Figure 2.6-15 Location of Chadron Arch and Cambridge Arch in Nebraska

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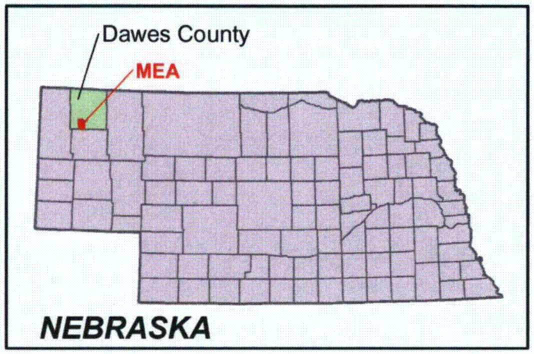

LEGEND

- City/Town
- Fault (Ball on downthrown side)
- Fault Interpretations by DeGraw (1971) (Ball on downthrown side; ? denotes inferred)
- Fault Interpretations by Hunt (1990)
- Anticline
- Syncline
- County Boundary
- Proposed Marsland Expansion Area (MEA)
- Crow Butte Facility (CPF) Permit Area
- Proposed North Trend Expansion Area (NTEA)
- Proposed Three Crow Expansion Area (TCEA)

Source:
Modified from DeGraw, 1969;
WFC-White River Fault only (Collings & Knode, 1984)

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-16
STRUCTURAL FEATURES MAP OF THE CRAWFORD BASIN

PROJECT: CO001636 MAPPED BY: JC CHECKED BY: JEC

ARCADIS
630 Plaza Drive, Ste. 100
Highlands Ranch, CO 80129
P: 720-344-3500 F: 720-344-3535
www.arcadis-us.com

Figure 2.6-17 Earthquake Hazard Ranking in the U.S.

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Figure 2.6-18 Seismic Hazard Map for Nebraska (2008)

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Figure 2.6-19 Seismicity of Nebraska 1973 – 2013

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Figure 2.6-20 Soils

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2.7 Hydrology

2.7.1 Surface Water

2.7.1.1 Water Features Descriptions

Rivers, Creeks and Drainages

The USGS maintains a hierarchical hydrologic unit code (HUC) system that divides the United States into 21 regions, 222 sub-regions, 352 accounting units, and 2,149 cataloging units based on surface hydrologic features or drainages (USGS 2011a). The smallest USGS unit, the 8-digit HUC (or 4th level HUC), averages about 448,000 acres, and is usually the level referred to as an HUC. The Hydrologic Unit system is a standardized watershed classification system. The State of Nebraska's major river basins are shown on **Figure 2.7-1**.

Below the cataloging units, the surface hydrologic features or drainages are further broken down into watersheds and subwatersheds. The MEA project site is located in the following HUC classification system (USGS 2011b):

Region:	Missouri (10)
Sub Region:	Niobrara River: The Niobrara River Basin and the Ponca Creek Basin [Nebraska South Dakota: Wyoming] (1015)
Accounting Unit:	Niobrara River [Nebraska: South Dakota: Wyoming] (101500)
Cataloging Unit:	Niobrara Headwaters [Nebraska: Wyoming] (10150002
Basin:	Niobrara River (**Figure 2.7-2, Table 2.7-1** ([NAC 2011a])
Subbasin:	Subbasin N14 (**Figure 2.7-3** [NAC 2011a])

The Niobrara Accounting Unit and Niobrara Headwaters Cataloging Unit consist of an area of 13,900 mi^2 (36,001 km^2) and 1,460 mi^2 (3,781 km^2), respectively (USGS 2011b). The Niobrara River Basin, with the majority of it located in Dawes and the adjacent Sheridan County, is composed of a watershed area of approximately 11,870 mi^2 (NDEQ 2005).

There are 25 segments within the Niobrara River Subbasin N14 (**Figure 2.7-3**). The MEA is located within the Niobrara River Subbasin N14, with the southernmost license boundary being located approximately 0.24 mile (0.4 km) from the Niobrara River in Segment 4000 (**Figure 2.7-3**). The distance from the southern boundary of Mine Unit MU-F (southernmost mine unit in the MEA site) to the nearest point on the Niobrara River is approximately 0.42 mile (0.7 km).

The Niobrara River originates near Manville, Niobrara County, eastern Wyoming and flows in an east-southeast direction into western Nebraska (**Figure 2.7-3 and 2.7-4**). The river flows across Sioux County in Nebraska, east through the Agate Fossil Beds National Monument, past Marsland to the south of the proposed MEA project site, and through Box Butte Reservoir. From the reservoir, the river flows east across northern Nebraska, and joins the Snake River approximately 13 miles (20.9 km) southwest of Valentine. The Niobrara River joins the Keya Paha River approximately 6 miles (9.6 km) west of Butte, Nebraska. The river eventually joins the Missouri River northwest of Niobrara, Nebraska in northern Knox County.

Water flow and water quality information on sampling points on the Upper Niobrara River are presented in Section 2.9.4.

Surface Impoundments

Based on available maps and site investigations conducted by CBR, no surface water impoundments, lakes, or ponds have been identified within the MEA. Rainfall runoff occasionally creates temporary small pools in a few places on the MEA site, but there is no evidence of persistent stream flow in recent times (Hayden-Wing 2011).

Box Butte Reservoir is located approximately 3 miles (4.8 km) to the east of the southeast corner of the MEA license boundary (**Figure 2.7-4**). Box Butte Reservoir Dam is located within Segment 4000 of Subbasin N14. The primary purpose of the reservoir is for irrigation with secondary benefits for recreation, fish, and wildlife (USBR 2008). The Box Butte Reservoir Dam has altered the hydrology of the Niobrara River by diverting water for irrigation (Alexander et al. 2010). The reservoir is part of the Mirage Flats Irrigation Project, which consists of the Box Butte Reservoir, the Dunlap Diversion Dam, and associated canal and laterals to irrigate 11,662 acres (**Figure 2.7-5**; USBR 2008). Dunlap Diversion Dam is located approximately 10 miles (16.1 km) downstream of the Box Butte Reservoir Dam. Average flows below the Box Butte Reservoir Dam are reduced by 90 percent relative to inflow to Box Butte Reservoir, but the river gains significant flow downstream from the Dunlap Diversion Dam, mainly due to groundwater seepage (Bentall and Shaffer 1979).

The Box Butte Reservoir was constructed from 1941 to 1946 and is under the control of the U.S. Bureau of Reclamation (USBR). The total storage capacity of the Box Butte Reservoir is 29,161 acre-feet (USBR 2008) and the pool elevation is 3997.6 feet. The reservoir occupies approximately 1,600 surface acres with 14 miles (22.5 km) of shoreline. The reservoir has stabilized the agricultural economy of the area that has resulted in larger farm populations and increased employment in related industries. The lake is well suited for recreation activities (aquatic and outdoor sports). Recreation at the reservoir is managed for the USBR by the Nebraska Game and Parks Commission (NGPC).

There are no direct drainages from the MEA project site to the reservoir. Any discharges from the MEA site that could enter the Niobrara River could commingle with river water flowing into Box Butte Reservoir.

The storage contents of the Box Butte Reservoir are discussed in Section 2.9.4.

2.7.2 Groundwater

This section describes the regional and local groundwater hydrology including local and regional hydraulic gradient and hydrostratigraphy, hydraulic parameters, baseline water quality conditions, and local groundwater use (including well locations related to the MEA). The discussion is based on information from investigations performed within the MEA, data presented in previous applications/reports for the current CPF where ISR mining is being conducted, the proposed NTEA and TCEA, and the geologic information presented in Section 2.6. In this regard, the hydrogeology of the MEA is expected to be similar in many respects to that encountered in the CPF, NTEA, and TCEA.

The hydrostratigraphic section of interest for MEA includes the following (presented in descending order):

- Alluvium
- Arikaree Group
- Brule Formation (first overlying aquifer in Orella Member)
- Chadron Formation (Upper Confining Unit including the combined upper and middle Chadron Basal sandstone of the Chadron Formation (Mining Unit)
- Pierre Shale (Lower Confining Unit)

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Deleted: confining layer, middle/upper Chadron sand [aquifer, where present], and middle Chadron confining layer)¶

With regard to the CPF, NTEA, TCEA, and MEA in particular, two groundwater sources are of interest in the Crow Butte and surrounding area. These are the Brule Formation sand and the basal sandstone of the Chadron Formation. The basal sandstone of the Chadron Formation contains the uranium mineralization at the CPF, NTEA, TCEA, and MEA.

2.7.2.1 Groundwater Occurrence And Flow Direction

In the vicinity of the MEA, water has been observed in the alluvium, Arikaree Group, Brule Formation, and basal sandstone of the Chadron Formation. Alluvial deposits are discontinuous at MEA and have not been shown to contain usable amounts of water. Of the wells identified in **Table 2.7-9**, none are known to be completed within alluvial deposits, and those that are shallow enough (e.g., less than 50 feet) are understood to be completed within bedrock aquifers. Additionally, except during large storms that produce surface runoff, water within the alluvium is expected to recharge to underlying porous units of the Arikaree Group. Similarly, the Arikaree Group is not typically considered to be a reliable water source; however, the Arikaree Group is locally used for domestic and livestock purposes.

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The Arikaree Group and Brule Formation within the MEA meet the NDEQ definition (Nebraska Administrative Code Title 122, Chapter 1, Part 006) of an aquifer: "a geological formation, group of formations, or part of a formation that is capable of yielding a useable amount of water to a well, spring, or other point of discharge." For the purposes of permitting at MEA, alluvium is not considered an aquifer. Likewise, although thin sandstones are present within the upper Chadron Formation, drill cuttings, cores, and geophysical logs have not indicated the presence of water within any portions of the upper Chadron or middle Chadron Formation. As described in Section 2.7.2.3 (confining layer), the upper Chadron and middle Chadron Formation constitute the confining unit between the basal sandstone of the Chadron Formation and overlying aquifers of the Brule Formation and Arikaree Group. Aquifer properties of the basal sandstone of the Chadron Formation are discussed in Section 2.7.2.2 in relation to aquifer pumping tests conducted in 2011.

Hydraulic conductivity for the Arikaree Group and Brule Formation was estimated using particle grain-size distribution data from core samples. Results of the particle size distribution analyses indicate sediments variably dominated by sands, silts, and clays. Hydraulic conductivity estimates were developed using the Kozeny-Carman equation, which is appropriate for sands and silts, but not for cohesive clayey soils with a high degree of plasticity. Published literature validates the use of the Kozeny-Carman equation for fine grained non-plastic silts (Carrier 2003). For samples that have high plasticity, hydraulic conductivity values are likely overestimated.

Therefore, the Kozeny-Carman equation provides a conservative estimate of hydraulic conductivity.

Arikaree Group

The Arikaree Group contains multiple sand-dominated units that may represent locally water-bearing units. In general, these deposits are most likely to occur as buff to gray fine sand without abundant silt and clay within the Upper Harrison Beds, massively bedded, and poorly consolidated fine grained grey sandstones within the Harrison-Monroe Creek Formation, and coarse to fine grained sandstones of the Gering Formation. Many of the potential water-bearing units have limited lateral extent and are interbedded with low-permeability mudstone units. The lateral and horizontal distribution of these sandy-dominated units are highly variable, as they may range between ten to several hundred feet wide and can be up to 50 feet thick.

In 2013, ten wells were installed across the MEA to acquire Arikaree Group water level and water quality data (**Figure 2.7-8**). Nine of the ten wells encountered measurable water (**Figure 2.9-4; Table 2.9-7**). The greatest saturated thickness (78 feet) was observed on the north end of the MEA in well AOW-8 with considerably thinner saturated intervals (0 to 35 feet) observed near the central portion of the project. Saturated thickness increased from the central portion of the MEA southward toward the Niobrara River to approximately 30 to 35 feet. One well (AOW-7) located in the west-central portion of the MEA, did not contain measureable water during well development or monitoring, even though a review of the well completion data indicate that the screened interval is below the observed potentiometric surface shown in **Figure 2.9-4**. This well demonstrates the potential for locally restricted groundwater flow and overall unreliable nature of water within the Arikaree Group that has been observed elsewhere in Dawes and Sioux Counties.

A total of 10 core samples have been collected from the Arikaree Group for grain size analysis. Samples were collected from core intervals demonstrating visually observed textural compositions that ranged from siltstones to sandstones. Grain size analysis of core samples collected from the Arikaree Group indicates four samples dominated by sand-sized particles (M-533C Run 1 Sample 1; M-1912C Run 1 Sample 1; M-1912C Run 2 Sample 1; and M-1956C Run 1 Sample 1). Calculated hydraulic conductivity values for these samples range from 1.0×10^{-4} to 2.9×10^{-3} cm/sec. By contrast, the remaining core samples from the Arikaree Group are silt-dominated and have calculated hydraulic conductivity values ranging from 2.3×10^{-5} to 9.2×10^{-5} cm/sec. Based on grain size distributions, the average intrinsic permeability of sand-dominated units within the Arikaree Group is estimated to be approximately 1.5×10^{-6} cm^2.

Brule Formation

Within the Orella Member of the Brule Formation, sandy siltstones, overbank sheet sandstones, and occasional thick channelized sandstones may be locally water-bearing units. These sandstone and siltstone units can be difficult to correlate over any large distance and are often discontinuous lenses rather than laterally continuous strata. The Brule Formation produces widely variable amounts of water at MEA. CBR experience shows that, in typical water wells, flow at the Brule Formation can vary between 0.5 gpm to 50 gpm. At the upper end of the spectrum, agricultural well #732 produces in excess of 800 gpm from a 16-inch well. This variability in flow rate between wells within the same aquifer makes water production and aquifer thickness difficult to predict. Despite this characteristic, water supply wells are frequently completed in this unit.

Deleted: that occur throughout the Orella Member of the Brule Formation

Deleted: the Brule Formation has historically been considered the shallowest aquifer above the basal sandstone of the Chadron Formation, and water supply wells have been completed in this unit.

At the base of the Orella Member is a channel sandstone that has incised into the underlying upper Chadron and constitutes the first overlying aquifer above the production zone. This 10- to 35-foot thick sandstone is present across the entire MEA, as observed in drill cuttings and geophysical logs. Other sand-rich horizons that may produce water within the Brule are also present above this lower sandstone, but are limited in lateral extent and do not extend across the entire MEA. **Figure 2.9-5b** shows the potentiometric surface as determined by groundwater level gauging of the 11 water wells that are completed in the Brule Formation. Because the Brule Formation potentiometric surface extends upward into the Arikaree Group, it can be assumed that the entire thickness of the Brule is saturated where local aquifer properties permit the flow of groundwater. That said, not all stratigraphic horizons of the Brule Formation are capable of producing water in useable quantities.

A total of 12 core samples have been collected from the Brule Formation for grain size analysis, from units demonstrating a range in visually observed textural composition (mudstones to sandstones). However, grain size analysis of core samples collected from the Brule Formation indicate that all 12 samples are dominated by silt-sized particles. The two samples with the highest weight percent of sand (39.31 percent [M-1956C Run 4 Sample 1; 48.09 percent [M-1912C Run 3 Sample 1]) have calculated hydraulic conductivity values of 1.4×10^{-4} cm/sec and 2.3×10^{-4} cm/sec, respectively. By comparison, the geometric mean of all samples collected from the Brule Formation is 9.2×10^{-5} cm/sec. Based on grain size distributions, average intrinsic permeability of Brule Formation core samples is estimated to be approximately 4.2×10^{-7} cm^2.

The coefficient of variation (standard deviation divided by geometric mean) for all Brule Formation samples is an order of magnitude less than for all Arikaree Group samples. This may represent a higher level of lithologic heterogeneity within the Arikaree Group and higher potential for local barriers to groundwater flow to be present.

Baseline groundwater monitoring for private water supply wells and CBR monitor wells (water levels and water quality) is presented in Section 2.9.3.

Basal Sandstone of the Chadron Formation

Discussions of the groundwater conditions for the basal sandstone of the Chadron Formation are presented below in Sections 2.7.2.2 and 2.7.2.3.

2.7.2.2 Aquifer Testing And Hydraulic Parameter Identification Information

Prior to initiation of ISR mining activities, the NDEQ regulations require hydrologic testing and baseline water quality sampling. During the initial permitting and development activities within the MEA, an aquifer pumping test was performed between May 16 and May 20, 2011. The final report on pumping test activities in the MEA (Marsland Regional Hydrologic Testing Report – Test #8 [Aqui-Ver 2011]) is included in **Appendix F**. The pumping test was performed in accordance with the NDEQ approved Regional Pumping Test Plan dated September 27, 2010 (WorleyParsons 2010) and subsequent approved changes to the Regional Pumping Test Plan dated March 16, 2011 (Snowhite 2011). Testing activities and findings from pumping test activities in the MEA are summarized below.

Prior to testing activities, CBR installed 14 monitoring wells in the basal sandstone of the Chadron Formation (CPW-1, CPW-2010-1A, Monitor-1, Monitor-2, Monitor-3, Monitor-4, Monitor 4A, Monitor-5, Monitor-6, Monitor-7, Monitor-8, Monitor-9, Monitor-10, and Monitor-11) and nine wells in the Brule Formation (BOW-2010-1, BOW-2010-2, BOW-2010-3, BOW-2010-4, BOW-2010-4A, BOW-2010-5, BOW-2010-6, BOW-2010-7, and BOW-2010-8; **Figure 2.7-6 and 2.7-8**). Well information for wells used during the 2011 pumping test is summarized in **Table 2.7-2**. Monitor-4 and BOW-2010-4 were abandoned prior to pumping test activities. To assess pre-test baseline water level fluctuations, water level data and barometric pressure data were recorded prior to the pumping period starting on May 6, 2011 for a period of 7 days before initiating the pumping test. The locations of wells used during pumping test #8 are shown in **Figure 2.7-7**. These data were interpreted as representative of static conditions within the aquifer. Based on these data, groundwater in the Brule Formation was interpreted to flow predominantly to the southeast toward the Niobrara River with a lateral hydraulic gradient of 0.011 ft/ft. (**Appendix F**).

To provide baseline groundwater elevation data for the pumping test, static water levels were collected from all 12 wells in the monitoring network on November 12, 2010 from the Brule Formation and the basal sandstone of the Chadron Formation. Water levels ranged from approximately 4,134 to 4,213 feet amsl in the Brule Formation and 3,709 to 3,714 feet amsl in the basal sandstone of the Chadron Formation (**Table 2.7-2**).

Static water levels of the Arikaree Group, Brule Formation, and Chadron Formation measured for existing and new CBR monitor wells in 2013 are discussed in Section 2.9.3.2.

As part of the NRC License Amendment Application to conduct ISR operations in the MEA, the 2011 regional groundwater pumping test was designed to accomplish the following:

- Evaluate the degree of hydraulic communication between the production zone pumping well and the surrounding production zone observation wells
- Evaluate the presence or absence of the production zone aquifer within the test area
- Assess the hydrologic characteristics of the production zone aquifer within the test area including the presence or absence of hydraulic boundaries
- Demonstrate sufficient confinement (hydraulic isolation) between the production zone and the overlying aquifer for the purpose of ISR mining

The 2011 pumping test was conducted while pumping at CPW-2010-1A at an average discharge rate of 27.08 gpm for 103 hours (4.29 days). Based on the drawdown response observed at the most distant observation well locations (Monitor 2 and Monitor 8), the radius of influence (ROI) during the pumping test was estimated to be in excess of approximately 8,800 feet. More than 0.8 foot of drawdown was achieved during testing in all observation wells completed in the basal sandstone of the Chadron Formation in the observation well network, with a maximum drawdown of 23.40 feet observed in CPW-2010-1A (pumping well) during the test.

The drawdown response measured in all basal sandstone of the Chadron Formation observation wells monitored during the test confirm hydraulic communication between the production zone pumping well and the surrounding observation wells across the entire test area. During the test (pumping and recovery periods), no discernible drawdown or recovery responses attributed to the test were observed in overlying Brule Formation observation wells, which supports the conclusion that adequate confinement exists between the overlying Brule Formation and the basal sandstone of the Chadron Formation.

Drawdown and recovery data collected from observation wells were graphically analyzed to determine the aquifer properties, including transmissivity and storativity. The methods of analysis included the Theis (1935) drawdown and recovery methods and the Jacob Straight-Line Distance-Drawdown method (Cooper and Jacob 1946).

Estimated hydraulic parameters for individual well locations for the 2011 pumping test are summarized in **Table 2.7-3**. Results of the 2011 pumping test within the basal sandstone of the Chadron Formation indicate a mean hydraulic conductivity of 25 feet per day (ft/day; ranging from 7 to 62 ft/day) or 8.82×10^{-3} centimeters per second (cm/sec) based on an average net sand thickness of 40 feet and a mean transmissivity of 1,012 square feet per day (ft^2/day; ranging from 230 to 2,469 ft^2/day). Based on both the drawdown and recovery analyses, hydraulic conductivities of the aquifer materials in the vicinity of the pumping well (CPW-2010-1A, CPW-2010-1, and Monitor-3) were approximately three to nine times greater than hydraulic conductivities estimated for other observation wells in the pumping test area. An apparent higher conductivity boundary condition effect in these wells was indicated by a flattening of drawdown and recovery curves. Transmissivities for the recovery data were slightly higher than for the drawdown data and are considered more representative of the aquifer properties due to the slight variability in the discharge rate during the drawdown phase of the test. The mean storativity was 2.56×10^{-4} (ranging from 1.7×10^{-3} to 8.32×10^{-5}). Storativity units are a measure of the volumes of water that a permeable unit will absorb or expel from the storage unit per unit of surface area per unit of change in head. Storativity is a dimensionless quantity.

The hydrologic parameters observed at the MEA are consistent with, although slightly higher than, the aquifer properties determined for the areas of the CPF, TCEA, and NTEA (**Table 2.7-4**). No water level changes of concern were observed in any of the overlying wells during testing. The pumping test results demonstrate the following important conclusions:

- The pumping well and all observation wells completed in the basal sandstone of the Chadron Formation exhibited significant and predictable drawdown during the test, demonstrating that the production zone has hydraulic continuity throughout the MEA test area.
- The average transmissivity of the basal sandstone of the Chadron Formation within the portion of the MEA investigated during the test is significantly higher than the areas investigated within the TCEA, NTEA, and existing Crow Butte operations.
- A zone of relatively lower permeability is apparent in the vicinity of the pumping well (CPW-2010-1A) and observation wells CPW-1 and Monitor-3, with significantly higher transmissivity noted elsewhere within the ROI of the test.
- Adequate confinement exists between the overlying Brule Formation and the basal sandstone of the Chadron Formation, as evidenced by no discernible drawdown in the Brule Formation observation wells.
- The hydrologic properties of the basal sandstone of the Chadron Formation have been adequately characterized within the majority of the proposed MEA to proceed with Class III UIC permitting and an NRC License Amendment Application for the MEA.

These conclusions indicate that, though variance in thickness and hydraulic conductivity may impact mining operations (e.g., well spacing, completion interval, and injection/production rates), it is not anticipated to impact regulatory issues.

2.7.2.3 Hydrologic Conceptual Model for the Marsland Expansion Area

Tables 2.6-1 and 2.6-2 present the regional and local stratigraphic columns in the vicinity of MEA. As discussed above in Section 2.7.2.1, aquifers within the stratigraphic section present at the MEA include permeable intervals of the Arikaree Group, permeable intervals in the Orella Member of the shallow Brule Formation, and the deeper confined basal sandstone of the Chadron Formation. Discussions below describe the upper and lower confining units and the hydrologic conditions for the water-bearing intervals present at the MEA.

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Confining Layers

Upper confinement for the basal sandstone of the Chadron Formation within the MEA is represented by 650 to 710 feet of smectite-rich mudstone and siltstones of the upper Chadron and middle Chadron (**Figures 2.6-3a** through **2.6-3n, 2.6-8, and 2.6-9**). Particle grain-size analyses of six core samples from the upper confining layer within the MEA indicate that all samples were clayey siltstone (**Appendix G-1 and G-2**). XRD analyses indicate that compositions of mudstone and claystone intervals of core samples from the middle Chadron are highly similar to the Pierre Shale (e.g., predominantly mixed-layered illite/smectite or montmorillonite with quartz), which would be expected if the Pierre Shale was a source of materials for the overlying middle Chadron (**Appendix G-1**). As a result, the Brule Formation is vertically and hydraulically isolated from the underlying aquifer proposed for exemption.

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Deleted: siltstones
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Deleted: Significant water-bearing sandstones of the upper/middle Chadron are not present within the MEA.

Lower confinement for the basal sandstone of the Chadron Formation in the vicinity of the MEA is represented by approximately 750 to more than 1,000 feet of black marine shale deposits of the Pierre Shale. Additional low permeability confining units are represented by the underlying Niobrara Formation, Carlile Shale, Greenhorn Limestone, and Graneros Shale. Together with the Pierre Shale, these underlying low permeability units hydraulically isolate the basal sandstone of the Chadron Formation from the underlying "D", "G", and "J" sandstones of the Dakota Group by more than 1,000 vertical feet (**Table 2.6-1**). The Pierre Shale is not a water-bearing unit, exhibits very low permeability, and is considered a regional aquiclude.

The Pierre Shale consists primarily of illite and smectite clays, as indicated by x-ray diffraction of CBR core samples collected in 2011 and 2013 (**Appendix G-1 and G-2**). The swelling nature of these clays in the presence of water makes it unlikely that any fractures or penetrations within the Pierre would provide a pathway for loss of confinement through this thick unit. Regional estimates of hydraulic conductivity for the Pierre Shale range from 10^{-7} to 10^{-12} cm/sec (Neuzil and Bredehoeft 1980; Neuzil et al. 1982; Neuzil 1993). The Pierre Shale has a measured vertical hydraulic conductivity at the CPF of less than 1×10^{-10} cm/sec (WFC 1983), which is consistent with other studies in the region. Particle grain size analyses of two samples collected from the Pierre Shale within the MEA indicate low permeability silty clay compositions.

The upper surface of the Pierre Shale, illustrated on **Figure 2.6-13** and cross-section A-A' (**Figure 2.6-3a**), is a gentle, southeasterly sloping surface consistent with that described by DeGraw (1971). This sloping surface rises northwesterly to the axial crest of the Cochran Arch north of the MEA. Cross-section A-A' does not show evidence of major folding across the axis of the Cochran Arch that could have created significant vertical fractures within the Pierre Shale." Regional studies also indicate that there is no observed transmissivity between vertical fractures in the Pierre Shale, which appear to be short and not interconnected (Neuzil et al. 1982). All oil and gas wells in the area of review which penetrate the Pierre Shale were abandoned in

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accordance with accepted regulatory practices at that time. Oil and gas well plugging records are provided as **Appendix D-1**.

As described in Section 2.7.2.1, estimated hydraulic conductivities for the upper confining unit were developed using particle grain size distribution data from the six core samples collected from the upper Chadron and middle Chadron. Results of the particle size distribution analyses indicate sediments dominated by silts and clays. Estimated hydraulic conductivities of the four core samples collected within the upper Chadron and middle Chadron ranged from 1.7 x 10^{-5} to 5.9 x 10^{-5} cm/sec. Estimated hydraulic conductivities of the two core samples collected from within the middle Chadron ranged from 1.7 x 10^{-5} to 2.9 x 10^{-5} cm/sec. Hydraulic conductivities for the seven core samples collected within the Pierre Shale were not estimated by the Kozeny-Carman method due to significant levels (up to 76 weight percent) of clay. The vertical hydraulic conductivity across the upper and lower confining layers is likely to be even lower due to vertical anisotropy. Additionally, hydraulic resistance to vertical flow is expected to be low due to the significant thickness of the upper confining zone within the MEA, which ranges between 650 and 710 ft.

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Hydrologic Conditions

Potentiometric maps and cross-sections of the basal sandstone of the Chadron Formation indicate confined groundwater flow (**Figures 2.9-6a and 2.9-6b** and **2.6-3a** through **2.6-3n**). Elevations of the potentiometric surface of the basal sandstone of the Chadron Formation indicate that the recharge zone must be located above a minimum elevation of 3,715 feet amsl. Confined conditions exist at the MEA as a result of an elevated recharge zone most likely located west or southwest of the MEA. The top of the basal sandstone of the Chadron Formation occurs at much lower elevations within the MEA, ranging from approximately 3,210 to 3,290 feet amsl (**Figures 2.6-3a** through **2.6-3n**).

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In the vicinity of the MEA, groundwater flow in the basal sandstone of the Chadron Formation is predominantly to the northwest toward the White River drainage at a lateral hydraulic gradient of 0.0004 ft/ft (Aqui-Ver 2011). Regional water level information for the basal sandstone of the Chadron Formation is currently only available in the vicinity of the current production facility and the NTEA, but suggest a discharge point at an elevation of at least 3,700 feet amsl (or below) located east of Crawford, presumably at a location where the basal sandstone of the Chadron Formation is exposed.

Regional water level information for the Brule Formation is currently only available in the vicinity of the current production facility. However, within the MEA, groundwater generally flows to the southeast across the entire MEA toward the Niobrara River at a lateral hydraulic gradient of 0.011 ft/ft (Aqui-Ver 2011). Though the Brule Formation is the primary groundwater supply in the vicinity of the MEA, low production rates indicate that the discontinuous sandstone lenses of the Orella Member may not be hydraulically well connected. Recharge to this unit likely occurs directly within the MEA, as the unit is unconformably overlain by 50 to 210 feet of overlying Arikaree Group and 0 to 30 feet of unconsolidated alluvial and colluvial deposits (depending on local topography). Alluvial deposits along the margins of the Niobrara River may offer limited groundwater storage depending on river levels.

Deleted: Monitoring wells will be installed in the Brule Formation between the license boundary and the Niobrara River to monitor water quality in the event of failure of an injection well or production well, and to prevent potential communication of mining fluids with surface water (see Section 2.7.2.4 for a more detailed discussion). Installation of such monitoring wells is required under the Class III injection well permit.

At MEA, groundwater elevations for the Arikaree Group and the Brule Formation are distinctly different from those of the basal sandstone of the Chadron Formation (**Figures 2.6-3a** through

Deleted: within the MEA have distinct and differing water level elevations

2.6-3n, **Table 2.9-7**). The available water level data suggest hydrologic isolation of the basal sandstone of the Chadron Formation with respect to the overlying water-bearing intervals in the MEA. This inference is further supported by the difference in geochemical groundwater characteristics between the basal sandstone of the Chadron Formation and the Brule Formation (see Section 2.9.3; **Tables 2.9-8, 2.9-9, 2.9-10,** and **2.9-11**).

In summary, the following multiple lines of evidence indicate adequate hydrologic confinement of the basal sandstone of the Chadron Formation within the MEA.

- Results of the May 2011 aquifer pumping test demonstrate no discernable drawdown in the overlying Brule Formation observation wells screened throughout the MEA (see Section 2.7.2.2).
- Large differences in observed hydraulic head (330 to 500 feet) between the Brule Formation and the basal sandstone of the Chadron Formation indicate strong vertically downward gradients and minimal risk of naturally occurring impacts to the overlying Brule Formation (see Section 2.7.2.1).
- Significant historical differences exist in geochemical groundwater characteristics between the basal sandstone of the Chadron Formation and the Brule Formation (Section 2.9.3.3).
- Site-specific XRD analyses, particle grain-size distribution analyses, and geophysical logging confirm the presence of a thick (between 650 and 710 feet), laterally continuous upper confining layer consisting of low permeability mudstone and claystone, and a thick (more than 750 feet), regionally extensive lower confining layer composed of very low permeability black marine shale (see Section 2.7.2.3).
- Analyses of particle size distribution results suggest a maximum estimated hydraulic conductivity of 5.9×10^{-5} cm/sec for core samples from the upper confining layer.
- Hydraulic resistance to vertical flow is expected to be low due to the significant thickness of the upper confining zone within the MEA.
- The vertical hydraulic conductivity across the upper and lower confining layers is likely to be even lower than 10^{-5} cm/sec due to vertical anisotropy (see Section 2.7.2.3).

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2.7.2.4 Description of the Proposed Mining Operation and Relationship to Site Geology and Hydrology

The basal sandstone of the Chadron Formation is currently mined using ISR techniques within the mine units of the current Crow Butte operations and represents the production zone and target of solution mining in the MEA. Ore-grade uranium deposits underlying the MEA are located in the basal sandstone of the Chadron Formation (**Figure 1.4-1**). The ore body located within the MEA is a stacked roll-front system, which occurs at the boundary between the up-dip and oxidized part of a sandstone body and the reduced part of the sandstone body. Stratigraphic thickness of the unit within the MEA ranges from approximately 20 to 110 feet, with an average thickness of approximately 55 feet.

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The unit occurs at depths ranging from about 817 to 1,130 feet bgs within the MEA (**Figures 2.6-3a** through **2.6-3n and 2.6-12**). The competent upper confining layer consists of the overlying middle Chadron and upper Chadron, which are composed of predominantly clay, claystone, and siltstone. Based on extensive exploration hole data collected to date (more than 1,650 drill locations), the thickness of the upper confining layers in the MEA range from 650 to 710 feet (**Figures 2.6-3a** through **2.6-3n** and **2.6-8**). Estimated hydraulic conductivities based on particle grain-size distribution analyses for site-specific core samples collected within the upper confining layer are on the order of 10^{-5} cm/sec (see Section 2.7.2.3). Geophysical logs from nearby oil and gas wells indicate that the thickness of the Pierre Shale lower confining layer ranges from approximately 750 to more than 1,000 feet (see discussions in Montana Group under Section 2.6.1.1). The full thickness of the Pierre Shale is not depicted on **Figures 2.6-3a** through **2.6-3n**, as the required scale would obscure stratigraphic details of the overlying White River Group. The Pierre Shale exhibits very low permeabilities on the order of 0.01 millidarcies (md; less than 1 x 10^{-10} cm/sec; Wyoming Fuel Company 1983).

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Based on similar regional deposition, the MEA ore body is expected to be similar mineralogically and geochemically to that of the CPF. The ore bodies in the two areas are within the same geologic unit (i.e., basal sandstone of the Chadron Formation) and have the same mineralization source (see Section 2.6). The sites are separated by only a few miles, and the cause of mineral deposition in the two areas appears to be similar (see Section 2.6). Neither site is anticipated to be affected by any recharge or other processes that would uniquely affect each area, so the groundwater characteristics of the current Crow Butte mineralized zone are presumed to be representative of the MEA. **Table 2.7-5** is the Baseline and Restoration Values for MU 1 in the current Crow Butte operations area. The values in this table are expected to be representative of the geochemical characteristics of the MEA ore body. The MEA ore body, the outline of which is provided on **Figure 1.4-1,** is considered a zone of distinct water quality characteristics primarily due to the presence of relatively concentrated uranium and radium in the zone when compared to the concentrations of these parameters outside of the production zone (e.g., **Table 2.9-4**).

During the course of mining, the water quality is expected to change as outlined in **Table 2.7-6**. The chemicals used in the mining and recovery process will include sodium bicarbonate ($NaHCO_3$), and total dissolved solids (TDS). Significant increases are also likely to occur in calcium concentrations as a result of IX with clays. The oxidant will cause significant increases in uranium, vanadium, and radium and minor increases in trace metals such as copper, arsenic, molybdenum, and selenium. The genesis of the ore body and the facies of the host rock at the MEA are similar to that of the current Crow Butte site, so it is probable the change in water quality at the MEA will be similar to that experienced at the current Crow Butte site. Historical restoration activities at the current Crow Butte site have demonstrated the ability to successfully restore groundwater to established restoration standards. Groundwater restoration is discussed in detail in Section 6.

The site-specific ISR mining process for the MEA is described in Section 3.1.5.

Net withdrawal within the wellfield must be maintained in order to capture injected mining solutions (see discussion below). Under NDEQ Title 122, Chapter 19, Section 002.02, injection of mining solutions shall not exceed the formation fracture pressure (see Section 3.1.3), but must be significant enough to overcome existing pressure heads within the confined aquifer while assuring that the pressure in the injection zone during injection does not cause migration of injection fluids into an underground source of drinking water. From an operations standpoint, procedures must be in place for responding to leaking well casings or well valves (see Section 3.1). Mechanical integrity testing is conducted following installation of all wells and subsequently every 5 years after a well begins operation. In addition, all wells that have had rig work completed with the drill string entering the well casing will be tested for mechanical integrity before being returned to service. Water quality is sampled bi-weekly at all monitoring well locations, which would detect an excursion (i.e., presence of mining solutions). Contingency plans in the event of well failure are discussed in Section 7.5.4, which may either include identifying and patching the leaking well casing or abandoning the well if the leak cannot be repaired.

Maintenance of hydraulic control will be demonstrated by exterior monitoring wells surrounding each wellfield. Planned procedures for monitoring the capture of injected mining solutions are discussed in Section 3.1.3. These procedures include routine water level measurements in the production zone and overlying water-bearing zones and water quality sampling at monitoring wells every 2 weeks. Any changes in water levels or water quality within the production zone will be evaluated after sample collection to ensure that the system is operating properly and successfully. The proposed procedures will also allow for flow rate adjustments to ensure capture of mining fluids. ISR mining at the MEA will be undertaken via a recirculation system with a close mass balance resulting from the over-production (or bleed) rates. Within the wellfield and its vicinity, there will be local changes in head and flow direction. However, beyond the MEA license boundary, the magnitude of regional groundwater flow will not be meaningfully affected and will resume to regional flow conditions within a few hundred feet outside the license boundary. The monitoring procedures proposed in Section 3.1.3 are considered an adequate trigger for hydraulic adjustments to the production system in response to increases in pumping by private wells screened in basal sandstone of the Chadron Formation.

The hydrologic properties of the basal sandstone of the Chadron Formation must be known to formulate the best injection/extraction well arrays and for appropriate containment. Based on the pumping rate, test duration, and formation characteristics, the ROI (i.e., the area over which drawdown occurs) can also be determined for a given test. **Tables 2.7-3** and **2.7-4** present relevant hydrologic information based on an aquifer test performed in the MEA in May 2011, compared with the same properties in the CPF, NTEA, and TCEA. These data indicate that mean transmissivity and hydraulic conductivity at the MEA are more than adequate to successfully develop the MEA for ISR mining activities.

2.7.2.5 Lateral and Vertical Extent of the Proposed Exempt Aquifer

The lateral extent of the area requested being requested by CBR for an aquifer exemption under a separate application to the NDEQ is shown on **Figure 1.4-1**. The lateral extent of the proposed aquifer exemption is equivalent to the proposed NDEQ Class III UIC Application license boundary.

The vertical extent of the requested exemption is the full thickness of the basal sandstone of the Chadron Formation, which extends from the top of the Pierre Shale to the base of the middle Chadron (**Table 2.6-2; Figures 2.6-3a** through **2.6-3n**). This vertical extent is slightly different than the vertical extent requested and received in the 1983 Aquifer Exemption Petition for the current Crow Butte operations, which includes the middle Chadron and upper/middle Chadron, but it is similar to the vertical extent requested for the NTEA and TCEA.

2.7.3 References

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Table 2.7-1 Stream Classification of Niobrara River Subbasin N14

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Table 2.7-2 Summary of 2011 Marsland Pumping Test #8 Well Information

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Table 2.7-3 Summary of 2011 Marsland Pumping Test Results

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Table 2.7-4 Summary of Marsland Pumping Test Results Compared to Previous Testing

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Table 2.7-5 Baseline and Restoration Values for Mine Unit 1 of Current Commercial License Area

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Table 2.7-6 Anticipated Changes in Water Quality during Mining

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Figure 2.7-1 Nebraska's Major River Basins

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Figure 2.7-2 Niobrara River Basin (And Subbasins)

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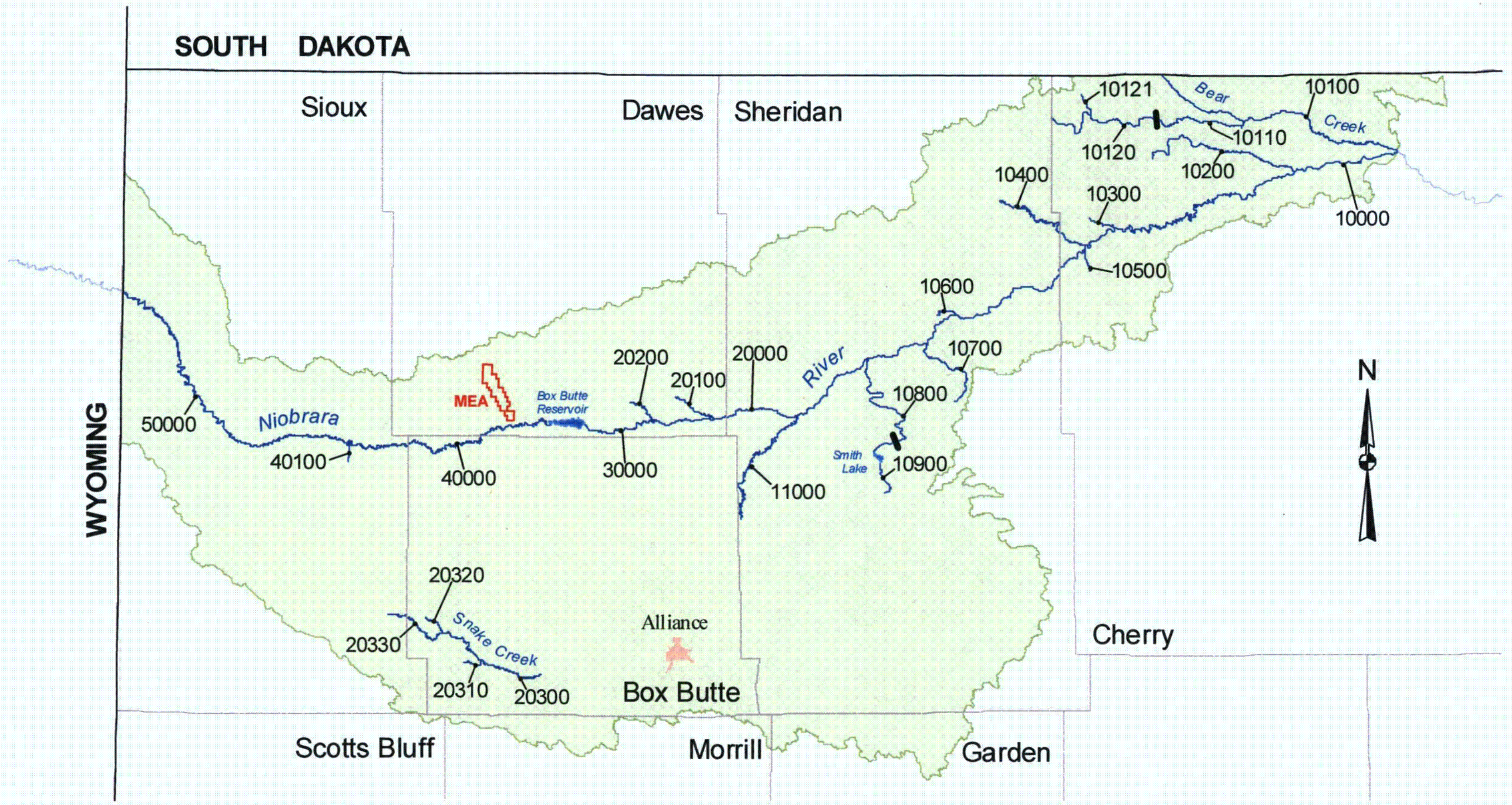
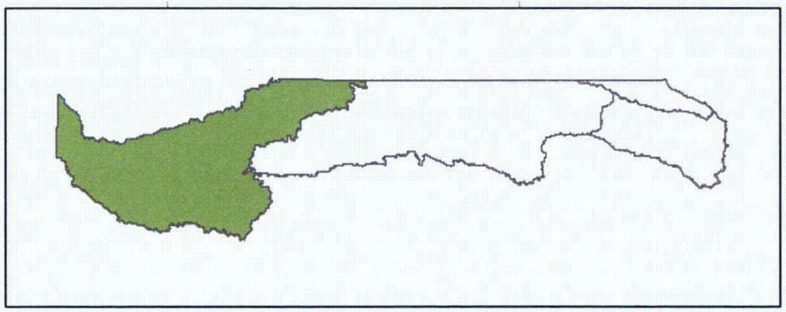


Note: the X0,000 series numbers are Stream Segment Numbers.

10 0 10 20 30 40 50 60 Miles



Source: NAC 2012

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-3

NIOBRARA RIVER SUBBASIN N14

PROJECT: CO001636 MAPPED BY: JC CHECKED BY: JEC

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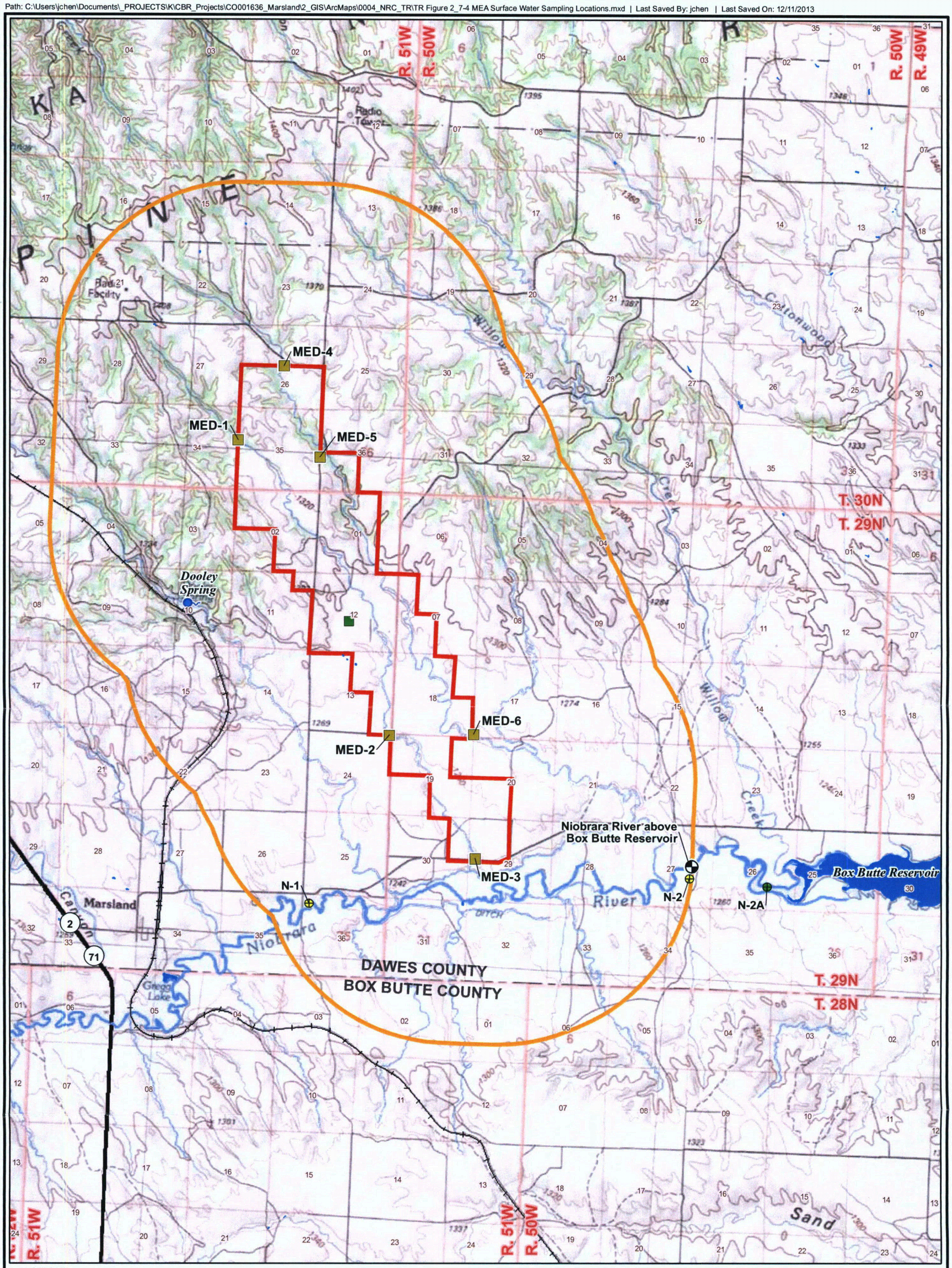
K:\CBR_Projects\CO001636_Marsland\3_IMAGES\Illustrator\UIC_Fig_F 1-3 Niobrara River Subbasin N14.ai @ 04/06/2012

Path: C:\Users\jchen\Documents_PROJECTS\K\CBR_Projects\CO001636_Marsland\2_GIS\ArcMaps\0004_NRC_TR\TR Figure 2_7-4 MEA Surface Water Sampling Locations.mxd | Last Saved By: jchen | Last Saved On: 12/11/2013



LEGEND

- Proposed Marsland Expansion Area
- Area of Review (AOR)
- Proposed Marsland Satellite Facility Site
- CBR Surface Water/ Sediment Sampling Location
- CBR Sampling Point Abandoned as of 3/2013
- Marsland Ephemeral Drainage (MED) Sediment and Surface Runoff Sampling Point
- USGS/NDNR 06454500 and NDEQ SNI4NIOBR402 Gaging Station
- Natural Spring
- Reservoir/Lake/Pond
- Perennial River
- Ephemeral Drainage
- Railroad
- State Highway

Note: Fish sampling for radiological analysis occurs in headwaters of Box Butte Reservoir.

N

0 0.5 1
Miles

PROJECTION: NAD 1983, STATE PLANE NEBRASKA NORTH, FIPS 2600
SOURCES: US TOPO MAPS, SERVICED BY ESRI ARCGIS ONLINE

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FIGURE 2.7-4
SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

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Figure 2.7-5 Mirage Flats Project, Nebraska

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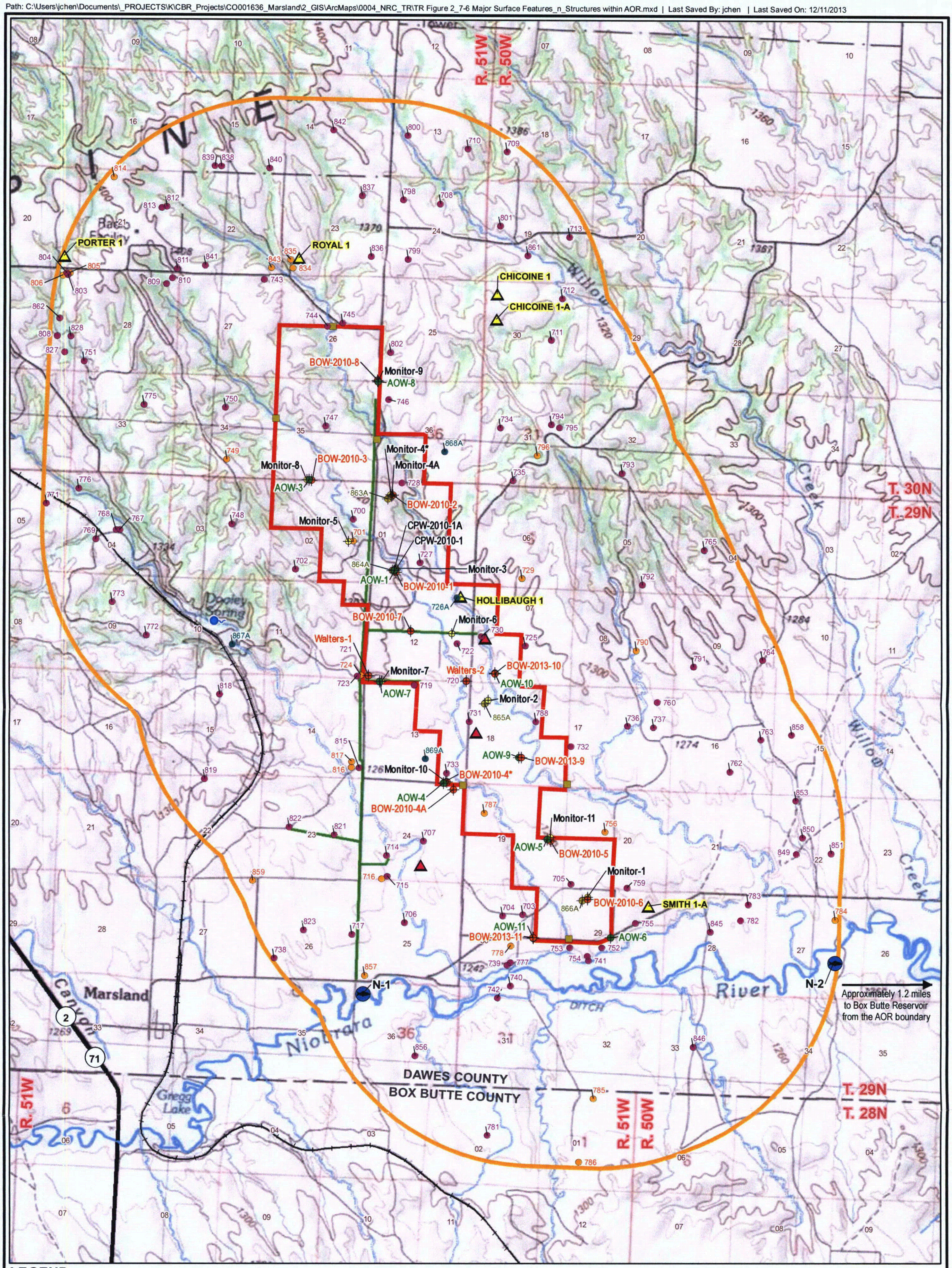
Path: C:\Users\jchen\Documents_PROJECTS\K\CBR_Projects\CO001636_Marsland\2_GIS\ArcMaps\0004_NRC_TR\TR Figure 2_7-6 Major Surface Features_n_Structures within AOR.mxd | Last Saved By: jchen | Last Saved On: 12/11/2013



LEGEND

- Proposed Marsland Expansion Area
- Area of Review (AOR)
- Surface Water/Fish Sampling Location
- Ephemeral Drainage Sediment Sampling Point
- Natural Spring

Pumping Test Monitoring Wells

- Monitor-5 — Basal Sandstone of the Chadron Formation Well and Well ID
- BOW-2010-6 — Brule Formation Well and Well ID
- AOW-3 — Arikaree Group Well and Well ID

- 865A — Abandoned Chadron Monitor Well and Well ID
- Sand/Gravel Pit, Inactive
- Dry Hole, Dry and Abandoned

Private Water Supply Wells

- 781 — Active Well and Well ID
- 786 — Inactive Well and Well ID
- 726A — Abandoned Well and Well ID
- Powerline
- Railroad

* BOW-2010-4 and Monitor-4 are inactive and scheduled to be abandoned.

N

0 0.5 1

Miles

PROJECTION: NAD 1983, STATE PLANE NEBRASKA NORTH, FIPS 2600
SOURCES: US TOPO MAPS, SERVICED BY ESRI ARCGIS ONLINE

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-6
MAJOR SURFACE FEATURES/STRUCTURES WITHIN AOR AS PER TITLE 122, CHAPTER 11, SECTION 006.09

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Figure 2.7.7 Marsland Expansion Area Pumping Test Well Locations

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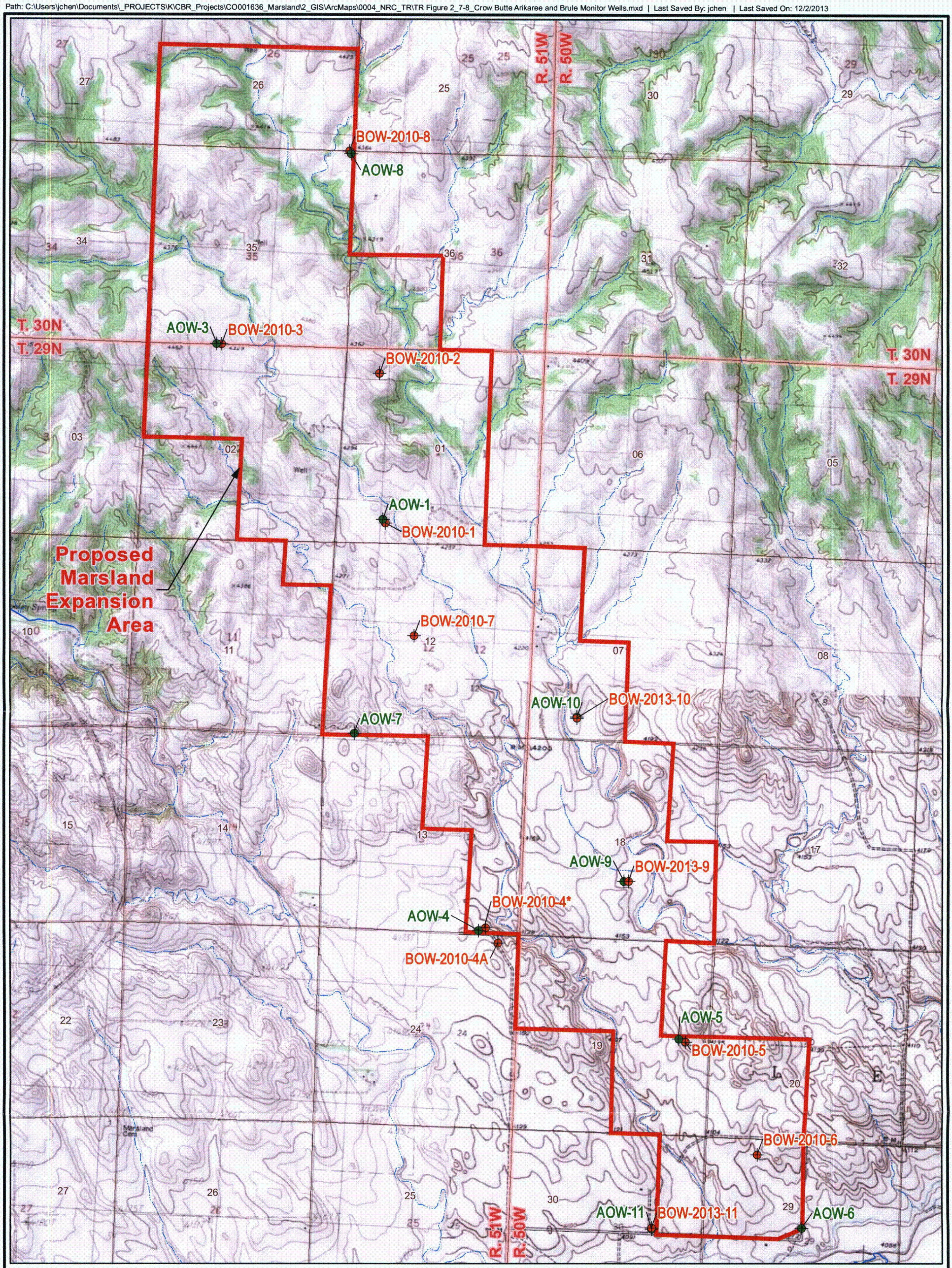
Path: C:\Users\jchen\Documents_PROJECTS\K\CBR_Projects\CO001636_Marsland\2_GIS\ArcMaps\0004_NRC_TR\TR Figure 2_7-8_Crow Butte Arikaree and Brule Monitor Wells.mxd | Last Saved By: jchen | Last Saved On: 12/2/2013



LEGEND

- Arikaree Group Well
- Brule Formation Well
- Proposed Marsland Expansion Area
- Intermittent Stream/River

* BOW-2010-4 is inactive and scheduled to be abandoned.

N

0 1,250 2,500

Feet

PROJECTION: NAD 1983, STATE PLANE NEBRASKA NORTH, FIPS 2600
SOURCES: US TOPO MAPS, SERVICED BY ESRI ARCGIS ONLINE

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FIGURE 2.7-8
MARSLAND
ARIKAREE AND BRULE MONITOR WELLS

PROJECT: CO001636	MAPPED BY: JC	CHECKED BY: MS

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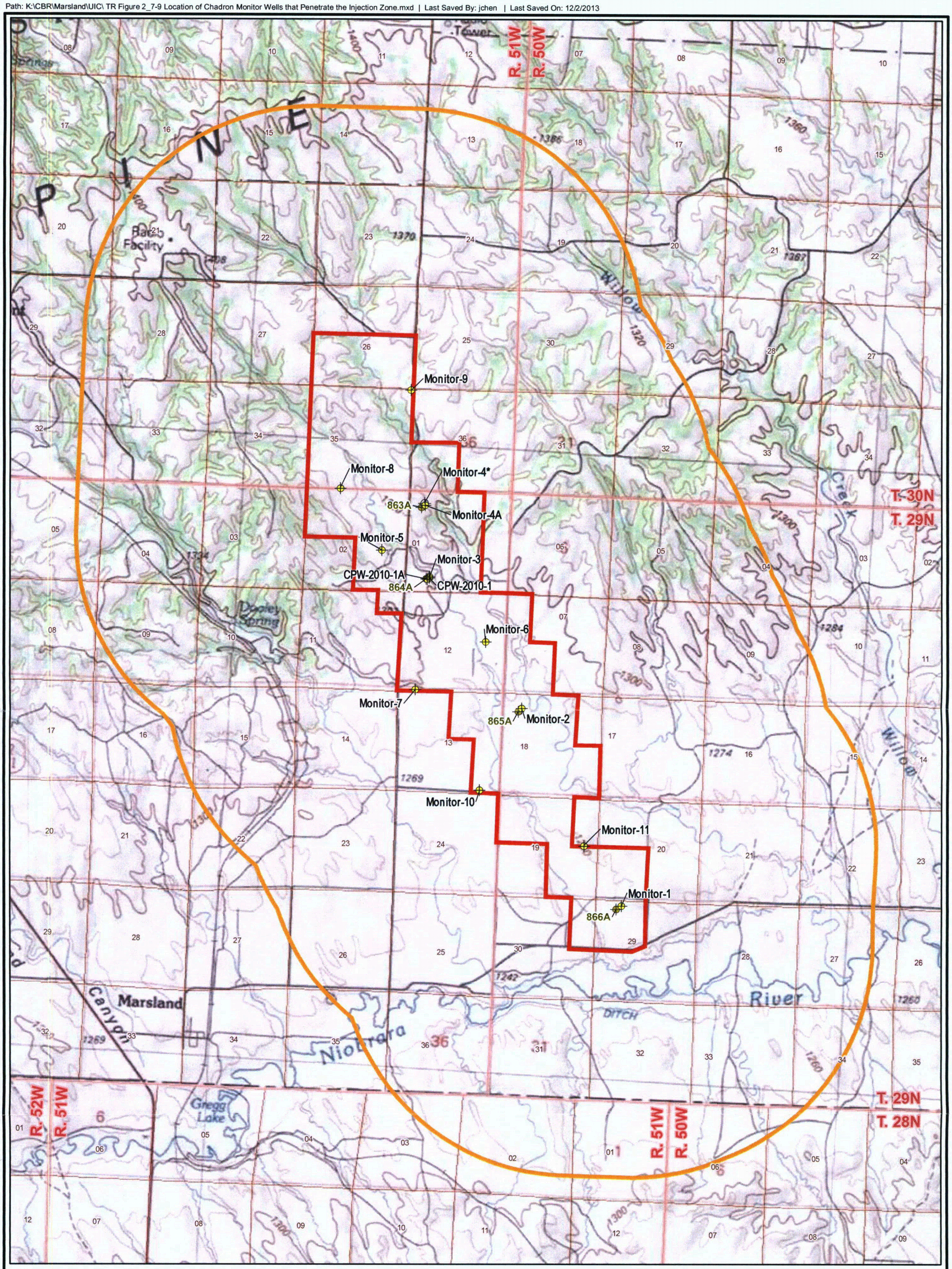
Path: K:\CBR\Marsland\UIC\ TR Figure 2_7-9 Location of Chadron Monitor Wells that Penetrate the Injection Zone.mxd | Last Saved By: jchen | Last Saved On: 12/2/2013



LEGEND

- Proposed Marsland Expansion Area
- Area of Review (AOR)

Pumping Test Monitoring Wells

- Monitor-5 — Active Basal Sandstone of the Chadron Formation Well and Well ID
- Monitor-4* — Inactive Basal Sandstone of the Chadron Formation Well and Well ID
- 865A — Abandoned Chadron Monitor Well and Well ID

N

0 0.5 1
Miles

PROJECTION: NAD 1983, STATE PLANE NEBRASKA NORTH, FIPS 2600
SOURCES: US TOPO MAPS, SERVICED BY ESRI ARCGIS ONLINE

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-9
LOCATION OF MEA ACTIVE, INACTIVE AND ABANDONED CHADRON MONITOR WELLS THAT PENETRATE THE INJECTION ZONE

PROJECT: CO001636 | MAPPED BY: JC | CHECKED BY: AH

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2.8 Ecological Resources

This section describes the existing ecological resources within the MEA. The potential impacts associated with the proposed project and mitigation measures that would offset such impacts are discussed in Section 7. The analysis consisted of a review of documents, databases, and reports in conjunction with biological field surveys to determine the potential impacts, if any, to special-status plant and wildlife species and their habitats in the proposed expansion area. Pre-existing baseline ecological studies, including field observations, agency contacts, and literature searches, have been conducted for several other uranium ISR projects in the general area of the MEA, including CBR's main processing facility and for the proposed NTEA and TCEA uranium ISR satellite facilities. Baseline studies date from 1982 through 2008 for these project sites. These studies are discussed in more detail in this section. The purpose of the consultations and associated correspondence was to help identify biological issues and potential occurrences and distribution of special-status plants and wildlife and their habitats.

2.8.1 Regional Setting

The project area occurs within the Western High Plains Level III ecoregion and is characterized by a semi-arid to arid climate, with annual precipitation ranging from 13 to 20 inches. Higher and drier than the Central Great Plains to the east, much of the Western High Plains comprises a smooth to slightly irregular plain having a high percentage of dryland agriculture. Potential natural vegetation in the Western High Plains ecoregion is dominated by drought-tolerant short-grass prairie and large areas of mixed-grass prairie in the northwest portion of the state. The northern portion of the project area occurs within the Pine Ridge Escarpment Level IV ecoregion, with ponderosa pine (*Pinus ponderosa*) woodlands associated with mixed-grass prairie on ridge tops and north-facing and east-facing slopes. The southern portion of the project area, predominantly rangelands, is made up of mixed-grass prairie with areas of moderate relief and is characteristic of the Sandy and Silty Tablelands Level IV ecoregion (Chapman et al. 2001).

2.8.2 Local Setting - Marsland Expansion Area

The proposed MEA is located in southwest Dawes County, Nebraska within sections 26, 35, and 36 T30N:R51W; sections 1, 2, 11, 12, and 13 T29N:R51W; and sections 7, 18, 19, 20, 29, and 30 T29:R50W. The project area encompasses 4,622.3 acres approximately 4.6 miles (7.4 km) northeast of Marsland, Nebraska (centerpoint of MEA satellite building to centerpoint of Town of Marsland; **Figure 1.7-3, Figure 2.2-1**). All of the land surface within the MEA license boundary and AOR is privately owned, with the exception of section 36 T30N R51W, which is State Trust Land. The southwest ¼ of section 36 is located within the MEA license boundary, with the surface and mineral rights under lease between Cameco and the State of Nebraska. **Figure 1.3-2** shows surface land ownership in the proposed MEA.

2.8.3 Climate

The proposed MEA near Crawford, Nebraska is located in a semi-arid or steppe climate. The area is characterized by abundant sunshine, low relative humidity, and sustained winds which lead to high evaporative demand. There are also large diurnal and annual variations in temperature. The region has cold, harsh winters; hot, dry summers; and relatively warm, moist springs and autumns. Temperature extremes range from roughly -25° F in the winter to 100° F in the summer. The "last freeze" occurs during late May and the "first freeze" in mid to late September. The area has a growing season of approximately 120 days (HPRCC 2011).

Historical average minimum and maximum meteorological data (i.e., temperature, precipitation, and snowfall) typical of the Scottsbluff area are presented in **Table 2.8-1** (HPRCC 2011). Scottsbluff is located approximately 45 miles (72.4 km) to the southwest of the MEA. A detailed discussion of more recent and expanded meteorological data (2010 through 2011) considered representative of the MEA project site can be found in Section 2.5.

2.8.4 Pre-existing Baseline Data

Ecological studies have been conducted for several other mines in the general area of the MEA, including the CBR Crow Butte Uranium Project (Radioactive Source Materials License SUA-1534) and the TCEA. The first baseline study was conducted for the Crow Butte Mine in 1982 (WFC 1983) and additional baseline data were collected in 1987, 1995, 1996, 1997, and 2004 (CBR 2007). Baseline data, including field observations, agency contacts, and literature searches, were conducted for the TCEA in 2005 and 2008 (CBR 2010).

2.8.5 Terrestrial Ecology

The information presented in this report summarizes the baseline data collected for the Crow Butte Mine and TCEA between 1982 and 2008, and from field observations, surveys, and mapping conducted for the MEA in in 2011.

2.8.5.1 Methods

Baseline studies were performed during 2011 to determine presence or absence of federally or state-listed species as well as regional species of concern deemed by the state. Surveys were conducted in accordance with approved protocols established by state and federal agencies for: (1) winter bald eagle (*Haliaeetus leucocephalus*) roosts, (2) raptor nests, (3) burrowing owl (*Athene cunicularia*) nests, (4) black-tailed prairie dog (*Cynomys ludovicianus*) colonies, (5) swift fox (*Vulpes velox*), (6) threatened and endangered fish species, and (7) wetland habitat. In addition, amphibian breeding habitat was opportunistically documented, as well as all other wildlife species observed within or near the project area.

The goal was to document and summarize the ecological resources not only within the project area but also within a 2.5-mile (4.0-km) radius of the project area, referred to as the Ecological Study Area (ESA). The 2.5-mile (4.0-km) ESA boundary overlaps the 2.25-mile (3.62 km) AOR buffer. Aerial surveys conducted included the entire 2.5-mile (4.0-km) ESA, but groundwork was almost entirely restricted to the project area due to limited access to private lands. Thus, certain ecological resources within the 2.5-mile (4.0-km) ESA were identified using aerial surveys, documented from public roads, and/or mapped using National Agriculture Imagery Program (NAIP) imagery (e.g., prairie dog colonies). When possible, these resources were later verified and mapped from the ground if landowner permission was granted.

Information was also gleaned from recent field surveys conducted for the TCEA in 2005 and 2008, and from the baseline surveys conducted for the Crow Butte Mine in 1982. In 2005, primary floral and faunal species were identified through observation to determine the distribution and composition of vegetation communities that occurred within the project area.

Raptor surveys were also conducted and compiled with past ecological data collected during 2008.

2.8.5.2 Existing Disturbance

Human expansion into the region was prompted by the development of the transcontinental railroad by the Union Pacific Railroad during the late 1800s. As a result of this expansion, the region became a regional railroad trade hub and eventually a source for agriculture, intensive rangeland, mining, and human development. Disturbance within the project area is limited to one small residence (i.e., farmhouse), farming and ranching activity, watering sites for cattle (e.g., windmills, water tanks), improved gravel and unimproved two-track roads, and one small gravel pit.

2.8.5.3 Vegetation and Land Cover Types

Vegetation classifications were applied to the MEA through heads-up digitizing of NAIP imagery and categorized into eight vegetation communities similar to the definitions in the TCEA Technical Report (**Figure 2.8-1**). These communities include mixed-grass prairie, degraded rangeland, mixed-conifer, cultivated, drainage, structure biotope, range-rehabilitation, and deciduous streambank forest. The mixed-conifer vegetation type was not defined in the TCEA Technical Report, but was present in the MEA. The degraded rangeland class was added following field observations. Vegetation types were ground-truthed, and species composition of each type was recorded. Vegetation types represent a variety of species compositions and relative abundances. **Table 2.8-2** summarizes the abundance of vegetation types within the MEA.

The Chadron State College herbarium contains 468 plant species from Dawes County (WFC 1983). In addition, the Institute of Agriculture and Natural Resources lists 603 native and 123 introduced plant species that occur in Dawes County. During the 1982 baseline study (WFC 1983), more than 400 species of plants were collected (**Appendix H-1**).

Mixed-Grass Prairie

The most common vegetation type present in the MEA is mixed-grass prairie, comprising 65 percent of the area (**Table 2.8-2**). Common species observed in this vegetation type include the following grasses: needle-and-thread grass (*Hesperostipa comata*), junegrass (*Koeleria macrantha*), Sandberg bluegrass (*Poa secunda*), and threadleaf sedge (*Carex filifolia*). The non-native species cheatgrass (*Bromus tectorum*) and Kentucky bluegrass (*Poa pratensis*) were also abundant in this vegetation type. Common forbs observed included white sagebrush (*Artemisia ludoviciana*), fringed sagebrush (*A. frigida*), phlox (*Phlox sp.*), locoweed (*Oxytropis sp.*), lupine (*Lupinus sp.*), pussytoes (*Antennaria sp.*), and yucca (*Yucca glauca*). This vegetation type is the most common in the northern portion of the project area, and is quite variable in composition (**Figure 2.8-1**).

Degraded Rangeland

Areas where non-native species, predominantly cheatgrass, have overtaken the landscape are classified as degraded rangeland. Considerable portions of the southern half of the project area were observed to have larges patches dominated by cheatgrass (*Bromus tectorum*) and Kentucky bluegrass (*Poa pratensis*). The southernmost portion of the project area has large patches dominated by smooth brome (*Bromus inermus*). Overall biodiversity in these areas is lower than in areas of mixed-grass prairie. While non-native grasses are common throughout the project area, the southern portion of the project area had sections that were particularly dominated by these species. The degraded rangeland vegetation type comprises 14.0 percent of the project area (**Table 2.8-2**; **Figure 2.8-1**).

Mixed Conifer

Mixed-conifer forests are concentrated along drainages in the northern third of the project area, often expanding out onto nearby hills and plains (**Figure 2.8-1**). This vegetation type is dominated by Ponderosa pine, with chokecherry (*Prunus virginiana*), skunkbush sumac (*Rhus trilobata*), and snowberry (*Symphoricarpus albus*) common in the understory. A combination of native and non-native grasses were common, with smooth brome (*Bromus inermus*) being particularly abundant in low-lying areas. Pussytoes was a commonly observed forb. Mixed-conifer forests comprise 9.1 percent of the project area, making this the most common of the forested vegetation types (**Table 2.8-2**).

Cultivated

Cultivated fields make up approximately 6.3 percent of the project area and include crops such as alfalfa (*Medicago sativa*), wheat (*Triticum* spp.), oats (*Avena* spp.), corn (*Zea mays*), barley (*Hordeum* spp.), and rye (*Secale cereale*). In an environment not altered by humans, areas occupied by this vegetation type would most likely be occupied by mixed-grass prairie.

Drainages

Drainages in the south end of the project area are well drained and usually dry, covering 2.9 percent of the project area (**Table 2.8-2**; **Figure 2.8-1**). The vegetation composition in these intermittent tributaries to the Niobrara River is similar to that of surrounding grassland, though the vegetation is generally more robust. Meadow death camas *(Zigadenus venenosus)*, wild onion (*Allium sp.)*, and monkeyflower (*Mimulus sp.)* were observed in these areas. In the north side of the project area, conifers dominate the overstory of drainages with smooth brome in the understory. Standing water was only observed in the northern portion of the survey area, mostly in the area mapped as deciduous streambank forest. The weed houndstongue (*Cynoglossum officinale*) was observed in low densities.

Deciduous Streambank Forest

Deciduous stands found along ephemeral streams make up a very small portion of the project area, totaling less than 1 percent (**Table 2.8-2**; **Figure 2.8-1**). The most common overstory species observed within this habitat type include eastern cottonwood (*Populus deltoides*), boxelder (*Acer negundo*), and willow (*Salix sp.*). Snowberry was the dominant shrub, with Kentucky bluegrass, smallwing sedge (*Carex microptera*), *Rumex sp.*, and annual mustards (*Brassicaceae sp.*) common in the understory.

Structure Biotopes

The term "structure biotopes" refers to man-made features, with the exception of cultivated land. Common examples include roads, highways, buildings, farmlands, cities, and industry infrastructure. This cover type comprises 1.5 percent of the project area (**Table 2.8-2**; **Figure 2.8-1**). Dominant plant species in these areas are often non-native weedy species, including smooth brome, cheatgrass, white sweetclover (*Melilotus alba*), yellow sweetclover (*Melilotus officinalis*), and mustard species.

Range Rehabilitation

Previously cultivated fields are defined as range rehabilitation areas, and are generally heavily grazed. Seasonal haying is also an important component of these areas. Vegetation of this habitat type is variable, with weedy species being more prevalent in areas with greater disturbance from cattle. Crested wheatgrass (*Agropyron cristatum*) was the dominant grass species observed, while fringed sagebrush was also common. This habitat type comprises less than 1.5 percent of the project area (**Table 2.8-2; Figure 2.8-1**).

2.8.6 Mammals

Information concerning current and historical mammal observations and distribution within and near the MEA were obtained from a variety of sources including the NGPC and the Nebraska Natural Heritage Program (NNHP). The NNHP is a primary repository for wildlife information in the State of Nebraska and contains records of wildlife observations for birds, mammals, herptiles, fish, and species at risk in the state. Wildlife information for the MEA was supplemented with survey data collected by Hayden Wing Associates during spring/summer 2011 as part of the baseline and monitoring data requirements. A list of known and expected mammal species for Dawes County can be found in **Appendix H-2**.

2.8.6.1 Big Game

Six big game species occur or potentially occur in the vicinity of the MEA, including pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus elaphus*), bighorn sheep (*Ovis canadensis*), and bison (*Bison bison*). Big game populations are managed by the NGPC. Population objectives are set annually based on multiple factors including, but not limited to, the carrying capacity of the habitat, herd production and health, and weather (e.g., drought).

Pronghorn

Pronghorn typically inhabit grasslands and semi-desert shrublands of the western and southwestern United States. This species is most abundant in short- and mixed-grass habitats and is less abundant in more xeric habitats. Home ranges for pronghorn can vary between 400 and 5,600 acres, according to several factors including season, habitat quality, population characteristics, and local livestock occurrence. Typically, daily movement does not exceed 6 miles (9.6 km). Some pronghorn make seasonal migrations between summer and winter habitats, but these migrations are often triggered by availability of succulent plants and not local weather conditions (Fitzgerald et al. 1994). Pronghorn occur mainly in the western half of Nebraska, with the highest densities occurring in Sioux and Dawes Counties. In Nebraska, this species primarily inhabits short-grass prairies and badlands (NGPC 2011b).

The project area is located in the Box Butte Antelope Hunt Unit, which extends from the Wyoming/Nebraska border, north from the North Platte River, east to Nebraska Highway 250, and south from the Pine Ridge Escarpment. In 2007 and 2008, 34 and 32 pronghorn, respectively, were harvested within this hunt unit (NGPC 2008a). In 2009, 36 pronghorn were harvested (NGPC 2010), and in 2010, 48 pronghorn were harvested (NGPC 2011c). Pronghorn populations in Nebraska are increasing, and harvest is at a 25-year high (NGPC 2011c). Pronghorn were observed regularly throughout the project area in 2011 and they appear to be relatively common year-round.

Mule Deer

Mule deer occur throughout western North America from central Mexico to northern Canada. Mule deer are found throughout Nebraska, but are more common in the western half of the state (NGPC 2011b). They inhabit a wide variety of habitats (e.g., sagebrush-steppe, grasslands, foothills) and feed on succulent grasses, forbs, shrubs, and agricultural crops. Mule deer tend to have elevational migrations, moving from uplands during the warmer months to lowlands in the winter where denser, taller vegetation cover allows for manageable snow levels for foraging (Fitzgerald et al. 1994). Mule deer fawn mortality is typically due to predation or starvation. Adult mortality often occurs from hunting, winter starvation, and automobile collisions. Typical mule deer predators may include coyotes, bobcats, golden eagles, mountain lions, bears, and domestic dogs (Fitzgerald et al. 1994).

The MEA is located within the Pine Ridge Mule Deer Hunt Unit, which encompasses areas of Box Butte, Dawes, Sheridan, and Sioux Counties north of the Niobrara River and west of Nebraska Highway 27. Due to concerns with harvest of buck deer, the NGPC conducted a study (based on aged sample projected by total kill) of adult bucks 2.5 years or older during the 1987, 1992, and 1997 regular firearm hunting seasons. Adult mule deer buck harvest in the Pine Ridge unit for 1987, 1992, and 1997 was 202, 446, and 385, respectively (NGPC 2011d). The adult mule deer buck harvest for the Pine Ridge unit was 735 in 2008 (NGPC 2008a) and 922 in 2009 (NGPC 2010). In 2010, 10,709 mule deer were harvested in Nebraska; 957 of these were adult bucks harvested in the Pine Ridge Unit (NGPC 2011c). Mule deer were seen within the project area during field work in 2011 but not in high numbers, though numbers are likely higher during winter.

White-tailed Deer

White-tailed deer occur throughout North America from the southern United States to Hudson Bay in Canada. Across much of its range, this species inhabits forests, swamps, brushy areas, and nearby open fields. In Nebraska, white-tailed deer are found throughout the state, but have higher densities in the eastern half. They are typically concentrated in riparian woodlands, mixed-shrub riparian areas, and irrigated agricultural lands, and are generally absent from dry grasslands and coniferous forests (NGPC 2011b). White-tailed deer have a diverse diet, capitalizing on the most nutritious plant matter available at any time. In addition to native browse, grass, and forbs, this species often relies on agricultural crops, fruits, acorns, and other nuts. Mortality of white-tailed deer is typically related to hunting, winter starvation, collisions with automobiles, and predation. Predators may include coyotes; mountain lions; wolves; and occasionally bears, bobcats, and eagles (Fitzgerald et al. 1994).

White-tailed deer hunting in the region encompasses the same unit as previously described for mule deer. Results of the white-tailed deer buck harvest for the Pine Ridge area were 186, 318, and 363 in 1987, 1992, and 1997, respectively (NGPC 2011d). In 2008 and 2009, the white-tailed deer adult buck harvest for the Pine Ridge unit was 824 (NGPC 2008a) and 1,053 (NGPC 2010), respectively. In 2010, the white tailed deer adult buck harvest for the Pine Ridge Unit was 1,252 (NGPC 2011c). According to the NGPC (2011b), the fall white-tailed deer population in

Nebraska is estimated to be between 150,000 and 180,000 animals. Currently, the NGPC has a goal of reducing white-tailed deer populations in eastern Nebraska by increasing harvest numbers. In 2010, a record 77,028 white-tailed deer were harvested in the state (NGPC 2011e).

Within the MEA, white-tailed deer were commonly seen during the 2011 survey around the agricultural and riparian habitats, but they were also seen in the higher elevations and in the forested areas.

Elk

Elk formerly ranged over much of central and western North America from the southern Canadian Provinces and Alaska south to the southern United States, and eastward into the deciduous forests. In Nebraska, this species occurs primarily in the northwestern region in a variety of habitats, including coniferous forests, meadows, short- and mixed-grass prairies, and sagebrush and other shrub lands. Similar to other members of the deer family, this species relies on a combination of browse, grasses, and forbs, depending on their availability throughout the seasons. Elk tend to be migratory, moving between summer and winter ranges. Typically, mortality is a result of predation on calves, hunting, and winter starvation. Predators may include coyotes, mountain lions, bobcats, bears, and golden eagles (Fitzgerald et al. 1994).

NGPC estimates the state elk population at approximately 2,300 individuals, and most of the population inhabits the Pine Ridge area (NGPC 2011f). The Marsland Project Area is located in the Pine Ridge area, within the Ash Creek Elk Unit, specifically located east of Nebraska Highway 2, north of Spur L7E and west of U.S. Highway 385. The 2008 elk harvest was 73 individuals in the Pine Ridge area, and 10 individuals in the Ash Creek Elk Unit (NGPC 2008a). The 2009 elk harvest was 85 individuals in the Pine Ridge area, and 17 individuals in the Ash Creek Elk Unit (NGPC 2010). In 2010, elk harvest in the Pine Ridge included 114 individuals (17 in the Ash Creek Elk Unit) with an estimated 1,000 to 1,200 individuals comprising the population (NGPC 2011c).

Relatively large numbers of elk are known to occur year-round within the project area. During the fall and winter, the elk occupy many of the agricultural fields and lower elevation upland habitat. Although still found in the lower elevations during the spring and summer, the majority of the herd appears to move north to higher elevations in the forested portions of the Pine Ridge during the warmer portions of the year.

Bighorn Sheep

Prior to the 1900s, the Audubon bighorn sheep (*O. canadensis auduboni*) inhabited parts of western Nebraska including the Wildcat Hills, the Pine Ridge, along the North Platte River to eastern Lincoln County, and along the Niobrara River. It is thought that the Audubon bighorn probably became extinct in the early 1900s, with its last stronghold being the South Dakota badlands (NGPC 2011b).

Bighorn sheep were reintroduced into Nebraska in the early 1980s; the current population is estimated at 300 sheep, divided between two populations in the Pine Ridge and Wildcat Hills (NGPC 2011c). The reintroduction project began in 1981, when 12 bighorn sheep were first released in Fort Robinson State Park. Between 1988 and 1993, a total of 44 sheep were released in the state park. Twenty-two sheep were released in the Wildcat Hills south of Gering, Nebraska in 2001, and in 2005, an additional 49 were released into the Pine Ridge area. The most recent reintroduction occurred in 2007, with 51 bighorn sheep from Montana released in the Wildcat Hills south of McGrew, Nebraska (NGPC 2011g). As a result of disease, herd growth is limited; consequently, only a single lottery and a single auction permit were authorized for bighorn sheep hunting in 2011 (NGPC 2011c). Appropriate escape terrain habitat is not present within the MEA, and it is therefore extremely unlikely that bighorn sheep would occur within the project area.

Bison

Fort Robinson State Park currently manages a herd of 200 bison. These bison are contained in a compound and do not occur within the project area boundary.

2.8.6.2 Carnivores

The following species have been documented or are expected to be present within the MEA: coyotes (*Canis latrans*) and red foxes (*Vulpes vulpes*) typically occupy grassland, shrub-steppe, and agricultural habitats; long-tailed weasels (*Mustela frenata*) are habitat generalists and can be found in a wide variety of habitats; bobcats (*Lynx rufus*) tend to occupy woodland and shrubland habitat; badgers (*Taxidea taxus*) inhabit areas with loose soils that are suitable for digging burrows which frequently includes roadsides, prairie dog colonies, and areas near surface disturbance; and mountain lions (*Puma concolor*) prey upon mule and white-tailed deer and tend to occupy wooded habitats. Coyotes are considered non-game species, and residents do not need a permit to harvest this species. Mountain lion permits are not available, and lions cannot be trapped or hunted in Nebraska. Badger, bobcat, long-tailed weasel, raccoon (*Procyon lotor*), red fox, and striped skunk (*Mephitis mephitis*) are open to hunting and trapping with appropriate permits.

Using infrared-triggered remote trail cameras, which were deployed for documenting the presence/absence of swift fox (see Section 2.8.9). Hayden Wing Associates documented the presence of coyotes and badgers within the project area (HWA 2011). Several other carnivore species are expected to be present, such as red fox, bobcat, raccoon, striped skunk, and long-tailed weasel, even though they were not detected by the cameras.

2.8.6.3 Small Mammals

Small mammals occupy a wide variety of habitats within the region but most are considered common and widespread. Species known to occur or that are potentially present in the MEA include the deer mouse (*Peromyscus maniculatus*), white-footed mouse (*Peromyscus leucopus*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), meadow jumping mouse (*Zapus hudsonius*), plains pocket gopher (*Geomys bursarius*), least chipmunk (*Tamias minimus*) and meadow vole (*Microtus pennsylvanicus*). Muskrat (*Ondatra zibethicus*) and beaver (*Castor canadensis*) are known to occur in or near the project area, especially near the Niobrara River along the southern edge of the project area. Porcupine (*Erethizon dorsatum*) occurs in the wooded areas of the project area, as does the eastern fox squirrel (*Sciurus niger*). Four rabbit species are known or suspected to occur within the project area, including the white-tailed jackrabbit (*Lepus townsendii*), black-tailed jackrabbit (*Lepus californicus*), eastern cottontail (*Sylvilagus floridanus*), and desert cottontail (*Sylvilagus audubonii*) (HWA 2011).

Two bat species have been recorded within a few miles of the MEA: the fringe-tailed myotis (*Myotis thysanodes pahasapensis*) and the long-legged myotis (*Myotis volans*). Both bat species are listed at Tier I At-Risk species by Nebraska Natural Legacy Project (NNLP), and the fringe-tailed myotis is listed as Sensitive in the nearby Pine Ridge Ranger District by the U.S. Forest Service (USFS) Nebraska National Forest. According to the USFS (Abegglen, pers. comm. 2011), the fringe-tailed myotis is known to occur in the Ponderosa pine habitat near the MEA. Both species may be present in the project area if suitable hibernacula exist (e.g., caves, mines, buildings, cliff crevices, hollows in snags, or hollow areas under the bark of trees). Also, it is likely that these and other bat species use the project area for foraging, but no formal bat surveys were conducted by HWA in 2011.

Black-tailed prairie dogs, which are listed as Sensitive in the Pine Ridge Ranger District by the USFS, are known to occur in the vicinity of the project area. Four colonies were found during aerial surveys: two are situated along the project area border, and two are located within a 2.5-mile (4.0-km) ESA (HWA 2011). All four are occupied with prairie dogs. The smallest is only 0.63 acre in size, which is located just east of the project boundary in section 7, T29N:R50W. The other colony that borders the project area is approximately 20 acres in size and is located in section 30, T29N:R50W. The current boundaries of both of these colonies were mapped on foot in 2011. The two colonies in the 2.5-mile (4.0-km) ESA were much larger: one south of the project area measured 47 acres and one east of the project area measured 151 acres in size. The southernmost colony (section 36, T29N:R51W and sections 2 and 3, T28N:R51W) was mapped entirely using NAIP 2010 imagery due to a lack of access, but the colony to the east (sections 16 and 21, T29N:R50W) was partly mapped from the ground (i.e., portion in section 21), and the remaining portion was mapped using NAIP imagery due to a lack of landowner access permission. Prairie dogs, groundhogs (*Marmota monax*), and porcupine are considered non-game species in Nebraska, and residents do not need a permit to harvest these species. Prairie dog colonies, however, provide habitat for several other at-risk or sensitive species, such as swift foxes, long-billed curlews (*Numenius americanus*), ferruginous hawks (*Buteo regalis*), and burrowing owls. Therefore, avoidance of prairie dog colonies is recommended by the U.S. Fish Wildlife Service (USFWS) and NGPC for projects involving ground disturbance activity.

2.8.7 Birds

The Nebraska Ornithologists Union lists 291 bird species occurring in Dawes County (**Appendix H-3**) and 455 species recorded in the state (NOU 2011). Of the 455 species in the state, 329 occur regularly (reported 9 out of the past 10 years); 78 are accidental (occurring less than two times in the past 10 years); 42 are casual (occurring between four and seven times in the past 10 years); four are extirpated, and two are extinct (NOU 2011). During a survey conducted in 1982, 201 bird species were documented in an area just north of the MEA (CBR 2010). Although formal point count bird surveys were not performed for the project area, a total of 73 bird species were documented in and around the project area in 2011, the majority of which are believed to breed locally (HWA 2011). Of the 73 species, 68 were documented during the 1982 baseline survey, four were listed as "reported by knowledgeable individual" in previous ecological surveys (blue jay [*Cyanocitta cristata*], eastern bluebird [*Sialia sialis*], northern mockingbird [*Mimus polyglottos*], and peregrine falcon [*Falco peregrinus*]), and one was new for the list of species (Eurasian collared-dove [*Streptopelia decaocto*]).

2.8.7.1 Passerines

Many species of passerines (perching birds, including songbirds) use the MEA for breeding, feeding, migration, wintering, and as year-round habitats. All habitats throughout the project area are likely used to some degree by various species. The Migratory Bird Treaty Act (16 USC, §703 *et seq.)* protects 836 migratory bird species (to date) and their eggs, feathers, and nests from disturbances (USFWS 2011a). See **Appendix H-3** for a list of known or expected bird species for the project area and surrounding 2.5-mile (4.0-km) ESA .

The Crawford Breeding Bird Survey (BBS) route passes within 4 miles (6.4 km) of the MEA to the north. In an analysis of data collected along this BBS route from 1966 to 2007, the five most abundant species were western meadowlark (*Sturnella neglecta*; 181.1 birds per route), mourning dove (*Zenaida macroura*; 56.1 birds per route); American robin (*Turdus migratorius*; 18.1 birds per route); American crow (*Corvus brachyrhynchos*; 16.4 birds per route); and lark sparrow (*Chondestes grammacus*; 16.3 birds per route) (Sauer et al. 2011).

2.8.7.2 Upland Game Birds

Wild turkey (*Meleagris gallopavo*), ring-necked pheasant (*Phasianus colchicus*), gray partridge (*Perdix perdix*), and sharp-tailed grouse (*Tympanuchus phasianellus*) occur in the MEA. The site is located in the Panhandle hunting region for upland game birds and is managed by the NGPC. Wild turkeys in the Pine Ridge area use habitats in the foothills, plateaus, forest habitats, and riparian draws and are likely to be distributed throughout the project area. Ring-necked pheasants often use open grasslands and agricultural areas and are fairly common. Gray partridge, which are introduced and uncommon, are often located in areas near dense shrub cover. Sharp-tailed grouse inhabit open grassland and steppe habitats with scattered trees and shrubs. The scattering of trees and shrubs plays an important role in their life cycle for food and cover, and this species is known to occur in the project area in low numbers. Upland game birds designated as migratory that are confirmed or potentially present in the project area include mourning dove, Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), and Wilson's snipe (*Gallinago delicata*). Mourning doves occupy a wide variety of habitats including sagebrush, grasslands, shrubland, and riparian areas. Sora and Virginia rail typically occupy areas near wetlands, and snipe are frequently found in flooded fields and ditches (HWA 2011).

2.8.7.3 Raptors

Several raptor species are known or expected to occur in or around the MEA. Grasslands, shrublands, and scattered trees provide suitable nest substrates for a variety of species for breeding, hunting, and wintering. The Niobrara River drainage immediately south of the site provides habitat for tree-nesting species and provides potential roosting sites for wintering raptors (e.g., bald eagle, rough-legged hawk [*Buteo lagopus*]). All raptors and their nests are protected from "take" or disturbance under the Migratory Bird Treaty Act (16 USC, §703 *et seq.*; USFWS 2011a). Golden eagles and bald eagles also are afforded additional protection under the Bald and Golden Eagle Protection Act, amended in 1973 (16 USC, §669 *et seq.*). In addition, several raptor species are considered at-risk or sensitive by NNLP and/or Nebraska National Forest-Pine Ridge Ranger District.

Aerial surveys were conducted for documenting raptor nests throughout the MEA and the 2.5-mile (4.0-km) ESA on April 28 and May 13, 2011. A ground survey for confirming nest locations, determining nest status, and searching for new nests was conducted from May 10 to 12,

2011. The ground survey was limited to the project area and areas adjacent to public roads in the 2.5 ESA due to minimal access to private lands. Additional ground surveys for determining productivity of known nests, including nests in the 2.5-mile (4.0-km) ESA found during the aerial surveys, were conducted from June 7 to 8 and July 7 to 8, 2011 (HWA 2011).

A total of seven raptor nests were documented within the MEA during 2011, including two active red-tailed hawk (*Buteo jamaicensis*) nests, two active burrowing owl nests, one active great horned owl (*Bubo virginianus*) nest, and two inactive stick nests of unknown species (**Figure 2.8-2**). An additional 19 nests were documented within the 2.5-mile (4.0-km) ESA, including five active red-tailed hawk nests, two active great horned owl nests, nine active burrowing owl nests, one active Swainson's hawk (*Buteo swainsoni*) nest, one active ferruginous hawk nest, and one inactive stick nest of an unknown species. One additional active great horned owl nest was located just outside the 2.5-mile (4.0-km) ESA (HWA 2011). Of the five species documented to be nesting in and around the MEA, two (ferruginous hawk and burrowing owl) are designated by the NNLP as Tier I At-Risk species. All but one of the burrowing owl nests were found in active prairie dog colonies.

Of the five active nests in the MEA, only one great horned owl nest (nest #13) and one red-tailed hawk nest (nest #20) were confirmed productive (i.e., at least one fledged chick) at the time of the last survey. Both great horned owl nests in the 2.5-mile (4.0-km) ESA had large chicks during the first ground survey and both likely fledged young, and red-tailed hawk nest #12 in the 2.5-mile (4.0-km) ESA was confirmed productive during the last survey. The remaining active nests still had young to medium-aged nestlings when surveyed last or, in the case of the burrowing owl nests, production could not be determined due to chicks remaining underground or the burrow entrances being too obscured by vegetation to observe chicks during the final ground survey (HWA 2011).

Several additional raptor species were observed in and around the project area during the spring surveys, including Cooper's hawk (*Accipiter cooperii*), northern harrier (*Circus cyaneus*), golden eagle (*Aquila chrysaetos*), American kestrel (*Falco sparverius*), and peregrine falcon (HWA 2011).

With the exception of peregrine falcons, for which little nesting habitat exists within the project area, all the other species are possible breeders in and around the project area. Other species documented within 10 miles (16.1 km) of the MEA and that have the potential to occur and breed within the MEA include bald eagle, osprey (*Pandion haliaetus*), merlin (*Falco columbarius*), prairie falcon (*Falco mexicanus*), sharp-shinned hawk (*Accipiter striatus*), northern goshawk (*Accipiter gentilis*), short-eared owl (*Asio flammeus*), long-eared owl (*Asio otus*), barn owl (*Tyto alba*), northern saw-whet owl (*Aegolius acadicus*), and eastern screech owl (*Megascops asio*). Rough-legged hawks are common within the MEA during the winter, and other species that have the potential to occur during migration or winter include broad-winged hawk (*Buteo platypterus*), red-shouldered hawk (*Buteo lineatus*), gyrfalcon (*Falco rusticolus*), and snowy owl (*Bubo scandiacus*).

Northern goshawk, Cooper's hawk, and sharp-shinned hawk are typically forest-nesting raptors. Potential nesting habitat includes scattered, mixed-conifer forests which are located in the northern portion of the project area and in the 2.5-mile (4.0-km) ESA. These forests may also provide nesting habitat for red-tailed hawks, osprey, merlins, American kestrels, and long-eared owls. Owls and falcons with only a few exceptions are dependent on other species for the availability of nests. Long-eared owls and merlins are secondary stick nesters (they use stick nests of other species, such as magpies and crows), and the smaller owls and kestrels are secondary cavity nesters (they use tree cavities established by other species, such as woodpeckers). Ferruginous hawks are found primarily in mixed-grass prairie and sagebrush steppe habitats during the spring, summer, and fall. They generally build nests on the ground, rock outcrops, cliff ledges, or small isolated trees. The one ferruginous hawk nest documented in the 2.5-mile (4.0-km) ESA of the project is in a small isolated tree. Swainson's hawks typically nest in small trees or large shrubs along water features (e.g., irrigation ditches, streams), frequently near agricultural areas. Within the project area, the majority of *Buteo* nests are located in the deciduous trees along the Niobrara River, shelterbelts, trees around farmhouses and old homesteads, and the Ponderosa pine trees in the northern portion of the project area. Golden eagles commonly nest on cliffs and in large trees. Although cliff habitat is limited within the project area, golden eagle nests are known to occur just north of the project area, and suitable nesting habitat (i.e., large trees) occurs within the MEA and the 2.5-mile (4.0-km) ESA. Prairie falcons and peregrine falcons are strictly cliff-nesting species, and although they have been documented near the project area, cliff habitat within the project area is limited and nests are unlikely (HWA 2011).

Wintering Bald Eagles

All potential bald eagle roosting habitat within 2.5 miles (4.0 km) of the MEA was surveyed on three separate occasions during the 2010/2011 winter (HWA 2011). Potential roosting habitat was defined as any medium or large deciduous or coniferous tree or group of trees. All potential habitat was identified and delineated using NAIP imagery from 2010. Aerial surveys were conducted using a Cessna 172 fixed-winged aircraft. Survey dates included December 14, 2010, January 12 and February 8, 2011, and all surveys were conducted between 30 minutes pre-sunrise to 1 hour post-sunrise or between 1 hour pre-sunset to 30 minutes post-sunset. Large blocks of potential habitat (i.e., conifer forest) were flown using north-south transects spaced by 0.5 mile (0.8 km). Linear habitat (i.e., riparian habitat) was flown by flying parallel to the habitat type. Information recorded for each eagle sighting included number of adults, number of subadults, behavior, and perch type.

During the winter surveys, no bald eagles were seen within the MEA and one adult bald eagle was seen on one occasion (Dec. 14, 2010) in the 2.5-mile (4.0-km) ESA. The results suggest bald eagles are present in the vicinity of the MEA during the winter and likely use the surrounding habitat for feeding and roosting, but apparently regularly attended roost locations are not present even though suitable roosting habitat exists in the area (HWA 2011).

2.8.7.4 Waterfowl

During spring and fall migration, some waterfowl species may use the area for feeding, nesting, or resting, specifically those areas along the Niobrara River which occur within the 2.5-mile (4.0-km) ESA, but little open water exists within the project area. Box Butte Reservoir is likely used heavily during migration; however, this waterway is just outside the 2.5-mile (4.0-km) ESA. The baseline study in 1982 documented 24 species of waterfowl (CBR 2010). A complete list of waterfowl species that may potentially occur in the project area is included in **Appendix H-3**.

2.8.8 Reptiles and Amphibians

The baseline study in 1982 documented 13 species of reptiles and amphibians (CBR 2010). Though formal surveys were not conducted for the MEA, several species of herptiles were documented opportunistically, including: plains spadefoot toad (larval stage) (*Spea bombifrons*), northern leopard frog (*Rana pipiens*), and common snapping turtle (*Chelydra serpentina*). Only the spadefoot toads were found within the project area; the other two species were found along the Niobrara River corridor near the project area. The spadefoot toad tadpoles were found in a small ephemeral wetland in NW section 13, T29N:R51W. Identification of the tadpoles to species was aided by D. Ferraro, Extension Associate Professor and Herpetologist, School of Natural Resources, University of Nebraska-Lincoln (Ferraro, pers. comm. 2011). A complete list of known or expected herptiles for Dawes and Box Butte Counties can be found in **Appendix H-4** (Fogell 2010).

2.8.9 Threatened, Endangered, or Candidate Species

Under the Federal Endangered Species Act (FESA) of 1973 and the Nongame and Endangered Species Conservation Act (Neb. Rev. Stat. §37-430 *et seq.*), several species receive unique protections due largely to their rarity, population declines, and/or habitat loss. A summary of potentially occurring threatened and endangered species within the MEA is presented in **Table 2.8-3** (also see **Appendix H-7** for range maps in Nebraska).

Black-footed Ferret

The black-footed ferret (*Mustela nigripes*) is listed by the USFWS as endangered and is considered the most endangered mammal species in the United States. Several factors have contributed to declines in ferret populations, including eradication of prairie dogs by humans and disease outbreaks (i.e., sylvatic plague and canine distemper). Distributions of black-footed ferrets closely correspond to those of prairie dogs. Black-footed ferrets depend heavily on prairie dogs for food and they also use prairie dog burrows for shelter, parturition, and raising young. Black-tailed prairie dog colonies occur in the project area. However, no known ferret populations occur in Nebraska (NGPC 2011b), therefore, the likelihood of black-footed ferrets occurring within the project area is minimal.

Whooping Crane

The whooping crane (*Grus americana*) is North America's tallest bird, with males close to 5 feet tall. The species is listed as endangered by USFWS and NGPC, and according to USFWS, they have the potential to occur in Dawes County (USFWS 2011b). Whooping cranes migrate through central Nebraska during spring and fall, and primarily stop over along the Platte River Valley (NGPC 2011b). Whooping cranes use a variety of habitats during the non-breeding season, including wetland mosaics, cropland, and riverine habitat in Nebraska. They depend on seasonally and semi-permanently flooded wetlands for roosting. Such habitat is limited or absent in the MEA. The USFWS maintains a database of confirmed whooping crane sightings within the known migration corridor for this species. According to this database, there has been one confirmed whooping crane sighting in Dawes County in the last 50 years: a sighting of one individual adult whooping crane in 1991, approximately 17 miles (27.3 km) north of the MEA (USFWS 2011c). It is unlikely that whooping cranes would occur within or near the project area due to the lack of suitable habitat.

Gray Wolf

Gray wolves were first listed as endangered in the lower 48 states in 1967. After decades of intensive management, including reintroductions in Idaho and Wyoming, the species was delisted in the Northern Rocky Mountain Distinct Population Segment (DPS) except Wyoming on May 5, 2011 (USFWS 2011d). There are no known populations of wolves in Nebraska. However, dispersing individuals from either Montana or Wyoming into the state would be afforded full protection under the FESA as an endangered species. Wolves are capable of dispersing significant distances, but it is extremely unlikely that wolves would occur in or near the project area.

Swift Fox

The swift fox is a state-listed endangered species that inhabits short-grass and mixed-grass prairies over most of the Great Plains. It appears to prefer flat to gently rolling terrain. Swift foxes feed primarily on lagomorphs, but arthropods and birds are also included in their diets. They mate between late December and February. A mating pair can bear two to five pups in late March to early May, and pups emerge from the den in June. Dens are generally located along slopes or ridges that offer good views of the surrounding area (Fitzgerald et al. 1994). In a study completed in southeastern Colorado, the home range size of an adult swift fox was approximately 3 mi^2 (9.4 square km) at night, and their day ranges are typically much smaller (Schauster et al. 2002).

The swift fox is found in native short-grass prairies in northwestern Nebraska. Unlike coyotes or red fox, the swift fox uses dens in the ground year-round. Some characteristics of swift fox dens differentiate them from other dens. Swift fox den entrances measure about 8 inches in diameter, similar to the size of a badger den. However, swift fox usually have more than one entrance, whereas badgers and most other animals have only one. Swift fox tend to spread excavated soil over a larger area than most other animals, resulting in a less prominent mound near the burrow's entrance. Dens are located on relatively flat ground away from human activity. Where coyotes are abundant, predation by coyotes is a significant cause of mortality for swift fox, and den availability is an important aspect of swift fox survival (Schauster et al. 2002).

Numerous natural and anthropocentric factors influence swift fox populations. Natural factors include fluctuating prey availability, interspecies competition, disease, and landscape physiography. Anthropogenic factors include habitat loss from agricultural, industrial, and urban conversion; land uses on remaining habitat, including hydrocarbon production, military training, and grazing; and pesticide use. Competition with coyotes and red foxes may currently be the most significant threat to swift fox populations, though habitat loss is also a major threat (Stephens and Anderson 2005).

Presence of swift foxes has been confirmed by NGPC in Dawes, Box Butte, and Sioux Counties (NGPC 2009), and potentially suitable habitat occurs in and around the project area; thus, the presence of swift fox within the MEA is possible. However, much of the habitat within the project area appears to be marginal, and previous site-specific surveys in the area have failed to detect the species. Grass height in particular appears to create unsuitable conditions throughout the majority of the project area, where dense fields of cheatgrass exceed 14 inches in many areas during summer (HWA 2011).

As general surveillance for carnivore species in the project area, and with a focus on sampling areas most suitable for swift fox, Hayden Wing Associates deployed remote infrared trail cameras throughout mixed-grassland portions of the project area in 2011. Cameras were used instead of the conventional track station methods because of time and budget constraints. HWA used Reconyx® HyperFire™ HC600 passive infrared (no glow illuminator) remote trail cameras for the monitoring. A total of four cameras were deployed simultaneously among eight locations throughout the southern half of the project area. Cameras were deployed continuously from June 6 to July 7, 2011. Number of sampling days per location was largely determined by the timing of other field surveys, but cameras were deployed for 9 to 22 days per location. Cameras were positioned along fencelines and other likely travel corridors and baited with a combination of skunk scent (to act as a long-distance lure) and fish oil. Camera locations were deliberately selected based on quality of habitat, proximity to prairie dog colonies, and presence of cattle (to protect cameras).

No swift fox were detected using the remote cameras during 2011. Only two species of carnivores were detected: coyote and badger. Other species detected using the cameras included pronghorn, white-tailed deer, elk, cottontail *sp.*, jackrabbit *sp.*, cattle, and a lark bunting (*Calamospiza melanocorys*) (HWA 2011).

Fish

Three species of state-listed fish are found in the Niobrara River system and may potentially be impacted by a reduction in river flow or impairment of stream quality (**Table 2.8-3**).

The blacknose shiner (*Notropis heterolepis*), a state-listed endangered species that was once commonly distributed throughout the state, is now restricted to three main areas along the Niobrara and Snake Rivers (NGPC 2009). This species typically inhabits cool weedy creeks, rivers, and lakes, usually with a sand substrate (NatureServe 2010). Reductions in stream flows and/or quality are important considerations for this species, as it resides downstream from the project area.

The northern redbelly dace (*Phoxinus eos*) and finescale dace (*Phoxinus neogaeus*) are state-listed threatened species. These species are both found in pools and beaver ponds in the headwaters of creeks and small rivers, usually in areas with a silty substrate (NatureServe 2010). Both of these species are downstream residents from the project area and could be impacted by reductions in water quantity and/or quality.

2.8.10 Aquatic Ecology

The MEA is located within the Niobrara River Basin. Annual flows within the Niobrara River Basin are regulated mainly by snowmelt, precipitation, and groundwater discharge. No perennial streams occur within the MEA. The Niobrara River, located just south of the project area, is the prominent drainage in the vicinity of the MEA and flows into Box Butte Reservoir. Other small drainages include Dooley Spring, Willow Creek, and other small unnamed drainages, but all are dry and re-vegetated. All lack distinct stream channels and banks. Occasional runoff may create small pools in a few places, but there is no evidence of persistent stream flows in recent times (HWA 2011). Based on existing land uses, intensive grazing and agricultural practices are likely the largest factors influencing water quality in the area.

2.8.10.1 Fish

The 1982 and 1996 studies for the Crow Butte Mine recorded 21 species of fish throughout various streams and the White River (CBR 2010; **Appendix H-5**). Game fish collected included rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and white sucker (*Catostomus commersonii*). Minnow species included longnose dace (*Rhinichthys cataractae*), common shiner (*Luxilus cornutus*), fathead minnow (*Pimephales promelas*), and creek chub (*Semotilus atromaculatus*). Many of the same species are thought to occur, or to have formerly occurred, in the Niobrara River. According to a local landowner (Troester, pers. comm. 2011), trout previously occurred in the Niobrara River just south of the MEA. However, a combination of drought and northern pike (*Esox lucius*) becoming more numerous upstream from Box Butte Reservoir during the past 10 years may have altered the fish community dramatically because pike are major predators of minnows and small trout (NPS 2002).

The local fish population was sampled at three sites along the Niobrara River during early June and mid-September, 2011 (HWA 2011). The goal was to collect baseline information on the species composition and general abundance upstream and downstream of the proposed project for comparison with future monitoring efforts. The sampling was intended also as surveillance for the state-listed species (black-nose shiner, northern redbelly dace, and finescale dace) known to occur in the Niobrara River. Sampling methods involved mainly electroshocking techniques, but seine nets were also used. Methods complied with the U.S. Environmental Protection Agency's Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (Barbour et al. 1999).

During the June sampling effort, only two species were detected: northern pike and white sucker. Green sunfish (*Lepomis cyanellus*) and red shiner (*Cyprinella lutrensis*) were also detected during the training period. None of the state-listed species were detected (HWA 2011).

During the September sampling effort, eight species were detected: northern pike, white sucker, common carp (*Cyprinus carpio*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), bluegill (*Lepomis macrochirus*), pumpkinseed sunfish (*Lepomis gibbosus*), and central stoneroller (*Campostoma anomalum*). Again, no state-listed species were detected (HWA 2011).

2.8.10.2 Macroinvertebrates

Macroinvertebrates were also sampled during the baseline study in 1982, and results suggested that streams in the Crow Butte area were stressed, with low water quality and degraded stream habitats (CBR 2010; **Appendix H-6**). Aquatic conditions within the MEA may be similar, but macroinvertebrates were not sampled directly, although crayfish (unknown species) were commonly found during the fish sampling in the Niobrara River (HWA 2011).

2.8.10.3 Wetlands

The MEA was surveyed for areas that qualify as wetlands as defined by the U.S. Army Corps of Engineers (USACE 2008). All locations within the MEA identified in the National Wetlands Inventory (NWI) as wetlands or potential mesic sites were assessed as well (USFWS 2011e). Because ground-disturbing activity is not planned for wetland areas, only wetland habitat was surveyed and delineated. All drainages and low-lying areas were surveyed by all-terrain vehicle (ATV) or on foot. Three types of indicators were used for assessing whether a site qualified as a wetland, including hydric soil, hydrophytic vegetation, and hydrology. Sites containing all three indicators of hydric conditions were classified and delineated as wetlands.

A total of four sites were evaluated as potential wetlands within the MEA (**Figure 2.8-1**):

- Site #1 – location identified in the NWI as "freshwater emergent wetland." Low-lying depression in a grassy field with ephemeral open water created by run-off and rainwater. Tadpoles were present. Location had appropriate hydric soil, vegetation, and hydrology. Qualifies as wetland.
- Site #2 – representative location in bottom of dry drainage. Wetland-like conditions not present, but location assessed in order to compare dry drainages to mesic locations. Does not qualify as wetland or mesic.
- Site #3 – location identified in the NWI as "freshwater emergent wetland." Site satisfied the vegetation and hydrology indicators for a wetland, but hydric soils were absent. Does not qualify as wetland, but mesic conditions exist.
- Site #4 – location not identified in the NWI, but found during ground surveys. Site satisfied the vegetation and hydrology indicators for a wetland, but hydric soils were absent. Does not qualify as wetland, but mesic conditions exist.

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Table 2.8-1 Monthly Climate Summary for Scottsbluff WSO Airport, NE (257665)

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Table 2.8-2 Marsland Expansion Area Vegetation and Land Cover Types

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Table 2.8-3 Federal and State Threatened, Endangered, and Candidate Species with the Potential to Occur within the Vicinity of the Marsland Expansion Area

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Figure 2.8-1 Wetland and Vegetation

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Figure 2.8-2 Wildlife Map

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2.9 Background Radiological and Non-radiological Characteristics

2.9.1 Introduction

CBR is in the process of completing the remaining sampling task of the PPMP in support of the MEA application, following the criteria outlined in RG 4.14 (NRC 1980). PPMP monitoring was delayed in order to allow for the collection of 1 year of onsite meteorological data. The meteorological (MET) data were needed for the proper location of the air and other environmental sampling locations and for completion of the MILDOS calculations. At the time of this application, a considerable amount of the PPMP has been completed, with at least 1 year of data collected for the following:

- Air particulate monitoring
- Radon gas
- Ore zone groundwater monitoring (CBR MWs in Basal SS of Chadron Formation)
- Non-ore zone groundwater monitoring (CBR MWs in Brule Formation)
- Surface water (Niobrara River)
- Fish tissue samples (Niobrara River)
- Sediment samples (ephemeral drainages and Niobrara River)

Remaining PPMP tasks are identified in **Figure 2.9-1**. These consist of surface water sampling of ephemeral drainages (as available), sediment sampling for the Niobrara River during dry season, alternative soil sampling for vegetable food crop uptake calculations, forage sampling, and direct radiation sampling. Sediment samples of the Niobrara during the wet season were collected in March 2013 and the analytical data are pending. With the exception of remaining food sampling (livestock), the other sampling tasks will be completed by the end of the third quarter 2013.

This section discusses the environmental sampling program that has been implemented to assess PPMP radiological background conditions in the vicinity of the MEA. The results of the PPMP, in contrast to the operational monitoring program implemented during satellite operations, will be used to determine the effects on the environment, if any, of the satellite facility and associated operations. The operational monitoring program is discussed in Section 5.7.7.

2.9.2 Baseline Air Monitoring

The PPMP and operational monitoring plans are designed to be consistent with the criteria outlined in RG 4.14 (NRC 1980). Monitoring began in the fourth quarter of 2011 and was completed in the fourth quarter 2012.

2.9.2.1 Selection of Air Monitoring Locations

Figure 2.9-2 shows the locations of the air monitoring stations, two nearby occupiable structures, with one located inside the license boundary, and the satellite facility. **Figure 7.3-2** depicts all of the residences within the vicinity of the MEA license boundary and the estimated dose predicted by MILDOS modeling.

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In regard to collection of air particulate samples, RG-4.14 states that air particulates should be:

- Collected continuously at a minimum of three locations at or near the site boundary
- Collected continuously at or near the residence or occupiable structure within 10 kilometers of the site that is most likely to be impacted by the milling operation
- Collected from a remote location representing background, usually upwind from the project site and milling operation

RG-4.14 also enumerates five criteria that should be considered when determining the sampling locations:

1. Average meteorological conditions
2. Prevailing wind direction
3. Site boundaries nearest to mill
4. Direction of nearest occupiable structure
5. Location of estimated maximum concentrations of radioactive materials

In accordance with these criteria, **Figure 2.9-2** shows three sampling sites at the project boundary (Sites MAR-1, MAR-4 and MAR-3). One of these (Site MAR-1) also coincides with the nearest, and most likely to be impacted, occupiable structure. A fourth sampling site (Site MAR-5) is intended to represent background conditions. Because the on-site wind rose indicates northeasterly winds to be the least frequent, this background monitoring site is located southwest of the project boundary at a distance of approximately 4 miles (6.4 km). A summary of monitor locations and elevations for each of the monitors is shown in **Table 2.9-1**.

Site MAR-2 is directly south of the proposed mill, and slightly outside the project boundary. Sites MAR-3 and MAR-4 on the southernmost boundary of the project combine with Site MAR-2 to represent prominent downwind locations. The on-site wind rose shows north-northwesterly, northwesterly, and northerly winds to be the most frequent, accounting for more than 25 percent of the time. Hence, these three monitoring sites are located south-southeast, southeast and south of the proposed milling operation. The wind roses are shown in **Figures 2.5-20** and **2.5-21**.

When selecting air monitor locations, it was expected that the maximum short-term concentrations of radioactive materials would be found in the vicinity of the combined satellite facility and mine unit source terms. Similarly, long-term maximum concentrations are also expected in the vicinity of the satellite plant, given the larger proportion source term present at that location. In addition, maximum concentrations were expected where the radon has the longest residence time with the least mixing, allowing the ingrowth of Radium 226. It was believed that this would occur where the wind was less frequent and at lower velocity. Based upon the wind rose, this would occur WSW and SW of the satellite facility. That information was considered in selecting the location for MAR-1. **Figure 7.3.-2** validates that conclusion.

The wind rose was developed from data generated at an MEA onsite MET station. The MET monitoring station monitored temperature, precipitation, evaporation, wind speed and direction, and the standard deviation of the wind direction. The local meteorological station was operated from August 28, 2010 through August 29, 2011. From this information, joint frequency data were compiled. Further information on meteorological conditions is provided in Section 2.5.

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2.9.2.2 Air Particulate Monitoring Program

RG 4.14 recommends that a total of five particulate monitoring stations be established as discussed above in Section 2.9.2.1. The locations of the air particulate samplers are shown on **Figure 2.9.2**. There are no operations at the satellite facility that could cause a significant release of airborne particulate radionuclides (e.g., lack of yellowcake drying). Therefore, radiological-contaminated air particulates are expected to be minimal.

Five quarters of air particulate monitoring have been conducted and are discussed in this section. The PPMP monitoring program will be incorporated into the operations monitoring program. The results of the air monitoring data at sampling sites MAR-1 through MAR-5 for the fourth quarter of 2011 through the fourth quarter 2012 are presented in **Table 2.9-2** are summarized as follows:

- Lead 210 measurements were a consistent 2E-14 microCuries per milliliter (µCi/ml) at all monitor sites (reporting limit of 2E-15 µCi/ml) for all quarters except for the second quarter of 2012, when the lead level was 1E-14 µCi/ml (reporting limit of 2E-15 µCi/ml).

- Radium 226 levels at all monitor sites for all quarters exhibited a level at or less than 1E-16 µCi/ml (reporting limit of 1E-16 µCi/ml), except for the third quarter of 2012 when the radium-226 µCi/ml level was 5E-10 µCi/ml. Thorium 230 levels at monitor sites M-1 through M-4 for all quarters were at or less than 1E-16 µCi/ml, while the thorium 230 level at M-3 was 2E-16 µCi/ml (reporting limit of 1E-16 µCi/ml).

- Uranium levels all monitor sites for all quarters were measured at <1E-16 µCi/ml (reporting limit of 1E-16 µCi/ml), with the exception of the first quarter of 2012, when levels of 3E-16 µCi/ml (reporting limit of 1E-16 µCi/ml) were measured at MA-2, MA-3 and MA-4, with MA-5 exhibiting a level of 2E-16 µCi/ml (reporting limit of 1E-16 µCi/ml.

The air sampling analytical laboratory reports and QA/QC summary reports are shown in **Appendix U**.

The airborne particulate samples are collected on the inlet filter of a regulated vacuum pump on a Type A/E 47 mm glass fiber filter paper. The low volume air samplers employed is the F&J Portable DF-75L-BL-AC brushless powered air sampler, 60 liter/min, 24 voltage current direct (VCD). This air particulate sampler runs on solar power and batteries. The sampler has a filter holder and a set flowrate maintained automatically in case of dust loading. It does not require operator attention.

The sampler is placed in protective enclosures (with an exhaust fan and temperature controller) that provides protection from the elements while allowing unimpeded sampling of the ambient air. The vendor provided CBR with a standard operating procedure (SOP) for the F&J DF-75L-BL-AC that provides guidance in meeting NRC requirements **(Appendix I)**.

Clean filters are installed in the filter holder at the beginning of each sampling period. The pump flow-rate is adjusted as necessary. The filter replacement schedule is determined based on the dust loading at a particular location. In general, historical operations of samplers without automatic flow rate controllers at the CPF have shown that samplers can run for 1 to 2 weeks without a significant reduction in the flow rate due to dust loading.

The air sampler draws air and suspended particulate matter through a 47 millimeter (mm) collection filter at a known volumetric rate for a known period of time. The collected set of filters for each air sampling unit is sent for contract laboratory analysis at the end of each quarter using standard chain-of-custody procedures. The filters are composited according to location. The composite samples are analyzed for the concentrations of natural uranium, radium-226, lead-210, and thorium-230. Filter sample replacement and additional handling procedures are described in the air sampler SOP.

The flowrate on the F&J portable sampler is calibrated at 6-month intervals using accepted calibration methods to ensure the accuracy of the volume of air sampled. Records of sampler calibration are available on file at the CPF. Calibration records for the air sampling pumps for the first year of sampling are shown in **Appendix V-1.** CBR will continue to operate all five samplers as part of the operational air particulate monitoring.

2.9.2.3 Radon Gas Monitoring Program

RG 4.14 recommends collection of radon gas samples at each of the air particulate monitoring stations (five or more sample points). Continuous sampling will be performed, or at least one week per month, representing about the same time of the month. Samples are analyzed for radon gas. The proposed PPMP and operational monitoring programs are shown in **Tables 2.9-41 and 5.7-1**.

Monitoring is being performed using RadTrak® Type DRNF outdoor air radon detectors. RadTrak® cups contain a sensitized chip covered with a selectively permeable material allowing only the infiltration of radon. The sensitized chip records alpha disintegrations from radon daughters, allowing determination of average radon concentrations. The analysis of quarterly sampling has a sensitivity of 30 pCi/L -days. The semiannual interval was chosen to ensure that monitoring results meet the lower limit of detection (LLD) requirement of 0.2 pCi/L (2×10^{-10} mCi/ml) from RG 4.14 and to be consistent with the semiannual intervals approved by NRC for the current operational monitoring.

The PPMP and operational monitoring plan are designed to meet the criteria outlined in RG 4.14 (NRC 1980). Radon-222 monitoring for sampling site MAR-1 through MAR-5 was conducted from the fourth quarter of 2011 through the fourth quarter of 2012 (**Table 2.9-3**). The gross count for the entire time period for all sampling points ranged from 43 to 362, with an average of 168. The gross count for sampling points MAR-1 through MAR-4 ranged from 43 to 362 (average of 163), compared to MAR-5 (background location) with a range of 70 to 255 (average of 191). The average radon concentration for the entire sampling period ranged from 0.07 to 1.6 uCi/ml (average of 0.5 uCi/ml). The average radon concentrations for sampling points MAR-1 through MAR-4 ranged from 0.07 to 1.6 uCi/ml (average of 0.5), compared to MAR-5 (background location) with a range of 0.1 to 1.0 uCi/ml (average of 0.6 uCi/ml).

The radon laboratory records are shown in **Appendix V-2**.

2.9.2.4 Quality of Air Measurements

The accuracy of monitoring data is critical to ensure that the PPMP air monitoring program precisely reflects air quality. RG 4.14 specifies the following LLDs for air measurements:

Radionuclide	Recommended LLD µCi/ml	Actual LLD µCi/ml
Natural Uranium	1×10^{-16}	1×10^{-16}
Thorium-230	1×10^{-16}	1×10^{-16}
Radium-226	1×10^{-16}	1×10^{-16}
Radon-222	2×10^{-10}	2×10^{-10}
Lead-210	2×10^{-15}	2×10^{-15}

Note: µCi/ml – microCurie per milliliter

2.9.3 Baseline Groundwater Monitoring

This section discusses the results of the radiological and non-radiological analyses for private water supply wells with the MEA and CBR monitor wells installed within the MEA for purposes of assessing the MEA site. In general, groundwater quality in the vicinity near the MEA is poor (Engberg and Spalding 1978). Groundwater obtained from the basal sandstone of the Chadron Formation has a strong sulfur odor as a result of localized reducing conditions associated with the ore body. Background and restoration values are discussed in Section 6.

Locations of all Araikaree, Brule, and basal sandstone of the Chadron Formation monitoring wells in the vicinity of the MEA are shown on **Figures 2.7-6** and **2.9-3**.

Water quality analyses for private water wells provided in this section are from March 24, 2011 to March 21, 2013. Groundwater samples for the CBR monitor wells were collected from March 4 to May 3, 2011 for the Brule monitor wells and March 12, 2011 to August 20, 2012 for CBR basal sandstone of the Chadron Formation monitor wells. In the March 2013 sampling event for the private water supply wells, there were a total of 45 water supply wells sampled. An additional 24 water supply wells could not be sampled for a variety of reasons, including wells being inoperable, powered off, turned off for the season, windmill was not working, and well was not in use. These wells are privately owned and in the control of the owners.

A summary of all groundwater quality data (radiological and non-radiological analytes) collected to date in the vicinity of the MEA, are presented in **Tables 2.9-4.** The data are presented for the three water-bearing zones at the MEA: the Arikaree Group, Brule Formation, and basal sandstone of the Chadron Formation. Based on sampling to date, water quality results for all private water supply wells completed in the Arikaree and Brule Formations and MEA monitoring wells for the Brule Formation indicate that TDS ranged from 200 to 537 milligrams per liter (mg/L), while TDS for the basal sandstone of the Chadron Formation is generally greater than 1,000 mg/L

(**Table 2.9-4**). Similarly, conductivity for the private wells and the Brule Formation monitor wells ranged from 241 to 763 micromhos per centimeter (µmhos/cm), while conductivity for the basal sandstone of the Chadron Formation is generally greater than 1,000 µmhos/cm. Major cations and anions for the private wells and monitor wells in the Brule Formation ranged from 2.75 to 6.87 milliequivalents per liter (meq/L), whereas cations and anions ranged from 13.85 to 25 meq/L for monitor wells completed in the basal sandstone of the Chadron Formation. This would be expected when compared to the concentrations of TDS.

2.9.3.1 Private Water Supply Wells

Pre-operational baseline groundwater sampling and analyses of private wells are being carried out in two phases:

Phase 1

A select number of private water supply wells located within the MEA license boundary, and less than 0.5 miles (0.8 km) from the license boundary, were sampled in 2011 and analyzed for radiological and non-radiological parameters. The locations of these wells were based on placement around the license boundary and future MUs, with emphasis on downgradient locations. Within the license boundary, wells 705, 747 and 788 were monitored for three sampling events 2 weeks apart in 2011. Well 727 (within the license boundary) and wells 703, 723, 725, 741, 745, and 759 (less than 0.5 mile [0.8 km]) outside of the license boundary) were sampled and analyzed for four quarters in 2011. The locations of these wells are shown in **Figures 2.7-6** and **2.9-3**.

Phase 2

Consistent with requirements of RG 4.14, a more comprehensive monitoring program for additional private wells located within 1.24 miles (2 km) of the MEA license boundary was implemented in the second quarter 2012. An additional 47 private wells were added to the sampling program, resulting in a total of 57 wells being sampled:

Private Wells Sampled in 2011	Private Wells Sampled in 2012
703, 705, 723, 725, 727, 741, 745, 747, 759, 788,	700, 702, 703, 704, 705, 706, 707, 714, 715, 716, 719, 720, 721, 722, 723, 725, 727, 728, 730, 731, 732, 733, 734, 735, 736, 737, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 750, 752, 753, 754, 755, 759, 760, 777, 788, 794, 795, 799, 802, 809, 810, 811, 815, 821, 836, 841, 845
Private Wells Sampled in 2013	
700, 702, 703, 704, 705, 706, 707, 714, 719, 720, 721, 722, 725, 727, 728, 734, 737, 739, 742, 743, 744, 745, 746, 747, 748, 750, 752, 753, 754 755, 760, 777, 788, 794, 795, 799, 802, 809, 810, 811, 815, 821, 836, 841, 845	

Whenever operational, each of the active private wells located within 1.24 miles (2 km) of the license boundary, where landowner access could be obtained, will be monitored quarterly (**Figures 2.7-6 and 2.9-3**).

There were a total of 134 active and inactive private water supply wells within the license boundary and associated AOR identified during the water user survey. The number of wells and their general location within the MEA project AOR can be broken down as follows:

- Located within License Boundary: 13 active and two inactive
- Located within 0.62 miles (1 km) radius of the License Boundary: 25 active and seven inactive
- Located between 0.62 miles (1 km) and 1.24 miles (2 km) radius of the license boundary: 18 active and six inactive
- Located between 1.24 miles (2 km) radius and to the 2.25-mile (3.62 km)AOR radius of the License Boundary: 54 active, eight inactive and one unknown

The remainder of this section discusses the results of the radiological and non-radiological analyses for private water supply wells within the MEA. Other information on the selected wells, including formation, depth, and usage, is shown in **Appendix A**. Available well registration and well completion records are shown in **Appendix E**.

The radiological and non-radiological analytical results for the individual private wells are shown in **Tables 2.9-5** and **2.9-6,** respectively, and summarized in **Table 2.9-4**.

The radiological analytical results for the Arikaree and Brule Formations were at levels that would be expected for background concentrations of the area (**Table 2.9-4 and 2.9-5**).

Suspended uranium concentrations for the private wells completed in the Arikaree and Brule Formations were at a range of <0.0003 mg/L to 0.001 mg/L (average of 0.00021 mg/L), and dissolved uranium levels were 0.0028 to 0.0373 mg/L (average of 0.00745 picoCuries per liter [pCi/L]). Suspended uranium activity for the private wells ranged from <2.0E-10 to 0.4 µCi/L (average of 0.000151 µCi/mL)., and dissolved uranium ranged from 3.8E-10 to 18.1 µCimL (average of 1.335 µCi/mL).

Suspended radium-226 values for the private wells ranged from <0.06 U to 0.2 pCi/L (average of 0.07 pCi/L) and dissolved radium-226 ranged from <0.1 U to 9.5 pCi/L (average of 0.21 pCi/L). The majority of the values for suspended and dissolved lead-210, polonium-210, and thorium-230 were below the reporting limit.

The concentrations of dissolved uranium in the private wells completed in the Arikaree and Brule Formations within the NTEA, TCEA, and MEA compared as follows based on available data:

NTEA	<0.0003 to 0.05 mg/L
TCEA	0.004 to 0.04 mg/L
MEA	0.0028 to 0.0373 mg/L

Dissolved uranium values for the TCEA tended to be somewhat higher than those for the NTEA and MEA.

Concentrations of dissolved radium-226 from private wells in the NTEA, TCEA, and MEA compared as follows:

NTEA	<0.2 to 1.3 x 10^{-9} pCi/L
TCEA	0.006 to 1.5 pCi/L
MEA	<0.1 to 9.5 pCi/L

The non-radiological analytical results were at levels consistent with what would be expected for background concentrations for the area (**Tables 2.9-4** and **2.9-6**). Concentrations of the parameters for the private wells versus CBR monitor wells completed in the Brule Formation are comparable, with some parameters for the private wells having somewhat lower average values than for the CBR monitor wells (e.g., dissolved sodium, sulfate, chloride, and conductivity; **Table 2.9-4**). The average values for sodium and sulfate for the private wells versus CBR Brule Formation monitor wells was 20 versus 77 mg/L and 10 versus 33 mg/L, respectively. The average values for sodium and sulfate for the Brule Formation monitor wells versus the CBR basal sandstone of the Chadron Formation monitor wells was 77 versus 408 mg/L and 33 versus 173 mg/L, respectively.

Overall, similar trends in the NTEA and TCEA were seen for the same MEA water-bearing units.

2.9.3.2 CBR Groundwater Monitor Wells

Water Level Measurements

- Arikaree Group and Brule Formation

Ten Arikaree Group monitoring wells (AOW-1, AOW-3 through AOW-11) were installed in 2013. There are 11 active monitoring wells screened in the Brule Formation (BOW-2010-1, BOW-2010-2, BOW-2010-3, BOW-2010-4A, BOW-2010-5, BOW-2010-6, BOW-2010-7, BOW-2010-8, BOW-2013-9, BOW-2013-10 and BOW-2013-11). Three of these wells (BOW-2013-9, BOW-2013-10, and BOW-2013-11) were screened in the Arikaree Group in September 2013. The Walters Drillers Pond-720 (Walters-2) and Walters Drillers Pond-721 (Walters-1) wells have been employed as monitoring wells for the Brule Formation, but these wells will not be part of future monitoring, specifically for the Brule Formation, because these wells are screened across the Arikaree and Brule Formations. In September 2013, ten wells were screened in the Ariakaree Group. The primary purpose of the Arikaree and Brule monitor wells is to further the site-specific understanding of the hydrologic characteristics of the Arikaree Group and Brule Formation. Installation and subsequent monitoring of water levels and water quality is intended to provide more information about potentiometric surfaces of groundwater within aquifers and provide data by which the hydrologic connectivity between the aquifers, or lack thereof, can be determined. The locations of CBR's Arikaree and Brule monitor wells within the MEA are shown on **Figure 2.7-8**.

Well BOW-2010-4 is not being used for baseline monitoring, and plans are to abandon this well in the future. During reaming of this well for casing, the driller lost a bit that he was unable to retrieve. Unsuccessful attempts made to convert the well to a shallow monitor well resulted in the well being considered unacceptable for baseline monitoring. A new replacement well (BOW-2010-4A) was drilled nearby. Well completion records for these monitoring wells are included in **Appendix E-2.**

Thirteen active monitoring wells are screened in the basal sandstone of the Chadron Formation (CPW-2010-1, CPW-2010-1A, Monitor-1, Monitor-2, Monitor-3, Monitor-4A, Monitor-5, Monitor-6, Monitor-7, Monitor-8, Monitor-9, Monitor-10, and Monitor-11; **Figures 2.7-6** and **2.7-9**). Well completion reports for these monitoring wells are included in **Appendix E-2**.

Water levels were measured for the Arikaree Group at 10 monitoring wells on October 17, 2013 (**Table 2.9-7**). The static water level for wells screened in the Arikaree Group ranged from 19 to 149 feet bgs. Calculated groundwater elevations ranged from approximately 4,049 to 4,293 feet amsl. A potentiometric surface map and groundwater flow directions for the October 17, 2013 event are depicted on **Figure 2.9-4**. Groundwater level data collected in October 2013 indicate that groundwater flow within the Arikaree Group is to the south-southeast toward the Niobrara River at an average lateral hydraulic gradient of approximately 0.009 ft/ft.

In addition to the water level measurements for 11 monitoring wells on October 17, 2013, water levels were also measured for the Brule Formation at six monitoring wells on February 22, 2011 and nine monitoring wells on October 17, 2013 (**Table 2-9-7**). The static water level for wells screened in the Brule Formation in the vicinity of the MEA typically ranges from approximately 37 to 155 feet btoc. Groundwater elevations measured during the two measurement events ranged from approximately 4,050 to 4,295 feet amsl. Potentiometric surface maps and groundwater flow directions for October 17, 2013 and February 22,2011events are depicted on **Figure 2.9-5a and 2.9-5b**. Groundwater in the Brule Formation flows predominantly to the south-southeast across the entire MEA toward the Niobrara River drainage at a lateral hydraulic gradient of 0.011 ft/ft (Aqui-Ver 2011). Regional water level information for the Brule Formation is currently only available in the vicinity of the current production facility.

As shown in **Figures 2.9-4** and **2.9-5a**, October 2013 groundwater level data for the Arikaree Group and Brule Formation indicate potentiometric surfaces that are nearly equal in elevation. Particular care was taken during installation of monitoring wells to avoid screening individual wells within both the Arikaree and Brule. Although the wells are screened at different intervals, nearby pairs of monitoring wells screened in the two units demonstrate groundwater elevations with differences of approximately 5 feet or less. While some minor variation exists between the two potentiometric surfaces, the similarity in groundwater elevations and shared south-southeast groundwater flow direction indicates significant hydraulic connectivity between the Arikaree Group and Brule Formation within the MEA. The shared hydraulic head between the two geologic units likely indicates that groundwater within the Brule Formation is not confined by overlying units, and the Arikaree Group and Brule Formation function as a single hydrogeologic unit.

- Basal Sandstone of the Chadron Formation

Water levels were also measured on February 22, 2011 for the basal sandstone of the Chadron Formation at 12 monitoring wells and at 13 wells on October 17, 2013 (**Tables 2-9-6a** and **2.9-6b**). The static water level for wells screened in the basal sandstone of the Chadron Formation in the vicinity of the MEA typically ranges from approximately 380 to 660 feet bgs. Groundwater elevations measured during the two measurement events ranged from approximately 3,695 to 3,717 feet amsl. A potentiometric surface map and groundwater flow directions for the October 17, 2013 event are depicted on **Figure 2.9-6a**. The locations of the Chadron wells that were measured are shown on **Figure 2.7-9**. Groundwater in the basal sandstone of the Chadron Formation flows predominantly to the northwest toward the White River drainage at a lateral hydraulic gradient of 0.0004 ft/ft (Aqui-Ver 2011). A minor variation in flow direction during the February 2011 event indicated localized westward flow in the vicinity of Monitor-10, but is not observed in the October 2013 data. Regional water level information for the basal sandstone of the Chadron Formation is currently only available in the vicinity of the current production facility.

- Risk Conclusions

Strong vertically downward gradients exist at all locations within the MEA, indicating minimal, if any, risk for potential impacts to the Arikaree Group and Brule Formation from the underlying basal sandstone of the Chadron Formation under natural conditions. Observed head differences between the two water-bearing zones at six well pairs (BOW-2010-1 and Monitor-3, BOW-2010-2 and Monitor-4A, BOW-2010-3 and Monitor-8, BOW-2010-4 and Monitor-10, BOW-2010-5 and Monitor-11, and BOW-2010-6 and Monitor-1) ranged from approximately 346 to 518 feet during the October 2013 measurement event.

Available groundwater data for the Arikaree Group and Brule Formation and basal sandstone of the Chadron Formation at the MEA do not indicate any documented flow rate variations or recharge issues that would impact groundwater quality as a result of ISR recovery operations in the basal sandstone of the Chadron Formation. There are no surface water ponds within the MEA license boundary and only limited, intermittent flow in ephemeral drainages. The Arikaree Group and Brule Formation, while considered to be overlying aquifers, are not exceptionally productive in the MEA area.

The presence of high-capacity irrigation wells both within and near the MEA screened within the Arikaree Group and Brule Formation will have a seasonal impact on those aquifers. Agricultural wells near MEA are primarily used for irrigation water between mid-May and early August, with lesser volumes of water extraction lasting into September. These wells are metered, but data are only collected annually; therefore, daily, weekly, and monthly extraction rates are unavailable. Estimated flow rates for wells provided by well users are provided in Appendix A.

CBR has installed additional monitoring wells within the Arikaree Group and Brule Formation located between the anticipated wellfield and the irrigation wells. The monitoring wells will be sampled seasonally to establish baseline data for both water quality and water levels. The fourth consecutive quarterly monitoring event will be completed in the summer of 2014. This sampling will allow for a full assessment of the impacts that the irrigation wells may have upon those aquifers within the MEA. **Figure 2.7-8** shows the locations of the Arikaree Group and Brule Formation monitoring wells.

Pumping test data show that the basal sandstone of the Chadron Formation is hydraulically isolated from the overlying Arikaree Group and Brule Formation aquifers due to the presence of several hundred feet of claystones, mudstones, and siltstones of the upper Chadron Formation and middle Chadron Formation. Estimated hydraulic conductivity data based on particle size distribution analysis of core samples from the upper confining zone discussed in Section 2.7.2.2 support the effectiveness of these confining units indicated by the pumping test. No agricultural wells are completed in the basal sandstone of the Chadron Formation. Groundwater extraction by agricultural wells completed in the Arikaree Group or Brule Formation will have no influence on the containment of production fluids within the basal sandstone of the Chadron Formation.

2.9.3.3 Groundwater Quality Data for Brule and Chadron Formations

This section does not include preoperational water quality monitoring results for the newly installed (September 2013) Arikaree Group monitoring wells or the new Brule Formation monitoring wells. The ten Arikaree monitoring wells and the 11 Brule Formation monitoring wells will be sampled monthly for a 12-month period, the results of which will serve as additional preoperational monitoring data. The first of four quarterly sampling rounds commenced in early November 2013. Submittal of the first quarter data is expected to occur in early 2014.

Three bi-weekly sampling events were conducted at ten Brule Formation monitoring wells (BOW-2010-1, BOW-2010-2, BOW-2010-3, BOW-2010-4A, BOW-2010-5, BOW-2010-6, BOW-2010-7, and BOW-2010-8 for March 9, March 24, and April 6, 2011. The analytical results are shown in **Tables 2.9-4** and **2.9-8**, and **Table 2.9-9**. Well 720 (Walters-1) and Well 721 (Walters-2; used for drilling makeup water) are screened across the Arikaree Group and Brule Formation. Therefore, these wells, which were previously used 2011 as monitoring wells for the Brule Formation, have been removed from **Tables 2..9-8** and **2.9-9**, and the summary values in **Table 2.9-4** have been updated to reflect deletion of these wells data. These wells will not be part of future monitoring specifically for the Brule Formation. As stated above, the results of the sampling of newly installed Arikaree monitoring wells and the 11 Brule monitoring wells will be reported in the future.

Bi-weekly sampling events were conducted in March and April 2011 at ten monitoring wells completed in the basal sandstone of the Chadron Formation (Monitor-1, Monitor-2, Monitor-4A, Monitor-5, Monitor-6, Monitor-7, Monitor-8, Monitor-9, Monitor-10 and Monitor-11). In addition, four quarterly sampling events were conducted for these wells in November 2011, and February, June and August 2012. The analytical results are reported in **Tables 2.9-10** and **2.9-11**, with the summary of the data presented in **Table 2.9-4**.

Groundwater analytical laboratory reports are provided in **Appendix J**. **Tables 2.9-8** and **2.9-10** presents the groundwater sampling results for non-radiological analytes for the Brule and basal sandstone of the Chadron formations. TDS concentrations for the Brule Formation ranged from 200 to 537 mg/L, whereas TDS for the basal sandstone of the Chadron Formation ranged from 778 to 1, 420 mg/L. Alkalinity for the Brule Formation ranged from 125 to 217 mg/L, while alkalinity in the basal sandstone of the Chadron Formation was consistently detected above 245 mg/L at all sampling locations. Conductivity for the Brule Formation was detected up to 763 µmhos/cm, while conductivity for the basal sandstone of the Chadron Formation was detected above 1,340 µmhos/cm at all sampling locations. Major ion concentrations for the Brule Formation ranged from 423 to 775 mg/L, while concentrations for the basal sandstone of the Chadron Formation ranged from 1,319 to 2,227 mg/L. In general, concentrations of TDS, specific conductance, and major ions in the basal sandstone of the Chadron Formation appear to be an order of magnitude larger than those observed in the Brule Formation at the MEA. Similar trends in relative concentrations for the MEA were observed in water quality sampling at the TCEA and NTEA for these two water-bearing zones. Groundwater analytical laboratory reports are provided in **Appendix J**.

The groundwater sampling results for radionuclides of the Brule and basal sandstone of the Chadron formations are presented in **Table 2.9-9 and 2.9-11**, respectively. Groundwater analytical laboratory reports are provided in **Appendix J**.

Deleted: <#>Brule Formation¶
<#>Water level were measured for the Brule Formation at six monitoring wells on February 22, 2011 and nine monitoring wells on August 12, 2011 (**Table 2.9-7**). The static water level for wells screened in the Brule Formation in the vicinity of the MEA typically ranges from 50 to 150 feet bgs. Groundwater elevations measured during the two measurement events ranged from approximately 4,051 to 4,274 feet amsl. A potentiometric surface map and groundwater flow directions for the February 22, 2011 event are depicted on **Figure 2.9-4**. Groundwater in the Brule Formation flows predominantly to the southeast across the entire MEA toward the Niobrara River drainage at a lateral hydraulic gradient of 0.011 ft/ft (Aqui-Ver 2011). Regional water level information for the Brule Formation is currently only available from the vicinity of the CPF.¶
<#>Basal Sandstone of the Chadron Formation¶
<#>Water level were also measured on February 22 and August 12, 2011 for the basal sandstone of the Chadron Formation at 12 monitoring wells (CPW-2010-1, Monitor-1, Monitor-2, Monitor-3, Monitor-4A, Monitor-5, Monitor-6, Monitor-7, Monitor-8, Monitor-9, Monitor-10, and Monitor-11) (**Table 2.9-7**). The static water level for wells screened in the basal sandstone of the Chadron Formation in the vicinity of the MEA typically ranges from approximately 380 to 660 feet bgs. Groundwater elevations measured during the two measurement events ranged from approximately 3,703 to 3,717 feet amsl. A potentiometric surface map and groundwater flow directions for the February 22, 2011 event are depicted on **Figure 2.9-5**. Groundwater in the basal sandstone of the Chadron Formation flows predominantly to the northwest toward the White River drainage at a lateral hydraulic gradient of 0.0004 ft/ft (Aqui-Ver 2011). A minor variation in flow direction during the February 2011 event indicated localized westward flow in the vicinity of Monitor-10. Regional water level information for the basal sandstone of the Chadron Formation is currently only available in the vicinity of the CPF.¶
<#>Strong, vertically downward gradients exist at all locations within the MEA, indicating minimal, if any, risk for potential impacts to the Brule Formation from the underlying basal sandstone of the Cl ... [4]

Deleted: **Tables 2.9-8, 2.9-9, 2.9-10 and 2.9-11** report the detailed results (radiological and non-radiological analytes) of three bi-weekly sampling events in March and April 2011 and four seasonal sampling events were conducted in November 2011 and February, June and August 2012 for monitoring wells screened in the Brule Formation and basal sandstone of the Chadron Formation within tl ... [5]

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Dissolved concentrations of selected radionuclides appear to be largely absent from the Brule Formation, with the exceptions of uranium and radium-226. For the CBR Brule monitor wells, suspended uranium concentrations ranged from <0.0003 to 0.0017 mg/L (average of 0.00025 mg/L) and dissolved uranium concentrations ranged from 0.002 to 0.0095 mg/L (average of 0.0052 mg/L). For the basal sandstone of the Chadron Formation monitor wells, suspended uranium concentrations ranged from <0.0003 to 0.0843 mg/L (average of 0.00246 mg/L), and dissolved uranium levels ranged from <0.0003 to 0.084 mg/L (average of 0.00828 mg/L).

Suspended uranium activity for the Brule monitor wells ranged from <2.0E-10 to 1.2E-09 uCi/mL (average of 1.59E-10 uCi/mL), and dissolved uranium activity ranged from 1.3E-09 to 6.4E-09 uCi/mL (Average of 3.8E-09 uCi/mL). For the basal sandstone of the Chadron Formation monitor wells, suspended uranium activity levels ranged from <2.0E-10 to 6.2 uCi/mL (average of 0.151 uCi/mL) and dissolved uranium levels ranged from <2.0E-10 to 6.2 uCi/mL (average of 3.87E-10 uCi/mL).

For the Brule Formation monitor wells, suspended radium-226 values ranged from <0.1 to 0.6 pCi/L (average of 0.14 pCi/L) and dissolved radium-226 ranged from <0.1 to 0.66 pCi/L (average 0.22 pCi/L). For the basal sandstone of the Chadron Formation monitor wells, suspended radium-226 values ranged from <0.1 to 45 pCi/L (average of 1.82 pCi/L) and dissolved radium-226 values ranged from <0.1 to 390 pCi/L (average of 30 pCi/L).

The concentrations of dissolved thorium-230 for the Brule Formation were below the reporting limit (RL) at all locations, whereas dissolved thorium-230 for the basal sandstone of the Chadron Formation ranged up to 1.7 pCi/L; however, the majority of the sample results were below <0.1 and <0.2 pCi/L. As expected, suspended radionuclides were significantly higher in the wells of the basal sandstone of the Chadron Formation than those of the Brule Formation.

To date, water quality sampling indicates that the Brule Formation and the basal sandstone of the Chadron Formation have unique geochemical signatures within the MEA.

2.9.3.4 Quality of Groundwater Measurements

The accuracy of monitoring data is critical to ensure that the water monitoring program precisely reflects water quality. In addition to recommending the use of approved analytical methods for water quality measurements (contained in 40 CFR 136), the NRC also specifies analytical quality requirements in RG 4.14.

The private laboratory employed by CBR, Energy Laboratories, Inc. (ELI), reported the lower limits of detection for the surface and groundwater analyses as Minimum Detectable Concentrations/Lower Limits of Detection (MDC/LLD) values. ELI stated in a letter dated April 23, 2012 (ELI 2012; **Appendix Q**) that the reported MDC/LLD values for the MEA samples were in compliance with RG 4.14, Section 5 "LLD".

Radionuclide	MDC/LLD for Water	
	µCi/ml	pCi/L
Natural Uranium	2×10^{-10}	0.2
Thorium-230	2×10^{-10}	0.2
Radium-226	2×10^{-10}	0.2
Polonium-210	1×10^{-9}	1.0
Lead-210	1×10^{-9}	1.0

Source: ELI 2012 (Appendix Q)
Note: For analytes reported in two significant figures. MDC/LLD values rounded off to only one significant figure (e.g., 1.3 pCi/L = 1 pCi/L).

ELI met the criteria of the guidance suggested by the NRC when reasonably achievable by available conventional laboratory methodology. If for some reason the MDC/LLD was not met on the original analysis, the samples were recounted or re-analyzed until RG 4.14 MDC/LLDs were achieved. See **Appendix Q** for additional discussions by ELI of MDC/LLD reporting.

MDC levels for surface and groundwater radiological analytes are presented in the respective data tables of this document as well as in the individual Analytical Summary Reports of **Appendix J**.

2.9.4 Baseline Surface Water Monitoring

Surface water sampling in RG 4.14 calls for sampling of surface water passing through the project site or offsite surface waters that may be subject to drainage from potentially contaminated areas or that could be affected by a "tailings impoundment failure". Grab samples are to be collected monthly with samples analyzed for suspended and dissolved natural uranium, radium-226, and thorium-230.

in RG 4.14 also requires surface water sampling from each large onsite body of water or offsite impoundments that may be subject to direct surface drainage from potentially contaminated areas that could be affected by a tailings impoundment failure. Grab samples are to be collected quarterly with samples analyzed for suspended and dissolved natural uranium, radium-226, and thorium-230. Semiannually, samples should be analyzed for suspended and dissolved lead-210 and polonium-210.

Lack of water flow in ephemeral drainages in the MEA has prevented collection of surface water samples. Water samples were collected from the Niobrara River, which flows east to west to the south of the MEA license boundary (**Figure 2.7-4**). The results of this sampling program are discussed below. Historical water flow and water quality data were obtain from NDNR, NDEQ, and USGS databases (see discussions below). Water level measurements of the Box Butte Reservoir were obtain from the USBR (see discussions below).

2.9.4.1 NDNR Niobrara River Ambient Stream Monitoring Program

Flow Measurements for Niobrara River

The NDNR maintains stream gaging stations on the Niobrara River, with data reported on its web page at http://dnr.ne.gov/docs/hydrologic.htm. Flow data reported in this section are for the section of the Niobrara River in close proximity to the proposed MEA (**Figure 2.7-4**). The description of the stream gaging stations and their locations is presented in **Table 2.9-12**. The stream gaging measurements from 1999 through 2012 for the designated stream gaging stations are summarized in **Table 2.9-13.** The sampling location at Agate is an exception, with data being available from 2006 through 2012. Monthly flow measurements for stream gaging stations in the upper reaches of the Niobrara River for each of the designated years are presented in **Table 2.9-14.** A graph of the average flow in cubic feet per second (cfs) for the four Niobrara River stream gaging stations from 2006 through September 2012 is shown on **Figure 2.9-7**. As seen on **Figure 2.9-7**, flows for the gaging stations above the Niobrara River are fairly consistent over this time period. The year 2006 was used as the starting date because of the lack of flow data at the Agate gaging station prior to 2006. In the Niobrara River west of Valentine, NE, which includes the area of the river in the vicinity of MEA, groundwater is the primary source of flow into the Niobrara River (Alexander et al 2010). In this area of the river, the discharge of the river is steady and persistent, with overbank flooding being uncommon except during winter ice jams (Shaffer 1975). As can be seen on **Figure 2.9-7**, the average flow of the Niobrara River at the Wyoming/Nebraska state line is consistently lower than the average flows at the gaging stations located at Agate and above the Box Butte Reservoir. **Figure 2.9-7** clearly shows the time periods during which water is stored and released from Box Butte Reservoir. These data can be correlated with the flow data presented in **Table 2.9-14.** Peak discharge extremes and minimum discharge flows for the years 1999 through 2010 are presented in **Table 2.9-13**.

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Water Quality

The NDNR has not collected water quality data on the Niobrara River in the area of the Marsland project since sampling was shared with the USGS prior to 1998 (Hayden 2011).

2.9.4.2 NDEQ Niobrara River Ambient Stream Monitoring Program

Water quality data for the NDEQ Niobrara River sampling stations were obtained from the NDEQ (Ihrie 2013a). Water quality data presented in this report are for the years 2003 through 2011 and consisted of major ions, physical properties, and metals, but no radiological analyses. Water samples were collected at a sampling station above the Niobrara River (NDEQ sample station SNI4NIOBR402/USGS 06454500) and a sampling point below Box Butte Reservoir (NDEQ sample station SNI4NIOBRA20/USGS 06455500) (**Figure 2.9-8**).

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Nebraska Department of Environmental Quality Water Quality Sampling for Niobrara River Above Box Butte Reservoir (SNI4NIOBR402)

Monthly water quality data from the sample location above Box Butte Reservoir (SNI4NIOBR402) are shown in **Tables 2.9-15** through **2.9-25**. A summary of the water quality data for 2003 through 2011 in **Tables 2.9-17 through 2.9-25** is presented in **Table 2.9-26**. Water quality samples were analyzed for eight major ions. The dominant cation at the sampling location above Box Butte Reservoir (SNI4IOBR402) was calcium (range of 42.82 to 58.20 mg/L), followed by sodium (range of 21.4 to 40.6 mg/L), magnesium (range of <0.15 to 11.5 mg/L), and chloride (range of 3.46 to 7.35 mg/L) (**Table 2.9-26**).

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Nutrients such as nitrogen and phosphorus compounds occur naturally in surface water, but elevated concentrations may occur due to agricultural runoff and wastewater discharges and septic systems. There are at least two cattle feeding operations in close proximity to the stretch of the Niobrara River near the MEA project site (NDEQ 2005). Maximum values for nitrite plus nitrate, total ammonia nitrogen, and total kjeldahl nitrogen were all less than 2.17 mg/L for the above-referenced NDEQ samples. Thirteen of 152 total phosphorus samples yielded concentrations higher than (maximum of 0.71 mg/L) the EPA recommendation of 0.1 mg/L for avoiding algal blooms.

The average of the dissolved O_2 readings was 8.85 mg/L, ranging from 3.34 to 12.9 mg/L. There were only six readings below 6.0 mg/L and three between 6.1 and 6.3 mg/L, with 148 of the total samples being above 6.5 mg/L. Lower readings appeared to occur during low or high flows.

The NDEQ water quality standards state that, in order for water to support aquatic life, the pH standard unit (su) should be maintained between 6.5 and 9.0 unless the pH values are outside this range due to natural conditions. One of 91 of the pH readings for the Niobrara River (9.92 su) was outside the acceptable range of 6.5 to 9 su. The average of the pH values was 8.09 su and ranged from 7.1 to a maximum value of 9.92 su recorded on May 21, 2007.

Temperature readings averaged 11.13 °C, and ranged from -0.26 to 29.0 °C. Seasonal fluctuations indicate that water temperature is primarily dependent upon the ambient air temperatures.

Turbidity field measurements indicated an average of 27.7 nephelometric turbidity units (NTU), with a range of 0.2 to 233. The majority of the turbidity measurements were 30 NTU or less (103 of 13 readings [74 percent]). The majority of the turbidity measures above 30 NTU were during periods of either high flow or low flow conditions. There were only 18 readings above 40 NTU.

Total suspended solids (TSS) measurements ranged from <5 to 297 mg/L, with an average of 24.7 mg/L. The maximum value of 297 mg/L was the only value to exceed 100 mg/L, and the cause of the exceptionally high value is unknown based on available information. Daily readings for the months before and after this high reading were 49.5 and 61 mg/L, respectively. TSS values of 103 of the total number of 138 samples (75 percent) analyzed were 30 mg/L or lower. Specific conductance values ranged from 100 to 539 µmhos/cm, with an average of 386 µmhos/cm. All 91 readings were 314 µmhos/cm and above except for two readings of 244 and 297 µmhos/cm.

The above-mentioned NDEQ water quality data support the classification of the Niobrara River by stream segment in the vicinity of the MEA project site. The Niobrara River segments provide a basic unit for assigning site-specific standards and for applying water quality management programs of the NDEQ. The NDEQ Water Quality Body ID N14-4000 is located to the south of the MEA (**Figure 2.7-3**). This segment is rated as Supported Beneficial Use for aquatic life, agricultural water supply, and aesthetics. However, it is also classified as Impaired for recreational use due to the measured presence of *E. coli* (NDEQ 2010 and 2005). As a result, the water body category for this segment of the Niobrara River has been established as Category 5 (waterbodies where one or more beneficial uses are determined to be impaired by one or more pollutants and all of the Total Maximum Daily Loads [TMDLs] have not been developed)

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(NDEQ 2010). A TMDL is the maximum quantity of a pollutant a water body can receive and still meet its appropriate water quality criteria or goal (NDEQ 2010).

Nebraska Department of Environmental Quality Water Quality Sampling for Niobrara River Below Box Butte Reservoir (SNI4NIOBRA20)

NDEQ water quality data were only available for 2008 for the Niobrara River below Box Butte Reservoir (SNI4NIOBRA20) (**Table 2.9-27**). The ranges for data available for the year 2008 are shown in **Table 2.9-28**. This sampling location is an NDEQ Basin Rotation site that was sampled as part of the 6-year Basin Rotation Cycle. There was no sampling done at the site in 2009, 2010, 2011, and 2012 because sampling is only conducted every 6 years at Basin Rotation sites. Although scheduled for 2014, it may or may not be sampled in 2014, depending on site selections by the NDEQ for the Basin Rotation Cycle (Ihrie 2013b).

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Box Butte Reservoir

Box Butte Reservoir is rated as Supported Beneficial Use for recreation, agricultural water supply, and aesthetics, but Impaired Beneficial Use for aquatic life (NDEQ 2010). The impairment classification is due to a fish consumption advisory for northern pike because of elevated mercury levels identified in tissues. As a result, the water body category for this lake has been established as Category 5 (waterbodies where one or more beneficial uses are determined to be impaired by one or more pollutants and all of the TMDLs have not been developed) (NDEQ 2010).

2.9.4.3 Crow Butte Sampling of the Niobrara River

CBR established two water quality sampling locations on the Niobrara River, with one sampling point (N-1) established upstream (west) of the MEA license boundary and one point (N-2) located downstream (east) of the license boundary (**Figure 2.7-4**). Water quality and sediment samples are collected at N-1 and N-2.

Based on Requests for Additional Information (RAI) by the NRC and further discussions, the downstream sampling location on the Niobrara River was moved approximately 2.3 river miles (3.7 km) upstream to the USGS/NDNR 06454500 and NDEQ SNI4NIOBR402 Gaging Station, which is referred to as the Niobrara River above Box Butte Reservoir for sampling purposes (**Figure 2.7-4**). N-1 and N-2 are located such that potential impacts from either of the two major ephemeral drainages that drain the MEA site from northwest to southeast, and connect to the Niobrara River between N-1 and N-2.

CBR has collected samples for baseline water quality analysis for non-radiological and radiological parameters from January 2011 through March 2013, prior to the relocation of N-2. The objective was to collect 1 year of monthly data for the radiological parameters and quarterly data for non-radiological parameters. Fourteen months of sampling data (January 2011 through March 2012) are now available for dissolved radiological parameters (**Table 2.9-29**), 13 months of sampling data (January 2011 through May – March 2012 [excluding the month of April 2011 due to a commercial lab error]) for suspended radiological parameters (**Table 2.9-30**), and 7 months of sampling data (February 2011 through February 2012) (**Table 2.9-31**) for non-radiological parameters (major ions, physical properties, and dissolved metals). A summary of the baseline suspended and dissolved radiological parameters is presented in **Table 2.9-32**, and a summary of the baseline nonradiological parameters is shown in **Table 2.9-33**.

The results of the radiological analyses indicated that background levels were low, with the majority of the results at or below the RL (**Table 2.9-32**). The levels for dissolved uranium (as a metal) and uranium activity were all above the RL, except for the January 2012 measurements. The concentrations at N-1 and N-2 appear to be similar. The minimum and maximum radiological analytical results for N-1 and N-2 are summarized below.

Radiological Analyte Results for N-1 and N-2 Sample Points on Niobrara River				
	Dissolved Radiological Analyte		Suspended Radiological Analyte	
Analyte	Minimum	Maximum	Minimum	Maximum
Lead-210, pCi/L	< 0.6	50	< 0.5	< 2.11
Polonium-210, pCi/L	< 0.4	4.6	< 0.2	0.4
Radium-226, pCi/L	< 0.1	1.7	< 0.06	0.14
Thorium-230, pCi/L	< 0.1	< 0.8	< 0.04	0.2
Uranium Activity, µCi/ml	2.0E-10	4.9E+00	< 2.0E-10	4.5E-09
Uranium, mg/L	<3.0E-04	1.04E-02	< 3.0E-04	6.6E-03

The analytical results, with reporting limits, for the non-radiological parameters, are presented in **Table 2.9-31**. A total of six quarterly samples have been collected. The analytical results for the major ions and physical parameters are summarized in **Table 2.9-33**, showing the minimum and maximum values. The results for N-1 and N-2 are similar, with the majority of the results for the dissolved metals at or below the RL. The surface water laboratory records are presented in **Appendix W-1**.

Future sampling at N-1and the relocated N-2 will be conducted for a 12-month period beginning in September 2013. Preoperational monthly sampling and analysis will be conducted for suspended and dissolved natural uranium, radium-226, and thorium-230, with semi-annual sampling for suspended and dissolved lead-210 and polonium-210.

2.9.4.4 USBR Box Butte Reservoir Storage Content

The USBR monitors the contents of the Box Butte Reservoir daily (USBR 2013). Measurements (acre-feet) for the reservoir from 2003 through September 2013 are shown in **Table 2.9-34**. The average values for the content of the reservoir was 9,627 acre-feet between 2003 and September 2013. The minimum and maximum values were 2,352 and 24,942 acre-feet, respectively (see summary values in **Table 2.9-35**). Since the 1950s, groundwater depletions of base flow and numerous farm conservation practices have greatly reduced inflow into the reservoir (USBR 2008).

Box Butte Reservoir is used as a source of irrigation water; consequently, the reservoir storage content (in acre-feet) can vary considerably annually due to the use of the water for irrigation purposes downstream of the reservoir dam. Historically, the reservoir has experienced the highest reservoir elevations during the months of May and June, while September and October exhibit the lowest reservoir elevations following irrigation releases (USBR 2008). As seen in **Table 2.9-34**, the reservoir contained an average of 12,336 and 12,965 acre-feet in May and June 2013, respectively, whereas in August and September, 2013, the reservoir contained an average of 6,541 and 5,295 acre-feet, respectively.

Deleted: Samples for radiological analyses have been collected monthly; however, a sample for suspended radiological parameters for sampling point N-2 was not analyzed during the first quarter of 2011 due to an error on the part of the commercial lab being used by CBR. Samples for non-radiological parameters were collected quarterly for N-1 and N-2, although for the second and third quarters of 2011 samples were collected on May 16 and June 24.¶

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Under an agreement among the Mirage Flats Irrigation District, the NGPC, and the USBR, a minimum pool elevation is maintained at 3,978 acre-feet to support and maintain a viable fishery resource in the reservoir (USBR 2008).

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2.9.4.5 Quality of Surface Water Measurements

The accuracy of monitoring data is critical to ensure that the water monitoring program precisely reflects water quality. See discussions in Section 2.9.3.4 that address surface and groundwater analytical quality requirements.

2.9.5 Baseline Vegetation, Food, and Fish Monitoring

Reference is made in this section to "milling" or "mill site" as it applies to RG 4.14. Milling or mill site typically refer to a primary recovery method or facility used to extract uranium from mined operations, e.g., conventional milling. ISR facilities perform uranium "milling" under an expanded NRC definition of by-product material that includes discrete surface wastes resulting from uranium solution extraction processes. Therefore, references to millingor mill site in this section can be extrapolated to uranium *in-situ* operations.

2.9.5.1 Vegetation

RG 4.14 recommends sampling of grazing areas near the site in different sectors that will exhibit the highest predicted air particulate concentrations during the milling operations.

Vegetation will be sampled as described in **Table 2.9-36** following guidance in RG 4.14. Using the recently acquired meteorological data and completed MILDOS calculations, vegetation samples will be collected in grazing areas located downwind of the Marsland satellite facility in sectors having the highest predicted air particulate concentrations during operations. A minimum of three samples will be collected three times during the grazing season and analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210.

2.9.5.2 Food

Crops

RG 4.14 recommends that crops raised within ~1.86 miles (3 km) of the mill site be sampled at the time of harvest. The NRC has indicated that other food sources should be explored for sampling, such as private gardens in the area (e.g., sampling a variety of available garden plants). Grab samples should be analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210.

Cameco is proposing an alternative approach to estimating baseline radionuclide concentrations in vegetables because the quantity of vegetables required to meet LLDs is very large, and in many instances will decimate the homeowner's crop. The proposal relies heavily on the approach developed by Powertech for use at the Dewey Burdock site (ML11208B714).

Cameco will sample the soil in the vegetable garden rather than the vegetables. To estimate the radionuclide concentrations, CBR will use Equation 1, Section 5 (Equation 5.5) of NUREG-5512 to calculate the vegetable concentration factors.

$$Csvhj = 1000\,(MLv + Bjv)\,Wv\ \{ACsj, tgv\}/Csj \quad \text{(Equation 1)}$$

Where:

Csvhj = concentration factor for radionuclide j in plant v at harvest from an initial unit concentration of parent radionuclide i in soil (pCi/kg wet-weight plant per pCi/g dry-weight soil)

Bjv = concentration factor for uptake of radionuclide j from the soil in plant v (pCi/kg dry-weight plant per pCi/g dry-weight soil)

MLv = plant soil mass-loading factor for re-suspension of soil to plant v (pCi/kg dry-weight plant per pCi/g dry-weight soil)

Wv = dry to wet-weight conversion factor (unitless)

{ACsj, tgv} = decay operator notation used to develop the concentration of radionuclide j in soil at the end of the crop growing period t0' (pCi/g dry-weight)

C'j = concentration of radionuclide j in soil during the growing period (pCi/g dry-weight)

C'j(O) = initial concentration of radio nuclide j in soil during the growing period (pCi/g dry-weight)

tgv = growing period for food crop (days)

1000 = unit conversion factor (g/kg)

RG 4.14 specifies analysis of natural uranium, thorium-230, radium-226, lead-210, and polonium-210 in vegetables. With the exception of polonium-210, these radionuclides have long half-lives when compared to the growing season. For that reason, the decay correction can be ignored. For polonium-210, CBR will assume that the initial soil concentration and the soil concentration during the growing season remain identical. Thus, Equation 1 is simplified to Equation 2:

$$Csvhj = 1000\,(MLv + Bjv)\,Wv \qquad \text{(Equation 2)}$$

Based upon Equation 2, **Table 2.9-36** presents the parameters that will be used to estimate wet-weight vegetable concentrations from dry-weight soil concentrations. The PPMP baseline plan employed a ~1.86-mile (3 km) area around the centerpoint of the satellite facility to determine the locations of the gardens.

CBR will seek approval from the garden owner to collect soil samples. A schedule for remaining baseline sampling is provided on **Figure 2.9-1**.

Vegetation samples will be collected in accordance with the Safety Health Environment and Quality Management System (SHEQMS) Volume VI Environmental Manual (CBR 2010).

Livestock

RG 4.14 recommends that livestock raised within ~1.86 miles (3 km) of the mill site be sampled at the time of slaughter. Grab samples should be analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210. Cattle are the livestock present in the area. Samples will be collected from three locally fed cattle.

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Samples will be analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210. A schedule for remaining baseline sampling is provided on **Figure 2.9-1**.

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Samples for crops and livestock will be obtained at the time of harvest or slaughter. Samples would

2.9.5.3 Fish

RG 4.14 requires that fish be collected, if available, from lakes and streams in the project site area that may be subject to seepage or direct surface runoff from potentially contaminated areas or that could be affected by a tailings impoundment failure. Fish should be collected, sampled, and analyzed semiannually for natural uranium, radium-226, thorium-230, lead-210, and polonium-210. There are no streams or water impoundments located within the MEA license boundary. There are only two dry drainages that cross the license area. Therefore, fish sampling within the MEA license boundary is not feasible.

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The nearest permanent stream is the Niobrara River located just to the south of MEA license boundary which flows into Box Butte Reservoir. Given the large sample size required to attain LLDs (14 pounds) and the limited fish population present in the stream, the fish sampling focused on northern pike in the inlet of Box Butte Reservoir. Box Butte Reservoir is overpopulated with northern pike, which allows for a larger bag limit than elsewhere in Nebraska. As the most prevalent species, a popular gamefish and known human food source, sampling the meat of the northern pike is the only feasible approach to assessing potential dietary contribution to humans. Collection of fish tissue at N-1 and N-2 is not feasible due to the small fish population with insufficient fish biomass. Attempting to collect the required amount of fish tissue needed for the analytical laboratory to obtain the required LLD would decimate the limited fish population.

Tissue samples were collected from northern pike on August 22, 2011 and May 25, 2012, and analyzed for lead-210, polonium-210, radium-226, thorium-230, uranium and uranium activity (**Table 2.9-37**). The analytical results were considered low. The sampling results are reported on a wet weight basis (as received). Sampling results for lead-210 were classified as "U" or undetected at minimum detectable concentration (<1.0E-06 and 7.9E-07 microcuries per kilogram [µCi/kg], respectively). One analytical result for polonium-210 was at the RL limit of 5.0E-07 µCi/kg, with the other value not detected at the RL of 2.8E-07 uCi/kg. For radium 226, the sampling results were at or below the RL of 2.0E-07 and 2.2E-07 uCi/kg. The thorium-230 concentration was 1.0E-5 µCi/kg versus the RL of 8.0E-06 uCi/kg for one sampling event, and not detected at the RL of 6.7E-08 uCi/kg for the other sampling event.. The uranium and uranium activity values were below the RLs of <0.0003 mg/kg and <2E-07 µCi/kg, respectively, for one sampling event, while for the other sampling event, levels of 0.00099 mg/kg and 6.7E-07 uCi/kg were reported, respectively.

The analytical data sheets and the QA/QC summary reports for the fish tissue samples are shown in **Appendix X**.

As of May 2010, the Nebraska Department of Human and Health Services (NDHHS) with the NDEQ, the NGPC and the Nebraska Department of Agriculture (NDA), have issued fish consumption advisories for warning to limit the consumption of northern pike in Box Butte Reservoir due to elevated mercury concentrations (NDEQ 2011a).

Due to the lack of background data from the study area with which to compare the current findings, radionuclide data interpretation is impracticable at this time, other than that the concentrations are considered low. The radiological results will serve as background information for future sampling events and the development of long-term trends.

2.9.5.4 Quality of Food, Vegetation, and Fish (wet) Measurements

As noted above, CBR proposes to use an alternative approach to estimate baseline radionuclide concentrations in food crops. CBR will estimate wet-weight vegetable concentrations from dry-weight soil concentrations and will use the MDC/LLDs provided in RG 4.14 for dry soil and sediment. Specifically:

$2\ 10^{-7}$ uCi/g for uranium-natural, thorium-230, radium-226, and lead-210

RG 4.14 does not provide an LLD for polonium-210 in dry soil. CBR will work with laboratories to justify an appropriate LLD when the data are submitted to NRC. A schedule for remaining baseline sampling is provide on **Figure 2.9-1**.

Deleted: Appendix 2.9-1

The private laboratory employed by CBR, ELI, reported the lower limits of detection for fish tissue as MDC/LLD values. ELI stated in a letter dated April 23, 2012 (ELI 2012, **Appendix Q**) that the reported MDC/LLD values for the MEA fish samples were in compliance with RG 4.14, Section 5 "LLD". The LLD levels specified in RG 4.14 will be met for future fish and vegetation sample analyses.

Deleted: food,

Radionuclide	**MDC/LLD for Vegetation, Food and Fish (wet)**	
	µCi/kg	**pCi/g**
Natural Uranium	2×10^{-7}	0.2 pCi/g
Thorium-230	2×10^{-7}	0.2 pCi/g
Radium-226	5×10^{-8}	0.05 pCi/g
Polonium-210	1×10^{-6}	1.0 pCi/g
Lead-210	1×10^{-6}	1.0 pCi/g

Source: ELI 2012 (Appendix Q)

Note: For analytes reported in two significant figures. MDC/LLD values rounded off to only one significant figure (e.g., 1.3 pCi/g = 1 pCi/g).

ELI met the criteria of the guidance suggested by the NRC when reasonably achievable by available conventional laboratory methodology. If for some reason the MDC/LLD was not met on the original analysis, the samples were recounted ore re-analyzed until RG 4.14 MDC/LLDs were achieved. See **Appendix Q** for additional discussions by ELI of MDC/LLD reporting.

MDC levels for fish tissue radiological analytes are presented in **Table 2.9-37.**

2.9.6 Baseline Soil Monitoring

RG 4.14 recommends soil samples be collected as follows:

- Up to 40 surface soil samples would be collected at 300-meter intervals to a distance of 1,500 meters in each of eight directions from the center of the milling area. Surface soil samples would be collected to a depth of 5 cm using consistent sampling methods. Sampling would be conducted once prior to construction and repeated for locations disturbed by excavation, leveling, or contouring. All samples would be analyzed for radium-226, and 10 percent of the samples analyzed for natural uranium, thorium-230, and lead-210.
- Five or more surface soil samples (to a depth of 5 cm) would be collected at the same locations used for air particulate samples. Samples would be collected once prior to construction. Samples would be analyzed for natural uranium, radium-226, thorium-230, and lead-210.
- Five subsurface samples would be collected at the center point location and distances of 750 meters in each of four directions. Subsurface soil samples would be collected to a depth of 1 meter and divided into three equal sections for analysis. Samples would be collected once prior to construction and repeated for locations disturbed by construction. All samples would be analyzed for radium-226, and one set of the samples would be analyzed for natural uranium, thorium-230, and lead-210.

Soil samples will be collected at 300-meter intervals to a distance of 1,500 meters in each of eight directions from the centerpoint of the satellite facility. In addition, transects will be made through the center areas of each proposed mine unit to collect samples at 300-meter intervals.. Sampling distances for some sampling points on transects from centerpoint of satellite facility and through the mine units may be modified to obtain a more representative sampling of the project area (e.g., proposed wellfield layouts).

Surface soil samples to a depth of 5 cm will be collected at 300-meter intervals to a distance of 1,500 meters (where feasible) along established transects. Any areas disturbed by excavation, leveling, or contouring would be resampled. All surface samples (5 cm) will be analyzed for radium-226, and 10 percent of the samples for natural uranium, thorium-230, and lead-210. Surface soils samples at each air monitoring station will be analyzed for natural uranium, radium-226, thorium-230, and lead-210. All surface soil sampling will occur once prior to construction and repeated for any locations disturbed by excavation, leveling, or contouring. Subsurface samples will be analyzed once prior to construction and repeated for any locations disturbed by construction.

In this application, Cameco requests a soil sampling program different from that specified in NUREG-1569, Standard Review Plan for In Situ Leach Uranium Extraction License Applications. Specifically, Cameco proposes taking soil samples at both 5 cm and 15 cm depths as recommended by NUREG-1569, Acceptance Criteria 2.9.3 (2) for background decommissioning, with the exception of samples taken at the air monitoring stations. In a public meeting (ML 12255A258), NRC stated that in light of the EPA's technical basis for its radium-226 soil cleanup standard (refer to EPA 520/4-82-013-2, Final Environmental Impact Statement for remedial Action Standards for Inactive Uranium Processing Sites [40 CFR 192], Volume II, October 1982, pages D-51, 52), where EPA found no difference in health protection between averaging contamination throughout the top 5 cm of soil versus the top 15 cm of soil, it is not necessary to sample to 15 cm at the air monitoring stations. That rationale is applicable here.

For background samples (excluding the air monitoring stations), subsurface samples will be collected at the satellite facility center reference location and at a distance of 750 meters (alternate distances in some cases as explained above) in each of four directions. Additional subsurface samples will be collected along the additional transects discussed above. Any areas disturbed by construction will be resampled. Subsurface soil profile samples would be collected to a depth of 1 meter. Samples would be divided into three equal sections for analysis. All subsurface samples would be analyzed for radium-226, and one set of samples for natural uranium, thorium-230, and lead-210.

Soil samples will be collected in accordance with the SHEQMS Volume VI Environmental Manual (CBR 2010).

Quality of Soil Measurements

The accuracy of monitoring data is critical to ensure that the soil monitoring program precisely reflects radionuclide concentrations. RG 4.14 specifies the following LLDs:

Radionuclide	Recommended LLD µCi/g (dry)
Natural Uranium	2×10^{-7}
Radium-226	2×10^{-7}
Thorium-230	2×10^{-7}
Lead-210 (dry)	2×10^{-7}

Soil samples collected by CBR will adhere to the requirements of RG 4.14.

2.9.7 Baseline Sediment Sampling

Sediments of lakes, reservoirs, and flowing bodies of surface water may become contaminated as a result of direct liquid discharges, wet surface deposition, or from runoffs associated with contaminated soils. Because of various chemically and physically binding interactions with radionuclides, sediments serve as integrating media that are important to environmental monitoring.

RG 4.14 recommends that sediment samples be collected from sediments of surface water passing through the project site or offsite surface waters that may be subject to drainage from potentially contaminated areas. The PPMP and operational monitoring plan will be designed to meet the criteria outlined in RG 4.14 (NRC 1980). Samples are to be collected once following spring runoff and in late summer following a period of extended low flow.

2.9.7.1 Niobrara River Sediments

Sediment sampling in RG 4.14 requires samples from each large onsite body of water or offsite surface waters that may be subject to direct surface drainage from potentially contaminated areas that could be affected by a tailings impoundment failure. There are no onsite surface impoundments, so such sampling is not required. Sediment samples will be collected from the Niobrara River, which could receive surface water runoff by means of ephemeral drainages located on the MEA project site (**Figure 2.7-4**). Sediments of the Niobrara River were sampled at designated upstream and downstream sampling locations (sample points N-1 and N-2) (**Figure 2.7-4**). Water samples are also collected at these sampling points. The downstream sampling point is located to assess potential impacts from either of the two ephemeral drainages that drain the MEA.

Deleted: One sample is to be collected prior to construction and analyzed for natural uranium, radium-226, thorium-230, and lead-210.

Sediment samples at N-1 and N-2 sampling points were collected on March 20, 2013. The radiological sample analytical results for lead-210, radium-226, thorium-230, and natural uranium are shown in **Table 2.9-38**. The analytical results for lead-210, radium-226, thorium-230 and uranium were the same for each parameter for both sampling sites, with all but radium-226, being at or near the reporting limits. (i.e., lead-210 at 0.3 pCi/g – dry weight [RL 0.2 pCi/g – dry wt], radium-226 at 0.4 pCi/g – dry weight [RL 0.04 mg/kg – dry weight], thorium-230 at 0.2 pCi/g – dry weight [RL 0.2 pCi/g – dry weight], and uranium at 0.4 mg/kg – dry weight [RL 0.3 mg/kg – dry weight] and 0.3 pCi/g – dry weight [RL 0.2 pCi/g – dry weight]).

As discussed in Section 2.9.4.3, the N-2 sampling point was moved upstream closer to the MEA project site after the completion of the sampling described above. N-1and the relocated N-2 will be sampled twice more before construction begins. Sampling is scheduled for the fall of 2013 and the spring of 2014. The samples will be analyzed for natural uranium, radium-226, thorium-230, and polonium-210.

2.9.7.2 Ephemeral Drainages

There are two major ephemeral drainages that traverse across the MEA license area north to south (**Figure 2.7-4).** Six upgradient and downgradient sampling points have been selected on these drainages to measure radiological concentrations in the sediment (MED-1 through MED-6).

The ephemeral drainages and the Niobrara River at designated sampling points will be sampled twice, once following spring runoff, and in late summer following period of extended low flow. Samples will be analyzed for natural uranium, radium-226, thorium-230, and lead-210.

Sediment sampling at Marsland was conducted in the fourth quarter of 2011 and the first quarter of 2013. The proposed PPMP and operational monitoring program is shown in **Tables 2.9-41 and 5.7-1**.

The 2012 and 2013 radionuclide measurements are shown in **Table 2.9-39**. A summary of the analytical results is as follows:

Analyte	Units	Minimum	Maximum	Reporting Limit
Lead-210	pCi/g-dry	<0.2	1.5	0.2
Radium-226	pCi/g-dry	0.2	0.8	0.02 to 0.04
Thorium-230	pCi/g-dry	< 0.2	0.5	0.2
Uranium Activity	pCi/g-dry	<0.2	0.7	0.2
Uranium (metal)	mg/kg-dry	<0.3	1.0	0.3

Sediment samples were collected in accordance with the SHEQMS Volume VI Environmental Manual (CBR 2010). The analytical data sheets and the QA/QC summary reports for the Niobrara River (N-1 and N-2) and ephemeral drainages sediment samples are provided in **Appendix W-2**

2.9.7.3 Quality of Sediment Measurements

The private laboratory employed by CBR, ELI, reported the lower limits of detection for ephemeral drainage sediment samples as MDC/LLD values. ELI stated in a letter dated April 23, 2012 (ELI 2012, **Appendix Q**) that the reported MDC/LLD values for the MEA sediment samples were in compliance with RG 4.14, Section 5 "LLD".

Radionuclide	**MDC/LLD for Soil/Sediment (dry)**	
	µCi/ml	**pCi/l**
Natural Uranium	2×10^{-7}	0.2 pCi/g
Thorium-230	2×10^{-7}	0.2 pCI/g
Radium-226	2×10^{-7}	0.2 pCi/g
Polonium-210	No guidance	No guidance
Lead-210	2×10^{-7}	0.2 pCi/g

Source: ELI 2012 (Appendix Q)

Note: For analytes reported in two significant figures. MDC/LLD values rounded off to only one significant figure (e.g., 1.3 pCi/g = 1 pCi/g).

ELI met the criteria of the guidance suggested by the NRC when reasonably achievable by available conventional laboratory methodology. If for some reason the MDC/LLD was not met on the original analysis, the samples were recounted ore re-analyzed until RG 4.14 MDC/LLDs were achieved. See **Appendix Q** for additional discussions by ELI of MDC/LLD reporting.

MDC levels for ephemeral drainage sediment radiological analytes are presented in **Table 2.9-39.**

2.9.8 Baseline Direct Radiation Monitoring

2.9.8.1 Survey Intervals

RG 4.14 recommends direct radiation measurements be collected at 150-meter intervals to a distance of 4,921.26 feet (1,500 meters) in each of eight directions from the centerpoint of the milling area or at a point equidistant from the milling area and tailings disposal area. The direct gamma radiation sampling at MEA will be designed to meet or exceed this guidance. Because there are no milling or tailings disposal areas, CBR will use the satellite facility as the centerpoint.

A baseline sampling plan with details on where and how direct radiation monitoring will occur will be submitted for NRC review in December 2013. Following resolution of any issues, the application will be revised to highlight the elements of that plan. Sampling will be conducted in late spring or early summer of 2014, prior to construction.

Deleted: In addition, gamma readings will be made at 150-meter intervals along established transects through the center portion of each proposed mine unit. The sampling locations will be consistent with the soil sampling locations as discussed in Section 2.9.6.¶
Samples are to be collected once prior to construction and repeated for areas disturbed by site preparation or construction. The timeline for completion of this sampling is the third quarter of 2013 (**Figure 2.9-1**). Gamma exposure rate is to be derived, using a passive integrating device su[illegible] optically stimulated luminescence dosimeter (OSLD), pressurized ionization chamber, or a properly calibrated portable survey instrument. ¶

2.9.8.2 Survey Measurements at Air Particulate Monitoring Stations

The PPMP baseline radiation monitoring program includes routine monitoring of direct radiation levels at the air monitoring stations.

Deleted: <#>Gamma will be measured using an environmental OSLD. The OSLDs are the most advanced technology available for measuring radiation exposure, including being accurate within +1 millirems (mRem), while in contrast, thermoluminescent dosimeters (TLDs) and film badges require 10 mRem to begin reporting (Landauer 2010).¶

Monitoring has been conducted by placing the OSLDs provided by Landauer, Inc. quarterly at the air particulate monitoring sites (**Figure 2.9-2**). The monitors were located approximately 1 meter above ground level. They were exchanged with new monitors quarterly, and the exposed monitors were returned to the vendor for processing. These devices provide an integrated exposure for the period between annealing and processing.

The PPMP and operational monitoring plan has been designed to meet the criteria outlined in RG 4.14 (NRC 1980). As with air particulate and radon-220 monitoring, gamma monitoring began in the fourth quarter of 2011 and was completed in the fourth quarter of 2012 (five quarters of data). The proposed PPMP and operational monitoring program is shown in **Tables 2.9-41 and 5.7-1**.

The results of gamma measurements conducted at the air particulate monitoring stations (MAR-1 through MAR-5) for the fourth quarter of 2011 through the fourth quarter 2012 are presented in **Table 2.9-40**. The gross and net measurements for all sampling locations over the entire sampling period ranged from 19.9 to 40.9 (average of 33.3) and 4.5 to 14.5 (average of 8.0) mRems ambient dose equivalent, respectively. The range of the gross and net measurements for MAR-1 through MAR-4 was 19.9 through 40.9 (average of 33.8) and 4.6 to 14.5 (average of 8.5), respectively, compared to MAR-5 with a range of 20.9 through 38.1 (average of 31.8) and 4.5 to 7.7 (average of 6.2), respectively. The gamma laboratory records are provided in **Appendix V-3**.

The average background gamma level in the Western Great Plains has been reported to be 0.014 milli-Roentgens per hour (mR/hr; NRC 1979).

NRC RG 4.14 guidance recommends a combination of direct gamma radiation measurements and exposure measurements made with integrating devices (i.e., OSLDs) during the PPMP.

In addition to the environmental gamma monitors, NRC recommends that the background gamma radiation in the area of the facility be measured with a scintillometer. As per RG 4.14, CBR will perform PPMP gamma radiation measurements at 150-meter intervals as discussed above. Note that some alternate sampling locations may be employed as discussed in Section 2.9.6. These measurements will be made once prior to construction and be repeated for area disturbed by site preparation or construction.

Deleted: The type of survey instrument and procedures employed would be as described below for measurements previously conducted at the proposed satellite facility.

2.9.9 Preoperational/Preconstruction Baseline Monitoring Program Summary

The MEA PPMP is summarized on **Table 2.9-41.** The remaining monitoring tasks and completion timelines are presented on **Figure 2.9-1.**

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Table 2.9-1 Locations of Environmental Sampling Stations, SAT Facility, and MET Station at the Marsland Expansion Area Site

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Table 2.9-2 Airborne Particulate Concentrations for Marsland Expansion Area

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Table 2.9-3 Ambient Atmospheric Radon-222 Concentration for Marsland Expansion Area

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Table 2.9-4 Summary of Water Quality for the Marsland Expansion Area and Vicinity (2011-2013)

Constituent	Units	Private Wells in AOR[a] Arikaree Group and Brule Formations		MEA Wells[b] Brule Formation		MEA Wells[c] Basal Sandstone of Chadron Formation	
		Range	Mean	Range	Mean	Range	Mean
Calcium	mg/l	21-73	38.9	5-32	12.7	2 - 19	6.52
Magnesium[d]	mg/l	3 - 13	8.8	<1 U - 7	2.2	<1 U - 3	1.06
Sodium	mg/l	8 - 49	19.8	24-156	89.7	298 - 550	408
Potassium	mg/l	2 -13	4.2	4 - 12	9.1	8 - 41	19.5
Bicarbonate as HCO_3	mg/l	160 - 480	201.9	48 - 202	150.2	125 - 918	348
Sulfate	mg/l	3 - 44	10.2	2 - 62	37.9	45 - 396	173
Chloride	mg/l	2 - 9	3.5	2 - 63	24.6	137 - 605	270
Conductivity @ 25 °C	µmhos/cm	241 - 578	329.9	307 - 763	482	1340 - 2740	1848
Total Dissolved Solids @ 180 C	mg/l	202 - 400	250.2	200 - 537	341	778 - 1420	1086
Total Dissolved Solids Calculated	mg/l	166 - 870	270.7	241 - 567	376	770 - 1470	1096
pH	s.u.	7.64 - 8.5	8.1	8.19 - 10.00	9.03	8.25 - 10	8.87
Cations	meq/l	2.75 - 6.29	3.6	3.24 - 7.36	4.94	13.5 - 25	18.7
Anions	meq/l	2.94 - 6.71	3.7	3.1 - 7.44	4.99	13.6 - 24.6	17.9
Uranium, Suspended[d]	mg/l	<0.0003 U - 0.001	0.00021	<0.0003 U - 0.0017	0.00025	<0.0003 U - 0.0843	0.00246
Uranium, Dissolved[d]	mg/l	0.0028 - 0.0373	0.00745	0.002 - 0.0095	0.0052	<0.0003 U - 0.084	0.00828
Radium-226, Dissolved[d]	pCi/l	<0.1 U - 9.5	0.21	<0.10 - 0.66	0.22	<0.1 - 390	30
Radium-226, Suspended[d]	pCi/l	<0.06 U - 0.2	0.07	<0.1 U - 0.6	0.14	<0.1 - 45	1.82
Uranium Activity, Dissolved[d]	uCi/mL	3.8E-10 - 18.1	1.3349	1.3E-09 - 6.4E-09	3.8E-09	<2.0E-10 - 6.2	3.87E-10[e]
Uranium Activity, Suspended[d]	uCi/mL	<2.0E-10 - 0.4	.000151[e]	<2.0E-10 - 1.2E-09	1.59E-10	<2.0E-10 - 6.2	0.151

Notes:

[a] 57 private water supply wells (700, 702, 703, 704, 705, 706, 707, 714, 715, 716, 719, 720, 721, 722, 723, 725, 727, 728, 730, 731, 732, 733, 734, 735, 736, 737, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 750, 752, 753, 754, 755, 759, 760, 777, 788, 794, 795, 799, 802, 809, 810, 811, 815, 821, 836, 841, 845) (March 24, 2011 - March 21, 2013).

[b] 10 CBR MEA Brule monitor wells (BOW-2010-1, BOW-2010-2, BOW-2010-3, BOW-2010-4A, BOW-2010-5, BOW-2010-6, BOW-2010-7, BOW-2010-8 (March 4 - May 3, 2011).

[c] 12 CBR MEA Basal Chadron monitor wells (Monitor-1, Monitor-2, Monitor-3, Monitor-4A, Monitor-5, Monitor-6, Monitor-7, Monitor-8, Monitor-9, Monitor-10, Monitor-11, CPW-2010-1) (March 12, 2011 - August 20, 2012).

[d] Values less than detection limits reduced by one-half in order to provide a conservative estimate.

[e] All data collected during Quarter 3 2012 was recorded with a RL of 0.2, average reported using RL of 2.0E-10 to prevent bias

mg/l = milligrams/liter
meq/l = milliequivalents per liter
pCi/l = picocuries per liter

<0.0003 U = non-detect result and detection limit
µmhos/cm = micromhos per centimeter
s.u. = standard units

AOR = Area of Review
CBR = Crow Butte Resources, Inc.
MEA = Marsland Expansion Area

Table 2.9-5 Radiological Analyses for Private Water Supply Wells in Marsland Area of Review

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Table 2.9-6 Non-Radiological Analyses for Private Water Supply Wells in Marsland Area of Review

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Table 2.9-7 **Water Levels - Arikaree Group, Brule Formation and Basal Sandstone of Chadron Formation**

Well	TOC Elevation (ft amsl)	2/22/11 Water Level (ft TOC)	2/22/11 Groundwater Elevation (ft amsl)	10/17/13 Water Level (ft TOC)	10/17/13 Groundwater Elevation (ft amsl)
ARIKAREE GROUP					
AOW-1	4261.64	--	--	126.4	4135.24
AOW-3	4351.97	--	--	142.2	4209.77
AOW-4	4161.91	--	--	87.3	4074.61
AOW-5	4125.42	--	--	72.0	4053.42
AOW-6	4068.60	--	--	20.0	4048.60
AOW-7	4243.94	--	--	DRY	4093.94
AOW-8	4365.02	--	--	71.7	4293.32
AOW-9	4146.41	--	--	74.9	4071.51
AOW-10	4198.60	--	--	113.3	4085.30
AOW-11	4091.02	--	--	35.4	4055.62
BRULE FORMATION					
BOW 2010-1	4260.10	125.74	4134.36	124.9	4135.20
BOW 2010-2	4324.96	150.03	4174.93	151.4	4173.56
BOW 2010-3	4352.80	137.20	4215.60	139.6	4213.20
BOW-2010-4	4163.13	86.65	4076.48	--	--
BOW 2010-4A	--	--	--	93.7	4069.43
BOW 2010-5	4127.88	71.19	4056.69	74.0	4053.88
BOW 2010-6	4100.43	49.30	4051.13	50.3	4050.13
BOW-2010-7	4248.37	--	--	155.6	4092.77
BOW-2010-8	4369.29	--	--	74.0	4295.29
BOW-2013-9	4145.90	--	--	74.6	4071.30
BOW-2013-10	4197.84	--	--	113.8	4084.04
BOW-2013-11	4091.87	--	--	37.4	4054.47
BASAL SANDSTONE OF CHADRON FORMATION					
CPW-2010-1	4261.35	551.63	3709.72	565.3	3696.05
CPW-2010-1A	4263.28	--	--	567.0	3696.28
Monitor 1	4103.28	387.65	3715.63	399.4	3703.88
Monitor 2	4199.50	484.99	3714.51	500.3	3699.20
Monitor 3	4261.40	550.90	3710.50	565.5	3695.90
Monitor 4A	4329.72	618.09	3711.64	634.3	3695.42
Monitor 5	4340.80	628.87	3711.93	645.4	3695.40
Monitor 6	4216.40	502.80	3713.60	518.2	3698.20
Monitor 7	4246.28	531.20	3715.08	548.0	3698.28
Monitor 8	4355.90	644.97	3710.93	660.5	3695.40
Monitor 9	4367.02	656.54	3710.48	669.7	3697.32
Monitor 10	4163.99	449.01	3714.98	465.0	3698.99
Monitor 11	4128.07	412.74	3715.33	427.9	3700.17

NOTES:

Groundwater elevations for the Brule Formation and Basal Chadron Sandstone are based on depth to water measurements.

TOC = top of casing

ft TOC = feet below top of casing

ft amsl = feet above mean sea level

DRY = measurable water not present in well at time of sampling