3 DESCRIPTION OF THE AFFECTED ENVIRONMENT

3.1 Land Use

This section provides data to evaluate the effects to the physical, ecological, and social characteristics of the proposed uranium mining on the surrounding environs. A discussion of land and water use in the CPF license area is contained in the permit application submitted for NRC License Number SUA-1534. A discussion of land and water use for the proposed NTEA is presented in a license amendment application submitted to the NRC on May 30, 2007. That application is pending.

This section describes the nature and extent of present and projected land and water use and trends in population or industrial patterns. The information for the CPF was initially developed over a 9-month period in 1982 as part of the R&D License Application, updated in 1987 for the Commercial License Application, and in 1997 and 2007 during license renewal. The information for the TCEA was developed in 2008 and updated in 2009 and 2010. Preliminary data were obtained from several sources followed by field studies to check land uses. Interviews with various state and local officials provided additional information.

NUREG 1569 requires a discussion of land and water use in the proposed TCEA, and within a 2.0-mile (3.3 km) distance from the site boundary. The NDEQ requires an assessment of a 2.25-mile radius (3.62 km) of the proposed project site boundary (Area of Review [AOR]) for the Class III UIC application. Therefore, the NRC's 2.0-mile radius has been extended to 2.25-miles for consistency with differing agency requirements. Land use within the TCEA and the 2.25-mile AOR is illustrated on **Figure 3.1-1**. Population, land use, and water use data were updated from previous CBR license applications through additional data collection and review, personal communications, and site reconnaissance. Population distribution characteristics were updated in 2004 and 2009 using current U.S. Census data and other applicable sources (U.S. Census 2010).

In general, little change has been noted in area land use in recent decades, reflecting the stagnant nature of economic activity in the area and slight decline in the populations of the City of Crawford and Dawes County.

3.1.1 General Setting

The TCEA is located in western Dawes and eastern Sioux Counties, Nebraska, just north of the Pine Ridge Area. The center of the TCEA is located approximately 4.0 miles southwest of the City of Crawford (**Figure 3.1-1**). The main access route to the TCEA is via State Highway 2/71 south from the City of Crawford, then west along Four Mile Road. U.S. Highway 20 provides access to the City of Crawford from points east and west. The CPF license area is 4.0 miles east of the TCEA.

3.1.2 Land Use

Land use of the TCEA and surrounding AOR is dominated by agricultural uses (**Figure 3.1-1 and Figure 3.5-1**). **Table 3.1-1** describes major land use types, including those depicted on **Figure 3.1-1**. Land use acreages for the AOR (**Table 3.1-2**) and TCEA (**Table 3.1-3**) are presented in **Figure 3.1-1** in 22 1/2° sectors centered on each of 16 compass points radiating out from the proposed satellite facility. Major land uses within the TCEA and AOR are further discussed below.

Livestock grazing on rangeland comprises the greatest portion of land use within the 2.25-mile AOR (42.5 percent). Recreational lands of Fort Robinson State Park (26.9 percent), cropland (18.4 percent), and forest land (11.7 percent) are the other significant land uses. Scattered rural residences are mostly associated with agricultural operations.

Recreational lands are the secondary land uses for the 2.25-mile AOR. Fort Robinson State Park, the largest state park in Nebraska, is located along the northern boundary of the TCEA and is partially located within the 2.25-mile AOR (**Figure 3.1-1**). The park is west of the City of Crawford, and includes portions of the Red Cloud Agency Historical Site and the White River Trail.

Residential and commercial land uses in Dawes County are concentrated within the city limits of Crawford and Chadron. Industrial land uses within the city limits of Crawford are generally associated with railroad facilities.

Within the TCEA, crop production is the dominant land use (57.6 percent), primarily for the cultivation and production of wheat. Livestock production is the secondary land use of the TCEA (35.2 percent).

Figure 3.5-1 and **Table 3.1-3** indicate that additional minor land uses occur within the TCEA. Areas of rangeland that have been variously degraded by agricultural, commercial, or industrial uses are present throughout Nebraska. Within the TCEA, these areas (Rangeland Rehabilitation) are currently being rehabilitated for more sustainable use as cropland or rangeland. Likewise, the presence of structural modifications to the landscape in the form of houses, barn, and other outbuilding is indicated by the Structural Biotope land use. Because these modifications are scattered and do not alter the overall land use of their surroundings, they are not considered to be major land uses such as those presented in **Table 3.1-1, Table 3.1-2, Figure 3.1-1** and **Figure 3.5-1**. Minor amounts of forested land are also present in the TCEA.

3.1.2.1 Agriculture

Several of the soil types found in the vicinity of the TCEA are classified as prime farmland. However, in Dawes County, soils are classified by the U.S. Natural Resource Conservation Service (NRCS) as prime farmland only if irrigated. According to 2009 Census of Agriculture for Nebraska (NASS 2009a), nearly 9 percent of Dawes County agricultural land is irrigated, and about 16 percent of harvested cropland acreage is irrigated (NASS 2009a). The remainder of the irrigated land is used for pasture, habitat, or rangeland (NASS 2009b).

Table 3.1-4 through **Table 3.1-6** show agricultural productivity within Dawes County and the TCEA. Wheat and hay are the major crops grown on croplands within the area. Most of these crops are used for livestock feed while the remaining crops are commercially sold. In 2007, total wheat production in Dawes County was 1,163,400 bushels, a decrease of 12 percent from 2006 production (NASS 2009c). Sorghum for grain, sunflowers, and sugar beets were produced in Dawes County prior to 2002, but were no longer produced in 2008. Native grasslands are often used for grazing or for cut hay.

In 2007, an average of 54,000 head of livestock was reported in Dawes County (NASS 2009b). The livestock inventory for Dawes County indicates that cattle account for more than 90 percent of all livestock. According to a report prepared for the Economic Development Department of the Nebraska Public Power Corporation (NPPC 2005), the market value of livestock products accounted for 85.7 percent of the total market value of all agricultural products sold in 2002. Livestock values remained consistent between the years 1990 and 2002, the most recent year for which livestock values are available. In 2002, cash receipts for livestock and products totaled $34.0 million in Dawes County (NASS 2009b). Livestock and livestock products had a value of $28.61 per acre, indicating that livestock production on rangeland within the AOR has a potential value of approximately $290,000.

3.1.2.2 Recreational

Recreational opportunities provided by federal and state lands in the county have become an increasingly important component of the local economy. There are no developed recreation facilities within the TCEA; however, developed recreation is located within portions of the AOR occupied by Fort Robinson State Park, and includes camping and hiking facilities along the White River. Other Park facilities include lodging, showers, electrical hookups, pit toilets, ski and snowmobile trails, a rodeo arena, and a museum. Additional recreational activities available within the Park include hunting, fishing, hiking, swimming, and horseback riding. The Park also contains commercial establishments that provide activities such as historic interpretation, museums, and an activity center.

No other recreation areas or facilities are located within the TCEA and the surrounding AOR. Nearby recreational facilities in Dawes County include the Ponderosa State Wildlife Management Area (SWMA), Chadron State Park, Soldier Creek Wilderness Area, the Red Cloud Picnic Area and several trails in the Nebraska National Forest (DeLorme Maps 2005). Approximate distances from the proposed satellite facility to local and regional recreational facilities are presented in **Table 3.1-7**.

3.1.2.3 Residential

In 2008, there were a total of 533 houses in the City of Crawford, with 468 occupied (345 owner occupied and 123 renter occupied) (City-Data 2010a). The housing density was 467 houses/condos per square mile. The last US census was in 2000, with Crawford reported to contain 537 housing units, of which 473 were occupied (US Census 2010).

Based on site reconnaissances in October 2008 and February 2010 and a Nebraska Department of Natural Resources aerial photo of the area, there is one occupied housing unit in the TCEA. This residence is located in NW1/4 SE1/4 Section 29, T31N, R52W, as shown on **Figure 3.1-2**. Three abandoned housing units, with associated outbuildings, were also identified in the TCEA. The AOR contains an additional 37 housing units, of which 23 are occupied. There are a total of 24 occupied housing units within the TCEA and the 2.25-mile AOR.

Table 3.1-8 shows the distance to the nearest residence within the 2.25-mile AOR and to the nearest site boundary from the center of the TCEA for each 22 1/2° sector centered on each compass point. There are two housing units within 1 km (0.62 miles) of the center point of the proposed TCEA. Six dwelling units are within 2 km (1.24 miles).

3.1.2.4 Habitat

Habitat lands are those dedicated wholly or partially to the production, protection, or management of species of fish or wildlife. Significant areas classified as habitat nearest to the TCEA include the Peterson SWMA, located nearly 2.5 miles west of the TCEA boundary; the Fort Robinson SWMA, located four miles north of the TCEA boundary; and the Ponderosa SWMA, which is five miles east of the TCEA boundary and adjacent to the current license area as shown in **Figure 3.1-1** (NGPC 2007). There is no land within the TCEA that is used primarily for wildlife habitat. Wildlife habitat is a secondary use of rangeland, forestland, and recreational land within the TCEA and the 2.25-mile AOR. An evaluation of habitat in the TCEA is included in Section 2.8, with habitat types in the TCEA shown in **Figure 3.5-1**.

3.1.2.5 Industrial and Mining

Other than exploratory mining drilling and oil and gas test holes, there are no industrial or mining activities within the TCEA. Two abandoned gravel pits are located on Fort Robinson State Park within the 2.25-mile AOR that may be mined periodically for local road construction purposes **(Figure 3.1-3)**.

Besides CBR, Conoco, Amoco Minerals, Santa Fe Mining, and Union Carbide have also drilled exploratory testing holes for uranium mining in the general area. There are no other industrial facilities within the 2.25-mile review area.

There are no oil and gas test holes located within the TCEA or the 0.25-mile Zone of Endangering Influence (ZOEI), but four abandoned wells are present within the 2.25-mile AOR (**Figure 3.1-3**). Based on review of public records, all the referenced oil and gas test holes have been properly plugged and abandoned in accordance with the Nebraska Oil and Gas Conservation Commission regulations (NOGCC 2009). A discussion of oil and gas test holes pertinent to the TCEA is presented in Section 3.3.1.2 (Montana Group: Pierre Shale).

Other than CBR uranium recovery activities, there are no other known planned uranium recovery operations in Nebraska. There are no other nuclear fuel cycle facilities located or proposed within an 80-km (50-mile) radius of the proposed TCEA. Project descriptions and locations of operating and proposed uranium recovery facilities in neighboring Wyoming and South Dakota can be found at the NRC website (NRC 2009). The nearest operating uranium recovery facility to the proposed TCEA is the Smith Ranch-Highland uranium in situ leach facility located near Douglas (Converse County) of western Wyoming (NRC 2009). Other proposed uranium in situ facilities nearest to the TCEA that have filed applications in the region are Powertech Uranium's Dewey-Burdock facility located in Fall River and Custer Counties of South Dakota and Uranium One's Moore Ranch project that will be located in Converse County Wyoming.

3.1.2.6 Commercial and Services

There are retail and commercial establishments at Fort Robinson State Park. These establishments include museums, a restaurant, an activity center, room rental, a campground, and other facilities that provide recreation activities to Park visitors. The establishments are clustered within the developed areas of the Park along State Highway 20, approximately 1.4 miles north of the TCEA north boundary. No other commercial establishments are located within the TCEA and the 2.25-mile review area.

3.2 Transportation and Utilities

Nebraska Highway 2/71 and U.S. Highway 20 converge in the City of Crawford north-northeast of the TCEA. The TCEA is accessed from Highway 2/71 on Four Mile Road. The 2008 average daily traffic counts for a segment of Highway 2/71 near the Four Mile Road intersection was 895 vehicles, including 115 heavy commercial vehicles. Traffic levels on SH-2 increase to 915 vehicles just south of the City of Crawford, and are generally lower to the south of Four Mile Road on Highway 2/71 (NDOR 2009). Private roads connect with Four Mile Road to provide access to residences and agriculture within the TCEA. The junction of the Burlington Northern and D M & E Railroads is located in the City of Crawford. No railways cross the TCEA 2.25-mile AOR.

3.3 Geology and Seismology

3.3.1 Regional Setting

As shown on **Figure 1.1-2**, the proposed TCEA is located approximately 3.5 miles southwest of the City of Crawford, Nebraska in Sections 28, 29, 30, and 33 of Township 31 North, Range 52 West and in Section 25 of Township 31 North, Range 53 West. The City of Crawford is 25 miles west of Chadron, Nebraska and 70 miles north of Scottsbluff, Nebraska. The City of Crawford is 21 miles south of the South Dakota state line and 33 miles east of the Wyoming state line. The CBR area is located near the northern limits of the High Plains section of the Great Plains physiographic province. Topography of the CBR area includes gently sloping, rolling hills with outlying, broad ridges which are dissected by intermittent and perennial streams. The most prominent physiographic feature in the region is the Pine Ridge Escarpment, which rises roughly 300 to 900 feet above the basal plain. The escarpment bounds three sides of the Crawford Basin. Colluvial and alluvial deposits originating from this escarpment cover the CPF license area. The elevation of the CBR area ranges from 3,880 to 4,100 feet above mean sea level (amsl).

3.3.1.1 Regional Stratigraphy

Table 3.3-1 summarizes the regional stratigraphic section for northwest Nebraska that includes the White River Group (Brule Formation through Basal Chadron Sandstone). A geologic map of bedrock in northwest Nebraska is shown on **Figure 3.3-1**. The bedrock map depicts the occurrence in northwest Nebraska of the Miocene Ogallala Group, Miocene Arikaree Group, the Eocene-Oligocene White River Group, and Upper Cretaceous strata belonging to the Montana Group and Colorado Group. The Upper Cretaceous Pierre Shale, the unconformably overlying White River Group (i.e, Brule Formation, Chadron Formation, and Chamberlain Pass Formation), and the Arikaree Group outcrop in the vicinity of the City of Crawford and TCEA (**Figure 3.3-1**, see inset).

3.3.1.2 TCEA Stratigraphy

The local stratigraphy present within the TCEA consists of the following geological units in descending order: alluvial sediments, Brule Formation, Chadron Formation, Basal Chadron Sandstone and Pierre Shale. The channel sandstone facies of the Chamberlain Pass Formation, informally referred to herein as the Basal Chadron Sandstone, represents the production zone and target of solution mining in the TCEA. The general stratigraphic section for the TCEA is summarized in **Table 3.3-2**. **Figure 3.3-2** illustrates the locations of five north-south and east-west cross-sections through the TCEA depicted on **Figures 3.3-3a through 3.3-3e**.

Though a thick (approximately 1,200 to 1,500 feet), regionally extensive stratigraphic section of sedimentary units underlies the Pierre Shale, those units are not relevant to this proposal. The absence of sandstone units for more than 1,000 feet below the top of the Pierre Shale precludes the need for monitoring zones below the surface of the Pierre Shale. Discussion in this report is limited to those formations immediately above and below the Basal Chadron Sandstone (Petrotek 2004; Wyoming Fuel Company 1983).

This section provides a detailed description of the stratigraphy of the TCEA based on an extensive review of existing site-specific drilling logs and published literature. Geological units are described from stratigraphically youngest to stratigraphically oldest. Revised nomenclature for these stratigraphic units is discussed, where applicable, and referred to throughout this application. To be consistent with historical permitting, the stratigraphic nomenclature used in previous submittals to the NRC and the NDEQ has been preserved.

Alluvium

Alluvial deposits occur between the surface and the top of the Brule Formation and vary in thickness (depending upon topography) from 0 to 30 feet. In general, the alluvium consists of Miocene age rock fragments, sand, gravel and sandy soil horizons, and may include weathered portions of the Brule Formation. Because alluvium is generally unconsolidated and contains either shallow groundwater or is within the vadose zone, log signatures within this unit may vary significantly when compared to signatures for underlying units. On most TCEA logs, resistivity is very high (beyond the log scale), indicating the presence of either soil vapor or fresh water. In general, shallow zones with elevated resistivity also indicated a negatively deflected SP curve, suggesting the presence of a permeable zone and formation fluid with lower resistivity than the fluid within the borehole. Although these log signatures suggest the base of the alluvium can be interpreted, this relationship has not been verified and the Alluvium-Brule Formation contact is not depicted on cross-sections included with this application.

White River Group

The Eocene-Oligocene White River Group consists of the Chamberlain Pass Formation overlain by the Chadron Formation, which is, in turn, overlain by the Brule Formation **(Table 3.3-2)**. Strata assigned to this group were deposited within fluvial, lacustrine, and eolian environments (Terry and LaGarry 1998). In northwest Nebraska, it rests unconformably on pedogenically modified Pierre Shale. The bulk of the White River Group is composed of airfall and reworked volcaniclastics derived from sources in Nevada and Utah (Larson and Evanoff 1998; Terry and LaGarry 1998).

The history of stratigraphic nomenclature for the White River Group of Nebraska and South Dakota has had various interpretations as described by Harksen and Macdonald (1969). The following stratigraphic nomenclature represents a preservation of formal and informal members based on nomenclature by Schultz and Stout (1955) with representation of more recent nomenclature (Terry and LaGarry 1998; Terry 1998; LaGarry 1998; Hoganson et al. 1998).

Brule Formation

The Oligocene Brule Formation represents the youngest unit within the White River Group which outcrops throughout most of the CBR area. The unit conformably overlies the Chadron Formation and is unconformably overlain by sandstones of the Arikaree Group (**Figure 3.3-1**). The White River Group was originally subdivided by Swinehart et al. (1985) and later revised by LaGarry (1998) into three members, from youngest to oldest: the "brown siltstone" member, the Whitney Member, and underlying Orella Member (**Table 3.3-2**). The "brown siltstone" member consists of pale brown and brown, nodular, cross-bedded eolian volcaniclastic siltstones and sandy siltstones. The contact with the underlying Whitney Member varies from gradational to a sharp unconformity where the brown siltstone fills valleys and depressions. The Whitney Member consists of pale brown, massive, typically nodular eolian siltstones with occasional thin interbeds of brown and bluish-green sandstone, and volcanic ash. In contrast, the lowest 10 meters consist of white or green laminated fluvial siltstones, sheet sandstones, and channel sandstones. The contact between the Whitney Member and the underlying Orella Member is intertonguing. The Orella Member consists of pale brown, brown, and brownish-orange volcaniclastic overbank clayey siltstones and silty claystones, brown and bluish-green overbank sheet sandstones, and volcanic ash. Occasional thick, fine- to medium-grained, channelized sandstones occur throughout the Orella Member. These sandstones appear to have very limited lateral extent. The overall thickness of the Brule Formation within the TCEA is generally less than 200 feet and ranges from approximately 120 to 180 feet. The majority of the Brule Formation present at the TCEA consists of the Orella Member, as the entire "brown siltstone" member and most of the Whitney Member have been eroded.

The contact between the Brule Formation and underlying Chadron Formation is sometimes difficult to ascertain, as the contact between the two formations is inter-tonguing (LaGarry 1998). Regionally, the contact is recognized as the lithologic change from thinly interbedded and less pedogenically-modified brown, orange, and tan volcaniclastic clayey siltstones and sheet sandstones of the Orella Member to pedogenically-modified green, red, and pink volcaniclastic silty claystones of the Upper Chadron (Big Cottonwood Creek Member) (Terry and LaGarry 1998). On geophysical logs, the Brule Formation is characterized by rapidly fluctuating log curves, or "log chatter" (**Figure 3.3-4**). This response is recognized in resistivity curves, and to a lesser extent SP curves, throughout the TCEA. The fluctuations are produced by resistivity contrasts between the thinly interbedded siltstones and sandstones of the Orella Member. Because the sandstones are porous and part of the regional aquifer, the contacts with the interbedded, dry siltstones are sharp and easily recognized on logs. Lateral correlation of beds within the Brule Formation is very difficult due to generally thin bed thicknesses and limited lateral extent.

The contact between the interbedded siltstones and sandstone of the Brule Formation and the silty claystones of the Upper Chadron Formation is distinguished by a drop off of "log chatter" and establishment of relatively flat or straight curves (i.e., the shale baseline) on both resistivity and SP logs (**Figure 3.3-4**). Because of the intertonguing nature of the Lower Brule and Upper Chadron Formations, thin, isolated sandstones and siltstones may be present in the Upper Chadron, making it appear that the formation contact is deeper in some wells.

Chadron Formation

The Eocene-Oligocene Chadron Formation is a member of the lower White River Group (**Table 3.3-2**). The Chadron Formation conformably overlies the Basal Chadron Sandstone and is conformably overlain by the Brule Formation. From top to bottom, the Chadron Formation historically consists of the following stratigraphic units: Big Cottonwood Creek Member (herein referred to as the Upper Chadron and Upper/Middle Chadron to be consistent with historical permitting), Peanut Peak Member (herein referred to as the Middle Chadron to also be consistent with historical permitting), and Basal Chadron Sandstone. The Basal Chadron Sandstone represents the production zone and target of ISL mining within the TCEA. **Figures 3.3-3a** through **3.3-3e** depict the subsurface geology of the Chadron Formation within the TCEA.

Upper Chadron and Upper/Middle Chadron

The Upper Chadron and Upper/Middle Chadron are composed primarily of volcaniclastic overbank silty claystones interbedded with tabular and lenticular channel sandstones, lacustrine limestones, pedogenic calcretes, marls, volcanic ashes, and gypsum (Terry and LaGarry 1998). Tuffs in the Toadstool Park area that occur in the Upper Chadron were dated by $^{40}Ar/^{39}Ar$ methods as late Eocene (~34 Ma) in age (Terry and LaGarry 1998). The lower boundary of this member is an intertonguing contact with the underlying Middle Chadron of the Chadron Formation, or is a local unconformity where the Upper/Middle Chadron fills valleys and depressions (Terry and LaGarry 1998) (**Table 3.3-2**). The upper boundary is recognized by a lithologic change from pedogenically modified green, red, and pink volcaniclastic silty claystones of the Upper Chadron to thinly interbedded and less pedogenically modified brown, orange, and tan volcaniclastic clayey siltstones and sheet sandstones of the Orella Member of the Brule Formation (Terry and LaGarry 1998) (**Table 3.3-2**).

The Upper Chadron is the youngest member of the Chadron Formation (**Table 3.3-2**). The upper part of the Upper Chadron is light green-gray bentonitic clay grading downward to green and frequently red clay, though interbedded sandstones also occur. Based on the predominance of fine-grained lithologies that comprise the Upper Chadron, this unit represents a distinct and rapid facies change from the coarse-grained lithologies present in the underlying Upper/Middle Chadron and Basal Chadron Sandstone. Based on available well control data, the Upper Chadron is continuous across the TCEA. The Upper Chadron ranges in stratigraphic thickness from approximately 270 to 380 feet in the TCEA (**Figures 3.3-3a** through **3.3-3e**).

Four core samples (T-1050c Run 1, T-1050c Run 2, T-1051c Run1, and T-1051c Run 2) were collected from the Upper Chadron by CBR at boreholes T-1050c and T-1051c in Section 30 of the TCEA (**Figure 3.3-2**). X-ray diffraction analyses of both the T-1050c Run 1 and T-1050c Run 2 samples indicate compositions of primarily montmorillonite with minor amounts of calcite, quartz, plagioclase, K-feldspar, and illite/mica. Particle grain size distribution analyses of the T-1050c Run 1 and T-1050c Run 2 samples indicate silts composed of approximately 82 percent silt and clay particles (i.e., approximately 70 percent silt and 12 percent clay particles) and approximately 73 percent silt and clay particles (i.e., approximately 56 percent silt and 16 percent clay particles), respectively. X-ray diffraction analysis of the T-1051c Run 1 sample indicates a composition of primarily montmorillonite with minor amounts of quartz, plagioclase, K-feldspar, and illite/mica. Particle grain size distribution analysis of the T-1051c Run 1 sample indicates a sandy silt composed of approximately 72 percent silt and clay particles (i.e., approximately 58 percent silt and 14 percent clay particles). X-ray diffraction analysis of the T-

1051c Run 2 sample indicates a composition of primarily montmorillonite with minor amounts of gypsum, calcite, quartz, plagioclase, K-feldspar, and illite/mica. Particle grain size distribution analysis of the T-1051c Run 2 sample indicates a clayey silt composed of approximately 95 percent silt and clay particles (i.e., approximately 66 percent silt and 29 percent clay particles).

Typical gamma ray (GR), spontaneous potential (SP), and resistivity log signatures for the Upper Chadron exhibit curves representative of the relatively flat shale baseline (**Figure 3.3-4**). Fluctuations are present among Upper Chadron log curves, representing interbedded siltstones, sandstones, limestones, and volcanic ash deposits that occur less commonly than in the overlying Brule Formation.

The Upper/Middle Chadron is directly overlain by the Upper Chadron (**Table 3.3-2**). At some locations, the Upper/Middle Chadron is similar in appearance to the channel sandstone facies of the upper portion of the Basal Chadron Sandstone (described later in this section) and is typically a very fine to fine grained, well-sorted, poorly cemented sandstone. An isopach map of the Upper/Middle Chadron is shown on **Figure 3.3-5**. Extensive review of available data from the TCEA and vicinity strongly indicates that the extent of the sandstone is limited to the southern half of the central and eastern portions of the TCEA (**Figure 3.3-3a through 3.3-3e and Figure 3.3-5**). The unit is completely absent in the western, northern, and southernmost portions of the TCEA (**Figure 3.3-5**). The available data suggest that the Upper/Middle Chadron, where present, typically ranges in thickness from approximately 0 to 50 feet across the TCEA.

The GR curve distinctly marks the top and bottom of the Upper/Middle Chadron (**Figure 3.3-4**). The curve responses of the logs are not as large as those seen in the Basal Chadron Sandstone (discussed below), indicating lower concentrations of radioactive materials. The GR shifts distinctly to the right at the lower boundary, most likely indicating a sandstone containing uranium. The GR curve can also shift to the left within this unit, indicating sandstone with no uranium. The resistivity curve shift described for the Upper/Middle Chadron at the NTEA is not recognized at the TCEA.

For unknown reasons, possibly the continued or renewed uplift of the Black Hills or Chadron Dome, reworked sediment and fluvial deposits of the Upper and Upper/Middle Chadron were concentrated in northwestern Nebraska (Terry and LaGarry 1998). At some locations, initial deposition of the Upper/Middle Chadron occurred within paleovalleys incised into the underlying Middle Chadron (Terry and LaGarry 1998). At other locations (e.g., Toadstool Park), the lower boundary is intertonguing (Terry and LaGarry 1998).

Middle Chadron

The Middle Chadron is described as a clay-rich interval that grades from brick red to grey in color with interbedded bentonitic clay and sands. A light green-gray "sticky" clay within this unit serves as an excellent marker bed in drill cuttings and has been observed in virtually all regional test holes both within the TCEA, NTEA and the CPF license area. The Middle Chadron unconformably overlies the Basal Chadron Sandstone (Chamberlain Pass Formation) in South Dakota and Nebraska (Terry 1998) (**Table 3.3-2**). As described above, the upper boundary is variable and is overlain either by the Upper/Middle Chadron, where present, or by the Upper Chadron (**Table 3.3-2**). The Middle Chadron differs from the overlying Upper/Middle and Upper Chadron in that the Middle Chadron is composed of bluish-green, smectite-rich mudstone and claystone, weathers into hummocky, "haystack-shaped" hills and slopes with a popcorn-like surface, is less variegated in color, and has less silt (Terry 1998). The predominantly clay lithology of the Middle Chadron represents a distinct and rapid facies change from the underlying Basal Chadron Sandstone. Within the TCEA, the unit ranges in stratigraphic thickness from about 130 to 190 feet. A "red clay" horizon that occurs at the base of the Middle Chadron is indicated on more than half of the geophysical logs and driller's notes that were reviewed and is discussed in more detail below (Appendix D). This "red clay" is formally referred to as the Upper Interior Paleosol and is discussed in more detail below.

Two core samples (T-1050c Run 3 and T-1051c Run 3) were collected from the Middle Chadron by CBR at boreholes T-1050c and T-1051c in Section 30 of the TCEA (**Figure 3.3-2**). X-ray diffraction analysis of the T-1050c sample indicates a composition of primarily mixed-layered illite/smectite with minor amounts of quartz plagioclase, K-feldspar, gypsum and illite/mica. Particle grain size distribution analysis indicates a clayey silt composed of approximately 85 percent silt and clay particles (i.e., approximately 58 percent silt and 27 percent clay particles). X-ray diffraction analysis of the T-1051c sample indicates a composition of primarily montmorillonite with minor amounts of quartz, plagioclase, and K-feldspar. Particle grain size distribution analysis indicates a silty clay composed of 100 percent silt and clay particles (i.e., approximately 62 percent clay and 38 percent silt particles).

Typical GR, SP, and resistivity log signatures for the Middle Chadron exhibit curves representative of the shale baseline (**Figure 3.3-4**). The top of the Middle Chadron is noted where the curves break either distinctly to the left or to the right, representing the sandstone of the Upper/Middle Chadron, where present. Where overlain by the Upper Chadron, the contact between units is very difficult to ascertain due to similarities in grain size.

The Upper, Upper/Middle and Middle Chadron units represent the upper confining zone for the Basal Chadron Sandstone within the TCEA (see detailed discussion in Section 3.4.3.4). An isopach map of the upper confining zone is shown in **Figure 3.3-6**. The thickness of the upper confining zone ranges from approximately 400 to 560 feet in the vicinity of the TCEA. The zone appears to generally thicken toward the south and southwest across the permit boundary with a narrow northwest-trending high ridge in the central northern portion of the TCEA.

Basal Chadron Sandstone – Mining Unit

The Basal Chadron Sandstone is the oldest unit in the White River Group. The lower section is a coarse-grained, arkosic sandstone with frequent interbedded thin silt and clay lenses of varying thickness and continuity that lies on a marked regional unconformity with the underlying Yellow Mounds Paleosol (Terry 1998). The lower contact is easily recognized by a change in color and lithology from the underlying black or bright yellow, pedogenically modified surface of the Pierre Shale (i.e., the Yellow Mounds Paleosol) to white channel sandstone. Occasionally, the Basal Chadron Sandstone grades upward to fine-grained sandstone containing varying amounts of interstitial clay material and persistent clay interbeds. Vertebrate fossils from the Basal Chadron Sandstone in northwestern Nebraska and South Dakota indicate a late Eocene age (Chadronian) (Clark et al. 1967; LaGarry 1996; Lillegraven 1970; Vondra 1958). The Upper Interior Paleosol, occurring as a persistent clay horizon, typically brick red in color, developed on top of the Basal Chadron Sandstone and generally marks the upper limit of the Basal Chadron Sandstone (**Table 3.3-2**).

The Basal Chadron Sandstone occurs at depths ranging from about 580 to 940 feet bgs and was encountered at all exploration holes. An isopach map of the Basal Chadron Sandstone in the vicinity of the TCEA is presented on **Figure 3.3-7**. Stratigraphic thickness of the unit within the TCEA ranges from approximately 70 to 250 feet. The thickest sections of the unit occur in the central and western portions of the TCEA (**Figure 3.3-7**). Up to four distinct sandstone units are present in the thickest portions of this unit and are separated by variable amounts of interbedded clay. The Basal Chadron Sandstone thins significantly to the north and east where only two sandstone units appear to be present on the outermost edges of the TCEA. This observation is consistent with the occurrence of only two distinct channel sandstone intervals at the CPF license area located approximately 3 miles to the east. Structure contour maps of the top of the Basal Chadron Sandstone indicate that the unit dips slightly to the west-northwest across the TCEA (**Figures 3.3-8** and **3.3-9**). This shallow dip is also depicted on selected cross sections (**Figures 3.3-3a, 3b, and 3d**). Regionally, the unit ranges in thickness from 0 to 250 feet (**Figure 3.3-10**).

The greenish-white channel sandstones of the Basal Chadron Sandstone that overlie the Yellow Mounds Paleosol are the target of ISL mining activities in the TCEA. Regionally, deposition of the Basal Chadron Sandstone has been attributed to large, high-energy braided streams. In this regard, the Basal Chadron Sandstone is lenticular with numerous facies changes occurring within short distances. The interbedded thin silt and clay lenses most likely represent flood plain or low velocity deposits normally associated with fluvial sedimentation.

Mineralogical investigations within the TCEA indicate that the Basal Chadron Sandstone is comprised of 50 to 95 percent clear quartz and minor chert, 2 to 15 percent variably-colored (white, green and pink) feldspars, trace to 30 percent lithics (primarily mudstone and shale fragments), and trace weakly altered to fresh pyrite. An increase in organic matter and pyrite appears to be associated with mineralization. A change was noted in overall composition of the sandstones from arkosic in oxidized or unaltered sandstones to a notably less feldspathic, cleaner sandstone in the mineralized intervals, which may indicate better permeability and porosity that was favorable for transport of mineralizing fluids and deposition of uranium. The sandstones that comprise the Basal Chadron Sandstone within the CPF license area are dominated by quartz (50% monocrystalline) and feldspar (30-40% undifferentiated feldspar) with the remainder made up of chert, pyrite, and various heavy metals and polycrystalline and chalcedonic quartz (Collings and Knode, 1984). X-ray diffraction analyses indicate that the Basal Chadron Sandstone within the CPF license area is 75 percent quartz with the remaining composition composed of potassium feldspar and plagioclase and the following clay minerals: illite, smectite, expandable mixed layer illite-smectite, and minor amounts of kaolinite (Collings and Knode, 1984).

Geophysical logs record a unique signature for the Basal Chadron Sandstone (**Figure 3.3-4**). A distinct GR spike is present at the base of the unit in most of the TCEA exploration boreholes, indicating an abundance of radioactive material. Increased resistivity (i.e., log curve shift to the right), decreased N-N count (i.e., log curve shift to the left), and decreased SP (i.e., log curve shift to the left) are typically associated with GR spikes. These log signatures support interpretations of a uranium-bearing, fluid-filled sandstone interval. Overlying channel sandstone intervals that are present in the middle and upper portions of the unit typically have lower GR readings, indicative of both lower amounts of radioactive materials and potentially non-uranium bearing intervals. Such intervals are typically marked by increased resistivity (i.e., higher porosity and fluid-filled) and lower N-N counts and, in contrast to the uranium-bearing units, typically have positive SP curve deviations. This log response indicates that within the higher uranium-bearing units, mud filtrate resistivity is higher than formation water resistivity, which may be the result of the presence of higher salinity waters in uranium-bearing units. Pervasive interbedded clay intervals are indicated by high GR responses accompanied by lower resistivity (i.e., reduced porosity and decrease in water content), an interpretation that is further supported by driller or geologist notes. The high radioactivity of these clay units likely suggests the presence of rhyolitic ash. The top of the formation is marked by a gradual return of SP and resistivity curves to the shale baseline.

Montana Group

Interior Paleosol (Upper Interior Paleosol and Yellow Mounds Paleosol)

The Interior Paleosol of Schultz and Stout (1955) was subsequently divided into the younger Eocene Upper Interior Paleosol and the Cretaceous Yellow Mounds Paleosol (Pierre Shale) (Terry 1991; Evans and Terry 1994; Terry and Evans 1994; Terry 1998) (**Table 3.3-2**). The Upper Interior Paleosol represents pedogenically modified distal overbank deposits of a distinct fluvial system developed on the surface of the Basal Chadron Sandstone which predates deposition of the Chadron Formation. The Yellow Mounds Paleosol developed on the Cretaceous Pierre Shale and altered the normally black marine shale to bright yellow, purple, lavender, and orange.

Review of available data for the TCEA indicates that neither of the two paleosol units could be consistently interpreted based solely on geophysical logs. For simplicity, these units are not represented on the type log or cross-sections.

Pierre Shale

The Cretaceous Interior Seaway resulted in the offshore deposits of the late Cretaceous Pierre Shale (**Table 3.3-2**). The Pierre Shale is a thick, homogenous black marine shale with low permeability that represents one of the most laterally extensive formations of northwest Nebraska. Regional geologic data indicate that this formation can be up to 1,500 feet thick in the Dawes County area (Wyoming Fuel Company 1983; Petrotek 2004). The southward retreat of the Cretaceous Interior Seaway resulted in the subaerial exposure and weathering of rock units from Early Cretaceous to Eocene age across the northern Great Plains (Lisenbee 1988). This event resulted in the erosion and pedogenic modification of the surface of the Pierre Shale to form the brightly-colored Yellow Mounds Paleosol (Terry and LaGarry 1998) (**Table 3.3-2**). Consequently, the pedogenically modified surface of the Pierre Shale marks a major unconformity with the overlying White River Group and exhibits a paleotopography with considerable relief (DeGraw 1969). The Pierre Shale is underlain by organic-rich shale and marl with minor amounts of sandstone, siltstone, limestone, and chalk of the Niobrara Formation (**Table 3.3-1**). Structure contour maps of the top of the Pierre Shale indicate that the unit dips slightly to the west across the TCEA (**Figures 3.3-11 and 3.3-12**). This shallow dip is also depicted on selected cross sections (**Figures 3.3-3a and 3b**).

Two core samples (T-1050c Run 5 and T-1051c Run 5) were collected from the Pierre Shale by CBR at boreholes T-1050c and T-1051c in Section 30 of the TCEA (**Figure 3.3-2**). X-ray diffraction analysis of the T-1050c sample indicates a composition of primarily quartz and mixed-layered illite/smectite with minor amounts of illite/mica, K-feldspar, kaolinite, and chlorite. Particle grain size distribution analysis indicates a silty clay composed of approximately 99 percent silt and clay particles (i.e., approximately 58 percent clay and 42 percent silt particles). X-ray diffraction analysis of the T-1051c sample indicates a composition of primarily quartz and montmorillonite with minor amounts of plagioclase, K-feldspar, dolomite, chlorite, and illite/mica. Particle grain size distribution analysis indicates a clayey silt composed of approximately 97 percent silt and clay-sized particles (i.e., approximately 57 percent silt and 40 percent clay particles).

Typical geophysical log responses for the Pierre Shale exhibit curves that are relatively flat or straight and represent the shale/clay log signature (**Figure 3.3-4**; **Appendix D**). The GR has established the shale/clay baseline. The top of the Pierre Shale is noted where the curves break either sharply to the left or to the right and represent the occurrence of the Basal Chadron Sandstone. Spontaneous potential and resistivity curves qualitatively indicate a lack of permeable, water-bearing zones within the Pierre Shale.

Eight deep oil and gas exploration wells were drilled in the vicinity of the TCEA (Farner 1, Federal 1, Hamaker, Heath 1, Heckman 1, Homrighausen, Roby 3, and Sikorski) (**Figure 3.1-3, Appendix D**). Well abandonment records are shown in **Appendix B**. Oil and gas exploration wells have typically been drilled to depths much greater than on-lease uranium exploration wells. The character of the entire Pierre Shale in the vicinity of the TCEA can best be observed in geophysical logs from five of the eight nearby abandoned oil and gas wells (Federal, Heath 1, Homrighausen, Roby 3, and Sikorski), and the CBR deep disposal well (CBR UCI #1), as these logs were completed through the entire thickness of the unit. Based on observations from logging, the thickness of the Pierre Shale in the vicinity of the TCEA ranges from approximately 600 to 740 feet. The top of the Pierre Shale was encountered in all wells at depths ranging from approximately 600 to 1,300 feet bgs. The Farner 1 well is located approximately 2 miles east of the TCEA permit boundary (T31N, R52W, Section 26) and has a total depth of 3,463 feet bgs. The Federal 1 well (W030995) is located approximately 2 miles north of the TCEA permit boundary (T31N, R52W, Section 17) and has a total depth of 3,818 feet bgs. The Hamaker well is located approximately 5 miles south of the TCEA permit boundary and has a total depth of 4,037 feet bgs. The Heath 1 well is located within approximately 1 mile of the southeastern corner of the TCEA permit boundary (T30N, R52W, Section 26) with a total depth of 3,348 feet bgs. The Heckman 1 well is located approximately 3 miles northeast of the TCEA permit boundary (T31N, R52W, Section 24) and has a total depth of 4,590 feet bgs. The Homrighausen well is location approximately 2.5 miles southeast of the TCEA permit boundary (T30N, R52W, Section 10) and has a total depth of 2,749 feet bgs. The Roby 3 well is located approximately 4 miles east of the TCEA permit boundary (T31N, R51W, Section 31) and has a total depth of 3,399 feet bgs. The Sikorski 1 well is located approximately 2 miles southeast of the TCE permit boundary (T30N, R52W, Section 10) and has a total depth of 3,626 feet bgs. Deep disposal well CBR UIC #1 is located approximatley 4.5 miles east of the TCEA permit boundary (T31N R52W Section 19) and has a total depth of 3,910 feet bgs. At UIC #1, the Pierre Shale was encountered from 925 to 1,560 feet bgs, where the base of the Pierre Shale is indicated by an increase in resistivity at the contact with the underlying Niobrara Formation (**Appendix D**).

Pre-Pierre Shale Stratigraphy

Underlying the Pierre Shale is a thick sequence of Mississippian through Cretaceous age strata that unconformably overlie pre-Cambrian granite (**Table 3.3-1**). Together with the Pierre Shale, the underlying Niobrara Formation, Carlile Shale, Greenhorn Limestone, and Graneros Shale compose a composite lower confining interval approximately 2,500 feet thick which immediately underlies the Basal Chadron Sandstone. There do not appear to be significant sandstone units within this thick sequence of low-permeability strata.

All geologic units encountered during the drilling of oil and gas exploration wells in the vicinity of the TCEA appear to be consistent with known regional stratigraphy. Geologic units that are consistently identified in all wells include the Niobrara Formation, Carlile Shale, Greenhorn Limestone, "D" and "J" sands of the Dakota Group, and the Skull Creek Formation (**Table 3.3-1**).

3.3.2 Geochemical Description of the Mineralized Zone

The depth to the ore body within the Basal Chadron Sandstone in the TCEA ranges from approximately 580 to 940 feet below ground surface (bgs) (**Table 3.3-2**). The width of the ore body varies from approximately 2,100 to 4,000 feet. Indicated ore resources as U_3O_8 for the TCEA are 3,750,481 pounds (lbs) with an additional inferred estimate of 1,135,452 lbs. Total reserves are estimated at 4,900,000 lbs. The ore grade as U_3O_8 ranges from 0.05 to 0.5 percent with an average ore grade of 0.22 percent.

Hansley et al (1989) conducted detailed geochemical analysis of the CBR uranium ore to assess both ore genesis and composition. The CBR deposits, including Three Crow, are roll-type deposits with coffinite being the predominant uranium mineral species present. The origin of the uranium is rhyolitic ash, which is abundant within the matrixof the Basal Chadron. Coffinite is associated with pyrite, and high silica activity due to dissolution of the rhyolitic ash which favored formation of coffinite over uraninite in most parts of this sandstone. In addition, smectite is present in the samples examined, with the most common minerals in the sandstone being quartz, plagioclase, K-feldspar, coffinite, pyrite, marcasite, calcite, illite/smectite and tyuyamunite. The heavy mineral portion of the samples contained several minerals including those above as well as garnet, magnetite, marcasite, and illmenite. Vanadium was detected in the samples primarily as an amorphous species presumed to have originated from the in-situ ash. Hansley et al state that at least some uranium and vanadium remain bound to amorphous volcanic material and/or smectite rather than as discrete mineral phases.

Petrographic data obtained and examined by Hansley et al (1989) suggest that uranium mineralization occurred before lithification of the Basal Chadron. Hansley states: *"Dissolution of abundant rhyolitic volcanic ash produced uranium (U)- and silicon (Si)- rich ground waters that were channeled through permeable sandstone at the base of the Chadron by relatively impermeable overlying and underlying beds. The precipitation of early authigenic pyrite created a reducing environment favorable for precipitation and accumulation of U in the basal sandstone. The U has remained in a reduced state, as evidenced by the fact that the unoxidized minerals, coffinite and uraninite, comprise the bulk of the ore."*

Based on similar regional deposition, the TCEA ore body is expected to be similar mineralogically and geochemically to that of the CPF license area. The ore bodies in the two areas are within the same geologic unit (the Basal Chadron Sandstone) and have the same mineralization source. The sites are separated by only a few miles, and the cause of mineral deposition in the two areas appears to be similar. Neither site is anticipated to be significantly affected by recharge or other processes.

3.3.3 Structural Geology

Regional uplift during the Laramide Orogeny forced the southward retreat of the Cretaceous Interior Seaway, resulting in the subaerial exposure and weathering of rock units from Early Cretaceous to Eocene age across the northern Great Plains (including the Pierre Shale). The depositional basin associated with deformation of the Wyoming thrust belt and initial Laramide uplifts to the west of Nebraska, represented a structural foredeep. The greatest uplift occurred in the Black Hills, which lie north of Sioux and Dawes Counties in southwestern South Dakota. Lisenbee (1988) provides a comprehensive summary of the tectonic history of the Black Hills uplift. The pre-Oligocene Black Hills uplift (<37 Ma) occurred prior to the deposition of the Eocene-Oligocene strata of the White River Group. Strata of the White River Group cover most of the eroded roots of the Black Hills uplift as well as the syntectonic sedimentary rocks in the Powder River and Williston basins. The Hartville, Laramie, and Black Hills uplifts supplied sediment for rivers that flowed east-southeast across the study area (Clark 1975; Stanley and Benson 1979; Swinehart et al. 1985).

The most prominent structural expression in northwest Nebraska is the Chadron Arch (**Figure 3.3-13, Figure 3.3-13a**). Together with the Chadron Arch, the Black Hills Uplift produced many of the prominent structural features presently observed in the region. The Chadron Arch represents an anticlinal feature that strikes roughly northwest-southeast along the northeastern boundary of Dawes County. Swinehart et al. (1985) suggested multiple phases of probable uplift in northwestern Nebraska near the Chadron Arch between c.a. 28 Ma and <5 Ma. The only known surficial expressions of the Chadron Arch are outcroppings of Cretaceous rocks that predate deposition of the Pierre Shale in the northeastern corner of Dawes County, as well as in small portions of Sheridan County, Nebraska and Shannon County, South Dakota. The general locations of faults in northwest Nebraska are depicted on the State Geologic Map shown on **Figure 3.3-1**.

The CBR area, including the CPF license area, NTEA, and TCEA, lie in what has been named the Crawford Basin (DeGraw, 1969). DeGraw (1969) substantiated known structural features and proposed several previously unrecognized structures in western Nebraska based on detailed studies of primarily deep, oil test hole data collected from pre-Tertiary subsurface geology. The Crawford Basin was defined by DeGraw (1969) as a triangular asymmetrical basin about 50 miles long in an east-west direction and 25 to 30 miles wide. The basin is bounded by the Toadstool Park Fault on the northwest, the Chadron Arch and Bordeaux Fault to the east, and the Cochran Arch and Pine Ridge Fault to the south (**Figure 3.3-13**). The Crawford Basin is structurally folded into a westward-plunging syncline that trends roughly east-west. Note that the Bordeaux Fault, Pine Ridge Fault, and Toadstool Park Fault proposed by DeGraw (1969) are not presented on the State Geologic Map (**Figure 3.3-1**). The Toadstool Park Fault has been mapped at one location (T33N, R53W) and is estimated to have had approximately 60 feet of displacement (Singler and Picard 1980). The City of Crawford is located near the axis of the Crawford Basin. More recent fault interpretations by Hunt (1990) for northwest Nebraska are also shown on **Figure 3.3-13**, which include the Whetstone Fault, Eagle Crag Fault, Niobrara Canyon Fault and Ranch 33 Fault in the vicinity of the City of Harrison in Sioux County. The faults identified by Hunt (1990) all trend to the northeast-southwest, sub-parallel to the Pine Ridge Fault (**Figure 3.3-13**).

Former drilling activities at the CPF license area identified a structural feature referred to as the White River Fault located between the CPF Class III permit area and the NTEA (**Figure 3.3-13**). Evidence of a fault was identified during the exploration drilling phase of the CPF license area (Collings and Knode 1984). The fault is manifested in the vicinity of the NTEA as a significant northeast-trending, subsurface fold. The detailed kinematics of the White River Fault were investigated during preparation of the NTEA Petition for Aquifer Exemption. Based on an extensive review of drilling and logging data, it was determined that while the White River Fault may cut the Pierre Shale at depth along with stratigraphically lower units, there is no evidence that a fault offsets the geologic contact between the Pierre Shale and overlying White River Group nor individual members of the White River Group. This fault does not appear to be present in the vicinity of the TCEA.

3.3.3.1 Pine Ridge Fault

Approximately one mile south of the TCEA is the inferred Pine Ridge Fault, located along the northern edge of the Pine Ridge escarpment (**Figure 3.3-13**). The 230-mile long Pine Ridge escarpment exhibits an average of 1,200 feet of topographic relief (Nixon 1995). The Pine Ridge is an arc roughly concentric to the Black Hills Dome, which suggests an apparent structural relationship. The escarpment has been interpreted to represent the southern outermost cuesta of the Black Hills Dome (Nixon 1995). The escarpment is capped by sandstone of the Arikaree Group with exposed deposits of the White River Group mapped along the topographically lower, northern side of the escarpment.

The Pine Ridge Fault is inferred from several lines of evidence, though detailed studies are currently unavailable. The fault was initially proposed by DeGraw (1969) based on subsurface data. The fault trends east to west across both Sioux and Dawes Counties, is sub-parallel to the Cochran Arch, and has a reported north side down displacement of roughly 300 feet (**Figure 3.3-13**). Swinehart and others (1985) reported normal faulting along the feature that post-dates the deposition of the Upper Harrison beds of the Arikaree Group. This interpretation would confine that age of inferred fault slip to post-early Miocene.

Diffendal (1994) performed lineament analyses based on a mosaic of synthetic-aperture radar data of the Alliance, Nebraska area prepared by the USGS. Observed landforms and lineaments were reported to align well with known faults in the vicinity of Chadron. Lineaments in the radar image along Pine Ridge, located to the south of Chadron, are attributed to jointing or faulting and trend N40E and N50W (Diffendal 1982). Similar features are also noted west of Fort Robinson. Swinehart and others (1985) report that these features are likely an extension of the Whalen trend in Wyoming (Hunt 1981).

The Pine Ridge Fault, as inferred by DeGraw (1969), trends across the southeast corner of the 2.25-mile AOR at approximately 1.5 miles south of the TCEA permit boundary (**Figure 3.3-14**). Borehole data is sparse in the southern third of the AOR, making identification and characterization of the fault difficult. CBR geologists have reviewed the available drill data to determine the extent and impact of this fault on operations. Using the single point resistance on geophysical logs, the depth to the contact between the Pierre Shale and overlying Chadron Formation was determined. Cross sections have been prepared using this data to show the contact surface elevations.

Cross sections which transect the inferred location of the Pine Ridge Fault are shown in **Figure 3.3-14**. Because of the limited amount of drill data, four of the cross sections are located to the east of the TCEA boundary, but are significant in that they provide the closest spaced drill data available for fault characterization. Sections F-F', G-G', H-H' and I-I' are located approximately 5 miles, 2 miles, 1 mile and 0.5 miles east of the TCEA boundary respectively. Section J-J' along the western side of the TCEA, consists of boreholes that are widely spaced, particularly in the area of the proposed fault. Such widely spaced data makes definitive interpretation in this area difficult.

Cross section F-F' shown in **Figure 3.3-15a** provides the most reliable close spaced data for interpreting the fault. Located approximately five miles east of the TCEA, cross section F-F' consists of 20 boreholes along a 6.3-mile trend. The drill holes that comprise this cross section are located along the main axis of the current license area. Moving southward along F-F', this section shows a gentle rise in elevation from R-831 to E-19 that is likely a result of the presence of the Cochran Arch to the south (DeGraw, 1969). From E-19 to Wa-5, a decline of 63 feet is observed over a distance of approximately three quarters of a mile that is roughly in line with the Pine Ridge Fault inferred by DeGraw (1969). The 63 feet of potential displacement is well short of DeGraw's reported 300-feet. It is plausible that this decline may represent the eroded surface of the Pierre Formation prior to deposition of the overlying units. The top surface of the Pierre Shale rises southward from Wa-5 towards the Cochran arch.

Cross section G-G' shown in **Figure 3.3-15a** is located approximately 2 miles east of the TCEA and is comprised of nine drill holes along an approximately 9-mile traverse. Cross section G-G' shows a structural low at drill hole RSm-2 that is in line with the westward-plunging synclinal axis of the Inner Crawford Basin (Collings and Knode 1983). Similar structural lows have been observed in cross sections within the TCEA, which coincide with the thickest intervals of Basal Chadron Sandstone. Cross section G-G' does not show definitive evidence of faulting; however, the south end of the cross section does show a slight increase in elevation that is likely due to the presence of the Cochran Arch to the south.

Cross sections H-H' and I-I' shown in **Figure 3.3-15b** are located approximately 1.0 miles and 0.5 miles east of the TCEA boundary, respectively. These two sections show the Inner Crawford Basin structural low in the northern portions of the cross sections. The top surface of the Pierre Shale rises out of the basin at the northern end of the cross section and then decreases in elevation southward. The observed southward decrease in the top surface of the Pierre Shale does not match well with observations from cross sections to the east and west or with the concept of north side down displacement along the inferred Pine Ridge Fault. Due to the distance between drill locations along the southern extent of cross sections H-H' and I-I', potential errors in estimates of the top surface of the Pierre Shale, topographic lows on the eroded surface of the Pierre Shale, or flexing related to the Crawford Basin may account for the observed southward decrease in elevation. The Pine Ridge Fault, as inferred by DeGraw (1969), would be located in the vicinity of borehole C-7; however, there is no observed displacement in this location on the order of magnitude suggested by DeGraw (1969) (**Figure 3.3-14**).

Cross section J-J' shown in **Figure 3.3-15b** is the westernmost cross section that transects the inferred fault. This cross section is located along the western edge of the TCEA and extends nearly six miles southward. Similar to previously described cross sections, the north end of cross section J-J' shows the synclinal axis of the Inner Crawford Basin and the gradual rise in elevation southward. Due to sparse drilling data and distance between drill locations, the interpreted cause for the approximately 200 feet of elevation change between C-14 and C-27 is speculative. The elevation change may be due to the presence of the Pine Ridge Fault, the Cochran Arch, or both.

Based on the available information, the existence the Pine Ridge Fault within the AOR, as inferred by DeGraw (1969), cannot be confirmed. Furthermore, cross sections F-F' through J-J' do not substantiate the reported vertical displacement of 300 feet within the AOR. It is possible, however, that the displacement within the AOR was significantly less than reported. In general, available information for the top surface of the Pierre Shale in the vicinity of the inferred fault does indicate a rise in elevation to the south of the AOR. Given the magnitude of folding observed elsewhere in the Crawford Basin, it is entirely feasible that displacement along an inferred fault would not be required to explain these observations. In addition, the inferred fault, if present, is located well to the south of the TCEA permit boundary and would have minimal impact upon mining activities.

3.3.4 Seismology

3.3.4.1 National Seismic Hazard Maps and Risks

The USGS finalized an update of the National Seismic Hazard Maps in 2008, which includes changes to the methodology and mathematical equations it uses to model future earthquakes (Petersen 2008). The revised maps incorporate new seismic, geologic, and geodetic information on earthquake rates and associated ground shaking. The maps supersede versions released in 1996 and 2002. The National Hazard Maps show the distribution of earthquake shaking levels that have a certain probability of occurring in the U.S. (**Figure 3.3-16**). The hazard ranking ranges from the lowest hazard (0.4 %g) to the highest (64+ %g), with the City of Crawford area and the majority of Nebraska being located in a low hazard ranking level of 4 to 8 %g. The term "%g" is a unit of acceleration (movement of earth) measured in terms of gravity (g), i.e., acceleration due to gravity. Peak acceleration refers to the maximum acceleration (movement) experienced during a non-uniform earthquake event (i.e., starts off small, achieves a maximum and then decreases).

The seismic hazard map for Nebraska is shown in **Figure 3.3-17**, which shows the peak acceleration (%g) with a 2% probability of exceedance in 50 years for the State of Nebraska (USGS 2009a). The time of 50 years is the time interval for during which all possible earthquakes may occur to determine the shaking hazard. **Figure 3.3-17** also shows that the peak acceleration in the City of Crawford area of 6 to 8 %g for the majority of the immediate area, with some isolated areas of 8 to 10 %g. The 2% probability value means that there would be a 92% to 94% chance that shaking would not exceed the 6 to 8 %g values over a 50 year period, and a 90% to 92% chance that shaking would not exceed the 8 to 10 %g values over fifty years. Although this measurement is somewhat complex, it demonstrates that the Three Crow and City of Crawford area are at the low end of the USGS hazard ranking system for earthquake risks. Note that the difference between **Figure 3.3-16** and **3.3-17** as to the hazard ranking values are due to the use of different scales, i.e., 4 to 8 versus 6 to 8, respectively.

3.3.4.2 Earthquake Magnitude and Intensity

Earthquakes release different amounts of energy and the strength of this energy can be measured by *magnitude* and *intensity* (CDERA 2009). A comparison of the magnitude and intensity scales is shown in **Table 3.3-3** as well as the USGS abbreviated descriptions of the twelve levels on the

Modified Mercalli (MM) scale. The Richter Scale is used to measure the *magnitude* of an earthquake and is a measure of the physical energy released or the vibrational energy associated with the earthquake. In general, earthquakes below 4.0 on the Richter scale do not cause damage, and earthquakes below 2.0 usually can't be felt. However, earthquakes over 5.0 on the Richter scale can cause damage. An earthquake of a magnitude 6.0 is considered strong and a magnitude of 7.0 is considered a major earthquake.

The MM scale measures the *intensity* and consists of twelve increasing levels of intensity that range from imperceptible shaking to catastrophic destruction (USGS 2009b). It is an arbitrary ranking by the USGS based on observed effects rather than a mathematical basis.

For states in the U.S. that had reported earthquakes with a magnitude of 3.5 or greater from 1974 to 2003, the State of Nebraska had a total of 8 (less than 0.05 % of the total of 21,080 earthquakes occurring in the U.S) (USGS 2009d). **Figure 3.3-17** is a seismic hazard map of Nebraska (USGS 2009e). A seismicity map of Nebraska that shows the distribution of earthquakes from 1990 to 2006 is shown in **Figure 3.3-18**.

The first significant earthquake recorded in Nebraska occurred on April 24, 1867, apparently centered near Lawrence, Kansas. It affected an estimated area of 780,000 square kilometers including much of Nebraska. Since 1867 there have been at least seven earthquakes of Intensity V or greater originating within Nebraska boundaries. It is thought that the strongest earthquake in Nebraska occurred on November 15, 1877. The total area affected was approximately 360,000 square kilometers including most of Nebraska. The most recent earthquake occurred on March 20, 2010 (depth of 5 km), approximately 20 miles north of Ainsworth, NE in Brown County, north central Nebraska (lat. 42.83N long. 99.78W). The magnitude of this earthquake was 2.7 with an Intensity of I. The epicenter was approximately 180 miles east southeast of the City of Crawford.

<u>Earthquakes along the Chadron and Cambridge Arches in Western Nebraska</u>

The locations of the Chadron and Cambridge Arches in Nebraska are shown in **Figure 3.3-13a** (Stix 1982). Earthquakes that have occurred in Nebraska in the vicinity of the Chadron and Cambridge Arches from 1884 to 2009 are shown in **Table 3.3-4**. The MM Intensity of these earthquakes ranged from I to VI, with the majority between I and III. The strongest of these earthquakes centered in Dawes County occurred July 30, 1934 with an intensity of VI and was centered near Chadron. It affected an estimated area of approximately 60,000 square kilometers in Nebraska, South Dakota and Wyoming. This earthquake resulted in damaged chimneys, plaster, and china. An earthquake occurred on March 24, 1938 near Fort Robinson. This earthquake had an intensity of IV; no additional information is available. An Intensity IV earthquake should be felt indoors by many and cause dishes, windows, and doors to be disturbed. An earthquake occurred on March 9, 1963 near Chadron. This earthquake was reported to last about a second and was not accompanied by any damage or noise and was not even noticed by many of the residents of Chadron. An earthquake occurred on March 28, 1964 near Merriman. The vibrations from this earthquake lasted about a minute and caused much alarm but no major damage occurred. Books were knocked off shelves and closet and cupboard doors swung open. On May 7, 1978 an earthquake with Intensity V occurred in southwestern Cherry County, also near the Chadron Arch. No major damage was reported from this earthquake.

Earthquakes occurring from 1992 through 2009 within 125 miles of the City of Crawford, in Wyoming and South Dakota are shown in **Table 3.3-5**. The Richter Magnitude measurements ranged from 3.0 to 3.8 for Wyoming and 2.5 to 4.0 for South Dakota. The Modified Mercalli Intensity values for Wyoming ranged from II to IV, with all but one of the total 9 observations ranging from II to III. The Modified Mercalli Intensity values for South Dakota ranged from I to IV, with all but one of the total observations ranging from I to III.

Although the risk of major earthquakes in Dawes County and the State of Nebraska is low (Burchett 1990), some low to moderate tectonic activity has occurred (Rothe 1981). This tectonic movement is also suggested by geomorphic and sedimentation patterns during the Pleistocene (Rothe 1981), which reflect such movement. Previous seismic activity along the Cambridge Arch has been reported as possibly related secondary recovery of oil in the Sleepy Hollow oil field located in Red Willow County in southwest Nebraska (Rothe et al 1981). However, deeper events suggest more recent low level tectonic activity on the Chadron and Cambridge Arches.

Based on information discussed above, and the historical records for the proposed TCEA in northwest Nebraska, no major effects would be expected from earthquakes on in situ mining within the TCEA area.

3.3.5 Inventory of Economically Significant Deposits and Paleontological Resources

According to the Nebraska Oil and Gas Conservation Commission (NOGCC) there was no oil and gas production in Dawes County between 2004 and 2009. There are also no current applications for permits to drill in Dawes County. Two wells are currently producing in Sioux County, but are located at a significant distance southwest of TCEA in T25N, R55W and R56W (NOGCC 2010). The only non-fuel mineral produced in Dawes County is sand and gravel. Coal is not produced anywhere in Nebraska (Nebraska 2010), nor are coal beds expected to be encountered during drilling within the TCEA.

Significant fossil resources, particularly mammalian, are recognized from the Arikaree Group and White River Group in northwestern Nebraska (e.g., Hunt 1981, Terry and LaGarry 1998, Tedford et al. 2004). However, within the TCEA, the Arikaree Group is not present and sediments of the White River Group are typically buried by alluvium.

3.3.6 Soils

The CPF current license area and the TCEA are located in the semiarid northwest region of Nebraska. The majority of the proposed TCEA lies within Dawes County. The western-most portion of the TCEA is located in Sioux County. To the south lies the Pine Ridge, an area of rough steep terrain dissected by steep drainage ways. Vegetative cover in the Pine Ridge region is typically mixed grass and Ponderosa pine trees. South of the Pine Ridge is the Niobrara River drainage basin.

The TCEA is located within the White River watershed in an area dominated by flat or rolling topography – the Cherry Creek drainage is the most distinct topographic feature. Project area elevation is generally just below 4,000 feet above mean sea level. Climate is semiarid (precipitation averages from 16 to 18 inches per year), and natural vegetation is dominated by drought-tolerant short-grass prairie and areas of mixed-grass prairie, which have been replaced by agricultural crops across much of the project area.

An investigation of the TCEA soils included review of available published soils data and field sampling for radionuclide properties. Soils data for the TCEA was obtained from the United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS) Web Soil Survey. The sources for the Dawes County soils data available from the Web Soil Survey includes the Soil Survey of Dawes County, Nebraska, published in February 1977 (NRCS 1977), and updated unpublished materials derived from remote sensing images and other digitized soils mapping of Dawes County. The sources for the Sioux County soils available on the Web Soil Survey include the Soil Survey of Dawes County, Nebraska, published in 1998, and updated unpublished materials derived from remote sensing images and other digitized soils mapping of Sioux County. The following descriptions and classifications for soils in the TCEA were extracted from NRCS Web Soil Survey, which provided the results of a search for soils in the TCEA with a custom Soil Resource Report (NRCS 2010). Twenty-eight soil map units are identified in the project area. Their spatial distributions are illustrated in **Figure 3.3-19**, and their aerial extents summarized in **Table 3.3-6.**

Soils in the project area formed through the weathering of Tertiary bedrock material, loess (windblown silt), or unconsolidated alluvium. Most of the soils in the Three Crow area are weathered from the massive sandstones and interbedded siltstones and mudstones of the Miocene Arikaree Group, or a mixture of Arikaree sandstone and loess (NRCS 2009). Texturally, most soils in the project area are silt loams and very fine sand loams. Soils are generally deep or moderately deep, moderately well or well drained, and have a moderate rate of water transmission (SSS 2010).

Due to the silty or loamy texture of most soils in the TCEA, wind and water erosion pose the most significant risks to soil health and productivity. These soil textures also dictate the good drainage and high infiltration rates characteristic of most soils in the TCEA.

The Canyon-Bridget-Oglala soil association is the most extensive within the TCEA, making up approximately 35% of all soils and is found throughout the project area. Bridget series silt loams and very fine sandy loams make up about 70% of this association (25% of the total project area). The Canyon-Bridget-Oglala association contains "deep and shallow, moderately steep to very steep, well-drained loamy and silty soils that formed in colluvium and in material weathered from sandstone, on uplands and foot slopes". Areas of this association are mostly south of the TCEA along the Pine Ridge.

The second-most extensive soil unit is the Duroc very fine sandy loam (1 to 3 percent slopes; approximately 20% of the project area). The Duroc soil unit dominates the western portion of the project area. The Busher-Tassel-Vetal association makes up approximately 15% of the project area and is mainly found east of Cherry Creek and in the Sioux County portion of the project area. Alliance series silt loams also comprise approximately 15% of the project area and are mostly found in the central and eastern portions of the project area.

In certain areas, the soil material is so rocky, so shallow, so severely eroded or so variable that it has not been classified by soil series. These areas are called land types and are given descriptive names. An example of this is "sandy alluvial land" found within the Busher-Tassel-Vetal association.

One other minor soil association is found in the TCEA. The Kadoka-Keith-Mitchell association contains "deep, nearly level to steep, well drained silty soils that formed in loess and in material weathered from siltstones, on uplands and foot slopes". Typically this association consists of undulating to rolling uplands that are dissected by many spring-fed creeks. Areas of this association are mostly north of the TCEA near the White River.

3.3.6.1 Soil Limitations

The NRCS characterizes soil mapping units and their limitations for a variety of uses based on a wide range of properties such as soil texture, slope, clay content. In general, TCEA soils are moderately susceptible to water erosion, with K-factors of dominant soil map units ranging from 0.32 to 0.43. Hazards for wind erosion vary throughout the TCEA, but are generally moderate to moderately-high in the vicinity of Mine Units 1-4, high to moderate in Mine Units 5-9 and moderate to moderately low elsewhere. Almost all soils in the TCEA have severe or moderate limitations to their suitability as natural road surfaces and potential for rutting and compaction. However, all TCEA soils that are likely to be disturbed by project activities, except those in the immediate vicinity of Cherry Creek, are also considered to have high soil resiliency (i.e., inherent ability to recover degradation) and have high potential for successful restoration. The Tassel soils near Cherry Creek have moderate, or generally favorable, characteristics for restoration. Soils in the area proposed for evaporation ponds are moderately to severely limited in their suitability as pond reservoirs, due to seepage potential (SSS 2010).

3.3.6.2 Soils Range Classifications

Plant cover of soils in the TCEA depends upon the site condition. There are three major soils range classifications in the TCEA: limy range, sandy range, and silty range. Sites that are the most productive for forage are silty range.

The shallow limy range site classification in which Tassel (map units 5118, 6028 and 6036) and Canyon (map units 1742 and 5211) soils fall contains more alkaline soils as the name implies. Approximately 75 percent of climax plant cover is a mixture of decreaser grasses such as little bluestem, sand bluestem, side-oats grama, needle-and-thread, prairie sandreed, plains muhly and western wheatgrass. Perennial grasses, forbs and shrubs make up the remaining 25 percent. These increasers include blue grama, hairy grama, threadleaf sedge, fringed sagewort, common prickly pear, broom snakeweed, skunkbush sumac, and western snowberry.

Map units 5124, 5128, 5129, 5964, 6109, 6090, 5291, and 5292 are classified as sandy range sites. Moderately rapid to rapid permeability of the soils heavily influences vegetation types on these soils. A typical climax plant community is about 50 percent a mixture of decreaser plants such as sand bluestem, little bluestem, and prairie junegrass. The remaining 50 percent is perennial grass, forbs and shrubs. The principal increasers are blue grama, threadleaf sedge, prairie sandreed, needle-and-thread, sand dropseed, western wheatgrass, fringed sagewort and small soapweed. A site in poor condition will commonly have blue grama, threadleaf sage, sand dropseed and western ragweed.

Map units 5105, 5106, 5107, 1356, 1357, 1363, 1364, 5947, 1618, 1620, 1631, 5200, and 1862 are classified as silty range sites. The vegetation which grows on these sites is influenced mainly by the moderately slow or moderate permeability of the soils and by their moderate to high available water capacity. About 50 percent of the climax plant cover is a mixture of such decreaser grasses as big bluestem, little bluestem, side-oats grama, western wheatgrass, and prairie junegrass. About 50 percent consists of other perennial grasses, forbs, and shrubs. Blue grama, buffalograss, threadleaf sedge, needle-and-thread, Arkansas rose, and numerous forbs such as dotted gayfeather, false boneset, heath aster, skeletonplant, and scarlet globemallow are the principal increasers. A site in poor condition will typically have blue grama, buffalograss, threadleaf sedge, and sand dropseed.

3.3.6.3 Soil Mapping Units

As defined by the NRCS, a map unit is identified and named according to the taxonomic classification of the dominant soils. A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. **Table 3.3-6** summarizes the soils in map units found within the TCEA. The table provides the map unit symbols, map unit names, and estimated acres of the dominant soils in the TCEA. The descriptions of each soil mapping unit includes the potential for wind erosion, water erosion, the farmland classification, and the hydric rating. The farmland classification identifies map units as prime farmland, farmland of statewide importance, farmland of local importance, or unique farmland. The classification identifies the soils that are best suited to food, feed, fiber, forage, and oilseed crops. The hydric rating indicates the proportion of the map units that meets the criteria for hydric soils, which are an indicator for wetlands. The soils in the TCEA are also shown as soil map units in **Figure 3.3-19**.

Certain mapping units are composed of soil complexes or undifferentiated soil groups. A soil complex consists of areas of two or more soils so intricately mixed or so small in size that they cannot be shown separately on the soil map. Undifferentiated soil groups are made up of two or more soils that could be delineated individually but are shown as one unit because, for the purpose of the soil survey, there is little value in separating them. The name states the two dominant soil series represented in the group. Two of the mapping units within the TCEA belong to this category, where the names of dominant soils are joined by "and".

The following section describes the soil series and mapping units for those soils in Dawes and Sioux Counties, which occur within the TCEA as shown in **Figure 3.3-19**. The descriptions of soil map units that occur within the TCEA, as shown in **Figure 3.3-19** and listed in **Table 3.3-6** are extracted from the NRCS custom Soil Resource Report as provided by the NRCS Web Soil Survey.

<u>Glenberg Series Soils</u>

The Glenberg series consists of very deep, well drained soils that formed in stratified calcareous alluvium from mixed sources. Glenberg soils are on flood plains and low terraces. Slopes range from 0 to 8 percent. Organic content is moderate to low. Glenberg series soils are suitable for dry-farming and irrigated farming. Because they are restricted to steeper areas near drainages, only portions of the Glenberg soils within the TECA are currently cultivated. Glenberg soils found in the TCEA include the following:

1031 - Glenberg fine sandy loam, channeled, frequently flooded

This map unit is on flood plains on valleys and is dissected by meandering stream channels. The Glenberg, channeled, frequently flooded component makes up 100 percent of the map unit. Slopes are 0 to 2 percent.

The parent material consists of stratified calcareous alluvium. Depth to a root-restrictive layer is greater than 60 inches. It has a fine sandy loam surface layer and moderately rapidly permeable fine sandy loam underlying material. This soil is frequently flooded. It is not a hydric soil.

If the surface is not protected, the hazards of soil blowing and water erosion are slight on this soil. Runoff is negligible to low.

Alliance Series Soils

These soils are used primarily as pastureland and irrigated cropland. Nearly all the acreage for this soil is in native grass and is used for grazing. Because of the moderately steep slopes, this soil is better suited to grass than other uses. The soil is not considered prime farmland. Ecological classification is sandy lowland site.

The Alliance series consists of deep, well-drained soils that formed in material weathered from sandstone. The soils are on upland. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. About half the Alliance soils are cultivated and are suited to dry-farming and irrigation. Alliance soils found in the TCEA include the following:

5105 - Alliance silt loam, 1 to 3 percent slopes

This soil is mainly on smooth upland areas that are as large as 500 acres. This soil has the profile described as representative for the Alliance series. In some areas, lime is below a depth of 30 inches. The soil is partially hydric.

Included with this soil during mapping were small areas of Rosebud soils on high elevations, Duroc soils in swales, and Richfield soils.

If the surface is not protected, the hazards of soil blowing and water erosion are moderate on this soil. Runoff is slow.

Most areas of this soil are cultivated. Wheat, oats, and alfalfa are the principal crops. Wheat is the main cash crop. Nearly all the cropland is dry-farmed, but a few small areas are irrigated. Corn is the main irrigated crop. Areas in native grasses or areas that have been reseeded to tame grasses are used for grazing or for hay. This soil is prime farmland if irrigated. Range classification is silty range site.

5106 - Alliance silt loam, 3 to 9 percent slopes

This soil is located on upland areas that are as large as 300 acres. This soil has a profile similar to the one described for the Alliance series, but its surface layer is slightly thinner. In places a few small areas have a surface layer of very fine sandy loam, a few areas have a surface layer less than 7 inches thick, and in some areas lime is below a depth of 30 inches. The soil is partially hydric.

Included with this soil during mapping were a few areas of soils that have a surface layer of fine sandy loam. Areas of Rosebud soils that occupy higher positions on the landscape than this Alliance soil, Duroc soils in swales, and Keith soils were included, and they make up as much as 15 percent of some mapped areas.

Water erosion and soil blowing are the main hazards in cultivated areas. Runoff is medium.

Most of the acreage of this soil is in native grass, which is used for grazing or hay. This soil is suited to cultivation, but suitable management practices and cropping systems are needed to help control erosion. The soil is prime farmland if irrigated. Range classification is silty range site.

5107 - Alliance silt loam, 3 to 9 percent slopes, eroded

This soil is located on upland areas that are as large as 300 acres. This soil has a profile similar to the one described for the Alliance series, but about 50 percent of the area has a surface layer less than 7 inches thick. In places where the surface layer and the upper part of the subsoil have been mixed by cultivation, the surface layer is light silty clay loam. This soil includes areas where lime is at or near the surface, areas where the subsoil is thinner and less clayey than in the representative profile, and areas where the surface layer is light brownish gray or very pale brown. The soil is partially hydric.

Included with this soil in mapping were small areas of Duroc soils in swales and Rosebud, Oglala, Keith, and Bridget soils. In some areas outcrops of rock are common on knolls.

Water erosion and soil blowing are hazards if the soil surface is not protected. Runoff is medium.

Nearly all the acreage of this soil is cultivated. Winter wheat, alfalfa, and oats are the main crops. Areas of this soil are suited to irrigation, but steepness of slopes and a lack of irrigation water limit the development of irrigation. Some areas are seeded to native or tame grasses and are used for grazing or hay. The soil is prime farmland if irrigated. Range classification is silty range site.

Bridget Series Soils

The Bridget series consists of deep, well-drained soils that formed in loamy colluvial and alluvial sediment on foot slopes and on stream terraces. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. In areas where slopes are less than 9 percent, these soils are used mostly for cultivated dry-farmed crops. Bridget soils found in the TCEA include the following:

1356 - Bridget silt loam, 1 to 3 percent slopes

This soil is on foot slopes and stream terraces near large drainages. Areas are as much as 500 acres in size. This soil has the profile described as representative for the Bridget series. In places the surface layer is light brownish gray; in other places lime is at a depth of 20 to 42 inches; and in still other places buried soils are below a depth of 24 inches.

Included with the soil in mapping were areas of soils that occupy slightly higher positions than this Bridget soil. The soils have a surface layer or transitional layer of fine sandy loam. Bayard soils, mainly at higher elevations, were included, and they maker up as much as 15 percent of some mapped areas. The soil is partially hydric.

Water erosion or gullying are hazards in areas that receive runoff from adjacent slopes. Soil blowing is a hazard if soil surface is unprotected. Runoff is slow to medium.

Nearly all areas of this soil are dry-farmed to wheat, oats, or alfalfa. Areas in native grass are used for grazing or hay. The soil is prime farmland if irrigated. Range classification is silty range site.

1357 - Bridget silt loam, 3 to 9 percent slopes

This soil is on colluvial foot slopes on upland areas that are up to 200 acres in size. This soil has a profile similar to the one described as representative for the Bridget series, but its surface layer is slightly thinner. In some areas the surface layer is more than 20 inches thick; in other areas the surface layer is very fine sandy loam; and in still other areas the surface layer is light brownish gray to pale brown. In places lime is below a depth of 20 inches. The soil is partially hydric.

Included with this soil in mapping were soils in higher areas than this Bridget soil that have a surface layer of fine sandy loam. Some areas of Bayard, Keith or Rosebud soils in the Pine Ridge make up as much as 25 percent of the mapped areas. A few areas of Rock outcrop were also included.

Water erosion is a hazard because of runoff received from adjacent higher areas. Soil blowing is a hazard if the soil surface is unprotected. Runoff is medium.

About half of the acreage of this soil is in native grass and is used for range. Cultivated areas are dry-farmed to wheat, oats, or alfalfa. A small acreage is seeded to tame grasses and is used for grazing and hay. The soil is prime farmland if irrigated. Range classification is silty range site.

1363 - Bridget very fine sandy loam, 3 to 6 percent slopes

This mapping unit is found in the Sioux County portion of the TCEA. This unit is on hillslopes or uplands. The Bridget component makes up 100 percent of the map unit. Slopes are 3 to 6 percent. The parent material consists of loamy colluvium. Depth to a root-restrictive layer is greater than 60 inches. The soil is well drained. Runoff is slow to rapid depending on the degree of slope. Permeability is moderate. Shrink-swell potential is low. This very deep, gently sloping, well drained soil has a very fine sandy loam surface layer and moderately permeable, calcareous very fine sandy loam underlying material. The soil is not hydric.

The soil has a very high potential for water erosion. Soil blowing is a hazard if the soil surface is unprotected. Runoff is medium.

Most Bridget soils are produce winter wheat. Some areas are irrigated corn, sugar beets, potatoes, dry beans and alfalfa. The soil is prime farmland if irrigated. The steeper areas are in native grasses used for grazing. Range classification is silty range site.

1364 - Bridget very fine sandy loam, 6 to 9 percent slopes

This mapping unit is found only in the Sioux County portion of the TCEA. Detailed information for the mapping unit was not available to CBR, but the soil series information should provide adequate information for the purposes of this amendment application.

Busher Series Soils

The Busher series consists of deep, well-drained to somewhat excessively drained soils that formed in material weathered from sandstone. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility is medium to low, and organic matter content is moderate. Busher soils are mostly in native grasses. Busher soils found in the TCEA include the following:

5124 - Busher loamy very fine sand, 1 to 6 percent slopes, eroded

This soil is on uplands. Areas are as much as 200 acres in size. This oil has a profile similar to the one described as representative for the Busher series, but its surface layer is 4 to 7 inches thick and is light brown to light brownish gray. In places lime is at a depth of 12 to 18 inches. The soil is partially hydric.

Included with this soil in mapping were areas of soils that have a surface layer if fine sandy loam and areas where bedrock is at a depth of 20 to 36 inches. Also included were areas of Bridget, Jayem, or Vetal soils, which make up as much as 15 percent of the mapped areas. Tassel soils, on ridgetops and knolls, were included, and they make up as much as 35 percent of the mapped areas.

Water erosion and soil blowing are severe hazards on this soil. Moderately rapid permeability and moderate available water capacity make this soil droughty. Runoff is slow.

Nearly all areas of this soil are cultivated and dry-farmed. Wheat, alfalfa, and oats are the principal crops. The soils are designated as farmland of statewide importance. A few areas are seeded to grass, which is used for grazing or hay. Range classification is sandy range site.

5128 - Busher loamy very fine sand, 6 to 9 percent slopes, eroded

This soil is on uplands. Areas are as much as 100 acres in size. This soil has a profile similar to the one described as representative of the Busher series, but its surface layer is 4 to 7 inches thick. In areas of this soil on middle and upper parts of slopes the surface layer is brown to light brownish gray. In places lime is at a depth of 10 to 18 inches. The soil is partially hydric.

Included with this soil in mapping were areas of soils that have a surface layer of fine sandy loam and areas where bedrock is at a depth of 20 to 36 inches. Jayem, Bridget, and Vetal soils were included, and they make up as much as 15 percent of some mapped areas. Small areas of Rock outcrop and Tassel soils on high elevations were also included.

Soil blowing and water erosion are serious hazards. Fertility is low. This soil is somewhat droughty. Runoff is medium.

Nearly all areas of this soil are dry-farmed. Wheat, alfalfa, and oats are the main crops. The soil is not prime farmland. A few areas are seeded to grass, which is used for grazing or hay. Range classification is sandy range site.

5129 - Busher loamy very fine sand, 9 to 20 percent slopes

This soil is on uplands. Areas are as much as 200 acres in size. This soil has the profile described as representative of the Busher series. In some areas the surface layer is 3 to 7 inches thick and lime is at a depth of less than 18 inches. The soil is not hydric.

Included with this soil in mapping were areas of soils that have a surface layer of fine sandy loam; areas of soils that have a surface layer of fine sandy loam; and areas where bedrock is at a depth of 20 to 36 inches. Jayem, Bridget, Tassel or Vetal soils make up as much as 15 percent of some mapped areas. Small areas of Rock outcrop and Tassel soils on high elevations were also included.

Soil blowing and water erosion are serious hazards if the native grass cover is removed from this soil. Conserving soil moisture is a major concern of management. Runoff is medium.

Nearly all areas of this soil are in native grass, which is sued for grazing or for hay. A small acreage is cultivated along with areas of less sloping soils. The hazard of erosion and steepness of slope make this soil unsuited to cultivation. The soil is not prime farmland. Most areas that were once cultivated have been seeded to native or tame grasses and are now used for grazing or hay. Range classification is sandy range site.

5118 - Busher and Tassel loamy very fine sands, 6 to 20 percent slopes

This mapping unit is on uplands. Slopes are mostly 9 to 20 percent, but range from 6 to 20 percent. Areas are as much as 100 acres in size. Busher loamy very fine sand makes up about 60 percent of this unit, and Tassel loamy very fine sand makes up about 40 percent. A delineated area, however, can contain either one or both of these soils. Busher soils are on the middle and lower part of the slopes, and Tassel soils are on ridgetops, knolls, and sides of small drainages. The soil is not hydric.

In places Busher soils have a surface layer that is less than 7 inches thick and that is brown to light gray. Included in mapping were areas where bedrock is at a depth of 20 to 36 inches. Bridget, Jayem, and Vetal soils and small outcrops of sandstone were included, and they make up as much as 15 percent of some mapped areas.

Soil blowing and water erosion are serious hazards if the native grass cover is removed from this soil. Runoff is medium.

Some areas of this mapping unit are in native grass. Most are used for grazing, and some are cut for hay. The soils are generally not suited to cultivation. The soil is not prime farmland. Classification of Busher soil is sandy range site and Tassel soil is shallow loamy range site.

Duroc Series Soils

The Duroc series consists of deep, well-drained soils that formed in colluvial or alluvial materials derived mostly from loess and weathered sandstone. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. Duroc soils are well suited to cultivation and irrigation. Duroc soils found in the TCEA include the following:

5947 - Duroc very fine sandy loam, 1 to 3 percent slopes

This map unit is found in upland swales and on stream terraces. Areas are as much as 300 acres in size. In some areas the surface layer is silt loam. Included in mapping were areas of soils that have a surface layer of fine sandy loam or loamy very fine sand. Also included were small areas of Alliance, Bridget, Keith, Richfield, and Rosebud soils, all generally on slightly higher elevations. Inclusions make up less than 15 percent of the mapped areas. The soil is partially hydric.

In some places, this soil receives additional moisture from adjacent areas. Runoff is slow.

Much of the acreage of this soil is cultivated. It is suited to irrigation but is mostly dry-farmed to wheat, oats, and alfalfa. The soil is prime farmland if irrigated. The rest of the acreage is in native and tame grasses, which are used for grazing or for hay. Range classification is silty range site.

Jayem Series Soils

The Jayem series consists of deep, well-drained to somewhat excessively drained soils that formed in eolian sands. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility is medium, and organic matter content is moderate. Jayem soils are suited to both dry-farmed and irrigated crops. Jayem soils found in the TCEA include the following:

5964 - Jayem and Vetal loamy very fine sands, 6 to 9 percent slopes

This mapping unit is on uplands and foot slopes. The areas are as much as 300 acres in size. Jayem and Vetal soils each make up about 50 percent of the acreage of this mapping unit. The areas, however, can contain either one or both of the soils. Jayem soils are on the upper part of side slopes and on ridgetops. Vetal soils are on the lower part of side slopes and in swales. The soil is not hydric.

Included with this mapping unit were areas of soils that have a surface layer of loamy fine sand and areas where lime is at a depth of 10 to 36 inches. Also included and making up as much as 15 percent of some mapped areas were Busher and Tassel soils and Sarben soils that occupy high positions.

Water erosion is a hazard in cultivated areas. Soil blowing is a hazard if the soil surface is not protected. These soils are easy to work. Runoff is slow to medium.

Most areas of these soils are in native grasses, which are used for grazing and for hay. A small acreage is cultivated to wheat, alfalfa, and oats. These soils are suited to irrigation. The soil is not prime farmland. Range classification is sandy range site.

Keith Series Soils

The Keith series consists of deep, well-drained soils that formed in loess. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. Keith soils are suited to both dry-farmed and irrigated crops. Keith soils found in the TCEA include the following:

1618 - Keith silt loam, 1 to 3 percent slopes

This soil is on uplands. Areas are as much as 500 acres in size. This soil has a profile similar to the one described as representative for the Keith series, but its subsoil is thicker. In some places the A horizon is loam or very fine sandy loam and is 3 to 7 inches thick. In places lime is at a depth of 12 to 18 inches. Dark-colored buried soils are common. The soil is no hydric.

Included with this soil in mapping were areas of soils that have a surface layer of fine sandy loam. Also included were small areas of Alliance soils, Duroc soils in swales, and Richfield soils.

Water erosion is a hazard in some areas, but soil blowing is the main hazard. These soils are easy to work. Runoff is slow.

This soil is used for both crops and range. Winter wheat, alfalfa, and oats are the principal dry-farmed crops. A few small areas of alfalfa are irrigated. The soil is prime farmland if irrigated. Some areas are in grass, which is used for hay or for grazing. Range classification is silty range site.

1631 - Keith silt loam, 3 to 9 percent slopes

This soil is on ridges and side slopes. Areas are as much as 300 acres in size. This soil has the profile described as representative for the Keith series. In some areas the surface layer is loam of very fine sandy loam. The soil is partially hydric.

Included with this soil in mapping are areas of higher soils that have a surface layer of fine sandy loam. Also included were areas of Duroc soils in swales and Kadoka variant, Richfield, and Ulysses soils, which generally make up less than 20 percent of the mapped area.

Water erosion is a hazard in cultivated areas. Soil blowing is a concern in management. Runoff is medium.

A small acreage of this soil is used for crops, but most areas are in native grass and are used for grazing or hay. Wheat and alfalfa are the main cultivated crops, and some oats are grown. The soil is prime farmland if irrigated. Range classification is silty range site.

Oglala Series Soils

The Oglala series consists of deep, well-drained soils that formed in material weathered from fine-grained sandstone. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. Oglala soils are suited to native grasses. Oglala soils found in the TCEA include the following:

5200 - Oglala loam, 9 to 30 percent slopes

This soil is on hillsides. Areas are as much as 200 acres in size. This soil has the profile described as representative for the Oglala series. Included in the mapping were areas of soils that have a surface layer 3 to 6 inches thick; areas of soils that have a surface layer of fine sandy loam to loamy very fine sand; and areas where lime is at a depth of less than 20 inches. The soil is not hydric. Also included were areas of eroded soils that have a pale brown to very pale brown surface layer. Areas of Bridget, Canyon, and Rosebud and Ulysses soils were also included and make up as much as 15 percent of some mapped areas.

Soil blowing and water erosion are hazards if the soil surface is not protected. Runoff is medium to rapid, depending on the gradient of the slope and the kind and amount of cover.

Nearly all the acreage off this soil is in native grass. A few areas are seeded to tame grasses. This soil is unsuited to cultivation because of steepness of slopes. The soil is no designated prime farmland. Range classification is silty range site.

5211 - Oglala-Canyon loams, 9 to 20 percent slopes

The soils in this unit are on the side slopes and on ridges and knolls. Each area is about 60 to 75 percent Oglala soils and 25 to 40 percent Canyon soils. The areas are as much as 1,000 acres in size. The Oglala soils are on the middle and lower part of the side slopes, and the Canyon soils are on the tops of ridges and knolls.

In some areas the soils have a light brownish-gray surface layer, and in other layers lime is at a depth of less than 20 inches. The soil is not hydric. Included in mapping were small areas of Bridget, Duroc, Keith, Rosebud, and Ulysses soils, which make up less than 25 percent of the mapped areas. Fragments of sandstone are on the surface in some areas.

Water erosion is a hazard if the cover of native grass is removed from these soils. Wind erosion presents a moderately load hazard. Runoff is medium to rapid, depending on the gradient of the slope and the kind and amount of vegetation.

Nearly all the acreage of this unit is in native grass and is used mostly for grazing. Nearly all of the areas that were cultivated have been seeded to grass. These soils are not suited to cultivation. They are not designated prime farmland. Classification of Oglala soil is silty range site and Canyon soil is shallow limy range site.

Rosebud Series Soils

The Rosebud series consists of moderately deep, well-drained soils that formed in material weathered from sandstone. Permeability is moderate, and available water capacity is moderate.

Natural fertility is medium, and organic matter content is moderate. Rosebud soils are suited to both dry-farmed and irrigated crops. Rosebud soils found in the TCEA include the following:

1742 - Rosebud-Canyon loams, 3 to 9 percent slopes

This mapping unit is on gently rolling and rolling uplands. Areas are as much as 500 acres in size. Rosebud loam makes up about 50 to 70 percent of each mapped area. Canyon loam 15 to 30 percent, and other soils 10 t0 25 percent. The Rosebud soils are on side slopes, and the Canyon soils are on ridgetops and knolls. The Rosebud soils have a profile similar to the one described as representative for the Rosebud series, but their surface layer is loam. The soils are partially hydric. The Canyon soils have a profile similar to the one described as representative for the Canyon series. Included in the mapping were areas of Alliance, Bridget, Duroc, Keith, and Oglala soils.

If the soils are cultivated, water erosion and soil blowing are hazards. In some places erosion has removed a part of the surface layer, and tillage has mixed the material remaining in the surface layer with that from the subsoil. In places small areas of Canyon soils on low ridgetops and knolls are cultivated along with deeper soils. In such areas the Canyon soils are easily recognized because of their whitish color and sandstone fragments on the surface. Runoff is medium.

A large acreage of this mapping unit is cultivated. Dry-farmed wheat, alfalfa and oats are the principal crops. The soils are not designated prime farmland. The rest of the areas are in native grass, which is used for grazing or hay. Classification of Rosebud soils is silty range site and Canyon soils are shallow limy range site.

Sarben Series Soils

The Sarben series consists of deep, well-drained soils that formed in wind-deposited sands. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility is medium to low, and organic matter content is low. Sarben soils are suited to both dry-farmed and irrigated crops. Sarben soils found in the TCEA include the following:

6109 - Sarben loamy very fine sand, 9 to 30 percent slopes

This mapping unit is found only in the Sioux County portion of the TCEA. The Sarben component makes up 100 percent of the map unit. Slopes are 9 to 30 percent. This component is on hillslopes on uplands.

The parent material consists of sandy and loamy eolian deposits. Depth to a root-restrictive layer is greater than 60 inches. The soil is well drained, and has a low shrink-swell potential. The soil is not hydric.

Soil blowing and water erosion are serious hazards if the soil surface is not protected. Runoff is low to rapid, depending on the gradient of the slope and the kind and amount of cover.

Nearly all the acreage of this unit is in native grass and is used mostly for grazing. These soils are suited to cultivation of wheat crops. They are not designated prime farmland soils. Range classification is sandy range site.

Tassel Series Soils

The Tassel series consists of shallow, well-drained soils that formed in material weathered from fine-grained sandstone. Permeability is moderately rapid, and available water capacity is very low. Natural fertility and organic matter content are low. Tassel soils are suited to range and to habitat for wildlife. Tassel soils found in the TCEA include the following:

6028 - Tassel soils, 3 to 30 percent slopes

These soils are on ridges and knolls and the sides of upland drainages. Areas are as much as 500 acres in size. These soils have a profile similar to the one described as representative for the Tassel series, but the surface layer is fine sandy loam, loamy very fine sand, or loamy sand. Included in the mapping were areas where sandstone is at a depth of 20 to 40 inches, areas where sandstone is at a depth of 4 to 10 inches, and areas of soils that have a surface layer of loam and very fine sandy loam. Small outcrops of sandstone are included. Also included were areas of Bayard, Busher, Canyon, Jayem, and Sarben soils, which make up as much as 20 percent of some mapped areas. Tassel soils are not hydric.

Soil blowing is a hazard if the grass cover is destroyed. These soils tend to be droughty because the available moisture capacity is low. Conserving moisture is a concern of management. Runoff is slow to rapid, depending on the degree of slope and the kind and amount of vegetation.

Nearly all the acreage of this mapping unit is in native grass and is used for grazing. Steepness of slope and shallow depth to bedrock make Tassel soils unsuited to cultivation. Where these soils occur in areas of deeper soils, they are cultivated along with those soils. Areas of Tassel soils in cultivated areas are easily recognizable by their light color and coarse sandstone fragments on the surface. The soils are not designated prime farmland. Range classification is shallow limy range site.

6036 - Tassel-Busher-Rock outcrop complex, 6 to 30 percent slopes

This mapping unit is found only in the Sioux County portion of the TCEA. Tassel soils are shallow, strongly sloping to very steep, somewhat excessively drained, loamy soils formed in weathered sandstone and eolian material on uplands. Busher soils are deep, strongly sloping to steep, well- to somewhat excessively drained, loamy soils formed in eolian material and weathered sandstone on uplands;. Rock outcrops are very shallow, very steep, excessively drained, weathered sandstone on uplands. All soils in the complex are well drained, with a low shrink-swell potential.

The soils have a very high potential for wind and water erosion. Runoff is medium to rapid, depending on the gradient of the slope and the kind and amount of cover.

This soil is unsuited to cultivation because of steepness of slopes. The soil is not designated prime farmland. Range classification is shallow limy range site.

Ulysses Series Soils

The Ulysses series consists of deep, well-drained soils that formed in loess on uplands. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. Where slopes are less than 9 percent, Ulysses soils are suited to both dry-farmed and irrigated crops. Ulysses soils found in the TCEA include the following:

1862 - Ulysses silt loam, 9 to 20 percent slopes

This soil is on uplands. Areas are as much as 200 acres in size. This soil has the profile described as representative for the Ulysses series. In some areas the surface layer is loam or very fine sandy loam, in other areas lime is below a depth of 16 inches, and in still other areas the surface layer is less than 7 inches thick. The soil is not hydric

Included with this soil in mapping were areas of soils that occupy slightly higher positions on the landscape than this Ulysses soil. The soils have a surface layer of fine sandy loam. Duroc soils in swales and Oglala, Bridget, and Mitchell soils were included. These areas make up as much as 15 percent of some mapping areas.

Water erosion is a very severe hazard if the grass cover is destroyed. Wind erosion presents a moderately low hazard. Runoff is medium.

Nearly all the acreage for this soil is in native grass and is used for grazing. In a few places, the grass is cut for hay. Because of the moderately steep slopes, this soil is better suited to grass than other uses. The soil is not designated prime farmland. Range classification is silty range site.

Vetal Series Soils

The Vetal series consists of deep, well-drained soils that formed in sandy alluvium and colluvium on foot slopes in upland swales. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility is medium, and organic matter content is moderate. Where slopes are less than 9 percent, Vetal soils are suited to both dry-farmed and irrigated crops. Vetal soils found in the TCEA include the following:

5291 - Vetal very fine sandy loam, 1 to 3 percent slopes

This mapping unit is found in the Sioux County portion of the TCEA on upland swales. The Vetal component makes up 99 percent of the map unit. Slopes are 1 to 3 percent. The parent material consists of loamy alluvium over eolian deposits. Depth to a root-restrictive layer is greater than 60 inches. These soils well drained. Permeability is moderately rapid. Shrink-swell potential is low. The soil is partially hydric.

The potential for water erosion is very low. Soil blowing potential is high if the soil surface is not protected. Surface runoff is slow to medium.

These soils are primarily used as native rangeland and hayland. Some areas produce small grains, corn, alfalfa, and sorghum. The soils are designated as prime farmland if irrigated. Native vegetation includes blue grama, needle-and-thread, prairie sandreed, big bluestem, little bluestem, and western wheatgrass.

5292 - Vetal very fine sandy loam, 3 to 6 percent slopes

This mapping unit is found in the Sioux County portion of the TCEA. This unit is on hillslopes on uplands. The Vetal component makes up 99 percent of the map unit. Slopes are 3 to 6 percent. The parent material consists of loamy alluvium over eolian deposits. These soils well drained. Surface runoff is medium. Permeability is moderately rapid. Shrink-swell potential is low. The soil is partially hydric.

The potential for water erosion is very low. Soil blowing potential is high if the soil surface is not protected.

These soils are primarily used as native rangeland and hayland. Some areas produce small grains, corn, alfalfa, and sorghum. These soils are designated as prime farmland if irrigated. Native vegetation includes blue grama, needle-and-thread, prairie sandreed, big bluestem, little bluestem, and western wheatgrass.

9903 – Fluvaquents, sandy, frequently flooded

The Fluvaquents, frequently flooded component makes up 100 percent of the map unit. Slopes are 0 to 1 percent. This component is on flood plains on valleys. The parent material consists of silty alluvium. The soil is very poorly drained, and is frequently flooded and ponded. These soils are hydric.

The potential for water erosion is very low. Soil blowing potential is moderate if the soil surface is not protected.

The soils are not designated as prime farmland. As hydric soils, Fluvaquents typically support a mix of floating (when submerged) and emergent hydrophytic vegetation such as cattails, sedges, rushes, and algae. Due to frequent flooding, these soils are not utilized for agriculture.

3.4 Water Resources

3.4.1 Water Use

3.4.1.1 Dawes County Water Use

Every five years since 1950 the USGS has assessed U.S. water use (USGS 2009) and includes water-use estimates for the State of Nebraska. For Nebraska water-use data, the USGS works in cooperation with the Nebraska Department of Natural Resources (NDNR). The latest study examines usage in 2005. These USGS water use reports are generated every five (5) years, with 2005 being the most recent data compilation. The 2005 USGS report presents water usage in each state by county. The next report will be issued in 2010.

Estimated water use in 2005 for Dawes County, Nebraska is presented in **Table 3.4-1** (USGS 2005). The total 2005 population for Dawes County was 8,636 people, with public supply groundwater and surface water use totaling 2.59 million gpd (Mgal/da). Irrigation utilizing groundwater and surface water accounted for a total of 24.55 Mgal/da to irrigate an estimated 13 thousand acres.

A summary of the number and types of registered non-abandoned water wells located in Dawes County as of February 18, 2010, is presented in **Table 3.4-2.** Note this table refers to registered wells. Under current Nebraska law, water supply wells used solely for domestic purposes and completed prior to September 09, 1993, do not have to be registered (NRS 2008). Therefore, there are a number of domestic/agricultural and agricultural unregistered wells located in Dawes County. CBR identifies such wells through interviews with landowners and local drillers.

There are a total of 5,512 registered water wells in Dawes County used for a variety of purposes, as described in **Table 3.4-2**. According to the NDNR, there are a total of 226 domestic and 224 livestock wells located in Dawes County. There are 37 public water supply wells located in Dawes County (NDNR 2010a). Domestic and livestock water wells make up the majority of the wells identified in the TCEA.

3.4.1.2 City of Crawford Community Water Supply

Public Water Supply Description

The White River and associated tributaries indirectly supply some of the drinking water to the City of Crawford citizens via an infiltration gallery. The City of Crawford municipal water system, which consists of this infiltration gallery (850 gpm), is also supplied by two water supply wells (**Table 3.4-3**) (City of Crawford 2010a; NDHHS 2010). These wells have an average depth of 100 feet. The water system has a pumping capacity of 155 gallons per minute (gpm) and serves approximately 90 percent of the city population of 1,028 (City-Data.com 2010). The overhead storage capacity is 1,750,000 gallons and the raw water storage is 500,000 gallons. The average daily demand is 250,000 gallons, with a historic peak daily demand of 1,000,000 gallons. The system has a maximum capacity of 2,830,000 gpd. The static pressure is 58 pounds per square inch and the residual pressure is 25 pounds per square inch. The city rapid sand filters water treatment plant has a daily capacity of 1,500,000. Additional information regarding the City of Crawford water system is summarized in **Table 3.4-4** (Teahon, L. 2007, Teahon, L. and Grantham, R. 2010, City of Crawford 2010a).

Based on the Crawford Municipal Water Conservation Plan (Spring 2003), the average per capita water use in 2002 (including residential and business customers; public facilities including parks etc.; and water lost to system leaks) was 323 gpd.

Wellhead Protection Area

The City of Crawford has a designated wellhead protection area and adopted controls pursuant to the Nebraska Wellhead Protection Area Act (Nebraska Revised Statutes § 46-1501 – 46-1509) for the purpose of protecting the public water supply system. The boundaries of the Wellhead Protection Area (WHPA) are described in the City of Crawford Ordinance 575 [May 10, 2005] (City of Crawford 2010b). The area includes 960 acres in Sections 15, 16, 21 and 22 of T31N R52W, Dawes County. The WHPA boundary is shown in **Figure 3.4-1**. There are two public water supply wells located within the designated WHPA (Wells 454 and 455). The minimum allowable horizontal distance in feet separating a city water supply well from potential sources of contamination are listed in **Table 3.4-5**.

As shown in **Figure 3.4-1**, the nearest point of the northern TCEA permit boundary to the nearest boundary of the City of Crawford WHPA is approximately 4,500 linear feet (approximately 0.85 mile). The City's Well W-454 within the WHPA boundary, the closest well to the TCEA permit boundary, is located approximately 9,600 feet (approximately 1.82 miles) from the nearest TCEA permit boundary. Therefore, all proposed assets within the TCEA boundary that could be affected by constraints in **Table 3.4-5** are located at a distance of over 4-times the minimum allowed distances separating the city water supply wells from other water wells, including but not limited to domestic supply wells, irrigation wells, and stock wells. Therefore, operations at the TCEA would not be expected to impact the city WHPA.

3.4.1.3 Three Crow Project Area

The TCEA lies within the watersheds of Bozle Creek, Cherry Creek, and the eastern portion of Dead Man's Creek, which are small southern tributaries to the major regional water course, the White River **(Figure 3.4-3, Figure 3.4-4)**. These creeks originate in the Pine Ridge south of the TCEA. From the headwaters, these creeks drain north over range and agricultural land to the White River. Contributions to flow come from springs in the Arikaree Group, snowmelt, runoff and the shallow Brule sands. The latter may receive inflow from the creek during periods of high flow. Due to the time variable nature of these water sources, discharges at various points along the creeks may experience wide fluctuations on a month to month and yearly basis.

The White River is used to support agricultural production, wildlife habitat, and both warm- and cold-water aquatic life. For the period of record from 1931 to 1991, USGS data (USGS 2004) indicate that the average monthly mean flow ranged from 6.3 to 122 ft^3/sec, with a mean value of 20.4 ft^3/sec. Based on data from the NDNR (NDNR 2010b), for the White River at the City of Crawford, the flow of the White River from 1999 to 2007 ranged from 4.1 to 21.9 ft^3/sec, with an annual mean of 20.2 ft^3/sec. Average flow measurements by the NDEQ for this sampling location from 2003 to 2009 averaged approximately 20.6 ft^3/sec (Lund 2010). Historical extremes related to flow in the White River are discussed in Section 3.4.2.3.

The Crawford National Fish Hatchery formerly was located near Crawford City Park, adjacent to the White River.

No surface water impoundments are located within the TCEA. There are four impoundments located within the AOR **(Figure 3.4-4)**. The Grabel Ponds (identified as one pond), Cherry Creek Pond and Ice House Pond are located on the Fort Robinson State Park. The Sulzbach Pond is located on private property. These surface ponds are discussed in Section 3.4.2.2.

In general, groundwater supplies in the vicinity of the TCEA are limited due to topography and shallow geology (University of Nebraska-Lincoln 1986). Groundwater quality within the White River drainage generally is poor (Engberg and Spalding 1978). Locally, groundwater is obtained at limited locations from shallow alluvial sediments. The primary groundwater supply is the Brule Formation, typically encountered at depths from approximately 30 to 200 feet, with the exception of locations where the overlying alluvium is not present. In general, the static water level for Brule Formation wells in the TCEA ranges from 30 to 80 feet below ground surface (bgs), depending on local topography **(Figures 3.3-3a through 3.3-3e and 3.4-8)**. Groundwater from the underlying Basal Chadron Sandstone aquifer is not used as a domestic supply within the TCEA because of the greater depth (580 to 940 feet bgs) and inferior water quality. Gosselin et al. (1996) state that: (1) "*the sands near the bottom of the Chadron Formation yield sodium-sulphate water with high total dissolved solids,*" and (2) in proximity to "*uranium deposits in the Crawford area, groundwater from the Chadron Formation is not suitable for domestic or livestock purposes because of high radium concentrations.*"

In addition, it is economically impractical to install water supply wells into the deeper Basal Chadron Sandstone in the vicinity of the TCEA, in contrast to the vicinity of the NTEA where most Basal Chadron Sandstone wells either flow at the surface or have water levels very close to surface elevation because of artesian pressure.

Based on National Groundwater Association website (NGWA 2004), average water use for rural (domestic) wells in Nebraska is approximately 380 gpd. Assuming an average family size of four persons, this correlates well with data from USGS who suggest an average per capita use on the order of 97 gpd (USGS 1999). Since there is only one residence located within the proposed TCEA (NW1/4 SE1/4 Section 29, T31N R52W), water use would be expected to use an average of 380 gpd. Since there are twenty-three occupied residences within the 2.25-mile AOR, water use would be expected to average about 8,740 gpd for the entire area.

A summary of groundwater quality data collected in 2007, 2008 and 2009 that establish background conditions in the vicinity of the TCEA are presented in **Table 3.4-6**. The data are presented for two hydrogeologic units: the Chadron Sandstone (mining zone) and the Brule Formation, which supplies the majority of groundwater in the project area. Four of the private wells being monitored are located within the TCEA permit boundary (Wells 270, 272. 273 and 277) and the remaining wells (Wells 269, 274, 275, 313, and 314) are located less than 0.5 mile from the permit boundary (**Figure 3.4-1**). Detailed discussions of the groundwater baseline data collected for TCEA are presented in Section 3.4.3.

CBR conducted a water user survey in 2005 to identify and locate all private water supply wells with a 2.25-mile radius of the proposed TCEA. The water user survey determined the location, depth, casing size, depth to water, and flow rate of all wells within the area that were (or potentially could be) use for domestic, agricultural, or livestock uses. CBR updated the well survey in 2008, 2009, and 2010 for all groundwater wells within the AOR. **Table 3.4-7** and **Appendices F and G** list the active and abandoned groundwater wells, respectively, within the TCEA and AOR. The locations of all identified active and abandoned water supply wells are depicted on **Figure 3.4-1**.

There are a total of eighty-nine active private/public water supply wells within the TCEA and AOR (**Table 3.4-7, Appendix F**). Forty-nine wells are classified as agricultural use, seventeen wells are classified as domestic use, twelve wells are domestic/agricultural use, four wells are classified as livestock or observation use, one well is used by the City of Crawford as a test well for a municipal system, and six City of Crawford water supply wells, with four of these six wells being part of the city infiltration gallery (**Figure 3.4-1, Appendix F**). Within the TCEA, there are seven private water supply wells that are completed in the Brule Formation. There are an additional seventy-two private water supply wells and ten public water supply wells located outside of the TCEA permit boundary. The majority of the total eighty-nine private water supply wells are completed in the Brule Formation. However, there are six groundwater wells without well construction (e.g., well depth) or water quality information (Wells 300, 322, 395, 400, 402, and 432). Well construction and water quality information for these wells are not available in the NDNR water well data retrieval database (NDNR 2010a) or known by the well owner. Wells 300 and 432 are old wells with hand pumps, and Wells 322 and 402 have windmills, which would suggest that these are shallow wells completed in the Brule Formation.

Well depth information is unknown for Well 270, which is located within the TCEA permit boundary; however, water quality data from this well is consistent with the Brule Formation (see Section 2.10). Similarly, well depth information is unknown for Well 364, but a field conductivity measurement collected by CBR (386 μhmos) indicates that this is a Brule Formation well. There are five private water supply wells located outside, but within one mile, of the TCEA permit boundary, that are part of the project monitoring program (Wells 269, 274, 275, 313, and 314). The completion depths and water quality information collected to date for these wells indicate that they are completed in the Brule Formation. Well 313 will be replaced with Well 312 for future monitoring of private water supply wells. Well 313 and 314 are located close together, so additional data are only needed from one of these wells. Well 312 will allow for more representative sampling of the area north of the permit boundary.

Based on available information, all water supply wells within the TCEA and AOR are completed in the relatively shallow Brule Formation, with no domestic or agricultural use of groundwater from the Basal Chadron Sandstone (**Figure 3.4-1 and Table 3.4-7**).

Based on population projections (see Section 3.10.1.3), future water use within the TCEA and the AOR will likely will be a continuation of present use. It is unlikely that any irrigation development will occur within the license area due to the limited water supplies, topography, and climate. Irrigation within the review area is anticipated to be consistent with the past (e.g., limited irrigation in the immediate vicinity of the White River). It is anticipated that the City of Crawford municipal water supply will continue to be provided by the groundwater and infiltration galleries related to the White River and associated tributaries.

3.4.2 Surface Water

3.4.2.1 Rivers, Creeks and Drainages

The U.S. Geological Survey (USGS) maintains a hierarchical hydrologic unit code (HUC) system that divides the United States into 21 regions, 222 subregions, 352 accounting units, and 2,149 cataloging units based on surface hydrologic features, or drainages (USGS 2009a). 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 a "HUC". The TCEA project site is located in the following HUC classification system (USGS 2009b):

- Region: Missouri (10)
- Subregion: White River-White (1014)
- Accounting Unit: White River [Nebraska: South Dakota] (101402)
- Cataloging Unit: Upper White River [Nebraska: South Dakota] (10140201)
- Basin: White-River-Hat Creek (**Figure 3.4-2, Table 3.4-8** [NDEQ 2010])
- Subbasin: WH1 (**Figure 3.4-3** [NDEQ 2010])

The White River Accounting Unit and Upper White River Cataloging Unit consist of an area of 9,870 and 2,810 square miles, respectively (USGS 2009b). The White River-Hat Basin, which is located in Dawes, Sioux and Sheridan counties, is comprised of a watershed area of 2,130 square miles. (NDEQ 2005)

The White River-Hat Creek Basin originates in northwestern Nebraska and heads in a northeastern pattern to a confluence with the Missouri River via the White River and the Cheyenne River (Hat Creek) in South Dakota (**Figure 3.4-2**).

The White River-Hat Basin is one of the roughest in the state, topographically. Northern tributaries in the City of Crawford area cross upland portions of the Pierre Shale, an impermeable formation. These streams are dry except for runoff flow. Southern tributaries originate in the Pine Ridge escarpment and flow primarily over forest, range, and agricultural land. These streams are ephemeral except where spring-fed. In general, stream flow in this basin is a function of surface run-off and groundwater contributions. The major land use is agriculture, with approximately 55 percent of the White River-Hat Creek Basin in rangeland or pasture and 15 percent of cropland (NDEQ 2005).

The TCEA lies within the watersheds of Bozle, Cherry, and the eastern portion of Dead Man's Creek, which are small southern tributaries to the major regional water course, the White River (**Figure 3.4-3**, **Figure 3.4-4**). These creeks head in the Pine Ridge south of the TCEA. From the headwaters, these creeks drain north over range and agricultural land to the White River. Contributions to flow come from springs in the Arikaree Group, snowmelt, runoff and the shallow Brule sands. The latter may receive inflow from the creek during periods of high flow. Due to the time variable nature of these water sources, discharges at various points along the creeks may experience wide fluctuations on a month to month and yearly basis. It should be noted that all are typically dry and are more of a drainage area than a stream.

Bozle Creek drainage (south to north) is not located in TCEA permit boundary, but is located just outside the eastern permit boundary (Sections 28 and 33 T31N R52W) (**Figure 3.4-4**). Bozle Creek is typically a dry drainage in this area of the permit boundary, and remains dry throughout its course along the TCEA except for runoff flow.

Cherry Creek drainage transects the southern TCEA permit boundary (Section 29 T31N R52W) and exits the northern boundary and eventually enters the White River to the north (**Figure 3.4-4**). This creek drainage within and south of the TCEA area is dry except for runoff flow. The current drainage within the TCEA permit boundary has been modified by agricultural activities, exhibiting no defined creek bottom/sediments or banks.

Dead Man's Creek drainage does not enter the TCEA license area, being located approximately 3,000 feet from the nearest points on the creek and the TCEA western permit boundary (**Figure 3.4-4**). Based on the topography, this area of the creek is hydraulically isolated from the TCEA license area.

Monitoring results of the White River, Cherry Creek, and Bozle Creek are discussed in Section 6.1.4.

3.4.2.2 Surface Impoundments

Based on available maps and site investigations conducted by CBR, no surface water impoundments, lakes or ponds have been identified within the TCEA. Impoundments do occur within the AOR. Ice House Pond, Cherry Creek Pond and Grabel Ponds are located to the north and downgradient of the license area and to the south of the White River. Cherry Creek Pond is located in the Cherry Creek drainage and the Grabel Ponds located to the east of Bozle Creek

(**Figure 3.4-4**). The Grabel Ponds are spring fed and discharge to Bozle Creek. Sulzbach Pond is located just outside the northwest corner of the permit boundary in an unnamed drainage. The headwaters of this unnamed drainage originates a short distance to the southwest of the permit boundary, moves across the northwest corner of the permit boundary and drains north to the White River. Just prior to this drainage entering the White River, another pond, Ice House Pond, is located within this drainage. The Grabel Ponds, Cherry Creek Pond and Ice House Pond are located on the Fort Robinson State Park. The Sulzbach Pond is located on private property.

The Sulzbach Pond is a man-made impoundment that consists of a low berm constructed across an unnamed ephemeral drainage course. The berm forms a small pond which is used for livestock watering. The Ice House and Cherry Creek Ponds are man-made impoundments formed by small earthen dams. These ponds are used principally for recreation in the Fort Robinson State Park.

Monitoring results for the Sulzbach, Grabel, Ice House and Cherry Creek Ponds are discussed in Section 6.1.4.

3.4.2.3 Surface Water Flow

<u>Stream Flow</u>

Historic monthly flow measurements, field water quality measurements and laboratory water quality data by the USGS and NDEQ for the above-referenced White River sampling points are presented in Sections 6.1.4.

No flow measurements were attempted on Cherry Creek, Dead Man's Creek, Bozle Creek or unnamed drainages in the TCEA area due to the ephemeral nature of flow in these features.

<u>Assessment of Flooding Potential</u>

As shown in **Tables 1.3-4** and **1.3-5**, the average monthly stream flow of the White River at the Crawford gauge station is about 20 ft^3/sec. The highest discharge and gauge height on record between 1920 and 2004 occurred on May 10, 1991. On that date, severe thunderstorms resulted in significant rainfall, the gauge height was 16.32 feet and the stream flow exceeded 13,300 ft^3/sec (NDNR 2004). Several city facilities were damaged by floodwaters and hail, including the local golf course and fish hatchery, and the event was considered a "100 year" flood. The Rocky Mountain News (May 12, 1991) reported that mobile homes were swept away and the city water system was knocked out of service. However, it is noted that, while there are certainly historical extremes, the average gauge height on the White River at Crawford is less than 5 feet, with an average annual stream flow of 20 ft^3/sec.

An assessment of the potential for flooding or erosion that could impact the in-situ mining processing facilities and surface impoundments has been performed based on data from the Federal Emergency Management Agency (FEMA 1995). FEMA has not mapped unincorporated Dawes County south of the City of Crawford, Nebraska; however, FEMA maps are available for the City of Crawford, and an analogy can be drawn between the flooding potential in the City of Crawford and that southeast of the City of Crawford adjacent to the proposed TCEA. As shown in **Figure 3.4-5**, FEMA has classified the portion of Crawford between the D M & E Railroad (immediately west of First Street) as Zone A (i.e., an area that could be impacted by a 100-year flood) (FEMA 1995). The elevation of the White River in the Zone A classification ranges from 3,669 to 3,659 feet AMSL. The surface elevation of the railroad tracks ranges from 3,678 to

3,671 feet AMSL. These data suggest that significant flooding potential exists with a rise in the White River elevation of 9 to 12 feet above base flow conditions. This is consistent with the data from the 1991 100-year flood event, where the river elevation was approximately 11.3 feet above base gauge height (approximately 5 feet).

The proposed TCEA surface facilities are to be located in the north-west portion of Section 30of T31N R52W, approximately 0.72 miles south of the White River, and approximately 139 feet topographically above the common river elevation. Proposed wellfields are planned for portions of Sections 28, 29, 30 and 33 of T31N R52W, and Section 25 of T31N R53W. (**Figure 3.4-4**). All of the wellfields are projected to be at least 116.6 feet above the White River elevation (**Table 3.4-9**).

There is no portion of the proposed TCEA with a reasonable potential of flooding due to flooding of the White River. Elevations of different points of the proposed TCEA permit boundary and centerpoint of the assets (i.e., wellfields, satellite facility main building and evaporation ponds) indicate that elevations at these locations in relation to the nearest point on the White River range from 116.6 to 219.1 feet higher than the river (**Table 3.4-9**). Based on these data, the TCEA surface facilities and mine units occur outside of the 100 year flood plain, and are not considered to be in a "flood prone" area. Therefore, consistent with NUREG-1623, erosion modeling was not performed.

3.4.2.4 Surface Water Quality

NDEQ White River Sampling Program

NDEQ surface water results for the White River are presented in Section 6.1.4.

Crow Butte White River and Tributary Sampling Program

Water samples were collected from the White River, Cherry Creek, Bozle Creek, Sulzbach Pond, Cherry Creek Pond, Ice House Pond and Grabel Pond. Sampling location numbers assigned to all of the creeks and ponds except for the Grabel Ponds include the Bozle Creek (B-1), Cherry Creek (C-1), Sulzbach Pond (I-9), and Ice House Pond (I-10) and Cherry Creek Pond (I-11). Sampling locations are shown in **Figure 3.4-4.** The laboratory analytical results for the ponds are discussed in Sections 2.9.

3.4.3 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 TCEA. The discussion is based on information from investigations performed within the TCEA, data presented in previous applications/reports for the CPF license area where ISL mining is being conducted, the proposed NTEA and the geologic information presented in Section 2.6. In this regard, the hydrogeology of the TCEA is expected to be similar in many respects to that encountered in the CPF and NTEA license areas.

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

- Alluvium

- Brule Formation (including the first "aquifer" in the Brule sand/clay)
- Chadron Formation (Upper Confining Unit including the Upper Chadron confining layer, Middle/Upper Chadron sand [aquifer, where present], and Middle Chadron confining layer)
- Basal Chadron Sandstone (Mining Unit)
- Pierre Shale (Lower Confining Unit)

With regard to the CPF, and particularly the NTEA and the TCEA, two groundwater sources are of interest in the City of Crawford and CBR area. These are the Brule Formation sand and the Basal Chadron Sandstone. The Basal Chadron Sandstone contains the uranium mineralization in the CPF, NTEA and TCEA license areas.

3.4.3.1 Groundwater Occurrence and Flow Direction

Within the Crawford Basin, the alluvium, Brule Formation, and Basal Chadron Sandstone are considered water-bearing intervals. The alluvial deposits are not typically considered a reliable water source. Sandy siltstones, overbank sheet sandstones and occasional thick channelized sandstones that occur throughout the Orella Member of the Brule Formation may be locally water-bearing units. These sandstone and siltstone units are difficult to correlate over any large distance and are discontinuous lenses, rather than laterally continuous strata. Although the Brule Formation is a local water- bearing unit, it does not always produce usable amounts of water. Despite this characteristic, the Brule Formation has historically been considered the shallowest aquifer above the Basal Chadron Sandstone aquifer and water supply wells have been completed in this unit.

Locations of all groundwater monitoring wells in the vicinity of the TCEA are shown on **Figure 3.4-1**. There are seven active monitoring wells screened in the Brule Formation (BOW 2006-1, BOW 2006-2, BOW 2006-3, BOW 2006-4, BOW 2006-5, BOW 2006-6, and BOW 2006-7). The private Miller Well (W-273) is also being utilized as a monitoring well for the Brule Formation. Ten active monitoring wells are screened in the Basal Chadron Sandstone (CPW 2006-1, COW 2006-1, COW 2006-2, COW 2006-3, COW 2006-4, COW 2006-5, COW 2006-6, COW 2006-7, UBCOW 2006-1, and UBCOW 2006-2). Well completion reports for these monitoring wells are included in **Appendix A**. No completion report is available for W-273.

Water level measurements and water quality results for groundwater monitor wells are presented and discussed in Sections 6.1.

3.4.3.2 Groundwater Quality Data

Groundwater monitoring results and discussions are presented in sections 3.4.3 and 6.1.3. The data are presented for the two water-bearing zones at the TCEA: the Brule Formation and the Basal Chadron Sandstone.

3.4.3.3 Aquifer Testing and Hydraulic Parameter Identification Information

Prior to initiation of ISL mining activities, the NDEQ UIC regulations require hydrologic testing and baseline water quality sampling. During the initial permitting and development activities within the TCEA, an aquifer pumping test was performed on April 7, 2008. The final report on pumping test activities in the TCEA (Three Crow Regional Hydrologic Testing Report – Test #7 (Petrotek 2008) is included in **Appendix E**. Testing activities and findings from pumping test activities in the TCEA are summarized below.

Prior to testing activities, CBR installed eight new monitoring wells in the Basal Chadron Sandstone (CPW 2006-2, COW 2006-1, COW 2006-2, COW 2006-3, COW 2006-4, COW-2006-5, UBCOW 2006-1, and UBCOW 2006-2) and three wells in the Brule Formation (BOW 2006-1, BOW 2006-2, and BOW 2006-3) (**Figure 3.4-6**). Well information for wells used during the 2008 pumping test is summarized in **Table 3.4-10**. CPW 2006-1 was abandoned in place due to breakage of the screen during well construction (**Appendix B**). Static water levels were collected from all eleven wells in the monitoring network on April, 21 2008 from the Brule Formation and the Basal Chadron Sandstone (6 days after completion of the pumping test), following recovery from pumping test activities. Water levels ranged from approximately 3,863 to 3,879 feet amsl in the Brule Formation and 3,719 to 3,725 feet amsl in the Basal Chadron Sandstone (**Table 3.4-10**). The static water level at CPW 2006-2 was approximately 3,722 feet amsl, indicating that there was 108 feet of hydraulic head above the pump.

The 2008 pumping test was designed to assess the following:

- The degree of hydraulic communication between the pumping well installed in the Basal Chadron Sandstone and the surrounding Basal Chadron Sandstone monitoring wells;
- The presence or absence of hydraulic boundaries within the Basal Chadron Sandstone over the test area;
- The hydraulic characteristics of the Basal Chadron Sandstone within the test area; and
- The degree of hydraulic isolation between the Basal Chadron Sandstone and the overlying Brule Formation.

The 2008 pumping test was conducted while pumping at CPW 2006-2 at an average of 44.7 gpm for 183 hours (7.63 days). The radius of influence (ROI) was estimated to be in excess of approximately 4,600 feet. More than 113 feet of drawdown was achieved during testing and with the exception of one well, all Basal Chadron Sandstone wells monitored during the test indicated adequate drawdown of more than 2 feet, confirming hydrologic communication within the Basal Chadron Sandstone aquifer. The one exception was 1.2 feet of drawdown at COW 2006-1, which was the farthest monitoring well from the pumping well. No responses attributed to the pumping test were observed in monitoring wells installed in the Brule Formation.

Results of the 2008 pumping test indicate a mean hydraulic conductivity of 7.5 feet per day [ft/day] (ranging from 4.1 to 11.6 ft/day) or 2.65 x 10^{-3} centimeters per second [cm/sec], a mean transmissivity of 477 square feet per day (ft^2/day; ranging from 267 to 743 ft^2/day), and a mean permeability of approximately 2,990 millidarcies (md) based on an assumed water viscosity of 1.35 centipoises (cP) (at 50 degrees Fahrenheit) and a density of 1.0 (**Table 3.4-11**). The mean storativity was 8.8 x 10^{-4} (ranging from 4.8 x 10^{-5} to 1.6 x 10^{-4}) (**Table 3.4-11**). Estimated hydraulic parameters for individual well locations for the 2008 pumping test are summarized in **Table 3.4-12**. The hydrologic parameters observed at the TCEA are consistent with, although slightly higher than, the aquifer properties determined for the CPF. No water-level changes of note were observed in any of the overlying wells during testing. The pumping test results demonstrate the following:

- All Basal Chadron Sandstone monitoring wells and the pumping well are in communication throughout the TCEA pumping test area;
- The upper and lower Basal Chadron Sandstone wells are in communication;
- The Basal Chadron Sandstone has been adequately characterized with respect to hydrogeologic conditions within the majority of the proposed TCEA test area;
- Adequate confinement exists between the Basal Chadron Sandstone and the overlying Brule Formation throughout the proposed TCEA test area; and
- The 2008 pumping test was sufficient to proceed with UIC Class III permitting and a NRC license amendment application for the TCEA.

It should be noted that cross-sections presented in the Three Crow Regional Hydrologic Testing Report - Test #7 (Petrotek 2008) differ from cross-sections presented in this petition. Cross-sections presented in this petition are revised interpretations based on a recent extensive review of available site-specific drilling logs and published literature.

3.4.3.4 Hydrologic Conceptual Model for the Three Crow Expansion Area

Tables 3.3-1 and **3.3-2** present the regional and local stratigraphic columns in the vicinity of TCEA. The water-bearing units within the stratigraphic section present at the TCEA include alluvial deposits (rarely), permeable intervals in the Orella Member of the shallow Brule Formation, and the deeper confined Basal Chadron Sandstone. This section describes the upper and lower confining units and the hydrologic conditions for the water-bearing intervals present at the TCEA.

Confining Layers

Upper confinement for the Basal Chadron Sandstone within the TCEA is represented by 400 to 560 feet of smectite-rich mudstone and claystones of the Upper Chadron and Middle Chadron (**Figure 3.3-3a through Figure 3.3-3e**). Particle grain-size analyses of six core samples from the upper confining layer within the TCEA indicate all samples were either silty claystone or clayey siltstone (**Appendix C**). X-ray diffraction analyses indicate 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 C**). The limited lateral extent and hydraulic isolation of sandstones of the Upper/Middle Chadron within the TCEA, which range from 0 to 50 feet thick, is insignificant as a productive water-bearing zone (**Figure 3.3-5**). As a result, the Brule Formation is vertically and hydraulically isolated from the underlying aquifer proposed for exemption.

Lower confinement for the Basal Chadron Sandstone in the vicinity of the TCEA is represented by approximately 600 to 740 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 Chadron Sandstone from the underlying "D", "G", and "J" sandstones of the Dakota Group by more than 1,000 vertical feet (**Table 3.3-1**). The Pierre Shale is not a water-bearing unit, exhibits very low permeability, and is considered a regional aquiclude. 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 et al. 1984; Neuzil 1993). The Pierre Shale has a measured vertical hydraulic conductivity in the CPF license area of less than 1 x 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 TCEA indicate low permeability silty clay and clayey silt compositions (**Appendix C**). Regional studies also indicate there is no observed transmissivity between vertical fractures in the Pierre Shale, which appear to be short and not interconnected (Neuzil et al. 1984).

Estimates of hydraulic conductivity were developed using particle grain-size distribution data from the eight core samples collected within the Upper Chadron, Middle Chadron, and Pierre Shale. Results of the particle size distribution analyses indicate mostly silts and clays (**Appendix C**). Hydraulic conductivity estimates were developed using the Kozeny-Carman equation, which is appropriate for sands and silts, but not for clayey soils with a high degree of plasticity. Estimated hydraulic conductivities of the four core samples collected within the Upper Chadron ranged from 3.4 x 10^{-5} to 8.6 x 10^{-6} cm/sec. Estimated hydraulic conductivities of the two core samples collected within the Middle Chadron ranged from 1.1 x 10^{-5} to 2.7 x 10^{-6} cm/sec. Estimated hydraulic conductivities for the two core samples collected within the Pierre Shale ranged from 5.1 x 10^{-6} to 2.7 x 10^{-6} cm/sec. 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 TCEA, which ranges between 400 and 560 ft (**Figure 3.3-6**).

Hydrologic Conditions

A potentiometric map and cross sections of the Basal Chadron Sandstone indicate confined groundwater flow (**Figure 3.3-3a** through **Figure 3.3-3e** and **3.4-7**). Elevations of the potentiometric surface of the Basal Chadron Sandstone indicate that the recharge zone must be located above a minimum elevation 3,720 feet amsl. Confined conditions exist at the TCEA as a result of an elevated recharge zone most likely located west or northwest of the TCEA. The top of the Basal Chadron Sandstone occurs at much lower elevations within the TCEA, ranging from approximately 3,190 to 3,320 feet amsl (**Figure 3.3-8**).

In the vicinity of the TCEA, groundwater flow in the Basal Chadron Sandstone aquifer is predominantly to the east-northeast, with an average hydraulic gradient of 0.0012 ft/ft. The elevation of the Basal Chadron Sandstone within the TCEA is typically more than 500 feet below the base of the White River, which flows to the northeast less than one mile from the northwestern corner of the permit boundary (**Figures 3.4-4, 3.3-3a**, and **3.3-3c**). Regional water level information for the Basal Chadron Sandstone is currently only available in the vicinity of the CPF 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 Chadron Sandstone is exposed.

Extensive review of available data from the TCEA and vicinity strongly indicates that the extent of the Upper/Middle Chadron sandstone is limited to the southern half of the central and eastern portions of the TCEA (**Figure 3.3-3a** through **Figure 3e** and **Figure 3.3-5**). The unit is completely absent in the western, northern, and southern-most portions of the TCEA (**Figure 3.3-5**). In contrast to the NTEA, where a strong resistivity curve shift was observed across this unit, the Upper/Middle Chadron does not appear to be a highly transmissive unit at the TCEA with no apparent curve shifts that might indicate an increase in porosity or water content (**Figure 3.3-4**).

Monitoring wells have not been completed in this unit as a result of the lack of recoverable water. Therefore, the unit is not considered a regional aquifer.

Available regional water-level information for the Brule Formation indicates unconfined groundwater flow generally toward the White River (**Figure 3.4-1** and **Figure 3.4-8**). Within the TCEA, groundwater generally flows to the north and northeast across the entire TCEA, with an average hydraulic gradient of 0.0168 ft/ft. Though the Brule Formation is the primary groundwater supply in the vicinity of the TCEA, 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 TCEA, as the unit is unconformably overlain by 0 to 30 feet of unconsolidated alluvial and colluvial deposits (depending on local topography) and is exposed throughout the vicinity (Beins 2008). This unit is likely in direct hydraulic communication with the White River, as observed at the NTEA where groundwater elevations indicate apparent recharge in the vicinity of the White River. In that context, gaining and losing conditions along the White River are probably seasonally influenced. A sufficient number of monitoring wells will be installed in the Brule Formation between the permit boundary and the White 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 3.4.3.3 for a more detailed discussion). Installation of such monitoring wells is required under the Class III injection well permit. Alluvial deposits along the margins of the White River may offer limited groundwater storage depending on river levels.

The two water-bearing zones in the TCEA have distinct and differing water-level elevations (**Figure 3.3-3a** through **Figure 3.3-3e**, **Table 3.4-13**). The available water-level data suggest hydrologic isolation of the Basal Chadron Sandstone with respect to the overlying water-bearing intervals in the TCEA. This inference is further supported by the difference in geochemical groundwater characteristics between the Basal Chadron Sandstone and the Brule Formation (see Section 3.4.3.2) (**Tables 3.4-6** and **6.1-13**).

In summary, the following multiple lines of evidence indicate adequate hydrologic confinement of the Basal Chadron Sandstone within the TCEA.

- Results of the April 2008 aquifer pumping test demonstrate no observed drawdown in observation wells screened in overlying Brule Formation throughout the TCEA (see Section 3.4.3.3).
- Large differences in observed hydraulic head (86 to 196 feet) between the Brule Formation and the Basal Chadron Sandstone indicate strong vertically downward gradients and minimal risk of naturally-occurring impacts to the overlying Brule Formation (see Section 3.4.3.1).
- Significant historical differences exist in geochemical groundwater characteristics between the Basal Chadron Sandstone and the Brule Formation (Section 3.4.3.2).
- Site-specific x-ray diffraction analyses, particle grain-size distribution analyses and geophysical logging confirm the presence of a thick (up to 560 feet), laterally continuous upper confining layer consisting of low permeability mudstone and claystone, and a thick (up to 740 feet), regionally extensive lower confining layer composed of very low permeability black marine shale.

- Analyses of particle size distribution results suggest a maximum estimated hydraulic conductivity of 10^{-5} cm/sec for core samples from the upper confining layer and 10^{-6} cm/sec for core samples from the lower confining layer, implying that the vertical hydraulic conductivity across the upper and lower confining layers is likely to be even lower due to vertical anisotropy.

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

The Basal Chadron Sandstone is currently mined via ISL mining techniques in the CPF license area and represents the production zone and target of solution mining in the TCEA. Ore-grade uranium deposits underlying the TCEA are located in the Basal Chadron Sandstone (**Figure 1.3-1**). The ore body located within the TCEA is a stacked roll-front system, which occurs at the boundary between the up-dip and oxidized part of a sandstone body and the deeper down-dip and reduced part of the sandstone body. Stratigraphic thickness of the unit within the TCEA ranges from approximately 70 to 250 feet, with an average thickness of approximately 180 feet. Depending on the presence of up to four interbedded clay units, the vertical thickness of sandstone within the Basal Chadron Sandstone can vary depending on location (**Figure 3.3-3a** through **Figure 3.3-3e**). The unit occurs at depths ranging from about 580 to 940 feet bgs within the TCEA (**Figure 3.3-3a** through **3.3-3e**). A competent upper confining layer consists of the overlying Middle Chadron and Upper Chadron, which consist predominantly of clay, claystone, and siltstone. Based on extensive exploration hole data collected to date (more than 720 drill locations), the thickness of the upper confining layers in the TCEA range from 400 to 560 feet (**Figure 3.3-3a** through **Figure 3.3-3e**). 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} to 10^{-6} cm/sec (see Section 3.4.3.4). Geophysical logs from nearby oil and gas wells indicate that the thickness of the Pierre Shale lower confining layer ranges from approximately 600 to 740 feet. The full thickness of the Pierre shale is not depicted in **Figure 3.3-3a** through **Figure 3.3-3e**, 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 1×10^{-10} cm/sec) (WFC 1983). Estimated hydraulic conductivities based on particle grain-size distribution analyses for core samples collected from the Pierre Shale within the TCEA are on the order of 10^{-6} cm/sec. Oil and gas test well logs are depicted in **Appendix D**.

Based on similar regional deposition, the TCEA ore body is expected to be similar mineraologically and geochemically to that of the current CBR operation. The ore bodies in the two areas are within the same geologic unit (i.e., Basal Chadron Sandstone) and have the same mineralization source (see Section 3.3). 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 3.3). 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 CBR mineralized zone are presumed representative of the TCEA. **Table 3.4-14** presents the Baseline and Restoration Values for Mine Unit 10 (additional data for MU 1-9 are presented in **Appendix L).** The values in this table are expected to be representative of the geochemical characteristics of the TCEA ore body. The TCEA ore body, the outline of which is provided on **Figure 1.3-1**, 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 6.1-4**).

During the course of mining the water quality is expected to change as outlined in **Table 3.4-15**. The chemicals used in the mining and recovery process will include sodium bicarbonate, an oxidizer such as oxygen, carbon dioxide, and chloride for elution. As a result, the greatest changes in water quality are expected to be in alkalinity, bicarbonate, chloride, sodium, conductivity, 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 TCEA are similar to that of the CPF license area so it is probable the change in water quality at the TCEA will be similar to that experienced at the CPF site. Historic restoration activities at the CPF site have demonstrated the ability to successfully restore groundwater to established restoration standards. Groundwater restoration is discussed in detail in Section 6.0.

3.5 Ecological Resources

3.5.1 Introduction

This section describes the existing ecological resources within the TCEA. The potential impacts associated with the proposed project and mitigation measures that would serve to offset such impacts are discussed in Section 5. 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. Agency coordination has consisted of telephone conversations and written correspondence between ARCADIS biologists and U.S. Fish and Wildlife Service (USFWS) and Nebraska Game and Parks Commission (NGPC) management and staff. The purpose of these consultations and associated correspondence was to help identify biological issues and potential occurrences and distribution of special-status plants and wildlife and their habitats.

3.5.2 Regional Setting

The project area occurs at the confluence of two Nebraska eco-regions, the Western High Plains and the Northwestern Great Plains. The Western High Plains eco-region 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 dry-land agriculture. Potential natural vegetation is dominated by drought tolerant short-grass prairie and large areas of mixed-grass prairie in the northwest portion of the state. The Northwestern Great Plains eco-region encompasses the Missouri Plateau section of the Great Plains. It is a semiarid rolling plain of shale, siltstone, and sandstone punctuated by occasional buttes. Native grasslands persist in areas of steep or broken topography, but they have been largely replaced by spring wheat and alfalfa over most of this eco-region. Agriculture exists on level to rolling hills and is generally limited by erratic precipitation patterns and limited opportunities for irrigation (Chapman et al. 2001).

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

3.5.3 Local Setting - Three Crow Expansion Area

The proposed 1,643-acre TCEA is located in west-central Dawes County and a very small portion of adjacent Sioux County, Nebraska, just south-southwest of the City of Crawford. The proposed TCEA is located within Sections 28, 29, 30, and 33 of Township (T) 31 North (N), Range (R) 52 West (W), and Section 25 of T31N, R53W (**Figure 1.1-2, Figure 3.5-1**).

3.5.4 Climate

The climate of the region is characterized by wide seasonal and day-to-day variations in temperature and precipitation. Dawes County is usually warm in the summer, with frequent spells of hot weather and occasional cool days interspersed throughout. These changes in weather can generate thunderstorms which deliver a majority of the total annual precipitation.

Climate data was collected at the Chadron National Weather Station (NWS) (Chadron 1 NW) (latitude 42° 50' north, longitude 103° 01' west with a ground elevation of 1021 m [3350 ft] above mean sea level). The NWS site is 1.4 km (0.9 miles) west northwest of Chadron, 37 km (23 miles) east northeast of Crawford, and 35 km (22 miles) east northeast of the proposed license area. The monthly climate summary for 08/01/1894 through 02/28/2009 is presented in **Table 3.5-1** (HPRCC 2010). A detailed discussion of more recent meteorological data (2000 – 2009) considered representative of the license area can be found in Section 3.6.

3.5.5 Pre-existing Baseline Data

In 1982, an ecological baseline study (WFC 1983) was conducted for the CPF license area (Radioactive Source Materials License SUA-1534). The 1982 study focused on conducting intensive studies within the principal study area, which included both the commercial study area and the five-mile adjacent area, and less intensive studies within the 50-mile outer area. Additional baseline data were collected within these three areas in 1987, 1995, 1996, 1997, and 2004 (CBR 2007). In 2005 and 2008, field observations, agency contact, and literature searches were conducted to obtain new baseline data for the TCEA.

3.5.6 Terrestrial Ecology

The information presented in this section includes a summary of the findings of the ecological baseline studies for the CPF license area and expansion areas in 1982, 1987, 1995, 1996, 1997, and 2004, and the field surveys conducted for the TCEA in 2005 and 2008.

3.5.6.1 Methods

A field reconnaissance of the TCEA was conducted on December 21, 2005. Through observation, principal floral and faunal species were identified, and the composition and distribution of each distinct vegetation association was described and mapped. Further, raptor nest surveys were conducted and past ecological data compilations were confirmed during a June 9 - 12, 2008 site visit.

3.5.6.2 Existing Disturbance

Since settlement in the late 1800s, past and current human activities in and surrounding the TCEA have caused substantial alteration of mixed-grass prairie grasslands, The primary sources of surface disturbance to natural vegetation communities have resulted from agriculture, intensive grazing, haying, sand and gravel mining, road and railroad construction, and rural and urban development.

3.5.6.3 Vegetation and Land Cover Types

The vegetation/habitat classification system detailed in "*Crow Butte Uranium Project Application and Supporting Environmental Report for NRC Research and Development Source Material License*" (WFC 1983) was combined with pedestrian surveys to identify and map vegetation community types within the TCEA. The community descriptions for the CPF license area (WFC 1983) are provided below, and supplemented with additional information that is specific to the TCEA.

Seven basic vegetation communities, which generally correlate with wildlife habitat types, were identified in the TCEA: riverine, deciduous streambank forest, mixed-grass prairie, range rehabilitation, cultivated land, and structure biotope. These broad categories often represent several combinations of species composition and relative abundance, as described below. The acres of occurrence and relative distribution of these habitat types within the TCEA are presented in **Table 3.5-2**. **Figure 3.5-1** shows the distribution of the six principal habitat types within the TCEA.

<u>Riverine</u>

Wetlands and their associated habitats are grouped into classifications, which provide several functions and values unique to each wetland complex. Wetlands perform many important hydrologic functions, such as floodwater storage, maintaining stream flows, slowing and storing floodwaters, stabilizing streambanks, nutrient removal and uptake, and groundwater recharge.

A number of wetland classification systems have been developed, but the Cowardin et al. (1979) classification method is the most widely recognized system, and thus was used for wetland classification within the project area. Riverine habitats are defined as non-tidal and tidal-freshwater wetlands within a channel. Vegetation, when present, is predominantly non-persistent emergent plants (non-persistent-emergent wetlands), or submersed and (or) floating plants (aquatic beds), or both. Riverine wetlands, defined by their close associations with perennial streams, occur along stream channels and are often associated with riparian areas. These areas are also supported by groundwater drainage associated with floodplains and by periodic flooding events. Riverine wetlands are divided into categories based on the nature of the adjacent stream (e.g., upper perennial or intermittent). Riverine wetlands can be further divided based on the dominant plant life form of the physiography and composition of the substrate (e.g., unconsolidated bottom, unconsolidated shore, or streambed) and the seasonal water regime (e.g., permanently flooded, semi-permanently flooded, seasonally flooded, or temporarily flooded) (Cowardin et al. 1979).

Riverine habitats in the TCEA only include an unnamed tributary of the White River located in the NE ¼ of Section 25 T31N R53W. The Cherry Creek drainage runs through an area of mixed grass prairie of Section 29 T31N R52W. However, this drainage lacks defined bed and banks and does not support riverine habitats. A portion of Bozle Creek streambed lies outside but in close proximity to the southeastern permit boundary (Section 33 T31N R52W) supports riverine habitats. . These drainages, with the exception of Cherry Creek, have been observed to periodically contain standing water.

Deciduous Streambank Forest

Deciduous streambank forest occupies streamside sites adjacent to the White River, Dead Man's Creek, Bozle Creek, and Cherry Creek (outside of permit boundary). Eastern cottonwood (*Populus deltoides*) is the most common dominant upper canopy species in this region, including the TCEA. Other species that may be present in the canopy include green ash (*Fraxinus pennslyanica*), boxelder (*Acer negundo*), American elm (*Ulmus americana*), peachleaf willow (*Salix amygdaloides*), narrowleaf willow (*S. exigua*), shining willow (*S. lucida*), American plum (*Prunus americana*), and chokecherry (*P. virginiana*). Understory vegetation varies widely, depending primarily upon the amount of grazing pressure. One of the more common understory species in the TCEA is Tatarian honeysuckle (*Lonicera tatarica).* Deciduous streambank forest habitats in the TCEA occur in conjunction with the riverine habitats, the locations of which are described above (**Figure 3.5-1**).

Mixed-Grass Prairie

The mixed-grass prairie vegetation community is dominated by cool- and warm-season mid-grasses, short-grasses, and sedges. Typical grass species may include blue grama (*Bouteloua gracilis*), hairy grama (*B. hirusuta*), little bluestem (*Schizachyrium scoparium*), threadleaf sedge (*Carex filifolia*), green needlegrass (*Nassella viridula*), Indian grass (*Sorghastrum nutans*), needle and thread grass (*Hesperostipa comata*), western wheatgrass (*Pascopyrum smithii*), sand dropseed (*Sporobolus cryptandrus*), and slender wheatgrass (*Elymus trachycaulus*). Characteristic forbs may include sand sagebrush (*Artemisia filifolia*), fringed sagebrush (*A. frigida*), Nuttall's violet (*Viola nuttallii*), prickly-pear cactus (*Opuntia* spp.), and yucca (*Yucca glauca*). The mixed-grass prairie habitat type is the second most common in the TCEA, typically occurring adjacent to the buttes and drainages (**Table 3.5-2, Figure 3.5-1**).

Range Rehabilitation

Range rehabilitation areas are previously cultivated fields that are subjected to intensive grazing and/or seasonal haying. Species common to this habitat type are smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), intermediate wheatgrass (*Thinopyrum intermedium*), tall wheatgrass (*Thinopyrum ponticum*), and crested wheatgrass (*Agropyron cristatum*). The quality and composition of the community type varies greatly, depending upon the interval between the intensity of grazing and haying. In addition, the aspect varies from pure to sparse grass stands, to annual weed complex or bare ground.

Species composition varies within the mixed-grass prairie and the range rehabilitation communities in the TCEA. The provided descriptions of these communities are more representative of areas that are located further from roads. Weed species are especially common in both of these community types where they occur adjacent to Four Mile Road (**Figure 3.5-1**). Weed presence is particularly high in the range rehabilitation community because of the greater level of disturbance from cattle. Common weed species in the area include Russian thistle (*Salsola iberica*), common mullein (*Verbascum thapsus*), wild oats (*Avena fatua*), prickly lettuce (*Lactuca serriloa*), witchgrass (*Panicum capillare*), and cheatgrass (*Bromus tectorum*). Other species that are indicative of disturbed areas and that are found within the range rehabilitation community in the TCEA include yucca (*Yucca glauca*) and prairie sandreed (*Calamovilfa longifolia*). The 1982 study (WFC 1983) estimated that 30 percent of species and more than 50 percent of plant cover throughout the CPF license area consisted of exotic species.

Cultivated

This habitat type is comprised of cultivated fields. Primary crops in the region include wheat (*Triticum* spp.), oats (*Avena* spp.), barley, corn, rye, and alfalfa (*Medicago sativa*). Cultivated land is the most common vegetation community in the TCEA (**Table 3.5-2**, **Figure 3.5-1**), with alfalfa and wheat being the most cultivated crop.

Structure Biotopes

Structure biotopes are defined as man-made features other than cultivation, including gravel pits, buildings and farmyards, parks, cemeteries, roads, and highways and associated rights-of-way. Also included in this category are reclaimed and un-reclaimed lands. Dominant plant species growing near these biotopes may include smooth brome, cheatgrass, white sweetclover (*Melilotus alba*), yellow sweetclover (*Melilotus officinalis*), and numerous mustard (Brassicaceae family) species. Structure biotopes in the TCEA are small farmsteads with buildings. According to the 1982 baseline study, more than 400 species of plants were collected from the CPF license area (WFC 1983) (**Appendix J**).

3.5.7 Mammals

During the 1982 baseline study (WFC 1983), 36 species of wild mammals were documented, and another 28 species, mostly bats, insectivores, and small rodents, were deemed likely to occur in the region (**Appendix J-2**). A summary of these findings for the CPF license area is provided below, and in some cases is supplemented with additional information that is specific to the TCEA.

3.5.7.1 Big Game

Big game species that are found in suitable habitats in or adjoining the project area include pronghorn (*Antilocapra americana*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), and bighorn sheep (*Ovis canadensis*) (Nordeen 2008).

Pronghorn Antelope

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 acres 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. 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).

Nebraska is on the eastern fringe of the pronghorn range, and there are large areas within the range boundary where pronghorns do not occur. The highest densities of pronghorn are in the northern and southern Panhandle, primarily located in the short-grass prairies and badlands.

The baseline study (WFC 1983) identified a "Fort Robinson" population that consisted of 12 animals that ranged in and out of the Fort Robinson State Park and northward to the outskirts of the City of Crawford, using the mixed-grass habitat type. The range of this population included the portion of the Park that is immediately adjacent to the northern boundary of the TCEA. During the 2005 field reconnaissance, a herd of pronghorn were observed in the Park, just north of Section 28 and 29 T31N R52W. Further, individuals were spotted within road adjacent pastures of the TCEA during a site visit in 2008.

The TCEA is located primarily in the Box Butte Antelope Hunting Unit (NGPC 2010a) **(Figure 3.5-2)**. Antelope harvest data for the North Sioux Unit in 2002 and 2003 are 206 and 136, respectively (NGPC 2006a). The overall population trend for the pronghorn inhabiting the region has seen an overall decline in herd numbers (Hams 2004). The presumed reasons for this declining trend are low breeding success and extreme drought that has limited forage availability (Hams 2004).

Mule Deer

Mule deer occur throughout western North America from central Mexico to northern Canada. Typical habitats include short-grass and mixed-grass prairies, sagebrush and other shrublands, coniferous forests, and forested and shrubby riparian areas. In Nebraska, mule deer occur in foothills, broken hill country, prairie grasslands, and shrublands. Browse is an important component of the mule deer diet throughout the year, making up as much as 60 percent of total intake during autumn, while forbs and grasses typically make up the rest of their diet (Fitzgerald et al. 1994). This species tends to be more migratory than white-tailed deer, traveling from higher elevations in the summer to winter ranges that provide more food and cover. Fawn mortality is typically due to predation or starvation. Adult mortality often occurs from hunting, winter starvation, and automobile collisions. Typical predators may include coyotes, bobcats, golden eagles, mountain lions, bears, and domestic dogs (Fitzgerald et al. 1994).

Mule deer are distributed primarily along the foothills and escarpments, ranging outward into mixed-grass prairie and cultivated land, and occasionally along watercourses. In the mule deer distribution mapping for the CPF license area, a portion of the TCEA was classified as primary mule deer range. This included the forested buttes in Sections 32, 33, and 34 of T31N R52W, and the surrounding mixed-grass prairie and cultivated habitats (WFC 1983). While Section 31 was not included in the Crow Butte project area, the buttes and surrounding area in this section are also considered primary mule deer range **(Figure 3.5-1)**.

The TCEA is located in the Pine Ridge Deer Hunting Unit (NGPC 2010b) **(Figure 3.5-3)**. Due to concerns with harvest of buck deer, the NGPC conducted a study (based on aged sample projected by total kill) of adult bucks 2½ 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 2006b). In 2008, the adult mule deer buck harvest for the Pine Ridge unit was 999 (NGPC 2010b). According to Hams (2004), the mule deer population in the Nebraska panhandle is stable to increasing.

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, typically concentrated in riparian woodlands, mixed shrubs riparian and associated irrigated agricultural lands, and are generally absent from dry grasslands and coniferous forests (Clark and Stromberg 1987). Their diet is diverse, capitalizing on the most nutritious plant matter available at any time. In addition to native browse, grass, and forbs, this species would rely 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).

In the CPF license area and TCEA, white-tailed deer are more widely distributed than mule deer. Because of the high amount of cultivated land, white-tailed deer distributions may be primarily associated with riparian habitats along the White River and associated intermittent and ephemeral stream drainages. In addition, due to the overlap of the mule deer range in this part of the state, white-tailed deer may be absent from large expanses of mixed-grass prairie and shrubland habitats. Individuals were spotted within agricultural habitats throughout the expansion site during the June 2008 field surveys. In the white-tailed deer distribution mapping for the current Crow Butte project area, a portion of the TCEA was classified as primary white-tailed deer range. This included all or portions of Sections 28 and 33 T31N R52W (WFC 1983). Whitetails are the predominant deer species in eastern Nebraska, but over the past few years they have continued to extend their range, moving westward along rivers and streams.

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 2006b). In addition, results of the overall deer (including both white-tailed and mule deer) harvest for the Pine Ridge unit in 2002 and 2003 season was 1,732 of 2,970 tags issued, and 1,724 of 3,186 tags issued, respectively (NGPC 2006b). In 2008, the white tail adult buck harvest for the Pine Ridge unit was 1,135 (NGPC 2010b). According to the NGPC (2010b), the State deer population (including white-tailed and mule deer) is estimated to be between 300,000 and 350,000 animals.

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.

There are an estimated 1,400 elk in the State of Nebraska, with most of the range concentrated in the Pine Ridge area (NGPD 2010c). The TCEA is located in the Pine Ridge area, within the Hat Creek elk hunting unit (NGPC 2010c) (**Figure 3.5-4**). Occasionally, elk may occur within the project area as transients primarily during the period between the summer and winter range movements (Nordeen 2004).

Elk are occasionally observed in the southeastern corner of the TCEA area in the Dead Man's Creek area. This same area in the Dead Man's Creek drainage also exemplifies prime mule deer habitat (Noordeen 2008).

Bighorn Sheep

Prior to the 1900s, the Audubon bighorn sheep 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 2006d).

In 1981, the NGPC began a bighorn sheep introduction project in the Pine Ridge area. A dozen bighorns were released into a 500-acre enclosure at Fort Robinson State Park near Crawford (NGPC 2010d; WFC 1983). In December 1988, 21 sheep were released from the pen and in January 1993, the remaining 23 sheep were released. A few bighorn sheep are known to have ranged from the Fort Robinson area as far east as the Bordeaux Creek drainage southeast of Chadron, south near Belmont, west near the Gilbert-Baker Wildlife Management Area, and north into the Oglala grasslands (NGPC 2006d). In January 2005, 49 sheep from Montana were released in the Pine Ridge east of Crawford on Bighorn Wildlife Management Unit NGPC 2010d). According to March 2008 surveys conducted by NGPC, there are an estimated 140 bighorn sheep in the Pine Ridge escarpments with approximately 60 adult bighorn sheep and their current year offspring in or near the project area. The TCEA falls within the State NGPC Bighorn Sheep Hunting Unit (NGPC 2010d).

Bison

About 200 bison are impounded at the Fort Robinson State Park. The bison winter compound is located in an area that is immediately adjacent to the northern boundary of the TCEA (WFC 1983); however, they do not graze within the proposed project boundary.

Carnivores

The coyote (*Canis latrans*), red fox (*Vulpes vulpes*), and long-tailed weasel (*Mustela frenata*) are distributed in low numbers throughout the Crow Butte project area. Coyotes occur most commonly in the grasslands, whereas red foxes occur primarily in cultivated habitat. Weasels occur in a variety of habitats in the project area (WFC 1983). The bobcat (*Lynx rufus*), badger (*Taxidea taxus*), mountain lion (*Puma concolor*), and striped skunk (*Mephitis mephitis*) may also occur in the Crow Butte project area, but less commonly. Bobcats most often occur in deciduous and coniferous woodland types, whereas badgers have been recorded in habitats near creeks. Striped skunks are seen most often in roadside situations (WFC 1983). Mountain lions occur in a variety of habitats, but prefer rougher, wooded areas (NGPC 2006e). Tracks of a single mink were observed along the White River within Fort Robinson State Park (WFC 1983). Based on the habitat descriptions and occurrence records, all of these species have the potential to occur in the TCEA, with the coyote, red fox, and long-tailed weasel having the greatest probability.

3.5.7.2 Small Mammals

The deer mouse (*Peromyscus maniculatus*), white-footed mouse (*Peromyscus leucopus*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), meadow jumping mouse (*Zapus hudsonius*), northern pocket gopher (*Thomomys talpoides*), and meadow vole (*Microtus pennsylvanicus*) occur in the highest abundances in the Crow Butte project area. The highest densities of these small mammals occur in the deciduous forest areas, whereas the lowest densities occur in the cultivated fields. The greatest diversity of small mammals was detected in the mixed- and short-grass community, and the lowest diversity was observed in the non-wooded riparian and lower deciduous forest areas (WFC 1983). Muskrat (*Ondatra zibethicus*) occur along watercourses, and beaver (*Castor canadensis*) occur in the White River Basin. Porcupine (*Erethizon dorsatum*), fox squirrel (*Sciurus niger*), white-tailed jackrabbit (*Lepus townsendii*), black-tailed jackrabbit (*Lepus californicus*), and eastern cottontail (*Sylvilagus floridanus*) are also expected to occur throughout the Crow Butte project area (WFC 1983). During the baseline study (WFC 1983), a small black-tailed prairie dog (*Cynomys ludovicianus*) colony was identified just north of Section 27 T31N R52W (**Figure 1.1-2**). Based on the habitat descriptions and occurrence records, all of these species have the potential to occur in the TCEA.

3.5.8 Birds

The Nebraska Ornithologists' Union (NOU) lists 447 birds (including two extinct species, passenger pigeon (*Ectopistes migratorius*) and Carolina parakeet (*Conuropsis carolinensis*)) occurring in Nebraska (NOU 2003). Johnsgard (1979) lists 430 species, including 54 apparently "accidental" (vagrant) species, and nine extinct, extirpated, or probably extirpated species. In addition, Johnsgard (1979) lists 27 "hypothetical" species, and four unsuccessfully introduced species. During the 1982 baseline study (WFC 1983), 201 species were documented in the Crow Butte project area (**Appendix J-3**).

Of the NOU 447 birds sighted in Nebraska, approximately 200 species breed in the State. The largest single component is arboreal, adapted to living in trees, woodlands, and forests, and make up approximately 45 percent of the State's total species. Aquatic and shoreline adapted species make up the second largest component, or 32 percent of the state's total avifauna (Johnsgard 1979). Species primarily associated with grasslands comprise a still smaller breeding component, or approximately 10 percent of the state's total avifauna. Bird species associated with semi-desert scrub are the least numerous.

3.5.8.1 Passerines

Passerines are anticipated to occur commonly within the cultivated fields in the Crow Butte project area, including the TCEA and include the American robin (*Turdus migratorius*), red-winged blackbird (*Agelaius phoeniceus*), mourning dove (*Zenaida macroura*), house wren (*Troglodytes aedon*), violet-green swallow, (*Tachycineta thalassina*) and horned lark (*Eremophila alpestris*). Birds likely to be associated with the riparian and woodland habitats include pine siskin (*Carduelis pinus*), red crossbill (*Loxia curvirostra*), black-capped chickadee (*Poecile atricapillus*), rufous-sided towhee (*Pipilo erythrophthalmus*), yellow warbler (*Dendroica petechia*), and house wren (*Troglodytes aedon*).

3.5.8.2 Upland Game Birds

The range of wild turkeys now includes most major river drainages in the State and the Pine Ridge area (NGPC 2006f). Populations of turkeys in the Pine Ridge and Niobrara River valley are primarily Merriam's turkey (*Meleagris gallopavo*). The turkey is widely distributed in the Crow Butte project area, primarily along the foothills and plateaus, within ponderosa pine habitat, and along drainages (WFC 1983). During the baseline study (WFC 1983), most were observed in structure biotopes, but deciduous woodlands and coniferous woodlands were also common sites. A small proportion of these birds were found in cultivated, mixed-grass prairies, and range rehabilitation types. In proximity to the TCEA, fair numbers of turkeys may exist within the White River basin. In addition, small, isolated populations may be found in suitable habitats outside of the White River basin.

Ring-necked pheasants (*Phasianus colchicus*) range from fairly abundant to common throughout the Crow Butte project area, with preferred habitats occurring in shelterbelts, drainages, and edges of cultivated fields. However, regional pheasant populations are subject to extreme fluctuation due primarily to the availability of suitable cover and the severity of winter weather. One pheasant was seen along Four Mile Road in the TCEA during the 2005 field reconnaissance.

Sharp-tailed grouse (*Tympanuchus phasianellus*) are most commonly found in short- and mixed-prairie grassland areas interspersed with serviceberry (*Amelanchier* spp.), chokecherry, and snowberry (*Symphoricarpos albus*). Shrubs and small trees play an important role in sharp-tailed grouse ecology, especially in winter when they provide both food and cover. Weed-grass types and cultivated crops (wheat and alfalfa) may be used in spring and summer. Sharp-tailed grouse may use agricultural fields by feeding on waste grain and associated insects. Sharptails are expected to occur in the mixed-grass prairie habitat in the TCEA.

3.5.8.3 Raptors

Several raptor species can occur in the Crow Butte project area, a reflection of the mixed grass and woodland habitat types and the existence of suitable nesting sites, such as tall, strong branched trees. Golden eagles (*Aquila chrysaetos)* are permanent residents of the Crow Butte area, occurring in a variety of habitats, but most often perched on cliffs and escarpments (WFC 1983). Other permanent resident raptors occurring in the cultivated fields and mixed-grass prairies of the Crow Butte project area, including the TCEA, are the red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), northern harrier (*Circus cyaneus*), prairie falcon (*Falco mexicanus*), turkey vulture (*Cathartes aura*), and great horned owl (*Bubo virginianus*). In addition, rough-legged hawks (*Buteo lagopus*) are common winter residents of the Pine Ridge area (WFC 1983).

Within the TCEA itself, few raptors and no nests were observed during the 2008 field surveys. It should be noted that there are a few clusters of Eastern cottonwoods dispersed throughout the area that could support raptors and their nests, mostly situated near structure biotopes. More suitable habitat exists outside of the project area in riverine habitat along White River, Dead Man's Creek, Cherry Creek, and Bozle Creek. Further, there are portions of suitable nesting habitat within the ponderosa pine forests, south of the project area boundary **(Figure 1.1-2)**. During the summer of 2008, pedestrian raptor nest surveys were conducted in suitable nesting habitat (i.e. forested habitat) within the project area and a 2.25 mile buffer of the project area. Great Horned Owl fledglings (8-10 weeks) were spotted in a prior year's raptor nest outside the project area alongside Dead Man's Creek, and a Red-Tail Hawk's nest was observed outside the project area alongside Cherry Creek. No nests or sign thereof were found within the project area.

3.5.8.4 Waterfowl

Waterfowl may occur throughout the region, primarily during the spring and fall migrations. However, due to the lack of wetlands and their associated habitats, the diversity and abundance of waterfowl is extremely low in the Crow Butte project area. Outside of the reaches of open water associated with the White River impoundments, wetland habitats are absent from the project area. During the 1982 baseline surveys, 24 species of waterfowl were observed, with the mallard duck (*Anas platyrhnchos*) being the most commonly observed species (WFC 1983).

3.5.9 Reptiles and Amphibians

Of the 22 species of reptiles and amphibians recorded in Dawes and Sioux Counties (Ferraro 2004) (**Appendix J-4**), 13 were documented during the 1982 baseline investigation (WFC 1983). Documented toads and frogs included Woodhouse's toad (*Bufo woodhousii*), Great Plains toad (*Bufo cognatus*), plains spadefoot (*Spea bombifrons*), western striped chorus frog (*Pseudacris triseriata*), northern leopard frog (*Rana pipiens*), and bullfrog (*Rana catesbeiana*). The snapping turtle (*Chelydra serpentina*) and painted turtle (*Chrysemys picta*) were also observed. Snakes identified included the bullsnake (*Pituophis catenifer*), plains garter snake (*Thamnophis radix*), red-sided garter snake (*Thamnophis sirtalis*), and racer (*Coluber constrictor*). During the 2008 field observations, bullsnakes were the most commonly noticed reptile.

3.5.10 Threatened, Endangered, or Candidate Species

Several species that could potentially occur within the project area are considered "threatened or endangered" because of their recognized rarity or vulnerability to various causes of habitat loss or population decline. These designated species receive specific protection defined in the federal Endangered Species Act of 1973, as amended, and the Nongame and Endangered Species Conservation Act (Neb. Rev. Stat. §37-430 et seq.). Other species have been designated as "candidate or sensitive" on the basis of adopted policies and expertise of state resource agencies or organizations with acknowledged expertise. A list of potentially occurring special-status species, along with specific occurrence records, was developed from an original list of target species based on records of the NGPC and the USFWS. **Table 3.5-3** summarizes the known or potential occurrence of each species within the TCEA. **Appendix J-7** provides distribution maps of these species.

3.5.10.1 Black-footed Ferret

The black-footed ferret (*Mustela nigripes*) is listed as endangered by the USFWS and NGPC, and has the potential to occur in Dawes County (**Appendix J-7**) (AGC Nebraska Chapter 2007, USFWS 2006). However, no recent confirmed populations of the black-footed ferret have been observed in the State of Nebraska. The last known specimen was an individual killed on a road near Overton in Dawson County in 1949, and no wild ferrets have been verified in Nebraska since the 1940s (NGPC 2008b). Based on this information, it can be presumed that the black-footed ferret is not expected to occur in the project area, and are not discussed further.

3.5.10.2 Black-tailed Prairie Dog

The black-tailed prairie dog (*Cynomy ludovicianus*) is one of five species of prairie dogs found in North America. It is an abundant and widely distributed species and is the only prairie dog found in Nebraska. In Nebraska, prairie dogs are found roughly in the western two-thirds of the state. It is considered a candidate for endangered status because it is a major food source for the Black-footed Ferret. When poison or other methods are used for control of this species, it also affects it natural predator, the endangered Black-footed Ferret (AGC Nebraska Chapter 2007). The US Fish and Wildlife Service (USFWS) announced on May 17, 2009 that it had denied a petition to reclassify three black-footed ferret reintroduced populations in Arizona, Wyoming and South Dakota under the Endangered Species Act (USFWS 2009).

These prairie dogs inhabit areas of short and mid-grass rangeland and live in colonies or "towns" that range in size from as small as one acre to several thousand acres. It is estimated that in the late 1800s, some 700 million acres of North American rangeland were inhabited by prairie dogs. Habitat changes and extensive eradication efforts have reduced the acreage by about 90 to 95 percent from historic levels (NGPC 2008c).

There is a low to moderate density of colony potential for this prairie dog within the TCEA (**Appendix J-7**) (AGC Nebraska Chapter 2007). The cattle grazed and short grass areas coincide with the mammal's preferential habitat. Recent year's numbers in Nebraska indicate healthy and increasing populations where the mammal is not controlled (NGPC 2008c). However due to the agricultural presence, it is likely that these small mammals have been a target of grazing competition.

3.5.10.3 Eskimo Curlew

The Eskimo Curlew (*Numenius borealis*) is a relatively short, slender curlew with a slightly down curved bill. The bird's northward migrations route encompasses the eastern portion of Nebraska, but it has been reported that the curlew has migrated through the all regions of the state during the months of Marsh, April, May and June. Newly plowed fields, burned prairies and marshes are particularly attractive to migrating curlews. It feeds in the plowed fields by 8 or 9 am, and can be observed consuming grasshopper egg pods, earthworms and locusts.

In the project area, there is potential feeding habitat for the bird, but there have not been possible or confirmed sightings within the area (AGC Nebraska Chapter 2007). It is unlikely that the bird uses the area for anything but stopover habitat during migration.

The Eskimo Curlew is listed as endangered by both the Nebraska Game and Parks Commission and the U.S. Fish and Wildlife Service.

3.5.10.4 Mountain Plover

The Mountain Plover (*Charadrius montanus*) is generally considered an inhabitant of the arid short grass prairie, which is dominated by blue grama, buffalo grass and is scattered with clumps of cacti and forbs. They are very selective in choosing nest sites, preferring expansive, arid flats with very short grass and lots of bare ground, and they often nest near prairie dog communities. They primarily feed on insects, especially spiders, beetles, grasshoppers, crickets and ants. It can thrive without drinking free-standing water because sufficient water is obtained from its food (AGC Nebraska Chapter 2007).

The bird is currently being considered for listing its federal status, and it is listed as threatened in the State of Nebraska. NPGC (2008d) describes that current distribution maps are misleading, showing plovers occurring over a large range. In reality, habitat within this range is limited. Breeding strongholds are confined to small areas of native prairies in Montana and Colorado. Most of the birds winter in California, principally in the San Joaquin Valley, an area experiencing high rates of human population growth. Today the mountain plover is considered endangered in Canada, a species of special interest or concern in Montana and Oklahoma, extirpated in North Dakota and South Dakota, on the watch list in Kansas and threatened in Nebraska. Beyond the Endangered Species Act, the Migratory Bird Treaty Act protects the mountain plover from unauthorized destruction of birds, nests and eggs. Nebraska law provides additional protection by requiring state agencies to ensure that their actions, or actions authorized or funded by them, do not jeopardize the mountain plover (NPGC 2008d).

There is potential habitat for the plover in southern Dawes and Sioux counties, and there been recent scattered observations in the neighboring Box Butte County (NPGC 2008d). It is possible that they may occur in isolated instances in the project area, but because prairie dogs are likely controlled in the area, strong plover nesting habitats are probably limited.

3.5.10.5 Swift Fox

The swift fox (*Vulpes velox*) was petitioned for listing under the Endangered Species Act in 1992. The 90-day finding from U.S. Fish and Wildlife Service concluded that a species listing may be warranted range-wide. However, the 12- month finding issued in 1995 by the U.S. Fish and Wildlife Service resulted in a "warranted, but precluded decision," concluding that the magnitude of threats to the species is low to moderate although the immediacy of threats remains imminent. Within Nebraska, the swift fox is listed as endangered under the Nongame and Endangered Species Conservation Act.

The swift fox is found in short- and mid-grass prairie habitats. It appears to prefer flat to gently rolling terrain. Swift fox 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 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 9.4 square kilometers at night, and their day ranges are typically much smaller (Schauster et al. 2002).

The swift fox is found in native shortgrass in northwestern Nebraska. Unlike coyotes or red fox, the swift fox uses dens in the ground the entire year. 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 source 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, interspecific competition, disease, and landscape physiography. Anthropogenic factors include habitat loss from agricultural, industrial, and urban conversion; competing land uses on remaining habitat including hydrocarbon production, military training, and grazing; and pesticide use. Of these, prey availability and habitat loss appear to have the most profound effects on swift fox populations.

Sightings of swift fox have been documented in northwestern Nebraska since the late 1970's (Godberson 2004). Most of these sightings have occurred in and around Oglala National Grasslands, primarily in large tracts of native prairie. Swift fox's have the potential to occur in the project area using rolling uplands between drainages and mixed-grass prairie habitats (**Appendix J-7**). Though, this species is sensitive to disturbance and may avoid otherwise suitable habitat in the vicinity of human disturbance.

3.5.10.6 Whooping Crane

The whooping crane (*Grus americana*) is listed as endangered by the USFWS and NGPC, with the potential to occur in Dawes County (**Appendix J-7**) (NGPC 2008b, USFWS 2006). The whooping crane is an occasional spring and fall migrant along the Platte Valley in Nebraska, which accounts for approximately 90 percent of the observations in Nebraska. The Platte Valley is located in central Nebraska, a considerable distance from the project area. Additionally, suitable habitat is lacking within the project area (e.g., rivers and streams with associated sandbars and islands, marshlands, wet meadows and croplands). The whooping crane is not expected to occur in the project area, and will not be discussed further.

3.5.11 Aquatic Resources

The Crow Butte project area is primarily contained within the White River basin. The White River originates on the Pine Ridge Escarpment in northwestern Nebraska. The river flows is a northeasterly direction into South Dakota, passing through boundaries of the Pine Ridge and Rosebud Sioux Indian reservations, then turns east and empties into the Missouri River near Chamberlain, South Dakota. The entire drainage basin is approximately 10,200 square miles, with 313 square miles in Dawes County, Nebraska. The White River is characterized as a larger basin with flat stream slopes that typically has high flows characterized by rapidly rising flows and gradually receding flows. The White River is primarily regulated by periods of snowmelt, direct precipitation, surface runoff, and ground water discharge from seeps and springs.

Drainages in the TCEA include: an unnamed tributary of the White River, and Cherry Creek. As of December 21, 2005, surface water was only present in Section 25 T31N R53W (**Figure 3.5-1**). Outside of these areas, the drainages within the TCEA showed no signs of water flow, lacking a defined bed and bank.

White River depth typically ranges from 0.5 to 2 meters, and width varies from about 3 to 5 meters. Cover for fish is provided by deep water, log jams, and undercut tree roots. Some riparian areas exist along the river, especially around Fort Robinson State Park. There is also limited riparian habitat in portions of the TCEA.

Within the TCEA, Cherry Creek consistently lacks a defined bed and bank. The vegetation is primarily mixed-grass prairie. Further south in central Section 5 T30N R52W, outside of the TCEA, there is evidence of occasional high water flow along this portion of Cherry Creek. A defined bed and bank is present, however, no wetland vegetation is present. As of June 12, 2008, this area was noted as dry.

In general, the aquatic habitats within the Crow Butte project area suffer from ongoing environmental stresses. Natural occurring stresses include unstable substrates and banks, low flows, and periodic high volume surface flows. Overgrazing on adjacent rangelands and riparian areas combined with farming practices along the stream courses further compound these problems. Livestock grazing and watering add to impoverished stream conditions. These stresses are reflected in a fishery mostly consisting of non-game, tolerant species. Periodic stocking by the NGPC has created some put-and-take sport fisheries in the area, but these are not self-sustaining due to environmental factors (WFC 1983).

3.5.12 Aquatic Ecology

Aquatic ecology baseline data collections were conducted in 1982 (WFC 1983) and 1996 (Ferret Exploration of Nebraska 1987) to assess aquatic resources in the Crow Butte project area.

3.5.12.1 Fish

During the 1982 and 1996 baseline collections, fish were collected in various streams, including the White River, to document their occurrence. Fifteen species of fish were collected during these collection periods (**Appendix J-5**). Game fish collected in the White River included rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and white sucker (*Catostomus commersoni*). Minnow species collected in the White River included longnose dace (*Rhinichthys cataractae*), common shiner (*Luxilus cornutus*), fathead minnow (*Pimephales promelas*), and creek chub (*Semotilus atromaculatus*).

A regionally important put-and-take fishery exists in the White River within and around Fort Robinson State Park. However, fluctuating flows, periodic flooding, sand and silt substrates, and warm water temperatures are probably the most important factors limiting natural trout production in the White River, especially in areas of intensive agricultural and grazing (WFC 1983).

3.5.12.2 Macroinvertebrates

Macroinvertebrate density, diversity, and number of taxa for various streams, including the White River, were sampled in 1982 (WFC 1983) and 1996 (Ferret Exploration of Nebraska 1987) (**Appendix J-6**). Analyses of the samples indicated that, in general, most aquatic streams in the Crow Butte project area have stressed environments. More than 90 percent of the total abundance of all sampled areas consisted of organisms that are considered tolerant. The most abundant groups of these tolerant species were: chironomidae (34 percent); simulidae (20 percent); oligochaeta (19 percent); and ceratopogonidae (15 percent). Exceptions occurred within the upper White River, where caddisflies and mayflies dominated the riffle habitat. These two taxa typically represent less-stressed environments than the above listed organisms.

Although densities of macroinvertebrates were high at most sampling stations, diversity values were low. Healthy streams usually have diversity values between 3.0 and 4.0, but many forms of stress reduce diversity by making the environment unsuitable for some species or by giving other species a competitive advantage. The White River did not have diversity values within this range, indicating relatively lower water quality and degraded stream habitats (WFC 1983).

3.6 Climate and Meteorology

The TCEA is located in the north central portion of the Nebraska panhandle, with weather patterns being typical of a semi-arid, continental climate. This climate is characterized by warm summers, cold winters, light precipitation, and frequent changes in the weather. The area is subject to wide seasonal and day-to-day variations in temperature and precipitation. Dawes County is usually warm in the summer, with frequent spells of hot weather and occasional cool days interspersed, although sporadically, throughout the summer. These changes in weather can generate thunderstorms, which deliver a majority of the total annual precipitation.

The Rocky Mountains, located to the west of the site, and the Black Hills, located to the north, effectively block moisture from these directions, while moisture from the south is directed eastward by a plateau south of the region. As a result of this topography, the project area is generally drier than the rest of the panhandle.

This section provides meteorological data that characterizes the TCEA area, providing historical information for temperature, precipitation, relative humidity, mean sea level pressure, and wind speed and wind direction.

3.6.1 Sources of Meteorological Data

Data sources for the meteorological conditions used for this report come from three major sources:

3.6.1.1 High Plains Regional Climatic Center

The High Plains Regional Climatic Center (HPRCC) is located in Lincoln, Nebraska. The partners of this organization consist of National Climatic Data Center, Regional Climatic Centers and State Climate Offices. The mission of the HPRCC is to increase the use and availability of climate data in the High Plains Region of the U.S (HPRCC 2010). The HPRCC maintains historical climate data, archiving all relevant data from National Weather Service surface weather networks.

Historical data for temperature and precipitation were obtained from the HPRCC website for the Chadron National Weather Station (NWS). The period of record for the Chadron NWS covers data for over 100 years of observations between 1894 to the present. Summaries of historical data of temperature and precipitation for the Chadron NWS were collected and used in this is section.

3.6.1.2 Chadron National Weather Station (NWS)

The HPRCC data were collected at the Chadron 1 NWS site (latitude 42° 50' north, longitude -103° 01' west with a ground elevation of 1021 meters [3350 feet] above mean sea level). The Chadron NWS is approximately 8.0 km (5.0 miles) west northwest of the City of Chadron, 32.2 km (20 miles) east northeast of the City of Crawford, and approximately 40.2 km (25 miles) northeast of the proposed satellite facility (**Figure 3.6-1**).

Wind speed and wind direction data were obtained for the Chadron site by purchasing data from the National Climatic Data Center (NCDC), the world's largest archive of weather data, and from the Weather Underground for relative humidity.

3.6.1.3 Whitney Coast Guard Station (WHN5)

The Whitney Coast Guard Station (WHN5) (latitude 42° 74' north longitude -103° 33' west with a ground elevation of 1071 meters [3514 feet], above mean sea level) is operated by the U.S. Coast Guard (USCG) on behalf of the U.S. Department of Transportation (DOT). The weather sensors at the site are owned by National Oceanic and Atmospheric Administration (NOAA). The Whitney station is located between the City of Chadron and the TCEA site, being located approximately 16.1 kilometers (10 miles) northeast of the proposed TCEA site (**Figure 3.6-1**).

Weather data for the Whitney station were obtained from the Earth Systems Research Laboratory (ESRL 2010). Meteorological data obtained for this site for use in this section consisted of hourly relative humidity and barometric pressure (no precipitation, winds speed or direction). Data for 2002 through 2009 was obtained for this station for relative humidity and barometric pressure (adjusted to mean sea level pressure).

3.6.1.4 CBR Onsite Meteorological Station

An onsite meteorological (MET) station was operated at the nearby current operating Crow Butte Project. This MET station was operating from May 1982 to April 1984. The MET Station is located approximately 3.7 miles northeast of the northeast corner of the TCEA license boundary (1093605 Easting 503789 Northing) (**Figure 3.6-1**). Wind speed and direction measurements at this location were used for inclusion in this section.

3.6.2 Temperature

3.6.2.1 Chadron NWS

Annual mean minimum and maximum temperatures for the Chadron NWS are 1.6° C and 16.5° C, respectively, with a mean average of 9.1° C (**Table 3.6-1**) (HPRCC 2010). The number of days of maximum and minimum temperatures is presented in **Table 3.6-2**. Temperatures at or greater than 0° C and 32.2° C, have been recorded for an average of 44.1 and 38.7 days, respectively, while temperatures at or less than 0° C and 17.8° C have been recorded for an average of 165.6 and 18.5 days, respectively. For the time-period between 1894 and 2009, the lowest recorded mean monthly average temperature was -11.3° C for the month of January and the highest recorded mean monthly average temperature was 31.9° C for the month of July (**Table 3.6-1**). July is the average warmest month and January is the average coolest month of the year.

3.6.2.2 Whitney WHN5 Station

Monthly average temperature measures for WHN5 station for 2002 through 2009 ranged from a minimum of -26.7 °C in 2009 to a maximum of 39.2 °C in 2003 (**Table 3.6-4**). Minimum temperatures ranged from -15.6 °C in 2003 to a maximum of -26.7 °C in 2009, while maximum temperatures ranged from 29.2 °C in 2004 to a maximum of 37.8 °C in 2009.

3.6.3 Precipitation

3.6.3.1 Chadron NWS

Precipitation occurs throughout the year (mean annual total of 41.9 centimeters), with yearly averages ranging from a monthly low of 1.2 centimeters in December through February with highs of 7.3 and 7.1 centimeters in May and June, respectively (**Table 3.6-3**). The highest maximum 24-hour event was 26.4 centimeters in the June time-frame and the lowest 24-hour event of 4.8 centimeters being for the month of December. The area has any average annual mean of 111.3 centimeters of snowfall, with annual amounts of snow events ranging from 14 to 22.6 centimeters for the months of November through April. The months of January, March and April had the highest maximum monthly snow fall amounts, i.e., 88.1, 88.1, and 84.8 centimeters, respectively. Historically, the most precipitation on average occurs in May.

3.6.4 Relative Humidity

3.6.4.1 Whitney WNH5 Station

Relative humidity measurements were taken from the Whitney WHN5 station for the years 2002 – 2009 (**Table 3.6-4**). The range of the average relative humidity (RH) measurements ranged from 54.2 to 63.7 percent. The range of the average minimum RH values ranged from 11.4 to 20.5 percent, and the average maximum values ranged from 94.0 to 98.5 percent.

3.6.5 Sea Level Pressure

3.6.5.1 Whitney WNH5 Station

Sea level pressure (SLP) for the City of Crawford area is calculated by using the site station pressure measurements and then correcting for the difference in elevation from sea level. Station pressure measurements were taken from the Whitney WHN5 station for the years 2002 – 2009 (**Table 3.6-4**).

The SLP data for eight years showed a range of 1015.0 to 1016.1 millibars (mb) for the average of measurements, a range of 946.3 to 1001.3 mb for the average minimum measurements, and a range of 1030.0 to 1044.7 mb for the average maximum measurements.

3.6.6 Mixing Height

The nearest national weather station to the TCEA that reports mixing height values is located at North Platte, Nebraska. This station is location approximately 170 miles southeast of the City of Crawford. Due to the distance, the data are not considered representative of the City of Crawford area. Default mixing height values can be obtained from different atmospheric stability classes. The U.S. Environmental Protection Agency (EPA) also provides a default value for calculating the mixing layer height. The default method for calculating mixing height is to use the interpolation scheme employed in the PCRAMMET meteorological processor, which uses the twice-daily mixing heights from the nearest NWS upper observation site, coupled with the stability category determined for the hour. The NRC MILDOS-AREA, a computer program for calculating radiation doses from uranium recovery operations, allows for the use of a default value of 1000 meters (NRC 1981).

3.6.7 Wind Speed and Direction

3.6.7.1 CBR Onsite MET Station and Chadron NWS

Wind speed and direction are key factors affecting the movement of air and other gases in the atmosphere. The wind speed and direction at a location directly affect how emissions are dispersed (affecting concentration and plume dimensions) and in which directions emissions will be conveyed from a source. A wind rose is developed from these data and depicts pictorially the frequency of occurrence of winds in each of the specified wind direction sectors and wind speed classes for a given location and time period.

CBR has used wind speed and direction data from the nearby CBR onsite meteorological data records for the preparation of the onsite wind rose (**Figure 3.6-1**). The results of this monitoring were compared to the data available for the Chadron NWS station, which is located at the airport.

Figure 3.6-2 shows the wind rose for the CBR onsite data from May 1982 to April 1984. **Figures 3.6-3** and **3.6-4** show the wind rose for Chadron NWS data from April 1982 to May 1984 and 2000 to 2009, respectively. A comparison of these three figures shows that the wind predominantly blows from the third quarter quadrant (S, SSW, WS, WS, WSW and W) of the wind rose for both CBR and the Chadron NWS site, with the Chadron NWS data showing a more predominant westerly wind direction. Both locations also show a minor trend of wind blowing from the NNE and NE.

For the CBR Onsite MET Station, **Table 3.6-5 - 3.6-11** shows the frequency of winds by direction and speed for the six stability classes. **Table 3.6-12** shows the annual relative joint frequency distribution. **Tables 3.6-13** and **3.6-14** present the wind direction and speed frequency distribution for the Chadron NWS for the time periods April 1982 – May 1983 and 2000 – 2009, respectively. The Chadron NWS had similar wind speed frequency distribution as that of the CBR Onsite MET Station data. The CBR Onsite MET Station data showed slightly higher frequencies of low wind speeds in the range of 1 – 4 knots than that of the Chadron NWS.

CBR will be installing an onsite meteorological station at or near the TCEA site at the outset of operations to verify specific site meteorological conditions. This station will provide measurements of wind speed, wind direction, relative humidity, barometric pressure, precipitation, temperature, evaporation rates and solar radiation. The station will be operated to collect 12 months of data acceptable to the appropriate regulatory agencies. These data will then be compared to the Chadron NWS data to ensure the data is considered representative of the TCEA area.

3.6.8 Air Quality

3.6.8.1 National Ambient Air Quality Standards

The NDEQ regulations are based on federal and/or state law, with the primary source of the authority for air quality regulations being the federal Clean Air Act (NDEQ 2010). The NDEQ adopts the majority of these federal regulations into Title 129 (Nebraska Air Quality of the Nebraska Administrative Code). The basic foundation of the NDEQ air program is the National Ambient Air Quality Standards (NAAQS), which are concentrations of pollutants the EPA has established (and adopted by the NDEQ) as being protective of human health and the environment. The standards are established for six "criteria" pollutants: particulate matter, sulfur dioxide, nitrogen oxides, carbon monoxide, ozone and lead (**Table 3.6-15**). The State of Nebraska is required to keep areas in compliance with the standards and restoring compliance in any areas out of compliance. The NDEQ has several ambient air monitors located throughout the state to measure the concentrations of pollutants in the ambient air (NDEQ 2010). An area may be classified as nonattainment if the concentration of one or more criteria pollutants in an area is found to exceed the regulated or "threshold" level for one or more of the NAAQS. Those areas with concentrations of criteria pollutants that are below the levels established by the NAAQS are considered in attainment or unclassifiable.

The overall air quality of the State of Nebraska is considered to be good. Nebraska is located in a part of US that is largely attainment with NAAQS, thereby minimizing the impact of pollutant transport from other states on Nebraska air quality (NDEQ 2009). All areas within the state are in attainment with state and federal air quality standards (i.e., NAAQS) (NDEQ 2009). The City of Omaha previously had a nonattainment designation for lead, but due to actions by Omaha Air Quality Control, NDEQ, EPA and local industries, the area is now classified as attainment. The City of Omaha is located over 375 miles from the TCEA area. The EPA proposed a new (and lower) ozone standard in the Jan. 19, 2010 Federal Register. When the rule is finalized, the Omaha/Council Bluffs area may be significantly impacted if its levels of ozone pollution are above the regulatory limits.

There are no ambient air quality monitoring data for criteria pollutants in the proposed TCEA license boundary. However, there are a limited amount of state (Nebraska and South Dakota) and federal monitoring sites in the region of the TCEA that can be used as levels representative of the region for the monitored parameters. These monitoring sites are maintained for a variety of purposes, including for regional background purposes by the NDEQ and South Dakota Department of Environment & Natural Resources (SD DENR), as per Appendix D of 40 CFR Part 58.

Regional monitoring sites and parameters measured are presented in **Table 3.6-16**. The locations of the monitor sites are shown in **Figure 3.6-5**. Sites are located in western Nebraska and western South Dakota. The summary of the data available at the time of preparation of this section are presented in **Tables 3.6-17** through **3.6-23**. The results of this monitoring indicates the regions being monitored, included the TCEA area, are well within compliance of NAAQS standards.

3.6.8.2 Prevention of Significant Deterioration

In addition to the ambient air quality standards, there are national standards for the Prevention of Significant Deterioration (PSD) of air quality (40 CFR 51.166). The PSD program is administered by the State of Nebraska and South Dakota, with their programs designed to protect the air quality in area that are in attainment with the NAAQS and to prevent degradation of air quality in areas below the standard (designed as clean air areas). PSD differs from the NAAQS in that the NAAQS provides for maximum allowable concentrations of pollutants, while PSD requirements provide maximum allowable increases in concentrations of pollutants for areas already in compliance with the NAAQS. The PSD requirements establish allowable pollution "increments" that may be added to the air in each area while still protecting air quality. The increment is the maximum allowable deterioration of air quality. The maximum allowable increments applicable to Nebraska and South Dakota are shown in **Table 3.6-24.**

The allowable increments vary by location across the states. Those areas characterized as Class I (i.e., National Parks and Wilderness Areas) allow for less incremental pollution increase. Class III areas are planning areas set aside for industrial growth. The areas classified as Class II are essentially all other areas of the state not designated as Class I or Class III. There are no Class I National Park and Wilderness Areas in Nebraska. The Soldier Creek Wilderness Area located north of Fort Robinson is not designated as Class I. The State of South Dakota has two Class I

Areas: Badlands and Wind Cave National Parks. The Wind Caves National Park is closer to the TCEA a distance of approximately 63 miles.

No potential impacts to NAAQS parameters or PSD Class I, II or III areas are expected to occur as the result of the TCEA operations. The primary emissions from the proposed TCEA will be tailpipe emissions of nitrogen oxides (NOx), carbon monoxide (CO), sulfur dioxide (SO2), non-methane-ethane volatile organic compounds (VOC and particulate matter with a diameter less than ten micrometers (PM10) resulting from vehicle traffic within the TCEA. The majority of the emissions generated during construction will be fugitive dust and vehicle combustion emissions. Effects of air emissions and impacts associated with construction and operations are discussed in Section 4.6.

3.7 Noise

The TCEA site and immediate area is predominantly rural and undeveloped, with the number of residences being minimal (**Figure 3.1-2**). Such rural areas tend to be relative quiet. Primary manmade noises that contribute to the background noise levels at the TCEA would include the following:

- Farm and ranching activities of area

  The TCEA is an area of ranching and farming, so noise associated with farm and ranch equipment would contribute to seasonal background noise levels at the TCEA.

- US and State Highway vehicle traffic

  Hwy 20 and 2/71 are located nearby and vehicle traffic would contribute to background noise levels.

- Train traffic

  The BNSF Railroad tracks pass through the City of Crawford and the train traffic would contribute to noise levels in the area.

- Fort Robinson State Park

  The Fort Robinson State Park is located just to the north of the proposed TCEA. Increased traffic on Hwy 20 and 2/71 would be expected to increase during the summer months due to public visitation of the park.

Noise impacts associated with construction of the satellite facilities would be of short duration compared to the operations period. Noise levels during site construction are expected to increase due to increased vehicle traffic in support of construction on SH 2/71. Additionally, heavy equipment used during construction may include bulldozers, scrapers, graders, front-end loaders, cranes and various trucks used for conveying personnel. Train usage would not increase as a result of construction. Noise from construction would not be generated during nighttime hours, and increases in noise levels would be intermittent and temporary.

Noise sources during operation are expected to increase due to increased vehicle travel as increased numbers of employees traveling to and from the City of Crawford and area for work and from resin transfer to the CPF. Processing equipment at the satellite facility would be minimal and is not expected to significantly add to existing noise sources. Increases due to operations are expected to be less than noise levels generated during construction. Therefore, it is expected that noise levels during operations would be barely perceptible over the existing ambient noise that is dominated by vehicle noise and the BSNF railroad.

Noise impacts are discussed in Section 4.7.

3.8 Regional Historic, Archeological, Architectural, Scenic and Natural Landmarks

3.8.1 Historic, Archeological, and Cultural Resources

Previous cultural resource investigations in the general area surrounding the City of Crawford and Fort Robinson State Historic Park indicate that a variety of prehistoric and historic resources of potential significance exist in the vicinity. Resources include the Hudson-Meng prehistoric bison kill to the north of the area, several prehistoric camps and artifact scatters in the general areas, fur-trade period sites associated with the early history of City of Chadron, Fort Robinson, the Sidney-Deadwood Trail, the two historic railroads that cross where the City of Crawford emerged, and the City of Crawford itself. There has been extensive farming around the City of Crawford, which may have disturbed many earlier sites, but has also created historic farming sites and features.

The proposed TCEA is on private lands immediately south of Fort Robinson State Park. An architectural and structural properties search was completed at the Nebraska State Historic Preservation Office (SHPO) and an archaeological site search was completed at the Archaeology Division of the Nebraska State Historical Society (NSHS) in November 2005 for the project area Two previous cultural resources inventories had been documented near State Highway 2/71 east of the project area and the SHPO had no record of documented standing structures in the area. However, the SHPO noted that there were buildings shown on the topographic maps of the area, and these might include historic structures that would need to be recorded. One archaeological site (25DW238) was identified in the archeological site search east of the project area. An updated records search was requested in November 2007, and no new cultural resource inventories or documented sites were reported. Fort Robinson State Park, north of the project area, contains Fort Robinson and the Red Cloud Indian Agency. Together these sites are a National Historic Landmark. The Red Cloud Indian Agency was relocated to the City of Crawford area from Wyoming in 1873 and Fort Robinson was established in 1874 to protect the agency. Fort Robinson remained an active military post until 1948. There are no other reported National Register Properties or National Natural Landmarks in the vicinity of the project.

On January 16, 2008 letters identifying the nature and location of the proposed project were sent to the Nebraska Commission on Indian Affairs and the following 14 tribes: the Apache Tribe of Oklahoma; the Cheyenne River Sioux Tribe; the Cheyenne and Arapaho Tribes of Oklahoma; the Crow Creek Sioux Tribe; the Crow Nation; the Kiowa Tribe of Oklahoma; the Lower Brule Sioux Tribe; the Northern Arapaho Tribe; the Northern Cheyenne Tribe; the Oglala Sioux Tribe; the Pawnee Nation of Oklahoma; the Rosebud Sioux Tribe, the Santee Sioux Nation; and the Standing Rock Sioux Tribe. Follow up telephone calls were made in February and March to verify that the information had reached the appropriate persons in each tribe and to ask whether the tribes had any concerns about the project or were aware of any traditional concerns in the immediate vicinity of the project. Harvey Whitewoman of the Oglala Sioux called before the follow up calls were begun to ask what effect the proposed project might have on water quality. In addition, the Northern Cheyenne Tribe sent a memo expressing concern about "peripheral effects and development outside the project, and the Rosebud Sioux sent a letter indicating that they had no records of any sites in the project area, but that the Rosebud Sioux Tribe was against any uranium mine.

The identification and assessment of cultural resources within the TCEA entailed a cultural resource inventory of a 2,100-acre area of anticipated development. This area was inventoried by Greystone (now ARCADIS) archaeologists between January 9 and January 15, 2006 (Späth 2007). The proposed TCEA includes approximately 1,643 acres, which is entirely within the 2,100 acre cultural resources survey area. The TCEA was surveyed for the presence of cultural resources that may be impacted by the proposed mine development. Seven historic sites, one isolated historic farm implement, one isolated historic artifact, and two isolated prehistoric artifacts were located and identified. In addition, there are two historic farms just outside the TCEA. The historic sites in the TCEA are two artifact scatters, one farm complex, one rural residence, two abandoned sites with collapsed buildings, and a collapsed windmill and water tank. The individual objects and artifacts are an abandoned plow, a historic fraternal medallion and two prehistoric flakes. None of these sites are distinctive or outstanding, and all of the sites are recommended as not eligible for the National Register of Historic Places. Because these resources are considered not eligible, they are not historic properties. The proposed TCEA will have no effect on historic properties, and no further cultural resource work is recommended. The Nebraska SHPO has concurred that the reported resources are not eligible for the National Register of Historic Places and that the proposed project will not affect archaeological, architectural, or historic context properties (Steinacher and Puschendorf 2007).

Specific information included in cultural resource investigation falls under the confidentiality requirement for archeological resources under the National Historic Preservation Act, Section 304 (16 U.S.C. 470w-3(a)). Additionally, disclosure of such information is protected under Nebraska State Stature Section 84-712.05 (13 and 14). Information that is not considered confidential is presented in Appendix O. This information consists of a report with project description, study area location map, affected environment, background information, methods, results (without confidential information) and evaluation and recommendations.

Under separate correspondence, the following information is being submitted to the NRC:

- A copy of the Cultural Resource Inventory Report and supporting correspondence including the Nebraska SHPO correspondence letter and the correspondence to the tribal authorities.

  The contents of Appendices B and C should as treated as "CONFIDENTIAL" information for the purpose of public disclosure of this NRC License Amendment.

  - Appendix B: Location Maps for Sites
  - Appendix C: Site Forms
- Figure 1 Site location map.

Each page of the protected cultural resource information has been marked as follows:

Privileged Information – Disclosure of Site Information is Restricted, NHPA Section 304 (16 U.S.C. 470w-3(a))

The cover pages for each of these appendices have been marked with a more detailed statement, as follows:

For official use only
Submitted under 10 CFR 2.390
Disclosure of Site Information is Restricted
NHPA Section 304 (16 U.S.C. 470w-3(a)
Nebraska Public Records Statutes (Neb. Rev. Stat. 84-712.05(13)).

3.9 Scenic Resources

3.9.1 Introduction

The TCEA is on private land that is not managed to protect scenic quality by any public agency. However, it is located in scenic landscape of the Pine Ridge area of northwestern Nebraska and is visible from sensitive viewing areas. The existing landscape and the visual effect of the proposed facilities have been inventoried and assessed for the proposed project using the Bureau of Land Management (BLM) Visual Resource Management (VRM) system.

3.9.2 Methods

The VRM system is the basic tool used by the BLM to inventory and manage visual resources on public lands. The VRM inventory process involves rating the visual appeal of a tract of land, measuring public concern for scenic quality, and determining whether the tract of land is visible from travel routes or observation points.

The scenic quality inventory was based on methods provided in BLM Manual 8410 – *Visual Resource Inventory*. The key factors of landform, vegetation, water, color, influence of adjacent scenery, scarcity, and cultural modifications were evaluated according to the rating criteria, and provided with a score for each key factor. The criteria for each key factor ranged from high to moderate to low quality based on the variety of line, form, color, texture, and scale of the factor within the landscape. A score was associated with each rating criteria, with a higher score applied to greater complexity and variety for each factor in the landscape. The results of the inventory and the associated score for each key factor are summarized in **Table 3.9-1**. According to NUREG-1569; 2.4.3(7), if the visual resource evaluation rating is 19 or less, no further evaluation is required. The total score of the scenic quality inventory is 13; however, an analysis was prepared to reflect the growing concern some residents may have for the scenic resource, as Dawes County is expected to continue to develop tourism in the region.

3.9.2.1 Visual Resource Management Classes

The elements used to determine the visual resource inventory class is the scenic quality, sensitivity levels, variety classes, and distance zones. Each of the elements used to identify the VRM Class is defined below:

Scenic Quality - Scenic quality is a measure of the visual appeal of a tract of land. In the visual resource inventory process, public lands are assigned an A, B, or C rating based on the apparent scenic quality, which is determined using seven key factors: landform, vegetation, water, color, adjacent scenery, scarcity, and cultural modifications. During the rating process, each of these factors is ranked comparatively against similar features within the physiographic province.

Sensitivity Level – A degree or measure of viewer interest in the scenic qualities of the landscape. Factors to consider include 1) type of users; 2) amount of use; 3) public interest; 4) adjacent land uses; and 5) special areas. Three levels of sensitivity have been defined:

- Sensitivity Level 1 – The highest sensitivity level, referring to areas seen from travel routes and use areas with moderate to high use.
- Sensitivity Level 2 – An average sensitivity level, referring to areas seen from travel routes and use areas with low to moderate use.
- Sensitivity Level 3 – The lowest sensitivity level, referring to areas seen from travel routes and use areas with low use.

Distance Zones – Areas of landscapes denoted by specified distances from the observer, particularly on roads, trails, concentrated-use areas, rivers, etc. The three categories are foreground-middleground, background, and seldom seen.

- Foreground-Middleground – The area visible from a travel route, use area, or other observer position to a distance of 3 to 5 miles. The outer boundary of this zone is defined as the point where the texture and form of individual plants are no longer apparent in the landscape and vegetation is apparent only in pattern or outline.
- Background - The viewing area of a distance zone that lies beyond the foreground and middleground. This area usually measures from a minimum of 3 to 5 miles to a maximum of about 15 miles from a travel route, use area, or other observer position. Atmospheric conditions in some areas may limit the maximum to about 8 miles or increase it beyond 15 miles.
- Seldom Seen – The area is screened from view by landforms, buildings, other landscape elements, or distance.

The visual resource inventory classes are used to develop visual resource management classes, which are generally assigned by the BLM through the resource management plan process. VRM objectives are developed to protect scenic public lands, especially those lands that receive the greatest amount of public viewing. The following VRM classes are objectives that outline the amount of disturbance an area can tolerate before it no longer meets the visual quality of that class.

- Class I Objective: To preserve the existing character of the landscape. The level of change to the characteristic landscape should be very low and must not attract attention.
- Class II Objective: To retain the existing character of the landscape. The level of change to the characteristic landscape should be low.
- Class III Objective: To partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate.

- Class IV Objective: To provide for management activities which require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high.

The Scenic Quality, Sensitivity Level, and Distance Zone inventory levels are combined to assign the VRM Class to inventoried lands as shown in **Table 3.9-2**.

3.9.2.2 Affected Environment

The TCEA lies in the Pine Ridge Escarpment ecoregion, which is a subregion of the Western High Plains ecoregion. The Pine Ridge Escarpment is distinguished from the surrounding shortgrass and mixed grass prairies of the Western High Plains in northwestern Nebraska by dramatic sandstone and siltstone bluffs, escarpments, areas of exposed bedrock, and Ponderosa pine woodlands. Ponderosa pine is found on ridge tops, north-facing and east-facing slopes and, in lesser density, on south-facing and west-facing slopes (EPA 2000). The ecoregion features diverse and beautiful scenery that provides a setting for a variety of recreational activities as well as agriculture and other land uses.

The TCEA landscape is rural and agricultural in character, and is composed primarily of scenery that is common for the ecoregion. Vegetation cover consists of grassy meadows and croplands interspersed with shrubby riparian growth along drainages. The landscape colors are dominated by tan, gold and green vegetation. The colors and values (degrees of lightness and darkness) of soils and vegetation are similar, exhibiting little contrast during most months of the year, although the dark greens of Ponderosa pine in the backdrop of the TCEA exhibit striking color contrasts throughout the year. The scenic quality of the TCEA is enhanced by the backdrop of the spectacular Red Cloud Buttes north of Fort Robinson State Park (located adjacent to the north TCEA boundary), and of slopes covered with Ponderosa pine in the Nebraska National Forest to the south.

The characteristic landscape of the TCEA consists of flat to rolling hills dissected by deeply incised gorges formed by tributaries of White River, which is located north of the TCEA. The terrain becomes progressively higher in elevation to the north. The TCEA is blocked from view of portions of Four Mile Road by low ridges located in close proximity to the road.

The visual character of the landscape includes human modification from a variety of land uses, including open lands, cropland, roadways, rural residences, and utility corridors. Open land used for grazing activities is the dominant land use in the TCEA. Croplands, primarily wheat, are also evident from Four Mile Road. The TCEA is accessible from Four Mile Road, a gravel-surfaced county road, which in turn connects to State Highway 2/71 (SH-2/71), one of the primary north-south roadways through Dawes County. Human modifications to the natural landscape evident in the TCEA include private roads, rural residences, and electric distribution lines.

3.9.2.3 TCEA Visual Inventory

Most of the TCEA is characterized by the low, rolling plains and agricultural land uses that are characteristic of the Pine Ridge area in northwestern Nebraska. The scenic quality of the TCEA landscape is typical of the ecoregion, and is rated as Class B. Class A landscapes consisting of the rugged buttes of the Fort Robinson State Park are visible to the north of the project area. The buttes provide a scenic backdrop to the project area that is visible to travelers on Nebraska State Highway (SH) 2/71, which forms the east boundary of the project area.

Sensitive Viewing Areas

Sensitive viewing areas in the TCEA include Four Mile Road, the primary transportation route through the TCEA, and rural residences. Fort Robinson State Park (Park), which is located to the north of the TCEA, is also a sensitive viewing area because of the potential visibility of proposed facilities to Park visitors. In general, residents and other users of the region are accustomed to viewing human modification in the rural landscape, but could be sensitive to increased levels of development.

The characteristic landscape of the TCEA as viewed from Four Mile Road and the residences consists of a broad expanse of mixed grass prairie and cropland with scenic backdrops to the north and south. The TCEA is located approximately 1.5 miles west of SH-2, and is not visible from the highway. Public use of county and private roads within the TCEA is relatively low with motorists falling into the categories of local ranchers and residents.

The greatest number of viewers of the proposed facilities would be traveling on Four Mile Road. The majority of motorists on the road would be residents within and outside of the TCEA. There are 2 occupied residences within the TCEA. The TCEA landscape is also within the viewshed of three residences within the 2.25-mile AOR that are also within 0.5 miles of the TCEA. An additional 15 residences within the 2.25-mile AOR do not have views of most of the TCEA landscape because views are blocked by vegetation or landforms, or because specific features of the TCEA landscape are made indistinct by distance.

The level of use on Four Mile Road and residences within or near to the TCEA is low to moderate, or a Sensitivity Level 2. Viewers at isolated rural residences with views of the project area are few compared with viewers at other sensitive viewing areas, but these residents would generally have a strong level of concern for changes in the viewshed.

A potential sensitive viewing area is the Fort Robinson State Park (Park), located along the north boundary of the TCEA. The Park features a variety of developed recreation facilities, including campgrounds and other lodging facilities, trails, and museums. The majority of facilities and associated recreational activities occur at historic structures and developed areas in close proximity to U.S. Highway 20, and along the White River. A site reconnaissance of the Park was conducted to identify those areas within the Park that would provide views of proposed activities in the TCEA. The view towards the TCEA from developed areas of the park is limited to the immediate foreground distance zone (up to 0.5 miles), because the TCEA is blocked from view by an escarpment along the south bank of the White River, at the north edge of a terrace formed by fluvial downcutting. The escarpment rises in elevation an estimated average of 100 feet above the White River valley bottom which contains the Parks developed facilities. While the level of concern for scenic landscapes would be high for many Park visitors, the TCEA would not be visible from most of the Park.

The TCEA is visible from Smiley Canyon Scenic Drive, which is accessed from Highway 20 at the historic Park facilities. Ridge and hilly terrain blocks views of the TCEA as seen from most of the Scenic Drive; however, a broad, expansive view of the TCEA is spread before east-bound motorists who descend the Scenic Drive to the highway. The TCEA is approximately two miles southeast of the Scenic Drive, so the lines and forms of structures currently within the TCEA are difficult to discern from the surrounding landscape. Although the level of concern for scenic landscapes for motorists on the Scenic Drive would be high, the distance minimizes the visibility of specific features within the landscape that are small in scale relative to the landscape. Therefore, motorists on Smiley Canyon Scenic Drive have a low viewer sensitivity level to changes in the Project area landscape based the distance between the viewer and the landscape, short duration of view, and low user volume

VRM Class

Based on the project area Class B scenic quality, the Sensitivity Level 2 (Medium) as viewed from the Four Mile Road, Smiley Canyon Scenic Drive, residences, and the location of the project area in the foreground-middleground distance zone as seen from the sensitive viewing areas, the TCEA has been assigned Class III for both the visual resource inventory and the VRM objective.

3.10 Population Distribution

Information presented in this section concerns those demographic and social characteristics of the environs that may be affected by the proposed expansion of the Crow Butte Uranium Project to include operations in the TCEA. Data were obtained through the 1980, 1990, and 2000 Decennial Census; the 2009 U.S. Census Population Estimates program; and various State of Nebraska government agencies.

3.10.1 Demography

3.10.1.1 Regional Population

The area within an 80-km (50-mile) radius of the project site includes portions of six counties in northwestern Nebraska, two counties in southwestern South Dakota, and two counties in eastern Wyoming. Because the 80-km radius extends only slightly into two very rural counties in Wyoming, the regional demography in Wyoming is not discussed in detail beyond data summarized in **Table 3.10-1** through **Table 3.10-3**. **Figure 3.10-1** depicts significant population centers within an 80 km radius of the proposed TCEA.

Historical and current population trends in the project area counties and communities are contained in **Table 3.10-1**. Between 1960 and 1980, Box Butte County exhibited the fastest rate of growth with more than a 17 percent population increase, largely occurring in the latter half of the 1970s. Box Butte County lost population between 1980 and 2008, with the greater population losses occurring during the 1990s.

All of the Nebraska counties comprising the project area experienced slight growth or actual population decline between 1960 and 1980 and population decline between 1980 and 2008. The state experienced its fastest growth since the 1920s during the years between 1990 and 2000. The total state population in 2000 was 1.7 million, which was an 8.4-percent increase over the 1990 population of 1.6 million. The Nebraska counties in the project area experienced little of the state growth spurt. However, with the exception of Box Butte, the counties experienced a reversal of the downward trends of the 1980's. In general, population trends for the past two decades show that population in urban areas is increasing, while population in rural areas is declining. Areas within 80 km of the project site that are defined as urban (all territory, population, and housing units in urbanized areas and in places of more than 2,500 persons outside of urbanized areas) by the U.S. Census 2000 are the Cities of Chadron and Alliance, Nebraska (USCB 2003a).

Dawes County grew slightly between 1990 and 2000, gaining 0.4 percent in population. Most of this growth occurred in the City of Chadron. However, these population gains reversed between 2000 and 2008, when population in the county and incorporated communities in the county declined to levels lower than the 1990 populations. The City of Chadron and City of Crawford located in Dawes County are the nearest communities to the project site. The City of Chadron is located approximately 40 km (25 miles) northeast of the project site with a 2000 population of 5,634, an increase of 0.8 percent from 1990 (USCB 2003a). The City of Crawford, within 10 km (2.0 miles) of the site, had a 2008 population of 1,028 (City-Data.com 2010). The population declines in the City of Crawford were greater than the losses in other incorporated communities and the county as a whole.

Sioux County lost population at a slower rate in the years between 1990 and 2000 than in the previous decade. The slower decline of the county population occurred in part because the City of Harrison gained nearly 16 percent, which is a reversal of a trend that shows a decline in population since 1960. Between 1980 and 1985, the downward trend continued in Sioux and Morrill Counties, with Sheridan County exhibiting a slight turnaround. Between 1985 and 1990, the downward trend continued in the Nebraska counties, with the exception of Morrill County, which experienced an increase of 6.3 percent. However, this growth is a decrease from the 1980 population. The years between 2000 and 2009 saw accelerating decreases in the rate of population decline, showing greater losses than other Nebraska counties in the 80 km radius area (USCB 2003a).

Sheridan County has experienced an overall decline of nearly 29 percent since 1970. Population has declined in the Cities of Hay Springs and Rushville between 1980 and 2008, despite earlier gains in the 1980s (USCB 2003a).

Scotts Bluff County experienced population gains between 1990 and 2000 primarily because the City of Scottsbluff, which is an urban area just beyond the 80-km radius of TCEA, showed a strong increase in population of 7.4 percent between 1990 and 2000. The city continued to grow at a considerably slower rate between 2000 and 2008. Overall, the county experienced relatively small losses in population since 2000 (USCB 2003a).

Within South Dakota, portions of Fall River and Shannon Counties fall inside the 80-km study area. Fall River County experienced an overall population decline by more than 30 percent between 1960 and 2000 and a small increase of 1.4 percent between 1990 and 2000. The county population declined between 2000 and the present; however, the declines were not as steep as those in the 1980s. The City of Ardmore lost more than 80 percent of its population between 1960 and 1980, and was disincorporated in 1984. Shannon County, on the other hand, grew by 25.9 percent between 1990 and 2000; more than doubling the 1960 population. Shannon County continued to grow between 2000 and the present, although at a slower rate than in the 1990s. Much of the growth occurred in the Pine Ridge and Oglala Census Designated Places (CDP), which are urban areas as defined by the U.S. Census, but are not incorporated municipalities. Most of Fall River County is included within 80 km of the project site; however, only the southwest portion of Shannon County is within 80 km of the project site (USCB 2003b).

The population declines in the counties within the 80-km radius reflect trends in the overall region, where declines have been attributed to the declines in the rural farming based economy and limited economic opportunities for youth. Persistent drought conditions have also contributed to the shrinking of the agriculture-based economy. Rural residents have been migrating to larger cities, depopulating the largely rural Great Plains states. Many of the people migrating out of the state are young adults and families, which results in fewer people of childbearing age, and therefore, fewer children. This trend also contributes to the increasing proportion of the elderly population in the state (UNRI 2008).

3.10.1.2 Population Characteristics

2008 population by age and sex for counties within 80 km of the TCEA is shown in **Table 3.10-2**. Overall, 74.8 percent of the population in the region is more than 18 years old. Sioux and Niobrara Counties reported the highest percentage of persons older than 18 with 81.4 percent and 82.5 percent, respectively. About 25.2 percent of the population was less than 18 years old in 2008. Shannon County reported the youngest population, with 41.3 percent less than 18 years old, a considerably larger percentage than the other counties within the 80 km radius. Females slightly outnumbered males in most counties, with an overall population of 51.1 percent female to 48.9 percent male (USCB 2009a).

In 2000 slightly more than 75 percent of the ten-county population was classified as white. American Indians and persons of Hispanic origin comprised 21.2 percent and 4.3 percent, respectively, of the total population. Nearly 80 percent of the American Indians were Sioux living on the Pine Ridge Reservation in Shannon County, South Dakota (USCB 2009a).

3.10.1.3 Population Projections

The projected population for selected years by county within the 80-km radius of the proposed Crow Butte Project is shown in **Table 3.10-3**. The population is expected to decrease in the counties surrounding the project area. These counties are primarily rural, with agriculture-based economies. It is anticipated that the declining population trends of the last two decades will continue into the foreseeable future for these counties as population shift to more urban counties (i.e., Douglas, Lancaster, Sarpy, etc.). The projected population for Dawes County is expected to decrease by approximately 55 people (0.6 percent) between 2010 and 2020. This rate reflects recent increases in the population of the City of Chadron that are expected to continue until approximately 2015 (UNL-BBR 2009). In addition, Dawes County provides a scenic setting for a variety of outdoor recreation activities. The Pine Ridge region will probably increase in popularity with visitors and recreationists from outside of the region, as participation in outdoor recreational activities is expected to increase nationwide. An increase in visitor utilization of recreation facilities in Dawes County would revitalize the local economy, adding to the overall attractiveness of the region to potential residents.

3.10.1.4 Seasonal Population and Visitors

According to the Final Environmental Impact Statement for the Northern Great Plains Management Plans Revision (May 2001), the various state parks in northwest Nebraska, the Pine Ridge Ranger District and the Oglala National Grassland, are increasingly becoming regional tourist destinations.

Approximately 361,000 people visited Fort Robinson State Park in 2007. This number represents a 5.6-percent increase from 342,000 in 2001, but a decrease of 4.2 percent from the 1981 visitation of 377,000 people (NDED 2008). Approximately 50 percent of the visitors in 2002 were from other states, which is an increase in the number of out-of-state visitors from 1981, as the majority of 1981 visitors were Nebraskan families. It is likely that the decline of visitors from Nebraska has resulted from the overall decline of population in rural counties within a few hours commuting distance of the park.

There were 55,000 visitors to the Pine Ridge District of the Nebraska National Forest in 2001. Camping and motorized travel/sightseeing are the two most popular recreation categories within the Pine Ridge Ranger District and the Oglala National Grassland.

The forest provides a wide range of other undeveloped backcountry recreation opportunities such as hunting, hiking, backpacking, fishing and wildlife observation. The district provides the greatest number of miles of mountain biking trails in the state. District trails also attract horseback riders and off-highway motorized vehicle use. The Pine Ridge is an important destination for deer hunting, and provides the most popular turkey hunting area in Nebraska.

One source of seasonal population in this region is Chadron State College, located approximately 35 km (21.6 miles) from the site. During the fall enrollment of 2005, 2006, 2007, 2008 and 2009, the enrollment was 2,601, 2,767, 2,726, 2,769, and 2,744, respectively (CSC 2010a, CSC 2010b and TCR 2010). The average enrollment from 1994 through 1999 was 2,944, with a range of 2,768 – 3,189 (NCCPE 2005). Enrollment from 2009 (2,744) versus this later average of 2,944 is a 0.068 percent reduction in student enrollment. For the past five years (2005 – 2009), enrollment has been fairly consistent.

3.10.1.5 Schools

The City of Crawford is served by the City of Crawford Public School District. The Crawford High School and grade school are presently under capacity (Vogl, B. pers. comm. 2010). Enrollment for the fall term of 2009 was 108 in the grade school and 112 in the high school (NDE 2009); a decline of about 14 percent in total enrollment for both schools from March 2007 (Vogl, T. pers. comm. 2007). The grade school currently has a student to teacher ratio of 13 to 1 and the high school has a ratio of 8 to 1.

Families moving into the Crawford district as a result of the proposed TCEA operations would not stress the current school system because it is presently under capacity.

3.10.1.6 Sectorial Population

Existing population, as determined for the original analysis in the CBR commercial license application prepared in 1987 for the 80-km radius, was estimated for 16 compass sectors, by concentric circles of 1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 70 and 80 km from the site (a total of 208 sectors). Sectorial population for the application prepared in 2004 was updated with data from the 2000 U.S. Census. Subtotals by sector and compass points as well as the total population are shown in **Table 3.10-4**.

Population within the 80-km radius was estimated using the following techniques:

U.S. Census 2000 data were used to estimate the total population within an 80-km radius, measured from the center of the proposed TCEA site. The data were created by Geographic Data Technology, Inc., a division of Earth Sciences and Research Institute (ESRI), from Census 2000 boundary and demographic information for block groups within the United States.

ArcInfo Geographic Information System (GIS) was used to extract data from U.S. Census 2000 population estimates for 40 Census Tract Block Groups located wholly or partially within the 80-km radius from the approximate center of the TCEA site. Urban areas within each county were generally assigned their own block group.

To assign a population to each sector, a percentage area of each sector within one or more block groups was calculated for all of the block groups.

2000 U.S. Census of population estimates for cities and counties in Nebraska, South Dakota and Wyoming were used to determine total urban population.

3.10.2 Local Socioeconomic Characteristics

3.10.2.1 Major Economic Sectors

In 2009, average annual unemployment rates in Dawes and Box Butte Counties decreased from the 2008 rates. **Table 3.10-5** summarizes unemployment rates and employment in the Nebraska project area counties, as well as the overall change in employment in economic sectors between 1994 and 2009. Dawes and Box Butte Counties exhibited unemployment rates at 4.4 percent in Dawes County and 6.8 percent in Box Butte County in 2009. The Dawes County unemployment rate was slightly less than the statewide rate of 4.7 percent, whereas the Box Butte County was significantly higher (NDOL 2010).

The major economic sectors in the project area have changed little in recent years, although individual sectors have shifted in their relative proportion in the overall economy. The area continues to depend on trades, government, and services. Economic sectors in the City of Crawford area include farming, ranching, cattle feed lots, tourism, and retail sales.

Agriculture accounted for a significant portion (19.2 percent) of the total employed labor force in Dawes County in 2009. During the same time period, farm employment was 2.0 percent of total employment in Box Butte County. Retail trade accounted for 14.7 percent of total employment in Dawes County, followed by local government employment (12.6 percent), leisure and hospitality (11.1 percent), education and health services (9.8 percent), and state government (6.5 percent). Mining and construction accounted for 5.0 percent. In Box Butte County, the largest four non-farm employment sectors are local transportation, communication and utility services (20.2 percent), local government (17.7 percent), production (8.6 percent), and leisure and hospitality (8.0 percent) (NDOL 2010).

Agriculture employment has a small share of total employment in both counties. However, agriculture provides the economic base for the counties, as other economic sectors support the agricultural industry. Events that affect agriculture are generally felt throughout rural economies. According to the Nebraska Department of Economic Development (NDED 2010), farm employment in Nebraska is expected to decline by nearly 14,000 jobs (20 percent) between 2000 and 2045, while overall non-farm employment will increase by nearly 26 percent. The decrease in jobs in the agricultural sector could continue to fuel migration from rural counties to urban areas, resulting in overall declines in other sectors of the local economy as dollars spent from personal income and agricultural business expenditures move out of the counties.

Per capita personal income is the income that is received by persons from all sources, including wages and other income over the course of one year. In 2007 (most recent available data), personal income in Dawes County was $23,537, which was 65 percent of the state average of $36,372. The county ranks 82nd out of 93 counties in the state (BEA 2010).

3.10.2.2 Housing

Between 1970 and 1980, total housing units increased by 17 percent in Dawes County from 3,388 to 3,965 units (USCB 1990a). After a decline in total units during the 1980s, growth increased by 2.4 percent from 3,909 units in 1990 to 4,004 units in 2000. The City of Chadron, the largest community in Dawes County and within 40 km (25 miles) of the project site, experienced a negligible increase (0.3 percent) in housing stock between 1980 and 1990, and a 5 percent increase between 1990 and 2000. Between 1980 and 1990, the City of Crawford housing stock decreased by nearly 7 percent to 576 (USCB 2003a). There were 4,021 housing units in Dawes County in 2008, an increase of 4 percent from the 4,004 housing units tallied in the 2000 Census (USCB 2010a). Box Butte County, which borders Dawes County to the south,) exhibited a 1 percent loss in total housing units between 1990 and 2000, and an increase of 35 percent from 2000 to 2007. In 2007, there were 5,485 housing units in Box Butte County (USCB 2003a, 2010b).

In 2000, Dawes and Box Butte Counties had homeowner vacancy rates of 1.7 and 1.4 percent, respectively. As of June 2007, there were six single family housing units for sale in the City of Crawford. Three of the units were listed at prices below $100,000. Two of the units were listed at prices between $100,000 and $150,000. One unit was listed at a price over $250,000. Three new single family housing units were constructed between 2006 and 2008 in the City of Crawford and average new home construction costs were $70,000 (NPPD 2009). The median gross rent for the City of Crawford in 2008 was $526 per month (City-Data.com 2010).

The demand for rental housing did not change significantly between 1990 and 2000, as rental vacancy rates were 11.8 percent in Dawes County and 15.4 percent in Box Butte County in 2000 (USCB 2003d), as compared with 1990 rental vacancy rates of 12.6 percent and 14.9 percent, respectively (USCB 1990b).

High interest rates and tax rates were the major deterrents for potential homebuyers in the project area in the past. Current deterrents are economic uncertainty and unemployment. Recent interest rates on most home mortgages have ranged between 5 and 7 percent.

The majority of housing demand expected over the next two decades in Dawes County is most likely to occur in the City of Chadron. However, housing stock in the City of Crawford increased slightly between 2000 and 2008. In the event that the various scenic and recreational amenities of the region stimulate the local tourist economy, it is likely that both population and housing stock would increase in the City of Crawford.

The purchase of homes by CBR employees provides the City of Crawford with ad valorem property taxes. The City of Crawford levies taxes at a dollar per hundred of valuation. In 2009, the total levy was 0.46834, which would result in taxes on a $50,000 property of approximately $234 per year (NDPA&T 2010).

3.10.3 Environmental Justice

The 2000 Census provides population characteristics for Census Tracts, which contain Block Groups that are further divided into Blocks. There are no intercensal (years between the decennial census years) population estimates for Census Tracts and Block Groups. The Blocks are the smallest Census area that contains the race characteristics of the population in Dawes County. The TCEA contains all or a portion of 3 Blocks within Census Tract 9506 in Dawes County, and 2 Blocks within Census Tract 9501 in Sioux County. Block Groups are the smallest Census area that contains poverty level information. There is no poverty data for individual Blocks within each Block Group. There are two Block Groups that are located partially within the TCEA; however, the Block Groups area also includes most of the south portion of Dawes County and the north half of Sioux County.

The affected area selected for the Environmental Justice analysis includes the racial characteristics of the population within Census Tract Blocks within the TCEA. The population with an annual income below the poverty level was determined from Block Group characteristics.

The State of Nebraska was selected to be the geographic area to compare the demographic data for the population in the affected Blocks. This determination was based on the need for a larger geographic area encompassing affected area Block Groups in which equivalent quantitative resource information is provided. The population characteristics of the TCEA are compared with Nebraska population characteristics to determine whether there are concentrations of minority or low income populations in the TCEA relative to the state.

According to the 2000 Census and summarized in **Table 3.10-6**, the combined population of the Census Block Groups within the Expansion Area was 23. There were no minority populations identified within the Block Groups; the entire population was white. The nearest minority populations resided within the City of Crawford, located 2.8 miles north-northeast of the TCEA. Races in the City of Crawford consist of white non-Hispanic (93.0%), American Indian (4.7%), Hispanic (2.0%), person reporting two or more races (1.9%) and other race (0.9%) (City-Data.com 2010). The total percentage is greater than 100 percent because Hispanics could be counted in other races.

No concentrations of minority populations were identified as residing in rural areas near the proposed Project facilities. There would be no disproportionate impact to minority population from the construction and implementation of the Three Crow Project.

Block Group 3 has a smaller percentage of people living below the poverty level than either the state or Dawes County. Block Group 1 in Sioux County, is very close to Dawes County in the percentage of people living below the poverty level, and is significantly larger than the state level. Lower income levels are characteristic of predominantly rural populations and small communities that serve as a local center of agricultural activity. No adverse environmental impacts would occur to the population within the TCEA from proposed Project activities; therefore, there would be no disproportionate adverse impact to populations living below the poverty level in these Block Groups.

3.11 Public and Occupational Health

3.11.1 Non-Radiological Impacts of the Current Operation

3.11.1.1 Chemical Impacts of the Current Operation

The current operation at the CPF involves the use of hazardous chemicals in the process in quantities that could present a hazard to workers and the environment. Specifically, CBR stores and uses hydrochloric acid, sodium hydroxide, hydrogen peroxide, liquid oxygen, and carbon dioxide. The design of facilities and the storage and handling of these chemicals at CBR is performed in accordance with accepted codes and standards as recommended in NUREG/CR-6733. CBR is also subject to the requirements of the Occupational Safety and Health Administration (OSHA) set forth in the Process Safety Management Standard contained in 29 CFR §1910.119. As a result of these requirements and the management and administrative controls implemented by CBR, there has never been a serious incident involving hazardous chemicals at the CPF.

As part of the SHEQMS Program, a risk assessment was completed to recognize potential hazards and risks associated with chemical storage facilities (and other processes) and to mitigate those risks to acceptable levels. The risk assessment process identified hydrochloric acid as the most hazardous chemical with the greatest potential for impacts to chemical and radiological safety. The hydrochloric acid storage and distribution system is located only at the CPF and will not be used at the satellite facility.

None of the hazardous chemicals used at the CPF are covered under the EPA's Risk Management Program (RMP) regulations. The RMP regulations require certain actions by covered facilities to prevent accidental releases of hazardous chemicals and minimize potential impacts to the public and environment. These actions include measures such as accidental release modeling, documentation of safety information, hazard reviews, operating procedures, safety training, and emergency response preparedness.

3.11.1.2 Potential Declines in Groundwater Quality

Excursions at the current operation represent a potential effect on the adjacent groundwater. During production, injection of the lixiviant into the wellfield results in a temporary degradation of water quality in the exempted aquifer compared to pre-mining conditions. Movement of this water out of the wellfield results in an excursion. Excursions of contaminated groundwater in a wellfield can result from an improper balance between injection and recovery rates, undetected high permeability strata or geologic faults, improperly abandoned exploration drill holes, discontinuity and unsuitability of the confining units which allow movement of the lixiviant out of the ore zone, poor well integrity, and hydrofracturing of the ore zone or surrounding units.

To date, there have been several confirmed horizontal excursions in the Chadron sandstone in the CPF license area. These excursions were quickly detected and recovered through overproduction in the immediate vicinity of the excursion. In the majority of cases, the reported vertical excursions were actually due to natural seasonal fluctuations in Brule groundwater quality and very stringent upper control limits (UCLs). In no case did the excursions threaten the water quality of an underground source of drinking water (USDW) since the monitor wells are located well within the aquifer exemption area approved by the EPA and the NDEQ. **Table 3.11-1** provides a summary of excursions reported for the CPF license area.

3.11.2 Radiological Impacts of the Current Licensed Operation

CBR is currently licensed to operate the CPF at a maximum production flow rate of 9,000 gpm and a maximum annual production of 2,000,000 pounds U_3O_8. Since the project is an in-situ operation, the particulate emission sources normally associated with the ore crushing and grinding and tailings disposal at a conventional uranium mill are not present. A vacuum dryer is in use at the commercial operation. The vacuum dryer works on the principle that gases or particulates released into the system are collected in a liquid condenser and there is no release of particulates. The effluent collection efficiency for this dryer system is, therefore 100 percent. The only routine radioactive emission is radon-222 (radon) gas.

Radon is present in the ore body and is formed from the decay of radium-226. The radon dissolves in the lixiviant as it travels through the ore body to a production well, when the solution is brought to the surface, the radon is released.

In order to assess the radiological effect of radon on the environment, an estimate of the quantity released during the operation was made in the License Renewal Application submitted to NRC in 2007. Meteorological data and MILDOS-AREAREA (June 1989) are used to predict the ground level air concentration at various points in the environment. The ingrowth of radon daughters is important and their concentration in the soil, vegetation and animals was calculated. Finally, the impact on man from these concentrations of radionuclides in the environment was determined.

Based on the MILDOS-AREA results for the current operation, the anticipated effects were not significantly above naturally occurring background levels. This background radiation, arising from cosmic and terrestrial sources, as well as naturally occurring radon, comprises the primary radiological impact to the environment in the region surrounding the project.

3.11.2.1 Exposures from Water Pathways

The solutions in the mining zone are controlled and adequately monitored to insure that migration does not occur. The overlying aquifers will also be monitored.

Three commercial evaporation ponds located approximately 2000 feet from the current CPF building have been constructed for commercial operation. There are also two R&D evaporation ponds located approximately 1,000 feet from the CPF building. The R&D evaporation ponds have a 34-mil Hypalon liner and a leak detection system. The commercial evaporation ponds are lined with double impermeable synthetic liners. The ponds, therefore, are not considered a source of liquid radioactive effluents. There is a leak detection system installed to provide a warning if the liner develops a leak.

The CPF is located on a curbed concrete pad to prevent any liquids from entering the environment. Solutions used to wash down equipment drain to a sump and are pumped to the ponds. The pad is of sufficient size to contain the contents of the largest tank in the event of its rupture.

Since there are no routine liquid discharges of process water from the CPF, there are no definable water related pathways.

3.11.2.2 Exposures from Air Pathways

The only source of radioactive emissions from the current operation is radon released into the atmosphere through the plant ventilation systems or from the wellfields. This radon release results in radiation exposure via the inhalation, ingestion, and external exposure pathways. The total effective dose equivalent (TEDE) to nearby residents in the region around the Crow Butte project was estimated in the 2007 License Renewal Application by using the computer simulation, MILDOS-AREA. The joint frequency data compiled from a site-specific meteorological station were used to define the atmospheric conditions in the project area.

Based on the site specific data and method of estimation of the source term, the emission rate of radon-222 from the Crow Butte project was estimated at 5,937 Curies/yr for a flow of 5,000 gpm in the upflow IX columns in the existing CPF. In order to show compliance with the annual dose limit found in 10 CFR §20.1301, CBR demonstrated by calculation that the total effective dose equivalent (TEDE) to the individual most likely to receive the highest dose from the current licensed operation was less than 100 mrem per year. The dose to the most effected resident was 23.2 mrem/yr (0.232 mSv/yr) or 23.2% of 100 mrem/yr dose constraint.

3.11.2.3 Exposure to Flora and Fauna

The exposure to flora and fauna was evaluated in the Environmental Report submitted in September of 1987 and the doses were found to be negligible.

The long term impacts on groundwater quality should also be minimal, as restoration activities have been shown to be successful in returning the groundwater quality to background or class of use standards. Additionally, there is no mechanism in EPA or NDEQ regulations to "unexempt" an aquifer. Therefore, the groundwater in the immediate mining area will never be used as a USDW. The primary purpose for restoration is to ensure that postmining conditions do not affect adjacent USDWs.

3.11.2.4 Occupational Safety

CBR has an exemplary safety record at the Crow Butte project. The company has been recognized on several occasions for this safety record including being named the recipient of the Governor's Safety Award and the Star Award, awarded by the Nebraska Safety Council. The Health and Safety Management System (HSMS) implemented at the project is designed to meet the OHSAS:18001 international HSMS standard.

3.12 Waste Management

The effluents of concern at the proposed satellite facility will include the release or potential release of radon gas (radon-222), radionuclides in liquid process streams, and dried yellowcake. Yellowcake processing and drying operations are conducted nearby at the CPF. Loaded IX resin from the satellite facility will be transported to the CPF for elution, precipitation, drying, and packaging. Effluent control systems will be used at the satellite facility to control the release of radioactive materials to the atmosphere.

The yellowcake drying facilities at the CPF are comprised of one vacuum dryer. The current license allows for the addition of a second dryer. By design, vacuum dryers do not discharge any uranium when operating. Effluent controls for yellowcake drying at the CBR CPF have been reviewed by NRC and approved in the current license.

3.12.1 Gaseous and Airborne Particulates

The principal radioactive airborne gaseous radiological effluent at the TCEA will be radon-222 gas. Processing at the satellite facility will occur in the form of water based solutions or wet slurry (no yellowcake processing or drying); therefore, airborne uranium concentrations are expected to be at or near local background levels. Airborne releases from in situ leach facilities normally are radon-222 and its daughters from process fluids and particulates from yellowcake drying and packaging operations (NRC 2001). One process area at the proposed TCEA where small quantities of airborne uranium particulates have the potential for occurring is the resin transfer station where minor spills may occur. The loaded IX resin is transferred to a truck for transport to the CPF for completion of uranium recovery. Spills can occur during the transfer of this loaded resin to trucks, and this is where exposure to uranium particulates is possible. All spills will be cleaned up as soon as possible to avoid the wet materials from drying and creating the potential for airborne particulates. Spills associated with resin transfer would involve the impregnated resin itself. The uranium is still bound to the resin at this stage, reducing the potential of employee exposure.

There could also be maintenance activities on piping containing pregnant lixiviant that could result in the release of radon and uranium. Any spills or releases during maintenance of these potential sources would be cleaned up promptly to avoid drying of the material and creation of particulates subject to dispersion.

Radon-222 is found in the pregnant lixiviant that comes from the wellfield into the satellite facility. The uranium is then separated from the lixiviant by passing the solution through fixed bed IX units operated in a pressurized downflow mode. Vessel vents from the individual IX vessels will be directed to a manifold that is exhausted to atmosphere outside the satellite building. Venting any released radon-222 gas to atmosphere outside the satellite facility via high-volume exhaust fans minimizes employee exposure. Small amounts of radon-222 may be released via solution sampling and spills, filter changes, IX resin transfer, RO system operation during groundwater restoration, and maintenance activities. These are minimal radon gas releases on an infrequent basis. The general building ventilation system in the satellite facility will further reduce employee exposure. The air in the satellite facility is sampled for radon daughters to assure that concentration levels of radon and radon daughters are maintained as low as reasonably achievable (ALARA).

Injection wells would generally be closed and pressurized, but periodically vented releasing radon to the atmosphere. Production wells will be continually vented to the surface, but water levels will typically be low and radon venting will be minimal. All of the well releases would be outside of buildings and directly vented to the atmosphere. Some venting would also occur from the well houses. Well houses would be vented so as to remove any radon releases from the building to the surrounding atmosphere. The exhaust fans are located in the wall directly opposite the entryway. Releases to the atmosphere from wells and well houses would result in radon emissions dispersing rapidly. Wellfield offgassing is not considered a significant source of radon or a safety issue. This statement is supported by MILDOS-AREA calculations (Section 4.12.2.3) and by monitoring at the current Crow Butte operations.

Employee radon daughter monitoring results and work area ventilation systems at the CPF are discussed in Section 5.0 of the TCEA Technical Report.

3.12.2 Liquid Wastes

As a result of in-situ leach mining, there are several sources of liquid waste. The potential wastewater sources that exist at the satellite facility include the following:

3.12.2.1 Liquid Waste Generated

Water Generated During Well Development

This water is recovered groundwater and has not been exposed to any mining process or chemicals. However, the water may contain elevated concentrations of naturally-occurring radioactive material if the development water is collected from the mineralized zone. The water will be discharged directly to the solar evaporation pond and silt, fines and other natural suspended matter collected during well development will settle out in the pond. Well development water may also be treated with filtration and/or RO and used as plant make-up water or disposed of in the deep disposal well.

Liquid Process Waste

The operation of the satellite facility results in one primary source of liquid waste, a production bleed, as previously discussed in Section 3.0. This bleed will be routed to either the deep disposal well or an evaporation pond.

Aquifer Restoration Waste

Following mining operations, restoration of the affected aquifer results in the production of wastewater. The current groundwater restoration plan consists of four activities:

1. Groundwater Transfer
2. Groundwater Sweep
3. Groundwater Treatment
4. Wellfield Circulation

Only the groundwater sweep and groundwater treatment activities will generate wastewater.

During groundwater sweep, water would be extracted from the mining zone without injection, causing an influx of baseline quality water to sweep the affected mining area. The extracted water must be sent to the wastewater disposal system during this activity, such as deep well disposal and/or onsite evaporation ponds. As has been the case with past operations at CBR, it is anticipated that during restoration groundwater at the TCEA will be treated using IX and RO. Using this method, there would be no water consumption activities and only the bleed has to be dealt with for disposal, with the rest of the treated water being reinjected.

Groundwater treatment activities involve the use of process equipment to lower the ion concentration of the groundwater in the affected mining area. A RO unit will be used to reduce the total dissolved solids (TDS) of the groundwater. The RO unit produces clean water (permeate) and brine. The permeate is either injected into the formation or disposed of in the wastewater disposal system. The brine is sent to the wastewater disposal system.

Stormwater Runoff

Stormwater may be contaminated by contact with industrial materials. Stormwater management is controlled under permits issued by the NDEQ. CBR is subject to stormwater National Pollutant Discharge Elimination System (NPDES) permitting requirements for industrial facilities and construction activities. The NDEQ NPDES regulatory program contained in Title 119 (NDEQ 2010a) requires that procedural and engineering controls be implemented such that runoff will not pose a potential source of pollution.

Domestic Liquid Waste

Domestic liquid wastes from the restrooms and lunchrooms will be disposed of in an approved septic system that meets the requirements of the State of Nebraska. The septic system will be designed with a capacity sufficient to handle the projected number of employees, contractors and visitors. CBR currently maintains a Class V UIC Permit issued by the NDEQ for operation of the septic system at the CPF. A similar permit will be required for the satellite facility.

Laboratory Waste

Liquid waste from the laboratory will be disposed of in either the evaporation pond or the deep disposal well.

Liquid Waste Disposal

Two methods of disposal are proposed for the satellite facility and are already permitted for use at the CPF:

- Deep disposal well injection; and
- Evaporation via evaporation ponds.

In addition to these two disposal methods, the NDEQ has issued CBR an NPDES permit for the CPF license area that allows land application of treated wastewater. CBR has not used this waste disposal method at the current operation. At this time, CBR does not intend to apply for an NPDES permit to allow land application at the satellite facility. It is expected that liquid waste generated in the TCEA will be managed in the same manner as at the existing CPF (i.e., by evaporation and deep well injection).

Deep Disposal Well

CBR currently operates a non-hazardous Class I injection well in the CPF license area for disposal of wastewater. The well is permitted under NDEQ regulations in Title 122 (NDEQ 2010b) and operated under a Class I UIC Permit. CBR has operated the deep disposal well at the CPF license area for over ten years with excellent results and no serious compliance issues. CBR expects that the liquid waste stream at the satellite facility will be chemically and radiologically similar to the waste disposed of in the current deep disposal well. Radiological data for the years

2008 and 2009 for CBR's current deep disposal well injection stream are shown in **Table 3.12-1.** The nonradiological data for the deep disposal well injection stream for 2009 is presented in **Table 3.12-2.**

CBR plans to install a deep disposal well at the satellite facility as the primary liquid waste disposal method. CBR has found that permanent deep disposal is preferable to evaporation in evaporation ponds. The basic reasons for this position are as follows:

- The potential for human contact while using a deep well is more limited due to the waste being handled in enclosed systems.
- The potential for emissions from the pond surface is greater than the enclosed deep well disposal system.
- Evaporation ponds have the potential for leaks and impacts to the environment.
- A larger amount of 11(e)(2) byproduct waste is created through the use of evaporation ponds.

All compatible liquid wastes at the satellite facility will be disposed of at a planned onsite Class I UIC deep disposal well. CBR will submit an application to the NDEQ for the construction and operation of a Class I UIC Permit at the satellite facility. The deep well will be installed in sufficient time to be used for wastewater disposal allowed by the permit.

Evaporation Ponds

Evaporation pond design, installation and operation criteria are those found in Reg. Guide 3.11 (NRC 2008). The evaporation pond configuration at the satellite facility will be similar to the existing ponds at the CPF license area. The exact number and capacity of the ponds will depend upon the results of the determination of the performance of the deep disposal well as far as waste water disposal rate. In addition, final pond design cannot be completed until completion of the site geotechnical assessment, including site-specific sampling and testing. This information is currently not available due to the stage of project development. A license amendment application with pond design and specifications, which meet the requirements of the most current pond design and construction regulatory guides, will be submitted to the NRC prior to pond construction. In addition, plans for monitor wells used to demonstrate compliance with 10 CFR 40, Appendix A, Criterion 7a, will be submitted as part of the license amendment.

Each pond will have the capability of being pumped to a water treatment plant before disposal. A variety of treatment options exist depending upon the specific chemical contaminants identified in the wastewater. In general, a combination of chemical precipitation and RO is adequate to treat the water to a quality that falls well within NPDES criteria.

CBR maintains three commercial and two R & D evaporation ponds in the CPF license area. The ponds are constructed with a primary and secondary liner system. An underdrain system consisting of perforated piping between the primary and secondary liners is installed to monitor for leaks. The underdrain slopes gradually to the ends of the ponds where they are connected to a surface monitor pipe. Checking for an increase in measurable moisture inside the leak detection system and/or analyzing the water in the pipe can indicate a leak in the pond liner. The design of the Three Crow evaporation ponds will include similar features.

3.12.2.2 Inspections

The current pond inspection program is based on NRC recommendations in Reg. Guide 3.11.1 (NRC 1980) and is approved in SUA-1534. Routine inspections are required as follows:

- Daily Inspections

  Daily inspections consist of checking the pond depth and visually inspecting the pond embankments for slumping, movement, or seepage. The pond depth measurements will be checked against the freeboard requirements.

- Weekly Inspections

  Weekly inspections consist of checking the perimeter game-proof fence and restricted area signs, checking the pond inlet piping, making underdrain measurements, checking the pond enhanced evaporation system (if installed), visually inspecting the liner, and measuring the vertical depth of fluid in the pond underdrain standpipes. During periods of seismic activity, flooding, severe rainfall, or other event that could cause the pond to leak, underdrain measurements will be taken daily and recorded.

- Monthly Inspections

  During monthly inspections, the waste piping from the satellite facility building to the ponds will be visually inspected for signs of seepage indicating a possible pipeline break. Diversion channels surrounding the ponds will be examined for channel bank erosion, obstruction to flow, undesirable vegetation, or any other unusual conditions.

- Quarterly Inspections

  Quarterly inspections will check for embankment settlement and for irregularities in alignment and variances from originally constructed slopes (i.e., sloughing, toe movement, surface cracking or erosion). Embankments will be inspected for any evidence of seepage, erosion, and any changes to the upstream watershed areas that could affect runoff to the ponds. Emergency lines will be inspected to ensure that the rope has not deteriorated and the ropes reach to the pond water level.

- Annual Inspection

  A technical evaluation of the pond system will be done annually which addresses the hydraulic and hydrologic capacities of the ponds and ditches and the structural stability of the embankments. A survey of the pond embankments will be done on an annual basis and the survey results documented and incorporated into the annual inspection report. The survey will be reviewed for evidence of embankment settlement, irregularities in embankment alignment, and any changes in the originally constructed slopes. The technical evaluation will be the result of an annual inspection and a review of the weekly, monthly, and quarterly inspection reports by a professional engineer registered in the State of Nebraska. Examination of the pond monitor well sampling data will also be reviewed for signs of seepage in the embankments. The inspection report will present the results of the technical evaluation and the inspection data collected since the last report. The report will be kept on file at the site for review by regulatory agencies. A copy will also be submitted to the NRC.

- Pond Leak Corrective Actions

If six inches or more of fluid is present in the standpipes, the contents will be analyzed for specific conductance. If the water quality in the standpipe is degraded beyond the action level, the water will be further sampled for chloride, alkalinity, sodium, and sulfate. The action level is defined as a specific conductivity of the fluid of the standpipe that is 50 percent of the specific conductivity of the pond contents.

If there is an abrupt increase in both the vertical fluid depth of a standpipe and the specific conductance of the fluid of the standpipe, the liner will be immediately inspected for liner damage. Abnormal increases of these two indicators confirm a potential liner leak and agency reporting (i.e., NRC and NDEQ) will be required.

Upon verification of a liner leak, the fluid level will be lowered by transferring the cell contents to the other cell. Water quality in the affected standpipes will be analyzed for the five parameters listed above once every seven days during the leak period, and once every seven days for at least two weeks following repairs.

3.12.2.3 Potential Pollution Events Involving Liquid Waste

Although there are a number of potential sources of pollution present at the CPF, existing regulatory requirements from the NRC and NDEQ and provisions of the SHEQMS have established a framework that significantly reduces the possibility of an occurrence. Extensive training of all personnel is standard policy at the existing CBR facility and will be implemented at the satellite facility. Frequent inspections of waste management facilities and systems will be conducted. Detailed procedures are included in the SHEQMS, which will be adapted for use at the satellite facility.

Potential sources of pollution include the following:

<u>Solar Evaporation Pond</u>

The solar evaporation pond could contribute to a pollution problem in several ways. First, a pond could fail, either in a catastrophic fashion or as a result of a slow leak. In addition, a pond could overflow due to excess production or restoration flow, as well as due to the addition of rainwater.

With respect to a pond failure, all ponds will be built to NRC standards, and will be equipped with leak detection systems. Standard operating procedures will require a periodic inspection of all ponds, liners, and berms. The inspection program will be similar to the program currently implemented by CBR for the commercial ponds at the CPF. In the event of a leak, the contents of the pond cell can be transferred to the other pond cell while repairs are made.

With respect to pond overflow, operating procedures will be such that no individual pond cell is allowed to fill to a point where overflow is considered a realistic possibility. Since the primary disposal method will be deep disposal, the flow rate of liquids to the pond cells is expected to be minimal and there will be ample time to reroute the flow to another pond. Regarding the addition of rainwater, the freeboards of ponds considered "full" will be sufficient to contain the addition of significant quantities of rainwater before an overflow occurs. The inclusion of the freeboard allowance also precludes over-washing of the walls during high winds.

3.12.2.4 Wellfield Buildings and Piping

Wellfield buildings are not considered to be a potential source of pollutants during normal operations, as there will be no process chemicals or effluents stored within them. The only instance in which a wellfield building could contribute to pollution would be in the event of a release of injection or recovery solutions due to pipe failure. The possibility of such an occurrence is considered to be minimal as the piping will be leak checked before it is initially placed into service. Piping from the wellfields will generally be buried, minimizing the possibility of an accident. In addition, the flows through the wellfield piping will be monitored and will be at a relatively low pressure. Flow monitoring will provide alarms in the event of a significant piping failure which will allow flow to be stopped, preventing any significant migration of process fluids. Wellfield buildings will also be equipped with wet alarms for early detection of leaks.

Satellite Facility

The satellite facility will serve as a central hub for the mining operations in the TCEA. Therefore, the satellite facility has the greatest potential for spills or accidents resulting in the release of potential pollutants. Spills could result from a release of solutions due to a piping failure or a process storage tank failure.

The design of the satellite facility building will be such that any release of liquid waste would be contained within the structure. A concrete curb will be built around the entire process building. This pad will be designed to contain the contents of the largest tank within the building in the event of a rupture. In the event of a piping failure, the pump system will immediately shut down, limiting any release. Liquid inside the building, both from a spill or from washdown water, will be drained through a sump and sent to the liquid waste disposal system.

Deep Well Pumphouse and Wellhead

The design of the deep well pumphouse and wellhead will be such that any release of liquids will be contained within the building or in a bermed containment area surrounding the facilities. Liquid inside the building will be contained and managed as appropriate.

Transportation Vehicles

The release of pollutants to the environment could occur due to accidents involving transportation vehicles. This could involve either vehicles transporting IX resin to and from the satellite facility to the CPF or transporting radioactive contaminated waste from the satellite facility to an approved disposal site.

All chemicals and products delivered to or transported from the satellite facility will be carried in DOT-approved packaging. In the event of an accident, procedures are currently in place in the SHEQMS Volume VIII, *Emergency Manual*, to insure a rapid response to the situation.

The uranium-loaded resin will be transported from the satellite facility to the CPF processing building in a specially designed, low profile, 4,000-gallon capacity tanker trailer. The primary access route is approximately 9.1 miles in length with the majority of the route following lightly traveled secondary roads. In the event of an accident, each resin transport vehicle will be equipped with an emergency contingency package whereby the driver could begin the containment of any spilled material. Because the uranium adheres to the resin and the resin is wet when transferred, the radiological and environmental impacts of a spill due to an accident will be minimal. Finally, each resin transfer vehicle will be equipped with a radio for communications with the CPF. This allows quick response and implementation of the emergency response plan for transportation accidents.

Spills

Spills can take two forms within an in-situ facility. These are surface spills (such as pond leaks, piping ruptures etc.) and subsurface releases such as a well casing failure, or a pond liner leak resulting in a release of waste solutions. Spill contingency plans are discussed in Section 5.7.1.3.

Engineering and administrative controls are in place at the CPF and will be implemented at the satellite facility to prevent both surface and subsurface releases to the environment, and to mitigate the effects should an accident occur. The most common form of surface release from in-situ mining operations occurs from breaks, leaks, or separations within the piping that transfers mining fluids from the satellite processing building to the wellfield and back. With the current CBR monitoring system, these are generally small releases and are quickly discovered and mitigated.

In general, piping from the satellite facility to and within the wellfield, will be constructed of HDPE with butt welded joints or the equivalent. All pipelines will be pressure tested before final operation. It is unlikely that a break would occur in a buried section of line because no additional stress is placed on the pipes. In addition, underground pipelines will be protected from a major cause of potential failure, which is vehicles driving over the lines causing breaks. Typically, the only exposed pipes will be at the satellite facility, at the wellheads, and in the wellhouses in the wellfield. Trunkline flows and manifold pressures will be monitored for spill detection and process control.

3.12.3 Solid Waste

Any facility or process with the potential to generate industrial waste should practice good housekeeping. This activity generally consists of keeping facilities, equipment, and process areas clean and free of industrial waste or other debris. Good housekeeping includes promptly cleaning any spillage or process residues that are on floors or other areas that could be spread and collecting solid wastes in designated containers or area until proper disposal.

Solid waste generated at the satellite facility is expected to include spent resin, resin fines, empty reagent containers, miscellaneous pipe and fittings, and domestic trash. Solid wastes will be classified as contaminated or non-contaminated waste according to survey results. The solid waste will be segregated based on whether it is clean or has the potential for contamination with 11(e).2 byproduct materials.

The largest volume of solid wastes requiring disposal at the TCEA site will be during facility decommissioning. Soils would be included in decommissioning surveys and any soils exceeding NRC release limits at 10 CFR Part 40, Appendix A, Criterion 6 would be removed and disposed of as 11e.(2) byproduct waste. Proposed decommissioning and reclamation activities are discussed in Section 6.0.

3.12.3.1. Non-contaminated Solid Waste

Non-contaminated solid waste is waste which is not contaminated with 11(e).2 byproduct material or which can be decontaminated and re-classified as non-contaminated waste. This type of waste may include trash, piping, valves, instrumentation, equipment and any other items which are not contaminated or which may be successfully decontaminated. Release of contaminated equipment and materials is discussed in further detail in Section 5.

CBR has recently estimated that the CPF produces approximately 1,055 cubic yards (yd^3) of non-contaminated solid waste per year. This estimate is based on the number of collection containers on site and the experience of the contract waste hauler. CBR estimates that the proposed satellite facility would produce approximately 700 yd^3 of non-contaminated solid waste per year. Non-contaminated solid waste will be collected on the site in designated areas and disposed of in the nearest permitted sanitary landfill.

3.12.3.2 11(e).2 Byproduct Material

Solid 11e.(2) byproduct wastes consists of solid waste contaminated with 11e.(2) byproduct material that cannot be decontaminated.

11(e).2 byproduct material generated at ISL facilities consists of filters, Personal Protective Equipment (PPE), spent resin, piping, etc. CBR has recently estimated that the CPF produces approximately 60 to 90 cubic yards (yd^3) of 11(e).2 byproduct material waste per year. This estimate is based on the number of historical number of shipments to the licensed disposal facilities. CBR estimates that the proposed satellite facility would produce approximately 60 yd^3 of 11(e).2 byproduct materials per year. These materials will be stored on site until such time that a full shipment can be shipped to a licensed waste disposal site or licensed mill tailings facility. CBR currently maintains an agreement for waste disposal at a properly licensed facility as a License Condition for SUA-1534. CBR is required to notify NRC in writing within 7 days if the disposal agreement expires or is terminated, and to submit a new agreement for NRC approval within 90 days of the expiration or termination.

If decontamination is possible, records of the surveys for residual surface contamination will be made prior to releasing the material. Decontaminated materials have activity levels lower than those specified in NRC guidance (NRC 1987). An area will be maintained inside the restricted area boundary for storage of contaminated materials prior to their disposal.

3.12.3.3 Septic System Solid Waste

Domestic liquid wastes from the restrooms and lunchrooms will be disposed of in an approved septic system that meets the requirements of the State of Nebraska. Disposal of solid materials collected in septic systems must be performed by companies or individuals licensed by the State of Nebraska. NDEQ regulations for control of these systems are contained in Title 124 (NRC 2010c).

3.12.3.4 Hazardous Waste

The potential exists for any industrial facility to generate hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA). In the State of Nebraska, hazardous waste is governed by the regulations contained in Title 128 (NDEQ 2010d). Based on waste determinations conducted by CBR as required in Title 128, CBR is a Conditionally Exempt Small Quantity Generator. To date CBR only generates universal hazardous wastes such as fluorescent light tubes, used waste oil and batteries. CBR recently estimated that the current operation generates approximately 1,325 liters of waste oil per year. CBR estimates that the proposed satellite facility would produce approximately 800 liters of waste oil per year. Waste oil is disposed of by a licensed waste oil recycler. CBR has management procedures in place in the SHEQMS Volume VI, *Environmental Manual,* to control and manage these types of wastes.

Table 3.1-1 Major Land Use Definitions

Croplands (C)	Harvested cropland, including grasslands cut for hay, cultivated summer-fallow, and idle cropland.
Commercial and Services (C/S)	Those areas are used predominantly for the sale of products and services. Institutional land uses, such as various educational, religious, health, and military facilities are also components of this category.
Forested Land (F)	Areas with a tree-crown density of 10 percent or more are stocked with trees capable of producing timber or other wood products and exert an influence on the climate or water regime. This category does not indicate economic use.
Habitat (H)	Land dedicated wholly or partially to the production, protection or management of species of fish or wildlife.
Industrial (I)	Areas such as rail yards, warehouses, and other facilities used for industrial manufacturing or other industrial purposes.
Mines, Quarries, or Gravel Pits (M)	Those extractive mining activities that have significant surface expression.
Pastureland (P)	Land used primarily for the long-term production of adapted, domesticated forage plants to be grazed by livestock or occasionally cut and cured for livestock feed.
Rangeland (R)	Land, roughly west of the 100th meridian, where the natural vegetation is predominantly grasses, grass like plants, forbs, or shrubs; which is used wholly or partially for the grazing of livestock. This category includes wooded areas where grasses are established in clearings and beneath the overstory.
Urban Residential (UR)	Residential land uses range from high-density, represented by multi-family units, to low-density, where houses are on lots of more than 1 acre. These areas are found in and around Crawford and Ft. Robinson. Areas of sparse residential land use, such as farmsteads, will be included in categories to which they are related.
Water (W)	Areas of land mass that are persistently water-covered.
Recreational (RC)	Land used for public or private leisure, including developed recreational facilities such as parks, camps, and amusement areas, as well as areas for less intensive use such as hiking, canoeing, and other undeveloped recreational uses.

Table 3.1-2 Present Major Land Use Within a 2.25-Mile (3.6-KM) Radius of the Proposed Three Crow License Boundary

COMPASS SECTOR[1]	LAND USE[2,3] (ACRES)						TOTAL ACRES
	C	F	R	RC	RR	SB	
E	700.4	-	1,158.2	112.7	22.0	4.5	1,997.8
ENE	649.5	-	369.6	857.1	0.3	-	1,876.5
ESE	522.7	100.5	1,561.8	-	-	6.4	2,191.5
N	-	-	13.5	836.0	-	-	849.5
NE	96.9	-	29.1	1,288.5	-	-	1,414.5
NNE	-	-	15.2	942.3	-	-	957.6
NNW	0.0	-	16.7	990.8	-	-	1,007.5
NW	8.1	-	344.9	928.0	-	-	1,281.0
S	148.7	571.6	560.1	-	0.5	-	1,280.9
SE	303.9	618.2	1,279.9	-	-	-	2,202.0
SSE	117.8	740.8	862.0	-	-	-	1,720.6
SSW	111.8	395.9	672.4	-	20.0	-	1,200.1
SW	340.7	321.1	690.8	-	39.0	-	1,391.5
W	621.6	0.4	787.9	-	-	11.0	1,420.9
WNW	226.0	6.7	772.9	408.1	-	1.1	1,414.8
WSW	522.0	19.4	944.4	-	5.9	0.8	1,492.4
TOTAL	4,370.0	2,774.6	10,079.5	6,363.5	87.7	23.8	23,699.1

1 22 1/2° sectors centered on each of the 16 compass points

2 See Table 2.2-1 for an explanation of major land use types: C = cropland; F = forested land; R = rangeland; RR = rangeland rehabilitation; SB = structural biotope; RC = recreational. Land uses not identified: mines, quarries or gravel pits; pastureland; water; habitat; commercial/services; urban residential; industrial

3 Values are inclusive of TCEA

Table 3.1-3 Present Land Use of the TCEA Within the Proposed Three Crow License Boundary

COMPASS SECTOR[1]	LAND USE[2] (ACRES)					TOTAL ACRES
	C	F	R	RR[3]	SB[3]	
E	190.7	-	122.4	22.0	4.5	339.6
ENE	60.6	-	11.8	0.3	-	72.7
ESE	237.8	-	157.2	-	6.4	401.4
N	-	-	11.4	-	-	11.4
NE	10.4	-	10.7	-	-	21.1
NNE	-	-	12.8	-	-	12.8
NNW	-	6.7	14.2	-	-	20.9
NW	6.6	-	20.4	-	-	27.0
S	33.9	-	3.2	0.5	-	37.6
SE	114.8	-	35.4	-	-	150.2
SSE	43.3	-	3.4	-	-	46.7
SSW	19.4	-	2.7	20.0	-	42.1
SW	23.1	-	6.6	39.0	-	68.8
W	66.5	0.4	65.8	-	11.0	143.7
WNW	54.4	-	41.9	-	1.1	97.4
WSW	84.3	-	58.9	5.9	0.8	149.8
TOTAL	945.9	7.1	578.8	87.7	23.8	1,643.2

[1] 22 1/2° sectors centered on each of the 16 compass points

[2] See Table 2.2-1 for an explanation of major land use types: C = cropland; F = forested; R = rangeland; RR = Rangeland Rehabilitation; SB = Structural Biotope. Land uses not identified: forested land; recreational; mines, quarries or gravel pits; pastureland; water; habitat; commercial/services; urban residential; industrial

[3] See Section 2.2.2 for a discussion of these land types.

Table 3.1-4 Agricultural Yields for Croplands in Dawes County 2008

Crop	Harvested		Yield		Production
	Acres[a]	km^2	Per acre	Per km^2	
Corn for Grain (bu)[b]	900	3.64	171.0 bu	42,255 bu	153,900 bu
Corn for Silage (bu))[b]	2,000	8.09	13.2 bu	3,262 bu	26,400 bu
Oats (bu)	400	1.62	22.0 bu	5,436 bu	8,800 bu
Winter Wheat (bu)	37,600	152.16	37.5 bu	9,266 bu	1,408,800 bu
All hay[c] (tons)	51,000	136.38	1.6 tons	455 tons	93,600tons

Source: NASS 2009b

Notes:
- bu bushels
- a 1 acre = 0.0040469 km^2
- b The most recent available data are from 2007.
- c Includes wild and tame alfalfa.

Table 3.1-5 Potential Agricultural Production for Cropland in the Three Crow Expansion Area and 2.25-Mile AOR

Crop	Percent of Total Planted[a]	Total Cropland (acres) [b]	Percent of Planted/ Harvested[a]	Harvested (acres)	Harvested (km^2)	County Yield (bu/acre)	County Yield (bu/km^2)	TCEA and AOR Yield (bu)
Wheat	33.3	4,430.4	89.03	3,956.3	16	37.5	9,266	148,361

Source: NASS 2009c

Notes:
[a] Same as average percent acres planted and harvested for Dawes County.
[b] 1 acre = .0040469 km^2.
bu bushels

Table 3.1-6 Livestock Inventory, Dawes County 2007

Livestock	Number	Percent of Total	Animal Units [a]	
			Pounds (000s)	Percent
All Cattle, except dairy	69,405	96.2	69,405	99.5
Dairy cattle	24	0.03	24	0.03
Hogs and pigs	321	0.4	71	0.1
Sheep and lambs	1,294	1.8	259	0.4
Chickens	1,092	1.5	5	0.008
Total animals	72,136	100.0	69,763.9	100.0

Source: NRCS 2007

Notes: [a] Animal unit conversions:
1 cow = 1,000 lb.
1 hog = 220 lb.
1 sheep = 200 lb.
1 chicken = 5 lb.
1 animal unit = 1,000 lb.

Table 3.1-7 Recreational Facilities Within 50 Miles of the Proposed Three Crow Expansion Area

Name of Recreational Facility	Distance From TCEA Satellite Facility (miles)
Fort Robinson State Park recreation facilities	2.4
Legend Buttes Golf Course	3.5
Crawford City Park	4.1
Peterson Wildlife Management Area	4.4
Ponderosa Wildlife Management Area HQ	6.6
Soldier Creek Wilderness	8.8
Whitney Lake	12.7
Roberts Trailhead and Campground	15.7
Hudson-Meng Bison Bonebed	16.3
Toadstool Geologic Park	16.7
Pine Ridge National Recreation Area	18.9
Box Butte Reservoir and Wildlife Area	21.1
Agate Fossil Beds National Monument	22.2
Chadron State Park	22.7
Red Cloud Campground	23.6
Warbonnet Battlefield	24.6
Gilbert-Baker Wildlife Area	25.6
Museum of the Fur Trade	29.8
Ridgeview County Club Golf Course	24.9
Walgren Lake State Recreation Area	42.0

Source: DeLorme Maps, 2005

Table 3.1-8 Distance to Nearest Residence and Site Boundary from Center of Three Crow Expansion Area for each Compass Sector

Compass Sector[1]	Nearest Residence (ft.)	Nearest Site Boundary (ft.)
North	None	1,580
North-Northeast	None	1,671
Northeast	None	2,115
East-Northeast	14,937	3,631
East	6,097	8,905
East-Southeast	3,903	9,501
Southeast	7,859	4,270
South-Southeast	14,108	3,155
South	6,498	2,853
South-Southwest	11,185	3,023
Southwest	2,775	3,839
West-Southwest	12,248	6,192
West	6,493	5,609
West-Northwest	11,503	4,790
Northwest	None	2,370
North-Northwest	None	1,752

[1] 22 $^1/_2$° Sectors centered on each of the 16 compass points
None = No residence within the 2.25-mile radius of the TCEA boundary for this specific sector.

Table 3.3-1 General Stratigraphic Chart for Northwest Nebraska

Geologic Period	Series	Formation or Group	Rock Types[1]	Thickness (ft)
Tertiary	Miocene	Ogallala	SS, Slt	1560*
	Oligocene/Eocene	Arikaree	SS, Slt	1070*
		White River	SS, Slt, Cly	1450*
Cretaceous	Upper	Pierre	Sh	1500
		Niobrara	Chalk, Ls, Sh	300
		Carlile	Sh	200-250
		Greenhorn	Ls	30
		Graneros	Sh	250-280
		D Sand	SS	5-30
		D Shale	Sh	60
		G Sand	SS	10-45
		Huntsman	Sh	60-80
	Lower	J Sand	SS	10-30
		Skull Creek	Sh	220
		Dakota	SS, Sh	180
Jurassic	Upper	Morrison	Sh, SS	300
		Sundance	SS, Sh, Ls	300
Permian	Guadalupe	Satanka	Ls, Sh, Anhy	450
	Leonard	Upper	Ls, Anhy	150
		Lower	Sh	150
	Wolfcamp	Chase	Anhy	80
		Council Grove	Anhy, Sh	300
		Admire	Dolo, Ls	70
Pennsylvanian	Virgil	Shawnee	Ls	80
	Missouri	Kansas City	Ls, Sh	80
	Des Moines	Marmaton/	Ls, Sh	130
		Cherokee		
	Atoka	Upper/Lower	Ls, Sh	200
Mississippian	Lower	Lower	Ls, Sh	30
Pre-Cambrian			Granite	

[1]Rock Type Abbreviations: Anhy: Anhydrate; Cly: claystone; Dolo: Dolomite; Ls: limestone; Sh: shale; Slt: siltstone; SS: sandstone,

* Maximum thickness based on Swinehart, et. al, 1985.

Table 3.3-2 Representative Stratigraphic Section – Three Crow Expansion Area

ELEVATION (FT-AMSL)	GROUP	FORMATION & MEMBER (SCHULTZ AND STOUT, 1955)			FORMATION & MEMBER (REVISED)		REFERENCES (REVISED)
Varying - 3725	White River Group	Brule Formation	Whitney Member		Brule Formation	"Brown Siltstones"	LaGarry (1998)
						Whitney Member	
			Orella Member	Orella D		Orella Member	
				Orella C			
				Orella B			
				Orella A			
3725 - 3425		Chadron Formation	Upper Chadron	Chadron C	Chadron Formation	Big Cottonwood Creek Member	Terry (1998) Terry & LaGarry (1998)
3475 - 3425			Upper/Middle Chadron	Chadron B			
3425 - 3275			Middle Chadron			Peanut Peak Member	Terry (1998) Terry & LaGarry (1998)
3275-3100			Red Clay Horizon	Chadron A	Chamberlain Pass Formation	Upper Interior Paleosol	Terry (1998)
			Basal Chadron Sandstone			Channel Sandstone	Terry (1998)
Varying	Montana Group	Pierre Shale	Interior Paleosol		Pierre Shale	Yellow Mounds Paleosol	Retallack (1983) Terry (1998)
3100 - ~2400			Pierre Shale			Pierre Shale	Terry (1998)

Notes:
1. The Shultz and Stout conventions for Formation & Member are utilized throughout this document.
2. Topsoil, colluvial and alluvial deposits are not shown, but are Quaternary in age and range in thickness from 0 to 30 ft-bgs.
3. FT-AMSL = feet above mean sea level
4. Elevations are representative averages for TCEA only.

Table 3.3-3 USGS Abbreviated Modified Mercalli (MM) Intensity Scale

Richter Magnitude	Modified Mercalli Scale	Description of MM Scale
1.0 – 3.0	I	Not felt except by a very few under especially favorable conditions.
3.0 – 3.9	II	Felt only by a few persons at rest, especially on upper floors of buildings.
	III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
4.0 – 4.9	IV	Felt indoors by many, outdoors by a few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
	V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
5.0 – 5.9	VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
	VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
6.0 – 6.9	VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
	IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	X	Some well-built wooded structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
	XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
	XII	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: FOO 2002

Table 3.3-4 Historical Earthquakes in Northwestern Nebraska in Close Proximity to the Chadron and Cambridge Arches (1884 – 2009)

Date	Location	Latitude	Longitude	Depth (km)[a]	Richter Magnitude[b]	Modified Mercalli Intensity[b]	Source
3/17/1884	North Platte, NE	41.133	100.75			IV	D
12/16/1916	Stapleton, NE	41.55	100.467	--	--	II-III	D
9/24/1924	Gothenberg, NE	40.95	100.133	--	--	IV	D
8/08/1933	Scottsbluff, NE	41.867	103.667	--	--	IV-V	D
7/30/1934	Chadron, NE	42.85	103	--	--	VI	D
3/24/1938	Fort Robinson, NE	42.683	103.417	--	--	IV	D
3/09/1963	Chadron, NE	42.85	103	--	--	II-III	D
3/28/1964	Merriman, NE	42.8	101.667	--	--	VII	D
5/7/1978	SW Cherry County, NE	42.26	101.95	--	--	V	E
3/06/1983	NE Sheridan, NE	42.96	102.2	--	--	III	E
1/01/1987	Crawford, NE	42.79	103.48	--	--	III	E
2/08/1989	Merriman, NE	42.8	101.6	--	--	IV	E
2/09/1989	39 Miles SE of WhiteClay, NE	42 41 21 38	101 54 00 32	5 (3.21 miles)	3.8	III	A
7/18/1990	7 miles SSE of Ord, NE	41 30 16 72 N	98 57 39 74 W	5 (3.21 miles)	3.0	II	A
9/30/1990	18 miles SE of Hyanus, NE	41 48 52 97 N	101 30 12 67 W	5 (3.21 miles)	3.0	II	A
8/26/1991	10 miles SE of Brownlee, NE	42 09 46 40 N	100 32 03 25 W	5 (3.21 miles)	3.4	II	A
2/20/1993	14 miles SE of Merriman, NE	42 49 48 00 N	101 27 44 36 W	5 (3.21 miles)	3.5	II - III	A
1/25/1994	5 miles ESE of Wood Lake, NE	42 37 36 39 N	100 08 25 90 W	5 (3.21 miles)	3.3	II	A
2/06/1996	1 mile N of Wausa, NE	42 30 47 42 N	97 32 35 99 W	5 (3.21 miles)	3.6	III	A
8/09/1997	5.5 miles NW of Chadron, NE	41 47 43 66 N	98 11 08 76 W	5 (3.21 miles)	3.4	II	A
6/18/1998	21 miles SE of Crawford, NE	42 37 23 70 N	103 00 16 58 W	5 (3.21 miles)	3.4	II	A

Table 3.3-4 Historical Earthquakes in Northwestern Nebraska in Close Proximity to the Chadron and Cambridge Arches (1884 – 2009)

Date	Location	Latitude	Longitude	Depth (km)[a]	Richter Magnitude[b]	Modified Mercalli Intensity[b]	Source
6/20/2002	5 miles NE of Scotia, NE	41 30 35 65 N	98 37 15 12 W	5 (3.21 miles)	3.5	II - III	A
11/03/2002	4 miles NW of Bassett, NE	42 46 02 38 N	98 54 10 63 W	5 (3.21 miles)	4.0	IV	A
2/14/2003	8 miles SE of Cambridge, NE	40 14 39 46 N	100 01 14 97 W	5 (3.21 miles)	2.9	I	A
2/01/2006	4 miles NE of Bassett, NE	42 36 55 52 N	99 28 23 72 W	5 (3.21 miles)	2.9	I	A
9/07/2006	16 miles SE of Whiteclay, NE	42 58 32 63 N	102 14 15 90	5 (3.21 miles)	3.1	II	A
4/16/2007	61 miles SE of Ogallala	40 36 40 42 N	100 44 50 99 W	5 (3.21 miles)	3.0	II	A
4/24/2007	25 miles SE of Crawford, NE	40 35 04 82 N	102 56 13 78 W	5 (3.21 miles)	2.7	I	A
12/16/2009	7 miles E of Johnson, NE	40 24 N	95.857 W	5 (3.21 Miles)	3.5	II - III	B

Source: A USGS 2009e [Note: Locations (lat and long) based on using USGS Google Earth Files for USGS/NEIC Catalog, so locations are approximate].
Source: B USGS 2009c
Source: C USGS 2010
Source: D Docekal 1970
Source: E National Earthquake Information Service
[a] Depth where the earthquake begins to rupture (Default values used).
[b]Ratings as per Table 2.6-3
--No data

Table 3.3-5 Earthquakes in Wyoming and South Dakota Within 125 miles of City of Crawford, NE (1992 – 2009)

Date	Location	Latitude	Longitude	Depth (km)[a]	Richter Magnitude[b]	Modified Mercalli Intensity[b]	Source
WYOMING							
8/29/2004	10 miles NW of Douglas, WY	42 54 05 38 N	105 30 33 39 W	5 (3.1 miles)	3.8	III	A
2/15/2004	12 miles N of Douglas, WY	42 56 27 51 N	105 24 12 32 W	10 (6.2 miles)	3.5	II - III	A
4/09/1996	5 miles SE of Redbird, WY	43 03 43 28 N	104 05 54 17 W	5 (3.1 miles)	3.7	III	A
12/13/1993	9 miles SW of Esterbrook, WY	42 20 11 47 N	105 30 04 15 W	5 (3.1 miles)	3.5	II - III	A
10/10/1993	26 miles W of Esterbrook, WY	42 25 25 99 N	105 52 21 90 W	5 (3.1 miles)	3.7	III	A
7/23/1993	18 miles WNW of Esterbrook, WY	42 28 34 03 N	105 42 18 29 W	5 (3.1 miles)	3.7	III	A
6/30/1993	15 miles N of Douglas, WY	42 59 02 58 N	105 22 48 50 W	5 (3.1 miles)	3.0	II	A
2/24/1993	11 miles SE of Wright, WY	43 42 46 50	105 17 20 18 W	0	3.6	III	A
11/02/1992	3 miles SE of Lusk, WY	42 44 49 37 N	104 53 22 98 W	5 (3.1 miles)	3.0	II	A
SOUTH DAKOTA							
2/07/2007	1 mile SW of Owanka, SD	44 01 56 13 N	102 34 47 35 W	5 (3.1 miles)	3.1	II	A
5/25/2003	35 miles E of Pine Ridge, SD	43.08 N	101.84 W	5 (3.1 miles)	4.0	IV	B
5/03/1996	18 miles NW of Ardmore, SD	43 02 32 88 N	104 01 11 30 W	5 (3.1 miles)	3.1	II	A
2/06/1996	8.3 miles NW of Hill City, SD	43 58 52 67 N	103 43 41 52 W	5 (3.1 miles)	3.7	III	A
3/20/1994	3 miles SW of Hot Springs, SD	43 23 51 02 N	103 29 57 16 W	5 (3.1 miles)	2.3	I	A

Table 3.3-5 Earthquakes in Wyoming and South Dakota Within 125 miles of City of Crawford, NE (1992 – 2009)

Date	Location	Latitude	Longitude	Depth (km)[a]	Richter Magnitude[b]	Modified Mercalli Intensity[b]	Source
3/18/1994	3 miles SW of Hot Springs, SD	43 23 51 02 N	103 29 57 16 W	5 (3.1 miles)	2.8	I	A
9/05/1993	2.5 miles NW of Central City, SD	44 24 11 63 N	103 48 07 76 W	5 (3.1 miles)	2.7	I	A
11/05/1991	1.5 miles SE of Central City, SD	44 21 10 54 N	103 45 01 27 W	0	2.5	I	A
3/02/1990	13 miles NW of Wounded Knee, SD	43 19 00 23 N	102 30 04 97 W	5 (3.1 miles)	3.2	II	A
1/28/1990	13 miles NW of Wounded Knee, SD	43 19 00 23 N	102 30 04 97 W	5 (3.1 miles)	4.0	IV	A

Source: A USGS 2009f [Note: Locations (lat and long) based on using USGS Google Earth Files for USGS/NEIC Catalog, so locations are approximate].
Source: B USGS 2009c

[a] D: Depth where the earthquake begins to rupture (Default values used).
[b] Rating as per Table 2.6-3

Table 3.3-6 Summary of Soil Resources Within the Three Crow Expansion Area

Map Unit	Map Unit Name	Acres	Percent of Project Area
1031	Glenberg fine sandy loam, channeled, frequently flooded	10.0	0.6
1180	Las Animas fine sandy loam, occasionally flooded	9.3	0.6
1356	Bridget silt loam, 1 to 3 percent slopes	239.8	14.6
1357	Bridget silt loam, 3 to 6 percent slopes	91.1	5.5
1363	Bridget very fine sandy loam, 3 to 6 percent slopes	9.6	0.6
1364	Bridget very fine sandy loam, 6 to 9 percent slopes	67.6	4.1
1618	Keith loam, 1 to 3 percent slopes	11.6	0.7
1620	Keith silt loam, 1 to 3 percent slopes	61.1	3.7
1631	Keith silt loam, 3 to 9 percent slopes	24.3	1.5
1742	Rosebud-Canyon loams, 3 to 9 percent slopes	7.7	0.5
1862	Ulysses silt loam, 9 to 20 percent slopes	55.5	3.4
5105	Alliance silt loam, 1 to 3 percent slopes	89.0	5.4
5106	Alliance silt loam, 3 to 9 percent slopes	7.5	0.5
5107	Alliance silt loam, 3 to 9 percent slopes, eroded	150.1	9.1
5118	Busher and tassel loamy very fine sands, 6 to 20 percent slopes	93.5	5.7
5124	Busher loamy very fine sand, 1 to 6 percent slopes, eroded	17.5	1.1
5128	Busher loamy very fine sand, 6 to 9 percent slopes, eroded	56.6	3.4
5129	Busher loamy very fine sand, 9 to 20 percent slopes	23.0	1.4
5200	Oglala loam, 9 to 30 percent slopes	69.8	4.2
5211	Oglala-Canyon loams, 9 to 20 percent slopes	93.1	5.7
5291	Vetal very fine sandy loam, 1 to 3 percent slopes	0.8	0.0
5292	Vetal very fine sandy loam, 3 to 6 percent slopes	55.4	3.4
5947	Duroc very fine sandy loam, 1 to 3 percent slopes	330.1	20.1
5964	Jayem and Vetal loamy very fine sands, 6 to 9 percent slopes	1.3	0.1
6028	Tassel soils, 3 to 30 percent slopes	44.2	2.7
6036	Tassel-Busher-Rock outcrop complex, 6 to 30 percent slopes	11.3	0.7
6109	Sarben loamy very fine sand, 9 to 30 percent slopes	8.5	0.5
9903	Fluvaquents, sandy, frequently flooded	4.0	0.2
TOTAL		**1643.4**	**100.0**

Table 3.4-1 USGS Estimated Water Use in Dawes County 2005

Total Population Served	Public Supply (Million Gallons Per Day [Mgal/da])				Irrigation (Mgal/da)			1000s
	Ground-water Withdrawals	Surface Water Withdrawals	Total Withdrawals	Domestic Deliveries	Groundwater Withdrawals	Surface Water Withdrawals	Total Withdrawals	Acres Irrigated Total
8,636	1.47	1.12	2.59	1.77	14.24	10.31	24.55	13

Source: USGS 2005

Table 3.4-2 Summary of Non-Abandoned Registered Water Wells for Dawes County, NE on File as of February 18, 2010

Number of Registered Wells						Average Well Depth	Average Static level	Average Pumping Level	Total Registered Acres, Irrigation [c]	Number Replacement Wells
Commercial	Domestic	Irrigation	Monitoring [a]	Other Wells [b]	Total					
500	226	97	628	4,061	**5,512**	536.15	176.70	293.90	13,773.90	23

Other Wells (Registered)

Ground Heat Exchange	Injection	Observation [d]	Other [e]	Recovery	Livestock	Public Water Supply [f]	Public Water Supply[g]	Total Other Wells
41	916	8	16	2,855	224	16	21	**4,061**

Source: NDNR 2010a.
[a] Monitoring (Ground Water Quality)
[b] Listed below [Other Wells (Registered)]
[c] The same acres may be reported under more than one well registration.
[d] Observation (Ground Water Levels)
[e] Other (Lake Supply, Fountain, Geothermal, Wildlife, Wetlands, Recreation, Plant & Lagoon, Sprinkler, Test, Vapor Monitoring)
[f] With spacing protection (A well owned and operated by a city, village, municipal corporation, metropolitan utilities district, reclamation district, or sanitary improvement district that provides water to the public fit for human consumption through at least 15 service connections, or regularly serve at least 5 individuals.
[g] Without spacing protection (A well *not* owned or operated by a city, village, municipal corporation, metropolitan utilities district, reclamation district, or sanitary improvement district that provides the public water fit for human consumption through at least 15 service connections or regularly serves at least 25 individuals.

Table 3.4-3 City of Crawford Community Water Supply System Sources of Water

Name of Sources of Water	Type	Status
971 Gallery Well East	Infiltration Gallery	Active
972 Gallery Well Middle	Infiltration Gallery	Active
973 Gallery Well West	Infiltration Gallery	Active
Soldier Creek Infiltration Gallery	Infiltration Gallery	Active
Well 981	Well	Active
Well 982	Well	Active
Dead Man's Creek Intake	Infiltration Gallery	Inactive
White River Infiltration Gallery	Infiltration Gallery	Inactive

Service connections: 50 commercial and 450 residential

Table 3.4-4 Summary of City of Crawford Water System

Description	Capacity
Raw Water Storage Capacity	500,000 gallons
Treated Water Capacity West Tank East Tank	 1,000,000 gallons 750,000 gallons
Average Daily Use (2006)	419,181 gallons
Maximum Daily Use	1,000,000 gallons
Supply Wells	
South Well #1 (100 feet deep); NDNR Registration No. G-93533 NW1/4 SW1/4 Section 15 T31N R52W	104 gpm
West Well #2 (100 feet deep); NDNR Registration No. G-93532 NW1/4 SW1/4 Section 15 T31N R52W	54 gpm
Infiltration Gallery	
Wet Well (27 feet); NDNR Registration No. G-93531 SE1/4 SW1/4 Section 8 T31N R52W	900 gpm
Dewatering Wells (20 to 26 feet deep); NDNR Registration Nos. G-093528, G-093529 and G-093530 SE1/4 SW1/4 Section 8 T31N R52W	33 gpm (each)
Wellhead Protection Area	
960 acres Sections 15, 16, 21, and 22 T31N R52W	--

Sources: Teahon, L. 2007
Teahon, L. and Grantham, R. 2010
City of Crawford 2010a

Table 3.4-5 City of Crawford Minimum Horizontal Distances Separating Public Water Supply Wells from Potential Sources of Contamination

Category	Distance	
	Feet	Meters
All water wells, including but not limited to: domestic supply wells, irrigation wells, stock wells, and heat pump wells	1,000	300
Sewage lagoon	1,000	300
Absorption or disposal field for waste	500	150
Cesspool	500	150
Dump	500	150
Feedlot or feedlot runoff	500	150
Corral	500	150
Pit toilet	500	150
Sanitary landfill	500	150
Chemical or petroleum product storage	500	150
Septic tank	500	150
Sewage treatment plant	500	150
Sewage wet well	500	150
Sanitary sewer connection	100	30
Sanitary sewer manhole	100	30
Sanitary sewer line	50	15
Sanitary sewer line (permanently watertight)	10	3

Source: City of Crawford 2010b.

Table 3.4-6 Summary of Groundwater Quality for Three Crow Vicinity

Constituent	Private Wells in AOR[a]		Three Crow Expansion Area Wells[b]		Three Crow Expansion Area Wells[c]	
	Brule Formation		Brule Formation		Basal Chadron Formation	
	Range	Mean	Range	Mean	Range	Mean
	mg/l (unless stated otherwise)					
Calcium	7 – 99	54	14 -101	50.25	8 - 24	13.0
Magnesium	1 – 9	4.2	1 - 14	4.96	2 - 7	3.7
Sodium	16 - 75	28.6	14 - 83	35	333 - 474	399
Potassium	6 - 20	11.7	6 - 12	9.1	6 - 9	9.6
Bicarbonate	170 - 313	227	194 - 478	246	353 - 418	396
Sulfate	4 - 75	19	9 -25	16.4	225 - 361	271.4
Chloride	1 - 42	10	4 - 23	8.54	166 - 274	186
Specific Conductance (µmhos/cm)	246 - 633	436	239 – 735	410	1690 - 2190	1867
Total Dissolved Solids (TDS)	215 - 448	313	221 - 499	302	980 - 1300	1098
pH (Std. units)	7.38 – 8.4	7.82	7.49 – 8.74	7.98	7.82 – 8.75	8.23
Anions (meq/l)	3.0 – 6.24	4.75	3.67 – 8.78	4.78	16.3 – 20.6	17.7
Cations (meq/l)	3.37 – 6.46	5.07	3.43 – 8.06	4.68	16 – 21.8	18.6
Uranium (mg/l)	0.008 – 0.0272	0.0161	0.0032– 0.0264	0.0134	0.0004 – 0.0385	0.0087
Dissolved Ra-226[d] (pCi/l)	0.006 – 0.5	0.28	0.065 – 0.41	0.126	0.23 - 181	18.1
Suspended Ra-226[d] (pCi/l)	--	--	0.04 – 0.20	0.087	--	--

[a] 9 private water supply wells (2007 – 2009)
[b] 7 CBR TCEA Brule monitor wells (includes Well 274 [Miller Well[) (2008 – 2009) [Note Suspended Ra-226 analyses were for 3 sampling events in 2009 for wells BOW 2006-5, BOW 2006-6 and BOW 2006-7]
[c] 10 CBR TCEA Basal Chadron monitor wells (2008 – 2009)
[d] Values less than detection limits reduced by one-half to provide a conservative estimate.
mg/l = milligrams/liter
meq/l = milliequivalents per liter
pCi/l = picocuries per liter
µmhos/cm = micromhos per centimeter

Table 3.4-7 Active and Abandoned Water Supply Wells in the TCEA and 2.25-Mile Area of Review

Well #	Estimated Depth (ft)	Formation	Well Use	Well Status	Within TCEA
ACTIVE WELLS					
0009	110	Brule Fm	Agricultural	Active	No
0010	80	Brule Fm	Agricultural	Active	No
0044	90	Brule Fm	Domestic	Active	No
0045	90	Brule Fm	Domestic	Active	No
0046	130	Brule Fm	Domestic	Active	No
0047	50	Brule Fm	Domestic	Active	No
0053	80	Brule Fm	Domestic	Active	No
0054	80	Brule Fm	Agricultural	Active	No
0070	125	Brule Fm	Agricultural	Active	No
0071	100	Brule Fm	Agricultural	Active	No
0073	120	Brule Fm	Other Use[b]	Active	No
0139	80	Brule Fm	Domestic/Agricultural	Active	No
0142	200	Brule Fm	Domestic/Agricultural	Active	No
0143	100	Brule Fm	Domestic	Active	No
0146	200	Brule Fm	Agricultural	Active	No
0147	100	Brule Fm	Agricultural	Active	No
0148	200	Brule Fm	Agricultural	Active	No
0260	260	Brule Fm	Domestic	Active	No
0261	300	Brule Fm	Agricultural	Active	No
0265	32	Brule Fm	Domestic	Active	No
0266	15 – 20	Brule Fm	Agricultural	Active	No
0267	15 – 20	Brule Fm	Agricultural	Active	No
0268	15 – 20	Brule Fm	Agricultural	Active	No
0269	65	Brule Fm	Domestic	Active	No
0270	a	Brule Fm	Domestic/Agricultural	Active	**Yes**
0271	100 – 120	Brule Fm	Domestic/Agricultural	Active	**Yes**
0272	60	Brule Fm	Domestic/Agricultural	Active	**Yes**
0273	140	Brule Fm	Agricultural	Active	**Yes**
0274	160	Brule Fm	Domestic	Active	No
0275	200	Brule Fm	Domestic	Active	No
0276	300	Brule Fm	Domestic	Active	No
0277	60	Brule Fm	Domestic	Active	**Yes**
0278	25 – 30	Brule Fm	Domestic/Agricultural	Active	No
0279	260	Brule Fm	Agricultural	Active	No
0280	160	Brule Fm	Agricultural	Active	No
0281	100	Brule Fm	Agricultural	Active	**Yes**
0282	200	Brule Fm	Agricultural	Active	No
0283	200	Brule Fm	Agricultural	Active	No
0284	90	Brule Fm	Agricultural	Active	No
0286	90	Brule Fm	Agricultural	Active	**Yes**
0287	50	Brule Fm	Agricultural	Active	No
0300	a	a	Agricultural	Active	No
0310	50	Brule Fm	Agricultural	Active	No

Table 3.4-7 Active and Abandoned Water Supply Wells in the TCEA and 2.25-Mile Area of Review

Well #	Estimated Depth (ft)	Formation	Well Use	Well Status	Within TCEA
0311	200	Brule Fm	Agricultural	Active	No
0312	150	Brule Fm	Agricultural	Active	No
0313	150	Brule Fm	Agricultural	Active	No
0314	150	Brule Fm	Agricultural	Active	No
0322	a	a	Agricultural	Active	No
0332	120	Brule Fm	Agricultural	Active	No
0333	100	Brule Fm	Agricultural	Active	No
0334	100	Brule Fm	Domestic	Active	No
0335	160	Brule Fm	Agricultural	Active	No
0337	90	Brule Fm	Domestic/Agricultural	Active	No
0338	60	Brule Fm	Agricultural	Active	No
0339	30	Brule Fm	Domestic/Agricultural	Active	No
0360	190	Brule Fm	Agricultural	Active	No
0361	250	Brule Fm	Agricultural	Active	No
0364	a	Brule Fm	Domestic/Agricultural	Active	No
0367	80	Brule Fm	Agricultural	Active	No
0368	170	Brule Fm	Domestic/Agricultural	Active	No
0369	120	Brule Fm	Agricultural	Active	No
0371	140	Brule Fm	Agricultural	Active	No
0372	80	Brule Fm	Agricultural	Active	No
0373	140	Brule Fm	Agricultural	Active	No
0374	200	Brule Fm	Domestic/Agricultural	Active	No
0381	40 -50	Brule Fm	Agricultural	Active	No
0386	160	Brule Fm	Agricultural	Active	No
0390	80	Brule Fm	Domestic	Active	No
0395	a	a	Domestic	Active	No
0398	95	Brule Fm	Domestic	Active	No
0400	a	a	Agricultural	Active	No
0402	a	a	Agricultural	Active	No
0412	133	Brule Fm	Agricultural	Active	No
0421	60	Brule Fm.	Agricultural	Active	No
0432	a	a	Agricultural	Active	No
0434	125	Brule Fm	Domestic/Agricultural	Active	No
0446	200	Brule Fm	Agricultural	Active	No
0447	60	Brule Fm	Agricultural	Active	No
0448	200	Brule Fm	Agricultural	Active	No
0450	260	Brule Fm	Livestock/Observation	Active	No
0451	200	Brule Fm	Livestock/Observation	Active	No
0452	200	Brule Fm	Livestock/Observation	Active	No
0453	200	Brule Fm	Livestock/Observation	Active	No
0454	103	Brule Fm	City of Crawford (public water supply)	Active	No
0455	102	Brule Fm	City of Crawford (public water supply)	Active	No

Table 3.4-7 Active and Abandoned Water Supply Wells in the TCEA and 2.25-Mile Area of Review

Well #	Estimated Depth (ft)	Formation	Well Use	Well Status	Within TCEA
0456	21	Alluvium	City of Crawford (public water supply)	Active	No
0457	20	Alluvium	City of Crawford (public water supply)	Active	No
0458	28	Alluvium	City of Crawford (public water supply)	Active	No
0459	27	Alluvium	City of Crawford (public water supply)	Active	No
ABANDONED WELLS					
0003	100	Brule Fm.	Agricultural	Abandoned	No
0279A	75	Brule Fm.	Agricultural	Abandoned	No
AW0285	a	a	Agricultural	Abandoned	No
0291	a	a	a	Abandoned	No
0292	a	a	a	Abandoned	No
0293	a	a	a	Abandoned	No
0294	a	a	a	Abandoned	No
0295	a	a	a	Abandoned	No
0296	a	a	a	Abandoned	No
0297	80	Brule Fm	a	Abandoned	**Yes**
0299	80	Brule Fm	a	Abandoned	No
0318	75	Brule Fm	a	Abandoned	No
0325	80	Brule Fm	Domestic	Abandoned	No
0365	a	a	Agricultural	Abandoned	No
0376	a	a	Agricultural	Abandoned	No
0388	a	a	Domestic	Abandoned	No
0391	a	a	a	Abandoned	No
0392	80	Brule Fm	Agricultural	Abandoned	No
0410	90 – 100	Brule Fm	a	Abandoned	**Yes**
0411	a	a	a	Abandoned	**Yes**
0413	a	a	a	Abandoned	**Yes**
0414	a	a	a	Abandoned	No
AW0415	200	Brule Fm	a	Abandoned	No
0419	a	a	a	Abandoned	No
0420	65	Brule Fm	a	Abandoned	No
0279AW	75	Brule Fm	a	Abandoned	No
G-022460A	100	Brule Fm	Agricultural	Abandoned	No
G-022460B	100	Brule Fm	Agricultural	Abandoned	No
200450	110	Brule Fm	Agricultural	Abandoned	No
200443	100	Brule Fm	Agricultural	Abandoned	No

[a] Unknown [b] Well used by City of Crawford as a test well for a municipal system

Note: Wells designated as completed in the Brule Formation, in many cases, are also included completed in the overlying alluvium.

Table 3.4-8 White River-Hat Creek Basin Stream Segment and Use Classification [1]

Stream Segment	Segment No.	Use Classification						
				Aquatic Life	Water Supply			
		State Resource Water	Recreation	Coldwater [2]	Public Drinking Water[3]	Agricultural[4]	Aesthetics	Key Species
White River – Soldier creek to Whitney Pipe Line (Aqueduct) (Sec. 26 T31N R51W)	20000		•	B		A	•	d, e
White Clay Creek	20100		•	B		A	•	c
Squaw Creek – NE National Forest boundary (Sec. 20 T31N R51W) to White Clay Creek	20110			B		A	•	
English Creek	20111			B		A	•	
Squaw Creek – Headwaters to NE National Forest boundary (Sec. 29 T31N R51W)	20120	A	•	B		A	•	c
Unnamed Creek (Sec. 36 T31N R52W)	20130		•	B		A	•	
Bozle Creek (Sec. 9 T31N R52W)	20200			B		A	•	
Soldier Creek – Middle Fork Soldier Creek to White river	20300	A		A	•	A	•	d, e
Middle Fork Soldier Creek	20310	A		A		A	•	d, e
Soldier Creek – Headwaters to Middle Fork Soldier Creek	20400	A		A		A	•	d, e
White River – Kyle Creek (Sec. 35 T31N R54W) to Soldier Creek	30000	B	•	A	•	A	•	d, e

Table 3.4-8 White River-Hat Creek Basin Stream Segment and Use Classification [1]

Stream Segment	Segment No.	Use Classification						
		State Resource Water	Recreation	Aquatic Life: Coldwater [2]	Water Supply: Public Drinking Water[3]	Water Supply: Agricultural[4]	Aesthetics	Key Species
Dead Man's Creek	30100		•	B	•	A	•	c
Deep Creek (Sec. 33 T31N R 53W)	30200			B		A	•	e
Bull Creek (Sec. 6 T30N R53W)	30300			B		A	•	
Kyle Creek (Sec. 35 T31N R54W)	30400			B		A	•	
White River – Headwaters to Kyle Creek (Sec. 35 T31N R54W)	40000	B		A	•	A	•	d, e

[1] Stream segments consist only of those in close proximity to the TCEA (NDEQ 2005). Note: See reference for remainder of segments.

[2] **Aquatic Life Class A**: These waters provide a habitat which supports natural reproduction of a salmonid (trout) population. These waters also are capable of maintaining year-round populations of a variety of other coldwater fish and associated vertebrate and invertebrate organisms and plants.

[2] **Aquatic Life Class B**: These are waters which provide, or could provide, a habitat capable of maintaining year-round populations of a variety of coldwater fish and associated vertebrate and invertebrate organisms and plants or which support the seasonal migration of salmonids. These waters do not support natural reproduction of salmonid populations due to limitations of flow, substrate composition, or other habitat conditions, but salmonid populations may be maintained year-round if periodically stocked.

[3] **Public Drinking Water:** These are surface waters which serve as a public drinking water supply. These waters must be treated (e.g., coagulation, sedimentation, filtration, chlorination) before the water is suitable for human consumption. After treatment, these waters are suitable for drinking water, food processing, and similar uses.

[4] **Water Supply Agricultural Class A**: These are waters used for general agricultural purposes (e.g., irrigation and livestock watering) without treatment.

c: Brook trout
d: Brown trout
e: Rainbow trout

Table 3.4-9 Differences in Elevation of Three Crow Assets and White River

Project Boundary and Facility Assets		Elevation of Nearest Point of White River	Difference in Elevation (ft)[b]	Distance of Asset from Nearest Point of White River (ft)
Individual Measurement Points[a]	Elevation (ft)			
Satellite Facility	3918	3779	139	7583
Evaporation Ponds	3912.5	3779	133.5	7249
MU1	3920.1	3779	141.1	8301
MU2	3895.6	3779	116.6	6159
MU3	3927.8	3779	148.8	7070
MU4	3987.6	3779	208.6	10131
MU5	3948.4	3760	188.4	10009
MU6	3955.5	3760	195.5	11335
MU7	3961.9	3760	201.9	11833
MU8	3951.7	3760	191.7	13619
MU9	3979.1	3760	219.1	15443
NW Corner of Permit Boundary	3924	3798.6	125.4	4365
SW Corner of Western Most Permit Boundary	4035.8	3858	177.8	7218
Center Point of North Permit Boundary	3941.6	3772.5	169.1	7133
Northeast Corner of Permit Boundary	3904.4	3761.6	142.8	10672

[a] Measurements made at center-point of satellite building, evaporation ponds, and mine units.

[b] Positive values indicate elevations of satellite facility and associated assets greater than nearest sampling point of White River.

Table 3.4-10 Three Crow Expansion Area Summary of 2008 Three Crow Pumping Test Well Information

Well	Distance to Pumping Well	Northing (ft)	Easting (ft)	Township & Range	Section	TOC Elev. (ft-amsl)	Surface Elevation (ft-amsl)	Casing Stickup (ft)	Depth Drilled (ft bgs)	Casing Depth (ft bgs)	Top Screen (ft bgs)	Bottom Screen (ft bgs)	Screen Length (ft)	Casing O.D. (in.)	04/21/08 Static Water Elevation (ft AMSL)
Basal Chadron Sandstone Pumping Well															
CPW 2006-2	0.00	492,983.11	1,068,178.21	30	T31N R52W	3,914.73	3,913.63	1.10	900	790	791	871	80	4.95	3722.26
Basal Chadron Sandstone Observation Wells															
COW 2006-1	4,601	494,341.24	1,063,782.51	25	T31N R53W	3,906.95	3,905.80	1.15	840	759	764	829	65	4.95	3724.93
COW 2006-2	2,138	494,512.66	1,066,684.93	30	T31N R52W	3,933.71	3,932.71	1.00	880	779	781	851	70	4.95	3721.50
COW 2006-3	1,155	494,006.65	1,068,713.99	30	T31N R52W	3,903.68	3,902.78	0.90	840	729	731	811	80	4.95	3718.77
COW 2006-4	2,718	490,369.75	1,068,924.73	29	T31N R52W	3,955.82	3,954.67	1.15	910	789	783	878	95	4.95	3722.61
COW 2006-5	3,877	490,191.11	1,070,868.10	29	T31N R52W	3,892.71	3,982.26	0.45	920	849	851	901	50	4.95	3721.64
UBCOW 2006-1	45	492,976.82	1,068,222.59	30	T31N R52W	3,915.06	3,913.96	1.10	760	649	654	744	90	4.95	3721.88
UBCOW 2006-2	2,711	490,371.92	1,068,906.48	29	T31N R52W	3,955.55	3,954.03	1.52	770	659	665	770	105	4.95	3721.75
Brule Formation Observation Wells															
BOW 2006-1	39	493,015.54	1,068,155.97	30	T31N R52W	3,915.50	3,914.75	0.75	170	39	45	50	5	4.95	3862.91
BOW 2006-2	2,444.00	491,217.68	1,066,488.62	30	T31N R52W	3,938.64	3,937.65	0.99	180	69	75	180	105	4.95	3878.85
BOW 2006-3	2,789	490,288.86	1,068,899.77	29	T31N R52W	3,957.36	3,956.23	1.13	200	45	45	190	145	4.95	3879.16

Table 3.4-11 Summary of Three Crow Pumping Test Results vs Current Crow Butte Facility and North Trend Expansion Area

	Tests #1-#4 Existing Class III Permit Area (mean)	Test #6 North Trend 2006 (mean)	Test #7 Three Crow 2008 (mean)
Transmissivity (ft^2/day)	363	60	477
Formation Thickness (feet)	39.0	26	64
Hyd. Cond. (ft/day)	9.3	2.3	7.5
Storativity	9.7E-05	5.3E-05	8.8E-04

Table 3.4-12 Three Crow Expansion Area Summary of 2008 Three Crow Pumping Test Results

Well	Distance from Pumping Well (feet)	Analytical Results	Theis Drawdown	Theis Recovery	Cooper & Jacob 'u' assumption satisfied (<0.01)	Averages
CPW 2006-2	Pumping Well	Transmissivity (ft²/day)	NA	3.35E+02	NA	3.35E+02
		Hyd. Cond. (ft/day)	NA	5.24E+00	NA	5.24E+00
		Storativity	--	--	--	--
COW 2006-1	4,601	Transmissivity (ft²/day)	6.38E+02	8.48E+02	NA	7.43E+02
		Hyd. Cond. (ft/day)	9.97E+00	1.32E+01	NA	1.16E+01
		Storativity	1.64E-04	--	--	1.64E-04
COW 2006-2	2,138	Transmissivity (ft²/day)	3.67E+02	4.73E+02	NA	4.20E+02
		Hyd. Cond. (ft/day)	5.74E+00	7.39E+00	NA	6.57E+00
		Storativity	9.65E-05	--	--	9.65E-05
COW 2006-3*	1,155	Transmissivity (ft²/day)	2.16E+02	3.22E+02	2.61E+02	2.67E+02
		Hyd. Cond. (ft/day)	3.38E+00	5.04E+00	4.08E+00	4.16E+00
		Storativity	4.83E-05	--	4.14E-05	4.49E-05
COW 2006-4	2,718	Transmissivity (ft²/day)	3.51E+02	5.31E+02	NA	4.41E+02
		Hyd. Cond. (ft/day)	5.48E+00	8.29E+00	NA	6.89E+00
		Storativity	6.68E-05	--	--	6.68E-05
COW 2006-5	3,877	Transmissivity (ft²/day)	4.42E+02	5.83E+02	NA	5.12E+02
		Hyd. Cond. (ft/day)	6.90E+00	9.11E+00	NA	8.01E+00
		Storativity	6.83E-05	--	--	6.83E-05

* - The 'u' assumpition limitation (<0.01) inherent to the Cooper & Jacob method was satisfied for monitor well COW 2006-3 only.

Avg. Transmissivity (ft²/day)	4.77E+02
Avg. Hyd. Cond. (ft/day)	7.45E+00
Avg. Storativity	8.81E-05

Discharge Rate: 44.7 [U.S. gal/min]

Aquifer Thickness: 64 [ft]

Table 3.4-13 Water Levels – Brule Formation and Basal Chadron Sandstone (January 2009 and 2010)

Well	1/9/2009	1/30/2009	1/22/2010 & 2/8/2010
BRULE FORMATION			
BOW 2006-1	3862.90	3863.34	3863.83
BOW 2006-2	3879.01	3879.07	3878.50
BOW 2006-3	3878.25	3878.05	3877.20
BOW 2006-4	3857.78	3857.50	3861.58
BOW 2006-5	NM	NM	3842.83
BOW 2006-6	NM	NM	3904.43
BOW 2006-7	NM	NM	3913.02
Well 273 (Miller Well)	NM	NM	3819.13
BASAL CHADRON SANDSTONE			
CPW2006-2	3,721.22	3,721.01	3,717.26
COW2006-1	3,723.94	3,723.64	3,720.36
COW2006-2	3,721.11	3,720.85	3,717.13
COW2006-3	3,720.43	3,720.22	3,716.73
COW2006-4	3,720.81	3,720.46	3,717.02
COW2006-5	3,720.26	3,720.03	3,716.46
COW2006-6	3,713.43	3,712.89	3,708.23
COW2006-7	3,711.76	3,712.20	3,707.55
UBCOW2006-1	3,720.51	3,720.36	3,716.73
UBCOW2006-2	3,720.84	3,720.61	3,716.96

Notes:

1) Groundwater elevations are in feet above mean sea level (ft-amsl).

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

3) A single water level measurement was collected from Well 273 on 2/8/2010.

NM - not measured

Table 3.4-14 Baseline and Restoration Values for CPF Mine Unit 10

Baseline and Restoration Values for CPF Mine Unit 10	Groundwater Standard [a]	MU-10 Baseline (Primary Standard)	MU-10 Standard Deviation	MU-10 NDEQ Restoration Value
Ammonium (mg/l)	Not Listed	0.34	0.07	10
Arsenic (mg/l)	0.010	0.001	0.001	0.01
Barium (mg/l)	2	0.1	0.0	2.0
Cadmium (mg/l)	0.005	0.005	0.00--	0.005
Calcium	Not Listed	11.8	2/6	118.0
Chloride (mg/l)	250	185	14	250
Copper (mg/l)	1.3	0.01	0.01	1.3
Fluoride (mg/l)	4	0.72	0.10	4
Iron (mg/l)	0.3	0.03	0.01	0.3
Lead (mg/l)	0.015	0.001	0.0	0.015
Manganese (mg/l)	0.05	0.01	0.0	0.05
Magnesium	Not Listed	3.4	0.7	34
Mercury (mg/l)	0.002	0.001	0.0	0.002
Molybdenum (mg/l)	Reserved	1.0	0.0	1
Nickel (mg/l)	Reserved	0.05	0.0	0.15
Nitrate (mg/l)	10	0.1	0.0	10
Potassium (mg/l)	N/A	10.1	1.6	101
Radium-226 (pCi/L)	5	87.3	161.0	409.3
Selenium (mg/l)	0.05	0.003	0.002	0.05
Sodium (mg/l)	Reserved	388	12	3880
Sulfate (mg/l)	250	329	25	379
Uranium (mg/l)	0.030	0.0378	0.0351	0.108
Vanadium (mg/l)	Reserved	0.1	0.0	0.2
Zinc (mg/l)	5	0.01	0.01	5
pH (Std. Units)	6.5 - 8.5	8.51	0.19	6.5 – 8.89
Total Carbonate (mg/l)	N/A	394	15	550.5
TDS (mg/l)	500	1101	26	1127

[a] Title 118 numerical standards in effect at the time the Notice of Intent was filed with the NDEQ.

Table 3.4-15 Anticipated Changes in Water Quality During Mining

Average Ore Zone Water Quality			
Analyte	**Units**	**Pre-Mining (Well W-007)**	**Typical Water Quality During Mining at CPF**
Alkalinity, Total as CaCO3	mg/L	328	1,600
Carbonate as CO3	mg/L	0	<1.0
Bicarbonate as HCO3	mg/L	401	2,050
Calcium	mg/L	29.6	77
Chloride	mg/L	202	600
Fluoride	mg/L	1.23	0.6
Magnesium	mg/L	5.3	23
Ammonia as N	mg/L	0.74	<0.05
Nitrate+Nitrite as N	mg/L		0.46
Potassium	mg/L	15.0	35
Silica	mg/L	11.3	21
Sodium	mg/L	567	1,310
Sulfate	mg/L	737	900
Conductivity	umhos/cm	2,723	6,000
pH	s.u.	8.1	7.8
TDS	mg/L	1,804	4,080
Aluminum	mg/L	<0.10	<0.1
Arsenic	mg/L	<0.002	0.06
Barium	mg/L	<0.10	<0.1
Boron	mg/L	1.61	1.1
Cadmium	mg/L	<0.01	<0.005
Chromium	mg/L	<0.05	<0.05
Copper	mg/L	<0.01	0.04
Iron	mg/L	<0.05	<0.030
Lead	mg/L	<0.05	<0.05
Manganese	mg/L	0.01	0.05
Mercury	mg/L	<0.001	<0.001
Molybdenum	mg/L	<0.10	0.5
Nickel	mg/L	<0.05	<0.05
Selenium	mg/L	<0.175	0.07
Uranium	mg/L	<0.0032	44
Vanadium	mg/L	<0.10	2.5
Zinc	mg/L	<0.02	0.02
Radium 226	pCi/L	11.9	1,090

Table 3.5-1 Monthly Climate Summary for Chadron 1 NW, Nebraska (251575)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Spt	Oct	Nov	Dec	Annual
Average Maximum Temperature (°F)	35.8	40.4	48.2	59.2	69.4	80.5	89.5	88.1	77.6	64.6	48.2	38.6	61.7
Average Minimum Temperature (°F)	11.7	15.8	23.0	33.2	43.6	53.1	60.1	58.0	47.2	35.4	23.4	14.8	34.9
Average Total Precipitation (Inches)	0.49	0.49	0.94	1.93	2.89	2.81	2.09	1.38	1.40	1.03	0.56	0.46	16.48
Average Total Snowfall (Inches)	6.6	6.4	8.9	6.0	0.8	0.0	0.0	0.0	0.3	2.3	5.6	6.7	43.6
Average Snow Depth (Inches)	2	2	1	0	0	0	0	0	0	0	1	1	1

Source: HPRCC 2010. Period of Record : 8/ 1/1894 to 2/28/2009

Table 3.5-2 Three Crow Vegetation and Land Cover Types

Habitat	Acres	Percent
Riverine	0.26	<1.0
Deciduous Streambank Forest	7.14	<1.0
Mixed-grass Prairie	578.8	35.0
Range Rehabilitation	87.7	5.0
Cultivated	945.9	58.0
Structure Biotope	23.8	2.0
Total	**1643**	**100.0**

Table 3.5-3 Federal and State Threatened, Endangered, and Candidate Species with the Potential to Occur Within the Vicinity of the Three Crow Expansion Area*

Species	Listing Status		Habitat	Critical Habitat
	Federal	State		
Black-footed Ferret (*Mustela nigripes*)	Endangered	Endangered	Closely associated with prairie dogs found in short and mid-grass prairies	None designated
Black-Tailed Prairie Dog (*Cynomys ludovicianus)*	Not Listed	Candidate for endangered status	Short and mid-grass rangeland overgrazed by livestock	None designated
Eskimo Curlew (*Numenius borealis*)	Endangered	Endangered	Migrates through NE, with newly plowed fields, burned prairies and marshes being particularly attractive to the migrating bird	None designated
Mountain Plover *(Charadrius montanus)*	Not Listed	Threatened	Arid short grass prairie, dominated by blue grama, buffalo grass that is scattered with cacti and forbs	None designated
Swift Fox (*Vulpes velox*)	Not Listed	Endangered	Large tracts of short- and mid-grass prairie habitats.	None designated
Whooping Crane (*Grus americana)*	Endangered	Endangered	Wet meadows, croplands, and marshlands	None designated

**AGC Nebraska Chapter 2007; NGPC 2008a and 2008b*

Table 3.6-1 Chadron NWS Monthly Averages and Monthly Extremes Temperature Data (1894 to 2009)

Month	Monthly Averages			Monthly Extremes Record High		Monthly Extremes Record Low	
	Maximum	Minimum	Mean				
	(°C)	(°C)	(°C)	(°C)	Year	(°C)	Year
Jan	2.1	-11.3	-4.6	1.3	2006	-13.7	1949
Feb	4.7	-9.0	-2.2	5.3	1954	-13.8	1936
Mar	9.0	-5.0	2.0	7.2	1918	-4.8	1965
Apr	15.1	0.7	7.9	12.5	1930	-2.8	1920
May	20.7	6.4	13.6	19.8	1934	10.2	1995
June	26.9	11.7	19.3	24.6	1933	14.7	1945
July	31.9	15.6	23.8	29.1	1936	19.4	1915
Aug	31.2	14.4	22.8	26.2	1937	19.0	1927
Sept	25.3	8.4	16.9	20.9	1931	-10.9	1965
Oct	18.0	1.8	9.9	14.4	1963	-3.0	1925
Nov	9.1	-9.6	2.2	8.3	1999	-7.2	1985
Dec	3.7	-10.1	-2.9	3.6	1939	-13.7	1983
Year	16.5	1.6	9.1	11.5	1934	6.8	1951

Source: HPRCC 2010
Note: For months and annual means, thresholds and sums: months with 5 or more missing days are not considered; years with 1 or more missing days are not considered.

Table 3.6-2 Chadron NWS Temperature Occurrences (1894 to 2009)

Month	Mean Number of Days with Maximum Temperatures		Mean Number of Days with Minimum Temperatures	
	>= 32.2°C	>= 0°C	< =0°C	<= -17.8°C
Jan	0.0	11.2	29.9	7.1
Feb	0.0	7.9	26.2	4.0
Mar	0.0	4.8	25.4	1.6
Apr	0.0	0.9	14.2	0.0
May	1.0	0.0	2.8	0.0
June	6.1	0.0	0.1	0.0
July	16.3	0.0	-.0	0.0
Aug	15.0	0.0	0.0	0.0
Sept	5.5	0.0	1.7	0.0
Oct	0.2	0.5	11.7	0.0
Nov	0.0	4.0	24.6	0.9
Dec	0.0	9.4	29.1	4.8
Year	**44.1**	**38.7**	**165.6**	**18.5**

Source: HPRCC 2010 (Chadron NWS)

Table 3.6-3 Chadron NWS Mean and Maximum Precipitation Data (1894 to 2009)

Month	Water Equivalent		Snow Fall	
	Mean	Maximum 24-Hour	Mean	Maximum Monthly
	(cm)	(cm)	(cm)	(cm)
Jan	1.2	6.8	16.8	88.1
Feb	1.2	6.2	16.3	59.7
Mar	2.4	8.2	22.6	88.1
Apr	4.9	13.9	15.2	84.8
May	7.3	17.3	2.0	23.6
June	7.1	26.4	0.0	3.0
July	5.3	14.0	00	0.0
Aug	3.5	13.0	0.0	0.0
Sept	3.6	14.8	0.8	25.4
Oct	2.7	9.2	6.4	58.4
Nov	1.4	9.4	14.0	65.8
Dec	1.2	4.8	17.0	61.1
Year	**41.9**	**67.2**	**111.3**	**206.5**

Source: HPRCC 2010 (Chadron NWS)

Table 3.6-4 Whitney WHN5 Sea Level Pressure and Relative Humidity Measurements (2002 to 2009)

Year	Temperature °C			Relative Humidity (Percent)			Sea Level Pressure (mb)		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
2002	-18.2	--	32.4	16.3	55.6	95.3	946.3	1015.7	1036.3
2003	-15.6	--	39.2	13.5	58.8	98.5	997.3	1015.4	1030.0
2004	-19.3	--	29.2	20.3	59.9	94.6	1001.3	1016.1	1031.8
2005	-20.1	--	32.9	18.6	58.8	94.0	998.5	1015.6	1030.1
2006	-25.8	--	34.9	14.6	55.5	94.6	998.2	1015.6	1032.4
2007	-18.7	--	31.8	20.5	54.2	95.1	995.5	1015.5	1030.6
2008	-22.8	--	35.0	19.5	60.1	95.3	994.9	1015.0	1034.8
2009	-26.7	--	37.8	11.4	63.7	97.7	985.1	1015.8	1044.7

Source: WHN5 2010
mb = millibar
RH (Percent) = percent of saturation humidity.

Table 3.6-5 Frequency of Winds by Direction and Speed (Stability Class A)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.98	8.63	2.62	0.11	0.00	0.00	12.34	4.90
NNE	2.61	8.74	2.95	0.11	0.00	0.00	14.31	4.60
NE	1.64	8.52	1.31	0.00	0.00	0.00	11.47	4.50
ENE	0.66	4.37	0.55	0.00	0.00	0.00	5.58	4.40
E	1.20	1.97	0.77	0.00	0.00	0.00	3.94	4.40
ESE	0.33	0.87	0.22	0.00	0.00	0.00	1.42	4.00
SE	0.98	1.75	1.64	0.00	0.00	0.00	4.37	5.10
SSE	0.44	2.61	1.64	0.11	0.00	0.00	4.70	5.30
S	0.98	3.72	1.53	0.00	0.00	0.00	6.23	5.00
SSW	0.55	1.97	2.08	0.22	0.00	0.00	4.82	6.00
SW	0.77	3.72	1.53	0.00	0.00	0.00	6.02	5.00
WSW	0.66	2.08	1.53	0.00	0.00	0.00	4.27	5.30
W	0.66	1.75	1.75	0.11	0.00	0.00	4.27	5.50
WNW	0.77	1.42	0.98	0.44	0.00	0.00	3.61	5.70
NW	0.66	2.30	1.53	0.11	0.00	0.00	4.60	5.50
NNW	1.53	3.93	1.86	0.44	0.00	0.00	7.76	5.30
ALL	15.32	58.25	24.49	1.65	0.00	0.00	99.71	5.00

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.3%
Period mean wind speed = 5.0 knots
Percent occurrence for A stability class = 5.6%

Table 3.6-6 Frequency of Winds by Direction And Speed (Stability Class B)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	1.01	2.68	5.53	0.67	0.00	0.00	9.89	6.40
NNE	1.34	3.52	3.77	0.34	0.00	0.00	8.97	5.70
NE	0.92	5.28	5.45	0.50	0.00	0.00	12.15	6.00
ENE	0.84	1.76	2.85	0.25	0.00	0.00	5.70	6.00
E	0.17	0.84	0.75	0.08	0.00	0.00	1.84	6.00
ESE	0.59	0.59	1.09	0.00	0.00	0.00	2.27	5.80
SE	0.08	1.26	2.26	0.25	0.00	0.00	3.85	6.90
SSE	0.67	1.17	2.43	0.50	0.00	0.00	4.77	6.50
S	1.09	1.01	4.02	0.92	0.00	0.00	7.04	7.00
SSW	1.01	2.01	2.26	0.75	0.00	0.00	6.03	6.30
SW	0.92	3.19	2.61	0.59	0.00	0.00	7.21	6.10
WSW	0.59	2.01	2.60	0.84	0.08	0.00	6.12	6.90
W	0.42	1.34	2.35	0.42	0.08	0.00	4.61	7.20
WNW	0.67	1.09	2.10	0.34	0.00	0.00	4.20	6.60
NW	0.25	1.09	4.02	1.09	0.08	0.00	6.53	7.80
NNW	0.42	1.51	4.95	1.68	0.08	0.00	8.64	7.80
ALL	10.99	30.35	48.94	9.22	0.32	0.00	99.82	6.60

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.2%
Period mean wind speed = 6.5 knots
Percent occurrence for B stability class = 7.4%

Table 3.6-7 Frequency of Winds by Direction and Speed (Stability Class C)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.74	1.54	2.68	0.74	0.00	0.00	5.70	6.70
NNE	0.63	2.62	2.90	0.85	0.00	0.00	7.00	6.60
NE	0.91	2.28	5.69	1.20	0.00	0.00	10.08	7.00
ENE	0.46	1.03	2.96	0.97	0.00	0.00	5.42	7.30
E	0.00	0.57	0.74	0.28	0.00	0.00	1.59	7.60
ESE	0.23	0.34	0.91	0.23	0.00	0.00	1.71	7.00
SE	0.17	0.68	1.82	0.74	0.00	0.00	3.41	7.70
SSE	0.46	0.74	2.22	1.48	0.00	0.00	4.90	8.00
S	0.97	1.65	5.30	2.28	0.00	0.00	10.20	7.70
SSW	1.14	3.02	3.93	0.97	0.00	0.00	9.06	6.60
SW	1.03	3.36	4.67	1.14	0.11	0.00	10.31	6.80
WSW	0.97	3.02	3.59	1.14	0.06	0.06	8.84	6.80
W	0.11	0.91	1.99	1.03	0.11	0.00	4.15	8.40
WNW	0.17	0.51	1.03	1.25	0.06	0.00	3.02	9.10
NW	0.40	0.74	3:70	2.22	0.06	0.00	7.12	8.70
NNW	0.40	1.42	3.42	2.11	0.00	0.00	7.35	8.20
ALL	8.79	24.43	47.55	18.63	0.40	0.06	99.86	7.40

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.2%
Period mean wind speed = 7.4 knots
Percent occurrence for C stability class = 10.8%

Table 3.6-8 Frequency of Winds by Direction And Speed (Stability Class D)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.17	0.52	1.14	0.83	0.20	0.02	2.88	9.20
NNE	0.16	1.12	2.34	2.90	0.89	0.19	7.60	10.70
NE	0.13	1.53	2.65	2.72	0.46	0.08	7.47	9.80
ENE	0.04	0.47	0.79	0.50	0.06	0.00	1.86	8.30
E	0.02	0.06	0.28	0.22	0.04	0.00	0.62	9.50
ESE	0.01	0.25	0.35	0.13	0.00	0.00	0.74	7.40
SE	0.06	0.42	0.71	0.52	0.18	0.01	1.90	9.50
SSE	0.13	1.78	1.50	2.60	1.21	0.34	7.56	11.10
S	0.34	1.67	3.58	7.77	3.57	0.58	17.51	12.40
SSW	0.22	1.37	3.82	3.60	0.76	0.12	9.89	10.00
SW	0.17	2.11	5.80	3.80	0.29	0.02	12.19	8.80
WSW	0.17	0.61	2.28	2.74	0.54	0.16	6.50	10.70
W	0.10	0.20	0.64	1.03	0.47	0.19	2.63	12.60
WNW	0.05	0.17	0.91	1.39	0.66	0.28	3.46	13.20
NW	0.05	0.31	1.60	5.13	2.68	1.55	11.32	15.00
NNW	0.04	0.49	1.80	2.34	0.90	0.20	5.77	11.90
ALL	1.86	13.08	30.09	38.22	12.91	3.74	99.90	11.20

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.1%
Period mean wind speed = 11.2 knots
Percent occurrence for D stability class = 51.3%

Table 3.6-9 Frequency Of Winds By Direction And Speed (Stability Class E)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.85	2.92	0.65	0.04	0.00	0.00	4.46	4.60
NNE	0.97	2.80	1.82	0.00	0.00	0.00	5.59	5.20
NE	0.97	3.32	1.90	0.08	0.00	0.00	6.27	5.10
ENE	0.45	1.26	0.73	0.00	0.00	0.00	2.44	5.10
E	0.16	0.73	0.20	0.00	0.00	0.00	1.09	4.70
ESE	0.28	0.65	0.45	0.00	0.00	0.00	1.38	4.80
SE	0.49	1.82	0.85	0.12	0.00	0.00	3.28	5.10
SSE	1.70	7.62	1.05	0.08	0.00	0.00	10.45	4.40
S	2.23	11.06	4.34	0.16	0.00	0.00	17.79	5.00
SSW	2.11	10.53	2.80	0.04	0.00	0.00	15.48	4.70
SW	1.78	8.18	5.67	0.12	0.04	0.00	15.79	5.50
WSW	1.05	2.88	2.47	0.04	0.00	0.00	6.44	5.40
W	0.65	0.97	0.36	0.04	0.00	0.00	2.02	4.30
WNW	0.36	0.97	0.81	0.00	0.00	0.00	2.14	5.50
NW	0.45	1.18	0.85	0.20	0.00	0.00	2.68	5.70
NNW	0.61	1.34	0.49	0.00	0.00	0.00	2.44	4.50
ALL	15.11	58.23	25.44	0.92	0.04	0.00	99.74	5.00

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.2%
Period mean wind speed = 5.0 knots
Percent occurrence for E stability class = 15.2%

Table 3.6-10 Frequency Of Winds By Direction And Speed (Stability Class F)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	3.30	1.65	0.00	0.00	0.00	0.00	4.95	2.80
NNE	1.65	1.33	0.00	0.00	0.00	0.00	2.98	3.00
NE	0.95	1.40	0.00	0.00	0.00	0.00	2.35	3.10
ENE	1.40	0.76	0.00	0.00	0.00	0.00	2.16	2.80
E	1.27	0.44	0.00	0.00	0.00	0.00	1.71	2.80
ESE	1.78	1.02	0.00	0.00	0.00	0.00	2.80	2.60
SE	1.72	1.78	0.00	0.00	0.00	0.00	3.50	3.00
SSE	3.75	4.76	0.00	0.00	0.00	0.00	8.51	3.10
S	7.50	12.07	0.00	0.00	0.00	0.00	19.57	3.30
SSW	7.24	13.15	0.00	0.00	0.00	0.00	20.39	3.30
SW	6.48	8.01	0.00	0.00	0.00	0.00	14.49	3.20
WSW	2.73	2.60	0.00	0.00	0.00	0.00	5.33	3.00
W	1.78	1.46	0.00	0.00	0.00	0.00	3.24	2.90
WNW	0.83	0.95	0.00	0.00	0.00	0.00	1.78	3.00
NW	1.33	1.21	0.00	0.00	0.00	0.00	2.64	3.00
NNW	1.33	0.51	0.00	0.00	0.00	0.00	1.84	2.60
ALL	45.04	53.10	0.00	0.00	0.00	0.00	98.14	3.10

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 1.8%
Period mean wind speed = 3.1 knots
Percent occurrence for F stability class = 9.7%

Table 3.6-11 Frequency of Winds by Direction and Speed (All Stability Classes)

Wind Direction	Speed Class Intervals (Knots)							
	1 – 3	3 – 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.75	1.72	1.53	0.57	0.10	0.01	4.68	6.50
NNE	0.70	2.16	2.24	1.61	0.46	0.10	7.27	8.20
NE	0.57	2.64	2.69	1.57	0.23	0.04	7.64	7.70
ENE	0.37	0.99	1.08	0.38	0.03	0.00	2.85	6.50
E	0.24	0.42	0.35	0.15	0.02	0.00	1.18	6.20
ESE	0.31	0.46	0.44	0.09	0.00	0.00	1.30	5.50
SE	0.35	0.93	0.95	0.38	0.09	0.01	2.71	7.00
SSE	0.81	2.84	1.44	1.55	0.62	0.17	7.43	8.20
S	1.48	4.17	3.45	4.33	1.83	0.30	15.56	9.30
SSW	1.36	4.17	3.09	2.03	0.39	0.06	11.10	7.20
SW	1.21	3.91	4.62	2.13	0.17	0.01	12.05	7.10
WSW	0.70	1.60	2.21	1.60	0.29	0.09	6.49	8.20
W	0.40	0.69	0.87	0.68	0.26	0.10	3.00	8.90
WNW	0.27	0.54	0.91	0.90	0.35	0.14	3.11	10.20
NW	0.32	0.75	1.73	2.99	1.39	0.79	7.97	12.80
NNW	0.40	0.99	1.84	1.58	0.47	0.10	5.38	9.50
ALL	10.24	28.88	29.44	22.64	6.70	1.92	99.72	8.40

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.3%
Period mean wind speed = 8.4 knots
Percent occurrence for A stability class = 100.0%

Table 3.6-12 CBR Onsite MET Station Joint Frequency Distribution

Stability Class A					
0.00056	0.00488	0.00148	0.00006	0.00000	0.00000
0.00142	0.00495	0.00167	0.00006	0.00000	0.00000
0.00093	0.00482	0.00074	0.00000	0.00000	0.00000
0.00037	0.00247	0.00031	0.00000	0.00000	0.00000
0.00068	0.00111	0.00043	0.00000	0.00000	0.00000
0.00019	0.00049	0.00012	0.00000	0.00000	0.00000
0.00056	0.00099	0.00093	0.00000	0.00000	0.00000
0.00025	0.00142	0.00093	0.00006	0.00000	0.00000
0.00056	0.00210	0.00087	0.00000	0.00000	0.00000
0.00031	0.00111	0.00117	0.00012	0.00000	0.00000
0.00043	0.00210	0.00087	0.00000	0.00000	0.00000
0.00037	0.00117	0.00087	0.00000	0.00000	0.00000
0.00037	0.00099	0.00099	0.00006	0.00000	0.00000
0.00043	0.00080	0.00056	0.00025	0.00000	0.00000
0.00037	0.00130	0.00087	0.00006	0.00000	0.00000
0.00087	0.00223	0.00105	0.00025	0.00000	0.00000
Stability Class B					
0.00074	0.00198	0.00408	0.00049	0.00000	0.00000
0.00099	0.00260	0.00278	0.00025	0.00000	0.00000
0.00068	0.00389	0.00402	0.00037	0.00000	0.00000
0.00062	0.00130	0.00210	0.00019	0.00000	0.00000
0.00012	0.00062	0.00056	0.00006	0.00000	0.00000
0.00043	0.00043	0.00080	0.00000	0.00000	0.00000
0.00006	0.00093	0.00167	0.00019	0.00000	0.00000
0.00049	0.00087	0.00179	0.00037	0.00000	0.00000
0.00080	0.00074	0.00297	0.00068	0.00000	0.00000
0.00074	0.00148	0.00167	0.00056	0.00000	0.00000
0.00068	0.00235	0.00185	0.00043	0.00000	0.00000
0.00043	0.00148	0.00192	0.00062	0.00006	0.00000
0.00031	0.00099	0.00173	0.00031	0.00006	0.00000
0.00049	0.00080	0.00155	0.00025	0.00000	0.00000
0.00019	0.00080	0.00297	0.00080	0.00006	0.00000
0.00031	0.00111	0.00365	0.00124	0.00006	0.00000
Stability Class C					
0.00080	0.00167	0.00291	0.00080	0.00080	0.00000
0.00068	0.00284	0.00315	0.00093	0.00093	0.00000
0.00099	0.00247	0.00618	0.00130	0.00130	0.00000
0.00049	0.00111	0.00321	0.00105	0.00105	0.00000
0.00000	0.00062	0.00080	0.00031	0.00031	0.00000
0.00025	0.00037	0.00099	0.00025	0.00025	0.00000
0.00019	0.00074	0.00198	0.00080	0.00080	0.00000
0.00049	0.00080	0.00241	0.00161	0.00161	0.00000
0.00105	0.00179	0.00575	0.00080	0.00000	0.00000
0.00124	0.00328	0.00427	0.00093	0.00000	0.00000
0.00111	0.00365	0.00507	0.00130	0.00012	0.00000
0.00105	0.00328	0.00389	0.00105	0.00006	0.00006
0.00012	0.00099	0.00216	0.00031	0.00012	0.00000
0.00019	0.00056	0.00111	0.00025	0.00006	0.00000

Table 3.6-12 CBR Onsite MET Station Joint Frequency Distribution

0.00043	0.00080	0.00402	0.00080	0.00006	0.00000
0.00043	0.00155	0.00371	0.00161	0.00000	0.00000
Stability Class D					
0.00087	0.00266	0.00587	0.00427	0.00105	0.00012
0.0008	0.00575	0.01205	0.0149	0.00457	0.00099
0.00068	0.00785	0.01311	0.01397	0.00235	0.00043
0.00019	0.00241	0.00408	0.0026	0.00031	0.00000
0.00012	0.00031	0.00142	0.00111	0.00019	0.00000
0.00006	0.0013	0.00179	0.00068	0.00000	0.00000
0.00031	0.00216	0.00365	0.00266	0.00093	0.00006
0.00068	0.00915	0.00773	0.01335	0.00624	0.00173
0.00173	0.00859	0.01842	0.04	0.01836	0.00297
0.00111	0.00705	0.01966	0.01854	0.00389	0.00062
0.00087	0.01088	0.02986	0.01953	0.00148	0.00012
0.00087	0.00315	0.01175	0.01409	0.00278	0.0008
0.00049	0.00105	0.00328	0.00532	0.00241	0.00099
0.00025	0.00087	0.0047	0.00717	0.0034	0.00142
0.00025	0.00161	0.00822	0.0264	0.01379	0.00797
0.00019	0.00253	0.00927	0.01205	0.00464	0.00105
Stability Class E					
0.00130	0.00445	0.00099	0.00006	0.00000	0.00000
0.00148	0.00427	0.00278	0.00000	0.00000	0.00000
0.00148	0.00507	0.00291	0.00012	0.00000	0.00000
0.00068	0.00192	0.00111	0.00000	0.00000	0.00000
0.00025	0.00111	0.00031	0.00000	0.00000	0.00000
0.00043	0.00099	0.00068	0.00000	0.00000	0.00000
0.00074	0.00278	0.00130	0.00019	0.00000	0.00000
0.00260	0.01162	0.00161	0.00012	0.00000	0.00000
0.00340	0.01688	0.00661	0.00025	0.00000	0.00000
0.00321	0.01607	0.00427	0.00006	0.00000	0.00000
0.00272	0.01249	0.00865	0.00019	0.00006	0.00000
0.00161	0.00439	0.00377	0.00006	0.00000	0.00000
0.00099	0.00148	0.00056	0.00006	0.00000	0.00000
0.00056	0.00148	0.00124	0.00000	0.00000	0.00000
0.00068	0.00179	0.00130	0.00031	0.00000	0.00000
0.00093	0.00204	0.00074	0.00000	0.00000	0.00000
Stability Class F					
0.00321	0.00161	0.00000	0.00000	0.00000	0.00000
0.00161	0.00130	0.00000	0.00000	0.00000	0.00000
0.00093	0.00136	0.00000	0.00000	0.00000	0.00000
0.00136	0.00074	0.00000	0.00000	0.00000	0.00000
0.00124	0.00043	0.00000	0.00000	0.00000	0.00000
0.00173	0.00099	0.00000	0.00000	0.00000	0.00000
0.00167	0.00173	0.00000	0.00000	0.00000	0.00000
0.00365	0.00464	0.00000	0.00000	0.00000	0.00000
0.00729	0.01175	0.00000	0.00000	0.00000	0.00000
0.00705	0.01280	0.00000	0.00000	0.00000	0.00000

Table 3.6-12 CBR Onsite MET Station Joint Frequency Distribution

0.00631	0.00779	0.00000	0.00000	0.00000	0.00000
0.00266	0.00253	0.00000	0.00000	0.00000	0.00000
0.00173	0.00142	0.00000	0.00000	0.00000	0.00000
0.00080	0.00093	0.00000	0.00000	0.00000	0.00000
0.00130	0.00117	0.00000	0.00000	0.00000	0.00000
0.00130	0.00049	0.00000	0.00000	0.00000	0.00000

Table 3.6-13 Chadron NWS Wind Speed Frequency Distribution (April 1982 – May 1984)

Direction (Degrees)	Wind Speed (Knots)						
	1-4	4-7	7-11	11-17	17-21	>=22	Total
348.75 - 11.25	0.132	1.406	1.515	1.818	1.204	0.249	6.324
11.25 - 33.75	0.202	1.6	2.214	2.75	1.002	0.163	7.931
33.75 - 56.25	0.179	1.445	1.81	2.105	0.396	0.07	6.005
56.25 - 78.75	0.109	0.831	0.909	0.676	0.085	0.008	2.618
78.75 - 101.25	0.155	0.924	0.909	0.73	0.093	0.031	2.842
101.25 - 123.75	0.101	0.777	0.785	0.404	0.07	0.023	2.16
123.75 - 146.25	0.023	0.505	0.761	0.66	0.194	0.016	2.159
146.25 - 168.75	0.109	0.792	1.111	2.004	0.699	0.194	4.909
168.75 - 191.25	0.311	1.896	2.284	4.086	2.051	0.777	11.405
191.25 - 213.75	0.218	1.655	1.67	1.562	0.373	0.093	5.571
213.75 - 236.25	0.28	2.222	2.074	1.445	0.202	0.062	6.285
236.25 - 258.75	0.311	2.54	1.973	1.274	0.218	0.062	6.378
258.75 - 281.25	0.287	2.843	2.96	3.488	1.616	0.396	11.59
281.25 - 303.75	0.163	1.095	1.554	2.564	1.981	1.352	8.709
303.75 - 326.25	0.14	0.606	0.707	1.08	0.552	0.722	3.807
326.25 - 348.75	0.109	0.645	0.637	0.567	0.218	0.078	2.254
Total	2.829	21.782	23.873	27.213	10.954	4.296	90.947
						Calms	0
						Missing/Incomplete	0.1
						Total	1

Table 3.6-14 Chadron NWS Wind Speed Frequency Distribution (2000 - 2009)

Direction (Degrees)	Wind Speed (Knots)						
	1-4	4-7	7-11	11-17	17-21	>=22	Total
348.75 - 11.25	0.389	1.535	0.821	0.854	0.113	0.091	3.802
11.25 - 33.75	0.315	1.964	1.399	1.983	0.301	0.109	6.07
33.75 - 56.25	0.303	2.174	1.807	1.851	0.163	0.032	6.33
56.25 - 78.75	0.25	1.5	0.938	0.553	0.035	0.005	3.281
78.75 - 101.25	0.25	1.446	0.723	0.344	0.032	0.005	2.801
101.25 - 123.75	0.175	0.81	0.374	0.296	0.027	0.008	1.69
123.75 - 146.25	0.23	1.041	0.554	0.465	0.054	0.032	2.376
146.25 - 168.75	0.26	1.1	0.933	1.432	0.367	0.266	4.359
168.75 - 191.25	0.442	1.802	1.546	3.035	1.021	0.663	8.51
191.25 - 213.75	0.52	1.7	0.928	1.048	0.118	0.032	4.346
213.75 - 236.25	0.885	3.662	1.293	0.774	0.036	0.012	6.661
236.25 - 258.75	1.048	6.801	2.689	1.029	0.116	0.045	11.729
258.75 - 281.25	0.992	4.804	2.2	2.348	0.37	0.183	10.897
281.25 - 303.75	0.291	1.16	1.217	3.351	1.041	0.625	7.684
303.75 - 326.25	0.211	1.057	0.986	2.092	0.772	0.719	5.837
326.25 - 348.75	0.177	0.869	0.458	0.439	0.077	0.027	2.047
Total	6.738	33.425	18.866	21.894	4.643	2.854	88.42
						Calms	0.11
						Missing/Incomplete	0.05
						Total	1

Table 3.6-15 National Ambient Air Standards (NAAQS) Primary and Secondary Limits and State of South Dakota

Pollutant	National			State of Nebraska			State of South Dakota		
	Primary Standards	Averaging Standards	Secondary Standards	Primary Standards	Averaging Times	Secondary Standards	Primary Standards	Averaging Times	Secondary Standards
Particulate Matter (PM_{10})	Revoked[1]	Annual[1] (Arithmetic Mean)	Same as Primary	Revoked	Annual[1] (Arithmetic Mean)	Same as Primary	Revoked	Annual[1] (Arithmetic Mean)	Same as Primary
	150 ug/m^3	24-Hour[2]		150 ug/m^3	24-Hour[2]		150 ug/m^3	24-Hour[2]	
Particulate Matter ($PM_{2.5}$)	15.0 ug/m3	Annual[3] (Arithmetic Mean)	Same as Primary	15.0 ug/m^3	Annual[3] (Arithmetic Mean)	Same as Primary	15 ug/m^3	Annual[3] (Arithmetic Mean)	Same as Primary
	35 ug/m^3	24-Hour[4]	--	35 ug/m^3	24-Hour[4]	--	35 ug/m^3	24-Hour[4]	--
Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Mean)	--	0.03 ppm	Annual (Arithmetic Mean)	--	0.03 ppm	Annual[4] (Arithmetic Mean)	--
	0.14 ppm	24-Hour[5]	--	0.14 ppm	24-Hour[5]	--	0.14 ppm	24-Hour[5]	--
	--	3-Hour[5]	0.50 ppm (100 ug/m^3)	--	3-Hour[5]	0.50 ppm (1300 ug/m^3)	--	3-Hour[5]	0.50 ppm (1300 ug/m^3)
Nitrogen Dioxide	0.053 ppm (100 ug/m^3)	Annual (Arithmetic Mean)	Same as Primary	0.050 ppm (1300 ug/m^3)	Annual (Arithmetic Mean)	Same as Primary	0.053 ppm (100 ug/m^3)	Annual (Arithmetic Mean)	Same as Primary
Ozone	0.08 ppm	8-Hour[6]	Same as Primary	0.08 ppm	8-Hour[6]	Same as Primary	0.08 ppm	8-Hour[6]	Same as Primary
	0.12 ppm	1-Hour[7] (Limited Areas)	Same as Primary	0.12 ppm	1-Hour[7] (Limited Areas)	Same as Primary	--	--	--
Carbon Monoxide	9 ppm (10 mg/m^3)	8-Hour[5]	None	9 ppm (10 mg/m^3)	8-Hour[5]	None	9 ppm (10 mg/m^3)	8-Hour[5]	None
	35 ppm (40 mg/m^3)	1-Hour[5]	None	35 ppm (40 mg/m^3)	1-Hour[5]	None	35 ppm (40 mg/m^3)	1-Hour[5]	None
Lead	1.5 ug/m3	Quarterly Average	Same as Primary	1.5 ug/m3	Quarterly Average	Same as Primary	1.5 ug/m3	Quarterly Average	Same as Primary

[1]Annual PM_{10} standard evoked due to lack of evidence linking health problems to long-term exposure to coarse particle pollution.
[2]Not to be exceeded more than once per year on average over 3 years.
[3]To attain this standard, the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed 15.0 ug/m^3.
[4]To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 ug/m^3 (effective December 17, 2006).5[4] Not to be exceeded more than once per year. The 98th percentile value is higher than 98 percent of 24-hour values for the year.
[5]Not to be exceeded more than once per year.
[6]To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm .
[7]The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is <1.

Table 3.6-16 Nebraska and South Dakota Ambient Air Monitoring Network in Region of Three Crow Expansion Area

Site	Operating Agency	Location			Parameters Monitored	Monitoring Objective	Distance from TCEA
		State	County	Coordinates			
Wind Cave National Park	SD DENR	SD	Custer	43.557800 -103.483900	PM_{10} $PM_{2.5}$ SO_2 NO_2 Ozone	Background (Regional) Pollutant Transport	63 Miles
Badlands National Park	SD DENR	SD	Jackson	43.745610 -101.941218	PM_{10} $PM_{2.5}$ SO_2 NO_2 Ozone	PM2.5: Regional Others: Background (Regional) & Pollutant Transport	90 Miles
Black Hawk	SDDENR	SD	Meade	44.155636 -103.315765	PM_{10} Ozone	PM10: Population & Urban Background Ozone: Population & High Concentration	73 miles
Agate Fossil Beds	National Park Service	NE	Sioux	42.429300 -103.729400	Ozone	Background (regional)	16 miles
Scottsbluff	NDEQ	NE	Scotts Bluff	41.865000 -103.664444	$PM_{2.5}$	Background (Regional) Population	55 miles
Rapid City National Guard	SD DENR	SD	Pennington	44.083489 -103.269603	PM_{10}	Population High Concentration	96 miles

Sources: NDEQ 2009; SD DENR 2009

Note: Clarification of mining objectives:

- **Background Level** monitoring is used to determine general background levels of air pollutants. This can be applied to areas such as regions, neighborhoods, and urban areas.
- **High Concentration** monitoring is conducted at sites to find the highest concentration of an air pollutant in an area within a given monitoring network. A monitoring network may have multiple high concentration sites as a result of varying meteorology, source area variability, etc.
- **Population Exposure** monitoring is conducted to represent the air pollutant concentrations to which a populated area is exposed.
- **Pollutant Transport** is the movement of pollutant(s) between air basins or areas within an air basin. Pollutant transport monitoring is used to assess and address sources from upwind areas when those transported pollutant(s) affect neighboring downwind areas. Transport monitoring can also be used to determine the extent of regional pollutant transport.

Table 3.6-17 PM$_{10}$ Annual Average Monitoring Data for South Dakota Monitoring Sites

Year	Wind Cave		Badlands		Black Hawk		Rapid City (Natl. Guard)	
	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average
	ug/m^3							
1992	--	--	--	--	--	--	37	No Data
1993	--	--	--	--	--	--	34	No Data
1994	--	--	--	--	--	--	39	No Data
1995	--	--	--	--	--	--	33	No Data
1996	--	--	--	--	--	--	35	No Data
1997	--	--	--	--	--	--	41	No Date
1998	--	--	--	--	--	--	31	87
1999	--	--	--	--	--	--	28	117
2000	--	--	12	39	--	--	32	97
2001	--	--	12	48	21	70	35	82
2002	--	--	10	26	19	77	34	105
2003	--	--	16	74	21	77	36	92
2004	--	--	10	24	20	42	35	72
2005	7	32	9	40	15	52	27	94
2006	7	28	9	30	16	50	29	124
2007	10	44	12	50	18	42	32	93
2008	9	51	11	85	16	70	26	89

Standard of 150 ug/m^3 is not to be exceeded more than once per year on average over 3 years.
Source: USEPA 2010a; SD DENR 2009.

Table 3.6-18 Comparison Of Ambient Particulate Matter (PM_{10}) Monitoring Data For Regional Monitoring Sites

Site	2006	2007	2008	3-Year Average	Attainment with NAAQS[2]
			ug/m^3		
PM_{10} Annual Averages for Monitoring Sites					
Wind Cave, SD	7	7	10	9	[1]
Bad Lands, SD	9	9	12	11	[1]
Black Hawk	15	16	18	16	[1]
Rapid City, SD. (Natl. Guard)	27	29	32	28	[1]
Second Highest 24-Hour Concentration					
Wind Cave, SD	26	43	47	39	Yes
Bad Lands, SD	30	40	56	42	Yes
Black Hawk	47	42	36	42	Yes
Rapid City, SD. (Natl. Guard)	91	89	84	88	Yes

[1] Annual PM_{10} standard was revoked by the USEPA in 2006 and later removed by the states of Nebraska and South Dakota.
[2] Standard of 150 ug/m^3 is not to be exceeded more than once per year on average over 3 years.

Table 3.6-19 $PM_{2.5}$ Annual Average Monitoring Data for Regional Monitoring Sites

Year	Wind Cave		Badlands		Black Hawk		Rapid City (Natl. Guard)		Scottsbluff	
	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average
	ug/m³									
1998	--	--	--	--	--	--	--	--	--	--
1999	--	--	--	--	--	--	--	--	8.17	32.0
2000	--	--	5.38	13.9	--	--	7.94	29.5	6.31	21.8
2001	--	--	5.60	12.7	6.09	23.2	8.44	24.5	6.21	16.9
2002	--	--	5.15	15.1	6.29	35.5	7.73	26.7	5.69	19.8
2003	--	--	5.77	24.0	6.38	26.6	7.71	21.2	6.10	23.0
2004	--	--	5.25	13.5	6.29	24.4	8.09	13.6	5.69	15.4
2005	5.39	16.2	5.35	15.4	--	--	--	--	5.28	20.1
2006	5.34	16.5	5.38	15.7	--	--	--	--	5.76	27.3
2007	6.21	22.4	5.49	18.7	--	--	--	--	7.10	19.8
2008	5.55	41.6	5.80	51.2	--	--	--	--	7.17	31.1

Source: NDEQ 2009; SD DENR 2009; USEPA 2010a and b

1 To determine attainment status, the 3-year average of the annual 98th percentile value is compared to the 35 ug/m³ NAAQS. The 98th percentile value is higher than 98 percent of 24-hour values for the year.

2 To determine attainment status, the 3-year average of the annual averages is compared to the 15 ug/m³ NAAQS.

Table 3.6-20 Comparison of Ambient Particulate Matter ($PM_{2.5}$) Monitoring Data for Regional Monitoring Sites

Site	2006	2007	2008	3-Year Average	Attainment with NAAQS
	ug/m³				
Comparison of 98th Percentile, 24-Hour Concentrations for $PM_{2.5}$ to NAAQS[1]					
Wind Cave, SD	12.2	17.5	10.8	14.0	Yes
Bad Lands, SD	12.2	12.4	12.8	13.0	Yes
Scottsbluff, NE	19.0	17.7	19.3	19.8	Yes
Rapid City, SD. (Natl. Guard)	--	--	--	--	--
Comparison of 3-Year Annual Averages for $PM_{2.5}$ to NAAQS[2]					
Wind Cave, SD	5.3	6.2	4.9	5.5	Yes
Bad Lands, SD	5.3	5.5	5.2	5.3	Yes
Scottsbluff, NE	5.76	7.10	6.77	6.68	Yes
Rapid City, SD (Natl. Guard_	--	--	--	--	--

[1] To determine attainment status, the 3-year average of the annual 98th percentile value is compared to the 35 ug/m³ NAAQS. The 98th percentile value is higher than 98 percent of 24-hour values for the year.
[2] To determine attainment status, the 3-year average of the annual averages is compared to the 15 ug/m³ NAAQS.

Table 3.6-21 Comparison of Sulfur Dioxide Values for Wind Cave and Badlands Monitor Sites

Monitor Site	SO_2 Annual Average Concentration (2008)	SO_2 24-Hr 2nd Maximum Concentration (2008)	SO_2 3-Hr Average 2nd Maximum Concentration (2008)
Wind Cave	0.001	0.001	0.002
Badlands	0.002	0.005	0.006

SD DENR Standards: 0.5 ppm (3-hour average), 0.14 ppm (24-hour average), 0.030 ppm (annual mean)
Note: The 3 –year averages shown above are used to evaluate compliance with the sulfur dioxide standard.

Table 3.6-22 Comparison of Nitrogen Dioxide Annual Average Values for Wind Cave and Badlands Monitor Sites

Monitoring Site	2005	2006	2007	2008
	ppm			
Wind Cave	0.001	0.001	0.001	0.001
Badlands	0.001	0.001	0.001	0.001

SD DENR Standards: Nitrogen Dioxide: 0.053 ppm (annual mean)

Table 3.6-23 Ozone Yearly 4th Highest 8-Hour Averages for Regional Monitoring Sites [1,2]

Location	2003	2004	2005	2006	2007	2008	3-Year Average (2006-2008)	Percent NAAQS
	ppm							
Wind Cave, SD	No Data	No Data	0.070	0.073	0.069	0.059	0.067	89%
Bad Lands, SD	0.067	0.063	0.069	0.071	0.064	0.053	0.063	84%
Black Hawk	No Data	No Data	No Data	No Data	0.053	0.060	0.056[6]	75%
Agate Fossil Beds[1,2]	No Data	No Data	No Data	No Data	0.066	0.067	0.0665[3,4]	88%[5]

[1] The design value is the 3-year average of the 4th highest maximum for each year. The 4th highest 8-hour average are used to evaluated compliance with the ozone standard.

[2] NAAQS = 0.075 ppm (8-hour average). Standard promulgated 3/27/2008.

[3] The ozone monitor at the Agate Fossil beds was operated by the National park Service. It operated from mid-July 2007 through September 2008 with some down-time in July and August 2008. Approximately one year of data was collected from the site over the 2007 and 2008 monitoring period. The 4th highest maximum value over the 2007 through 2008 time frame was 0.069 ppm. The highest value was 0.072 ppm.

[4] The monitoring method used was not a Federal Reference or Equivalent Method (FRM/FEM). This, it cannot be used to evaluate attainment with the NAAQS. Method comparison work conducted by the National Park Service indicates the results should compare closely to FRM/FEM results.

[5] The two-year average of the 4th highest maximums was 0.0665 ppm or 88% of the 3-year average NAAQS.

[6] The two-year average of the 4th highest maximums was 0.056 ppm or 75% of the 3-year average NAAQS.

Table 3.6-24 Prevention of Significant Deterioration (PSD) of Air Quality Allowable Increments

Pollutant	Averaging Time	PSD Increment ug/m_3	
		Class I	Class II
Particulate Matter (PM_{10})	24-Hour Maximum	8	30
	Annual Arithmetic Mean	4	17
Sulfur Dioxide (SO^2)	24-Hour Maximum	5	91
	3-Hour Maximum	25	512
	Annual Arithmetic Mean	2	20
Nitrogen Dioxide (NO^2)	Annual Arithmetic Mean	2.5	25

Table 3.9-1 Scenic Quality Inventory and Evaluation for the Three Crow Expansion Area

Key Factor	Rating Criteria	Score
Landform	Flat to rolling terrain with no interesting landscape features	1
Vegetation	Some variety of vegetation; cropland, range, riparian	3
Water	Water is present, but not evident as viewed from residences and roads	0
Color	Some variety in colors and contrasts with vegetation and soil.	3
Influence of adjacent scenery	Buttes of Fort Robinson State Park provide a scenic backdrop	5
Scarcity	Landscape is common for the region	1
Cultural modifications	Existing modifications are agricultural, and introduce no discordant elements.	0
	Total Score	13

Table 3.9-2 Determining BLM Visual Resource Inventory Classes

Visual Sensitivity		High			Medium			Low
Special Areas		I	I	I	I	I	I	I
Scenic Quality	A	II	II	II	II	II	II	II
	B	II	III	III/IV	III	IV	IV	IV
	C	III	IV	IV	IV	IV	IV	IV
Distance Zones		f/m	b	ss	f/m	b	ss	ss

f/m = foreground-middleground
b = background
ss – seldom seen

Table 3.10-1 Historical and Current Population Change for Counties and Cities within 80 Km of the Three Crow Expansion Area Site 1970-2008

State County City	Population					Average Annual Percent Change			
	1970	1980	1990	2000	2008	1970/ 1980	1980/ 1990	1990/ 2000	2000/ 2008
NEBRASKA									
Dawes	9,761	9,609	9,021	9,060	8,728	-1.6%	-6.1%	0.4%	-3.7%
Chadron	5,921	5,933	5,588	5,634	5,429	0.2%	-5.8%	0.8%	-3.6%
Crawford	1,291	1,315	1,115	1,107	1,028	1.9%	-15.2%	-0.7%	-7.1%
Whitney	82	72	38	87	87	-12.2%	-47.2%	128.9%	0.0%
Box Butte	10,094	13,696	13,130	12,158	11,043	35.7%	-4.1%	-7.4%	-9.2%
Alliance	6,862	9,869	9,765	8,959	8,109	43.8%	-1.1%	-8.3%	-9.5%
Hemingford	734	1,023	953	993	882	39.4%	-6.8%	4.2%	-11.2%
Morrill County	5,813	6,085	5,423	5,440	4,989,	4.7%	-10.9%	0.3%	-8.3%
Scotts Bluff County	36,432	38,344	36,025	36,951	36,554	5.2%	-6.0%	2.6%	-1.1%
Scottsbluff	14,507	14,156	13,711	14,732	14,785	-2.4%	-3.1%	7.4%	0.4%
Sheridan	7,285	7,544	6,750	6,198	5,337	3.6%	-10.5%	-8.2%	-13.9%
Hay Springs	682	794	693	652	549	16.4%	-12.7%	-5.9%	-15.8%
Rushville	1,137	1,217	1,127	999	849	7.0%	-7.4%	-11.4%	-15.0%
Sioux	2,034	1,845	1,549	1,475	1,187	-9.3%	-16.0%	-4.8%	-12.7%
Harrison	377	361	241	279	242	-4.2%	-33.2%	15.8%	-13.3%
SOUTH DAKOTA									
Fall River	7,505	8,439	7,353	7,453	7,145	12.4%	-12.9%	1.4%	-4.1%
Hot Springs	4,434	4,742	4,325	4,129	4,028	6.9%	-8.8%	-4.5%	-2.4%
Oelrichs	94	124	138	145	139	31.9%	11.3%	5.1%	-4.1%
Ardmore[1]	14	16	NA	NA	NA	14.3%			
Shannon	8,198	11,323	9,902	12,466	13,637	38.1%	-12.5%	25.9%	9.4%
WYOMING									
Goshen	10,885	12,040	12,373	12,538	12,072	10.6%	2.8%	1.3%	-3.7%

Table 3.10-1 Historical and Current Population Change for Counties and Cities within 80 Km of the Three Crow Expansion Area Site 1970-2008

State County City	Population					Average Annual Percent Change			
	1970	1980	1990	2000	2008	1970/ 1980	1980/ 1990	1990/ 2000	2000/ 2008
Niobrara	2,924	2,924	2,499	2,407	2,428	0.0%	-14.5%	-3.7%	0.9%
Van Tassell	21	10	8	19	NA	-52.4%	-20.0%	125.0%	NA

1 – 1980 was the last year that Ardmore had a recorded population.
Sources: U.S. Bureau of the Census 2003a, 2003b, 2003c, 2009b

Table 3.10-2 Population by Age and Sex for Counties within the 80-Km Radius of the Three Crow Expansion Area 2008

County	Age	Male	Female	Total	Total Percent Breakdown
		Nebraska			
Box Butte	Under 18	1,386	1,299	2,685	24.3%
	18 - 64	3,462	3,298	6,760	61.2%
	65+	660	938	1,598	14.5%
	Total	5,508	5,535	11,043	100.0%
Dawes	Under 18	896	831	1,727	19.8%
	18 - 64	2,753	2,893	5,646	64.7%
	65+	583	768	1,351	15.5%
	Total	4,232	4,492	8,724	100.0%
Morrill	Under 18	563	542	1,105	22.1%
	18 – 64	1507	1432	2,939	58.9%
	65+	402	543	945	19.0%
	Total	2,472	2,517	4,989	100.0%
Scotts Bluff	Under 18	4547	4470	9,017	24.7%
	18 - 64	10,314	10,933	21,247	58.1%
	65+	2,576	3,714	6,290	17.2%
	Total	17,437	19,117	36,554	100.0%
Sheridan	Under 18	624	561	1,185	22.2%
	18 - 64	1,499	1,452	2,951	55.3%
	65+	509	692	1,201	22.5%
	Total	2,632	2,705	5,337	100.0%
Sioux	Under 18	136	104	240	18.6%
	18 - 64	446	409	855	66.4%
	65+	95	97	192	14.9%
	Total	677	610	1,287	100.0%
		South Dakota			
Fall River	Under 18	766	605	1,371	19.2%
	18 – 64	2,021	1,994	4,015	56.2%
	65+	861	898	1,759	24.6%
	Total	3,648	3,497	7,145	100.0%
Shannon	Under 18	2,808	2,824	5,632	41.3%
	18 – 64	3,572	3,751	7,323	53.7%
	65+	293	389	682	5.0%
	Total	6,673	6,964	13,637	100.0%
		Wyoming			
Goshen	Under 18	1,367	1,218	2,585	21.4%
	18 – 64	3,724	3,528	7,252	60.1%
	65+	1,002	1,233	2,235	18.5%
	Total	6,093	5,979	12,072	100.0%
Niobrara	Under 18	220	205	425	17.5%

Table 3.10-2 Population by Age and Sex for Counties within the 80-Km Radius of the Three Crow Expansion Area 2008

County	Age	Male	Female	Total	Total Percent Breakdown
	18 - 64	707	804	1,511	62.2%
	65+	223	269	492	20.3%
	Total	1,150	1,278	2,428	100.0%

Source: U.S. Bureau of the Census, 2009a

Table 3.10-3 Population Projections for Counties within an 80-Km Radius of the Current Crow Butte Project Area 2000-2020

County	Census 2000	Projected 2005	Projected 2010	Projected 2015	Projected 2020
Box Butte	12,158	11,374	11,023	10,319	9,588
Dawes	9,060	8,636	8,701	8,736	8,646
Morrill	5,423	5,165	5,084	4,993	4,886
Scotts Bluff	36,025	36,752	36,429	36,055	35,627
Sheridan	6,198	5,668	5,492	5,362	5,261
Sioux	1,475	1,458	1,407	1,344	1,271
Fall River	7,453	N/A	N/A	N/A	N/A
Shannon	12,466	N/A	N/A	N/A	N/A
Goshen	12,538	12,083	12,050	11,980	11,820
Niobrara	2,407	2,228	2,310	2,340	2,330

N/A No projection available

Sources: University of Nebraska-Lincoln, Bureau of Business Research 2009.
Wyoming Department of Administration and Information 2010.

Table 3.10-4 2004 Population Within An 80-Km (50-Mile) Radius Of The TCEA[a]

	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	Total
N	0	0	0	1	1	525	37	58	73	107	137	162	183	1,284
NNE	0	0	0	1	1	327	44	63	88	113	137	169	289	1,232
NE	0	0	0	1	1	7	33	60	249	233	134	133	682	1,533
ENE	0	0	0	1	1	7	29	48	679	5100	138	159	437	6,599
E	0	0	0	1	1	7	29	48	70	103	282	733	247	1,521
ESE	0	0	0	1	1	7	29	48	68	114	187	128	63	646
SE	0	0	0	1	1	7	29	58	161	242	262	471	8230	9,462
SSE	0	0	0	1	1	7	29	111	188	211	158	185	640	1,531
S	0	0	0	1	1	7	29	88	128	136	133	193	875	1,591
SSW	0	0	0	1	1	6	15	21	29	62	97	115	1083	1,430
SW	0	0	0	1	1	3	13	21	29	41	69	103	315	596
WSW	0	0	0	0	0	3	13	21	29	38	58	85	98	345
W	0	0	0	0	0	3	13	21	29	38	52	62	72	290
WNW	0	0	0	0	0	3	13	21	29	38	33	32	37	206
NW	0	0	0	1	1	3	13	21	29	38	60	89	66	321
NNW	0	0	0	1	11	270	17	21	29	65	133	153	168	868
Total	0	0	0	13	23	1,192	385	792	1,907	6,679	2,070	2,972	13,485	29,455

Notes:

[a] Current population living between 10 and 80 km of the mine site were estimated using 2000 census data. Field reconnaissance was conducted in 2004 to verify data collected within 2.25 miles (3.6 km). See Section 2.3.1 for a detailed description of the methodology.

Table 3.10-5 Annual Average Labor Force and Employment Economic Sectors For Dawes and Box Butte Counties 1994 And 2009

Sectors	Dawes		Box Butte	
	1994	2009	1994	2009
Labor Force	4,490	4,788	6,156	5,821
Unemployment	149	210	235	397
Unemployment Rate	3.3	4.4	3.8	6.8
Employment	4,341	4,578	5,921	5,424
Farm Employment	862	877	763	213
Non-Farm Employment Total	3,479	3,701	5,446	5,315
Manufacturing	165	13	402	N/A
Construction and Mining	136	228	80	126
Transportation, Communication, and Utilities	N/A	N/A	1,909	2,305
Retail	824	673	840	429
Wholesale	128	87	265	298
Financial, Insurance, and Real Estate	77	123	215	168
Information	N/A	46	N/A	103
Professional and Business Services	N/A	N/A	N/A	170
Education and Health Services	N/A	449	N/A	428
Leisure and Hospitality	N/A	507	N/A	433
Other Services	N/A	119	N/A	145
Government	1,384	1,000	955	1,095
Federal	144	124	65	61
State	721	297	67	75
Local	519	579	824	960

N/A = not available
Sources: NDOL 2010

Table 3.10-6 Race and Poverty Level Characteristics of the Population in the State of Nebraska, Dawes County, and Block Groups Within the TCEA 2000

Population	Nebraska	Percent of Nebraska Pop.	Dawes County	Percent of Dawes County Pop.	Block Group 3, Census Tract 9506, Dawes County						Block Group 1, Census Tract 9501, Sioux County			
					Block 3145	Percent of Block 3145	Block 3148	Percent of Block 3148	Block 3149	Percent of Block 3149	Block 1200	Percent of Block 1200	Block 1360	Percent of Block 1360
Total Population	1,711,263	100.0%	9,060	100.0%	16	100.0%	0	0	2	100.0%	5	100.0%	0	0
White alone	1,533,261	89.6%	8,457	93.3%	16	100.0%	0	0	2	100.0%	5	100.0%	0	0
Black or African American	68,541	4.0%	73	0.8%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
American Indian and Alaska Native	14,896	0.9%	261	2.9%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
Asian alone	21,931	1.3%	28	0.3%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
Native Hawaiian and Other Pacific Islander	836	0.0%	5	0.1%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
Some other race	47,845	2.8%	93	1.0%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
Two or more races	23,953	1.4%	143	1.6%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
Hispanic or Latino	94,425	5.5%	220	2.4%										
Percent below poverty level:	9.40%	-	17.10%	-	8.3%*	-	8.3%*	-	8.3%*	-	17.2%*	-	17.2%*	-

* - data for Block Group only
Source: USCB 2000a, 2000b, 2001

Table 3.11-1 Crow Butte Resources Excursion Summary

Monitor Well ID	Date On Excursion	Date Off Excursion	Causal Factor(s)
SM4-5	January 25, 1995	March 9, 1995	Poor Well Development
SM4-2	April 2, 1995	March 13, 1996	Poor Well Development
SM4-7	December 27, 1995	March 13, 1996	Poor Well Development
I-196	March 29, 1996	August 19, 1999	Casing Leak
I-752	November 8, 1996	May 7, 1997	Casing Leak
SM6-26	March 19, 1998	No record available	High Water Table
CM6-6	July 1, 1999	September 23, 1999	Excursion of mining solutions
I-567	September 20, 1999	October 12, 1999	Casing Leak
PR-15	January 13, 2000	March 23, 2000	Mine Unit 1 interior monitor well affected by adjacent groundwater restoration (unrelated to mining activities)
SM6-18	March 6, 2000	April 11, 2001	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
IJ-13	April 20, 2000	July 20, 2000	Mine Unit 1 interior monitor well affected by adjacent groundwater restoration (unrelated to mining activities)
SM7-23	April 27, 2000	January 13, 2004	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM6-28	May 25, 2000	June 22, 2000	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM6-13	May 25, 2000	July 20, 2000	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM6-12	September 8, 2000	November 2, 2000	Surface leak
SM6-13	March 1, 2001	April 12, 2001	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM7-23	December 4, 2001	January 9, 2004	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
CM5-11	September 10, 2002	June 3, 2003	Excursion of mining solutions
CM6-7	April 4, 2002	April 25, 2002	Excursion of mining solutions
PR-8	December 23, 2003	Ongoing	Mine Unit 1 interior monitor well affected by adjacent groundwater restoration (unrelated to mining activities)
CM5-19	May 2, 2005	July 26, 2005	Excursion of mining solutions
SM6-28	June 16, 2005	July 5, 2005	High water table due to heavy spring rains (unrelated to mining activities)
SM6-12	June 27, 2005	July 26, 2005	High water table due to heavy spring rains (unrelated to mining activities)
CM9-16	August 4, 2005	November 8, 2005	Excursion of mining solutions
CM8-21	January 18, 2006	April 4, 2006	Excursion of mining solutions
PR-15	September 26, 2006	Ongoing	See IJ-13 and PR-8
CM9-5	May 15, 2008	June 24, 2008	Excursion of mining solutions

Table 3.11-1 Crow Butte Resources Excursion Summary

Monitor Well ID	Date On Excursion	Date Off Excursion	Causal Factor(s)
CM9-3	May 30, 2008	July 15, 2008	Excursion of mining solutions
SM6-20	April 27, 2009	August 25, 2009	Excursion of mining solutions
CM9-4	June 11, 2009	July 21, 2009	Excursion of mining solutions
SM6-20	March 16, 2010	Ongoing	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM8-6	April 13, 2010	Ongoing	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM6-23	June 3, 2010	Ongoing	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM6-28	June 3, 2010	Ongoing	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM8-28	June 3, 2010	Ongoing	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM6-21	June 22, 2010	Ongoing	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM8-5	June 22, 2010	Ongoing	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)

Table 3.12-1 Deep Disposal Well Injection Radiological Data for Current Crow Butte CPF (2008 and 2009)

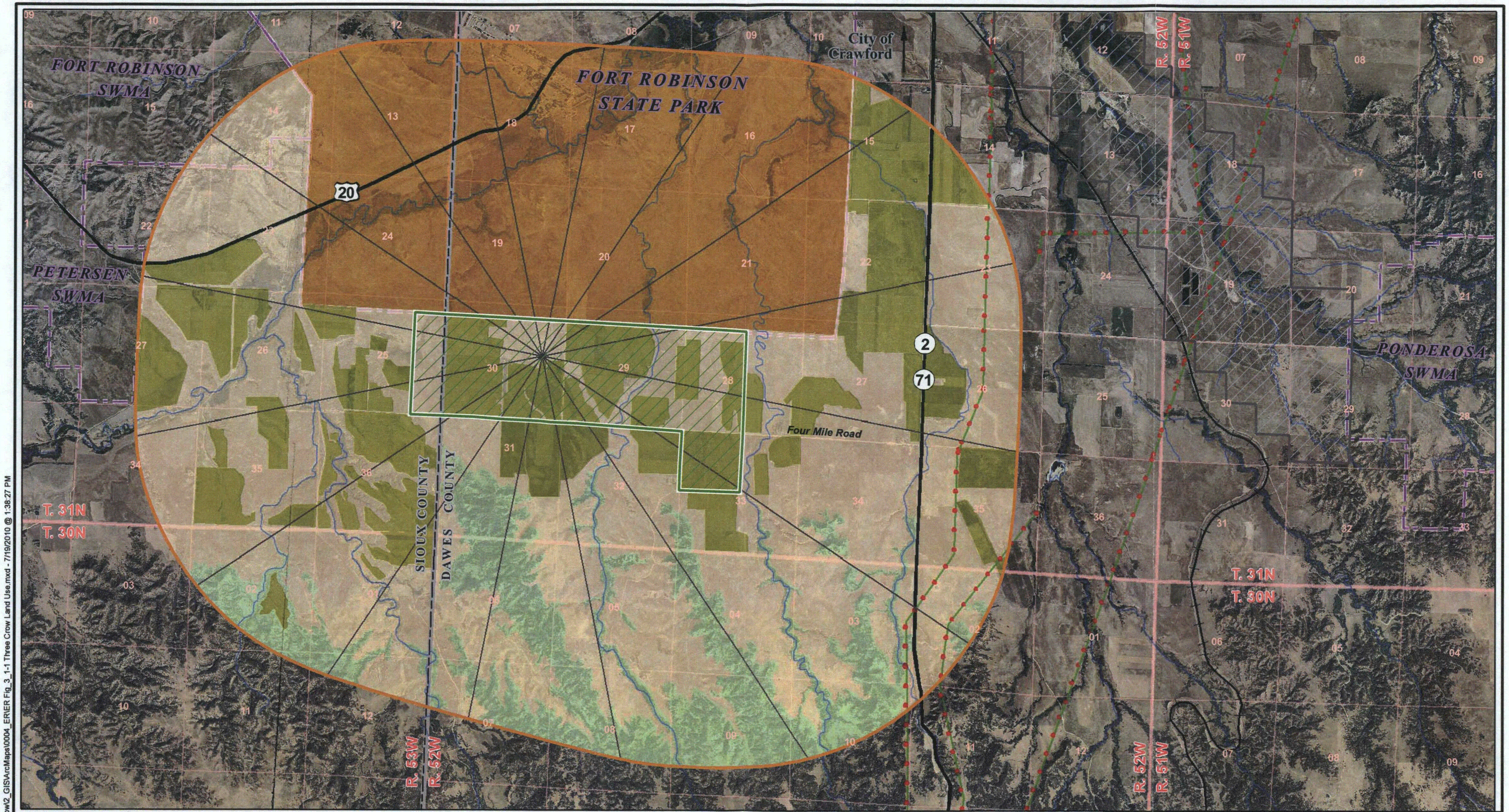
Month	Total Gallons Injected	Average Natural Uranium (mg/l)[a]	Total Natural Uranium Injected (mg)	Total Natural Uranium Injected (uCi)	Average Radium-226 (uCi/l)[a]	Total Radium-226 Injected (uCi/l)
January 2009	4,656,906	5	8.81E+07	5.97E+04	707	1.25E+04
February 2009	4,208,406	3	4.78E+07	3.24E+04	752	1.20E+04
March 2009	3,849,464	3	4.37E+07	2.96E+04	656	9.56E+03
April 2009	3,761,898	5	7.12E+07	4.82E+04	686	9.77E+03
May 2009	4,821,589	4	7.30E+07	4.94E+04	892	1.63E+04
June 2009	5,634,712	4	8.53E+07	5.78E+04	1,000	2.13E+04
Semi-Annual Totals	**26,932,975**	--	**4.09E+08**	**2.77E+05**	--	**8.14E+04**
July 2009	5,467,407	3	6.21E+07	4.20E+04	1,120	2.32E+04
August 2009	5,519,131	6	1.25E+08	8.49E+04	991	2.07E+04
September 2009	5,418,568	5	1.03E+08	6.94E+04	652	1.34E+04
October 2009	5,791,232	4	8.77E+07	5.94E+04	866	1.90E+04
November 2009	6,060,190	6	1.38E+08	9.32E+04	1,090	2.50E+04
December 2009	6,730,245	7	1.78E+08	1.21E+05	1,250	3.18E+04
Semi-Annual Totals	**34,986,773**	--	**6.94E+08**	**4.70E+05**	--	**1.33E+05**
January 2008	5,132,667	3	5.83E+07	3.95E+04	669	1.30E+04
February 2008	3,388,598	4	5.13E+07	3.47E+04	751	9.63E+03
March 2008	2,565,135	5	4.85E+07	3.29E+04	795	7.72E+03
April 2008	3,724,924	3	4.23E+07	2.86E+04	818	1.15E+04
May 2008	3,650,359	4	5.53E+07	3.74E+04	818	1.13E+04
June 2008	3,946,776	3	4.48E+07	3.03E+04	739	1.10E+04
Semi-Annual Totals	**22,408,459**	--	**3.01E+08**	**2.03E+05**	--	**6.42 E+04**
July 2008	4,051,240	4	6.13E+07	4.15E+04	698	1.07E+04
August 2008	4,664,934	5	8.83E+07	5.98E+04	775	1.37E+04
September 2008	4,823,374	6	1.10E+08	7.42E+04	753	1.37E+04
October 2008	5,202,468	5	9,85E+07	6.67E+04	693	1.36E+04
November 2008	4,823,009	4	7.30E+07	4.94E+04	763	1.39E+04
December 2008	4,553,541	6	1.03E+08	7.00E+04	741	1.28E+04
Semi-Annual Totals	**28,118,566**	--	**5.34E+08**	**3.62E+05**	--	**7.85E+04**

[a] Maximum deep well injection limits: ra-226 – 5,000 uCi/l; U-Natural – 25 mg/l

Table 3.12-2 Deep Disposal Well Injection Non-Radiological Data for Current Crow Butte Operations 2009

Parameter	Annual Composite Results mg/l[a]		Maximum Injection Level	Laboratory
	Annual Average	Range		
Sodium	1794	11422 - 3382	40,000	Crow Butte Lab
Calcium	104	76 – 137	Report Only	Crow Butte Lab
Sulfate	1092	661 – 1530	10,000	Crow Butte Lab
Chloride	3232[c]	505 – 30,490[c]	40,000	Crow Butte Lab
Vanadium	2.83	1.0 - 13.0	50	Crow Butte Lab
Alkalinity	1598	1150 – 1875	4,100	Crow Butte Lab
pH (std. units)	8.18	8.02 – 8.33	5.0-9.5	Crow Butte Lab
Arsenic	[b]	<0.1 – 0.037	5	Energy Lab
Barium	<0.01	<0.1 - <0.1	100	Energy Lab
Cadmium	<0.01	<0.1 - <0.1	1	Energy Lab
Chromium	<0.5	<0.5 - <0.05	5	Energy Lab
Lead	<0.5	<0.5 - <0.5	5	Energy Lab
Mercury	<0.0001	<0.0001 - <0.0001	0.2	Energy Lab
Selenium	[b]	<0.1 – 0.037	1	Energy Lab
Silver	<0.5	<0.5 - <0.5	5	Energy Lab

[a] mg/l unless noted otherwise.
[b] Eleven results at <0.1 with one at 0.037.
[c] Maximum result for 11 samples was 1702, with the one highest at 30,490 (without latter reading average is 754)
Note: Reporting data based on 12 monthly samples (January – December, 2009)



LEGEND

- Proposed Three Crow Expansion Area (TCEA)
- 2.25-Mile Buffer of Proposed TCEA Boundary
- Current License Area
- State Park or State Wildlife Management Area (SWMA)
- Grid Sector
- River/Creek
- Transmission Line
- Highway
- County Boundary
- Railroad

Land Use

- Cropland
- Forested Land
- Rangeland
- Recreational Land

0 2,000 4,000

Scale in Feet

PROJECTION:
NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601

SOURCE:
AERIALS: NAIP 2006, DAWES COUNTY AND SIOUX COUNTY, NE
LAND USE: CROW BUTTE RESOURCES, INC.
STATE PARK & SWMA: USGS 1:100,000 TOPOGRAPHIC MAP - CRAWFORD (1986), NE

N W E

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FIGURE 3.1-1
THREE CROW EXPANSION AREA
LAND USE

PROJECT: CO001396.00002 | MAPPED BY: JC | CHECKED BY: JEC

ARCADIS

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LEGEND

- Occupied Dwelling
- Unoccupied Structure
- Proposed Three Crow Expansion Area (TCEA)
- 2.25-Mile Buffer of Proposed TCEA Boundary
- Proposed Three Crow Satellite Facility
- River/Creek
- Highway
- Railroad
- County Boundary
- Fort Robinson State Park

0 2,000 4,000
Scale in Feet

PROJECTION:
NAD_1927_STATEPLANE_
NEBRASKA_NORTH_FIPS_2601

SOURCE:
AERIALS: NAIP 2006, DAWES COUNTY AND SIOUX COUNTY, NE
RURAL RESIDENTIAL AND NON-RESIDENTIAL
STRUCTURES WERE DIGITIZED OFF AERIALS.

N W E

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FIGURE 3.1-2
AERIAL PHOTO DEPICTING LOCATION OF RURAL RESIDENCES AND OTHER LAND FEATURES IN THE AREA OF REVIEW

PROJECT: CO001396.00002 | MAPPED BY: JC | CHECKED BY: JEC

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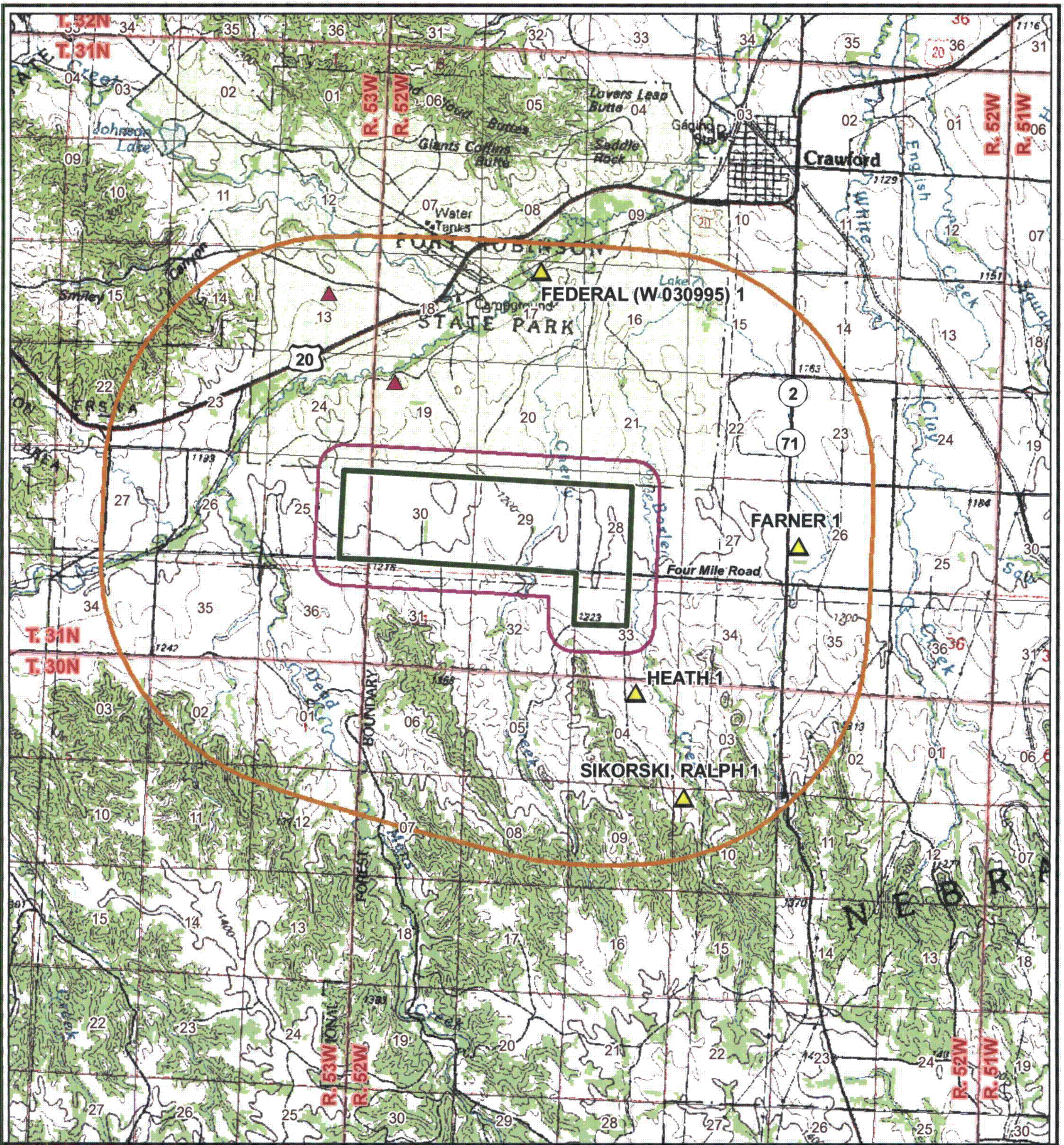
K:\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0004_ERER Fig_3_1-2_Aerial Photo Depicting Rural Residences.mxd - 7/19/2010 @ 1:39:00 PM



LEGEND

▲ Gravel Pit, Abandoned

Oil/Gas Exploration Holes

△ Dry Hole: Dry and Abandoned

Proposed Three Crow Expansion Area

ZOEI Boundary (1/4-Mile Buffer)

AOR Boundary (2 1/4-Mile Buffer)

SOURCES

Gravel Pits - Conservation and Survey Division, University of Nebraska - Lincoln, 1996 (http://nesen.unl.edu/csd/index.html)

O/G Test Holes - Nebraska Oil and Gas Conservation Commission, (http://www.nogcc.ne.gov/NOGCCPublications.aspx), 01/25/2010

USGS 1: 100,000 topographic map - Crawford (1984), NE
Contour Elevations in Meter

0 3,000 6,000
Scale in Feet

N W E

PROJECTION:
NAD_1927_STATE_PLANE_NEBRASKA_NORTH_FIPS_2601

CROW BUTTE RESOURCES, INC.

FIGURE 3.1-3
THREE CROW EXPANSION AREA LOCATIONS OF GRAVEL PITS AND OIL/GAS TEST HOLES

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: LW

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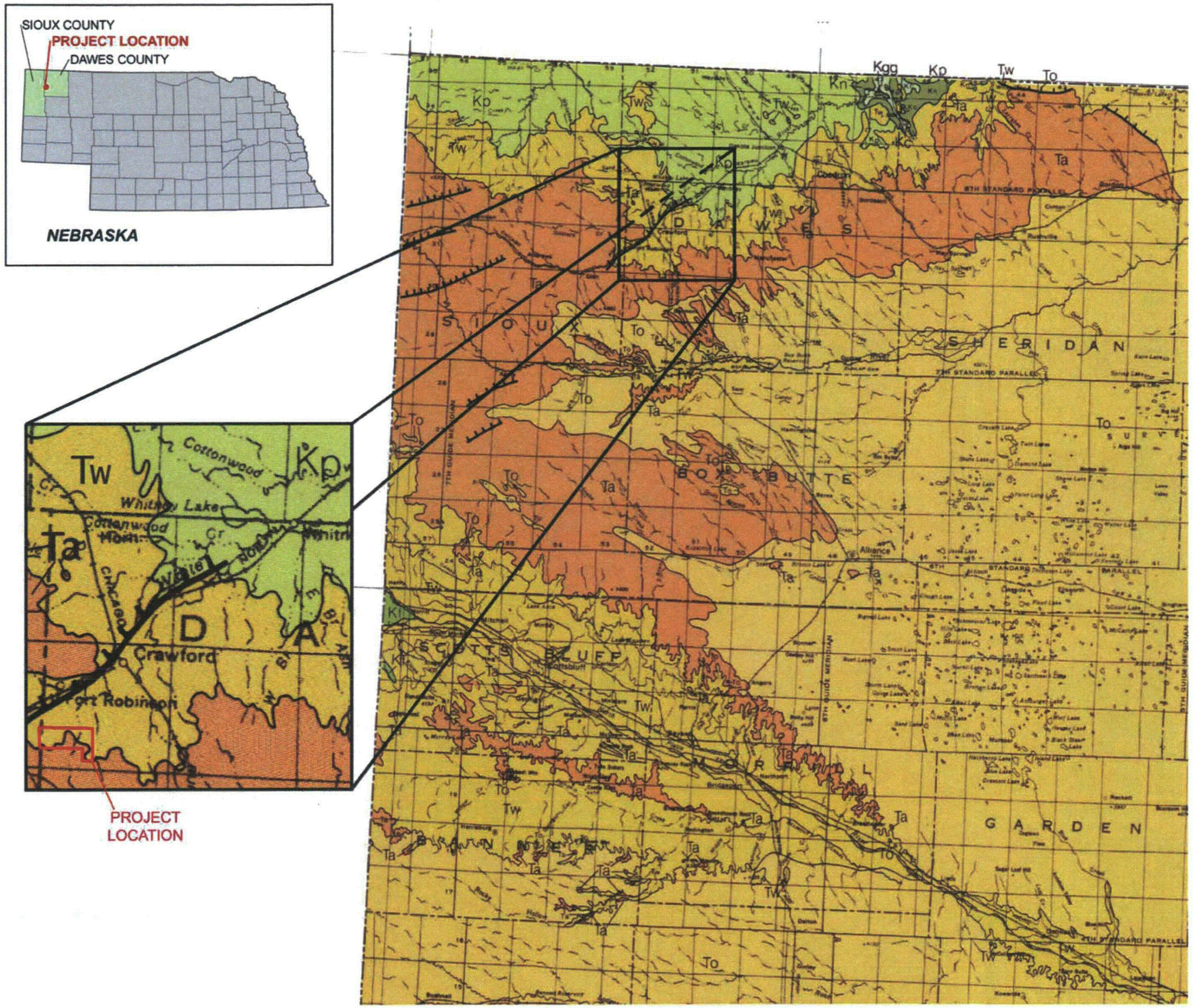

LEGEND

GEOLOGIC PERIOD	SERIES		GROUP OR FORMATION	
T TERTIARY	MIOCENE		OGALLALA	To
			ARIKAREE	Ta
	OLIGOCENE		WHITE RIVER	Tw
K CRETACEOUS	UPPER CRETACEOUS	MONTANA	Fox Hills	Kf
			Pierre	Kp
		COLORADO	Niobrara	Kn
			Carlile	Kc
			Greenhorn-Graneros	Kgg
	LOWER CRETACEOUS		DAKOTA	Kd
Jr JURASSIC				
P PERMIAN	BIG BLUE		CHASE	Pc
			COUNCIL GROVE	Pcg
			ADMIRE	Pa
			WABAUNSEE	IPw
IP PENNSYLVANIAN	VIRGIL		SHAWNEE	IPs
			DOUGLAS	IPd
	MISSOURI		LANSING	IPl
			KANSAS CITY	IPkc
	DES MOINES		MARMATON	IPm
M MISSISSIPPIAN				
D DEVONIAN				
SILURIAN				
O ORDOVICIAN (Middle & Upper)				
CO CAMBRIAN & ORDOVICIAN (Lower)				
PC PRECAMBRIAN				

(PLIOCENE AND QUATERNARY deposits not shown)

Source: Nebraska Geological Survey

N
W — E

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FIGURE 3.3-1
BEDROCK GEOLOGY OF THE THREE CROW EXPANSION AREA

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: MS

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K:\CBR_Projects\CO001396_ThreeCrow\3_IMAGES\Photoshop\ER Fig_3_3-1_Bedrock Geology.psd

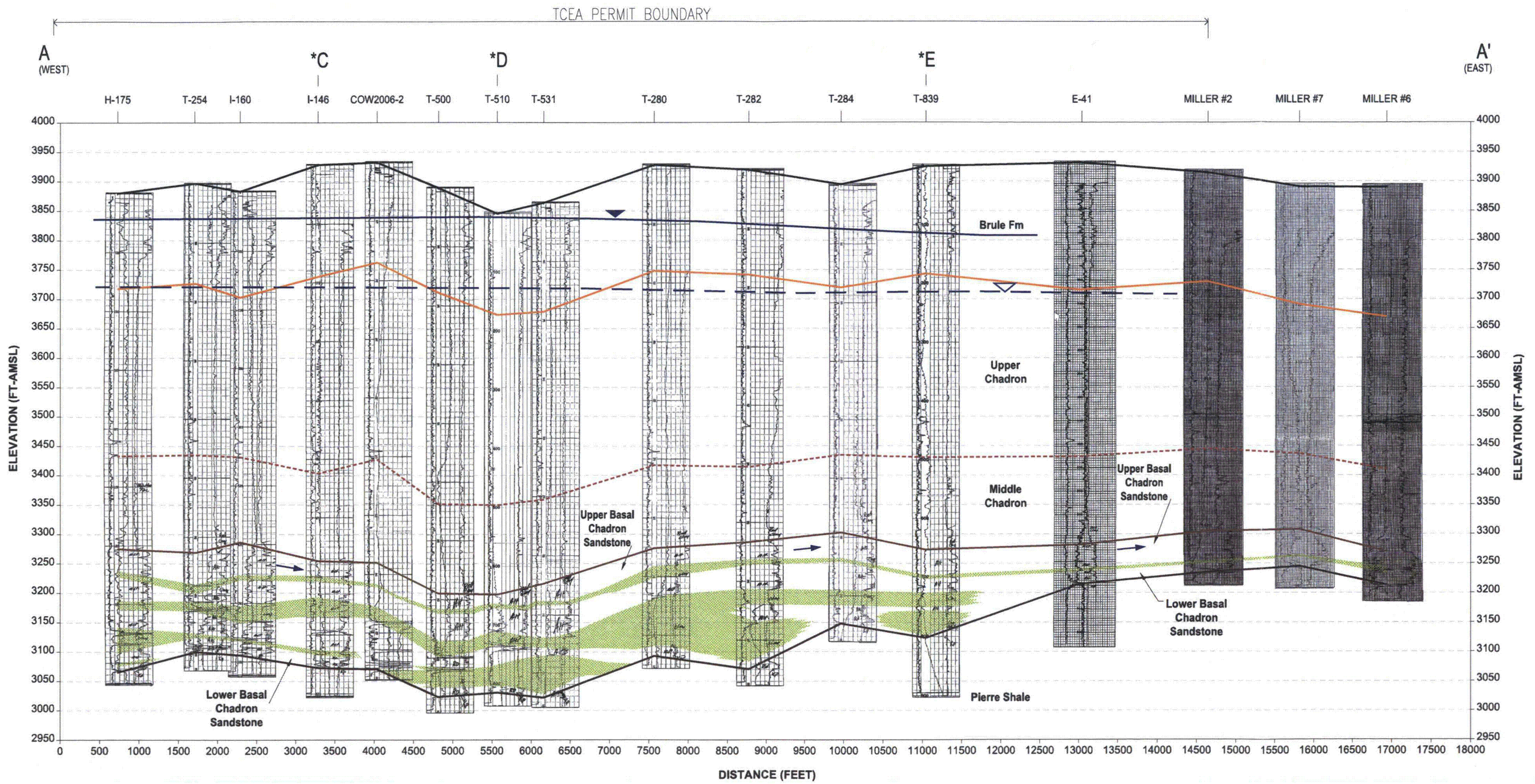
THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

"FIGURE 3.3-2 THREE CROW CROSS-SECTION LOCATION MAP"

WITHIN THIS PACKAGE...OR BY SEARCHING USING THE DOCUMENT/REPORT NO.

D-01



Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) For locations where the Upper/Middle Chadron Fm was not observed in e-logs, the contact between the Upper Chadron Fm and the Middle Chadron Fm was extrapolated based on known occurrence, and is shown as dashed lines.

* Letter indicates location of intersecting cross-section lines shown on Figure 2.6-2.

Legend:

- Topographic Surface
- Top of Upper Chadron
- Top of Middle Chadron
- Top of Basal Chadron Sandstone
- Interbedded Clay
- Top of Pierre Shale
- Water Table (Brule Fm) - 1/22/10 & 2/08/10
- Potentiometric Surface (Basal Chadron Sandstone) - 1/22/10
- Groundwater Flow Direction

0 100' 200'
VERTICAL GRAPHIC SCALE

0 750' 1,500'
HORIZONTAL GRAPHIC SCALE

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-3a
THREE CROW STRUCTURAL CROSS-SECTION: A-A'

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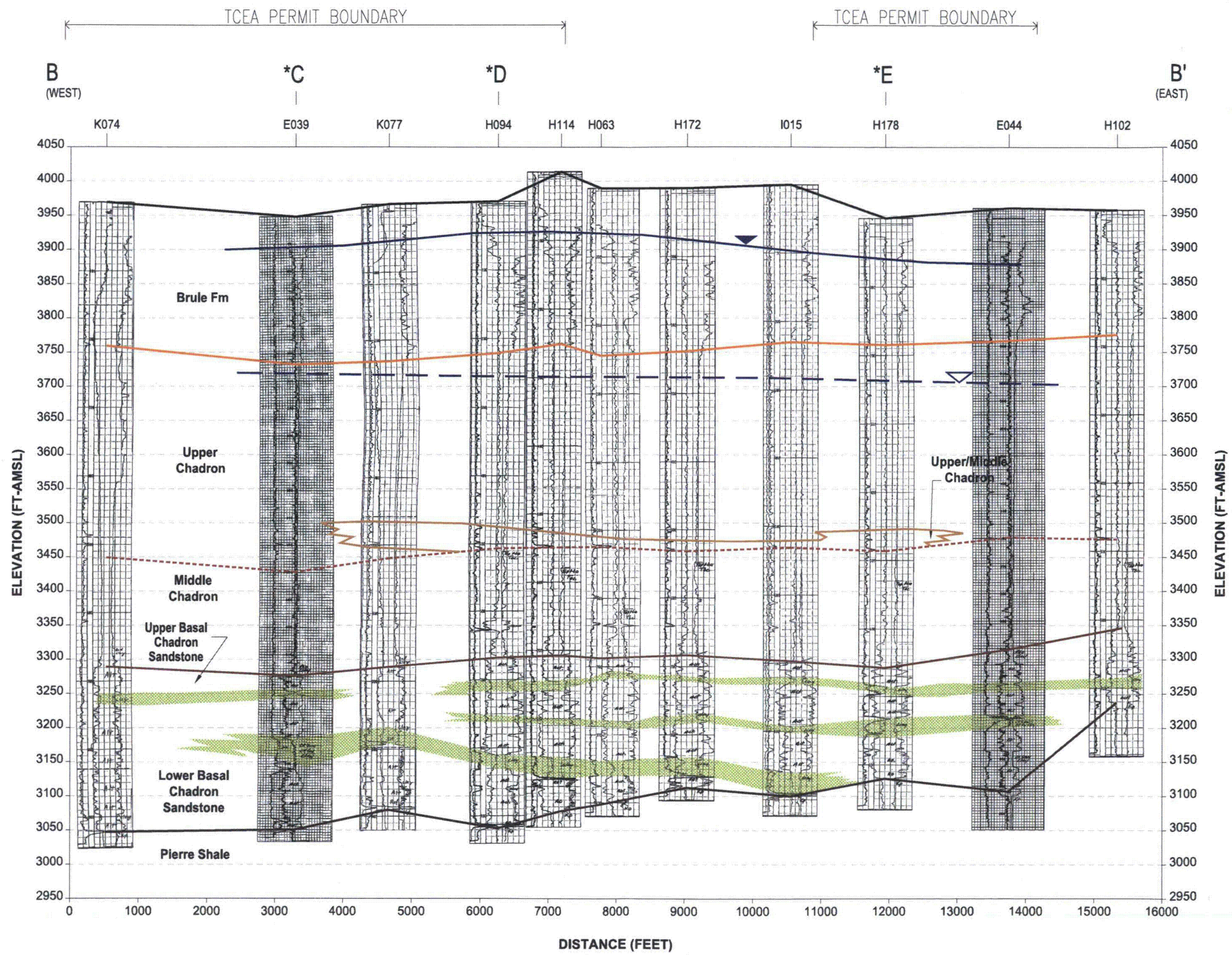

Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) For locations where the Upper/Middle Chadron Fm was not observed in e-logs, the contact between the Upper Chadron Fm and the Middle Chadron Fm was extrapolated based on known occurrence, and is shown as dashed lines.

* Letter indicates location of intersecting cross-section lines shown on Figure 2.6-2.

Legend:

- Topographic Surface
- Top of Upper Chadron
- Top of Upper/Middle Chadron
- Top of Middle Chadron
- Top of Basal Chadron Sandstone
- Interbedded Clay
- Top of Pierre Shale
- Water Table (Brule Fm) - 1/22/10
- Potentiometric Surface (Basal Chadron Sandstone) - 1/22/10 & 2/08/10

0 100' 200'
VERTICAL GRAPHIC SCALE

0 1,000' 2,000'
HORIZONTAL GRAPHIC SCALE

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-3b
THREE CROW STRUCTURAL CROSS-SECTION: B-B'

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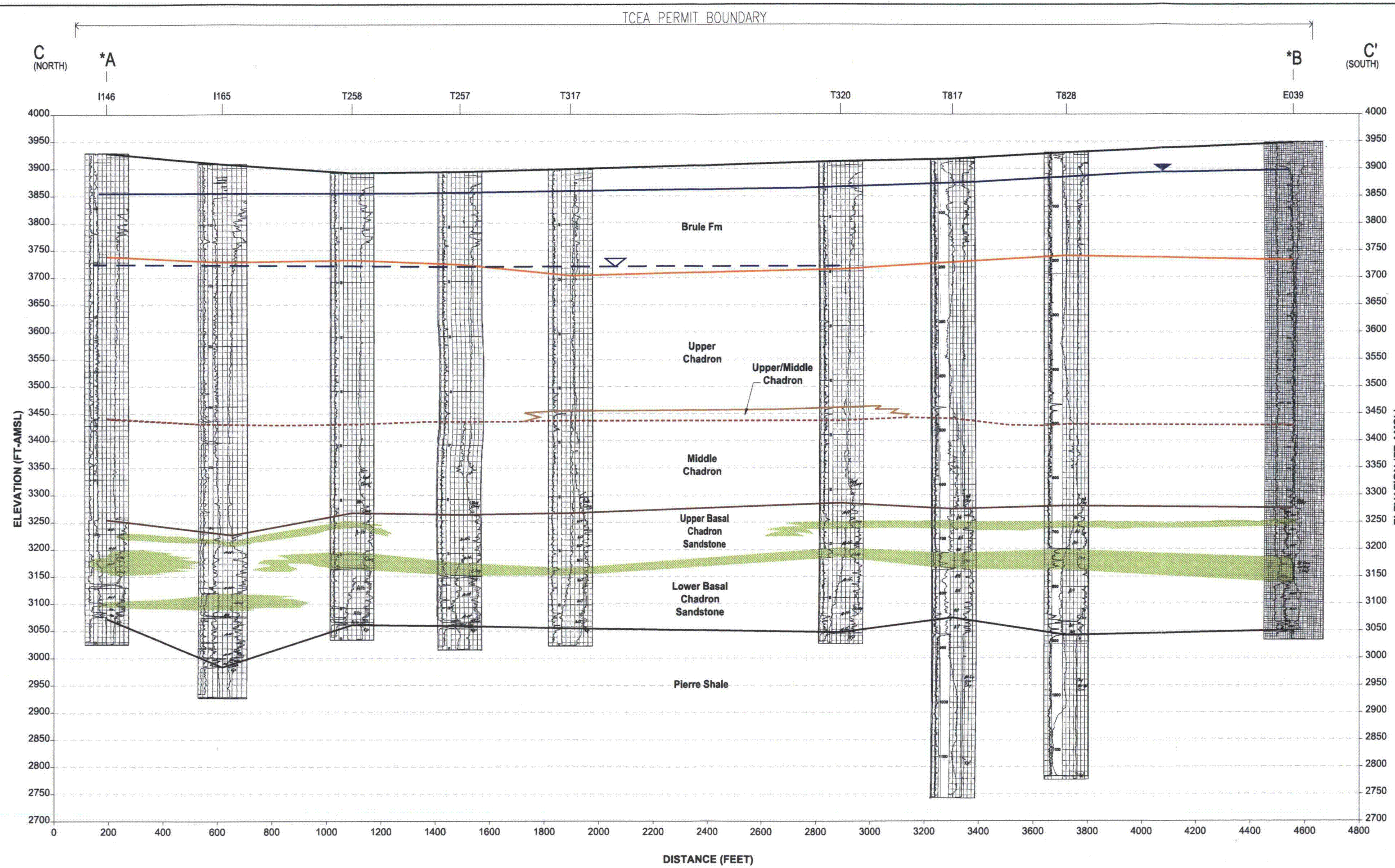
PATH: K:\CBR_Projects\CO001396_ThreeCrow\1_ACAD\e-transmit\XS_BB.dwg LAYOUT: ER SAVED DATE/TIME: 7/19/2010 2:06 PM



Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) For locations where the Upper/Middle Chadron Fm was not observed in e-logs, the contact between the Upper Chadron Fm and the Middle Chadron Fm was extrapolated based on known occurrence, and is shown as dashed lines.

* Letter indicates location of intersecting cross-section lines shown on Figure 2.6-2.

Legend:

- Topographic Surface
- Top of Upper Chadron
- Top of Upper/Middle Chadron
- Top of Middle Chadron
- Top of Basal Chadron Sandstone
- Interbedded Clay
- Top of Pierre Shale
- Water Table (Brule Fm) - 1/22/10
- Potentiometric Surface (Basal Chadron Sandstone) - 1/22/10 & 2/08/10

0 100' 200'
VERTICAL GRAPHIC SCALE

0 200' 400'
HORIZONTAL GRAPHIC SCALE

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-3c
THREE CROW STRUCTURAL CROSS-SECTION: C-C'

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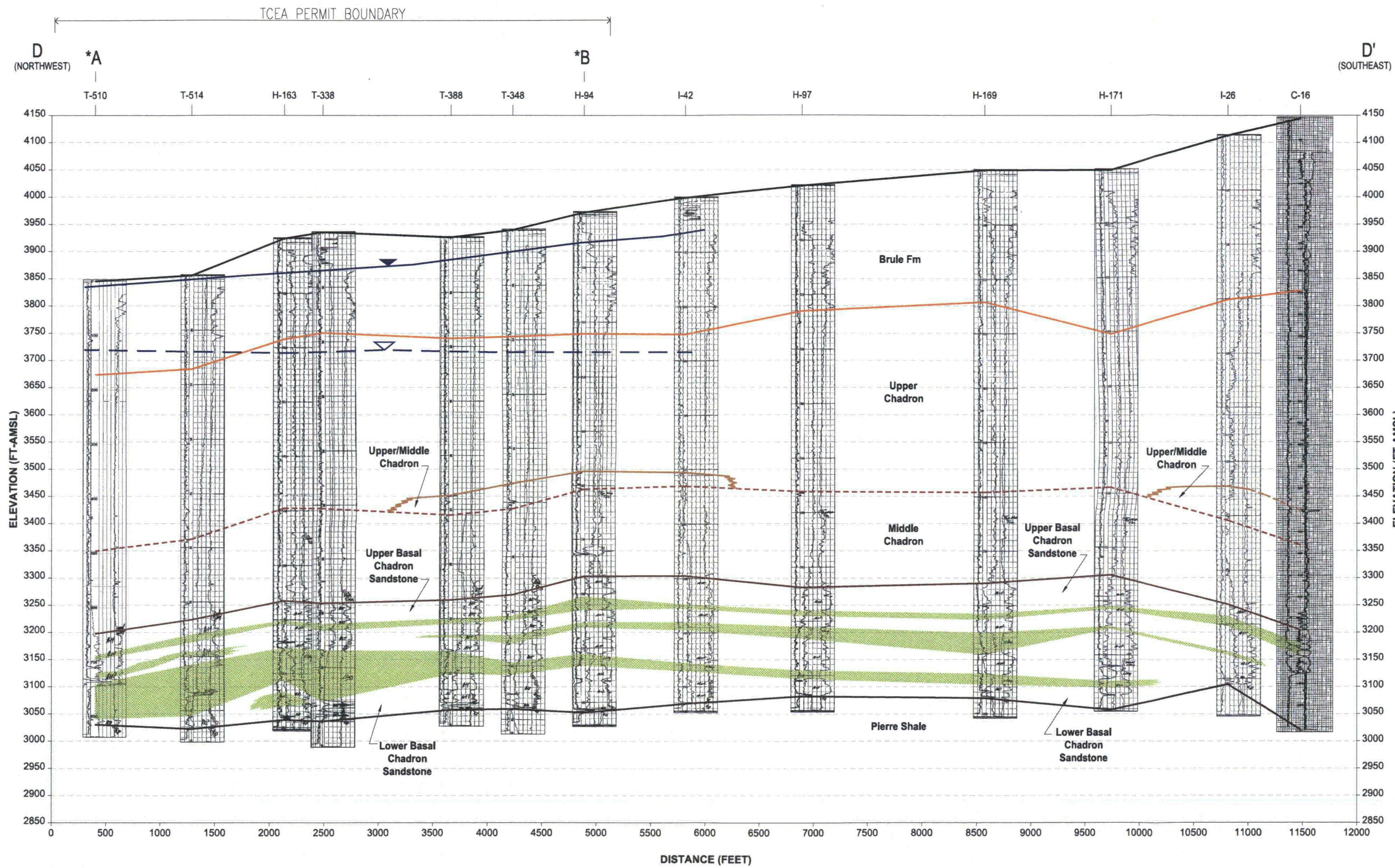

Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) For locations where the Upper/Middle Chadron Fm was not observed in e-logs, the contact between the Upper Chadron Fm and the Middle Chadron Fm was extrapolated based on known occurrence, and is shown as dashed lines.

* Letter indicates location of intersecting cross-section lines shown on Figure 2.6-2.

Legend:

- Topographic Surface
- Top of Upper Chadron
- Top of Upper/Middle Chadron
- Top of Middle Chadron
- Top of Basal Chadron Sandstone
- Interbedded Clay
- Top of Pierre Shale
- Water Table (Brule Fm) - 1/22/10 & 2/08/10
- Potentiometric Surface (Basal Chadron Sandstone) - 1/22/10

0 100' 200' VERTICAL GRAPHIC SCALE

0 500' 1,000' HORIZONTAL GRAPHIC SCALE

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-3d
THREE CROW STRUCTURAL CROSS-SECTION: D-D'

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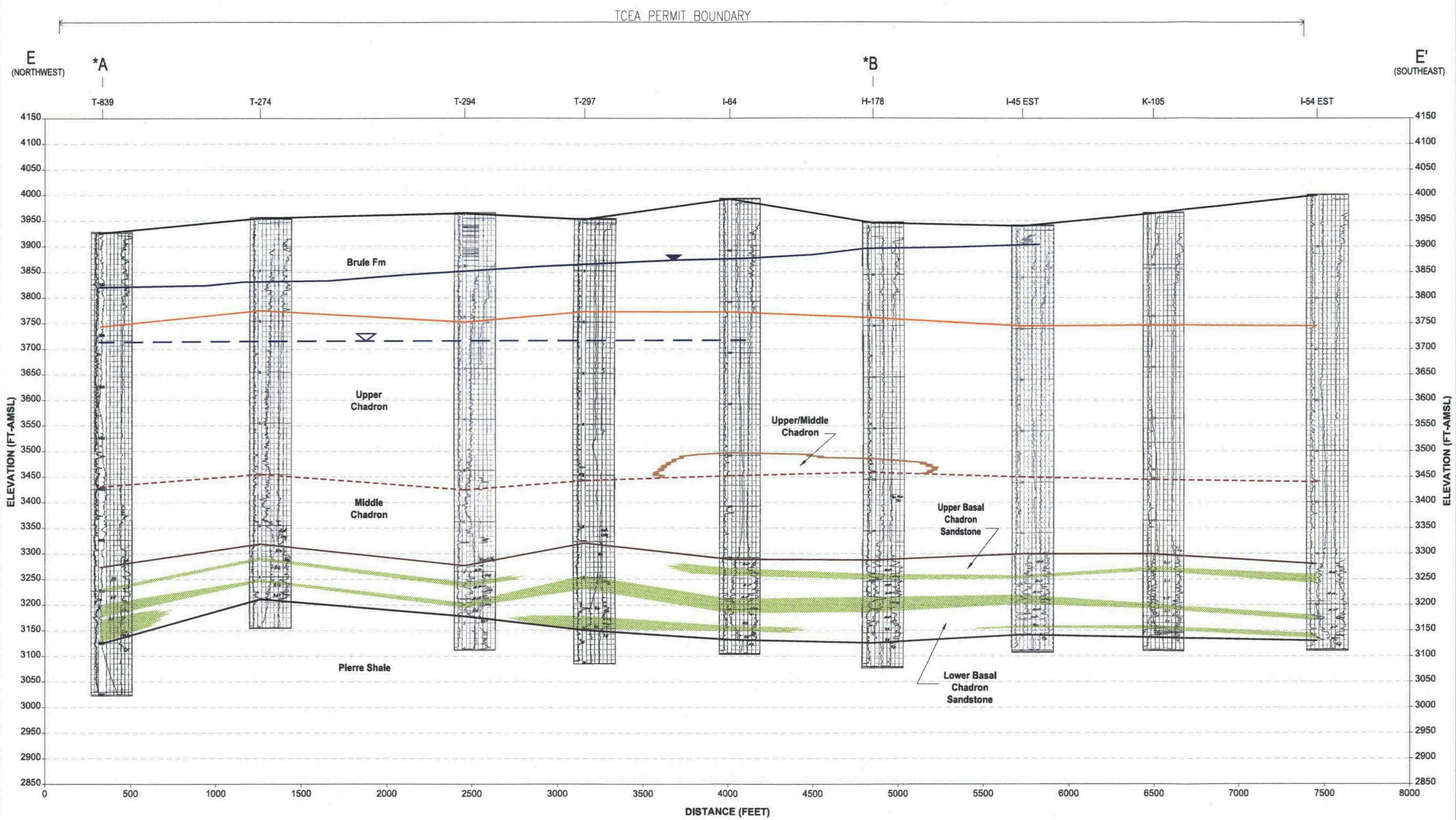

Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) For locations where the Upper/Middle Chadron Fm was not observed in e-logs, the contact between the Upper Chadron Fm and the Middle Chadron Fm was extrapolated based on known occurrence, and is shown as dashed lines.

* Letter indicates location of intersecting cross-section lines shown on Figure 2.6-2.

Legend:

- Topographic Surface
- Top of Upper Chadron
- Top of Upper/Middle Chadron
- Top of Middle Chadron
- Top of Basal Chadron Sandstone
- Interbedded Clay
- Top of Pierre Shale
- Water Table (Brule Fm) - 1/22/10
- Potentiometric Surface (Basal Chadron Sandstone) - 1/22/10 & 2/08/10

0 100' 200'
VERTICAL GRAPHIC SCALE

0 500' 1,000'
HORIZONTAL GRAPHIC SCALE

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-3e
THREE CROW STRUCTURAL CROSS-SECTION: E-E'

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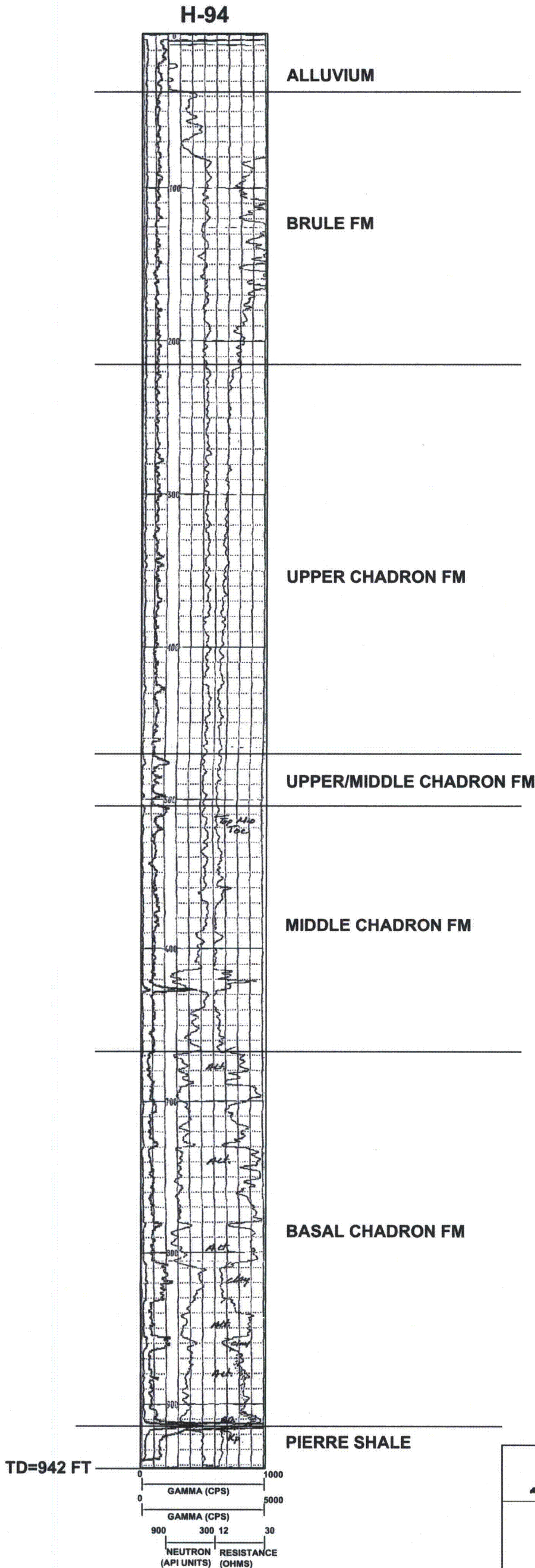
PATH: K:\CBR_Projects\CO001396_ThreeCrow\1_ACAD\e-transmit\XS_EE.dwg LAYOUT: ER SAVED DATE/TIME: 8/3/2010 10:31 PM



NOTE:

1). E-LOGS NEWER THAN 1990 USE SP RATHER THAN NUETRON LOGGING.

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-4
THREE CROW EXPANSION AREA
TYPE LOG (H-94)

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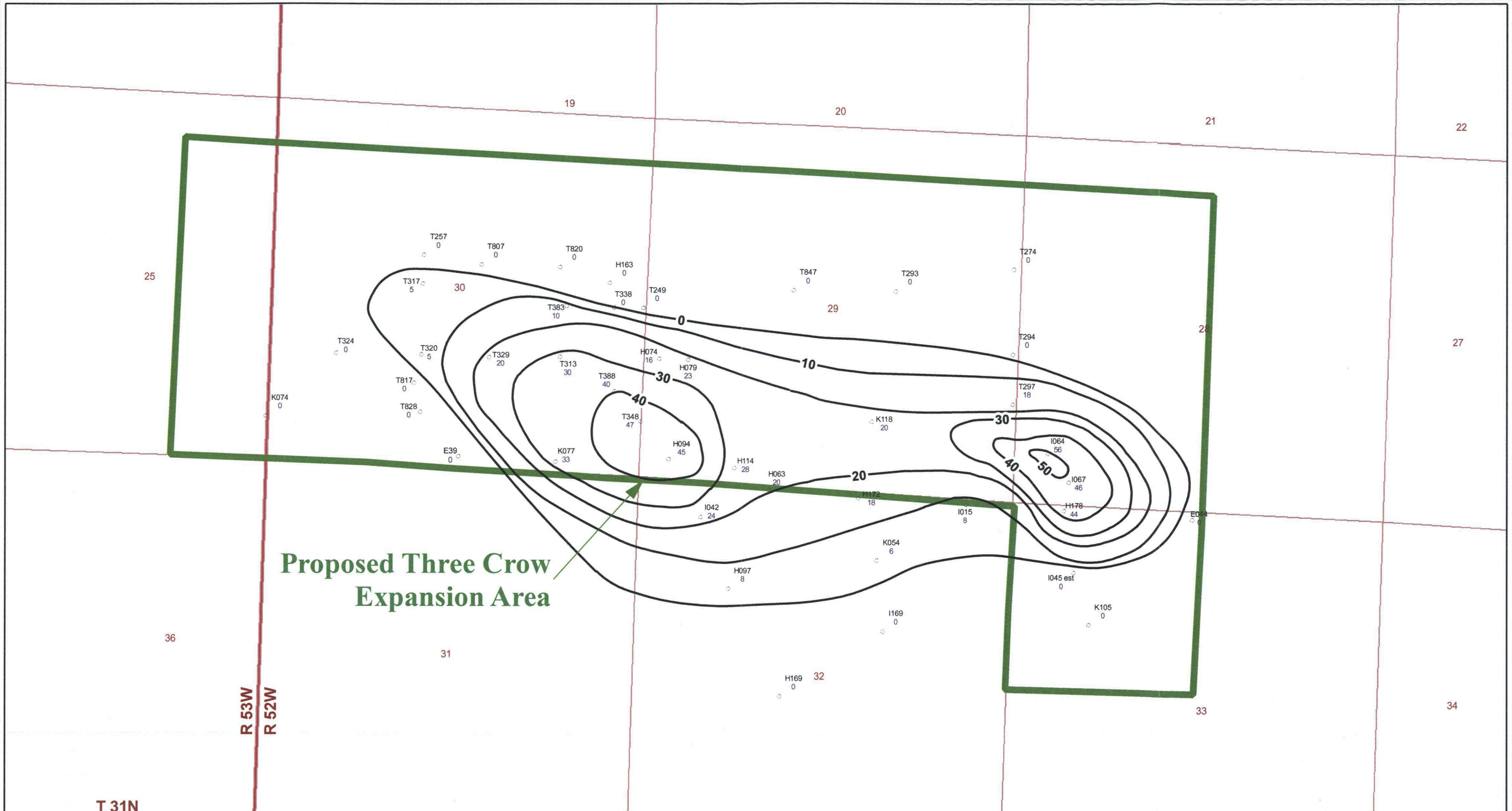

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LEGEND

- Exploration Borehole
- Isopach Contour (Feet)
- Proposed Three Crow Expansion Area

T828 ← Borehole/Well ID
238 ← Unit Thickness (Feet)

0 1,000 2,000
Scale in Feet

PROJECTION:
NAD 1927, STATE PLANE
NEBRASKA NORTH FIPS 2601

N W E

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-5
THREE CROW ISOPACH MAP -
UPPER/MIDDLE CHADRON FORMATION

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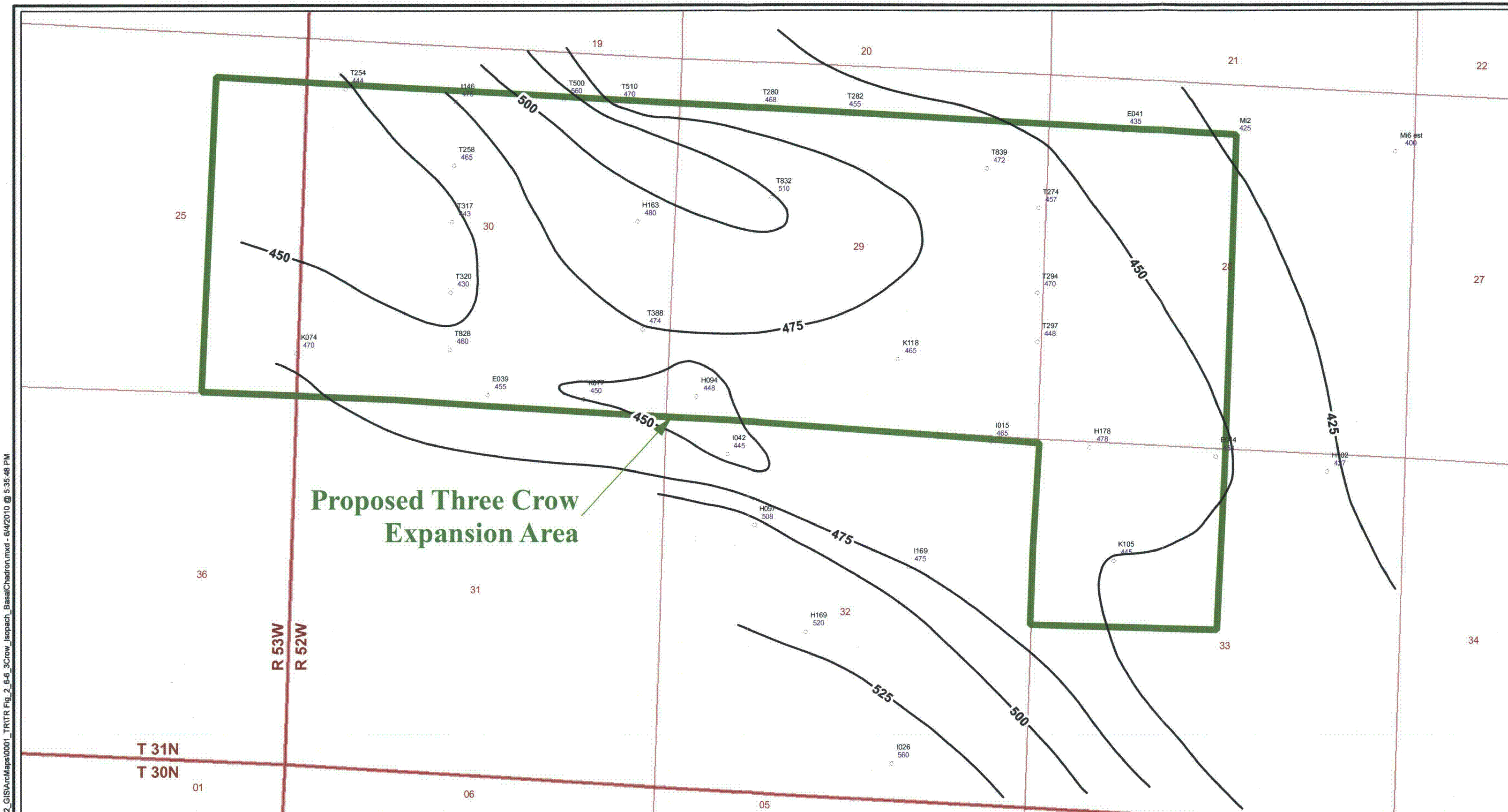

LEGEND

- Exploration Borehole
- Thickness Contour (Upper Confining Zone)
- Proposed Three Crow Expansion Area

T828 ← Borehole/Well ID
238 ← Unit Thickness (Feet)

Note: 1) The upper confining zone represents the interval between the base of the Brule Formation and the top of the underlying Basal Chadron Sandstone.

0 1,000 2,000
Scale in Feet

PROJECTION:
NAD 1927, STATE PLANE
NEBRASKA NORTH FIPS 2601

N / W / E

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-6
THREE CROW ISOPACH MAP - UPPER CONFINING ZONE

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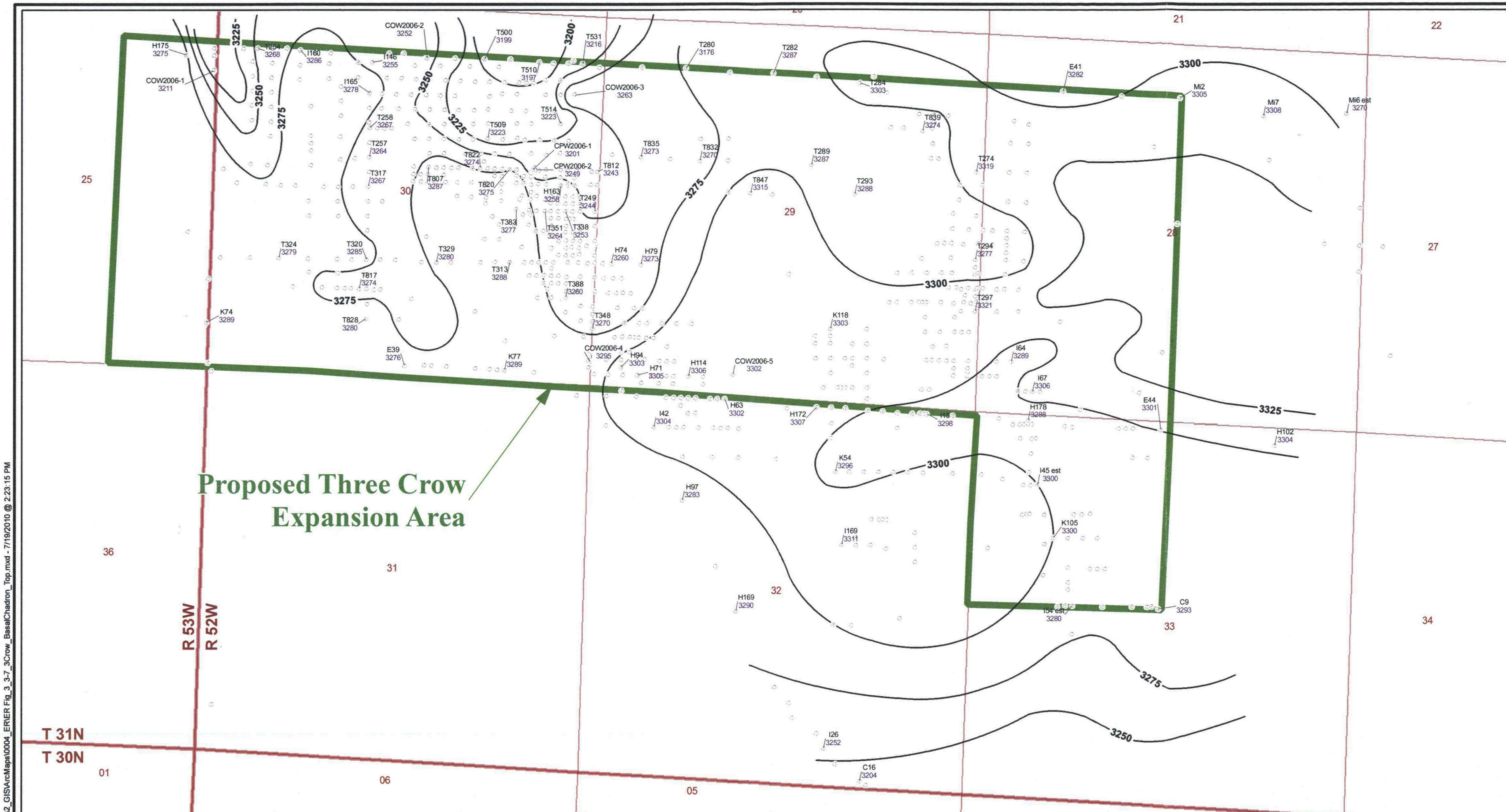

LEGEND

Exploration Borehole

Top of Basal Chadron Contour (FT-AMSL)

Proposed Three Crow Expansion Area

T329 — Borehole/Well ID

3280 — Top of Basal Chadron (FT-AMSL)

0 1,000 2,000

Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-7
THREE CROW STRUCTURE CONTOUR MAP
TOP OF BASAL CHADRON SANDSTONE

PROJECT: CO001396.0003 | MAPPED BY: JC | CHECKED BY: MS

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LEGEND

- Exploration Borehole
- Isopach Contour (Feet)
- Proposed Three Crow Expansion Area

T828 — Borehole/Well ID
238 — Unit Thickness (Feet)

0 — 1,000 — 2,000
Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601

N / W / E

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-8
THREE CROW ISOPACH MAP - UPPER AND LOWER BASAL CHADRON SANDSTONE

PROJECT: CO001396.00003	MAPPED BY: JC	CHECKED BY: MS

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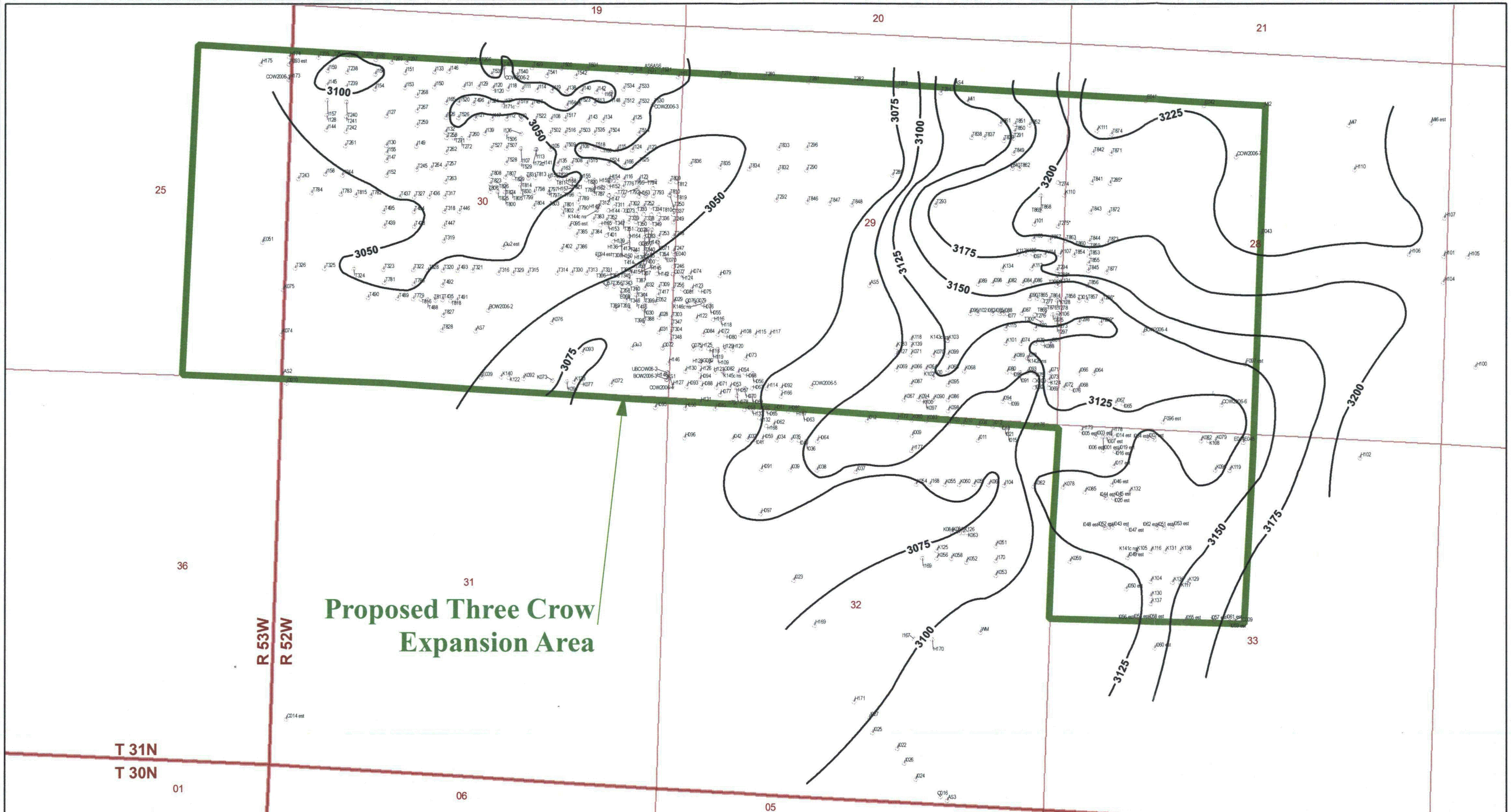

LEGEND

- Exploration Borehole
- Top of Pierre Shale Contour (FT-AMSL)
- Proposed Three Crow Expansion Area

0 1,000 2,000
Scale in Feet

PROJECTION:
NAD_1927_STATEPLANE_
NEBRASKA_NORTH_FIPS_2601

N W E

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-9
THREE CROW STRUCTURE CONTOUR MAP - TOP OF PIERRE SHALE

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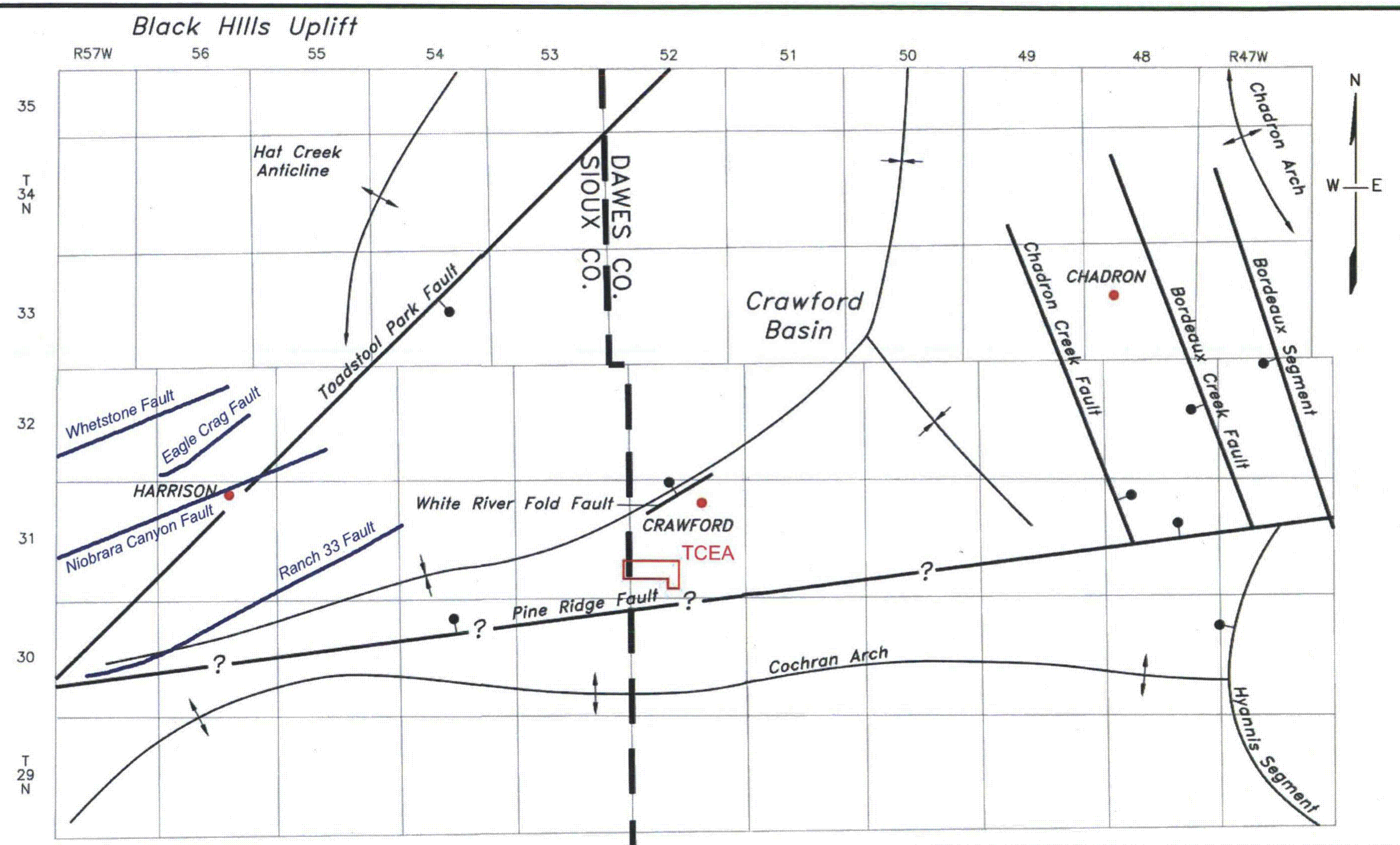


LEGEND

Fault (Ball on downthrown side)

Anticline

Syncline

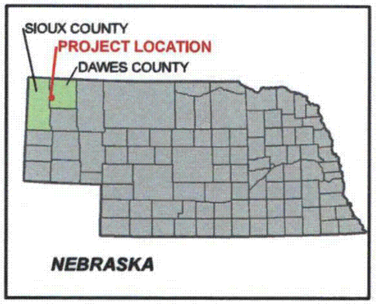
Proposed Three Crow Expansion Area (TCEA)

Fault interpretations by Hunt (1990)

0 5 10

SCALE IN MILES

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



CROW BUTTE RESOURCES, INC.

FIGURE 3.3-10
STRUCTURAL FEATURES MAP OF THE CRAWFORD BASIN

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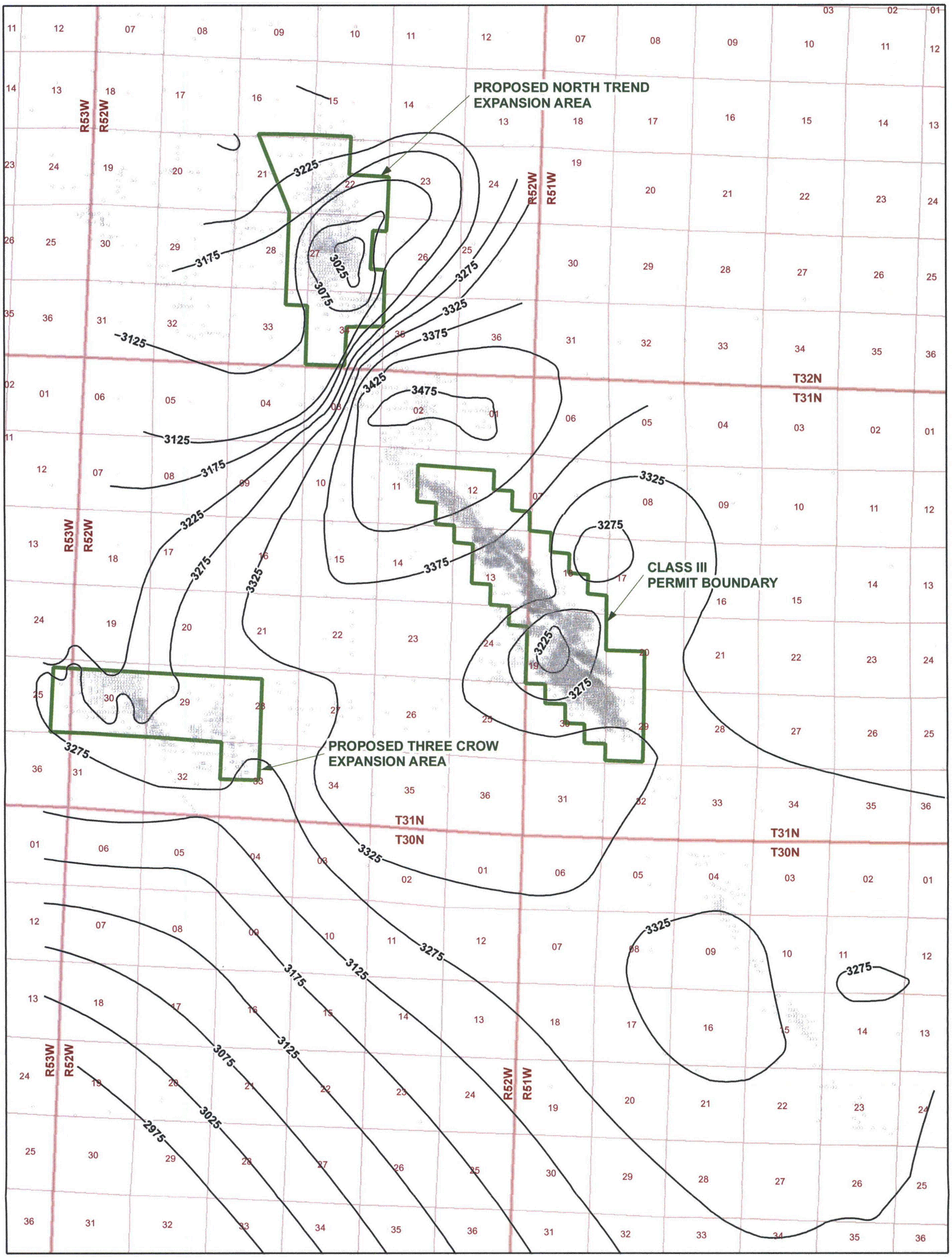

LEGEND

Exploration Borehole

Groundwater Potentiometric Surface (FT-AMSL)

N
W E

0 5,000 10,000

Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-11
REGIONAL STRUCTURE CONTOUR MAP - TOP OF BASAL CHADRON SANDSTONE

PROJECT: CO001396.0003 MAPPED BY: JC CHECKED BY: MS

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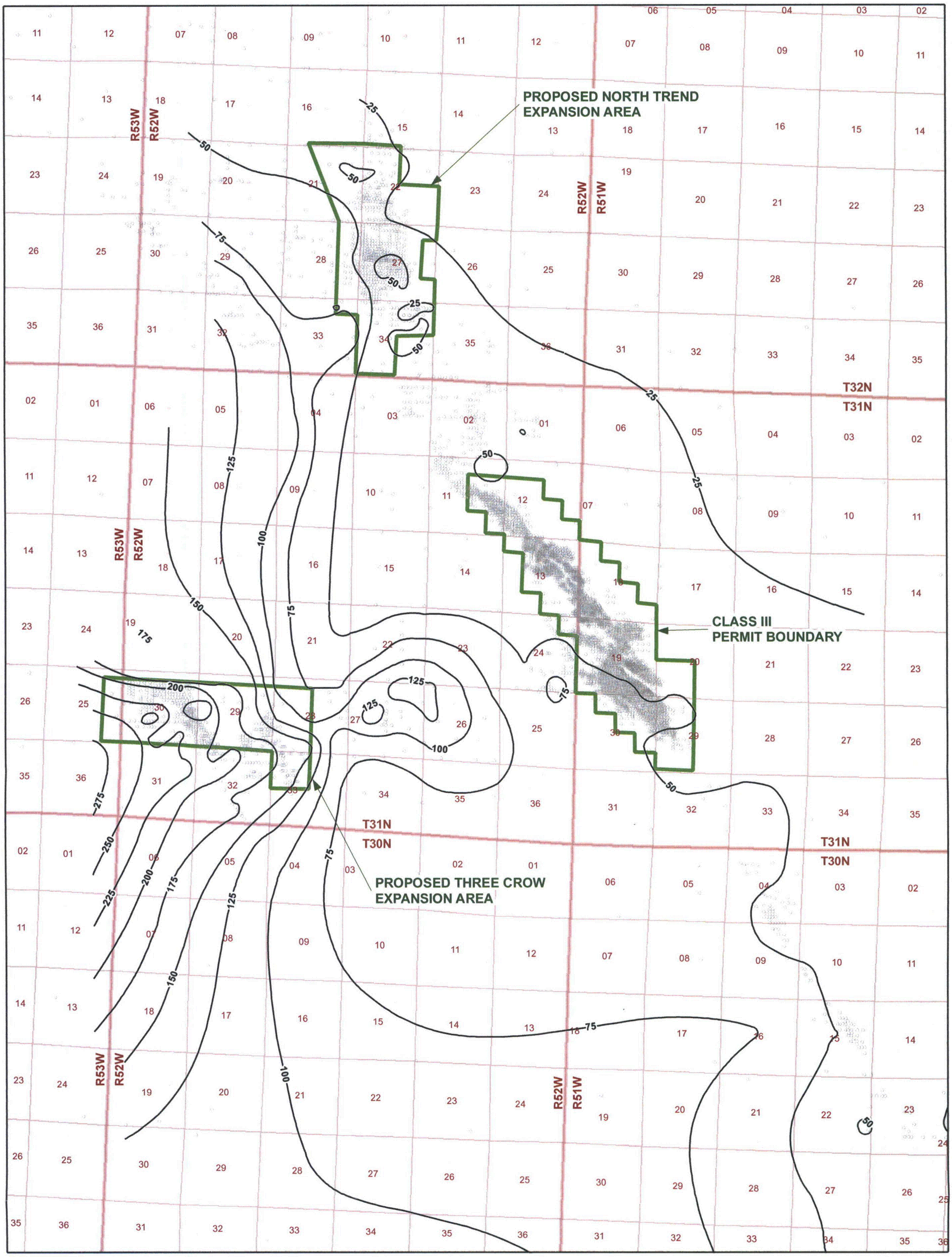

LEGEND

- Unit Thickness (Feet)
- Exploration Borehole

N
W E

0 5,000 10,000

Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-12
REGIONAL ISOPACH MAP - BASAL CHADRON SANDSTONE

PROJECT: CO001396.0003 MAPPED BY: JC CHECKED BY: MS

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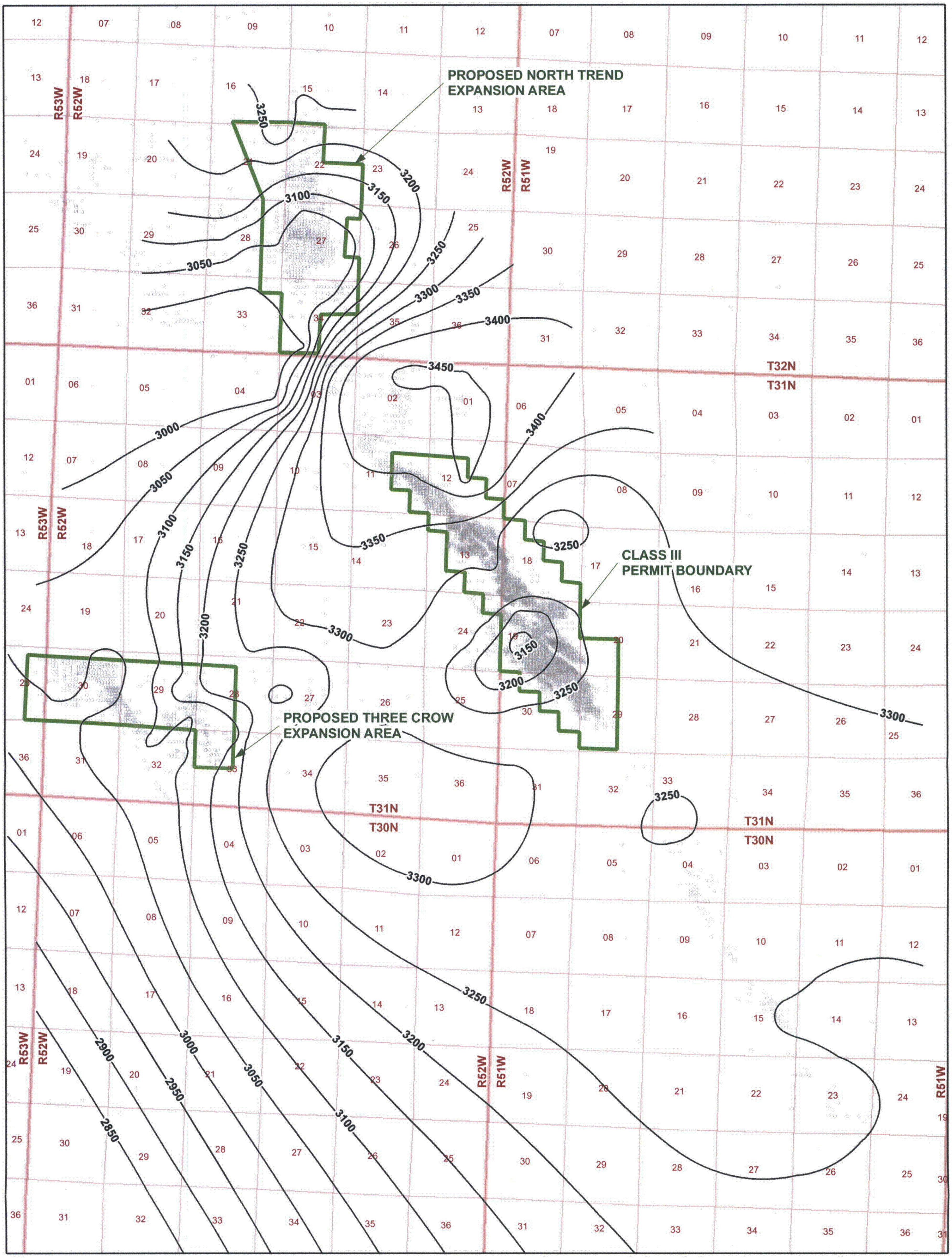

LEGEND

Elevation Contour (FT-AMSL)

Exploration Borehole

N
W E

0 5,000 10,000

Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-13
REGIONAL STRUCTURE CONTOUR MAP - TOP OF PIERRE SHALE

PROJECT: CO001396.0003 MAPPED BY: JC CHECKED BY: MS

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K:\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0004_ERER Fig_3_3-13_Regional_Structure_Contour_Map_Top_of_PierreShale.mxd - 7/19/2010 @ 2:29:29 PM

LEGEND

- Proposed Three Crow Expansion Area (TCEA)
- Nebraska County Boundary
- Nebrask State Boundary

0 15 30
Miles

PROJECTION:
NAD 1927, STATE PLANE
NEBRASKA NORTH FIPS 2601

SOURCE: STIX, J. 1982

N
W — E

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FIGURE 3.3-13a
LOCATION OF CHADRON ARCH AND CAMBRIDGE ARCH IN NEBRASKA

PROJECT: CO001396.00003 MAPPED BY: JC CHECKED BY: JEC

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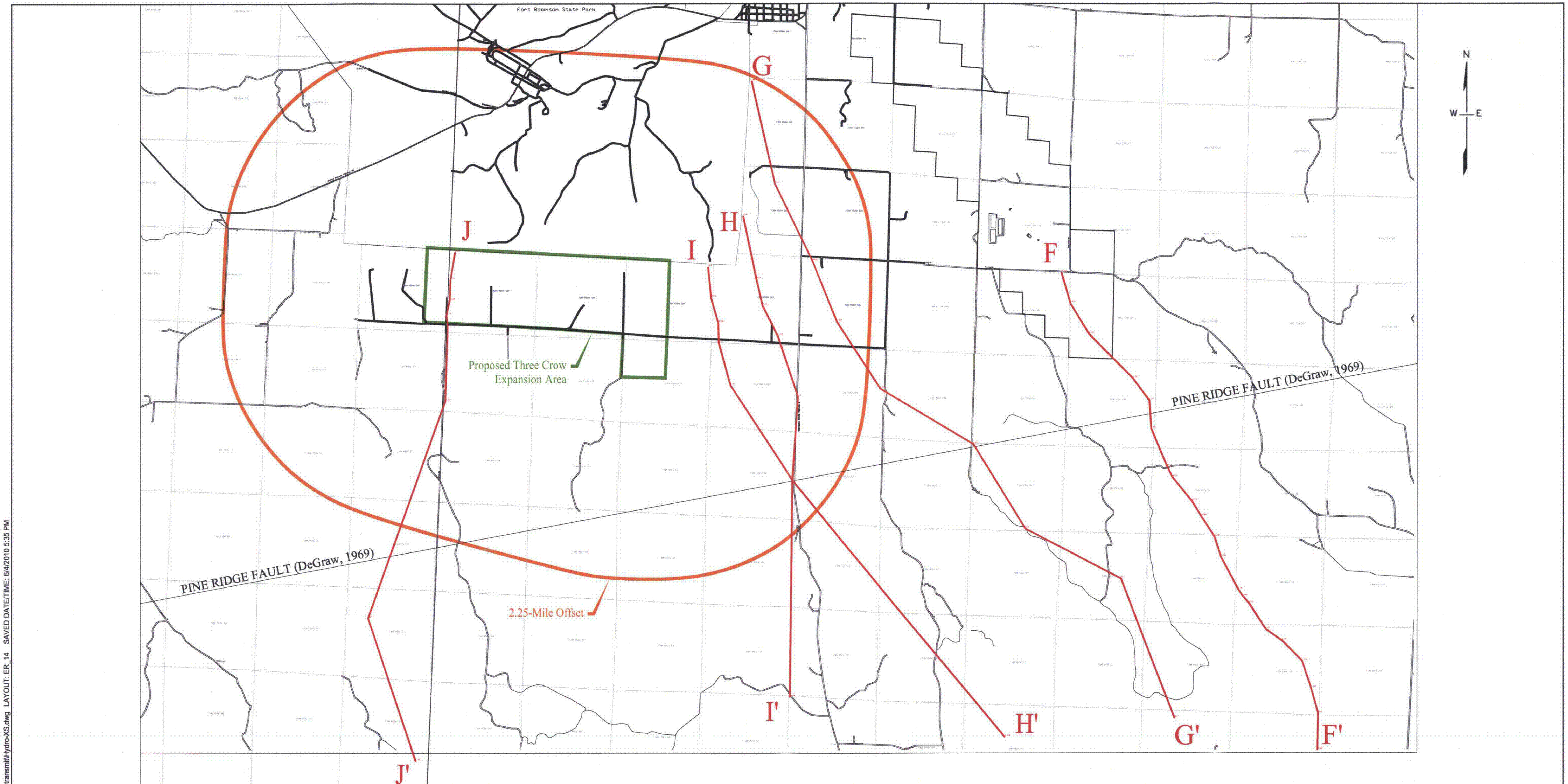
K:\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0004_ER\ER Fig_3_3-13a_Location of Chadron Arch and Cambridge Arch in NE.mxd - 7/19/2010 @ 2:28:36 PM



PROJECTION:
NAD 1927, STATE PLANE
NEBRASKA NORTH FIPS 2601

2000 0 2000 4000 6000 8000 Feet

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FIGURE 3.3-14
REGIONAL CROSS-SECTION LOCATION MAP

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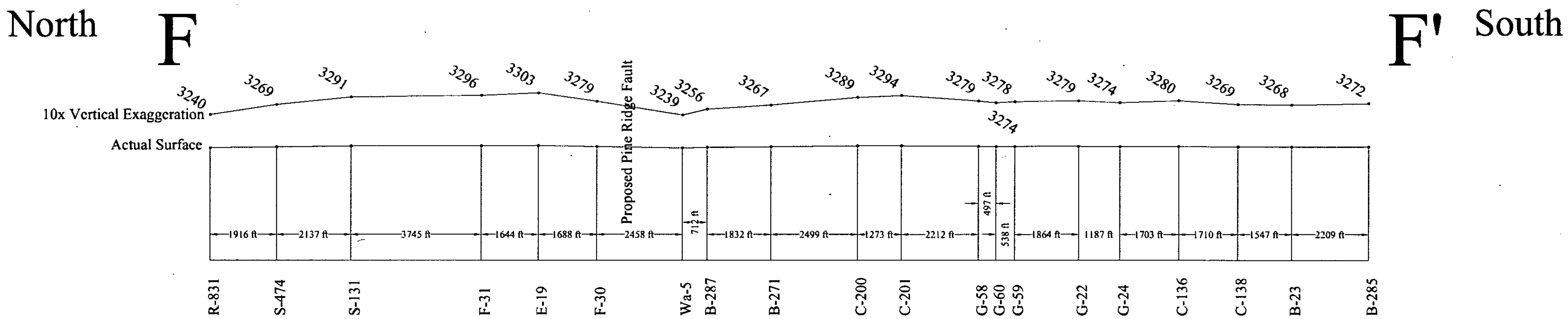
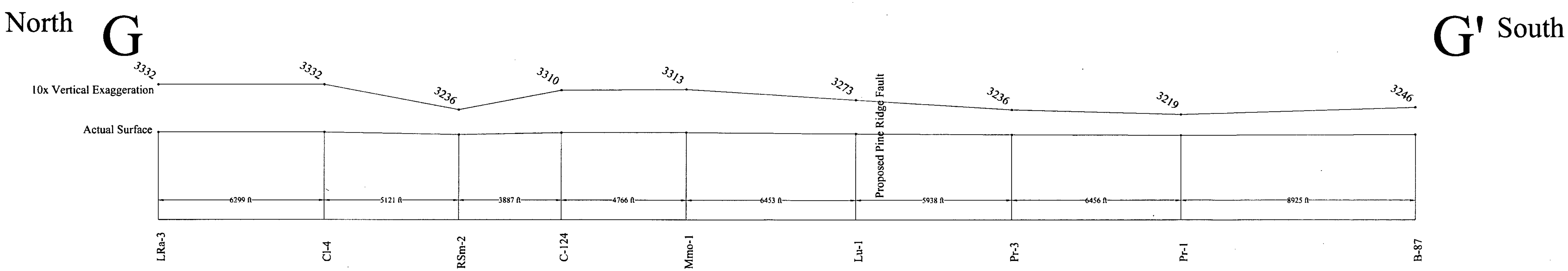
PATH: K:\CBR_Projects\CO001396_ThreeCrow\1_ACAD\e-transmit\Hydro-XS.dwg LAYOUT: ER_14 SAVED DATE/TIME: 6/4/2010 5:35 PM





2000 0 2000 4000 6000 8000 Feet

CROW BUTTE RESOURCES, INC.

FIGURE 3.3-15a
THREE CROW STRUCTURAL CROSS-SECTIONS F-F' AND G-G' (TOP OF PIERRE SHALE)

PROJECT: CO001396 MAPPED BY: JC CHECKED BY: MS

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