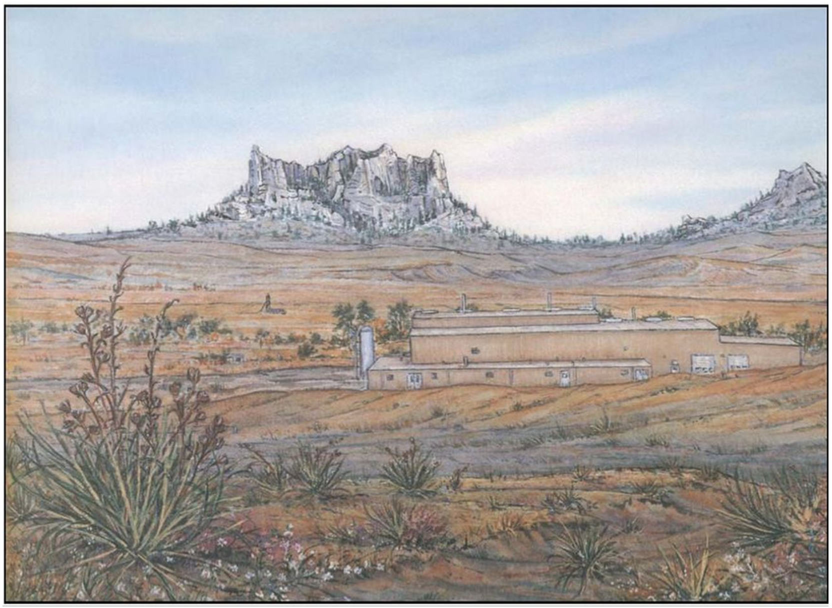
Application for 2024 License Renewal

NRC Source Materials License SUA-1534

Crow Butte Project and Marsland Expansion Area



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CHAPTER 9 - COST-BENEFIT ANALYSIS

CHAPTER 10 - ENVIRONMENTAL APPROVALS AND CONSULTATIONS

LIST OF ACRONYMS

°C	Degree Centigrade
°F	Degree Fahrenheit
ACL	alternate concentration limit
ALARA	as low as reasonably achievable
amsl	above mean sea level
AOR	area of review
API	American Petroleum Institute
ATV	all-terrain vehicle
BBS	breeding bird survey
bgs	below ground surface
BNSF	Burlington Northern Santa Fe
BPT	Best Practicable Technology
CBR	Crow Butte Resources, Inc.
CDP	Census Designated Place
CEDE	Committed Effective Dose Equivalent
CESQG	Conditionally Exempt Small Quantity Generator
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfm	cubic feet per minture
cm/sec	centimeter per second
CPF	Central Processing Facility
cpm	counts per minute
DAC	derived air concentration
dBA	A-weighted decibel
DDE	Deep Dose Equivalent
DDW	deep disposal well
DOT	Department of Transportation
DQO	Data Quality Objective
EA	Environmental Assessment
EDR	electro dialysis reversal
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ER	Environmental Report
ESA	Ecological Study Area
FEMA	Federal Emergency Management Act
FEN	Ferret of Nebraska, Inc.
FESA	Federal Endangered Species Act of 1973
ft/ft	feet per feet
ft/mi	feet per mile
g/L	grams per liter
gpd	gallons per day
gpm	gallons per minute
HPRCC	High Plains Regional Climatic Center
HPT	health physics technician
HSMS	Health and Safety Management Systems
ISR	in-situ recovery

IX	ion exchange
km	kilometer
LAN	local area network
LC	license condition
LEU	low-enriched uranium
LLD	lower limit of detection
LRA	license renewal application
LSA	Low Specific Activity
m/s	meters per second
MARLAP	Multi-Agency Radiological Laboratory Analytical Protocols Manual
MCL	maximum contaminant level
MDC	minimum detection concentration
MEA	Marsland Expansion Area
MeV	mega electronvolt
μS/cm	microSiemens per centimeter
$\mu g/m^3$	micrograms per cubic meter
μCi/ml	microCuries per milliliter
mg/L	milligrams per liter
MIT	mechanical integrity test
MPC	Maximum Permissible Concentration
mph	miles per hour
mRem	miliroentgen equivalent, man
MU	mine unit
NAAQS	National Ambient Air Quality Standards
NAIP	National Agriculture Imagery Program
NDEE	Nebraska Department of Environment and Energy
NDEQ	Nebraska Department of Environmental Quality
NDNR	Nebraska Department of Natural Resources
NGPC	Nebraska Game and Parks Commission
NNHP	Nebraska Natural Heritage Program
NNLP	Nebraska Natural Legacy Project
NOAA	National Oceanic Atmospheric Association
NOI	Notice of Intent
NOU	Nebraska Ornithologists Union
NOV	Notice of violation
NPDES	National Pollutant Discharge Elimination System
NRC	United States Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NSHS	Nebraska State Historical Society
NTEA	North Trend Expansion Area
NTU	nephelometric turbidity units
NWI	National Wetlands Inventory
OSHA	Occupational Safety and Health Administration
OSL	Optically-Stimulated Luminescent
PBL	Peformance-Based License
pCi/g	picoCuries per gram
PPE	personal protective equipment

ppb	parts per billion
ppm	parts per million
PPMP	preoperational/preconstruction monitoring program
PVC	polyvinyl chloride
QC	quality control
QAM	Quality Assurance Manual
QAP	Quality Assurance Program
RAI	request for additional information
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RG	Regulatory Guide
RMP	Risk Management Program
RPPA	Respiratory Protection Program Administrator
RO	reverse osmosis
ROI	radius of influence
RSO	radiation safety officer
RWP	Radiation Work Permit
SCADA	Sequential Control and Data Acquisition
SD DANR	South Dakota Department of Agriculture & Natural Resources
SDR	Standard Dimension Ratio
SDS	safety data sheet
SHEQ	Safety, Health, Environment and Quality
SHEQ	Safety, Health, Environment and Quality Management System
SERP	Safety and Environmental Review Panel
SH	State Highway
SHPO	State Historic Preservation Office
SIV	self-identified violation
SOP	standard operating procedure
SPCC	Spill Prevention, Control, and Countermeasure
SS	stainless steel
SSC	structure, system, or component
s.u.	standard unit
SWPPP	Stormwater Pollution Prevention Plan
SRWP	Standing Radiation Work Permit
TCEA	Three Crows Expansion Area
TCP	traditional cultural property
TDS	total dissolved solids
TEDE	Total Effective Dose Equivalent
TER	Technical Evaluation Report
THC	Total hydrocarbon
TOC	top of casing
TR	Technical Report
TSP	total suspended particulates
TSS	total suspended solids
TWE	Time Weighted Exposure
U_3O_8	triuranium octoxide
UCL	Upper Control Limits
UIC	Underground Injection Control

UMTRCA	Uranium Mill Tailings Radiation Control Act
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USDW	Underground source of drinking water
USGS	United States Geologic Survey
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
VMT	vehicle mile travelled
VRM	Visual Resource Management
WFC	Wyoming Fuel Company
WL	working level
WLM	working level month
XRD	X-Ray Diffraction

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1.0 PROPOSED ACTIVITIES

1.1 LICENSE ACTION REQUESTED

Crow Butte Resources, Inc. (CBR) submits this combined Technical Report (TR) and Environmental Report (ER) in support of a license renewal application (LRA) of the Radioactive Source Materials License SUA-1534 for submittal to the United States Nuclear Regulatory Commission (NRC). CBR requests that SUA-1534 is renewed to a 20-year license. This LRA concerns the Crow Butte Project and Marsland Expansion Area located in Dawes County, Nebraska.

This LRA is prepared to supplement and update the information presented to the NRC in support of issuance of Source Materials License SUA-1534 in 1989 and the subsequent renewals in 1997 and 2007 and provides the supplemental information necessary to determine the environmental impacts of continuing uranium leach activities in the Crow Butte License Area under SUA-1534. This LRA is submitted in accordance with the licensing requirements contained in 10 Code of Federal Regulations (CFR) Part 40 and provides the NRC staff with the necessary information to support the preparation of an Environmental Assessment (EA) as required in 10 CFR Part 51.

This LRA has been prepared using suggested guidelines and standard formats from both state and federal agencies. The application is presented primarily in the NRC format found in Regulatory Guide (RG) 3.46. NRC document NUREG-1569, Standard Review Plan for In Situ Leach Uranium Extraction License Applications (NRC 2003a) was used to ensure that all information is provided to allow NRC Staff to complete their review of this amendment application. NUREG-1748, Environmental Review Guidance for Licensing Actions Associated with NMSS Programs (NRC 2003b) was also used to ensure information typically found in the ER was appropriately incorporated into this LRA. This Combined ER/TR provides an update to the 2008 LRA Combined ER/TR and incorporates information from the Marsland Expansion Area (MEA) license amendment application (Technical Report [CBR 2015] and Environmental Report [2012]) as well as the Final Environmental Assessment for the License Renewal of U.S. Nuclear Regulatory Commission License No. SUA-1534 (NRC 2014; herein referred to as 2014 EA) and the Environmental Assessment for the Marsland Expansion Area License Amendment Application (NRC 2018; herein referred to as 2018 MEA EA). In accordance with NUREG-1569, Appendix A, this Combined ER/TR provides updates and changes to site characterization information and includes the historical record of site operations since the last LRA. Each section of this Combined ER/TR provides a brief summary of any changes between the previous license documents and incorporates by reference as appropriate.

CBR reviewed the SUA-1534 license conditions and proposes several changes. Table 1.1-1 provides a summary of the license conditions CBR seeks to revise. Additional supporting details are provided in various sections of this LRA as referenced in the table.

1.2 SUA-1534 BACKGROUND

1.2.1 History

The Crow Butte Project was originally developed by Wyoming Fuel Corporation, which constructed an R&D facility in 1986. The project was subsequently acquired and operated by

Ferret Exploration Company of Nebraska until May 1994, when the name was changed to Crow Butte Resources, Inc. Only the name of the company changed, not its ownership. CBR is the current owner and operator of the Crow Butte Project. CBR does business as Cameco Resources, a Nebraska corporation. CBR is owned by Cameco US Holdings, Inc., which is a U.S. corporation registered in Nevada. Cameco US Holdings is held by Cameco Corporation, which is a Canadian corporation that is publicly traded on both the Toronto and New York Stock Exchanges.

CBR has successfully operated the Crow Butte Project since commercial operations began in 1991. In the second quarter of 2016, Cameco made the decision to curtail production and defer all wellfield development at all US operations. As a result of the 2016 decision, commercial production at the Crow Butte Project ceased in 2018. A total of 11.8 million pounds of uranium were extracted from the Crow Butte Project. Groundwater restoration in Mine Unit (MU) 1 has been completed and approved by the NRC and Nebraska Department of Environmental Quality (NDEQ), with NRC issuing the final approval on February 12, 2003. It should be noted that effective July 1, 2019, the Nebraska Energy Office merged with the NDEQ to become the Nebraska Department of Environment and Energy (NDEE). Operating history and timelines are discussed in detail in Section 1.7.

By letter dated May 16, 2012, CBR submitted an application to the NRC to amend the existing source materials license SUA-1534 to authorize construction and operation of a satellite facility, named the Marsland Expansion Area (MEA). The NRC amended license SUA-1534 in May 2018 (Amendment 3) to include the MEA. No construction or operation has occurred at the MEA to date.

1.2.2 Operational History

The following provides the operational history of SUA-1534 since the last renewal (2007).

1.2.2.1 Amendment and Changes to Operating Plans and Procedures

Approved amendments to SUA-1534 since the renewed license was issued on November 5, 2014 (ADAMS Accession No. ML13324A101) are listed below:

- Amendment 1: modified SUA-1534 license conditions (LCs) 9.2, 10.8, 10.12, 11.11, 11.14, 11.15, and 11.16 (ADAMS Accession No. ML16078A235).
- Amendment 2: modified SUA-1534 LC 10.6 to incorporate alternate decommissioning (groundwater restoration) schedule for MU2-5, removed LC 9.12, and modified LCs 9.2, 10.16, 11.9, and 11.2 (ADAMS Accession No. ML17013A659).
- Amendment 3: Added MEA to SUA-1534 (ADAMS Accession No. ML18117A293).
- Amendment 4: modified SUA-1534 LC 10.2.2 to incorporate alternate decommissioning (groundwater restoration) schedule for MU2-6 (ADAMS Accession No. ML18268A211).
- Amendment 5: modified SUA-1534 LC 10.2.2 to incorporate alternate decommissioning (groundwater restoration) schedule for MU2-6 and revised LC 9.5 to include updated surety amount (ADAMS Accession No. ML20324A073).

All safety and environmental evaluations made by the Safety and Environmental Review Panel (SERP) resulting in changes to operating practices and procedures under SUA-1534 are summarized below. Additional details of each SERP action are located in the applicable Annual Reports.

- SERP 11-01 – Wellhouse 55 approval to operate
- SERP 11-02 – Replace baseline well in MU3
- SERP 11-03 – Replace baseline well in MU4
- SERP 11-04 – Excursion control well 3945 in MU8
- SERP 11-05 – Wellhouse 60 approval to operate
- SERP 11-06 – Release area south of RO building from restricted use
- SERP 11-07 – Add an additional well for use in MU3 and MU4
- SERP 11-08 – Deep disposal well #2 approval to operate
- SERP 11-09 - Wellhouse 62 approval to operate
- SERP 12-01 – Approve organizational change
- SERP 12-02 – HPT qualifications
- SERP 12-03 – Wellhouse 56 approval to operate
- SERP 12-04 – Approval to operate well RES-1i in MU4 Wellhouse 10
- SERP 12-05 – Wellhouse 63 approval to operate
- SERP 12-06 – Approval to operate additional wells in Wellhouse 56
- SERP 12-07 - Approval to operate additional wells in Wellhouse 62
- SERP 12-08 – Approval to operate wells RES-2i, RES-3i, and RES-4i in MU4 Wellhouse 11
- SERP 12-09 – Approval to operate 2 new 250 gpm reverse osmosis (RO) units
- SERP 12-10 – Approval to conduct a pilot test to receive and extract uranium loaded resin from a small community water system
- SERP 12-11 – Approval to operate one additional well in Wellhouse 60
- SERP 12-12 – Approval to expand restricted area in the CPP to include two portable Conex containers
- SERP 13-01 – Approval to operate eight additional wells in Wellhouse 17
- SERP 13-02 – Wellhouse 64 approval to operate
- SERP 13-03 – Approval to operate MU11 booster pump station
- SERP 13-04 – Approval to expand the restricted areas at the CPP and RO building
- SERP 13-05 – Approval of health physics technician (HPT).
- SERP 13-06 – Wellhouse 57 approval to operate, approval of 3 replacement wells and updated MU10 baseline restoration values.

- SERP 14-01 - Wellhouse 35A approval to operate, approval of 5 new monitor wells and updated MU8 baseline restoration values.
- SERP 14-02 – Approval of 5 production wells and 5 injection wells in Wellhouse 47A/65 for operation.
- SERP 14-03 - Approval of 3 production wells and 8 injection wells in Wellhouse 47A/65 for operation.
- SERP 14-04 – Approval to replace MU11 perimeter monitor well CM11-13.
- SERP 14-05 - Approval of 6 production wells and 10 injection wells in Wellhouse 47A/65 for operation.
- SERP 14-06 – Approval of radiation safety officer (RSO).
- SERP 14-07 – Approval of HPT.
- SERP 14-08 – Approval of revisions to the corporate organizational structure in the approved license renewal application.
- SERP 14-09 - Approval of 6 production wells and 1 injection wells in Wellhouse 47A/65 for operation.
- SERP 14-10 - Approval of HPT.
- SERP 15-01 - Approval of revisions to the Cameco divisional organizational structure in the approved license renewal application.
- SERP 15-02 – Approval to operate additional restoration wells in MU4 and MU5.
- SERP 15-03 - Approval to operate additional restoration wells in MU4 and MU5.
- SERP 15-04 – Approval to operate 3 additional wells in MU11.
- SERP 15-05 – Approval of major modification to Class I UIC Permit (NE0211670) Deep Disposal Well #1
- SERP 15-06 – Approval on expanding restricted areas at the CPP and RO.
- SERP 15-07 - Approval to operate additional restoration wells in MU5.
- SERP 16-01 – Approval of replacement of baseline restoration well in MU5 with a nearby well.
- SERP 16-02 – Approval of revisions made to Figure 1, 2, and 5 in the Evaporation Pond Onsite Inspection Program, which are forms used for pond inspections. *Rescinded in SERP 17-01*.
- SERP 16-03 - Approval of revisions to the Cameco divisional organizational structure in the approved license renewal application.
- SERP 16-04 – Approval of minor changes to the approved license renewal application.
- SERP 16-05 – Approval of changes to the security plan that occurred as a result of organizational changes.

- SERP 17-01 – Rescinded SERP 16-02.
- SERP 17-02 - Approval of revisions to the Cameco divisional organizational structure in the approved license renewal application.
- SERP 17-03 – Approval of new liner and leak detection system for commercial evaporation pond #4.
- SERP 17-04 – Approval of changes to the organization structure in the approved license renewal application.
- SERP 18-01 – Approval of RSO.
- SERP 19-01 – Approval of changes to the Quality Assurance Program (QAP).
- SERP 22-01 – Approval to receive and extract uranium from uranium loaded resin from a small community water system.

1.2.2.2 License Violations Identified During NRC Site Inspections

NRC conducts routine inspections to determine whether written operating procedures and approved radiation safety and environmental monitoring programs are in place, and that pre-operational testing is complete. Since 2010, NRC performed eight inspections at the Crow Butte Project. As a result of the inspections, NRC issued six Severity Level IV Notice of Violations (NOVs). Table 1.2-1 summarizes the NOVs and resolution. In all cases, the NOVs were resolved and closed.

1.2.2.3 Self-Identified Violations

CBR also maintains records of self-identified violations (SIVs) that have occurred at the Crow Butte Project. Since 2010, CBR has self-identified nine violations. Table 1.2-2 summarizes the SIVs and resolution. In all cases, the SIVs were resolved.

1.2.2.4 Reportable Spills

CBR adheres to the spill reporting requirements outlined in 10 CFR Part 20, Subpart M and 10 CFR 40.60. Since 2007, one reportable spill occurred. Details of the spills are as follows:

- A spill from an injection well (P5309I) was discovered on September 12, 2017, while preparing the well for MIT following an excursion detected at nearby shallow monitor well SM10-18. The injection well was leaking from a split in the wellhead casing several inches below the ground surface, which resulted in saturated soil and green vegetation in the area. The estimated volume of the spill was 27,287 gallons. Analysis showed that the spilled solution had a uranium content of 0.9 mg/L.

1.3 SITE LOCATION AND DESCRIPTION

1.3.1 Crow Butte Project

The Crow Butte Project is located approximately 4 miles southeast of the City of Crawford in portions of Sections 11, 12, 13, and 24 of Township (T) 31 North (N), Range (R) 52 West (W) and Sections 18, 19, 20, 29, and 30 of T31N, R51W, Dawes County, Nebraska. Figure 1.3-1 provides a general location of the site. The Crow Butte Central Processing Facility (CPF) is located in Section 19, T31N, R51W. This license area occupies approximately 2,875 acres, and the surface area affected over the estimated life of the project is approximately 1,265 acres.

Approximately 100 percent of the minerals leased in the license area are on private lands. Surface landownership includes state/local government and private ownership as shown in Table 1.3-1. Figure 1.3-2 shows the land ownership within the Crow Butte license area.

1.3.2 Marsland Expansion Area

The MEA is located within Sections 26, 35, 36 of T30N, R51W, Sections 1, 2, 11, 12, 13 of T29N, R51W and Sections 7, 18, 19, 20, 29, 20 of T29N, R50W (Figure 1.3-3). The project area encompasses 4,622.3 acres. The MEA satellite facility is located approximately 11 miles south-southeast of the CPF and approximately 5 miles northeast of the community of Marsland.

All of the mineral resources leased within the MEA are privately owned, with the exception of the SW1/4 section of Section 36, T30N, R51W. This quarter section is designated as State Trust Land and is a small part of the nearly 1,300,00 acres of land now held in trust for Nebraska's K-12 public schools. The Trustee of Nebraska's School Trust lands is the Board of Educational Land and Funds. The surface and mineral rights are leased by Cameco from the State of Nebraska. There are no federal lands or minerals in the MEA license boundary. Figure 1.3-3 shows the land ownership within the MEA license area.

1.4 ORE BODY DESCRIPTION

1.4.1 Crow Butte Project

In the Crow Butte license area, uranium is recovered by *in situ* recovery (ISR) from the Chadron Sandstone at a depth that varies from 400 to 900 feet (ft) below ground surface (bgs). The overall width of the mineralized area varies from 1000 to 5000 ft. The ore body ranges from less than 0.05 percent to greater than 0.5 percent triuranium octoxide (U_3O_8), with an average grade estimated at 0.26 percent equivalent U_3O_8.

1.4.2 Marsland Expansion Area

Uranium within the MEA license area will be recovered from the basal sandstone of the Chadron Formation. The depth of the ore body in the MEA ranges from 850 to 1,200 ft bgs. The ore body width varies from approximately 1,000 to 4,000 ft. The ore body ranges in grade from 0.11 to 0.33 percent U_3O_8, with an average grade estimated at 0.22 percent U_3O_8.

1.5 SOLUTION MINING METHOD AND RECOVERY PROCESS

The ISR process for uranium recovery consists of an oxidation step and a dissolution step. Gaseous oxygen or hydrogen peroxide is used to oxidize the uranium, and bicarbonate is used for dissolution. The uranium bearing solution that results from the leaching of uranium underground is recovered from the wellfield and the uranium extracted in the process plant. The plant process uses the following steps:

- Loading of uranium complexes onto ion exchange resin;

- Reconstitution of the solution by the addition of carbonate and an oxidizer;
- Elution of the uranium complexes from the resin; and
- Drying and packaging of the uranium.

Chapter 3 provides a detailed description of the solution mining process and equipment at the Crow Butte Project and MEA.

1.5.1 Advantages of ISR Uranium Mining

ISR uranium mining is a proven technology that has been successfully demonstrated commercially in Wyoming, Texas, and at the Crow Butte Project. ISR mining of uranium is environmentally superior to conventional open pit and underground uranium mining as evidenced by the following:

- ISR mining results in significantly less surface disturbance because mine pits, waste dumps, haul roads, and tailings ponds are not needed.
- ISR mining carries a much lower water demand than conventional mining and milling, avoiding the water usage associated with pit dewatering, conventional milling, and tailings transport.
- The lack of heavy equipment, haul roads, waste dumps, and other features results in very little air quality degradation.
- Fewer employees are needed at ISR mines, thereby reducing transportation and socioeconomic concerns.
- Aquifers are not excavated, but remain intact during and after ISR mining.
- Tailings ponds are not used, thereby eliminating a major groundwater pollution concern.
- The majority of other contaminants (e.g., heavy metals) remain where they occur naturally instead of being relocated to waste dumps and tailings ponds with additional environmental concerns.

1.5.2 Ore Amenability to the ISR Mining Method

The amenability of the uranium deposits in the CBR license area to ISR mining was demonstrated initially through core studies. Results of the core studies were confirmed in the R&D project using bicarbonate/carbonate leaching solutions with oxygen. Reports concerning the results of the R&D activities, including restoration of affected groundwater, were submitted to NRC and the NDEQ.

The information and experience gained during these pilot programs formed the basis for the commercial uranium ISR mining operations. CBR believes that the current commercial project, including the successful restoration of groundwater in MU1, demonstrates that such a program can be implemented with minimal short-term environmental impacts and with no significant risk to the public health or safety. The remainder of this application describes the mining and reclamation plans for the current Crow Butte Project and the MEA, and the concurrent environmental monitoring programs employed to ensure that any impact to the environment or public is minimal.

1.6 OPERATING PLANS, DESIGN THROUGHPUT, AND PRODUCTION

In accordance, with SUA-1534 LC 10.2.3 the maximum flow rate of the CPF is 9,000 gallons per minute (gpm), excluding restoration flow. Total annual yellowcake production is limited to 2 millions pounds.

The uranium-bearing solution extracted from the Crow Butte wellfields is transported via pipeline to CPF for elution, drying, and packaging. This cycle continues until the ore zone is depleted or leach of the uranium is no longer economically viable.

Uranium extracted from the MEA wellfields will be processed at a satellite facility located within the MEA. SUA-1534 LC 10.3.3 limits the maximum flow rate at the satellite facility to 5,400 gpm, excluding restoration flow. The uranium extracted from the MEA will be loaded onto IX resin in the MEA satellite facility, which will then be transported by tanker truck to the CPF for elution, precipitation, drying, and packaging. Barren resin will be returned to the MEA satellite facility by tanker truck.

1.7 PROPOSED OPERATING SCHEDULES

1.7.1 Crow Butte Project

Mine Unit 1 at Crow Butte has been restored. Mine Units 2-5 are being sampled quarterly for stability. This quarterly sampling will continue until an ACL is approved for Mine Units 2-5. The ACL for Mine Units 2-5 is planned to be submitted after the new Source Materials License is approved for CBR. Mine Unit 6 is undergoing quarterly stability sampling. Mine Units 7 and 8 are currently undergoing IX and Reverse Osmosis treatment. Mine Units 9, 10 and 11 are in Standby. In standby a bleed is being taken on these mine units until a decision is made to either return the mine units to production, or to begin restoration treatment.

The current restoration schedule for each mine unit is provided in Figure 1.7-1. The decision to return mine units 9-11 to production will be based on economic factors. If for example the economic conditions were favorable to begin adding lixiviant to Mine Units 9-11, the restoration schedules would pause and resume after mining is complete. A resumption of mining in Mine Units 9-11 could for example last for 5 to 7 years. CBR will provide NRC with an updated schedule when operations resume in Mine Units 9-11. In addition, CBR is required to submit an alternate schedule when groundwater restoration activities exceed 24 months in accordance with LC 10.1.5 of SUA-1534.

1.7.2 Marsland Expansion Area

The proposed MEA project timeline is provided in Figure 1.7-2. There is a potential for 11 mine units. The MEA project timeline is purely hypothetical. Economic conditions will determine when construction is started on the MEA. It is estimated that the MEA project will last for 25 years. Starting order, and mine unit naming is an approximate representation. Future conditions will dictate the operation of the MEA. It is most likely that wellfield operations at

CBR are purely in restoration when construction begins at the MEA but mine unit 10 and 11 of CBR may potentially be in production.

1.8 WASTE MANAGEMENT AND DISPOSAL

1.8.1 Gaseous and Airborne Particulate

The only radioactive airborne effluent at the Crow Butte Project and MEA is radon-222 gas. As yellowcake drying and packaging at the CPF is carried out using a vacuum dryer, there are no airborne effluents from that system.

The radon-222 is contained in the pregnant lixiviant that comes from the wellfield to the process plant and satellite plant. The majority of this radon is released in the ion exchange columns and process tanks. These vessels are covered and vented to a manifold, which are in turn exhausted to atmosphere outside the building through stacks. The manifolds are equipped with an exhaust fan.

1.8.2 Liquid Waste

1.8.2.1 Crow Butte Project

There are currently three wastewater disposal options for the Crow Butte Project: evaporation in solar evaporation ponds, deep well injection, and land application. The specific method utilized depends upon the volume and characterization of the waste stream.

The operation of the CPF results in three sources of water that are collected on the site. They include the following:

- **Water generated during well development** – This water is recovered groundwater that has not been exposed to any mining process or chemicals. The water is discharged directly to one of the solar evaporation ponds and silt, fines and other natural suspended matter collected during well development is settled out. This water may be used in plant processing, disposed of in a deep disposal well, or land applied following treatment.
- **Liquid process waste** – The operation of the process plant results in two primary sources of liquid waste, an eluant bleed and a production bleed. This water is also routed to the evaporation ponds or injected into the deep disposal well.
- **Aquifer restoration -** Following mining operations, restoration of the affected aquifer commences which results in the production of wastewater. The restoration waste is primarily brine from the reverse osmosis unit, which is sent to the waste disposal system. The permeate is either reinjected into the wellfield or sent to the waste disposal system.

Domestic waste is disposed of in an approved septic system.

1.8.2.2 Marsland Expansion Area

The proposed method of disposal at the MEA is injection into a deep disposal well (DDW) without supporting surge/evaporation ponds or surge tanks. There are currently no plans for any point source discharges or land application of wastewaters. However, the land application option could be applied in the future if such disposal is deemed feasible and more beneficial for a specific wastewater stream. The land application option would require an NRC license amendment and a discharge permit from the NDEE.

The operation of the MEA satellite plant will result in the following liquid waste streams:

- **Water generated during well development** – This water is recovered groundwater similar to well development water currently produced at the CPF. This water will be injected into the onsite DDW.
- **Liquid process waste** – The operation of the satellite facility will result in one primary source of liquid waste - a production bleed. This bleed will be routed to the onsite DDW.
- **Aquifer restoration** – Restoration of the affected aquifer (which commences following mining operation) results in the production of wastewater similar to that produced during current restoration activities at the CPF. This wastewater will be injected into the onsite DDW.

Domestic sewage will be disposed of in an onsite wastewater treatment (i.e., septic) system permitted by the NDEE under the Class V UIC Regulations.

Based on the proposed project development schedule and the water balance for the MEA, liquid waste disposal methods will be phased. For approximately the first 6 years of operation, the MEA operations will discharge liquid waste to storage tanks located in the satellite building, which will discharge to two onsite DDWs. The proposed waste management system will be sufficient to handle the total quantities of liquid waste that will be generated and require disposal.

When restoration flows increase, additional liquid waste management and controls will be needed, because the increased flows are expected to exceed the capacity of two DDWs. CBR will use the first 5 to 6 years of operation to assess the maximum injection rates of the DDWs and the overall efficiency of the liquid waste management system. Efforts will be made to maximize the DDW injection rates, minimize the amounts of liquid waste generated during operation and restoration, better quantify actual liquid waste flows, and further assess viable waste management alternatives and environmental implications. This time period will allow CBR time to develop an updated waste management system that will provide the most optimum long-term economic and technically viable approach to managing liquid waste. Additional liquid waste management systems to be evaluated include additional DDWs, surge tanks, surge/evaporation ponds, land application, treatment with a permitted discharge, and process optimization/modifications to minimize liquid waste generation. CBR will submit an evaluation for proposed changes to the liquid waste management system for NRC written verification and if necessary submit a license amendment request.

1.8.3 Solid Waste

Solid wastes generated at the site consist of spent resin, resin fines, filters, empty reagent containers, miscellaneous pipe and fittings, and domestic waste. These wastes are classified as contaminated 11e.(2) byproduct material or non-contaminated waste according to radiological survey results. Contaminated byproduct waste that cannot be decontaminated is packaged and stored until it can be shipped to a licensed 11e.(2) byproduct material waste disposal site or licensed mill tailings facility. Non-contaminated solid waste is collected on the site on a regular basis and disposed of in a sanitary landfill permitted by the NDEE.

1.8.4 Contaminated Equipment

Materials and equipment that become contaminated as a result of normal operations are decontaminated if possible and disposed of by conventional methods. Equipment and materials that cannot be decontaminated are treated in the same manner as other contaminated solid waste.

1.9 GROUNDWATER RESTORATION

Restoration activities will be carried out concurrent within mining activities. The restoration process will be similar to that used to restore the mine units at the Crow Butte Project and include the following:

- **Groundwater transfer** – groundwater is transferred between the MU commencing restoration and an MU commencing production or another water source.
- **Groundwater sweep** – water is pumped from the wellfield with no injection, which results in an influx of baseline quality water from the wellfield perimeter.
- **Groundwater treatment** – water from production wells is pumped to the satellite plant, where combinations of ion exchange (IX), RO, filtration, and other treatment methods take place.
- **Wellfield recirculation** – water is recirculated from the production wells and reinjecting the solution. This homogenizes the quality of the aquifer.

Following these restoration phases, a groundwater stabilization monitoring program is initiated. Once the restoration values are reached and maintained, restoration is deemed complete. Results are documented in a Restoration Report and submitted to the NDEE and NRC for approval. Groundwater restoration is described in more detail in Chapter 6.

1.10 DECOMMISSIONING AND RECLAMATION

At the completion of mine life and after groundwater restoration has been completed, all injection and recovery wells will be plugged and the site decommissioned. Decommissioning will include plant disassembly and disposal, pond reclamation and land reclamation of all disturbed areas. Applicable NRC Regulatory Guidelines will be followed. Decommissioning and reclamation are discussed in more detail in Chapter 6.

1.11 SURETY ARRANGEMENTS

CBR maintains a NRC-approved financial surety arrangement consistent with 10 CFR 40, Appendix A, Criterion 9 to cover the estimated costs of reclamation activities. Crow Butte maintains an Irrevocable Standby Letter of Credit issued by the Royal Bank of Canada in favor of the State of Nebraska in the present amount of $62,605,869. The surety amount will be revised annually in accordance with the requirements of SUA-1534.

1.12 REFERENCES

CBR (Crow Butte Resources), 2012, Application for Amendment of USNRC Source Materials License SUA-1534, Marsland Expansion Area Crawford, Nebraska Environmental Report. ADAMS Accession Nos. ML12160A513, ML12160A515, ML12160A517, ML12160A518, ML12160A519, ML12160A520, ML12160A523, ML12160A524, ML12160A525, and ML12160A526.

CBR (Crow Butte Resources), 2015, Submittal of Revised Marsland Expansion Area Technical Report, incorporating all Responses to the Request for Additional Information Received During Period May 2012 through September 2015. ADAMS Accession No. ML15328A422.

NRC (U.S. Nuclear Regulatory Commission), 2003a, NUREG-1569, Standard Review Plan for In Situ Leach Uranium Extraction License Applications.

NRC (U.S. Nuclear Regulatory Commission), 2003b, NUREG-1748, Environmental Review Guidance for Licensing Actions Associated with NMSS Programs.

NRC (U.S. Nuclear Regulatory Commission), 2014, Final Environmental Assessment for the License Renewal of U.S. Nuclear Regulatory Commission License No. SUA-1534. ADAMS Accession No. ML14288A517.

NRC (U.S. Nuclear Regulatory Commission), 2018, Environmental Assessment for the Marsland Expansion Area License Amendment Application. ADAMS Accession No. ML18103A145.

Table 1.1-1. Proposed Modifications to SUA-1534 License Conditions

LC #	*Current License Condition*	*Intent of Modification*	*Proposed License Condition Language*[1]
9.7	The licensee shall follow the guidance set forth in NRC Regulatory Guide 8.22, “Bioassay at Uranium Mills” (as revised), and 8.30, “Health Physics Surveys in Uranium Recovery Facilities” (as revised), or NRC-approved equivalent. The licensee shall follow the guidance set forth in Regulatory Guide 8.31, “Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facilities Will Be as Low as Is Reasonably Achievable” (as revised), or NRC approved equivalent, with the following exception: The licensee may identify one or more qualified designees to perform daily inspections in the occupational absence of the radiation safety officer (RSO) and health physics technicians (HPTs). A qualified designee will meet the minimum qualifications and perform only those duties as outlined for a qualified Designated Operator as specified in the licensee’s submittals dated March 4, 2014 (ML14064A143) and May 15, 2014 (ML14135A414). A qualified designee may perform daily inspections on weekends, holidays, and times when both the RSO and HPTs must both be absent (e.g., illness or offsite training). With the exceptions of those instances when a Federal holiday falls on a Friday or Monday, the Thanksgiving holiday, or a site closure due to weather or other safety or security related event, qualified designees will not conduct the daily inspections for more than a total of two days per week. When a Federal holiday falls on a Friday or Monday, qualified designees may perform the daily inspections for a total of three consecutive days. For the Thanksgiving holiday only, qualified designees may perform the daily inspections for a total of four consecutive days. When weather or other safety or security related event causes a site closure, a qualified designee, if available, will continue performing the daily inspections until the RSO or HPT can access the site after such an event. The licensee will also have the RSO or HPT available by telephone while a qualified designee is performing the daily inspections. Reports generated by a qualified designee will be reviewed by the RSO or an HPT as soon as practicable, but not later than the close of business of the next work day following an absence (including site closure due to weather or other safety or security related event), weekend, or holiday. The RSO or HPT review shall be annotated with date and time on the report or other document that can be inspected upon request.	Revise for more flexibility. See Section 5.5.4 of this LRA.	The licensee shall follow the guidance set forth in NRC Regulatory Guide 8.22, “Bioassay at Uranium Mills” (as revised), and 8.30, “Health Physics Surveys in Uranium Recovery Facilities” (as revised), or NRC-approved equivalent. The licensee shall follow the guidance set forth in Regulatory Guide 8.31, “Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facilities Will Be as Low as Is Reasonably Achievable” (as revised), or NRC approved equivalent, with the following exception: The licensee may identify one or more qualified designees to perform daily inspections in the occupational absence of the radiation safety officer (RSO) and health physics technicians (HPTs). A qualified designee will meet the minimum qualifications and perform only those duties as outlined for a qualified Designated Operator as specified in the licensee’s submittals dated March 4, 2014 (ML14064A143) and May 15, 2014 (ML14135A414). ~~A qualified designee may perform daily inspections on weekends, holidays, and times when both the RSO and HPTs must both be absent (e.g., illness or offsite training). With the exceptions of those instances when a Federal holiday falls on a Friday or Monday, the Thanksgiving holiday, or a site closure due to weather or other safety or security related event, qualified designees will not conduct the daily inspections for more than a total of two days per week. When a Federal holiday falls on a Friday or Monday, qualified designees may perform the daily inspections for a total of three consecutive days. For the Thanksgiving holiday only, qualified designees may perform the daily inspections for a total of four consecutive days. When weather or other safety or security related event causes a site closure, a qualified designee, if available, will continue performing the daily inspections until the RSO or HPT can access the site after such an event. The licensee will also have the RSO or HPT available by telephone while a qualified designee is performing the daily inspections.~~ A qualified designated operator may only perform the daily inspections on weekends, holidays, and times when no adequately qualified health physics staff (RSO, HPT) are available to perform the inspection (e.g. illness, offsite training, periods of leave). With the exceptions of those instances when observed holidays, in conjunction with health physics staff’s scheduled time off (e.g. weekends or other leave), or a site closure due to weather or other safety or security related event, qualified designated operators will not conduct the inspection for more than two days per week. When an observed holiday falls on a Friday or Monday, qualified designated operators may perform the daily inspections for a total of three consecutive days. For those instances where the observed holiday in conjunction with health physics staff’s scheduled time off results in the absence of health physics staff for greater than three consecutive days (Thanksgiving, Christmas, etc.), a qualified designated operator may perform the daily inspections for a total of four consecutive days. When a weather or other safety or security related event causes a site closure or inability to safely access the site, a qualified designated operator, if available, will continue performing the daily inspections until an RSO or HPT can access the site after such an event. The licensee will also have the RSO or HPT available by telephone while a qualified designated operator is performing the daily inspections. Reports generated by a qualified designee will be reviewed by the RSO or an HPT as soon as practicable, but not later than the close of business of the next work day following an absence (including site closure due to weather or other safety or security related event), weekend, or holiday. The RSO or HPT review shall be annotated with date and time on the report or other document that can be inspected upon request.

Table 1.1-1. Proposed Modifications to SUA-1534 License Conditions

LC #	*Current License Condition*	*Intent of Modification*	*Proposed License Condition Language[1]*
10.2.1	Emission Controls (Dryer). The licensee shall maintain effluent control systems as specified in Sections 4.1 and 5.8.1 of the approved license application, with the following exceptions: A) If any of the yellowcake emission control equipment fails to operate within specifications set forth in the standard operating procedures, the drying and packaging room shall immediately be closed-in as an airborne radiation area and heating operations shall be switched to cooldown, or packaging operations shall be temporarily suspended. Packaging operations shall not be resumed until the vacuum system is operational to draw air into the system. B) The licensee shall, during all periods of yellowcake drying operations, assure that the negative pressure specified in the standard operating procedures for the dryer heating chamber is maintained. This shall be accomplished by: (1) performing and documenting checks of air pressure differential approximately every four hours during operation; or (2) installing instrumentation which will signal an audible alarm if the water flow or air pressure differential falls below the recommended levels. If an audible alarm is used, its operation shall be checked and documented at the beginning and end of each drying cycle when the differential pressure is lowered.	Correct section number reference to align with the LRA section.	Emission Controls (Dryer). The licensee shall maintain effluent control systems as specified in Sections 4.1 and ~~5.8.1~~ 5.7.1 of the approved license application, with the following exceptions: A) If any of the yellowcake emission control equipment fails to operate within specifications set forth in the standard operating procedures, the drying and packaging room shall immediately be closed-in as an airborne radiation area and heating operations shall be switched to cooldown, or packaging operations shall be temporarily suspended. Packaging operations shall not be resumed until the vacuum system is operational to draw air into the system. B) The licensee shall, during all periods of yellowcake drying operations, assure that the negative pressure specified in the standard operating procedures for the dryer heating chamber is maintained. This shall be accomplished by: (1) performing and documenting checks of air pressure differential approximately every four hours during operation; or (2) installing instrumentation which will signal an audible alarm if the water flow or air pressure differential falls below the recommended levels. If an audible alarm is used, its operation shall be checked and documented at the beginning and end of each drying cycle when the differential pressure is lowered.
11.1.3	Establishment of Background Water Quality. Prior to injection of lixiviant for each mine unit, the licensee shall establish background ground water quality data for the ore zone and overlying aquifers. The background water quality will be used to define the background ground water protection standards required to be met in 10 CFR Part 40, Appendix A, Criterion 5B(5), for the ore zone aquifer and surrounding aquifers. Water quality sampling shall provide representative background ground water quality data and restoration criteria as described in Sections 5.8.8 and 6.1.3 of the approved Crow Butte Project license application and Sections 5.7.9 and 6.1.3 of the approved Marsland Expansion Area license application. The data shall consist, at a minimum, of the following sampling and analyses: A) Four samples shall be collected from production and injection wells at a minimum density of one production or injection well per four acres. These samples shall be collected at least 14 days apart. B) Four samples shall be collected from each designated monitoring well at a minimum density of: 1) one upper aquifer monitoring well per five acres of mine unit area, and 2) all perimeter monitoring wells. These samples shall be collected at least 14 days apart. The results of these analyses shall constitute the baseline for each designated well. C) The samples shall be analyzed for ammonia, arsenic, barium, cadmium, calcium, chloride, copper, fluoride, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, nitrate, pH, potassium, radium-226, selenium, sodium, sulfate, total carbonate, total dissolved solids, uranium, vanadium, zinc, and gross alpha. D) Prior to operation of a mine unit, representative background concentrations shall be established on a parameter-by-parameter basis using either the mine unit or well-specific mean value or other NRC-approved statistically valid analysis.	Correct section number reference to align with the LRA sections.	Establishment of Background Water Quality. Prior to injection of lixiviant for each mine unit, the licensee shall establish background ground water quality data for the ore zone and overlying aquifers. The background water quality will be used to define the background ground water protection standards required to be met in 10 CFR Part 40, Appendix A, Criterion 5B(5), for the ore zone aquifer and surrounding aquifers. Water quality sampling shall provide representative background ground water quality data and restoration criteria as described in Sections ~~5.8.8~~ 5.7.8 and 6.1.3 of the approved ~~Crow Butte Project license application and Sections 5.7.9 and 6.1.3 of the approved Marsland Expansion Area~~ license application. The data shall consist, at a minimum, of the following sampling and analyses: A) Four samples shall be collected from production and injection wells at a minimum density of one production or injection well per four acres. These samples shall be collected at least 14 days apart. B) Four samples shall be collected from each designated monitoring well at a minimum density of: 1) one upper aquifer monitoring well per five acres of mine unit area, and 2) all perimeter monitoring wells. These samples shall be collected at least 14 days apart. The results of these analyses shall constitute the baseline for each designated well. C) The samples shall be analyzed for ammonia, arsenic, barium, cadmium, calcium, chloride, copper, fluoride, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, nitrate, pH, potassium, radium-226, selenium, sodium, sulfate, total carbonate, total dissolved solids, uranium, vanadium, zinc, and gross alpha. D) Prior to operation of a mine unit, representative background concentrations shall be established on a parameter-by-parameter basis using either the mine unit or well-specific mean value or other NRC-approved statistically valid analysis.
11.1.9	The licensee shall develop a survey program for beta/gamma contamination for personnel exiting from restricted areas, and beta/gamma contamination in unrestricted and restricted areas that will meet the requirements of 10 CFR Part 20, Subpart F and submit the program to NRC for review and written verification. The licensee shall provide for NRC review and written verification the surface contamination detection capability (minimum detection concentration (MDC)) for radiation survey instruments, including scan MDC for portable instruments, used for contamination surveys to release equipment and materials for unrestricted use and for personnel contamination surveys. The detection capability in the scanning mode for the alpha and beta radiation expected shall be provided in terms of dpm per 100 cm^2.	Remove survey program for beta/gamma contamination for personnel exiting from restricted areas. As described in Section 5.7.6.4 of this LRA, surveys for the presence of alpha contamination adequately demonstrate the presence of contamination on skin and personal clothing. Based on this and in alignment with RG 8.30, Section 2.6, CBR proposes to continue alpha surveys for contamination of skin and personal clothing.	The licensee shall develop a survey program for ~~beta/gamma contamination for personnel exiting from restricted areas, and~~ beta/gamma contamination in unrestricted and restricted areas that will meet the requirements of 10 CFR Part 20, Subpart F and submit the program to NRC for review and written verification. The licensee shall provide for NRC review and written verification the surface contamination detection capability (minimum detection concentration (MDC)) for radiation survey instruments, including scan MDC for portable instruments, used for contamination surveys to release equipment and materials for unrestricted use ~~and for personnel contamination surveys~~. The detection capability in the scanning mode for the alpha and beta radiation expected shall be provided in terms of dpm per 100 cm^2.

Table 1.1-1. Proposed Modifications to SUA-1534 License Conditions

LC #	*Current License Condition*	*Intent of Modification*	*Proposed License Condition Language[1]*
11.2.3	The licensee shall establish and conduct an effluent and environmental monitoring program in accordance with the program described in Sections 5.8.7 (Airborne Effluent and Environmental Monitoring Programs) and 5.8.8 (Groundwater/Surface Water Monitoring Program) of the approved application dated November 27, 2007 (ADAMS package ML073480264) as revised by verification submittals dated January 2, 2015, May 11, 2015, June 30, 2015, September 21, 2015, November 24, 2015, and December 4, 2015.	Correct section number reference to align with the LRA sections.	The licensee shall establish and conduct an effluent and environmental monitoring program in accordance with the program described in Sections ~~5.8.7~~ 5.7.7 (Airborne Effluent and Environmental Monitoring Programs) and ~~5.8.8~~ 5.7.8 (Groundwater/Surface Water Monitoring Program) of the approved application dated November 27, 2007 (ADAMS package ML073480264) as revised by verification submittals dated January 2, 2015, May 11, 2015, June 30, 2015, September 21, 2015, November 24, 2015, and December 4, 2015 and the approved license application.

Table 1.2-1. SUA-1534 Notice of Violations

Inspection Date	ADAMS Accession No.	Severity Level	Description
Jun 4-6, 2013	ML13184A360	IV	Failure to ensure that the dose in any unrestricted area does not exceed 2 millirem in one hour
Jun 3-5, 2014	N/A	--	No violations
Mar 8-10, 2016	ML16092A101	IV	Failure to collect required underdrain samples during leak period
		IV	Failure to submit a corrective action plan for a pond liner leak as required
Jun 20-22, 2017	ML17194A721	--	No violations
Nov 5-8, 2018	ML18341A002	--	No violations
Jul 28-Aug 1, 2019	ML19219B387	--	No violations
Aug 2-4, 2022	ML22341A205	IV	Failure to submit a license-required report to the NRC in a timely manner
		IV	Failure to generate a new SERP evaluation to reflect changes in operations
Oct 31-Nov 2, 2023	ML23324A176	IV	Failure to establish program for surveying personal items removed from restricted areas

Table 1.2-2. Self-Identified Violations

Agency	Date	Description
NRC and NDEE	2011	Injection pressure exceeded 100 psi
NRC and NDEE	2011	Missed composite sample for DDW No. 2
NRC and NDEE	2013	Missed daily pond inspection
NRC	2016	Failure to complete radon gas monitoring at all tank vent locations
NRC	2017	Failure to appropriately survey and label an environmental sample prior to shipment
NRC	2018	Use of an incorrect efficiency calculation to calculate removable surface contamination levels
NRC	2021	Use of an out of calibration breathing zone pump calibrator
NRC	2022	Failure to acquire a medical evaluation prior to admitting an employee to the respirator program
NRC	2023	Failure to attain an updated letter of credit

Table 1.3-1. Land Ownership within the Crow Butte License Area

Owner	Percent Ownership
State/Local Government	1.4
Private	98.6

Table 1.7-1. Crow Butte Mine Unit Status

Mine Unit	Production Initiated	Production Ceased	Current Status
1	April 1991		Restored
2	March 1992	January 1996	Stability monitoring
3	January 1993	July 1999	Stability monitoring
4	March 1994	October 2003	Stability monitoring
5	January 1996	August 2007	Stability monitoring
6	March 1998	October 2010	Stability monitoring
7	July 1999	September 2018	Undergoing restoration
8	July 2002	February 2018	Undergoing restoration
9	October 2003	February 2018	Standby
10	August 2007	February 2018	Standby
11	November 2010	February 2018	Standby

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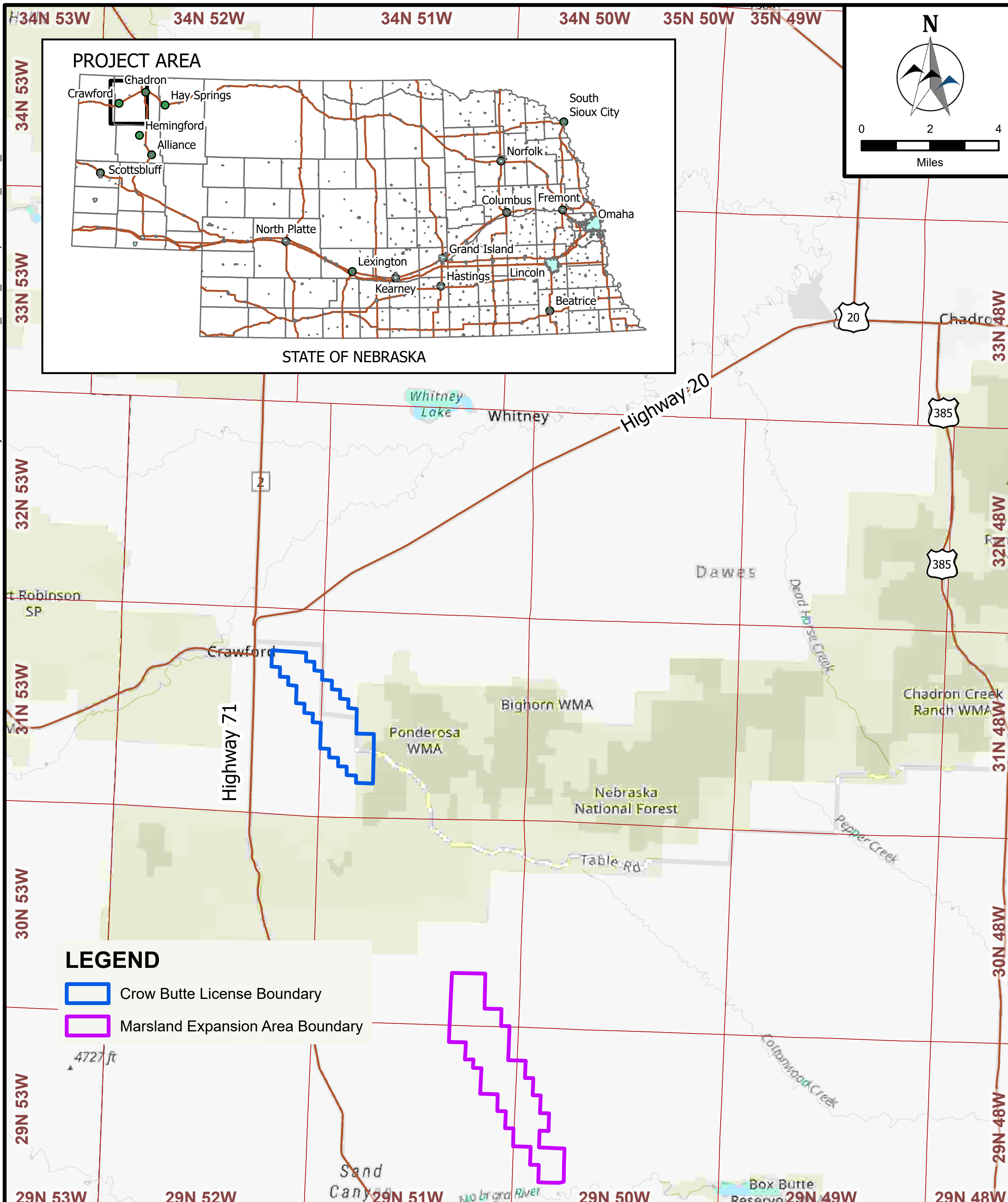

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CROW BUTTE RESOURCES, INC., 86 CROW BUTTE ROAD, CRAWFORD, NE 69339

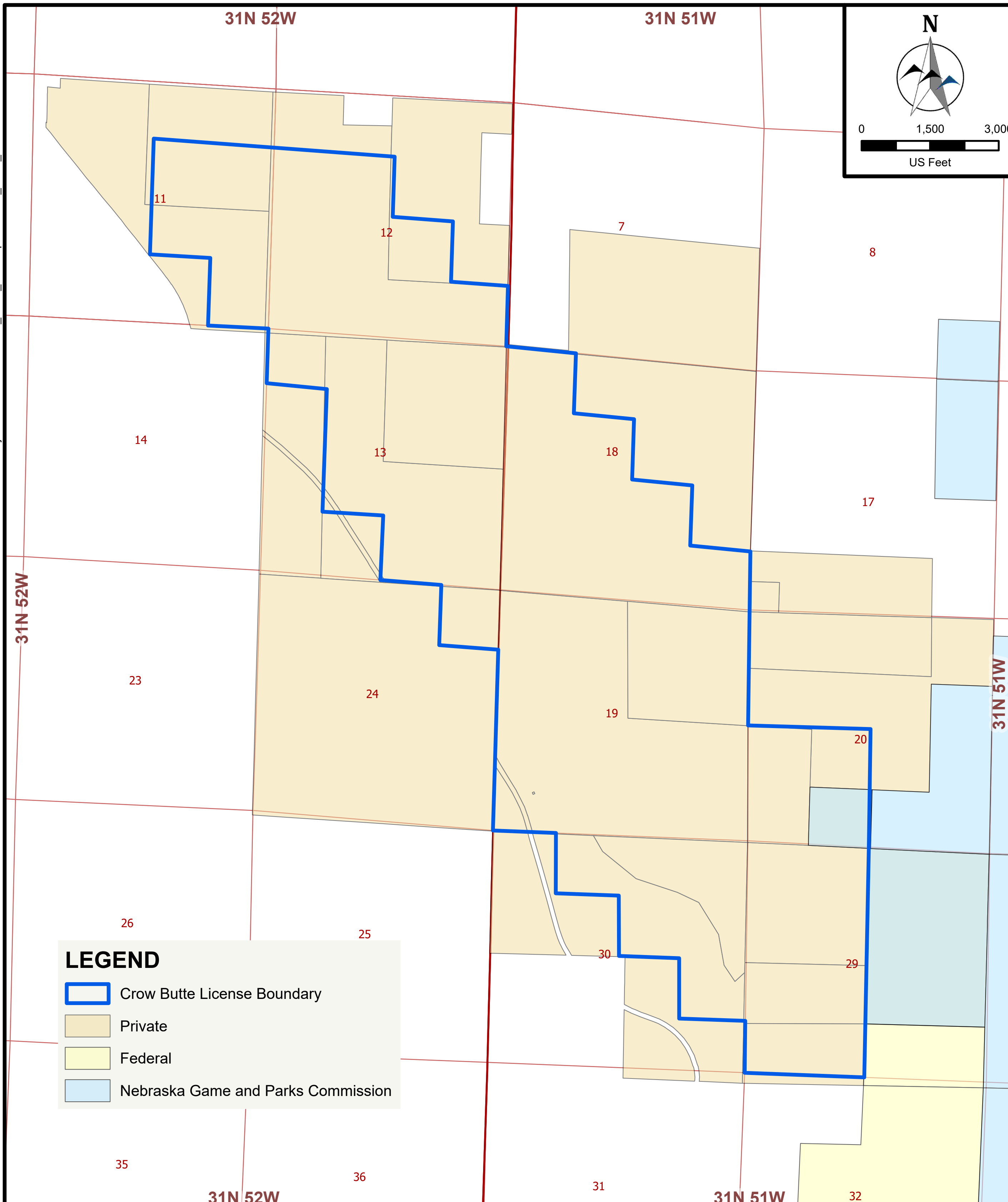
CROW BUTTE RESOURCES, INC.

DAWES COUNTY, NEBRASKA

DRAWN BY:	RAV
CHECKED BY:	BAW
APPROVED BY:	--
DATE:	09/2024

CROW BUTTE PROJECT AND MEA GENERAL LOCATION MAP

FIGURE 1.3-1



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CROW BUTTE RESOURCES, INC.

DAWES COUNTY, NEBRASKA

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APPROVED BY: --
DATE: 09/2024

CROW BUTTE PROJECT SURFACE OWNERSHIP

FIGURE
1.3-2

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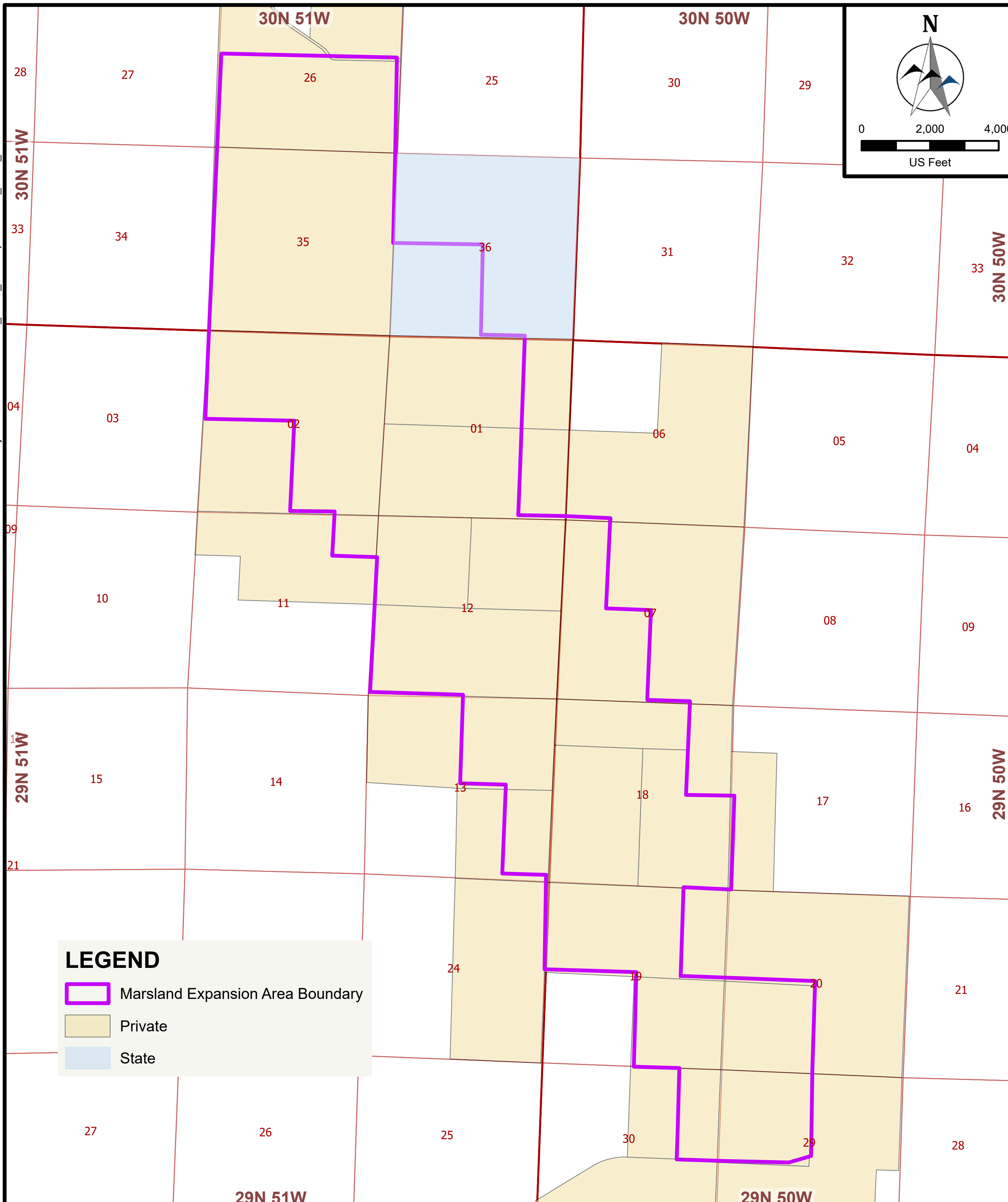

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CROW BUTTE RESOURCES, INC., 86 CROW BUTTE ROAD, CRAWFORD, NE 69339

CROW BUTTE RESOURCES, INC.

DAWES COUNTY, NEBRASKA

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CHECKED BY: BAW
APPROVED BY: ---
DATE: 09/2024

MARSLAND EXPANSION AREA
SURFACE OWNERSHIP

FIGURE
1.3-3

Figure 1.7-1. Crow Butte Project Schedule

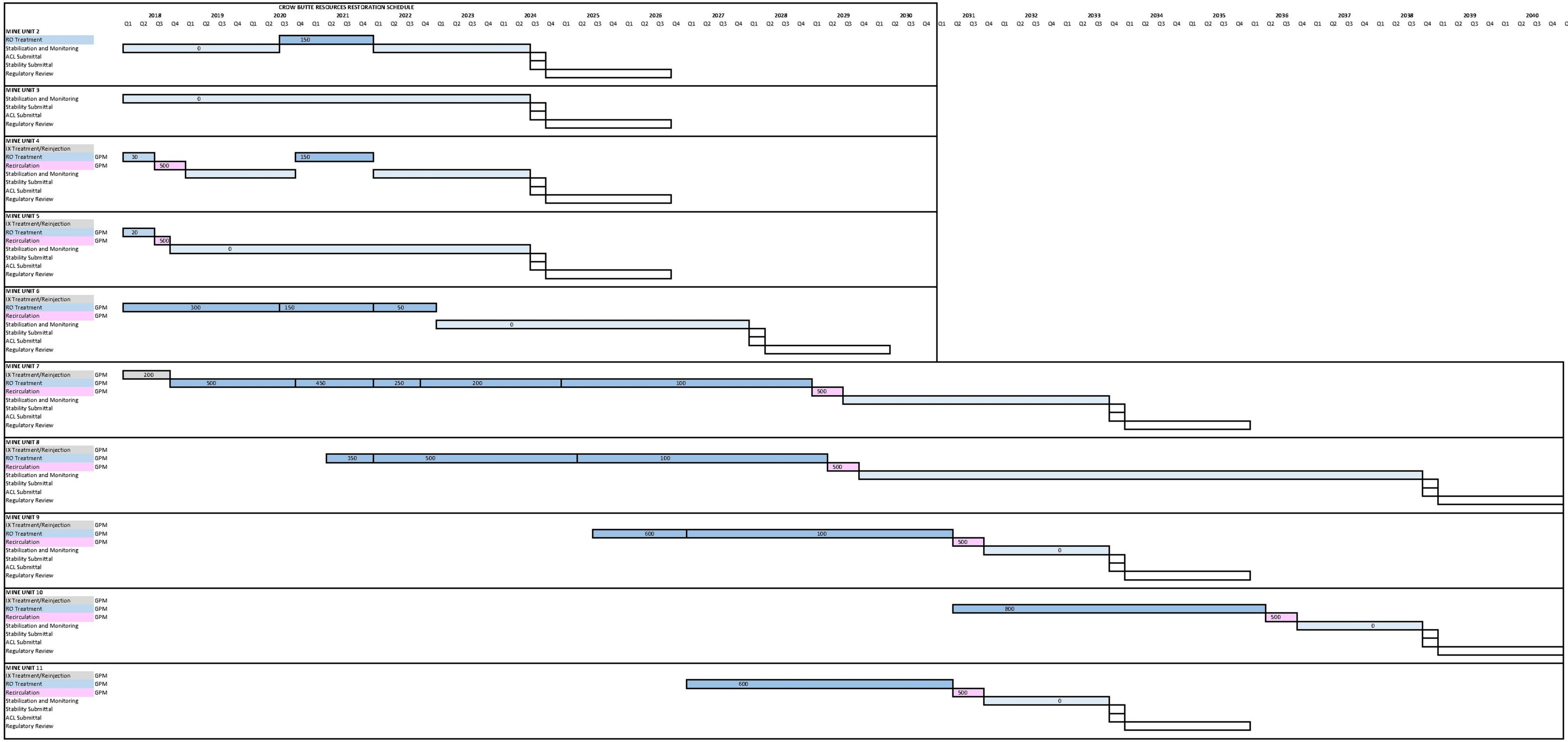
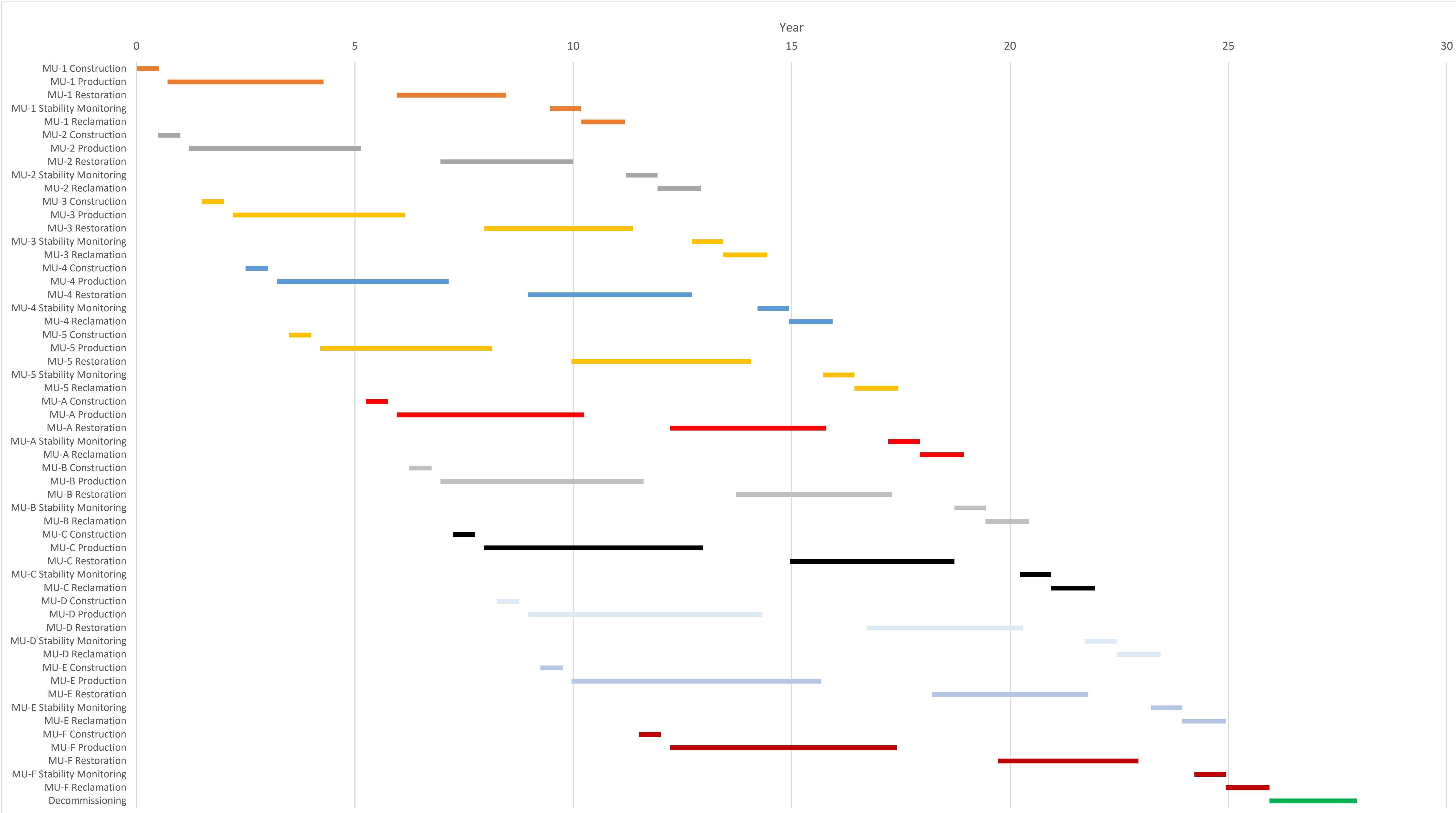


Figure 1.7-2. Marsland Expansion Area Schedule



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2.0 SITE CHARACTERIZATION

2.1 SITE LOCATION AND LAYOUT

Section 2.1 of the 2008 Crow Butte LRA and Section 2.1 of the MEA TR provide a description of the site location and layout. The information from these reports were incorporated into this Combined ER/TR. Based on the information presented in this section there is no significant change between the 2008 Crow Butte LRA, MEA TR and this Combined ER/TR.

2.1.1 Crow Butte Project

The location of the Crow Butte Project is in Sections 11, 12, 13 and 24 of T31N, R52W and Sections 18, 19, 20, 29, and 30 of T31N, R51W, Dawes County, Nebraska. The CPF is located in Section 19 of T31N, R51W.

Figure 2.1-1 shows the general project location with topographical features, drainage and surface water features, nearby population centers as well as principal highways, railroads, and waterways. Access to the site is from State Highway (SH) 71 from points north and south of Crawford. U.S. Highway 20 provides access from points east and west.

Figure 3.1-4 shows the site layout for the Crow Butte Project including the CPF area, the R&D facility, the current mine unit boundaries, the deep disposal well, and the R&D and commercial evaporation ponds. Buildings and storage areas that have been constructed since the most recent license renewal, (maintenance, electrical, storage and drilling supply buildings), are illustrated along with the expansions of the Main Plant offices and RO building area.

2.1.2 Marsland Expansion Area

The location of the MEA is Sections 26, 35, 36 of T30N, R51W, Sections 1, 2, 11, 12, and 13 of T29N, R51W, and Sections 7, 18, 19, 20, 29, 30 of T29N, R50W, Dawes County, Nebraska. The MEA is located approximately 4.6 miles northeast of the unincorporated community of Marsland, Nebraska.

Figure 2.1-2 shows topographical features, drainages and surface water features, nearby population centers, principal highways, railroads, and waterways. The main access route to the MEA is via SH 2/71 west of Marsland, then east along the Niobrara River and River Road, and then north on either Squaw Mound Road or Hollibaugh Road.

Figure 3.1-6 depicts the proposed location of the satellite facility, mine units, access roads, and DDWs within the MEA.

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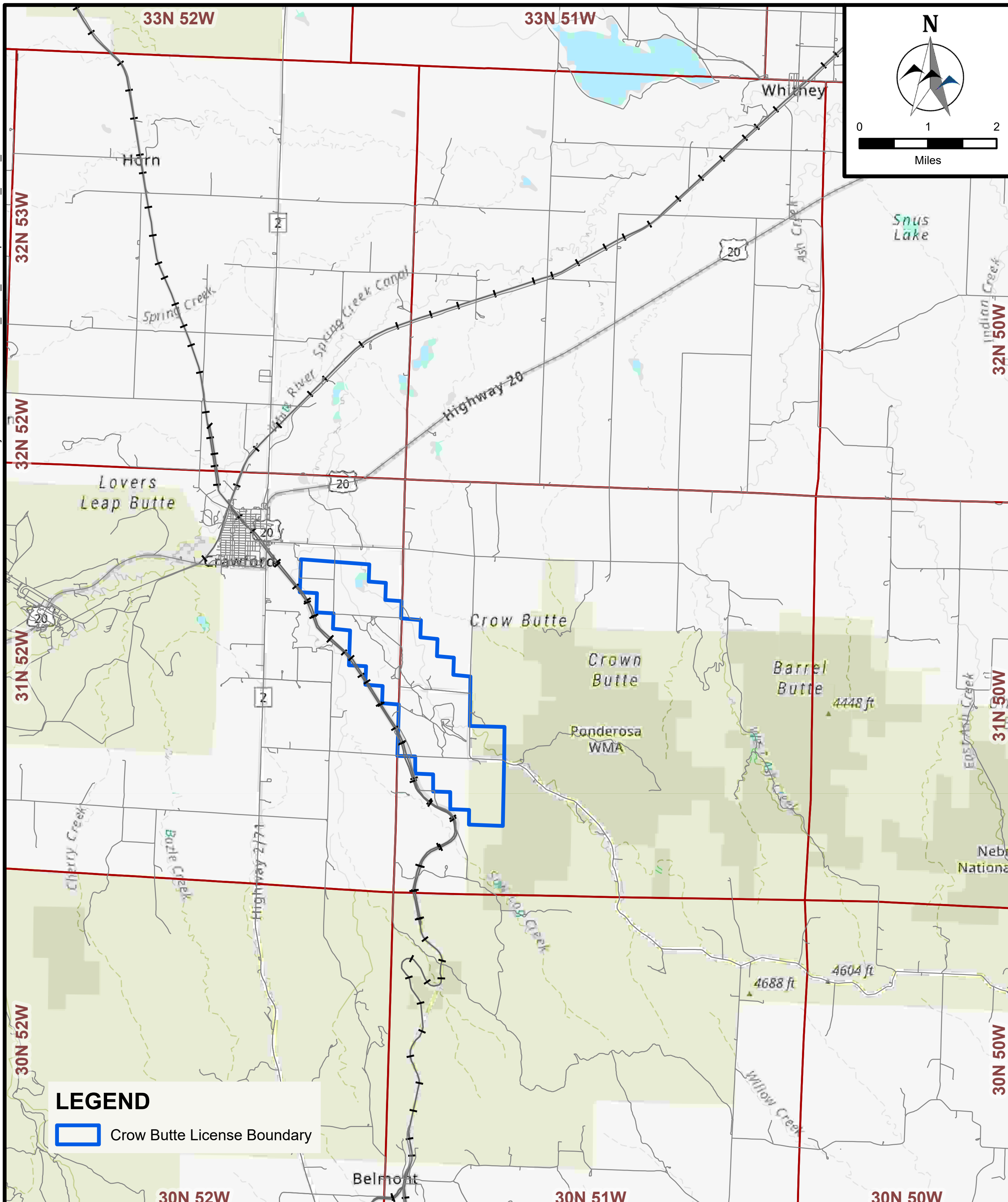

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CROW BUTTE RESOURCES, INC.

DAWES COUNTY, NEBRASKA

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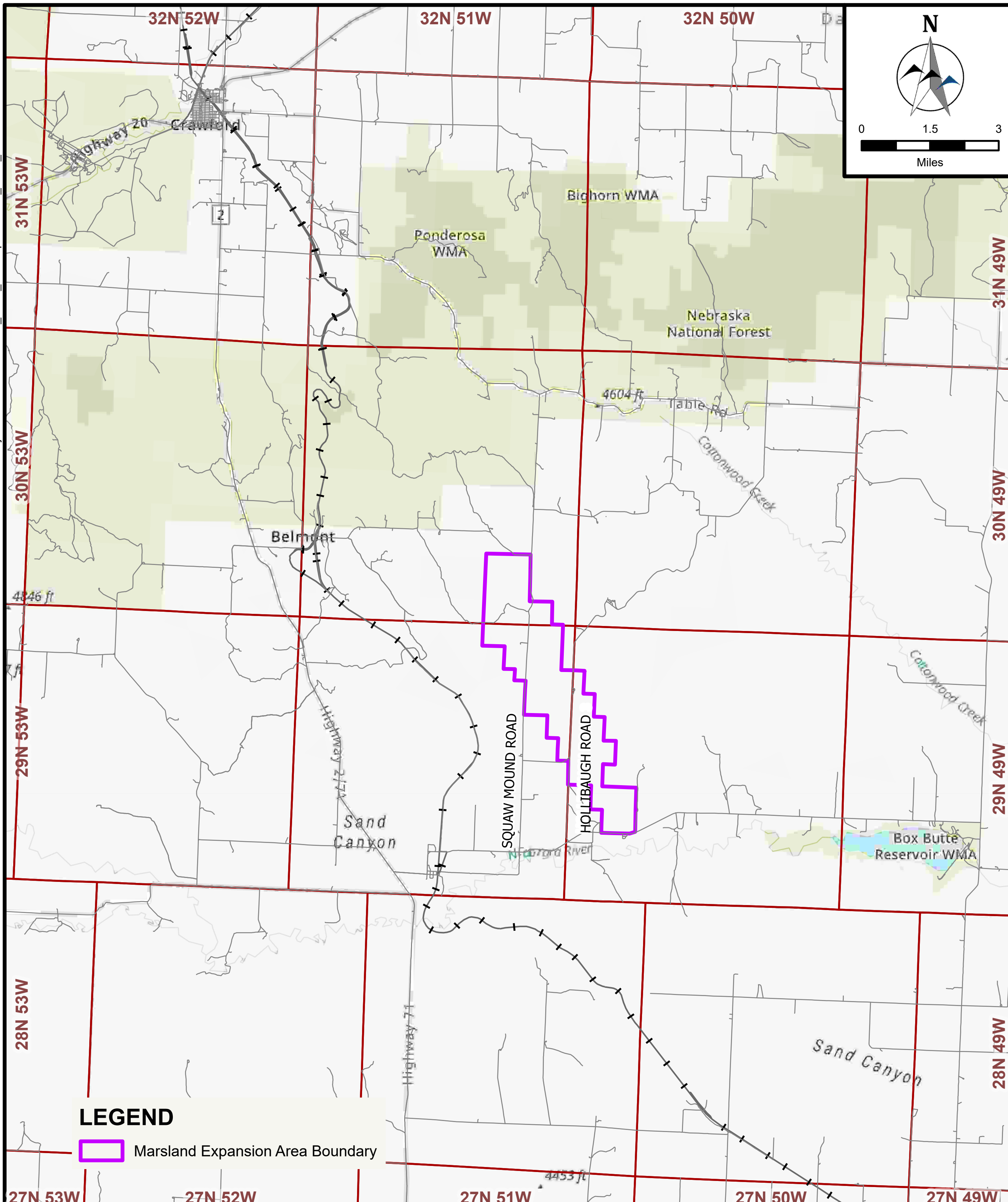
CHECKED BY: BAW
APPROVED BY: --
DATE: 09/2024

CROW BUTTE PROJECT
GENERAL LOCATION

FIGURE
2.1-1



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CROW BUTTE RESOURCES, INC.

DAWES COUNTY, NEBRASKA

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CHECKED BY:	BAW
APPROVED BY:	---
DATE:	09/2024

MARSLAND EXPANSION AREA GENERAL LOCATION

FIGURE 2.1-2

2.2 USES OF ADJACENT LANDS AND WATERS

Section 2.2 of the 2008 Crow Butte LRA and Section 2.2 of the MEA TR provide a general discussion of uses of adjacent lands and water. The information from these reports were incorporated into this Combined ER/TR. This section provides updated information regarding land use, agriculture, recreation, residences, industrial and mining, transportation, and water use. Based on the information presented in this there is no significant change between the 2008 Crow Butte LRA, MEA TR and this Combined ER/TR.

This section evaluates the effects of the Crow Butte Project and MEA on the physical, ecological, and social characteristics of the surrounding environments. NUREG-1569 requires a discussion of land and water use within the Crow Butte Project and MEA and within a 3.2-km (2.0-mile) distance from each site boundary. The NDEE requires an assessment of a 3.6-km (2.25-mile) radius of the site boundaries for Class III UIC applications. Therefore, the NUREG-1569 radius has been extended to 3.6 km (2.25 miles) for consistency. This area is referred to as the Area of Review (AOR).

2.2.1 General Setting

2.2.1.1 Crow Butte Project

The Crow Butte Project site is located in west central Dawes County, Nebraska, just north and west of the Pine Ridge Area. Figure 2.1-1 shows the general location of the project site. The Crow Butte Project site is about 4.0 miles southeast of the City of Crawford via Squaw Creek Road.

Areas of disturbance currently within the license area include the CPF area, ponds, wellfields and associated appurtenances in Mine Units 1-11, roads, utilities, and activities associated with agriculture.

2.2.1.2 Marsland Expansion Area

The MEA is located in southwestern Dawes County, Nebraska, just south of the Pine Ridge. The MEA is located approximately 6.4 km (4.6 miles) northeast of the community of Marsland (Figure 2.1-2). No disturbance has occurred within the MEA license area.

2.2.2 Land Use

2.2.2.1 Crow Butte Project

Land uses found within the Crow Butte Project and the AOR are depicted in Figure 2.2-1. Table 2.2-1 explains each of the land use types. Table 2.2-2 presents land uses within the Crow Butte Project area and AOR.

Herbaceous comprises the greatest portion of land use within the Crow Butte Project and AOR area (66 percent) and is used for hay production. Within the project area emergent herbaceous wetland (4.5 percent) and cultivated crops (3.5 percent) are the other significant land uses.

Residential and industrial land uses in the county are concentrated within the city limits of Crawford and Chadron. Industrial land uses are located within the city limits of Crawford and occur primarily around railroad facilities.

2.2.2.2 *Marsland Expansion Area*

Land use of the MEA and surrounding AOR is dominated by agricultural uses (Figure 2.2-2). Table 2.2-3 lists the major land use types by acreage within the MEA and AOR.

Herbaceous comprises the greatest land cover within the AOR (83 percent). Within the project area cultivated crops (5.3 percent) and evergreen forests (3.3 percent) are the other significant land cover types. Scattered rural residences are mostly associated with agricultural operations.

2.2.3 Agriculture

In 2022, Dawes County generated $60.2 million from the sale of livestock, poultry and their products, which is up from $47.0 million in 2017 (USDA-NASS 2019, 2024). Table 2.2-4 provides the 2022 livestock inventory for Dawes County. Cattle accounted for over 92 percent of the livestock within the county. According to the most recent agricultural census data (2022), there are 1,074 horses and ponies in Dawes County.

Table 2.2-5 shows agricultural yields for croplands in Dawes County (USDA-NASS 2024). Wheat and hay are the major crops grown on croplands within the license areas. Most of these crops are used for livestock feed, while the remaining crops are commercially sold.

2.2.4 Recreation

There are no recreational facilities within the Crow Butte Project or the MEA. However, recreational lands are present in Dawes County. Table 2.2-6 and Figure 2.2-3 provide the recreational opportunities within 4 km (2.5 miles) of the Crow Butte Project and the MEA. The table include the approximate distance to each recreational facility from both the Crow Butte Project and the MEA.

Fort Robinson State Park, the largest state park in Nebraska, is located within the Crow Butte Project AOR. The state park is west of Crawford and includes portions of the Red Cloud Agency Historical Site, the White River Trail, and several scenic landforms in a rugged area of buttes and ponderosa pine forest. Other facilities at the park include lodging, showers, electrical hookups, pit toilets, ski and snowmobile trails, a rodeo arena, and a museum. Visitors to the park may go hunting, fishing, hiking, swimming, or horseback riding. Other recreational facilities in Dawes County include the Nebraska National Forest, Box Butte Reservoir State Recreation Area as well as the Fort Robinson and Chadron State Parks.

Recreational opportunities provided by federal and state lands in Dawes County have become an important component of the local economy. 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 of the Nebraska National Forest, and the Oglala National Grassland are increasingly becoming regional tourist destinations.

In 2018, the Nebraska National Forest had 288,000 visitors (USFS 2024). The Nebraska National Forest provides a wide range of other undeveloped backcountry recreation opportunities such as hunting, hiking, backpacking, fishing, horseback riding, off-highway motorized vehicle use, and wildlife observation. Camping and motorized travel/sightseeing are the two most popular recreation categories within the Pine Ridge Ranger District and the Oglala National Grassland.

2.2.5 Residential

A combination of Google Earth and Nebraska Department of Natural Resources (NDNR) aerial imagery was used to identify residences within each license area and the AOR around each license area.

2.2.5.1 *Crow Butte Project*

As of August 2024, there are no occupied dwellings within the Crow Butte Project. There are several within the AOR, including the town of Crawford. In 2020, Crawford had a population of 840 people (U.S. Census Bureau 2024). Residences within and surrounding the Crow Butte Project are depicted on Figure 2.2-4.

Table 2.2-7 shows the distance to the nearest residence and to the nearest site boundary of residences within the AOR from the center of the License area for each 22 ½ sector centered on each compass point. The nearest dwelling is 0.9 mile west-southwest of the center point of the Crow Butte Project.

2.2.5.2 *Marsland Expansion Area*

There are two houses located within the MEA, only one of which is occupied. The occupied residence is located in SW1/4 NW1/4 Section 7 of T29N, R50W, and the unoccupied residence is located in T29N, R50W and SW1/4 NE1/4 Section 2 of T29N, R51W, as shown on Figure 2.2-5. The AOR contains an additional 21 residences.

Table 2.2-8 shows the distance to the nearest residences within the AOR to the nearest site boundary from the center of the MEA for each 22 ½ sector centered on each compass point.

2.2.6 Industrial and Mining

2.2.6.1 *Crow Butte Project*

Besides CBR, Conoco, Amoco Minerals, Sante Fe Mining, and Union Carbide have also drilled exploratory testing holes in the area for a variety of natural resources. Other industrial facilities within the AOR include the railroad station and maintenance yard at the City of Crawford.

There are no other industrial or mining uses within the Crow Butte Project or the AOR. There are gravel pits on Fort Robinson State Park. Most of the pits are inactive, although a few are mined periodically for local road construction purposes.

There are no oil and gas wells within the Crow Butte Project. There are six dry holes within the AOR (Figure 2.2-6).

The nearest licensed uranium recovery facility is the Dewey-Burdock ISR Project, located near Edgemont, South Dakota approximately 65 miles north. No construction has occurred at the Dewey-Burdock ISR Project.

2.2.6.2 *Marsland Expansion Area*

Numerous exploratory wells targeting mineral resources and hydrocarbons have been drilled in the MEA and the AOR. CBR has an ongoing exploratory drilling program that, to date, has completed more than 1,800 drill holes in the MEA. Besides CBR, Conoco, Amoco Minerals, Santa Fe Mining, and Union Carbide have also drilled exploratory test holes for uranium industrial facilities within the AOR.

There is one dry hole within the MEA and four other dry holes within the AOR (Figure 2.2-7). In addition, there is abandoned oil and gas exploratory well within the AOR. Based on review of records, the oil and gas well within the AOR has been plugged and abandoned in accordance with the Nebraska Oil and Gas Conservation Commission.

The nearest uranium recovery facility is the Crow Butte Project, located 11 miles to the north-northeast. The next nearest licensed uranium recovery facility is the Dewey-Burdock ISR Project, located near Edgemont, South Dakota approximately 80 miles north. No construction has occurred at the Dewey-Burdock ISR Project.

2.2.7 Transportation

2.2.7.1 *Crow Butte Project*

SH 2/71 and U.S. Highway 20 converge in Crawford. The annual average daily traffic counts for 2023 range between 1,230 south of Crawford and 575 north of Crawford on Nebraska Highway 2, and 1,500 on U.S. Highway 20 northeast of Crawford (NDOT 2024). Although unpaved, Squaw Creek Road provides access to the Crow Butte Project. Private roads providing access to operational areas of the Crow Butte Project exist and are demarcated by signage to prevent public access.

Maintenance of state and county roads is performed by the Nebraska Department of Transportation (NDOT) and Dawes County, respectively. CBR is responsible for maintenance and upgrades (i.e., grading, watering, and paving) of all private access roads within the license area.

A Burlington Northern Santa Fe (BNSF) Railroad runs in a northwesterly direction approximately 1.2 km (0.75 miles) west of the Crow Butte Project. Several transmission lines traverse the license area.

2.2.7.2 *Marsland Expansion Area*

SH 2/71 runs west of the MEA. It converges with U.S. Highway 20 in the City of Crawford, north-northwest of the MEA. The northern portion of the MEA is accessed from SH 2/71 via East Belmont Road; the southern portion of the MEA is accessed from SH 2/71 via River Road and Hollibaugh Road. The 2023 average daily traffic counts for a segment of Highway 2/71 south of Marsland at the intersection with SH 71 (Dodge Road) was 840 total vehicles, including 95 heavy commercial vehicles. The traffic level on SH 2/71 was 750 total vehicles, including 100 heavy commercial vehicles in the vicinity of East Belmont Road (NDOT 2024). Secondary and private roads connect with East Belmont Road, River Road, Hollibaugh Road, and Squaw Mound Road to provide access to residences and agricultural lands within the MEA.

No railways cross the MEA; a BNSF rail line runs to the west of the MEA and through a small portion of the AOR between the MEA and SH 2/71.

2.2.8 Water Use

Every 5 years since 1950, the U.S. Geological Survey (USGS) assesses U.S. water use and includes water use estimates (USGS 2024). The latest study for the State of Nebraska examined usage in 2015. The USGS compiles these data at the county level to produce water-use information aggregated at the county, state, and national levels.

Estimated water use in 2015 for Dawes County, Nebraska is presented in Table 2.2-9. The total 2015 population served for Dawes County was 7,320 people, with public supply groundwater and surface water use totaling 1,180,000 gallons per day (gpd). Irrigation using groundwater and surface water accounted for a total of 16,700,000 gpd to irrigate an estimated 31,150 acres. Essentially all of the rural residents of Dawes County use groundwater for their domestic supply.

A summary of the number and types of registered non-abandoned water wells located in Dawes County as of July 10, 2024, is presented in Table 2.2-10. Note that this table refers to registered wells. Under current Nebraska law, water supply wells used solely for domestic purposes and completed prior to September 9, 1993, do not have to be registered (Nebraska Statute 46-602). 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 6,193 registered water wells in Dawes County used for a variety of purposes, as presented in Table 2.2-10. According to the Nebraska Department of Natural Resources (NeDNR), there are a total of 289 domestic and 355 livestock wells located in Dawes County (NeDNR 2024). There are 39 public water supply wells located in Dawes County.

2.2.8.1 Crow Butte Project

The Crow Butte Project is drained by Squaw Creek and is within the White River Watershed. Squaw Creek is used by local landowners for irrigation, livestock watering, and domestic purposes, and by fish and wildlife habitat. Figure 2.2-8 depicts the surface water rights within the Crow Butte Project and AOR. Warm-water fishing and hunting also occur downstream from the Crow Butte Project.

The White River supports agricultural production, wildlife habitat, and both warm-and-cold-water fish. Eight surface water impoundments are located within or adjacent to the Crow Butte Project (Figure 2.2-8). These eight impoundments are identified as I-1 through I-8. Impoundments I-1, I-2, I-7, and I-8 are located outside the Crow Butte Project, while impoundments I-3 through I-6 are located inside the Crow Butte Project.

Impoundment I-1 consists of a low earthen berm constructed across an unnamed ephemeral drainage course, which is tributary to Squaw Creek. This berm forms a small seasonal pond which is used for livestock watering. Impoundment I-2 is formed by a small earthen dam on White Clay Creek. Water from this pond is used for livestock watering and crop irrigation. Impoundments I-3, I-4, I-5, and I-7 are formed by small earthen dams across English Creek. Water from these ponds is used for livestock watering. Impoundment I-6 is formed by an earthen dam across Squaw Creek. Water from this pond is used for livestock watering. Impoundment I-8 is located in the alluvial valley of White Clay Creek and is also used for livestock watering.

Groundwater within the AOR is supplied by either the Brule or Chadron Formations (Williams 1982). A water well survey conducted by Wyoming Fuel Company (WFC) indicated that most of the groundwater pumped from wells surveyed within the 3.6-km (2.25-miles) radius of the Crow Butte Project were used either to water livestock or for domestic purposes.

As of April 2025, the NeDNR lists 4,735 active registered wells within the Crow Butte Project and 4,804 active registered wells within the 2.25-mile (3.62-km) AOR of the Crow Butte Project. A summary of the active wells by use is provided in Table 2.2-11. There are no domestic or livestock wells within the Crow Butte Project. The locations of all active wells are depicted on Figure 2.2-9. Table 2.2-11 lists the active wells within the Crow Butte Project and AOR that are not associated with CBR operations and includes well ID, owner, location, pump rate, and total depth.

Crawford's municipal water system, an infiltration gallery, is supplied by two wells which have an average pumping capacity of 155 gallons per minute (City of Crawford 2024). The overhead storage capacity is 1,750,000 gallons with raw water storage of 500,000 gallons. The system has a maximum capacity of 2,830,000 gallons with an average daily demand of 250,000 gallons.

2.2.8.2 Marsland Expansion Area

The MEA is located within the Niobrara River Basin. The distance from the southernmost mine unit in the MEA to the nearest point on the Niobrara River is approximately 0.42 mile (0.7 km). The Niobrara River is used for irrigation outside of the MEA license area, but within the AOR as depicted on Figure 2.2-10. Based on available maps and site investigations conducted by CBR, no surface water impoundments, lakes, or ponds have been identified within the MEA.

As of April 2025, the NeDNR lists 60 active wells within the 2.25-mile (3.62-km) AOR of the MEA. A summary of the active wells by use is provided in Table 2.2-13. There are 2 livestock wells and 1 irrigation well located within the MEA. The locations of the active wells are depicted on Figure 2.2-11. Table 2.2-14 lists the active wells within the MEA and AOR and includes well ID, owner, location, pump rate, and total depth.

2.2.9 References

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Table 2.2-1. Major Land Use Definitions

NLCD Land Use	Rating Criteria
Barren Land	Generally, vegetation accounts for less than 15% of total cover.
Cultivated Crops	Areas used for the production of annual crops. Crop vegetation accounts for greater than 20% of total vegetation.
Deciduous Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
Developed, High Intensity	Highly developed areas where people reside or work in high numbers. Impervious surfaces account for 80% to 100% of the total cover.
Developed, Low Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover.
Developed, Medium Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover.
Developed, Open Space	Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Evergreen Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
Hay/Pasture	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
Herbaceous	Areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation.
Mixed Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
Open Water	Areas of open water, generally with less than 25% cover of vegetation or soil.
Shrub/Scrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation.
Woody Wetlands	Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Source: MRLC 2024

Table 2.2-2. Land Use within the Crow Butte Project and AOR

Land Use Type	Crow Butte Project		Crow Butte Project and 2.25-mile AOR	
	acres	%	acres	%
Cultivated Crops	99	3.5%	3,621	12.5%
Deciduous Forest	7	0.2%	77	0.3%
Developed, High Intensity	1	0.0%	53	0.2%
Developed, Low Intensity	19	0.7%	540	1.9%
Developed, Medium Intensity	8	0.3%	222	0.8%
Developed, Open Space	9	0.3%	354	1.2%
Emergent Herbaceous Wetlands	128	4.5%	701	2.4%
Evergreen Forest	47	1.6%	3530	12.2%
Hay/Pasture	36	1.3%	321	1.1%
Herbaceous	2,461	85.6%	19,079	65.7%
Open Water	26	0.9%	28	0.1%
Shrub/Scrub	26	0.9%	67	0.2%
Woody Wetlands	8	0.3%	357	1.2%
Total	**2,875**	**100%**	**29,042**	**100%**

Table 2.2-3. Land Use within the Marsland Expansion Area and AOR

Land Use Type	MEA		MEA and 2.25-mile AOR	
	acres	%	acres	%
Barren Land	--	--	2	0.0%
Cultivated Crops	246	5.3%	2,368	6.3%
Deciduous Forest	--	--	1	0.0%
Developed, High Intensity	--	--	1	0.0%
Developed, Low Intensity	--	--	18	0.0%
Developed, Medium Intensity	--	--	10	0.0%
Developed, Open Space	1	0.0%	14	0.0%
Emergent Herbaceous Wetlands	0.3	0.0%	385	1.0%
Evergreen Forest	154	3.3%	3,176	8.4%
Hay/Pasture	--	--	15	0.0%
Herbaceous	4,241	91.0%	31,244	82.6%
Mixed Forest	--	--	201	0.5%
Open Water	--	--	0.4	0.0%
Shrub/Scrub	20	0.4%	378	1.0%
Woody Wetlands	--	--	12	0.0%
Total	**4,662.3**	**100%**	**37,828**	**100%**

Table 2.2-4. Livestock Inventory for Dawes County, 2022

Type of Livestock	Number	Percent	Animal Units[1] Equivalent	Animal Units[1] Percent
All Cattle	67,843	92.6	67,843	98.9
Sheep and Lambs	3,424	4.7	685	1.0
Goats	597	0.8	101	0.1
All Poultry	1,434	2.0	3	0.0
Total Animals	73,298	100	68,632	100

Source: USDA-NASS 2024

1 Animal unit conversions: 1 cow = 1 AU equivalent.
1 sheep = 0.2 AU equivalent
1 goat =0.17 AU equivalent
1 layer chicken = 0.002 AU equivalent

Table 2.2-5. Agricultural Yields for Croplands in Dawes County, 2022

Crop	Harvested Acre	Yield		Production	
		Per Acre	Units	Total	Units
Beans (Dry edible)	306	26.6	cwt	8,138	cwt
Corn for Grain	8,516	113.4	bu	965,586	bu
Corn for Silage	2,404	8.8	tons	21,187	tons
Oats	1,014	35.1	bu	35,633	bu
Hay Alfalfa (Dry)	50,488	1.7	tons	83,359	tons
Hay Other (Dry)	26,496	1.5	tons	38,511	tons
Hay All (Dry)	76,984	1.6	tons	121,870	tons
Proso Millet	1,388	26.6	bu	36,938	bu
Winter Wheat	18,476	32.0	bu	591,243	bu

Source: USDA-NASS 2024
1 Units: cwt = Hundred weight
bu = Bushel

Table 2.2-6. Recreational Facilities near the Crow Butte Project and Marsland Expansion Area

Name	Distance from Crow Butte Project		Distance from MEA	
	mi	km	mi	km
Red Cloud Campground	19	31	16	26
Pine Ridge National Recreation Area	13	21	16	26
Crawford City Park	2	3	12	19
Whitney Lake	10	16	16	26
Legend Buttes Golf Course	2	3	11	18
Box Butte Reservoir	24	39	3	5
Ponderosa Wildlife Management Area	2	3	5	8
Peterson Wildlife Management Area	11	18	14	23
Soldier Creek Wilderness	7	11	16	26
Chadron State Park	17	27	16	26
Fort Robinson State Park	1	2	9	14

Table 2.2-7. Residences within 2.5 miles Radius of the Crow Butte Project

Sector	Number of Structures	Distance to Nearest Residence from Center of Crow Butte Project (miles)
North	2	2.4
North-Northeast	0	--
Northeast	0	--
East-Northeast	0	--
East	0	--
East-Southeast	1	2.3
Southeast	0	--
South-Southeast	0	--
South	2	1.4
South-Southwest	1	1.6
Southwest	3	2.3
West-Southwest	1	0.9
West	5	1.8
West-Northwest	216	2.3
Northwest	226	2.9
North-Northwest	2	2.2

Table 2.2-8. Residences within 2.5 miles Radius of the Marsland Expansion Area

Sector	Number of Structures	Distance to Nearest Residence from Center of MEA (miles)
North	3	3.8
North-Northeast	1	2.3
Northeast	0	--
East-Northeast	0	--
East	1	0.3
East-Southeast	0	--
Southeast	2	3.5
South-Southeast	2	3.0
South	1	2.3
South-Southwest	1	1.6
Southwest	1	0.9
West-Southwest	0	--
West	1	3.3
West-Northwest	5	3.6
Northwest	3	3.8
North-Northwest	2	4.9

Table 2.2-9. USGS Estimated Water Use in Dawes County 2015

Total Population Served	Public Supply (mgal/day)				Irrigation (mgal/day)			1000s
	Ground-water Withdrawals	Surface Water Withdrawals	Total Withdrawals	Domestic Deliveries	Ground-water Withdrawals	Surface Water Withdrawals	Total Withdrawals	Acres Irrigated Total
7,320	0.38	0.80	1.18	0.67	4.91	11.79	16.70	31.15

Source: USGS 2024
mgal/day = million gallons per day

Table 2.2-10. Summary of Non-Abandoned Registered Water Wells for Dawes County on File as of July 10, 2024

Number of Registered Wells						Average Well Depth	Average Static Level	Average Pumping Rate	Total Registered Acres, Irrigation[c]	Number of Replacement Wells
Commercial	**Domestic**	**Irrigation**	**Monitoring[a]**	**Other Wells[b]**	**Total**					
497	289	84	696	4,627	**6,193**	523	134	35	13,885	3
Other Wells (Registered)										
Ground Heat Exchange	Injection	Observation[d]	Other[e]	Recovery	Livestock	Public Water Supply[f]	Public Water Supply[g]	Heat Pump	Total Other Wells	
6	938	7	17	3,264	355	16	23	1	**4,627**	

Source: NeDNR 2024, 2025
[a] Monitoring (Groundwater Quality)
[b] Listed below (Other Wells [Registered])
[c] The same acreage may be reported under more than one well registration.
[d] Observation (Groundwater 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 utility 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 serves at least 5 individuals)
[g] Without spacing protection (A well not owned or operated by a city, village, municipal corporation, metropolitan utility district, reclamation district, or sanitary improvement district that provides the public with water fit for human consumption through at least 15 service connections or regularly serves at least 25 individuals)

Table 2.2-11. Summary of Active Wells within the Crow Butte Project and AOR

Well Use	Number of Wells within Crow Butte License area	Number of Wells Outside of Crow Butte License area but within AOR
Commercial/Industrial	487	7
Domestic	0	17
Injection	844	1
Livestock	0	14
Monitoring	457	23
Observation	1	0
Recovery	2,946	7
TOTAL	**4,735**	**69**

Source: NeDNR 2025

Table 2.2-12. Active Wells within Crow Butte Project and AOR

Well ID	Well Use	Name	Location	Pump Rate	Total Depth
94325	Domestic	Warren Madison	NENW S10-T31N-R52W	12	60
100684	Domestic	Arleigh Deines	NWNW S35-T32N-R52W	6	60
104015	Livestock	Mike Dyer	NWNE S23-T31N-R52W	30	110
107730	Domestic	George Franklin	SWSW S13-T31N-R52W	10	105
107924	Livestock	Alan L & Debra L Soester	NENW S8-T31N-R51W	10	310
110496	Domestic	Jim Hornung	NESW S34-T31N-R51W	10	160
113088	Domestic	John Dodd	NENW S10-T31N-R52W	10	55
125926	Livestock	Laverne E & Shirley R Stetson	NESE S18-T31N-R51W	4	160
136625	Domestic	Gibbons Family Trust	SWNW S20-T31N-R51W	10	113
149554	Domestic	Dewayne Lambert	SWNE S10-T31N-R52W	12	56
155125	Livestock	Lynne L and Michael P Reeder & Lux	NWSW S5-T30N-R51W	4	320
156758	Livestock	Kalvin & Kristie Dodd	NESW S14-T31N-R52W	10	60
158168	Domestic	Roger A & Julie A Hasz	NWSW S34-T31N-R51W	10	210
158169	Livestock	Melburn Franey	NWNW S7-T31N-R51W	3	55
160854	Livestock	Kenneth E & Laure Chantal Sinn	NWSE S34-T32N-R52W	20	60
165710	Monitoring	Crawford Coop	SWSE S3-T31N-R52W	0	33
165711	Monitoring	Crawford Coop	SWSE S3-T31N-R52W	0	30
165712	Monitoring	Crawford Coop	SWSE S3-T31N-R52W	0	30
166097	Livestock	Martha Raben	NWNE S15-T31N-R52W	4	94
169621	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	26
169622	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	25
169623	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	22
169624	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	23
169625	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	24
169626	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	26
169627	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	21
171825	Domestic	Tom Wendelin	SENW S34-T31N-R51W	10	260
180438	Domestic	Jack Galt	SESW S7-T31N-R51W	15	200
180892	Livestock	Denny Bell	SWSW S25-T31N-R52W	10	130
184139	Domestic	Fred Prelle	SWNE S10-T31N-R52W	12	360
185938	Domestic	Robert Buckley	SESE S3-T31N-R52W	10	75
191780	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	25

Table 2.2-12. Active Wells within Crow Butte Project and AOR (Cont.)

Well ID	Well Use	Name	Location	Pump Rate	Total Depth
191781	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	25
191782	Recovery	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	25
192377	Domestic	John Ereckson	NENE S3-T31N-R52W	10	200
192593	Domestic	Wayne H & Julie A Gibbons	SENW S35-T32N-R52W	10	37
196107	Livestock	Roy Norgard	NESE S34-T32N-R52W	17	160
197460	Livestock	Dave Moore	SESE S35-T32N-R52W	4	58
201168	Domestic	Samantha Dyer	SWSW S17-T31N-R51W	10	180
202100	Livestock	Mike Dyer	NENW S26-T31N-R52W	12	200
204844	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	22
204845	Monitoring	Panhandle Cooperative Association	SWSE S3-T31N-R52W	0	22
209043	Domestic	Shawn & Amy Patras	SWSE S15-T31N-R52W	12	120
219356	Domestic	Alicia Hunter Robertson	SWNW S26-T31N-R52W	15	140
221046	Domestic	John Carle	NWNE S10-T31N-R52W	9	55
230825	Monitoring	Panhandle Coop	SWSE S3-T31N-R52W	0	23
230827	Monitoring	Panhandle Coop	SWSE S3-T31N-R52W	0	23
234129	Monitoring	Nebraska Department of Environmental Quality	SWSE S3-T31N-R52W	0	23
234131	Monitoring	Nebraska Department of Environmental Quality	SWSE S3-T31N-R52W	0	22
234132	Monitoring	Nebraska Department of Environmental Quality	SWSE S3-T31N-R52W	0	25
259113	Livestock	Mick Franey	SWSE S2-T31N-R52W	10	100

Source: NDNR 2025

Table 2.2-13. Summary of Active Wells within the Marsland Expansion Area and AOR

Well Use	**Number of Wells within MEA License area**	**Number of Wells Outside of MEA License area but within AOR**
Domestic	0	4
Irrigation	1	9
Livestock	2	12
Monitoring	22	10
TOTAL	**25**	**35**

Source: NeDNR 2025

Table 2.2-14. Active Wells within Marsland Expansion Area and AOR

Well ID	Well Use	Name	Location	Pump Rate	Total Depth	Within MEA License area
601	Livestock	Patrick S & Teresa L Furman	NESW S25-T29N-R51W	0	0	
3611	Irrigation	Steve Klaes	NWSE S22-T29N-R50W	500	0	
4854	Irrigation	Thomas A & Geneice A Walters	SWSW S24-T29N-R51W	808	0	
29030	Irrigation	Steve Klaes	SENW S22-T29N-R50W	840	200	
51298	Irrigation	Patti Hollibaugh	NESE S18-T29N-R50W	1300	280	X
76743	Irrigation	Gregory & Kirk Oetken	NWSW S15-T29N-R50W	1000	200	
76744	Irrigation	Gregory Oetken	SWNE S17-T29N-R50W	900	200	
90424	Livestock	Gary Oetken	NESW S29-T29N-R50W	20	190	
97608	Livestock	Bruce Troester	NENW S31-T29N-R50W	20	60	
100059	Livestock	Geraldine Hollibaugh	NENW S1-T29N-R51W	10	260	X
105027	Domestic	Wayne Bruno	SENE S29-T30N-R51W	16	155	
105200	Livestock	Geraldine Hollibaugh	SWNW S18-T29N-R50W	3	180	X
110776	Livestock	Bonnie Chapman	NWSE S7-T29N-R50W	3	240	
112372	Livestock	Bert & Laura Lee Oetken	NWSW S33-T30N-R51W	10	220	
113701	Livestock	Lonnie Wilkins	SWSW S26-T29N-R51W	3	260	
118707	Livestock	John Keane	SESE S11-T29N-R51W	10	220	
122880	Domestic	Jeffrey L & Debra A Kennedy	NESE S29-T30N-R51W	10	160	
123384	Irrigation	Bruce Troester	SWSE S30-T29N-R50W	850	100	
137618	Livestock	Bruce Troester	NWSE S30-T29N-R50W	10	60	
141301	Domestic	Mike Graves	SWNW S19-T30N-R50W	15	220	
147650	Irrigation	Steve Klaes	NENW S22-T29N-R50W	600	160	
168230	Irrigation	P Bruce & Vicki J Troester	NENE S28-T29N-R50W	500	100	
192378	Livestock	Bruce Troester	NENE S28-T29N-R50W	10	70	
221788	Monitoring	Crow Butte Resources Inc	NWNW S1-T29N-R51W	25	111	X
221789	Monitoring	Crow Butte Resources Inc	NESE S2-T29N-R51W	25	112	X
221790	Monitoring	Crow Butte Resources Inc	NESE S12-T29N-R51W	25	103	X
221791	Monitoring	Crow Butte Resources Inc	SWSW S12-T29N-R51W	25	105	
221792	Monitoring	Crow Butte Resources Inc	NENW S2-T29N-R51W	25	113	X
221793	Monitoring	Crow Butte Resources Inc	NENE S35-T30N-R51W	25	114	X
221794	Monitoring	Crow Butte Resources Inc	SESE S13-T29N-R51W	25	970	
221795	Monitoring	Crow Butte Resources Inc	NESE S19-T29N-R50W	25	947	X
221796	Monitoring	Crow Butte Resources Inc	SWSW S1-T29N-R51W	5	106	X
221797	Monitoring	Crow Butte Resources Inc	SWSW S12-T29N-R51W	2	89	
221798	Monitoring	Crow Butte Resources Inc	SESE S12-T29N-R51W	5	225	X

Table 2.2-14. Active Wells within Marsland Expansion Area and AOR (Cont.)

Well ID	Well Use	Name	Location	Pump Rate	Total Depth	Within MEA License area
221799	Monitoring	Crow Butte Resources Inc	SESW S1-T29N-R51W	5	365	X
221800	Monitoring	Crow Butte Resources Inc	NWNW S1-T29N-R51W	5	398	X
221801	Monitoring	Crow Butte Resources Inc	NENW S2-T29N-R51W	5	416	X
221802	Monitoring	Crow Butte Resources Inc	NENE S24-T29N-R51W	5	311	
221803	Monitoring	Crow Butte Resources Inc	NESE S19-T29N-R50W	5	237	X
221804	Monitoring	Crow Butte Resources Inc	NENW S29-T29N-R50W	5	220	X
221805	Monitoring	Crow Butte Resources Inc	NESW S12-T29N-R51W	5	347	X
221806	Monitoring	Crow Butte Resources Inc	NENE S35-T30N-R51W	5	416	X
225776	Domestic	Kevin & Denise Christy	NWNW S4-T29N-R51W	15	280	
228993	Monitoring	Crow Butte Resources Inc	NENW S2-T29N-R51W	1	150	X
229006	Monitoring	Crow Butte Resources Inc	SENW S29-T29N-R50W	10	80	X
229007	Monitoring	Crow Butte Resources Inc	NENE S35-T30N-R51W	2	150	X
229024	Monitoring	Crow Butte Resources Inc	SWNE S30-T29N-R50W	15	160	
229025	Monitoring	Crow Butte Resources Inc	SWNE S30-T29N-R50W	10	66	
229041	Monitoring	Crow Butte Resources Inc	SWSW S1-T29N-R51W	1	131	X
229042	Monitoring	Crow Butte Resources Inc	SWSW S12-T29N-R51W	0	150	
229043	Monitoring	Crow Butte Resources Inc	SWSW S7-T29N-R50W	1	140	X
229044	Monitoring	Crow Butte Resources Inc	SWSW S7-T29N-R50W	15	270	X
229045	Monitoring	Crow Butte Resources Inc	NWSE S18-T29N-R50W	15	220	X
229046	Monitoring	Crow Butte Resources Inc	NWSE S18-T29N-R50W	2	110	X
229047	Monitoring	Crow Butte Resources Inc	NESE S19-T29N-R50W	2	101	X
229048	Monitoring	Crow Butte Resources Inc	SESE S13-T29N-R51W	1	100	
234442	Irrigation	Thomas A & Geneice A Walters	NWNW S25-T29N-R51W	300	210	
250085	Livestock	Arlee & Betty Phillips	SENW S14-T30N-R51W	6	350	
274898	Livestock	Arlee & Betty Phillips	NWNE S22-T30N-R51W	11	320	
274926	Livestock	Arlee & Betty	NENE S22-T30N-R51W	11	280	

Source: NeDNR 2025

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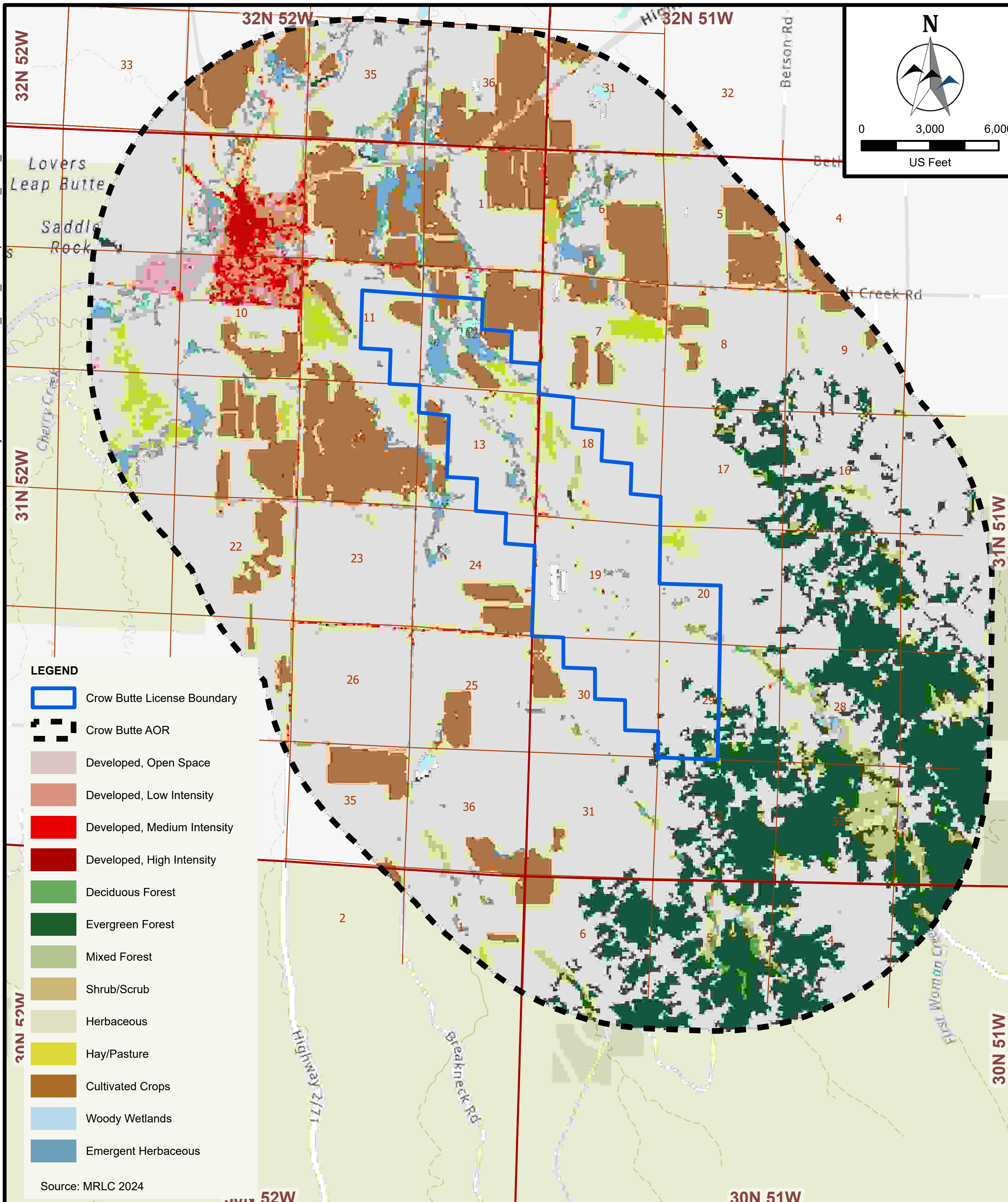

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CROW BUTTE PROJECT LAND USE

FIGURE **2.2-1**

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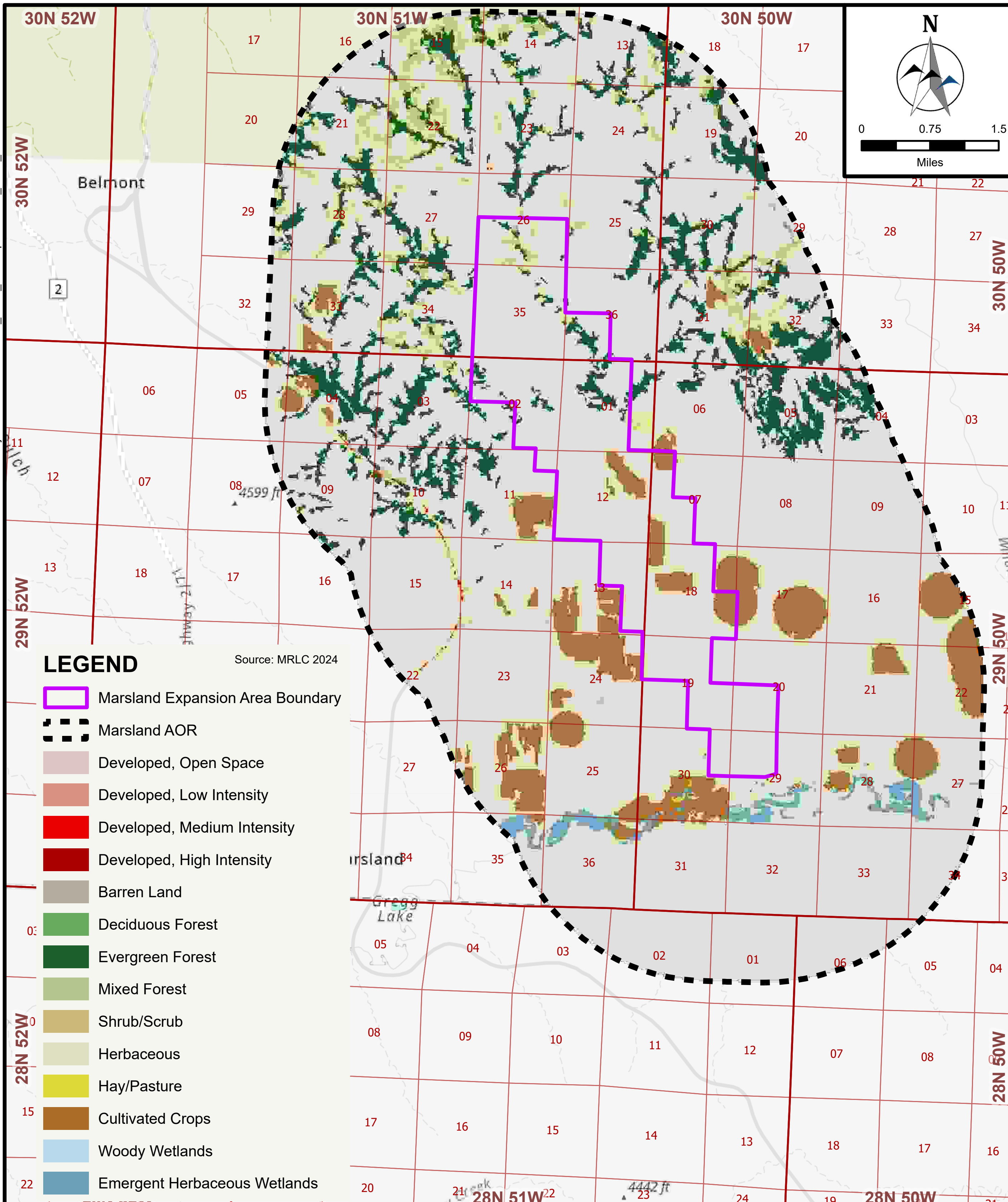

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MARSLAND EXPANSION AREA LAND USE

FIGURE 2.2-2

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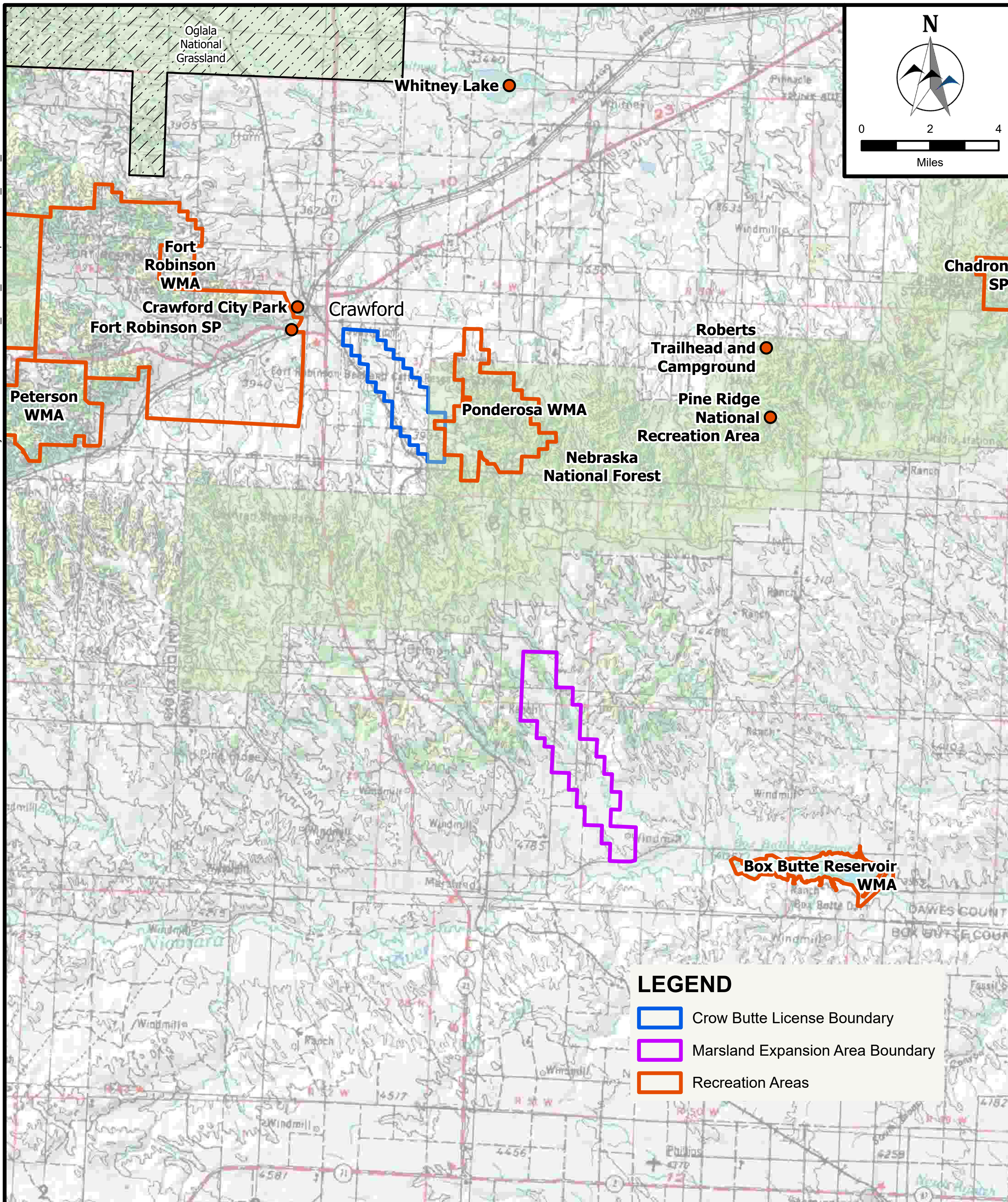

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RECREATION AREAS

FIGURE 2.2-3

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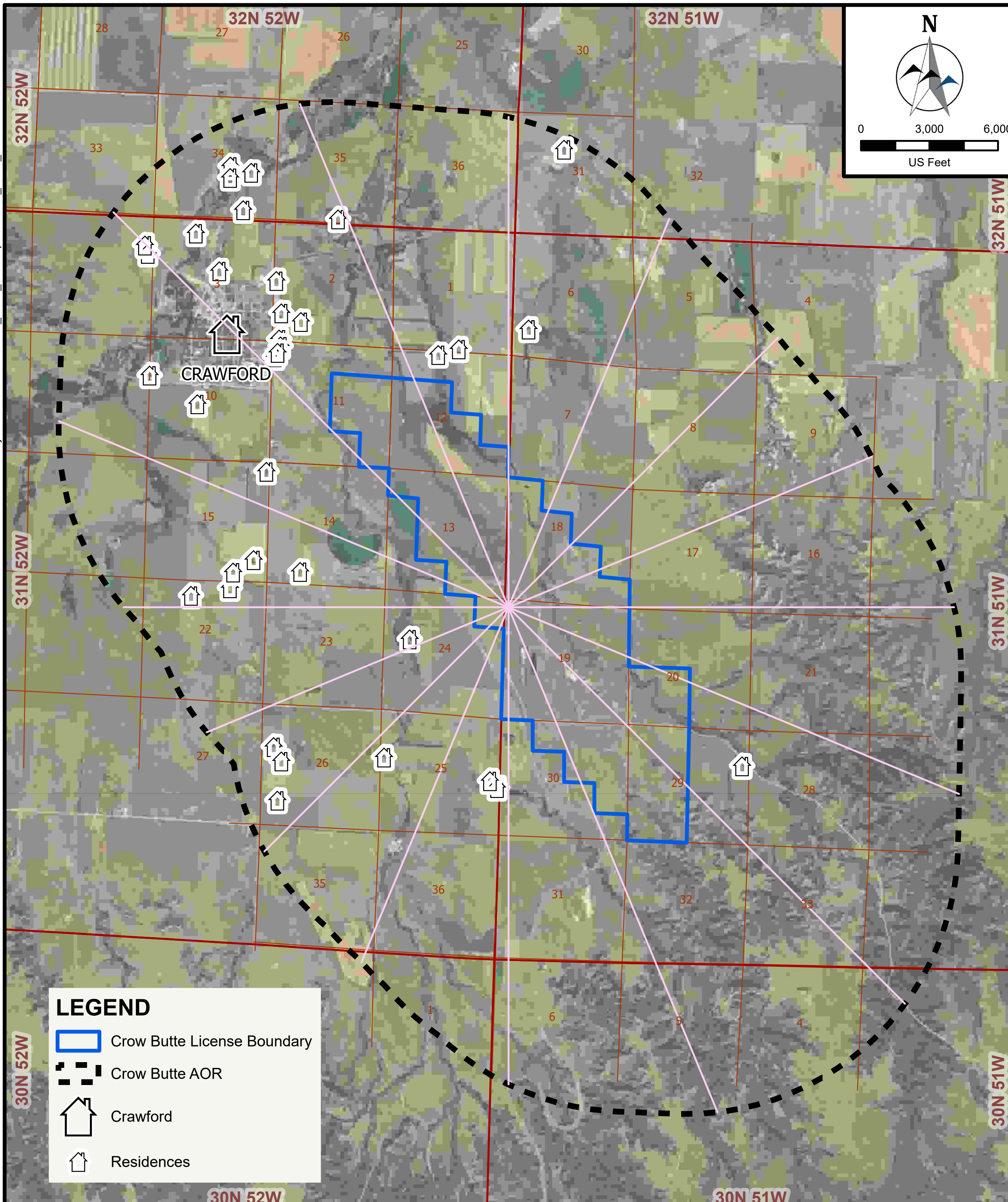

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CROW BUTTE PROJECT RESIDENCES

FIGURE 2.2-4

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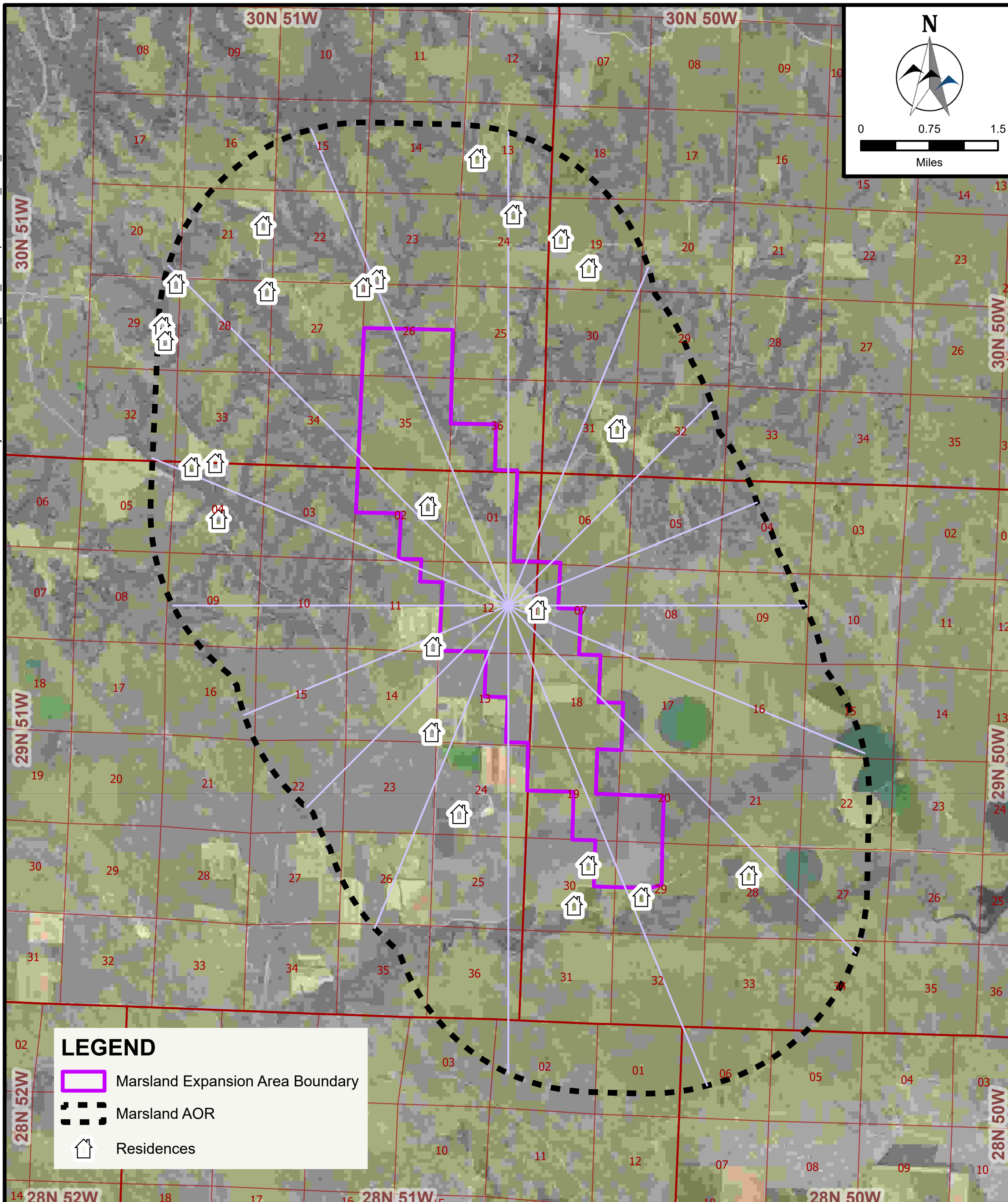

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MARSLAND EXPANSION AREA RESIDENCES

FIGURE 2.2-5

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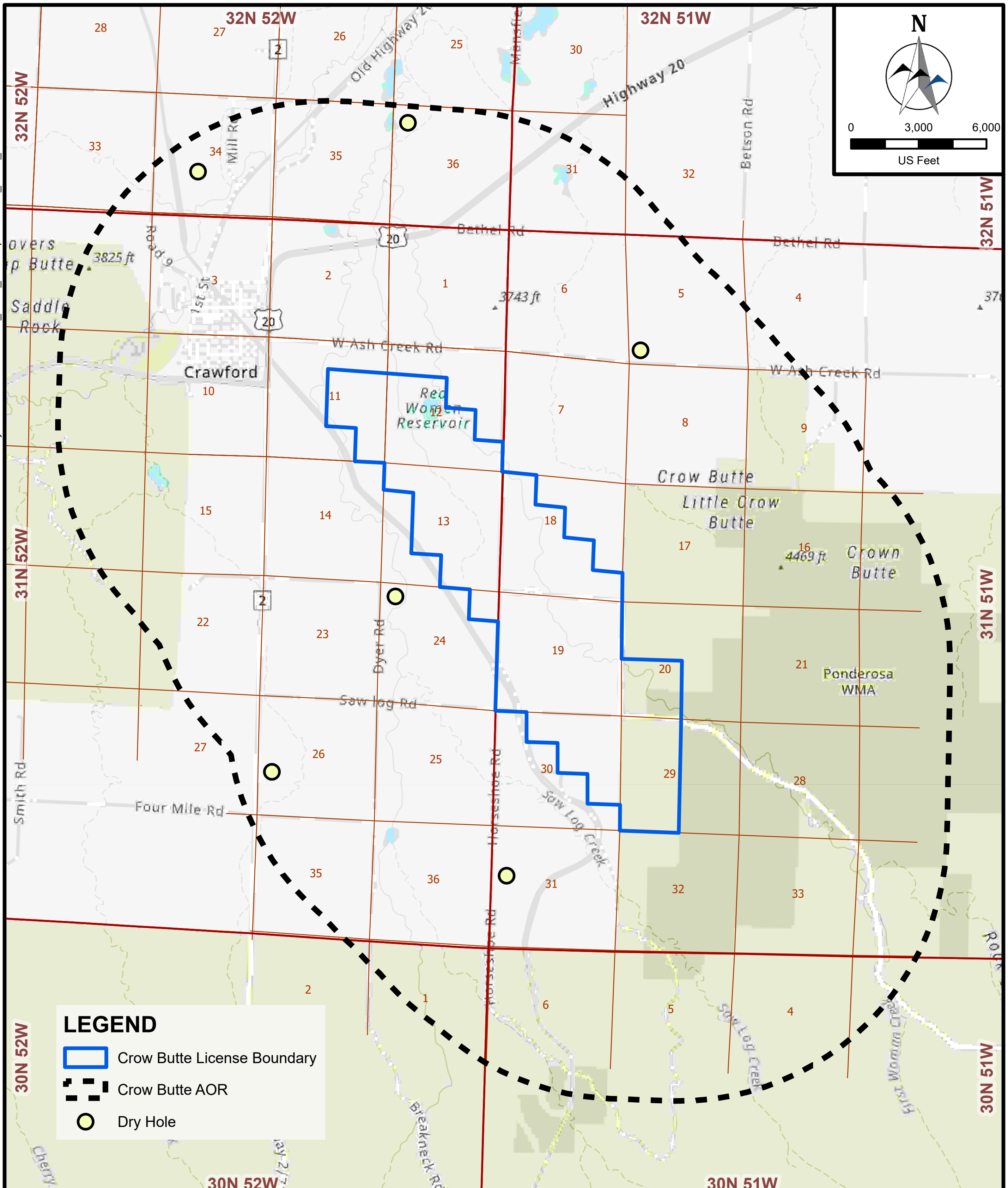

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CROW BUTTE RESOURCES, INC.

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CROW BUTTE PROJECT OIL AND GAS WELLS

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FIGURE
2.2-6

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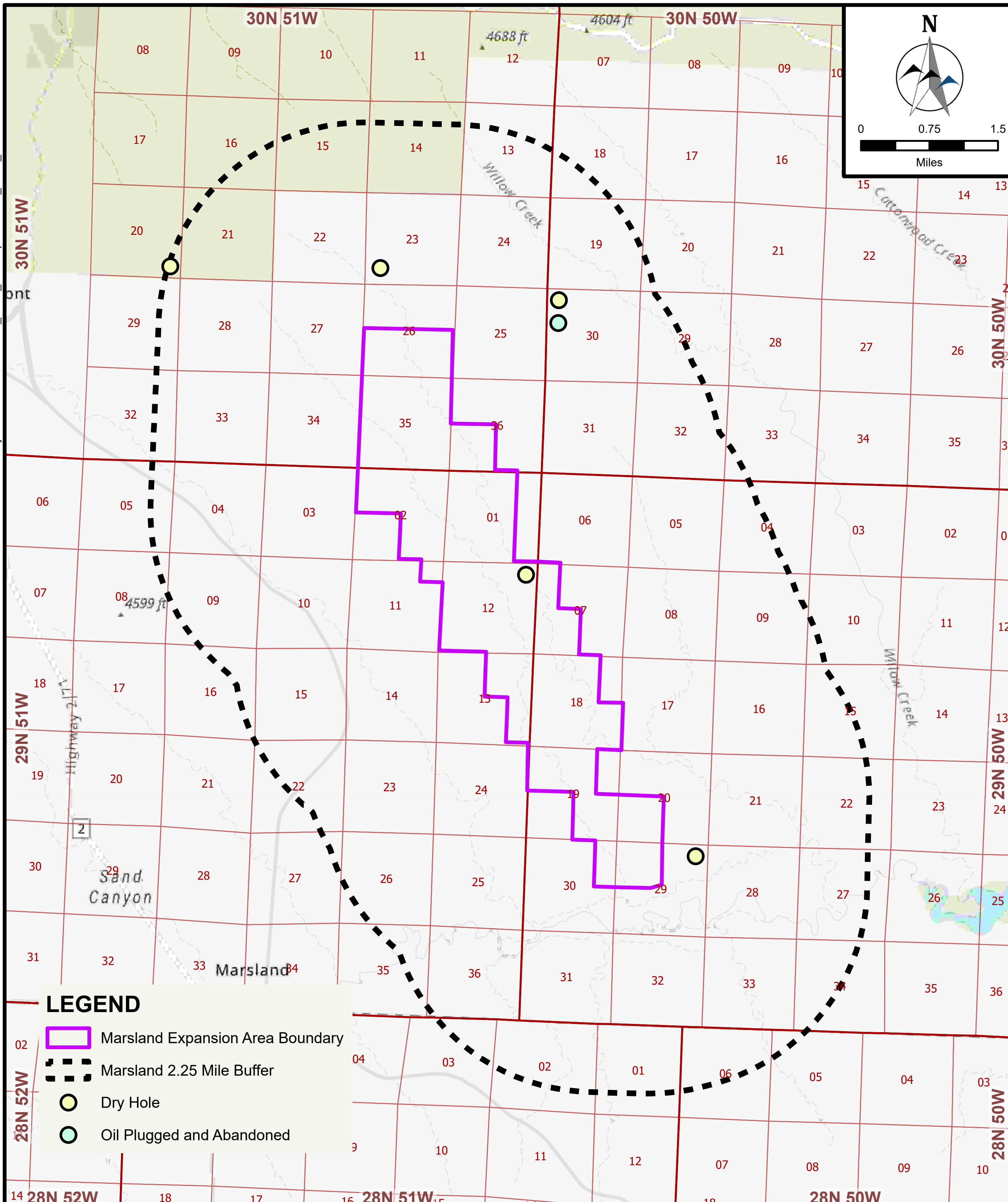

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MARSLAND EXPANSION AREA OIL AND GAS WELLS

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FIGURE **2.2-7**

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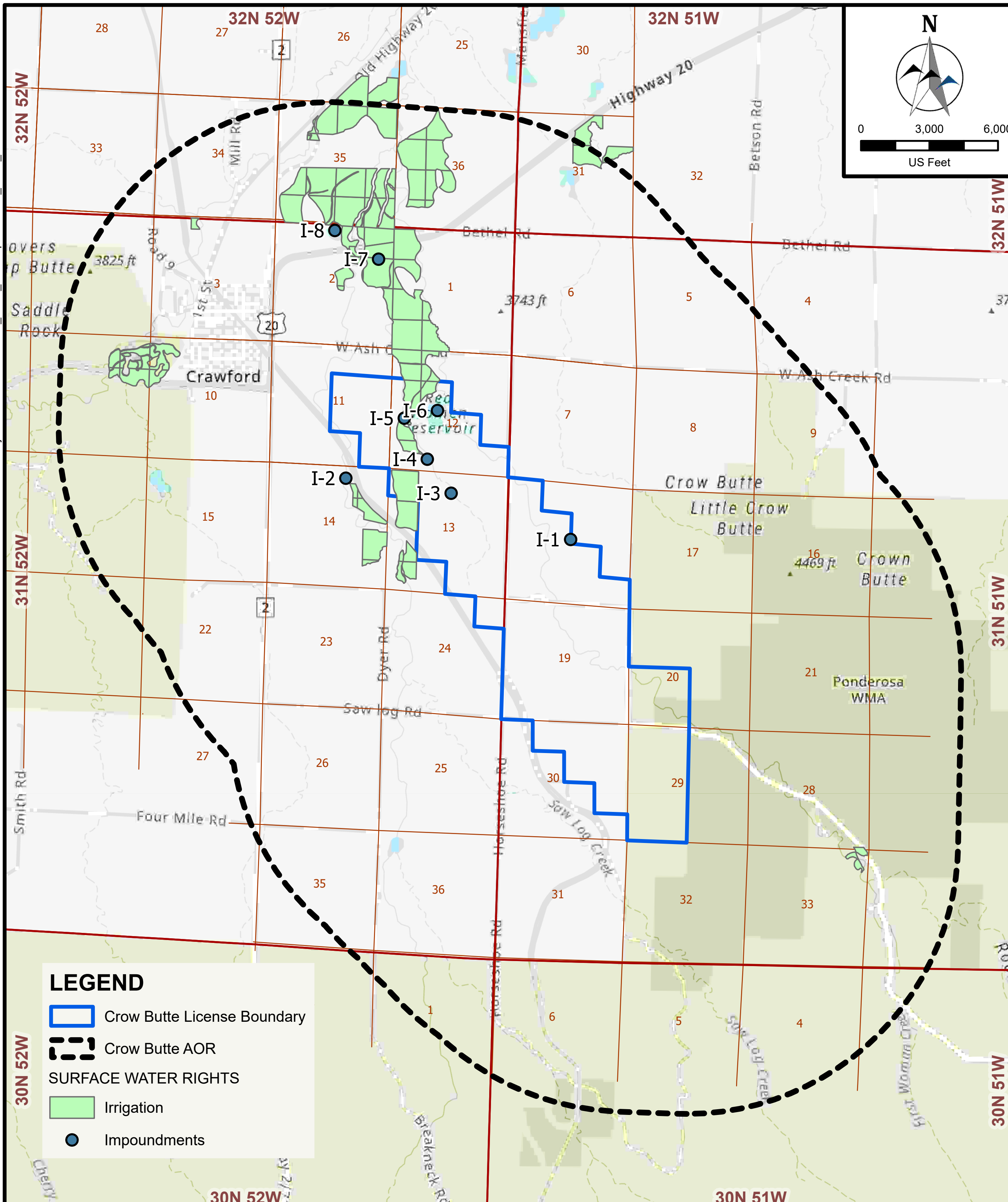

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CROW BUTTE PROJECT
SURFACE WATER RIGHTS

FIGURE
2.2-8

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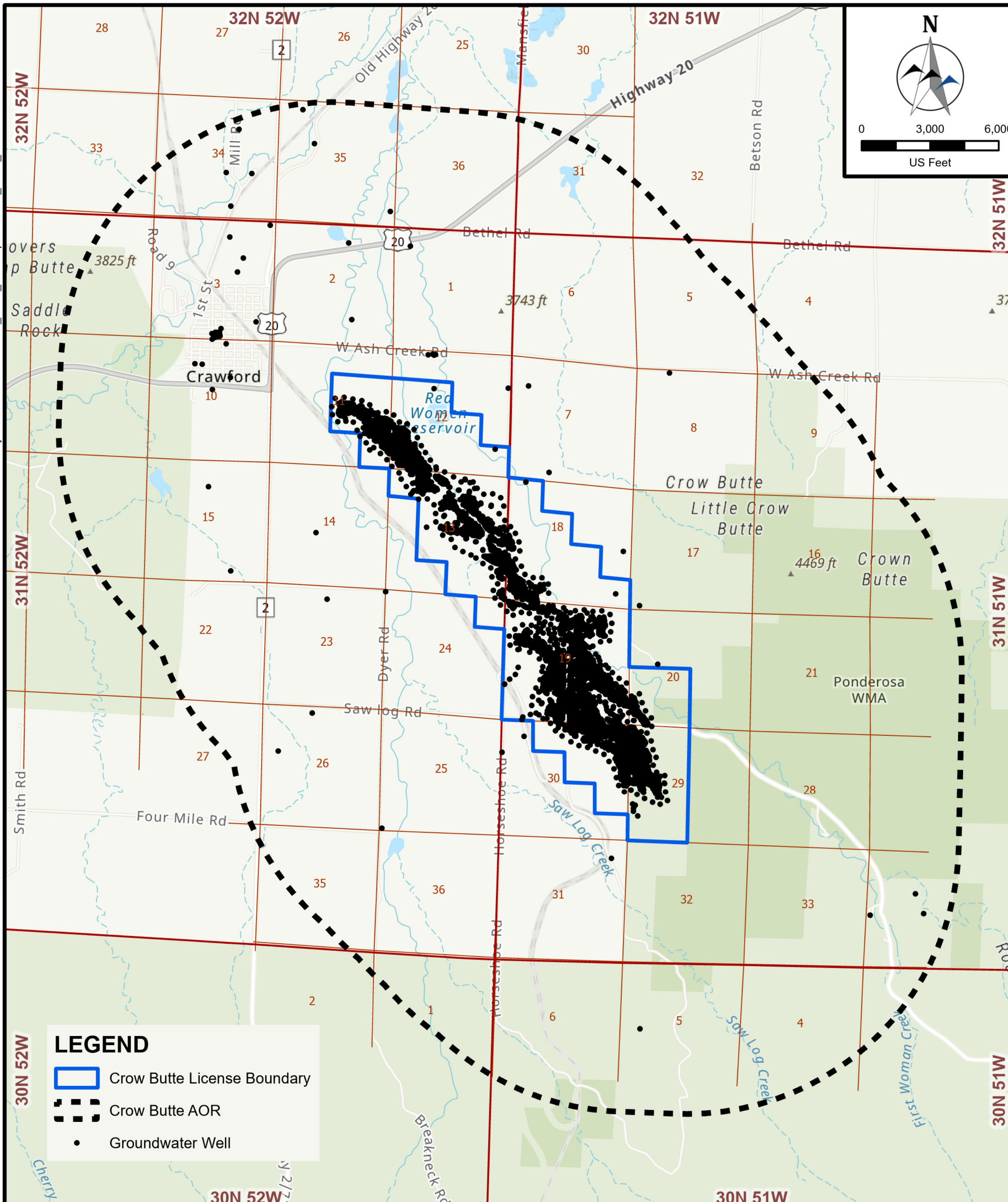

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CROW BUTTE PROJECT GROUNDWATER WELLS

FIGURE 2.2-9

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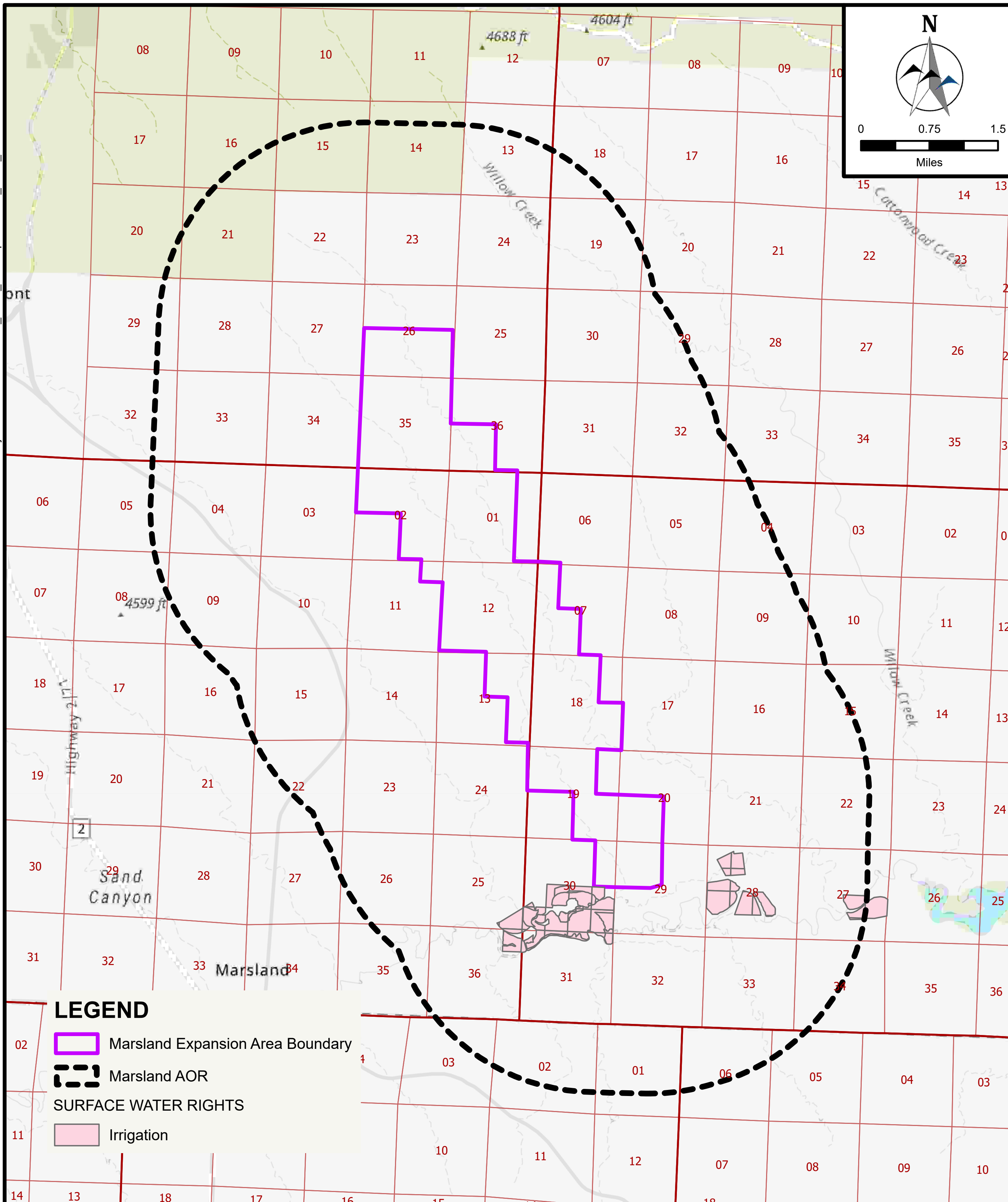

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MARSLAND EXPANSION AREA SURFACE WATER RIGHTS

FIGURE 2.2-10

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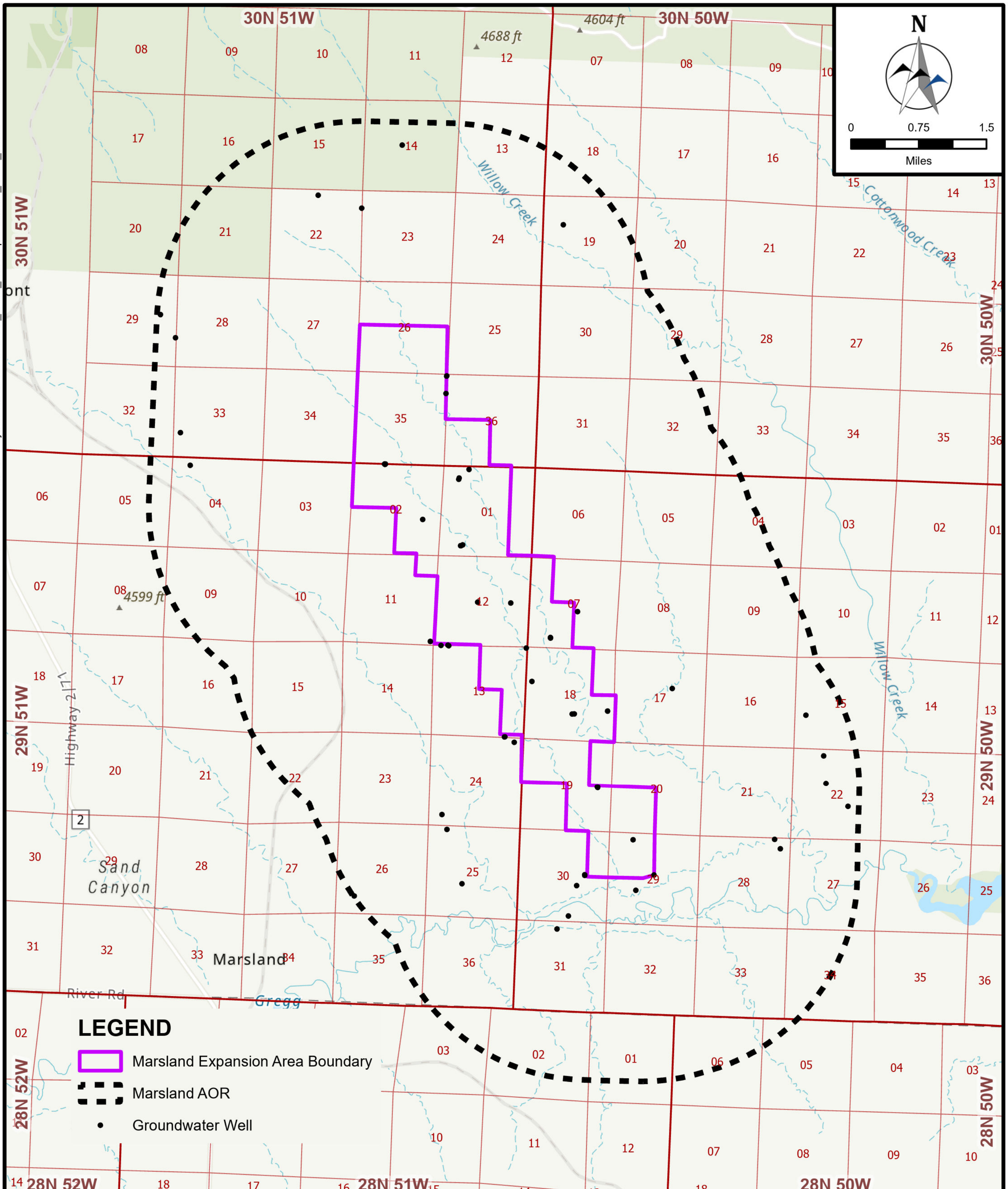

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MARSLAND EXPANSION AREA GROUNDWATER WELLS

FIGURE **2.2-11**

2.3 POPULATION DISTRIBUTION

Section 2.3 of the 2008 Crow Butte LRA and Section 2.3 of the MEA TR provides information on the population distribution for each project area. The section provides updated information on the regional population as well as population characteristics and population projections. This section also includes an updated discussion on environmental justice. Based on the information presented in this section there is no significant change between the 2008 Crow Butte LRA, MEA TR and this Combined ER/TR.

The demographic and social characteristics of the area that may be affected by operations in the Crow Butte Project and MEA license areas are considered in this section. This section presents and discusses data for population centers within 80 km (50 miles) from the approximate center between the Crow Butte Project and the MEA. Food production data is described in detail in Section 2.2 of this Combined ER/TR.

2.3.1 Demography

2.3.1.1 Regional Population

The area within an 80-km (50-mile) radius of the approximate center between the Crow Butte Project and the MEA includes portions of six counties in northwestern Nebraska, two counties in southwestern South Dakota, and two counties in eastern Wyoming. There are also four population centers within 80 km of the license area – Alliance City, Chadron City and Crawford City, Nebraska, and the Pine Ridge Census Designated Place (CDP) in South Dakota. Figure 2.3-1 depicts significant population centers within 80 km (50 miles) of the approximate center between the license areas.

The 80 km (50 miles) radius only extends into very rural portions of Morrill County in Nebraska and Niobrara and Goshen Counties in Wyoming. Less than one percent of the total population within 80 km (50 miles) of the license area resides in each of these counties. Table 2.3-3 shows population by county. Data for these areas is included in Tables 2.3-1 to 2.3-5, but because of the very small populations they are not evaluated further.

Figure 2.3-1 and Table 2.3-2 show the separate and cumulative total population by sector and annular ring within 80 km (50 miles) of the approximate center between the license areas.

Historical and current population trends for population centers are shown in Table 2.3-1. Nearly all of these population centers have experienced an ongoing decline in population. The exception is Oglala Lakota County in South Dakota (formerly known as Shannon County), where the population has increased over the last 30 years.

2.3.1.2 Population Characteristics

The 2020 population by sex and age for population centers within 80 km of the license areas is shown in Table 2.3-3. The percentage of female residents ranges from 48.5% to 52.5%, and the percentage of male residents ranges from 47.5% to 51.5%. The percentage of the population under age 18 is generally 22% to 26%. A lower percentage of the population in Dawes County, Chadron City and Fall River County (17-19%) is under age 18. A much higher percentage of the population Oglala Lakota County and Pine Ridge CDP (>30%) is under age 18. The percentage of the population over age 65 varies. Notable outliers are Oglala Lakota County and Pine Ridge CDP, with a very low percentage of the population (>7.5%) over age 65. Crawford City and Sheridan and Fall River counties have a higher percentage of the population (>25%) over age 65.

In most population centers, the population is predominantly (>78%) white. Notable exceptions are Oglala Lakota County and Pine Ridge CDP, which are located within the Pine Ridge Indian Reservation. The population in these areas is predominantly (>90%) American Indian.

2.3.1.3 Population Projections

The projected population for selected years by county within 80 km of the license areas is shown in Table 2.3-5. In Nebraska, the total population in counties within 80 km of the license areas is expected to remain nearly the same, with a population decrease in Scotts Bluff, Sheridan and Sioux counties and a population increase in Box Butte and Dawes County. In South Dakota, the population of Fall River County is expected to vary slightly over time, within 10% of the current population. Population projection data was not available for Oglala Lakota County.

2.3.1.4 Population and Visitor Statistics

The City of Crawford is located within two miles of the Crow Butte Project and is the main population center near the license area. No hospitals are located within 2 miles of the license area. Visitor and use statistics are not available for most City facilities.

The Crawford Public School District operates Crawford Elementary School, which has 102 students in pre-kindergarten through 6th grade, and Crawford High School, which has 72 students in 7th through 12th grades (National Center for Education Statistics 2023). District enrollment has declined significantly from 238 students in 2013 (City of Crawford 2017).

The only industrial facility in Crawford is the Crawford Livestock Auction, which holds weekly auctions throughout the year and commonly auctions several thousand head of cattle each week (USDA 2024).

Crawford City Park is a recreation complex with rodeo grounds, a shooting range, picnic and RV camping facilities, and a playground. Baseball fields and a swimming pool are located at Ellis Peabody Hale Park. The city also operates the Legend Buttes Golf Course.

2.3.2 Environmental Justice

US Census Bureau 2020 data were evaluated to determine if the potential human health or environmental impacts of the Crow Butte Project and MEA on minorities or low-income populations would be disproportionate to the other population in the vicinity.

Table 2.3-4 compares population by race for population centers within an 80 km radius of the license area with statewide data. The data show that in Nebraska, the percentage of minorities in population centers within 80 km of the license area is less than or approximately equal to the statewide percentage. Similarly, in South Dakota, Fall River County has a lower percentage of minorities than the State of South Dakota. However, the population centers within 80 km of the license area in Nebraska and South Dakota generally have a higher percentage of American

Indian than statewide. Oglala Lakota County and the Pine Ridge CDP are located within the Pine Ridge Indian Reservation and have a much higher percentage of American Indian than statewide. The total population within Oglala Lakota County and within 80 km of the Project is approximately 3,900. The majority of this population (3,138) resides in the Pine Ridge CDP, which is located approximately 77 km from the Project center. The Oglala Lakota County is the only county with the percentage of the population belonging to a minority group greater than 50 percent. Based on this, a minority environmental justice population is present but since it is 77 km from the license areas should not be impacted by the Crow Butte Project or the MEA.

Table 2.3-3 compares the percentage of the population below the poverty level for population centers within an 80 km radius of the license area with statewide data. In Nebraska, the percentage of the population below the poverty level near the license areas varies, but is slightly higher than the statewide average. In South Dakota, the percentage of the population below the poverty level is slightly higher than the statewide average in Fall River County, and significantly higher than the statewide average in Oglala Lakota County and Pine Ridge CDP.

2.3.3 References

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Table 2.3-1. Historical and Current Population Change for Population Centers within 80-km (50-mile) Radius of the License area, 1980-2020

STATE County/City/CDP	Population					Average Annual Percent Change			
	1980	1990	2000	2010	2020	1980/ 1990	1990/ 2000	2000/ 2010	2010/ 2020
NEBRASKA									
Box Butte	13,696	13,130	12,158	11,308	10,842	-4.1	-7.4	-7.0	-4.1
Alliance City	9,869	9,765	8,959	8,491	8,151	-1.1	-8.3	-5.2	-4.0
Dawes	9,609	9,021	9,060	9,182	8,199	-6.1	0.4	1.3	-10.7
Chadron City	5,933	5,588	5,634	5,851	5,206	-5.8	0.8	3.9	-11.0
Crawford City	1,315	1,115	1,107	997	840	-15.2	-0.7	-9.9	-15.7
Morrill	6,085	5,423	5,440	5,042	4,555	-10.9	0.3	-7.3	-9.7
Scotts Bluff	38,344	36,025	36,951	36,970	36,084	-6.0	2.6	0.1	-2.4
Sheridan	7,544	6,750	6,198	5,469	5,127	-10.5	-8.2	-11.8	-6.3
Sioux	1,845	1,549	1,475	1,311	1,135	-16.0	-4.8	-11.1	-13.4
SOUTH DAKOTA									
Fall River	8,439	7,353	7,453	7,094	6,973	-12.9	1.4	-4.8	-1.7
Oglala Lakota[1]	11,323	9,902	12,466	13,586	13,672	-12.6	25.9	9.0	0.6
Pine Ridge CDP	N/A	2,596	3,483	3,308	3,138	N/A	34.2	-5.0	-5.1
WYOMING									
Goshen	12,040	12,373	12,538	13,249	12,498	2.8	1.3	5.7	-5.7
Niobrara	2,924	2,499	2,407	2,484	2,467	-14.5	-3.7	3.2	-0.7

CDP = Census Designated Place
N/A = Not Available
[1] Previously Shannon County, renamed in 2015.
Source: U.S. Census Bureau 2020b

Table 2.3-2. 2020 Population within an 80-km (50-mile) Radius of the License area

Sector	Distance from Project Center, km							
	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80
N	16	12	128	5	12	16	168	138
Cumulative	*16*	*28*	*156*	*161*	*173*	*189*	*357*	*495*
NNE	-	52	56	87	40	28	34	193
Cumulative	*-*	*52*	*108*	*195*	*235*	*263*	*297*	*490*
NE	4	18	166	5,645	197	55	78	3,674
Cumulative	*4*	*22*	*188*	*5,833*	*6,030*	*6,085*	*6,163*	*9,837*
ENE	16	21	124	43	134	760	238	912
Cumulative	*16*	*37*	*161*	*204*	*338*	*1,098*	*1,336*	*2,248*
E	13	14	25	26	147	190	56	79
Cumulative	*13*	*27*	*52*	*78*	*225*	*415*	*471*	*550*
ESE	4	24	44	15	83	61	33	19
Cumulative	*4*	*28*	*72*	*87*	*170*	*231*	*264*	*283*
SE	-	-	38	955	182	226	8,479	113
Cumulative	*-*	*-*	*38*	*993*	*1,175*	*1,401*	*9,880*	*9,993*
SSE	4	8	37	112	134	190	179	59
Cumulative	*4*	*12*	*49*	*161*	*295*	*485*	*664*	*723*
S	10	17	20	38	29	17	51	465
Cumulative	*10*	*27*	*47*	*85*	*114*	*131*	*182*	*647*
SSW	18	13	15	3	23	23	34	1,834
Cumulative	*18*	*31*	*46*	*49*	*72*	*95*	*129*	*1,963*
SW	35	8	-	9	6	7	21	221
Cumulative	*35*	*43*	*43*	*52*	*58*	*65*	*86*	*307*
WSW	16	31	23	1	20	12	19	21
Cumulative	*16*	*47*	*70*	*71*	*91*	*103*	*122*	*143*
W	-	19	46	13	24	21	73	41
Cumulative	*-*	*19*	*65*	*78*	*102*	*123*	*196*	*237*
WNW	15	22	-	-	255	20	55	49
Cumulative	*15*	*37*	*37*	*37*	*292*	*312*	*367*	*416*
NW	3	882	41	66	17	9	25	17
Cumulative	*3*	*885*	*926*	*992*	*1,009*	*1,018*	*1,043*	*1,060*
NNW	8	80	23	9	1	5	20	27
Cumulative	*8*	*88*	*111*	*120*	*121*	*126*	*146*	*173*
All Sectors	**162**	**1,221**	**786**	**7,027**	**1,304**	**1,640**	**9,563**	**7,862**

Source: U.S. Census Bureau 2020b

Table 2.3-3. Population by Sex and Age, and Poverty Level, for Population Centers within 80-km (50-mile) Radius of the License area, 2020

STATE County City/CDP	Sex		Age		Percent Below the Poverty Level	Population within 80 km of the License area
	Female	Male	Under 18	Over 65		
NEBRASKA					**10.4%**	
Box Butte	5,430 (50.1%)	5,412 (49.9%)	2,701 (24.9%)	1,952 (18.0%)	12.8%	10,842
Alliance City	4,104 (50.3%)	4,047 (49.7%)	2,112 (25.9%)	1,337 (16.4%)	13.3%	8,151
Dawes	4,191 (51.1%)	4,008 (48.9%)	1,584 (18.2%)	1,587 (18.3%)	13.1%	8,199
Chadron City	2,684 (51.6%)	2,522 (48.4%)	1,102 (18.5%)	742 (13.5%)	12.7%	5,206
Crawford City	441 (52.5%)	399 (47.5%)	233 (22.8%)	280 (27.5%)	17.7%	840
Morrill	2,255 (49.5%)	2,300 (50.5%)	1,103 (23.4%)	971 (20.6%)	9.7%	166
Scotts Bluff	18,492 (51.2%)	17,592 (48.8%)	8,914 (24.8%)	6,831 (19.0%)	13.0%	2,194
Sheridan	2,576 (50.2%)	2,551 (49.8%)	1,167 (22.4%)	1,349 (25.9%)	19.0%	2,642
Sioux	550 (48.5%)	585 (51.5%)	311 (24.0%)	262 (20.2%)	8.1%	984
SOUTH DAKOTA					**12.8%**	
Fall River	3,470 (49.8%)	3,503 (50.2%)	1,161 (17.3%)	1,958 (29.1%)	15.9%	441
Oglala Lakota[1]	6,730 (49.2%)	6,942 (50.8%)	5,244 (36.7%)	1,008 (7.1%)	44.8%	3,876
Pine Ridge CDP	1,534 (48.9%)	1,604 (51.1%)	963 (32.3%)	141 (4.7%)	41.1%	3,138
WYOMING					**10.8%**	
Goshen	5,969 (47.8%)	6,529 (52.2%)	2,710 (20.4%)	2,923 (22.0%)	9.3%	84
Niobrara	1,338 (54.2%)	1,129 (45.8%)	509 (21.4%)	429 (18.0%)	21.5%	137

Source: U.S. Census Bureau 2020a and 2020b

Table 2.3-4. Population by Race for Population Centers within 80-km (50-mile) Radius of the License area, 2020

STATE County City/CDP	White		Black or African American		American Indian and Alaska Native		Asian		Native Hawaiian and Other Pacific Islander		Two or More Races		Hispanic or Latino of Any Race	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
NEBRASKA	1,538,052	78.4	96,535	4.9	23,102	1.2	52,951	2.7	1,534	0.1	144,163	7.3	234,715	12.0
Box Butte	9,063	83.6	66	0.6	365	3.4	75	0.7	5	0.0	853	7.9	1,246	11.5
Alliance City	6,582	80.8	62	0.8	340	4.2	67	0.8	5	0.1	710	8.7	1,150	14.1
Dawes	7,069	86.2	164	2.0	341	4.2	53	0.6	6	0.1	446	5.4	328	4.0
Chadron City	4,288	82.4	160	3.1	283	5.4	44	0.8	4	0.1	327	6.3	236	4.5
Crawford City	786	93.6	0	0.0	6	0.7	0	0.0	0	0.0	43	5.1	44	5.2
Morrill	3,892	85.4	20	0.4	54	1.2	21	0.5	0	0.0	317	7.0	648	14.2
Scotts Bluff	28,265	78.2	287	0.8	768	2.1	281	0.8	25	0.1	3,794	10.5	8,203	22.7
Sheridan	4,143	80.8	15	0.3	566	11.0	30	0.6	2	0.0	286	5.6	222	4.3
Sioux	1,065	92.8	0	0.0	2	0.2	4	0.4	2	0.2	44	3.9	43	3.8
SOUTH DAKOTA	715,336	80.7	17,842	2.0	77,748	8.8	13,476	1.5	543	0.1	46,665	5.3	38,741	4.4
Fall River	5,992	85.9	35	0.5	416	6.0	47	0.7	11	0.2	413	5.9	180	2.6
Oglala Lakota[1]	446	3.3	24	0.2	12,822	93.8	39	0.3	0	0.0	296	2.2	402	2.9
Pine Ridge CDP	73	2.3	2	0.1	3,001	95.6	4	0.1	0	0.	44	1.4	83	2.6
WYOMING	488,374	84.7	5,232	0.9	13,898	2.4	5,212	0.9	579	0.1	43,473	7.5	59,046	10.2
Goshen	11,113	88.9	76	0.6	111	0.9	49	0.4	1	0.0	695	5.6	1,212	9.7
Niobrara	2,288	92.7	6	0.2	30	1.2	13	0.5	5	0.2	112	4.5	76	3.1

Source: U.S. Census Bureau 2020b

Table 2.3-5. Population Projections for Population Centers within an 80-km (50-mile) Radius of the License area, 2020-2050

STATE County	Population (Actual)	Population (Projected)			
	2020	2030	2040	2050	2060
NEBRASKA					
Box Butte	10,842	11,654	11,978	12,394	12,940
Dawes	8,199	8,872	8,638	8,483	8,665
Morrill	4,555	4,767	4,841	5,013	5,272
Scotts Bluff	36,084	35,229	34,160	33,656	33,970
Sheridan	5,127	4,723	4,433	4,272	4,207
Sioux	1,135	1,147	1,079	1,061	1,087
Total	65,942	66,393	65,129	64,879	66,141
SOUTH DAKOTA					
Fall River	6,973	6,590	6,431	6,643	7,257
Oglala Lakota	13,672	N/A	N/A	N/A	N/A
WYOMING					
Goshen	12,498	14,460	15,052	15,857	17,129
Niobrara	2,467	2,776	3,035	3,464	4,004

N/A = not available
Source: NASA Socioeconomic Data and Applications Center 2021. SSP2 (Middle of the Road) estimate.

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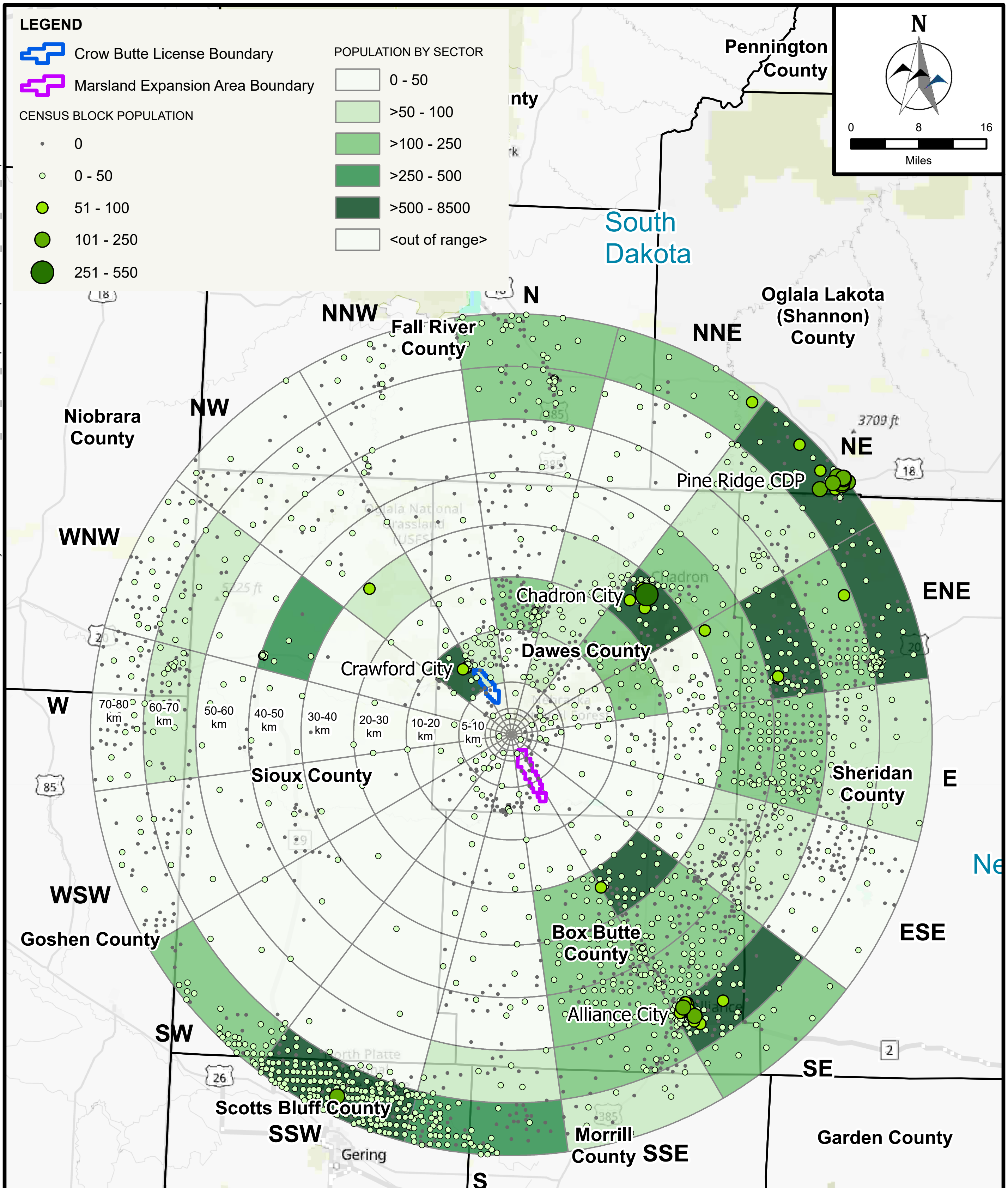

PERMIT TO MINE NO.			
NO.	REVISION	BY	DATE
4	---	---	---
3	---	---	---
2	---	---	---
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0	---	---	---

CROW BUTTE RESOURCES, INC., 86 CROW BUTTE ROAD, CRAWFORD, NE 69339

CROW BUTTE RESOURCES, INC.

DAWES COUNTY, NEBRASKA

DRAWN BY: RAV
CHECKED BY: BAW
APPROVED BY: --
DATE: 08/2024

SIGNIFICANT POPULATION CENTERS WITHIN 80 Km

FIGURE 2.3-1

2.4 REGIONAL HISTORIC, ARCHEOLOGICAL, ARCHITECTURAL, SCENIC AND NATURAL LANDMARKS

Section 2.4 of the 2008 Crow Butte LRA and Section 2.4 of the MEA TR provide information on the regional historic, archaeological and cultural resources for each project area. The information from these reports were incorporated into this Combined ER/TR. This section includes information from the Section 106 process completed for the 2008 Crow Butte LRA, which resulted in a supplement to the EA for the license renewal (NRC 2022). Based on the information presented in this section there is no significant change between the 2008 Crow Butte LRA, MEA TR and this Combined ER/TR.

2.4.1 Historic, Archeological, and Cultural Resources

2.4.1.1 Crow Butte Project

Identification and assessment of cultural resources within the Crow Butte Project involved two separate field investigations. The R&D stage of cultural resources investigation within the project was carried out during March and April 1982 by the University of Nebraska. Further investigations were completed for the remaining project area during April and May 1987 by the Nebraska State Historical Society (NSHS).

This section summarizes the results and recommendations of both studies. For detailed descriptions of each identified resource, refer to the original 1987 license application.

Preliminary background and archival research were initiated in conjunction with intensive field surveys to obtain data required for preparation of both R&D and commercial applications. This work established a basis for addressing potential effects of the project on identified cultural resources. Preliminary literature and records research indicated that systematic investigations had not been previously conducted within the project area and that no National Register of Historic Places (NRHP) eligible properties had been recorded within or immediately adjacent to the survey unit.

Limited previous studies in surrounding areas provided evidence that a wide range of paleontological, prehistoric and historic resources of potential significance to regional studies are present in the near vicinity and could likely be encountered within the project area. Registered National Historic Landmarks representing military and Native American reservation period use are located near the Crow Butte Project.

Intensive (100 percent coverage) pedestrian inspection of the R&D area (in 1982) and the full CSA survey unit (in 1987) resulted in identification of 21 newly recorded resource locations, including eight sites representing Native American components, 12 Euro-American locations, and a buried bone deposit of undetermined cultural association.

Fifteen of the newly identified resources contained limited evidence of scientifically important cultural remains or were not determined to be of significant historic value. These sites did not warrant further National Register consideration.

The remaining six sites were of potential archeological data recovery importance (25DW114, 25DW192, 25DW194 and 25DW198) or possible architectural interest (25DW112 and

25DW00-25). These six sites were potentially eligible for the NRHP, but fully assessing the eligibility of these sites was not within the scope of this work.

Field observation in August of 1995 confirmed that the current commercial operation would not directly affect any of the six potentially significant sites. Project development staff has detailed location maps of these properties, and LC 9.8 of SUA-1534 requires coordination with the NSHS before any development occurs in the immediate vicinity of the six potentially eligible sites.

2.4.1.2 Marsland Expansion Area

Cultural resource surveys are described in Section 2.4.1 of the MEA TR. An archaeological files search through the Archaeology Division of the NSHS indicated that there have been no previous archaeological investigations within 1.6 km (1 mile) of the MEA and that no archaeological sites have been previously reported. An architectural and structural properties search through the Nebraska State Historic Preservation Office (SHPO) indicated that four historic structures (DWOO-240, DWOO-241, DWOO-242, and DWOO-243) had been reported in the study area. Two of these structures are within the MEA and the other two are in proximity to the MEA.

ARCADIS completed an intensive pedestrian block cultural resources inventory of approximately 4,500 acres for the MEA during the period from November 2010 to February 2011 (Graves et al. 2011). The survey recorded 15 newly discovered historic sites and five historic isolated finds and updated the documentation on two of the previously recorded historic farmstead sites (DWOO-242 and DWOO-243). The newly recorded historic sites included six farmsteads (25DW359, 25DW360, 25DW361, 25DW365, 25DW366, and 25DW370), three artifact scatters (25DW357, 25DW363, and 25DW369), two cisterns (25DW358 and 25DW364), one corral and windmill (25DW367), one bridge (25DW362), one dugout depression and berm (25DW368), and one stone quarry (25DW371). All of these sites were recommended not eligible for the NRHP. Isolated finds are by definition not eligible for the NRHP. Historic farmstead DWOO-242 is recommended not eligible for the NRHP but appears to be currently or recently occupied. Site DWOO-243 may have the potential to yield information important in history and may be potentially eligible for the NRHP. Avoidance of the two historic farmstead sites is recommended.

ARCADIS submitted the “Cameco Resources Marsland Expansion Area Uranium Project Cultural Resource Inventory” report and associated Nebraska Archeological Site Survey Forms to the NSHS on April 28, 2011 (Graves 2011), and SHPO concurrence was granted by the Deputy State Historic Preservation Officer (SHPO) on May 19, 2011. The SHPO approval was issued via a stamped concurrence on the April 28, 2011 submittal letter. CBR requested that ARCADIS complete a field survey of an additional 160 acres in Section 36 of T30N R51W. The 160 acres was investigated by ARCADIS on February 19, 2011, and no new cultural resources were discovered. One historic bridge (25DW362) was identified and reported within the original cultural resource inventory report. An addendum to the original cultural resources report was prepared to address the additional 160 acres (Graves and Graves 2012). Historic site 25DW362 was recommended not eligible for listing on the NRHP with SHPO concurrence. The Nebraska SHPO concurred with the findings of the addition to the cultural resources report that no archaeological, architectural, or historic context property resources would be affected by the project (NSHS 2012).

2.4.1.3 Section 106

The NRC is responsible for the government-to-government National Historic Preservation Act (NHPA) Section 106 consultation for the Crow Butte Project and the MEA.

2.4.1.3.1 Crow Butte Project

Following the 2007 LRA, the Board found that NRC staff did not meet its identification obligations under the NHPA and found that the 2014 EA did not take a hard look at potential traditional cultural properties (TCPs) within the Crow Butte license area.

During the first half of 2021, the NRC staff held several meetings with representatives of the Oglala Sioux Tribe. These meetings culminated in the development of a methodology for conducting a tribal cultural survey to identify sites of historic, cultural, and religious significance to the Tribe within the Crow Butte license area that could be affected by the continued operation of the Crow Butte Project under the renewed license. The tribal cultural survey was conducted in November-December 2021. In 2022, NRC published a supplement to the EA for the license renewal of NRC License SUA-1534. The following summarizes the information presented in the 2022 supplemental EA (NRC 2022).

The survey report identified 28 locations with archaeological resources (artifacts or features), and 31 sites of historic, cultural, or religious significance to the Tribe, which the survey report refers to as TCPs. The following summarizes the survey results:

- Of the 28 locations with archaeological resources, 11 were identified as isolated finds not eligible for NRHP listing, 13 were identified archaeological sites recommended as being not eligible for NRFP listing, two sites were recommended as eligible for the for NRHP listing and two other sites were recommended to be considered unevaluated.
- The survey identified 21 plant species as being culturally significant within the license area, including 12 species which were very common, seven that were common, and two that were occasional. Two fossils were identified on private land, and the report did not address the NRHP eligibility.
- Three small creeks in the license area were identified as TCPs because they represent the types of waterways that were important to providing food, medicine, and raw materials. These creeks are, from west to east, White Clay Creek, English Creek, and First Woman Creek. The identified waterways are mostly on private lands, except for the farthest upstream portion of First Woman Creek within the license area, which is on Nebraska State lands. Within the license area, First Woman Creek, which trends south-to-north toward the White River, is narrow enough in some places that it can be stepped across. English Creek, which has intermittent water (it was dry in November 2021), also trends south-to-north through the center of the license area. And a small portion of White Clay Creek, also a small perennial waterway, cuts through the northwest corner of the project area.
- Two locations within the license area contained skeletal remains of bison. The survey did not establish whether these locations represent kill and butchering sites or that the animals died of natural causes.

- Three sites were identified as *hanbleciya*, or vision quest, sites. All three sites are located on relatively level areas near the tops of buttes, with clear views of Crow Butte and Lovers Leap. All three vision quest sites are on private property.

The following summarizes the NHPA eligibility evaluations and analysis under NHPA and NEPA as described in the 2022 supplemental EA

- The NRC staff agreed that the four archaeological sites are potentially eligible for listing in the NRHP. The survey report determined that none of the remaining 24 sites met any criteria for eligibility. In the 2022 EA, the sites were analyzed for potential effects under NHPA. The report stated that these four sites would not be affected by licensed activities because they are located outside the developed area. The NRC staff concluded that there will be no historic properties affected by the license renewal.
- The NRC staff concluded that the 21 plant species identified during the survey are not eligible for NRHP because the plants identified during the survey are indistinguishable from identical plants that are widespread across much of North America. Their cultural significance lies not in a specific location where the species is found today, but in the cultural values assigned to those plant species by Lakota traditionalists. Potential impacts to these plant species were analyzed under NEPA and it was concluded that there will be no significant impact on these culturally significant plants by the license renewal.
- The NRC staff determined that the two fossil sites are not eligible for listing in the NRHP because they do not maintain integrity of relationship or integrity of condition. Potential impacts on these fossil resources were analyzed under NEPA. Because the fossil sites are located sufficiently outside the developed area it was concluded that there would be no significant impacts on this site from licensed activities, including reclamation.
- The NRC staff determined that the opportunistic use of the three creeks at an unknown point in the past does not establish the necessary integrity of relationship for NHPA eligibility purposes. In addition, the 2022 supplemental EA states that "the three waterways are not relevant to the survival of tribal cultural practices given that the Tribe has not had access to these waterways within the license area since the original licensing of the CBR ISR facility." The impacts of the license renewal, including decommissioning activities, on surface water quality were addressed in the 2014 EA and resolved in the 2015 license renewal hearing. The NRC concluded that there will be no significant impacts from the license renewal on these three creeks.
- The NRC staff concluded that the two bison skeletons identified during the survey are not eligible for NRHP listing because there is no definitive evidence that these specific animal remains are associated with cultural practices or beliefs of a living community, and because there is no integrity of condition (due to disarticulation of the remains) or integrity of relationship. The potential impacts to these resources were analyzed under NEPA and it was concluded that there will be no significant impacts on the bison skeletons because they are located outside of the developed area.
- The NRC staff concluded that the three vision quest sites identified by the Tribe are not eligible for NRHP listing because they are opportunistic, which is not sufficient to

establish integrity of relationship. The potential impacts to these sites were analyzed under NEPA and the NRC staff concluded that there would be no significant impacts on these sites from licensed activities, including reclamation.

The final finding of no significant impact (FONSI) and notice of issuance were published in the Federal Register on October 25, 2022 (87 FR 64524). In addition, the NRC sent a letter to officially inform the parties that the commission declined to review the decision of the ASLB in its January 5, 2023, Memorandum and Order, Granting Motion to Terminate Proceeding (LBP-23-01) and indicating final agency action.

2.4.1.3.2 MEA

In the 2018 MEA EA, Section 3.6 discusses how the NRC fulfilled its responsibilities under Section 106 of the NHPA for CBR's license amendment. Within the MEA a Class III archaeological survey, TCP surveys completed by the Crow and Santee Sioux Nations and the NRC's cultural resources expert, a literature review, and overall Tribal consultations resulted in the recording of 15 historic resource sites. None of the sites were evaluated as eligible for listing on the NRHP, although two were recommended as requiring additional evaluation should they be directly impacted by future project development (Graves et al., 2011). In a letter dated November 18, 2014, the SHPO concurred with the NRC's finding that the MEA would not impact archaeological, architectural, or historic context property resources (NSHS 2014).

2.4.2 Scenic Resources

2.4.2.1 Introduction

The Crow Butte Project and the MEA are located on private land that is not managed to protect scenic quality by any public agency. The Crow Butte Project and the MEA are located on generally level ground south of the Pine Ridge area of northwestern Nebraska and may be visible from some public roads in the areas. The existing landscape and the visual effect of the existing and proposed facilities have been inventoried and assessed for the projects using the BLM Visual Resource Management (VRM) system.

The VRM system is the basic tool used by the BLM to inventory and manage visual resources on public lands and is used in this analysis. 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.

2.4.2.2 Crow Butte Project

The scenic quality inventory was based on methods provided in BLM Manual 8410 – Visual Resource Inventory (BLM 1986). 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 2.4-1. According to NUREG-1569, 2.4.3(7), if the visual resource evaluation rating is 19 or lower, no further evaluation is required. The total score of the scenic quality inventory was 14; therefore, the visual effect of the Crow Butte Project on the local visual resources was not further analyzed.

2.4.2.3 Marsland Expansion Area

Scenic resources are described in Section 2.4.2 of the MEA TR. The results of the scenic quality inventory for the MEA and the associated score for each key factor are summarized in Table 2.4-2. The total score of the scenic quality inventory for the MEA was 9; however, an analysis was prepared to reflect the growing concern some residents had for the scenic resource, as Dawes County is expected to continue to develop tourism in the region. The visual inventory is presented in detail in Section 2.4.2.4 of the MEA TR. The inventory indicated that the scenic quality of the MEA landscape is typical of the ecoregion, and is rated as Class B. The Sensitivity Level was Level 2 (Medium) as viewed from E. Belmont Road, River Road, Squaw Mound Road, or Hollibaugh Road, and residences; and the location of the MEA project area in the background distance zone as seen from the Nebraska National Forest. Overall, the MEA was assigned VRM Class III. The objective of VRM Class III is to partially retain the existing character of the landscape and maintain a moderate level of change to the characteristic landscape.

2.4.3 References

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U.S. Nuclear Regulatory Commission, 2022, Supplement to the Environmental Assessment for the License Renewal of U.S. Nuclear Regulatory Commission License Number SUA-1534 for the Crow Bute Resources, Inc. In-Situ Uranium Recovery Facility in Dawes County, Nebraska. ADAMS Accession No. ML22278A108.

Table 2.4-1 Scenic Quality Inventory and Evaluation for the Crow Butte Project

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	Low influence due to lack of topographical relief and similar adjacent scenery	1
Scarcity	Landscape is common for the region	1
Cultural modifications	Existing modifications are agricultural, and introduce no discordant elements	5
	Total Score	**14**

Table 2.4-2 Scenic Quality Inventory and Evaluation for the Marsland 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	Low influence due to lack of topographical relief and similar adjacent scenery	1
Scarcity	Landscape is common for the region	1
Cultural modifications	Existing modifications are agricultural, and introduce no discordant elements	0
	Total Score	**9**

2.5 METEOROLOGY, CLIMATOLOGY, AND AIR QUALITY

Section 2.5 of the 2008 Crow Butte LRA and Section 2.5 of the MEA TR provide information on the meteorology, climatology, and air quality for each project area. The information from these reports were incorporated into this Combined ER/TR. This section updates, as applicable, the regional and site-specific meteorology, climatology, and air quality conditions in the region surrounding the Crow Butte Project and the MEA. Based on the information presented in this section there is no significant change between the 2008 Crow Butte LRA, MEA TR and this Combined ER/TR.

Data sources for the meteorological conditions used for this report come from the High Plains Regional Climatic Center (HPRCC 2024a), National Climatic Data Center (NCDC 2024), and National Oceanic and Atmospheric Administration (NOAA 2024) for sites located in Chadron, Nebraska and Scottsbluff, Nebraska. The Crow Butte Project on-site monitoring data were collected between May 1982 and April 1984, and included temperature, precipitation, evaporation, wind speed, and wind direction. In December 2014, CBR resumed operation of the meteorological station at the Crow Butte Project. The MEA on-site monitoring data were collected between August 2010 and August 2011, and included temperature, precipitation, evaporation, wind speed, and wind direction.

2.5.1 Introduction

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

Yearly precipitation totals typically range from 13 to 16 inches. Migratory storm systems that originate in the Pacific Ocean release a majority of their moisture over the Rocky Mountains. Major precipitation events can occur when these systems regain moisture already present in the area or moisture advected from the Gulf of Mexico. The region is prone to severe thunderstorm events throughout the spring and early summer months, and much of the precipitation is attributed to these events. In a typical year, the area will experience four or five severe thunderstorm events (as defined by the National Weather Service [NWS] criteria) and 40 to 50 thunderstorm days. Autumn stratiform rain events also contribute to precipitation totals, but to a lesser degree. Snow frequents the region throughout winter months (30 to 50 inches per year), but generally provides less moisture than rain events.

Windy conditions are fairly common to the area. Roughly 3 percent of the time, hourly wind speed averages exceed 25 miles per hour (mph). The predominant wind directions are north-northwesterly and northwesterly, with the wind blowing from those directions roughly 25 percent of the time. Surface wind speeds are relatively moderate at a year-round, hourly average of 10 to 11 mph. Higher average wind speeds are encountered during the winter months, while summer months experience lower average wind speeds.

For the regional analysis, meteorological data have been compiled for 2 sites surrounding the Crow Butte Project and the MEA. The Scottsbluff Airport and the Chadron Airport were selected as most representative of the meteorology. Scottsbluff is approximately 50 miles (80 km) south of the Crow Butte Project and the MEA, with an elevation roughly 300 ft lower. The Chadron Airport is around 20 miles (32 km) northeast of the Crow Butte Project and the MEA, with an elevation roughly 300 ft higher.

For the site-specific analysis, meteorological data from the Crow Butte Project and MEA meteorological station were used. The Crow Butte meteorological data were collected between August 2020 and August 2024, and include temperature, precipitation, relative humidity, solar radiation, wind speed, and wind direction. The MEA meteorological data were collected between August 2010 and August 2011.

Table 2.5-1 provides the station IDs, coordinates, and periods of operation for the regional and site-specific meteorological stations. The locations of the regional and site-specific meteorological stations are shown on Figure 2.5-1.

In the information that follows, a regional overview is presented first. This section includes a discussion of the maximum and minimum temperatures and relative humidity, annual precipitation including snowfall estimates, a brief wind speed and direction summary, and a discussion of evapotranspiration rates. A combination of monitoring stations is analyzed for the regional overview of temperature, snowfall, and total precipitation. The site-specific analysis follows the regional overview. The site-specific analysis includes a justification for using wind data from the baseline monitoring year to predict meteorological conditions over the long term. This is necessary to validate air sampling locations and MILDOS dispersion modeling inputs.

2.5.2 Regional Meteorology

2.5.2.1 Temperature

The annual average temperature for the region is approximately 44 to 48 °F. Table 2.5-2 presents monthly average temperatures for the Scottsbluff Airport and Chadron Airport sites, along with the monthly maximum and minimum temperatures. July has the highest average monthly temperature, followed by August. January records the lowest average temperatures for the year, followed by December. Low temperatures in the region can drop to below 40 ºF, while high temperatures can reach up to 114 °F.

2.5.2.2 Relative Humidity

The Scottsbluff Airport site records relative humidity (dew point) data. The graph on Figure 2.5-2 charts monthly average relative humidity values for the Scottsbluff Airport from January 2003 through June 2024. These data indicate that June has the driest air, with relative humidity averaging around 57 percent. The winter months of December, January, and February make up the most humid part of the year, with average relative humidity approaching 68 percent. The overall average relative humidity is 62 percent at Scottsbluff Airport.

Relative humidity is a temperature-based calculation which reflects the fraction of moisture present relative to the amount of moisture for saturated air at that temperature. Warmer air holds more moisture at saturation than colder air. Therefore, for a given amount of moisture in the air, relative humidity maximum values occur more frequently in the early mornings, while minimum values typically occur during the mid-afternoon hours.

2.5.2.3 Precipitation

The region is characterized by moderately dry conditions. The Scottsbluff Airport and Chadron Airport received measurable (>0.01 in) precipitation on an average of 87 and 79 days per year between 2000 and June 2024, respectively. Average annual precipitation during that period was 15 inches per year at the Scottsbluff Airport and 18 inches per year at the Chadron Airport. Spring showers and thunderstorms produce nearly half of the precipitation (Figure 2.5-3). May and June are typically the wettest months of the year, while January and December are the driest months.

Severe weather does arise throughout the region but is limited on average to five or six severe events per year. These severe events are generally split between hail and damaging wind events. Tornadoes can occur but are rare in western Nebraska.

Average annual snowfall varies throughout the region. Major snowstorms (more than 5 in/day) are relatively infrequent in the region. The region experiences fewer than three major snowstorms per year. Snowfall at the Scottsbluff Airport site averaged 41.5 inches per year over the period of record (1893-July 2024) and the Chadron Airport site averaged 48.9 inches per year over the period of record (November 1894-July 2024). Monthly average snow amounts are depicted on Figure 2.5-4, which shows the highest amount of snowfall in March.

2.5.2.4 Wind Patterns

Year-round wind speeds in the area average between 3.6 and 4.9 m/s (8 and 11 mph). Table 2.5-3 shows monthly average wind speeds for the Scottsbluff Airport site. The overall average wind speed at this site was 4.2 m/s (9.3 mph) for the 2003 through June 2024 period analyzed in this study. Mean monthly average wind speeds were the lowest in the summer months and highest in April at nearly 5.4 m/s (12 mph).

Table 2.5-3 also shows monthly maximum hourly wind speeds for the Scottsbluff Airport. High wind events are fairly common in this region; wind data from this site show every month recording peak hourly wind speeds greater than 26.8 m/s (60 mph) during the period analyzed.

Figure 2.5-5 shows the wind rose for the Scottsbluff Airport site for the 2003 through June 2024 period. Predominant winds are generally from the west-northwesterly or northwesterly directions. These winds, often associated with storm fronts, dominate the late fall, winter, and early spring seasons. A secondary mode occurs from the east-southeasterly or easterly directions. These winds are generally associated with the summer season when regional high pressure dominates. The highest wind speeds tend to occur from the northwesterly direction.

Winds at the Scottsbluff Airport site and throughout the region exhibit a diurnal pattern. Figure 2.5-6 shows the pattern at Scottsbluff for each season of the year. Wind speeds peak during the afternoon for the spring, summer, and fall seasons. This is largely due to longer daylight hours and the predominant effect of solar heating on wind patterns. Figure 2.5-6 also shows that the highest average wind speeds occur during the spring season, when the atmosphere tends to be least stable and storm systems are the strongest. The lowest wind speeds occur during summer, when the atmosphere is generally stable and storm systems are weak.

2.5.2.5 Heating, Cooling, and Growing Degree Days

Figure 2.5-7 summarizes the monthly cooling, heating, and growing degree days for Scottsbluff Airport site. The data are assumed to be indicative of the project area due to its proximity and comparable elevation.

The heating and cooling degree days are included to show deviation of the average daily temperature from a predefined base temperature. In this case, 50 °F has been selected as the base temperature for computation of growing degree days. The base temperature for computing heating and cooling degree days is 65 °F. The number of heating degree days is computed by taking the average of the high and low temperatures occurring that day and subtracting it from the base temperature. The calculation for growing and cooling degree days is the same, except that the base temperature is subtracted from the average of the high and low temperatures for the day. Negative values are disregarded for both calculations.

As expected, the graphs of heating degree days and cooling degree days are inversely related, and the growing and cooling degree days are directly related. The maximum number of heating degree days occurs in December and January, at roughly 1,200 degree days. This coincides with the months having the lowest minimum average temperatures. Conversely, July registers the most growing degree days with over 700, and the most cooling degree days at around 300. This also corresponds to July having the highest average temperature.

2.5.2.6 Evapotranspiration

The project region is characterized by high evaporative demand during much of the year. This demand is related to dry air (low dew points), high daytime temperatures, and moderate wind speeds. ET was calculated by the University of Nebraska (2011) at five locations, including Scottsbluff. Meteorological inputs included wind speed, air temperature, relative humidity, solar radiation, and rain. For the Scottsbluff site, the average annual ET was 57.7 inches per year and 41.1 inches during the growing season (May 1 through September 30).

2.5.3 Site Specific Analysis

The site specific analysis for both the Crow Butte Project and the MEA were presented in the license applications. The following updates the site specific meteorological data for the Crow Butte Project for the time period of August 2020 through August 2024. In addition, this section summarizes the historic wind data for each site provided in the original license applications and includes a summary of the justification for long-term representativeness at each site.

2.5.3.1 Crow Butte Project

2.5.3.1.1 Current Meteorological Conditions

In December 2014, CBR constructed a new meteorological station at the Crow Butte Project. A summary of the sensors installed at the station is provided in Table 2.5-4. The station is audited semi-annually by EcologicDNA, LLC. The following summarizes the meteorological data collected from the station between August 2020 and August 2024.

2.5.3.1.1.1 Temperature

Temperature at the Crow Butte Project is measured at the 2 and 10-meter heights. Monthly average, minimum, and maximum temperatures are provided in Table 2.5-5. The annual average project site temperature is similar to the regional average temperature at 47.6°F at the 2-meter height. The average temperature was slightly higher (48.6°F) at the 10-meter height. The maximum temperature for the time period was 107°F and the minimum temperature was -23°F. July is the warmest month at the site, while January is typically the coldest month.

2.5.3.1.1.2 Relative Humidity

The annual average relative humidity at the Crow Butte Project is 55%. Monthly relative humidity is graphed on Figure 2.5-8 and shows that the relative humidity is the lowest between July and September, which corresponds to the hottest, driest months.

2.5.3.1.1.3 Precipitation

Precipitation at the Crow Butte Project is measured as rainfall into a tipping bucket. The monthly precipitation for each year (August 2020 to August 2024) is provided in Figure 2.5-9. The figure shows that May is typically the wettest month at the Crow Butte Project. Precipitation in 2023 was anomalously high. The HPRCC (2024b) reported that Chadron, Nebraska observed its wettest year on record, with 23.85 inches (60.58 cm) of precipitation beating out the previous record of 21.60 in (54.86 cm) set in 1947.

2.5.3.1.1.4 Wind Patterns

The average wind speed for the Crow Butte Project was 3.9 m/sec (8.8 mph) over the four-year monitoring period, which is similar to the average wind speed measured at the Scottsbluff Airport. Average, maximum, and minimum wind speeds for each month are provided in Table 2.5-6. The maximum wind speed measured at the Crow Butte Project was 29.9 m/sec (66.9 mph) measured on December 23, 2020. A minimum wind speed of 0 m/sec was recorded in approximately 31 percent of the hourly data.

Figure 2.5-10 shows the wind rose for the Crow Butte Project. Predominant winds are generally from the south and southeasterly directions. A secondary mode occurs from the west-northwesterly or northwesterly directions. These winds, often associated with storm fronts, dominate the late fall, winter, and early spring seasons. The highest wind speeds tend to occur from the northwesterly direction.

2.5.3.1.1.5 Solar Radiation

Solar radiation for the Crow Butte Project to presented in Figure 2.5-11. The highest solar radiation is measured in the summer months (June, July, August), while the lowest solar radiation is measured in December.

2.5.3.1.2 Historic Wind Data

The 1982 to 1984 meteorological data from the Crow Butte Project station were used to show the trends in wind patterns for the project site in the original license application. The evaluation of wind patterns found that the older data from the actual site were more representative than recent data from available off-site weather stations. The wind patterns are largely impacted by local terrain and wind patterns (e.g., wind roses) have not changed significantly over a 40-year period for Scottsbluff and Rapid City, which suggests there would be no significant changes with wind patterns at the CBR meteorological monitoring site.

In the 2014 SER, NRC staff agreed with the assessment as the information used for comparison is from an authoritative source and has found no technical reason for invalidating previous wind data. Moreover, staff previously analyzed the original wind data and concluded that operation of the Crow Butte Project is protective of health and safety (NRC 1998).

2.5.3.2 Marsland Expansion Area

Site-specific meteorological data for the MEA is provided in Section 2.5.3 of the MEA TR and incorporated into the Combined ER/TR. Onsite meteorological data at the MEA were collected for the baseline monitoring from August 2010 through August 2011.

Figure 2.5-12 presents the wind rose for the MEA during the 12-month baseline monitoring period. The predominant wind direction is north-northwesterly and northwesterly, with the highest wind speeds also coming from those directions. Synoptic weather systems during the late spring and summer generally interrupt this pattern, producing high north-northwesterly winds.

The average wind speed for the MEA was 10.6 mph over the 12 months of monitoring, slightly higher than the 9.3 mph long-term average at Scottsbluff. Table 2.5-7 lists the annual JFD for the MEA. Tables 2.5-8 through 2.5-11 list the seasonal JFDs. Similar to the Crow Butte Project, the majority of the winds at the MEA fall into stability class D, which represents near neutral to slightly unstable conditions. The light winds which accompany stable environments are reflected in the stability class F summary.

To demonstrate that the baseline year is representative of the longer-term wind conditions, the Scottsbluff Airport was chosen to represent wind conditions in the vicinity of the MEA due to proximity, similar elevation, similar terrain, and the limited availability of hourly wind data in the region. IML Air Science developed a statistical methodology for assessing the degree to which the distributions of wind speed class and wind direction frequencies from 1 year of monitoring at a particular location represent the long-term distributions at that same location.

In the 2018 MEA SER, the NRC staff noted that although the data recovery for monitored parameters satisfied the greater than 90 percent data recovery in RG 3.63, the analysis used for demonstrating that 1-year baseline monitoring data represent long-term meteorological conditions was not satisfactory. NRC staff indicated that while linear regression and correlation analyses describe relationships between variables, a statistical test for representativeness requires an analysis of data populations (e.g., short- and long-term wind data at a given site). Thus, the NRC staff imposed LC 11.3.2 of SUA-1534 requiring continued meteorological monitoring to substantiate that the data collected at the MEA and used for assessing radiological impacts is representative of expected long-term conditions at and near the site. The data collected shall include, at a minimum, wind speed, wind direction, and an annual wind rose. When CBR believes it has representative data, CBR will submit the data, a summary of the stability classification, and an analysis demonstrating that the data are representative of long-term conditions at the MEA.

2.5.4 Air Quality

The NDEE air quality 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 (NDEE 2024). The NDEE adopts the majority of these federal regulations into Title 129 of the Nebraska Administrative Code. The basic foundation of the NDEE air program is the National Ambient Air Quality Standards (NAAQS), which are concentrations of pollutants the EPA has established (and adopted by the NDEE) 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 2.5-12; EPA 2024a). The State of Nebraska is required to keep areas in compliance with the standards and restore compliance in any areas out of compliance. The NDEE has several ambient air monitors located throughout the state to measure the concentrations of pollutants in the ambient air (NDEE 2024). 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 below the levels established by the NAAQS are considered in attainment or unclassifiable.

There are no ambient air quality monitoring data for criteria pollutants in the Crow Butte Project or the MEA. However, there are a limited amount of state and federal monitoring sites in the region 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 NDEE and South Dakota Department of Agriculture & Natural Resources (SD DANR), as per Appendix D of 40 CFR Part 58.

Regional monitoring sites and parameters measured are presented in Table 2.5-13. The locations of the monitor sites in western Nebraska are shown on Figure 2.5-13. The data available at the time of preparation of this section are summarized in Tables 2.5-14 through 2.5-19. The results of this monitoring indicate that the regions being monitored, including the Crow Butte Project and the MEA areas, are well within compliance of NAAQS standards.

2.5.5 References

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Table 2.5-1. Meteorological Stations Included in Climate Analysis

Name	Agency	X	Y	Z (ft)	Years Operation
Chadron	NWS	-103° 10'	42° 84'	3,297	1894 - 2024
Scottsbluff	NWS	-103° 36'	41° 52'	3,950	1893 - 2024
Crow Butte Project	CBR	-103° 21'	42° 38'	3,890	1982 – 1984
	CBR	-103° 21'	42° 38'	3,840	2014 - current
MEA	CBR	-103° 15'	42° 30'	4,250	2010 - 2011

Source: NOAA 2024
Note: NWS = National Weather Service

Table 2.5-2. Monthly Temperature Statistics for Scottsbluff Airport and Chadron Airport

Month	Monthly Average (˚F)		Monthly High (˚F)		Monthly Low (˚F)		Average Daily High (˚F)		Average Daily Low (˚F)	
	Scottsbluff	Chadron	Scottsbluff	Chadron	Scottsbluff	Chadron	Scottsbluff	Chadron	Scottsbluff	Chadron
Jan	26.2	25.4	74	70	-33	-28	27.9	28.0	24.1	23.1
Feb	29.5	27.9	77	80	-46	-44	34.4	34.9	25.7	24.6
Mar	37.1	37.1	87	96	-27	-26	41.3	42.0	32.0	31.2
Apr	46.8	46.0	93	83	-8	-8	50.5	50.3	32.1	40.3
May	56.9	56.6	103	98	12	17	61.6	62.3	41.7	49.6
Jun	67.4	67.5	106	107	30	31	72.7	73.5	50.7	60.8
Jul	73.9	75.1	110	110	35	37	75.0	77.5	61.7	72.4
Aug	71.9	73.2	106	114	30	31	74.0	75.4	72.1	69.8
Sep	62.1	63.6	105	110	14	15	68.9	71.0	69.3	57.4
Oct	49.5	49.8	93	94	-10	-13	56.8	58.7	56.8	41.3
Nov	36.6	37.0	83	86	-21	-16	41.5	41.5	42.0	31.5
Dec	27.5	27.2	77	78	-42	-40	32.3	34.6	31.2	23.2

Source: NOAA 2024
Scottsbluff AP period of record: 1893-01-01 to 2024-08-01
Chadron AP period of record: 1894-08-16 to 2024-08-01

Table 2.5-3. Scottsbluff Airport Monthly Wind Parameters Summary

	Average		Minimum		Maximum	
Month	**m/s**	**mph**	**m/s**	**mph**	**m/s**	**mph**
January	4.0	8.9	0	0	38.6	86.3
February	4.5	10.0	0	0	28.8	64.4
March	4.7	10.5	0	0	31.4	70.2
April	5.2	11.7	0	0	37.1	82.9
May	4.6	10.2	0	0	32.4	72.5
June	4.1	9.2	0	0	35.0	78.2
July	3.7	8.3	0	0	35.5	79.4
August	3.5	7.8	0	0	32.4	72.5
September	3.6	8.0	0	0	36.0	80.6
October	3.9	8.8	0	0	43.7	97.8
November	3.9	8.7	0	0	43.2	96.7
December	4.2	9.5	0	0	29.8	66.7

Source: Synoptic 2024, hourly data from January 2003 through June 2024

Table 2.5-4. Crow Butte Project Meteorological Station Equipment Specifications

Parameter	Instrument	Operating Range	Instrument Height
Wind Speed	RM Young Model: 05305-5	0-50 m/s	10 m
Wind Direction	RM Young Model: 05305-5	0-360 °	10 m
Temperature	Met One Model: 062 MP	-50 to +50 °C -50 to +50 °C	2 m 10 m
Solar Radiation	LiCor Model: 200 Pyranometer	0-1,400 W/m^2	1.33 m
Relative Humidity	Vaisala Model: HMP45AC	0-100%	2 m
Precipitation	Met One Model: TE525WS	N/A	N/A

Table 2.5-5. Crow Butte Project Temperature (2 and 10 meter)

Month	2-meter Temperature (˚F)			10-meter Temperature (˚F)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
January	26.8	-23.5	64.4	28.5	-21.6	64.2
February	26.6	-22.3	64.0	27.9	-20.3	63.1
March	35.4	-11.9	79.6	36.3	-8.2	78.0
April	43.9	9.5	84.8	44.6	12.3	83.6
May	54.7	22.2	92.3	55.2	25.4	90.8
June	68.5	36.5	99.9	68.9	37.6	98.5
July	76.0	44.9	105.6	75.9	46.4	103.8
August	74.4	37.3	107.1	74.7	40.8	102.8
September	64.9	29.4	102.8	65.8	31.2	102.2
October	47.3	-7.0	88.4	48.7	-2.4	87.6
November	38.7	-4.2	78.0	40.6	-0.6	77.4
December	30.5	-21.2	73.5	32.3	-20.9	72.8

Period of Record: 8/13/2020 to 8/13/2024 hourly data

Table 2.5-6. Crow Butte Project Wind Speeds

Month	Average		Minimum		Maximum	
	m/s	mph	m/s	mph	m/s	mph
January	3.7	8.2	0	0	28.7	64.3
February	3.9	8.8	0	0	19.8	44.3
March	4.2	9.4	0	0	23.5	52.5
April	5.1	11.4	0	0	26.6	59.4
May	4.3	9.5	0	0	26.8	59.9
June	3.4	7.7	0	0	26.4	59.0
July	3.9	8.7	0	0	26.8	60.0
August	3.7	8.3	0	0	21.8	48.7
September	3.3	7.5	0	0	18.5	41.3
October	3.5	7.9	0	0	24.9	55.6
November	3.8	8.6	0	0	27.0	60.4
December	4.3	9.5	0	0	29.3	65.5

Period of Record: 8/13/2020 to 8/13/2024 hourly data

Table 2.5-7. Marsland Expansion Area Annual Joint Frequency Distribution

Stability Class	Wind Direction	Wind Speed (mph) - One Year (Calm = 1.0%)					
		0 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24
A	N	0.001414	0.002357				
	NNE	0.000236	0.001532				
	NE	0.000707	0.001886				
	ENE	0.000825	0.001768				
	E	0.000943	0.001768				
	ESE	0.001296	0.002593				
	SE	0.001061	0.002004				
	SSE	0.002121	0.002121				
	S	0.001768	0.002121				
	SSW	0.003536	0.002593				
	SW	0.001414	0.002239				
	WSW	0.000943	0.004007				
	W	0.001179	0.001179				
	WNW	0.000825	0.001179				
	NW	0.000589	0.002004				
	NNW	0.000589	0.002121				
B	N		0.002004	0.000236			
	NNE		0.002239				
	NE		0.002475	0.000118			
	ENE		0.001768				
	E		0.001768	0.000118			
	ESE	0.000354	0.002475	0.000354			
	SE	0.000118	0.003418	0.000354			
	SSE	0.000471	0.002475	0.000236			
	S	0.000471	0.002357	0.000707			
	SSW	0.000943	0.003182	0.000589			
	SW	0.000118	0.003064				
	WSW		0.002593	0.000471			
	W	0.000118	0.001296	0.000236			
	WNW	0.000118	0.001650	0.000118			
	NW		0.002357	0.000707			
	NNW		0.002121	0.000471			
C	N	0.000118	0.000589	0.010253			
	NNE		0.000589	0.004714			
	NE		0.000589	0.002946			
	ENE		0.000825	0.003418			
	E		0.001179	0.003300			
	ESE		0.001768	0.005539			
	SE	0.000354	0.001886	0.004125			
	SSE	0.000118	0.001532	0.004361			
	S	0.000354	0.001532	0.004950			
	SSW	0.000236	0.001414	0.004361			
	SW	0.000118	0.001886	0.005657			
	WSW		0.000825	0.006600			
	W		0.000707	0.004361			
	WNW		0.000471	0.004714			
	NW		0.000589	0.008132			
	NNW		0.000943	0.007778			

Table 2.5-7. Marsland Expansion Area Annual Joint Frequency Distribution (Cont.)

Stability Class	Wind Direction	Wind Speed (mph) - One Year (Calm = 1.0%)					
		0 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24
D	N	0.000236	0.007307	0.019093	0.017796	0.004125	0.001414
	NNE	0.000236	0.004714	0.010725	0.008603	0.002239	0.000118
	NE		0.001886	0.009193	0.003064	0.000118	
	ENE		0.003064	0.007307	0.002004		0.000118
	E	0.000118	0.005775	0.010371	0.003182	0.000118	
	ESE	0.000471	0.008839	0.009193	0.003064	0.000236	0.000118
	SE	0.000236	0.010489	0.012139	0.003889	0.000354	
	SSE	0.000118	0.007543	0.016500	0.009546	0.003418	0.000118
	S	0.000118	0.005186	0.013082	0.013789	0.002829	0.000118
	SSW	0.000118	0.003889	0.008957	0.006718	0.001179	
	SW	0.000236	0.004832	0.007896	0.003654	0.001414	
	WSW	0.000118	0.005068	0.014614	0.008721	0.002475	0.000236
	W		0.004125	0.012728	0.012610	0.002946	0.002357
	WNW	0.000118	0.003771	0.014850	0.019564	0.007189	0.002946
	NW	0.000118	0.006836	0.019093	0.030053	0.016971	0.005893
	NNW	0.000707	0.013553	0.023689	0.028167	0.012375	0.004478
E	N	0.001532	0.002357	0.000471			
	NNE	0.000707	0.001296	0.000354			
	NE		0.001650	0.000236			
	ENE		0.002004	0.000471			
	E	0.000589	0.001532	0.000589			
	ESE	0.000354	0.003064	0.000236			
	SE	0.000825	0.002004	0.000236			
	SSE	0.000707	0.002475	0.000471			
	S	0.000354	0.002711	0.000236			
	SSW		0.002004	0.000236			
	SW	0.000354	0.002946	0.000589			
	WSW	0.000354	0.002829	0.001061			
	W	0.000118	0.002004	0.000943			
	WNW	0.000707	0.001296	0.000825			
	NW	0.000589	0.003536	0.001414			
	NNW	0.000943	0.009664	0.001886			
F	N	0.009782	0.007071				
	NNE	0.006953	0.002829				
	NE	0.006364	0.001179				
	ENE	0.005421	0.002593				
	E	0.004478	0.003536				
	ESE	0.005186	0.003182				
	SE	0.006718	0.003418				
	SSE	0.006128	0.004832				
	S	0.007543	0.003418				
	SSW	0.006600	0.004950				
	SW	0.005775	0.004361				
	WSW	0.007307	0.004714				
	W	0.005657	0.002946				
	WNW	0.005775	0.005539				
	NW	0.006718	0.004596				
	NNW	0.013318	0.008368				

Table 2.5-8. Marsland Expansion Area Winter Joint Frequency Distribution

Stability Class	Wind Direction	Wind Speed (mph) - Winter (Calm = 1.7%)						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
A	N	0.000512	0.000463					0.000975
	NNE		0.000463					0.000463
	NE	0.001025	0.000463					0.001488
	ENE							
	E	0.001025	0.000926					0.001951
	ESE	0.000512	0.001389					0.001901
	SE	0.001537	0.001389					0.002926
	SSE	0.001025	0.000463					0.001488
	S	0.000512	0.001389					0.001901
	SSW	0.002562	0.001389					0.003951
	SW	0.002050	0.001852					0.003902
	WSW	0.001025	0.001389					0.002414
	W	0.000512	0.001389					0.001901
	WNW	0.000512	0.000926					0.001438
	NW	0.000512	0.002778					0.003290
	NNW	0.000512	0.001852					0.002364
B	N		0.000463					0.000463
	NNE		0.000926					0.000926
	NE		0.001852					0.001852
	ENE		0.000463					0.000463
	E		0.000463	0.000463				0.000926
	ESE	0.001025	0.000926					0.001951
	SE		0.000463					0.000463
	SSE	0.000512	0.001389					0.001901
	S		0.000463					0.000463
	SSW		0.001852	0.000463				0.002315
	SW		0.002315					0.002315
	WSW		0.000463					0.000463
	W		0.001389					0.001389
	WNW		0.002778					0.002778
	NW		0.001852					0.001852
	NNW		0.000926	0.000463				0.001389
C	N		0.000463	0.005093				0.005556
	NNE			0.003704				0.003704
	NE		0.000463	0.001852				0.002315
	ENE			0.000463				0.000463
	E		0.000463	0.000463				0.000926
	ESE		0.001389					0.001389
	SE	0.000512	0.003241	0.001389				0.005142
	SSE		0.000926	0.001852				0.002778
	S	0.000512	0.000926	0.001389				0.002827
	SSW	0.000512	0.000463	0.000926				0.001901
	SW	0.000512	0.001852	0.002315				0.004679
	WSW			0.004630				0.004630
	W		0.000926	0.001389				0.002315
	WNW			0.003704				0.003704
	NW		0.000463	0.005556				0.006019
	NNW		0.000463	0.005556				0.006019

Table 2.5-8. Marsland Expansion Area Winter Joint Frequency Distribution (Cont.)

Stability Class	Wind Direction	Wind Speed (mph) - Winter (Calm = 1.7%)						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
D	N	0.000512	0.008333	0.026852	0.014815	0.003241	0.001389	0.055142
	NNE	0.000512	0.005556	0.013426	0.003704			0.023198
	NE		0.001389	0.009259	0.001389	0.000463		0.012500
	ENE		0.003704	0.009259	0.000463		0.000463	0.013889
	E	0.000512	0.005556	0.005556	0.000463			0.012086
	ESE	0.001537	0.009259	0.009259	0.000926			0.020982
	SE		0.007407	0.010648	0.004167	0.000926		0.023148
	SSE		0.004167	0.013889	0.005093	0.002315		0.025463
	S		0.004630	0.011574	0.011111	0.001389		0.028704
	SSW		0.002778	0.007407	0.003704	0.000463		0.014352
	SW		0.003241	0.006944	0.002315	0.000463		0.012963
	WSW	0.000512	0.006944	0.021296	0.012037	0.005093		0.045883
	W		0.008333	0.023148	0.021296	0.006019	0.002778	0.061574
	WNW	0.000512	0.004167	0.025000	0.033796	0.012500	0.002778	0.078753
	NW	0.000512	0.007407	0.023148	0.047222	0.025926	0.003241	0.107457
	NNW	0.000512	0.009259	0.029167	0.036111	0.011111	0.006481	0.092642
E	N	0.000512	0.002315	0.000926				0.003753
	NNE	0.001537	0.000463					0.002000
	NE		0.000926	0.000463				0.001389
	ENE		0.001852					0.001852
	E	0.000512	0.000926	0.000463				0.001901
	ESE		0.000926	0.000463				0.001389
	SE	0.000512	0.001389					0.001901
	SSE	0.000512	0.000926					0.001438
	S	0.000512	0.002778					0.003290
	SSW		0.001389	0.000926				0.002315
	SW	0.000512	0.003241	0.000463				0.004216
	WSW	0.001025	0.004630	0.001389				0.007043
	W		0.002778	0.003241				0.006019
	WNW	0.001537	0.000926	0.001389				0.003852
	NW	0.000512	0.004630	0.001852				0.006994
	NNW	0.001537	0.006019	0.000926				0.008482
F	N	0.013323	0.005556					0.018878
	NNE	0.008199	0.001852					0.010051
	NE	0.006149						0.006149
	ENE	0.005124	0.003241					0.008365
	E	0.004612	0.003241					0.007853
	ESE	0.008199	0.002315					0.010514
	SE	0.007686	0.003241					0.010927
	SSE	0.010248	0.003704					0.013952
	S	0.010761	0.002778					0.013539
	SSW	0.012298	0.004630					0.016928
	SW	0.009736	0.005556					0.015292
	WSW	0.010761	0.005093					0.015853
	W	0.009736	0.005093					0.014829
	WNW	0.005124	0.006944					0.012069
	NW	0.006149	0.005556					0.011705
	NNW	0.012810	0.005093					0.017903

Table 2.5-9. Marsland Expansion Area Spring Joint Frequency Distribution

Stability Class	Wind Direction	Wind Speed (mph) - Spring (Calm = 0.6%)						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
A	N	0.001473	0.001836					0.003309
	NNE		0.001836					0.001836
	NE	0.000491	0.001377					0.001868
	ENE	0.000982	0.000918					0.001900
	E	0.000982	0.002295					0.003277
	ESE	0.000491	0.002295					0.002786
	SE		0.002295					0.002295
	SSE	0.001473	0.000918					0.002391
	S	0.001473	0.002754					0.004226
	SSW	0.001473	0.002295					0.003767
	SW	0.000491	0.002295					0.002786
	WSW	0.000491	0.005507					0.005998
	W	0.000982	0.001377					0.002359
	WNW	0.001964	0.002295					0.004258
	NW	0.000491	0.000918					0.001409
	NNW	0.000491	0.002295					0.002786
B	N		0.001836					0.001836
	NNE		0.001836					0.001836
	NE		0.002295					0.002295
	ENE		0.000918					0.000918
	E		0.001836					0.001836
	ESE		0.001377	0.001377				0.002754
	SE		0.003212					0.003212
	SSE	0.000491	0.002295					0.002786
	S	0.000491	0.003671	0.000918				0.005080
	SSW		0.002754	0.000459				0.003212
	SW		0.002754					0.002754
	WSW		0.003212	0.000918				0.004130
	W		0.002295	0.000459				0.002754
	WNW		0.001836					0.001836
	NW		0.002754	0.000459				0.003212
	NNW		0.001836					0.001836
C	N			0.015603				0.015603
	NNE		0.000459	0.007802				0.008261
	NE		0.000459	0.005048				0.005507
	ENE		0.000918	0.006425				0.007343
	E		0.000918	0.003212				0.004130
	ESE		0.001836	0.006884				0.008720
	SE		0.001377	0.005048				0.006425
	SSE		0.001377	0.005507				0.006884
	S		0.002295	0.007343				0.009637
	SSW		0.000459	0.004589				0.005048
	SW		0.001377	0.007802				0.009179
	WSW		0.000459	0.009179				0.009637
	W		0.000459	0.005966				0.006425
	WNW			0.005048				0.005048
	NW		0.000459	0.009637				0.010096
	NNW		0.000918	0.009637				0.010555

Table 2.5-9. Marsland Expansion Area Spring Joint Frequency Distribution (Cont.)

Stability Class	Wind Direction	Wind Speed (mph) - Spring (Calm = 0.6%)						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
D	N		0.005048	0.020193	0.033043	0.005048		0.063332
	NNE		0.005507	0.013768	0.012391	0.004130		0.035796
	NE		0.002754	0.012850	0.006884			0.022487
	ENE		0.002754	0.006884	0.004130			0.013768
	E		0.005048	0.015603	0.009179	0.000459		0.030289
	ESE		0.008720	0.010096	0.006425	0.000459		0.025700
	SE	0.000491	0.011014	0.011473	0.006425			0.029403
	SSE		0.006884	0.019734	0.010555	0.009637	0.000459	0.047269
	S		0.003671	0.010096	0.012850	0.007343	0.000459	0.034419
	SSW		0.005507	0.010096	0.010555	0.003212		0.029371
	SW	0.000491	0.004130	0.007343	0.001377	0.000918		0.014259
	WSW		0.001377	0.013768	0.008261	0.001836	0.000918	0.026159
	W		0.001836	0.010096	0.015603	0.003212	0.006425	0.037173
	WNW		0.002295	0.018816	0.014227	0.008720	0.003671	0.047728
	NW		0.006884	0.019275	0.033961	0.013309	0.008261	0.081689
	NNW		0.007343	0.024782	0.032584	0.015603	0.003212	0.083525
E	N	0.000491	0.001377	0.000459				0.002327
	NNE	0.000491	0.000918	0.000459				0.001868
	NE		0.002754					0.002754
	ENE		0.001836					0.001836
	E	0.000491	0.002754	0.001377				0.004621
	ESE		0.003671	0.000459				0.004130
	SE	0.000982	0.002295					0.003277
	SSE	0.000491	0.002754					0.003245
	S	0.000491	0.002295					0.002786
	SSW		0.000459					0.000459
	SW	0.000491	0.002295	0.000459				0.003245
	WSW		0.001377					0.001377
	W		0.000459					0.000459
	WNW	0.000982	0.002295					0.003277
	NW	0.000491	0.001377	0.000918				0.002786
	NNW	0.000491	0.005048	0.001377				0.006916
F	N	0.004418	0.005507					0.009926
	NNE	0.004909	0.001836					0.006745
	NE	0.003928	0.000918					0.004845
	ENE	0.001473	0.002295					0.003767
	E	0.003437	0.003671					0.007108
	ESE	0.003437	0.004589					0.008026
	SE	0.004418	0.002295					0.006713
	SSE	0.004909	0.004130					0.009040
	S	0.004909	0.002754					0.007663
	SSW	0.000982	0.005048					0.006030
	SW	0.002946	0.002295					0.005240
	WSW	0.002455	0.002754					0.005208
	W	0.001964	0.002754					0.004717
	WNW	0.004418	0.002754					0.007172
	NW	0.006873	0.003671					0.010545
	NNW	0.007364	0.004130					0.011494

Table 2.5-10. Marsland Expansion Area Summer Joint Frequency Distribution

Stability Class	Wind Direction	Wind Speed (mph) - Summer (Calm = 0.2%)						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
A	N	0.002875	0.004710					0.007585
	NNE	0.000958	0.003297					0.004256
	NE		0.004710					0.004710
	ENE	0.001438	0.005181					0.006619
	E	0.001438	0.002826					0.004264
	ESE	0.001438	0.005181					0.006619
	SE	0.000958	0.003768					0.004727
	SSE	0.002875	0.005652					0.008527
	S	0.003833	0.003297					0.007131
	SSW	0.005750	0.005652					0.011403
	SW	0.001917	0.002355					0.004272
	WSW	0.000958	0.005652					0.006611
	W	0.001917	0.001413					0.003330
	WNW		0.000942					0.000942
	NW	0.000958	0.002355					0.003314
	NNW		0.003297					0.003297
B	N		0.004239	0.000942				0.005181
	NNE		0.005181					0.005181
	NE		0.005652	0.000471				0.006123
	ENE		0.005652					0.005652
	E		0.003768					0.003768
	ESE	0.000479	0.007537					0.008016
	SE		0.008008	0.000942				0.008950
	SSE	0.000479	0.005652	0.000942				0.007074
	S	0.000479	0.005181	0.001413				0.007074
	SSW	0.000479	0.003768	0.000942				0.005189
	SW		0.003768					0.003768
	WSW		0.003768	0.000942				0.004710
	W	0.000479	0.001413	0.000471				0.002363
	WNW	0.000479	0.001413	0.000471				0.002363
	NW		0.002826	0.001884				0.004710
	NNW		0.003768	0.001413				0.005181
C	N	0.000479	0.000471	0.013660				0.014610
	NNE		0.000471	0.006123				0.006594
	NE		0.000471	0.003768				0.004239
	ENE		0.001884	0.005652				0.007537
	E		0.002355	0.008008				0.010363
	ESE		0.003297	0.015073				0.018370
	SE		0.002355	0.009421				0.011776
	SSE		0.003297	0.007537				0.010834
	S		0.000942	0.009421				0.010363
	SSW		0.002826	0.007537				0.010363
	SW		0.002355	0.008008				0.010363
	WSW		0.002355	0.010363				0.012718
	W		0.000471	0.007537				0.008008
	WNW		0.001884	0.007065				0.008950
	NW		0.001413	0.007065				0.008479
	NNW		0.000471	0.008479				0.008950

Table 2.5-10. Marsland Expansion Area Summer Joint Frequency Distribution (Cont.)

Stability Class	Wind Direction	Wind Speed (mph) - Summer (Calm = 0.2%)						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
D	N		0.005652	0.014131	0.009892	0.002826	0.000942	0.033443
	NNE	0.000479	0.005181	0.009421	0.010834	0.002355	0.000471	0.028741
	NE		0.001413	0.012718	0.002355			0.016486
	ENE		0.005181	0.009421	0.003297			0.017899
	E		0.008950	0.013660	0.002826			0.025436
	ESE	0.000479	0.009421	0.013660	0.003768			0.027328
	SE	0.000479	0.015073	0.016957	0.003297			0.035807
	SSE		0.008950	0.014131	0.009892	0.001413		0.034385
	S		0.007065	0.015544	0.021196	0.000942		0.044748
	SSW		0.005652	0.012247	0.009421	0.000942		0.028262
	SW		0.004239	0.010834	0.005181	0.001413		0.021667
	WSW		0.005181	0.007537	0.005181	0.001413		0.019312
	W		0.001413	0.006594	0.001884	0.000471		0.010363
	WNW		0.001884	0.000471	0.002826			0.005181
	NW		0.002826	0.003297	0.013189	0.003768		0.023081
	NNW	0.000958	0.009892	0.016486	0.016015	0.004239	0.000942	0.048533
E	N	0.000958	0.003297	0.000471				0.004727
	NNE		0.001884					0.001884
	NE		0.000942					0.000942
	ENE		0.002826	0.000942				0.003768
	E		0.001884					0.001884
	ESE		0.002826					0.002826
	SE	0.000479	0.003297					0.003776
	SSE	0.000958	0.004239	0.000942				0.006140
	S		0.003768	0.000942				0.004710
	SSW		0.004239					0.004239
	SW		0.003768					0.003768
	WSW	0.000479	0.002826	0.000471				0.003776
	W		0.002355					0.002355
	WNW		0.000471					0.000471
	NW	0.000479	0.003297	0.000471				0.004247
	NNW		0.010363	0.002826				0.013189
F	N	0.008625	0.011305					0.019930
	NNE	0.006229	0.002826					0.009056
	NE	0.007667	0.001884					0.009551
	ENE	0.005750	0.002355					0.008105
	E	0.003833	0.006123					0.009957
	ESE	0.004792	0.003768					0.008560
	SE	0.008146	0.005181					0.013327
	SSE	0.003354	0.008008					0.011362
	S	0.007188	0.004710					0.011898
	SSW	0.007667	0.005181					0.012848
	SW	0.003833	0.003297					0.007131
	WSW	0.005750	0.004710					0.010460
	W	0.005271	0.001884					0.007155
	WNW	0.004792	0.005652					0.010444
	NW	0.006229	0.003297					0.009527
	NNW	0.012938	0.008950					0.021887

Table 2.5-11. Marsland Expansion Area Fall Joint Frequency Distribution

Stability Class	Wind Direction	Wind Speed (mph) - Fall (Calm = 1.7%)						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
A	N	0.001028	0.002364					0.003392
	NNE		0.000473					0.000473
	NE	0.001541	0.000946					0.002487
	ENE	0.001028	0.000946					0.001973
	E	0.000514	0.000946					0.001459
	ESE	0.003083	0.001418					0.004501
	SE	0.002055	0.000473					0.002528
	SSE	0.003596	0.001418					0.005015
	S	0.001541	0.000946					0.002487
	SSW	0.005138	0.000946					0.006083
	SW	0.001541	0.002364					0.003905
	WSW	0.001541	0.003310					0.004851
	W	0.001541	0.000473					0.002014
	WNW	0.001028	0.000473					0.001500
	NW	0.000514	0.001891					0.002405
	NNW	0.001541	0.000946					0.002487
B	N		0.001418					0.001418
	NNE		0.000946					0.000946
	NE							
	ENE							
	E		0.000946					0.000946
	ESE							
	SE	0.000514	0.001891	0.000473				0.002878
	SSE	0.000514	0.000473					0.000987
	S	0.001028		0.000473				0.001500
	SSW	0.003596	0.004255	0.000473				0.008325
	SW	0.000514	0.003310					0.003823
	WSW		0.002837					0.002837
	W							
	WNW		0.000473					0.000473
	NW		0.001891	0.000473				0.002364
	NNW		0.001891					0.001891
C	N		0.001418	0.006147				0.007565
	NNE		0.001418	0.000946				0.002364
	NE		0.000946	0.000946				0.001891
	ENE		0.000473	0.000946				0.001418
	E		0.000946	0.001418				0.002364
	ESE		0.000473					0.000473
	SE	0.001028	0.000473	0.000473				0.001973
	SSE	0.000514	0.000473	0.002364				0.003351
	S	0.001028	0.001891	0.001418				0.004337
	SSW	0.000514	0.001891	0.004255				0.006660
	SW		0.001891	0.004255				0.006147
	WSW		0.000473	0.001891				0.002364
	W		0.000946	0.002364				0.003310
	WNW			0.002837				0.002837
	NW			0.009929				0.009929
	NNW		0.001891	0.007092				0.008983

Table 2.5-11. Marsland Expansion Area Fall Joint Frequency Distribution (Cont.)

Stability Class	Wind Direction	Wind Speed (mph) - Fall (Calm = 1.7%)						Row Total
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24	
D	N	0.000514	0.009929	0.014184	0.012293	0.005201	0.003310	0.045431
	NNE		0.002364	0.005674	0.007092	0.002364		0.017494
	NE		0.001891	0.001418	0.001418			0.004728
	ENE		0.000473	0.003310				0.003783
	E		0.003310	0.006147				0.009456
	ESE		0.007565	0.003310	0.000946	0.000473	0.000473	0.012766
	SE		0.008038	0.008983	0.001418	0.000473		0.018913
	SSE	0.000514	0.009929	0.017494	0.012293			0.040230
	S	0.000514	0.005674	0.014657	0.009456	0.001418		0.031719
	SSW	0.000514	0.001418	0.005674	0.002837			0.010443
	SW	0.000514	0.007565	0.006147	0.005674	0.002837		0.022736
	WSW		0.006619	0.015130	0.008983	0.001418		0.032151
	W		0.004728	0.010402	0.010875	0.001891		0.027896
	WNW		0.006619	0.014184	0.026478	0.007092	0.005201	0.059574
	NW		0.009929	0.029787	0.024113	0.024113	0.011820	0.099764
	NNW	0.001541	0.027423	0.023168	0.026478	0.017967	0.007092	0.103669
E	N	0.004624	0.002364					0.006988
	NNE	0.001028	0.001891	0.000946				0.003864
	NE		0.001891	0.000473				0.002364
	ENE		0.001418	0.000946				0.002364
	E	0.001541	0.000473	0.000473				0.002487
	ESE	0.001541	0.004728					0.006269
	SE	0.001541	0.000946	0.000946				0.003433
	SSE	0.001028	0.001891	0.000946				0.003864
	S	0.000514	0.001891					0.002405
	SSW		0.001891					0.001891
	SW	0.000514	0.002364	0.001418				0.004296
	WSW		0.002364	0.002364				0.004728
	W	0.000514	0.002364	0.000473				0.003351
	WNW	0.000514	0.001418	0.001891				0.003823
	NW	0.001028	0.004728	0.002364				0.008120
	NNW	0.002055	0.017021	0.002364				0.021440
F	N	0.015413	0.005674					0.036053
	NNE	0.010276	0.004728					0.030110
	NE	0.009248	0.001891					0.019538
	ENE	0.010789	0.002364					0.009591
	E	0.007193	0.000946					0.011140
	ESE	0.005652	0.001891					0.011165
	SE	0.008221	0.002837					0.009100
	SSE	0.007707	0.003310					0.017032
	S	0.009248	0.003310					0.014060
	SSW	0.007193	0.004728					0.011682
	SW	0.008221	0.006147					0.012097
	WSW	0.012331	0.006147					0.011656
	W	0.007707	0.001891					0.013519
	WNW	0.010276	0.006619					0.018945
	NW	0.009248	0.005674					0.021865
	NNW	0.023634	0.015130					0.041199

Table 2.5-12. EPA National Ambient Air Quality Standards (NAAQS)

Pollutant [final rule citation]		Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide [76 FR 54294, Aug 31, 2011]		primary	8-hour	9 ppm	Not to be exceeded more than once per year
			1-hour	35 ppm	
Lead [81 FR 71906, Oct 18, 2016]		primary and secondary	Rolling 3-month average	0.15 µg/m^3	Not to be exceeded
Nitrogen Dioxide [77 FR 20218, Apr 3, 2012] [83 FR 17226, Apr 18, 2018]		primary	1-hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		primary and secondary	Annual	53 ppb	Annual mean
Ozone [85 FR 87256, Dec 31, 2020]		primary and secondary	8-hour	0.070 ppm	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution [85 FR 82684, Dec 18, 2020]	$PM_{2.5}$	Primary	Annual	9.0 µg/m^3	Annual mean, averaged over 3 years
		Secondary	Annual	15.0 µg/m^3	Annual mean, averaged over 3 years
		primary and secondary	24-hour	35 µg/m^3	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24-hour	150 µg/m^3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide [84 FR 9866, Mar 18, 2019] [77 FR 20218, Apr 3, 2012]		primary	1-hour	75 ppb [(4)]	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

Source: EPA 2024a

Table 2.5-13. Nebraska and South Dakota Ambient Air Monitoring Network in Project Region

Site	Operating Agency	Location			Parameters Monitored	Monitoring Objective	Distance from Projects
		State	County	Coordinates °			
Wind Cave National Park	SD DANR	SD	Custer	UTM Zone 13, NAD 83 E 622,471.56 N 4,823, 856.93	PM_{10} $PM_{2.5}$ Ozone	SLAMS	60-70 miles
Badlands National Park	SD DANR	SD	Jackson	UTM Zone 14, NAD 83 E 263, 173.81 N 4,847, 799.95	PM_{10} $PM_{2.5}$ SO_2 NO_2 Ozone	SLAMS	100-110 miles
Black Hawk Elementary School Grounds	SD DANR	SD	Meade	UTM Zone 13, NAD 83 E 634,683.07 N 4,890, 309.65	PM_{10} Ozone	SLAMS	100-110 miles
Scottsbluff (Senior High School)	NDEE	NE	Scotts Bluff	40.942099 −98.364967	$PM_{2.5}$	SLAMS	45-55 miles
Rapid City Credit Union	SD DANR	SD	Pennington	UTM Zone 13, NAD 83 E 638,199.75 N 4,882, 811.92	$PM_{2.5}$ PM_{10} SO_2 NO_2	SLAMS	95-105 miles

Sources: EPA 2024b

Table 2.5-14. PM_{10} Annual Average and Maximum 24-Hour Monitoring Data for Regional Monitoring Sites

Year	Wind Cave			Badlands			Black Hawk			Rapid City		
	Annual Average	Max 24-Hour	3-Year Average	Annual Average	Max 24-Hour	3-Year Average	Annual Average	Max 24-Hour	3-Year Average	Annual Average	Max 24-Hour	3-Year Average
	micrograms per cubic meter (µg/m^3)											
2010	8.0	142	--	7.6	32	--	14.3	30	--	25.1	105	--
2011	6.9	34	--	8.3	52	--	12.4	42	--	31.5	141	--
2012	8.9	48	74.7	11.0	64	49.3	16.2	44	38.7	33.5	111	119
2013	7.2	36	39.3	9.0	51	55.7	13.0	41	42.3	37.7	141	131
2014	6.4	24	36.0	8.5	31	48.7	14.8	33	39.3	36.5	131	128
2015	8.9	65	41.7	9.5	58	46.7	12.6	43	39.0	35.7	163	145
2016	7.5	37	42.0	9.4	38	42.3	13.1	76	50.7	31.3	155	150
2017	8.8	99	67.0	9.1	79	58.3	13.8	60	59.7	29.0	158	159
2018	8.2	42	59.3	9.5	55	57.3	13.3	60	65.3	33.0	127	147
2019	6.3	31	57.3	7.9	31	55.0	9.5	57	59.0	35.7	185	157
2020	10.9	71	48.0	11.6	45	43.7	13.5	70	62.3	35.7	128	147
2021	11.2	155	85.7	13.7	190	88.7	13.0	153	93.3	40.6	260	191
2022	6.4	55	93.7	11.6	55	96.7	10.8	62	95.0	40.7	185	191
2023	7.0	106	105	10.7	156	134	12.1	109	108	45.9	215	220

Source: EPA 2024b

Note:

1. On January 1, 2016, the Black Hawk PM_{10} sampler changed from a Hi Vol sampler to Met One BAM 1020 continuous particulate monitor
2. Rapid City 2023 three PM_{10} concentrations exceeded the 24-hour standard due to exceptional events of high winds and fires (SD DENR AQD 2024b)
3. Rapid City 2022 two PM_{10} concentrations exceeded the 24-hour standard due to exceptional events of high wind and fires (SD DENR AQD 2023)
4. Rapid City 2021 two PM_{10} concentrations exceeded the 24-hour standard due to exceptional events of high wind and three exceedances were related to fires (SD DENR AQD 2022)
5. Rapid City 2019 three PM_{10} concentrations exceeded the 24-hour standard due to exceptional events of high wind (SD DENR AQD 2020)
6. Rapid City 2017 one PM_{10} concentrations exceeded the 24-hour standard due to exceptional events of fires (SD DENR AQD 2020)
7. Rapid City 2016 one PM_{10} concentrations exceeded the 24-hour standard due to exceptional event (SD DENR AQD 2017)
8. Rapid City 2015 one PM_{10} concentrations exceeded the 24-hour standard due to exceptional event (SD DENR AQD 2016)

Table 2.5-15. $PM_{2.5}$ Annual Average Monitoring Data for Regional Sites

Year	Wind Cave		Badlands		Rapid City		Scottsbluff	
	Annual Average	3-Year Average	Annual Average	3-Year Average	Annual Average	3-Year Average	Annual Average	3-Year Average
	µg/m³							
2010	4.7	--	3.8	--	7.5	--	5.3	--
2011	3.7	--	3.5	--	4.6	--	4.8	--
2012	4.9	4.4	4.2	3.8	6.2	6.1	5.6	5.2
2013	3.0	3.9	5.4	4.4	7.9	6.2	5.1	5.2
2014	2.4	3.4	4.3	4.6	6.0	6.7	5.2	5.3
2015	4.1	3.2	4.4	4.7	9.5	7.8	5.8	5.4
2016	1.9	2.8	2.5	3.7	6.2	7.2	5.5	5.5
2017	5.2	3.7	3.7	3.5	7.6	7.8	7.5	6.3
2018	3.6	3.6	5.0	3.7	6.7	6.8	6.3	6.4
2019	2.6	3.8	3.7	4.1	5.9	6.7	4.8	6.2
2020	3.3	3.2	4.2	4.3	6.8	6.5	2.9	4.7
2021	4.7	3.5	5.9	4.6	8.2	7.0	4.8	4.2
2022	4.3	4.1	3.4	4.5	7.0	7.3	3.2	3.6
2023	4.8	4.6	7.6	5.6	8.4	7.9	5.4	4.5

Source: EPA 2024b
-- data not available

Table 2.5-16. $PM_{2.5}$ 24-hour 98th Percentile Monitoring Data for Regional Sites

Year	Wind Cave		Badlands		Rapid City (Credit Union)		Scottsbluff	
	24-Hour 98th Percentile	3-Year Average	24-Hour 98th Percentile	3-Year Average	24-Hour 98th Percentile	3-Year Average	24-Hour 98th Percentile	3-Year Average
	µg/m³							
2010	12.4	--	13.6	--	15.6	--	14.0	--
2011	11.5	--	10.0	--	13.1	--	12.6	--
2012	47.9	23.9	12.9	12.2	17.1	15.3	17.9	14.8
2013	9.4	22.9	13.9	12.3	15.3	15.2	12.2	14.2
2014	7.1	21.5	11.4	12.7	15.0	15.8	20.4	16.8
2015	21.3	12.6	23.3	16.2	30.4	20.2	24.9	19.2
2016	9.7	12.7	8.6	14.4	15.7	20.4	14.6	20.0
2017	17.6	16.2	12.7	14.9	23.6	23.2	24.1	21.2
2018	15.9	14.4	18.5	13.3	26.5	21.9	17.6	18.8
2019	8.2	13.9	9.4	13.5	15.7	21.9	12.3	18.0
2020	15.8	13.3	16.6	14.8	22.7	21.6	9.2	13.0
2021	21.8	15.3	21.9	16.0	26.5	21.6	17.4	13.0
2022	15.5	17.7	14.7	17.7	20.7	23.3	9.3	12.0
2023	15.8	17.7	31.6	22.7	31.3	26.2	19.6	15.4

Source: EPA 2024b
-- data not available

Table 2.5-17. Sulfur Dioxide 1-Hour 99th Percentile and 3-Hour Maximum Monitoring Data for Regional Sites

Site/Year	1-Hour 99th Percentile	1-Hour 99th Percentile 3-Year Average	3-Hour Maximum
	parts per billion (ppb)		
Rapid City Credit Union			
2010	--	--	--
2011	8.2	--	10.8
2012	9.6	--	7.8
2013	9.4	9.1	10.4
2014	7.2	8.7	7.2
2015	4.5	7.0	4.5
2016	0.6	4.1	0.6
2017	4.9	3.3	5.1
2018	1.7	2.4	1.7
2019	7.2	4.6	7.2
2020	7.5*	5.5	9.6
2021	4.3	6.3	4.7
2022	1.0	4.3	0.9
2023	1.6	2.3	2.8
Badlands			
2010	9	--	12.3
2011	5.9	--	7.3
2012	2.6	5.8	2.3
2013	9.1	5.9	8.3
2014	1.8	4.5	2.3
2015	6.6	5.8	5.6
2016	1.7	3.4	2.5
2017	1.6	3.3	1.7
2018	1.4	1.6	1.4
2019	19.1	7.4	28.9
2020	1.3	7.3	0.9
2021	3.1	7.8	5.8
2022	1.2	1.9	1.1
2023	--	--	--

Source: EPA 2024b
* 2020 data at the Credit Union Site did not meet completeness criteria due to multiple machine malfunctions.

Table 2.5-18. Nitrogen Dioxide Annual Average and 1-Hour 98th Percentile Monitoring Data for Regional Sites

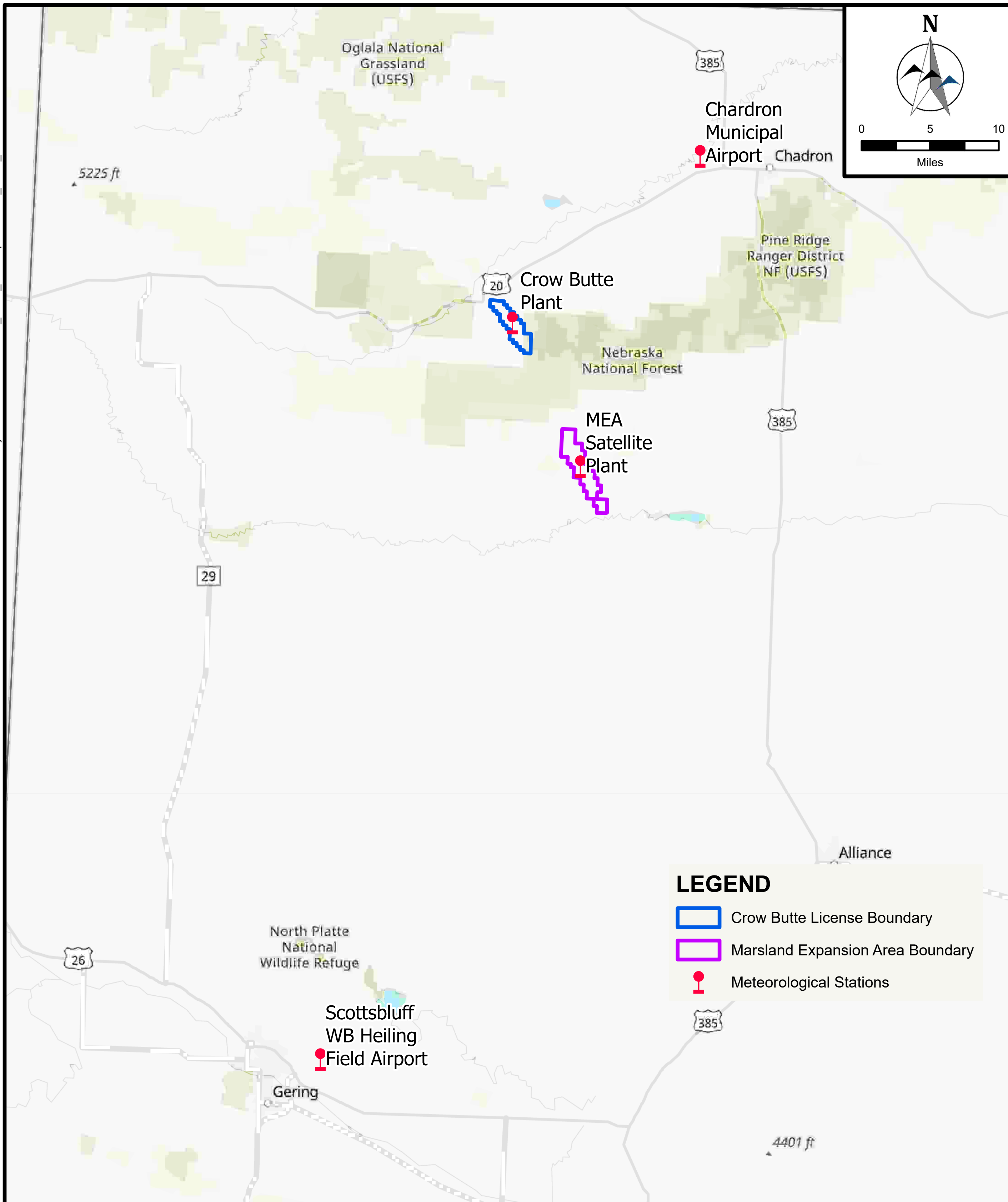
Site/Year	Annual Average	1-Hour 98th Percentile Concentration	1-Hour 98th Percentile 3-Year Average
	parts per billion (ppb)		
Rapid City Credit Union			
2010	--	--	
2011	8.4	47.0	
2012	7.5	42.2	
2013	7.5	38.6	42.6
2014	6.7	33.8	38.2
2015	7.3	37.3	36.6
2016	7.2	37.6	36.2
2017	6.2	39.9	38.3
2018	6.4	39.4	39.0
2019	5.6	38.4	39.2
2020	4.8	33.9	37.2
2021	3.6	33.4	35.2
2022	4.5	32.3	33.2
2023	4.5	30.6	32.1
Badlands			
2010	0.51	5.0	--
2011	0.90	4.4	--
2012	0.90	6.9	5.4
2013	1.04	6.0	5.8
2014	0.66	3.3	5.4
2015	0.88	2.7	4.0
2016	0.44	3.5	3.2
2017	0.64	3.8	3.3
2018	0.64	3.8	3.7
2019	0.92	8.0	5.2
2020	0.58	3.8	5.2
2021	0.79	7.6	6.5
2022	0.24	2.8	4.7
2023		--	--

Source: EPA 2024b

Table 2.5-19. Ozone Yearly 4th Highest 8-Hour Monitoring Data for Regional Sites

Year	Wind Cave		Badlands		Black Hawk	
	4th Highest Maximum	3-Year Average	4th Highest Maximum	3-Year Average	4th Highest Maximum	3-Year Average
	parts per million (ppm)					
2010	0.059	--	0.058		0.057	--
2011	0.060	--	0.052		0.057	--
2012	0.069	0.063	0.064	0.058	0.068	0.061
2013	0.061	0.063	0.062	0.059	0.063	0.063
2014	0.057	0.062	0.057	0.061	0.056	0.062
2015	0.059	0.059	0.057	0.059	0.059	0.059
2016	0.060	0.059	0.060	0.058	0.058	0.058
2017	0.065	0.061	0.067	0.061	0.045	0.054
2018	0.063	0.063	0.063	0.063	0.045	0.049
2019	0.057	0.062	0.058	0.063	0.055	0.048
2020	0.063	0.061	0.061	0.061	0.062	0.054
2021	0.065	0.062	0.054	0.058	0.072	0.063
2022	0.063	0.064	0.065	0.060	0.059	0.064
2023	0.065	0.064	0.068	0.062	0.068	0.066

Source: EPA 2024b



PERMIT TO MINE NO.			
NO.	REVISION	BY	DATE
4	---	---	---
3	---	---	---
2	---	---	---
1	---	---	---
0	---	---	---

CROW BUTTE RESOURCES, INC., 86 CROW BUTTE ROAD, CRAWFORD, NE 69339

CROW BUTTE RESOURCES, INC.

DAWES COUNTY, NEBRASKA

DRAWN BY: RAV
CHECKED BY: BAW
APPROVED BY: ---
DATE: 09/2024

REGIONAL AND SITE METEOROLOGICAL STATIONS

FIGURE **2.5-1**

Figure 2.5-2. Relative Humidity at the Scottsbluff Airport

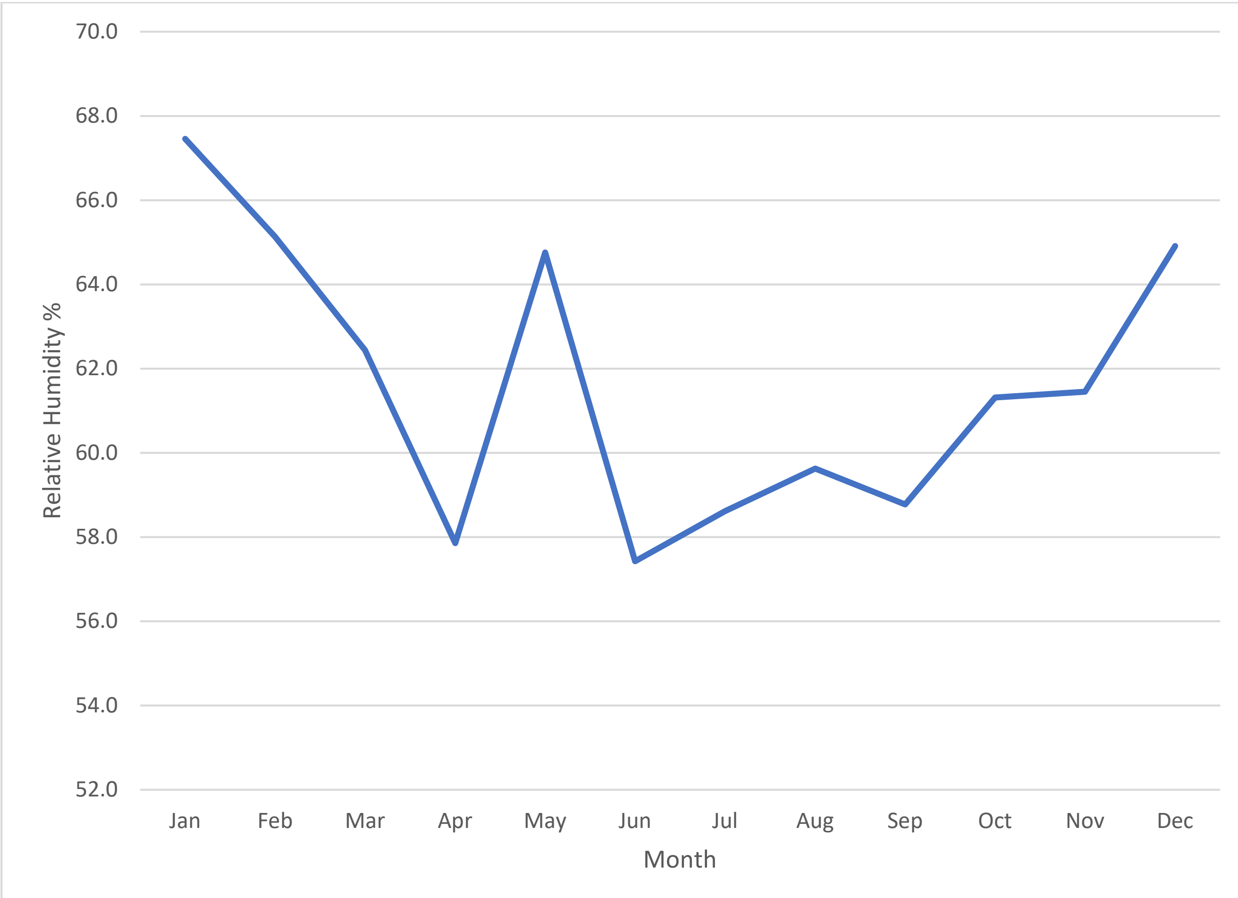


Figure 2.5-3. Monthly Precipitation at the Scottsbluff Airport and Chadron Airport

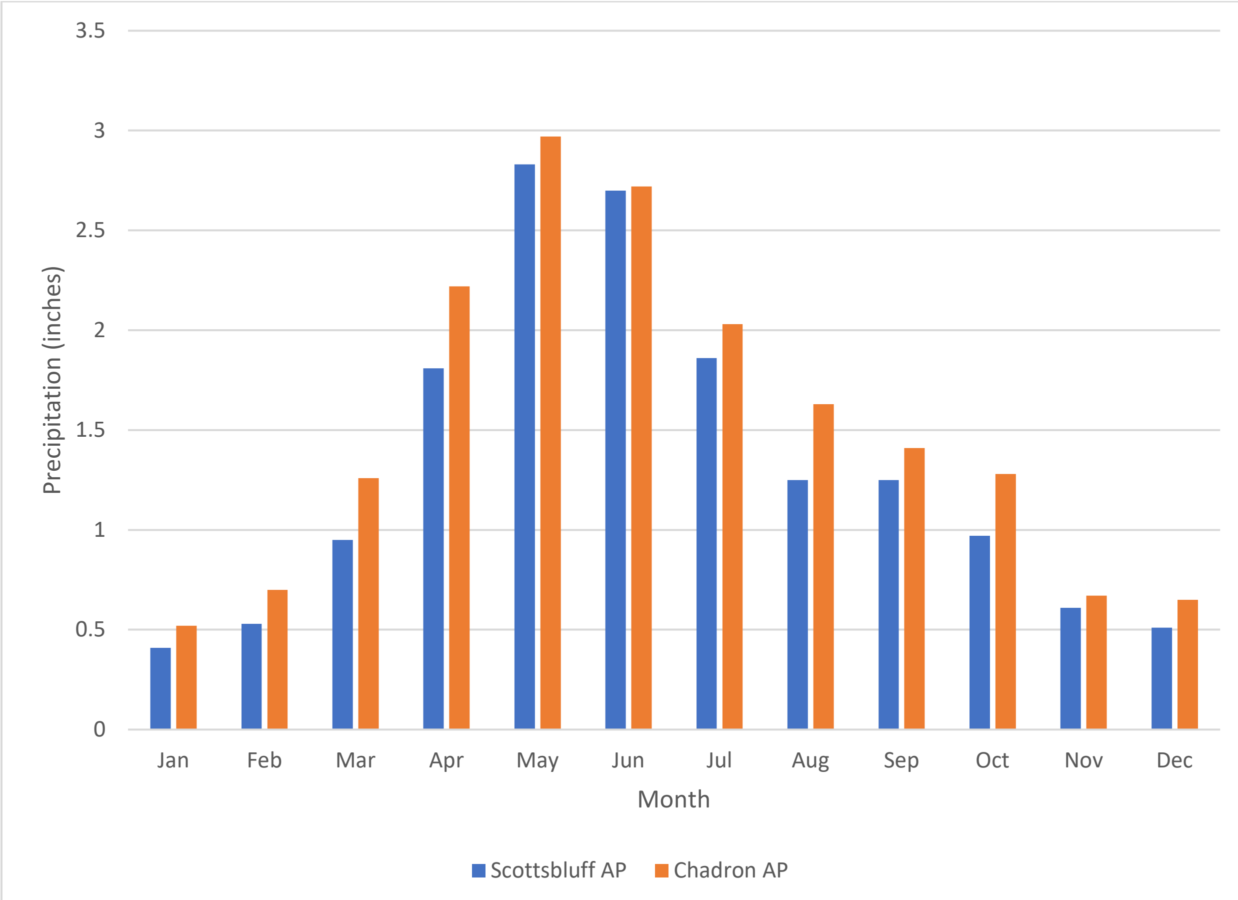
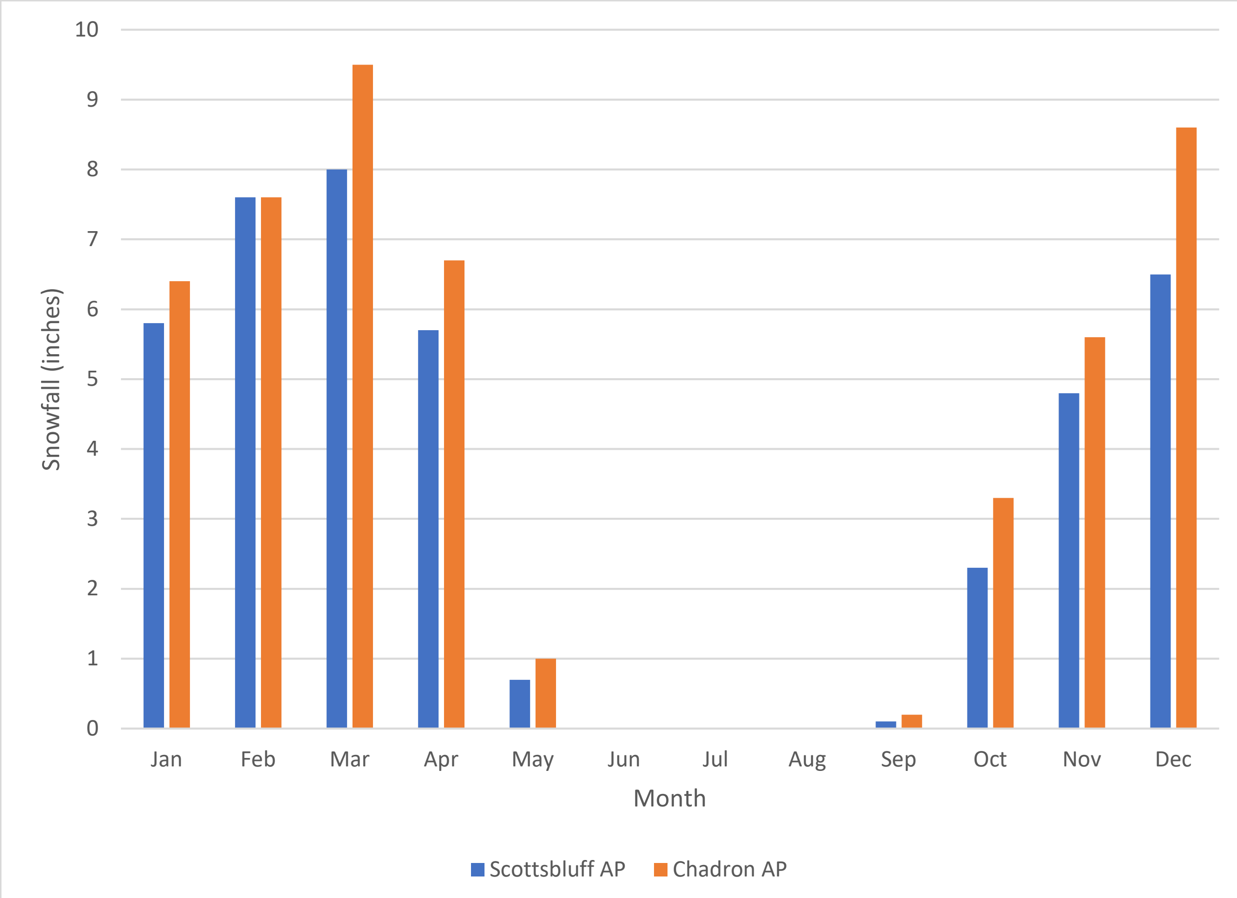


Figure 2.5-4. Monthly Snowfall at the Scottsbluff Airport and Chadron Airport

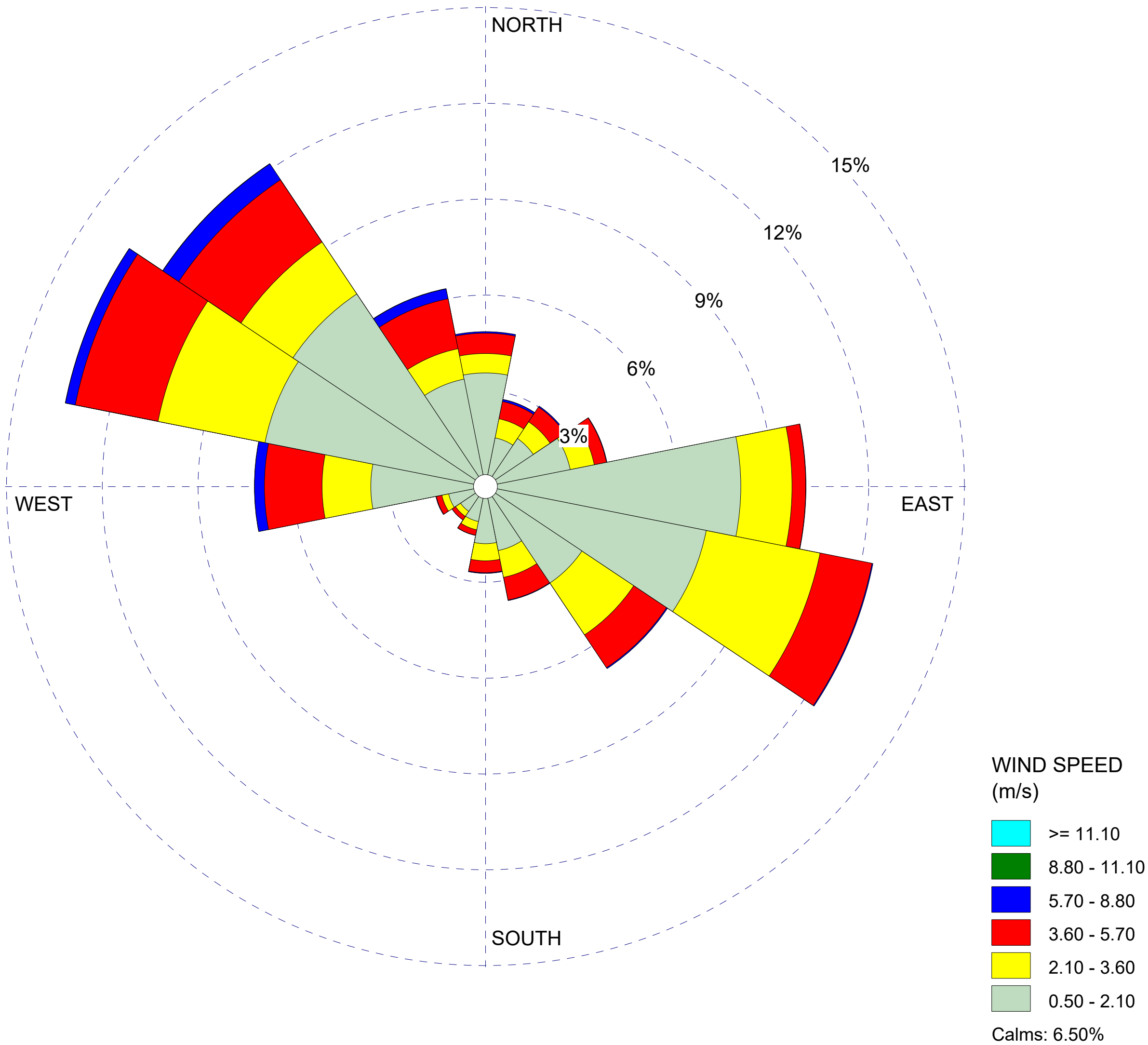


WIND ROSE PLOT:

Station: Scottsbluff Airport

DISPLAY:

Wind Speed
Direction (blowing from)



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
	Start Date: 1/1/2003 - 00:00 **End Date: 6/30/2024 - 00:00**	MODELER:	FIGURE 2.5-5 SCOTTSBLUFF AIRPORT WIND ROSE
	CALM WINDS: **6.50%**	TOTAL COUNT: **186734 hrs.**	
	AVG. WIND SPEED: **2.16 m/s**	DATE: **8/6/2024**	PROJECT NO.:

WRPLOT View - Lakes Environmental Software

Figure 2.5-6. Scottsbluff Airport Diurnal Wind Speeds by Season

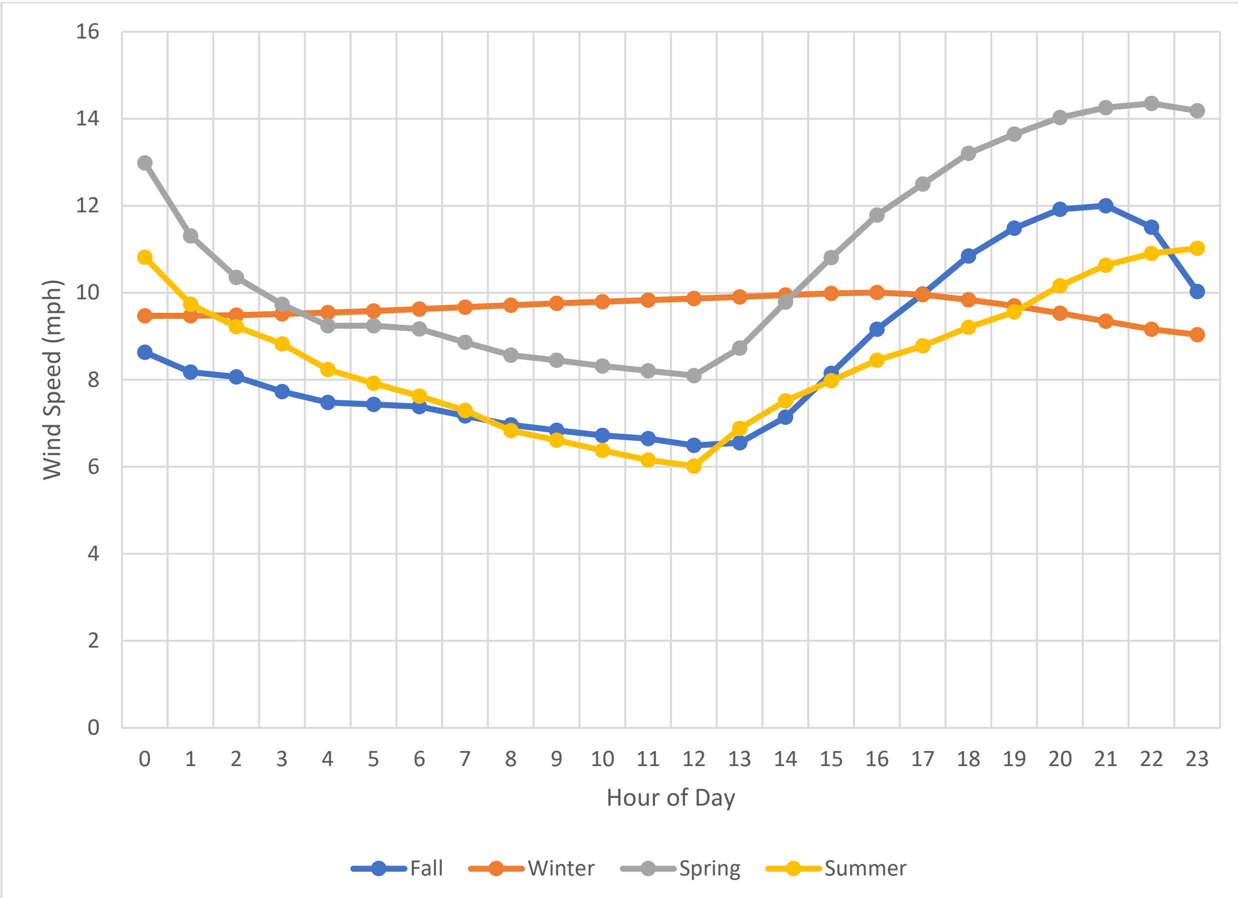


Figure 2.5-7. Heating, Cooling and Growing Degree Days at the Scottsbluff Airport

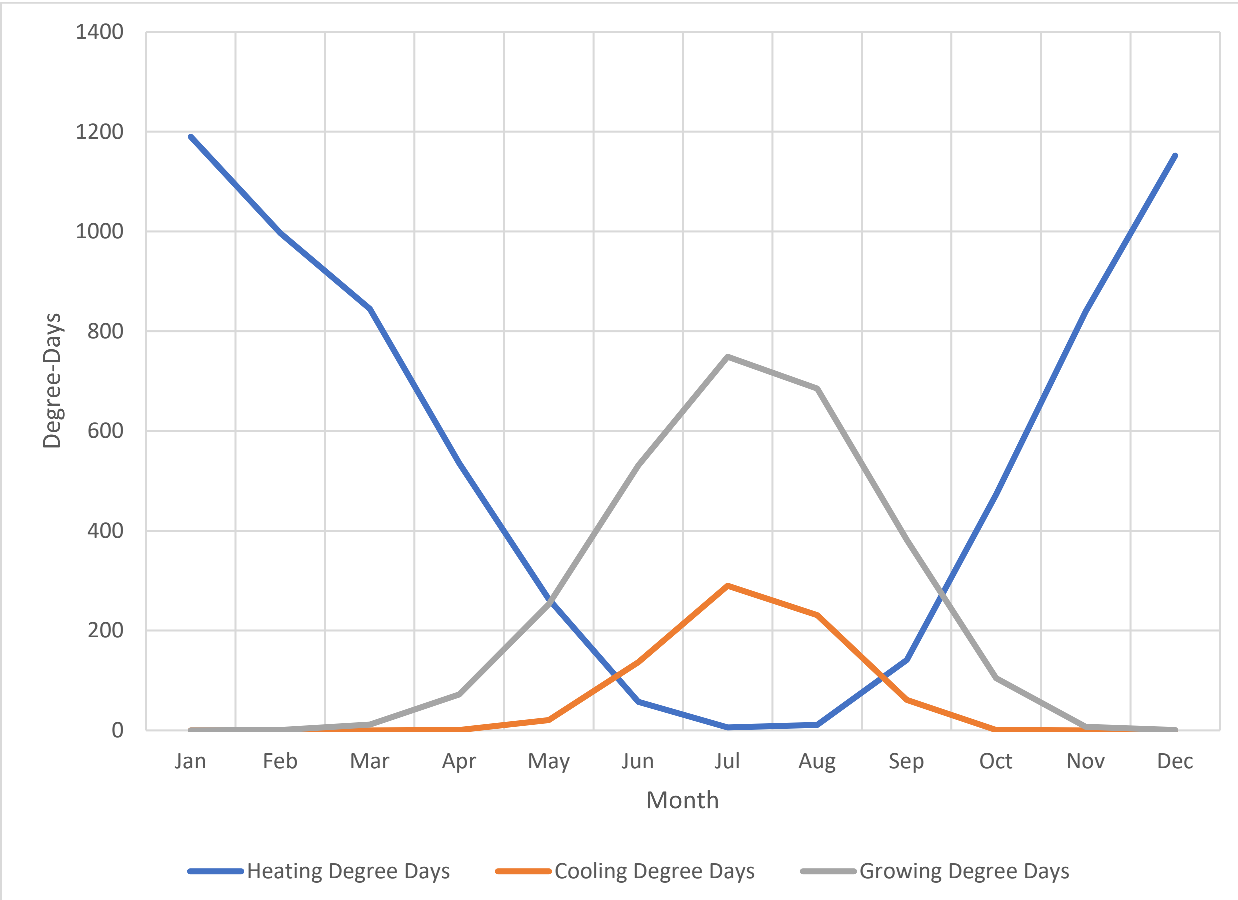
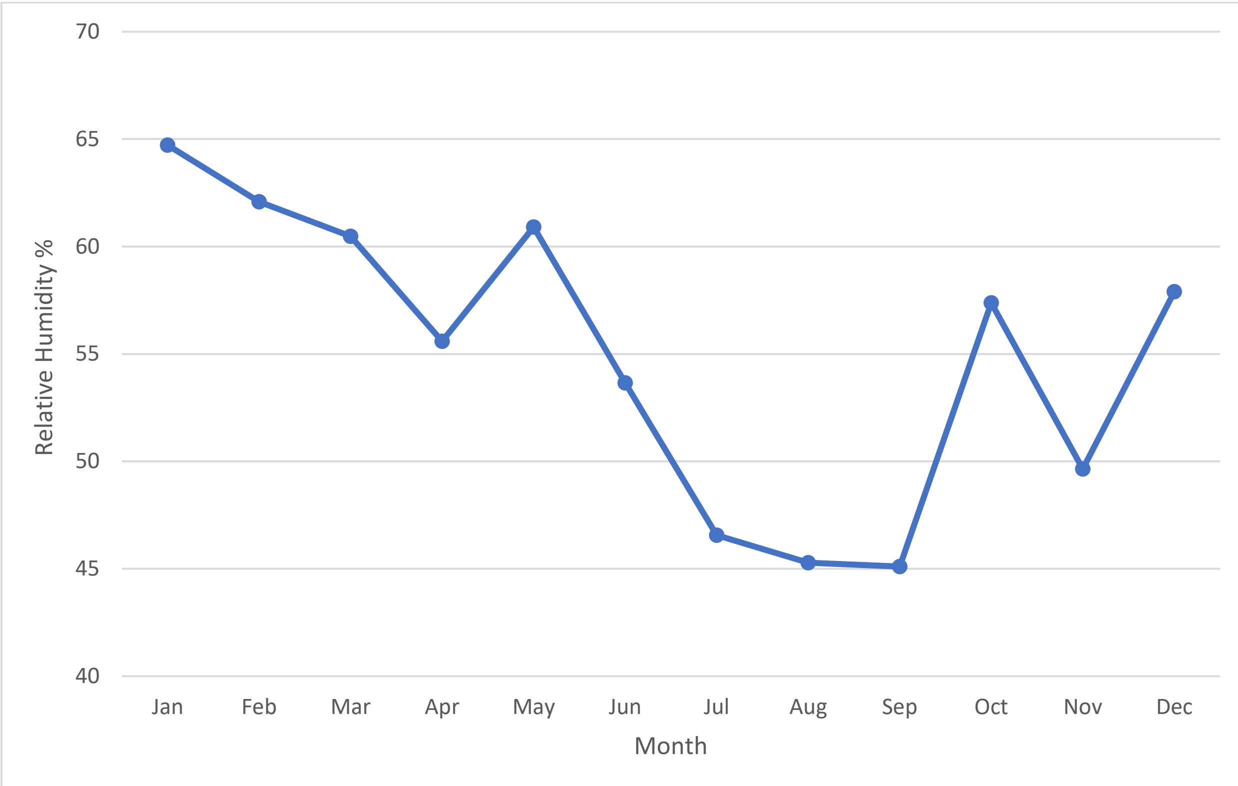
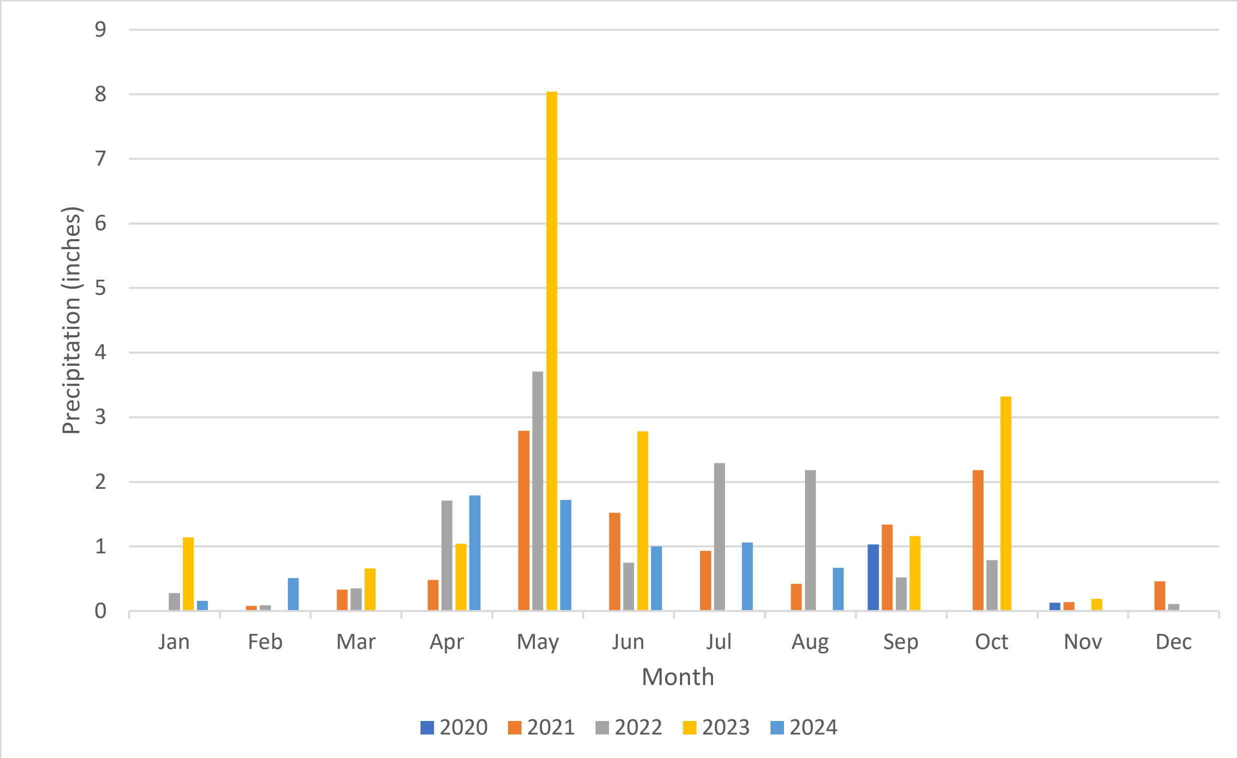


Figure 2.5-8. Crow Butte Project Relative Humidity



Period of Record: 8/13/2020 to 8/13/2024 hourly data

Figure 2.5-9. Crow Butte Project Precipitation



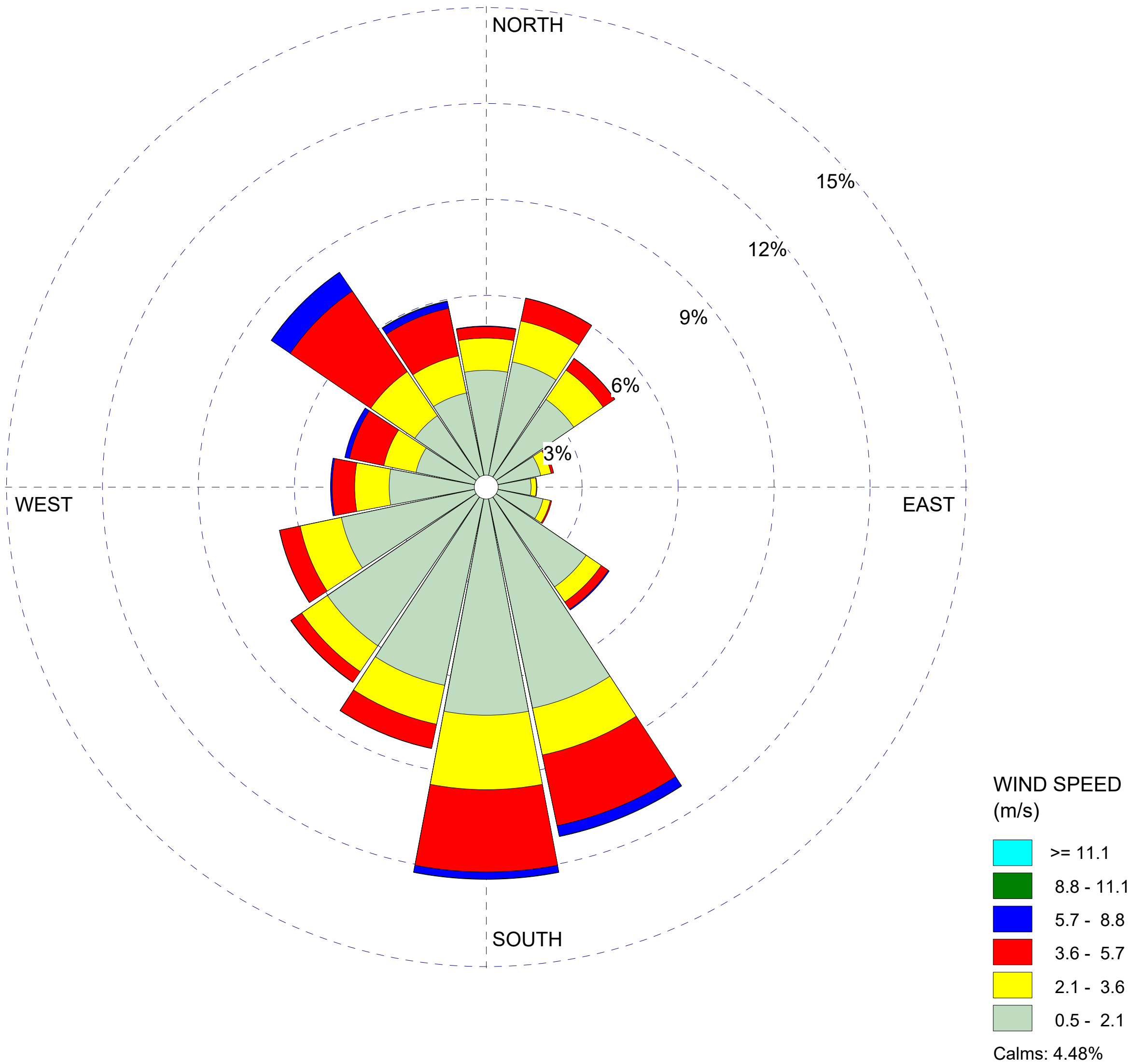
Period of Record: 8/13/2020 to 8/13/2024 hourly data

WIND ROSE PLOT:

Crow Butte Project

DISPLAY:

Wind Speed
Direction (blowing from)



COMMENTS:

DATA PERIOD:

Start Date: 8/13/2020 - 00:00
End Date: 8/13/2024 - 13:00

COMPANY NAME:

MODELER:

FIGURE 2.5-10
CROW BUTTE
PROJECT
WIND ROSE

CALM WINDS:

4.48%

TOTAL COUNT:

32724 hrs.

AVG. WIND SPEED:

2.03 m/s

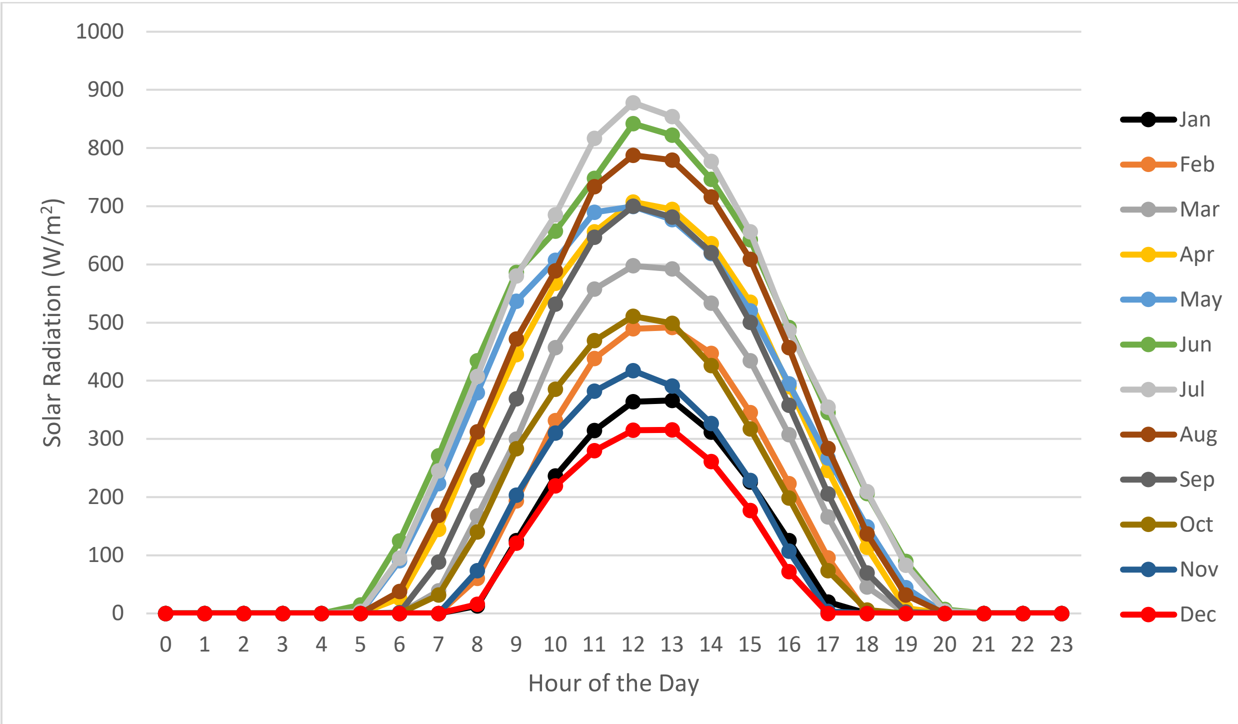
DATE:

9/11/2024

PROJECT NO.:

WRPLOT View - Lakes Environmental Software

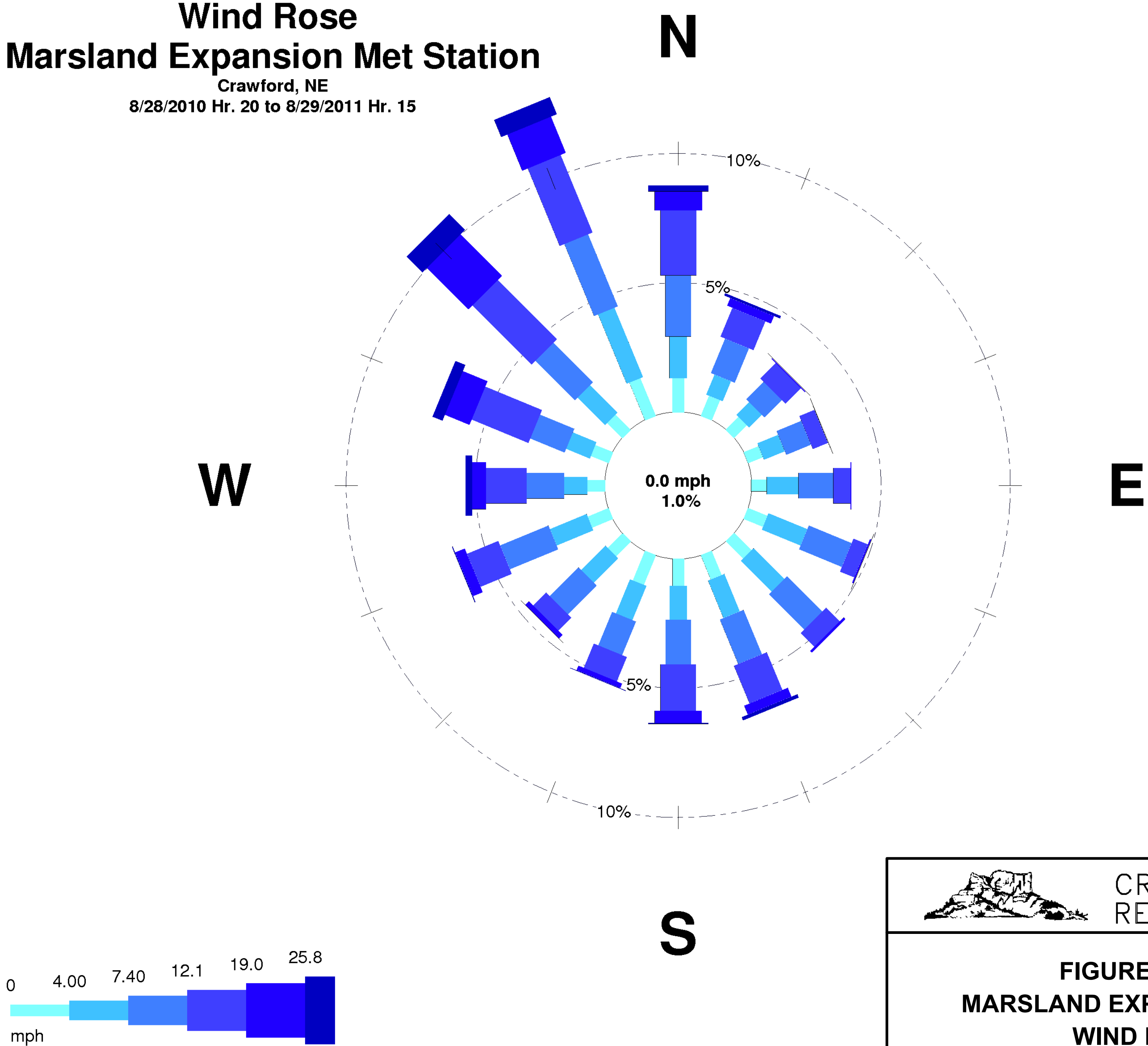
Figure 2.5-11. Crow Butte Project Solar Radiation



Period of Record: 8/13/2020 to 8/13/2024 hourly data

Wind Rose
Marsland Expansion Met Station

Crawford, NE
8/28/2010 Hr. 20 to 8/29/2011 Hr. 15



Source: Inter-Mountain Lab (IML) Air Science, 2011.

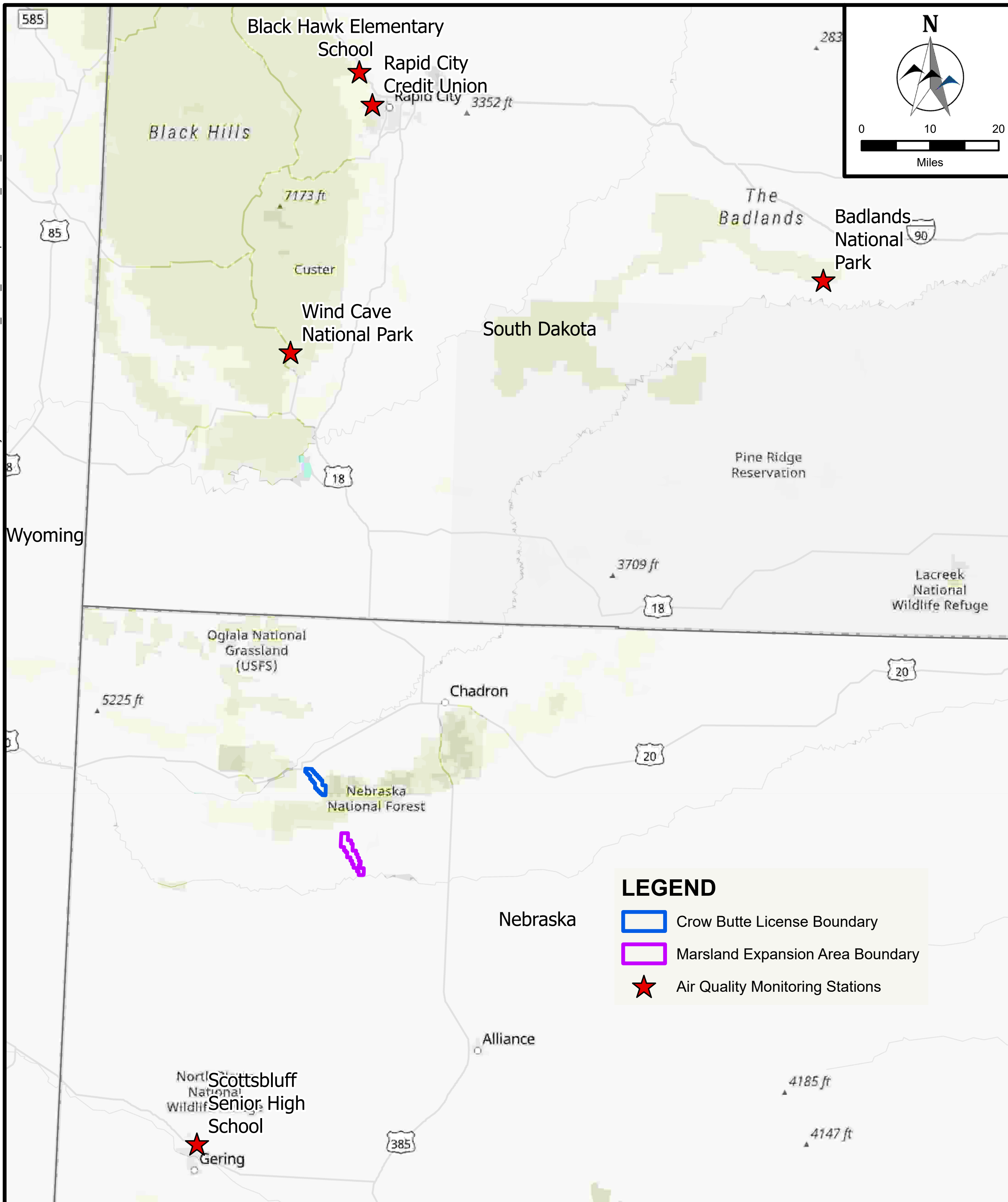
K:\CBR_Projects\CO001636_Marsland\3_IMAGES\Illustrator\TR Figure 2_5-20 Marsland Expansion Area Wind Rose.ai @ 10/17/2011

CROW BUTTE RESOURCES, INC.

FIGURE 2.5-12
MARSLAND EXPANSION AREA
WIND ROSE

PROJECT: CO001636	MAPPED BY: JC	CHECKED BY: JEC

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



PERMIT TO MINE NO.

NO.	REVISION	BY	DATE
4	---	---	---
3	---	---	---
2	---	---	---
1	---	---	---
0	---	---	---

CROW BUTTE RESOURCES, INC., 86 CROW BUTTE ROAD, CRAWFORD, NE 69339

CROW BUTTE RESOURCES, INC.

DAWES COUNTY, NEBRASKA

DRAWN BY: RAV
CHECKED BY: BAW
APPROVED BY: ---
DATE: 09/2024

REGIONAL AIR QUALITY MONITORING STATIONS

FIGURE **2.5-13**

2.6 GEOLOGY, SOILS, AND SEISMOLOGY

Section 2.6 of the 2008 Crow Butte LRA and Section 2.6 of the MEA TR provide information on the geology, soils, and seismology for each project area. Information from these reports has been incorporated into this Combined ER/TR. In addition, discussion of the geology of the Crow Butte Project has been presented in previous reports (WFC 1983; FEN 1987). Information contained in these reports include laboratory results and field data that describe formation characteristics (mineralogy, permeability, etc.) for the Pierre Shale, Brule Formation, Chadron Formation, and the basal Chadron Sandstone and has been incorporated into this Combined ER/TR. This section provides an update to seismology, including earthquakes. Based on the information presented in this section there is no significant change between the 2008 Crow Butte LRA, MEA TR and this Combined ER/TR.

2.6.1 Regional Setting

The topography of the Crow Butte Project consists of low rolling hills dominated by the Pine Ridge Escarpment south and west of the project area. The elevation of the Crow Butte Project ranges from 3,700 to 4,300 feet above mean sea level (amsl). The topography of the MEA includes gently sloping, rolling hills with outlying, broad ridges dissected by intermittent 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 and bounds three sides of the Crawford Basin. Colluvial and alluvial deposits originating from this escarpment cover the MEA. The elevation of the MEA ranges from 3,880 to 4,400 feet amsl.

2.6.1.1 Stratigraphy

Sedimentary strata ranging from late Cretaceous through Tertiary are exposed throughout northwest Nebraska. Pleistocene alluvial-colluvial material is abundant along the north slope of the Pine ridge. Table 2.6-1 (Crow Butte Project and MEA) is a generalized stratigraphic chart for the region.

2.6.1.1.1 Pre-Paleogene Stratigraphy

Formations older than the Cretaceous Pierre Shale are listed on the general stratigraphic chart (Table 2.6-1). This chart has been developed from the published literature and nearby oil and gas test holes. The Upper Cretaceous Niobrara, Carlile, and Greenhorn-Graneros Formations outcrop in the Chadron Arch about 30 miles northeast of Crawford.

The principal water bearing rocks below the Pierre Shale are the G Sand, J Sand, and the Dakota, Morrison and Sundance Formations. The total dissolved solids (TDS) of the water below the Pierre Shale has been interpreted from deep oil and gas exploration logs. The Dakota Sandstone is at a depth of 2,972 to 3,020 feet in the Bunch No. 1 hole (Section 5 of T31N, R51W). The minimum TDS of the water in the Dakota Sandstone calculated from the spontaneous potential and sonic logs is estimated to range from 14,000 to 26,000 ppm.

2.6.1.1.2 Pierre Shale

The Pierre Shale of Cretaceous age is the oldest formation of interest since it is the lower confining formation for the uranium mineralization. All company test holes are terminated as soon as the Pierre Shale is intersected. The Pierre is a widespread dark gray to black marine shale, with relatively uniform composition throughout. The Pierre outcrops extensively in Dawes and Sioux Counties along the South Dakota boundary.

The Pierre is essentially impermeable. In areas of outcropping Pierre, water for domestic and agricultural needs is piped in from wells from other formations. A number of shallow wells are reported as having the Pierre Shale as the bedrock unit (Spalding, 1982) in T32N, R51-52W. These wells range in depth from 18 to 100 feet with an average depth of 44 feet. These wells are in an area with considerable alluvium along Sand Creek, Cottonwood Creek, Spring Creek, and the White River between Crawford and Whitney Lake. These wells are probably producing water from Quaternary alluvium overlying the Pierre Shale.

Although the Pierre Shale is up to 5,000 feet thick regionally, in Dawes County deep oil tests have indicated thicknesses of 1,200 to 1,500 feet. Aerial exposure and subsequent erosion greatly reduced the vertical thicknesses of the Pierre Shale prior to Oligocene sedimentation. Consequently, the top of the present day Pierre Shale contact marks a major unconformity and exhibits a paleotopography with considerable relief (DeGraw 1969). As a result of the extended exposure to atmospheric weathering, an ancient soil horizon or paleosol was formed on the surface of the Pierre Shale. It is known as the "Interior Paleosol Complex" of the Pierre Shale (Shultz and Stout 1955) and is readily observed in certain outcrop exposures.

2.6.1.1.3 White River Group

The White River Group is Oligocene in age and consists of the Chadron and Brule Formations. The White River Group outcrops as a band at the base of the Pine Ridge in northwest Nebraska.

<u>Chadron Formation</u>

The Chadron is the oldest Paleogene Formation in northwest Nebraska. The Chadron lies with marked regional unconformity on top of the Pierre Shale. The Chadron Formation frequently has a sandstone and conglomerate at the base with overlying siltstone, mudstone, and claystone that is typically green hued (Singler and Picard 1980). Ash beds and limestone lenses have also been recognized. Occasionally the lower portion of the Chadron Sandstone is a very coarse, very poorly sorted conglomerate. Where present the conglomerate consists of well rounded, predominantly quartz and chalcedony cobbles ranging up to 6 inches across. Regionally, the vertical thickness of the Chadron Formation varies greatly. On outcrop the Chadron Formation has been noted to vary from 135 to 205 feet (Singler and Picard 1980). More recently the maximum thickness of the Chadron Formation has been estimated at 300 feet (Swinehart et al. 1985). These differences are attributed to the variable thickness of the Chadron Sandstone.

The Chadron Sandstone contains sandstone and conglomerate with some interbedded clay and is the depositional product of a large, vigorous braided stream system which occurred during early Oligocene (approximately 36 to 40 million years before present) (Swinehart et al. 1985). Regionally, the Chadron Sandstone thickness has been estimated in company drill holes to range from 0 to 350 feet.

The upper part of the Chadron represents a distinct and rapid facies change from the underlying sandstone. The Chadron above the sandstone unit is a light green-gray bentonitic claystone at the top grading downward to green and frequently red claystone often containing gray-white bentonitic clay interbeds.

Brule Formation

The Brule Formation lies conformably on top of the Chadron Formation and consists of interbedded siltstone, mudstone, and claystone with occasional sandstone. The Brule Formation is reported to range in thickness from 130 to 530 feet (Singler and Picard 1980). The Brule had previously been subdivided into two separate members, the Orella and the Whitney (Schultz and Stout 1938). More recently, the maximum thickness of the Brule Formation has been described as 1,150 feet. This is due to the inclusion of the newly recognized Brown Siltstone beds (Swinehart et al. 1985).

The Orella is composed of interbedded siltstone, mudstone, and claystone with occasional sandstones. The color of the Orella grades from green-blue and green-browns upward to buff and browns. The Orella was deposited in a fluvial setting with some eolian activity (Singler and Picard 1980).

The Whitney Member of the Brule is comprised of fairly massive buff to brown siltstones, dominantly eolian in origin (Singler and Picard 1980). Several volcanic ash horizons have been reported in outcrops (Swinehart et al. 1985). Some moderate to well defined channel sands are present in the upper part of the Whitney Member. These channel sands are commonly water bearing in the otherwise generally impermeable Brule Formation.

The Brown Siltstone beds have been recognized as an informal member in the upper part of the Brule Formation by Swinehart and others in northwest Nebraska (Swinehart et al. 1985). This unit is described as volcanic sandy siltstones and very fine-grained sandstones. Fine to medium-grained sandstones occur locally at or near the base of the Brown Siltstone beds.

2.6.1.1.4 Arikaree Group

The Miocene Arikaree Group includes three Miocene Sandstone Formations that form the Pine Ridge Escarpment that trends from west to east across northwest Nebraska.

Gering Formation

The Miocene Gering Sandstone is the oldest formation of the Arikaree Group and lies unconformably on the Brule Formation. The Gering Formation is predominantly buff to brown, fine-grained sandstones and siltstones. These represent channel and flood plain deposits. Thickness of the Gering Formation ranges from 100 to 200 feet (Witzel 1974).

Monroe Creek Formation

The Monroe Creek Formation overlies the Gering Formation and is the middle unit of the Arikaree Group. The Monroe Creek Formation is lithologically similar to the Gering Formation with buff to brown fine grained sandstone. The unique characteristic of the Monroe Creek Formation is the presence of large "pipy" concretions. These concretions consist of fine-grained sand similar to the rest of the formation with calcium carbonate cement and are extremely hard and resistant to weathering. The reported thickness of the Monroe Creek Formation is 280 to 360 feet (Lugn 1938, in Witzel 1974).

Harrison Formation

The Harrison Formation is the youngest unit of the Arikaree Group. It is described as lithologically similar to the Gering and Monroe Creek Formations, with fine-grained unconsolidated sands, buff to light gray in color. The Harrison Formation is also noted for its abundance of fossil remains (Witzel 1974).

2.6.1.1.5 Ogallala Group

The Miocene Ogallala Group overlies the Arikaree Group and is the outcropping unit south of the Pine Ridge. The Ogallala Group rocks are primarily sandstone and are coarser grained, more poorly sorted and contain only small amounts of volcanic material as compared to the underlying Arikaree Group rocks (Souders 1981). Some siltstone and mudstone are complexly interbedded with the sandstones and gravels.

The Ogallala Group is the principal aquifer where it is present in northwest Nebraska while The Arikaree Group is the principal water-bearing geologic unit in Sioux, Dawes, and Box Butte counties.

2.6.1.2 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 (Figures 2.6-2 and 2.6-3). This anticlinal feature 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 about 28 Ma and <5 Ma. The only surficial expression of the Chadron Arch is the outcropping of pre-Pierre Cretaceous rocks in the northeastern corner of Dawes County (Figure 2.6-1), as well as 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 2.6-1.

The 230-mile (370-km) long Pine Ridge Escarpment exhibits an average of 1,200 feet of relief (Nixon 1995). The Pine Ridge is an arc roughly concentric to the Black Hills Dome, which suggests an apparent structural relationship. Nixon (1995) interpreted the escarpment as representing the southern outermost cuesta of the Black Hills Dome. 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 Crow Butte Project is within the Crawford Basin (DeGraw 1969). The MEA lies just outside of the southern boundary of the basin along the Cochran Arch. 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-Paleogene subsurface geology. The Crawford Basin was defined by DeGraw (1969) as a triangular asymmetrical basin about 50 miles (80 km) long in an east-west direction and 40.2 km (25 miles) to 48.3 km (30 miles) wide. The Crawford 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 (Figures 2.6-2 and 2.6-3). 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 2.6-1). 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 2.6-3, which include the Whetstone Fault, Eagle Crag Fault, Niobrara Canyon Fault, and Ranch 33 Fault in the vicinity of the Town 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 2.6-3). The Niobrara and Pine Ridge faults are discussed in more detail in Section 2.6.2.4 of this LRA.

2.6.2 Project Areas

2.6.2.1 Crow Butte Project Stratigraphy

A stratigraphic column for the Crow Butte Project is shown in Figure 2.6-4. The stratigraphic nomenclature of Swinehart, et al (1985) and CBR are shown on the column.

A series of five east-west cross sections have been constructed through the wellfield area and the Area of Review to demonstrate the geology of the Basal Chadron Sandstone and its relationship to the confining horizons (Figures 2.6-5 to 2.6-12). Three northwest-southeast cross sections are included to show the continuity of the geology (Figures 2.6-6, 2.6-12 and 2.6-13). Reduced electric geophysical logs from representative CBR exploration holes were used in the cross sections. These logs consist of two curves, single point resistance on the right and either neutron-neutron or spontaneous potential on the left. The Pierre Shale, Chadron Formation, Brule Formation, and Arikaree Group, if present, are subdivided on these cross sections based on log characteristics that are the most important consideration in an ISR project. These sections demonstrate the continuity of the Basal Chadron Sandstone and the excellent confinement provided by the overlying Chadron and Brule formations and the underlying Pierre Shale (Figures 2.6-5 to 2.6-13).

2.6.2.1.1 Pierre Shale – Lower Confinement

The Pierre Shale is a black marine shale and is the oldest formation encountered in any CBR test holes within the Area of Review. The Pierre Shale is the confining bed below the Chadron

Sandstone that is the host for uranium mineralization. The description provided under Section 2.6.1.1 also describes the Pierre Shale within the AOR.

The ancient soil horizon known as the Interior Paleosol has been scoured away by the overlying Chadron Sandstone throughout most of the AOR.

The character of the entire Pierre Shale can be observed in a nearby oil and gas geophysical log, Heckman No. 1. This hole is about 1 mile west (Section 24, T31N, R52W) of the wellfield area. The log from Heckman No. 1 is believed to be representative of the Pierre Shale within the AOR. At the location of Heckman No. 1, the base of the Chadron Formation is at a depth of 525 feet. The Pierre Shale is 1,565 feet thick and rests on the Niobrara Formation at 2,090 feet. Based on several additional oil and gas holes within the Area of Review the Pierre Shale ranges from about 1,250 to 1,565 feet in thickness.

X-ray diffraction analyses of two core samples indicate that the Pierre Shale is primarily comprised of quartz and montmorillonite with minor kaolinite-chlorite and mica illite (Table 2.6-2). The black marine shale is an ideal confining bed with measured vertical hydraulic conductivity in the Area of Review of less than 2.0×10^{-9} centimeters per second (cm/sec).

2.6.2.1.2 Chadron Sandstone – Mining Unit

The Chadron Sandstone is generally present at the base of the Chadron Formation and is coarse grained arkosic sandstone with frequent interbedded thin clay beds and clay galls. Occasionally the Chadron Sandstone grades upward to fine grained sandstone containing varying amounts of interstitial clay material and persistent clay interbeds. The Chadron Sandstone is the host member and mining unit of the Crow Butte ore deposit, and no other uranium mineralization is present in overlying units.

The vertical thickness of the Chadron Sandstone within the AOR averages about 60 feet. An isopach of the Chadron Sandstone in the Area of Review indicates a range in thickness of 0 feet on the northeast to nearly 100 feet on the west (Figure 2.6-14).

A persistent clay horizon typically brick red in color generally marks the upper limit of the Chadron Sandstone. Occasionally younger sandstone immediately overlies the red clay and is well enough developed to be included in the Chadron Sandstone unit. This upper sandstone is similar in appearance to the rest of the Chadron Sandstone, and is typically very fine to fine grained, well sorted, poorly cemented sandstone.

Thin section examination of the Chadron Sandstone reveals its composition to be 50 percent monocrystalline quartz, 30 to 40 percent undifferentiated feldspar, plagioclase feldspar and microcline feldspar. The remainder includes polycrystalline quartz, chert, chalcedonic quartz, various heavy minerals and pyrite. X-ray diffraction analyses indicate that the Chadron Sandstone is 75 percent quartz with the remainder K-feldspar and plagioclase (Table 2.6-2).

Core samples and outcrops of the Chadron Sandstone exhibit numerous clay galls up to a few inches in diameter, frequent thin silt and clay lenses of varying thickness and continuity, and occasionally a sequence of upward fining sand. These probably represent flood plain or low velocity deposits that normally occur during fluvial sedimentation. Within the License area varying thicknesses of clay beds and lenses often separate the Chadron Sandstone into fairly distinct subunits as shown on the electric logs. Drill holes A-287 (Figure 2.6-8), and WD-4 (Figure 2.6-9), and Re-2 (Figure 2.6-10) illustrate the subunits.

2.6.2.1.3 Chadron-Brule Formations-Upper Confinement

The upper part of the Chadron Formation and the Brule Formation are the upper confinement overlying the Chadron Sandstone. This is observable by the epigenetic occurrence of the uranium mineralization, which is strictly confined to the Chadron Sandstone. The upper part of the Chadron represents a distinct and rapid facies change from the underlying sandstone unit. The upper part of the Chadron Formation is light green-gray bentonitic clay grading downward to green and frequently red clay. X-ray diffraction analyses of the red clay indicate that it is primarily comprised of montmorillonite and calcite (Table 2.6-2).

This portion of the Chadron often contains gray-white bentonitic clay interbeds. The light green-gray "sticky" clay of the Chadron serves as an excellent marker bed in drill cuttings and has been observed in virtually all drill holes within the Area of Review. The measured vertical hydraulic conductivity of the upper confinement is less than 1.0×10^{-10} cm/sec. The contact with the overlying Brule Formation is gradational and cannot be consistently picked accurately in drill cuttings or on electric logs. Therefore, the upper part of the Chadron Formation and the lower part of the Brule Formation are combined within the AOR.

The Brule Formation lies conformably on top of the Chadron Formation. The Brule Formation is the outcropping formation throughout most of the AOR. The lower part of the Brule Formation consists primarily of siltstones and claystones. Infrequent fine-to-medium grained sandstone channels have been observed in the lower part of the Brule Formation. When observed, these sandstone channels have very limited lateral extent.

2.6.2.1.4 Upper Part of the Brule Formation - Upper Monitoring Unit

The upper part of the Brule Formation is primarily buff to brown siltstones that have a larger grain size than the lower part of the Brule Formation. Occasional sandstone units are encountered in the upper part of the Brule Formation. The small sand units have limited lateral continuity and, although water bearing, do not always produce usable amounts of water. These sandstones have been included in the upper part of the Brule Formation and are illustrated on the series of cross sections as overlying the upper confinement (Figures 2.6-5 to 2.6-13). The lowest of these water-bearing sandstones would be monitored by shallow monitor wells during mining. This unit may correlate with the Brown Siltstone beds recognized by Swinehart et al. (1985).

2.6.2.2 Marsland Expansion Area Stratigraphy

Stratigraphy of the MEA is described in Section 2.6.1 of the MEA TR and incorporated into the Combined ER/TR. The local stratigraphy at the MEA consists of the following geological units in descending order: alluvial sediments, Harrison Formation, Monroe Creek – Harrison Formation, Gering Formation, Brule Formation, Chadron Formation, and Pierre Shale. The channel sandstone facies of the basal sandstone of the Chadron Formation represents the production zone and target of solution mining.

The general stratigraphic section for the MEA is summarized in Table 2.6-3. Figure 2.6-15 is a cross-section index map depicting the locations of 14 north-south and east-west cross-sections through the MEA depicted on Figures 2.6-16a through 2.6-16n. Expanded views of two cross-sections are presented as Figures 2.6-16o through 2.6-16u to provide more detailed examples of the geophysical logs within the basal sandstone of the Chadron Formation. Typical geophysical log responses for the geologic units encountered within the MEA are shown on a type log on Figure 2.6-18.

CBR completed coring programs in 2011 and 2013 across the MEA. In 2011, two core holes were completed and an additional five were completed in 2013. Data were collected from these cores to provide site-specific information across the MEA. The site-specific results of the coring programs have been incorporated into discussions of stratigraphy, lithology, and hydraulic properties throughout the document. Coring locations are illustrated on Figure 2.6-17.

A thick (approximately 1,200 to 1,500 feet), regionally extensive stratigraphic section of sedimentary units underlies the Pierre Shale; however, those units are not relevant. 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 the Arikaree Group, White River Group, and Pierre Shale (Petrotek 2004; WFC 1983).

This section provides a detailed description of the stratigraphy of the MEA. Geological units are described from stratigraphically youngest to stratigraphically oldest.

2.6.2.2.1 Alluvium

Quaternary alluvium as thick as 30 feet overlies the Arikaree Group along drainages in the study area. In general, the alluvium consists of fragments of locally outcropping Oligocene-Miocene sedimentary rocks, sand, gravel, sandy soil horizons, and may include weathered portions of the Arikaree Group. Because alluvium is unconsolidated and may incorporate one or both of the vadose and phreatic (shallow groundwater) zones, log signatures within this unit vary in comparison with those of geologic units in the underlying units. The alluvium-Arikaree Group contact illustrated on cross-section Figure 2.6-16a through Figure 2.6-16n is based on lithologic descriptions of drill cuttings recovered from individual boreholes.

2.6.2.2.2 Arikaree Group (Oligocene-Miocene)

The Oligocene–Miocene Arikaree Group lies unconformably above the Brule Formation and is subdivided from youngest to oldest into the upper Harrison Beds, Harrison-Monroe Creek and Gering formations, respectively (Table 2.6-3; Schultz and Stout 1955; Swinehart et al. 1985; Terry and LaGarry 1998; Retallack 1983).

Literature has named the upper Harrison Beds the Marsland Formation or split the beds into the Harrison and Monroe Creek Formations. This application uses nomenclature presented in Swinehart et al. (1985), which uses the upper Harrison Beds, Harrison-Monroe Creek, and Gering formations.

The Arikaree Group contains numerous interbedded channel and flood plain deposits, along with the eolian volcaniclastics. Grain size analyses of core samples provided with the original application support observations of drill cuttings and cores, which demonstrate that a wide range of interbedded lithologies are present within the Arikaree Group, including illite/smectite-dominated mudstones, siltstones, and fine-grained sandstones. The coarsest materials are epiclasts from the White River Group and the Rocky Mountains (Bradley and Rainwater 1956; Tedford et al. 1985; Hoganson et al. 1998).

An isopach map of the undifferentiated Arikaree Group is shown on Figure 2.6-19. Within the license boundary, the thickness of the Arikaree Group ranges from approximately 40 to 160 feet and averages about 105 feet. The unit is thickest in the northern portion of the license boundary, and generally thins southward. The unit is stratigraphically continuous across the MEA. All three subunits of the Arikaree Group are represented on the northern end of the MEA, but due to stratigraphic pinch-out and erosion from the Niobrara River, it is likely that only portions of the Monroe Creek and Gering formations are present on the south end of the MEA.

Upper Harrison Beds

The Upper Harrison Beds are composed of eolian volcaniclastic sandstones interbedded with lenticular freshwater limestones. The thickness of this unit is interpreted to be significantly thinner than 150 feet within the MEA license boundary based on observations of outcrops in the northern MEA; however, distinction between the Upper Harrison Beds and underlying Harrison-Monroe Creek Formation based on geophysical logs is difficult. Published grain size and mineralogic analysis indicate that the upper Harrison Beds contain three dominant units of buff to gray fine sand without abundant silt and clay, white sand with abundant silt and clay, and a siliceous pedogenic horizon.

Harrison – Monroe Creek Formation

Upper and middle portions of the Harrison – Monroe Creek Formation consist of fine-grained grey sandstone. In the northern MEA, outcrops of this formation consist of massively bedded, fine-grained, grey, poorly consolidated sandstone. Grey concretions, which weather into elongated irregular masses, are common. The massive gray sandstones of the Harrison-Monroe Creek Formation are interpreted to represent channel fill deposits (McFadden and Hunt Jr. 1998).

The lower portion of the formation is composed of compact fine sandy silt and clay, pinkish to buff in color, and a fine to medium grained gray sand (McFadden and Hunt 1998). Gray concretions composed of long, irregular, fine grained cylindrical masses are found in the middle and lower portions of the Harrison-Monroe Creek Formation (Lugn 1939; Collings and Knode 1984). According to Schultz (1941) and Svoboda (1950), the concretions were formed when groundwater enriched with calcium carbonate flowed through deposited sediments and calcite was precipitated “...in a situation similar to stalactite formation only in a horizontal direction” (Svoboda 1950). Schultz (1941) mapped the orientations of the concretions and found that, within northwest Nebraska, the orientation trend was to the southeast and away from uplift.

Gering Formation

The Gering Formation is mainly composed of gray, grayish-brown volcaniclastic fine to medium grained sandstones; silty sandstones; silt and local beds of ash; coarse sand; and fine gravel. Most of the sand is laminated and contains local cross beds. Beds of greenish-white bentonitic diatomaceous earth, which weathers into hard white layers, are found throughout most of the Gering Formation. Wellman (1964) divided the Gering Formation into upper and lower units. The two portions of the Gering Formation are separated by a volcanic ash which is up to 6 feet thick (Cady and Scherer 1946; Collings and Knode 1984; McFadden and Hunt 1998). The upper portion of the Gering Formation is finer grained than the lower portion. Lithologic observations of outcrops in the northern MEA and Pine Ridge area north of MEA, drill cuttings, and interpretation of geophysical logs indicate that the Gering Formation makes up the majority of the stratigraphic thickness of the Arikaree Group at the MEA.

The unconformable contact between the Brule and Gering Formations is readily observed when coarse sediments of the Gering Formation are in contact with the finer grained Brule Formation. When the sediments of the Gering Formation are fine grained, the contact is more difficult to discern based on observations of drill cuttings.

2.6.2.2.3 White River Group (Eocene-Oligocene)

At the MEA, the Eocene-Oligocene White River Group consists of the Chadron Formation overlain by the Brule Formation (Table 2.6-3). Sediments of the White River group were deposited within fluvial, lacustrine, and eolian environments (Terry and LaGarry 1998).

<u>Brule Formation</u>

The Oligocene Brule Formation represents the youngest unit within the White River Group present in the subsurface of the MEA. The Brule Formation conformably overlies the Chadron Formation and is unconformably overlain by the Arikaree Group. The Brule Formation is subdivided by LaGarry (1998) into three members, from youngest to oldest: the Brown Siltstone Member, the Whitney Member, and the Orella Member (Table 2.6-3).

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 a gradational contact to a sharp disconformity where the Brown Siltstone fills valleys incised into the older strata of the Whitney Member. Thick, fine to medium grained sandstones appear near the base of the Brown Siltstone Member. These sandstones are present across the MEA. The Whitney Member consists mostly of pale brown, massive, typically nodular eolian siltstones with rare thin interbeds of brown and bluish-green sandstone, and volcanic ash. The basal 33 ft (10 m) of the Whitney Member consist of white or green laminated fluvial siltstones and thin sheet sandstones. The Whitney Member intertongues with the underlying Orella Member. 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 thin volcanic ashes. The overall thickness of the Brule Formation within the MEA ranges from approximately 350 to 550 feet. In approximately the northern third of the MEA, the Brule Formation is generally 475 feet thick or more and thins southward to a thickness generally between 350 and 450 feet. An isopach map of the undifferentiated Brule Formation is shown on Figure 2.6-20. Figure 2.6-23 illustrates the elevation of the top of the Brule Formation across the MEA.

The contact between the lower Brule Formation and the upper Chadron Formation is difficult to identify on geophysical logs because of intertonguing of the siltstones and thin sandstones.

As a result, the formation contact appears deeper on some geophysical logs and varies locally on the Brule Formation isopach map (Figure 2.6-20). Observed lithologic changes from brown and tan siltstones towards green and gray silty-claystones in drill cuttings have been used to assist in identifying this contact. Figure 2.6-16a through 2.6-16n depict the subsurface geology of the Brule Formation within the MEA.

Chadron Formation

The Eocene-Oligocene Chadron Formation is in the lower part of the White River Group and unconformably overlies the Cretaceous Pierre Shale. From top to bottom, the Chadron Formation historically consists of the following stratigraphic units: upper Chadron and upper/middle Chadron, middle Chadron, and basal sandstone of the Chadron Formation (also known formally as the Chamberlain Pass Formation). The basal sandstone of the Chadron Formation represents the production zone and target of ISR mining within the MEA. Figures 2.6-16a through 2.6-16n depict the subsurface geology of the Chadron Formation within the MEA. Figure 2.6-24 illustrates the elevation of the top of the Chadron Formation across the MEA.

Upper Chadron Formation

The upper Chadron is the youngest subdivision of the Chadron Formation recognized at the MEA (Table 2.6-2). Descriptions of the upper Chadron indicate that the unit is 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). Drill cuttings, cores, and geophysical logs from the MEA support these observations, except the presence of limestones which have not been observed. At the MEA, the upper part of the upper Chadron is light green-gray bentonitic clay grading downward to green and frequently red clay, though thin interbedded sheet sandstones also occur. This observation is consistent with Terry and LaGarry’s (1998) observation of thin sandstones at Toadstool Park. Water has not been observed in upper Chadron sandstones at the MEA. Tuffs in the Toadstool Park area that occur in the upper Chadron were dated by 40Ar/39Ar methods as late Eocene (~34 Ma) in age (Terry and LaGarry 1998). Based on geophysical data, the upper Chadron is continuous across the MEA. The available data suggest that the upper Chadron ranges in stratigraphic thickness from approximately 190 to 250 feet and averages about 220 feet across the MEA (Figure 2-16a through Figure 2-16n). Hydraulic properties of the upper Chadron based on grain size analysis of core samples are discussed in Section 2.7.2 of this LRA.

As supported by observations at the MEA, the lower boundary of this unit is an intertonguing contact with the underlying middle Chadron (Terry and LaGarry 1998; Table 2.6-2). The upper boundary is recognized by a lithologic change from thinly bedded and less pedogenically modified brown, orange, and tan volcaniclastic clayey siltstones and sheet sandstones of the overlying Orella Member of the Brule Formation to more pedogenically modified green, red, and pink volcaniclastic silty claystones of the upper Chadron Formation (Terry and LaGarry 1998; Table 2.6-2).

Middle Chadron

The middle Chadron is a variegated clay-rich interval that may be red, grey, grey-green, or bluish-green 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 within the MEA and the Crow Butte Project. The middle Chadron differs from the overlying Chadron in that the middle Chadron is composed of bluish-green, smectite-rich mudstone and claystone is less variegated in color; and contains less silt (Terry 1998). The predominantly clay lithology of the middle Chadron represents a distinct and rapid facies change from the underlying basal sandstone of the Chadron Formation. The available data suggest that the middle Chadron typically ranges in thickness from approximately 150 to 290 feet and averages about 180 feet across the MEA. Hydraulic properties of the middle Chadron based on grain size analysis of core samples are discussed in Section 2.7.2 o this LRA.

Together, the upper and middle Chadron units represent the upper confining zone for the basal sandstone of the Chadron Formation within the MEA. An isopach map created for the combined upper and middle Chadron Formation that comprises the upper confining zone is presented on Figures 2.6-21. The total thickness of the upper confining zone ranges from approximately 360 to 450 feet, averages about 410 feet, and generally appears to thin toward the south across the MEA.

Basal Sandstone of the Chadron Formation – Mining Unit

The basal sandstone of the Chadron Formation is the oldest unit in the White River Group. The Upper Interior Paleosol, occurring as a persistent clay horizon, typically brick red in color (referred to locally as the “red clay”), developed on top of the basal sandstone of the Chadron Formation and generally marks the upper limit of the basal sandstone of the Chadron Formation (Table 2.6-3). Figure 2.6-25 illustrates the elevation of the top of the basal sandstone of the Chadron Formation across the MEA. The “red clay” horizon is indicated on more than half of the geophysical logs and driller’s notes that were reviewed. The Upper Interior Paleosol is interpreted to represent pedogenically modified distal overbank deposits of a distinct fluvial system developed on the surface of the basal sandstone of the Chadron Formation prior to deposition of the remainder of the Chadron Formation (Terry 1998).

The basal sandstone of the Chadron Formation consists of coarse grained, arkosic sandstone with common, discontinuous interbedded thin silt and clay lenses of varying thickness. Cross sections providing a more detailed view of the basal sandstone of the Chadron Formation are presented as Figure 2.6-16o through Figure 2.6-16u.

The lower contact is easily recognized as a change from the underlying black or bright yellow, pedogenically modified surface of the Pierre Shale (i.e., the Yellow Mounds Paleosol) to white channel sandstone. In places, the basal sandstone of the Chadron Formation grades upward to fine sandstone containing varying amounts of interstitial clay and persistent clay interbeds.

The basal sandstone of the Chadron Formation occurs at depths ranging from about 850 to 1,200 feet bgs and was encountered in all exploration holes. An isopach map of the basal sandstone of the Chadron Formation across the MEA is presented on Figure 2.6-22. Stratigraphic thickness of the unit within the MEA ranges from approximately 25 to 90 feet and averages about 55 feet. The thickest sections of the unit occur in the western portions of the MEA. Up to four distinct sandstone packages are present in the thickest portions of this unit and are separated by variable amounts of interbedded clay. Cross-sections depicting the basal sandstone of the Chadron Formation in detail are presented as Figures 2.6-16o through 2.6-16u.

Variations in the number and thickness of individual sandstone packages present in individual boreholes is interpreted to have resulted from facies changes and from varying degrees of erosion of fine-grained interbedded sediments and stacking of multiple channel deposits.

A structure contour map was generated of the contact between the basal sandstone of the Chadron Formation and the Pierre Shale (Figure 2.6-26). The structure map indicates that the elevation of the unconformity separating the Chadron Formation from the underlying Pierre Shale decreases to the south-southeast across the MEA from approximately 3,240 to 3,160 feet amsl.

The greenish-white channel sandstones of the basal sandstone of the Chadron Formation are the target of ISR mining activities in the MEA. Regionally, deposition of the basal sandstone of the Chadron Formation has been attributed to large, high-energy braided streams (Collings and Knode 1984; Hansley et al. 1989; Hansley and Dickinson 1990). This depositional environment produced lenticular sandstone deposits with numerous facies changes occurring within short distances. Interbedded thin silt and clay lenses most likely represent flood plain or low velocity deposits normally associated with fluvial sedimentation.

Geophysical logs record a unique signature for the basal sandstone of the Chadron Formation (Figure 2.6-18). A distinct GR spike is often present at the base of the unit in most of the MEA exploration boreholes, indicating an abundance of radioactive material. Increased resistivity (i.e., log curve shift to the right) and a decreased SP (i.e., log curve shift to the left) are often associated with GR spikes. These log signatures support interpretations of a uranium-bearing, fluid-filled sandstone interval. Other channel sandstone intervals present in the unit may 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 and decreased SP curve deviations (log curves shift to the left) without the associated GR spike. 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's notes. The high radioactivity of these clay-rich units suggests the presence of rhyolitic ash (Hansley and Dickinson 1990). The top of the formation is marked by a gradual return of SP and resistivity curves to the shale baseline.

Sediments rich in rhyolitic ash contained both within and above the basal sandstone are considered to be the most likely source of the uranium compounds that make up the ore body (Gjelsteen and Collings 1988). Larson and Evanoff (1998) used 40Ar/39Ar dating methods on nine known White River tuff deposits. The ages ranged from 35.97 to 30.05 Ma. Dissolution of these uranium compounds most likely occurred shortly after deposition. This period represents the time of greatest permeability for solutions to liberate the uranium compounds as they moved through the various ash-rich zones prior to compaction and alteration.

2.6.2.2.4 Pierre Shale

Offshore deposition in the Cretaceous Interior Seaway produced the late Cretaceous Pierre Shale (Table 2.6-3). 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 (WFC 1983; Petrotek 2004). Observations from nearby oil and gas wells, the thickness of the Pierre Shale in the vicinity of the MEA ranges from approximately 750 to more than 1,000 feet. 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 and formation of the brightly colored Yellow Mounds Paleosol (Terry and LaGarry 1998; Table 2.6-3). 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 2.6-1). The structure contour map of the top of the Pierre Shale indicates that the contact between the Pierre Shale and the overlying basal sandstone of the Chadron Formation dips slightly to the south-southeast across the MEA (Figure 2.6-26). This sloping surface is consistent with the surface described by DeGraw (1971) and rises to the axial crest of the Cochran Arch located north of the MEA.

Stratigraphy of Units Below the Pierre Shale

Underlying the Pierre Shale is a thick sequence of Mississippian through Cretaceous age strata that unconformably overlie Precambrian granite (Table 2.6-1). 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 sandstone of the Chadron Formation. With exception of the hydrocarbon-bearing "D", "G", and "J" sandstones of the Dakota Group (occasionally interbedded with the Graneros and Huntsman Shales; Table 2.6-1), there do not appear to be significant sandstone units within this thick sequence of low-permeability strata.

2.6.2.3 Crow Butte Project Structural Geology

The structure of the Crow Butte Project is illustrated on Figure 2.6-27. Elevation contours of the contact between the Cretaceous Pierre Shale and the Tertiary Chadron Formation demonstrate the regional structure. The features present are a result of the erosional paleotopographic surface of the Pierre Shale prior to deposition of the Chadron Formation and some amount of structural folding and faulting that occurred after deposition of the Chadron Formation. Regionally, the White River Group, Chadron and Brule Formations in general dip gently to the south at about 0.5 to 1 degree.

Previous drilling identified a structural feature, referred to as the White River Fault, located between the license area and the previously proposed North Trend Expansion Area (NTEA). The feature is oriented NE-SW generally along the White River drainage at the extreme northwest edge of the Area of Review. Historical drill data suggested a total vertical displacement of 200 to 400 feet with the up thrown side on the south. Previous reports and maps by CBR and others show the White River Fault to transect the Chadron and Brule Formations, suggesting that the fault displacement occurred post-depositionally.

Recent close spaced drilling activity in this area demonstrates that cross-section correlations are readily made without showing the fault to transect the Chadron Formation and overlying units. Figures 2.6-6 and 2.6-12 depict two structural cross sections that transect the White River structural feature from the northern and central portions of the NTEA southward into Mine Unit

10 of the Crow Butte Project. While structure contour maps clearly indicate the presence of a feature in the area, an extensive review of available geophysical logs indicates the upper confining unit of the basal Chadron Sandstone is continuous from Mine Unit 10 northward across the White River structural feature into the NTEA. The thickness of the upper confining unit between the structural feature and Mine Unit 10 ranges from 125 to 175 feet. Following review of more than 130 geophysical logs, three-dimensional geologic modeling indicates that the fault associated with the structural feature does not truncate or offset members of the White River Group along a discrete fault surface. Rather, members of the White River Group are broadly folded and are continuous across the structural feature. Based on the data available to date and presented herein, it is possible that the referenced structural feature is a fault at depth, movement along which is expressed up-section in the Pierre, Chadron and Brule Formations as a fold. It is also possible that displacement along a discrete fault surface at depth was manifested as localized and distributed faulting within the White River Group. The White River Fault/Fold is located approximately 1.5 miles northwest of the northern extent of the wellfield area.

Close spaced drill data throughout the Area of Review indicate that no other significant faulting is present in the wellfield area. Small faults have been identified in and near the Area of Review (Souders and Swinehart 1988) which have offsets of a few feet. However, these faults do not affect the confinement of the Chadron Sandstone based on hydrologic testing in the area.

A synclinal feature trends east-west and plunges west through the Area of Review. An associated east-west trending anticlinal feature is present along the southern part of the Area of Review. This anticlinal axis is subparallel to the Cochran Arch proposed by DeGraw (1969) and is probably a related feature.

2.6.2.4 Marsland Expansion Area Structural Geology

The structural geology of the MEA is described in Section 2.6.1.3 of the MEA TR and incorporated into the Combined ER/TR.

2.6.2.4.1 Niobrara River Fault

The structural map by DeGraw (1969) was subsequently modified by DeGraw (1971) to include additional features. Of these, the Niobrara River Fault is most relevant to the MEA. DeGraw (1971) mapped the Niobrara River Fault as occurring parallel to the Niobrara River in southernmost Dawes County and northernmost Box Butte County (Figure 2.6-3). No description of the Niobrara River Fault is provided, nor is evidence provided in DeGraw (1971) to support the interpretation of its location. As described above, many of the fault locations (e.g., Pine Ridge Fault) interpreted by DeGraw (1969), were based on the apparent displacement of the pre-Tertiary geologic surface (e.g., top of Pierre Shale) or an unpublished structural contour map of western Nebraska. It is unknown whether the published location of the Niobrara River Fault (DeGraw 1971) is based on an unpublished revision of the pre-Tertiary geologic surface provided in DeGraw (1969) or other data sources. Structural contour mapping of the pre-Paleogene surface by CBR does not provide evidence of displacement by the Niobrara River Fault within the MEA.

As presented by DeGraw (1971), the Niobrara River Fault appears to be a western extension of the Hyannis-North Platte Fault and forms the northern boundary of a graben which contains the Niobrara River valley. An unnamed fault forms the southern boundary of the graben. These faults appear to be generally continuous with the Agate Spring Fault complex of eastern Sioux County (Hunt 1990; Figure 2.6-3). Approximately 60 feet of vertical displacement of Arikaree Group sediments has occurred along the Agate Springs Fault in T28N, R55W. Radiometric dating of volcanic tuff displaced by the Agate Springs Fault indicates a maximum age of approximately 19.2 million years for the Agate Springs Fault, and by extension, the Niobrara River Fault (Hunt 1990). Because the Agate Springs and Niobrara River Faults are not included in the USGS Quaternary Fold and Fault Database (USGS 2010), a compendium of faults with evidence of movement between 1.6 million years ago and the present), it can be inferred that the most recent movement along both faults was between 19.2 and 1.6 million years ago. Neither the exact location of the Niobrara River Fault, nor the amount of potential offset of the fault at depth in the vicinity of the MEA can be determined based on known information.

Cameco geophysical data was reviewed to determine if additional data supports the location of the Niobrara River Fault and associated graben proposed by Stout et al. (1971). Figure 2.6-26 presents a regional structural contour map of the top of the Pierre Shale. Boring data indicate the presence of a west-east trending structural trough along the top of the Pierre Shale in the vicinity of the Niobrara River. This trough is generally parallel to, but slightly to the north of the proposed graben location (Figure 2.6-3). The best evidence of the structural trough is from Cameco exploration borings located west of the MEA license boundary and the feature may extend to the southern portion of the MEA license boundary. Due to lithologic similarities between the lower Arikaree Group and upper Brule Formation, identifying the geologic contact between those units based on geophysical logs or drill cuttings observation is tenuous; therefore, potential offset of the Arikaree Group correlative to that observed in outcrop at the Agate Springs Fault has not been assessed. It cannot be determined from existing data whether the structural trough represents a graben related to the proposed Niobrara River Fault, a synclinal feature related to the southern limb of the Cochran Arch, or a paleotopographical feature. As further work is completed at MEA, more data will become available regarding the potential presence of the proposed Niobrara River Fault. Additional aquifer pumping tests will be conducted to provide coverage to all areas to be mined to demonstrate the natural confinement of the basal sandstone of the Chadron Formation in the southern portion of the MEA.

Diffendal (1994) performed lineament analyses on a mosaic of early Miocene synthetic-aperture radar images and largely confirmed 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 were also noted west of Fort Robinson. Swinehart et al. (1985) report that these features are likely an extension of the Wheatland-Whalen trend in Wyoming (Hunt 1981; Wheeler and Crone 2001).

Structural features, such as faults and folds, can be identified and characterized using borehole geophysical data. These data, when correlated and combined with additional borehole data from other nearby holes, provides one of the best methods for identifying and describing subsurface features. Drill hole density (distance between successive drill holes) must be high enough to provide confidence that any observed potential structure seen between two drill holes is the result of movement along a fault and not the result of erosion, depositional variation, or lateral discontinuity. It is only when many of these individual data points (drill holes) are plotted together along with other observations that they can be interpreted to discover the presence of these structural features. As drilling density increases, the minimum size of offset required for detection decreases. Within MEA, the drill holes are located mostly on 100-foot centers with scattered areas of greater density. CBR estimates that with this density of drilling, it would require an offset of at least 10 to 15 feet to be obviously notable, and the offsets would need to be noted within multiple holes across more than a single horizon.

2.6.2.4.2 Pine Ridge Fault

Approximately 5 miles north of the MEA is the inferred Pine Ridge Fault, located along the northern edge of the Pine Ridge Escarpment (Figure 2.6-3). The east-west trending fault is inferred from several lines of evidence, but no detailed study of it has yet been published. The fault was initially proposed by DeGraw (1969) based on subsurface oil and gas test hole data which indicated the possible presence of a normal fault, with north-side down displacement of about 300 feet. The fault is inferred to be sub-parallel to the Cochran Arch as shown in Figure 2.6-3. Souders (1981) inferred the presence of an unnamed fault near the same location proposed by DeGraw but estimated only 120 feet of displacement on the basis of limited test well data south of the fault and extrapolated measurements of the dip of the Pierre Shale from outcrop several miles to the north. Swinehart et al. (1985) reported normal faulting along the feature that post-dates the Upper Harrison (Arikaree Group) but does not describe the location where the observation was made.

Geophysical data from Cameco Resources exploration test holes were used to substantiate the presence of the inferred Pine Ridge Fault and determine the extent and potential impact of this fault on operations at the MEA. A detailed discussion along with cross sections are included in Section 2.6.1.3 of the MEA Amendment Technical Report. The Three Crow Expansion Area Technical Report also addressed concerns for the presence of the Pine Ridge Fault. Five cross-sections were prepared showing the Pierre Shale surface contact with the overlying Chadron Formation as determined on geophysical logs. The surface depicted has been plotted with vertical exaggeration to visually accentuate any structural features present. These sections do not support the presence of the Pine Ridge Fault within the Area of Review for the TCEA permit as inferred by DeGraw (1969), nor do they support the presence within the MEA Area of Review. The cross-sections do not substantiate a reported north side down vertical displacement of 300 feet and in two of the cross-sections, the top of the Pierre Shale surface elevations decrease southward, which is contradictory to a north side down vertical displacement. The sections show gentle increases in the elevation for the top of the Pierre Shale that are most likely a result of topographic lows on the eroded surface of the Pierre Shale or structural dip due to flexing associated with the formation of the Crawford Basin. 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 observed elevation changes for the top surface of the Pierre Shale.

While the data presented refutes the estimated offset of the Pine Ridge Fault, it does not entirely rule out the possibility that a short offset fault may be present. The data clearly shows however, that there is not a large offset fault that could act as a boundary for groundwater flow and movement that would impact production operations at MEA.

2.6.3 Ore Mineralogy and Geochemistry

Hansley et al. (1989) conducted detailed geochemical analysis of the Crow Butte uranium ore to assess both ore genesis and composition. The Crow Butte deposits, including the MEA, the current Crow Butte site, North Trend, and 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 matrix of the basal sandstone of the Chadron Formation (Hansley et al. 1989). 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. (1989) 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 sandstone of the Chadron formation. 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."*

The ore bodies in the Crow Butte Project and the MEA are within the same geologic unit (the basal sandstone of the Chadron Formation) 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.

2.6.4 Soils

2.6.4.1 Crow Butte Project

The Crow Butte Project is located in the semiarid west-central portion of Dawes County, Nebraska, southeast of the City of Crawford. The local soils were investigated for the project. Soils data were obtained from the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Soil Survey of Dawes County, Nebraska, published in February 1977, and field sampling for radionuclide, physical, and chemical properties was conducted (NRCS 1977).

The Crow Butte Project is situated in the White River watershed along the Squaw Creek tributary. The terrain is generally flat with gentle rolling hills. To the south lies the Pine Ridge, an area of rough steep terrain dissected by steep drainages. Native vegetative cover is typically mixed grass and ponderosa pine trees, but they have been largely replaced by agricultural crops within the Crow Butte Project.

Dawes County soils were formed by weathering of materials of the underlying geologic formations or of materials deposited by wind and water. The Brule Formation - widely exposed on lower slopes - is soft and has weathered rapidly, producing the Epping, Kadoka, Deota, Schamber and Mitchell soils. As this material weathered, it produced the Epping, Kodaka variant, Keota, and Mitchell soils. The overlying Tertiary-age bedrock at higher elevations is the Arikaree Group. This massive sandstone contains interbedded layers of compacted silt and clay. Soils formed from this fine-grained material are Alliance, Busher, Canyon, Oglala, Tassel, and Rosebud. Sandstone mixed with loess formed soils such as Bayard, Bridget, and Vetal formed in colluvial and alluvial materials.

A soil association is a landscape that has a distinctive proportional pattern of soils, consisting of one or more major soils and at least one minor soil. Three soil associations exist within the Crow Butte Project: Kadoka-Keith-Mitchell, Busher-Tassel-Vetal, and Tripp-Haverson-Glenberg.

The Kadoka-Keith-Mitchell soils are 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 west of the Crow Butte Project. Approximate percentages of soils in this association are Kadoka at 28 percent, Keith at 23 percent, and Mitchell at 18 percent. Minor soils and land types make up the remaining 31 percent. Minor soils in this series are Bridget, Duroc, Epping, Ulysses, Keota, and Schamber series, and areas of Loamy alluvial land and Badland.

The Busher-Tassel-Vetal soils are deep and shallow, very gently sloping to steep, well drained to somewhat excessively drained sandy soils that formed in colluvium and in material weathered from sandstone. These sandy soils are found on undulating to hilly uplands which are crossed by numerous creeks and intermittent drainages.

Approximate percentages of soils in this association are Busher 35 percent, Tassel 32 percent, and Vetal 15 percent. Minor soils and land types make up the remaining 18 percent. These include the Bayard, Jayem, and Sarben soil types and sandy alluvial land.

The Tripp-Haverson-Glenberg soils are deep and shallow, very gently sloping to steep, well-drained to somewhat excessively drained sandy soils that formed in colluvium and in material weathered from sandstone on uplands and foot slopes. These soils are found in undulating and hilly uplands that are crossed by numerous creeks and intermittent drainage ways. Approximate percentages of soils in this association area are Busher soils at 35 percent, Tassel soils at 32 percent, and Vetal soils at 15 percent. Minor soils and land types make up the remaining 18 percent. Minor soils in this association are soils in the Bayard, Jayem, and Sarben series and areas of sandy alluvial land and rock outcrop.

In certain areas, the soil material is so rocky, shallow, severely eroded or 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.

Some of the 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 given uses the two dominant soil series represented in the group. Four of the mapping units within the restricted area belong to this category, where the names of dominant soils are joined by "and".

2.6.4.1.1 Soils Mapping Unit Descriptions

Table 2.6-4 summarizes those soils found within Crow Butte Project. The first capital letter is the initial of the soil name. The lower case letter that follows separates mapping units having names that begin with the same letter except that it does not separate sloping or eroded phases. The second capital letter indicates the class of the slope. Symbols without a slope letter are for soils that have a slope range of 0 to 2 percent or miscellaneous land types that have a wide range of slopes. A final number 2 in the symbol indicates that the soil is eroded. Those soils are also shown on Figure 2.6-28.

<u>BuF Busher loamy very fine sand, 9 to 20 percent slopes</u>

This soil is on uplands, occurring in areas up to 200 acres in size. The Busher soil series consists of deep, well drained to somewhat excessively drained soils that formed in material weathered from sandstone. The soil profile is typical of that for the series. The 3- to 7-inch-thick surface layer is described as grayish brown or dark grayish brown when wet; weak, fine granular structure; soft, very friable; neutral; with a gradual smooth boundary. Lime occurs at a depth of less than 46 cm (18 in) in some areas. The A horizon ranges from 7 to 20 inches in thickness and is neutral to mildly alkaline. The AC horizon is from 8 to 21 inches thick. It is fine sandy loam or loamy very fine sand. Lower horizons become progressively coarser with sandstone fragments typical in the C horizon.

Permeability of Busher series soils is moderately rapid, and water capacity is moderate. Conservation of soil moisture is a major concern in management for control of blowing soil. Runoff is medium.

Natural fertility is medium to low, and organic matter content is moderate. This supports a growth of native grasses, which are used for grazing or hay. The hazard of erosion and steepness of slope make this soil unsuited to cultivation. Classification is sandy range site.

<u>BxF Busher and Tassel loamy very fine sands, 5 to 20 percent slopes</u>

The majority of occurrences of this uplands soil are 9 to 20 percent slope but range from 5 to 20 percent. The soil covers areas up to 100 acres in size. The group is composed of about 60 percent Busher loamy very fine sand and 40 percent Tassel loamy very fine sand; however, any mapped area may contain either or both soils. Busher soils are found on middle and lower slope areas, and Tassel soils are on ridgetops, knolls, and sides of small drainageways.

The brown to light gray surface layer may be less than 7 inches thick in places. Bedrock occurs at depths of 20 to 36 inches in certain areas. Small areas of outcropping sandstone are also included.

This mapping area may be vegetated in native grass, used for grazing or cut for hay. Cultivation is not suitable, as serious soil blowing and water erosion may occur if cover is removed. Runoff is medium. Classification of Busher soil is sandy range site, and Tassel soil is shallow limy range site.

JvD-Jayem and Vetal loamy very fine sands, 5 to 9 percent slopes

This unit is on uplands and foot slopes in areas up to 300 acres in size. Jayem soils are found on upper parts of side slopes and on ridgetops. Each soil may comprise 50 percent of the unit. Soils of the Jayem series are deep, soldiering to somewhat excessively drained that formed in eolian sands. The representative surface layer is very friable, loamy very fine sand about 13 inches thick underlain by a transitional layer 7 inches thick. The A horizon ranges from 14 to 20 inches, and the AC horizon from 8 to 20 inches in thickness.

Permeability of both soils is moderately rapid, and available water capacity is moderate. Natural fertility is medium, and organic matter content is moderate. Water erosion and soil blowing may be hazards in cultivated or unprotected areas. Runoff is slow to medium. Most areas are in native grasses; however, small acreages may be cultivated by dry land or irrigated methods. Classification is sandy range site.

Sn Sandy alluvial land, 0 to 3 percent slopes

Calcareous alluvial material make up this land type on bottom lands and the short, steep sides of intermittent drainageways. The surface material is fine sandy loam to very fine sandy loam with small rounded fragments of sandstone interspersed. Gravel is common below a depth of 40 inches. Material on the steep sides of drainages ranges from fine sand to fine sandy loam.

Bottomlands are subject to periodic short-duration flooding, especially in the spring. Permeability is moderately rapid, and available water capacity is low to moderate. Runoff is slow on low slope bottomlands and rapid on steep drainageway sides. The water table is below a depth of 10 feet in most places.

Most areas are vegetated in native grass, as they are generally unsuited to cultivation due to flooding hazards. Classification is sandy lowland range site.

SvF Sarben and Vetal loamy very fine sands, 9 to 30 percent slopes

This mapping unit consists of deep, well-drained soils that formed in wind-deposited sands. This soil is found on uplands and foot slopes in areas up to 300 acres in size. Sarben soils are 60 to 80 percent, and Vetal soils are 20 to 40 percent of the unit.

Upper portions of side slopes and ridgetops are generally Sarben. The surface layer on A horizon is loamy very fine sand about 6 inches thick, but ranges from 3 to 10 inches in thickness. Underlying material, C horizon, is fine sandy loam, with no AC horizon development present. Lime may occur at a depth of 24 inches. Vetal soils occur in swales and on lower portions of foot slopes. The Vetal soils are typically deep and well-drained. The A horizon may be up to 31 inches thick with lime occasionally at less than 24 inches deep.

Permeability is moderately rapid, and available water capacity is moderate. Runoff is medium. Natural fertility is medium to low, and organic matter content is low. Moisture conservation is by a cover of native grass. This prevents water erosion and soil blowing. Slopes are too steep for cultivation; thus, the classification is sandy range site.

<u>VeC Vetal and Bayard soils, 1 to 5 percent slopes</u>

The soils of this mapping unit are deep, well drained and formed in sandy alluvium and colluvium. They occur on foot slopes and stream terraces in areas up to 300 acres in size. Vetal soils make up 55 to 75 percent of the total acreage and Bayard soils 25 to 46 percent.

Both soils are loamy very fine sand, neutral to mildly alkaline and very friable. The surface layer includes very fine sandy loam, fine sandy loam, and loamy very fine sand. In some areas the A horizon is less than 7 inches thick, and in other areas silty material is below a depth of 2 feet. Buried soils are common.

Permeability is moderately rapid, and available water capacity is moderate. Runoff is slow. Natural fertility is medium, and organic matter content is moderate. Approximately half the acreage is cultivated in crops such as wheat, alfalfa, oats, and seeded grasses. The other half is range. Conservation of soil moisture and prevention of wind and water erosion are important in farmed areas. Classification is sandy range site.

Plant cover depends on the site condition. A climax population for sandy alluvial land (Sn) consists of 40 percent sand bluestem, little bluestem, switchgrass, and Canada wild rye. About 60 percent is other grasses and forbs such as prairie sandreed, needleandthread, blue grama, Scribner panicum, sand dropseed, western wheatgrass, and members of the sedge family. Plant communities common in poor condition sites are blue grama, sand dropseed, Scribner panicum, and western ragweed.

The shallow limy range site classification in which Tassel soils of BxF 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, needleandthread, 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. These sites are less commonly in poor condition due to their terrain.

The BuF, part of BxF, JvD, and VeC mapping units are classified as sandy range sites. The vegetation that occurs on these soils is influenced by the moderately rapid to rapid permeability of the soils. A typical climax plant community is about a 50 percent 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, needleandthread, 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.

2.6.4.2 Marsland Expansion Area

Soils within the MEA are described in Section 2.6.1.6 of the MEA TR and incorporated into the Combined ER/TR. Physiographically, the MEA is located along the southern flank of Pine Ridge, an area of steep dissected terrain. The numerous drainages present within and adjacent to the MEA are tributaries to the Niobrara River, located immediately to the south. Box Butte is the dominant physiographic feature immediately south of the Niobrara River and is slightly lower than, but topographically similar to the Pine Ridge. Native vegetative cover in the Pine Ridge region is typically mixed-grass prairie and Ponderosa pine trees, but varies across the MEA, with significant areas that are currently cultivated or are degraded rangeland.

An investigation of MEA soils included review of available published soils data. Soils data for the MEA were obtained from the USDA NRCS Web Soil Survey (NRCS 2011). The sources for the Dawes County soil data available from the Web Soil Survey include the Soil Survey of Dawes County, Nebraska, published in February 1977 (SCS 1977), and updated unpublished materials derived from remote sensing images and other digitized soils mapping of Dawes County.

Soils in the MEA formed through the weathering of Tertiary bedrock material, loess (windblown silt), colluvium, or unconsolidated alluvium. Soils are shallow to deep silt loams and loamy very fine sands. Soil depth, grain size, and drainage typically increase closer to the Niobrara River and away from the steeper uplands of the MEA (SCS 1977).

Due to the loamy and fine sandy texture of most soils in the MEA, wind and water erosion pose the most significant risks to soil health and productivity, especially where vegetation has been disturbed. These soil textures also dictate the good drainage and high infiltration rates characteristic of most soils in the MEA.

From specific to general, the MEA landscape is composed of various soil series (soils with similar profiles), complexes (two or more series or miscellaneous areas that cannot be mapped separately), and associations (two or more geographically associated series or miscellaneous areas that have a consistent pattern and relative proportion of soils). 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. The General Soil Map of Dawes County, Nebraska (SCS 1977) illustrates the three soil associations that dominate the MEA, which are generally segregated north-to-south according to topographic and physiographic regimes and parent material. The three soil associations described below are not depicted on Figure 2.6-29; however, the individual components of each association are illustrated and described fully later in this section. The Canyon-Alliance-Rosebud soil association is generally found in the northern portion of the MEA and makes up approximately 40 percent of the project area. This upland soil association consists of “deep to shallow, gently sloping to steep, well-drained loamy and silty soils that formed in material weathered from sandstone”. Canyon series soils make up about 25 percent of this association, Alliance series soils about 24 percent, and Rosebud series soils about 16 percent. Minor soils and land types make up the remaining 35 percent (SCS 1977).

The Busher-Tassel-Vetal soil association is the most extensive within the MEA (35 percent of the project area) and is found on uplands and footslopes. This soil association consists of “deep and shallow, very gently sloping to steep, well-drained to somewhat excessively drained, sandy soils that formed in colluvium and in material weathered from sandstone". Busher series soils make up about 35 percent of this association, Tassel series soils about 32 percent, and Vetal series soils about 15 percent. Minor soils and land types make up the remaining 18 percent (SCS 1977).

The Valent-Dwyer-Jayem soil association makes up about 25 percent of the project area and is typically found in uplands adjacent to the Niobrara River in the southern portion of the MEA. This soil association consists of "deep, gently sloping to steep, well-drained to excessively drained sandy soils". Together, the Valent and Dwyer series soils (which are typically mapped as one unit) make up 68 percent of the association, with Jayem series soils and minor soils and land types both making up about 16 percent each (SCS 1977).

2.6.4.2.1 Soils Mapping Units

Thirty-one soil map units are identified in the project area. Their spatial distributions are illustrated on Figure 2.6-29, and their aerial extents summarized in Table 2.6-5. The table provides the map unit symbols, map unit names, and estimated acres of the dominant soils in the MEA. The description 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 by identifying which soils 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.

Soil map units illustrated in Figure 2.6-29 consist of soil series, soil complexes, and soil associations, as described above. In addition, certain soil map units represent undifferentiated soil groups, which are made up of two or more soils that could be delineated individually but are shown as one unit because similar interpretations can be made for use and management. The name states the two dominant soil series represented in the group, joined by "and". Four soil map units within the MEA (1742, 5118, 5211, and 6043) are soil complexes, two soil map units (1882 and 5070) are undifferentiated soil groups, and one soil map unit (6043) is a soil association with minor distribution within the MEA (Figure 2.6-20). The remaining soil map units represent soil series.

Soil map units 1014, 1356, 1882, 5105, 5126, and 5153 depicted on Figure 2.6-29 are composite map units consisting of multiple NRCS units. All units combined are divisions of the same soil series, complex, group, or association and were combined to provide a less complex soil map. The map unit number used to label composite map units represents the NRCS map unit with the greatest extent. Soil map units that represent combined NRCS map units are noted below and their constituent NRCS map units are described individually.

<u>Bankard Series Soils</u>

The Bankard series consists of deep, somewhat poorly drained soils that formed in sandy alluvium on bottom lands along tributaries to the Niobrara River. Slopes range from 0 to 2 percent. Within the MEA, the water table is typically at a depth of 2 to 4 feet, and soils are occasionally frequently flooded. Permeability is rapid, and available water capacity is low.

Natural fertility is medium to low, and organic matter content is low. Runoff is slow. Although suited for irrigation, most areas of Bankard series soils are in areas of native grass used for hay or grazing. These soils are not considered prime farmland. They are partially hydric. Bankard soils comprise approximately 7 percent of the MEA. They are mapped as composite unit 1014 on Figure 2.6-29 and include the following map units:

1013 – Bankard loamy coarse sand, frequently flooded

This soil is found in bottom lands in the southern portion of the MEA. It is similar to unit 1014 as described below but is formed in coarser grained alluvial material. Approximately 127 acres of this soil unit are present in the MEA.

1014 – Bankard loamy fine sand, frequently flooded

This soil is found in bottom lands in the MEA. It is similar to other frequently flooded Bankard soils. Some areas are strongly affected by salts and alkali, and salts are visible on the surface in early spring. This soil is marginal for cultivation of alfalfa and forage crops, and drainage systems are necessary to lower the water table in this unit prior to irrigation. Deep-rooted dry farmed crops benefit from the high water table during dry periods. Soil blowing is a hazard if the soil surface is not protected. Approximately 189 acres of this soil unit are present in the MEA.

Glenberg Series Soils

The Glenberg series consists of very deep, well drained soils that formed in stratified calcareous alluvium on floodplains and river terraces. Slopes range from 0 to 8 percent. Permeability is rapid, and available water capacity is moderate. Natural fertility and organic content are 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 MEA are currently cultivated. Glenberg soils comprise less than 1 percent of the MEA and include the following map unit:

1036 – Glenberg loamy very fine sand, 0 to 3 percent slopes

This map unit is located on high bottom land areas that are seldom flooded. A lime layer may be present at the surface, and stratification may be less distinct than in other Glenberg soils. Soil blowing is a hazard if the soil is unprotected. Runoff is slow. This map unit is dry farmed for wheat, oats, and alfalfa and irrigated for alfalfa to a lesser extent. This map unit occurs in areas as large as 100 acres. Approximately 8.5 acres of this soil unit are present within the MEA.

Bridget Series Soils

The Bridget series consists of deep, well-drained soils that formed in loamy colluvial and alluvial sediment on foot slopes and 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 wheat, oats, or alfalfa. These soils are prime farmland if irrigated. The Bridget soils present within the MEA are partially hydric. Bridget series soils comprise approximately 8 percent of the MEA. They are mapped as composite map unit 1356 on Figure 2.6-29 and include the following map units:

1356 – Bridget silt loam, 1 to 3 percent slopes

This soil occurs in areas as large as 500 acres on foot slopes and stream terraces near large drainages. Minor areas in higher landscape positions may have a fine sandy loam surface layer or transitional horizon. This soil is partially hydric. Water erosion and gullying are hazards in areas that receive runoff from adjacent slopes. Soil blowing is a hazard if the soil surface is unprotected. Runoff is slow to medium. Approximately 269 acres of this soil unit are present within the MEA.

1357 – Bridget silt loam, 3 to 6 percent slopes

This soil occurs in areas as large as 200 acres on colluvial foot slopes and uplands. It is similar to map unit 1356 but has a thinner surface layer and occurs on steeper slopes. Bayard, Keith, or Rosebud series soils may make up 25 percent of this unit in the Pine Ridge area. Water erosion is a hazard due to runoff received from adjacent higher areas. Soil blowing is a hazard if the soil surface is unprotected. Runoff is medium. Approximately 105 acres of this soil unit are present within the MEA.

Keith Series Soils

The Keith series consists of deep, well drained soils that formed in loess on uplands and tablelands. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. Keith series soils are suited for dry farmed and irrigated crops, primarily winter wheat and alfalfa. These soils are prime farmland if irrigated. Keith series soils comprise approximately 1 percent of the MEA and include the following map unit:

1620 – Keith silt loam, 1 to 3 percent slopes

This soil occurs in areas as large as 500 acres on uplands. The soil profile of this unit is similar to other Keith series soils but has a thicker subsoil and may have a loam or fine sandy loam surface layer. Small areas of Alliance, Duroc, and Richfield soils may be present within this map unit. Water erosion is a hazard in some areas, but soil blowing is the main hazard. Runoff is slow. This soil unit is partially hydric. Approximately 53 acres of this soil unit are present in the MEA.

Rosebud-Canyon Complex Soils

The Rosebud-Canyon soil complex consists of intricately adjoining areas of Rosebud series and Canyon series soils. Rosebud soils are moderately deep, well drained soils that formed in material weathered from sandstone on upland areas. Permeability is moderate, and available water capacity is moderate. Natural fertility is medium, and organic matter content immoderate. Rosebud soils are suited to both dry farmed and irrigated crops, such as wheat, oats, and alfalfa. Canyon series soils are described further below. Rosebud-Canyon complex soils comprise approximately 4 percent of the MEA and include the following map unit:

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

These soils occur in areas as large as 500 acres on gently rolling and rolling uplands. Rosebud soils make up approximately 50 to 70 percent of the map unit, and Canyon soils approximately

15 to 30 percent. Lesser amounts of other soil series make up 10 to 25 percent. Rosebud soils are found on side slopes, and the Canyon soils are on ridgetops and knolls. Soil blowing and water erosion are hazards if these soils are cultivated, and the soil surface is not protected. Runoff is medium to rapid, depending on slope gradient and the type and amount of vegetative cover. Canyon soils are shallow but may be cultivated where adjacent to deeper soils. This soil unit is partially hydric. Approximately 188 acres of this soil unit are present in the MEA.

Valent and Dwyer Group Soils

The Valent and Dwyer soil group consists of intermingled areas of Valent series and Dwyer series soils. Both Valent and Dwyer soils are deep, excessively drained soils that formed in eolian sands on uplands and stream terraces. Both soils have rapid permeability and low available water capacity. Natural fertility and organic matter content of both soils are low. Runoff is slow because both soils absorb water rapidly. Dwyer soils have lime higher in the profile than Valen soils but are otherwise very similar. These soils are best suited for rangeland grasses, but not for dryland farming. Some irrigated alfalfa is grown in these soils. Both Valent and Dwyer soil units present within the MEA are partially hydric. These soils comprise approximately 23 percent of the MEA. Valent and Dwyer group soils are mapped as composite unit 1882 on Figure 2.6-29 and include the following units:

1881 – Valent and Dwyer loamy fine sands, 0 to 3 percent slopes

This map unit occurs in areas as large as 200 acres on uplands and stream terraces, either of which may be hummocky. Soil component distribution varies, and some areas consist almost entirely of either soil series or may have both. Dwyer soils may have pebbles on the surface and throughout the profile. Soil blowing is a hazard in cultivated areas. Approximately 284 acres of this soil unit are present in the MEA.

1882 – Valent and Dwyer loamy fine sands, 3 to 20 percent slopes

This map unit occurs in areas as large as 1,000 acres on uplands. It is very similar to map unit 1881 but occurs on steeper slopes. Wind erosion is a very severe hazard if grass is removed, and blowouts occur in some areas. Approximately 786 acres of this soil unit are present in the MEA.

Vetal and Bayard Group Soils

The Vetal and Bayard soil group consists of intermingled areas of Vetal series and Bayard series soils. Both Vetal and Bayard soils are deep, well-drained soils that formed in sandy alluvium and colluvium on foot slopes. Vetal soils are found on upland swales, and Bayard soils may be found on stream terraces as well as foot slopes. Both soils have moderately rapid permeability and moderate available water capacity. Natural fertility and organic matter content of both soils are moderate. Bayer soils have a thinner surface horizon than Vetal soils. Both soils are suited for dry farmed and irrigated crops such as wheat, oats, and alfalfa. These soils are prime farmland if irrigated. Vetal and Bayard group soils comprise approximately 2.4 percent of the MEA and include the following map unit:

5070 – Vetal and Bayard soils, 1 to 6 percent slopes

This map unit occurs in areas as large as 300 acres on foot slopes and stream terraces. Vetal soils make up 55 to 75 percent of the map unit, and Bayard soils make up 25 to 45 percent.

Areas may be dominated by a single component or may have both present. Soil blowing is a hazard in cultivated areas, and runoff is slow due to rapid absorption of rainfall. Approximately 111 acres of this soil unit are present in the MEA.

Alliance Series Soils

The Alliance series consists of deep, well drained soils that formed in material weathered from sandstone on uplands. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. These soils are generally suited for dry farmed and irrigated crops and are prime farmland if irrigated. All Alliance series soils present within the MEA are partially hydric. All Alliance soil units present within the MEA are partially hydric. Alliance series soils comprise approximately 8 percent of the MEA. Alliance series soils are mapped as composite unit 5105 on Figure 2.6-29 and include the following map units:

5105 – Alliance silt loam, 1 to 3 percent slopes

This map unit occurs in areas as large as 500 acres on smooth upland areas. This map unit is similar to other Alliance series soils but may have lime present below a depth of 30 inches. Small areas of Rosebud, Dwyer, and Richfield series soils may be present. Soil blowing and water erosion are a moderate hazard if the soil surface is not protected. Runoff is slow. Most crops are dry farmed, and wheat is the primary crop, with lesser amounts of oats and alfalfa. Corn is the main crop in irrigated areas. Approximately 242 acres of this soil unit are present in the MEA.

5106 – Alliance silt loam, 3 to 9 percent slopes

This map unit occurs in areas as large as 300 acres on uplands. The soil profile of this map unit is similar to other Alliance series soils but has a slightly thinner surface layer. This soil is partially hydric. Water erosion and soil blowing are hazards in cultivated areas. Runoff is medium. This soil is used primarily for rangeland or native grass hay. It is suited for cultivation, but effective management practices and cropping systems are needed to help control erosion. Approximately 88 acres of this soil unit are present in the MEA.

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

This map unit is similar to unit 5106 but has a surface layer thinner than 7 inches which has been at least partially removed by erosion. Lime may be present at the surface, and the subsoil may be thinner than other Alliance series soils. Slope steepness limits irrigation development. Approximately 29 acres of this soil unit are present in the MEA.

Busher and Tassel Complex Soils

The Busher and Tassel soil complex consists of intricately adjoining areas of Busher series and Tassel series soils on uplands. Busher soils are found on the middle and lower portions of slopes and Tassel soils are on ridgetops, knolls, and sides of small drainages. This soil unit is not hydric. Busher and Tassel complex soils comprise approximately 4 percent of the MEA and include the following map unit:

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

This map unit occurs in areas as large as 100 acres on uplands. Slopes are mostly from 9 to 20 percent but may be as low as 6 percent. Busher loamy very fine sand makes up about 60 percent of this unit, and Tassel loamy very fine sand makes up about 40 percent. Areas of shallower soils are present where bedrock is at a depth of 20 to 36 inches. Soil blowing and water erosion are serious hazards if the native grass cover is removed. Runoff is medium. Most of this soil unit is used for native grass rangeland. Approximately 185 acres of this soil unit are present in the MEA.

Busher Series Soils

The Busher series consists of deep, well drained to somewhat excessively drained soils that formed in material weathered from sandstone on uplands. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility is medium to low, and organic matter content is moderate. Soil blowing and water erosion are serious hazards on all Busher series soils if the protective vegetation cover is removed. Where slopes are less than 9 percent, these soils are suited for cultivation and irrigation. Areas with slopes less than 6 percent (map units 5123 and 5124 below) are considered Farmland of Statewide Importance. No other Busher soils are considered prime farmland. Soil units 5123, 5124, and 5128 are partially hydric, but unit 5126 is not. Busher series soils comprise approximately 15 percent of the MEA. Busher series soils are mapped as composite unit 5136 on Figure 2.6-29 and include the following map units:

5123 – Busher loamy very fine sand, 1 to 6 percent slopes

This map unit occurs in areas as large as 100 acres on uplands. This unit is similar to other Busher series soils but may have a surface layer consisting of very fine sandy loam or sandy loam, a transitional layer of loam or very fine sandy loam, or areas of shallower soil where bedrock is at a depth of 20 to 40 inches. Areas of Bridget, Jayem, Vetal, and Tassel soils may be present and make up as much as 15 percent of this unit. Management concerns include conserving soil moisture and maintaining soil fertility. This soil unit typically occurs in areas of native grass. Approximately 142 acres of this soil unit are present in the MEA.

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

This map unit is similar to unit 5123 but occurs in areas as large as 200 acres and typically has a thinner (4 to 7 inches) surface layer due to erosion. This soil unit typically occurs in areas cultivated for dry farmed wheat, alfalfa, and oats. Approximately 131 acres of this soil unit are present in the MEA.

5126 – Busher loamy very fine sand, 6 to 9 percent slopes

This map unit occurs in areas as large as 250 acres on uplands. This unit is similar to other Busher series soils but may have a surface layer thinner than 7 inches and may have lime at a depth of 12 to 18 inches. Areas of Bridget, Jayem, Vetal, and Tassel soils are present and make up as much as 15 percent of this unit. This soil unit typically occurs in areas of native grass. Approximately 162 acres of this soil unit are present in the MEA.

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

This map unit is similar to unit 5126 but occurs in areas as large as 100 acres and has a surface layer that is 4 to 7 inches thick. Bedrock may be present in areas of shallow soils at a depth of 20 to 36 inches. Small areas of rock outcrop may be present within this unit. This soil is somewhat droughty and typically occurs in areas cultivated for dry farmed wheat, alfalfa, and oats. Approximately 135 acres of this soil unit are present in the MEA.

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

This map unit occurs in areas as large as 200 acres on uplands. This unit is similar to other Busher series soils but has a surface layer that is 4 to 7 inches thick and lime at a depth of 10 to 18 inches in places. Bedrock may be present in areas of shallow soils at a depth of 20 to 36 inches. Conserving soil moisture is a major management concern in this soil. Runoff is medium. This unit occurs primarily in areas of native grass. Areas with flatter slopes are cultivated, but the steepness of this unit makes most areas unsuitable. Approximately 141 acres of this soil unit are present in the MEA.

<u>Canyon Series Soils</u>

The Canyon series consists of shallow, well drained soils that formed in material weathered from sandstone on ridges, knolls, and the sides of upland drainages. These soils are found only in the northern half of the MEA. Canyon soils are typically loams that are at 15 inches or shallower. Permeability is moderate, and available water capacity is low. Natural fertility and organic matter content are also low. Because Canyon soils are steep and shallow, cultivation is limited to areas where they are adjacent to deeper, more suitable soils. These soils are not hydric. Canyon series soils comprise approximately 12 percent of the MEA. Canyon series soils are mapped as composite unit 5153 on Figure 2.6-29 and include the following map units:

5152 – Canyon soils, 3 to 30 percent slopes

This map unit occurs in areas as large as 500 acres. This unit is similar to other Canyon series soils but has a surface layer that may be silt loam or very fine sandy loam. Bedrock may be present at depths of less than 10 inches. Areas of Bridget, Rosebud, Oglala, and Tassel series soils make up less than 20 percent of this unit. Water erosion and soil blowing are very severe hazards if the soil surface is unprotected. These soils are droughty due to low available water capacity and shallow root zones. Conserving soil moisture is a management concern. Runoff is medium until soils are saturated, and then becomes rapid. This unit is typically found in areas of native grass used for grazing. Approximately 13 acres of this soil unit are present in the MEA.

5153 – Canyon soils, 30 to 50 percent slopes

This map unit occurs in areas as large as 500 acres on the sides of upland drainages. These soils are similar to map unit 5152 but occur in areas of steeper slopes that may also contain rock outcroppings. Very steep slopes, shallowness, and rock outcrops limit the use of these soils to range, woodland, and wildlife habitat. Runoff is very rapid. Approximately 537 acres of this soil unit are present in the MEA.

Oglala Series Soils

The Oglala series consists of deep, well drained soils that formed in material weathered from fine-grained sandstone on the middle and lower parts of side slopes in uplands. These soils are found only in the northern half of the MEA. Oglala soils typically have a loam surface layer overlying a silt loam subsoil. Permeability is moderate, and available water capacity is high. Natural fertility and organic matter content are moderate. In general, these soils are better suited to native grass than cultivation due to steep slopes. These soils are not hydric. Oglala series soils comprise less than 1 percent of the MEA and include the following map unit:

5200 – Oglala loam, 9 to 30 percent slopes

This map unit occurs in areas as large as 200 acres on hillsides. The surface horizon of this unit may be thinner (3 to 6 inches) in areas and lime may be present at depths of less than 20 inches. Areas of Bridget, Canyon, Rosebud, and Ulysses soils may be present and make up less than 15 percent of this unit. Water erosion and soil blowing are hazards if the soil surface is not protected. Runoff is medium to rapid, depending on slope steepness and type and amount of vegetative cover. Most of this unit is used for livestock grazing on native grass. Approximately 2 acres of this soil unit are present in the MEA.

Oglala-Canyon Complex Soils

The Oglala-Canyon soil complex consists of intricately adjoining areas of Oglala series and Canyon series soils on side slopes, ridges, and knolls in the northern portion of the MEA. Oglala soils are found on the middle and lower part of side slopes, and Canyon soils are on ridgetops and knolls. These soils are not hydric. The Oglala-Canyon complex comprises approximately 5 percent of the MEA and includes the following map unit:

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

This map unit is found in areas as large as 1,000 acres. Oglala soils make up approximately 60 to 75 percent of this unit, and Canyon soils approximately 25 to 40 percent. Areas of Bridget, Duroc, Keith, Rosebud, and Ulysses soils may be present and make up 25 percent or less of this unit. Fragments of sandstone may be present at the surface in some areas. Water erosion is a hazard if the soil surface is not protected. Runoff is medium to rapid, depending on slope steepness and the type and amount of vegetative cover. This unit is not suited for cultivation and is typically found in areas of native grass. Approximately 236 acres of this soil unit are present in the MEA.

Schamber Series Soils

The Schamber series consists of shallow, somewhat excessively drained soils that occur on escarpments of stream terraces along tributaries of the Niobrara River in the southern portion of the MEA. Schamber series soils typically have a gravelly, very fine sandy loam surface layer and subsoil overlying coarse sandstone gravel at a depth of approximately 12 inches. Permeability is rapid to very rapid, and available water capacity is very low. Natural fertility and organic matter content are low. These soils are not well suited for cultivation and are not hydric. Schamber series soils comprise less than 1 percent of the MEA and include the following map unit:

5254 – Schamber soils, 3 to 30 percent slopes

This map unit is found in areas as large as 50 acres. The surface layer of this unit may be gravelly loam in areas. Areas of deeper soil exist where gravel is present at a depth of 20 to 40 inches. Areas of Keith, Mitchell, and Pierre series soils are present at lower elevations and may comprise up to 15 percent of this unit. Soil blowing and water erosion are hazards if the soil surface is not protected. Runoff is medium to rapid. These soils are typically found in areas of native grass that are used for grazing. The substrate of these soils may be a useful source of gravel for construction activities. Approximately 13 acres of this soil unit are present in the MEA.

Haverson Series Soils

The Haverson series consists of deep, well-drained soils that formed in stratified silty and loamy alluvium on bottom lands and low stream terraces. Areas on very low bottom lands are subject to occasional to frequent flooding. Haverson soils are found only in the northern portion of the MEA. Permeability is moderate to moderately slow, and the available water capacity is high. Natural fertility is medium to low, and organic matter content is low. These soils are rich in lime, which typically occurs at the surface, and are suited for grass and irrigated crops. Haverson soils comprise approximately 1 percent of the MEA and include the following map unit:

5640 – Haverson loam, frequently flooded

This map unit is found in areas of irregular size and shape on low bottom lands and low stream terraces. Flooding frequently occurs due to their low position on the landscape. Areas of Glenberg soils may be included in higher elevation portions of this unit. Flooding is the main hazard and management concern in this unit. Soil blowing can also be a hazard if the soil surface is unprotected. Runoff is slow. Alfalfa is the main crop where cultivated and is suited for irrigation if flooding can be controlled. This soil unit is partially hydric. Approximately 50 acres of this soil unit are present in the MEA.

Tripp Series Soils

The Tripp series consists of deep, well drained soils that formed in silty and loamy alluvium on stream terraces along major drainages. Permeability is moderate in the upper part of the subsoil and decreases with depth where lime has accumulated. Available water capacity is high, natural fertility is medium, and organic matter content is moderate. These soils are suited for dry farming and irrigation. Tripp soils comprise less than 1 percent of the MEA and include the following map unit:

5871 – Tripp silt loam, 1 to 3 percent slopes

This map unit occurs in areas as large as 200 acres on stream terraces in the north-central portion of the MEA. This unit is similar to other Tripp soils but may be thinner and may have lime at shallower depths. This map unit may include areas of Bayard and Bridget soils at high elevations and Duroc and Halverson soils at low elevations. Soil blowing and water erosion are hazards if the soil surface is not protected. Runoff is slow. If irrigated, this soil is categorized as prime farmland; however, it is mostly used for dry farming of alfalfa, wheat, and oats. This soil unit is partially hydric. Approximately 20 acres of this soil unit are present in the MEA.

Duroc Series Soils

The Duroc series consists of deep, well drained soils that formed in colluvium and alluvium derived from loess and weathered sandstone. Permeability is moderate, and available water capacity is high. Natural fertility and organic matter content are moderate. These soils are well suited to cultivation and irrigation. Duroc soils are primarily found as minor components of other soil map units within the MEA. Areas mapped as Duroc soils comprise less than 1 percent of the MEA and include the following map unit:

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

This map unit occurs on the northern boundary of the MEA on a stream terrace. It occurs in areas as large as 300 acres elsewhere in Dawes County. Alliance, Bridget, Keith, Richfield, and Rosebud soils may be associated with this unit at higher elevations. This soil is partially hydric. Runoff is slow. This unit is suited to irrigation but is mostly dry farmed for wheat, oats, and alfalfa. This soil is prime farmland if irrigated. Less than 1 acre of this soil unit is present in the MEA.

Jayem Series Soils

The Jayem series consists of deep, well drained to somewhat excessively drained soils that formed in eolian sands on uplands. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility and organic matter content are moderate. These soils are suited to both dry farmed and irrigated crops. Jayem soils comprise less than 1 percent of the MEA and include the following map unit:

5978 – Jayem loamy very fine sand, 1 to 6 percent slopes

This map unit is found in areas as large as 200 acres on uplands. The surface horizon may consist of very fine sandy loam, and lime occurs at a depth of 10 to 26 inches. Areas of Keith, Sarben, and Vetal soils make up less than 15 percent of this unit. Soil blowing is a hazard if the soil surface is unprotected. Runoff is slow due to moderately rapid infiltration of rainfall. This unit is primarily found in areas of native grass used for grazing or hay but is well suited for irrigation. This unit is considered to be Farmland of Statewide Importance. Wheat and alfalfa are the most commonly cultivated crops. This soil unit is partially hydric. Approximately 11 acres of this soil unit are present in the central portion of the MEA.

Tassel Series Soils

The Tassel series consists of shallow, well drained soils that formed in material weathered from fine grained sandstone on uplands. The surface horizon and subsoil of Tassel soils are typically composed of loamy very fine sand. Permeability is moderately rapid, and available water capacity is very low. Natural fertility and organic matter content are low. The shallow nature of these soils makes them poorly suited for commonly cultivated crops and better suited for range and wildlife habitat. Lime is typically present at the surface of Tassel series soils. These soils are not hydric. Tassel soils comprise approximately 8 percent of the MEA and include the following map unit:

6028 – Tassel soils, 3 to 30 percent slopes

This map unit is found in areas as large as 500 acres on ridges, knolls, and the sides of upland drainages in the northern and central portions of the MEA. Areas of shallow soils where sandstone occurs at depths of 4 to 10 inches and areas of deeper soils where sandstone occurs at depths of 20 to 40 inches are present within this unit. Small outcrops of sandstone are also included in this unit. Areas of Bayard, Busher, Canyon, Jayem, and Sarben soil comprise up to 20 percent of this unit. Soil blowing is a hazard if the grass cover is removed or damaged. These soils are often droughty, and conserving moisture is a management concern. Runoff is slow to rapid, depending on the slope steepness and type and amount of vegetative cover. This unit is primarily found in areas of native grass used for grazing. Because shallowness and steep slopes make this unit unsuitable for cultivation, it is typically only cultivated where adjacent to deeper soils. Approximately 346 acres of this soil unit are present in the MEA.

Tassel-Ponderosa-Rock Outcrop Association

The Tassel-Ponderosa-Rock outcrop soil association consists of well drained soils that are mapped together in steep upland areas. Tassel series soils are found on ridges. Ponderosa series soils are deep, well drained, very fine sandy loams that formed from residuum weathered from fine-grained sandstone on side slopes. Available water capacity of Ponderosa soils is moderate, and permeability is high (NRCS 2011). Rock outcrops are very shallow, excessively drained weathered sandstone that occur on ridges. These soils are not hydric. This soil association comprises less than 1 percent of the project area and includes the following map unit:

6043 – Tassel-Ponderosa-Rock outcrop association, 9 to 70 percent slopes

This map unit occurs along the western margin of the MEA in areas smaller than 10 acres. These soils have a very high potential for wind and water erosion. Runoff is medium to rapid, depending on the slope steepness, type and amount of cover, and presence of rock outcrops. This association is unsuited for cultivation due to steep slopes and shallow soils. Approximately 1 acre of this soil unit is present in the MEA.

Sarben Series Soils

The Sarben series consists of deep, well drained soils that formed in eolian sands on uplands. Permeability is moderately rapid and available water capacity is moderate. Natural fertility is medium to low, and organic matter content is low. Lime occurs at a depth of 24 inches. These soils are suited to dry farming and irrigation and are considered prime farmland if irrigated. Sarben series soils present within the MEA are not hydric. Sarben soils comprise less than 1 percent of the MEA and include the following map unit:

6091 – Sarben fine sandy loam, 1 to 6 percent slopes

This map unit occurs in areas as large as 100 acres on gently rolling uplands in the south-central portion of the MEA. This unit is similar to other Sarben soils but has lime deeper in the profile and may be deeper than other variations. Soil blowing and water erosion, to a lesser extent, are hazards if vegetative cover is removed. These soils are moderately droughty, and conserving moisture and improving fertility are management concerns. Runoff is slow. Dry farmed wheat, alfalfa, and oats are the main uses of this unit, but grass for grazing and hay is also cultivated. Approximately 19 acres of this soil unit are present in the MEA.

2.6.5 Seismology

The seismic hazard map for Nebraska (Figure 2.6-30), represents the peak acceleration (%g) with a 2 percent probability of exceedances in 50 years (USGS 2024a), meaning that in a given 50-year period, there is only a 2 percent chance of seismic shaking exceeding any given equivalent percentage of acceleration due to Earth's gravity. Figure 2.6-30 shows that the modeled peak acceleration due to seismic shaking near the Crow Butte Project is 10-14 %g and near the MEA is 8 to 10 %g. This means that the maximum shaking due to any given earthquake in the region during a 50-year period would be equivalent to only 14 percent or less of the force of gravity at Earth's surface. These estimates demonstrate that the Crow Butte Project and the MEA are at the low end of the USGS' hazard ranking system for earthquake risks.

Earthquakes release different amounts of energy, and the strength of this energy can be measured by magnitude and intensity. A comparison of the magnitude and intensity scales is shown in Table 2.6-6 as well as the USGS abbreviated descriptions of the 12 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 cannot 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.

Figure 2.6-31 shows the earthquakes that have occurred in Nebraska and within 125 km (78 miles) of Crawford since 1970. The table shows that 23 earthquakes greater than 2.5 magnitude have occurred within 125 kilometers of Crawford, with the largest earthquakes (4.0 magnitude) occurring on November 14, 2011 and January 28, 1990 (USGS 2024b).

2.6.6 References

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Table 2.6-1. General Stratigraphic Chart for Northwestern Nebraska

Geologic Period	Series	Formation or Group	Rock Types[1]	Thickness (ft)
Tertiary	Miocene	Ogallala	SS, Slt	1,560*
		Arikaree	SS, Slt	1,070*
	Oligocene/Eocene	White River	SS, Slt, Cly	1,450*
Cretaceous	Upper	Pierre	Sh	1,500
		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/ Cherokee	Ls, Sh	130
	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 2.6-2. Estimated Weight Percent as Determined by X-Ray Diffraction

Phase	Upper Part Chadron Formation (2) Upper Confinement	Chadron Sandstone (4) (Mining Unit)	Pierre Shale (2) Lower Confinement
Quartz	22.5	75.5	26
K Feldspar	2	13	4
Plagioclase	1	9.5	1
Kaolinite-Chlorite	--	<1	9
Montmorillonite	44	<1	32
Mica-Illite	1	<1	15
Calcite	22	--	1.5
Fluorite	0.5	--	--
Amorphous	7	1	10.5
Unidentified	--	<1	1
TOTAL	**100**	**100**	**100**

Notes: -- = Not encountered

Table 2.6-3. Representative Stratigraphic Section

Elevation (ft amsl)	Average Depth (ft bgs)	Group	Formation & Member (Schultz and Stout 1955)			Formation and Member (Revised)		References (Revised)
Varying 4150 - 4,380	15 - 135	Arikaree Group	Monroe Creek Formation			Upper Harrison Beds		Swinehart et al. (1985)
						Monroe Creek-Harrison Formation		
			Gering Formation			Gering Formation		
Varying 4,140 - 4.020	135 - 285	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		Big Cottonwood Creek Member	Terry (1998) Terry and LaGarry (1998)
4,020 - 3,890	285 – 650		Chadron Formation	Upper Chadron	Chadron C	Chadron Formation		
				Upper/Middle Chadron	Chadron B			
3,890 - 3,380	650 -925			Middle Chadron			Peanut Creek Member	Terry (1998) Terry and LaGarry (1998)
3,380 - 3,180	925 – 1,025			Upper Interior Paleosol	Chadron A	Chamberlain Pass Formation	Upper Interior Paleosol	Terry (199)
				basal sandstone of the Chadron Formation			Channel Sandstone	Terry (1998) Terry and LaGarry (1998)
		Montana Group	Pierre Shale	Interior Paleosol		Pierre Shale	Yellow Mounds Paleosol	Retallack (1983) Terry (1998)
3,180 – 3,130	1,025 - ? (Bottom not seen in logs)			Pierre Shale			Pierre Shale	Terry (1998) Terry and LaGarry (1998)

Notes:
1) The Shultz and Stout conventions for Formation & Member are utilized throughout this document, with the exception of the Red Clay Horizon, which is referred to as the Upper Interior Paleosol.
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; ft bgs = feet below ground surface
4) Elevations are representative averages for MEA only and based on Log M-1252.

Table 2.6-4. Summary of Soil Resources within the Crow Butte Project

Map Unit	Map Unit Name	Percent of License area
AcB	Alliance silt loam, 1 to 3 percent slopes	1.6
AcD	Alliance silt loam, 3 to 9 percent slopes	0.2
AcD2	Alliance silt loam, 3 to 9 percent slopes, eroded	1.5
Bg	Bridget silt loam, 0 to 1 percent slopes	1.9
BgB	Bridget silt loam, 1 to 3 percent slopes	0.5
BgD	Bridget silt loam, 3 to 9 percent slopes	1.3
BuC2	Busher loamy very fine sand, 1 to 5 percent slopes, eroded	0.2
BuD	Busher loamy very fine sand, 5 to 9 percent slopes	2.1
BuD2	Busher loamy very fine sand, 5 to 9 percent slopes, eroded	3.9
BuF	Busher loamy very fine sand, 9 to 20 percent slopes	7.0
BxF	Busher and tassel loamy very fine sands, 5 to 20 percent slopes	13.0
CaG	Canyon-Bridget-Rock outcrop association, steep	5.4
DuB	Duroc very fine sandy loam, 1 to 3 percent slopes	0.8
EpF	Epping silt loam, 3 to 30 percent slopes	0.0
JvD	Jayem and Vetal loamy very fine sands, 5 to 9 percent slopes	5.4
KaB	Kadoka silt loam, deep variant, 1 to 3 percent slopes	0.0
KaD	Kadoka silt loam, deep variant, 3 to 9 percent slopes	0.1
KaD2	Kadoka silt loam, deep variant, 3 to 9 percent slopes, eroded	0.2
KeB	Keith silt loam, 1 to 3 percent slopes	1.9
KfD	Keith and Ulysses silt loams, 3 to 9 percent slopes	0.8
KpD	Keota-Epping silt loams, 3 to 9 percent slopes	0.2
La	Las Animas soils, 0 to 2 percent slopes	3.3
Lo	Loamy alluvial land	0.2
MxF	Mitchell-Epping complex, 9 to 30 percent slopes	1.2
OhF	Oglala-Canyon loams, 9 to 20 percent slopes	0.4
RxD	Rosebud-Canyon loams, 3 to 9 percent slopes	4.6
Sn	Sandy alluvial land	5.9
SvF	Sarben and Vetal loamy very fine sands, 9 to 30 percent slopes	9.2
SyF	Schamber soils, 3 to 30 percent slopes	0.7
TaF	Tassel soils, 3 to 30 percent slopes	1.1
Tr	Tripp silt loam, 0 to 1 percent slopes	0.9
Ts	Tripp silt loam, saline-alkali, 0 to 2 percent slopes	1.8
VeC	Vetal and Bayard soils, 1 to 5 percent slopes	18.5
W	Water	0.9
Wx	Wet alluvial land	3.1

Source: NRCS 1977

Table 2.6-5. Summary of Soil Resources within the MEA

Map Unit	Map Unit Name	Acres	Percent of Project Area
1013	Bankard loamy coarse sand, frequently flooded	127.2	2.8
1014	Bankard loamy fine sand, frequently flooded	188.6	4.1
1036	Glenberg loamy very fine sand, 0 to 3 percent slopes	8.5	0.2
1356	Bridget silt loam, 1 to 3 percent slopes	269.1	5.8
1357	Bridget silt loam, 3 to 6 percent slopes	105.0	2.3
1620	Keith silt loam, 1 to 3 percent slopes	53.3	1.2
1742	Rosebud-Canyon loams, 3 to 9 percent slopes	188.3	4.1
1881	Valent and Dwyer loamy fine sands, 0 to 3 percent slopes	283.5	6.1
1882	Valent and Dwyer loamy fine sands, 3 to 20 percent slopes	786.1	17.0
5070	Vetal and Bayard soils, 1 to 6 percent slopes	110.6	2.4
5105	Alliance silt loam, 1 to 3 percent slopes	242.0	5.2
5106	Alliance silt loam, 3 to 9 percent slopes	87.5	1.9
5107	Alliance silt loam, 3 to 9 percent slopes, eroded	29.3	0.6
5118	Busher and Tassel loamy very fine sands, 6 to 20 percent slopes	185.1	4.0
5123	Busher loamy very fine sand, 1 to 6 percent slopes	142.2	3.1
5124	Busher loamy very fine sand, 1 to 6 percent slopes, eroded	131.2	2.8
5126	Busher loamy very fine sand, 6 to 9 percent slopes	162.3	3.5
5128	Busher loamy very fine sand, 6 to 9 percent slopes, eroded	134.5	2.9
5129	Busher loamy very fine sand, 9 to 20 percent slopes	141.3	3.1
5152	Canyon soils, 3 to 30 percent slopes	13.3	0.3
5153	Canyon soils, 30 to 50 percent slopes	536.7	11.6
5200	Oglala loam, 9 to 30 percent slopes	2.0	0.0
5211	Oglala-Canyon loams, 9 to 20 percent slopes	235.9	5.1
5254	Schamber soils, 3 to 30 percent slopes	12.7	0.3
5640	Haverson loam, frequently flooded	49.7	1.1
5871	Tripp silt loam, 1 to 3 percent slopes	19.5	0.4
5947	Duroc very fine sandy loam, 1 to 3 percent slopes	0.1	0.0
5978	Jayem loamy very fine sand, 1 to 6 percent slopes	10.9	0.2
6028	Tassel soils, 3 to 30 percent slopes	345.7	7.5
6043	Tassel-Ponderosa-Rock outcrop association, 9 to 70 percent slopes	1.0	0.0
6091	Sarben fine sandy loam, 1 to 6 percent slopes	19.4	0.4
TOTAL		**4622.3**	**100.0**

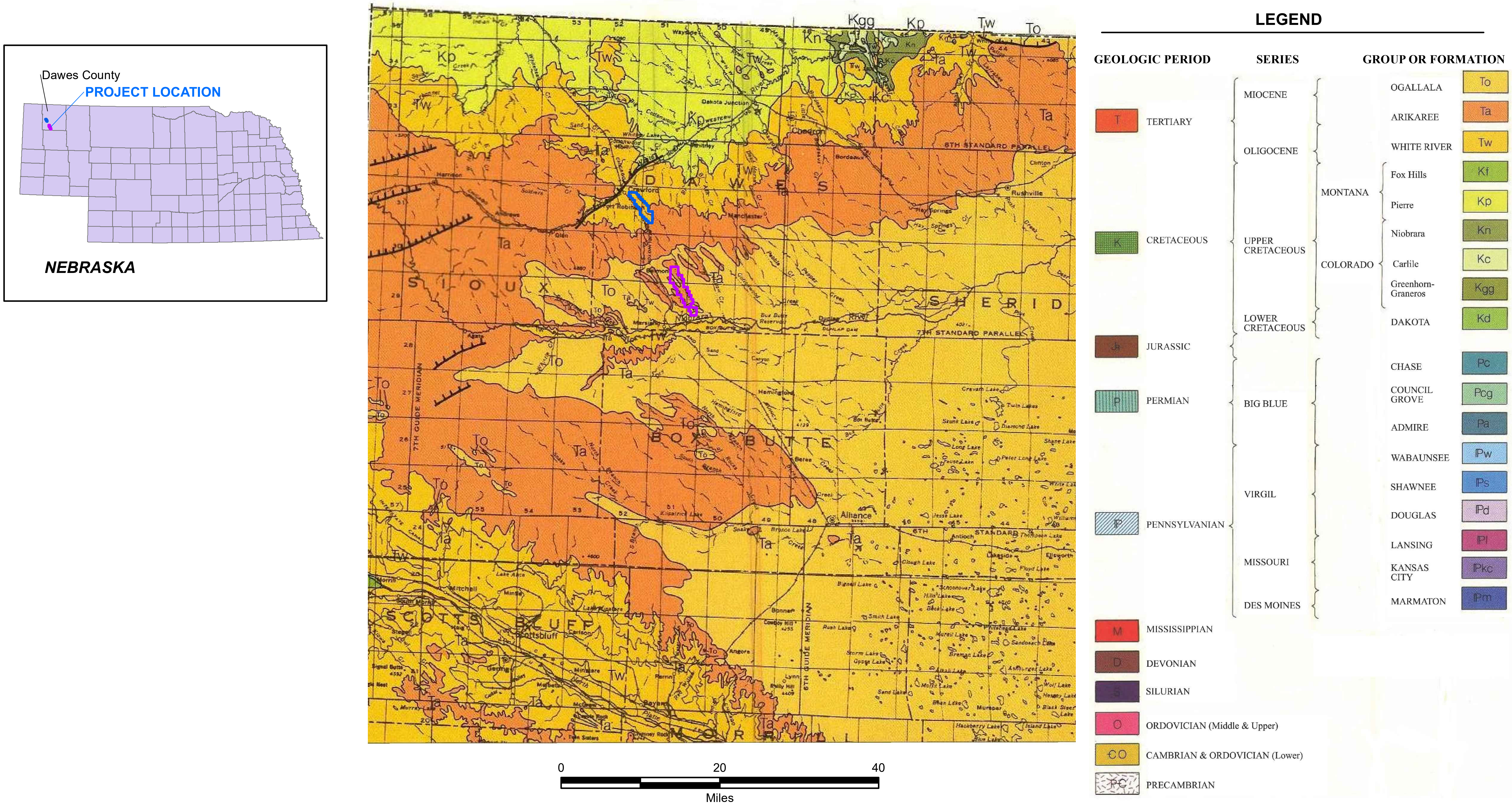
Table 2.6-6. USGS Abbreviated Modified Mercalli (MM) Intensity Scale

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 rock 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.

Table 2.6-7. Earthquakes within 125 km of Crawford, Nebraska

Date	Location	Latitude	Longitude	Magnitude
2024-06-16	7 km NE of Buffalo Gap, South Dakota	43.3065	-103.704	2.8
2021-03-26	10 km E of Edgemont, South Dakota	42.7092	-103.568	3.4
2021-02-27	13 km WNW of Crawford, Nebraska	43.3104	-103.161	2.6
2016-07-17	15 km NNE of Oelrichs, South Dakota	43.487	-102.996	2.8
2012-01-16	25 km E of Buffalo Gap, South Dakota	42.911	-103.082	3
2011-11-19	11 km NW of Chadron, NE	43.05	-103.504	2.8
2011-11-15	26 km WSW of Oelrichs, South Dakota	43.043	-103.415	3.3
2011-11-14	South Dakota	42.861	-104.087	4
2011-03-10	22 km N of Van Tassell, Wyoming	43.075	-104.289	2.9
2008-08-22	29 km E of Lance Creek, Wyoming	42.584	-102.936	3.1
2007-04-24	23 km WSW of Hay Springs, Nebraska	42.977	-102.236	2.7
2006-09-07	19 km N of Gordon, Nebraska	43.598	-103.995	2.6
2004-01-05	28 km SSE of Hill View Heights, Wyoming	42.622	-103.003	2.8
1998-06-18	23 km S of Chadron, Nebraska	43.045	-104.022	3.1
1996-05-03	32 km SSW of Edgemont, South Dakota	43.069	-104.102	3.1
1996-04-09	34 km SW of Edgemont, South Dakota	43.4	-103.5	3.7
1994-03-18	4 km SSW of Hot Springs, South Dakota	42.74	-104.389	2.8
1992-11-02	5 km ESE of Lusk, Wyoming	43.3	-102.5	3
1990-03-02	7 km N of Manderson-White Horse Creek, South Dakota	43.313	-102.504	3.2
1990-01-28	8 km N of Manderson-White Horse Creek, South Dakota	42.685	-101.898	4
1989-02-09	28 km ESE of Gordon, Nebraska	42.788	-103.482	3.8
1987-01-01	12 km NNW of Crawford, Nebraska	42.955	-102.198	3.5
1983-05-06	16 km N of Gordon, Nebraska	43.3065	-103.704	3.3

Source: USGS 2024b



Source:
Burchett, R.R., 1986, Geologic bedrock map of Nebraska: University of Nebraska Conservation and Survey Division, Geologic Maps and Charts 1, scale 1:1000000.

PROJECTION: NAD 1927, STATE PLANE NEBRASKA NORTH FIPS 2601

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-1
BEDROCK GEOLOGY

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

Path: K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\Figure 2_6-2_Location of Chadron Arch and Cambridge Arch in NE.mxd | Last Saved By: rventling | Last Saved On: 8/22/2024

LEGEND

- Chadron Arches
- Marsland Expansion Area Boundary
- Crow Butte Project Boundary
- Nebraska State Boundary
- Nebraska County Boundary

PROJECTION:
NAD 1983, STATE PLANE
NEBRASKA NORTH FIPS 2600

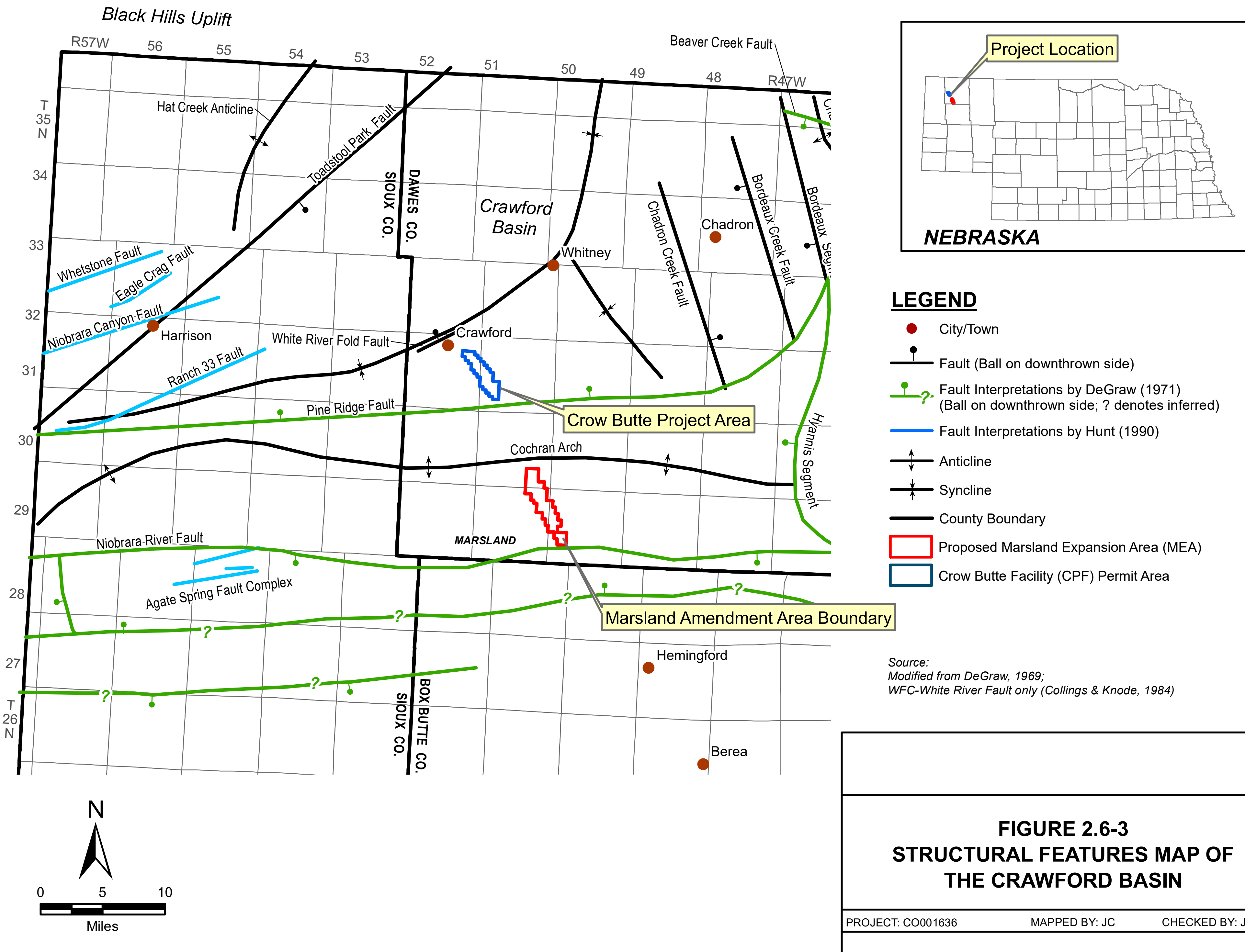
SOURCE: STIX, J. 1982

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-2
LOCATION OF CHADRON ARCH AND CAMBRIDGE ARCH IN NEBRASKA

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

Path: K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\2.6 Geology\Figure 2_6-3 Structural Features Map of the Crawford Basin.mxd | Last Saved By: rventling | Last Saved On: 9/17/2024



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

FIGURE 2.6-3
STRUCTURAL FEATURES MAP OF THE CRAWFORD BASIN

PROJECT: CO001636 MAPPED BY: JC CHECKED BY: JEC

Figure 2.6-4

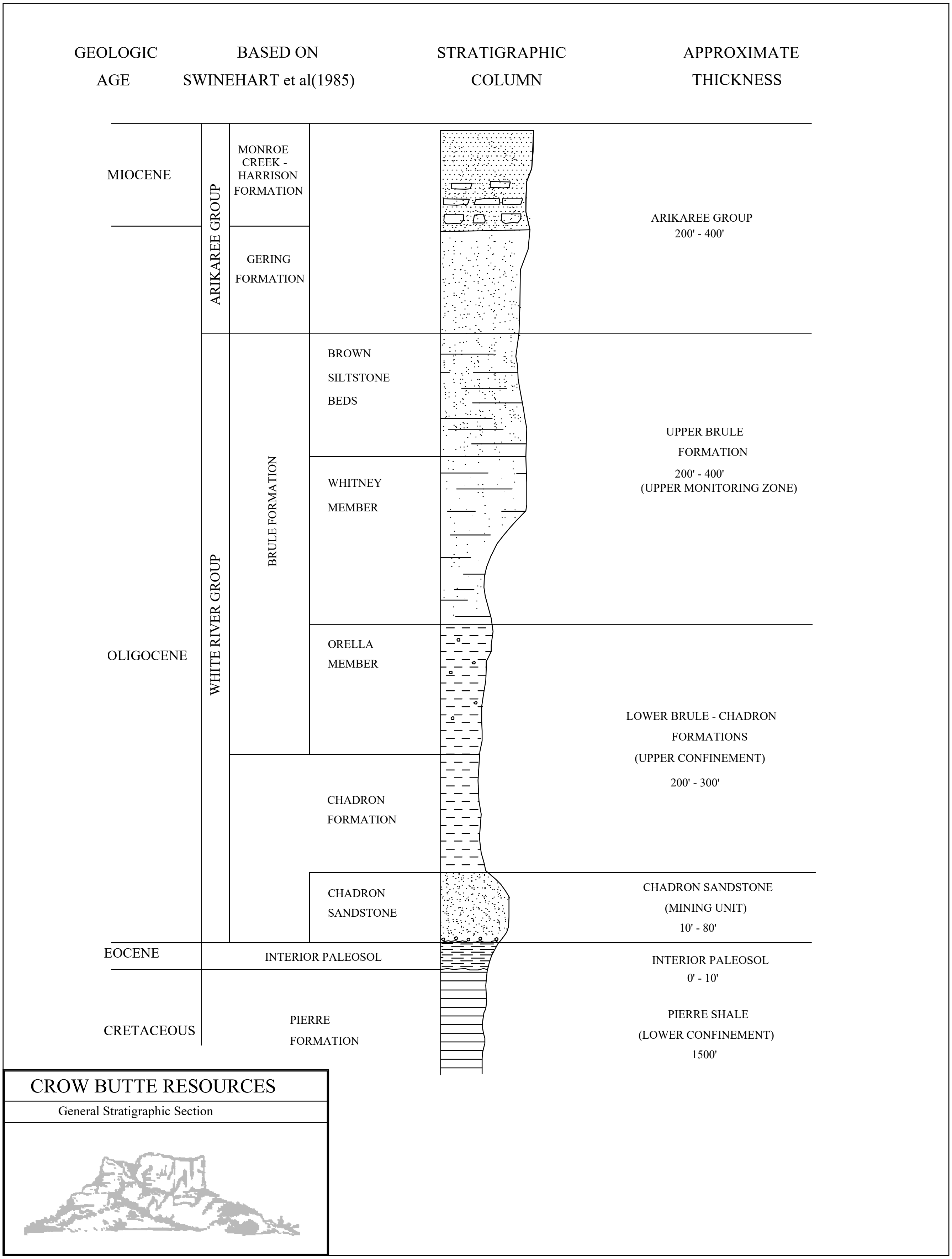

GEOLOGIC AGE
BASED ON SWINEHART et al(1985)
STRATIGRAPHIC COLUMN
APPROXIMATE THICKNESS
MIOCENE
OLIGOCENE
EOCENE
CRETACEOUS
ARIKAREE GROUP
WHITE RIVER GROUP
MONROE CREEK - HARRISON FORMATION
GERING FORMATION
BRULE FORMATION
BROWN SILTSTONE BEDS
WHITNEY MEMBER
ORELLA MEMBER
CHADRON FORMATION
CHADRON SANDSTONE
INTERIOR PALEOSOL
PIERRE FORMATION
ARIKAREE GROUP 200' - 400'
UPPER BRULE FORMATION 200' - 400' (UPPER MONITORING ZONE)
LOWER BRULE - CHADRON FORMATIONS (UPPER CONFINEMENT) 200' - 300'
CHADRON SANDSTONE (MINING UNIT) 10' - 80'
INTERIOR PALEOSOL 0' - 10'
PIERRE SHALE (LOWER CONFINEMENT) 1500'
CROW BUTTE RESOURCES
General Stratigraphic Section

Figure 2.6-5: Cross Section Location

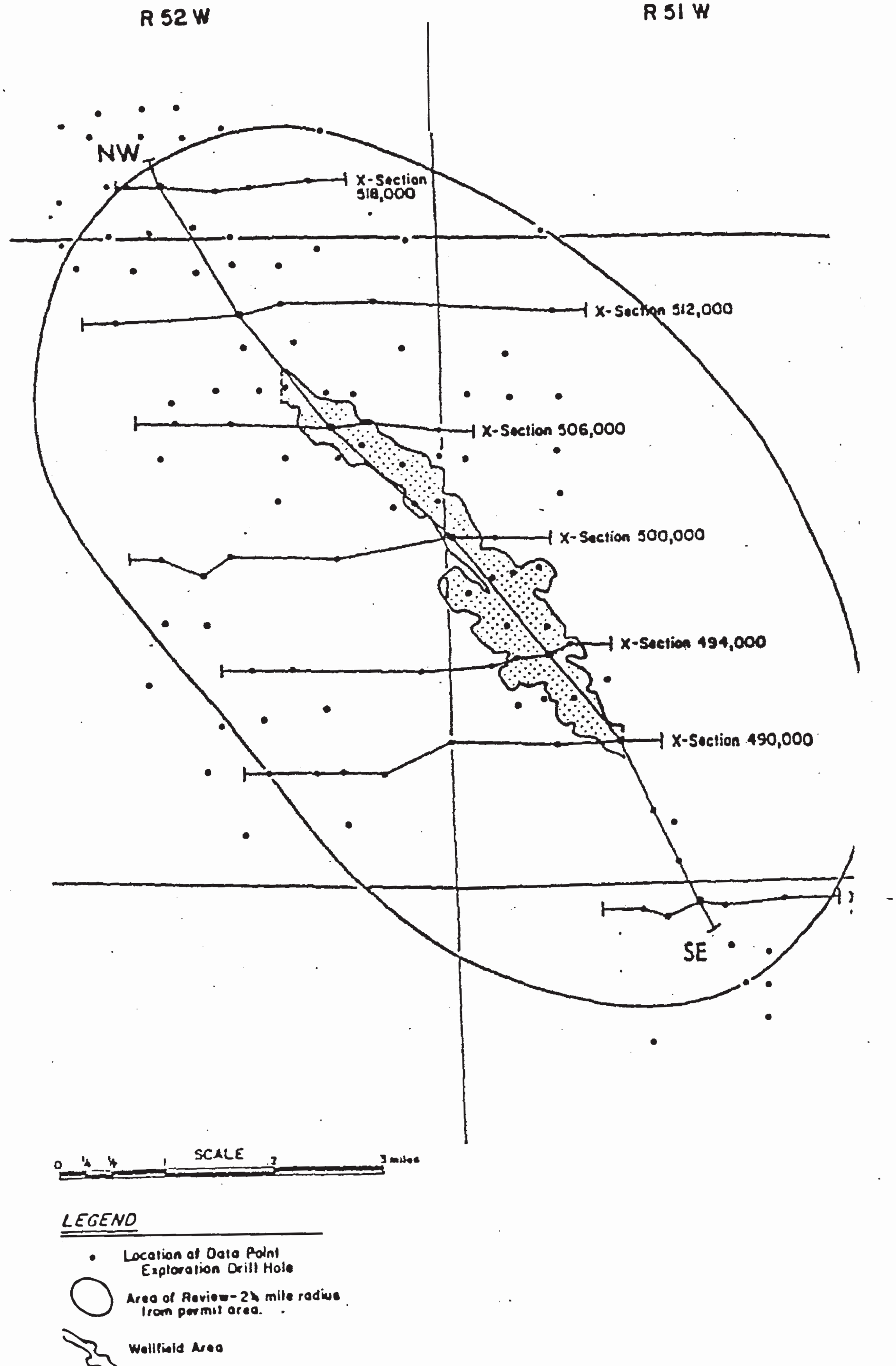


Figure 2.6-6. Cross-Section A-A'

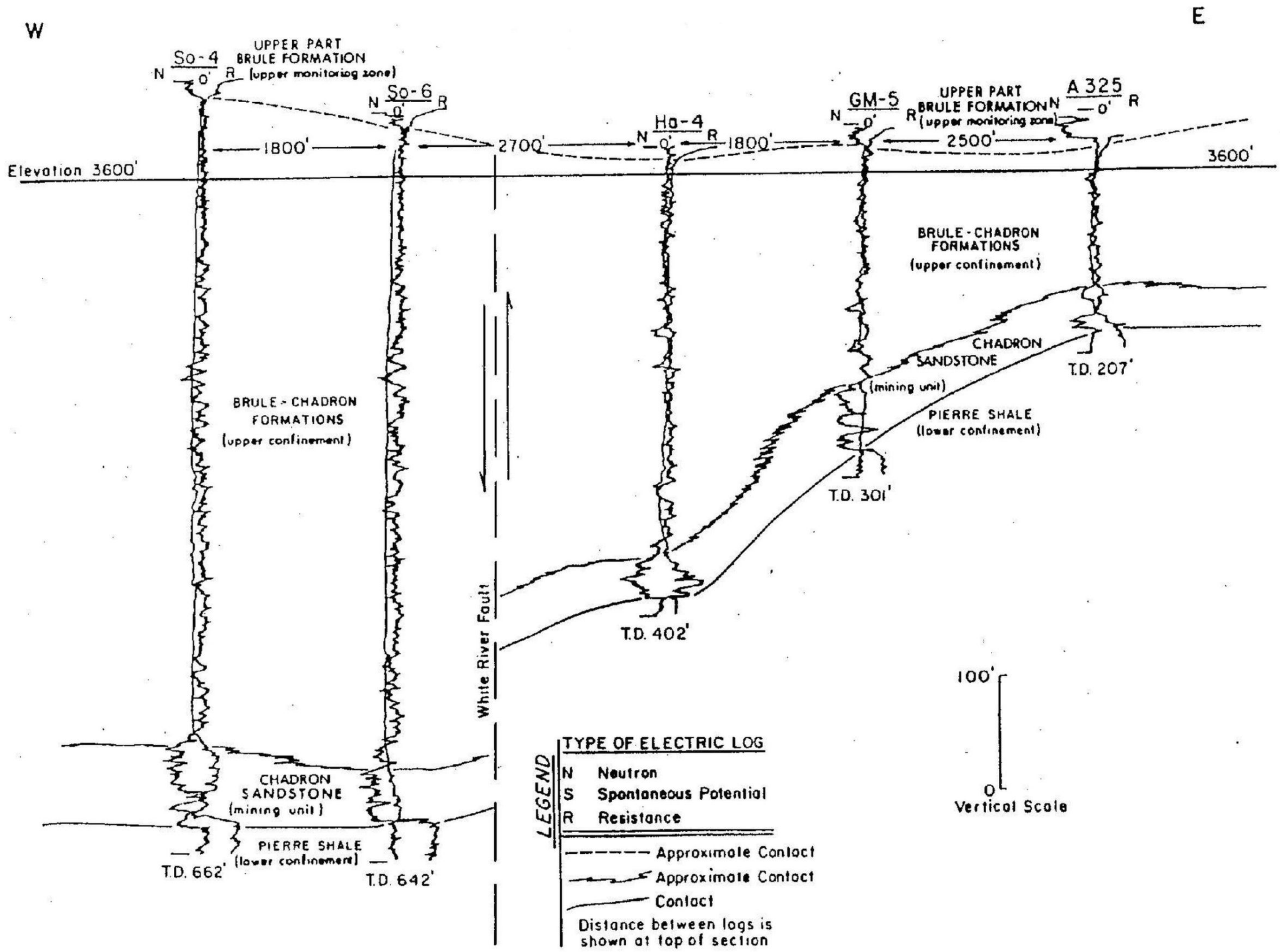


Figure 2.6-7. Cross-Section 512,000 E-W

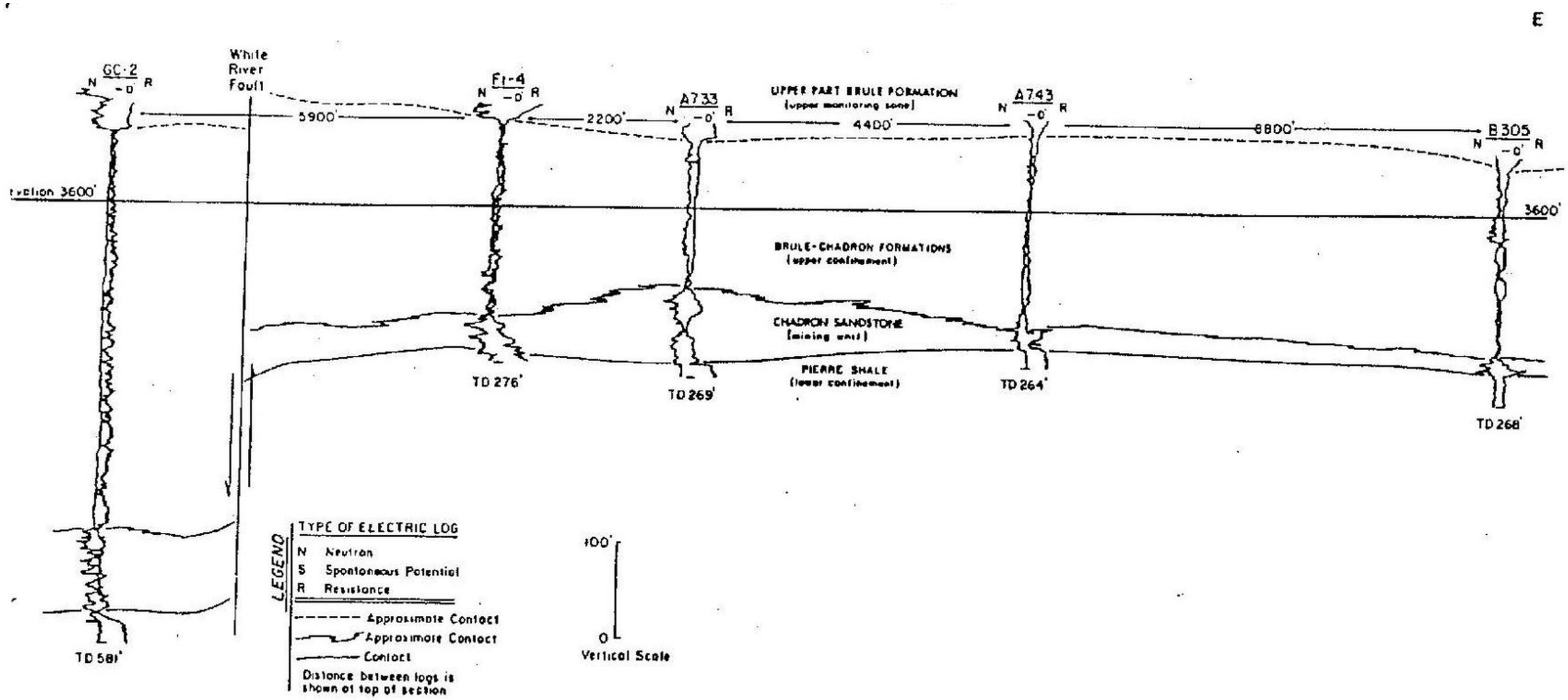


Figure 2.6-8. Cross-Section 506,000 E-W

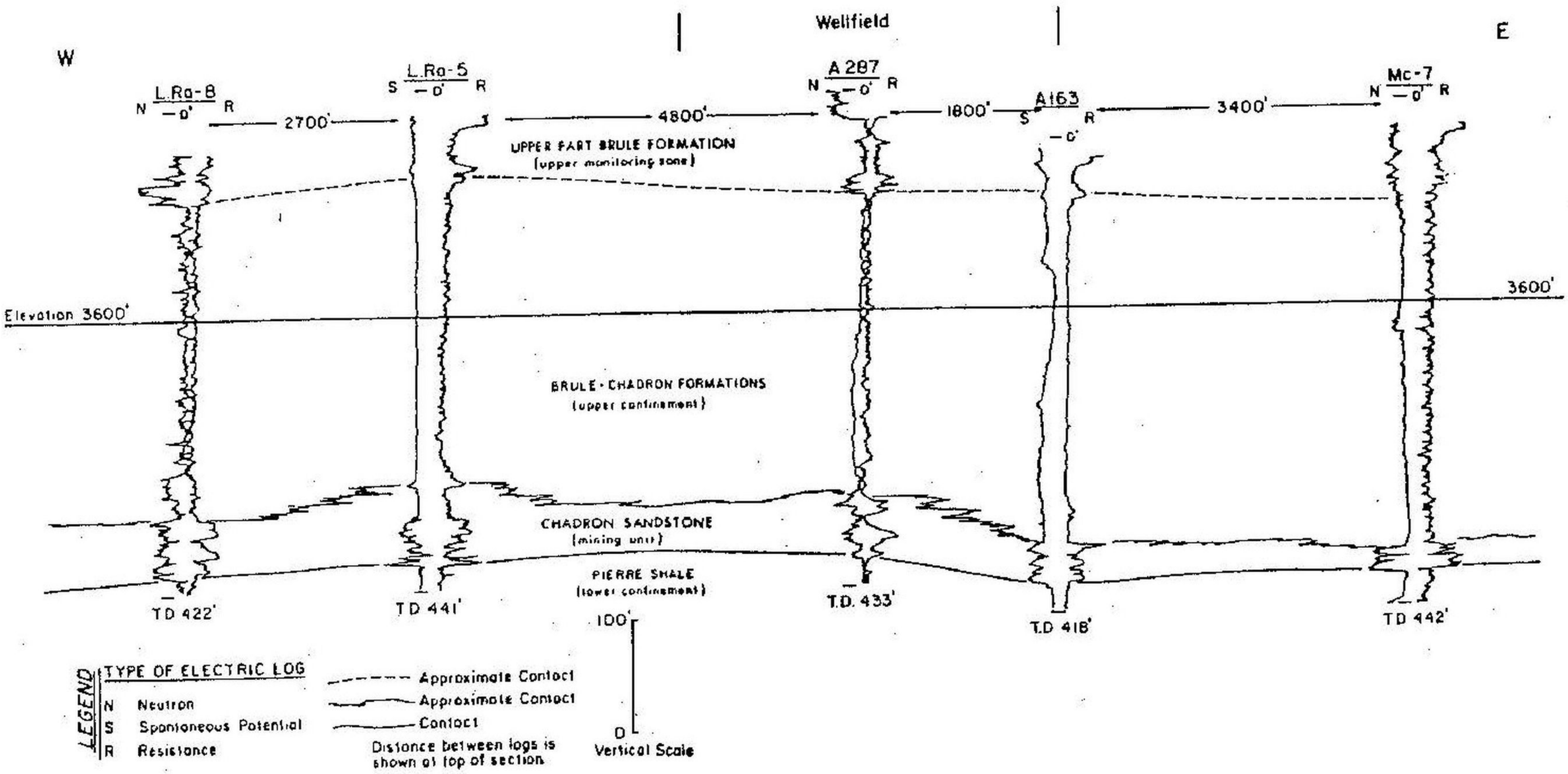


Figure 2.6-9. Cross-Section 500,000 E-W

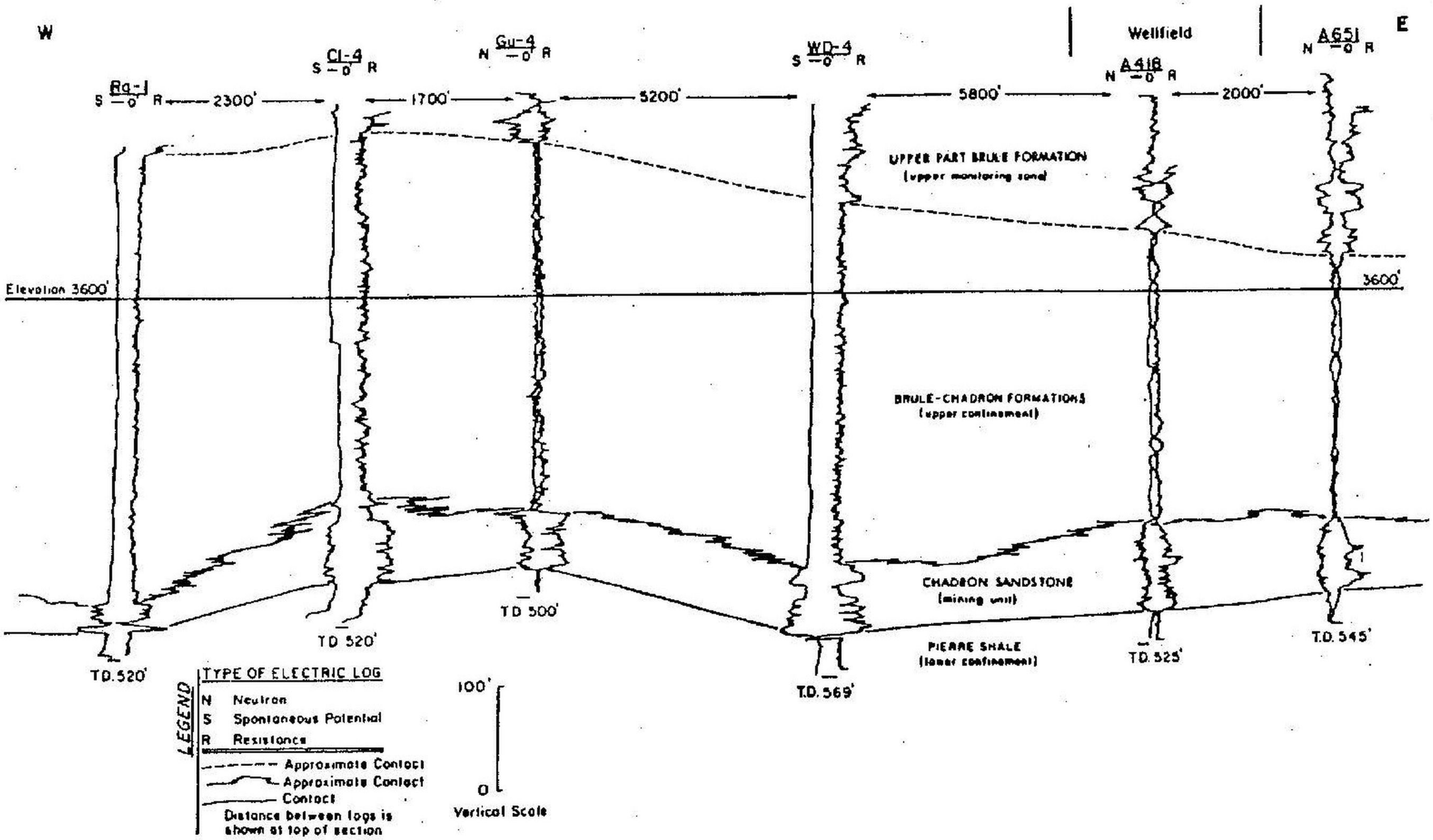


Figure 2.6-10. Cross-Section 494,000 E-W

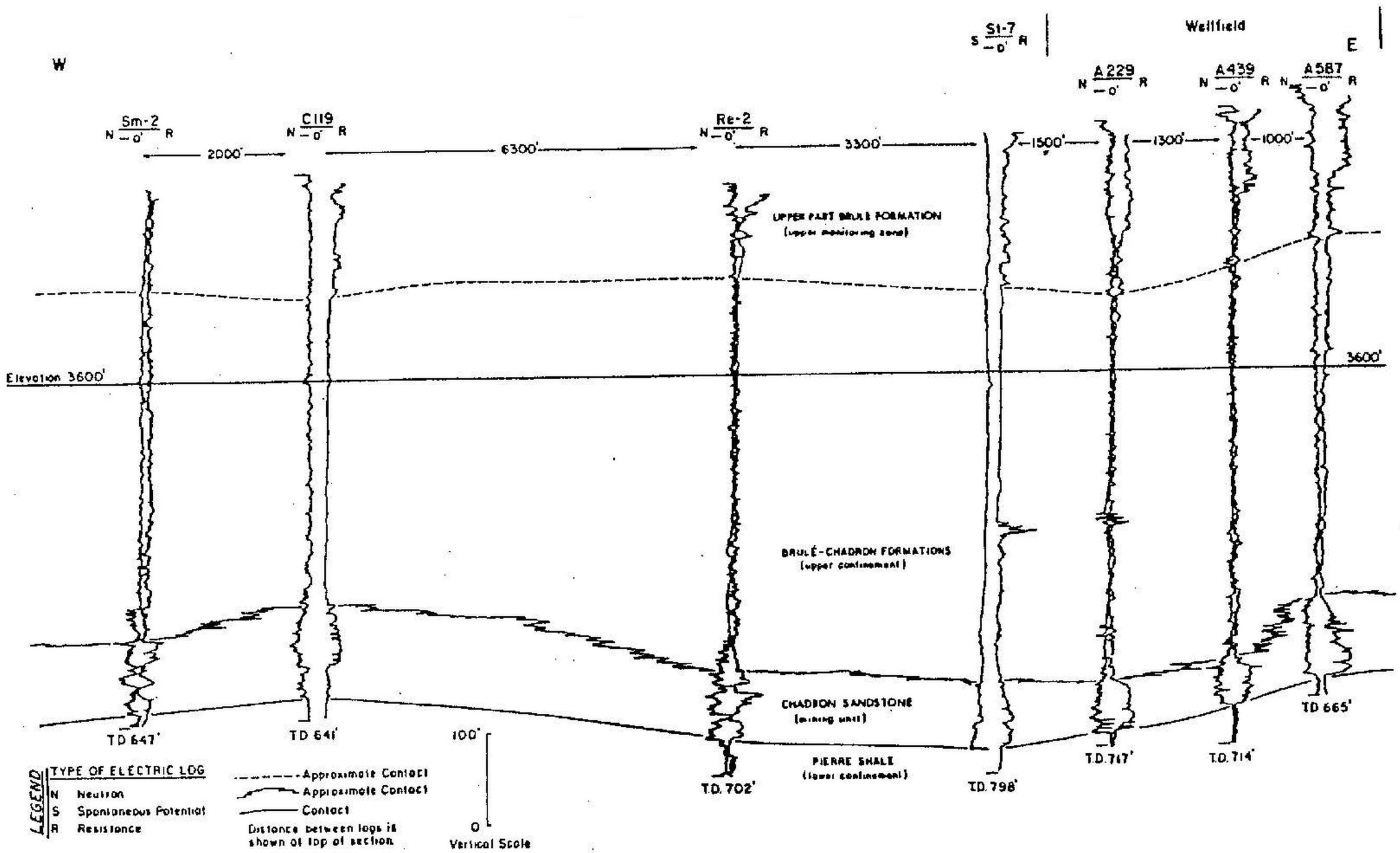


Figure 2.6-11. Cross-Section 490,000 E-W

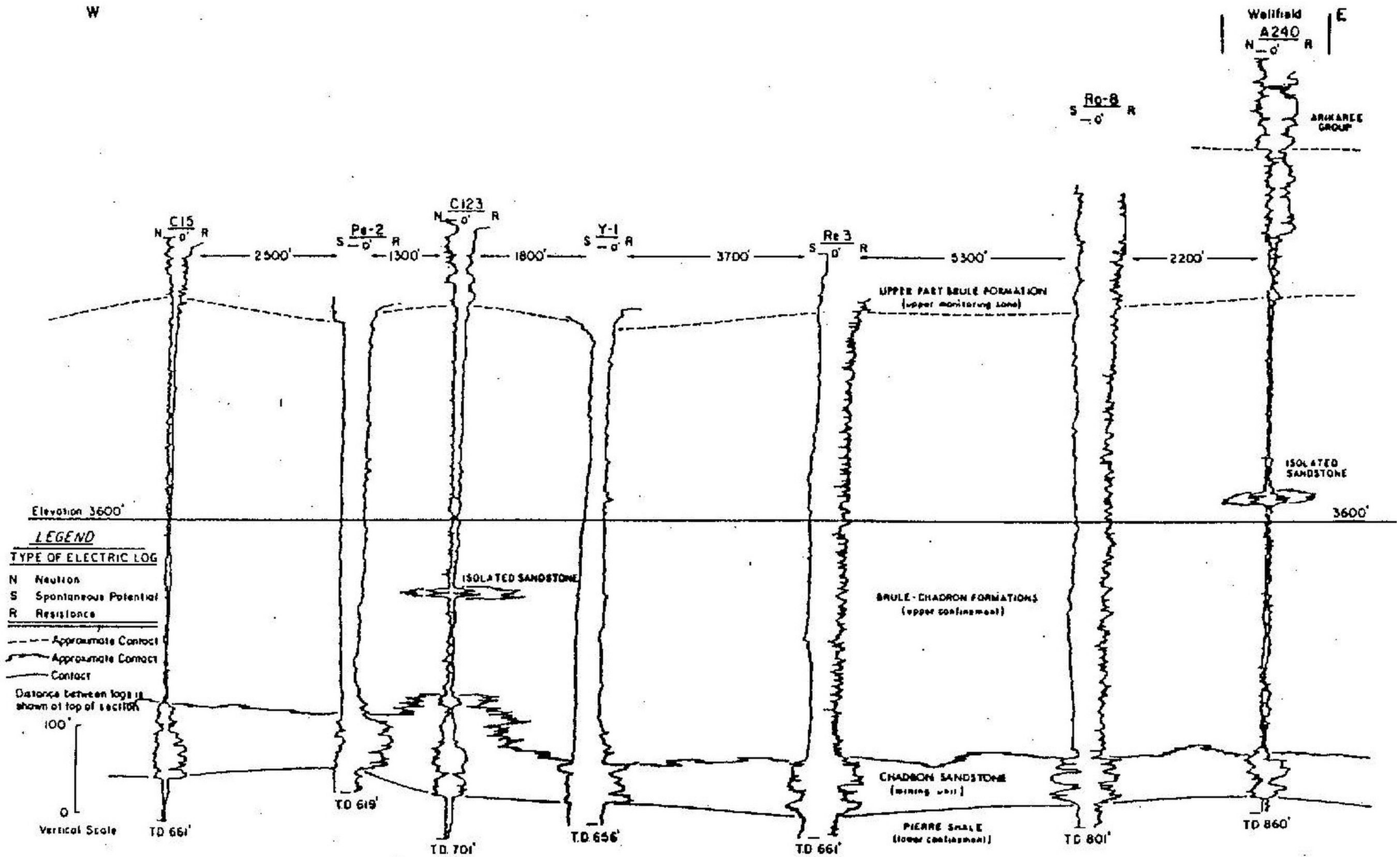


Figure 2.6-12. Cross-Section D-D'

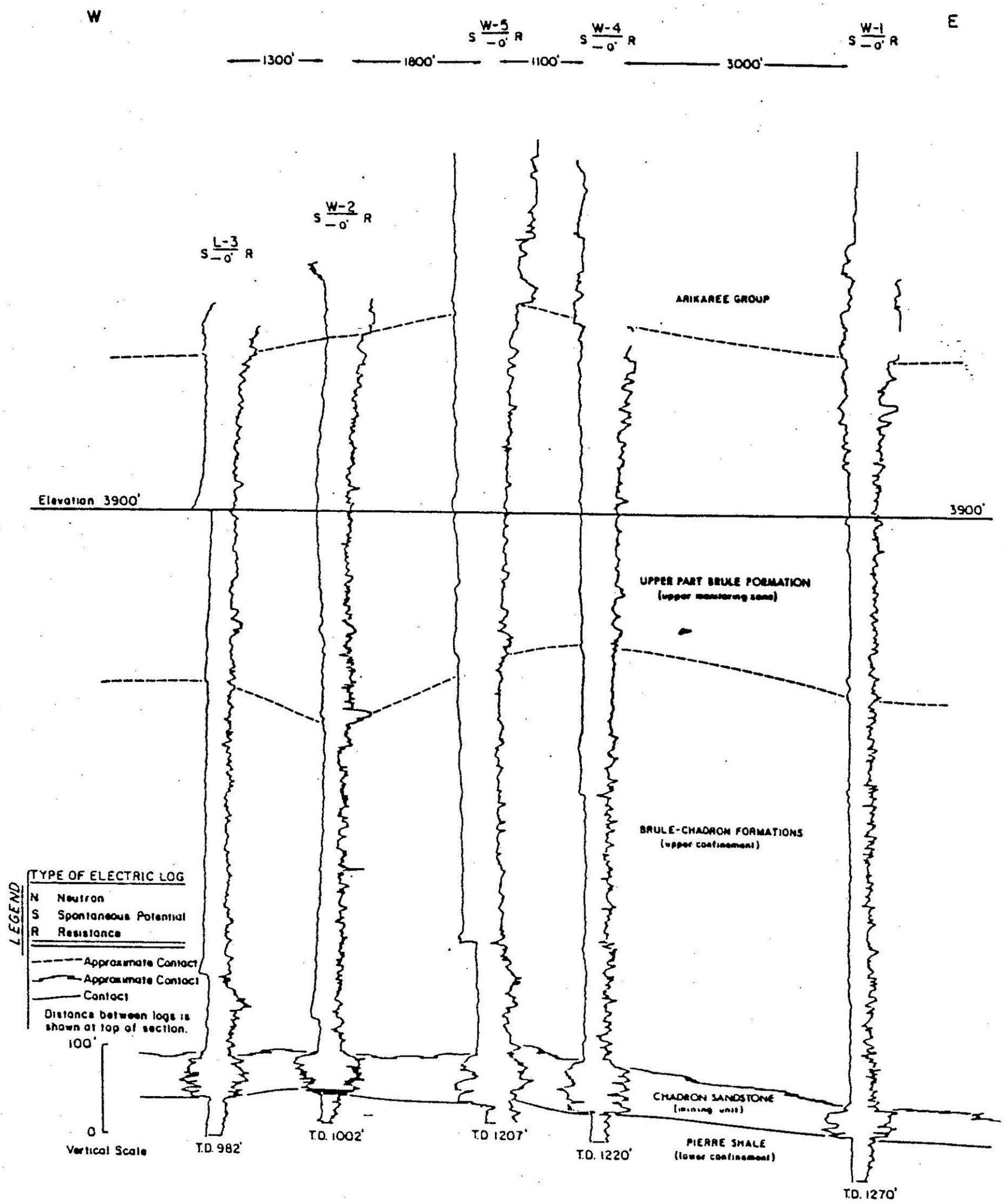


Figure 2.6-13. Cross Section NW-SE

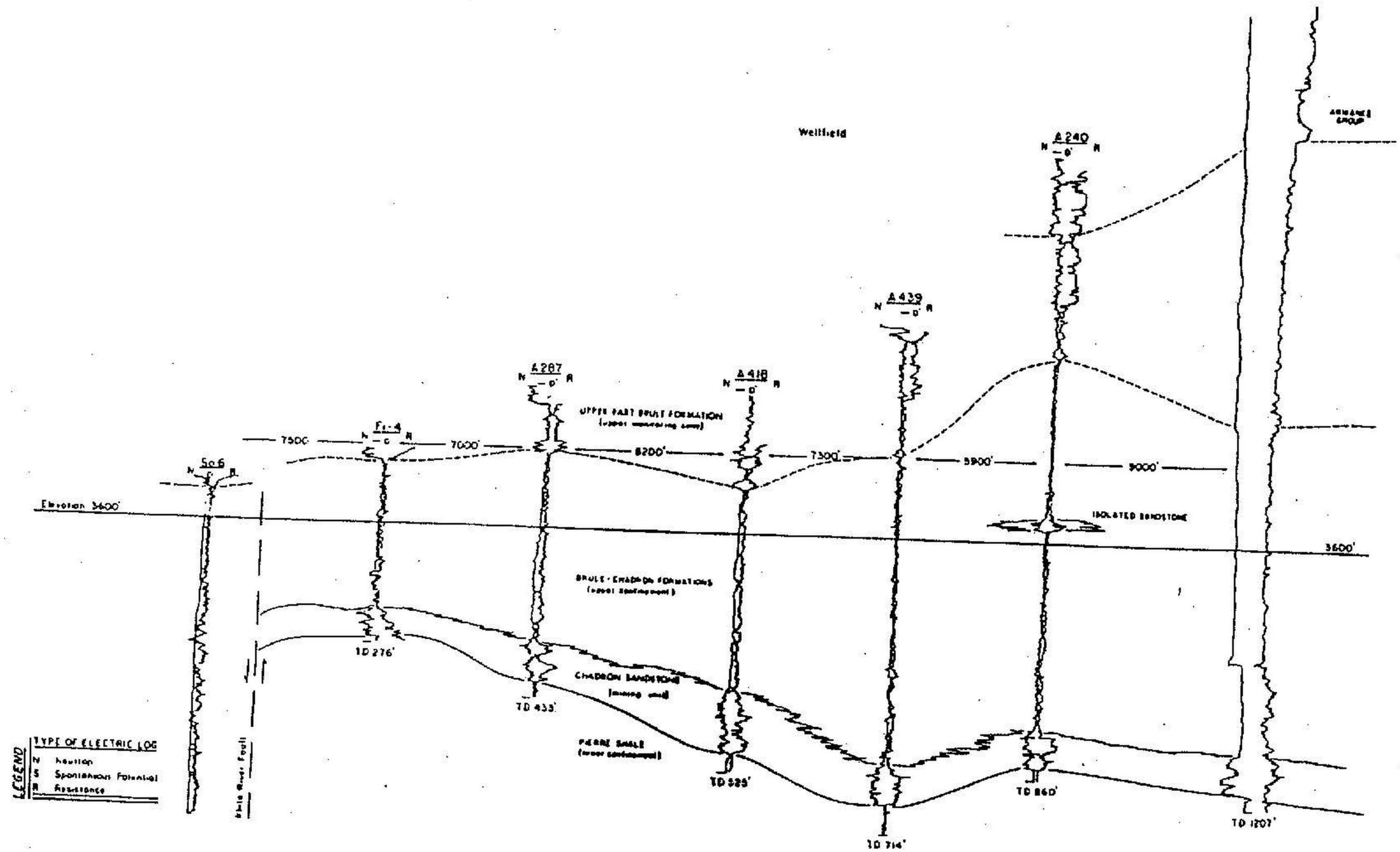
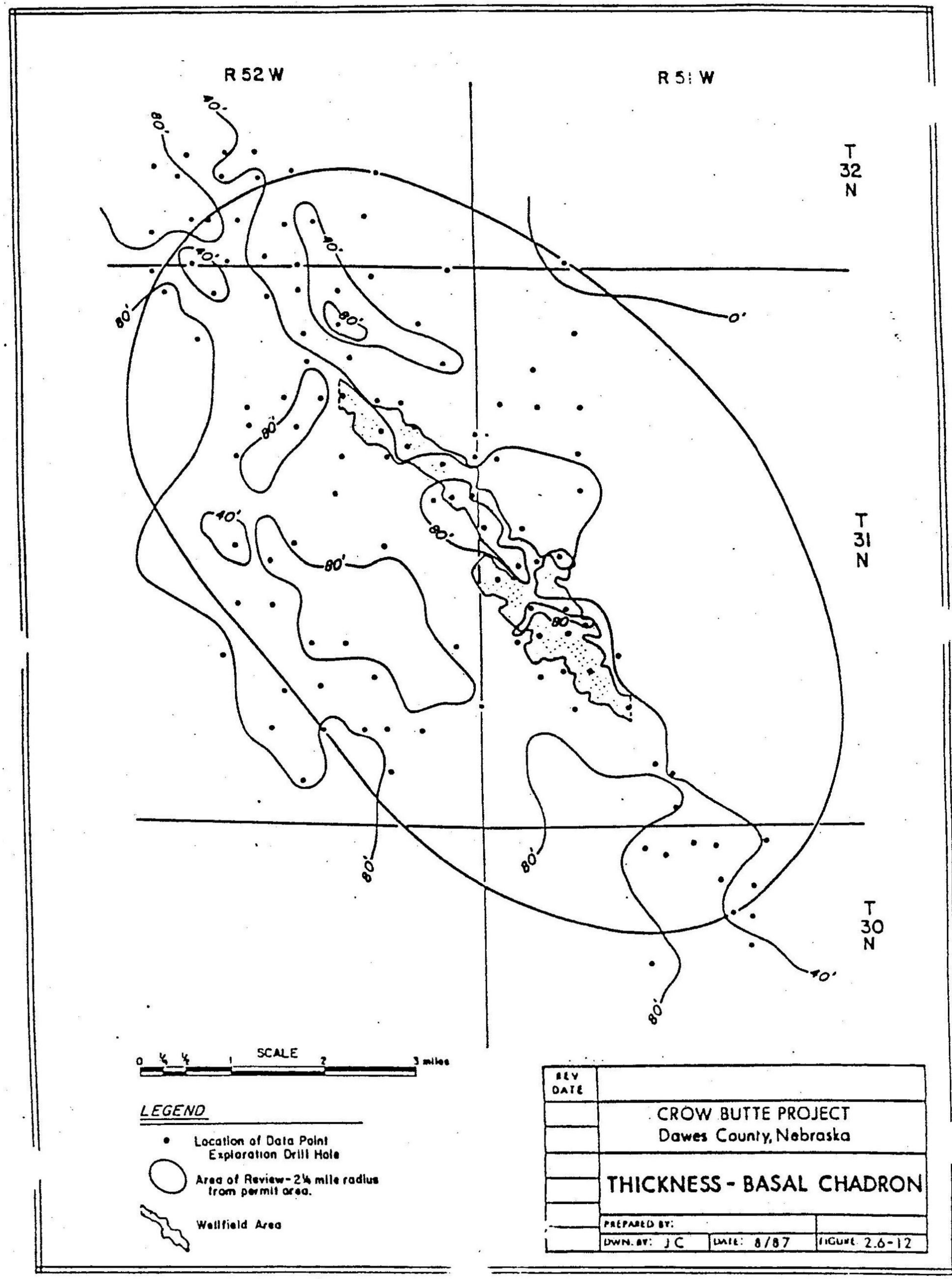
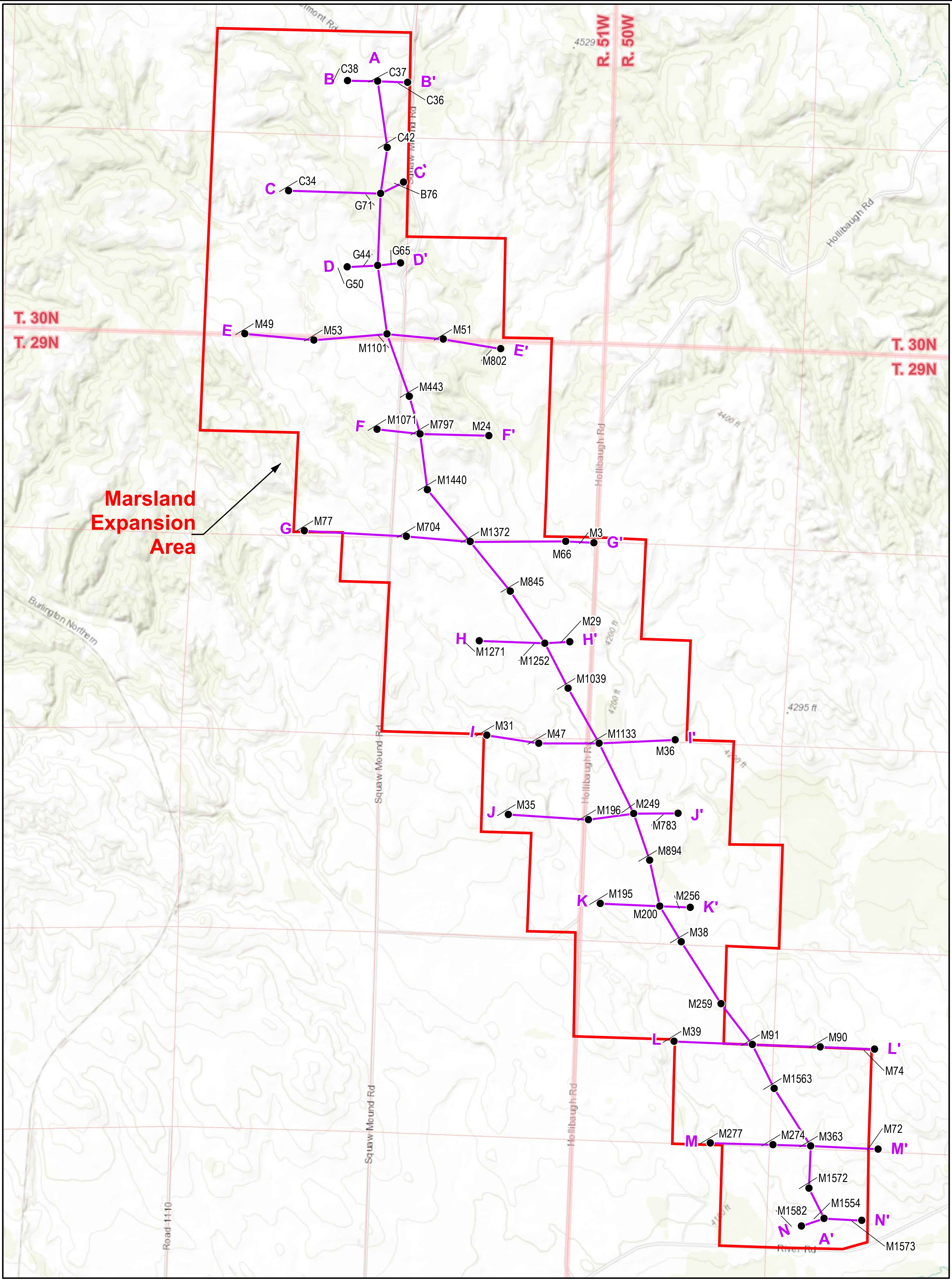


Figure 2.6-14. Thickness- Basal Chadron





LEGEND

- Borehole
- Cross Section Line
- Proposed Marsland Expansion Area

N

0 1,500 3,000

Feet

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

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-15
MARSLAND CROSS-SECTION MAP SHOWING ARTIFICIAL PENETRATIONS

PROJECT: CO001636 MAPPED BY: JC CHECKED BY: JA

A
North
A'
South
C-37
C-42
G-71
G-44
M-1101
M-443
M-797
M-1440
M-1372
M-845
M-1252
M-1039
M-1133
M-249
M-894
M-200
M-38
M-259
M-91
M-1563
M-363
M-1572
M-1554
1799'
1209'
1909'
1838'
1756'
1031'
1488'
1792'
1686'
1652'
1347'
1675'
2074'
1312'
1242'
1106'
1946'
1367'
1297'
1806'
1126'
889'
Elevation (Feet Above Mean Sea Level)
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Vertical Scale
0
50 meters
100
200 feet
1"= 100'
Horizontal Scale
0
150 meters
300
600 feet
1"= 300'
Legend
Main Litholoy Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
REVISIONS
NO.
DATE
BY
Cameco
Cameco Resources
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Casper, WY 82601
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Figure 2.6-16a
Marsland Cross Section A-A'
SIZE
0
DATE
April 6, 2011
DEPARTMENT:
Development
Drawing Number
Area–Drawing Type–XXXX
REV
0

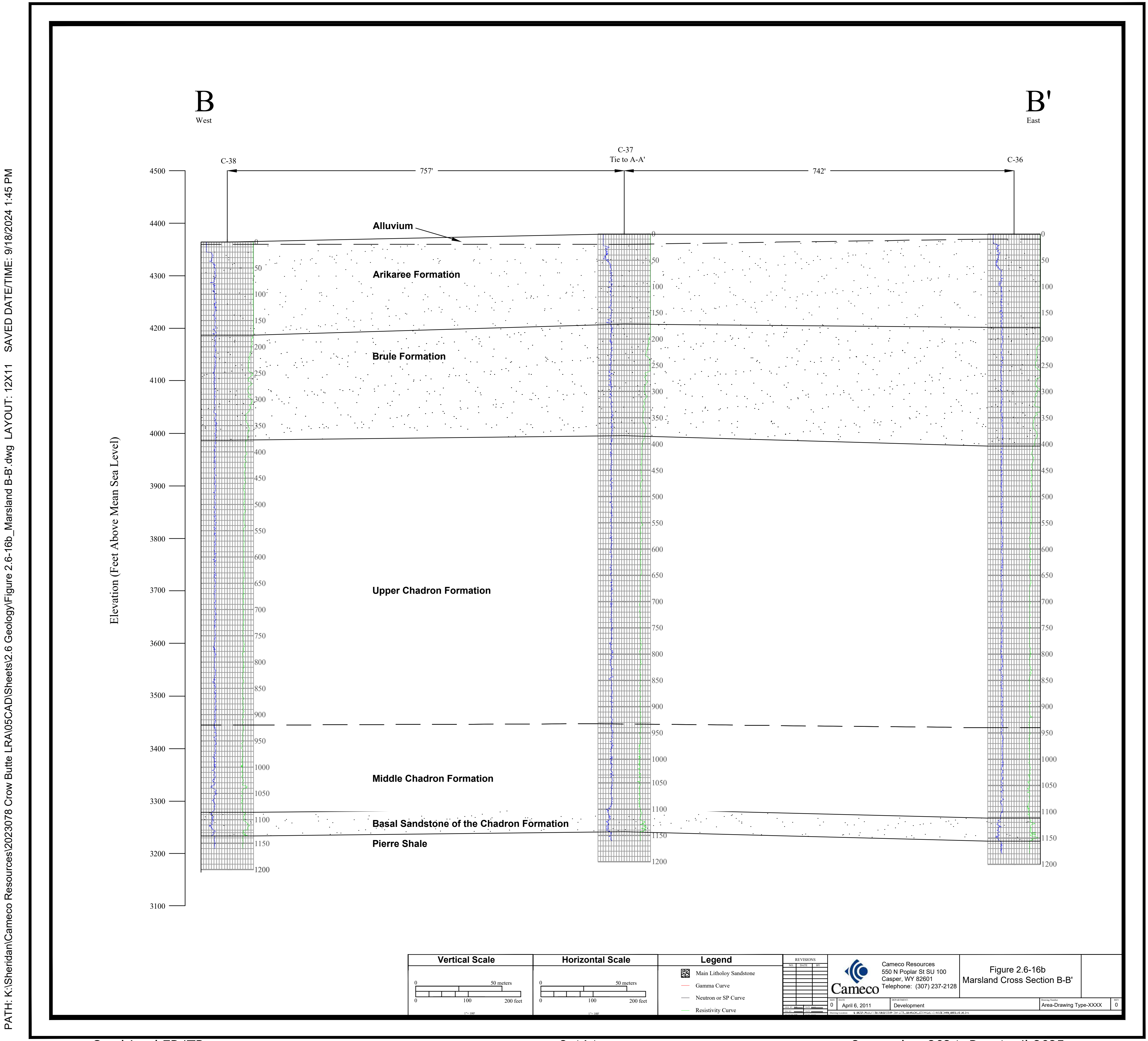
PATH: K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\05CAD\Sheets\2.6 Geology\Figure 2.6-16b_Marsland B-B'.dwg LAYOUT: 12X11 SAVED DATE/TIME: 9/18/2024 1:45 PM
B
West
B'
East
C-38
C-37
Tie to A-A'
C-36
757'
742'
Elevation (Feet Above Mean Sea Level)
4500
4400
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Vertical Scale
Horizontal Scale
0
50 meters
100
200 feet
Legend
Main Litholoy Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
REVISIONS
Cameco
Cameco Resources
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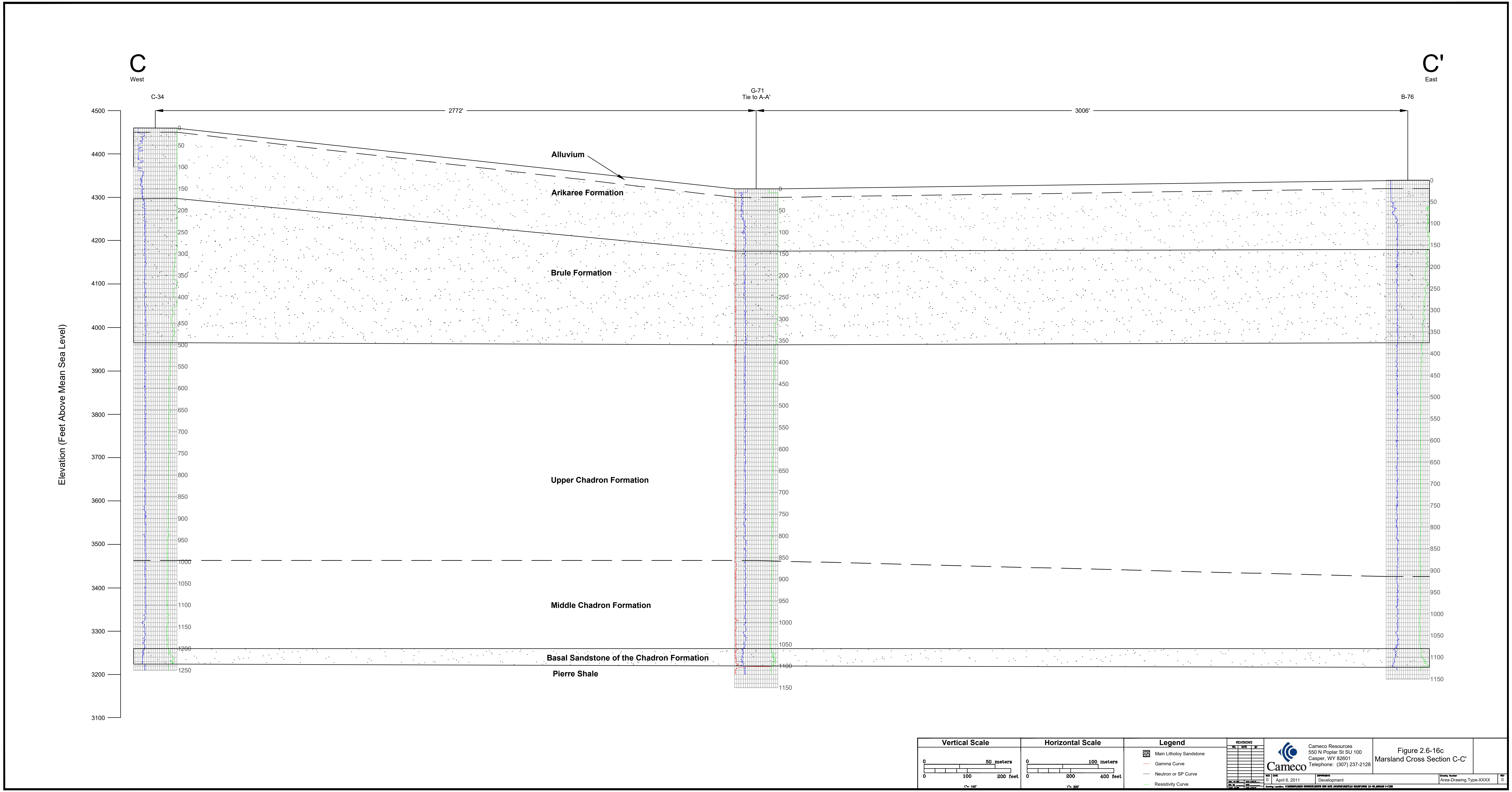
Figure 2.6-16b
Marsland Cross Section B-B'
April 6, 2011
Development
Area-Drawing Type-XXXX
0



C
West
C'
East
C-34
G-71
Tie to A-A'
B-76
2772'
3006'
Elevation (Feet Above Mean Sea Level)
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Vertical Scale
50 meters
200 feet
1"= 100'
Horizontal Scale
100 meters
400 feet
1"= 200'
Legend
Main Litholoy Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
REVISIONS
Cameco
Cameco Resources
550 N Poplar St SU 100
Casper, WY 82601
Telephone: (307) 237-2128
Figure 2.6-16c
Marsland Cross Section C-C'
April 6, 2011
Development
Area-Drawing Type-XXXX

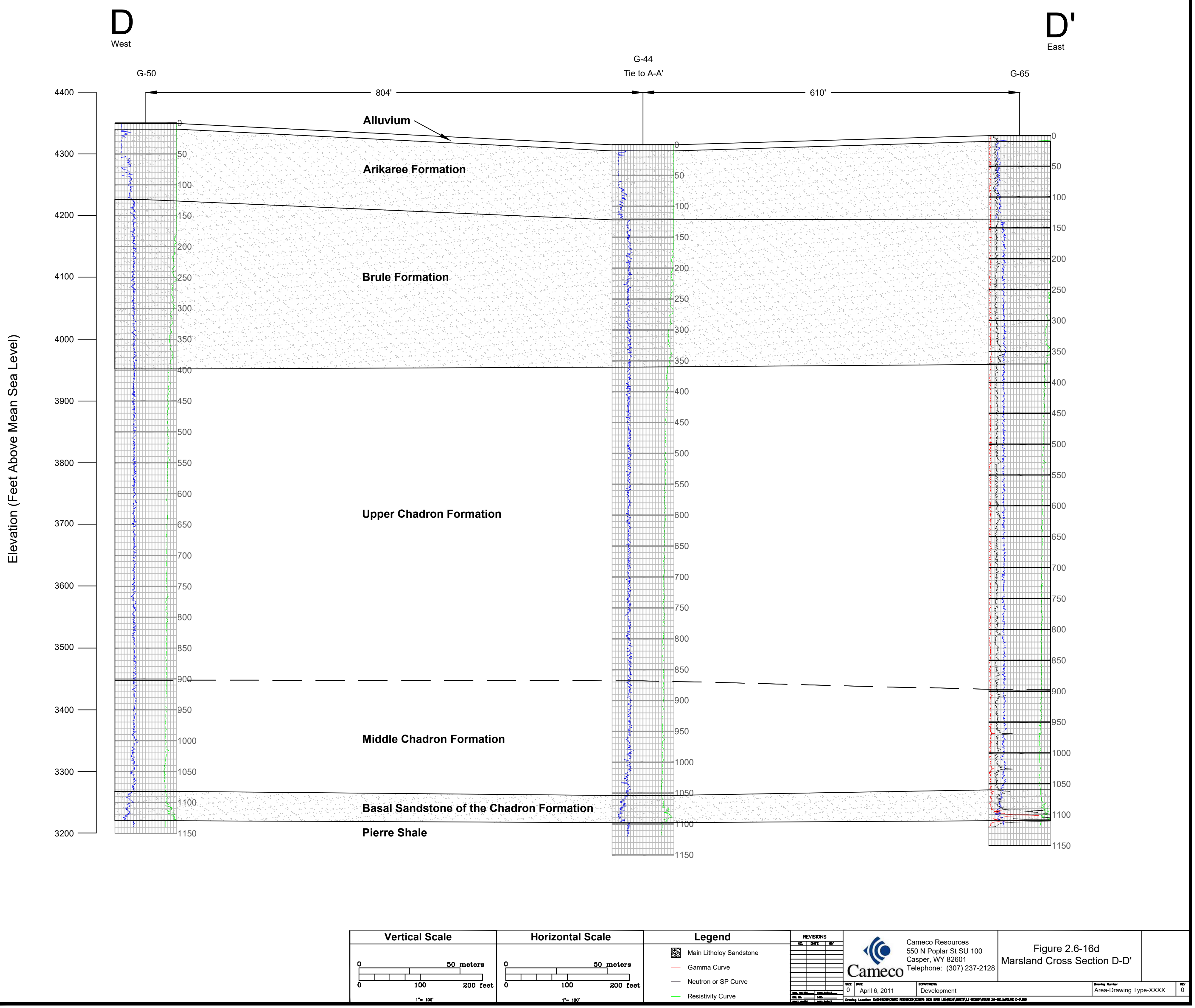
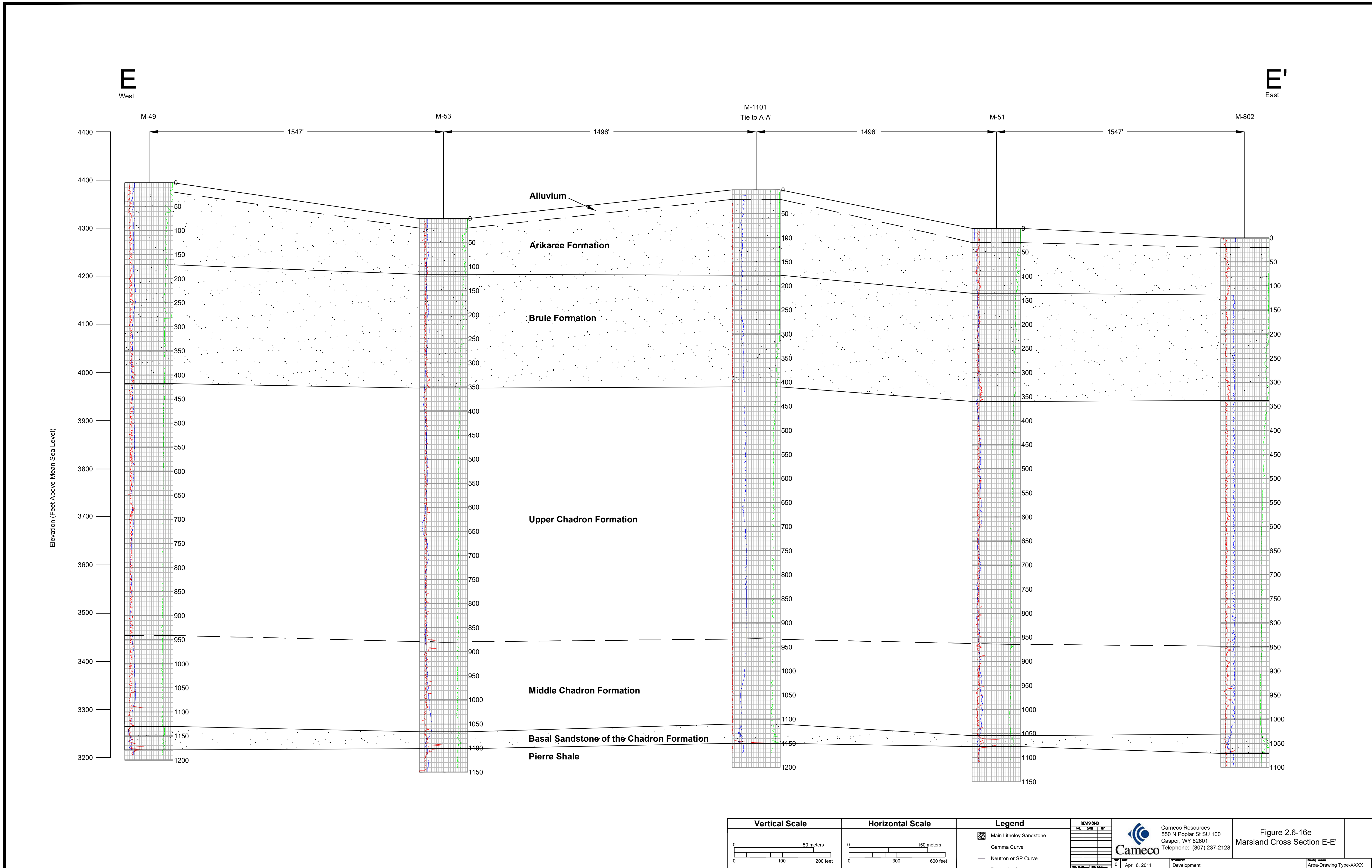
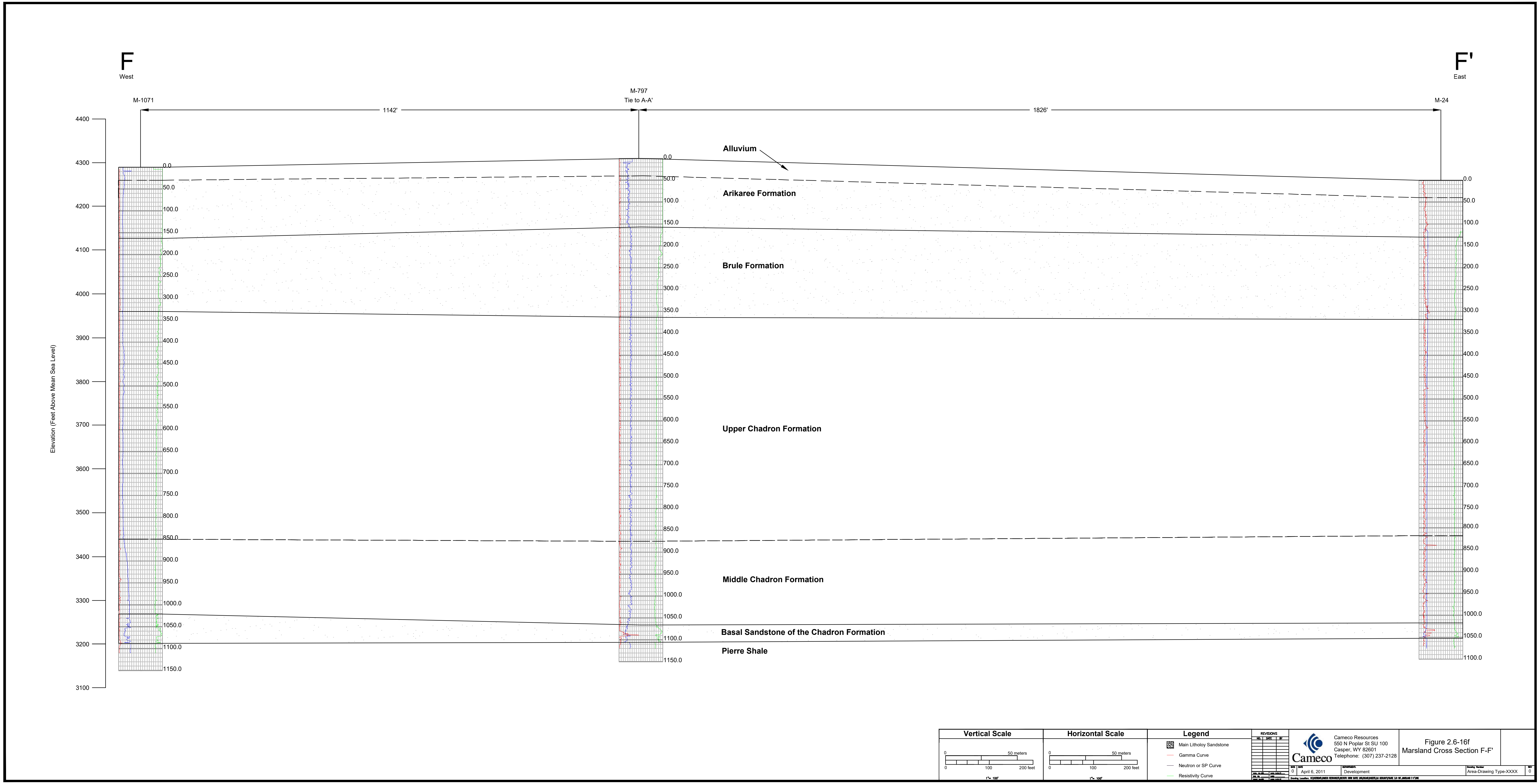
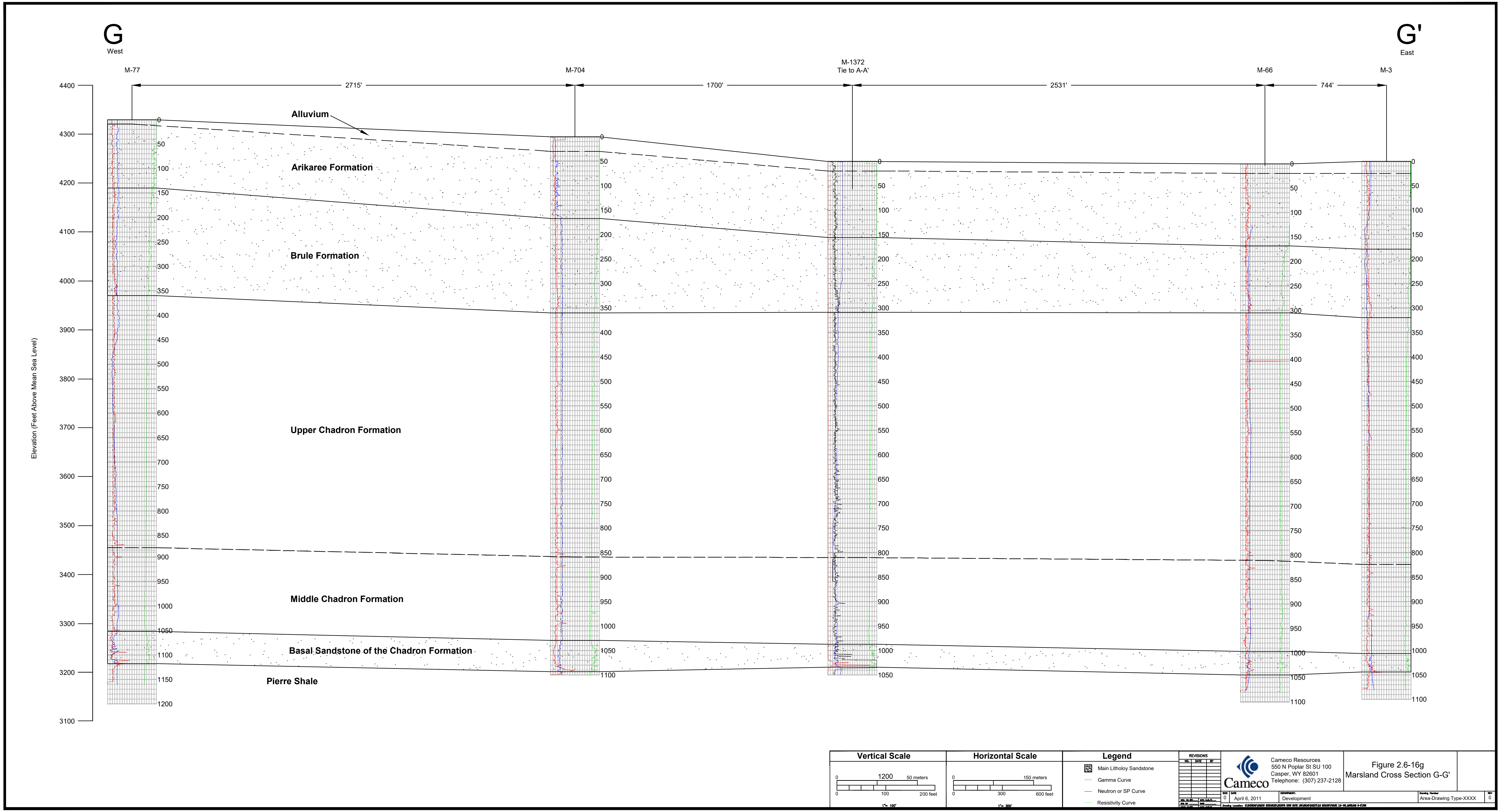
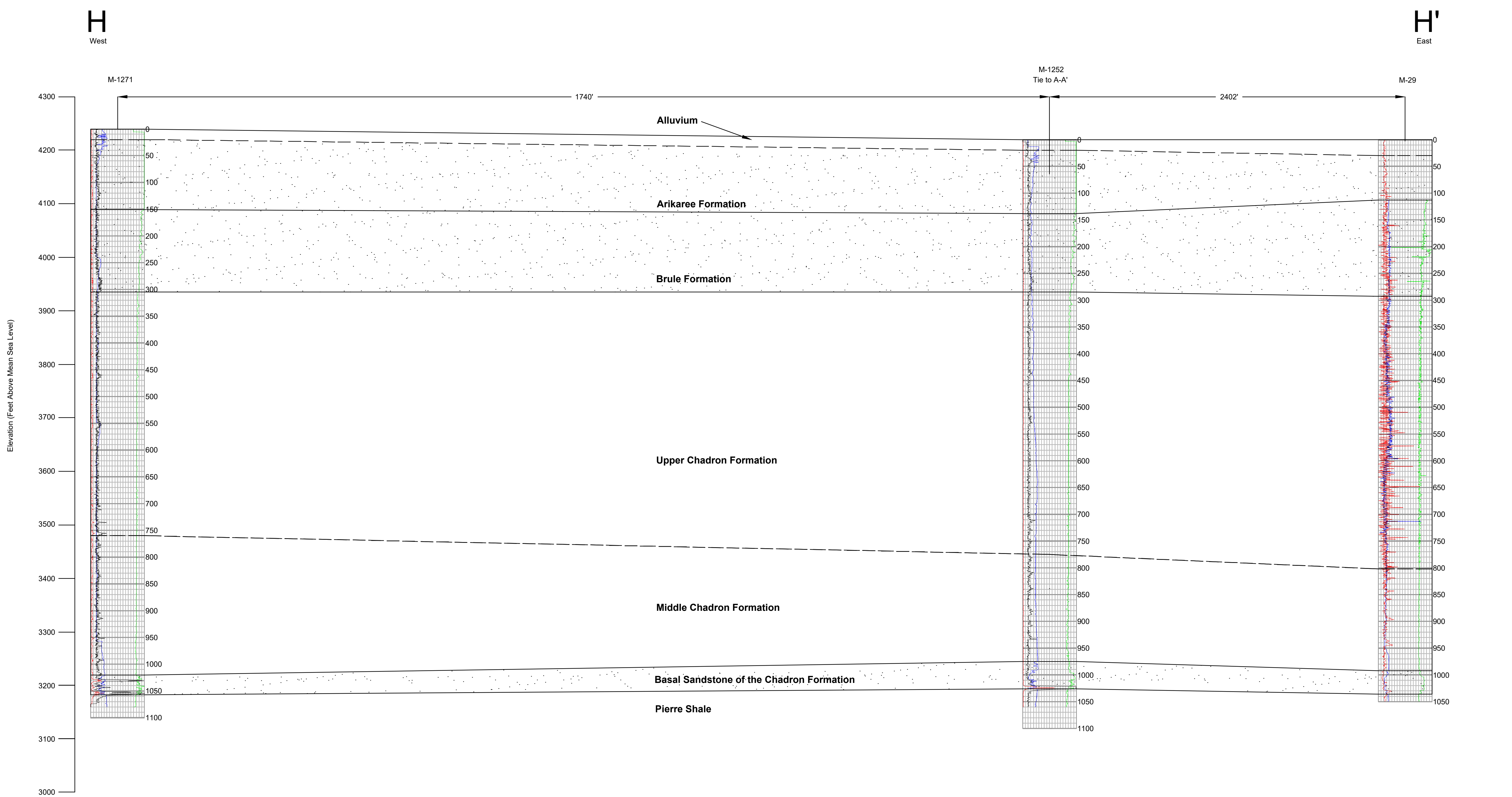


Figure 2.6-16d
Marsland Cross Section D-D'


E
West
E'
East
M-49
M-53
M-1101
Tie to A-A'
M-51
M-802
1547'
1496'
1496'
1547'
Elevation (Feet Above Mean Sea Level)
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Vertical Scale
Horizontal Scale
Legend
Main Lithology Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
Cameco Resources
550 N Poplar St SU 100
Casper, WY 82601
Telephone: (307) 237-2128
Figure 2.6-16e
Marsland Cross Section E-E'
April 6, 2011
Development
Area-Drawing Type-XXXX


F
West
F'
East
M-1071
M-797
Tie to A-A'
M-24
1142'
1826'
Elevation (Feet Above Mean Sea Level)
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Vertical Scale
Horizontal Scale
Legend
Main Litholoy Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
Cameco Resources
550 N Poplar St SU 100
Casper, WY 82601
Telephone: (307) 237-2128
Figure 2.6-16f
Marsland Cross Section F-F'
April 6, 2011
Development
Area-Drawing Type-XXXX


G
West
G'
East
M-77
M-704
M-1372
Tie to A-A'
M-66
M-3
2715'
1700'
2531'
744'
Elevation (Feet Above Mean Sea Level)
4400
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Vertical Scale
1200
50 meters
100
200 feet
1" = 100'
Horizontal Scale
150 meters
300
600 feet
1" = 300'
Legend
Main Litholoy Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
REVISIONS
Cameco
Cameco Resources
550 N Poplar St SU 100
Casper, WY 82601
Telephone: (307) 237-2128
Figure 2.6-16g
Marsland Cross Section G-G'
April 6, 2011
Development
Area-Drawing Type-XXXX



Vertical Scale	Horizontal Scale	Legend
0 50 meters; 0 100 200 feet; 1"= 100'	0 50 meters; 0 100 200 feet; 1"= 100'	Main Litholoy Sandstone; Gamma Curve; Neutron or SP Curve; Resistivity Curve

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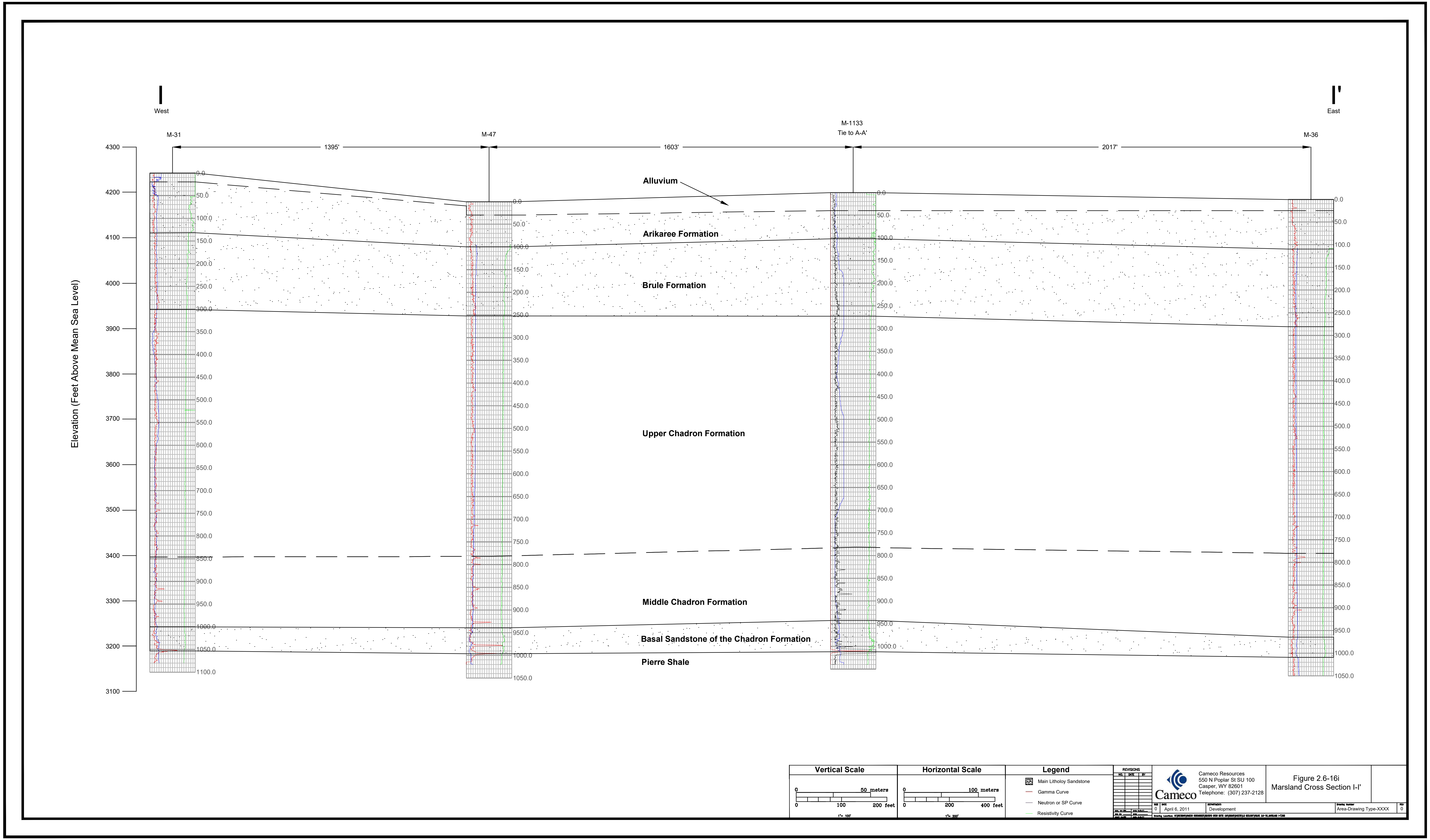
Figure 2.6-16h
Marsland Cross Section H-H'

Size: 0 | Date: April 6, 2011 | Department: Development | Drawing Number: Area-Drawing Type-XXXX | Rev: 0


I
West
I'
East
M-31
M-47
M-1133
Tie to A-A'
M-36
1395'
1603'
2017'
Elevation (Feet Above Mean Sea Level)
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Vertical Scale
0 50 meters
0 100 200 feet
1"= 100'
Horizontal Scale
0 100 meters
0 200 400 feet
1"= 200'
Legend
Main Litholoy Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
REVISIONS
NO. DATE BY
Cameco
Cameco Resources
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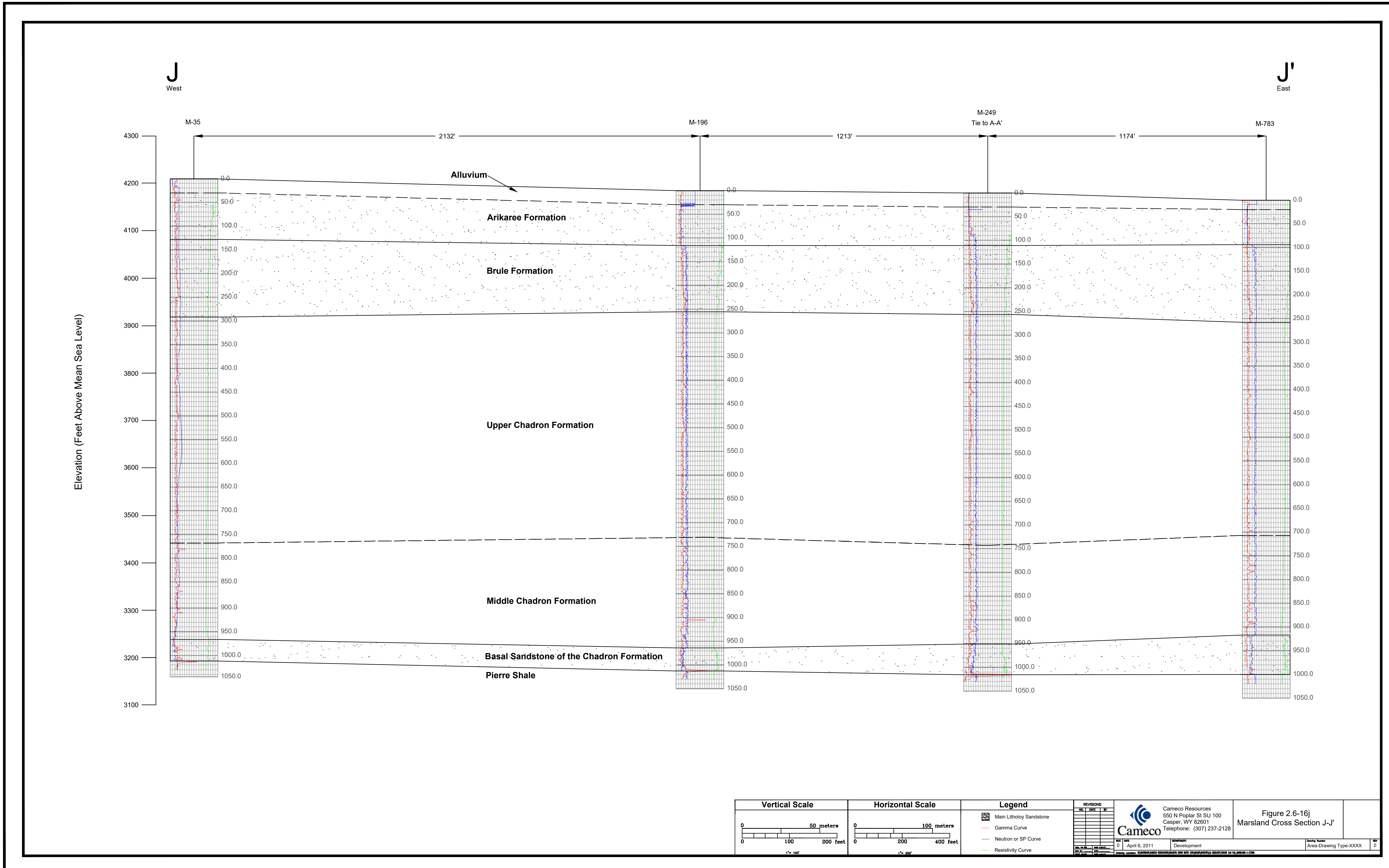
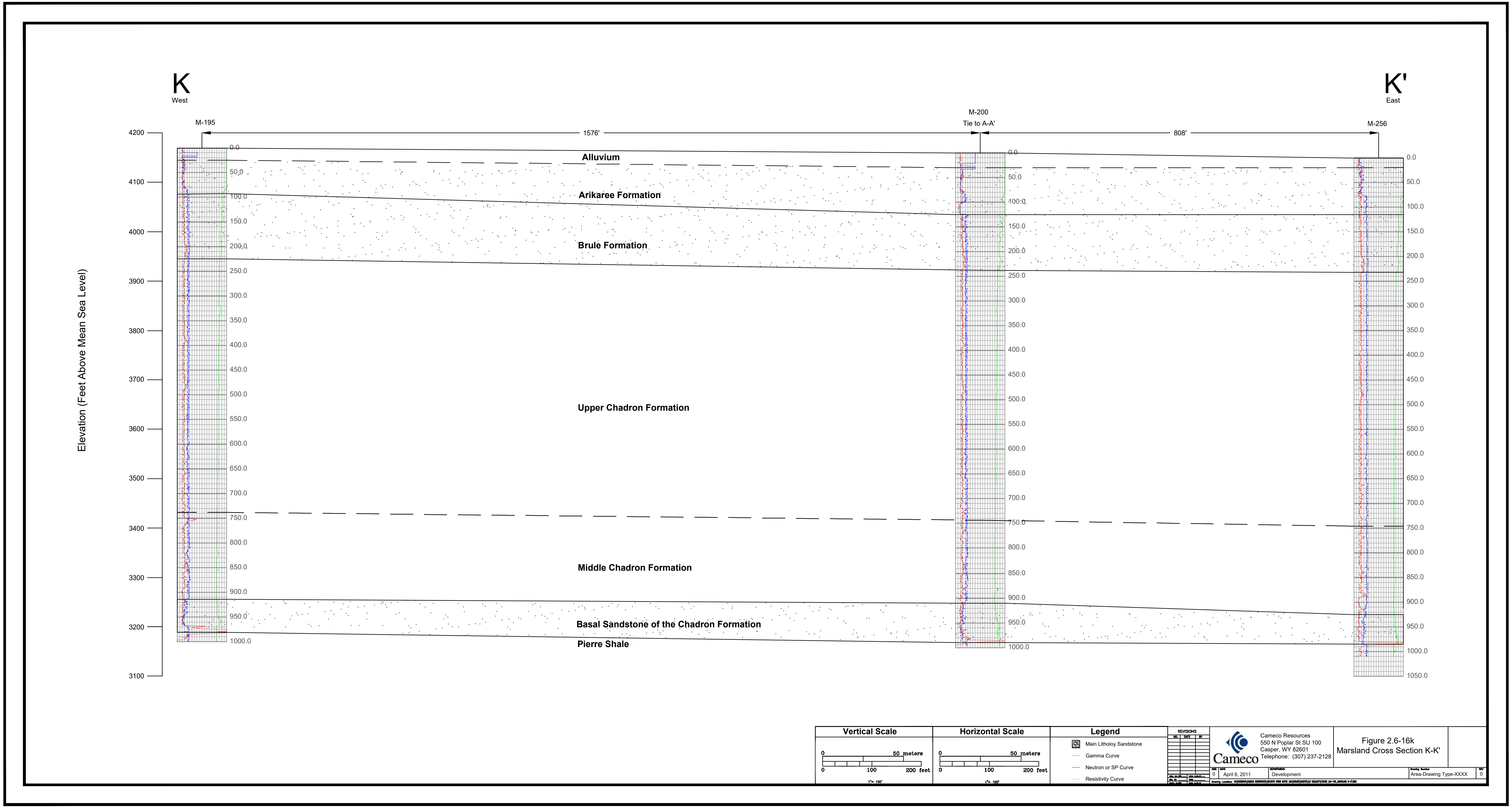
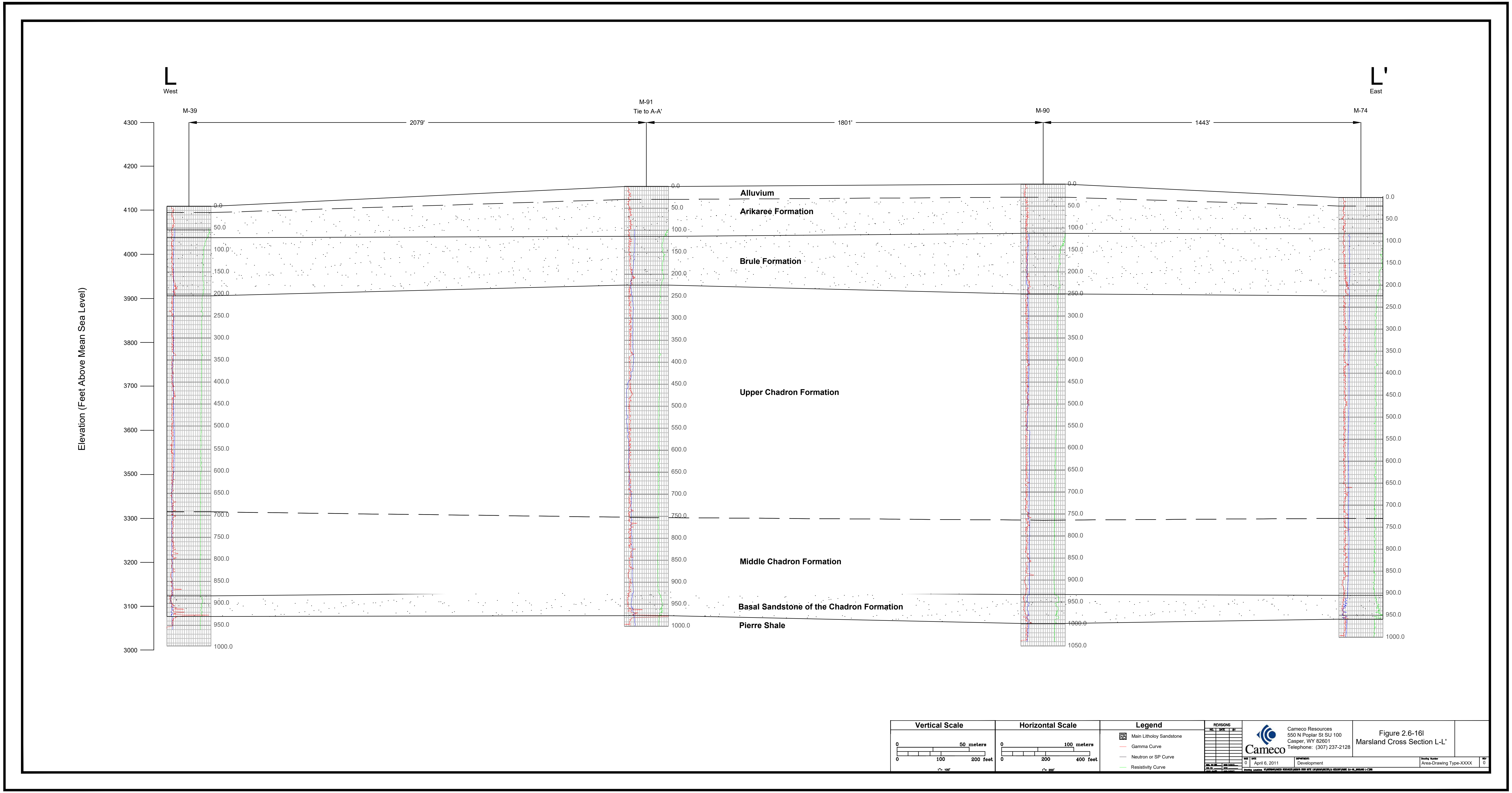
Casper, WY 82601
Telephone: (307) 237-2128
Figure 2.6-16i
Marsland Cross Section I-I'
SIZE 0
DATE April 6, 2011
DEPARTMENT Development
Drawing Number Area-Drawing Type-XXXX
REV 0


J
West
J'
East
M-35
M-196
M-249
Tie to A-A'
M-783
2132'
1213'
1174'
Elevation (Feet Above Mean Sea Level)
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Vertical Scale
0 50 meters
0 100 200 feet
Horizontal Scale
0 100 meters
0 200 400 feet
Legend
Main Lithology Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
Cameco
Cameco Resources
550 N Poplar St SU 100
Casper, WY 82601
Telephone: (307) 237-2128
Figure 2.6-16j
Marsland Cross Section J-J'
April 6, 2011
Development
Area-Drawing Type-XXXX



K
West
K'
East
M-195
M-200
Tie to A-A'
M-256
1576'
808'
Elevation (Feet Above Mean Sea Level)
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Vertical Scale
Horizontal Scale
Legend
Main Lithology Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
Cameco Resources
550 N Poplar St SU 100
Casper, WY 82601
Telephone: (307) 237-2128
Figure 2.6-16k
Marsland Cross Section K-K'
April 6, 2011
Development
Area-Drawing Type-XXXX


L
West
L'
East
M-39
M-91
Tie to A-A'
M-90
M-74
2079'
1801'
1443'
Elevation (Feet Above Mean Sea Level)
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Vertical Scale
0 50 meters
0 100 200 feet
1"= 100'
Horizontal Scale
0 100 meters
0 200 400 feet
1"= 200'
Legend
Main Litholoy Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
REVISIONS
NO. DATE BY
Cameco
Cameco Resources
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Casper, WY 82601
Telephone: (307) 237-2128
Figure 2.6-16l
Marsland Cross Section L-L'
April 6, 2011
Development
Area-Drawing Type-XXXX

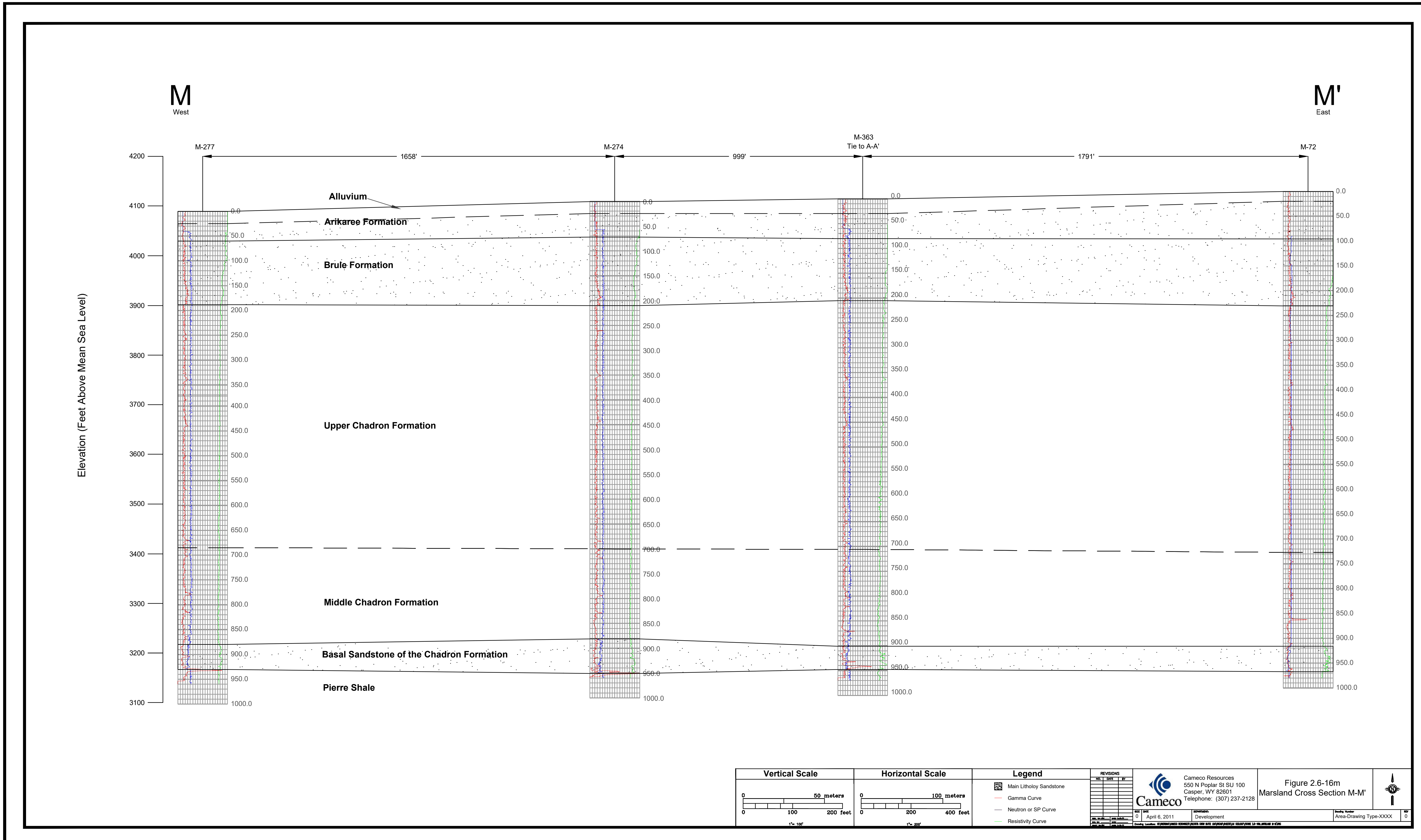
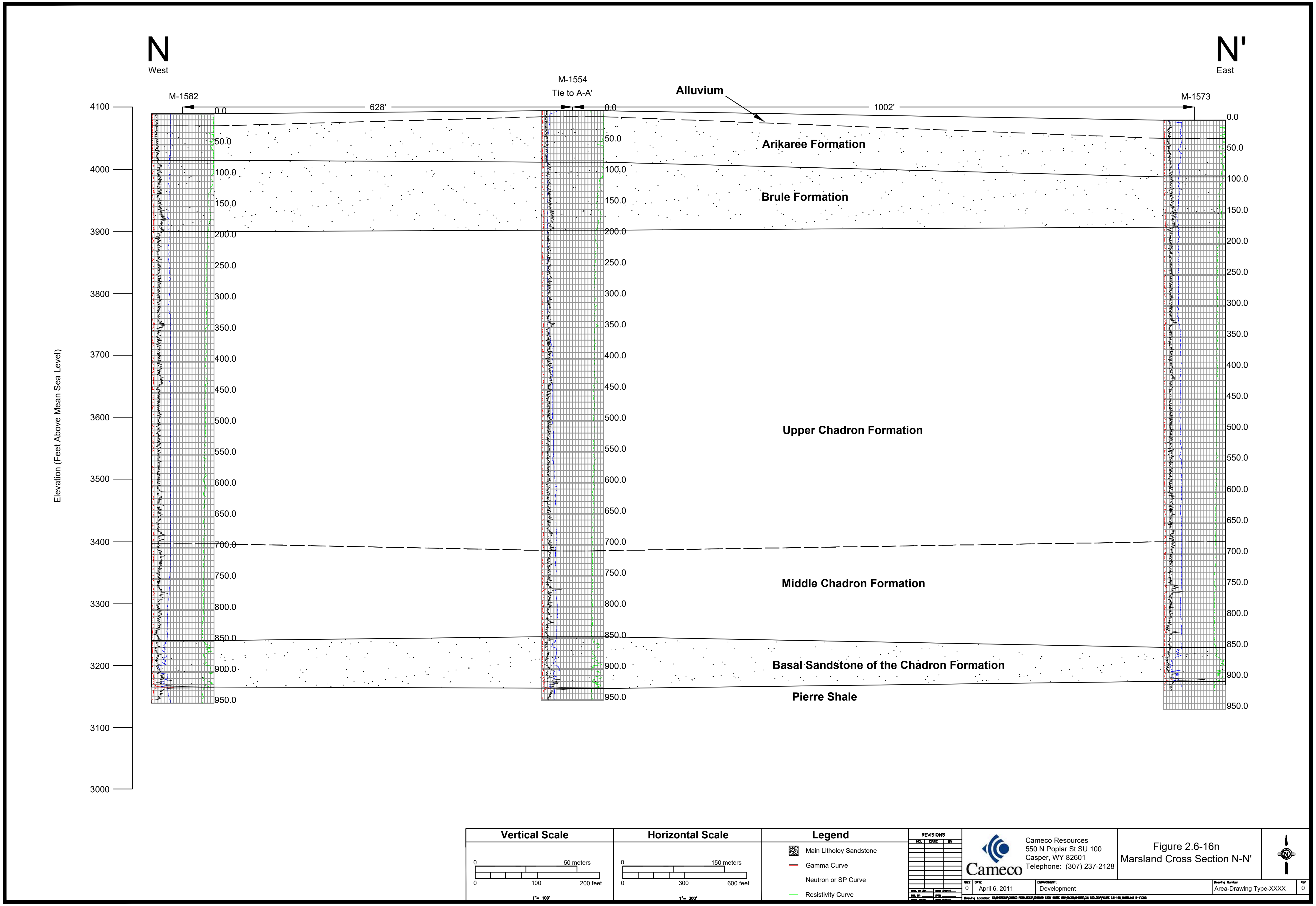
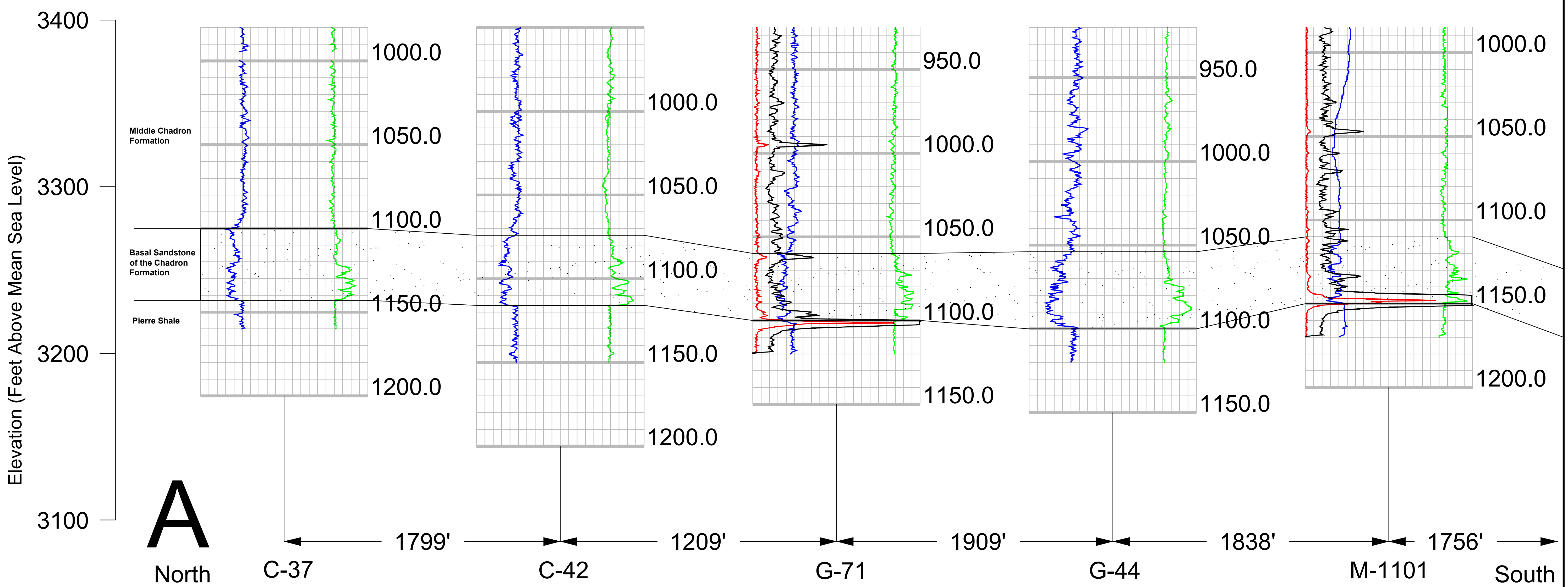


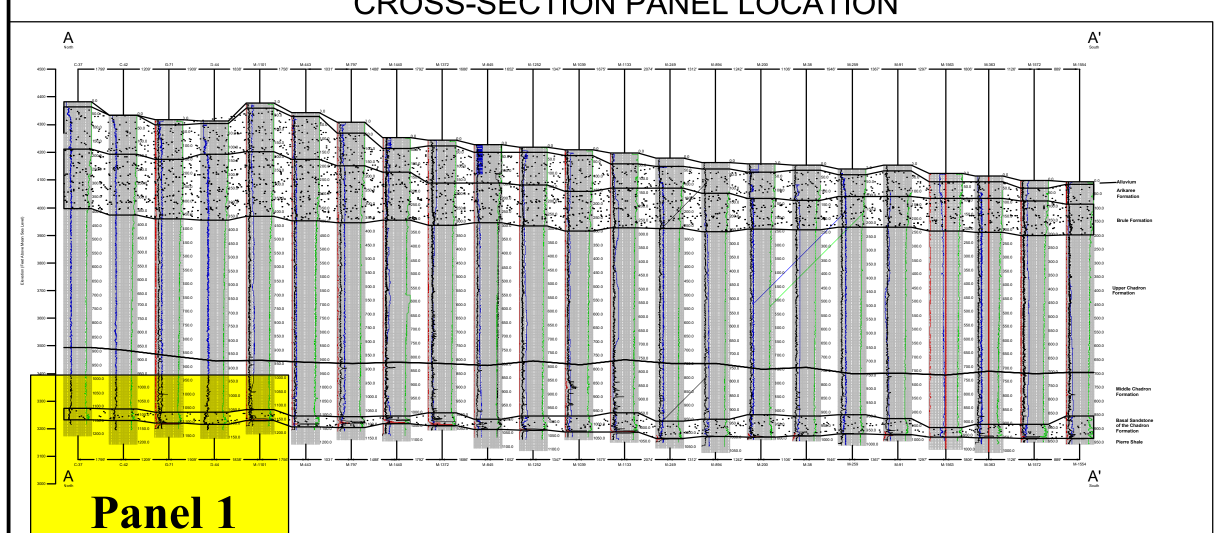
Figure 2.6-16m
Marsland Cross Section M-M'


N
West
N'
East
M-1582
M-1554
Tie to A-A'
M-1573
628'
1002'
Alluvium
Arikaree Formation
Brule Formation
Upper Chadron Formation
Middle Chadron Formation
Basal Sandstone of the Chadron Formation
Pierre Shale
Elevation (Feet Above Mean Sea Level)
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
Vertical Scale
50 meters
100
200 feet
1"= 100'
Horizontal Scale
150 meters
300
600 feet
1"= 300'
Legend
Main Litholoy Sandstone
Gamma Curve
Neutron or SP Curve
Resistivity Curve
REVISIONS
Cameco
Cameco Resources
550 N Poplar St SU 100
Casper, WY 82601
Telephone: (307) 237-2128
Figure 2.6-16n
Marsland Cross Section N-N'
April 6, 2011
Development
Area-Drawing Type-XXXX

Expanded Marsland Cross-Section A-A' - Panel 1



CROSS-SECTION PANEL LOCATION



Vertical Scale	Legend
0 — 25 Meters	Main Lithology Sandstone
0 — 50 — 100 Feet	Gamma Curve
	Neutron or SP Curve
	Resistivity Curve

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Crow Butte Resources
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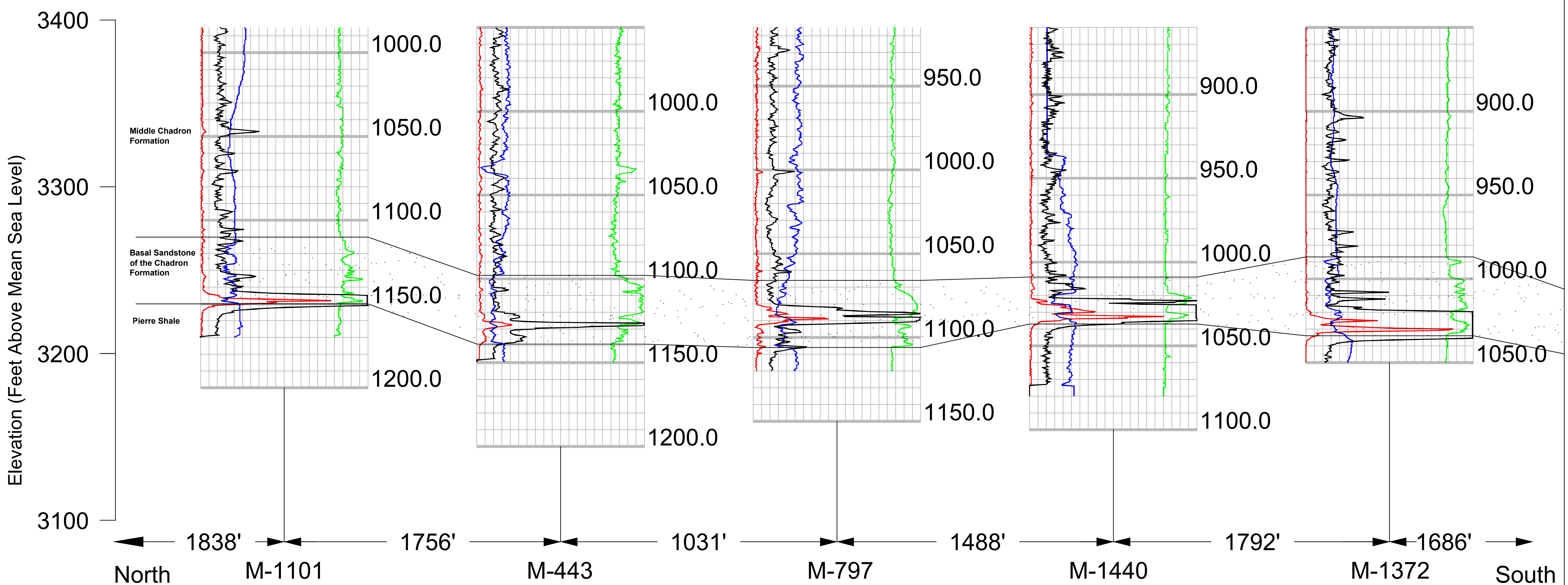
Crawford, NE 69339
Telephone: (308) 665-2215

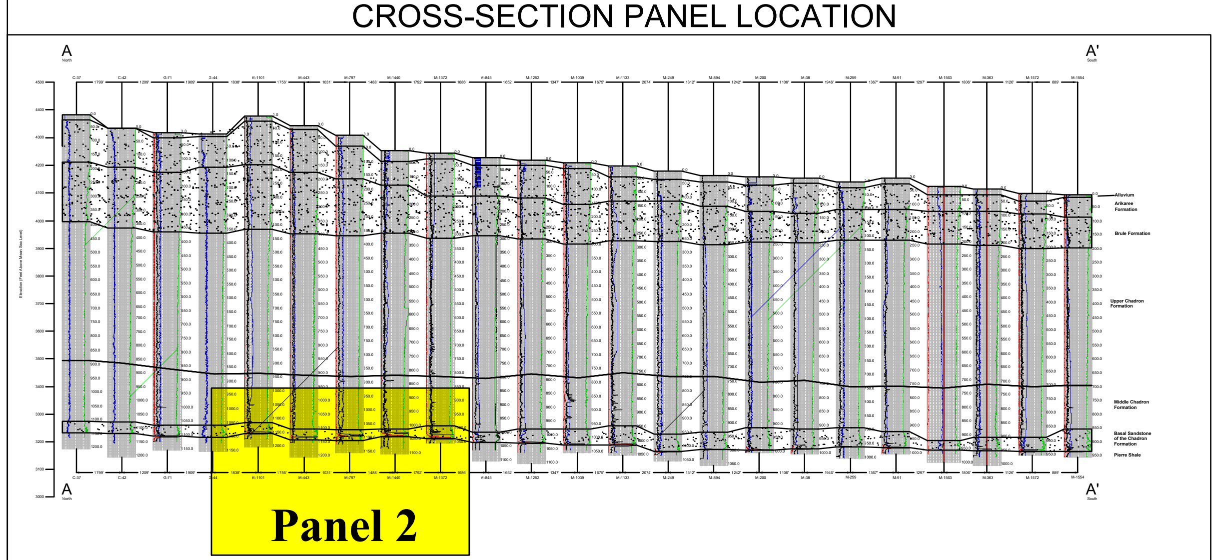
Figure 2.6-16o
Epanded Marsland
Cross Section A-A'
Panel 1

SIZE	DATE	DEPARTMENT:	Drawing Number	REV
0	October 6, 2013	Development	Area-Drawing Type-XXXX	0

Expanded Marsland Cross-Section A-A' - Panel 2



CROSS-SECTION PANEL LOCATION



Vertical Scale	Legend
0 25 Meters / 0 50 100 Feet	Main Lithology Sandstone Gamma Curve Neutron or SP Curve Resistivity Curve

REVISIONS			
NO.	DATE	BY	

Cameco

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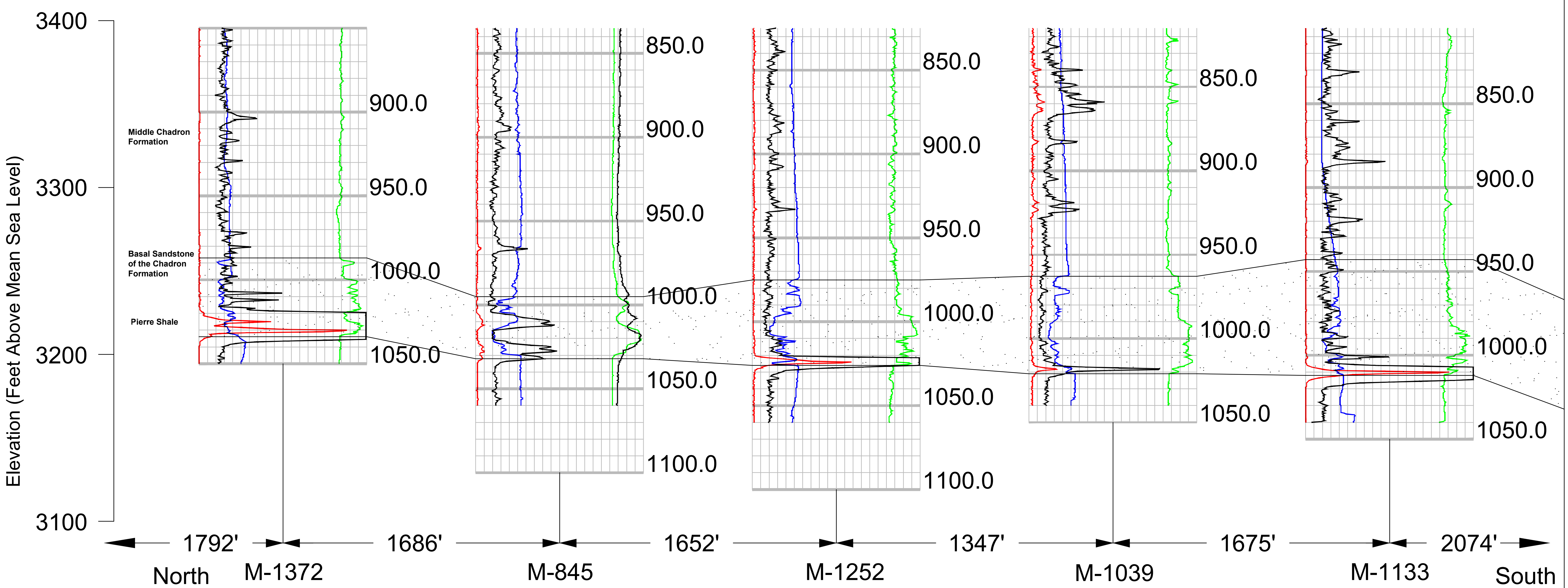
Crawford, NE 69339
Telephone: (308) 665-2215

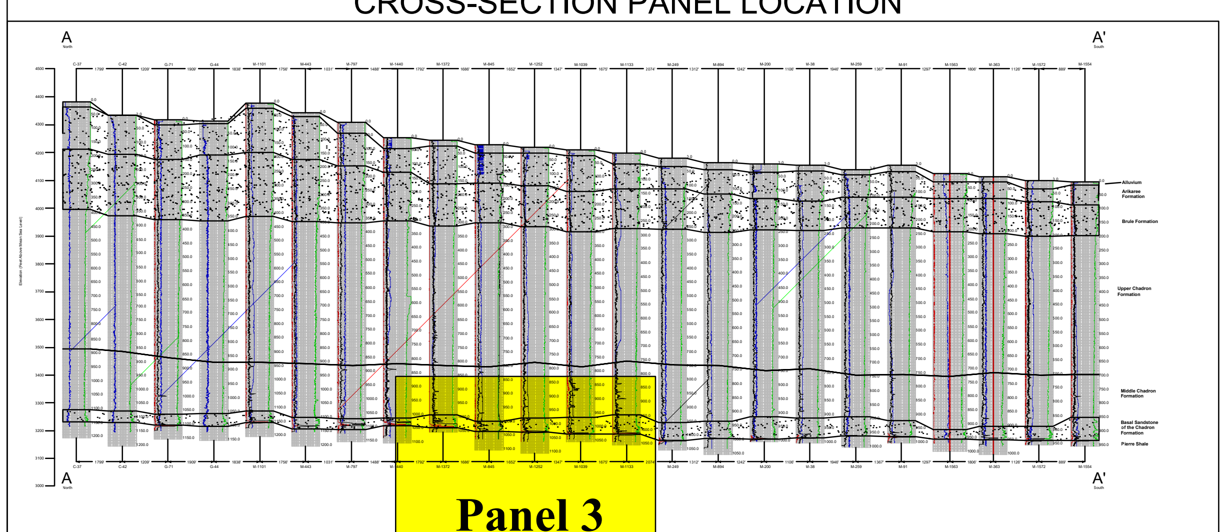
Figure 2.6-16p
Expanded Marsland
Cross Section A-A'
Panel 2

SIZE	DATE	DEPARTMENT:	Drawing Number	REV
0	October 6, 2013	Development	Area-Drawing Type-XXXX	0

Expanded Marsland Cross-Section A-A' - Panel 3



CROSS-SECTION PANEL LOCATION



Vertical Scale	Legend
0 — 25 Meters; 0 — 50 — 100 Feet	Main Lithology Sandstone Gamma Curve Neutron or SP Curve Resistivity Curve

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Crawford, NE 69339
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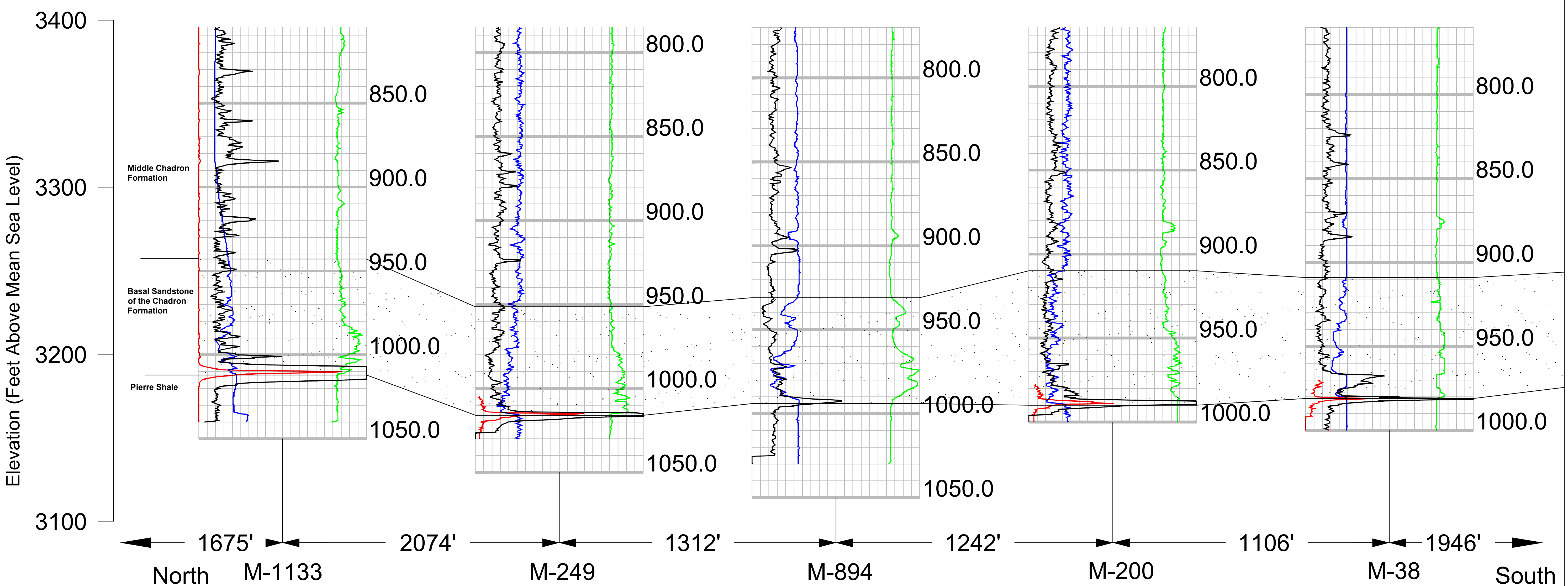
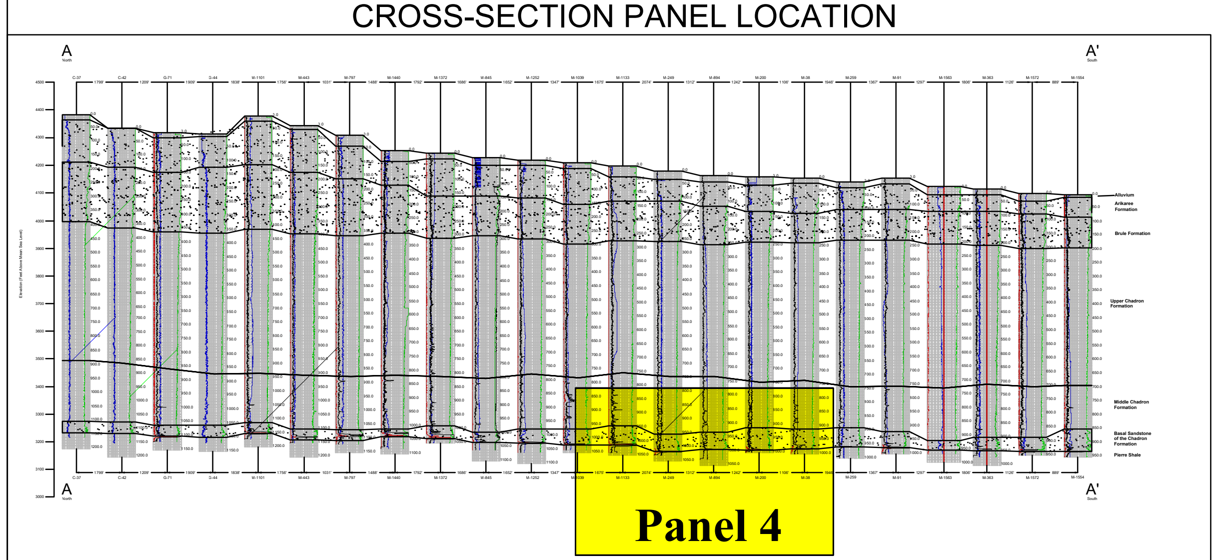
Figure 2.6-16q
Expanded Marsland
Cross Section A-A'
Panel 3

SIZE	DATE	DEPARTMENT	Drawing Number	REV
0	October 6, 2013	Development	Area-Drawing Type-XXXX	0

Expanded Marsland Cross-Section A-A' - Panel 4



CROSS-SECTION PANEL LOCATION



Vertical Scale

0 — 25 Meters

0 — 50 — 100 Feet

Legend

Main Lithology Sandstone

Gamma Curve

Neutron or SP Curve

Resistivity Curve

REVISIONS		
NO.	DATE	BY

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Crawford, NE 69339
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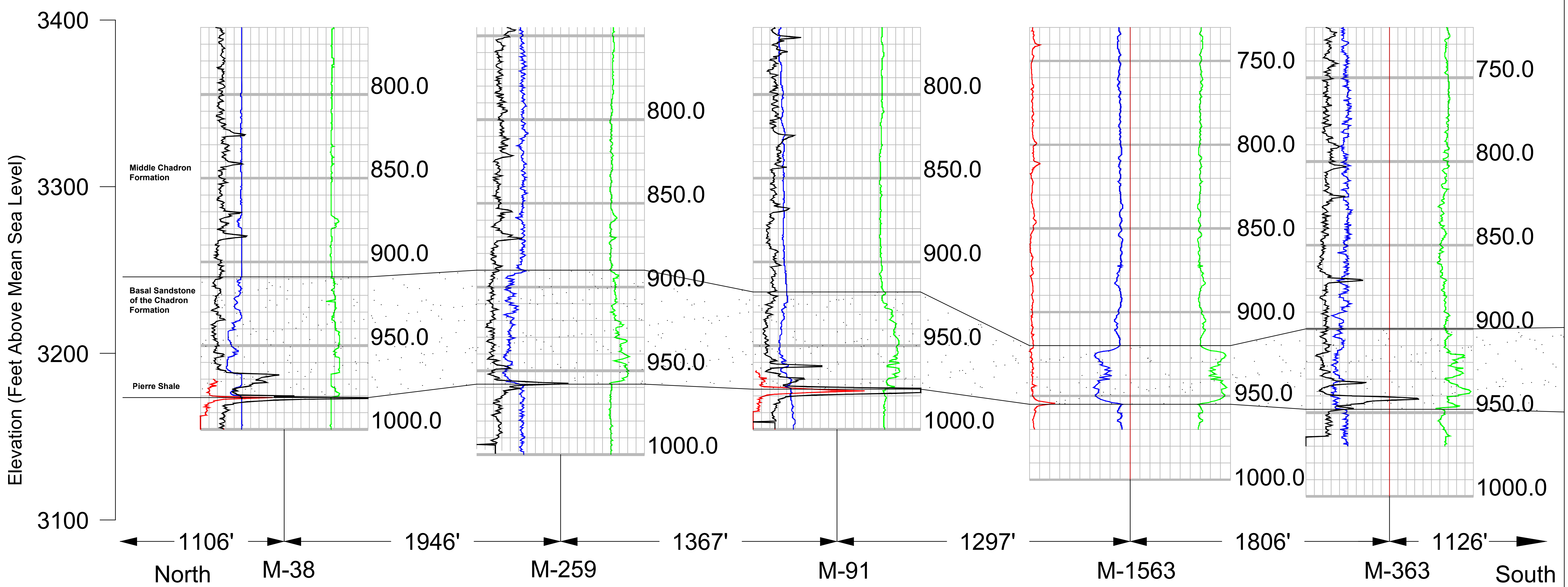
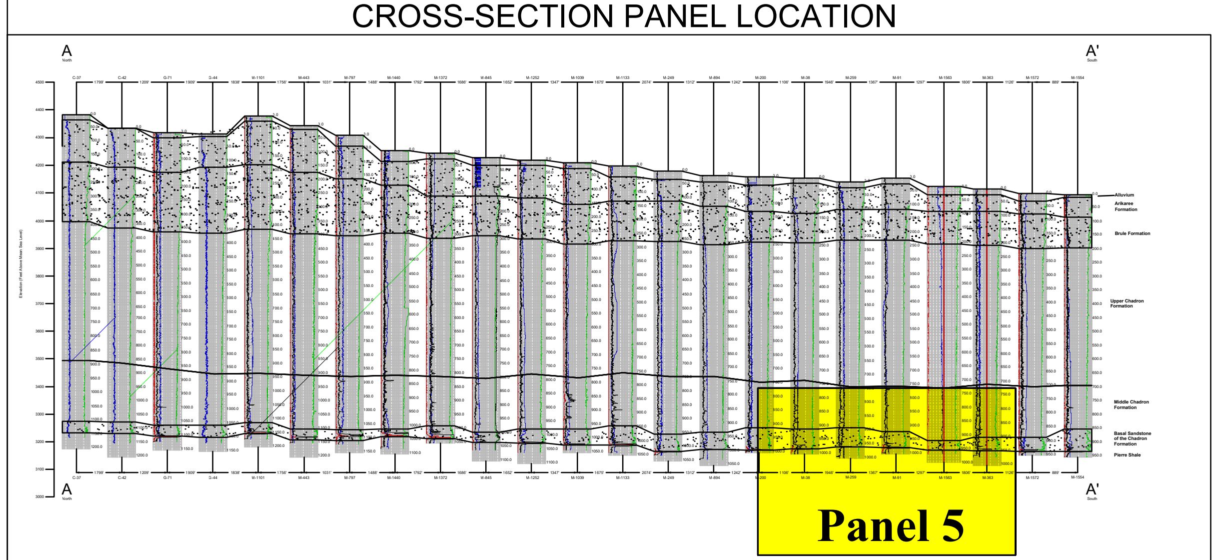
Figure 2.6-16r
Expanded Marsland
Cross Section A-A'
Panel 4

SIZE	DATE	DEPARTMENT:	Drawing Number	REV
0	October 6, 2013	Development	Area-Drawing Type-XXXX	0

Expanded Marsland Cross-Section A-A' - Panel 5



CROSS-SECTION PANEL LOCATION



Vertical Scale	Legend
0 — 25 Meters; 0 — 50 — 100 Feet	Main Lithology Sandstone
	Gamma Curve
	Neutron or SP Curve
	Resistivity Curve

REVISIONS

NO.	DATE	BY

Cameco

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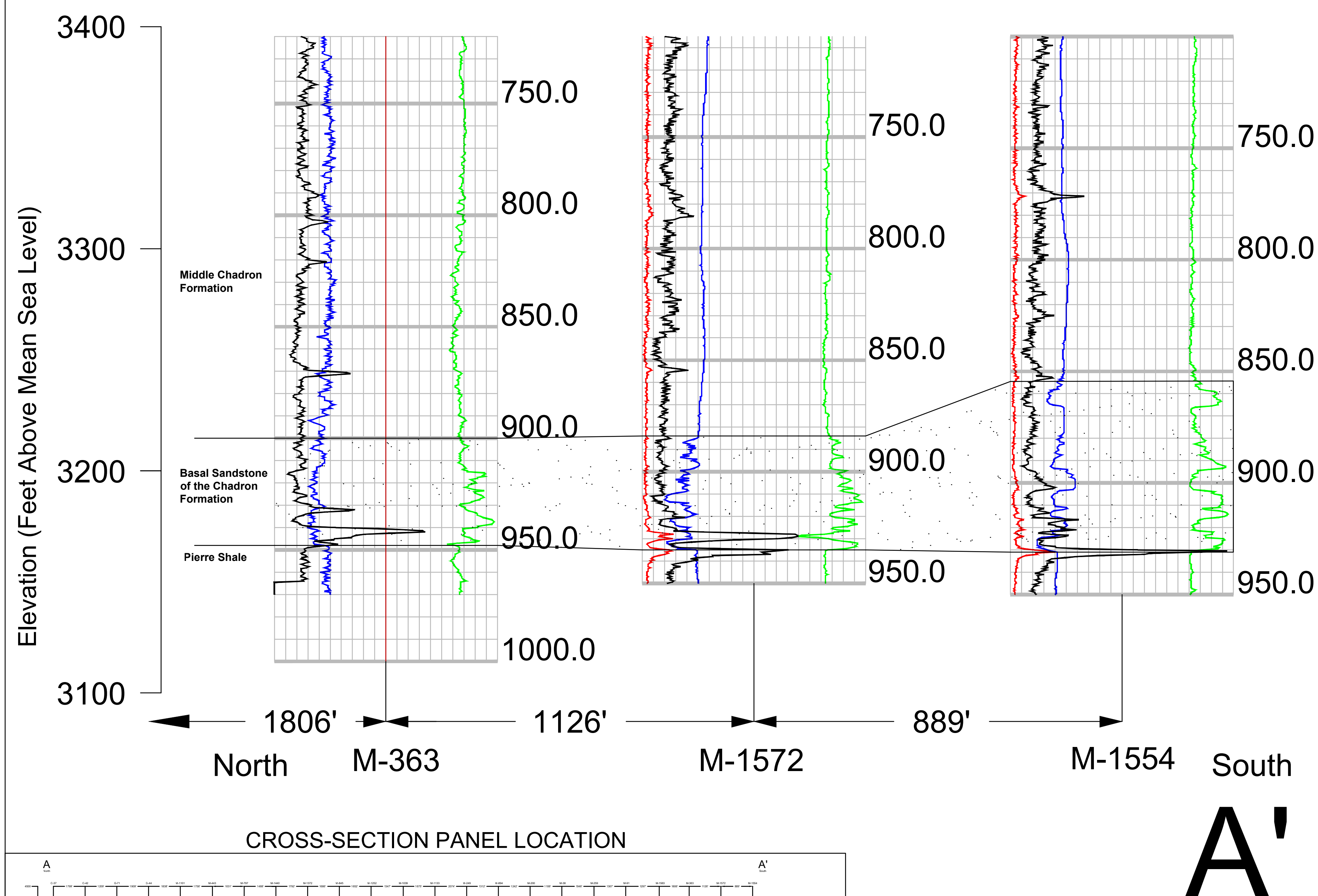
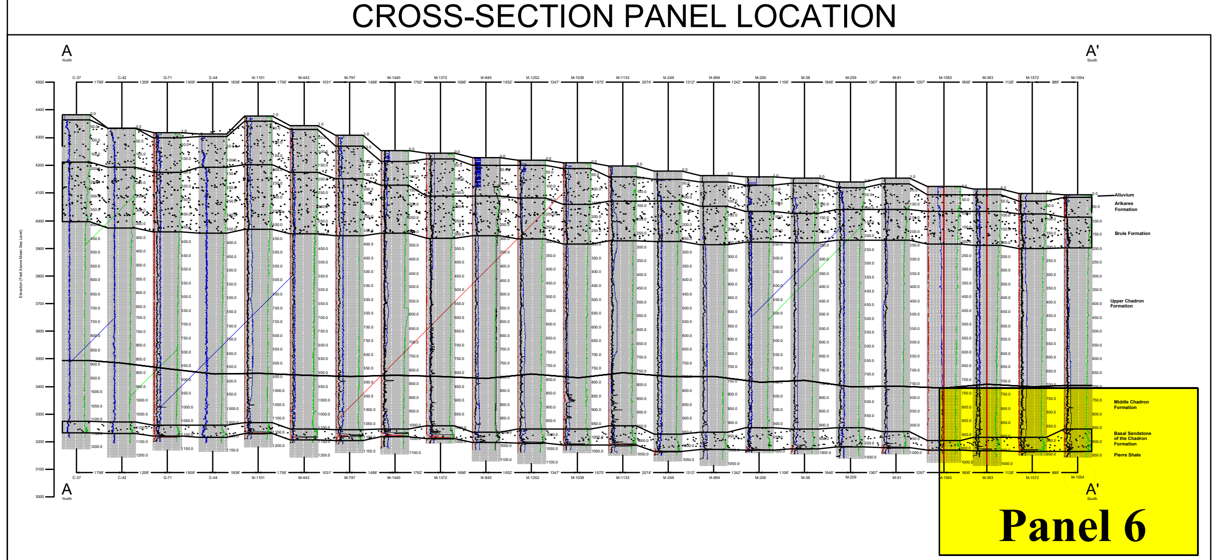
Figure 2.6-16s
Expanded Marsland
Cross Section A-A'
Panel 5

SIZE	DATE	DEPARTMENT:	Drawing Number	REV
0	October 6, 2013	Development	Area-Drawing Type-XXXX	0

Expanded Marsland Cross-Section A-A' - Panel 6



CROSS-SECTION PANEL LOCATION



Vertical Scale	Legend
0 25 Meters; 0 50 100 Feet	Main Lithology Sandstone; Gamma Curve; Neutron or SP Curve; Resistivity Curve

REVISIONS

NO.	DATE	BY

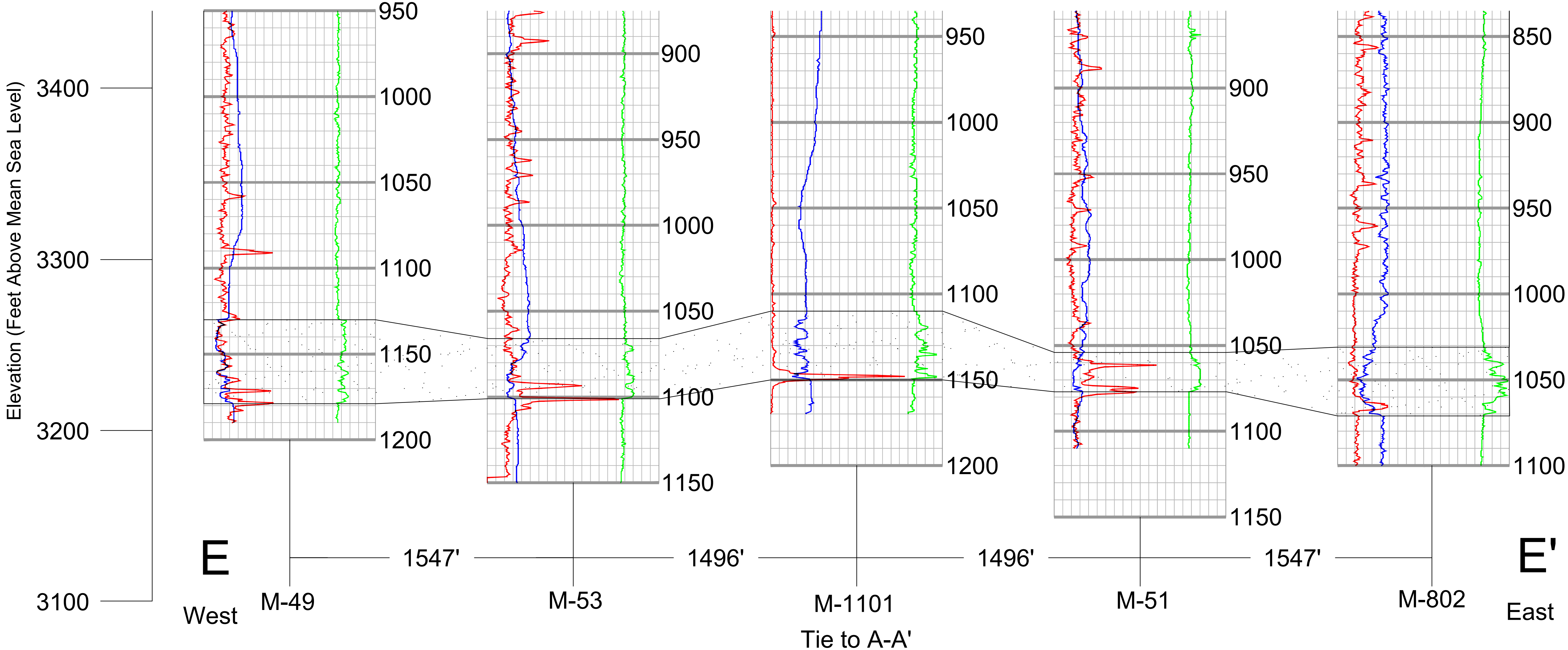
Cameco

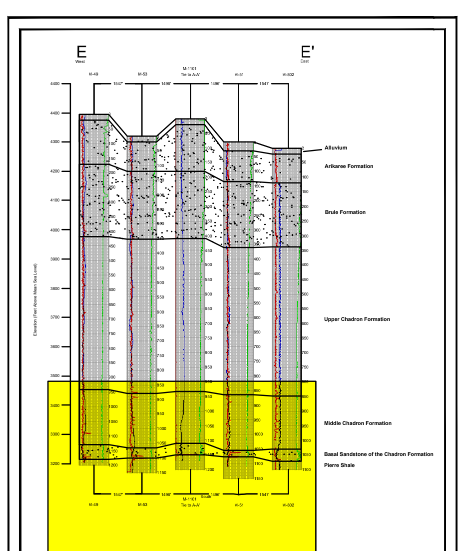
Crow Butte Resources
86 Crow Butte Road
Crawford, NE 69339
Telephone: (308) 665-2215

Figure 2.6-16t
Expanded Marsland
Cross Section A-A'
Panel 6

SIZE	DATE	DEPARTMENT:	Drawing Number	REV
0	October 6, 2013	Development	Area-Drawing Type-XXXX	0

Expanded Marsland Cross-Section E-E'





Vertical Scale	Legend
0 — 25 Meters; 0 — 50 — 100 Feet	Main Lithology Sandstone; Gamma Curve; Neutron or SP Curve; Resistivity Curve

REVISIONS (NO. DATE BY)

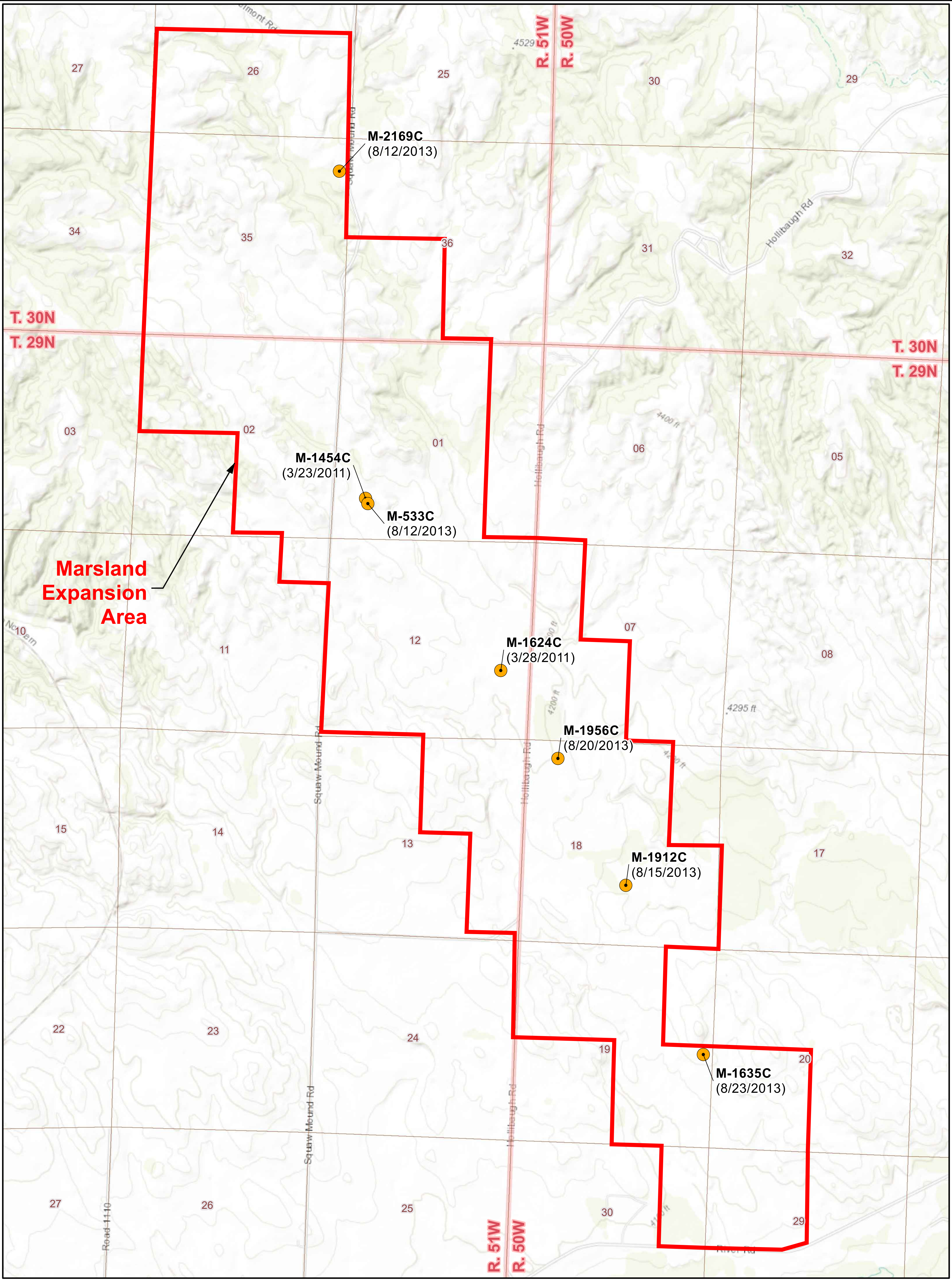
Cameco

Crow Butte Resources
86 Crow Butte Road
Crawford, NE 69339
Telephone: (308) 665-2215

Figure 2.6-16e
Expanded Marsland
Cross Section E-E'

SIZE	DATE	DEPARTMENT:	Drawing Number	REV
0	October 6, 2013	Development	Area-Drawing Type-XXXX	0

Path: K:\CBR_Projects\CO001636_Marsland\2_GIS\ArcMaps\0002_AEP\Figure 2_6-17 Marsland Expansion Area Coring Location.mxd | Date: 9/17/2024 | User: rventling



LEGEND

- Coring Location
- Proposed Marsland Expansion Area
- **M-1635C** Location ID
- (8/23/2013) Date of Collection

N

0 1,250 2,500
Feet

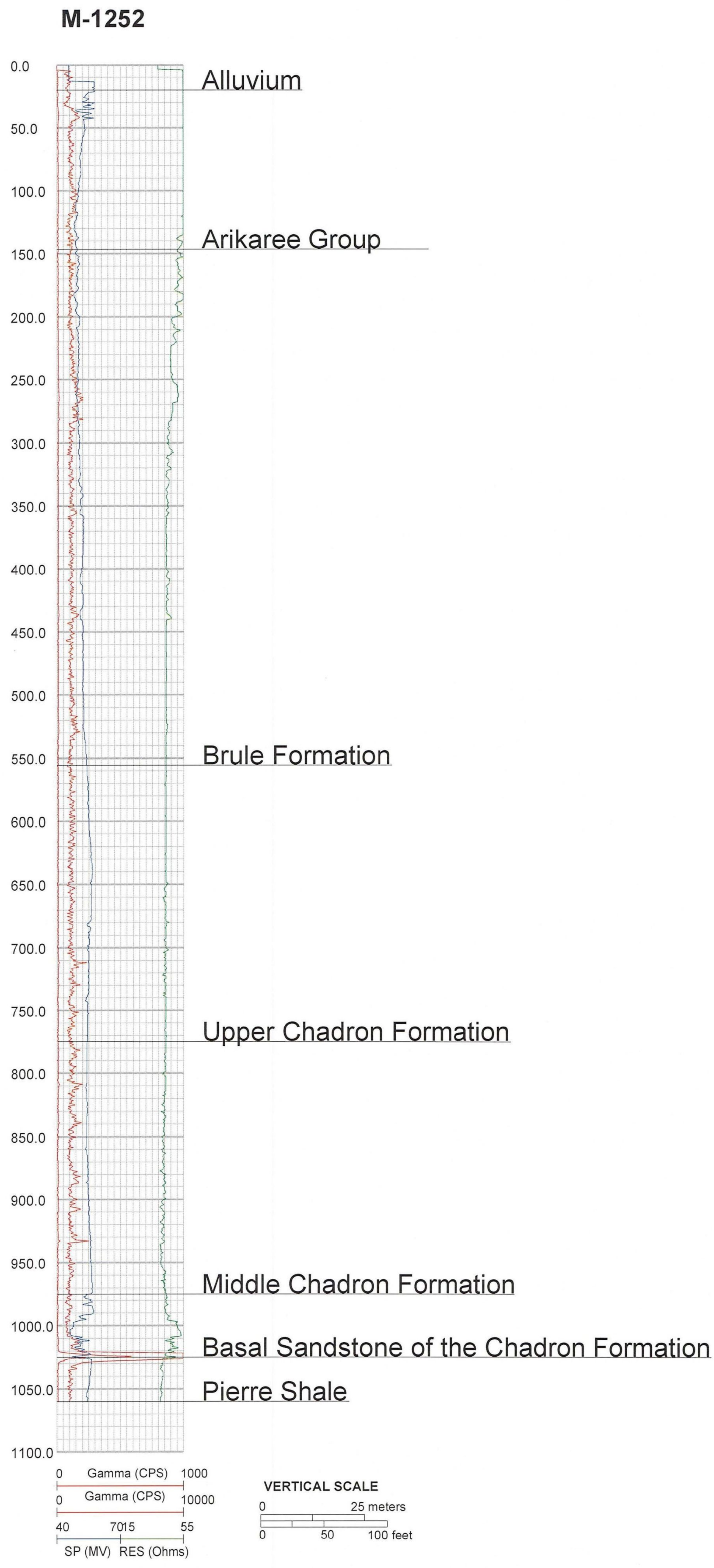
PROJECTION: NAD 1983, STATE PLANE NEBRASKA NORTH, FIPS 2600
SOURCES: US TOPO MAPS, SERVICED BY ESRI ARCGIS ONLINE

CROW BUTTE RESOURCES, INC.

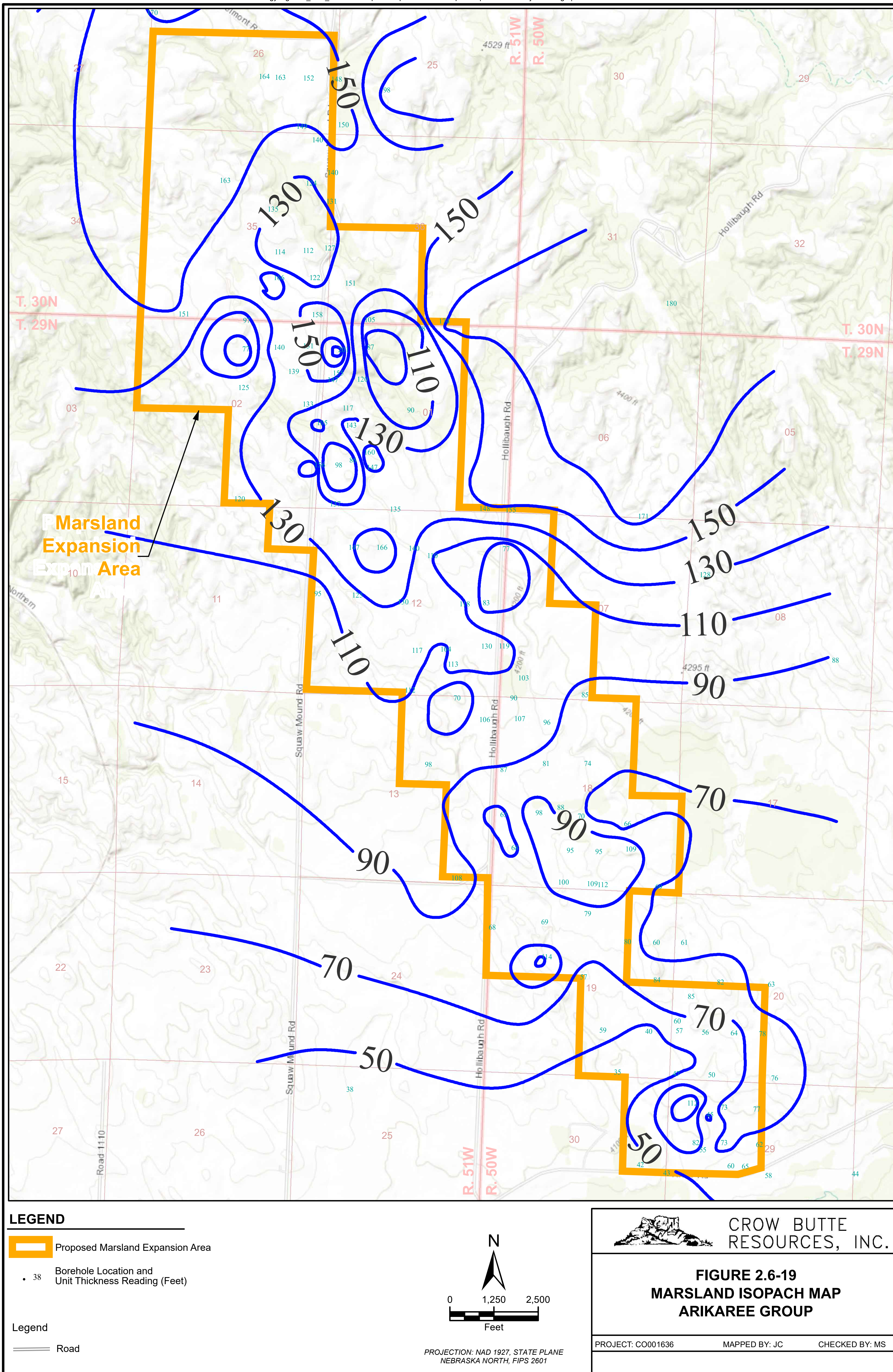
FIGURE 2.6-17
MARSLAND EXPANSION AREA
CORING LOCATIONS

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

Figure 2.6-18. Marsland Expansion Area Type Log (M-1252)



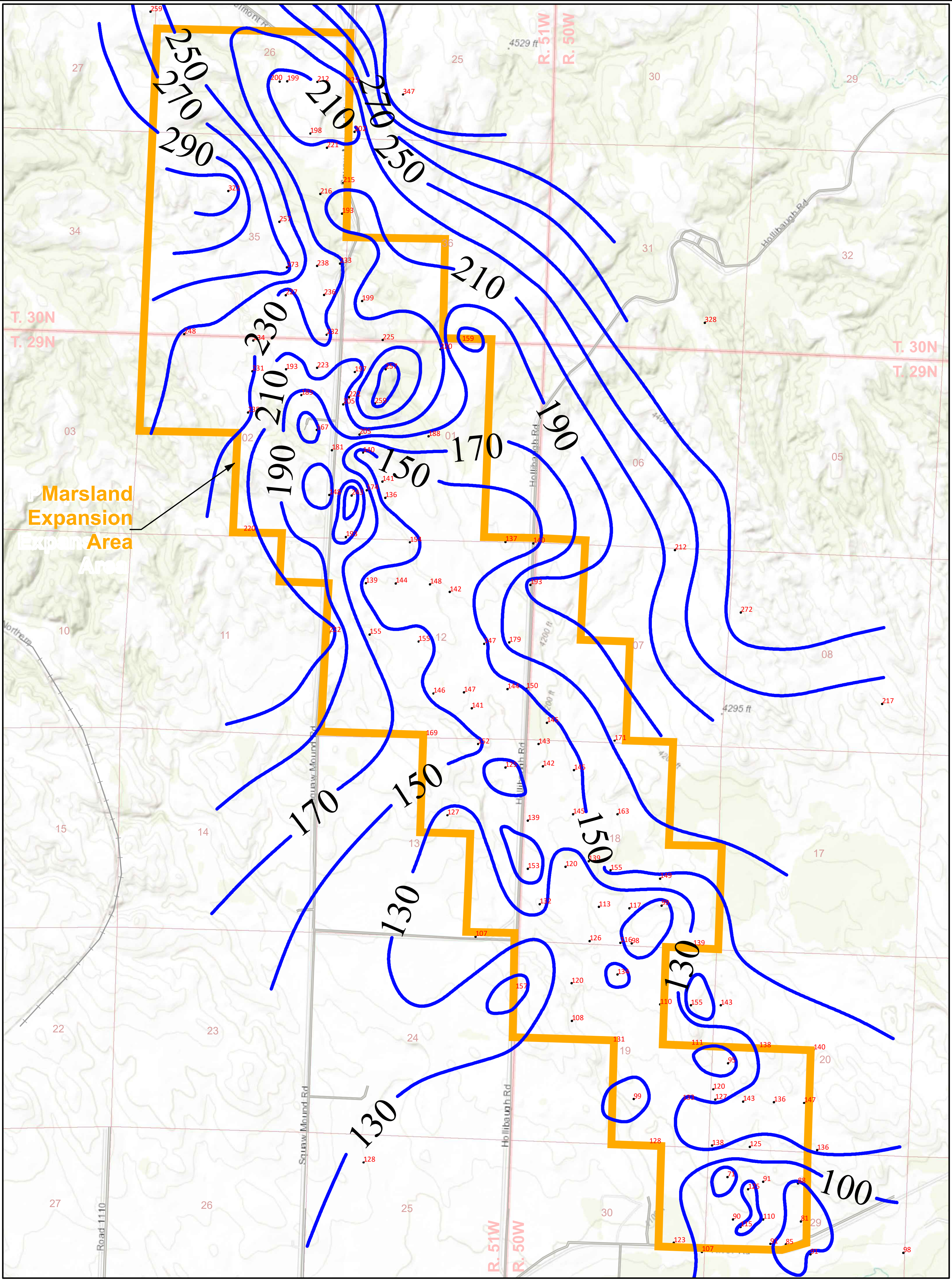
Source: Cameco Resources, 2011



CROW BUTTE RESOURCES, INC.

FIGURE 2.6-19
MARSLAND ISOPACH MAP
ARIKAREE GROUP

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



LEGEND

Proposed Marsland Expansion Area

128 Borehole Location and Unit Thickness Reading (Feet)

Isopach Contour (Feet)

Railroad

Road

N

0 1,250 2,500

Feet

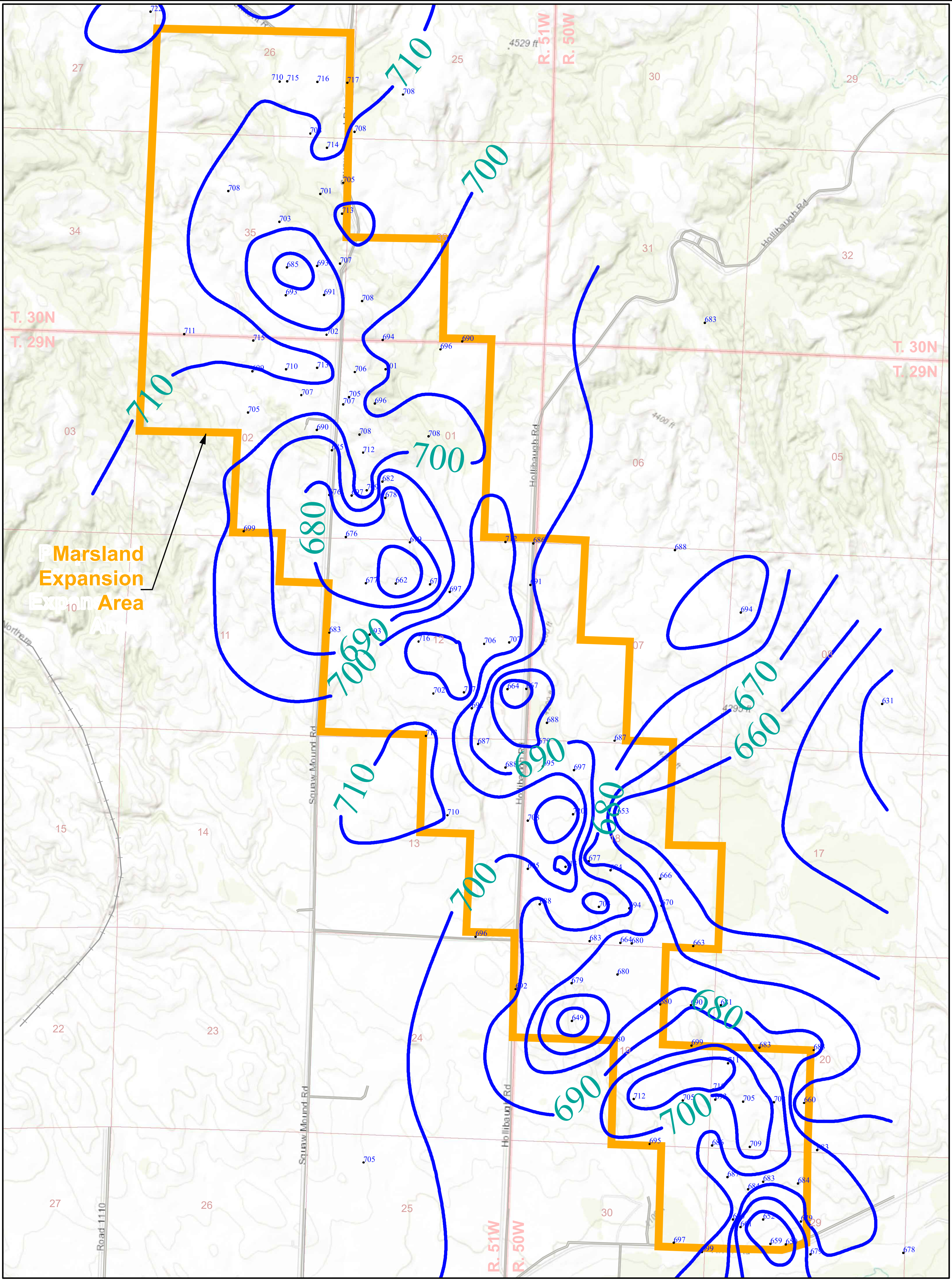
PROJECTION: NAD 1927, STATE PLANE NEBRASKA NORTH, FIPS 2601

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-20
MARSLAND ISOPACH MAP
BRULE FORMATION

PROJECT: CO001636 MAPPED BY: JC CHECKED BY: MS

Path: K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\2.6 Geology\Figure 2_6-21 Marsland_Isopach_Chadron.mxd | Last Saved By: rventling | Last Saved On: 9/17/2024



LEGEND

Proposed Marsland Expansion Area

• 705 Borehole Location and Unit Thickness Reading (Feet)

Isopach Contour (Feet)

Railroad

Road

N

0 1,250 2,500

Feet

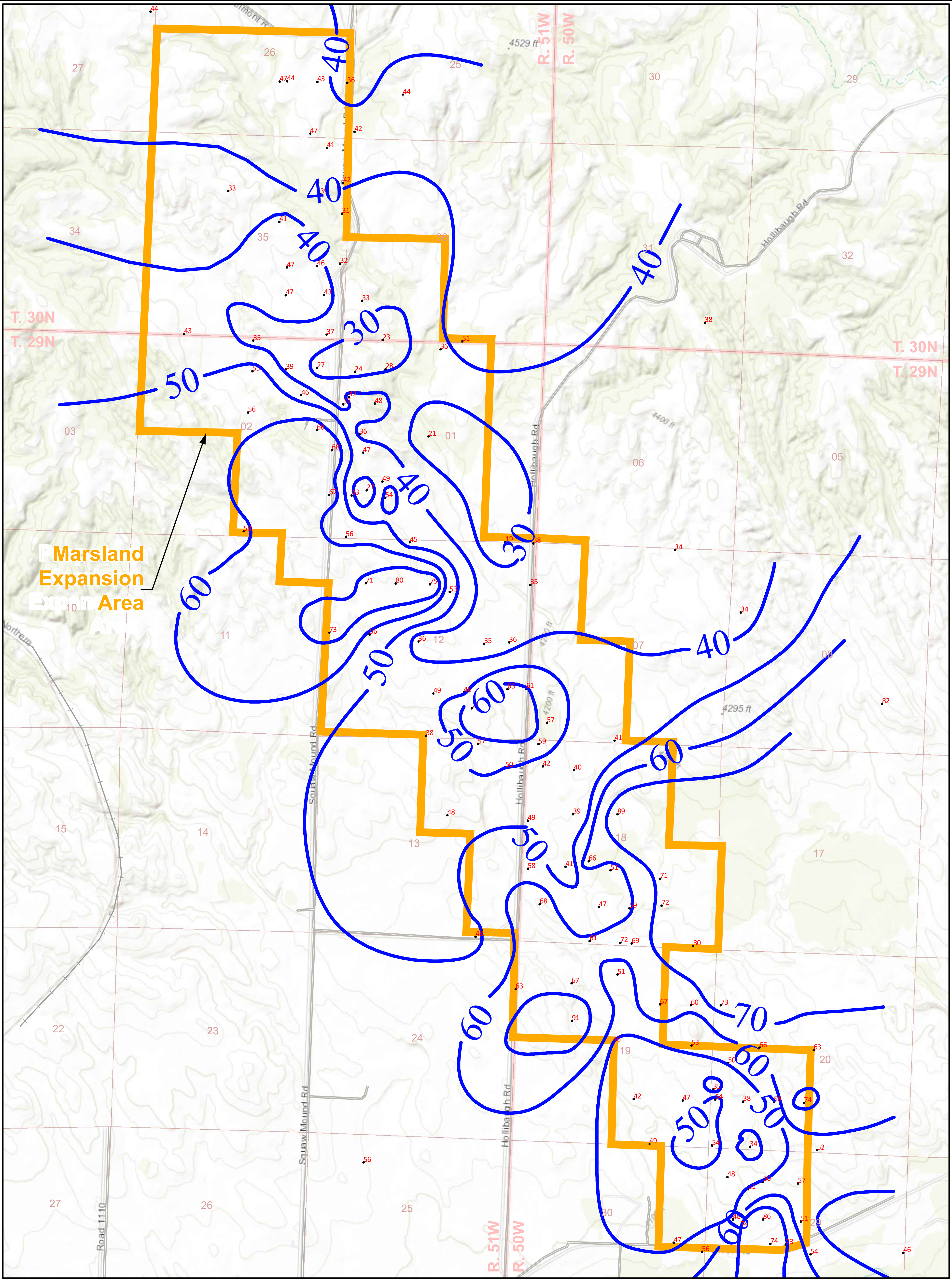
PROJECTION: NAD 1927, STATE PLANE NEBRASKA NORTH, FIPS 2601

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-21
MARSLAND ISOPACH MAP
UPPER AND MIDDLE
CHADRON FORMATION

PROJECT: CO001636 MAPPED BY: JC CHECKED BY: MS

Path: K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\2.6 Geology\Figure 2_6-22 Marsland_Isopach_BasalSand.mxd | Last Saved By: rventling | Last Saved On: 9/17/2024



LEGEND

Proposed Marsland Expansion Area

46 Borehole Location and Unit Thickness Reading (Feet)

Isopach Contour (Feet)

Railroad

Road

N

0 1,250 2,500
Feet

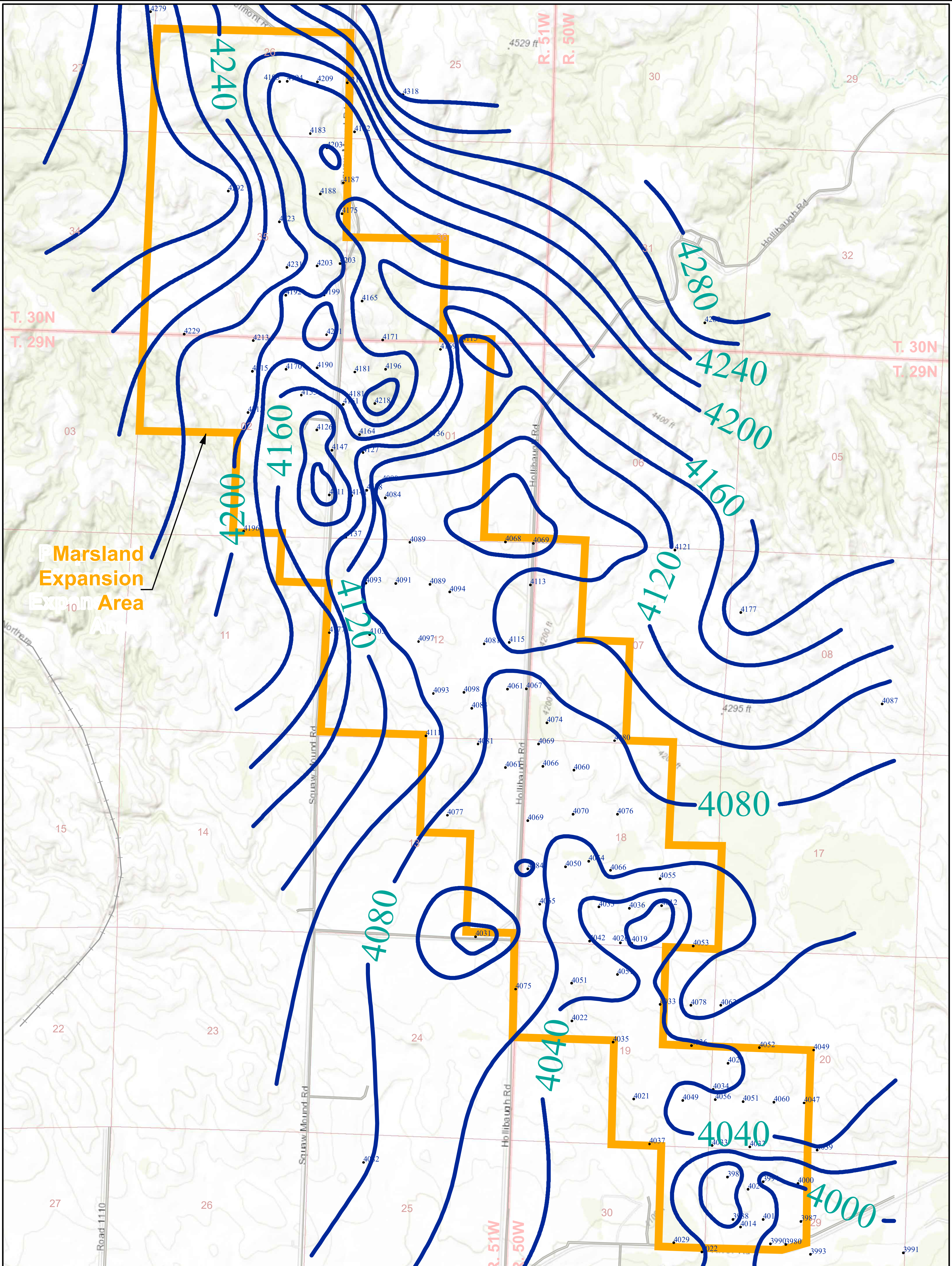
PROJECTION: NAD 1927, STATE PLANE NEBRASKA NORTH, FIPS 2601

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-22
MARSLAND ISOPACH MAP
BASAL SANDSTONE OF
THE CHADRON FORMATION

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

Path: K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\2.6 Geology\Figure 2_6-23 Marsland_Structure_TopOfBrule.mxd | Last Saved By: rventling | Last Saved On: 9/17/2024



LEGEND

Proposed Marsland Expansion Area

4021 Borehole Location and Elevation - Top of Brule Formation (FT-AMSL)

Elevation Contour - Top of Brule Formation (FT-AMSL)

Railroad

Road

FT-AMSL = Feet Above Mean Sea Level

N

0 1,250 2,500

Feet

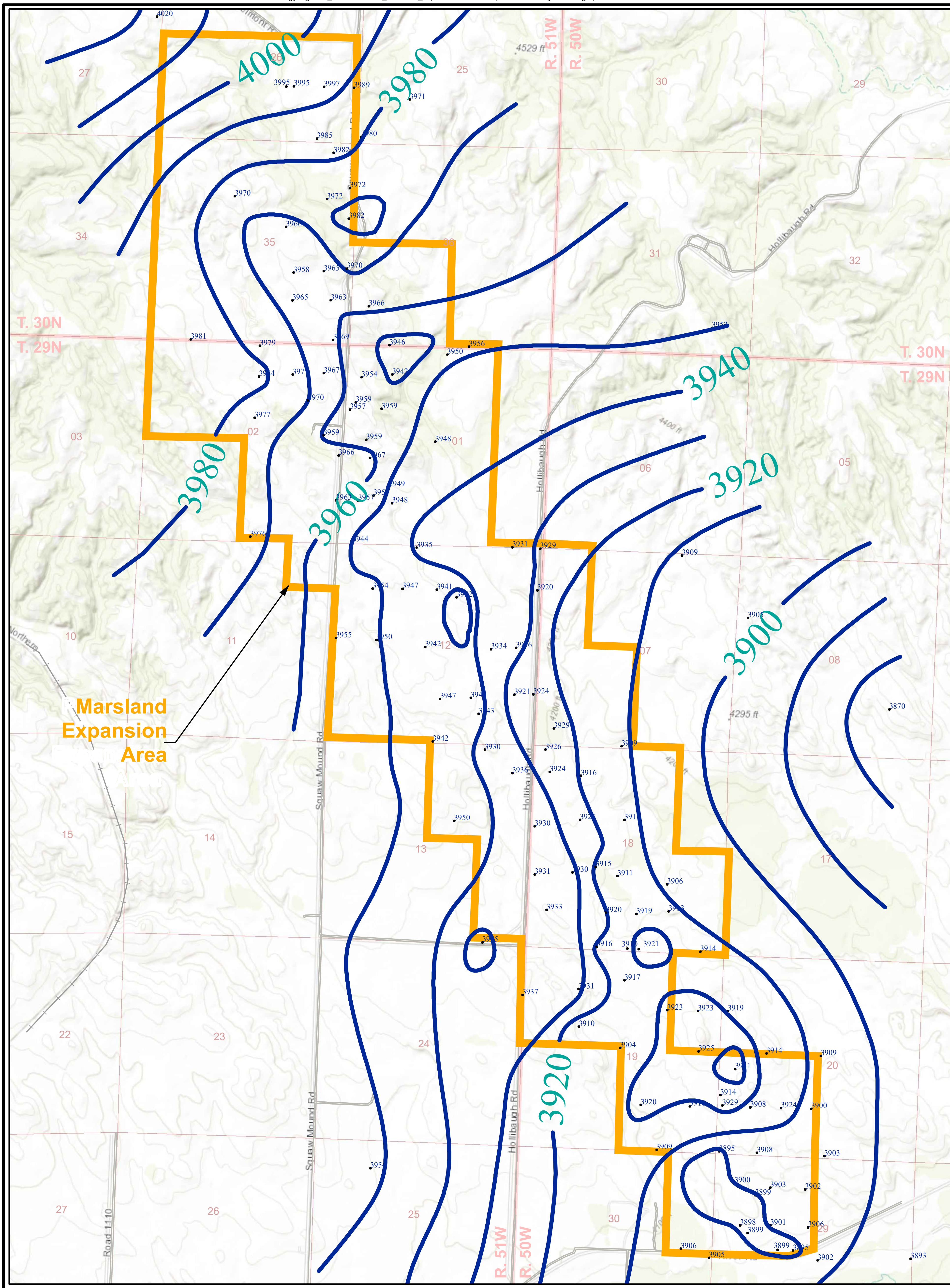
PROJECTION: NAD 1927, STATE PLANE NEBRASKA NORTH, FIPS 2601

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-23
MARSLAND STRUCTURE MAP
TOP OF BRULE FORMATION

PROJECT: CO001636 MAPPED BY: JC CHECKED BY: MS

Path: K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\2.6 Geology\Figure 2_6-24 Marsland_Structure_TopOfChadron.mxd | Last Saved By: rventling | Last Saved On: 9/17/2024



LEGEND

Proposed Marsland Expansion Area

3920 Borehole Location and Elevation - Top of Chadron Formation (FT-AMSL)

Elevation Contour - Top of Chadron Formation (FT-AMSL)

Railroad

Road

FT-AMSL = Feet Above Mean Sea Level

N

0 1,250 2,500

Feet

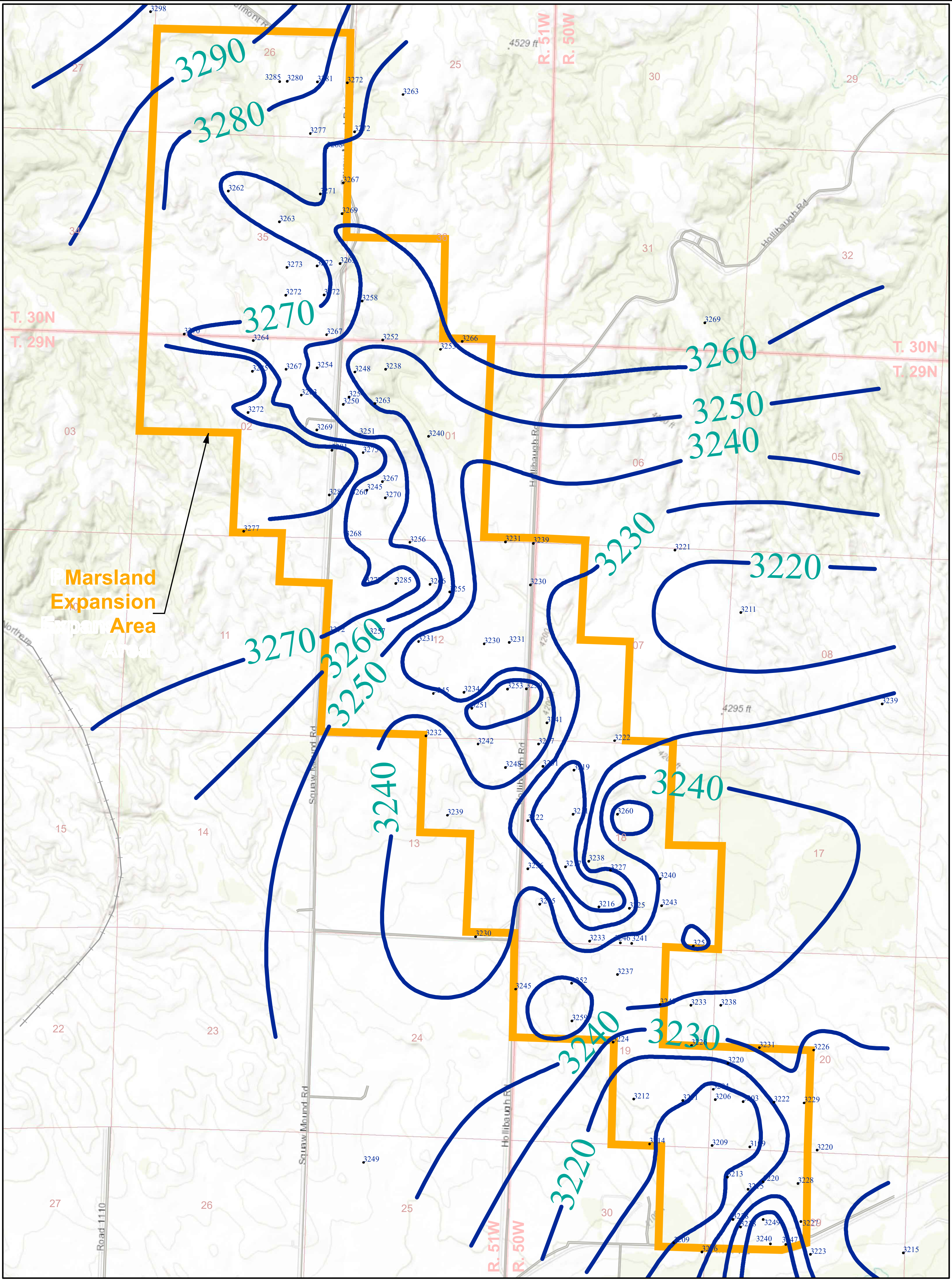
PROJECTION: NAD 1927, STATE PLANE NEBRASKA NORTH, FIPS 2601

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-24
MARSLAND STRUCTURE MAP
TOP OF CHADRON FORMATION

PROJECT: CO001636 MAPPED BY: JC CHECKED BY: MS

Path: K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\2.6 Geology\Figure 2_6-25 Marsland_Structure_TopOfBasalSand.mxd | Last Saved By: rventling | Last Saved On: 9/17/2024



LEGEND

- Proposed Marsland Expansion Area
- 3249 Borehole Location and Elevation - Top of Basal Sandstone (FT-AMSL)
- Elevation Contour - Top of Basal Sandstone (FT-AMSL)
- Railroad
- Road

FT-AMSL = Feet Above Mean Sea Level

N

0 1,250 2,500
Feet

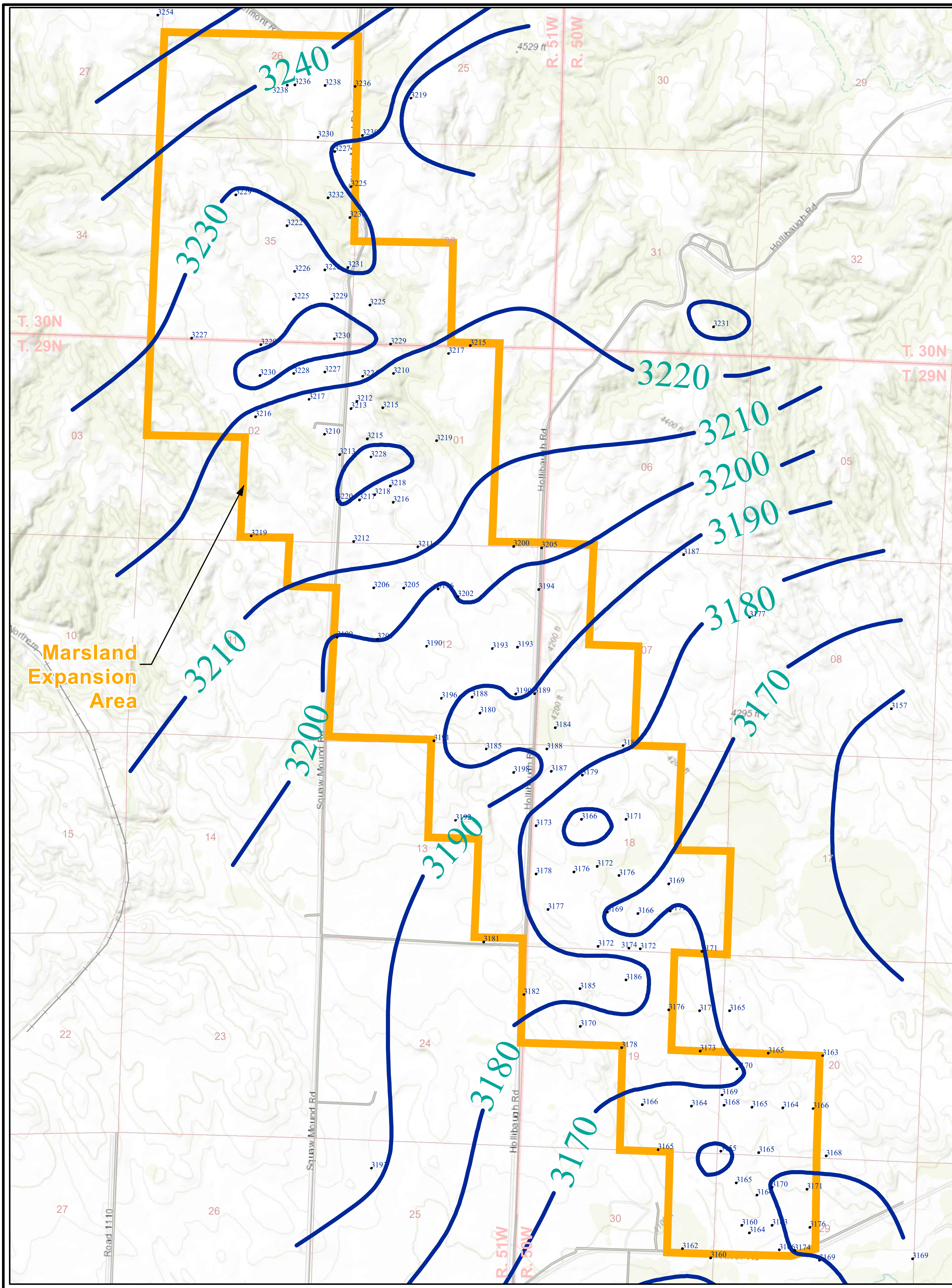
PROJECTION: NAD 1927, STATE PLANE NEBRASKA NORTH, FIPS 2601

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-25
MARSLAND STRUCTURE MAP
TOP OF BASAL SANDSTONE OF THE CHADRON FORMATION

PROJECT: CO001636 MAPPED BY: JC CHECKED BY: MS

Path: K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\2.6 Geology\Figure 2_6-26 Marsland_Structure_TopOfPierre.mxd | Last Saved By: rventling | Last Saved On: 9/17/2024



LEGEND

- Proposed Marsland Expansion Area
- 3193 Borehole Location and Elevation - Top of Pierre Shale (FT-AMSL)
- Elevation Contour - Top of Pierre Shale (FT-AMSL)
- Railroad
- Road

FT-AMSL = Feet Above Mean Sea Level

N

0 1,250 2,500
Feet

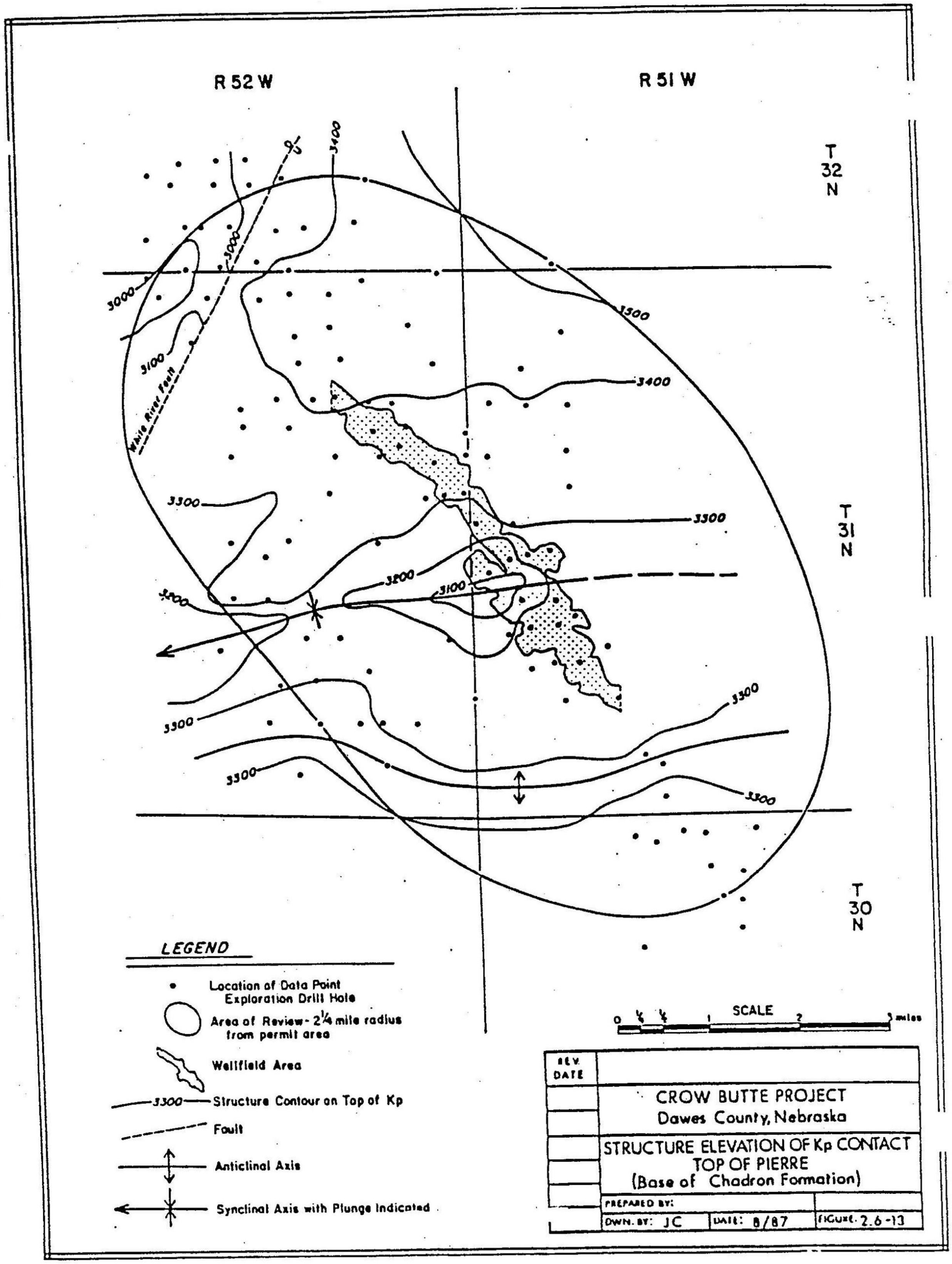
PROJECTION: NAD 1927, STATE PLANE NEBRASKA NORTH, FIPS 2601

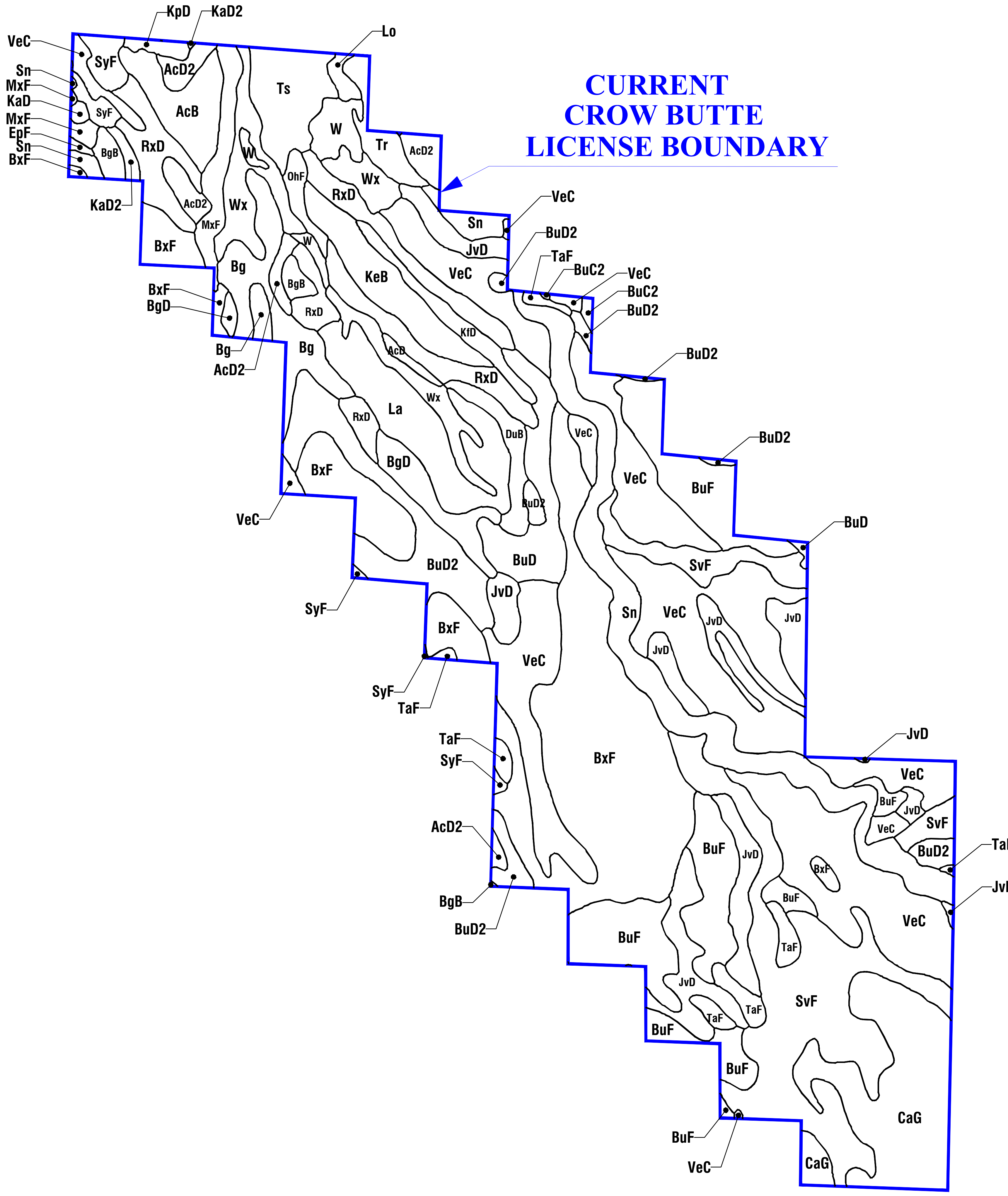
CROW BUTTE RESOURCES, INC.

FIGURE 2.6-26
MARSLAND STRUCTURE MAP
TOP OF PIERRE SHALE

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

Figure 2.6-27 Structure Elevation of Kp Contact Top of Pierre (Base of Chadron Formation)





Source: NRCS, Soil Survey of Dawes County, Nebraska, 1977, 2006 NAIP Aerial Photograph.

LEGEND

SrF MAP UNIT ID

MAP UNIT BOUNDARY

2000 0 1000 2000 3000 Feet

CROW BUTTE PROJECT

REGIONAL AREA BASE MAP

DAWES & SIOUX COUNTIES, NEBRASKA

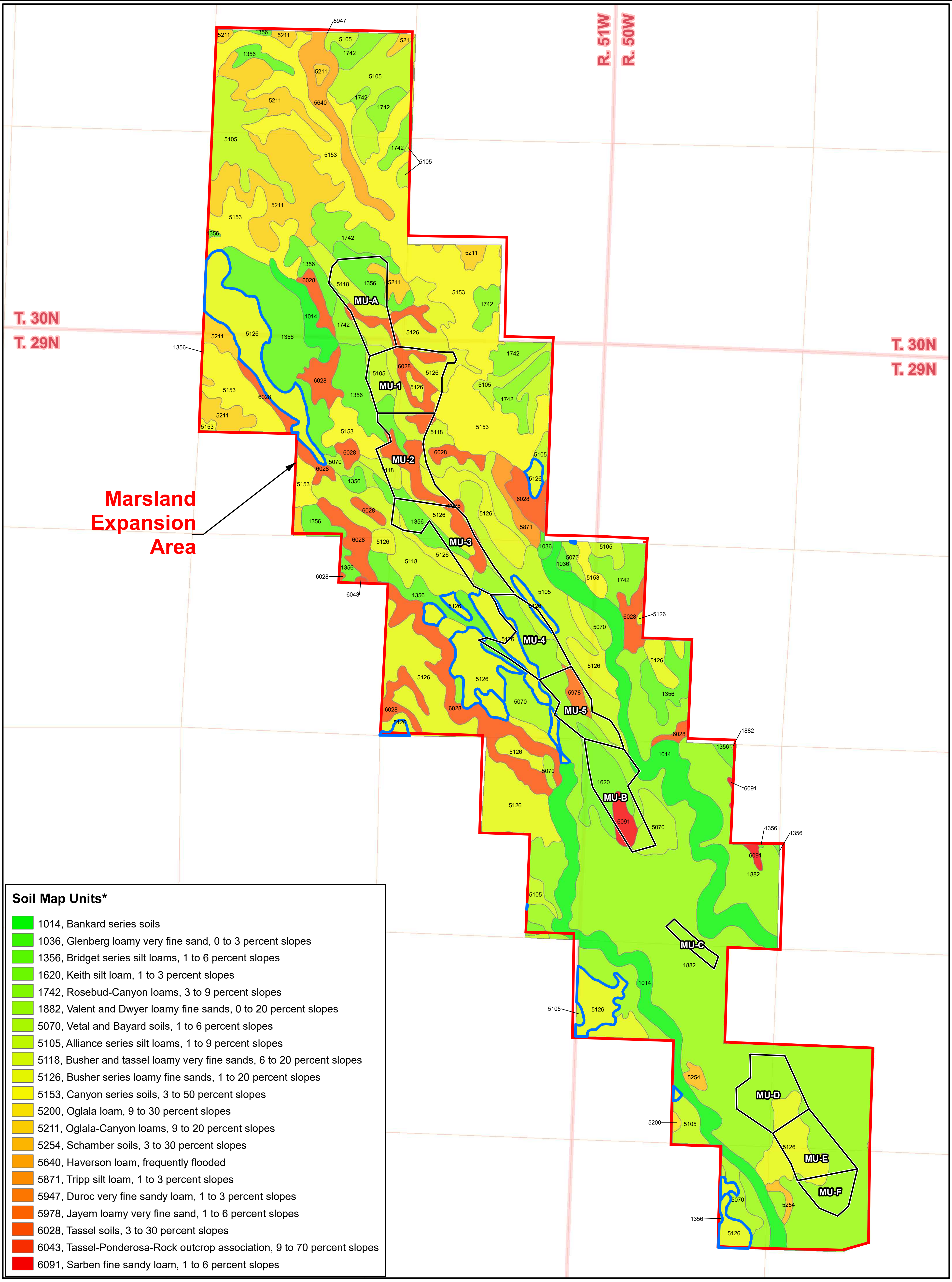
FIGURE 2.6-28 CROW BUTTE LICENSE AREA SOILS MAP

NEBRASKA

Date:3/7/07 | Drawn:PBE | Fig. 2.6-29

K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\05CAD\Sheets\2.6 Geology\Figure 2.6-32 Crow Butte Soils.dwg

Path: K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\2.6 Geology\Figure 2_6-33 Marsland Soils.mxd | Last Saved By: rventling | Last Saved On: 9/17/2024



LEGEND

Mine Unit

Soil units mapped by NRCS as exhibiting prevelant erosion

Proposed Marsland Expansion Area

* Soil map units 1014, 1356, 1882, 5105, 5126, and 5153 represent combined NRCS map units. The map unit number represents the NRCS map unit with the greatest extent within the Proposed Marsland Expansion Area. See text for complete description of soil map units.

N

0 1,500 3,000
Feet

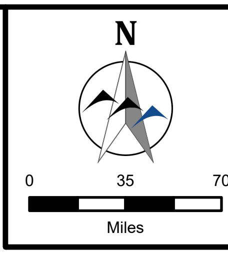
PROJECTION: NAD 1983, STATE PLANE NEBRASKA NORTH, FIPS 2600
SOURCES: US TOPO MAPS, SERVICED BY ESRI ARCGIS ONLINE

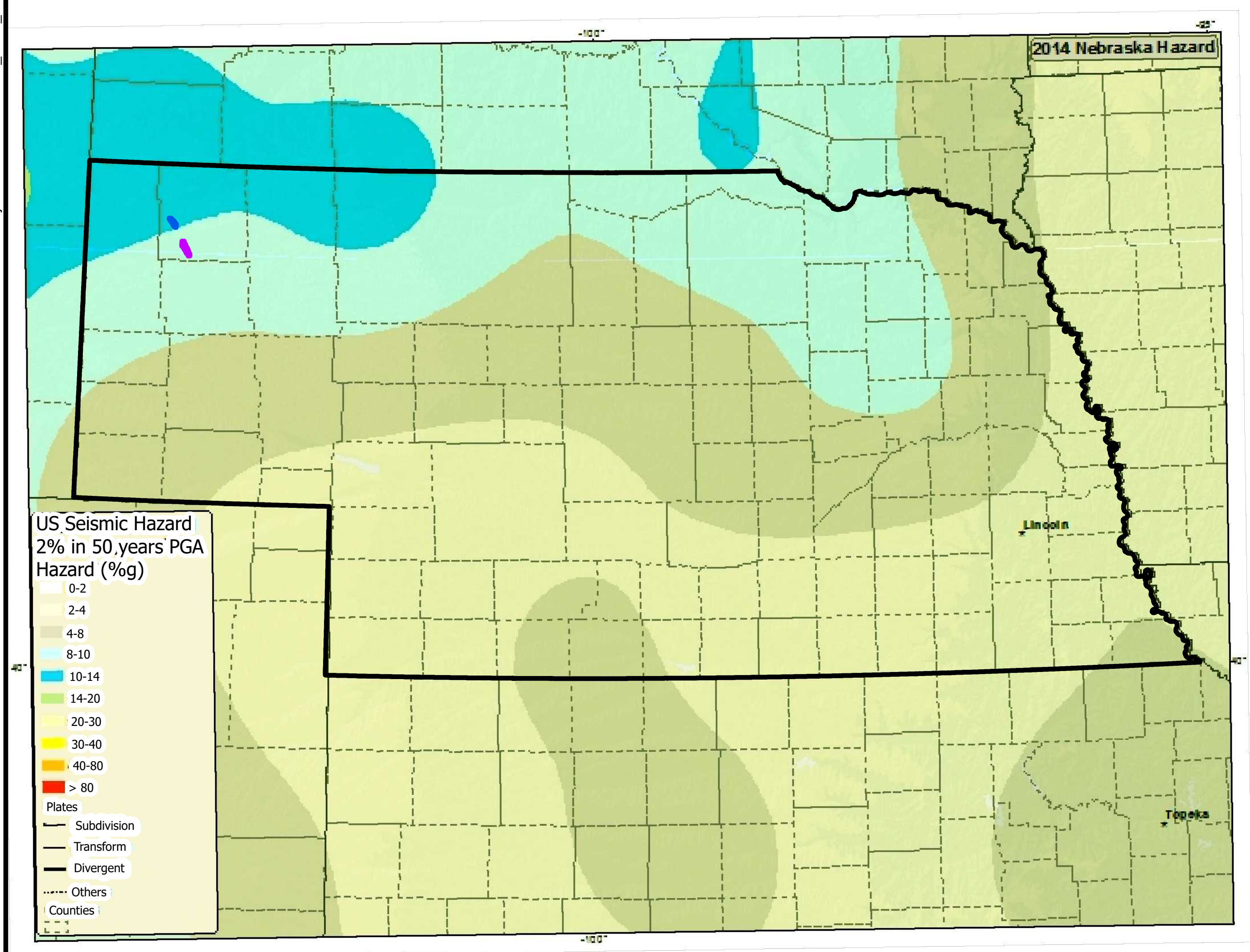
CROW BUTTE RESOURCES, INC.

FIGURE 2.6-29
MARSLAND EXPANSION AREA SOILS

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

K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\SENV New ArcPro Project\ArcPro Files\23078_Crow_Butte\23078_Crow_Butte.aprx 23078_Crow_Butte 9/19/2024 7:58 AM





LEGEND

- Crow Butte License Boundary
- Marsland Expansion Area Boundary

PERMIT TO MINE NO.			
NO.	REVISION	BY	DATE
4	---	---	---
3	---	---	---
2	---	---	---
1	---	---	---
0	---	---	---

CROW BUTTE RESOURCES, INC., 86 CROW BUTTE ROAD, CRAWFORD, NE 69339

CROW BUTTE RESOURCES, INC.

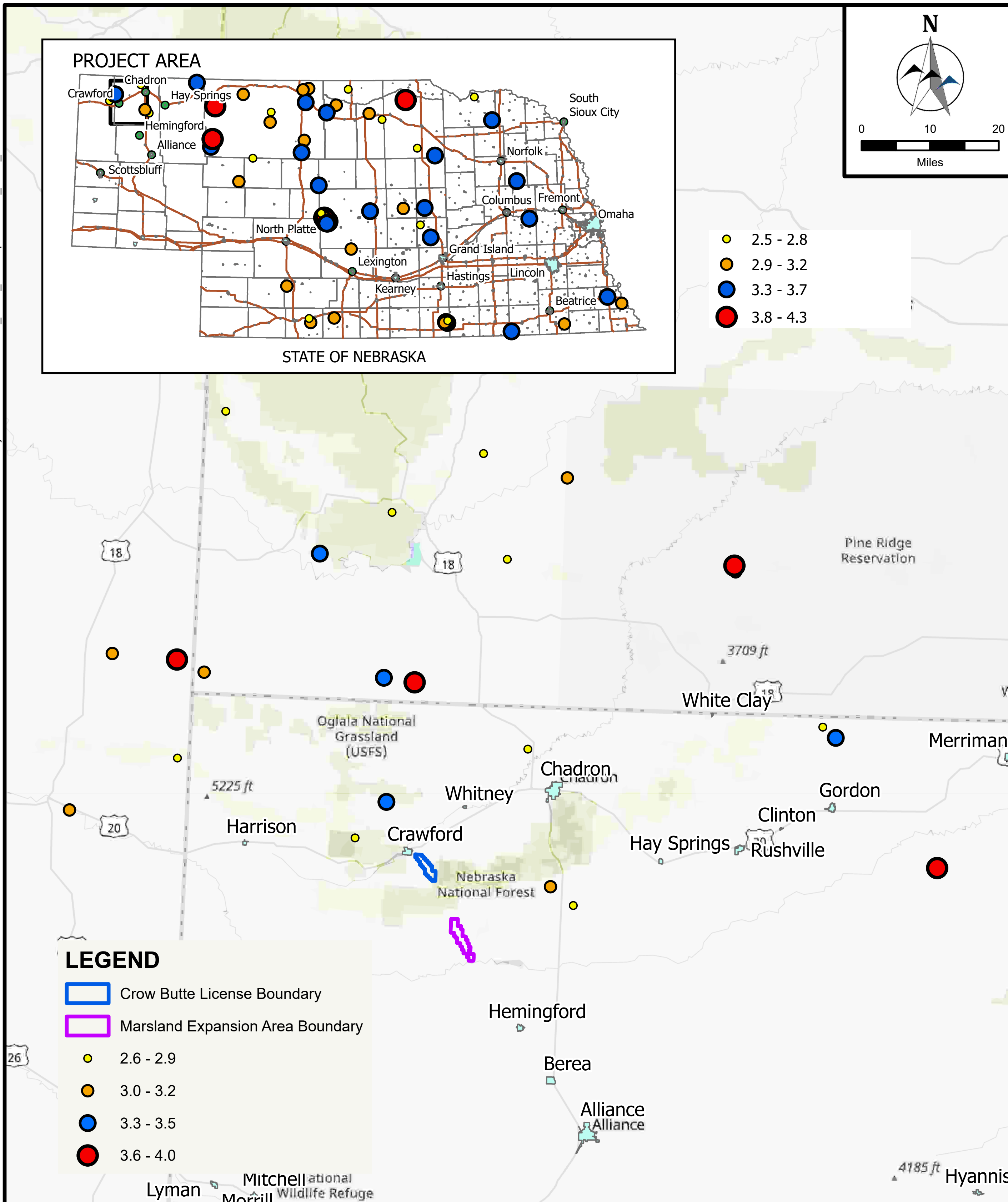
DAWES COUNTY, NEBRASKA

NEBRASKA SEISMIC HAZARD 2% IN 50 YEARS

DRAWN BY:	RAV
CHECKED BY:	BAW
APPROVED BY:	--
DATE:	09/2024

FIGURE **2.6-30**

K:\Sheridan\Cameco Resources\2023078 Crow Butte LRA\06GIS\SENV New ArcPro Project\ArcPro Files\23078_Crow_Butte.aprx 23078_Crow_Butte 9/17/2024 7:33 AM



PERMIT TO MINE NO.

NO.	REVISION	BY	DATE
4	---	---	---
3	---	---	---
2	---	---	---
1	---	---	---
0	---	---	---

CROW BUTTE RESOURCES, INC., 86 CROW BUTTE ROAD, CRAWFORD, NE 69339

CROW BUTTE RESOURCES, INC.

DAWES COUNTY, NEBRASKA

EARTHQUAKES IN NEBRASKA AND WITHIN 125km OF CRAWFORD NE

DRAWN BY: RAV
CHECKED BY: BAW
APPROVED BY: ---
DATE: 09/2024

FIGURE **2.6-31**