CCR ASSESSMENT OF CORRECTIVE MEASURES REPORT

Ash Storage/Disposal Area
Crystal River Energy Complex
15760 W. Power Line Street
Crystal River, Citrus County, Florida

Prepared for

Duke Energy Florida, LLC

Prepared by

Geosyntec Consultants, Inc.
12802 Tampa Oaks Blvd., Suite 151
Tampa, Florida 33637

Project FR3319

June 2019

Geosyntec consultants

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Digitally signed by Todd D. Anderson, PE
Date: 2019.06.19 12:31:31 -04'00'

Michael Lodato, P.G.	Todd Anderson, P.E. - Florida PE No. 51277
Principal	Senior Engineer

Project Number: FR3319/06

June 2019

CERTIFICATION STATEMENT

Need for Additional Time to Complete
Assessment of Corrective Measures 60-Day Extension

Pursuant to 40 C.F.R. § 257.96(a), the undersigned, being a qualified professional engineer, as that term is defined under 40 C.F.R. § 257.53, hereby certifies that a 60-day extension is required to complete the Assessment of Corrective Measures for the Ash Storage/Disposal Area at the Crystal River Energy Complex in Crystal River, Florida due to site-specific circumstances. Additional wells were installed to better define the nature and extent characterization currently being conducted in accordance with 40 C.F.R. § 257.95(g)(1) to evaluate relevant site conditions that may affect the remedy ultimately selected. Additional time is required to examine sample results from the expanded monitoring well network.

TODD D. ANDERSON
LICENSE
No. 51277
STATE OF
FLORIDA
PROFESSIONAL ENGINEER

Digitally signed by Todd D. Anderson, PE
Date: 2019.04.09 15:52:09 -04'00'

[P.E. Signature]

09 April 2019
[Date]

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ACRONYMS AND ABBREVIATIONS

ACM	Assessment of Corrective Measures
AS/DA	Ash Storage/Disposal Area
ASD	Alternate Source Determination
BLS	Below Land Surface
CCCP	Citrus Combined Cycle Plant
CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
cm/s	Centimeters per Second
COI	Constituent of Interest
CSM	Conceptual Site Model
Duke Energy	Duke Energy Florida, LLC
ft	Feet
GCL	Geosynthetic Clay Liner
GWPS	Groundwater Protection Standard
MNA	Monitored Natural Attenuation
NAVD88	North American Vertical Datum, 1988
NPDES	National Pollutant Discharge Elimination System
PRB	Permeable Reactive Barrier
RCRA	Resource Conservation and Recovery Act
SAS	Surficial Aquifer System
SSL	Statistically Significant Level
UFA	Upper Floridan Aquifer
USD	Undifferentiated Surficial Deposits
USEPA	United States Environmental Protection Agency

1. REQUIREMENTS

This report was prepared to meet the requirements found in the United States Environmental Protection Agency (USEPA) Coal Combustion Residuals (CCR) Rule, 40 Code of Federal Regulations (CFR) § 257.96. This section of the rule requires an Assessment of Corrective Measures (ACM) when any constituents listed in Appendix IV of the rule have been detected at a statistically significant level (SSL) exceeding groundwater protection standards (GWPS), and the owner or operator has been unable to demonstrate that the exceedance was caused by a source other than the CCR unit. One or more Appendix IV parameters were detected above an SSL exceeding a GWPS at the Duke Energy Florida, LLC (Duke Energy) Crystal River Energy Complex (CREC, or the Site) Ash Storage/Disposal Area (AS/DA), located in Citrus County, Florida (**Figure 1**). This report provides details regarding any GWPS exceedances for this Site and documents the fulfillment of the requirement to conduct an ACM.

1.1 Requirements for ACM Preparation in 40 CFR 257.96(a)

The CCR Rule in 40 CFR § 257.96(a) requires that an owner or operator initiate an assessment of corrective measures to prevent further release, to remediate any releases, and to restore affected areas to original conditions if any Appendix IV constituent has been detected at an SSL exceeding a GWPS. The assessment of corrective measures must be completed within 90 days after initiating the ACM. The CCR Rule allows up to an additional 60 days to complete the ACM if a demonstration is made that more time is needed due to site-specific conditions or circumstances. A certification from a qualified professional engineer attesting that the demonstration is accurate is required. The owner or operator must include the certified demonstration in the annual groundwater monitoring and corrective action report required by § 257.90(e). For informational purposes the 60 day extension is included in this report immediately behind the cover page.

1.2 Requirements for ACM Content in 40 CFR 257.96(c)

The CCR Rule in 40 CFR § 257.96(c) states the following:

> *The assessment under paragraph (a) of this section must include an analysis of the effectiveness of potential corrective measures in meeting all of the requirements and objectives of the remedy as described under § 257.97 addressing at least the following:*
>
> > *(1) The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to any residual contamination;*
> >
> > *(2) The time required to begin and complete the remedy;*
> >
> > *(3) The institutional requirements, such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).*

These requirements form the basis for the evaluation of potential corrective measure remedial technologies outlined in this report. Potential remedial technologies are listed in **Section 4.3** and described in **Appendix A**. Potential technologies are evaluated against these requirements in **Appendix B**, as described in **Section 4.4** and summarized in **Table 1**. Therefore, this document supports compliance with § 257.96(c) of the CCR Rule.

1.3 Requirements for Remedy Selection in 40 CFR § 257.97

Following preparation of this ACM Report and the public meeting required in § 257.96(e), the process of remedy selection will begin to select a remedy or remedies that meet(s) the requirements of § 257.97(b) of the CCR Rule, consider(s) the standards in § 257.97(c), and address(es) the schedule and other factors specified in § 257.97(d). Once a remedy is selected, a final remedy selection report must be prepared to document details of the selected remedy and how the selected remedy meets § 257.97 requirements. **Appendix C** outlines the selection of remedy requirements found in § 257.97. In the event a final remedy is not able to be selected without further study or consideration, § 257.97 requires a semi-annual report be prepared to document progress toward remedy selection and design.

2. SITE BACKGROUND AND CHARACTERISTICS

On April 17, 2015, the USEPA published 40 CFR Parts 257 and 261: Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule (USEPA, 2015). This regulation addresses the safe disposal of CCR as solid waste under Subtitle D of the Resource Conservation and Recovery Act (RCRA) and is referred to herein as the CCR Rule. The CCR Rule, which became effective on October 19, 2015, provides national minimum criteria for "the safe disposal of CCR in new and existing CCR landfills, surface impoundments, and lateral expansions, design and operating criteria, groundwater monitoring and corrective action, closure requirements and post closure care, and recordkeeping, notification, and internet posting requirements." As part of the CCR Rule, groundwater monitoring is required for new and existing CCR landfills, CCR surface impoundments, and lateral expansions of CCR units.

The CCR Rule applies to the AS/DA at the CREC. This report assesses potential corrective measures to remediate groundwater downgradient of the CREC AS/DA.

2.1 Site Description

Duke Energy owns and operates the CREC, which is located in Crystal River, Citrus County, Florida (**Figure 1**). CREC is an electrical power generation facility located on a 4,730-acre parcel in west central Florida. The CREC is located at 15760 West Power Line Street on the Gulf of Mexico in Crystal River, Citrus County, Florida. The property is in Sections 28 through 36, Township 18, Range 16 with the center of the facility at approximately 28˚28'2" north latitude and 82˚41'49" west longitude. Approximately 1,462 acres of the CREC have been developed, with the remaining property consisting of salt marsh and coastal lowland areas.

The CREC consists of four coal-fired steam units (Units 1, 2, 4, and 5) and a nuclear facility (Unit 3) that was retired in 2013. Plant operations began at the Site in 1966 (Unit 1), and additional units were added in 1969 (Unit 2), 1977 (Unit 3), 1982 (Unit 4), and 1984 (Unit 5). In the early 1970s Units 1 and 2 converted from coal burning operations to oil-fired operations and reverted to coal burning operations in 1976 and 1979, respectively. Throughout its operational history, ash generated from coal combustion has been typically been sent directly off-Site for beneficial use, stored on-Site awaiting beneficial use, or disposed on-Site in the permitted AS/DA. The AS/DA is approximately 100 acres, although approximately 62 acres are used and maintained for the storage of CCR material. About 5.5 acres are lined with a geosynthetic clay liner (GCL). CCR from coal-fired operations at the CREC has been stored in the AS/DA area since 1982.

2.2 CCR Unit Description – AS/DA

The AS/DA is shown on **Figures 1** and **2**. It is bounded to the east, south, and north by unlined stormwater ditches and to the southwest by an unlined stormwater pond connected to the stormwater ditches. Stormwater runoff management for the AS/DA consists of procedures for sloping the ash as material is transferred and compacted, and the use of a storm water retention and conveyance system (AS/DA runoff system) to manage stormwater runoff from the AS/DA. The collection system was designed and constructed to retain the area runoff from a 10-year, 24-hour rainfall event (approximately 8.34 inches) with disposal by means of evaporation and percolation (KBN, 1987). Runoff is designed to overflow as an internal outfall to the Units 4 and

5 stormwater collection system via an overflow structure and weir (Outfall I-C40 northeast of Units 4 and 5 on **Figure 2**) as outlined in the National Pollutant Discharge Elimination System (NPDES) Permit FL0036366.

Surface water monitoring is conducted per discharge event at the AS/DA overflow weir (I-C40) during discharge into the runoff collection system. Samples are analyzed for total recoverable metals including arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, vanadium, and zinc (NPDES Permit FL0036366, Condition I.A.12).

The approximate size of the AS/DA is 62 acres with a total estimated ash inventory of 4,300,000 tons. Currently, the ash landfill's north and east slopes are closed with a GCL. The remaining slopes of the ash landfill are generally covered with vegetation with the center of the ash landfill available for additional ash disposal. The ash landfill has a permitted stack height of 120 feet with a base elevation of approximately 10 feet North American Vertical Datum of 1988 (NAVD88). The waste boundary for the AS/DA is defined as the perimeter of the permitted waste disposal area and is shown on **Figure 1**.

2.3 Conceptual Site Model

The Conceptual Site Model (CSM) is a written and illustrative representation of the hydrogeologic conditions. The purpose of the CSM is to provide an understanding of the anticipated distribution of constituents with regard to the Site-specific geological/hydrogeological and geochemical processes controlling the transport and potential impacts of constituents in various media and potential exposure pathways to human and ecological receptors.

2.3.1 Hydrostratigraphic Units

The geologic and hydrogeologic units, in order of increasing depth below land surface, at the Site are summarized below.

- *Undifferentiated Surficial Deposits (USDs)* - The USDs are comprised of brown to grey silty sands to sandy clays with organic soils ranging in thickness from 0 to 20 feet (ft) below land surface (BLS) (AMEC, 2013 and Terracon, 2015). The thickness of the USDs is variable as a result of the irregular surface of the underlying limestone. Due to the limited extent of the USDs, the Surficial Aquifer System (SAS) is only locally present at the Site where saturated unconsolidated sediments are present.

- *Inglis Formation of the Ocala Group* - Encountered between land surface and 20 ft BLS, this white, fossiliferous, and friable limestone is the uppermost hydrogeologic unit of the Upper Floridan Aquifer (UFA). The Inglis Formation contains karst features such as solution channels and cavities of varying size. Permeable zones within the Inglis Formation are present at depths of less than 30 ft BLS and between 40 and 60 ft BLS (the base of the Inglis Formation).

- *Avon Park Formation* - Encountered between 45 and 70 ft BLS, the Avon Park Formation is comprised of an occasionally dolomitized limestone and well indurated limestone (AMEC, 2013 and Spencer, 1984). The Avon Park Formation is the formation utilized for water supply for CREC operations.

2.3.2 Hydrogeologic Setting

The UFA and the SAS (where present) are hydraulically connected and have similar flow patterns with groundwater predominantly flowing from northeast to southwest at the Site. Locally, flow directions may vary due to the complex subsurface character of the UFA caused by karst features, tidal fluctuations, Site production wells near Power Line Street and US-19, and surface water features.

Groundwater elevations were collected from the Site monitoring wells during low and high tides on 17 December 2015 (low tide) and 21 December 2015 (high tide) to estimate groundwater flow direction. Groundwater elevations and estimated flow directions from both events are presented on **Figures 3** and **4**. The groundwater flow direction during both tide events was estimated to be flowing generally from northeast to southwest across the Site. Flow directions may vary due to the complex subsurface character of the UFA and surface water features (e.g., intake and discharge canals, percolation ponds, production wells, and stormwater ditches).

Site lithologic logs have identified void spaces and solution cavities within the Inglis Formation. Water levels in monitoring wells with documented void spaces and solution cavities have a subdued response to external stresses such as rain events and tidal fluctuations indicating an increased permeability (ESE, 1981). A tidal study conducted by ESE in 1980 demonstrated that the response of groundwater level fluctuation was dependent upon the distance of the monitoring well from the discharge canals and the subsurface character of the Inglis Formation.

Historical evaluations have shown that the hydraulic conductivity at the CREC ranges from 2×10^{-3} to 6×10^{-2} centimeters per second (cm/s) near the AS/DA.

2.3.3 Potential Receptors

Groundwater at the CREC generally moves from northeast to southwest. The CREC is located on the Gulf of Mexico and therefore there are no downgradient residential properties or public water supply wells.

3. SITE GROUNDWATER MONITORING AND CHARACTERIZATION SUMMARY

Groundwater monitoring around the AS/DA has been implemented in accordance with the Federal CCR Rule. Monitoring results from both monitoring programs indicate groundwater quality has been affected by the release of CCR related constituents from the active AS/DA. Appendix IV constituents with groundwater concentrations exceeding GWPSs are primarily along the northern, southwestern, and southern edge of the AS/DA consistent with the direction of groundwater near the AS/DA.

3.1 Summary of Groundwater Monitoring

The CCR groundwater monitoring system at the AS/DA consists of 15 groundwater monitoring wells that were installed in December 2015 and February 2016. The CCR groundwater monitoring wells were designed and installed according to industry practice and in general accordance with USEPA 40 CFR §257.91(e). **Figure 2** displays the location of the CCR monitoring wells for the AS/DA and **Table 2** provide monitoring well construction details.

Groundwater sampling has been conducted in accordance with USEPA 40 CFR §257.3(a) with the appropriate sampling equipment and procedures for calibration, measurement of groundwater levels, well purging and sampling, sample preservation and handling, decontamination and field documentation, and sample labeling, packing, and delivery. The wells at the AS/DA were sampled using peristaltic pumps and disposable tubing to reduce the risk of cross-contamination from well to well. The tubing intake is generally set within the center of each well screen.

The detection monitoring program was initiated in 2016, as required by § 257.90(b)(1)(iii). Sampling was performed to establish background concentrations of constituents listed in 40 CFR §257, Appendices III and IV. Sampling for detection monitoring was initiated to meet the requirements of § 257.94. Nine groundwater sampling events were performed during detection monitoring activities for Appendix III and Appendix IV constituents between January 2016 and September 2017. Assessment monitoring was initiated in 2018 after statistically significant increases (SSIs) were detected for several Appendix III constituents in groundwater samples collected downgradient of the AS/DA. Sampling for assessment monitoring was initiated in 2018 to meet the requirements of § 257.95. An alternate source determination (ASD) (Geosyntec, 2019) for total radium was successfully completed in accordance with § 257.94(e)(2). Sampling for the assessment monitoring program occurred in May and October 2018 and March 2019.

3.2 Appendix IV Constituents Detected at SSLs above GWPS

An initial assessment monitoring event to sample and analyze the groundwater for all constituents listed in Appendix IV was conducted in March 2018 in accordance with § 257.95(b). Subsequent semi-annual monitoring events that included both Appendix III and IV constituents were conducted in May and October 2018 in accordance with § 257.95(d)(1). **Figures 5, 6, and 7** show potentiometric contours for shallow (20 ft BLS) monitoring wells based upon the May and October 2018 and March 2019 water levels, respectively. Groundwater elevations for each of these sampling events are summarized in **Table 3**. **Figure 8** shows the groundwater contours for wells installed to 50 ft BLS during the March 2019 sampling event. Groundwater elevations for this sampling event are summarized in **Table 3**. These contours support the overall groundwater flow system described in the CSM, **Section 2.3**.

Vertical gradients have been calculated between the 20 ft BLS and the 50 ft BLS zone wells for the October 2018 and March 2019 sampling events. These vertical gradients are shown in Table 4. The table suggests that there is little vertical gradient which is consistent with the AS/DA's placement within the discharge zone as described within the CSM.

Table 5 provides a comparison of May 2018 analytical results to established GWPS. In the 20 ft BLS zone, concentrations of arsenic, lithium, molybdenum, and total radium were detected at SSLs greater than GWPSs in one or more monitoring wells. Arsenic was generally detected along the northern and western portion of the AS/DA. Lithium and molybdenum were both detected along the southwestern portion of the landfill. While the total radium exceeded the GWPS in several monitoring wells around the AS/DA, it is not considered an exceedance of the GWPS at the CREC based on the findings of the ASD (Geosyntec, 2019). It should be noticed that the ASD will be published as part of the Annual Groundwater Monitoring Report for 2019. The October 2018 and March 2019 results are summarized in **Tables 6 and 7**.

Maps showing the locations of SSLs for Appendix IV constituents in May 2018, October 2018, and March 2019 monitoring for the shallow monitoring zone (20 ft BLS) and deeper monitoring zone (50 ft BLS) are provided on **Figures 9 through 13**.

3.3 Groundwater Characterization Required by CFR 257.95(g)

Since one or more constituents in Appendix IV were found at SSLs above their applicable GWPSs, the CCR Rule in 40 CFR § 257.95(g)(1) states that the owner or operator of the CCR unit must:

> *Characterize the nature and extent of the release and any relevant site conditions that may affect the remedy ultimately selected. The characterization must be sufficient to support a complete and accurate assessment of the corrective measures necessary to effectively clean up all releases from the CCR unit pursuant to § 257.96.*

Based on the presence of Appendix IV constituents reported at SSLs above their GWPS, additional site characterization was required and performed by Duke Energy at the AS/DA as described below.

3.4 Summary of Groundwater Characterization

Due to the presence of Appendix IV constituents observed at SSLs greater than their applicable GWPS for arsenic, lithium and molybdenum, further characterization of the nature and extent of groundwater was performed according to the CCR Rule in 40 CFR § 257.95(g)(1) and is summarized below.

3.4.1 Installation of Additional Monitoring Wells

Ten additional CCR monitoring wells (CCRW-20 through CCRW-30) were installed downgradient of the AS/DA in 2018 and 2019 to characterize the nature and extent of SSLs for Appendix IV constituents (arsenic, lithium and molybdenum) identified during assessment monitoring activities conducted in accordance with § 257.95. Well construction details are summarized in **Table 2** and locations are shown on **Figure 2**.

3.4.2 Nature and Extent Data

Tables 5 and 6 summarize the Appendix IV assessment monitoring data and data collected from the nature and extent wells. **Figures 5 through 8** show groundwater contours for the CCR and nature and extent wells during October 2018 and March 2019. **Figures 9 through 13** show wells with concentrations above the GWPS for the CCR wells and nature and extent wells in May and October 2018 and March 2019.

Molybdenum exceeded the GWPS in monitoring wells CCRW-11, CCRW-12, CCRW-14 and CCRW-18 immediately adjacent to the west and southwest portion of the AS/DA and only in the 20 ft BLS zone. The extent of these exceedances is delineated by the current network of CCR and nature and extent wells.

Lithium exceeded the GWPS in the 20 ft BLS zone monitoring wells CCRW-11, CCRW-12, CCRW-14, and CCRW-18 immediately adjacent to the west and southwest portion of the AS/DA and in CCRW-20 located approximately 1000 ft south of the AS/DA. Lithium also exceeded the GWPS in 50 ft BLS zone monitoring wells CCRW-21 and CCRW-29; however, these concentrations may be attributed to an alternate source believed to be associated with saltwater intrusion and the tidally influenced ditch that runs along West Power Line Street. Additional characterization may be necessary to confirm the alternate source of lithium in these wells.

Arsenic exceeded the GWPS in a majority of the CCR and nature and extent wells around the perimeter and downgradient of the AS/DA. Arsenic exceeded the GWPS in nature and extent wells CCRW-24 and CCRW-25 along the northern portion of the AS/DA and northern property boundary of the CREC. This area of the CREC is hydraulically downgradient of the United States Gypsum Facility which located just north of the CREC property boundary. Therefore, additional characterization of arsenic will not be pursued north of this area due to the presence of upgradient arsenic impacted groundwater observed at the United States Gypsum facility (Golder, 2016).

Arsenic did not exceed the GWPS in 20 ft BLS zone wells CCRW-14 and CCRW-15 located along the southern boundary of the AS/DA or in downgradient 20 ft BLS zone wells CCRW-20 and CCRW-30. However, arsenic exceedances were observed in the 50 ft BLS zone wells CCRW-21 and CCRW-29, downgradient of the AS/DA. Since an upward gradient is observed from the 50 ft BLS zone to the 20 ft BLS zone in this area of the Site, the AS/DA does not appear to be the source of arsenic in these 50 ft BLS zone wells. Arsenic was not detected above the GWPS in the downgradient, 50 ft BLS zone well CCRW-22 in October 2018 but did exceed the GWPS in the sample collected in March 2019. Additional characterization may be necessary to confirm the source and nature and extent of arsenic exceeding the GWPS in the vicinity and downgradient of the AS/DA.

3.4.3 Installation and Sampling of Monitoring Wells at Property Line

Monitoring well CCRW-27 was installed at the downgradient property as shown on **Figure 6** in accordance with 40 CFR § 257.95(g)(1)(iii). The collected data has shown that the groundwater at this downgradient location is not impacted with constituents associated with the AS/DA at concentrations exceeding the AS/DA.

3.5 Summary of Alternate Source Demonstration

An ASD was successfully prepared for total radium at the AS/DA in compliance with 40 CFR § 257.94(e)(2). The ASD showed that total radium does not leach from materials stored in the AS/DA and that total radium in the groundwater is naturally occurring (Geosyntec, 2019).

4. ASSESSMENT OF CORRECTIVE MEASURES

CCR groundwater monitoring at the AS/DA has detected arsenic, lithium, and molybdenum (Appendix IV constituents) at SSLs exceeding respective GWPSs defined under 40 CFR § 257.95(h). The objective of this ACM Report is to address these groundwater exceedances by identifying and evaluating remedial strategies that can be utilized to meet the CCR Rule requirements. **Section 4.3** identifies potential groundwater remedial technologies for implementation at the AS/DA and **Appendix A** summarizes each technology. **Section 4.4** describes the ACM evaluation of these remedial technologies to meet requirements of 40 CFR § 257.96. **Appendix B** presents the remedial technology evaluation and **Table 1** summarizes the technology evaluation.

The evaluation of source control methods will be provided separate from this ACM Report, as required by the CCR Rule. However, potential source control methods are described in **Section 4.2**.

4.1 Objectives of Remedial Technology Evaluation

As indicated in 40 CFR § 257.96(a), the objectives of the corrective measures evaluated in this ACM report are "to prevent further releases [from the AS/DA], to remediate any releases, and to restore affected area to original conditions." As required in 40 CFR § 257.97(b), corrective measures, at minimum, must meet the following criteria:

> *(1) Be protective of human health and the environment;*
>
> *(2) Attain the groundwater protection standard as specified pursuant to § 257.95(h);*
>
> *(3) Control the source(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of constituents in appendix IV to this part into the environment;*
>
> *(4) Remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible, taking into account factors such as avoiding inappropriate disturbance of sensitive ecosystems;*
>
> *(5) Comply with standards for management of wastes as specified in § 257.98(d).*

The following evaluation will summarize the potential remedial technologies in the context of these objectives.

4.2 Potential Source Control Measures

The objective of source control measures is to prevent further releases from the source (i.e., the AS/DA). On page 21406 in the preamble to 40 CFR 257, the following is stated regarding source control:

> *Source control measures need to be evaluated to limit the migration of the plume, and to ensure an effective remedy. The regulation does not limit the definition of source control*

to exclude any specific type of measures to achieve this. Remedies must control the source of the contamination to reduce or eliminate further releases by identifying and locating the cause of the release. Source control measures may include the following: Modifying the operational procedures (e.g., banning waste disposal); undertaking more extensive and effective maintenance activities (e.g., excavate waste to repair a liner failure); or, in extreme cases, excavation of deposited wastes for treatment and/ or offsite disposal. Construction and operation requirements also should be evaluated.

If closure of the AS/DA is considered as part of the source control measures, one or more of the following methods could be used:

- Installation of a final cover system;
- Excavation of the ash for beneficial reuse, including the solids in the AS/DA stormwater ditch system; or
- Excavation and disposal of ash off-Site, including the solids in the AS/DA stormwater ditch system.

Another approach is a hybrid approach that includes beneficial reuse of some of the ash along with relocating a portion of the ash into a smaller landfill footprint on-Site. This smaller landfill does not currently exist and would require new construction with liner and final cover systems. Also, stormwater runoff and leachate from a new on-Site landfill will need to be controlled.

Regardless of the approach taken, the ditches and stormwater ponds will need to be remediated by removing sedimented CCR. These source control measures will substantially reduce the introduction of additional constituent of interest (COI) mass into groundwater from the AS/DA

4.3 Potential Groundwater Remedial Technologies

While there are numerous technologies to remediate organic constituents, fewer options exist to address inorganic constituents (i.e., arsenic, lithium, molybdenum). The potential remedial alternatives are limited for these inorganic constituents due to the variable geochemical properties.

As summarized in **Section 3.2**, arsenic, lithium, and molybdenum (Appendix IV constituents) were detected at SSLs exceeding their GWPSs in one or more of the CCR monitoring wells during the May 2018, October 2018, and March 2019 CCR assessment monitoring events. These COI are primarily observed at SSLs for arsenic around the perimeter of the AS/DA and for lithium and molybdenum along the south western portion of the AS/DA. **Figures 9 through 13** depict the GWPS exceedances for the Appendix IV constituents.

The following list includes groundwater remedial technologies that exist for potential implementation at CREC based on Site conditions:

- In-Situ Technologies;
    - Groundwater Migration Barriers;
    - In-Situ Chemical Immobilization;

    - Permeable Reactive Barriers (PRBs);
- Groundwater Extraction;
    - Conventional Vertical Well Systems;
    - Phytoremediation;
- Groundwater Treatment; and
- Monitored Natural Attenuation (MNA)

Appendix A summarizes each technology and **Section 4.4** evaluates the remedial technologies as part of the ACM process.

4.4 Evaluation to Meet Requirements in 40 CFR § 257.96(c)

An ACM is necessary for the AS/DA due to the detection of one or more Appendix IV constituents at SSLs above respective GWPSs. 40 CFR § 257.96(c) outlines the assessment of corrective measures requirements as the following:

> *The assessment under paragraph (a) of this section must include an analysis of the effectiveness of potential corrective measures in meeting all of the requirements and objectives of the remedy as described under § 257.97 addressing at least the following:*
>
> > *(1) The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to any residual contamination;*
> >
> > *(2) The time required to begin and complete the remedy;*
> >
> > *(3) The institutional requirements, such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).*

Appendix B provides the evaluation of potential remedies (listed in **Section 4.3**) using these criteria from 40 CFR § 257.96(c) and **Table 1** summarizes the results. **Appendix C** outlines the selection of remedy requirements and considerations found in 40 CFR § 257.97 that will be used in the remedial selection process following the ACM.

The object of this ACM is to provide a high-level assessment of measures that address Site SSLs and Site conditions. Based on the remedial evaluation results conducted under 40 CFR § 257.96, Duke Energy must, as soon as feasible, select a remedy that meets the minimum standards listed in 40 CFR § 257.97(b) with consideration to evaluation factors listed in 40 CFR § 257.97(c). In accordance with 40 CFR § 257.96(e), Duke Energy must also hold a public meeting at least 30 days prior to remedy selection, as mentioned in **Section 5.3**.

5. SELECTION OF REMEDY PROCESS

The remedy selection begins following completion of the ACM report. 40 CFR § 257.97(a) states that:

> *Based on the results of the corrective measures assessment conducted under §257.96, the owner or operator must, as soon as feasible, select a remedy that, at a minimum, meets the standards listed in paragraph (b) of this section. This requirement applies to, not in place of, any applicable standards under the Occupational Safety and Health Act. The owner or operator must prepare a semiannual report describing the progress in selecting and designing the remedy. Upon selection of a remedy, the owner or operator must prepare a final report describing the selected remedy and how it meets the standards specified in paragraph (b) of this section. The owner or operator must obtain a certification from a qualified professional engineer that the remedy selected meets the requirements of this section. The report has been completed when it is placed in the operating record as required by §257.105(h)(12).*

5.1 Additional Data or Characterization Needs

CCR assessment monitoring wells will continue to be sampled as required. Existing nature and extent wells will be sampled as necessary. Additional nature and extent delineation activities will continue until groundwater with constituents exceeding the GWPS has been delineated as required.

5.2 Schedule for Selecting Remedy

The process of selecting a remedy or remedial approach begins following submittal of this ACM Report. The owner or operator must select a remedy and begin implementing that remedy as soon as feasible. Progress toward selecting a preferred remedy must be documented in a semiannual report in accordance with § 257.97. Bench-scale and on-Site pilot testing may be required to evaluate the effectiveness of one or more remedial technologies under Site-specific conditions. One or more preferred remedial approach should be developed based upon technology effectiveness under Site conditions, implementability, cost effectiveness, and other considerations. A public meeting with citizen and government stakeholders should be scheduled once one or more preferred remedial approach(s) are identified. Requirements for conducting public meetings are presented in **Section 5.3**.

5.3 Public Meeting Requirement in 40 CFR § 257.96(e)

Following preparation of the ACM Report, and based upon assessment results, a corrective measure remedy must be selected as soon as feasible. However, before the final remedy can be selected, a public meeting to discuss ACM results with interested and affected stakeholders must be held at least 30 days prior to remedy selection in accordance with § 257.96(e).

Duke Energy will notify interested and affected stakeholders when the public meeting is scheduled.

6. REFERENCES

AMEC. 2013. *Site Characterization and Preliminary Geotechnical Design Recommendations*. Lakeland, FL. December.

ESE. 1984. *Proposed Ground Water Monitoring Plan for Crystal River Energy Complex.* Gainesville, FL. February.

Geosyntec. 2019. *CCR Annual Groundwater Monitoring and Corrective Action Report*. Tampa, FL.

Golder, 2016. *Fifth Semiannual Groundwater Monitoring Report United States Gypsum Company.* Tampa, FL

KBN Engineering and Applied Sciences, Inc. 1987. *Florida Power Corporation Crystal River Units 4 & 5, Site Certification Application Revision for Ash Disposal Area*.

Spencer, Steven M. 1984. *Geology of Citrus County, Florida.* Florida Geological Survey, Open File Report No. 5, Tallahassee, FL.

Terracon. 2015. *Geotechnical Engineering Report Citrus County Combined Cycle Project*. Charlotte, NC. October.

USEPA. 2015. *Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities.* United States Environmental Protection Agency. EPA-HQ-RCRA-2009-0640. April.

TABLES

TABLE 1
REMEDIAL TECHNOLOGIES SCREENING MATRIX
40 CFR § 257.96(c) REQUIREMENTS
Crystal River Energy Complex
Crystal River, FL

	In-Situ Strategies				Ex-Situ Strategies		
	Permeable Reactive Barriers	**Groundwater Flow Barriers**	**Chemical Immobilization**	**Monitored Natural Attenuation**	**Conventional Groundwater Extraction**	**Phytoremediation**	**Groundwater Treatment**
40 CFR § 257.96(c)(1)							
Performance	Low to Moderate - commercially-available media for lithium treatment are not well documented; groundwater may migrate around or beneath reactive zones in karst features	Low to Moderate - groundwater may migrate around or beneath low permeability zones in karst features	Low to Moderate - commercially-available reagents for lithium treatment are not well documented; karst features present reagent delivery challenges	Moderate to High - physical processes including dilution, dispersion, and sorption will reduce concentrations in conjunction with source control	Moderate to High - established technology; karst features could impact hydraulic control	Moderate to High - growing conditions conducive; self-sustaining and predictable after root network forms; challenges with high concentrations of TDS and chloride and high transmissivity of the aquifer	Moderate to High - established technology with adaptability for treatment; high concentrations of dissolved ions likely to generate concentrated secondary waste streams
Reliability	Low to Moderate - karst features will require extensive grouting of voids; absence of low permeability zone at barrier base may increase flow beneath; bench-scale studies will be required to evaluate lithium removal	Low to Moderate - karst features will require extensive grouting of voids; absence of low permeability zone at barrier base may increase flow beneath	Low to Moderate - lithium treatment is not well documented and would require bench-scale studies to evaluate removal; karst features can minimize the effective distribution of chemical agents that limits treatment effectiveness	High - inherent porous nature of limestone and karst features at shallow depths readily promote physical attenuation mechanisms; groundwater flow regime is predictable and reliable	Moderate to High - designed to capture and contained dissolved plume; dependent on consistent O&M to mitigate mechanical fouling; potential corrosion issues from high chloride concentrations across Site	Moderate to High - trees able to grow most of the year in Florida; performance is reliable after establishing root network; limited O&M activities that include pruning and vegetation maintenance	High - wide variety of adaptable treatment options; the use of multiple technologies is likely to treat COI

TABLE 1
REMEDIAL TECHNOLOGIES SCREENING MATRIX
40 CFR § 257.96(c) REQUIREMENTS

Crystal River Energy Complex
Crystal River, FL

	In-Situ Strategies				Ex-Situ Strategies		
	Permeable Reactive Barriers	**Groundwater Flow Barriers**	**Chemical Immobilization**	**Monitored Natural Attenuation**	**Conventional Groundwater Extraction**	**Phytoremediation**	**Groundwater Treatment**
Ease of Implementation	Difficult - extensive geological and geotechnical investigations required prior to construction due to karst features; extensive grouting and/or other ground improvement to fills detected voids; significant construction timelines, costs, and effort	Difficult - extensive geological and geotechnical investigations required prior to construction due to karst features; extensive grouting and/or other ground improvement to fills detected voids; significant construction timelines, costs, and effort	Moderate - less extensive geological investigations to identify karst features prior to installation of permanent injection wells compared to installing barriers; less construction timelines, costs, and efforts required to install injection wells	Easy - periodic groundwater sampling in existing well network; results may dictate the addition of more wells to support lines of evidence	Moderate - aquifer testing and modeling required prior to implementation for well network design; implementation involves installing extraction and injection well network and associated plumbing, pumps, and wiring; routine O&M and cleaning requirements	Moderate - aquifer testing and modeling required prior to implementation for well network design; implementation involves installing wells and planting trees; routine landscape maintenance requirements such as pruning and fertilizing	Moderate - aquifer testing and modeling required prior to implementation for well network design; implementation involves installing extraction and injection well network and associated treatment train; routine O&M and cleaning requirements
Potential Safety Impacts	High - construction hazards for workers including deep, open trenches and heavy construction equipment	High - construction hazards for workers including deep, open trenches and heavy construction equipment	Low - potential for chemical exposure during injection events; potential worker risks with long-term storage of on-Site chemicals	Low - potential worker safety issues during drilling, installation, and construction of wells; minimal safety risks compared to other strategies during groundwater sampling	Moderate - potential worker safety issues during drilling, installation, and construction of wells; potential physical and/or electrical safety concerns during routine O&M	Low - potential worker safety issues during drilling, installation, and construction of wells; reduced maintenance requirements with fewer physical risks compared to groundwater extraction	Moderate - potential worker safety issues during drilling, installation, and construction of wells and treatment train; potential physical, chemical, and/or electrical safety concerns during routine O&M
Potential Cross-Media Impacts	Moderate - potential for groundwater to flow beneath or around barriers	Moderate - potential for groundwater to flow beneath or around barriers	Low - potential for unintended chemical releases aboveground that do not pose adverse environmental impacts for uncontaminated surficial soils	Low - potential for contaminant storage in aquifer matrix through sorption	Low - potential associated with unintended releases in aboveground plumbing or pumps to uncontaminated surficial soils	Low - potential associated with vegetation maintenance	Low - potential associated with unintended releases in aboveground plumbing or pumps to uncontaminated surficial soils

TABLE 1
REMEDIAL TECHNOLOGIES SCREENING MATRIX
40 CFR § 257.96(c) REQUIREMENTS
Crystal River Energy Complex
Crystal River, FL

	In-Situ Strategies				**Ex-Situ Strategies**		
	Permeable Reactive Barriers	**Groundwater Flow Barriers**	**Chemical Immobilization**	**Monitored Natural Attenuation**	**Conventional Groundwater Extraction**	**Phytoremediation**	**Groundwater Treatment**
Potential Exposure to Residual Contamination	Low - potential for exposure during the installation and construction phase; additional potential during reactive media replacement	Low - potential for exposure during the installation and construction phase	Low - potential for exposure during the installation and construction phase	Low - potential for exposure during the installation and construction phase of monitoring wells (as needed); possible exposure pathways if the aquifer's capacity to attenuate is exceeded over time	Low - potential human exposure to contaminated groundwater during routine O&M and unintended releases	Low - potential for environmental receptors to consume edible portions of trees that may accumulate COI	Low - potential human exposure to contaminated groundwater during routine O&M and unintended releases
40 CFR § 257.96(c)(2)							
Time Required to Begin Remedy	12 to 18 months	1 to 2 years	6 to 12 months	3 to 6 months	1 to 2 years	6 to 18 months	1 to 2 years
Time Required to Complete Remedy	greater than 30 years - does not specifically address source removal	greater than 30 years - does not specifically address source removal	5 to 10 years	greater than 30 years - does not specifically address source removal	greater than 30 years - does not specifically address source removal	greater than 30 years - does not specifically address source removal	5 to 10 years
40 CFR § 257.96(c)(3)							
State, Local, or Other Environmental Permit Requirements That May Substantially Affect Implementation	State and local permitting of construction activities may be required	State and local permitting of construction activities may be required	SWFWMD permitting for injection wells; FDEP UIC permit	SWFWMD permitting for monitoring wells (as needed)	State and local permitting of construction activities may be required; SWFWMD permitting for injection wells; FDEP UIC permit	SWFWMD permitting for wells to plant trees	State and local permitting of construction activities may be required; SWFWMD permitting for injection wells; FDEP UIC permit

Notes

COI - constituents of interest
FDEP - Florida Department of Environmental Protection
O&M - operations and maintenance
SWFWMD - Southwest Florida Water Management District
TDS - total dissolved solids
UIC - underground injection control

Table 2: Monitoring Well Construction Details

Crystal River Energy Complex
Crystal River, FL

Well ID	Diameter (in)	Designation	CCR Unit Monitored	Northing	Easting	Ground Surface Elevation	TOC Elevation	Total Depth (ft bls)	Screen Interval (ft bls)	Top of Screen Elevation	Bottom of Screen Elevation
CCRBW-2	2	Background	AS/DA Landfill	1684327.487	437004.706	8.48	8.57	20	10-20	-1.52	-11.52
CCRW-5	2	Detection	AS/DA Landfill	1685764.352	435524.800	6.00	8.98	20	10-20	-4.00	-14.00
CCRW-6	2	Detection	AS/DA Landfill	1685762.561	436167.540	6.10	8.83	20	10-20	-3.90	-13.90
CCRW-7	2	Detection	AS/DA Landfill	1685760.703	436481.554	6.19	9.45	20	10-20	-3.81	-13.81
CCRW-8	2	Detection	AS/DA Landfill	1685712.995	436901.453	9.36	12.59	20	10-20	-0.64	-10.64
CCRW-9	2	Detection	AS/DA Landfill	1685201.772	435632.332	8.54	11.76	20	10-20	-1.46	-11.46
CCRW-10	2	Detection	AS/DA Landfill	1684831.307	435841.956	7.35	10.62	20	10-20	-2.65	-12.65
CCRW-11	2	Detection	AS/DA Landfill	1684055.690	435869.500	5.72	8.55	20	10-20	-4.28	-14.28
CCRW-12	2	Detection	AS/DA Landfill	1683815.262	435864.677	5.91	9.08	20	10-20	-4.09	-14.09
CCRW-13	2	Detection	AS/DA Landfill	1683546.974	436109.647	5.36	8.49	20	10-20	-4.64	-14.64
CCRW-14	2	Detection	AS/DA Landfill	1683225.250	436598.381	6.60	9.74	20	10-20	-3.40	-13.40
CCRW-15	2	Detection	AS/DA Landfill	1683243.794	436896.326	5.78	8.99	20	10-20	-4.22	-14.22
CCRW-16	2	Detection	AS/DA Landfill	1685511.490	435436.050	9.42	12.25	20	10-20	-0.58	-10.58
CCRW-17	2	Detection	AS/DA Landfill	1684659.390	435791.870	8.92	8.70	20	10-20	-1.08	-11.08
CCRW-18	2	Detection	AS/DA Landfill	1684259.560	435793.770	9.12	8.84	20	10-20	-0.88	-10.88
CCRW-20	2	Detection	AS/DA Landfill	1682140.828	436689.782	4.87	8.04	20	10-20	-5.13	-15.13
CCRW-21	2	Detection	AS/DA Landfill	1682142.844	436674.949	4.85	7.87	50	40-50	-35.15	-45.15
CCRW-22	2	Detection	AS/DA Landfill	1683440.519	434457.474	6.75	9.92	50	40-50	-33.25	-43.25
CCRW-23	2	Detection	AS/DA Landfill	1684918.923	434891.301	8.15	11.39	20	10-20	-1.86	-11.86
CCRW-24	2	Detection	AS/DA Landfill	1685922.669	435202.194	8.60	8.28	20	10-20	-1.40	-11.40
CCRW-25	2	Detection	AS/DA Landfill	1685913.607	436223.836	8.66	8.32	20	10-20	-1.34	-11.34
CCRW-26	2	Detection	AS/DA Landfill	1685913.767	436207.719	8.63	8.28	50	40-50	-31.37	-41.37
CCRW-27	2	Detection	AS/DA Landfill	1684067.448	431481.619	4.22	7.04	20	10-20	-5.78	-15.78
CCRW-28	2	Detection	AS/DA Landfill	1685913.760	436216.110	8.65	8.21	100	90-100	-81.35	8.65
CCRW-29	2	Detection	AS/DA Landfill	1682833.810	436689.650	5.72	8.37	50	40-50	-34.28	-44.28
CCRW-30	2	Detection	AS/DA Landfill	1682834.900	436678.730	5.65	8.14	20	10-20	-4.35	-14.35

Notes

1. in indicates inches
2. TOC indicates Top of Casing
3. ft bls indicates Feet Below Land Surface
4. Horizontal datum surveyed to the North American Datum (NAD) of 1983.
5. Vertical datum surveyed to the National Geodetic Vertical Datum (NGVD) of 1929.
6. AS/DA Landfill indicates Ash Storage/Disposal Area Landfill

Table 3: Groundwater Elevation Data

Crystal River Energy Complex
Crystal River, Florida

Well ID	CCR Unit Monitored	Northing	Easting	Ground Surface Elevation	TOC Elevation	September 2017 GW Elevation	March 2018 GW Elevation	May 2018 GW Elevation	October 2018 GW Elevation	March 2019 GW Elevation
CCRBW-2	AS/DA Landfill	1684327.487	437004.706	8.48	8.57	6.37	3.94	3.07	4.02	4.07
CCRW-5	AS/DA Landfill	1685764.352	435524.800	6.00	8.98	4.55	3.30	2.92	3.95	3.96
CCRW-6	AS/DA Landfill	1685762.561	436167.540	6.10	8.83	4.50	3.34	2.87	3.90	3.97
CCRW-7	AS/DA Landfill	1685760.703	436481.554	6.19	9.45	4.49	3.31	2.83	4.05	3.90
CCRW-8	AS/DA Landfill	1685712.995	436901.453	9.36	12.59	4.56	3.55	2.73	3.96	4.05
CCRW-9	AS/DA Landfill	1685201.772	435632.332	8.54	11.76	5.86	2.95	2.79	3.71	3.62
CCRW-10	AS/DA Landfill	1684831.307	435841.956	7.35	10.62	5.87	2.86	2.79	3.52	3.52
CCRW-11	AS/DA Landfill	1684055.690	435869.500	5.72	8.55	5.75	2.90	2.72	3.60	3.49
CCRW-12	AS/DA Landfill	1683815.262	435864.677	5.91	9.08	5.98	3.01	2.73	3.66	3.58
CCRW-13	AS/DA Landfill	1683546.974	436109.647	5.36	8.49	5.97	3.09	2.62	3.54	3.47
CCRW-14	AS/DA Landfill	1683225.250	436598.381	6.60	9.74	5.84	3.69	2.74	3.64	3.62
CCRW-15	AS/DA Landfill	1683243.794	436896.326	5.78	8.99	5.83	3.74	2.67	3.59	3.62
CCRW-16	AS/DA Landfill	1685511.490	435436.050	9.42	12.25	4.17	2.93	2.70	3.60	3.59
CCRW-17	AS/DA Landfill	1684659.390	435791.870	8.92	8.70	5.82	2.80	2.73	3.60	3.45
CCRW-18	AS/DA Landfill	1684259.560	435793.770	9.12	8.84	5.74	2.76	2.69	3.54	3.41
CCRW-20	AS/DA Landfill	1682140.828	436689.782	4.87	8.04	NI	NI	NI	3.41	NM
CCRW-21	AS/DA Landfill	1682142.844	436674.949	4.85	7.87	NI	NI	NI	3.04	NM
CCRW-22	AS/DA Landfill	1683440.519	434457.474	6.75	9.92	NI	NI	NI	4.06	3.06
CCRW-23	AS/DA Landfill	1684918.923	434891.301	8.15	11.39	NI	NI	NI	3.53	3.34
CCRW-24	AS/DA Landfill	1685922.669	435202.194	8.60	8.28	NI	NI	NI	3.62	3.63
CCRW-25	AS/DA Landfill	1685913.607	436223.836	8.66	8.32	NI	NI	NI	3.81	3.79
CCRW-26	AS/DA Landfill	1685913.767	436207.719	8.63	8.28	NI	NI	NI	3.78	3.80
CCRW-27	AS/DA Landfill	1684067.448	431481.619	4.22	7.04	NI	NI	NI	2.21	2.24
CCRW-28	AS/DA Landfill	1685913.760	436216.110	8.65	8.21	NI	NI	NI	NI	3.86
CCRW-29	AS/DA Landfill	1682833.810	436689.650	5.72	8.37	NI	NI	NI	NI	3.37
CCRW-30	AS/DA Landfill	1682834.900	436678.730	5.65	8.14	NI	NI	NI	NI	3.18

Notes

1. in = Inches
2. TOC = Top of Casing
3. ft bls = Feet Below Land Surface
4. Horizontal datum surveyed to the North American Datum (NAD) of 1983.
5. Vertical datum surveyed to the National Geodetic Vertical Datum (NGVD) of 1929.
6. AS/DA Landfill = Ash Storage/Disposal Area Landfill
7. NI indicates not installed
8. NM indicates not measured

TABLE 4
VERTICAL GROUNDWATER GRADIENTS
CRYSTAL RIVER ENERGY COMPLEX
CRYSTAL RIVER, FL

Well Name	Zone	March 2019		October 2018	
		Groundwater Elevation (ft., NGVD29)	Gradient	Groundwater Elevation (ft., NGVD29)	Gradient
CCRW-30	20 ft	3.2	0.0057	NI	-
CCRW-29	50 ft	3.37		NI	
CCRW-20	20 ft	NM	-	3.41	-0.0123
CCRW-21	50 ft	NM		3.04	
CCRW-25	20 ft	3.79	0.0003	3.81	-0.0010
CCRW-26	50 ft	3.8	0.0020	3.78	
CCRW-28	100 ft	3.86		NI	-

Notes:
1) Positive gradient means upward flow. Negative gradient means downward flow.
2) NM = Not Measured
3) NI = Well was not yet installed

TABLE 5
MAY 2018 SAMPLING EVENT
Crystal River Energy Complex
Crystal River, FL

Appendix IV Constituent		Antimony, total	Arsenic, total	Barium, total	Beryllium, total	Cadmium, total	Chromium, total	Cobalt, total	Lead, total	Lithium, total	Mercury, total	Molybdenum, total	Radium, total	Selenium, total	Thallium, total
Units		mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	pCi/L	ug/L	ug/L
Groundwater Protection Standard[1]		6	10	2000	4	5	100	6[*]	15[*]	40[*]	2	100[*]	5	50	2
Well ID	Date Sampled	May 2018 Assessment Monitoring Results													
CCRBW-2	5/1/2018	5 U	5 U	5 U	0.5 U	0.5 U	2.5 U	5 U	5 U	16.6 I	0.1 U	5.5 I	1.91 U	7.5 U	0.5 U
CCRW-5	5/1/2018	5 U	5.9 J	20.3	0.5 U	0.5 U	2.5 U	5 U	5 U	13.7 J	0.1 U	9.2 J	4.28	7.5 U	0.5 U
CCRW-6	5/2/2018	5 U	**12.8**	9.8 J	0.5 U	0.5 U	2.5 U	5 U	5 U	5.1 J	0.1 U	18	3.71	7.5 U	0.5 U
CCRW-7	5/2/2018	5 U	**23.7**	17.4	0.5 U	0.5 U	2.5 U	5 U	5 U	4.6 J	0.1 U	5.6 J	**8.32**	7.5 U	0.5 U
CCRW-8	5/2/2018	5 U	**12.6**	16.2	0.5 U	0.5 U	2.5 U	5 U	5 U	10.3 J	0.1 U	11.4	3.74	7.5 U	0.5 U
CCRW-9	5/2/2018	5 U	5 U	49.3	0.5 U	0.5 U	2.5 U	5 U	5 U	8.1 J	0.1 U	27	4.98	7.5 U	0.5 U
CCRW-10	5/1/2018	5 U	7.8 J	32.1	0.5 U	0.5 U	2.5 U	5 U	5 U	23 J	0.1 U	89	4.88	7.5 U	0.5 U
CCRW-11	5/1/2018	5 U	**31.8**	59.6	0.5 U	0.5 U	2.5 U	5 U	5 U	**71.3**	0.1 U	90.5	**5.46**	7.5 U	0.5 U
CCRW-12	5/2/2018	5 U	**53.9**	132	0.5 U	0.5 U	2.5 U	5 U	5 U	38.6 J	0.1 U	**212**	**6.26**	7.5 U	0.5 U
CCRW-13	5/2/2018	5 U	**22.4**	20.4	0.5 U	0.5 U	2.5 U	5 U	5 U	8.5 J	0.1 U	22.1	**5.33**	7.5 U	0.5 U
CCRW-14	5/2/2018	5 U	5 U	31.2	0.5 U	0.5 U	2.5 U	5 U	5 U	**370**	0.1 U	**222**	**5.44**	7.5 U	0.5 U
CCRW-15	5/2/2018	5 U	5 U	30.5	0.5 U	0.5 U	2.5 U	5 U	5 U	15.2 J	0.1 U	16.3	**5.13**	7.5 U	0.5 U
CCRW-16	5/1/2018	5 U	**11.1**	45.1	0.5 U	0.5 U	2.5 U	5 U	5.5 J	23.4 J	0.1 U	25.2	**14**	7.5 U	0.5 U
CCRW-17	5/1/2018	1.3	6.3 J	54.4	0.5 U	0.5 U	2.5 U	5 U	5 U	27.5 J	0.1 U	61.5	3.38	7.5 U	0.5 J
CCRW-18	5/1/2018	5 U	**57.1**	49.3	0.5 U	0.5 U	2.5 U	5 U	5 U	**117**	0.1 U	**167**	**17.2**	7.5 U	0.5 U

Notes:

[1] - Groundwater protection standard represents USEPA Maximum Contaminant Level unless specified otherwise.

[*] - Groundwater protection standard represents values noted in USEPA'S Amendments to the National Minimum Criteria (Phase One, Part One), Disposal of Coal Combustion Residuals from Electric Utilities; effective July 17, 2018.

µg/L - micrograms per litre

J - Estimated concentration above the method detection limit and below the reporting limit.

mg/L - milligrams per litre

Radium, total - the sum of radium-226 + radium-228

STD - standard units

U – Analyte was analyzed for, but not detected above the reporting limit.

- Bold, highlighted text indicates concentration is above the groundwater protection standard. Note total radium is subject to an Alternate Source Demonstration

TABLE 6
OCTOBER 2018 SAMPLING EVENT
Crystal River Energy Complex
Crystal River, FL

Appendix IV Constituent		Antimony, total	Arsenic, total	Barium, total	Beryllium, total	Cadmium, total	Chromium, total	Cobalt, total	Lead, total	Lithium, total	Mercury, total	Molybdenum, total	Radium, total	Selenium, total	Thallium, total
Units		mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	pCi/L	ug/L	ug/L
Groundwater Protection Standard[1]		6	10	2000	4	5	100	6[*]	15[*]	40[*]	2	100[*]	5	50	2
Well ID	Date Sampled	October 2018 Assessment Monitoring Results													
CCRBW-2	10/25/2018	0.50U	0.64 I	7.8 I	1.6U	0.33U	1.7U	0.96U	1.2	14.7 I	0.10U	5.5 I	1.50U ± 0.97	0.50U	0.50U
CCRW-5	10/25/2018	0.50U	5.3	23.1	1.6U	0.33U	1.7U	0.96U	0.50U	9.1 I	0.10U	12.8	3.63 ± 1.48	0.88 I	0.50U
CCRW-6	10/25/2018	0.50U	1.6	7.2 I	1.6U	0.33U	1.7U	1.2 I	0.50U	3.8U	0.10U	17	2.81 ± 1.32	3.4	0.50U
CCRW-7	10/25/2018	0.50U	**58.4**	14.2	1.6U	0.33U	1.7U	4.9 I	0.50U	5.1 I	0.10U	6.4 I	**12.1 ± 2.60**	7.9	0.50U
CCRW-8	10/25/2018	0.50U	**30.6**	16.9	1.6U	0.33U	1.7U	2.9 I	0.50U	8.0 I	0.10U	21.7	3.98 ± 1.52	4	0.50U
CCRW-9	10/24/2018	0.50U	2.7	56.6	1.6U	0.33U	1.7U	0.96U	0.50U	7.5 I	0.10U	13.7	**7.21 ± 1.99**	0.87 I	0.50U
CCRW-10	10/24/2018	0.50U	**12.9**	52.5	1.6U	0.33U	1.7U	0.97 I	0.50U	24.2 I	0.10U	74.3	**6.73 ± 1.90**	2.2	0.50U
CCRW-11	10/24/2018	0.50U	**27.2**	57.3	1.6U	0.33U	1.7U	0.96U	0.50U	62.4	0.10U	**130**	**10.7 ± 2.40**	4.5	0.50U
CCRW-12	10/24/2018	0.50U	**79.8**	132	1.6U	0.33U	1.7U	0.96U	0.50U	**48.1 I**	0.10U	**217**	**7.63 ± 2.12**	11.7	0.50U
CCRW-13	10/24/2018	0.50U	**24.6**	19.4	1.6U	0.33U	1.7U	0.96U	0.50U	14.4 I	0.10U	23.6	**7.22 ± 2.06**	4	0.50U
CCRW-14	10/24/2018	0.50U	5.9	37.6	1.6U	0.33U	1.7U	0.96U	0.50U	**487**	0.10U	**338**	**8.46 ± 2.27**	1.3	0.50U
CCRW-15	10/24/2018	0.50U	1.8	37.1	1.6U	0.33U	1.7U	0.96U	0.50U	16.3 I	0.10U	18.5	**6.36 ± 1.69**	0.72 I	0.50U
CCRW-16	10/24/2018	0.50U	**12.4**	50.9	1.6U	0.33U	1.7U	0.96U	0.50U	25.8 I	0.10U	24.3	**15.4 ± 2.92**	2.2	0.50U
CCRW-17	10/24/2018	1.1	**16.3**	47.2	1.6U	0.33U	1.7U	1.1 I	0.50U	24.5 I	0.10U	64	2.83 ± 1.20	2.8	0.69 I
CCRW-18	10/24/2018	0.50U	**48.3**	49.3	1.6U	0.33U	1.7U	1.8 I	0.50U	**75.4**	0.10U	**125**	**14.6 ± 2.84**	7.2	0.50U
CCRW-20	10/25/2018	0.50U	9.6	29.2	1.6U	0.33U	1.7U	0.96U	0.50U	**51.5**	0.10U	8.4 I	4.98 ± 1.56	1.2	0.50U
CCRW-21	10/25/2018	0.50U	**15**	30	1.6U	0.33U	1.7U	0.96U	0.50U	**69.7**	0.10U	9.5 I	**13.1 ± 2.77**	2	0.50U
CCRW-22	10/26/2018	0.50U	3.7	26.6	1.6U	0.33U	1.7U	0.96U	0.50U	5.6 I	0.10U	13.5	**10.1 ± 2.39**	0.62 I	0.50U
CCRW-23	10/25/2018	0.50U	**10.6**	64.6	1.6U	0.33U	1.7U	0.96U	0.50U	32.0 I	0.10U	61.2	5.26 ± 1.64	1.8	0.50U
CCRW-24	10/25/2018	0.50U	**11.5**	50.7	1.6U	0.33U	1.7U	0.96U	0.50U	10.6 I	0.10U	35.5	4.18 ± 1.42	1.8	0.50U
CCRW-25	10/25/2018	0.50U	**63.2**	38.6	1.6U	0.33U	1.7U	2.1 I	0.50U	3.8U	0.10U	9.8 I	**7.65 ± 1.99**	9	0.50U
CCRW-26	10/25/2018	0.50U	**38.5**	26.8	1.6U	0.33U	1.7U	2.3 I	0.50U	9.6 I	0.10U	15.2	**9.42 ± 2.23**	5.4	0.50U
CCRW-27	10/26/2018	0.50U	1.2	28.2	1.6U	0.33U	1.7U	0.96U	0.50U	22.3 I	0.10U	6.4 I	**10.8 ± 2.42**	0.50U	0.50U

Notes:

[1] - Groundwater protection standard represents USEPA Maximum Contaminant Level unless specified otherwise.

[*] - Groundwater protection standard represents values noted in USEPA'S Amendments to the National Minimum Criteria (Phase One, Part One), Disposal of Coal Combustion Residuals from Electric Utilities; effective July 17, 2018.

µg/L - micrograms per litre

J - Estimated concentration above the method detection limit and below the reporting limit.

mg/L - milligrams per litre

Radium, total - the sum of radium-226 + radium-228

STD - standard units

U – Analyte was analyzed for, but not detected above the reporting limit.

- Bold, highlighted text indicates concentration is above the groundwater protection standard.

TABLE 7
MARCH 2019 SAMPLING RESULTS
Crystal River Energy Complex
Crystal River, FL

Appendix IV Constituent		Antimony, total	Arsenic, total	Barium, total	Beryllium, total	Cadmium, total	Chromium, total	Cobalt, total	Lead, total	Lithium, total	Mercury, total	Molybdenum, total	Radium, total	Selenium, total	Thallium, total
Units		mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	pCi/L	ug/L	ug/L
Groundwater Protection Standard[1]		**6**	**10**	**2000**	**4**	**5**	**100**	**6[*]**	**15[*]**	**40[*]**	**2**	**100[*]**	**5**	**50**	**2**
Well ID	**Date Sampled**	**March 2019 Assessment Monitoring Results**													
CCRBW-2	3/19/2019	0.50U	1.1	5.1I	1.6U	0.33 U	1.7 U	1.6I	0.50U	15.4I	0.10U	3.7I	1.70U ± 1.05	0.50U	0.50U
CCRW-5	3/18/2019	0.52 I	3.8	22.4	1.6U	0.33U	1.7U	1.8 I	0.50U	12.5 I	0.10U	10.8	4.08 ± 1.61	0.77 I	0.50U
CCRW-6	3/18/2019	0.50U	4.5	6.7 I	1.6U	0.33U	1.7U	1.9 I	0.50U	6.3 I	0.10U	21.9	2.16 ± 1.27	2.2	0.50U
CCRW-7	3/18/2019	0.50U	**41.7**	13	1.6U	0.33U	1.7U	4.9 I	0.50U	6.9 I	0.10U	7.3 I	**8.94 ± 2.29**	0.66 I	0.50U
CCRW-8	3/18/2019	0.50U	**34.6**	15.7	1.6U	0.33U	1.7U	3.1 I	0.50U	8.0 I	0.10U	20.4	3.70 ± 1.44	0.50U	0.50U
CCRW-9	3/18/2019	0.50U	4.1	57.7	1.6U	0.33U	1.7U	1.2 I	0.50U	6.1 I	0.10U	6.8 I	6.21 ± 2.02	0.95 I	0.50U
CCRW-10	3/18/2019	0.50U	**12.4**	48.8	1.6U	0.33U	1.7U	1.4 I	0.50U	18.8 I	0.10U	77.2	6.48 ± 1.79	1.3	0.50U
CCRW-11	3/18/2019	0.50U	**40**	55.4	1.6U	0.33U	1.7U	2.0 I	0.50U	**220**	0.10U	**173**	**12.3 ± 2.71**	1.4	0.50U
CCRW-12	3/18/2019	0.50U	**67**	116	1.6U	0.33U	1.7U	1.2 I	0.50U	33.8 I	0.10U	**156**	5.41 ± 1.62	2.2	0.50U
CCRW-13	3/18/2019	0.50U	**24.8**	19.8	1.6U	0.33U	1.7U	0.96U	0.50U	13.3 I	0.10U	20.2	3.99 ± 1.55	1.1	0.50U
CCRW-14	3/18/2019	0.50U	7.4	40	1.6U	0.33U	1.7U	1.7 I	0.50U	**502**	0.10U	**261**	4.70 ± 1.44	1.8	0.50U
CCRW-15	3/18/2019	0.50U	2.4	35.5	1.6U	0.33U	1.7U	0.96U	0.50U	12.7 I	0.10U	17.6	**7.29 ± 2.00**	1.2	0.50U
CCRW-16	3/18/2019	0.50U	**12.5**	46.8	1.6U	0.33U	1.7U	1.5 I	0.50U	19.7 I	0.10U	22.8	**12.3 ± 2.61**	1.8	0.50U
CCRW-17	3/19/2019	1.8	5.9	42	1.6	0.33U	1.7U	1.6I	0.50U	21.5I	0.10U	60.2	2.74 ± 1.43	1.2	0.50U
CCRW-18	3/19/2019	0.50U	**49.1**	47.5	1.6U	0.33U	1.7U	4.1I	0.50U	**121**	0.10U	**257**	**16.6 ± 3.19**	0.50U	0.50U
CCRW-20	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
CCRW-21	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
CCRW-22	3/19/2019	0.50U	**16.9**	31.6	1.6U	0.33U	1.7U	3.6I	0.50U	14.6I	0.10U	6.4I	**12.1 ± 2.67**	0.50U	0.50U
CCRW-23	3/19/2019	0.53I	5.1	32.5	1.6U	0.33U	1.7U	1.2I	0.50U	27.2I	0.10U	43.7	3.39 ± 1.38	0.66I	0.50U
CCRW-24	3/19/2019	0.50U	**10.7**	45	1.6U	0.33U	1.7U	1.6I	0.50U	14.9I	0.10U	35.8	5.40 ± 1.68	0.56I	0.50U
CCRW-25	3/19/2019	0.50U	**74.8**	33.9	1.6U	0.33U	1.7U	3.5I	0.50U	7.0I	0.10U	6.5I	**9.95 ± 2.3**	0.50U	0.50U
CCRW-26	3/19/2019	0.50U	**39**	24.4	1.6U	0.33U	1.7U	3.5I	0.50U	11.5I	0.10U	10.9	**10.1 ± 2.38**	0.50U	0.50U
CCRW-27	3/19/2019	0.50U	1.8	30.8	1.6U	0.33U	1.7I	2.6I	0.50U	9.4I	0.10U	5.7I	**13.6 ± 2.83**	0.50U	0.50U
CCRW-28	3/19/2019	0.50U	0.83I	12.4	1.6U	0.33U	1.7U	1.4I	0.50U	12.3I	0.10U	10.9	2.05U ± 1.3	0.50U	0.50U
CCRW-29	3/19/2019	0.50U	**21.7**	31	1.6U	0.33U	1.7U	2.0I	0.50U	**76.6**	0.10U	7.4I	**9.10 ± 2.61**	0.68I	0.50U
CCRW-30	3/19/2019	0.50U	1	8.2I	1.6U	0.33U	1.7U	1.2I	0.50U	3.8U	0.10U	1.8I	2.01U ± 0.987	0.78I	0.50U

Notes:

[1] - Groundwater protection standard represents USEPA Maximum Contaminant Level unless specified otherwise.

[*] - Groundwater protection standard represents values noted in USEPA'S Amendments to the National Minimum Criteria (Phase One, Part One), Disposal of Coal Combustion Residuals from Electric Utilities; effective July 17, 2018.

µg/L - micrograms per litre

J - Estimated concentration above the method detection limit and below the reporting limit.

mg/L - milligrams per litre

Radium, total - the sum of radium-226 + radium-228

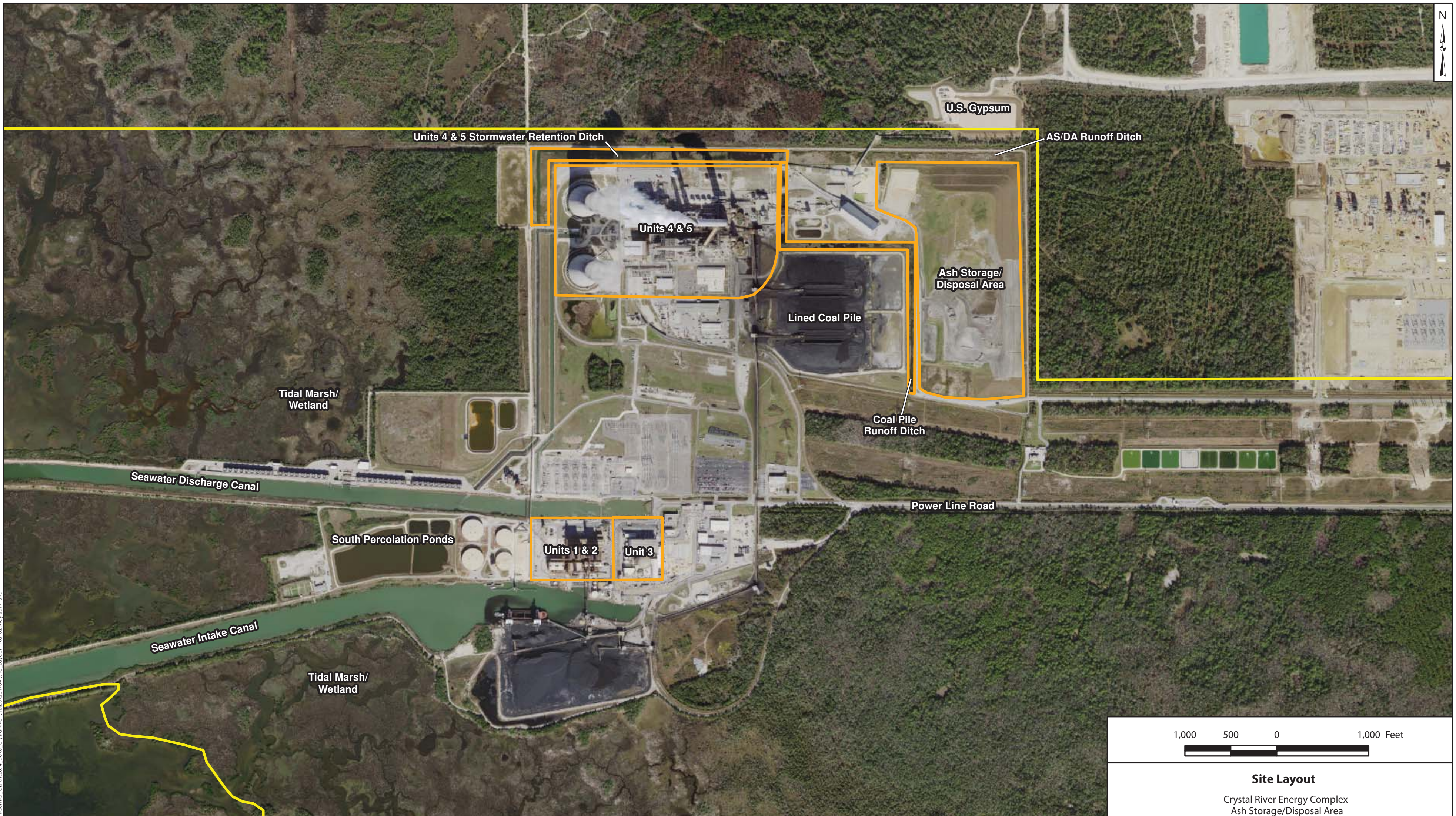
STD - standard units

U – Analyte was analyzed for, but not detected above the reporting limit.

NM indicates not measured

- Bold, highlighted text indicates concentration is above the groundwater protection standard. Note total radium is subject to an Alternate Source Determination.

FIGURES



Legend

Property Boundary

Notes:
1. Property boundary obtained from the Citrus County Property appraiser's office.
2. 2017 World Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Path: (Titusville-01\DATA) T:\0GIS\Duke_Confidential_GIS\FR2674_Duke_CrystalRiver\MXDs\201904\Site_Layout.mxd 02 May 2019 JRB

Site Layout

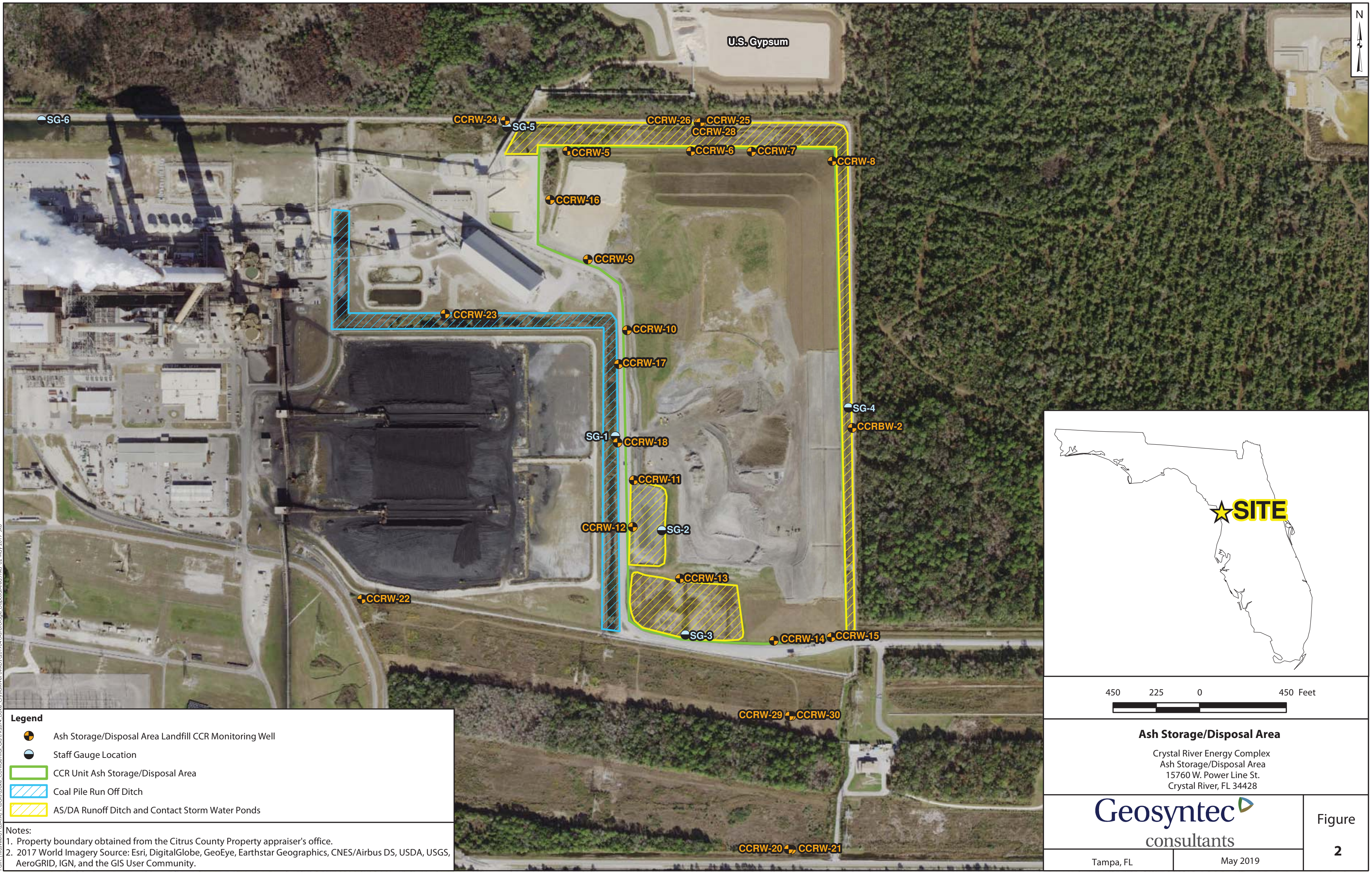
Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Figure **1**

Tampa, FL

May 2019



Legend

- Ash Storage/Disposal Area Landfill CCR Monitoring Well
- Staff Gauge Location
- CCR Unit Ash Storage/Disposal Area
- Coal Pile Run Off Ditch
- AS/DA Runoff Ditch and Contact Storm Water Ponds

Notes:
1. Property boundary obtained from the Citrus County Property appraiser's office.
2. 2017 World Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

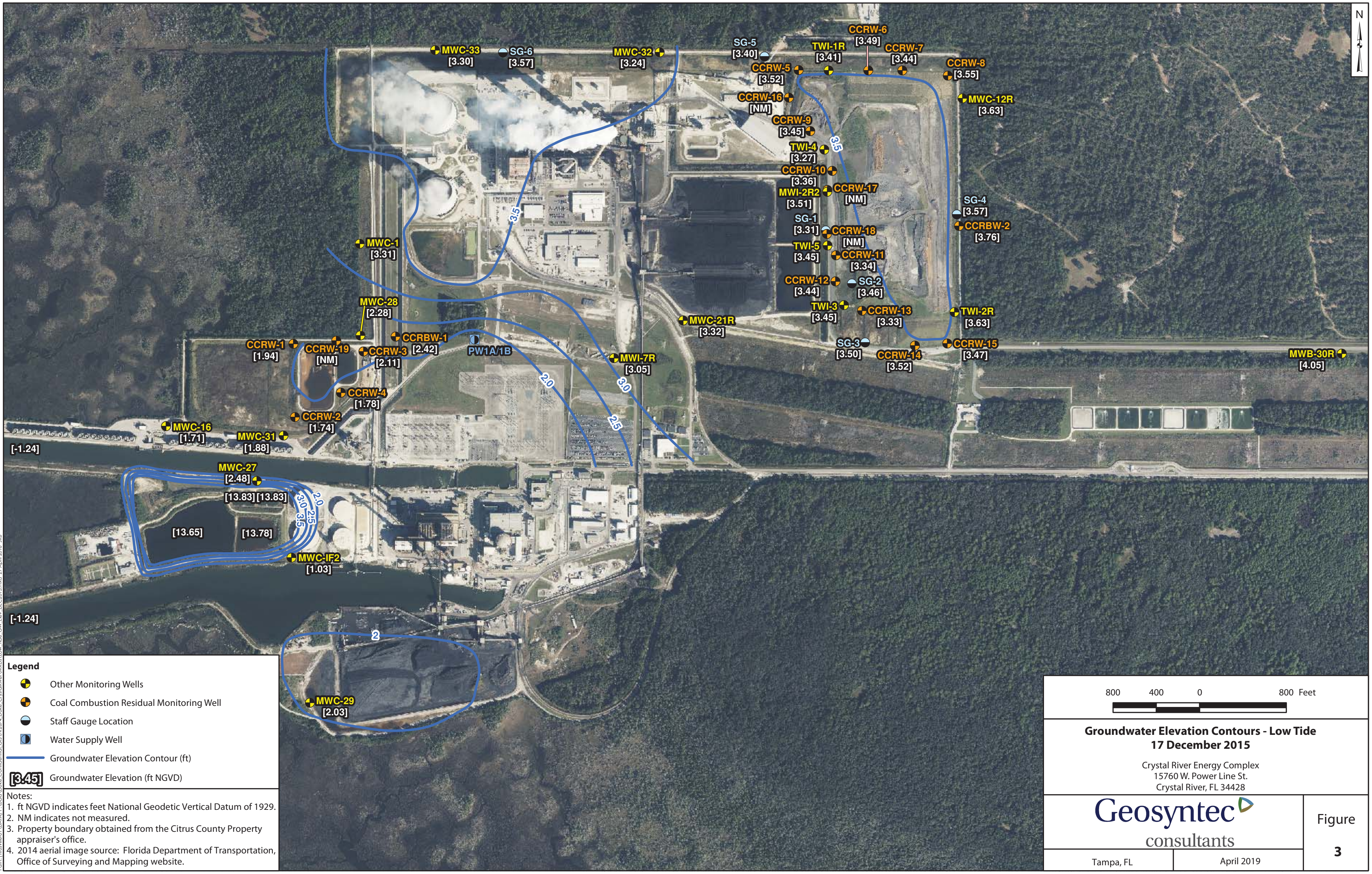
Ash Storage/Disposal Area

Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Tampa, FL | May 2019

Figure 2



Legend

- Other Monitoring Wells
- Coal Combustion Residual Monitoring Well
- Staff Gauge Location
- Water Supply Well
- Groundwater Elevation Contour (ft)
- [3.45] Groundwater Elevation (ft NGVD)

Notes:
1. ft NGVD indicates feet National Geodetic Vertical Datum of 1929.
2. NM indicates not measured.
3. Property boundary obtained from the Citrus County Property appraiser's office.
4. 2014 aerial image source: Florida Department of Transportation, Office of Surveying and Mapping website.

Groundwater Elevation Contours - Low Tide
17 December 2015

Crystal River Energy Complex
15760 W. Power Line St.
Crystal River, FL 34428

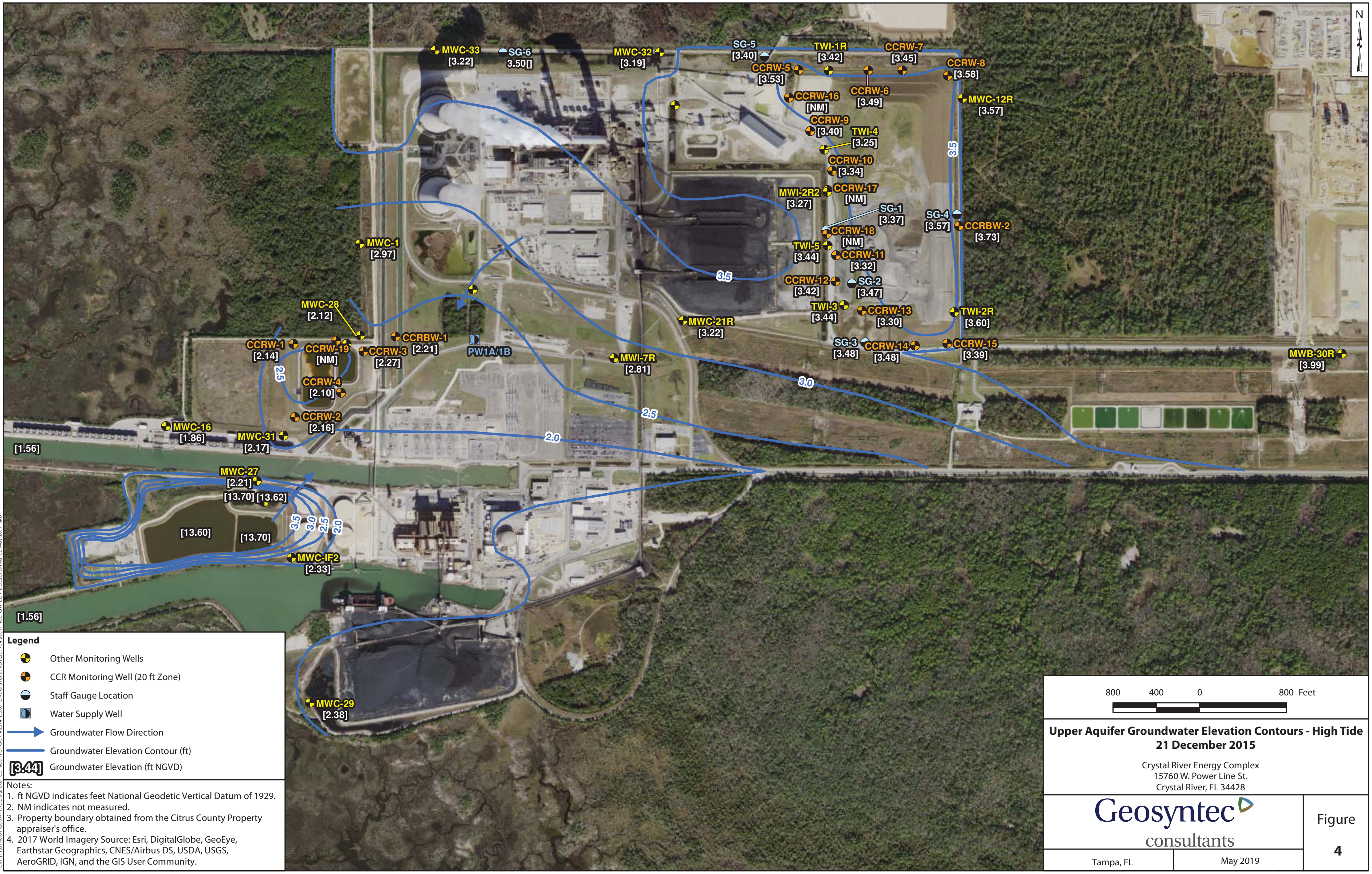
Geosyntec consultants

Figure

3

Tampa, FL

April 2019



Legend

- Other Monitoring Wells
- CCR Monitoring Well (20 ft Zone)
- Staff Gauge Location
- Water Supply Well
- Groundwater Flow Direction
- Groundwater Elevation Contour (ft)
- [3.44] Groundwater Elevation (ft NGVD)

Notes:
1. ft NGVD indicates feet National Geodetic Vertical Datum of 1929.
2. NM indicates not measured.
3. Property boundary obtained from the Citrus County Property appraiser's office.
4. 2017 World Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

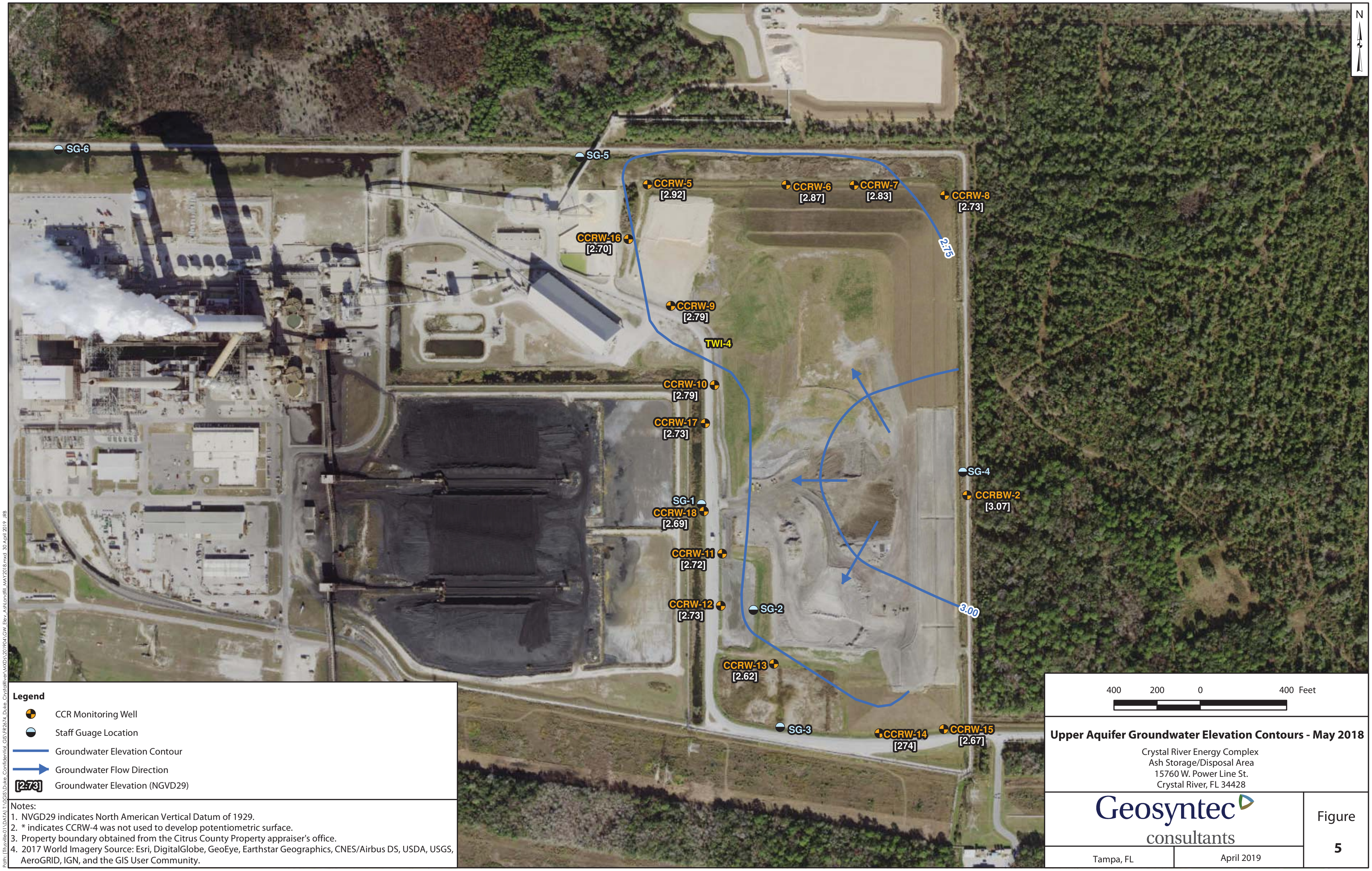
Upper Aquifer Groundwater Elevation Contours - High Tide
21 December 2015

Crystal River Energy Complex
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Figure 4

Tampa, FL | May 2019



Legend

- CCR Monitoring Well
- Staff Guage Location
- Groundwater Elevation Contour
- Groundwater Flow Direction
- [2.73] Groundwater Elevation (NGVD29)

Notes:
1. NVGD29 indicates North American Vertical Datum of 1929.
2. * indicates CCRW-4 was not used to develop potentiometric surface.
3. Property boundary obtained from the Citrus County Property appraiser's office.
4. 2017 World Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

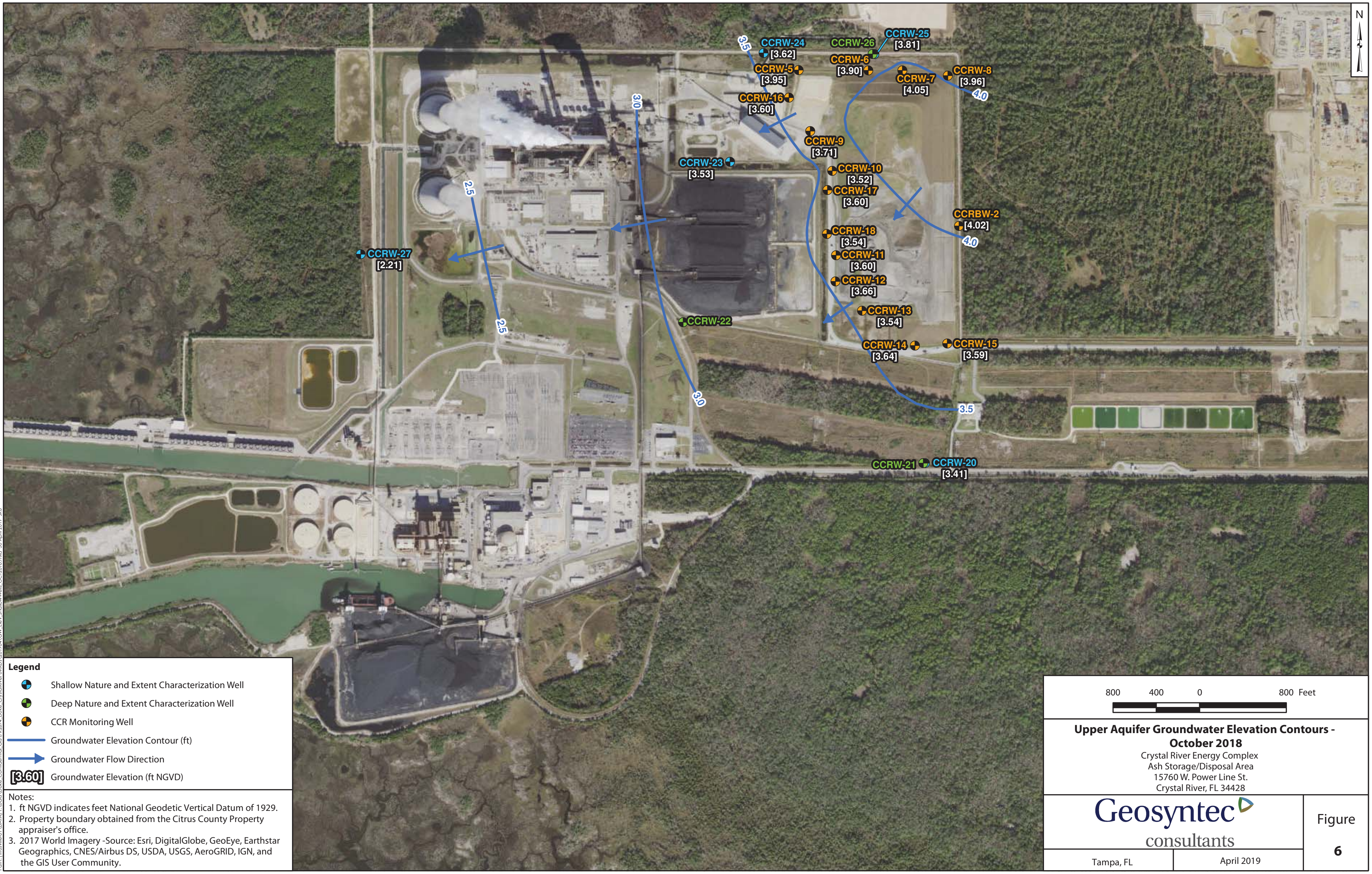
Upper Aquifer Groundwater Elevation Contours - May 2018

Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Tampa, FL | April 2019

Figure 5



Legend

- Shallow Nature and Extent Characterization Well
- Deep Nature and Extent Characterization Well
- CCR Monitoring Well
- Groundwater Elevation Contour (ft)
- Groundwater Flow Direction
- [3.60] Groundwater Elevation (ft NGVD)

Notes:
1. ft NGVD indicates feet National Geodetic Vertical Datum of 1929.
2. Property boundary obtained from the Citrus County Property appraiser's office.
3. 2017 World Imagery -Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

800 400 0 800 Feet

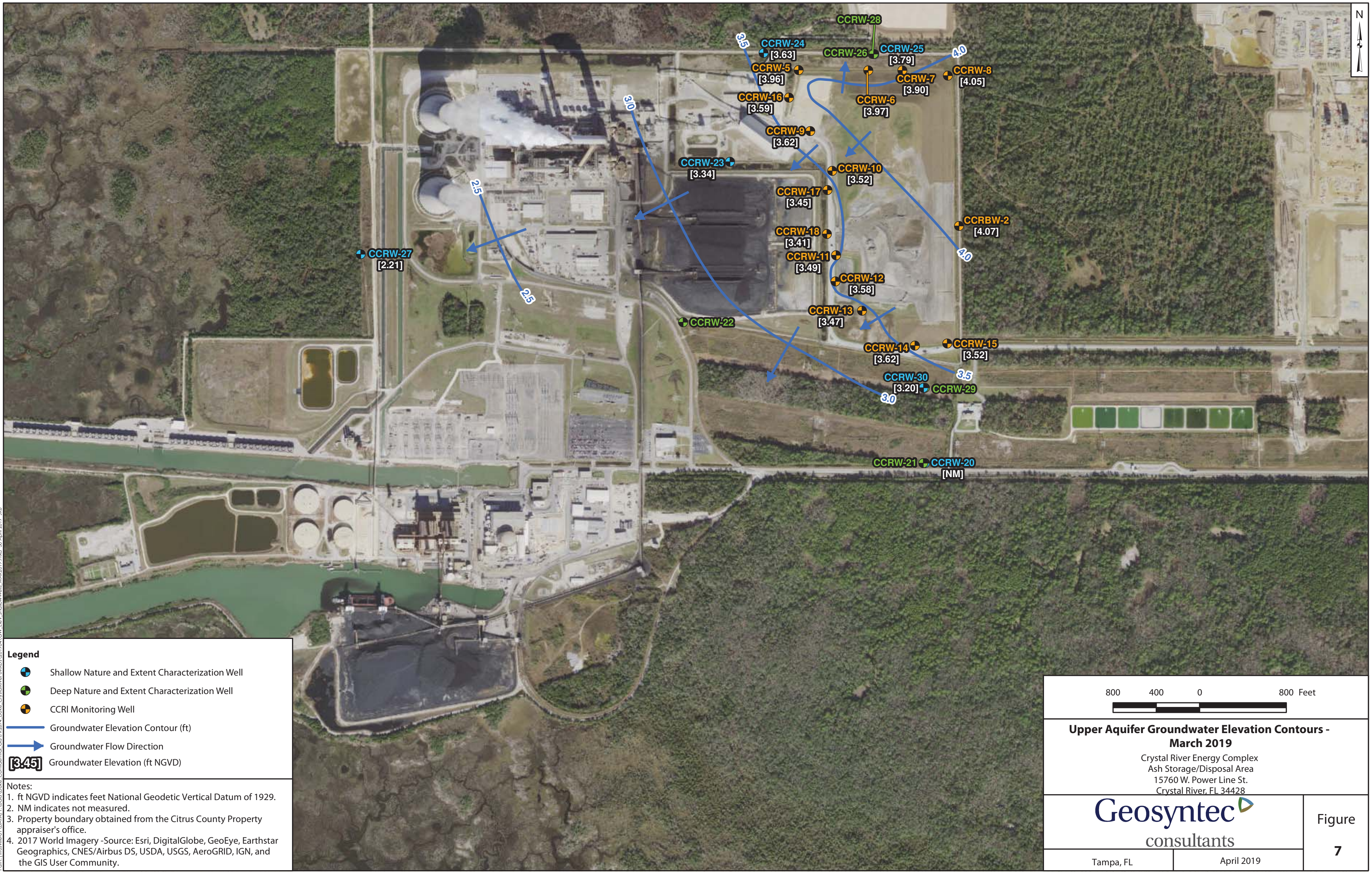
Upper Aquifer Groundwater Elevation Contours - October 2018

Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Figure 6

Tampa, FL | April 2019



Legend

- Shallow Nature and Extent Characterization Well
- Deep Nature and Extent Characterization Well
- CCRI Monitoring Well
- Groundwater Elevation Contour (ft)
- Groundwater Flow Direction
- [3.45] Groundwater Elevation (ft NGVD)

Notes:
1. ft NGVD indicates feet National Geodetic Vertical Datum of 1929.
2. NM indicates not measured.
3. Property boundary obtained from the Citrus County Property appraiser's office.
4. 2017 World Imagery -Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

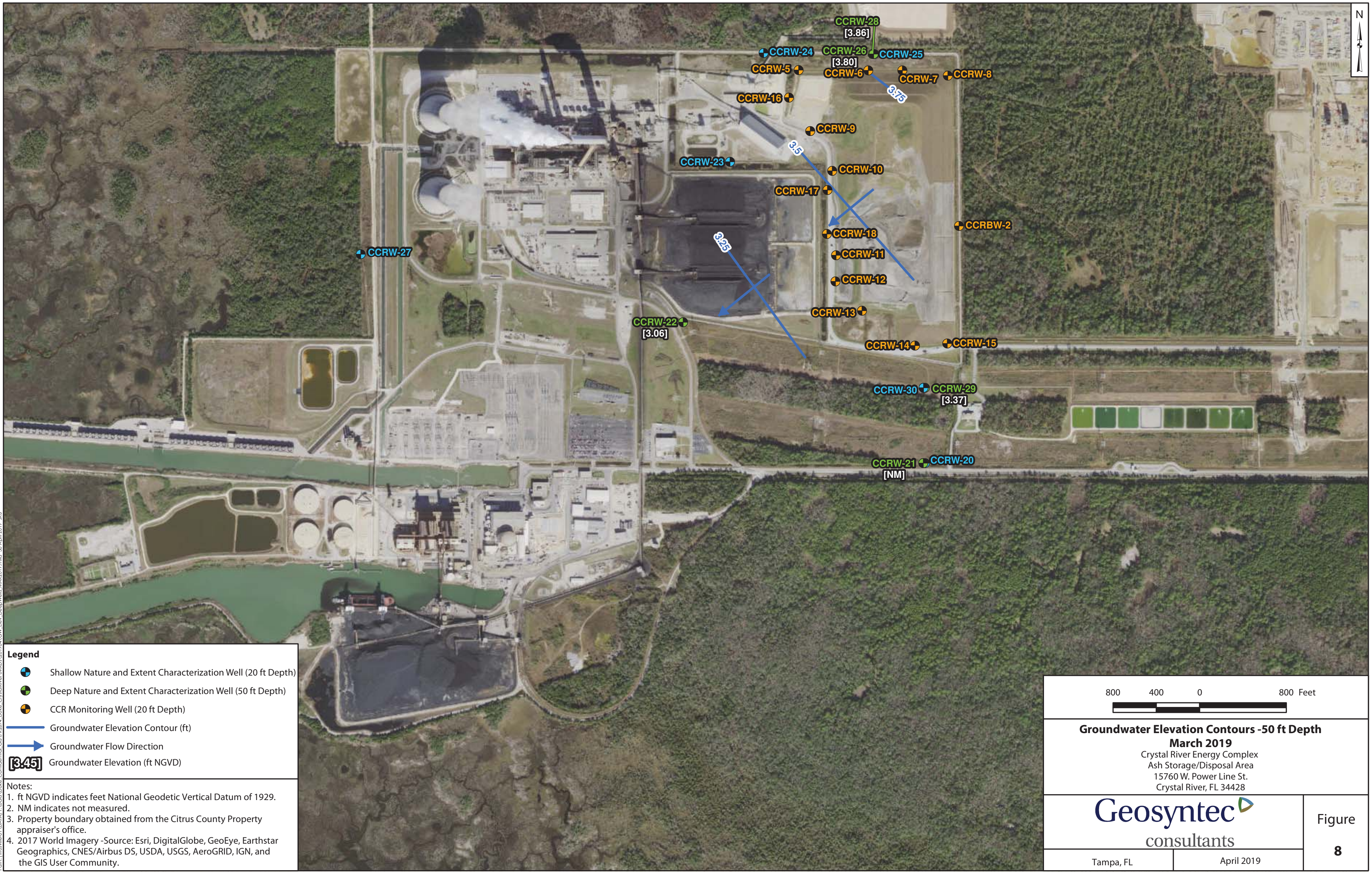
Upper Aquifer Groundwater Elevation Contours - March 2019

Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Tampa, FL | April 2019

Figure 7



Legend

- Shallow Nature and Extent Characterization Well (20 ft Depth)
- Deep Nature and Extent Characterization Well (50 ft Depth)
- CCR Monitoring Well (20 ft Depth)
- Groundwater Elevation Contour (ft)
- Groundwater Flow Direction
- [3.45] Groundwater Elevation (ft NGVD)

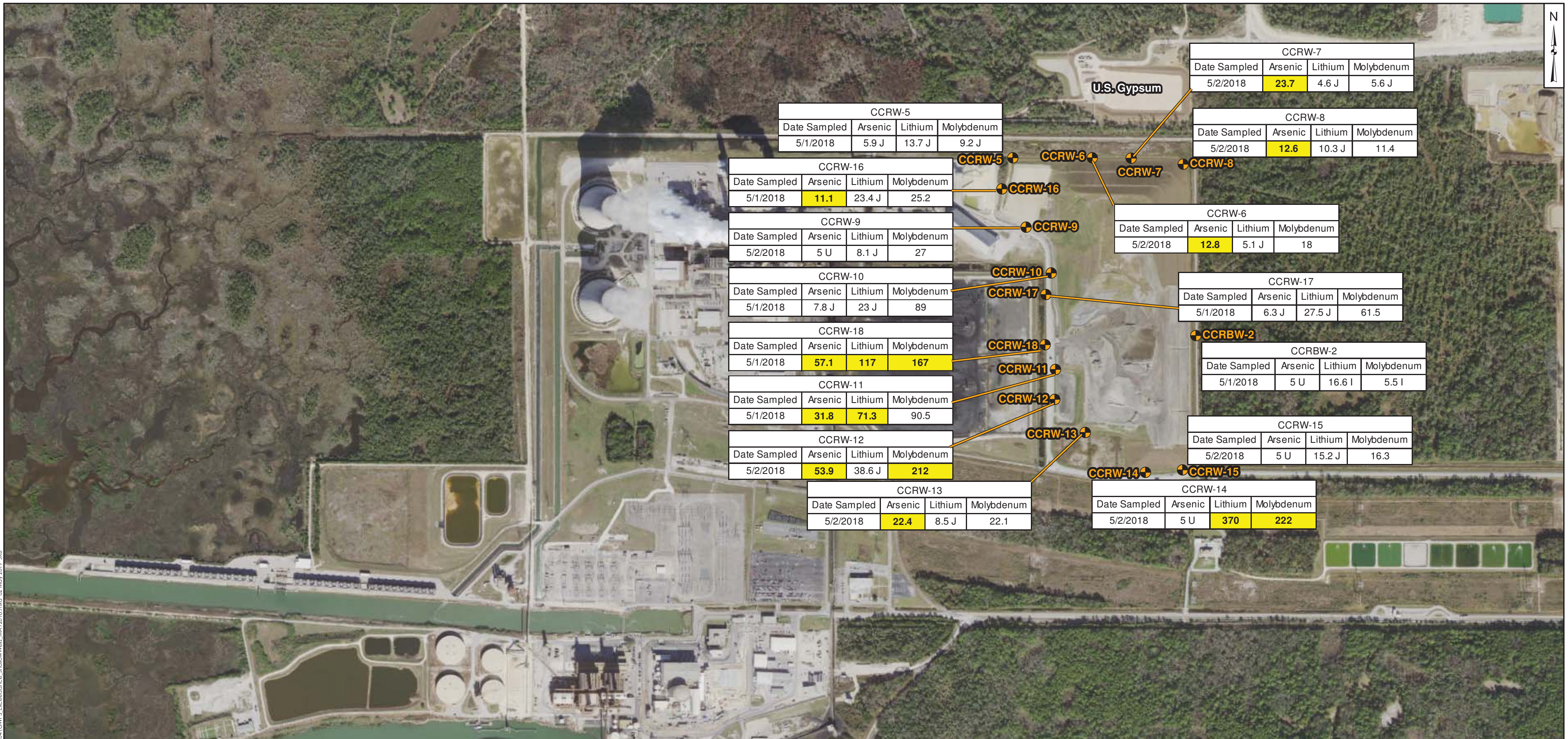
Notes:
1. ft NGVD indicates feet National Geodetic Vertical Datum of 1929.
2. NM indicates not measured.
3. Property boundary obtained from the Citrus County Property appraiser's office.
4. 2017 World Imagery -Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Groundwater Elevation Contours -50 ft Depth
March 2019
Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Tampa, FL | April 2019

Figure **8**



CCRW-7			
Date Sampled	Arsenic	Lithium	Molybdenum
5/2/2018	**23.7**	4.6 J	5.6 J

CCRW-5			
Date Sampled	Arsenic	Lithium	Molybdenum
5/1/2018	5.9 J	13.7 J	9.2 J

CCRW-8			
Date Sampled	Arsenic	Lithium	Molybdenum
5/2/2018	**12.6**	10.3 J	11.4

CCRW-16			
Date Sampled	Arsenic	Lithium	Molybdenum
5/1/2018	**11.1**	23.4 J	25.2

CCRW-6			
Date Sampled	Arsenic	Lithium	Molybdenum
5/2/2018	**12.8**	5.1 J	18

CCRW-9			
Date Sampled	Arsenic	Lithium	Molybdenum
5/2/2018	5 U	8.1 J	27

CCRW-10			
Date Sampled	Arsenic	Lithium	Molybdenum
5/1/2018	7.8 J	23 J	89

CCRW-17			
Date Sampled	Arsenic	Lithium	Molybdenum
5/1/2018	6.3 J	27.5 J	61.5

CCRW-18			
Date Sampled	Arsenic	Lithium	Molybdenum
5/1/2018	**57.1**	**117**	**167**

CCRBW-2			
Date Sampled	Arsenic	Lithium	Molybdenum
5/1/2018	5 U	16.6 I	5.5 I

CCRW-11			
Date Sampled	Arsenic	Lithium	Molybdenum
5/1/2018	**31.8**	**71.3**	90.5

CCRW-15			
Date Sampled	Arsenic	Lithium	Molybdenum
5/2/2018	5 U	15.2 J	16.3

CCRW-12			
Date Sampled	Arsenic	Lithium	Molybdenum
5/2/2018	**53.9**	38.6 J	**212**

CCRW-13			
Date Sampled	Arsenic	Lithium	Molybdenum
5/2/2018	**22.4**	8.5 J	22.1

CCRW-14			
Date Sampled	Arsenic	Lithium	Molybdenum
5/2/2018	5 U	**370**	**222**

Legend

CCR Monitoring Well (20 ft Depth)

Appendix IV Constituent	Arsenic, total	Lithium, total	Molybdenum, total
Units	ug/L	ug/L	ug/L
Groundwater Protection Standard[1]	10	40*	100*

Notes:
1. Groundwater protection standard (GWPS) represents USEPA Maximum Contaminant Level unless specified otherwise.
2. * indicates groundwater protection standard represents values noted in USEPA'S Amendments to the National Minimum Criteria (Phase One, Part One), Disposal of Coal Combustion Residuals from Electric Utilities; effective July 17, 2018.
3. Results are presented in micrograms per liter (µg/L).
4. U indicates analyte was analyzed for, but not detected above the reporting limit.
5. I indicates the result is between the laboratory method detection limit and the practical quantitation limit.
6. J indicates estimated concentration above the method detection limit and below the reporting limit.
7. Bold, yellow highlighted text indicates the concentration is above the groundwater protection standard.
8. Property boundary obtained from the Citrus County Property appraiser's office.
9. 2017 World Imagery -Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

800 400 0 800 Feet

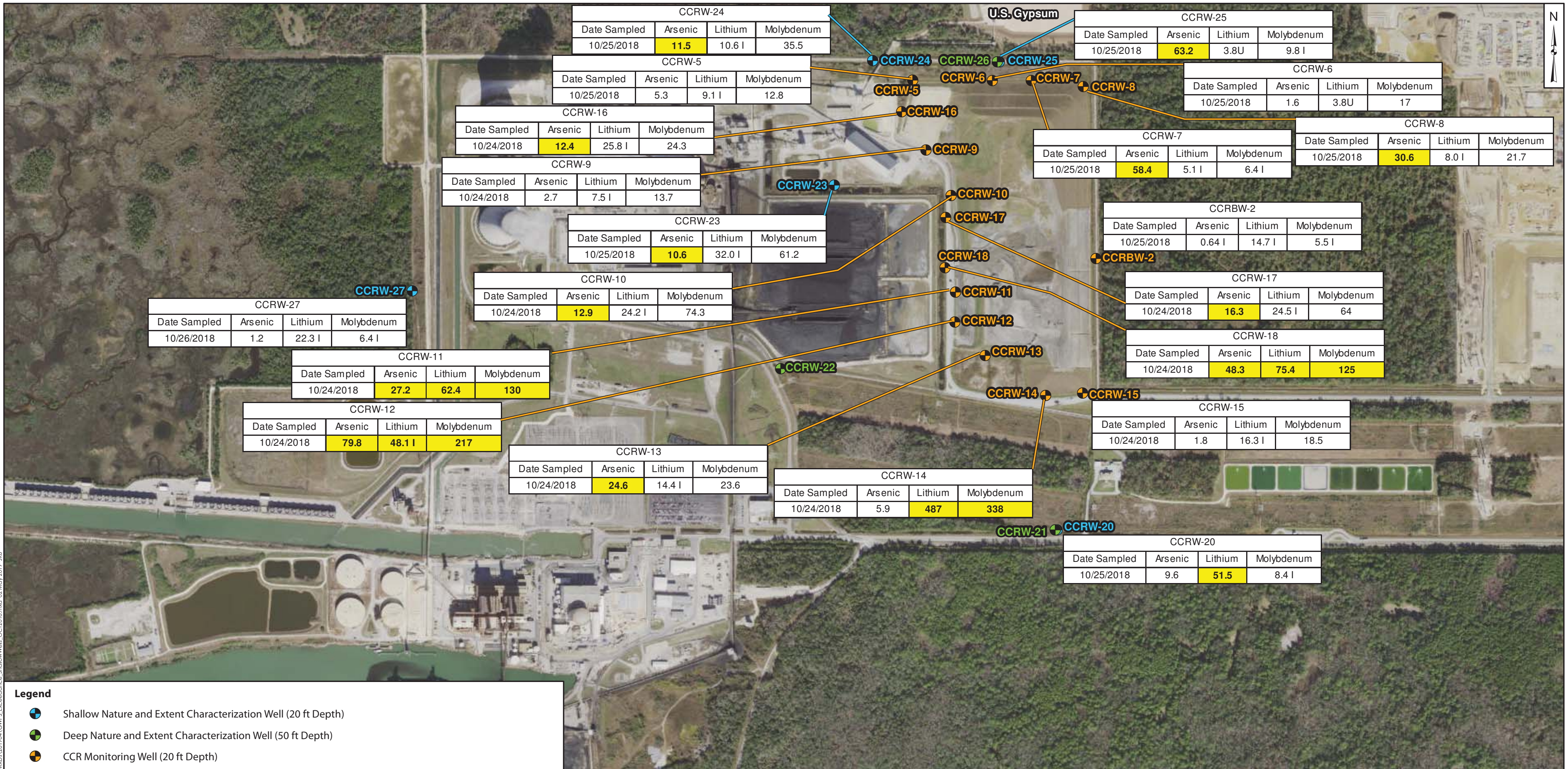
Appendix IV GWPS Exceedances - 20 ft Depth Wells
May 2018

Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Tampa, FL | May 2019

Figure 9



CCRW-24

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	**11.5**	10.6 I	35.5

CCRW-5

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	5.3	9.1 I	12.8

CCRW-16

Date Sampled	Arsenic	Lithium	Molybdenum
10/24/2018	**12.4**	25.8 I	24.3

CCRW-9

Date Sampled	Arsenic	Lithium	Molybdenum
10/24/2018	2.7	7.5 I	13.7

CCRW-23

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	**10.6**	32.0 I	61.2

CCRW-10

Date Sampled	Arsenic	Lithium	Molybdenum
10/24/2018	**12.9**	24.2 I	74.3

CCRW-27

Date Sampled	Arsenic	Lithium	Molybdenum
10/26/2018	1.2	22.3 I	6.4 I

CCRW-11

Date Sampled	Arsenic	Lithium	Molybdenum
10/24/2018	**27.2**	**62.4**	**130**

CCRW-12

Date Sampled	Arsenic	Lithium	Molybdenum
10/24/2018	**79.8**	**48.1 I**	**217**

CCRW-13

Date Sampled	Arsenic	Lithium	Molybdenum
10/24/2018	**24.6**	14.4 I	23.6

CCRW-14

Date Sampled	Arsenic	Lithium	Molybdenum
10/24/2018	5.9	**487**	**338**

CCRW-25

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	**63.2**	3.8U	9.8 I

CCRW-6

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	1.6	3.8U	17

CCRW-8

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	**30.6**	8.0 I	21.7

CCRW-7

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	**58.4**	5.1 I	6.4 I

CCRBW-2

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	0.64 I	14.7 I	5.5 I

CCRW-17

Date Sampled	Arsenic	Lithium	Molybdenum
10/24/2018	**16.3**	24.5 I	64

CCRW-18

Date Sampled	Arsenic	Lithium	Molybdenum
10/24/2018	**48.3**	**75.4**	**125**

CCRW-15

Date Sampled	Arsenic	Lithium	Molybdenum
10/24/2018	1.8	16.3 I	18.5

CCRW-20

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	9.6	**51.5**	8.4 I

Legend

- Shallow Nature and Extent Characterization Well (20 ft Depth)
- Deep Nature and Extent Characterization Well (50 ft Depth)
- CCR Monitoring Well (20 ft Depth)

Appendix IV Constituent	Arsenic, total	Lithium, total	Molybdenum, total
Units	ug/L	ug/L	ug/L
Groundwater Protection Standard[1]	10	40*	100*

Notes:
1. Groundwater protection standard (GWPS) represents USEPA Maximum Contaminant Level unless specified otherwise.
2. * indicates groundwater protection standard represents values noted in USEPA'S Amendments to the National Minimum Criteria (Phase One, Part One), Disposal of Coal Combustion Residuals from Electric Utilities; effective July 17, 2018.
3. Results are presented in micrograms per liter (µg/L).
4. U indicates analyte was analyzed for, but not detected above the reporting limit.
5. I indicates the result is between the laboratory method detection limit and the practical quantitation limit.
6. Bold, yellow highlighted text indicates the concentration is above the groundwater protection standard.
7. Property boundary obtained from the Citrus County Property appraiser's office.
8. 2017 World Imagery -Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

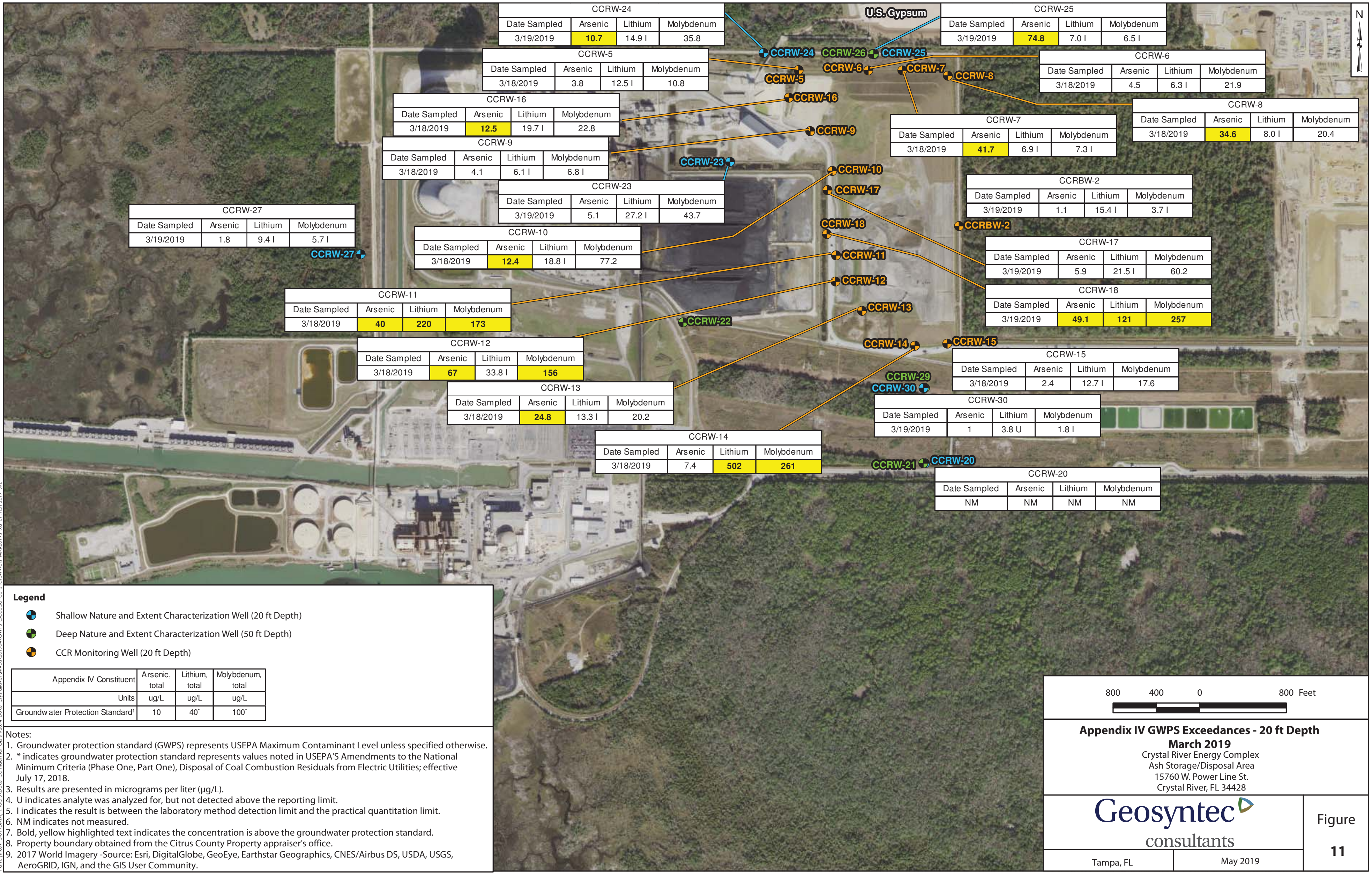
Appendix IV GWPS Exceedances - 20 ft Depth
October 2018

Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Tampa, FL | May 2019

Figure **10**



CCRW-24

Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	**10.7**	14.9 I	35.8

CCRW-25

Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	**74.8**	7.0 I	6.5 I

CCRW-5

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	3.8	12.5 I	10.8

CCRW-6

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	4.5	6.3 I	21.9

CCRW-16

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	**12.5**	19.7 I	22.8

CCRW-8

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	**34.6**	8.0 I	20.4

CCRW-7

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	**41.7**	6.9 I	7.3 I

CCRW-9

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	4.1	6.1 I	6.8 I

CCRW-23

Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	5.1	27.2 I	43.7

CCRBW-2

Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	1.1	15.4 I	3.7 I

CCRW-27

Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	1.8	9.4 I	5.7 I

CCRW-10

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	**12.4**	18.8 I	77.2

CCRW-17

Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	5.9	21.5 I	60.2

CCRW-18

Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	**49.1**	**121**	**257**

CCRW-11

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	**40**	**220**	**173**

CCRW-12

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	**67**	33.8 I	**156**

CCRW-15

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	2.4	12.7 I	17.6

CCRW-13

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	**24.8**	13.3 I	20.2

CCRW-30

Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	1	3.8 U	1.8 I

CCRW-14

Date Sampled	Arsenic	Lithium	Molybdenum
3/18/2019	7.4	**502**	**261**

CCRW-20

Date Sampled	Arsenic	Lithium	Molybdenum
NM	NM	NM	NM

Legend

- Shallow Nature and Extent Characterization Well (20 ft Depth)
- Deep Nature and Extent Characterization Well (50 ft Depth)
- CCR Monitoring Well (20 ft Depth)

Appendix IV Constituent	Arsenic, total	Lithium, total	Molybdenum, total
Units	ug/L	ug/L	ug/L
Groundwater Protection Standard[1]	10	40*	100*

Notes:
1. Groundwater protection standard (GWPS) represents USEPA Maximum Contaminant Level unless specified otherwise.
2. * indicates groundwater protection standard represents values noted in USEPA'S Amendments to the National Minimum Criteria (Phase One, Part One), Disposal of Coal Combustion Residuals from Electric Utilities; effective July 17, 2018.
3. Results are presented in micrograms per liter (µg/L).
4. U indicates analyte was analyzed for, but not detected above the reporting limit.
5. I indicates the result is between the laboratory method detection limit and the practical quantitation limit.
6. NM indicates not measured.
7. Bold, yellow highlighted text indicates the concentration is above the groundwater protection standard.
8. Property boundary obtained from the Citrus County Property appraiser's office.
9. 2017 World Imagery -Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

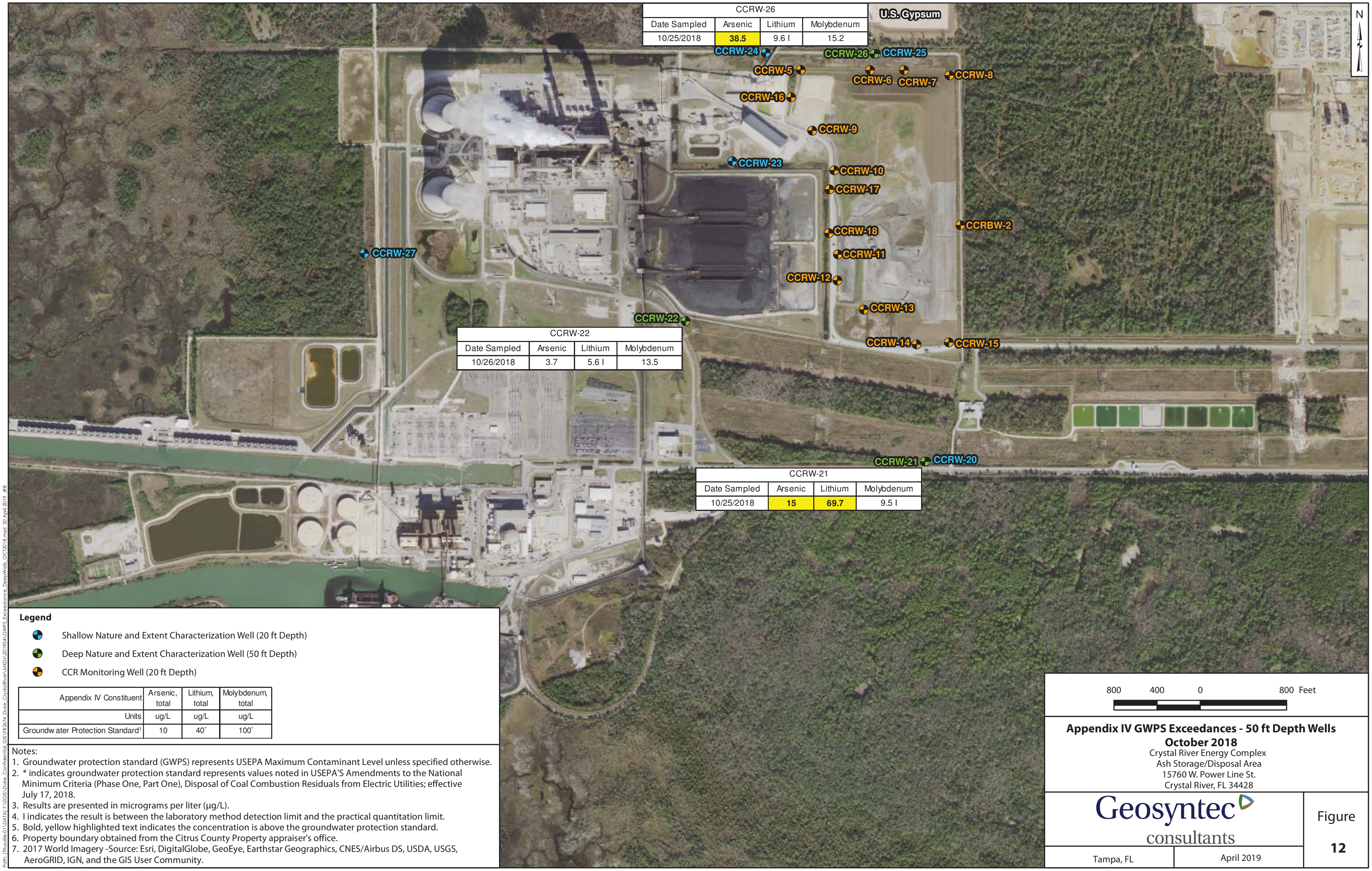
Path: (Titusville-01\DATA) T:\0GIS\Duke_Confidential_GIS\FR2674_Duke_CrystalRiver\MXDs\201904\GWPS_Exceedance_ShallowWells_MAR2019.mxd 01 May 2019 JRB

Appendix IV GWPS Exceedances - 20 ft Depth
March 2019
Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Tampa, FL | May 2019

Figure **11**



CCRW-26

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	**38.5**	9.6 I	15.2

CCRW-22

Date Sampled	Arsenic	Lithium	Molybdenum
10/26/2018	3.7	5.6 I	13.5

CCRW-21

Date Sampled	Arsenic	Lithium	Molybdenum
10/25/2018	**15**	**69.7**	9.5 I

Legend

- Shallow Nature and Extent Characterization Well (20 ft Depth)
- Deep Nature and Extent Characterization Well (50 ft Depth)
- CCR Monitoring Well (20 ft Depth)

Appendix IV Constituent	Arsenic, total	Lithium, total	Molybdenum, total
Units	ug/L	ug/L	ug/L
Groundwater Protection Standard[1]	10	40*	100*

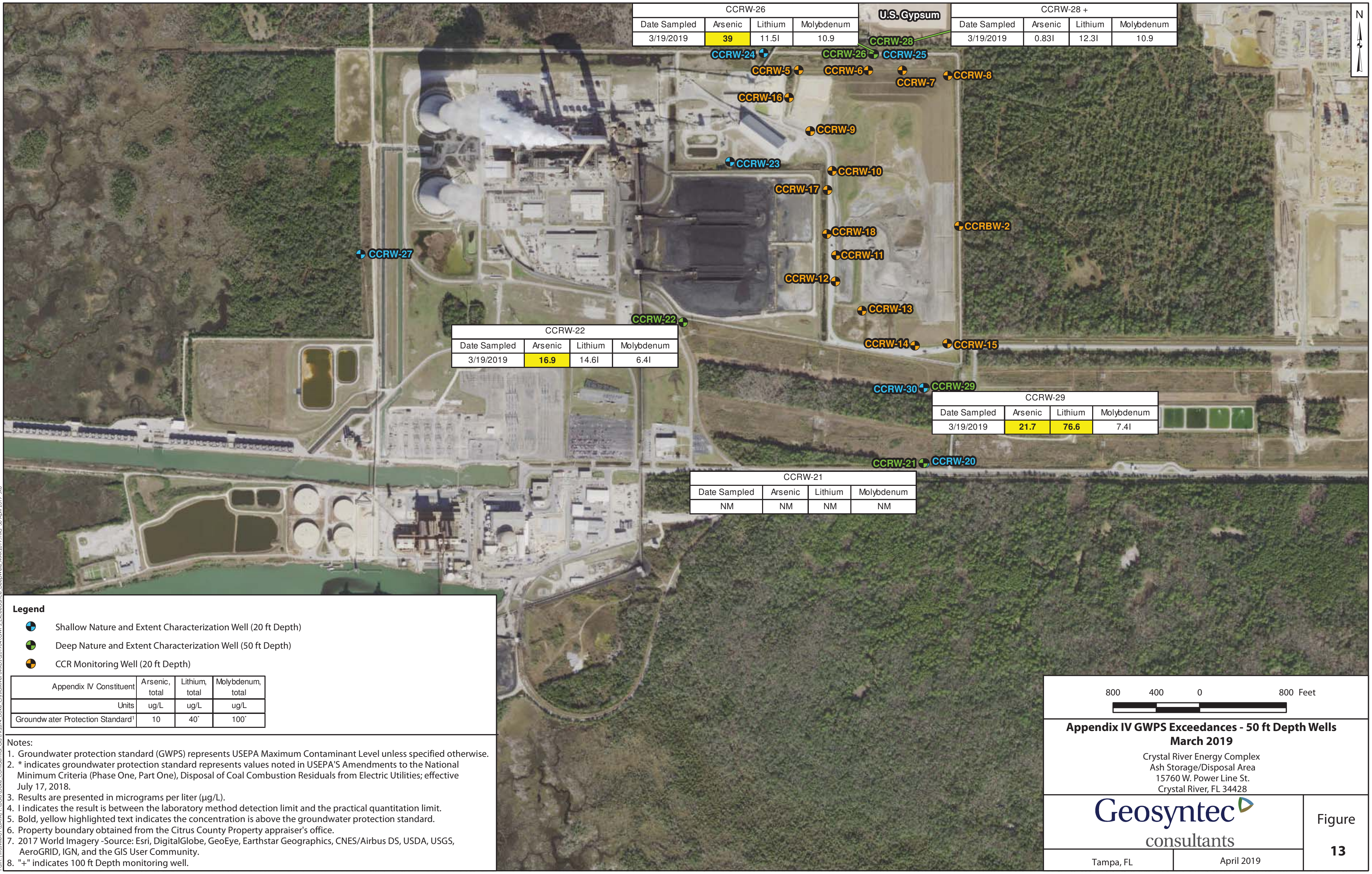
Notes:
1. Groundwater protection standard (GWPS) represents USEPA Maximum Contaminant Level unless specified otherwise.
2. * indicates groundwater protection standard represents values noted in USEPA'S Amendments to the National Minimum Criteria (Phase One, Part One), Disposal of Coal Combustion Residuals from Electric Utilities; effective July 17, 2018.
3. Results are presented in micrograms per liter (µg/L).
4. I indicates the result is between the laboratory method detection limit and the practical quantitation limit.
5. Bold, yellow highlighted text indicates the concentration is above the groundwater protection standard.
6. Property boundary obtained from the Citrus County Property appraiser's office.
7. 2017 World Imagery -Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Appendix IV GWPS Exceedances - 50 ft Depth Wells
October 2018
Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Tampa, FL | April 2019

Figure **12**



CCRW-26			
Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	**39**	11.5I	10.9

CCRW-28 +			
Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	0.83I	12.3I	10.9

CCRW-22			
Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	**16.9**	14.6I	6.4I

CCRW-29			
Date Sampled	Arsenic	Lithium	Molybdenum
3/19/2019	**21.7**	**76.6**	7.4I

CCRW-21			
Date Sampled	Arsenic	Lithium	Molybdenum
NM	NM	NM	NM

Legend

- Shallow Nature and Extent Characterization Well (20 ft Depth)
- Deep Nature and Extent Characterization Well (50 ft Depth)
- CCR Monitoring Well (20 ft Depth)

Appendix IV Constituent	Arsenic, total	Lithium, total	Molybdenum, total
Units	ug/L	ug/L	ug/L
Groundwater Protection Standard[1]	10	40*	100*

Notes:
1. Groundwater protection standard (GWPS) represents USEPA Maximum Contaminant Level unless specified otherwise.
2. * indicates groundwater protection standard represents values noted in USEPA'S Amendments to the National Minimum Criteria (Phase One, Part One), Disposal of Coal Combustion Residuals from Electric Utilities; effective July 17, 2018.
3. Results are presented in micrograms per liter (µg/L).
4. I indicates the result is between the laboratory method detection limit and the practical quantitation limit.
5. Bold, yellow highlighted text indicates the concentration is above the groundwater protection standard.
6. Property boundary obtained from the Citrus County Property appraiser's office.
7. 2017 World Imagery -Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
8. "+" indicates 100 ft Depth monitoring well.

Appendix IV GWPS Exceedances - 50 ft Depth Wells
March 2019

Crystal River Energy Complex
Ash Storage/Disposal Area
15760 W. Power Line St.
Crystal River, FL 34428

Geosyntec consultants

Figure **13**

Tampa, FL | April 2019

Path: (Titusville-01\DATA) T:\0GIS\Duke_Confidential_GIS\FR2674_Duke_CrystalRiver\MXDs\201904\GWPS_Exceedance_DeepWells_MAR2019.mxd 30 April 2019 JRB

APPENDIX A
Potential Groundwater Remedies

APPENDIX A – POTENTIAL GROUNDWATER REMEDIES

CCR Assessment of Corrective Measures Report

Ash Storage/Disposal Area

Crystal River Energy Complex

15760 W. Power Line Street

Crystal River, Citrus County, Florida

Prepared for

Duke Energy Florida, LLC

Prepared by

Geosyntec Consultants, Inc.
12802 Tampa Oaks Blvd., Suite 151
Tampa, Florida 33637

Project FR3319

June 2019

TABLE OF CONTENTS

1. INTRODUCTION

The following sections summarize the groundwater remedial technologies that were evaluated to address arsenic, lithium, and molybdenum that have been detected at statistically significant levels exceeding their respective groundwater protection standards at the Ash Storage/Disposal Area (AS/DA). These technologies correspond with **Section 4.3** in the Assessment of Corrective Measures report and include in-situ, groundwater extraction, and groundwater treatment technologies and monitored natural attenuation (MNA). **Appendix B** presents the remedial technologies evaluation and **Table 1** summarizes the treatment technology evaluation.

2. IN-SITU TECHNOLOGIES

In-situ groundwater treatment technologies address constituents of interest (COI) through in place treatment without extraction of impacted media. The following sections summarize the in-situ treatment technologies evaluated to address groundwater impacts at the AS/DA.

2.1 Permeable Reactive Barriers (PRB)

PRBs consists of a permeable treatment zone installed in a trench excavated below the water table and aligned perpendicular to groundwater flow to intercept and treat contaminated groundwater. Reactive materials (e.g., zero valent iron [ZVI], mulch, activated carbon, and zeolites) are installed within the permeable treatment zone for passive groundwater treatment as it flows through the barrier (USEPA, 2014). Within the treatment zone, a series of chemically and/or biologically-mediated reactions occur to immobilize or chemically transform groundwater constituents (USEPA, 1998). Conceptually, PRBs can consist of (a) funnel-and-gate configurations in which low permeability zones or walls (funnel) are installed to direct groundwater flow through the PRB (gate) or (b) continuous PRB trenches that completely intersect the width of the contaminant plume (USEPA, 2019). In both scenarios, the optimal design involves extending the PRB to a lower confining unit to reduce the potential for groundwater flow beneath the treatment zone. This design criteria presents a challenge at the Crystal River Energy Complex (CREC) due to the karstic nature of the underlying sediments (limestone of the Ocala Formation containing numerous voids and secondary porosity) at the Site. Implementation is constrained by the uncertainty in the geology due the presence of karst and the absence of a low permeability layer to key the base of the PRB into. A PRB installed in this type of setting would be less effective as soluble constituents in groundwater would likely flow beneath the PRB and bypass the treatment zone. An impractical level of geologic exploration and design would be required to ensure efficacy of the PRB.

Another consideration for PRBs is the selection of reactive material for the permeable zone to meet performance criteria concerning media longevity and treatment effectiveness. Reactive materials commonly utilized in PRBs have finite treatment lifecycles that are impacted by Site-specific groundwater characteristics (e.g., the geochemical composition, abundance of biological activity, and chemical composition of the groundwater). Furthermore, different reactive materials have varying reactive potentials with COI. ZVI is effective in reducing dissolved arsenic concentrations and other cationic metals in groundwater; however, its specific effectiveness for treating molybdenum and lithium is not well documented (USEPA, 2019). Pilot studies would be necessary to evaluate the treatment effectiveness and longevity of different reactive materials in treating the Site groundwater with high concentrations of chloride and total dissolved solids (TDS) that range from 6.7 to 1,809 milligrams per liter (mg/L) and 407 to 3,440 mg/L, respectively, in the CCR monitoring well network across the Site.

2.2 Groundwater Flow Barriers

Low permeability groundwater flow barriers isolate contaminated groundwater at the source and prevent contaminated groundwater from migrating outside the contained location. In contrast to PRBs, low permeability barriers do not provide treatment of contaminated groundwater. The installation of low permeability barriers can serve dual purposes by minimizing the movement of contaminated groundwater into uncontaminated areas and minimizing the movement of uncontaminated groundwater into contaminated areas. Low permeability barriers can be constructed from natural (soil and bentonite), synthetic (cement or sheet piling), or composite (bentonite and cement) materials (USEPA, 1992). By disrupting the natural groundwater flow regime, low permeability barriers lead to altered groundwater flow patterns, such as groundwater mounding due to surface infiltration or the diversion of groundwater beneath or around the barriers, that must be addressed to retain the long-term effectiveness of the remedy. Groundwater extraction wells can be installed to mitigate these effects but will require ex-situ treatment of the dissolved contaminants. However, the challenges discussed above for PRBs in creating a competent seal at the base of the barrier in the underlying karstic limestone still apply.

2.3 Chemical Immobilization

This remedial strategy involves the injection of chemical reagents (e.g., ZVI), into contaminated areas of the aquifer to immobilize metals by absorption or precipitation reactions to form less toxic by-products (USEPA, 2019). Chemical reagents for immobilizing arsenic are documented; however, chemical reagents capable of immobilizing lithium and molybdenum are not well-documented.

The effectiveness of chemical immobilization is limited by contact of chemical reagents with COI within groundwater. The karst features at the CREC present a reagent delivery challenge for injecting amendments into the subsurface due to the uncertainty of contacting COI because of preferential flow. Karst features may also contain secondary sources of COI or lingering coal combustion residual (CCR) sources that consume chemical reagents, reducing the concentrations available to react with COI.

Remobilization of stabilized metals may occur following treatment, depending upon the geochemical conditions (e.g., pH and redox conditions) that persist in the aquifer following treatment (USEPA, 2019). To mitigate the effects of remobilization reactions from immobile to dissolved phases, additional amendments or chemical reagents can be periodically injected into the treatment areas, which requires the installation of a permanent injection well network and periodic groundwater performance monitoring. Additionally, the immobilization of one constituent through chemical reduction may mobilize different constituents. Pilot scale treatment studies with Site-specific groundwater would be necessary to evaluate the behavior of COI and the mineral phases that form in response to the addition of different chemical reagents.

3. EX-SITU TECHNOLOGIES

In contrast to in-situ technologies, ex-situ remedial alternatives involve the extraction of contaminated groundwater for subsequent treatment. Contaminated groundwater can be treated on-Site for reintroduction into the aquifer via infiltration galleries (trenches) or injection wells or removed for off-Site treatment and/or disposal. The use of injection wells would likely require a State of Florida Underground Injection Control permit.

3.1 Conventional Groundwater Extraction

Groundwater extraction removes constituent mass from the groundwater for subsequent treatment and disposal and can provide hydraulic control to reduce or prevent groundwater constituent migration. Hydraulic containment controls the movement of the contaminated groundwater and prevents the continued migration and expansion of the groundwater plume (USEPA, 1996). Groundwater extraction techniques that could apply to CREC include the following:

- Conventional vertical extraction wells in unconsolidated soils or limestone;
- Horizontal wells that are directionally drilled; and
- Collection trenches (depths are dependent upon excavation techniques but are typically shallower than horizontal wells).

Groundwater extraction is feasible at CREC due to the shallow depth to water and high aquifer permeability. However, hydraulic capture is directly related to the spacing of extraction wells and screened intervals. Extraction well design and hydraulic capture in karstic sediments would prove difficult due to preferential flowpaths and interconnected secondary porosity within the aquifer. Aquifer testing (e.g., pumping tests) and numerical groundwater modeling would be required to design the extraction system. The karst features also present challenges in predicting and controlling the groundwater flow behavior through these features when coupled with active pumping and reinjection. In addition, groundwater extraction could also require measures to avoid impacts to wetlands in surrounding lands. Extraction wells and equipment must be selected to prevent fouling and corrosion associated with the high TDS and chloride concentrations present in groundwater at the Site.

3.2 Phytoremediation – Groundwater Extraction

In comparison to conventional groundwater extraction methods, phytoremediation is a passive groundwater extraction method that relies on the diurnal metabolic activity of trees for extracting groundwater from the subsurface. During sunlight exposure, the metabolic activity of trees increases from increased photosynthesis and consequently, results in the increased uptake ("pumping") of groundwater through root systems. For remediation applications, trees are installed in engineered "tree wells" that provide the necessary depth for roots to intercept impacted groundwater flow. As the roots extract and "pump" groundwater, there is hydraulic containment of the contamination to mitigate further migration of the impacted groundwater. Additionally, different tree species are capable of uptake, metabolism, and sequestration of inorganics in the root zone.

Design of an effective phytoremediation system may be limited due to the karstic nature of the sediments, the high permeability of the aquifer at the CREC, and the number of tree wells required to capture and contain contaminated groundwater. Additionally, the high TDS and chloride concentrations present in the groundwater at CREC may limit the number of appropriate plant species for this required for this treatment strategy.

3.3 Groundwater Treatment

Extracted groundwater must be treated to remove constituent mass prior to discharge or re-injection into the aquifer. The strategy is frequently utilized with groundwater extraction techniques and is commonly known as "pump-and-treat." The following sections summarize specific groundwater treatment strategies for inorganics.

3.3.1 Adsorption Technologies

This treatment strategy involves passing contaminated groundwater through adsorptive granular media that physically and chemically interact with COI to remove them from the liquid phase (USEPA, 2019; Nicomel et al., 2016). Over time, the number of available adsorption sites decreases and requires regeneration or replacement of the media to maintain effectiveness. Regeneration or replacement of spent media creates a secondary waste stream that requires off-Site disposal.

Common granular media include activated alumina, zirconium-based media, titanium-based media, iron-based media, and carbon-based media (USEPA, 2019). Different media types are selective in terms of absorbing different inorganics. The presence of cations at elevated concentrations at CREC (e.g., calcium at up to 706 mg/L, magnesium at up to 353 mg/L, and sodium up to 3,060 mg/L) would require bench testing and/or pilot studies to understand the behavior of Site-specific groundwater with different media types (Geosyntec, 2018).

3.3.2 Filtration Technologies

This treatment strategy uses permeable membranes with unique pore sizes to remove dissolved COI from groundwater. The filtration process is selective and is dictated by constituent size and not the constituent type. Common filtration processes for removing inorganics include reverse osmosis (smallest relative pore size), nanofiltration, ultrafiltration, and microfiltration (largest relative pore size). Of the common filtration processes, reverse osmosis effectively removes monovalent (e.g., Li^{+1}) and multivalent (e.g., As^{+3} or As^{+5} and Mo^{+2} or Mo^{+3}) ions, whereas ultrafiltration and nanofiltration are sufficient for removing multivalent ions and larger constituents (Nicomel et al., 2016). External pressure, generally requiring electrical input, is utilized to force groundwater through the low permeability membranes, and the pressure requirement is a function of pore size (e.g., reverse osmosis has highest pressure demand).

The inherent non-selective nature of membranes leads to unintended recovery of non-target ions or particulates from groundwater, which can lead to concentrated secondary waste streams from the membrane reject stream or membrane cleaning processes. The high concentrations of other non-targeted ions in CREC groundwater is an important design consideration for membrane technologies.

3.3.3 Ion Exchange Technologies

This technology uses physical and chemical processes to remove COI from the aqueous phase in exchange for innocuous ions on a solid resin phase (FRTR, 2019; USEPA, 2019). The process involves exchanging resin ions of similar charges to those in solution that have a stronger exchange affinity or selectivity for the resin material. Common resin materials include synthetic organic materials, inorganic materials, or natural polymeric materials.

The efficiency of ion exchange is impeded by high concentrations of non-target ions with similar affinities that compete with target ions for active sites on the exchange resin. High concentrations of TDS and sulfate (up to 3,440 mg/L and 902 mg/L, respectively, at CREC) in groundwater have been shown to reduce the effectiveness of ion exchange (USEPA, 2019). The exchange reaction at the active sites of resin materials is reversible and the resins can be regenerated following saturation with target ions, which creates a secondary waste stream requiring additional treatment. Bench testing and/or pilot studies with Site-specific groundwater would be necessary to determine the behavior and effectiveness of different ion exchange resins.

3.3.4 Precipitation Technologies

Precipitation is well-established for removing inorganics from solution and uses chemical reagents or flocculants in solution to form precipitates. The flocculation process involves chemical reactions that convert soluble, dissolved constituents into insoluble, solid forms, such as hydroxides, carbonates, or sulfides, through the addition of a chemical reagent or flocculent, pH adjustment, and mixing (FRTR, 2019). Following flocculation of the insoluble metal precipitates, the liquid phase is physically separated from solution using clarification and/or filtration processes and can be reinjected, while the solid phase requires appropriate disposal.

The determination of the proper chemical reagent or flocculent, the optimal pH, mixing requirements, and efficient chemical dosing rates varies based on Site-specific groundwater conditions and requires bench-scale jar testing (FRTR, 2019). The presence of other high concentration cations (e.g., sodium) and TDS in CREC groundwater that may interfere with the intended precipitation reactions should be considered for process design of this technology.

4. MONITORED NATURAL ATTENUATION

MNA incorporates natural destructive and non-destructive mechanisms to reduce COI in groundwater. MNA is demonstrated using one or more lines of evidences that the natural capacity of an aquifer can reduce constituent concentrations through a series of biological, chemical, and/or physical subsurface interactions over time without human intervention. An important distinction between MNA mechanisms for organic and inorganic constituents is that inorganic constituents may persist in immobilized forms within the aquifer compared to organic constituents that generally attenuate or degrade through MNA mechanisms (USEPA, 2007). While inorganic constituents may persist in immobilize forms, the tiered approach published by USEPA provides guidance for establishing lines of evidence for MNA mechanisms (USEPA, 2007 and 2015).

Attenuation mechanisms for inorganic constituents generally consist of physical and chemical processes such as dispersion, dilution, sorption, and/or precipitation and biological processes including microbial oxidation or reduction reactions. MNA can serve as a primary remedial strategy or a secondary strategy following an active in-situ or ex-situ treatment method. Demonstrating MNA involves long-term monitoring of select groundwater monitoring wells for specific COI.

5. REFERENCES

FRTR. "2.8.3 Common Treatment Technologies for Inorganics in Ground Water, Surface Water, and Leachate." Remediation Technologies Screening Matrix and Reference Guide, Version 4. https://frtr.gov/matrix2/section2/2_8_3.html. (accessed 19 April 2019).

Geosyntec. 2018. *Site Assessment Report – Former North Ash Pond: Crystal River Energy Complex.* Tampa, FL. August

Nicomel, N. R., Leus, K., Folens, K., Van Der Voort, P., and Laing, G. D. 2016. "Technologies for Arsenic Removal from Water: Current Status and Future Perspectives." *Int J Environ Res Public Health*. 13(1).

USEPA. 1992. *Engineering Bulletin: Slurry Walls*. United States Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/S-92/008. October.

USEPA. 1996. *Pump-and-Treat Ground-Water Remediation: A Guide for Decision Makers and Practitioners*. United States Environmental Protection Agency, Office of Research and Development. EPA/625/R-95/005. July.

USEPA. 1998. *Permeable Reactive Barrier Technologies for Contaminant Remediation*. United States Environmental Protection Agency, Office of Research and Development and Office of Solid Waste and Emergency Response. EPA/600/R-98/125. September.

USEPA. 2007. *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 1 – Technical Basis for Assessment*. United States Environmental Protection Agency, Office of Research and Development. EPA/600/R-07/139. October.

USEPA. 2014. *Reference Guide to Treatment Technologies for Mining-Influenced Water*. United States Environmental Protection Agency, Office of Superfund Remediation and Technology Innovation. EPA 542-R-14-001. March.

USEPA. 2015. *Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites*." United States Environmental Protection Agency, Office of Solid Waste and Emergency Response. Directive 9283.1-36. August.

USEPA. "Arsenic Virtual Trade Show: Adsorption Media." Arsenic in Drinking Water. https://cfpub.epa.gov/safewater/arsenic/arsenictradeshow/arsenic.cfm?Action=Adsorption. (accessed 19 April 2019).

USEPA. "In Situ Chemical Reduction: Overview." Contaminated Site Clean-Up Information. https://clu-in.org/techfocus/default.focus/sec/In_Situ_Chemical_Reduction/cat/Overview/. (accessed 19 April 2019).

USEPA. "Permeable Reactive Barriers, Permeable Treatment Zones, and Application of Zero-Valent Iron: Overview." Contaminated Site Clean-Up Information. https://clu-in.org/techfocus/default.focus/sec/Permeable_Reactive_Barriers%2C_Permeable_Treatment_Zones%2C_and_Application_of_Zero-Valent_Iron/cat/Overview/ (accessed 19 April 2019).

APPENDIX B

Evaluation of Potential Groundwater Remedies Using Evaluation Criteria

APPENDIX B – EVALUATION OF POTENTIAL GROUNDWATER REMEDIES USING EVALUATION CRITERIA

CCR Assessment of Corrective Measures Report
Ash Storage/Disposal Area
Crystal River Energy Complex
15760 W. Power Line Street
Crystal River, Citrus County, Florida

Prepared for

Duke Energy Florida, LLC

Prepared by

Geosyntec Consultants, Inc.
12802 Tampa Oaks Blvd., Suite 151
Tampa, Florida 33637

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1. INTRODUCTION

Appendix IV constituents arsenic, lithium, and molybdenum were detected at statistically significant levels (SSLs) above respective groundwater protection standards (GWPS) at the Ash Storage/Disposal Area (AS/DA) at the Crystal River Energy Complex (CREC). As a result, an assessment of corrective measures is required under 40 Code of Federal Regulations (CFR) § 257.96 of the "CCR Rule". The selection of a groundwater remedy, outlined in 40 CFR § 257.97, must also be considered in evaluating potential corrective measures for constituents present above GWPS. The following sections provide a summary-level assessment of corrective measures that address Site SSLs.

1.1 Requirements of ACM Analysis in 40 CFR § 257.96(c)

40 CFR § 257.96(c) states the following:

> *The assessment under paragraph (a) of this section must include an analysis of the effectiveness of potential corrective measures in meeting all of the requirements and objectives of the remedy as described under § 257.97 addressing at least the following:*
>
> 1. *The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to any residual contamination;*
> 2. *The time required to begin and complete the remedy; and*
> 3. *The institutional requirements, such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).*

The following sections summarize the evaluation of appropriate remedies to meet the requirements of 40 CFR § 257.96(c). **Table 1** summarizes the findings in a screening matrix.

2. INORGANIC TREATMENT

Arsenic, lithium, and molybdenum (Appendix IV constituents) were detected at SSLs that exceeded respective GWPS and require an evaluation of corrective measures at the AS/DA. The following section focus on treating these constituents in the context of the requirements of 40 CFR § 257.96(c).

2.1 Performance

This criterion evaluates the ability of a technology to achieve the corrective measures including preventing further releases from the AS/DA, remediating existing releases, and restoring the affected area to original conditions.

2.1.1 In-Situ Technologies

Groundwater flow barriers and permeable reactive barriers (PRBs) are established technologies for isolating and immobilizing (respectively) constituents of interest (COI) in groundwater. The low permeability barriers are designed to prevent contaminated groundwater from mixing with uncontaminated portions of the aquifer. The reactive zones in PRBs are designed to immobilize COI as groundwater passes through them. The karst features at CREC present challenges for mitigating the movement of groundwater beneath the low permeability barriers. Extensive grouting or general ground improvement strategies can be utilized to fill voids along the axis of the barrier prior to barrier construction; however, this may not be feasible if existing karst features are too extensive. However, groundwater extraction wells can be utilized in conjunction with barriers to maintain hydraulic control upgradient, downgradient, and beneath the barrier.

Immobilization of monovalent cations (e.g., lithium) with the reactive media is also a performance related challenge for PRBs. Currently, the treatment of lithium using PRBs is not well documented. Additional bench- or pilot-scale studies would be required to evaluate COI removal with commercially-available reactive media using Site-specific groundwater.

The performance of in-situ stabilization for the reduction of COI concentrations from groundwater is a function of effective reagent distribution and contact with contaminants within the aquifer. An injection well network can be designed to maximize constituent contact and effectively distribute reagents within the aquifer. The implementation challenge for this treatment method is the treatment of lithium; methods for the chemical reduction or oxidation of lithium with commercially-available reagents is not well documented.

2.1.2 Groundwater Extraction

Conventional groundwater extraction for hydraulic control is a well-established remedial strategy for preventing the migration of contaminated groundwater across the Site. Extraction wells are designed and installed to intercept contaminated groundwater. The design of a groundwater extraction system is typically developed using a numerical groundwater flow model to demonstrate hydraulic capture. The challenge for groundwater extraction at CREC is designing a system to maintain hydraulic control in a karst aquifer.

The performance of phytoremediation as a groundwater extraction technology is a function of growing conditions and species selection. The growing conditions (e.g., moisture, sunlight, nutrients, warmth, etc.) at CREC are sufficient for tree growth. Once a sufficient root network has been established to intercept contaminated groundwater in the aquifer, the performance of phytoremediation will be self-sustaining and removal efficiencies will be predictable. Also, tree species can be selected for constituent uptake within herbaceous or woody material in the trees or selected based on Site-specific conditions. The challenges for phytoremediation at CREC involve the design of a network that can provide hydraulic capture in a high transmissivity aquifer and finding tree species that can tolerate and grow in groundwater containing high total dissolved solids (TDS) and chloride concentrations.

2.1.3 Groundwater Treatment

Groundwater treatment technologies can be combined with conventional groundwater extraction technologies to remove contaminant mass from groundwater. The treatment strategies are well established and are known to treat inorganic COIs. The performance of these treatment strategies is a function of constituents within groundwater. The performance challenges at CREC involve high concentrations of dissolved ions that are likely to produce a concentrated waste stream requiring disposal and generate the need for frequent media replacement. Additional bench-scale studies would be warranted prior to the design phase to evaluate contaminant removal efficiencies using commercially available groundwater treatment technologies with Site-specific groundwater.

2.1.4 Monitored Natural Attenuation

The performance of monitored natural attenuation (MNA) relies on biological, chemical, and/or physical mechanisms to attenuate COI concentrations in groundwater. Inorganic constituents are susceptible to these mechanisms and will generally attenuate over time and under specific geochemical and physical conditions. This strategy involves documenting lines of evidence for the occurrence of the destructive and non-destructive mechanisms through routine groundwater monitoring and data analysis to follow concentration trends over time. Groundwater monitoring can be accomplished using the majority of the existing monitoring wells with the network around the AS/DA. Overall, this approach can be effective as a standalone strategy or in combination with other strategies along the downgradient flow path or along the plume boundaries.

2.2 Reliability

This criterion evaluates the degree of certainty that a technology will consistently achieve corrective measure over time.

2.2.1 In-Situ Technologies

Groundwater flow barriers are used for isolating contaminant mass. The reliability of low permeability barriers at CREC depends on construction methods in the karst aquifer. The presence of karst features will require extensive grouting of bedrock voids to facilitate the installation of a barrier; however, the absence of a low permeability layer at the base of the barrier will increase the potential for groundwater flow beneath it. Groundwater extraction wells can be used in conjunction with the barrier to maintain hydraulic control and minimize but not prevent the unintended movement of groundwater around or beneath the barrier.

The reliability of low permeability barriers will depend on the compatibility of the backfill material with the Site-specific groundwater. Bench-scale studies would be conducted during the design phase to evaluate the behavior and compatibility of different materials with Site-specific groundwater and demonstrate a reduction in permeability is produced to create an effective barrier.

PRBs are capable of immobilizing constituent mass (permeable reactive zones). The reliability of the PRBs includes similar construction and implementation issues to groundwater flow barriers. The reliability of PRBs is a function of the reactive media lifecycle within the permeable zones. The media requires periodic removal and replacement for effective immobilization of COI. The data gaps on reactive media options for the lithium immobilization is a significant consideration for the reliability of this treatment method. Bench-scale studies will be required to evaluate lithium removal as well as arsenic and molybdenum removal with different commercially-available reactive media and Site-specific groundwater.

The reliability of in-situ stabilization for the reduction of inorganic COIs depends on delivery of chemical reagents into the subsurface. The effectiveness of this treatment strategy is a function of delivering chemical reagents into target treatment areas to contact and treat inorganic COI. The presence of karst features in the subsurface can minimize the reliability of this technology by limiting the effective distribution of chemical reagents into the subsurface by reducing contact with COIs. Another consideration is the limited testing of lithium treatment using chemical reagents. Bench-scale studies will be required to evaluate the effectiveness of different chemical reagents on the removal of lithium from Site-specific groundwater.

2.2.2 Groundwater Extraction

Conventional groundwater extraction systems are generally considered reliable for maintaining hydraulic control of dissolved plumes. The extraction and injection well networks are designed and provide complete capture and containment of the dissolved plume. The reliability of these systems depends on consistent and routine operations and maintenance (O&M) activities to mitigate mechanical fouling in the pumps and plumbing and other problems that arise with a mechanical remedy. The reliability of a system installed at CREC will depend on establishing adequate hydraulic control of the dissolved phase plume in a karst aquifer. Corrosion issues with mechanical components (i.e., pumps) will need to be addressed due to the high chloride concentrations.

The reliability of phytoremediation is dependent on the ability of the tree root network to intercept groundwater flow and provide hydraulic control and/or containment. Tree wells can be designed to target the contaminated depth interval by selecting tree species that can grow roots to the desired depth. The reliability of phytoremediation is dependent on the ability of the trees to grow throughout the year. Due to the abundance of sunlight, nutrients, warmth, and moisture in Florida, the growing season is exceptional for trees and occurs throughout most of the year. After trees are established, the reliability of phytoremediation for hydraulic control of contaminated groundwater is consistent with limited O&M activities that includes routine pruning and vegetation maintenance.

2.2.3 Groundwater Treatment

Groundwater treatment of extracted groundwater is considered highly reliable, as a wide variety of options exist to treat the target constituents. Treatment depends on commercially-available options for extracted groundwater discharge. Groundwater treatment could be reliably employed at the Site since treatment technologies exist that could target most constituents and the methods are adaptable; however, multiple technologies would likely be required to treat the COI at the Site.

2.2.4 Monitored Natural Attenuation

MNA mechanisms for the inorganic COI at CREC involve physical mechanisms including dilution, dispersion, and sorption. The inherent porous nature of limestone and prevalent karst at shallow depths in the aquifer across the Site readily promote dilution and dispersion mechanisms. The lithologic features coupled with the groundwater flow regime are predictable and reliable mechanisms that contribute to attenuation of inorganic COI at CREC. Additionally, the minimization of continued contaminant mass loading to the aquifer (control of runoff from the AS/DA) of COI will ultimately improve the reliability of an MNA remedy.

2.3 Ease of Implementation

This criterion evaluates the ease at which a technology can be implemented at the Site.

2.3.1 In-Situ Technologies

Groundwater flow barriers and PRBs face similar implementation challenges at CREC. Prior to design and implementation, extensive geological and geotechnical investigations would be required to evaluate and delineate the presence of karst features and weak zones along the axis of the barriers. Karst features identified during these investigations would require extensive grouting and/or other ground improvement techniques to prevent groundwater flow around and beneath the installed barriers. Since the Ocala Formation is only a few feet below ground surface, any barrier must be constructed by trenching through the upper portion of the weathered limestone to a desired depth; the construction difficulty of trenching through limestone is greater than that in unconsolidated sediments. The installation of low permeability barriers and PRBs will require relatively significant construction timelines, costs, and effort.

A dedicated injection well network would be required for delivery of chemical reagents into the subsurface for repeated injection events. Prior to the installation of the injection well network, geological investigations would be required to evaluate and delineate karst features to reduce the potential for amendment loss in karst conditions. The installation of dedicated injection wells would require well drilling and construction methods similar to monitoring wells that a variety of local, licensed driller contractors can perform. The installation and construction of injection wells would not be as difficult to implement and require less construction time, cost, and effort compared to trenching and installing barriers.

2.3.2 Groundwater Extraction

Groundwater extraction through use of extraction wells (vertical, horizontal, or angular) would require a significant amount of permitting, design, and pilot testing. However, the technologies are not generally difficult to implement. Conventional groundwater extraction systems and phytoremediation are similar in the implementation stages. Prior to implementation, aquifer testing and hydraulic capture simulations produced using a calibrated numerical groundwater flow model would be required to design the well network or tree planting grid and pumping flow rate (conventional groundwater extraction). During implementation, conventional groundwater extraction and phytoremediation systems require the construction and installation of wells.

Conventional groundwater extraction requires additional installation of groundwater pumps, plumbing, wiring, etc., whereas phytoremediation involves planting trees within the wells. Compared to groundwater extraction technologies, drilling larger diameter boreholes in limestone and delivering nutrient amendments to the trees in the wells within the karst environment at CREC are several additional implementation challenges for phytoremediation.

The O&M requirements for conventional groundwater extraction systems require routine cleaning and sampling, whereas the requirements for phytoremediation systems involve routine landscape maintenance activities (e.g., occasional pruning and fertilizing) and replacing any trees that die.

2.3.3 Groundwater Treatment

Groundwater treatment could be implemented at the Site. Groundwater treatment technologies would involve constructing a treatment train facility aboveground to supplement the groundwater extraction well network. Prior to implementation, additional bench-scale and/or pilot testing would be required to evaluate the effectiveness of different treatment technologies for Site-specific groundwater. During implementation, the construction activities would include installation pumps, plumbing, wiring, vessels, etc. and possibly erecting a building structure to protect the treatment train. The O&M requirements would include routine cleaning and maintenance of the treatment facility and associated vessels, pumps, etc. and sampling.

2.3.4 Monitored Natural Attenuation

Compared to the other treatment strategies, MNA would be the simplest strategy to implement. MNA would involve periodic groundwater sampling within select existing monitoring wells around the AS/DA to provide lines of evidence for the attenuation of COI over time. During the implementation of MNA, groundwater sampling results may dictate the addition of more wells to the monitoring network to support the demonstration of MNA.

2.4 Potential Safety Impacts

This criterion evaluates potential safety impacts that may result from implementation and use of a technology at the Site.

2.4.1 In-Situ Technologies

The construction phases for groundwater flow barriers and PRBs poses relatively high risks for worker safety. These risks are associated with the heavy construction equipment, such as long reach excavators and dump trucks, required to construct the barriers and to remove bulk media. The installation phase involves deep, open trenches for extended periods that create fall hazards and must be safely cordoned off. These hazards would also re-emerge during the removal and replenishment of spent reactive material on a periodic basis in PRBs. Following construction activities, there are relatively minimal worker safety considerations since the structures are below land surface.

Potential safety concerns related to in-situ chemical stabilization are minimal. The potential for incident during injection well construction or unintended worker contact with the chemicals used for treatment would be the primary safety concerns associated with the technology. The construction activities can potentially expose workers to physical hazards during injection well installation. During the injection events, there are safety concerns with exposing workers to potentially hazardous chemical reagents; however, the consistent and proper use of personal protection equipment (PPE) during these injection events can mitigate these occurrences. The potential of storing chemical reagents on-Site long-term could pose safety risks to on-Site workers. These risks can be mitigated by designing a dedicated structure to contain the chemical reagents, storing the reagents in secondary containment vessels to prevent spills, and preparing a Site-specific Health and Safety Plan.

2.4.2 Groundwater Extraction

Groundwater extraction through use of extraction wells would involve drilling, construction, and installation of extraction wells, pumps, and associated control wiring and piping. Potential safety concerns exist with the activities associated with installation of the extraction system as well as the ongoing O&M of the system, including inspection, maintenance, or replacement of the various system components. O&M activities for conventional groundwater extraction (i.e., cleaning fouled pumps with chemical reagents or replacing pumps) could pose chemical, physical, or electrical risks for Site workers. O&M activities for phytoremediation systems is not as intensive as conventional groundwater extraction system; however, the maintenance and pruning of trees may pose physical risks for workers.

2.4.3 Groundwater Treatment

Groundwater treatment would have potential safety impacts associated with the construction, installation, and O&M of the aboveground treatment system. Groundwater treatment assumes the groundwater has been extracted, so there are potential safety concerns associated with construction of a groundwater extraction system in addition to safety concerns associated with the aboveground system infrastructure. Operational safety concerns may also exist with the components of the treatment facility and potential for unintended worker contact with the groundwater and chemical reagents. The O&M phase poses risks depending on the treatment technology. Technologies that utilize toxic or harmful concentrations of chemical reagents in the treatment train could pose chemical hazards for Site workers. Additionally, the technologies may utilize electrical equipment and aboveground pumps with exposed, rotating components that could pose a physical hazard.

2.4.4 Monitored Natural Attenuation

Safety considerations for MNA are primarily associated with worker safety should additional monitoring well installations be required. The installation of wells requires the use of hydraulic drill rigs. Additional worker safety and PPE considerations are minimal for groundwater sampling compared to installation and construction activities associated with other remedial strategies.

2.5 Potential Cross-Media Impacts

This criterion evaluates potential cross-media impacts that may result from implementation and use of the technology at the Site.

2.5.1 In-Situ Technologies

The risk for cross-media impacts is low for groundwater flow barriers and PRBs. These barriers are designed to isolate (i.e., flow barriers) or immobilize (i.e., PRBs) contaminants from migrating into uncontaminated portions of the aquifer. There is some risk that contaminated groundwater may flow beneath or around the low permeability barriers, which could lead to the potential sorption of dissolved COI onto uncontaminated sediments.

There is a low potential for cross-media impacts through the in-situ chemical stabilization technologies. Chemical reagents can be injected into contaminated groundwater through permanent or temporary methods and mismanagement or human error during injection events could result in chemical reagent spills aboveground on soil or surface water bodies. Despite the potential for spills, the chemical reagents do not pose adverse environmental impacts for uncontaminated surficial soils. Proper management will minimize the risk of chemical spills to the environment.

2.5.2 Groundwater Extraction

The potential for cross-media impacts from groundwater extraction technologies is low and would primarily be associated with leaks or spills of untreated groundwater to uncontaminated media (soil and surface water). If used in conjunction with a groundwater treatment, untreated effluent has the potential to be discharged to uncontaminated soil and groundwater surface water bodies.

The potential for cross-media impacts through phytoremediation is low. Residual vegetation from the tress (e.g., leaf and woody material and dead trees) would need to be properly managed and disposed to reduce the risk of cross media impacts.

2.5.3 Groundwater Treatment

The potential cross-media impacts for groundwater treatment technologies are similar to those mentioned for conventional groundwater extraction methods. The primary method of cross-media impacts would occur through unintended and/or untreated discharges from the system to uncontaminated soil, groundwater, and surface water. Proper management of secondary waste streams generated from spent treatment media need to be properly managed to prevent cross-media impacts.

2.5.4 Monitored Natural Attenuation

The cross-media impact potential for MNA is low. In an MNA scenario, the potential for contaminant storage in the aquifer matrix (i.e., via sorption) would continue to exist, although by definition this contaminant mass is not migratory. There is a low potential for groundwater COI to adsorb to uncontaminated sediments during dilution and dispersion of COI through physical attenuation mechanisms.

2.6 Control of Exposure to Residual Contamination

This criterion evaluates the ability to control human and environmental exposure to residual contamination through implementation and use of technology at the Site.

2.6.1 In-Situ Technologies

In-situ technologies involve placement or injection of an object or reagent within the subsurface in order to treat impacted groundwater in-situ; therefore, the risk of exposure of humans and the environment to residual contamination is minimal. The potential for exposure would exist during installation of the in-situ components, as well as during any maintenance or replacement of components that would be needed during the life of the remedy.

2.6.2 Groundwater Extraction

Conventional groundwater extraction systems remove contaminated groundwater from the subsurface and transport it aboveground for treatment and discharge to surface water or re-injection into different areas of the aquifer. There is limited potential for human exposure to contaminated groundwater through routine O&M activities and unintended releases.

The exposure to residual contamination from a phytoremediation strategy is very low. However, some tree species may uptake and store organic constituents in leafy or woody material. This could lead to the potential for environmental receptors (e.g., insects, birds, and/or small animals) to consume edible portions of the tree containing COI.

2.6.3 Groundwater Treatment

Groundwater treatment presumes that the impacted groundwater has been extracted and brought to the surface. Therefore, risks identified for groundwater treatment would be in addition to those described above for groundwater extraction. However, the objective of groundwater treatment is to treat the impacted groundwater to levels that meet permit limits or other remedial cleanup goals. The failure of the treatment system and discharge of untreated effluent can result in human and environmental exposure to residual contamination.

2.6.4 Monitored Natural Attenuation

An MNA remedy assumes that the dissolved groundwater plume is effectively attenuated by natural processes (physical, chemical, and/or biological). Exposure to residual contamination is possible if there are unidentified exposure pathways or the aquifer's capacity to attenuate the dissolved plume is exceeded over time.

2.7 Time Required to Begin Remedy

This criterion evaluates the time for pre-implementation activities, procurement, installation, and start-up of technology at the Site.

2.7.1 In-Situ Technologies

Groundwater flow barriers and PRBs require a relatively significant amount of construction time compared to the other evaluated strategies. The presence of karst features at CREC adds further complexity to the implementation phase, which will increase the project timeline. Prior to implementation, pre-design activities including groundwater modeling and assessment will be required for determining the groundwater flow regime. Furthermore, pre-design activities including geotechnical and geological investigations will be required to determine constructability of the low permeability barriers in karst features. Following installation, there is no additional start-up time for the technologies, since the intended effects of these passive systems are immediate.

In-situ chemical stabilization will require time to conduct bench- or pilot-scale tests to evaluate the behavior of Site-specific groundwater and different chemical reagents on COI immobilization.

The installation and construction of the permanent injection well network will require additional time during the implementation phase. The remedial phase requires time for injection and reinjection events of chemical reagents, which depends on the size of the injection well network and the amount of injectate required.

2.7.2 Groundwater Extraction

Prior to implementation, this treatment strategy will require time for groundwater modeling and assessment, permitting the injection wells, and designing injection well network. During the implementation phase, time will be required to install and construct the extraction well network. Following system construction, the system start-up time would involve testing all system components

Phytoremediation will require time to conduct groundwater modeling prior to implementation. During the implementation phase, time will be required to install and plant the tree network that may involve drilling boreholes for planting trees. After construction, time will be required for tree growth and the establishment of a root network that will intercept the contaminated groundwater. The time required to establish a functional phytoremediation system is highly variable.

2.7.3 Groundwater Treatment

The required time to begin using groundwater treatment is similar to conventional groundwater extraction with additional construction and installation requirements for building the treatment train. Additionally, prior to implementation, time would be required for conducting pilot-scale tests to evaluate the effectiveness and behavior of different treatment media with Site-specific groundwater.

2.7.4 Monitored Natural Attenuation

MNA would require the least amount of time to implement compared to the other evaluated treatment methods due to the extensive existing monitoring well network around the AS/DA. Time would be required to confirm the efficacy of MNA at the Site and develop a groundwater monitoring plan.

2.8 Time Required to Complete Remedy

The time required to complete each treatment remedy varies significantly. The treatment strategies that will take longer than 30 years include those that do not specifically address source removal. These strategies include groundwater flow barriers, PRBs, conventional groundwater extraction, phytoremediation, and MNA:

- Groundwater flow barriers and PRBs are designed to isolate and immobilize, respectively, COI with groundwater around the source area.
- Conventional groundwater extraction and phytoremediation technologies are designed to provide hydraulic containment of the contaminated groundwater with some limited COI mass removal.
- MNA relies on natural attenuation mechanisms that are reliable yet take time for concentration reduction.

The strategies that will take less than 30 years (estimated 5 to 10 years) include chemical immobilization and groundwater treatment technologies.

- The injection well network for chemical immobilization would be installed to target the source area. As chemical reagents are injected into the source area, the reagents react with COI to immobilize the constituents, reducing the concentrations in groundwater. Repeated chemical reagent injections are anticipated over time to effectively remove COI.
- Groundwater treatment technologies remove COI concentrations during groundwater extraction prior to re-injection or discharge.

2.9 State, Local, or Other Environmental Permit Requirements that May Substantially Affect Implementation

This criterion evaluates anticipation of any state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the technology at CREC.

2.9.1 In-Situ Technologies

State and local (county) permitting of the construction activities for low flow barriers or PRBs may be required but is not anticipated to substantially affect implementation time frames.

In-situ chemical stabilization technologies will require Southwest Florida Water Management District (SWFWMD) permitting for the installation of the injection well network. It will also include an Underground Injection Control (UIC) permit from the Florida Department of Environmental Protection (FDEP) for injecting chemical reagents into the subsurface. Based on similar projects, it is anticipated that permitting with take up to six months for agency review and approval.

2.9.2 Groundwater Extraction

State and local (county) permitting of the construction activities for a groundwater extraction system may be required but is not anticipated to substantially affect implementation time frames. However, SWFWMD will require permits for the installation of the extraction well network and a consumptive use. A UIC permit will be required from the FDEP for injecting treated water into the subsurface. Based on similar projects, it is anticipated that permitting with take up to six months for agency review and approval

2.9.3 Groundwater Treatment

The groundwater treatment strategy would require FDEP review and approval of a UIC permit for the subsurface disposal of groundwater (via injection wells) at the Site. This permitting process would likely require an additional 3 to 6 months to plan, report, and receive FDEP approval but could be implemented in parallel with the other permitting requirements for groundwater extraction.

2.9.4 Monitored Natural Attenuation

MNA would require the least amount of permitting. The majority of the MNA monitoring well network exists at CREC. If additional monitoring wells are needed for delineation purposes, minimal and routine monitoring well installation permits would be required through SWFWMD and would not affect remedy implementation.

APPENDIX C
Selection of Groundwater Remedy Requirements in 40 CFR § 257.97

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APPENDIX C – SELECTION OF GROUNDWATER REMEDY REQUIREMENTS IN 40 CFR § 257.97

CCR Assessment of Corrective Measures Report
Ash Storage/Disposal Area
Crystal River Energy Complex
15720 W. Power Line Street
Crystal River, Citrus County, Florida

Prepared for

Duke Energy Progress, LLC

Prepared by

Geosyntec Consultants, Inc.
12802 Tampa Oaks Blvd., Suite 151
Tampa, Florida 33637

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1. INTRODUCTION

Requirements for the remedy selection process under the Coal Combustion Residual (CCR) Rule are outlined in 40 Code of Federal Regulations (CFR) § 257.97(a-e). The corrective measure remedy for the Ash Storage/Disposal Area (AS/DA) must be selected as soon as feasible following the preparation of this Assessment of Corrective Measures (ACM) Report. Prior to final remedy selection, a public meeting to discuss the ACM results with interested parties and affected stakeholders must be held at least 30 days prior to remedy selection.

40 CFR § 257.97(a) states the following:

> *Based on the results of the corrective measures assessment conducted under § 257.96, the owner or operator must, as soon as feasible, select a remedy that, at a minimum, meets the standards listed in paragraph (b) of this section. This requirement applies to, not in place of, any applicable standards under the Occupational Safety and Health Act. The owner or operator must prepare a semiannual report describing the progress in selecting and designing the remedy. Upon selection of a remedy, the owner or operator must prepare a final report describing the selected remedy and how it meets the standards specified in paragraph (b) of this section. The owner or operator must obtain a certification from a qualified professional engineer that the remedy selected meets the requirements of this section. The report has been completed when it is placed in the operating record as required by § 257.105(h)(12).*

40 CFR § 257.97(b) states the following regarding the standards of remedy selection:

Remedies must:

1. *Be protective of human health and the environment;*
2. *Attain the groundwater protection standard as specified pursuant to § 257.95(h);*
3. *Control the source(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of constituents in appendix IV to this part into the environment;*
4. *Remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible, taking into account factors such as avoiding inappropriate disturbance of sensitive ecosystems;*
5. *Comply with standards for management of wastes as specified in § 257.98(d).*

Furthermore, 40 CFR § 257.97(c) states the following:

In selecting a remedy that meets the standards of paragraph (b) of this section, the owner or operator of the CCR unit shall consider the following evaluation factors:

1. *The long- and short-term effectiveness and protectiveness of the potential remedy(s), along with the degree of certainty that the remedy will prove successful based on consideration of the following:*
    i. *Magnitude of reduction of existing risks;*

ii. *Magnitude of residual risks in terms of likelihood of further releases due to CCR remaining following implementation of a remedy;*

iii. *The type and degree of long-term management required, including monitoring, operation, and maintenance;*

iv. *Short-term risks that might be posed to the community or the environment during implementation of such a remedy, including potential threats to human health and the environment associated with excavation, transportation, and re-disposal of contaminant;*

v. *Time until full protection is achieved;*

vi. *Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, re-disposal, or containment;*

vii. *Long-term reliability of the engineering and institutional controls; and*

viii. *Potential need for replacement of the remedy.*

2. *The effectiveness of the remedy in controlling the source to reduce further releases based on consideration of the following factors:*

   i. *The extent to which containment practices will reduce further releases; and*

   ii. *The extent to which treatment technologies may be used.*

3. *The ease or difficulty of implementing a potential remedy(s) based on consideration of the following types of factors:*

   i. *Degree of difficulty associated with constructing the technology;*

   ii. *Expected operational reliability of the technologies;*

   iii. *Need to coordinate with and obtain necessary approvals and permits from other agencies;*

   iv. *Availability of necessary equipment and specialists; and*

   v. *Available capacity and location of needed treatment, storage, and disposal services.*

4. *The degree to which community concerns are addressed by a potential remedy(s).*

40 CFR § 257.97(d) states the following for the schedule of remedial activities:

> *The owner or operator must specify as part of the selected remedy a schedule(s) for implementing and completing remedial activities. Such a schedule must require the completion of remedial activities within a reasonable period of time taking into consideration the factors set forth in paragraphs (d)(1) through (6) of this section. The owner or operator of the CCR unit must consider the following factors in determining the schedule of remedial activities:*

1. *Extent and nature of contamination, as determined by the characterization required under § 257.95(g);*
2. *Reasonable probabilities of remedial technologies in achieving compliance with the groundwater protection standards established under § 257.95(h) and other objectives of the remedy;*
3. *Availability of treatment or disposal capacity for CCR managed during implementation of the remedy;*
4. *Potential risks to human health and the environment from exposure to contamination prior to completion of the remedy;*
5. *Resource value of the aquifer including:*
   - i. *Current and future uses;*
   - ii. *Proximity and withdrawal rate of users;*
   - iii. *Groundwater quantity and quality;*
   - iv. *The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to CCR constituents;*
   - v. *The hydrogeologic characteristic of the facility and surrounding land; and*
   - vi. *The availability of alternative water supplies; and*
6. *Other relevant factors.*

Following preparation of this ACM Report, the process of remedy selection will begin in order to select an effective remedy that meets the requirements of § 257.97(b) and considers the factors of § 257.97(c). Paragraph (a) of § 257.97 requires that a semi-annual report be prepared to document progress toward remedy selection and design. Once a remedy is selected, a final remedy selection report must be prepared to document details of the selected remedy and how the selected remedy meets § 257.97(b) requirements. The final selected remedy report must also be certified by a professional engineer and placed in the operating record.

The final remedy selection report will include an evaluation of the requirements of § 257.97(b) and the considerations of § 257.97(c). The following sections further describe the aspects of each selection requirement and consideration.

1.1 Protection of Human Health and the Environment

This criterion will include the effectiveness of a technology in protecting human health and the environment. While Site assessment results indicate there are no imminent hazards to human health or the environment, corrective action is necessary due to exceedances in regulatory groundwater protection standards (GWPS). Additionally, the remedial alternative assessment will evaluate the future protection of human health and the environment.

Technologies and remedial alternatives will be assessed to determine the short- and long-term protection of human health and the environment, including mitigation of risks from constituents of interest (COI) by eliminating, reducing, or controlling exposures to concentrations consistent with remedial goals. The protection of human health and the environment draws on the assessments of other evaluation criteria including long-term effectiveness and permanence, short-term effectiveness, and compliance with applicable regulations.

1.2 Attainment of GWPS

This criterion includes the capability of the remedial strategy to meet GWPS for Appendix IV COI above statistically significant levels (arsenic, lithium, and molybdenum) in a reasonable period of time at the CCR unit waste boundary. The criterion objective supports the corrective measure goal for restoring the impacted area to previous conditions.

1.3 Attainment of Source Control

This criterion includes the capability of the remedial strategy to provide source control within a reasonable period of time at the CCR unit. The criterion objective supports the corrective measure goal of preventing future releases from the AS/DA to the extent feasible.

1.4 Removal of Contaminated Material

This criterion includes the capability of the remedial strategy to remove as much of the contaminated material released from the CCR unit as technically feasible, while accounting for Site-specific conditions (e.g., avoiding inappropriate disturbance of sensitive wetlands).

1.5 Compliance with Waste Management Standards – 40 CFR § 257.98(D)

This criterion includes the capability of the remedial strategy to comply with standards for waste management specified in 40 CFR § 257.98(d).

1.6 Reduction of Existing Risks

This consideration includes evaluating the magnitude of existing risk reduction achieved by implementing the remedial strategy at the Site.

1.7 Magnitude of Remaining Residual Risks

This consideration evaluates the magnitude of the remaining residual risks in terms of the potential for future CCR releases following the implementation of the remedial strategy at the Site.

1.8 Long-Term Management

This consideration includes the long-term management requirements for monitoring, operating, and maintaining the remedial technology implemented at the Site.

1.9 Short-Term Implementation Risks

This consideration evaluates the implications of short-term risks to human health or the environment during implementation of the remedial strategy, such as the potential risks posed by trenching, transportation, or disposal of the contaminant.

1.10 Timeframe Until Full Protection

This consideration includes the amount of time anticipated to achieve the full protection of the contaminated media through implementation of the remedial strategy at the Site.

1.11 Potential Exposure of Receptors to Remaining Wastes

This consideration includes the potential receptors that could be exposed to remaining wastes through excavation, transportation, re-disposal, or containment of CCR material.

1.12 Long-Term Reliability

This consideration includes the long-term reliability of the engineering and institutional controls for the remedial strategy implemented at the Site.

1.13 Potential for Remedy Replacement

This consideration includes the potential for technology replacement over time.

1.14 Reduction of Further Releases

This consideration includes the capability of the technology to mitigate further CCR releases.

1.15 Extent of Treatment Technology Use

This consideration includes the capability of the technology to reduce further releases based on the extent of which treatment technologies are utilized.

1.16 Constructability

This consideration includes the ease of implementation for the remedial technology and accounts for the technical difficulties and unknown variables that could affect the construction phase.

1.17 Expected Operational Reliability

This consideration includes the ease of operation for the remedial technology and accounts for the difficulties and unknowns that could affect the operation of the technology.

1.18 Regulatory Permitting and Approvals

This consideration includes the ease and time associated with coordinating and obtaining necessary approvals and/or permits from regulatory agencies.

1.19 Equipment and Specialists Availability

This consideration includes the ease of obtaining remedial technology for the Site including the availability of equipment and/or specialists to implement the remedial strategy.

1.20 Availability and Location of Treatment, Storage, and Disposal Services

This consideration includes the availability of adequate treatment, storage capacity, and disposal capacity and services. Additionally, the necessary provisions for additional resources are also evaluated.

1.21 Addressment of Community Concerns

This consideration includes the extent that the remedial strategy addresses the community concerns. This assessment includes an evaluation of the opposition and support from stakeholders regarding the intended remedial strategy and may not be fully realized until comments from the public meeting on the proposed strategy are reviewed. General assumptions regarding stakeholder involvement and comments can be made based on previous experience at similar sites.