The Intersection of the CCR Rule, Superfund, and Irrigation on the Great Plains

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Abstract

Groundwater investigations stemming from the 2015 Coal Combustion Residual (CCR) Rule at the Whelan Energy Center (WEC) in Hastings, Nebraska detected selenium above the USEPA's MCL up-gradient of the CCR unit. Because selenium is regulated under the CCR Rule and can originate from CCR, understanding its origin is important. The region is agricultural with groundwater being the main irrigation water source. Also, three Superfund sites exist up-gradient. While the Superfund sites are focused on chlorinated solvents, other contaminants are not ruled out and part of the treatment included oxygenation to stimulate microbes. For part of the Superfund remedy, the WEC installed an upgradient production well to capture the chlorinated solvents as they approached the WEC (the plume passed this point prior to installing the well, but the well cuts the plume's distal end from its source). Generally, selenium has increased regionally in the groundwater over the past several decades. Why selenium has increased is not explicitly known; however, the processes involved for agriculture and the Superfund sites are all potential sources. This presentation discusses the approach and activities performed for the hydrogeological and hydro-geochemical evaluation of the CCR unit and the development of a detailed conceptual site model to better understand the presence of selenium.

1 Introduction

On April 17, 2015, the U.S. Environmental Protection Agency (USEPA) published the final rule for the regulation and management of Coal Combustion Residuals (CCR) under the Resource Conservation and Recovery Act (RCRA). The CCR Rule – effective on October 19, 2015 – applies to electric utilities and independent power producers that fall within NAICS code 221112, and facilities which produce or store CCR materials in surface impoundments or landfills. The Gerald T. Whelan Energy Center (WEC) in Hastings, Nebraska has two fossil fuel combustion units with active storage of CCR in the on-site WEC Temporary Ash Disposal Area permitted with the State of Nebraska Department of Environment and Energy (NDEE Permit Number NE0204129, Facility ID 58048). Figure 1 shows the location of WEC and Hastings, Nebraska and Figure 2 shows the layout of the WEC CCR facilities. The WEC Temporary Ash Disposal Area is an existing CCR surface impoundment under the CCR Rule. The CCR rule established requirements for groundwater monitoring and corrective action in the U.S. Code of Federal Regulations (CFR) Title 40 Parts §257.90 through §257.98.

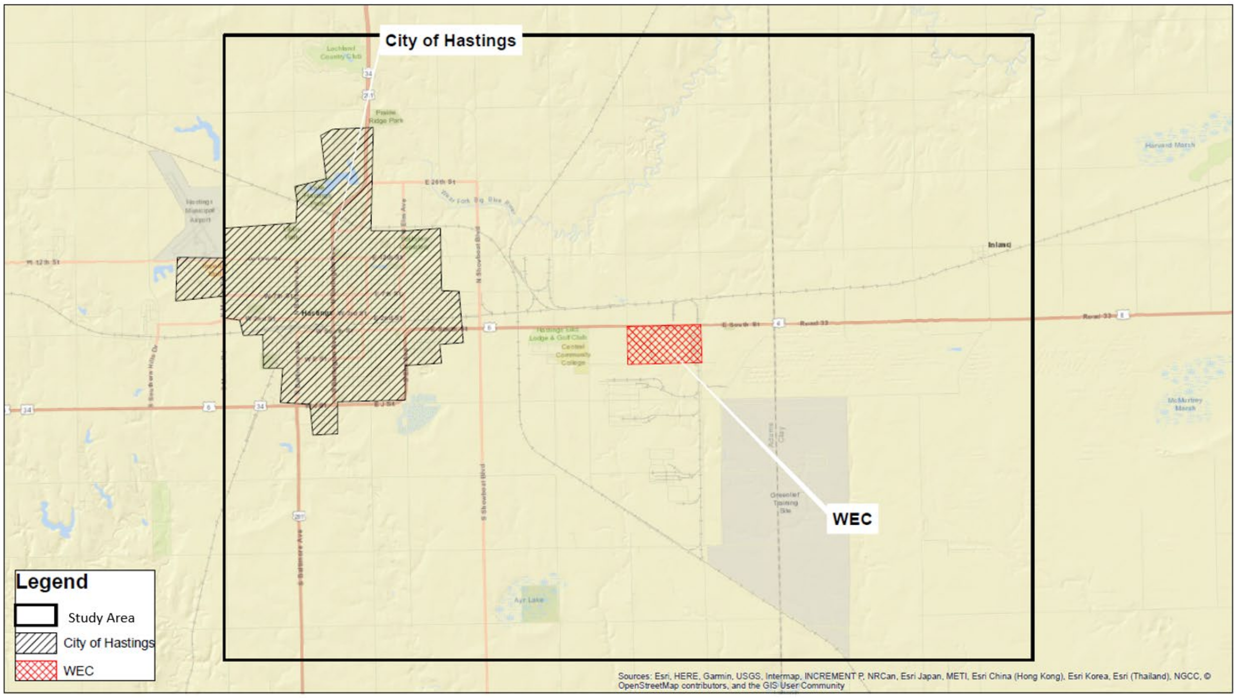

Figure 1- WEC Location

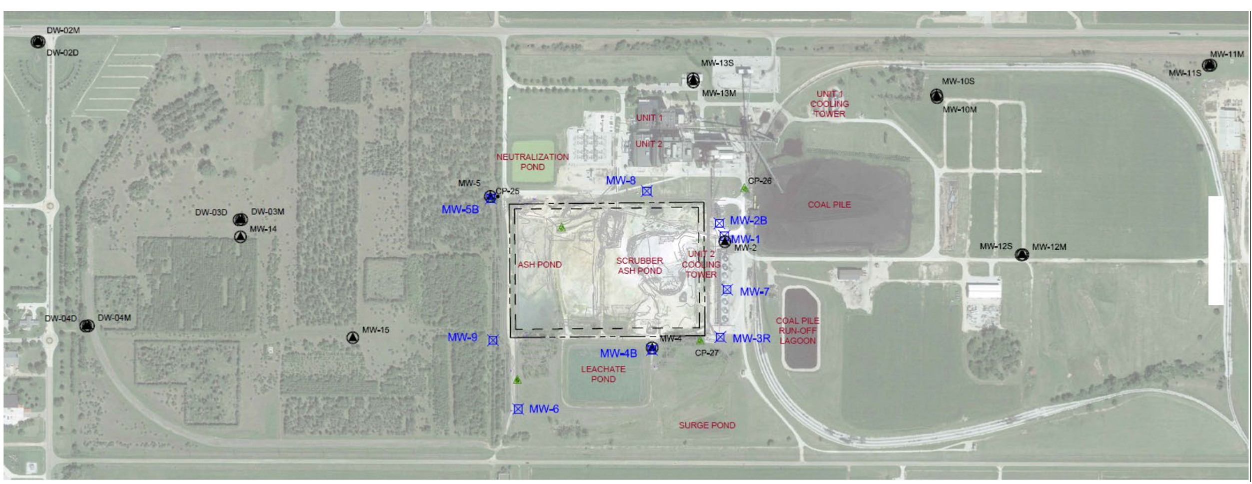

Figure 2 - Site Layout and Monitoring Well Locations

1.1 Site History

City of Hastings, Hastings Utilities (HU) owns and operates an existing fossil fuel combustion ash disposal area (designated as the WEC Temporary Ash Disposal Area) that is used exclusively by the WEC. The WEC is located at 4520 East South Street, Hastings, Adams County, Nebraska, approximately two miles east of the City of Hastings, Nebraska (Figure 1). The WEC site is a parcel located within the Hastings Naval Ammunition Depot (NAD) and as such is included in the Superfund activities for this subsite of the Hasting Groundwater Contamination Superfund Site. The Superfund actions include groundwater and soil restoration. Buried by-products of NAD have been found on the site. NAD extends south, east and west of the site. The WEC is also down-gradient of the various Superfund sites and subsites of the Hastings Groundwater Contamination Superfund Site located in the City of Hastings. These sites include, but are not limited to, the Colorado Avenue Subsite, Second Street Subsite, North Landfill Subsite, and the Far-Mar-Co Subsite.

WEC consists of two fossil fuel combustion units. WEC Unit No. 1 (WEC1) is owned and operated by HU. WEC Unit No. 2 (WEC2) is owned by Public Power Generation Agency (PPGA) of which HU is a member and acts as operating agent for PPGA. WEC Temporary Ash Disposal Area is an existing unlined CCR surface impoundment and serves the two fossil fuel combustion units. The WEC Temporary Ash Disposal Area is located directly south of WEC1 and WEC2 in the NW quarter section of Section 14, Township 7 North, Range 9 West of Adams County, Nebraska. The WEC Temporary Ash Disposal Area (NDEE Permit No. NE0204129, Facility ID 58048), permitted with the State of Nebraska, is approximately 23.2 acres.

CCR disposal at this site began in 1981, the same year that commercial operation of WEC1 began. Fossil fuel bottom ash and fly ash mixture (pond ash) from WEC1 is sluiced to the WEC Temporary Ash Disposal Area. Commercial operation of WEC2 began on May 1, 2011. Fly ash from the WEC2 silo is normally direct loaded into trucks for off-site beneficial use. WEC2 bottom ash is hauled in dump trucks and stockpiled within the limits of the disposal area. Scrubber ash from WEC2 is moisture conditioned and also hauled to the disposal area. Pond ash and scrubber ash are kept apart in the WEC Temporary Ash Disposal Area by a separation berm. Hastings Utilities has marketed and utilized the CCR for beneficial reuse.

The source of process water for the WEC is well water supplied from six wells (A through F); five of which are on site. Well D is located approximately 1.5 miles west, up-gradient of the WEC. Well D was installed to capture volatile organic compound contaminants from some of the Superfund subsites, with the mid-point in the plume location selected to accelerate cleanup. At the time of installation, the contamination plume had already passed Well D's location on its way towards the WEC, so some of the plume may still exist between Well D and the WEC.

1.2 Regulatory Framework

On March 1, 2018, WEC published statistically significant increases (SSIs) in down-gradient monitoring wells at the WEC Temporary Ash Disposal Area (WEC, 2018) from the CCR Rule Appendix III detection monitoring program. The SSIs were based on calcium, TDS, chloride, and sulfate being detected in down-gradient monitoring wells at concentrations that were higher than the up-gradient wells. An alternative source demonstration (ASD) evaluation was conducted for the published SSIs (dated May 1, 2018). The ASD evaluation did not fully demonstrate an alternative source for all of the detected SSIs within the timeframe allowed. As a result, WEC initiated an assessment monitoring program, as required in the CCR Rule, for the WEC Temporary Ash Disposal Area within the 90-day period specified in §257.95.

Groundwater sampling was completed as part of an assessment monitoring program for the WEC Temporary Ash Disposal Area in July 2018 [as specified in §257.95(b)] and October 2018 [as specified in §257.95(d)]. As specified in §257.95(b), the July 2018 sampling event was analyzed for the full Appendix III and Appendix IV constituent lists. As specified in §257.95(d)(1), the October 2018 sampling event was analyzed for all parameters in the Appendix III list and those constituents in Appendix IV that are detected in response to §257.95(b). Selenium and lead were detected above the USEPA MCL in both down-gradient and up-gradient wells. Groundwater protection standards (GWPS) were established for all detected Appendix IV constituents in accordance with 40 CFR §257.95(h). Down-gradient sampling results since October 2018 assessment monitoring were used to evaluate for SSIs over background and statistically significant levels (SSLs) over the GWPS. No Appendix IV constituents were detected over the GWPS and the WEC Temporary Ash Disposal Area remains in assessment monitoring. All wells in the CCR groundwater monitoring network are sampled at least semi-annually, in accordance with the assessment monitoring program requirements (40 CFR §257.95).

3 Conceptual Model

The WEC exists in the Great Plains, where precipitation falling on the ground will either be returned to the air by evaporation and transpiration, run off to nearby streams, or infiltrate into the ground as recharge to groundwater. Irrigation, ponding, and planned recharge basins can also add water to the groundwater recharge. Recharge to the groundwater from precipitation and other sources percolates through the unsaturated vadose zone until it arrives at the saturated portions of subsurface becomes groundwater. Under natural conditions, groundwater flows through the subsurface material (the aquifer) from its point of recharge (high head) to point of discharge (low head), usually at a surface water body such as a stream or lake. Hydrogeologic properties of the subsurface material control both the percolation through the vadose zone and flow through the aquifer. Human activities such as water withdrawals from wells and water storage in ponds both interrupt and add to this process. While the water is moving through the subsurface it can geochemically interact with the subsurface material where properties of the water are changed, and chemical constituents are added to the groundwater. Human activities can also add chemical constituents to the groundwater through many mechanisms including leaking of liquids, discharge of water containing high concentrations constituents and adding material, such as CCR, which percolating water can come in contact and interact with, adding dissolve constituents. The geochemical conditions of the subsurface along with the advective forces of both percolating water in the vadose zone and flowing water in the aquifer will control the fate and transport of the constituents. Where the groundwater discharges or is withdrawn, there is a potential for these constituents to come into contact with both human and ecological receptors.

3.1 Hydrostratigraphy

The geology and hydrogeology of the former Blaine Naval Ammunition Depot (NAD), which includes the WEC and surrounding area, have been studied. The following is a summary of the hydrostratigraphic units reported in United States Army Corp of Engineers (USACE, 2010):

> *In general, the unsaturated zone consists of topsoil, loess (silty clay), and sand and gravel deposits. This zone is comprised of shallow soil (<10 feet bgs), and the vadose zone, which includes layers of soil from 10 feet bgs to the top of groundwater. The groundwater surface underlying the former NAD is located approximately 95 to 120 feet bgs. Groundwater exists in the following general hydrogeologic units (from top to bottom):*
>
> - *Unconfined Aquifer: This unit is comprised of sand, gravel, and clayey or silty sand between the groundwater surface and the upper-confining layer. This unit has a saturated thickness of generally less than 15 feet.*
> - *Upper-Confining Layer: Generally, a silty clay, up to 11 feet thick, predominantly present in the northern portion of the former NAD.*
> - *Semi-Confined Aquifer: This is the primary hydrogeologic unit in the region and is comprised of sand and gravel with thin discontinuous layers of silty clay and clayey sand inter-bedded within the unit. The unit has a thickness of approximately 120 to 140 feet. In areas where the upper-confining layer is absent, the semi-confined aquifer acts as an unconfined aquifer.*
> - *Lower-Confining Unit: Generally comprised of silty clay and clayey silt deposits overlying bedrock. The depth to the top of the lower-confining unit beneath the former NAD is approximately 230 to 265 feet bgs. This hydrostratigraphic unit represents the predominantly shale Niobrara Formation and the top surface represents the base of the principal aquifer (Layne GeoSciences, 1997).*

The same concept for the hydrostratigraphy was applied by Olsson Associates (2009) for their groundwater model layering at WEC, but they describe the Upper-Confining Layer as thin and discontinuous. The geology of the Hastings area is described by Keech and Dreeszen (1968), as reported in Layne GeoSciences (1997), as unconsolidated deposits of Pleistocene and Pliocene (Quaternary) age having a combined thickness of about 100 to 500 feet, with a composition of the deposits consisting of clay, silt, sand, and gravel. The unconsolidated deposits rest on the unconsolidated Ogallala Group (Miocene) where present west of Hastings. Underlying these deposits is a thick sequence of consolidated rocks of Cretaceous and other ages (Keech and Dreeszen, 1986), which are considered the base of the aquifer due to relatively low permeability.

3.2 Historic Groundwater Levels

Groundwater flows generally from the west (Platte River) to the southeast and east, however around the site groundwater has been shown to fluctuate between northeast and southeast (HDR, Inc., 2016c). Between 2000 and 2021, groundwater has generally dropped approximately 4-7 feet as can be seen on Figure 3 with an increase in static groundwater levels from 2018 to 2021. The average groundwater levels range from 1762.8 ft to 1786.8 ft. Pumping of surrounding on-site and off-site industrial and irrigation wells influences the local groundwater flow direction. Remediation occurring to the southeast at the NAD has the potential to significantly affect groundwater movement in the region.

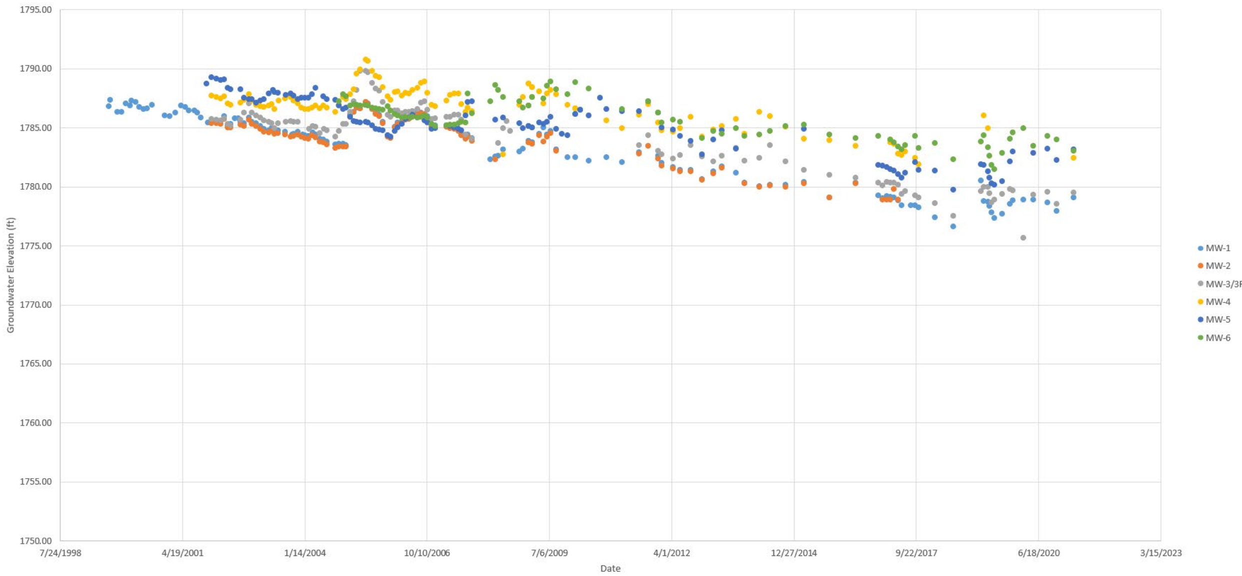

Figure 3 - Groundwater Hydrographs From Select Wells

3.4 Summary of Nearby Environmental Investigations

HDR, Inc. reviewed the USEPA Website to identify sites in the area of the WEC that are being investigated or remediated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, Superfund) and Formerly Used Defense Sites (FUDS). Three Superfund sites, one with seven sub-sites, and one FUDS were identified in the area surrounding the WEC. Groundwater remediation is taking place at some of these sites, including intensive groundwater removal and treatment at the FUDS (Naval Ammunition Depot) and introduction of oxygenating and oxidizing chemicals to the aquifer up-gradient of the WEC at some of the Superfund sites to remediate groundwater with volatile organic compounds originating from the Superfund sites. Information from environmental investigations contributes to this CSM. Some of these sites may have contributed constituents to the groundwater that are found in the groundwater at WEC, so need to be considered as part of the evaluations of impacts from CCR. Further, remedial activities change both groundwater chemistry and movement (e.g., changing the oxidation state of an aquifer has the potential to mobilize constituents such as selenium). Figure 4 shows the locations of each of the nearby environmental investigation sites as well as monitoring wells near the WEC associated with environmental investigations and groundwater contamination plumes associated with some of the sites (based on a figure prepared by Hasting Utilities of known plumes in 2010).

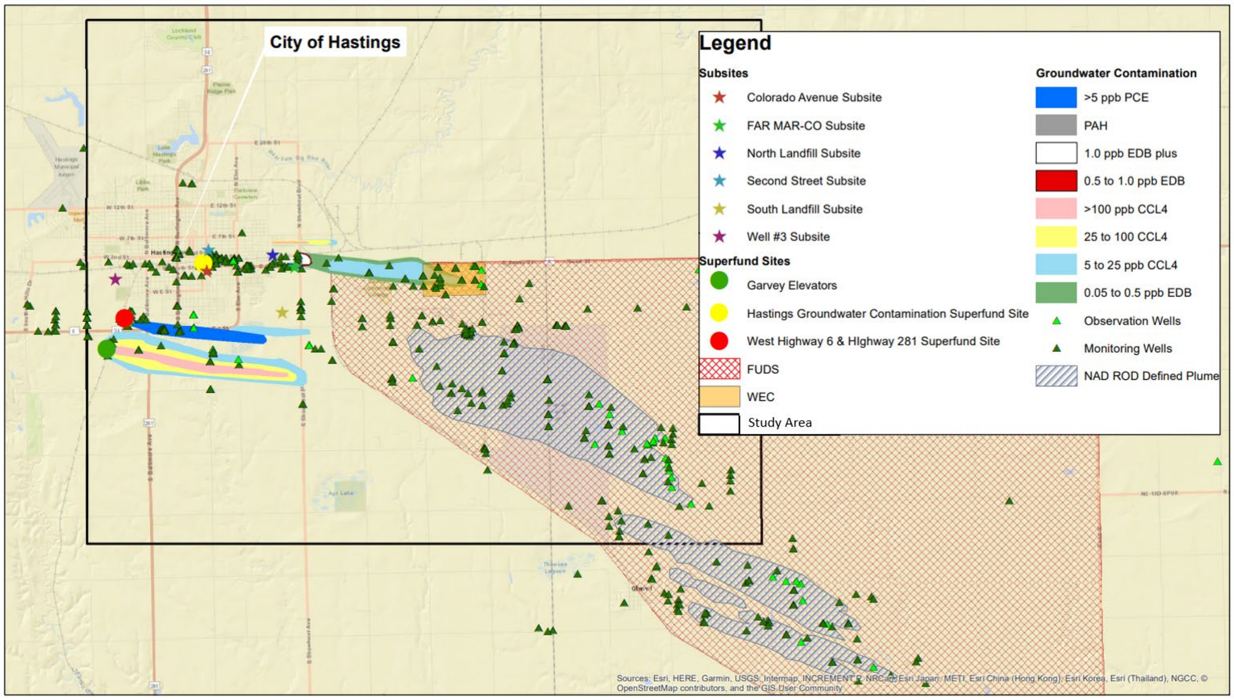

Figure 4 - Contaminated Sites and Groundwater Contamination near WEC

3.3 Background Aqueous Geochemistry

Water from the site's background wells contain somewhat elevated levels of selenium, sulfate, and some metals (As, B, Ca, Cl, Cr, F, Li and Mo) and the source of these constituents is unclear. The nearby up-gradient Superfund sites have plumes that contain various constituents, including chromium and selenium. The Superfund sites are a few to several miles up-gradient of the WEC, so the relationship between these plumes and the sites is not yet fully determined. Analyses from samples collected in up-gradient wells installed in 2018 detected selenium, but at concentrations lower than detected just up-gradient of the CCR facilities in MW-5B (as high as 0.17 mg/l). The newly installed wells were not directly in the flow path of MW-5B, so an up-gradient source cannot be ruled out.

Selenium is commonly enriched (increased in concentration) in irrigated agricultural areas, especially in the western U.S. (Seiler et al., 1999). Engberg (1973) established that this was also true for sites in Nebraska and documented natural selenium levels in Nebraska's groundwater up to 480 µg/L (0.480 mg/L), which is higher than selenium concentrations detected in the site's background wells.

Field parameters measured during groundwater sampling at the WEC generally include pH, conductivity and dissolved oxygen (DO). From field data sheets which record these parameters during sampling, pH is generally about 6.5 and does not go below 6.4 or above 7.05, DO is between 0.21 and 0.35 mg/l and averages about 0.25 mg/l, conductivity is about 0.450 to 0.650, average around 0.550.

Analysis of untreated well water used for the local water supply indicate that background concentrations of arsenic and selenium in the groundwater approximately 6 miles up-gradient of the site range up to 5.2 and 33 µg/L, respectively. These wells are withdrawing water from the same aquifer as the wells being sampled at the site, though at greater depths.

3.4 Regional and Local Irrigation

Agricultural water uses, which are primarily irrigation wells, represents 64.2 percent of the groundwater users and potential receptors in the area of interest. Figure 3.4 shows a map of the water users within the CSM model domain. The blue triangles represent the location of irrigation wells. The wells are generally evenly spread out throughout the entire area of interest with the exception of the City of Hastings and the southeast corner where both have a significantly reduced number of irrigation wells. Irrigation is limited to the growing season, which can span as early as April and May and extend through August or September.

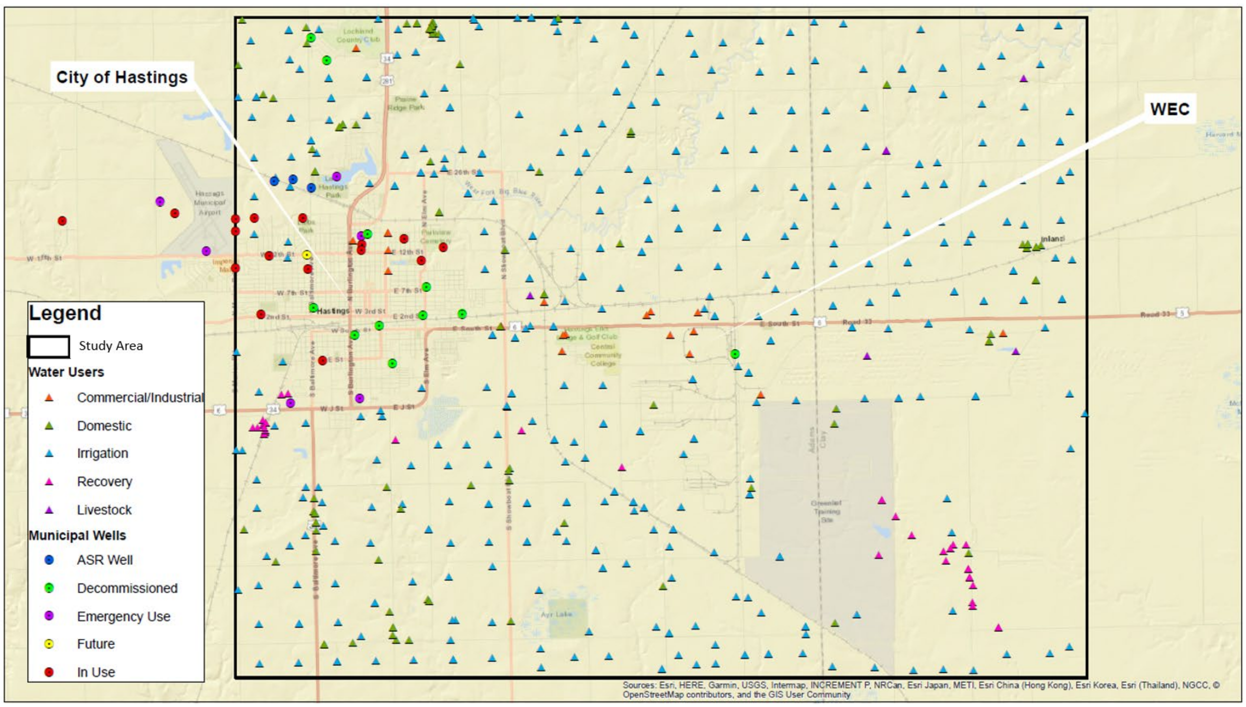

Figure 5 - Regional Water Supply Wells

4 Site Characterization

4.1 Monitoring Well Locations and Depths

Five groups of monitoring wells have been installed at the WEC (Figure 2). These groups include:

- Upgradient deep wells (3 wells, 215 to 216 feet deep)
- Upgradient intermediate wells (3 wells, 165 to 187 feet deep)
- Far upgradient shallow wells (2 well, 140 feet deep)

- Near upgradient shallow wells (3 wells used for CCR monitoring, 110 to 121 feet deep)
- Downgradient shallow wells (6 used for CCR monitoring and 4 additional wells, 111 to 150 feet deep), and
- Downgradient intermediate wells (4 wells, 170 to 187 feet deep).

Groundwater samples have been collected from these wells starting in 2000 (for wells that existed at that time) and with the frequency required by the CCR rule starting in 2017. The youngest wells were installed in 2018 and have been sampled with the remaining wells since that time. The groundwater collected is analyzed for CCR Rule Appendix III and Appendix IV constituents.

4.2 SPLP Analyses

Ash samples were collected from the major ash streams at the WEC and analyzed by Synthetic Precipitation Leachate Procedure (SPLP) to assess the potential for CCR constituents to be leached from the ash by percolating water. The ash that was tested included:

- Bottom Chain Ash
- Fly Ash Unit #2
- Non Spec Scrubber Ash
- Pond Ash, and
- Spec Scrubber Ash

SPLP elutriate was analyzed for the CCR Appendix III and Appendix IV constituents so that it could be compared with the groundwater analyses.

4.3 Ponds

The onsite process water ponds were included for sampling with the scheduled CCR sampling starting in 2019. Water samples were collected from each pond and analyzed for the same constituents as the groundwater samples and the SPLP.

5 Constituent Distribution and Statistical Evaluation

Samples from off-site monitoring wells and WEC ponds/surface water samples were collected from 2000 through June of 2021 to better refine the characterization of the constituents onsite and in the surrounding WEC area. Two constituents, Selenium and Fluoride, are used exemplify the distribution of constituents at the WEC and the ambiguity associated with the distribution.

5.1 Selenium distribution

Figure 6 is a box and whisker plot of selenium detected in groundwater, pond and SPLP samples. Selenium was detected in the upgradient shallow wells but not in deep and intermediate wells or ash SPLP. While there are a few higher concentration detections in the ponds, the mean is similar to the upgradient deep wells and SPLP results. This suggests that the ponds and the ash cannot be the source of the selenium seen in the shallow upgradient and downgradient wells which have similar ranges of concentrations.

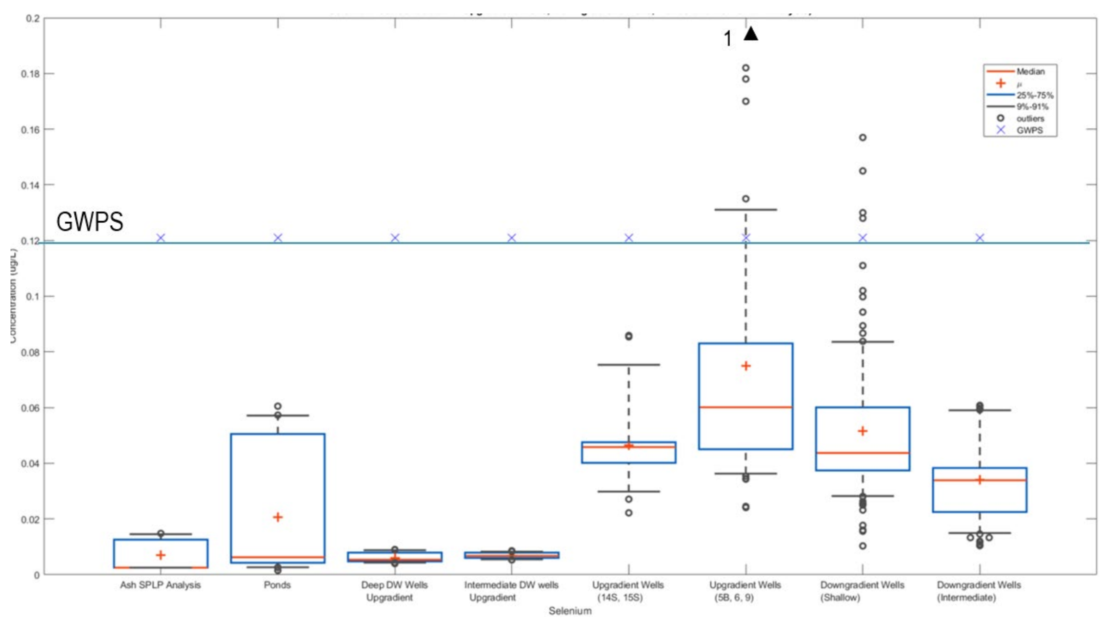

Figure 6 - Selenium Distribution

5.2 Fluoride distribution

Figure 7 is a box and whisker plot showing the distribution of fluoride in the groundwater pond and SPLP samples. The upgradient deep and intermediate wells have similar concentration ranges to down gradient wells showing that fluoride is present in aquifer upgradient at the same concentrations as downgradient. Both the SPLP and the ponds have a wide range of concentrations and their means similar to near upgradient. This suggest that while some fluoride may be contributed from the CCR storage, it does not greatly change the mean concentration down gradient.

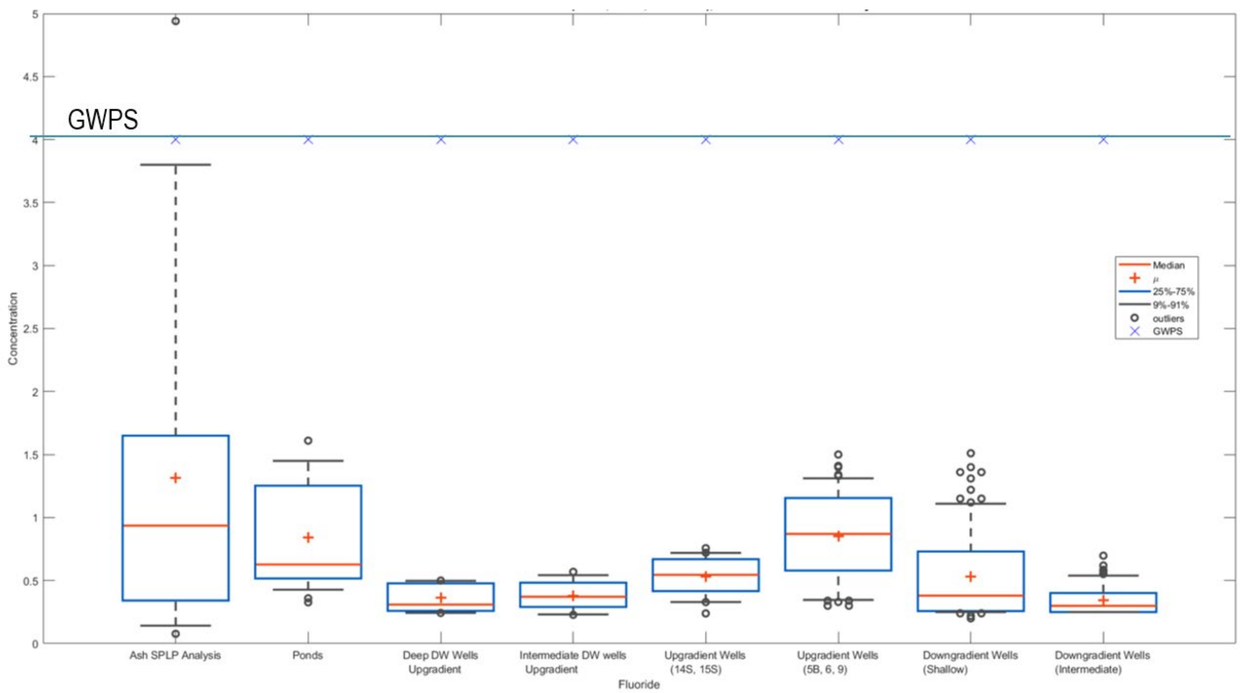

Figure 7 - Fluoride Distribution

6 Conclusions

The WEC is located in the midst of several potential sources of selenium and other constituents that can be sourced from CCR. For this reason, the constituents seen at the WEC (in these examples selenium and fluoride) are not necessarily from the CCR facility – other processes in aquifer systems (e.g., superfund remediation and irrigation) can also result in CCR-like constituents being liberated in an aquifer. It is important to develop a comprehensive conceptual site model that includes the surrounding area and other activities that may impact groundwater flow and quality.

The WEC will remain in assessment monitoring for the foreseeable future and SSL's are not expected. The simple statistical analyses done to evaluate the distribution of constituents, including in the potential sources (SPLP and process water) are useful for future alternate source demonstrations if needed. These relatively simple tools can be applied at other sites.

7 References

Engberg, R. A. (1973) Selenium in Nebraska's Groundwater and Streams. Nebraska Water Survey paper #35, University of Nebraska, Conservation and Survey Division, Lincoln, Nebraska.

HDR, Inc., 2016c. Semi-Annual Groundwater Monitoring Report. Whelan Energy Center Temporary Ash Disposal Area. Groundwater Statistical Analysis prepared for PPGA and Hastings Utilities, July.

Keech, C.F., and Dreeszen, V.H., 1968. Availability of Ground Water in Adams County, Nebraska. U.S. Geological Survey Hydrologic Investigations Atlas HA-287.

Layne GeoSciences, Inc., 1997. Groundwater Modeling Study and Well Head Protection Area Delineation for Hastings Utilities Municipal Wellfield. Prepared for Hastings Utilities. October.

Olsson Associates, Inc., 2009. Hydrogeologic Study for the Proposed New Water Wells, Hastings, Nebraska. Final Groundwater Model Report. Prepared for Public Power Generation Authority. March.

Seiler, R. L., J. P. Skorupa, & L. A. Peltz (1999) Areas Susceptible to Irrigation-Induced Selenium Contamination of Water and Biota in the Western United States. USGS Survey Circular 1180, Carson City, Nebraska.

USACE, 2010. Final Sitewide Groundwater Record of Decision. Former Naval Ammunition Depot, Hastings, Nebraska. August.