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January 3, 2025

Francisco J. Herrera
Illinois Environmental Protection Agency
2520 West Iles Avenue
P.O. Box 19276
Springfield, IL 62794

Re: Illinois Power Generating Company - Newton Power Plant
Log No. 2021-100018
Bureau ID # W0798070001
CCR Surface Impoundment Operating and Construction Permit Application Review Letter Response – Second Submittal

Mr. Herrara:

Illinois Power Generating Company (IPGC) received the Newton Power Plant CCR Surface Impoundment Operating and Construction Permit Application Review Letter dated October 10, 2023. In a letter dated March 8, 2024, IPGC provided data and information that was reasonably and readily available to the IEPA. This letter provides the additional information and data that was not included in the first response letter. All documents and responses will be provided in hard copy, as requested by IEPA, as well as through a courtesy email.

Following the initial submittal, IEPA, IPGC representatives and their consultants met on May 2, 2024, and May 30, 2024, to discuss the initial comments and responses. During those discussions IEPA requested clarification of the following aspects included in the groundwater flow and transport model submitted per Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845.220(d)(3):

- The use of porewater data to represent CCR source concentrations;
- The appropriateness of using a surrogate parameter to calculate the time to reach the groundwater protection standard (GWPS) in comparing closure alternatives; and
- The relevance of geochemical reactions to modeling outcomes.

Additional clarification has been developed and included in **Attachment 1**.

Initial Operating Permit Application

Groundwater Sampling and Analysis Program [35 Ill. Adm. Code 845.230(d)(2)(I)(iii)]

Comment 8: *The appropriate minimum detection limits for each constituent must be used to evaluate the constituent statistically and to compare against the numerical groundwater protection standard in 35 IAC 845.600(a)(1). The following constituents have a calculated groundwater protection/background value that does not exhibit the correct use of the statistics:*

- *Arsenic*
- *Radium 226 and 228*

Response: IPGC has received and reviewed IEPA's December 28, 2023 letter regarding additional comments on statistical methods proposed in the initial operating permit applications. IPGC and IEPA met on May 2, 2024 to discuss the comments in this initial review letter and in the December 28, 2023 letter. A response to the December 28, 2023 letter is included in **Attachment 2.**

History of Known Groundwater Exceedances [35 IAC 845.230(d)(2)(M)]

Comment 11: *The appropriate minimum detection limits for each constituent must be used to evaluate the constituent statistically and to compare against the numerical groundwater protection standard in 35 IAC 845.600(a)(1). The following constituents have a calculated groundwater protection/background value that does not exhibit the correct use of the statistics:*

- *Arsenic*
- *Lower end of pH*
- *Radium 226 and 228*

Response: IPGC has received and reviewed IEPA's December 28, 2023 letter regarding additional comments on statistical methods proposed in the initial operating permit applications. IPGC and IEPA met on May 2, 2024 to discuss the comments in this initial review letter and in the December 28, 2023 letter. A response to the December 28, 2023 letter is included in **Attachment 2.**

Groundwater Monitoring Program and Modeling [35 Ill. Adm. Code 845.220(a)(7), 845.220(d)(3), and Subpart F]

Comment 26: *The groundwater information must also include a new or updated groundwater monitoring program that includes groundwater sampling and analysis program including the statistical procedures meeting requirements of Section 845.640 and 845.650.*

Response: IPGC has received and reviewed IEPA's December 28, 2023 letter regarding additional comments on statistical methods proposed in the initial operating permit applications. IPGC and IEPA met on May 2, 2024 to discuss the comments in this initial review letter and in the December 28, 2023 letter. A response to the December 28, 2023 letter is included in **Attachment 2**.

Should you have any questions or comments regarding the above responses, please contact Rhys Fuller at rhys.fuller@vistracorp.com or (618) 975-1799.

Sincerely,

Phil Morris, P.E.
Sr. Director, Environmental

ATTACHMENTS

ATTACHMENT 1

RESPONSE TO IEPA COMMENTS ON GROUNDWATER MODELING FOR CLOSURE ALTERNATIVES ANALYSIS

Response to IEPA Comments on Groundwater Modeling for Closure Alternatives Analysis

Illinois Power Generating Company (IPGC) received the Newton Power Plant CCR Surface Impoundment Operating and Construction Permit Application Review Letter from Illinois Environmental Protection Agency (IEPA) dated October 10, 2023, and provided an initial response on March 8, 2024. In the March 8th response, IPGC requested meetings with IEPA to discuss the initial comments to ensure IPGC is providing complete responses. In meetings with IPGC representatives and consultants on May 2, 2024, and May 30, 2024, IEPA requested clarification regarding the following aspects of the groundwater flow and transport model submitted per Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845.220(d)(3):

1. The use of porewater data to represent CCR source concentrations;
2. The appropriateness of using a surrogate parameter to calculate the time to reach the groundwater protection standard (GWPS) in comparing closure alternatives; and
3. The relevance of geochemical reactions to modeling outcomes.

These topics are addressed below.

1. Use of Porewater Data to Represent CCR Source Concentrations

The April 18, 2024, initial response from IPGC to Comment 2 provided several United States Environmental Protection Agency (USEPA) references supporting the conclusion that porewater analysis represents the best and most accurate data available for source characterization. During subsequent meetings, IEPA requested additional support for use of surrogate parameter concentrations in porewater as the CCR source concentration in the groundwater model. The use of porewater constituent concentrations as a source term for modeling the effects of CCR surface impoundments on downgradient groundwater is consistent with USEPA's approach to evaluating potential effects of CCR surface impoundments as detailed below.

The initial promulgation of a federal CCR rule was proposed to "address the risks from the disposal of CCR generated from the combustion of coal."[1] The risk of CCR stored in impoundments and landfills was characterized by USEPA in the 2014 final Human and Ecological Risk Assessment of Coal Combustion Residuals.[2] The purpose of this risk assessment was to "provide a scientific basis for the development of regulations necessary to protect human health and the environment."[3]

In the conceptual model for potential risks of impounded CCR, "chemical constituents can be released from surface impoundments through the leaching of soluble constituents into the water that comes in contact with the CCRs and percolation of the resulting leachate into the subsurface soil and ground water."[4] The risk assessment uses data from "impoundment pore water", defined as "the water present within interstitial spaces of the settled CCRs", to characterize CCR waste source chemical concentrations.[5] The risk assessment clarifies that whole CCR waste concentrations[6] are a poor indicator

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[1] 80 Fed. Reg. 21311 (Apr. 17, 2015). https://www.federalregister.gov/d/2015-00257/p-64.

[2] USEPA. 2014. Human and Ecological Risk Assessment of Coal Combustion Residuals. Final. Office of Solid Waste and Emergency Response and Office of Resource Conservation and Recovery. 2050-AE81. December.

[3] Ibid.

[4] Section 2.2.1, Ibid.

[5] Section 3.1, Ibid.

[6] "Whole waste represents the concentrations within CCRs at the time of generation," Ibid.

of what constituents may be released from a CCR impoundment. Instead, pore water "concentrations are representative of leachate released from impoundments to downgradient receptor wells"[7] and are subsequently used throughout the risk assessment.[8] In the 2023 draft update to the risk assessment in support of the 2024 Final Rule – Legacy CCR Surface Impoundments and CCR Management Units, USEPA confirms that "it was most appropriate to use porewater data to model leakage from surface impoundments."[9]

The use of porewater constituent concentrations as source water concentrations in the groundwater model is therefore consistent with USEPA's well-documented conceptual site model of CCR SIs and approach for modeling potential migration of chemical constituents within groundwater.

2. Appropriate Use of Surrogate Parameters

IEPA stated in their October 10, 2023, preliminary comments on the Operating and Construction Permit Application that all constituents present in the East Ash Pond should be included in groundwater modeling (Comment 23). The initial April 18, 2024, response to IEPA's comments provided rationale for the interpretation that 35 I.A.C. § 845 does not require modeling of all constituents regulated under 35 I.A.C. § 845.600 as well as an independent subject matter expert review validating the modeling approach for evaluating closure alternatives (Attachment E). Additional considerations are provided here.

The surrogates selected for groundwater flow and transport modeling are conservative parameters (*i.e.*, aqueous concentrations are predominantly affected by physical processes such as dilution and dispersion rather than by chemical attenuation mechanisms) and therefore represent the maximum plume extent. The use of a conservative parameter to represent plume extent and clean-up times is consistent with USEPA modeling examples intended for evaluating relative remedy effectiveness.[10]

Conservative parameters are most acutely affected by closure: once the source is controlled via closure, concentrations of surrogate parameters in the groundwater will respond in timeframes consistent with groundwater flow. Source control will control, minimize, or eliminate, to the maximum extent feasible, infiltration of liquids through the CCR (per 35 I.A.C. 845 § 845.750(a)(1)), mitigating the flux of not only the surrogate parameters but all other parameters potentially leaching from the unit. The time to reach the GWPS determined by modeling surrogate parameters correlates to the effectiveness of the proposed closure as source control. Therefore, the existing model is appropriate for assessing the effect of closure on the flux of all CCR SI porewater constituents.

3. Relevance of Geochemical Reactions to Groundwater Modeling Outcomes

As described above, methods of source control that meet the performance criteria in 35 I.A.C. § 845.750 will mitigate the flux of all CCR SI porewater constituents to the groundwater after closure. However, the presence of downgradient groundwater concentrations of a surrogate parameter exceeding the GWPS is an indication that other parameters observed in CCR SI porewater may also have migrated from the unit into the groundwater or aquifer solids. These constituents may be currently

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[7] Section 3.4.1, Ibid.

[8] Leachate data collected using EPA Leaching Evaluation Assessment Framework methods were "only used […] to characterize the leachate for the range of materials resulting from various air pollution control technologies" (80 FR 21,322 [April 17 2015]) for which insufficient porewater data were available.

[9] USEPA. 2023. Risk Assessment of Coal Combustion Residuals: Legacy Impoundments and CCR Management Units. Draft. Office and Land and Emergency Management; Office of Resource Conservation and Recovery. October.

[10] USEPA. 1994. Ground-Water Modeling Compendium. Second Edition. Office of Solid Waste and Emergency Response. 500-B-94-004. July.

attenuated in the subsurface (*i.e.*, immobilized to the solid phase by sorption or mineral precipitation) and are therefore not observed above groundwater protection standards in downgradient groundwater. During in-person meetings, IEPA expressed concern that the current flow and transport modeling used in the closure alternatives analysis does not account for this possibility.

All potential source control measures will mitigate the flux of CCR SI porewater to the groundwater, driving a shift toward greater influence of background groundwater on subsurface geochemistry. This creates a trailing gradient where "upgradient groundwater or rainwater flows into the infiltrating plume or enters the zone affected by the plume."[11] As IEPA noted, the trailing gradient may affect the mobility of constituents previously released to the groundwater. However, **a return to background groundwater conditions and potential creation of a trailing gradient would occur regardless of the selected closure alternative**.

Although the method of closure does not affect the behavior of constituents that may have previously migrated from the subsurface, an understanding of the geochemical controls on those constituents is important for evaluating conditions in the subsurface post-closure. The creation of a trailing gradient may cause changes in regulated constituent mobility that should not be mistaken for a failure of source control. **Attachment A** to this document provides a geochemistry overview of parameters that may have been previously released from the CCR SI based on detected concentrations in porewater. This analysis is intended to provide a foundation for future understanding of chemical behavior within the subsurface during the thirty-year post-closure care monitoring period.

In conclusion, the existing flow and transport model is appropriate for assessing the effectiveness of closure alternatives to "control, minimize, or eliminate, to the maximum extent feasible, infiltration of liquids through the CCR" (35 I.A.C. § 845.750(a)(1)). The performance of closure will be documented through post-closure care, and monitoring will occur in accordance with 35 I.A.C. § 845.780. Post-closure monitoring will be informed by the geochemistry overview presented in **Attachment A**.

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[11] Savannah River National Laboratory. 2011. The Scenarios Approach to Attenuation-Based Remedies for Inorganic and Radionuclide Contaminants. Prepared for the United States Department of Energy, Contract No. DE-AC09-08-SR22470. SRNL-STI-2011-00459. August.

ATTACHMENT A

GEOCHEMICAL BEHAVIOR OF IEPA-REGULATED CONSTITUENTS IN NATURAL SYSTEMS

TECHNICAL MEMORANDUM

DATE January 2, 2025

Reference No. 23RAM01-1

TO Brian G. Hennings - Ramboll
Eric Tlachac - Ramboll

CC Stu Cravens - Vistra

FROM Shannon Zahuranec, Allie Wyman, and
Pam Rohal

EMAIL: shannon@lifecyclegeo.com

DRAFT - GEOCHEMICAL BEHAVIOR OF IEPA-REGULATED CONSTITUENTS IN NATURAL SYSTEMS

1.0 INTRODUCTION

Life Cycle Geo, LLC (LCG) has prepared this white paper to provide a geochemical overview of parameters that are measured at detectable levels in one or more of the Luminant coal combustion residual (CCR) surface impoundments in the State of Illinois. The measurable presence of constituents in porewater[1] does not necessarily lead to elevated constituent concentrations in groundwater downgradient. The fate and transport of constituents in groundwater is controlled by a variety of mechanisms including physical factors such as the rate of groundwater flow and dilution as well as through geochemical interaction with aquifer solids and associated attenuation by mechanisms of adsorption, ion exchange, and mineral precipitation and dissolution.

This white paper focuses on the geochemical controls on the transport and mobility of parameters detected in porewater at the Luminant Illinois fleet of CCR surface impoundments. Only a few constituents found in CCR porewater have been detected above groundwater protection standards (GWPS) in downgradient groundwater. The information presented here aims to provide a foundational explanation for the observed discrepancy between constituents detected in porewater and those in groundwater and identifies geochemical conditions that may be monitored for future assessments regarding how closure-related changes could affect the transport and attenuation of CCR constituents regulated under Illinois Environmental Protection Agency (IEPA)[2] and federal[3] programs. This white paper does not directly relate these fundamental principles to site-specific conditions, but rather provides a foundational geochemical understanding of the subsurface behavior of regulated parameters.

2.0 GROUNDWATER GEOCHEMISTRY

An overview of the geochemical behaviors and controls for each of the constituents regulated under Title 35 of the Illinois Administrative Code (35 IAC) § 845, which have been detected in CCR porewater at one or more of the Luminant sites in Illinois, is provided. The dominant geochemical controls on constituent behavior in groundwater are pH, oxidation and reduction (redox) conditions, and the presence of reactive mineral phases, which collectively influence solubility, mobility, and the potential for attenuation or transport. Constituents in groundwater are therefore grouped and discussed according to their geochemical behavior and transport mechanisms, allowing for a clearer understanding of their interactions within

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[1] The USEPA Human and Ecological Risk Assessment of Coal Combustion Residuals (2024) defines “impoundment pore water” as “the water present within interstitial spaces of the settled CCRs”.

[2] Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845.600(a)(1)

[3] Title 40 of the Code of Federal Regulations § 257 Appendices III and IV

subsurface environments. Groupings established for this white paper are based on fundamental geochemical principles and include conservative ions, oxyanions, alkaline earth metals, metals and transition metals, pH, and fluoride (Table 1). Boron, sulfate, total dissolved solids, calcium, and turbidity are also required monitoring parameters under 35 IAC § 845 but are not discussed here for the following reasons:

- Boron and sulfate: These are the primary contaminants of concern at most Luminant sites in Illinois and geochemical behaviors are discussed at length in the geochemical conceptual site models, the groundwater modeling reports, and closure applications for each respective site.
- Total dissolved solids: Total dissolved solids behavior at most CCR sites is significantly correlated with sulfate or chloride and thus is handled in the same documents by proxy.
- Calcium and turbidity: These are required monitoring parameters but do not have regulatory limits. For this reason, they are not discussed further.

Inclusion of parameters within this document does not imply parameters are detected in downgradient groundwater. However, several Luminant fleet CCR surface impoundments have concentrations of boron and/or sulfate above the respective GWPS in downgradient groundwater, suggesting other parameters observed in CCR porewater may also migrate into the subsurface prior to closure. Closure of CCR surface impoundments, regardless of the closure method, will reduce the contribution of porewater to groundwater chemistry and will drive a shift toward greater influence of background groundwater on subsurface water chemistry. The geochemical evolution of groundwater chemistry toward background conditions is the primary factor that could potentially influence the behavior of previously released constituents, rather than the specific method of closure itself. Although the method of closure does not affect the behavior of constituents that may have previously migrated to the subsurface, an understanding of the geochemical controls on those constituents is important for evaluating conditions in the subsurface post-closure. To provide a foundation for understanding post-closure geochemical behavior within the subsurface, this document provides a geochemistry overview of parameters that may have been previously released from the CCR surface impoundments.

Table 1: IEPA regulated parameters discussed in the text.

Grouping	Parameter	35 I.A.C. § 845 Limit[1]	Section
pH	pH (field)	6.5 to 9.0 S.U.	Section 2.1
Conservative Ion	Chloride, total	200 mg/L	Section 2.2
Fluoride	Fluoride, total	4.0 mg/L	Section 2.3
Oxyanion	Antimony, total	0.006 mg/L	Section 2.4
	Arsenic, total	0.010 mg/L	
	Molybdenum, total	0.1 mg/L	
	Selenium, total	0.05 mg/L	
Alkaline Earth	Barium, total	2.0 mg/L	Section 2.5
	Beryllium, total	0.004 mg/L	
	Radium 226 and 228 combined	5 pCi/L	
Metal/Transition Metal	Cadmium, total	0.005 mg/L	Section 2.5
	Chromium, total	0.1 mg/L	
	Cobalt, total	0.006 mg/L	
	Lead, total	0.0075 mg/L	
	Mercury, total	0.002 mg/L	
	Thallium, total	0.002 mg/L	
	Lithium, total	0.04 mg/L	

Notes: mg/L - milligrams per liter; pCi/L - picocuries per liter; S.U. - standard units

1. In accordance with 35 I.A.C. Section 845.600(a)(1), compliance with specific groundwater protection standards is required. Furthermore, per Section 845.600(a)(2), if the background concentrations of any constituents are higher than the listed groundwater protection standards, the background concentration must serve as the applicable compliance limit.

2.1 PH

Groundwater pH is a critical parameter regulated by the IEPA, as it influences the mobility of metals, transition metals, and other contaminants. Groundwater pH in the natural environment typically ranges from slightly acidic to neutral, but various natural and anthropogenic processes can drive fluctuations, affecting the transport or immobilization of dissolved species. Groundwater pH is shaped by processes like carbonate dissolution, sulfate reduction, iron oxidation, and organic matter decomposition. The net outcome of these key processes (plus additional secondary processes) drives the measured groundwater pH. Acidic conditions resulting from these processes typically enhance metal mobility (for cationic, or positively charged species, in particular), while neutral to alkaline conditions tend to promote immobilization through sorption and precipitation, limiting contaminant transport. Key influences on groundwater pH are as follows:

- **Carbonate Equilibria -** the dissolution of carbonate minerals, such as calcite ($CaCO_3$), plays a major role in buffering groundwater pH. Interaction of groundwater with carbonates raises pH toward neutral to alkaline conditions, which promotes the immobilization of metals through sorption and precipitation as metal hydroxides (Stumm and Morgan, 1996; Langmuir, 1997).

- **Sulfate Reduction -** In reducing environments, microbial oxidation of organic matter coupled with sulfate reduction produces hydrogen sulfide and acidity, decreasing the groundwater pH. This shift toward acidic pH enhances the solubility of metals such as beryllium, thereby increasing the potential for transport (Stumm & Morgan, 1996).

- **Oxidation of Dissolved Iron -** Oxidation of dissolved ferrous iron (Fe^{2+}) in groundwater can generate acidic conditions. When ferrous iron (Fe^{2+}) oxidizes to ferric iron (Fe^{3+}), it precipitates as ferric hydroxide ($Fe(OH)_3$), releasing protons (H^+) and lowering pH. This process can result in more acidic groundwater, increasing the mobility of metals like chromium (Cr(VI)) due to decreased sorption capacity (Stumm & Morgan, 1996).

- **Organic Matter Decomposition** – The decomposition of organic matter influences groundwater pH through the production of organic acids. Organic acids such as humic and fulvic acids can lower pH (Langmuir, 1997), especially in organic-rich environments like wetlands. This drop in pH enhances the solubility and transport of metals like lead and beryllium by reducing sorption to mineral surfaces (Hem, 1985). Additionally, organic matter can form complexes with certain metals, influencing their mobility independently of pH shifts.

2.2 CONSERVATIVE IONS

Chloride is the only conservative ion regulated by the IEPA that is considered in the discussion of this white paper[4]. Chloride is considered conservative because it generally is not involved in sorption, mineral precipitation, or redox reactions (Hem, 1985). Chloride can precipitate as various salts through evaporation, though this is unlikely in groundwater environments.

2.3 FLUORIDE

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[4] Boron and sulfate are also considered to be generally conservative in terms of groundwater transport but are not discussed in this white paper for the reasons described in Section 2.0.

Fluoride is a major ion regulated by the IEPA and is primarily present as a dissolved anion (F^-) in natural groundwaters. Fluorite (CaF_2) precipitation is the primary control on fluoride mobility, with notable decreases in concentration in calcium rich waters (Hem, 1985). Fluoride mobility can also decrease due to the precipitation of apatite-group minerals (fluorapatite, $Ca_5(PO_4)_3F$). The precipitation of these minerals is pH-dependent, with less mobility (i.e., greater precipitation) at low pH. Conversely, fluoride mobility increases at more alkaline pH due to the increase in fluorite solubility.

Fluoride mobility also decreases due to sorption onto clay minerals as well as iron and aluminum hydroxides. The fluoride ion also has a similar ionic radius to the hydroxide ion (OH^-) and can replace hydroxide in mineral structures (Hem, 1985). While fluoride itself does not participate in any redox reactions, redox changes in a system can influence sorption as iron and aluminum hydroxides either precipitate (oxic environments) and sorb more fluoride, or dissolve (reduced environments) and release sorbed or coprecipitated fluoride.

2.4 OXYANIONS

Oxyanions, constituents that are present as negatively charged oxygen compounds in natural groundwaters, include the IEPA-regulated constituents' antimony, arsenic, molybdenum, and selenium. Chromium can also behave as an oxyanion but is primarily considered a metal based on the most prevalent behavior in groundwater and is therefore discussed in Section 2.6. Oxyanion behavior in groundwater is controlled by redox conditions, pH, and sorption to mineral surfaces, which determine whether these contaminants become mobile or remain immobilized (Oladoja, 2021).

Under oxic conditions, many oxyanions, including arsenate ($As(V)O_4^{3-}$), molybdate ($Mo(VI)O_4^{2-}$), and selenate ($Se(VI)O_4^{2-}$), exhibit strong sorption to mineral surfaces like ferrihydrite and aluminum oxides. This sorption is enhanced at low pH due to the increasingly positive charge on the oxide mineral surface under low pH, reducing oxyanion mobility. As the pH rises, desorption may occur, increasing the transport potential (Davis and Leckie 1978; Tian et al. 2017). For example, as the pH increases, arsenate can desorb from mineral surfaces, increasing mobility and potential for groundwater transport. In contrast, under reducing conditions, oxyanions like arsenite ($H_3As(III)O_3$) and selenite ($Se(IV)O_3^{2-}$) become more mobile due to redox-driven transformation and weakened sorption.

Sorption competition further influences mobility (Oladoja, 2021; Hem 1985). Oxyanions with similar charge and ionic radii can compete for sorption sites, displacing one another, particularly as pH rises. This interplay of redox conditions, pH, and sorption dynamics is key in determining the transport or immobility of oxyanions in groundwater systems.

2.5 ALKALINE EARTH METALS

Alkaline earth metals, including beryllium, barium, and radium, exist as divalent ions in natural systems (Hem, 1985). These metals, regulated by the IEPA, behave differently in groundwater based on their interactions with other chemical species and geochemical conditions, particularly the presence of sulfate, redox conditions, and sorption dynamics.

- **Beryllium -** though less commonly detected in groundwater than barium or radium, beryllium exhibits behavior strongly influenced by pH and sorption to mineral surfaces (Hem, 1985; Boschi and Willenbring, 2016). In neutral to alkaline conditions, beryllium tends to form insoluble hydroxides ($Be(OH)_2$), which limit its mobility (Boschi and Willenbring, 2016). However, under acidic conditions, beryllium generally remains dissolved as Be^{2+} and is therefore more mobile. In the divalent dissolved form, sorption to mineral surfaces, particularly clay minerals and organic compounds, also limits beryllium mobility in neutral pH environments. The transport potential of beryllium increases in low-pH conditions where sorption of cations is weakened, causing beryllium to remain dissolved in the groundwater (Boschi and Willenbring, 2016).

- **Barium -** the mobility of barium in groundwater is primarily controlled by the presence of sulfate. When sulfate is present, barium reacts to form the relatively insoluble mineral barite ($BaSO_4$), limiting the mobilization of barium (Hem, 1985; Gilkeson et al., 1978; Gilkeson et al., 1983). This has been observed in Illinois groundwater, where the mixing of barium-rich/sulfate-poor waters with sulfate-rich/barium-poor waters has caused barite precipitation, even leading to pump failure due to clogging (Gilkeson et al., 1978; Gilkeson et al., 1983). In the absence of sulfate, barium concentrations can become elevated due to water-rock interactions, as barium is released from bedrock minerals into the groundwater (Gilkeson et al., 1983). Additionally, sorption onto iron and manganese oxides, clay minerals, and organic matter can limit barium mobility under certain geochemical conditions. Sulfate reduction, driven by microbial activity under reducing conditions, can lower sulfate concentrations and thereby increase barium mobility (Hem, 1985).

- **Radium (Radium-226 and Radium-228) -** Radium is regulated by the IEPA as a combined parameter of $Ra^{226}+Ra^{228}$ and represents radioactive isotopes derived from the decay of uranium and thorium (Gilkeson et al., 1983). Radium behaves similarly to barium in groundwater and is often found in the same locations where barium concentrations are elevated (Gilkeson et al., 1978; Gilkeson et al., 1983). Like barium, radium can form the insoluble sulfate mineral radium sulfate ($RaSO_4$) in the presence of sulfate, which limits its mobility (Gilkeson et al., 1983; Hem, 1985). Furthermore, radium can substitute for barium in the barite structure via isomorphous replacement, further contributing to its immobilization in groundwater (Gilkeson et al., 1978).

- **Radium** can also sorb to ferrihydrite, clay minerals, and weakly to silicate surfaces. Sorption to ferrihydrite and clays can play a role in limiting radium mobility, but factors such as increases in ionic strength can lead to radium desorption, thereby enhancing its mobility (Gilkeson et al., 1983). Additionally, radium mobility can be influenced by the radioactive decay process itself whereby radium may be ejected from a mineral surface during the decay of sorbed thorium (Gilkeson et al., 1983).

2.6 METALS AND TRANSITION METALS

Metals and transition metals regulated by the IEPA in groundwater include chromium, lead, cobalt, cadmium, lithium, mercury, and thallium. The mobility of these metals is controlled by redox conditions, pH, and ability to sorb to mineral surfaces, with behavior varying based on the specific metal and groundwater chemistry (Hem 1985, Smith and Huyck, 1999). Metals and transition metals are grouped by general behavior in groundwater as follows:

- **Cadmium, Cobalt, and Lead -** These metals exhibit varying mobility depending on redox conditions and pH and are generally immobile in sulfidic environments or in neutral to alkaline conditions.
    - **Cadmium** is generally immobile under neutral to alkaline pH conditions due to mineral precipitation (e.g. $Cd_3(PO_4)_2$, $CdCO_3$, etc.) and adsorption predominantly to iron and manganese oxy-hydroxides and clay minerals such as montmorillonite, illite, and kaolinite (Kubier et al., 2019; McComish and Ong, 1988). Similarly, cadmium is less mobile under reducing environments due to precipitation of cadmium sulfide (McComish and Ong, 1988) and co-precipitation with other sulfide minerals (e.g. sphalerite, galena, and chalcopyrite). Cadmium tends towards mobility in groundwater (as Cd^{2+}) when pH is less than 6.5 standard units (S.U.) and under oxygenated conditions due to sulfide oxidation (Kubier et al., 2019).

  - **Cobalt** primarily exists as a divalent cation (Co^{2+}), which is generally immobile under neutral pH conditions due to sorption onto iron and manganese oxide mineral surfaces and coprecipitation with iron or manganese oxides. Cobalt exhibits increased mobility under acidic, oxidized conditions. The presence of organic ligands can reduce the overall sorption of cobalt in solution (Krumpka and Serne, 2002). Reducing environments can cause the solubilization of iron oxides, which will release sorbed or co-precipitated cobalt. However, as conditions become further reducing, cobalt can precipitate as cobalt sulfide in the presence of reduced sulfur (e.g., $Co(HS)_2^0$) (Krumpka and Serne, 2002).

  - **Lead** is generally immobile under neutral to alkaline pH conditions, due to precipitation as $Pb(OH)_2$ or sorption onto iron and manganese oxide mineral surfaces. Under reducing conditions, lead can also form insoluble lead sulfides (e.g., PbS) (McComish and Ong, 1988). Lead can generally be more mobile as a divalent cation (Pb^{2+}) under acidic conditions.

- **Lithium** primarily exists as a monovalent cation (Li^+) in solution and is generally more mobile than other trace elements but can be immobilized through sorption onto clay minerals with the amount of sorption dependent on cation exchange capacity (Anghel et al., 2002; Anderson et al., 1989; Robinson et al., 2018). Under certain weathering conditions, lithium may be strongly immobilized by incorporation into the matrix of secondary minerals, particularly kaolinite and vermiculite (Li and Liu 2020; Pogge von Strandmann et al., 2021; Steinhoefel et al., 2022). Lithium can also sorb onto amorphous aluminum oxides, with increased sorption occurring at higher pH (Prodromou, 2016).

- **Chromium** primarily exists as Cr(VI) in very oxidizing environments, which tends to be mobile due to weak sorption to hydroxides or clays, although it may sorb to organic matter (McComish and Ong, 1988). Cr(III), by contrast, is immobile in reducing environments due to strong sorption onto mineral surfaces or precipitation as $Cr(OH)_3$. Cr(III) is typically stable and immobile in neutral to alkaline conditions. Redox reactions facilitate oxidation of Cr(III) to Cr(VI) in the presence of oxidizers like manganese oxides while Cr(VI) can be reduced to Cr(III) in waters with organic matter, reduced iron, or sulfur compounds, as is typical of CCR porewater (McComish and Ong, 1988). Reduced iron and sulfur can also drive the reduction of chromium.

- **Thallium** primarily exists as a monovalent cation (Tl^+) and forms a stable and immobile sulfide mineral (Tl_2S) in reducing environments, such as is typical of CCR porewater (McComish and Ong, 1988). Thallium can also sorb strongly to montmorillonite clays. Conversely, thallium is mobile in oxidized environments, independent of groundwater pH.

- **Mercury** can exist as elemental mercury (Hg^0), divalent mercury (Hg^{2+}), or as methylmercury (CH_3Hg^+) in organic-rich environments. Hg^{2+} is immobile in neutral to alkaline conditions due to precipitation as $Hg(OH)_2$ or sorption onto mineral surfaces, and once sorption occurs, desorption is often negligible (McComish and Ong, 1988). In sulfidic conditions, mercury forms highly insoluble sulfides (e.g., HgS) (McComish and Ong, 1988). By contrast, mercury is generally mobile under acidic and oxidized conditions.

3.0 CONCLUSIONS

The transport and attenuation of most IEPA-regulated constituents in groundwater are primarily controlled by pH, redox, and availability of iron and sulfide, all of which can influence mineral precipitation/dissolution and sorption processes. Constituents can be broadly grouped according to geochemical characteristics to include, pH, conservative ions, fluoride, oxyanions, alkaline earth metals, and metals/transition metals. Yet, even within these broad groups, many constituents behave uniquely under specific redox and pH conditions and understanding these interactions is foundational for predicting contaminant movement and designing effective groundwater monitoring strategies.

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ATTACHMENT 2

WRITTEN RESPONSE TO IEPA COMMENTS DATED DECEMBER 28, 2023

January 3, 2025

Heather Mullenax
Illinois Environmental Protection Agency
1021 North Grand Avenue East
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Springfield, IL 62794

Re: Newton Power Plant Primary Ash Pond, W0798070001-01
Comments on Statistical Methods Proposed in Initial Operating Permit Application

Ms. Mullenax:

Illinois Power Generating Company (IPGC) received the Newton Power Plant CCR Surface Impoundment Operating and Construction Permit Application Review Letter dated October 10, 2023. We submitted the responses to Illinois Environmental Protection Agency's (IEPA's) initial comments dated March 8, 2024, with data and information that was reasonably and readily available. An additional letter was received by IPGC on December 28, 2023, regarding the statistical methods proposed in the Statistical Analysis Plan. The Statistical Analysis Plan was submitted as Attachment A to the Groundwater Monitoring Plan, included as Attachment I to the Newton Power Plant CCR Surface Impoundment Operating and Construction Permit Application. We submit the below responses to IEPA. The content of these responses was previously discussed with IEPA personnel in a meeting held May 2, 2024.

Comment 1a: *The statistical methods must define the following in order to review the statistical plan in accordance with Illinois EPA Quality Management Plan (A17-001), Guidance on Assessing Quality Systems (EPA QA/G-3), Data Quality Assessment: Statistical Methods for Practitioners EPA QA/G-9S, Data Quality Assessment: A Reviewer's Guide EPA QA/G-9R and/or Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8):*

a. The software program that is being used for statistical evaluation must be identified. If the software program is proprietary, software validation must be performed, documents, and signed off by at least the software validation draftee, senior reviewer, and project manager/quality manager. (EPA QA/G-3)

i. Software validation packages must include at least a known data set, empirical evaluation including formulas to prove the validity of the software, and outputs from both the software and the empirical calculations exhibiting that the software is producing the same output as the empirical evaluation. (EPA QA/G-3)

Response: All of the statistical results used in exceedance determinations were calculated using R. R is an open-source programming language with a strong focus on statistical analysis and is used by both the United States Environmental Protection

Agency (USEPA)[1] and United States Geological Survey (USGS)[2] in various applications. The statistical calculations used to determine exceedances are described in detail in the Statistical Analysis Plan submitted as Attachment A to the Groundwater Monitoring Plan. Each analysis described in that plan is associated with calculations done in R according to equations presented in USEPA's Unified Guidance (USEPA 2009)[3]. Table 1 identifies R functions used for these calculations, the package that is the source of the function, and the alpha associated with a statistically significant result (if applicable).

Two functions used are from the EnvStats[4] package. This package is widely used, including in USGS recommendations for statistical analyses[5]. Two functions are not from a published package: the code used to compute the Kaplan-Meier adjusted mean and standard deviation, and the code used to calculate the confidence band around the Thiel-Sen trend line. The code used to calculate the Kaplan-Meier adjusted mean and standard deviation are directly based on the equations presented in the USEPA 2009, Chapter 15, Section 15.3. The code used to calculate the confidence band around the Thiel-Sen trend line is derived from Appendix C.3.2 of USEPA 2009.

These functions are used to calculate aspects of background (upper tolerance limit) and compliance (confidence interval) statistics, respectively. Figure 1 and Figure 2 present flow charts to clarify how the upper tolerance limit and confidence interval calculations, respectively, are performed. The outcomes of the statistical evaluates are provided quarterly to IEPA as part of the detection of exceedances of the GWPSs.

Comment 1b:

b. *All input data sets for each constituent must be provide in a table in accordance with SW-846 chapter 1, incorporated by reference in 35 IAC 845. Chapter 1 of SW846 states that regulatory decisions must be made with environmental data.*

    i. *All data sets, used for statistical analysis, must be within the last eight consecutive quarterly sampling events in order to validate the statistical methods for recent activity (35 IAC 845.650(b)).*

Response: Title 35 of the Illinois Administrative Code (35 I.A.C.) § 845.650(b)(A) specifies that exceedance evaluations must use a *minimum* of eight independent samples for

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[1] Examples include Tools for Automated Data Analysis (https://www.epa.gov/waterdata/TADA) and Causal Analysis/Diagnosis Decision Information System (https://www.epa.gov/caddis/download-r-scripts-and-sample-data).

[2] Examples include the many projects and tutorials listed here: https://waterdata.usgs.gov/blog/tags/r/.

[3] USEPA. 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance. EPA 530-R-09-007.

[4] Documented in Millard, S.P. 2013. EnvStats: An R Package for Environmental Statistics. Springer, ISBN 978-1-4614-8455-4

[5] Helsel, D.R., Hirsch, R.M., Ryberg, K.R., Archfield, S.A., and Gilroy, E.J., 2020, Statistical methods in water resources: U.S. Geological Survey Techniques and Methods, book 4, chap. A3, https://doi.org/10.3133/tm4a3.

each background and downgradient well. There are several statistical advantages to using larger sample sizes. In general, a minimum of eight samples is required to adequately characterize the statistical features of the data, but statistical evaluations uniformly benefit from larger sample sizes (USEPA 2009, 5-3). Larger sample sizes increase the power of statistical tests (USEPA 2009, p. 3-21). Appropriate use of parametric statistics also typically gives greater statistical power and predictive ability. Parametric statistics can only be used if the data are normally distributed, or if they can be transformed to achieve normality. Data with larger sample sizes are more likely to approximate a normal distribution (the Central Limit Theorem; see USEPA 2009, p. 3-16). A test with greater statistical power "translates into a greater probability of identifying contaminated groundwater when it really exists," (USEPA 2009, p. 3-18). For these reasons, it is appropriate to use all representative data when calculating background and compliance statistics.

Comment 1c:

c. *Illinois Power Generating Company (Illinois Power) must provide the laboratory reports or EDD to validate the data input sets are accurate and follow 845.640(i) and 845.640(j).*

Response: IEPA has received the electronic data deliverables associated with all data used in statistical calculations, including those for data collected prior to the promulgation of 35 I.A.C. § 845, as part of previous responses to operating permit application comments.

Comment 1d:

d. *Illinois Power must identify the assumptions being used to analyze the data sets and any other methods. (EPA QA/G-9S).*

Response: The assumptions being used in analyzing the data sets is described in the Statistical Analysis Plan and are summarized below.

Statistical Independence – The primary means of ensuring statistical independence of groundwater samples is allowing sufficient time to elapse between sampling events to ensure that different volumes of groundwater are being sampled. However, the sampling schedules specified in 35 I.A.C. § 845.650(b) conflict with the ability to collect independent samples, and instead represents a successive sampling design.

The testing strategy presented in the Statistical Analysis Plan based on guidance in USEPA 2009 accounts for a lack of statistical independence that may be inherent in frequent sampling programs: "Tests constructed in this way at each successive evaluation period will not be statistically independent; instead, the proposed testing strategy falls into the realm of sequential analysis," (USEPA 2009, p. 7-14).

Lack of outliers: Rigorous data validation and review is used in lieu of formal outlier testing to ensure that all data used in statistical evaluations is representative of field conditions. Quality control/quality assurance data are collected and data validation is completed in accordance with the Quality Assurance Project Plan. Project staff familiar with the site and historical data review the data generated each quarter and facilitate additional validation as needed. Exclusion of potential outliers may be considered only for data and that could cause extremely elevated background concentrations (see response to Comment 1f).

Stationarity: Groundwater data would fulfill the assumption of stationarity if measurements are consistent over both time and space. Statistical analyses of trend are used to evaluate the assumption that groundwater quality values (i.e., constituent means) are stationary over time. A 99% confidence Mann-Kendall test was used to perform the trend analysis. For the calculation of upper tolerance limits (*i.e.*, background evaluation), if any data set exhibited a statistically significant trend, each scenario was investigated case-by-case. For the calculation of confidence intervals (*i.e.*, compliance evaluation), if any data exhibited a statistically significant trend, the confidence level around either the least squares linear regression line (when residuals of that regression met the assumption of data normality; see below) or the Thiel-Sen trend line (when residuals of the least squared linear regression did not meet the assumption of data normality) was calculated. Changes in concentrations over time may also be evaluated by analysis of variance tests. Although spatial variability may occur, it cannot be addressed by using intra-well comparisons (as recommended in USEPA 2009) due to an absence of groundwater data prior to unit operation.

Data normality: Data and log-transformed data is tested for normality using a 99% confidence Shapiro-Wilk test as recommended in the Unified Guidance: "If the normal distribution is rejected by a goodness-of-fit test, one should generally test the normality of the logged data, in order to check for lognormality of the original observations. If this test also fails, one can […] use a non-parametric technique," (USEPA 2009, p. 10-9). In cases where neither the data nor log-transformed data meet the normal distribution, a non-parametric technique is used (see response to Comment 1g).

Comment 1e:

e. Illinois Power must identify the non-detects within the data set. Illinois Power must review the statistical methods guidance for appropriate use of non-detects in the statistical methods provided and provide a detailed explanation of the rationale including empirical formulas for examples of the implementation of the statistical methods. (EPA QA/G-9S).

Response: Non-detect data processing is described in the Statistical Analysis Plan, submitted as Attachment A to the Groundwater Monitoring Plan, and is summarized below.

The treatment of non-detects is based on the percent of non-detected data relative to the total number of results. If the frequency of non-detect data is less than or equal to 15%, half of the reporting limit is substituted for these data. If the non-detect frequency is greater than 15% and less than or equal to 50% and the data are normally or log-normally distributed, the Kaplan-Meier is used to estimate the mean and standard deviation adjusted for the presence of left-censored values. If the non-detect frequency is greater than 15% and data cannot be normalized, or the non-detect frequency is greater than 50%, a non-parametric test is used. This is consistent with USEPA 2009 Section 15.6.

Comment 1f:

f. The Agency's position on outliers is that verified data from a NELAP certified laboratory is representative of the aquifer properties analyzed. Outliers cannot be evaluated for exclusion from any dataset without explicit data validation identifying discrepancies from the laboratory and/or field procedures that would qualify a data point to be considered an outlier. Illinois Power must use the USEPA data validation procedures to determine when or if a data point is to be excluded from a data set. (EPA QA/G-8).

Response: No data were excluded from any Newton data set. Data are not excluded from the compliance well data set solely on the basis of being statistical outliers. The only circumstance in which a data point may be excluded without specific field or laboratory quality evidence that it is not representative of actual field conditions are rare, extreme cases in which a high outlier disproportionately affects the distribution of the background data and evaluation of background concentrations (USEPA 2009, p. 5-5). The exclusion of extremely elevated background data, even when no cause of the extreme observation in known, is a conservative measure intended to be protective of downgradient groundwater. This data would be retained in the database and in data presentation but would be marked as inappropriate for inclusion in statistical analysis.

TABLES

Table 1. R functions used in statistical calculations

Response to Comments on Statistical Methods Proposed in Initial Operating Permit Application
Newton Power Plant
Newton, Illinois

Calculation	Function	Alpha	Source	Notes
Mean	mean()	NA	Base R	
Median	median()	NA	Base R	
Log transformtion	log()	NA	Base R	
Exponentiation	exp()	NA	Base R	Used to back-transform results from calculations on log()-transformed data
Standard deviation	sd()	NA	Base R	
Normality test	shapiro.test()	0.01	Base R	
Least-squared linear regression	lm()	0.01	Base R	
Confidence band around linear regression	predict()	0.01	Base R	
t statistic	qt()	0.01	Base R	Used to determine multiplier for the standard deviation when calculating the confidence interval around a mean or geometric mean
Quantile function	qnorm()	0.01	Base R	Used to determine the rank for the confidence interval around a median
Tolerance interval k	tolIntNormK()	0.05	EnvStats	Used to determine the multiplier for the standard deviation when calculating the 95% confidence/95% coverage tolerance interval around a mean or geometric mean
Mann-Kendall trend test	kendallTrendTest()	0.01	EnvStats	

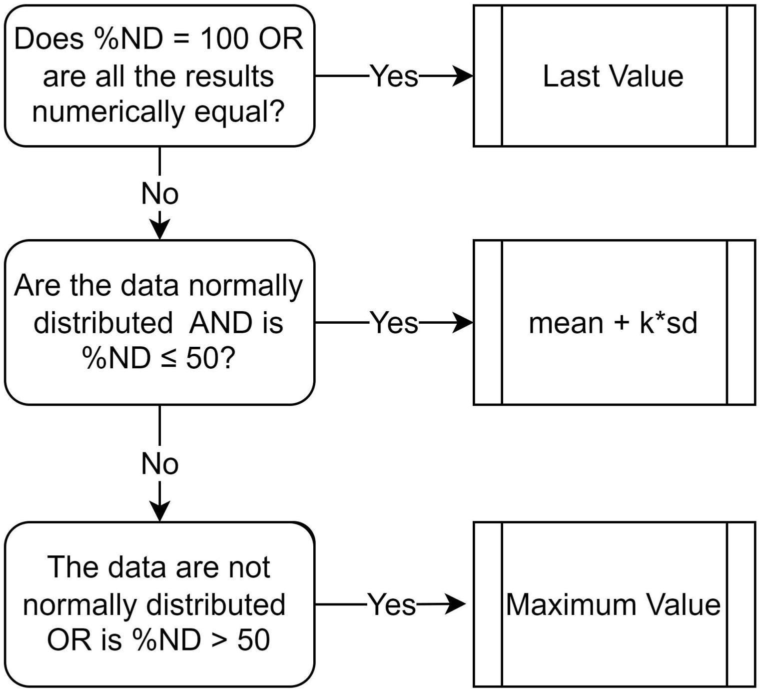
FIGURES

Notes

%ND = Percent non-detected samples

sd = standard deviation

k = kappa for tolerance limit (95% confidence/95% coverage)



RAMBOLL

Statistical Methodology for Determination of Upper Tolerance Limits
Response to Comments on Statistical Methods Proposed in Initial Operating Permit Application
Newton Power Plant
Newton, Illinois

Figure 1

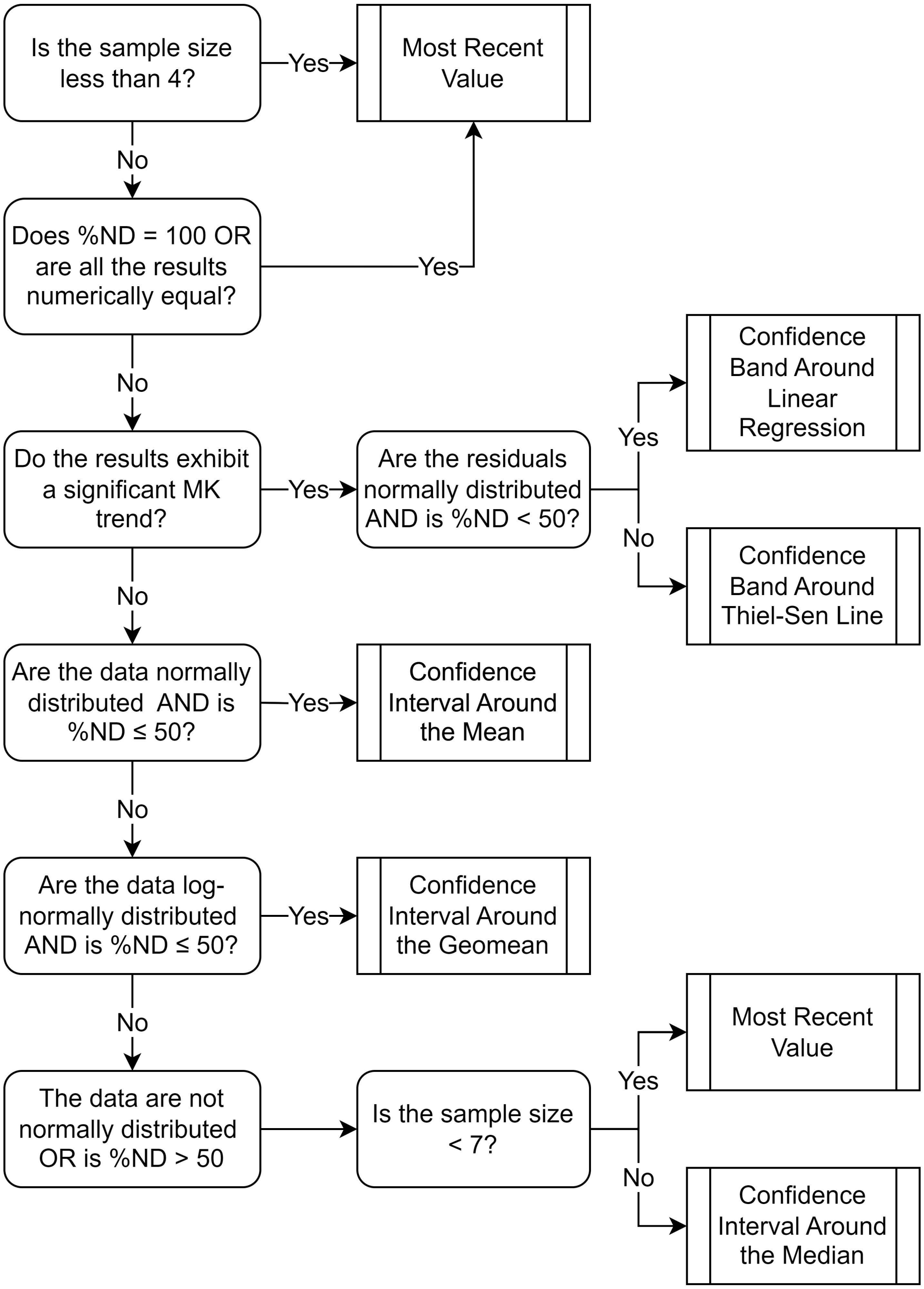
Notes

%ND = Percent non-detected samples

MK = Mann-Kendall Trend Test

Alpha Levels:

- Normality = 0.01
- MK Trend = 0.01
- Confidence Level = 0.01



Statistical Methodology for Determination of Confidence Intervals
Response to Comments on Statistical Methods Proposed in Initial Operating Permit Application
Newton Power Plant
Newton, Illinois

Figure 2