Memorandum

To: *FDEP*

From: *Lee Wiseman, P.E., BCEE and Seenu Anandam, P.E.*

Date: *July 12, 2013*

Subject: *Groundwater Flow Modeling in Support of City of Jacksonville Trail Ridge Landfill Phase 6-14 Class I Cell Expansion*

1.0 Background

Trail Ridge Landfill (TRLF) is a Class I landfill that is owned by the City of Jacksonville, Florida (City) and operated by Trail Ridge Landfill, Inc. (a Waste Management Company). The landfill serves the City of Jacksonville, Duval County, and Northeast Florida. The types of waste accepted at the landfill typically consist of residential/household, office, commercial, agricultural, and industrial wastes. Based on facility waste records, the annual tonnage for 2010 was approximately 713,040 tons. As shown on **Figure 1**, the landfill property is located along the central-western border of Duval County, in Sections 18 through 21, Township 3 South, Range 23 East, approximately 3 miles south of Interstate Highway 10. The total land area is approximately 978 acres, of which approximately 148 acres are used as part of the existing cell area. The existing cell area has been developed via five stages of cell construction over 20 years and is within 5 to 7 years of completion. As part of the *Trail Ridge Landfill Master Site Plan Phasing Report* (CDM Smith, 2012a) CDM Smith evaluated various build-out options of the site to increase the capacity of the landfill. **Figure 2** shows the proposed extents of each expansion (Phases 6 through 14) located to the North of the existing landfill cell (Phases 1 through 5). To support design of the future expansion phases, CDM Smith developed a groundwater flow model to provide guidelines and input for the engineering design of the landfill liner and stormwater management systems on the expansion property.

2.0 Groundwater Modeling Purpose and Objectives

The purpose of this technical memorandum was to document the surficial aquifer groundwater flow modeling performed in support of the design of the landfill liner and stormwater management systems for the TRLF expansion project. The objectives of the groundwater flow modeling task are to:

- Collect hydrologic and hydrogeologic data from onsite and offsite locations to use in constructing a groundwater model of the TRLF;

- Use the collected data to develop a three-dimensional groundwater flow model that represents the hydrologic and hydrogeologic conditions of the surficial aquifer at the TRLF expansion site;
- Calibrate the groundwater model to match measured groundwater elevation data at monitor wells that are installed by CDM Smith in the expansion area as well as the monitor wells that are located near the existing landfill cell; and
- Use the calibrated groundwater flow model to provide guidelines and input for the engineering design of the proposed landfill expansion.

3.0 Hydrology and Hydrogeology

3.1 Rainfall Conditions

Duval County has a subtropical climate. There is a distinct wet season, which occurs from June through the end of September, and a distinct dry season that starts in October and extends through the end of May. Based on data compiled by the St.Johns Water Management District (SJRWMD) for the period from 1996 through 2011 at the nearby (approximately 3 miles from the of the TRLF site) Black Creek Maxville station (**Figure 3**), the average annual rainfall is 47.7 inches. Rainfall is unevenly distributed with approximately 56 percent of the annual rainfall occurring during the wet season summer months of June through September. Historic annual rainfall and monthly rainfall distribution at Black Creek Maxville station are shown on **Figure 4**. Based on the data, annual rainfall in 2009, 2010, and 2011 near the project site was recorded to be approximately 59.3, 42.1, and 47.7 inches, respectively. Therefore, annual rainfalls in 2009, 2010, and 2011 represent a high rainfall year, a low rainfall year, and an average rainfall year, respectively. The monthly rainfall at this station between January 2009 and December 2011 is presented on **Figure 5**.

3.2 Physiography

As shown on **Figure 6**, TRLF site is located within the Trail Ridge sub-district of the Sea Island District, which belongs to the Atlantic Coastal Plain Section. The Trail Ridge sub-district is surrounded by St. Marys Upland in the east and High Flatwoods in the west. Trail Ridge is one of several long, low north-trending broad sand ridges that extend from northern Carlton County in southeastern Georgia to the southern parts of Clay and Bradford counties in north-central peninsular Florida (Brooks, 1981). It is a distinctive landform in this area of low topographic relief. The ridges are complex sand dunes formed during the Pleistocene, when sea level was some 150 feet higher than it is today. Heavy minerals are concentrated in the sandy sediments, which were eroded from rocks of the Appalachian highland to the north. These sediments were alluvial deposits that have been re-worked by beach shoreline and Aeolian effects. Trail Ridge has historically been mined for the industrial minerals ilmenite, leucoxene, and rutile. These titanium minerals and zircon are the principal minerals of the deposit. DuPont has been mining Trail Ridge since the late 1940s and is currently actively mining adjacent and upgradient to the Trail Ridge Landfill site (Pirkle, 1984).

3.3 Topography

A United States Geological Survey (USGS) quadrangle survey map showing 5-foot interval contours of the site is presented on **Figure 7.** There is approximately a 60 feet elevation difference across the site with topographic elevations ranging from 155 feet National Geodetic Vertical Datum (NGVD) along the southwestern border of the landfill boundary to 95 feet NGVD along the northeastern extents. A professional surveyor and mapper registered in the State of Florida (Robert M. Angus & Associates) was contracted to provide 1 foot topographic contours for the existing landfill expansion property. These contours are depicted on Sheet C-1 of the project design plans titled *City of Jacksonville, Florida Trail Ridge Landfill Construction Phases 6-14 Class I Cell Expansion*. These 1 foot topographic contours were used in the groundwater model to define existing site conditions.

3.4 Regional and Site Geology

The geology of TRLF site and Duval County in General consists of six geologic units (Miller, 1986; Krause and Randolph, 1989; Phelps, 1993; Leve, 1966; Fairchild, 1972) as listed below in descending order:

- Undifferentiated clastic deposits of Holocene, Pleistocene, and Pliocene age;
- Hawthorn Group of Miocene age;
- Ocala Limestone late Eocene age;
- Avon Park of middle Eocene age;
- Oldsmar middle to early Eocene age; and
- Cedar Keys Formation of early Eocene and late Paleocene age.

An east to west geologic section through Duval County is presented on **Figure 8**. The undifferentiated clastic deposits of Holocene, Pleistocene, and Pliocene age are composed of unconsolidated soils, predominantly sand, clayey sands, and sandy clay, which were deposited during former high sea levels. Where present, these deposits make up the surficial aquifer. These sediments, which comprise the surficial aquifer system, are located across the county and range in thickness from 10 feet to 100 feet (Phelps, 1993).

Detailed descriptions of other geologic units can be found in *Hydrogeologic Summary and Background Monitoring Report for the Trail Ridge Landfill Phases 6-14 Class I Cell Expansion* (CDM Smith, 2013) located in **Appendix P** of the Solid Waste Landfill Permit application package.

3.5 Regional Hydrogeology

In order of occurrence from the land surface, there are three distinct hydrogeologic units of interest within Duval County: the surficial aquifer, the intermediate confining unit (ICU), and the Floridan Aquifer (Phelps, 1993; Leve, 1966; Fairchild, 1972). Figure 8 shows the hydrogeologic units and corresponding geologic units in an east-west direction through Duval County taken from literature (Phelps, 1993). The surficial aquifer system exists throughout Duval County and consists of two water bearing units: the upper water table unit and the lower limestone unit. The surficial deposits, which include the surficial aquifer system, extend from land surface to the top of the upper confining bed of the ICU. The ICU is generally composed of mostly clay and sandy, phosphatic limestone and ranges in thickness from 300 feet to 600 feet. The Floridan Aquifer System (FAS) consists of thick sequence of limestone and dolomite and is the principal source of drinking water in Duval County. The thickness of the FAS ranges from 1,600 feet in southwest Duval County to 2,200 feet in the northeast portion of the county.

3.5.1 Surficial Aquifer System

The surficial aquifer system exists throughout Duval County and consists of two water bearing units: the upper water table unit and the lower limestone unit. The average thickness of the surficial aquifer system ranges from 10 feet near the St. Johns River Valley to 100 feet thick in western Duval County. The thickness of the surficial aquifer system at the Trail Ridge Landfill varies from approximately 90 feet to 100 feet. Groundwater flow in the surficial aquifer system generally follows the land surface. As shown on **Figure 9,** groundwater elevation mapping from 1969, the direction of groundwater flow, west of the St. Johns River, is from west to east toward the river. East of the St. Johns River, there is a high in the water surface and groundwater flow radially away from the high toward the river and the coast. Also shown on Figure 9 is an east–west profile showing the groundwater elevation of the surficial aquifer system relative to the land surface elevation and the potentiometric surface of the Floridan Aquifer.

3.5.1.1 Water Table Unit

The water-table unit is the upper part of the surficial aquifer system and consists of sediments ranging from 25 feet to 50 feet that were deposited during the formation of the marine terraces and beach ridges. The surficial sediments consist mostly of fine to medium-grained quartz sand, but could contain thin beds of sandy clay. In places, shell beds are present in the surficial sediments, especially near the coast. In some areas, the sand or shell is stained reddish brown or orange by iron oxide (a compound of iron and oxygen). Discontinuous (unevenly distributed) layers of sand cemented by iron oxide, known as hardpan, underlie parts of the county and range in thickness from about 0.5 feet to 20 feet. Water levels in wells that tap the water table and limestone units of the surficial aquifer system fluctuate seasonally in response to rainfall. The water-table unit receives most of its recharge directly from rainfall. The water table can fluctuate as much as 5 feet between the wet and dry seasons.

3.5.1.2 Limestone Unit

The limestone unit is the lower part of the surficial aquifer system and contains deposits ranging in thickness from less than 10 feet in the southwestern part of Duval County to as much as 130 feet in the west-central part of the county (Fairchild, 1972). The varying thickness is due to irregularities in the surface of the underlying Hawthorn Formation. The limestone unit deposits consist of interbedded lenses of fine-to-medium sand, shell, green calcareous silty clay, and limestone. The limestone is a soft, cavernous, sandy limestone that is dolomitic in places. Along the coast and in the southern part of the county, the limestone becomes discontinuous and grades into medium-to-coarse sand and shell deposits. Water levels in wells completed in the limestone unit, like those in the water-table zone, fluctuate seasonally. Generally, the seasonal water-level fluctuation in the limestone unit is about 1 foot to 5 feet.

3.5.2 Intermediate Confining Unit

Underlying the surficial aquifer is the ICU. The ICU in Duval County is relatively thick (250 feet to 500 feet) and consists primarily of clay that contains some sand, limestone, phosphatic clay, marl, calcareous sandstone, and limestone residuum (Phelps, 1993). The leakance of the ICU ranges from approximately 10^{-5} to 10^{-7} feet/day/feet in Duval County (Boniol *et al.,* 1993).

3.5.3 Floridan Aquifer System

Underlying the ICU are the permeable limestone sediments of the Upper Floridan aquifer including the Ocala Limestone, the Avon Park Formation, and the Oldsmar Formation (Phelps, 1993). The transmissivity of this aquifer is quite high and it is the primary source of water supply in Duval County. From aquifer performance tests conducted in the county, transmissivity ranges from 22,000 $feet^2$/day to 202,000 $feet^2$/day (Phelps, 1993; Krause and Randolph, 1989).

3.5.4 Fernandina Permeable Zone

The Fernandina permeable zone is a high-permeability unit that lies at the base of the FAS. In the Jacksonville area, the unit includes the lower Oldsmar and upper Cedar Keys Formations (Krause and Randolph, 1989). Little is known about the extent or thickness of the Fernandina permeable zone because of the scarcity of data. Only four wells in Duval County and one test well each in Fernandina Beach and Ponte Vedra are known to penetrate the Fernandina permeable zone. In the Jacksonville area, the zone is estimated to be about 100 feet thick. No aquifer test data are available to calculate the transmissivity of the Fernandina permeable zone.

3.5.5 Sub-Floridan Confining Unit

Beneath the FAS is a confining unit known as the Sub-Floridan Confining Unit. The Sub-Floridan Confining Unit generally corresponds to the Cedar Keys Formation.

3.6 Site Hydrogeology

3.6.1 Surficial Aquifer System

The soil profiles presented in *Appendix F, Attachment A* of the Geotechnical Data report (CDM Smith, 2012b) were converted to hydrogeologic cross sections through the landfill expansion property. **Figure 10** shows the locations for eight cross sections through the site. All eight cross sections are presented in **Attachment A** of this memorandum. One representative west-east (section 3) and one representative south-north (section 6) hydrogeologic cross section are presented on **Figure 11** and **Figure 12**, respectively.

As shown on the cross-sections, there are two units that comprise the surficial aquifer system in the proposed landfill expansion area. In order of increasing depth, these include: the water table unit (40 feet to 130 feet thick), which consists of sand and slightly silty sand and the limestone unit (0 feet to25 feet thick). The limestone unit is not continuous across the site. Between these two aquifer units, there is a semi-confining zone of low permeability sediments comprised of clay, clayey sand and silty sand, which is not continuous across the site. Where present, the semi-confining unit ranges in thickness from 6 to 45 feet. These hydrogeologic units are consistent with the regional hydrogeology of the surficial aquifer system described in Section 3.5.1 above. The lithologic, hydrogeologic, and geotechnical data were generally used to establish the layers in the groundwater flow model.

The background groundwater monitoring well network described in Section 7.0 of *Hydrogeologic Summary and Background Monitoring Report* (see Appendix P of the of the Solid Waste Landfill Permit application package)consists of monitor wells installed to three different depths generally described as shallow, intermediate and deep. The shallow monitor wells are installed to depths ranging from 10 feet to 30 feet below land surface (bls) representative of the uppermost portion of the water table unit of the surficial aquifer system. The intermediate (depth) monitor wells are installed to depths ranging from 40 feet to 65 feet bls representative of the middle to lower portion of the water table unit of the surficial aquifer system. The deep monitor wells are installed to depths ranging from 100 feet to 110 feet bls representative of the limestone unit of the surficial aquifer system.

The semi-confining unit of the surficial aquifer system that separates the water table and limestone units is thinner or absent in the western portions of the site and thickens from west to east. The head differentials (groundwater elevation differences) between the shallow, intermediate and deep monitor wells clearly show the effects of the semi-confining unit, where present. As shown on the times series of onsite groundwater levels presented in *Attachment B* of the *Hydrogeologic Summary and Background Monitoring Report*, groundwater levels in the deep monitor wells are higher than groundwater levels in the shallow monitor wells in the eastern portion of the site. Groundwater levels in the deep monitor wells are slightly lower than or coincident with groundwater levels in the shallow monitor wells in the western portions of the site. This indicates that there is a high recharge area for the surficial aquifer system that is most likely occurring to the west of the landfill property (Trail Ridge). The recharge surcharges groundwater levels in the limestone unit in the ridge and when the limestone unit comes into contact with the semi-confining beds along the eastern margin of the ridge and the site an artesian condition (and sometimes free flowing condition) develops. The pressure head in the limestone unit is slowly dissipated with upward flow through the semi-confining unit and with continued flow through the water table unit. In the eastern portions of the site, the groundwater levels in the intermediate depth monitor wells are higher than groundwater levels in the shallow monitor wells.

4.0 Groundwater Flow Model

4.1 Conceptual Groundwater Flow Model

The formulation of a conceptual model is one of the first steps in groundwater flow model development. The conceptual model provides a basic understanding of the general groundwater flow directions in the aquifer systems in both the vertical and horizontal directions, and forms the basis for the establishment of the model dimensions and grid system, model layering, and the boundary conditions that represent the aquifer system in the numerical groundwater flow model.

There are three distinct hydrogeologic units of interest within the TRLF site:

- Surficial Aquifer;
- Intermediate Confining Unit (ICU); and
- Floridan Aquifer.

Only surficial aquifer was represented in the groundwater flow model developed for the TRLF site. The underlying ICU is relatively thick (250 feet to 500 feet) with leakance ranging from approximately 10^{-5} to 10^{-7} feet/day/feet impeding any significant interaction between the surficial aquifer and the underlying Floridan aquifer. The top of the ICU is assumed to be a no flow boundary in the model. For this project, seven model layers are used to represent the hydrogeologic aquifer units within surficial aquifer. The model layers and corresponding hydrogeologic units used in the TRLF model are:

- Layer 1 – Upper Surficial Unit A;
- Layer 2 – Low Permeability Unit 1;
- Layer 3 – Upper Surficial Unit B;
- Layer 4 - Low Permeability Unit 2;
- Layer 5 – Upper Surficial Unit C;
- Layer 6 - Low Permeability Unit 3; and
- Layer 7 – Deep Surficial or Limestone Unit.

Model layers 1 through 5 correspond to the water table portion of the surficial aquifer and Layer 7 corresponds to the limestone portion of the surficial aquifer as described in Section 3.6.1 above.

The low permeability units typically occur along the eastern site boundary and gradually pinch out when moving from east to west. The regional groundwater flow direction of the surficial aquifer is from west to east toward the St. Johns River. In the TRLF site, the groundwater flow direction in the surficial aquifer is from west-southwest to east-northeast. The groundwater gradient is relatively steep at the TRLF site due to its location on the slope of Trail Ridge. The groundwater divide is located just west of the TRLF site on top of the ridge. The groundwater levels at the TRLF site are also influenced by the drainage ditches that run west to east at several wetland locations within the site. Groundwater levels in the deep surficial aquifer unit are slightly below or closer to upper surficial aquifer along the western boundary of the site. However, along the eastern boundary the groundwater levels in the deep surficial aquifer are higher than the shallow surficial aquifer indicating upward groundwater flow.

4.2 Groundwater Flow Model Code Selection

In selecting the numerical flow model for this project, considerations were given to the following factors:

- Availability - The models should be available commercially or be in the public domain, i.e. the code is open to review and modification for all users;
- Documentation - The background theory, usage, and limitations of the models should be well documented;
- Capability - The models should be capable of providing realistic representations of the groundwater systems at the project site; and
- Acceptability - The models should be widely accepted and used by the regulatory agencies.

Based on the above considerations, the USGS MODFLOW model was selected for groundwater flow modeling for this project. MODFLOW, which is available in the public domain, is a modular three-dimensional finite difference model capable of simulating complex groundwater flow conditions. The model was originally developed by Michael McDonald and Arlen Harbaugh (1988) of the United States Geological Survey (USGS), and has been improved and updated by the USGS and other program developers. The MODFLOW model is very versatile, can accept a variety of boundary conditions, and can incorporate various elements such as rivers, drains, wells, streams, recharge, evapotranspiration, *etc*. It can simulate groundwater flow under steady-state or transient conditions. The Groundwater Vistas (GV) software with powerful graphics capabilities was used along with MODFLOW for pre and post processing of data.

4.3 Model Extent and Grid Design

The model area selected for this project spans a distance of 10 miles in the north-south direction, and 11 miles in the east-west direction, encompassing approximately 110 square miles. As shown on **Figure 13**, the model covers portions of Baker, Clay, Duval, and Nassau counties. The entire model area was discretized into cells using a non-uniform grid system (*i.e.*, a grid system with variable grid spacing), as illustrated on **Figure 14**. As shown, the model area was divided into 469 rows and 433 columns, with a grid spacing ranging from 25 feet near the proposed perimeter and interceptor ditches at the TRLF expansion site to 200 feet at the model boundary. The State Plane East coordinates of the southwest corner of the model grid (model origin) are 309,000 feet Easting and 2,118,910 feet Northing.

4.4 Temporal Discretization

The groundwater flow model was temporally discretized into 36 monthly stress periods covering 12 months each in 2009 (high rainfall year), 2010 (low rainfall year), and 2011 (average rainfall year). Each of the 36 stress periods is 31, 30, or 28 days in length depending on the month. The total time length of the groundwater flow model simulations is 1,095 days.

4.5 Model Layers

The site geotechnical data were carefully evaluated and analyzed to determine the hydrostratigraphic units or model layers. Realistic model simulations are dependent on an accurate representation of the hydrostratigraphic units in the groundwater flow model. A hydrostratigraphic unit is one of similar composition and hydraulic conductivity. From a groundwater modeling standpoint, the layering must consider the hydrostratigraphic properties of the stratum. Therefore, based on careful review and evaluation of the results from CDM Smith geotechnical field exploration and testing program (CDM Smith, 2012b) at the TRLF expansion site and the proposed borrow pit site (located south of the existing landfill cell) as well as review of historic boring logs of the site, the surficial aquifer beneath the TRLF site was divided into multiple hydrostratigraphic layers for groundwater modeling purposes. A total of seven hydrostratigraphic units were selected for the groundwater flow model. All seven layers represent the full thickness of the surficial aquifer in this area. The ICU beneath the surficial aquifer is a no flow boundary that forms the base of the model. These seven layers in descending order are as follows:

- Layer 1 (Upper Surficial Unit A) represents the uppermost layer of sand and sand with silt;
- Layer 2 (Low Permeability Unit 1) contains sand with clay, clayey sand, and clay;
- Layer 3 (Upper Surficial Unit B) contains poorly-graded to well-graded sand
- Layer 4 (Low Permeability Unit 2) contains poorly-graded sand with silt and clayey sand;
- Layer 5 (Upper Surficial Unit C) contains poorly-graded to well-graded sand and poorly graded sand with silt;
- Layer 6 (Low Permeability Unit 3) contains clayey sand, silty sand, and low to high plasticity clay; and
- Layer 7 (Deep Surficial Unit) represents the limestone unit.

The boring logs also show that, the thickness of each hydrostratigraphic layer varies spatially within the TRLF site. The average thicknesses of each layer within the TRLF site are shown in **Table 1.** A typical cross-section showing all the model layers are shown on **Figure 15**. Due to lack of availability of hydrostratigraphy data outside the TRLF site, the layer elevations and thicknesses were extrapolated using 2 feet LIDAR contours and onsite hydrostratigraphy data.

Table 1. Groundwater Model Layer Thickness

Model Layer No.	Model Layer Name	Average Thickness (feet)
1	Upper Surficial Unit A	20.0
2	Low Permeability Unit 1	7.0
3	Upper Surficial Unit B	20.2
4	Low Permeability Unit 2	11.8
5	Upper Surficial Unit C	22.3
6	Low Permeability Unit 3	8.8
7	Deep Surficial Unit	14.9

4.6 Hydrogeologic Properties

Hydrogeologic properties, including horizontal hydraulic conductivity, vertical hydraulic conductivity, and storage coefficients, were required for input to each layer of the groundwater flow model. The primary source of data used to establish reasonable ranges of these hydrogeologic properties was the geotechnical field exploration performed by CDM Smith. Specifically, horizontal hydraulic conductivities obtained from slug tests were used to establish reasonable ranges of hydrogeologic properties for the calibration of the groundwater flow model. Vertical hydraulic conductivity was assumed to be 10% of horizontal hydraulic conductivity. Specific yield and storage coefficients were assumed to be 0.1 and 1×10^{-3}, respectively throughout the model. After reasonable ranges of initial hydrogeologic properties were established for each layer, a number of iterations were made to calibrate the model-predicted groundwater elevations to match the measured groundwater elevations in all the seven layers. During calibration, the hydrogeologic properties (primarily horizontal and vertical hydraulic conductivity) were adjusted within a reasonable range of published values for the lithologic characteristics of each layer to achieve the best overall agreement between the measured and model-predicted groundwater elevations.

4.7 Aquifer Recharge and Evapotranspiration

Typically aquifer recharge is calculated by subtracting the runoff and evapotranspiration (ET) from rainfall. Spatial distribution of recharge for the TRLF groundwater flow model was adopted from the modified North East Florida (NEF) model developed by the St. Johns River Water Management District (Birdie, et al., 2008) . Since the NEF model is a steady state model that uses average annual 1995 rainfall, factors representing monthly rainfall from January 2009 through December 2011 were calculated and applied to the average annual 1995 recharge to the generate 2009 through 2011 monthly recharge distribution. The advantage of using the recharge distribution from the NEF model is that it account for runoffs as well as irrigation return flow. The spatial distribution of maximum ET rate and extinction depth were also obtained from the modified NEF model and used in the TRLF model.

The Evapotranspiration Package in MODFLOW simulates the effect of direct evaporation from the water surface and plant transpiration in the model based on following assumptions:

- When the water table is at or above a specified elevation, termed the "ET surface" (typically the land surface), evaporation loss from the water table occurs at a maximum ET rate specified by the user.
- When the depth of the water table below the ET surface elevation exceeds a specified interval, termed the "extinction depth", evapotranspiration from the water table ceases.
- Between the limits above, evapotranspiration from the water table varies linearly with water table elevation.

During calibration, the recharge factors were adjusted to achieve the best overall agreement between the measured and model-predicted groundwater elevations for the period between 2009 and 2011.

4.8 Boundary Conditions

There are three types of boundary conditions typically used in numerical groundwater flow modeling as follows:

- Constant head boundary;
- Specified flow boundary; and
- Head-dependent boundary.

All three boundary conditions are used in the TRLF groundwater flow model. The boundary conditions used in the model are shown on **Figure 16**.

Constant head boundaries are used to represent the existing borrow pit pond and mining ponds located south of the TRLF site.

Specified flow boundaries are used when the flow across a given area is known. A no flow boundary is a specified flow boundary where the flow is zero. The no flow boundary is assigned to the bottom of layer 7 to represent the ICU beneath the surficial aquifer system. Recharge and well pumping are the other specified flow boundaries used in the model. Please refer to Section 4.7 for detailed description on the recharge distribution used in the model. There are only two permitted wells that tap into the surficial aquifer within the model domain. These two wells belong to Global Shredding Technologies and they are located approximately 4 miles northeast of the TRLF site. Actual pumping rates for the 2009 -2011 time period were obtained from the SJRWMD and used in the model.

Head-dependent boundaries are used when the flow across a boundary is calculated given a boundary head value. There are several types of head-dependent boundary conditions. Rivers that can act as either a source or a sink for groundwater, General Head Boundaries (GHB) that are typically used along the lateral edges of the model and Drains which act only as a sink for groundwater. In the TRLF model, the MODFLOW River package was used to represent natural streams, rivers, tributary wetlands, ponds and ditches and the DuPont North Maxville mining ponds. The River package was used to represent Turkey Creek to the west, Deep Creek to the north, Yellow Water Creek to the east, and Long Branch Creek to the south. Water levels from on-site staff gauges and continuous simulation results from the project Surface Water Management Model (SWMM) were used to define the MODFLOW River boundary elevations. The locations of the on-site staff gauges, which were used to help define onsite surface elevations in the model, are shown on Figure 16.

Settling ponds at the DuPont North Maxville mining facility are located within 0.5 mile west of the TRLF site. Since water level data for these ponds are not in the public domain and are not easily accessible, surface water elevations for these ponds were assigned based on hydrographic data in Google Earth. However, when the measured water level of a pond adjacent to the existing landfill cell was compared to their corresponding Google Earth hydrography value, they were 11 feet higher. To account for this discrepancy, the Google Earth water levels for the DuPont settling were reduced by 11 feet before using in this data in the model.

All four lateral edges of the model were assigned the MODFLOW General Head Boundary (GHB). These boundaries are far away from the TRLF site on western, northern, and southern directions to not have any significant impact on the groundwater levels and flow direction at the TRLF site. The General Head Boundary along the western edge of the model domain is only three miles from TRLF site. However, the groundwater divide falls in between the TRLF site and the western GHB along Trail Ridge, mitigating any impact of the GHB on the groundwater levels and flow direction at TRLF site.

All the constant head boundaries and river boundaries are present only in Layer 1 of the groundwater flow model. The GHB boundaries are present in layers 1 through 7, while wells are exist only in Layer 7.

4.9 Groundwater Flow Model Calibration

Prior to using TRLF groundwater flow model for predictive simulations, the model was calibrated to match known conditions (*i.e.*, groundwater elevations and groundwater flow patterns) within the model domain. Acceptable flow model calibration is accomplished by finding a set of hydraulic properties (typically hydraulic conductivity and recharge rate) and boundary conditions within a prescribed range of published values that produce simulated heads and fluxes that match field measurements with a reasonable degree of accuracy.

4.9.1 Calibration Data

For TRLF groundwater model calibration, the simulated groundwater levels were compared with measured groundwater elevations at 94 monitoring locations within the TRLF site. Out of the 94 monitoring locations, 28 were part of the 12 monitor well clusters installed by CDM Smith, 4 were piezometers installed by CDM Smith, 16 were the piezometers installed by ETM in the wetlands just north of the existing landfill cell in the vicinity of ditch B, and 46 were part of cluster wells installed by Waste Management, Inc. around the existing landfill cell. The locations of these monitor wells and piezometers are shown on **Figure 17**. The groundwater model was calibrated to match the simulated groundwater elevation to measured groundwater elevations at these monitor well and piezometer locations for the period 2009-2011.

4.9.2 Calibration Parameters

The model hydrogeologic parameters were modified to match the simulated groundwater elevations to the observed groundwater levels in all 94 monitor wells for 36 monthly stress periods for the period 2009-2011. Modified model parameters included;

- Horizontal and vertical hydraulic conductivities; and
- Recharge.

4.9.3 Calibration Criteria

There are several references that can be used for guides to groundwater flow model calibration (ASTM, 2002; Hill and Tiedeman, 2007; Anderson and Woessner, 1992). The following criteria were taken from these guides and applied to the modeling for this project. The model calibration was completed when the following criteria were met by the transient groundwater flow model:

- The average of residuals (observed minus model-computed) in groundwater elevations is less than 1 foot in all layers;
- The average of absolute residuals in groundwater elevations is less than 2.0 feet in all layers;
- The standard deviation of residuals in groundwater elevations is less than 2.0 feet in all layers;
- The ratio of average of residuals to the total observed head change is less than 5 percent in all layers;
- The ratio of average of absolute residuals to the total observed head change are less than 10 percent in all layers; and
- The ratio of standard deviation of the residuals to the total observed head change are less than 10 percent in all layers.

In addition to these numerical criteria, some subjective criteria were also considered:

- The model needed to adequately represent the measured flow patterns both laterally and vertically; and
- There should be little to no spatial bias in residuals.

The calibration parameters were varied systematically until these criteria were met.

4.9.4 Calibration Results

ASTM D 5490-93 (Reapproved 2002) titled "*Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information*" provides industry-accepted guidance for groundwater flow model calibration. This guide covers techniques that should be used to compare the results of groundwater flow model simulations to measured field groundwater levels as part of the process of calibrating a groundwater flow model. This ASTM standard includes several calibration metrics. CDM Smith followed this guide to present groundwater calibration results, including comparison of simulated and measured groundwater level residuals, and standard deviation of residuals, as well as several other calibration metrics.

4.9.4.1 Groundwater Levels

With the adjustment of calibration parameters, CDM Smith was able to achieve good match of the simulated and measured groundwater elevations at all the monitor wells and piezometers except six Waste Management, Inc. monitor wells that are located around the existing landfill cell. These wells are B-10S, B-11I, B-11D, B-13SR, B-13IR, and B-17I. These monitor wells seem to have their measuring point elevation set at different vertical datum than the standard NGVD 1929 vertical datum used in this groundwater flow model and other monitor wells. These monitor wells were not used in the analysis of the calibration results.

As part of the process of calibrating groundwater models, scattergram comparisons of the observed and model-computed groundwater elevations are recommended. A comparison between the observed and model-computed groundwater elevations across all model layers is depicted on **Figure 18** using a scattergram at 88 monitor wells.

The correlation between the measured and model simulated groundwater elevations at each of the CDM Smith monitor well cluster CDM-1 through CDM-8 are presented in **Figures 19** through **44**. Hydrographs comparing the measured and model simulated groundwater elevations for all the monitor wells and piezometers are presented in **Attachment B**. The model calibration statistics for all of the aquifer layers and each individual layer are summarized in **Table 2**. **Table 3** shows the comparison calibration results to the numerical calibration criteria set forth in Section 4.9.3. As shown in these figures and tables, there is a very strong correlation between observed and model simulated groundwater elevations across all model layers.

Table 2 TRLF Groundwater Flow Model Calibration Statistics

Layer	Average of Residuals (feet)	Average of Absolute Residuals (feet)	Standard Deviation of Residual (feet)	Observed Head Range (feet)	Average of Residuals/Head Range (%)	Average of Absolute Residuals/Head Range (%)	Standard Deviation of Residuals/Head Range (%)
1	0.05	0.59	0.69	52.42	0.1%	1.1%	1.3%
2	-0.09	0.45	0.56	7.28	-1.2%	6.1%	7.7%
3	-0.07	1.44	0.79	41.19	-0.2%	3.5%	1.9%
4	0.28	1.51	1.09	23.03	1.2%	6.5%	4.7%
5	0.11	0.33	0.46	24.89	0.4%	1.3%	1.8%
6	-0.70	0.93	0.82	18.29	-3.8%	5.1%	4.5%
7	0.10	1.09	0.70	29.60	0.3%	3.7%	2.4%
Overall	***-0.04***	***0.90***	***0.73***	***28.10***	***-0.4%***	***3.9%***	***3.5%***

Table 3 Comparison of Calibration Results with Calibration Criteria

Calibration Parameter	Calibration Criteria	Model Results
Average of Residuals (feet)	< 1.0	-0.04
Average of Absolute Residuals (feet)	< 2.0	0.9
Standard Deviation of Residuals (feet)	< 2.0	0.73
Ratio of Average of Residuals to the Total Observed Head Change (%)	< 5%	-0.4%
Ratio of Average of Absolute Residuals to the Total Observed Head Change (%)	< 10%	3.9%
Ratio of Standard Deviation of the Residuals to the Total Observed Head Change (%)	< 10%	3.5%

4.9.4.2 Groundwater Flow Patterns

As shown on **Figure 45** the model simulated groundwater elevation contours for stress period 34 (October 2011) shows that the predominant groundwater flow in water table aquifer (Layer 1) is from west-southwest to east-northeast across the TRLF site. This overall model simulated groundwater flow pattern is consistent with groundwater flow pattern observed in the site during October 2011 (**Figure 46**).

4.9.4.3 Vertical Head Differences

As shown on **Figures 47** through **50**, vertical head differences between each layer (i.e., Layers 1 through 7) are significant along the eastern edge of the TRLF site. Significant vertical head differences generally indicate that there is a confining or semi-confining layer between each hydrogeologic layer, which is consistent with field exploration. **Figures 51** through **54** shows the model simulated groundwater elevations at these cluster well locations. Comparison of the observed and simulated vertical head differences show that the model has simulated the vertical head differences fairly well.

4.10 Groundwater Modeling Simulations

The purpose of the groundwater modeling simulations was to use the calibrated groundwater flow model to provide guidelines and input for the engineering design of the TRLF expansion.

Various components of the proposed landfill expansion are shown on **Figure 55**. For the purposes of the groundwater modeling, the TRLF was assumed to be expanded in the following sequential order:

- Fill in the existing ditches and wetlands within the TRLF expansion area;
- Construct the stormwater management pond and bypass pond (ponds A and B);
- Construct the perimeter and interceptor ditches around the entire TRLF expansion area;
- Construct interim stormwater ditches that run from south to north in the middle of the expansion area;
- Install landfill liner for Phases 6 and 7; and
- After Phases 6 and 7 gets filled, the landfill will expand to Phases 8 through 14 over a period of 30 years. The interim ditches will be filled as the landfill continues to expand towards the north.

Several modeling simulations were run to determine the water table elevation after each of the landfill components listed above are constructed. The water table elevations were compared with simulated groundwater elevations at the end of August 2011 (stress period 32), which represents existing average Seasonal High Water Table (SHWT) conditions at the site based on available on-site data from 2009 through 2011. In general, all the modeling simulations can be grouped under two categories:

- Simulations for the construction of Phases 6 and 7 of the landfill (Phases6&7); and
- Simulations for the construction of the entire landfill (Build-Out).

4.10.1 Construction of Phases 6 & 7 (Phases6&7)
A total of five simulations were performed to predict the changes in water table elevations during construction of various components of the Phase 6 & 7 of the landfill. These simulations are listed in **Table 4** along with the construction components they represent.

Table 4 Simulations for the Construction of Phases 6 and 7

Simulations	Existing On-site Ditches	Stormwater Management Ponds	Perimeter and Interceptor Ditches	Interim Interior Ditches	Landfill Liner	Under Drain
Phases 6&7_SIM1	Not Filled	Not Constructed	Not Constructed	Not Constructed	Not Installed	Not Used
Phases 6&7_SIM2	Filled	Not Constructed	Not Constructed	Not Constructed	Not Installed	Not Used
Phases 6&7_SIM3	Filled	Constructed	Constructed	Constructed	Not Installed	Not Used
Phases 6&7_SIM4	Filled	Constructed	Constructed	Constructed	Not Installed	Installed
Phases 6&7_SIM5	Filled	Constructed	Constructed	Constructed	Installed	Removed

A brief description of these simulations is given below:

- Phases 6&7_SIM1 represent the baseline or existing conditions, which is represented by the calibrated groundwater flow model.

- Phases 6&7_SIM2 was used to simulate the water table elevations after the existing on-site ditches and wetlands are filled. This was modeled by removing the river cells that represent the on-site ditches.

- Phases 6&7_SIM3 was used to simulate the water table elevations after the interceptor ditch, perimeter ditch, interim interior ditches, and the stormwater management ponds A and B were constructed. The MODFLOW Drain package was used to represent all of the ditches. The interceptor and perimeter ditches are lined with Filter Point Lining material to allow groundwater seepage. A hydraulic conductivity of 25 feet/day was used to represent this lining material in the MODFLOW Drain package. Since the interim ditches are shallow and do not have any liners the hydraulic conductivity of the soil beneath the ditches was used to represent the hydraulic conductivity drain bed material in Drain package. A MODFLOW constant head boundary condition was used to represent the stormwater management ponds A and B. A normal water level of 100.5 feet NGVD and 97.0 feet NGVD were used as constant head elevations for ponds A and B, respectively.

- Phases 6&7_SIM4 was used to simulate the drop in water table elevations after an underdrain was installed along the ditch B alignment just north of the existing landfill cell. An underdrain may be necessary to drain pockets of perched groundwater that are present within the former wetland area. The underdrain will also keep the water table lower to allow the installation of landfill liner during Phases 6 and 7.

- Phases 6&7_SIM5 was used to simulate the water table elevations after the landfill liner was installed. This was simulated by changing the recharge and ET within the liner extent in Phases 6 and 7 to zero. Recharge was still applied to the remainder of the expansion property (Phases 8 through 14) for this simulation.

4.10.2 Build-Out of Landfill Expansion Property (BuildOut)

A total of four simulations were performed to simulate the changes in water table elevations during construction of various components leading up to the build-out of the TRLF Expansion Property. These simulations are listed in **Table 6** along with the construction components they represent.

Table 5 Simulations for the Build-Out of Landfill Expansion Property

Simulations	Existing On-site Ditches	Stormwater Management Ponds	Perimeter and Interceptor Ditches	Interim Ditches	Landfill Liner	Under Drain
Build-Out_SIM1	Not Filled	Not Constructed	Not Constructed	Not Constructed	Not Installed	Not Used
Build-Out_SIM2	Filled	Not Constructed	Not Constructed	Not Constructed	Not Installed	Not Used
Build-Out_SIM3	Filled	Constructed	Constructed	Not Constructed	Not Installed	Not Used
Build-Out_SIM4	Filled	Constructed	Constructed	Not Constructed	Installed	Not Used

A brief description of these simulations is presented below:

- Build-Out_SIM1 represents the baseline or existing conditions, which is represented by the calibrated groundwater flow model.
- Build-Out_SIM2 was used to simulate the water table elevations after the on-site ditches and wetlands are filled in. This was modeled by removing the river cells that represent the on-site ditches.
- BuildOut_SIM3 was used to simulate the water table elevations after the interceptor ditch, perimeter ditch, and the stormwater management ponds A and B were constructed. The MODFLOW Drain package was used to represent the ditches while a constant head boundary was used to represent the stormwater management ponds A and B. The bottom elevations and hydraulic properties of the ditches as well as the stage of the stormwater management ponds were the same as used for the Phase 6&7 simulations.
- Build-Out_SIM4 was used to simulate the water table elevations after the landfill liner was installed for Phases 6 through 14. This was simulated by changing the recharge and ET to zero within the entire liner extent in Phases 6 through 14.

4.11 Groundwater Modeling Results

Results of the groundwater flow modeling simulations are presented in the form of groundwater elevation contours and groundwater drawdown/recovery contours. The model simulated water table elevation contours represent the SHWT (stress period 32) during various phases of landfill construction. Groundwater level drawdown/recovery is calculated from the simulated baseline groundwater levels (Existing Conditions) representing the SHWT (August 2011).

4.11.1. Construction of Phases 6 & 7 (Phases 6&7)

The baseline water table elevations (*i.e.*, Layer 1) (Phases 6&7_SIM1) and water table elevations after the ditches are filled (Phases 6&7_SIM2) are shown on **Figure 56** and **57**, respectively. The changes in water table elevations due to filling in of the wetland ditches are shown on **Figure 58**. The figure shows that the water table has recovered (risen above existing elevations) as much as 8 feet at locations where the wetland ditches used to be.

Figure 59 shows the water table elevations after the interceptor ditch, perimeter ditch, interim ditches, and the stormwater management ponds A and B area constructed (Phases 6&7_SIM3). The changes in water table elevations due to these improvements when compared to the baseline conditions are shown on **Figure 60**. As shown on the figure, the water table elevation has been lowered by 3 feet to 4 feet along the western edge and 4 feet to 5 feet along the northern edge of the proposed landfill expansion foot print. The water table elevation has dropped as much as 8 feet along the stormwater management pond A. When compared to Figure 58, the recovery at the locations where the ditches used to be has been reduced from 8 feet to 3 feet, indicating an overall lowering of water table within the landfill expansion area footprint. The decline in water table can be clearly seen in **Figure 61**, which shows the change in water table elevations when compared with Phases 6&7_SIM2. This figure shows that the water table has dropped 0.5 foot to 8 feet across Phases 6 and 7 of the TRLF landfill expansion. The lowering of water table is attributed mostly to the stormwater management pond A (onsite stormwater management facility).

Figure 62 shows the water table elevations after an underdrain was installed along the existing wetland ditch B just north of the existing landfill cell (Phases 6&7_SIM4). The changes in water table elevations due to the under drain along with the interceptor ditch, perimeter ditch, interim ditches, and the stormwater management ponds A and B when compared to the baseline conditions are shown on **Figure 63**. **Figure 64** shows that the under drain has caused the water table to drop an additional 2.0 feet at the Phase 6 and 7 landfill expansion location. **Figure 65** shows that the under drain along with the interceptor ditch, perimeter ditch, interim ditches, and the stormwater management ponds A and B, have caused 1 to 8 feet of drawdown beneath the Phases 6 and 7 landfill foot print.

Figure 66 shows the water table elevations after the landfill liner is installed for Phases 6 and 7 cells (Phases 6&7_SIM5). The changes in water table elevations due to liner installation when compared to the baseline condition are shown on **Figure 67**. **Figure 68** shows that the water table has dropped 1 to 9 feet after the installation of liner when compared to Phases6&7_SIM2.

4.11.2 Build-Out of Landfill Expansion Property

The baseline water table elevations (*i.e.*, Layer 1) (BuildOut_SIM1) and water table elevations after the ditches are filled (Build-Out_SIM2) are shown on **Figure 69** and **70**, respectively. The changes in water table elevations due to filling in of the wetland ditches are shown on **Figure 71**. The figure shows that the water table has recovered as much as 8 feet at locations where the ditches used to be.

Figure 72 shows the water table elevations after the interceptor ditch, perimeter ditch, and the stormwater management ponds A and B area constructed (Build-Out_SIM3). The changes in water table elevations due to these improvements when compared to the baseline condition are shown on **Figure 73**. As shown on the figure, the water table has been lowered by as 3 feet to 4 feet along the western edge and 4 feet to 5 feet along the northern edge of the proposed landfill expansion foot print. The water table elevation has dropped as much as 8 feet along the stormwater management pond A. When compared to Figure 71, the recovery at the locations where the wetland ditches used to be has reduced from 8 feet to 3 feet, indicating an overall lowering of water table within the landfill expansion area footprint. The decline in water table can be clearly seen in **Figure 74**, which shows the change in water table elevations when compared with Build-Out_SIM2. This figure shows that the water table has dropped 1 to 8 feet across the landfill expansion foot print. The lowering of water table is attributed mostly to stormwater management pond A.

Figure 75 shows the water table elevations after the landfill liner is installed under landfill expansion footprint (Build-Out_SIM4). The changes in water table elevations due to liner installation when compared to the baseline conditions are shown on **Figure 76**. **Figure 77** shows that the water table has dropped 1 to 9 feet after the installation of liner when compared with BuildOut_SIM2.

5.0 Conclusions and Recommendations

Groundwater modeling simulations for the TRLF expansion project were completed using a groundwater flow model that was developed and calibrated by CDM Smith. Simulations were run for Phases 6 & 7 construction only and complete build-out of the entire landfill expansion property. Based the analysis of groundwater modeling results, the following conclusions can be reached:

- The water table recovers at the locations of existing wetland ditches when they are filled in. At some locations, the existing ditches are quite deep causing the water table to rise 5 feet to 8 feet at these locations to attain equilibrium. The existing wetland ditches not only conveyed stormwater runoff across the site but also had a significant water table lowering effect within the wetland areas.

- The interceptor ditch and perimeter ditch provide hydraulic control around the edges of landfill expansion site. However, at some locations the bottom of the ditches is above the water table and hence does not lower the water table at these locations. Where the water table is above the ditch bottom, the ditches lower the water table by 3 feet to 5 feet.

- The interim interior ditches are shallow and do not intercept sufficient groundwater to lower the water table significantly during construction.

- Stormwater Management Pond A (Onsite Stormwater Management Facility) has the largest impact on the water table elevations at the TRLF expansion site. With a normal water level of 100.5 feet NGVD, this pond lowers the water table by up to 8 feet when compared to the baseline condition. Cumulatively, Pond A lowers the SHWT by 13 feet at the pond location.

- Stormwater Management Pond B (Bypass Pond) with a normal water level of 97.0 feet NGVD, lowers the water table by as much as 2 feet when compared to the baseline condition. Cumulatively, Pond B lowers the SHWT by 4 feet at the pond location.

Analysis of groundwater modeling results also show that an underdrain may be necessary to drain perched groundwater (above the apparent water table) near the existing wetland ditch B north of the existing landfill cell. As shown in Figure 64, the underdrain lowers the water table by 2 feet within the filled in wetland area. This underdrain may be used during installation of the landfill liner in Phase 6 and 7 cells and removed after the installation of the liner. Underdains may be needed within the filled in wetland areas during liner installation of future phases of landfill construction (Phases 8 through 14).

6.0 References

Anderson, M.P. and W.W. Woessner, 1992. *Applied Groundwater Modeling, Simulation of Flow and Advective Transport*. Academic Press. 381 p.

ASTM Int'l, 2002. *Standard Guide for Comparing Ground-Water Flow Model Simulations to Site Specific Information*. Designation: D 5490-93 (Reapproved 2002).

ASTM Int'l, 2002. *Standard Guide for Defining Boundary Conditions in Ground-Water Flow Modeling*. Designation: D 5609-94 (Reapproved 2002).

ASTM Int'l, 2002. *Standard Guide for Defining Initial Conditions in Ground-Water Flow Modeling*. Designation: D 5610-94 (Reapproved 2002).

ASTM Int'l, 2002. *Standard Guide for Calibrating a Ground-Water Flow Model Application*. Designation: D 5981-96 (Reapproved 2002).

Birdie, T.R., Burger, P., Huang, C., and D. Munch, 2008. *Northeast Florida Regional Groundwater Flow Model: Model Revision and Expansion*. St. Johns River Water Management District Special Publication SJ2008-SP26.

Boniol, D., Williams, M., and D. Munch, 1993. *Mapping Recharge to the Floridan Aquifer System using a Geographic Information System*. St. Johns River Water Management District Technical Publication SJ93-5.

Brooks, H.K. 1981. *Guide to the Physiographic Divisions of Florida*. Institute of Food and Agricultural Sciences, University of Florida.

CDM Smith, 2013. *Hydrogeologic Summary and Background Monitoring Report for the Trail Ridge Landfill Phases 6-14 Class I Cell Expansion*. Draft Report dated July 2013 prepared for the City of Jacksonville, Florida.

CDM Smith, 2012a. *Trail Ridge Landfill Master Site Plan Phasing Report*. Final Report dated June 2012 prepared for the City of Jacksonville, Florida.

CDM Smith, 2012b. *Geotechncial Data Report, Trail Ridge Landfill Expansion*. Final Report dated July 2012 prepared for the City of Jacksonville, Florida.

Fairchild, R.W., 1972. *The Shallow-Aquifer System in Duval County, Florida*. Florida Geological Survey Report of Investigations No. 59.

Hill, M.C, and C.R. Tiedeman, 2007. *Effective Groundwater Model Calibration with Analysis of Data Sensitivities, Predictions, and Uncertainty*. Wiley-Interscience - A John Wiley & Sons, Inc Publication, Hoboken, NJ, 455p.

Krause, R.E. and R.B. Randolph, 1989. *Hydrology of the Floridan Aquifer System in Southeast Georgia and Adjacent Parts of Florida and South Carolina*. U.S. Geological Survey Professional Paper 1403-D.

Leve, G.W., 1966. *Ground Water in Duval and Nassau Counties, Florida*. Florida Geological Survey Report of Investigations No. 43.

McDonald, M. G. and Harbaugh, A. W. (1988). *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model*. Techniques of Water-Resources Investigations of the U.S. Geological Survey, Modeling Techniques, Chapter A1, Book 6.

Miller, J.A., 1986. *Hydrogeologic Framework of the Floridan Aquifer System in Florida and Parts of Georgia, Alabama and South Carolina*. U.S. Geological Survey Professional Paper 1403-B.

Pirkle, E. C., 1984. *The Yulee Heavy Mineral Sand Deposits of Northeastern Florida*. Journal of Economic Geology, Vol. 79, p. 725-737.

Phelps, G.G., 1993. *Water Resources of Duval County, Florida*. U.S Geological Survey Water-Resources Investigations Report 93-4130.

Figures

Legend

Trail Ridge Landfill Property Boundary

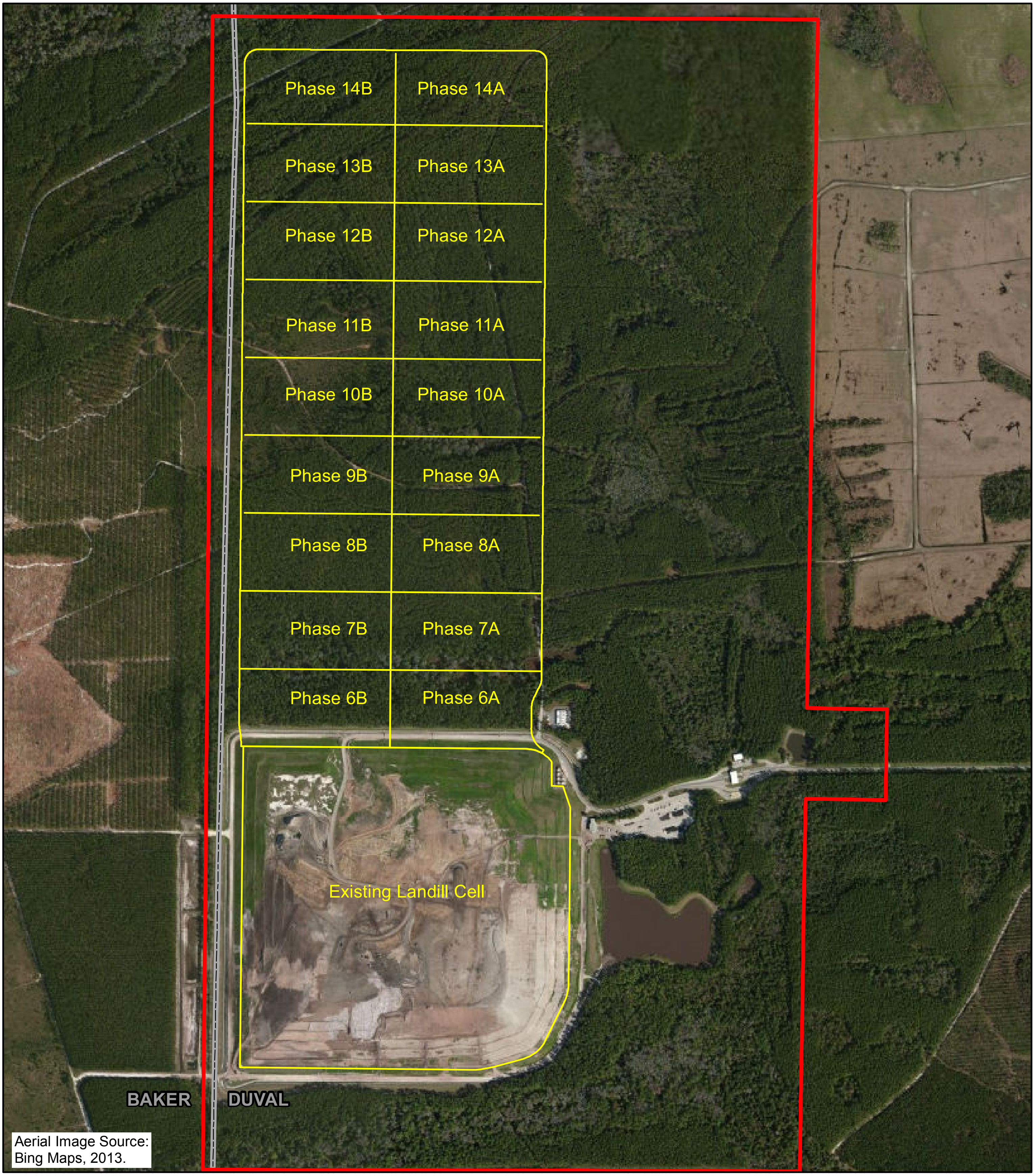
N W E S

0 0.5 1 Miles

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 1 General Location Map.mxd anandams 06/14/13

CDM Smith

Figure 1
General Location Map
Trail Ridge Landfill Expansion Project



Legend

- Landfill Cell Expansion Phases
- Trail Ridge Landfill Property Boundary
- County Boundary

N
W E
S

0 500 1,000 Feet

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 2 Proposed Expansion Phases.mxd anandams 06/14/13

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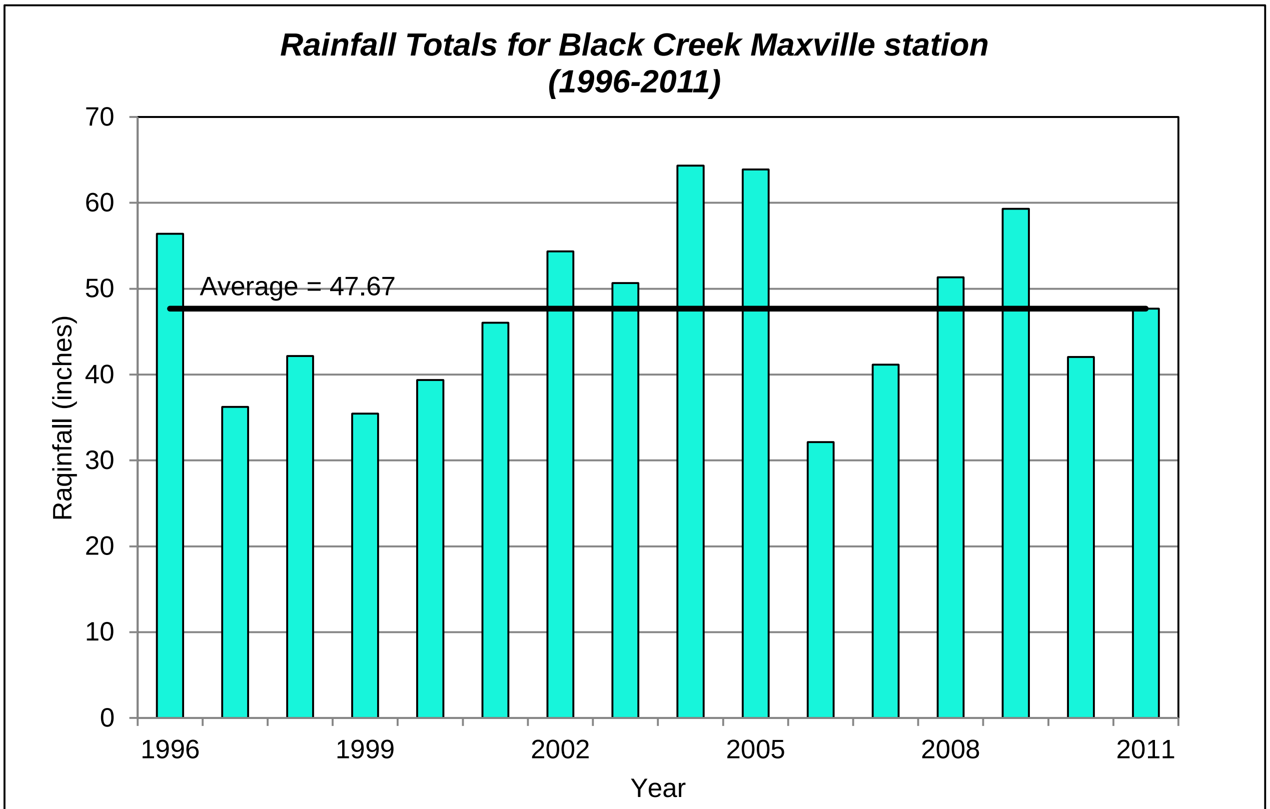
Figure 2
Proposed Phases of Landfill Expansion
Trail Ridge Landfill Expansion Project

CDM Smith

Figure 3
Black Creek Maxville Rainfall Station
Trail Ridge Landfill Expansion Project



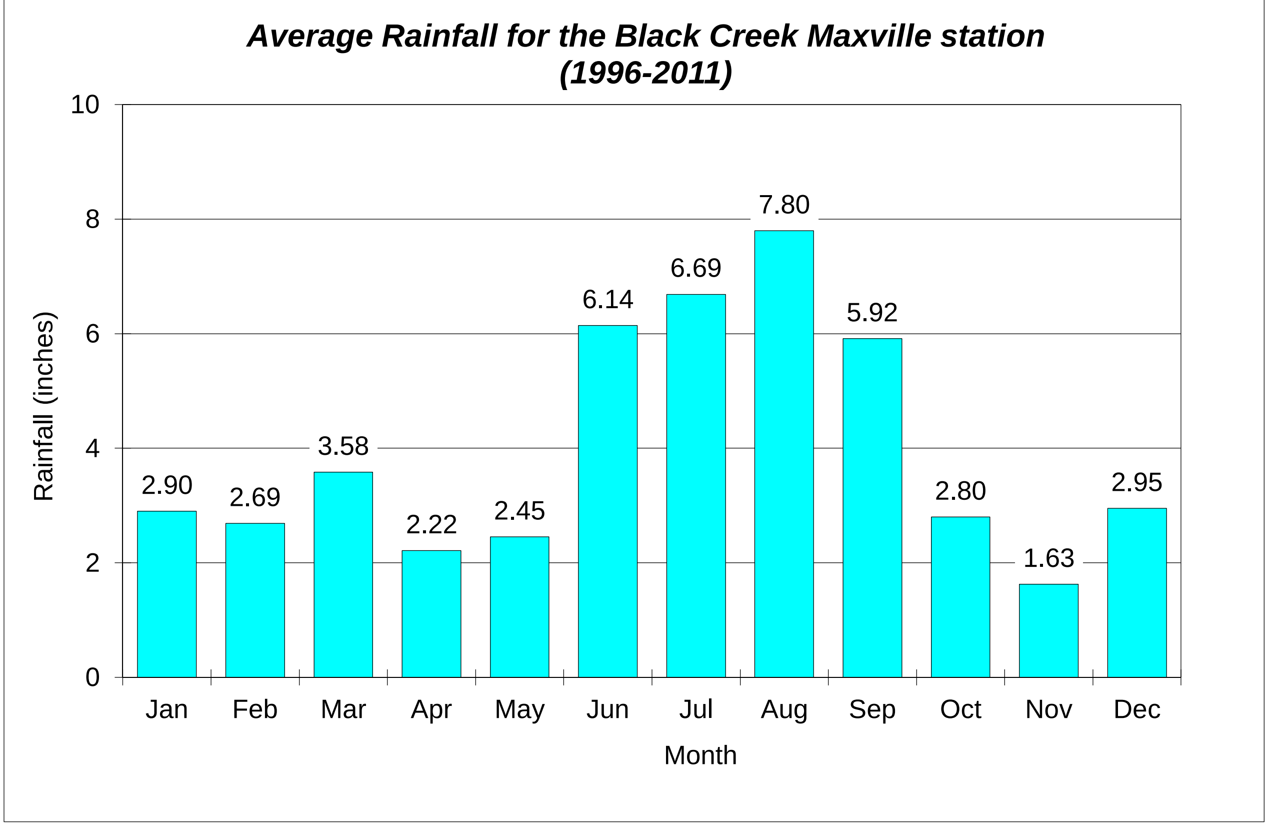


Figure 4
Annual and Monthly Rainfall Distribution at Black Creek Maxville Station
Trail Ridge Landfill Expansion Project

CDM Smith

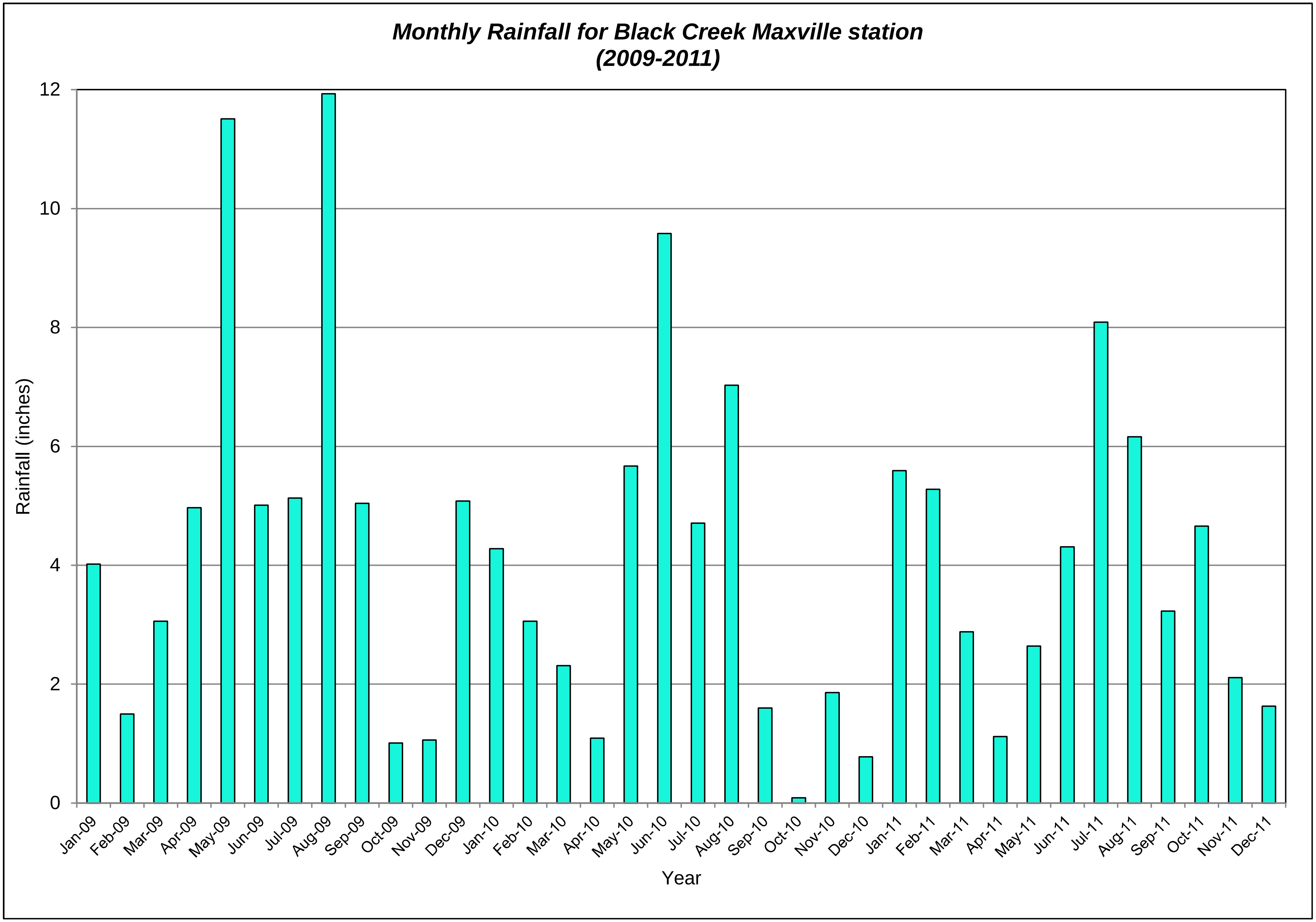
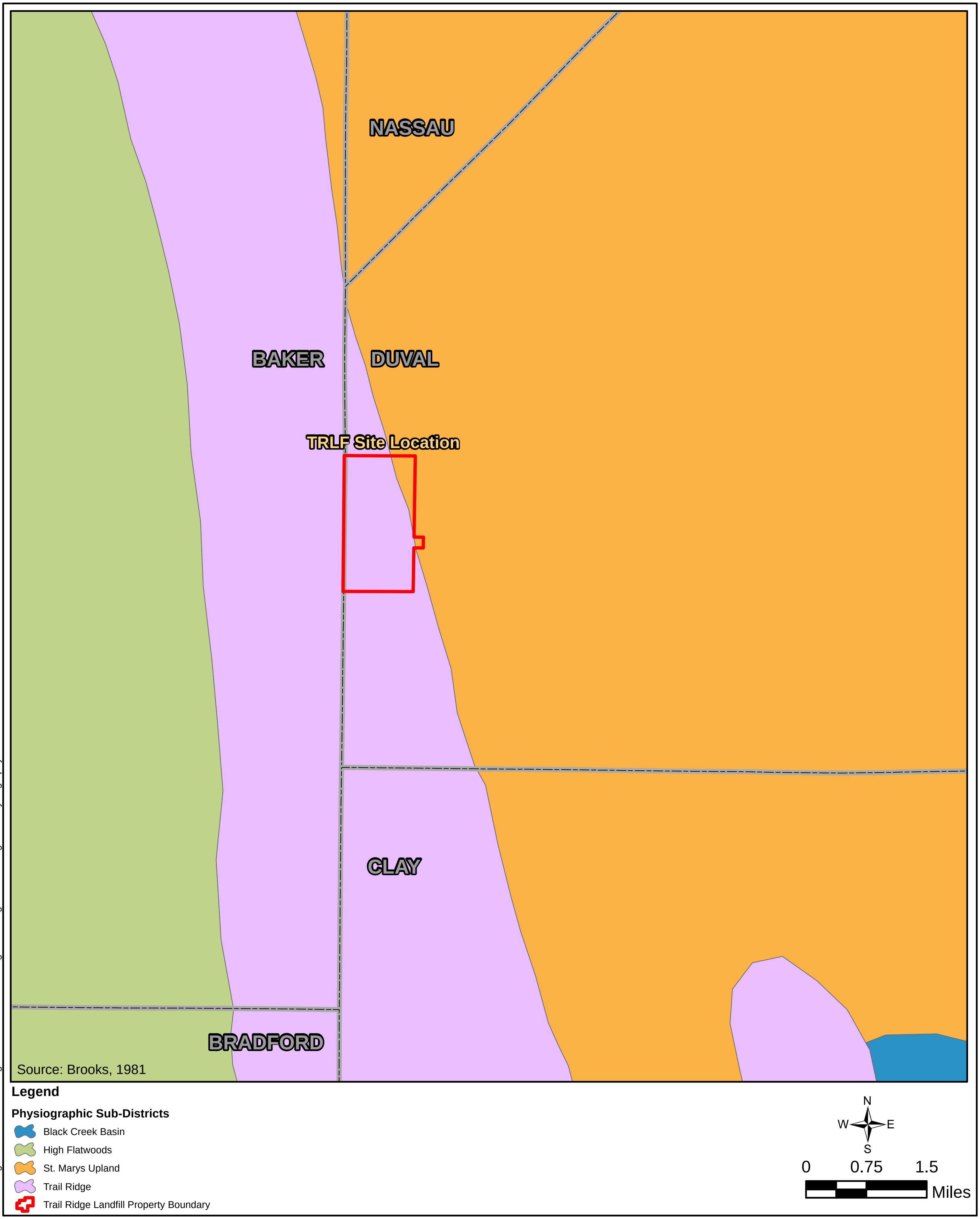


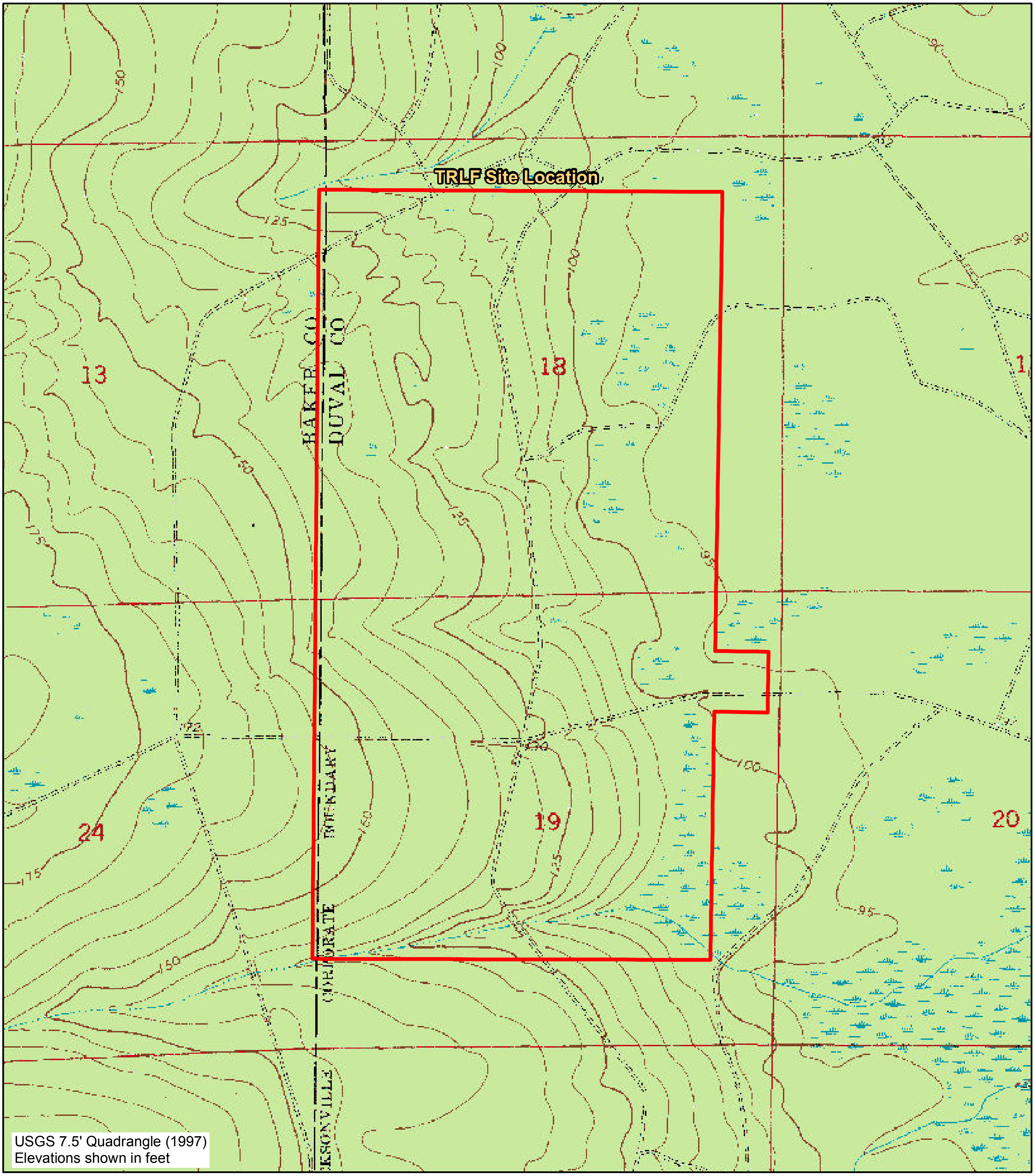
Figure 5
Monthly Rainfall Distribution at Black Creek Maxville Station During 2009 - 2011
Trail Ridge Landfill Expansion Project



\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 6 Physiography.mxd anandams 06/15/13

CDM Smith

Figure 6
Physiographic Sub-Districts
Trail Ridge Landfill Expansion Project



\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 7 USGA Topo Map.mxd anandams 06/14/13

Legend

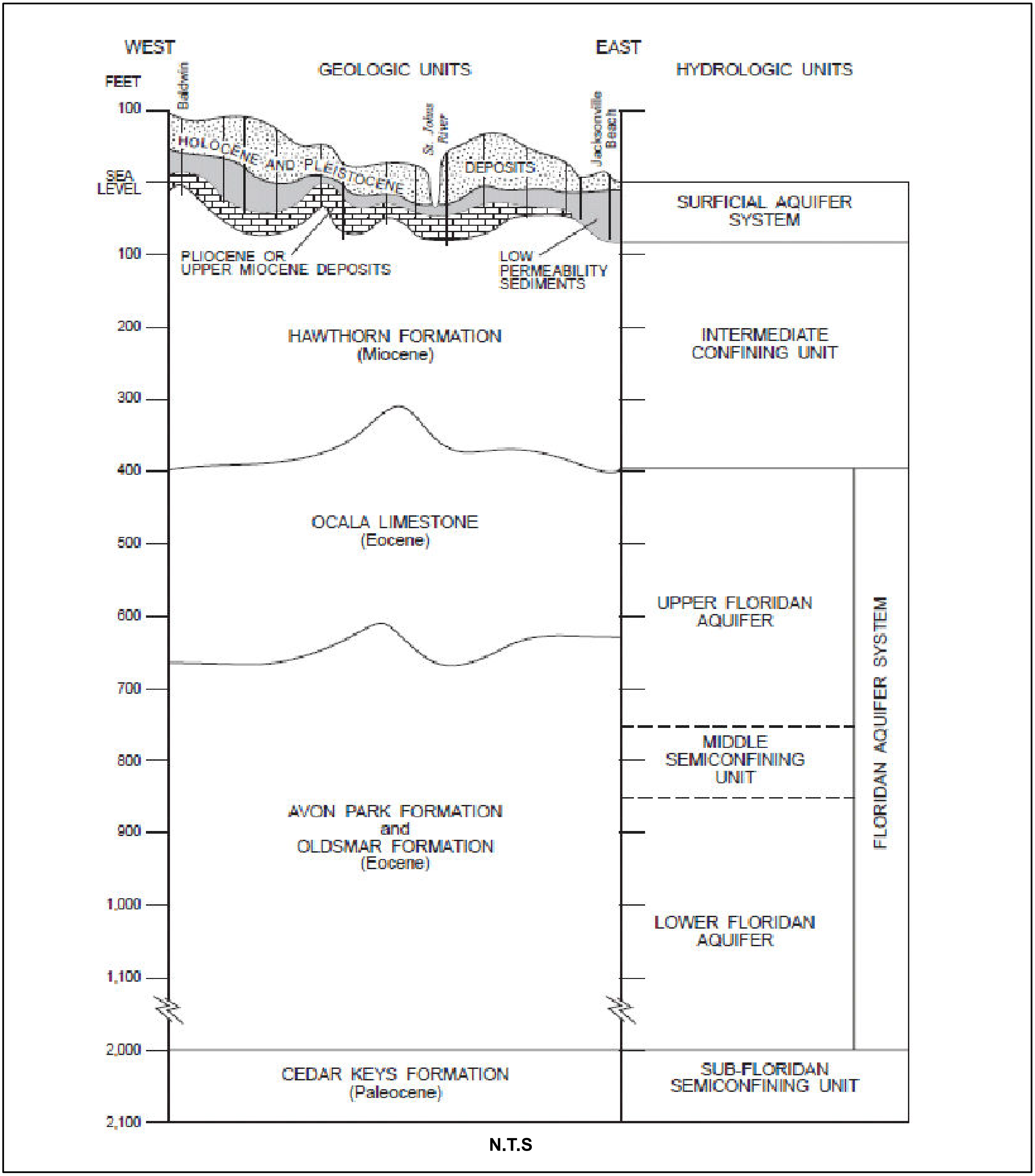
Trail Ridge Landfill Property Boundary

N
W E
S

0 750 1,500
Feet

CDM Smith

Figure 7
USGS Quadrangle Topographic Map
Trail Ridge Landfill Expansion Project

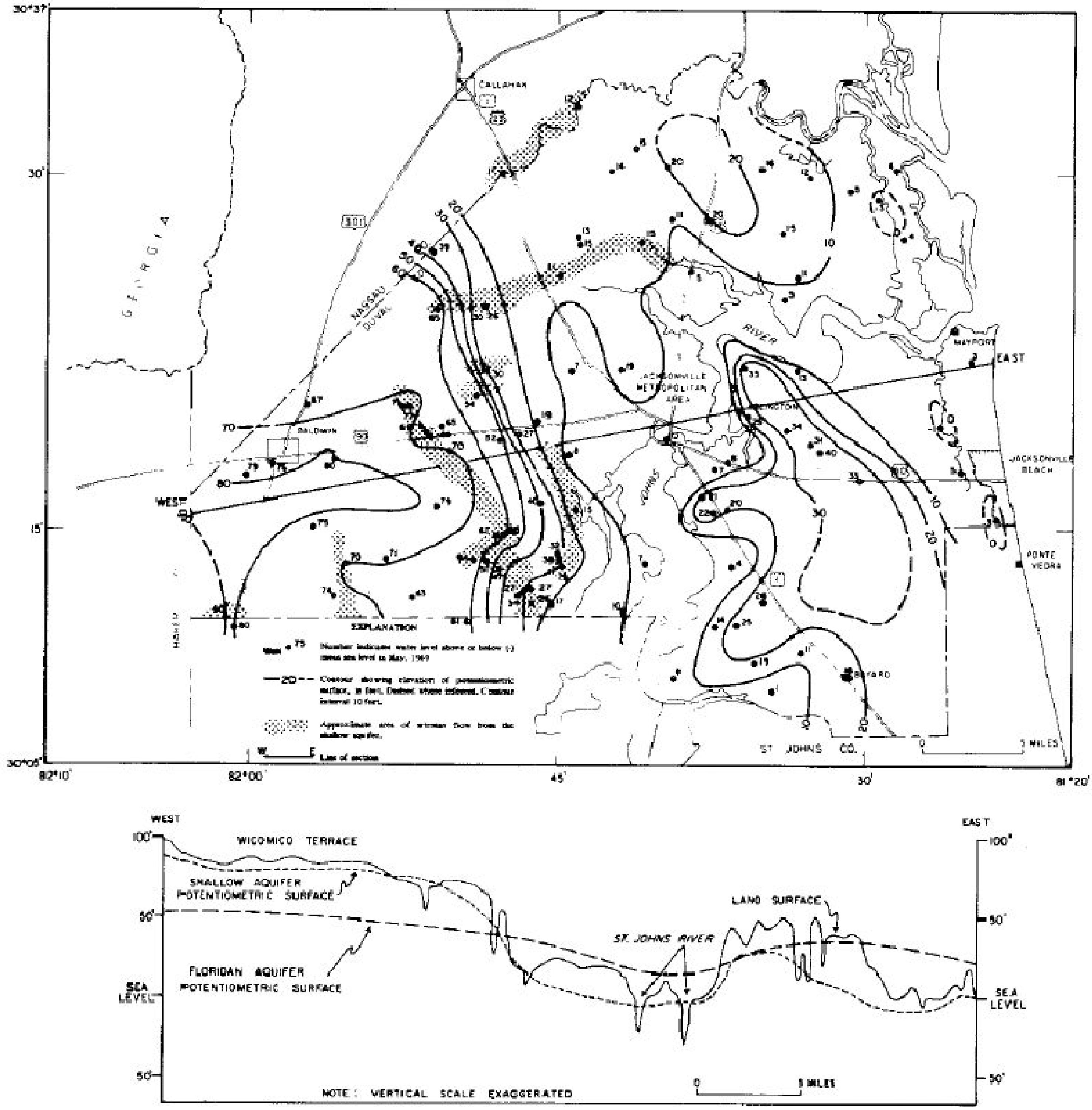


Source: Phelps, 1993

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 8 Duval East-West Cross-section.mxd anandams 06/14/13

CDM Smith

Figure 8
East-West Hydrogeologic/Geologic Cross-Section through Duval County, FL
Trail Ridge Landfill Expansion Project



N.T.S

Source: Fairchild, 1972

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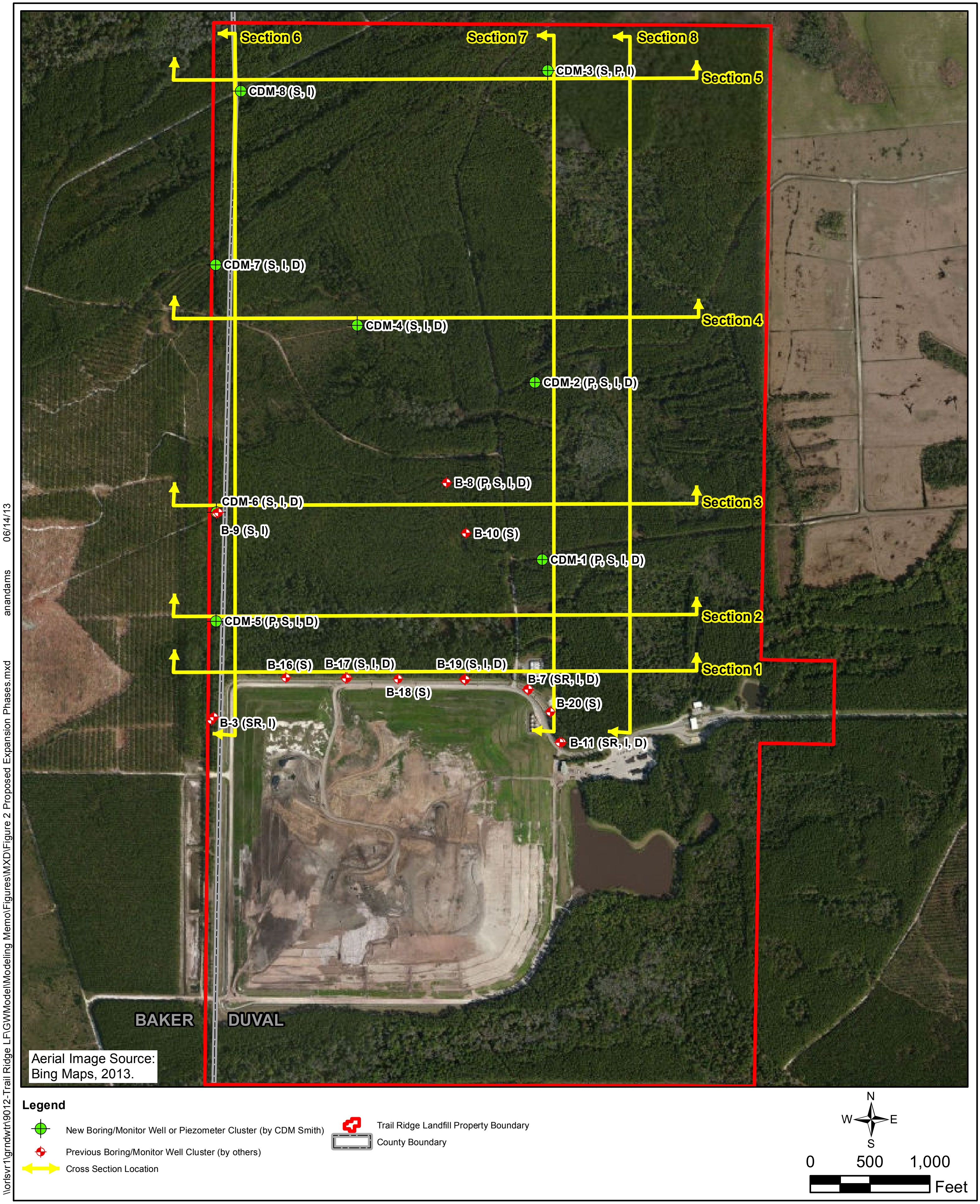
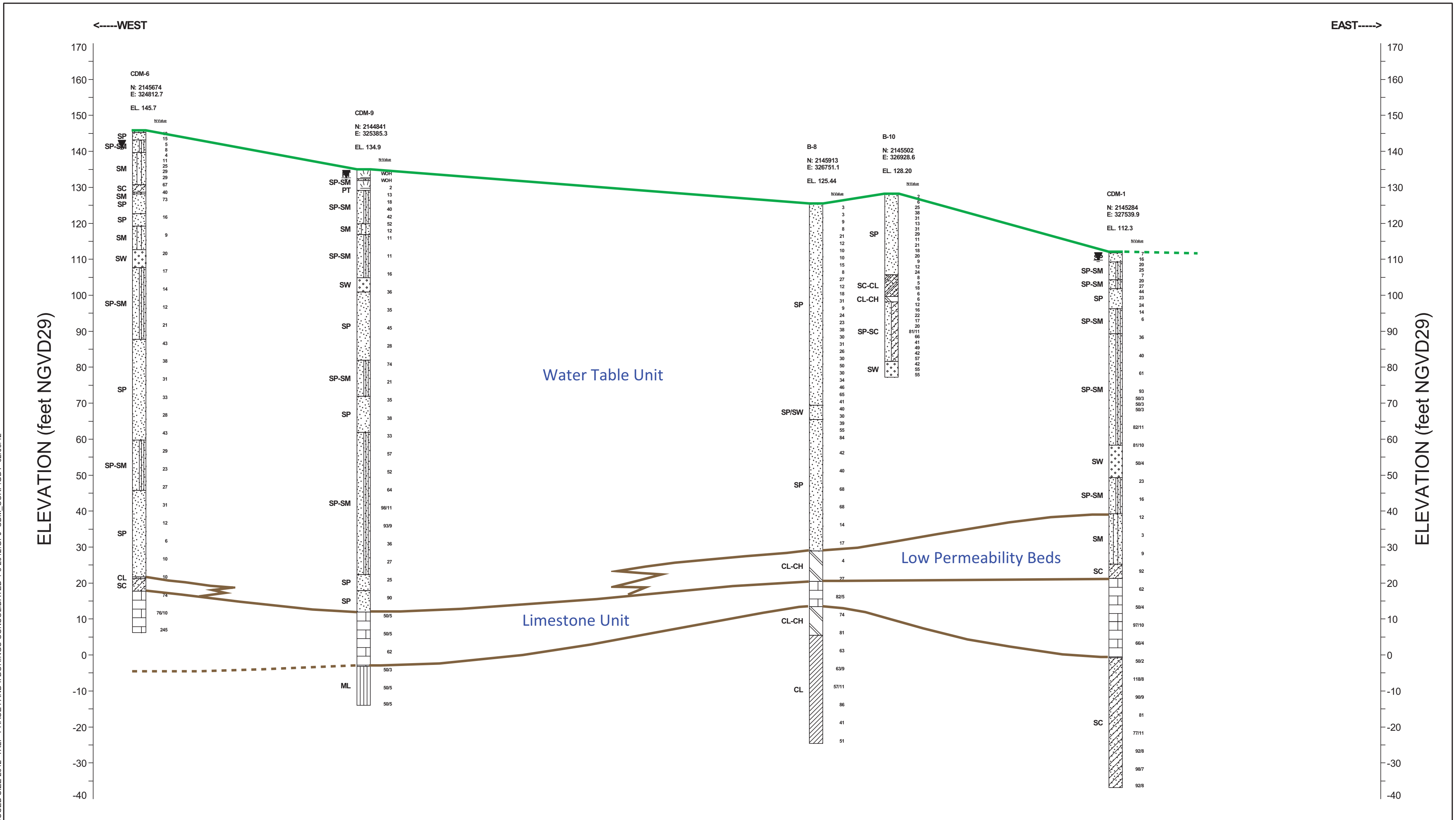
CDM Smith

Figure 9
Groundwater Elevation Contour Map for the Surficial Aquifer System, May 1969
Trail Ridge Landfill Expansion Project



CDM Smith

Figure 10
Locations of Cross Sections
Trail Ridge Landfill Expansion Project



LEGEND

- USCS Poorly-graded Sand
- Clayey Sand and Sandy Clay
- USCS Low to High Plasticity Clay
- USCS Poorly-graded Sand with Clay
- USCS Well-graded Sand
- Limestone
- USCS Low Plasticity Clay
- Topsoil
- USCS Poorly-graded Sand with Silt
- USCS Silty Sand
- USCS Clayey Sand
- USCS Peat
- Water Level

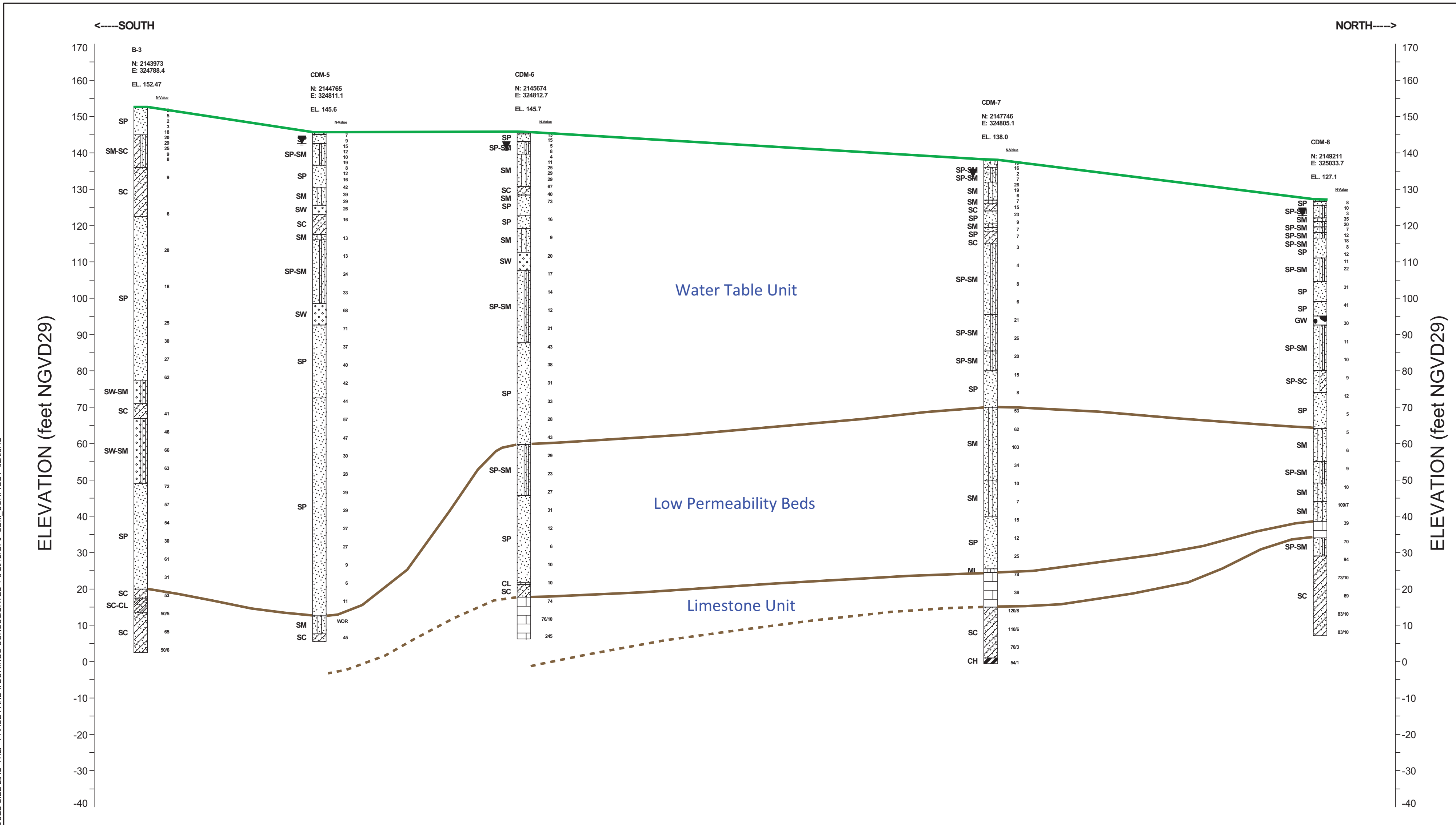
CDM Smith

0 250
Horizontal Scale (ft.)

City of Jacksonville

Trail Ridge Landfill Expansion

Figure 11
Section 3 West-East Cross Section
Trail Ridge Landfill Expansion Project



LEGEND

- USCS Poorly-graded Sand
- USCS Silty Sand - Clayey Sand
- USCS Clayey Sand
- USCS Well-graded Sand with Silt
- Clayey Sand and Sandy Clay
- Topsoil
- USCS Poorly-graded Sand with Silt
- USCS Silty Sand
- USCS Well-graded Sand
- USCS Low Plasticity Clay
- Limestone
- USCS Silt
- Water Level

CDM Smith

0 400
Horizontal Scale (ft.)

City of Jacksonville

Trail Ridge Landfill Expansion

Figure 12
Section 6 South-North Cross Section
Trail Ridge Landfill Expansion Project

FENCE - TRLF - 11X17 REDUCED SIZE 2012 TRLF- PHASE I AND II BORINGS CONSOLIDATED 1-3-2012.GPJ CDM_CORP.GDT 02/08/12

Legend

Groundwater Flow Model Domain (11 miles x 10 miles)

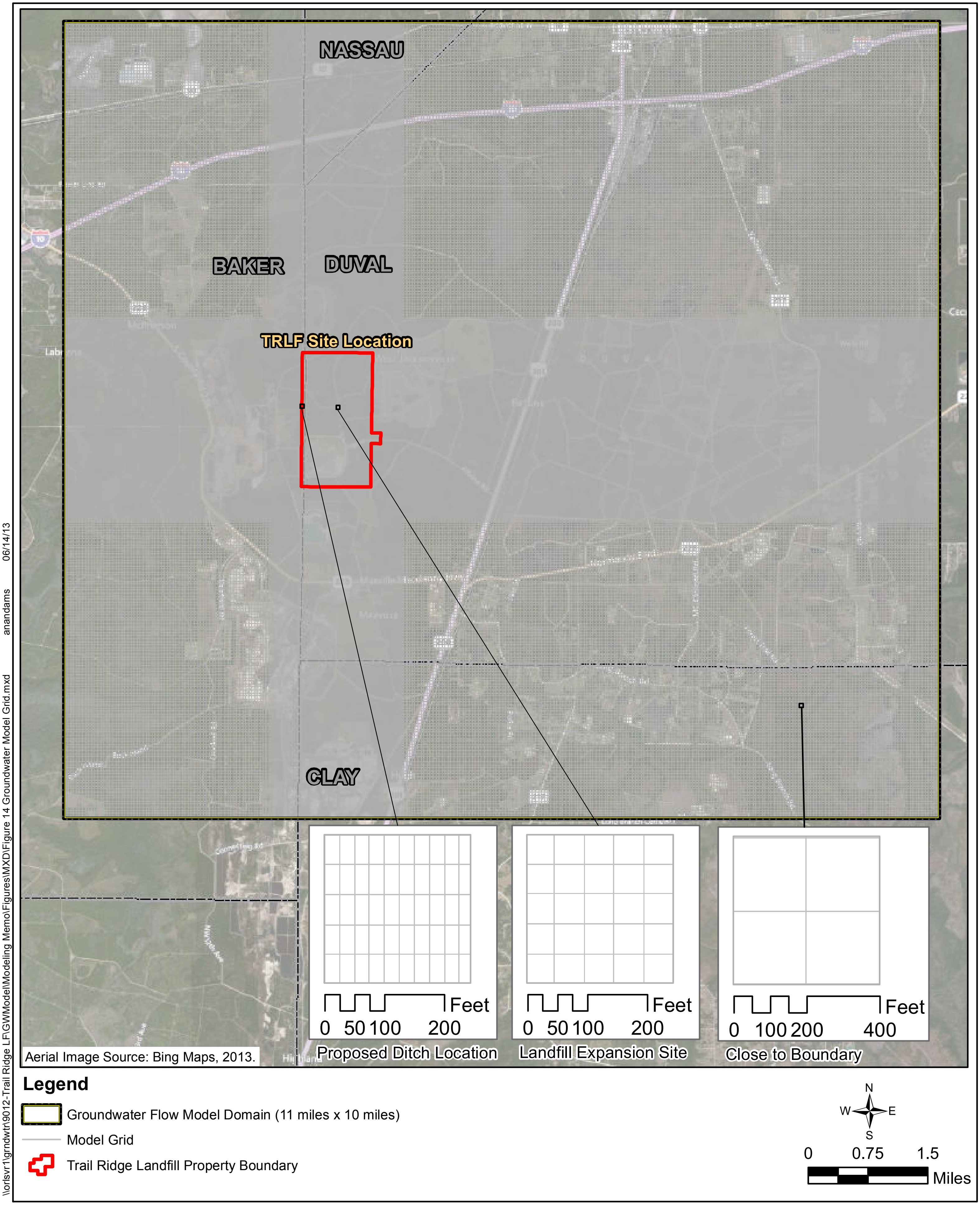
Trail Ridge Landfill Property Boundary

0 0.75 1.5 Miles

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 13 Groundwater Model Domain.mxd anandams 06/14/13

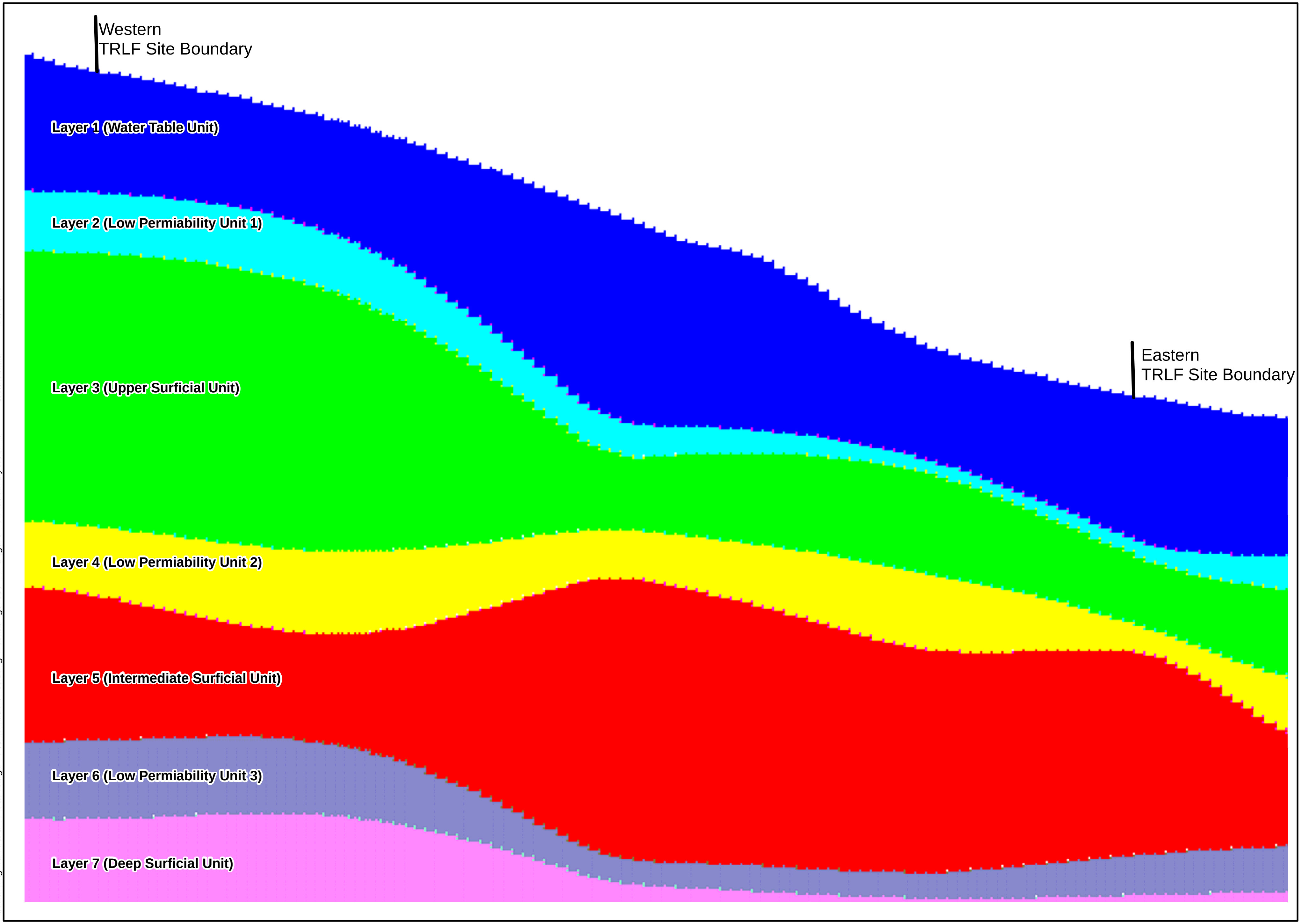
CDM Smith

Figure 13
Groundwater Flow Model Domain
Trail Ridge Landfill Expansion Project



CDM Smith

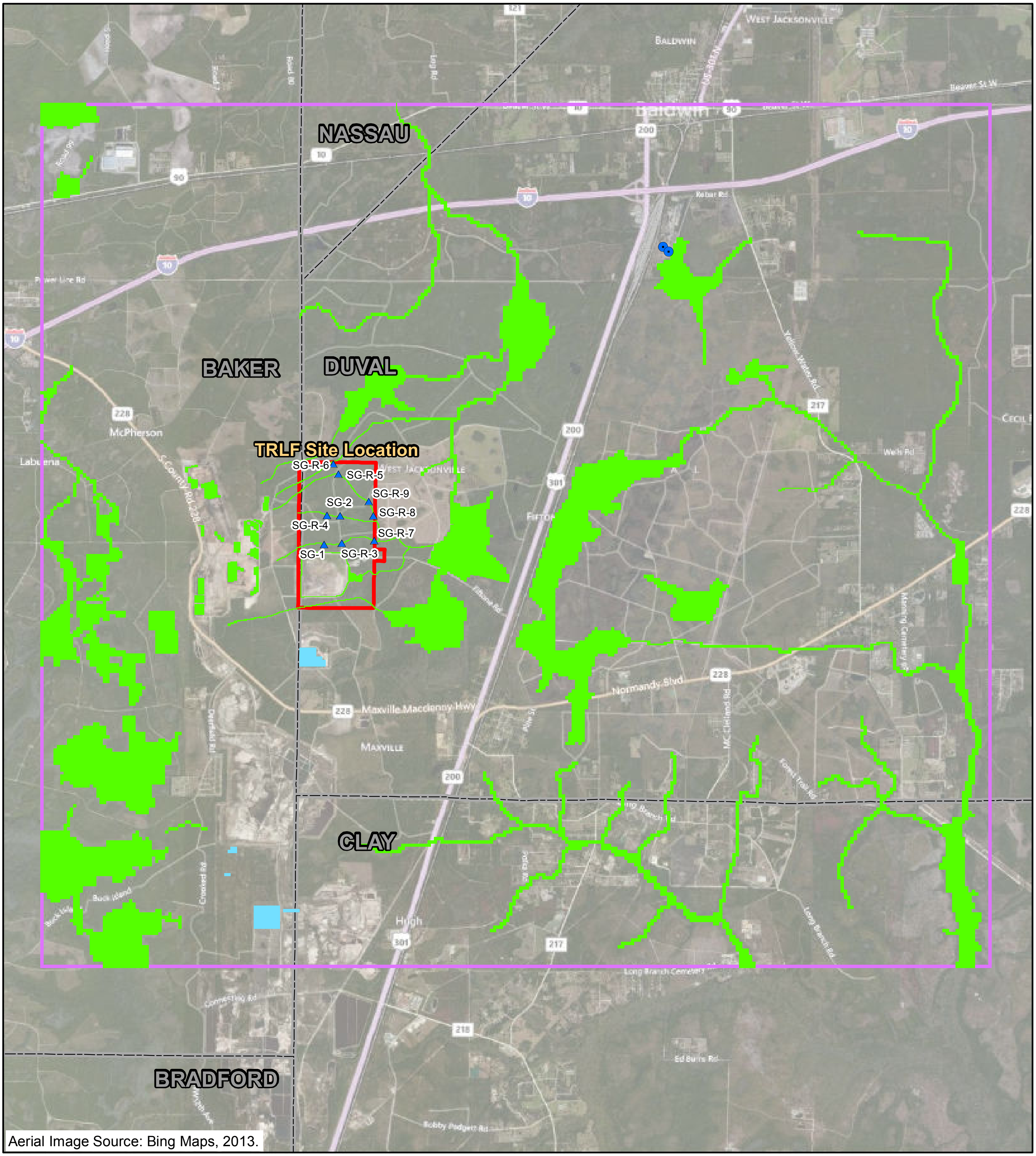
Figure 14
Groundwater Flow Model Grid System
Trail Ridge Landfill Expansion Project



\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 15 Model Layers.mxd anandams 06/14/13

CDM Smith

Figure 15
West-East Cross Section Through TRLF Groundwater Model
Trail Ridge Landfill Expansion Project



Legend

MODFLOW Boundary

- Constant Head Boundary
- General Head Boundary
- River Boundary
- Well Boundary
- Staff Gauge
- Trail Ridge Landfill Property Boundary

N S W E

0 0.75 1.5 Miles

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 13 Groundwater Model Domain.mxd anandams 06/14/13

CDM Smith

Figure 16
Groundwater Flow Model Boundaries
Trail Ridge Landfill Expansion Project

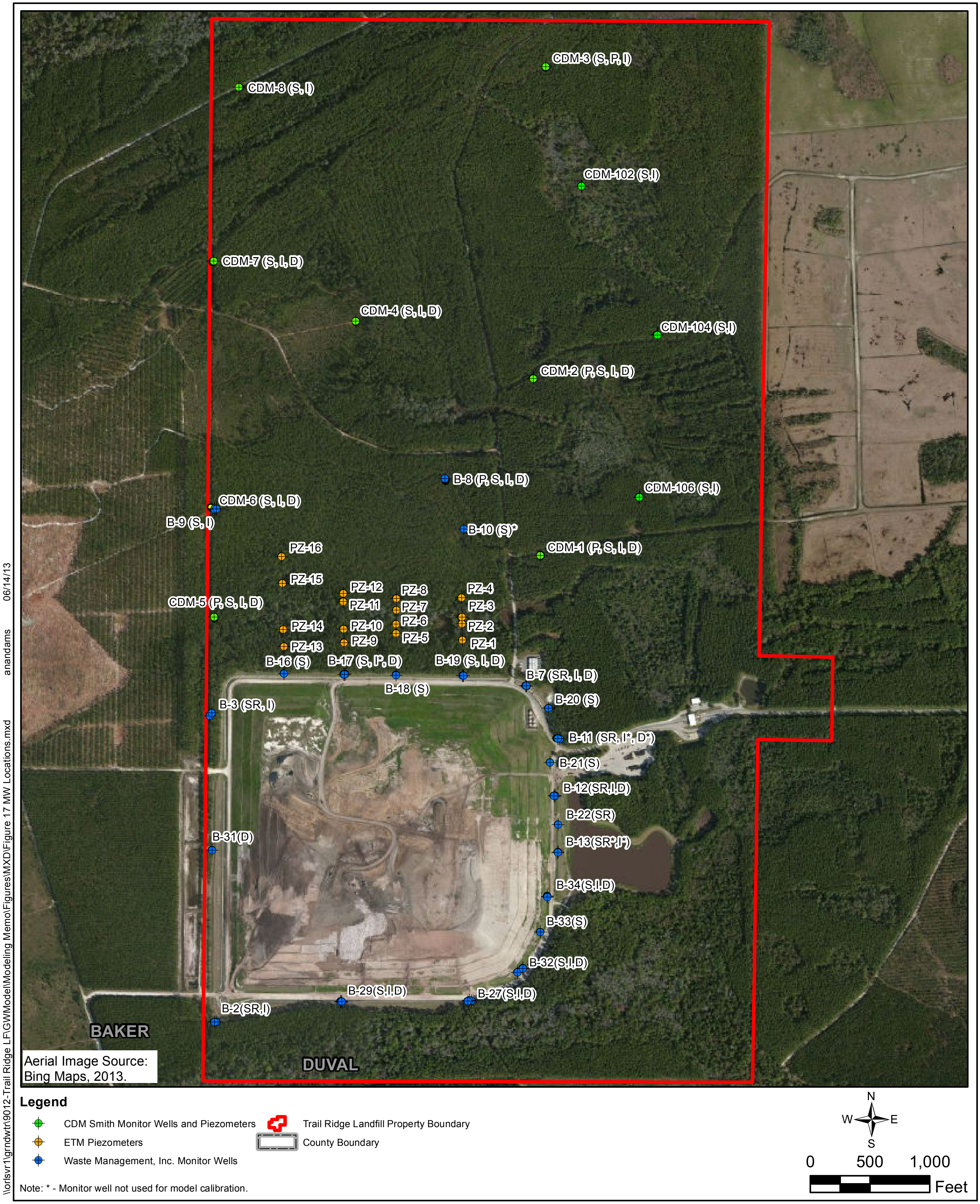


Figure 17
Locations of Monitor Wells and Piezometers Used for Model Calibration
Trail Ridge Landfill Expansion Project

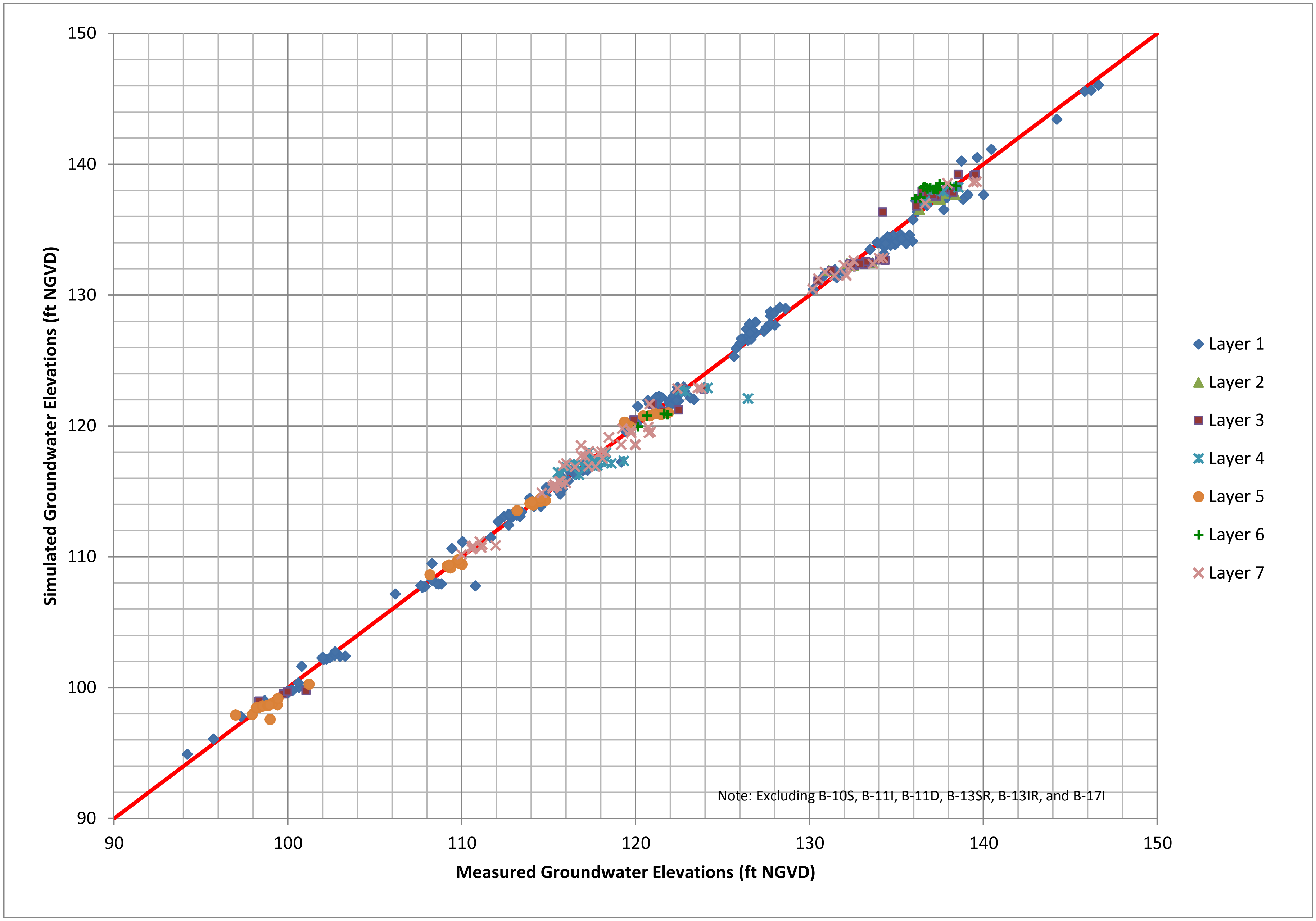


Figure 18
Scattergram Comparison of Measured Versus Model Simulated Groundwater Elevations
Trail Ridge Landfill Expansion Project

CDM Smith

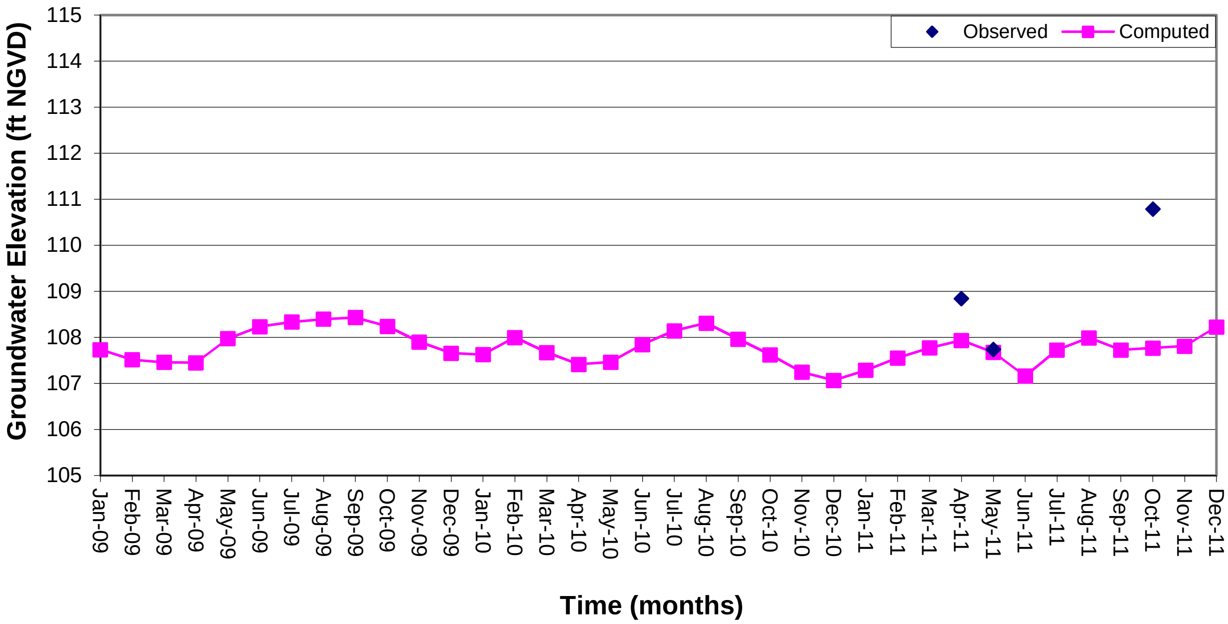


Figure 19
Comparison of Measured versus Simulated Groundwater Levels at CDM-1P (Layer 1)

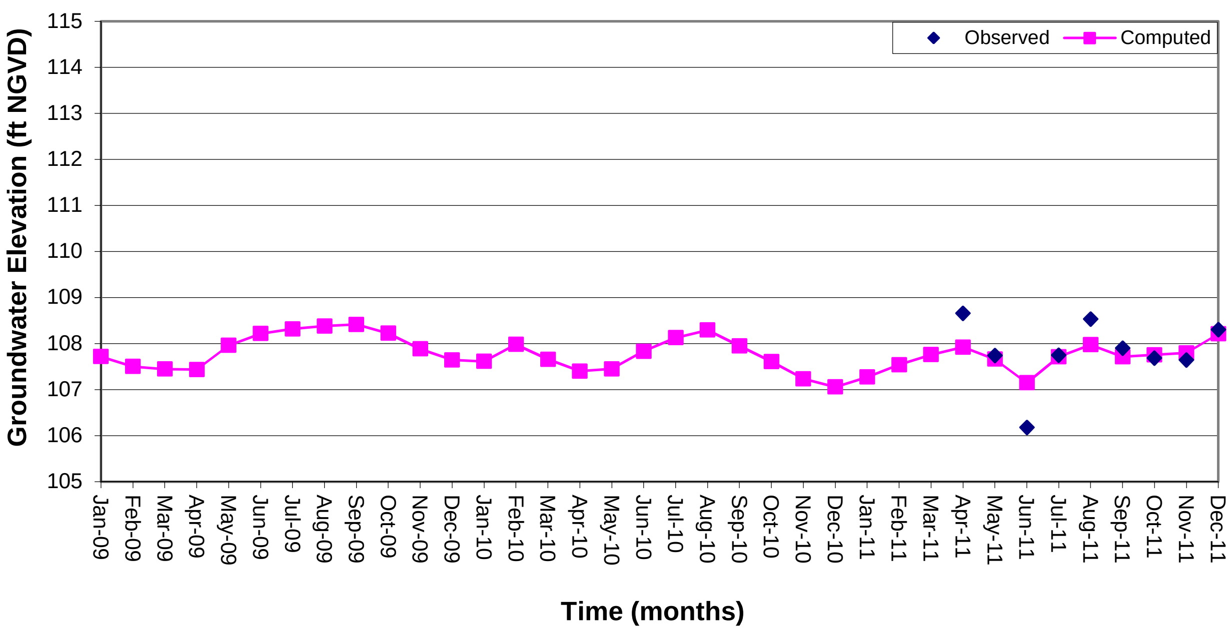


Figure 20
Comparison of Measured versus Simulated Groundwater Levels at CDM-1S (Layer 1)

CDM Smith

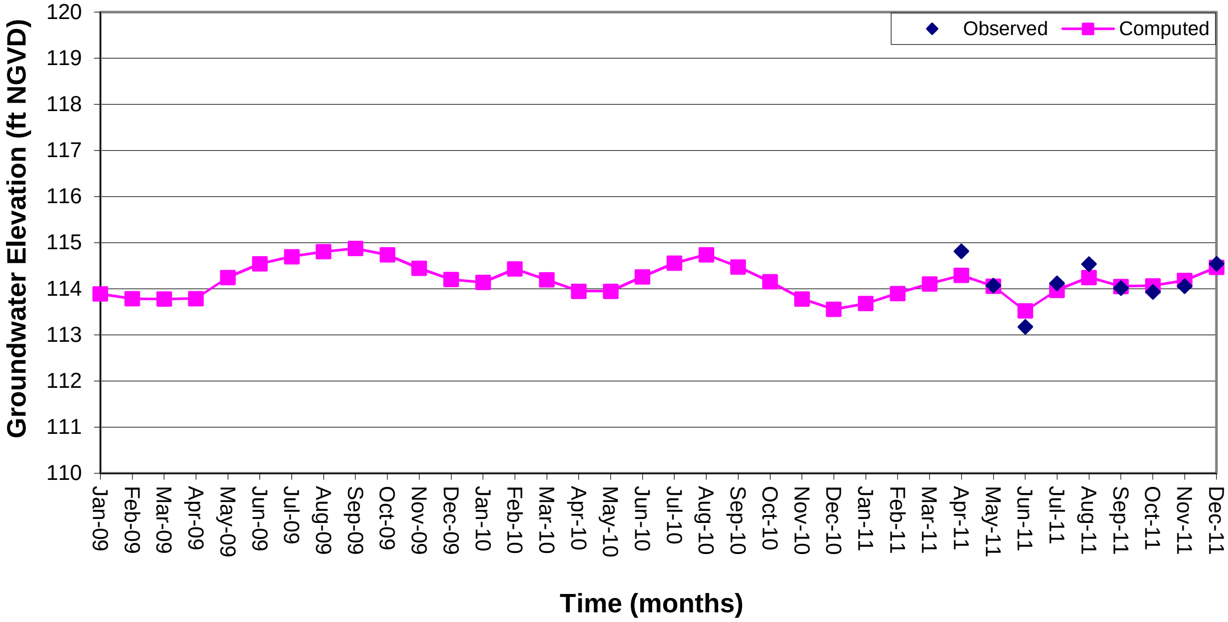


Figure 21
Comparison of Measured versus Simulated Groundwater Levels at CDM-1I (Layer 5)

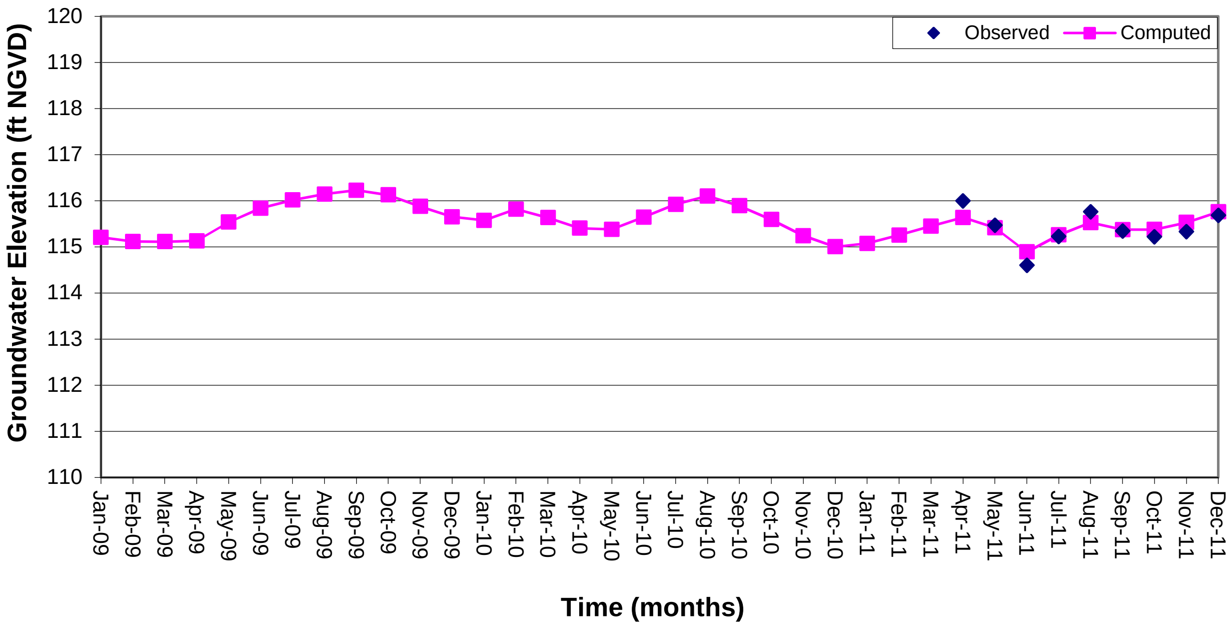


Figure 22
Comparison of Measured versus Simulated Groundwater Levels at CDM-1D (Layer 7)

CDM Smith

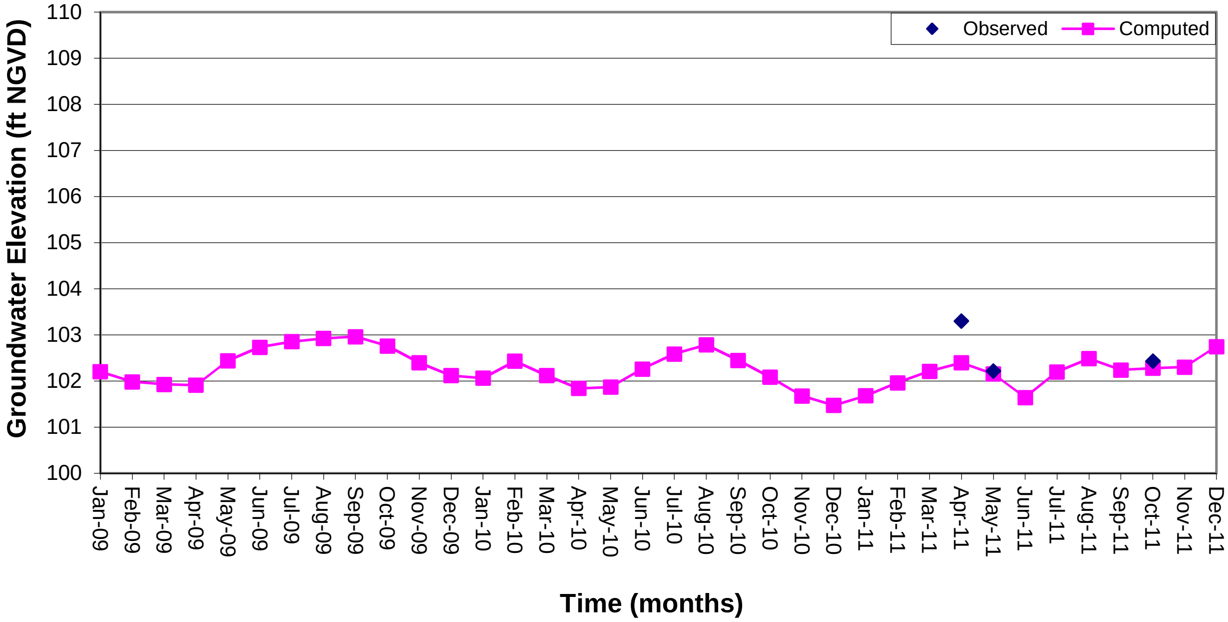


Figure 23
Comparison of Measured versus Simulated Groundwater Levels at CDM-2P (Layer 1)

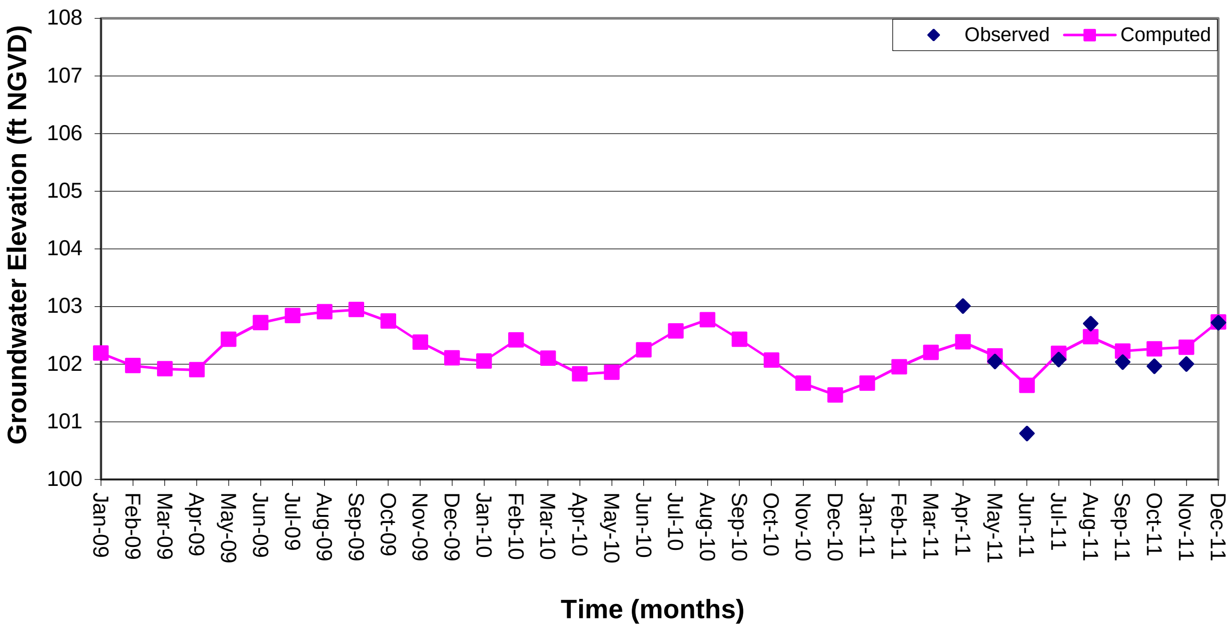


Figure 24
Comparison of Measured versus Simulated Groundwater Levels at CDM-2S (Layer 1)

CDM Smith

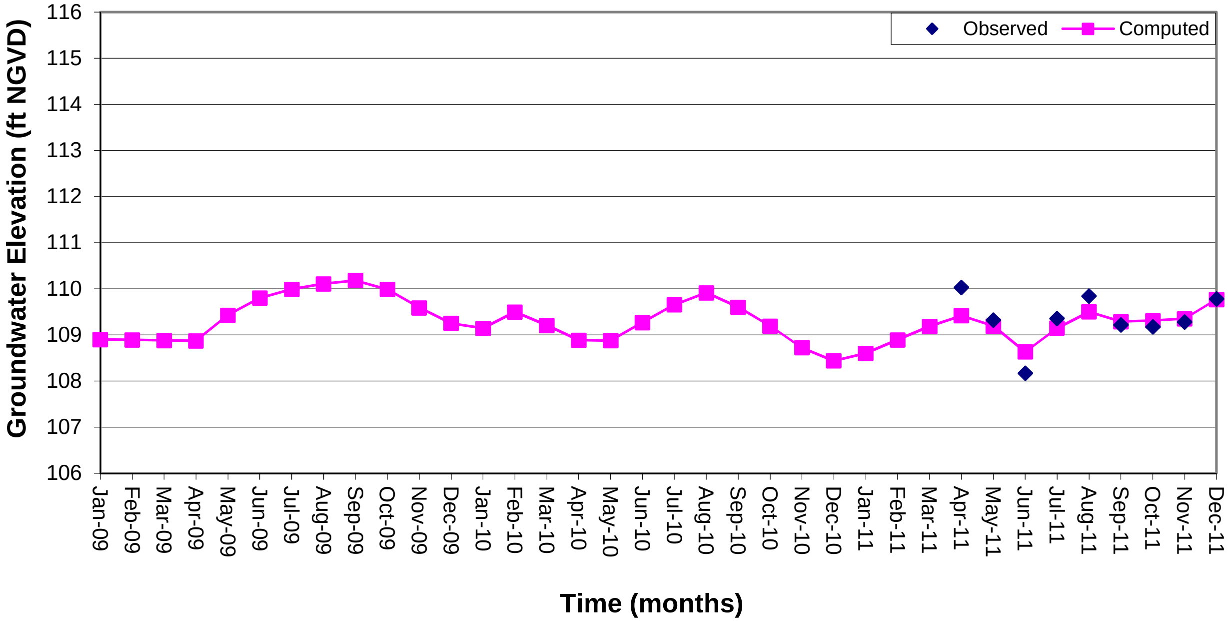


Figure 25
Comparison of Measured versus Simulated Groundwater Levels at CDM-2I (Layer 5)

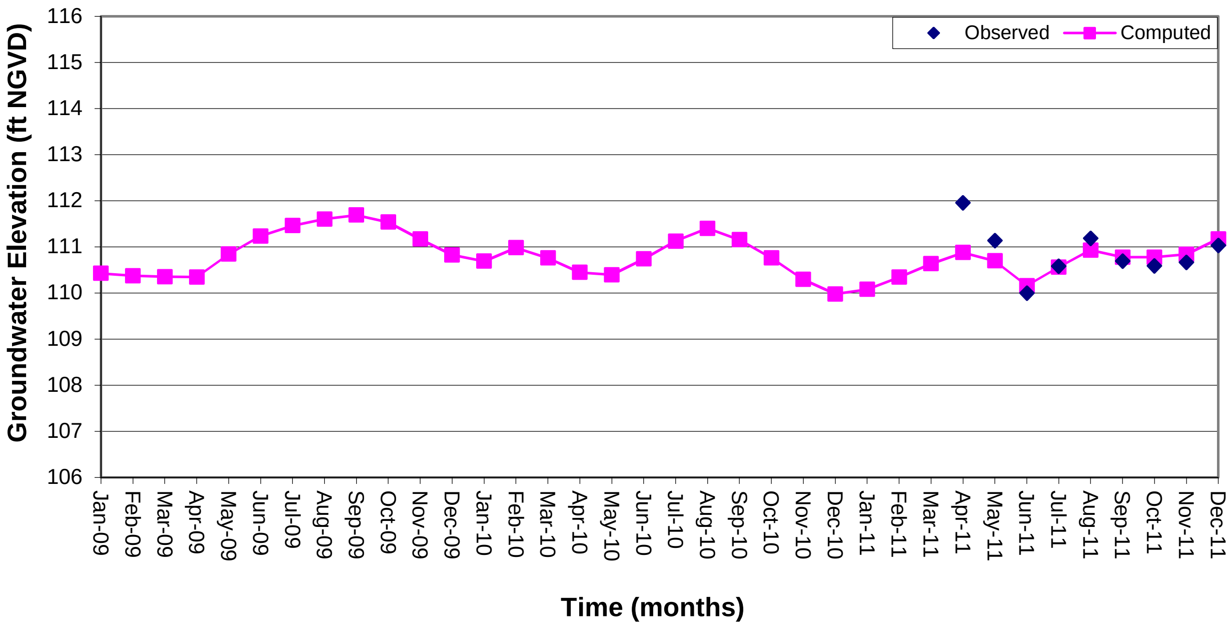


Figure 26
Comparison of Measured versus Simulated Groundwater Levels at CDM-2D (Layer 7)

CDM Smith

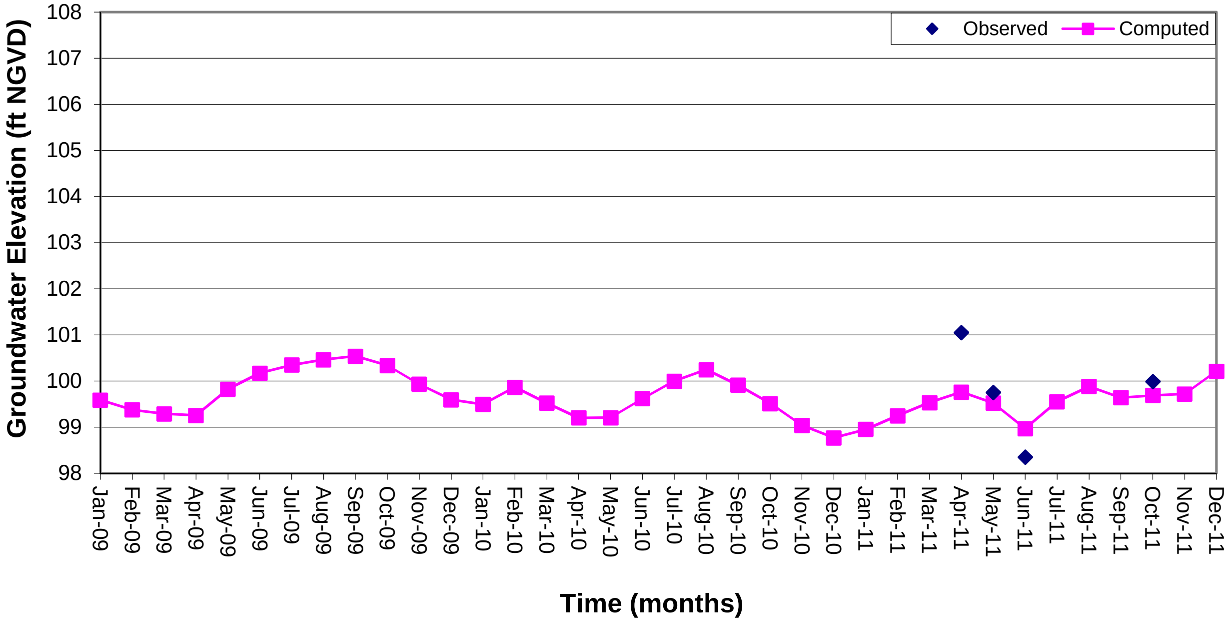


Figure 27
Comparison of Measured versus Simulated Groundwater Levels at CDM-3P (Layer 3)

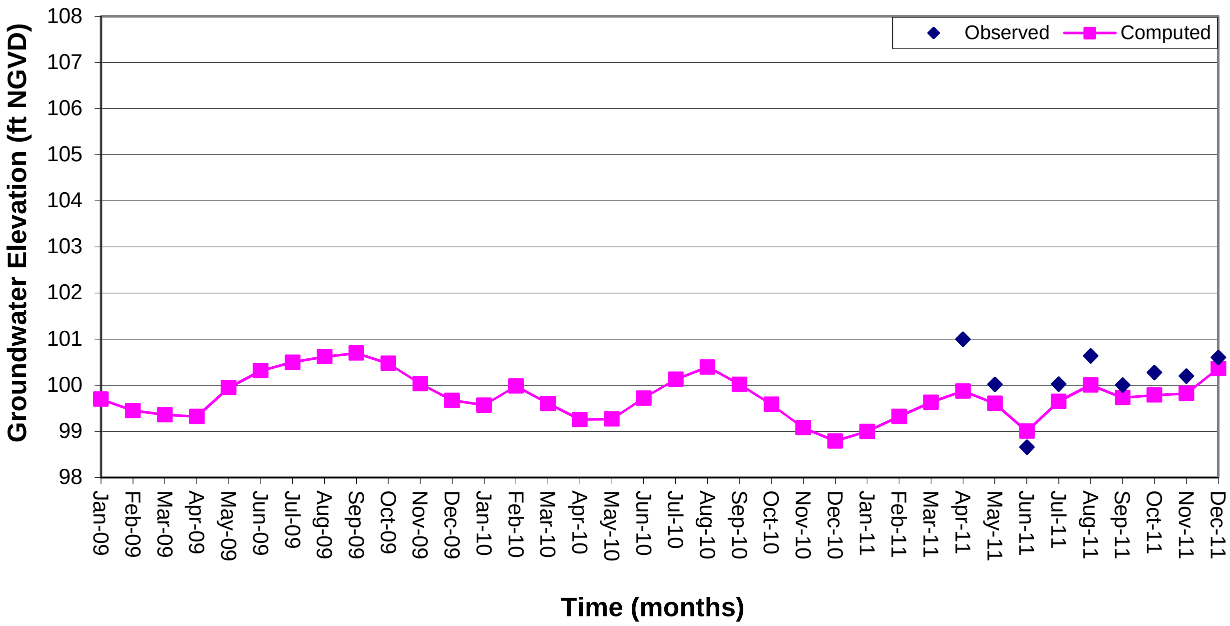


Figure 28
Comparison of Measured versus Simulated Groundwater Levels at CDM-3S (Layer 1)

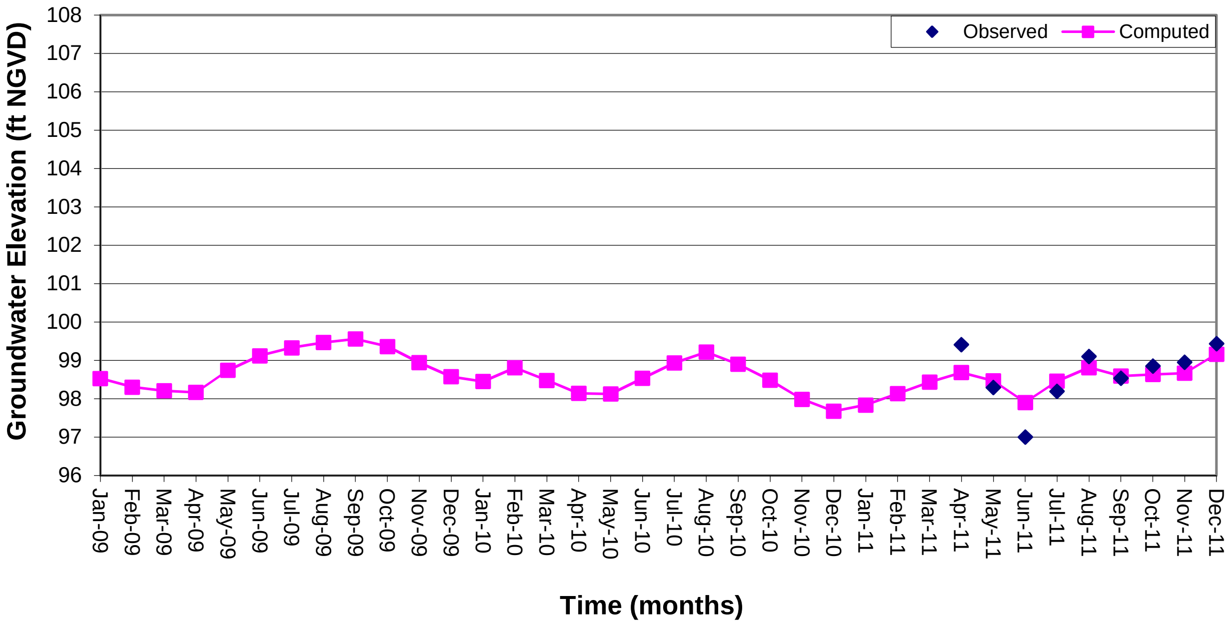


Figure 29
Comparison of Measured versus Simulated Groundwater Levels at CDM-3I (Layer 5)

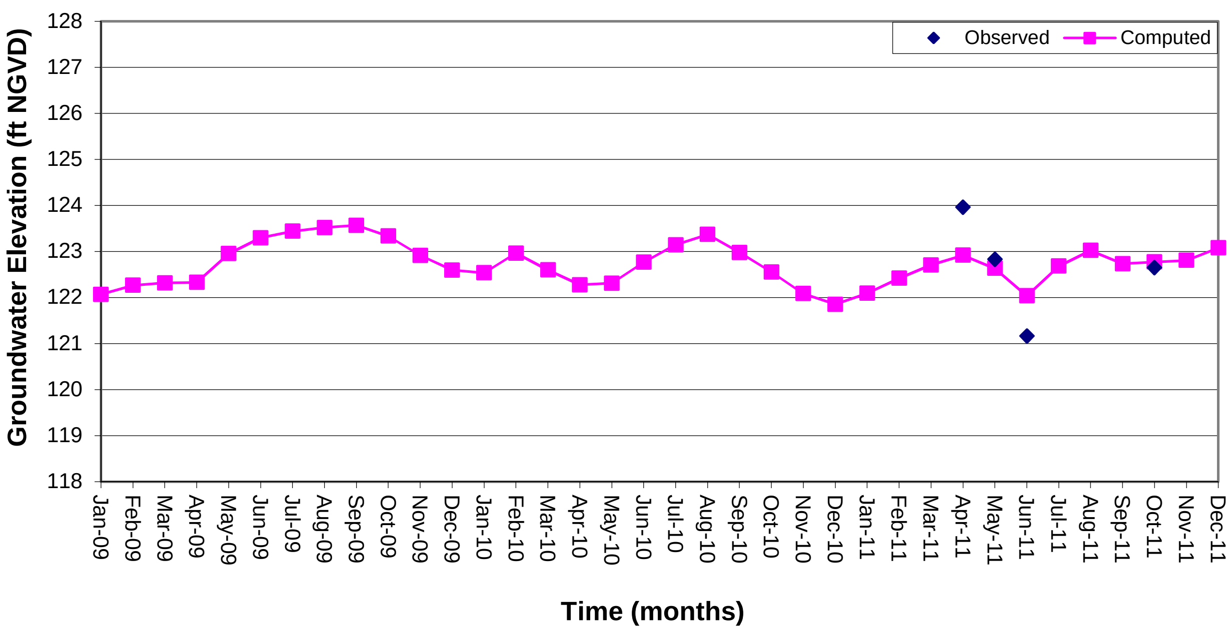


Figure 30
Comparison of Measured versus Simulated Groundwater Levels at CDM-4S (Layer 1)

CDM Smith

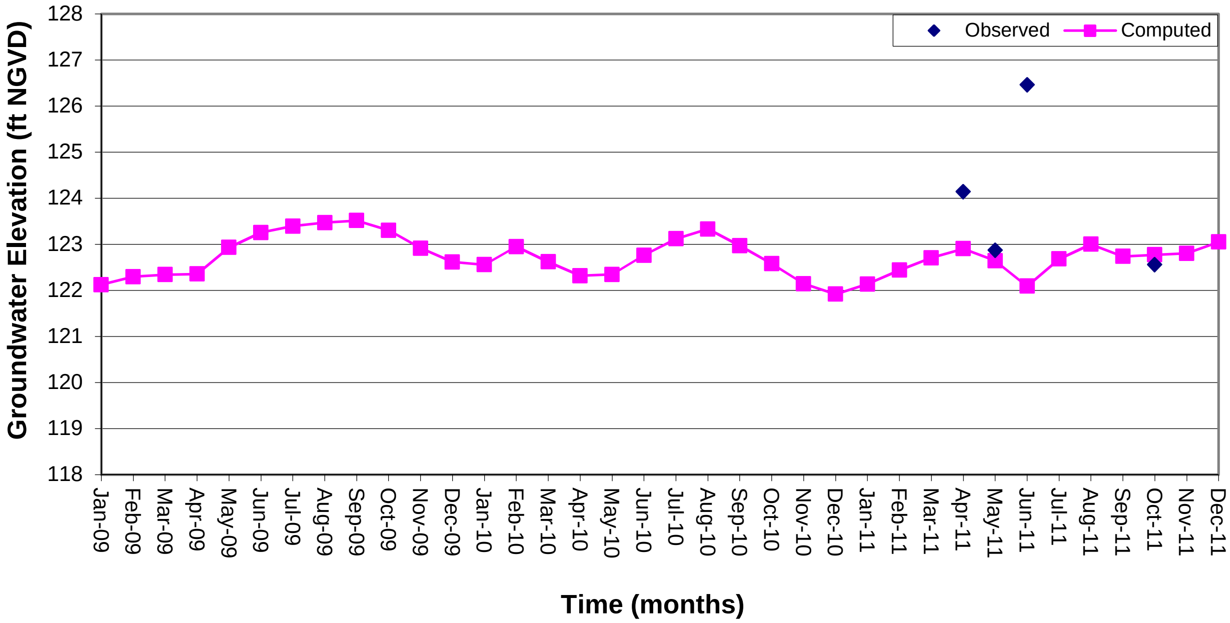


Figure 31
Comparison of Measured versus Simulated Groundwater Levels at CDM-4I (Layer 4)

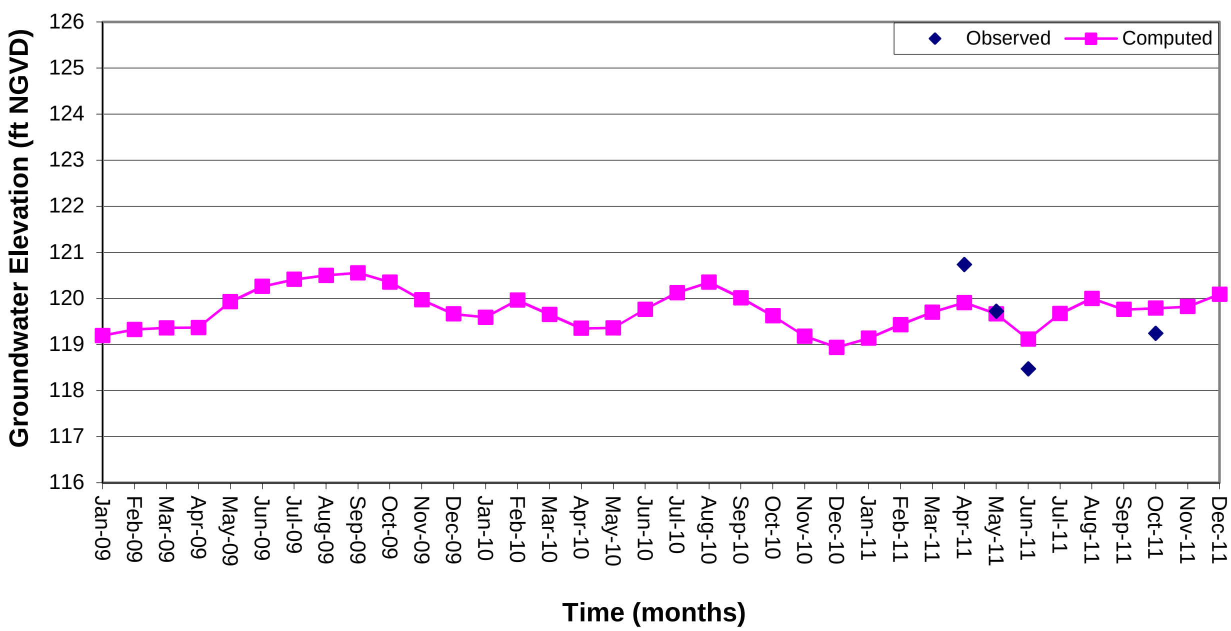


Figure 32
Comparison of Measured versus Simulated Groundwater Levels at CDM-4D (Layer 7)

CDM Smith

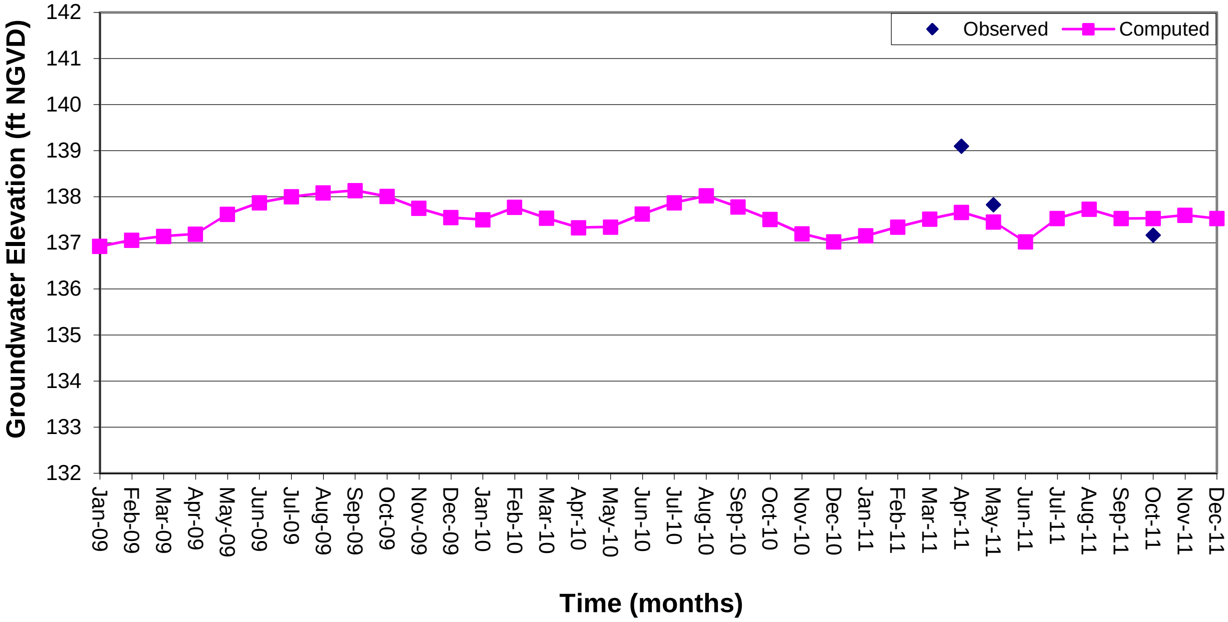


Figure 33
Comparison of Measured versus Simulated Groundwater Levels at CDM-5P (Layer 1)

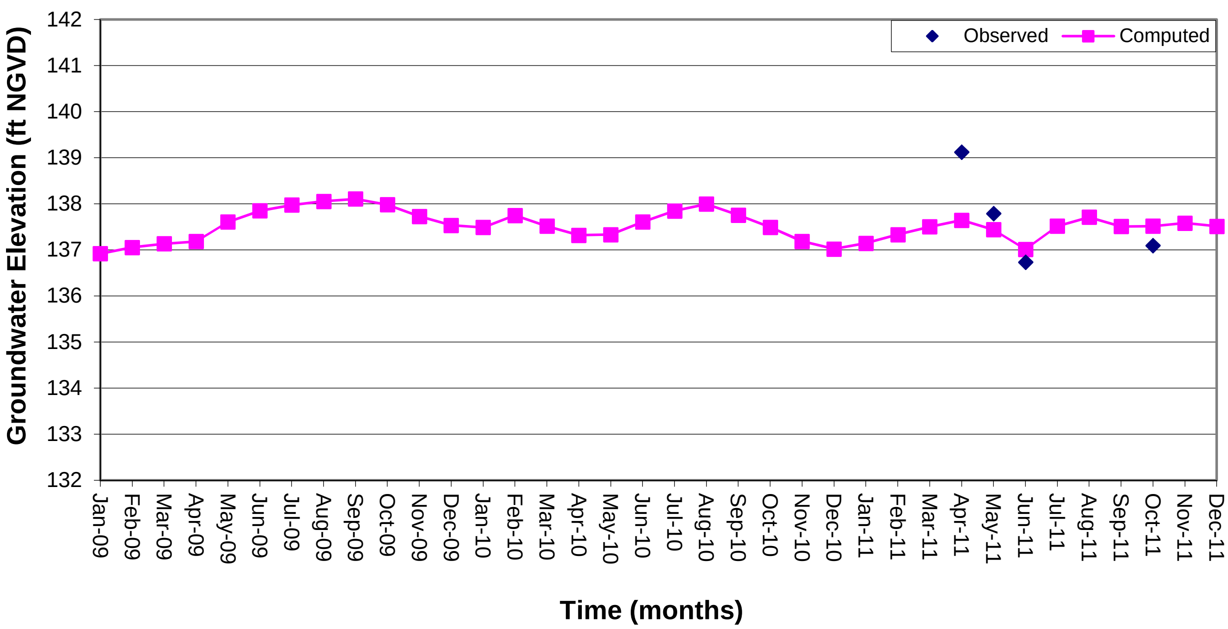


Figure 34
Comparison of Measured versus Simulated Groundwater Levels at CDM-5S (Layer 1)

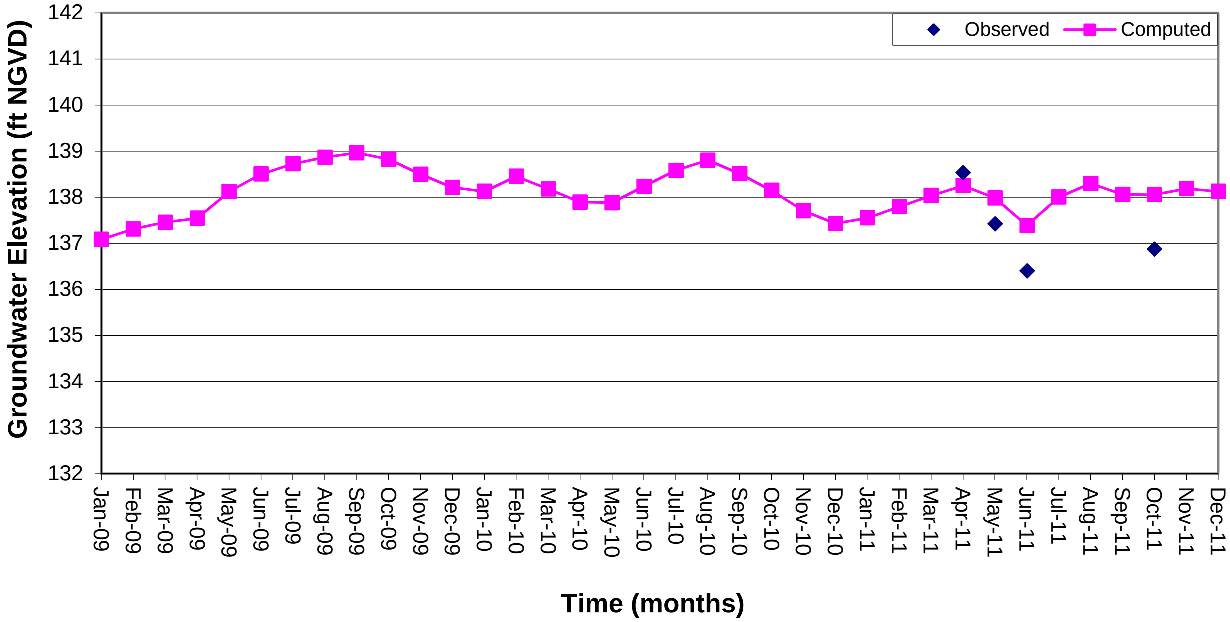


Figure 35
Comparison of Measured versus Simulated Groundwater Levels at CDM-5I (Layer 3)

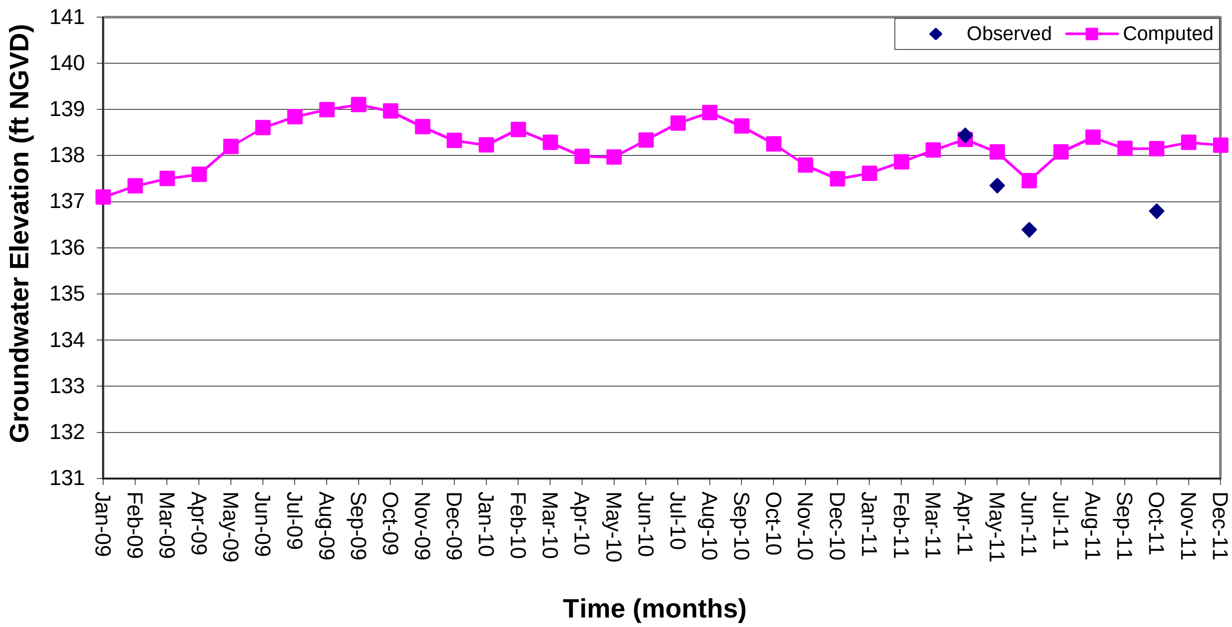


Figure 36
Comparison of Measured versus Simulated Groundwater Levels at CDM-5D (Layer 6)

CDM Smith

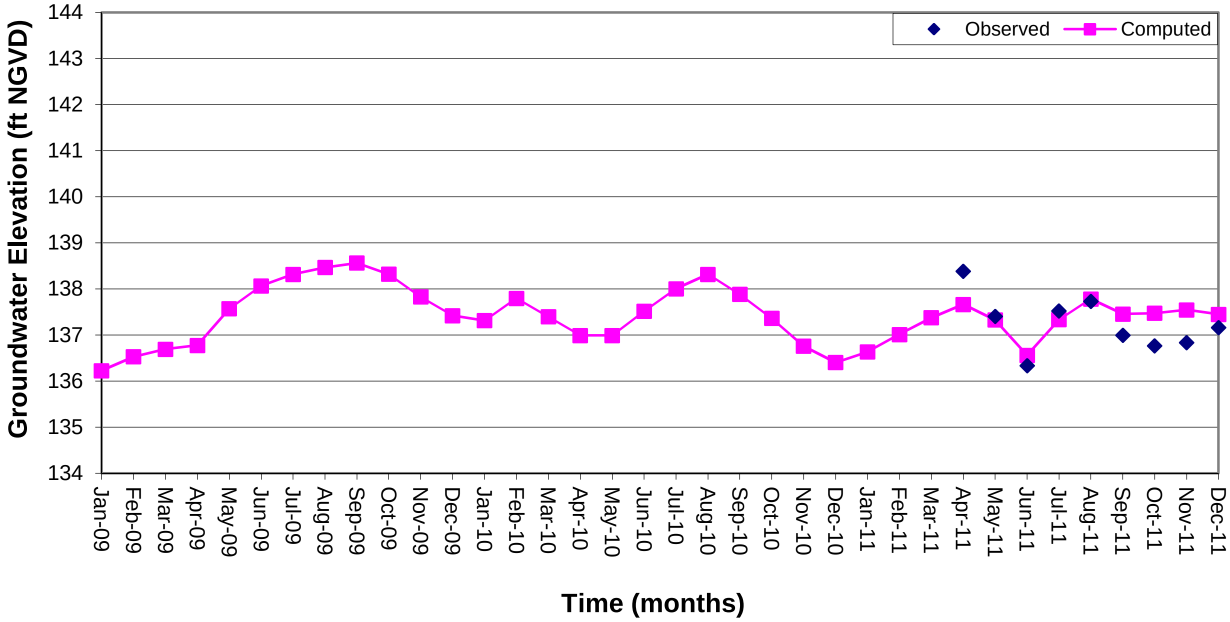


Figure 37
Comparison of Measured versus Simulated Groundwater Levels at CDM-6S (Layer 2)

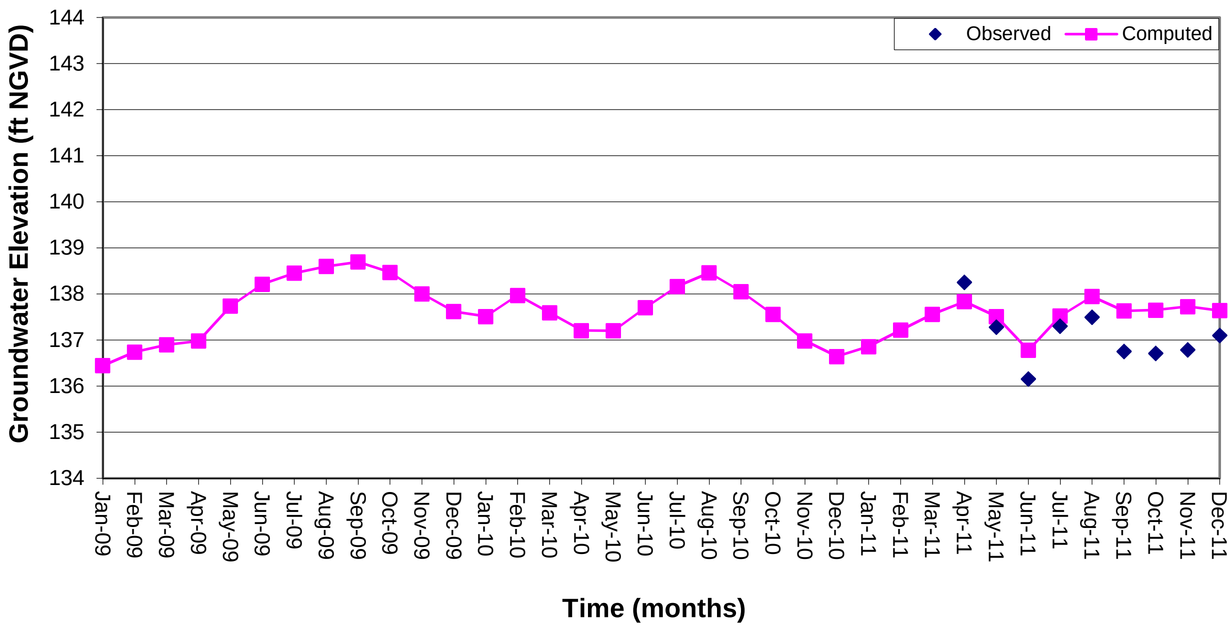


Figure 38
Comparison of Measured versus Simulated Groundwater Levels at CDM-6I (Layer 3)

CDM Smith

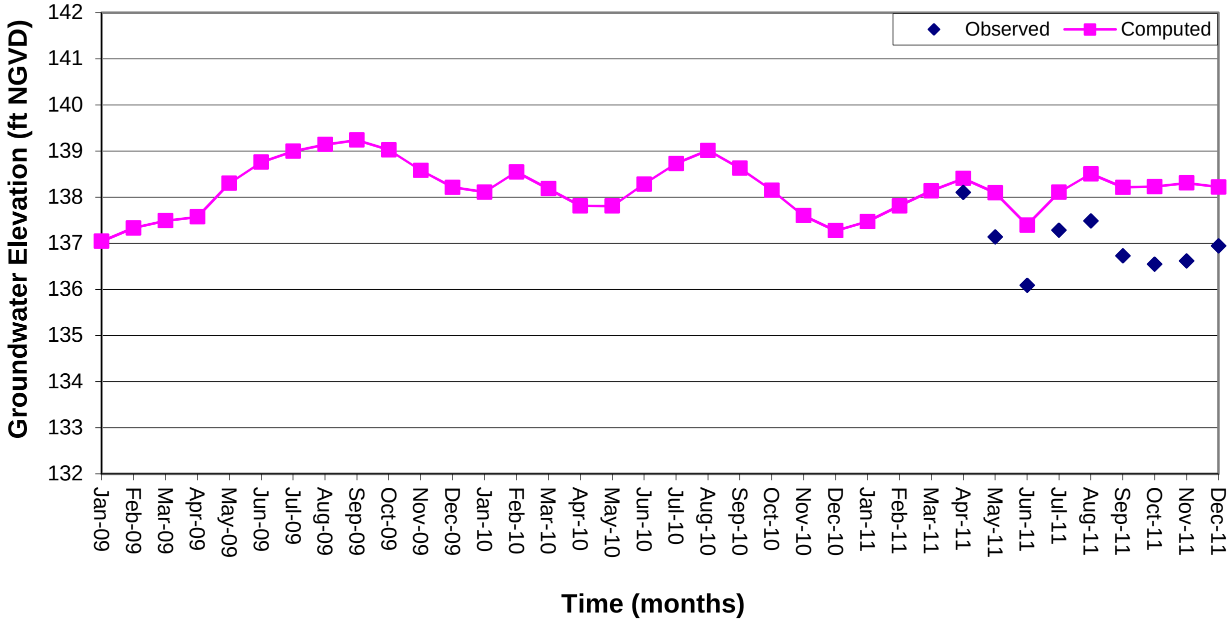


Figure 39
Comparison of Measured versus Simulated Groundwater Levels at CDM-6D (Layer 6)

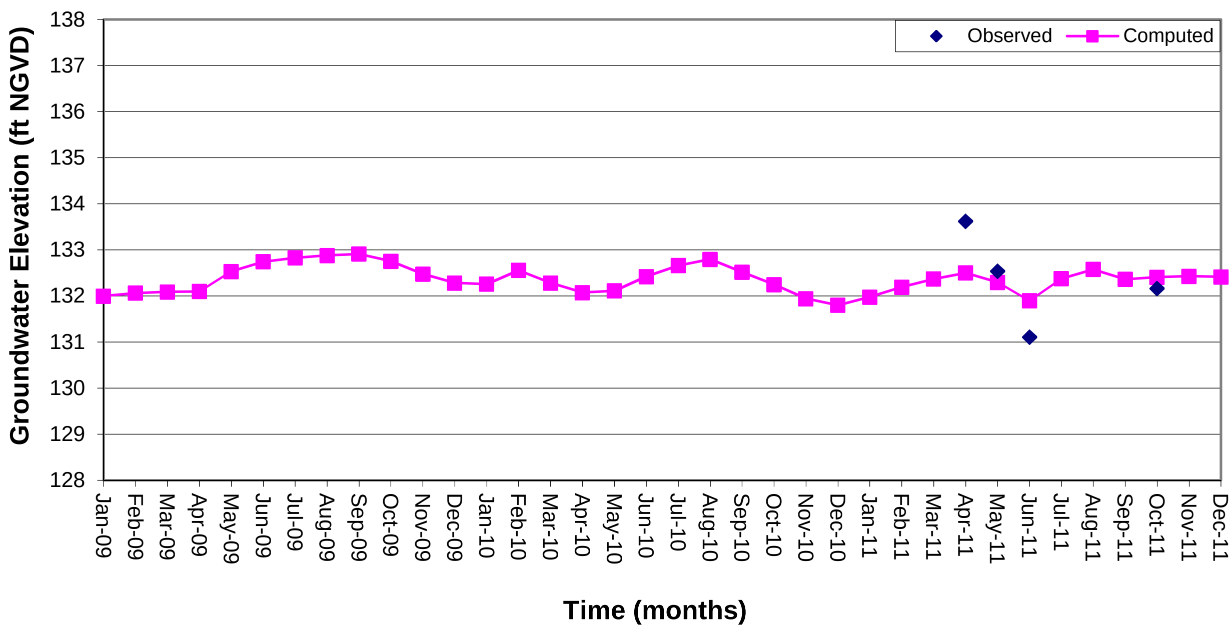


Figure 40
Comparison of Measured versus Simulated Groundwater Levels at CDM-7S (Layer 2)

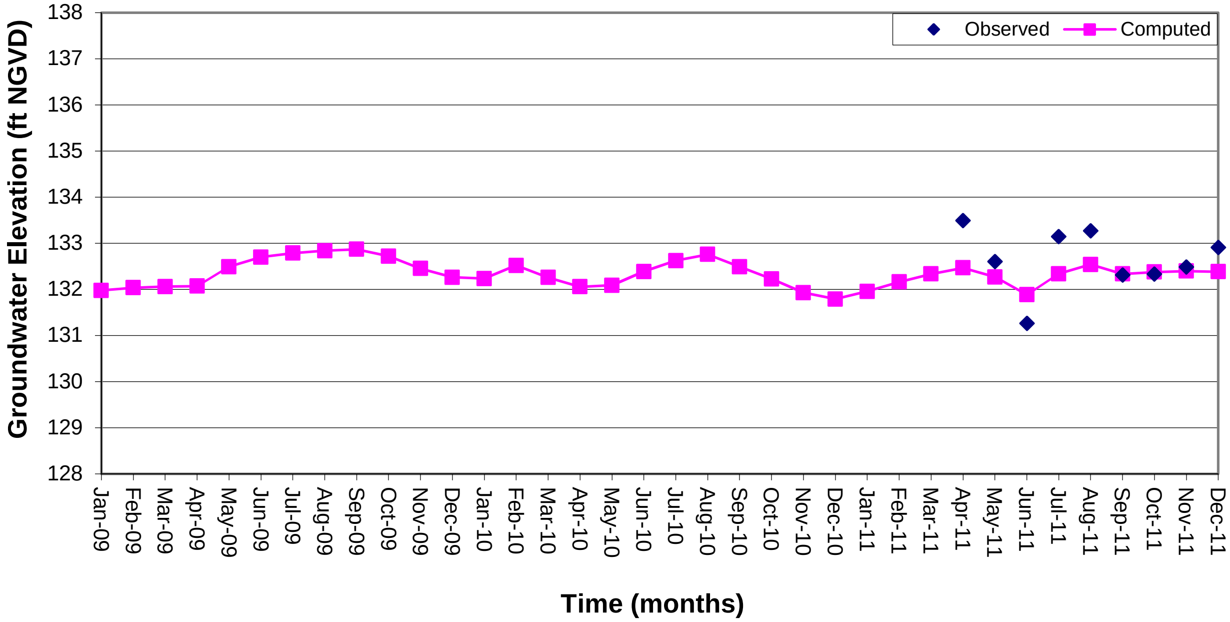


Figure 41
Comparison of Measured versus Simulated Groundwater Levels at CDM-7I (Layer 3)

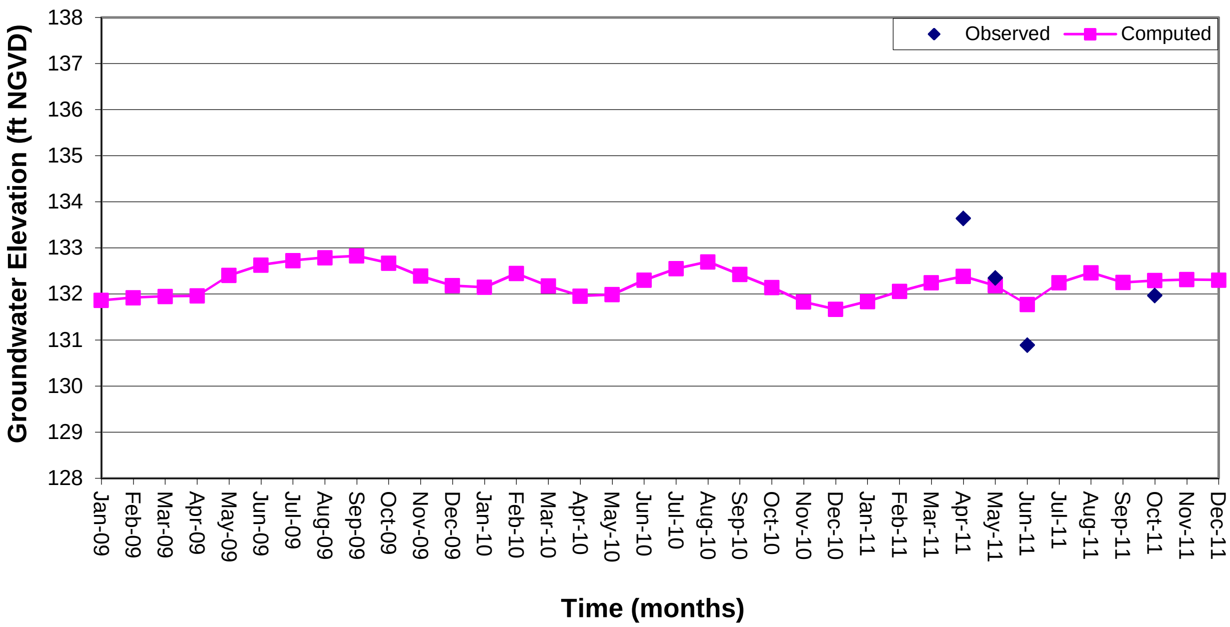


Figure 42
Comparison of Measured versus Simulated Groundwater Levels at CDM-7D (Layer 7)

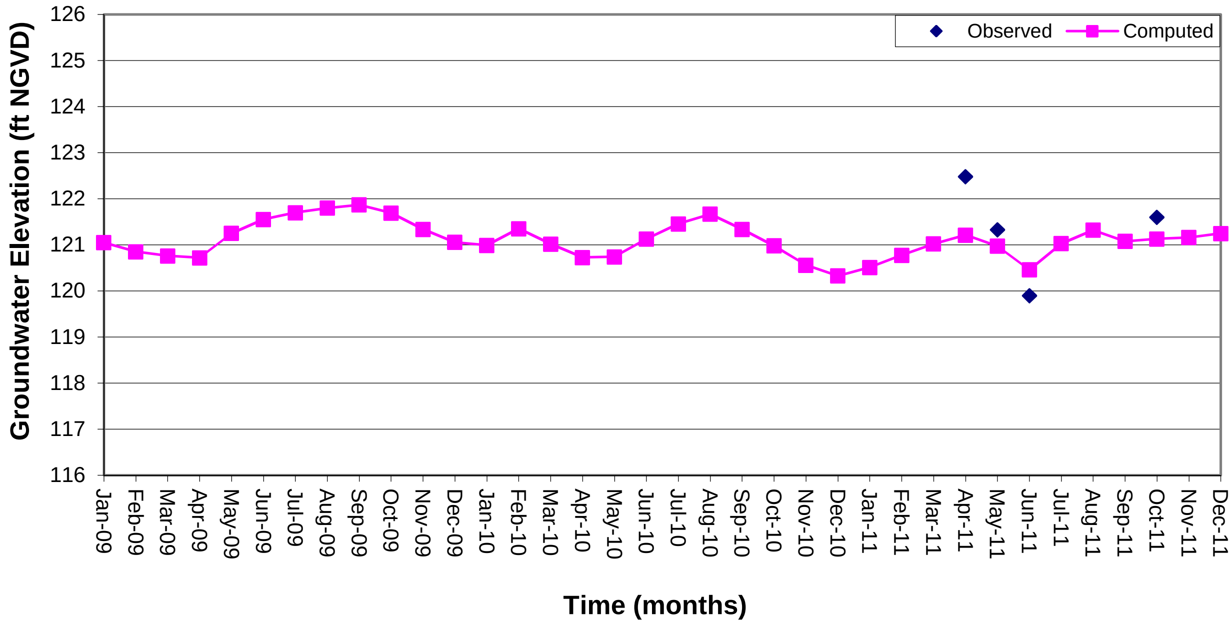


Figure 43
Comparison of Measured versus Simulated Groundwater Levels at CDM-8S (Layer 3)

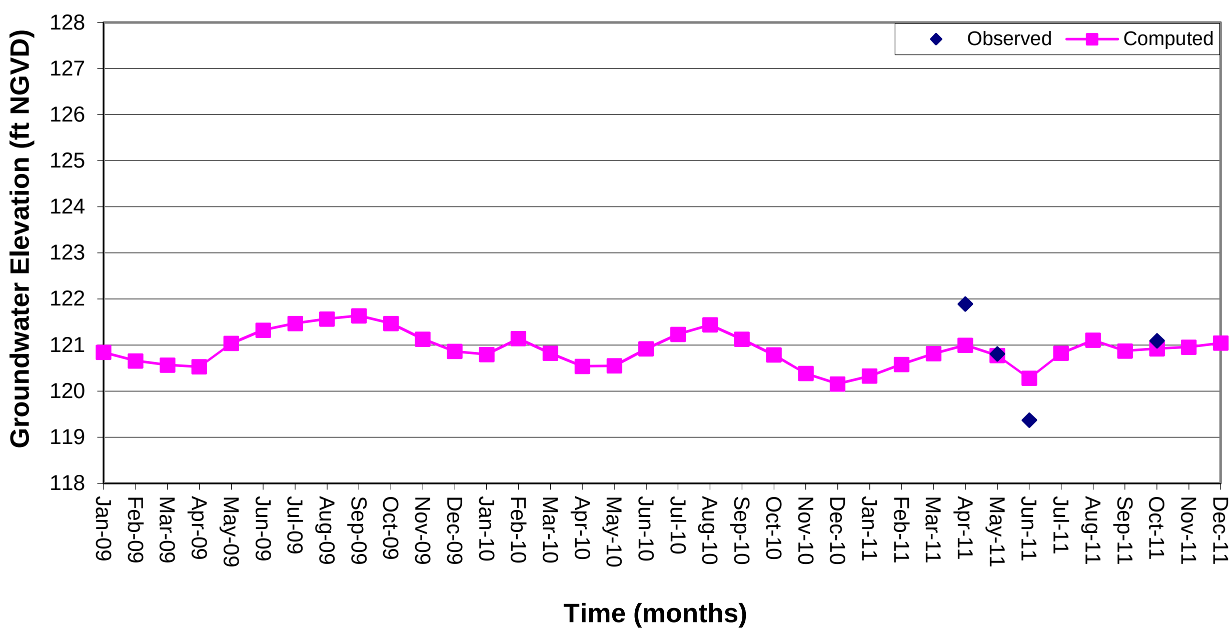
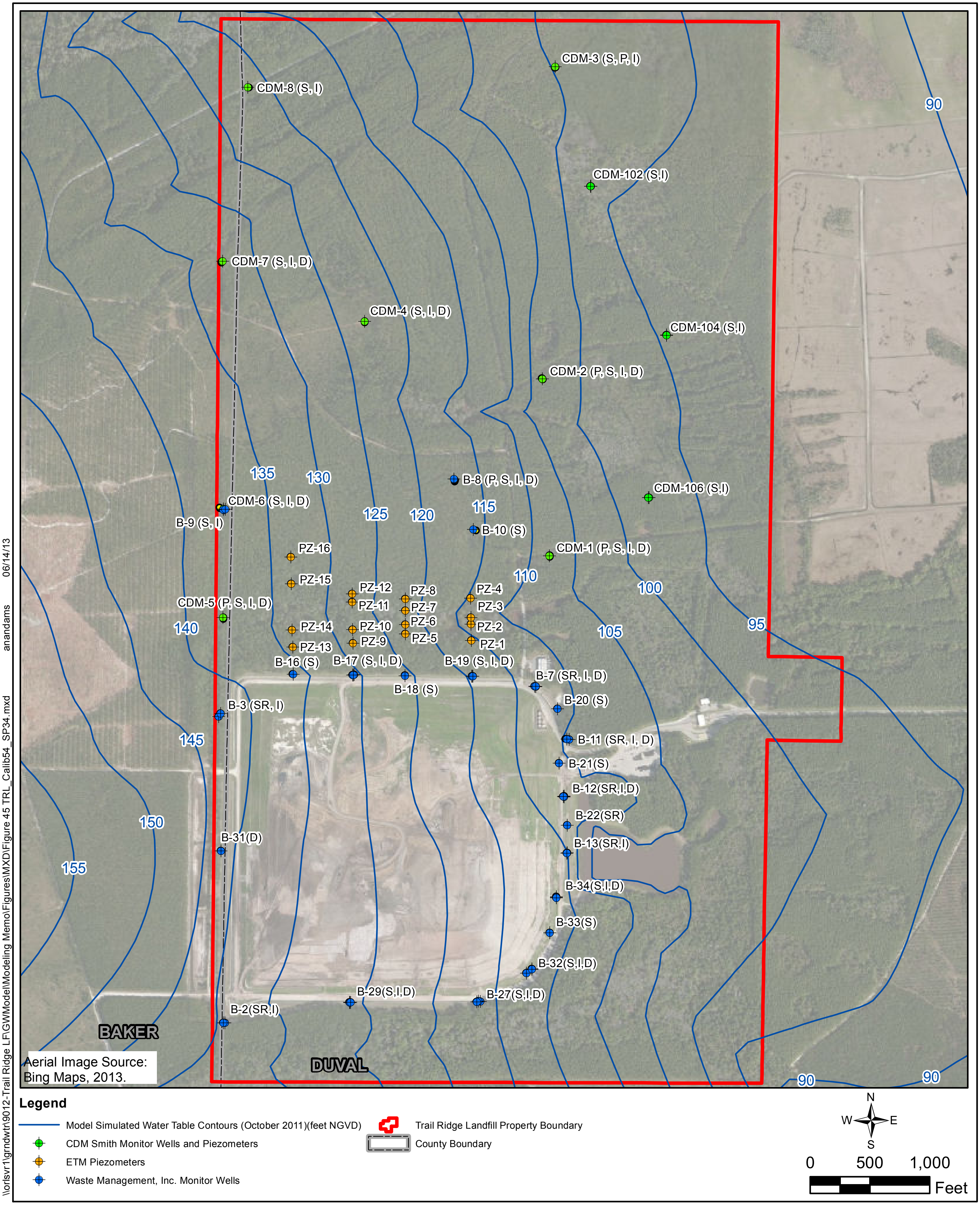


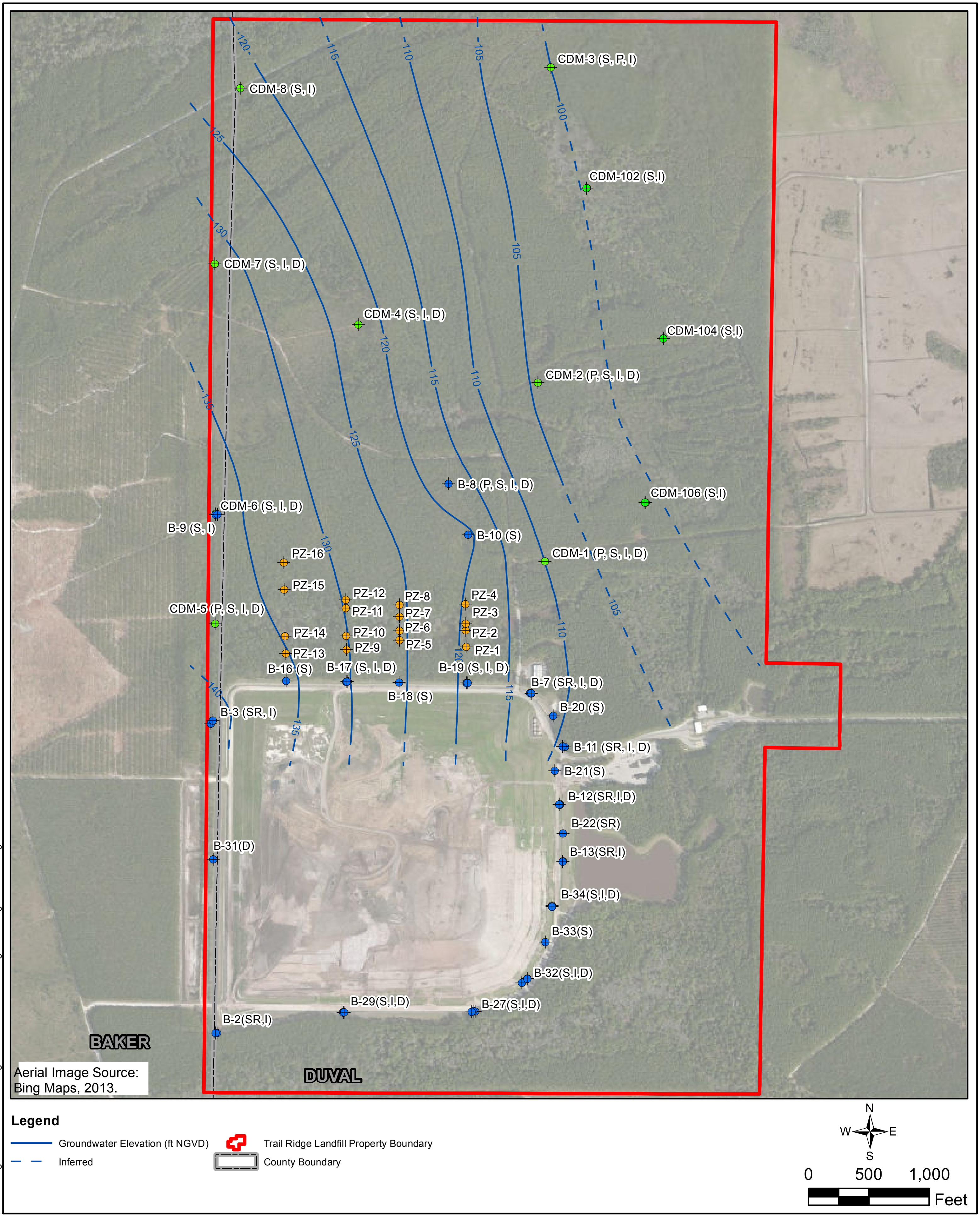
Figure 44
Comparison of Measured versus Simulated Groundwater Levels at CDM-8I (Layer 5)

CDM Smith



CDM Smith

Figure 45
Model Simulated Water Table Elevation Contours in October 2011
Trail Ridge Landfill Expansion Project



CDM Smith

Figure 46
Observed Shallow Surficial Groundwater Elevation Contours in October 2011
Trail Ridge Landfill Expansion Project

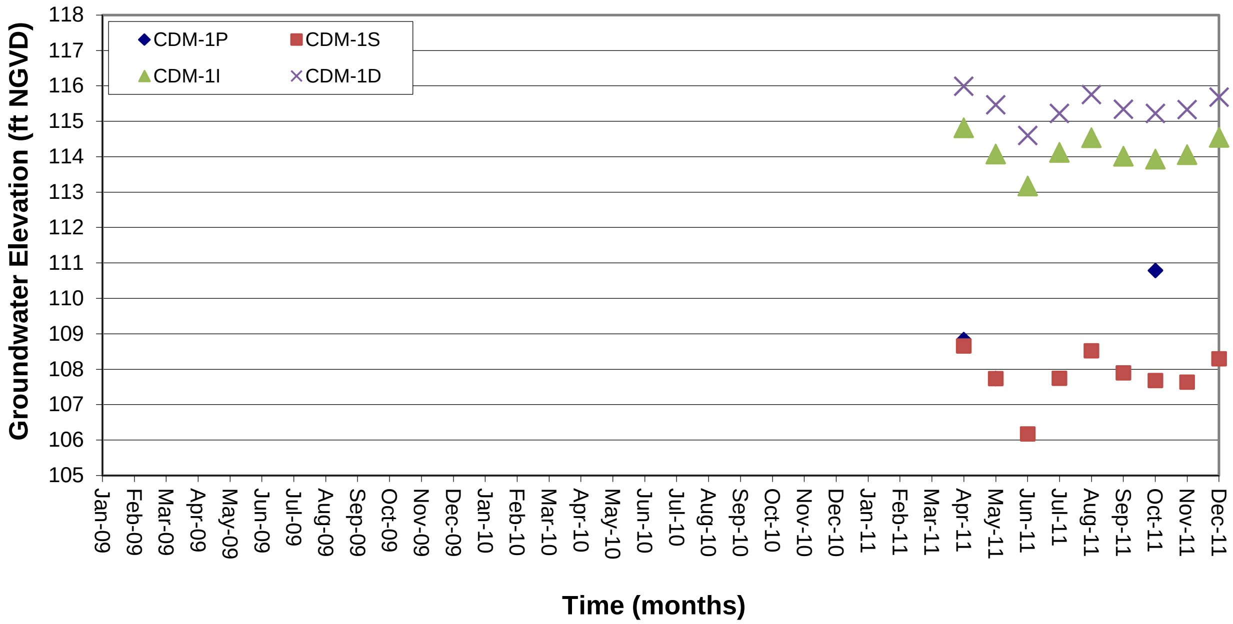


Figure 47
Observed Vertical Head Difference
in CDM-1 Cluster

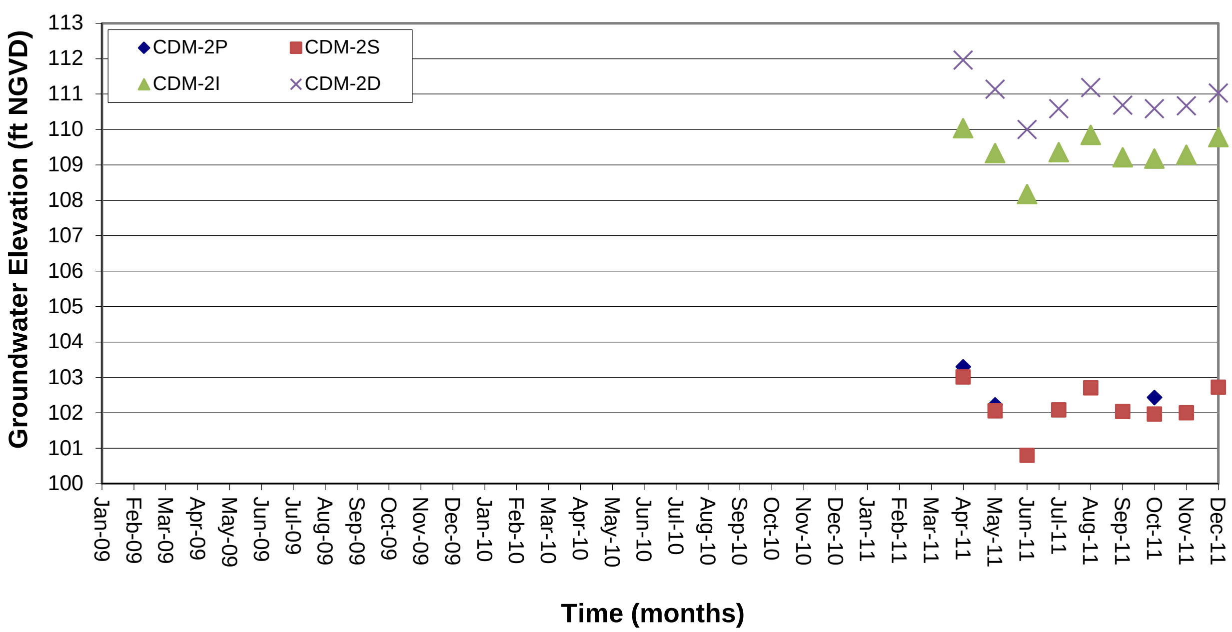


Figure 48
Observed Vertical Head Difference
in CDM-2 Cluster

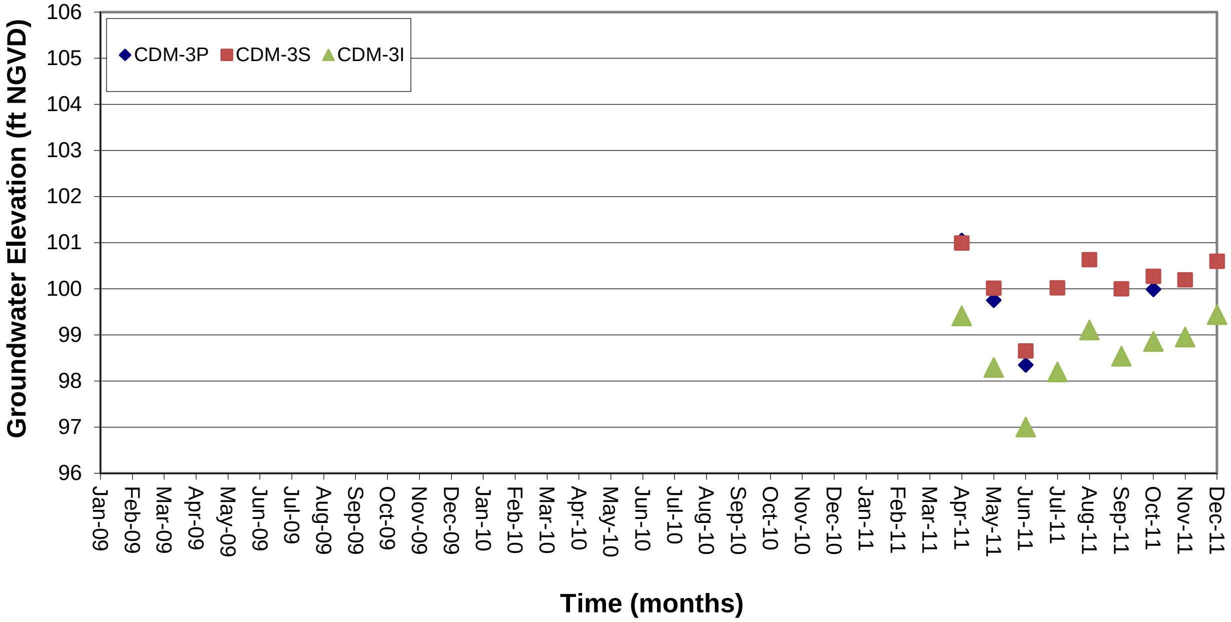


Figure 49
Observed Vertical Head Difference
in CDM-3 Cluster

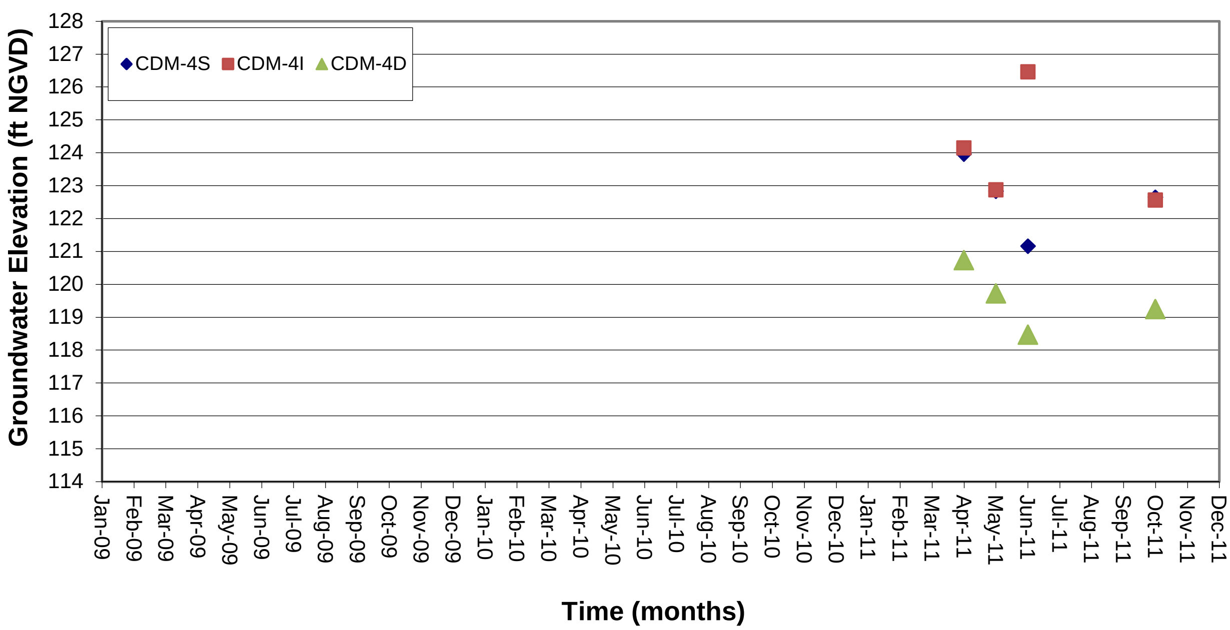


Figure 50
Observed Vertical Head Difference
in CDM-4 Cluster

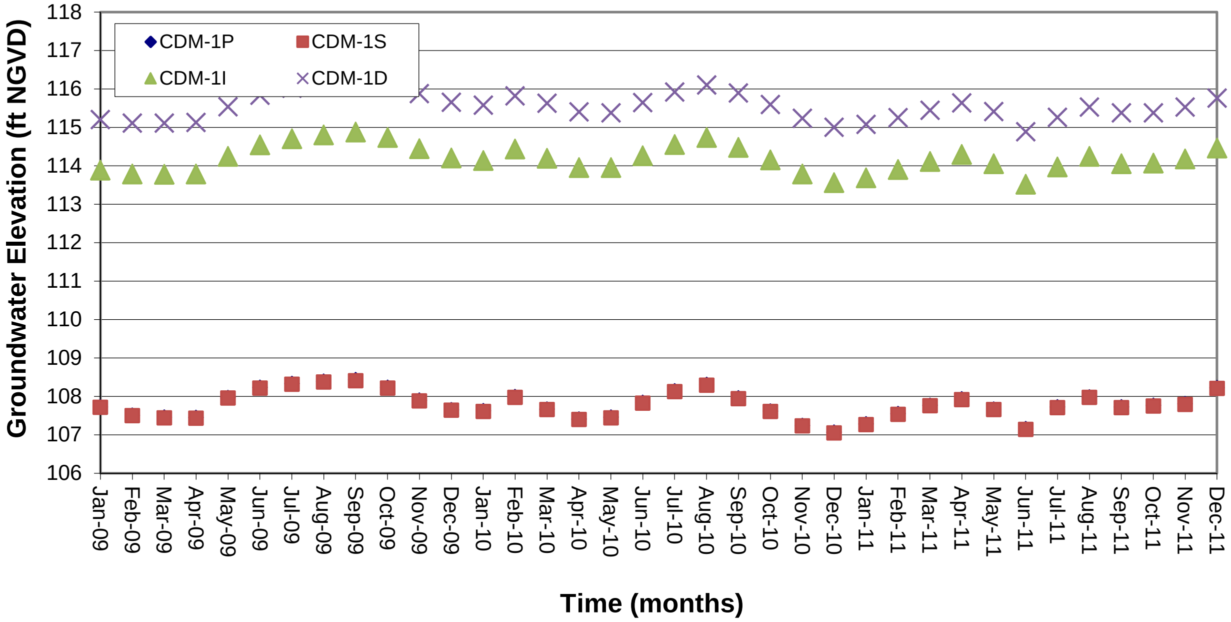


Figure 51
Model Simulated Vertical Head Difference
in CDM-1 Cluster

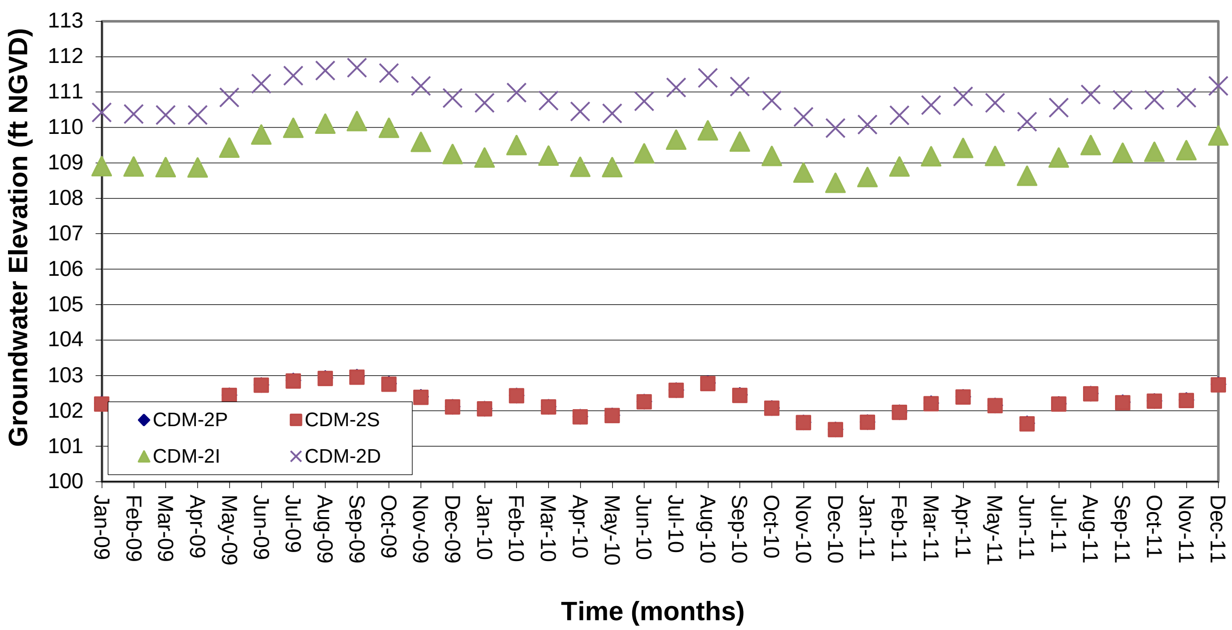


Figure 52
Model Simulated Vertical Head Difference
in CDM-2 Cluster

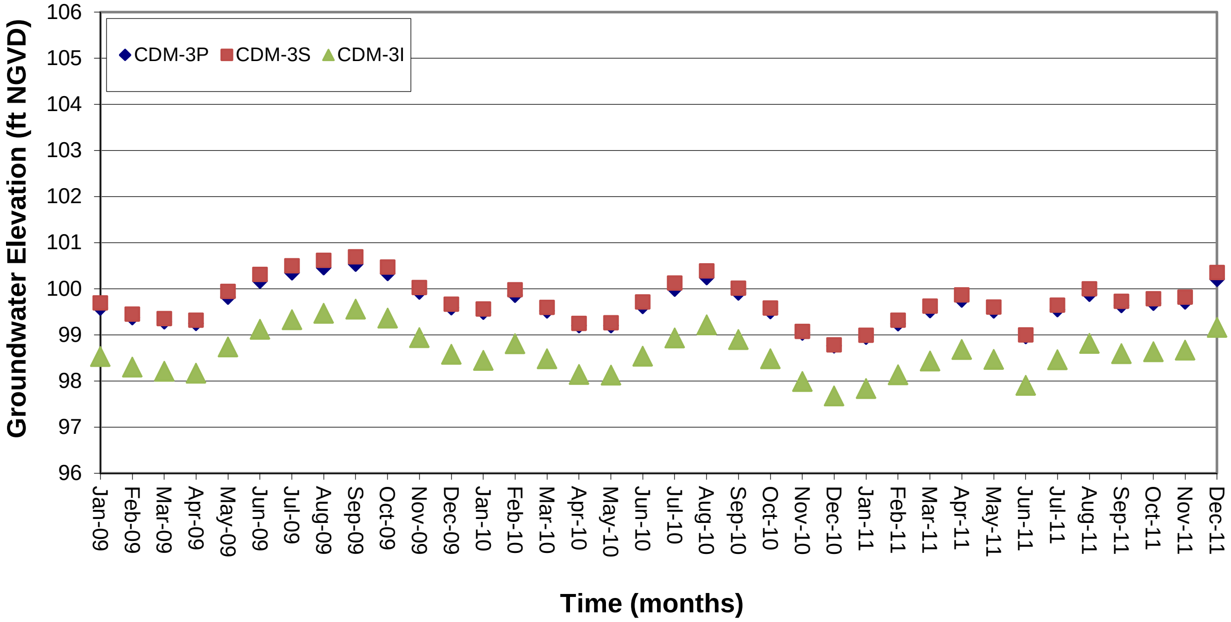


Figure 53
Model Simulated Vertical Head Difference
in CDM-3 Cluster

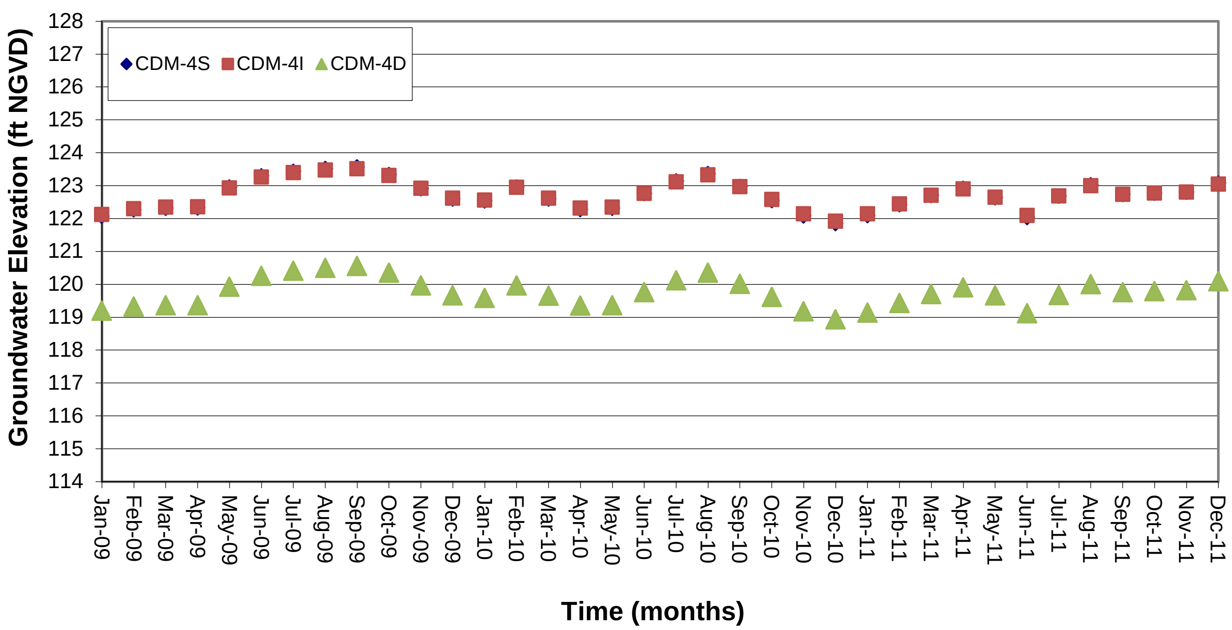
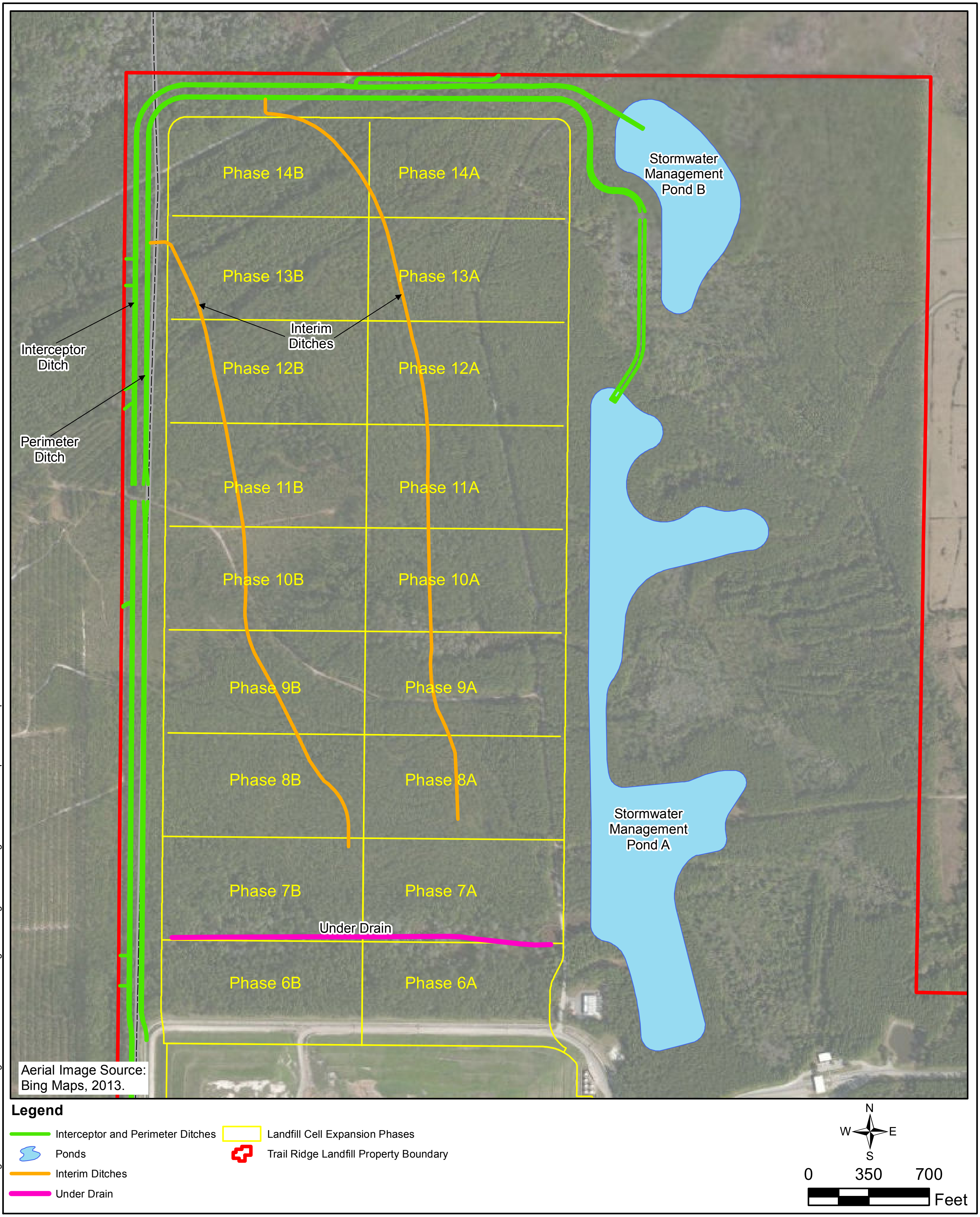


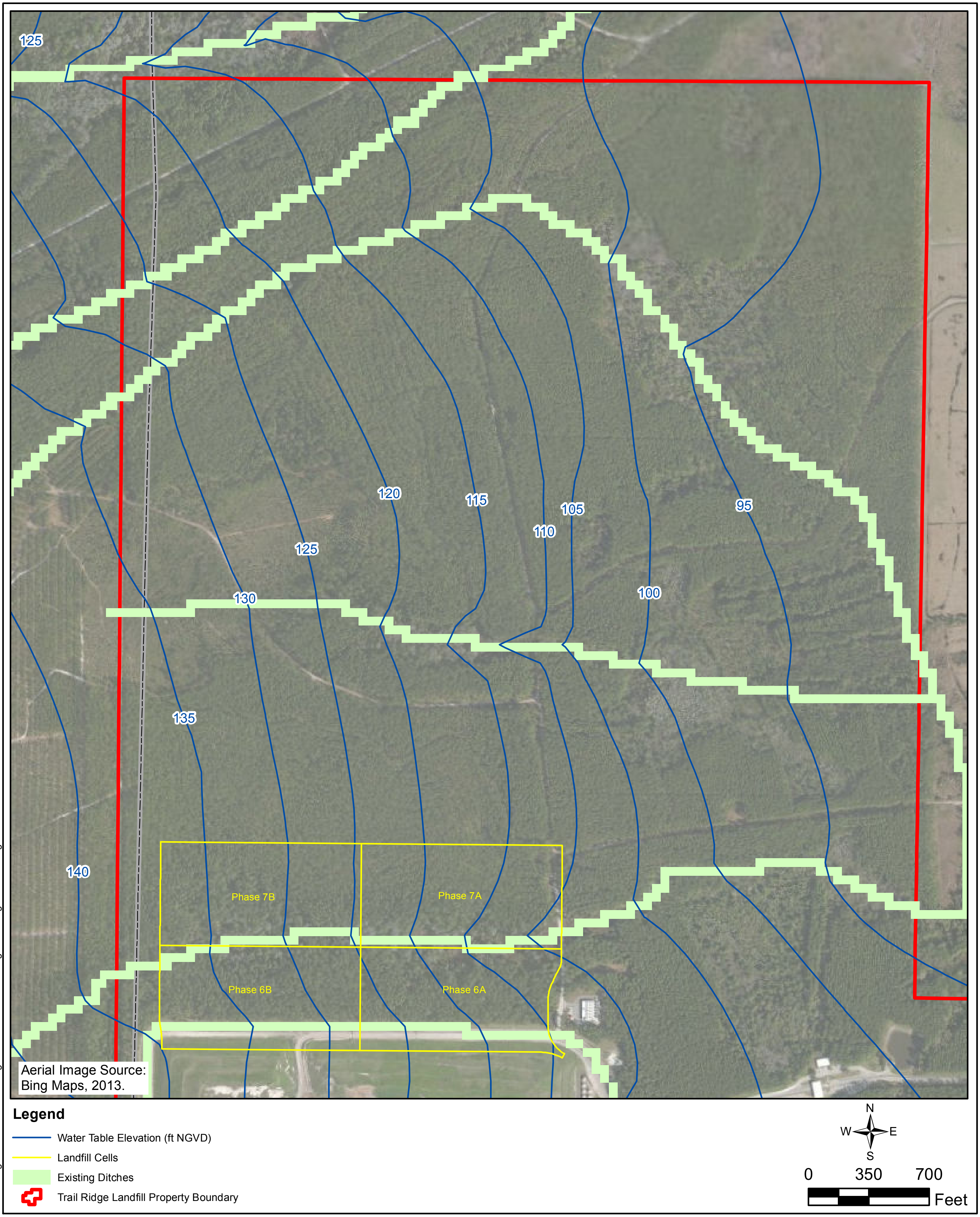
Figure 54
Model Simulated Vertical Head Difference
in CDM-4 Cluster



\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 55 Landfill Expansion Components.mxd anandams 06/14/13

CDM Smith

Figure 55
Major Components of the TRLF Expansion
Trail Ridge Landfill Expansion Project



\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 56Phase6&7 SIM1 Head.mxd anandams 06/14/13

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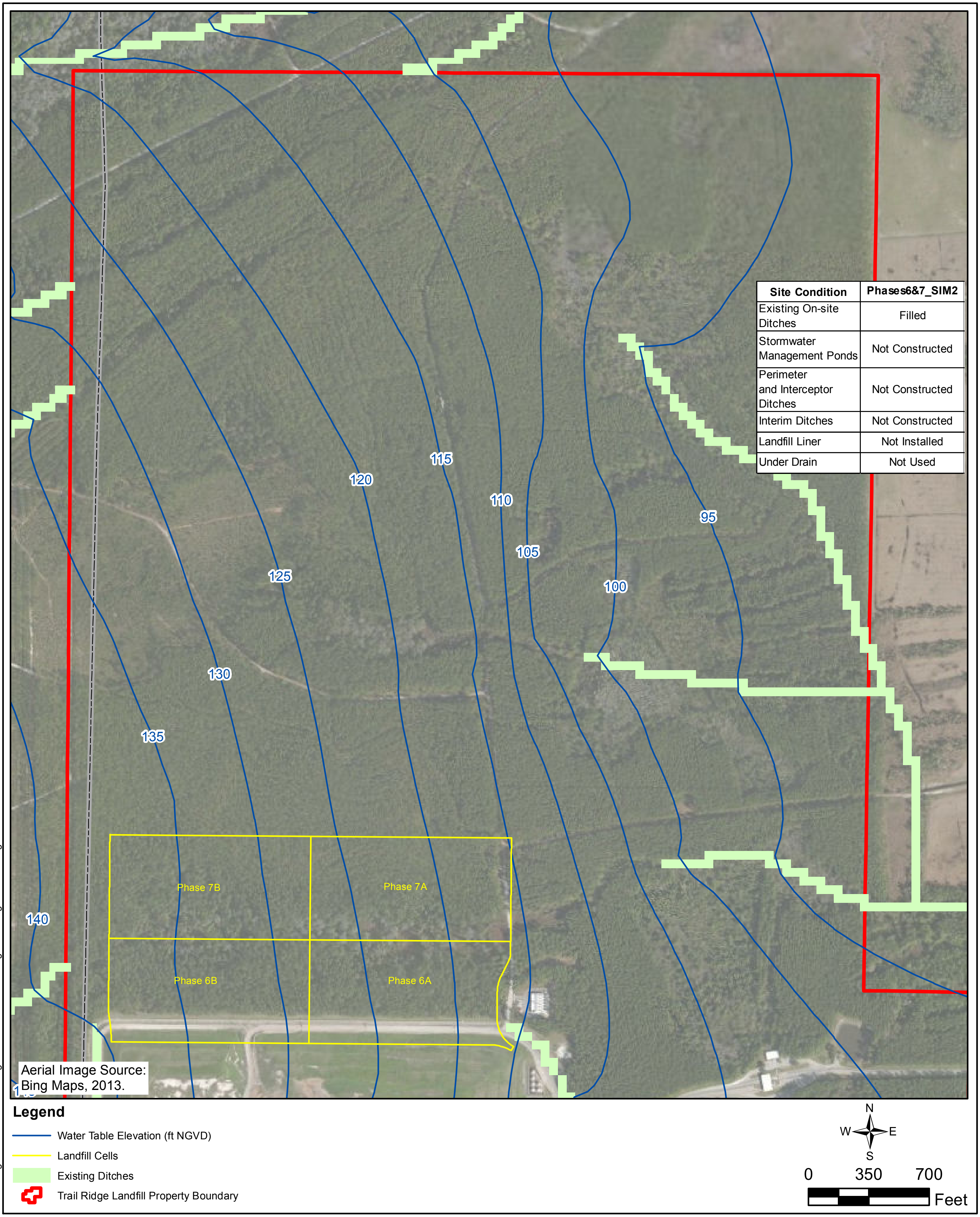
Figure 56
Simulated Seasonal High Water Table Elevations
Baseline Condition (Phases6&7_SIM1)
Trail Ridge Landfill Expansion Project



Site Condition	Phases6&7_SIM2
Existing On-site Ditches	Filled
Stormwater Management Ponds	Not Constructed
Perimeter and Interceptor Ditches	Not Constructed
Interim Ditches	Not Constructed
Landfill Liner	Not Installed
Under Drain	Not Used

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 57 Phase6&7 SIM2 Head.mxd anandams 06/14/13

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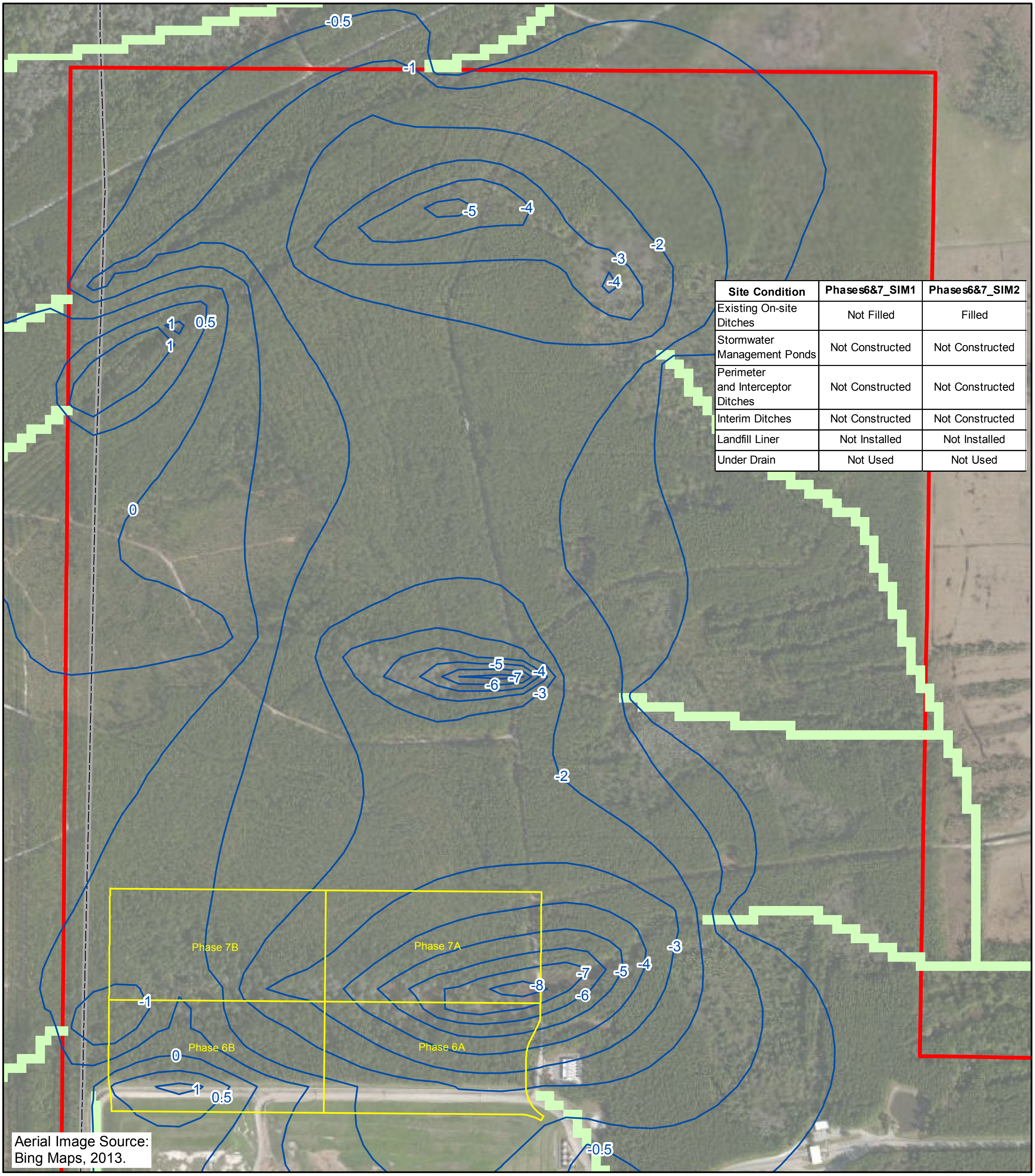
Figure 57
Simulated Seasonal High Water Table Elevations After Existing Ditches are Filled (Phases6&7_SIM2)
Trail Ridge Landfill Expansion Project



Site Condition	Phases6&7_SIM1	Phases6&7_SIM2
Existing On-site Ditches	Not Filled	Filled
Stormwater Management Ponds	Not Constructed	Not Constructed
Perimeter and Interceptor Ditches	Not Constructed	Not Constructed
Interim Ditches	Not Constructed	Not Constructed
Landfill Liner	Not Installed	Not Installed
Under Drain	Not Used	Not Used

Legend

- Water Table Drawdown / Recovery (feet)
- Landfill Cells
- Existing Ditches
- Trail Ridge Landfill Property Boundary

Note: "-" sign indicates recovery of water table.

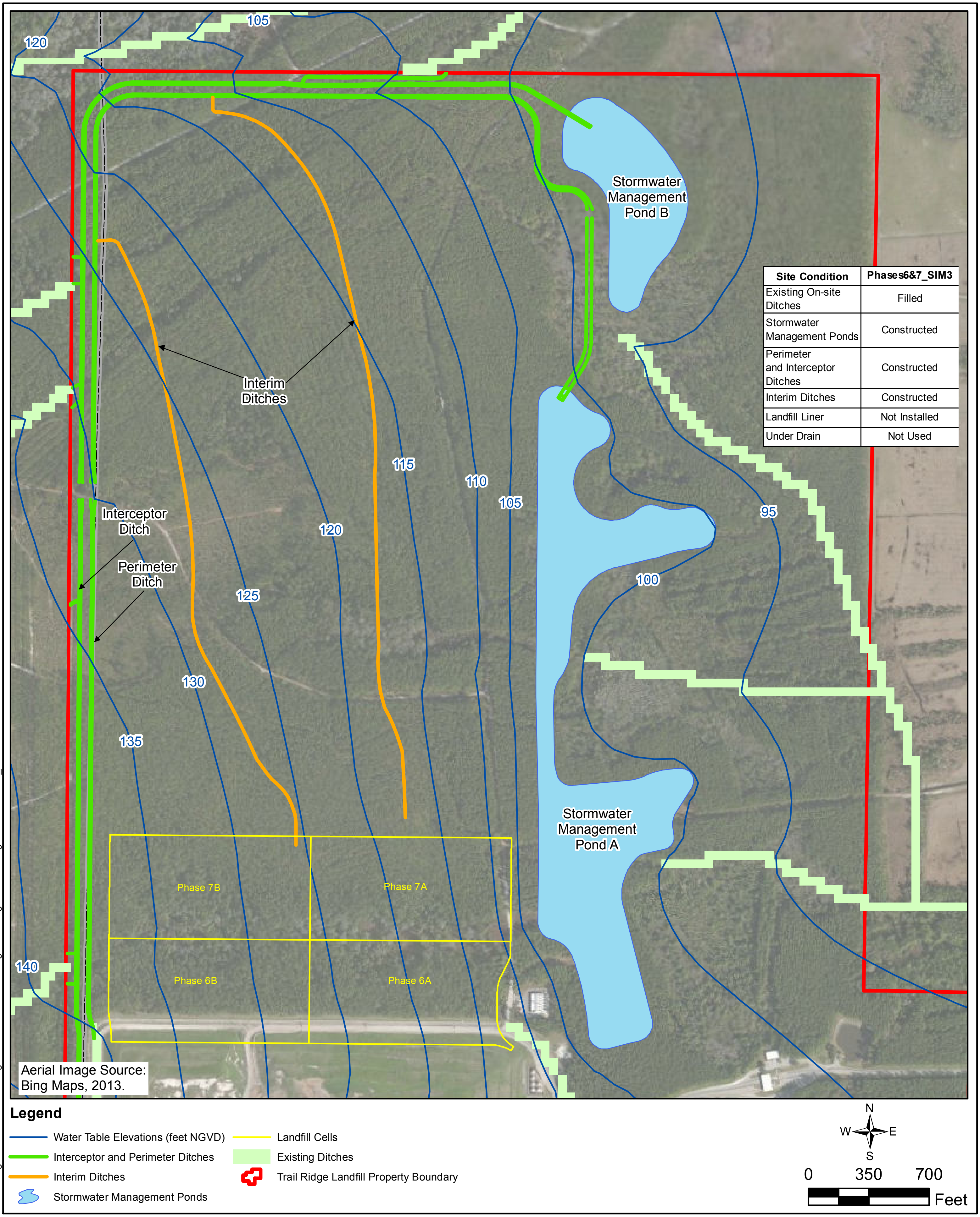
N W E S

0 350 700 Feet

CDM Smith

Figure 58
Simulated Water Table Drawdown / Recovery
After Existing Ditches are Filled (Phases6&7_SIM1-Phases6&7_SIM2)
Trail Ridge Landfill Expansion Project

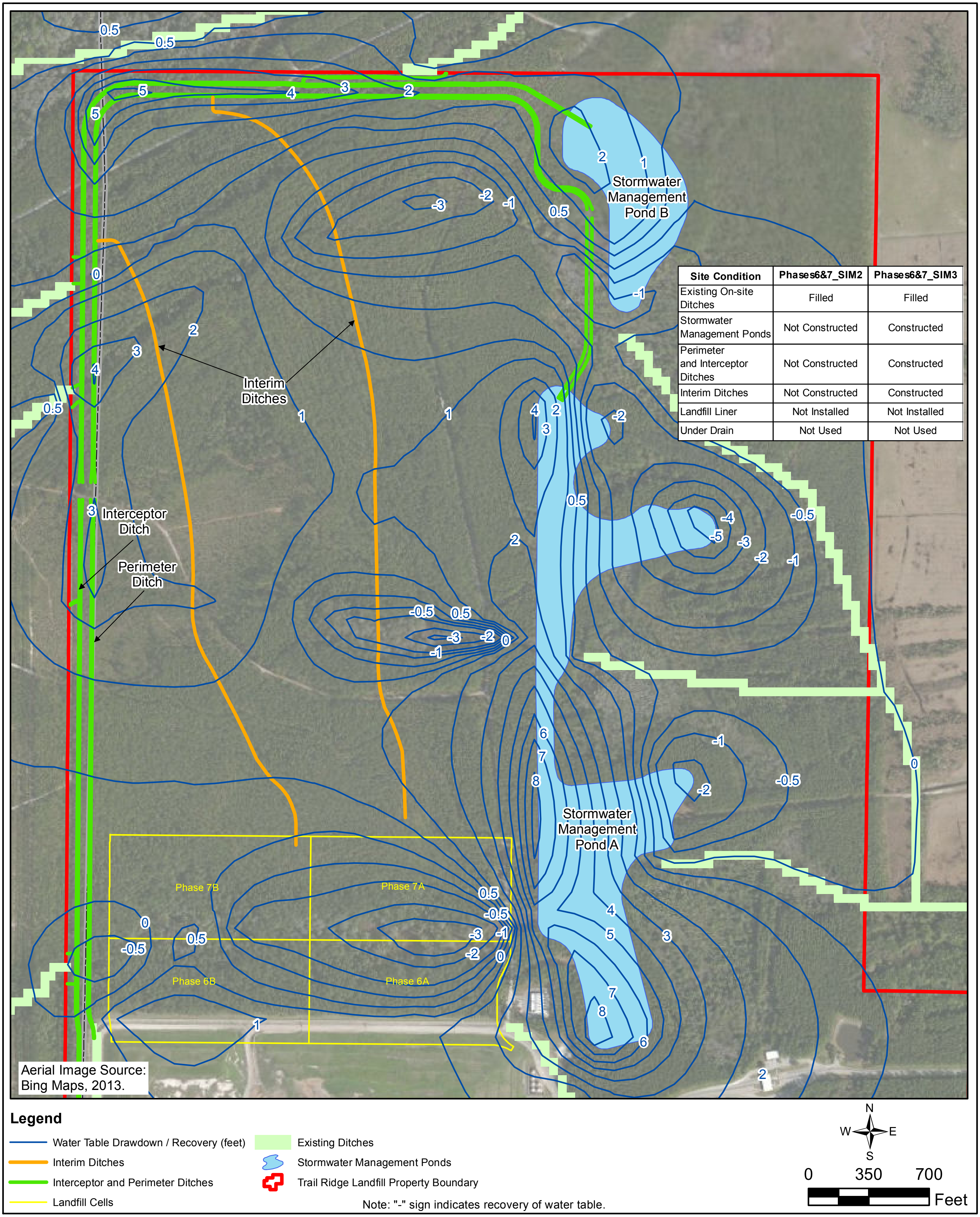
\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 70 BuildOut_SIM2 Head.mxd anandams 06/14/13



Site Condition	Phases6&7_SIM3
Existing On-site Ditches	Filled
Stormwater Management Ponds	Constructed
Perimeter and Interceptor Ditches	Constructed
Interim Ditches	Constructed
Landfill Liner	Not Installed
Under Drain	Not Used

CDM Smith

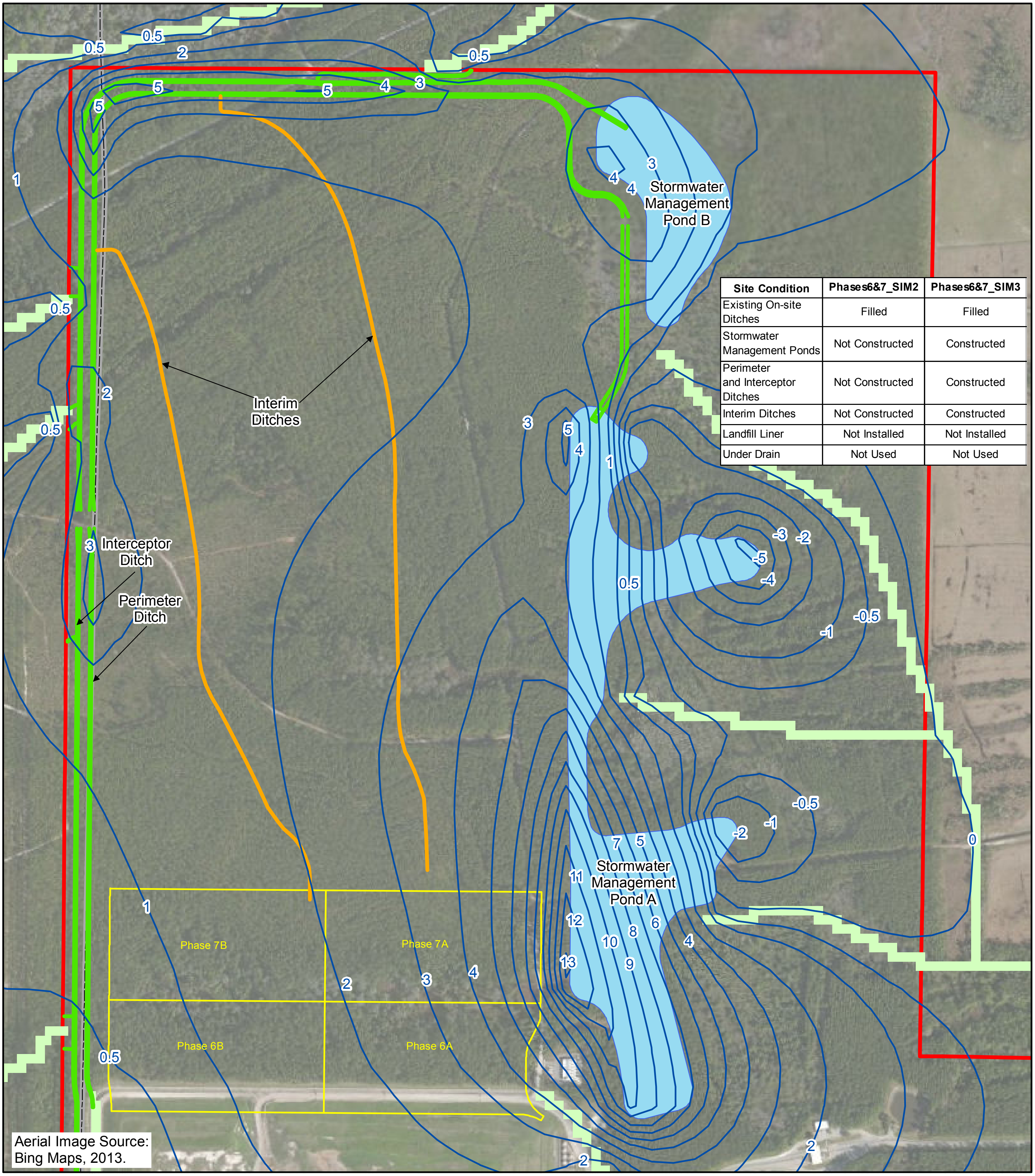
Figure 59
Simulated Seasonal High Water Table Elevations
Under Phases6&7_SIM3 Conditions (Phases6&7_SIM3)
Trail Ridge Landfill Expansion Project



Site Condition	Phases6&7_SIM2	Phases6&7_SIM3
Existing On-site Ditches	Filled	Filled
Stormwater Management Ponds	Not Constructed	Constructed
Perimeter and Interceptor Ditches	Not Constructed	Constructed
Interim Ditches	Not Constructed	Constructed
Landfill Liner	Not Installed	Not Installed
Under Drain	Not Used	Not Used

CDM Smith

Figure 60
Simulated Water Table Drawdown / Recovery
Under Phases6&7_SIM3 Conditions (Phases6&7_SIM1 - Phases6&7_SIM3)
Trail Ridge Landfill Expansion Project



Site Condition	Phases6&7_SIM2	Phases6&7_SIM3
Existing On-site Ditches	Filled	Filled
Stormwater Management Ponds	Not Constructed	Constructed
Perimeter and Interceptor Ditches	Not Constructed	Constructed
Interim Ditches	Not Constructed	Constructed
Landfill Liner	Not Installed	Not Installed
Under Drain	Not Used	Not Used

Legend

- Water Table Drawdown / Recovery (feet)
- Interim Ditches
- Interceptor and Perimeter Ditches
- Landfill Cells
- Existing Ditches
- Stormwater Management Ponds
- Trail Ridge Landfill Property Boundary

Note: "-" sign indicates recovery of water table.

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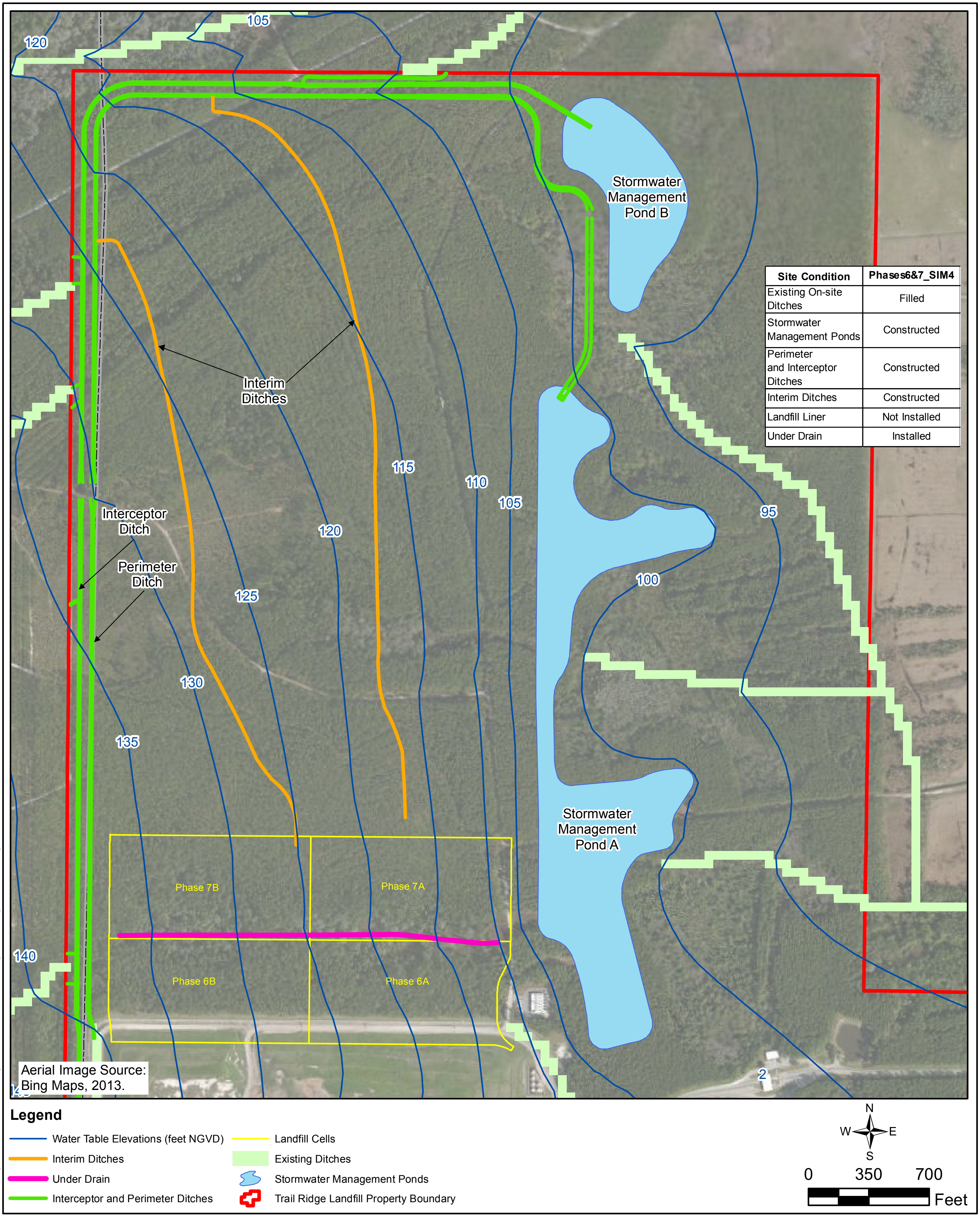
Figure 61
Simulated Water Table Drawdown / Recovery
Under Phases6&7_SIM3 Conditions (Phases6&7_SIM2 - Phases6&7_SIM3)
Trail Ridge Landfill Expansion Project

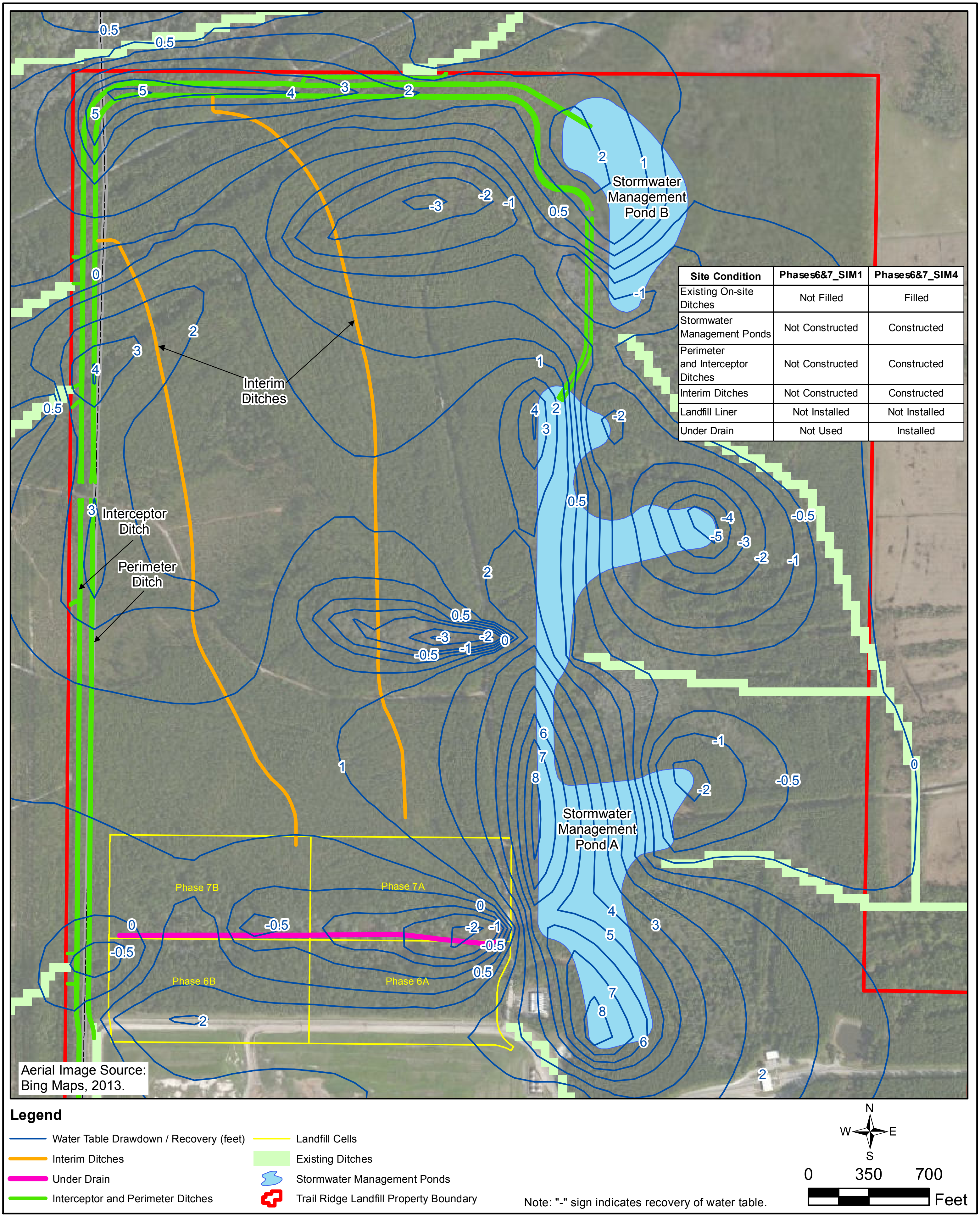


Site Condition	Phases6&7_SIM4
Existing On-site Ditches	Filled
Stormwater Management Ponds	Constructed
Perimeter and Interceptor Ditches	Constructed
Interim Ditches	Constructed
Landfill Liner	Not Installed
Under Drain	Installed

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 62 Phase6&7 Sim4 Head.mxd anandams 06/14/13

CDM Smith

Figure 62
Simulated Seasonal High Water Table Elevations
Under Phases6&7_SIM4 Conditions (Phases6&7_SIM4)
Trail Ridge Landfill Expansion Project

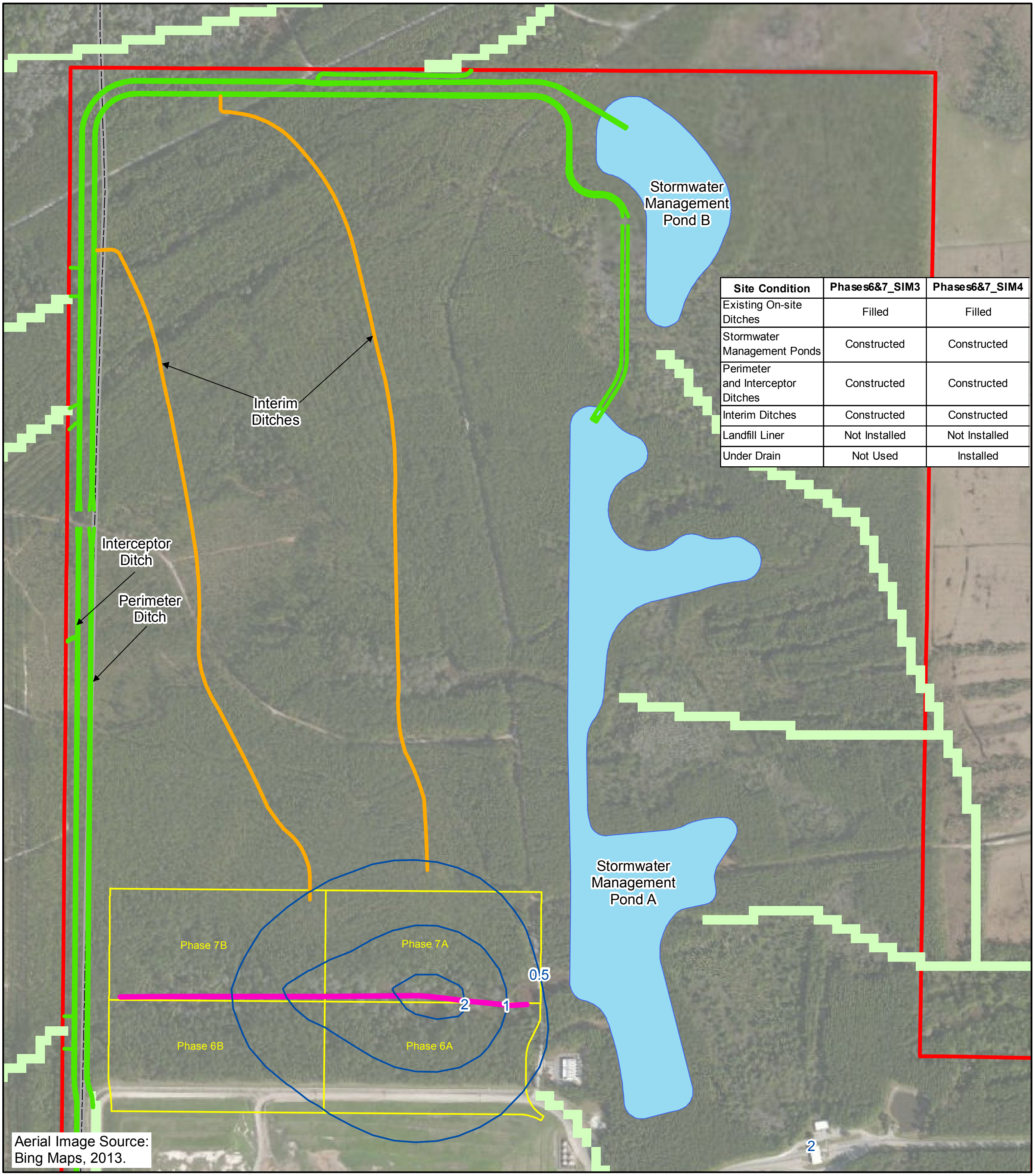


Site Condition	Phases6&7_SIM1	Phases6&7_SIM4
Existing On-site Ditches	Not Filled	Filled
Stormwater Management Ponds	Not Constructed	Constructed
Perimeter and Interceptor Ditches	Not Constructed	Constructed
Interim Ditches	Not Constructed	Constructed
Landfill Liner	Not Installed	Not Installed
Under Drain	Not Used	Installed

J:\9012-Trail Ridge LF\GWModel\Modeling Memo\MXD\Figures\Figure 63 Phase6&7 Sim1-SIM4 dd.mxd anandams 06/14/13

CDM Smith

Figure 63
Simulated Water Table Drawdown / Recovery
Under Phases6&7_SIM4 Conditions (Phases6&7_SIM1 - Phases6&7_SIM4)
Trail Ridge Landfill Expansion Project



Site Condition	Phases6&7_SIM3	Phases6&7_SIM4
Existing On-site Ditches	Filled	Filled
Stormwater Management Ponds	Constructed	Constructed
Perimeter and Interceptor Ditches	Constructed	Constructed
Interim Ditches	Constructed	Constructed
Landfill Liner	Not Installed	Not Installed
Under Drain	Not Used	Installed

Legend

- Water Table Drawdown (feet)
- Interim Ditches
- Under Drain
- Interceptor and Perimeter Ditches
- Landfill Cells
- Existing Ditches
- Stormwater Management Ponds
- Trail Ridge Landfill Property Boundary

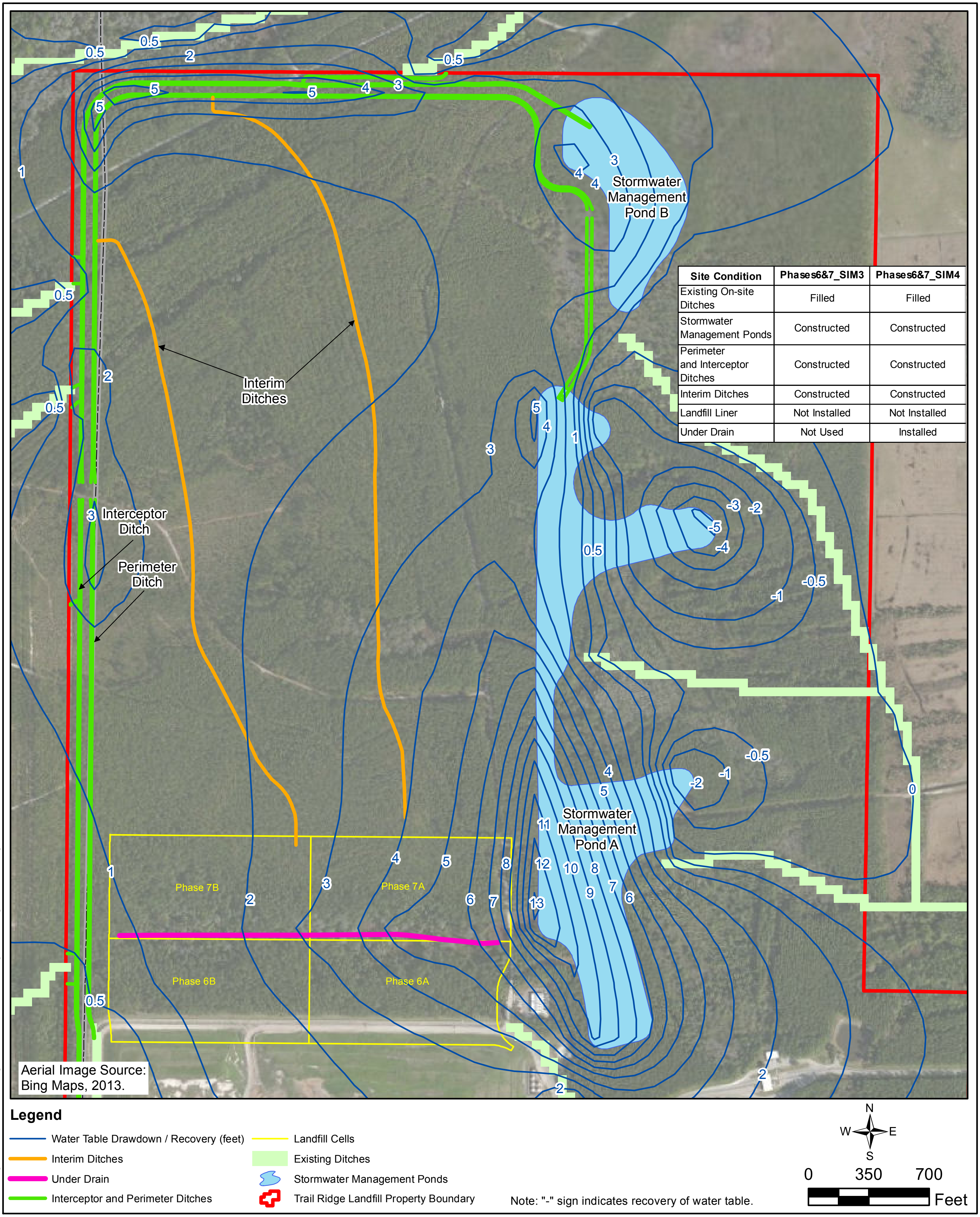
N
W E
S

0 350 700
Feet

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 64 Phase6&7 Sim3-SIM4 dd.mxd anandams 06/14/13

CDM Smith

Figure 64
Simulated Water Table Drawdown
Under Phases6&7_SIM4 Conditions (Phases6&7_SIM3 - Phases6&7_SIM4)
Trail Ridge Landfill Expansion Project

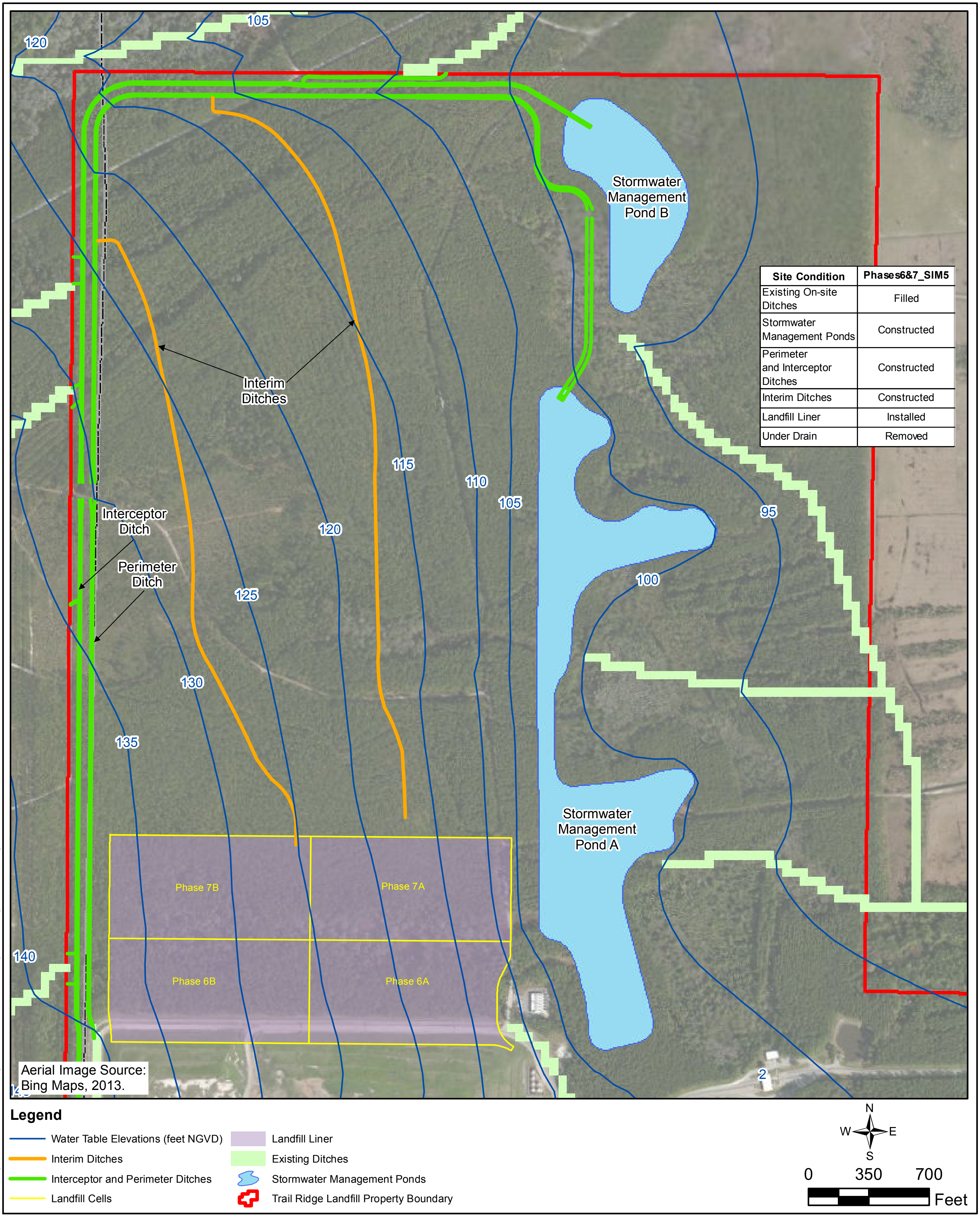


Site Condition	Phases6&7_SIM3	Phases6&7_SIM4
Existing On-site Ditches	Filled	Filled
Stormwater Management Ponds	Constructed	Constructed
Perimeter and Interceptor Ditches	Constructed	Constructed
Interim Ditches	Constructed	Constructed
Landfill Liner	Not Installed	Not Installed
Under Drain	Not Used	Installed

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 65 Phase6&7 Sim2-SIM4 dd.mxd anandams 06/14/13

CDM Smith

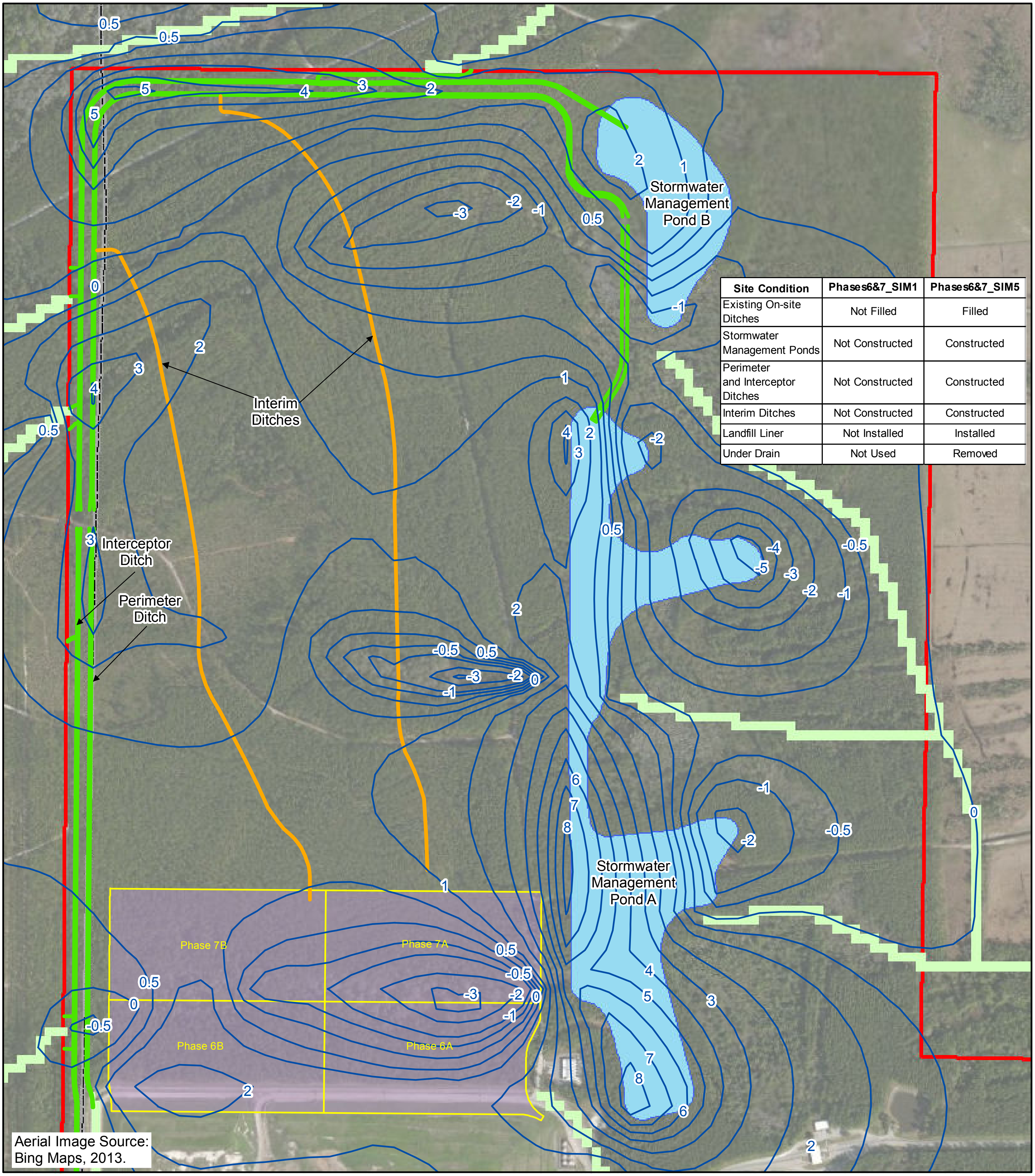
Figure 65
Simulated Water Table Drawdown / Recovery
Under Phases6&7_SIM4 Conditions (Phases6&7_SIM2 - Phases6&7_SIM4)
Trail Ridge Landfill Expansion Project



Site Condition	Phases6&7_SIM5
Existing On-site Ditches	Filled
Stormwater Management Ponds	Constructed
Perimeter and Interceptor Ditches	Constructed
Interim Ditches	Constructed
Landfill Liner	Installed
Under Drain	Removed

CDM Smith

Figure 66
Simulated Seasonal High Water Table Elevations
Under Phases6&7_SIM5 Conditions (Phases6&7_SIM5)
Trail Ridge Landfill Expansion Project



Site Condition	Phases6&7_SIM1	Phases6&7_SIM5
Existing On-site Ditches	Not Filled	Filled
Stormwater Management Ponds	Not Constructed	Constructed
Perimeter and Interceptor Ditches	Not Constructed	Constructed
Interim Ditches	Not Constructed	Constructed
Landfill Liner	Not Installed	Installed
Under Drain	Not Used	Removed

Legend

- Water Table Drawdown / Recovery (feet)
- Interim Ditches
- Interceptor and Perimeter Ditches
- Landfill Cells
- Landfill Liner
- Existing Ditches
- Stormwater Management Ponds
- Trail Ridge Landfill Property Boundary

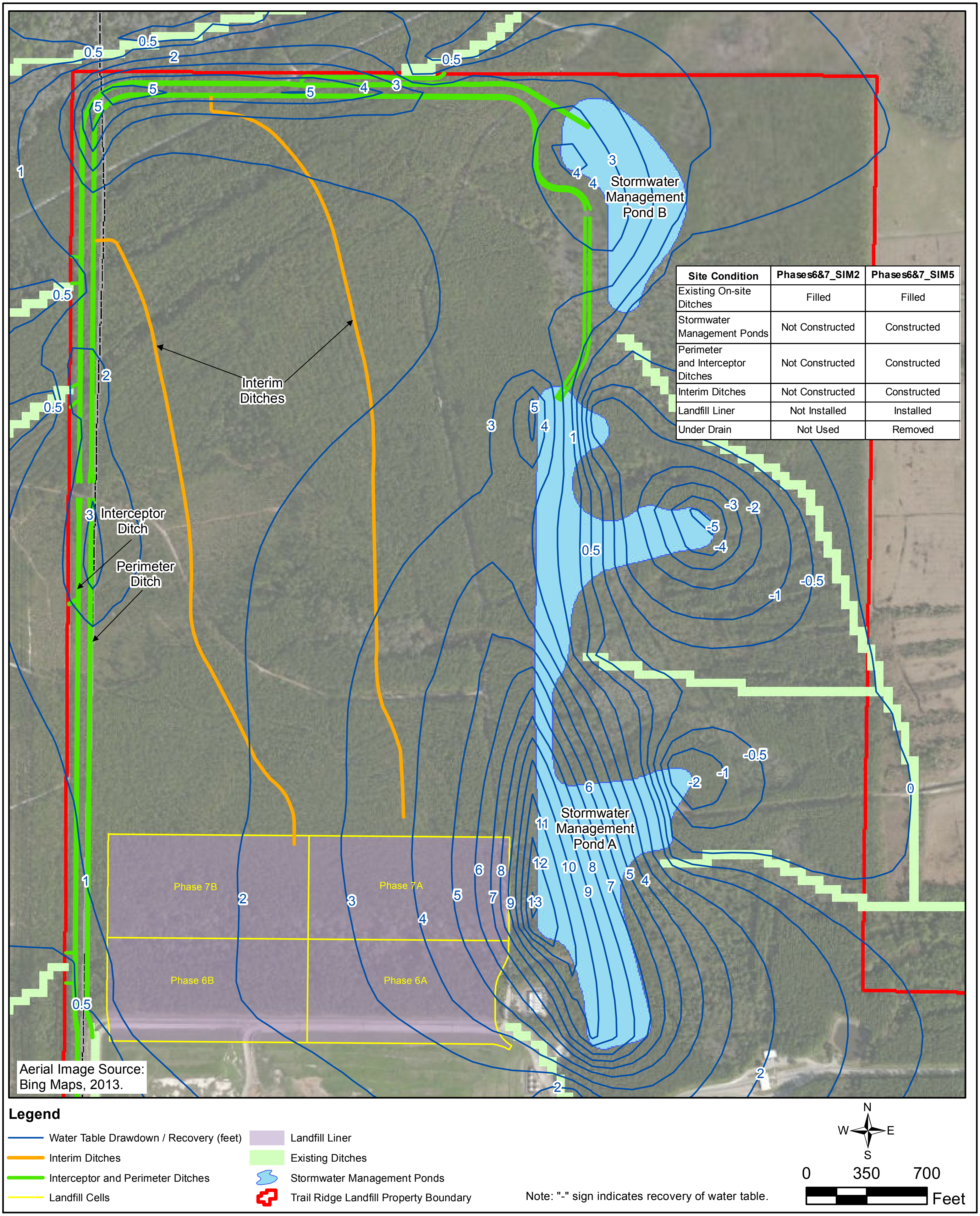
Note: "-" sign indicates recovery of water table.

N W E S

0 350 700 Feet

CDM Smith

Figure 67
Simulated Water Table Drawdown / Recovery
Under Phases6&7_SIM5 Conditions (Phases6&7_SIM1 - Phases6&7_SIM5)
Trail Ridge Landfill Expansion Project

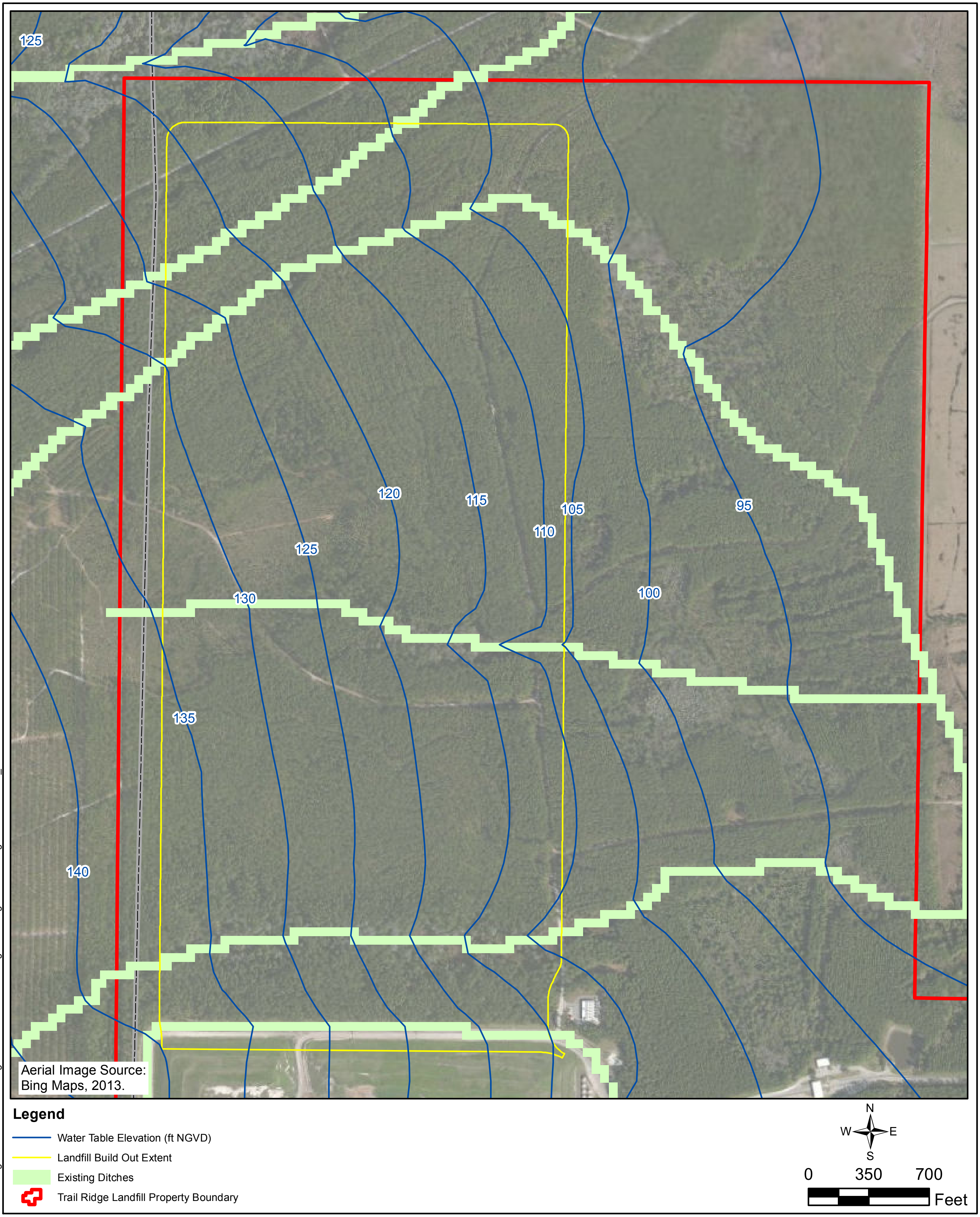


Site Condition	Phases6&7_SIM2	Phases6&7_SIM5
Existing On-site Ditches	Filled	Filled
Stormwater Management Ponds	Not Constructed	Constructed
Perimeter and Interceptor Ditches	Not Constructed	Constructed
Interim Ditches	Not Constructed	Constructed
Landfill Liner	Not Installed	Installed
Under Drain	Not Used	Removed

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 68 Phase6&7 SIM2-Sim5 dd.mxd anandams 06/14/13

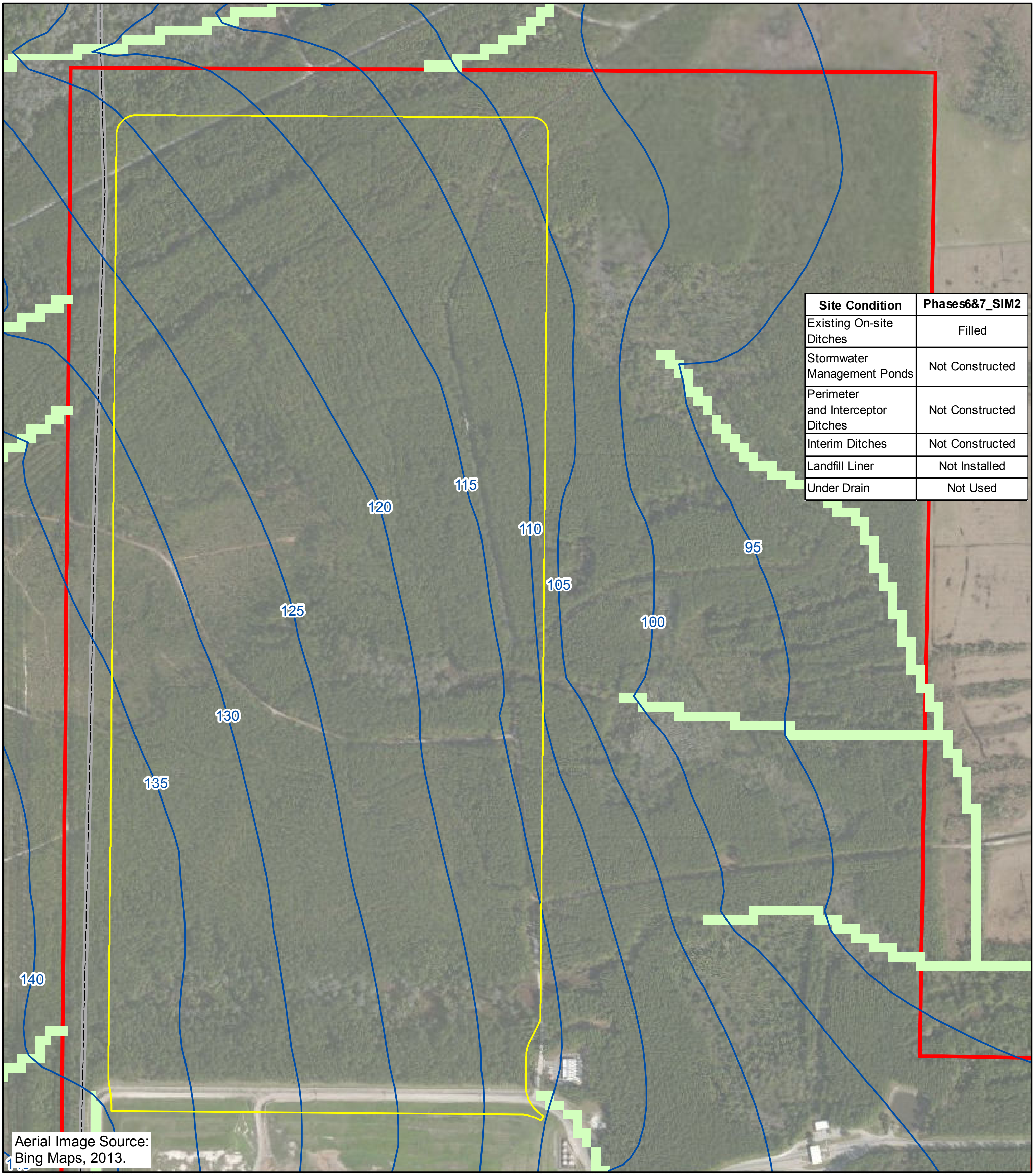
CDM Smith

Figure 68
Simulated Water Table Drawdown / Recovery
Under Phases6&7_SIM5 Conditions (Phases6&7_SIM2 - Phases6&7_SIM5)
Trail Ridge Landfill Expansion Project



CDM Smith

Figure 69
Simulated Seasonal High Water Table Elevations
Baseline Condition (BuildOut_SIM1)
Trail Ridge Landfill Expansion Project



Site Condition	Phases6&7_SIM2
Existing On-site Ditches	Filled
Stormwater Management Ponds	Not Constructed
Perimeter and Interceptor Ditches	Not Constructed
Interim Ditches	Not Constructed
Landfill Liner	Not Installed
Under Drain	Not Used

Legend

- Water Table Elevation (ft NGVD)
- Landfill Build Out Extent
- Existing Ditches
- Trail Ridge Landfill Property Boundary

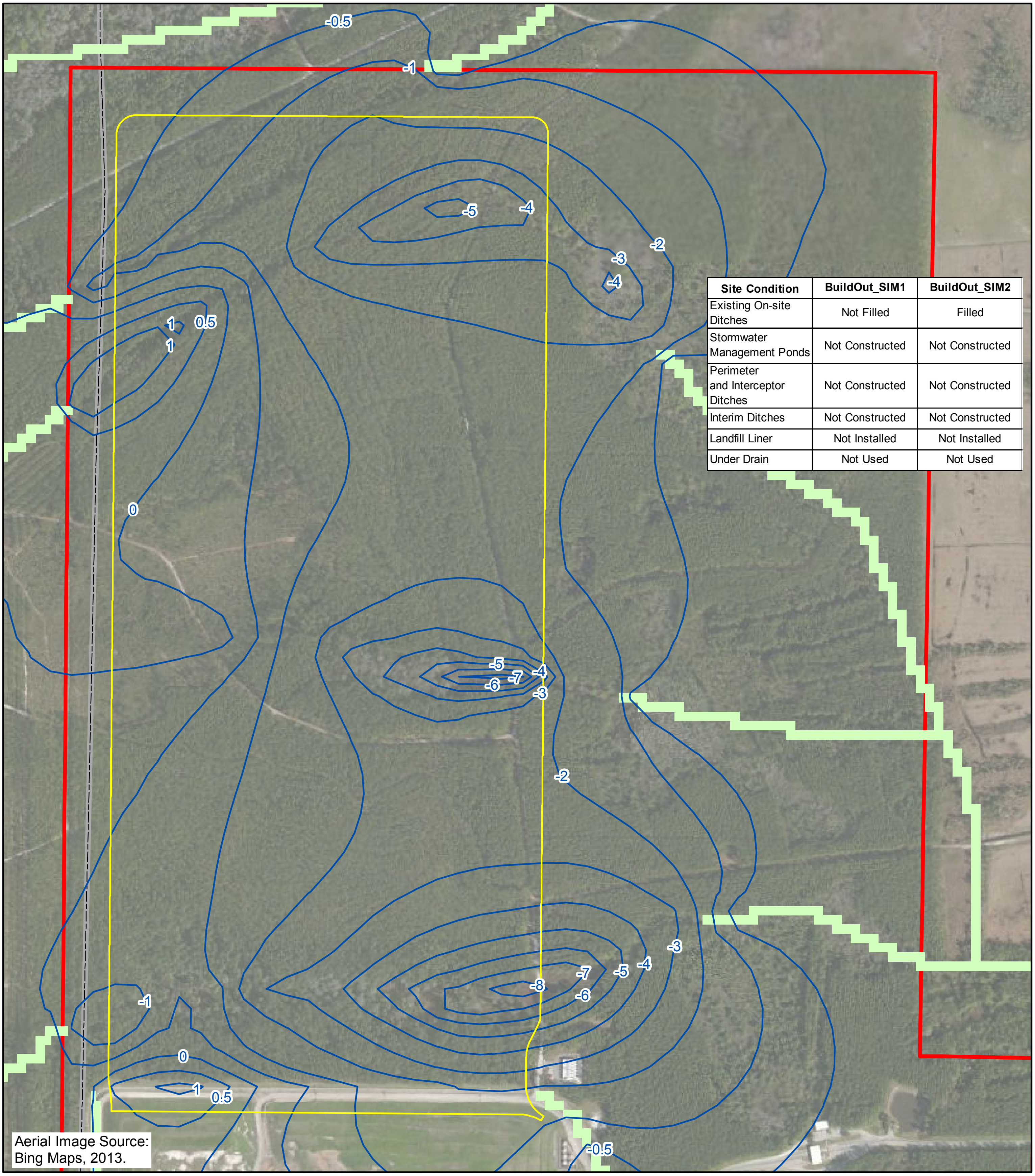
N W E S

0 350 700 Feet

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 70 BuildOut_SIM2 Head.mxd anandams 06/14/13

CDM Smith

Figure 70
Simulated Seasonal High Water Table Elevations After Existing Ditches are Filled (BuildOut_SIM2)
Trail Ridge Landfill Expansion Project



Site Condition	BuildOut_SIM1	BuildOut_SIM2
Existing On-site Ditches	Not Filled	Filled
Stormwater Management Ponds	Not Constructed	Not Constructed
Perimeter and Interceptor Ditches	Not Constructed	Not Constructed
Interim Ditches	Not Constructed	Not Constructed
Landfill Liner	Not Installed	Not Installed
Under Drain	Not Used	Not Used

Legend

- Water Table Drawdown / Recovery (feet)
- Landfill Build Out Extent
- Existing Ditches
- Trail Ridge Landfill Property Boundary

Note: "-" sign indicates recovery of water table.

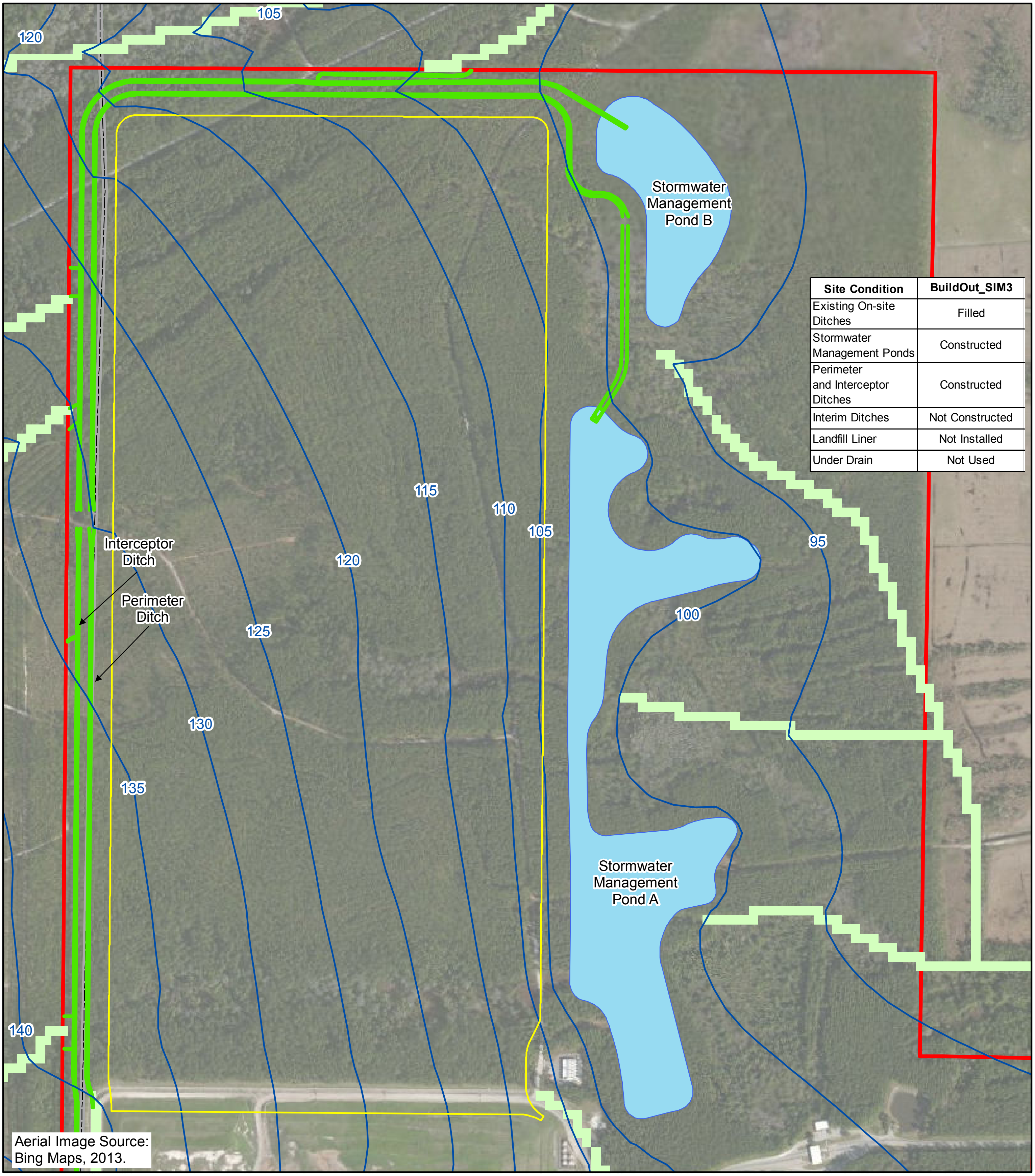
N W E S

0 350 700 Feet

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 71 Phase6&7 SIM1-SIM2 Head.mxd anandams 06/14/13

CDM Smith

Figure 71
Simulated Water Table Drawdown / Recovery
After Existing Ditches are Filled (BuildOut_SIM1 - BuildOut_SIM2)
Trail Ridge Landfill Expansion Project



Site Condition	BuildOut_SIM3
Existing On-site Ditches	Filled
Stormwater Management Ponds	Constructed
Perimeter and Interceptor Ditches	Constructed
Interim Ditches	Not Constructed
Landfill Liner	Not Installed
Under Drain	Not Used

Legend

- Water Table Elevation (ft NGVD)
- Interceptor and Perimeter Ditches
- Stormwater Management Ponds
- Landfill Build Out Extent
- Existing Ditches
- Trail Ridge Landfill Property Boundary

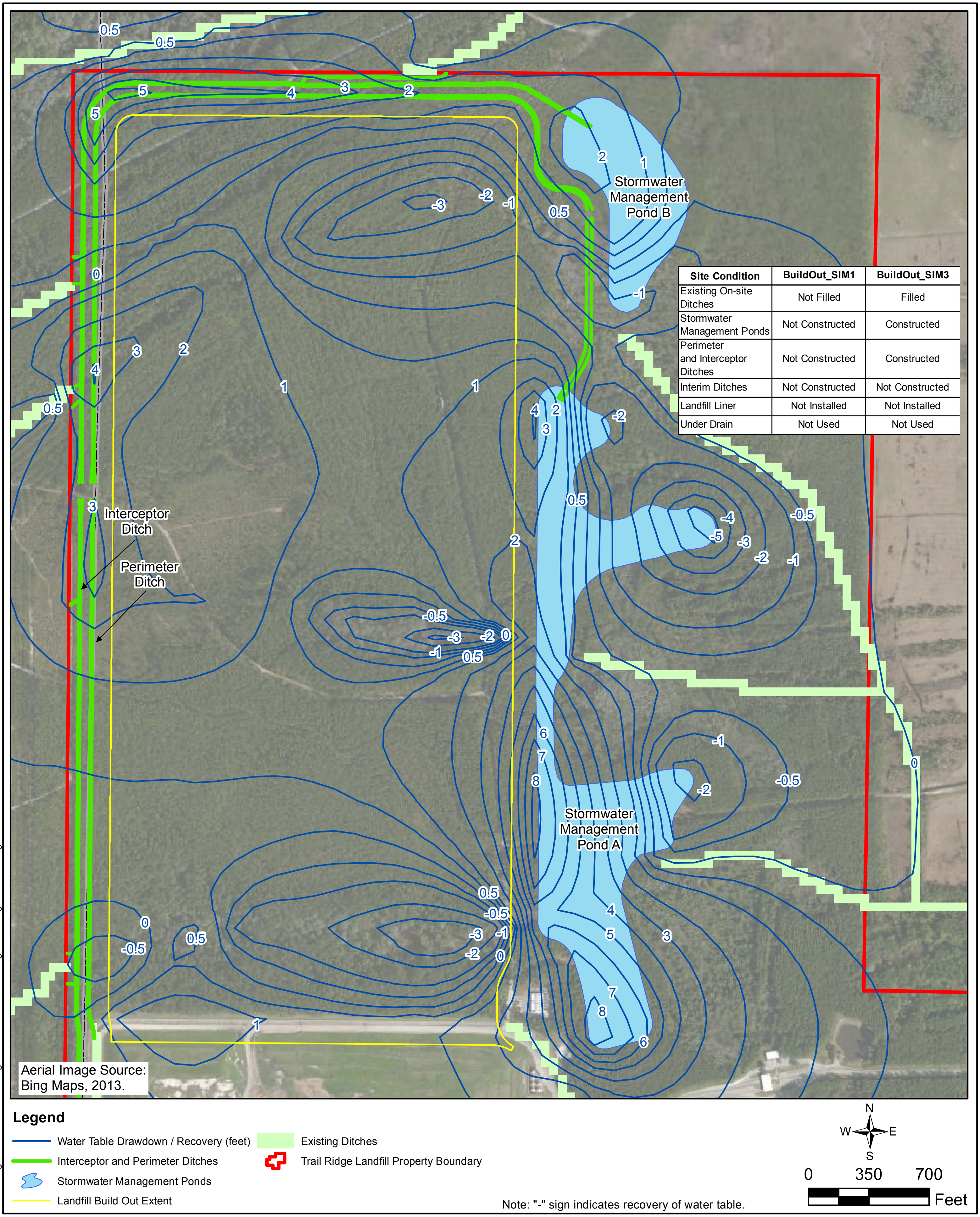
N W E S

0 350 700 Feet

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 72 BuildOut SIM3 Head.mxd anandams 06/14/13

CDM Smith

Figure 72
Simulated Seasonal High Water Table Elevations Under BuildOut_SIM3 Conditions (BuildOut_SIM3)
Trail Ridge Landfill Expansion Project

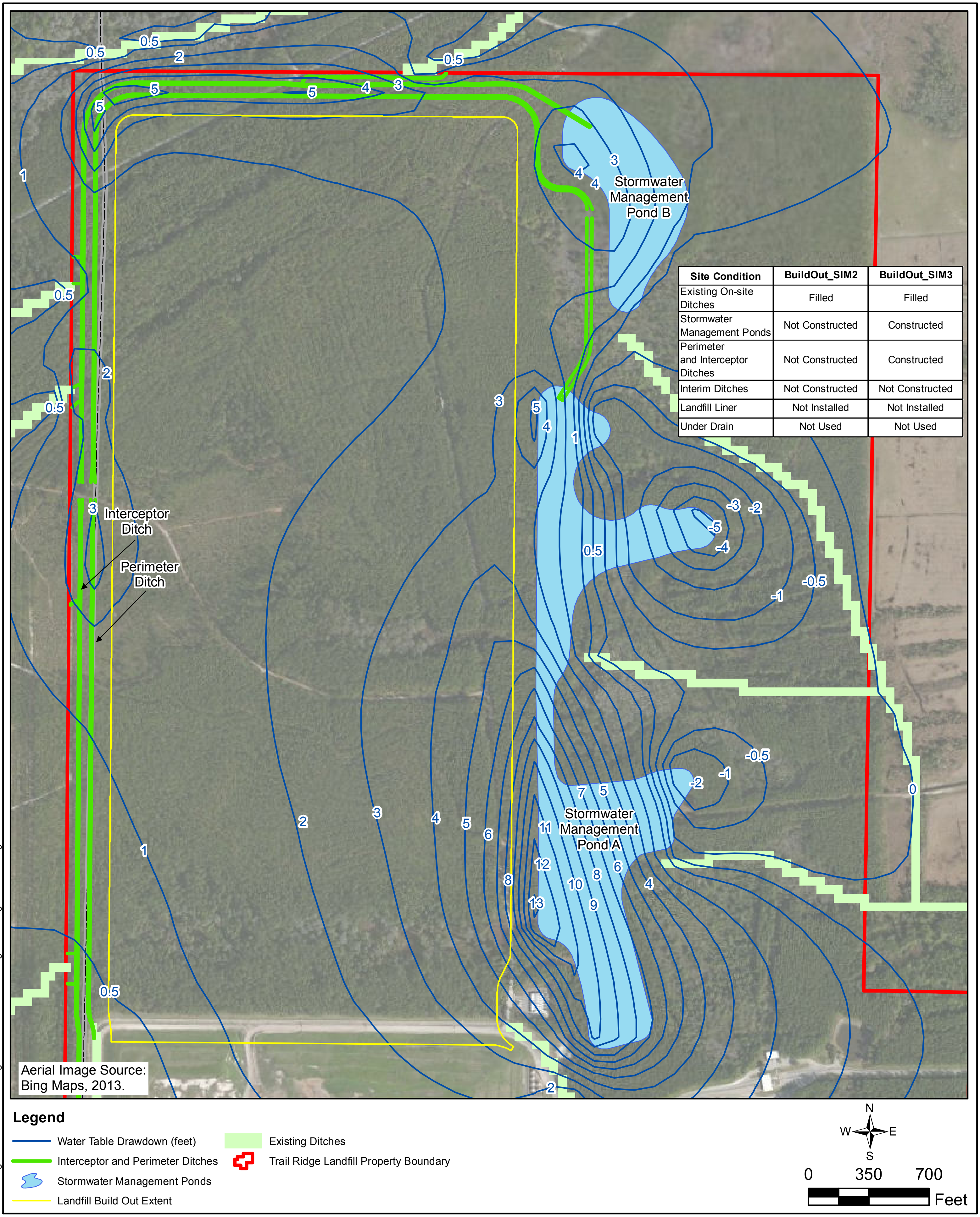


Site Condition	BuildOut_SIM1	BuildOut_SIM3
Existing On-site Ditches	Not Filled	Filled
Stormwater Management Ponds	Not Constructed	Constructed
Perimeter and Interceptor Ditches	Not Constructed	Constructed
Interim Ditches	Not Constructed	Not Constructed
Landfill Liner	Not Installed	Not Installed
Under Drain	Not Used	Not Used

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 72 BuildOut SIM3 Head.mxd anandams 06/14/13

CDM Smith

Figure 73
Simulated Water Table Drawdown / Recovery
Under BuildOut_SIM3 Conditions (BuildOut_SIM1 - BuildOut_SIM3)
Trail Ridge Landfill Expansion Project

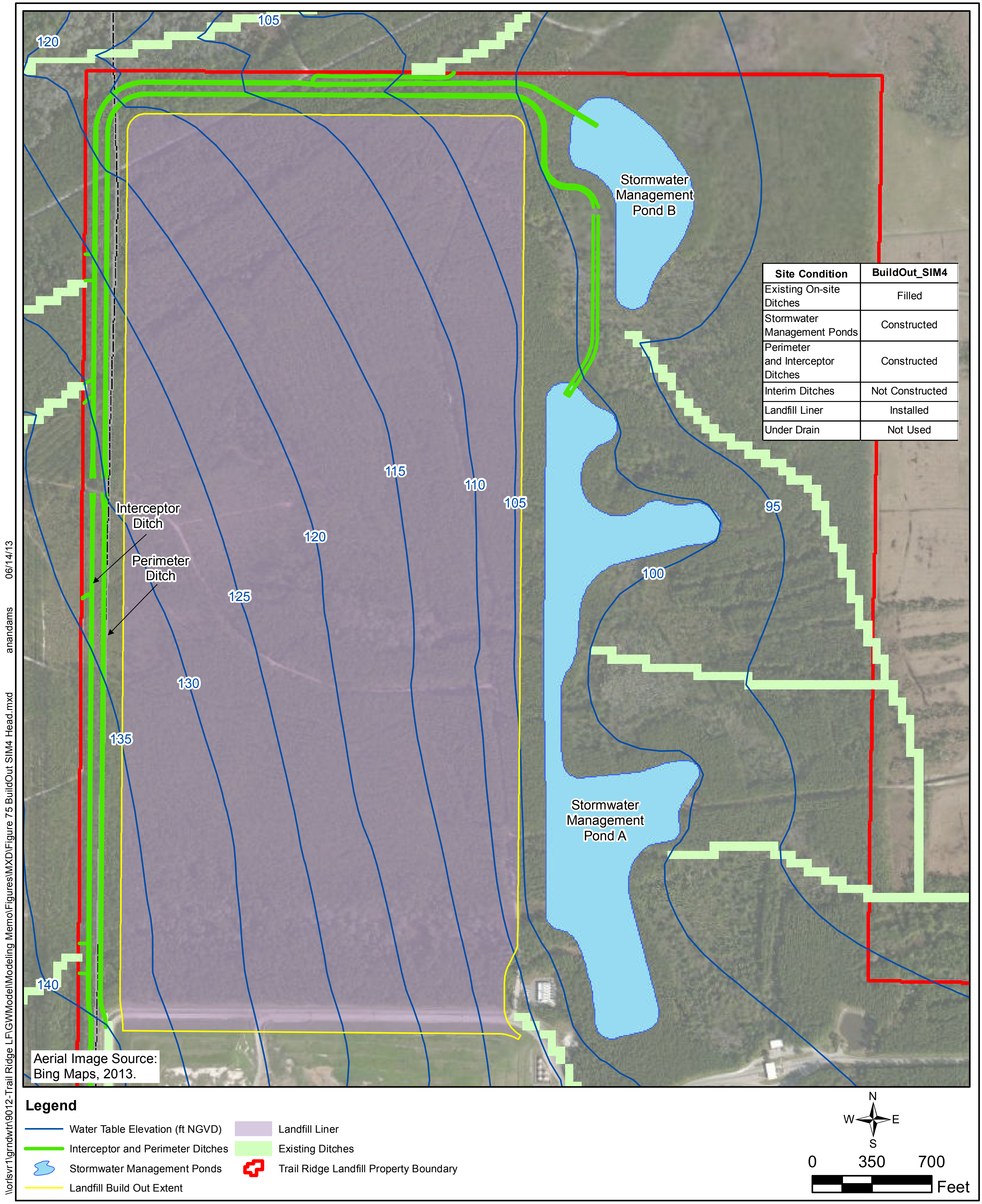


Site Condition	BuildOut_SIM2	BuildOut_SIM3
Existing On-site Ditches	Filled	Filled
Stormwater Management Ponds	Not Constructed	Constructed
Perimeter and Interceptor Ditches	Not Constructed	Constructed
Interim Ditches	Not Constructed	Not Constructed
Landfill Liner	Not Installed	Not Installed
Under Drain	Not Used	Not Used

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 74 BuildOut SIM2-SIM3 dd.mxd anandams 06/14/13

CDM Smith

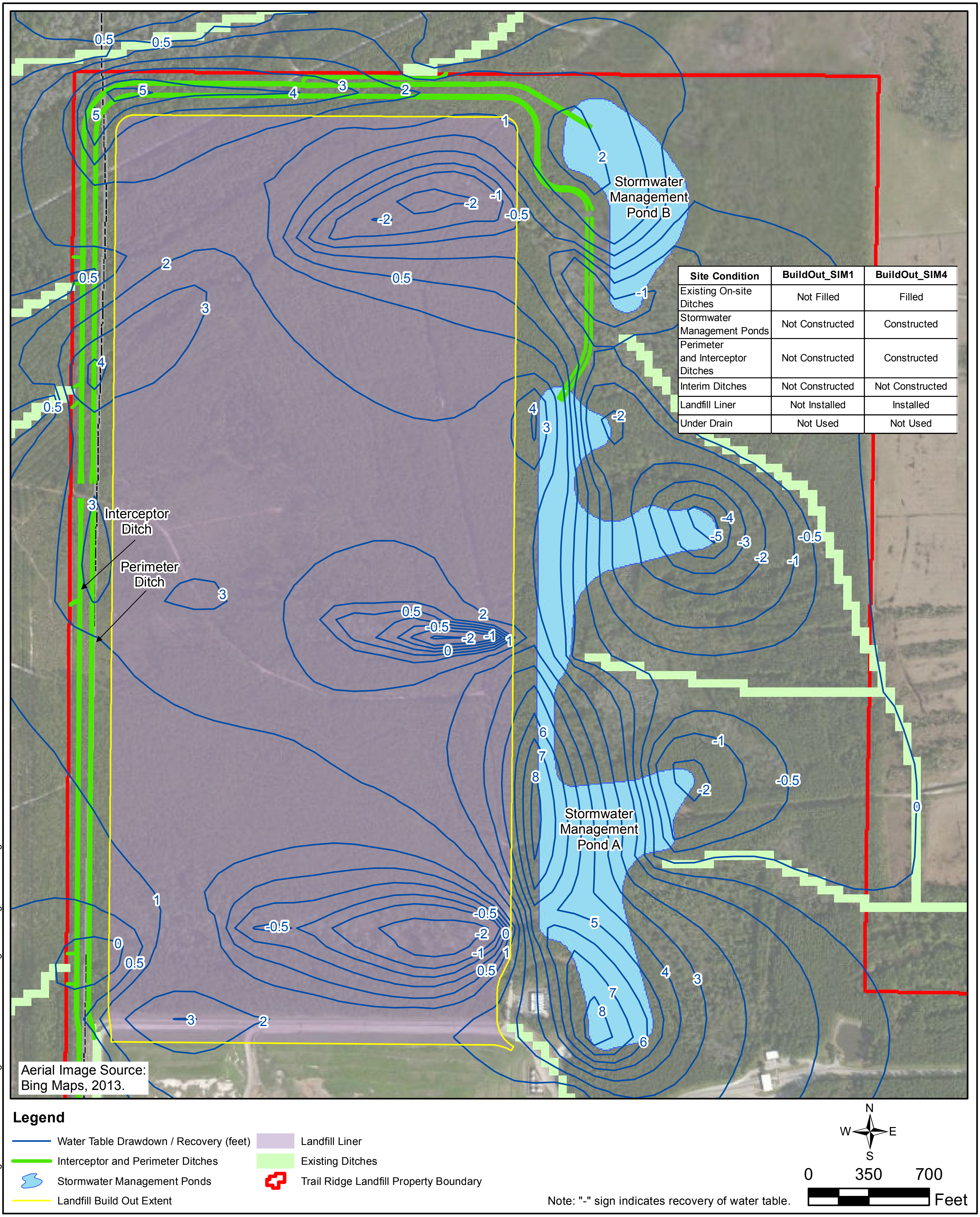
Figure 74
Simulated Water Table Drawdown / Recovery
Under BuildOut_SIM3 Conditions (BuildOut_SIM2-BuildOut_SIM3)
Trail Ridge Landfill Expansion Project



Site Condition	BuildOut_SIM4
Existing On-site Ditches	Filled
Stormwater Management Ponds	Constructed
Perimeter and Interceptor Ditches	Constructed
Interim Ditches	Not Constructed
Landfill Liner	Installed
Under Drain	Not Used

CDM Smith

Figure 75
Simulated Seasonal High Water Table Elevations Under BuildOut_SIM4 Conditions (BuildOut_SIM4)
Trail Ridge Landfill Expansion Project

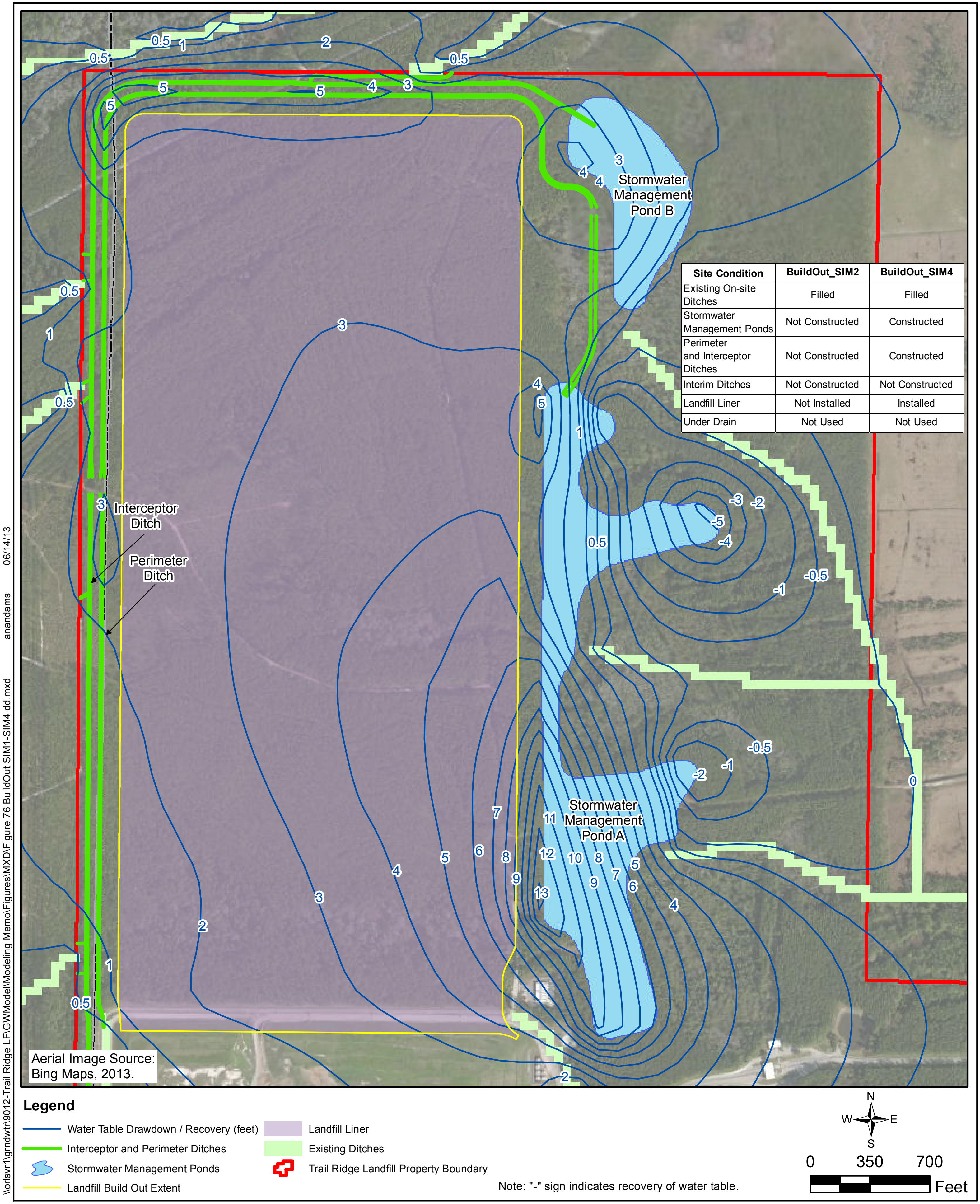


Site Condition	BuildOut_SIM1	BuildOut_SIM4
Existing On-site Ditches	Not Filled	Filled
Stormwater Management Ponds	Not Constructed	Constructed
Perimeter and Interceptor Ditches	Not Constructed	Constructed
Interim Ditches	Not Constructed	Not Constructed
Landfill Liner	Not Installed	Installed
Under Drain	Not Used	Not Used

\\orlsvr1\grndwtr\9012-Trail Ridge LF\GWModel\Modeling Memo\Figures\MXD\Figure 76 BuildOut SIM1-SIM4 dd.mxd anandams 06/14/13

CDM Smith

Figure 76
Simulated Water Table Drawdown / Recovery
Under BuildOut_SIM4 Conditions (BuildOut_SIM1 - BuildOut_SIM4)
Trail Ridge Landfill Expansion Project



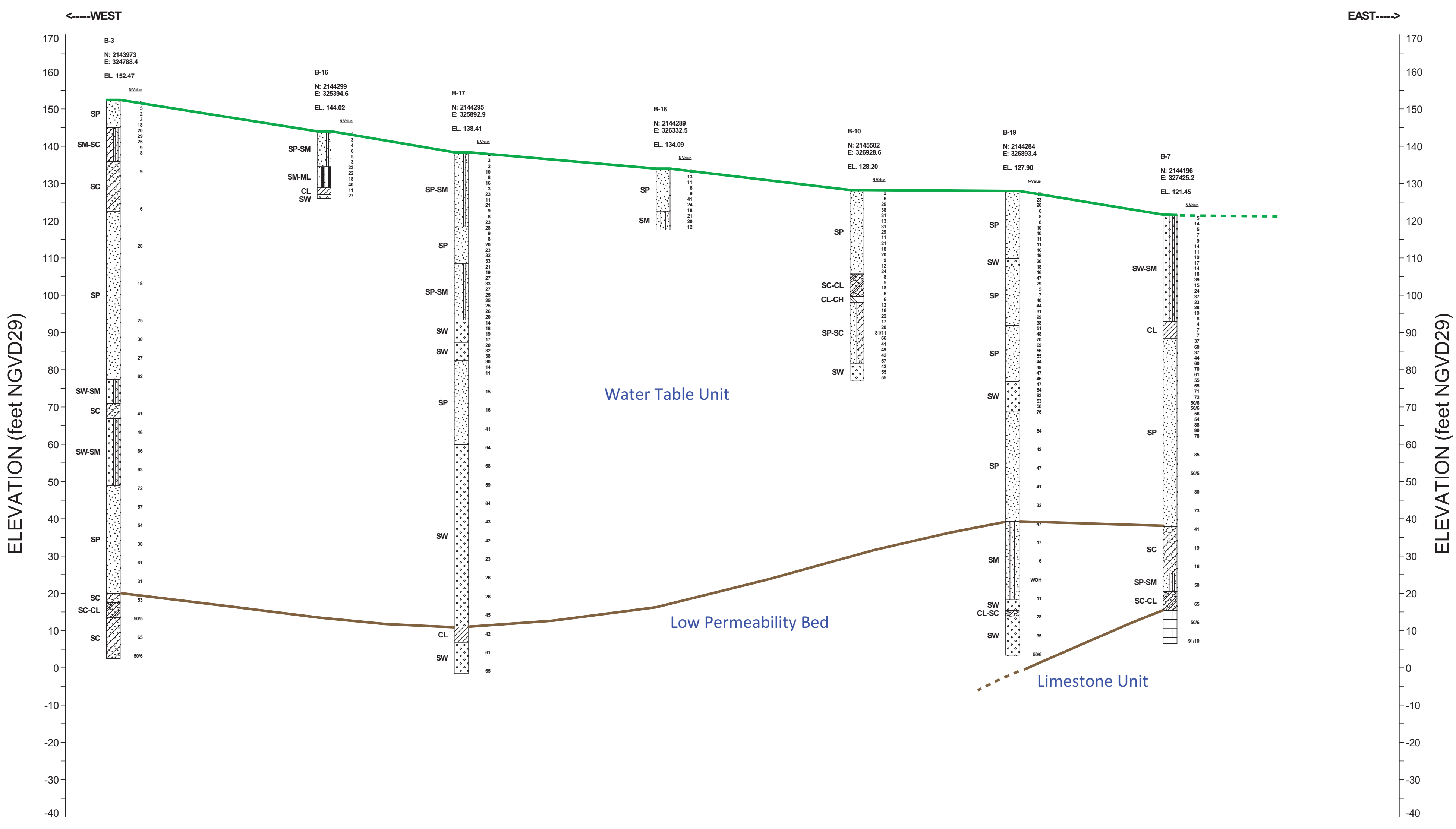
Site Condition	BuildOut_SIM2	BuildOut_SIM4
Existing On-site Ditches	Filled	Filled
Stormwater Management Ponds	Not Constructed	Constructed
Perimeter and Interceptor Ditches	Not Constructed	Constructed
Interim Ditches	Not Constructed	Not Constructed
Landfill Liner	Not Installed	Installed
Under Drain	Not Used	Not Used

CDM Smith

Figure 77
Simulated Water Table Drawdown / Recovery
Under BuildOut_SIM4 Conditions (BuildOut_SIM2 - BuildOut_SIM4)
Trail Ridge Landfill Expansion Project

Attachments

Attachment A



LEGEND

- USCS Poorly-graded Sand
- Clayey Sand and Sandy Clay
- USCS Low to High Plasticity Clay
- USCS Poorly-graded Sand with Clay
- USCS Well-graded Sand
- USCS Poorly-graded Sand with Silt
- USCS Elastic Silt with Sand
- USCS Low Plasticity Clay
- USCS Silty Sand
- USCS Silty Sand - Clayey Sand
- USCS Clayey Sand
- USCS Well-graded Sand with Silt
- Water Level

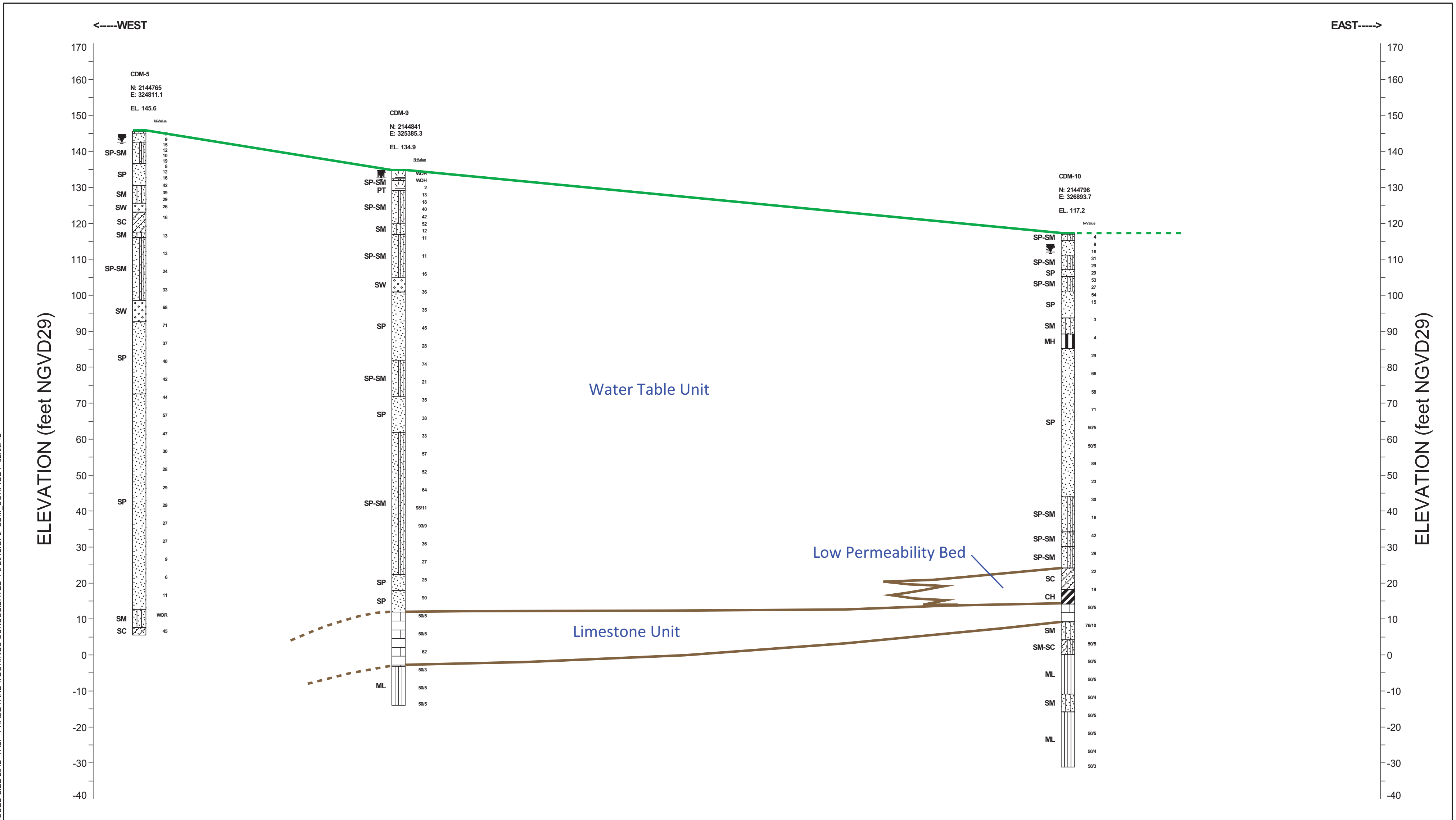
CDM Smith

0 200
Horizontal Scale (ft.)

City of Jacksonville

Trail Ridge Landfill Expansion

SECTION 1
WEST-EAST
South Side of Cell 6



LEGEND

Topsoil	USCS Silty Sand	USCS High Plasticity Clay	USCS Silt	Water Level
USCS Poorly-graded Sand with Silt	USCS Elastic Silt	Limestone	USCS Well-graded Sand	
USCS Poorly-graded Sand	USCS Clayey Sand	USCS Silty Sand - Clayey Sand	USCS Peat	

CDM Smith

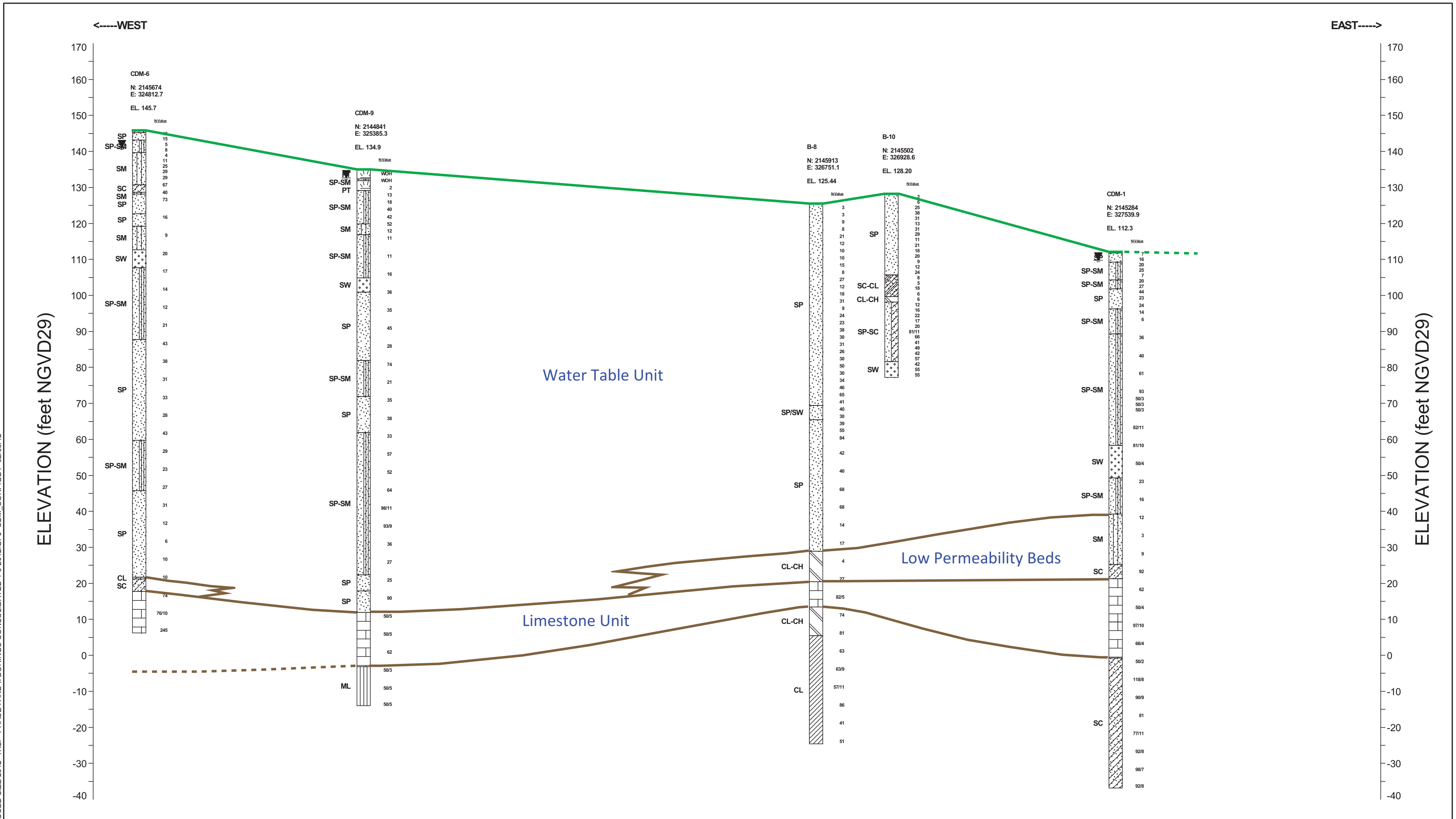
0 200
Horizontal Scale (ft.)

City of Jacksonville

Trail Ridge Landfill Expansion

SECTION 2
WEST-EAST
Middle of Cell 6

FENCE - TRLF - 11X17 REDUCED SIZE 2012 TRLF- PHASE I AND II BORINGS CONSOLIDATED 1-3-2012.GPJ CDM_CORP.GDT 02/08/12



LEGEND

- USCS Poorly-graded Sand
- Clayey Sand and Sandy Clay
- USCS Low to High Plasticity Clay
- USCS Poorly-graded Sand with Clay
- USCS Well-graded Sand
- Limestone
- USCS Low Plasticity Clay
- Topsoil
- USCS Poorly-graded Sand with Silt
- USCS Silty Sand
- USCS Clayey Sand
- USCS Peat
- Water Level

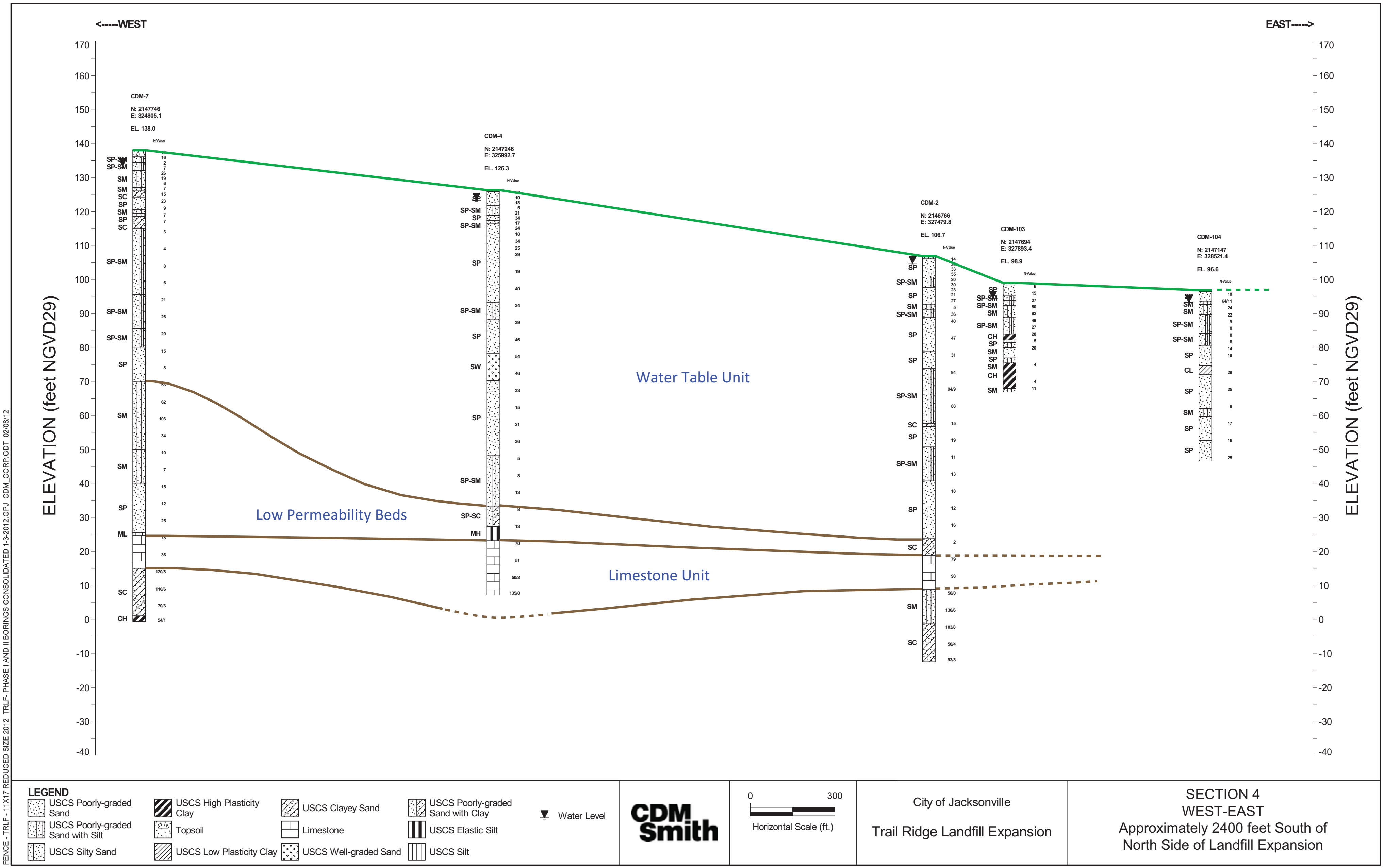
CDM Smith

0 250
Horizontal Scale (ft.)

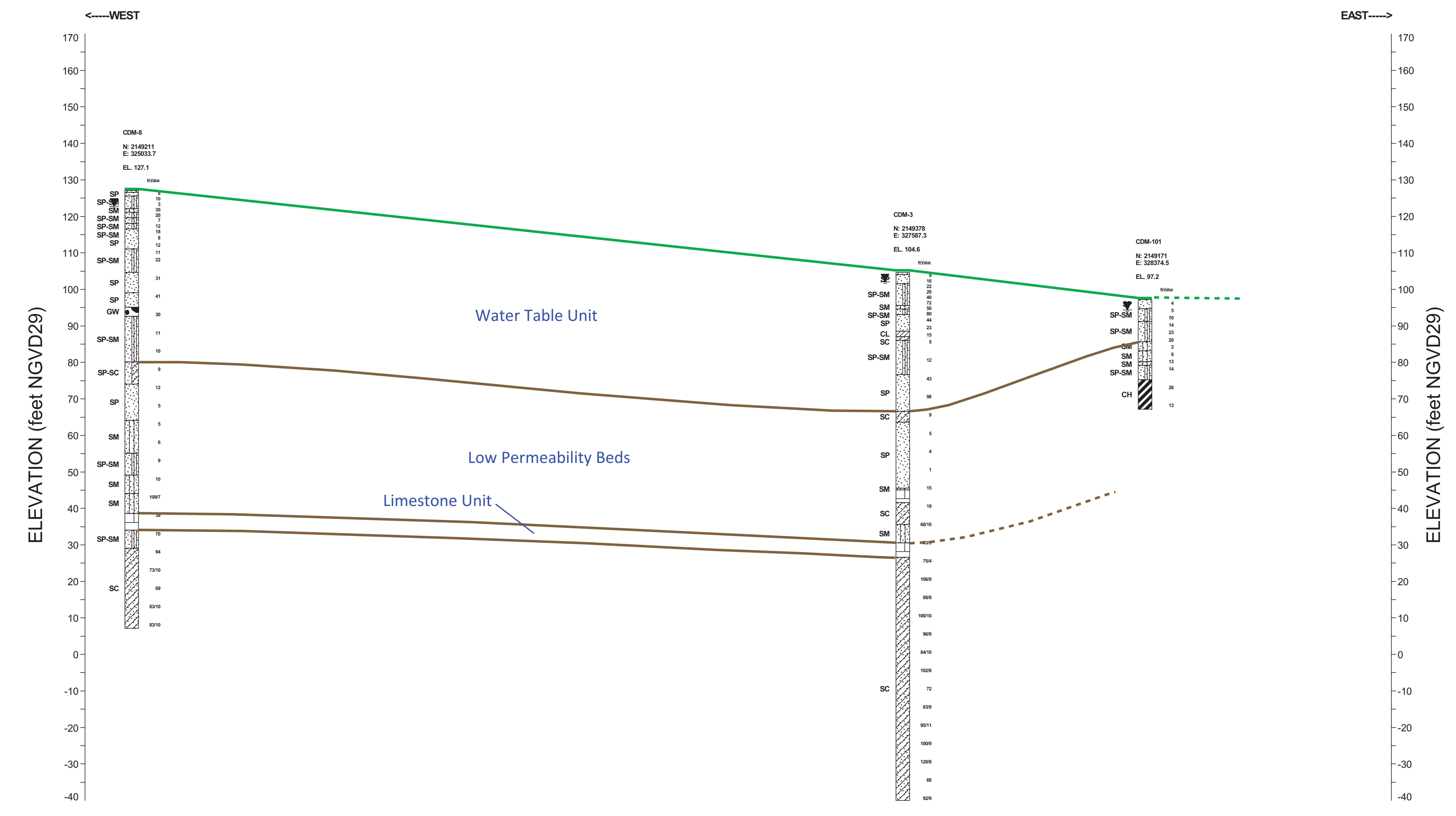
City of Jacksonville

Trail Ridge Landfill Expansion

SECTION 3
WEST-EAST
North Side of Cell 6



<-----WEST
EAST----->
ELEVATION (feet NGVD29)
CDM-7
N: 2147746
E: 324805.1
EL. 138.0
CDM-4
N: 2147246
E: 325992.7
EL. 126.3
CDM-2
N: 2146766
E: 327479.8
EL. 106.7
CDM-103
N: 2147694
E: 327893.4
EL. 98.9
CDM-104
N: 2147147
E: 328521.4
EL. 96.6
Water Table Unit
Low Permeability Beds
Limestone Unit
LEGEND
USCS Poorly-graded Sand
USCS Poorly-graded Sand with Silt
USCS Silty Sand
USCS High Plasticity Clay
Topsoil
USCS Low Plasticity Clay
USCS Clayey Sand
Limestone
USCS Well-graded Sand
USCS Poorly-graded Sand with Clay
USCS Elastic Silt
USCS Silt
Water Level
CDM Smith
0
300
Horizontal Scale (ft.)
City of Jacksonville
Trail Ridge Landfill Expansion
SECTION 4
WEST-EAST
Approximately 2400 feet South of North Side of Landfill Expansion
FENCE - TRLF - 11X17 REDUCED SIZE 2012 TRLF- PHASE I AND II BORINGS CONSOLIDATED 1-3-2012.GPJ CDM_CORP.GDT 02/08/12



LEGEND

- USCS Poorly-graded Sand
- USCS Poorly-graded Sand with Silt
- USCS Silty Sand
- USCS High Plasticity Clay
- Topsoil
- USCS Low Plasticity Clay
- USCS Clayey Sand
- Limestone
- USCS Well-graded Gravel
- USCS Poorly-graded Sand with Clay
- Water Level

CDM Smith

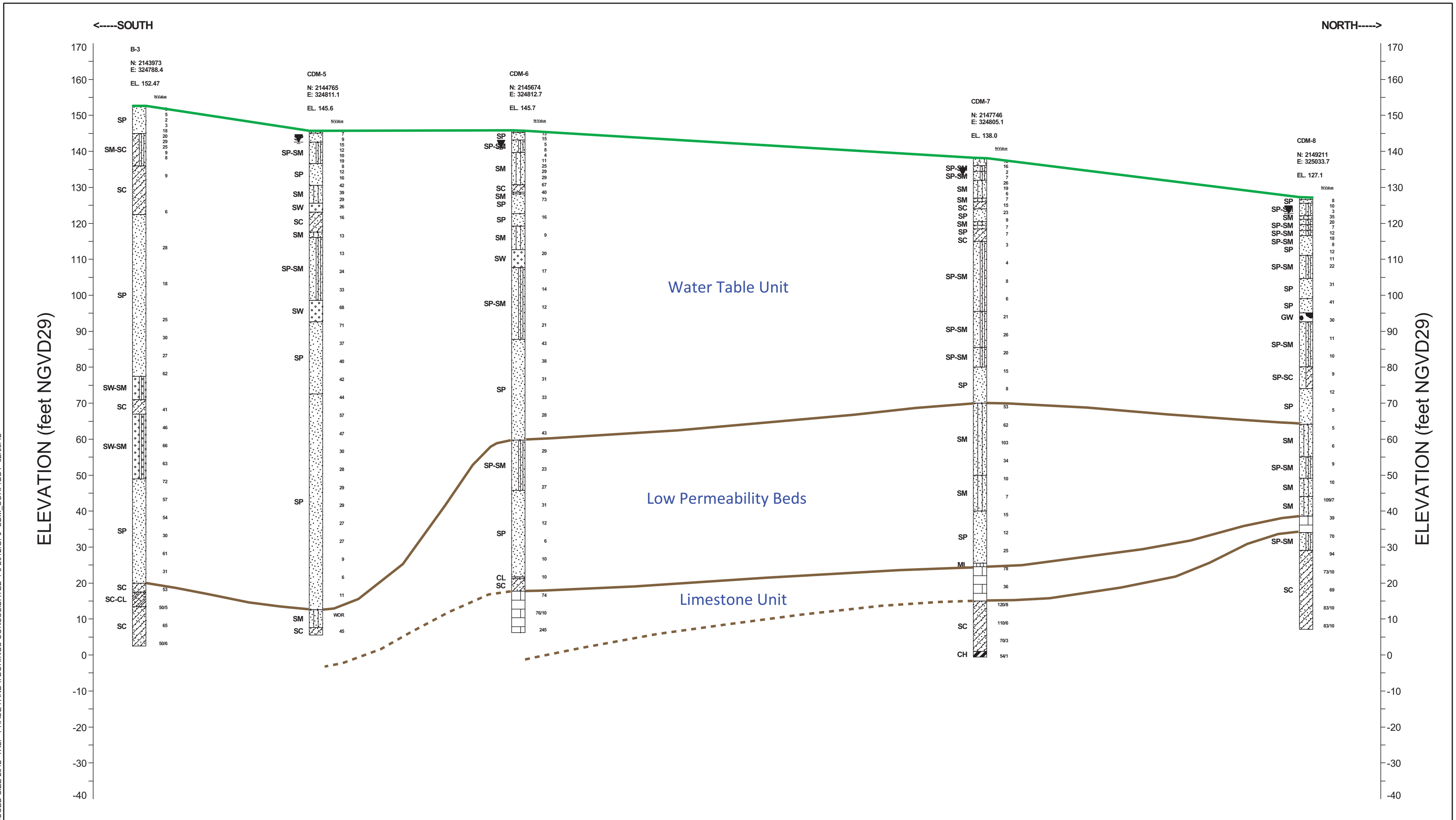
0 — 300
Horizontal Scale (ft.)

City of Jacksonville

Trail Ridge Landfill Expansion

SECTION 5
WEST-EAST
North Side of Landfill Expansion

FENCE - TRLF - 11X17 REDUCED SIZE 2012 TRLF- PHASE I AND II BORINGS CONSOLIDATED 1-3-2012.GPJ CDM_CORP.GDT 02/08/12



LEGEND

- USCS Poorly-graded Sand
- USCS Silty Sand - Clayey Sand
- USCS Clayey Sand
- USCS Well-graded Sand with Silt
- Clayey Sand and Sandy Clay
- Topsoil
- USCS Poorly-graded Sand with Silt
- USCS Silty Sand
- USCS Well-graded Sand
- USCS Low Plasticity Clay
- Limestone
- USCS Silt
- Water Level

CDM Smith

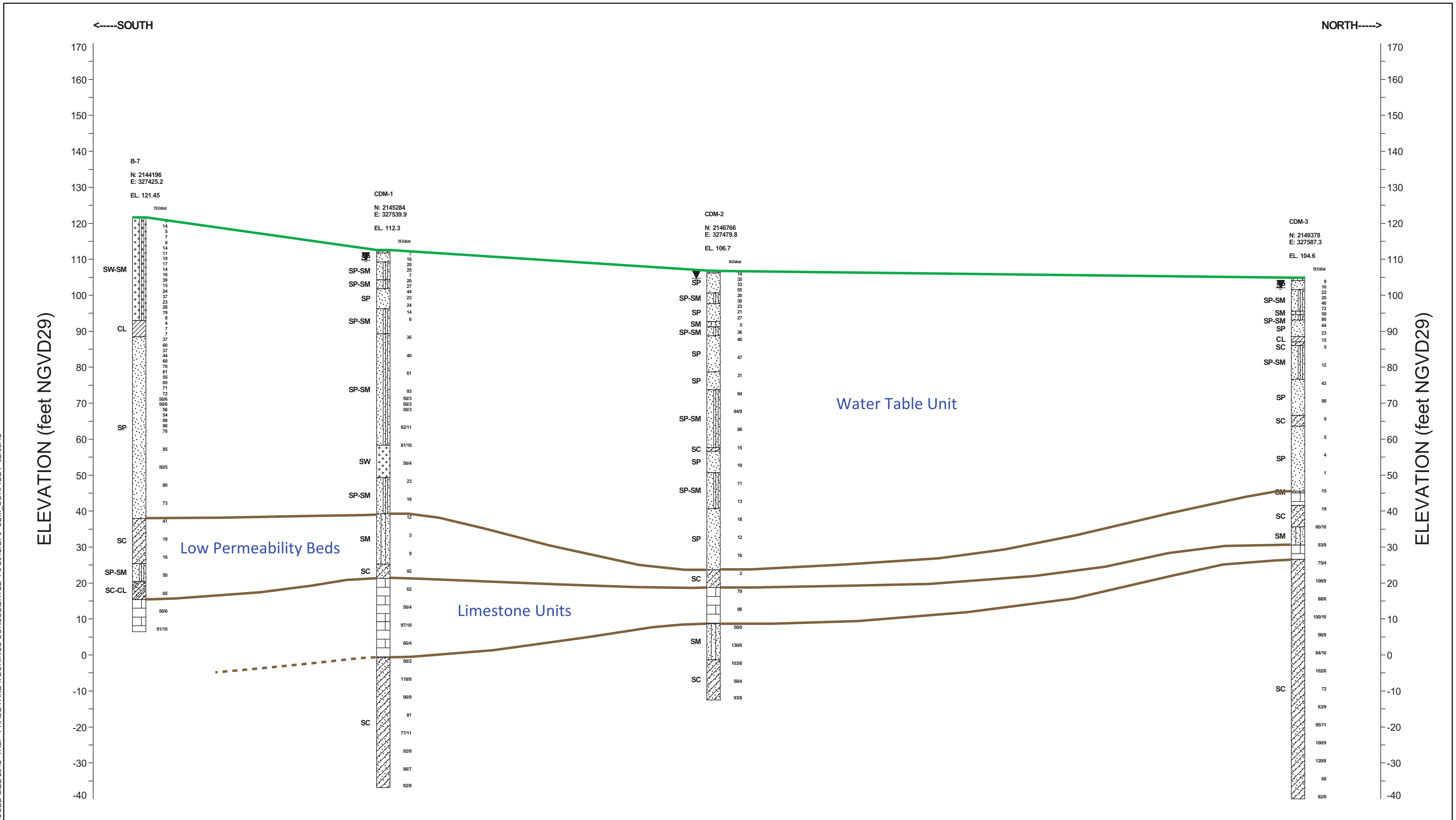
0 400
Horizontal Scale (ft.)

City of Jacksonville

Trail Ridge Landfill Expansion

SECTION 6
SOUTH-NORTH
West Side of Landfill Expansion

FENCE - TRLF - 11X17 REDUCED SIZE 2012 TRLF- PHASE I AND II BORINGS CONSOLIDATED 1-3-2012.GPJ CDM_CORP.GDT 02/08/12



LEGEND

- USCS Well-graded Sand with Silt
- USCS Low Plasticity Clay
- USCS Poorly-graded Sand
- USCS Clayey Sand
- USCS Poorly-graded Sand with Silt
- Clayey Sand and Sandy Clay
- Limestone
- Topsoil
- USCS Well-graded Sand
- USCS Silty Sand
- Water Level

CDM Smith

0 400

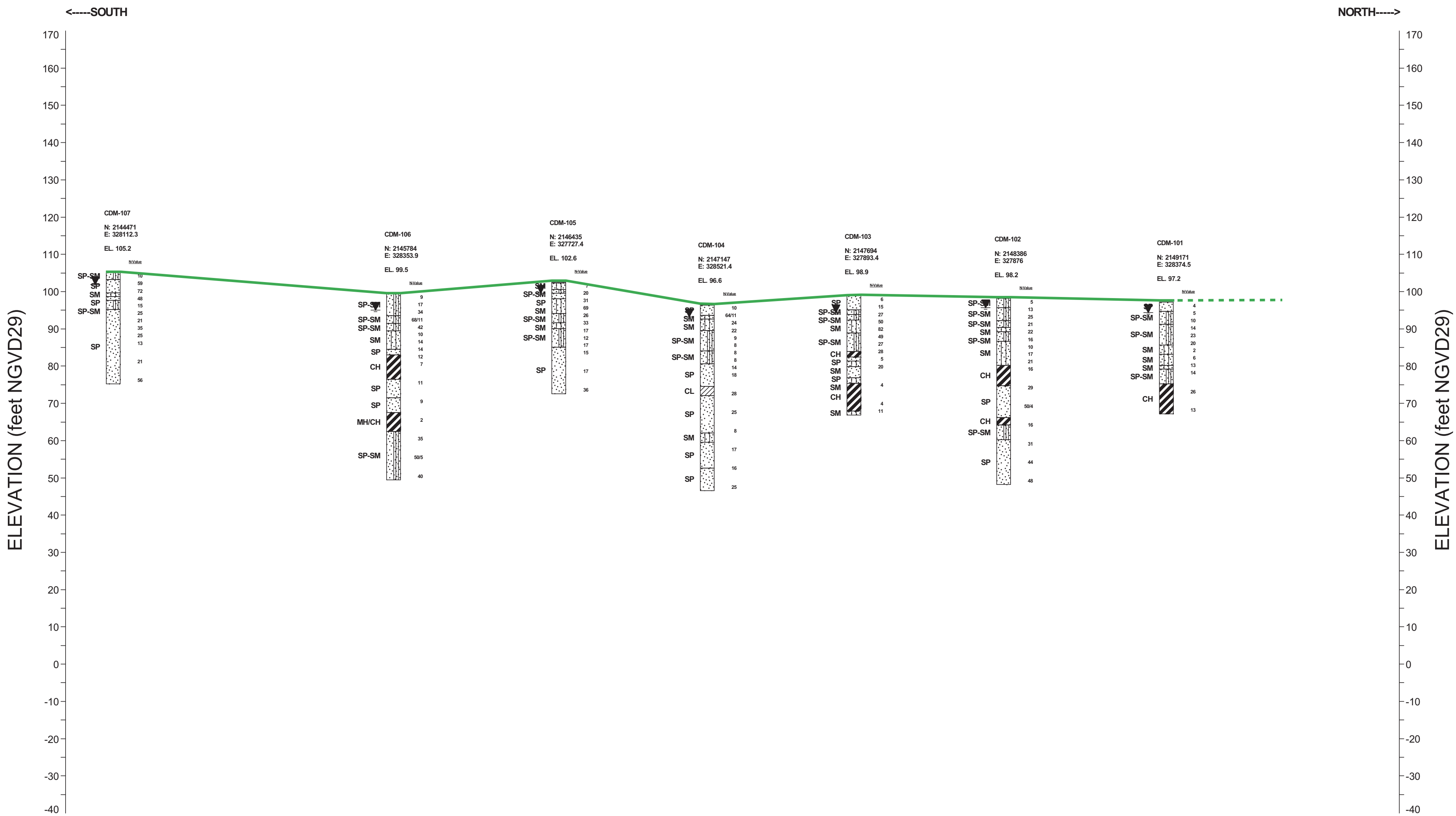
Horizontal Scale (ft.)

City of Jacksonville

Trail Ridge Landfill Expansion

SECTION 7
SOUTH-NORTH
East Side of Landfill Expansion

FENCE - TRLF - 11X17 REDUCED SIZE 2012 TRLF- PHASE I AND II BORINGS CONSOLIDATED 1-3-2012.GPJ CDM_CORP.GDT 02/08/12



LEGEND

- USCS Poorly-graded Sand
- USCS Poorly-graded Sand with Silt
- USCS Silty Sand
- USCS High Plasticity Clay
- Topsoil
- USCS Low Plasticity Clay
- Water Level

CDM Smith

0 400
Horizontal Scale (ft.)

City of Jacksonville

Trail Ridge Landfill Expansion

SECTION 8
SOUTH-NORTH
Stormwater Ponds

FENCE - TRLF - 11X17 REDUCED SIZE 2012 TRLF- PHASE I AND II BORINGS CONSOLIDATED 1-3-2012.GPJ CDM_CORP.GDT 02/08/12

Attachment B

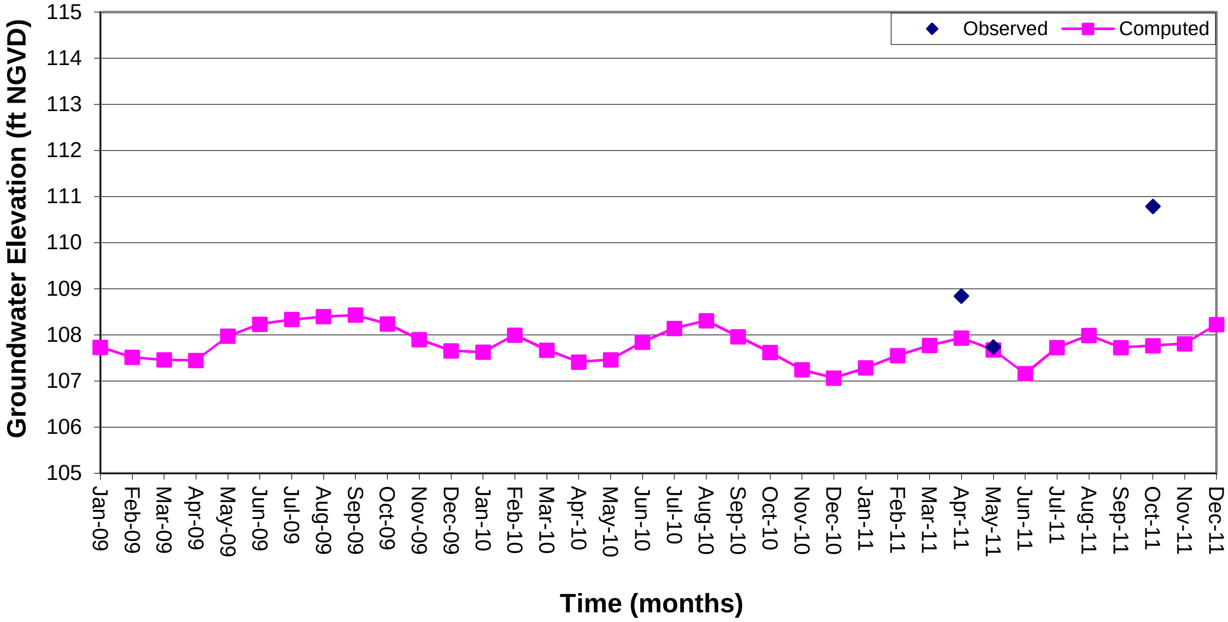


Figure 1
Comparison of Measured versus Simulated Groundwater Levels at CDM-1P (Layer 1)

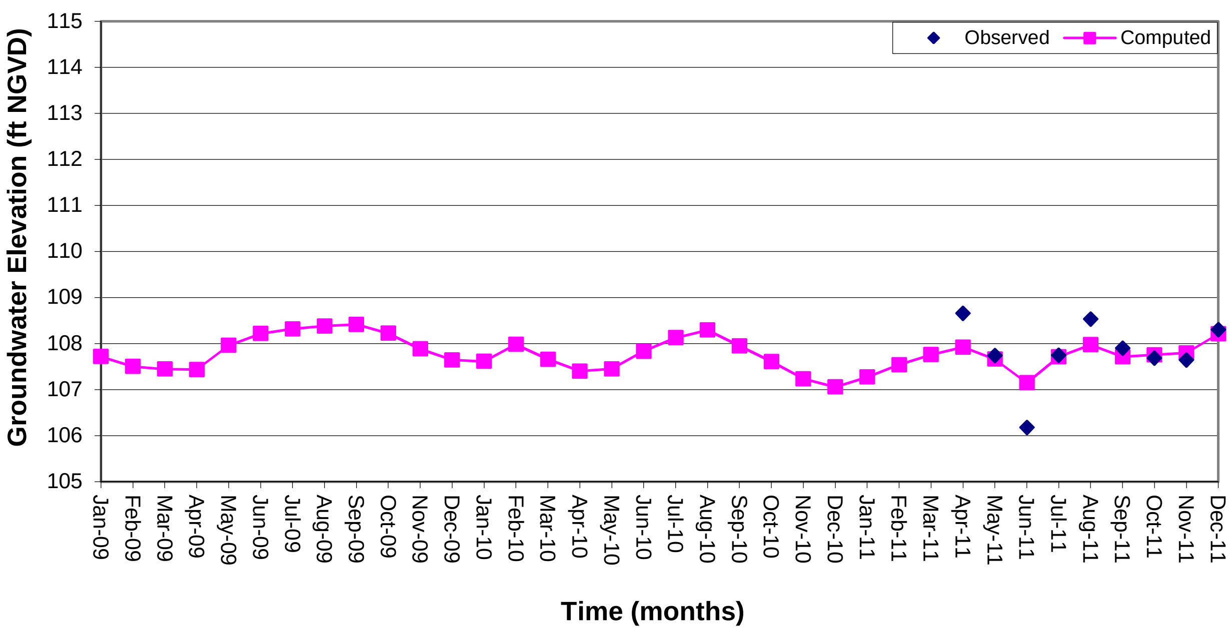


Figure 2
Comparison of Measured versus Simulated Groundwater Levels at CDM-1S (Layer 1)

CDM Smith

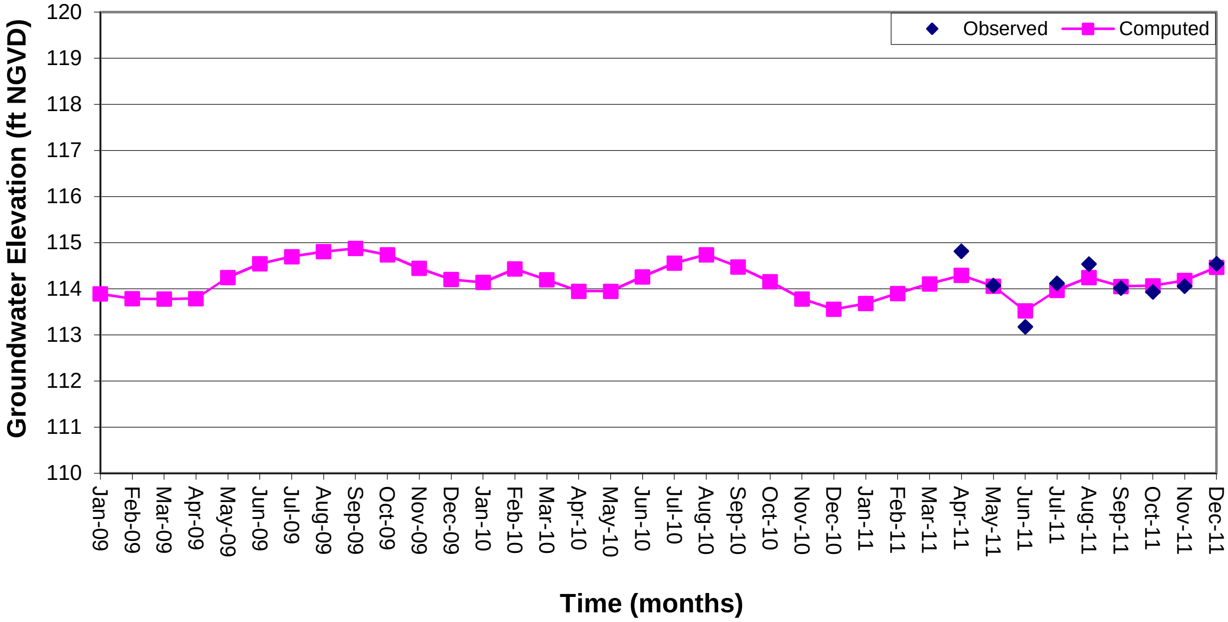


Figure 3
Comparison of Measured versus Simulated Groundwater Levels at CDM-1I (Layer 5)

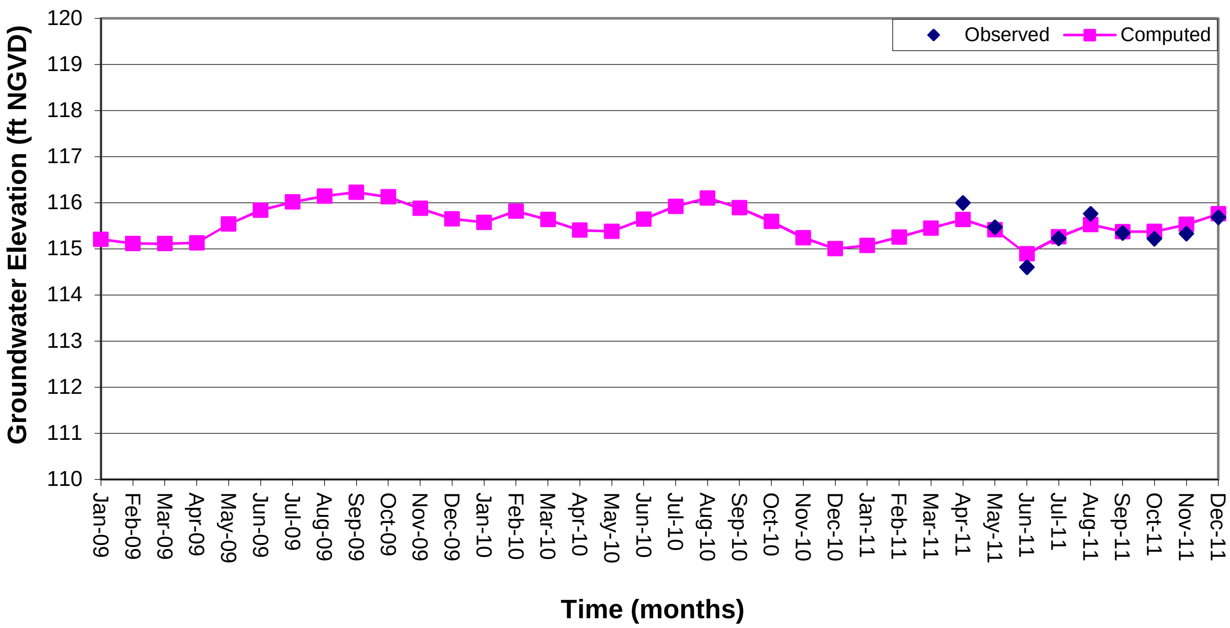


Figure 4
Comparison of Measured versus Simulated Groundwater Levels at CDM-1D (Layer 7)

CDM Smith

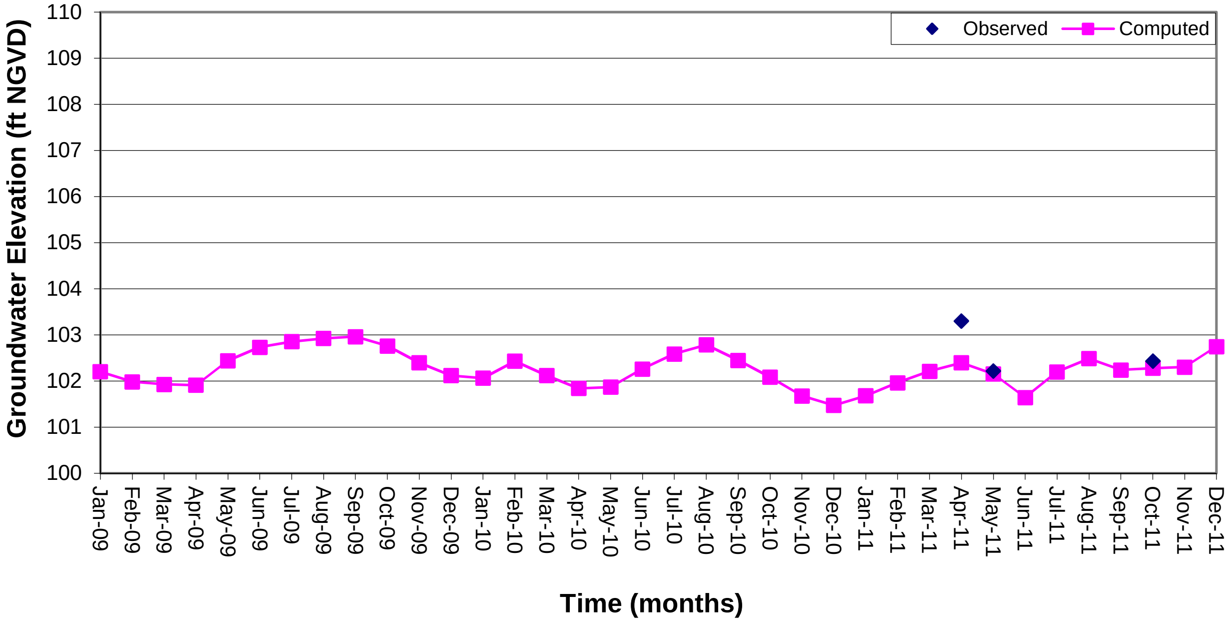


Figure 5
Comparison of Measured versus Simulated Groundwater Levels at CDM-2P (Layer 1)

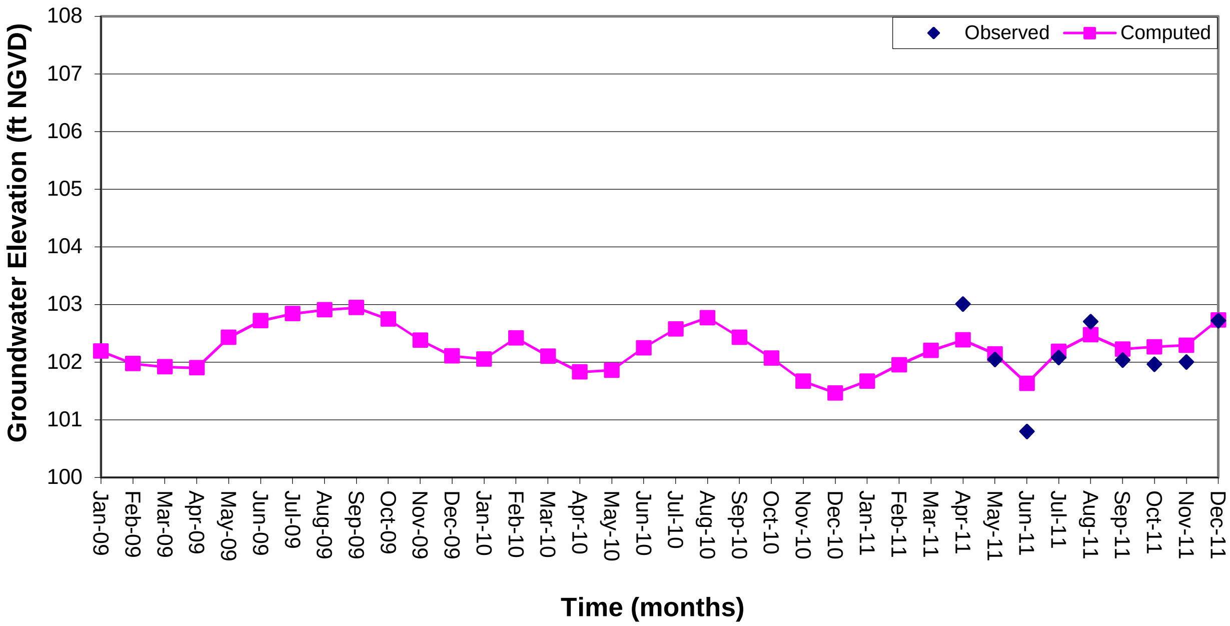


Figure 6
Comparison of Measured versus Simulated Groundwater Levels at CDM-2S (Layer 1)

CDM Smith

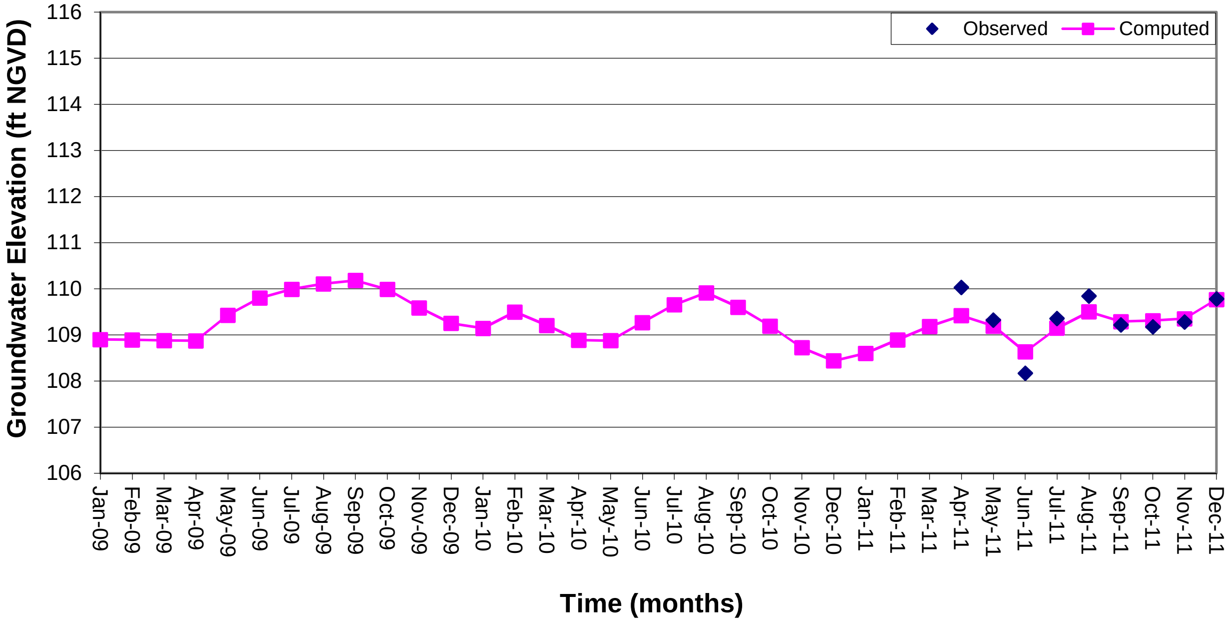


Figure 7
Comparison of Measured versus Simulated Groundwater Levels at CDM-2I (Layer 5)

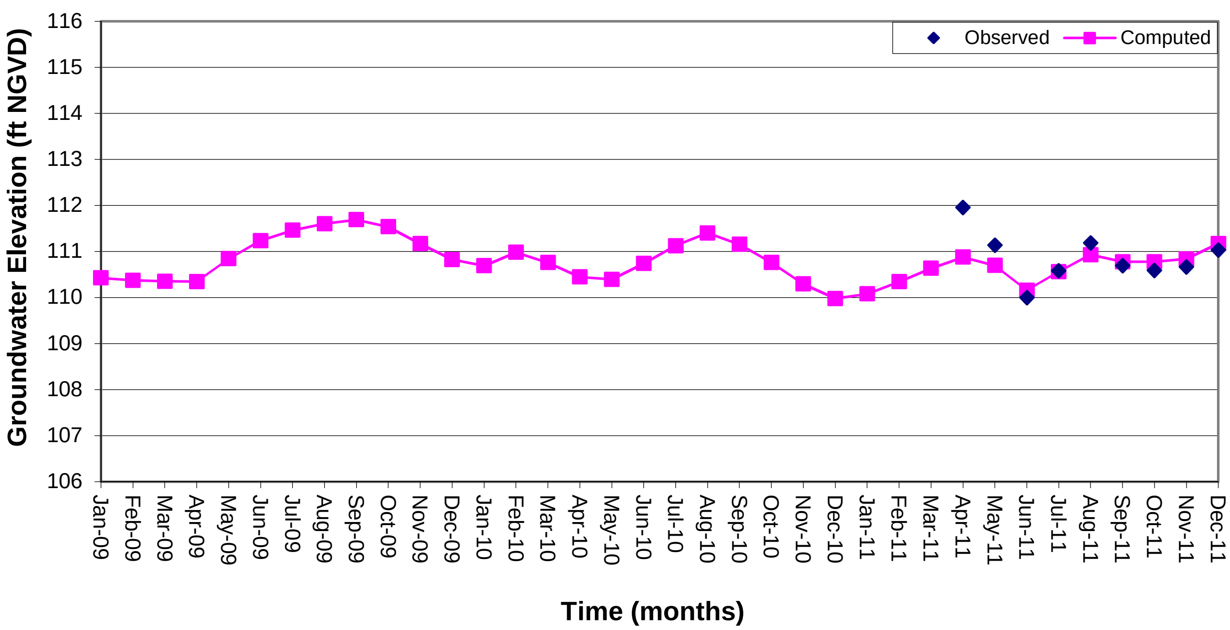


Figure 8
Comparison of Measured versus Simulated Groundwater Levels at CDM-2D (Layer 7)

CDM Smith

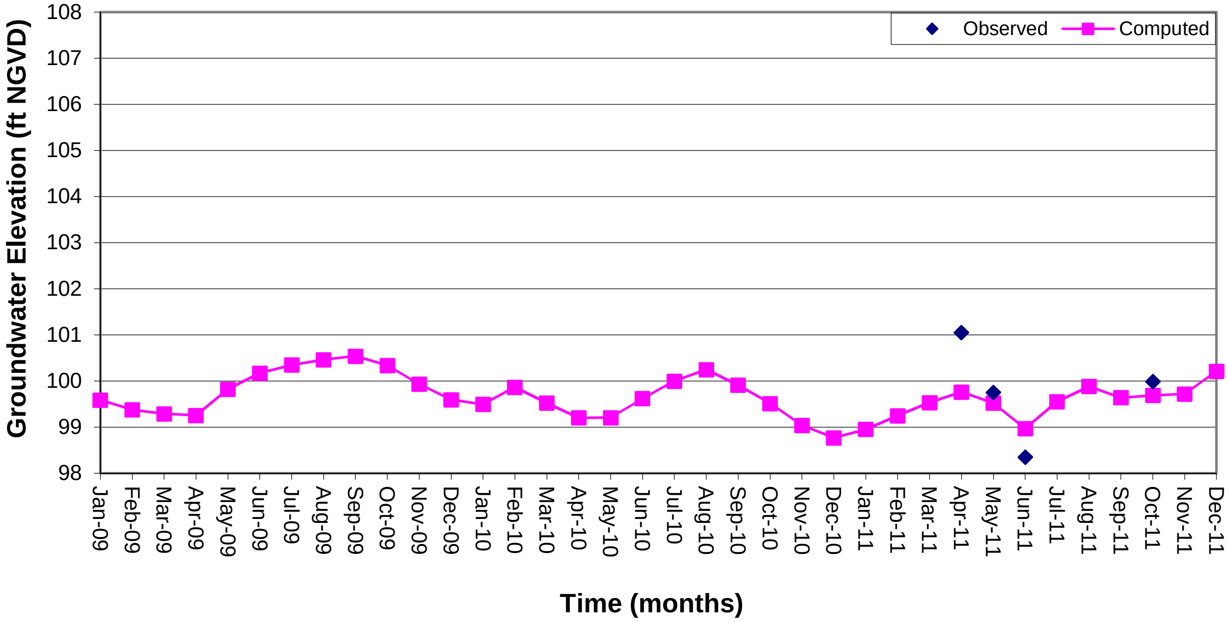


Figure 9
Comparison of Measured versus Simulated Groundwater Levels at CDM-3P (Layer 3)

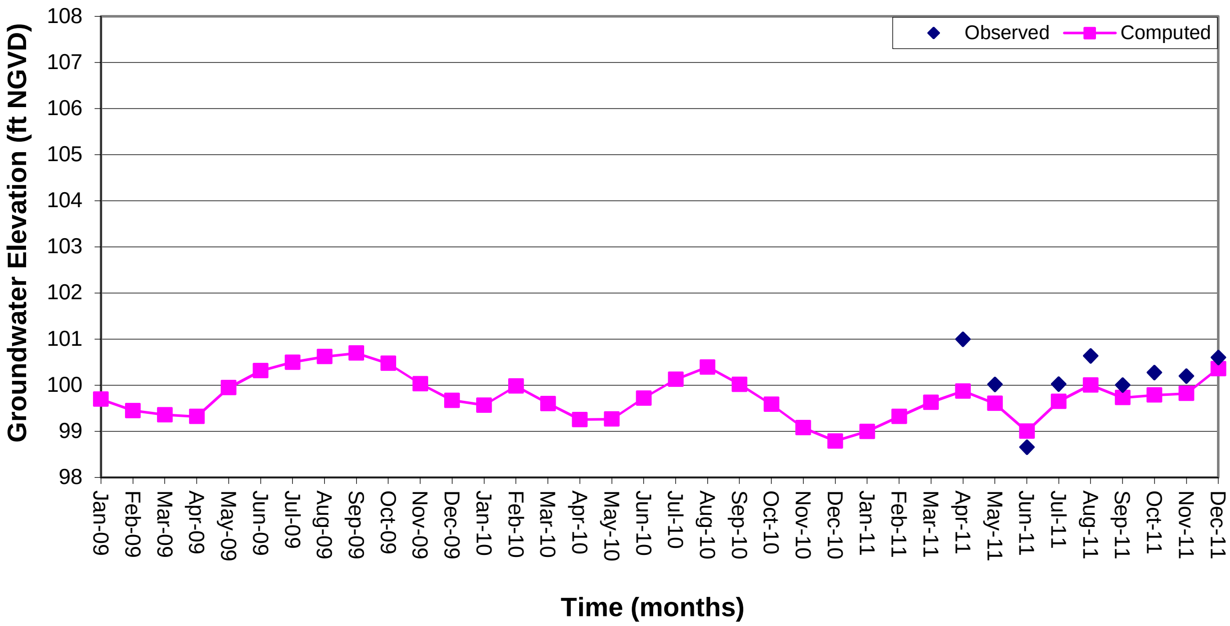


Figure 10
Comparison of Measured versus Simulated Groundwater Levels at CDM-3S (Layer 1)

CDM Smith

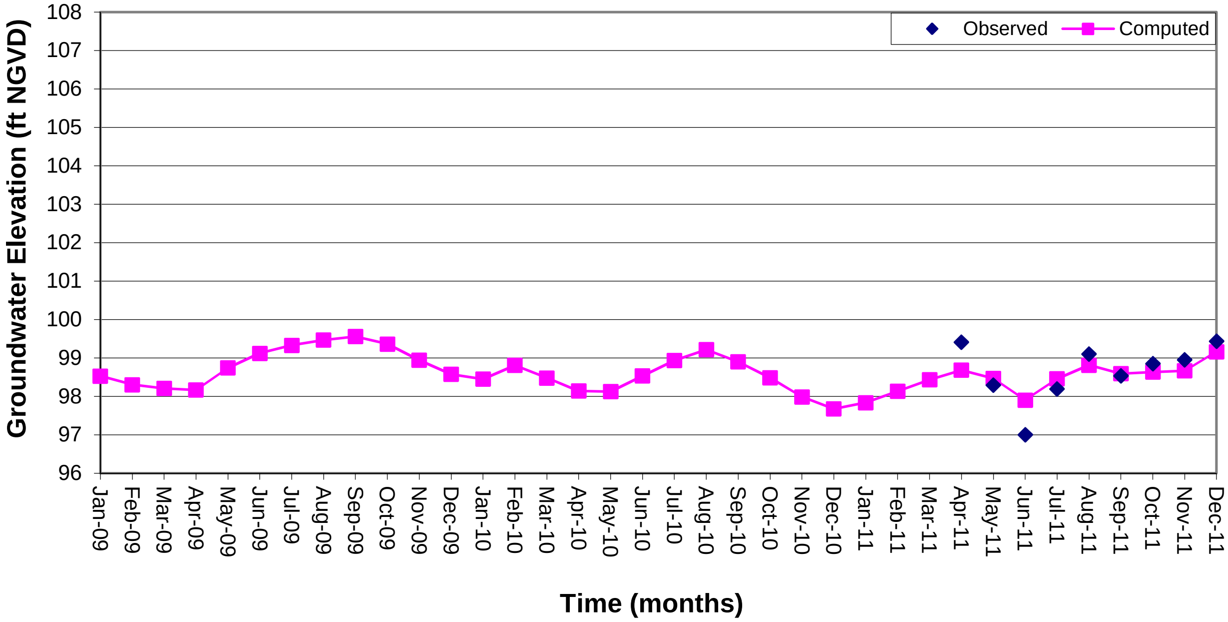


Figure 11
Comparison of Measured versus Simulated Groundwater Levels at CDM-3I (Layer 5)

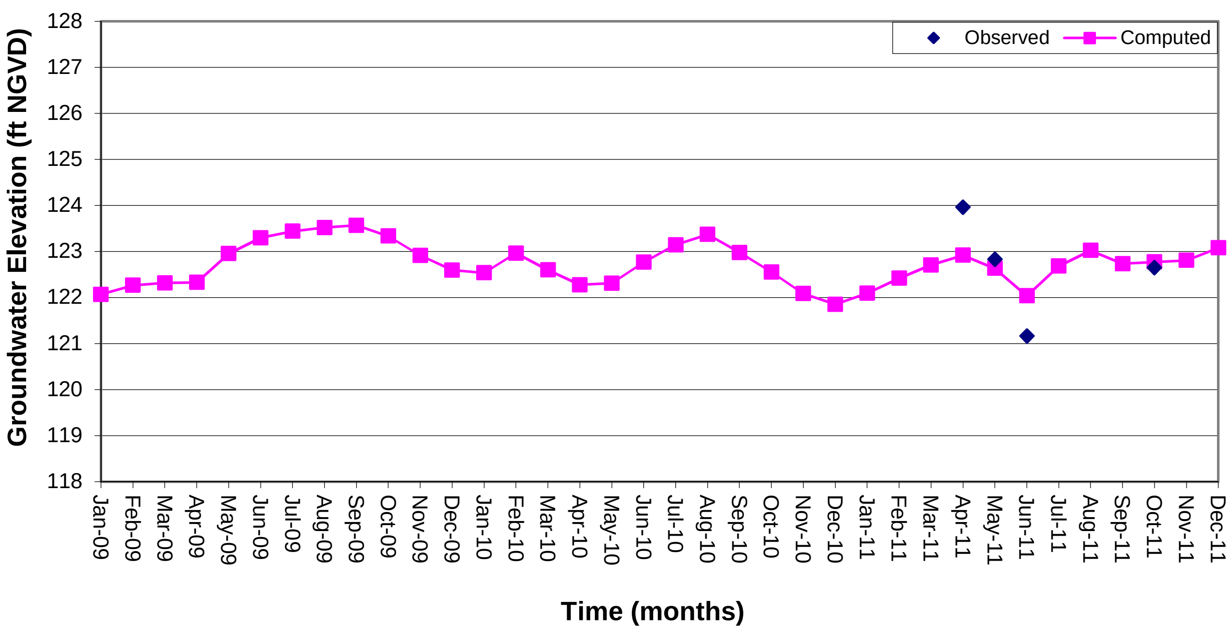


Figure 12
Comparison of Measured versus Simulated Groundwater Levels at CDM-4S (Layer 1)

CDM Smith

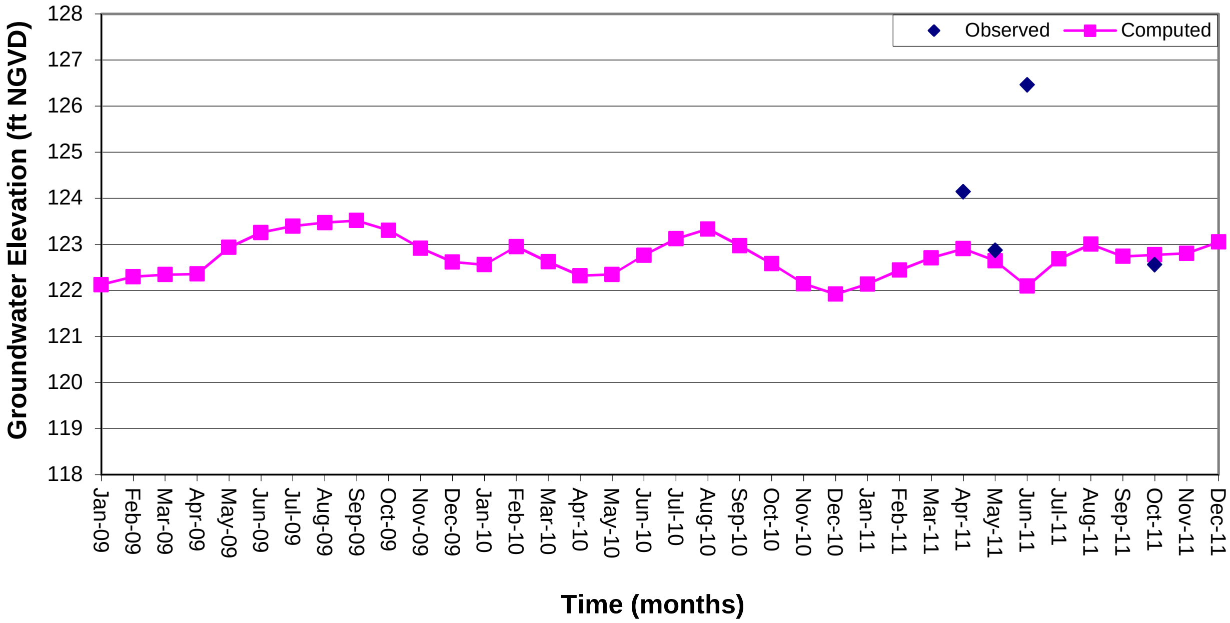


Figure 13
Comparison of Measured versus Simulated Groundwater Levels at CDM-4I (Layer 4)

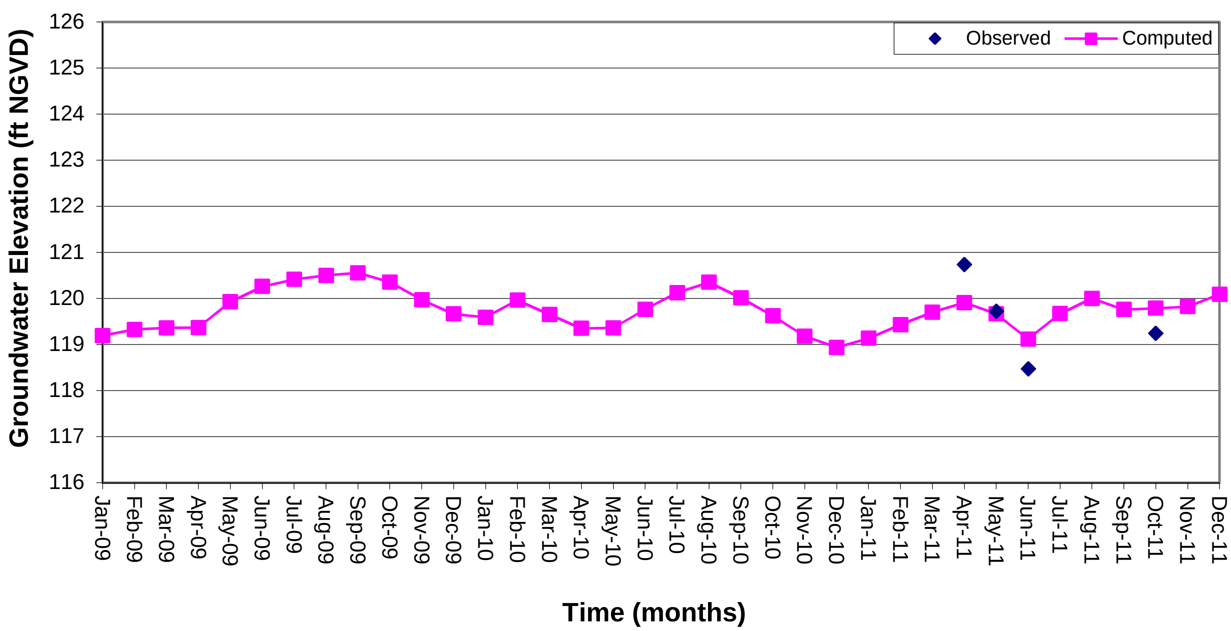


Figure 14
Comparison of Measured versus Simulated Groundwater Levels at CDM-4D (Layer 7)

CDM Smith

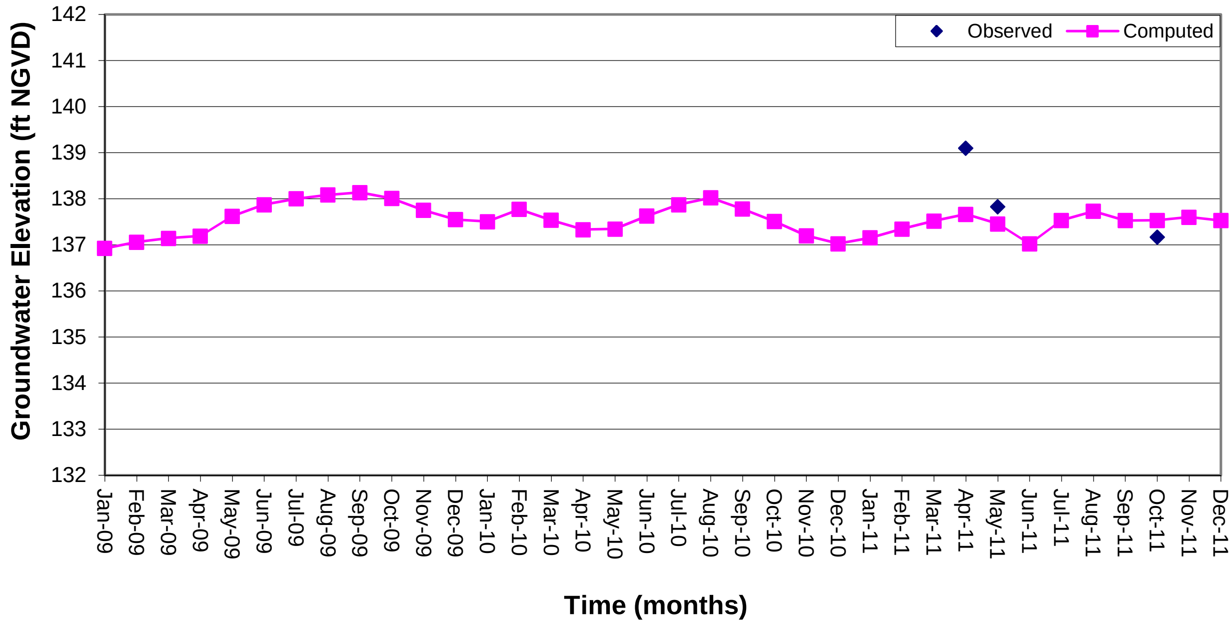


Figure 15
Comparison of Measured versus Simulated Groundwater Levels at CDM-5P (Layer 1)

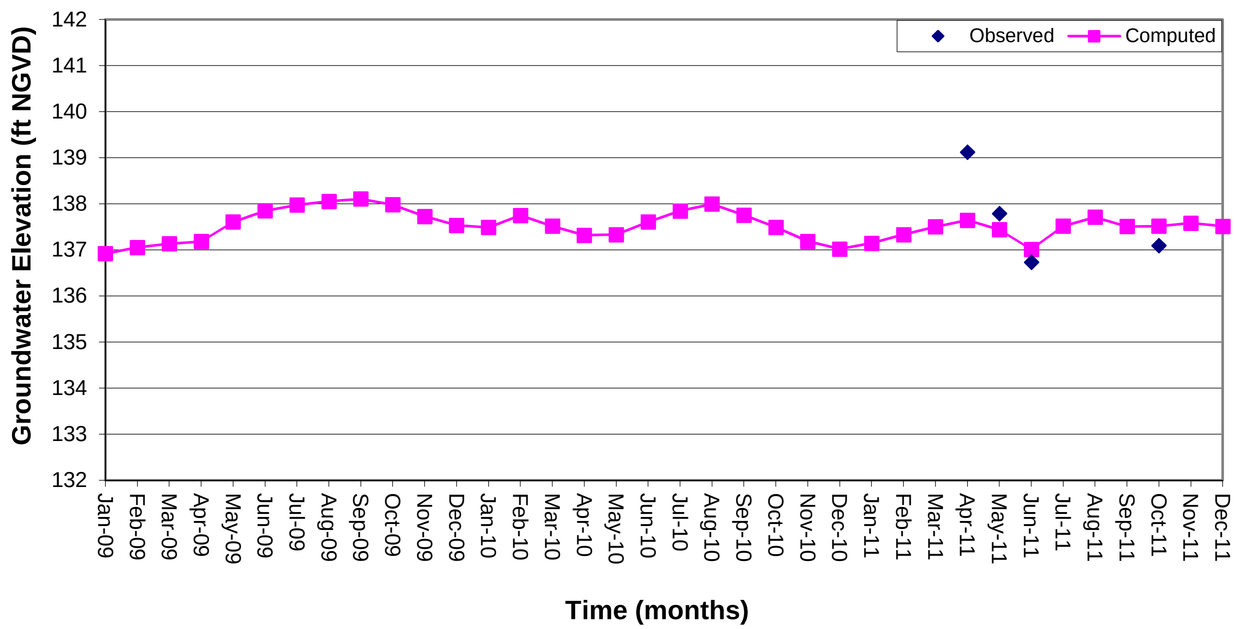


Figure 16
Comparison of Measured versus Simulated Groundwater Levels at CDM-5S (Layer 1)

CDM Smith

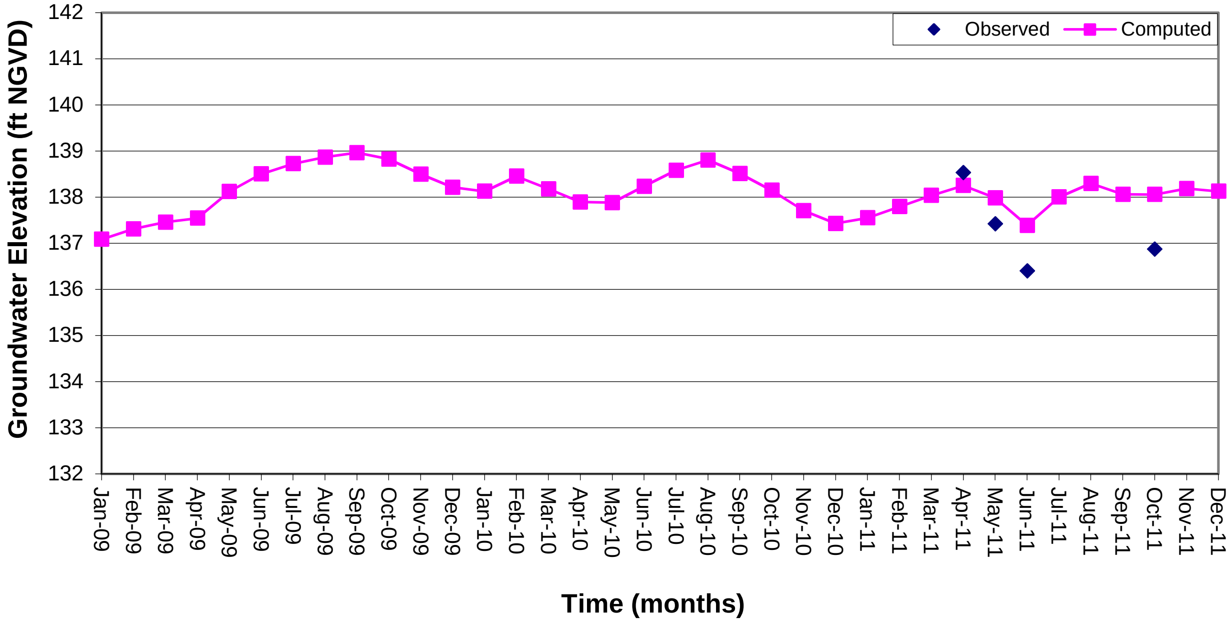


Figure 17
Comparison of Measured versus Simulated Groundwater Levels at CDM-5I (Layer 3)

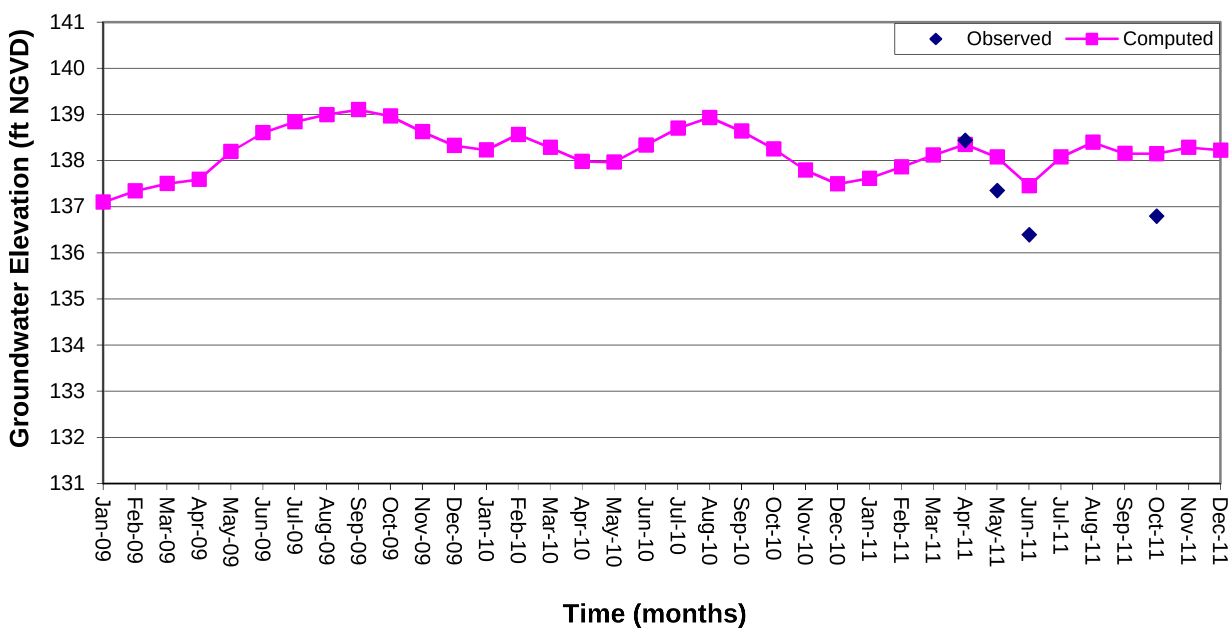


Figure 18
Comparison of Measured versus Simulated Groundwater Levels at CDM-5D (Layer 6)

CDM Smith

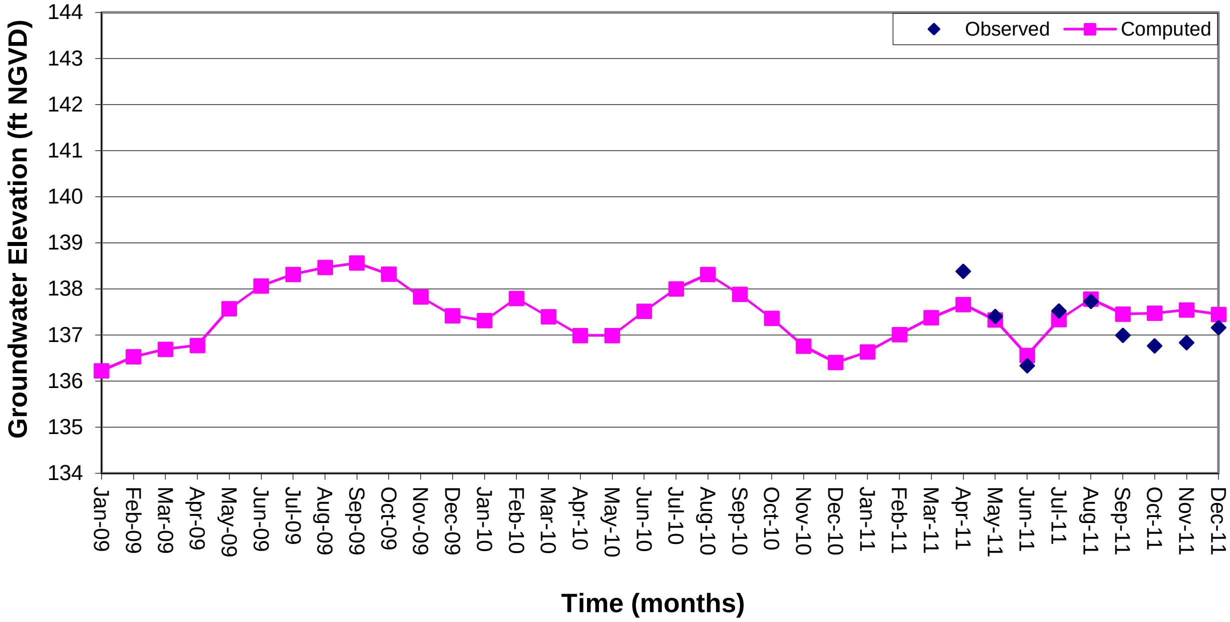


Figure 19
Comparison of Measured versus Simulated Groundwater Levels at CDM-6S (Layer 2)

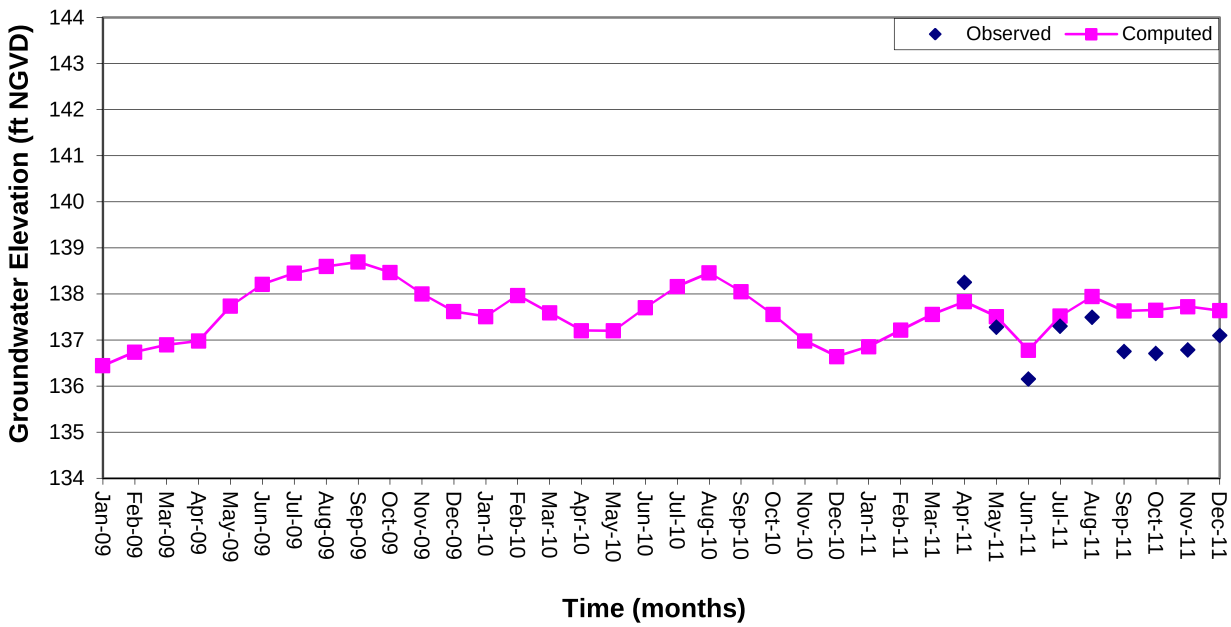


Figure 20
Comparison of Measured versus Simulated Groundwater Levels at CDM-6I (Layer 3)

CDM Smith

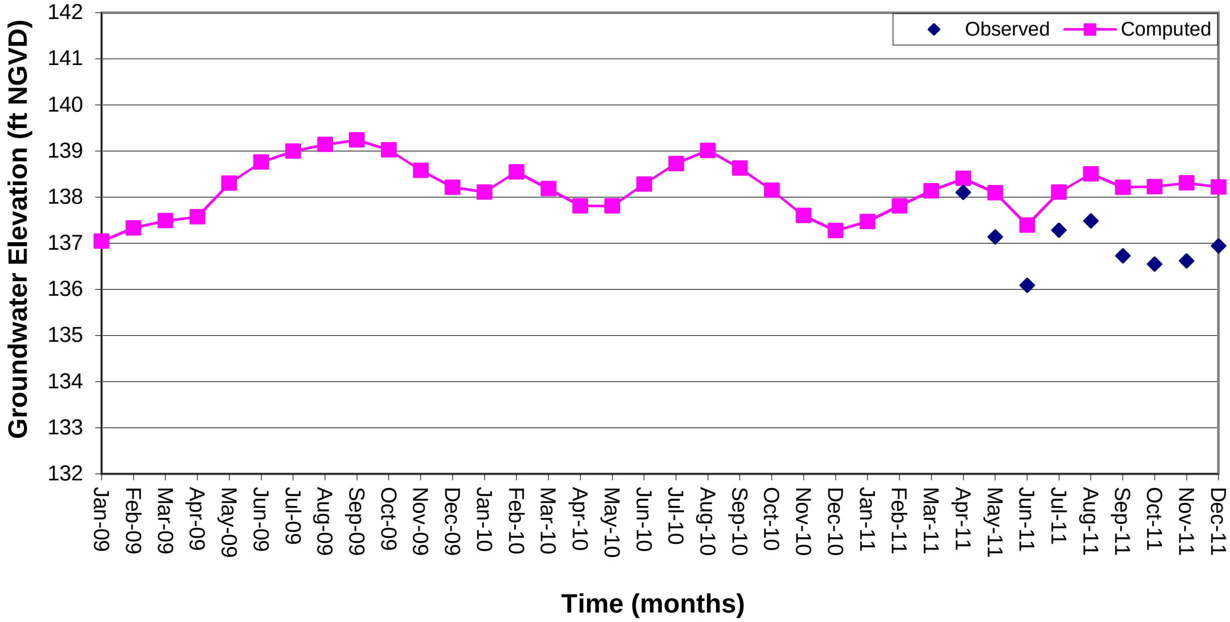


Figure 21
Comparison of Measured versus Simulated Groundwater Levels at CDM-6D (Layer 6)

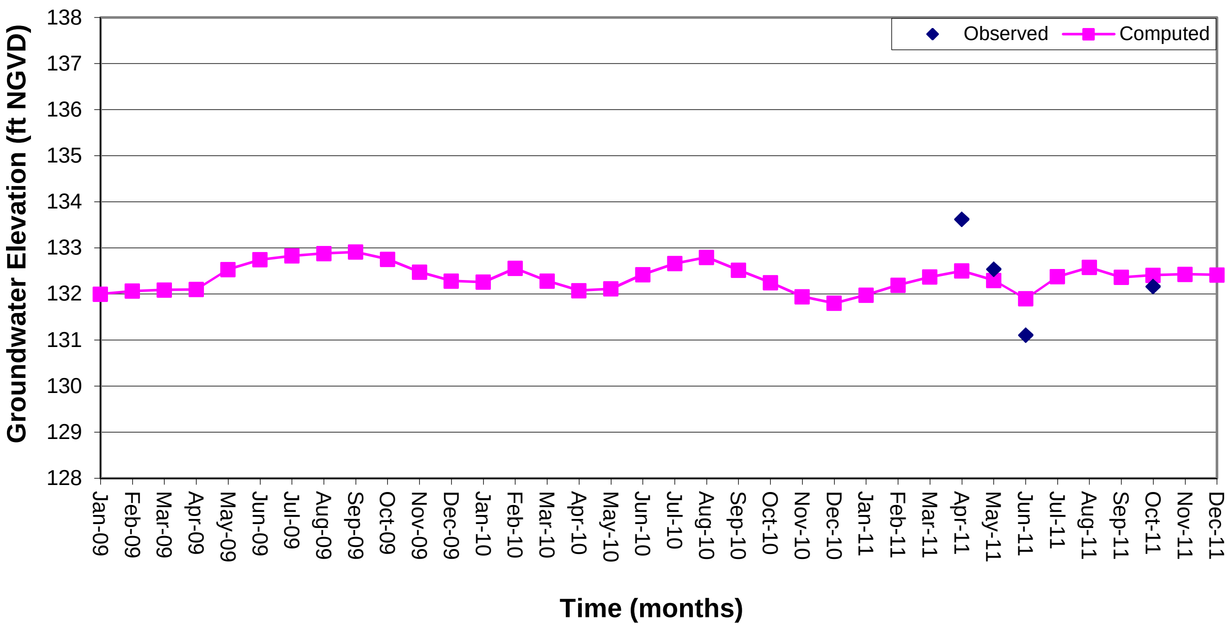


Figure 22
Comparison of Measured versus Simulated Groundwater Levels at CDM-7S (Layer 2)

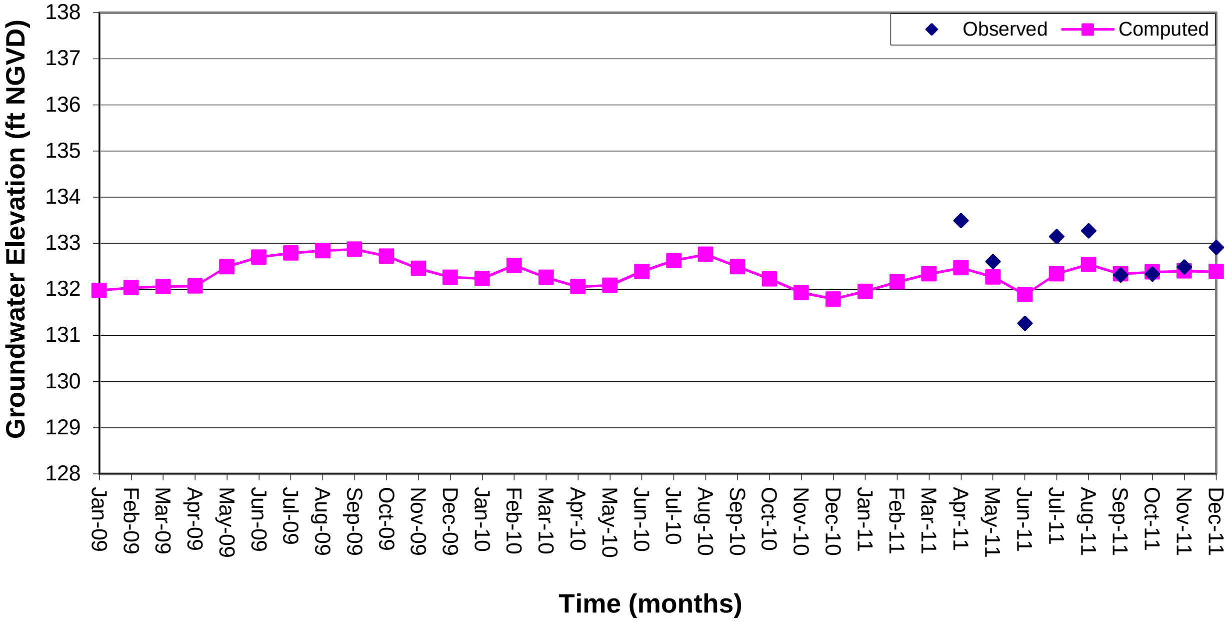


Figure 23
Comparison of Measured versus Simulated Groundwater Levels at CDM-7I (Layer 3)

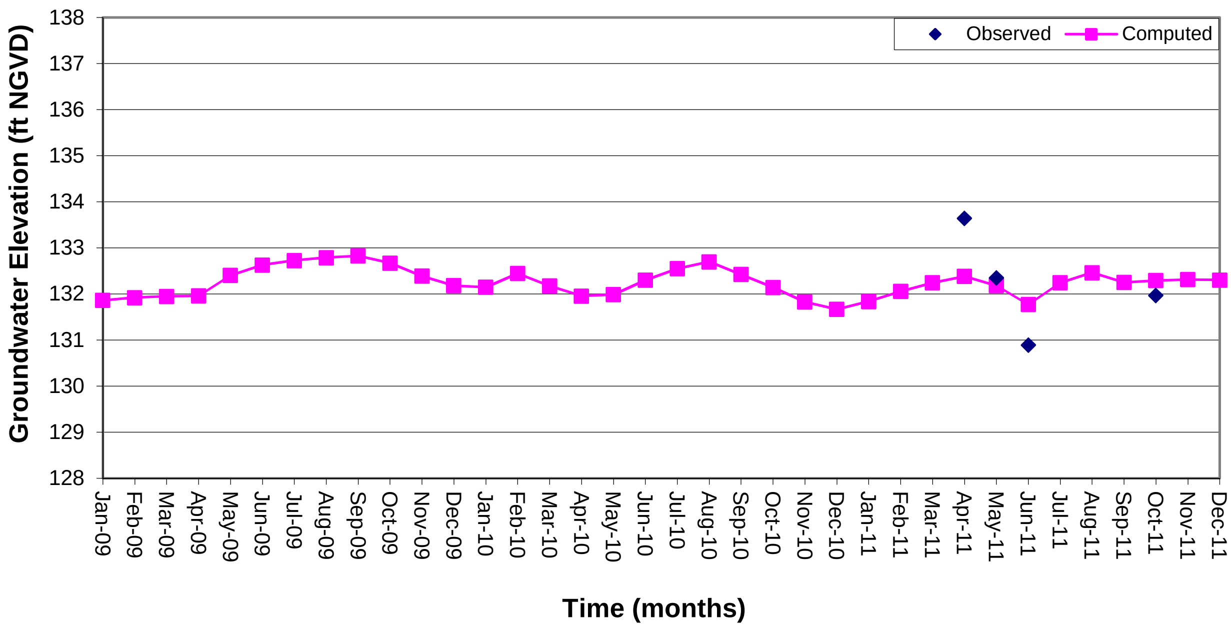


Figure 24
Comparison of Measured versus Simulated Groundwater Levels at CDM-7D (Layer 7)

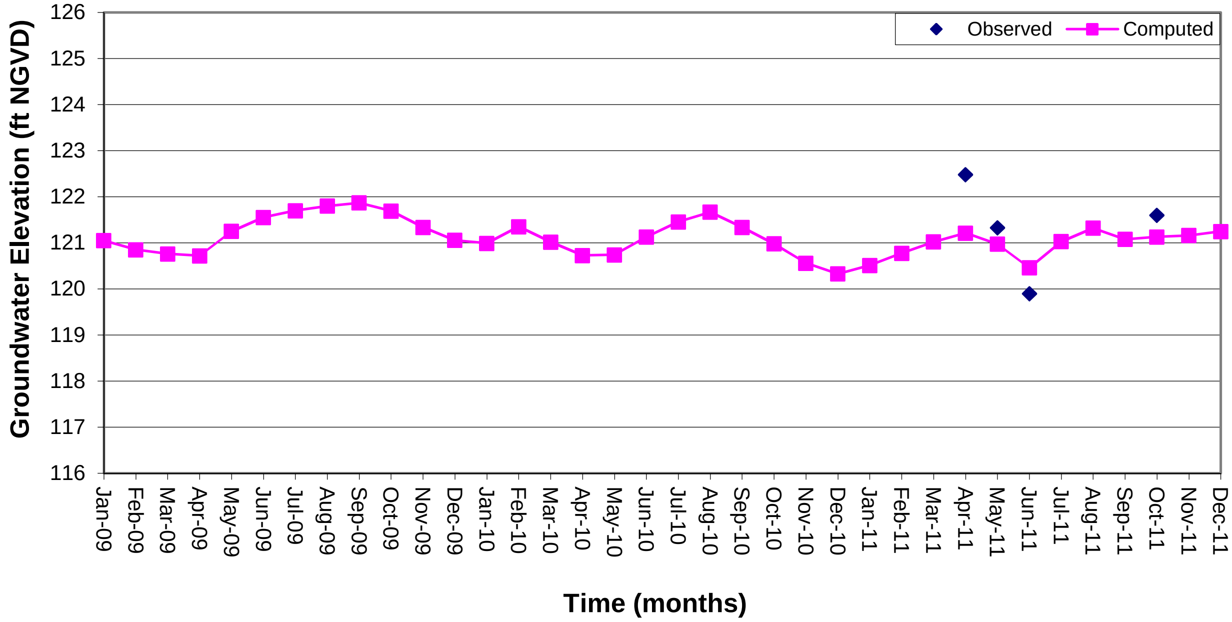


Figure 25
Comparison of Measured versus Simulated Groundwater Levels at CDM-8S (Layer 3)

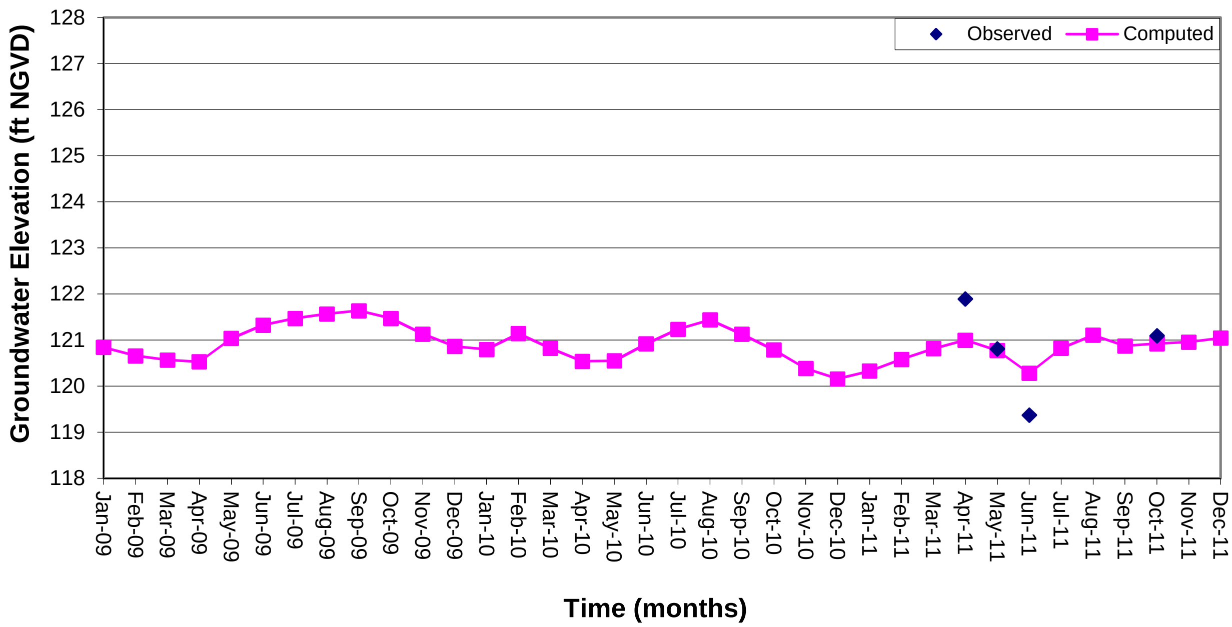


Figure 26
Comparison of Measured versus Simulated Groundwater Levels at CDM-8I (Layer 5)

CDM Smith

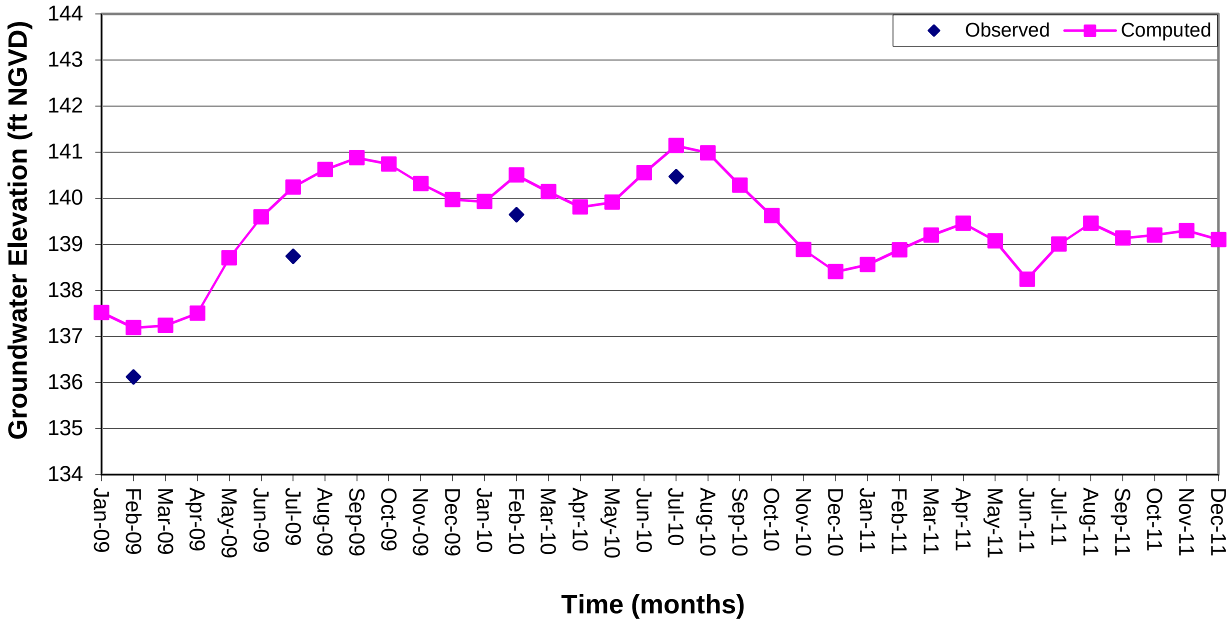


Figure 27
Comparison of Measured versus Simulated Groundwater Levels at B-2(SR) (Layer 1)

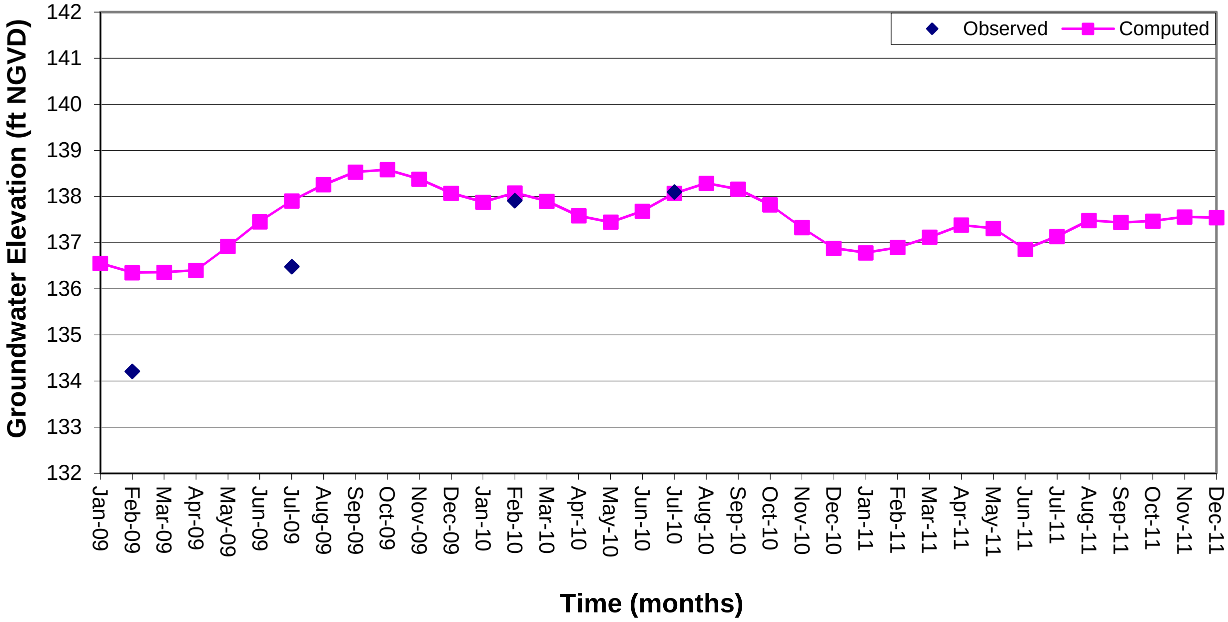


Figure 28
Comparison of Measured versus Simulated Groundwater Levels at B-2(I) (Layer 3)

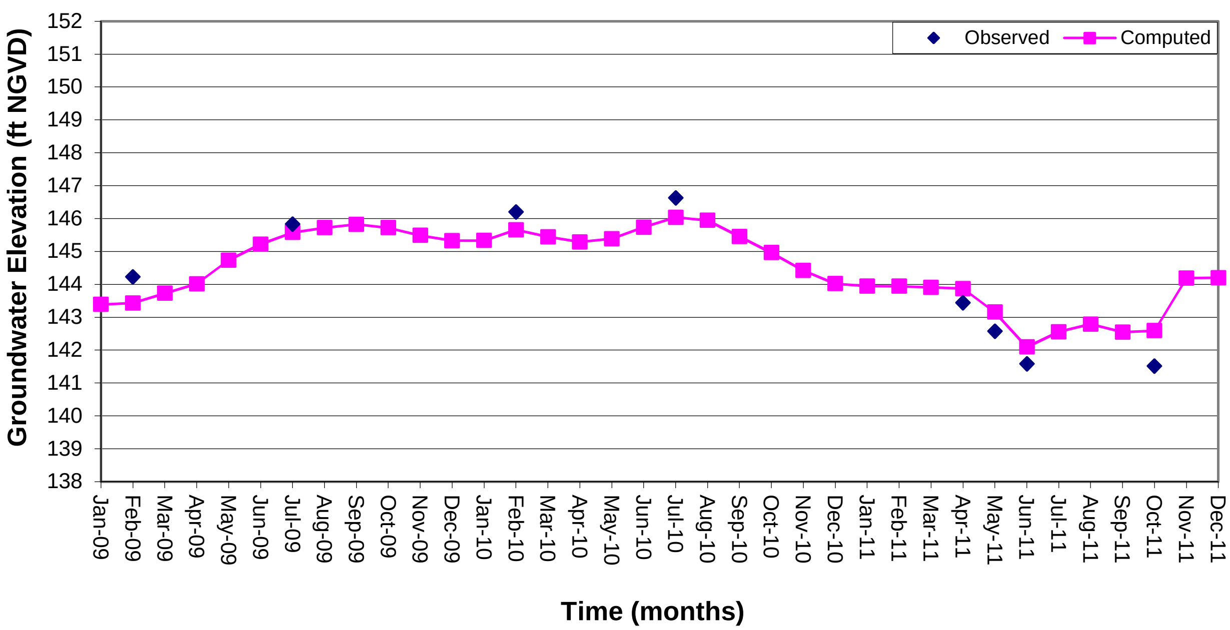


Figure 29
Comparison of Measured versus Simulated Groundwater Levels at B-3(SR) (Layer 1)

CDM Smith

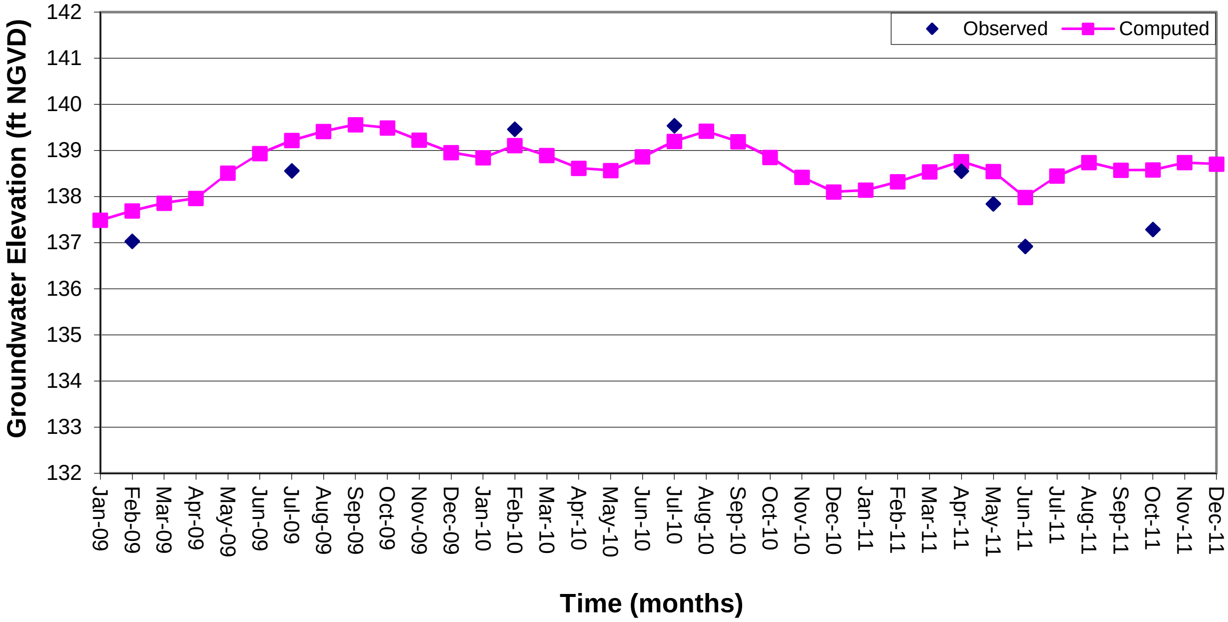


Figure 30
Comparison of Measured versus Simulated Groundwater Levels at B-3(I) (Layer 3)

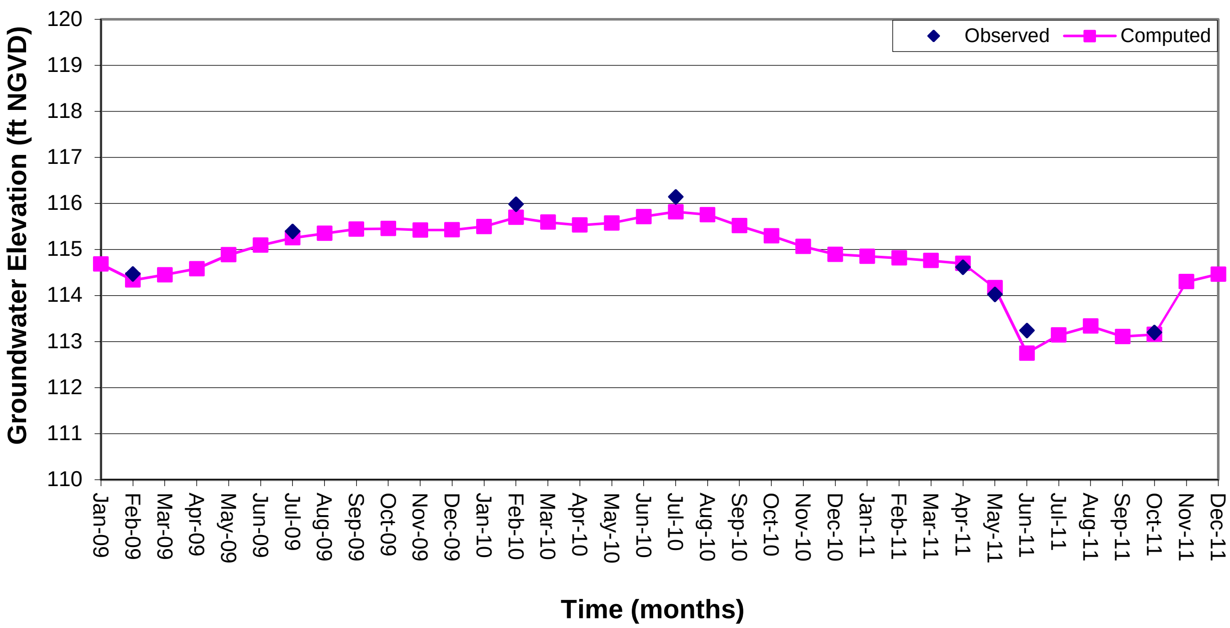


Figure 31
Comparison of Measured versus Simulated Groundwater Levels at B-7(SR) (Layer 1)

CDM Smith

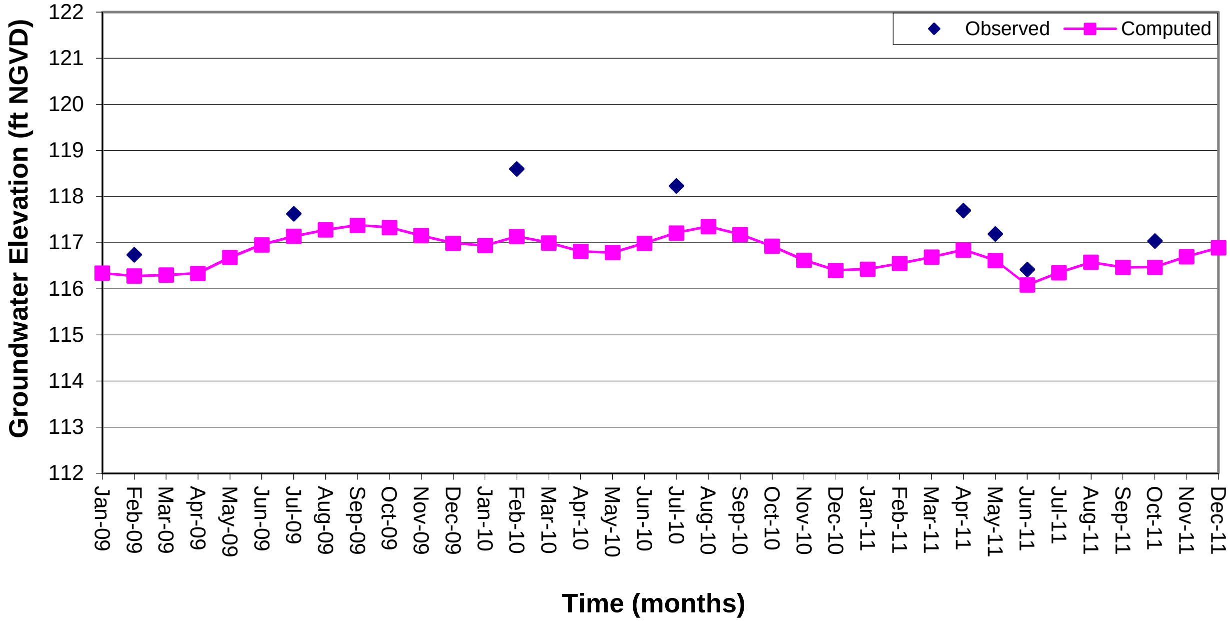


Figure 32
Comparison of Measured versus Simulated Groundwater Levels at B-7(I) (Layer 4)

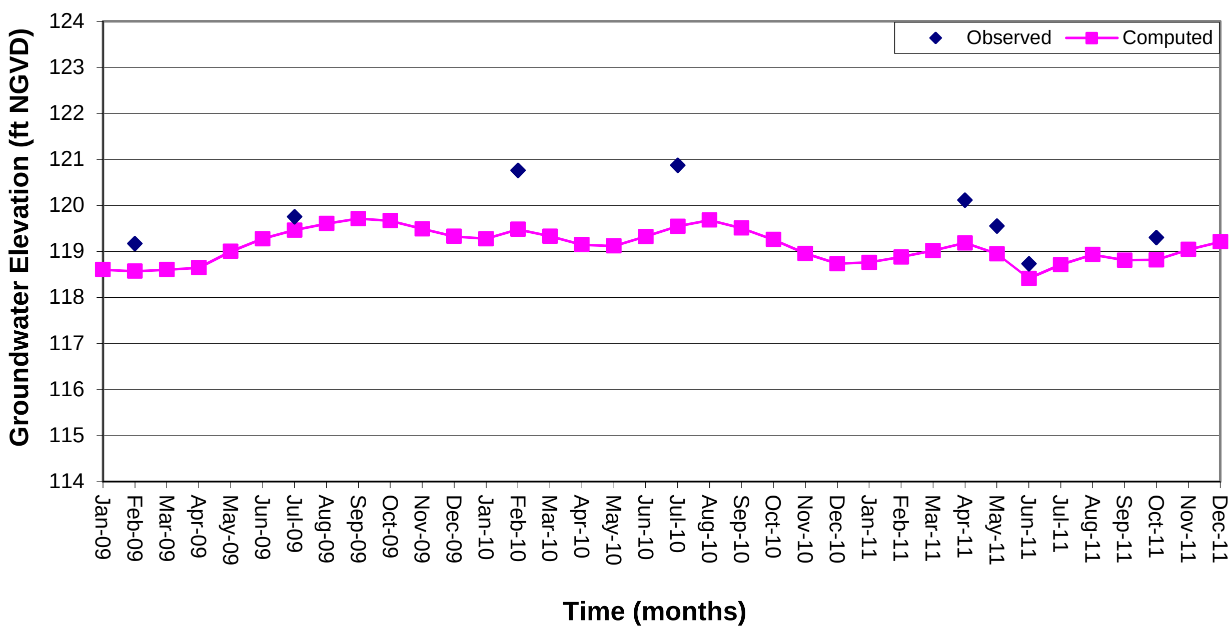


Figure 33
Comparison of Measured versus Simulated Groundwater Levels at B-7(D) (Layer 7)

CDM Smith

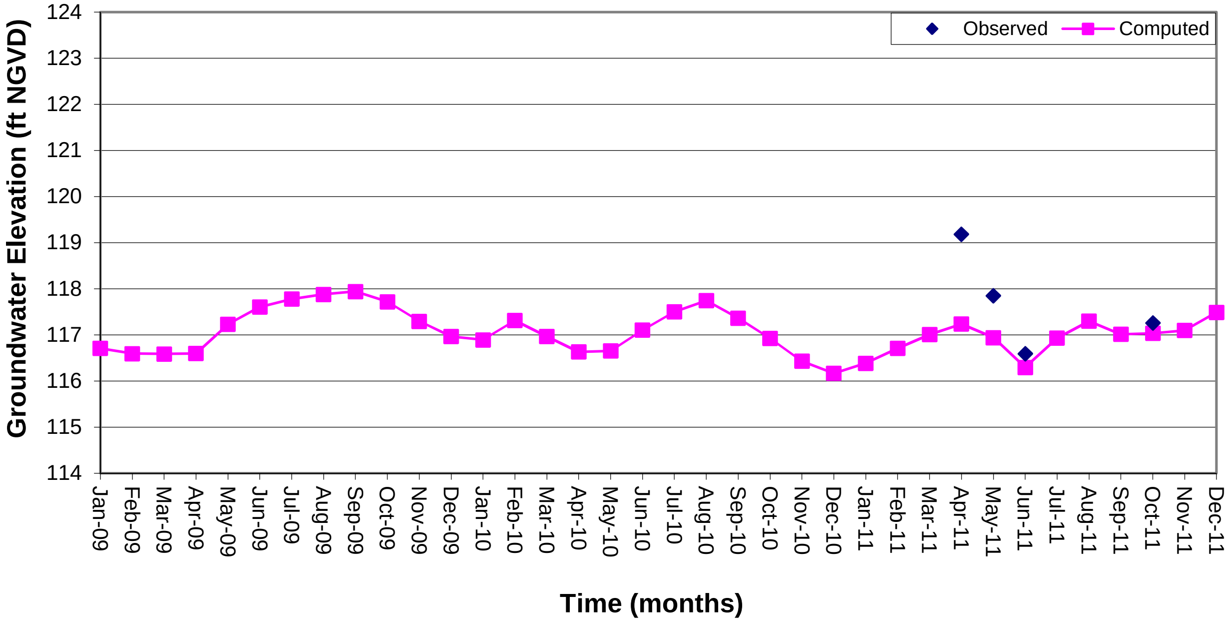


Figure 34
Comparison of Measured versus Simulated Groundwater Levels at B-8(S) (Layer 1)

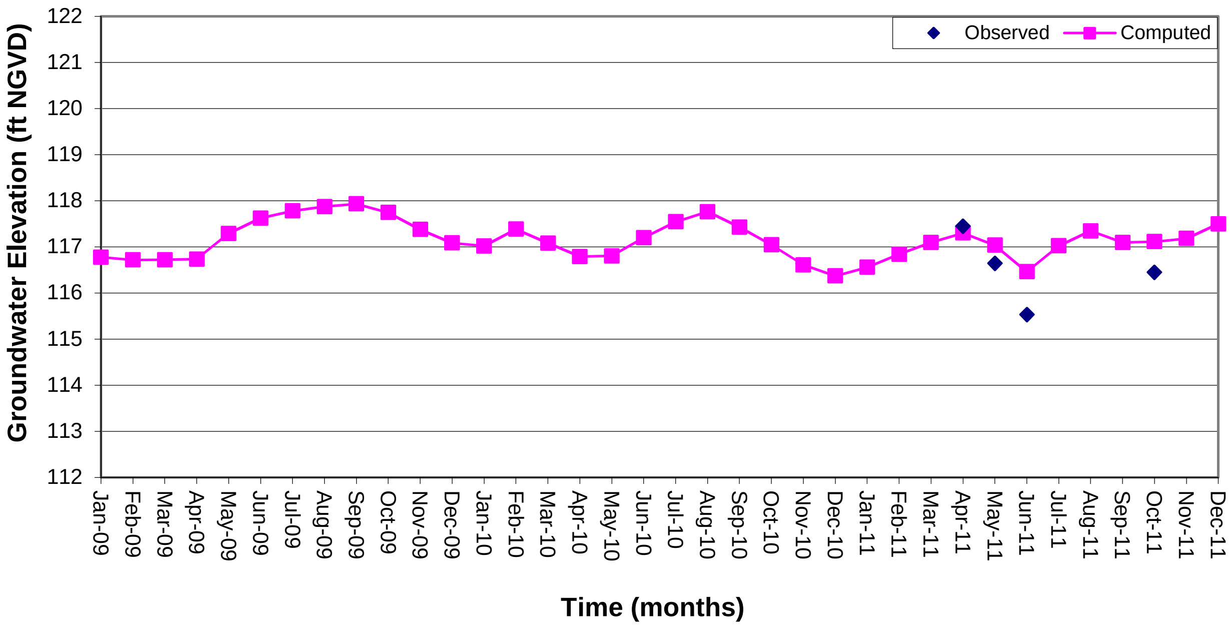


Figure 35
Comparison of Measured versus Simulated Groundwater Levels at B-8(I) (Layer 4)

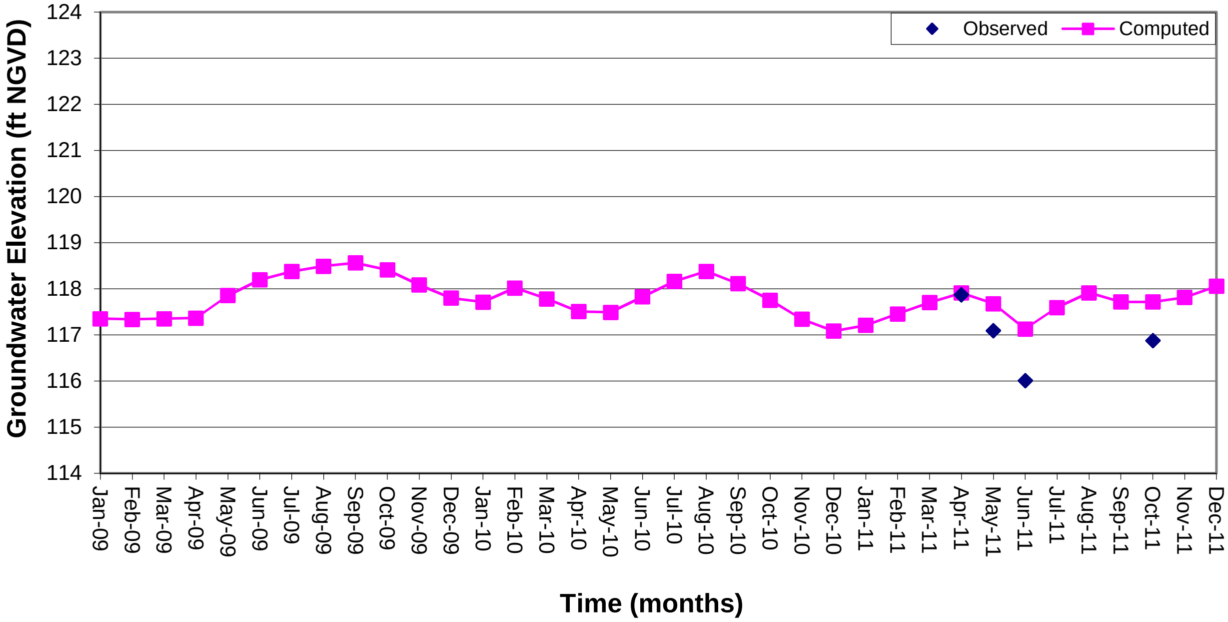


Figure 36
Comparison of Measured versus Simulated Groundwater Levels at B-8(D) (Layer 7)

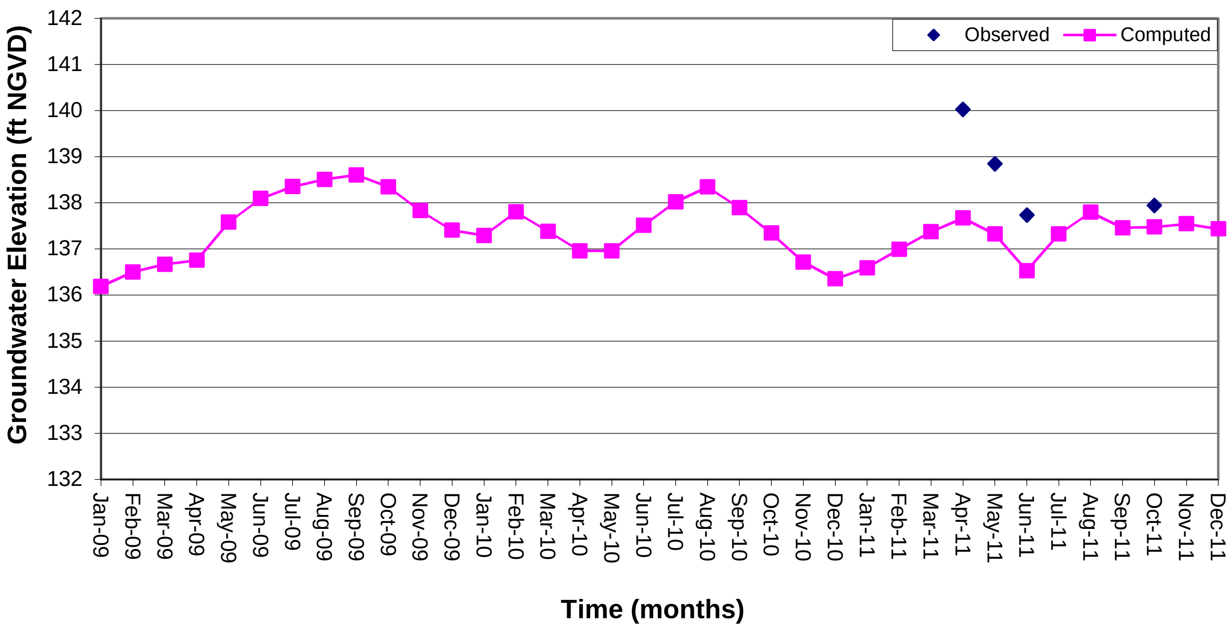


Figure 37
Comparison of Measured versus Simulated Groundwater Levels at B-9(S) (Layer 1)

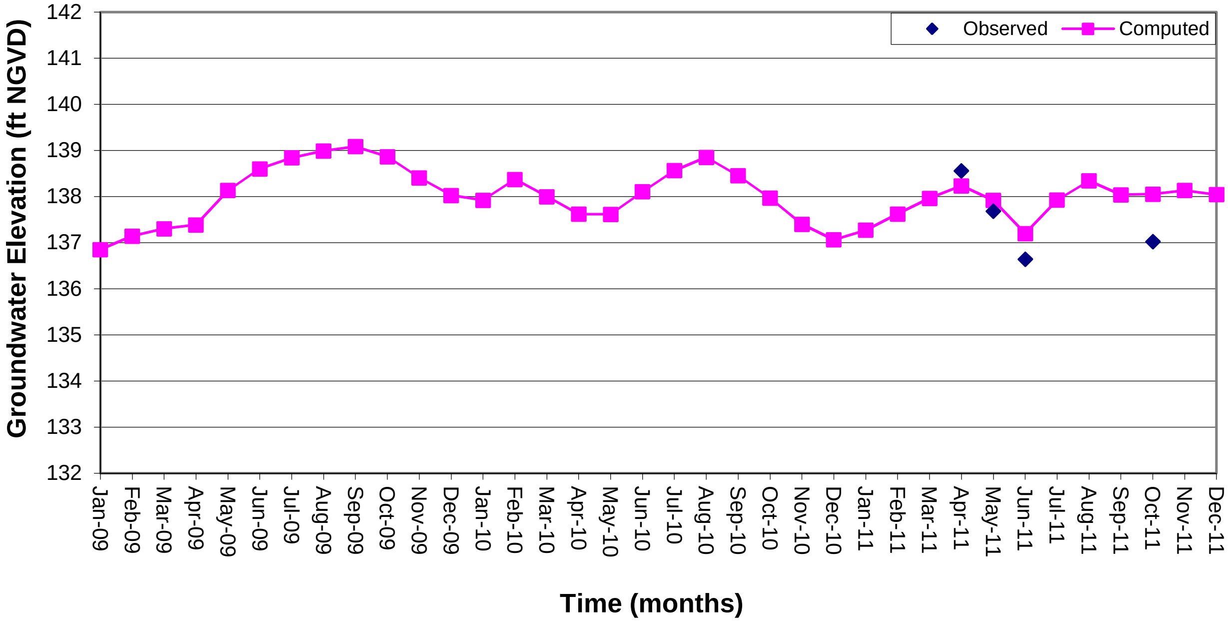


Figure 38
Comparison of Measured versus Simulated Groundwater Levels at B-9(I) (Layer 4)

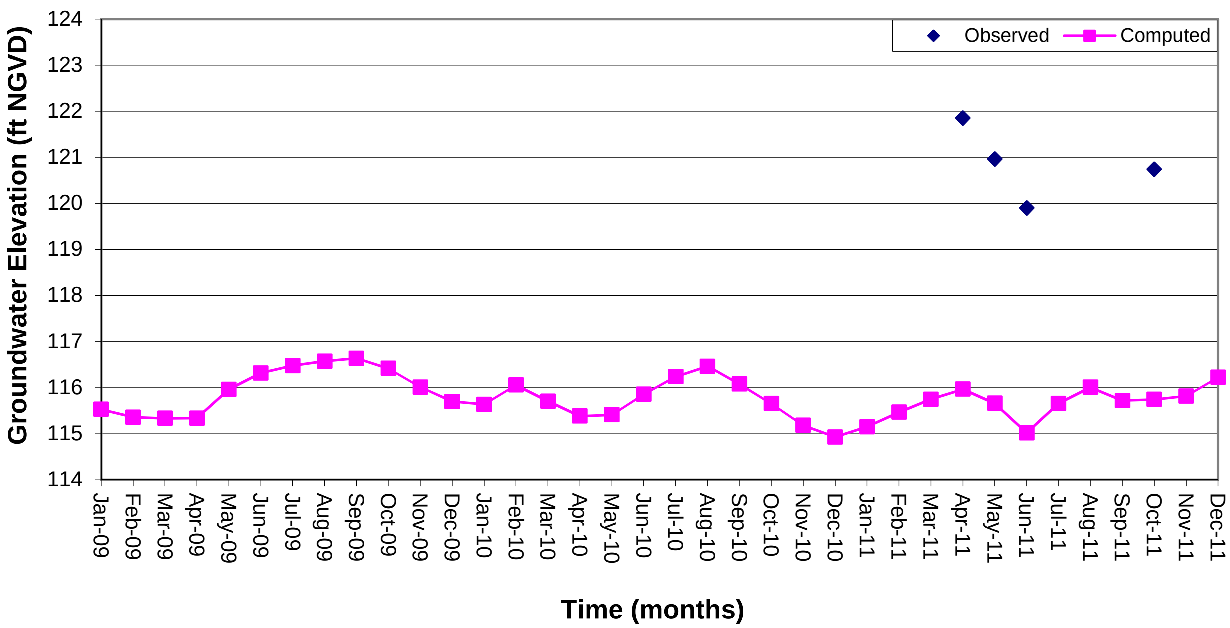


Figure 39
Comparison of Measured versus Simulated Groundwater Levels at B-10(S) (Layer 1)

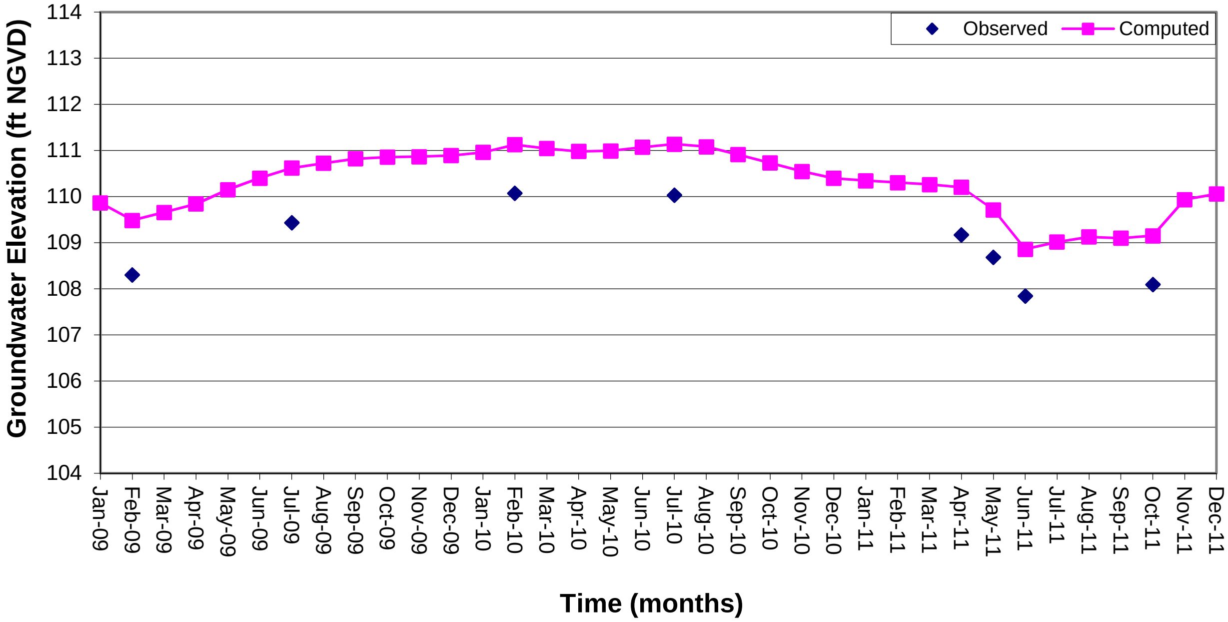


Figure 40
Comparison of Measured versus Simulated Groundwater Levels at B-11(SR) (Layer 1)

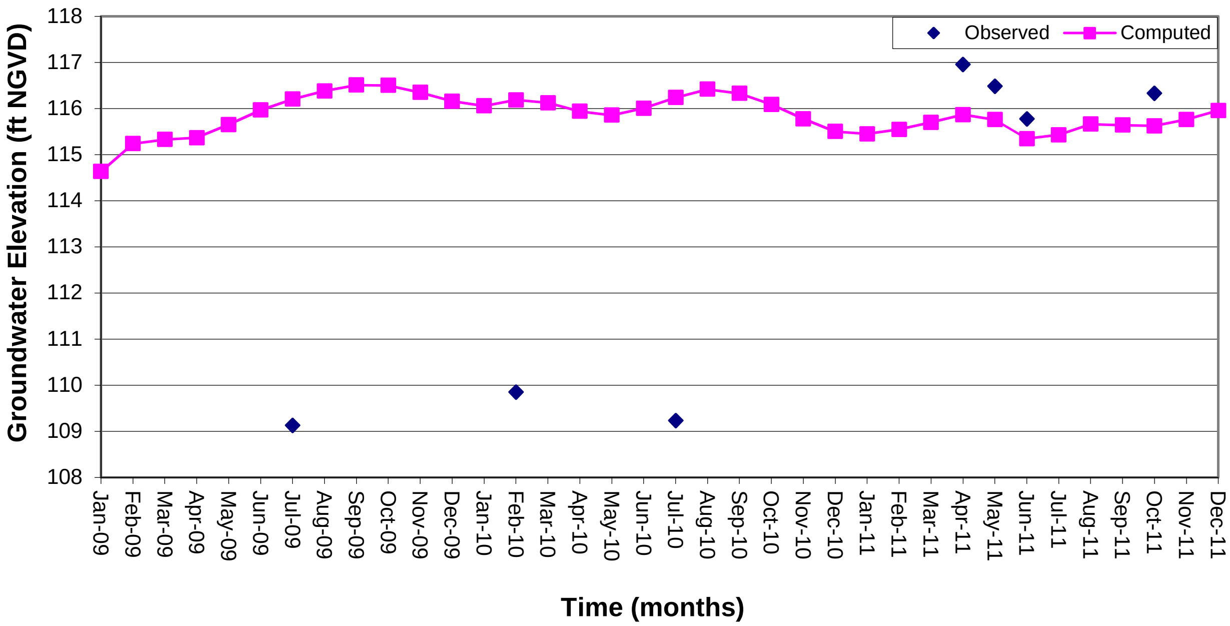


Figure 41
Comparison of Measured versus Simulated Groundwater Levels at B-11(I) (Layer 4)

CDM Smith

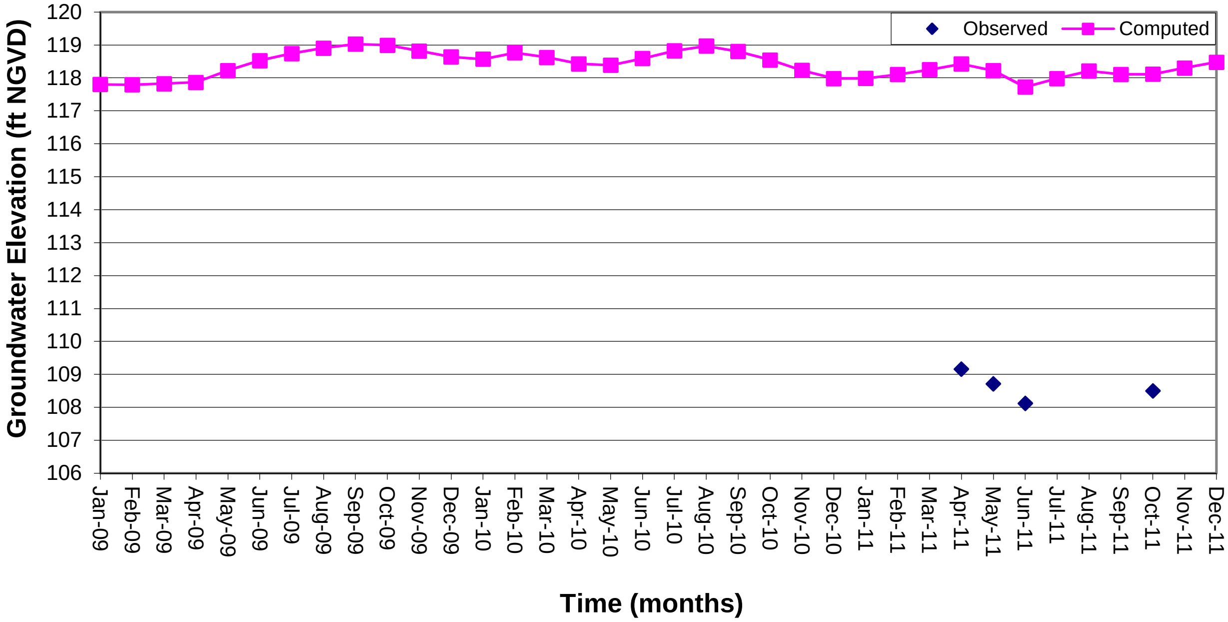


Figure 42
Comparison of Measured versus Simulated Groundwater Levels at B-11(D) (Layer 7)

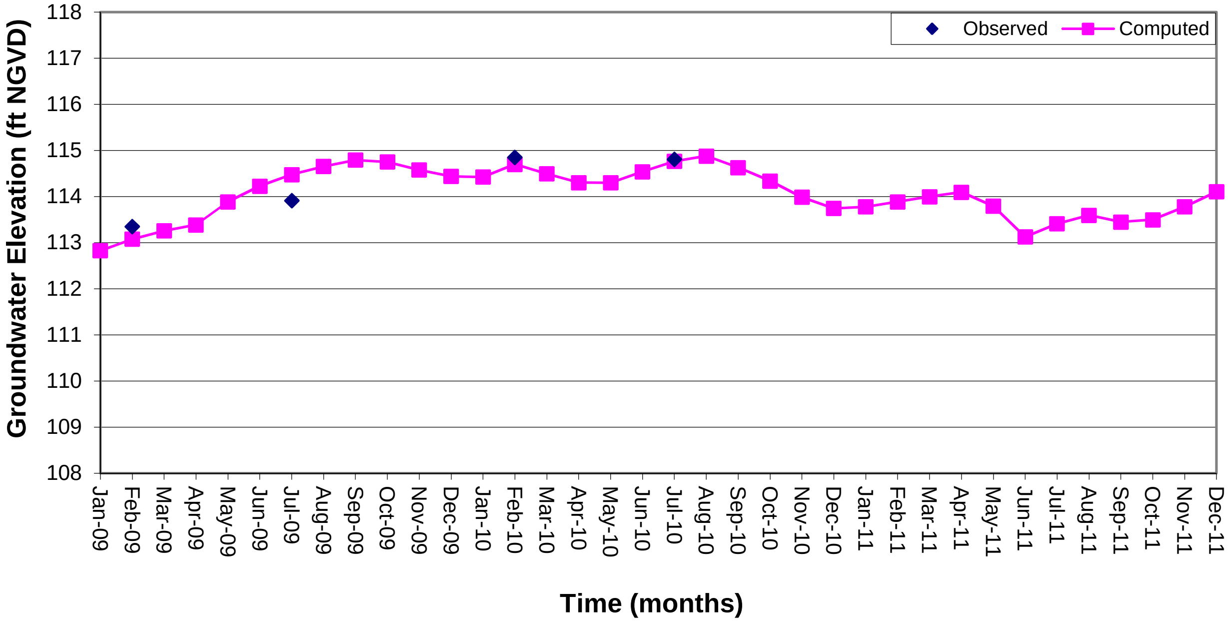


Figure 43
Comparison of Measured versus Simulated Groundwater Levels at B-12(SR) (Layer 1)

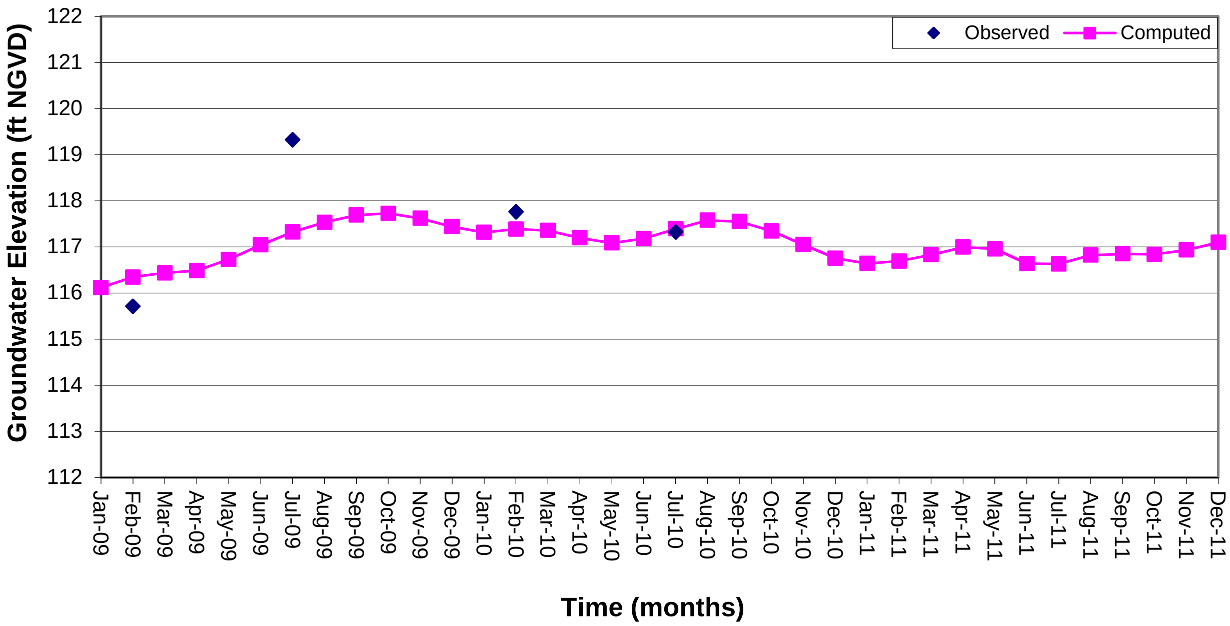


Figure 44
Comparison of Measured versus Simulated Groundwater Levels at B-12(I) (Layer 4)

CDM Smith

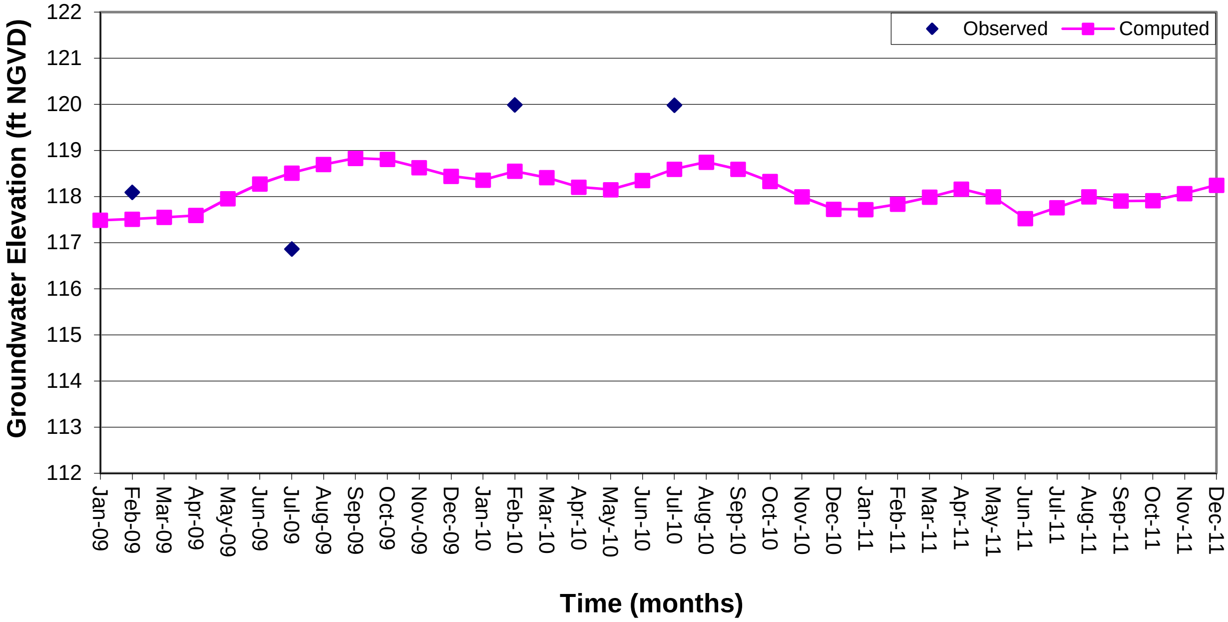


Figure 45
Comparison of Measured versus Simulated Groundwater Levels at B-12(D) (Layer 7)

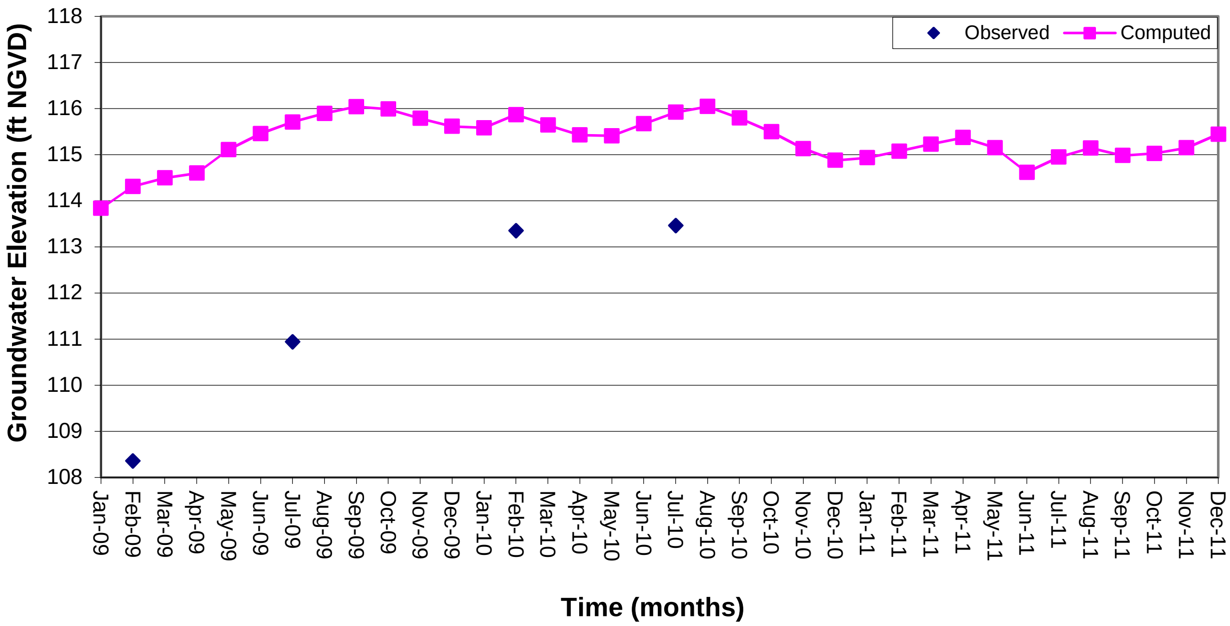


Figure 46
Comparison of Measured versus Simulated Groundwater Levels at B-13(SR) (Layer 1)

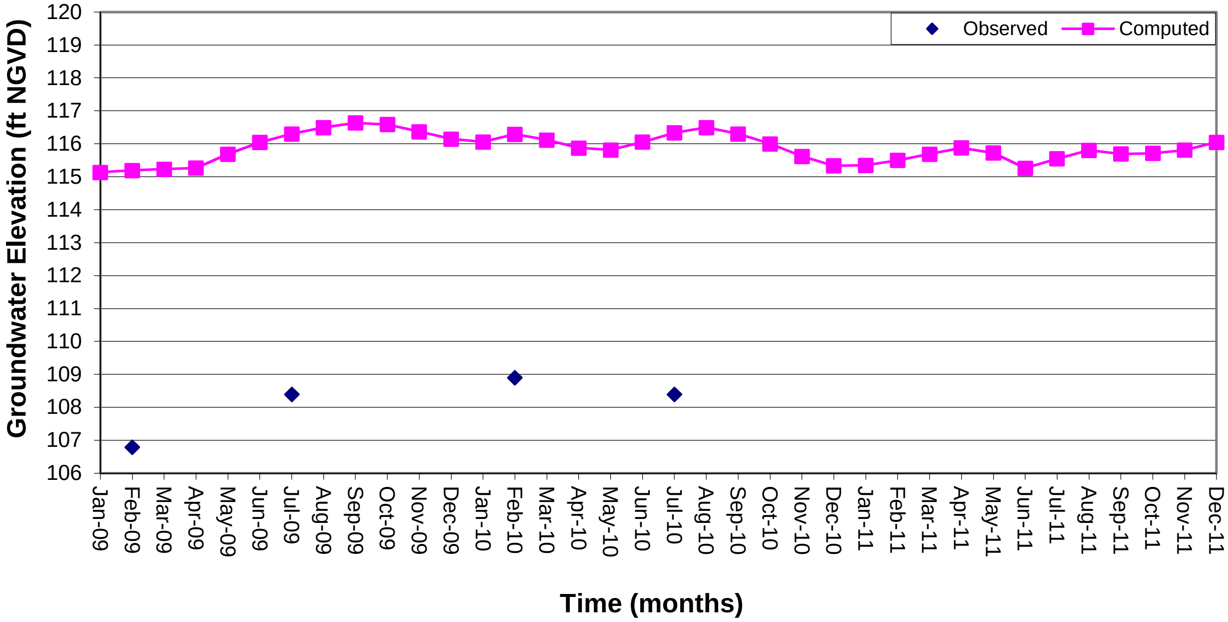


Figure 47
Comparison of Measured versus Simulated Groundwater Levels at B-13(IR) (Layer 3)

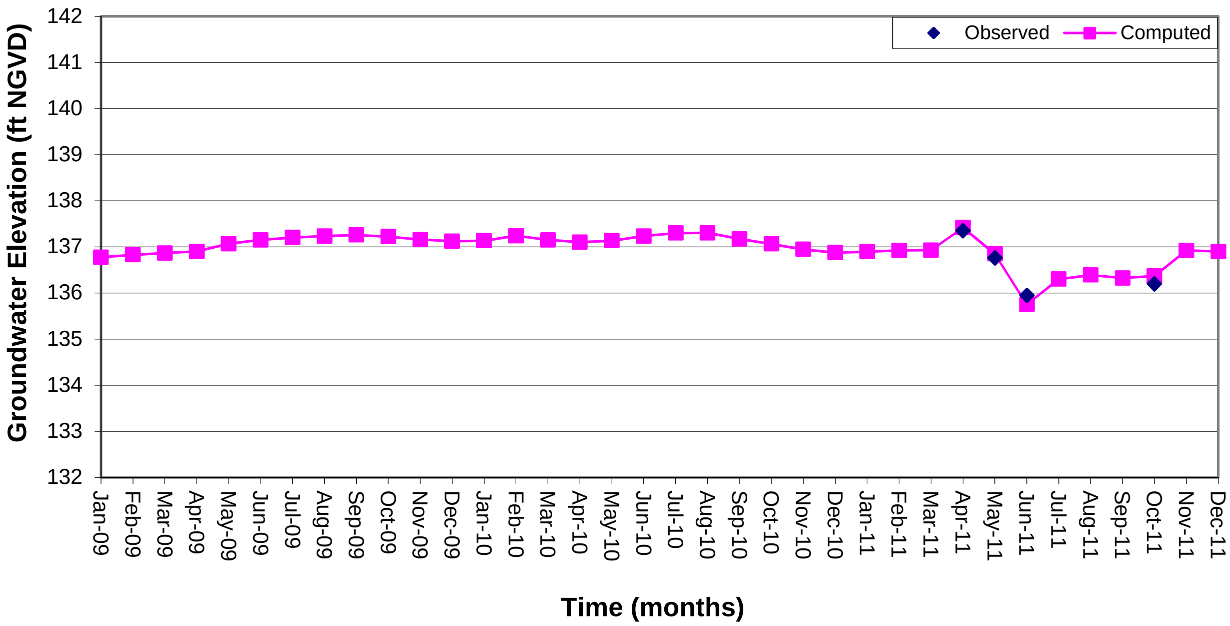


Figure 48
Comparison of Measured versus Simulated Groundwater Levels at B-16(S) (Layer 1)

CDM Smith

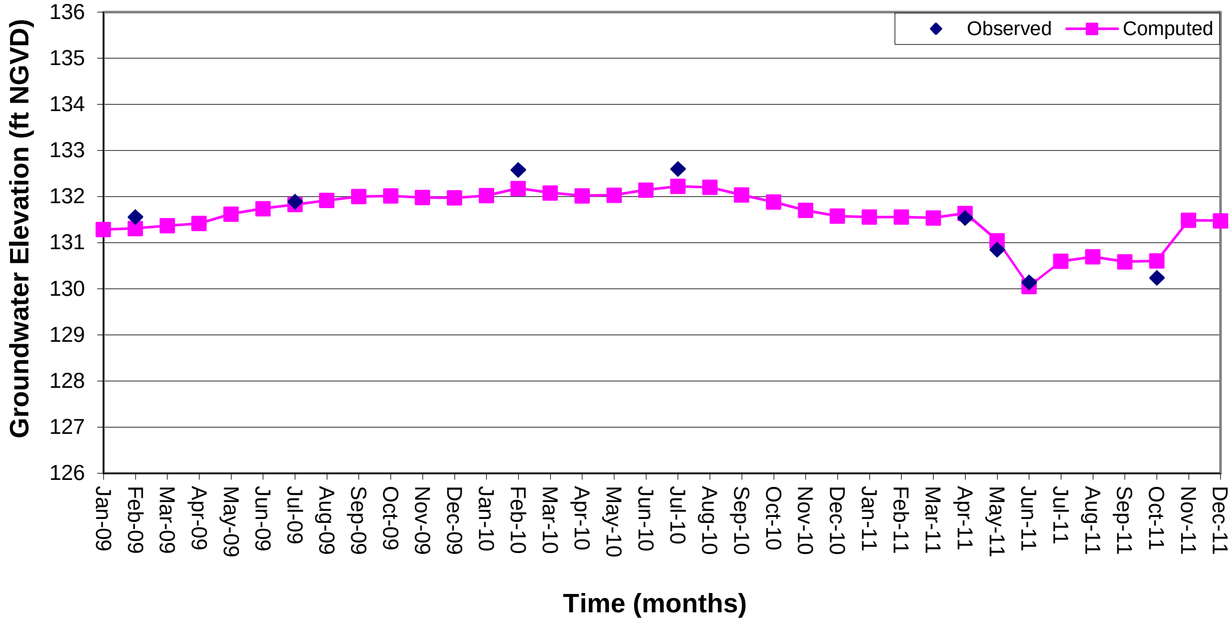


Figure 49
Comparison of Measured versus Simulated Groundwater Levels at B-17(S) (Layer 1)

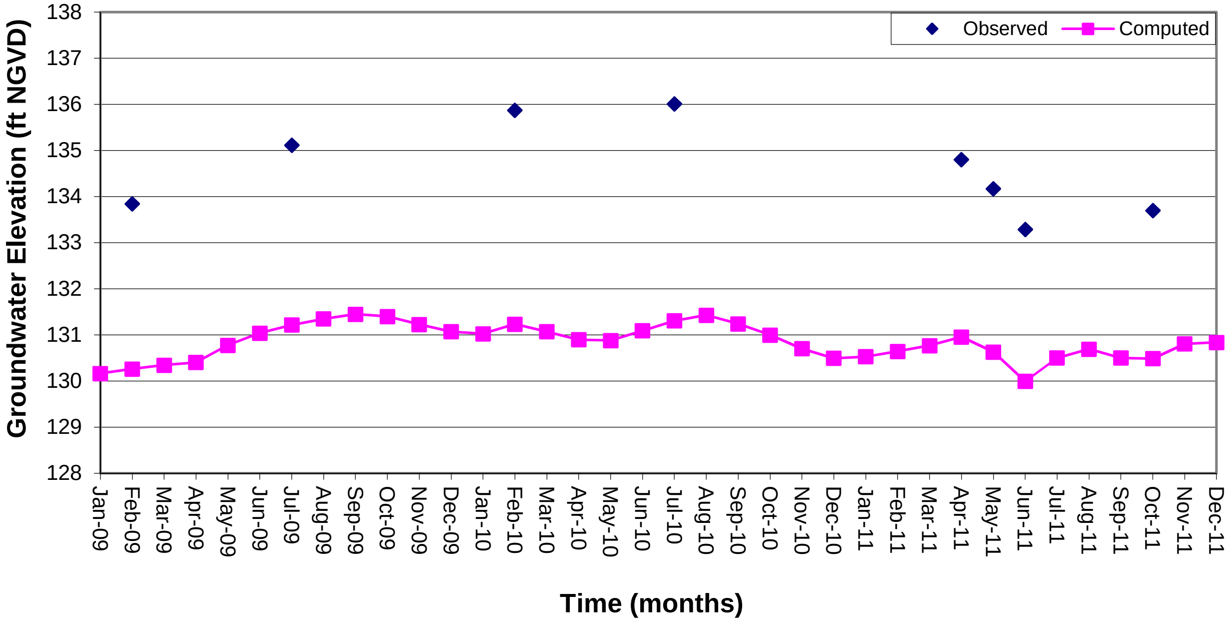


Figure 50
Comparison of Measured versus Simulated Groundwater Levels at B-17(I) (Layer 3)

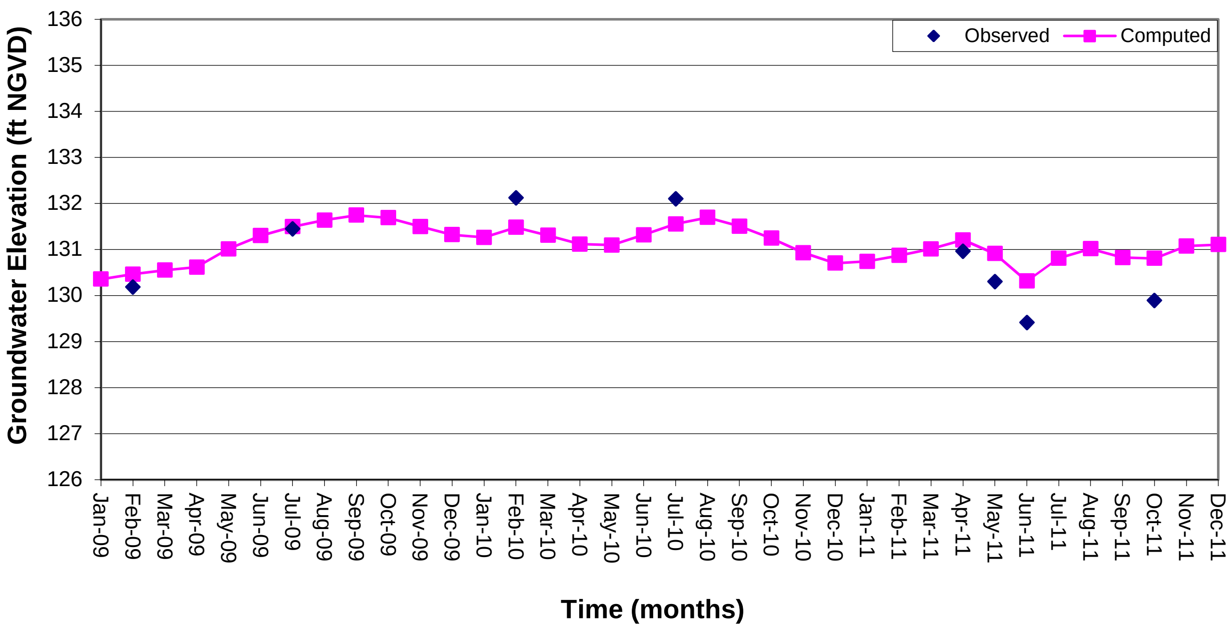


Figure 51
Comparison of Measured versus Simulated Groundwater Levels at B-17(D) (Layer 7)

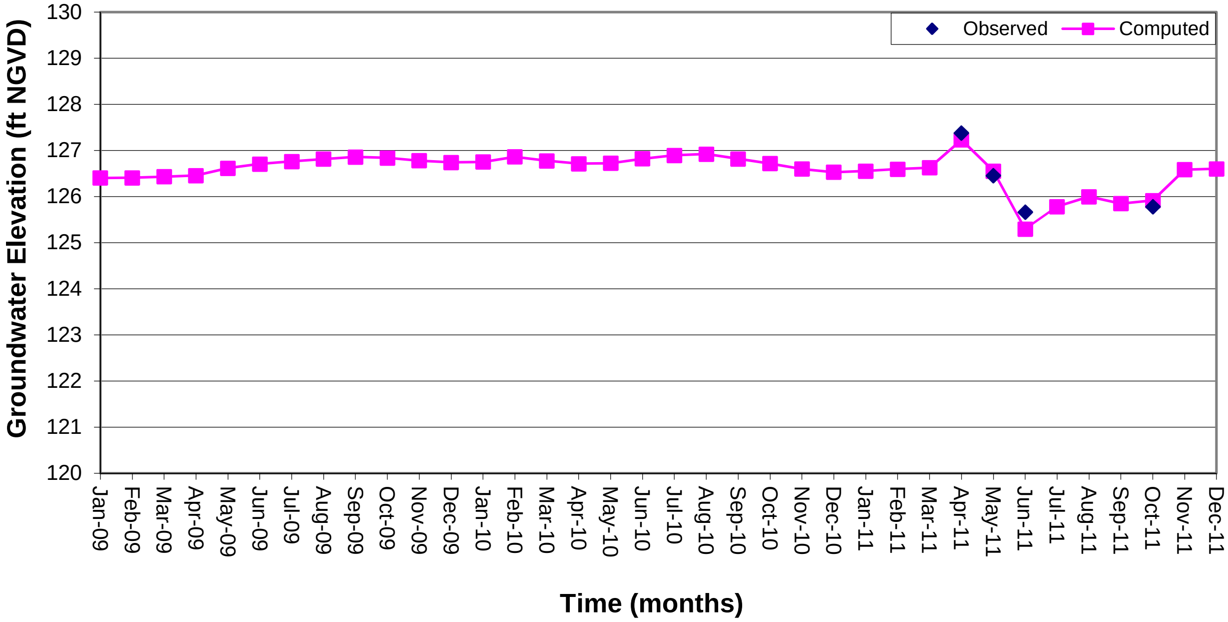


Figure 52
Comparison of Measured versus Simulated Groundwater Levels at B-18(S) (Layer 1)

CDM Smith

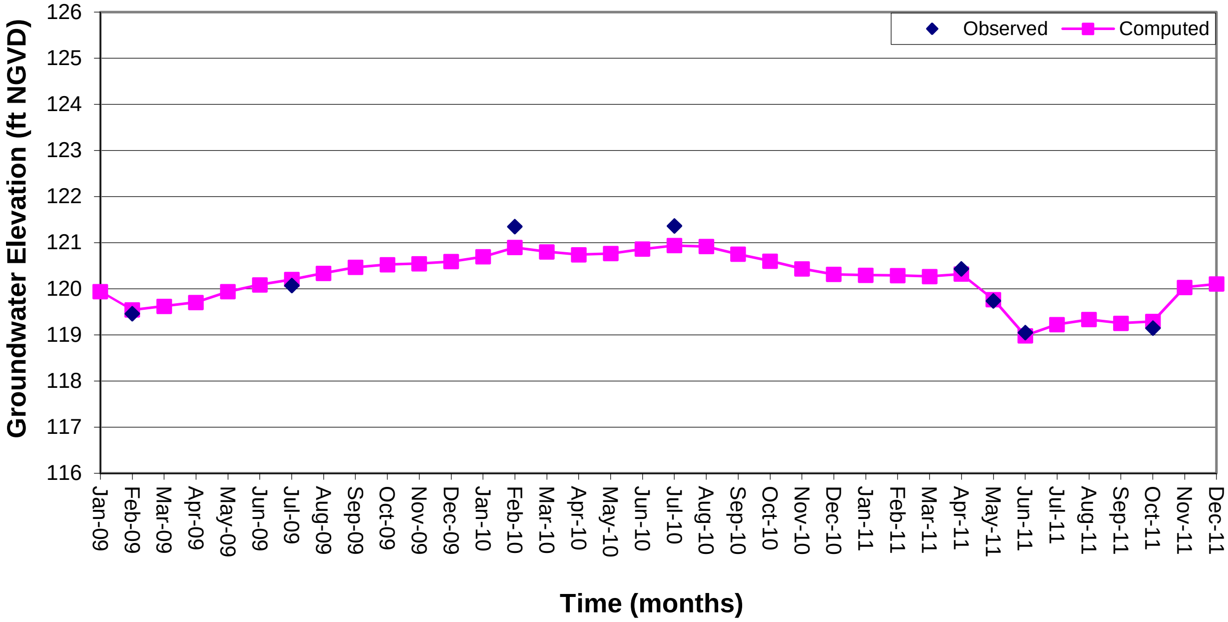


Figure 53
Comparison of Measured versus Simulated Groundwater Levels at B-19(S) (Layer 1)

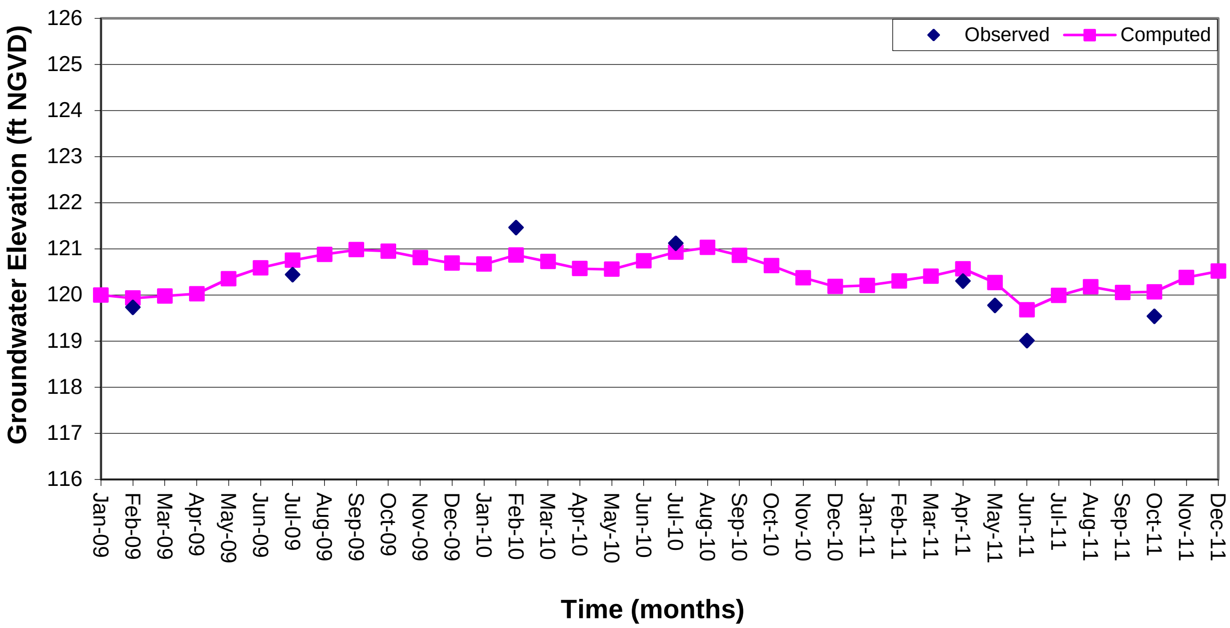


Figure 54
Comparison of Measured versus Simulated Groundwater Levels at B-19(I) (Layer 5)

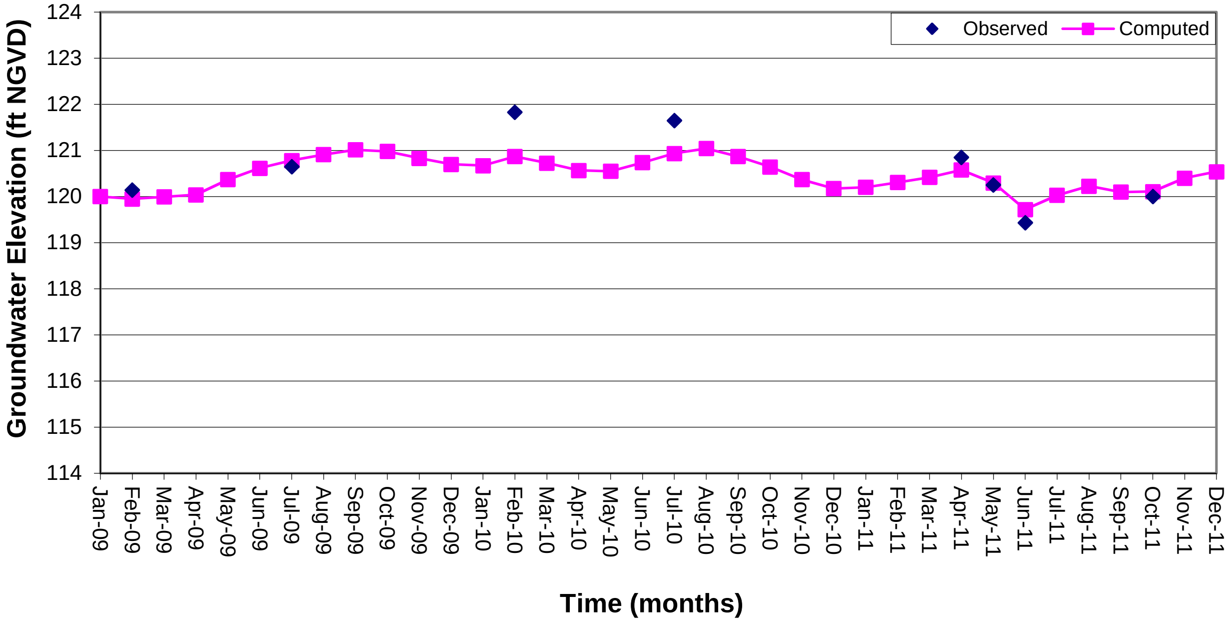


Figure 55
Comparison of Measured versus Simulated Groundwater Levels at B-19(D) (Layer 7)

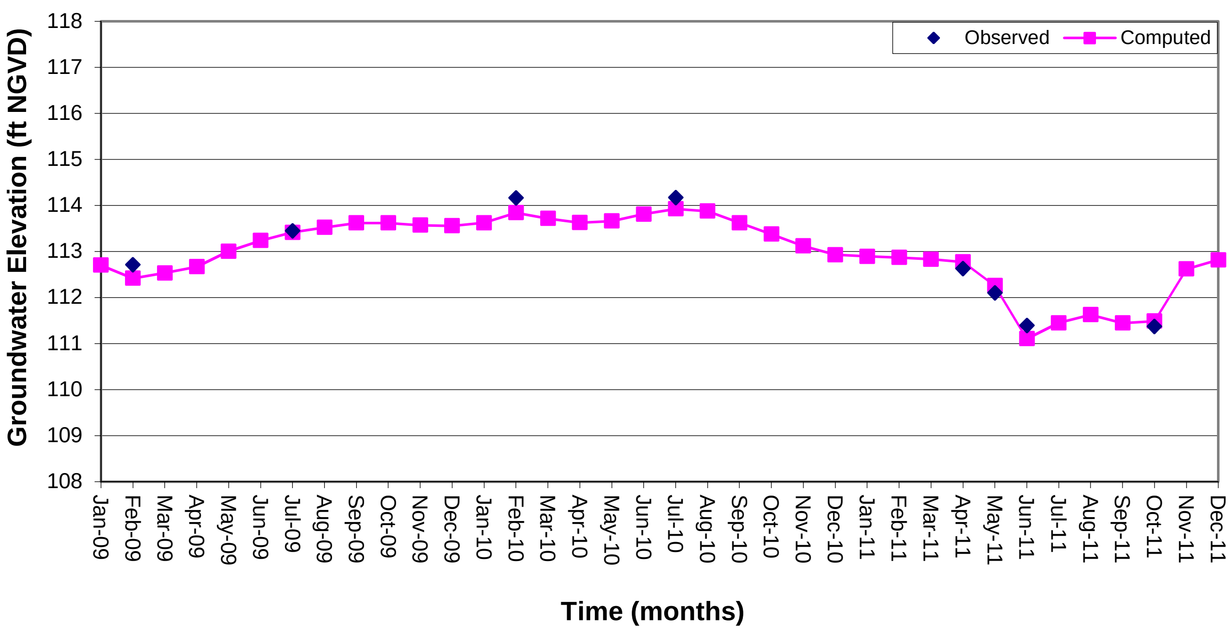


Figure 56
Comparison of Measured versus Simulated Groundwater Levels at B-20(S) (Layer 1)

CDM Smith

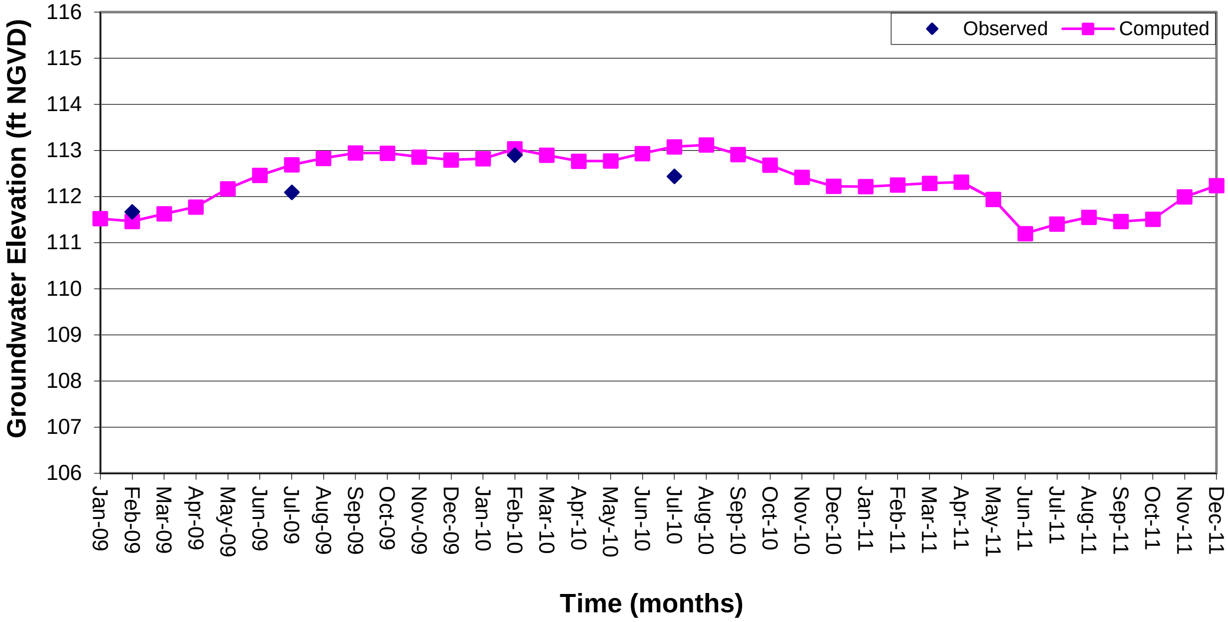


Figure 57
Comparison of Measured versus Simulated Groundwater Levels at B-21(S) (Layer 1)

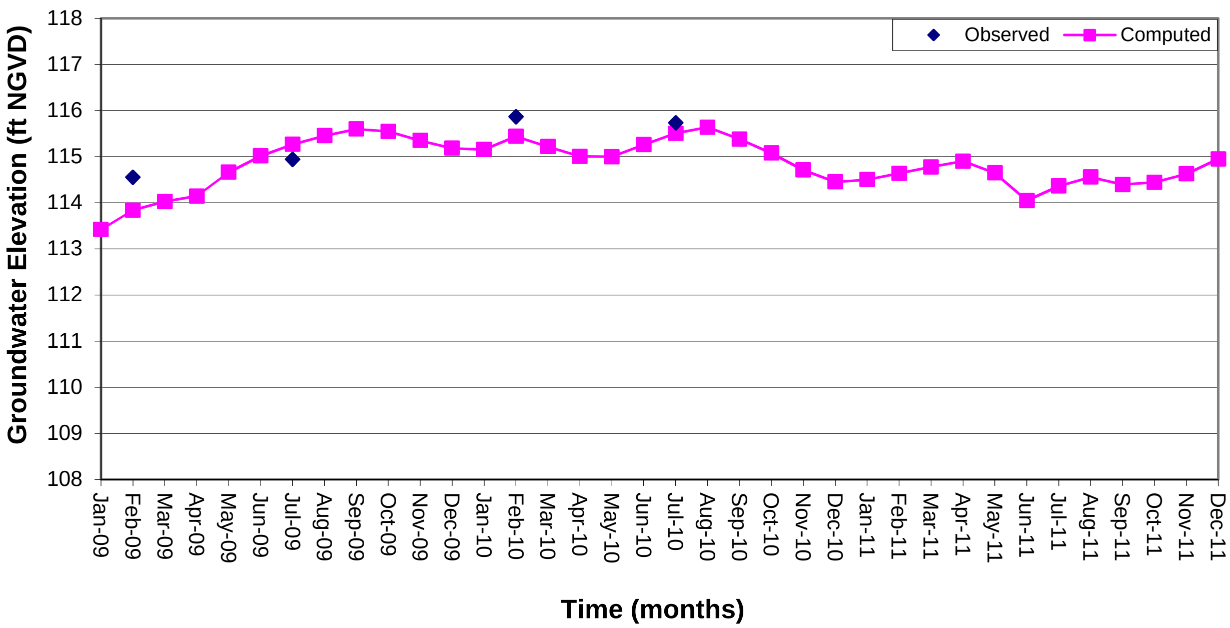


Figure 58
Comparison of Measured versus Simulated Groundwater Levels at B-22(SR) (Layer 1)

CDM Smith

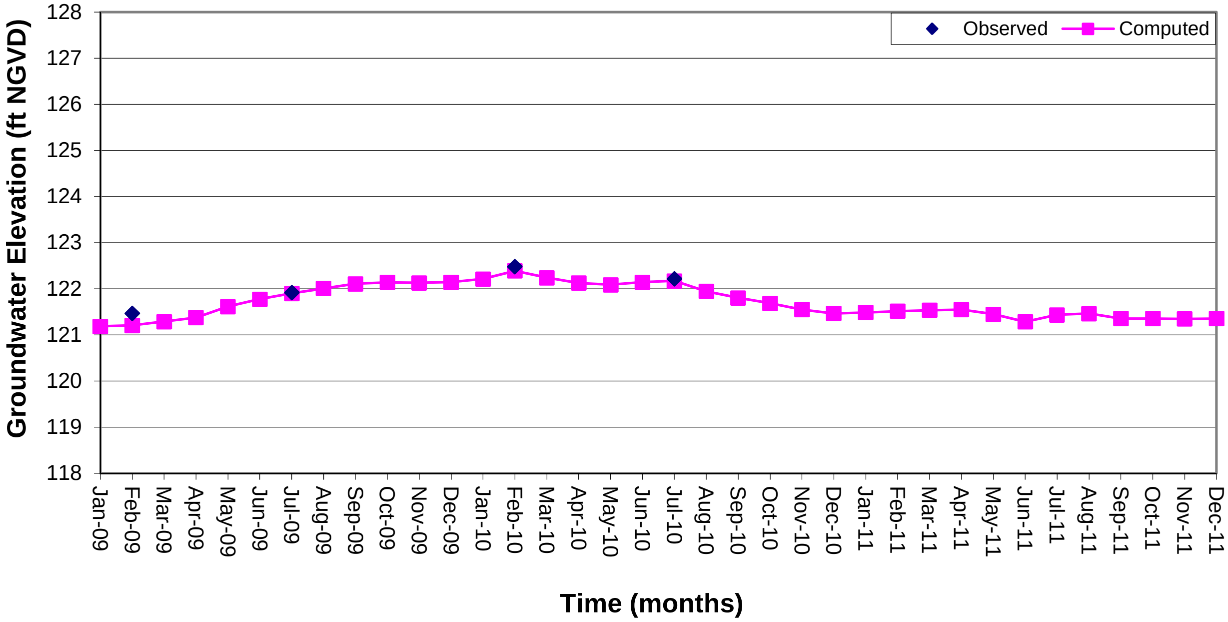


Figure 59
Comparison of Measured versus Simulated Groundwater Levels at B-27(S) (Layer 1)

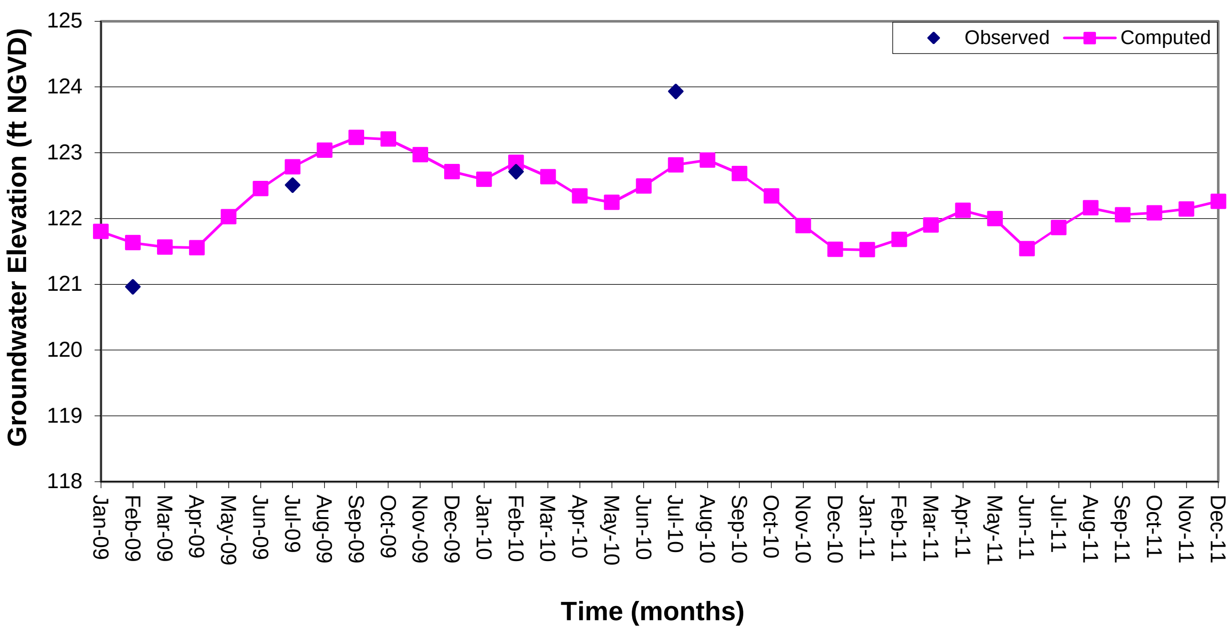


Figure 60
Comparison of Measured versus Simulated Groundwater Levels at B-27(I) (Layer 3)

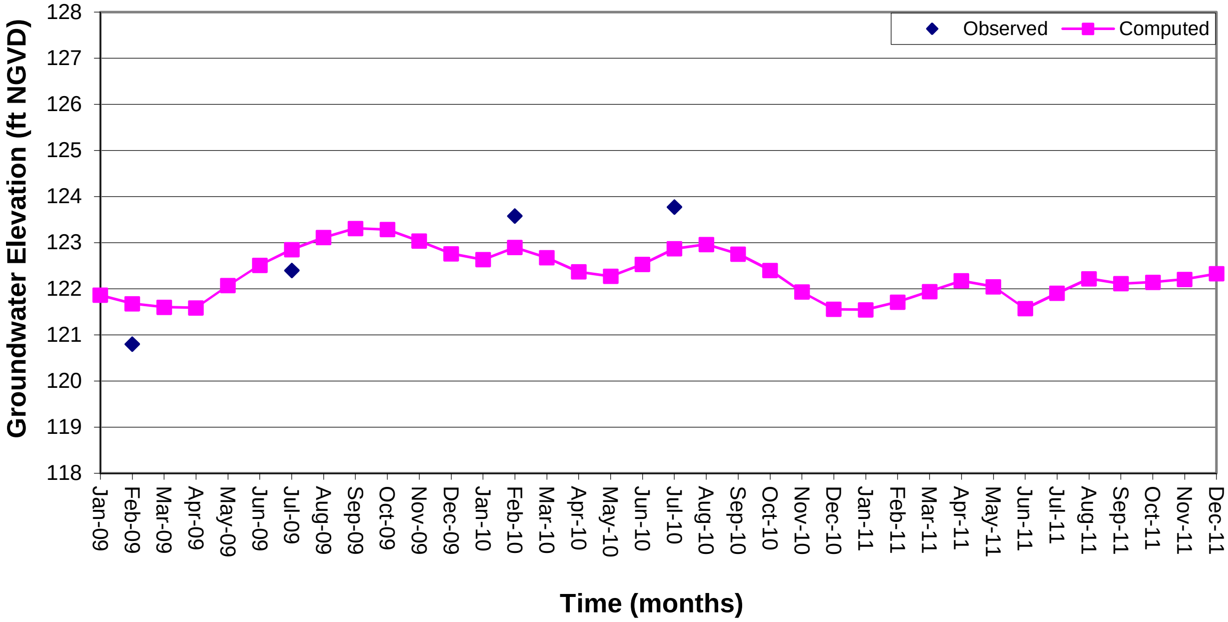


Figure 61
Comparison of Measured versus Simulated Groundwater Levels at B-27(D) (Layer 7)

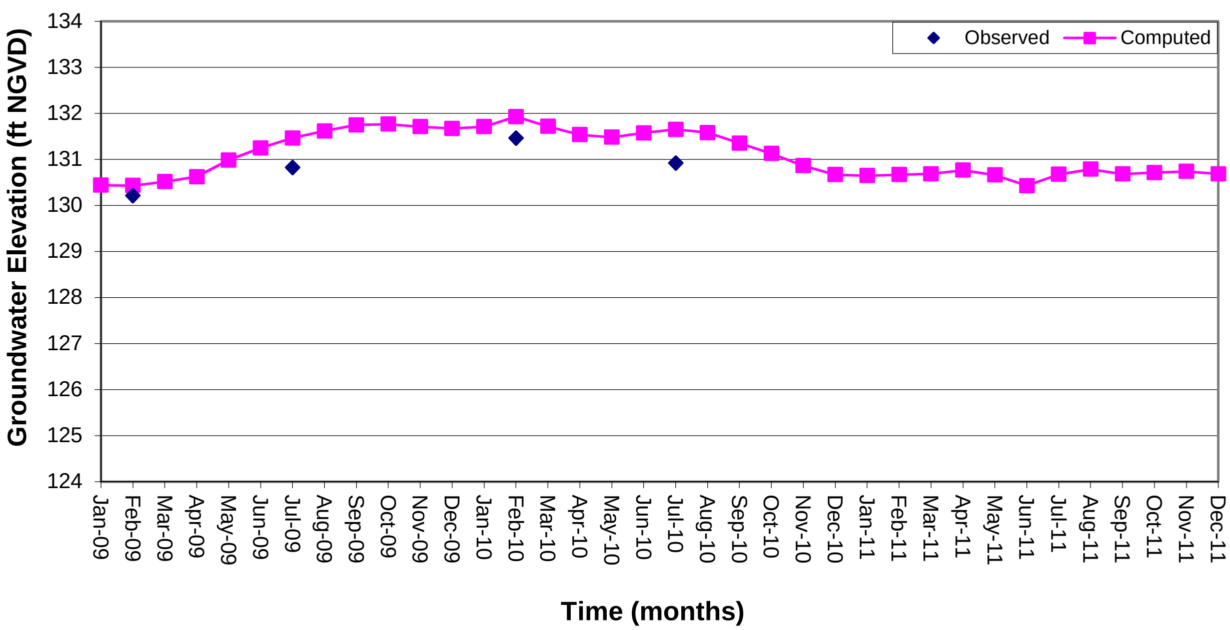


Figure 62
Comparison of Measured versus Simulated Groundwater Levels at B-29(S) (Layer 1)

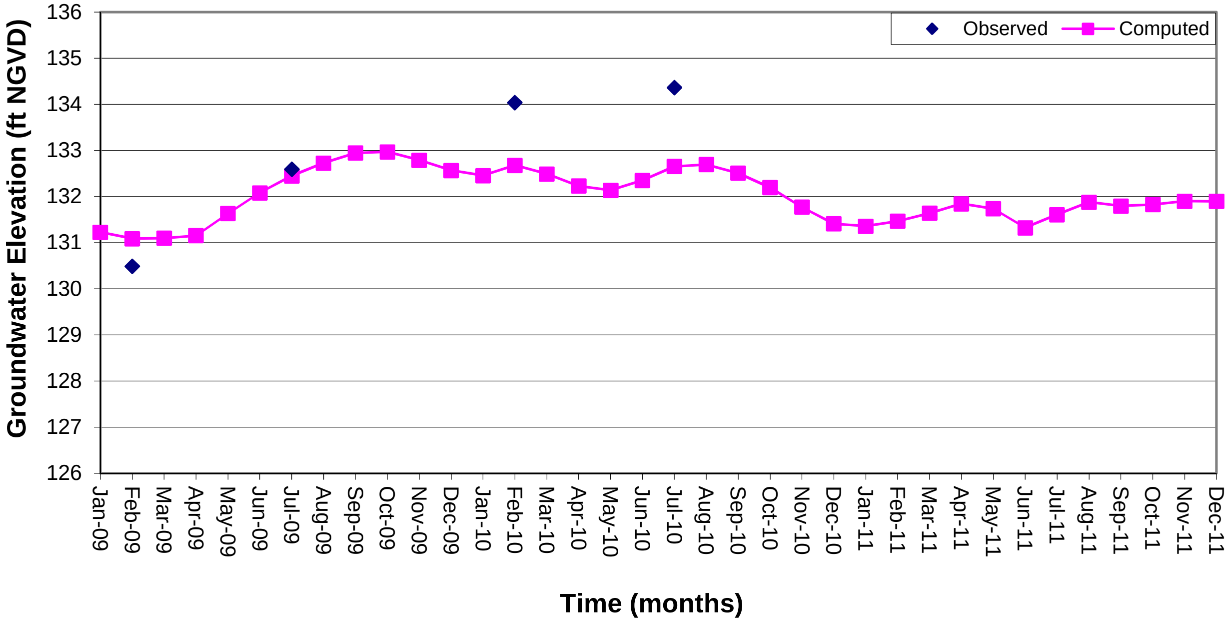


Figure 63
Comparison of Measured versus Simulated Groundwater Levels at B-29(I) (Layer 3)

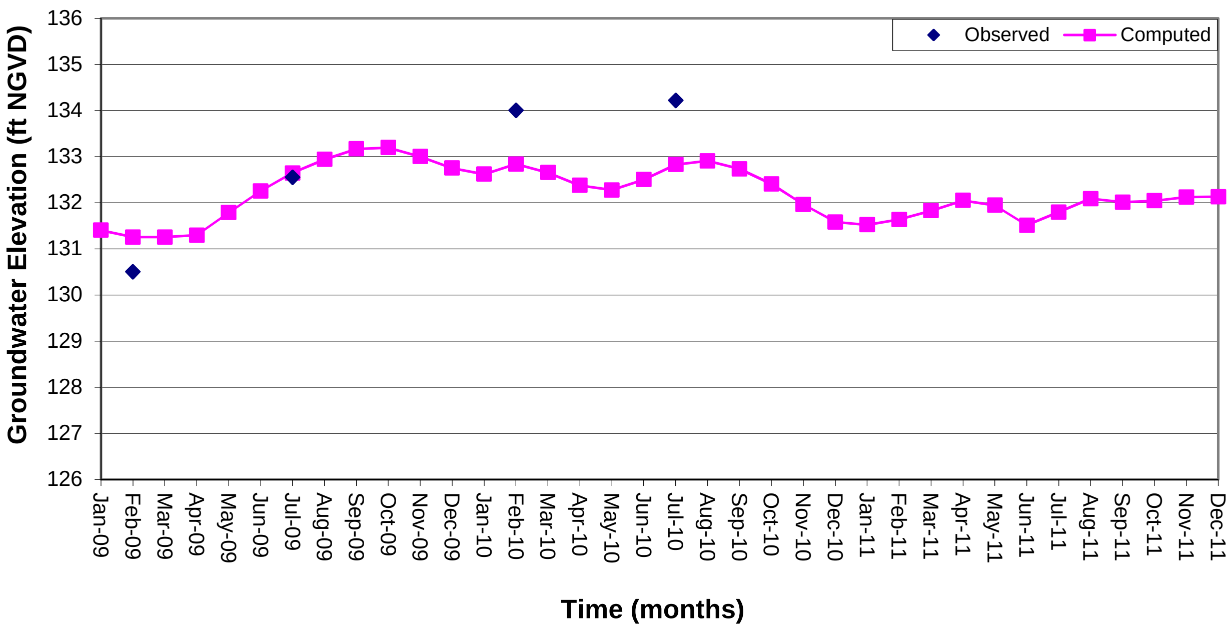


Figure 64
Comparison of Measured versus Simulated Groundwater Levels at B-29(D) (Layer 7)

CDM Smith

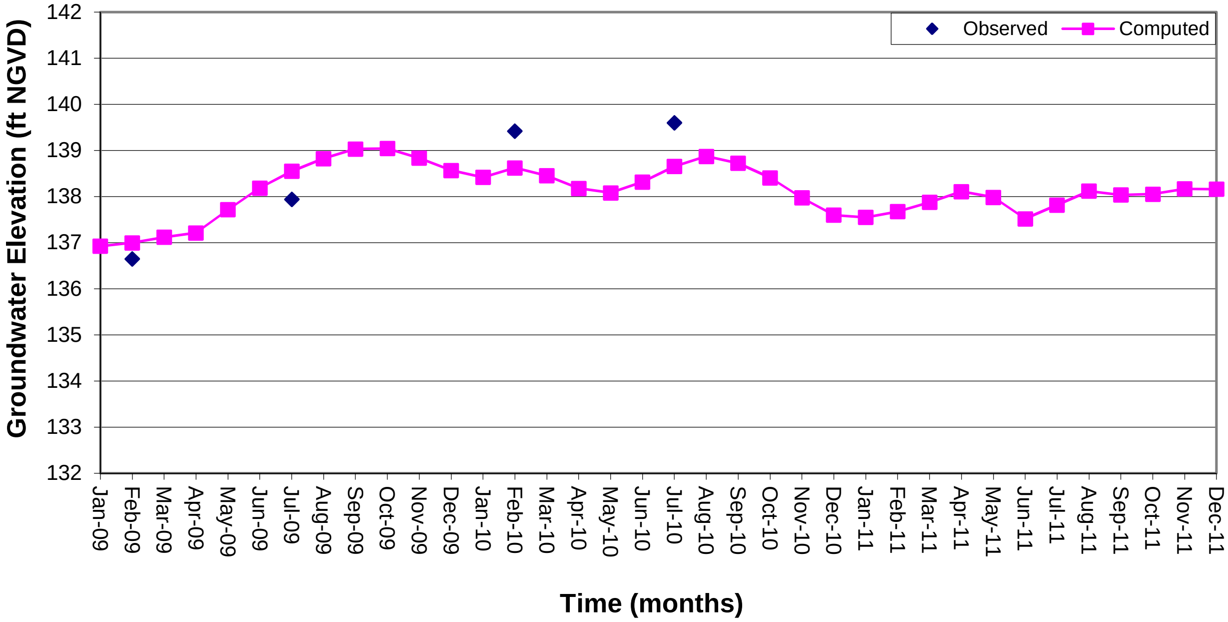


Figure 65
Comparison of Measured versus Simulated Groundwater Levels at B-31(D) (Layer 7)

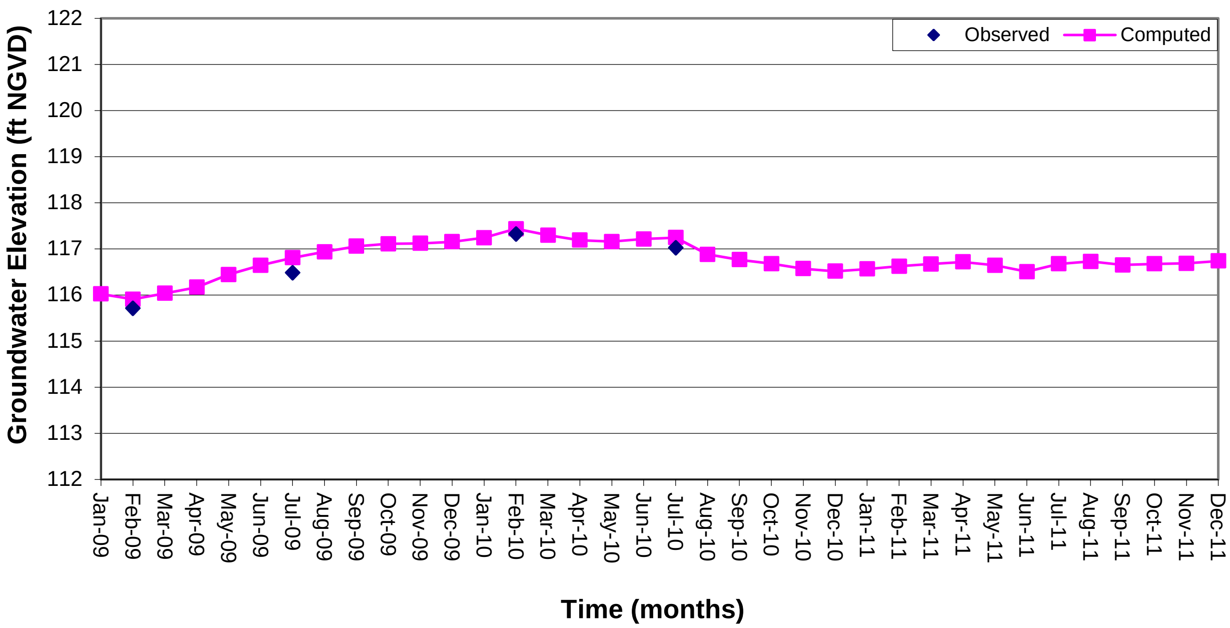


Figure 66
Comparison of Measured versus Simulated Groundwater Levels at B-32(S) (Layer 1)

CDM Smith

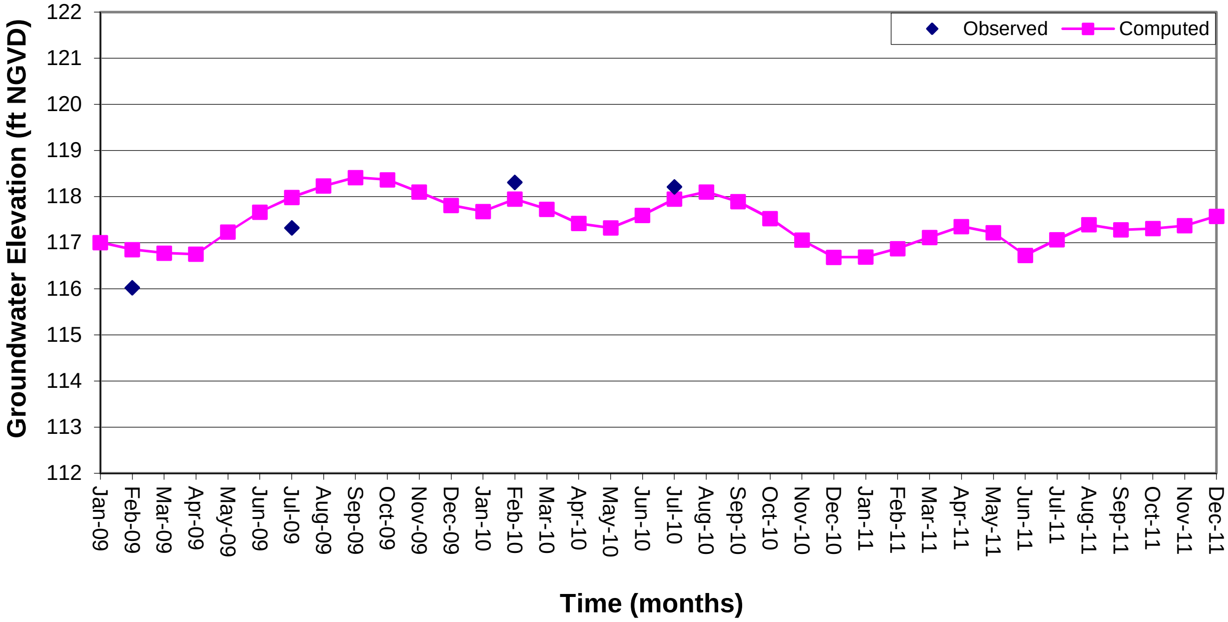


Figure 67
Comparison of Measured versus Simulated Groundwater Levels at B-32(I) (Layer 4)

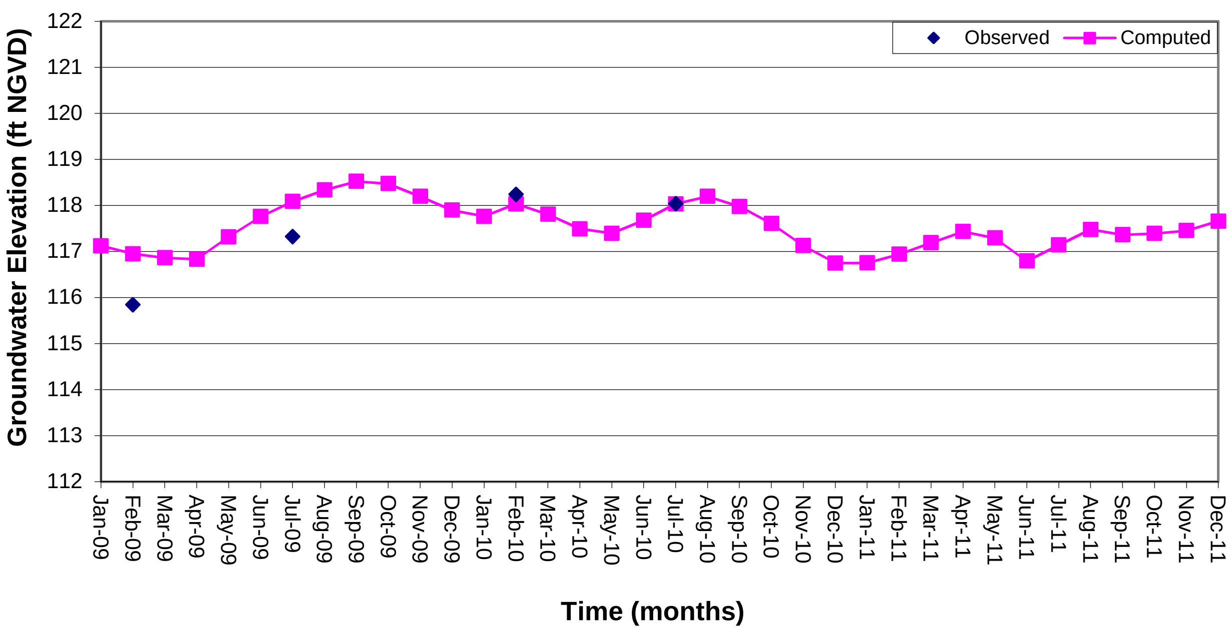


Figure 68
Comparison of Measured versus Simulated Groundwater Levels at B-32(D) (Layer 7)

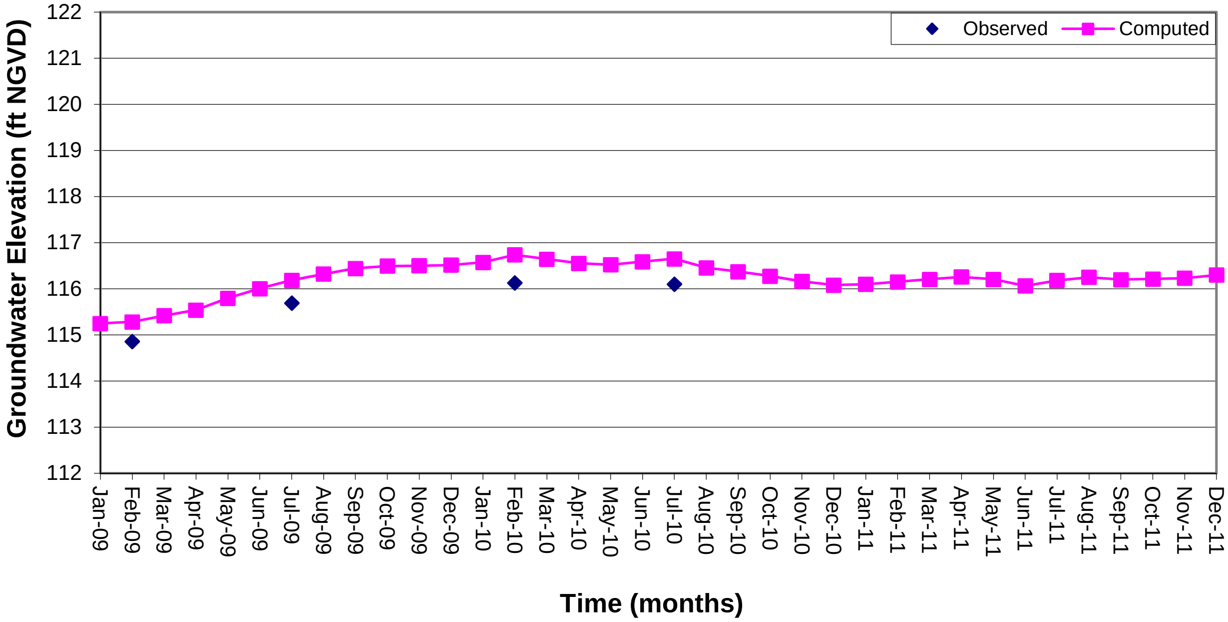


Figure 69
Comparison of Measured versus Simulated Groundwater Levels at B-33(S) (Layer 1)

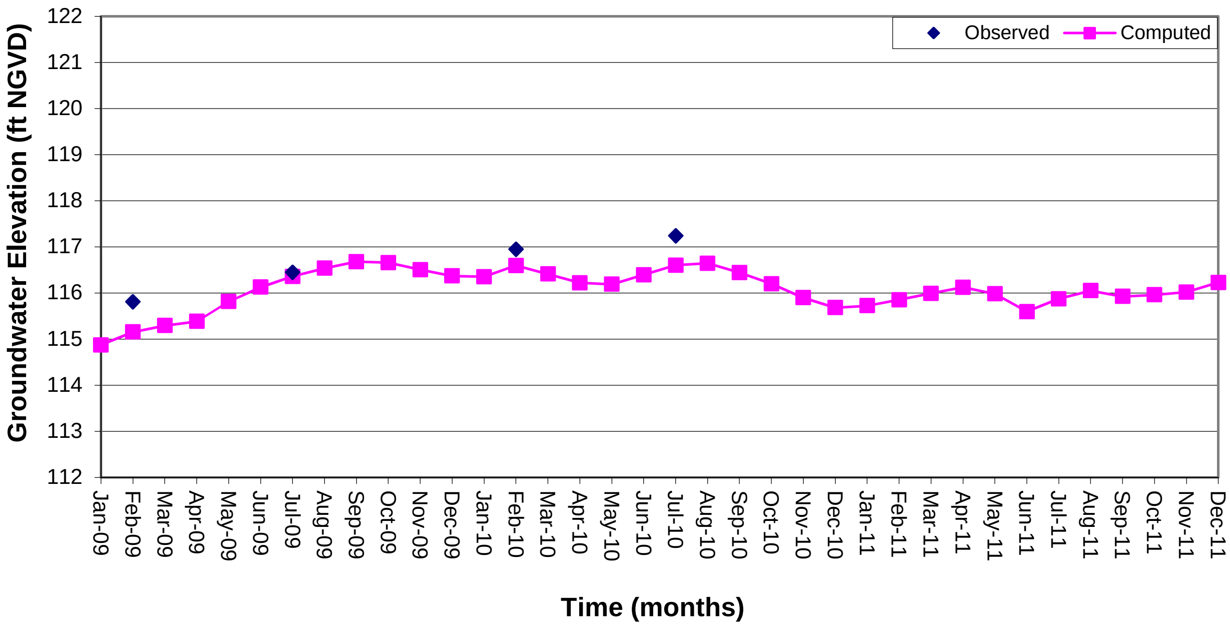


Figure 70
Comparison of Measured versus Simulated Groundwater Levels at B-34(S) (Layer 1)

CDM Smith

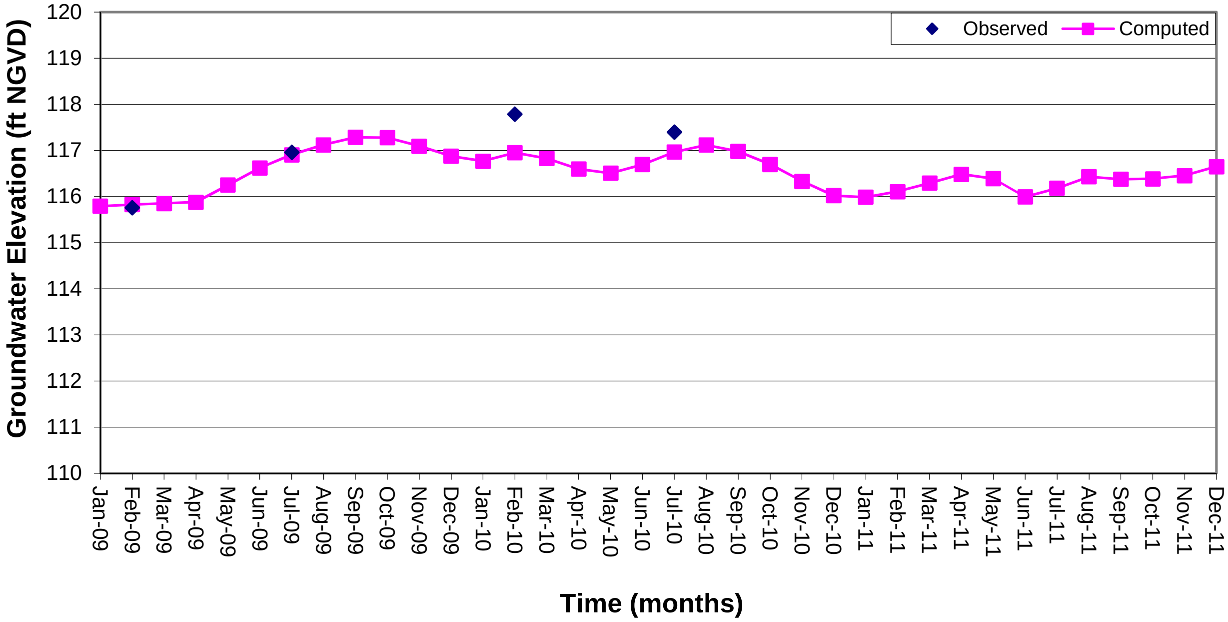


Figure 71
Comparison of Measured versus Simulated Groundwater Levels at B-34(I) (Layer 4)

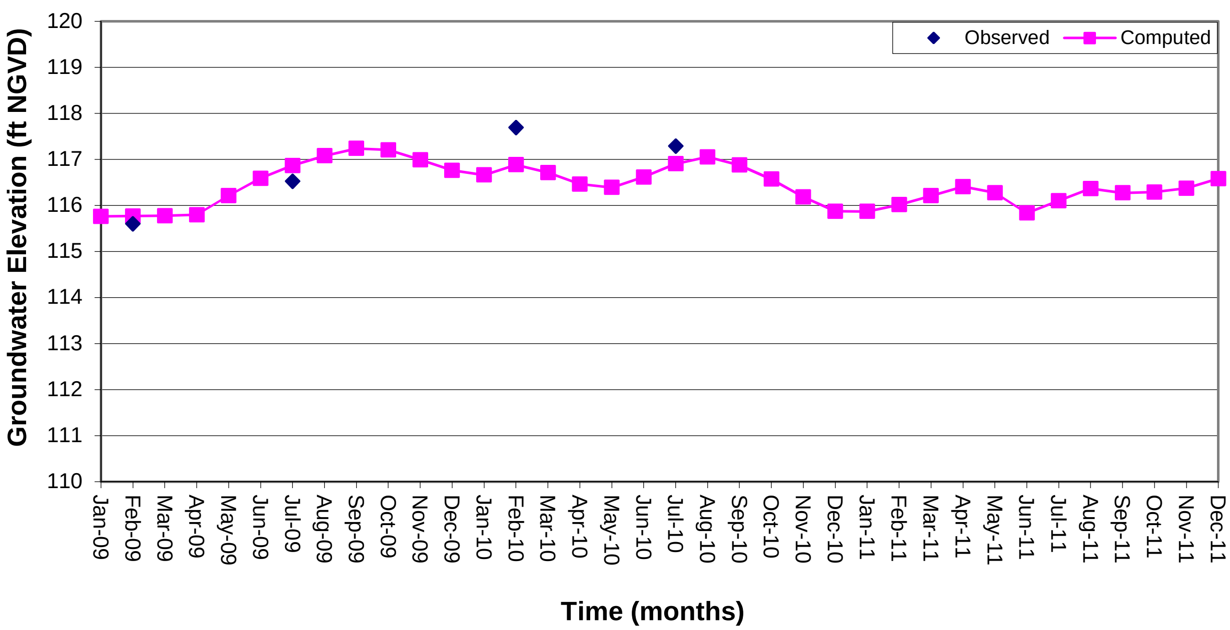


Figure 72
Comparison of Measured versus Simulated Groundwater Levels at B-34(D) (Layer 7)

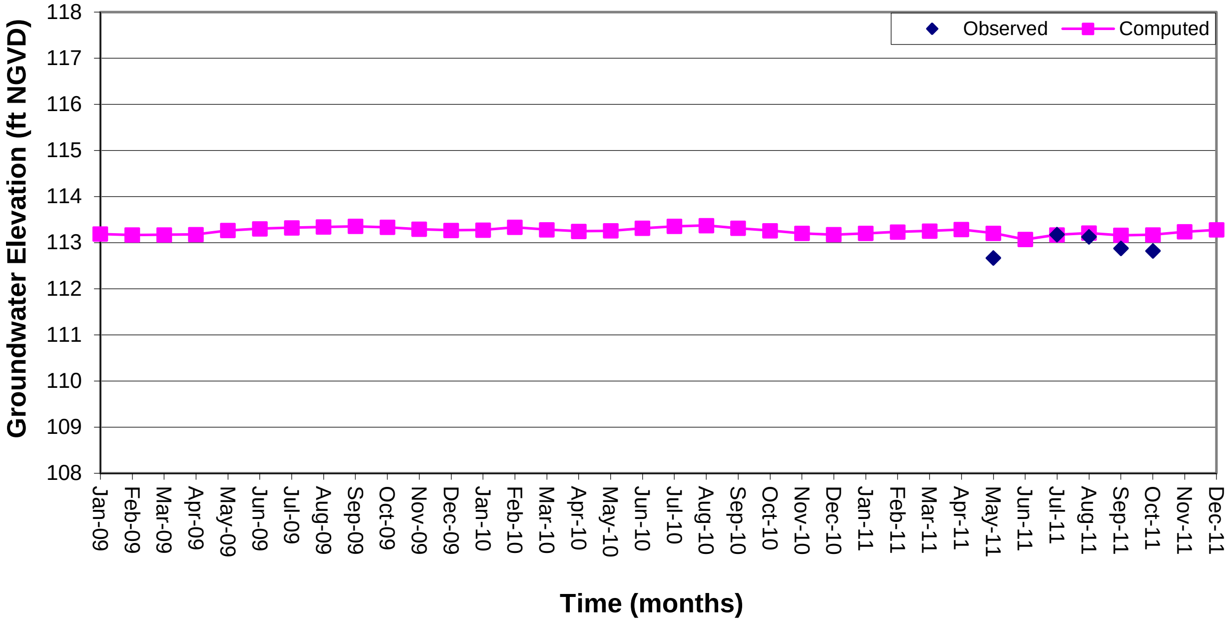


Figure 73
Comparison of Measured versus Simulated Groundwater Levels at PZ-2 (Layer 1)

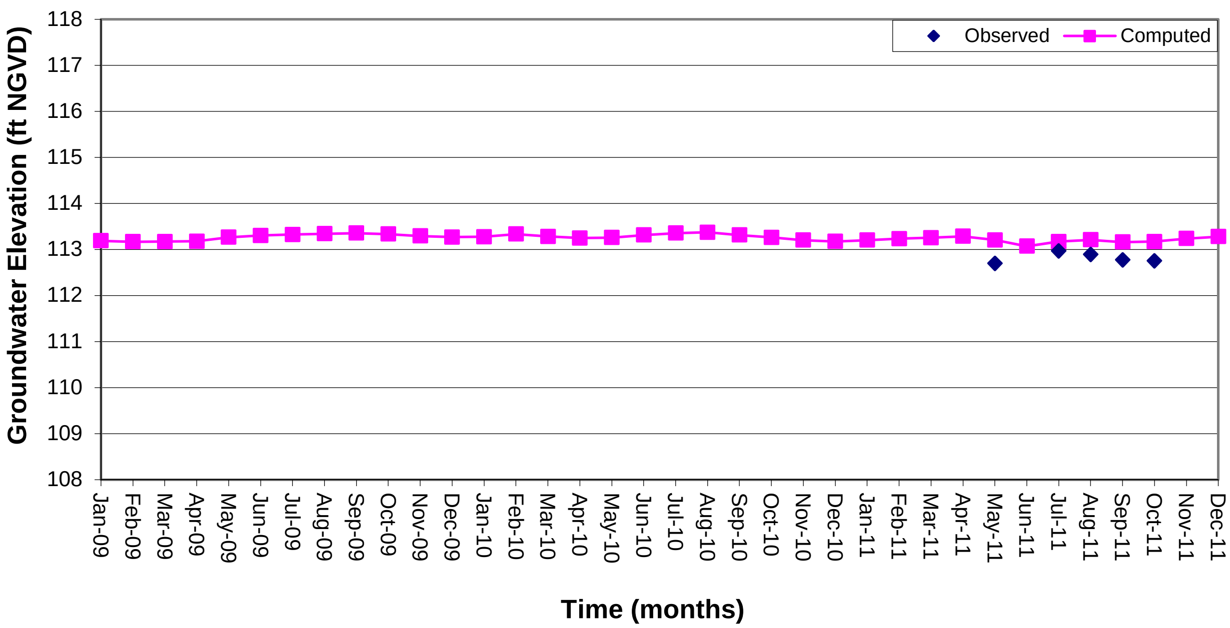


Figure 74
Comparison of Measured versus Simulated Groundwater Levels at PZ-3 (Layer 1)

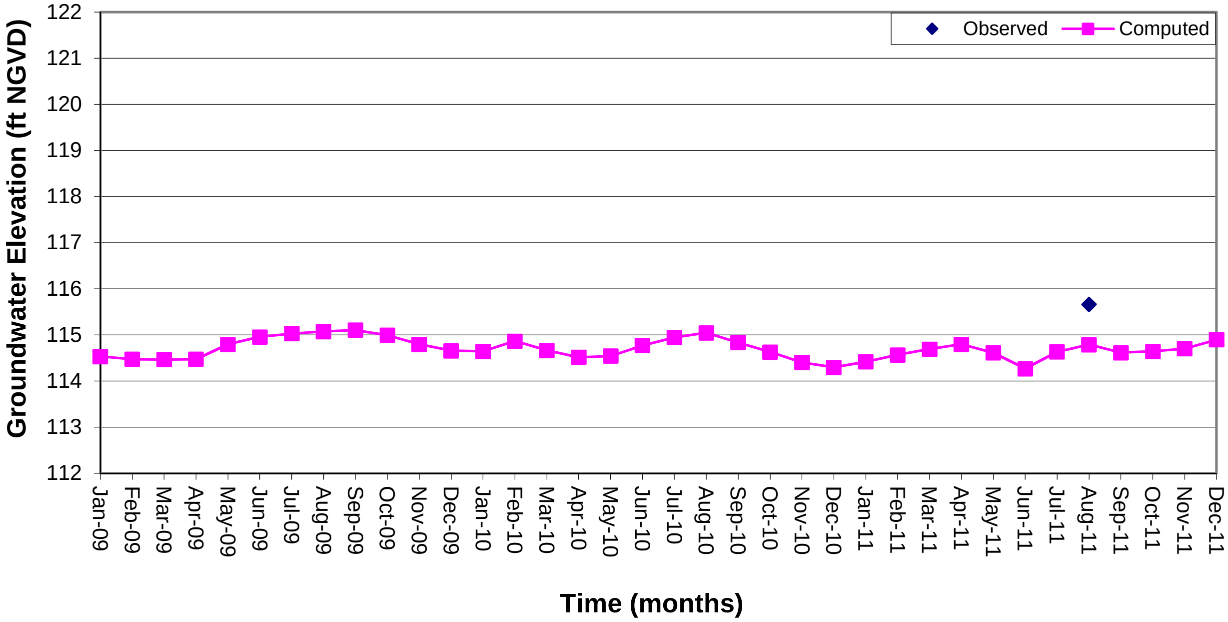


Figure 75
Comparison of Measured versus Simulated Groundwater Levels at PZ-4 (Layer 1)

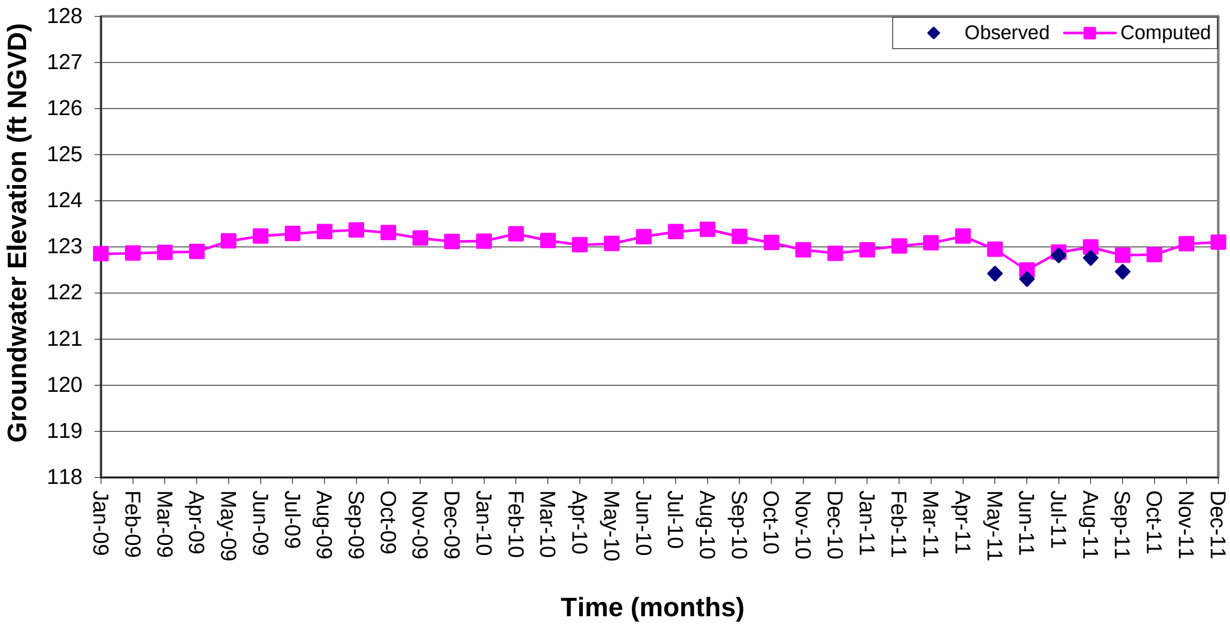


Figure 76
Comparison of Measured versus Simulated Groundwater Levels at PZ-5 (Layer 1)

CDM Smith

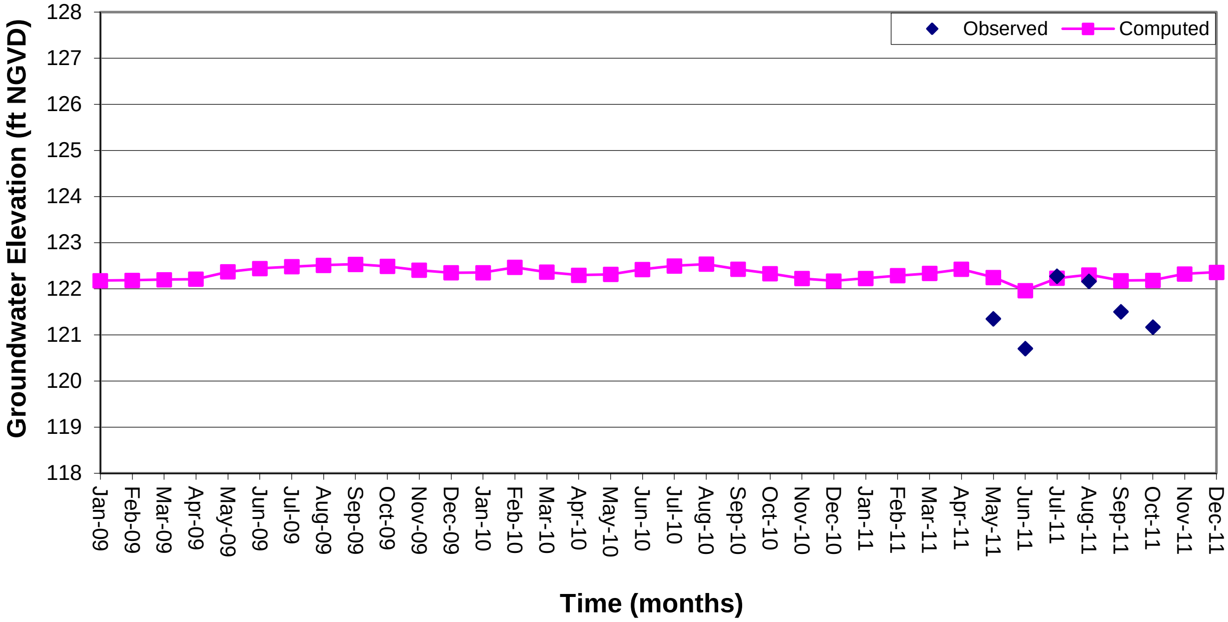


Figure 77
Comparison of Measured versus Simulated Groundwater Levels at PZ-6 (Layer 1)

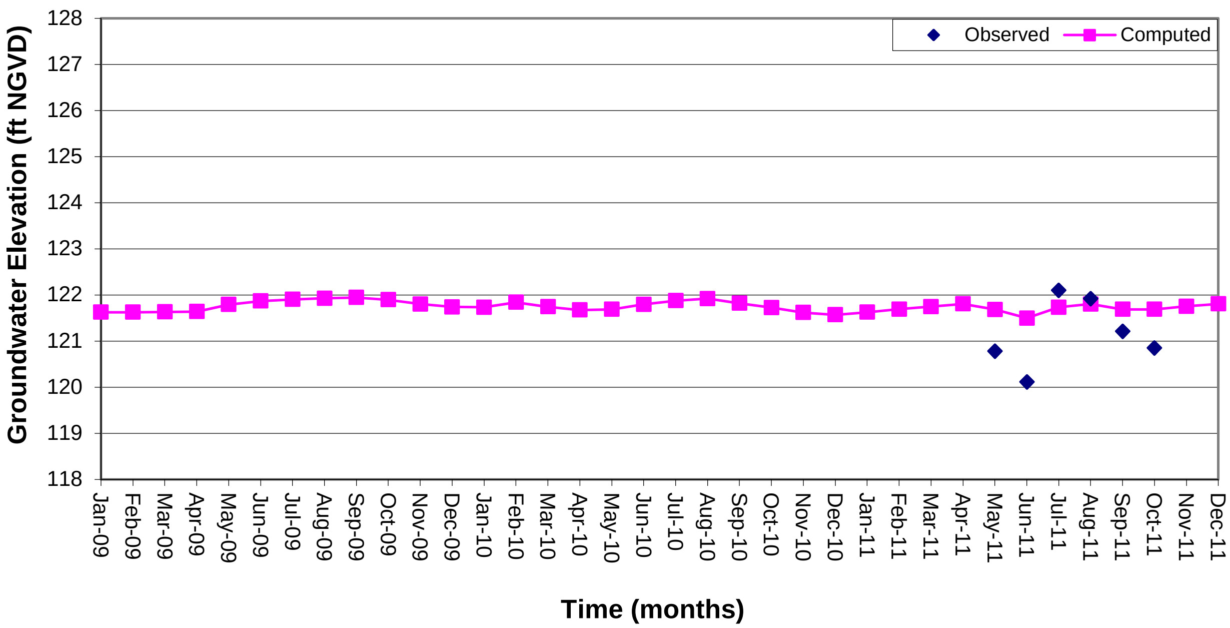


Figure 78
Comparison of Measured versus Simulated Groundwater Levels at PZ-7 (Layer 1)

CDM Smith

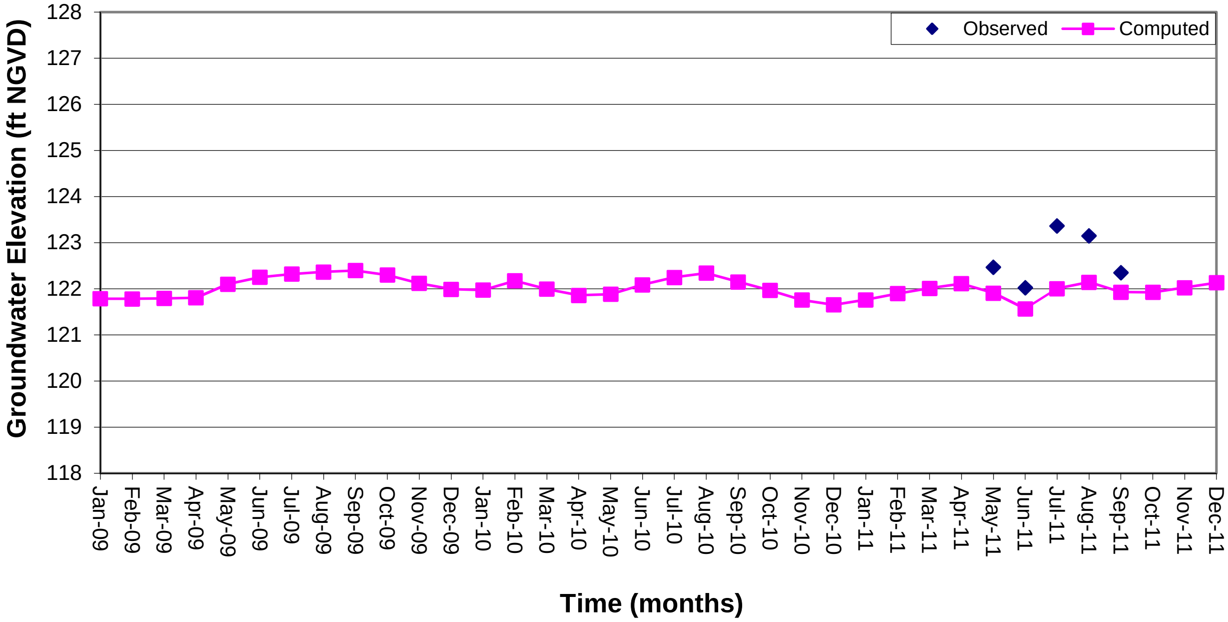


Figure 79
Comparison of Measured versus Simulated Groundwater Levels at PZ-8 (Layer 1)

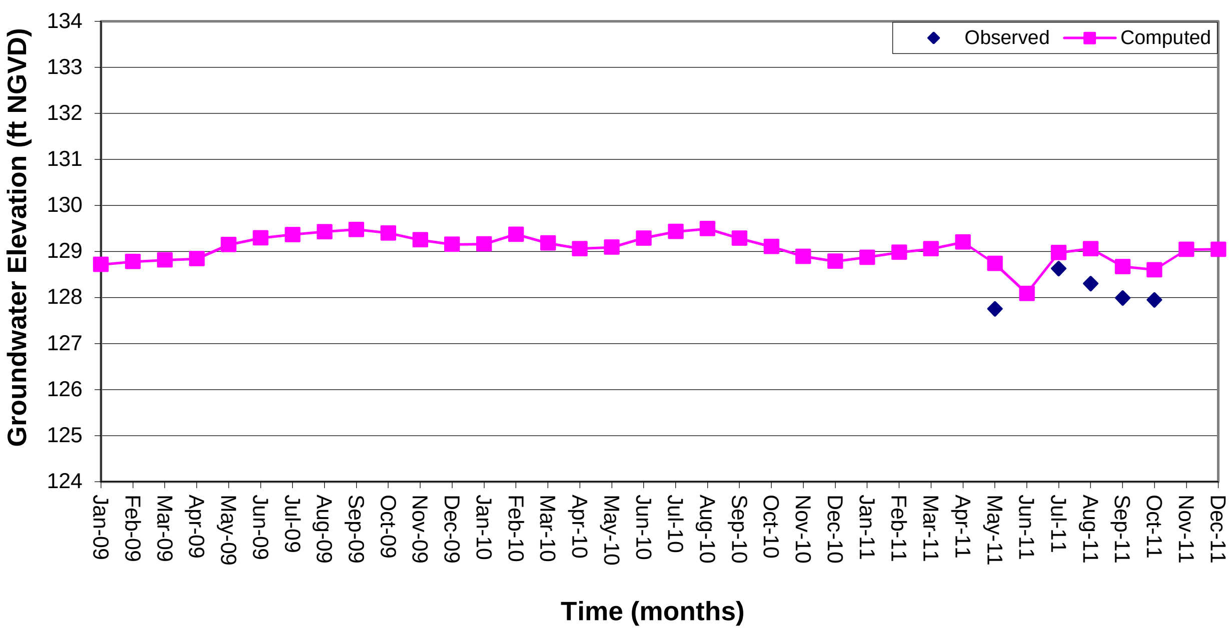


Figure 80
Comparison of Measured versus Simulated Groundwater Levels at PZ-9(Layer 1)

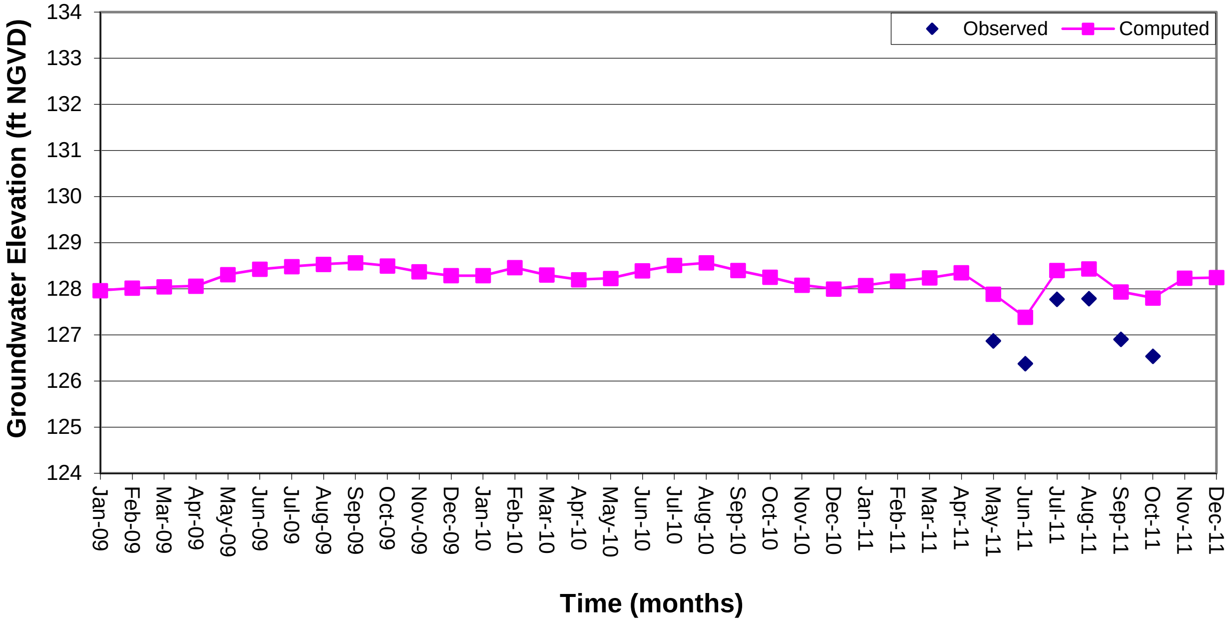


Figure 81
Comparison of Measured versus Simulated Groundwater Levels at PZ-10 (Layer 1)

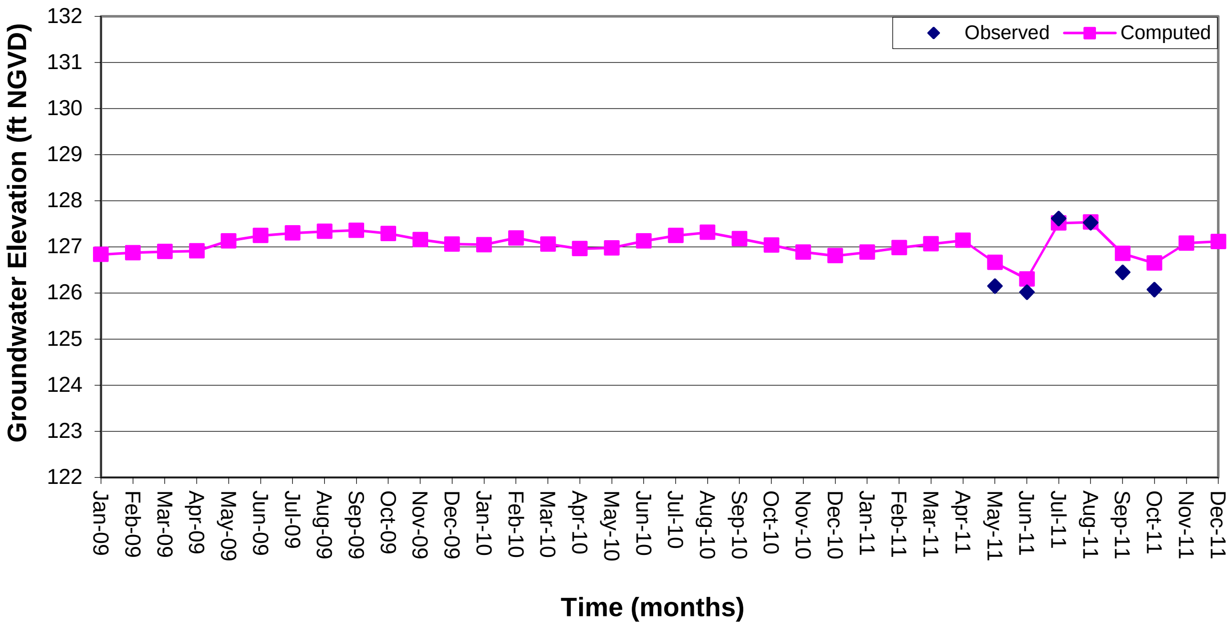


Figure 82
Comparison of Measured versus Simulated Groundwater Levels at PZ-11 (Layer 1)

CDM Smith

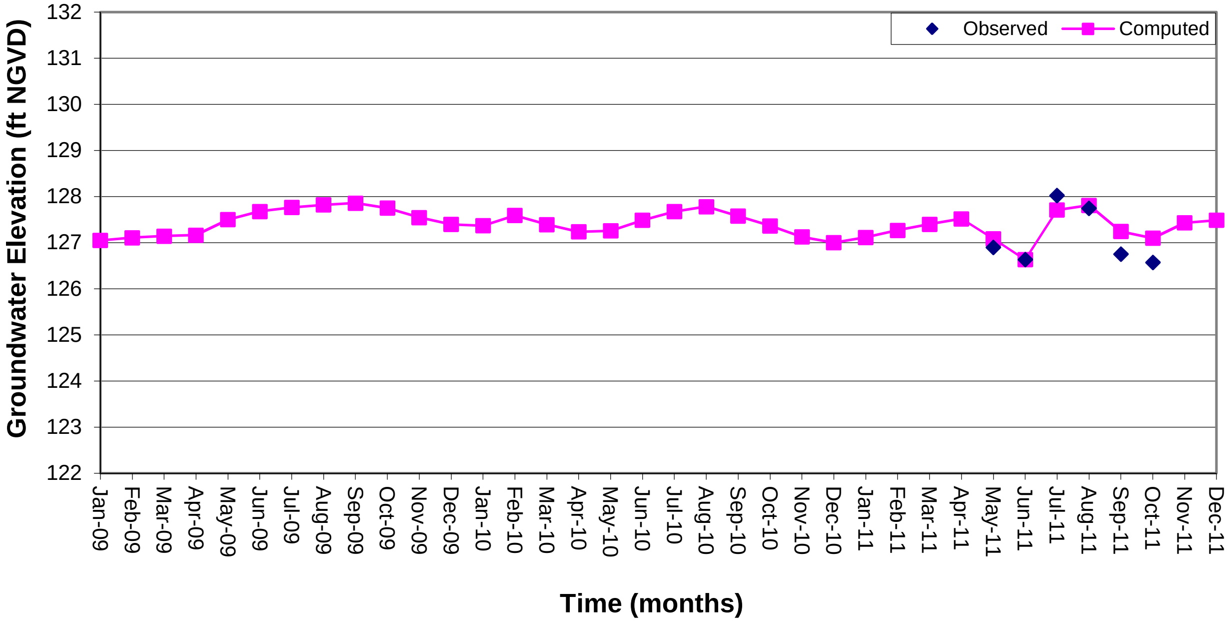


Figure 83
Comparison of Measured versus Simulated Groundwater Levels at PZ-12 (Layer 1)

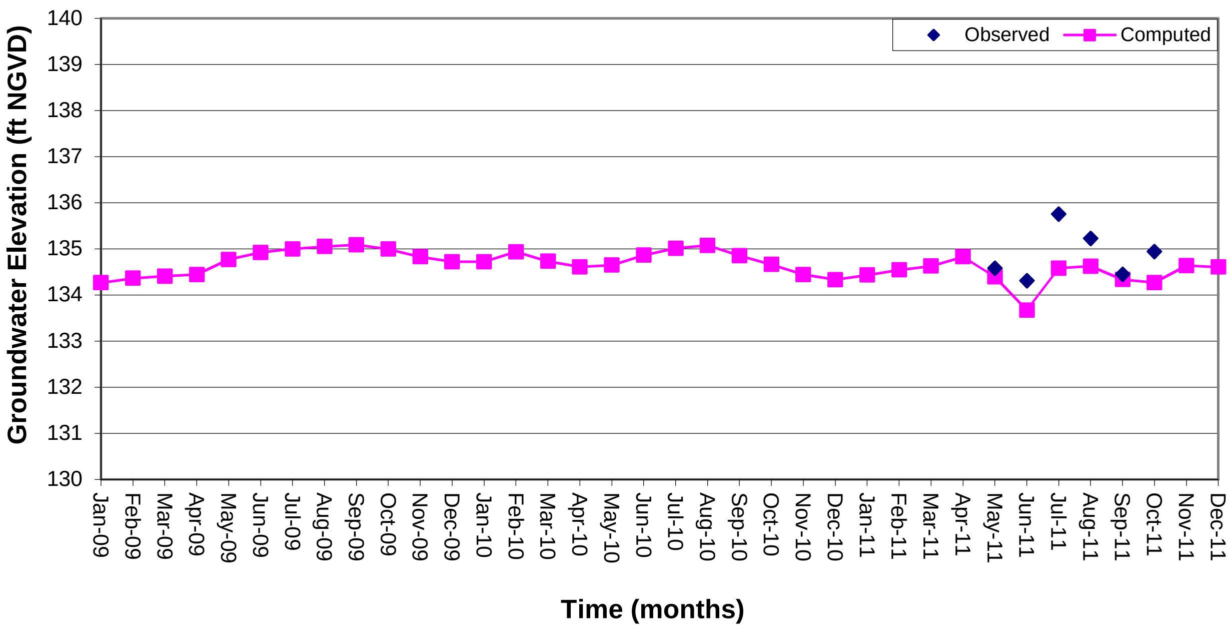


Figure 84
Comparison of Measured versus Simulated Groundwater Levels at PZ-13 (Layer 1)

CDM Smith

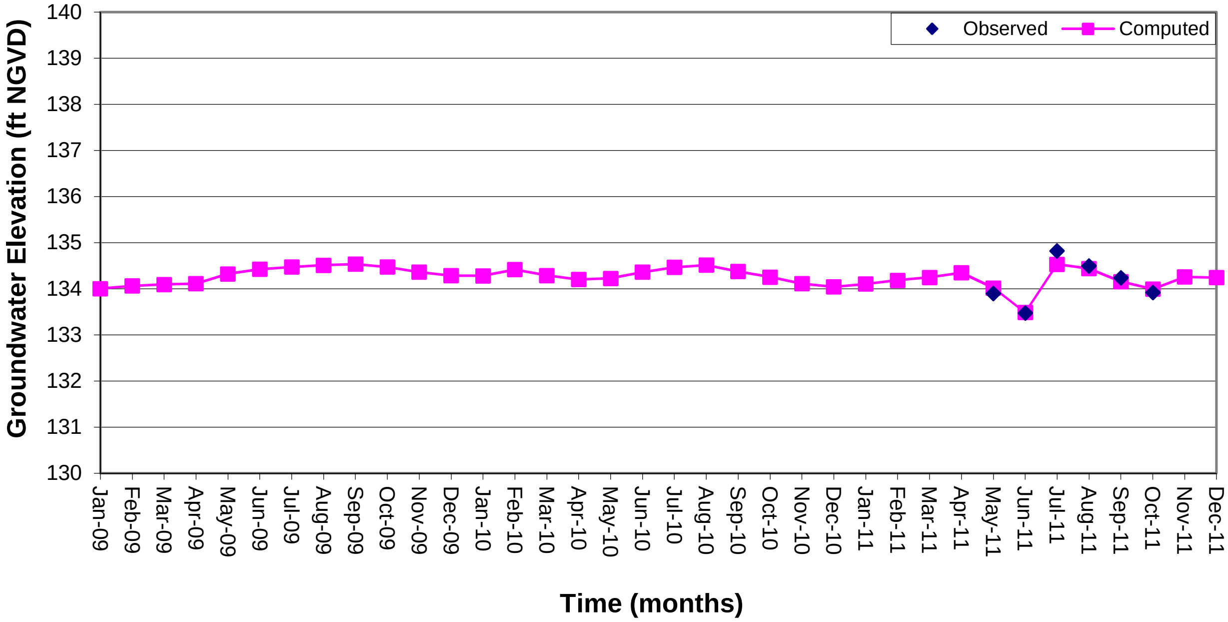


Figure 85
Comparison of Measured versus Simulated Groundwater Levels at PZ-14 (Layer 1)

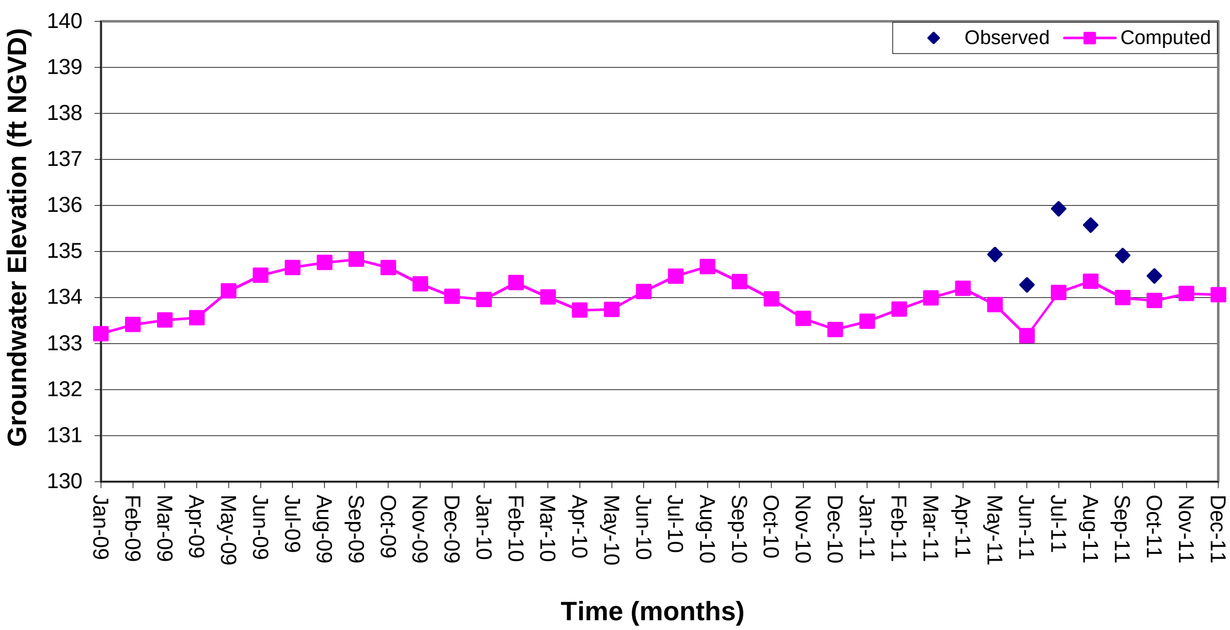


Figure 86
Comparison of Measured versus Simulated Groundwater Levels at PZ-15 (Layer 1)

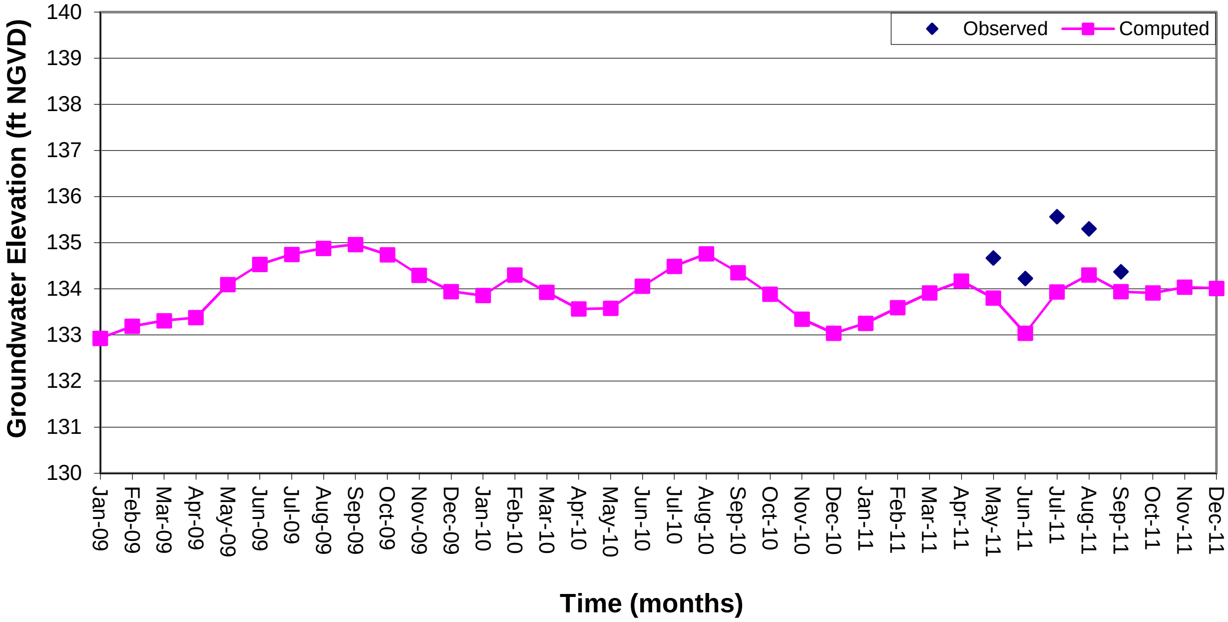


Figure 87
Comparison of Measured versus Simulated Groundwater Levels at PZ-16 (Layer 1)

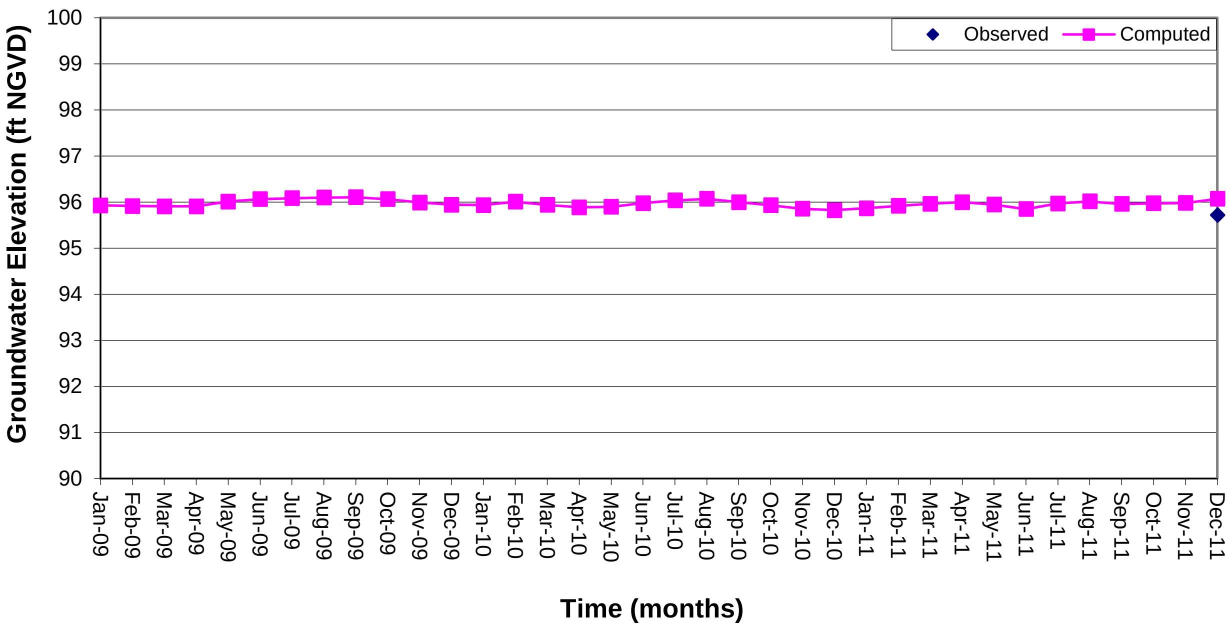


Figure 88
Comparison of Measured versus Simulated Groundwater Levels at CDM-102S (Layer 1)

CDM Smith

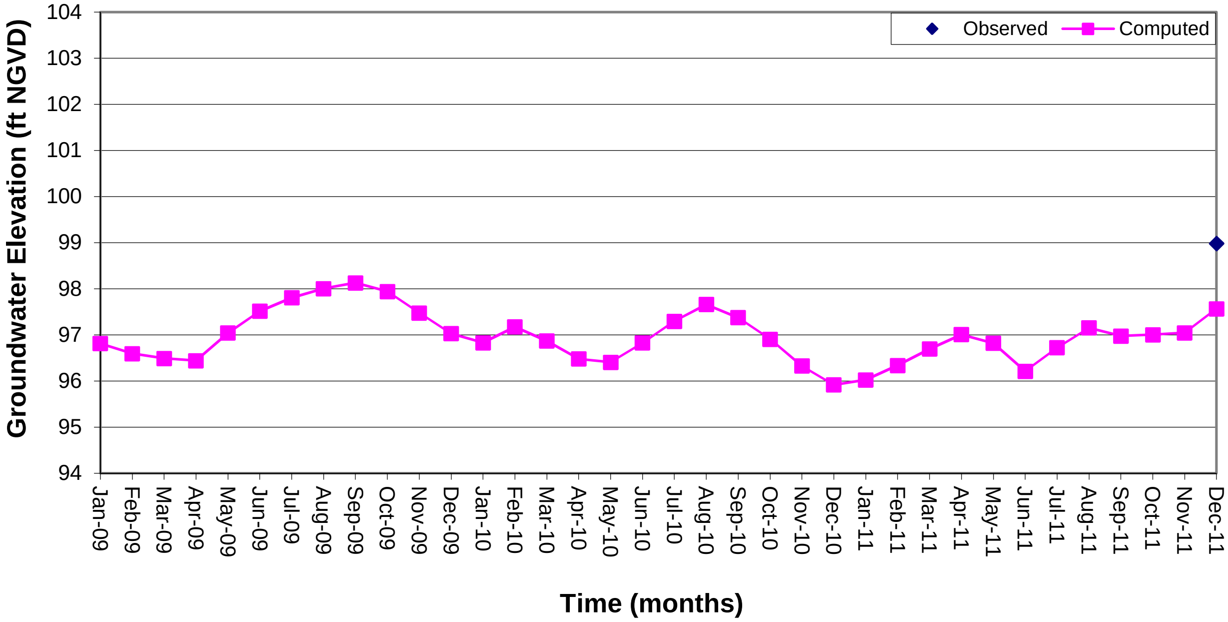


Figure 89
Comparison of Measured versus Simulated Groundwater Levels at CDM-102I (Layer 5)

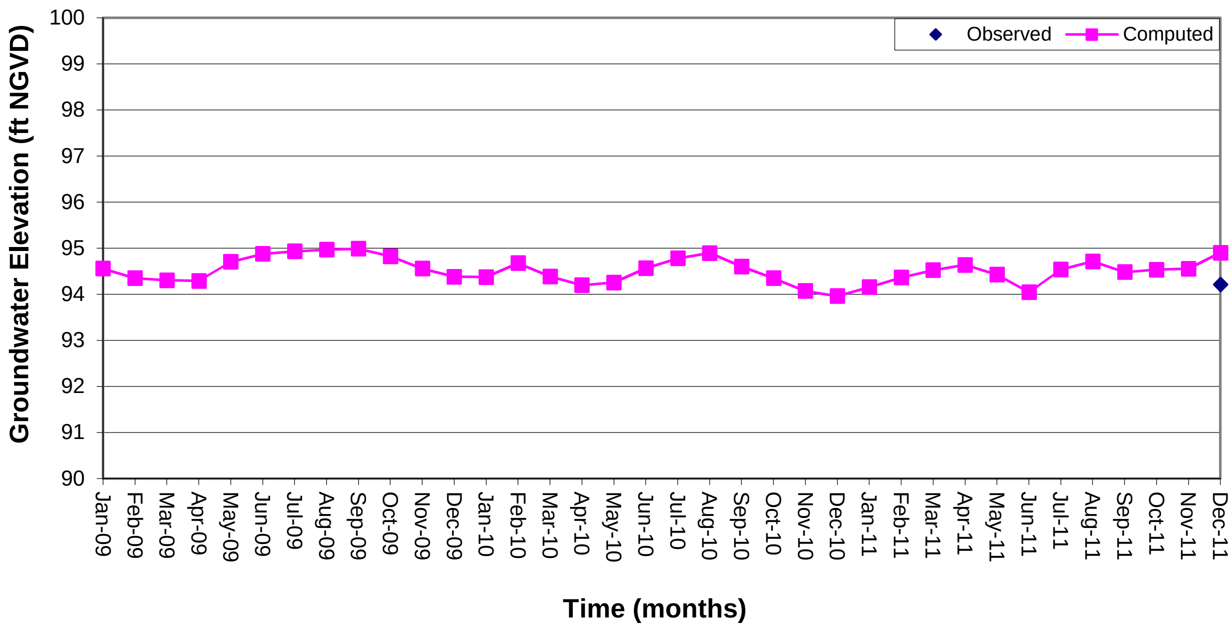


Figure 90
Comparison of Measured versus Simulated Groundwater Levels at CDM-104S (Layer 1)

CDM Smith

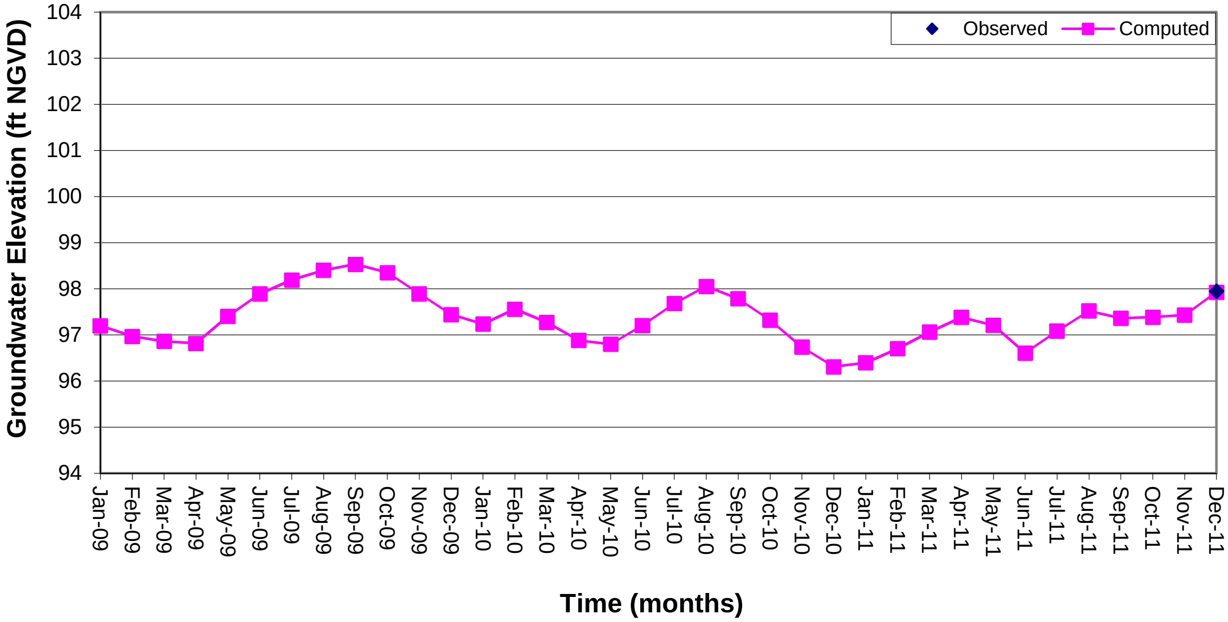


Figure 91
Comparison of Measured versus Simulated Groundwater Levels at CDM-104I (Layer 5)

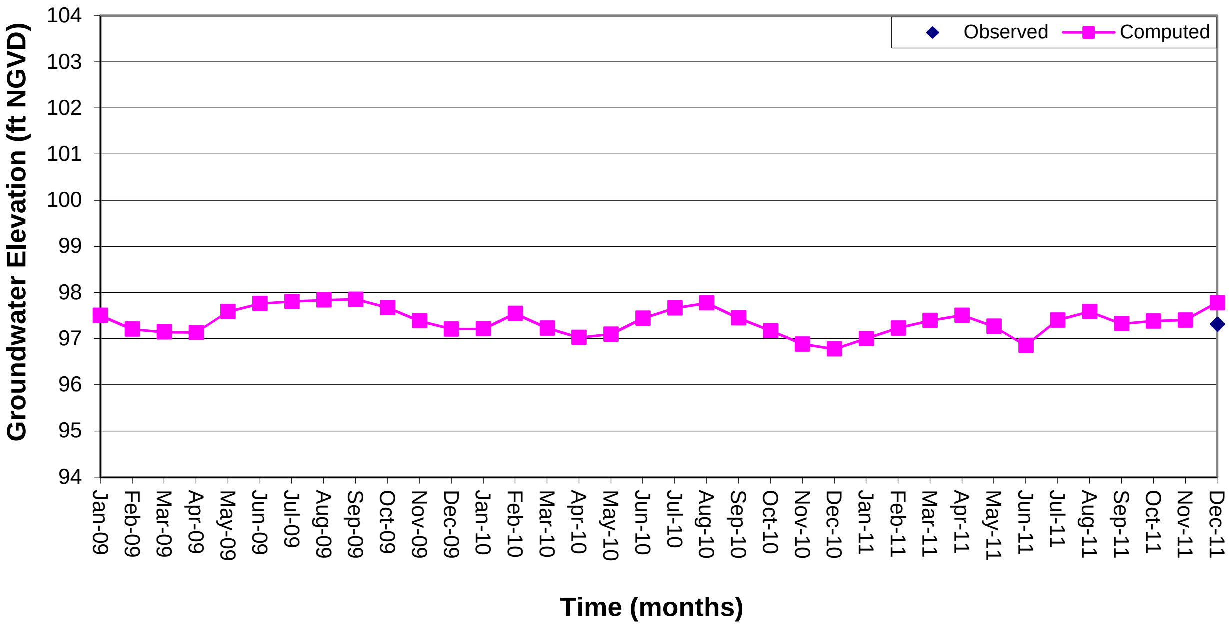


Figure 92
Comparison of Measured versus Simulated Groundwater Levels at CDM-106S (Layer 1)

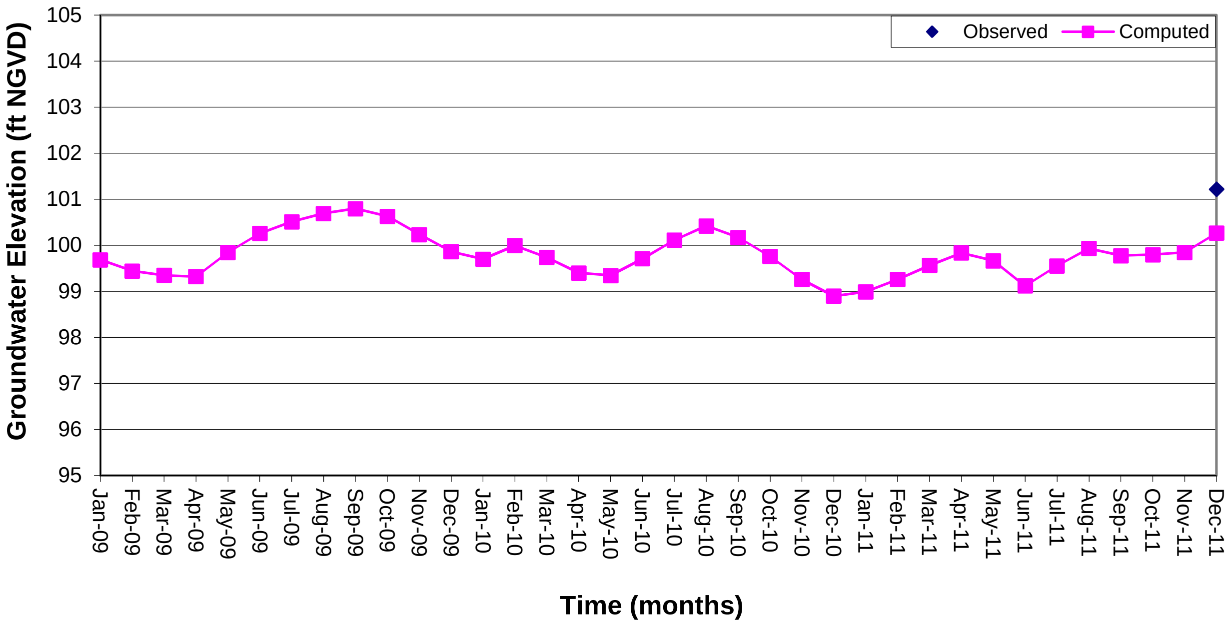


Figure x-93
Comparison of Measured versus Simulated Groundwater Levels at CDM-106I (Layer 5)

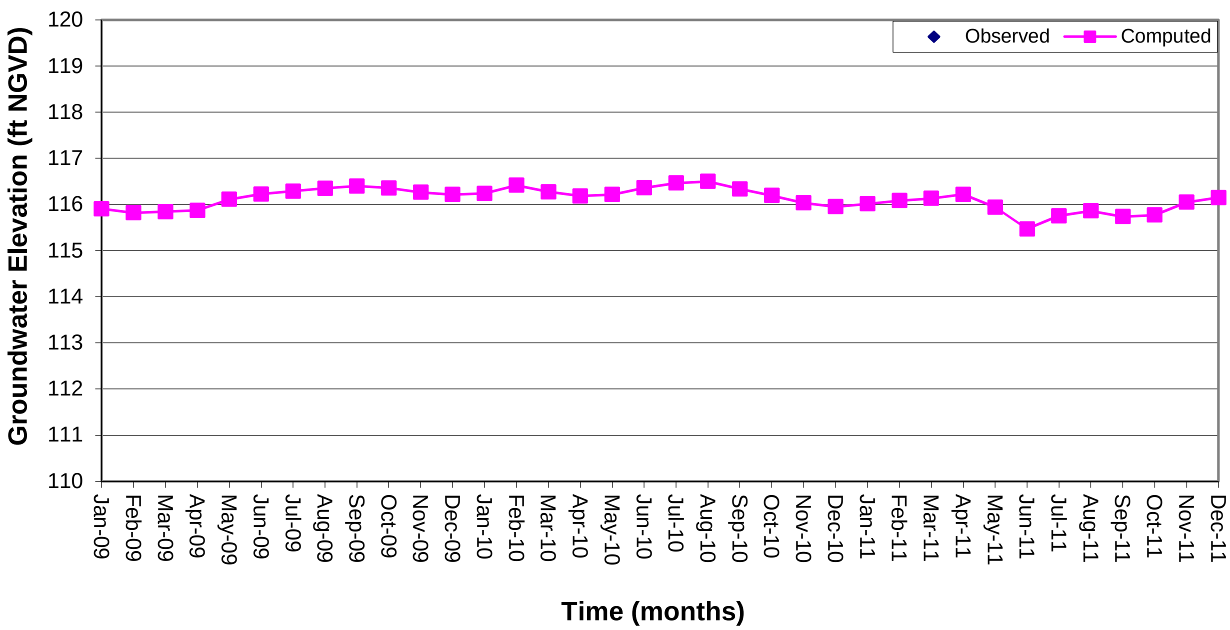


Figure 94
Comparison of Measured versus Simulated Groundwater Levels at PZ-1 (Layer 1)

CDM Smith