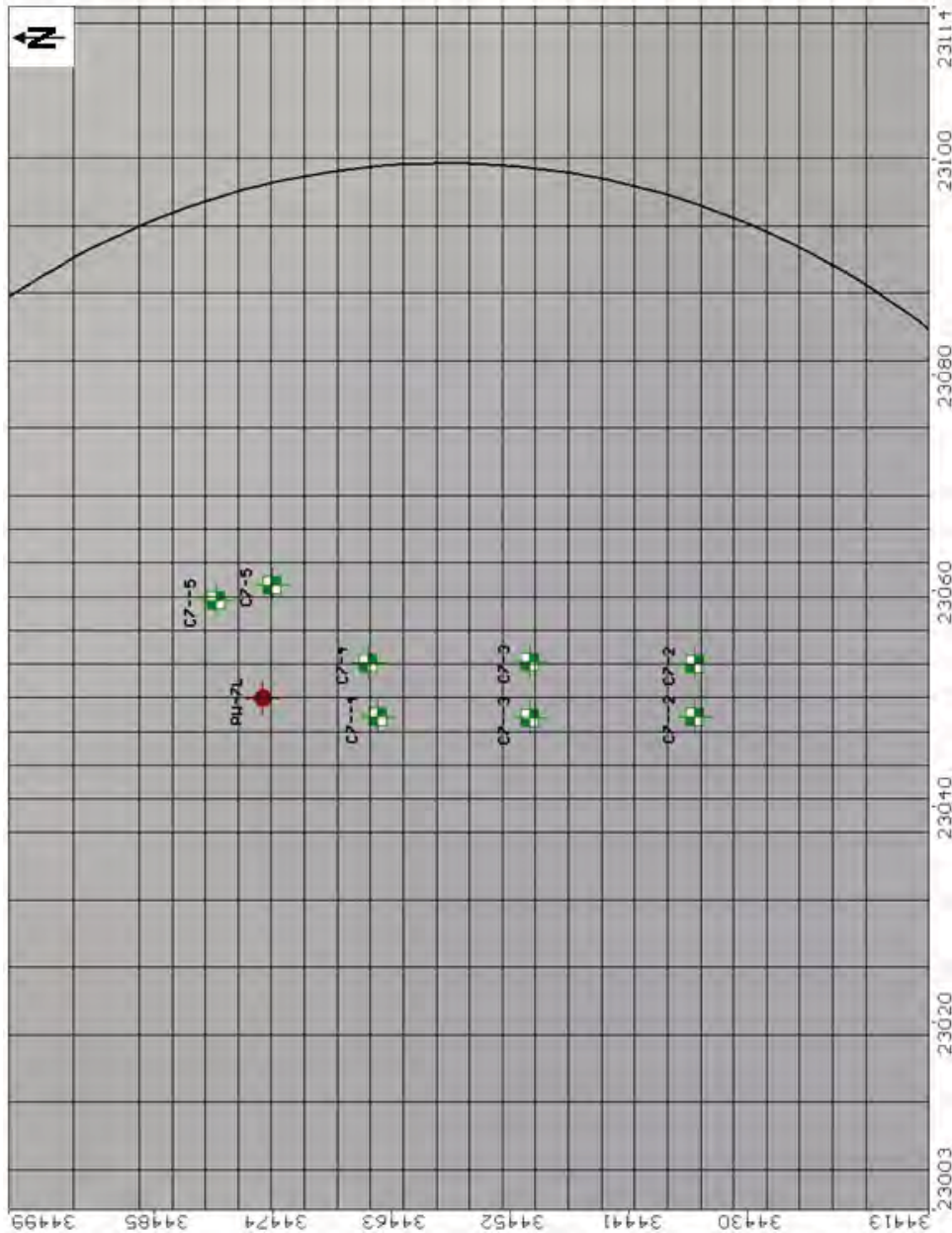
Note: Red symbol = pumping well. Green symbol = observation well. Black line represents eastern edge of Unit 7 reactor building.

Figure 31. Test Well PW-7L: Observed Versus Calculated Drawdowns

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations
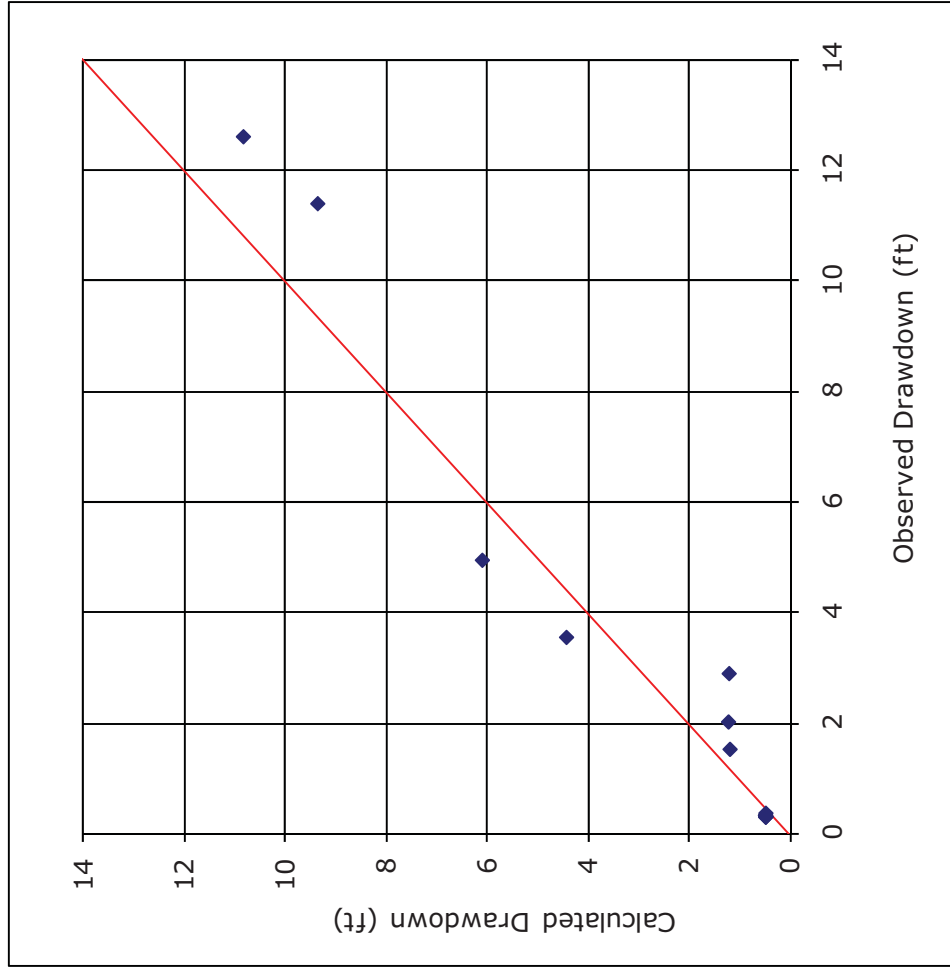
Figure 32. Model Calibration – Pumping and Monitoring Wells Layout for Pumping Test PW-1

Figure 33. Model Calibration – Finite Difference Grid and Well Layout for Test PW-1
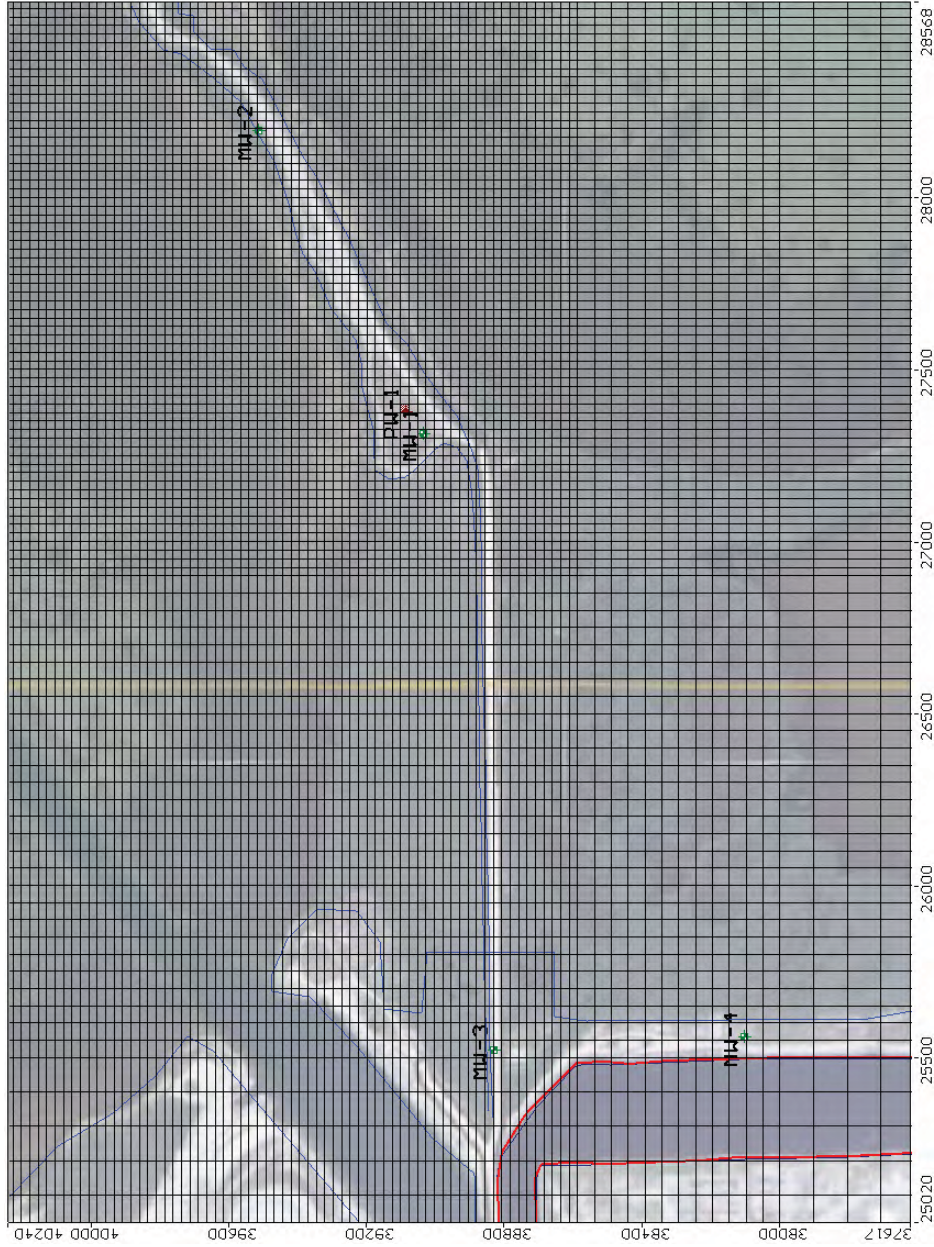
Note: Blue line = shoreline. Red line = CCS outline. Red symbol = pumping well. Green symbol = observation well.
Location of RCWs and laterals are shown in Figure 55.

Figure 34. Test Well PW-1: Observed versus Calculated Drawdowns

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations
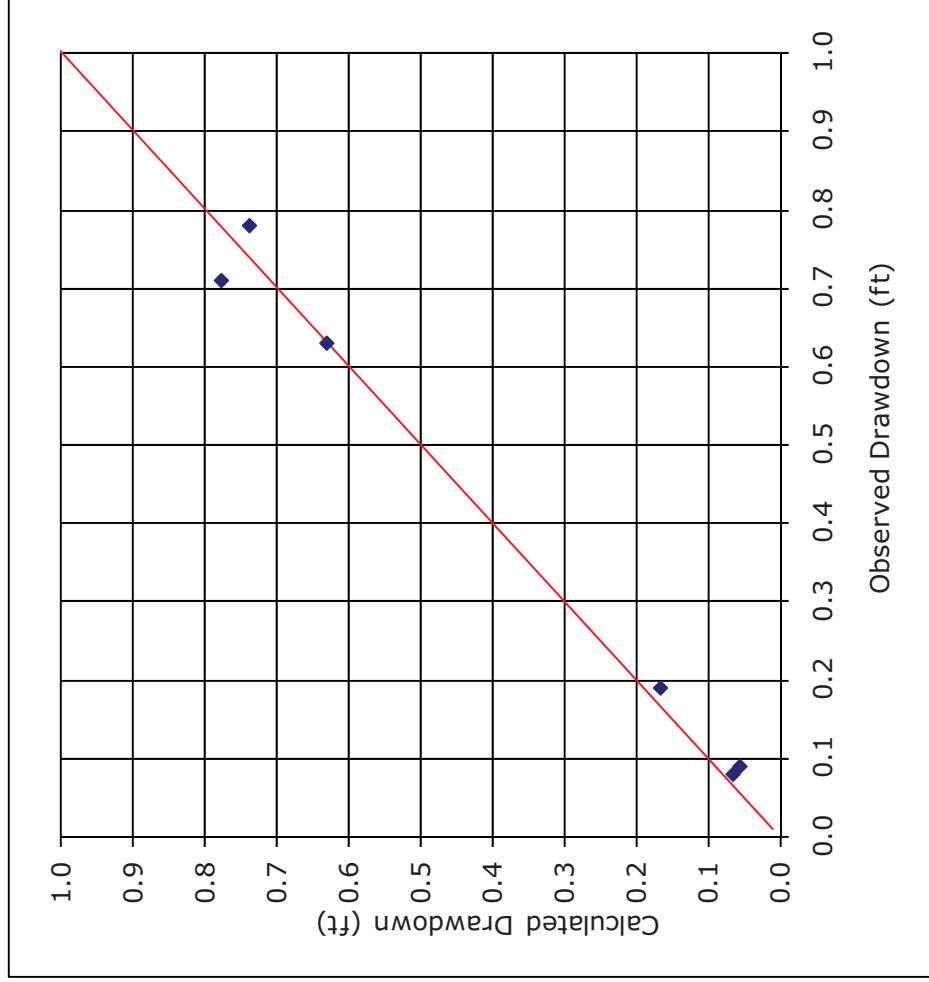
Figure 35. Model Calibration – Finite Difference Grid and Well Layout for Test PW-7U
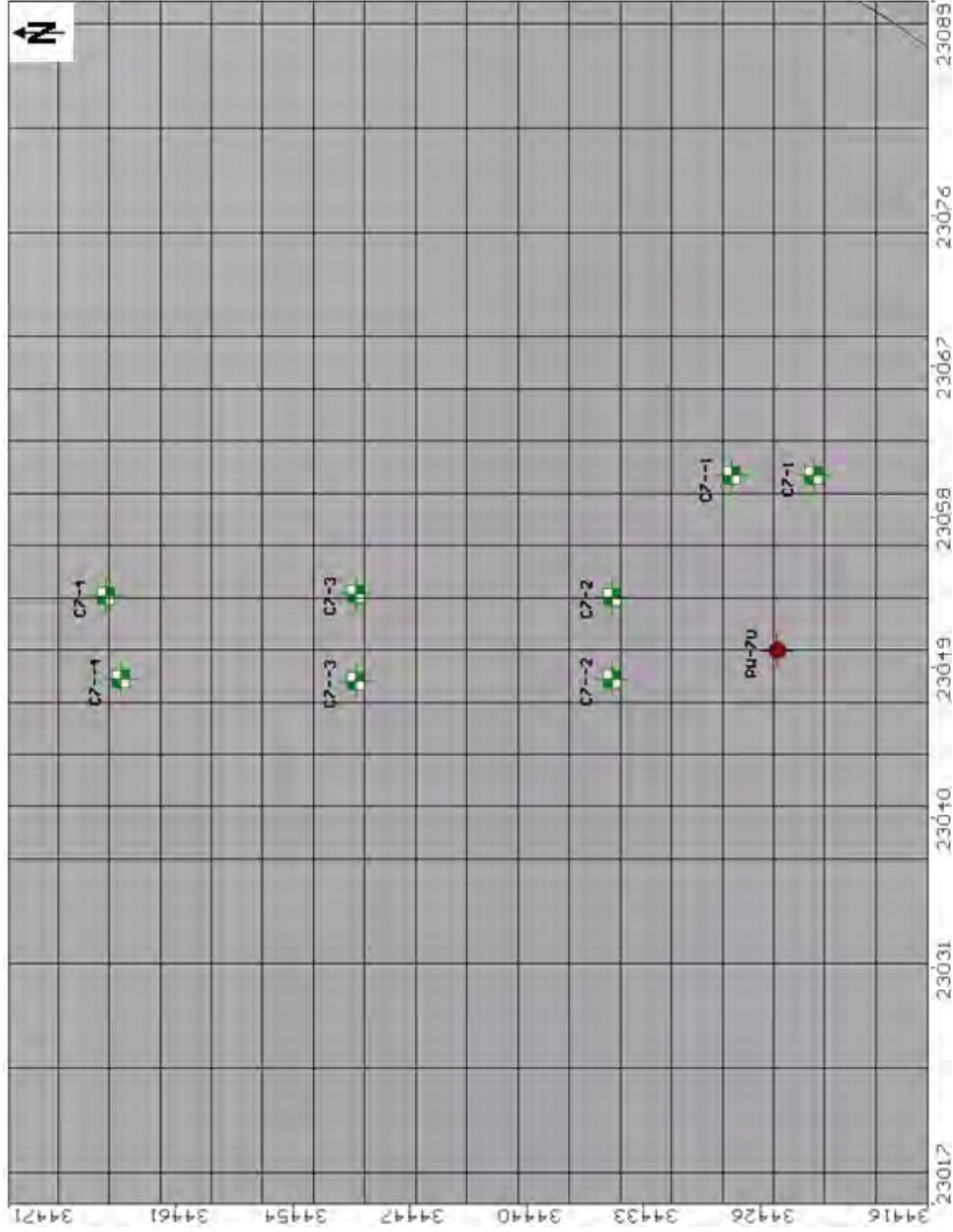
Note: Red symbol = pumping well. Green symbol = observation well.

Figure 36. Test Well PW-7U: Observed versus Calculated Drawdowns
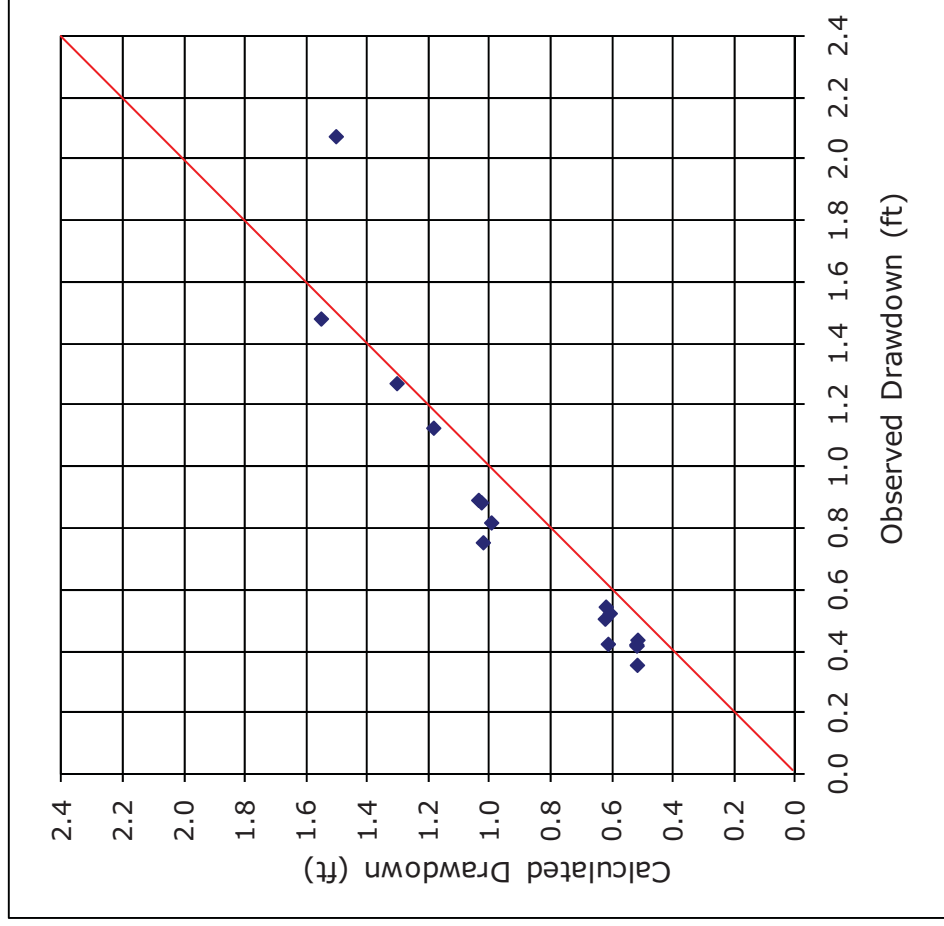
**Figure 37. Simulated Groundwater Contours – Model Layer 1 – Onshore
Muck and Offshore Sand/Sediments and Miami Limestone**

Legend: Contour interval is 0.2 feet (NAVD 88).
Note: Light yellow portion in top right is where aerial imagery is not available.

Figure 38. Simulated Groundwater Contours – Model Layer 3 – Miami Limestone
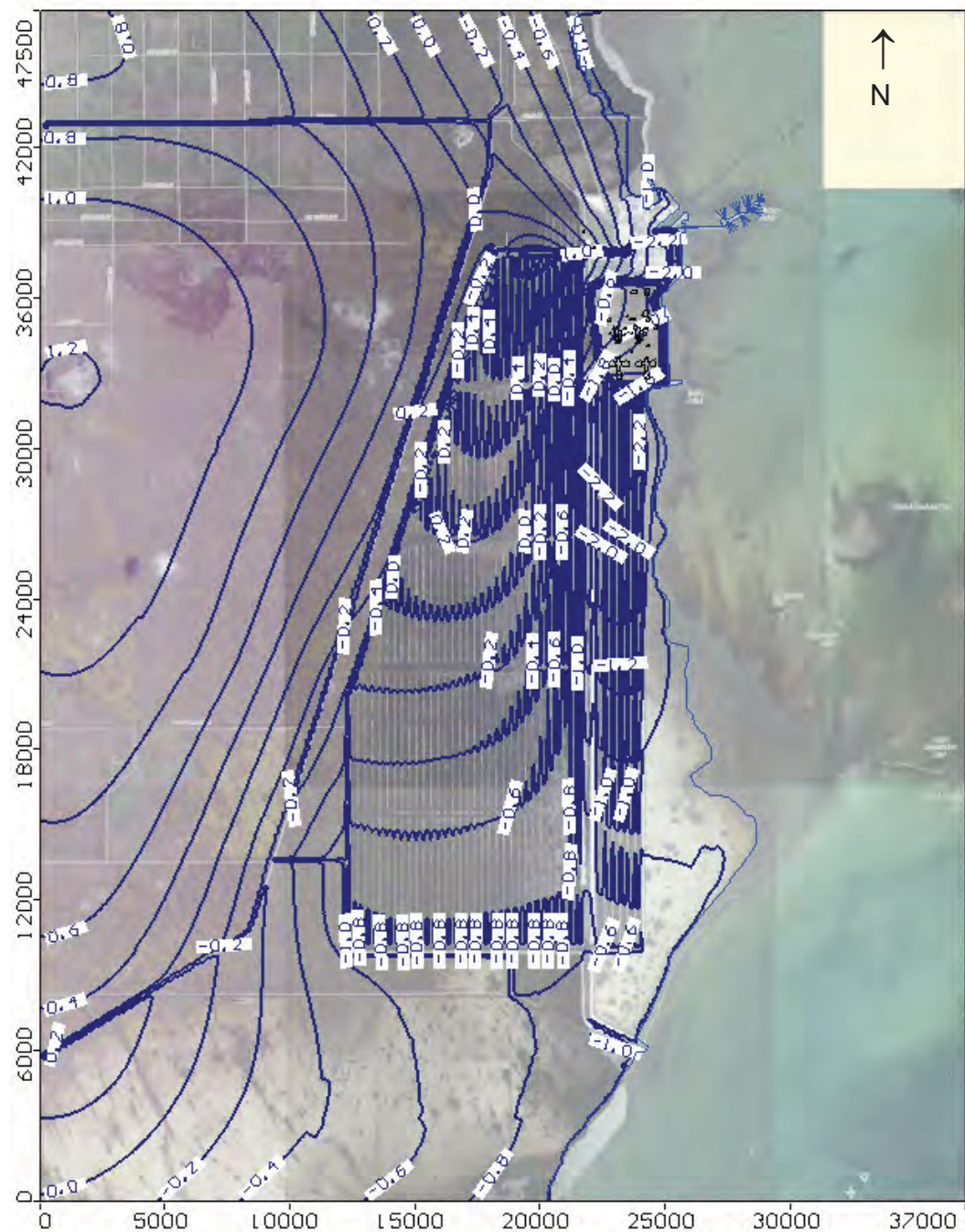
Legend: Contour interval is 0.2 feet (NAVD 88)
Note: Light yellow portion in top right is where aerial imagery is not available.

Figure 39. Simulated Groundwater Contours – Model Layer 4 – Upper Higher Flow Zone

Legend: Contour interval is 0.2 feet (NAVD 88)
Note: Light yellow portion in top right is where aerial imagery is not available.
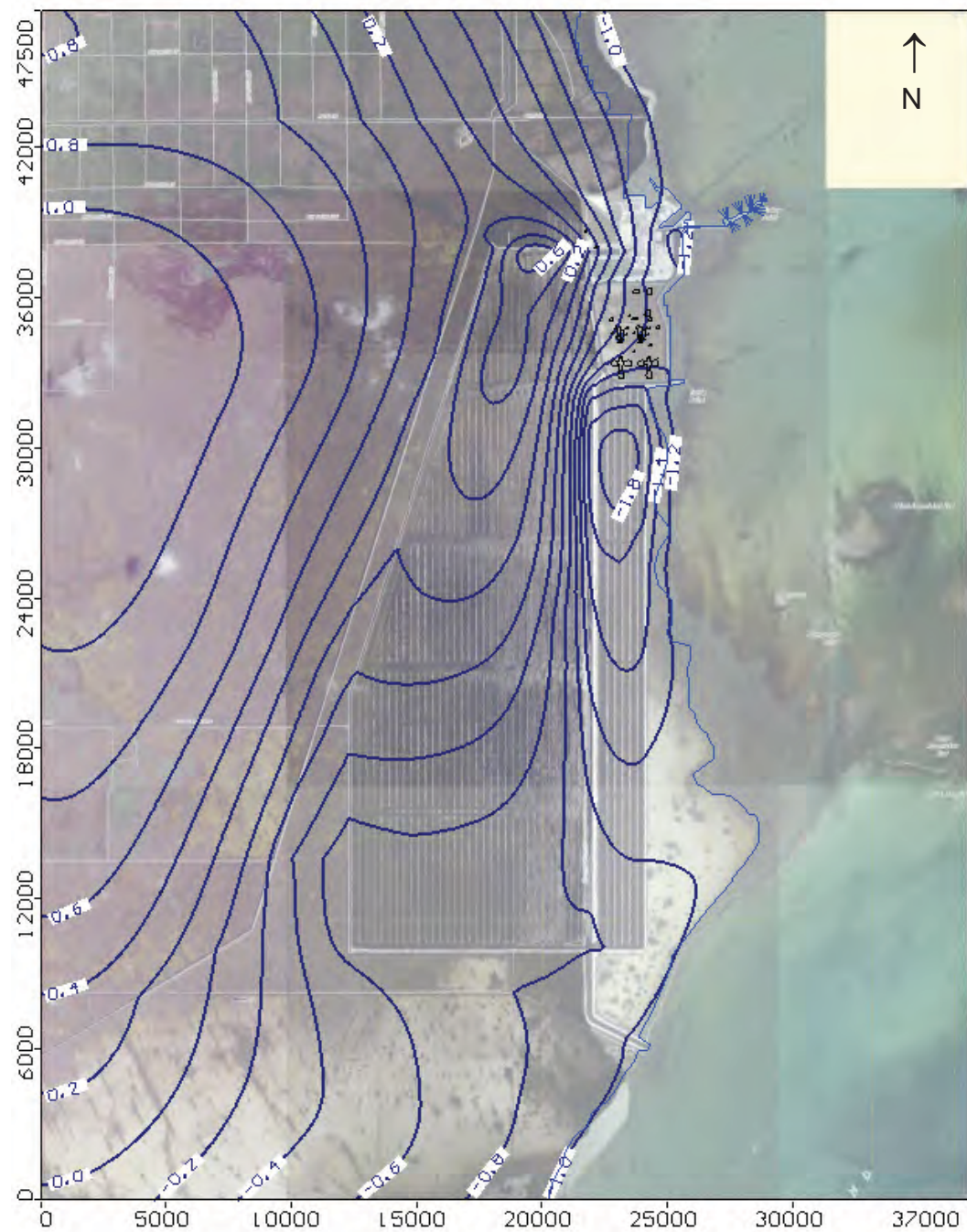
Figure 40. Simulated Groundwater Contours – Model Layer 5 – Key Largo Limestone
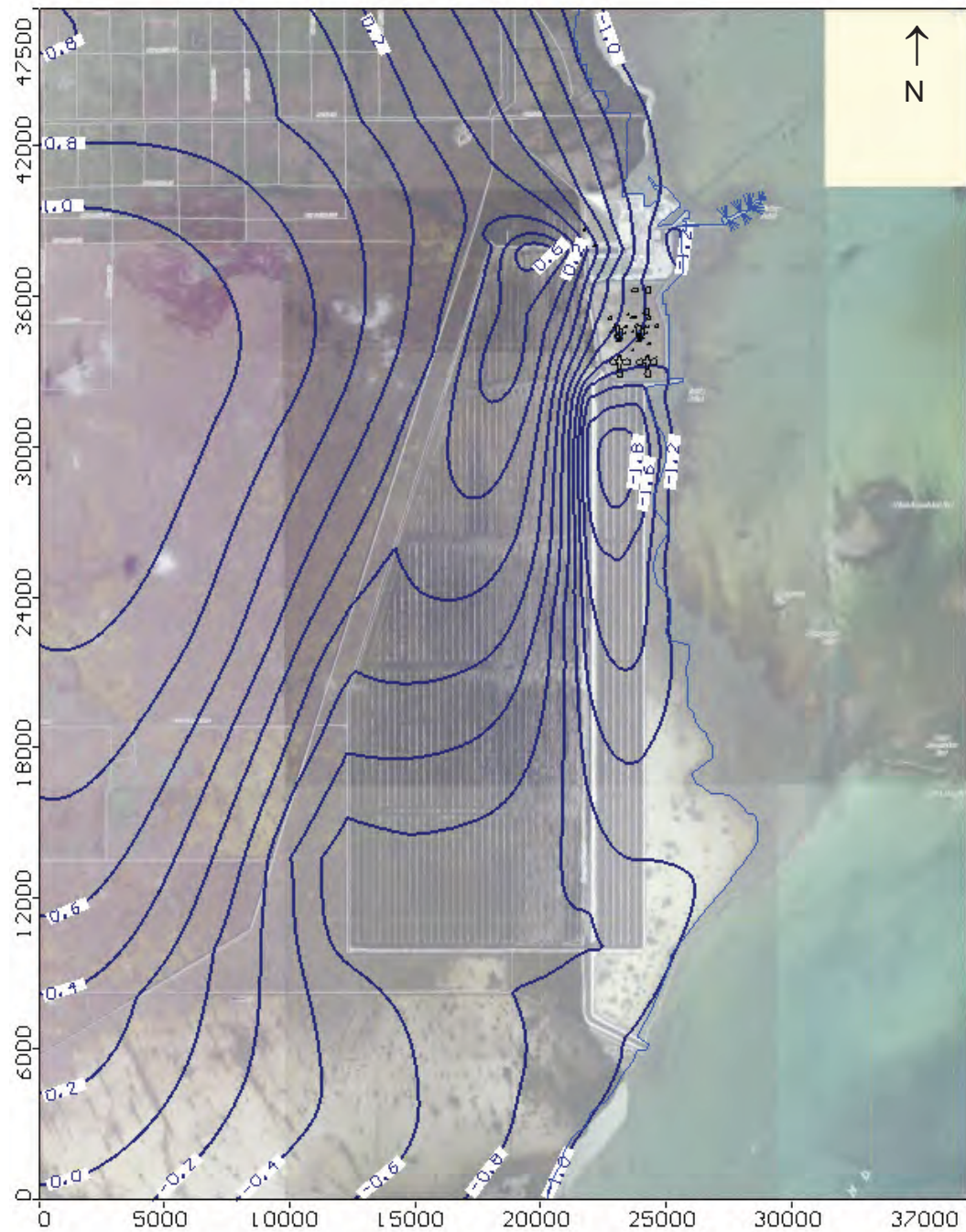
Legend: Contour interval is 0.2 feet (NAVD 88)
Note: Light yellow portion in top right is where aerial imagery is not available.

Figure 41. Simulated Groundwater Contours – Model Layer 7 – Freshwater Limestone

Legend: Contour interval is 0.2 feet (NAVD 88)
Note: Light yellow portion in top right is where aerial imagery is not available.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 42. Simulated Groundwater Contours – Model Layer 9 – Fort Thompson Formation
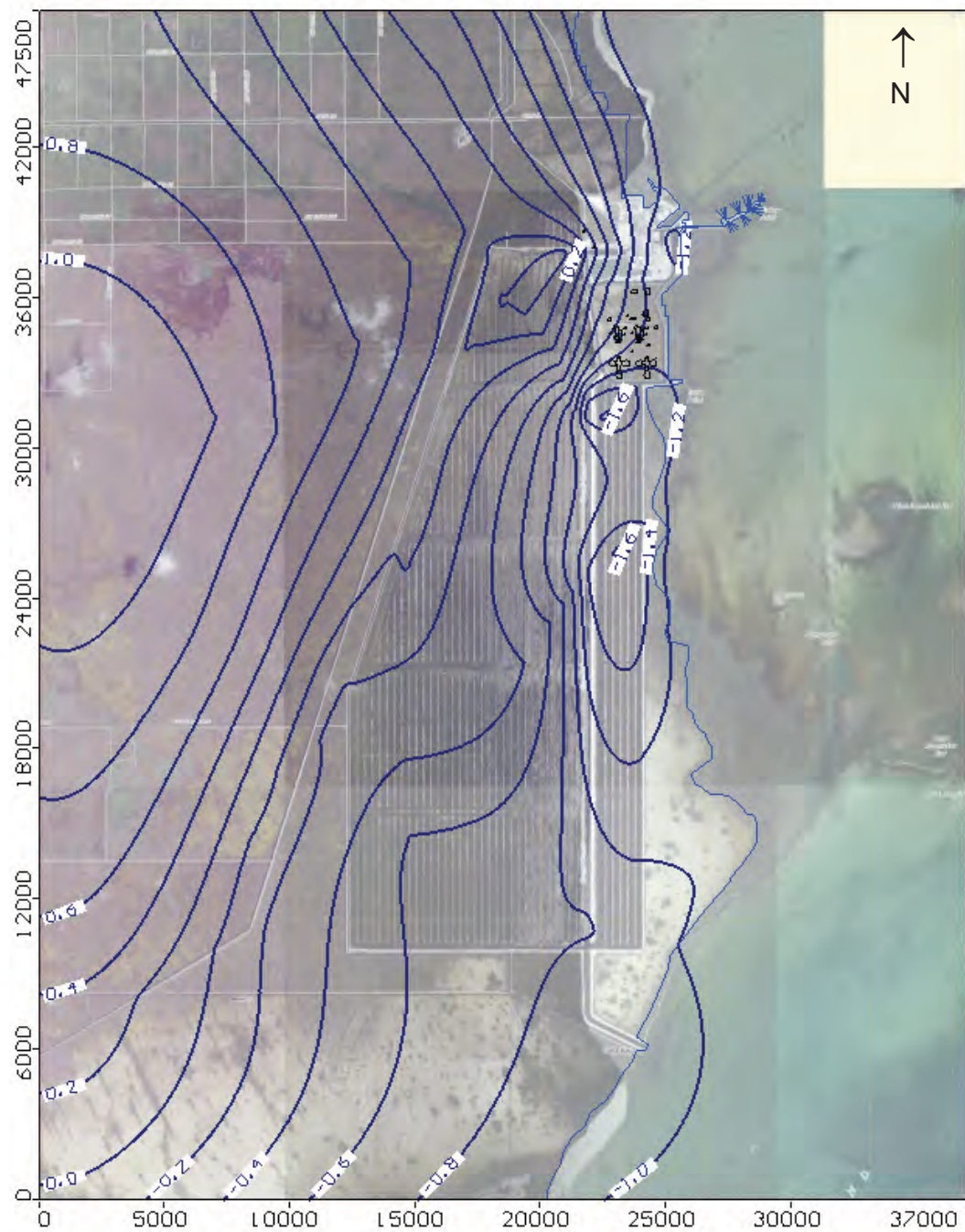
Legend: Contour interval is 0.2 feet (NAVD 88)
Note: Light yellow portion in top right is where aerial imagery is not available.

Figure 43. Simulated Groundwater Contours – Model Layer 10 – Lower Higher Flow Zone
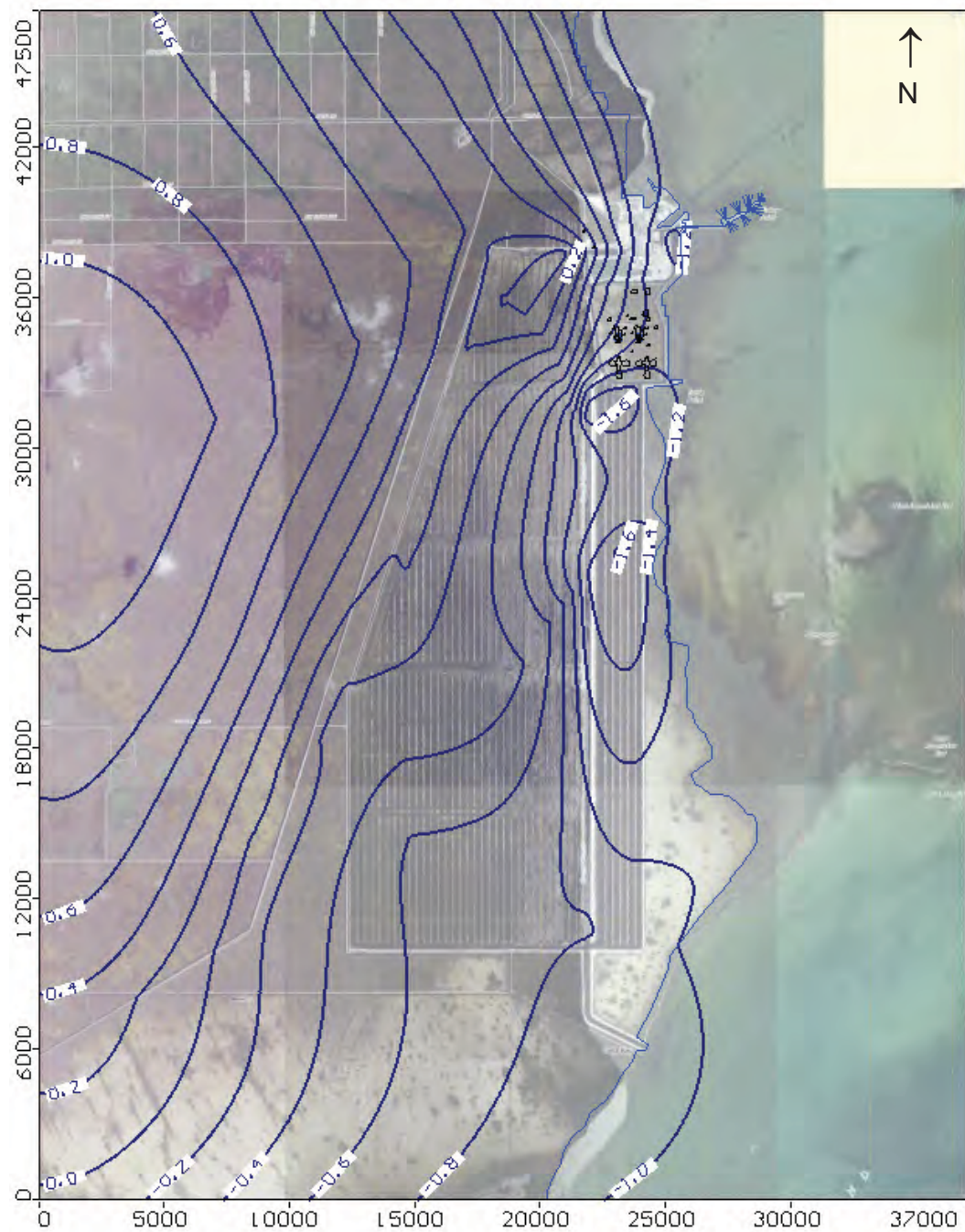
Legend: Contour interval is 0.2 feet (NAVD 88)
Note: Light yellow portion in top right is where aerial imagery is not available.

Figure 44. Simulated Groundwater Contours – Model Layer 14 – Tamiami Formation
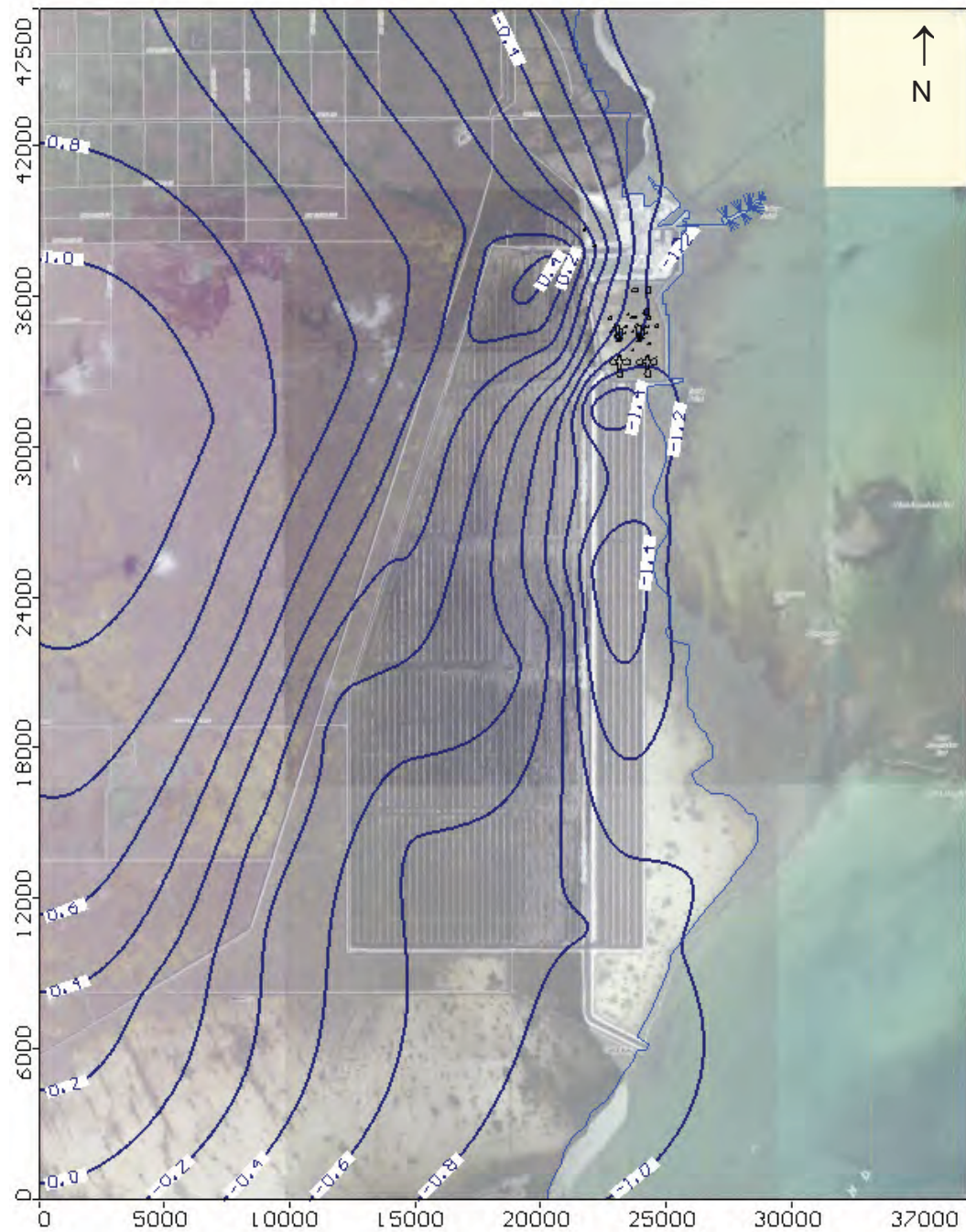
Legend: Contour interval is 0.2 feet (NAVD 88)
Note: Light yellow portion in top right is where aerial imagery is not available.

Figure 45. Existing Cooling Canals Water Balance – Comparison with Groundwater Model
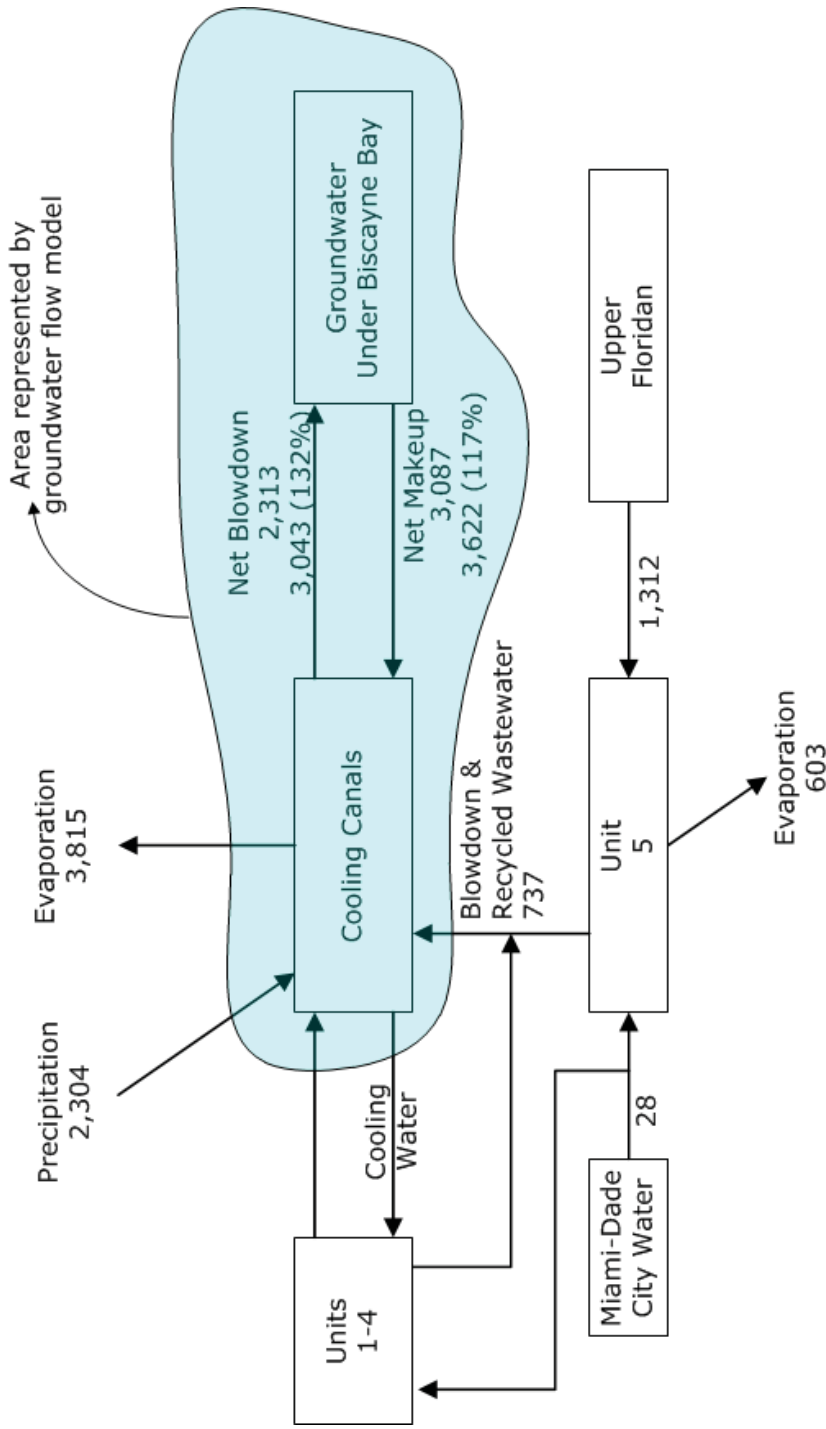
Note: Values in acre-ft/month.

Top value is plant at full capacity from surface water model (Reference 32). Lower value is from groundwater model at average plant conditions. Value in parentheses is percentage difference between surface water model and groundwater model.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 46. Model Validation – Layout of Pumping and Observation Wells for Pumping Test PW-6U

Figure 47. Test Well PW-6U: Observed versus Calculated Drawdowns

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations
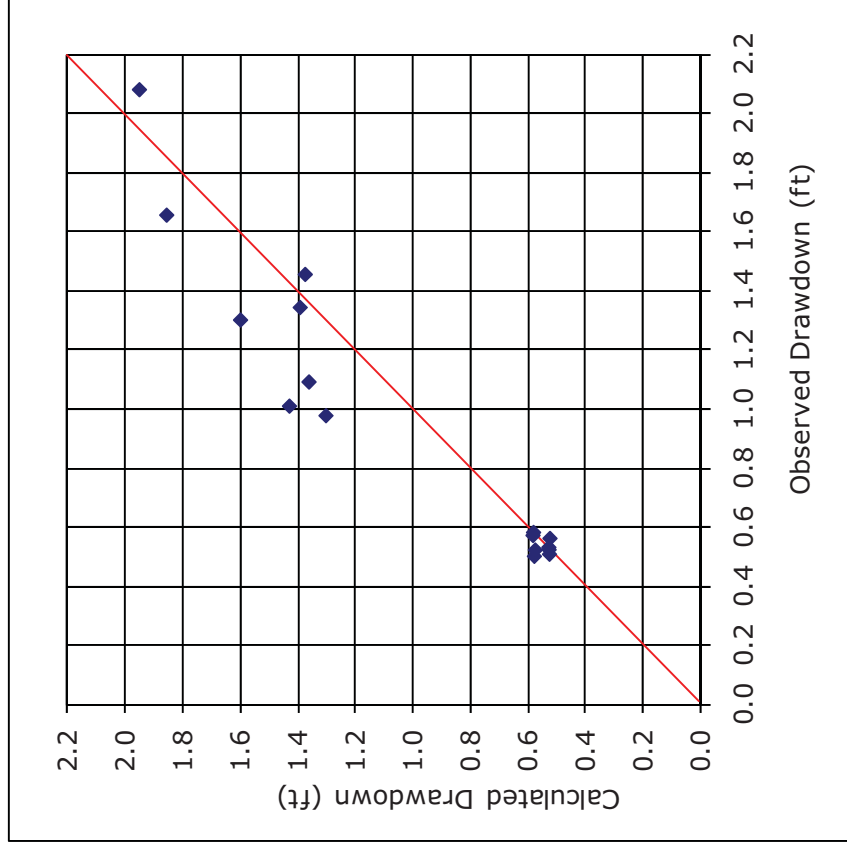
Figure 48. Location of Units 6 & 7 Construction Dewatering Cut-Off Walls

Legend: Blue lines represent cut-off walls.

Figure 49. Location of Units 6 & 7 Construction Cut-Off Walls, Simulated Sump Pumps, and Gridlines
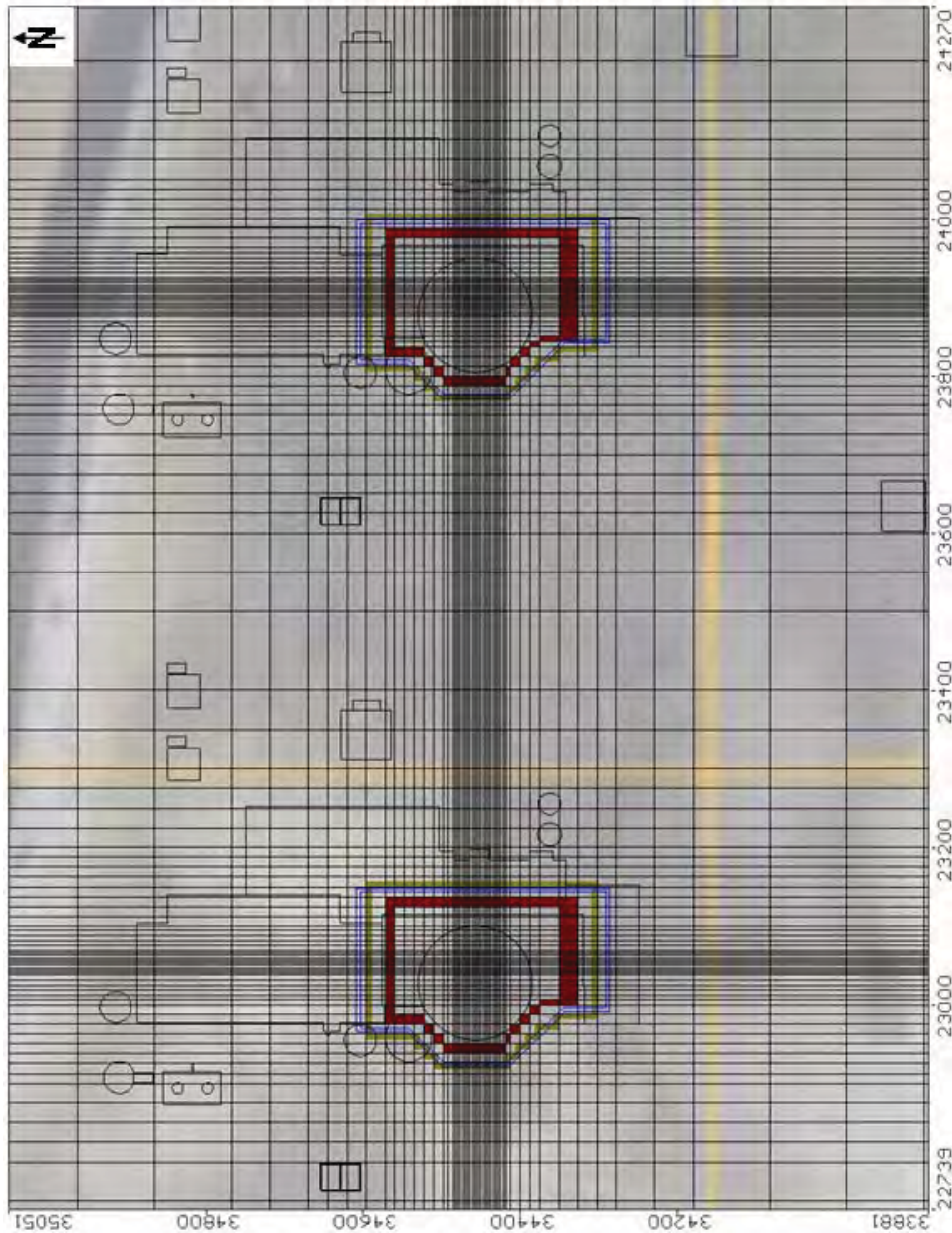
Legend: Blue lines represent reactor building and associated structures. Khaki cells represent implementation of MODFLOW's HFB flow package in model to represent cut-off walls. Red cells represent sump pumps (inside cut-off walls).

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 50. Cross Section of Model Setup for Unit 7 Excavation

Note: Cut-off walls extended to top of model domain for illustration only
Section Across Row 218. Vertical Exaggeration 5:1
Excavation for Unit 6 has similar configuration.

Figure 51. Grouting Holes Spacing and Frequency during Proposed Grouting Method

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations
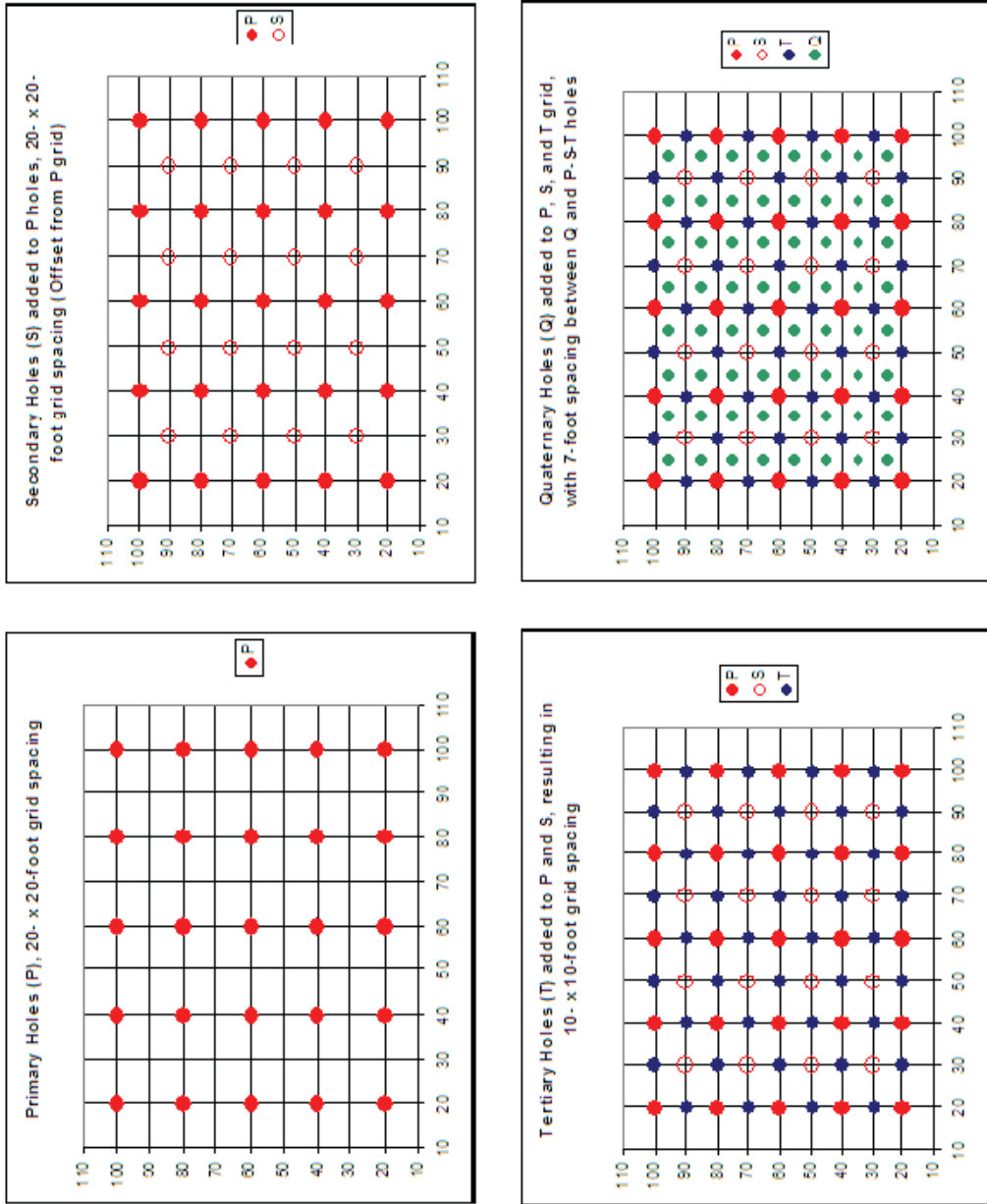
Figure 52. Comparison of Pumping Rates under Different Grouting Scenarios
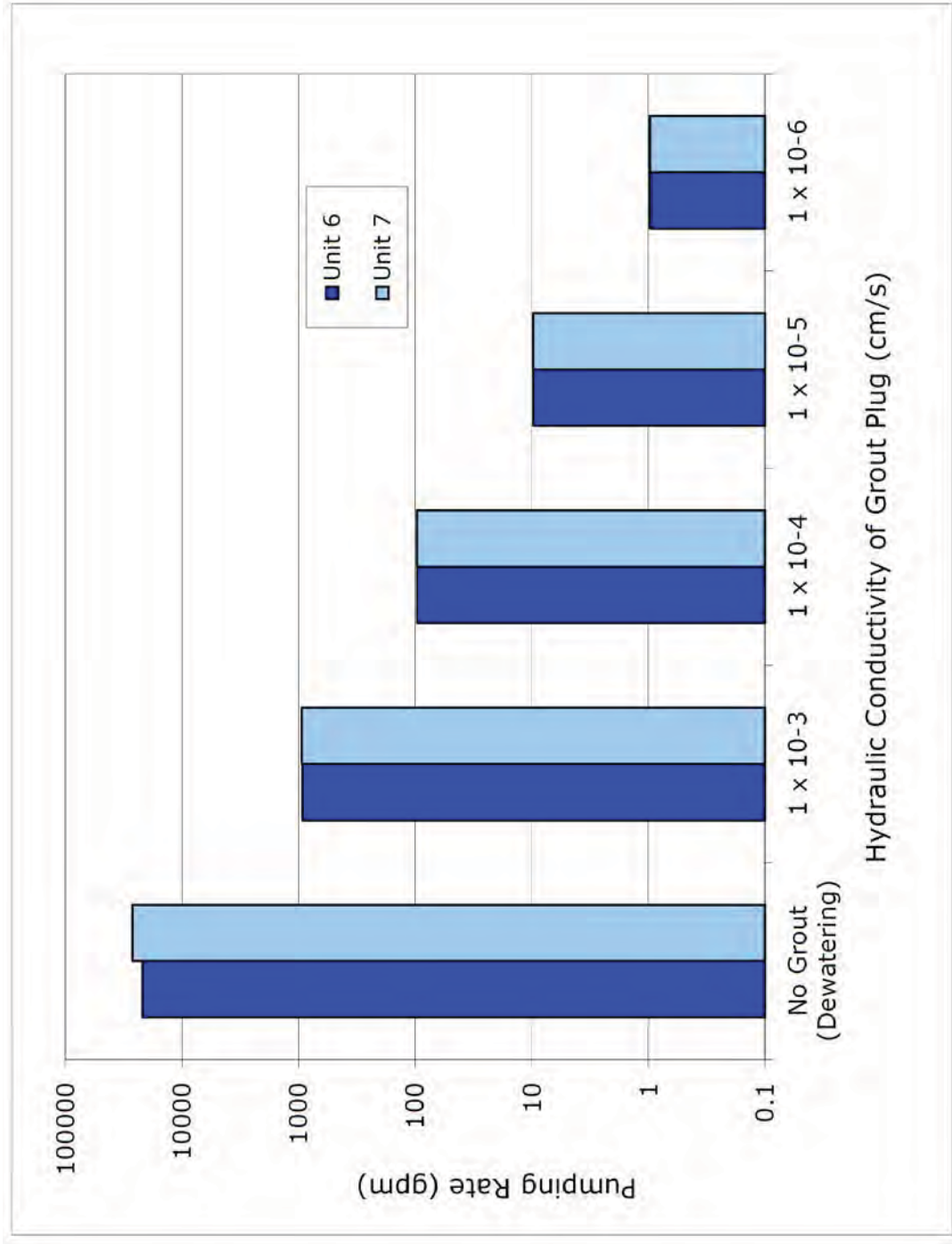
Figure 53. Post-Construction Recharge Zones for Units 6 & 7

Green:
Grass
Recharge = 2 in/yr

Reservoir:
Inactive to flow
Recharge = 0 in/yr

Khaki:
Mechanically Stabilized Earth
(MSE) Retaining Wall

Turquoise:
Gravel surface
Recharge = 10 in/yr

Red:
Proposed structures,
Makeup reservoir
Roads
Recharge = 0 in/yr
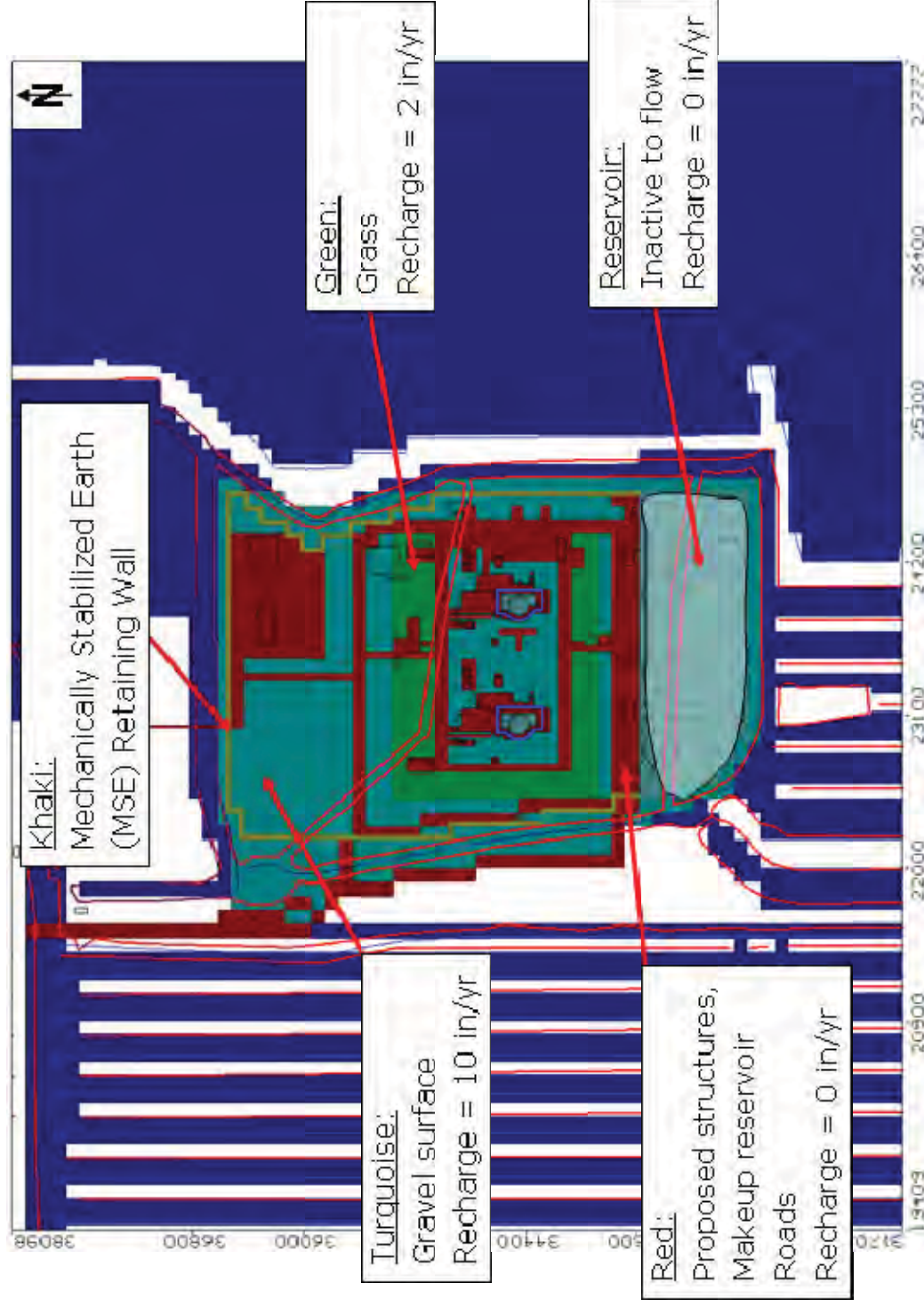
Figure 54. Location of Mechanically Stabilized Earth Retaining Walls around Perimeter of the Turkey Point Units 6 & 7 Plant Area (Excluding the Makeup Water Reservoir)
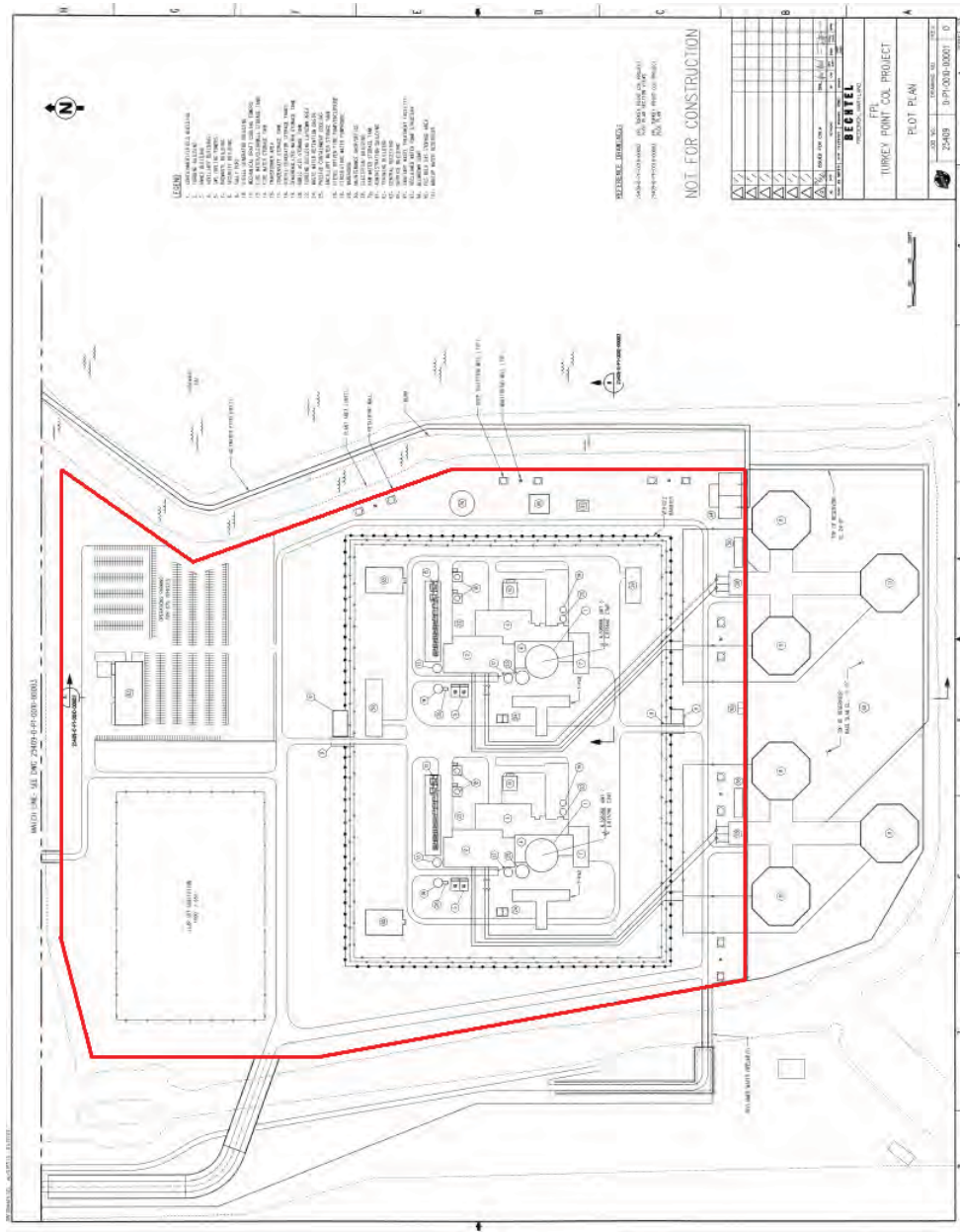
Note: Mechanically stabilized earth retaining walls highlighted in red.

Figure 55. Location of Radial Collector Wells and Laterals, with Finite-Difference Grid and Pumping Well Locations Overlaid
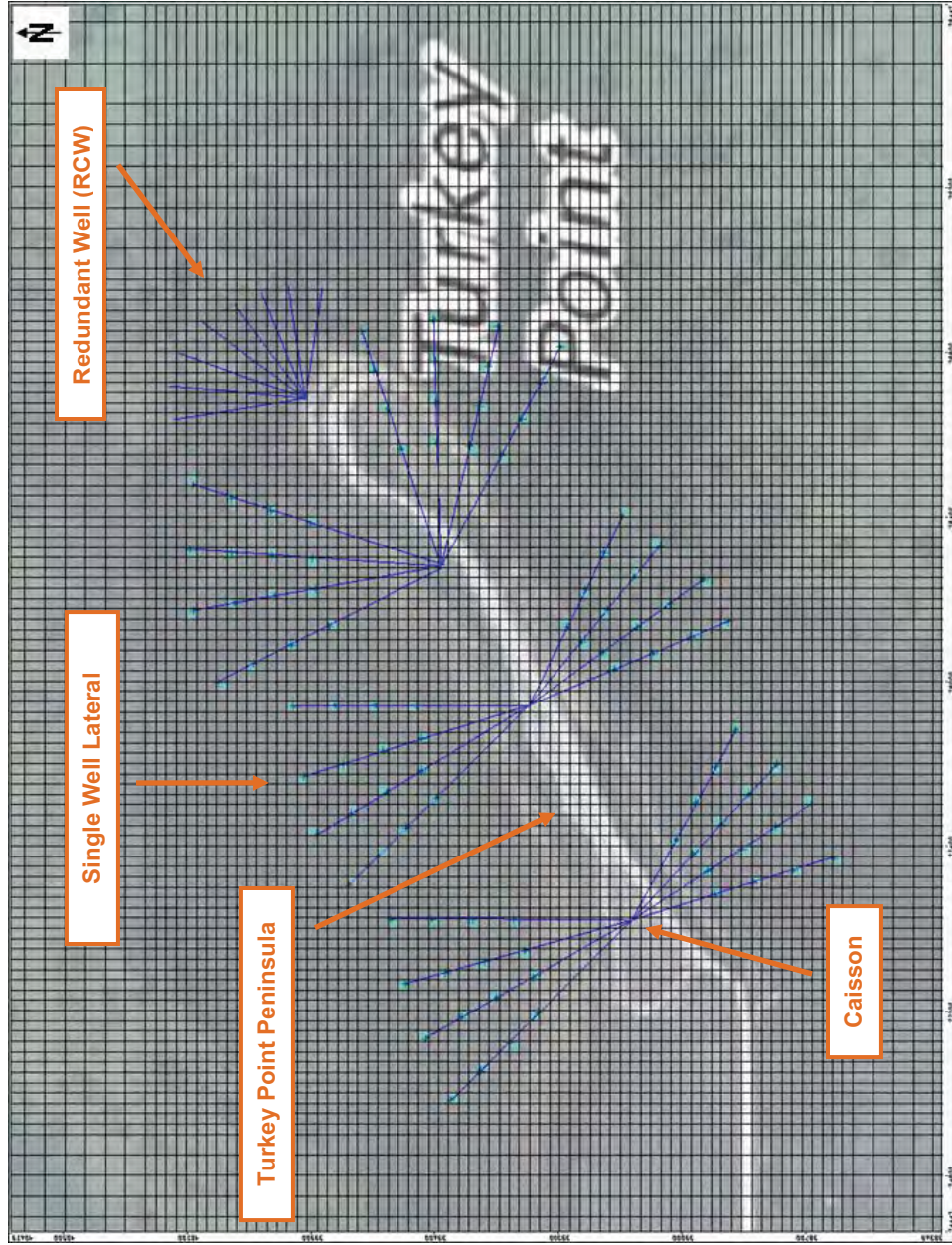
Note: Dark Blue lines = RCW arms. Light Blue symbol = pumping well node.

Figure 56. Potentiometric Surface within the Upper Higher Flow Zone during Radial Collector Well Simulations

Legend: Blue lines are equipotentials in 0.5 feet increments.
Note: The Upper Higher Flow Zone is above the Key Largo Limestone and is the zone from which the RCW system is pumped. Light yellow portion in top right is where aerial imagery is not available.

Figure 57. Head Contours in Layer 1 during Radial Collector Well Simulations

Legend: Blue lines are equipotentials in 1 foot increments.
Note: Light yellow portion in top right is where aerial imagery is not available.

Figure 58. Cross Section through Turkey Point Peninsula Showing Groundwater Contours Resulting from Operation of the RCW System
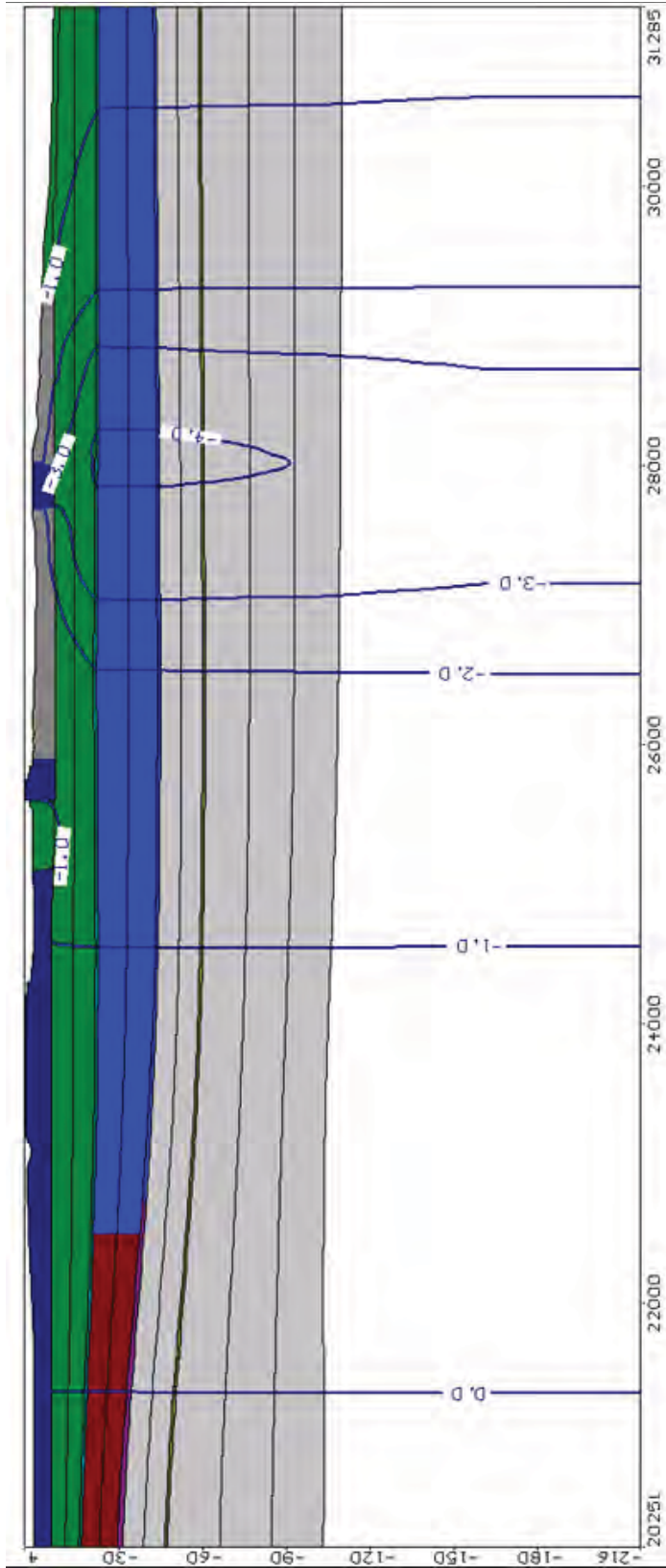
Legend: Blue lines are equipotentials in 1 foot increments.
Note: Section Across Row 120, Vertical Exaggeration = 20:1

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 59. RCW Drawdown within the Top Layer
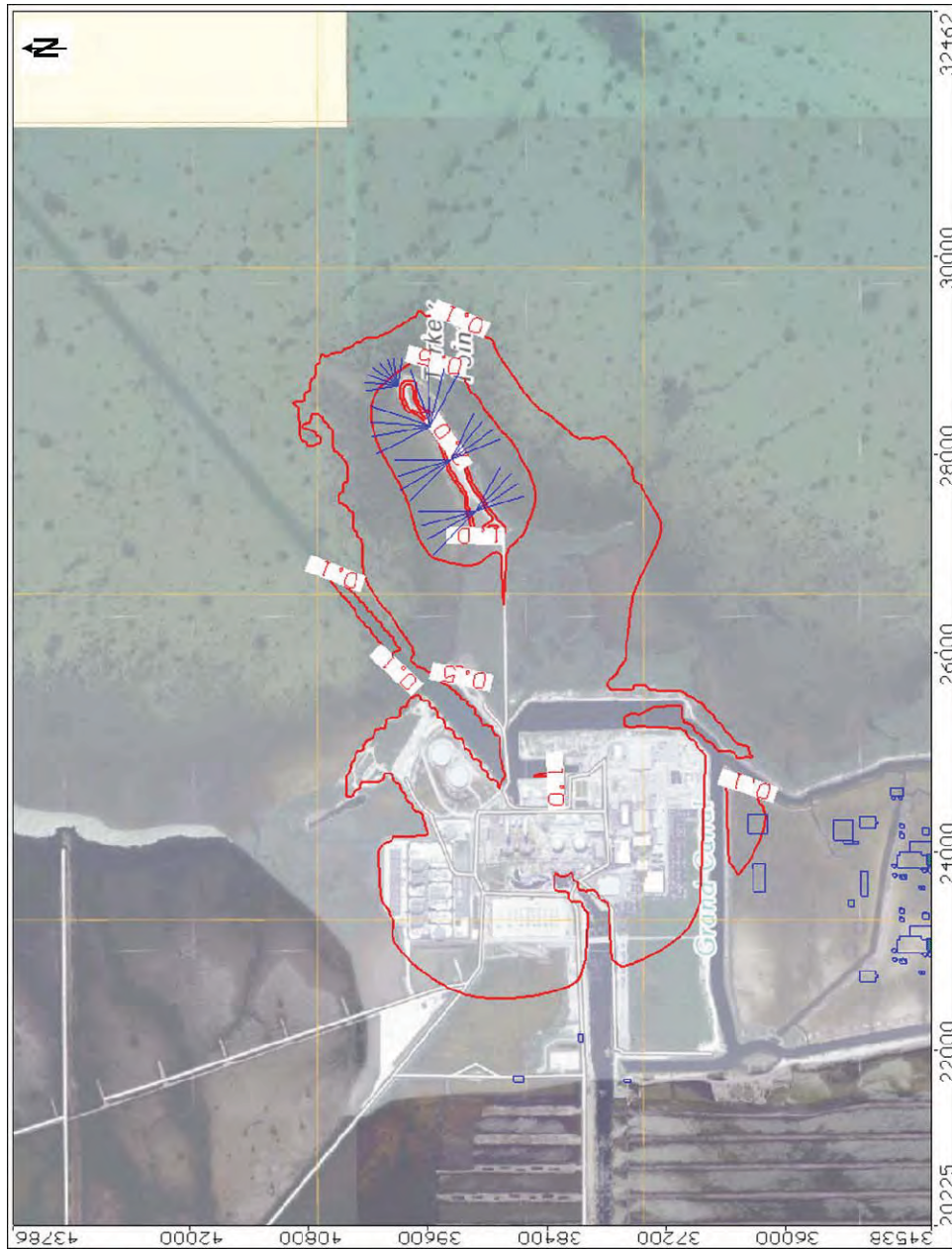
Note: Thin red line = 0.1, 0.5, 1.0, 2.0, and 3.0 foot drawdown contours. Light yellow portion in top right is where aerial imagery is not available.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 60. RCW Drawdown within the Pumped Layer (Upper Higher Flow Zone)
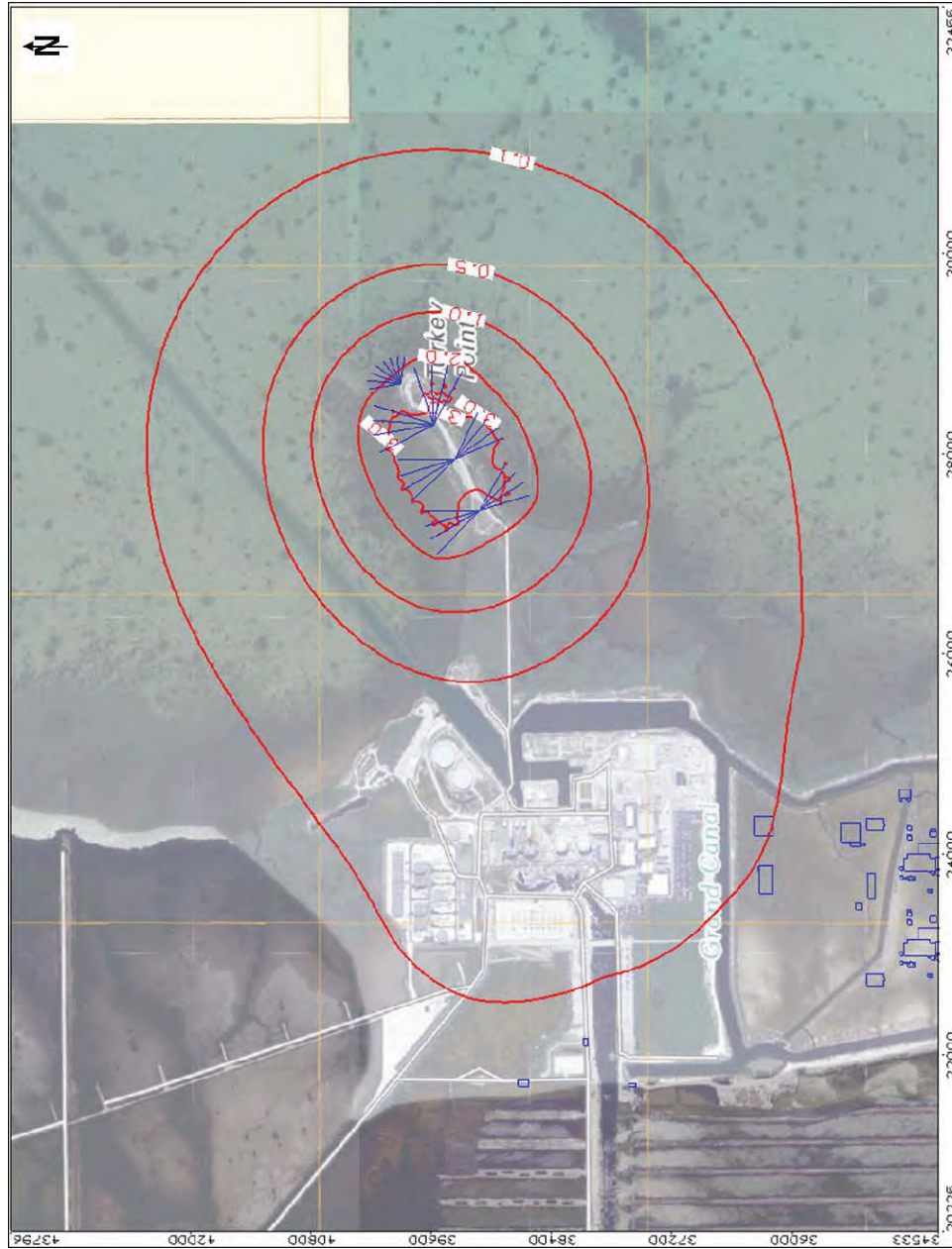
Note: Thin red line = 0.1, 0.5, 1.0, 2.0, and 3.0 foot drawdown contours. Light yellow portion in top right is where aerial imagery is not available. Approximate elevation of Upper Higher Flow Zone underneath Turkey Point Peninsula is -22 feet NAVD 88.

Figure 61. Origin of Flow to the RCW System (Layer 1)
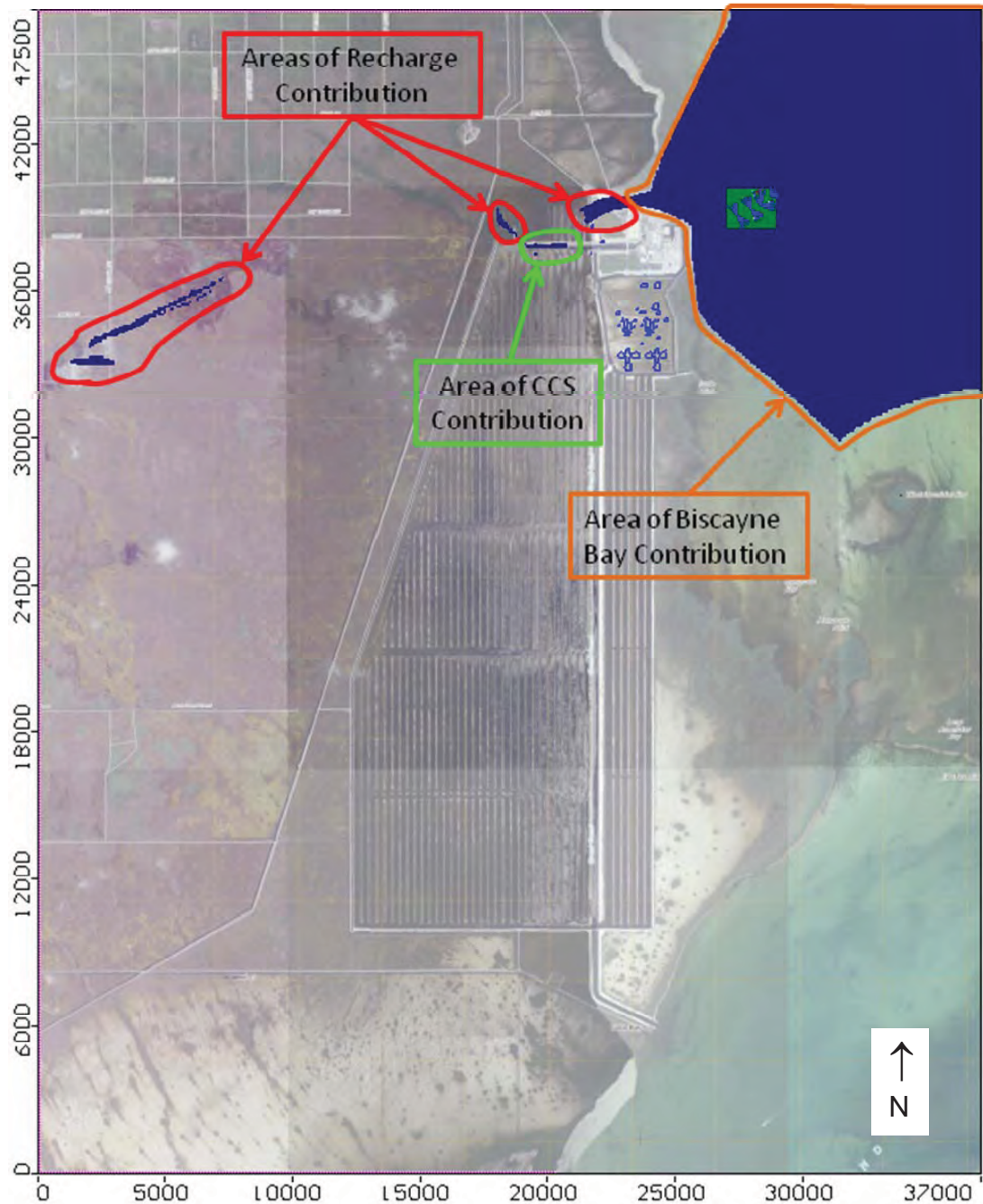
Note: Blue areas show origins of water contributing to RCW system.

Figure 62. Origin of Flow to the RCW System (Layer 2)

Note: Blue areas show origins of water contributing to RCW system. Light yellow portion in top right is where aerial imagery is not available.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

Figure 63. Additional Areas for RCW Approach Velocity Calculation

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations
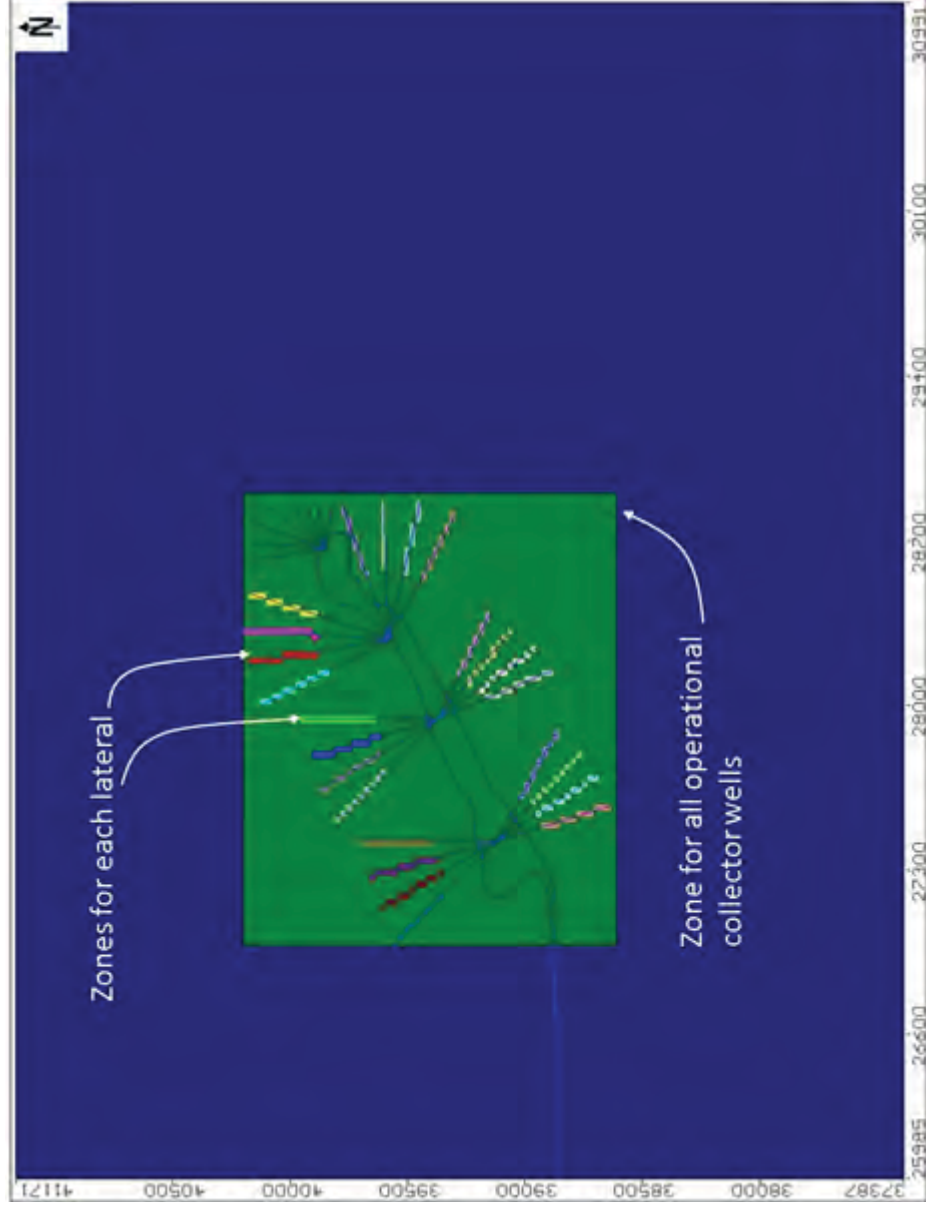
Figure 64. Calculated Flux of Water between Layers 1 and 2 (Darcy Velocity)
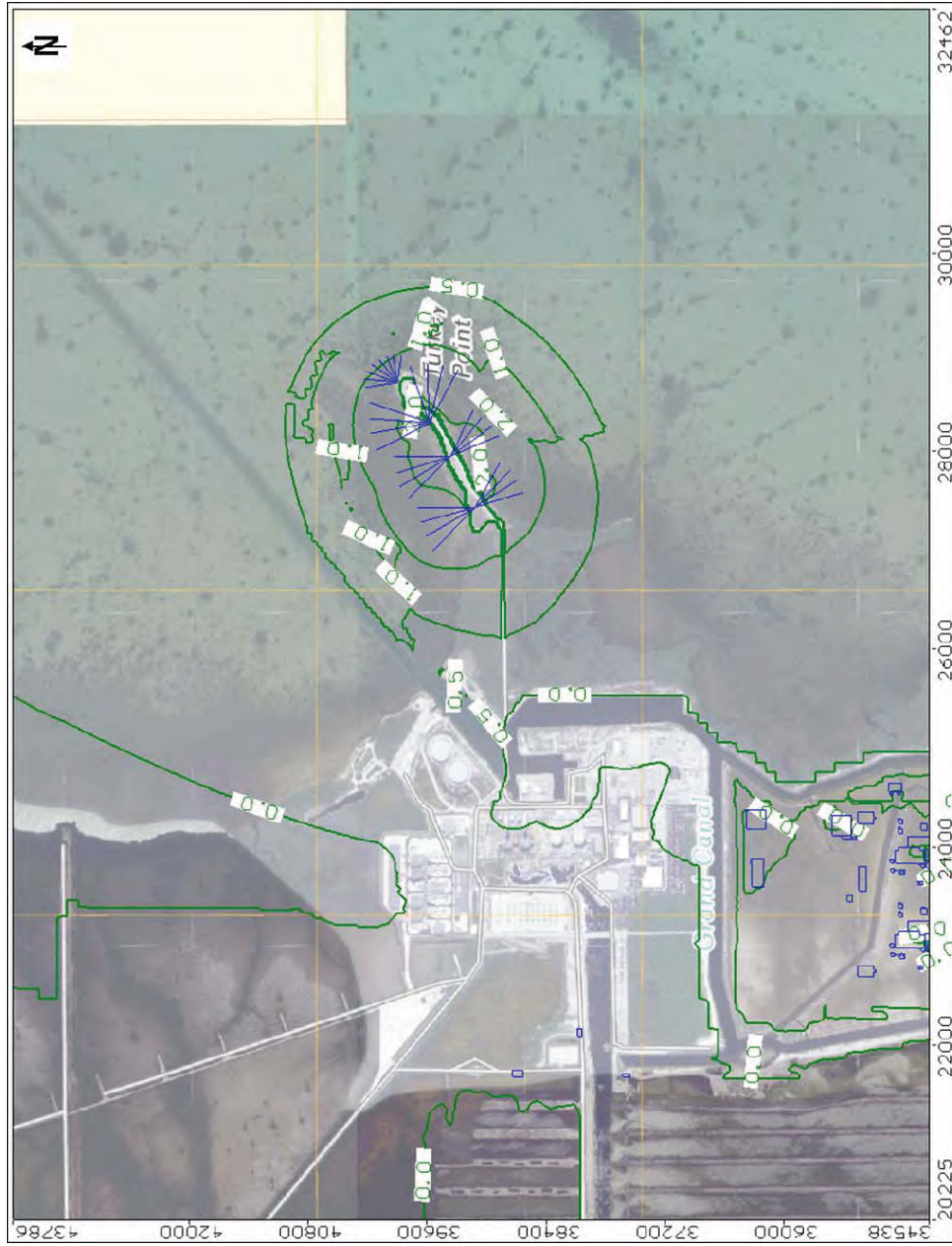
Notes: Units in ft/day. Light yellow portion in top right is where aerial imagery is not available.

Groundwater Model Development and Analysis: Units 6 & 7
Dewatering and Radial Collector Well Simulations

**Figure 65. RCW Drawdown within the Top Layer (0.1 Foot Drawdown Contour) –
Seasonal High and Low Water Level Biscayne Bay**

All cases plot virtually on top of one another.
Where they diverge the following colors distinguish them.

Base Case: Light Blue
Seasonal High WL: Orange
Seasonal Low WL: Purple
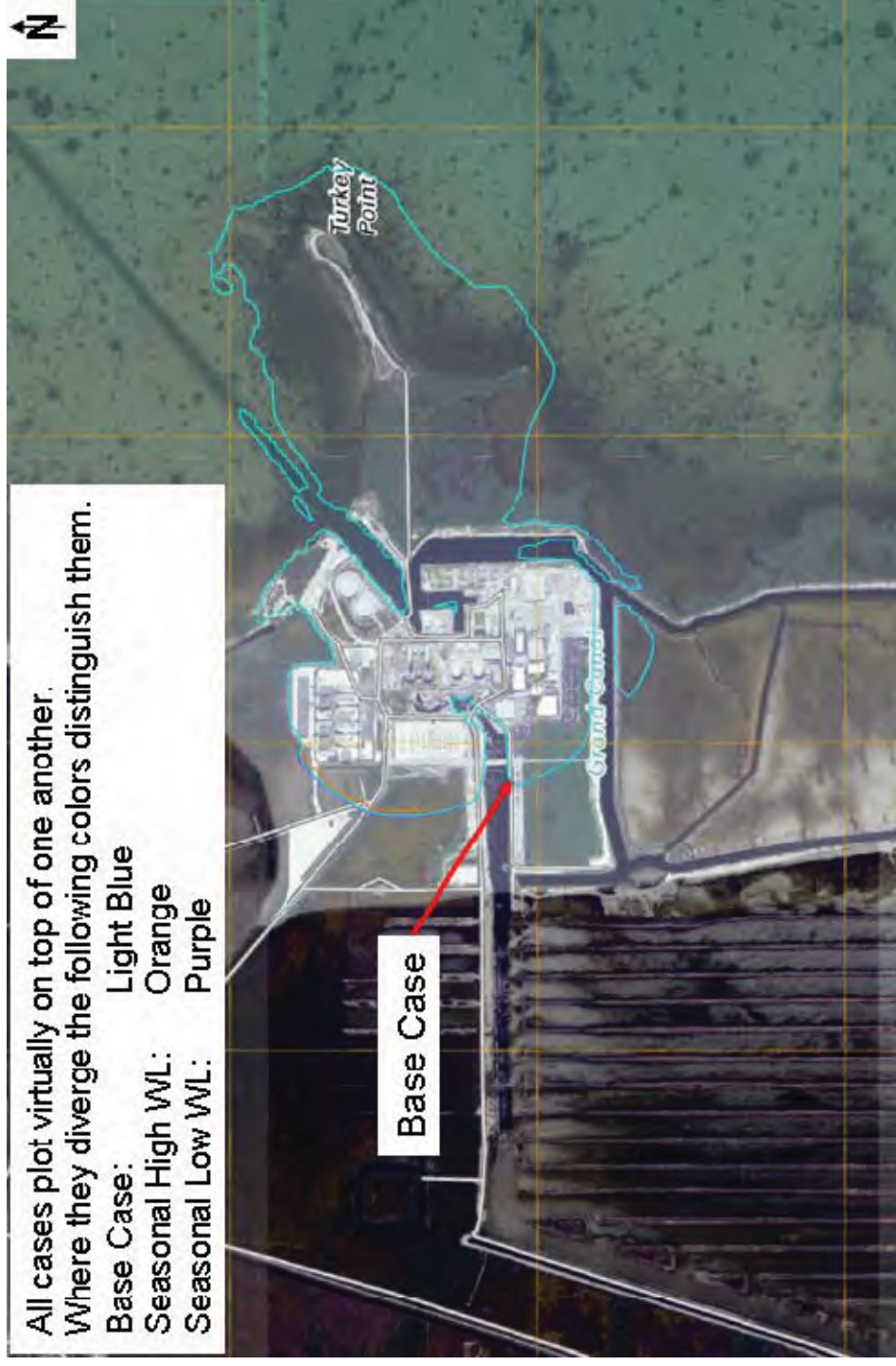
Note: Divergence of drawdown lines is seen to the west and northwest of the existing Turkey Point plant where the drawdown contour for the seasonal high water level is to the east of the base case contour and the seasonal low water level contour is to the west of the base case contour where distinguishable.

Figure 66. RCW Drawdown within the Top Layer (0.1 Foot Drawdown Contour) – Sensitivity Case Biscayne Bay Vertical Hydraulic Conductivity

Figure 67. RCW Drawdown within the Top Layer (0.1 Foot Drawdown Contour) – Hydraulic Conductivity of Key Largo Limestone

Enclosure 2

Turkey Point Nuclear Plant Units 6 and 7
COL Application

GROUNDWATER FLOW MODEL REVISION

Groundwater Flow Model for Biscayne Aquifer Calculation
Input/Output Files (Revision 6) – September 2012 (5 OSM)

FPL G&HES Groundwater Calculation 25409-000-K0C-0000-00005 Revision 006
Groundwater Flow Model for Biscayne Aquifer
Disc 1 of 5 "calibration"

6.1 Main/Start:

📁 model_runs_final	9/14/2012 12:24 PM	File folder	
📊 readme.xlsx	9/14/2012 10:02 AM	Microsoft Office Excel Worksheet	9 KB

6.2 Inside model_runs_final folder:

📁 calibration	9/14/2012 12:24 PM	File folder

6.3 Inside calibration folder:

📦 PW-1.zip	7/19/2012 7:09 PM	WinZip File	218,106 KB
📦 PW-7L.zip	7/19/2012 7:09 PM	WinZip File	218,055 KB
📦 PW-7U.zip	7/19/2012 7:09 PM	WinZip File	221,560 KB

FPL G&HES Groundwater Calculation 25409-000-K0C-0000-00005 Revision 006
Groundwater Flow Model for Biscayne Aquifer
Disc 2 of 5 "dewatering"

6.4 Main/Start:

📁 model_runs_final	9/14/2012 12:12 PM	File folder

6.5 Inside model_runs_final folder:

📁 dewatering	9/14/2012 12:12 PM	File folder

6.6 Inside dewatering folder:

📦 both.zip	7/19/2012 7:10 PM	WinZip File	208,720 KB
📦 unit_6.zip	7/19/2012 7:10 PM	WinZip File	213,422 KB
📦 unit_7.zip	7/19/2012 7:10 PM	WinZip File	213,365 KB

FPL G&HES Groundwater Calculation 25409-000-K0C-0000-00005 Revision 006
Groundwater Flow Model for Biscayne Aquifer
Disc 3 of 5 "grouting"

6.7 Main/Start:

📁 model_runs_final	9/14/2012 12:16 PM	File folder

6.8 Inside model_runs_final folder:

📁 grouting	9/14/2012 12:16 PM	File folder

6.9 Inside grouting folder:

Grouting_Unit6_1e-3.zip	7/19/2012 7:11 PM	WinZip File	208,439 KB
Grouting_Unit6_1e-4.zip	7/19/2012 7:11 PM	WinZip File	208,408 KB
Grouting_Unit6_1e-5.zip	7/19/2012 7:11 PM	WinZip File	208,272 KB
Grouting_Unit6_1e-6.zip	7/19/2012 7:12 PM	WinZip File	208,254 KB
Grouting_Unit7_1e-3.zip	7/19/2012 7:12 PM	WinZip File	208,646 KB
Grouting_Unit7_1e-4.zip	7/19/2012 7:13 PM	WinZip File	208,255 KB
Grouting_Unit7_1e-5.zip	7/19/2012 7:13 PM	WinZip File	208,188 KB
Grouting_Unit7_1e-6.zip	7/19/2012 7:13 PM	WinZip File	208,206 KB

FPL G&HES Groundwater Calculation 25409-000-K0C-0000-00005 Revision 006
Groundwater Flow Model for Biscayne Aquifer
Disc 4 of 5 "rcw"

6.10 Main/Start:

model_runs_final	9/14/2012 12:49 PM	File folder

6.11 Inside model_runs_final folder:

rcw	9/14/2012 12:49 PM	File folder

6.12 Inside rcw folder:

RCW_0.5Kv.zip	9/12/2012 4:38 PM	WinZip File	757,266 KB
RCW_0.09ft.zip	9/12/2012 4:39 PM	WinZip File	719,819 KB
RCW_-1.40ft.zip	9/12/2012 4:40 PM	WinZip File	725,580 KB
RCW_2Kv.zip	9/12/2012 4:42 PM	WinZip File	703,452 KB
RCW_Blue.zip	9/13/2012 6:58 PM	WinZip File	538,681 KB
RCW_KL.zip	9/13/2012 7:04 PM	WinZip File	527,988 KB
RCW_Red.zip	9/13/2012 7:15 PM	WinZip File	512,630 KB

FPL G&HES Groundwater Calculation 25409-000-K0C-0000-00005 Revision 006
Groundwater Flow Model for Biscayne Aquifer
Disc 5 of 5 "rcw" cont. and "validation"

6.13 Main/Start:

model_runs_final	9/14/2012 1:01 PM	File folder

6.14 Inside model_runs_final folder:

rcw (continued from Disc 4)	9/14/2012 1:01 PM	File folder
validation	9/14/2012 1:01 PM	File folder

6.15 Inside rcw (continued from Disc 4) folder:

RCW_UHFZ.zip	9/13/2012 7:23 PM	WinZip File	534,461 KB

6.16 Inside validation folder:

PW-6U.zip	7/19/2012 7:22 PM	WinZip File	218,045 KB