CROW BUTTE RESOURCES, INC.

141 Union Blvd., Suite 330
Lakewood, Colorado 80228
Tel: (720) 879-5140
Fax: (720) 917-0188

November 27, 2007

Mr. Charles L. Miller, Director
Office of Federal and State Materials and Environmental Management Programs
U. S. Nuclear Regulatory Commission
Two White Flint North, Mailstop T8F5
11545 Rockville Pike
Rockville, MD 20852

RE: Request for License Renewal
Docket No. 40-8943
License No. SUA-1534

Dear Mr. Miller:

Crow Butte Resources, Inc. (CBR) hereby applies for the renewal of Source Materials License No. SUA-1534 for the continued operation of the Crow Butte in situ leach uranium mine. The current expiration date for License SUA-1534 is February 28, 2008. Application for license renewal is made pursuant to the requirements of 10 CFR 40.43 (a).

Enclosed with this letter is NRC Form 313, with associated additional information. Under separate cover CBR is sending three copies of the renewal application.

If you or your staff has any questions regarding CBR's application for the license renewal please contact me.

Sincerely,

Stephen P. Collings

Stephen P. Collings
President

NRC FORM 313 (10-2005) 10 CFR 30, 32, 33, 34, 35, 36, 39, and 40 — U.S. NUCLEAR REGULATORY COMMISSION	APPROVED BY OMB: NO. 3150-0120 EXPIRES: 10/31/2008
APPLICATION FOR MATERIAL LICENSE	Estimated burden per response to comply with this mandatory collection request: 4.4 hours. Submittal of the application is necessary to determine that the applicant is qualified and that adequate procedures exist to protect the public health and safety. Send comments regarding burden estimate to the Records and FOIA/Privacy Services Branch (T-5 F53), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by internet e-mail to infocollects@nrc.gov, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202, (3150-0120), Office of Management and Budget, Washington, DC 20503. If a means used to impose an information collection does not display a currently valid OMB control number, the NRC may not conduct or sponsor, and a person is not required to respond to, the information collection.

INSTRUCTIONS: SEE THE APPROPRIATE LICENSE APPLICATION GUIDE FOR DETAILED INSTRUCTIONS FOR COMPLETING APPLICATION. SEND TWO COPIES OF THE ENTIRE COMPLETED APPLICATION TO THE NRC OFFICE SPECIFIED BELOW.

APPLICATION FOR DISTRIBUTION OF EXEMPT PRODUCTS FILE APPLICATIONS WITH:

DIVISION OF INDUSTRIAL AND MEDICAL NUCLEAR SAFETY
OFFICE OF NUCLEAR MATERIALS SAFETY AND SAFEGUARDS
U.S. NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555-0001

ALL OTHER PERSONS FILE APPLICATIONS AS FOLLOWS:

IF YOU ARE LOCATED IN:

ALABAMA, CONNECTICUT, DELAWARE, DISTRICT OF COLUMBIA, FLORIDA, GEORGIA, KENTUCKY, MAINE, MARYLAND, MASSACHUSETTS, MISSISSIPPI, NEW HAMPSHIRE, NEW JERSEY, NEW YORK, NORTH CAROLINA, PENNSYLVANIA, PUERTO RICO, RHODE ISLAND, SOUTH CAROLINA, TENNESSEE, VERMONT, VIRGINIA, VIRGIN ISLANDS, OR WEST VIRGINIA, SEND APPLICATIONS TO:

LICENSING ASSISTANCE TEAM
DIVISION OF NUCLEAR MATERIALS SAFETY
U.S. NUCLEAR REGULATORY COMMISSION, REGION I
475 ALLENDALE ROAD
KING OF PRUSSIA, PA 19406-1415

IF YOU ARE LOCATED IN:

ILLINOIS, INDIANA, IOWA, MICHIGAN, MINNESOTA, MISSOURI, OHIO, OR WISCONSIN, SEND APPLICATIONS TO:

MATERIALS LICENSING BRANCH
U.S. NUCLEAR REGULATORY COMMISSION, REGION III
2443 WARRENVILLE ROAD, SUITE 210
LISLE, IL 60532-4352

ALASKA, ARIZONA, ARKANSAS, CALIFORNIA, COLORADO, HAWAII, IDAHO, KANSAS, LOUISIANA, MONTANA, NEBRASKA, NEVADA, NEW MEXICO, NORTH DAKOTA, OKLAHOMA, OREGON, PACIFIC TRUST TERRITORIES, SOUTH DAKOTA, TEXAS, UTAH, WASHINGTON, OR WYOMING, SEND APPLICATIONS TO:

NUCLEAR MATERIALS LICENSING BRANCH
U.S. NUCLEAR REGULATORY COMMISSION, REGION IV
611 RYAN PLAZA DRIVE, SUITE 400
ARLINGTON, TX 76011-4005

PERSONS LOCATED IN AGREEMENT STATES SEND APPLICATIONS TO THE U.S. NUCLEAR REGULATORY COMMISSION ONLY IF THEY WISH TO POSSESS AND USE LICENSED MATERIAL IN STATES SUBJECT TO U.S.NUCLEAR REGULATORY COMMISSION JURISDICTIONS.

1. THIS IS AN APPLICATION FOR *(Check appropriate item)* ☐ A. NEW LICENSE ☐ B. AMENDMENT TO LICENSE NUMBER ☑ C. RENEWAL OF LICENSE NUMBER SUA-1534	2. NAME AND MAILING ADDRESS OF APPLICANT *(Include ZIP code)* Crow Butte Resources, Inc. 141 Union Blvd. Suite 330 Lakewood, CO 80228
3. ADDRESS WHERE LICENSED MATERIAL WILL BE USED OR POSSESSED Crow Butte Resources, Inc. Dawes County Nebraska 86 Crow Butte Road Crawford, NEE 69339	4. NAME OF PERSON TO BE CONTACTED ABOUT THIS APPLICATION Stephen P. Collings TELEPHONE NUMBER (720) 879-5518

SUBMIT ITEMS 5 THROUGH 11 ON 8-1/2 X 11" PAPER. THE TYPE AND SCOPE OF INFORMATION TO BE PROVIDED IS DESCRIBED IN THE LICENSE APPLICATION GUIDE.

5. RADIOACTIVE MATERIAL a. Element and mass number; b. chemical and/or physical form; and c. maiximum amount which will be possessed at any one time.	6. PURPOSE(S) FOR WHICH LICENSED MATERIAL WILL BE USED.
7. INDIVIDUAL(S) RESPONSIBLE FOR RADIATION SAFETY PROGRAM AND THEIR TRAINING EXPERIENCE.	8. TRAINING FOR INDIVIDUALS WORKING IN OR FREQUENTING RESTRICTED AREAS.
9. FACILITIES AND EQUIPMENT.	10. RADIATION SAFETY PROGRAM.
11. WASTE MANAGEMENT.	12. LICENSE FEES *(See 10 CFR 170 and Section 170.31)* FEE CATEGORY 2.A.(2) AMOUNT ENCLOSED $ 0.00

13. CERTIFICATION. *(Must be completed by applicant)* THE APPLICANT UNDERSTANDS THAT ALL STATEMENTS AND REPRESENTATIONS MADE IN THIS APPLICATION ARE BINDING UPON THE APPLICANT.

THE APPLICANT AND ANY OFFICIAL EXECUTING THIS CERTIFICATION ON BEHALF OF THE APPLICANT, NAMED IN ITEM 2, CERTIFY THAT THIS APPLICATION IS PREPARED IN CONFORMITY WITH TITLE 10, CODE OF FEDERAL REGULATIONS, PARTS 30, 32, 33, 34, 35, 36, 39, AND 40, AND THAT ALL INFORMATION CONTANED HEREIN IS TRUE AND CORRECT TO THE BEST OF THEIR KNOWLEDGE AND BELIEF.

WARNING: 18 U.S.C. SECTION 1001 ACT OF JUNE 25, 1948 62 STAT. 749 MAKES IT A C RIMINAL OFFENSE TO MAKE A WILLFULLY FALSE STATEMENT OR REPRESENTATION TO ANY DEPARTMENT OR AGENCY OF THE UNITED STATES AS TO ANY MATTER WITHIN ITS JURIS DICTION.

CERTIFYING OFFICER -- TYPED/PRINTED NAME AND TITLE	SIGNATURE	DATE
Stephen P. Collings, President	Stephen P. Collings	11-26-07

FOR NRC USE ONLY

TYPE OF FEE	FEE LOG	FEE CATEGORY	AMOUNT RECEIVED	CHECK NUMBER	COMMENTS
			$		
APPROVED BY				DATE	

APPLICATION FOR RENEWAL OF SOUCE MATERIALS LICENSE SUA-1534 DOCKET NUMBER 40-8943

Responses to Items 5 through 11, NRC Form 313 Page One

Licensee: Crow Butte Resources, Inc.
141 Union Blvd, Suite 330
Lakewood, Colorado 80228

5. RADIOACTIVE MATERIAL:

a) Element and Mass Number:

Uranium (natural uranium, or Unat; a mixture of U_{238}, U_{234}, and U_{235})

b) Chemical and/or physical form:

Chemical form is U_3O_8; uranium product is termed yellowcake and is present as a solution (0 to 50 grams/liter), a slurry (1% to 50% U), or dried product (50% to 80% U).

c) Maximum amount which will be possessed at any one time:

Crow Butte Resources, Inc. requests Unlimited possession amount.

6. PURPOSE FOR WHICH LICENSED MATERIAL WILL BE USED:

Fuel for the generation of electricity by nuclear power plants.

7. INDIVIDUAL(S) RESPONSIBLE FOR RADIATION SAFETY PROGRAM AND THEIR TRAINING EXPERIENCE:

This information is provided in detail in Section 5.0 of Crow Butte Resources, Inc.'s "Application for Renewal of USNRC Source Materials License SUA-1534".

8. TRAINING FOR INDIVIDUALS WORKING IN OR FREQUENTING RESTRICTED AREAS:

This information is provided in detail in Section 5.0 of Crow Butte Resources, Inc.'s "Application for Renewal of USNRC Source Materials License SUA-1534".

9. FACILITIES AND EQUIPMENT:

This information is provided in detail in Section 3.0 of Crow Butte Resources, Inc.'s "Application for Renewal of USNRC Source Materials License SUA-1534".

10. RADIATION SAFETY PROGRAM:

This information is provided in detail in Section 5.0 of Crow Butte Resources, Inc.'s "Application for Renewal of USNRC Source Materials License SUA-1534".

11. WASTE MANAGEMENT:

This information is provided in detail in Section 5.0 of Crow Butte Resources, Inc.'s "Application for Renewal of USNRC Source Materials License SUA-1534".

CROW BUTTE RESOURCES, INC.

86 Crow Butte Road
P.O. Box 169
Crawford, Nebraska 69339-0169

(308) 665-2215
(308) 665-2341 – FAX

November 27, 2007

Mr. Steven J. Cohen, PG, Hydrogeologist
U.S. Nuclear Regulatory Commission
Office of Federal and State Materials and Environmental Management Program
Mail Stop T7E18
Washington, D.C. 20555-0001

Dear Mr. Cohen:

Enclosed are three copies of the Application for Renewal of Source Materials License No. SUA-1534, copies of the submittal letter for the Application and the NRC Form 313. An electronic copy of the License Renewal Application will follow under separate cover.

Should you have any questions concerning any of the enclosures please don't hesitate to call. I can be reached by telephone at (308) 665-2234 ext. 115 or by email at rgrantham@bbc.net.

Sincerely,

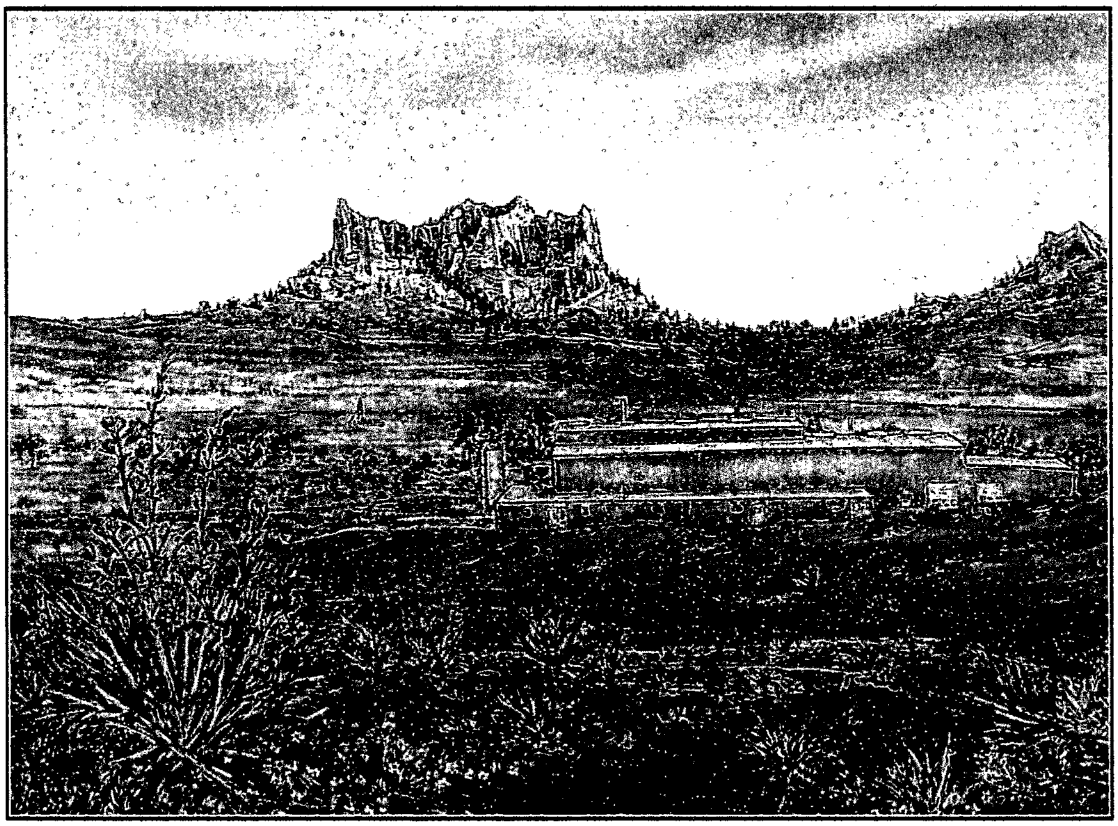
Rhonda Grantham, Supervisor
Radiation Safety and Regulatory Affairs

Enclosure

Application for 2007 License Renewal

USNRC Source Materials License SUA-1534

Crow Butte License Area



Prepared by:

Crow Butte Resources, Inc.

86 Crow Butte Road

Crawford Nebraska 69339

and

ARCADIS U.S., Inc.

630 Plaza Drive #100

Highlands Ranch Colorado 80129

November 2007

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FIGURES

TABLES

APPENDIX

ACRONYMS

ALARA	as low as reasonably achievable
Amsl	above mean sea level
bgs	below ground surface
BLM	Bureau of Land Management
BNSF	Burlington Northern Santa Fe
BPT	Best Practicable Technology
CAD	computer aided design
CBR	Crow Butte Resources, Inc.
CDP	Census Designated Places
CESQG	Conditionally Exempt Small Quantity Generator
CFR	Code of Federal Regulations
cfs	cubic feet per second
cm	Centimeter
cm/sec	centimeter per second
CO_2	carbon dioxide
cpm	counts per minute
CSA	Commercial Study Area
DAC	derived air concentration
dBA	A-weighted decibel
DDE	Deep Dose Equivalent
DEM	digital elevation model
DLG	Digital line graphic
DOT	Department of Transportation
DQO	Data Quality Objective
EA	Environmental Assessment
EDR	electro dialysis reversal
EHSMS	Environmental, Health and Safety Management System
EMS	Environmental Management System
ER	Environmental Report
ESRI	Environmental System Research Institute
FEMA	Federal Emergency Management Act
GIS	Geographic Information System
GNIS	Geographical Names Information System
gpd	gallons per day
gpdpp	gallons per day per person
gpm	gallons per minute
GPS	Geographic Positioning System
HP	horse power
HPRCC	High Plains Regional Climatic Center
HSMS	Health and Safety Management Systems
ISL	in-situ leach
km	kilometer
LLD	lower limit of detection
LRA	license renewal application
m/s	meters per second
MARLAP	multi-Agency Radiological Laboratory Analytical Protocols Manual

MeV	mega electronvolt
μg/m^3	micrograms per cubic meter
mg/L	milligrams per liter
MIT	mechanical integrity test
mph	miles per hour
mREM	miliroentgen equivalent, man
MSDS	material data safety sheet
msl	mean sea level
NAAQS	National Ambient Air Quality Standards
NASS	National Agricultural Statistics Service
NDED	Nebraska Department of Economic Development
NDEQ	Nebraska Department of Environmental Quality
NDNR	Nebraska Department of Natural Resources
NGPC	Nebraska Game and Parks Commission
NGS	National Geodetic Survey
NOAA	National Oceanic Atmospheric Association
NOI	Notice of Intent
NOU	Nebraska Ornithologists' Union's
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NTEA	North Trend Expansion Area
NUREG-1569	Standard Review Plan for In-situ Leach Uranium Extraction License Application
pCi/g	pico curies per gram
PPE	personal protective equipment
ppm	parts per million
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAM	Quality Assurance Manual
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RMP	Risk Management Program
RO	reverse osmosis
ROI	radius of influence
RWP	Radiation Work Permit
SERP	Safety and Environmental Review Panel
SH	State Highway
SHEQMS	Safety Health Environment and Quality Management System
SHPO	State Historic Preservation Office
SOP	standard operating procedure
SPCC	Spill Prevention, Control, and Countermeasure
SSC	Structure, System, or Component
S.U.	Standard nits
SWPPP	Stormwater Pollution Prevention Plan
SRWP	standing radiation work permits
TDS	total dissolved solids

TEDE	Total Effective Dose Equivalent
TER	Technical Evaluation Report
TR	Technical Report
TSP	total suspended particulates
U_3O_8	triuranium octoxide
UCL	Upper Control Limits
UIC	Underground Injection Control
UMTRCA	Uranium Mill Tailings Radiation Control Act
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USDW	Underground source of drinking water
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
USFWS	United States Fish and Wildlife Service
USNRC	United States Nuclear Regulatory Commission
VRM	Visual Resource Management
WFC	Wyoming Fuel Company
WL	working levels
ww	Water well

1 PROPOSED ACTIVITIES

1.1 LICENSING 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 (USNRC). At the request of the USNRC, the ER and TR have been combined into one document, referred to from here on as the LRA, and incorporates applicable USNRC guidance regulations for both the TR and ER. This LRA concerns the continued commercial operation of uranium leach in-situ (ISL) mining resources located in Dawes County, Nebraska.

This LRA is prepared to supplement and update the information presented to the USNRC in support of issuance of Source Materials License SUA-1534 in 1989 and the subsequent renewal in 1997, 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 USNRC 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 USNRC format found in Regulatory Guide 3.46, *"Standard Format and Content of License Applications, Including Environmental Reports, For In Situ Uranium Solution Mining"* (June 1982). USNRC document NUREG-1569, *Standard Review Plan for In Situ Leach Uranium Extraction License Applications* (June 2003) was used to ensure that all information is provided to allow USNRC Staff to complete their review of this amendment application. NUREG-1748, *Environmental Review Guidance for Licensing Actions Associated with NMSS Programs* (August 2003) was also used to ensure information typically found in the ER was appropriately incorporated into this LRA.

1.2 CROW BUTTE PROJECT BACKGROUND

What is now the Crow Butte Project was originally developed by Wyoming Fuel Corporation, which constructed a R&D facility in 1985 - 1986. In 1986 the project was 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.

The land (fee and leases) at the Crow Butte facility is owned by Crow Butte Land Company, which is a Nebraska Corporation. All of the officers and directors of Crow Butte Land Company are U.S. Citizens. Crow Butte Land Company is owned by Crow Butte Resources, Inc., which is the licensed operator of the facility. Crow Butte

Resources, which does business as Cameco Resources, is also a Nebraska cooperation. All of its officers are U.S. Citizens, as are 2/3 of its directors. Crow Butte Resources is owned by Cameco US Holdings, Inc., which is a U.S. corporation registered in Nevada. For Cameco US Holdings, ¾ of the officers are U.S. citizens, as are 2/3 of the directors. Cameco US Holdings is held by Cameco Corporation, which is a Canadian corporation. Cameco Corporation is publicly traded on both the Toronto and New York Stock Exchanges.

The R&D facility was located in the N1/2SE1/4 of Section 19, Township 31 North, Range 51 West, Dawes County, Nebraska. Operations at this facility were initiated in July 1986, and mining took place in two wellfields (WF-1 and WF-2). Mining in WF-2 was completed in 1987, and restoration of that wellfield has been completed. WF-1 was incorporated into Mine Unit 1 of commercial operations.

CBR has successfully operated the current production area since commercial operations began in 1991. Production of uranium has been maintained at design quantities throughout that period with no adverse environmental impacts.

1.3 SITE LOCATION AND DESCRIPTION

The location of the Crow Butte License Area (License Area) is in portions of Sections 11, 12, 13, and 24 of Township 31 North, Range 52 West and Sections 18, 19, 20, 29, and 30 of Township 31 North, Range 51 West, Dawes County, Nebraska (**Figure 1.3-1**). The plant site is situated approximately 4.0 miles southeast of the City of Crawford. The current production and planned wellfields are located within the License Area as shown in **Figure 1.3-2**. The process plant is located in Section 19, Township 31 North, Range 51 West, Dawes County, Nebraska. The current License Area occupies approximately 2,875 acres, and the surface area affected over the estimated life of the project is approximately 1,265 acres (**Figure 1.3-3**).

Approximately 100 percent of the minerals leased in the License Area are on private lands. Surface landownership includes federal, state/local government, and private ownership as shown in **Table 1.3-1**. **Figure 1.3-4** shows the land ownership within the License Area.

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

Owner	Percent Ownership
Federal Government	4
State/Local Government	9
Private	89

Note: Percent ownership rounded up to the nearest whole percent.

Figure 1.3-1: Current License Area Boundary & Proposed North Trend Boundary

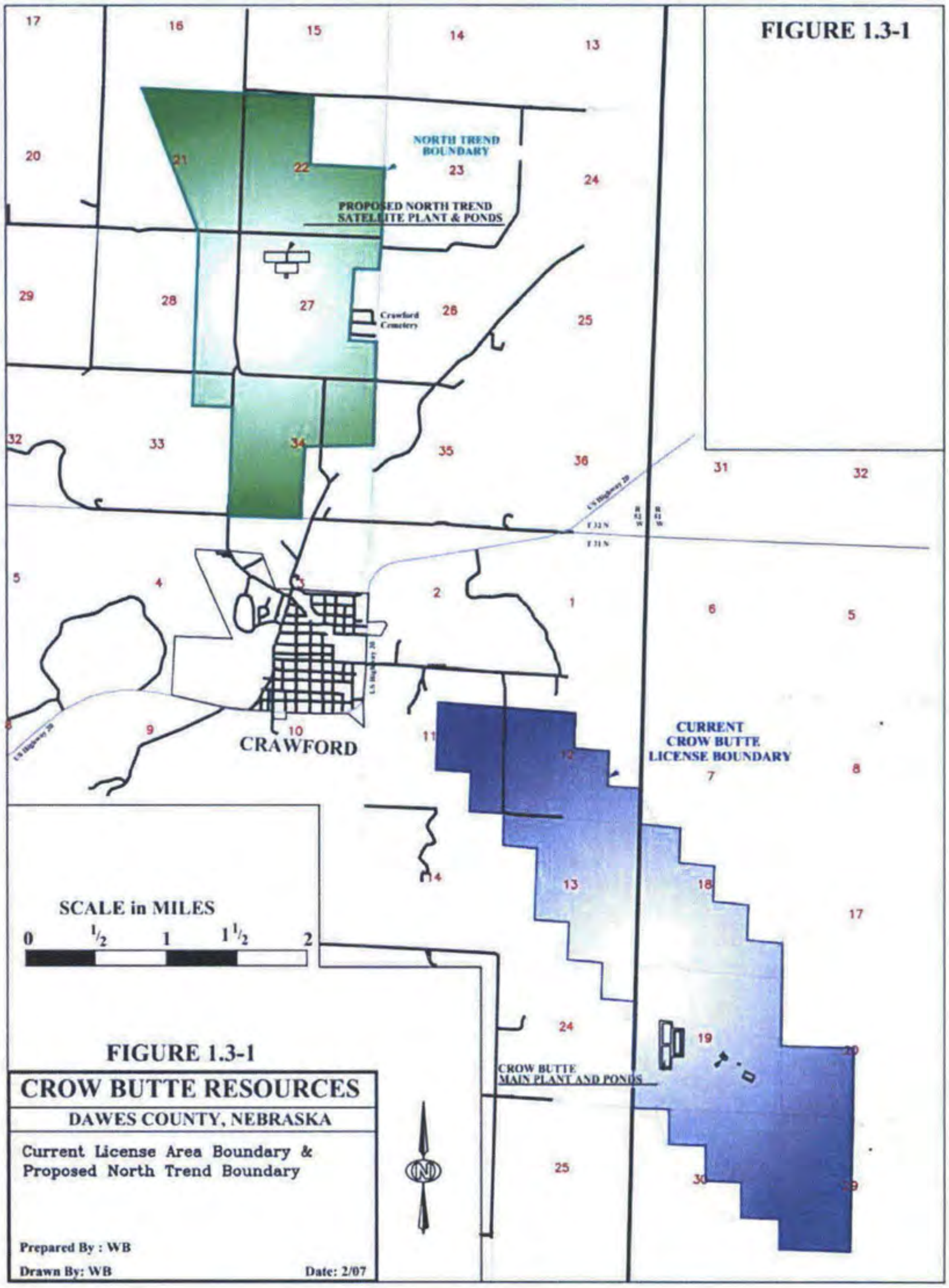

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Figure 1.3-2: Current License Area and Mine Units

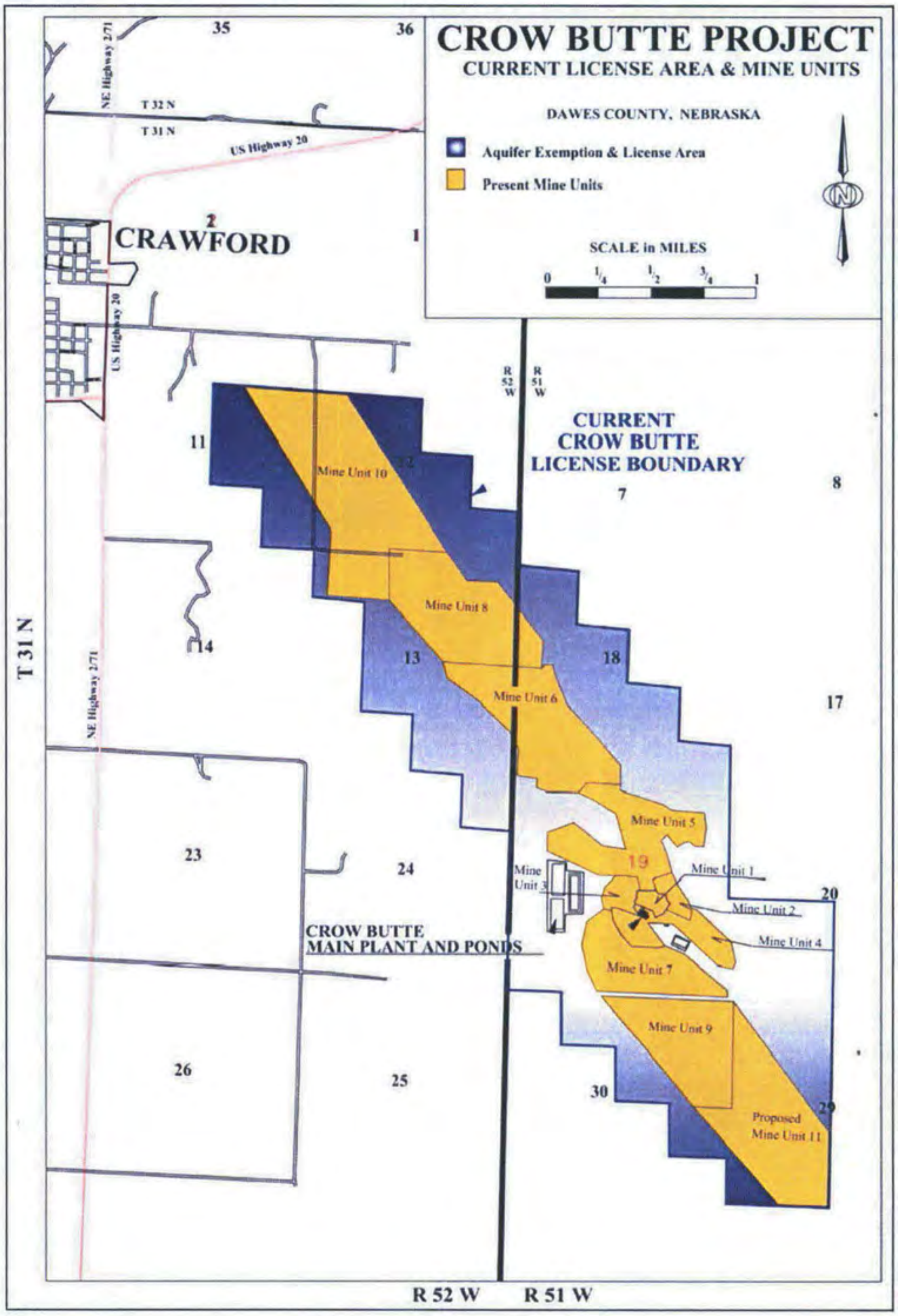

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Figure 1.3-3: Crow Butte Project Surface Disturbance Area and Acreage including Mine Unit 11

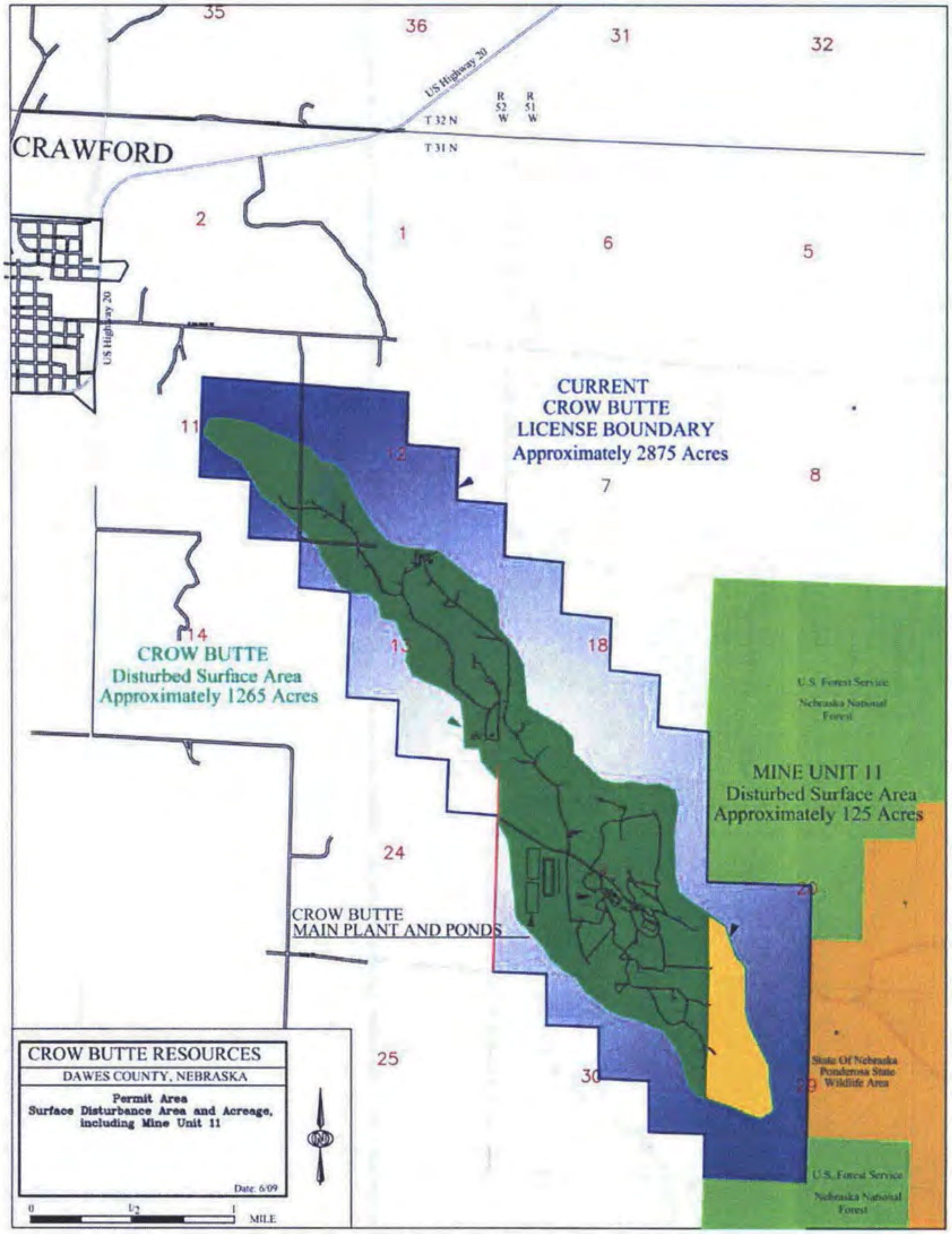

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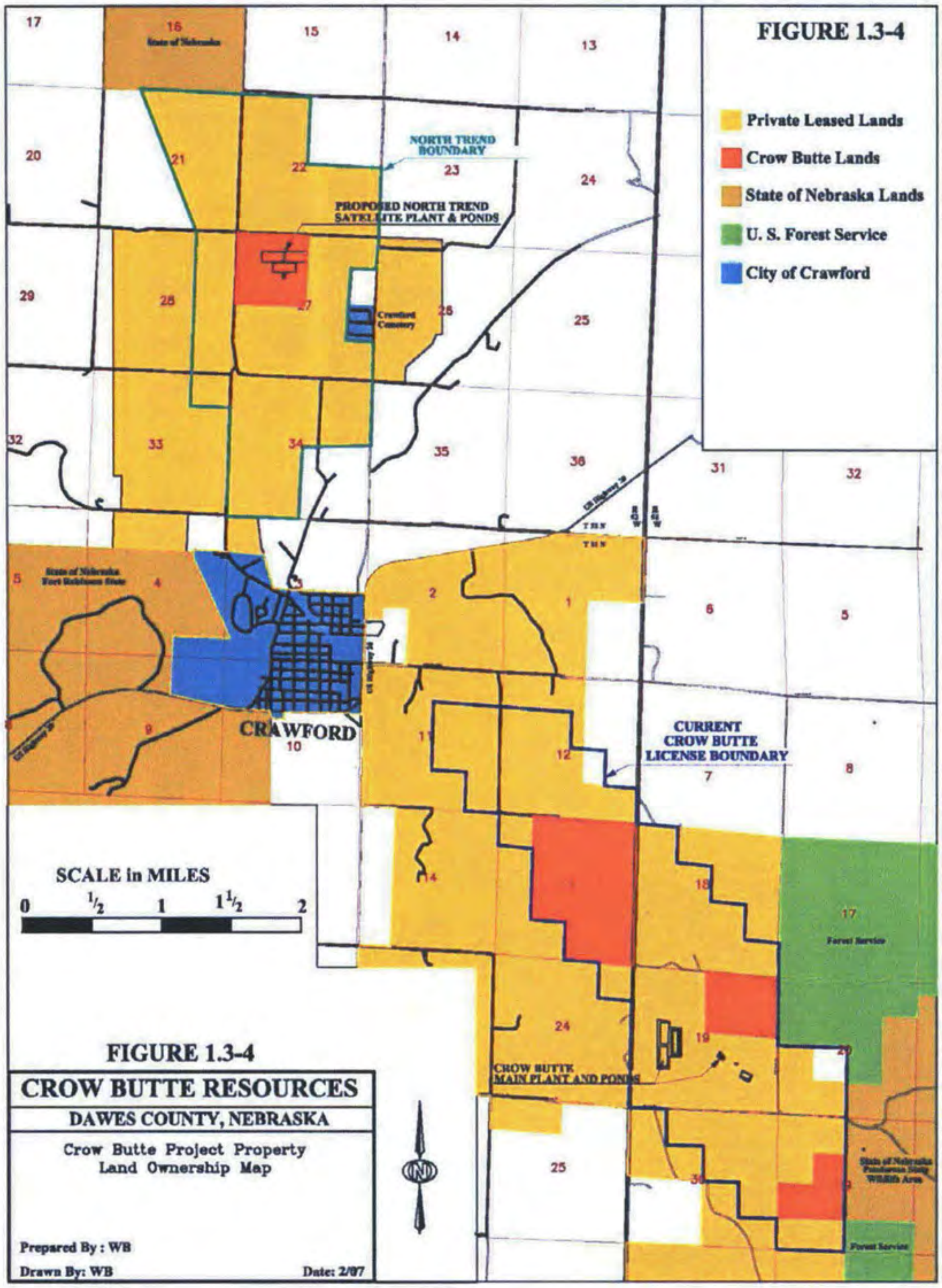
Figure 1.3-4: Crow Butte Project Property Land Ownership Map



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1.4 ORE BODY DESCRIPTION

In the current license area, uranium is recovered by ISL from the Chadron Sandstone at a depth that varies from 400 feet to 900 feet. The overall width of the mineralized area varies from 1000 feet to 5000 feet. 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, with an estimated at 0.27 percent U_3O_8.

1.5 SOLUTION MINING METHOD AND RECOVERY PROCESS

The ISL 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.

Section 3.0 (Description of Proposed Facility) provides a detailed description of the solution mining process and equipment.

1.5.1 Advantages of ISL Uranium Mining

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

- ISL mining results in significantly less surface disturbance since mine pits, waste dumps, haul roads, and tailings ponds are not needed;
- ISL mining requires much less 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, etc. result in very little air quality degradation at ISL mines;
- Fewer employees are needed at ISL mines, thereby reducing transportation and socioeconomic concerns;
- Aquifers are not excavated, but remain intact during and after ISL mining;

- Tailings ponds are not used, thereby eliminating a major groundwater pollution concern. State of the art lined evaporation ponds may be used to manage liquid waste streams; and
- ISL uranium mining results in leaving the majority of other contaminants (e.g., heavy metals) where they naturally occur instead of moving them to waste dumps and tailings ponds where their presence is of more environmental concern.

1.5.2 Ore Amenability to the ISL Mining Method

Amenability of the uranium deposits in the License Area to ISL mining was demonstrated initially through core studies. Results of the core studies were confirmed in the R&D project at the Crow Butte site using bicarbonate/carbonate leaching solutions with oxygen. Reports concerning the results of the R&D activities, including restoration of affected groundwater, were previously submitted to USNRC and the Nebraska Department of Environmental Quality (NDEQ).

The information and experience gained during these pilot programs formed the basis for the commercial uranium ISL mining operations. CBR believes that the current commercial project, including the successful restoration of groundwater in Mine Unit 1, 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 this project 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

The current Crow Butte Central Plant is licensed for a process flow rate of 5,000 gallons per minute (gpm), excluding restoration flow, under SUA-1534. Total annual production is limited to 2 million pounds of yellowcake. On October 16, 2006, CBR submitted a request to the USNRC for a license amendment to increase the plant throughput from 5,000 to 9,000 gpm. USNRC approval is pending.

The uranium-bearing solution extracted from the subsurface of the Crow Butte License Area is transported via pipeline to the Crow Butte Central Plant for elution, drying, and packaging. This cycle will continue until the ore zone is depleted or leach of the uranium is no longer economically viable.

1.7 PROPOSED OPERATING SCHEDULE

Based on current plans, mining schedules, and reserve estimates, CBR could continue production at the present annual level of approximately 800,000 pounds U_3O_8 until 2012, when reserves would begin to deplete. CBR estimates that by 2014, production in the current license area would decrease to the point where commercial operations would no longer be economical and would be discontinued. Groundwater restoration, surface

reclamation, and decommissioning would become the primary activities. Completion of groundwater restoration in the current License Area is scheduled for 2023.

Projected production and restoration schedules for the current production area are shown in **Figure 1.7-1**. Status of the current mine unit operations is shown in **Table 1.7-1.** The layout of the current and planned mine units in the License Area is shown in **Figure 1.7-2.**

Table 1.7-1: Current Crow Butte Production Area Mine Unit Status

Mine Unit	Production Initiated	Current Status
Mine Unit 1	April 1991	Groundwater Restored; Reclamation Underway
Mine Unit 2	March 1992	Groundwater restoration
Mine Unit 3	January 1993	Groundwater restoration
Mine Unit 4	March 1994	Groundwater restoration
Mine Unit 5	January 1996	Groundwater restoration
Mine Unit 6	March 1998	Production
Mine Unit 7	July 1999	Production
Mine Unit 8	July 2002	Production
Mine Unit 9	October 2003	Production
Mine Unit 10	August 2007	Production
Mine Unit 11	Pending	Under construction

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Figure 1.7-1 Current Production Area Mine Unit Schedule

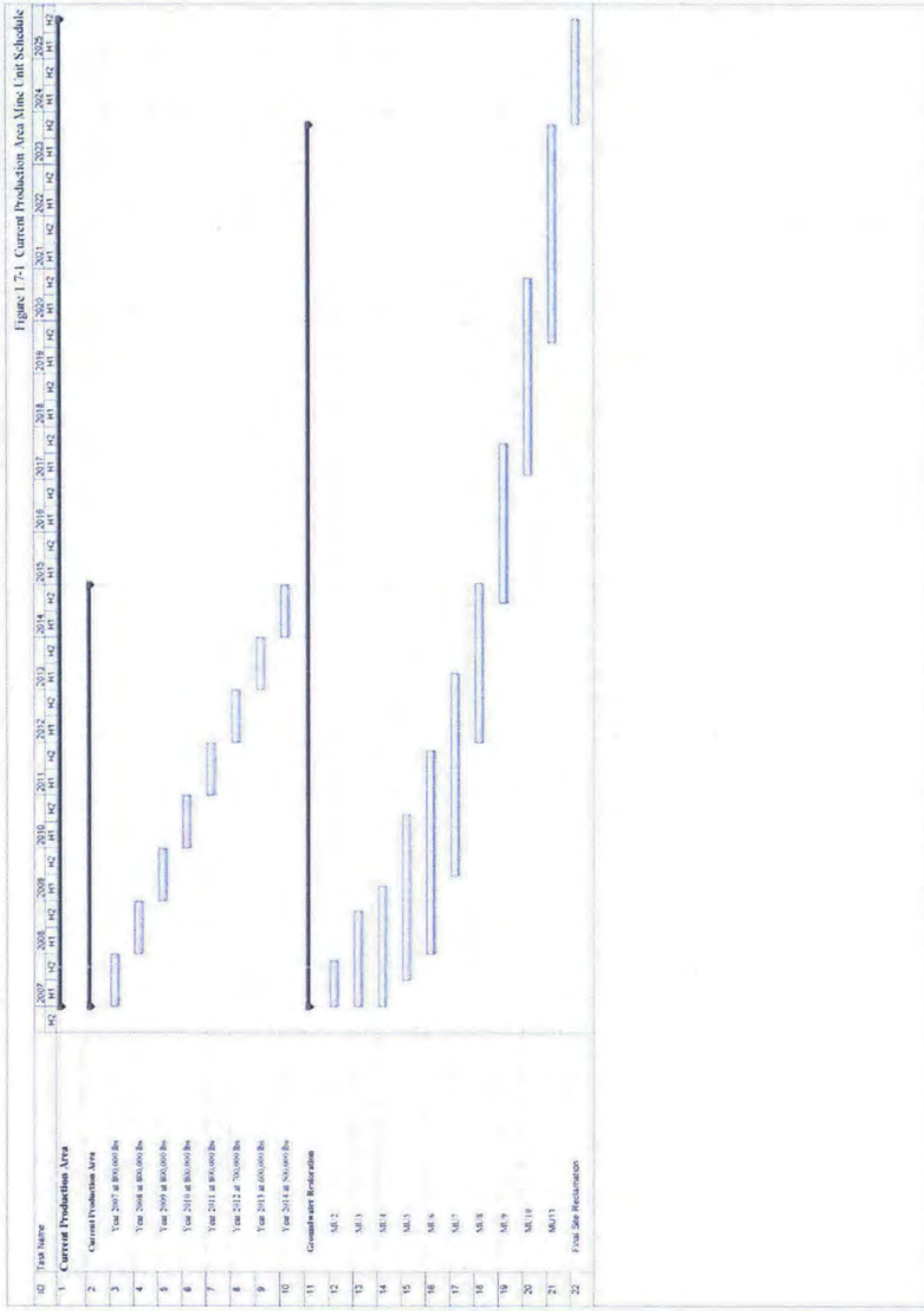

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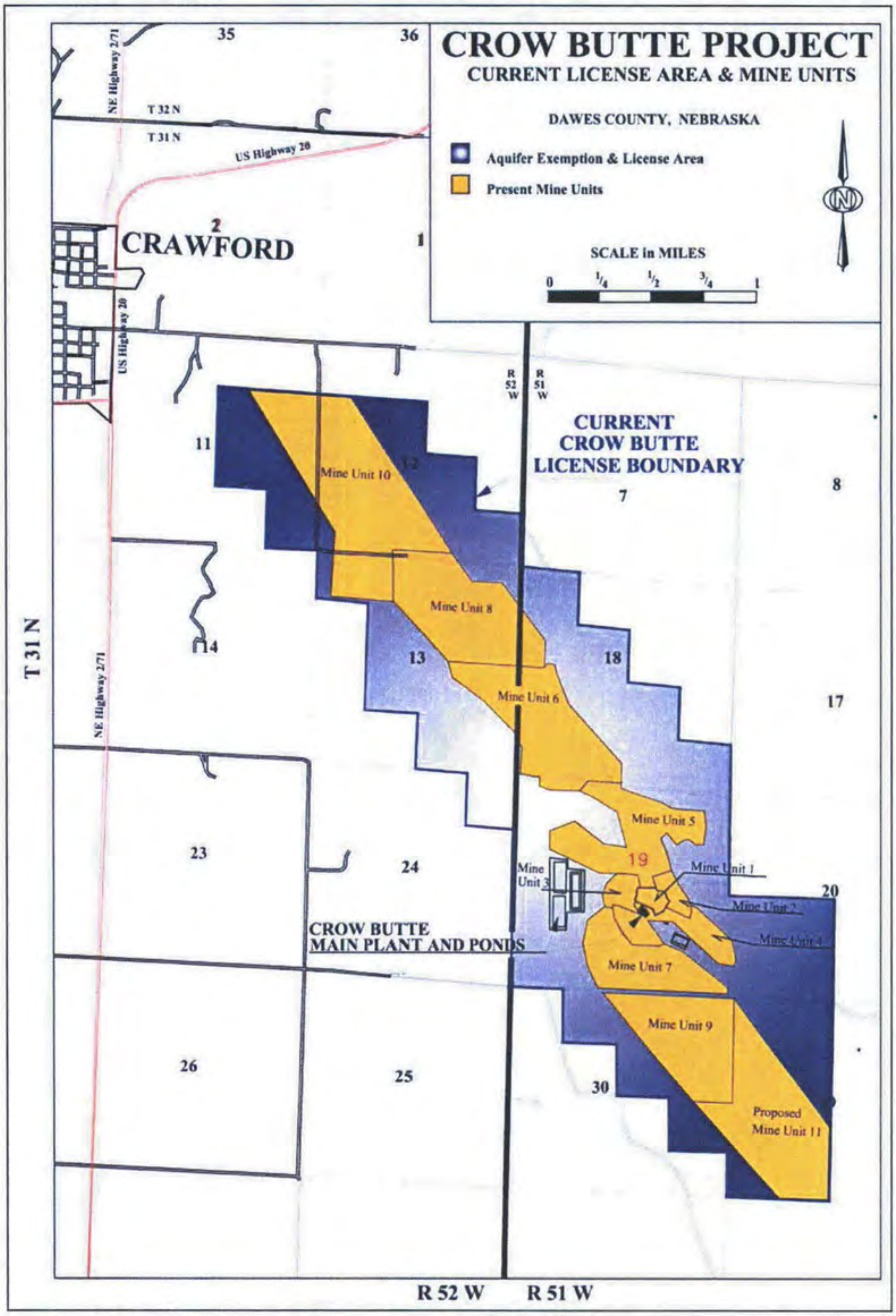
Figure 1.7-2: Current License Area and Mine Units



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1.8 WASTE MANAGEMENT AND DISPOSAL

1.8.1 Gaseous and Airborne Particulates

The only radioactive airborne effluent at the Crow Butte Project is radon-222 gas. As yellowcake drying and packaging 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. 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 exhausting fan.

1.8.2 Liquid Waste

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 process facility 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.

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 or non-contaminated waste according to their radiological survey results. Contaminated byproduct waste that cannot be decontaminated is packaged and stored until it can be shipped to a licensed 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 NDEQ. Domestic waste is disposed of in an approved septic system.

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.

Section 4.0 (Effluent Control Systems) presents a detailed discussion of the effluent control systems for the current CBR project operations.

1.9 GROUNDWATER RESTORATION

Restoration activities will be carried out at the License Area concurrent with mining activities. The restoration process will be similar to that used to restore Wellfield No. 2 at the Crow Butte R&D site and Mine Unit 1 of the current commercial production area, and consist of four basic activities:

- **Groundwater transfer-** groundwater is transferred between the mining unit commencing restoration and a mine unit commencing production or another water source.
- **Groundwater sweep-** water is pumped from the wellfield, which results in an influx of baseline quality water from the wellfield perimeter.
- **Groundwater treatment-** water from injection wells is pumped to the restoration plant where ion exchange, reverse osmosis, filtration or other treatment methods take place.
- **Wellfield recirculation-** water is recirculated by pumping from the production wells and reinjecting the recovered solution. This will act to homogenize 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 NDEQ and the USNRC for approval. Groundwater restoration is described in more detail in

Section 6 (Groundwater Quality Restoration, Surface Reclamation and Facility Decommissioning).

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. Appropriate USNRC Regulatory Guidelines will be followed as required. Decommissioning and reclamation are discussed in more detail in **Section 6** (Groundwater Quality Restoration, Surface Reclamation and Facility Decommissioning).

1.11 SURETY ARRANGEMENTS

CBR maintains a USNRC-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 $22,980,913. The surety amount will be revised annually in accordance with the requirements of SUA-1534.

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2 SITE CHARACTERISTICS

2.1 SITE LOCATION AND LAYOUT

The location of the current license area of the Crow Butte project is in Sections 11, 12, 13 and 24 of Township 31 North, Range 52 West and Sections 18, 19, 20, 29, and 30 of Township 31 North, Range 51 West, Dawes County, Nebraska.

The maps used in this section and other sections of this amendment application are Vector 7.5 minute quad maps. These are computer-aided design (CAD) and geographic information systems (GIS) drawings where each road, stream, and contour line are individual entities. The layers in these maps were derived from the U.S. Census Bureau's TIGER/Line data, United States Geological Survey (USGS) Digital Line Graph (DLG) Data, USGS Digital Elevation Model (DEM) data, Bureau of Land Management (BLM) Section Line data, National Geodetic Survey (NGS) Benchmark data, and USGS Geographical Names Information System (GNIS) data. This base map was then used for each of the Figures prepared for this document with the addition of the pertinent information for that Figure.

Figure 2.1-1 shows the general area surrounding the License Area. **Figure 2.1-1** also shows the original Commercial Study Area (CSA) and the 3.2-kilometer (km) (2.0-mile) review area.

Figure 2.1-2 shows the general project site layout and Restricted Areas for the License Area including the Central Processing Plant building 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 R.O. building area.

Figure 2.1-3 shows the project location with topographical features, drainage and surface water features, nearby population centers and political boundaries as well as principal highways, railroads, transmission lines, and waterways.

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Figure 2.1-1

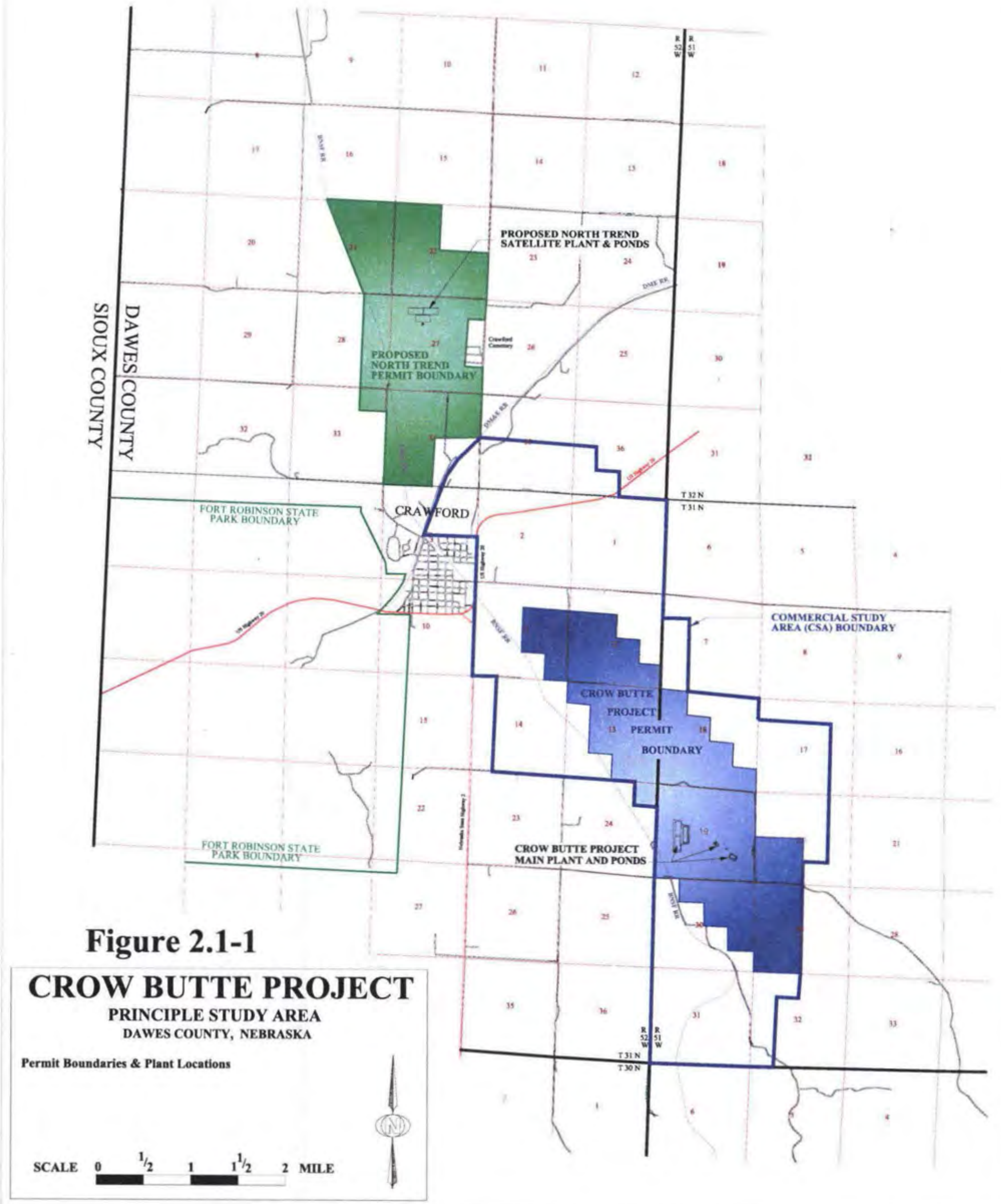
PROPOSED NORTH TREND
SATELLITE PLANT & PONDS
PROPOSED
NORTH TREND
PERMIT BOUNDARY
DAWES COUNTY
SIOUX COUNTY
FORT ROBINSON STATE
PARK BOUNDARY
CRAWFORD
COMMERCIAL STUDY
AREA (CSA) BOUNDARY
CROW BUTTE
PROJECT
PERMIT
BOUNDARY
FORT ROBINSON STATE
PARK BOUNDARY
CROW BUTTE PROJECT
MAIN PLANT AND PONDS
T 32 N
T 31 N
T 31 N
T 30 N
R 52 W
R 51 W
Figure 2.1-1
CROW BUTTE PROJECT
PRINCIPLE STUDY AREA
DAWES COUNTY, NEBRASKA
Permit Boundaries & Plant Locations
SCALE 0 1/2 1 1 1/2 2 MILE

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Figure 2.1-2: Current Project and Operation Site Layout

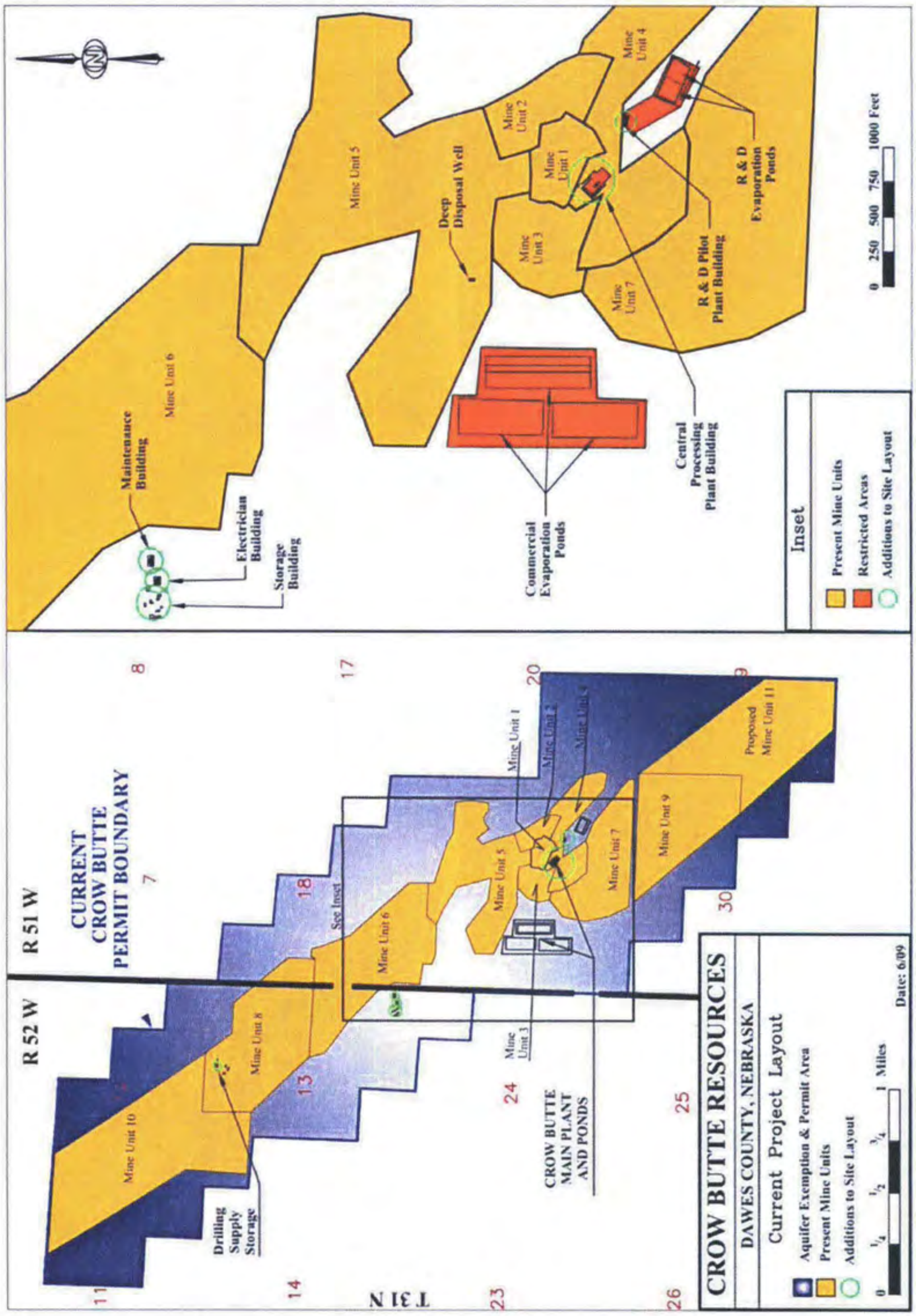

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Figure 2.1-3

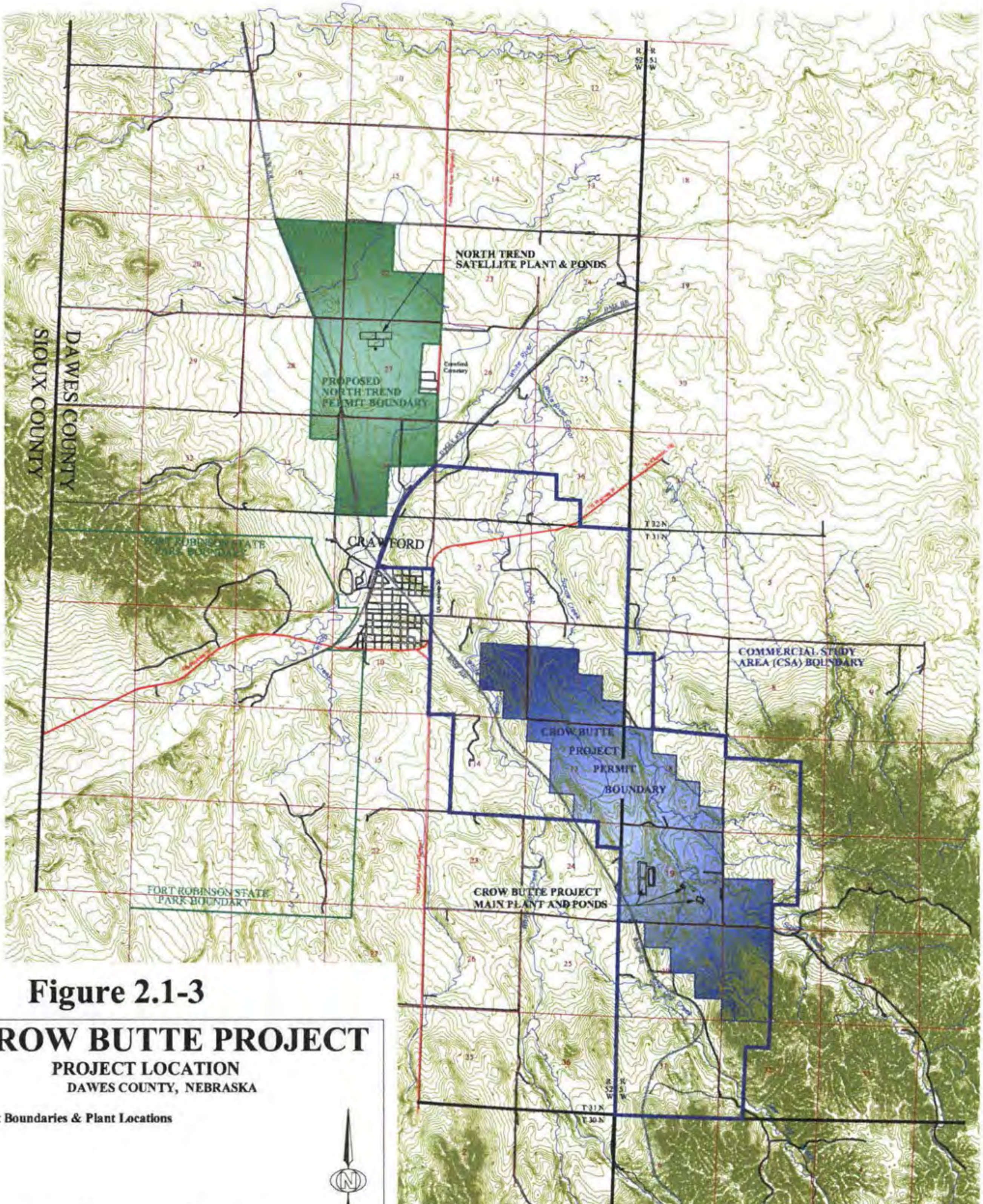

Figure 2.1-3

CROW BUTTE PROJECT

PROJECT LOCATION

DAWES COUNTY, NEBRASKA

Permit Boundaries & Plant Locations

SCALE 0 1/2 1 1 1/2 2 MILE

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2.2 USES OF ADJACENT LANDS AND WATERS

The information in this section provides relevant data concerning the physical, ecological and social characteristics of the commercial study area and surrounding environs for uranium in-situ mining.

This section indicates the nature and extent of present and projected land and water use and trends in population or industrial patterns. The information in this section was initially developed over a 9-month period in 1982 as part of the Research and Development (R&D) License Application and updated in 1987 for the Commercial License Application and in 1997 for the LRA. Preliminary data were obtained from several sources followed by field studies to collect on-site data to check land uses. Interviews with various state and local officials provided additional information.

NUREG 1569 requires discussion of land and water use in the proposed License Area, and within a 3.2 km (2.0-mile) radius surrounding the License Area. Because previous historical studies were performed assuming a 3.6-km (2.25-mile) review area, some data in this section are based on a 3.6-km (2.25-mile) radius. A 3.6-km (2.25-mile) radius was used rather than the required 3.2 km (2.0-mile) radius to remain consistent with other resource descriptions. For water resources, oil and gas resources and well locations, the standard 3.2 km (2.0-mile) review area is used.

2.2.1 General Setting

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 proposed project site. The Crow Butte Project site is about 4.0 miles southeast of the City of Crawford via Squaw Creek Road. State Highway (SH) 71 provides access to the License Area from points north and south of Crawford. U.S. Highway 20 provides access to Crawford and the License Area from points east and west.

Approximately 4 percent of the area within an 8-km (5-mile) radius of the License Area is located within the Nebraska National Forest. Also identified as the Pine Ridge, this area is covered with mixed evergreens and Ponderosa pines. The predominant land use in Dawes County, as well as the License Area, is livestock production. An annual average of 56,833 cattle valued at approximately $21.35 million was reported on Dawes County farms for the years 1978, 1979 and 1980 (Nebraska Crop and Livestock Reporting Service 1980, 1981). Cropland is used primarily for the production of winter wheat, alfalfa, and oats. Native grasslands are used for grazing or for cut hay. Livestock values and agricultural uses in 1987 have not changed appreciably in Dawes County in the last five years (Huls 1987, SCS 1987).

Recreational lands are also prevalent in Dawes County (**Figure 2.2-1** and **Table 2.2-1**). Fort Robinson State Park, the largest State Park in Nebraska, is located just outside the Crow Butte 8-km (5-mile) radius. Facilities at the park consist of lodging, showers, electrical hookups, pit toilets, ski and snowmobile trails, a rodeo arena, and museum. Visitors to the park may go hunting, fishing, hiking, swimming, or horseback riding. Other recreational facilities in Dawes County include the Ponderosa Wildlife Area, Chadron State Park, Soldier Creek Management Unit, Cochran Wayside Area, and the Red Cloud Picnic Area and associated trails in the Nebraska National Forest (Nebraska Game and Parks Commission 1982).

Urban land uses in the county are concentrated within the city limits of Crawford and Chadron. Approximately 73 rural occupied dwellings are located within the 8-km radius (USGS 1980, EH&A 1982).

2.2.2 Land and Mineral Ownership

Approximately 4.0 percent of land within the 8-km (5-mile) radius is owned by the federal government, while another 9.0 percent is owned by the state or local government (Bump Abstract, 1979). Except for lands within the City of Crawford, private land is predominantly owned by ranching families. Approximately 90 percent of all minerals leased in Dawes County are on private lands (Mathis, 1982). No Indian lands are present in the 8-km (5 mile) radius of the License Area.

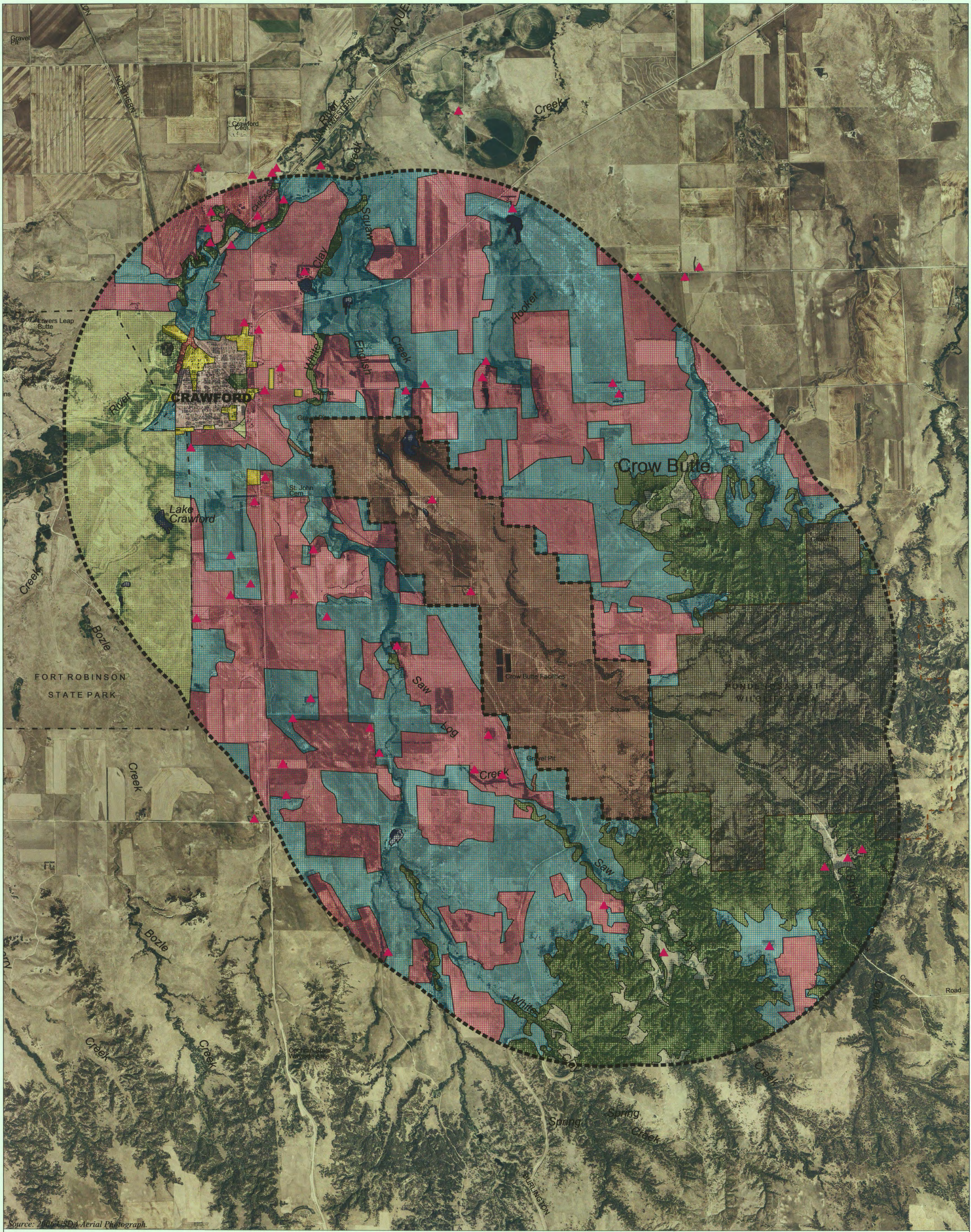
2.2.3 Land Use

The Crow Butte License Area is located in west central Dawes County, Nebraska, just north and west of the Pine Ridge area (**Figure 2.2-1**). The License Area is approximately 4 miles southeast of the City of Crawford on Squaw Creek Road. SH 2/71 provides access to the License Area from points north and south of Crawford. U.S. Highway 20 provides access to Crawford and the License Area from points east and west.

Land uses found within the License Area and 3.6-km (2.25-mile) review area 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 in 22 1/2° sectors centered on each of the 16 compass points within the License Area and 3.6-km (2.25-mile) review area. These sectors radiate out from the geographic center of the License Area. The total areas of the sectors vary because of the irregular site boundary.

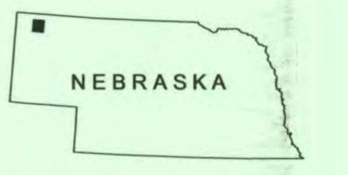
Pastureland comprises the greatest portion of land use within the License Area and surrounding 3.6-km (2.25-mile) area (43 percent) and is used for the production of hay. Cropland (29 percent), forest land (12 percent), and wildlife habitat (15 percent) are the other significant land uses.

CBR-011



LEGEND

- Cropland
- Commercial/Services
- Forested Land
- Habitat
- Industrial
- Mines, Quarries, or Gravel Pits
- Pastureland
- Rangeland
- Recreational
- Urban Residential
- Water
- Commercial Study Area (CSA)
- Crow Butte License Area
- Rural Residence



LOCATION MAP
N.T.S.

N

0 2000 4000
Scale in Feet

D-01

CROW BUTTE RESOURCES, INC.	
LAND USE MAP	
CROW BUTTE PROJECT Dawes County, Nebraska	
Scale: as shown	Date: 10/07	Figure 2.2-1

G:\AProject\Crow Butte Resources\CO001269.0001\ACAD\Figure 2.2-1 Land Use.dwg

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Table 2.2-1: Land Use Definitions

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

Table 2.2-2: Land Use of the Crow Butte Review Area 3.6-km (2.25-mile) Radius, By Sector and Category (in acres)

	N[b]	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Subtotal
C[a]	394.6	155.0	94.6	119.1	92.0		33.4		74.5	95.2	306.3	366.1	332.6	174.8	349.4	274.0	2,869.6
F	0.9	58.9	230.4	364.1	0.9	10.8	109.8	313.1	53.0	11.7		0.9	6.3	3.6	9.4	18.6	1,192.4
H				67.9	491.1	529.3	377.4	1.8									1,467.5
M										3.6			3.6		5.7		12.9
P	233.0	412.8	229.0	69.5	55.6	88.5	106.3	232.0	501.2	518.2	316.8	261.6	286.3	450.3	261.4	336.1	4,347.6
R		1.8	74.7				1.8	81.6									159.9
W											5.6				2.8		8.4
Total[b]	**628.5**	**628.5**	**628.7**	**620.6**	**639.6**	**628.6**	**628.7**	**628.5**	**628.7**	**628.7**	**628.7**	**628.6**	**628.8**	**628.7**	**628.7**	**628.7**	**10,058.3[c]**

Notes:

a See **Table 2.2-1** for land-use definitions.

b Calculations used in this Table for each of the 22-1/2 degree compass points:
0-1.8 km = 157.158 acres
1.8-3.6 km = 471.747 acres
Total 3.6 km = 628.91 acres

c Actual area of the 3.6-km radius is equal to 10,058.3 acres. However, multiplying the total acreage used for each compass point (628.91) by 16 equals 10,062.48 acres. Differences between these total as well as other subtotals are due to rounding.

Cropland is the second largest land use found within the License Area and is primarily used for the production of wheat. A small amount of cropland within the License Area is used for producing alfalfa. In 2003, the total wheat production in Dawes County was 1,836,500 bushels, an increase of 169 percent over the 2002 wheat production of 682,200 bushels.

Rangeland accounts for 4.2 percent of the total land acreage within the License Area. In 2006, an average of 52,000 head of livestock was reported in Dawes County (NASS 2007a). Native grasslands are used for grazing or for cut hay. Livestock values have remained consistent between the years 1990 and 2001, the last year for which livestock values are available. In 2001, cash receipts for livestock and products totaled $21.0 million in Dawes County.

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.

2.2.3.1 Recreation

Recreational lands also are present in Dawes County (**Table 2.2-3**). Recreational opportunities provided by federal and state lands in the county have become an increasingly important component of the local economy. Fort Robinson State Park, the largest state park in Nebraska, is located within the 3.6-km (2.25-mile) review area. Approximately 9 percent of the area within an 80-km (50-mile) radius of the License Area is located within the Fort Robinson State Park. This part of 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 Ponderosa Wildlife Management Area, Chadron State Park, Soldier Creek Management Unit, and the Red Cloud Picnic Area and associated trails in the Nebraska National Forest (NGPC 2007).

Table 2.2-3: Recreational Facilities within 80-km (50-Mile) of the Crow Butte License Area

Name of Recreational Facility	Distance From Current Crow Butte License Area (km)
Red Cloud Campground	30.58
Pine Ridge National Recreation Area	20.92
Roberts Trailhead and Campground	17.70
Museum of the Fur Trade	38.62
Toadstool Park	28.97
Warbonnet Battlefield	38.62
Hudson-Meng Bison Kill Site	27.36

Table 2.2-3: Recreational Facilities within 80-km (50-Mile) of the Crow Butte License Area

Name of Recreational Facility	Distance From Current Crow Butte License Area (km)
Crawford City Park	3.22
Whitney Lake	16.09
Legend Buttes Golf Course	3.22
Box Butte Reservoir	38.62
Ponderosa Wildlife Area	3.22
Peterson Wildlife Area	17.70
Walgren Lake State Recreation Area	61.15
Soldier Creek Wilderness	11.27
Chadron State Park	27.36
Agate Fossil Beds National Monument	43.45

Source: Nebraska Department of Travel and Tourism 2004.
DeLorme Maps 2006.

2.2.3.2 Agriculture

Several of the soil types found in the vicinity of the License Area are classified as prime farmland (NRCS 2007). However, in Dawes County, soils are classified by the Natural Resources Conservation Service (NRCS 2007) as prime farmland only if irrigated. According to 2004 Nebraska State Agricultural Statistics, only 2 percent of Dawes County agricultural land is irrigated, and about 10 percent of harvested cropland acreage is irrigated. The remainder of the irrigated land is used for pasture, habitat, or rangeland (NASS 2007b).

Table 2.2-4 through **Table 2.2-6** show agricultural productivity within Dawes County and the License Area. Wheat and hay are the major crops grown on croplands within the License Area. Most of these crops are used for livestock feed, while the remaining crops are commercially sold. Data for the acres of land planted and harvested, and production for beans, sunflowers, and sugar beets, were last reported by the National Agricultural Statistics Service (NASS) for the years 2001 and 2002. These crops are not produced in the License Area and surrounding 3.2 km (2.0-mile) review area. The livestock inventory for Dawes County indicates that cattle account for more than 80 percent of all livestock. According to a report prepared for the Economic Development Department of the Nebraska Public Power Corporation (2005), the market value of livestock products accounted for 85.7 percent of the total market value of all agricultural products sold in 2002. Livestock and livestock products had a value of $28.81 per acre, indicating that livestock production on rangeland within the review area has a potential value of more than $440,000.

2.2.3.3 Habitat

Habitat lands are those dedicated wholly or partially to the production, protection, or management of species of fish or wildlife. Significant areas classified as habitat include the Ponderosa State Wildlife Management Area, which is south and adjacent to the License Area as shown in **Figure 2.2-1**. Deer and turkey hunting are permitted within the Ponderosa State Wildlife Management Area. There is no land within the License Area that is used primarily for wildlife habitat. Wildlife habitat is a secondary use of rangeland, forestland, and recreational land within the License Area and the 3.6-km (2.25-mile) review area.

Table 2.2-4: 2006 Agricultural Yields for Croplands in Dawes County

Commodity	Planted		Harvested		Yield		Production
	Acres[a]	km^2	Acres[a]	km^2	Per acre	Per km^2	
Wheat Winter All	37,000	150	35,300	143	38 bu	9,291 bu	1,325,900 bu
Corn For Grain	2,500	10	700	3	161 bu	39,784 bu	112,700 bu
Corn For Silage	na	na	1,700	7	11 ton	2,743 ton	18,900 ton
Oats	4,000	16	500	2	16 bu	3,954 bu	8,000 bu
Hay Alfalfa (Dry) [b]	na	na	32,500	132	2 ton	381 ton	49,900 ton
Hay Other (Dry)	na	na	24,000	97	1 ton	198 ton	19,200 ton
Hay All (Dry)	na	na	56,500	229	1 ton	301 ton	69,100 ton

Notes:
bu bushels
[a] 1 acre = 0.0040469 square kilometer (km^2)
[b] Includes wild and tame alfalfa.
Na Not available
Source: National Agricultural Statistics Service 2007b.

Table 2.2-5: Potential Agricultural Production for Cropland in the License Area and the 3.2 km (2.0-Mile) Review Area

	Percent of Total Planted[a]	Total Cropland (acres) [b]	Percent of Planted/ Harvested[c]	Harvested (acres)	Harvested (km^2)	Production[d] (bushels)
Wheat	33.3	9,718.6	95.4	9,271.54	120,530.02	352,318.52

Notes:
[a] Same as for Dawes County..
[b] 1 acre = .0040469 km^2.
[c] assume 95.4 percent is harvested
[d] assume 38 bushels per acre
Source: National Agricultural Statistics Service 2007b.

Table 2.2-6: Livestock Inventory for Dawes County, 2002

Livestock Type	Number	Percent of Total	Animal Units [a]	
			Pounds (000s)	Percent
All cattle, except dairy	47,258	94.7	47,258	98.8
Dairy cattle	148	<1	148	<1
Hogs	305	<1	67.1	<1
Sheep	1,740	<1	348	<1
Chickens	431	<1	2.2	<1
Total animals	49,882	100.0	47,823.3	100.0

Notes:
[a] Animal unit conversions:
1 cow = 1,000 lb.
1 hog = 220 lb.
1 sheep = 200 lb.
1 chicken = 5 lb.
1 animal unit = 1,000 lb.
Source: Nebraska Department of Economic Development 2007

2.2.3.4 Residential

According to 1980 USGS 7.5 minute quadrangle maps, on-site field investigations, and USGS aerial photos flown in 2006, there are 73 occupied dwelling units located in the rural area outside of Crawford in the Crow Butte License Area 8-km (5-mile) radius (**Table 2.2-7**). According to U.S. Census 2000, the average persons per household estimate for Dawes County of 2.28 people per housing unit results in an estimated 166 persons who reside in the 8-km (5-mile) radius, a decrease from the 1982 estimate of 181 persons. An additional 1,035 persons reside in Crawford, approximately 4 miles from the site center point (U.S. Bureau of the Census 2006). Two dwelling units are within 0.62 mile, and another five dwelling units are within 1.24 miles of the center point of the License Area.

Table 2.2-7 shows the distance to the nearest residence and to the nearest site boundary of residences within the 8-km (5-mile) review area from the center of the License Area for each 22 1/2° sector centered on each compass point. There are no dwelling units within 0.62 mile of the center point of the proposed License Area. Four dwelling units are within 1.24 miles.

Table 2.2-7: Residence Count and Distance within the 8-km (5-mile) Radius of License Area Center Point

Sector [c]	Structure Count [a]	Nearest Residence (km)	Nearest Vegetable Garden (km)	Nearest Project Boundary (km)
North	2	5.7	--	2.4
North-Northeast	1	4.0	--	2.0
Northeast	3	4.3	--	2.5
East-Northeast	6	0.6	0.6	2.1
East	0	--	--	2.1
East-Southeast	5	0.6	--	1.4
Southeast	1	4.5	--	2.9
South-Southeast	1	4.5	--	2.9
South	3	3.8	--	4.0
South-Southwest	2	5.0	--	2.3
Southwest	3	1.6	--	1.5
West-Southwest	3	3.1	--	1.3
West	3	2.5	--	1.3
West-Northwest	27[b]	4.4	--	1.3
Northwest	510[b]	3.1	--	5.4
North-Northwest	10	1.1	1.1	2.4

Notes:
[a] Residences.
[b] U.S. Census 2000 reported 537 housing units within the City of Crawford. As with the sectorial population, housing units for Crawford are allocated as 5 percent for the WNW sector and 95 percent for the NW sector.
[c] 22 1/2 ° sectors centered on each of the 16 compass points.
-- Not present
Sources: USDA FSA 2006; U.S. Bureau of the Census 2000.

2.2.3.5 Industrial and Mining

There are seven gravel pits within the 8-km (5-mile) radius of the License Area (**Figure 2.2-2**). Most of the pits are inactive, although a few are mined periodically for local road construction purposes. Gravel Pit #7 (GP-7) is located within the License Area and is currently being excavated by Crow Butte Resources for mine site road construction. Use of GP-4 and GP-5 by Crow Butte Resources has been discontinued due the limitied availability of gravel or the presence of nearby piping infrastructure. It is possible that GP-5 may be re-opened for excavation in the future.

Besides Crow Butte Resources, 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 8-km (5-mile) radius include the railroad station and maintenance yard at the City of Crawford.

There are no other industrial or mining uses within the License Area. 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.

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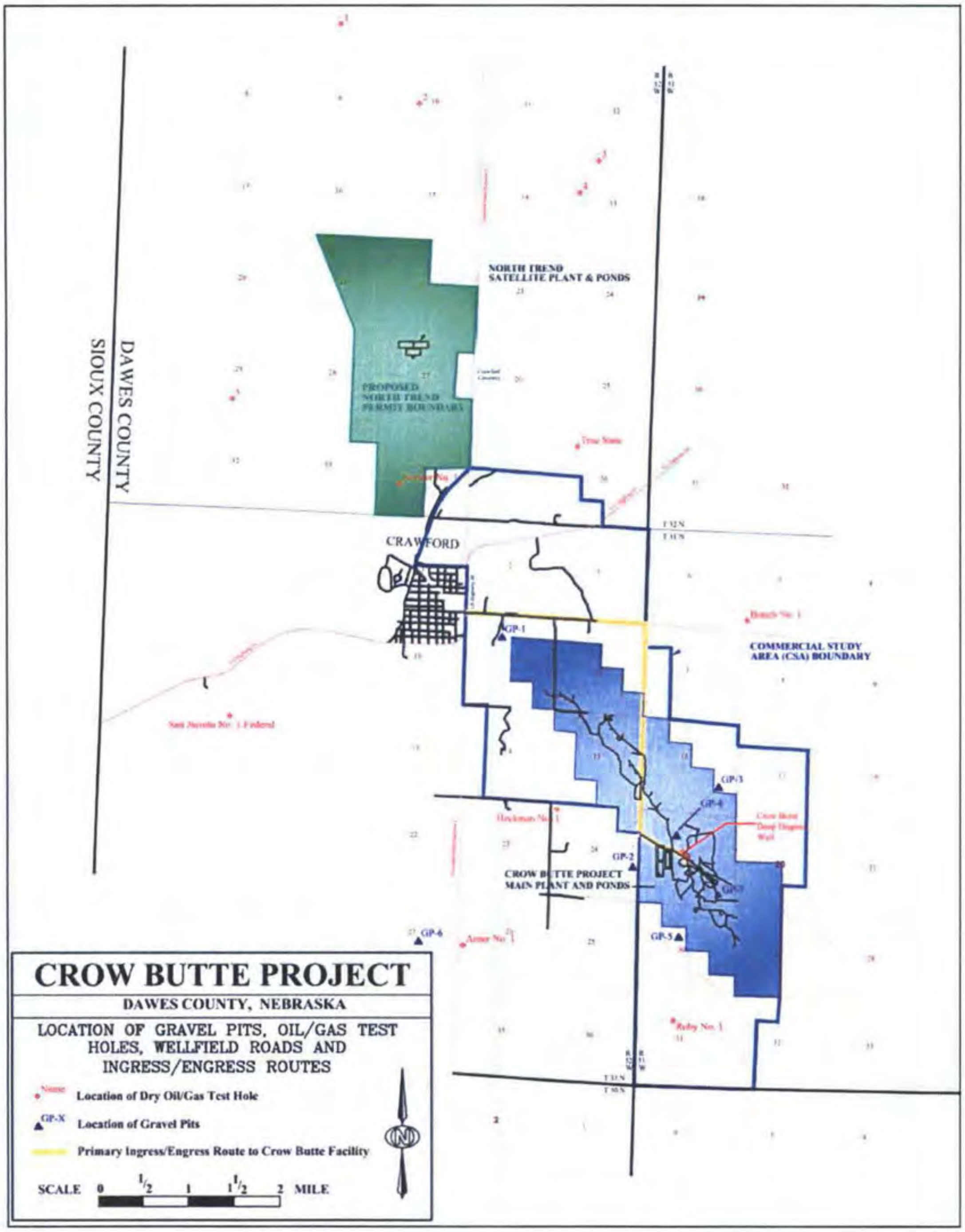
Figure 2.2-2: Crow Butte Location of Gravel Pits, Oil/Gas Test Holes, Wellfield Roads and Ingress/Egress Routes



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2.2.3.6 Transportation

Nebraska Highway 2/71 and U.S. Highway 20 converge in Crawford. The annual average daily traffic counts for 2004 range between 1,195 south of Crawford and 540 north of Crawford on Nebraska Highway 2, and 1,795 on U.S. Highway 20 north of the License Area (Nebraska Department of Roads 2007). Although unpaved, Squaw Creek Road provides access to the License Area. Preferred ingress and egress routes are indicated on **Figure 2.2-2**. Private roads providing access to operational areas of the Crow Butte License Area exist and are demarcated by signage to prevent public access.

Maintenance of state and county roads is performed by the Nebraska Department of Roads and Dawes County, respectively. Crow Butte Resources 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 0.75 miles west of the site. Several transmission lines traverse the License Area, including one less than 1 km west of the designated center point.

2.2.4 Water Use

The Crow Butte License Area 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. 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. Within 6.2 miles upstream of the License Area, the White River supplies drinking water to the citizens of Crawford. In 1981, average daily usage ranged from a low of 199 gallons per day per person (gpdpp) in February to a high of 508 gpdpp in July. The maximum recorded daily water usage in Crawford was nearly 1 million gallons.

Lake Crawford, as well as approximately 20 unnamed reservoirs ranging from 1 to 17 acres of surface area, is also located within a 10-km (6.2-mile) radius.

Groundwater within the 8-km (5-mile) License Area is supplied by either the Brule or Chadron Formations (Williams 1982). A water well survey conducted by Wyoming Fuel Company (WFC) indicates that most of the groundwater pumped from 123 wells surveyed within the 3.6-km (2.25-miles) radius of the proposed commercial License Area is used either to water livestock or for domestic purposes. A spring, located in Fort Robinson State Park, produces an average of 972,000 gallons per day (gpd) (Storbeck 1987).

Eight surface water impoundments are located within or adjacent to the License Area (**Figure 2.2-3**). 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 License Area, while impoundments I-3 through I-6 are located inside the License Area.

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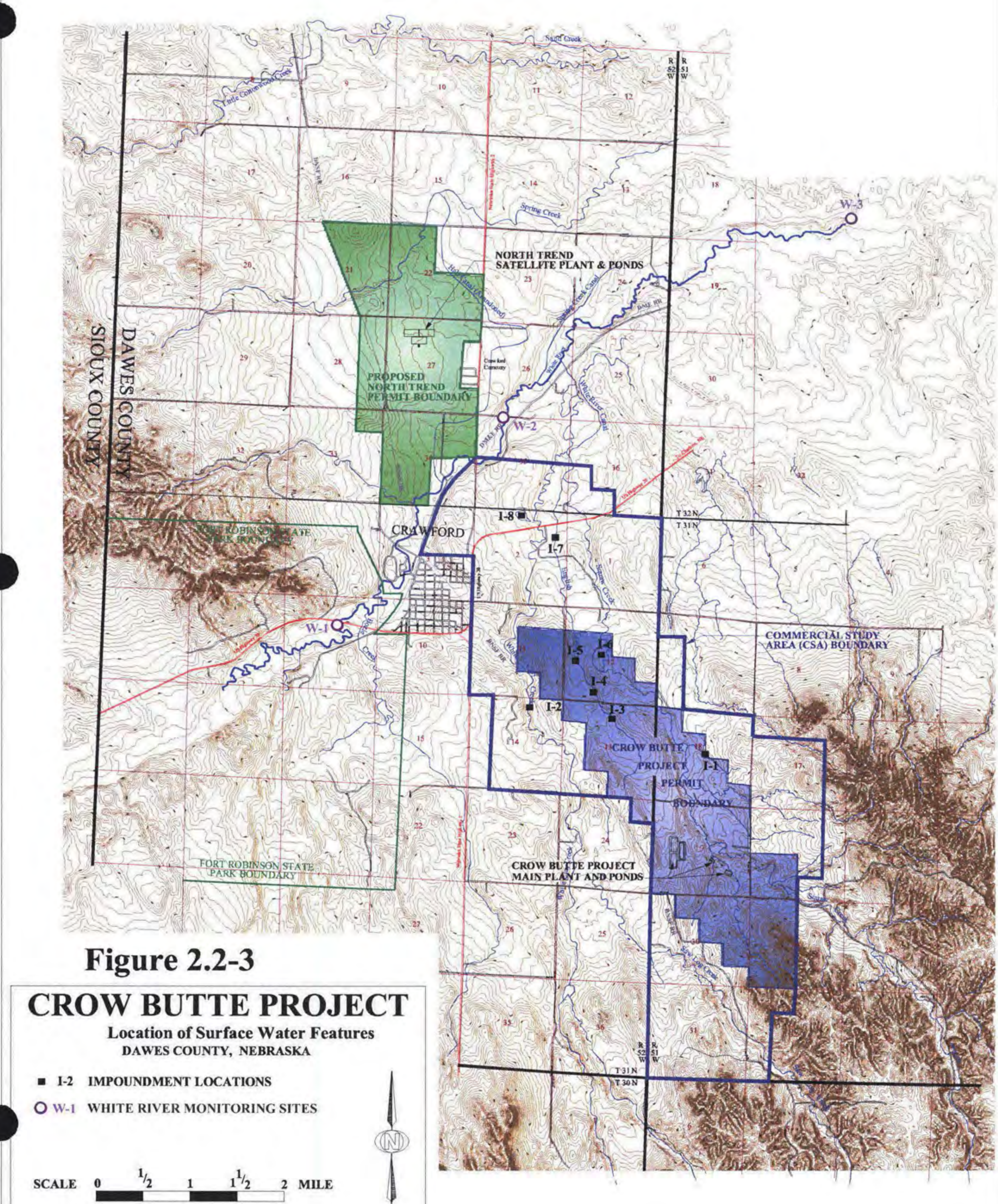
Figure 2.2-3



NORTH TREND
SATELLITE PLANT & PONDS
PROPOSED
NORTH TREND
PERMIT BOUNDARY
W-1
W-2
W-3
DAWES COUNTY
SIOUX COUNTY
CRAWFORD
FORT ROBINSON STATE
PARK BOUNDARY
Spring Creek
Little Cottonwood Creek
COMMERCIAL STUDY
AREA (CSA) BOUNDARY
CROW BUTTE
PROJECT
PERMIT
BOUNDARY
CROW BUTTE PROJECT
MAIN PLANT AND PONDS
I-1
I-2
I-3
I-4
I-5
I-6
I-7
I-8
T 32 N
T 31 N
T 30 N
R 52 W
R 51 W
Figure 2.2-3
CROW BUTTE PROJECT
Location of Surface Water Features
DAWES COUNTY, NEBRASKA
I-2 IMPOUNDMENT LOCATIONS
W-1 WHITE RIVER MONITORING SITES
SCALE 0 1/2 1 1 1/2 2 MILE
N

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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.

The White River and associated tributaries indirectly supply some of the drinking water to the citizens of Crawford. The city system, which serves a population of 1,115 (Nebraska Department of Health & Human Services 2004), is supplied by three infiltration galleries (located along the White River, Dead Man's Creek, and Soldier Creek) and two wells which produce "groundwater under the influence of surface water" (University of Nebraska, Lincoln undated).

Based on the Crawford Municipal Water Conservation Plan (Spring 2003), the average per capita water use in 2002 (including residential and business customers, public facilities including parks, and water lost to system leaks) was 323 gallons per day. Information regarding the City of Crawford water system is summarized in **Table 2.2-8** (CBR 2007).

Table 2.2-8: Summary of City of Crawford Water System

Description	Capacity
Raw Water Storage Capacity	500,000 gallons
Treated Water Capacity West Tank East Tank	 1,000,000 gallons 750,000 gallons
Average Daily Use (2006)	419,181 gallons
Maximum Daily Use	1,000,000 gallons
Supply Wells South Well #1 (100 feet deep); Reg: G-93533 NW1/4 SW1/4 Sec. 15, T31N, R52W West Well #2 (100 feet deep); Reg: G-93532 NW1/4 SW1/4 Sec. 15, T31N, R52W	104 gpm 54 gpm
Infiltration Gallery Pump #1; 27 feet; Reg: G-93551 SE1/4 SW1/4 Sec. 8 T31N R52W Pump #2; 27 feet; Reg: G-93551 SE1/4 SW1/4 Sec. 8 T31N R52W	420 gpm 420 gpm
Dewatering Wells; 20 to 26 feet deep SE1/4 SW1/4 Sec. 8 T31N R52W Reg Nos: 93528, 93529, 93530	33 gpm (each)

Source: CBR 2007

Alternate supplies of stock water are provided by the underlying Basal Chadron Sandstone (400 to 900 feet). However, because of greater depth and inferior water quality, the Basal Chadron is not used for a domestic supply within the License Area. In this regard, Gosselin et al. (1996) state that (1) "the sands near the bottom of the Chadron Formation yield sodium-sulfate water with high total dissolved solids", and (2) "near uranium deposits in the Crawford area, groundwater from the Chadron Formation is not suitable for domestic or livestock purposes because of high radium concentrations". Because of artesian pressure, most Chadron wells in the vicinity of the License Area either flow at the surface, or have water levels very close to surface elevation.

A summary of groundwater quality data collected from 1982 to 1987 to establish background conditions in the vicinity of the Crow Butte Project follows (**Table 2.2-9**). The data are presented for three hydrogeologic units: (1) the Chadron Sandstone (mining zone), the Brule Formation, which supplies the majority of groundwater in the project area, and (3) the Brule Alluvium. It is noted that supplies of Brule Alluvium are limited, and few wells produce from this interval, none of which are located in the License Area.

Table 2.2-9: Summary of Groundwater Quality Data – Crow Butte Vicinity

Constituent[1]	Brule Formation		Chadron Formation		Brule Alluvium	
	Range	Mean	Range	Mean	Range	Mean
Calcium	7.1 - 98	48	11 - 41	20	67 - 74	70.6
Magnesium	0.3 - 16	6.6	0.8 - 7.2	3.2	6.4 - 10	8.7
Sodium	12 - 340	104	340 - 540	411	34 - 41	36.5
Potassium	4.1 - 15.9	9.9	7.0 - 19.8	12.4	10.3 - 13	11.1
Bicarbonate	137 - 627	364	308 - 411	368	299 - 364	321
Sulfate	1 - 23	10	254 - 620	407	11 - 20	16.3
Chloride	1.6 - 192	48	134 - 250	176	5 - 10	6.7
Specific Conductance (μmhos)	246 - 1481	714	1500 - 2500	1932	507 - 614	548
PH (pH units)	6.80 - 8.50	7.80	7.60 - 8.70	8.20	7.10 - 8.40	7.70
Uranium (mg/L)	0.001 - 0.021	0.0064	<0.001 - 2.40	0.092	0.006 - 0.022	0.015
Radium-226 (pCi/l)	0.1 - 3.0	0.7	0.1 - 619	53	0.4 - 18.3	2.5

[1] Concentrations in mg/L, unless otherwise noted.

Future water use within the 2-mile review area will likely be a continuation of present use. Detailed surface and groundwater analysis is provided in **Section 2.7**.

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2.3 POPULATION DISTRIBUTION

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

2.3.1 Demography

2.3.1.1 Regional Population

The area within an 80-km (50-mile) radius of the License Area includes portions of six counties in northwestern Nebraska, two counties in southwestern South Dakota, and two counties in eastern Wyoming. Because the 80-km radius extends only slightly into two very rural counties in Wyoming (with populations of less than 2,000 persons), the regional demography in Wyoming is not discussed in detail beyond that summarized in **Tables 2.3-1** through **Table 2.3-3**. **Figure 2.3-1** depicts significant population centers within an 80-km radius of the License Area.

Historical and current population trends in the License Area counties and communities are contained in **Table 2.3-1**. Between 1960 and 1980, Box Butte County exhibited the fastest rate of growth with more than a 17 percent population increase, largely occurring in the latter half of the 1970s. Box Butte County lost population between 1980 and 2000, with the greater population losses occurring during the 1990s.

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

Table 2.3-1: Historical and Current Population Change for Counties and Towns within 80-km (50-mile) Radius of the License Area, 1960-2000

STATE County City	Population					Average Annual Percent Change			
	1960	1970	1980	1990	2000	1960/1970	1970/1980	1980/1990	1990/2000
NEBRASKA									
Dawes	9,536	9,761	9,609	9,021	9,060	2.4	-1.6	-6.1	0.4
Chadron	5,079	5,921	5,933	5,588	5,634	16.6	0.2	-5.8	0.8
Crawford	1,588	1,291	1,315	1,115	1,107	-18.7	1.9	-15.2	-0.7
Box Butte	11,688	10,094	13,696	13,130	12,158	-13.6	35.7	-4.1	-7.4
Alliance	7,845	6,862	9,869	9,765	8,959	-12.6	43.8	-1.1	-8.3
Hemingford	904	734	1,023	953	993	-18.8	39.4	-6.8	4.2
Sheridan	9,049	7,285	7,544	6,750	6,198	-19.5	3.6	-10.5	-8.2
Hay Springs	823	682	794	693	652	-17.1	16.4	-12.7	-5.9
Rushville	1,228	1,137	1,217	1,127	999	-7.4	7.0	-7.4	-11.4
Sioux	2,575	2,034	1,845	1,549	1,475	-21.0	-9.3	-16.0	-4.8
Harrison	448	377	361	241	279	-15.8	-4.2	-33.2	15.8
SOUTH DAKOTA									
Fall River	10,688	7,505	8,439	7,353	7,453	-29.8	12.4	-12.9	1.4
Hot Springs	4,943	4,434	4,742	4,325	4,129	-10.3	6.9	-8.8	-4.5
Oelrichs	132	94	124	138	145	-28.8	31.9	11.3	5.1
Ardmore	73	14	16	N/A	N/A	-80.8	14.3	N/A	N/A
Shannon	6,000	8,198	11,323	9,902	12,466	36.6	38.1	-12.6	25.9
Pine Ridge CDP	N/A	N/A	N/A	422	1,229	N/A	N/A	N/A	191.2
WYOMING	1,256	2,768	3,059	2,596	3,171	120.4	10.5	-15.1	22.1
Goshen	11,941	10,885	12,040	12,373	12,538	-8.8	10.6	2.8	1.3
Niobrara	3,750	2,924	2,924	2,499	2,407	-22.0	0.0	-14.5	-3.7
Lusk	1,890	1,495	1,650	1,504	1,447	-20.9	10.4	-8.8	-3.8

Note – CDP (Census Designated Place) is a statistical entity defined for each decennial census according to Census Bureau guidelines, comprising a densely-settled concentration of population that is not within an incorporated place, but is locally identified by a name.
N/A = Not Available
Sources: U.S. Bureau of the Census, 1972a, 1972b, 1972c, 1979, 1981, 1990a, 1990b, 1990c, 2003

Table 2.3-2: Population by Age and Sex for Counties within 80-km (50-mile) Radius of the License Area, 2000

State County	Age	Male	Female	Total	Total Percent Breakdown
South Dakota					
Fall River	Under 5	214	145	359	4.8
	5 – 19	847	661	1,508	20.2
	20 – 34	397	406	803	10.8
	35 – 64	1,596	1,513	3,109	41.7
	65+	846	828	1,674	22.6
	Total	3,900	3,553	7,453	100.0
Shannon	Under 5	676	684	1,360	10.9
	5 – 19	2,460	2,294	4,754	38.1
	20 – 34	1,205	1,297	2,502	20.1
	35 – 64	1,614	1,642	3,256	26.1
	65+	265	329	594	4.8
	Total	6,220	6,246	12,466	100.0
Wyoming					
Goshen	Under 5	378	349	727	5.8
	5 – 19	1,460	1,322	2,782	22.2
	20 – 34	1,001	946	1,947	15.5
	35 – 64	2,459	2,451	4,910	39.2
	65+	936	1,236	2,172	17.3
	Total	6,234	6,304	12,538	100.0
Niobrara	Under 5	60	55	115	4.8
	5 - 19	268	219	487	20.2
	20 - 34	134	180	314	13.0
	35 - 64	507	533	1,040	43.2
	65+	205	246	451	18.7
	Total	1,174	1,233	2,407	100.0

Source: U.S. Bureau of the Census 2003

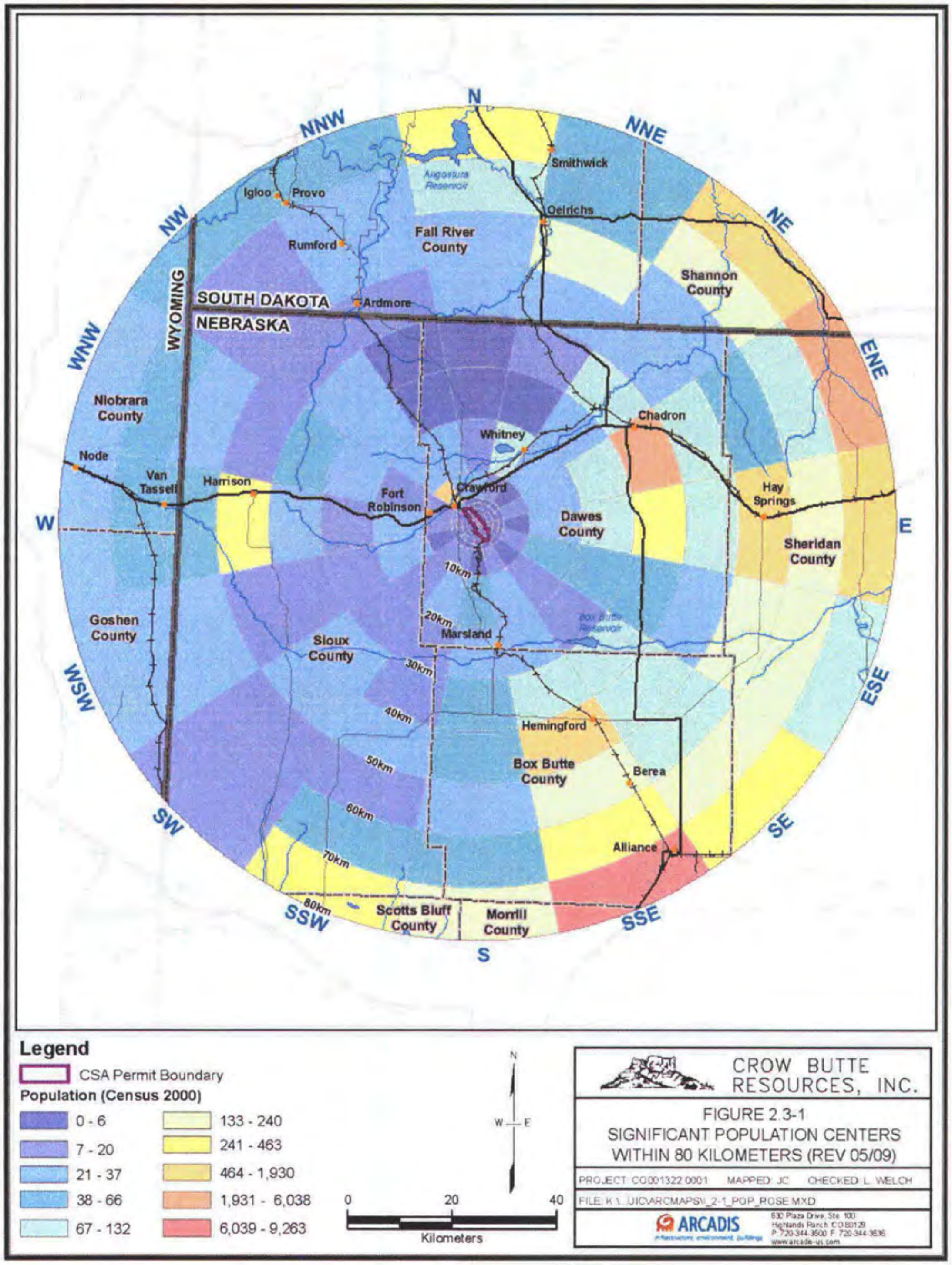
Table 2.3-3: Population Projections for Counties within an 80-km (50-mile) Radius of the License Area, 2000-2020

County	Census 2000	Projected 2005	Projected 2010	Projected 2015	Projected 2020
Box Butte	12,158	11,759	11,387	11,048	10,662
Dawes	9,060	9,168	9,273	9,339	9,368
Sheridan	6,198	5,962	5,732	5,540	5,368
Sioux	1,475	1,424	1,364	1,294	1,215
Fall River	7,453	N/A	N/A	N/A	N/A
Shannon	12,466	N/A	N/A	N/A	N/A
Goshen	12,538	12,401	12,429	N/A	N/A
Niobrara	2,407	2,399	2,399	N/A	N/A

N/A = not available

Sources: University of South Dakota, Bureau of Business Research 2004. University of Nebraska-Lincoln, Bureau of Business Research 2004. Wyoming Department of Administration and Information 2004.

Figure 2.3-1: Significant Population Centers within 80 Kilometers



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Dawes County grew slightly between 1990 and 2000, gaining 0.4 percent in population. Most of this growth occurred in the City of Chadron. The Dawes County communities of Chadron and Crawford are the nearest communities to the License Area. Chadron is located approximately 25 miles northeast of the License Area with a 2000 population of 5,634, an increase of 0.8 percent from 1990. The community of Crawford, within 6.2 miles of the site, had a 2000 population of 1,107. Chadron experienced a small population gain between 1990 and 2000, while Crawford lost population.

Sioux County lost population at a slower rate in the years between 1980 and 1990 than in the previous decade. The slower decline of the county population occurred in part because the town of Harrison gained nearly 16 percent, which is a reversal of a trend that shows a decline in population since 1960. Between 1980 and 1985, the downward trend continued in Sioux and Morrill Counties, with Sheridan County exhibiting a slight turnaround. Between 1985 and 1990, the downward trend continued in the Nebraska counties, with the exception of Morrill County, which experienced an increase of 6.3 percent. However, this growth is a decrease from the 1980 population.

Sheridan County has experienced an overall decline of nearly 32 percent since 1960. Population has declined in the towns of Hay Springs and Rushville between 1980 and 2000, despite earlier gains in the 1980s. Scotts Bluff County experienced gradual population growth over the two-decade period between 1960 and 1980.

The two South Dakota counties in the 80-km (50-mile) study area include Fall River and Shannon. Fall River County experienced an overall population decline by more than 30 percent between 1960 and 2000; however, between 1990 and 2000, there was a small increase of 1.4 percent. The town of Ardmore lost more than 80 percent of its population between 1960 and 1980, and was disincorporated in 1984 (U.S. Census 1990e). Shannon County, on the other hand, grew by 25.9 percent between 1990 and 2000; more than double the 1960 population. Much of the growth occurred in the Pine Ridge and Oglala Census Designated Places (CDP), which are urban areas as defined by the U.S. Census, but are not incorporated municipalities. Most of Fall River County is included within the 80-km (50-mile) radius of the License Area; however, only the southwest portion of Shannon County is within the 80-km (50-mile) radius of the License Area.

The population declines in the counties within the 80-km (50-mile) radius reflect trends in the overall region, where declines have been attributed to the declines in the rural farming based economy and limited economic opportunities for youth. Persistent drought conditions have also contributed to the shrinking of the agriculture-based economy. Rural residents have been migrating to larger cities, depopulating the largely rural Great Plains states. Many of the people migrating out of the state are young adults and families, which results in fewer people of childbearing age, and therefore, fewer children. This trend also contributes to the increasing proportion of the elderly population in the state.

2.3.1.2 Population Characteristics

The 2000 population by age and sex for counties within 80-km of the License Area is shown in **Table 2.3-2**. Overall, 67.7 percent of the population in the region is more than 20 years old. Fall River and Niobrara Counties reported the highest percentage of persons older than 18 with 75.0 percent. About 6.7 percent of the population was less than 5 years old in 2000. Shannon County reported the youngest population, with 10.9 percent less than 5 years old and slightly more than half (51.0 percent) at 18 years of age and under. Females slightly outnumbered males in most counties, with an overall population of 50.1 percent female to 49.9 percent male.

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

2.3.1.3 Population Projections

The projected population for selected years by county within the 80-km radius of the License Area is shown in **Table 2.3-3**. The population is expected to decrease in the Nebraska Counties of Box Butte, Sheridan, and Sioux. These counties are primarily rural, with agriculture-based economies. It is anticipated that the declining population trends of the last two decades will continue into the foreseeable future for these counties. The projected population for Dawes County is expected to increase at an annual rate of less than 1 percent over the next 20 years. This rate reflects recent increases in the population of Chadron that are expected to continue. In addition, Dawes County provides a scenic setting for a variety of outdoor recreation activities. The Pine Ridge region will probably increase in popularity with visitors and recreationists from outside of the region, as participation in outdoor recreational activities is expected to increase nationwide. An increase in visitor utilization of recreation facilities in Dawes County would revitalize the local economy, adding to the overall attractiveness of the region to potential residents.

2.3.1.4 Seasonal Population and Visitors

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

Approximately 358,000 people visited Fort Robinson State Park in 2002. This number represents a 4.8-percent increase from 2001, but a decrease of 5.1 percent from the 1981 visitation of 377,000 people and a slight decrease of less than 1 percent from the 359,000 visitors in 1984 (Nebraska Department of Economic Development 2003). Visitor Figures were up slightly for 2005, with a total of 361,230 visitors to the park (Nebraska Department of Economic Development 2007). Approximately 50 percent of the visitors

in 2002 were from other states, which is an increase in the number of out-of-state visitors from 1981, as the majority of 1981 visitors were Nebraskan families. It is likely that the decline of visitors from Nebraska has resulted from the overall decline of population in rural counties within a few hours commuting distance of the park.

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

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

One source of seasonal population in this region is Chadron State College, located approximately 21.6 miles from the site. During the 2001 fall semester, enrollment was 2,804, an increase of 25 percent over the fall 1986 enrollment of 2,240 (Nebraska Department of Economic Development 2002; Schmiedt 1987). In the 1994 fall semester, a total of 3,296 students were enrolled at the college (Taylor 1995).

2.3.1.5 Schools

Crawford is served by the Crawford Public School District. The Crawford High School and grade school are presently under capacity. Total enrollment in these two schools as of fall 2001 was 146 in the high school and 140 in the elementary school with maximum capacities of 545 and 185, respectively (National Center for Educational Statistics 2004; Crawford High School 1995, Crawford Elementary School 1995). Current enrollment numbers are 134 in the grade school and 134 in the high school (Crawford Public Schools 2007) and are comparable to annual enrollments since 1987 for both schools. The grade school currently has a student to teacher ratio of 13 to 1 and the high school has a ratio of 8 to 1. No historical high enrollment was given for the grade school. However, it was estimated in 1995 that the high school historical high enrollment was more than 200 pupils.

There is one rural school supporting grades one through eight within the Crawford district. The Belmont School is a two-room schoolhouse. Students living in the rural district attend Crawford High School. There were 6 pupils as of fall 2007 at the Belmont School from which Crawford High School draws, a decline from the 1995 enrollment of an estimated 100 pupils in seven rural school districts.

Families moving into the Crawford district as a result of the Crow Butte Project would not stress the current school system because it is presently under capacity.

2.3.1.6 Sectorial Population

Existing population, as determined for the original analysis in the CBR commercial license application prepared in 1987 for the 80-km (50-mile) radius, centered on the License Area, was estimated for 16 compass sectors, by concentric circles of 1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 70 and 80-km from the site (a total of 208 sectors). Sectorial population for this LRA was updated with data from the 2000 U.S. Census. Subtotals by sector and compass points as well as the total population are shown in **Table 2.3-4**.

Table 2.3-4: 2000 Population within an 80-km (50-mile) Radius of the License Area[a]

	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	Total
N	0	0	0	0	0	24	12	0	4	29	31	78	463	641
NNE	0	0	0	0	4	18	131	1	16	22	168	40	38	438
NE	0	0	0	0	0	0	36	34	132	37	32	219	1,930	2,420
ENE	0	0	0	0	0	15	28	91	6,038	104	66	102	4,217	10,661
E	0	0	0	0	0	1	26	130	340	114	902	150	1,201	2,864
ESE	0	0	0	0	0	15	41	42	42	30	176	177	78	601
SE	0	0	1	0	0	0	14	12	77	115	124	225	313	881
SSE	0	0	0	0	0	12	32	29	88	1,173	240	299	9,263	11,136
S	0	0	0	0	0	0	41	29	60	40	25	49	177	421
SSW	0	0	2	0	0	11	24	14	17	22	10	64	323	487
SW	0	0	0	11	0	9	17	13	24	22	15	13	17	141
WSW	0	3	0	0	0	0	27	20	8	15	29	35	34	171
W	0	0	0	0	8	16	25	18	26	292	48	52	32	517
WNW	0	0	4	0	15	15	12	25	42	18	24	39	35	229
NW	0	1	0	0	45	1,091	27	26	24	8	15	15	38	1,290
NNW	0	0	0	0	2	29	33	3	6	13	24	35	55	200
Total	0	4	7	11	74	1,256	526	487	6,944	2,054	1929	1,592	18,214	33,098

Notes:

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

Population within the 80-km (50-mile) radius was estimated using the following techniques:

- U.S. Census 2000 data were used to estimate the total population within an 80-km (50-mile) radius, measured from the center of the License Area site. The data were created by Geographic Data Technology, Inc., a division of Environmental System Research Institute (ESRI) Inc., from Census 2000 boundary and demographic information for block groups within the United States.
- ArcInfo GIS was used to extract data from U.S. Census 2000 population estimates for 40 Census Tract Block Groups located wholly or partially within the 80-km (50-mile) radius from the approximate center of the License Area. Urban areas within each county were generally assigned their own block group.
- To assign a population to each sector, a percentage area of each sector within one or more block groups was calculated for all of the block groups.
- 2000 U.S. Census of population estimates for cities and counties in Nebraska, South Dakota and Wyoming were used to determine total urban population.

2.3.2 Local Socioeconomic Characteristics

2.3.2.1 Major Economic Sectors

In 2002, average annual unemployment rates in Dawes and Box Butte Counties decreased from the 1994 rates. **Table 2.3-5** summarizes unemployment rates and employment in the License Area counties. Dawes and Box Butte Counties exhibited unemployment rates at 3.8 percent in Dawes County and 5.0 percent in Box Butte County. Unemployment rates for both counties increased between 1994 and 2002. In 1994, unemployment levels declined from February 1987 levels. These rates were a little higher than the statewide rate of 3.5 percent. Dawes County was close to the state unemployment rate, while the Box Butte rate was higher.

Table 2.3-5: Annual Average Labor Force and Employment Economic Sectors* for Dawes and Box Butte Counties, 1994 and 2002

Employment Economic Sectors	Dawes		Box Butte	
	1994	2002	1994	2002
Labor Force	4,490	4,663	6,156	5,670
Unemployment	149	175	235	282
Unemployment Rate	3.3	3.8	3.8	5.0
Employment	4,341	4,489	5,921	5,387
Farm Employment	564	550	763	760
Non-Farm Employment Total	3,479	3,903	5,446	5,241
Manufacturing	165	201	402	465
Construction and Mining	136	179	80	0
Transportation, Communication, and Utilities	N/A	N/A	1,909	1,288
Trade	952	N/A	1,106	825

Table 2.3-5: Annual Average Labor Force and Employment Economic Sectors* for Dawes and Box Butte Counties, 1994 and 2002

Employment Economic Sectors	Dawes		Box Butte	
	1994	2002	1994	2002
Retail	824	636	840	539
Wholesale	128	N/A	265	286
Financial, Insurance, and Real Estate	77	117	215	205
Services	548	N/A	779	N/A
Information	N/A	0	N/A	110
Professional and Business Services	N/A	N/A	N/A	219
Education and Health Services	N/A	358	N/A	424
Leisure and Hospitality	N/A	533	N/A	372
Other Services	N/A	133	N/A	203
Government	1,384	1,450	955	1,130
Federal	144	161	65	67
State	721	719	67	62
Local	519	571	824	1,001

* Industry employment estimates are based on the Standard Industry Classification System before 2001, and on the North American Industry Classification System after 2001.
N/A = not available

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

Agriculture accounts for slightly more than 1 percent of the total employed labor force in Dawes County, while farm employment was 14 percent of total employment in Box Butte County. Government employment in Dawes County makes up 37 percent of total non-farm employment, followed by trade (16 percent), leisure and hospitality services (14 percent), and education and health services (9 percent). Construction and mining account for 5 percent. In Box Butte County, the largest four non-farm employment sectors are transportation (25 percent), government (22 percent), trade (16 percent), and manufacturing (9 percent).

Agriculture employment has a small share of total employment in both counties. However, agriculture provides the economic base for the counties, as other economic sectors support the agricultural industry. Events that affect agriculture are generally felt throughout rural economies. According to the Nebraska Department of Economic Development (2002), Farm employment in Nebraska is expected to decline by nearly 14,000 jobs (20 percent) between 2000 and 2045, while overall non-farm employment will increase by nearly 26 percent. The decrease in jobs in the agricultural sector could continue to fuel migration from rural counties to urban areas, resulting in overall declines

in other sectors of the local economy as dollars spent from personal income and agricultural business expenditures move out of the counties.

Per capita personal income is the income that is received by persons from all sources, including wages and other income over the course of 1 year. In 2002, personal income in Dawes County was $19,760, which was 68 percent of the state average of $29,182. The county ranks 84th out of 93 counties in the state (BEA 2004).

2.3.2.2 Housing

Between 1970 and 1980, total housing units increased by 17 percent in Dawes County from 3,388 to 3,965 units. By 2002, the growth of the preceding decades had slowed, and total housing units increased by 2.4 percent to 4,004 units from 3,909 units in 1990. Chadron, the largest community in Dawes County and within 25 miles of the License Area, experienced a 25 percent increase in housing stock between 1970 and 1980, and a 5 percent increase between 1990 and 2000. In 1990, Crawford housing stock decreased by nearly 7 percent from 576 units. By 2000, there were 2,441 housing units in Chadron and 537 units in Crawford. Alliance, in Box Butte County (approximately 72 km [45 miles] from the License Area) exhibited a 1 percent loss in total housing units between 1990 and 2000. In 2000, there were 4,062 housing units in Box Butte County (USCB 1981a, 1990d, 2004).

In 2000, Dawes and Box Butte Counties had homeowner vacancy rates of 1.7 and 1.4 percent, respectively. A June 2004 listing of property for sale revealed two ranch properties near Crawford. Housing prices averaged $53,915 in 1999. According to the Dawes County Tax Assessor, no new houses are being built, as current housing needs are being met.

A local Crawford realtor indicated in 1999 that rental property in Crawford was scarce. The rental housing stock has not increased in 2000, as rental vacancy rates were 4.4 percent in Dawes County and 4.7 percent in Box Butte County (USCB 2004), compared with rental vacancy rates in 1990, which were 12.6 percent in Dawes County and 14.9 percent in Box Butte County (USCB 1990a).

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

Population projections for Dawes County indicate an average annual growth rate of 10 percent between 2000 and 2020. Most of this growth is likely to occur in Chadron, as suggested by population growth between 1990 and 2000, rather than Crawford, which lost population. The majority of housing demand expected over the next two decades is most likely to occur in Chadron. However, housing stock in Crawford has decreased so that homeowner vacancy rates have also decreased. In the event that the various scenic

and recreational amenities of the region stimulate the local tourist economy, it is likely that both population and housing stock would increase in Crawford.

The purchase of homes by Crow Butte employees provides the town of Crawford with ad valorem property taxes. The town of Crawford levies taxes at a dollar per hundred of valuation. In 2001, the total levy was 0.43346, which would result in taxes on a $50,000 property of approximately $217 per year (Nebraska Department of Property Assessment and Taxation 2001).

2.3.3 Environmental Justice

The 2000 Census provides population characteristics for Census Tracts, which contain Block Groups that are further divided into Blocks. The Blocks are the smallest Census area that contains the race characteristics of the population in Dawes County. The CSA contains all or a portion of 68 Blocks within Census Tract 9506. Block Groups are the smallest Census area that contains poverty level information. There is no poverty data for individual Blocks within each Block. There are three Block Groups that are located partially within the CSA; however, the Block Groups area includes most of the north portion of Dawes County.

The affected area selected for the Environmental Justice analysis includes the race characteristics of the population within the City of Crawford and the surrounding Census Tract Blocks within the CSA. The population with an annual income below the poverty level was determined from Block Group characteristics.

According to the 2000 Census and summarized in **Table 2.3-6**, the combined population of the city of Crawford and the surrounding Census Blocks within the CSA was 1,265. Minority populations accounted for a small percentage of the total population. The majority of minority populations resided within Crawford.

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

The data in **Table 2.3-6** shows that minority populations in the affected Blocks account for considerably smaller proportion of the total CSA population than the proportion of minority populations at the state level. No concentrations of minority populations were identified as residing near the proposed Project facilities, as residents nearest to the License Area rural populations, while most of the minority population lives in Crawford.

Table 2.3-6: Race and Poverty Level Characteristics of the Population in the State of Nebraska, Dawes County, and the CSA

	Nebraska	Percent of Nebraska Pop.	Dawes County	Percent of Dawes County Pop.	Crawford City	Total Block Pop.	Crawford & Block Pop. (CSA)	Percent of Crawford & Block Pop.	Block Group 1	Block Group 2	Block Group 3
Total Population	1,711,263	100.0%	9,060	100.00%	1,107	158	1,265	100.0%	1,111	1,137	890
White alone	1,533,261	89.6%	8,457	93.34%	1,037	151	1,188	93.9%	-	-	-
Black or African American	68,541	4.0%	73	0.81%	1	0	1	0.1%	-	-	-
American Indian and Alaska Native	14,896	0.9%	261	2.88%	38	6	44	3.5%	-	-	-
Asian alone	21,931	1.3%	28	0.31%	0	0	0	0.0%	-	-	-
Native Hawaiian and Other Pacific Islander	836	0.0%	5	0.06%	0	0	0	0.0%	-	-	-
Some other race	47,845	2.8%	93	1.03%	10	1	11	0.9%	-	-	-
Two or more races	23,953	1.4%	143	1.58%	21	0	21	1.7%	-	-	-
Hispanic or Latino	94,425	5.5%	220	2.43%	22	3	25	2.0%	-	-	-
Percent below poverty level:	9.4%	-	17.1%	-	14.4%	-	-	-	21.3%	14.0%	8.3%

Source: USCB 2000

With the exception of Block Group 3, the populations within the Block Groups have higher rates of people living below the poverty level than the state. However, lower income levels are characteristic of predominantly rural populations and small communities that serve as a local center of agricultural activity. No adverse environmental impacts would occur to the population within the CSA as a result of project activities; therefore there would be no disproportionate adverse impact to populations living below the poverty level in these Block Groups.

2.3.4 References

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

2.4.1 Historic, Archeological, and Cultural Resources

Identification and assessment of cultural resources within the Crow Butte License Area have 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 CSA lands during April and May 1987 by the Nebraska State Historical Society.

This section summarizes the results and recommendations of both studies. For detailed descriptions of each identified resource, please 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 CSA 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 CSA. Registered National Historic Landmarks representing military and Native American reservation period use of the CSA are located near the Crow Butte License Area.

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 (Table 2.4-1).

including eight sites representing Native American components, 12 Euro-American locations, and a buried bone deposit of undetermined cultural association. A figure depicting the location of these sites is provided, under a request for confidentiality in the Environmental Report.

Fifteen of these newly identified resources contained limited observed evidence of scientifically important cultural remains or were not determined to be of significant historic value based on the archival research. These sites do not warrant further National Register consideration.

Table 2.4-1: Summary of Cultural Resources Identified During the 1982 and 1987 Investigations Crow Butte Project, Dawes County, Nebraska

Site Number	Description and Temporal Assignment	Topographical Location	Area (m²)	Field Investigation
1982				
25DW111 (Harvey Homestead)	surface; glass, ceramic, metal; bone debris; Euro-American; late 19th century (?)	top and slope of small knoll	1,000	survey, sketch map, photographs
25DW112/00-17 (Wulf/Daniels Place)	surface/buried; abandoned farmstead (house, depression, 11 outbuildings); Euro-American late 19th/early 20th century	broad terrace; Squaw Creek	6,000	survey, sketch plan, photographs
25DW113 (Fiandt Homestead)	surface/buried; glass, ceramic, metal, wood, leather debris (25 to 40 cm S.D.); 4 depressions; Euro-American; late 19th century (?)	broad terrace; Squaw Creek	9,000	survey, transit map, soil probe/shovel test, photographs
25DW114	surface; chipped stone tools, flaking debris, trade goods, bone, primary component is Middle Archaic, although Paleo-Indian, Late Archaic, Late Prehistoric and Historic components are also present.	broad terrace; Squaw Creek	150,000	survey, transit map, controlled surface collection, photographs
25DW115 (School Dist. 25)	surface; glass, brick debris; former location of First Presbyterian Church and public school; Euro-American; late 19th century	small rise on upper slope	900	survey, sketch map
25DW116	Surface; chipped stone flaking debris; unassigned Native American	terrace slope; Squaw Creek	2	survey, sketch map, photographs
25DW117 (Fleming Homestead)	surface; windmill, cistern, stock tank complex; Euro-American (possibly associated with Fleming homestead); late 19th century (?)	terrace slope; Squaw Creek	250	survey, sketch plan, photographs
FN-1	1 chipped stone flake; unassigned Native American	terrace slope; Squaw Creek	1	Survey
FN-2	buried; bone, charcoal; unknown cultural association	eroding cutbank; Squaw Creek	50 (length)	survey, bank profile, collection, sketch map, photographs
FN-3	Crow Butte Cemetery; Euro-American; 1880 through 1971	level ridge top	2,700	survey, sketch plan, photographs
1987				
25DW191 (Dougherty/Smith)	surface/buried; outbuilding; 2 depressions; farm machinery; Euro-American; late 19th century	foot of Pine Ridge colluvial slope	50,000	survey, sketch map, photographs
25DW192	surface/buried; glass and metal debris; 2 depressions, 2	top and slope of small	1,000	survey, sketch map, uncontrolled surface

Table 2.4-1: Summary of Cultural Resources Identified During the 1982 and 1987 Investigations Crow Butte Project, Dawes County, Nebraska

Site Number	Description and Temporal Assignment	Topographical Location	Area (m^2)	Field Investigation
(Stetson/Roby)	foundations; Euro-American; late 19th century	knoll overlooking Squaw Creek tributary		collection, photographs
25DW193	surface/buried; school, foundations, debris, and artifacts; Euro-American early 20th century through 1970s	upland ridge west of Squaw Creek	2,500	survey, sketch map, photographs
25DW194	surface/buried; human burial, chipped stone tools, flaking debris, bone; Plains Equestrian and unassigned Native American	ridge slope west of Squaw Creek	1,600	survey, sketch map, photographs, collected, tested
25DW195	surface; chipped stone tools, flaking debris, fire-cracked rock; unassigned Native American, possibly Archaic	ridge slope east of English Creek	1,000	survey, sketch map, photographs, shovel test
25DW196	surface; chipped stone tool, flaking debris, bone; unassigned Native American	upland ridge divide between Squaw and English Creeks	80,000	survey, transit map, uncontrolled surface collection, controlled test (4), photographs
25DW197	surface; chipped stone tools, flaking debris, bone; unassigned Native American	upland ridge divide between Squaw and English Creeks	150,000	survey, sketch map, uncontrolled surface collection, photographs
25DW198	surface/buried (plow zone only); chipped stone tools and flaking debris; unassigned Native American	saddle and adjacent knolls on divide between English and White Clay Creeks	30,000	survey, transit map, uncontrolled surface collection, controlled test (3), photographs; controlled test 2003
25DW199 (Crawford Ice House)	surface/buried; foundation, pond; Euro-American; early to mid 20th century	narrow terrace, White Clay Creek	2,000	survey, sketch map, photographs
25DW00-25 (Stetson Place)	surface/buried; occupied farmstead (house, 8 outbuildings, corral); Euro-American late 19th century to present	broad terrace, Squaw Creek	18,000	survey, sketch plan, photographs
25DW00-26 (Gibbons/Ehlers Place)	surface/buried; occupied farmstead (house, 11 outbuildings, corral); Euro-American; early 20th century to present	broad terrace, Squaw Creek	25,000	survey, sketch plan, photographs

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The remaining six sites are of potential archeological data recovery importance (25DW114, 25DW192, 25DW194, and 25DW198) or possible architectural interest (25DW112 and 25DW00-25). These six sites are potentially eligible for the National Register, 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 has not directly affected any of the six potentially significant sites. Additionally, there are no properties within the CSA listed in the National Register or registered as natural or historic landmarks. Project development staff has detailed location maps of these properties, and there is coordination with the Nebraska State Historical Society before any development occurs in the immediate vicinity of the six potentially eligible sites.

2.4.2 **Visual/Scenic Resources**

2.4.2.1 Introduction

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

2.4.2.2 Methods

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.

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 2.4-2**. 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 is 14; therefore, the visual effect of the Crow Butte Project on the local visual resources was not further analyzed.

Table 2.4-2: Scenic Quality Inventory and Evaluation for the Crow Butte License 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	Adjacent scenery is very similar to Crow Butte License Area and provides little contrast	1
Scarcity	Landscape is common for the region	1
Cultural modifications	Existing modifications consist of Crow Butte Project facilities.	5
Total Score		**14**

2.4.3 References

U.S.D.I. Bureau of Land Management (BLM). 1986. Visual Resource Inventory. BLM Manual Handbook 8410-1.

2.5 METEOROLOGY, CLIMATOLOGY, AND AIR QUALITY

2.5.1 Introduction

This section describes the meteorological conditions in the region surrounding the License Area. The data presented in this section were used to determine the effect of the local climate on the development area. The joint frequency data can be used to assess the atmospheric dispersion characteristics present in the region.

Data sources for the meteorological conditions used for this report come from the High Plains Regional Climatic Center (HPRCC 2004, 2009), National Climatic Data Center (NCDC (2009), and Weather Underground (WUG 2009) for sites located in Chadron, Nebraska, Scottsbluff, Nebraska, Rapid City, South Dakota and from an on-site monitoring station near the Crow Butte facility. The period of record for the HPRCC data covers 60 years of observation between 1948 and 2008. However, in accessing recent data, missing data for the years 2004, 2005 and 2008 for Chadron, Nebraska resulted in these data not being representative and therefore not useable. The on-site monitoring data were collected between May 1982 and April 1984, and include temperature, precipitation, evaporation, wind speed, and wind direction. Data are also included from the National Weather Service Stations in Scottsbluff, Nebraska and Rapid City, South Dakota.

Precipitation was recorded at the on-site meteorological station with a heated tipping bucket rain gauge. Evaporation was measured using a 48-inch evaporation pan and an evaporation gauge with analog output. The air temperature was also recorded using a precision linear thermistor and fan-aspirated radiation shield. All of the information was recorded on strip chart recorders. In addition, the information was run through a microprocessor and recorded on magnetic tape. The information from the tape was transferred to a computer and then verified by comparison from the strip charts and from visual observation records.

The License Area is located in Dawes County (in the north central portion of the Nebraska panhandle), which shares its northern border with South Dakota. The weather patterns are typical of a semi-arid, continental climate. This climate is characterized by warm summers, cold winters, light precipitation, and frequent changes in the weather.

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

The HPRCC data were collected at the Chadron 1 NW site (latitude 42° 50' north, longitude 103° 01') west with a ground elevation of 1021 meters (3350 feet) above mean sea level (amsl). The monitor is 0.9 miles west northwest of Chadron, 23 miles east northeast of Crawford, and 22 miles east northeast of the License Area.

2.5.2 Temperature

Table 2.5-1 summarizes mean daily maximum and minimum and mean monthly temperature data for Chadron, Nebraska from 1948 to 2003. The months of November through March all have mean daily minimum temperatures below freezing, with January as the coldest month. December, January, and Feruary all have monthly mean temperatures below freezing.

Table 2.5-1: Mean Daily Maximum and Minimum and Mean Monthly Temperature Data for Chadron, Nebraska

Month	Mean Daily Maximum (°C)	Mean Daily Minimum (°C)	Mean Monthly (°C)	Record High		Record Low	
				(°C)	Year	(°C)	Year
Jan	2.0	-11.8	-4.9	21.1	1989	-33.9	1949
Feb	5.0	-9.2	-2.1	24.4	1982	-32.8	1982
Mar	8.9	-5.4	1.8	28.3	1967	-32.2	1989
Apr	15.1	0.2	7.7	33.9	1989	-23.9	1975
May	20.9	6.3	13.6	36.7	1969	-8.9	1954
June	27.1	11.6	19.3	41.7	1989	-3.3	1969
July	31.8	15.2	23.5	43.3	1954	3.3	1971
Aug	31.3	14.3	22.8	42.2	1980	2.2	1962
Sept	25.3	8.1	16.7	40.0	1978	-8.3	1984
Oct	18.2	1.3	9.7	34.4	1953	-21.7	1991
Nov	8.9	-5.4	1.8	27.2	1999	-27.8	1959
Dec	3.6	-10.1	-3.3	22.2	1980	-40.0	1989
Year	**16.5**	**1.2**	**8.9**	**43.3**	**Jul-54**	**-40.0**	**Dec-89**

Notes: °C = degrees Celsius
Source: HPRCC 2004

The warmest months are July and August. The mean yearly temperature is 8.9°C (48.0°F).

The temperature extremes for the period of record are also given in **Table 2.5-1**, along with the year of occurrence. These data show that temperatures can exceed 38°C (100°F), and freezing or near-freezing temperatures can occur throughout the year.

Table 2.5-2 lists the mean number of days per month with temperatures above or below selected values. The average date of the last yearly 0°C (32°F) temperature is May 18 while the first fall freeze is expected on September 18. The average growing season is 120 to 130 days long (USDA 1981). These are average values, and the exact occurrence of freezing temperatures depends on exposure.

Table 2.5-3 summarizes Mean Monthly and Mean Maximum and Minimum Monthly Temperature Data for Chadron, Nebraska (2006 and 2007) (HPRCC 2009).

Table 2.5-2: Temperature Occurrences for Chadron, Nebraska (From 1948 to 2003)

Month	Mean Number of Days with Maximum Temperatures		Mean Number of Days with Minimum Temperatures	
	> 32.2°C	< 0°C	< 0°C	< -17.8°C
January	0.0	11.4	30.1	7.5
February	0.0	7.8	26.7	4.3
March	0.0	4.7	26.2	1.7
April	0.1	0.8	15.4	0.0
May	0.9	0.0	2.9	0.0
June	6.0	0.0	0.1	0.0
July	15.9	0.0	0.0	0.0
August	15.6	0.0	0.0	0.0
September	5.6	0.0	1.9	0.0
October	0.3	0.5	12.4	0.1
November	0.0	4.5	25.6	1.0
December	0.0	9.1	29.6	4.7
Year	**44.3**	**38.7**	**170.8**	**19.3**

Source: HPRCC 2004

Table 2.5-3: Mean Monthly and Mean Maximum and Minimum Monthly Temperature Data for Chadron, Nebraska (2006 and 2007)

Month	Mean Daily Maximum °C	Mean Daily Minimum °C	Mean Daily Monthly °C
2006			
Jan	11.0	-8.4	1.3
Feb	3.9	-12.1	-4.1
Mar	9.4	-5.3	2.0
Apr	19.2	1.1	10.2
May	22.9	5.1	14.0
Jun	30.6	11.2	20.9
Jul	35.1	16.4	25.7
Aug	31.5	12.8	22.1
Sept	22.2	4.4	13.3
Oct	16.3	-1.3	7.5
Nov	10.7	-7.3	1.7
Dec	6.9	-11.1	-2.1
Annual	**18.3**	**0.5**	**9.4**
2007			
Jan	2.3	-13.5	-5.6
Feb	2.5	-12.5	-5.0
Mar	16.1	-3.0	6.6
Apr	13.7	-1.7	6.0
May	23.9	6.3	15.1
Jun	29.6	11.2	20.4
Jul	34.7	17.2	25.9
Aug	33.0	15.1	24.0
Sept	27.7	7.0	17.3
Oct	19.5	0.7	10.1
Nov	--	--	--
Dec	-0.2	-14.0	-7.1
Annual	**18.4**	**1.2**	**9.8**

Source: HPRCC 2009

Temperature data for the years 2004, 2005 and 2008 had an insufficient number of days without data measurements to make these results unrepresentative for the annual measurement periods; therefore, these data were not used. The temperature in Chadron, Nebraska is comparable to the temperature in Crawford, Nebraska. To demonstrate this trend, high and low temperature data for both locations for April through August 1999 are displayed in **Figure 2.5-1**. The source for Chadron and Crawford temperature data is Weather Underground (WUG 2009) and the National Climatic Data Center (NCDC 2009) operated by National Oceanic and Atmospheric Administration (NOAA), respectively. **Figure 2.5-1** shows the Comparison of Chadron and Crawford Temperatures for Spring and Summer 1999, and shows that the temperature data from the two weather stations are consistent.

The WUG website uses temperature data from the Chadron weather station for predicting weather both in Crawford and Chadron. The 1999 data were selected for comparison because 1999 was the most recent year for which actual Crawford temperature data were available. Since complete meteorological data from Crawford are not available and the temperature data from Chadron are consistent with Crawford, the Chadron data would be most appropriate for usage in air emission modeling and evaluation.

2.5.3 Precipitation

Precipitation in the region is generally light, with the heaviest occurrences in the spring and summer. **Table 2.5-4** lists the monthly precipitation totals for the period of record (1948 – 2003) along with the maximum 24-hour precipitation events. The month of May has the heaviest precipitation, with precipitation occurring through July. The driest months are November through February. The mean yearly precipitation is 40.79 centimeters (cm) (16.06 inches).

The monthly mean and maximum snowfalls for the period of record are listed in **Table 2.5-4**. The mean annual snowfall is 107.44 cm (42.30 inches). July and August are the only 2 months without a reported snowfall. The maximum mean monthly snowfall occurred in March.

Precipitation data from NOAA were also reviewed. The site in Scottsbluff, Nebraska is 60.9 miles south of the License Area, and the site in Rapid City, South Dakota is 98.2 miles north of the License Area. These data indicate that precipitation in excess of 0.03 cm (0.01 inch) can be expected on an average of 91 and 96 days per year, respectively. These data are listed in **Table 2.5-5**.

For comparison of rainfall in Chadron and Crawford, rainfall data collected at the two locations were compared for April of 1999 to August of 1999. The source for rainfall data for both locations was the NCDC (NCDC 2009). **Figure 2.5-2** shows a bar graph of daily rainfall measured at the two locations. While the rainfall data were not found to be exactly the same on a daily basis, the trend demonstrates that rainfall events are typically logged in both locations. **Table 2.5-6** shows monthly and seasonal rainfall totals of the data in **Figure 2.5-2**. The total rainfall for the spring and summer seasons are consistent.

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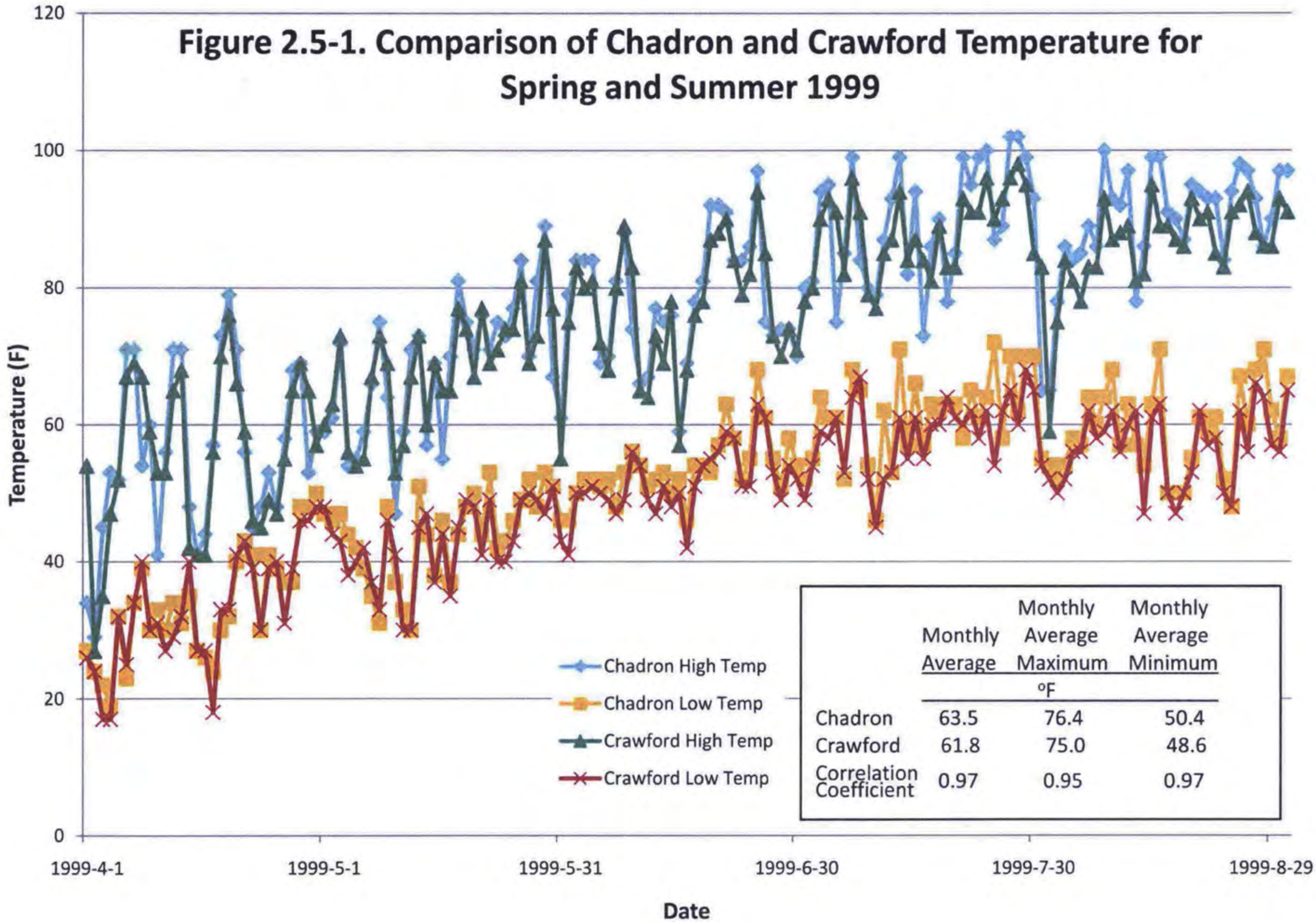

Figure 2.5-1. Comparison of Chadron and Crawford Temperature for Spring and Summer 1999

	Monthly Average	Monthly Average Maximum	Monthly Average Minimum
	°F		
Chadron	63.5	76.4	50.4
Crawford	61.8	75.0	48.6
Correlation Coefficient	0.97	0.95	0.97

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Table 2.5-4: Mean and Maximum Precipitation Data for Chadron, Nebraska (From 1948 to 2003)

Month	Water Equivalent		Snow Fall	
	Mean (cm)	**Maximum 24-Hour (cm)**	**Mean (cm)**	**Maximum Monthly (cm)**
January	1.12	2.72	16.51	88.14
February	1.17	3.81	16.51	59.69
March	2.16	3.51	21.84	88.14
April	4.47	6.22	13.21	49.28
May	7.52	6.50	1.52	23.62
June	7.14	5.38	0.00	3.05
July	5.41	5.08	0.00	0.00
August	3.48	4.62	0.00	0.00
September	3.66	11.18	0.76	25.40
October	2.36	3.81	5.59	28.45
November	1.24	1.78	13.21	42.93
December	1.04	1.80	17.78	46.99
Year	**40.79**	**11.18**	**107.44**	**196.85**

Source: HPRCC 2004

Table 2.5-5: Precipitation Events (1982 to 1990)

Month	Mean Number of Days with Precipitation	
	Scottsbluff, NE	**Rapid City SD**
January	5.4	5.4
February	5.4	6.2
March	7.3	9.2
April	9.2	8.0
May	12.0	10.8
June	9.2	11.3
July	8.6	8.3
August	8.2	8.6
September	8.0	8.3
October	5.3	6.6
November	6.6	6.2
December	6.2	6.8
Year	91.4	95.7
Period of Record (years)	9	9

Source: NOAA 1993

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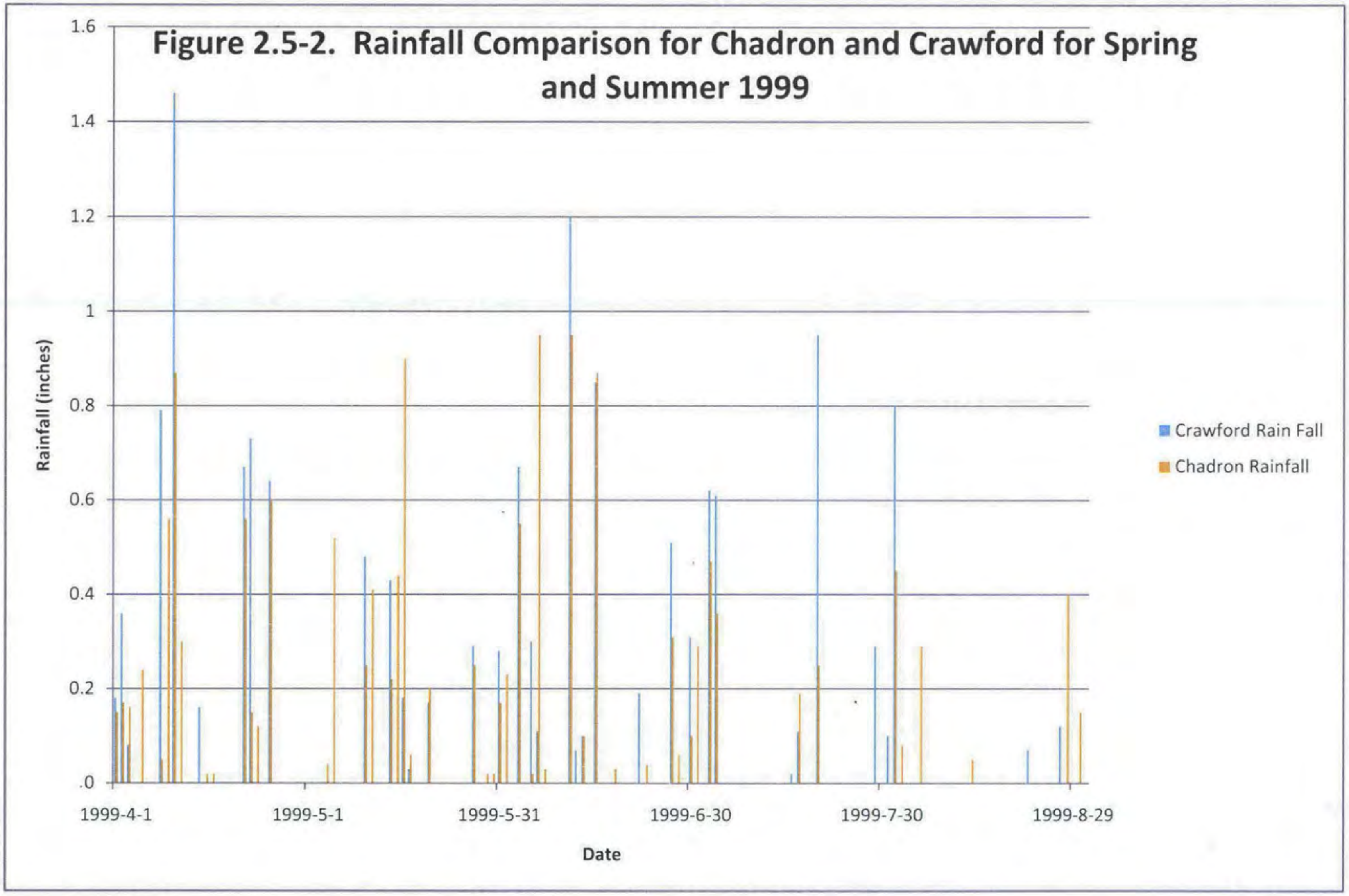
Figure 2.5-2. Rainfall Comparison for Chadron and Crawford for Spring and Summer 1999
Rainfall (inches)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
.0
1999-4-1
1999-5-1
1999-5-31
1999-6-30
1999-7-30
1999-8-29
Date
Crawford Rain Fall
Chadron Rainfall

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Table 2.5-6. Rainfall for Spring and Summer at Towns of Crawford and Chadron 1999

1999	Total Rainfall (inches)	
	Crawford	**Chadron**
April	5.07	3.97
May	1.86	3.5
June	4.31	4.24
July	2.7	1.56
August	0.99	1.42
Total (April to August)	**14.93**	**14.69**

2.5.4 Humidity

Relative percent humidity at the Scottsbluff and Rapid City weather stations is given in **Table 2.5-7**. The humidity at 0500, 1100, 1700, and 2300 hours is listed. Both locations have about the same humidity during the night; but in the early morning, Scottsbluff is slightly more humid. By noon and throughout the afternoon, Scottsbluff becomes less humid than Rapid City. These data indicate that humidity differences are slight and the humidity within the License Area can be expected to be similar to these locations.

While Rapid City, South Dakota and Scottsbluff, Nebraska are greater than 50 miles from Crawford, Nebraska, the humidity is comparable for these locations and provides the best estimate of humidity at Crawford. To illustrate this point, 2006 humidity data for weather stations at Rapid City and Scottsbluff and also for Chadron, Nebraska (within 50 miles of Crawford) were obtained from the Weather Underground website (WUG 2009). Humidity data for Crawford were not available.

Figure 2.5-3 of this document shows the average daily humidity for 2006 for all three locations with available data. The solid trend lines on the graph show the moving 30-day average humidity for each of the three locations.

Overall, the humidity in Chadron is slightly higher than it is in either in Rapid City or Scottsbluff. The average humidity for 2006 in Chadron, Scottsbluff, and Rapid City were 61.6 %, 57.5 %, and 56.8 %, respectively. While Chadron may be slightly closer in distance to the project location in Crawford, the elevation of Crawford (3,679 ft) is more consistent with the average elevations of Scottsbluff and Rapid City (average elevation of 3,565 ft) in comparison to Chadron (3,369 feet [ft]). The higher elevation of Crawford may make the humidity slightly lower than Chadron, which is consistent with the data provided in the original report.

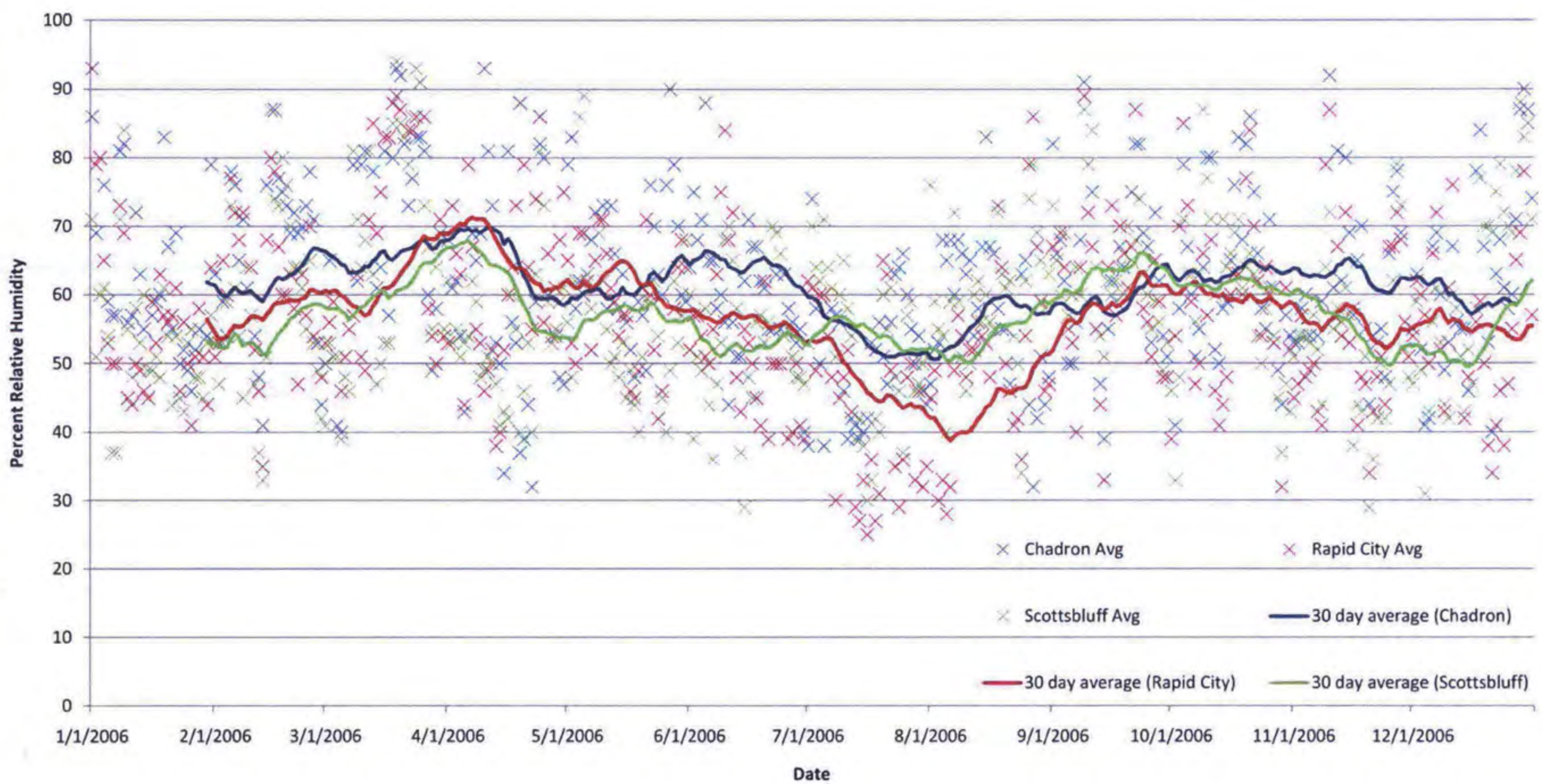
Table 2.5-7: Percent Relative Humidity Data (From 1982 - 1990)

Month	0500 Hours		1100 Hours		1700 Hours		2300 Hours	
	NE[a]	SD[b]	NE[a]	SD[b]	NE[a]	SD[b]	NE[a]	SD[b]
January	72.0	67.7	54.3	55.7	53.4	61.0	68.3	67.0
February	75.0	71.0	52.6	54.8	47.6	56.1	70.0	70.0
March	76.0	76.2	50.9	56.3	44.1	54.9	68.4	73.7
April	75.3	70.6	42.9	44.9	39.1	43.2	65.0	65.1
May	80.3	75.4	44.4	49.2	41.2	47.5	68.8	70.8
June	80.0	77.0	43.0	49.8	38.4	46.1	66.8	71.3
July	81.1	72.3	40.7	41.3	35.1	37.8	65.4	62.8
August	82.6	73.4	42.6	41.3	37.2	36.8	69.2	64.7
September	79.5	71.9	42.7	44.1	37.8	42.0	68.0	65.8
October	76.6	69.7	43.4	45.2	40.9	48.2	67.6	66.4
November	76.2	72.3	51.2	54.3	53.9	60.5	71.3	70.9
December	76.1	69.1	57.4	56.6	59.6	63.3	73.4	68.1
Year	77.6	72.2	47.2	49.5	44.0	49.8	68.5	68.1
Period of Record (years)	9	9	9	9	9	9	9	9

Source: NOAA 1993

[a] Scottsbluff, NE

[b] Rapid City, SD



CROW BUTTE PROJECT

DAWES & SIOUX COUNTIES, NEBRASKA

FIGURE 2.5-3
COMPARISON OF RELATIVE HUMIDITY FOR CHADRON, NE, SCOTTSBLUFF, NE AND RAPID CITY, SD - 2006

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While the differences in humidity are slight for the three weather stations discussed above, the use of slightly lower humidity data would be more conservative from an air emissions modeling standpoint. A lower humidity would predict impacts at a greater distance from the emission source. It is noted that humidity data are not expected to be required as an input parameter into modeling at North Trend (i.e., MILDOS and RESRAD). However, if future modeling is needed that requires humidity data input, an average of values for Scottsbluff and Rapid City (lower humidity than Chadron) would be used, resulting in a more conservative number for air modeling (i.e., use of lower humidity data).

Data from Scottsbluff, Nebraska and Rapid City, South Dakota were used because those cities have near-by weather stations that monitor many meteorological parameters hourly and provide complete, hourly data to the public. Crawford, Nebraska does not have a local weather station to provide that type of complete data. Data collected at the nearby Fort Robinson National Climatic Data Center Coop Station (i.e., temperature and precipitation) have not been shown to be consistently representative due to the number of periods with missing data (e.g., 1980 through 2008). Therefore, these data were not used.

2.5.5 Winds

Figure 2.5-4 and **Figure 2.5-5** are the wind roses for Scottsbluff, Nebraska and Rapid City, South Dakota, respectively. These Figures show predominant wind patterns that are similar; however, the finer details are greatly influenced by the local topography. Rapid City has a predominant wind from the north-northwest while Scottsbluff has a slightly bimodal distribution with the predominant winds from the west-northwest and the east-southeast. The least prevalent wind direction at Scottsbluff and Rapid City is from the southwest.

As shown by the wind rose for the License Area in **Figure 2.5-6**, the predominant air pollutant dispersion would be towards the north to northeast. The next most common directions would be towards the southwest to south-southwest.

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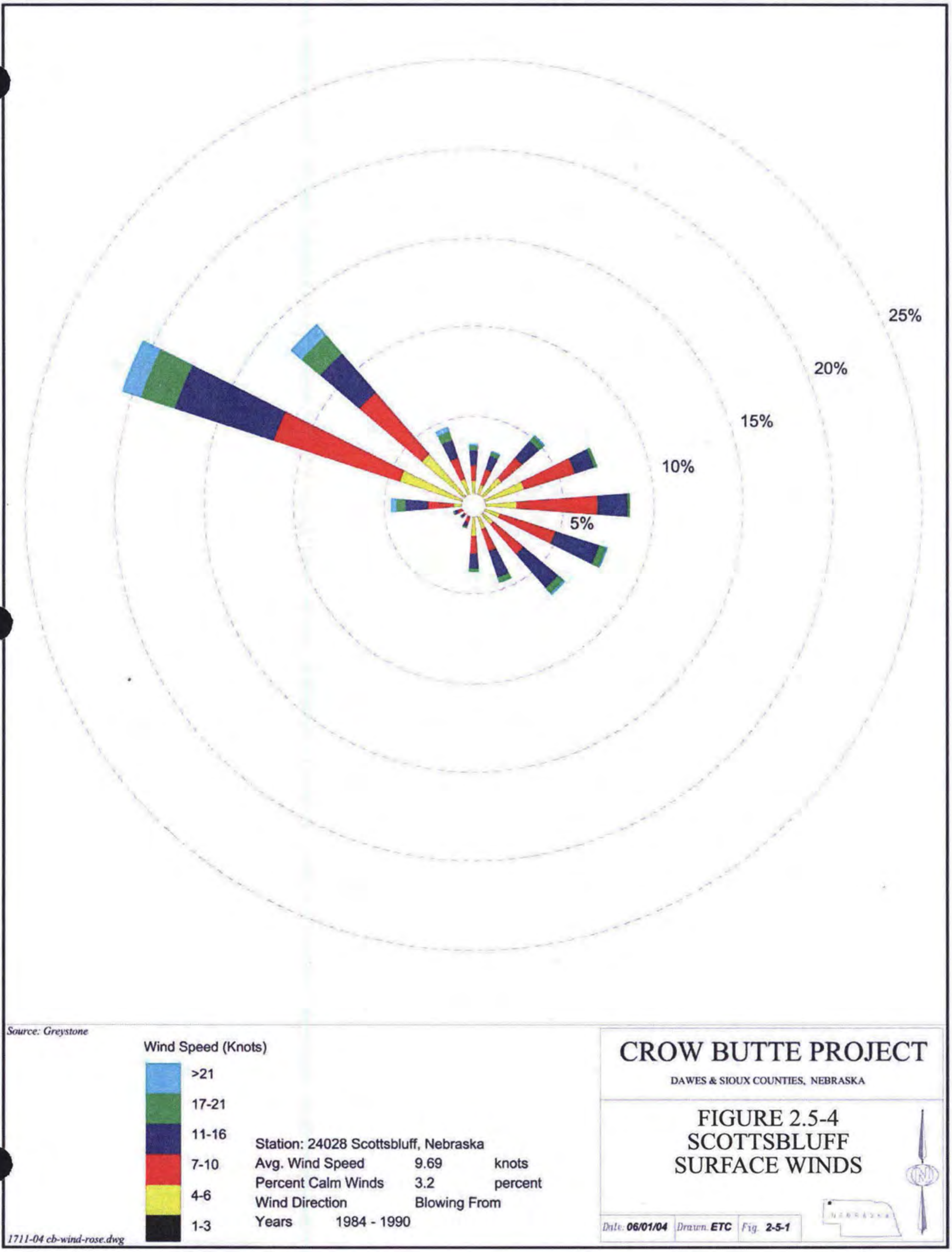

CROW BUTTE PROJECT

DAWES & SIOUX COUNTIES, NEBRASKA

FIGURE 2.5-4
SCOTTSBLUFF
SURFACE WINDS

Date: 06/01/04 Drawn: ETC Fig. 2-5-1

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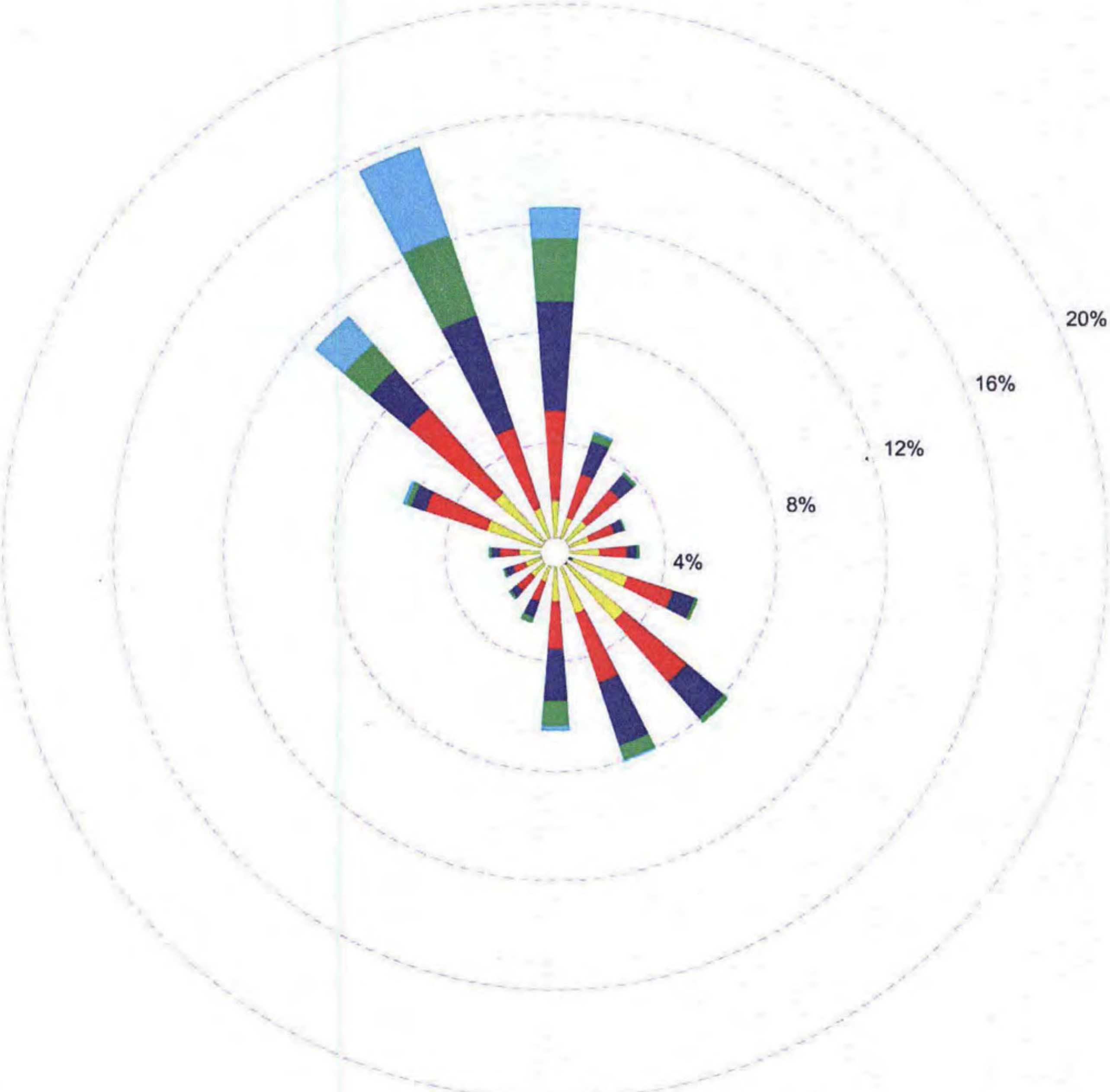

Source: Greystone

Wind Speed (Knots)

- >21
- 17-21
- 11-16
- 7-10
- 4-6
- 1-3

Station: 27090 Rapid City, South Dakota
Avg. Wind Speed 10.49 knots
Percent Calm Winds 2.88 percent
Wind Direction Blowing From
Years 1984 - 1990

CROW BUTTE PROJECT

DAWES & SIOUX COUNTIES, NEBRASKA

FIGURE 2.5-5
RAPID CITY SURFACE WINDS

Date: 06/01/04 Drawn: ETC Fig. 2-5-2

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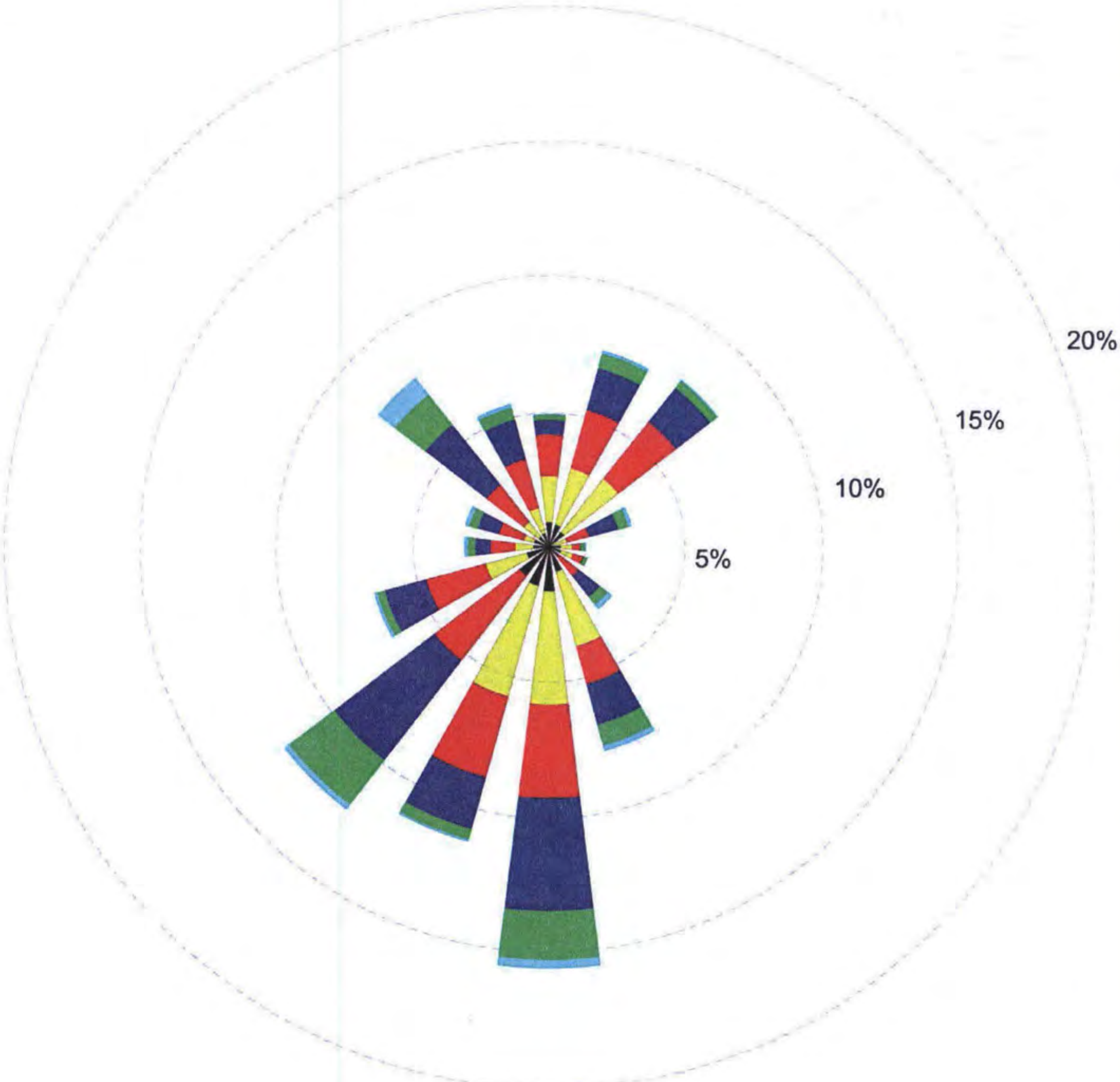

Source: Greystone

Wind Speed (Knots)

- >21
- 17-21
- 11-16
- 7-10
- 4-6
- 1-3

Avg. Wind Speed	8.40	knots
Percent Calm Winds	0.3	percent
Wind Direction	Blowing From	
Years	May 1982 - April 1984	

1711-04 cb-wind-rose.dwg

CROW BUTTE PROJECT

DAWES & SIOUX COUNTIES, NEBRASKA

FIGURE 2.5-6 CROW BUTTE SURFACE WINDS

Date: 06/01/04 Drawn: ETC Fig. 2-5-3

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Local terrain will have a significant influence on the wind patterns in a given area. Because of this, a meteorological station was installed within the License Area. This station was capable of measuring wind speed, direction, and the standard deviation of the wind direction. Joint frequency data was compiled from this information. **Figure 2.5-6** exhibits the wind rose that was identified for the site and **Table 2.5-8** through **Table 2.5-14** shows the frequency of winds by direction and speed for the six stability classes. **Table 2.5-15** shows the annual relative joint frequency distribution.

As shown on **Figure 2.5-6**, the predominant wind direction of the site is from a south-southwest direction approximately 45 percent of the time. Because of the differences among the site, Rapid City, and Scottsbluff, the two-year Crow Butte site wind record is considered the most representative.

Wind patterns at a specific site do not change significantly from year to year, but will change significantly for different locations. Unlike some other meteorological parameters, wind patterns are notably influenced by local topography. This is the case for the Crawford area.

The wind rose diagram in **Figure 2.5-4** shows the wind direction for Scottsbluff, Nebraska for 1984 to 1990. A comparison of this wind rose to the monthly wind roses located on the Natural Resources Conservation Service (NRCS) website (NRCS 2009) for 1961 to 2003 for Scottsbluff, Nebraska shows consistent wind direction trends. The same comparison and conclusion was made for **Figure 2.5-5** (wind rose for Rapid City, South Dakota, 1984 to 1990) and the wind roses on the NRCS website (NRCS 2009) for 1961 to 2003 for Rapid City, South Dakota. This shows that over time the wind patterns for a specific location remain consistent. However, a comparison of **Figures 2.5-4 and 2.5-5** to **Figure 2.5-6** (NTEA) show that Scottsbluff and Rapid City have different predominant wind patterns than the project site. Due to differences between the sites discussed above (Rapid City, and Scottsbluff), the 2-year wind record for the CBR site is considered the most representative.

CBR recognizes the importance of capturing local wind patterns since these data are used to determine the predominant air pollutant dispersion direction. 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. These older data are the only data available from the on-site monitoring station. For the evaluation of wind patterns, older data from the actual site are more representative than recent data from available off-site weather stations. The wind patterns are largely impacted by local terrain, and these 1982 to 1984 data should be considered to still be climatologically valid, and hence, appropriate for regulatory purposes. If data requirements, characteristics of the surrounding area, or approved air quality/radiological model requirements change, the meteorological data may need to be reprocessed for use. However, at the current time, with the limited air/radiological modeling required for an in-situ facility, the current meteorological database appears adequate for the CBR operation.

Table 2.5-8: Frequency of Winds by Direction and Speed (Stability A)

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

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

Table 2.5-9: Frequency of Winds by Direction and Speed (Stability B)

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

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

Table 2.5-10: Frequency of Winds by Direction and Speed (Stability C)

Wind Direction	Speed Class Intervals (Knots)							
	1 – 3	**3 - 6**	**6 - 10**	**10 – 16**	**16 - 21**	**>21**	**All**	**Mean Speed**
N	0.74	1.54	2.68	0.74	0.00	0.00	5.70	6.70
NNE	0.63	2.62	2.90	0.85	0.00	0.00	7.00	6.60
NE	0.91	2.28	5.69	1.20	0.00	0.00	10.08	7.00
ENE	0.46	1.03	2.96	0.97	0.00	0.00	5.42	7.30
E	0.00	0.57	0.74	0.28	0.00	0.00	1.59	7.60
ESE	0.23	0.34	0.91	0.23	0.00	0.00	1.71	7.00
SE	0.17	0.68	1.82	0.74	0.00	0.00	3.41	7.70
SSE	0.46	0.74	2.22	1.48	0.00	0.00	4.90	8.00
S	0.97	1.65	5.30	2.28	0.00	0.00	10.20	7.70
SSW	1.14	3.02	3.93	0.97	0.00	0.00	9.06	6.60
SW	1.03	3.36	4.67	1.14	0.11	0.00	10.31	6.80
WSW	0.97	3.02	3.59	1.14	0.06	0.06	8.84	6.80
W	0.11	0.91	1.99	1.03	0.11	0.00	4.15	8.40
WNW	0.17	0.51	1.03	1.25	0.06	0.00	3.02	9.10
NW	0.40	0.74	3.70	2.22	0.06	0.00	7.12	8.70
NNW	0.40	1.42	3.42	2.11	0.00	0.00	7.35	8.20
ALL	**8.79**	**24.43**	**47.55**	**18.63**	**0.40**	**0.06**	**99.86**	**7.40**

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

Table 2.5-11: Frequency of Winds by Direction and Speed (Stability D)

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

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

Table 2.5-12: Frequency of Winds by Direction and Speed (Stability E)

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

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

Table 2.5-13: Frequency of Winds by Direction and Speed (Stability F)

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

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

Table 2.5-14: Frequency of Winds by Direction and Speed (All Stabilities)

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

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

Table 2.5-15 Joint Frequency Distribution[a]

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

Table 2.5-15 Joint Frequency Distribution[a]

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

Table 2.5-15 Joint Frequency Distribution[a]

0.00093	0.00136	0.00000	0.00000	0.00000	0.00000
0.00136	0.00074	0.00000	0.00000	0.00000	0.00000
0.00124	0.00043	0.00000	0.00000	0.00000	0.00000
0.00173	0.00099	0.00000	0.00000	0.00000	0.00000
0.00167	0.00173	0.00000	0.00000	0.00000	0.00000
0.00365	0.00464	0.00000	0.00000	0.00000	0.00000
0.00729	0.01175	0.00000	0.00000	0.00000	0.00000
0.00705	0.01280	0.00000	0.00000	0.00000	0.00000
0.00631	0.00779	0.00000	0.00000	0.00000	0.00000
0.00266	0.00253	0.00000	0.00000	0.00000	0.00000
0.00173	0.00142	0.00000	0.00000	0.00000	0.00000
0.00080	0.00093	0.00000	0.00000	0.00000	0.00000
0.00130	0.00117	0.00000	0.00000	0.00000	0.00000
0.00130	0.00049	0.00000	0.00000	0.00000	0.00000

[a]Joint frequency distribution is a set of data that represents a summary of meteorological conditions at the meteorological station location from May 1982 through April 1984. Joint frequency distribution is computed by compiling meteorological data, determined and recorded for each hour, over a designated time interval and computing the frequency of occurrence of each joint frequency category. Each joint frequency category represents a band of wind speeds, directions, and stability conditions.

In addition as discussed above, wind patterns (e.g., wind roses) have not changed significantly over a 40-year period for Scottsbluff and Rapid City, which would suggest there would be no significant changes with wind patterns at the CBR meteorological monitoring site.

Tornadoes are rare in the License Area. In the USNRC, "Draft Generic Environmental Impact Statement on Uranium Milling" (USNRC 1979), the authors calculated a mean annual frequency of 0.6 for tornadoes in intensity Category I at Rapid City. The annual probability of occurrence at this location is 4.8 x 10^{-4}. A tornado in intensity Category I has a rotational speed of 134 meters per second (m/s) and a translational speed of 26 m/s.

2.5.6 Air Quality

Although there are no ambient air quality monitoring data for non-radiological pollutants within the License Area, PM10[1] concentrations have been measured in Rapid City, South Dakota and Badlands National Park in South Dakota. Both locations are geographically similar to the License Area.

The Rapid City data were collected at the National Guard Camp Armory site about 2 mile west of the city. This area is classified as suburban. The Badlands data were collected in an area classified as rural. Because of the degree of urbanization, the air quality at the License Area would probably fall somewhere between the air quality at these two locations. These data were obtained from the United States Environmental Protection Agency (USEPA) air quality monitoring database (USEPA 2007), and are presented in **Table 2.5-16**.

Table 2.5-16: PM_{10} Monitoring Summary (micrograms per cubic meter)

	Maximum 24-hr Average		Annual Average	
Year	**Black Hills, SD**	**Rapid City, SD**	**Black Hills, SD**	**Rapid City, SD**
1998	NA	87.4	NA	30.7
1999	NA	116.9	NA	28.2
2000	38.5	97.4	12.0	31.3
2001	47.9	81.5	12.6	34.6
2002	26.0	104.7	9.9	34.9
2003	74.4	91.8	16.3	36.2
2004	24.0	72.0	10.0	30.0
2005	40.0	94.00	9.0	27.0
2006	30.0	124.0	10.0	29.0

Notes: NA = Not Available

The National Ambient Air Quality Standards (NAAQS) for PM_{10} are 150 micrograms per cubic meter (24-hour average), and 50 micrograms per cubic meter (annual average). All counties within the 80-km radius or the project are in attainment of NAAQS.

[1] Particulate matter with a diameter less than or equal to 10 microns.

2.5.7 Noise

Noise standards and sound measurement equipment have been designed to account for the sensitivity of human hearing to different frequencies. This varying sensitivity is accommodated by applying "A-Weighted" correction factors. This correction de-emphasizes the very low and very high frequencies of sound in a manner similar to the response of the human ear. The primary assumption is that the A-weighted decibel (dBA) is a good correlation to a human's subjective reaction to noise. In general, a residential area at night is 40 dBA; a residential area during the day is 50 dBA; a rural area during the day is 40 dBA and a typical construction site is 80 dBA (USEPA 1974). As a comparison, a normal conversation at 5 feet is 60 dBA (USEPA 1974).

The nearest noise receptor (residence) to the License Area is on SH 2/71 along the eastern License Area boundary. This residence is located approximately 0.5 mile from the satellite plant. The next closet residence is located along the southern License Area boundary at a distance of approximately 1.5 miles south of the satellite plant.

According to Sandy Seidel, Crawford City Clerk, the City of Crawford does not have a noise ordinance. A review of the City of Crawford Municipal Code revealed a noise ordinance related to industrial equipment. Section 2-103, Excessive Noise Control (Crawford 2007) reports that it is "unlawful to operate industrial equipment, heavy machinery, jack hammer and other industrial equipment emitting loud noise or to race automobile engines within the City between the hours of 8:00 P.M. and 7:00 A.M., in such a manner so as to disturb the peace unless such activity has been approved in advance by the City Council." Construction activities associated with the License Area would be conducted outside of the City of Crawford limits. The Dawes County Clerk's office did not know of a noise ordinance for Dawes County.

The License Area is bounded on the west by the Burlington Northern Santa Fe (BNSF) rail line and on the east by Nebraska SH 2/71. Therefore, the existing ambient noise in the vicinity of the License Area is dominated by the traffic noise from SH 2/71 and trains on the BNSF rail line.

The State of Nebraska, Department of Roads, reports that the annual 24-hour average number of total vehicles to travel SH 2/71 along the eastern project boundary in 2004 was 965 (Nebraska 2007a). Thirty-five of these vehicles were reported to be heavy commercial vehicles. **Table 2.5-17** (USDOT 1995) presents typical noise levels for automobiles at a distance of 15 meters (45 feet) at speeds ranging from 50-miles per hour (mph) to 70 mph.

Traffic noise is a combination of traffic density and vehicle speed. According to the Nebraska Department of Roads (NDOR), the speed limit along SH 2/71 near the License Area is 60 miles per hour (NDOR 2007). The closest noise receptor (residence) to SH 2/71 is located adjacent to the road. Therefore, the existing noise level at that receptor due to existing traffic noise alone would be expected to be 65 dBA.

Table 2.5-17: Typical Automobile Noise Levels

Speed (mph)	Noise Level at 45 Feet (dBA)
50	62
55	64
60	65
65	66.5
70	68

The precise noise levels caused by trains is a complex calculation that considers the train speed, the train length, the conditions of the wheels, and the condition of the track (Harris 1991). Noise from trains has been measured (Harris 1991) to range from 87 to 96 dBA at 100 feet from a track. The BNSF rail line runs through the town of Crawford. Assuming that a resident may live as close as 100 feet from the track, the existing noise for that receptor would be expected to be at least 87 dBA due to train noise alone.

The propagation of noise depends on many factors including atmospheric conditions, ground cover, and the presence of any natural or man-made barriers. As a general rule, noise decreases by approximately 6 dBA with every doubling of the distance from the source (Bell 1982). Therefore, noise levels at various distances can be predicted. The closest noise receptor, residence along SH 2/71, is located approximately 1.2 miles east of the BNSF. Using the doubling rule, the train noise at the residence would be 51 dBA, assuming a distance of 6400 feet. Because the effect of multiple noise sources is not a simple addition, but rather is a logarithmic addition, the existing noise levels at the closest receptor, based on noise from highway traffic and the BNSF, is likely to be 65 dBA or greater.

2.5.8 References

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2.6 GEOLOGY, SOILS AND SEISMOLOGY

This section describes the regional and local geology and seismology related to the current License Area and CSA. In this regard, discussion of the geology of the License Area and CSA, in particular, 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 in the CSA. These data, in addition to new information from exploratory drilling/logging activities within the License Area, are used to describe the geology and seismology in this section.

2.6.1 Regional Setting

The Crow Butte Project is in Dawes County in northwestern Nebraska. Crawford is the principal town in the area and lies approximately 4 miles northwest of the current plant site. Crawford is 25 miles west of Chadron and 70 miles north of Scottsbluff, Nebraska. Crawford is 21 miles south of the South Dakota State line and 33 miles east of the Wyoming State line (**Figure 2.6-1**). The topography consists of low rolling hills dominated by the Pine Ridge south and west of the project area.

2.6.1.1 General 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** is a generalized stratigraphic chart for the region.

2.6.1.2 Pre-Pierre Shale 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 2972 to 3020 feet in the Bunch No. 1 hole (Section 5, 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.

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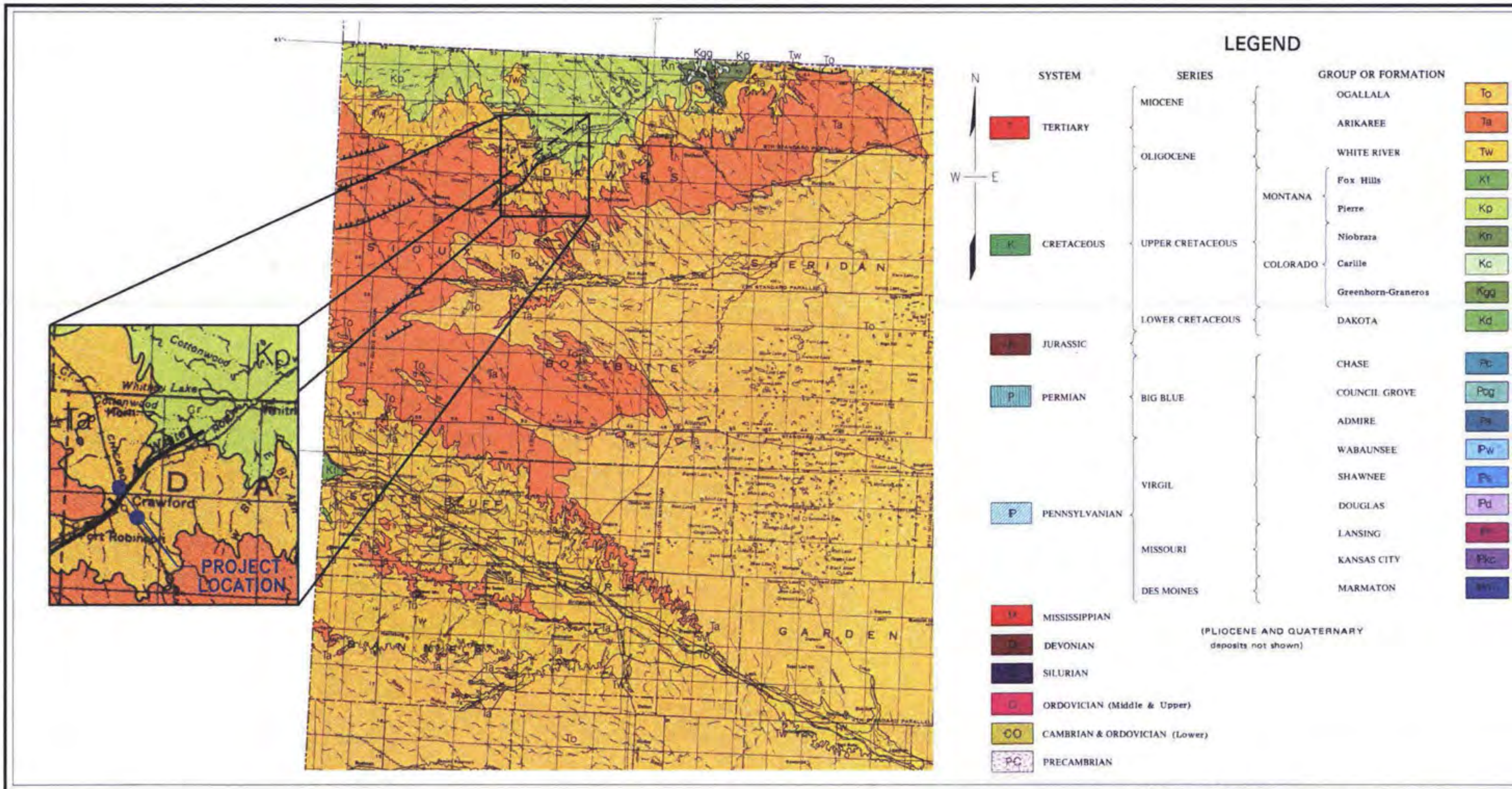

Source: Nebraska Geological Survey

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-1
BEDROCK GEOLOGY MAP, DAWES COUNTY

PROJECT: 223-37	DATE: MARCH 2007
NTLAAFig2.6-1.dwg	BY: KRS CHECKED: HPD

Petrotek

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Table 2.6-1: General Stratigraphic Chart for Northwest Nebraska

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

Notes: * Maximum thickness based on Swinehart et al. 1985.

2.6.1.3 Pierre Shale

The Pierre Shale of Cretaceous age is the oldest formation of interest for the Crow Butte project 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 north of the area of review.

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 Township 32 North, Range 51-52 West. 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 a few tens of feet of Quaternary alluvium overlying the Pierre Shale. The bottom few tens of feet in those wells provide storage. It is stated in this Spalding reference that: "In very shallow wells (a few tens of feet) significant amounts of water utilized may be contained in the thin Quaternary sediments overlying the designated hydrogeologic unit. This situation is particularly true for those wells noted as completed in the Pierre Shale". In the geologic summary of this Spalding reference the groundwater potential of the Pierre Shale is discussed by Marvin Carlson. Mr. Carlson states: "The oldest bedrock unit in the area, the Pierre Shale of Cretaceous Age, is not considered as a potential aquifer. It is, however, included in the discussion of completion horizons and hydrogeologic units. A few of the shallow wells produce from the Quaternary sediments immediately 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 prior to Oligocene sedimentation. Consequently, the top of the present day Pierre 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, p.24) and is readily observed in certain outcrop exposures.

2.6.1.4 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.

2.6.1.5 Chadron Formation

The Chadron is the oldest Tertiary 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.

2.6.1.6 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 1150 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 Brule channels are commonly water bearing in the otherwise generally impermeable Brule.

Recently, the Brown Siltstone beds have been recognized by Swinehart and others in northwest Nebraska (Swinehart et al. 1985). This informal member has been added to the upper part of the Brule Formation. 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.

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 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, p.50).

Monroe Creek Formation

The Monroe Creek Formation overlies the Gering and is the middle unit of the Arikaree Group. The Monroe Creek Formation is lithologically similar to the Gering with buff to brown fine grained sandstone. The unique characteristic of the Monroe Creek 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, p. 53.).

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, p.55).

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 is complexly interbedded with the sandstones and gravels.

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

2.6.1.7 Regional Structure

The most prominent structural expression in northwest Nebraska is the Chadron Arch. This anticlinal feature strikes roughly northwest-southeast along the northeastern boundary of Dawes County. 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 Black Hills lie north of Sioux and Dawes Counties in southwestern South Dakota. Together with the Chadron Arch, the Black Hills Uplift has produced many of the prominent structural features presently observed in the area today. As a result of the uplift, formations underlying the area dip gently to the south. The Tertiary deposits dip slightly less than the older Mesozoic and Paleozoic Formations (Witzel 1974, p.18). The Crow Butte ore body lies in what has been named the Crawford Basin (DeGraw 1969). DeGraw made detailed studies of the pre-Tertiary subsurface in western Nebraska using primarily deep oil test hole information. He was able to substantiate known structural features and propose several structures not earlier recognized. The Crawford Basin was defined by DeGraw as being a triangular asymmetrical basin 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 (DeGraw 1969). The town of Crawford is located near the axis of the Crawford Basin that is about 50 miles long in an east-west direction and about 25-30 miles wide at Crawford.

The geologic map of northwest Nebraska reproduced from the State Geologic Map, Figure 2.6-1, illustrates the recognized faulting in northwest Nebraska. Six northeast trending faults are present in Sioux and Dawes Counties. All of these faults are down thrown to the north. One of these faults, the White River Fault, follows the White River north of Crawford and was discovered during the exploration drilling phase of the Crow Butte project (Collings and Knode 1984). The only other fault illustrated, the White Clay Fault, terminates the Arikaree Group rocks on the east from White Clay to about six miles east of Gordon (Nebraska Geological Survey 1986).

The Bordeaux Fault, Pine Ridge Fault, and Toadstool Park Fault were proposed by DeGraw (1969) but have not been included on the State Geologic Map. The Toadstool Park Fault has been noted on outcrop at one location in T33N, R53W, to have a displacement of about 60 feet (Singler and Picard 1980). Other smaller faults may be present.

The Cochran Arch was also proposed by DeGraw (1969, p.36) on the basis of subsurface data. The Cochran Arch trends east-west through Sioux and Dawes Counties, parallel to the Pine Ridge Fault proposed by DeGraw. Structural features subparallel to the Cochran Arch have been recognized based on CBR drill hole data. The existence of the Cochran Arch may explain the structural high south of Crawford.

The synclinal axis of the Crawford Basin trends roughly east-west and plunges to the west into what CBR informally calls the Inner Crawford Basin located west of the Area of Review (**Figure 2.6-2**) (Collings and Knode 1984). The Inner Crawford Basin is characterized by an increase in the thickness of the Chadron Sandstone.

2.6.2 Crow Butte License Area Geology

An Area of Review Stratigraphic Column for the Crow Butte License Area has been prepared and is shown as **Figure 2.6-2**. The stratigraphic nomenclature of Swinehart, et al (1985) and Crow Butte Resources are shown on the column.

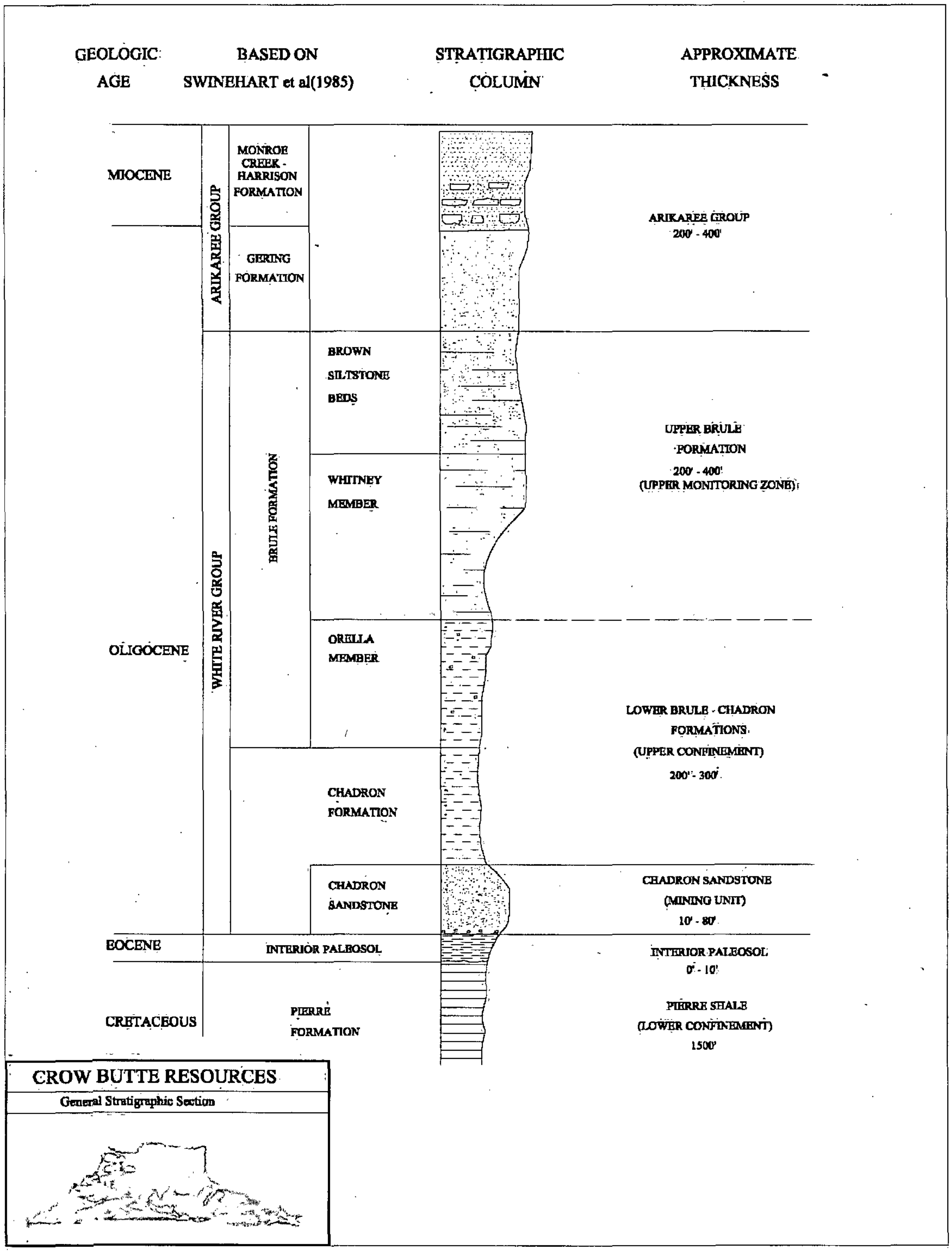
A series of five east-west cross sections have been constructed through the proposed wellfield area and the Area of Review to demonstrate the geology of the Basal Chadron Sandstone and its relationship to the confining horizons (**Figure 2.6-3** to **Figure 2.6-10**). Three northwest-southeast cross sections are included to show the continuity of the geology (**Figure 2.6-4, 2.6-10 and 2.6-11**). 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 a solution mining 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 (**Figure 2.6-3** to **Figure 2.6-11**).

2.6.2.1 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 (**Figure 2.6-1** to **Figure 2.6-9**). The Pierre Shale is the confining bed below the Chadron Sandstone that is the host for uranium mineralization (**Figure 2.6-1** to **Figure 2.6-9**). The description provided under General Stratigraphy also describes the Pierre Shale within the Area of Review.

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

Figure 2.6-2: Area of Review, Stratigraphic Column



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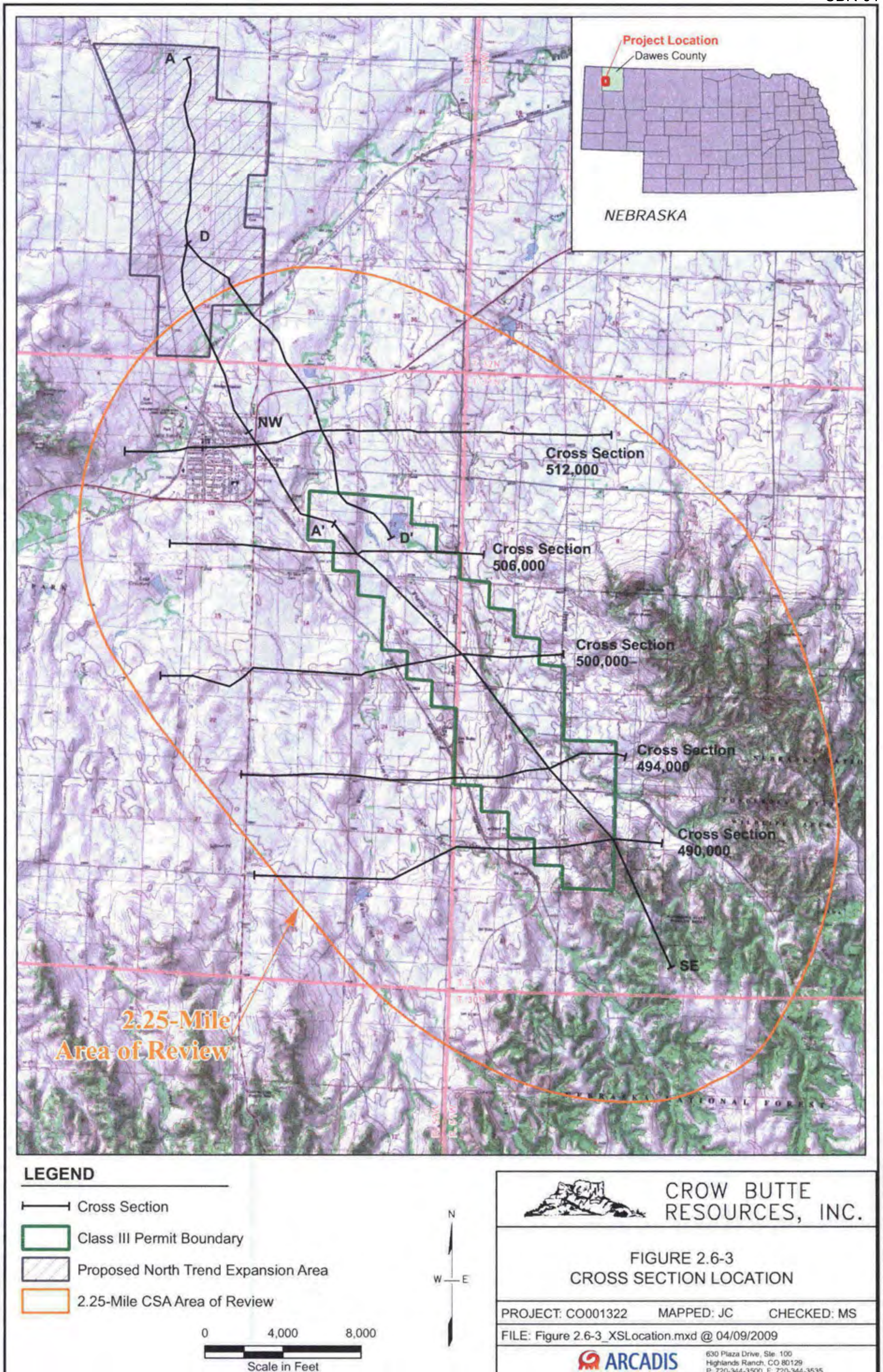

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-3
CROSS SECTION LOCATION

PROJECT: CO001322 MAPPED: JC CHECKED: MS

FILE: Figure 2.6-3_XSLocation.mxd @ 04/09/2009

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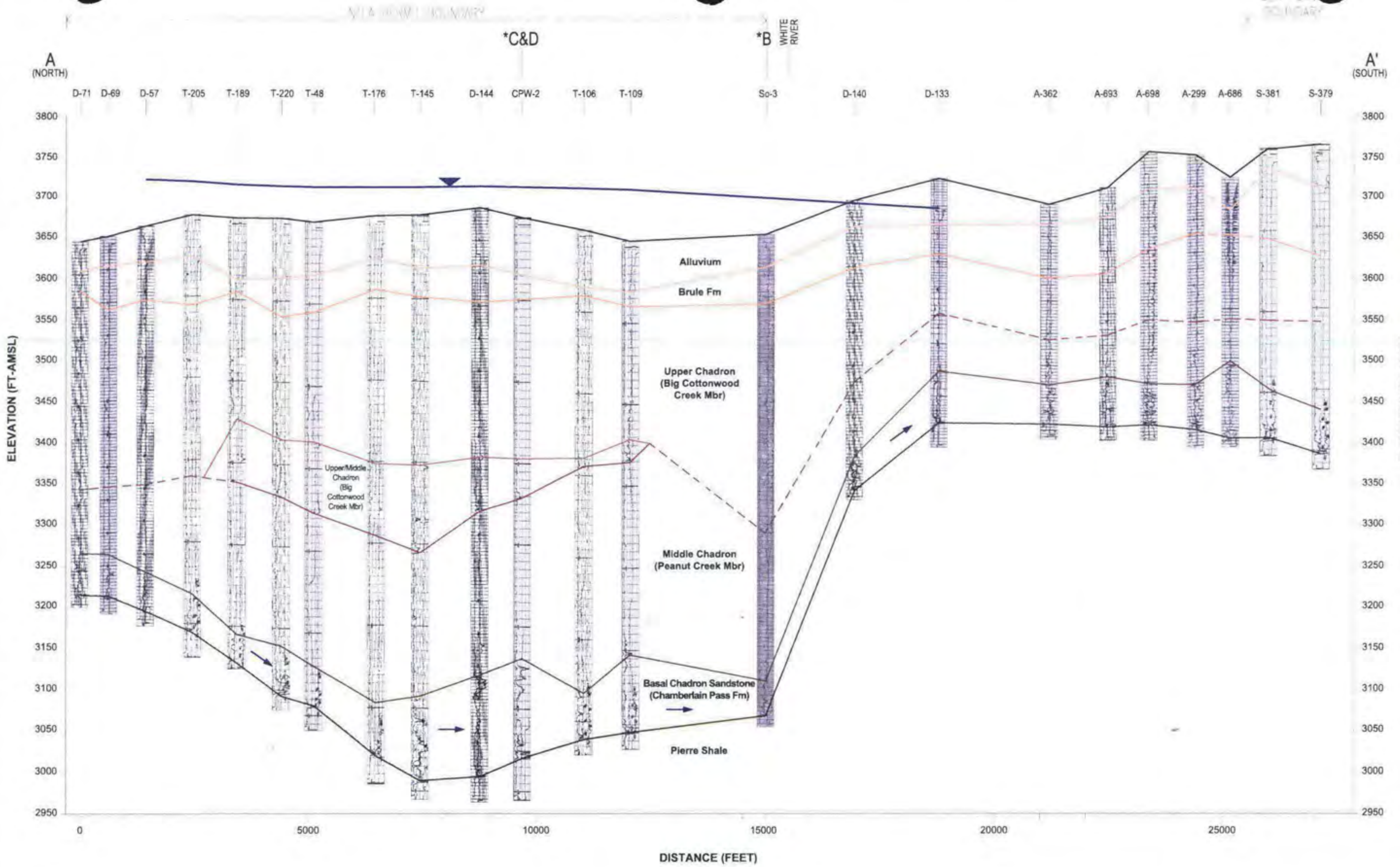
CBR-011



Notes:

1) Geologic units that underlie the Pierre Shale are not shown.
2) Occurrences of the Upper Interior Paleosol (Chamberlain Pass Fm) and Yellow Mounds Paleosol could not be discerned on available elogs.
3) For locations where the Upper/Middle Chadron Fm (Big Cottonwood Creek Mbr) was not observed in elogs, the contact between the Upper Chadron Fm (Big Cottonwood Creek Mbr) and the Middle Chadron Fm (Peanut Peak Mbr) was extrapolated based on known occurrence, and is shown as dashed lines.
4) Groundwater elevations were measured on 4/16/2008 (FT-AMSL).

* Letter indicates location of intersecting cross-section lines shown on Figure 4.

Legend:

- Topographic Surface
- Top of Brule Fm
- Top of Upper Chadron (Big Cottonwood Creek Mbr)
- Top of Upper/Middle Chadron (Big Cottonwood Creek Mbr)
- Top of Middle Chadron (Peanut Creek Mbr)
- Top of Basal Chadron Sandstone (Chamberlain Pass Fm)
- Top of Pierre Shale
- Potentiometric Surface (Basal Chadron Sandstone) - 4/16/08
- Groundwater Flow Direction
- NTEA North Trend Expansion Area
- CSA Class III Area

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-4
CROSS-SECTION A-A'

PROJECT: CO001322 MAPPED: JC CHECKED: MS

FILE: Fig 5a_Extended.dwg CSA LRA DATE/TIME: 4/9/2009 6:21 AM

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Figure 2.6-5: Cross Section 512,000 E-W

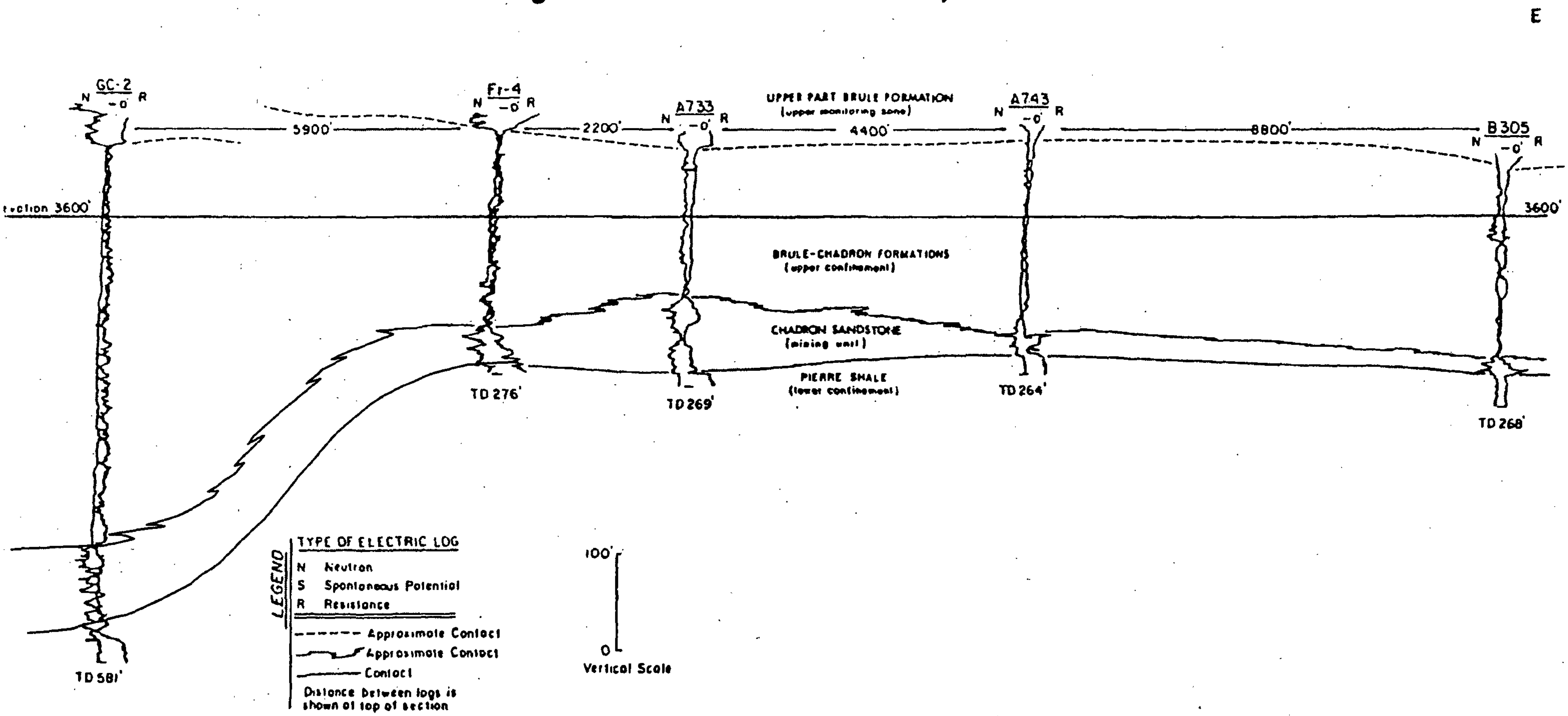

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Figure 2.6-6: Cross Section 506,000 E-W

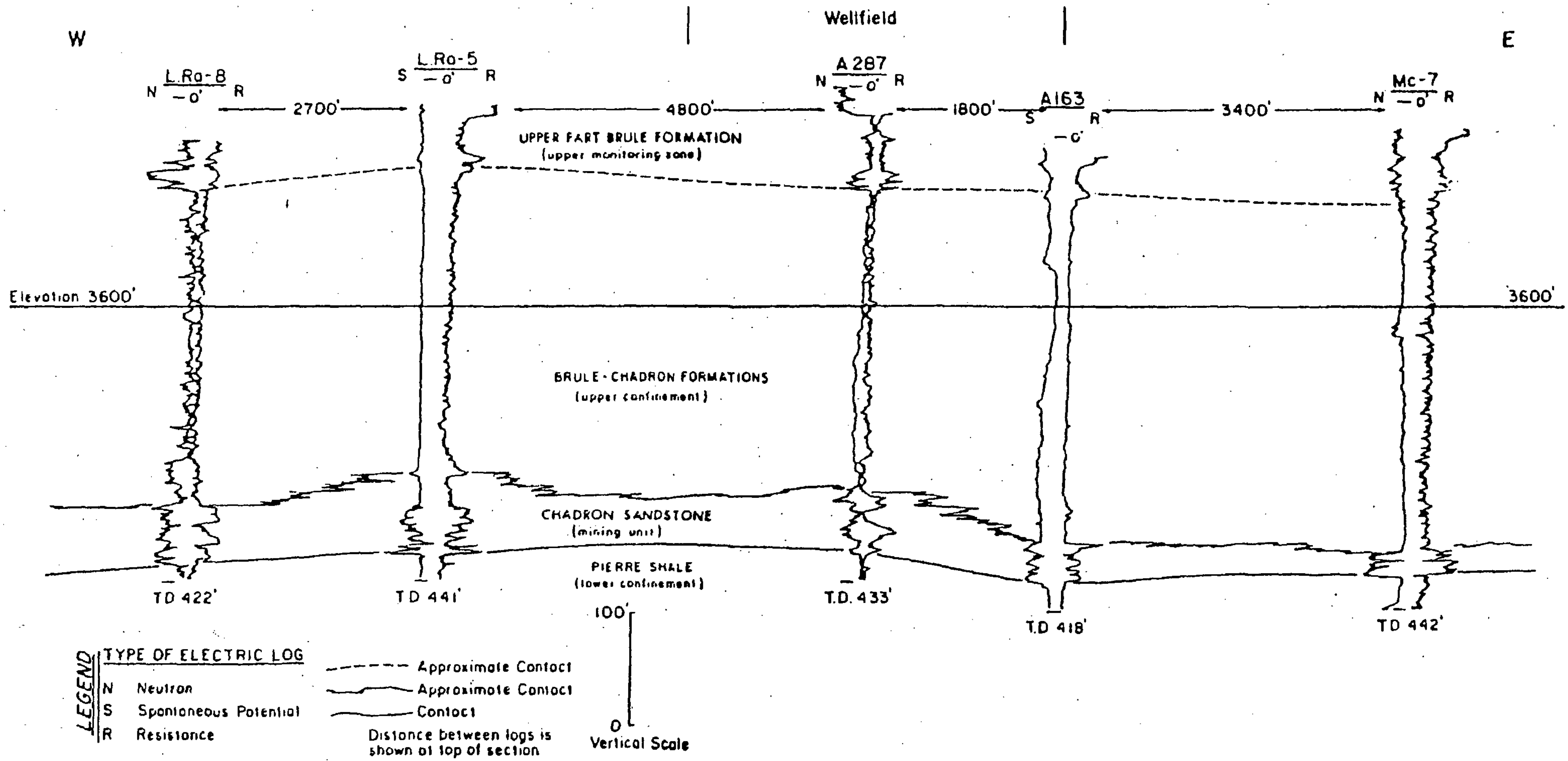

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Figure 2.6-7: Cross Section 500,000 E-W

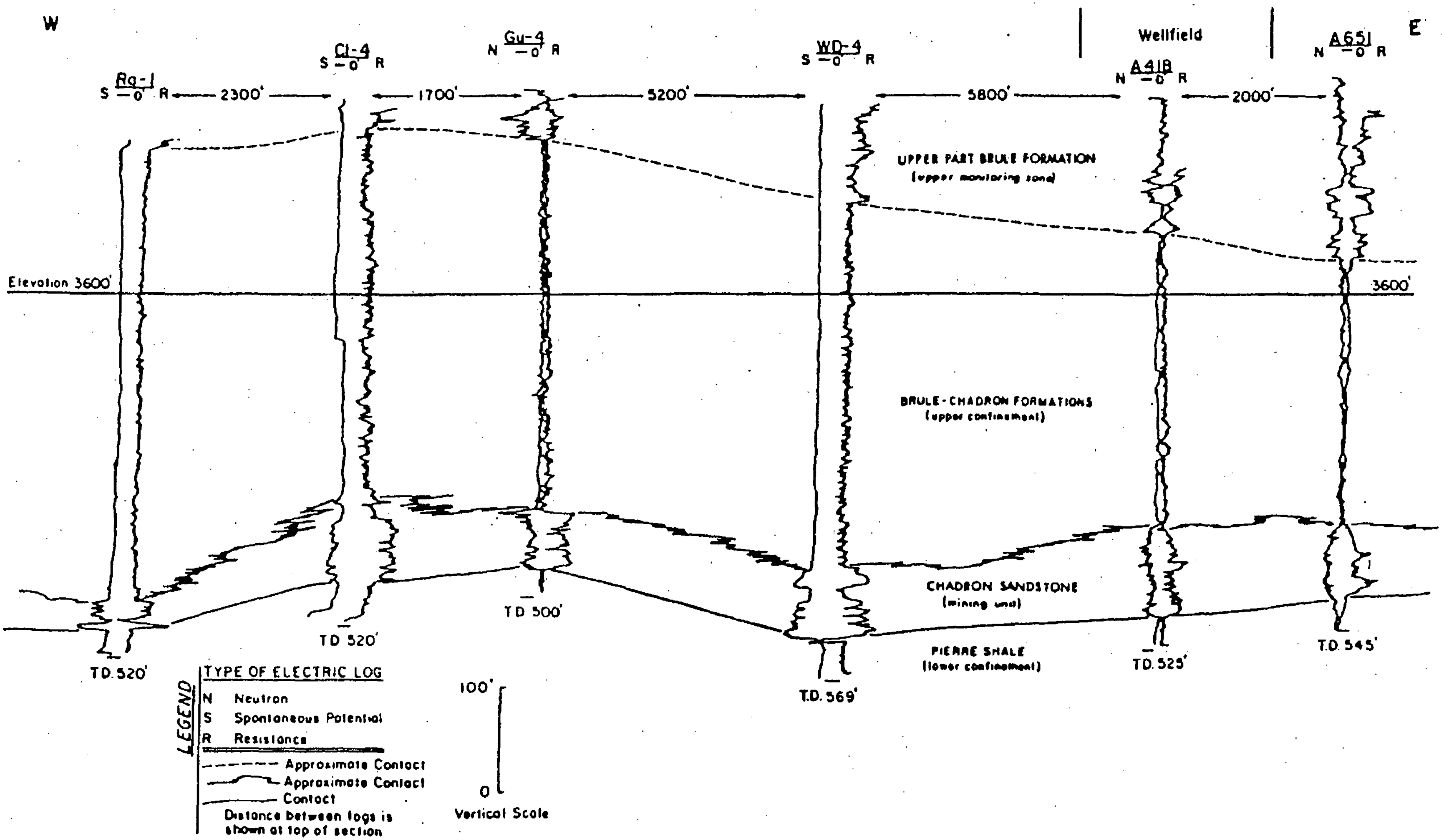

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Figure 2.6-8: Cross Section 494,000 E-W

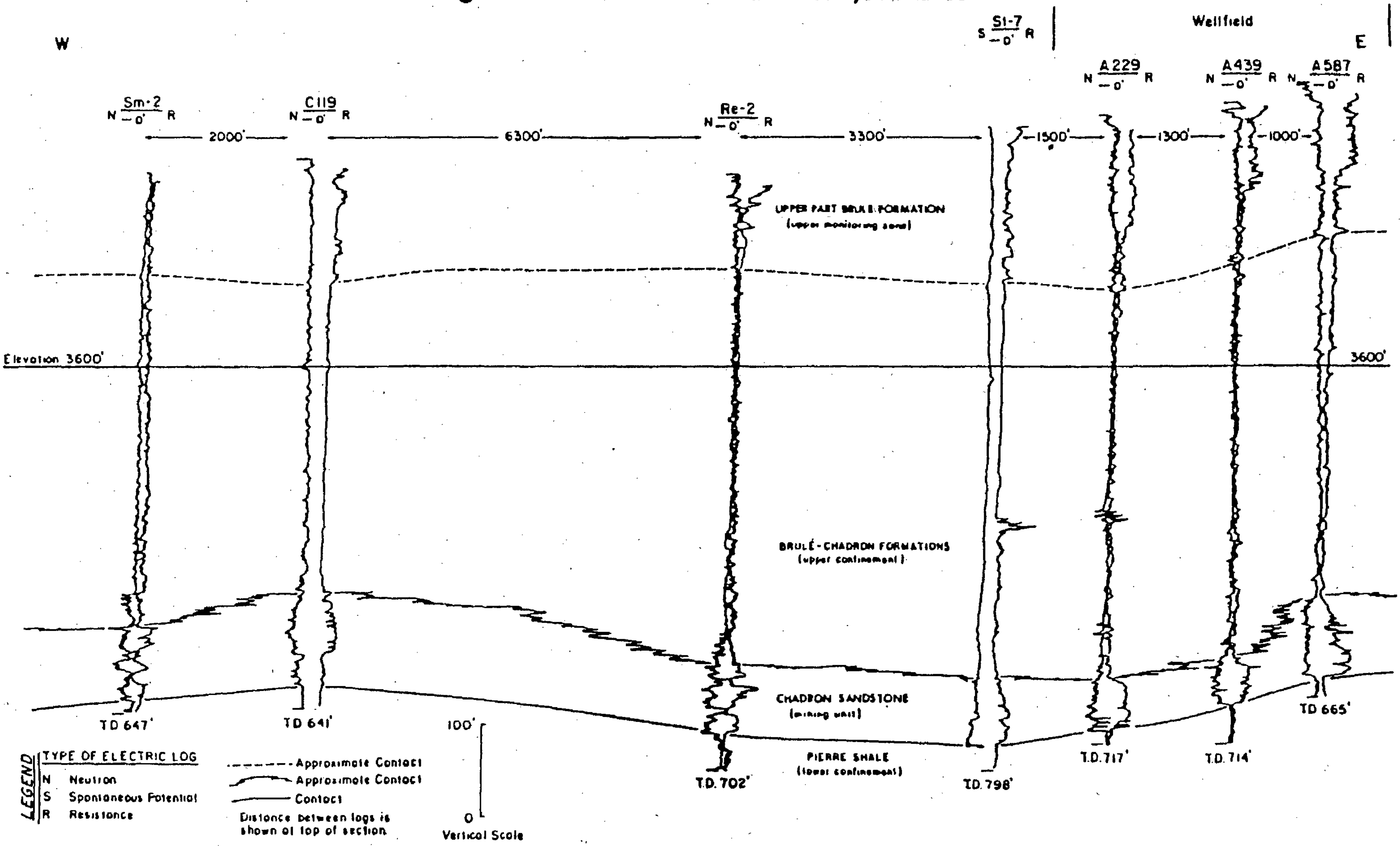

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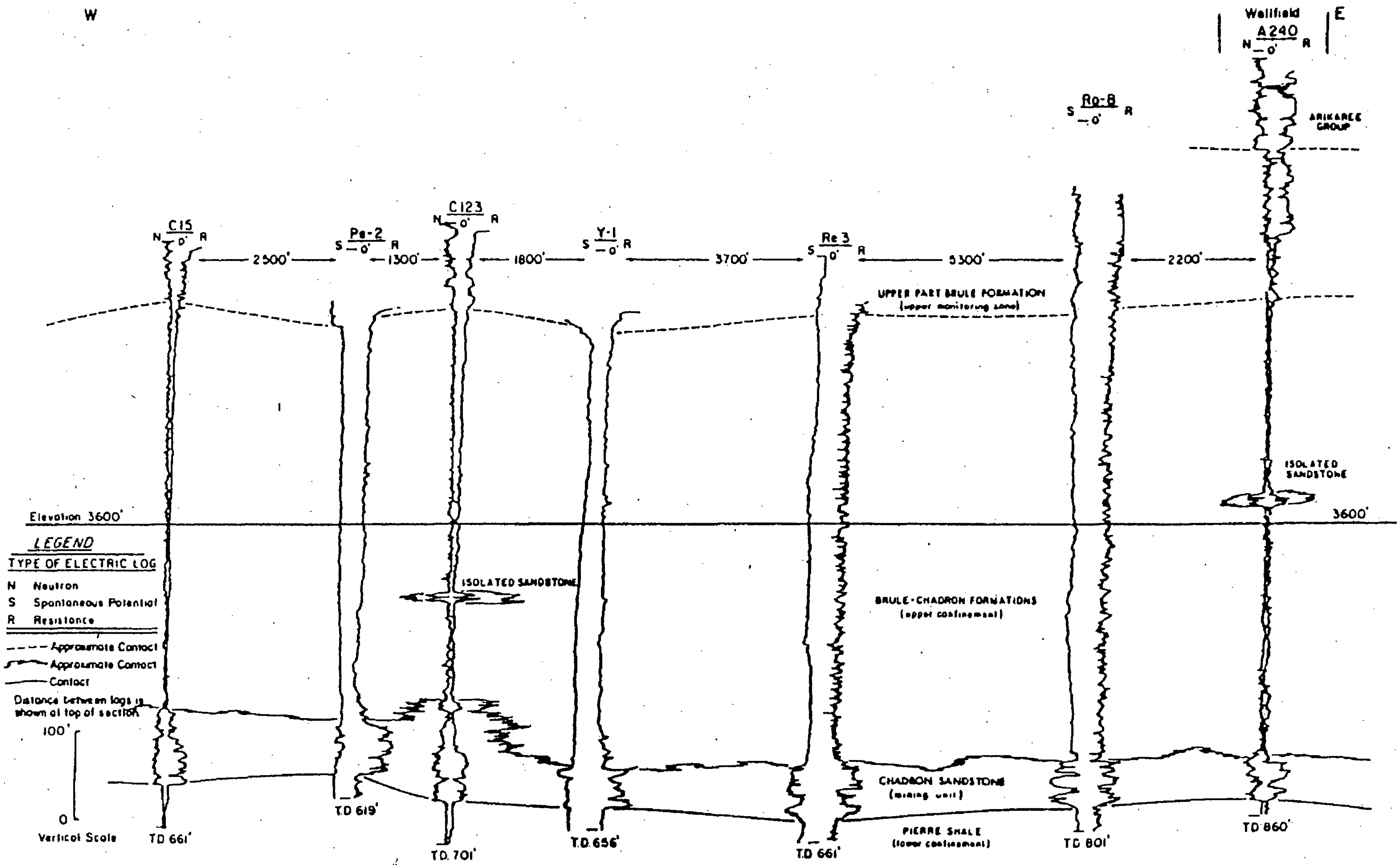
Figure 2.6-9: Cross Section 490,000 E-W



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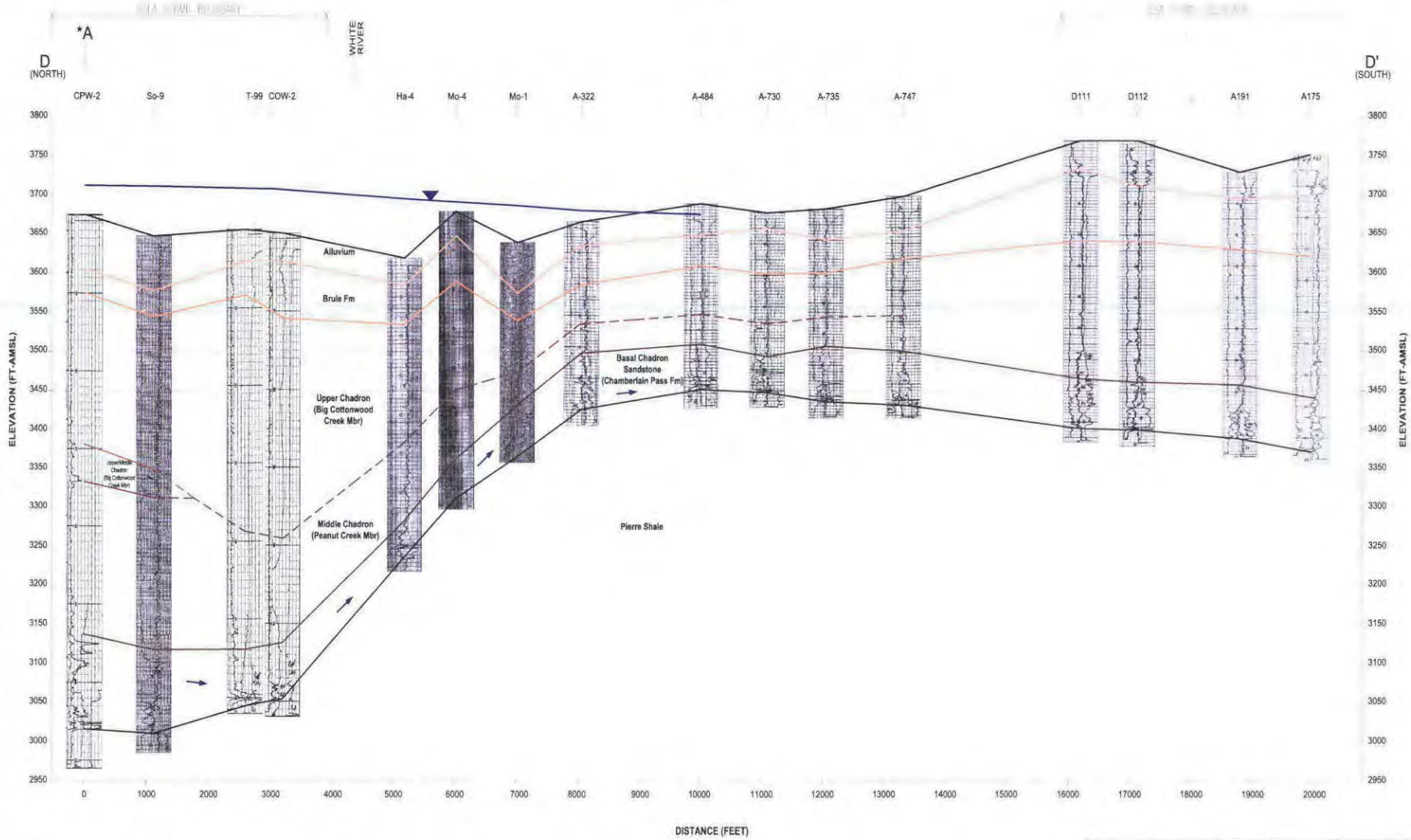

Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) Occurrences of the Upper Interior Paleosol (Chamberlain Pass Fm) and Yellow Mounds Paleosol could not be discerned on available elogs.

3) For locations where the Upper/Middle Chadron Fm (Big Cottonwood Creek Mbr) was not observed in elogs, the contact between the Upper Chadron Fm (Big Cottonwood Creek Mbr) and the Middle Chadron Fm (Peanut Peak Mbr) was extrapolated based on known occurrence, and is shown as dashed lines.

4) Groundwater elevations were measured on 4/16/2008 (FT-AMSL).

* Letter indicates location of intersecting cross-section lines shown on Figure 4.

Legend:

- Topographic Surface
- Top of Brule Fm
- Top of Upper Chadron (Big Cottonwood Creek Mbr)
- Top of Upper/Middle Chadron (Big Cottonwood Creek Mbr)
- Top of Middle Chadron (Peanut Creek Mbr)
- Top of Basal Chadron Sandstone (Chamberlain Pass Fm)
- Top of Pierre Shale
- Potentiometric Surface (Basal Chadron Sandstone) - 4/16/08
- Groundwater Flow Direction
- NTEA North Trend Expansion Area
- CSA Class III Area

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-10
CROSS-SECTION D-D'

PROJECT: CO001322 MAPPED: JC CHECKED: MS

FILE: Fig 5d_Extended.dwg CSA LRA DATE/TIME: 4/9/2009 8:31 AM

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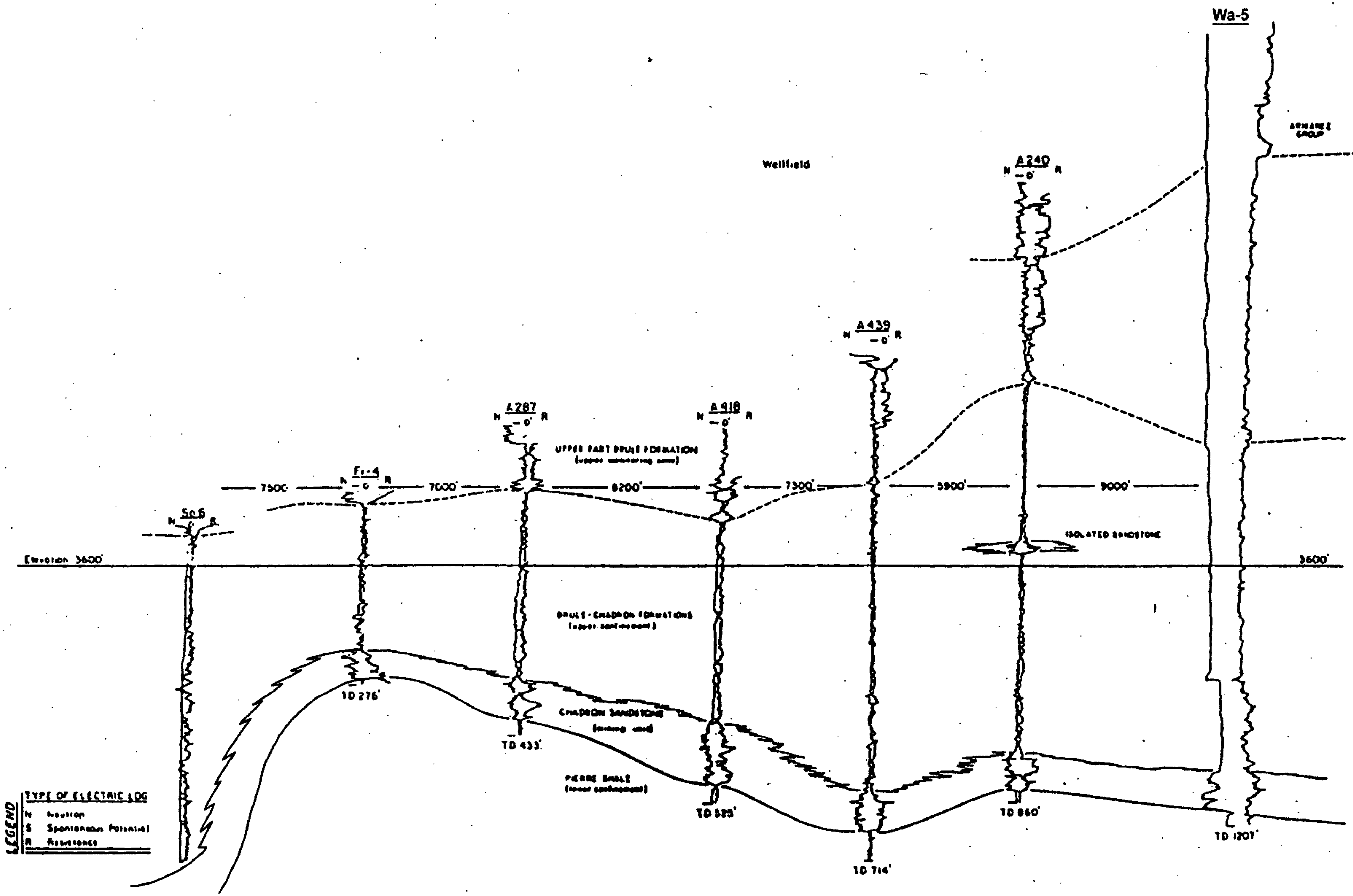
Figure 2.6-11: Cross Section NW-SE



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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 Area of Review. At the location of Heckman No. 1 the base of the Chadron Formation is at a depth of 525 feet. The Pierre Shale is 1565 feet thick and rests on the Niobrara Formation at 2090 feet. The spontaneous potential and resistivity curves of this hole indicate there are no permeable zones within the Pierre Shale. Based on several additional oil and gas holes within the Area of Review the Pierre Shale ranges from about 1250 to 1565 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 $2.0x10^{-9}$ centimeters per second (cm/sec). The electric log characteristics of the Pierre Shale and overlying units are shown on logs included on the cross sections, and illustrate the impermeable nature of the Pierre Shale.

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

2.6.2.2 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 Area of Review 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 2.6-12**).

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.

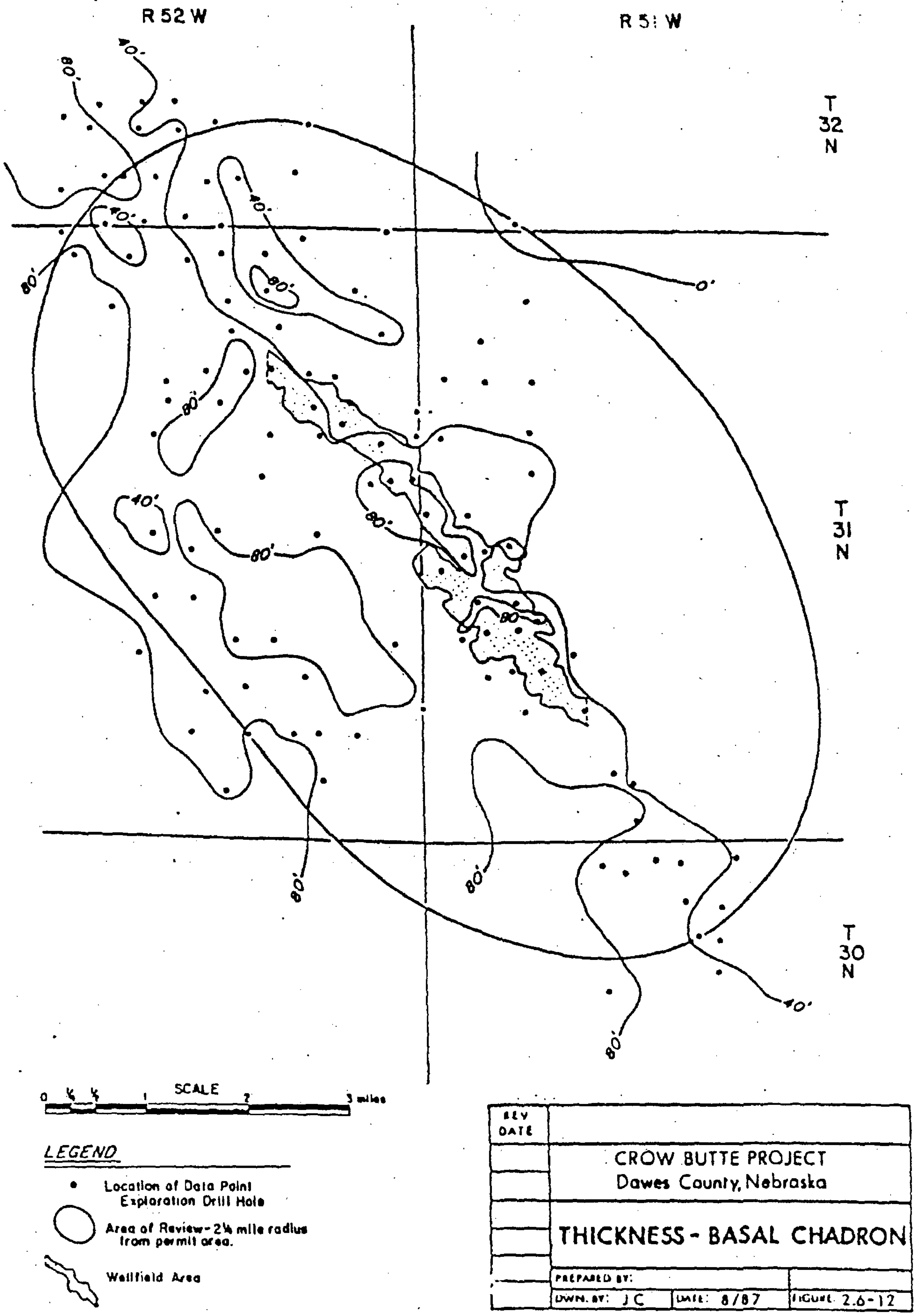
Thin section examination of the Chadron Sandstone reveals its composition to be 50 percent monocrystalline quartz, 30 to 40 percent undifferentiated feldspar, plagioclase feldspar and microcline feldspar. The remainder includes polycrystalline quartz, chert, chalcedonic quartz, various heavy minerals 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 2.6-6**), and WD-4 (**Figure 2.6-7**), and Re-2 (**Figure 2.6-8**) illustrate the subunits.

2.6.2.3 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**).

Figure 2.6-12: Thickness- Basal Chadron



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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 Area of Review.

The Brule Formation lies conformably on top of the Chadron Formation. The Brule Formation is the outcropping formation throughout most of the Area of Review. 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.

2.6.2.4 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 (**Figure 2.6-3** to **Figure 2.6-11**). 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).

2.6.2.5 Area of Review Structure

The structure of the Area of Review is illustrated on **Figure 2.6-13**. Elevation contours of the contact between the Cretaceous Pierre Shale and the Tertiary Chadron Formation demonstrate the regional structure. The features present in the Area of Review 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 and within the Area of Review, the White River Group, Chadron and Brule Formations in general dip gently to the south at about 0.5 to 1 degree.

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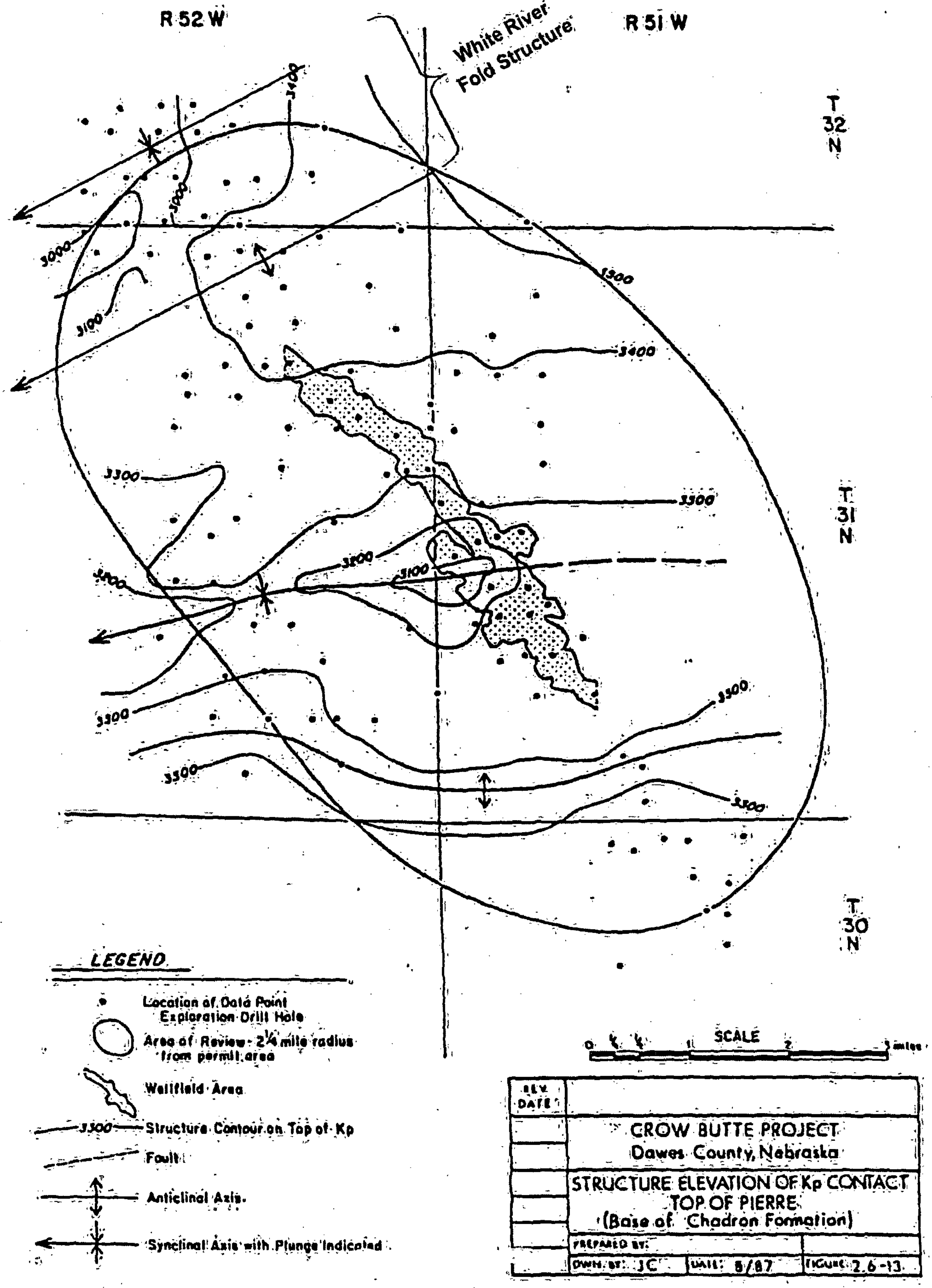
Figure 2.6-13: Structure Elevation of Kp Contact Top of Pierre (Base of Chadron Formation)



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Previous drilling identified a structural feature, referred to as the White River Fault, located between the current permit area and the proposed North Trend permit area. 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 and overlying units. Figures 2.6-4 and 2.6-10 depict two structural cross sections that transect the White River structural feature from the northern and central portions of the North Trend Expansion Area (NTEA) southward into Mine Unit 10 of the Commercial License Area. 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 one and one half miles northwest of the proposed 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 (personal communication, Vern Souders and Jim Swinehart, Conservation Survey Division, University of Nebraska, 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.

2.6.2.6 Discussion of Confining Strata

The Crow Butte ore body represents a situation favorable for in-situ mining of uranium. The lower confining bed is the Pierre Shale and is over 1,000 feet in thickness. The

Pierre Shale is thick, homogenous black shale with very low permeability and is one of the most laterally extensive formations of northwest Nebraska.

The upper confinement is composed of the Chadron Formation above the Chadron Sandstone and that portion of the Brule Formation underlying the intermittent Brule sandstones (**Figure 2.6-3** to **Figure 2.6-11**). This part of the Chadron Formation is impermeable clay grading upward into several hundred feet of siltstones and claystones of the Brule Formation. These units separate the zone of injection (Chadron Sandstone) from the nearest overlying water bearing unit with several hundred feet of clay and siltstones. The Chadron Formation clays also have a large lateral extent and have been observed in all holes within the Area of Review.

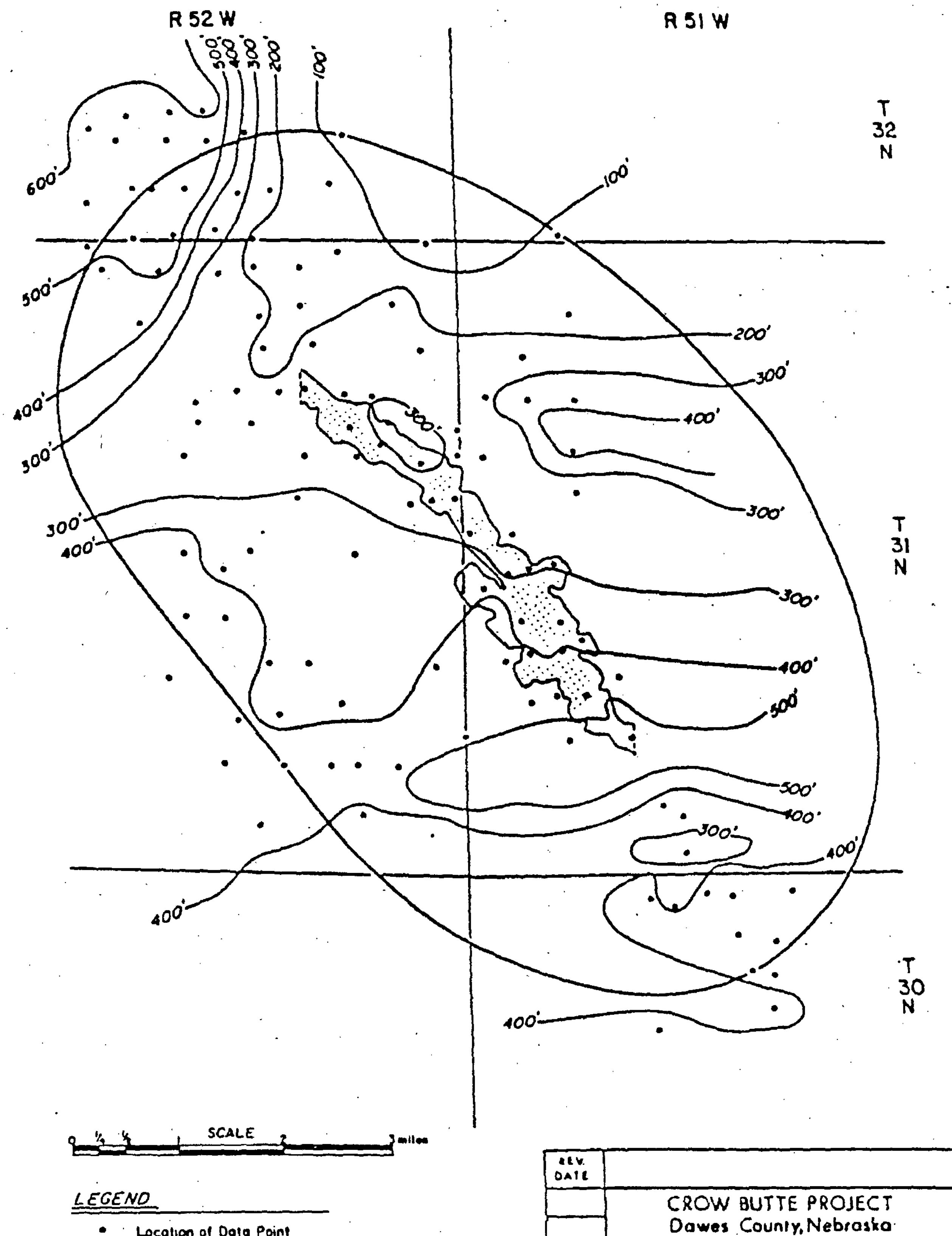
From **Table 2.6-2** one can see that the upper and lower confining beds (the Chadron-Brule Formation clay and Pierre Shale) contain significant percentages of montmorillonite clay and other clays and/or calcite. These two analyses would indicate the presence of clay minerals with very fine grain sizes. Size distribution analyses of these beds verify that the material is quite fine grained. These two facts indicate that both the upper and lower confinement are significantly less permeable than the ore zone and essentially impermeable.

It is recognized that small faults and fractures may occur in the sediments overlying the Chadron Sandstone unit. Additionally, there may be areas of secondary permeability within isolated areas of the Brule Formation. However, two pump tests conducted in the Area of Review indicate no faulting or fracturing which affects the confinement of the Chadron Sandstone or which would affect in-situ mining of the uranium mineralization (see **Section 2.7**). The thickness of the upper confinement ranges from approximately 100 feet along the northeast boundary of the Area of Review to over 500 feet locally (**Figure 2.6-14**). Stratigraphically above the wellfield area the upper confinement ranges from 200 feet on the north to 500 feet on the south (**Figure 2.6-14**). This variation in thickness is primarily due to erosion of the rocks overlaying the Chadron Sandstone during Pleistocene time.

2.6.3 Seismology

The Crow Butte License Area in northwest Nebraska is within the Stable Interior of the United States. The project area along with most of Nebraska is in seismic risk Zone 1 on the Seismic Risk Map for the United States compiled by Algermissen (1969). Most of the central United States is within seismic risk Zone 1 and only minor damage is expected from earthquakes that occur within this area. The nearest area to the project area of higher seismic risk is in the southeastern part of Nebraska within the eastern part of the central Nebraska Basin (Burchett 1979) about 300 miles from the project area.

Figure 2.6-14: Thickness- Upper Confinement



REV. DATE	
	CROW BUTTE PROJECT Dawes County, Nebraska
	THICKNESS- UPPER CONFINEMENT
	PREPARED BY:
	DWN. BY: JC · DATE: 8/87 · FIGURE: 2.6-14

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Although the License Area is within an area of low seismic risk occasional earthquakes have been reported. Over 1100 earthquakes have been catalogued within the Stable Interior of the U.S. since 1699 by Docekal (1970). This study, considered complete to 1966, noted several earthquake epicenters within northwest Nebraska. All but two of these earthquakes were classified within the lowest category, Intensity I-IV, on the Modified Mercalli Intensity Scale of 1931.

Figure 2.6-15 is a seismic hazards map of Nebraska (USGS 2007). **Figure 2.6-16** illustrates earthquake epicenters, shown as orange circles, and seismicity in Nebraska (Burchett 1979, USGS 2007). The location of the Chadron and Cambridge Arches are shown on this map. The earthquakes that have been recorded along these two structural features are tabulated in **Table 2.6-3**.

The strongest earthquake in northwest Nebraska (No. 21) occurred July 30, 1934 with an intensity of VI and was centered near Chadron. This earthquake resulted in damaged chimneys, plaster, and china. Earthquake No. 25 occurred on March 24, 1938 near Fort Robinson. This earthquake had an intensity of VI and no additional information is available. An Intensity IV earthquake should be felt indoors by many and cause dishes, windows, and doors to be disturbed. Earthquake No. 29 occurred on March 9, 1962. This earthquake was reported to last about a second and was not accompanied by any damage or noise and was not even noticed by many of the residents of Chadron. Earthquake No. 31 occurred on March 28, 1964 near Merriman. The vibrations from this earthquake lasted about a minute and caused much alarm but no major damage occurred. Books were knocked off shelves and closet and cupboard doors swung open. On May 7, 1978 an earthquake (No. 34) with Intensity V occurred in southwestern Cherry County, also near the Chadron Arch. No major damage was reported from this earthquake.

Although the risk of major earthquakes in Nebraska is slight (Burchett 1979, p.14), some low to moderate tectonic activity is occurring (Rothe 1981). This tectonic movement is also suggested by geomorphic and sedimentation patterns during the Pleistocene (Rothe 1981). Recent seismicity on the Cambridge Arch appears to be related to secondary recovery in the Sleepy Hollow oil field (Rothe et al. 1981). Deeper events, however, suggest current low level tectonic activity on the Chadron and Cambridge Arches. This activity is not expected to affect the mining operations.

The most recent earthquake recorded in Nebraska occurred April 16, 2007. The epicenter was about 45 miles north-northwest of McCook, Nebraska, and was about 180 miles southeast of Crawford. This earthquake had a recorded magnitude of 3.0, but was not felt at Crawford or the License Area. According to the USGS, no earthquakes have been felt in Nebraska since the April 16, 2007 event (USGS 2007).

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Figure 2.6-15: Seismic Hazard Map for Nebraska

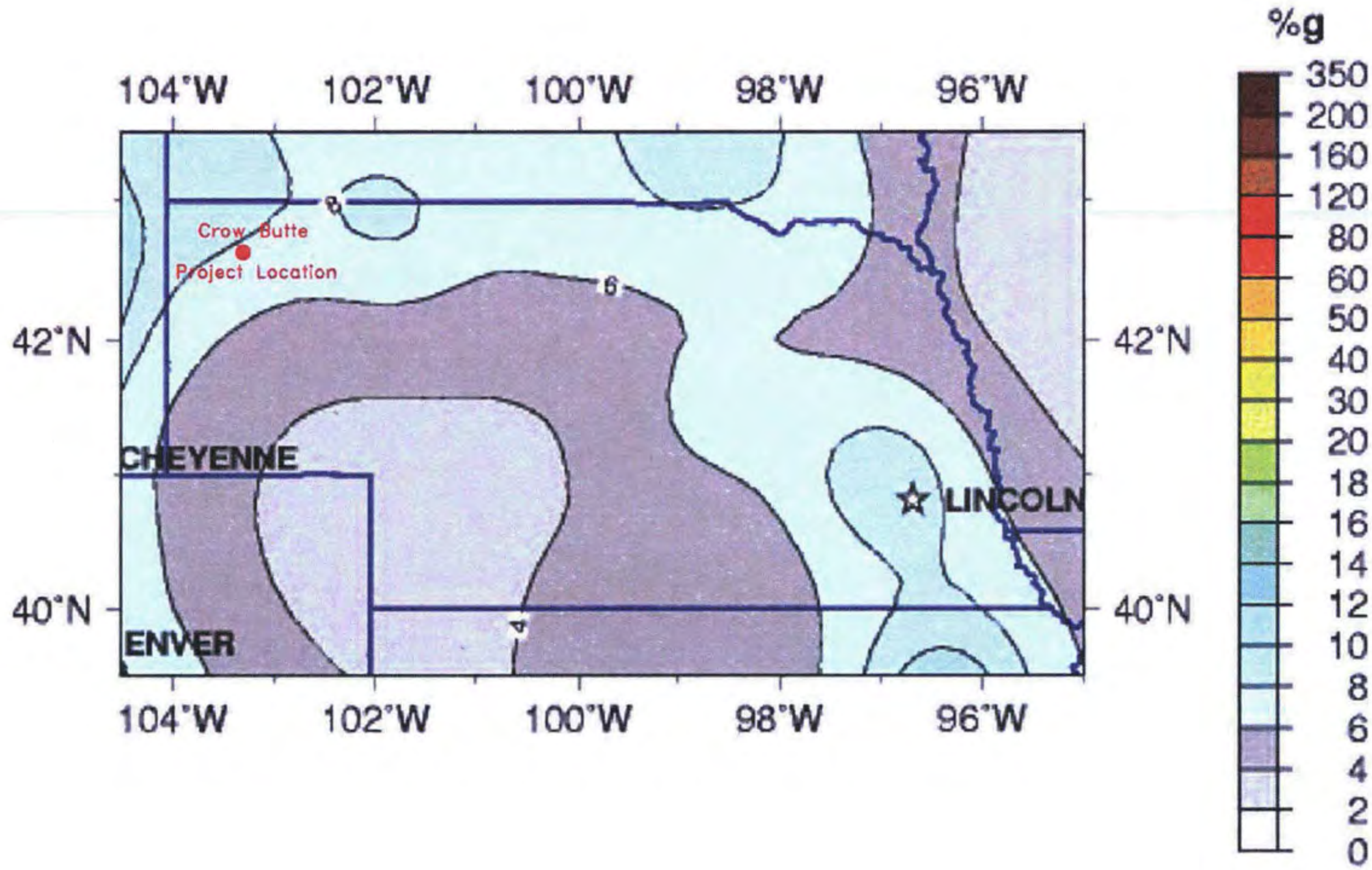

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Figure 2.6-16: Epicenter Locations (orange circles) and Seismicity Map of Nebraska

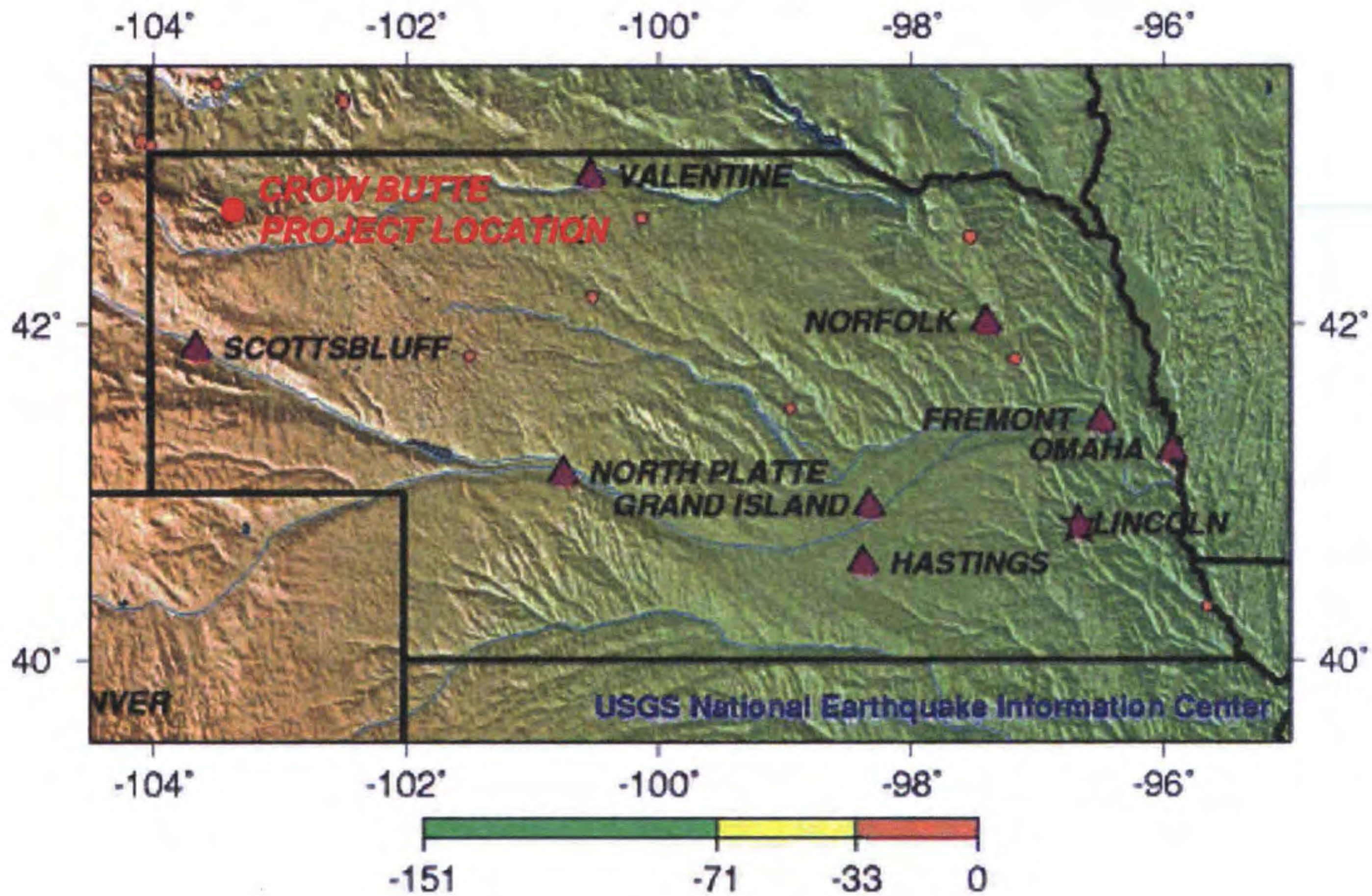

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Table 2.6-3: Earthquakes in Nebraska

Date	Central Standard Time	Locality	Latitude Degrees North	Longitude Degrees West	Modified Mercalli (MM) Intensity	Source
March 17, 1984	14:00	North Platte	41.133	100.75	IV	A
December 16, 1916	-----	Stapleton	41.55	100.467	II-III	A
September 24, 1924	5:00	Gothenburg	40.95	100.133	IV	A
August 8, 1933	-----	Scottsbluff	41.867	103.667	IV-V	A
July 30, 1934	1:20	Chadron	42.85	103	VI	A
March 24, 1938	7:11	Fort Robinson	42.683	103.417	IV	A
March 9, 1963	9:25	Chadron	42.85	103	II-III	A
March 28, 1964	4:21	Merriman	42.8	101.667	VII	A
May 7, 1978	10:06	SW Cherry County	42.26	101.95	V	B
May 6, 1983	0:15	NE Sheridan County	42.96	102.2	III	B
January 1, 1987	2:02	Crawford	42.79	103.48	III	B
February 8, 1989	23.16	Merriman	42.8	101.6	IV	B

Sources: A = Docekal 1970
B = National Earthquake Information Service 2004

2.6.4 Soils

The License Area 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 proposed project. Soils data for the License Area 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 (USDA 2006, NRCS 1977).

The License Area is situated in the White River watershed along the Squaw Creek tributary. The terrain is gently rolling to hilly. 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 drainage ways. Vegetative cover is typically mixed grass and ponderosa pine trees, but they have been largely replaced by agricultural crops within the License Area.

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 is widely exposed on lower slopes, is soft and 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 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 License Area: 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 License Area. 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 drainage ways.

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.

Certain 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".

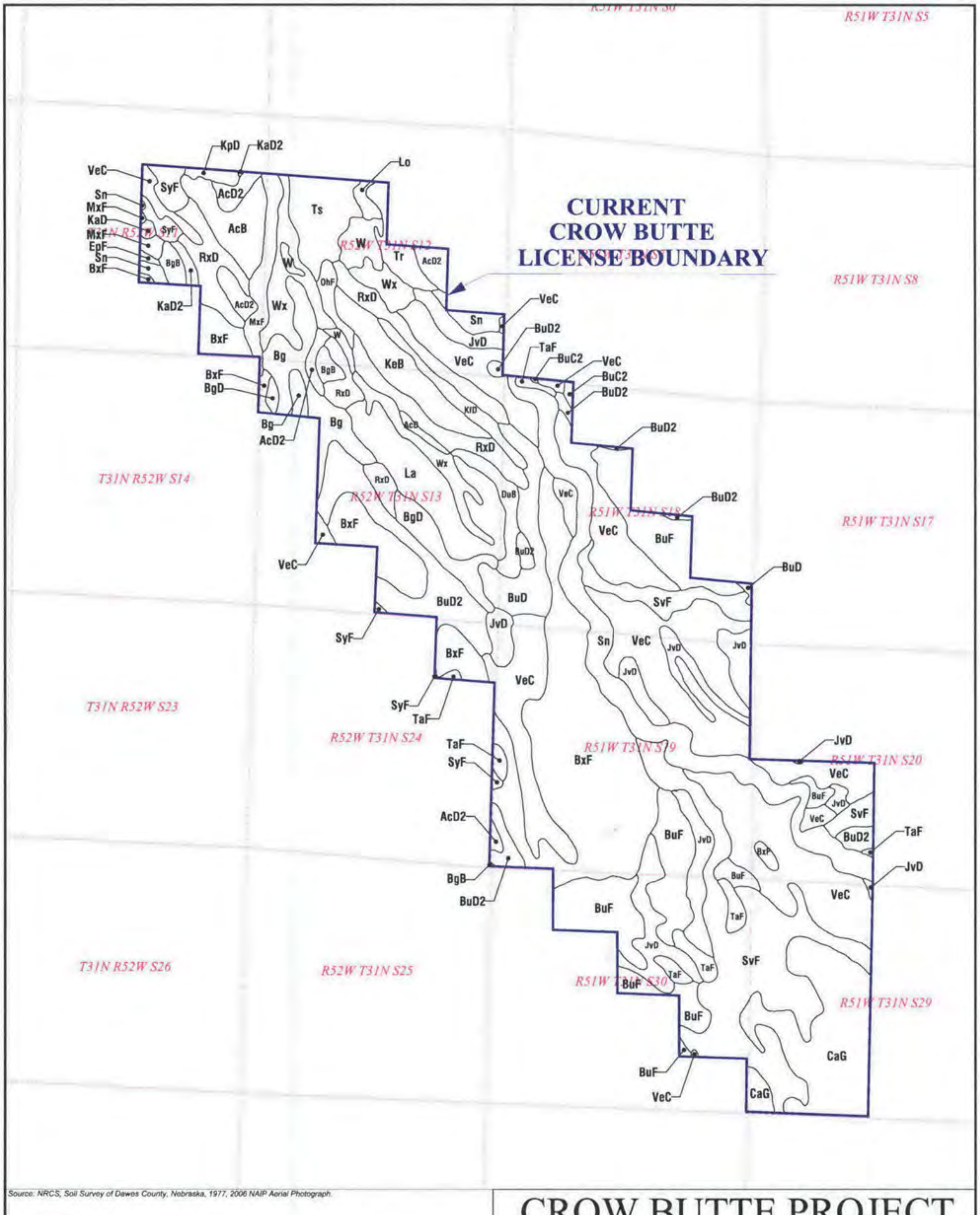
2.6.4.1 Soils Mapping Unit Descriptions

Table 2.6-4 summarizes those soils found within License Area. 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 2.6-17**.

Table 2.6-4: Summary of Soil Resources within the License Area

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: USDA 2006, NRCS 1977



CROW BUTTE PROJECT

REGIONAL AREA BASE MAP

DAWES & SIOUX COUNTIES, NEBRASKA

FIGURE 2.6-17 CROW BUTTE LICENSE AREA SOILS MAP

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

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BuF Busher loamy very fine sand, 9 to 20 percent slopes

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.

BxF Busher and Tassel loamy very fine sands, 5 to 20 percent slopes

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.

VeC Vetal and Bayard soils, 1 to 5 percent slopes

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.

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Oil and Gas Logs in the Area of Review
Bunch No. 1, Section 5, Township 31 North, Range 51 West
Heckman No. 1, Section 24, Township 31 North, Range 52 West
Arner No. 1, Section 26, Township 31 North, Range 52 West
Roby No. 1, Section 31, Township 31 North, Range 51 West
Soester 1, Section 34, Township 32 North, Range 52 West
True State, Section 36, Township 32 North, Range 52 West
CBR Deep Disposal Well, Section 19, Township 31 North, Range 51 West

2.7 HYDROLOGY

NUREG 1569 Section 2.7 states: "Characterization of the hydrology at *in situ* leach uranium extraction facilities must be sufficient to establish the potential effects of *in situ* operations on the adjacent surface-water and groundwater resources and the potential effects of surface-water flooding on the *in situ* leach facility." To meet these requirements, this section addresses surface water features (**Section 2.7.1**), groundwater characteristics (**Section 2.7.2**), and surface water and groundwater quality (**Section 2.7.1.5**).

2.7.1 Surface Water

The License Area is located within the watershed of Squaw Creek and English Creek, which are small tributaries to the major regional water course, the White River. As a part of the preoperational environmental study, flow measurements and water quality samples were taken from Squaw Creek in the vicinity of the study area.

2.7.1.1 Location

The License Area is located in Sections 18, 19, 20, 29, and 30 of T31N, R51W and Sections 11, 12, and 13 of T31N and R52W within the drainage basin of the White River. The White River heads in Sioux County and flows northeasterly across Dawes County into South Dakota. Northern tributaries in the Crawford area cross upland portions of the Pierre Shale, an impermeable formation. These streams are dry except for runoff flow. The southern tributaries originate in the Pine Ridge escarpment, and flow primarily over forest, range, and agricultural land. These streams are generally ephemeral except where they are spring-fed.

Squaw Creek is one of the southern tributaries of the White River. This creek heads in the Pine Ridge southeast of the License Area. From the headwaters, it flows northwest over range and agricultural land to the White River. Contributions to flow come from springs in the Arikaree Formation, snowmelt, runoff, and the shallow Brule sands. The latter may receive inflow from the creek during periods of high flow. Due to the time-variable nature of these water sources, discharge rates at various points along the creek may experience wide fluctuations monthly and yearly.

Squaw Creek enters the License Area on the southeast corner, travels through the entire length of the License Area approximately paralleling its long axis, and exits to the north. Two branches of an unnamed tributary enter along the southern boundary, join just north of the Mine Unit 1 wellfield, and exit the northern boundary before converging with Squaw Creek.

Figure 2.7-1 illustrates the location of the License Area with respect to the Squaw Creek and English Creek watercourses and the locations of the commercial evaporation ponds.

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Figure 2.7-1

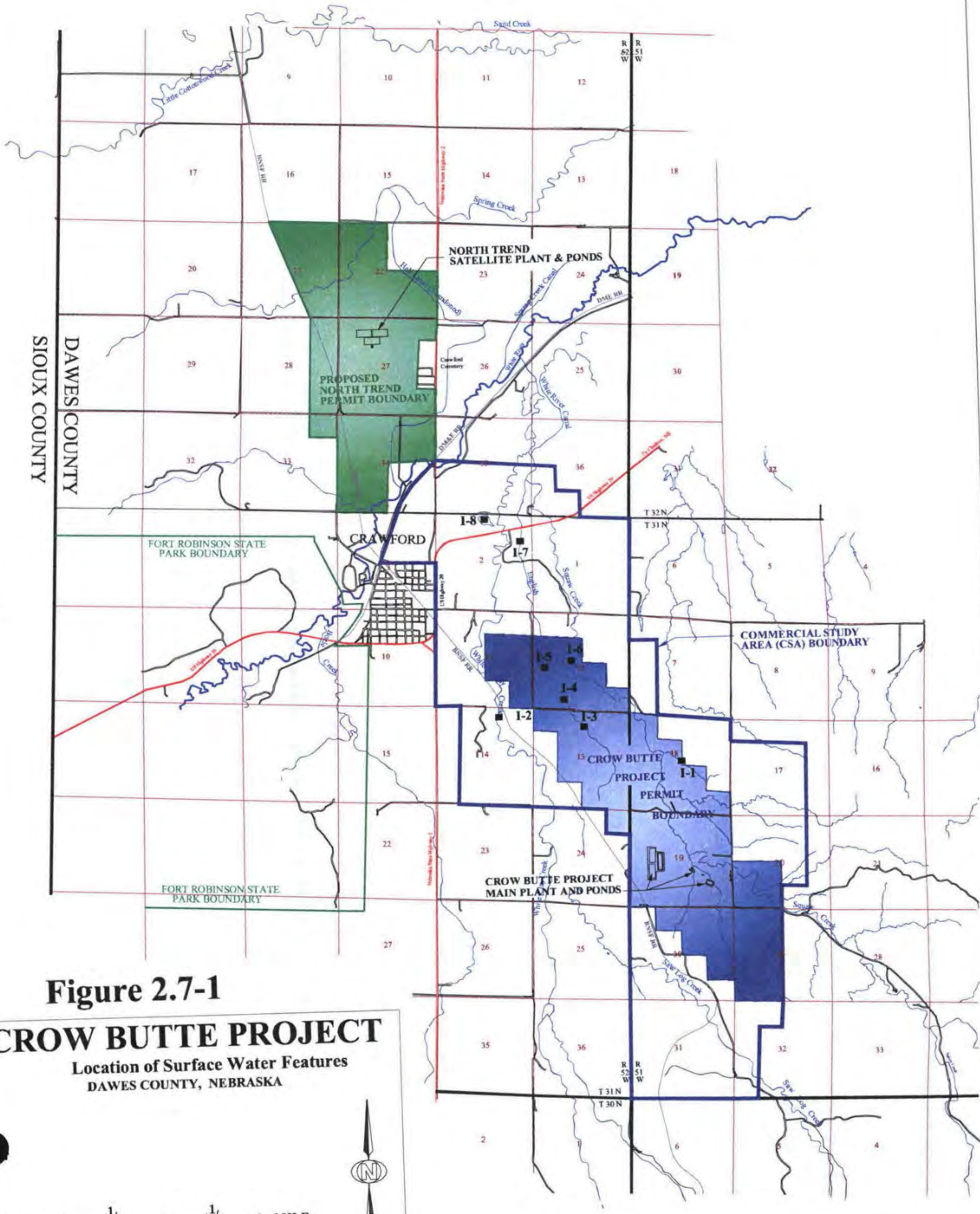

Figure 2.7-1

CROW BUTTE PROJECT

Location of Surface Water Features

DAWES COUNTY, NEBRASKA

SCALE 0 1/2 1 1 1/2 2 MILE

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2.7.1.2 Stream Flow

Table 2.7-1 shows the mean monthly discharge of the White River as compared to the mean monthly precipitation over several years. These extended data show that a general correlation can be made between the direct precipitation and discharge. Higher flows are recorded in spring and early summer with lowest flow rates in late summer to early fall, reflecting seasonal changes related to precipitation. Between 1931 and 2004, the average normal annual mean discharge at the White River Station at Crawford was 20.3 cubic feet per second (cfs) with a standard deviation of 2.8 cfs. The maximum was 27 cfs and the minimum was 13 cfs.

Table 2.7-1: Comparison of Mean Monthly Precipitation with Normal Mean Monthly Discharge of the White River at Crawford, Nebraska

	Mean Precipitation [a]		Mean Discharge [b]	
Month	inches	centimeters	ft^3/sec	m^3/sec
January	0.61	1.55	21	0.59
February	0.76	1.93	23	0.65
March	1.74	4.42	27	0.76
April	2.65	6.73	25	0.71
May	3.11	7.9	27	0.76
June	2.42	6.15	22	0.62
July	2.77	7.04	16	0.45
August	1.21	3.07	13	0.37
September	1.38	3.51	14	0.4
October	1.66	4.22	17	0.48
November	0.82	2.08	19	0.54
December	0.79	2.01	20	0.57

Notes:
[a] - Climatology of the US No. 81, 1971-2000, NOAA, 25-Nebraska
[b] – USGS National Water Information System for USGS gaging station 06444000
m^3/sec = cubic meters per second

Peak rainfall at Harrison and Scottsbluff, Nebraska occurs in May and June (NOAA 1976 and 1980), and this precipitation pattern appears to be representative of the Crawford area. **Table 2.7-2** provides mean monthly discharge information for the White River for 1992 through September 2007. The recent data for the White River are comparable to the stream flow data shown in **Table 2.7-1**.

Table 2.7-2 Normal Mean Monthly Discharge of the White River at Crawford (06444000), Nebraska, 1999 through September, 2007

Monthly	1992[a]	1993[a]	1994[a]	1995[a]	1996[a]	1997[a]	1998[a]	1999[a]	2000[b]
	(ft³/sec)								
January	21.4	20.7	21.4	20.3	22.3	23.3	23.1	22.6	21.7
February	22.5	23.5	23	21.5	24.4	20.4	22.7	22.4	24.1
March	22.3	31.2	23.3	19.7	24.0	19.4	24.8	23.1	25.5
April	20.0	26.1	21.3	22.1	23.4	22.8	24.2	26.1	29.1
May	18.8	19.7	19.6	27	26.3	27.6	22.1	23.7	10.0
June	18.1	30.6	14	29.8	20.4	27.0	10.9	27.1	20.5
July	15.6	25.3	12.3	18.5	17.5	17.3	17.4	21.4	15.4
August	12.4	16.4	9.87	12.9	14.1	16.4	15.6	15.0	11.5
September	12.4	17.8	11.1	13.6	14.5	14.4	13.4	17.0	12.1
October	16.0	20.9	16.3	18.8	16.6	17.2	20.9	19.4	17.4
November	18.8	21.2	17.9	19.8	20.1	20.4	22.5	20.8	20.1
December	22.9	26.4	18.8	19.7	20.8	21.7	21.3	21.4	20.7
Average	**18.4**	**23.3**	**17.4**	**20.3**	**20.4**	**20.7**	**19.9**	**21.7**	**16.7**

Monthly	2001[b]	2002[b]	2003[b]	2004[b]	2005[b]	2006[b]	2007[b]	--	--
	(ft³/sec)								
January	21.0	22.9	22.6	23.0	23.9	24.1	18.9		
February	24.3	23.6	24.0	24.8	23.3	24.5	20.2		
March	27.0	26.8	26.4	25.9	24.5	26.4	22.6		
April	26.4	25.3	26.5	22.7	25.3	25.9	23.4		
May	24.7	23.9	25.9	21.1	26.5	23.2	20.2		
June	18.6	16.6	23.2	17.1	26.5	17.8	15.9		
July	14.4	10.3	13.2	17.4	17.6	11.0	10.0		
August	12.5	10.1	11.7	11.3	18.1	10.0	4.1		
September	12.9	13.7	23.3	17.8	14.8	14.8	8.7		
October	17.2	18.1	17.5	20.8	18.5	18.6	[c]		
November	22.0	22.3	22.6	21.3	21.0	21.1	[c]		
December	22.2	22.2	23.1	22.1	23.1	21.3	[c]		
Average	**20.3**	**19.7**	**21.6**	**20.4**	**21.9**	**19.9**	**16.0**		

[a] USGS 2009 (USGS National Water Information System for USGS gauging station 06444000)
[b] Nebraska Department of Natural Resources (NDNR) 2009.
[c] Data not available for fourth quarter of 2007 The USGS ceased flow data measurements at this gaging station on June 14, 2007 (D.L. Curtis 2009).

2.7.1.3 Surface Water Impoundments

Eight surface water impoundments are located near or within the boundaries of the commercial License Area. **Figure 2.7-1** shows the locations of these impoundments. These eight impoundments are identified as I-1 through I-8. Impoundments I-1, I-2, I-7, and I-8 are outside the License Area, while impoundments I-3 through I-6 are inside the License Area.

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.

2.7.1.4 Assessment of Surface Water Features

As shown in **Table 2.7-1** and **Table 2.7-2**, the average monthly stream flow of the White River at the Crawford gauge station is about 20 cfs. The highest discharge and gauge height on record between 1920 and 2004 occurred on May 10, 1991. On that date, severe thunderstorms resulted in significant rainfall, the gauge height was 16.32 feet, and the stream flow exceeded 13,300 cfs (State of Nebraska Department of Natural Resources 2004). Several city facilities were damaged by floodwaters and hail, including the local golf course and fish hatchery, and the event was considered a "100-year" flood. The Rocky Mountain News (May 12, 1991) reported that mobile homes were swept away and the town's water system was knocked out of service. However, it is noted that, while there are certainly historical extremes, the average gauge height on the White River at Crawford is less than 5 feet, with an average annual stream flow of 20.2 cfs.

The potential for flooding or erosion that could impact the in-situ mining processing facilities and surface impoundments have been assessed based on data from the Federal Emergency Management Agency (FEMA 2007). FEMA has not mapped unincorporated Dawes County north of Crawford, Nebraska; however, FEMA maps are available for the City of Crawford, which depict the flooding potential of the White River in Crawford. As shown in **Figure 2.7-2**, FEMA has classified the portion of Crawford between the D M & E Railroad (immediately west of First Street) as Zone A (i.e., an area that could be impacted by a 100-year flood) (FEMA 1995). All surface facilities within the License Area occur outside of the 100-year flood plain of the White River, and are not likely to be within a "flood-prone" area. Therefore, consistent with NUREG-1623, erosion modeling was not considered necessary or performed.

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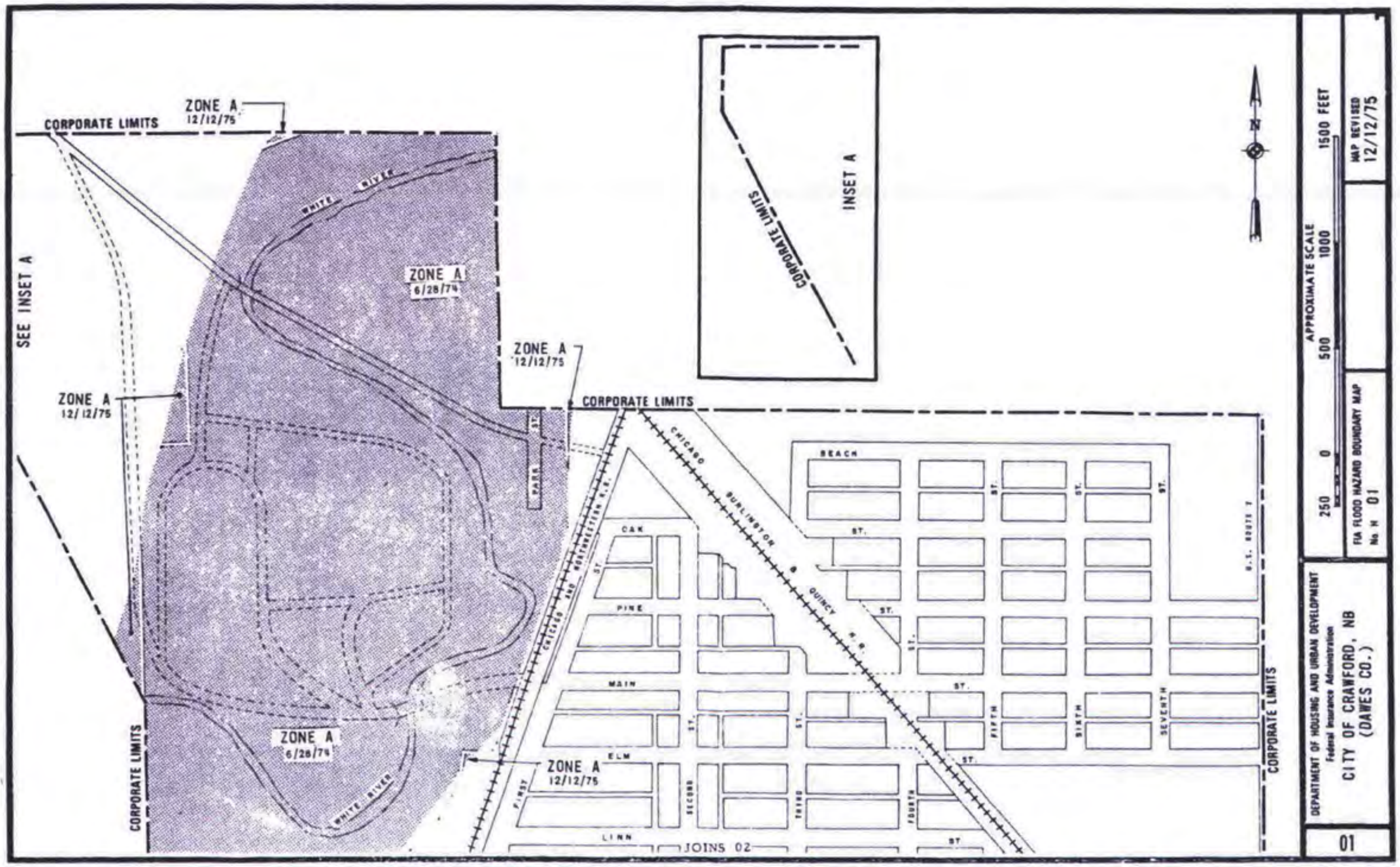
Figure 2.7-2: FEMA Zone A Flood Map



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Existing Crow Butte surface facilities are located in Section 19, approximately 3 miles southeast of White River (river segment in Crawford), and more than 150 feet topographically above the common river elevation. All existing and planned surface facilities are least 50 feet above the White River elevation.

2.7.1.5 Water Quality

Preoperational background surface water samples for the CBR site were collected from the White River and all surface bodies of water within the commercial License Area (FEN 1987a). This schedule was begun in 1982 and continued into 1987 for specified locations. These data were included in the 1987 application and supporting environmental report for USNRC Source Material License for the CBR site which was submitted to the NRC by Ferret of Nebraska, Inc. (previous owner) in August, 1987 (FEN 1987a). These water quality data are presented in **Section 2.9-4.**

White River water quality data were assembled by the U.S. Environmental Protection Agency (USEPA) for various years from 1968 to 1973, 1981 and 1994 (**Table 2.7-3**). Water quality data collected by the Nebraska Department of Environmental Quality (NDEQ) for the year 2003 and reported in USEPA STORET database (USEPA 2007) is presented in **Table 2.7-4**.

Data from the USEPA STORET database for the White River at Crawford (60 sampling events from 1968 to 1980) indicate an average specific conductance of 380 microSiemens per centimeter (μS/cm) (USEPA 2007). USEPA STORET data from the White River tributaries in the vicinity of the NTEA (Soldier Creek [west of Crawford]; Squaw Creek, White Clay Creek and English Creek [all east of Crawford]; and Dead Man's Creek [south of Crawford]) indicated that the specific conductance for these tributaries ranged from 36 to 507 μS/cm (eight sampling events from 1981 to 1995).

Based on NDEQ data collected from the White River at the Crawford sampling station in 2003, specific conductance ranged from 349 to 386 μS/cm, with an average of 374 μS/cm (USEPA 2007).

Table 2.7-3 Historic White River Water Quality Data, 1968 through 1994*

PARAMETER	RESULTS										
	8/20/1968	5/6/1969	7/15/1969	5/24/1970	8/28/1970	8/5/1971	6/5/1972	10/2/1972	6/4/1973	9/23/1981	7/13/1994
Number used in sample accounting procedure	66	66	65	95	77	109	no data	no data	no data	1	1
Temperature, water (degrees centigrade)	21	18	28	18.5	21	19.5	22	12.5	17	no data	20
Temperature, air (degrees centigrade)	32	21	36	23	27	30	21	11.1	23	no data	no data
Flow, stream, mean daily (cfs)	10	22	10	22	21	12	19	12	24	no data	no data
Turbidity (jackson candle units)	41	62	10	45	337	5	36	4	4	no data	no data
Specific conductance (umhos/cm @ 25°C)	400	390	355	353	305	340	340	340	400	330	700
Oxygen, dissolved (mg/l)	7.4	8.5	6.9	7.8	7	8	8.1	9.6	7.9	no data	6.9
Oxygen, dissolved, percent of saturation	82.2321	89.4889	87.3453	82..106	77.7793	85.1096	92.0463	88.8907	81 .4491	no data	75
pH (standard units)	7.7	8.2	8.2	7.9	7	8.5	8.4	8.5	7.6	no data	8.3
Alkalinity, total (mg/l as $CaCo^3$)	208	108	180	184	168	176	192	200	189	188	no data
Residue, total filtrable (dried at 105°C) (mg/l)	258	270	250	250	220	250	240	260	no data	288	no data
Nitrogen, Nitrite (NO_2) + Nitrate (NO_3), (mg/l as N)	0.1	0.1	1	0.1	0.6	0.1	0.2	0.1	no data	no data	no data
Phosphate, total (mg/l as PO4)	0.8	0.1	0.5	0.2	0.3	0.1	0.2	0.1	no data	no data	no data
Hardness, total (mg/l as CaCO3)	176	148	168	160	156	172	160	172	172	no data	159
Calcium, dissolved (mg/l as Ca)	39	35	51	50	52	46	51	56	no data	no data	no data
Magnesium, dissolved (mg/l as Mg)	10	1	10	9	6	14	8	8	no data	no data	no data
Sodium, dissolved (mg/l as Na)	36	24	43	24	22	16	15	15	no data	no data	no data
Sodium adsorption ratio	0.4	0.9	1.5	0.8	0.8	0.5	0.5	0.5	no data	no data	no data
Potassium, dissolved (mg/l as K)	6	8	13	8	9	9	10	9	no data	no data	no data
Chloride, total in water (mg/l)	12	18	4	1	2	4	1	2	7	5	no data
Hardness, Ca Mg calculated (mg/l as $CaCO_3$)	138.563	91.513	168.527	161.912	154.552	172.514	160.291	172.776	no data	174.528	159.437

* Data are summarized. See http://www.epa.gov/storet/updates.html, USEPA's STORET database, for full data sets (USEPA 2009)

Table 2.7-4 Water Quality Data for the White River at Crawford [Station WH1WHITE208], 2003*

	RESULTS											
PARAMETER	1/13	02/01	03/03	04/08	05/06	06/03	07/09	08/04	09/09	10/06	11/03	12/01
Temperature, water (degress centigrade)	0.81	6.42	5.08	9.32	13.34	18.33	21.5	12.2	No data	12.17	4.45	4.31
Flow, stream, mean daily (cfs)	22E[a]	24	25	28	25	23	15	12	18	17	24	23
Turbidity, (jackson candle units)	0.9	7.5	4.9	4.8	23.6	20.7	11.9	12.2	2711	3.4	4.4	3.8
Specific Conductance (umho/cm @ 25°C)	386	368	367	381	383	372	374	349	No data	375	375	379
Oxygen, dissolved (mg/l)	14.20	10.9	11.51	10.92	9.56	8.5	8.83	7.85	No data	10.44	10.71	10.48
pH (standard units)	8.11	7.95	8.19	8.48	8.22	8.30	8.25	8.05	No data	8.37	8.06	8.25
Residue, total filterable (dried at 105°C), mg/l	No data	No data	No data	30	48	49	22	14	2900	No data	No data	No data
Nitrogen, Nitrite(NO_2) + Nitrate (NO_3), mg/l[b]	No data	No data	No data	0.38	0.35	0.28	0.18	0.20	0.61	No data	No data	No data
Nitrogen, Ammonia (NH_3) as NH_3, Total (mg/l)	No data	No data	No data	0.05	0.06	0.05	0.05	0.05	0.23	No data	No data	No data
Nitrogen, Kjeldahl, Total (mg/l)	No data	No data	No data	0.5	0.5	0.5	0.5	0.5	8.35	No data	No data	No data
Phosphorus as P, Total (mg/l)	No data	No data	No data	0.04	0.07	0.08	0.07	0.06	2.44	No data	No data	No data
Chloride (mg/l)	No data	No data	No data	3.59	3.67	3.61	3.04	3.65	4.68	No data	No data	No data

* Water quality data are summarized. See http://www.epa.gov/storet/updates.html, USEPA STORET database, for full data sets [Data source: Nebraska Department of Environmental Quality] (USEPA 2007). Flow data (NDNR 2009).

[a]E: Estimated.

2.7.2 Groundwater

This section provides a summary of the regional and local groundwater hydrology including local and regional hydraulic gradient and hydrostratigraphy, hydraulic parameters, baseline water quality conditions, and local groundwater use including well locations related to the License Area. The discussion is based on information from investigations performed within the License Area, data presented in previous applications and reports for the Commercial License Area (CSA) where ISL mining is being conducted, and the geologic information presented in **Section 2.6**.

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

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

With regard to the Crow Butte Project, two groundwater sources are of interest in the Crawford and the License Area. These are the Brule Formation sand and the Basal Chadron Sandstone. The Basal Chadron Sandstone contains the uranium mineralization in the CSA.

2.7.2.1 Regional Groundwater Hydrology

A map prepared by Souders (2004) indicates that the water table configuration in the region trends north-northeast. No published regional water level maps are available for the Basal Chadron Sandstone or the local Brule sands. Souders (2004) states that aquifers within the White River Basin, which encompasses the northern half of Dawes County, are "nearly nonexistent". He indicates that a groundwater divide occurs to the south of the CSA along the Pine Ridge; groundwater north of this divide in the CSA and License Area flows to the north, northwest, and northeast, depending on location with respect to the White River. The Brule, Chadron, and Pierre Shale outcrop progressively northward from the Pine Ridge divide through the White River Basin, and Souder states that none of these formations "are considered major sources of groundwater".

Souder indicates that the Brule is a tight formation with a minimal hydraulic conductivity of less than 25 feet per day (feet/day), although in a few areas, there may be a significant saturated thickness, presumably where sandier intervals are present. The Chadron is described as consisting of claystones with extensive volcanic ash that is tight with low hydraulic conductivity comparable to the Brule Formation, except where fractured, although the coarse Basal Chadron Sandstone is present at the bottom of the formation.

The Pierre is described by Souders (2004) as a dark grey, bentonitic shale that is "very tight and is not considered to hold any extractable groundwater" except where fractured. Fractures may increase Brule and Chadron permeability in localized areas (Souders 2004). It is noted that CBR operations in the CSA to date do not support evidence of fracturing in the Pierre to a degree such that it would impact the designation of the Pierre as a lower confining unit below the Basal Chadron Sandstone.

Prior to mining in the CSA, water levels were measured in existing wells throughout the Crawford-Crow Butte area for the local Brule sand and the Basal Chadron Sandstone. Maps showing the potentiometric surfaces for these two aquifers are included as **Figures 2.7-3a** through **2.7-3e** and **Figure 2.7-4a through Figure 2.7-4e**.

Water level maps for the Brule Formation are provided for historical dates (1982-1983), as well as for more recent water levels collected from the CSA in March-April 2008 and February-March 2009 and from the North Trend Expansion Area (NTEA) in June 2008. Groundwater flow within the Brule Formation converges in the vicinity of the White River, with southeast and east-directed flow north of the White River and northwest-directed flow south of the White River. It is highly likely that the White River is a significant groundwater discharge point for the Brule Formation. Water levels collected from the Brule Formation within the CSA in 1982-1983 indicate groundwater flow to the northwest with an average hydraulic gradient of 0.012 ft/ft. Water levels collected from the Brule Formation in March-April 2008, October 2008 and February-March 2009 similarly all indicate groundwater flow to the northwest with slightly higher average hydraulic gradients of 0.025, 0.041 and 0.043 ft/ft, respectively. Based on these 2008 and 2009 water levels, steeper gradients generally occur south of Mine Unit 8 compared to the 1982-1983 time period. Water levels in the Brule Formation have not significantly changed within the southern and central portions of the CSA during the 1982-1983 to 2009 time period. However, higher water levels (approximately 15 feet) were observed in Mine Unit 10 during the 2008 to 2009 than during the 1982 to 1983 time period. There were no significant seasonal changes to water levels, flow directions or range of hydraulic gradients observed in the Brule Formation between spring (March-April 2008) and fall (October 2008) conditions.

The Basal Chadron Sandstone is an artesian (confined) aquifer, and wells completed in it may flow to the surface near the White River. Historical water levels collected from the Basal Chadron sandstone in 1982-1983 indicate groundwater flow to the south and southwest north of the Town of Crawford and flow to the north and northwest within the CSA. More recent water levels collected from the Basal Chadron Sandstone in March-April 2008 (also depicted on **Figures 2.6-4** and **2.6-10**) indicate groundwater flow in the vicinity of the White River and NTEA is predominantly directed to the southeast across the White River structural feature toward the CSA. Water levels collected from the Basal Chadron Sandstone within the CSA around the same time frame (March-April 2008) indicate groundwater flow is similarly directed to the southeast in the southern portion of Mine Unit 10 (flow patterns in this area influenced by mining) and shifts to predominantly north and northeast-directed flow south of Mine Unit 8.

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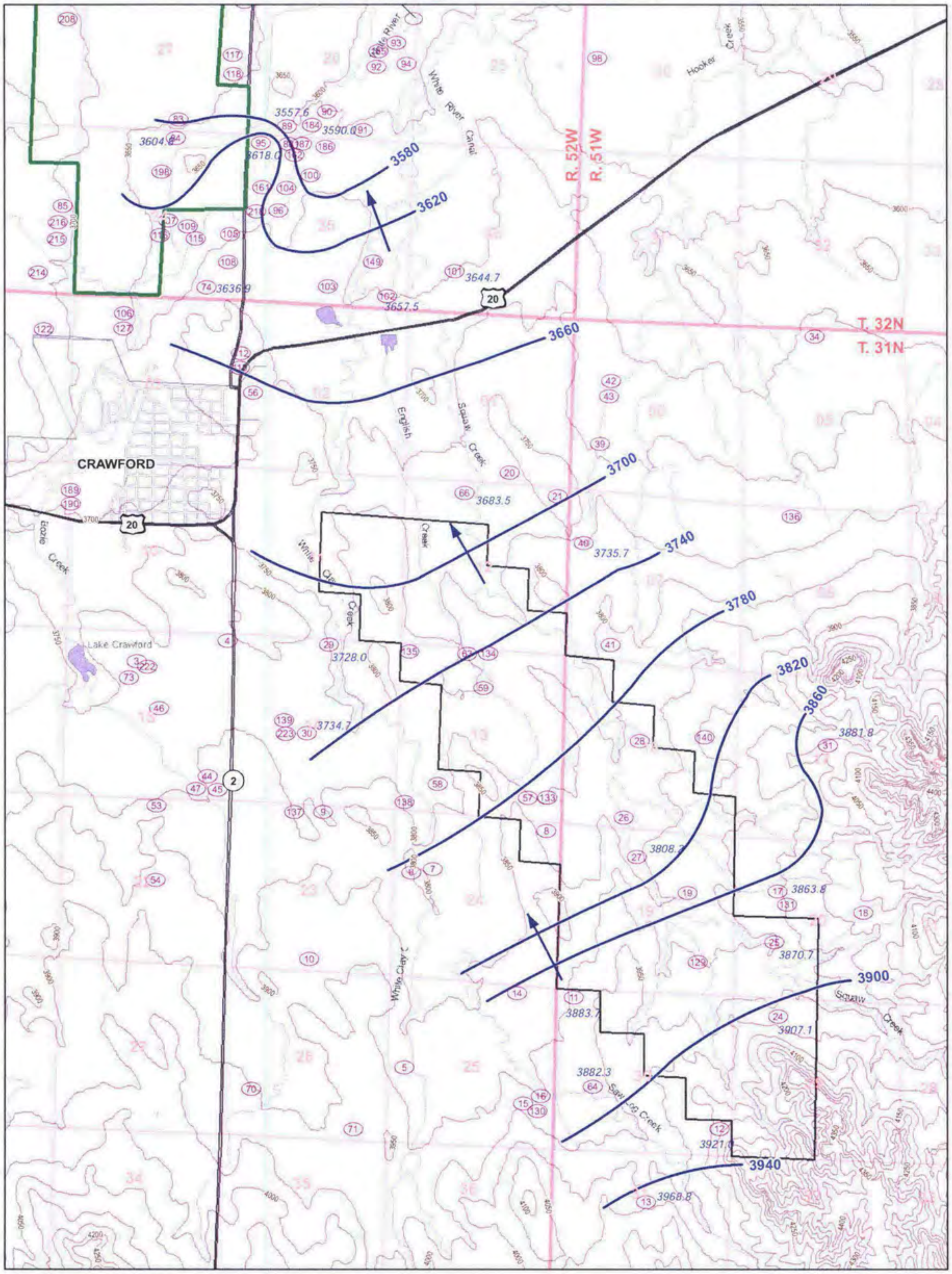

LEGEND

- Groundwater Elevation (Brule Formation, FT-AMSL)
- Elevation Contours (FT-AMSL, 40-Ft Interval)
- 129 / 3968.8 Brule Formation Water Well and Water Level Elevation (FT-AMSL)
- Proposed North Trend Expansion Area
- Class III Permit Boundary
- Groundwater Flow Direction

0 3,000 6,000
Scale in Feet

N W E

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-3a
REGIONAL WATER LEVEL MAP
BRULE FORMATION 1982-1983

PROJECT: CO001322 MAPPED: JC CHECKED: MS

FILE: CSA_Fig 2.7-3a_Regional_WL_Brule.mxd

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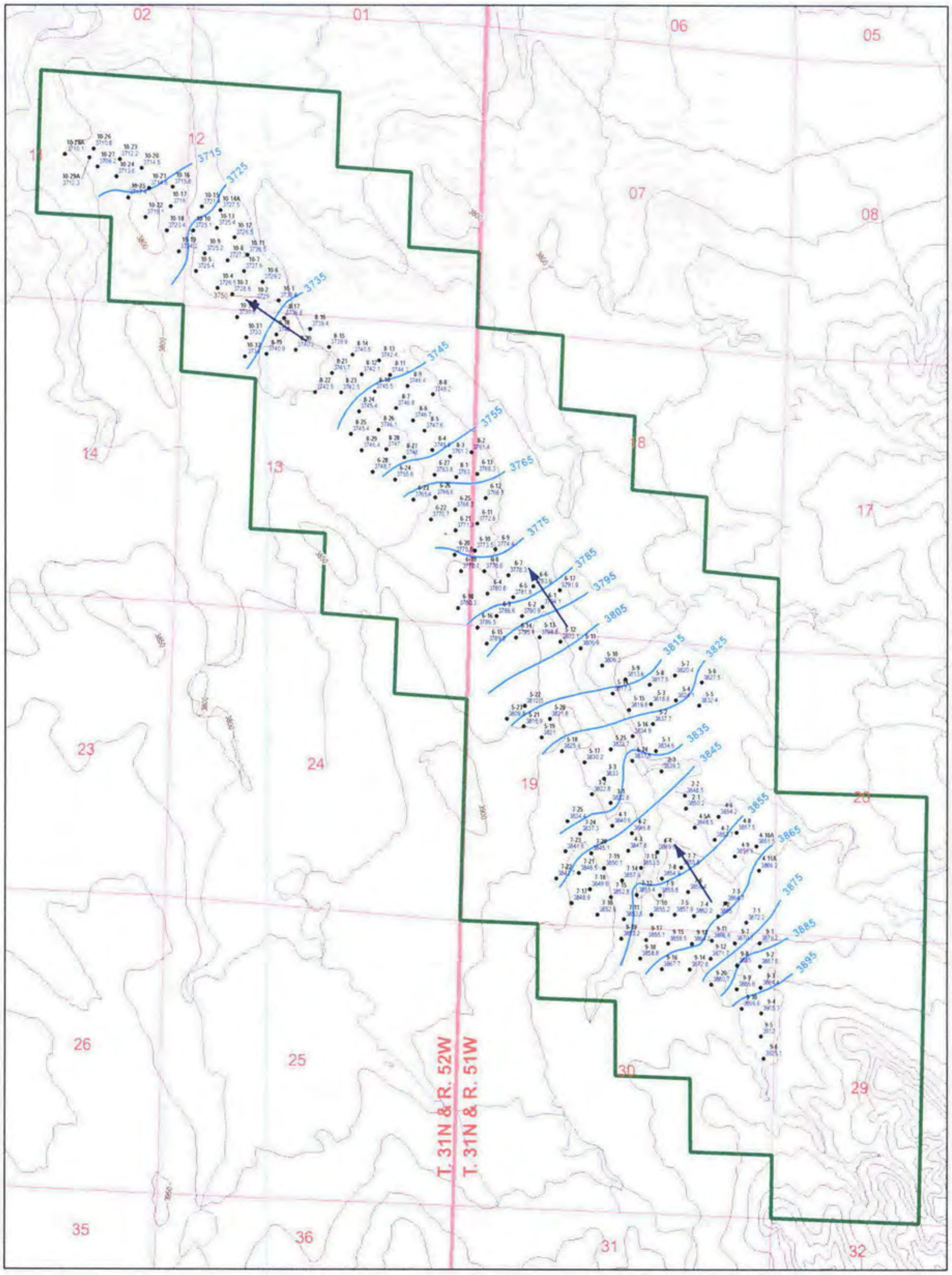

LEGEND

7-25 ← Well ID
Brule Formation Water Well
3834.3 ← Groundwater Elevation (FT-AMSL)

Elevation Contours (FT-AMSL)

Groundwater Elevation Contour (10-FT Interval)
3895 ← Groundwater Elevation (FT-AMSL)

Stream or Canal

Direction of Groundwater Flow

Class III Permit Boundary

N
W — E

0 1,500 3,000
Scale in Feet

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-3b
CURRENT LICENSE AREA
WATER LEVEL MAP -
BRULE FORMATION (3/31/08 – 4/14/08)

PROJECT: CO001322 MAPPED: JC CHECKED: MS

FILE: CSA_BF_WATERLEVEL_0308.MXD

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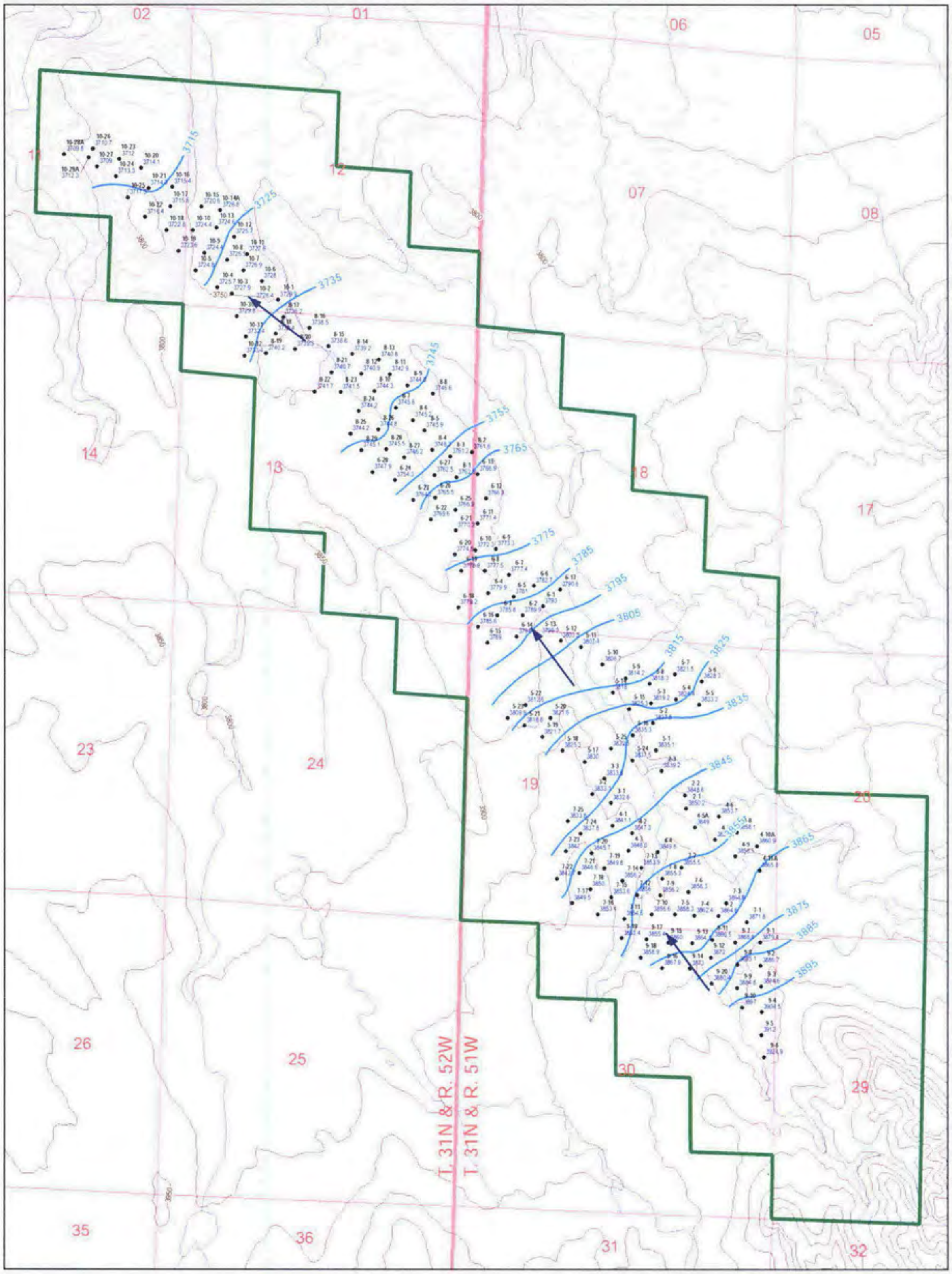

LEGEND

Well ID
Brule Formation Water Well
Groundwater Elevation (FT-AMSL)

Elevation Contours (FT-AMSL)

Groundwater Elevation Contour (10-FT Interval)
Groundwater Elevation (FT-AMSL)

Stream or Canal

Direction of Groundwater Flow

Class III Permit Boundary

N

W — E

0 1,500 3,000
Scale in Feet

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-3c
CURRENT LICENSE AREA
WATER LEVEL MAP -
BRULE FORMATION (10/20/08 – 10/30/08)

PROJECT: CO001322 MAPPED: JC CHECKED: MS

FILE: CSA_BF_WATERLEVEL_1008.MXD

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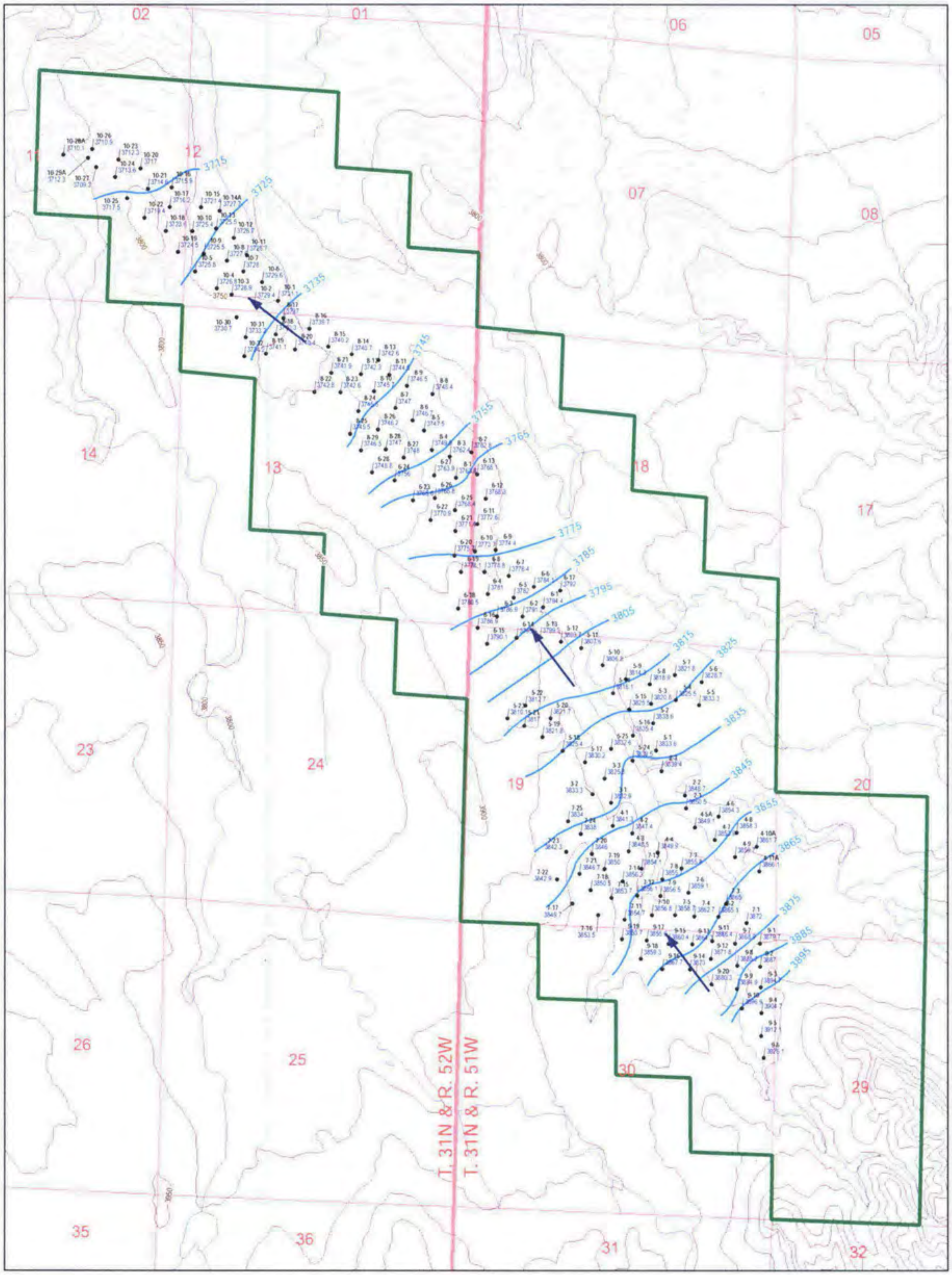

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-3d
CURRENT LICENSE AREA
WATER LEVEL MAP -
BRULE FORMATION (2/23/09 – 3/5/09)

PROJECT: CO001322 MAPPED: JC CHECKED: MS

FILE: CSA_BF_WATERLEVEL_0309.MXD

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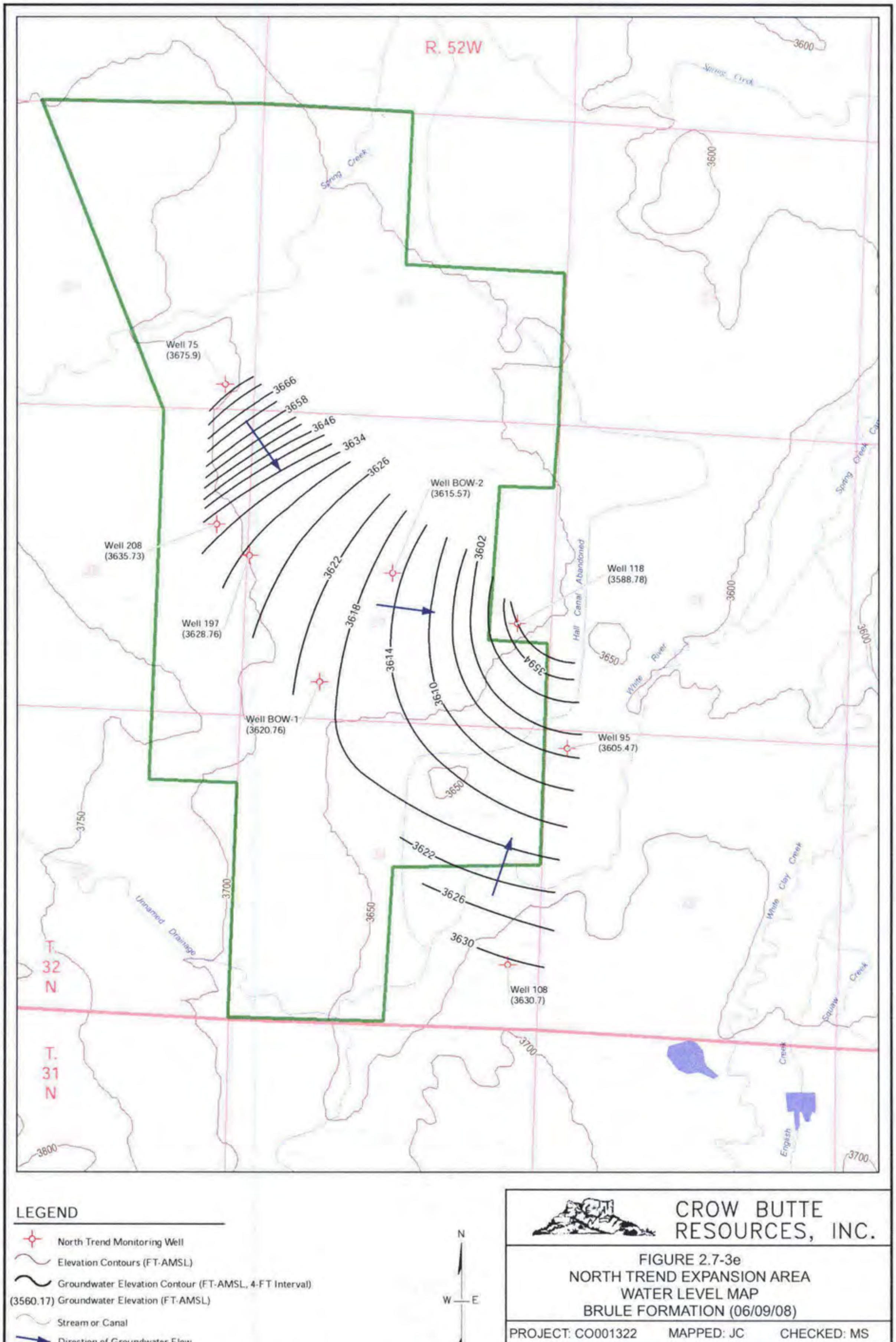

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-3e
NORTH TREND EXPANSION AREA
WATER LEVEL MAP
BRULE FORMATION (06/09/08)

PROJECT: CO001322 MAPPED: JC CHECKED: MS

FILE: CSA_Fig 2.7-3e_NT_WL_Brule.mxd

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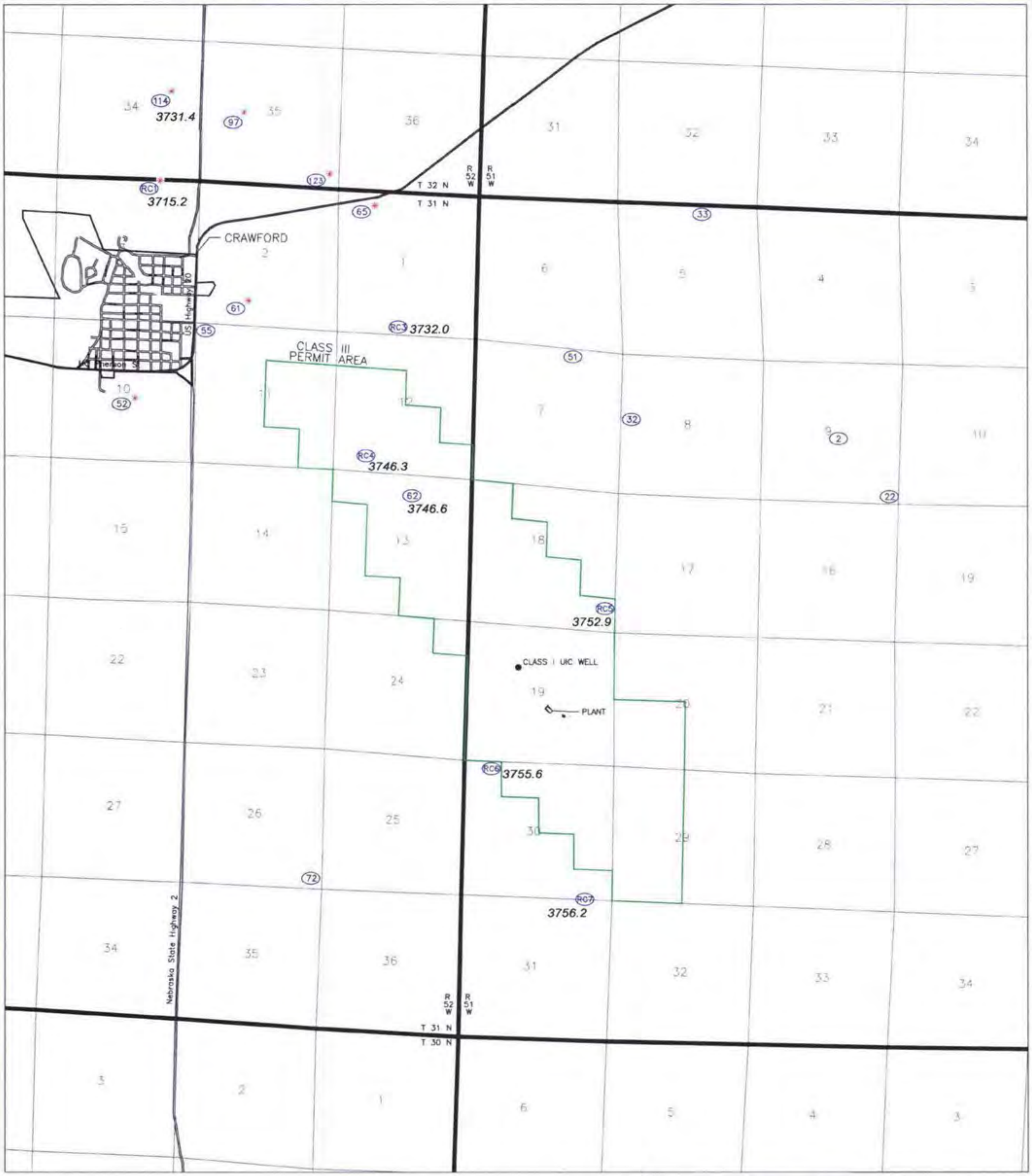

LEGEND

3756.2 Chadron Formation Water Level Elevation (ft–amsl)

* Chadron Formation Artesian Well

Notes: Wells 52, 65, 114 and RC–3 have been abandoned.

0 0.5 1.0 2.0

SCALE IN FEET 1" = 1 MILE

N

W — E

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-4a
REGIONAL WATER LEVEL MAP
BASAL CHADRON SANDSTONE 1982-1983

PROJECT: CO001322.0001	MAPPED: JC	CHECKED: MS

FILE: CSA_FIGURE 2.7-4a REGIONAL WATER LEVEL_BCS.psd

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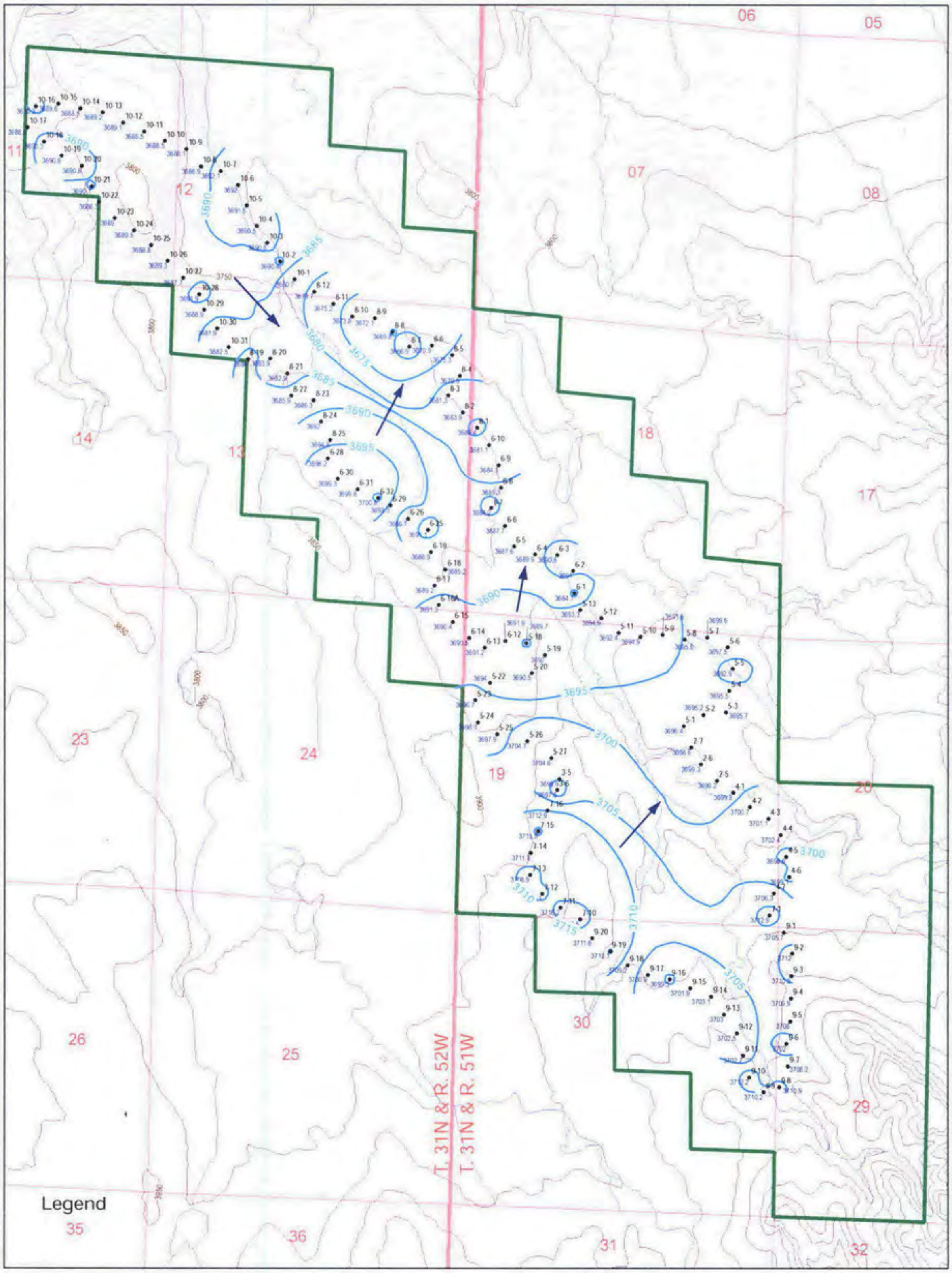

LEGEND

- Well ID
- Basal Chadron Sandstone Water Well
- Groundwater Elevation (FT-AMSL)
- Elevation Contours (FT-AMSL)
- Groundwater Elevation Contour (5-FT Interval)
- Groundwater Elevation (FT-AMSL)
- Stream or Canal
- Direction of Groundwater Flow
- Class III Permit Boundary

N W E

0 1,500 3,000

Scale in Feet

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-4b
CURRENT LICENSE AREA
POTENTIOMETRIC SURFACE -
BASAL CHADRON SANDSTONE (3/31/08 – 4/15/08)

PROJECT: CO001322 MAPPED: JC CHECKED: MS

FILE: CSA_BCS_POTENTIOMETRIC_0308.MXD

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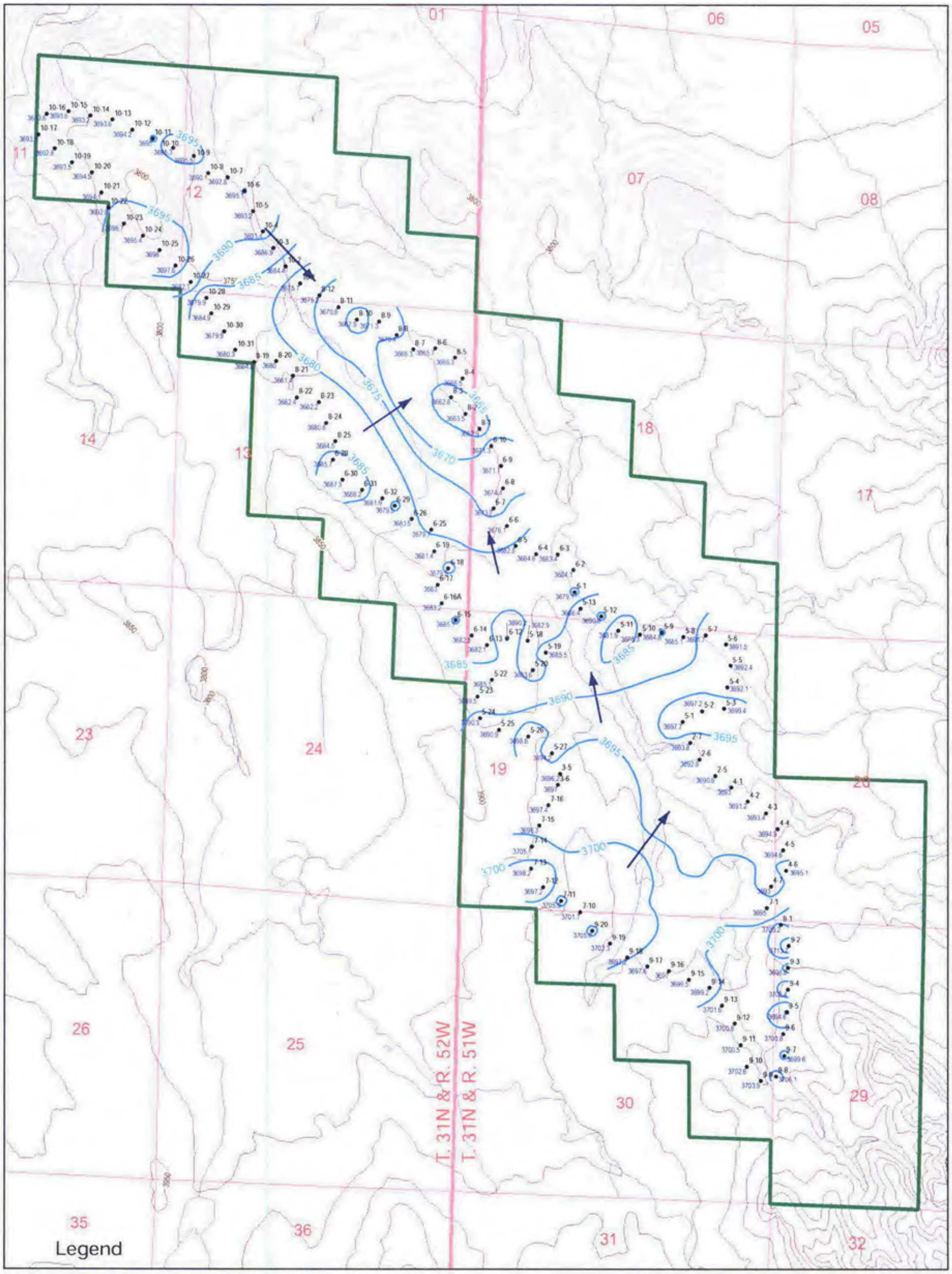

LEGEND

10-1 Well ID
Basal Chadron Sandstone Water Well
3694.2 Groundwater Elevation (FT-AMSL)

Elevation Contours (FT-AMSL)

Groundwater Elevation Contour (5-FT Interval)
3690 Groundwater Elevation (FT-AMSL)

Stream or Canal

Direction of Groundwater Flow

Class III Permit Boundary

N W E

0 1,500 3,000
Scale in Feet

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-4c
CURRENT LICENSE AREA
POTENTIOMETRIC SURFACE -
BASAL CHADRON SANDSTONE (10/6/08 – 10/30/08)

PROJECT: CO001322	MAPPED: JC	CHECKED: MS

FILE: CSA_BCS_POTENTIOMETRIC_0308.MXD

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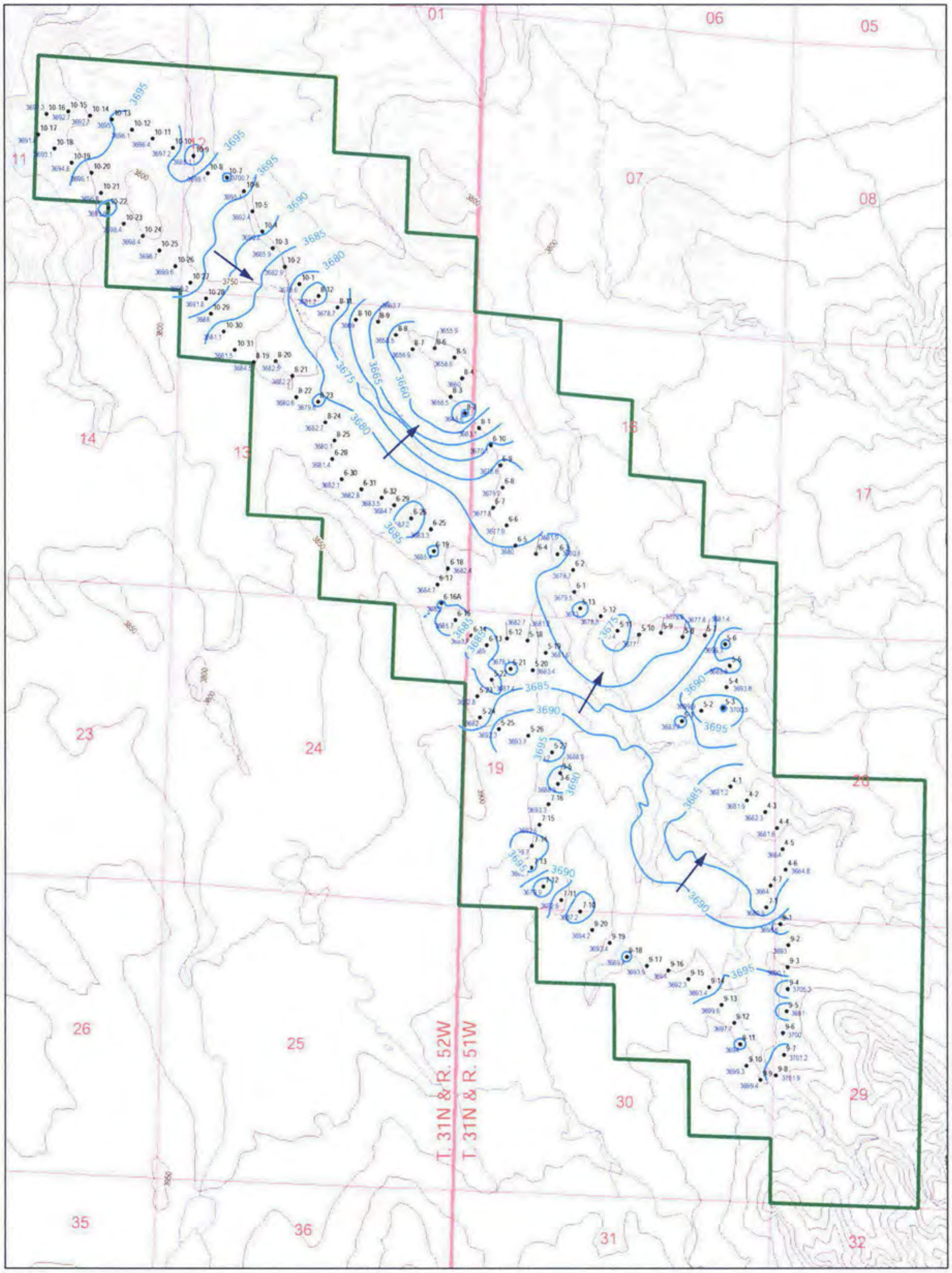

LEGEND

- 10-1 Well ID / Basal Chadron Sandstone Water Well / 3694.2 Groundwater Elevation (FT-AMSL)
- Elevation Contours (FT-AMSL)
- Groundwater Elevation Contour (5-FT Interval) / 3690 Groundwater Elevation (FT-AMSL)
- Stream or Canal
- Direction of Groundwater Flow
- Class III Permit Boundary

N / W — E

0 1,500 3,000

Scale in Feet

CROW BUTTE RESOURCES, INC.

FIGURE 2.7-4d
CURRENT LICENSE AREA
POTENTIOMETRIC SURFACE -
BASAL CHADRON SANDSTONE (2/23/09 – 3/5/09)

PROJECT: CO001322	MAPPED: JC	CHECKED: MS

FILE: CSA_BCS_POTENTIOMETRIC_0309.MXD

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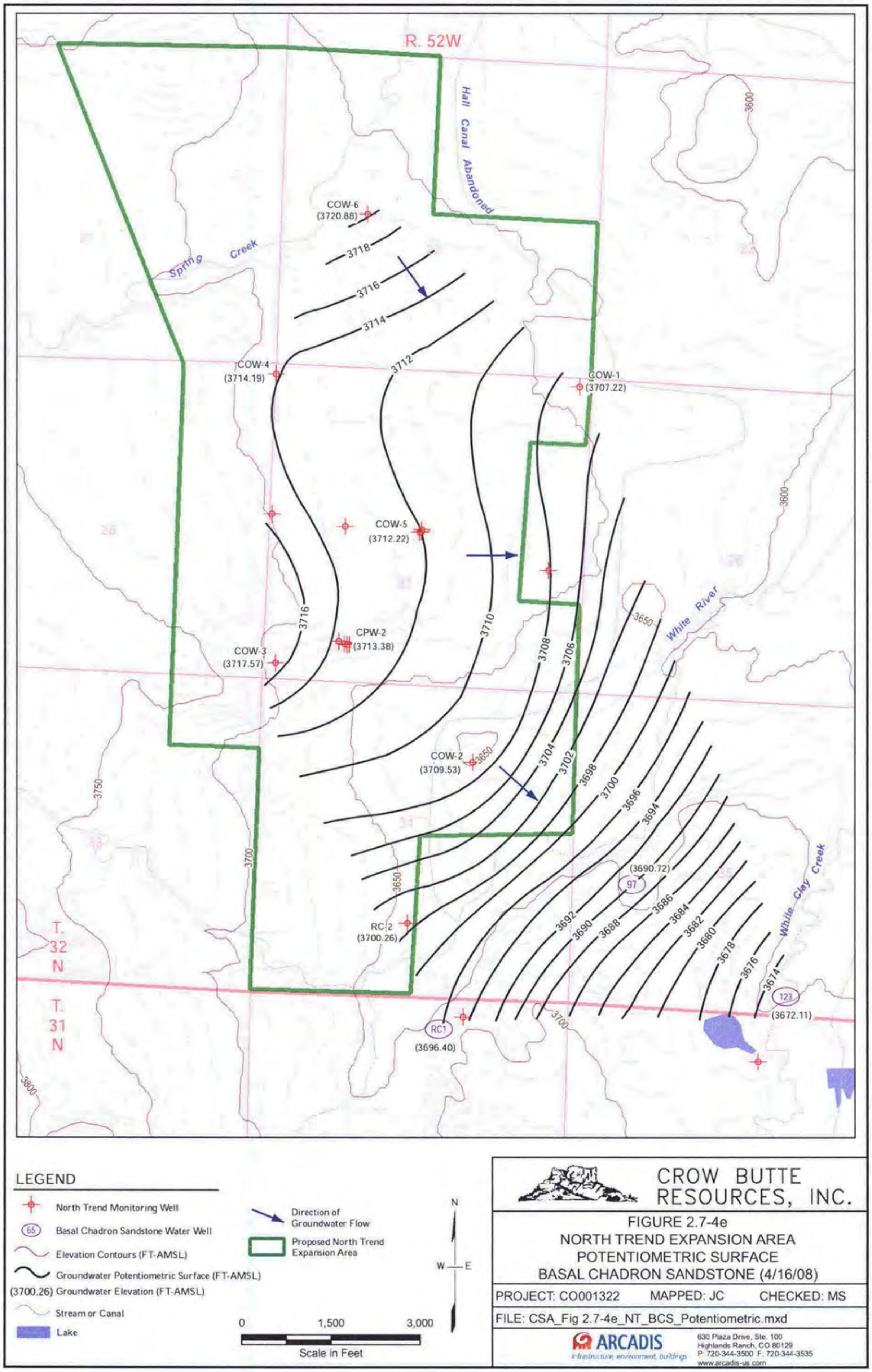

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FIGURE 2.7-4e
NORTH TREND EXPANSION AREA
POTENTIOMETRIC SURFACE
BASAL CHADRON SANDSTONE (4/16/08)

PROJECT: CO001322 MAPPED: JC CHECKED: MS

FILE: CSA_Fig 2.7-4e_NT_BCS_Potentiometric.mxd

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More recent water levels collected from the Basal Chadron Sandstone within the CSA in October 2008 and February-March 2009 indicate similar regional flow directions. Therefore, regional groundwater flow in the Basal Chadron Sandstone generally converges in the central portion of the CSA (in the vicinity of Mine Unit 8). It should be noted that local variations in groundwater flow that occur in most of the mine units, most significantly in the northern portion of Mine Unit 10, are the result of production activities. Local hydraulic gradients are highly variable within the permit area as a result of production activities and ranged from 0.004 to 0.064 ft/ft during the 2008 to 2009 time period. Water levels in the Basal Chadron Sandstone have decreased from approximately 40 to 60 feet across the permit area between the 1982-1983 and 2008-2009 time period. Water levels have been lowered by 40 to 60 feet across the permit area in order to maintain a cone of depression. Within each mine unit, more water is produced than injected by using a bleed stream in order to create an overall hydraulic cone of depression in the production zone. There were no significant seasonal changes to water levels, flow directions or range of hydraulic gradients observed in the Basal Chadron Sandstone between spring (March-April 2008) and fall (October 2008) conditions.

Historical water level data for a one-year period from wells located in the CSA are included on **Tables 2.7-5** (Brule wells) and **Table 2.7-6** (Basal Chadron wells).

Regionally, 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) concentrations of the water below the Pierre Shale have 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, T31N, R52W). 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 milligrams per liter (mg/L) (as NaCl). Based on samples collected during the installation and testing of the Crow Butte deep disposal well (DW #1, Section 19, T31N, R51W) TDS levels in the Morrison Formation (3,580 feet midpoint depth) and Sundance Formation (3,784 feet) are approximately 24,000 and 40,000 mg/L, respectively.

Table 2.7-5: Brule Water Levels (in feet above mean sea level)

	1982												**1993**	**1993**
Well	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**	**April**	**July**
11**	3831.7	3831.5	3831.8	3833	3833	3833.6	3833	3832.6	3831.5	3830.6	3830.3	3830.3	3843.5*	3837
12**	3928	3924	3923	3922.7	3923.7	3921.1	3922.1	3921.5	3922.2	3921.3	3903.3*	3918.7	3922.9	3920
13	3968.5	3968.7	3968.8	3969.4	3969.6	3969.2	3969.5	3968.9	3968.1	3967.5	3968.1	3968.4	3969	3970
17	3865	3863.5	3863.3	3862.6	3863.6	3864.8	3863.3	3862.8	3863.5	3863.8	3865.3	3864.6	3864.8	3862.8
24**	3902	3910.5	3909	3903	3910.9	3910.5	3910.5	3910	3904.7	3901.5	3895.7*	3910.1	3910.4	3911
25	3870	3870.8	3870	3871	3871	3871.3	3869.5	3870.9	3870.6	3870.5	3870.8	3870.9	3870.1	3871.6
31**	3883.1	3883.1	3883.2	3883.1	3883.3	3883	3882.6	3882.3	3882.6	3880	3882.3	3882.5	3882.5*	3872.3*
64	3882	3882.9	3882.6	3883.5	3883.6	3883.8	3881.4	3880.8	3881.5	3880	3880.4	3882	3884.3	3883.5
	1982				**1983**									
	Sept	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept**	
RA-2	3737.1	3737	3738.5	3737.9	3739.2	3739.1	3739.7	3740.2	3740.9	3741	3739.9	3739.2	3738.1	
RB-3	3962.6	3961.2	3963.5	3963.6	3963.8	3963.8	3963.3	3969.7*	3963.7	3963.7	3964.2	3964.1	3964.2	
PM-6	------	3844.9	3844.9	------	3843.5*	3844.5	3844.9	3845.3	3845.5	3846	3845.9	3945.9	3845.7	
PM-7	------	3845.7	3845.5	------	3845.9	3845.8	3845.7	3846.1	3846.3	3846.9	3846.7	3846.7	3846.6	

Notes:
* Suspect Data
** Well may have been pumped prior to water level reading.
------ = measurement not taken

Table 2.7-6: Basal Chadron Water Levels (in feet above mean sea level)

	1982				1983								
Well	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	August	Sept
62	3748.4	3748	3747.2	3746.6	------	------	3746.1	3746.2	------	------	3746.1	3745.8	3745.4
RC-4	------	------	------	3746.7	------	------	------	3746.2	------	------	3746.2	3746.2	3746.3
RC-5	3753.6	3753.4	3753.4	3753.2	3753	3752.6	3752.7	3752.9	3752.8	3752.9	3752.7	3752.5	3752.4
RC-6	3755.2	3755.2	3755.7	3756.8	3757.5	3754.7	3754.9	3755.7	3755.6	3755.6	3755.4	3755.2	3754.7
RC-7	3755.2	3756.8	3756.3	3756.2	3756.4	3755.8	3756	3756.4	3756.5	3756.7	3756.2	3756.1	3755.9
PM-1	------	3754.5	3754.4	3754.1	3754.3	3754	3753.8	3754	3754.2	3754.1	3753.8	3753.5	3753.5
PM-4	------	3755.2	3755.2	3754.4	3754.4	3754.1	3754.2	3754.4	3754.8	3754.6	3754.3	3753.9	3754.6
PT-2	------	3747.1*	3747.1*	3754	3754.6	3754.3	3754.1	3754.3	3754.5	3754.7	3754.3	3753.9	3753.7
PT-7	------	3755.1	3755	3754.2	3754.2	3754	3754	3754.1	3754.8	3754.6	3754.3	3754.1	3753.9
PT-8	------	3755.5	3755.6	3754.6	3754.4	3754.4	3755.7	3754.4	3754.5	3754.6	3754.2	3753.8	3753.7
PT-9	------	3753.5	3753.5	3754.9	3754.6	3754.6	3754.6	3754.8	3854.8	3754.9	3754.5	3754.3	3754.1

Notes:
* Suspect Data
------ = measurement not taken

The Pierre is essentially impermeable which precludes its use as a water supply. A number of shallow wells are reported as having the Pierre Shale as the bedrock unit (Spalding, 1982) in Township 32 North, Range 51-52 West. These wells range in depth from 18 to 100 feet with an average depth of 44 feet, and were drilled in areas that have considerable alluvium atop the Pierre, including locations along Spring Creek and the White River between Crawford and Whitney Lake. These wells produce water from a few tens of feet of Quaternary Alluvium overlying the Pierre Shale, with the bottom few tens of feet in those wells providing storage. Spalding (1982) states that, *"In very shallow wells (a few tens of feet) significant amounts of water utilized may be contained in the thin Quaternary sediments overlying the designated hydrogeologic unit. This situation is particularly true for those wells noted as completed in the Pierre Shale".* In the geologic summary of the Spalding report, the groundwater potential of the Pierre Shale is discussed as (page 14), *"The oldest bedrock unit in the area, the Pierre Shale of Cretaceous Age, is not considered as a potential aquifer. It is, however, included in the discussion of completion horizons and hydrogeologic units. A few of the shallow wells produce from the Quaternary sediments immediately overlying the Pierre Shale".*

2.7.2.2 Crow Butte Area Groundwater Hydrology

The hydrogeologic system within and surrounding the Crow Butte CSA is similar to that found regionally. Alluvial deposits occur intermittently in ephemeral drainages, but are not considered to be a reliable water source. Over most of the Crow Butte License Area, the Brule Formation outcrops, and is underlain by the Chadron Formation (including the Basal Chadron Sandstone) and the Pierre Shale. The occurrence and thickness of these geologic units within the License Area have been confirmed during exploratory drilling and logging activities. Based on these data, the relationship of the hydrostratigraphic units within the License Area is shown on a cross-section location map (**Figure 2.7-5**) and two cross-sections (**Figures 2.7-6** and **2.7-7**).

The Basal Chadron Sandstone, the aquifer which is host to the uranium mineralization, is bounded above and below by strata which form aquicludes. The term "aquiclude" is used to describe strata capable of transmitting only minor amounts of fluid either vertically or horizontally. Typical values for vertical and horizontal permeability of "aquicludes" are in the range of 10^{-4} to 10^{-5} darcys (Todd 1980), which is equivalent to a hydraulic conductivity of 10^{-7} to 10^{-8} centimeters per second (cm/sec). The vertical hydraulic conductivities of the aquicludes calculated from pumping tests conducted in the CSA are on the order of 10^{-11} cm/sec (FEN 1987b). Laboratory analysis of cores from wells in the CSA indicates vertical hydraulic conductivities on the order of 10^{-10} to 10^{-11} cm/sec (FEN 1987b). Local groundwater flow within the Basal Chadron is to the east, with a gradient of 0.0016 feet per feet (ft/ft) or 8.5 feet per mile (ft/mile).

Figure 2.7-5: Hydrostratigraphic Cross Section Location Map

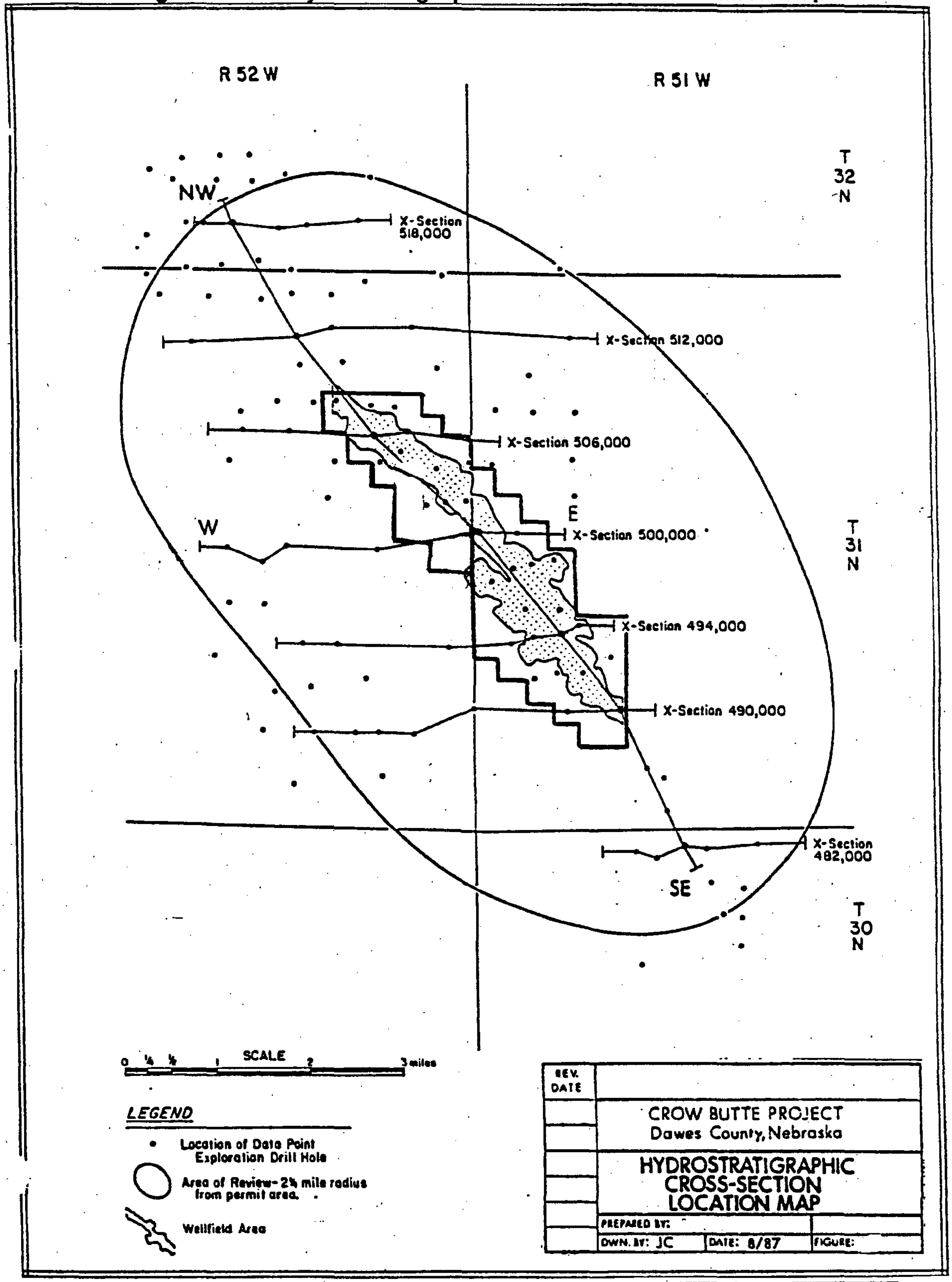

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Figure 2.7-6: Northwest-Southeast Hydrostratigraphic Cross Section

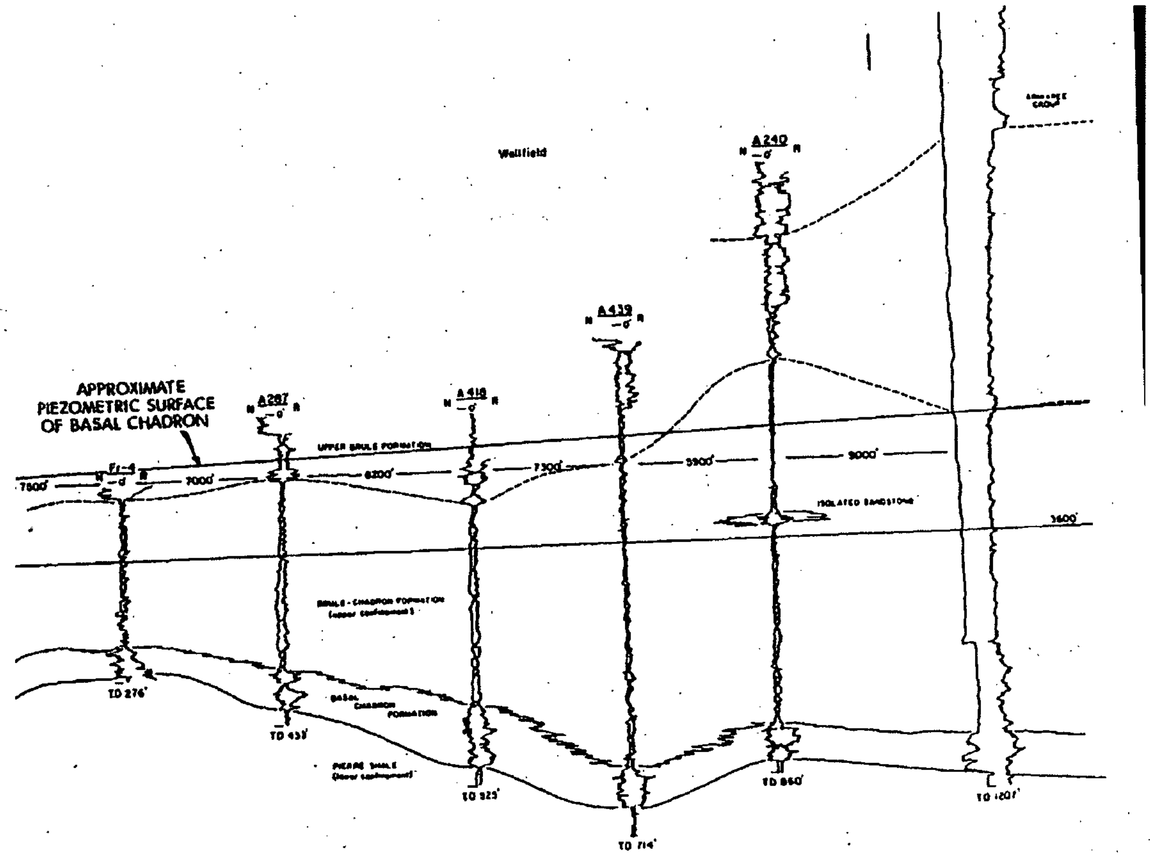
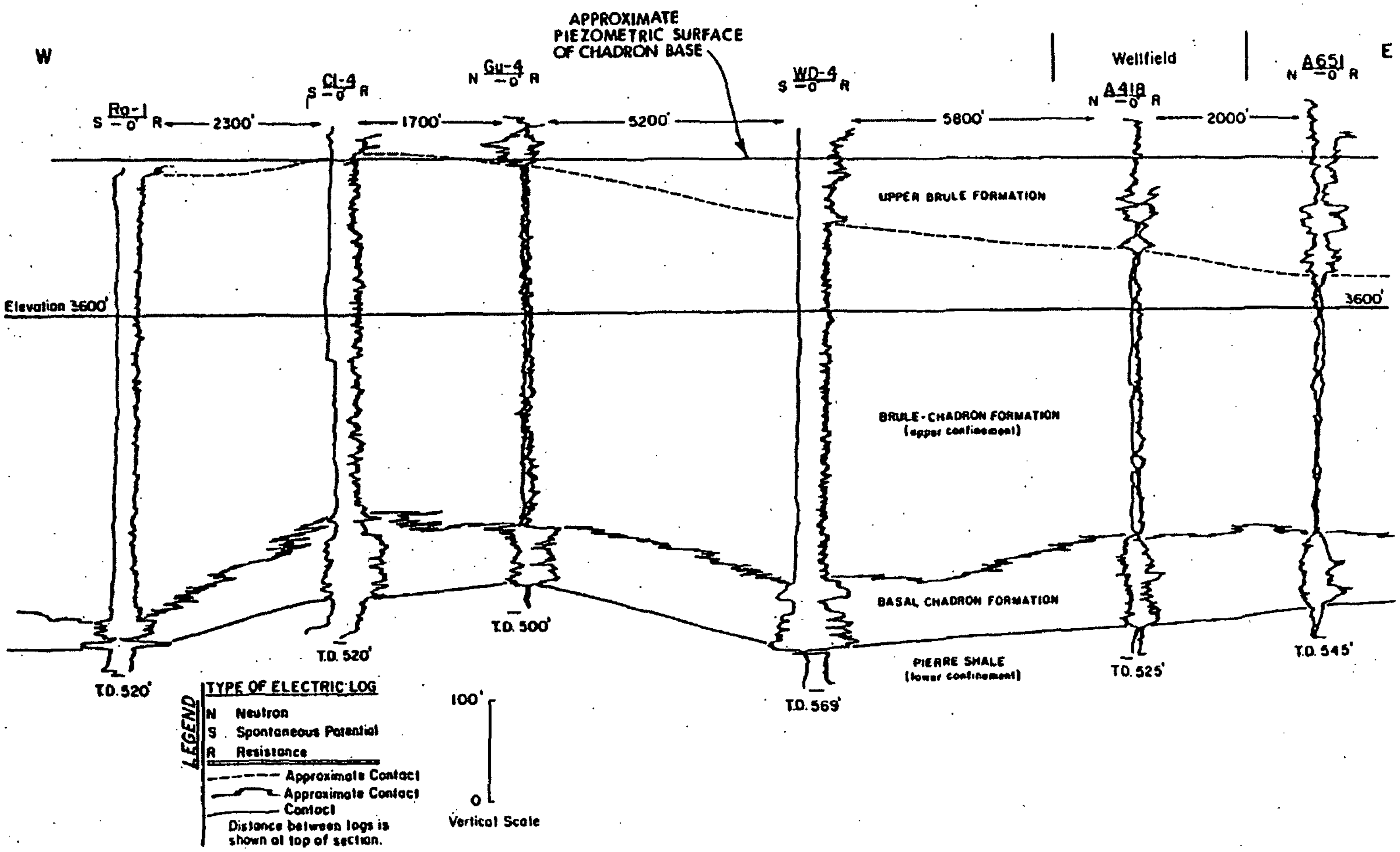


Figure 2.7-7: East-West Hydrostratigraphic Cross Section



The sandstones and sandy siltstones in the upper part of the Brule Formation may be water-bearing locally. However, these sandstones, siltstones, and clay stringers are difficult to correlate over any large distance and are discontinuous lenses rather than laterally continuous strata. As stated previously, these different sand lenses may exhibit different water levels. Brule wells PM-6 and PM-7, monitor wells in the R&D wellfield, exhibit differences in water levels which average 1 foot and range from 0.7 to 2.4 feet. In addition, recharge capacity is low in these lenses as evidenced by the low productivity of these wells and the difficulty in developing these wells. Based on only four data points, flow in the Brule is to the east/northeast at 0.005 ft/ft or 26.4 ft/mile.

Water level data support hydrologic isolation of the Basal Chadron Sandstone with respect to the other water-bearing intervals of interest in the CSA. Groundwater production rates within the Brule and Upper/Middle Chadron sands are low to exceptionally low.

The geochemical groundwater characteristics of the Brule and Chadron further indicate that the two zones are not naturally interconnected.

2.7.2.3 Aquifer Testing

CBR operates an in-situ uranium mine in Dawes County, Nebraska, southeast of the City of Crawford (**Figure 1.3-2**). The mine area spans portions of Sections 11, 12, and 13 of Township 31 North, Range 51 West and Sections 7, 19, 20, 29, and 30 of Township 31 North, Range 52 West. The NDEQ authorized CBR to operate the mine according to Underground Injection Control (UIC) regulations via UIC Permit Number NE 0122611. This permit requires CBR to complete aquifer pumping tests to demonstrate the integrity of the confining layer above the mining zone prior to mine development within the License Area. Data collected and analyzed as part of these aquifer pumping tests included pumping rate, test duration, formation characteristics, transmissivity, hydraulic conductivity, storativity, and radius of influence (ROI) so the hydraulic characteristics of the aquifer and the integrity of the confining layers near the mining sites can be evaluated.

In general, aquifer pumping tests are field experiments performed to evaluate an aquifer's recovery to the induced stress of pumping. Typically, aquifer pump tests involve the design and construction of multiple wells, both a pump well and observation wells, to monitor the aquifer's response to pumping. During the pump test, groundwater is pumped from pump wells at determined rate and for a fixed time, and water levels are measured in the surrounding observation wells throughout the test to determine the effect of pumping on the aquifer and adjacent water bearing formations. Aquifer pump tests usually involve monitoring water levels during the pumping phase, as well as after pumping has stopped, in order to determine the aquifer's recovery time. The well data are then analyzed to compute hydraulic properties of the aquifer including hydraulic conductivity, transmissivity, storativity, and ROI (Heath 1982).

CBR performed four groundwater pumping tests within the License Area boundary between 1982 and 2002 in order to comply with the requirements of the UIC permit. **Figure 2.7-8** illustrates the locations of the four pumping tests within the License Area. This section of the report summarizes the hydrogeologic characteristics of the License Area and the methods used in the aquifer pumping tests, test results, and conclusions regarding the aquifer and integrity of the confining layer within the License Area.

Purpose & Objectives of Aquifer Testing

The objectives of the aquifer pumping tests are to assess the integrity of the confining layer above the mining zone and characterize the hydrogeology of the ore-bearing aquifer in order to comply with NDEQ and USNRC permit requirements. The hydrogeologic investigation was also designed to address environmental and operational questions pertinent to ISL uranium mining at the site raised by the USNRC. Specifically, these tests address requirements are outlined by the USNRC in Regulatory Guide 3.46, Section 2.7.1 and Draft Staff Technical Position Paper WM-8203, Section 3.1.2. In general, the hydrogeologic investigation was oriented toward the characterization of the hydraulic properties of the ore-bearing aquifer and the hydraulic relationship of the aquifer to the overlying and underlying confining strata.

In addition to its use in the commercial permit application, the information gathered from the aquifer pump tests may be used for:

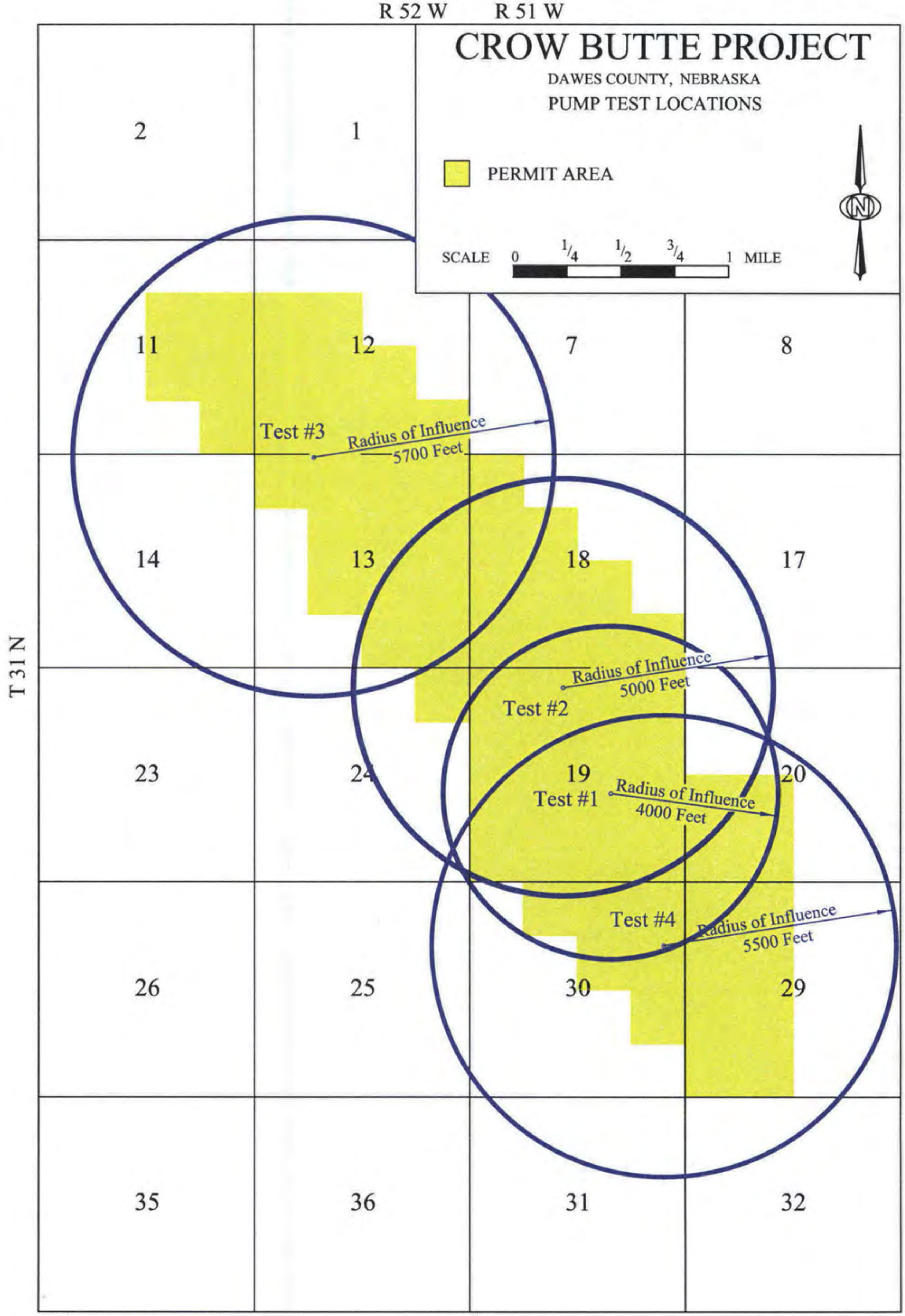
- design of the commercial wellfield,
- selection of commercial production parameters,
- design of the groundwater monitoring system, and
- prediction of the mining and restoration efficiency.

Site Characterization

CBR developed the mine to recover uranium from the Chadron Sandstone Formation. The uranium-bearing aquifer is formed by coarse-grained arkosic sandstone which is locally known as the Basal Sandstone Member of the Chadron Formation. The Basal Sandstone is believed to be the depositional product of a large, vigorous, braided-stream system which occurred during the early Oligocene age (approximately 36 to 40 million years before present).

Ore-grade uranium deposits underlying the CBR site are predominantly located in the Chadron Sandstone Formation, which occurs at depths ranging from 400 to 1,200 feet and averages 50 feet in thickness, of which 35 feet are net sand. A confining layer exists above the Chadron Sandstone Formation that is composed of the Upper Chadron and Brule Formations, which averages 300 feet thick across the site. The general stratigraphy of the site in both the northern and southern portions of the License Area is summarized in **Section 2.6**.

FIGURE 2.7-8


R 52 W
R 51 W
CROW BUTTE PROJECT
DAWES COUNTY, NEBRASKA
PUMP TEST LOCATIONS
PERMIT AREA
SCALE 0 1/4 1/2 3/4 1 MILE
N
T 31 N
2
1
11
12
7
8
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17
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19
20
26
25
30
29
35
36
31
32
Test #3
Radius of Influence
5700 Feet
Test #2
Radius of Influence
5000 Feet
Test #1
Radius of Influence
4000 Feet
Test #4
Radius of Influence
5500 Feet

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The Pierre Shale of late Cretaceous age forms the underlying confining layer for the Basal Chadron Sandstone. The Pierre Shale is a widespread dark gray to black marine shale which is essentially impermeable. Regionally, the Pierre Shale is up to 5,000 feet thick. In Dawes County, deep oil test holes have encountered thicknesses of 1,200 to 1,500 feet of Pierre Shale. The clays, claystones, and siltstones of the Middle and Upper Members of the Chadron Formation and the Lower Brule Formation form the overlying confining layer for the Basal Chadron Sandstone.

Further geologic characterization of the general area surrounding the CBR project site is available in "Application and Supporting Environmental Report for the State of Nebraska Underground Injection Control Program Commercial Permit" (FEN 1987b).

Aquifer Pumping Tests

Four aquifer pumping tests were performed at the CBR mine area between November 1982 and August 2002 in order to evaluate hydraulic characteristics of the Chadron Sandstone in the License Area, assess the integrity of the confining layer above the mining zone, and to comply with requirements outlined in the UIC permit.

The methods, results and conclusions regarding the hydrogeologic properties of the aquifer and confining layer above the mining zone are discussed below.

Methods

In general, the four aquifer tests employed the following methodology.

- Review of existing geologic and hydrogeologic data for the area,
- Design of appropriate aquifer test,
- Design and construction of appropriate well array for aquifer test,
- Laboratory tests of core samples from confining layers,
- Performance of aquifer test,
- Analysis of data from aquifer test, and
- Interpretation of results of test.

Aquifer pump test data collected as part of this investigation were analyzed using a variety of the following methods.

- Theis' Non-Equilibrium Method (Theis 1935) for analyzing non-equilibrium pumping test data.
- Theis' Recovery Method (Theis 1935) for analyzing recovery test data.
- Jacob's Modified Non-Equilibrium Method (Cooper and Jacob 1946) for analyzing non-equilibrium pumping test data.

- Cooper and Jacob's Distance-Drawdown Method (Cooper and Jacob 1946) for determining radius of influence.
- Hantush's Method (Hantush 1966) for determining the magnitude and direction of the major the minor horizontal axes of transmissivity in an anisotropic aquifer.
- Neuman and Witherspoon's Method (Neuman and Witherspoon 1972) for determining the hydraulic diffusivity and vertical hydraulic conductivity of confining layers.
- Darcy's Law (Darcy 1856) to determine the average pore velocity and the groundwater flux across the aquifer test site.
- Standard Consolidation Test (ASTM 1985) to determine the coefficient of consolidation, compression index, coefficient of compressibility, and vertical hydraulic conductivity of the confining layer.

The locations of each of the four aquifer tests within the CBR License Area are illustrated in **Figure 2.7-8**. Tests numbers 1 and 2 were carried out in the central portion of the License Area within Section 19 of Township 31 North, Range 51 West. Test number 3 was performed in the northwestern portion of the License Area on the border between Sections 12 and 13 of Township 31 North, Range 52 West. Test number 4 was performed in the southeastern section of the License Area within Section 30 of Township 31 North, Range 51 West.

First Aquifer Test

The first multiple-well aquifer test (Test #1) was conducted in the R&D wellfield in November 1982. The pumping period of this test was 50.75 hours and the recovery period was 27.6 hours. During this test, water levels were measured in four production zone observation wells and two shallow Brule monitor wells were measured. The data from the first aquifer test were analyzed using the Theis Non-Equilibrium Method (1935), the Jacob Modified Non-Equilibrium Method (1946) and the Theis Recovery Method (1935). The results of these analyses show that the Basal Chadron Sandstone, which is the ore-bearing aquifer at the Crow Butte site, is a non-leaky, confined, anisotropic aquifer. The effective transmissivity of the Basal Chadron Sandstone ranged from 2,453 gpd/ft (327 ft^2/day) to 3,863 gpd/ft (516 ft^2/day). The average thickness of the aquifer at the test site was about 40 feet. Average hydraulic conductivity ranged from about 61 gpd/ft^2 (8.2 ft/day) to about 97 gpd/ft^2 (13 ft/day). The average coefficient of storage ranged from 9.66×10^{-5} to 1.75×10^{-4}. The azimuth and magnitude of the major axis of transmissivity were about 2° and 3,000 gpd/ft (401 ft^2/day), respectively. The azimuth and magnitude of the minor axis of transmissivity were about 92° and 2169 gpd/ft (290 ft^2/day), respectively. Evidence from the test showed that the Basal Chadron Sandstone is not hydraulically connected to the overlying aquifer in the Brule Sand.

Results from Test #1 imply that aquicludes which overlie and underlie the Basal Chadron Sandstone probably yielded some small amount of water as recharge (or leakage) to the aquifer during the pump test. However, the amount of this recharge or leakage was

extremely small as evidenced by the results of the laboratory test of the core samples and the drawdown analysis of the Basal Chadron Sandstone. The lack of substantial leakage was the result of the extremely low vertical hydraulic conductivity of the confining layers. The vertical hydraulic conductivity of the overlying confining layer, as determined from the laboratory tests of core samples, was about $7.8x10^{-7}$ ft/day ($2.8x10^{-10}$ cm/sec), and that of the underlying confining layer was about $9.6x10^{-8}$ ft/day ($3.4x10^{-11}$ cm/sec). Confining layers with vertical hydraulic conductivities this low are, by definition, called aquicludes rather than aquitards.

The integrity of confinement of the ore-zone aquifer (Basal Chadron Sandstone) may be characterized by the hydraulic resistance factor. The hydraulic resistance factor of an aquitard to vertical flow (c) is defined as the reciprocal of the leakage coefficient K/B, where K is the vertical hydraulic conductivity of the aquitard, and B is the aquitard thickness; thus c=B/K and has the dimensions of time. Hydraulic resistance is typically expressed in units of days or years. The hydraulic resistance of the overlying aquiclude is about 1,050,000 years and that of the underlying aquiclude is about 34,000,000 years. The time needed for a water molecule to travel through the entire thicknesses of the aquicludes is calculated as the hydraulic resistance times the effective porosity. Assuming an effective porosity of 2.0 percent and a unit gradient of 1 foot of head loss per foot of movement in the direction of flow, these result in travel time of about 21,000 years for the overlying aquiclude and about 685,000 years for the underlying aquiclude.

The piezometric surface of the Basal Chadron Sandstone dips toward the north at a gradient of about 0.04 percent (0.0004) which is equal to 1 foot per 2500 feet. Using a directional hydraulic conductivity of 10 ft/day, a gradient of 4×10^{-4} and a porosity of 29 percent, the average pore velocity across the R&D site was computed to be 5.0 ft/year. The groundwater flux across the site was computed to be 0.16 ft^3/day per unit width of the aquifer.

Second Aquifer Test

A second multiple-well aquifer test (Test #2) was performed between 10 June and 3 July 1987 in the mineralized area near the northern boundary of Section 19, Township 31 North, Range 51 West and approximately 2,800 feet north of the R&D site. The second aquifer pumping test was performed in order to characterize the hydrogeology of the mining area developed in 1987. At the Test #2 site, the Basal Sandstone is approximately 550 to 600 feet below ground surface and averages 40 feet in thickness. The Chadron Formation lies with marked unconformity on top of the Pierre Shale.

The well array used for Test #2 consisted of five wells and two high-sensitivity piezometers. One pumping well (CPW-1) and three observation wells (COW-1, COW-2, COW-3) were completed in the ore-bearing aquifer (Basal Chadron Sandstone). The three observation wells were located in an equiangular arrangement around the central pumping well. This configuration provided the data needed to define the magnitude and direction of the major and minor axes of transmissivity, the effective transmissivity, the hydraulic conductivity and the storativity of the ore-bearing aquifer. One monitor well

(BMW-1) was completed in the first overlying sand of the Brule Formation. This well was used to monitor the water level in the first overlying sand during the aquifer test. Two piezometers (UCP-1, LCP-1) were completed in the confining layers which overlie and underlie the ore-bearing aquifer to provide data to calculate the vertical hydraulic conductivities of these confining layers under in-situ field conditions.

During Test #2, the pumped well (CPW-1) was equipped with a 7.5 HP submersible pump which was set at a depth of about 500 feet. Discharge pumped from the well was measured with an electronic pressure transducer and was recorded by the data-logger throughout the course of the test. The pumping phase of the aquifer test endured 72 hours between June 30, 1987 and July 3, 1987. Prior to the start of the pumping, static water levels of all the wells were measured and recorded. The recovery phase of the test lasted 72.5 hours between July 3, 1987 and July 6, 1987.

The average discharge rate during the pumping phase of the test was 47.74 gpm, and the total volume of water discharged was 206,288 gallons. Throughout the pumping phase, the discharge rate was regularly monitored to ensure that it remained constant. The static water level in the pumped well was approximately 484 feet above the top of the aquifer.

The calculated maximum drawdown in the pumped well was 36.86 feet, which is approximately 447 feet above the top of the aquifer. Barometric pressure did vary considerably during the 6-day test, which was likely the result of the passage of a low pressure system and a cold front with associated thunderstorms and subsequent high pressure.

The Jacob Non-Equilibrium Method, the Theis Non-Equilibrium Method and the Theis Recovery Method were used to analyze the aquifer test data from the three Basal Chadron Sandstone wells. A confined non-leaky type of analysis was made because leakage effects were not apparent in the test data and the piezometric surface is well above the top of the aquifer. Inspection of the results of the analyses verifies that these assumptions are valid. The Neuman-Witherspoon Method (1972) to determine the vertical hydraulic conductivity of both the over- and underlying confining area of the ore-bearing aquifer under in-situ conditions.

The transmissivities calculated from the drawdown data from the three Basal Chadron Sandstone observation wells (COW-1, COW-2, COW-3), ranged from 2682 gpd/ft (359 ft^2/day) to 2795 gpd/ft (374 ft^2/day). The storage coefficients for these wells, calculated from the same analyses, ranges from 8.44×10^{-5} to 1.31×10^{-4}. The transmissivities calculated from the recovery data from the three observation wells are slightly lower, ranging from 2604 gpd/ft (348 ft^2/day) to 2659 gpd/ft (355 ft^2/day). The average thickness of the aquifer at the test site is 40 feet. Therefore, the hydraulic conductivities calculated from the drawdown data ranged from approximately 67 gpd/ft^2 (8.96 ft/day) to 70 gpd/ft^2 (9.34 ft/day). The hydraulic conductivities calculated from the recovery data ranged from approximately 65 gpd/ft^2 (8.7 ft/day) to about 66 gpd/ft^2 (8.89 ft/day).

The Hantush Method was used to determine the direction and magnitude of the major and minor axes of transmissivity of the Basal Chadron Sandstone. The major axis of transmissivity in the Basal Chadron Sandstone lies along an azimuth of about 51° and has a magnitude of 2760 gpd/ft (369 ft^2/day). The minor axis of transmissivity has an azimuth of about 141° and a magnitude of 2692 gpd/ft 360 ft^2/day.

The overlying confining layer piezometer (UCP-1) showed no response to the pumping from the Basal Chadron Sandstone during the aquifer test. However, this piezometer did respond to the rapid changes in barometric pressure from the low pressure weather front. Because UCP-1 did not respond to pumping, laboratory data from the consolidation tests of core samples from UCP-1 were used to calculate the hydraulic properties of the overlying confining layer. The calculated average coefficient of compressibility, a_v, of the red clay portion of the overlying confining layer, is 3.99 x 10^{-7} cm^2/g, and the calculated average vertical hydraulic conductivity is 3.49 x 10^{-11} cm/sec. Using these consolidation test data, the calculated specific storage of the red clay portion of the overlying confining layer is 3.08 x 10^{-7} cm^{-1}, and the calculated hydraulic diffusivity is 1.13 X 10^{-4} cm^2/sec. Given that the red clay is approximately 30 feet thick and the total overlying confining layer is approximately 325 feet thick, the hydraulic resistance, c, (Kruseman and de Ridder 1979) is about 830,200 years for the red clay and 9,000,000 years for the entire confining layer. Assuming an average effective porosity of the overlying confining layer of 2.0 percent, the travel time through the red clay portion of the upper confining layer would be about 16,600 years and that of the entire upper confining layer would be about 180,000 years under unit gradient.

Because the vertical hydraulic conductivity of the underlying confining layer (Pierre Shale), as determined from the laboratory consolidation tests, is of the same order of magnitude as the vertical hydraulic conductivity of the upper confining layers (10 to 11 cm/sec) little drawdown of LCP-1 resulted. The calculated average coefficient of compressibility, a_v, of the Pierre Shale is 5.13 x 10^{-7} cm^2/g, and the calculated average vertical permeability is 3.63 x 10^{-11} cm/sec. Using these consolidation test data, the calculated specific storage of the top 5 feet of the underlying confining layer (Pierre Shale) is 2.78 x 10^{-7} cm^{-1}, and the calculated hydraulic diffusivity is 5.22 x 10^{-3} cm^2/sec. Applying the Neuman-Witherspoon Method to the data from the aquifer test and the consolidation test produces a field vertical hydraulic conductivity of 1.45 x 10^{-9} cm/sec. Oil test holes have shown that the Pierre Shale is approximately 1,200 feet thick in the vicinity of the aquifer test site. Therefore, the calculated hydraulic resistance, c, using field measured vertical hydraulic conductivity, is about 799,900 years. The calculated hydraulic resistance using the vertical hydraulic conductivity calculated from the laboratory consolidation tests is about 31,919,000 years. The average effective porosity of the Pierre Shale is estimated to be 2.0 percent. Therefore, the travel time through the Pierre Shale would be about 16,000 years using field determined vertical hydraulic conductivity and about 638,000 years using laboratory determined vertical hydraulic conductivity under unit gradient.

The overlying aquifer monitor well, BMW-1, showed no response to the pumping from the Basal Chadron Sandstone during the aquifer test. However, this well did respond to barometric changes that occurred during the aquifer test. Because BMW-1 did not respond to pumping, it is evident that the overlying aquifer is not in hydraulic communication with the Basal Chadron Sandstone. Therefore, the test data from BMW-1 were not further analyzed. Further, the piezometric surface of the Basal Chadron Sandstone is approximately 495 feet above the top of the aquifer, and the piezometric surface of the overlying aquifer is about 204 feet above the top of the Brule Sand. The difference between the piezometric surfaces of the two aquifers is about 59 feet. This also supports the theory that the Basal Chadron Sandstone is confined and that it is not hydraulically connected to the overlying aquifer.

The results of Test #2 indicate the Basal Chadron Sandstone, which is the ore-bearing aquifer, is a non-leaky, confined, slightly anisotropic aquifer. The effective transmissivity of the Basal Chadron Sandstone is 2726 gpd/ft. The average thickness of the aquifer at the test site is about 40 feet. Therefore, the average hydraulic conductivity is about 68 gpd/ft^2 (9.10 ft/day). The average storativity is 1.04 x 10^{-4}. The azimuth and magnitude of the major axis of transmissivity are about 51° and 2760 gpd/ft (369 ft^2/day). The azimuth and magnitude of the minor axis of transmissivity are about 141° and 2692 gpd/ft (360 ft^2/day).

The aquiclude which overlie and underlie the Basal Chadron Sandstone probably yielded some small amount of water as recharge (leakage) to the aquifer during the pumping of the aquifer test. However, the amount of this recharge or leakage was extremely small, as evidenced by the piezometer responses and the drawdown analysis of the Basal Chadron Sandstone. The overlying confining layer piezometer did not show any response attributable to the pumping. The underlying confining layer piezometer did show a maximum drawdown of 0.06 foot about 4300 minutes after pumping began. However, it is suspected that this small amount of drawdown is attributable to leakage at the annulus of the packer and borehole rather than to leakage from the confining layer.

The lack of substantial drawdown in the confining layer piezometers is attributable to the extremely low vertical hydraulic conductivity of the confining layers. The vertical hydraulic conductivity of the overlying confining layer is about 2.8 x 10^{-10} cm/sec to 3.49 x 10^{-11} cm/sec, and that of the underlying confining layer is about 1.45 x 10^{-9} to 3.63 x 10^{-11} cm/sec, based on the first and second aquifer test results, which is evident of an aquiclude. The calculated hydraulic resistance (c) of the entire thickness of the overlying aquiclude is between 1,050,000 and 9,000,000 years and that of the underlying aquiclude is between 799,900 years and 31,919,000 years. The times needed for a given water molecule to travel through the entire thicknesses of the aquiclude under unit gradient (one foot of head loss per foot of movement in the direction of flow) are about 21,000 to 180,000 years for the upper aquiclude and about 16,000 years to 638,000 years for the lower. Because the gradients would be much smaller during mining, actual travel times would be much longer than those stated above.

The piezometric surface of the Basal Chadron Sandstone dips approximately to the north at a gradient of 7.84×10^{-4}, which is equal to 1 foot per 1,275 feet. Using a directional hydraulic conductivity of 9.11 ft/day, a gradient of 7.84×10^{-4}, and a porosity of 29 percent, the average pore velocity across this part of the commercial study area was about 9.00 ft/year. The groundwater flux across the test site was computed to be about 0.29 ft^3/day per unit width of the aquifer (Darcy 1856).

Using the Cooper-Jacob Distance-Drawdown Method (Cooper and Jacob 1946), the ROI of the aquifer test in the Basal Chadron Sandstone was calculated to be about 5,000 feet. Therefore, the area investigated and characterized by Test #2 was approximately 1,803 acres.

Third Aquifer Test

A third groundwater pumping test (Test #3) was conducted in Sections 12 and 13, Township 31 North, Range 51 West, Dawes County, Nebraska between September 11, 1996 and September 13, 1996 for a duration of 55 hours. The recovery period monitoring was conducted between September 13, 1996 and September 15, 1996 and endured 44 hours. This test consisted of pumping one well (CPW96.1) completed in the Chadron Sandstone and monitoring groundwater levels in three wells (COW96.1, RC-4, A251/62) in the Chadron Sandstone, and in one well (BOW96.1) in the overlying Brule Formation. The pump test was performed using a 5 HP electrical submersible pump powered by a portable generator, which was set at a depth of 200 feet in well CPW96.1. Discharge pumped from the well was measured and recorded using a digital flow meter, and water levels were measured manually with a battery-powered level meter. Water levels in each observation well were digitally measured with a pressure transducer and recorded using a data-logger.

Aquifer pump test data were analyzed using conventional techniques including, log-log, semi-log, and distance drawdown methods developed by Theis, Jacob, and Cooper and Cooper and Jacob, respectively, using the Aquifer Test software package (Waterloo Hydrogeologic, Inc.). Data were analyzed to determine aquifer response to pumping and assess the hydraulic properties of the Chadron Sandstone.

The average pumping rate was determined to be 51.2 gallons per minute (gpm), and the drawdown of the pumping well (CPW96.1) was 65 feet. The drawdowns measured in the observation wells COW96.1, RC-4, A251/62 were 11.3 ft, 9.2 ft, and 4.5 ft, respectively. Average transmissivity (T) ranged from 300 to 350 ft^2/day. Average hydraulic conductivity (k) ranged from 8.9 to 10.3 ft/day, and average storativity ranged from 1.1×10^{-4} to 7.0×10^{-5}. Results of T, k, and storativity analyses are based on type-curve match points derived from late-time data during both pumping and recovery periods. No response to pumping or recovery period was observed in the well completed in the Brule Formation (BOW96.1). Minor fluctuations, however, in water level were observed in the Brule well, which may be attributed to barometric variations and changes in ambient temperature. The ROI was determined to be approximately 5,700 ft and to span the entire portion of the northern License Area.

Test results demonstrate the integrity of the confining layer above the mining zone and the homogeneity and isotropy of the Chadron Sandstone in the northern portion of the CBR License Area. Therefore, results confirm the integrity of the confining layer between the Chadron Sandstone and the Brule Formation.

Fourth Aquifer Test

A fourth aquifer test (Test #4) was performed in the areas of new mining development in the southeastern portion of the CBR License Area, Township 31 North, Range 52 West, between August 19, 2002 and August 25, 2002. The pump test endured 64.5 hours and recovery monitoring was completed between 22 and 26 August. Test #4 involved the installation of one new pumping well (CPW2002) at a depth of 740 ft and four new observation wells (COW2002, CM9-04, CM9-13 and CM9-14) at depths ranging from 740 to 840 ft in the Chadron Sandstone. Also, one new monitoring well (SM9-10) was installed in the Brule Formation at a depth of 250 ft.

Test #4 was performed using a 7.5 HP electrical submersible pump powered by a portable generator and set to an approximate depth of 440 ft in well CPW2002. Water levels in each well were measured using pressure transducers and recorded using data loggers for the duration of the test. The average pumping rate was 50.2 gpm. The drawdown in the pumping well at the end of the pumping period was 45.3 ft. Drawdown in the Chadron observation wells (CM9-04, CM9-13, CM9-14, and COW2002) were 4.9 ft, 5.8 ft, 5.2 ft, and 2.4 ft, respectively. No drawdown was observed in the Brule Formation observation well (SM9-10).

Similar to Test #3, aquifer pump data for Test #4 were analyzed using conventional techniques including, log-log, semi-log, and distance drawdown methods developed by Theis, Jacob, and Cooper and Cooper and Jacob, respectively, using the Aquifer Test software package (Waterloo Hydrogeologic, Inc.) and based on an average aquifer thickness of 40 ft. Analyses of T, k, and storativity are based on type-curve match points derived from middle-time data during both pumping and recovery periods. Assumptions made in the analyses included a constant flow rate in an infinite, homogeneous, and isotropic aquifer. ROI was determined based on distance-drawdown analysis of data from pumping well COW2002 and observation wells CM9-04, CM9-13, and CM9-14, as well as a minimum drawdown of 1.0 ft.

T values for the observation wells in the Chadron Sandstone ranged from 658 ft^2/day (CM9-14) to 1,261 ft^2/day (COW2002) and averaged 826 ft^2/day. Hydraulic conductivity (k) values ranged from 16.4 ft/day (CM9-14) to 31.5 ft/day (COW2002) and averaged 20.6 ft/day. Storativity values ranged from 4.8×10^{-5} to 8.2×10^{-5}. Distance-drawdown analysis of observation well data produced a T value of 747 ft^2/day and a storativity of 8.1×10^{-5}. No significant response to pumping or recovery period was observed in the Brule Formation observation well. The ROI was found to be approximately 5,500 ft and to encompass the entire southern portion of the License Area.

Analysis of pumping well COW2002 data produced the highest T and k values. Storativity values imply a highly confined aquifer. Minor water level fluctuations observed in the wells during the test may be attributed to mining operations occurring in Mine Units 5 and 7 as well as barometric effects.

Results

Table 2.7-7 summarizes the results of the four aquifer tests performed at the CBR in-situ uranium mine site between 1982 and 2002. Duration of the four pump tests ranged from 51 to 72 hours and averaged 61 hours. Test pumping rates ranged from about 24 to 51 gpm and averaged 43 gpm. Minimum transmissivity was 330 ft^2/day (Test #2) and maximum transmissivity was 836 ft^2/day (Test #4). Average transmissivity was 479 ft^2/day. Hydraulic Conductivities ranged from 9.0 ft/day to 20.6 ft/day and averaged 12.13 ft/day. Average storativity was calculated to be 8.8 x 10^{-5} and ranged from 9.0 x 10^{-5} to 1.0 x 10^{-4}. Average ROI was 5,050 ft and ranged from 4,000 (Test #1) to 5,700 ft (Test #3).

Table 2.7-7: Summary of Aquifer Pumping Tests Performed within the CBR License Area

Test Number	1	2	3	4	Arithmetic Average
Date Conducted (month, year)	November, 1982	June, 1987	September, 1996	August, 2002	
Test Duration (hours)	51	72	55	64.5	61
Pumping Rate (gpm)	23.8	47.2	51.2	50.2	43.1
Transmissivity (ft^2/day)	400	360	330	826	479
Hydraulic Conductivity (ft/day)	9.0	9.1	9.8	20.6	12.13
Storativity	1.0 X 10^{-4}	1.0 X 10^{-4}	9.0 X 10^{-5}	6.2 X 10^{-5}	8.8 X 10^{-5}
Radius of Influence (ft)	4000	5000	5700	5500	5050

Analysis of Results

The increase in transmissivity from Test #1 to Test #4 is expected as average aquifer thickness is about 33 ft in the northern License Area and 45 ft in the southern License Area. Tests #1 and #2 characterized the aquifer as anisotropic to slightly anisotropic, whereas Tests #3 and #4 characterized the aquifer as isotropic. The differences in isotropy may be attributed to more variability in hydraulic conductivities in the central portion of the License Area (sites of Test #1 and #2) compared to the northern (site of Test #3) and southern portions (site of Test #4) of the License Area. Higher k values found in Test #4 may indicate that higher quality sand is found in the southern portion of the License Area compared to the northern portions of the property. Even though the k value was determined to be higher for Test #4 than the other tests, they are all the same order of magnitude, which indicate a homogeneous aquifer. Low storativity values from all tests indicate a confined aquifer. Decreasing storativity values from north to south within the License Area may imply a more deeply confined aquifer in the south. Test results also indicated a non-leaky aquifer.

Conclusions

In general, pump test results indicate that the Chadron Sandstone is relatively homogeneous within the CBR License Area. Results demonstrate the integrity of the confining layer above the mining zone throughout the CBR License Area. Due to the stability of the confining layer above the mining zone, it is likely that the mining development at the site will not significantly impact the aquifer.

2.7.3 Surface Water and Groundwater Quality

Historical surface water quality data for the White River (assembled by USEPA) and historical groundwater quality data from the CSA for the Brule Alluvium, Brule Formation, and Basal Chadron Formation are presented in **Section 6**.

Monitoring was conducted to establish baseline groundwater quality conditions in the License Area. The program was conducted in 1996 and 1997, and includes samples from a Basal Chadron well (Well 81) and Brule well (Well 78) in the License Area. The radiological results of baseline sampling for these wells and a detailed analysis are included in **Section 6**. These data establish the groundwater conditions associated with the mineralized Basal Chadron sandstone and Brule in the CSA at a location immediately outside and northeast of the License Area.

Table 2.7-8 through **Table 2.7-17** are the Baseline and Restoration Values for Mine Units 1 through 5 in the CSA area. The License Area ore body is considered a zone of distinct water quality characteristics primarily due to the presence of relatively concentrated uranium and radium in the zone when compared to the concentration of these parameters outside of the zone.

Table 2.7-8: Baseline and Restoration Values for Mine Unit 1

Parameter	Groundwater Standard	MU-1 Baseline	MU-1 Standard Deviation	MU-1 NDEQ Restoration Value
Ammonium (mg/L)	10.0	<0.372		10.0
Arsenic (mg/L)	0.05	<0.00214		0.05
Barium (mg/L)	1.0	<0.1		1.0
Cadmium (mg/L)[1]	0.01	<0.00644		0.005[1]
Chloride (mg/L)	250.0	203.9	38	250.0
Copper (mg/L)	1.0	<0.017		1.0
Fluoride (mg/L)	4.0	0.686	0.04	4.0
Iron (mg/L)	0.3	<0.0441		0.3
Mercury (mg/L)	0.002	<0.001		0.002
Manganese (mg/L)	0.05	<0.011		0.05
Molybdenum (mg/L)	1.0	<0.0689		1.0
Nickel (mg/L)	0.15	<0.0340		0.15
Nitrate (mg/L)	10.0	<0.050		10.0
Lead (mg/L)	0.05	0.0315		0.05
Radium (pCi/L)	5.0	229.7	177.1	584.0
Selenium (mg/L)	0.01	<0.00323		0.05
Sodium (mg/L)	N/A	412	19.2	4120
Sulfate (mg/L)	250.0	356.2	9.4	375
Uranium (mg/L)	5.0	0.0922	0.089	5.0
Vanadium (mg/L)	0.2	<0.0663		0.2
Zinc (mg/L)	5.0	<0.036		5.0
pH (Std. Units)	6.5 - 8.5	8.46	0.2	6.5 – 8.5
Calcium (mg/L)	N/A	12.5	3.2	125.0
Total Carbonate (mg/L)	N/A	351	31.1	585
Potassium (mg/L)	N/A	12.5	1.5	125.0
Magnesium (mg/L)	N/A	3.2	0.8	32.0
TDS (mg/L)	N/A	1170.2	47.6	1170.2

[1] Standard for Cadmium lowered in modification to UIC permit dated March 9, 2001 following NDEQ approval of Mine Unit 1 restoration.

Table 2.7-9: Baseline and Restoration Values for Mine Unit 2

Parameter	Groundwater Standard	MU-2 Baseline	MU-2 Standard Deviation	MU-2 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.37	0.07	10.0
Arsenic (mg/L)	0.05	<0.001		0.05
Barium (mg/L)	1.0	<0.1		1.0
Cadmium (mg/L)	0.005	<0.007		0.005
Chloride (mg/L)	250.0	208.6	30.8	250.0
Copper (mg/L)	1.0	<0.013		1.0
Fluoride (mg/L)	4.0	0.67	0.04	4.0
Iron (mg/L)	0.3	<0.045		0.3
Mercury (mg/L)	0.002	<0.001		0.002
Manganese (mg/L)	0.05	<0.01		0.05
Molybdenum (mg/L)	1.0	<0.073		1.0
Nickel (mg/L)	0.15	<0.037		0.15
Nitrate (mg/L)	10.0	<0.039		10.0
Lead (mg/L)	0.05	<0.035		0.05
Radium (pCi/L)	5.0	234.5	411.8	1058.0
Selenium (mg/L)	0.05	<0.001		0.05
Sodium (mg/L)	N/A	410.8	18.2	4108
Sulfate (mg/L)	250.0	348.2	10.3	369.0
Uranium (mg/L)	5.0	0.046	0.037	5.0
Vanadium (mg/L)	0.2	<0.07		0.2
Zinc (mg/L)	5.0	<0.026		5.0
pH (Std. Units)	6.5 - 8.5	8.32	0.2	6.5 – 8.5
Calcium (mg/L)	N/A	13.4	2.4	134.0
Total Carbonate (mg/L)	N/A	366.9	13.3	585.0
Potassium (mg/L)	N/A	12.6	2.5	126.0
Magnesium (mg/L)	N/A	3.5	0.4	35.0
TDS (mg/L)	N/A	1170.4	41	1170.4

Table 2.7-10: Baseline and Restoration Values for Mine Unit 3

Parameter	Groundwater Standard	MU-3 Baseline	MU-3 Standard Deviation	MU-3 NDEQ Restoration Value
Ammonium (mg/L)	10.0	<0.329		10.0
Arsenic (mg/L)	0.05	<0.001		0.05
Barium (mg/L)	1.0	<0.1		1.0
Cadmium (mg/L)	0.005	<0.01		0.005
Chloride (mg/L)	250.0	197.6	16.7	250.0
Copper (mg/L)	1.0	<0.0108		1.0
Fluoride (mg/L)	4.0	0.719	0.05	4.0
Iron (mg/L)	0.3	<0.05		0.3
Mercury (mg/L)	0.002	<0.001		0.002
Manganese (mg/L)	0.05	<0.01		0.05
Molybdenum (mg/L)	1.0	<0.1		1.0
Nickel (mg/L)	0.15	<0.05		0.15
Nitrate (mg/L)	10.0	<0.0728		10.0
Lead (mg/L)	0.05	<0.05		0.05
Radium (pCi/L)	5.0	165	222.5	611.0
Selenium (mg/L)	0.05	<0.00115		0.05
Sodium (mg/L)	N/A	428	27.6	4280
Sulfate (mg/L)	250.0	377.0	13.4	404.0
Uranium (mg/L)	5.0	0.115	0.158	5.0
Vanadium (mg/L)	0.2	<0.1		0.2
Zinc (mg/L)	5.0	<0.0131		5.0
pH (Std. Units)	6.5 - 8.5	8.37	0.3	6.5 – 8.5
Calcium (mg/L)	N/A	13.3	3.1	133.0
Total Carbonate (mg/L)	N/A	358.7	24.8	592.0
Potassium (mg/L)	N/A	13.9	4.0	139.0
Magnesium (mg/L)	N/A	3.5	0.9	35.0
TDS (mg/L)	N/A	1183.0	47.4	1183.0

Table 2.7-11: Baseline and Restoration Values for Mine Unit 4

Parameter	Groundwater Standard	MU-4 Baseline	MU-4 Standard Deviation	MU-4 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.288	0.08	10.0
Arsenic (mg/L)	0.05	<0.00209		0.05
Barium (mg/L)	1.0	<0.1		1.0
Cadmium (mg/L)	0.005	<0.01		0.005
Chloride (mg/L)	250.0	217.5	34.9	250.0
Copper (mg/L)	1.0	<0.0114		1.0
Fluoride (mg/L)	4.0	0.745	0.05	4.0
Iron (mg/L)	0.3	<0.0504		0.3
Mercury (mg/L)	0.002	<0.001		0.002
Manganese (mg/L)	0.05	<0.01		0.05
Molybdenum (mg/L)	1.0	<0.1		1.0
Nickel (mg/L)	0.15	<0.05		0.15
Nitrate (mg/L)	10.0	<0.114		10.0
Lead (mg/L)	0.05	<0.05		0.05
Radium (pCi/L)	5.0	154.3	171.5	496.0
Selenium (mg/L)	0.05	<0.00244		0.05
Sodium (mg/L)	N/A	416.6	27.8	4166
Sulfate (mg/L)	250.0	337.2	19.3	375.0
Uranium (mg/L)	5.0	<0.122		5.0
Vanadium (mg/L)	0.2	<0.0984		0.2
Zinc (mg/L)	5.0	<0.0143		5.0
pH (Std. Units)	6.5 - 8.5	8.68	0.3	6.5 – 9.28
Calcium (mg/L)	N/A	11.2	2.9	112.0
Total Carbonate (mg/L)	N/A	374.4	28	610.0
Potassium (mg/L)	N/A	16.7	4.7	167.0
Magnesium (mg/L)	N/A	2.8	0.8	28.0
TDS (mg/L)	N/A	1221.1	73.5	1221.1

Table 2.7-12: Baseline and Restoration Values for Mine Unit 5

Parameter	Groundwater Standard	MU-5 Baseline	MU-5 Standard Deviation	MU-5 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.28	0.05	10.0
Arsenic (mg/L)	0.05	<0.001		0.05
Barium (mg/L)	1.0	<0.10		1.0
Cadmium (mg/L)	0.005	<0.01		0.005
Chloride (mg/L)	250.0	191.9	7.9	250.0
Copper (mg/L)	1.0	<0.01		1.0
Fluoride (mg/L)	4.0	0.64	0.07	4.0
Iron (mg/L)	0.3	<0.05		0.3
Mercury (mg/L)	0.002	<0.001		0.002
Manganese (mg/L)	0.05	<0.01		0.05
Molybdenum (mg/L)	1.0	<0.10		1.0
Nickel (mg/L)	0.15	<0.05		0.15
Nitrate (mg/L)	10.0	<0.1		10.0
Lead (mg/L)	0.05	<0.05		0.05
Radium (pCi/L)	5.0	166.0	184.6	535.0
Selenium (mg/L)	0.05	<0.002		0.05
Sodium (mg/L)	N/A	397.6	14.4	3976
Sulfate (mg/L)	250.0	364.5	10.5	385.0
Uranium (mg/L)	5.0	0.072	0.056	5.0
Vanadium (mg/L)	0.2	<0.10		0.2
Zinc (mg/L)	5.0	<0.02		5.0
pH (Std. Units)	6.5 - 8.5	8.5	0.1	6.5 – 8.5
Calcium (mg/L)	N/A	12.6	1.8	126.0
Total Carbonate (mg/L)	N/A	372	13.0	590.0
Potassium (mg/L)	N/A	11.5	1.2	115.0
Magnesium (mg/L)	N/A	3.4	0.4	34.0
TDS (mg/L)	N/A	1179.5	22.5	1202.0

Table 2.7-13: Baseline and Restoration Values for Mine Unit 6

Parameter	Groundwater Standard	MU-6 Baseline	MU-6 Standard Deviation	MU-6 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.32	0.05	10.0
Arsenic (mg/L)	0.05	0.002		0.05
Barium (mg/L)	1.0	0.100		1.0
Cadmium (mg/L)	0.005	0.009		0.005
Chloride (mg/L)	250.0	206	15.4	250.0
Copper (mg/L)	1.0	0.012		1.0
Fluoride (mg/L)	4.0	0.65	0.03	4.0
Iron (mg/L)	0.3	0.050		0.3
Mercury (mg/L)	0.002	0.001		0.002
Manganese (mg/L)	0.05	0.010		0.05
Molybdenum (mg/L)	1.0	0.102		1.0
Nickel (mg/L)	0.15	0.050		0.15
Nitrate (mg/L)	10.0	0.1		10.0
Lead (mg/L)	0.05	0.050		0.05
Radium (pCi/L)	5.0	80.6	121.9	325
Selenium (mg/L)	0.05	0.001		0.05
Sodium (mg/L)	N/A	400	12.8	4000
Sulfate (mg/L)	250.0	361	14.6	390
Uranium (mg/L)	5.0	0.133	0.212	5.0
Vanadium (mg/L)	0.2	0.098		0.2
Zinc (mg/L)	5.0	0.011		5.0
pH (Std. Units)	6.5 - 8.5	8.6	0.2	6.5 – 9.0
Calcium (mg/L)	N/A	12.8	2.3	128
Total Carbonate (mg/L)	N/A	367.1	22.9	596
Potassium (mg/L)	N/A	11.9	1.7	119
Magnesium (mg/L)	N/A	3.2	0.7	32
TDS (mg/L)	N/A	1192	28.1	1220

Table 2.7-14: Baseline and Restoration Values for Mine Unit 7

Parameter	Groundwater Standard	MU-7 Baseline	MU-7 Standard Deviation	MU-7 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.42	0.08	10.0
Arsenic (mg/L)	0.05	0.001		0.05
Barium (mg/L)	1.0	0.10		1.0
Cadmium (mg/L)	0.005	0.007		0.005
Chloride (mg/L)	250.0	198	22.6	250.0
Copper (mg/L)	1.0	0.01		1.0
Fluoride (mg/L)	4.0	0.70	0.05	4.0
Iron (mg/L)	0.30	0.05		0.30
Mercury (mg/L)	0.002	0.001		0.002
Manganese (mg/L)	0.05	0.01		0.05
Molybdenum (mg/L)	1.00	0.10		1.00
Nickel (mg/L)	0.15	0.05		0.15
Nitrate (mg/L)	10.0	0.1		10.0
Lead (mg/L)	0.05	0.05		0.05
Radium (pCi/L)	5.0	142	148.0	438
Selenium (mg/L)	0.05	0.004		0.05
Sodium (mg/L)	N/A	387	21.6	3,870
Sulfate (mg/L)	250.0	346	20.1	386
Uranium (mg/L)	5.0	0.110	0.138	5.0
Vanadium (mg/L)	0.2	0.10		0.2
Zinc (mg/L)	5.0	0.01		5.0
pH (Std. Units)	6.5 - 8.5	8.6	0.3	6.5 – 9.2
Calcium (mg/L)	N/A	12.2	2.6	122
Total Carbonate (mg/L)	N/A	356		588
Potassium (mg/L)	N/A	12.9	3.0	129
Magnesium (mg/L)	N/A	3.2	0.7	32
TDS (mg/L)	N/A	1,176	40.7	1,217

Table 2.7-15: Baseline and Restoration Values for Mine Unit 8

Parameter	Groundwater Standard	MU-8 Baseline	MU-8 Standard Deviation	MU-8 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.682	0.222	10.0
Arsenic (mg/L)	0.05	0.002	0.001	0.05
Barium (mg/L)	1.0	0.099	0.005	1.0
Cadmium (mg/L)	0.005	0.005		0.005
Chloride (mg/L)	250	196	53.8	250
Copper (mg/L)	1.0	0.01		1.0
Fluoride (mg/L)	4.0	0.638	0.048	4.0
Iron (mg/L)	0.30	0.135	0.086	0.30
Mercury (mg/L)	0.002	0.001		0.002
Manganese (mg/L)	0.05	0.01		0.05
Molybdenum (mg/L)	1.0	0.093	0.023	1.00
Nickel (mg/L)	0.15	0.049	0.003	0.15
Nitrate (mg/L)	10.0	0.2		10.0
Lead (mg/L)	0.05	0.049	0.003	0.05
Radium (pCi/L)	5.0	124.4	151.8	428
Selenium (mg/L)	0.05	0.004		0.05
Sodium (mg/L)	N/A	416.8	41.8	4,168
Sulfate (mg/L)	250	312	33	378
Uranium (mg/L)	5.0	0.188	0.140	5.0
Vanadium (mg/L)	0.2	0.127	0.122	0.2
Zinc (mg/L)	5.0	0.013	0.008	5.0
pH (Std. Units)	6.5 - 8.5	8.67	0.37	6.5 – 9.41
Calcium (mg/L)	N/A	12.3	3.5	123
Total Carbonate (mg/L)	N/A	377	15.6	569
Potassium (mg/L)	N/A	11.8	3.2	117.8
Magnesium (mg/L)	N/A	2.7	0.92	27.1
TDS (mg/L)	N/A	1,137	97.4	1,234

Table 2.7-16: Baseline and Restoration Values for Mine Unit 9

Parameter	Groundwater Standard	MU-9 Baseline	MU-9 Standard Deviation	MU-9 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.40	0.05	10.0
Arsenic (mg/L)	0.05	0.001	0.000	0.05
Barium (mg/L)	1.0	0.1	0.0	1.0
Cadmium (mg/L)	0.005	0.005	0.000	0.005
Chloride (mg/L)	250	203	13	250
Copper (mg/L)	1.0	0.01	0.00	1.0
Fluoride (mg/L)	4.0	0.8	0.0	4.0
Iron (mg/L)	0.3	0.04	0.01	0.3
Mercury (mg/L)	0.002	0.001	0.000	0.002
Manganese (mg/L)	0.05	0.01	0.00	0.05
Molybdenum (mg/L)	1.0	0.1	0.0	1.0
Nickel (mg/L)	0.15	0.05	0.00	0.15
Nitrate (mg/L)	10.0	0.06	0.01	10.0
Lead (mg/L)	0.05	0.05	0.00	0.05
Radium (pCi/L)	5.0	164	238	640
Selenium (mg/L)	0.05	0.003	0.001	0.05
Sodium (mg/L)	N/A	380	11	3,800
Sulfate (mg/L)	250	320	15	350
Uranium (mg/L)	5.0	0.1	0.24	5.0
Vanadium (mg/L)	0.2	0.1	0.0	0.2
Zinc (mg/L)	5.0	0.01	0.00	5.0
pH (Std. Units)	6.5 - 8.5	8.35	0.30	6.5 – 9.41
Calcium (mg/L)	N/A	13.6	4.6	136
Total Carbonate (mg/L)	N/A	383	14	595
Potassium (mg/L)	N/A	13.9	3.0	139
Magnesium (mg/L)	N/A	3.5	1.2	35.0
TDS (mg/L)	N/A	1,152	38	1,190

Table 2.7-17: Baseline Well Restoration Table Mine Unit 10

Parameter	Groundwater Standard	MU-10 Baseline	MU-10 Standard Deviation	MU-10 NDEQ Restoration Value
Ammonia (NH_4 as N) (mg/L)	10.0	0.34	0.07	10.0
Arsenic (As) (mg/L)	0.010	0.001	0.001	0.010
Barium (Ba) (mg/L)	2.0	0.1	0.00	2.0
Cadmium (Cd) (mg/L)	0.005	0.005	0.000	0.005
Calcium (Ca) (mg/L)	---	11.8	2.6	118.0
Chloride (Cl) (mg/L)	250	185	14	250
Copper (Cu) (mg/L)	1.3	0.01	0.01	1.3
Fluoride (F) (mg/L)	4.0	0.72	0.10	4.0
Iron (Fe) (mg/L)	0.3	0.03	0.01	0.3
Lead (Pb) (mg/L)	0.015	0.001	0.0	0.015
Magnesium (Mg) (mg/L)	---	3.4	0.7	34.0
Managanese (Mn) (mg/L)	0.05	0.01	0.0	0.05
Mercury (Hg) (mg/L)	0.002	0.001	0.0	0.002
Molybdenum (Mo) (mg/L)	1.0	0.1	0.0	1.0
Nickel (Ni) (mg/L)	0.15	0.05	0.0	0.15
Nitrite + Nitrate as N ($NO_3 + NO_2$)[1] (mg/L)	10.0	0.1	0.0	10.0
pH (Std. Units)	6.5 - 8.5	8.51	0.19	6.5 - 8.89
Potassium (K) (mg/L)	---	10.1	1.6	101
Radium-226 (mg/L)	5.0	87.3	161.0	409.3
Selenium (Se) (mg/L)	0.05	0.003	0.002	0.05
Sodium (Na) (mg/L)	---	388	12	3880
Sulfate (SO4) (mg/L)	250.0	329	25	379
Total Carbonate ($CO_3 + HCO_3$)[2] (mg/L)	---	394	15	550.5
Total Dissolved Solids (mg/L)	---	1101	26	1127
Uranium (U) (mg/L)	0.03	0.0378	0.0351	0.108
Vanadium (V) (mg/L)	0.2	0.1	0.0	0.2
Zinc (Zn) (mg/L)	5.0	0.01	0.01	5.0

1 Nitrate was reported by the lab as $NO_3 + NO_2$ instead of NO_3 as required in the permit. However, only two samples, well 4024 collected 6/09/06 and well CM8-6 collected 5/02/02, were above the detection limits. The restoration value is 10.0 mg/L while the average is 0.1 mg/L. Therefore, including NO_2 has no bearing on determining the restoration value. Nitrite, NO_2, was also analyzed for and all samples were below the detection limit of 0.10 mg/L.

2 Total carbonate = alkalinity as $CaCO_3$ x 1.2

Standard formulas were used to calculate the average and standard deviation but the true values, especially for the standard deviation, are most likely significantly smaller than shown. This results in a conservative estimate of the standard deviation.

--- no NDEQ standard

Available groundwater data for both the Brule and Chadron do not indicate that there are any documented flow rate variations or recharge issues that would impact groundwater quality. There are no surface water ponds within the area, and only limited stream flow (**Section 2.7.1**). The Brule, while considered an overlying aquifer, is not an extensive or exceptionally productive system. The available monitoring data do not indicate any seasonality or pumping effects by domestic wells within this zone. With respect to the Basal Chadron sandstone, there are no domestic wells completed within this interval in the immediate License Area, and there is no information to indicate that there are recharge or flow rate issues associated with the Basal Chadron sandstone that would affect groundwater quality.

During the course of mining, the water quality is expected to change as outlined in **Table 2.7-18.** The chemicals used in the mining and recovery process will include sodium bicarbonate, an oxidizer (such as oxygen), carbon dioxide, and chloride for elution. As a result, the greatest changes in water quality are expected to be in alkalinity, bicarbonate, chloride, sodium, conductivity, and TDS. Significant increases are also likely to occur in calcium concentrations as a result of ion exchange with clays. The oxidant will cause significant increases in uranium, vanadium, and radium and minor increases in trace metals such as copper, arsenic, molybdenum, and selenium. Historic restoration activities at the CSA have demonstrated the ability to successfully restore groundwater to established restoration standards.

Table 2.7-18: Changes in Water Quality during Mining

Average Ore Zone Water Quality			
Analyte	**Units**	**MU 1-10 Pre-Mining Average**	**Typical Water Quality During Mining at CSA**
Total Carbonate ($HCO_3 + CO_3$)	mg/L	370	1,920
Calcium	mg/L	12.6	77
Chloride	mg/L	201	600
Fluoride	mg/L	0.697	0.6
Magnesium	mg/L	3.2	23
Ammonia as N	mg/L	0.38	<0.05
Nitrate+Nitrite as N	mg/L	0.094	0.46
Potassium	mg/L	12.8	35
Sodium	mg/L	404	1,310
Sulfate	mg/L	345	900
pH	s.u.	8.51	7.8
TDS	mg/L	1,168	4,080
Arsenic	mg/L	0.001	0.06
Barium	mg/L	0.10	<0.1
Cadmium	mg/L	0.007	<0.005
Copper	mg/L	0.011	0.04
Iron	mg/L	0.054	<0.030
Lead	mg/L	0.042	<0.05
Manganese	mg/L	0.01	0.05

Table 2.7-18: Changes in Water Quality during Mining

Average Ore Zone Water Quality			
Analyte	**Units**	**MU 1-10 Pre-Mining Average**	**Typical Water Quality During Mining at CSA**
Mercury	mg/L	0.001	<0.001
Molybdenum	mg/L	0.094	0.5
Nickel	mg/L	0.047	<0.05
Selenium	mg/L	0.002	0.07
Uranium	mg/L	0.102	44
Vanadium	mg/L	0.096	2.5
Zinc	mg/L	0.016	0.02
Radium 226	pCi/L	155	1,090

2.7.4 References

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2.8 ECOLOGICAL RESOURCES

2.8.1 Introduction

During 1982, an ecological study was performed specifically for the Crow Butte Project. Data was collected to fulfill the objectives specified in USNRC's permit application guide (USNRC 1982). A review and update to the original study was conducted in 1987, 1995, and 1997.

There have been no documented changes to ecological resources within the License Area since the 1997 LRA. The original analysis consisted of a review of documents, databases, and reports in conjunction with a biological reconnaissance field survey to determine the potential impacts, if any, to the habitats for special-status plant and wildlife species in the License Area. Agency coordination included telephone and written correspondence among Greystone (now ARCADIS) biologists, U.S. Fish and Wildlife Service (USFWS), and Nebraska Game and Parks Commission (NGPC) management and staff. This coordination is ongoing. The purpose of these consultations and associated correspondence was to help identify biological issues and potential occurrences and distribution of special-status plants, wildlife, and their habitats.

2.8.2 Regional Setting

The License Area occurs at the confluence of two Nebraska ecoregions – the Western High Plains and the Northwestern Great Plains (Chapman et al. 2001). The transition from Central Great Plains in the eastern part of the state to Western High Plains westward is primarily a factor of the reduction in effective precipitation associated with the Western High Plains. There is a general conformity in the composition of the plant cover, as many species are common to both ecoregions. Physiographically, this area comprises smooth to slightly irregular plains that support native communities, croplands or grazing.

The Western High Plains ecoregion is characterized by a semi-arid to arid climate, with annual precipitation ranging between 13 to 20 inches. Higher and drier than the Central Great Plains to the east, much of the Western High Plains comprises a smooth to slightly irregular plain with a high percentage of dryland agriculture. Natural vegetation is dominated by drought-tolerant, short-grass prairie and large areas of mixed-grass prairie in the northwest portion of the state.

The Northwestern Great Plains ecoregion encompasses the Missouri Plateau portion of the Great Plains. It is a semi-arid rolling plain of shale and sandstone punctuated by occasional buttes. Native grasslands persist in areas of steep or broken topography, but they have been largely replaced by spring wheat and alfalfa over most of this ecoregion. Agriculture exists on level to rolling hills and is generally limited by erratic precipitation patterns and limited opportunities for irrigation.

Nearly 470 plant species are described in the Chadron State College herbarium contains for Dawes County (WFC 1983). The Institute of Agriculture and Natural Resources lists

603 native and 123 introduced species that occur in Dawes County. During the 1982 baseline study, more than 400 species of plants were collected (WFC 1983).

2.8.3 Local Setting - License Area

The License Area is located in west-central Dawes County, Nebraska, just southeast of Crawford. The License Area is located within portions of Sections 11, 12, 13, and 24 of Township 31 North, Range 52 West and Sections 18, 19, 20, 29, and 30 of Township 31 North, Range 51 West. **Figure 1.3-1** shows the general location of the current License Area.

2.8.4 Climate

The climate of the region is characterized by wide seasonal and day-to-day variations in temperature and precipitation. Dawes County is usually warm in the summer, with frequent spells of hot weather and occasional cool days interspersed, although sporadically, throughout the summer. These changes in weather can generate thunderstorms, which deliver a majority of the total annual precipitation. Annual average minimum and maximum temperatures are 34°F and 62°F, respectively, with a mean monthly average of 48°F (High Plains Regional Climate Center [HPRCC] 2004). Average total precipitation is 16.07 inches (HPRCC 2004). Precipitation occurs throughout the year, with yearly averages ranging from a low of 0.41 inches in December to a high of 2.96 inches in May (HPRCC 2004). Winter precipitation is typically relegated to storms with snow and the occasional blizzard. In this portion of Nebraska, the average annual seasonal snowfall is approximately 42 inches (HPRCC 2004).

2.8.5 Baseline Data

An ecological study was performed for a commercial CBR Uranium Project application in 1982 (Radioactive Source Materials License SUA-1534). Baseline flora and fauna data were collected to fulfill the objectives specified in USNRC Regulatory Guide 3.46, *Standard Format and Content of License Applications, Including Environmental Reports, For In Situ Uranium Solution Mining*. The 1982 baseline study focused on conducting intensive research within the principal License Area, which included both the commercial License Area and the five-mile adjacent area, and less intensive research within the 50-mile outer area. Additional baseline data was collected within the three areas in 1987, 1995, 1996, and 1997.

For more detailed descriptions of the data, please refer to the *Crow Butte Uranium Project Application and Supporting Environmental Report for USNRC Research and Development Source Material License* (WFC 1983) or the *Crow Butte Uranium Project Application and Supporting Environmental Report for USNRC Commercial Source Material License* (FEN, 1987).

2.8.6 Terrestrial Ecology

The information presented in this section summarizes the findings of the ecological baseline studies conducted in support of the Crow Butte project in 1982, 1987, 1995, 1996, and 1997.

A one-year ecological baseline study was initiated in January 1982. The principal study area **Figure 2.8-1** includes both the Commercial Study Area (CSA) and the Adjacent Area (AA). Intensive studies were conducted on the CSA. Comparable but less intense studies were conducted within the 8 km (5 mi) AA, to assess the ecological importance of the CSA in relation to the adjacent environments. Additional investigations were conducted within an 80-km (50 mi) Outer Area (OA) centered on Section 19, drawing primarily upon published sources of information.

2.8.6.1 Methods

Methods of investigation were chosen to describe the principal floral and faunal species of the area. Whenever possible, methods were used that would provide continuity and compatibility with ongoing investigations in the state and the region.

Plant collections were conducted throughout the growing season to prepare a comprehensive voucher of plant species within the study area. Vegetation communities mapping was completed at a scale of 1:12,000 for the CSA, and 1:24,000 for the AA. Vegetation/Habitat types were chosen according to the system developed by the Montana Agriculture Experiment Station (Coenenberg et al. 1977), modified to conform to the ecological characteristics of the Crow Butte area. The system was deemed appropriate to describe floristic characteristics and to describe wildlife habitat affinities.

General observation was used to generate a species list for the study area and to obtain information on faunal distribution. In addition to routine sightings, time was devoted specifically for 1) aircraft raptor nest surveys, 2) aircraft big game surveys, 3) movement and migration route delineation, 4) game bird winter concentrations, 5) game bird brood counts, 6) grouse strutting ground "lek" surveys, 7) waterfowl breeding pair counts, 8) waterfowl brood surveys and production counts, 9) prairie dog colony surveys, 10) small mammal trapping, 11) carnivore spotlight surveys, and 11) reptile and amphibian surveys. Refer to WFC (1983) for detailed descriptions of these methodologies.

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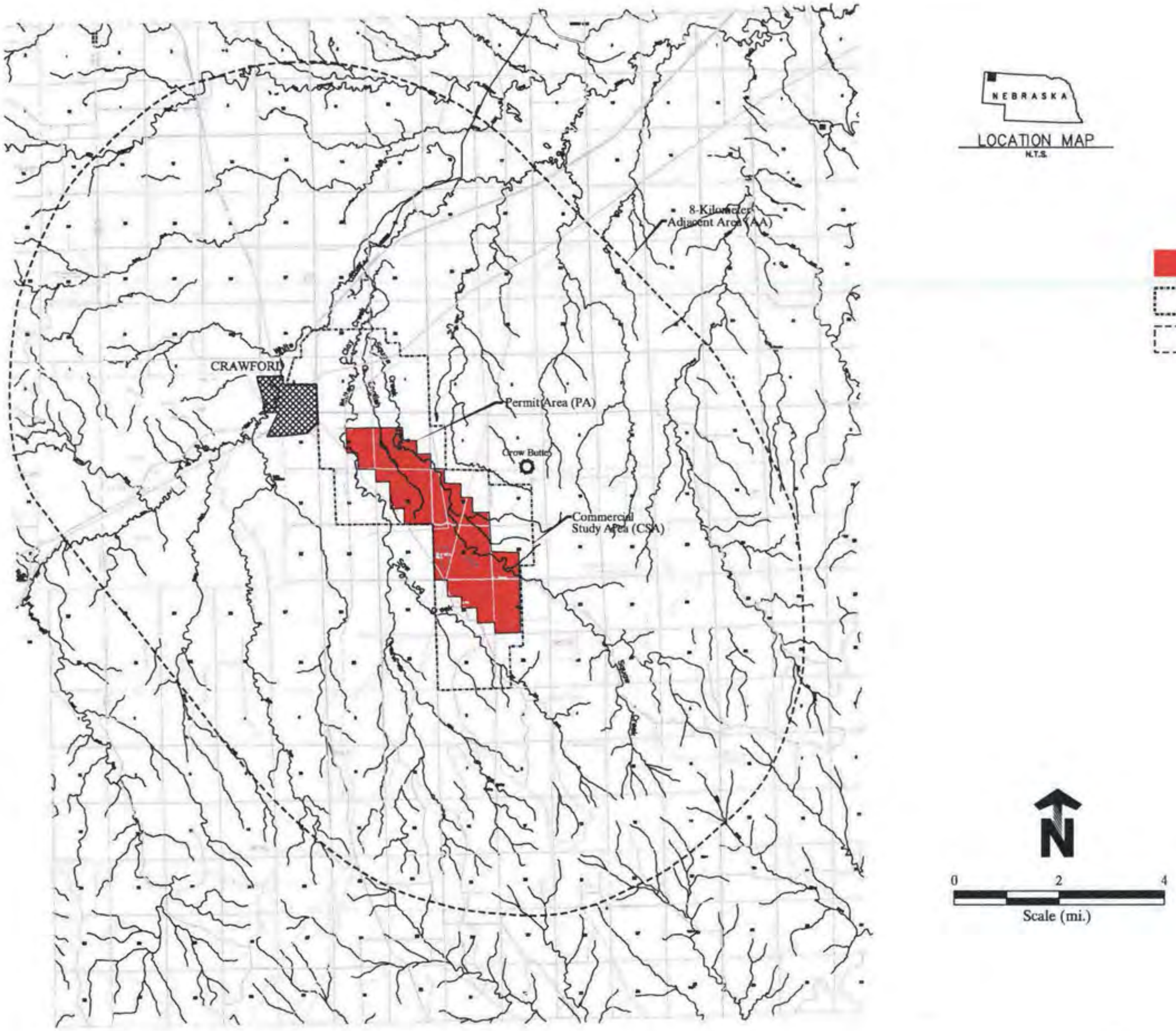

GREYSTONE®

ECOLOGICAL STUDY AREA

CROW BUTTE PROJECT
Dawes County, Nebraska

Scale: 1"=2 miles	Date: 10/95	Figure 2.8-1

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2.8.6.2 Existing Disturbance

The agricultural value of the two ecoregions has tremendously impacted mixed-grass prairie grasslands and the resulting landscape has been substantially altered since settlement in the late 1800s. Economic incentives to convert natural landscapes to agriculture have been intensive and resulted in the loss of significant areas of mixed-grass prairie grassland. Agriculture, intensive grazing, haying, sand and gravel mining, road and railroad construction, and rural and urban development are the primary sources of surface disturbance to native vegetation communities.

2.8.6.3 Vegetation

Study Area General Vegetation Description

The Pine Ridge area of Nebraska, as with the adjacent Black Hills of South Dakota, is represented by two principal vegetation regions (Van Bruggen 1977). These are described briefly below:

- **Plains and Prairie Flora** - The main features that describe this vegetation region are a dominance of grasses, absence of trees, rolling topography, and a characteristic xerophytic flora. Species occurring on the study area include big bluestem, little bluestem, Canada wild rye, Kentucky bluegrass, sage, purple cornflower, breadrood scurf pea, golden rod and related species.
- **Rocky Mountain Forest Flora (Black Hills Montane Element)** - Although geographically separated from the Rocky Mountains, the Pine Ridge and Black Hills have affinities to this region, which lies principally 200 km to the west. Floral species suggest that the two areas were contiguous during Pleistocene times. Species on the study area typical of this region include Oregon grape, Rocky Mountain juniper, ponderosa pine and Mariposa lily.

Many non-native plant species occur in the study area. The 1982 study estimated that 30 percent of species and more than 50 percent of plant cover consists of non-native plant species that are conspicuously successful and include smooth brome, cheatgrass, white sweetclover, yellow sweetclover and several Brassicaciae, including the species tumble mustard, tansy mustard, pennycress charlock, and Shephard's purse. Cultivated species include wheat, oats, rye, corn, milo and alfalfa.

Plants

According to the Great Plains Flora Association (1977), about 1,020 species of plants should be expected to occur within 80-km of the CSA. During the baseline study between March and Mid-July, 1982, more than 400 species of plant were collected within the study area (CSA and AA). Of that number, 163 species were recorded within a specific Section 19 study (**Table 2.8-1**).

Table 2.8-1: Plant Species List

Scientific Name	Common Name
EQUISETACEAE	
Equisetum laevigatum	Smooth horsetail
PINACEAE	
Pinus ponderosa	Ponderosa pine
RANUNCULACEAE	
Anemone patens	Pasque-flower
Clematis ligusticifolia	Western clematis
Ranunculus abortivus	Early wood buttercup
Thalictrum dasycarpum	Purple meadowrue
PAPAVERACEAE	
Argemone polyanthemos	Prickle poppy
FUMARIACEAE	
Corydalis aurea	Golden corydalis
ULMACEAE	
Ulmus americana	American elm
Ulmus pumila	Siberian elm
CANNABACEAE	
Humulus lupulus	Common hop
URTICACEAE	
Urtica dioica	Stinging nettle
CACTACEAE	
Coryphantha vivipara	Pincushion cactus
Opuntia fragilis	Brittle prickly pear
CARYOPHYLLACEAE	
Arenaria hookeri	Hooker sandwort
Cerastium arvense	Prairie chickweed
Paronychia jamesii	James nailwort
Stellaria media	Common chickweed
CHENOPODIACEAE	
Chenopodium album	Lamb's-quarters
Chenopodium fremontii	Fremont goosefoot
Chenopodium leptophyllum	Maple-leaved goosefoot
CHENOPODIACEAE	
Kochia scoparia	Kochia
Salsola iberica	Russian thistle
AMARANTHACEAE	
Amaranthus graecizans	Tumbleweed
Amaranthus retroflexus	Rough pigweed
POLYGONACEAE	
Polygonum convolvulus	Wild buckwheat
Polygonum ramosissimum	Bushy knotweed
MALVACEAE	
Malva rotundifolia	Common mallow
Sphaeralcea coccinea	Red false mallow
VIOLACEAE	
Viola canadensis	Canada violet
Viola nuttallii	Yellow prairie violet
SALICACEAE	
Populus deltoids	Plains cottonwood

Table 2.8-1: Plant Species List

Scientific Name	Common Name
Salix exigua	Coyote willow
CAPPARACEAE	
Cleome serrulata	Rocky mountain beeplant
BRASSICACEAE	
Arabis holboellii	Rockcress
Brassica kaber	Charlock
Capsella bursa-pastoris	Shepherd's purse
Chorispora tenella	Blue mustard
Descurainia pinnata	Tansy mustard
Descurainia sophia	Flixweed
Draba reptans	White whitlowwort
Erysimum asperum	Western wallflower
Erysimum repandum	Bushy wallflower
Lesquerella ludoviciana	Bladderpod
Sisymbrium altissimum	Tumbling mustard
Thlaspi arvense	Penny cress
PRIMULACEAE	
Androsace occidentalis	Western rock jasmine
SAXIFRAGACEAE	
Ribes odoratum	Buffalo currant
ROSACEAE	
Prunus americana	Wild plum
Prunus virginiana	Chokecherry
Rosa acicularis	Prickly wild rose
Rosa arkansana	Prairie wild rose
Rosa woodsii	Western wild rose
FABACEAE	
Astragalus gracilis	Slender milkvetch
Astragalus missouriensis	Missouri milkvetch
Lupinus argentus	Silvery lupine
Medicago falcata	Yellow lupine
Medicago sativa	Alfalfa
Melilotus alba	White sweetclover
Melilotus officinalis	Yellow sweetclover
Oxytropis lambertii	Purple locoweed
Psoralea argophylla	Silver-leaf scurf pea
Psoralea esculenta	Breadroot scurf pea
Psoralea lanceolata	Lemon scurf pea
Vicia americana	American vetch
ONAGRACEAE	
Gaura coccinea	Velvety gaura
Oenothera caespitosa	Gumbo lily
Oenothera nuttallii	White-stemmed evening primrose
CORNACEAE	
Comandra umbellata	Bastard toadflax
EUPHORBIACEAE	
Croton texensis	
Euphorbia podperae	
VITACEAE	

Table 2.8-1: Plant Species List

Scientific Name	Common Name
Parthenocissus vitacea	Woodbine
ACERACEAE	
Acer negundo	Box elder
ANACARDIACEAE	
Rhus amomatica	Aromatic sumac
Toxicodendron rydbergii	Poison ivy
ZYGOPHYLLACEAE	
Tribulus terrestris	Puncture vine
LINACEAE	
Linum perenne	Blue flax
Linum rigidum	Stiffstem flax
POLYGALACEAE	
Polygala alba	White milkwort
APIACEAE	
Lomatium nuttallii	Wild parsley
APOCYNACEAE	
Apocynum cannabinum	Hemp dogbane
ASCLEPIADACEAE	
Asclepias speciosa	Showy milkweed
SOLANACEAE	
Solanum rostratum	Buffalo bur
CONVOLVULACEAE	
Convolvulus arvensis	Field bindweed
Convolvulus sepium	Hedge bindweed
POLEMONIACEAE	
Phlox andicola	Moss phlox
BORAGINACEAE	
Cryptantha jamesii	James' cryptantha
Lappula redowskii	Low stickseed
Lithospermum incisum	Narrow-leaved puccoon
LAMIACEAE	
Mentha arvensis	Field mint
Monarda pectinata	Spotted beebalm
PLANTAGINACEAE	
Plantago patagonica	Buckhorn
OLEACEAE	
Fraxinus pennsylvanica	Green ash
SCROPHULARIACEAE	
Penstemon albidus	White beardtongue
Penstemon angustifolius	Narrow beardtongue
Penstemon glaber	Smooth beardtongue
Penstemon grandiflorus	Large beardtongue
Verbascum thapsus	Common mullein
CAMPANULACEAE	
Campanula rotundifolia	Harebell
RUBIACEAE	
Galium aparine	Catchweed bedstraw
CAPRIFOLIACEAE	
Symphoricarpos occidentalis	Western snowberry

Table 2.8-1: Plant Species List

Scientific Name	Common Name
ASTERACEAE	
Achillea millefolium	Yarrow
Agoseris glauca	False dandelion
Antennaria rosea	Rose pussytoes
Artemisia campestris	Western sagebrush
Artemisia frigida	Fringed sagebrush
Artemisia ludoviciana	White sage
Chrysopsis villosa	Golden aster
Cirsium undulatum	Wavyleaf thistle
Cirsium vulgare	Bull thistle
Crepis runcinata	Hawk's-beard
Echinacea angustifolia	Purple coneflower
Erigeron pumilus	Low fleabane
Grindelia squarrosa	Curly-top gumweed
Gutierrezia sarothrae	Broom snakeweed
Helianthus annuus	Common sunflower
Helianthus petiolaris	Plains sunflower
Lygodesmia juncea	Skeleton-weed
Ratibida columnifera	Prairie coneflower
Ridbeckia hirta	Black-eyed susan
Senecio plattensis	Prairie ragwort
Taraxacum officinale	Dandelion
Townsendia exscapa	Easter daisy
Tragopogon dubius	Goatsbeard
COMMELINACEAE	
Tradescantia occidentalis	Prairie spiderwort
JUNCACEAE	
Juncus balticus	Baltic rush
CYPERACEAE	
Carex filifolia	Thread-leaved sedge
Carex hystericina	Bottlebrush sedge
Carex lanuginose	Wooly-headed sedge
Carex nebraskensis	Nebraska sedge
Carex rossii	Ross' sedge
POACEAE	
Agropyron cristatum	Crested wheatgrass
Agropyron intermedium	Intermediate wheatgrass
Agropyron pectiniforme	Smooth crested wheatgrass
Agropyron smithii	Western wheatgrass
Agropogon scoparius	Little bluestem
Aristida longiseta	Red threeawn
Bouteloua gracilis	Blue grama
Bromus inermis	Smooth brome
Bromus japonicus	Japanese brome
Bromus tectorum	Cheatgrass
Buchloe dactyloides	Buffalo-grass
Cenchrus longispinus	Field sandbur
Elymus canadensis	Canada wild rye
Festuca octoflora	Six-weeks fescue

Table 2.8-1: Plant Species List

Scientific Name	Common Name
Hordeum jubatum	Foxtail barley
Hordeum pusillum	Little barley
Koeleria pyramidata	Junegrass
Oryzopsis hymenoides	Indian ricegrass
Panicum capillare	Witchgrass
Poa compressa	Canada bluegrass
Poa pratensis	Kentucky bluegrass
Poa sandbergii = (P. secunda)	Sandberg bluegrass
Setaria glauca	Yellow foxtail
Setaria viridis	Green foxtail
Sitanion hystrix	Squirreltail
Stipa comata	Needle-and-thread
Stipa viridula	Green needlegrass
Triticum aestivum	Wheat
LILIACEAE	
Allium textile	White wild onion
Calochortus nuttallii	Mariposa lily
Leucocrinum montanum	Mountain lily
Smilacina stellata	Spikenard
Yucca glauca	Yucca
Zigadenus venenosus	Death camass
IRIDACEAE	
Sisyrinchium montanum	Blue-eyed grass

2.8.6.4 Habitat Types

A habitat classification system (**Table 2.8-2**) was derived for the study area, sufficient to include the flora within the 80-km radius, with particular reference to generating a system useful in identifying faunal habitat affinities. **Table 2.8-3** summarizes the habitat types and amounts of each that comprise the CSA. Specific descriptions of each habitat classification are given in 1983 WFC.

Table 2.8-2: Habitat Classification System

Habitat Classification
000 - Wetlands (Closed Basin Features)
001 - Class I Wetland (Mixed Grass Prairie)
002 - Class II Wetland (Wet Meadow)
003 - Class III Wetland (Shallow Marsh Flora)
004 - Class IV Wetland (Deep Marsh Flora)
005 - Class V Wetland (Permanent Marsh)
006 - Class VI Wetland (Alkaline Lake)
007 - Class VII Wetland (Fen/Bog)
008 - Dugout
009 - Excavated Wetland
010 - Special Features
011 - Cliff

Table 2.8-2: Habitat Classification System

Habitat Classification	
012 -	Talus Slope, Scree
013 -	Caves
014 -	Marl Formation ("Badlands")
050 - Riverine Habitats (Open Basin and Drainage Features)	
050 -	Complex Riparian
051 -	Mixed Grass Prairie Riparian
052 -	Wet Meadow Riparian
053 -	Shallow Marsh Riparian
054 -	Deep Marsh Riparian
055 -	Permanent Water - Streams and Rivers
056 -	Alkaline Streambank
057 -	Streamside Bog
058 -	Stream Dugout
059 -	Impoundments - Lakes and Ponds
100 - Woodlands	
110 -	Deciduous Streambank Forest
111 -	Deciduous Basin Forest
120 -	Deciduous "Wooded Draw" - Intermittent Drainages
130 -	Tree Plantings - Orchards, Shelterbelts, Plantations
140 -	Ponderosa Pine Forest
	141 - Ponderosa Pine/Juniper
	142 - Ponderosa Pine/Deciduous Woodland
	143 - Ponderosa Pine/Grassland
	144 - Ponderosa Pine/Shrubland
150 -	Juniper
160 -	Aspen
200 - Xerophytic Shrublands	
211 -	Big Sagebrush
212 -	Big Sagebrush/Grassland
221 -	Sand Sagebrush
222 -	Sand Sagebrush/Grassland
231 -	Sumac/Grassland
240 -	Mixed Shrub/Half Shrub
300 - Mesophytic Shrublands	
311 -	Upland Drainage Seep
320 -	Chionophilous Copse
330 -	Flood Plain/Mud Flat Shrubland
400 - Grasslands	
405 -	Shortgrass Prairie
410 -	Mixed Grass Prairie
420 -	Range Rehabilitation
500 - Cultivated	
510 -	Grains
520 -	Hay
530 -	Root Crops

Table 2.8-2: Habitat Classification System

Habitat Classification
540 - Vegetables
550 - Fallow
551 - Bare Ground/Summer Fallow
552 - Annual Weed Complex
600 - Structure Biotopes
610 - Surface Disturbance Unreclaimed
611 - Surface Disturbance Reclaimed
630 - Human Biotopes - Towns, Buildings, Farmyards
640 - Cemeteries, Parks
650 - Roads and Roadside/Fencerow Complex

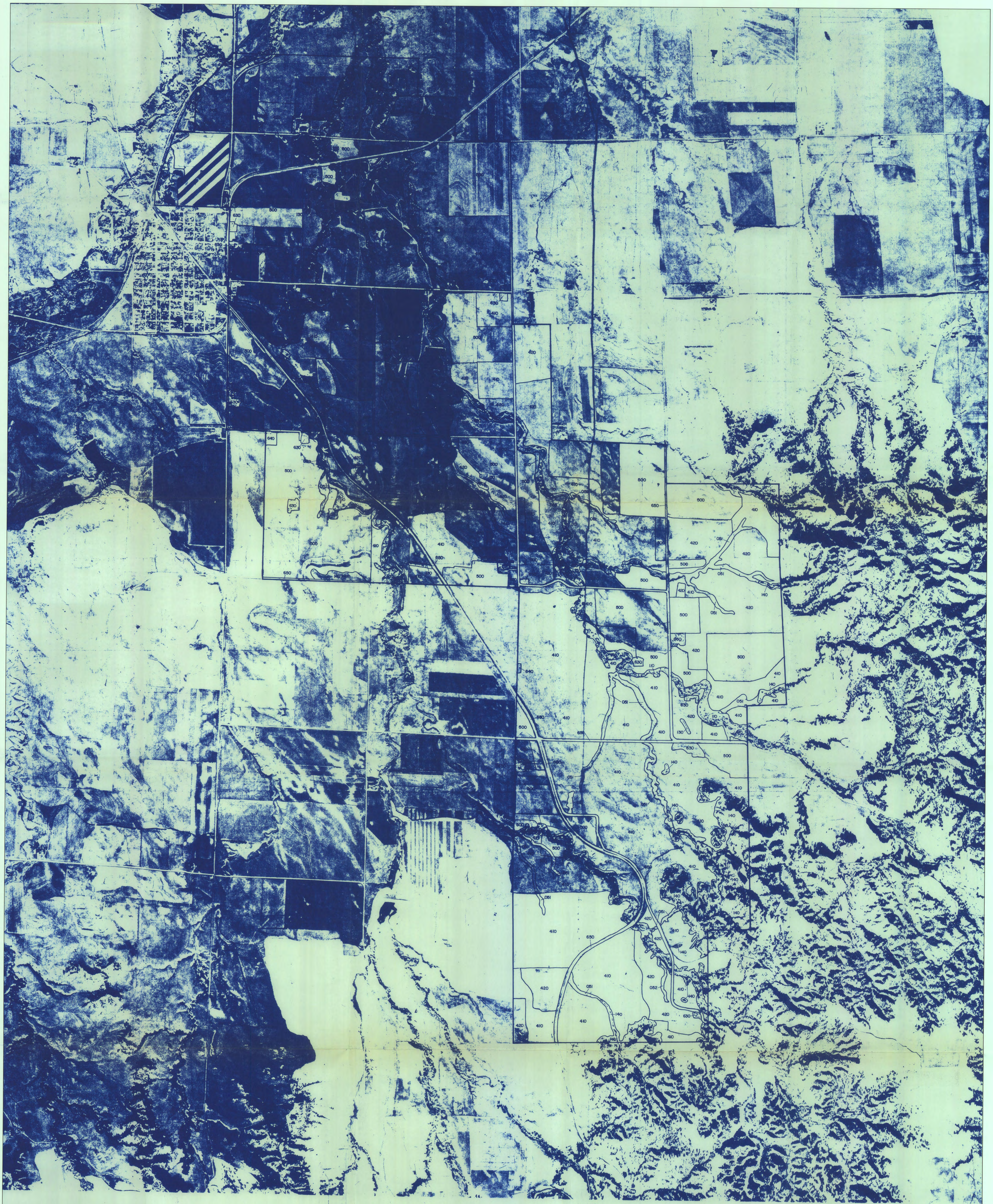
Sixteen habitat types were originally identified in the License Area as described in the 1983 report. These have remained relatively unchanged and include; wet meadow, mixed prairie–riparian, wet meadow–riparian, deep marsh–riparian, riverine, impoundment, deciduous streambank forest, shelterbelts and tree plantings, ponderosa pine, mixed grass prairie, range rehabilitation, cultivated, surface disturbance, human biotopes, cemeteries, and roads and roadside complex (**Figure 2.8-2**). These broad categories often represent several vegetation community types that are generally defined by both species composition and relative abundance. The acres of occurrence and relative distribution of habitat types within the CSA (**Figure 2.8-1**) are presented in **Table 2.8-3**. Detailed descriptions of each habitat classification are given in the 1983 WFC.

Table 2.8-3: CSA Habitat Types

Habitat Classification		Acreage	Hectares	Percent
002	Wet Meadow	4.07	1.65	0.05
051	Mixed Prairie - Riparian	119.65	48.42	1.38
052	Wet Meadow - Riparian	47.27	19.13	0.55
054	Deep Marsh - Riparian	23.50	9.51	0.27
055	Riverine	32.86	13.34	0.38
059	Impoundment	46.57	18.84	0.54
110	Deciduous Streambank Forest	510.43	206.56	5.89
130	Shelterbelts, Tree Plantings	27.27	11.04	0.31
140	Ponderosa Pine	325.85	131.86	3.76
410	Mixed Grass Prairie	2840.18	1149.42	32.74
420	Range Rehabilitation	1370.77	554.74	15.80
500	Cultivated	2856.08	1155.86	32.92
610	Surface Disturbance	2.58	1.04	0.03
630	Human Biotopes	105.05	42.51	1.21
640	Cemeteries	5.02	2.03	0.06
650	Roads and Roadside Complex	356.55	144.30	4.11
Totals		**8,673.70**	**3,510.25**	**100.00**

Source: WFC 1983

CBR-011



LEGEND

002	Class II Wetlands	140	Ponderosa Pine Forest
051	Mixed Grass Prairie Riparian	410	Mixed Grass Prairie
052	Wet Meadow Riparian	420	Range Rehabilitation - Permanent Pasture
054	Deep Marsh Riparian	500	Cultivated
055	Permanent Water - Streams and Rivers	610	Surface Disturbance Unreclaimed
059	Impoundments - Lakes and Ponds	630	Human Biotopes - Buildings, Towns, Farmyards, etc.
110	Deciduous Streambank Forest	640	Cemeteries, Parks
130	Tree Plantings - Orchards, Shelterbelts, Windbreaks	650	Roads and Roadside / Fencerow Complex

N

NOTE: PHOTOMOSAIC COMPILED FROM U.S.G.S. PHOTOS. DATE: 1976.

WYOMING FUEL COMPANY

CROW BUTTE PROJECT
Dawes County, Nebraska

COMMERCIAL STUDY AREA HABITAT TYPES

REV	DESCRIPTION	BY	DATE	REV	DESCRIPTION	BY	DATE

SCALE 1:12,000
1" = 1000'

1000 500 0 1000 2000 3000
FEET

WO NO:

FIGURE 2.8-2

DRAWN BY: D&D Graphics | PREPARED BY: F. Harrington & Assoc. | DATE: 8-1-82

D-02

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Wetlands perform many important hydrologic functions such as floodwater storage, regulating stream flows, streambank stabilization, nutrient removal and uptake, and groundwater recharge. Wetlands and/or waterbodies (classification numbers 002, 051, 052, 054, 055, and 059) make up only 3.17 percent (273.92 acres) of the habitat within the CSA.

Woodlands are generally defined as vegetation communities that contain structure dominated by trees where canopy foliage covers 10 to 30 percent of the ground area (Butler et al. 1997). Forested habitat (classification numbers 110, 130, and 140) makes up 9.96 percent (863.55 acres) of the CSA.

Grasslands are characterized by grasses and other erect herbs, usually without trees or shrubs (Butler et al. 1997). The mixed-grass prairie vegetation community is dominated by cool- and warm-season midgrasses, short-grasses, and sedges. Mixed grass prairie (classification number 410) is a large habitat component of the CSA and accounts for 32.74 percent (2,840.18 acres).

Range rehabilitation areas (classification number 420) are previously cultivated fields subjected to intensive grazing or seasonal haying and account for 15.80 percent (1,370.77 acres) of habitat. Cultivated areas (classification number 500) consist mostly of domesticated cereal crops such as spring wheat, oats, and barley, making up 32.92 percent (2,856.08 acres) of the CSA, the largest component at the site.

The remaining land uses within the CSA (classification numbers 610, 630, 640, and 650) includes farmsteads and associated buildings, gravel and dirt roads, and highways and associated rights-of-way. Urban or developed land includes areas of intensive use with much of the land covered by structures (e.g., houses and farm outbuildings). Human disturbed lands account for only 5.41 percent (189.88 acres) of the land use within the CSA.

2.8.6.5 Mammals

Thirty-six species of wild mammals were documented during the 1982 baseline study, and another 28 species, mostly bats, insectivores, and small rodents, were deemed likely to occur in the region (**Table 2.8-4**).

Table 2.8-4: Mammal Species List

Order/Common Name	Scientific Name	Documented Status[1]
	CARNIVORES	
Carnivora		
Raccoon	*Procyon lotor*	D
Long-tailed weasel	*Mustela frenata*	D
Mink	*Mustela vison*	D
Black-footed ferret	*Mustela nigripes*	E
Badger	*Taxidea taxus*	D
Spotted skunk	*Spilogale putorius*	E

Table 2.8-4: Mammal Species List

Order/Common Name	Scientific Name	Documented Status[1]
Striped skunk	*Mephitis mephitis*	D
Coyote	*Canis latrans*	D
Swift fox	*Vulpes velox*	R
Red fox	*Vulpes fulva*	D
Bobcat	*Lynx rufus*	D
Mountain lion	*Felis concolor*	R
BIG GAME MAMMALS		
Artiodactyla		
Mule deer	*Odocoileus hemionus*	D
White-tailed deer	*Odocoileus virginianus*	D
Pronghorn	*Antilocapra americana*	D
Elk	*Cervus elaphus*	D
Bighorn sheep	*Ovis canadensis*	D
Bison	*Bison bison*	D
Moose	*Alces alces*	R
Mule deer/White-tailed deer hybrid	*O. hemionus x virginianus*	D
SMALL MAMMALS		
Chiroptera		
Keen myotis	*Myotis keeni*	E
Little brown myotis	*Myotis lucifugus*	E
Fringed myotis	*Myotis thysanodes*	E
Long-eared myotis	*Myotis evotis*	E
Long-legged myotis	*Myotis volans*	E
Small-footed myotis	*Myotis subulatus*	E
Silver-haired bat	*Lasionycteris noctivagans*	E
Red bat	*Lasiurus borealis*	E
Big brown bat	*Eptesicus fuscus*	E
Hoary bat	*Lasiurus cinereus*	E
Western big-eared bat	*Plecotus townsendi*	E
Insectivora		
Masked shrew	*Sorex cinereus*	E
Dwarf shrew	*Sorex nanus*	E
Merriam shrew	*Sorex merriami*	E
Least shrew	*Cryptotis parva*	E
Eastern mole	*Scalopus aquaticus*	D
Lagomorpha		
White-tailed jackrabbit	*Lepus townsendi*	D
Black-tailed jackrabbit	*Lepus californicus*	D
Eastern cottontail	*Sylvilagus floridanus*	D
Desert cottontail	*Sylvilagus auduboni*	D
Rodentia		
Black-tailed prairie dog	*Cynomys ludovicianus*	D
Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*	D
Spotted ground squirrel	*Citellus spilosoma*	D
Least chipmunk	*Eutamias minimus*	D

Table 2.8-4: Mammal Species List

Order/Common Name	Scientific Name	Documented Status[1]
Eastern fox squirrel	*Sciurus niger*	D
Northern pocket squirrel	*Thomomys talpoides*	D
Plains pocket gopher	*Geomys bursarius*	E
Wyoming pocket mouse	*Perognathus fasciatus*	E
Plains pocket mouse	*Perognathus flavescens*	E
Silky pocket mouse	*Perognathus flavus*	E
Hispid pocket mouse	*Perognathus hispidus*	E
Ord kangaroo rat	*Dipodomys ordii*	D
Beaver	*Castor canadensis*	D
Plains harvest mouse	*Reithrodontomys montanus*	E
Western harvest mouse	*Reithrodontomys megalotis*	E
White-footed mouse	*Peromyscus leucopus*	D
Deer mouse	*Peromyscus maniculatus*	D
Northern grasshopper mouse	*Onychomys leucogaster*	E
Eastern woodrat	*Neotoma floridana*	E
Bushy-tailed woodrat	*Neotoma cinerea*	E
Brown rat	*Rattus norvegicus*	E
House mouse	*Mus musculus*	D
Meadow vole	*Microtus pennsylvanicus*	D
Prairie vole	*Microtus ochrogaster*	D
Muskrat	*Ondatra zibethicus*	D
Meadow jumping mouse	*Zapus hudsonicus*	D
Porcupine	*Erethizon dorsatum*	D

[1] D Documented in the 1982 baseline study.
E Expected to occur - historical or recent evidence.
R Reported by knowledgeable individual(s).

Big Game Mammals

Big game species that may occur in suitable habitats throughout the project area include pronghorn antelope (*Antilocapra americana*), white-tailed deer (*Odocoileus virginianus*), and mule deer (*Odocoileus hemionus*). Elk (*Cervus elaphus*) and bighorn sheep (*Ovis canadensis*) may occur as transient species because of their known distribution in the Pine Ridge area (Nordeen 2004).

Pronghorn Antelope

Pronghorn typically inhabit grasslands and semi-desert shrublands of the western and southwestern United States. This species is most abundant in short- and mixed-grass habitats and is less abundant in more xeric habitats. Typically, daily movement does not exceed 6 miles. Some pronghorn migrate seasonally between summer and winter habitats, but these migrations are often triggered by availability of succulent plants and not local weather conditions (Fitzgerald et al. 1994).

Nebraska is on the eastern fringe of the pronghorn's range, and there are large areas within the range boundary where pronghorns do not occur. According to Nordeen (2004), a large herd of approximately 60 to 100 antelope may use the area north of Crawford as winter range.

Mule Deer

In Nebraska, mule deer occur in foothills, broken hill country, prairie grasslands, and shrublands. Browse is an important component of the mule deer's diet throughout the year, making up as much as 60 percent of total intake during autumn, while forbs and grasses typically make up the rest of their diet (Fitzgerald et al. 1994). This species tends to be more migratory than white-tailed deer, traveling from higher elevations in the summer to winter ranges that provide more food and cover.

Mule deer are distributed primarily along the foothills and escarpments, ranging outward into mixed-grass prairie and cultivated land. However, the distribution and abundance of mule deer varies by vegetation type in the project area. According to Nordeen (2004), approximately 100 to 200 mule deer and white-tailed deer may occupy a 1 to 2 square-mile area within the project area.

White-tailed Deer

White-tailed deer are found throughout the state of Nebraska, typically concentrated in riparian woodlands, mixed shrubs riparian, and associated irrigated agricultural lands, and are generally absent from dry grasslands and coniferous forests (Clark and Stromberg 1987).

In the License Area, white-tailed deer are expected to be more widely distributed than mule deer. However, because of the high amount of cultivated land, white-tailed deer distributions may be primarily associated with riparian habitats along the White River and associated intermittent and ephemeral stream drainages. In addition, white-tailed deer may be absent from large expanses of mixed-grass prairie and shrub land habitats because they lack sufficient cover and browse.

Elk

In Nebraska, this species occurs primarily in the northwestern region in a variety of habitats, including coniferous forests, meadows, short- and mixed-grass prairies, and sagebrush and other shrub lands.

Elk ranges are concentrated in the Pine Ridge area and associated habitats in the Bordeaux and Hat Creek units. There are an estimated 200 to 250 elk in the state, with most of the herd concentrated in the Pine Ridge area (Nordeen 2004). Occasionally, elk may occur within the project area as transients primarily between the summer and winter range movements.

Bighorn Sheep

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

In 1981, the Nebraska Game and Parks Commission began introducing bighorn sheep in the Pine Ridge area. A dozen bighorns were released into a 500-acre enclosure at Fort Robinson State Park near Crawford. In December 1988, 21 sheep were released from the pen and in January 1993, the remaining 23 sheep were released. Nebraska's bighorn sheep population is now estimated to be between 80 and 140 animals (Nordeen 2004). A few bighorn sheep are known to have ranged from the Fort Robinson area as far east as the Bordeaux Creek drainage southeast of Chadron, south near Belmont, west near the Gilbert-Baker Wildlife Management Area, and north into the Oglala grasslands (Nordeen 2004). No bighorn sheep are expected to occur within the License Area because of in sufficient habitia.

Carnivores

The coyote (*Canis latrans*), red fox (*Vulpes vulpes*), and long-tailed weasel (*Mustela frenata*) are expected to range freely and widely throughout the project area. Bobcat (*Lynx rufus*), badger (*Taxidea taxus*), and striped skunk (*Mephitis mephitis*) may also occur in the License Area, but they are less common.

Small Mammals

The deer mouse (*Peromyscus maniculatus*), white-footed mouse (*Peromyscus leucopus*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), meadow jumping mouse (*Zapus hudsonius),* northern pocket gopher (*Thomomys talpoides*), and meadow vole (*Microtus pennsylvanicus*) are expected to occur in the highest abundances. The highest densities of these small mammals are expected to occur in the deciduous forest areas, whereas the lowest abundance of small mammals would most likely occur in the cultivated fields. According to results of the 1982 baseline study (WFC 1983), the greatest diversity of small mammals was detected in the mixed- and short-grass community, and the lowest diversity was observed in the non-wooded riparian and lower deciduous forest areas.

Muskrat (*Ondatra zibethicus*) may occur along watercourses, and beaver (*Castor canadensis*) may occur in the White River Basin. Porcupine (*Erethizon dorsatum*), fox squirrel (*Sciurus niger*), white-tailed jackrabbit (*Lepus townsendii*), black-tailed jackrabbit (*Lepus californicus*), and eastern cottontail (*Sylvilagus floridanus*) are also expected to occur throughout the License Area.

Domestic Mammals

Domestic livestock within the CSA include cattle, horses, and swine. Cattle management includes cow-calf operations on native range and range rehabilitation areas, winter pasturing and feedlots. Cattle numbers on the CSA range from about 600 to 900 seasonally. In addition, 30 horses and 80 swine are pastured and fed year-round (WFC 1983).

2.8.6.6 Birds

The Nebraska Ornithologists' Union's (NOU) "Official" list 434 birds (including two extinct species – passenger pigeon and Carolina parakeet) occurring in Nebraska (NOU 1997). Accordingly, Johnsgard (1979) lists 430 species, including 54 apparently "accidental" (vagrant) species, and nine extinct, extirpated, or probably extirpated species. In addition, Johnsgard (1979) lists 27 "hypothetical" species, and four unsuccessfully introduced species. Researchers documented 201 species during the 1982 baseline study (**Table 2.8-5**).

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]
GAVIIFORMES		
Common loon	*Gavia immer*	R
Arctic loon	*Gavia arctica*	R
PODICIPEDIFORMES		
Red-necked grebe	*Podiceps grisegena*	R
Horned grebe	*Podiceps auritus*	D
Eared grebe	*Podiceps caspicus*	D
Western grebe	*Aechmophorus occidentalis*	D
Pied-billed grebe	*Podilymbus podiceps*	
PELECANIFORMES		
White pelican**	*Pelicanus erythrorhynchos*	D
Double-crested cormorant**	*Phalacrocorax auritus*	D
CICONIFORMES		
Great blue heron	*Ardea herodias*	D
Green heron	*Butorides virescens*	R
Cattle egret	*Bubulcus ibis*	R
Great egret	*Casmerodius albus*	R
Snowy egret	*Leucophoyx thula*	R
Black-crowned night heron**	*Nycticorax nycticorax*	D
Yellow-crowned night heron	*Nyctanassa violacea*	R
American bittern**	*Botaurus lentiginosus*	D
White-faced ibis	*Plegadia chihi*	R
ANSERIFORMES		
Whistling swan	*Olor columbianus*	R
Trumpeter swan	*Olor buccinator*	D
Canada goose	*Branta canadensis*	D
Brant	*Branta bernicla*	R

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]
White-fronted goose	*Anser albifrons*	D
Snow goose	*Chen hyperborea*	D
Mallard*	*Anas plantyrhynchos*	D
Black duck	*Anas rubripes*	R
Gadwall**	*Anas strepera*	D
Pintail**	*Anas acuta*	D
Green-winged teal**	*Anas carolinensis*	D
Blue-winged teal**	*Anas discors*	D
Cinnamon teal	*Anas cyanoptera*	D
American wigeon	*Mareca americana*	D
Northern shoveler	*Spatula clypeata*	D
Wood duck	*Aix sponsa*	D
Redhead	*Aythya americana*	D
Ring-necked duck	*Aythya collaris*	D
Canvasback	*Aythya valisineria*	D
Lesser scaup	*Aythya affinis*	D
Common goldeneye	*Bucephala clangula*	D
Barrow's goldeneye	*Bucephala islandica*	R
Bufflehead	*Bucephala albeola*	D
Oldsquaw	*Clangula hyemalis*	R
White-winged scoter	*Melanitta deglandi*	R
Surf scoter	*Melanitta perspicillata*	R
Black scoter	*Oidemia nigra*	R
Ruddy duck	*Oxyura jamaicensis*	D
Hooded merganser	*Lophodytes cucullatus*	D
Common merganser	*Mergus merganser*	D
Red-breasted merganser	*Mergus serrator*	R
FALCONIFORMES		
Turkey vulture	*Cathartes aura*	D
Goshawk	*Accipiter gentilis*	D
Sharped-shinned hawk	*Accipiter striatis*	D
Cooper's hawk	*Accipiter cooperi*	D
Red-tailed hawk	*Buteo jamaicensis*	
Red-shouldered hawk	*Buteo lineatus*	R
Broad-winged hawk	*Buteo platypterus*	R
Swainson's hawk	*Buteo swainsoni*	R
Rough-legged hawk	*Buteo lagopus*	D
Ferruginous hawk	*Buteo regalis*	D
Golden eagle	*Aquila chrysaetos*	D
Bald eagles	*Haliaeetus leucocephalus*	D
Northern harrier	*Circus cyaneus*	D
Osprey	*Pandion haliaetus*	R
Gyrfalcon	*Falco rusticolus*	D
Prairie falcon	*Falco mexicanus*	D
Peregrine falcon	*Falco peregrinus*	R

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]
Merlin	*Falco columbarius*	D
American kestrel	*Falco sparverius*	D
GALLIFORMES		
Sharp-tailed grouse*	*Pedioecetes phasianellus*	D
Bobwhite	*Colinus virginianus*	R
Ring-necked pheasant*	*Phasianus colchicus*	D
Turkey*	*Meleagris gallopavo*	D
Gray partridge**	*Perdix perdix*	D
GRUIFORMES		
Sandhill crane	*Grus canadensis*	D
Virginia rail**	*Rallus limicola*	D
Sora rail**	*Porzana carolina*	D
American coot**	*Fulica americana*	D
CHARADRIIFORMES		
Semipalmated plover	*Charadrius semipalmatus*	R
Mountain plover	*Charadrius montainus*	E
Piping plover	*Charadrius melodus*	R
Snowy plover	*Charadrius alexandrinus*	R
Killdeer*	*Charadrius vociferus*	D
American golden plover	*Pluvialis dominica*	R
Black-bellied plover	*Squatarola squatarola*	D
Marbled godwit	*Lemosa fedoa*	D
Whimbrel	*Numenius phaeopus*	R
Long-billed curlew**	*Numenius americanus*	D
Upland sandpiper**	*Bartramia longicauda*	D
Greater yellowlegs	*Totanus melanoleucus*	D
Lesser yellowlegs	*Totanus flavipes*	D
Solitary sandpiper	*Tringa solitaria*	D
Willet**	*Catoptrophorus semipalmatus*	D
Spotted sandpiper**	*Actitis macularia*	D
Common snipe*	*Capella gallinago*	D
Short-billed dowitcher	*Limnodromus griseus*	R
Long-billed dowitcher	*Limnodromus scolopaceus*	D
Red knot	*Calidris canutus*	R
Sanderling	*Calidris alba*	D
Semipalmated sandpiper	*Ereunetes pusillus*	D
Western sandpiper	*Ereunetes mauri*	R
Least sandpiper	*Eriola minutilla*	D
White-rumped sandpiper	*Eriola fuscicollis*	R
Baird's sandpiper	*Eriola bairdii*	D
Pectoral sandpiper	*Eriola melanotos*	R
Stilt sandpiper	*Micropalama himantopus*	D
CHARADRIIFORMES		
Buff-breasted sandpiper	*Tryngites subrufficollis*	R
American avocet**	*Recurvirostra americana*	D

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]
Wilson's phalarope**	*Steganopus tricolor*	D
Northern phalarope	*Lobipes lobatus*	D
Parasitic jaeger	*Stercorarius parasiticus*	R
Herring gull	*Larus argentatus*	R
California gull	*Larus californicus*	R
Ring-billed gull	*Larus delawarensis*	D
Black-headed gull	*Larus ridibundus*	R
Franklin's gull	*Larus pipixcan*	D
Bonaparte's gull	*Larus philadelphia*	R
Forster's tern	*Sterna forsteri*	D
Common tern	*Sterna hirundo*	R
Least (Least interior) tern	*Sterna albifrons*	R
Black tern**	*Chlidonias niger*	D
COLUMBIFORMES		
Mourning dove*	*Zenaidura macroura*	D
Rock dove*	*Columba livia*	D
CUCULIFORMES		
Yellow-billed cuckoo**	*Coccyzus americanus*	D
Black-billed cuckoo**	*Coccyzus erythropthalmus*	D
STRIGIFORMES		
Barn owl**	*Tyto alba*	D
Screech owl**	*Otus asio*	D
Great horned owl*	*Bubo virginianus*	D
Snowy owl	*Nyctea scandiaca*	R
Burrowing owl*	*Speotyto cunicularia*	D
Barred owl	*Strix varia*	R
Long-eared owl	*Asio otus*	R
Short-eared owl**	*Asio flammeus*	D
Saw-whet owl**	*Aegolius acadicus*	D
CAPRIMULGIFORES		
Common poor-will**	*Phalaenoptilus nuttallii*	D
Common nighthawk**	*Chordeiles minor*	D
APODIFORMES		
Chimney swift**	*Chaetura pelagica*	D
White-throated swift**	*Aeronautes saxatalis*	D
Broad-tailed hummingbird	*Selasphorus platycercus*	R
Rufous hummingbird	*Selasphorus rufus*	R
CORACIIFORMES		
Belted kingfisher**	*Megaceryle alcyon*	D
PICIFORMES		
Common flicker*	*Colaptes auratus*	D
Red-bellied woodpecker	*Centurus carolinus*	R
Red-headed woodpecker*	*Melanerpes erythrocephalus*	D
Lewis' woodpecker**	*Asyndesmus lewis*	D
Yellow-bellied sapsucker	*Sphyrapicus varius*	R

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]
Hairy woodpecker**	*Dendrocopos villosus*	D
Downy woodpecker**	*Dendrocopos pubescens*	D
PASSERIFORMES		
Eastern kingbird*	*Tyrannus tyrannus*	D
Western kingbird*	*Tyrannus verticalis*	D
Cassin's kingbird	*Tyrannus vociferans*	R
Scissor-tailed flycatcher	*Muscivora forfic*	R
Great crested flycatcher**	*Myiarchus crinitus*	D
Eastern phoebe**	*Sayornis phoebe*	D
Say's phoebe**	*Sayornis saya*	D
Black phoebe	*Sayornis nigricans*	D
Willow flycatcher**	*Empidonax traillii*	D
Least flycatcher	*Empidonax minimus*	D
Hammond's flycatcher	*Empidonax hammondii*	R
Western flycatcher	*Empidonax difficilis*	R
Eastern pewee**	*Contopus virens*	D
Western pewee*	*Contopus sordidulus*	D
Olive-sided flycatcher	*Nuttalornis borealis*	R
Horned lark*	*Eremophila alpestris*	D
Violet-green swallow**	*Tachycineta thallassina*	D
Tree swallow**	*Iridoprocne bicolor*	D
Bank swallow*	*Riparia riparia*	D
Rough-winged swallow**	*Stelgidopteryx ruficollis*	D
Barn swallow*	*Hirundo rustica*	D
Cliff swallow*	*Petrochelidon pyrrhonota*	D
Purple martin	*Progne subis*	R
Gray jay	*Perisoreus canadensis*	R
Blue jay**	*Cyanocitta cristata*	R
Stellar's jay	*Cyanocitta stelleri*	R
Black-billed magpie*	*Pica pica*	D
American crow*	*Corvus branchyrhynchos*	D
Pinyon jay**	*Gymnorhinus cyanocephalus*	D
Clark's nutcracker	*Nucifraga columbiana*	R
Black-capped chickadee**	*Parus atricapillus*	D
Tufted titmouse	*Parus bicolor*	R
White-breasted nuthatch**	*Sitta carolinensis*	D
Red-breasted nuthatch**	*Sitta canadensis*	D
Pygmy nuthatch**	*Sitta pygmaea*	D
Brown creeper**	*Certha familiaris*	D
Dipper	*Cinclus mexicanus*	R
Northern house wren**	*Troglodytes aedon*	D
Winter wren	*Troglodytes troglodytes*	R
Bewick's wren	*Thryomanes bewickii*	R
Carolina wren	*Thryothorus ludovicianus*	R
Marsh wren**	*Telmatodytes palustris*	D

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]
Canyon wren	*Catherpes mexicanus*	R
Rock wren**	*Salpinctes obsoletus*	D
Mockingbird	*Mimus polyglottos*	R
Gray catbird**	*Dumetella carolinensis*	D
Brown thrasher**	*Toxostoma rufum*	D
Sage thrasher	*Orescoptes montanus*	R
American robin*	*Turdus migratorius*	D
Wood thrush	*Hylocichla mustelina*	D
Hermit thrush	*Hylocichla guttata*	D
Swainson's thrush	*Hylocichla ustalata*	D
Gray-cheeked thrush	*Hylocichla ustalata*	D
Veery	*Hylocichla fuscenscens*	D
Eastern bluebird	*Sialia sialis*	R
Mountain bluebird**	*Sialia currucoides*	D
Townsend's solitaire**	*Myadestes townsendi*	D
Blue-gray gnatcatcher	*Polioptila caerulea*	R
Golden-crowned kinglet	*Rugulus satrapa*	R
Ruby-crowned kinglet	*Rugulus calendula*	D
Water pipit	*Anthus spinoletta*	D
Bohemian waxwing	*Bombycilla garrulus*	D
Cedar waxwing**	*Bombycilla cedrorum*	D
Northern shrike	*Lanius excubitor*	D
Loggerhead shrike**	*Lanius ludovicianus*	D
European starling*	*Sturnus vulgaris*	D
White-eyed vireo	*Vireo griseus*	R
Bell's vireo**	*Vireo bellii*	D
Yellow-throated vireo	*Vireo flavifrons*	R
Solitary vireo	*Vireo solitarius*	R
Red-eyed vireo**	*Vireo olivaceus*	D
Philadelphia vireo	*Vireo philadelphicus*	R
Warbling vireo**	*Vireo gilvus*	D
Black and white warbler	*Mniotilta varia*	D
Prothonotary warbler	*Protonotaria citrea*	R
Tennessee warbler	*Vermivora peregrina*	D
Orange-crowned warbler	*Vermivora celata*	D
Nashville warbler	*Vermivora ruficapilla*	D
Northern parula	*Parula americana*	R
Yellow warbler**	*Dendroica petechia*	D
Magnolia warbler	*Dendroica magnolia*	R
Cape May warbler	*Dendroica tigrina*	R
Yellow-rumped warbler	*Dendroica coronata*	
(Audubon race)**	*Dendroica coronata*	D
(Myrtle race)	*Dendroica coronata*	D
Townsend's warbler	*Dendroica townsendi*	R
Black-throated green warbler	*Dendroica virens*	R

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]
Cerulean warbler	*Dendroica cerulea*	R
Blackburnian warbler	*Dendroica fusca*	R
Chestnut-sided warbler	*Dendroica pensylvanica*	R
Blackpoll warbler	*Dendroica striata*	D
Palm warbler	*Dendroica palmarum*	R
Ovenbird**	*Seiurus aurocapillus*	D
Northern waterthrush	*Seiurus noveboracensis*	D
PARULIDAE		
Mourning warbler	*Oporornis philadelphia*	R
MacGillivray's warbler	*Oporornis tolmiei*	R
Common yellowthroat**	*Geothlypis trichas*	D
Yellow-breasted chat**	*Icteria virens*	D
Hooded warbler	*Wilsonia citrina*	R
Wilson's warbler	*Wilsonia pusilla*	D
American redstart**	*Setophaga ruticilla*	D
House sparrow*	*Passer domesticus*	D
Bobolink**	*Dolichonyx oryzivorus*	D
Eastern meadowlark**	*Sturnella magna*	D
Western meadowlark*	*Sturnella neglecta*	D
Yellow-headed blackbird**	*Xanthocephalus xanthocephalus*	D
Red-winged blackbird*	*Agelaius phoeniceus*	D
Orchard oriole**	*Icterus spurius*	D
Northern (Bullock) oriole**	*Icterus galbula*	D
Rusty blackbird	*Euphagus carolinus*	R
Brewer's blackbird**	*Euphagus cyanocephalus*	D
Common grackle**	*Quiscalus quiscula*	D
Brown-headed cowbird**	*Molothrus ater*	D
Western tanager**	*Piranga ludoviciana*	D
Scarlet tanager	*Piranga olivacea*	R
Cardinal	*Richmondena cardinalis*	R
Rose-breasted grosbeak	*Pheucticus ludovicianus*	R
Blue grosbeak**	*Guiraca caerulea*	D
Indigo bunting**	*Passerina cyanea*	D
Lazuli bunting**	*Passerina amoena*	D
Indigo x lazuli hybrid**	*P. cyanea x amoena*	D
FRINGILLIDAE		
Dickcissel	*Spiza americana*	R
Evening grosbeak	*Herperiphona vespertina*	D
Purple finch	*Carpodacus purpureus*	R
Cassin's finch	*Carpodacus cassinii*	R
House finch	*Carpodacus mexicanus*	D
Pine grosbeak	*Pinicola enucleator*	R
Gray-crowned rosy finch	*Leucosticte tephrocotis*	R
Common redpoll	*Acanthis flammea*	R
Pine siskin**	*Spinus pinus*	D

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]
American goldfinch**	*Spinus tristis*	D
Red crossbill**	*Loxia curvirostra*	D
White-winged crossbill	*Loxia leucoptera*	R
Green-tailed towhee	*Chlorura chlorura*	R
Rufous-sided towhee**	*Pipilo erythrophthalmus*	D
Lark bunting**	*Calamospiza melanocoryx*	D
Savannah sparrow	*Passerculus sandwichensis*	D
Grasshopper sparrow	*Ammodramus savannarum*	D
Vesper sparrow**	*Pooecetes gramineus*	D
Lark sparrow*	*Chondestes grammacus*	D
Black-throated sparrow	*Amphispiza bilineata*	R
Dark-eyed junco	*Junco hyemalis*	
(White-winged race)**	*Junco hyemalis*	D
(Slate-colored race)	*Junco hyemalis*	D
(Oregon race)	*Junco hyemalis*	D
(Gray-headed race)	*Junco hyemalis*	D
Tree sparrow	*Spizella arborea*	D
Chipping sparrow**	*Spizella passerina*	D
Clay-colored sparrow**	*Spizella pallida*	D
Brewer's sparrow**	*Spizella breweri*	D
Field sparrow	*Spizella pusilla*	R
Harris' sparrow	*Zonotrichia querula*	R
White-crowned sparrow	*Zonotrichia leucophrys*	D
White-throated sparrow	*Zonotrichia albicollis*	R
Fox sparrow	*Passerella iliaca*	R
Lincoln's sparrow	*Melospiza lincolnii*	D
Swamp sparrow	*Melospiza georgiana*	R
Song sparrow	*Melospiza melodia*	D
McCown's longspur**	*Rhynchophanes mccownii*	D
Lapland longspur	*Calcarius lapponicus*	D
Chestnut-collared longspur**	*Calcarius ornatus*	D
Snow bunting	*Plectyrophenax nivalis*	D

1 - Documentation:
D Documented in the 1982 study.
E Expected to occur - historical or recent evidence.
R Reported by knowledgeable individual(s).
*confirmed breeder
**suspected breeder

Of the NOU 434 birds sighted in Nebraska, approximately 200 species nest in the state. The largest single component is arboreal species adapted to living in trees, woodlands, and forests which make up approximately 45 percent of the state's total species, while aquatic and shoreline adapted species make up the second largest component or 32 percent of the state's total avifauna (Johnsgard 1979). Species primarily associated with grasslands comprise a still smaller breeding component, or approximately 10 percent of

the state's total avifauna. Bird species associated with semi-desert scrub are the least numerous.

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

Upland game birds such as wild turkey (*Meleagris gallopavo*), ring-necked pheasants (*Phasianus colchicus*), and sharp-tailed grouse (*Tympanuchus phasianellus*) may occur in the area as well. Waterfowl may occur throughout the region primarily during both the spring and fall migrations. However, because there are only a few low productivity wetlands and waterbodies (approximately 274 acres, or 3 percent), the diversity and abundance of waterfowl is extremely low in the project area.

Several raptor species are expected to occur in the project area, a reflection of the diversity in habitat types and the existence of many suitable nesting sites, such as tall trees. Golden eagles are permanent residents of the area, occurring in a variety of habitats. The most common permanent resident raptors occurring in the cultivated fields and mixed-grass prairies may include red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), northern harrier (*Circus cyaneus*), prairie falcon (*Falco mexicanus*), turkey vulture (*Cathartes aura*), and great horned owl (*Bubo virginianus*). In addition, rough-legged hawks (*Buteo lagopus*) are common winter residents of the Pine Ridge area (WFC 1983).

2.8.6.7 Reptiles and Amphibians

Of the 22 species of reptiles and amphibians recorded in Dawes and Sioux Counties (Ferraro 2004) (**Table 2.8-6**), 13 were documented during the 1982 baseline investigation. Documented toads and frogs included Woodhouse's toad (*Bufo woodhousii*), great plains toad (*Bufo cognatus*), plains spadefoot (*Spea bombifrons*), western striped chorus frog (*Pseudacris triseriata*), northern leopard frog (*Rana pipiens*), and bullfrog (*Rana catesbeiana*). Two species of turtles observed were the snapping turtle (*Chelydra serpentina*) and painted turtle (*Chrysemys picta*). Snakes identified included the bullsnake (*Pituophis catenifer*), plains garter snake (*Thamnophis radix*), red-sided garter snake (*Thamnophis sirtalis*), and racer (*Coluber constrictor*).

Table 2.8-6: Reptile and Amphibian List

Common Name	Scientific Name	Status
AMPHIBIANS		
Eastern tiger salamander	*Ambystoma tigrinum*	
Great plains toad	*Bufo cognatus*	
Woodhouse's toad	*Bufo woodhousii*	
Western chorus frog	*Pseudacris triseriata*	
Plains spadefoot	*Spea bombifrons*	
Northern leopard frog	*Rana pipiens*	
Bullfrog	*Rana catesbeiana*	
REPTILES		
Lesser earless lizard	*Holbrookia maculata*	
Short-horned lizard	*Phrynosoma hernandesi*	
Prairie lizard	*Sceloporus undulatus*	
Many-lined skink	*Eumeces multivirgatus*	R
Bullsnake	*Pituophis catenifer*	
Yellow-bellied racer	*Coluber constrictor*	
Plains garter snake	*Thamnophis radix*	
Red-sided/Common garter snake	*Thamnophis sirtalis*	
Plains hognose snake	*Heterodon nasicus*	
Prairie rattlesnake	*Crotalus viridis*	
W. terrestrial garter snake	*Thamnophis elegans*	R
Plains milk snake	*Lampropeltis triangulum*	R
Northern water snake	*Nerodia sipedon*	R
Common snapping turtle	*Chelydra serpentina*	
Painted turtle	*Chrysemys picta*	

R = Rare

2.8.7 Threatened, Endangered, or Candidate Species

Several species that could potentially occur within the License Area are designated as "threatened or endangered" because of their recognized rarity or vulnerability to various causes of habitat loss or population decline. These designated species receive specific protection defined in the federal Endangered Species Act of 1973, as amended, and the Nongame and Endangered Species Conservation Act (Neb. Rev. Stat. §37-430 et seq.). Other species have been designated as "candidate or sensitive" on the basis of adopted policies and expertise of state resource agencies or organizations with acknowledged expertise. A list of potentially occurring special-status species, along with specific occurrence records, was developed from an original list of target species based on records of the NGPC and the USFWS. **Table 2.8-7** summarizes the potential occurrence of each species within the vicinity of the License Area.

Table 2.8-7: Federal and State Threatened, Endangered, and Candidate Species with the Potential to Occur within the Vicinity of the License Area

Species	Federal/State Listing Status		Habitat	Critical Habitat
	Federal	State		
Swift fox (*Valpesvelox*)	Not Listed	Endangered	Large tracts of short- and mid-grass prairie habitats.	None designated
Bald eagle (*Haliaeetus leucocephalus*)	Delisted	Threatened	Migrates spring and fall statewide, but primarily along the major river courses.	None designated
Black-Footed Ferret (*Mustela nigripes*)	Endangered	Endangered	Closely associated with prairie dogs found in short and mid-grass prairies	None designated
Whooping Crane (*Grus Americana*)	Endangered	Endangered	Slow-moving rivers/streams with sandbars/islands; nearby wet meadows, croplands and marshlands	None designated

Source: NGPC 2007. USFWS 2006.

2.8.7.1 Swift Fox

The swift fox (*Vulpes velox*) is listed as endangered by the NGCP. The USFWS does not list the species as endangered, threatened or as a candidate species. The USFWS notes the swift fox has the potential to occur in Dawes County. The swift fox is widely distributed throughout the Great Plains and there are small, disjunct populations in western Nebraska and Kansas (USFWS 1995). There is high quality swift fox habitat in the Oglala National Grassland immediately northwest of the project area. The swift fox is closely associated with lagomorph populations, prairie dog colonies, ground squirrels, and other small mammals, which exist in varying densities and abundance throughout the License Area.

2.8.7.2 Bald Eagle

On June 28, 2007, the USFWS removed the bald eagle (*Haliaeetus leucocephalus*) from the list of threatened and endangered species (USFWS 2007). Even though the bald eagle has been delisted, it is still protected by the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act. The Nebraska Game and Parks Commission currently lists the bald eagle as threatened. Any changes in the status of the bald eagle in the state will have to have approval of the Commission, following public hearings. It is anticipated that a decision as to the state delisting of the bald eagle will occur during the next 6 to 12 months (Fritz 2007).

Nebraska's wintering bald eagle population is highly variable, ranging from 409 in 1984 to 1,292 in 1992, with an average of 714 bald eagles counted in Nebraska during the annual midwinter surveys between 1980 and 1993 (NGPC 2007). Most of the wintering bald eagle population is found in close association with open water. Bald eagles are

known to occasionally occur in this region, primarily during the winter months (November through March). No bald eagle nests are known to occur within the project area. Moreover, no winter concentration areas or winter roosts have been documented within the project area (Fritz, 2004).

2.8.7.3 Black-footed Ferret

The black-footed ferret (*Mustela nigripes*) is listed as endangered by the USFWS and NGPC, and has the potential to occur in Dawes County (NGPC 2007, USFWS 2006). However, no recent confirmed populations of the black-footed ferret have been observed in the state of Nebraska. The last known specimen was an individual killed on a road near Overton in Dawson County in 1949, and no wild ferrets have been verified in Nebraska since the 1940s (NGPC 2007). Therefore, the black-footed ferret is not expected to occur in the project area.

2.8.7.4 Whooping Crane

The whooping crane (*Grus americana*) is listed as endangered by the USFWS and NGPC, with the potential to occur in Dawes County (NGPC 2007, USFWS 2006). The whooping crane is an occasional spring and fall migrant along the Platte Valley in the state, which accounts for approximately 90 percent of the sitings in Nebraska. The Platte Valley is located in central Nebraska, a considerable distance from the License Area. Any presence of whooping cranes on the project site and immediate area would be expected to be infrequent and transient. There is a lack of suitable habitat within the License Area, e.g., rivers and streams with associated sandbars and islands, marshlands, wet meadows and croplands.

2.8.8 Aquatic Resources

Objectives of the aquatic ecology baseline data collections conducted in 1982 were to provide information to assess the aquatic resources occurring within the CSA. The data results are summarized below. For more detailed information, please refer to the 1983 WFC.

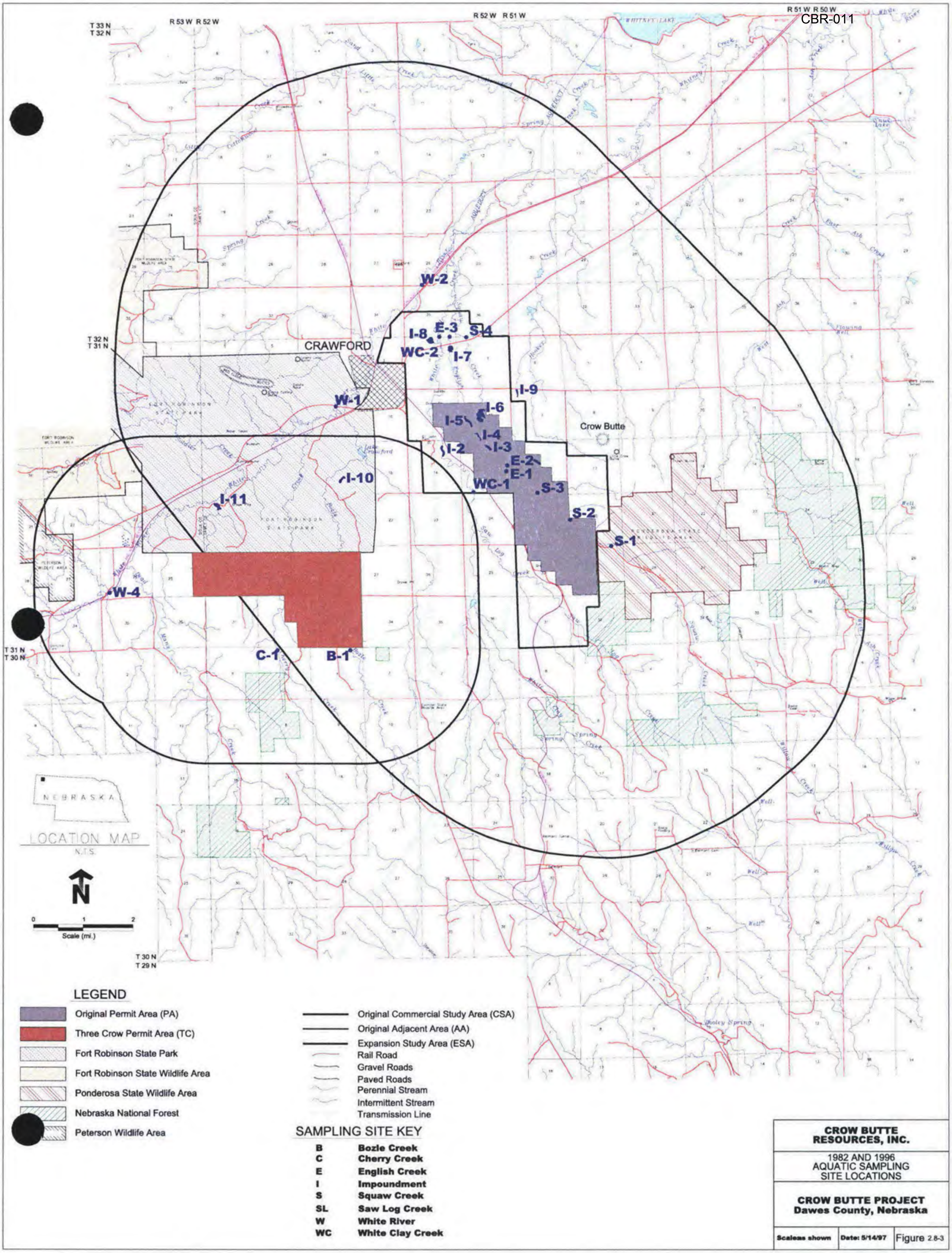
2.8.8.1 Aquatic Study Area Description

Aquatic habitats on the CSA consist of three streams and eight impoundments. English Creek, Squaw Creek, and White Clay Creek are first-order streams that form the drainage basin within the CSA (**Figure 2.8-3**). Four of the impoundments are on English Creek, two on White Clay Creek, and one on Squaw Creek. The remaining impoundment is a stock pond created by a dam on a small drainage area.

In general, the aquatic habitats on the CSA suffer from ongoing environmental stresses. Naturally occurring stresses include unstable substrates and banks, low flows, and periodic flooding. Overgrazing on adjacent rangelands and in riparian areas, and farming practices along the stream courses further compound these problems. Commercial baitfish practices such as poisoning, dewatering, and introducing bait minnows have

affected many of the impoundments. Livestock grazing and watering add to impoundment problems. These stresses are reflected in a fishery mostly consisting of non-game, tolerant species. Periodic stocking by the NGPC has created some put-and-take sport fisheries in the area but these are not self-sustaining due to environmental factors.

- English Creek is entirely within the CSA originating from springs and flowing northerly for about 5.6-km where it empties into Squaw Creek. Low flow and a vegetation-choked stream channel provide little suitable fish habitat. On-stream impoundments and pools created by washouts below culverts provide about the only suitable fish habitat.
- Squaw Creek originates in the Nebraska National Forest and the Ponderosa State Wildlife Area and flows through the CSA to its confluence with White Clay Creek. Squaw Creek changes dramatically from the upstream areas to the lower reaches. Much of the upper watershed is forested, mainly because it is within the Ponderosa Wildlife Area where livestock grazing and cultivation is prohibited. In contrast, the middle and lower watershed consists of heavily grazed rangeland or cultivated small grains.
- At the upper sampling station (S-1) the pine and grass-covered slopes, and thick, undisturbed riparian zone provide a relatively stable watershed. Substrates in this area consist of hardpan, gravel riffle areas, and some silted-in pools. Streambanks are relatively stable with overhanging vegetation and with some undercutting. Log jams, undercut banks, and pools up to 1.5 m deep provide cover and probable overwintering areas for fish.
- From station S-2 downstream to I-6, Squaw Creek looks entirely different. The understory in this lower section has virtually been eliminated by livestock grazing. Stream banks are degraded and unstable and the substrate is mostly sand. Few gravel riffle areas are present and most of the pools are heavily silted. Aquatic vegetation is relatively sparse in this section of stream with some Cladophora growing in shallow fast-flowing areas. The watershed in this lower area is unstable and, as evidenced by high-water debris, is subjected to periodic severe flooding (WFC 1983).
- White Clay Creek drains from the national forest to the south and flows northerly through the CSA and empties into the White River. At WC-1, the creek flows through a riparian grass area and has relatively stable stream banks. Habitat consists of mud and sand substrates and no well defined pools or riffles. At station WC-2 the creek flows through pasture land. In this section the substrate consists of sand, gravel and rubble with some silted pools. The stream banks appear to be relatively stable.


R 53 W R 52 W
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CRAWFORD
Crow Butte
W-1
W-2
W-4
I-2
I-4
I-3
I-5
I-6
I-7
I-8
I-9
I-10
I-11
E-1
E-2
E-3
S-1
S-2
S-3
S-4
WC-1
WC-2
C-1
B-1
NEBRASKA
LOCATION MAP
N.T.S.
N
0 1 2
Scale (mi.)
LEGEND
Original Permit Area (PA)
Three Crow Permit Area (TC)
Fort Robinson State Park
Fort Robinson State Wildlife Area
Ponderosa State Wildlife Area
Nebraska National Forest
Peterson Wildlife Area
Original Commercial Study Area (CSA)
Original Adjacent Area (AA)
Expansion Study Area (ESA)
Rail Road
Gravel Roads
Paved Roads
Perennial Stream
Intermittent Stream
Transmission Line
SAMPLING SITE KEY
B Bozle Creek
C Cherry Creek
E English Creek
I Impoundment
S Squaw Creek
SL Saw Log Creek
W White River
WC White Clay Creek
CROW BUTTE RESOURCES, INC.
1982 AND 1996 AQUATIC SAMPLING SITE LOCATIONS
CROW BUTTE PROJECT
Dawes County, Nebraska
Scale as shown
Date: 5/14/97
Figure 2.8-3

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- Impoundments range in size from 0.4 ha (I-1) to 7.7 ha (I-6). Impoundments I-4, 5, 6, 7, and 8 have been or are now being, managed for raising baitfish. Impoundment I-9 has been stocked with brook trout for recreational fishing and serves for stock watering.

2.8.8.2 Methods

Fish were collected at each location to document their occurrence and to determine their relative abundance. The sampling effort was not standardized due to differences in the types of habitats sampled, sampling equipment, and abundance of fish present at each location.

Quantitative triplicate samples of benthic macroinvertebrates were collected from the stream and impoundment sample locations. Soft substances were sampled with a Ponar Dredge ($0.22m^2$) and gravel riffle substrates with a Surber sampler ($0.0093m^2$). Shannon-Weaver diversity indices were calculated from all samples.

Single qualitative samples of periphyton were collected at each sampling location by scraping the surface of several rocks, sticks, plant or other substrate material with a pocket knife. Diatom proportional counts were performed at the generic level. Green and blue-green algae were identified and their occurrence noted for each sampling location.

<u>Fish</u>

The status and distribution of fish species for the study area are presented in **Table 2.8-8**. Fourteen species of fish were collected from the CSA streams and impoundments (**Table 2.8-9**). Game fish collected included black bullheads, rainbow trout, brown trout, and brook trout.

Brook trout, which are not stocked, were collected in low numbers from Squaw Creek at several locations (**Table 2.8-10**). Although rainbow trout are periodically stocked by the NGPC in the upstream section, none were sampled at either S-1 or S-2. Periodic severe flooding is probably the most important factor limiting the effectiveness of stocking and reducing the trout population in Squaw Creek.

Table 2.8-8: Fish Species List

Family/Common Name	Scientific Name	Status[1]
CATOSTOMIDAE		
River sucker	*Carpiodes carpio*	R
Longnose sucker	*Catostomus catostomus*	R
White sucker	*Catostomus commersoni*	D
CENTRARCHIDAE		
Green sunfish	*Lepomis cyanellus*	D
Bluegill	*Lepomis macrochirus*	D
Smallmouth bass	*Micropterus dolomieui*	R

Table 2.8-8: Fish Species List

Family/Common Name	Scientific Name	Status[1]
Largemouth bass	*Micropterus salmoides*	D
Rock Bass	*Amblo plites rupestrinis*	D
Black crappie	*Pomoxis nigromaculatus*	D
CYPRINIDAE		
Carp	*Cyprinus carpio*	D
Plains minnow	*Hybognathus placitus*	D
Flathead chub	*Hybopsis gracilis*	R
Common shiner	*Luxilus cornutus*	D
Golden shiner	*Notemigonus crysoleucas*	D
Red shiner	*Notropis lutrensis*	R
Sand shiner	*Notropis stramineus*	D
Flathead minnow	*Pimephales promelas*	D
Longnose dace	*Rhinichthys cataractae*	D
Creek chub	*Semotilus atromaculatus*	D
CYPRINODONTIDAE		
Plains topminnow	*Fundulus sciadicus*	D
ESOCIDAE		
Northern pike	*Esox lucius*	R
HIODONTIDAE		
Goldeye	*Hiodon alosoides*	R
ICTALURIDAE		
Black bullhead	*Ictalurus melas*	D
Channel catfish	*Ictalurus punctatus*	R
Stonecat	*Noturus flavus*	R
PERCICHTHYIDAE		
White bass	*Morone chrysops*	D
PERCIDAE		
Walleye	*Stizostedion vitreum*	D
SALMONIDAE		
Rainbow trout	*Oncorhynchus mykiss*	D
Brown trout	*Salmo trutta*	D
Brook trout	*Salvelinus fontinalis*	D

Notes

[1] Documentation:

D Documented in the course of the present study.

E Expected to occur - historical or recent evidence.

R Reported by knowledgeable individual(s).

Table 2.8-9: Occurrence of Fish Species by Habitat

FISH SPECIES	STREAMS					IMPOUNDMENTS								
	English Creek	Squaw Creek	White Clay Creek	White River		1	2	3	4	5	6	7	8	9
SALMONIDAE														
Brook trout		X												X
Brown trout				X										
Rainbow trout				X										
CYPRINIDAE														
Creek chub	X		X	X			X							
Fathead minnow	X	X	X	X						X	X	X		
Longnose dace		X	X	X										
Plains minnow			X											
Sand shiner				X			X							
Golden shiner	X		X							X	X			
CATOSTOMIDAE														
White sucker			X	X			X							
ICTALURIDAE														
Black bullhead			X											
Stone Cat				X										
CYPRINODONTIDAE														
Plains topminnow	X		X											
CENTRARCHIDAE														
Green sunfish	X		X	X			X			X				
NUMBER OF SPECIES	5	3	9	9		0	4	0	0	3	2	1	0	1
SAMPLING METHOD														
Electrofishing	X	X	X	X			X			X				X
Gill Netting														
Pond Netting														
Minnow Trapping	X	X	X	X			X			X				X
Rod and Reel Angling														X

Table 2.8-10: Relative Abundance (Percent Occurrence) of Fish Collected at Each Sampling Location (1982)

	STREAMS									IMPOUNDMENTS								
FISH SPECIES	E-3	S-1	S-2S-3	S-4	WC-1	WC-2	W-1	W-2		1	2	3	4	5	6	7	8	9
SALMONIDAE																		
Brook trout		5.7	1.2															100
Brown trout							18.5	3.2										
Rainbow trout							3.7											
CYPRINIDAE																		
Creek chub	0.3				44.8	1.1												
Fathead minnow	71.1	11.3	65.5	100	30.6	64.1								89.0	100	100		
Longnose dace		83.0	33.3		6.0	11.1	59.3	76.3										
Plains minnow						0.3												
Sand shiner																		
Golden shiner	3.9					0.6								2.4				
CATOSTOMIDAE																		
White sucker					2.2	1.1	18.5	20.4										
Black bullhead						0.9												
CYPRINODONTIDAE																		
Plains topminnow						0.3												
CENTRARCHIDAE																		
Green sunfish	24.7				16.4	20.5					100		100	8.6				
Electrofishing Total	55	106	174	18	112	335	27	93						193	126			
Minnow Trap Total	249			31	71	16					3		21	52	21	5		
Angling Total																		6
GRAND TOTAL	304	106	174	49	183	351	27	93			3		21	245	147	5		6

Brown trout and rainbow trout were collected in the White River at station W-1 and brown trout were collected at W-2. A regionally important put-and-take fishery exists in the White River around the Fort Robinson State Park area. Longnose dace were captured at all White River stations. Fluctuating flows, periodic flooding, sand and silt substrates, and warm water temperatures are probably the most important factors limiting natural trout production in the White River.

Impoundment I-9 has been stocked with brook trout but is not a public area and therefore provides only a limited amount of recreational fishing. The other impoundments have been or are now managed for baitfish production.

Macroinvertebrates

Macroinvertebrate analyses of the samples indicate that, in general, the study streams and impoundments have stressed environments. More than 90 percent of the total abundance of all stations consisted of organisms considered tolerant. The most abundant groups of these tolerant species were: chironomidae – 34 percent, simulidae - 20 percent, oligochaeta - 19 percent, and ceratopogonidae - 15 percent. Exceptions occurred at the upper Squaw Creek stations (S-1 and S-2), where caddisflies and mayflies dominated the riffle habitat. These two taxa typically represent less stressed environments than the above listed organisms.

Macroinvertebrate density and diversity values for the aquatic stations are presented in **Table 2.8-11**. Additionally, percent contributions of the dominant macroinvertebrate taxa are given. Although densities were high at most sampling stations, diversity values were low. Healthy streams usually have diversity values between 3.0 and 4.0, but many forms of stress reduce diversity by making the environment unsuitable for some species or by giving other species a competitive advantage. The upper Squaw Creek station (S-1) was the only station that had diversity values within this range indicating relatively higher quality and a more stable habitat.

Periphyton

The Periphyton communities at the aquatic sample stations were composed of 21 diatoms, 8 green algae, and one blue-green alga genera. Diatom percent occurrence and general occurrence of other algae are presented in **Table 2.8-12**. *Cymbella, Navicula, Nitzschia, Surirella, and Synedra*, were the most common diatom genera and were found in every sample. Green algae were found in all sampling locations, with greatest development occurring in the impoundments (WFC 1983). Cladophora was the most common and abundant green algae found in the streams and at some locations formed thick mats.

Table 2.8-11: Benthic Macroinvertebrate Community Values for Study Area Streams and Impoundments Derived from Samples Taken in April 1982

	Sampling Locations																					
	Streams													Impoundments								
Parameter/sample	E-1	E-2	E-3	S-1	S-2	S-2	S-3	S-4	WC-1	WC-2	W-1	W-2		1	2	3	4	5	6	7	8	9
Sampling Method*	D	D	D	S	D	S	S	D	D	D	D	D		D	D	D	D	D	D	D	D	D
Density (Org./m²)																						
1	5695	3766	3674	549	8451	377	8468	4777	322	459	505	3261		0	6992	6155	4731	5190	138	965	505	12998
2	15387	1378	2251	785	6071	1754	3325	1883	9186	367	276	5741		0	1288	6063	7165	8543		1010	138	10151
3	18188	92	4271	785	2664	560	5896	2526	6798	459	276	8451		46	13432	14698	2480	459		965	184	7578
Ö	13090	1745	3399	706	5729	897	5896	3062	5435	428	352	5818		15	7237	8972	4792	4731	138	980	276	10242
Diversity (d)																						
1	0.75	1.40	0.71	3.07	0.10	1.59	1.09	1.44	1.38	0.72	1.24	1.28			1.07	0.96	0.85	1.06	0	1.37	0	1.48
2	0.48	1.60	1.33	3.07	0.13	1.22	1.24	2.00	1.95	1.41	0.92	1.37			1.09	1.17	1.31	0.17		1.37	0	2.10
3	0.24	0	1.01	3.41	0.34	1.20	1.13	2.09	0.65	1.36	0.92	0.78		0	0.64	0.66	1.47	1.96		2.07	0	1.49
Ö	0.49	1.0	1.02	3.18	0.19	1.34	1.15	1.84	1.33	1.16	1.03	1.14		0	0.93	0.93	1.21	1.06	0	1.60	0	1.69
No. of Taxa	11	9	7	22	5	8	16	9	8	4	3	7		1	8	8	9	6	1	7	1	13
Community Structure (% Occurrence)																						
Taxon																						
Chironomidae	0.9	17.5	82.0	10.7	98.1	18.0	14.1	45.5	71.8	42.9	47.8	72.4			3.8	19.2	12.3	87.7	48.4	100	37.4	33.6
Oligochaeta		1.8	5.0	3.6	0.8	3.2	0.2	36.0	14.4	50.0	47.8	19.7		100	89.8	78.3	81.3	3.6	39.1		39.5	19.1
Ephemeroptera				20.3		65.2	6.8					7.9					0.9		4.7		16.6	7.0
Trichoptera			0.5	37.1	0.5	0.4	0.5				4.3	0.5										1.4
Ceratopogonidae	94.5	56.1		0.5		0.4	0.2	1.0	8.7	7.1		0.3			1.7	0.6					4.2	14.5
Simulidae				8.6		11.6	76.8															20.0
*D = Ponar Dredge Sample; S = Surber Sample																						

Table 2.8-12: Diatom Proportional Counts (Percent Occurrence) and Occurrence of Other Algae by Sample Location (April 1982)

	STREAMS											IMPOUNDMENTS							
	E-1	E-2	E-3	S-1	S-2	S-3	S-4	WC-1	WC-2	W-1	W-2	1	2	3	4	5	7	8	9
DIATOMS																			
Acnanthes	17.9	1.2	0.3	76.7		14.3	19.7	22.3	2.0	40.3			2.8				4.3	2.6	2.1
Amphora	0.5			0.5				0.3									0.3	1.8	
Cocconeis			0.3	2.4	0.7	4.8	1.7	1.2	11.3	1.9	0.3	1.1			0.4	0.6	0.3	1.4	0.7
Cyclotella			2.1		2.2	1.0	8.2	7.6		0.6				0.3		6.6	6.0	1.0	0.9
Cymatopleura							0.4												
Cymbella	6.3	0.3	0.3	1.9	6.1	2.9	8.2	25.9	7.0	7.8	1.8		7.1	1.3	11.8	3.9	1.4	8.5	13.7
Diatoma		0.6		1.9				6.4	1.0	0.9	21.6		0.7						17.9
Epithemia	1.1						1.3		0.4					12.6	2.1	1.7	2.6	4.4	
Fragilaria	3.3	66.5	0.3	0.5	2.9			0.3					0.7		9.3		0.6		0.2
Gomphonema	14.4	0.3	80.5	3.4	4.3			0.3			7.5		17.3	0.3	1.7	5.8	2.3	9.9	0.7
Gyrosigma									0.4							0.3			
Hantzschia													0.4	0.5	0.4		0.3		
Melosira																	0.6		
Meridion	0.8		0.3				2.1												
Navicula	3.8	2.6	8.2	5.3	15.8	16.2	13.7	9.8	58.6	33.4	47.7		3.2	6.2	5.5	2.5	18.2	21.0	1.2
Nedium	0.3																		
Nitzschia	13.0	6.6	3.8	5.3	65.9	58.1	13.7	15.2	10.6	11.3	19.1		6.0	12.9	7.6	3.6	30.4	12.1	34.4
Rhopalodia									0.4					3.2		0.3	1.4	0.2	
Stauroneia	0.3													0.3				0.4	
Surirella	0.5	0.3	1.0	0.5	0.4	1.9	3.9	1.2	6.6	3.4	0.5		0.7	0.3	2.5	5.8	12.5	1.0	0.2
Synedra	37.8	22.0	2.7	1.5	1.8	1.0	27.0	9.5	2.0	0.3	1.5		60.1	62.2	58.6	69.1	19.0	35.6	27.9
GREEN ALGAE																			
Ceratophylum															x				
Chara															x	x			
Cladophora			x	x	x	x	X	x	x	x	x								
Mougeotia	x	x												x					
Oedigonium															x		x		
Rhizoclonium							X												
Spirogyra	x	x					X	x							x		x		
Zygnema	x	x					X								x		x		
BLUE-GREEN ALGAE																			
Anabaena																	x		

2.8.9 References

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2.9 BACKGROUND NONRADIOLOGICAL CHARACTERISTICS

In order to establish baseline conditions of the commercial scale site and surrounding areas, a preoperational monitoring program was conducted for nonradiological characteristics. Categories chosen for sampling included water, sediment and soils. Wherever possible, sites for radiological and nonradiological samples were the same. **Table 2.9-1** provides a summary of the preoperational monitoring program implemented for the Crow Butte Project.

During the year of 1982 and continuing into 1983, a preoperational nonradiological environmental monitoring program was conducted for the Crow Butte Project. This program was designed to collect baseline environmental data for both the R&D and the commercial scale operations simultaneously. Coordination of these two programs allowed more comprehensive surveys plus availability of regional data for the R&D phase. The results of the R&D project preoperational monitoring are presented in this section. The R&D operational monitoring and the commercial preoperational data that were collected from 1985 through 1987 are also presented in this section.

The nonradiological monitoring program was adapted from the monitoring recommended in USNRC Regulatory Guide 4.14 to provide companion data to the Crow Butte preoperational radiological monitoring program described in **Section 2.10** of this report. Site specific data have been collected from monitor and baseline wells, Squaw Creek that passes through the restricted area, and soils. Other groundwater and impoundment samples were obtained within the License Area. Soils reported here were collected within the License Area and at a greater frequency in Section 19 that contains the present restricted area. All preoperational nonradiological sample points identified in this section are shown in **Figure 2.9-1**. The Sampling locations for the White river are depicted in **Figure 2.2-3.**

2.9.1 Groundwater

In addition to the preoperational data collected as described above, preoperational baseline groundwater quality data have been, and continue to be, collected for all new wellfield units during development but prior to operations. These data are to provide representative pre-operational groundwater quality data and restoration quality as described in CBR's approved license application. Baseline and restoration groundwater quality data for the different mine units are presented in Section 6.1.3 of this application. The groundwater quality parameters are listed in paragraph 10.3 B. of the current license: 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 and zinc. Preoperational baseline groundwater quality data for the CBR site were initially reported in the 1987 *Application and Supporting Environmental Report for USNRC Commercial Source Material License* submitted to the NRC by Ferret of Nebraska, Inc. (FEN 1987). The nonradiological groundwater parameters that were analyzed for are shown in **Table 2.9-2.**

Table 2.9-1: Non-Radiological Preoperational Monitoring Program

Sample Collection					Sample Analysis	
Type of sample	Number	Location	Method	Frequency	Frequency	Type of Analysis
WATER						
Groundwater						
	One from each water supply well	All wells within 1 km of restricted area boundary	Grab	3 Times	Each Sample	Complete Table 2.9-2 list
	One from each well	Selected Regional wells	Grab	3 Times	Each Sample	Same
	One from each DEQ baseline & monitor well	As required by DEQ	Grab	Quarterly	Quarterly	Complete Table 2.9-2 list once; common ions only other quarters
Surface Water						
	One from each pond or impoundment		Grab	Once	Once	Complete Table 2.9-9 list
	Two from. Squaw Creek	One up-stream, one down stream of restricted area	Grab	Quarterly	Quarterly	Complete Table 2.9-9 list once; common ions only other quarters
	Two from White Clay Creek	Upstream and down stream of License Area.	Grab	Four Times	Quarterly	Complete Table 2.9-9 list once; common ions other quarters
	Two from English Creek	Upstream and down stream of License Area	Grab	Four Times	Quarterly	Complete Table 2.9-9 once; common ions other quarters
	Two from Squaw Creek	One upstream and one down stream of restricted area	Grab	Quarterly	Quarterly	Suspended sediment
Water Levels						
	One from each monitor		Electric line	Monthly	Monthly	Map

Table 2.9-1: Non-Radiological Preoperational Monitoring Program

	Sample Collection				Sample Analysis	
Type of sample	Number	Location	Method	Frequency	Frequency	Type of Analysis
	well, baseline well, and selected private wells					
Flow						
	Two from Squaw Creek	One upstream and one down stream of restricted area	Flow	Monthly through 1982; then quarterly	Monthly	Tabular
SOILS						
Surface						
	One each	Six locations in Section 19	Grab	Once	Once	Arsenic, Selenium
	One each.	Nine locations in License Area	Grab	Once	Once	Arsenic, Selenium
	One each	Seven Locations In restricted area	Grab	Once	Once	Vanadium

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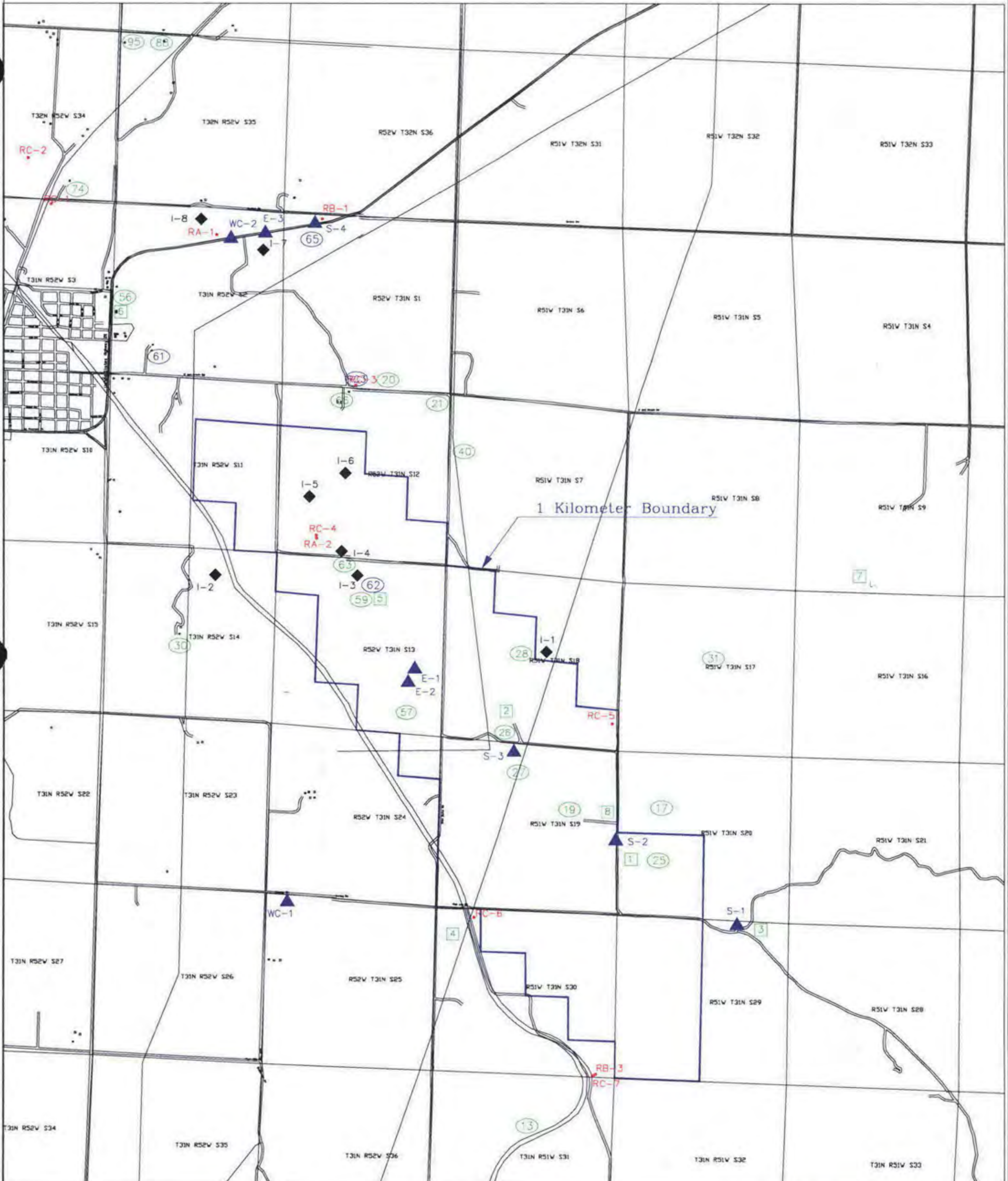
Figure 2.9-1



CROW BUTTE RESOURCES

DAWES COUNTY, NEBRASKA

Preoperational Nonradiological Sampling Points

Prepared By : RG

Drawn By: WB

Date: 10/07

Air Monitoring Station, Radon, Vegetation, Soil, Direct Radiation

Water Supply Wells - Brule Formation

Impoundment Water Sample Location

English Creek Water Sample Location

Squaw Creek Water Sample Location

Regional Baseline Water Wells

CROW BUTTE RESOURCES

0 500 1000 2000 meters

0 1000 3000 5000 feet

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Table 2.9-2 Baseline Groundwater Quality Indicators	
Physical Indicators	
Specific Conductivity	Temperature
Alkalinity	Ph
Total Dissolved Solids	
Common Constituents	
Ammonia	Chloride
Silica	Magnesium
Sodium	Calcium
Nitrate	Total Carbonate
Nitrite	Sulfate
Potassium	
Trace and Minor Elements	
Arsenic	Fluoride
Nickel	Iron
.Selenium	Barium
Lead	Vanadium
Cadmium	Manganese
Zinc	Mercury
Copper	Molybdenum
Radionuclides	
Radium-226	Uranium

Investigations of the groundwater quality and usage for the License Area were made for this report.

The first step was to identify the aquifers present on a regional basis between the White River to the north and the Pine Ridge escarpment to the south. Geologic literature and maps were consulted to determine boundaries of outcropping formations and the local stratigraphy. Electric logs were examined and sand units within the formations identified. The water user survey provided information on which aquifers are currently being tapped for potable water. In some cases potentiometric data were also available.

Existing hydrologic studies were then compared with these findings. A thorough discussion of the groundwater hydrology is found in **Section 2.7.2** of this document.

Water samples were taken from selected representative wells within the License Area and surrounding areas. The objective of this sampling was to characterize the water quality in the mineralized production zone and any overlying aquifer(s). This was accomplished in several ways. Eighteen of the nearby private wells identified in the water user survey were chosen for quarterly sampling during 1982. Sampling continued on a quarterly basis from 1982 and 1983 went to semiannual in 1984 and annual in 1985 and 1986. Their selection was to provide information supplemental to that from wells installed by Wyoming Fuel Company and since taken over by CBR. A majority of the local private wells and all but three of those sampled are completed in shallow Brule sands due to the lower drilling costs and more desirable quality water than that of the deeper Chadron Formation aquifer. **Table 2.9-3** lists the private wells that were sampled to evaluate the local water quality.

Eleven wells originally drilled by WFC and since taken over by CBR expressly for baseline determination were sampled. The well screening interval, total depth and formation in which the baseline wells were completed are listed in **Table 2.9-4**. Four are completed in the Brule Formation and seven in the Chadron Sandstone (production zone).

Sample collection and preservation were performed using standard USEPA methods. Prior to sampling, all field pH and conductivity meters were calibrated using known standards. In some cases, a backup meter was also used to verify readings from the primary instrument. Also prior to sampling 1 to 1.25 casing volumes are removed from the well by pumping. The type pumping systems (submersible, pump jack, etc.) is determined by the depth and recharge characteristics of the well. The specific conductance, pH and temperature are measured periodically during pumping and samples are taken after these parameters have stabilized (typically 1 to 1.25 casing volumes). The preservatives as specified by Handbook for Sampling and Sample Preservation of Water and Wastewater (Report No. USEPA-600/4-82-029) are added to the samples and samples are transported to the lab for analysis.

Table 2.9-3: Private Wells Sampled within and around the License Area

Well Number	Formation	Estimated Depth (ft)	Use
13	Brule	---	Stock
17	Brule	80	Domestic, Stock
19	Brule	80	Stock
25	Brule	75	Domestic, Stock
26	Brule	80	Domestic, Stock
27	Brule	80	Stock
30	Brule	55	Stock
40	Brule	60	Stock
56	Brule	200	Domestic, Stock
57	Brule	25	Domestic, Stock
61	Chadron	280	Domestic, Stock
62	Chadron	470	Industrial Well
63	Brule	100	Domestic
65	Chadron	260	Stock
66	Brule	60	Domestic, Stock
74	Brule	60	Stock
88	Brule	60	Domestic, Stock
95	Brule	100	Domestic, Stock

Notes:
--- = unknown

Table 2.9-4: Baseline Wells Originally Drilled by WFC

Well Number	Formation	Screen Interval (ft)	Depth (ft) to Bottom of Screen Assembly
RA-1	Brule	7 - 27	32
RA-2	Brule	7 - 27	32
RB-1	Brule	100 - 110	115
RB-3	Brule	95 - 115	120
RC-1	Chadron	330 - 350	355
RC-2	Chadron	572 - 592	597
RC-3	Chadron	260 - 270	275
RC-4	Chadron	340 - 360	365
RC-5	Chadron	672 - 692	697
RC-6	Chadron	713 - 733	738
RC-7	Chadron	708 - 718	723

2.9.2 R&D Area Groundwater Quality

Initial baseline and operational samples have been collected from the R&D wellfield and selected monitor wells. **Figure 2.9-2** illustrates the locations of the production zone baseline and overlying aquifer baseline wells, and the monitor wells used during mining.

Table 2.9-4 lists the depth and geologic unit for each baseline well. A summary of the analytical results (Brule and Chadron formations) for the eleven baseline wells drilled by WFC is given in **Table 2.9-5**.

2.9.3 Water Levels

Monthly water level measurements were made on 23 representative wells within the License Area. Of these wells, 12 are completed in the Brule Formation and 11 in the Chadron Formation aquifer. The objective was to determine if seasonal or periodic fluctuation in the piezometric surfaces occurs in the License Area.

Seasonal fluctuations in water level are commonly observed in shallow unconfined aquifers where effects of the hydrologic cycle are more immediate. Decreases occur in response to aquifer discharge to surface water systems during dry periods. Infiltration of precipitation, runoff and excess stream flow will serve to recharge the aquifer. Confined aquifers should exhibit little fluctuation in the piezometric surface except where groundwater withdrawal rates are high and/or seasonal.

Water levels were determined using battery operated instruments. Measurements were recorded together with the date and name of individual taking the readings. Values were then corrected to mean sea level (msl). Selected results are presented in **Figure 2.9-3** and **Figure 2.9-4. Table 2.9-6** lists the depth (screen interval and total well depth) and geologic unit for each baseline well. All of the water level results are listed in **Table 2.9-7** and **Table 2.9-8**.

2.9.4 Surface Water Quality

Samples were collected from Squaw Creek, English Creek, White Clay Creek, the White River and all surface bodies of water within the License Area during preoperational sampling. **Table 2.9-1** outlines the preoperational sampling schedule and the parameters for analysis. The surface water quality parameters that were analyzed for are shown in **Table 2.9-9**. This schedule was begun in 1982 and continued until completed. These preoperational data [radiological and nonradiological] for the Crow Butte site were included in the 1987 application and supporting environmental report for USNRC Source Material License submitted to the NRC by Ferret of Nebraska, Inc. (previous owner) in August, 1987 (FEN 1987). Crow Butte Resources, Inc. continued with the monitoring program from 1987 through the third quarter of 1994. These data were submitted to the NRC via Semiannual Radiological Effluent & Environmental Monitoring Reports (USNRC Materials License SUA 1534. Starting with the fourth quarter of 1994, CBR was only required to monitor for natural uranium and radium-226, so monitoring for preoperational nonradiological parameters ceased.

Figure 2.9-2: R & D Wellfield Water Quality Wells

CBR-011

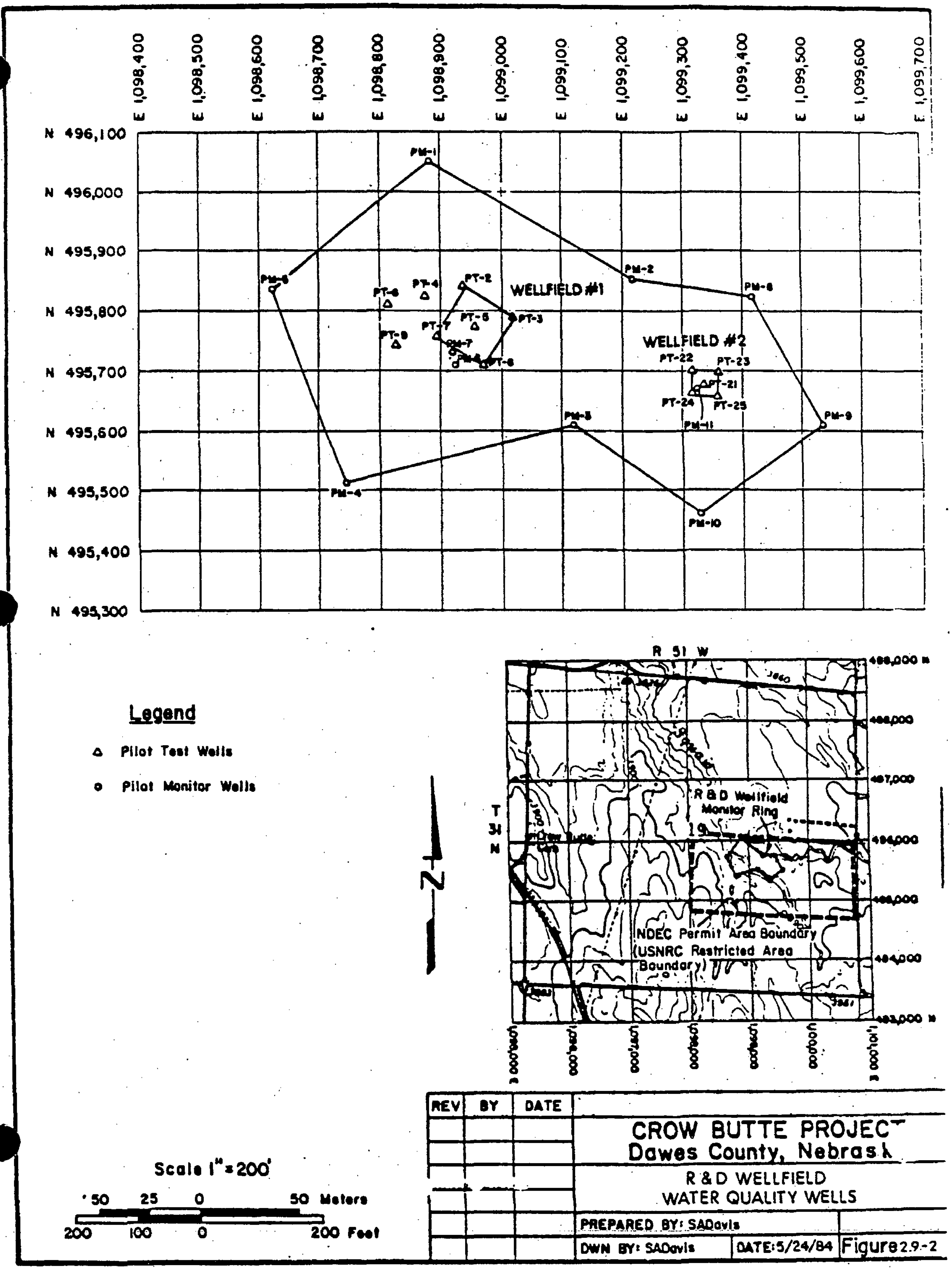

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Table 2.9-5: Aquifer Water Quality Summary

Parameter	Range	Mean
Brule Formation*		
Calcium	7.1 - 98	48
Magnesium	0.3 - 16	6.6
Sodium	12 - 340	104
Potassium	4.1 - 15.9	9.9
Bicarbonate	137 - 627	364
Sulfate	1 - 23	10
Chloride	1.6 - 192	48
Conductance	246 - 1481	714
pH	6.8 - 8.5	7.8
Uranium	0.001 - 0.021	0.0064
Radium-226	0.1 - 3.0	0.7
Chadron Formation*		
Calcium	11 - 41	20
Magnesium	0.8 - 7.2	3.2
Sodium	340 - 540	411
Potassium	7.0 - 19.8	12.4
Bicarbonate	308 - 411	368
Sulfate	254 - 620	407
Chloride	134 - 250	176
Conductance	1500 - 2500	1932
pH	7.6 - 8.7	8.2
Uranium	<0.001 - 2.40	0.092
Radium-226	0.1 - 619	53

* Summary of average values for baseline wells drilled by WFC listed in **Table 2.9-3**.
In mg/L, except pH (units), Ra-226 (pCi/l), and Conductance (umhos).

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Figure 2.9-3: Seasonal Water Level Fluctuations

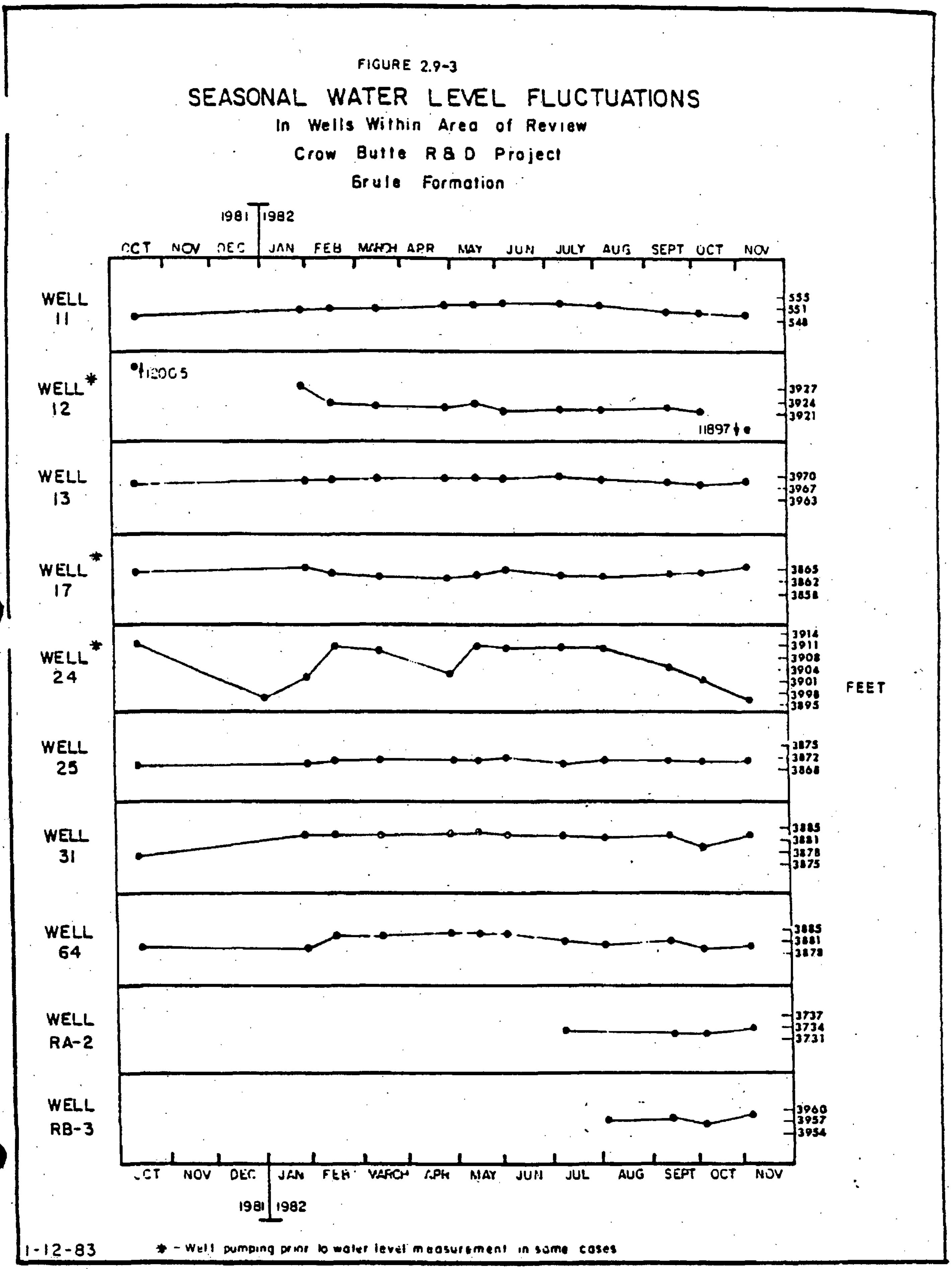

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Figure 2.9-4: Seasonal Water Level Fluctuations

CBR-011

FIGURE 2.9-4

SEASONAL WATER LEVEL FLUCTUATIONS

In Wells Within Area of Review

Crow Butte R & D Project

Chadron Formation

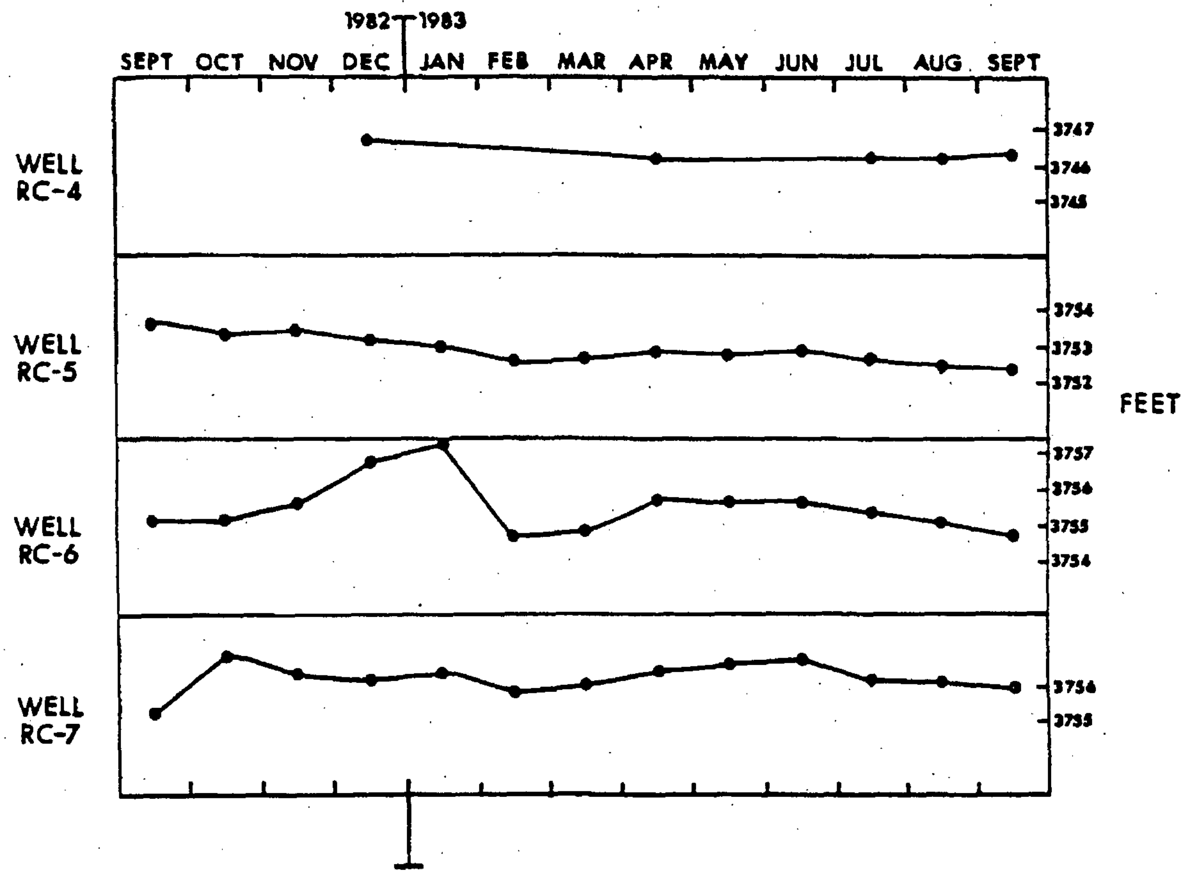

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Table 2.9-6: Water Quality Wells Used for Preoperational and Operational Data

Well Number	Formation	Screen Interval (ft)	Depth to Bottom of Screen Assembly (ft)
OB-1 (PT-4)	Chadron	637.1-647.1; 652.1-657.1	662.1
OB-2 (PT-6)	Chadron	652 – 667	667
Wellfield Domestic	Brule	20 – 60	60
PT-2	Chadron	641 – 656	661
PT-3	Chadron	638 – 648	653
PT-5	Chadron	638 – 653	670
PT-7	Chadron	649 – 664	669
PT-8	Chadron	653 – 668	673
PT-9	Chadron	659 – 674	680.2
PT-21	Chadron	652 – 657	660
PT-22	Chadron	652.5 - 657.5	662.5
PT-23	Chadron	655.5 - 660.5	665.5
PT-24	Chadron	647.1 - 652.1	654.1
PT-25	Chadron	650 – 655	659
PM-1	Chadron	649.5 - 669.5	674.5
PM-2	Chadron	641-651; 661-671	676
PM-3	Chadron	616-626; 631-641; 464-656	661
PM-4	Chadron	641.5-646.5; 654.5-669.5	674.5
PM-5	Chadron	648-658; 668-678; 683-688	693
PM-6	Brule	196 – 211	216
PM-7	Brule	89.5-94.5; 99.5-104.5;	
		109-114; 119.5-124.5	129.5
PM-8	Chadron	631-641; 651-661	666
PM-9	Chadron	633-643; 698-658	663
PM-10	Chadron	619-629; 635-645; 651-661	666
PM-11	Brule	252 – 267	272

Table 2.9-7: Brule Water Levels (in feet above mean sea level)

	1982												1993	
Well	Jan	Feb	Mar	April	May	June	July	August	Sept	Oct	Nov	Dec	April	July
11**	3831.7	3831.5	3831.8	3833.0	3833.0	3833.6	3833.0	3832.6	3831.5	3830.6	3830.3	3830.3	3843.5*	3837.0
12**	3928.0	3924.0	3923.0	3922.7	3923.7	3921.1	3922.1	3921.5	3922.2	3921.3	3903.3*	3918.7	3922.9	3920.0
13	3968.5	3968.7	3968.8	3969.4	3969.6	3969.2	3969.5	3968.9	3968.1	3967.5	3968.1	3968.4	3969.0	3970.0
17	3865.0	3863.5	3863.3	3862.6	3863.6	3864.8	3863.3	3862.8	3863.5	3863.8	3865.3	3864.6	3864.8	3862.8
24**	3902.0	3910.5	3909.0	3903.0	3910.9	3910.5	3910.5	3910.0	3904.7	3901.5	3895.7*	3910.1	3910.4	3911.0
25	3870.0	3870.8	3870.0	3871.0	3871.0	3871.3	3869.5	3870.9	3870.6	3870.5	3870.8	3870.9	3870.1	3871.6
31**	3883.1	3883.1	3883.2	3883.1	3883.3	3883.0	3882.6	3882.3	3882.6	3880.0	3882.3	3882.5	3882.5	3872.3*
64	3882.0	3882.9	3882.6	3883.5	3883.6	3883.8	3881.4	3880.8	3881.5	3880.0	3880.4	3882.0	3884.3	3883.5
	1982				1983									
	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	August	Sept	
RA-2	3737.1	3737.0	3738.5	3737.9	3739.2	3739.1	3739.7	3740.2	3740.9	3741.0	3739.9	3739.2	3738.1	
RB-3	3962.6	3961.2	3963.5	3963.6	3963.8	3963.8	3963.3	3969.7*	3963.7	3963.7	3964.2	3964.1	3964.2	
PM-6	------	3844.9	3844.9	------	3843.5*	3844.5	3844.9	3845.3	3845.5	3846.0	3845.9	3945.9	3845.7	
PM-7	------	3845.7	3845.5	------	3845.9	3845.8	3845.7	3846.1	3846.3	3846.9	3846.7	3846.7	3846.6	

Notes:

* Suspect data

** Well may have been pumping prior to water level measurement

------ = not measured

Table 2.9-8: Chadron Water Levels (in feet above mean sea level)

	1982				1983								
Well	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	August	Sept
62	3748.4	3748.0	3747.2	3746.6	------	------	3746.1	3746.2	------	------	3746.1	3745.8	3745.4
RC-4	------	------	------	3746.7	------	------	------	3746.2	------	------	3746.2	3746.2	3746.3
RC-5	3753.6	3753.4	3753.4	3753.2	3753.0	3752.6	3752.7	3752.9	3752.8	3752.9	3752.7	3752.5	3752.4
RC-6	3755.2	3755.2	3755.7	3756.8	3757.5	3754.7	3754.9	3755.7	3755.6	3755.6	3755.4	3755.2	3754.7
RC-7	3755.2	3756.8	3756.3	3756.2	3756.4	3755.8	3756.0	3756.4	3756.5	3756.7	3756.2	3756.1	3755.9
PM-1	------	3754.5	3754.4	3754.1	3754.3	3754.0	3753.8	3754.0	3754.2	3754.1	3753.8	3753.5	3753.5
PM-4	------	3755.2	3755.2	3754.4	3754.4	3754.1	3754.2	3754.4	3754.8	3754.6	3754.3	3753.9	3754.6
PT-2	------	3747.1*	3747.1*	3754.0	3754.6	3754.3	3754.1	3754.3	3754.5	3754.7	3754.3	3753.9	3753.7
PT-7	------	3755.1	3755.0	3754.2	3754.2	3754.0	3754.0	3754.1	3754.8	3754.6	3754.3	3754.1	3753.9
PT-8	------	3755.5	3755.6	3754.6	3754.4	3754.4	3755.7	3754.4	3754.5	3754.6	3754.2	3753.8	3753.7
PT-9	------	3753.5	3753.5	3754.9	3754.6	3754.6	3754.6	3754.8	3854.8	3754.9	3754.5	3754.3	3754.1

Notes:
* Suspect data
------ = not measured

Table 2.9-9 Baseline Surface Water Quality Parameters	
Physical Indicators	
Specific Conductivity	Temperature
Alkalinity (as $CaCO_3$)	pH
Total Dissolved Solids	Total Suspended Solids
Conductivity	
Common Constituents	
Ammonia – N	Chloride
Silica	Magnesium
Sodium	Calcium
Nitrate – N	Carbonate
Nitrite – N	Bicarbonate
Potassium	Sulfate
Trace and Minor Elements	
Aluminum	Lead
Arsenic	Manganese
Barium	Mercury
Boron	Molybdenum
Cadmium	Nickel
Chromium	Selenium
Cobalt	Vanadium
Copper	Zinc
Fluoride	
Iron	
Radionuclides	
Radium-226	Uranium

Squaw Creek passes through the License Area as it flows towards the White River. Four sampling points located on Squaw Creek were utilized. Locations W-1, W-2 and W-3 on the White River were also part of the commercial preoperational monitoring program.

The stream and river samples were also analyzed for suspended sediment content. Sampling was initiated in 1982 and samples were taken from sites S-1, S-2, S-3 and W-2 (White River) for four quarters in 1982. Sampling continued at sites S-2 and S-3 from 1982 through 1987. Results of the suspended sediment sampling are found in **Table 2.9-10**. Average Squaw Creek suspended sediment ranges from 5.6 to 29.1 mg/L with site S-3 consistently higher in suspended sediments than sites S-1 and S-2.

Table 2.9-10: Suspended Sediment in Flowing Waters of Squaw Creek and White River

	Time Period	Range	Average	Std. Dev.
S-1	1982	5-36	13.5	15.1
S-2	1982 - 1987	<1-24	5.6	5.6
S-3	1982 - 1987	2.7-76	29.1	24.4
W-2	1982	7-190	73.8	80.0

Notes: Results given as Total Suspended Solids in mg/L.

The White River suspended sediment was an average of 74 mg/L for the year period.

Eight impoundments are located within the CSA; I-1 through I-8. Samples were collected and handled in the same manner as described above. Sampling sites were also used for obtaining sediment material for radiometric determinations discussed in **Section 2.7**.

Total suspended solids measurements have not been collected since 1982 and there are no plans to sample in the future.

2.9.5 Stream Flow

Squaw Creek flows through the Crow Butte License Area from east to northwest. The flow rate of this perennial stream was monitored at two locations according to the schedule given in **Table 2.9-1**. In addition, discharge rates of the Squaw Creek above the License Area and the White River were monitored.

Flow was determined using a water current meter. This instrument operated utilizing a propeller driven photo-optical device to measure water velocity. It is a broad range, low threshold instrument. Measurement range is 0-6.1 m/sec (0-20 ft/sec) with an accuracy of ± 1 percent.

Flow rates were determined as follows. First the height of the water at the deepest point and width of water were measured and drawn on the cross-section. Next, the numbers of flow measurements to be taken were determined. If the stream width was less than one meter, then one measurement was taken at a point 0.5 times the width. The depth of measurement was 0.6 times the depth, down from the surface. If the width was greater

than one meter, then three sets of measurements were made at two depths each (USDI, 1981). Data were then analyzed by determining the cross-sectional area of the water and the average flow velocity.

Table 2.9-11 lists the flow rates measured during 1982. An upstream station, S-1 and a White River station, W-2, are included for comparison. The data are shown graphically in **Figure 2.9-5**.

Table 2.9-11: 1982 Stream Discharge Rates (m^3/sec)

Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Squaw Creek 1 (S-1)	.812	1.34	1.38	2.26	2.40	1.34	.918	.106	.600	1.17
Squaw Creek 2 (S-2)	.247	1.02	1.06	1.45	4.52	.282	.247	.071	.282	.459
Squaw Creek 3 (S-3)	.953	1.80	1.62	3.28	1.41	.812	.071	.000	.706	1.34
White River 2 (W-2)	25.0	27.6	31.8	29.8	26.9	21.0	16.3	11.1	28.5	20.2

A representative of the Nebraska Department of Natural Resources (NDNR) reported that the agency was not aware of any additional flow data collected for Squaw Creek and English Creek (T. Hayden 2009).

2.9.6 Soils

Soils samples were collected to determine baseline concentrations of selected elements in the different soil types. Nine samples were collected in the License Area. Six locations were chosen within and nearby Section 19 to provide background information on where the commercial process facility will be located and where maximum surface disturbance will occur (**Figure 2.9-6**). Seven sites were also sampled in the proposed restricted area (**Figure 2.9-7**). At the plant and pond locations, another set of samples were obtained before commercial construction and also after topsoil removal and excavation is complete.

Material collected for nonradiological analysis was in the form of surface samples. These were collected as follows: A two-meter transect was laid out in either a north-south or east-west direction at the desired location. Points along this line were situated at 0, 0.67, 1.33 and 2 meters. At each point soil was removed from a 5 to 7.6 cm (2 to 3 in.) diameter circular area to a depth of 5 cm (2 in.).

Three trace elements were chosen for consideration in this sampling. Arsenic, selenium and vanadium are commonly associated with uranium ore deposits. This is especially true in roll-front type deposits where halos of metal sulfides and other reduced compounds occur at the "nose" or in front of the uranium mineralization. When leaching takes place during mining, varying concentrations of companion compounds will be solubilized. Thus, a surface spill of leach solution might contain small amounts of these three elements. The leach solution will also contain uranium and radium-226. The baseline uranium and radium-226 levels in the soil are found in **Section 2.10**.

Figure 2.9-5: Stream Discharge Rates

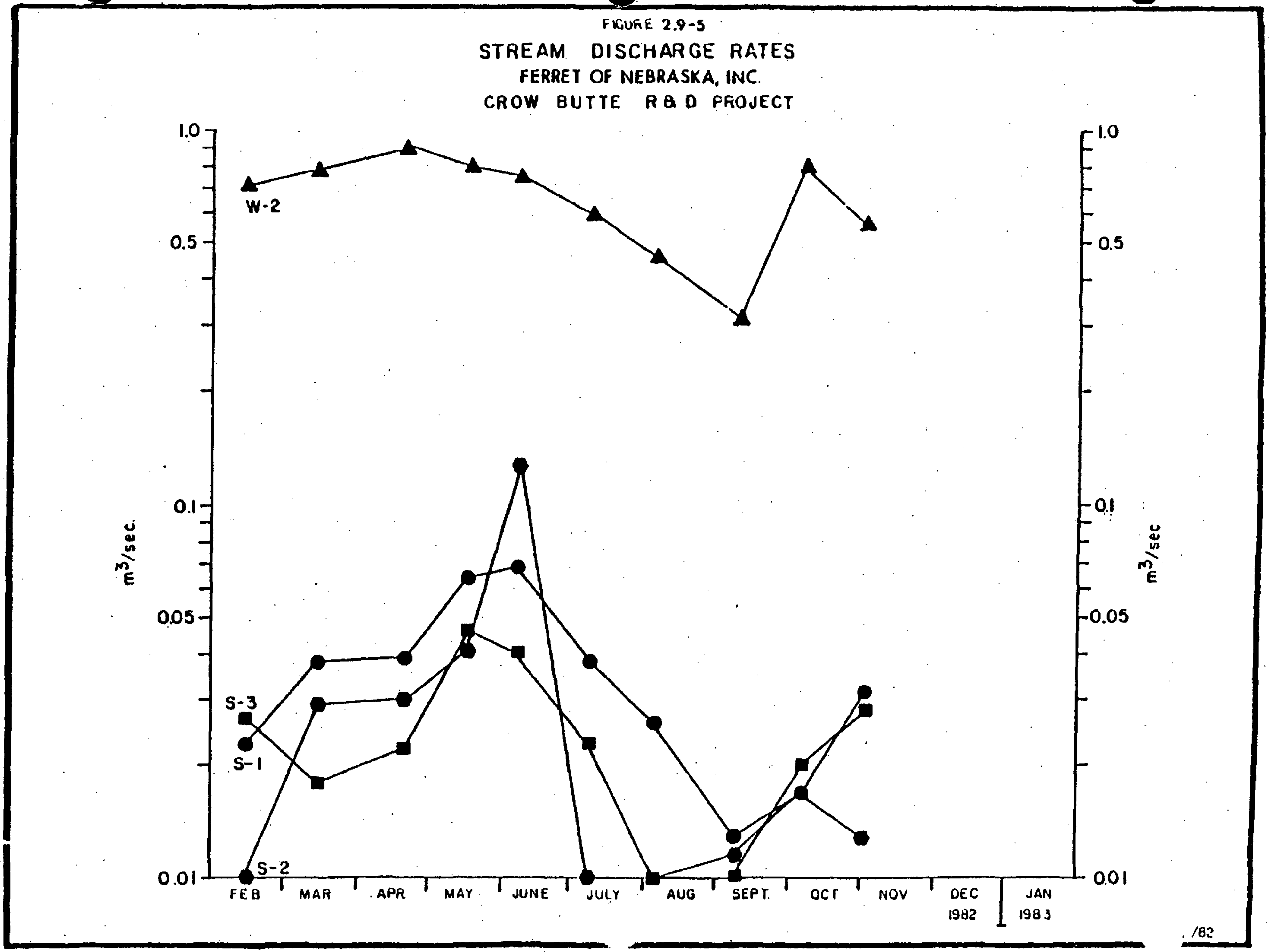

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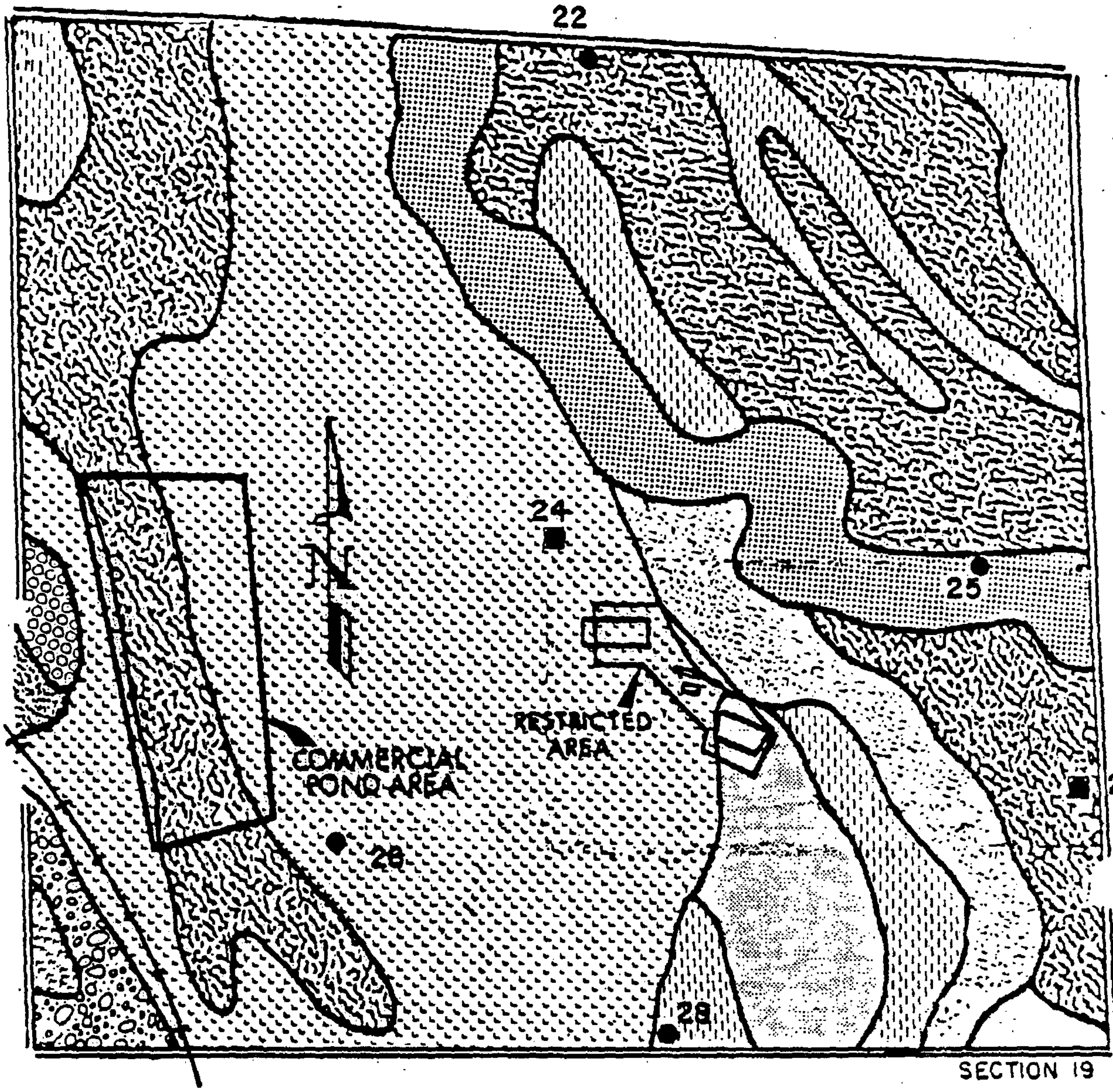
Figure 2.9-6: Soil Sample Location



AcD2	Alliance silt loam, 3 to 9% slopes, eroded	
BuD2	Busher loamy very fine sand, 5 to 9% slopes, eroded	
BuF	Busher loamy very fine sand, 9 to 20% slopes	
BxF	Busher and Tassel loamy very fine sands, 5 to 20% slopes	
JvD	Jayem and Vetal loamy very fine sands, 5 to 9% slopes	
Sn	Sandy alluvial land	
SvF	Sarben and Vetal loamy very fine sands, 9 to 30% slopes	
SyF	Schamber soils, 3 to 30%	
TaF	Tassel soils, 3 to 30% slopes	
VeC	Vetal and Bayard soils, 1 to 5% slopes	

● - Surface Sample Site

METERS: 400 200 0 400
FEET: 1250 750 250 0 1250

REV	BY	DATE	FERRET OF NEBRASKA, INC. CROW BUTTE PROJECT Dawes County, Nebraska
			SOIL SAMPLE LOCATION
			PREPARED BY: F.E.N.
			DWN BY: J C — DATE: 8/87 — FIGURE 2.9-6

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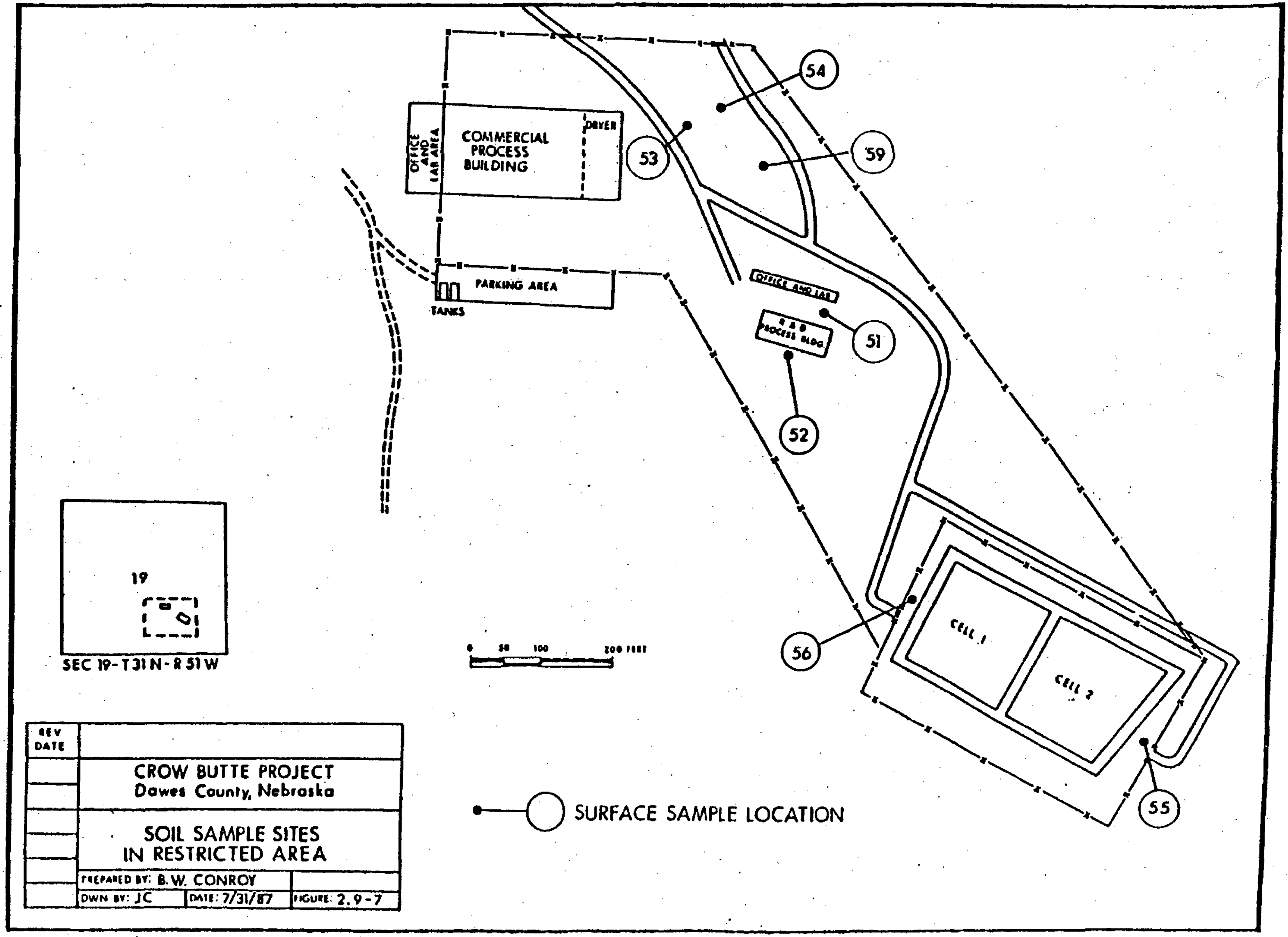
Figure 2.9-7: Soil Sample Sites in Restricted Area



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Samples from the License Area and the specific samples from Section 19 (**Figure 2.9-6**) were analyzed for arsenic and selenium and the samples from the proposed restricted area (**Figure 2.9-7**) were analyzed for vanadium.

Results of the soil sampling are found in **Table 2.9-12** and **Table 2.9-13**. As can be seen from the data in **Table 2.9-12** the arsenic concentration ranges from 0.59 µg/g to 3.30 µg/g and the selenium concentration ranges from <0.01 µg/g to 0.06 µg/g. There does not appear to be any relationship between the soil type and the levels of these elements. The vanadium analyses shown in **Table 2.9-13** indicates that the vanadium levels in the restricted area are very consistent with a range of 22 to 29 µg/g.

Table 2.9-12: Soils Analysis Results License Area and Section 19

Sample Site	Soils Map Unit	Sample Date	Arsenic (µg/g)	Selenium (µg/g)
2	Sarben	7/24/82	0.59	<0.01
5	Keith	7/23/82	1.10	0.04
6	Keith	7/23/82	1.00	0.03
10	Rosebud	7/23/82	1.00	0.03
11	Rosebud	7/24/82	0.80	0.03
13	Jayem	7/23/82	0.80	0.03
15	Duroc	7/24/82	0.70	0.06
19	Sarben	7/24/82	0.88	0.03
22	Vetal	7/24/82	0.88	<0.01
24	Busher	7/24/82	1.00	0.03
24	Sandy Alluvial	7/24/82	0.64	0.04
26	Busher	7/24/82	0.99	0.01
27	Vetal	7/24/82	0.72	0.05
28	Jayem	7/24/82	0.94	0.03
49	Sarben	7/23/82	3.30	0.04

Notes: See soils map in Section 2.7 for further information on soils map unit.

Table 2.9-13: Soils Analysis Results in Restricted Area

Sample Site	Sample Date	Vanadium (µg/g)
51	12/15/82	22
52	12/15/82	28
53	12/15/82	22
54	12/15/82	27
55	12/15/82	27
56	12/15/82	29
59	12/15/82	26

Soils develop over long periods of time and contain elements that are in equilibrium with the established chemical environment. Several factors govern solubility and stability of elements in soils. These include pH, drainage status, organic content, sulfate content, etc. In addition, many studies have pointed out there is no absolute correlation between the total concentration of an element in the soil and its uptake by plants. However, uptake of

arsenic, selenium, and vanadium by plants depends highly on the chemical form and availability of the elements and upon the plant species.

2.9.7 References

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3 DESCRIPTION OF FACILITY

Production of uranium by in-situ leach (ISL) mining techniques involves a mining step and a uranium recovery step. Mining is accomplished by installing a series of injection wells through which the leach solution is pumped into the ore body. Corresponding production wells and pumps promote flow through the ore body and allow for the collection of uranium-rich leach solution. Uranium is removed from the leach solution by ion exchange, and then from the ion exchange resin by elution. The leach solution can then be reused for mining purposes. The elution liquid containing the uranium (the "pregnant" eluant) is then processed by precipitation, dewatering, and drying to produce a transportable form of uranium.

The current Crow Butte ISL facility is capable of processing in excess of 5,000 gallons per minute (gpm) of leach solution. This 5,000 gpm flow does not include the restoration flow. On October 17, 2006, CBR submitted a request to the USNRC to increase the permitted flow to 9,000 gpm, excluding restoration flow. USNRC approval is pending.

The current facilities use a number of state of the art unit operations to recover uranium from the recovered leach solutions. These unit operations consist of:

- Ion exchange
- Uranium elution
- Uranium precipitation
- Uranium dewatering
- Uranium drying and packaging

3.1 SOLUTION MINING PROCESS AND EQUIPMENT

3.1.1 Ore Body

In the current Licensed Area, uranium is recovered by in-situ leaching from the Chadron Sandstone at a depth that varies from 400 feet to 800 feet. The overall width of the mineralized area varies from 1000 feet to 5000 feet. The ore body ranges in grade from less than 0.05 to greater than 0.5 percent U_3O_8, with an average grade estimated at 0.20 percent U_3O_8.

The Basal Chadron Sandstone in the area is approximately 40 feet thick. A detailed description of the geology can be found in **Section 2.6**, Geology and Seismology.

3.1.2 Well Construction and Integrity Testing

Three well construction methods and appropriate casing materials are used for the construction and installation of production and injection wells.

3.1.2.1 Well Materials of Construction

The well casing material used is polyvinyl chloride (PVC), which is 4.5 inch SDR-17 (or equivalent). The PVC casing joints normally have a length of approximately 20 feet each. With SDR-17 PVC casing, each joint is connected by a water tight o-ring seal which is located with a high strength nylon spline.

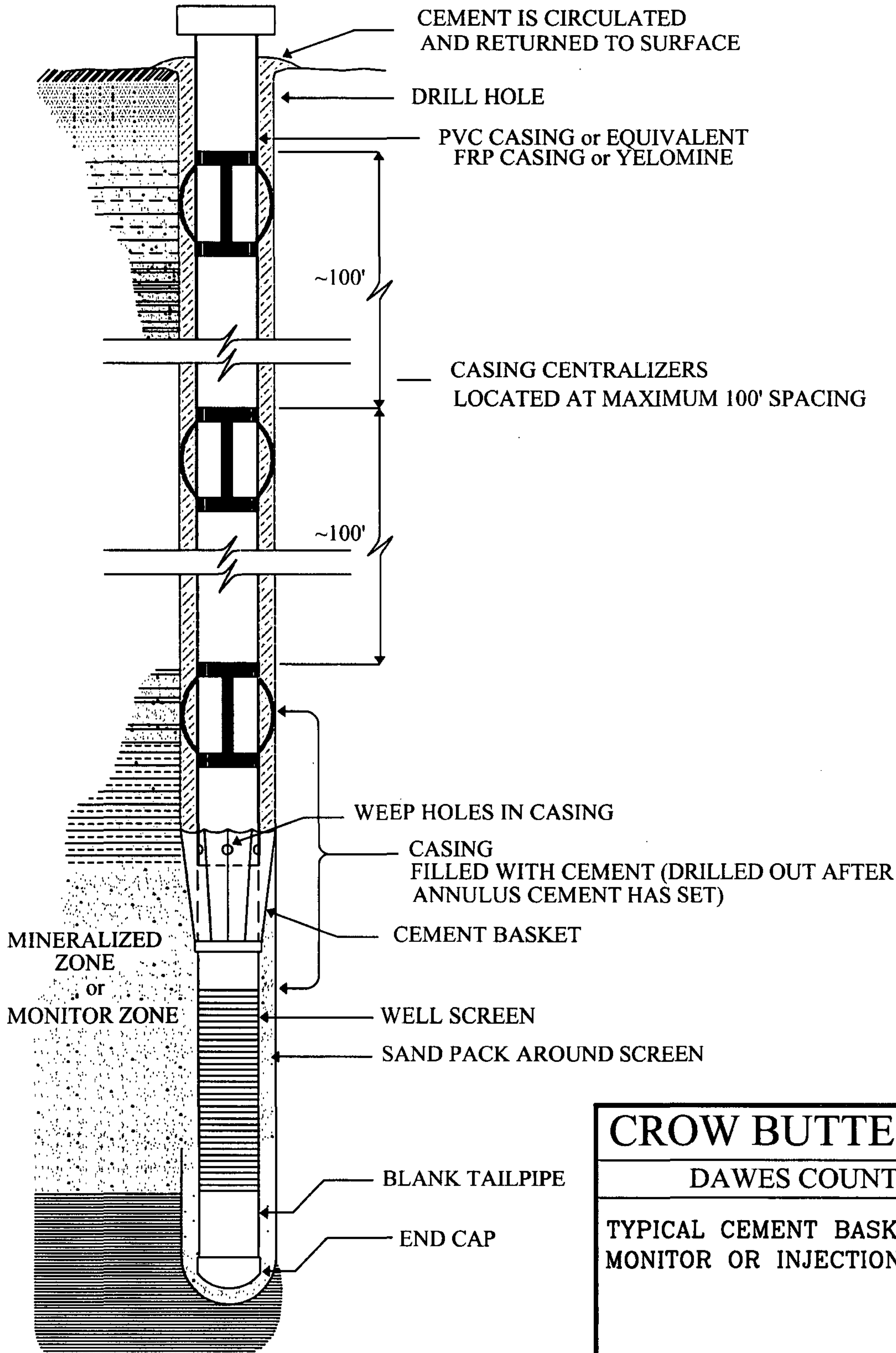
3.1.2.2 Well Construction Methods

Pilot holes for monitor, production, and injection wells are drilled to the top of the target completion interval with a small rotary drilling unit using native mud and a small amount of commercial drilling fluid additive for viscosity control. The hole is logged, reamed, casing set, and cemented to isolate the completion interval from all other aquifers. Three well construction methods are described and are not necessarily described in the order of their preferred use. Any of the methods are appropriate for monitor wells and has been approved by the NDEQ under the UIC Permit.

- **Method No. 1**, shown in **Figure 3.1-1**, involves the setting of an integral casing/screen string. The method consists of drilling a hole, geophysically logging the hole to define the desired screen interval, and reaming the hole, if necessary, to the desired depth and diameter. Next, a string of casing with the desired length of screen attached to the lower end is placed into the hole. A cement basket is attached to the blank casing just above the screen to prevent blinding of the screen interval during cementing. The cement is pumped down the inside of the casing to a plug set just below the cement basket. The cement passes out through weepholes in the casing and is directed by the cement basket back to the surface through the annulus between the casing and the drill hole. After the cement has cured sufficiently, the residual cement and plug are drilled out, and the well is developed by airlifting or pumping.
- **Method No. 2**, shown in **Figure 3.1-2**, uses a screen telescoped down inside the cemented casing. As in the first method, a hole is drilled and geophysically logged to locate the desired screen interval. The hole is then reamed if necessary only to the top of the desired screen interval. Next a string of casing with a plug at the lower end and weep holes just above the plug is set into the hole. Cement is then pumped down the casing and out the weep holes. It returns to the surface through the annulus. After the cement has cured, the residual cement in the casing and plug are drilled out, with the drilling continuing through the desired zone. The screen with a packer and/or shale traps is then telescoped through the casing and set in the desired interval. The packer and/or shale traps serve to hold the screen in the desired position while acting as a fluid seal. Well development is again accomplished by airlifting or pumping. Minor variations from these procedures may be used as conditions require.

Figure 3.1-1

Well Completion Method No. 1



CROW BUTTE RESOURCES

DAWES COUNTY, NEBRASKA

TYPICAL CEMENT BASKET COMPLETION FOR MONITOR OR INJECTION/PRODUCTION WELLS

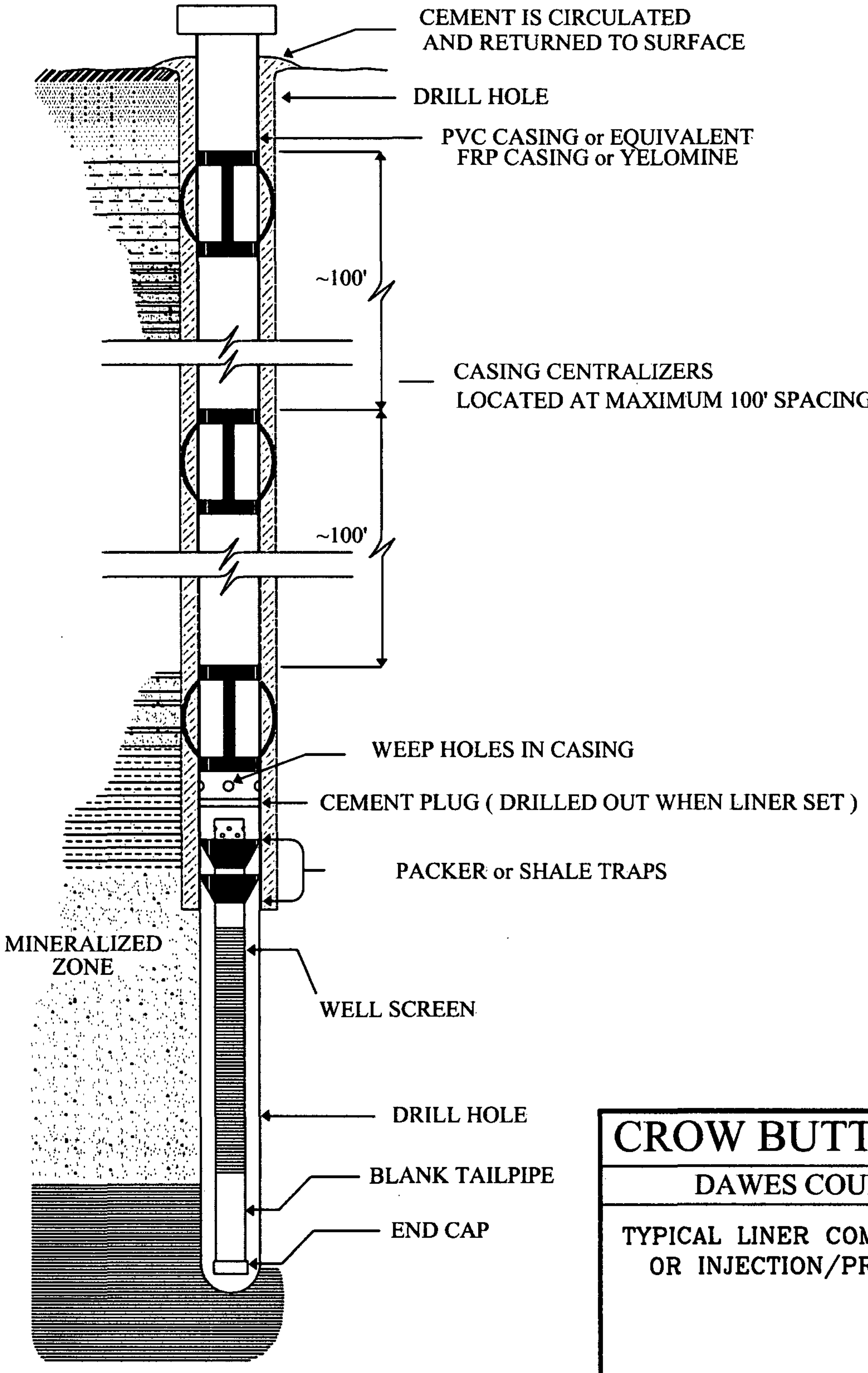
Prepared By : WB

Drawn By: WB

Date: 1/07

Figure 3.1-2

Well Completion Method No. 2



CROW BUTTE RESOURCES	
DAWES COUNTY, NEBRASKA	
TYPICAL LINER COMPLETION FOR MONITOR OR INJECTION/PRODUCTION WELLS	
Prepared By : WB	
Drawn By: WB	Date: 1/07

- **Method No. 3,** shown in **Figure 3.1-3**, is similar to methods one and two. The casing is cemented in place the entire length, and, after the cement grout has cured, the casing and grout are cut away to expose the interval to be mined or monitored. A screen is then telescoped into the open interval.

Casing centralizers, located at a maximum 100-foot spacing, are run on the casing to ensure it is centered in the drill hole and that an effective cement seal is provided. The purpose of the cement is to stabilize and strengthen the casing and plug the annulus of the hole to prevent vertical migration of solutions. The volume of cement used in each well is determined by estimating the volume required to fill the annulus and ensure cement returns to the surface. In almost all cement jobs, returns to the surface are observed. In rare instances, however, the drilling may result in a larger annulus volume than anticipated and cement may not return all the way to the surface. In these cases the upper portion of the annulus will be cemented from the surface to backfill as much of the well annulus as possible and stabilize the wellhead. This procedure is performed by placement of a tremie hose from the surface as far down into the annulus as possible. Cement is pumped into the annulus until return to the surface is observed.

A well completion report is completed on each well. This data is kept available on-site for review.

3.1.2.3 Well Development

Following well construction (and before baseline water quality samples are taken for restoration and monitoring wells), the wells must be developed to restore the natural hydraulic conductivity and geochemical equilibrium of the aquifer. All wells are initially developed immediately after construction using airlifting or other accepted development techniques. This process is necessary to allow representative samples of groundwater to be collected. Well development removes water and drilling fluids from the casing and borehole walls along the screened interval. The primary goal for well development is to allow formation water to enter the well screen.

The well is developed until the water produced is clear. This can be determined visually or with a turbidimeter. During the final stages of initial development, water samples will be collected in a transparent or translucent container and visually examined for turbidity (i.e., cloudiness and visual suspended solids). Development is continued until clear, sediment-free formation water is produced.

When the water begins to become clear, the development will be temporarily stopped and/or the flow rate will be varied. Sampling and examination for turbidity will be continued. When varying the development rate no longer causes the sample to become turbid, the initial development will be deemed complete.

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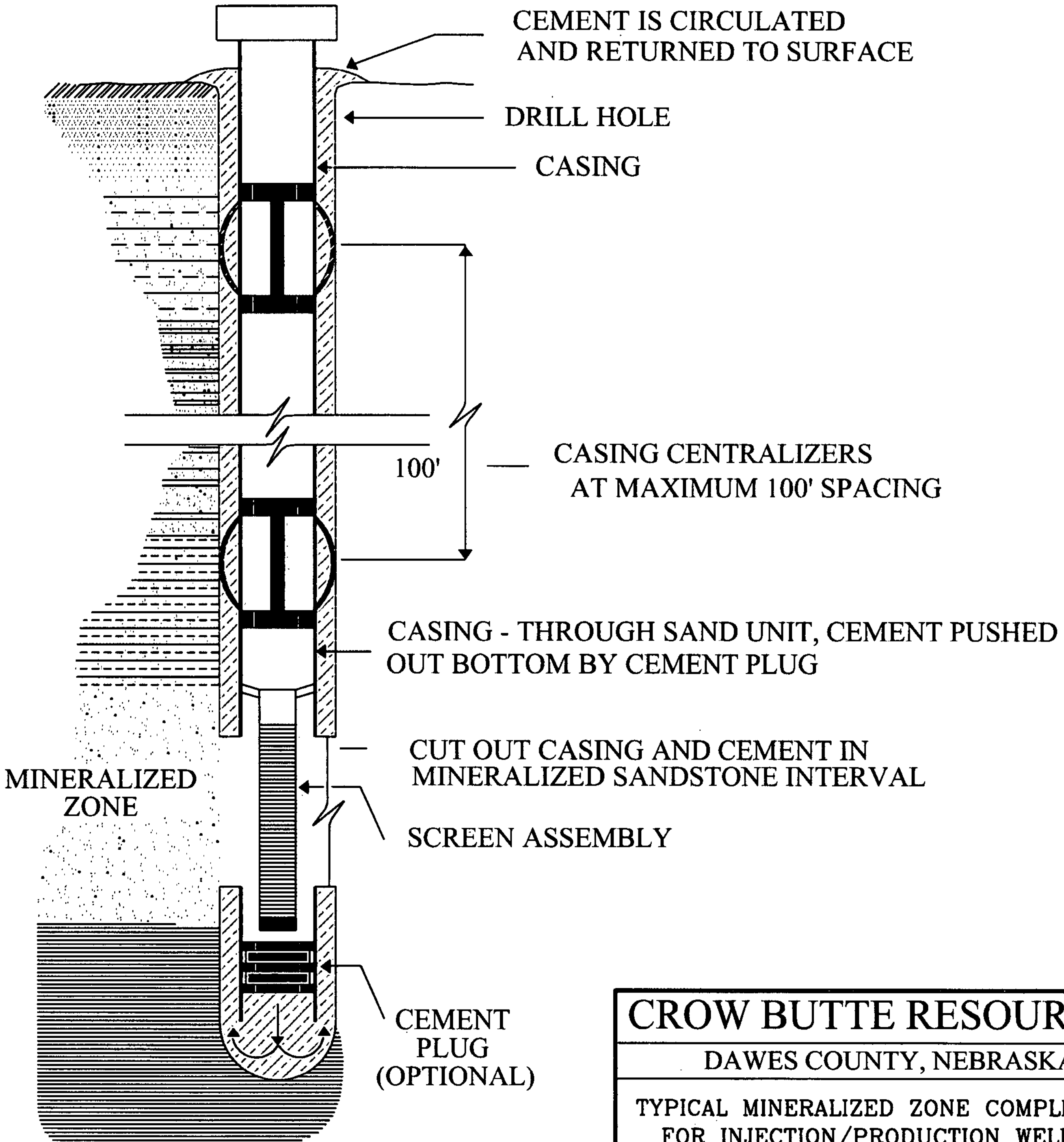
Figure 3.1-3

Well Completion Method No. 3



CROW BUTTE RESOURCES	
DAWES COUNTY, NEBRASKA	
TYPICAL MINERALIZED ZONE COMPLETION FOR INJECTION/PRODUCTION WELLS	
Prepared By : WB	
Drawn By: WB	Date: 1/07

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Before obtaining baseline samples from monitor or restoration wells, the well must be further developed to ensure that representative formation water is available for sampling. Final development is performed by pumping the well or swabbing for an adequate period to ensure that stable formation water is present. Monitoring for pH and conductivity is performed during this process to ensure that development activities have been effective. The field parameters must be stable at representative formation values before baseline sampling will begin.

3.1.2.4 Well Integrity Testing

Field-testing of all (i.e., injection, production, and monitor) wells is performed to demonstrate the mechanical integrity of the well casing. This mechanical integrity test (MIT) is performed using pressure-packer tests. Every well will be tested after well construction is completed before it can be placed in service, after any workover with a drill rig or servicing with equipment or procedures that could damage the well casing, at least once every five years, and whenever there is any question of casing integrity. To assure the accuracy of the integrity tests, periodic comparisons are made between the field pressure gauges and a calibrated test gauge. The MIT procedures have been approved by the NDEQ and are currently contained in the Safety Health Environment and Quality (SHEQ) Program Volume III, *Operating Manual.*

The following general MIT procedure is used:

- The test consists of placement of one or two packers within the casing. The bottom packer is set just above the well screen and the upper packer is set at the wellhead. The packers are inflated with nitrogen and the casing is pressurized with water to 125 percent of the maximum operating pressure (i.e., 125 psi).
- The well is then "closed in" and the pressure is monitored for a minimum of twenty minutes.
- If more than ten percent of the pressure is lost during this time period, the well has failed the integrity test. When possible, a well that fails the integrity testing will be repaired and the testing repeated. If the casing leakage cannot be repaired or corrected, the well is plugged and reclaimed as described in **Section 6.0.**

CBR submits all integrity testing records to the NDEQ for review after the initial construction of a mine unit or wellfield. Test results are also maintained on site for regulatory review.

3.1.3 **Wellfield Design and Operation**

The Crow Butte Mine Unit map, which shows the layout of the mine units and water well withdrawal points, is depicted in **Figure 3.1-4**. The mine schedule is shown in **Figure 1.7-2. Table 3.1-1** shows the history of mining operations to date.

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FIGURE 3.1-4

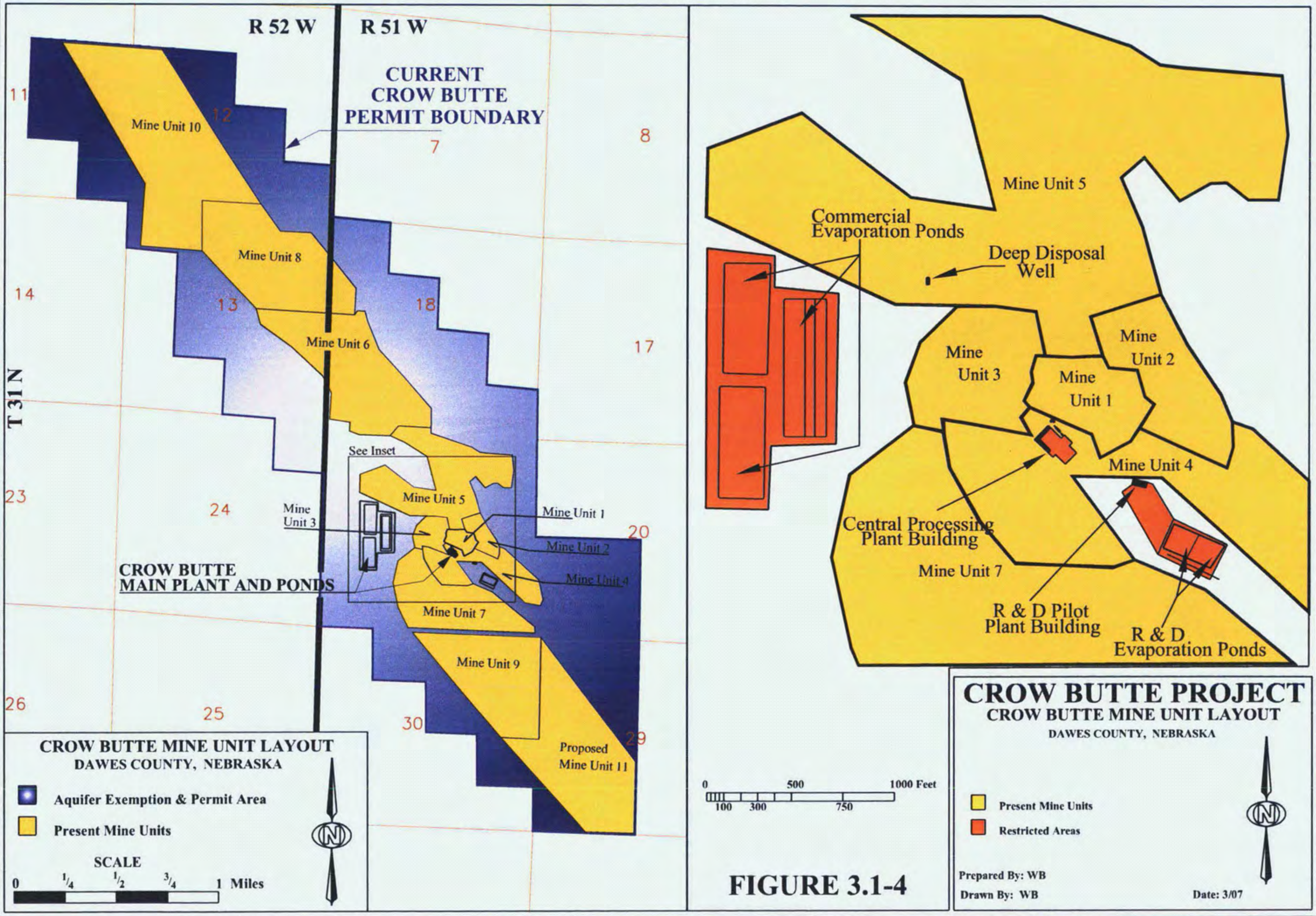


FIGURE 3.1-4

the process building are distributed to the individual wells. **Table 3.1-2** shows the current number of wellfield houses by Mine Unit. The injection and production manifold piping from the existing process facility to these wellfield houses is PVC, high-density polyethylene with butt welded joints or equivalent. In the wellfield house, injection pressure is monitored on the injection trunk lines. Oxygen is added to the injection stream in the wellfield house, and all injection lines off of the injection manifold are equipped with totalizing flowmeters that are monitored in the Control Room. Production solutions returning from the wells to the production manifold are also monitored with a totalizing flowmeter. All pipelines are leak tested and buried prior to production operations.

Table 3.1-1: Mine Unit Status

Mine Unit	Production Initiated	Current Status
Mine Unit 1	April 1991	Groundwater Restored; Reclamation Underway
Mine Unit 2	March 1992	Groundwater restoration
Mine Unit 3	January 1993	Groundwater restoration
Mine Unit 4	March 1994	Groundwater restoration
Mine Unit 5	January 1996	Groundwater restoration
Mine Unit 6	March 1998	Production
Mine Unit 7	July 1999	Production
Mine Unit 8	July 2002	Production
Mine Unit 9	October 2003	Production
Mine Unit 10	August 2007	Production
Mine Unit 11	Pending	Under construction

Table 3.1-2: Wellfield Houses by Mine Unit

Mine Unit	Wellfield Houses
Mine Unit 1	2
Mine Unit 2	3
Mine Unit 3	3
Mine Unit 4	5
Mine Unit 5	7
Mine Unit 6	7
Mine Unit 7	6
Mine Unit 8	8
Mine Unit 9	7
Mine Unit 10	9
Mine Unit 11	5

The wellfield injection/production pattern currently employed is based on a hexagonal seven spot pattern, which is modified as needed to fit the characteristics of the ore body. The standard production cell for the seven spot pattern contains six injection wells surrounding a centrally located recovery well.

The cell dimensions vary depending on the formation and the characteristics of the ore body. The injection wells in a normal pattern are expected to be between 65 feet and 150 feet apart. A typical wellfield layout is shown in **Figure 3.1-5**. The wellfield is a repeated seven spot design, with the spacing between production wells ranging from 65 to 150 feet. Other wellfield designs include alternating single line drives.

All wells are completed so they can be used as either injection or recovery wells, so that wellfield flow patterns can be changed as needed to improve uranium recovery and restore the groundwater in the most efficient manner. During operations, leaching solution enters the formations through the injection wells and flows to the recovery wells. Within the perimeter monitor well ring, prior to stability monitoring, more water is produced than injected to create an overall hydraulic cone of depression in the production/restoration zone. Under this pressure gradient the natural groundwater movement from the surrounding area is toward the wellfield providing additional control of the leaching solution movement. The difference between the amount of water produced and injected is the wellfield "bleed." The minimum bleed rate will be a nominal 0.5 percent of the total wellfield production rate and the maximum bleed rate typically approaches 1.5 percent. Bleed is adjusted as necessary to ensure that the perimeter ore zone monitor wells are influenced by the cone of depression until stability monitoring described in Section 6.1.5 begins.

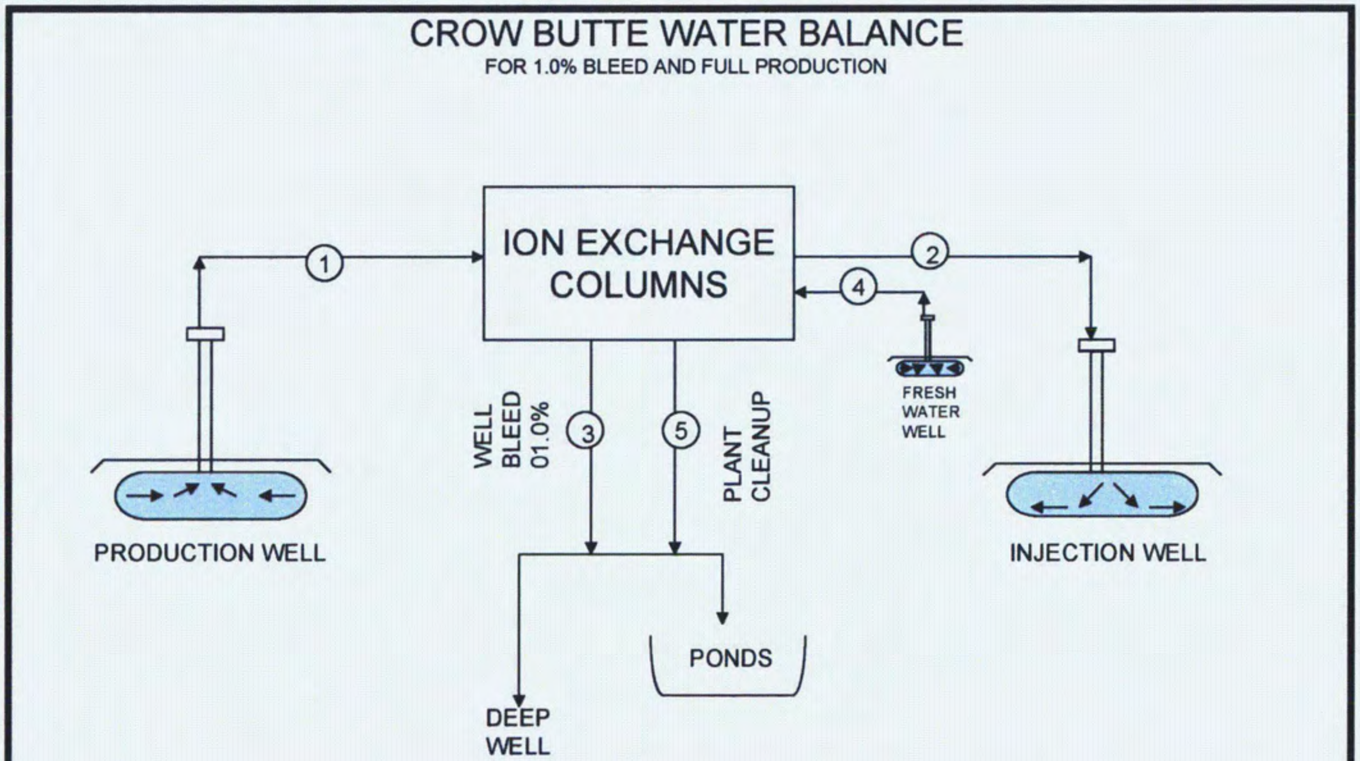
Monitor wells will be placed in the Chadron Formation and in the first significant water-bearing Brule sand above the Chadron Formation. All monitor wells will be completed by one of the three methods discussed above and developed prior to leach solution injection. The development process for monitor wells includes establishing baseline water quality before the initiation of mining operations.

Injection of solutions for mining will be at a rate of 9,000 gpm with a 0.5 percent to 1.0 percent production bleed stream. Production solutions returning from the wells to the production manifold will be monitored with a totalizing flowmeter. All pipelines and trunklines will be leak tested and buried prior to production operations.

A water balance for the current CBR Facility is shown on **Figure 3.1-6.** The liquid waste generated at the plant site will be primarily the production bleed which, at a maximum scenario, is estimated at 1.0 percent of the production flow. At 9,000 gpm, the volume of liquid waste would be 47,304,000 gallons per year. CBR adequately handles the liquid waste through the combination of deep disposal well injection and evaporation ponds.

Figure 3.1-5: Typical Wellfield Layout

Figure 3.1-6: Water Balance for Crow Butte Facility



STREAM #	1	2	3	4	5
SOLUTION GPM*	9000	8910	90	2	2

*BALANCE IS NOMINAL FOR A 1.0% BLEED. ACTUAL BALANCE MAY VARY ACCORDINGLY.

An Industrial Groundwater Use Permit application was submitted to NDEQ by Ferret of Nebraska, Inc. (predecessor to CBR) in 1991. The application states that water levels in the City of Crawford (approximately three miles northwest of the mining area) could potentially be impacted by approximately 20 feet by consumptive withdrawal of water from the Basal Chadron Sandstone during mining and restoration operations (based on a 20-year operational period). No impact to other users of groundwater is expected because (1) there is no documented existing use of the Basal Chadron in the CBR License Area, and (2) the potentiometric head of the Basal Chadron Sandstone in the CBR License Area ranges from approximately 10 to more than 50 feet above ground surface.

Because the Basal Chadron Sandstone (production zone) is a deep confined aquifer, surface water impacts are expected to be minimal. A detailed analysis of potential surface water impacts is provided in **Section 7.4**.

Further, the geologic and hydrologic data presented in **Sections 2.6** and **2.7**, respectively, demonstrate that (1) the occurrence of uranium mineralization is limited to the Basal Chadron Sandstone, and (2) the Basal Chadron is isolated from underlying and overlying sands. Hence, the mining operations are expected to impact water quality only in the Basal Chadron Sandstone, and restoration operations will be conducted in the Basal Chadron following completion of mining. Groundwater is expected because (1) there is no documented existing use of the Basal Chadron in the License Area, and (2) the potentiometric head of the Basal Chadron Sandstone within the License Area ranges from approximately 10 to more than 50 feet below ground surface.

Based on a bleed of 0.5 percent to 1.5 percent which has been successfully applied in the current Licensed Area, the potential impact from consumptive use of groundwater is expected to be minimal. In this regard, the vast majority (e.g., on the order of 99 percent) of groundwater used in the mining process will be treated and re-injected (**Figure 3.1-6**). Potential impacts on groundwater quality due to consumptive use outside the License Area are expected to be negligible.

To generally quantify the potential impact of drawdown due to mining and restoration operations, the following assumptions were used:

- Mining/restoration life: 20 years
- Average net consumptive use: 112 gpm
- Location of pumping centroid: Center of Section 19
- Observation radius: 3.4 miles radially from centroid of pumping
- Formation transmissivity: 330 ft^2/d
- Formation thickness: 40 ft
- Formation hydraulic conductivity: 9.0 ft/d
- Formation storativity: 9.0×10^{-5}

The data were evaluated using a Theis semi-steady state analytical solution, which includes the following assumptions:

- The aquifer is confined and has apparent infinite extent;
- The aquifer is homogeneous and isotropic, and of uniform effective thickness over the area influenced by pumping;
- The piezometric surface is horizontal prior to pumping;
- The well is pumped at a constant rate;
- No recharge to the aquifer occurs;
- The pumping well is fully penetrating; and,
- Well diameter is small, so well storage is negligible.

As discussed in **Section 5.8.8** of this application, an extensive water-sampling program will be conducted prior to, during and following mining operations at the Crow Butte facility to identify any potential impacts to water resources of the area.

The groundwater monitoring program will continue to be designed to establish baseline water quality prior to mining at each mine site; detect excursions of lixiviant either horizontally or vertically outside of the production zone; and determine when the production zone aquifer has been adequately restored following mining. The program will include sampling of monitoring wells and private wells within and surrounding the License Area to establish pre-mining baseline water quality. Water quality sampling will be continued throughout the operational phase of mining for detection of excursions. Water quality sampling will also be conducted during restoration, including stabilization monitoring at the end of restoration activities, to determine when baseline or otherwise acceptable water quality has been achieved.

During operation, the primary purpose of the wellfield monitoring program will continue to be to detect and correct conditions that could lead to an excursion of lixiviant or detect such an excursion, should one occur. The techniques employed to achieve this objective include monitoring of production and injection rates and volumes, wellhead pressure, water levels and water quality.

Monitoring of production (extraction) and injection rates and volumes enable an accurate assessment of water balance for the wellfields. A bleed system results in less leach solution being injected than the total volume of fluids (leach solution and native groundwater) being extracted. A bleed of 0.5 percent to 1.5 percent is maintained during production. Maintenance of the bleed will cause an inflow of groundwater into the production area and prevent loss of leach solution.

Injection pressures are monitored in the wellhouse at the manifold with an audible and visible alarm monitored 24 hours per day, seven days per week in the control room. The alarms are set to prevent pressure in excess of 100 psi at the wellhouse manifold, below

the 125psi integrity test pressure. Due to line losses, pressures at the wellheads remain below that which is monitored at wellhouse manifold.

Each new production well (extraction and injection) will continue to be pressure tested to confirm the integrity of the casing prior to being used for mining operations. Wells that fail pressure testing will be repaired or cemented and replaced as necessary.

Water level measurements will continue to be routinely performed in the production zone and overlying aquifer. Sudden changes in water levels within the production zone may indicate that the wellfield flow system is out of balance. Flow rates would be adjusted to correct this situation. Increases in water levels in the overlying aquifer may be an indication of fluid migration from the production zone. Adjustments to well flow rates or complete shut down of individual wells may be required to correct this situation. Increases in water levels in the overlying aquifer may also be an indication of casing failure in a production, injection or monitor well. Isolation and shut down of individual wells can be used to determine the well causing the water level increases.

To ensure the leach solutions are contained within the designated area of the aquifer being mined, the production zone and overlying aquifer monitor wells will continue to be sampled once every two weeks as discussed in **Section 5.8.8**.

3.1.4 Process Description

Uranium solution mining is a process that takes place underground, or in-situ, by injecting lixiviant (leach) solutions into the ore body and then recovering these solutions when they are rich in uranium. The chemistry of solution mining involves an oxidation step to convert the uranium in the solid state to a form that is easily dissolved by the leach solution. Hydrogen peroxide (H_2O_2) or gaseous oxygen (O_2) is typically used as the oxidant because both revert to naturally occurring substances. Carbonate species are also added to the lixiviant solution in the injection stream to promote the dissolution of uranium as a uranyl carbonate complex.

The reactions representing these steps at a neutral or slightly alkaline pH are:

Oxidation:

$$UO_{2\,(solid)} + H_2O_{2\,(in\ solution)} \longrightarrow UO_{3\,(at\ solid\ surface)} + H_2O$$

$$UO_{2\,(solid)} + \tfrac{1}{2}\,O_{2\,(in\ solution)} \longrightarrow UO_{3\,(at\ solid\ surface)}$$

Dissolution:

$$UO_3 + 2\,HCO_3^{-1} \longrightarrow UO_2(CO_3)_2^{-2} + H_2O$$

$$UO_3 + CO_3^{-2} + 2HCO_3^{-1} \longrightarrow UO_2(CO_3)_3^{-4} + H_2O$$

The principal uranyl carbonate complex ions formed as shown above are uranyl dicarbonate, $(UO_2)\,(CO_3)_2^{-2}$, (UDC), and uranyl tricarbonate $(UO_2)\,(CO_3)_3^{-4}$, (UTC). The relative abundance of each is a function of pH and total carbonate strength.

Solutions resulting from the leaching of uranium underground is recovered through the production wells and piped to the processing plant for extraction. The uranium recovery process utilizes the following steps:

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

The process flow sheet for the above steps is shown in **Figure 3.1-7**.

3.1.4.1 Uranium Extraction

Recovery of uranium takes place in the ion exchange columns. The uranium bearing leach solution enters the column and as it passes through, the uranium complexes in solution are loaded onto the IX resin in the column. This loading process is represented by the following chemical reaction:

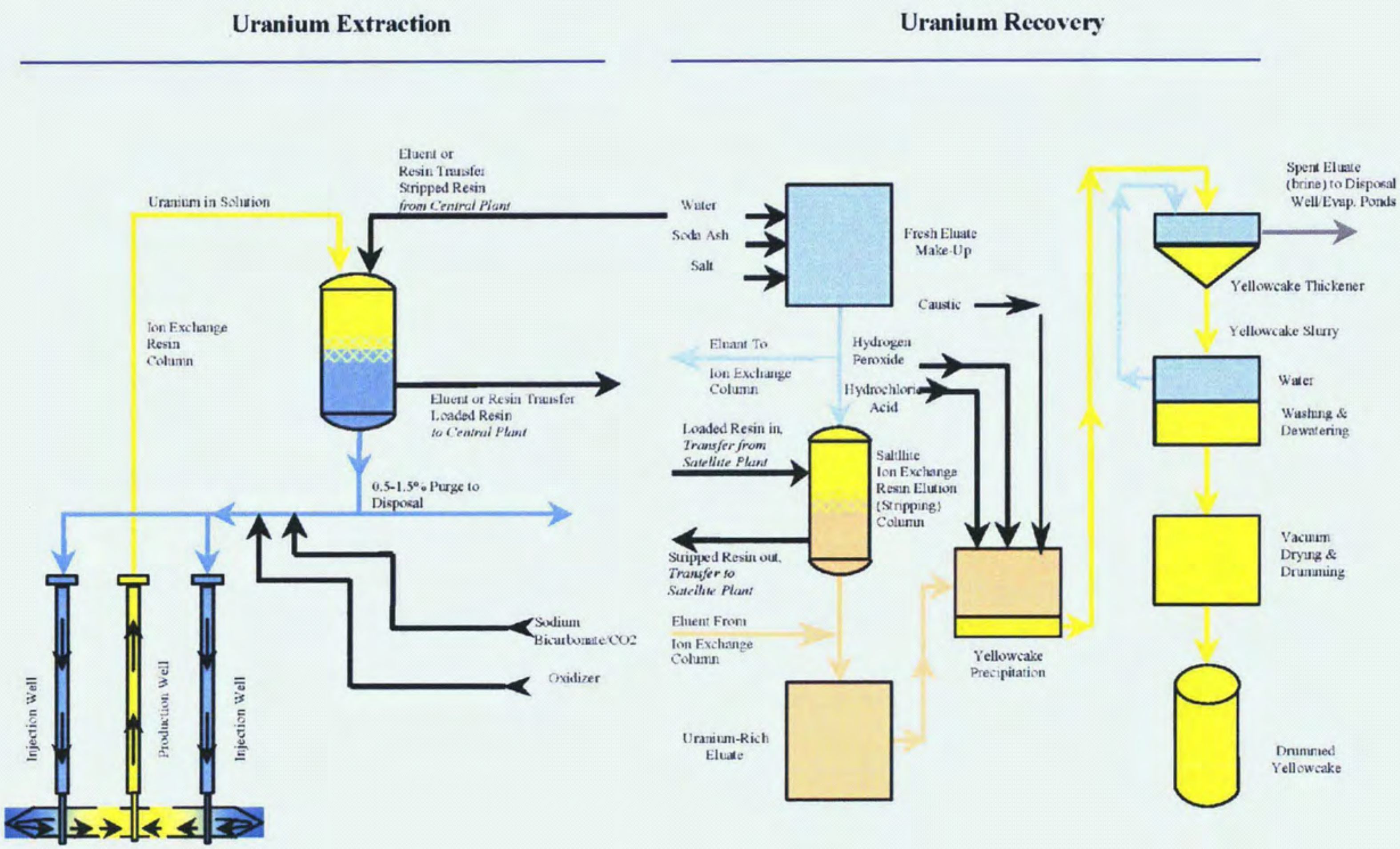
$$2\ R\ HCO_3 + UO_2(CO_3)_2^{-2} \text{--->} R_2UO_2(CO_3)_2 + 2HCO_3^{-1}$$

$$2\ RCl + UO_2(CO_3)_2^{-2} \text{--->} R_2UO_2(CO_3)_2 + 2Cl^-$$

$$R_2SO_4 + UO_2(CO_3)_2^{-2} \text{--->} R_2UO_2(CO_3)_2 + SO_4^{-2}$$

As shown in the reaction, loading of the uranium complex results in simultaneous displacement of chloride, bicarbonate or sulfate ions.

Figure 3.1-7: Process Flow Sheet for Central Plant and/or Satellite Plant



The now barren leach solution passes from the IX columns to be reinjected into the formation. The solution is refortified with sodium and carbonate chemicals, as required, and pumped to the wellfield for reinjection into the formation. The typical lixiviant concentration and composition is shown in **Table 3.1-3**.

Table 3.1-3: Typical Lixivant Concentration and Composition

Species	Range	
	Low	High
Na	≤ 400	6000
Ca	≤ 20	500
Mg	≤ 3	100
K	≤ 15	300
CO_3	≤ 0.5	2500
HCO_3	≤ 400	5000
Cl	≤ 200	5000
SO_4	≤ 400	5000
U_3O_8	≤ 0.01	500
V_2O_5	≤ 0.01	100
TDS	≤ 1650	12000
pH	≤ 6.5	10.5

* All values in mg/L except pH (units).

Note: The above values represent the concentration ranges that could be found in barren lixiviant or pregnant lixiviant and would include the concentration normally found in "injection fluid".

3.1.4.2 Elution

Once the majority of the ion exchange sites on the resin in an IX column are filled with uranium, the column is taken off stream. (In the current main process plant, there are eight IX columns. In each train, leach solution passes sequentially through the columns). The loaded resin is then stripped of uranium in place through an elution process based on the following chemical reaction:

$$R_2UO_2(CO_3)_2 + 2Cl^- + CO_3^{-2} \text{ ---> } 2\,RCl + UO_2(CO_3)_2^{-2}$$

During the elution process, the pregnant eluant is transferred to the precipitation tank and intermediate eluant is stored in a tank for use during the next elution cycle.

After the uranium has been stripped from the resin, the resin is rinsed with a solution containing sodium bicarbonate. The rinse may also be performed with raw water or with water from another source. This rinse removes the high chloride eluant physically entrained in the resin and partially converts the resin to bicarbonate form. In this way, chloride ion buildup in the leach solution can be controlled.

3.1.4.3 Precipitation

When a sufficient volume of pregnant eluant is held in storage it is acidified to destroy the uranyl carbonate complex ion. The solution is agitated to assist in removal of the resulting CO_2. The decarbonization can be represented as follows:

$$UO_2(CO_3)_3^{-4} + 6H^+ \longrightarrow UO_2^{++} + 3\ CO_2\uparrow + 3H_2O$$

Sodium hydroxide (NaOH) is added to raise the pH to a level conducive for precipitating pure crystals. Hydrogen peroxide is then added to the solution to precipitate the uranium according to the following reaction:

$$UO_2^{++} + H_2O_2 + 2H_2O \longrightarrow UO_4 \bullet 2H_2O + 2H^+$$

The precipitated uranyl peroxide slurry is pH adjusted, allowed to settle, and the clear solution decanted. The decant solution is recirculated back to the barren makeup tank, sent to fresh salt brine makeup, or sent to waste. The thickened uranyl peroxide is further dewatered and washed. The solids discharge is either sent to the dryer for drying before shipping or is sent to storage for shipment as slurry to a licensed recovery or converting facility.

3.1.5 Process Wastes

The operation of the Crow Butte Facility has several sources of liquid and solid wastes. These sources, and associated methods of handling, are discussed in **Section 4** (Effluent Control Systems). A summary of major process waste streams is provided below.

3.1.5.1 Air Emissions

Airborne emissions from yellowcake drying are maintained at a minimum by a vacuum drying system. It is only radon gas that is mobilized during process operations and vented to the atmosphere.

3.1.5.2 Liquid Wastes

The operation of the process plant results in two primary sources of liquid waste, a production bleed and an eluant bleed. The production bleed stream is continuously withdrawn from the recovered lixiviant stream at a rate between 0.5 to 1.5 percent of the total volume of recovered lixiviant. The production bleed stream is taken following the recovery of the uranium by ion exchange and has the same chemical characteristics as the lixiviant. The eluant bleed stream is currently produced at a rate of approximately 5 to 10 gpm. The eluant bleed waste stream is managed by reuse in the plant or disposal in existing ponds and/or by deep well injection. The production bleed waste stream is managed by a combination of evaporation pond and deep disposal well injection.

3.1.5.3 Solid Waste

Solid waste generated at the CBR Facility consists primarily of spent resin, resin fines, empty reagent containers, miscellaneous pipe and fittings, and domestic trash. The solid waste is segregated based on whether it is clean or has the potential for contamination with 11(e).2 byproduct materials.

Byproduct material generated at the CBR Facility consists of wastes such as filters, personal protective equipment (PPE), spent resin, piping, etc. All byproduct material is disposed of at a licensed facility approved for disposal of 11.e(2) byproduct material. All other non-byproduct solid waste is disposed of in an approved landfill. There is no on-site disposal of these materials.

Septic system solid waste is generated in a septic system. Solids generated during periodic cleanouts of the septic tank are disposed of by companies or individuals licensed by the State of Nebraska.

3.1.5.4 Hazardous Waste

To date, CBR has only generated universal hazardous waste such as waste oil and batteries. Waste oil is disposed of by a licensed waste oil recycler. The CBR Facility is currently classified as a Conditionally Exempt Small Quantity Generator (CESQG).

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3.2 CENTRAL PLANT, SATELLITE PLANT, WELLFIELDS, AND CHEMICAL STORAGE FACILITIES – EQUIPMENT USED AND MATERIAL PROCESSED

3.2.1 Process Plant Equipment

A general arrangement for the current main processing facility is presented in **Figure 3.2-1**. The recovery plant equipment can be placed in one of the following unit operations:

- Ion Exchange
- Filtration
- Lixiviant injection
- Elution/precipitation
- Dewatering/drying

The ion exchange system consists of eight up-flow and six down-flow ion exchange columns. The uranium loading process is continuous but the elution process is operated on a batch process. The loaded up-flow columns are eluted in place; the down-flow loaded resin is moved across a screen deck for washing before being eluted in a separate elution column.

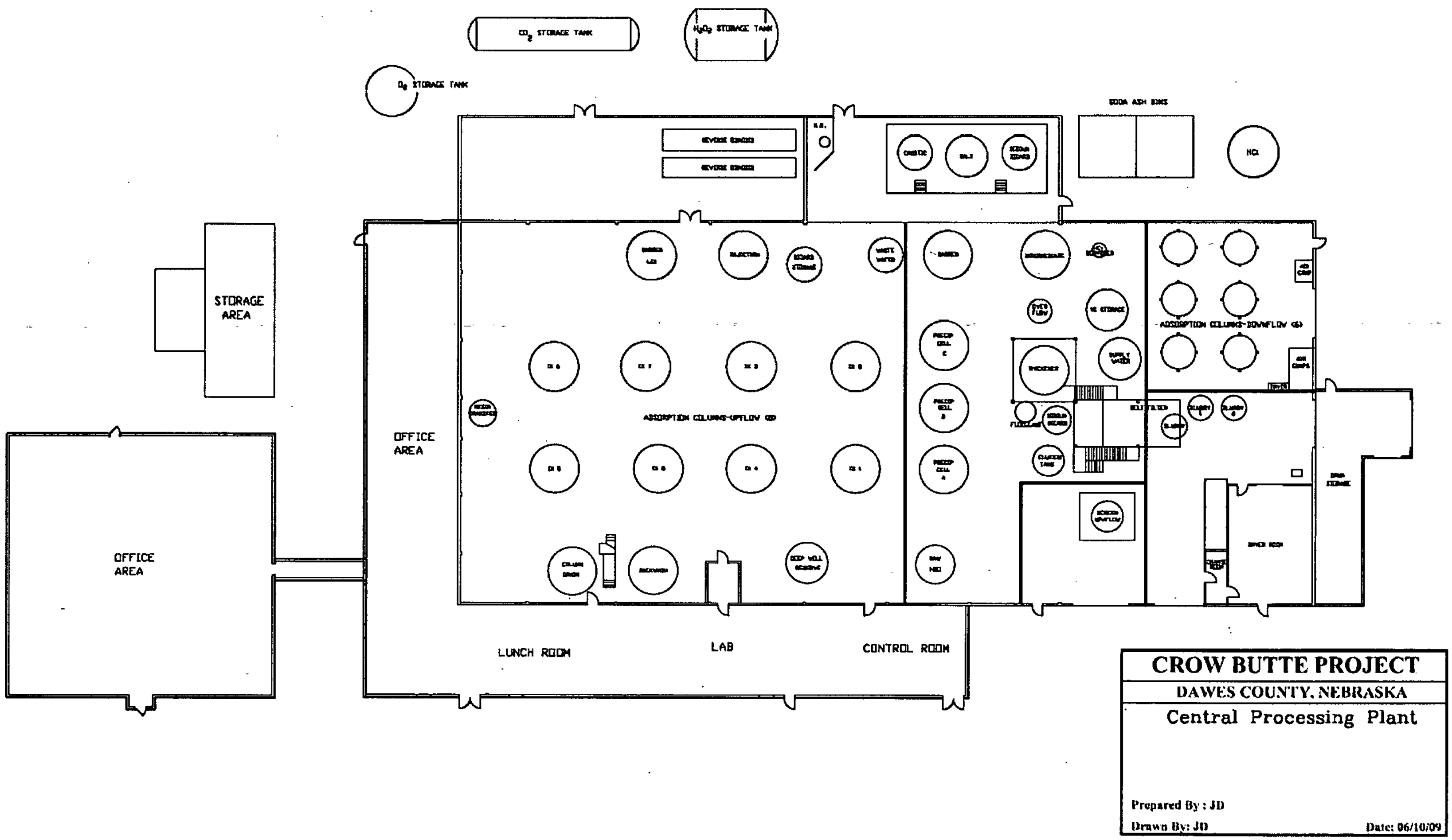
The up-flow injection filtration system consists of backwashable filters, with an option of installing polishing filters downstream. The down-flow system utilizes screens to prevent resin loss, and the resin itself acts as an injection filter, with an option of installing polishing filters downstream.

The up-flow lixiviant injection system consists of the injection surge tanks and the injection pumps. The tanks are fabricated out of FRP, and the injection pumps are centrifugal. The down-flow injection system depends on the down-hole submersible pumps to push through the sealed down-flow system and reinject the lixiviant. There is an option for in-line centrifugal booster pumps as needed to maintain pressures.

The elution/precipitation circuit consists of the barren eluant tanks and the acidizer/precipitator tanks. The barren eluant tanks and the precipitation tanks are constructed of FRP. The eluant is pumped from the barren eluant tanks to the ion exchange column that is in the elution mode. After the resin is eluted, the pregnant eluant is transferred to the acidizer/precipitator where the uranium is precipitated.

The areas in the processing plant where fumes or gases are generated are discussed in **Section 5.8**. Process tanks are vented for radon, O_2 and CO_2 removal. Building ventilation in the process equipment area is accomplished by the use of an exhaust system. This exhaust system draws fresh air in from ventilators and helps sweep radon, which can accumulate near the floor of the building, out to the atmosphere.

Figure 3.2-1: Central Processing Plant



3.2.2 Chemical Storage Facilities

Chemical storage facilities at the CBR Facility include both hazardous and non-hazardous material storage areas. Bulk hazardous materials, which have the potential to impact radiological safety, are stored outside and segregated from areas where licensed materials are stored. Other non-hazardous bulk process chemicals (e.g., sodium carbonate) that do not have the potential to impact radiological safety are stored in a designated area.

3.2.2.1 Process Related Chemicals

Process-related chemicals stored in bulk at the CBR Facility include carbon dioxide, hydrogen peroxide, oxygen, sodium hydroxide, hydrochloric acid, sodium carbonate, sodium bicarbonate, sodium chloride and sodium sulfide. Operating procedures, safety precautions and hazards associated with the handling and use of process-related chemicals are discussed in CBR's SHEQMS Volume V Industrial Safety Manual. CBR maintains current material safety data sheets (MSDSs) for each of the process-related chemicals onsite, and these sheets are available upon request.

- **Carbon Dioxide** - Carbon dioxide is stored at the CBR Facility where it is added to the lixiviant. Carbon dioxide serves as a pH buffer to keep oxidized uranium carbonate in solution.

  Carbon dioxide is a suffocating agent and may cause nausea, respiratory problems and asphyxia in a confined area. It is a slightly toxic, nonflammable, colorless and odorless gas, with a slightly pungent taste. It is soluble in water, ethanol and acetone. It is an acidic oxide and reacts with water to form carbonic acid, and it reacts with alkalis to produce carbonates and bicarbonates.

- **Hydrogen Peroxide** – Hydrogen peroxide (50% aqueous solution) is stored at the CBR Facility where it is added to the lixiviant. It serves as an oxidant used during the precipitation phase of uranium and can be used in place of oxygen. This phase of the process is described in Section 3.1.4.3. Hydrogen peroxide is a clear, colorless liquid that is soluble in water. It is a strong oxidizer capable of oxidizing uranium mineralization and killing some forms of well fouling bacteria. It can be corrosive to eyes, nose, throat and lungs, may cause skin irritation, and may cause irreversible tissue damage to the eyes including blindness. Hydrogen peroxide is not a stable compound; and as it decomposes, it generates oxygen and water, which cause an increase in the volume of product present. The storage container is vented to allow gaseous oxygen to escape as the hydrogen peroxide breaks down. The chemical is not allowed to become trapped in a closed vessel, valve or pipe, and this is accomplished through venting.

- **Oxygen** - Oxygen is also typically stored at the plant, or within wellfield areas, where it is centrally located for addition to the injection stream in each wellhouse. Since oxygen readily supports combustion, fire and explosion are the principal hazards that must be controlled. The oxygen storage facility is located a safe distance from the CBR plant and other chemical storage areas for isolation. The

storage facility has been designed to meet industry standards in NFPA-50 (NFPA 1996). Oxygen is added to the lixiviant used for extraction of uranium forming UO_3.

Oxygen service pipelines and components must be clean of oil and grease since gaseous oxygen will cause these substances to burn with explosive violence if ignited. All components intended for use with the oxygen distribution system are properly cleaned using recommended methods in CGA G-4.1 (CGA 2000). The design and installation of oxygen distribution systems is based on CGA-4.4 (CGA 1993).

The design locations of the carbon dioxide and oxygen storage tanks are shown on **Figure 3.2-1**.

- **Sodium Hydroxide** – Sodium hydroxide is used at the CBR Facility for pH adjustment during the uranium precipitation phase. The sodium hydroxide raises the pH to a level conducive for precipitating pure crystals. This phase of the process is described in Section 3.1.4.3. Sodium hydroxide is in the form of a fine granular, nonflammable, solid or a whitish liquid. It is stable under ordinary conditions of use and storage. It is very hygroscopic, and can slowly pick up moisture from the air and react with carbon dioxide from air to form sodium carbonate. Sodium hydroxide is a strong irritant, with effects from inhalation of dust or mist varying from mild irritation to serious damage of the upper respiratory tract, depending on the severity of exposure. Symptoms may include sneezing, sore throat or runny nose. Severe pneumonitis may also occur.

- **Hydrochloric Acid** – Hydrochloric acid (HCl) is used for pH adjustment during the uranium precipitation phase at the CBR Facility. The HCl acidifies the pregnant eluant in order to destroy the uranyl carbonate complex ion. HCl is highly corrosive, and the inhalation of vapors can cause coughing, choking, inflammation of the nose, throat, and can cause pulmonary edema, circulatory failure and death. It is very hazardous in with regard to skin contact (corrosive, irritant and permeator), eye contact (irritant, corrosive) and ingestion. It is a colorless liquid with a pungent odor, and is infinitely soluble.

  As part of the SHEQMS Program, a risk assessment was completed to recognize potential hazards and risks associated with chemical storage facilities (and other processes), and to mitigate those risks to acceptable levels. The risk assessment process identified HCl as the most hazardous chemical with the greatest potential for impacts to chemical and radiological safety. The HCl storage and distribution system at the Central Plant (**Figure 3.2-1**) has a maximum capacity of approximately 6,000 gallons. Strict unloading procedures are utilized to ensure that safety controls are in place during the transfer of HCl. Process safety controls are also in place at the Central Plant where HCl is added to the precipitation circuit. Since precipitation is not performed at CBR satellite

facilities, the use and storage of concentrated HCl will not be necessary in these areas.

- **Sodium Carbonate** – Sodium carbonate is stored at the CBR Facility and, when combined with CO_2 to form sodium bicarbonate, keeps oxidized uranium in solution. Sodium carbonate is used with carbon dioxide in oxidizing the uranium. Sodium carbonate is only slightly toxic, but can be very irritating to the eyes and skin, and poses as an inhalation hazard when it is in its salt stage (dust inhalation) or from small leaks in the form of a spray. Symptoms from excessive inhalation of dust may include coughing and difficult breathing. Its appearance is a white powder or granules, and it is stable under ordinary conditions of use and storage. It is hygroscopic and readily absorbs moisture from the air. Solutions are strong bases.
- **Sodium Bicarbonate** – Sodium Bicarbonate is stored at the CBR Facility and is used to keep oxidized uranium in solution. Sodium Bicarbonate is also used in the resin regeneration process. Sodium bicarbonate can be used without carbon dioxide in oxidizing the uranium. CBR maintains the option of using sodium carbonate/carbon dioxide or sodium bicarbonate in the oxidization of uranium. Inhalation of dust may cause irritation to the respiratory tract, and excessive contact is known to cause damage to the nasal septum. Symptoms from excessive inhalation of dust may include coughing and difficulty in breathing. Its appearance is in the form of a white powder or granules, and it is stable under ordinary conditions of use and storage. It is hygroscopic and readily absorbs moisture from the air. Solutions are strong bases.
- **Sodium Chloride** – Sodium chloride is stored at the CBR Facility and is used to regenerate/recycle the resin for further use in uranium extraction. Sodium chloride can be very irritating to the eyes and the skin and may cause mild irritation to the respiratory tract. However, it is not believed to present a significant hazard to health. Its appearance is in the form of crystals or white powder, odorless, and it is stable under ordinary conditions of storage and use. It is hygroscopic.
- **Sodium Sulfide** – Sodium sulfide is currently used at the existing licensed area during groundwater restoration activities as a chemical reductant. The use of sodium sulfide in groundwater restoration decreases the solubility of various heavy metals. To minimize potential impacts to radiological safety, this material is stored outside of process areas.

  The sodium sulfide consists of a dry, flaked product and is typically purchased on pallets of 55-pound bags or super sacks of 1,000 pounds. The bulk inventory is stored outside of process areas in a cool, dry, clean environment to prevent contact with any acid, oxidizer, or other material that may react with the product.

  Both solid and liquid sodium sulfide can be hazardous and toxic. The chemical, which becomes alkaline when moist, is corrosive. Protective clothing and PPE

should be worn to prevent any eye or skin contact, inhalation or ingestion. Contact lenses must not be worn when handling this material. Any contact with water, acids, oxidizers or heat can produce hydrogen sulfide gas, which is both flammable and toxic. Exposure to this gas, which, in low concentrations smells of rotten eggs, can result in loss of the sense of smell when present in concentrations greater than 100 ppm. At higher concentrations, hydrogen sulfide can cause paralysis and death. Fine sodium sulfide dust/air mixtures can also be explosive in confined spaces.

If the correct operating procedures are followed, the risk of generating hydrogen sulfide gas while mixing this reagent is extremely low. The saturation tank at CBR is vented outside the building as a precaution. During normal operating activities, Environmental, Health and Safety (EHS) personnel may monitor chemical makeup activities with a portable H_2S monitor, if required. Whenever possible, the chemical is mixed during the day shift, Monday through Friday.

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

3.2.2.2 Non-Process Related Chemicals

Non-process related chemicals that are stored at the CBR Facility include petroleum (gasoline, diesel) and propane. Due to the flammable and/or combustible properties of these materials, all bulk quantities are stored outside of process areas at the satellite plant. All gasoline and diesel storage tanks are located above ground and within secondary containment structures to meet USEPA requirements.

3.3 INSTRUMENTATION AND CONTROL

The basic control system at the Crow Butte site is built around an Allen-Bradley SCADA (Sequential Control and Data Acquisition) System. This system allows for extensive monitoring of all wellfield and recovery plant operations. The system is monitored twenty four hours per day, seven days per week by control room operators. The operators rely on visual and audible alarms from a variety of systems to control mine operations. Examples include but are not limited to: power failures, pressure exceedences, flow disruptions and the presence of liquids in the well houses..

The Allen-Bradley system consists of a series of menus which allows the plant operator to monitor and control a variety of systems and parameters. In addition, each wellfield house contains its own processor, which allows it to operate independent of the main computer. All critical equipment is equipped with uninterrupted power suppy systems with 30-minute supply in the event of a power failure.

Through this system, not only can the plant operators monitor and control every aspect of the operation on a real time basis, but management can review historical data to develop trend analysis for production operations. This not only ensures an efficient operation, but allows Crow Butte personnel to anticipate problem areas, and to remain in compliance with appropriate regulatory requirements.

Wellfield instrumentation is provided to measure total production and injection flow. In addition, instrumentation is provided to indicate the pressure that is being applied to the injection wells. Wellfield houses are equipped with wet alarms to detect the presence of liquids in the wellfield house sumps. The deep injection well is also equipped with a variety of sensors to monitor its status.

Instrumentation is provided to monitor the total flow into the plant, the total injection flow leaving the plant, and the total waste flow leaving the plant. Instrumentation is provided on the plant injection manifold to record an alarm in the event of any pressure loss that might indicate a leak or rupture in the injection system. The injection pumps are equipped with pressure reducing valves so that they are incapable of producing pressures high enough to exceed the design pressure of the injection lines or the maximum pressure to be applied to the injection wells. During power failures, overpressuring of wells is not possible as all pump systems are shut down.

In the process areas, tank levels are measured in chemical storage tanks as well as process tanks. A number of different monitors are in place for the dryer system, and drum logging is automated.

Handheld radiation detection instruments and portable samplers are used to monitor radiological conditions at the CBR facility. Specifications for this equipment are included in CBR's SHEQMS*Program Volume IV, Health Physics Manual,* and are discussed in further detail in Section 5. The location of monitoring points, monitoring procedures, and monitoring frequencies for in-plant radiation safety is also discussed in Section 5.

The types of health physics instrumentation that are used at the existing CBR facility include the following:

Air Sampling Equipment

- Eberline RAS-1 or Aircon 2 samplers (0-100 liters per minute (lpm) or equivalent

  Calibrated semiannually or after repair-on site with a primary standard instrument or a properly calibrated secondary standard instrument

- BDX II or SKC lapel samplers (0-5 lpm) or equivalent

  Calibrated daily before each use-on site with a primary standard instrument or a properly calibrated secondary standard instrument

External Radiation Equipment

- Ludlum Model 19 Gamma Meter (μR/hr) or equivalent
- Ludlum Model 3 Gamma Meter with Ludlum Model 44-38 G-M detector (mR/hr) or equivalent
- Ludlum Model 2221 Ratemeter/Scaler with a Ludlum Model 44-10 NaI detector (counts per minute [cpm]) or equivalent

  Calibrated annually or after repair-manufacturer or qualified accredited vendor

Surface Contamination Equipment

- Ludlum Model 2241 scaler or a Ludlum Model 12 Ratemeter with a Model 43-65 or Model 43-5 alpha scintillation probe or equivalent (Total Alpha)
- Ludlum Model 177 Ratemeter with a Ludlum Model 43-5 alpha scintillation probe or equivalent (Personnel Contamination)
- Ludlum Model 2000 Scaler or Model 2200 Scaler with an Eberline SAC-R5 or Ludlum Model 43-10 alpha scintillation sample counter or equivalent (Removable Alpha, Radon Daughters, Airborne Radioactivity)

Instruments are calibrated annually or at a frequency recommended by the manufacturer, whichever is more frequent. Repairs are by the manufacturer or by a qualified accredited vendor, and the instrument is calibrated following such repair. The calibration vendor provides the as-found calibration condition of each instrument. If greater than 10% of the instruments are out of calibration when received by the calibration vendor, consideration is given to increasing the calibration frequency.

The manufacturer or a qualified accredited vendor calibrates portable survey instruments, counter/scalers, mass flow meters and/or dry cell calibrators, and calibration sources. Calibration is performed as recommended in ANSI N323 and ANSI N323A. The ANSI

standard requires that radiation detection instruments are performance tested on an annual basis to verify that they continue to meet operational and design requirements. Instruments must be tested for range, sensitivity, linearity, detection limit, and response to overload. The specific calibration requirements for various types of instruments are discussed in CBR's SHEQMS Program *Volume IV, Health Physics Manual.*

Regulatory Guide 8.30 specifies requirements for routine maintenance and calibration of radiological survey instruments. Regulatory Guide 8.30 references the standards contained in ANSI N323-1978, *Radiation Protection Instrumentation Test and Calibration.* ANSI is in the process of a major revision of this Standard that will result in three separate Standards that apply to radiological instrumentation. The first revision, ANSI-N323A-1997, *Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments*, was incorporated in this Chapter. When conflicts arise between NRC Regulatory Guide 8.30 and the ANSI Standard, the Regulatory Guide recommendations are followed.

Calibration vendors provide a certificate of calibration for all instruments. These calibration certificates are maintained by the RSO on file for that instrument. Records of repair completed by the calibration vendor are also maintained in the instrument file.

Documentation of calibration of air samplers performed on site are be maintained. This documentation is maintained by the RSO in the sampler file.

Record of instrument checks, including the daily checks and initial checks, will be maintained in a format determined by the RSO. These records will be readily available and provided in a format that will allow the RSO to review the records for the types of potential problems (e.g., background drift in a continuous direction, battery check that does not respond, ratemeter that does not zero and alpha background rates greater than 0.5 cpm).

All records of instrument calibration and checks will be retained until NRC License termination. The RSO will be responsible for record retention.

Details as to calibration, functional tests, procedures and recordkeeping/retention are discussed in CBR's SHEQMS Program *Volume IV, Health Physics Manual.*

<u>Contract Laboratory Quality Control</u>

CBR's radiological quality assurance program is discussed in Section 2.9 of the SHEQMS Program *Volume IV, Health Physics Manual.* Quality control efforts are implemented to ensure that radiological data provided by contract laboratories are accurate and reliable. CBR conducts periodic audits of its QA/QC program as it relates to the health physics program; these audits are reviewed by facility and corporate management.

One purpose of the quality control program is to determine the precision and accuracy of the monitoring processes. Quality control sampling includes replicate samples to determine precision, spiked samples with a known concentration to determine accuracy, and blank samples to detect and measure contamination of analytical samples. NRC Regulatory Guide 4.15, *Quality Assurance for Radioloigcal Monitoring Programs (Normal Operations) – Effluent Streams and the Environment*, describes requirements for these types of quality control samples. Generally, NRC recommends that 5 to 10% of the analytical load at an environmental laboratory should be quality control samples. The contract laboratory quality assurance program is required to describe the program implemented to meet these requirements. Each qualified laboratory is required to have an acceptable QA/QC program in place. The Manager of Health Safety and Environmental Affairs or designee reviews the vendors QA/QC program and is responsible for approving the use of the vendor. Qualified laboratories are required to submit verification of an appropriate NRC License and certification(s) to meet NRC requirements.

3.3.1 References

Compressed Gas Association (CGA). 1993. CGA G-4.4, *Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems.*

Compressed Gas Association (CGA). 2000. CGA G-4.1, *Cleaning Equipment for Oxygen Service.*

National Fire Protection Association (NFPA). 1996. NFPA-50, *Standard for Bulk Oxygen Systems at Consumer Sites.*

4 EFFLUENT CONTROL SYSTEMS

This section describes the effluent control systems used at the Crow Butte Project. The effluents of concern at ISL operations include the release or potential release of radon gas (radon-222), radionuclides in liquid process streams, and dried yellowcake. Yellowcake processing and drying operations are conducted at the Central Plant.

The yellowcake drying facilities at the Central Plant are comprised of one vacuum dryer. The current license allows for the addition of a second dryer. Yellowcake processing and drying is carried out using a vacuum dryer with a wet condenser system, thus there are no airborne effluents from this system. By design, vacuum dryers do not discharge any uranium when operating. Effluent controls for yellowcake drying at the Central Plant have been reviewed by USNRC and approved in the current license.

4.1 GASEOUS AND AIRBORNE PARTICULATES

The only radioactive airborne effluent at the Crow Butte facility is radon-222 gas.

4.1.1 Tank and Process Vessel Ventilation Systems

Radon-222 is contained in the pregnant lixiviant that comes from the wellfield into the plant. The majority of the radon-222 is released in the injection surge tanks and in the ion exchange columns. These vessels are covered and vented to the atmosphere. The vents from the individual vessels go into a manifold that is exhausted to atmosphere outside the plant building via an induced draft fan. Venting the radon-222 gas to atmosphere outside the plant minimizes employee exposure. Redundant exhaust fans direct collected gases to discharge piping that exhaust fumes to the outside atmosphere. The design of the fans is such that the system is capable of limiting employee exposures with the failure of a single fan. Discharge stacks are located away from building ventilation intakes to prevent introducing exhausted radon into the facility as recommended in Regulatory Guide 8.31 (USNRC 2002). Airflow through any openings in the vessels is from the process area into the vessel and into the ventilation system, controlling any releases that may occur inside the vessel.

Small amounts of radon-222 may be released via solution spills, filter changes, RO operation, and maintenance activities, but these are minimal releases on an infrequent basis. The exhaust system in the plant further reduces employee exposure. The air in the plant is sampled for radon daughters (**Section 5.0**) to assure that concentration levels of radon and radon daughters is maintained as low as reasonably achievable (ALARA).

The type of dryer used in the Crow Butte process facility is a vacuum dryer. With this dryer, the yellowcake is dried in a heating chamber that is maintained at negative pressure. Airflow in a vacuum dryer is minimal and is from the outside of the drying chamber into the chamber. Any particulate that may be released goes to a bag filter, with the moisture-laden air going to a closed loop condenser where the water condenses and entrains any remaining particulate, with the vacuum source being a liquid ring vacuum

pump acting as a final filter against any particulate escape. The water is periodically transferred to the yellowcake thickener. With a vacuum dryer, there is no release of particulate by way of a stack since there is no positive airflow. During packaging, the drum is sealed via a gasket to the dryer discharge. As the dryer is operating under vacuum, any leaks around this gasket result in air being drawn into the drum during the packaging of yellowcake, thus no contaminants are released. The air that may enter the discharge to the drum is also routed to the condenser system described above.

If the yellowcake emission control equipment fails to operate within specifications established in standard operating procedures (SOPs), the drying and packaging room is immediately closed and declared an airborne radiation area. Heating operations are switched to cooldown, or packaging operations are temporarily suspended.

4.1.2 Work Area Ventilation System

As discussed in **Section 4.1.1**, the work area ventilation system has been designed to force air to circulate within the plant process areas. The ventilation system exhausts outside the building, drawing fresh air in. The design of the ventilation system is adequate to ensure radon daughter concentrations in the facility are maintained below 25 percent of the derived air concentration (DAC) from 10 CFR Part 20.

Operational radiological in-plant monitoring for radon concentrations has proven that the facility's ventilation system has been an effective method for minimizing employee exposure.

Other emissions to the air are limited to exhaust and dust from limited vehicular traffic.

4.2 LIQUIDS AND SOLIDS

4.2.1 Liquid Waste Sources and Disposal

As a result of ISL mining process, there are three sources of water that are collected on the site.

4.2.1.1 Primary Water Sources

Water generated during well development

This water is recovered groundwater and has not been exposed to any mining process or chemicals. However, the water may contain elevated concentrations of naturally-occurring radioactive material if the development water is collected from the mineralized zone. The water 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 in the pond. Well development water may be treated with filtration and/or reverse osmosis and used as plant make-up water or disposed of in the deep disposal well.

Liquid process waste

The operation of the process plant results in two primary sources of liquid waste, an eluant bleed and a production bleed. These bleeds are routed to either the deep disposal well or an evaporation pond.

Aquifer restoration

Following mining operations, restoration of the affected aquifer commences which results in the production of wastewater. The current groundwater restoration plan consists of four activities: 1) Groundwater Transfer, 2) Groundwater Sweep, 3) Groundwater Treatment, and 4) Wellfield Circulation. Only the groundwater sweep and groundwater treatment activities will generate wastewater.

During groundwater sweep, water is extracted from the mining zone without injection, causing an influx of baseline quality water to sweep the affected mining area. The extracted water must be sent to the wastewater disposal system during this activity, such as deep well disposal and/or onsite evaporation ponds. Historically CBR has not used groundwater sweep, but this option could be used in the future if warranted by site conditions. As has been the case with past operations at Crow Butte, it is anticipated that during restoration, groundwater will be treated using ion exchange (IX) and reverse osmosis (RO). Using this method, there will be no water consumption activities and only the bleed would need to be addressed for disposal; the remainder of the treated water would be reinjected.

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

4.2.1.2 Secondary Water Sources

Stormwater Runoff

The design of the Crow Butte facilities and existing engineering controls is such that runoff is not considered to be a potential source of pollution. Therefore, this water is not specifically collected and routed to a pond for disposal.

Stormwater management is controlled under permits issued by the NDEQ. CBR is subject to stormwater National Pollutant Discharge Elimination System (NPDES) permitting requirements for industrial facilities and construction activities. The NDEQ NPDES regulatory program contained in Title 119 (NDEQ 2005) requires that procedural and engineering controls be implemented such that runoff will not pose a potential source of pollution.

Domestic Liquid Waste

Domestic liquid wastes from the restrooms and lunchrooms are disposed of in an approved septic system that meets the requirements of the State of Nebraska. These systems are in common use throughout the United States and the effect of the system on the environment is known to be minimal when the systems are designed, maintained, and operated properly. CBR currently maintains a Class V UIC Permit issued by the NDEQ for operation of the septic system at the current License Area.

Laboratory Waste

Approximately 3,000 gallons per month of nonhazardous liquid waste from the laboratory, comprised of sample discards, lab solutions, dish washing wastewater and lab cleanup wastewater is disposed of in either the evaporation pond or the deep disposal well.

4.2.1.3 Liquid Waste Disposal

Two methods of disposal are used for the Crow Butte Central Plant:

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

Deep Disposal Well Injection

CBR currently operates two non-hazardous Class I injection well in the current license area for disposal of wastewater under Permits #NE0206369 and #NE0210825 (Well #1 and Well #2 respectively . The wells are permitted under NDEQ regulations in Title 122 (NDEQ 2002) and operated under a Class I UIC Permit. The permits for both wells allow unlimited flow and a maximum operating pressure of 650psi. To preserve optimum performance, Well #1 has typically been operated at up to 40 psi with a 200 gpm flow.

CBR has operated Well #1 at the current license area for over ten years with excellent results and no serious compliance issues. Well #2 was incorporated into the license by action of the CBR Safety and Environmental Review Panel on November 18, 2011, CBR has found that permanent deep disposal is preferable to evaporation in evaporation ponds.

Evaporation Pond

Evaporation pond design, installation and operation criteria are those found in USNRC Regulatory Guide 3.11 (USNRC 1977). CBR maintains three commercial and two R&D evaporation ponds in the current License Area. Each commercial pond is nominally 900 feet by 300 feet by 17 feet in depth. The ponds are constructed with a primary and secondary liner system. An underdrain system consisting of perforated piping between the primary and secondary liners is installed to monitor for leaks. The underdrain slopes gradually to the ends of the ponds where they are connected to a surface monitor pipe.

Checking for an increase in measurable moisture inside the leak detection system and/or analyzing the water in the pipe can discover a leak in the pond liner.

Each of the ponds has the capability of being pumped to a water treatment plant prior to discharge under the NPDES permit. A variety of treatment options exist depending upon the specific chemical contaminants identified in the wastewater. In general, a combination of chemical precipitation and reverse osmosis is adequate to restore the water to a quality that falls well within the NPDES criteria.

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

- Daily Inspections

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

- Weekly Inspections

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

- Monthly Inspections

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

- Quarterly Inspections

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

- Annual Inspection

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

- Pond Leak Corrective Actions

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

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

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

4.2.1.4 Potential Pollution Events Involving Liquid Waste

Although there are a number of potential sources of pollution present at the Crow Butte facility, existing regulatory requirements from the USNRC and NDEQ, and provisions of the CBR SHEQMS, have established a framework that significantly reduces the possibility of such an occurrence. Extensive training of all personnel is standard policy at the CBR facility. Frequent inspections of waste management facilities and systems are conducted. Detailed procedures are included in the CBR SHEQMS Program.

There are primarily six potential sources of pollution at the Crow Butte Project.

- Solar Evaporation Ponds
- Wellfield Buildings and Piping
- Process Building
- Piping
- Transportation Vehicles
- Spills

Solar Evaporation Ponds

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

With respect to a pond failure, all ponds have been built to USNRC standards, and are equipped with leak detection systems. SOPs require a periodic inspection of all ponds, liners, and berms. In the event of a leak, the contents of the pond can be transferred to another pond while repairs are made.

With respect to pond overflow, operating procedures are such that no individual pond is allowed to fill to a point where overflow is considered a realistic possibility. The flow rate of liquids to the ponds is minimal, thus there is ample time to reroute the flow to another pond. Regarding the addition of rainwater, the freeboards of ponds considered "full" are sufficient to contain the addition of significant quantities of rainwater before an overflow would occur. The inclusion of the freeboard allowance also precludes over-washing of the walls during high winds.

Wellfield Buildings and Piping

Wellfield buildings are not considered to be a potential source of pollutants during normal operations, as there are no process chemicals or effluents stored within them. The only instance in which a wellfield building could contribute to pollution would be in the event of a release of injection or recovery solutions due to pipe failure. The possibility of such an occurrence is considered to be minimal, as the piping is leak checked before it is initially placed into service. Piping from the wellfields is generally buried, minimizing the possibility of an accident. In addition, the flows through the piping and manifold pressure gauges in the wellhouses are monitored twenty four hours per day, seven days per week by control room operators using visual and audible alarms. . Flow monitoring provides alarms in the event of a significant piping failure which allow flow to be stopped, preventing any significant migration of process fluids. Wellfield buildings also are equipped with wet alarms for early detection of leaks.

Process Building

The process building serves a central hub for most of the mining operations, thus has the greatest potential for spills or accidents resulting in the release of potential pollutants. Spills could result due to a release of process chemicals from bulk storage tanks, piping failure, or a process storage tank failure.

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

Piping

As previously discussed, all piping is leak checked prior to operation. Piping from the wellfields is generally buried, minimizing the possibility of an accident. Large leaks in the pipe would quickly become apparent to the plant operators due to a decrease in flow and pressure, thus any release could be mitigated rapidly.

Transportation vehicles

The release of pollutants to the environment could occur due to accidents involving transportation vehicles. This could involve either vehicles delivering bulk chemical products, transport of radioactive contaminated waste from the site to an approved disposal site, or from vehicles carrying yellowcake slurry or dried yellowcake.

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

Spills can take two forms within an ISL facility; surface spills such as pond leaks, piping ruptures etc., and subsurface releases such as a well excursion, in which process chemicals migrate beyond the wellfield, or a pond liner leak resulting in a release of waste solutions.

Engineering and administrative controls are in place to prevent when possible both surface and subsurface releases to the environment, and to mitigate the effects should an accident occur.

Spills

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

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

In general, piping from the plant, to and within the wellfield is constructed of PVC, high-density polyethylene pipe (HDPE) with butt-welded joints or equivalent. All pipelines are pressure tested prior to final operation. It is unlikely that a break would occur in a buried section of line because no additional stress is placed on the pipes. n addition, underground pipelines are protected from a major cause of potential failure, which is vehicles driving over the lines causing breaks. Typically, the only exposed pipes are at the process plant, the wellheads and in the control house in the wellfield. Trunkline flows and manifold pressures are monitored each shift for process control.

4.2.2 Solid Waste

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

Solid waste generated at the site consists of spent resin, resin fines, empty reagent containers, miscellaneous pipe and fittings, and domestic trash. The solid waste is segregated based on whether it is clean or has the potential for contamination with 11(e).2 byproduct materials.

4.2.2.1 Non-contaminated Solid Waste

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

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

4.2.2.2 11(e).2 Byproduct Material

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

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

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

4.2.2.3 Septic System Solid Waste

Domestic liquid wastes from the restrooms and lunchrooms are disposed of in an approved septic system that meets the requirements of the State of Nebraska. Disposal of solid materials collected in septic systems must be performed by companies or individuals licensed by the State of Nebraska. NDEQ regulations for control of these systems are contained in Title 124 (USNRC 2005).

4.2.2.4 Hazardous Waste

The potential exists for any industrial facility to generate hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA). In the State of Nebraska, hazardous waste is governed by the regulations contained in Title 128 (NDEQ 2007). Based on waste determinations conducted by CBR as required in Title 128, CBR is a Conditionally Exempt Small Quantity Generator (CESQG). To date CBR only generates universal hazardous wastes such as used waste oil and batteries. CBR recently estimated that the current operation generates approximately 1,325 liters of waste oil per year. Waste oil is disposed of by a licensed waste oil recycler. CBR has management procedures in place in SHEQMS Program Volume VI, *Environmental Manual,* to control and manage these types of wastes.

4.2.3 References

Nebraska Department of Environmental Quality (NDEQ). 2002. Title 122, Rules and Regulations for Underground Injection and Mineral Production Wells (April 2002).

NDEQ. 2005. Title 119, Rules and Regulations Pertaining to the Issuance of Permits under the National Pollutant Discharge Elimination System, (May 2005).

NDEQ. 2005. Title 124, Rules and Regulations for the Design, Operation, and Maintenance of On-site Wastewater Treatment Systems, (May 2005).

NDEQ. 2007. Title 128, Nebraska Hazardous Waste Regulations, (January 2007).

U. S. Nuclear Regulatory Commission (USNRC). 1977. Regulatory Guide 3.11, Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills (Revision 2, December 1977).

USNRC. 1980. Regulatory Guide 3.11.1, Operational Inspection and Surveillance of Embankment Retention Systems for Uranium Mill Tailings (Revision 1, October 1980).

USNRC. 1987. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-Product, Source or Special Nuclear Material (May 1987).

USNRC. 2002. Regulatory Guide 8.31, Information Relevant to Ensuring That Occupational Radiation Exposures at Uranium Recovery Facilities Will Be As Low As Reasonably Achievable (Revision 1, May 2002).

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5 OPERATIONS

CBR operates a commercial-scale in-situ leach uranium mine (the Crow Butte Project) near Crawford, Nebraska. CBR maintains a headquarters in Denver, Colorado where site-licensing actions originate. All CBR operations, including the Crow Butte Project operations, are conducted in conformance with applicable laws, regulations, and requirements of the various regulatory agencies. The responsibilities described below have been designed to both ensure compliance and further implement CBR's policy for providing a safe working environment with cost-effective incorporation of the philosophy of maintaining radiation exposures as low as is reasonably achievable (ALARA).

5.1 CORPORATE ORGANIZATION/ADMINISTRATIVE PROCEDURES

CBR will maintain a performance-based approach to the management of the environment and employee health and safety, including radiation safety. The SHEQMS encompasses licensing, compliance, environmental monitoring, industrial hygiene, and health physics programs under one umbrella, and it includes involvement for all employees from the individual worker to senior management. This SHEQMS will allow CBR to operate efficiently and maintain an effective environment, health and safety program.

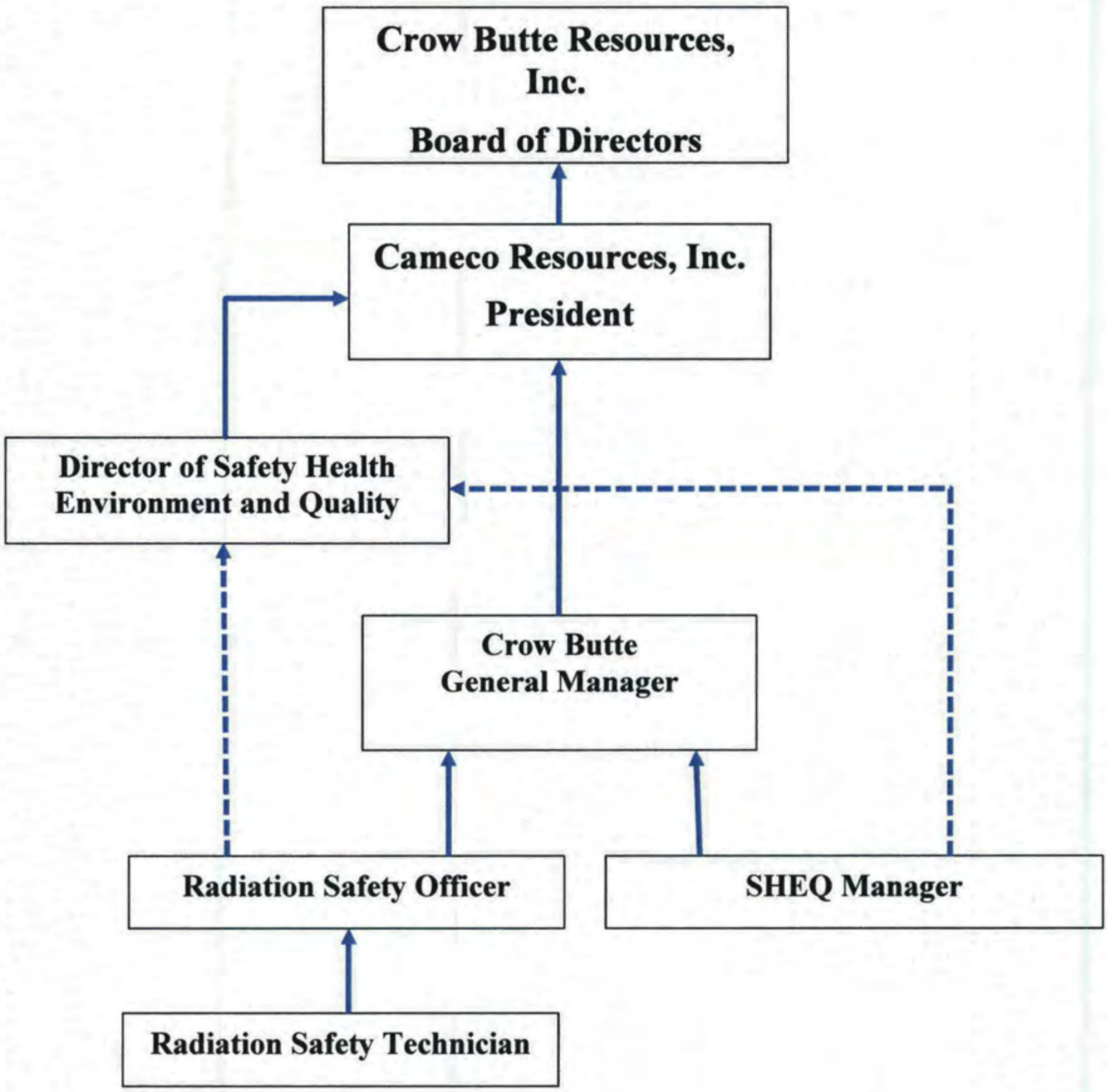
Figure 5.1-1 is a partial organization chart for CBR with respect to the operation of the CPF and associated operations and represents the management levels that play a key part in the SHEQMS that will also apply to the satellite facility. The personnel identified are responsible for the development, review, approval, implementation, and adherence to operating procedures, radiation safety programs, environmental and groundwater monitoring programs as well as routine and non-routine maintenance activities. These individuals may also serve a functional part of the Safety and Environmental Review Panel (SERP) described under Section 5.3.3.

Specific responsibilities of the organization are provided below.

5.1.1 Board of Directors

The CBR Board of Directors has the ultimate responsibility and authority for radiation safety and environmental compliance for CBR. The Board of Directors sets corporate policy and provides procedural guidance in these areas. The Board of Directors provides operational direction to the President of CBR.

Figure 5.1-1: Crow Butte Resources Organizational Chart



5.1.2 President

The President of Crow Butte Resources, Inc. is responsible for interpreting and acting upon the Board of Directors policy and procedural decisions. The President directly supervises General Manager of Operations. The President is empowered by the Board of Directors to have the responsibility and authority for the radiation safety and environmental compliance programs at the Crow Butte facility. The President is responsible for ensuring that CBR operations staff comply with all applicable regulations and permit/license conditions through direct supervision of the General Manager of Operations. The President has overall responsibility for approving the facility design including radiological controls (e.g., ventilation systems), and the manner in which the RSO is integrated into this process.

5.1.3 General Manager

The General Manager of Nebraska operations is responsible for all uranium production activities. The General Manager is also responsible for implementing any industrial and radiation safety and environmental protection programs associated with operations. The General Manager is authorized to immediately implement any action to correct or prevent hazards. The General Manager has the responsibility and the authority to suspend, postpone or modify, immediately if necessary, any activity that is determined to be a threat to employees, public health, the environment, or potentially a violation of state or federal regulations. The General Manager cannot unilaterally override a decision for suspension, postponement or modification if that decision is made by the Safety Health Environment and Quality Manager (SHEQ Manager) or the RSO. The General Manager reports directly to the President .

5.1.4 Director of Safety Health Environment and Quality

The Director of Safety Health Environment and Quality reports directly to the President and is responsible for ensuring that personnel comply with industrial safety, radiation safety, environmental and quality programs as required by NRC regulations and established in the Cameco program. The Director of SHEQ has the responsibility and authority to terminate immediately any activity that is determined to be a threat to employees or public health, the environment, or potentially a violation of state or federal regulations as indicated in reports from the RSO. The Director of SHEQ may also serve as Corporate Radiation Safety Officer (CRSO) and if doing so, shall meet the RSO qualifications described in Section 5.1.6.

5.1.5 Safety Health Environment and Quality Manager

The Manager of SHEQ is responsible for health and safety, and environmental programs as stated in the SHEQMS and for ensuring that CBR complies with all applicable regulatory requirements. The manager is located at the offices of site operations. This manager is responsible for the drafting, approving and updating SHEQMS procedures on an annual basis. The SHEQ Manager reports directly to the General Manager to ensure that the environmental monitoring and protection programs are conducted in a manner consistent with regulatory requirements. This position assists in the development and review of environmental sampling and analysis procedures and is responsible for routine auditing of the programs. The SHEQ Manager also has the responsibility and authority to suspend, postpone, or modify any activity that is determined to be a threat to employees, public health, the environment or potentially a violation of state or federal regulations. As such the Manager of SHEQ has a secondary reporting requirement to the Director of SHEQ. The Manager of SHEQ has no production-related

5.1.6 Radiation Safety Officer

Reporting directly to the General Manager of Operations and secondarily to the Director of SHEQ, The CBR RSO is responsible for the development, administration, and enforcement of all radiation safety programs. The RSO is authorized to conduct inspections and to immediately order any change necessary to preclude or eliminate radiation safety hazards and/or maintain regulatory compliance. The RSO is responsible for the implementation of all on-site environmental programs including emergency procedures. The RSO inspects facilities to verify compliance with all applicable requirements in the areas of radiological health and safety. The RSO works closely with all supervisory personnel to review and approve new equipment and changes in processes and procedures that may affect radiological safety and to ensure that established programs are maintained. The RSO is also responsible for the collection and interpretation of employee exposure-related monitoring including data from radiological safety. The RSO recommends improvements to any and all radiological safety-related controls. The RSO has no production-related responsibilities. The RSO reports directly to the Manager of Health, Safety, and Environmental Affairs.

5.1.7 Health Physics Technician

The CBR Health Physics Technician (HPT) assists the RSO with the implementation of the radiological and industrial safety programs. The HPT is responsible for the orderly collection and interpretation of all monitoring data, to include data from radiological safety and environmental programs. The HPT reports directly to the RSO.

5.1.8 Safety Supervisor

The CBR Safety Supervisor is responsible for the non-radiation-related health and safety programs. The Safety Supervisor is authorized to conduct inspections and to immediately order any change necessary to preclude or eliminate safety hazards and/or maintain regulatory compliance. The Safety Supervisor's responsibilities include the development and implementation of health and safety programs in compliance with Occupational Safety and Health Administration (OSHA) regulations. Responsibilities of the Safety Supervisor include development of industrial safety and health programs and procedures, coordination with the RSO where industrial and radiological safety concerns are interrelated, safety and health training of new and existing employees, and the maintenance of appropriate records to document compliance with regulations. The Safety Supervisor reports directly to the Manager of Health, Safety, and Environmental Affairs.

5.2 ALARA POLICY

The purpose of the ALARA (As Low As Reasonably Achievable) Policy is to keep exposures to all radioactive materials and other hazardous material as low as possible and to as few personnel as possible. The policy considers the state of technology and the economics of improvements related to benefits to the public health and safety, other societal and socioeconomic considerations, and the utilization of atomic energy in the public interest.

In order for an ALARA Policy to correctly function, all individuals, including management, supervisors, health physics staff, and workers, must take part in and share responsibility for keeping all exposures as low as reasonably achievable. This policy addresses this need and describes the responsibilities of each level in the organization.

5.2.1 Management Responsibilities

Consistent with Regulatory Guide 8.31 *Information Relevant to Ensuring That Occupational Radiation Exposures at Uranium Recovery Facilities Will Be As Low As Reasonably Achievable* (Revision 1, May 2002), the licensee management is responsible for the development, implementation, and enforcement of applicable rules, policies, and procedures as directed by regulatory agencies and company policies. These shall include the following:

- The development of a strong commitment to and continuing support of the implementation and operations of the ALARA program;
- An Annual Audit Program which reviews radiation monitoring results, procedural, and operational methods;
- A continuing evaluation of the Health Physics Program including adequate staffing and support; and
- Proper training and discussions that address the ALARA program and its function to all facility employees and, when appropriate, to contractors and visitors.

5.2.2 Radiation Safety Officer Responsibility

The RSO shall be charged with ensuring the technical adequacy of the radiation protection program, implementation of proper radiation protection measures, and the overall surveillance and maintenance of the ALARA program. The RSO shall be assigned the following:

- The responsibility for the development and administration of the ALARA program;
- Sufficient authority to enforce regulations and administrative policies that affect any radiological aspect of the SHEQMS Program;

- Assist with the review and approval of new equipment, process changes or operating procedures to ensure that the plans do not adversely affect the radiological aspects of the SHEQMS Program;
- Maintain equipment and surveillance programs to assure continued implementation of the ALARA program;
- Assist with conducting an Annual ALARA Audit as discussed in **Section 5.4.3** to determine the effectiveness of the program and make any appropriate recommendations or changes as may be dictated by the ALARA philosophy;
- Review annually all existing operating procedures involving or potentially involving any handling, processing, or storing of radioactive materials to ensure the procedures are ALARA and do not violate any newly established or instituted radiation protection practices; and
- Conduct or designate daily inspections of pertinent facility areas to observe that general radiation control practices, hygiene, and housekeeping practices are in line with the ALARA principle.

5.2.3 **Supervisor Responsibility**

Supervisors shall be the front line for implementing the ALARA program. Each supervisor shall be trained and instructed in the general radiation safety practices and procedures. The supervisor's responsibilities include:

- Receiving and providing adequate training to implement the general philosophy behind the ALARA program;
- Providing direction and guidance to subordinates in ways to adhere to the ALARA program;
- Enforcement of rules and policies as directed by the SHEQMS Program, which implement the requirements of regulatory agencies and company management; and
- Seeking additional help from management and the RSO should radiological problems be deemed by the supervisor to be outside their sphere of training.

5.2.4 **Worker Responsibility**

Because success of both the radiation protection and ALARA programs are contingent upon the cooperation and adherence to those policies by the workers themselves, the facility employees must be responsible for certain aspects of the program in order for the program to accomplish its goal of keeping exposures as low as possible. Worker responsibilities include:

- Adherence to all rules, notices, and operating procedures as established by management and the RSO through the SHEQMS Program;

- Making valid suggestions which might improve the radiation protection and ALARA programs;
- Reporting promptly, to immediate supervisor, any malfunction of equipment or violation of procedures which could result in an increased radiological hazard;
- Proper use of protective equipment; and
- Proper performance of required contamination surveys.

5.3 MANAGEMENT CONTROL PROGRAM

5.3.1 Environmental, Health, and Safety Management System

CBR's SHEQMS Program formalizes CBR's approach to environmental, health, and safety management to ensure consistency across its operations. The SHEQMS Program is a key element in assuring that all employees demonstrate "due diligence" in addressing environmental, health, and safety issues and describes how the operations of the facility will comply with the requirements of the CBR Environmental, Health, and Safety (EH&S) Policy and regulatory requirements.

The CBR SHEQMS Program:

- Assures that sound management practices and processes are in place to ensure that strong environmental, health, and safety performance is sustainable;
- Clearly sets out and formalizes the expectations of management;
- Provides a systematic approach to the identification of issues and ensures that a system of risk identification and management is in place;
- Provides a framework for personal, site, and corporate responsibility and leadership;
- Provides a systematic approach for the attainment of CBR's objectives; and
- Ensures continued improvement of programs and performance.

The SHEQMS Program has the following characteristics:

- The system is compatible with the ISO 14001 Environment Management System.
- The system is straightforward in design, is intended as an effective management tool for all types of activities and operations, and is capable of implementation at all levels of the organization.
- The system is supported by standards that clearly spell out CBR's expectations while leaving the means by which these are attained as a responsibility of line management.
- The system is readily auditable.

- The system is designed to provide a practical tool to assist the operations in identifying and achieving their objectives while satisfying CBR's governance requirements.

The SHEQMS Program uses a series of standards that align with specific management processes and sets out the minimum expectations for performance. The standards consist of management processes that include assessment, planning, implementation (training, corrective actions, safe work programs, and emergency response), checking (auditing, incident investigation, compliance management, and reporting), and management review.

5.3.1.1 Operating Procedures

CBR has developed procedures consistent with the corporate policies and standards and local, state and federal regulatory requirements to implement these management controls. The SHEQMS Program consists of the following standards and operating procedures contained in eight volumes:

Volume 1 – *Standards*

Volume 2 – *Management Procedures*

Volume 3 – *Operations Manual* (SOPs)

Volume 4 – *Health Physics Manual*

Volume 5 – *Industrial Safety Manual*

Volume 6 – *Environmental Manual*

Volume 7 – *Training Manual*

Volume 8 – *Emergency Manual*

Written operating procedures have been developed for all process activities including those involving radioactive materials for the Crow Butte Project. Where radioactive material handling is involved, pertinent radiation safety practices are incorporated into the operating procedure. Additionally, written operating procedures have been developed for non-process activities including environmental monitoring, health physics procedures, emergency procedures, and general safety.

The procedures enumerate pertinent radiation safety procedures to be followed. A copy of the written procedure will be kept in the area where it is used. All procedures involving radiation safety will be reviewed and approved in writing by the RSO or another individual with similar qualifications prior to being implemented. The RSO will also perform a documented annual review of the operating procedures.

5.3.1.2 Radiation Work Permits

In the case that employees are required to conduct activities of a non-routine nature where there is the potential for significant exposure to radioactive materials and for

which there is no operating procedure, a Radiation Work Permit (RWP) will be required. The RWP will describe the scope of the work, precautions necessary to maintain radiation exposures to ALARA, and any supplemental radiological monitoring and sampling to be conducted during the work. The RWP shall be reviewed and approved in writing by the RSO (or qualified designee in the absence of the RSO) prior to initiation of the work.

The RSO may also issue Standing Radiation Work Permits (SRWPs) for periodic tasks that require similar radiological protection measures (e.g., maintenance work on a specified plant system). The SRWP will describe the scope of the work, precautions necessary to maintain radiation exposures to ALARA, and any supplemental radiological monitoring and sampling to be conducted during the work. The SRWP shall be reviewed and approved in writing by the RSO (or qualified designee in the absence of the RSO) prior to initiation of the work.

5.3.2 Performance Based License Condition

This license application is the basis of the Performance-Based License (PBL) originally issued in 1998. Under that license, CBR may, without prior USUSNRC approval or the need to obtain a License Amendment:

- Make changes to the facility or process, as presented in the license application (as updated),
- Make changes in the procedures presented in the license application (as updated), and
- Conduct tests or experiments not presented in the license application (as updated).

A License Amendment and/or USNRC approval will be necessary prior to implementing a proposed change, test, or experiment if the change, test, or experiment would:

- Result in any appreciable increase in the frequency of occurrence of an accident previously evaluated in the license application (as updated);
- Result in any appreciable increase in the likelihood of occurrence of a malfunction of a structure, system, or component (SSC) important to safety previously evaluated in the license application (as updated);
- Result in any appreciable increase in the consequences of an accident previously evaluated in the license application (as updated);
- Result in any appreciable increase in the consequences of a malfunction of an SSC previously evaluated in the license application (as updated);
- Create a possibility for an accident of a different type than any previously evaluated in the license application (as updated);

- Create a possibility for a malfunction of an SSC with a different result than previously evaluated in the license application (as updated);
- Result in a departure from the method of evaluation described in the license application (as updated) used in establishing the final safety evaluation report, the EA, technical evaluation reports (TERs), or other analysis and evaluations for license amendments;
- For purposes of this paragraph as applied to this license, SSC means any SSC that has been referenced in a staff SER, TER, EA, or environmental impact statement (EIS) and supplements and amendments thereof.

Additionally, CBR must obtain a license amendment unless the change, test, or experiment is consistent with the USNRC conclusions, or the basis of, or analysis leading to, the conclusions of actions, designs, or design configurations analyzed and selected in the site or facility SER, TERs, EIS, or EA. This would include all supplements, amendments, TERs, EAs, and EISs issued with amendments to this license.

5.3.3 Safety and Environmental Review Panel

A SERP will determine compliance concerning the conditions discussed in **Section 5.3.2**. The SERP will consist of a minimum of three individuals. One member of the SERP will have expertise in management and will be responsible for managerial and financial approval for changes; one member will have expertise in operations and/or construction and will have expertise in implementation of any changes; and one member will be the RSO or equivalent. Other members of the SERP may be utilized as appropriate to address technical aspects of the change, experiment, or test in several areas such as health physics, groundwater hydrology, surface water hydrology, specific earth sciences, and others. Temporary members, or permanent members other than the three identified above, may be consultants.

The SERP is responsible for monitoring any proposed change in the facility or process, making changes in procedures, and conducting tests or experiments not contained in the current USNRC license. As such, they are responsible for ensuring that any such change results in no degradation in the essential safety or environmental commitments of CBR.

5.3.3.1 Safety and Environmental Review Panel Review Procedures

The CBR SERP will implement the following review procedures for the evaluation of all appropriate changes to the facility operations. The SERP may delegate any portion of these responsibilities to a committee of two or more members of the SERP. Any committees so constituted will report their findings to the full SERP for a determination of compliance with **Section 5.3.2** of this chapter. In their documented review of whether a potential change, test, or experiment (hereinafter called "the change") is allowed under the PBL (or Performance-Based License Condition [PBLC]) without a license amendment, the SERP shall consider the following.

Current USNRC License Requirements

The SERP will review the most current USNRC license conditions to assess which, if any, conditions will have an impact on or be impacted by the potential SERP action. If the SERP action will conflict with a specific license requirement, then a license amendment is necessary before initiating the change. This review includes information contained in the approved license application.

Ability to Meet USNRC Regulations

The SERP will determine if the change, test, or experiment conflicts with applicable USNRC regulations (example: 10 CFR Parts 20 and 40 requirements). If the SERP action conflicts with USNRC regulations, a license amendment is necessary.

Licensing Basis

The SERP will review whether the change, test, or experiment is consistent with USNRC's conclusions regarding actions analyzed and selected in the licensing basis. Documents that the SERP must review in conducting this evaluation include the SER and EA prepared in support of the 1997 LRA and any SERs, TERs, EAs, or EISs prepared to support amendments to the license. The RSO will maintain a current copy of all pertinent documents for review by the SERP during these evaluations.

Financial Surety

The SERP will review the proposed action to determine if any adjustment to financial surety arrangement or approved amount is required. If the proposed action will require an increase to the existing surety amount, the financial surety instrument must be increased accordingly before the change can be approved. The surety estimate must be updated either through a license amendment or through the course of the annual surety update to the USNRC. The USNRC incorporates the annual surety update by license amendment.

Essential Safety and Environmental Commitments

The SERP will assure that there is no degradation in the essential safety or environmental commitment in the license application, or as provided by the approved reclamation plan.

5.3.3.2 Documentation of SERP Review Process

After the SERP conducts the review process for a proposed action, the proceedings, findings, recommendations and conclusions will be provided in a written report format. All members of the SERP shall sign concurrence on the final report. If the report concludes that the action meets the appropriate PBL or PBLC requirements and does not require a license amendment, the proposed action may then be implemented. If the report concludes that a license amendment is necessary before implementing the action, the report will document the reasons why and what course CBR plans to pursue. The SERP report shall include the following:

- A description of the proposed change, test, or experiment (proposed action);
- A listing of all SERP members conducting the review and their qualifications (if a consultant or other member was not previously qualified);
- The evaluation of the proposed action including all aspects of the SERP review procedures listed above;
- Conclusions and recommendations;
- Signatory approvals of the SERP members; and
- Any attachments such as all applicable technical, environmental, or safety evaluations, reports, or other relevant information including consultant reports.

All SERP reports and associated records of any changes made pursuant to the PBL or PBLC shall be maintained through termination of the USNRC license.

CBR will submit an annual report to the USNRC that describes all changes, tests, or experiments made pursuant to the PBL or PBLC. The report will include a summary of the SERP evaluation of each change. In addition, CBR will annually submit any pages of the license renewal application to reflect changes or supplementary information. Each replacement page shall include both a change indicator for the area of change, (e.g., bold marking vertically in the margin adjacent to the portion actually change) and a page change identification (date of change, change number, or both).

5.4 MANAGEMENT AUDIT AND INSPECTION PROGRAM

The following internal inspections, audits, and reports are performed for the Crow Butte Project operations:

5.4.1 Radiation Safety Inspections

5.4.1.1 Daily Inspections

The RSO, HPT or a qualified designated operator conducts a daily walkthrough inspection of the plant. The inspection entails a visual examination of compliance or other problems, which are reviewed with the Operations Superintendent.

5.4.1.2 Weekly RSO Inspections

The RSO and Operations Superintendent (or designees in their absence) will conduct a weekly inspection of all facility areas to observe general radiation control practices and review required changes in procedures and equipment.

5.4.1.3 Monthly RSO Reports

The RSO provides a written summary of the month's radiological activities at the Crow Butte Uranium Project facilities. The report includes a review of all monitoring and exposure data for the month, a summary of worker protection activities, a summary of all

pertinent radiation survey records, a discussion of any trends in the ALARA program, and a review of adequacy of the implementation of the USNRC license conditions. Recommendations are made for any corrective actions or improvements in the process or safety programs.

5.4.2 **Evaporation Pond Inspections**

The inspection program developed by CBR for use on the ponds in the current production area is contained in SHEQMS Program Volume VI, *Environmental Manual* and is based on the guidance in USNRC Regulatory Guide 3.11.1. The inspection program is summarized below.

5.4.2.1 Daily Inspections

- Pond Depth - The depth of water in each pond is measured and recorded.
- Pond Embankments - The pond embankments are visually inspected for signs of cracking, slumping, movement, or a concentration of seepage.

5.4.2.2 Weekly Inspections

- Perimeter Fence - The game-proof perimeter fence is inspected for holes that would allow animals to enter the pond area.
- Inlet Pipes – The pond inlet piping is inspected to verify that it is not clogged with ice, dirt, etc.
- Underdrain Measurements - The underdrains are measured, and the vertical depth of fluid in the standpipe is recorded.
- Pond Sprays - When in use, the enhanced evaporation systems should be checked at regular intervals.
- Pond Liner - The liner is visually inspected weekly for holes or other signs of distress.
- Leak Detection System - The leak detection pipes for all ponds are measured for fluid in the standpipes, and the vertical depth of the fluid shall be recorded on the Pond Inspection Forms.

5.4.2.3 Quarterly Inspections

- Embankment Settlement - The tops of the embankments and downstream toe area are examined for settlement or depressions.
- Embankment Slopes - Embankment slopes are examined for irregularities in alignment and variances from originally constructed slopes (sloughing, toe movement, surface cracking, or erosion).
- Seepage - Evidence of seepage in any areas surrounding the ponds (especially the downstream toes) is investigated and documented.

- Slope Protection - Vegetation on the outslopes of the pond is examined. Any evidence of rills or gullies forming is noted.
- Post-Construction Changes - Any changes to the upstream watershed areas that could affect runoff to the ponds is noted.
- Emergency lines are inspected to ensure that the rope has not deteriorated and the ropes reach to the pond water level.

5.4.2.4 Annual Inspection

A technical evaluation of the pond system which addresses the hydraulic and hydrologic capacities of the ponds and ditches and the structural stability of the embankments will be conducted annually. A survey of the pond embankments will be conducted annually and the survey results documented and incorporated into the annual inspection report. The survey is reviewed for evidence of embankment settlement, irregularities in embankment alignment, and any changes in the originally constructed slopes.

The technical evaluation will be the result of an annual inspection and a review of the weekly, monthly, and quarterly inspection reports by a professional engineer registered in the State of Nebraska. The pond monitor well sampling data will also be reviewed for signs of seepage in the embankments.

The inspection report will present the results of the technical evaluation and the analysis of inspection data collected since the last report. The report will be kept on file at the site for review by regulatory agencies. A copy is also submitted to the USNRC within 1 month of the annual inspection.

5.4.3 **Annual ALARA Audits**

CBR will conduct annual audits of the radiation safety and ALARA programs. The Manager of Health, Safety, and Environmental Affairs may conduct these audits. Alternatively, CBR may use qualified personnel from other uranium recovery facilities or an outside radiation protection auditing service to conduct these audits. The purpose of the audits is to provide assurance that all radiation health protection procedures and license condition requirements are being conducted properly at the Crow Butte Project facility. Any outside personnel used for this purpose will be qualified in radiation safety procedures as well as environmental aspects of solution mining operations. Whether conducted internally or through the use of an audit service, the auditor will meet the minimum qualifications for education and experience for the RSO as described in **Section 5.5.**

The audit of the radiation protection and ALARA program is conducted in accordance with the recommendations contained in USNRC Regulatory Guide 8.31. A written report of the results is submitted to corporate management. The RSO may accompany the auditor but may not contribute to the conclusions.

The annual ALARA audit report summarizes the following data:

- Employee exposure records;
- Bioassay results,
- Inspection log entries and summary reports of mine and process inspections,
- Documented training program activities,
- Applicable safety meeting reports,
- Radiological survey and sampling data,
- Reports on any overexposure of workers, and
- Operating procedures that were reviewed during this period.

The ALARA audit report specifically discusses the following:

- Trends in personnel exposures;
- Proper use, maintenance, and inspection of equipment used for exposure control; and
- Recommendations on ways to further reduce personnel exposures from uranium and its daughters.

The ALARA audit report is submitted to and reviewed by the CBR President and Mine Manager. Implementation of the recommendations to further reduce employee exposures, or improvements to the ALARA program, is discussed with the ALARA auditor.

An annual audit of the Quality Assurance/Quality Control (QA/QC) program is also conducted. An individual qualified in analytical and monitoring techniques who does not have direct responsibilities in the areas being audited performs the audit. The results of the QA/QC audit are documented with the ALARA Audit. The RSO has the primary responsibility for the implementation of the radiological QA/QC programs at the Crow Butte Project facilities.

5.4.4 Records Management

Detailed discussions of recordkeeping policies, responsibilities and procedures are maintained in CBR's SHEQMS Program Volume II, Management Procedures Manual. Key components of the recordkeeping retention policies are discussed below.

<u>Determination of Records to be Maintained</u>

Records that are maintained as part of the CBR's records retention policy are identified by utilizing the following sources of information:

- Records and maintenance periods established by regulations (e.g., 10 CFR 20 and 10 CFR 40);
- Records and maintenance periods established by license or permit requirements;
- Records established by industry and international standards (e.g., ISO-14001:2004); and
- Records established by Company policies.

Records that are deemed critical to records retention includes, but is not limited to:

- Decision on communication of significant environmental aspects*;
- Record of changes to documented procedures resulting from corrective action*;
- External communication records*;
- Environmental Management System (EMS) audit records*;
- EMS management review records*;
- Records of calibration and maintenance of monitoring equipment*;
- Training records*;
- Information on applicable laws or other requirements;
- Process monitoring information, where it has a bearing on environmental, health and safety aspects, impacts, or operational controls;
- Monitoring data;
- Change management records;
- Nonconformance and incident reports;
- Information on emergency response situations; and
- Product information, including lists and composition of products (i.e. MSDS's).

* required by the ISO 14001:2004 and OHSAS-18001:1999 standards

Records are classified as permanent and non-permanent for purposes of retention timelines:

- Permanent records are maintained for the life of the project, operation or facility. **All such records must be maintained until the NRC has terminated any license authorizing operations.** These records may be required to meet any of the following criteria:

    1. Records that are required to maintain and decommission a facility (e.g., operating history);
    2. Information which may be of value in determination of an accident, a malfunction, etc., (e.g., test results);
    3. Baseline data;
    4. Personnel medical records, including health physics data;
    5. Facility design documents;
    6. Monitoring data identified in State permits and NRC licenses.

- Non-permanent records are those that do not meet any of the above criteria but are required to provide evidence that an activity was performed according to the requirements. Examples of these types of records are certificates, inspection reports, operator qualifications, purchase orders, personnel qualifications, inspections and test plans, audits, etc.

CBR complies with the record retention requirements stated in 10 CFR 20 and 10 CFR 40. For example, this would include, but not limited to, requirements specified in 10 CFR 20.2102 (Records of radiation protection programs), 20.2103 (Records of surveys), 20.2104 (determination of prior occupational doses), 20.2105 (Any records of planned special exposures), 20.2106 (Records of individual monitoring results), 20.2107 (Records of dose to individual members of the public) and 20.2108 (Records of waste disposal). In addition records would be retained as specified in 10 CFR 40.61 (Records) for the receipt, transfer, and disposal of source or byproduct material as specified in this regulation. Record retention timelines typically vary from 3 years following the generation of the record or until termination of the license that authorizes the activity and associated record. For example, as per 10 CFR 20.2102, records of CBR's radiation protection program (including provisions of the program) shall be maintained until the NRC terminates the site's radioactive material license requiring the record, and records of audits and other reviews shall be maintained for 3 years after the record is made.

Where possible, site records are identified in the appropriate project implementing procedures. Retention time and personnel responsible for handling of the records are also identified. For instance, record retention times for radiological monitoring records required by the NRC License are identified in CBR's SHEQMS Program Volume IV, Health Physics Manual.

All records are required to be legible and traceable to the applicable activity, product or service. The form of records is maintained as per 10 CFR 20.2110.

Record Storage

Obsolete versions of some documents may be considered a record and will be retained in the SHEQMS Program records. An example would be history copies of previous revisions of implementing procedures and operating manuals.

Records are filed as to allow for prompt retrieval in accordance with the retention time criteria stipulated in CBR's Record Management Matrix.

Records are stored in an environment that minimizes damage or deterioration and/or loss. Backup copies of critical and permanent records are maintained in a separate location. Backup copies may be paper or electronic versions.

Records are retained for a minimum of three years unless otherwise specified in other documents or subject to longer record retention requirements specified in regulations such as 10 CFR 20 and 10 CFR 40.

Review of Recordkeeping Requirements

The format and contents of the records will be reviewed **at least annually** as part of the established review of the site programs and changes initiated will be reflected in the revisions to this procedure.

As additional EMS-related records (including new or revised regulatory requirements) are identified, they will be incorporated into this recordkeeping review procedure as part of continual improvement to this procedure.

5.5 HEALTH PHYSICS QUALIFICATIONS

CBR project staff is highly experienced in the management of uranium development, mining, and operations. The following are the minimum required personnel specifications and qualifications.

5.5.1 Radiation Safety Officer Qualifications

The minimum qualifications for the RSO are as follows:

- Education - A Bachelor's degree in the physical sciences, industrial hygiene, or engineering from an accredited college or university or an equivalent combination of training and relevant experience in UR facililty radiation protection. Two years of relevant experience are generally considered equivalent to one year of academic study.
- Health Physics Experience - At least 1 year of work experience relevant to UR operations in applied health physics, radiation protection, industrial hygiene or similar work. This experience should involve actually working with radiation detection and measurement equipment, not strictly administrative or "desk" work.
- Specialized Training – At least 4 weeks of specialized classroom training in health physics specifically applicable to uranium recovery. In addition, the RSO should attend refresher training on UR facility health physics every 2 years.
- Specialized Knowledge - A thorough knowledge of the proper application and use of all health physics equipment used in the UR facility, the chemical and analytical procedures used for radiological sampling and monitoring, methodologies used to calculate personnel exposures to uranium and its daughters, and a thorough understanding of the UR process and equipment used in the facility and how hazards are generated and controlled during the UR process.

5.5.2 Health Physics Technician Qualifications

The HPT will have one of the following combinations of education, training, and experience:

- Education - An Associate's degree or 2 years or more of study in the physical sciences, engineering, or a health-related field;

  Training - At least a total of 4 weeks of generalized training (up to 2 weeks may be on-the-job training) in radiation health protection applicable to UR facilities;

  Experience - One year of work experience using sampling and analytical laboratory procedures that involve health physics, industrial hygiene, or industrial safety measures to be applied in a UR facility; or

- Education - A high school diploma is required.

  Training – A total of at least 3 months of specialized training (up to 1 month may be on-the-job training) in radiation health protection relevant to UR facilities;

- Experience - Two years of relevant work experience in applied radiation protection.

5.6 TRAINING

All site employees and contractor personnel at the Crow Butte Project are administered a training program based on the SHEQMS Program covering radiation safety, radioactive material handling, and radiological emergency procedures. This training program is administered in keeping with standard radiological protection guidelines and the guidance provided in USNRC Regulatory Guide 8.29, *Instructions Concerning Risks From Occupational Radiation Exposure* (Revision 1, February 1996); Regulatory Guide 8.31, *Information Relevant to Ensuring That Occupational Radiation Exposures at Uranium Recovery Facilities Will Be As Low As Reasonably Achievable* (Revision 1, May 2002); and Regulatory Guide 8.13, *Instruction Concerning Prenatal Radiation Exposure* (Revision 3, June 1999). The content of the training program is under the direction of the RSO. The RSO or a qualified designee conducts all radiation safety training.

5.6.1 Training Program Content

5.6.1.1 Visitors

Visitors to the Crow Butte Project who have not received training are escorted by on-site personnel who are properly trained and familiar with the hazards of the facility. At a minimum, visitors are instructed specifically on what they should do to avoid possible hazards in the area of the facility that they are visiting.

5.6.1.2 Contractors

Any contractors having work assignments at the facility are given appropriate radiological safety training. Contract workers who will be performing work on heavily contaminated equipment receive the same training normally required of Crow Butte workers as discussed in **Section 5.6.1.3**.

5.6.1.3 Crow Butte Resources Employees

The CBR SHEQMS Program Volume VII, *Training Manual*, incorporates the following topics recommended in USNRC Regulatory Guide 8.31, *Information Relevant to Ensuring That Occupational Radiation Exposures at Uranium Recovery Facilities Will Be As Low As Reasonably Achievable* (Revision 1, May 2002), USNRC Regulatory Guide 8.29, *Instruction Concerning Risks From Occupational Radiation Exposure (Revision 1, February 1996, and* USNRC Regulatory Guide 8.13, *Instruction Concerning Prenatal Radiation Exposure (Revision 3, June 1999)*:

<u>Fundamentals of Health Protection</u>

- The radiological and toxic hazards of exposure to uranium and its daughters.
- How uranium and its daughters enter the body (inhalation, ingestion, and skin penetration), and
- Why exposures to uranium and its daughters should be kept as low as reasonably achievable (ALARA).

Personal Hygiene at Uranium Mines

- Wearing protective clothing;
- Using respirators when appropriate;
- Eating, drinking, and smoking only in designated areas; and
- Using proper methods for decontamination.

Facility-provided Protection

- Cleanliness of working spaces,
- Safety designed features for process equipment,
- Ventilation systems and effluent controls,
- Standard Operating Procedures, and
- Security and access control to designated areas.

Health Protection Measurements

- Measurements of airborne radioactive material,
- Bioassay to detect uranium (urinalysis and in vivo counting),
- Surveys to detect contamination of personnel and equipment, and
- Personnel dosimetry.

Radiation Protection Regulations

- Regulatory authority of USNRC, MSHA, and state;
- Employee rights in 10 CFR Part 19; and
- Radiation protection requirements in 10 CFR Part 20.

Emergency Procedures

All new workers, including supervisors, are given specialized instruction on the health and safety aspects of the specific jobs they will perform. This instruction is performed in the form of individualized on-the-job training. Retraining is conducted annually and documented. Every 2 months, all workers attend a general safety meeting.

Consistent with USNRC Regulatory Guide 8.13, *Instruction Concerning Prenatal Radiation Exposure (Revision 3, June 1999),* all female workers and those supervisors who will work with them will be given specific instruction about prenatal exposure risks to the developing embryo and fetus.

5.6.2 **Testing Requirements**

A written test with questions directly relevant to the principals of radiation safety and health protection in the facility covered in the training course is given to each worker. The instructor reviews the test results with each worker and discusses incorrect answers

to the questions with the worker until worker understanding is achieved. Workers who fail the exam are retested, and test results remain on file.

5.6.3 **On-The-Job Training**

5.6.3.1 Health Physics Technician

On-the-job training is provided to HPTs in radiation exposure monitoring and exposure determination programs, instrument calibration, plant inspections, posting requirements, respirator programs, and health physics procedures contained in the SHEQMS Program Volume IV, *Health Physics Manual*.

5.6.4 **Refresher Training**

Following initial radiation safety training, all permanent employees and long-term contractors receive ongoing radiation safety training as part of the annual refresher training and, if determined necessary by the RSO, during monthly safety meetings. This ongoing training is used to discuss problems and questions that have arisen, any relevant information or regulations that have changed exposure trends, and other pertinent topics.

5.6.5 **Training Records**

Records of training are kept for 5 years for all employees trained as radiation workers (occupationally exposed employees).

5.6.6 **Qualifications and Requirements for Daily Inspections**

The Crow Butte Resources RSO will qualify Designated Operators to conduct daily walkthrough inspections of all work and storage areas at the Crow Butte Plant and associated satellite facilities. The Designated Operators will only conduct the inspections on weekends and holidays when neither the RSO or HPT is present. With the exception of the Thanksgiving holiday, the Designated Operator will not conduct the inspections for more than two days per week (three days if a Federal holiday falls on Friday or Monday). For the Thanksgiving holiday only, the Designated Operator may perform the daily inspections for four consecutive days.

Any problems noted by the Designated Operator during the daily inspection will be recorded on an inspection form, signed and dated, and retained on file. The RSO will review the inspection forms and take appropriate action to correct any noted problems.

A qualified Designated Operator has no authority for the development and administration of the radiation protection program, other than conducting daily inspections (emphasis added). He may not approve plans for new equipment, process changes, or changes in operating procedures that might affect the radiation protection program. He will not conduct radiation safety audits or make determinations about personnel dosimetry. A qualified Designated Operator may not authorize non-routine maintenance jobs involving potential for personnel radiation exposure or radioactive contamination for which there are not standard operating procedures nor an existing radiation work permit. The

designated operator will not have the authority to release materials for unrestricted use. In the event of an emergency, the on-call RSO or HPT will be responsible for radiation protection decisions.

At the Crow Plant and satellite facilities, the only activity required to be performed by the RSO or HPT on a daily basis is the daily inspection. Instrument calibrations are performed on a weekly basis, during the regular workweek by the RSO or HPT. For that reason it is not necessary for the, Designated Operator to perform any other RSO or HPT function on weekends or holidays.

The Designated Operator will observe, through visual inspection, radiation safety practices, housekeeping and implementation of the radiation safety program throughout the plant/satellite. Such duties include, but not be limited to, inspecting for compliance with radiation safety postings, contamination control, proper control point ingress and egress, control of airborne radioactivity, worker protection practices in the yellowcake drying and packaging area, and proper storage of byproduct material.

5.6.6.1 Minimum Qualifications for Designated Operators

Before a Designated Operator may conduct such inspections, he must be qualified by reason of training and experience to observe proper implementation of good radiation safety practices. In addition to the annual radiation worker training required by Regulatory Guide 8.31, Section 2.5, the operator seeking designation must not only complete one-time training specific to daily inspections, but also demonstrate proficiency. The additional training will emphasize how the inspections affect employee safety and contamination control.

At a minimum, the operator seeking designation must have the following combination of education, training and experience:

Education: a high school diploma or equivalent

Training: New employee radiation safety training, including guidance pertinent to prenatal radiation exposure (Regulatory Guide 8.13) and instruction concerning risks from occupational radiation exposure (Regulatory Guide 8.29); and additional training specific to conducting daily inspections at Crow Butte ISR facilities. In addition, the Designated Operator will be required to demonstrate proficiency during daily inspections to the RSO. Specifics on the additional training and the proficiency demonstration are provided below in the technical basis.

Experience: A minimum of three months work experience in operations or maintenance at a uranium recovery facility, including procedures that involve health physics, industrial safety or industrial hygiene at a uranium recovery facility to demonstrate qualification is required.

5.6.6.2 Additional Training for Designated Operators

The additional radiation safety training afforded to operators seeking designation involves four hours training and a test with an 80% passing grade, but does not include the more advanced topics required for the facility RSO or HPT.

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The additional radiation safety training afforded to operators seeking designation involves four hours training and a test covering the topics described below with an 80% passing grade, but does not include the more advanced topics required for the facility

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5.7 SECURITY

CBR security measures for the current operation are specified in the Security Plan and Security Threat chapter in Volume VIII, *Emergency Manual*. CBR is committed to:

- Providing employees with a safe, healthy, and secure working environment;
- Maintaining control and security of USNRC licensed material;
- Ensuring the safe and secure handling and transportation of hazardous materials; and
- Managing records and documents that may contain sensitive and confidential information.

The USNRC requires licensees to maintain control over licensed material (i.e., natural uranium ["source material"] and byproduct material defined in 10 CFR §40.4). 10 CFR 20, Subpart I, *Storage and Control of Licensed Material*, requires the following:

§20.1801 Security of Stored Material

The licensee shall secure from unauthorized removal or access licensed materials that are stored in controlled or unrestricted areas.

§20.1802 Control of Material not in Storage

The licensee shall control and maintain constant surveillance of licensed material that is in a controlled or unrestricted area and that is not in storage.

Stored material at the Crow Butte Project would include uranium packaged for shipment from the facility or byproduct materials awaiting disposal. Examples of material not in storage would include yellowcake slurry or loaded ion exchange resin removed from the restricted area for transfer to other areas.

5.7.1 License Area and Plant Facility Security

5.7.1.1 Central Processing Facility Area

All Central Processing Facility areas where source or byproduct material is handled are fenced. The main access road is equipped with a locking gate. Strategically placed surveillance cameras monitor the access road and areas around the Central Processing facility. A 24-hour-per-day, 7-day-per-week staff is on duty in the Central Processing facility.

Central Plant operators perform an inspection to ensure the proper storage and security of licensed material at the beginning of each shift. The inspection determines whether all licensed material is properly stored in a restricted area or, if in controlled or unrestricted

areas, is properly secured. In particular, operators ensure that loaded ion exchange resin, slurry, drummed yellowcake, and byproduct material are properly secured. If licensed material is found outside a restricted area, the operator will ensure that it is secured, locked, moved to a restricted area, or kept under constant surveillance by direct observation by site personnel or surveillance cameras. The results of this inspection will be properly documented.

5.7.1.2 Office Building

There is a reception area located at the main entrance into the office building. All other entrances are locked during off-shift hours. There are a limited number of traceable keys to the office, and they are given out to select employees. The main door and the door to the Central Plant Facility entrance are also equipped with an access keypad.

Visitors entering the office are greeted by the receptionist and announced to the receiving person. All visitors are required to sign the access log and indicate the purpose of their visit and the employee to be visited. The person being visited is responsible to supervise the visitors at all times when they are on site. Visitors are only allowed at the facility during regular working hours unless prior approval is obtained from the Mine Manager or the Manager of Health, Safety, and Environmental Affairs.

5.7.2 Transportation Security

CBR routinely receives, stores, uses, and ships hazardous materials as defined by the U.S. Department of Transportation (DOT). In addition to the packaging and shipping requirements contained in the DOT Hazardous Materials Regulations (HMR), 49 CFR 172, Subpart I, *Security Plans* requires that persons who offer for transportation or transport certain hazardous materials develop a Security Plan. Shipments may qualify for this DOT requirement under the following categories:

§172.800(b)(4) A shipment of a quantity of hazardous materials in a bulk package having a capacity equal to or greater than 13,248 L (3,500 gallons) for liquids or gases or more than 13.24 cubic meters (468 cubic feet) for solids;

§172.800(b)(5) A shipment in other than a bulk packaging of 2,268 kg (5,000 pounds) gross weight or more of one class of hazardous material for which placarding of a vehicle, rail car, or freight container is required for that class under the provisions of subpart F of this part;

§172.800(b)(7) A quantity of hazardous material that requires placarding under the provisions of subpart F of this part.

DOT requires that Security Plans assess the possible transportation security risks and evaluate appropriate measures to address those risks. All hazardous materials shippers and transporters subject to these standards must take measures to provide personnel security by screening applicable job applicants, prevent unauthorized access to the hazardous materials or vehicles being prepared for shipment, and provide for en route

security. Companies must also train appropriate personnel in the elements of the Security Plan.

Transport of licensed/hazardous material by CBR employees will generally be restricted to transferring contaminated equipment between company facilities. This transport generally occurs over short distances through remote areas. Therefore, the potential for a security threat during transport by CBR vehicle is minimal. The goal of the driver, cargo, and equipment security measures is to ensure the safety of the driver and the security and integrity of the cargo from the point of origin to the final destination by:

- Clearly communicating general point-to-point security procedures and guidelines to all drivers and non-driving personnel;
- Providing the means and methods of protecting the drivers, vehicles, and customer's cargo while on the road; and
- Establishing consistent security guidelines and procedures that shall be observed by all personnel.

For the security of all tractors and trailers, the following procedures will be utilized:

- If material is stored in the vehicle, access must be secured at all openings with locks and/or tamper indicators.
- Off-site tractors will always be secured when left unattended with windows closed, doors locked, the engine shut off, and no keys or spare keys in or on the vehicle.
- The unit is to be kept visible by an employee at all times when left unattended outside a restricted area.

The security guidelines and procedures apply to all transport assignments. All drivers and non-driving personnel are expected to know and adhere to these guidelines and procedures when performing any load-related activity.

5.8 RADIATION SAFETY CONTROLS AND MONITORING

CBR has a strong corporate commitment to and support for the implementation of the radiological control program at the Crow Butte Project facility. This corporate commitment to maintaining personnel exposures as low as reasonably achievable has been incorporated into the radiation safety controls and monitoring programs described in the following sections. This license renewal application contains the results through 2006 of the radiological control program since 1990. Where the monitoring results indicate that the program should be modified, proposed changes in the program are also discussed.

Radiological surveys and sampling were conducted between 1994 and 2006 in accordance with the requirements of license SUA-1534.

The CBR radiological monitoring program is based principally on the recommendations contained in USNRC Regulatory Guide 8.30 and includes operational monitoring for airborne uranium, radon daughters, external radiation, and surface contamination. Environmental monitoring performed by CBR is based principally on the recommendations contained in USNRC Regulatory Guide 4.14 and includes monitoring environmental media surrounding the Crow Butte Project such as air, water, soil, and sediment.

5.8.1 Effluent Control Techniques

5.8.1.1 Gaseous and Airborne Particulate Effluents

Under routine operations, the only radioactive effluent at the Crow Butte facility is the release of radon-222 gas from the production solutions. A vacuum dryer is used for drying the yellowcake product. There is no airborne effluent from the vacuum dryer system.

The radon-222 is found in the pregnant lixiviant that comes from the wellfield into the plant. The production flow is directed to the process building for separation of the uranium. The uranium is separated by passing the recovery solution through fluidized bed upflow ion exchange units or pressurized downflow ion exchange units. Radon gas is released from the solution in the ion exchange columns and in the injection surge tanks. The vents from the individual vessels are connected to a manifold that is exhausted outside the plant building through the plant stacks.

Venting to the atmosphere outside of the plant building minimizes personnel exposure. Small amounts of radon-222 may be released in the plant building during solution spills, filter changes, and maintenance activities. The plant building is equipped with exhaust fans to remove any radon that may be released in the plant building. No significant personnel exposure to radon gas has been noted during operation of the Crow Butte facility. Results of radon daughter monitoring in the process areas are discussed in **Section 5.8.3**.

5.8.1.2 Liquid Effluents

The liquid effluents from the Crow Butte Project can be classified as follows:

- **Water generated during well development** - This water is recovered groundwater and 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.
- **Liquid process waste** - The operation of the process plant results in two primary sources of liquid waste, an eluant bleed and a production bleed.
- **Aquifer restoration** - Following mining operations, restoration of the affected aquifer commences which results in the production of wastewater. The current groundwater restoration plan consists of four activities: 1) Groundwater Transfer, 2) Groundwater Sweep, 3) Groundwater Treatment, and 4) Wellfield Circulation. Only the groundwater sweep and groundwater treatment activities will generate wastewater.

  During groundwater sweep, water is extracted from the mining zone without injection causing an influx of baseline quality water to sweep the affected mining area.

  Groundwater treatment activities involve the use of process equipment to lower the ion concentration of the groundwater in the affected mining area. A RO unit may be used to reduce the total dissolved solids of the groundwater. The RO unit produces clean water (permeate) and brine. The permeate is either injected into the formation or disposed of in the waste disposal system. The brine is sent to the wastewater disposal system. The permeate may be further treated if necessary to meet the quality requirements of the NPDES permit for land application disposal.

The existing USNRC License allows CBR to dispose of wastewater by three methods:

- Evaporation from the evaporation ponds;
- Deep well injection; and
- Land application.

The design, installation, inspection and operation criteria for the solar evaporations ponds are those found to be applicable in USNRC Regulatory Guide 3.11, *Design, Construction and Inspection of Embankment Retention Systems for Uranium Mills* (Revision 2, December 1977). Each commercial pond is nominally 900 feet by 300 feet by 17 feet in depth. The ponds are membrane lined with a leak detection system under the membrane and are designed to allow the contents of any given pond to be transferred into another pond in the event of a pond problem.

Each of the ponds has the capability of being pumped for water treatment prior to discharge under the NPDES permit. A variety of treatment options exist depending upon

the specific chemical contaminants identified in the wastewater. In general, a combination of chemical precipitation and reverse osmosis is adequate to restore the water to a quality that falls within the NPDES parameters.

5.8.1.3 Spill Contingency Plans

The RSO is charged with the responsibility to develop and implement appropriate procedures to handle potential spills of radioactive materials. Personnel representing the engineering and operations functions of the Crow Butte Project facility will assist the RSO in this effort. Basic responsibilities include:

- Assignment of resources and manpower.
- Responsibility for materials inventory.
- Responsibility for identifying potential spill sources.
- Establishment of spill reporting procedures and visual inspection programs.
- Review of past incidents of spills.
- Coordination of all departments in carrying out goals of containing potential spills.
- Establishment of employee emergency response training programs.
- Responsibility for program implementation and subsequent review and updating.
- Review of new construction and process changes relative to spill prevention and control.

Spills can take two forms within an in-situ uranium mining facility; surface spills such as pond leaks, piping ruptures, transportation accidents, etc., and subsurface releases such as a well excursion, in which process chemicals migrate beyond the wellfield, or a pond liner leak resulting in a release of waste solutions.

Engineering and administrative controls are in place to prevent both surface and subsurface releases to the environment and to mitigate the effects should a release occur.

Surface Releases - The most common form of surface release from in-situ mining operations occurs from breaks, leaks, or separations within the piping that transfers mining fluids between the process plant and the wellfield. These are generally small releases due to engineering controls that detect pressure changes in the piping systems and alert the plant operators through system alarms.

In general, piping from the plant to and within the wellfield is constructed of PVC, high-density polyethylene pipe with butt-welded joints or equivalent. All pipelines are pressure tested at operating pressures prior to operation. It is unlikely that a break would occur in a buried section of line because no additional stress is placed on the pipes. In addition, underground pipelines are protected

from a major cause of potential failure - that of vehicles driving over the lines causing breaks. The only exposed pipes are at the process plant, the wellheads, at temporary transfer lines and in the control house in the wellfield. Trunkline flows and wellhead pressures are monitored each shift for process control. One section of underground piping that passes beneath Squaw Creek is double contained for additional protection. Spill response is specifically addressed in the Radiological Emergencies and Emergency Reporting chapters of SHEQMS Program Volume VIII, *Emergency Manual.*

CBR's spill control programs have been very effective at limiting surface releases from mining operations. CBR has never had a spill that was reportable under 10 CFR 20 reporting requirements. All spills are analyzed for root causes and contributing factors. Periodically, the CBR SERP meets to analyze recent spill events and to determine whether engineering or administrative improvements are indicated to reduce the frequency and magnitude of spills.

Transportation accidents - SHEQMS Program Volume VIII, *Emergency Manual* provides the CBR emergency action plan for responding to a transportation accident involving a radioactive materials shipment. The Emergency Manual provides instructions for proper packaging, documentation, driver emergency and accident response procedures, and cleanup and recovery actions. Spill response is also addressed in SHEQMS Program Volume VIII, *Emergency Manual.*

Sub-surface releases - Mining fluids are normally maintained in the production aquifer within the immediate vicinity of the wellfield. The function of the encircling monitor well ring is to detect any mining solutions that may migrate away from the production area due to fluid pressure imbalance. This system has been proven to function satisfactorily over many years of operating experience with in-situ mining.

At the Crow Butte Project site, an undetected excursion is highly unlikely. All wellfields are surrounded by a ring of monitor wells located no further than 300 feet from the wellfield and screened in the ore-bearing Chadron aquifer. Additionally, monitor wells are placed in the first overlying aquifer above each wellfield segment. Sampling of these wells is done on a biweekly basis. Past experience at in-situ leach mining facilities has shown that this monitoring system is effective in detecting leachate migration. The total effect of the close proximity of the monitor wells, the low flow rate from the well patterns, and over-production of leach fluids (production bleed) makes the likelihood of an undetected excursion extremely remote.

Migration of fluids to overlying aquifers has also been considered. Several controls are in place to prevent this. First, CBR has plugged all exploration holes to prevent co-mingling of Brule and Chadron aquifers and to isolate the mineralized zone. Successful plugging was tested by conducting four hydrologic tests prior to mining. Results indicated that no leakage or communication exists between the mineralized zone and overlying aquifers. In addition, prior to placing

requirement of the NDEQ UIC Program ensures that all wells are constructed properly and are capable of maintaining pressure without leakage. Finally, monitor wells completed in the overlying aquifer are also sampled on a regular basis for the presence of leach solution.

Seepage of solutions from the evaporation ponds into ground or surface water is also a potential pollution source. However, this has not been nor should it be a problem at the Crow Butte site. Construction and operational safeguards have been implemented to insure maximum competency of the synthetic liner and earthen embankments. The underdrain leak detection system allows sampling that would detect a leak. The pond soil foundation has low ambient moisture due to its elevation, soil type and preparation. In the unlikely event of pond fluids seeping into the compacted subsoil, the liquid would be quickly absorbed and would not migrate. Pond monitor wells are also located downstream of the evaporation ponds to detect leaks into the uppermost aquifer.

In addition to the spills described above, the accumulation of sediment or erosion of existing soils can lead to potential releases of pollutants. The likelihood of significant sediment or erosion problems is greatest during construction activities, which are completed at this time. Future construction activities could include additional wellfield development, or additional pond construction. During construction, there is a possibility that sediment load may increase in Squaw Creek. If rain, producing runoff, occurs during construction, a small amount of the fill may be carried into the creek. Significant precipitation during pond construction and plant facilities might also produce the same effect. Plant cover for erosion control will be established as soon as possible on exposed areas. Little additional suspendable material should be produced during mining operations and restoration activities. Site reclamation in the future with backfilling of ponds, grading the plant site, and replacing the topsoil will also expose unsecured soil for suspension in runoff waters. The increased sediment load as a result of precipitation during future construction or reclamation activities should not significantly affect the quality of Squaw Creek as the more sensitive areas of the stream are located upstream form the point of entry of the tributary.

Runoff from precipitation events should be controlled to minimize any exposure to pollutants on the site. At the Crow Butte Project site, runoff is not considered to be a major issue given the engineering design of the facilities, as well as the existing engineering and administrative controls. Rainwater entering a pond leading to a pond overflow would be the greatest item of concern. The design and operation of the ponds precludes a runoff-induced overflow as a realistic possibility. Should there be high runoff concurrent with a pipeline failure, some contamination could be spread depending upon the relative saturation of the soils beneath the leaking area. In any event, as only minimal releases of solutions would occur in the event of a pipeline failure and migration of pollutants due to runoff would still be minimal.

5.8.2 External Radiation Exposure Monitoring Program

5.8.2.1 Gamma Survey

Program Description

External gamma radiation surveys are performed routinely at the Crow Butte Project. The required frequency is quarterly in designated Radiation Areas and semiannually in all other areas of the plant. Surveys are performed at specified locations in worker occupied stations and areas of potential gamma sources such as tanks and filters. CBR establishes a Radiation Area if the gamma survey exceeds the action level of 5.0 mRem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates. An investigation is performed to determine the probable source and survey frequency for areas exceeding 5.0 mR/hr are increased to quarterly. Records are maintained of each investigation and the corrective action taken. If the results of a gamma survey identifies areas where gamma radiation is in excess of levels that delineate a "radiation area", access to the area is restricted and the area is posted as required in 10 CFR §20.1902 (a). Designated Radiation Areas are defined in 10 CFR 20.1003: *Radiation area* is an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

External exposure at the Crow Butte Project is monitored using Optically-Stimulated Luminescent (OSL) dosimeters provided by Landauer Corp. Landauer is a NVLAP-certified vendor for the use of this technology for monitoring external exposures. Dosimeters are exchanged on a quarterly basis.

Historical Program Results

Routine gamma surveys have been performed as required at the Crow Butte Project. A Radiation Area is established around the injection filter system due to gamma levels above 5.0 mR/hr. Radiation Areas have also been established around several other areas within the processing plant. These areas include the other process filter systems, around selected portions of the ion exchange piping, the waste demister box, the acid wash vat, and the reverse osmosis system. In addition, several of the wellhouses have been designated as Radiation Areas due to scale buildup in the injection manifold piping. Engineering controls such as lead sheeting and water block walls have been employed to maintain personnel exposures ALARA. Results of the gamma survey program are maintained at the Crow Butte Project site.

Proposed Beta and Gamma Survey Program

CBR proposes to continue with the same gamma exposure-monitoring program of worker occupied stations and areas likely to have significant gamma exposure rates at the Crow Butte Project that has been performed to date.

Gamma exposure rate surveys continue to be performed in accordance with the instructions currently contained in SHEQMS Program Volume IV, *Health Physics Manual*. Gamma survey instruments are operationally checked each day of use in accordance with the manufacturer's instructions.

Beta surveys of specific operations that involve direct handling of large quantities of aged yellowcake will continue to be performed as discussed in USNRC Regulatory Guide 8.30, *Health Physics Surveys in Uranium Recovery Facilities*, Section 1.4. Beta evaluations may be substituted for surveys using radiation survey instruments. Surveys or evaluations will be performed whenever a change in equipment or procedures has occurred that may significantly affect worker exposures.

5.8.2.2 Personnel Dosimetry

Program Description

All employees working in the process facility or wellfield operations who have the potential to receive ten percent of the annual allowable dose limits are issued dosimeters for determination of external gamma exposure. Dosimeters are provided by a vendor that is accredited by NVLAP of the National Institute of Standards and Technology as required in 10 CFR § 20.1501. The dosimeters have a range of 1 mR to 1000 R. Dosimeters are exchanged and read on a quarterly basis.

Historical Program Results

Figure 5.8.1 depicts the average and maximum external exposure levels for all employees at the Crow Butte Project from 1994 through 2006. The average annual exposures to gamma radiation have been well below the annual regulatory limit of 5 Rem and the CBR administrative limit of 1.25 Rem for this time period. The average external exposure for this 13-year period was 94 mREM, ranging from 33 to 165 mREM. The maximum external exposure for this time period ranged from 114 to 495 mREM.

For the years of 2000 through 2006, measurements indicated average external exposure levels of ranged from 81 to 129 mREM, with maximum exposures ranging from 238 to 448. The average and maximum exposure levels for 2006 (88 and 252 mREM, respectively) were lower than 2005 values (118 and 425, respectively) by approximately 24 percent and 41 percent, respectively.

As can be seen in **Figure 5.8-1**, there were noticeable elevations in the maximum exposure levels for the years 2001, 2002 and 2005. The most likely cause of these elevated maximum exposures in 2001 and 2002 was the requirement by CBR to store yellowcake during periods when the yellowcake dryer was unable to maintain production (CBR 2001, CBR 2002). The maximum exposure in 2005 (425 mREM) was received by a maintenance worker that was involved in several significant projects in areas with elevated gamma levels, including rebuilding one set of injection filters and installation of a new deep disposal well filtering system (CBR 2005).

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Figure 5.8-1: Average and Maximum External Exposure Analysis

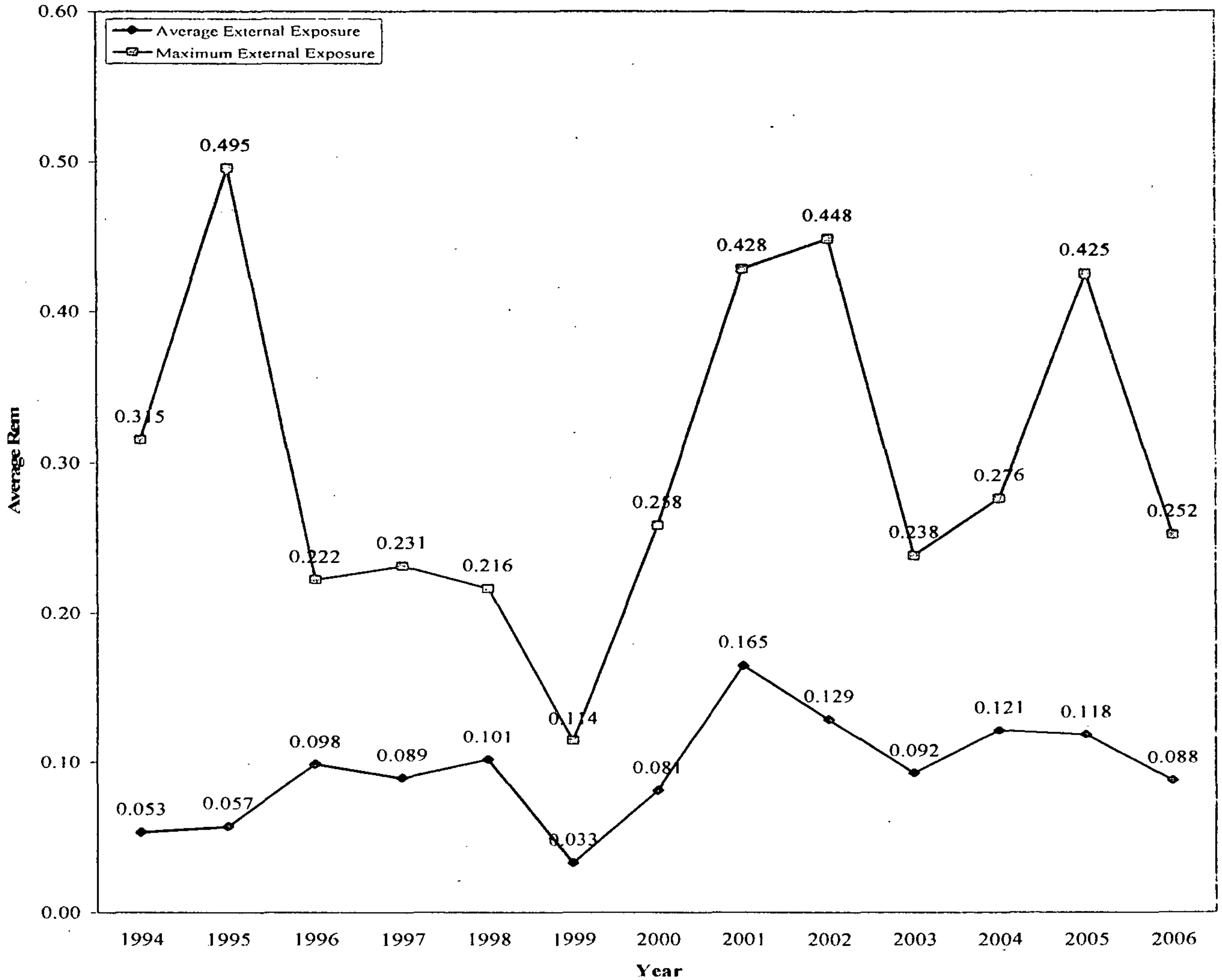


Figure 5.8-2 depicts the total Person-Rem due to external exposure for each year from 1994 through 2006. The results of the trend analysis indicate a significant decrease in the *combined external exposure* to gamma radiation from 2001/2002 to 2006 at the Crow Butte Project. As discussed above, once the yellowcake dryer was able to maintain production, the combined external exposure decreased from 5.28 Person-Rem in 2002, to 3.14 Person-Rem in 2003. The combined external exposure was further reduced from 3.44 Person-Rem in 2005 to 2.63 Person-Rem in 2006.

More detailed information as to the external exposure measurements are described in the CBR Semiannual Radiological Effluent and Environmental Monitoring Report and annual ALARA Review reports (1997 – 2006).

Personnel Dosimetry Program

10 CFR §20.1502 (a)(1) requires exposure monitoring for "Adults likely to receive, in 1 year from sources external to the body, a dose in excess of ten percent of the limits in §20.1201 (a)". Ten percent of the dose limit would correspond to a Deep Dose Equivalent (DDE) of 0.500 Rem. Maximum individual annual exposures at the Crow Butte Project facilities since 1987 have been well below ten percent of the limit. CBR believes that it is unlikely that any employee will exceed ten percent of the regulatory limit. Although monitoring of external exposure may not be required in accordance with §20.1201(a), CBR will continue to issue dosimeters to all process and wellfield employees with the potential to receive ten percent of the annual allowable dose limits and exchange them on a quarterly basis. Results from dosimeter monitoring will be used to determine individual DDE for use in determining Total Effective Dose Equivalent (TEDE) in accordance with the SHEQMS Program Volume IV, *Health Physics Manual*.

5.8.3 **In-Plant Airborne Radiation Monitoring Program**

5.8.3.1 Airborne Uranium Particulate Monitoring

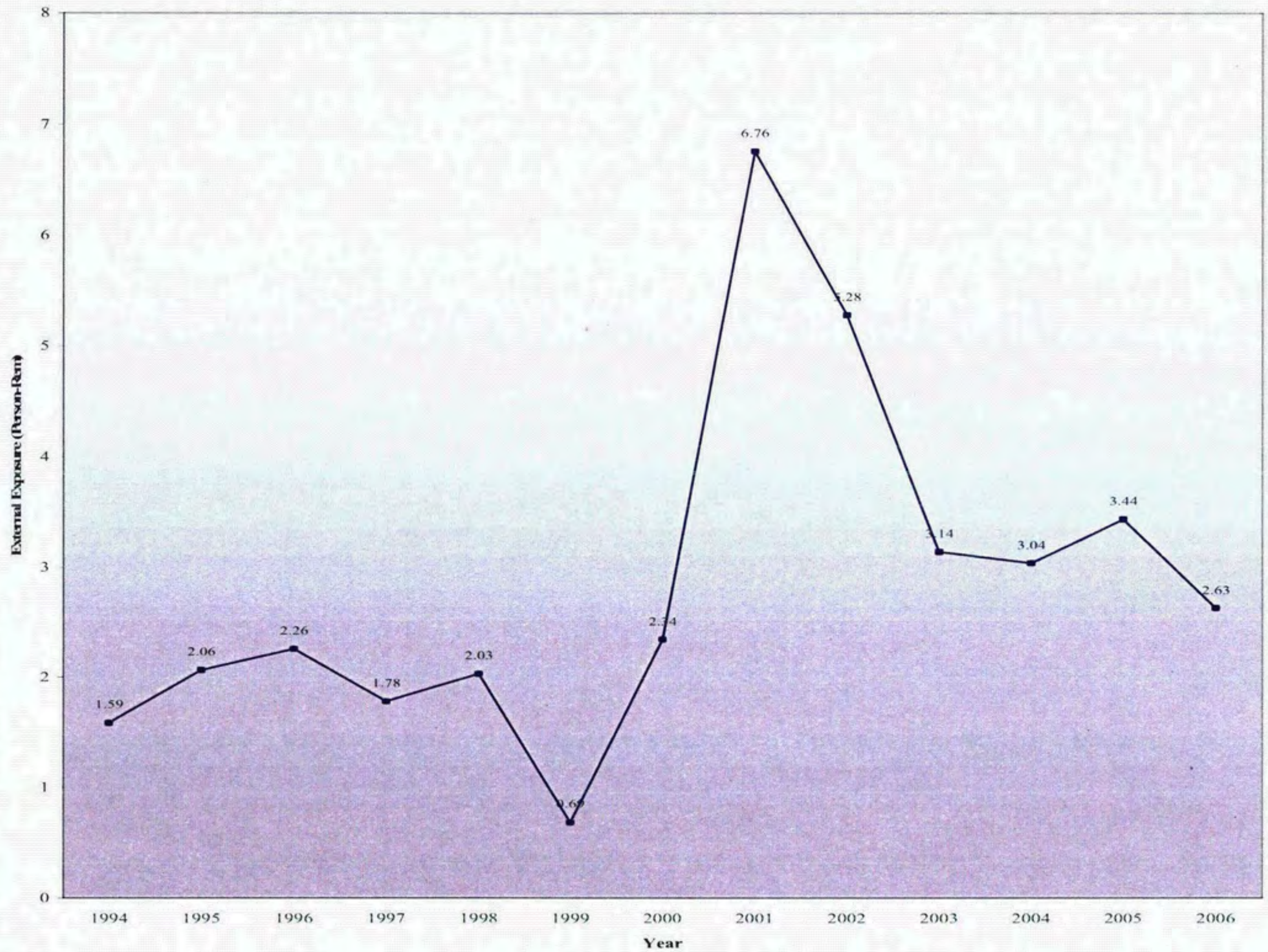
Program Description

Airborne particulate levels at solution mines which ship slurry yellowcake product are normally very low since the product is wet. Yellowcake drying operations began in 1993. Monitoring for airborne uranium has been performed routinely at Crow Butte Project through the use of area sampling and breathing zone sampling. The monitoring programs are described below.

Area Sampling

There are four required airborne uranium survey locations in the plant plus the dryer room. The monitoring frequency for the dryer room location is weekly, while the frequency for the other four locations is monthly. If a location meets the criteria for an Airborne Radioactivity Area as defined in 10 CFR §20.1003, the monitoring frequency increases to weekly. The only location at the Crow Butte Project that has met this criterion has been the dryer room during operation of the dryer.

Figure 5.8-2: Combined External Exposure Analysis



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During operation of the dryer, the dryer room is isolated and posted as an Airborne Radioactivity Area. CBR limits access to personnel wearing the proper respiratory protective equipment. A breathing zone sample for the dryer operator is collected during packaging operations. An area air sample is also collected outside of the dryer room. When packaging is completed, the room is washed down and the dryer is reloaded. To open the room, an area air sample is collected inside the dryer room to verify that the airborne concentrations are low enough to remove the Airborne Radioactivity Area designation and allow access without respiratory protection. The breathing zone sample obtained during dryer operation is used to determine internal exposure for the dryer operator. The results of the area samples are used, along with monitoring results for the other four monitoring locations, to determine monthly plant average airborne uranium concentrations for routine exposure calculations. Airborne uranium samples are analyzed for gross alpha at the plant. The conservative assumption is made that all alpha activity on the samples is due to airborne uranium.

Area samples are taken in accordance with the instructions currently contained in SHEQMS Program Volume IV, *Health Physics Manual*. Samples are taken with a glass fiber filter and a regulated air sampler such as an Eberline RAS-1 or equivalent. Sample volume is adequate to achieve the lower limit of detection (LLD) for uranium in air. The LLD value for uranium in air used for the CBR facility is 5 E-11, which is 10% of the current DAC of 5 E-10 Samplers are calibrated at the manufacturer's suggested interval or semiannually with a primary air flow calibrator. Sampler calibration is performed in accordance with the instructions currently in SHEQMS Program Volume IV, *Health Physics Manual*.

Measurement of airborne uranium is performed by gross alpha counting of the air filters using an alpha scaler such as a Ludlum Model 2000 or equivalent. Prior to 1994, the Maximum Permissible Concentration (MPC) value for natural uranium of 1 E-10 μCi/ml from Appendix B to 10 CFR §§ 20.1 - 20.601 was applied to the gross alpha counting results. After implementation of the new 10 CFR 20 on January 1, 1994, the Derived Air Concentration (DAC) for soluble (D classification) natural uranium of 5 E-10 μCi/ml from Appendix B to 10 CFR §§20.1001 - 20.2401 replaced the use of MPC. The expected mix of long-lived radionuclides is predominantly natural uranium with a lesser amount of Ra-226. The DAC for Ra-226 is 3 E-10 μCi/ml. The DAC for the mixture is between the natural uranium DAC and the Radium-226 DAC. CBR believes the use of natural uranium DAC for comparison to administrative action levels is appropriate since most of the expected mixture of airborne radionuclides is natural uranium and the DAC for natural uranium and Radium-226 are similar. An action level of 25% of the DAC for soluble natural uranium has been established at the Crow Butte facility. If an airborne uranium sample exceeds the action level of 25% of the DAC during routine monthly surveys, an investigation of the cause is performed. If a monthly airborne uranium sample exceeds 25% of the action level, the sampling frequency is increased from monthly to weekly until the airborne uranium levels do not exceed the action level for four consecutive weeks. As deemed necessary, the RSO may initiate corrective actions that may reduce future exposures.

No dose is calculated when comparing the measured airborne uranium concentrations to the natural uranium DAC. The purpose for this comparison is to determine whether the airborne uranium concentration is greater than the administrative action level of 25% DAC, which triggers an investigation. If internal doses are required to be estimated pursuant to 10 CFR 20.1202, methods described in Section 5.8.4 of the application are used.

As per 10 CFR 20.1201 (e), in addition to the annual dose limits, the intake of soluble uranium by an individual is limited to 10 mg in a week, with consideration of chemical toxicity. If exposure to soluble uranium exceeds 25% of the weekly allowable intake of 10 mg, which would be 2.5 mg/week, then the RSO initiates an investigation into the cause of the occurrence and initiates corrective actions that may reduce future exposures. As with any hazardous material handled on the site, the ALARA program is applied to such potential chemical exposures as described in Section 2.5 of CBR's SHEQMS Program Volume IV, Health Physics Manual.

Any worker likely to receive, in 1 year, an occupational dose in excess of 10% of the limits in 10 CFR 20 1201(a) is monitored. The RSO uses historical and current monitoring and survey data to ensure worker external radiation exposures. The external and internal dose that an individual is allowed to receive in the current year is reduced by the amount of occupational dose received or amount of intake while employed by any other person. The record of prior occupational dose that the individual received while performing work involving radiation exposure is obtained, as per 10 CFR 20.2104. All new employees are asked to provide their past radiological exposure history and asked to sign an Exposure Release Form so that previous radiological exposure history may be obtained. If a complete record of the individual's current and previously accumulated occupational dose is not available, it is assumed that in establishing administrative controls under 10 CFR 1201(f) for the current year, that the allowable dose limit for the individual be reduced by 1.25 rems (12.5 mSv) for each quarter for which records are unavailable and the individual worker engaged in activities that could have resulted in occupational radiation exposure. It would also be assumed that the individual would not be available for planned special exposures. As per 10 CFR 20.2104, CBR is not required to partition historical data between external dose equivalent(s) and internal committed dose equivalent(s).

Historical Program Results

- Airborne Uranium Monitoring – Main Plant

Airborne Uranium monitoring has been performed at the Central Plant at the locations shown in **Figure 5.8-5** since 1994. **Table 5.8-1** provides the results of gross alpha monitoring for airborne uranium from the period of 1994 through 2006. The annual average and maximum monthly average airborne gross alpha activity for this period are reported. All activity levels were well below 25 percent of the Derived Air Concentration (DAC).

The results of the airborne uranium monitoring program are fairly consistent since operation of the dryer began in 1993. The annual average for the years 1994 through 2006 was 2.96 x E-12 µCi/ml (0.6 percent of DAC), with a range of 1.28 E-12 to 4.02 E-12 µCi/ml. The maximum average airborne activity values ranged from 3.70 E-12 to 2.33 E-11 µCi/ml (0.7 percent and 4.7 percent of the DAC, respectively). In 2005 and 2006, the average airborne activity was 3.80 E-12 µCi/ml (0.8 percent DAC) and 3.86 E-12 µCi/ml (0.8 percent DAC), respectively, with a maximum value of 5.03 E-12 µCi/ml (1.0 percent DAC) and 4.87 E-12 µCi/ml (1.0 percent DAC), respectively.

- Airborne Uranium Exposures

Exposure to airborne uranium is based upon the results obtained from air sampling discussed in Area Sampling above. Routine exposure is based upon the monthly average plant airborne uranium concentrations. For personnel assigned full-time to the plant, a conservative occupancy time of 100 percent is used to determine exposure. For all other personnel, actual time in the plant is used for exposure calculations. Exposures assigned during work performed under a RWP or during routine dryer operations are based upon the results of specific monitoring and actual exposure times.

Table 5.8-1: In-plant Airborne Uranium Monitoring Results

Airborne Uranium Monitoring Period (Calendar Year)	Annual Average Airborne Activity µCi/Ml Gross α (% Dac)[1]	Maximum Monthly Average Airborne Activity µCi/Ml Gross α (%Dac)[1]
1994 (includes dryer room sample results)	3.22 E-12 (0.6% DAC)	6.07 E-12 (1.2% DAC)
1995	3.80E-12 (0.8%)	9.36E-12 (1.9%)
1996	1.28E-12 (0.3%)	4.71Ee-12 (0.9%)
1997	2.77 E-12 (0.5% DAC)	5.43 E-12 (1.1% DAC)
1998	3.06 E-12 (0.6% DAC)	5.36 E-12 (1.1% DAC)
1999	2.87 E-12 (0.6% DAC)	4.44 E-12 (0.9% DAC)
2000	2.63 E-12 (0.5% DAC)	5.84 E-12 1.1% DAC)
2001	3.30 E-12 (0.7% DAC)	7.05 E-12 (1.4% DAC)
2002	2.25 E-12 0.5% DAC)	3.70 E-12 (0.7% DAC)
2003	4.02 E-12 (0.8% DAC)	2.33 E-12 (4.7% DAC)
2004	1.65 E-12 (0.3% DAC)	5.99 E-12 1.0% DAC)

Table 5.8-1: In-plant Airborne Uranium Monitoring Results

Airborne Uranium Monitoring Period (Calendar Year)	Annual Average Airborne Activity µCi/Ml Gross α (% Dac)[1]	Maximum Monthly Average Airborne Activity µCi/Ml Gross α (%Dac)[1]
2005	3.80 E-12 (0.8% DAC)	5.03 E-12 (1.0% DAC)
2006	3.86e-12 (0.8%)	4.87e-12 (1.0%)

Notes:
[1] Samples compared to the DAC where DAC=5 E-10 µCi/ml (10 CFR §§ 20.1001-2401 App B)

Uranium intakes for the time period 1994 through 2006 have been well below the annual regulatory limit of 1 µCi and the CBR administrative action level of 0.25 µCi. The average and maximum values over this period of time have been relatively consistent.

The maximum individual uranium intake for 2005 and 2006 was 1.94×10^{-2} µCi and 2.14×10^{-2} µCi, respectively, corresponding to a dose of 97 mREM (2 percent of the regulatory limit) and 107 mREM (2 percent of the regulatory limit), respectively. The average for all monitored employees in 2005 and 2006 was 5.87×10^{-3} µCi and 6.94×10^{-3} µCi, respectively, corresponding to a dose of 29 mREM (0.6 percent of the regulatory limit) and 35 mREM (0.7 percent of the regulatory limit), respectively. The combined uranium intake at the Crow Butte Uranium Project for 2005 was 0.170 µCi for the 29 employees that were monitored. This corresponds to a combined dose due to uranium intake of 0.85 Person-Rem. Uranium intake for 2006 was 0.208 µCi for 30 monitored employees, which corresponds to a combined dose due to uranium intake of 1.04 Person-Rem.

Figure 5.8-3 depicts the average and maximum exposure in Rem for each year from 1994 through 2006. The results of the exposure analysis indicate a noticeable increase in the both the average and maximum exposure to airborne uranium at the Crow Butte Project in 2005 and 2006. The average exposure increased by 9 mREM from 2004 (20 mREM) to 2005 (29 mREM) and 6 mREM from 2005 to 2006 (35 mREM). The maximum exposure more than doubled from 46 mREM in 2004 to 97 mREM in 2005, followed by an additional higher value of 107 mREM in 2006.

The maximum airborne uranium exposure in 2006 was due increased yellowcake handling during the year. In the last half of the year CBR began receiving yellowcake slurry from the Smith Ranch Project for drying. The yellowcake shipments were unloaded from slurry trailers and the yellowcake was dried and packaged. Fifteen shipments containing approximately 30,000 pounds of yellowcake slurry per shipment were received between September 15 and December 29, 2006. Packaging of the additional yellowcake increased the dose of the dryer operator.

The maximum airborne uranium exposure in 2006 was due to increased yellowcake handling during the year. In the last half of the year CBR began receiving yellowcake

slurry from the Smith Ranch Project for drying. The yellowcake shipments were unloaded from slurry trailers and the yellowcake was dried and packaged. Fifteen shipments containing approximately 30,000 pounds of yellowcake slurry per shipment were received between September 15 and December 29, 2006. Packaging of the additional yellowcake increased the dose of the dryer operator.

Figure 5.8-4 plots the combined exposure due to airborne uranium exposure for each year from 1994 through 2006. The combined exposure increased from 0.470 Rem in 2004 to 0.851 Rem in 2005, followed by an additional increase to 1.041 Rem in 2006. This is an increase of approximately 45 percent from 2004 to 2006.

Average airborne uranium exposures for facility staff and maximum doses for individuals were found to be acceptably low, although trend review indicated an increase from 2004 through the years 2005 and 2006. These increases, even though well below permissible limits, were deemed to warrant some potential for minor ALARA reduction. ALARA opportunities to address these increases were identified in the site's calendar year 2005 and 2006 annual ALARA audits. One of the ALARA Opportunities identified during the 2006 audit was that during the remainder of 2007, new methods to reduce worker doses related to U_3O_8 airborne concentrations should be considered, and existing methods should be examined to determine whether improvements are feasible within ALARA constraints. Site personnel continue to examine the reasons for the 2005 and 2006 dose increases, with the objective to identify opportunities to reduce the impact of the primary contributors to airborne uranium exposure during 2005 and 2006.

Proposed In-Plant Airborne Uranium Monitoring Program

CBR proposes to continue with the same airborne uranium-monitoring program at the Crow Butte Project that has been performed to date with the following changes.

Airborne sampling will be performed on a monthly basis in accordance with the instructions currently contained in SHEQMS Program Volume IV, *Health Physics Manual.* These procedures implement the guidance contained in USNRC Regulatory Guide 8.25, *Air Sampling in the Workplace*. Sampler calibration will be performed in accordance with the instructions currently contained in SHEQMS Program Volume IV, *Health Physics Manual.*

5.8.3.2 In-Plant Radon Daughter Surveys

Program Description

There are 12 monitoring locations for radon daughter concentrations in the Central Plant, the RO Building, and the office areas. The required radon daughter monitoring frequency is monthly unless results are greater than 0.08 Working Levels (WL) (25 percent of the DAC). If this action level is exceeded, the monitoring frequency is increased to weekly until the levels are below the action level for 4 consecutive weeks.

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Figure 5.8-3: Average and Maximum Airborne Uranium Exposure

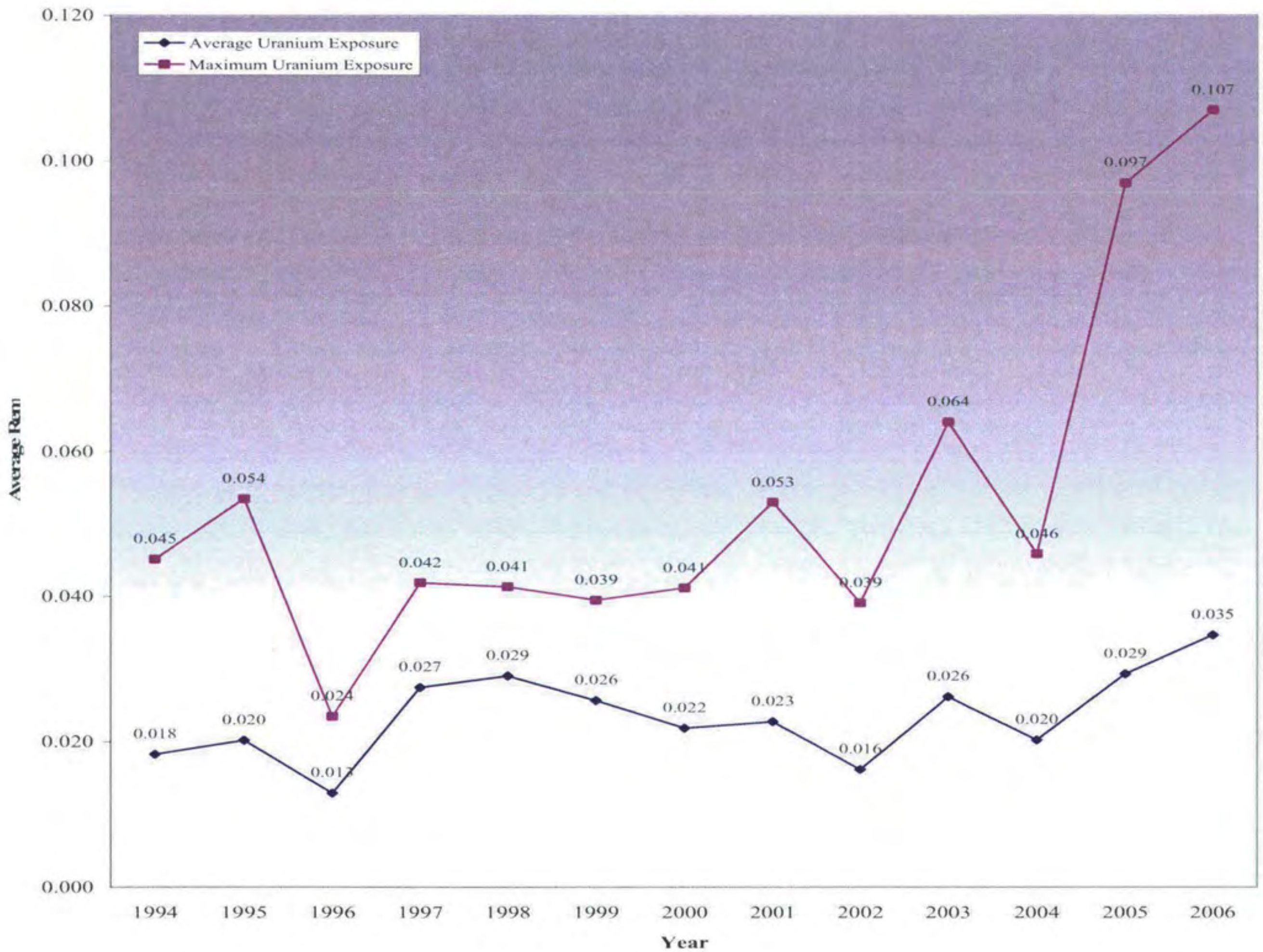

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Figure 5.8-4: Combined Airborne Uranium Exposure Analysis

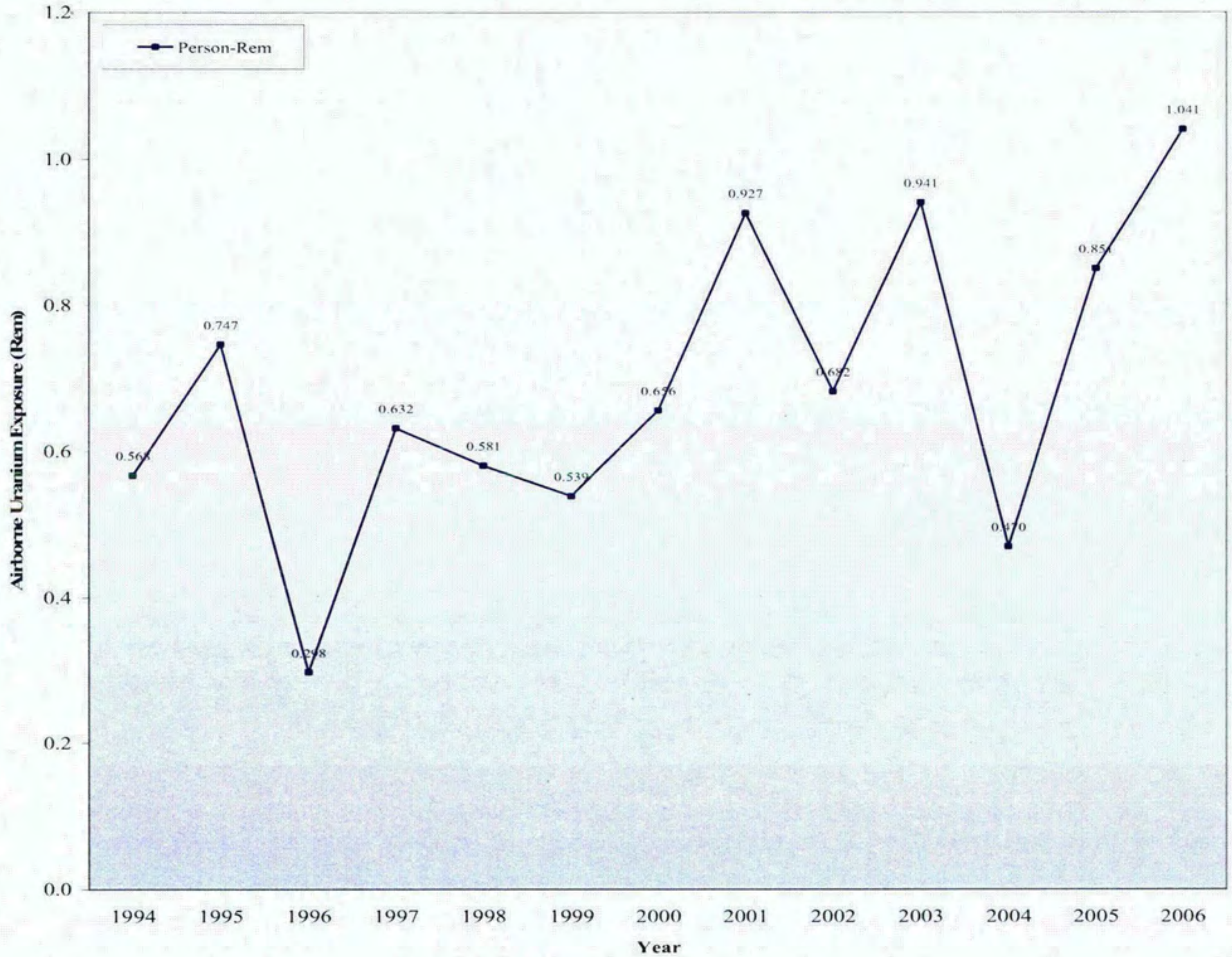

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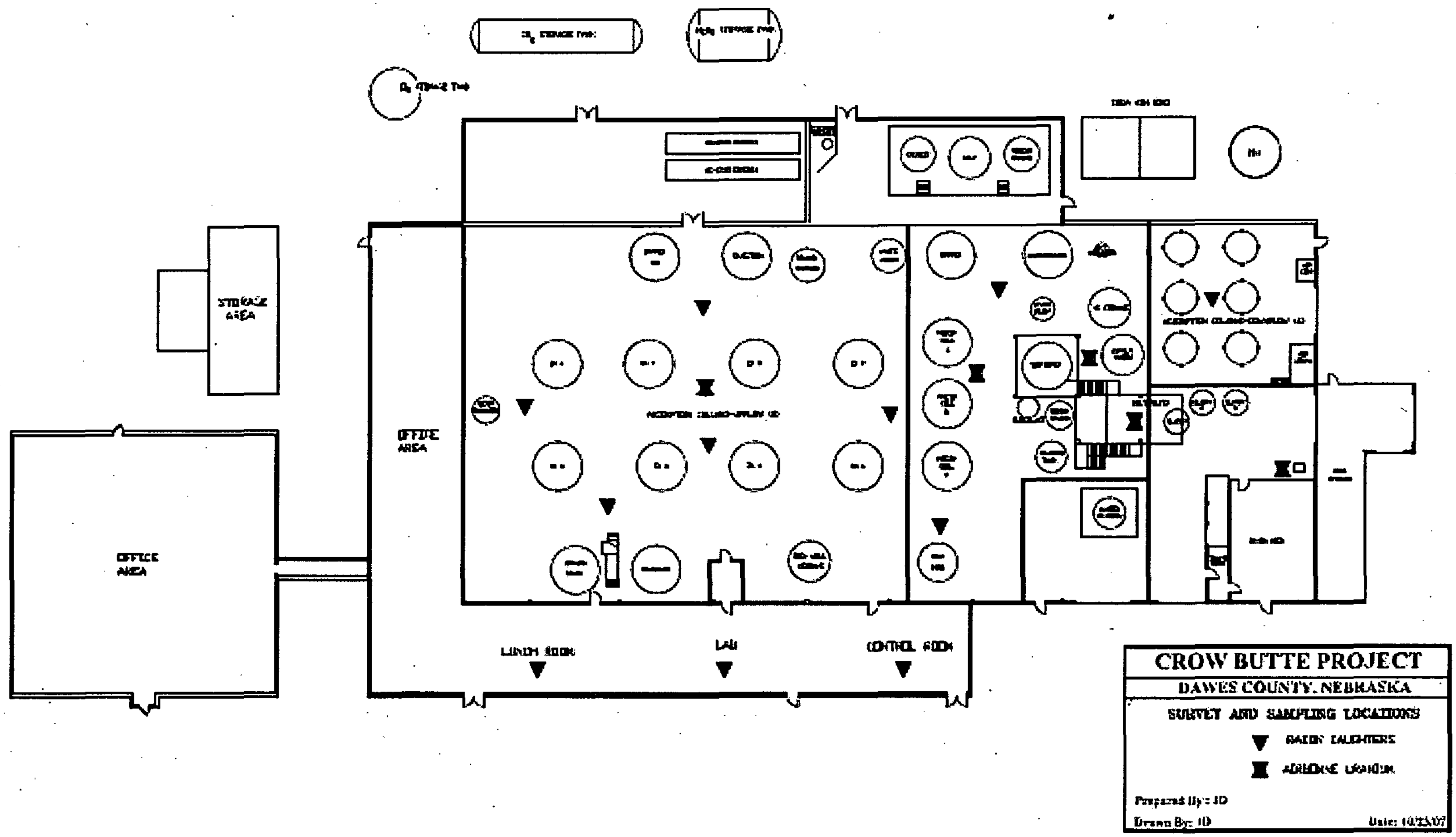
Figure 5.8-5: In-Plant Airborne Uranium Air Sampling Locations



Exposure calculations for radon daughters are based on the results of radon daughter sampling discussed below. Routine exposure is based on the monthly average of the plant radon daughter sampling. For personnel assigned full-time to the plant, a conservative occupancy time of 100 percent is used to determine exposure. For all other personnel, actual time in the plant is used for exposure calculations. Exposure received from work performed under a RWP is based on the results of monitoring performed during the work and the actual exposure times.

Samples are collected with a low-volume air pump and then analyzed with an alpha scaler using the Modified Kusnetz method described in ANSI-N13.8-1973. Air samplers are calibrated before each day's use.

Results of radon daughter sampling are expressed in WL where one WL is defined as any combination of short-lived radon-222 daughters in 1 liter of air without regard to equilibrium that emit 1.3×10^5 mega-electronvolt (MeV) of alpha energy. The DAC limit from Appendix B to 10 CFR §§ 20.1 - 20.601, as well as the current DAC limit from Appendix B to 10 CFR §§ 20.1001 - 20.2402, for radon-222 with daughters present is 0.33 WL. CBR has established an action level of 25 percent of the DAC or 0.08 WL. The LLD for radon measures is 0.033 WL, which is 10% of the DAC limit. Radon daughter results in excess of the action level trigger an investigation of the cause and an increase in the sampling frequency to weekly until the radon daughter levels do not exceed the action level for 4 consecutive weeks.

<u>Historical Program Results</u>

Radon Daughter Monitoring - Main Plant

Table 5.8-2 provides the results of monitoring for radon daughters from the period of 1995 through 2006. The annual average and maximum values are presented. The data show that the average radon daughter activity concentration at Crow Butte Uranium Project was consistently less than 25 percent of the regulatory limit.

The monthly plant average radon daughter concentrations from 1994 through 2006 averaged 0.030 WL (9 percent of DAC of 0.33 WL) with a range of 0.015 to 0.048. The average for the same period of the maximum monthly average radon concentrations was 0.049 WL (15 percent of DAC) with a range of 0.026 to 0.070 WL (8 percent and 21 percent of DAC). In 2005 and 2006, the average radon daughter concentrations were 0.015 WL (4.5 percent of DAC) and 0.020 WL (8.0 percent of DAC), respectively, with a maximum value of 0.026 WL.

Table 5.8-2: In-plant Radon Daughter Monitoring Results

Radon Daughter Monitoring Period (Calendar Year)	Annual Average Radon Daughter Activity In WL (% DAC)[1]	Maximum Monthly Average Radon Daughter Activity In WL (%DAC)[1]
1994	0.032 (9.6% DAC)	0.046 (13.9% DAC)
1995	0.041 (12% DAC)	0.070 (21% DAC)
1996	0.038 (12% DAC)	.069 (21% DAC)
1997	0.048 (14.5% DAC)	0.068 (30.6% DAC)
1998	0.027 (8% DAC)	0.042 (12.7% DAC)
1999	0.041 (12% DAC)	0.065 (20% DAC)
2000	0.023 (7% DAC)	0.042 (13% DAC)
2001	0.032 (10% DAC)	0.049 (15% DAC)
2002	0.027 (8% DAC)	0.048 (15% DAC)
2003	0.030 (9% DAC)	0.045 (14% DAC)
2004	0.024 (7% DAC)	0.036 (11% DAC)
2005	0.015 (4.5% DAC)	0.026 (8% DAC)
2006	0.020 (6.1% DAC)	0.026 (7.9% DAC)

Note:
[1] Samples compared to the DAC where DAC = 0.33 WL (10 CFR §§ 20.1001-2401 App B)

Radon Daughter Exposures

Individual exposures to radon daughters at the Crow Butte Uranium Project between 1994 and 2006 were well below the annual regulatory limit of 4 Working Level Months (WLM) and the CBR administrative action level of 1 WLM. The maximum individual radon daughter exposures for 2005 and 2006 were 0.213 WLM and 0.283 WLM, respectively, corresponding to a dose of 267 mREM (5 percent of the regulatory limit) and 350 mREM (7 percent of regulatory limit), respectively. The average exposure for all monitored employees was 0.101 WLM in 2005 and 0.161 WML in 2006, corresponding to a dose of 126 mREM (2.5 percent of the regulatory limit) and 200 mREM (4 percent of the regulatory limit), respectively. The combined radon daughter exposure at the Crow Butte Uranium Project for 2005 was 2.925 Person-WLM for the 29

monitored employees, corresponding to a dose of 3.656 Person-Rem. For 2006, the combined radon daughter exposure was 4.83 Person-WLM for the monitored employees, corresponding to a dose of 6.03 Person-Rem.

The results of the exposure analysis indicate a significant decrease in the individual average and maximum exposures to radon daughters at the Crow Butte Uranium Project in 2005 versus other years of operation. In 2005, there was also a significant decrease in the combined exposure in spite of an increase in the number of employees monitored for radon daughter exposure.

However, in 2006, there was an increase of 70 mREM for the average radon exposure and an increase of 80 mREM for the maximum radon exposure in 2006.

Figure 5.8-6 depicts the average and maximum radon exposures due to radon daughters for each year from 1994 through 2006. A comparison of these exposures indicates that individual average and maximum exposures in 2005 were at historic low levels for the project. The average radon exposure decreased almost 50 percent from 246 mREM in 2004 to 126 mREM in 2005. The maximum individual exposure also showed a significant decrease from 390 mREM in 2004 to 267 mREM in 2005. These exposure levels for radon daughters are the lowest recorded during the 12-year period. However, exposures increased from an average of 130 mREM in 2005 to an average of 200 mREM (70 mREM increase) in 2006 and an increase in the maximum exposures of 270 mREM in 2005 to 350 mREM in 2006 (80 mREM increase).

Figure 5.8-7 plots the combined exposure for all monitored employees for each year from 1994 through 2006. The combined exposure due to radon daughters in 2005 decreased from 5.67 Person-Rem in 2004 to 3.66 Person-Rem in 2005, which continues a downward trend from the last 4 years and is the lowest combined exposure in the 12-year period. This decrease occurred in spite of an increase in the number of employees monitored for radon daughter exposure, and was due to continued emphasis on effective engineering controls for radon. However, in 2006, the average radon daughter exposure increased from 3.66 Rem in 2005 to 6.03 Rem in 2006.

Even with the noted trend increases in radon exposures from 2005 to 2006 in **Figure 5.8-6** and **Figure 5.8-7**, average radon daughter exposures for facility staff and maximum doses for individuals, were found to be acceptably low. This increase, even though well below permissible limits, was deemed to warrant some potential for minor ALARA reduction. ALARA opportunities to address these increases were identified in the site's calendar year 2006 annual ALARA audits. One of the ALARA opportunities identified during the 2006 audit was that, during the remainder of 2007, new methods to reduce worker doses related to radon daughter concentrations should be considered, and existing methods should be examined to determine whether improvements are feasible within ALARA constraints. Site personnel continue to examine the reasons for the 2005/2006 dose increases, with the objective of identifying opportunities to reduce the impact of the primary contributors to radon exposures during 2005 and 2006.

Figure 5.8-6: Average and Maximum Radon Exposure

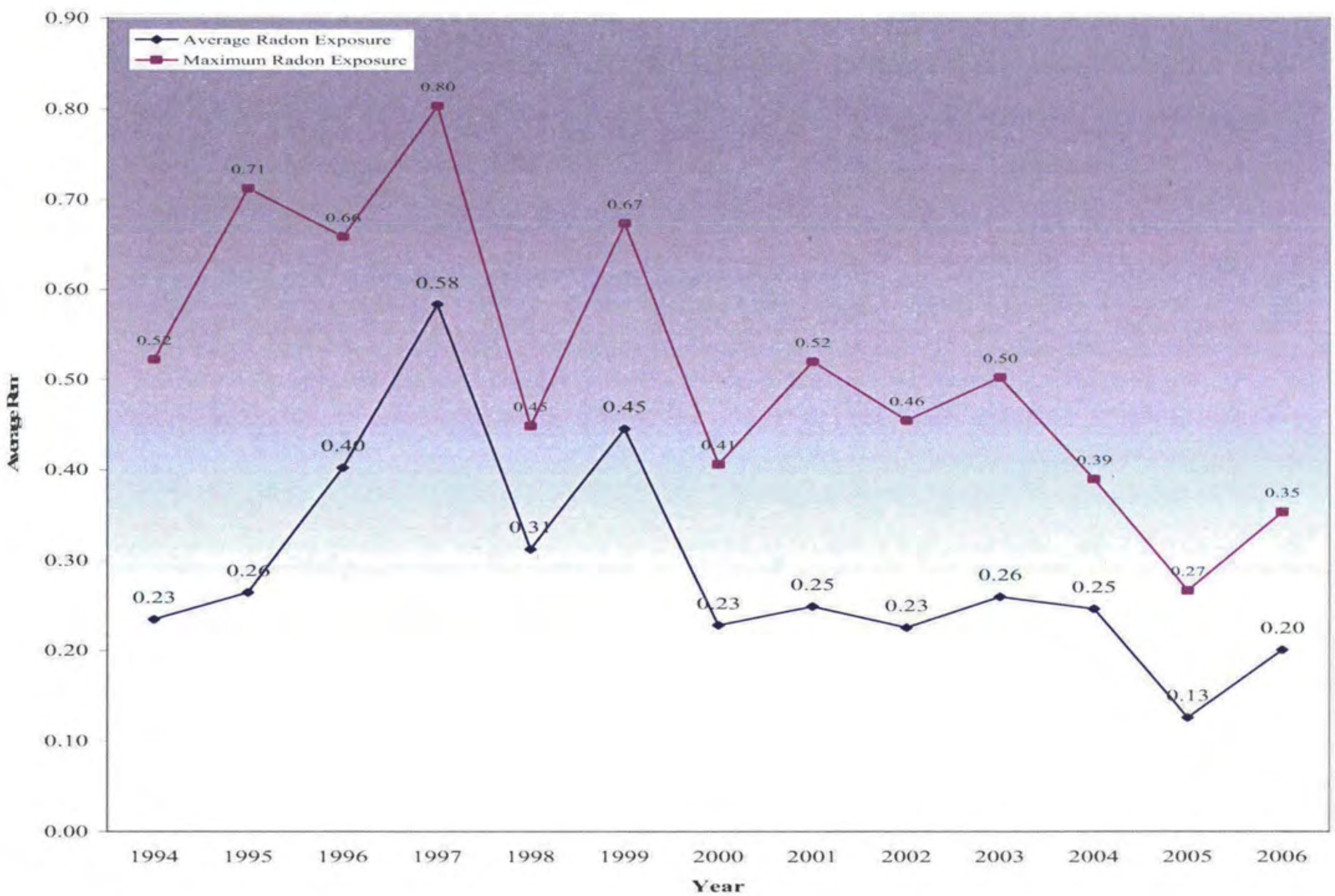
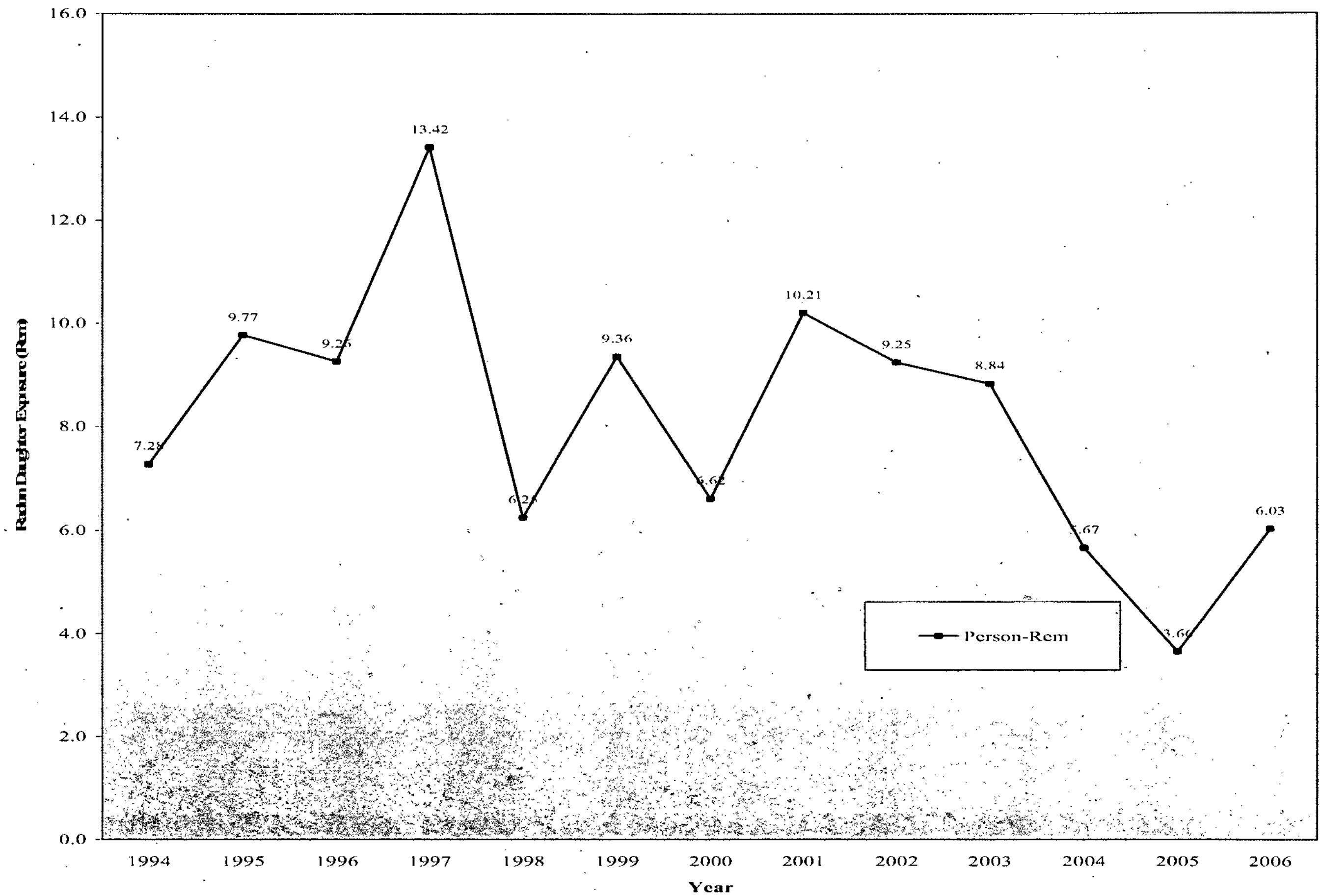


Figure 5.8-7: Combined Radon Daughter Exposure Trend Analysis



In-Plant Radon Daughter Monitoring Program

CBR proposes to continue with the same radon daughter monitoring program at the Crow Butte Project that has been performed to date with the following changes.

Based on operating experience, CBR proposes to continue radon daughter sampling at the locations shown in **Figure 5.8-5**. CBR believes that these locations provide accurate monitoring of plant radiological conditions.

Routine radon daughter monitoring will continue to be performed monthly in accordance with the instructions currently contained in SHEQMS Program Volume IV, *Health Physics Manual.*

Air samplers will continue to be calibrated in accordance with the instructions contained in SHEQMS Program Volume IV, *Health Physics Manual*.

5.8.3.3 Total Effective Dose Equivalent

The TEDE for each monitored employee at the Crow Butte Project from 1994 through 2006 was well below the annual regulatory limit of 5 Rem. **Figure 5.8-8** depicts the combined and average TEDE for the project in Person-Rem and mREM, respectively, for each year from 1994 through 2006. The combined dose from 1994 through 1996 averaged 11.6 Person-Rem, with a range of 7.9 to 17.9 Person-Rem.

The maximum individual TEDE for 2005 and 2006 was 675 mREM (15 percent of regulatory limit) and 713 mREM (14.3 percent of regulatory limit), respectively, with an average TEDE for all monitored employees of 103 mREM (2 percent of regulatory limit) and 0.323 mREM (6.5 percent of regulatory limit), respectively. The combined TEDE at the CBR Project for 2005 and 2006 was 7.943 Person-Rem (29 employees) and 9.7 Person-Rem (30 employees) who are monitored for occupational exposure.

The average TEDE values showed only a slight increase for the years 2002, 2003, and 2204 (370, 378, and 388 mREM, respectively). The average TEDE was reduced significantly from 388 mREM in 2004 to 274 mREM in 2005, but the average TEDE increased to 323 Person–Rem in 2006 (15 percent increase). However, the 2006 value was lower than measurements for the years 1995 through 2004.

Figure 5.8-9 shows the total dose contributions of external exposure, radon daughter exposure, and airborne uranium exposure to the total effective dose from 1994 through 2006. The primary contributors to dose during 2006 were radon daughter exposures and external radiation exposures. External exposures have remained relatively constant during the past several years, and in fact were reduced significantly in 2006. Airborne uranium and radon daughter exposures, on the other hand, increased. ALARA actions being taken to address these increases are discussed in **Sections 5.8.3.1 and 5.8.3.2**.

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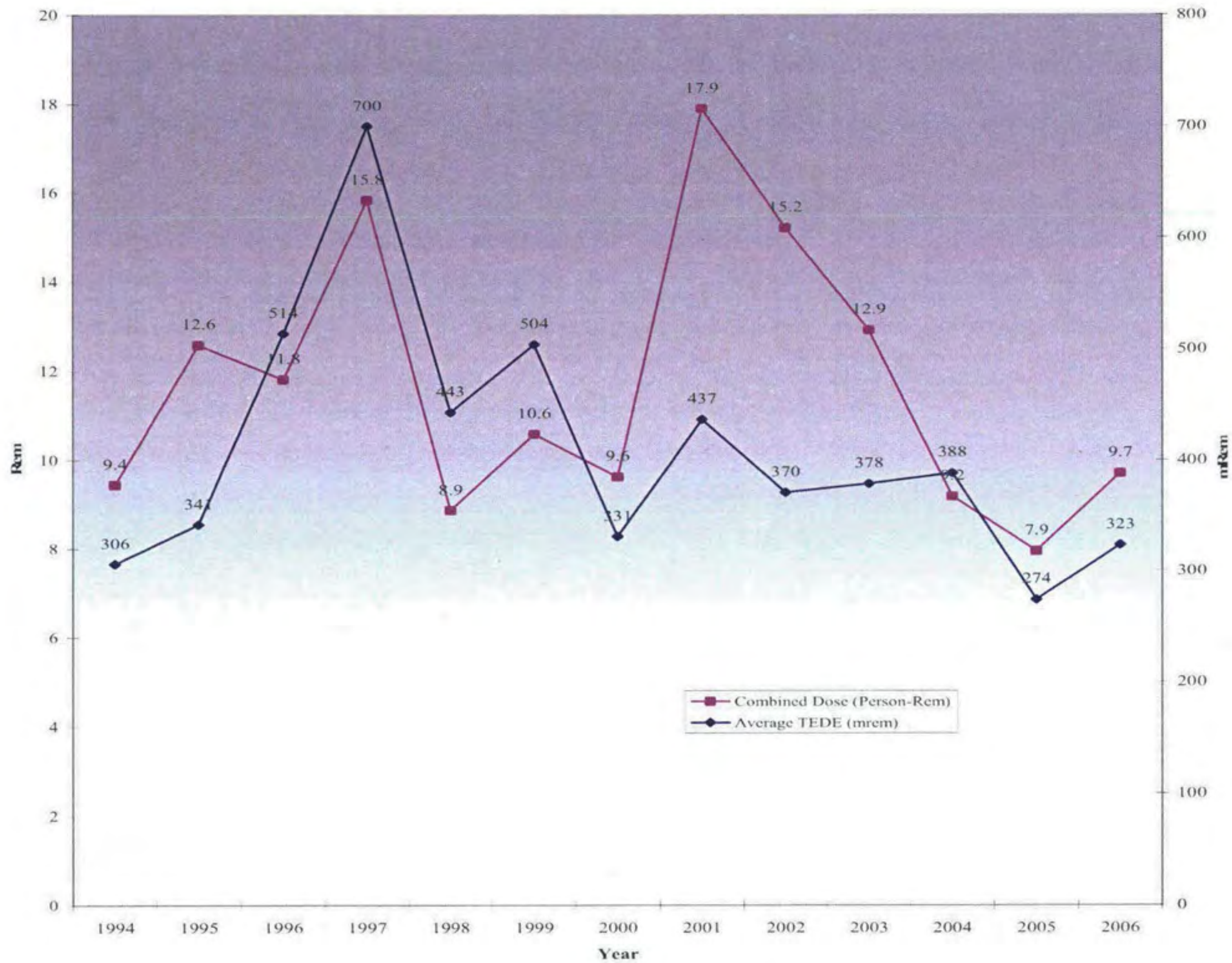
Figure 5.8-8: Average and Combined Total Effective Dose Equivalent Analysis



5.8.3.4 Respiratory Protection Program

Respiratory protective equipment is supplied by CBR for activities where engineering controls may not be adequate to maintain acceptable levels of airborne radioactive materials or toxic materials. Use of respiratory equipment at the Crow Butte Project is in accordance with the procedures currently set forth in the SHEQMS Program Volume IV, *Health Physics Manual.*

The respirator program is designed to implement the guidance contained in USNRC Regulatory Guide 8.15, *Acceptable Programs for Respiratory Protection.* The respirator program is administered by the RSO as the Respiratory Protection Program Administrator (RPPA).

5.8.4 **Exposure Calculations**

Employee internal exposure to airborne radioactive materials has been determined at the Crow Butte Project facility since commercial operations began in 1991. Since January 1, 1994, CBR has determined internal exposures based on the requirements of 10 CFR § 20.1204. Prior to January 1, 1994, internal exposure was calculated using the MPC-Hour method based on 10 CFR § 20.103. The following subsections present a discussion of the exposure calculation methods and results.

5.8.4.1 Natural Uranium Exposure

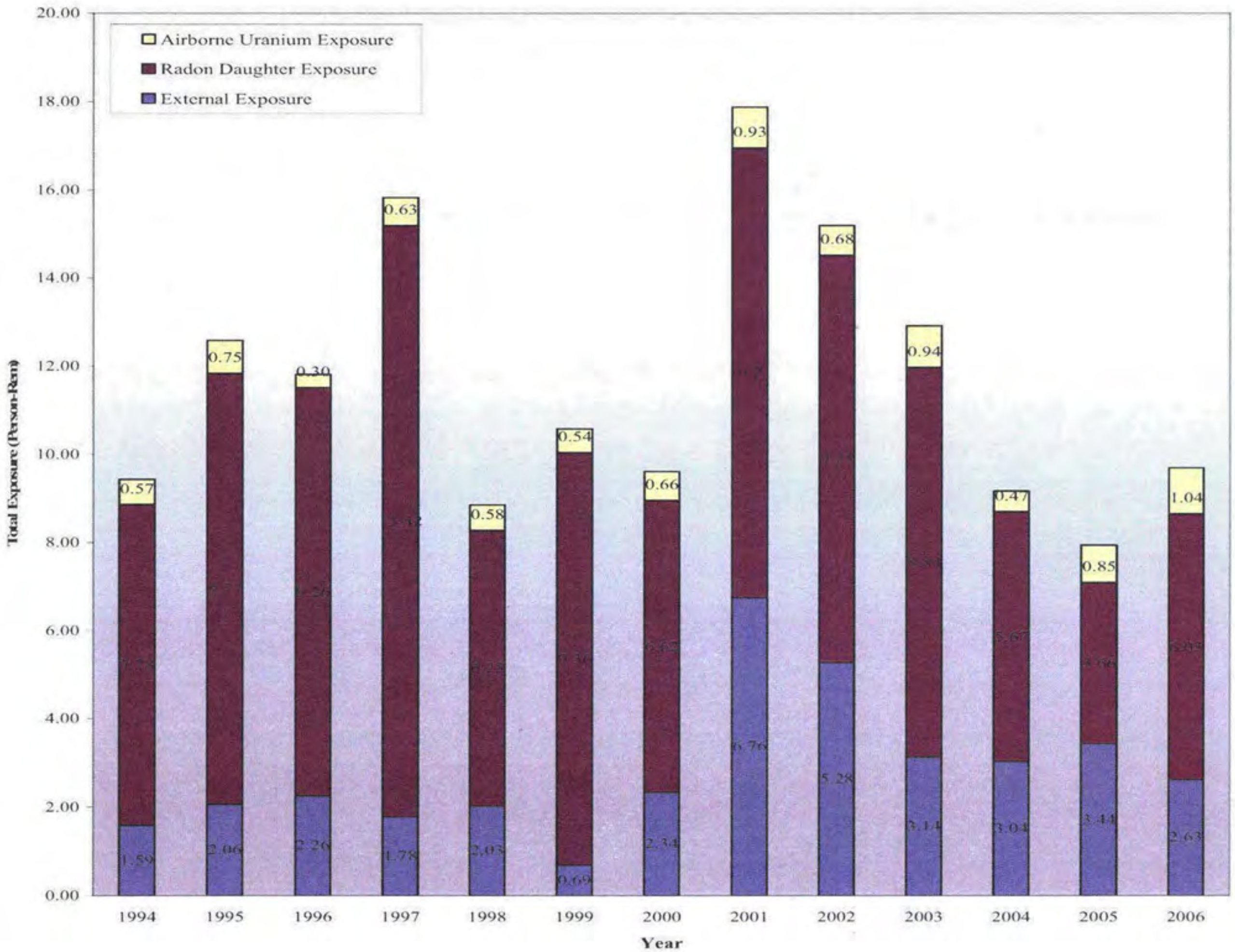
Exposure calculations for airborne natural uranium are carried out using the intake method from USNRC Regulatory Guide 8.30, *Health Physics Surveys in Uranium Recovery Facilities*, Revision 1, Section 3. The intake is calculated using the following equation:

$$I_u = b\sum_{i=1}^{n} \frac{X_i \times t_i}{PF}$$

where:

I_u	=	uranium intake, µg or µCi
t_i	=	time the worker is exposed to concentrations X_i (hr) [per sampling event]
X_i	=	average concentration of uranium in breathing zone, µg/m^3, µCi/m^3, with "i" representing the number of sampling events for uranium (X).
b	=	breathing rate, 1.2 m^3/hr
PF	=	respirator protection factor, if applicable
n	=	number of exposure periods during the week or quarter

Figure 5.8-9: Total Dose Contributions



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The intake for uranium is calculated on Time Weighted Exposure (TWE) forms. The intakes are totaled and entered onto each employee's Occupational Exposure Record.

The data required to calculate internal exposure to airborne natural uranium are determined as follows.

Time of Exposure Determination

When calculating radiological exposures for the CBR facility, the occupancy time for "routine" operations is an exposure period based on actual hours worked (12-hour shift period for plant personnel). This is considered to be a 100% occupancy time, which is used to determine routine worker exposures. For such routine exposures (i.e., 12-hour shift period), it is assumed that the worker was exposed to the measured "work area" average concentration of uranium for the entire work period (exposure 100% of the time). During part of that exposure period, the worker would be expected to spend some time in non-work areas such as the lunch room, office, restroom, hallways, etc. The 100% occupancy time approach generally results in a conservative (i.e., higher than actual) estimate of internal exposure to airborne natural uranium because it does not account for time the employee may have spent outside the work area, such as described above.

The measured average airborne uranium concentration is multiplied by the time of worker exposure (12 hours) to obtain the estimated average worker exposure for that time period. Routine operations refer to the facilities operating in a normal fashion with no upsets, maintenance activities, or other activities that may result in non-routine and elevated exposures. If a worker works more than the normal 12-hour shifts, the measured average airborne uranium concentration and the total hours actually worked are used to establish exposure levels.

For exposures during non-routine work tasks (e.g., maintenance or cleanup), measured exposures are based on actual time. The results of breathing zone samples collected during maintenance activities or RWPs are taken over a specific time period and are added to the calculations of routine employee exposures for a given work period. For example, a worker working under a RWP for 2 hours would have exposures based on measurements taken for that time period (actual time), with the exposures for the remaining 10 hours of routine work based on the measured average concentration of airborne uranium.

Airborne Uranium Activity Determination

Airborne uranium activity is determined from surveys performed as described in **Section 5.8.3.1**.

Historical Program Results

Table 5.8-3 summarizes internal exposure results at Crow Butte Project from airborne uranium. The data show that internal exposure at Crow Butte Uranium Project has been maintained ALARA. The maximum individual internal exposure to airborne uranium

during the period between 1994 and 2006 was significantly lower than the allowable regulatory limit of 1 µCi. For example, the average exposure level of 6.94 E^{-03} µCi in 2006 was 0.7 percent of the 1 µCi allowable, and the maximum exposure level of 2.14 E^{-02} µCi was 2.1 percent of the allowable level.

Table 5.8-3: Annual Airborne Uranium Exposure Results

Airborne Uranium Exposure Monitoring Period (Calendar Year)	Average Airborne Uranium Exposure (µCi)[1]	Maximum Airborne[1] Uranium Exposure (µCi)[1]
1994	3.66×10^{-3}	9.03×10^{-3}
1995	4.04×10^{-3}	1.07×10^{-2}
1996	2.59×10^{-3}	4.70×10^{-3}
1997	5.49×10^{-3}	8.37×10^{-3}
1998	5.81×10^{-3}	8.26×10^{-3}
1999	5.14×10^{-3}	7.89×10^{-3}
2000	4.38×10^{-3}	8.23×10^{-3}
2001	4.55×10^{-3}	$1,06 \times 10^{-2}$
2002	3.24×10^{-3}	7.82×10^{-3}
2003	5.24×10^{-3}	1.28×10^{-2}
2004	4.05×10^{-3}	9.17×10^{-3}
2005	5.87×10^{-3}	1.94×10^{-2}
2006	6.94×10^{-3}	2.14×10^{-2}

Note:[1]The annual uranium intake limit for calendar years 1990 through 1993 was 0.252 µCi based on 10 CFR 20.103. In 1994, the annual limit on intake (ALI) was 1 µCi based upon "D" class natural uranium.

<u>Proposed Airborne Uranium Exposure Monitoring Program</u>

CBR proposes to institute the same internal airborne uranium exposure calculation methods at Crow Butte Project that have been used to date and which are currently contained in SHEQMS Program Volume IV, *Health Physics Manual*. Exposures to airborne uranium will be compared to the site-specific Crow Butte Operations DAC developed in response to NRC comments. The information was provided pursuant to a request for confidentiality by email dated March 14, 2011 with further clarifications submitted by email on April 5, 2011 (ML11102020132). The results show that the average ALI for the Crow Butte Operations yellowcake is 0.98µCi and the average DAC is 4.8E-10µCi/ml. For consistency with the convention used to round values in the regulation, an ALI and DAC of 1µCi and 5E-10µCi/ml will be used. Footnote 3 in Table 1 of Appendix B to 10 CFR 20 states "the specific activity for natural uranium is 6.77 E-7 curies per gram U." This is equivalent to 6.77 E-7 µCi per microgram of natural uranium. This is the specific activity CBR uses to calculate the mass of uranium from an activity measurement and vice versa.

When required by 10 CFR 20.1202, CBR uses methods in NRC Regulatory Guide 8.30 to estimate internal doses. As an example, the Committed Effective Dose Equivalent (CEDE) can be calculated using Equation 2 in NRC Regulatory Guide 8.30 where:

H_{iE} = CEDE from radionuclide (rem)

I_i=	is the intake in µCi of Class D natural uranium as determined by the equation in Section 5.7.4.1 of the application
ALI_{iE} =	Value of the stochastic inhalation ALI for natural uranium from Column 2 of Table 1 in appendix B to 10 CFR Part 20 (2 µCi). ALI is the Annual Limit on Intake, which refers to the annual intake of a given radionuclide, e.g., natural uranium.
5 =	CEDE from intake of 1 ALI (rem)

If an intake (I_i) of 0.5 µCi was determined using the stated equation, the estimate CEDE from this intake would be:

$$H_{iE} = 5*0.5/2 = 1.25 \text{ rem}$$

If an intake (I_i) of 0.5 µg of natural uranium was determined using the stated equation, the estimated CEDE from this intake would be:

$$H_{iE} = 5*0.5*6.77 \text{ E-}7/2 = 8.5 \text{ E-}7 \text{ rem}$$

It should be noted that the weekly limit for soluble uranium in 10 CFR 20.1202 (e) due to chemical toxicity is 10 milligram (10,000 µg) which would be equivalent to a CEDE of 17 mrem per week or 844 mrem per year. The occupational weekly toxicity limit for Class D natural uranium is more restrictive than the radiological limit.

5.8.4.2 Radon Daughter Exposure

Exposure calculations for airborne radon daughters are carried out using the intake method from USNRC Regulatory Guide 8.30, *Health Physics Surveys in Uranium Recovery Facilities*, Revision 1, Section 3. The radon daughter intake is calculated using the following equation:

$$I_r = \frac{1}{170} \sum_{i=1}^{n} \frac{Wi \times t_i}{PF}$$

where:

I_r	=	radon daughter intake, working-level months).
t_i	=	time that the worker is exposed to concentrations W_i (hr) [per sampling event]
W_i	=	average number of working levels in the air near the worker's breathing zone during the time (t_i), where "i"

		represents the number of sampling events for working levels (W)
170	=	number of hours in a working month
PF	=	the respirator protection factor, if applicable
n	=	the number of exposure periods during the year

The data required to calculate exposure to radon daughters are determined as follows.

Time of Exposure Determination

When calculating radon daughter's exposures for the CBR facility, the occupancy time for "routine" operations is an exposure period based on actual hours worked (12-hour shift period for plant personnel). This is considered to be a 100% occupancy time, which is used to determine routine worker exposures. For such routine exposures (i.e., 12-hour shift period), it is assumed that the worker was exposed to the measured "work area" average concentration of radon daughters for the entire work period (exposure 100% of the time). During part of that exposure period, the worker would be expected to spend some time in non-work areas such as the lunch room, office, restroom, hallways, etc. The 100% occupancy time approach generally results in a conservative (i.e., higher than actual) estimate of internal exposure to radon daughters because it does not account for time the employee may have spent outside the work area, such as described above.

The measured average radon daughter's concentration is multiplied by the time of worker exposure (12 hours) to obtain the estimated average worker exposure for that time period. Routine operations refer to the facilities operating in a normal fashion with no upsets, maintenance activities, or other activities that may result in non-routine and elevated exposures. If a worker works more than the normal 12-hour shifts, the measured average radon daughter's concentration and the total hours actually worked are used to calculate exposure levels.

For exposures during non-routine work tasks (e.g., maintenance or cleanup), measured exposures are based on actual time. The results of breathing zone samples collected during maintenance activities or RWPs are taken over a specific time period and are added to the calculations of routine employee exposures for a given work period. For example, a worker working under a RWP for 2 hours would have exposures based on measurements taken for that time period (actual time), with the exposures for the remaining 10 hours of routine work based on the measured average concentration of radon daughters.

Radon Daughter Concentration Determination

Radon-222 daughter concentrations are determined from surveys performed as described in **Section 5.8.3.2**.

The working-level months for radon daughter exposure are calculated on the appropriate forms. The working-level months are totaled and entered onto each employee's Occupational Exposure Record.

Historical Program Results

Table 5.8-4 summarizes the results of radon daughter exposure calculations at Crow Butte Uranium Project between 1994 and 2006. The data show that internal exposure due to radon daughters at Crow Butte Uranium Project has been maintained ALARA, being significantly lower than the allowable level of 4.0 WLM. Since 1994, the average individual internal exposure to radon daughters was at its lowest in 2005 and 2006 (0.101 and 0.161 working-level months, respectively). These levels are approximately 3 percent and 4 percent, respectively, of the allowable regulatory limit of 4 working-level months. The maximum internal exposure to radon daughters was also at its lowest over this 13-year period at 0.213 in 2005 and 0.283 in 2006, (approximately 5 percent and 7 percent of the regulatory limit, respectively)

Table 5.8-4: Annual Radon Daughter Exposure Results

Radon Daughter Exposure Monitoring Period (Calendar Year)	Average Individual Exposure (Working-Level Months)[1]	Maximum Individual Exposure (Working-Level Months)[1]
1994	0.188	0.418
1995	0.212	0.570
1996	0.322	.0527
1997	0.467	0.643
1998	0.25	0.359
1999	0.356	0.539
2000	0.183	0.325
2001	0.199	0.416
2002	0.180	0.364
2003	0.208	0.402
2004	0.197	0.312
2005	0.101	0.213
2006	0.161	0.283

Note:
1 The annual limit was 4 working-level months.

CBR proposes to institute the same internal radon daughter exposure calculation methods at Crow Butte Project that have been used to date and which are currently contained in SHEQMS Program Volume IV, Health Physics Manual. Exposures to radon daughters

will be compared to the DAC for radon daughters from Appendix B of 10 CFR §§20.1001 - 20.2401 (0.33 WL).

The equation above calculates WLM. If required by 10 CFR 20.1202, CBR can calculate a CEDE from the WLM estimate using Equation 2 in NRC Regulatory Guide 8.30 where:

H_{iE} =	CEDE from radionuclide (rem)
I_i=	is the intake in WLM of radon-222 and its associated progeny as determined by the equation in Section 5.7.4.2 of the application
ALI_{iE} =	Value of the stochastic inhalation ALI for radon-222 with progeny present from Column 2 of Table 1 in appendix B to Part 20 (4 WLM)
5 =	CEDE from intake of 1 ALI (rem)

If an intake (I_i) of 1 WLM was determined using the stated equation, the estimate CEDE from this intake would be:

$$H_{iE} = 5*1/4 = 1.25 \text{ rem}$$

5.8.4.3 Prenatal and fetal Exposure

- Dose Equivalent to an Embryo/Fetus

10 CFR §20.1208 requires that licensees ensure that the dose equivalent to an embryo/fetus during the entire pregnancy, due to the occupational exposure of a declared pregnant woman does not exceed 0.5 Rem (5 mSv). Licensees are also required to make efforts to avoid substantial variation above a uniform monthly exposure rate to a declared pregnant woman that would satisfy the 0.5 Rem limit. The dose equivalent to the embryo/fetus is calculated as the sum of (1) the DDE to the declared pregnant woman; and, (2) the dose equivalent to the embryo/fetus resulting from radionuclides in the embryo/fetus and radionuclides in the declared pregnant woman. If the dose equivalent to the embryo is determined to have exceeded 0.5 rem (5 mSv), or is within 0.05 rem (0.5 mSv) of this dose, by the time the woman declares the pregnancy to the licensee, the licenses shall be deemed to be in compliance with 10 CFR 20.1208 if the additional dose equivalent to the embryo/fetus does not exceed 0.05 rem (0.5 mSv) during the remainder of the pregnancy.

- Individual Monitoring of External and Internal Occupational Exposure

The dose equivalent to the embryo/fetus is determined by the monitoring of the declared pregnant woman. 10 CFR §20.1502(a)(3) requires monitoring the exposure of a declared pregnant woman when the external dose to the embryo/fetus is likely to receive during the entire pregnancy, from radiation sources external to the body, a deep dose equivalent in excess of 0.1 rem (1 mSv). All of the occupational doses in 10 CFR 20.1201 continue to be applicable to the declared pregnant worker as long as the embryo/fetus dose limit is not exceeded. 10 CFR 20.1502(b)(3) requires the monitoring of the occupational intake of radioactive material by, and assess the committed effective dose equivalent to, a declared pregnant woman likely to receive, during the entire pregnancy, a committed effective dose equivalent in excess of 0.1 rem (1 mSv). Based on this 0.1 rem threshold, the dose to the embryo/fetus must be determined if the intake is likely to exceed 1% of Annual Limit on Intake (ALI) during the entire period of gestation.

Prior to declaration of pregnancy, the woman may not have been subject to monitoring based on the conditions specified in 10 CFR 20.1502. In this case, CBR will estimate the exposure during the period monitoring was not provided, using any combination of surveys or other available data (for example, air monitoring, area monitoring and bioassay). Exposure calculations will be performed, as recommended in USNRC Regulatory Guide 8.36 (NRC 1980).

- External Dose to the Embryo/Fetus

The DDE to the declared pregnant woman during the gestation period will be taken as the external dose for the embryo/fetus. The determination of external dose will consider all occupational exposures of the declared pregnant woman since the estimated date of conception and will be based on the methods discussed in Section 5.7.2. External dose to the declared pregnant woman after declaration for the duration of the pregnancy shall be accomplished by personnel dosimetry with exchanges on a monthly basis.

- Internal Dose to the Embryo/Fetus

The internal dose to the embryo/fetus will consider the exposure to the embryo/fetus from radionuclides in the declared pregnant woman and in the embryo/fetus. The dose to the embryo/fetus will include the contribution from any radionuclides in the declared pregnant woman (body burden) from occupational intakes occurring prior to conception.

The intake for the declared pregnant woman will be determined as discussed in Sections 5.8.3.1 and 5.8.3.2.

5.8.5 Bioassay Program

5.8.5.1 Program Description

CBR has implemented a urinalysis bioassay program at the Crow Butte Project facilities that meets the guidelines contained in USNRC Regulatory Guide 8.22, *Bioassay at Uranium Mills*, Revision 1. The primary purpose of the program is to detect uranium

intake in employees who are regularly exposed to uranium. The bioassay program consists of the following elements:

1. Prior to assignment to the facility, all new employees are required to submit a baseline urinalysis sample. Upon termination, an exit bioassay is required. Additionally, bioassay samples are obtained annually from all employees.
2. During operations, urine samples are collected from workers whose routine work assignment requires them to enter areas where the potential for inhalation of yellowcake exists. Samples from these workers are collected quarterly. Workers who have the potential for exposure to dried yellowcake are sampled monthly. Samples are analyzed by an outside analytical laboratory for uranium content. Blank and spiked samples are also submitted to the laboratory with employee samples as part of the Quality Assurance program. The measurement sensitivity for the analytical laboratory is 5 micrograms per liter (μg/L).
3. Action levels for urinalysis are established based on Table 1 in USNRC Regulatory Guide 8.22, *Bioassay at Uranium Mills*, Revision 1.
4. *In vivo* measurements are performed in accordance with the recommendations contained in Regulatory Guide 8.22, *Bioassay in Uranium Mills*, Revision 1. Because CBR does not produce insoluble, high-fired yellowcake (defined as yellowcake dried at more than 400°C), no *in vivo* measurements have been required.

5.8.5.2 Historical Program Results

The following subsections summarize the results of the bioassay program since 1990, as reported in the ALARAs.

<u>1990 – Bioassay Results</u>

All bioassay samples were reported at lower than the 5 μg/L detection limit.

<u>1991 – Bioassay Results</u>

All bioassay samples were reported at lower than the 5 μg/L detection limit.

<u>1992 – Bioassay Results</u>

All bioassay samples were reported at lower than the 5 μg/L detection limit.

<u>1993 – Bioassay Results</u>

All bioassay samples were reported at lower than the 5 μg/L detection limit.

1994 – Bioassay Results

All bioassay samples were reported at or lower than the 5 µg/L detection limit with the exception of one sample which was 13.9 µg/L. Resamples of the individual that submitted this sample were lower than 5 µg/L.

1995 – Bioassay Results

All bioassay samples were reported at lower than the 5 µg/L detection limit.

1996 – Bioassay Results

All bioassay samples were reported at lower than the 5 µg/L detection limit.

1997 – Bioassay Results

All bioassay samples had results that were lower than the detection limit of 5 µg/L.

1998 – Bioassay Results

All bioassay samples taken during 1998 yielded results that were lower than the detection limit of 5 µg/L with the exception of three quarterly samples. The three samples that were higher than the detection limit were 5.0 µg/L, 9.0 µg/L, and 10.7 µg/L, which are below the 15 µg/L criterion for increased surveillance from USNRC Regulatory Guide 8.22. Subsequent samples obtained from these individuals immediately after receipt of the results were lower than the detection limit.

1999 – Bioassay Results

All bioassay samples taken during 1999 yielded results that were lower than the detection limit of 5 µg/L with the exception of one sample. The one sample that was higher than the detection limit was 81 µg/L, which is well above the 15 µg/L criterion for increased surveillance from USNRC Regulatory Guide 8.22. An operator submitted this sample after noticing a loose drum ring when moving yellowcake drums in the Dryer Room. This event occurred during a weekend shift. The operator obtained a bioassay sample approximately 1 hour after the incident. The CRSO was not notified of the incident until the following Monday. Additional samples were obtained following a 48-hour and 72-hour elapsed time after the incident. All three samples were submitted for analysis. The 48- and 72-hour samples were lower than the detection limit. CBR believes that the 1-hour sample was probably contaminated during collection. If the initial sample result of 81 µg/L had been correct, natural uranium above the detection limit would have also been detected in the 48- and 72-hour samples due to retention time in the body. Subsequent samples from the operator were also below the detection level.

Diagnostic samples were also necessary when a plant operator performed maintenance work on the yellowcake belt filter during a weekend shift. The work was performed without an RWP, and the CRSO was not notified until the following Monday. The

bioassay samples obtained from the operator were lower than the detection limit. In response to this incident, the CRSO met with all operators to emphasize that work on yellowcake-related equipment must be cleared with the CRSO. The RWP SOP was also revised to specifically state what activities require the issuance of an RWP.

2000 – Bioassay Results

In addition to routine bioassays, diagnostic samples were necessary on several instances during 2000:

- A diagnostic bioassay was obtained when a wellfield operator was sprayed in the face with injection water.
- Diagnostic bioassays were obtained when problems with yellowcake drum lid integrity resulted in a visible release of material.
- Diagnostic bioassays were obtained when a plant engineer and maintenance worker tore down the deep well feed pump for repairs without an RWP.
- Diagnostic bioassays were obtained when plant operators moved a drum of yellowcake with a hole in the lid without an RWP or respiratory protection.
- Diagnostic bioassays were obtained from personnel who were in the plant during the yellowcake dryer oil leak.

In most cases, diagnostic bioassays were necessary due to unforeseen situations where representative air sample results were not available. The diagnostic bioassay samples were all lower than the detection limit of 5 μg/L.

2001 – Bioassay Results

All routine bioassay samples taken during 2001 yielded results that were lower than the detection limit of 5 μg/L.

In addition to routine bioassays, diagnostic samples were necessary on several instances during 2001:

- Bioassays were obtained from five welding contractor employees after completion of repairs on the yellowcake dryer in conjunction with RWP 01-04.
- Diagnostic bioassays were obtained from a drum handler and a Health Physics technician after yellowcake leaked around the drum ring on a dry product drum that was being loaded for shipment.
- A diagnostic bioassay was obtained from a plant operator after performing work on the yellowcake belt filter without obtaining an RWP.
- Diagnostic bioassays were obtained from three individuals after the yellowcake dryer was overfilled, spilling product on the dryer room floor.

- Bioassays were obtained in conjunction with RWP 01-32 for changing filters in the yellowcake dryer baghouse.

In most cases, diagnostic bioassays were necessary due to unforeseen situations where representative air sample results were not available. The diagnostic bioassay samples were all lower than the detection limit of 5 µg/L.

<u>2002 – Bioassay Results</u>

With two exceptions, all routine bioassay samples taken during 2002 had results that were lower than the detection limit of 5 µg/L. In April, samples taken from a Plant Operator yielded a bioassay result of 6.2 µg/L. In June, samples taken from a Wellfield Operator yielded a bioassay result of 7.1 µg/L. Investigations conducted by the RSO did not identify any potential cause for the positive bioassay results for these two individuals. Subsequent bioassay samples were below the 5 µg/L detection level.

In addition to routine bioassays, diagnostic samples were necessary on several instances during 2002:

- Bioassays were obtained from Plant Operators after a yellowcake feed hose was disconnected, causing yellowcake to leak onto Precipitation Cell A.
- Diagnostic bioassays were obtained from two engineering personnel after working on the yellowcake packaging scale in the Dryer Room without an RWP.
- A bioassay was obtained from the welder working on replacing the belt filter room floor.
- Bioassays were collected from Plant Operators after the dryer heat was left on following a loss of vacuum and subsequent dryer emissions into the dryer room.
- A bioassay was collected from a Plant Operator after completion of support at Power Resources, Inc. for toll drying CBR product.
- Bioassays were collected on four occasions from personnel working under RWPs in conjunction with work on the Yellowcake Dryer.

In most cases, diagnostic bioassays were necessary due to unforeseen situations where representative air sample results were not available. The diagnostic bioassay samples were all lower than the detection limit of 5 µg/L.

<u>2003 – Bioassay Results</u>

With six exceptions, all routine bioassay samples taken during 2003 yielded results that were lower than the detection limit of 5 µg/L.

- In March, samples taken from a Plant Lead Operator yielded a bioassay result of 5.4 µg/L, which is slightly above the detection limit.

- In December, samples taken from two Plant Operators yielded bioassay results of 8.0 and 14.0 μg/L.
- In December, samples taken from three contractors working on installation of the new yellowcake dryer yielded bioassay results of 6.0, 6.0, and 10.0 μg/L.

Investigations conducted by the RSO did not identify any potential cause for the positive bioassay results for these individuals. No work was performed on heavily contaminated equipment, and all air sampling results were normal. It is possible that the empty bioassay bottles became cross-contaminated in the CBR Laboratory. The bottles were replaced and moved to a different storage location in early 2004.

In addition to routine bioassays, diagnostic samples were necessary on several instances during 2003:

- Bioassays were obtained from three Plant Operators cleaning yellowcake out of the old dryer under RWP 03-2.
- Bioassays were obtained on two occasions from two Plant Operators replacing bag filters in the yellowcake dryer baghouse under RWPs 03-4 and 03-14.
- A bioassay was obtained from one Plant Operator replacing the yellowcake dryer plug valve handle under RWP 03-6.
- A diagnostic bioassay was obtained from a Plant Operator after elevated air sample results were noted during a yellowcake transfer from a Precipitation Cell.
- A diagnostic bioassay was obtained from a Plant Operator who was sprayed with yellowcake during a slurry transfer after a feed line broke.

The diagnostic bioassay samples were all lower than the detection limit of 5 μg/L.

<u>2004 – Bioassay Results</u>

With two exceptions, all routine bioassay samples taken during 2004 yielded results that were less than the detection limit of 5 μg/L.

- In February, samples taken from a Plant Lead Operator yielded a bioassay result of 96 μg/L. Rechecks of this sample yielded 101 μg/L and 103 μg/L. The investigation by the RSO concluded that the most likely cause of this uranium level was contamination of the sample at CBR or at the analytical laboratory. Follow-up samples yielded concentrations that were below the detection limit. Using the guidance contained in USNRC Regulatory Guide 8.9, subsequent samples should have shown measurable levels of uranium if the original concentration was accurate.
- In November, samples taken from the Dryer Operator yielded a bioassay result of 17 μg/L. The investigation conducted by the RSO concluded that improper use of

PPE and inadequate engineering design for transferring yellowcake to the dryer were the most likely causes of the elevated sample.

In addition to routine bioassays, diagnostic samples were necessary on several instances during 2004:

- Bioassays were obtained from three workers in February 2004 who were in the same area at the time the Pant Operator had the elevated bioassay noted above.
- Bioassays were obtained on two occasions in April from a maintenance worker involved in dryer maintenance.
- Bioassays were obtained on two occasions in November when breathing zone samples taken during dryer loading activities approached the DAC for soluble uranium.

The diagnostic bioassay samples were all lower than the detection limit of 5 µg/L.

<u>2005 – Bioassay Results</u>

With one exception, all routine bioassay samples taken during 2005 yielded results that were lower than the detection limit of 5 µg/L.

- In August, samples taken from the Dryer Operator yielded a bioassay result of 10 µg/L on a sample taken 5.5 hours after he relieved pressure from a drum of yellowcake. A follow-up 24-hour composite begun immediately after the 5.5-hour grab sample yielded 7.0 µg/L. A second 24-hour composite taken immediately after collection of the first yielded less than 5.0 µg/L.

In addition to routine bioassays, diagnostic samples were necessary on several instances during 2005:

- In April, samples were collected from employees involved in cleaning up yellowcake after the lower discharge valve was broken off of the yellowcake overflow tank.
- In July, samples were collected from employees working under RWP 05-12 to change the bags in the dryer baghouse.

The diagnostic bioassay samples were all lower than the detection limit of 5 µg/L.

<u>2006 – Bioassay Results</u>

All routine bioassay samples taken during 2006 yielded results that were lower than the detection limit of 5 µg/L. In addition to routine bioassays, the following bioassay samples were conducted:

- Diagnostic Bioassay. Employees who changed the bags in the baghouse of the yellowcake dryer were monitored for a 2-day period. All bioassay samples yielded concentrations that were lower than the detection limit of 5 µg/L.
- Bioassay Spike Agreement. A termination bioassay was conducted, resulting in a 10 to 20 µg/L spike that exceeded the Bioassay Spike Agreement range by 33 percent. All samples were rerun, and after the second run, the agreement range was 24 percent. The cause of the exceedance was an ELI analytical error made by the contract laboratory.

<u>Bioassay Quality Assurance Program Description and Historical Results</u>

Elements of the Quality Assurance requirements for the Bioassay Program are based on the guidelines contained in USNRC Regulatory Guide 8.22, *Bioassay in Uranium Mills*, Revision 1. These elements included the following:

- Each batch of samples submitted to the analytical laboratory is accompanied by two blind control samples. In mid-2005, the CBR facility began using control samples prepared from synthetic urine, rather than using urine from persons that were not occupationally exposed. The synthetic blind control samples are spiked to a uranium concentration of 10 mg/L to 20 mg/L and 40 mg/L to 60 mg/L. The results of analysis for these samples are required to be within ± 30 percent of the spiked value. CBR has tracked the results of the blind spike analysis since 1990. Historically, the majority of the samples have been within the ± 30 percent of the spiked value, with exceedances being rare. In 2006, there was only one exceedance and none have been observed through the first three quarters of 2007. Past exceedances have been due to either occasional laboratory error or the facility's spike results were incorrect. When these infrequent errors were observed, the most recent batch of affected samples were rerun and steps taken to review, and as necessary correct, the procedures for spiking or the procedures for laboratory analysis. Actions taken in regard to investigating spiked sample value exceedances are recorded and maintained on file at the facility.
- The analytical laboratory spikes 10 percent to 30 percent of all samples received with known concentrations of uranium and the recovery fraction determined. Results are reported to CBR. All results have been within ± 30 percent.

<u>Proposed Bioassay Program</u>

CBR proposes to continue the Bioassay Program including urinalysis and *in vivo measurements as* described in this Section in accordance with the guidance contained in USNRC Regulatory Guide 8.22, *Bioassay in Uranium Mills*, Revision 1 and with the instructions currently contained in SHEQMS Program Volume IV, *Health Physics Manual*.

5.8.6 Contamination Control Program

CBR's contamination control program at Crow Butte Project consists of the following elements.

5.8.6.1 Surveys for Surface Contamination

CBR performs surveys for surface contamination in operating and clean areas of the Crow Butte Project facilities in accordance with the guidelines contained in USNRC Regulatory Guide 8.30, *Health Physics Surveys in Uranium Recovery Facilities*, Revision 1. Surveys for alpha contamination in clean areas, such as lunchrooms change rooms and offices, are conducted weekly. An action level of 25 percent of the limits from USNRC Regulatory Guide 8.30 is used for clean areas.

5.8.6.2 Surveys for Contamination of Skin and Personal Clothing

All personnel leaving the restricted area are required to perform and document alpha contamination monitoring. In addition, personnel who could come in contact with potentially contaminated solutions outside a restricted area, such as in the wellfields, are required to monitor themselves prior to leaving the area. All personnel receive training in the performance of surveys for skin and personal contamination. Personnel are also allowed to conduct contamination monitoring of small, hand-carried items as long as all surfaces can be reached with the instrument probe and the item is used in another process area. All other items are surveyed as described in the next section.

As recommended in USNRC Regulatory Guide 8.30, *Health Physics Surveys in Uranium Recovery Facilities* Revision 1, CBR conducts quarterly unannounced spot checks of personnel to verify the effectiveness of the surveys for personnel contamination. Employees assigned to the mine site are spot-checked, concentrating on plant operators and maintenance personnel. The purpose of the surveys is to ensure that employees are adequately surveying and decontaminating themselves prior to exiting the restricted areas.

5.8.6.3 Surveys of Equipment Prior to Release to an Unrestricted Area

Consistent with Regulatory Guide 8.31, the RSO, radiation safety staff, or qualified employees will survey all items from the restricted areas with the exception of the small, hand-carried items described above. Lead Operators and plant/wellfield operators with a minimum of six months experience, will be trained by the RSO or radiation staff in the use of applicable radiation survey instruments and procedures, including hands-on use of the instrumentation. The operators will have also received job specific training as operators as well as the radiation safety training described in Section 5.6.1.3.

The release limits for beta gamma contamination are 0.2 mrad average and 1.0 mrad maximum at 1 cm as required by *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses For*

Byproduct, Source, or Special Nuclear Materials, USNRC, May 1987 ("Annex B"). Surveys are performed with the following equipment:

1. Total surface activity will be measured with an appropriate alpha survey meter. A Ludlum Model 2241 Scaler or a Ludlum Model 177 Ratemeter with a Model 43-65 or Model 43-5 alpha scintillation probe, or equivalent, will be used for the surveys.
2. Portable GM survey meter with a beta/gamma probe with an end window thickness of not more than 7 mg/cm^2, a Ludlum Model 3 survey meter with a Ludlum 44-38 probe or equivalent;
3. Swipes for removable contamination surveys as required;
4. Survey equipment is calibrated annually or at the manufacturer's recommended frequency, whichever is more frequent. Surface contamination instruments are checked daily when in use. Alpha survey meters for personnel surveys are response checked before each use with other checks performed weekly;
5. The contamination control program will continue in accordance with the instructions currently contained in SHEQMS Program Volume IV, *Health Physics Manual.*

5.8.6.4 Historical Program Results

The weekly contamination survey results indicate that the contamination control program at the Crow Butte Project is effective. The quarterly spot checks performed throughout the period show that the personnel contamination program is effective. Results of the contamination surveys, spot checks, and equipment release surveys are maintained at the Crow Butte Project site.

5.8.6.5 Contamination Control Program

CBR proposes to continue with the same contamination control program that is currently in use. The program has proven to be effective at controlling contamination of personnel and clean areas. The program is carried out in accordance with the instructions currently contained in SHEQMS Program Volume IV, *Health Physics Manual*

5.8.7 **Airborne Effluent and Environmental Monitoring Programs**

5.8.7.1 Program Description and Historical Monitoring Results

The airborne effluent and environmental monitoring programs are designed to monitor the release of airborne radioactive effluents from the Crow Butte Project facilities. To evaluate the effectiveness of the effluent control systems, the results of the monitoring

program are compared with the background levels and with regulatory limits. **Table 5.8-5** provides the sampling locations, types, frequency, methods, and parameters for the Crow Butte Project facilities.

5.8.7.2 Radon

The radon gas effluent released to the environment is monitored at seven locations (AM-1 through AM-6 and AM-8). Location AM-6 is considered the background location. Monitoring is performed using Track-Etch radon cups provided by Landauer Corporation. The cups are exchanged on a semiannual basis in order to achieve the required LLD. The SHEQMS Program Volume VI, *Environmental Manual* currently provides the instructions for radon gas monitoring. In addition to the manufacturer's Quality Assurance program, CBR exposes duplicate radon Track Etch cups for each monitoring period. The duplicate cups are identified as AB locations using the same number as the existing monitoring location (for example AB-3 is the duplicate cup at monitoring location AM-3). **Table 5.8-6** contains the results of radon monitoring for the Crow Butte Uranium Project facility between 1991 and 2007. **Figure 5.8-10** through **Figure 5.8-16** depict the trends for radon monitoring between 1991 and 2007 for each location. The total estimated radon release trend between 1991 and 2007 is shown in **Figure 5.8-17.**

As recommended in Regulatory Guide 8.37, a trend analysis of the radon monitoring results since commercial operations began in 1991 was performed. In 2003, three monitoring stations (AM-1, AM-2, and AM-8) exhibited significant spikes from historical radon concentrations in the second half. These sample locations are along the eastern and northern boundaries of the License Area and Section 19. In the 2003 ALARA Audit Review, CBR noted that the cause of the elevated radon-222 concentrations was not known. Radon release levels from the Crow Butte Project for the period are consistent with those since increased process flows were approved in 1998, so it did not appear that project releases were the source. Concentrations at the three locations ranged from 34 percent to 37 percent of the effluent concentration limit from 10 CFR Part 20, Appendix B Column 2, which is above normal concentrations at the environmental monitoring stations (generally less than 10 percent) but well below levels that are protective of the public.

Table 5.8-5: Operational Environmental and Effluent Monitoring Program

Sample Type	Location	Type	Number	Frequency	Analyses
Air (Radon)	Nearest residences and in the prevalent wind direction	Continuous	6	Semiannual	Rn-222
	Environmental control station near Crawford, NE.		1		
Air (particulate)	Same locations as radon air monitoring	Continuous	7	A minimum of 2 weeks per month when dryer is in use	U-nat Ra-226 Pb-210
Surface Soil (top 5 cm)	Plant site before topsoil removal	Grab	2	Once	U-nat Ra-226
	Plant site after topsoil removal	Grab	2	Once	U-nat Ra-226
	Evaporation ponds before excavation	Grab	2	Once	U-nat Ra-226
	Air sampling stations	Grab	7	Once	U-nat Ra-226
Subsurface soil	Plant site	1/3 meter composites to one meter	1	Once	U-nat Ra-226
Groundwater	Water supply wells within 1 km of area wellfield	Grab	1	Quarterly	U-nat Ra-226
Surface water	Each stream passing through wellfield area (one upstream and one downstream)	Grab	2	Quarterly	U-nat Ra-226
	Each water impoundment in wellfield area	Grab	1	Quarterly	U-nat Ra-226
Direct Radiation	Air sampling stations	Continuous	7	Quarterly exchange of dosimeters	External gamma
Sediment	Each body of water where surface water sampling is performed	Grab upstream and downstream of wellfields	1 or 2	Annually	U-nat Ra-226 Pb-210

Table 5.8-6: Ambient Radon Gas Monitoring Results (pCi\L) (1991-2007)

Monitoring Period	Monitoring Location								
	AM-1	AM-2	AM-3	AM-4	AM-5	AM-6	AM-8	AB-3 (AM-3)	AB-6 (AM-6)
First Quarter, 1991	0.3	0.3	0.5	0.5	0.4	0.5	0.3	0.3	0.4
Second Quarter, 1991	0.3	0.3	0.3	0.5	0.3	0.3	0.3	0.3	0.3
Third Quarter, 1991	0.3	0.6	0.3	0.9	0.4	1.0	0.6	0.3	0.5
Fourth Quarter, 1991	0.3	0.5	0.6	0.9	0.7	0.3	0.4	0.4	0.6
First Quarter, 1992	0.5	0.5	0.5	0.7	0.7	0.6	< 0.3	0.5	0.7
Second Quarter, 1992	0.7	0.4	0.3	0.7	0.4	0.6	0.7	0.6	< 0.3
Third Quarter, 1992	< 0.3	0.3	< 0.3	0.5	0.4	< 0.3	0.5	< 0.3	< 0.3
Fourth Quarter, 1992	0.4	0.4	0.5	0.7	0.9	0.7	0.7	0.6	0.3
First Quarter, 1993	0.5	0.4	0.5	< 0.3	0.5	< 0.3	< 0.3	< 0.3	< 0.3
Second Quarter, 1993	0.4	0.6	< 0.3	0.4	0.5	0.4	0.6	< 0.3	< 0.3
Third Quarter, 1993	0.5	1.0	0.6	1.0	0.6	0.4	0.4	0.4	0.5
Fourth Quarter, 1993	0.7	0.9	0.6	0.6	1.1	0.7	0.8	0.6	0.7
First Quarter, 1994	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Second Quarter, 1994	0.6	0.6	0.4	0.5	0.6	< 0.3	0.6	0.5	0.4
Third Quarter, 1994	0.9	0.7	0.9	0.7	0.8	0.8	0.8	0.5	0.7
Fourth Quarter, 1994	0.5	0.5	0.4	0.5	0.8	0.3	0.7	< 0.3	0.5
First Quarter, 1995	<0.3	0.5	<0.3	<0.3	<0.3	<0.3	0.4	<0.3	<0.3
Second Quarter, 1995	<0.3	0.5	<0.3	0.5	<0.3	<0.3	<0.3	0.6	<0.3
Third Quarter, 1995	<0.3	0.7	<0.3	<0.3	0.8	0.4	0.5	<0.3	0.6
Fourth Quarter, 1995	1.2	0.6	0.9	1.7	0.7	0.3	1.3	0.8	<0.3
First Quarter, 1996	<0.3	0.3	<0.3	0.4	<0.3	<0.3	<0.3	<0.3	<0.3
Second Quarter, 1996	0.5	<0.3	<0.3	0.5	<0.3	0.4	0.5	<0.3	<0.3
Third Quarter, 1996	0.7	0.7	0.5	0.6	1.1	0.8	0.9	0.5	1.0
Fourth Quarter, 1996	0.8	0.9	0.3	0.9	1.1	0.8	0.8	0.8	0.6
First Quarter, 1997	0.6 + 0.11	0.5+ 0.10	<0.3	<0.3	<0.3	<0.3	0.7+0.12	<0.3	0.5+0.11
Second Quarter, 1997	0.8+0.13	1.3+0.17	0.6+0.12	0.8+0.13	0.9+0.14	0.7+0.13	0.9+0.14	0.50.11	0.8+0.13

Table 5.8-6: Ambient Radon Gas Monitoring Results (pCi\L) (1991-2007)

Monitoring Period	Monitoring Location								
	AM-1	AM-2	AM-3	AM-4	AM-5	AM-6	AM-8	AB-3 (AM-3)	AB-6 (AM-6)
Third Quarter, 1997	0.6+0.11	0.9+0.14	1.0+0.15	1.2+0.17	1.5+0.19	0.9+0.14	1.2+0.16	0.8+0.13	1.0+0.15
Fourth Quarter, 1997	1.2+0.16	1.2+0.16	0.6+0.11	1.3+0.16	1.5+0.18	1.3+0.17	1.4+0.18	1.1+0.15	0.9+0.13
	Average Radon Concentration (x10^{-9} µCi/ml (Accuracy x 10^{-9} µCi/ml}								
First Half, 1998	0.2+0.03	0.7+0.08	0.4+0.06	0.4+0.06	0.7+0.08	<0.02	0.5+0.07	0.2+0.03	0.2+0.03
Second Half, 1998	0.4+0.05	0.7+0.07	0.6+0.07	0.6+0.07	0.9+0.08	0.4+0.05	0.7+0.07	0.4+0.05	0.4+0.05
First Half, 1999	0.2+0.03	0.5+0.07	0.2+0.04	0.3+0.05	0.4+0.06	0.2+0.04	0.4+0.06	0.3+0.05	0.4+0.06
Second Half, 1999	0.7+0.08	0.7+0.08	0.5+0.06	0.7+0.08	0.8+0.08	0.5+0.06	0.5+0.06	0.5+0.06	0.4+0.05
First Half, 2000	0.5+0.07	1.0+0.11	0.6+0.08	0.8+0.09	0.9+0.10	0.8+0.12	0.9+0.12	0.7+0.08	0.5+0.07
Second Half, 2000	1.2+0.14	1.1+0.11	0.8+0.09	1.2+0.11	1.6+0.14	0.9+0.09	1.1+0.11	1.0+0.10	1.1+0.11
First Half, 2001	0.4+0.06	0.9+0.10	0.3+0.05	0.5+0.08	0.4+0.05	0.4+0.05	0.6+0.08	0.5+0.08	0.5+0.06
Second Half, 2001	0.6+0.09	1.0+0.12	0.9+0.11	[a]	1.7+0.16	1.7+0.16	1.2+0.14	0.5+0.07	0.2+0.04
First Half, 2002	0.5+0.07	0.8+0.11	0.2+0.05	0.3+0.06	0.6+0.09	0.3+0.06	1.7+0.14	0.4+0.07	0.5+0.08
Second Half, 2002	0.5+0.07	0.6+0.08	0.2+0.04	0.2+0.04	0.4+0.06	0.5+0.08	0.8+0.10	0.2+0.04	0.2+0.04
First Half, 2003	0.4+0.07	0.9+0.12	0.4+0.07	0.7+0.10	0.9+0.12	0.9+0.12	1.0+0.12	0.7+0.10	0.5+0.08
Second Half, 2003	3.4+0.24	3.5+0.24	0.5+0.08	0.3+0.05	0.7+0.10	0.5+0.07	3.7+0.25	0.4+0.07	0.3+0.05
First Half, 2004	0.3+0.04	0.4+0.05	0.3+0.04	0.4+0.05	0.7+0.06	0.4+0.05	1.0+0.08	0.2+0.04	0.3+0.04
Second Half, 2004	0.3+0.04	0.5+0.05	0.2+0.03	0.2+0.03	0.6+0.06	0.2+0.04	0.3+0.04	0.2+0.04	0.2+0.2
								0.3+0.04[b]	0.6+0.06[d]
								0.4+0.05[c]	0.3+0.04[c]
First Half, 2005	0.4+0.05	0.6+0.06	0.3+0.04	0.4+0.04	0.7+0.06	0.3+0.04	0.6+0.06	0.2+0.04	0.2+0.03
								0.3+0.04[b]	0.8+0.07[d]
								0.6+0.06[c]	0.5+0.05[c]
Second Half, 2005	0.2+0.03	0.9+0.07	0.2+0.03	0.3+0.04	1.1+0.08	0.3+0.04	0.5+0.05	0.4+0.05	0.4+0.05
								0.4+0.05[b]	0.8+0.07[d]
								0.9+0.07[c]	0.6+0.06[c]
First half, 2006	0.5+0.05	0.6+0.06	0.3+0.04	0.5+0.05	0.8+0.07	0.5+0.05	0.7+0.06	0.3+0.04[b]	0.3+0.04

Table 5.8-6: Ambient Radon Gas Monitoring Results (pCi\L) (1991-2007)

Monitoring Period	Monitoring Location								
	AM-1	AM-2	AM-3	AM-4	AM-5	AM-6	AM-8	AB-3 (AM-3)	AB-6 (AM-6)
								0.8+0.07[c]	
Second Half, 2006	0.3+0.04	0.8+0.07	0.4+0.05	[a]	0.8+0.07	0.4+0.05	0.6+0.06	0.3+0.04[b]	0.4+0.05
								0.7+0.06[c]	
First half, 2007	0.3+0.04	0.3+0.04	0.3+0.04	0.3+0.04	0.7+0.06	0.4+0.05	0.6+0.06	0.5+0.05[b]	0.4+0.05
								0.7+0.06[c]	

Notes:

[a]Detector missing from cup – no data.

Monitoring Locations AB-3 and AB-6 are co-located with stations AM-3 and AM-6 (duplicate sampling locations modified beginning in the second half of 2004).

[b]AB-1 (AM-1 Duplicate)

[c]AB-2 (AM-2 Duplicate)

[d]AB-5 (AM-5 Duplicate)

[e]AB-8 (AM-8 Duplicate)

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Figure 5.8-10: Radon Environmental Monitoring for AM-1 (1991 – 2007)

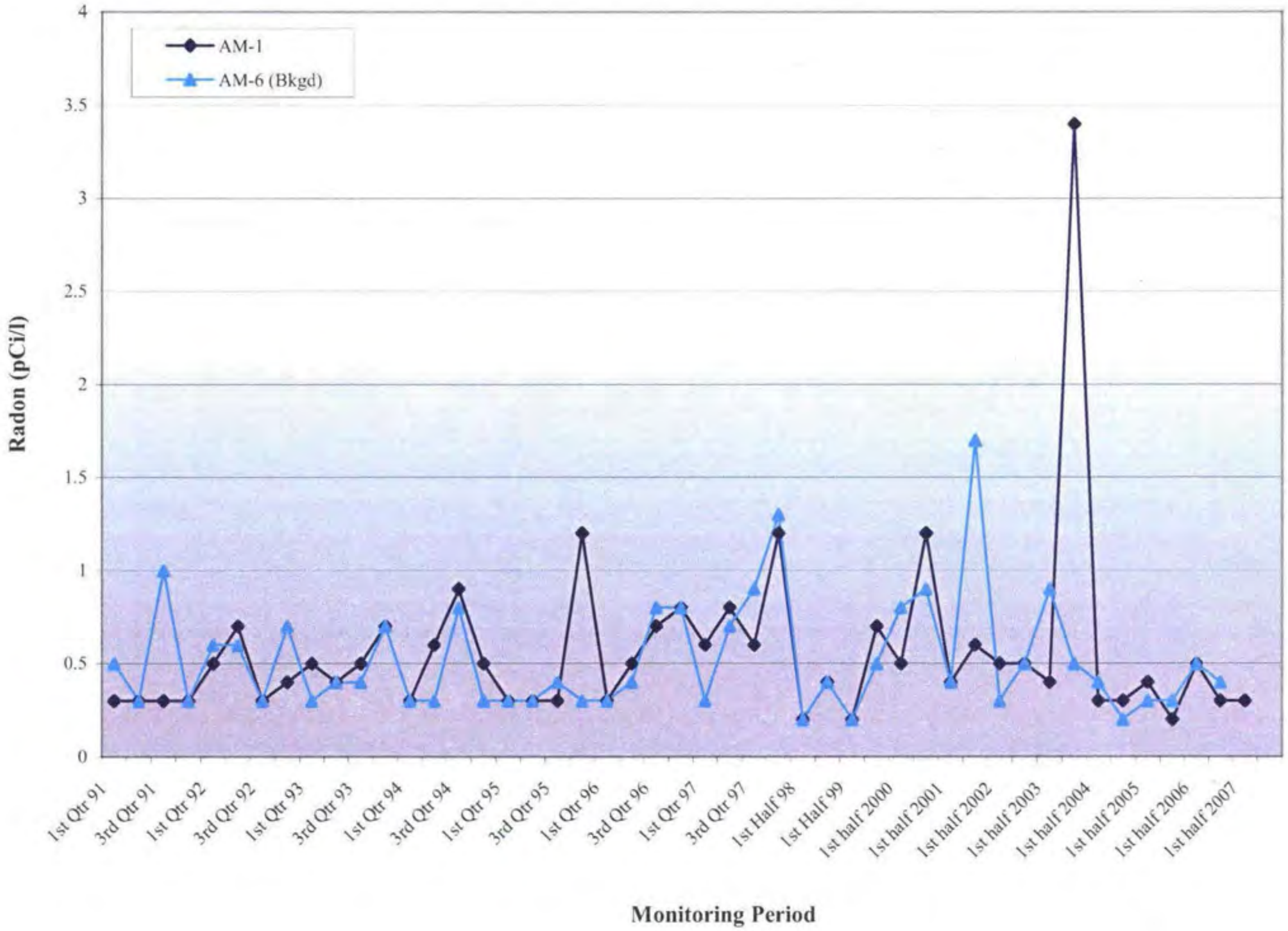


Figure 5.8-11: Radon Environmental Monitoring for AM-2 (1991 – 2007)

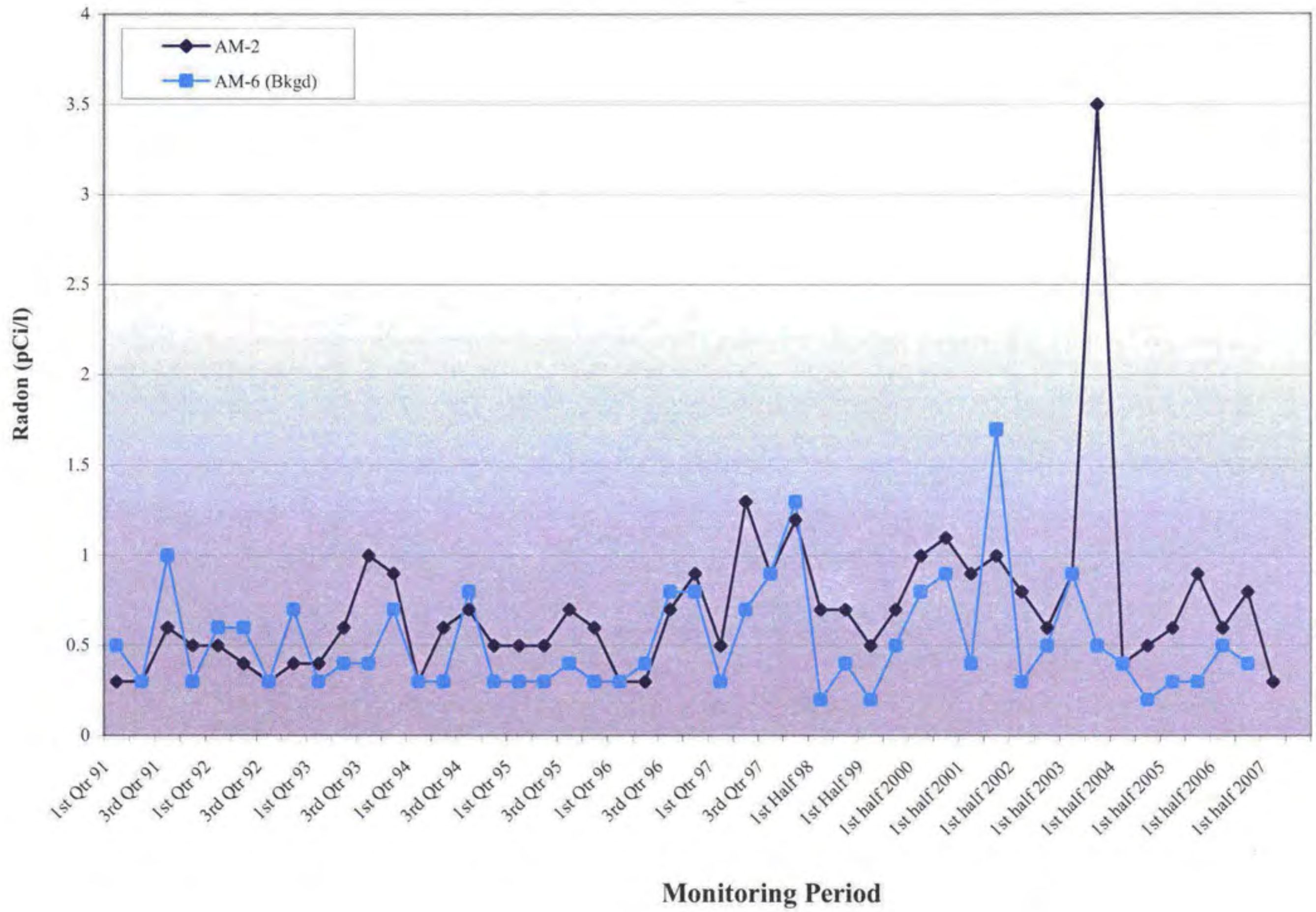


Figure 5.8-12: Radon Environmental Monitoring for AM-3 (1991 – 2007)

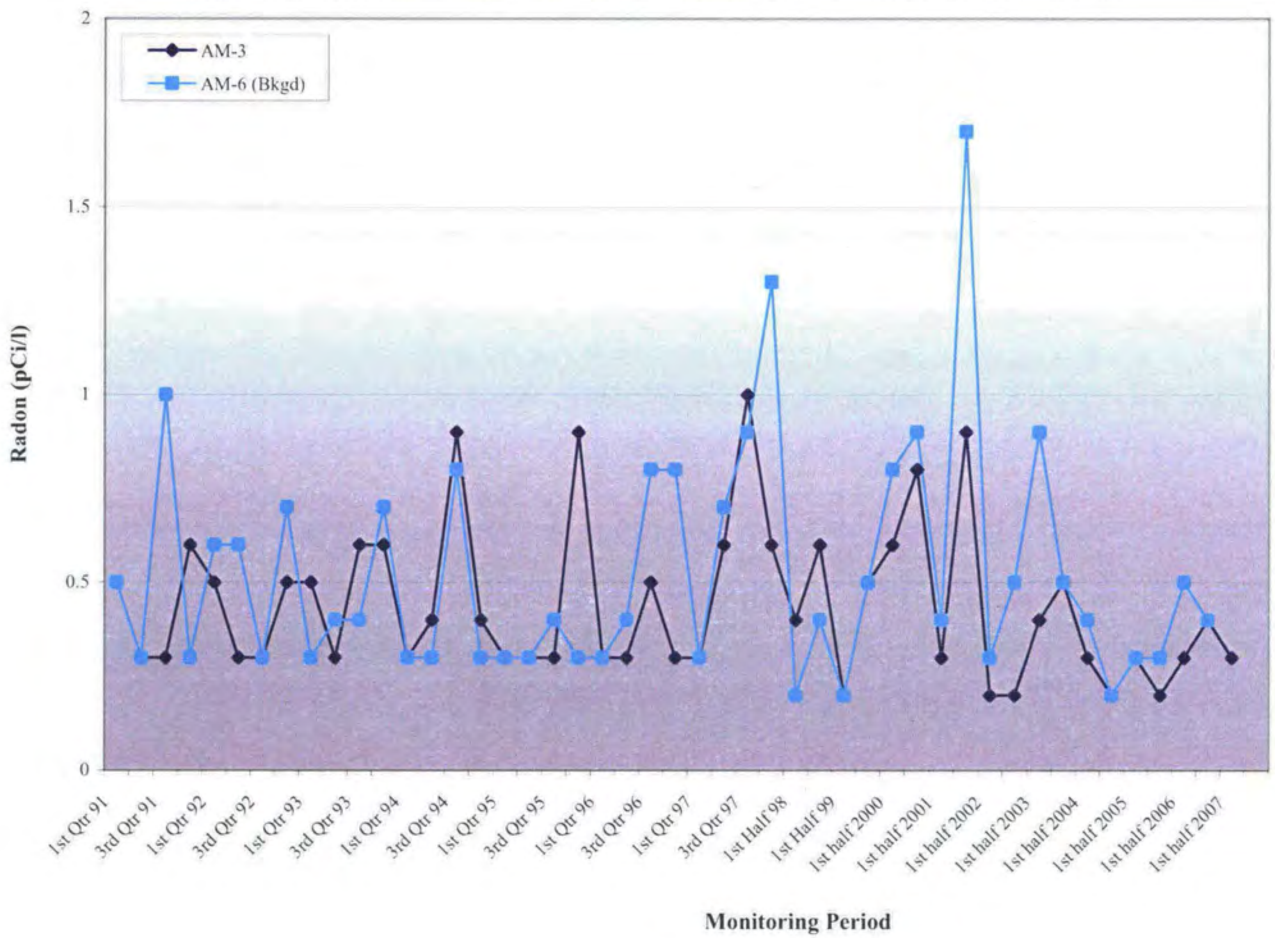


Figure 5.8-13: Radon Environmental Monitoring for AM-4 (1991 – 2007)

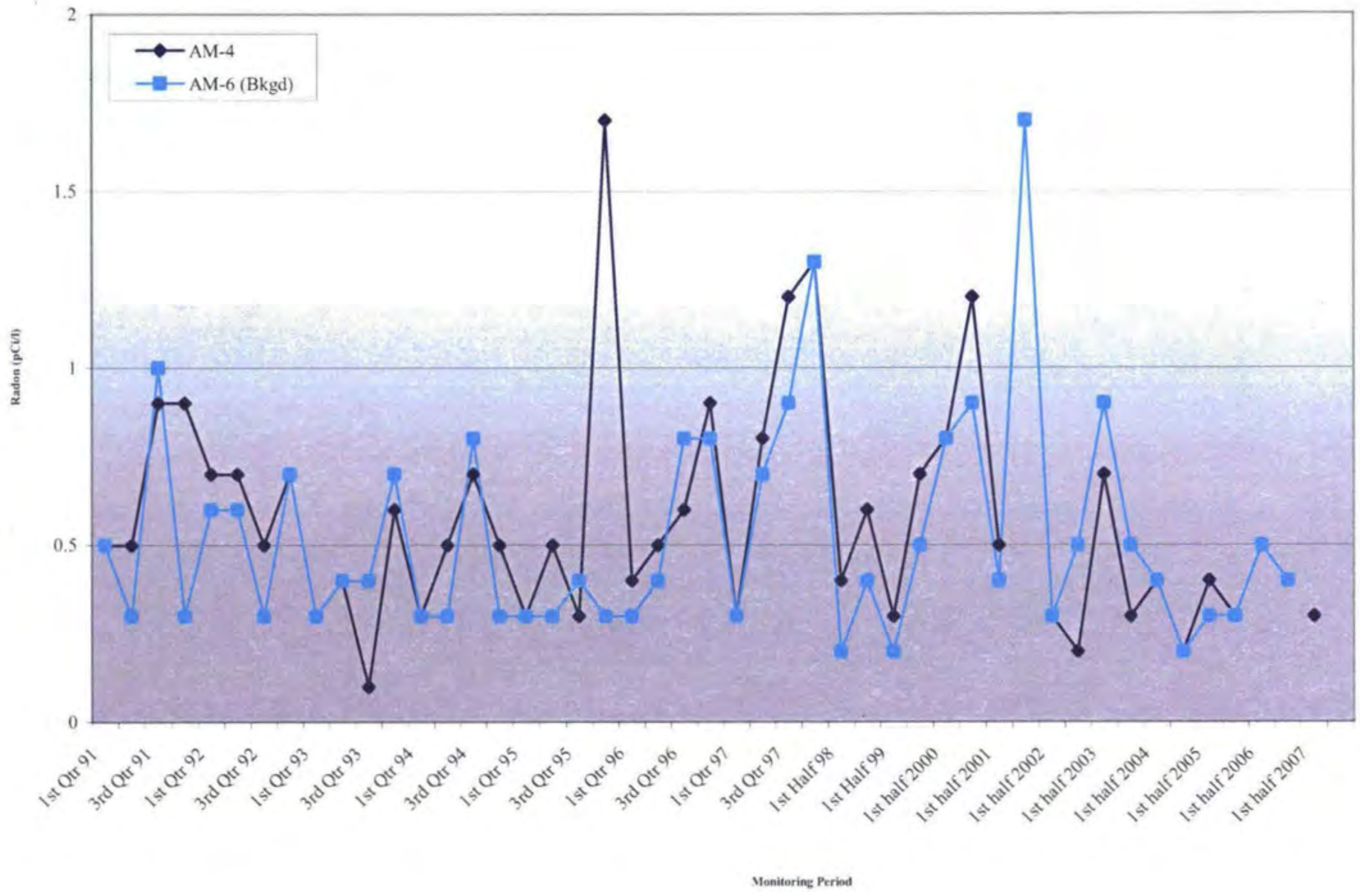


Figure 5.8-14: Radon Environmental Monitoring for AM-5 (1991 – 2007)

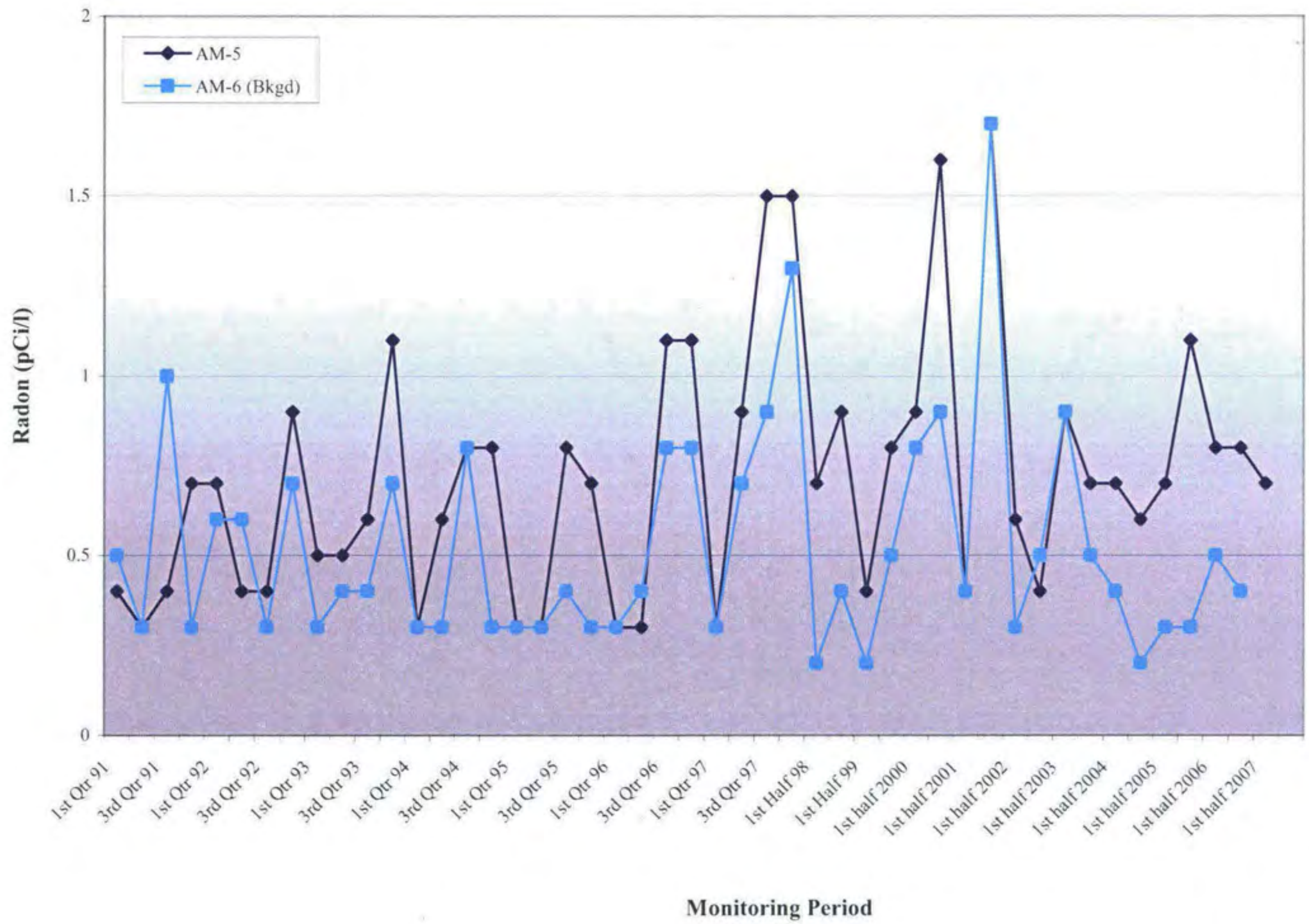


Figure 5.8-15: Radon Environmental Monitoring for AM-6 (1991 – 2007)

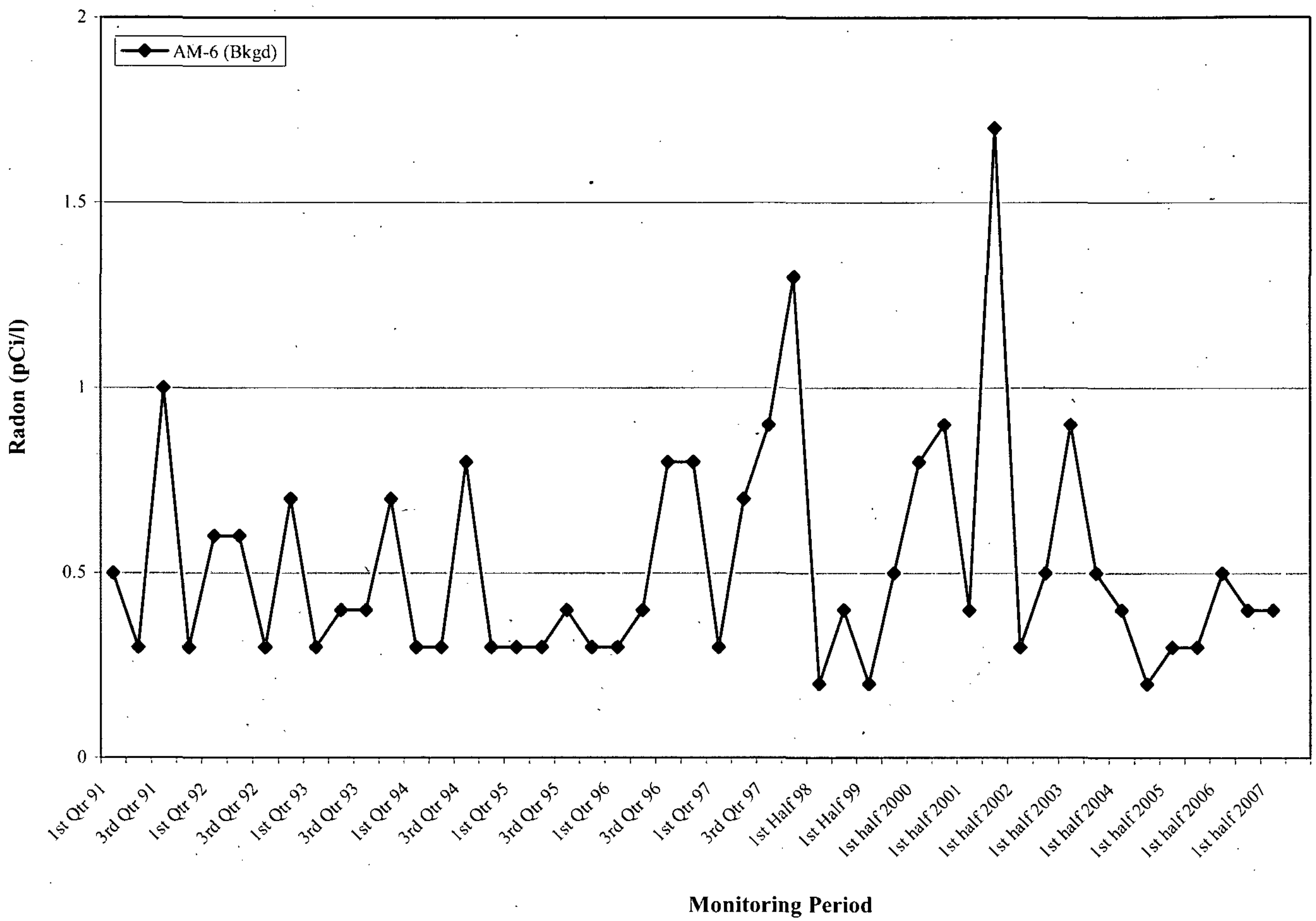


Figure 5.8-16: Radon Environmental Monitoring for AM-8 (1991 – 2007)

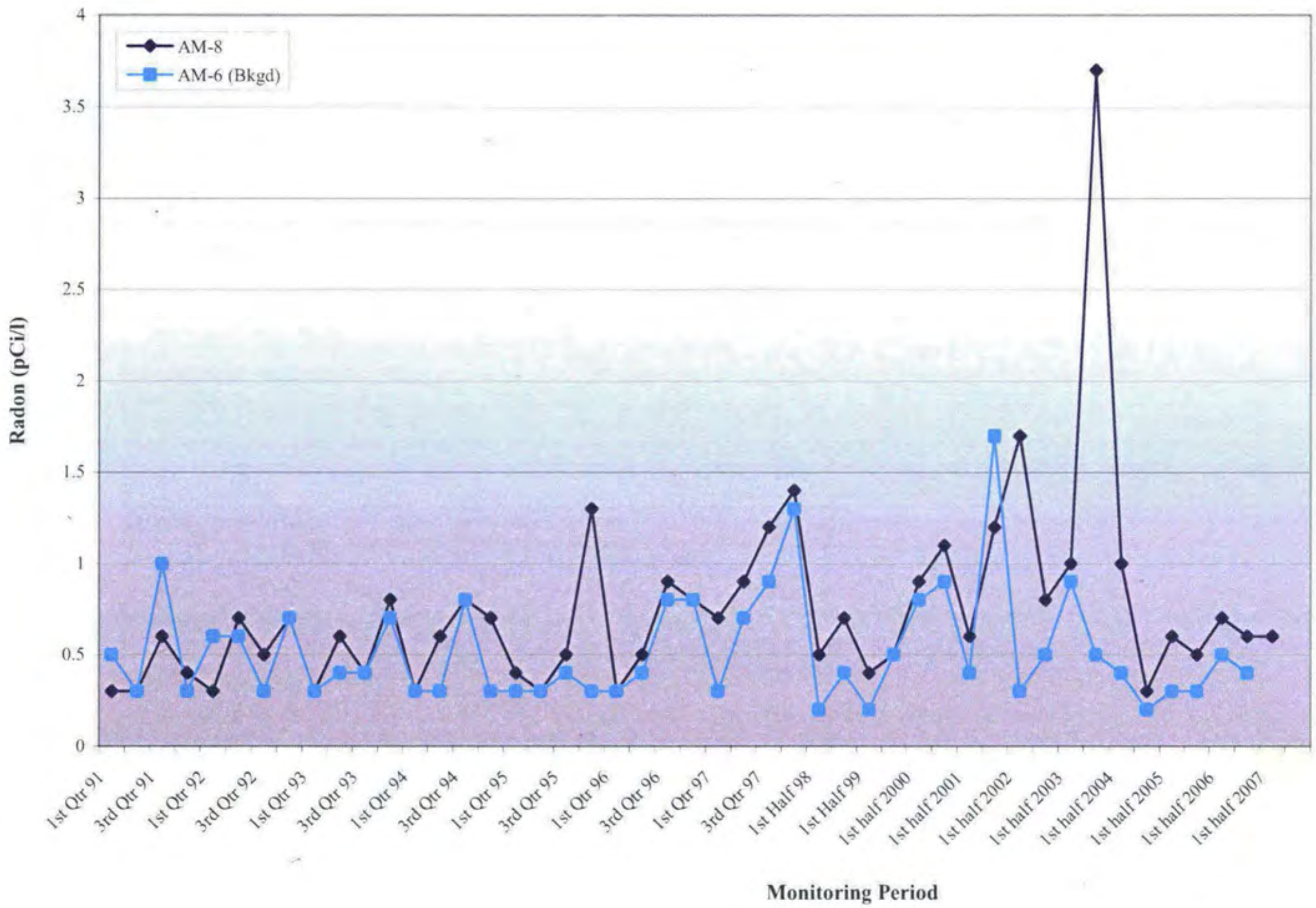
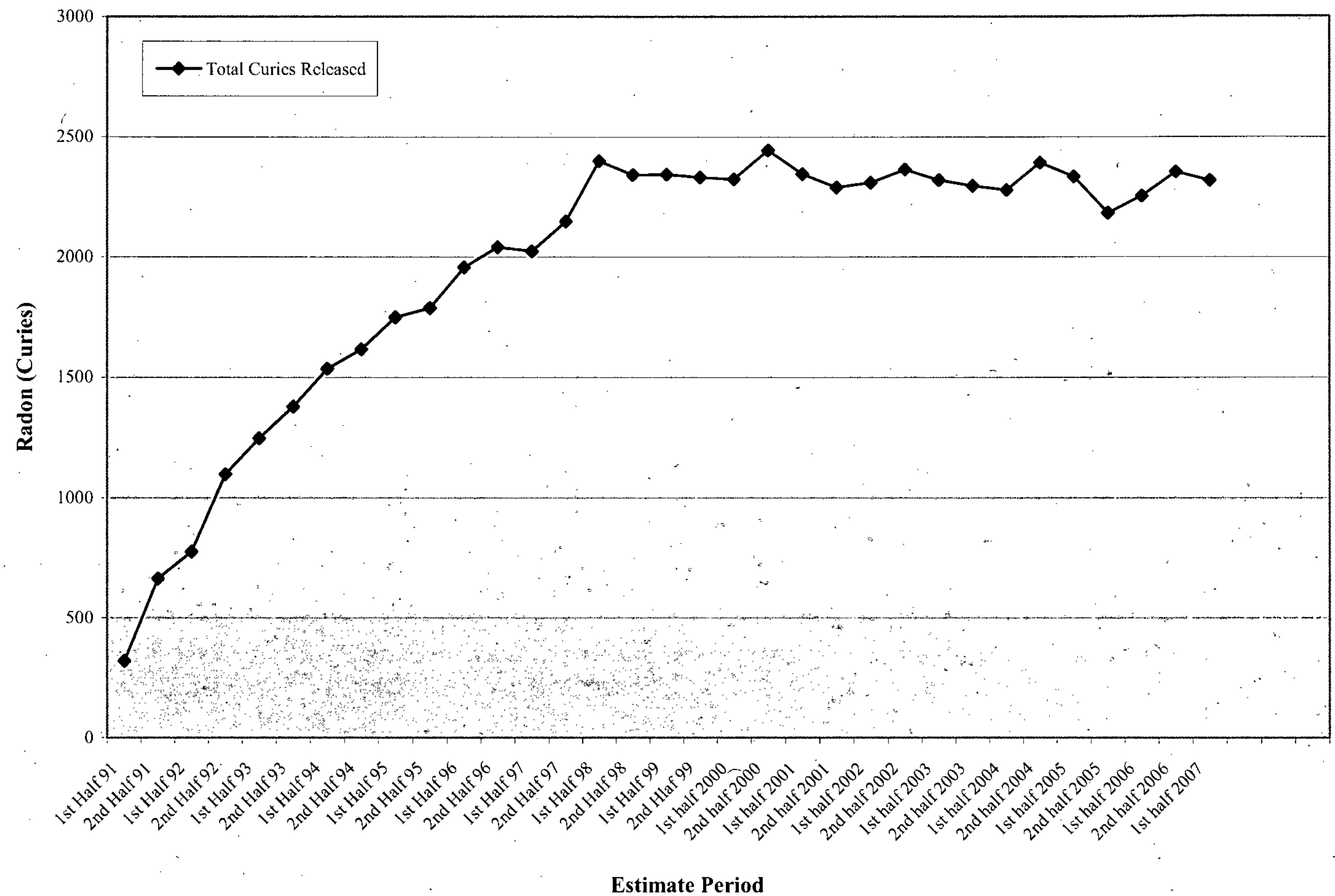


Figure 5.8-17: Total Estimated Radon Release (1991-2007)



In the 2003 ALARA Review, CBR noted that one possible cause for the anomalous results from the second half of 2003 was sampling or analytical error. The 2003 ALARA Audit conducted by Dr. Kenneth Baker recommended that duplicate monitors be deployed at the nearest residences. CBR deployed duplicate monitors at six stations for the second half of 2004 for comparison of results. In the initial analytical results provided by Landauer, Inc., the results from several stations were elevated and did not correlate well to the results from the duplicate monitors. CBR requested that Landauer reanalyze all monitors from the second half of 2004. The results of the reanalysis led to changes in reported values ranging from 0 percent to more than 120 percent. Landauer suggested that the variance in the reported values was due to a routine quarterly update of the background track density for manufacturing lots. The repeat analysis was performed after the background update and in all cases where the reanalysis resulted in a change. The reported values were lower and were consistent with historical concentrations. In the 2004 ALARA Audit Report, CBR reported that it was possible that a similar situation was the cause of the higher concentrations noted in the second half of 2003 and committed to place duplicate monitors at six stations through 2005 to determine the accuracy of the monitoring method.

Table 5.8-7 contains the results of the duplicate radon monitoring performed at the six selected monitoring locations for the second half of 2004 through the second half of 2005.

Table 5.8-7: Environmental Radon Duplicate Monitoring July 2004 to January 2006

Location	2nd half 2004		1st half 2005		2nd half 2005	
AM-1	0.3	0.3	0.4	0.3	0.2	0.4
AM-2	0.5	0.4	0.6	0.6	0.9	0.9
AM-3	0.2	0.2	0.3	0.2	0.2	0.4
AM-5	0.6	0.6	0.7	0.8	1.1	0.8
AM-6	0.2	0.2	0.3	0.2	0.3	0.4
AM-8	0.3	0.3	0.6	0.5	0.5	0.6

Notes: Units = x 10^{-9} µCi/ml
LLD = 0.2 x 10-9 µCi/ml

In addition to the environmental monitoring performed at the Crow Butte Project, release of radon from process operations is estimated and reported in the Semiannual Radiological Effluent and Environmental Monitoring Reports required by 10 CFR § 40.65 and License SUA-1534 Condition Number 12.1. **Table 5.8-8** contains annual calculated radon releases from the Crow Butte Project Facility since 1994.

Table 5.8-8: Radon Release to the Environment (Curies)

	1995	1996	1997	1998	1999	2000
1st Quarter [Leaching]	856	896	899	1,061	1,148	1,100
2ndQuarter [Leaching]	890	882	917	1,150	1,114	1,073
Startup	2.6	11	10	18	2	11
Semiannual Total						
• Leaching	1,749	1,789	1,826	2,229	2,264	2,184
• Restoration	--	--	201	170	79	139
Total	1749	1789	2,027	2,399	2,343	2,323
3rd Quarter	895	926	951	1,100	1,105	1,110
4th Quarter	888	939	1,133	1,101	1,120	1,152
Startup	5	8	9	9	10	29
Semiannual Total						
• Leaching	1,788	1,873	2,093	2,210	2,235	2,291
• Restoration	--	335	55	131	96	146
Total		2,208	2,148	2,341	2,331	2,437
Annual Total	3,537	3,997	4,175	4,740	4,674	4,760
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
1st Quarter [Leaching]	1,109	1,066	1,089	1,048	1,057	1,046
2ndQuarter [Leaching]	1,086	1,113	1,086	1,059	1,063	1,107
Startup	20	15	08	14	9	13
Semiannual Total						
• Leaching	2,215	2,195	2,183	2,121	2,129	2,166
• Restoration	129	115	136	158	205	86
Total	2,344	2,310	2,319	2,279	2,334	2,253
3rd Quarter	1,076	1,119	1,107	1,076	1,020	1,129
4th Quarter	1,082	1,098	1,083	1,094	1,036	1,110
Startup	7.6	20	21	17	16	09
Semiannual Total						
• Leaching	2,166	2,237	2,211	2,187	2,072	2,248
• Restoration	123	128	85	205	111	106
Total	2,289	2,365	2,296	2,392	2,183	2,354
Annual Total	4,633	4,675	4,615	4,671	4,517	4,607

5.8.7.3 Air Particulate

Composite airborne particulate samples for natural uranium, radium 226, and lead 210 are obtained quarterly from seven air monitoring locations. As recommended in USNRC Regulatory Guide 8.37, the results of airborne uranium monitoring performed since 1991 when commercial operations began were reviewed. There were no meaningful trends noted at any of the air monitoring locations. The results noted at these sampling stations indicate no significant impact on the environment or the public. **Figure 5.8-18** through **Figure 5.8-24** contain trend analysis graphs for airborne uranium at each air monitoring location between 1991 and 2006.

Figure 5.8-18: Airborne Uranium Environmental Monitoring AM-1 (1991 – 2007)

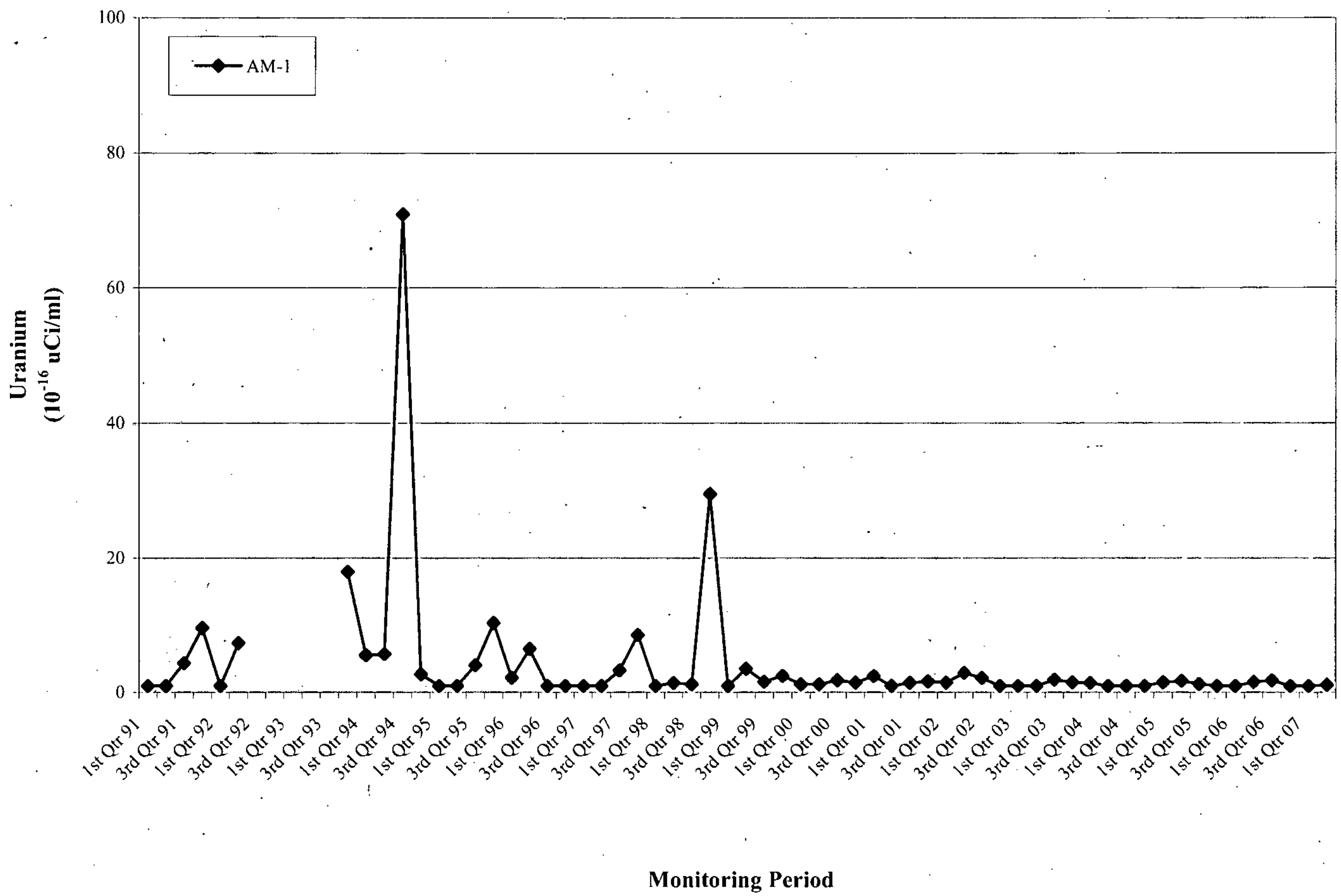


Figure 5.8-19: Airborne Uranium Environmental Monitoring AM-2 (1991 – 2007)

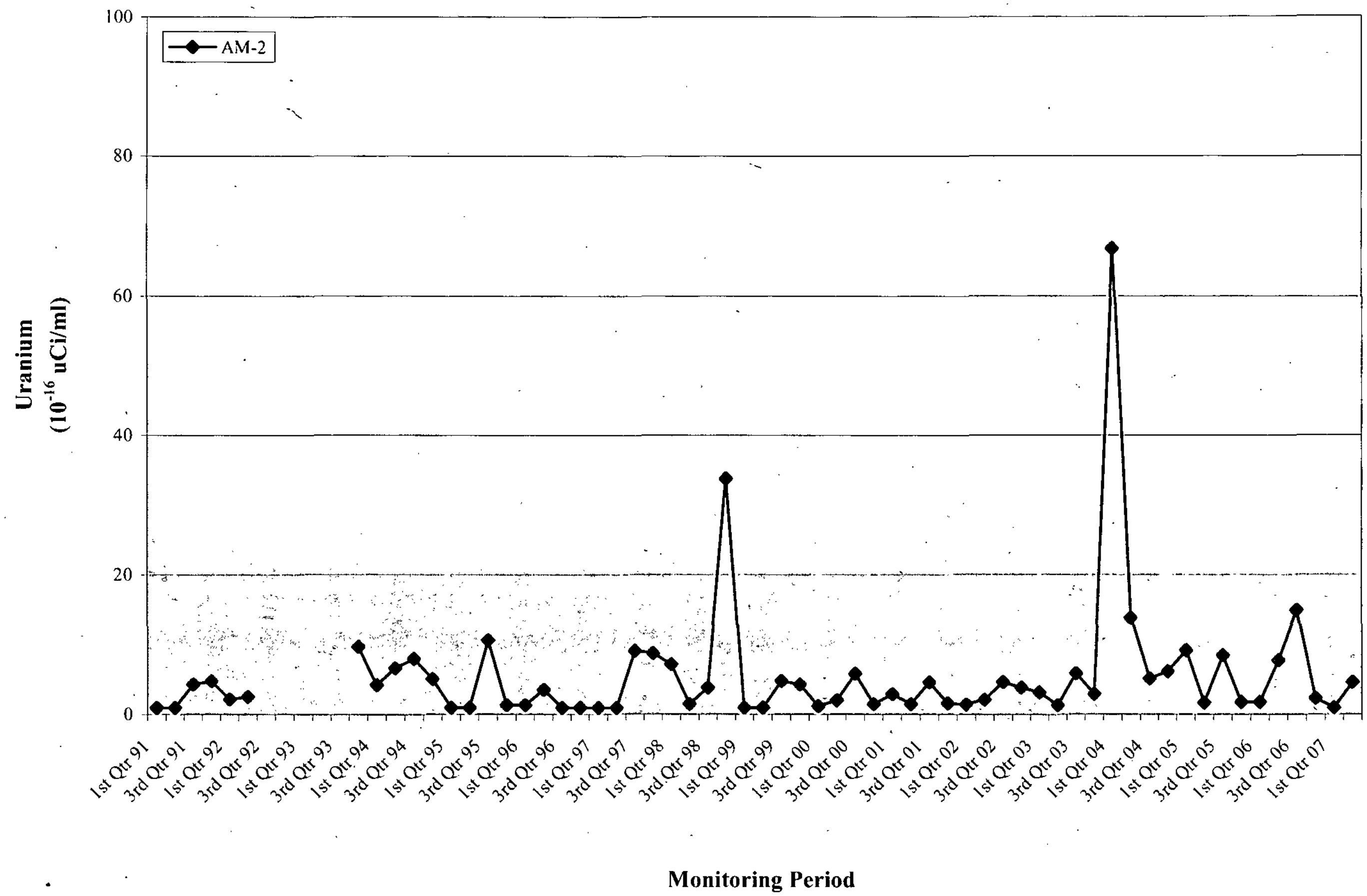


Figure 5.8-20: Airborne Uranium Environmental Monitoring AM-3 (1991 – 2007)

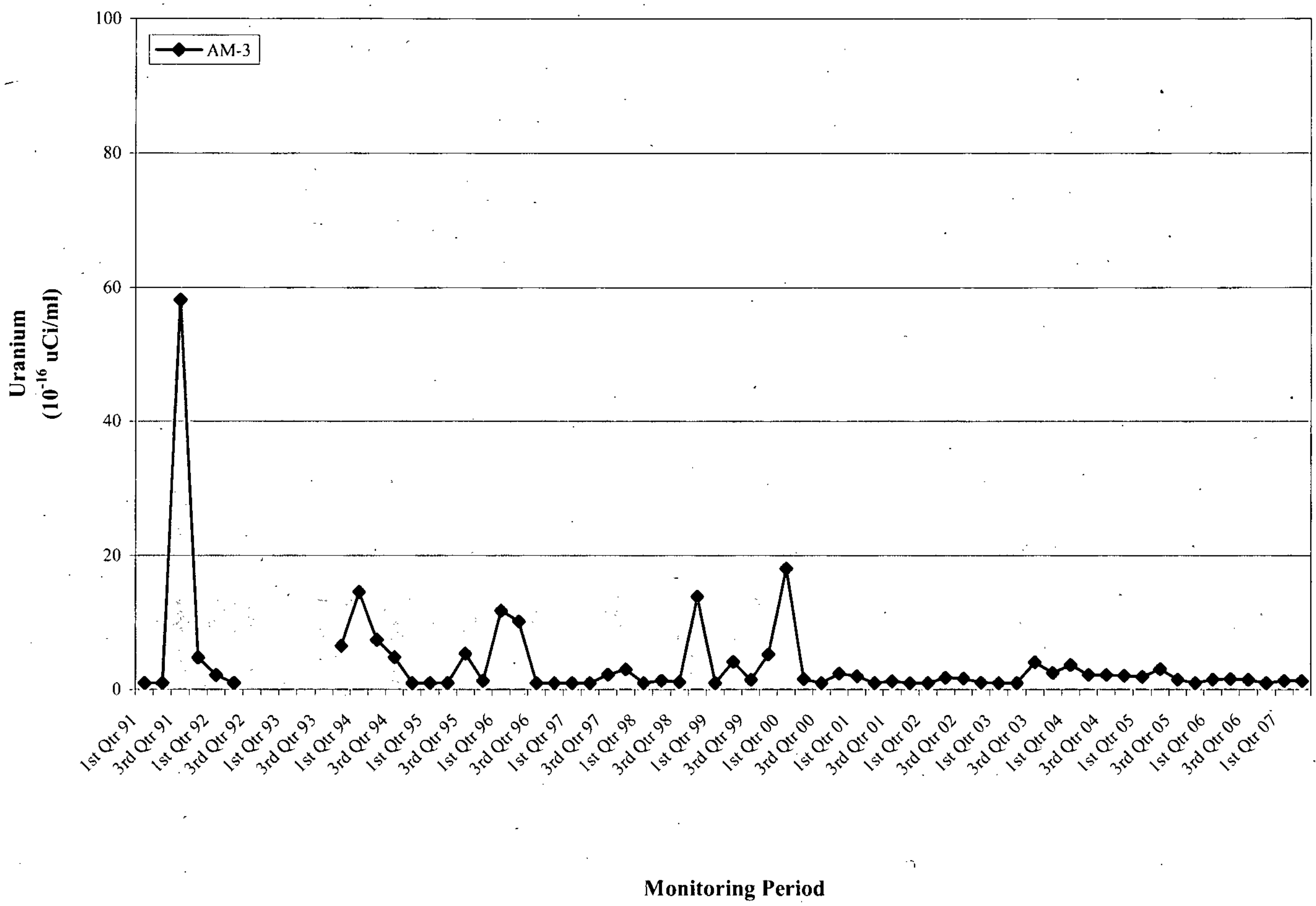


Figure 5.8-21: Airborne Uranium Environmental Monitoring AM-4 (1991 – 2007)

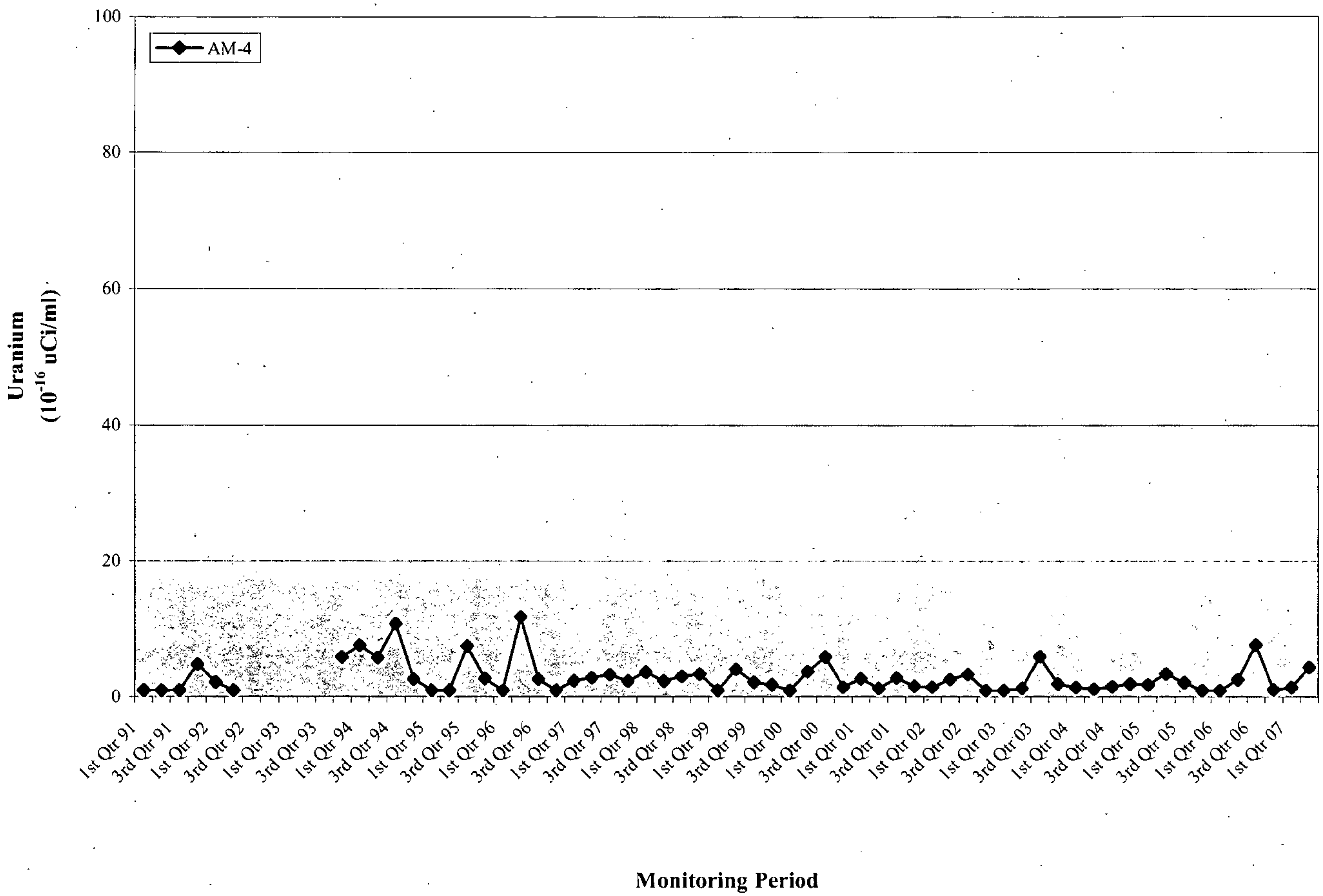


Figure 5.8-22: Airborne Uranium Environmental Monitoring AM-5 (1991 – 2007)

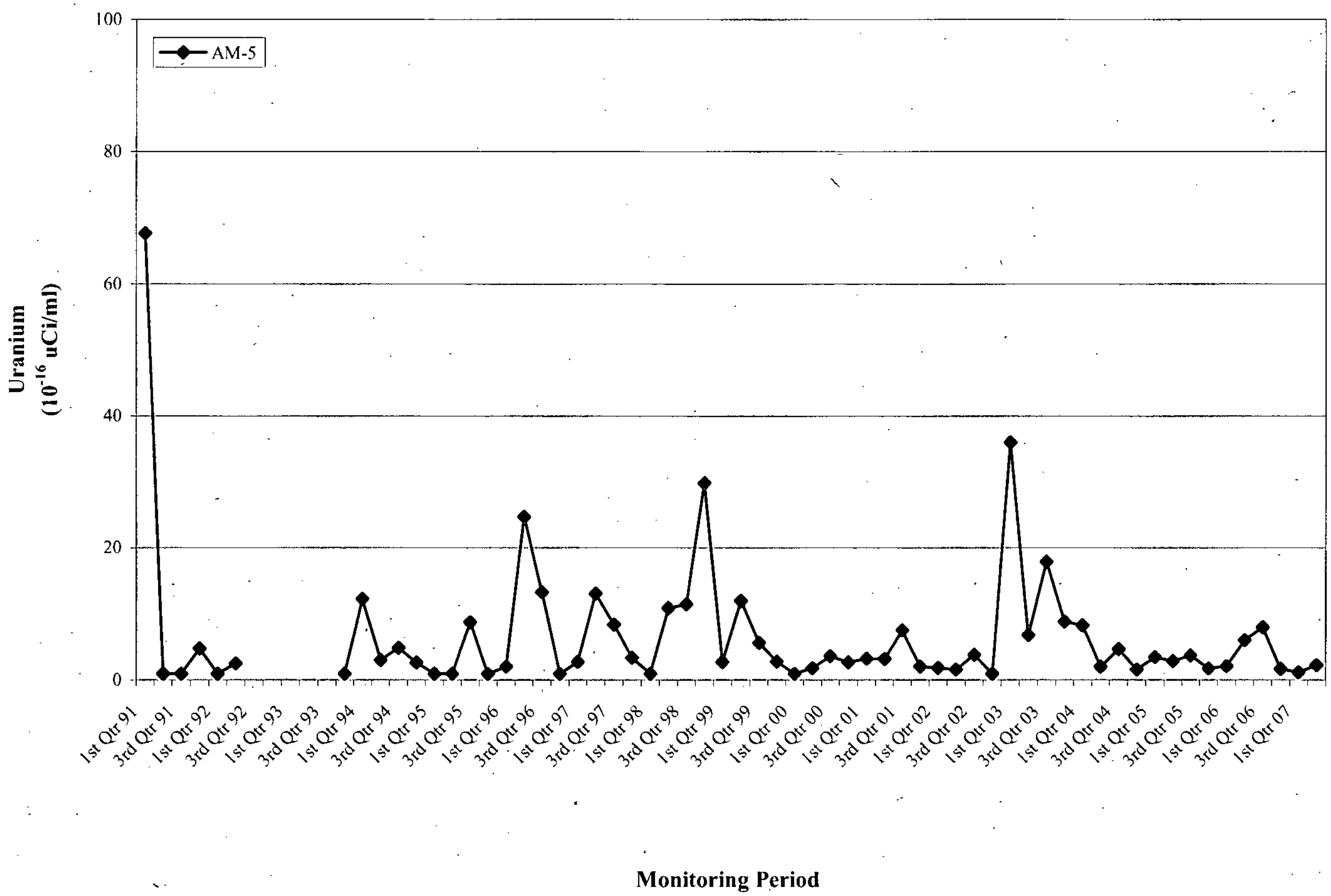


Figure 5.8-23: Airborne Uranium Environmental Monitoring AM-6 (1991 – 2007)

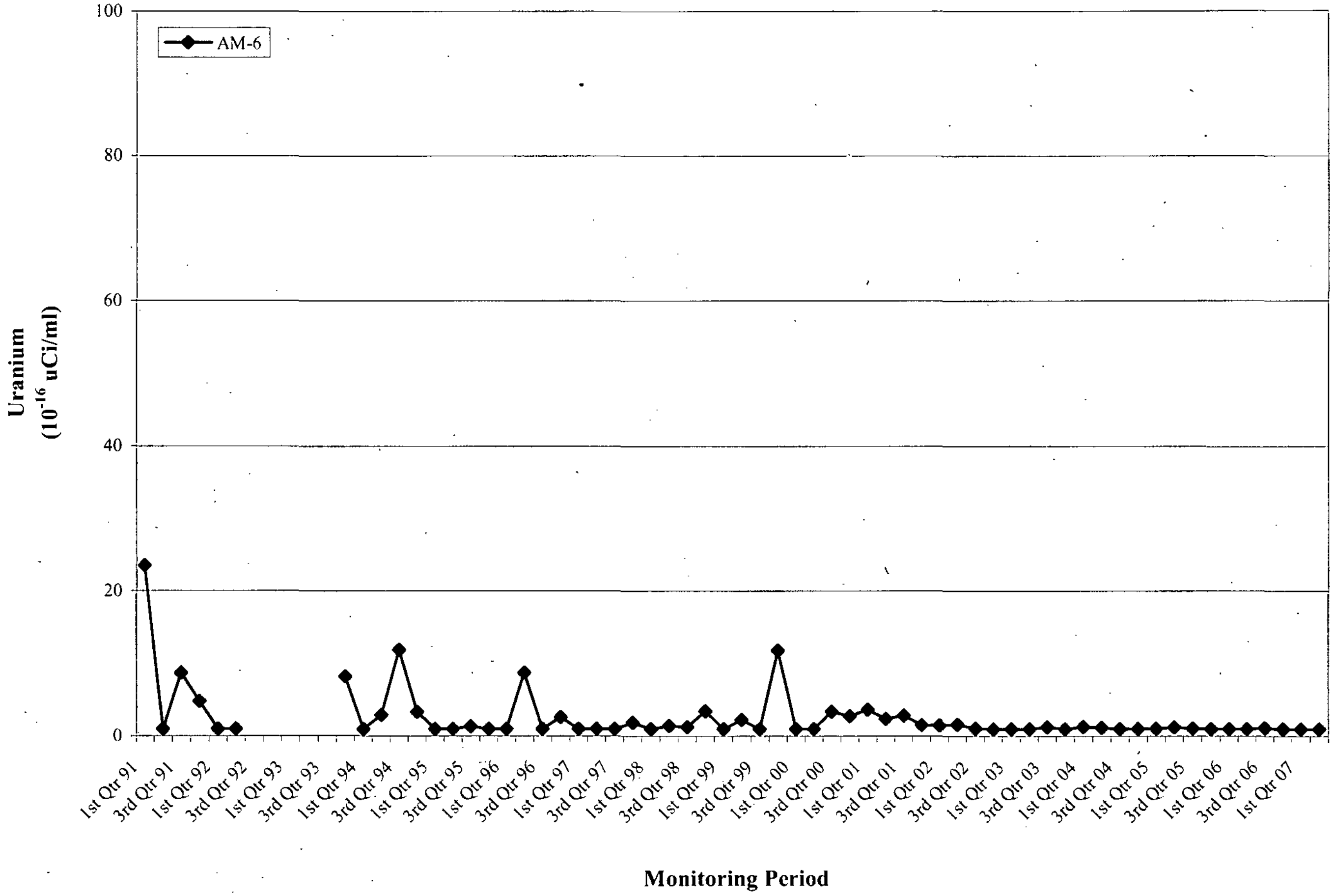
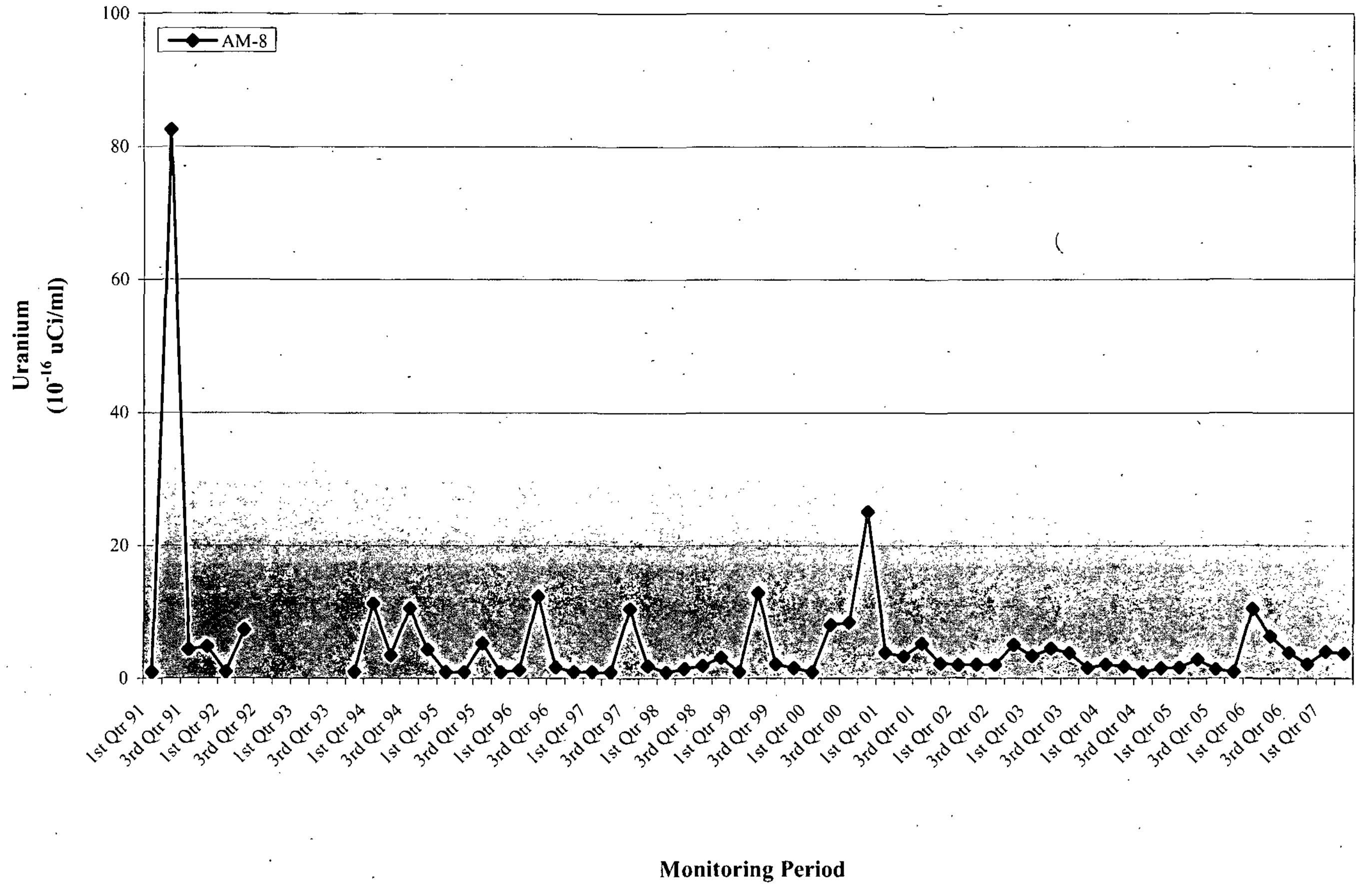


Figure 5.8-24: Airborne Uranium Environmental Monitoring AM-8 (1991 – 2007)



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The 1997 LRA states that the environmental airborne particulate monitoring will be performed for 2 weeks of each month when the yellowcake dryer is in operation. CBR determined in early 2001 that increasing the sample frequency to continuously during dryer operation would provide monitoring data that would be more complete. Environmental air sampling has been performed continuously since 2001.

5.8.7.4 Surface Soil

Surface soil has been sampled as described in **Table 5.8-5**. Surface soil samples will be taken at the air monitoring locations following conclusion of operations and will be compared to the results of the preoperational monitoring program.

5.8.7.5 Subsurface Soil

Subsurface soil has been sampled at the plant as described in **Table 5.8-5.** Subsurface soil samples will be taken following conclusion of operations and will be compared to the results of the preoperational monitoring program.

5.8.7.6 Vegetation

Vegetation samples from Crow Butte Project were collected annually in animal grazing areas in the direction of the prevailing wind. Sampling was normally performed during the summer months. The samples were collected using the following procedures:

A minimum of 1 pound of vegetation was composited on three occasions during the grazing season. The materials collected were primarily the seed/flower head and leafy portions of grasses and forbes along with young shoots of shrubs. Vegetation was analyzed for natural uranium, radium-226, thorium-230, lead-210, and polonium-210. The results of annual vegetation sampling at the Crow Butte Project facility are presented in **Table 5.8-9**. Vegetation sampling was discontinued with the license renewal in 1998.

Table 5.8-9: Annual Vegetation Sampling Program Results*

Sample Date	U-Natural µCi/kg	Ra-226 µCi/kg	Th-230 µCi/kg	Pb-210 µCi/kg	Po-210 µCi/kg
6/9/92	2.90E-06	2.16E-06	< 1.00E-07	1.14E-04	6.44E-06
7/10/92	4.06E-06	9.67E-06	< 9.67E-08	5.98E-05	2.76E-06
8/13/92	1.47E-05	2.71E-06	9.34E-09	7.34E-05	9.43E-06
6/23/93	7.30E-06	1.80E-06	< 7.50E-08	2.30E-05	< 3.80E-07
7/20/93	3.90E-06	< 3.10E-08	< 3.10E-08	1.40E-05	< 1.60E-07
8/24/93	3.10E-06	1.80E-06	1.70E-08	8.30E-05	1.80E-05
6/1/94	1.60E-05	1.90E-05	< 8.00E-08	5.60E-05	5.20E-05
7/8/94	5.70E-06	1.10E-05	< 6.00E-08	2.80E-05	1.90E-05
8/1/94	1.30E-05	7.00E-07	< 4.30E-08	3.70E-05	4.40E-06
6/21/95	4.60 E-6	6.00 E-6	<0.20 x E-7	33.0 E-6	3.80 E-6
7/21/95	4.01 E-6	1.02 E-05	<1,50 E-7	4.02 E-5	<7.3 E-7

Table 5.8-9: Annual Vegetation Sampling Program Results*

Sample Date	U-Natural µCi/kg	Ra-226 µCi/kg	Th-230 µCi/kg	Pb-210 µCi/kg	Po-210 µCi/kg
8/23/95	1.6 E-5	53.0 E-7	30.0 E-7	50.0 E-6	18.0 E-6
6/19/96	9.9 E-6	3.2 E-6	1.29 E-6	10.0 E-6	<1.8 E-7
7/12/96	15 E-6	6.5 E-6	1.5 E-6	31.0 E-6	2.0 E-6
8/09/96	53.0 E-6	15.0 E-6	10.8 E-6	66.0 E-6	24.0 E-6
6/10/97	1.0 E-5	5.90 E-6	1.48 E-6	5.60 E-5	4.0 E-4
7/08/97	3.10 E-5	4.20 E-6	1.27 E-6	6.5- E-5	4.90 E-6
8/06/97	4.40 E-5	4.20 E-6	2.30 E-6	1.00 E-4	6.50 E-6

*Vegetation sampling discontinued with license renewal in 1998.

5.8.7.7 Direct Radiation

Environmental gamma radiation levels are monitored continuously at the seven air quality monitoring stations. Gamma radiation is monitored using dosimeters obtained from a qualified vendor. Environmental dosimeters are exchanged quarterly. Results of the annual gamma radiation monitoring are shown in **Table 5.8-10**. The trend data for environmental gamma monitoring between 1994 and 2007 are depicted in **Figure 5.8-25 through Figure 5.8-31**. There were elevated gamma radiation levels from 2001 through 2002 at the designated monitoring sites. However, since 2003, there were no meaningful trends noted at any of the air monitoring locations. The results noted at these sampling stations indicate no significant impact on the environment or the public.

5.8.7.8 Sediment

Sediment in Squaw and English Creeks and impoundments were sampled at upstream and downstream locations semiannually for 1 year prior to any construction in the area. Following construction, samples have been taken annually as described in **Table 5.8-5**. Samples are taken upstream and downstream of the Crow Butte Uranium Project site and analyzed for natural uranium, radium-226, thorium-230, and lead-210. The results of sediment sampling are shown in **Table 5.8-11. Figure 5.8-32** through **Figure 5.8-37** contain graphs of the results of the annual sediment analysis program between 1991 and 2006. These graphs plot the upstream and downstream locations for each creek and the inlet to the impoundments for each radioisotope.

There were no apparent trends for any sample location for any analyte. The concentrations of natural uranium in several English Creek samples were well above regional background levels. However, these elevated concentrations were noted in the English Creek drainage during preoperational monitoring, which would indicate that these levels are anomalous natural background concentrations. Composite samples obtained from E-1 and E-1 as part of the preoperational sampling program between 1982 and 1986 had average results with elevated natural uranium (3.4 pCi/g) and lead-210 (1.4 pCi/g) when compared with the other surface water sample locations. Samples obtained

in 1998 before mining operations began in this area showed similar elevated uranium concentrations.

The sample locations are in a wetland are in the upper course of English Creek and downstream impoundments. The area has a large amount of organic matter and low water flows compared with the other surface water sampling locations for the project. CBR believes that the upper courses of English Creek are an area with reducing conditions that favor deposition of radionuclides. **Figure 5.8-35** is a trend graph for English Creek sediment sample points since 1998 that shows the elevated uranium concentrations noted in past sediment samples.

5.8.7.9 Proposed Airborne Effluent and Environmental Monitoring Program

CBR proposes to continue the Airborne Effluent and Environmental Monitoring Program described in this section.

5.8.8 Groundwater/Surface Water Monitoring Program

5.8.8.1 Program Description

During operations at the Crow Butte Project facilities, a detailed water sampling program is conducted to identify any potential impacts to water resources of the area. CBR's operational water monitoring program includes the evaluation of groundwater on a regional basis and groundwater within the permit or licensed area and surface water on a regional and site-specific basis. An overview of the groundwater and surface water monitoring programs at the Crow Butte Project can be found in **Table 5.8-5**.

5.8.8.2 Groundwater Monitoring

The groundwater excursion monitoring program is designed to detect excursions of lixiviant into the ore zone aquifer outside of the wellfield being leached and into the overlying water bearing strata. Excursion monitoring is performed throughout operations, restoration and stabilization, until stabilization is approved by NRC. The Pierre Shale below the ore zone is more than 1,200 feet thick and contains no water-bearing strata. Therefore, it is not necessary to monitor any water-bearing strata below the ore zone.

Table 5.8-10: Annual Gamma Monitoring Results (mREM)

Date	1000 Cont	1001 AM-1	1002 AM-2	1003 AM-6	1005 R&D	1006 Well	1007 Well	1008 AM-8	1009 AM-3	1010 AM-4	1011 AM-5	1012 Comm
4/24/91	23.8	30.2	30.6	30	29.2	31.8	34	28	28.2	31.2	33	
7/11/91	27.6	29.4	27.6	26.6	28.6	32.2	31.6	27.4	30	30.2	28.2	30.6
10/10/91	23.8	30.8	27.2	25.8	29.6	34.4	31.4	23.2	30.8	30.2	29.2	29
1/14/92	36.2	43.2	43.4	46.6	44	41.4	54.8	41.6	45.2	41.8	46.6	40.4
4/16/92	26.6	30	31.8	30.6	29.8	34	34	41.8		34.2	35	32.2
7/9/92	34.6	30.4	29.6	31	32	33	32.4	29.8	32.6	30.2	33.2	31
10/14/92	35.8	31.4	32.6	30	31.2	30.4	33.4	27.4	36.2	31.6	30.6	33
1/13/93	36.4	28.2	33.4	32.6	35	35.4	39.8	35.4	33.6	30.4	35.6	31.2
4/16/93	42.6	38.4	34	33.6	37	35.8	40.6	33.2	32.4	36.8	36.8	33.6
7/13/93	43.6	29.2	31.6	30.8	29.8	34.4	34.4	31	31.6	25.8	33.6	30.8
10/11/93	39.8	29	27.2	27.6	31.6	29.8	32.8	26.4	31.4	30	28	26.4
1/14/94	49.4	35.8	32	34.2	34.4	38.4	33.8	32.2	33.2	29.8	32.2	44.4
4/15/94	46.8	33	32.6	42.2	32.2	27.2	40	36.2	40.2	16.4	39.4	35.4
7/19/94	59.2	35.8	37	36.8	38.6	42.6	45.8	36	38.2	43.2	40	41.2
10/14/94	57.2	29.8	29.4	39.6	38.8	16	32.8	32.2	36.8	35.8	39.2	37.2
4/03/95	46.4	34.2	31.2	33.8	34.8	36.8	36.6	30.6	30.2	34.4	32.2	33.0
7/05/95	43.2	30.0	29.8	27.8	28.0	32.4	32.2	23.4	21.4	25.8	27.0	25.4
10/02/95	49.4	40.0	34.8	33.2	30.0	39.4	33.8	37.4	35.6	37.8	34.6	37.0
1/02/96	40.8	24.6	24.6	25.0	12.0	26.4	28.0	24.6	25.4	23.2	26.2	24.2
4/01/96	44.8	29.2	28.2	32.2	29.4	30.4	30.2	29.2	30.4	32.2	31.8	25.8
7/01/96	46.2	35.0	31.2	33.0	33.2	36.8	35.8	30.6	34.2	30.6	31.2	32.2
10/01/96	35.2	35.4	36.0	34.2	32.8	37.4	36.2	30.8	33.2	35.4	37.4	32.4
1/02/97	51.8	32.6	31.4	32.6	28.6	40.6	0.0	31.6	30.0	33.6	30.0	34.2
4/01/97	45.0	28.2	28.2	31.2	26.0	30.8	31.6	26.8	27.4	18.2	29.4	29.2

Table 5.8-10: Annual Gamma Monitoring Results (mREM)

Date	1000 Cont	1001 AM-1	1002 AM-2	1003 AM-6	1005 R&D	1006 Well	1007 Well	1008 AM-8	1009 AM-3	1010 AM-4	1011 AM-5	1012 Comm
7/01/97	50.0	40.2	29.0	31.0	30.6	32.8	32.6	28.2	29.6	29.4	30.0	31.6
10/01/97	60.4	31.6	33.0	31.8	29.8	30,4	30.8	30.0	35.2	29.2	32.2	32.0
1/02/98	56.8	34.4	32.0	29.6	32.8	37.2	32.8	32.2	34.8	34.0	36.6	30.6
4//01/98	48.0	29.8	34.3	34.2	30.2	33.4	30.3	31.8	31.4	33.6	30.0	30.6
7/01/98	63.4	34.6	36.0	37.4	-	-	-	36.2	38.0	34.4	35.4	-
10/01/98	61.2	26.6	27.4	33.8	-	-	-	25.8	34.8	29.2	31.0	-
1/05/99	67.6	33.8	35.8	35.2	-	-	-	38.0	35.0	34.4	29.0	-
4/01/99	72.2	36.8	33.8	27.0	-	-	-	35.2	34.6	31.0	40.0	-
7/01/99	53.8	29.4	29.4	27.0	-	-	-	29.2	28.8	25.0	29.2	-
10/04/99	57.8	25.0	29.0	26.2	-	-	-	26.0	21.6	24.8	27.6	-
1/04/00	52.2	28.0	32.2	28.6	-	-	-	31.2	32.4	30.0	32.6	-
4/03/00	70.2	35.2	34.8	36.4	-	-	-	38.8	36.2	30.8	34.2	-
7/05/00	67.8	29.6	32.2	31.4	-	-	-	36.4	32.8	30.2	29.4	-
10/15/00	75.2	30.8	30.6	30.2	-	-	-	33.0	30.8	30.8	32.0	-
1/18/01	54.2	32.6	26.0	27.4	-	-	-	28.6	-	27.4	29.4	-
4/16/01	53.8	33.6	34.6	35.0	-	-	-	35.6	35.4	35.8	38.8	-
7/09/01	77.6	55.4	54.6	55.0	-	-	-	59.4	57.2	55.6	58.0	-
10/04/01	71.6	41.8	42.8	44.0	-	-	-	44.2	45.8	43.2	45.8	-
1/09/02	81.2	47.4	47.6	45.0	-	-	-	48.4	45.2	45.2	47.0	-
4/08/02	84.0	36.6	35.4	41.0	-	-	-	44.2	40.6	41.0	42.6	-
7/08/02	41.8	49.2	49.2	51.4	-	-	-	51.4	52.8	52.0	51.0	-
10-03/02	25.4	34.6	32.0	33.8	-	-	-	40.2	38.2	44.0	34.8	-
1/07/03	44.2	49.0	47.4	49.0	-	-	-	51.6	49.6	50.8	52.0	-
4/03/03	44.8	52.2	48.6	62.6	-	-	-	52.0	49.4	a	49.6	-

Table 5.8-10: Annual Gamma Monitoring Results (mREM)

Date	1000 Cont	1001 AM-1	1002 AM-2	1003 AM-6	1005 R&D	1006 Well	1007 Well	1008 AM-8	1009 AM-3	1010 AM-4	1011 AM-5	1012 Comm
7/11/03	37.4	42.0	43.0	44.2	-	-	-	46.8	45.0	43.8	47.0	-
10/03/03	33.8	43.6	44.0	39.0	-	-	-	45.0	44.0	43.2	45.4	-
1/08/04	40.6	51.0	49.6	46.4	-	-	-	51.0	49.0	48.6	48.2	-
4/05/04	40.8	45.8	44.6	48.0	-	-	-	49.4	45.8	48.6	48.8	-
7/13/04	34.2	42.2	42.6	43.0	-	-	-	43.8	41.4	43.8	45.4	-
10/05/04	35.0	45.0	42.8	45.2	-	-	-	44.8	46.0	43.2	43.8	-
1/06/05	40.0	52.4	49.0	49.0	-	-	-	49.8	49.0	49.2	51.2	-
4/05/05	44.2	53.8	53.6	52.4	-	-	-	55.6	55.0	53.0	53.0	-
7/08/05	25.6	36.4	33.4	40.6	-	-	-	36.4	36.6	36.4	39.4	-
10/06/05	35.6	40.6	41.4	40.6	-	-	-	42.4	41.4	37.8	32.0	-
1/06/06	33.6	41.6	40.0	B	-	-	-	40.6	41.2	42.2	42.4	-
4/06/06	31.6	36.4	37.8	36.4	-	-	-	39.2	41.0	39.2	39.8	-
7/05/06	28.4	35.0	35.2	35.8	-	-	-	36.8	38.0	32.0	35.8	-
10/05/06	20.2	25.8	27.0	25.2	-	-	-	28.8	28.0	27.6	26.8	-
1/05/07	27.2	34.8	31.8	33.0	-	-	-	35.0	35.0	32.6	35.4	-
4/05/07	33.0	39.0	48.0	38.4	-	-	-	41.0	39.0	38.8	39.0	-
7/06/07	24.0	29.0	29.6	30.2	-	-	-	29.0	28.8	28.4	27.2	-

Sample Locations: 1000: Control
1005: R&D Pond Gate
1006: Wellfield
1007: Wellfield
1012: Commercial Pond Gate

[a]Received damage by laboratory.
[b]Dosimeter not returned to laboratory.

Figure 5.8-25: Environmental Gamma Monitoring AM-1 (1991 – 2007)

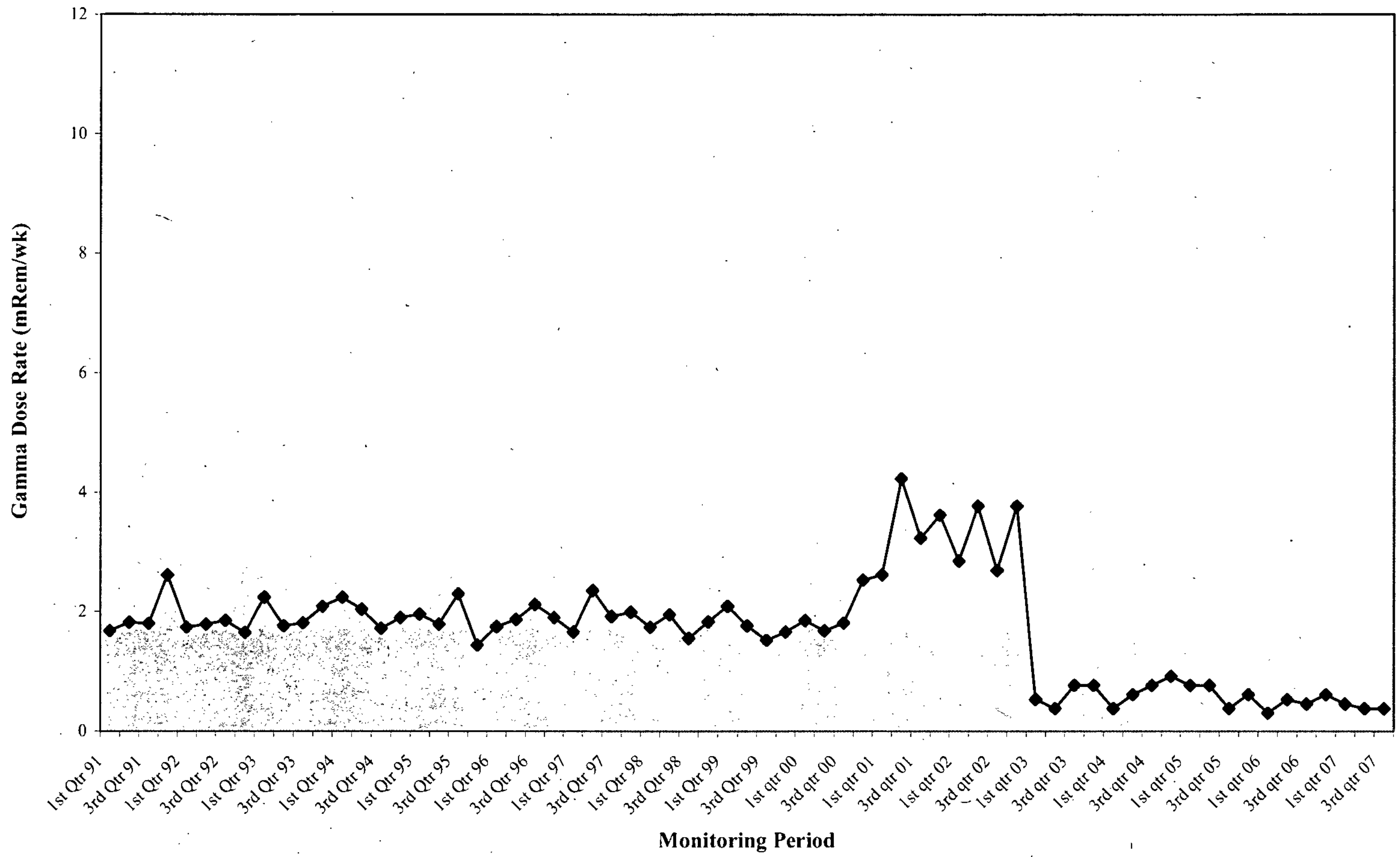

Figure 5.8-26: Environmental Gamma Monitoring AM-2 (1991 – 2007)

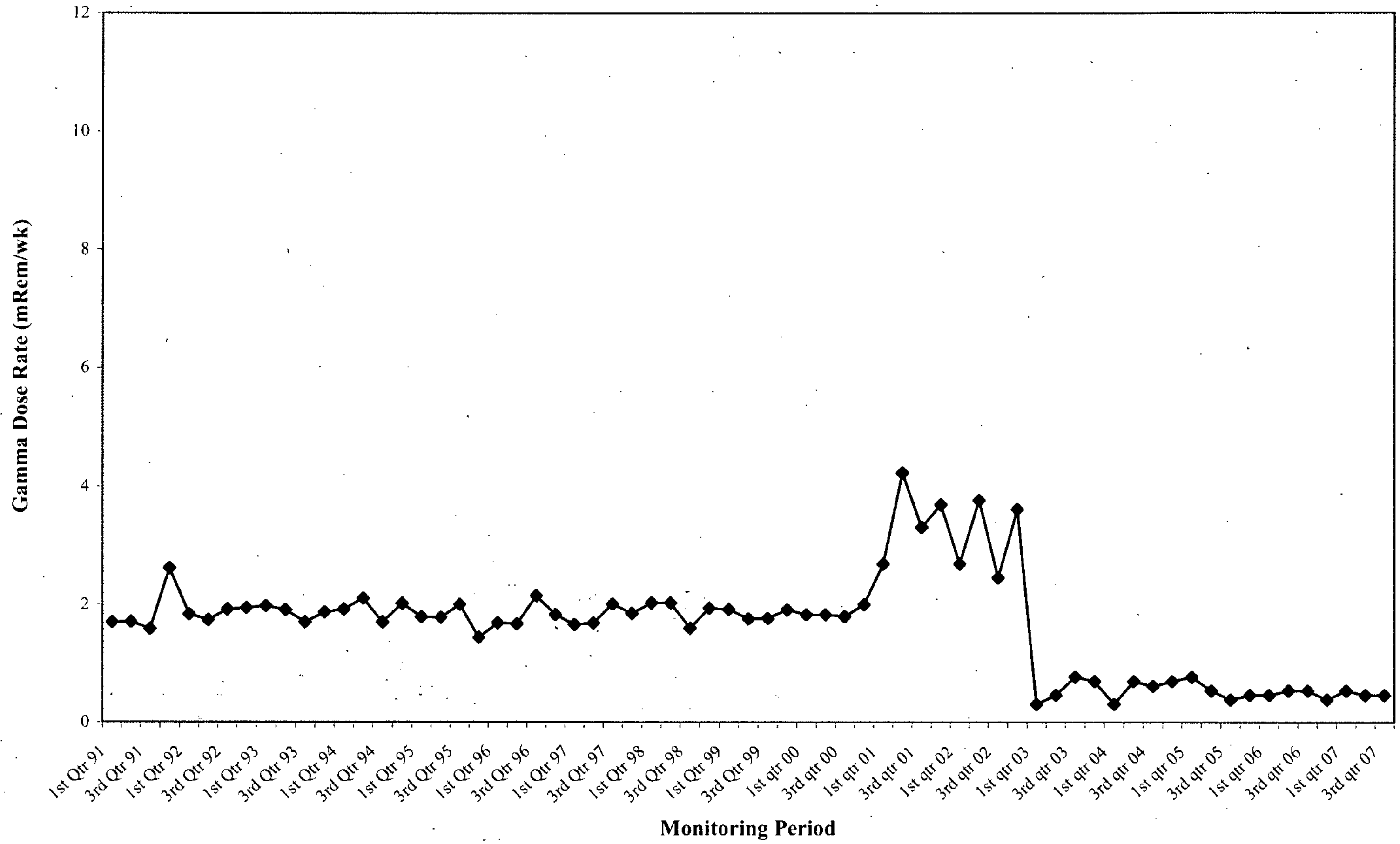

Figure 5.8-27: Environmental Gamma Monitoring AM-3 (1991 – 2007)

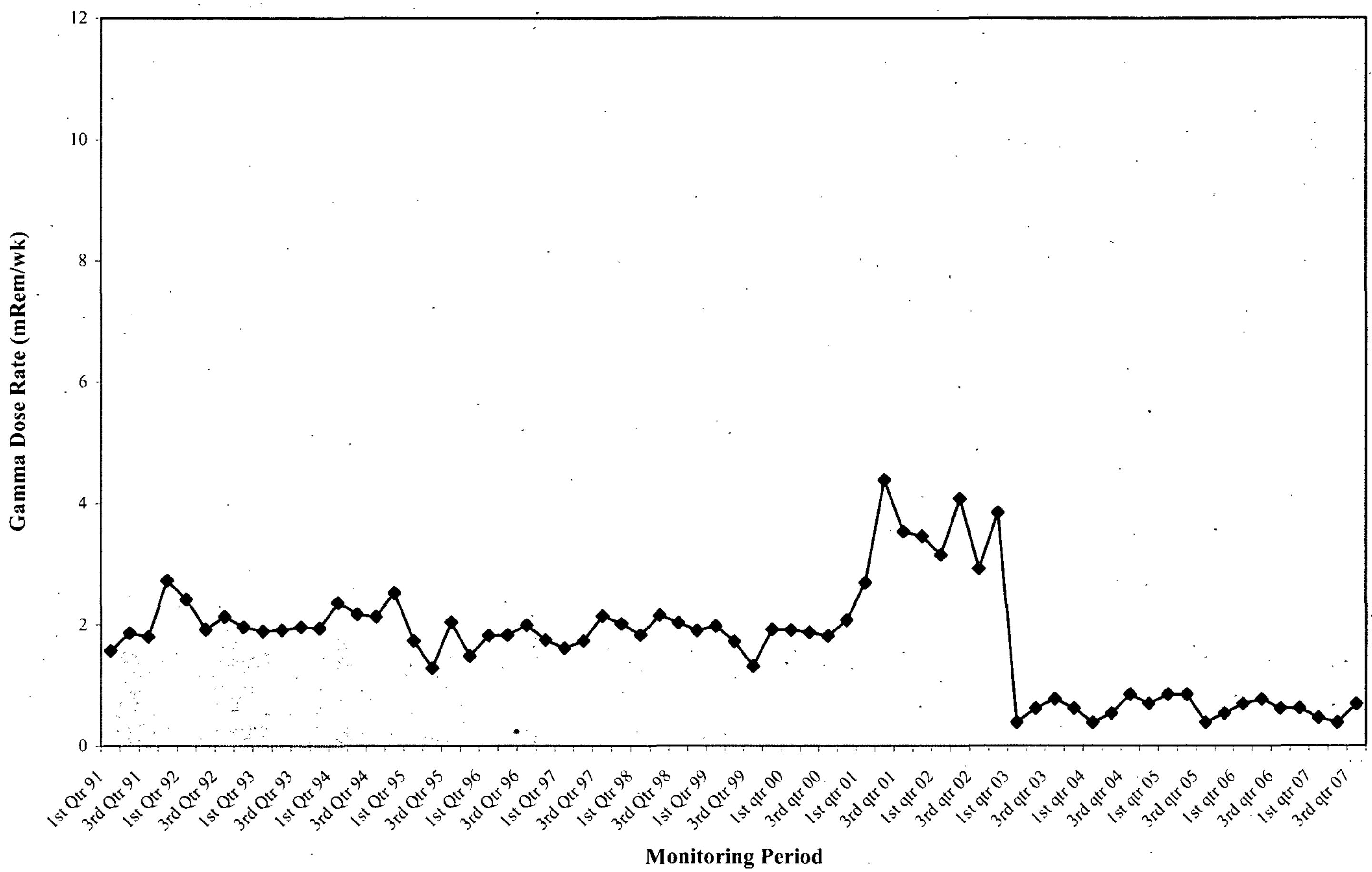

Figure 5.8-28: Environmental Gamma Monitoring AM-4 (1991 – 2007)

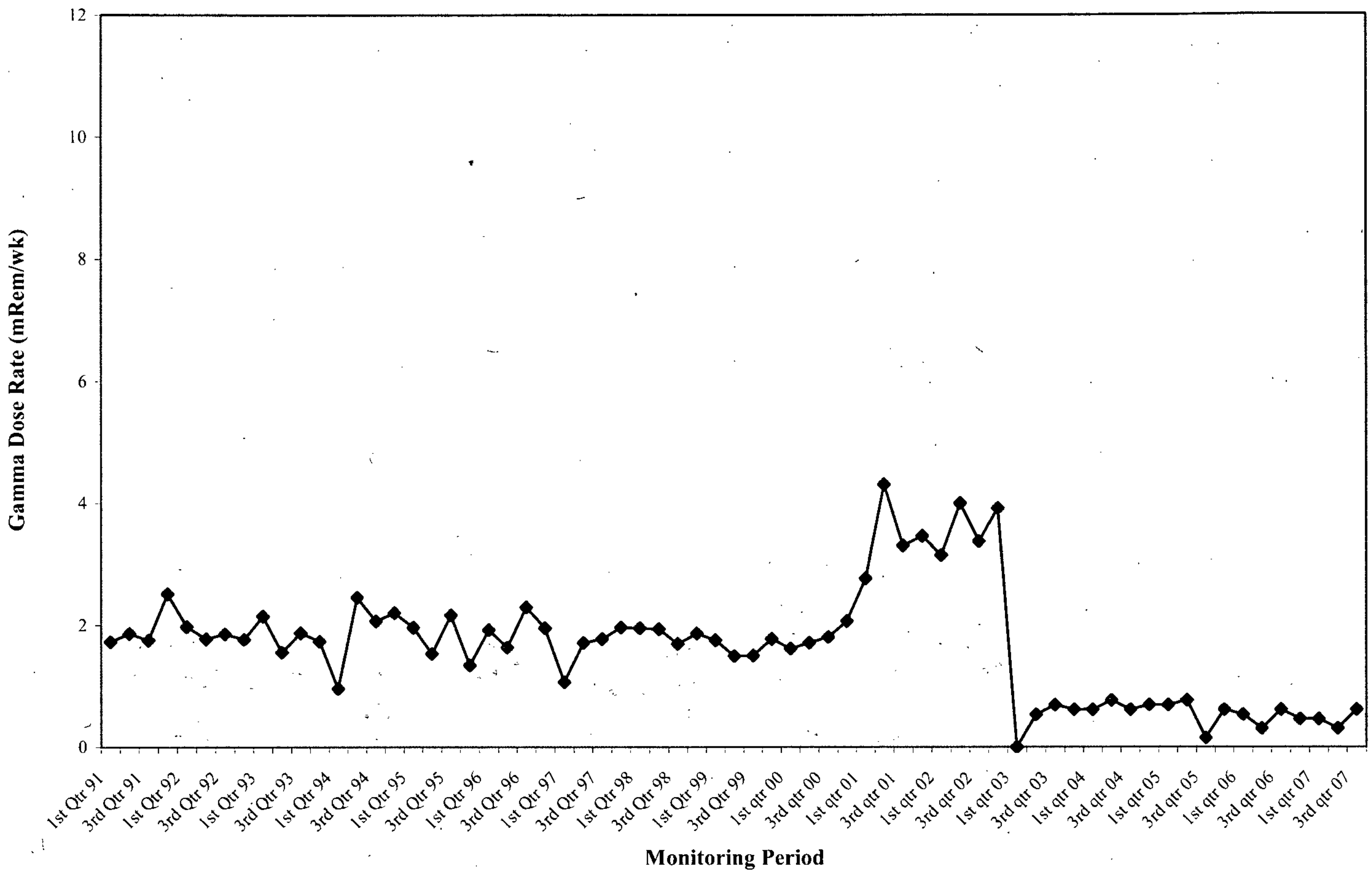

Figure 5.8-29: Environmental Gamma Monitoring AM-5 (1991 – 2007)

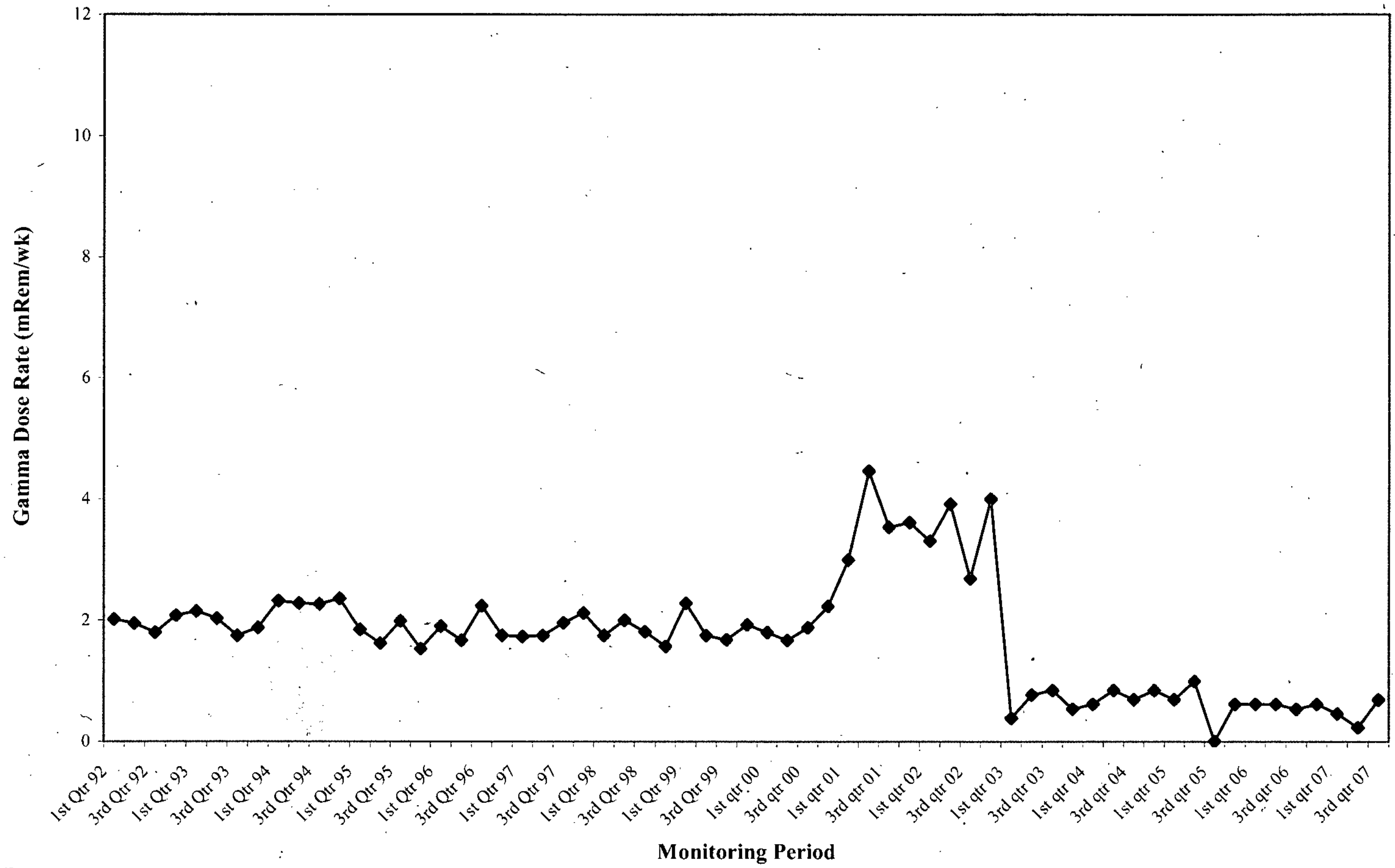

Figure 5.8-30: Environmental Gamma Monitoring AM-6 (1991 – 2007)

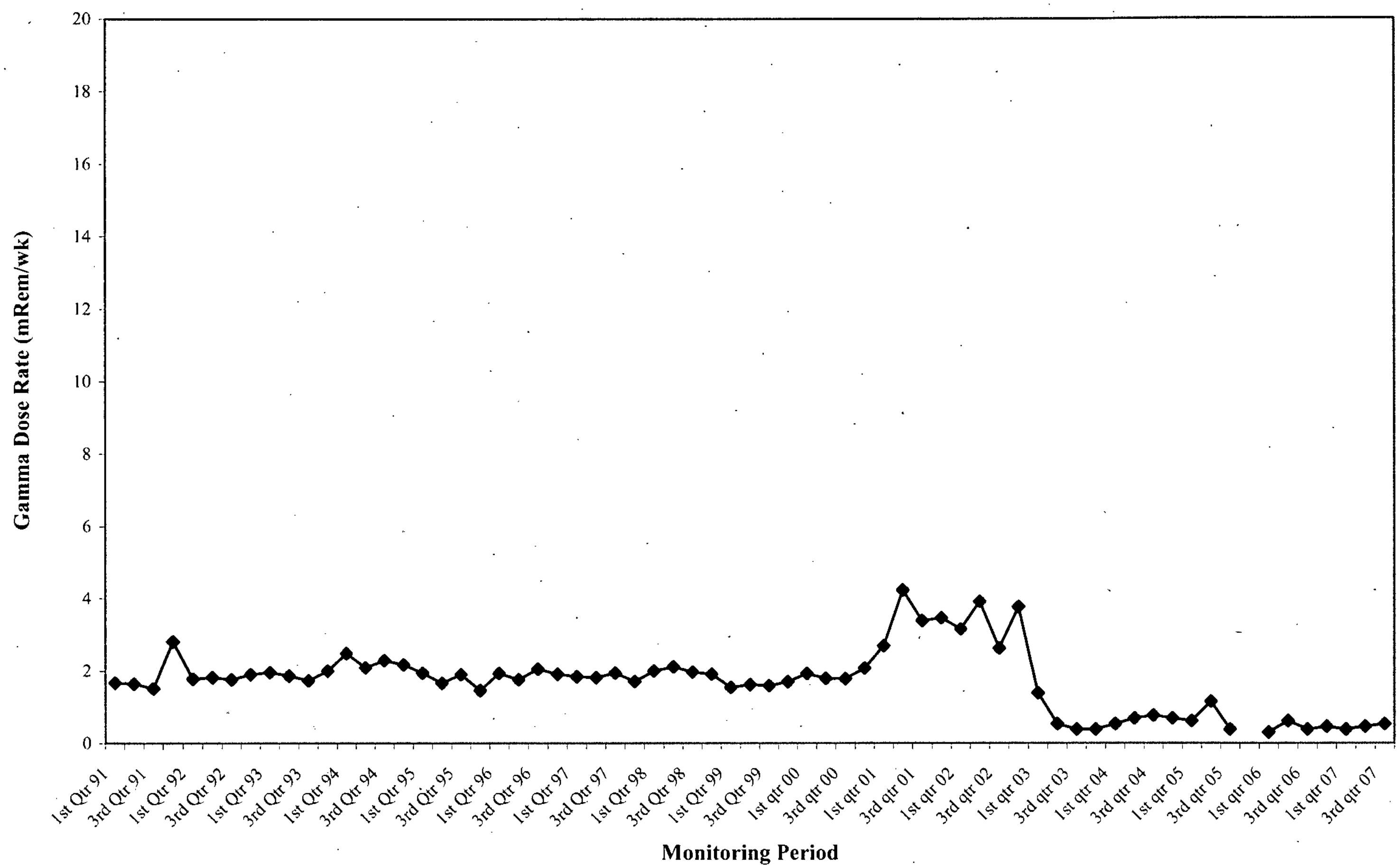

Figure 5.8-31: Environmental Gamma Monitoring AM-8 (1991 – 2007)

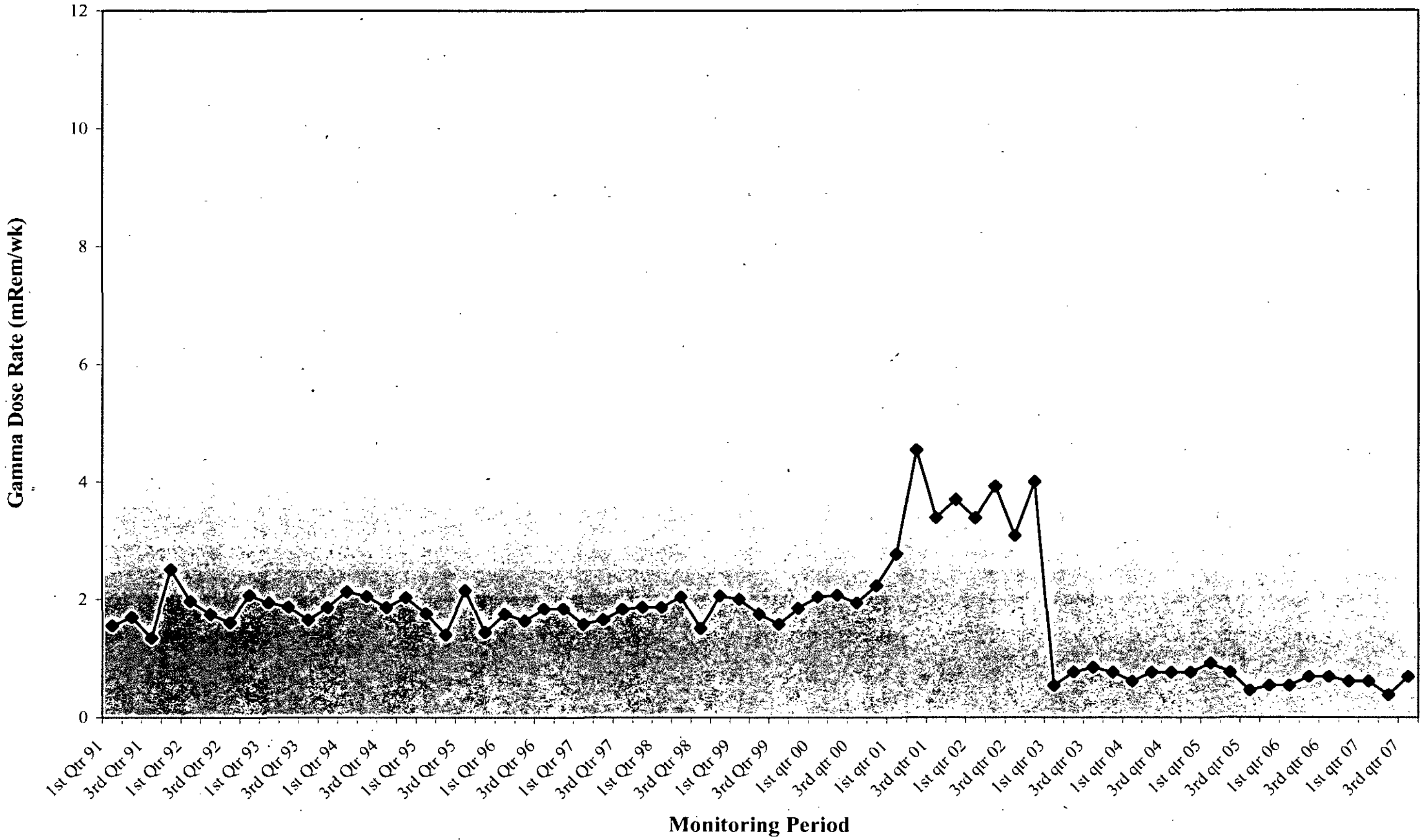

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Table 5.8-11: Annual Sediment Sampling Results

Station	Date	U-Natural pCi/g	Radium-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g
S-1	10/20/99	0.48	0.37	-	<0.05
	10/30/00	0.38	0.31	-	<0.05
	10/17/01	0.44	0.61	-	0.87
	11/08/02	0.43	0.4	-	ND
	11/14/03	0.9	0.4	-	ND
	11/08/04	0.05	0.40	-	ND
	11/07/05	0.66	0.3	-	ND
	10/20/06	1.04	0.6	-	1.3
S-2	11/5/92	0.5	0.1		
	11/5/93	< 0.2	0.7	< 0.2	0.3
	10/13/94	0.5	0.4	0.4	1.9
	10/05/95	0.7	0.4	0.3	0.1
	10/10/96	0.4	0.4	0.2	<0.1
	10/16/97	0.48	0.4	0.22	0.7
	10/20/99	0.71	0.43	-	<0.05
	10/30/00	0.33	0.35	-	<0.05
	10/17/01	0.49	0.44	-	ND
	11/08/02	0.39	0.4	-	ND
	11/14/03	1.1	0.4	-	0.5
	11/08/04	0.03	0.40	-	ND
	11/07/05	0.49	0.6	-	ND
	10/20/06	0.57	0.5	-	0.3
S-3	11/5/92	0.3	0.1		
	11/5/93	0.1	0.4	< 0.2	0.3
	10/13/94	0.3	0.4	< 0.2	1.4
	10/05/95	0.5	0.8	0.2	<0.1
	10/10/96	1.1	0.6	0.3	0.7
	10/16/97	0.56	0.6	0.32	0.8
	10/30/00	0.31	0.37	-	<0/05
S-5	10/20/99	0.55	0.39	-	<0.05
	10/17/01	0.45	0.51	-	0.48
	11/08/02	0.39	0.2	-	ND
	11/14/03	0.5	0.4	-	0.5
	11/08/04	0.03	0.40	-	ND
	11/07/05	0.47	0.6	-	ND
	10/20/06	0.24	0.3	-	ND
E-1 & E-2 Composite	10/20/99	3.70	0.85	-	1.40
	10/30/00	1.66	0.63	-	<0.05

Table 5.8-11: Annual Sediment Sampling Results

Station	Date	U-Natural pCi/g	Radium-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g
E-1	10/17/01	0.45	0.62	-	0.44
	11/08/02	2.11	0.70	-	ND
	11/14/03	5.5	0.60	-	ND
	11/08/04	0.13	0.09	-	ND
	11/07/05	2.94	0.80	-	ND
	10/23/06	1.81	0.90	-	0.40
E-4	10/20/99	6.30	0.64	-	1.32
	10/30/00	2.13	0.35	-	<0.05
	10/17 01	2.83	0.53	-	0.45
E-5	11/08/02	0.87	0.50	-	ND
	11/14/03	1.20	0.40	-	ND
	11/08/04	0.11	0.50	-	1.4
	11/07/05	1.64	0.7	-	1.4
	10/20/06	2.58	0.90	-	1.0
Impoundment I-3	11/08/02	1.09	0.70	-	ND
	11/14/03	1.70	0.60	-	ND
	11/08/04	0.13	0.50	-	ND
	11/07/05	6.25	0.1	-	ND
	10/20/06	5.85	1.0	-	1.6
Impoundment I-4	11/08/02	4.16	0.50	-	ND
	11/14/03	10.5	0.60	-	ND
	11/08/04	0.07	0.60	-	ND
	11/07/05	4.07	0.60	-	ND
	10/20/06	13.6	0.50	-	1.6

Notes:
- Denotes that no analysis was done for the listed parameter.
ND – Non-detect [0.2 pCi/g – dry]

Figure 5.8-32: Squaw Creek Sediment Uranium Concentration 1991 – 2006

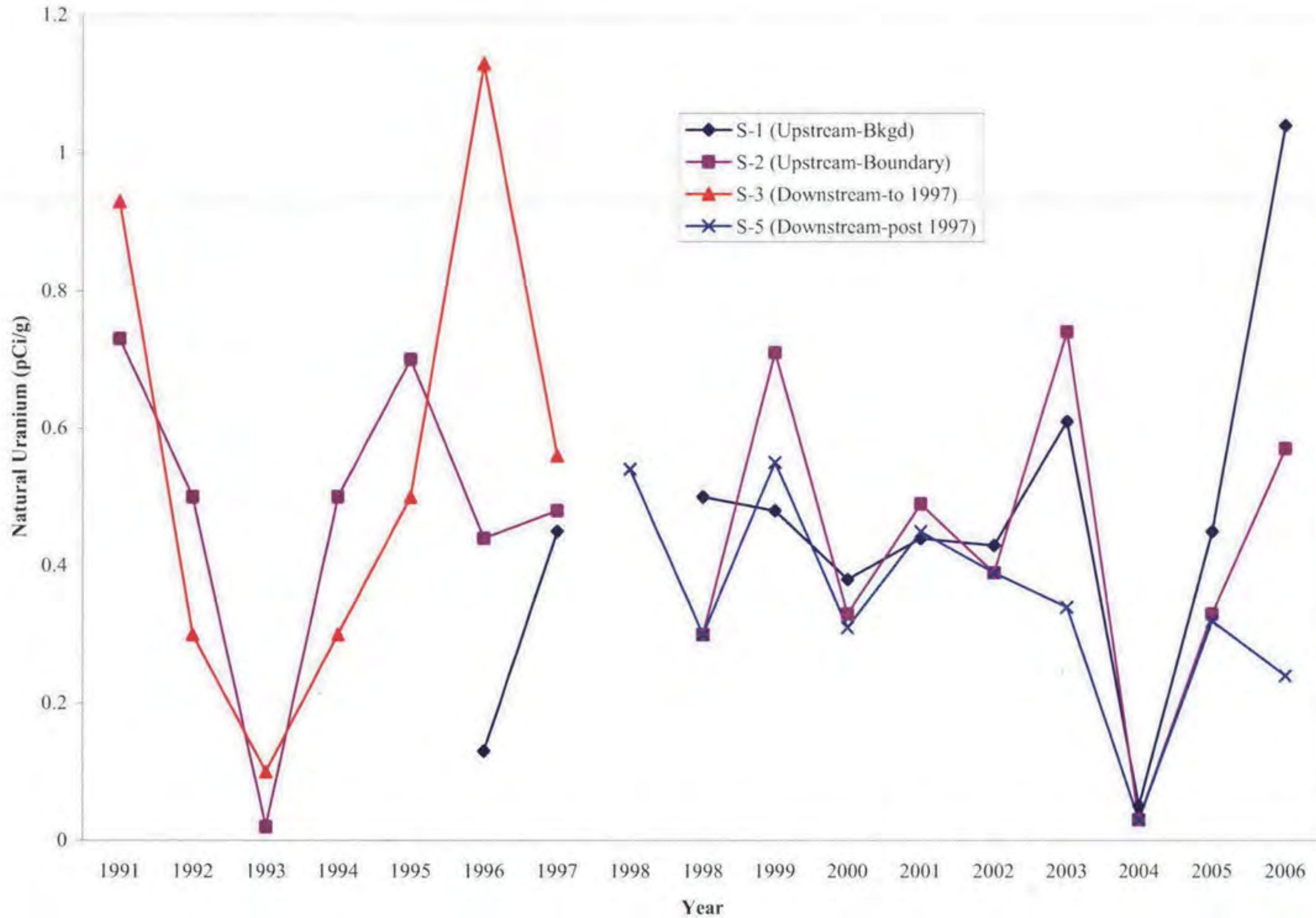


Figure 5.8-33: Squaw Creek Sediment Radium Concentration 1991 – 2006

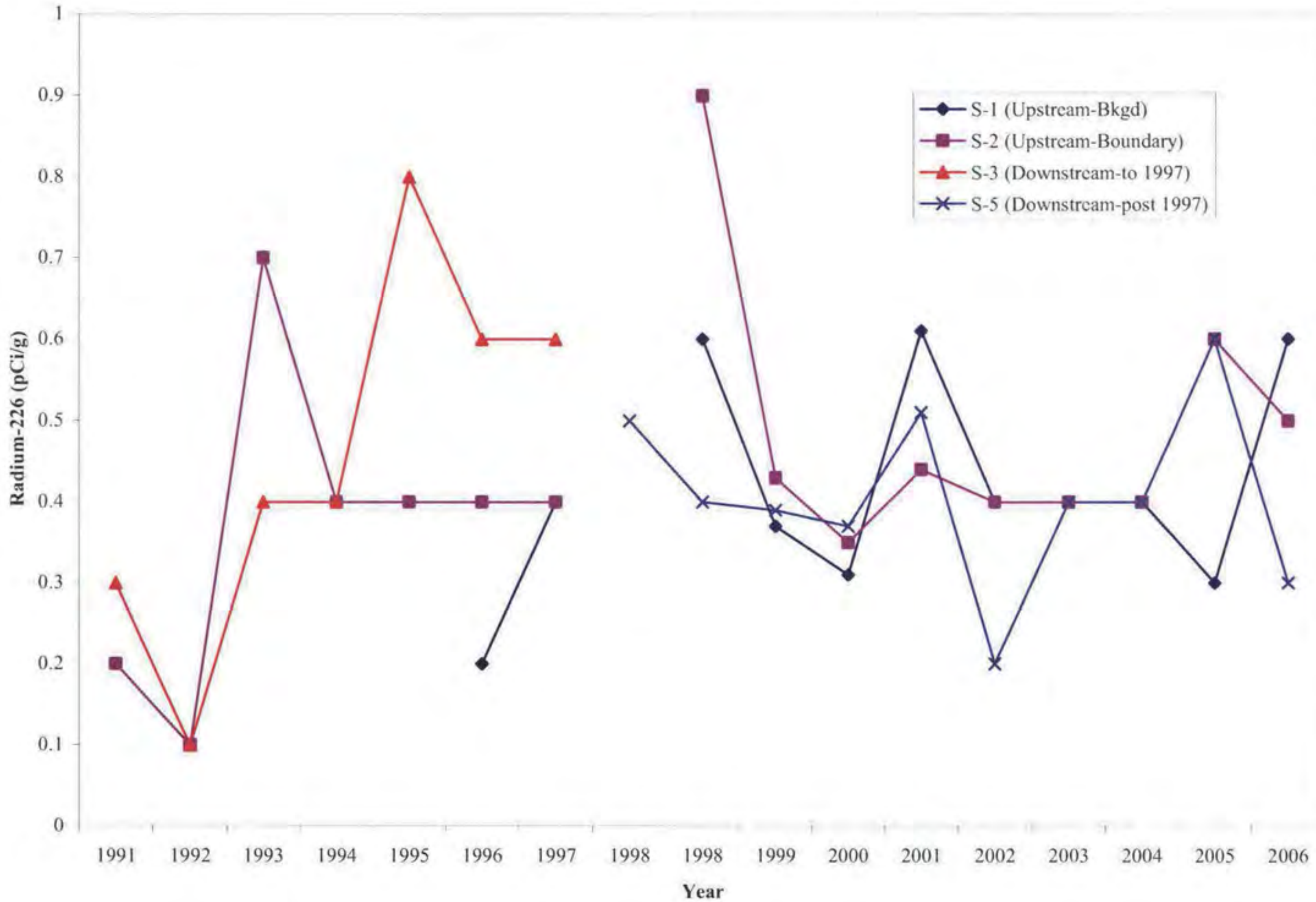


Figure 5.8-34: Squaw Creek Sediment Lead-210 Concentration 1991 – 2006

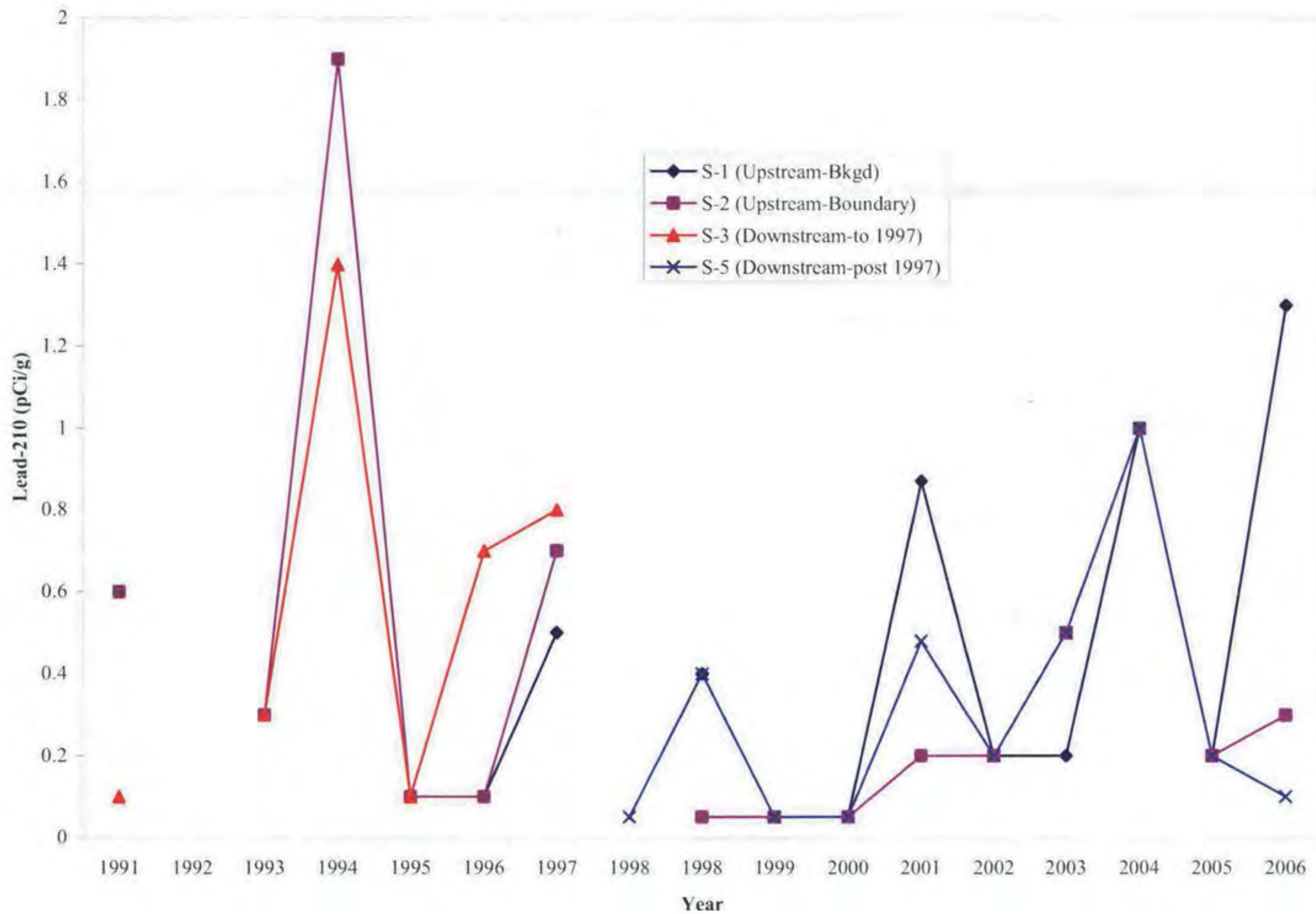


Figure 5.8-35: English Creek Sediment Uranium Concentration 1998 – 2006

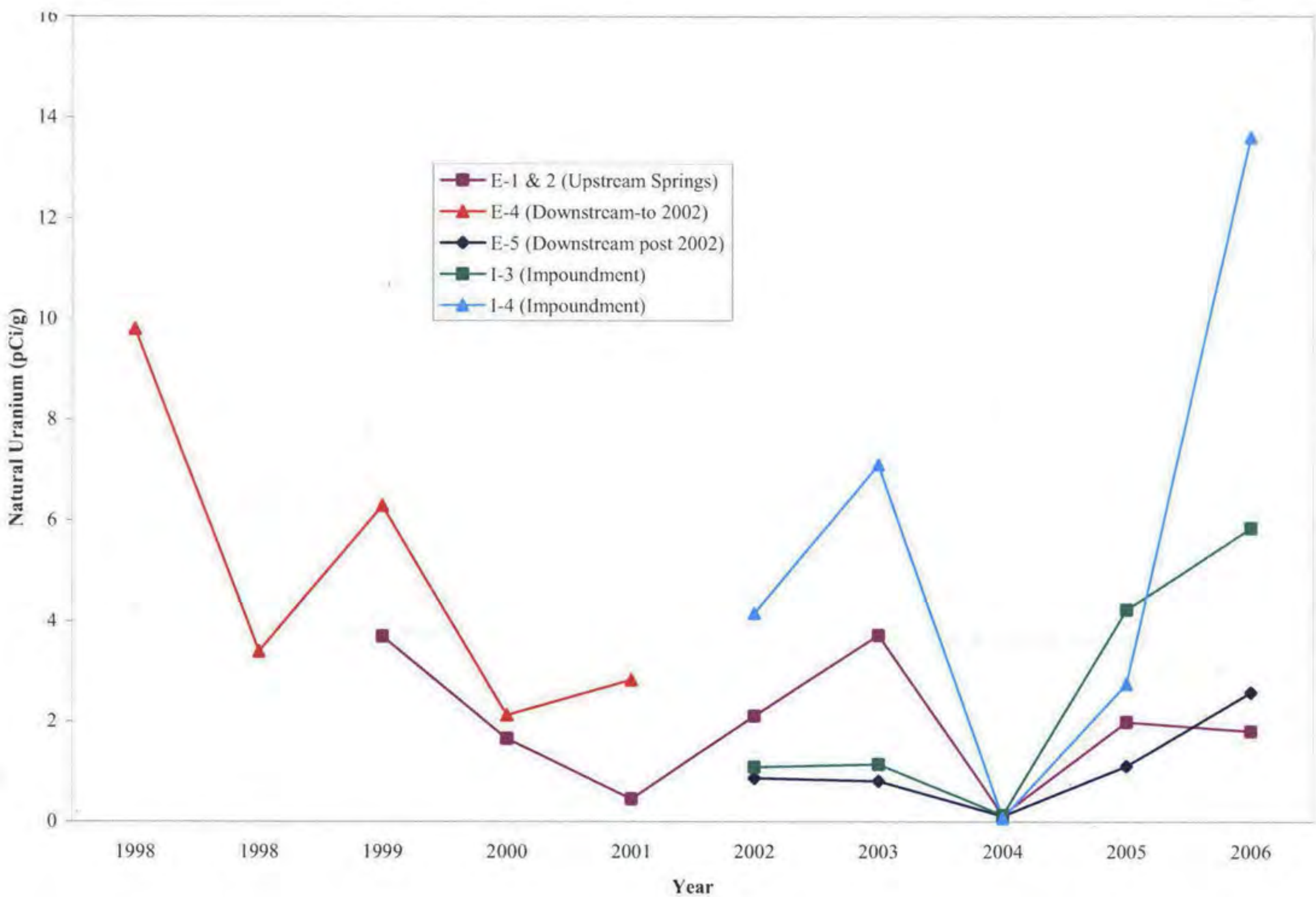


Figure 5.8-36: English Creek Sediment Radium Concentration 1998 – 2006

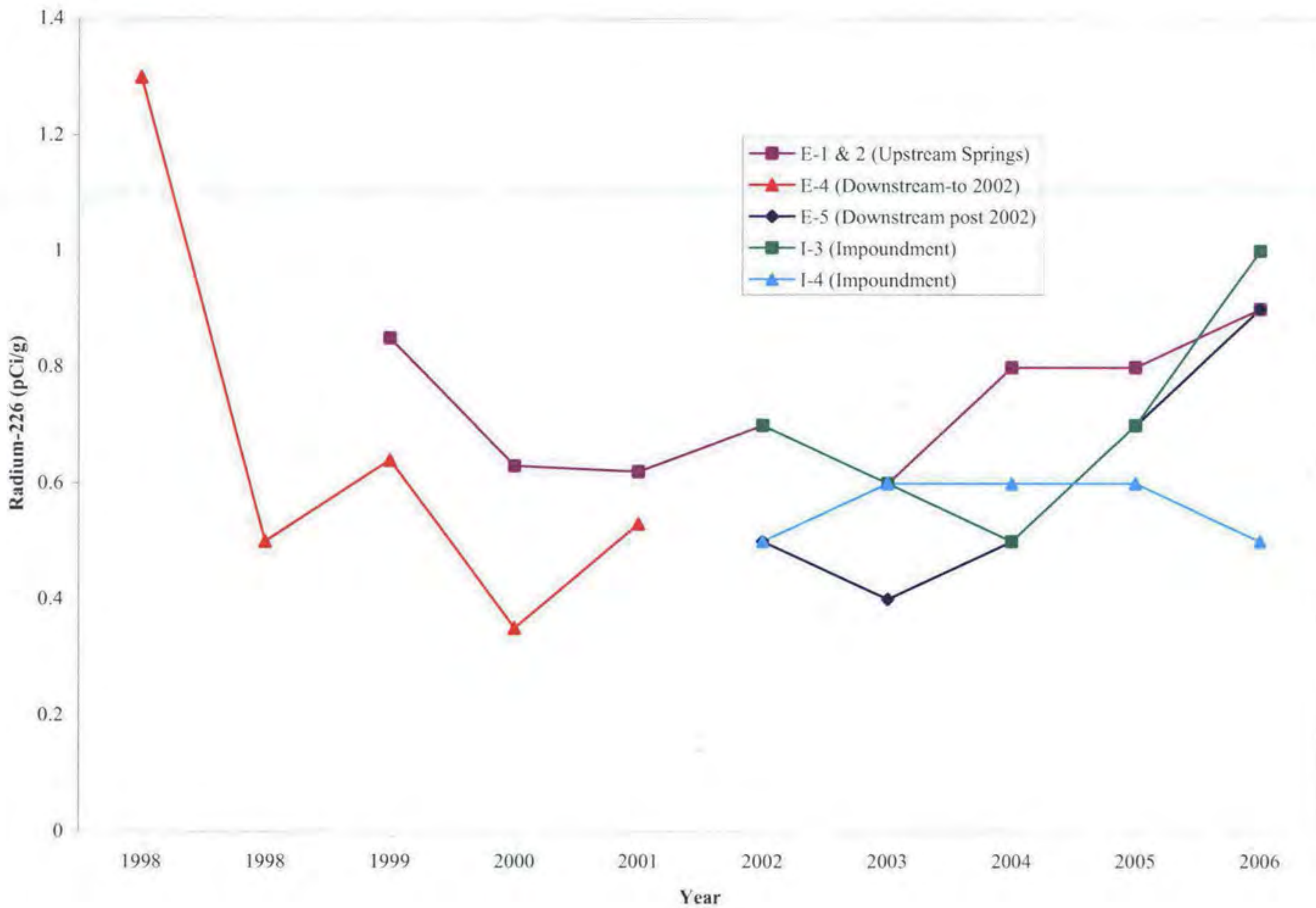
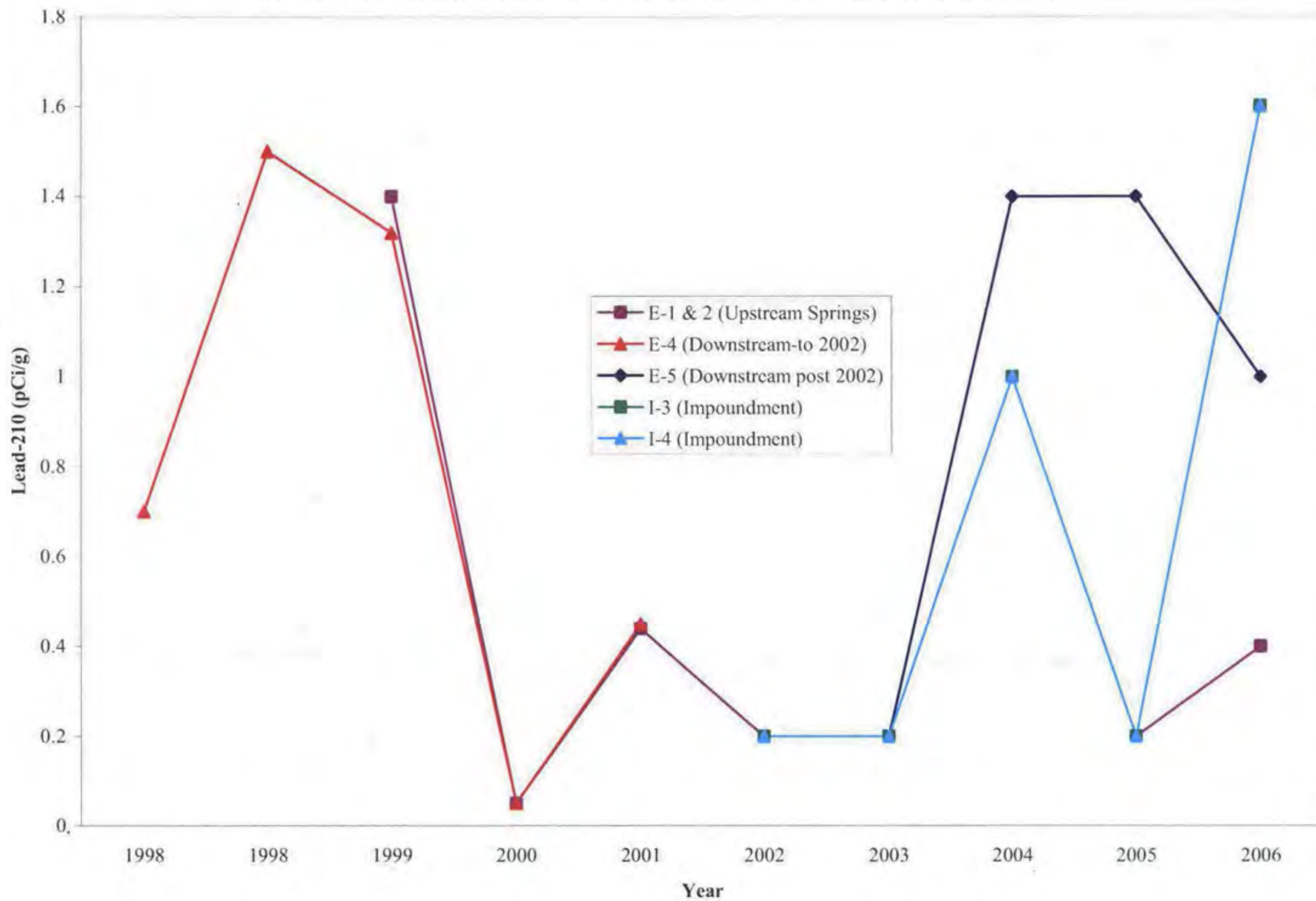


Figure 5.8-37: English Creek Sediment Lead-210 Concentration 1998 – 2006



Tables 5.8-12 through **5.8-15** summarizes all private wells and surface waters within 1 kilometer of the wellfield area boundary are sampled quarterly. Surface water samples are taken in accordance with the instructions contained in SHEQMS Program Volume VI, *Environmental Manual*. Samples are analyzed for natural uranium and radium-226. The most current results of this sampling for uranium are shown in **Table 5.8-12** for private wells and **Table 5.8-14** for surface waters. The results for radium are shown in **Tables 5.8-13** for private wells and **5.8-15** for surface waters. The maximum allowable uranium and radium concentration as specified by Nebraska Department of Environmental Quality (NDEQ) Title 118 – Ground Water Quality Standards and Use Classification, are 5 piC/L and 0.030 mg/L respectively. All sampling results reported have been well below the maximum allowable concentrations for uranium and radium.

Monitor Well Baseline Water Quality

After delineation of the production unit boundaries, monitor wells are installed approximately 300 feet from the wellfield boundary. After completion, wells are washed out and developed (by air flushing or pumping) until water quality in terms of pH and specific conductivity appears stable and consistent with the anticipated quality of the area. After development, wells are sampled to obtain baseline water quality. For baseline sampling, all wells are purged until field parameters are stable. Quarterly monitor well results for uranium are shown in **Table 5.8-14** and for radium in **Table 5.8-15**. All monitor wells including ore zone and overlying monitor wells are sampled three times at least 14 days apart. The first, second, and third samples are analyzed for the excursion indicator parameters (chloride, conductivity, and alkalinity). One sample for the baseline parameters shown in Table 2.9-2. Analytical results are presented in Section 6.1.3.

Results from the samples are averaged arithmetically to obtain a baseline value as well as an average value for determine upper control limits for excursion detection.

Upper Control Limits and Excursion Monitoring

After baseline water quality is established for the monitor wells for a particular production unit, upper control limits (UCLs) are set for certain chemical constituents that would indicate a migration of lixiviant from the wellfield. The parameters and constituents chosen for indicators of lixiviant migration and for which UCLs are set are chloride, conductivity, and total alkalinity. Chloride was chosen due to its low natural levels in the native groundwater and because chloride is introduced into the lixiviant from the ion exchange process (uranium is exchanged for chloride on the ion exchange resin). Chloride is also a highly mobile constituent in the groundwater and will show up very quickly in the case of a lixiviant migration to a monitor well. Conductivity was chosen because it is an excellent general indicator of overall groundwater quality. Total alkalinity concentrations should be affected during an excursion, as bicarbonate is the major constituent added to the lixiviant during mining. Water levels are obtained and recorded prior to each well sampling. However, levels were not used as an excursion indicator. All wells are purged until field parameters are stable prior to collection of the sample. Upper control limits are set at 20 percent above the maximum baseline

concentration for the excursion indicator. For excursion indicators with a baseline average below 50 mg/L, the UCL may be determined by adding 5 standard deviations or 15 mg/L to the baseline average for the indicator.

Operational monitoring consists of sampling the monitor wells no more than 14 days apart and analyzing the samples for the excursion indicators chloride, conductivity, and total alkalinity. In special circumstances, including inclement weather, wellhead mechanical failure, conditions which place an employee at risk while sampling, and conditions which could cause damage to the environment if sampling was performed, the sampling could be delayed by a period not to exceed 5 days. The circumstances requiring postponement of the sampling will be documented.

Excursion Verification and Corrective Action

During routine sampling, if two of the three UCL values are exceeded in a monitor well, or if one UCL value is exceeded by 20 percent, the well is resampled within 48 hours and analyzed for the excursion indicators. If the second sample does not exceed the UCLs, a third sample is taken within 48 hours. If neither the second nor third sample results exceeded the UCLs, the first sample is considered in error.

If the second or third sample verifies an exceedance, the well in question is placed on excursion status. Upon verification of the excursion, the USNRC Project Manager is notified by telephone within 48 hours and notified in writing within 30 days.

If an excursion is verified, the following methods of corrective action are instituted (not necessarily in the order given; depending on the circumstances):

- A preliminary investigation is completed to determine the probable cause.
- Production and/or injection rates in the vicinity of the monitor well are adjusted as necessary to increase the net over recovery, thus forming a hydraulic gradient toward the production zone.
- Individual wells are pumped to enhance recovery of mining solutions.

Injection into the wellfield area adjacent to the monitor well may be suspended. Recovery operations continue, thus increasing the overall bleed rate and the recovery of wellfield solutions.

In addition to the above corrective actions, sampling frequency of the monitor well on excursion status is increased to weekly. An excursion is considered concluded when the concentrations of excursion indicators do not exceed the criteria defining an excursion for three consecutive 1-week samples.

Table 5.8-12: Private Wells Water Monitoring Results Uranium Analysis (mg/L)

Date Sampled	Well #8	Well #11	Well #12	Well #24	Well #25	Well # 26	Well #28	Well #41	Well #63	Well #125	Well #129	Well #131	Well #133	Well #134	Well #135	Well #138	Well #140	Well #435	Drinking Water Well
Mar-91	-	-	-	-	0.0036	0.0045	-	-	-	-	-	-	-	-	-	-	-	-	-
Jun-91	-	-	-	-	0.0140	0.0030	-	-	-	0.0030	0.0030	-	-	-	-	-	-	-	-
Sep-91	-	-	-	-	0.0049	0.0059	-	-	-	0.0059	0.0069	-	-	-	-	-	-	-	-
Dec-91	-	-	-	-	0.0041	0.0062	-	-	-	0.0021	0.0052	-	-	-	-	-	-	-	-
Mar-92	-	-	-	-	0.0050	0.0070	-	-	-	0.0050	0.0040	-	-	-	-	-	-	-	-
Jun-92	-	-	-	-	0.0040	0.0040	-	-	-	0.0040	0.0040	-	-	-	-	-	-	-	-
Sep-92	-	-	-	-	0.0080	0.0100	-	-	-	0.0100	0.0100	-	-	-	-	-	-	-	-
Dec-92	-	-	-	-	0.0200	0.0080	-	-	-	<0.0003	<0.0003	-	-	-	-	-	-	-	-
Mar-93	-	-	-	-	0.0100	<0.0003	-	-	-	<0.0003	0.0070	-	-	-	-	-	-	-	-
Jun-93	-	-	-	-	<0.0003	< 0.0003	-	-	-	<0.0003	<0.0003	-	-	-	-	-	-	-	-
Sep-93	-	-	-	-	0.0130	0.0020	-	-	-	0.0030	0.0020	-	-	-	-	-	-	-	-
Dec-93	-	-	-	-	0.0080	0.0120	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	-
Mar-94	-	-	-	-	0.0250	0.0070	-	-	-	0.0070	0.0050	-	-	-	-	-	-	-	-
Jun-94	-	-	-	-	0.0050	0.0070	-	-	-	0.0050	0.0140	-	-	-	-	-	-	-	-
Sep-94	-	-	-	-	0.0030	0.0080	-	-	-	0.0050	0.0040	-	-	-	-	-	-	-	-
Dec-94	-	-	-	-	0.0050	0.0070	-	-	-	0.0060	0.0060	-	-	-	-	-	-	-	-
Mar-95	-	-	-	-	0.0100	0.0100	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	-
Jun-95	-	0.0080	-	0.0050	0.0060	0.0090	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	-
Sep-95	-	0.0088	-	0.0060	0.0058	0.0076	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	-
Dec-95	-	0.0070	-	0.0050	0.0050	0.0090	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	-
Mar-96	-	0.0091	-	0.0058	0.0058	0.0095	-	-	-	0.0067	0.0093	-	-	-	-	-	-	-	-
Jun-96	-	0.0074	-	0.0370	0.0037	0.0080	-	-	-	0.0064	0.0100	-	-	-	-	-	-	-	-
Sep-96	0.0200	0.0090	-	0.0060	0.0070	0.0100	-	-	-	0.0080	0.0100	-	-	-	-	-	-	-	-
Dec-96	0.0140	0.0040	-	0.0047	0.0052	0.0027	-	-	-	0.0063	0.0024	-	-	-	-	-	-	-	-
Mar-97	0.0100	0.0065	-	0.0016	0.0036	0.0073	-	-	-	0.0062	0.0018	-	-	-	-	-	-	-	-
Jun-97	0.0110	0.0071	-	0.0012	0.0031	0.0054	-	-	-	0.0030	0.0048	-	-	-	-	-	-	-	-
Sep-97	0.0190	0.0067	-	0.0052	0.0059	0.0078	-	-	-	0.0044	0.0067	-	-	-	-	-	-	-	-
Dec-97	0.0140	0.0078	-	0.0037	0.0040	0.0084	-	-	-	0.0058	0.0082	-	-	-	-	-	-	-	-
Mar-98	0.0139	0.0078	-	0.0041	0.5100	0.0076	-	-	-	0.0057	0.0076	-	-	-	-	-	-	-	-
Jun-98	0.0160	0.0086	-	0.0047	0.0057	0.0078	0.0068	0.0086	0.0127	0.0063	0.0081	-	-	-	-	-	-	-	-
Sep-98	0.0230	0.0100	-	0.0057	0.0062	0.0081	0.0073	0.0075	0.0140	0.0067	0.0100	-	-	-	-	-	-	-	-
Dec-98	0.0140	0.0085	-	0.0047	0.0057	0.0081	0.0064	0.0069	0.0133	0.0096	0.0067	-	-	-	-	-	-	-	-
Mar-99	0.0150	0.0085	-	0.0047	0.0054	0.0072	0.0063	0.0079	0.0130	0.0062	0.0099	-	-	-	-	-	-	-	-
Jun-99	0.0140	0.0086	-	0.0046	0.0061	0.0076	0.0067	0.0062	0.0120	0.0057	0.0085	-	-	-	-	-	-	-	-
Sep-99	0.0160	0.0087	-	0.0049	0.0057	0.0087	0.0075	0.0075	0.0110	0.0061	0.0086	-	-	-	-	-	-	-	0.0076
Dec-99	0.0043	0.0086	0.0042	0.0048	0.0057	0.0000	0.0071	0.0069	0.0130	0.0069	0.0089	-	-	-	-	-	-	-	0.0084
Mar-00	0.0200	0.0093	0.0039	0.0051	0.0062	0.0076	0.0000	0.0086	0.0150	0.0068	0.0094	-	-	-	-	-	-	-	0.0000
Jun-00	0.0160	0.0092	0.0037	0.0055	0.0068	0.0080	0.0000	0.0097	0.0160	0.0072	0.0093	-	-	-	-	-	-	-	0.0079
Sep-00	0.0170	0.0097	0.0047	0.0054	0.0057	0.0079	0.0066	0.0079	0.0140	0.0067	0.0100	-	-	-	-	-	-	-	0.0078
Dec-00	0.0200	0.0096	0.0044	0.0053	0.0061	0.0081	0.0000	0.0075	0.0130	0.0066	0.0090	-	-	-	-	-	-	-	0.0082

Table 5.8-12: Private Wells Water Monitoring Results Uranium Analysis (mg/L)

Date Sampled	Well #8	Well #11	Well #12	Well #24	Well #25	Well # 26	Well #28	Well #41	Well #63	Well #125	Well #129	Well #131	Well #133	Well #134	Well #135	Well #138	Well #140	Well #435	Drinking Water Well
Mar-01	0.0162	0.0100	0.0042	0.0000	0.0067	0.0084	0.0082	0.0100	0.0160	0.0074	0.0100	-	-	-	-	-	-	-	0.0110
Jun-01	0.0190	0.0087	0.0033	0.0000	0.0056	0.0071	0.0068	0.0097	0.0190	0.0065	0.0076	-	-	-	-	-	-	-	0.0076
Sep-01	0.0166	0.0099	0.0029	0.0049	0.0058	0.0075	0.0068	0.0080	0.0155	0.0061	0.0081	-	-	-	-	-	-	-	0.0073
Dec-01	0.0170	0.0095	0.0047	0.0053	0.0058	0.0092	0.0073	0.0081	0.0154	0.0070	0.0090	-	-	-	-	-	-	-	0.0079
Mar-02	0.0163	0.0085	0.0044	0.0046	0.0054	0.0076	WI	0.0116	0.0174	0.0079	0.0086	0.0046	-	-	-	-	-	-	0.0079
Jun-02	0.0177	0.0098	WI	0.0051	0.0063	0.0078	WI	WI	0.0173	0.0078	0.0087	0.0053	-	-	-	-	-	-	0.0085
Sep-02	0.0159	0.0159	0.0024	0.0041	0.0045	0.0057	0.0052	0.0061	0.0120	0.0060	0.0065	0.0038	-	0.0125	-	-	-	-	0.0060
Dec-02	0.0155	0.0091	0.0045	0.0046	0.0053	0.0082	0.0066	0.0073	0.0142	0.0063	0.0078	0.0046	0.0087	0.0114	-	-	-	-	0.0074
Mar-03	0.0135	0.0092	0.0033	0.0045	0.0054	0.0066	0.0064	0.0072	0.0132	0.0073	0.0074	0.0045	0.0090	0.0103	0.0211	-	-	-	0.0071
Jun-03	0.0140	0.0091	0.0035	0.0048	0.0057	0.0068	0.0067	0.0088	0.0150	0.0072	0.0079	0.0049	0.0093	0.0100	0.0220	-	-	-	0.0077
Sep-03	0.0177	WI	0.0042	0.0053	0.0056	0.0076	0.0065	0.0078	0.0155	0.0061	0.0080	0.0050	0.0092	0.0100	0.0216	-	-	-	0.0071
Dec-03	0.0150	0.0090	0.0040	0.0050	0.0060	0.0090	0.0070	0.0070	0.0170	0.0060	0.0080	0.0050	0.0110	0.0120	0.0230	-	-	-	0.0070
Mar-04	0.0156	0.0089	0.0043	0.0046	0.0056	0.0077	WI	0.0072	0.0178	0.0072	0.0076	0.0046	0.0117	0.0107	0.0212	-	-	-	0.0078
Jun-04	0.0160	0.0086	0.0034	0.0047	0.0055	0.0069	WI	0.0081	0.0170	0.0073	0.0071	0.0047	0.0091	0.0099	0.0190	-	0.0190	-	0.0061
Sep-04	0.0132	0.0085	0.0036	0.0047	0.0053	0.0071	0.0057	WI	0.0164	0.0069	0.0073	0.0047	0.0085	0.0097	0.0174	0.0178	0.0096	-	0.0074
Dec-04	0.0120	0.0069	0.0035	0.0038	0.0045	0.0062	0.0054	WI	0.0150	0.0060	0.0071	0.0039	0.0076	0.0087	0.0170	0.0150	0.0091	-	0.0060
Mar-05	0.0100	0.0080	0.0030	0.0050	0.0050	0.0070	WI	WI	0.0200	0.0070	0.0080	0.0040	0.0080	0.0100	0.0200	0.0100	0.0100	-	0.0070
Jun-05	0.0100	WI	0.0040	0.0050	0.0060	0.0070	WI	WI	0.0200	0.0070	0.0070	0.0060	0.0090	0.0100	0.0200	0.0100	0.0100	-	0.0070
Sep-05	0.0160	WI	0.0043	0.0052	0.0056	0.0092	0.0067	0.0071	0.0189	0.0077	0.0075	0.0048	0.0093	0.0103	0.0183	0.0221	0.0111	-	0.0074
Dec-05	0.0150	0.0085	0.0043	0.0047	0.0054	0.0088	0.0050	WI	0.0170	0.0058	0.0065	0.0047	0.0091	0.0089	WI	0.0140	0.0111	-	0.0066
Mar-06	0.0140	0.0087	0.0032	0.0048	0.0055	0.0077	WI	WI	0.0170	0.0050	0.0063	0.0052	0.0084	0.0093	0.0180	0.0140	0.0096	-	0.0067
Jun-06	0.0150	0.0092	0.0042	0.0047	0.0055	0.0077	0.0063	WI	0.0180	0.0062	0.0071	0.0049	0.0090	0.0090	0.0170	0.0200	0.0110	-	0.0078
Sep-06	0.0150	WI	0.0044	0.0051	0.0057	0.0080	0.0067	0.0071	0.0180	0.0073	0.0075	0.0050	0.0093	0.0110	0.0190	0.0260	0.0111	-	0.0086
Dec-06	0.0170	WI	0.0049	0.0050	0.0056	0.0081	0.0066	0.0070	0.0180	0.0072	0.0077	0.0050	0.0094	0.0110	0.0180	0.0180	0.0111	-	0.0081
Mar-07	0.0160	0.0088	0.0035	WI	WI	0.0067	WI	0.0068	0.0170	0.0063	0.0075	0.0050	0.0092	0.0096	0.0180	0.0210	0.0000	0.0075	0.0078
Jun-07	0.0160	0.0091	0.0043	WI	WI	0.0065	0.0064	0.0075	0.0170	0.0069	0.0073	0.0061	0.0094	0.0090	0.0180	0.0210	0.0120	0.0083	0.0078

Notes:

WI = Well Inoperable

- = Sample not taken

Table 5.8-13: Private Wells Water Monitoring Results Radium Analysis (mg/L)

Date Sampled	Well #8	Well #11	Well #12	Well #24	Well #25	Well # 26	Well #28	Well #41	Well #63	Well #125	Well #129	Well #131	Well #133	Well #134	Well #135	Well #138	Well #140	Well #435	Drinking Water Well
Mar-91	-	-	-	-	2.0000	3.2000	-	-	-	-	-	-	-	-	-	-	-	-	-
Jun-91	-	-	-	-	2.3000	0.5000	-	-	-	3.2000	1.8000	-	-	-	-	-	-	-	-
Sep-91	-	-	-	-	1.3000	0.9000	-	-	-	1.7000	0.9000	-	-	-	-	-	-	-	-
Dec-91	-	-	-	-	1.7000	0.5000	-	-	-	0.2000	0.7000	-	-	-	-	-	-	-	-
Mar-92	-	-	-	-	0.7000	0.5000	-	-	-	<0.2	1.0000	-	-	-	-	-	-	-	-
Jun-92	-	-	-	-	<0.2	0.4000	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-	-
Sep-92	-	-	-	-	0.7000	1.6000	-	-	-	0.5000	0.9000	-	-	-	-	-	-	-	-
Dec-92	-	-	-	-	0.8000	0.6000	-	-	-	<0.2	0.4000	-	-	-	-	-	-	-	-
Mar-93	-	-	-	-	1.2000	0.8000	-	-	-	1.2000	0.9000	-	-	-	-	-	-	-	-
Jun-93	-	-	-	-	2.7000	0.6000	-	-	-	0.3000	<0.2	-	-	-	-	-	-	-	-
Sep-93	-	-	-	-	0.5000	0.4000	-	-	-	0.8000	0.8000	-	-	-	-	-	-	-	-
Dec-93	-	-	-	-	0.5000	1.9000	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	-
Mar-94	-	-	-	-	0.3000	0.9000	-	-	-	3.4000	0.4000	-	-	-	-	-	-	-	-
Jun-94	-	-	-	-	0.2000	0.3000	-	-	-	<0.2	0.7000	-	-	-	-	-	-	-	-
Sep-94	-	-	-	-	1.5000	0.4000	-	-	-	0.4000	0.9000	-	-	-	-	-	-	-	-
Dec-94	-	-	-	-	<0.2	1.4000	-	-	-	0.3000	<0.2	-	-	-	-	-	-	-	-
Mar-95	-	-	-	-	<0.2	0.4000	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	-
Jun-95	-	0.3000	-	0.9000	<0.2	1.2000	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	-
Sep-95	-	1.0000	-	1.2000	1.5000	0.9000	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	-
Dec-95	-	<0.2	-	<0.2	0.4000	0.2000	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	-
Mar-96	-	0.2000	-	0.2000	0.2000	0.3000	-	-	-	0.4000	0.4000	-	-	-	-	-	-	-	-
Jun-96	-	0.3000	-	0.2000	0.4000	0.9000	-	-	-	0.3000	4.3000	-	-	-	-	-	-	-	-
Sep-96	1.1000	<0.2	-	1.1000	0.9000	0.8000	-	-	-	<0.2	1.0000	-	-	-	-	-	-	-	-
Dec-96	0.4000	0.4000	-	1.9000	0.7000	0.7000	-	-	-	0.5000	<0.2	-	-	-	-	-	-	-	-
Mar-97	<0.2	<0.2	-	0.5000	<0.2	<0.2	-	-	-	<0.2	1.0000	-	-	-	-	-	-	-	-
Jun-97	<0.2	<0.2	-	<0.2	1.3000	<0.2	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-	-
Sep-97	<0.2	<0.2	-	<0.2	1.9000	0.5000	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-	-
Dec-97	<0.2	<0.2	-	<0.2	<0.2	<0.2	-	-	-	0.8000	<0.2	-	-	-	-	-	-	-	-
Mar-98	<0.2	<0.2	-	<0.2	<0.2	<0.2	-	-	-	<0.2	<0.2	-	-	-	-	-	-	-	-
Jun-98	1.0000	0.3000	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	-
Sep-98	<0.2	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	-
Dec-98	<0.2	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	-
Mar-99	<0.2	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	-
Jun-99	<0.2	0.7000	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	4.2000	<0.2	-	-	-	-	-	-	-	-
Sep-99	<0.2	<0.2	-	<0.2	<0.2	<0.2	0.9000	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	<0.2
Dec-99	<0.2	<0.2	0.5000	<0.2	<0.2	0.0000	0.4000	<0.2	<0.2	0.3000	<0.2	-	-	-	-	-	-	-	<0.2
Mar-00	<0.2	0.7000	<0.2	<0.2	<0.2	<0.2	0.0000	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	0.0000

Table 5.8-13: Private Wells Water Monitoring Results Radium Analysis (mg/L)

Date Sampled	Well #8	Well #11	Well #12	Well #24	Well #25	Well # 26	Well #28	Well #41	Well #63	Well #125	Well #129	Well #131	Well #133	Well #134	Well #135	Well #138	Well #140	Well #435	Drinking Water Well
Jun-00	0.4000	<0.2	<0.2	<0.2	<0.2	<0.2	0.0000	<0.2	0.5000	<0.2	<0.2	-	-	-	-	-	-	-	<0.2
Sep-00	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	<0.2
Dec-00	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.0000	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	<0.2
Mar-01	0.5000	<0.2	<0.2	0.0000	<0.2	<0.2	<0.2	<0.2	0.6000	<0.2	<0.2	-	-	-	-	-	-	-	<0.2
Jun-01	0.4000	<0.2	<0.2	0.0000	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	<0.2
Sep-01	0.5000	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-	-	-	-	-	<0.2
Dec-01	<0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-	-	-	-	-	-	ND
Mar-02	0.4000	ND	ND	ND	ND	ND	WI	ND	ND	ND	ND	ND	-	-	-	-	-	-	ND
Jun-02	ND	ND	0.0000	ND	ND	ND	WI	WI	ND	ND	ND	ND	-	-	-	-	-	-	ND
Sep-02	0.3000	0.3000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	0.5000	-	-	-	-	ND
Dec-02	0.7000	ND	0.3000	ND	ND	ND	0.3000	0.4000	ND	ND	ND	ND	ND	ND	-	-	-	-	ND
Mar-03	0.4000	ND	ND	ND	ND	ND	ND	ND	0.4000	ND	ND	ND	0.3000	ND	ND	-	-	-	ND
Jun-03	0.6000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4000	-	-	-	ND
Sep-03	ND	0.0000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3000	-	-	-	ND
Dec-03	ND	0.2000	ND	0.2000	0.3000	ND	ND	0.3000	0.6000	ND	ND	0.2000	0.6000	ND	0.3000	-	-	-	ND
Mar-04	ND	ND	ND	ND	ND	ND	WI	ND	ND	ND	ND	ND	ND	0.5000	ND	-	-	-	ND
Jun-04	0.4000	ND	ND	ND	ND	ND	WI	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	-	ND
Sep-04	ND	ND	ND	ND	ND	ND	ND	WI	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND
Dec-04	0.4000	0.3000	0.4000	ND	0.3000	0.3000	0.4000	WI	0.2000	ND	ND	0.4000	0.4000	0.3000	ND	0.4000	0.3000	-	ND
Mar-05	ND	0.3000	ND	ND	ND	ND	WI	WI	0.4000	ND	ND	ND	ND	0.4000	0.2000	ND	ND	-	ND
Jun-05	0.3000	0.0000	0.3000	0.2000	0.3000	ND	WI	WI	0.2000	ND	ND	ND	0.5000	0.4000	0.4000	0.6000	0.4000	-	ND
Sep-05	0.2000	0.0000	ND	0.2000	ND	0.4000	ND	0.4000	0.8000	0.4000	ND	0.3000	ND	0.3000	0.4000	0.8000	ND	-	ND
Dec-05	ND	ND	ND	ND	ND	ND	ND	WI	0.8000	ND	ND	ND	ND	0.9000	WI	1.3000	1.3000	-	ND
Mar-06	ND	ND	ND	ND	ND	ND	WI	WI	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND
Jun-06	ND	ND	ND	ND	ND	ND	ND	WI	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND
Sep-06	1.4000	0.0000	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.7000	0.6000	ND	ND	ND	0.5900	-	ND
Dec-06	ND	0.0000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND
Mar-07	0.6000	ND	ND	0.0000	WI	ND	WI	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0000	ND	ND
Jun-07	ND	ND	ND	0.0000	WI	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.8000	ND	ND	ND

Notes:

WI = Well Inoperable.

ND = Non Detect

- = Sample not taken

Table 5.8-14: Surface Water Monitoring Results Uranium Analysis (mg/L)

Date Sampled	Stream S-1	Stream S-2	Stream S-5	Stream E-1 & E-2	Stream E-5	Impoundment I-3	Impoundment I-4	Impoundment I-5
Mar-91	-	ND	-	-	-	-	-	-
Jun-91	-	0.002	-	-	-	-	-	-
Sep-91	-	0.002	-	-	-	-	-	-
Dec-91	-	0.0031	-	-	-	-	-	-
Mar-92	-	ND	-	-	-	-	-	-
Jun-92	-	0.001	-	-	-	-	-	-
Sep-92	-	0.005	-	-	-	-	-	-
Dec-92	-	<0.0003	-	-	-	-	-	-
Mar-93	-	ND	-	-	-	-	-	-
Jun-93	-	<0.0003	-	-	-	-	-	-
Sep-93	-	<0.0003	-	-	-	-	-	-
Dec-93	-	0.001	-	-	-	-	-	-
Mar-94	-	0.004	-	-	-	-	-	-
Jun-94	-	0.006	-	-	-	-	-	-
Sep-94	-	0.002	-	-	-	-	-	-
Dec-94	-	0.003	-	-	-	-	-	-
Mar-95	-	0.01	-	-	-	-	-	-
Jun-95	-	0.004	-	-	-	-	-	-
Sep-95	-	0.004	-	-	-	-	-	-
Dec-95	-	0.005	-	-	-	-	-	-
Mar-96	-	0.00525	-	-	-	-	-	-
Jun-96	-	0.0047	-	-	-	-	-	-
Sep-96	0.005	0.004	-	-	-	-	-	-
Dec-96	0.0018	0.0051	-	-	-	-	-	-
Mar-97	0.0012	0.0055	-	-	-	-	-	-
Jun-97	0.0024	0.0024	-	-	-	-	-	-
Sep-97	0.0047	0.0048	-	-	-	-	-	-
Dec-97	0.0026	0.0038	-	-	-	-	-	-
Mar-98	0.0047	0.0045	-	-	-	-	-	-
Jun-98	0.0052	0.005	0.0054	0.035	-	-	-	-
Sep-98	0.0043	0.004	0.0037	0.011	-	-	-	-

Table 5.8-14: Surface Water Monitoring Results Uranium Analysis (mg/L)

Date Sampled	Stream S-1	Stream S-2	Stream S-5	Stream E-1 & E-2	Stream E-5	Impoundment I-3	Impoundment I-4	Impoundment I-5
Dec-98	0.0043	0.0043	0.0061	ND	-	-	-	-
Mar-99	0.0048	0.0048	0.0042	0.02	-	-	-	-
Jun-99	0.0041	0.004	ND	0.0086	-	-	-	-
Sep-99	0.0036	ND	ND	ND	-	-	-	-
Dec-99	0.0043	0.0042	0.0047	0.018	-	-	-	-
Mar-00	0.0051	0.005	0.0055	0.015	-	-	-	-
Jun-00	0.0059	0.0056	0.0057	ND	-	-	-	-
Sep-00	0.0041	0.0041	ND	ND	-	-	-	-
Dec-00	0.0048	0.0046	0.0058	ND	-	-	-	-
Mar-01	0.0055	0.0054	0.0064	ND	-	-	-	-
Jun-01	0.0052	0.0049	0.0055	ND	-	-	-	-
Sep-01	0.0042	0.0044	0.0056	ND	-	-	-	-
Dec-01	0.0042	0.0044	0.0054	ND	-	-	-	-
Mar-02	0.0045	0.0052	0.008	ND	-	-	-	-
Jun-02	0.0052	0.0049	0.0061	ND	-	-	-	-
Sep-02	0.0032	Dry	Dry	ND	-	-	-	-
Dec-02	0.0043	0.0043	0.0064	ND	-	-	-	-
Mar-03	0.0047	Frozen	Frozen	ND	Frozen	Frozen	Frozen	-
Jun-03	0.0046	0.004	0.0045	ND	0.0077	0.0411	0.0334	-
Sep-03	0.004	Dry	Dry	ND	0.004	0.0009	0.0079	-
Dec-03	0.005	0.004	0.006	ND	0.01	0.116	0.024	-
Mar-04	0.00521	0.0051	0.00578	ND	0.0118	Frozen	Frozen	-
Jun-04	0.0044	0.0038	0.0049	ND	0.007	0.039	0.023	-
Sep-04	0.0034	0.0034	0.0044	ND	0.0024	0.0133	0.0091	-
Dec-04	0.0033	0.0033	0.0038	ND	0.0054	0.011	0.0097	-
Mar-05	0.004	0.005	0.005	v	0.009	0.03	0.03	-
Jun-05	0.004	0.0044	0.005	0.02	0.004	0.02	0.01	-
Sep-05	0.0041	0.0041	0.0051	0.0123	0.0039	0.0066	0.00914	-
Dec-05	0.0041	0.0042	0.0045	0.018	0.0066	0.074	0.015	-
Mar-06	0.0041	0.0041	0.0046	0.037	0.0082	0.0095	0.0083	-
Jun-06	0.014	0.0045	0.005	0.011	0.0017	0.004	0.015	-

Table 5.8-14: Surface Water Monitoring Results Uranium Analysis (mg/L)

Date Sampled	Stream S-1	Stream S-2	Stream S-5	Stream E-1 & E-2	Stream E-5	Impoundment I-3	Impoundment I-4	Impoundment I-5
Sep-06	0.0041	Dry	Dry	0.011	0.0072	Dry	0.027	-
Dec-06	0.0042	0.0044	Dry	0.055	0.0075	Dry	0.04	0.0095
Mar-07	0.0046	0.0046	0.0057	0.019	0.013	0.11	0.13	0.012
Jun-07	0.0043	0.0041	0.0045	0.011	0.0031	0.02	0.037	0.0048

Notes:

Dry = Surface water monitoring point was dry, no sample taken
Frozen = Surface water monitoring point was frozen, no sample taken
- = Sample not taken

Table 5.8-15: Surface Water Monitoring Results Radium Analysis (piC/L)

Date Sampled	Stream S-1	Stream S-2	Stream S-5	Stream E-1 & E-2	Stream E-5	Impoundment I-3	Impoundment I-4	Impoundment I-5
Mar-91	-	0.0000	-	-	-	-	-	-
Jun-91	-	<0.2	-	-	-	-	-	-
Sep-91	-	1.0000	-	-	-	-	-	-
Dec-91	-	0.2000	-	-	-	-	-	-
Mar-92	-	0.0000	-	-	-	-	-	-
Jun-92	-	<0.2	-	-	-	-	-	-
Sep-92	-	4.8000	-	-	-	-	-	-
Dec-92	-	0.8000	-	-	-	-	-	-
Mar-93	-	0.0000	-	-	-	-	-	-
Jun-93	-	<0.2	-	-	-	-	-	-
Sep-93	-	1.0000	-	-	-	-	-	-
Dec-93	-	0.5000	-	-	-	-	-	-
Mar-94	-	<0.2	-	-	-	-	-	-
Jun-94	-	0.5000	-	-	-	-	-	-
Sep-94	-	0.7000	-	-	-	-	-	-
Dec-94	-	<0.2	-	-	-	-	-	-
Mar-95	-	2.1000	-	-	-	-	-	-
Jun-95	-	0.3000	-	-	-	-	-	-
Sep-95	-	<0.2	-	-	-	-	-	-
Dec-95	-	0.3000	-	-	-	-	-	-
Mar-96	-	0.2000	-	-	-	-	-	-
Jun-96	-	5.6000	-	-	-	-	-	-
Sep-96	7.7000	3.3000	-	-	-	-	-	-
Dec-96	0.3000	<0.2	-	-	-	-	-	-
Mar-97	<0.2	<0.2	-	-	-	-	-	-
Jun-97	<0.2	<0.2	-	-	-	-	-	-
Sep-97	2.5000	1.4000	-	-	-	-	-	-
Dec-97	<0.2	<0.2	-	-	-	-	-	-
Mar-98	<0.2	<0.2	-	-	-	-	-	-
Jun-98	<0.2	<0.2	<0.2	<0.2	-	-	-	-
Sep-98	<0.2	<0.2	<0.2	<0.2	-	-	-	-
Dec-98	<0.2	<0.2	<0.2	0.0000	-	-	-	-
Mar-99	<0.2	<0.2	<0.2	<0.2	-	-	-	-
Jun-99	<0.2	<0.2	0.0000	<0.2	-	-	-	-
Sep-99	<0.2	0.0000	0.0000	0.0000	-	-	-	-
Dec-99	<0.2	<0.2	<0.2	<0.2	-	-	-	-

Table 5.8-15: Surface Water Monitoring Results Radium Analysis (piC/L)

Date Sampled	Stream S-1	Stream S-2	Stream S-5	Stream E-1 & E-2	Stream E-5	Impoundment I-3	Impoundment I-4	Impoundment I-5
Mar-00	<0.2	<0.2	<0.2	<0.2	-	-	-	-
Jun-00	<0.2	<0.2	2.6000	0.0000	-	-	-	-
Sep-00	<0.2	<0.2	0.0000	0.0000	-	-	-	-
Dec-00	<0.2	<0.2	<0.2	0.0000	-	-	-	-
Mar-01	<0.2	<0.2	<0.2	0.0000	-	-	-	-
Jun-01	<0.2	<0.2	<0.2	0.0000	-	-	-	-
Sep-01	<0.2	<0.2	<0.2	0.0000	-	-	-	-
Dec-01	ND	ND	ND	0.0000	-	-	-	-
Mar-02	ND	ND	ND	0.0000	-	-	-	-
Jun-02	ND	ND	ND	0.0000	-	-	-	-
Sep-02	ND	Dry	Dry	0.0000	-	-	-	-
Dec-02	ND	ND	ND	0.0000	-	-	-	-
Mar-03	ND	Frozen	Frozen	0.0000	Frozen	Frozen	Frozen	-
Jun-03	0.4000	ND	ND	0.0000	ND	ND	ND	-
Sep-03	ND	Dry	Dry	0.0000	ND	0.4000	0.5000	-
Dec-03	ND	ND	ND	0.0000	ND	0.2000	ND	-
Mar-04	ND	ND	ND	0.0000	ND	Frozen	Frozen	-
Jun-04	ND	ND	ND	0.0000	ND	ND	ND	-
Sep-04	ND	ND	ND	0.0000	ND	ND	ND	-
Dec-04	ND	ND	ND	0.0000	0.3000	ND	0.4000	-
Mar-05	ND	ND	ND	0.0000	ND	ND	ND	-
Jun-05	0.5000	0.5000	ND	0.3000	ND	ND	0.2000	-
Sep-05	ND	ND	ND	0.2000	ND	ND	ND	-
Dec-05	ND	ND	1.2000	ND	2.7000	1.0000	ND	-
Mar-06	ND	ND	ND	ND	ND	ND	ND	-
Jun-06	ND	ND	ND	ND	ND	ND	ND	-
Sep-06	ND	Dry	Dry	0.9800	0.6100	Dry	ND	-
Dec-06	ND	ND	Dry	ND	ND	Dry	ND	ND
Mar-07	ND	ND	ND	ND	ND	ND	ND	ND
Jun-07	ND	ND	ND	0.5000	ND	ND	ND	ND

Notes:

ND = Non Detect

Dry = Surface water monitoring point was dry, no sample taken

Frozen = Surface water monitoring point was frozen, no sample taken

- = Sample not taken

5.8.8.3 Surface Water Monitoring

Initial baseline water quality measurements were completed prior to construction and operations of the current CBR licensed facility. Preoperational baseline groundwater quality data [radiological and non-radiological] for the CBR site from 1982 to 1987 were initially reported in the 1987 *Application and Supporting Environmental Report for USNRC Commercial Source Material License submitted to the NRC by the previous owner and operator*, Ferret of Nebraska, Inc. (FEN 1987). CBR continued with the surface water quality monitoring program for radiological and nonradiological parameters starting in 1987 and ending in the third quarter 1994. Following the third quarter of 1994, CBR was only required to monitor for two radiological parameters natural uranium and radium-226. The preoperational surface water nonradiological monitoring program is discussed in Section 2.9.4. The baseline surface water quality nonradiologial parameters that were analyzed for are shown in Table 2.9-9.

Development of a wellfield requires additional preoperational monitoring of surface water located within the affected mine unit(s). Therefore, the pre-operational water quality monitoring program assessed water quality and quantity for Squaw Creek due to mine development. CBR samples two surface water locations for Squaw Creek. The CBR SERP approved Mine Unit 6 on March 6, 1998. This expansion required that the downstream Squaw Creek monitoring location be relocated. The new sample point was designated as S-5. Sampling at the previous downstream location, S-3 was discontinued.

With the approval of Mine Unit 6, operational surface water sampling was initiated at the English Creek upstream and downstream locations. The upstream sample is a composite of the springs that are the sources of English Creek and were identified as E-1 and E-2 during the preoperational monitoring program. Preoperational monitoring location E-3 was not used for downstream monitoring because its location is well beyond the Mine Unit 6 wellfield. Instead, a new downstream location designated E-4 was chosen immediately outside the Mine Unit boundary and sampling was begun.

With the addition of Mine Unit 8, downstream sampling on English Creek was moved to location E-5. Additionally, the expansion to Mine Unit 8 requires sampling of the impoundments identified as I-3 and I-4 in the preoperational monitoring program when they are located within the wellfield. Samples from all locations are obtained quarterly. Surface monitoring results are submitted in the semi-annual activity and monitoring reports submitted to USNRC. A summary of the most recent regional surface water monitoring results can be found in **Table 5.8-14** and **Table 5.8-15**.

5.8.8.4 Evaporation Pond Leak Detection Monitoring

The evaporation ponds are lined and equipped with a leak detection system. During operations, the leak detection standpipes are checked for evidence of leakage. Visual inspection of the pond embankments, fences, and liners and the measurement of pond freeboard are also performed during normal operations. A minimum freeboard of 5 feet is allowed for the commercial ponds during normal operations. Anytime 6 inches or more

of fluid is detected in a leak detection system standpipe, it is analyzed for specific conductivity. Should the analyses indicate that the liner is leaking (by comparison to chemical analyses of pond water), the following actions are taken:

- The USNRC Project Manager is notified by telephone within 48 hours of leak verification.
- Transferring its contents into an adjacent pond lowers the level of the leaking pond. While lowering the water level in the pond, the liner is inspected to determine the cause and location of the leakage. The area of investigation first centers on the pond area specific for the particular standpipe that contains fluid.
- Once the source of the leakage is found, the liner is repaired and water is reintroduced to the pond.
- A written report is submitted to the USNRC within 30 days of leak verification. The report includes analytical data and describes the cause of the leakage, corrective actions taken, and the results of those actions.

5.8.9 Quality Assurance Program

A quality assurance program is in place at Crow Butte Project for all relevant operational monitoring and analytical procedures. The objective of the program is to identify any deficiencies in the sampling techniques and measurement processes so that corrective action can be taken and to obtain a level of confidence in the results of the monitoring programs. The QA program provides assurance to both regulatory agencies and the public that the monitoring results are valid.

The QA program addresses the following:

- Formal delineation of organizational structure and management responsibilities. Responsibility for both review/approval of written procedures and monitoring data/reports is provided.
- Minimum qualifications and training programs for individuals performing radiological monitoring and those individuals associated with the QA program.
- Written procedures for QA activities. These procedures include activities involving sample analysis, calibration of instrumentation, calculation techniques, data evaluation, and data reporting.
- Quality control (QC) in the laboratory. Procedures cover statistical data evaluation, instrument calibration, and duplicate and spike sample programs. Outside laboratory QA/QC programs are included.
- Provisions for periodic management audits to verify that the QA program is effectively implemented, to verify compliance with applicable rules, regulations and license requirements, and to protect employees by maintaining effluent releases and exposures ALARA.

The SHEQMS Program developed by CBR is a critical step to ensuring that quality assurance objectives are met. Current procedures exist for a variety of areas, including but not limited to:

1. Environmental monitoring procedures,
2. Testing procedures,
3. Exposure procedures,
4. Equipment operation and maintenance procedures,
5. Employee health and safety procedures,
6. Incident response procedures, and
7. Laboratory procedures.

5.8.10 **Monitoring Program Summary**

Section 5.8 of this renewal application has reviewed the radiological monitoring data produced at Crow Butte Project for the years 1990 through 2007. Each section has discussed the historical results of the data with an emphasis on regulatory compliance and trend analysis to determine whether CBR's ALARA goals are being met. Where the data indicated that some adjustments in the monitoring program were indicated, CBR has noted those changes in the "Proposed Program" portion of each Section. In order to aid the reviewer in comparing the elements of the current monitoring program with those of the proposed program, **Table 5.8-16** provides a tabular summary of both programs as well as the regulatory guidance provided in USNRC Regulatory Guide 8.30, *Health Physics Surveys In Uranium Recovery Facilities*, Revision 1.

Table 5.8-16: Radiological Monitoring Program Summary

Type of Survey	Type of Area	Current Frequency	Proposed Frequency	Reg. Guide 8.30 Recommended Frequency
Airborne uranium	• Airborne radioactivity areas • Other indoor process areas • Special maintenance involving high airborne concentrations of yellowcake	• Weekly grab samples[1] • Monthly grab samples • Extra breathing zone grab samples	• Weekly grab samples[1] • Monthly grab samples • Extra breathing zone grab samples	• Weekly grab samples • Monthly grab samples • Extra breathing zone grab samples
Radon daughters	• Areas that exceed 0.08WL • Areas that exceed 0.03WL • Areas below 0.03WL	• Weekly radon daughter grab samples • Monthly radon daughter grab samples • Quarterly radon daughter grab samples	• Weekly radon daughter grab samples • Monthly radon daughter grab samples • Quarterly radon daughter grab samples	• Weekly radon daughter grab samples • Monthly radon daughter grab samples • Quarterly radon daughter grab samples
External radiation: gamma	• Throughout mill • Radiation areas	• Semiannually • Quarterly	• Semiannually • Quarterly	• Semiannually • Quarterly
External radiation: beta	• Where workers are in close contact with yellowcake	• Survey by operation done once plus whenever procedures change	• Survey by operation done once plus whenever procedures change	• Survey by operation done once plus whenever procedures change
Surface contamination	• Yellowcake areas • Eating rooms, change rooms, control rooms, office	• Daily walkthrough • Weekly	• Daily walkthrough • Weekly	• Daily • Weekly
Skin and personal clothing	• Yellowcake workers who shower • Yellowcake workers who do not shower	• Each exit from controlled area[2] • Each exit from controlled area[2]	• Each exit from controlled area[2] • Each exit from controlled area[2]	• Quarterly • Each day before leaving
Equipment to be released	• Equipment to be released that may be contaminated	• Detailed survey before release	• Detailed survey before release	• Once before release
Packages containing yellowcake	• Packages	• Detailed survey before release	• Detailed survey before release	• Spot check before release
Ventilation	• All areas with airborne radioactivity	• Daily walkthrough	• Daily walkthrough	• Daily
Respirators	• Respirator face pieces and hoods	• Before reuse	• Before reuse	• Before reuse

Notes: [1] Increased sampling frequency based on administrative action level of 25 percent of the MPC or DAC; Sampling is performed in the dryer room during dryer operation.
[2] All employees required to survey upon exit; Quarterly spot checks of >25 percent process staff are also conducted.

5.8.11 References

Crow Butte Resources, Inc. (CBR). 1998. ALARA Audit Report for the Year Ending December 31, 1998. USNRC License Number SUA-1534.

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Crow Butte Resources, Inc. (CBR). 2006. Prepared by Robert Meyer, Tetra Tech, Inc. Annual ALARA Audit. USNRC License Number SUA-1534. April 24, 2007.

U. S. Nuclear Regulatory Commission. (NRC). 1980. Regulatory Guide 4.14, *Radiological and Environmental Monitoring at Uranium Mills.* (Revision 1, April, 1980)

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6 GROUNDWATER QUALITY RESTORATION, SURFACE RECLAMATION, AND FACILITY DECOMMISSIONING

6.1 PLANS AND SCHEDULES FOR GROUNDWATER RESTORATION

The objective of the Restoration and Reclamation Plan is to return the affected groundwater and land surface to conditions suitable for the uses for which they were suitable before mining. The methods to achieve this objective for both the affected groundwater and the surface are described in the following sections. Before discussing restoration methodologies, a discussion of the ore body genesis and chemical and physical interactions between the ore body and the lixiviant is provided.

6.1.1 Ore Body Genesis

The uranium deposit in the License Area is a roll front deposit in a fluvial sandstone and is similar to those in the Wyoming basins such as the Gas Hills, Shirley Basin and the Powder River Basin. The origin of the uranium in the deposit could lie within the host rock itself either from the feldspar or volcanic ash content of the Chadron Sandstone. The source of the uranium could also be volcanic ash of the Chadron Formation which overlays the Chadron Sandstone. Regardless of the source of the uranium, it has precipitated in several long sinuous roll fronts. The individual roll fronts are developed within subunits of the Chadron Sandstone. The Chadron Sandstone is divided into local subunits by thin clay beds that confined the uranium bearing waters to several distinct hydrological subunits of the sandstone. These clay beds are laterally continuous for hundreds of feet but control the deposition of the uranium over greater distances as other clay beds exert vertical control when the locally controlling beds pinch out. Precipitation of the uranium resulted when the oxidizing water containing the uranium entered reducing conditions. These reducing agents are likely hydrogen sulfide (H_2S) and, to a lesser degree, organic matter and pyrite.

Solution mining of the deposit is accomplished by reversing the natural processes that deposited the uranium. Oxidizing solution is injected into the mineralized portion of the Chadron Sandstone to oxidize the reduced uranium and to complex it with bicarbonates. Pumping from recovery wells draws the uranium bearing solution through the mineralized portion of the sandstone. The presence of reducing agents will increase oxidant requirements over that necessary to only oxidize the uranium.

Since the deposition of the uranium was controlled between clay beds within the Chadron Sandstone, the mining solutions will be largely confined to this portion of the sandstone by selectively screening these intervals. This will limit the contamination and thus the required restoration of unmineralized portions of the sandstone.

6.1.2 Chemical and Physical Interactions of Lixiviant with the Ore Body

The following discussion is based on a range of lixiviant conditions from 0.5 to 3.0 grams per liter total carbonate and a pH from 6.5 to 9.0 standard units (S.U.). This represents

the normal range of operating conditions for the Crow Butte License Area ISL operations.

6.1.2.1 Ion Exchange

The principal ion exchange reaction is the exchange of sodium from the lixiviant onto exchangeable sites on ore minerals with the release into solution of calcium, magnesium and potassium. This reaction can be shown as follows:

$$Ca_{clay} + 2\ Na^{+}_{solution} = 2\ Na_{clay} + Ca^{++}_{solution}$$

Similar reactions can be written for magnesium and potassium. Due to higher solubility of their sulfate and carbonate compounds and their low concentrations in Chadron Sandstone and the ore, magnesium and potassium in solution have no impact. The limited solubility of calcium carbonate ($CaCO_3$), and to a lesser degree, calcium sulfate, may lead to the potential for calcium precipitation.

Laboratory tests have indicated that the maximum calcium ion exchange capacity of the ore in a sodium lixiviant with 3.0 g/L total carbonate strength is 1.21 milliequivalents of calcium per 100 grams of ore. This equates roughly to 0.5 pound of calcium or about 1.2 pounds of calcium carbonate per ton of ore that could potentially precipitate. Not all of this calcium, however, will be realized since laboratory testing is run in such a way as to indicate the maximum amount of calcium that can be exchanged. Somewhat less than this amount will be released and only a portion of that precipitated. There is no way to directly control the buildup of calcium in the lixiviant circuit. In practice, the lixiviant carbonate concentration and the lixiviant pH is controlled. The formation characteristics dictate an equilibrium calcium concentration in the lixiviant system and ion exchange and/or precipitation will occur until the equilibrium is satisfied. The production bleed represents a departure from this equilibrium and as such has some effect on the amount of calcium exchanged. If the bleed is kept generally small, on the order of 0.5 percent, the effect of the bleed on the ion exchange is small.

6.1.2.2 Precipitation

In the presence of carbonate ions and bicarbonate ions in the lixiviant system, calcium ions will precipitate provided the limit of saturation has been reached. Calcium precipitation is a function of total carbonate, pH and temperature. For example, at 15° C, a pH of 7.5 S.U., and 1 g/L carbonate in lixiviant, the equilibrium solubility of calcium is approximately 40 to 100 ppm. Some uncertainty is seen in these numbers due to the effect of ionic strength and supersaturation considerations. However, these figures illustrate the effect of carbonate concentration and pH on the equilibrium solubility of calcium.

The amount of calcium produced depends on the ion exchange that is taking place, while the precipitation of calcium is a function of the lixiviant chemistry, and the degree of supersaturation that is observed in the system. As a first approximation, the proportion of calcium precipitation occurring above ground and underground will occur in the ratio of

the residence times. In other words, if the residence time is much longer underground than it is above ground, as is the case for most in-situ leach operations including Crow Butte, then more of the calcium will precipitate underground than above ground. The calcium precipitation is a function of turbulence in the solution, changes in dissolved carbon dioxide (CO_2) partial pressure or pH, and the presence of surface area. The most likely places for calcium to precipitate are underground where the ore provides abundant surface area for precipitation, at or near the injection or production wellbore where changes in pressure, turbulence and CO_2 partial pressure are all observed, and on the surface in the filters, in pipes, and in tanks. If all the calcium were to precipitate (based on 1.2 pounds of $CaCO_3$ per ton of ore) the precipitate would occupy about 0.15 percent of the void space in that ton of ore.

Calcium may be removed from the system in two ways:

- Filters will be routinely backwashed to the evaporation ponds and periodically acid cleaned, if necessary, to remove precipitated calcium carbonate from the filter housing or filter media; and
- The solution bleed (approximately 0.5 to 1.0 percent) taken to create overproduction and a hydrologic sink in the mining area serves to eliminate some calcium from the system.

Should precipitation of calcium carbonate at or near the wellbore of the wellfield wells become a problem, these wells may be air lifted, surged, water jetted, or acidified to remove the precipitated calcium. Any water recovered from these wells containing dissolved calcium carbonate or particulate calcium carbonate is collected and placed into the waste disposal system. A liquid seal is maintained on any calcium carbonate in the evaporation ponds. Upon decommissioning, calcium carbonate from the plant equipment and pond residues will be disposed of in either a licensed tailings pond or a commercial disposal site.

The other possible precipitating species that has been identified is iron, which could precipitate as either the hydroxide or the carbonate, causing some fouling. Such fouling is usually evidenced by a reduction in the ion exchange capacity of the resin in the extraction circuit. Should this fouling become a serious problem, the resin can be washed and the wash solution disposed of in the waste disposal system. Due to the small amount of iron present in the Chadron Sandstone, iron precipitation has not been a problem in mining operations to date.

6.1.2.3 Hydrolysis

Hydrolysis reactions, which involve minerals and hydrogen or hydroxide ions, do not play an important role in the ore/lixiviant interaction. In the pH range of 6.5 to 9.0 S.U., the concentration of hydrogen and hydroxide ions is so small that these types of reactions do not occur to any great degree. The only potential impact would be a small increase in the dissolved silica content of the lixiviant system and a possible small increase in the

cations associated with the siliceous minerals. The hydrolysis reaction does not have a significant effect on operations.

6.1.2.4 Oxidation

The oxidant consumers in the Chadron Sandstone are hydrogen sulfide in the groundwater, uranium, vanadium, iron pyrite, and other trace and heavy metals. The impact of these oxidant consumers on the operation of the plant is a general increase in the oxidant consumption over that which would be required for uranium alone. The second effect is a release of iron and sulfate into solution from the oxidation of pyrite. A third effect is an increase in the levels of some trace metals such as arsenic, vanadium and selenium into solution. As mentioned previously, the iron solubilized will most likely be precipitated as the hydroxide or carbonate, depending on its oxidation state. Any vanadium that is oxidized along with the uranium will be solubilized by the lixiviant, recovered with the uranium and could potentially contaminate the precipitated yellowcake product. Hydrogen peroxide precipitation of uranium is used to reduce the amount of vanadium precipitated in the product. Oxidation will also solubilize arsenic and selenium. The restoration program will return these substances to acceptable levels. A final potential oxidation reaction is the partial oxidation of sulfur species, increasing the concentrations of compounds such as polythionates, which can foul ion exchange resins. In in-situ operations with chemistries similar to Crow Butte, these sulfur species are completely oxidized to sulfate, which poses no problems.

6.1.2.5 Organics

Organic materials are generally not present in the CBR License Area ore body at levels greater than 0.1 to 0.2 percent. Where present organic materials effectively increase the oxidant consumption and reduce uranium leaching. On longer flow paths, organic material could potentially re-precipitate uranium should all of the oxidant be consumed and conditions become reducing. Another potential impact of mobilized organics could be the coloring and fouling of leach solutions. As the aquifer is maintained in the pH range of 6.5 to 9.0 S.U., mobilization of the organics and coloring of the leach solution is avoided.

6.1.3 Basis of Restoration Goals

The primary goal of the groundwater restoration program is to return groundwater affected by mining operations to pre-injection baseline values on a mine unit average as determined by the baseline water quality sampling program. This sampling program is performed for each mine unit before mining operations commence. Should restoration efforts be unable to achieve baseline conditions after diligent application of the best practicable technology (BPT) available, CBR commits, in accordance with the Nebraska Environmental Quality Act and NDEQ regulations, to return the groundwater to the restoration values set by the NDEQ in the CSA Class III UIC Permit. These secondary restoration values ensure that the groundwater is returned to a quality consistent with the use, or uses, for which the water was suitable prior to ISL mining. These secondary restoration values are approved by the NDEQ in the individual Notice of Intent (NOI) for

each mine unit based on the permit requirements and the results of the baseline monitoring program.

USEPA groundwater protection standards issued under the authority of the Uranium Mill Tailings Radiation Control Act (UMTRCA) are required to be followed by ISL licenses of the NRC and its Agreement States. The USEPA regulations issued under UMTRCA authority provide the principal standards for uranium ISL operations and groundwater protection, while the UIC regulations are considered additional requirements for ISL operations. CBR is required to restore groundwater quality to the standards listed in Criterion 5B (5) of 10 CFR Part 40, Appendix A as required by the UMTRCA, as amended. Under USEPA requirements, groundwater restoration at ISL facilities must meet the UMTRCA standards and not those associated with the Safe Drinking Water Act or analogous state regulations.

Under Criterion 5B (5) of 10 CFR Part 40, Appendix A of UMTRCA, at the point of compliance (mining zone after restoration), the concentration of hazardous constituents must not exceed:

a. The Commission approved background concentration of that constituent in the groundwater; or

b. The respective value given in Table 6.1-1_for the UMTRCA values if the constituent is listed in the table and the background level of the constituent is below the value listed; or

c. Alternate concentration limit established by the Commission.

CBR will comply with these provisions as to groundwater restoration limits. The NRC is currently developing rulemaking on groundwater protection standards in an effort to eliminate dual jurisdiction and interactions with the USEPA. Such new rulemaking could affect the groundwater restoration limits, but the new language will emphasize that UMTRCA would govern. CBR is requesting in this application that the NRC amend the current license condition 10.3 (C) to reflect these groundwater quality standards requirements.

6.1.3.1 Establishment of Baseline Water Quality

Before mining in each mine unit, the baseline groundwater quality is determined. The data are established in each mine unit by assigning and evaluating groundwater quality in "baseline restoration wells". A minimum of one baseline restoration well for each four acres is sampled to establish the mine unit baseline water quality. A minimum of three samples is collected from each well. The samples are collected at least 14 days apart. The samples are analyzed for the parameters listed in **Table 6.1-1**.

Tables 6.1-2 through 6.1-11 contain the restoration information for Mine Units one through ten in the current commercial license area. These tables provide the baseline

average and the range for all restoration parameters as well as the NDEQ restoration standard approved for that mine unit in the NOI.

Table 6.1-1: NDEQ Groundwater Restoration Standards

Parameter	NDEQ Title 118 Groundwater Standard	NDEQ Restoration Standard[1]
Ammonium (mg/L)	Not Listed	10.0
Arsenic (mg/L)	0.010	0.010
Barium (mg/L)	2.0	2.0
Cadmium (mg/L)	0.005	0.005
Chloride (mg/L)	250	250
Copper (mg/L)	1.3	1.3
Fluoride (mg/L)	4.0	4.0
Iron (mg/L)	0.3	0.3
Mercury (mg/L)	0.002	0.002
Manganese (mg/L)	0.05	0.05
Molybdenum (mg/L)	(Reserved)	1.0
Nickel (mg/L)	(Reserved)	0.15
Nitrate (mg/L)	10.0	10.0
Lead (mg/L)	0.015	0.015
Radium (pCi/L)	5.0	5.0
Selenium (mg/L)	0.05	0.05
Sodium (mg/L)	N/A	Note 2
Sulfate (mg/L)	250	250
Uranium (mg/L)	0.030	0.030
Vanadium (mg/L)	(Reserved)	0.2
Zinc (mg/L)	5.0	5.0
pH (Std. Units)	6.5 - 8.5	6.5 – 8.5
Calcium (mg/L)	N/A	Note 2
Total Carbonate (mg/L)	N/A	Note 3
Potassium (mg/L)	N/A	Note 2
Magnesium (mg/L)	N/A	Note 2
TDS (mg/L)	N/A	Note 4

1 NDEQ Restoration Standard based on groundwater standard (MCL) from Title 118. For parameters where the baseline concentration exceeds the applicable MCL, the standard is set as the mine unit baseline average plus two standard deviations.

2 One order of magnitude above baseline is used as the restoration value for some parameters due to the ability of some major ions to vary one order of magnitude depending on pH.

3 Total carbonate shall not exceed 50% of the total dissolved solids value.

4 The restoration value for Total Dissolved Solids (TDS) shall be the baseline mean plus one standard deviation.

Source: NDEQ Class III UIC Permit Number NE0122611

Table 6.1-2: Baseline and Restoration Values for Mine Unit 1

Parameter	Groundwater Standard	MU-1 Baseline	MU-1 Standard Deviation	MU-1 NDEQ Restoration Value
Ammonium (mg/L)	10.0	<0.372	N/A	10.0
Arsenic (mg/L)	0.05	<0.00214	N/A	0.05
Barium (mg/L)	1.0	<0.1	N/A	1.0
Cadmium (mg/L)[1]	0.01	<0.00644	N/A	0.005[1]
Chloride (mg/L)	250.0	203.9	38	250.0
Copper (mg/L)	1.0	<0.017	N/A	1.0
Fluoride (mg/L)	4.0	0.686	0.04	4.0
Iron (mg/L)	0.3	<0.0441	N/A	0.3
Mercury (mg/L)	0.002	<0.001	N/A	0.002
Manganese (mg/L)	0.05	<0.011	N/A	0.05
Molybdenum (mg/L)	1.0	<0.0689	N/A	1.0
Nickel (mg/L)	0.15	<0.0340	N/A	0.15
Nitrate (mg/L)	10.0	<0.050	N/A	10.0
Lead (mg/L)	0.05	0.0315	N/A	0.05
Radium (pCi/L)	5.0	229.7	177.1	584.0
Selenium (mg/L)	0.01	<0.00323	N/A	0.05
Sodium (mg/L)	N/A	412	19.2	4120
Sulfate (mg/L)	250.0	356.2	9.4	375
Uranium (mg/L)	5.0	0.0922	0.089	5.0
Vanadium (mg/L)	0.2	<0.0663	N/A	0.2
Zinc (mg/L)	5.0	<0.036	N/A	5.0
pH (Std. Units)	6.5 - 8.5	8.46	0.2	6.5 – 8.5
Calcium (mg/L)	N/A	12.5	3.2	125.0
Total Carbonate (mg/L)	N/A	351	31.1	585
Potassium (mg/L)	N/A	12.5	1.5	125.0
Magnesium (mg/L)	N/A	3.2	0.8	32.0
TDS (mg/L)	N/A	1170.2	47.6	1170.2

[1] Standard for Cadmium lowered in modification to UIC permit dated March 9, 2001 following NDEQ approval of Mine Unit 1 restoration.

N/A = Not Applicable

Table 6.1-3: Baseline and Restoration Values for Mine Unit 2

Parameter	Groundwater Standard	MU-2 Baseline	MU-2 Standard Deviation	MU-2 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.37	0.07	10.0
Arsenic (mg/L)	0.05	<0.001	N/A	0.05
Barium (mg/L)	1.0	<0.1	N/A	1.0
Cadmium (mg/L)	0.005	<0.007	N/A	0.005
Chloride (mg/L)	250.0	208.6	30.8	250.0
Copper (mg/L)	1.0	<0.013	N/A	1.0
Fluoride (mg/L)	4.0	0.67	0.04	4.0
Iron (mg/L)	0.3	<0.045	N/A	0.3
Mercury (mg/L)	0.002	<0.001	N/A	0.002
Manganese (mg/L)	0.05	<0.01	N/A	0.05
Molybdenum (mg/L)	1.0	<0.073	N/A	1.0
Nickel (mg/L)	0.15	<0.037	N/A	0.15
Nitrate (mg/L)	10.0	<0.039	N/A	10.0
Lead (mg/L)	0.05	<0.035	N/A	0.05
Radium (pCi/L)	5.0	234.5	411.8	1058.0
Selenium (mg/L)	0.05	<0.001	N/A	0.05
Sodium (mg/L)	N/A	410.8	18.2	4108
Sulfate (mg/L)	250.0	348.2	10.3	369.0
Uranium (mg/L)	5.0	0.046	0.037	5.0
Vanadium (mg/L)	0.2	<0.07	N/A	0.2
Zinc (mg/L)	5.0	<0.026	N/A	5.0
pH (Std. Units)	6.5 - 8.5	8.32	0.2	6.5 – 8.5
Calcium (mg/L)	N/A	13.4	2.4	134.0
Total Carbonate (mg/L)	N/A	366.9	13.3	585.0
Potassium (mg/L)	N/A	12.6	2.5	126.0
Magnesium (mg/L)	N/A	3.5	0.4	35.0
TDS (mg/L)	N/A	1170.4	41	1170.4

Notes:
N/A = Not Applicable

Table 6.1-4: Baseline and Restoration Values for Mine Unit 3

Parameter	Groundwater Standard	MU-3 Baseline	MU-3 Standard Deviation	MU-3 NDEQ Restoration Value
Ammonium (mg/L)	10.0	<0.329	N/A	10.0
Arsenic (mg/L)	0.05	<0.001	N/A	0.05
Barium (mg/L)	1.0	<0.1	N/A	1.0
Cadmium (mg/L)	0.005	<0.01	N/A	0.005
Chloride (mg/L)	250.0	197.6	16.7	250.0
Copper (mg/L)	1.0	<0.0108	N/A	1.0
Fluoride (mg/L)	4.0	0.719	0.05	4.0
Iron (mg/L)	0.3	<0.05	N/A	0.3
Mercury (mg/L)	0.002	<0.001	N/A	0.002
Manganese (mg/L)	0.05	<0.01	N/A	0.05
Molybdenum (mg/L)	1.0	<0.1	N/A	1.0
Nickel (mg/L)	0.15	<0.05	N/A	0.15
Nitrate (mg/L)	10.0	<0.0728	N/A	10.0
Lead (mg/L)	0.05	<0.05	N/A	0.05
Radium (pCi/L)	5.0	165	222.5	611.0
Selenium (mg/L)	0.05	<0.00115	N/A	0.05
Sodium (mg/L)	N/A	428	27.6	4280
Sulfate (mg/L)	250.0	377.0	13.4	404.0
Uranium (mg/L)	5.0	0.115	0.158	5.0
Vanadium (mg/L)	0.2	<0.1	N/A	0.2
Zinc (mg/L)	5.0	<0.0131	N/A	5.0
pH (Std. Units)	6.5 - 8.5	8.37	0.3	6.5 – 8.5
Calcium (mg/L)	N/A	13.3	3.1	133.0
Total Carbonate (mg/L)	N/A	358.7	24.8	592.0
Potassium (mg/L)	N/A	13.9	4.0	139.0
Magnesium (mg/L)	N/A	3.5	0.9	35.0
TDS (mg/L)	N/A	1183.0	47.4	1183.0

Notes:
N/A = Not Applicable

Table 6.1-5: Baseline and Restoration Values for Mine Unit 4

Parameter	Groundwater Standard	MU-4 Baseline	MU-4 Standard Deviation	MU-4 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.288	0.08	10.0
Arsenic (mg/L)	0.05	<0.00209	N/A	0.05
Barium (mg/L)	1.0	<0.1	N/A	1.0
Cadmium (mg/L)	0.005	<0.01	N/A	0.005
Chloride (mg/L)	250.0	217.5	34.9	250.0
Copper (mg/L)	1.0	<0.0114	N/A	1.0
Fluoride (mg/L)	4.0	0.745	0.05	4.0
Iron (mg/L)	0.3	<0.0504	N/A	0.3
Mercury (mg/L)	0.002	<0.001	N/A	0.002
Manganese (mg/L)	0.05	<0.01	N/A	0.05
Molybdenum (mg/L)	1.0	<0.1	N/A	1.0
Nickel (mg/L)	0.15	<0.05	N/A	0.15
Nitrate (mg/L)	10.0	<0.114	N/A	10.0
Lead (mg/L)	0.05	<0.05	N/A	0.05
Radium (pCi/L)	5.0	154.3	171.5	496.0
Selenium (mg/L)	0.05	<0.00244	N/A	0.05
Sodium (mg/L)	N/A	416.6	27.8	4166
Sulfate (mg/L)	250.0	337.2	19.3	375.0
Uranium (mg/L)	5.0	<0.122	N/A	5.0
Vanadium (mg/L)	0.2	<0.0984	N/A	0.2
Zinc (mg/L)	5.0	<0.0143	N/A	5.0
pH (Std. Units)	6.5 - 8.5	8.68	0.3	6.5 – 9.28
Calcium (mg/L)	N/A	11.2	2.9	112.0
Total Carbonate (mg/L)	N/A	374.4	28	610.0
Potassium (mg/L)	N/A	16.7	4.7	167.0
Magnesium (mg/L)	N/A	2.8	0.8	28.0
TDS (mg/L)	N/A	1221.1	73.5	1221.1

Notes:
N/A = Not Applicable

Table 6.1-6: Baseline and Restoration Values for Mine Unit 5

Parameter	Groundwater Standard	MU-5 Baseline	MU-5 Standard Deviation	MU-5 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.28	0.05	10.0
Arsenic (mg/L)	0.05	<0.001	N/A	0.05
Barium (mg/L)	1.0	<0.10	N/A	1.0
Cadmium (mg/L)	0.005	<0.01	N/A	0.005
Chloride (mg/L)	250.0	191.9	7.9	250.0
Copper (mg/L)	1.0	<0.01	N/A	1.0
Fluoride (mg/L)	4.0	0.64	0.07	4.0
Iron (mg/L)	0.3	<0.05	N/A	0.3
Mercury (mg/L)	0.002	<0.001	N/A	0.002
Manganese (mg/L)	0.05	<0.01	N/A	0.05
Molybdenum (mg/L)	1.0	<0.10	N/A	1.0
Nickel (mg/L)	0.15	<0.05	N/A	0.15
Nitrate (mg/L)	10.0	<0.1	N/A	10.0
Lead (mg/L)	0.05	<0.05	N/A	0.05
Radium (pCi/L)	5.0	166.0	184.6	535.0
Selenium (mg/L)	0.05	<0.002	N/A	0.05
Sodium (mg/L)	N/A	397.6	14.4	3976
Sulfate (mg/L)	250.0	364.5	10.5	385.0
Uranium (mg/L)	5.0	0.072	0.056	5.0
Vanadium (mg/L)	0.2	<0.10	N/A	0.2
Zinc (mg/L)	5.0	<0.02	N/A	5.0
pH (Std. Units)	6.5 - 8.5	8.5	0.1	6.5 – 8.5
Calcium (mg/L)	N/A	12.6	1.8	126.0
Total Carbonate (mg/L)	N/A	372	13.0	590.0
Potassium (mg/L)	N/A	11.5	1.2	115.0
Magnesium (mg/L)	N/A	3.4	0.4	34.0
TDS (mg/L)	N/A	1179.5	22.5	1202.0

Notes:
N/A = Not Applicable

Table 6.1-7: Baseline and Restoration Values for Mine Unit 6

Parameter	Groundwater Standard	MU-6 Baseline	MU-6 Standard Deviation	MU-6 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.32	0.05	10.0
Arsenic (mg/L)	0.05	0.002	N/A	0.05
Barium (mg/L)	1.0	0.100	N/A	1.0
Cadmium (mg/L)	0.005	0.009	N/A	0.005
Chloride (mg/L)	250.0	206	15.4	250.0
Copper (mg/L)	1.0	0.012	N/A	1.0
Fluoride (mg/L)	4.0	0.65	0.03	4.0
Iron (mg/L)	0.3	0.050	N/A	0.3
Mercury (mg/L)	0.002	0.001	N/A	0.002
Manganese (mg/L)	0.05	0.010	N/A	0.05
Molybdenum (mg/L)	1.0	0.102	N/A	1.0
Nickel (mg/L)	0.15	0.050	N/A	0.15
Nitrate (mg/L)	10.0	0.1	N/A	10.0
Lead (mg/L)	0.05	0.050	N/A	0.05
Radium (pCi/L)	5.0	80.6	121.9	325
Selenium (mg/L)	0.05	0.001	N/A	0.05
Sodium (mg/L)	N/A	400	12.8	4000
Sulfate (mg/L)	250.0	361	14.6	390
Uranium (mg/L)	5.0	0.133	0.212	5.0
Vanadium (mg/L)	0.2	0.098	N/A	0.2
Zinc (mg/L)	5.0	0.011	N/A	5.0
pH (Std. Units)	6.5 - 8.5	8.6	0.2	6.5 – 9.0
Calcium (mg/L)	N/A	12.8	2.3	128
Total Carbonate (mg/L)	N/A	367.1	22.9	596
Potassium (mg/L)	N/A	11.9	1.7	119
Magnesium (mg/L)	N/A	3.2	0.7	32
TDS (mg/L)	N/A	1192	28.1	1220

Notes:
N/A = Not Applicable

Table 6.1-8: Baseline and Restoration Values for Mine Unit 7

Parameter	Groundwater Standard	MU-7 Baseline	MU-7 Standard Deviation	MU-7 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.42	0.08	10.0
Arsenic (mg/L)	0.05	0.001	N/A	0.05
Barium (mg/L)	1.0	0.10	N/A	1.0
Cadmium (mg/L)	0.005	0.007	N/A	0.005
Chloride (mg/L)	250.0	198	22.6	250.0
Copper (mg/L)	1.0	0.01	N/A	1.0
Fluoride (mg/L)	4.0	0.70	0.05	4.0
Iron (mg/L)	0.30	0.05	N/A	0.30
Mercury (mg/L)	0.002	0.001	N/A	0.002
Manganese (mg/L)	0.05	0.01	N/A	0.05
Molybdenum (mg/L)	1.00	0.10	N/A	1.00
Nickel (mg/L)	0.15	0.05	N/A	0.15
Nitrate (mg/L)	10.0	0.1	N/A	10.0
Lead (mg/L)	0.05	0.05	N/A	0.05
Radium (pCi/L)	5.0	142	148.0	438
Selenium (mg/L)	0.05	0.004	N/A	0.05
Sodium (mg/L)	N/A	387	21.6	3,870
Sulfate (mg/L)	250.0	346	20.1	386
Uranium (mg/L)	5.0	0.110	0.138	5.0
Vanadium (mg/L)	0.2	0.10	N/A	0.2
Zinc (mg/L)	5.0	0.01	N/A	5.0
pH (Std. Units)	6.5 - 8.5	8.6	0.3	6.5 – 9.2
Calcium (mg/L)	N/A	12.2	2.6	122
Total Carbonate (mg/L)	N/A	356	N/A	588
Potassium (mg/L)	N/A	12.9	3.0	129
Magnesium (mg/L)	N/A	3.2	0.7	32
TDS (mg/L)	N/A	1,176	40.7	1,217

Notes:
N/A = Not Applicable

Table 6.1-9: Baseline and Restoration Values for Mine Unit 8

Parameter	Groundwater Standard	MU-8 Baseline	MU-8 Standard Deviation	MU-8 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.682	0.222	10.0
Arsenic (mg/L)	0.05	0.002	0.001	0.05
Barium (mg/L)	1.0	0.099	0.005	1.0
Cadmium (mg/L)	0.005	0.005	N/A	0.005
Chloride (mg/L)	250	196	53.8	250
Copper (mg/L)	1.0	0.01	N/A	1.0
Fluoride (mg/L)	4.0	0.638	0.048	4.0
Iron (mg/L)	0.30	0.135	0.086	0.30
Mercury (mg/L)	0.002	0.001	N/A	0.002
Manganese (mg/L)	0.05	0.01	N/A	0.05
Molybdenum (mg/L)	1.0	0.093	0.023	1.00
Nickel (mg/L)	0.15	0.049	0.003	0.15
Nitrate (mg/L)	10.0	0.2	N/A	10.0
Lead (mg/L)	0.05	0.049	0.003	0.05
Radium (pCi/L)	5.0	124.4	151.8	428
Selenium (mg/L)	0.05	0.004	N/A	0.05
Sodium (mg/L)	N/A	416.8	41.8	4,168
Sulfate (mg/L)	250	312	33	378
Uranium (mg/L)	5.0	0.188	0.140	5.0
Vanadium (mg/L)	0.2	0.127	0.122	0.2
Zinc (mg/L)	5.0	0.013	0.008	5.0
pH (Std. Units)	6.5 - 8.5	8.67	0.37	6.5 – 9.41
Calcium (mg/L)	N/A	12.3	3.5	123
Total Carbonate (mg/L)	N/A	377	15.6	569
Potassium (mg/L)	N/A	11.8	3.2	117.8
Magnesium (mg/L)	N/A	2.7	0.92	27.1
TDS (mg/L)	N/A	1,137	97.4	1,234

Notes:
N/A = Not Applicable

Table 6.1-10: Baseline and Restoration Values for Mine Unit 9

Parameter	Groundwater Standard	MU-9 Baseline	MU-9 Standard Deviation	MU-9 NDEQ Restoration Value
Ammonium (mg/L)	10.0	0.40	0.05	10.0
Arsenic (mg/L)	0.05	0.001	0.000	0.05
Barium (mg/L)	1.0	0.1	0.0	1.0
Cadmium (mg/L)	0.005	0.005	0.000	0.005
Chloride (mg/L)	250	203	13	250
Copper (mg/L)	1.0	0.01	0.00	1.0
Fluoride (mg/L)	4.0	0.8	0.0	4.0
Iron (mg/L)	0.3	0.04	0.01	0.3
Mercury (mg/L)	0.002	0.001	0.000	0.002
Manganese (mg/L)	0.05	0.01	0.00	0.05
Molybdenum (mg/L)	1.0	0.1	0.0	1.0
Nickel (mg/L)	0.15	0.05	0.00	0.15
Nitrate (mg/L)	10:0	0.06	0.01	10.0
Lead (mg/L)	0.05	0.05	0.00	0.05
Radium (pCi/L)	5.0	164	238	640
Selenium (mg/L)	0.05	0.003	0.001	0.05
Sodium (mg/L)	N/A	380	11	3,800
Sulfate (mg/L)	250	320	15	350
Uranium (mg/L)	5.0	0.1	0.24	5.0
Vanadium (mg/L)	0.2	0.1	0.0	0.2
Zinc (mg/L)	5.0	0.01	0.00	5.0
pH (Std. Units)	6.5 - 8.5	8.35	0.30	6.5 – 9.41
Calcium (mg/L)	N/A	13.6	4.6	136
Total Carbonate (mg/L)	N/A	383	14	595
Potassium (mg/L)	N/A	13.9	3.0	139
Magnesium (mg/L)	N/A	3.5	1.2	35.0
TDS (mg/L)	N/A	1,152	38	1,190

Notes:
N/A = Not Applicable

Table 6.1-11: Baseline and Restoration Values for Mine Unit 10

Parameter	Groundwater Standard	MU-10 Baseline	MU-10 Standard Deviation	MU-10 NDEQ Restoration Value
Ammonia (NH_4 as N) (mg/L)	10.0	0.34	0.07	10.0
Arsenic (As) (mg/L)	0.010	0.001	0.001	0.010
Barium (Ba) (mg/L)	2.0	0.1	0.0	2.0
Cadmium (Cd) (mg/L)	0.005	0.005	0.000	0.005
Calcium (Ca) (mg/L)	---	11.8	2.6	118.0
Chloride (Cl) (mg/L)	250	185	14	250
Copper (Cu) (mg/L)	1.3	0.01	0.01	1.3
Fluoride (F) (mg/L)	4.0	0.72	0.10	4.0
Iron (Fe) (mg/L)	0.3	0.03	0.01	0.3
Lead (Pb) (mg/L)	0.015	0.001	0.0	0.015
Magnesium (Mg) (mg/L)	---	3.4	0.7	34.0
Managanese (Mn) (mg/L)	0.05	0.01	0.0	0.05
Mercury (Hg) (mg/L)	0.002	0.001	0.0	0.002
Molybdenum (Mo)	1.0	0.1	0.0	1.0
Nickel (Ni) (mg/L)	0.15	0.05	0.0	0.15
Nitrite + Nitrate as N ($NO_3 + NO_2$)[1] (mg/L)	10.0	0.1	0.0	10.0
pH (Std, Units)	6.5 - 8.5	8.51	0.19	6.5 - 8.89
Potassium (K) (mg/L)	---	10.1	1.6	101
Radium-226 (mg/L)	5.0	87.3	161.0	409.3
Selenium (Se) (mg/L)	0.05	0.003	0.002	0.05
Sodium (Na) (mg/L)	---	388	12	3880
Sulfate (SO4) (mg/L)	250.0	329	25	379
Total Carbonate ($CO_3 + HCO_3$)[2] (mg/L)	---	394	15	550.5
Total Dissolved Solids (mg/L)	---	1101	26	1127
Uranium (U) (mg/L)	0.03	0.0378	0.0351	0.108
Vanadium (V) (mg/L)	0.2	0.1	0.0	0.2
Zinc (Zn) (mg/L)	5.0	0.01	0.01	5.0

1 Nitrate was reported by the lab as $NO_3 + NO_2$ instead of NO_3 as required in the permit. However, only two samples, well 4024 collected 6/09/06 and well CM8-6 collected 5/02/02, were above the detection limits. The restoration value is 10.0 mg/L while the average is 0.1 mg/L. Therefore, including NO_2 has no bearing on determining the restoration value. Nitrite, NO_2, was also analyzed for and all samples were below the detection limit of 0.10 mg/L.

2 Total carbonate = alkalinity as $CaCO_3$ x 1.2

Standard formulas were used to calculate the average and standard deviation but the true values, especially for the standard deviation, are most likely significantly smaller than shown. This results in a conservative estimate of the standard deviation.

--- = no NDEQ standard

6.1.3.2 Establishment of Restoration Goals

The baseline data are used to establish the restoration standards for each mine unit. As previously noted, the primary goal of restoration is to return the mine unit to preoperational water quality condition on a mine unit average. Since ISL operations alter the groundwater geochemistry, it is unlikely that restoration efforts will return the groundwater to the precise water quality that existed before operations.

Restoration goals are established by NDEQ to ensure that, if baseline water quality is not achievable after diligent application of best practicable technology (BPT), the groundwater is suitable for any use for which it was suitable before mining. USNRC considers these NDEQ restoration goals as the secondary goals. The NDEQ restoration values are established for each mine unit and are approved with the Notice of Intent to Operate submittals according to the following analysis:

- For parameters that have numerical groundwater standards established in Title 118 (NDEQ 2006), the restoration goal is based on the Title 118 maximum contaminant level (MCL).
- If the baseline concentration exceeds the applicable MCL, the standard is set as the mine unit baseline average plus two standard deviations.
- If there is no MCL for an element (e.g., vanadium), the restoration value is based on BPT.
- The restoration values for the major cations (Ca, Mg, K, and Na) allow the concentrations of these cations to vary by as much as one order of magnitude as long as the TDS restoration value is met. The total carbonate restoration criterion allows for the total carbonate to be less than 50 percent of the TDS. The TDS restoration value is set at the baseline mine unit average plus one standard deviation.

The current NDEQ restoration standards are listed in **Table 6.1-1**.

Under the provisions of the performance-based license, the CBR Safety and Environmental Review Panel (SERP) reviews and approves the establishment of restoration standards using the review procedures discussed in **Section 5**. **Table 6.1-1** lists the 27 parameters used at the Crow Butte project to determine groundwater quality.

The current MCLs from Title 118 are listed as well as the restoration standards from the CSA Class III UIC Permit. The restoration value for each mine unit is based on the current Title 118 standard at the time the Notice of Intent is approved by the NDEQ.

Mine Unit restoration values are contained in **Table 6.1-2** through **Table 6.1-11** as follows:

- Mine unit averages and secondary goals for Mine Units 1 through 5 are given in **Table 6.1-2** through **Table 6.1-6**. These restoration values were approved by USNRC based on submittals before operation of the Mine Unit.

- The mine unit average and NDEQ restoration values for Mine Unit 6 are given in **Table 6.1-7**. The CBR SERP determined these restoration values on March 4, 1998.
- The mine unit average and NDEQ restoration values for Mine Unit 7 are given in **Table 6.1-8**. The CBR SERP determined these restoration values on July 9, 1999.
- The mine unit average and NDEQ restoration values for Mine Unit 8 are given in **Table 6.1-9**. The CBR SERP determined these restoration values on July 10, 2002.
- The mine unit average and NDEQ restoration values for Mine Unit 9 are given in **Table 6.1-10**. The CBR SERP determined these restoration values on October 23, 2003.
- The mine unit average and NDEQ restoration values for Mine Unit 10 are given in **Table 6.1-11**. The CBR SERP determined these restoration values on April 10, 2007.

NDEQ Permit Number NE0122611 requires that a Mine Unit be returned to a wellfield average of these restoration values. These concentrations were approved by the NDEQ with the Notice of Intent to Operate submittals. Post mining water quality for Mine Unit 1 can be found in **Table 6.1-12**.

CBR operated a R&D Pilot Facility starting in July 1986 and initiated restoration activities of its Wellfield No. 2 in February 1987. Wellfield No. 1 was incorporated into Mine Unit 1, thus no restoration took place in that area. The techniques used during that program are the basis for the commercial restoration program outlined in this section. CBR will utilize ion exchange columns, a reverse osmosis unit and reductant addition equipment similar to those used in the R&D restoration during commercial restoration operations.

6.1.4 Groundwater Restoration Methods

6.1.4.1 Introduction

Restoration activities in the current license area have proven that the groundwater can be restored to the appropriate standards following commercial mining activities. As shown in **Table 1.7-1**, Mine Units 2 through 5 are currently undergoing restoration, with Mine Unit 2 undergoing extended stability monitoring following active restoration. Mine Unit 1 groundwater restoration has been approved by the NDEQ and the USNRC. On February 12, 2003, the USNRC issued the final approval of groundwater restoration in Mine Unit 1 at Crow Butte. This approval was the culmination of three years of agency reviews including a license amendment to accept the NDEQ restoration standards as the approved secondary goals. Mine Unit 1 consisted of 40 patterns installed in 9.3 acres immediately adjacent to the Central Plant. Included within the boundaries of Mine Unit 1 were five wells that were originally mined beginning in 1986 as part of the R & D pilot plant operation. Commercial mining activities began in 1991 and were completed in

Table 6.1-12: Post Mining Water Quality for Mine Unit 1 Restoration Well Sampling

	PM-1	PM-4	PM-5	PT-5	IJ-6	IJ-13	IJ-25	IJ-28	IJ-45	PR-8	PR-15	PR-19
Ca (mg/L)	87.9	87.1	80.8	87.9	87.6	93.9	89.4	89.6	89.9	85.4	86.7	98.3
Mg (mg/L)	22.6	20.6	22.7	23.8	21.4	23.9	22.5	23.1	24.8	23.2	23.1	23.8
Na (mg/L)	1154	942	1054	1144	1054	1174	1177	1182	1126	1144	1172	1083
K (mg/L)	32.7	26.3	30	30	27.2	31.3	30	31.3	32.7	30	30	28.6
CO_3 (mg/L)	0	0	0	0	0	0	0	0	0	0	0	0
HCO_3 (mg/L)	1099	900	972	981	1057	1086	1111	1207	1104	1170	1170	959
SO_4 (mg/L)	1109	959	1115	1240	1031	1209	1119	1112	1134	1115	1115	1283
Cl (mg/L)	598	455	586	594	544	598	594	619	607	603	603	590
NH_4 (mg/L)	0.33	0.67	0.14	0.33	0.44	0.07	< 0.05	< 0.05	0.33	0.27	0.15	0.49
NO_2 (mg/L)	< 0.01	0.02	0.09	< 0.01	0.11	< 0.01	< 0.01	< 0.01	0.04	0.05	< 0.01	0.05
NO_3 (mg/L)	1.06	< 0.1	0.97	0.99	1.29	0.74	0.86	1.3	1.25	1.46	1.6	0.46
F (mg/L)	0.37	0.26	0.54	0.45	0.45	0.37	0.38	0.45	0.43	0.43	0.4	0.35
SiO_2 (mg/L)	25.7	18.2	35.3	24.7	33.3	34.3	26.4	31.6	28.3	33.2	30	22.2
TDS (mg/L)	3694	3121	3756	3851	3515	3899	3751	3886	3873	3820	3807	3765
Conductivity (µmho/cm)	5843	4841	5590	5964	5445	6012	5807	6025	5916	5819	5940	5819
$CaCO_3$ (mg/L)	901	738	797	804	866	890	911	989	905	959	959	786
pH (Std. units)	7.65	6.87	6.85	7.28	7.16	7.35	7.65	7.81	7.37	7.46	7.78	6.92
Trace Metals												
Al (mg/L)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.29
As (mg/L)	0.018	0.007	0.018	0.017	0.031	0.028	0.02	0.028	0.023	0.028	0.024	0.011
Ba (mg/L)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
B (mg/L)	1.17	1.44	1.09	1.36	1.06	1.26	1.13	1.19	1.15	1.23	1.25	1.17
Cd (mg/L)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cr (mg/L)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Cu (mg/L)	< 0.01	< 0.01	0.05	< 0.01	0.02	< 0.01	< 0.01	< 1	< 0.01	< 0.01	< 0.01	< 0.01
Fe (mg/L)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.38
Pb (mg/L)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Mn (mg/L)	0.02	0.11	0.05	0.04	0.14	0.15	0.08	0.06	0.06	0.02	< 0.01	0.16

Table 6.1-12: Post Mining Water Quality for Mine Unit 1 Restoration Well Sampling

	PM-1	PM-4	PM-5	PT-5	IJ-6	IJ-13	IJ-25	IJ-28	IJ-45	PR-8	PR-15	PR-19
Hg (mg/L)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mo (mg/L)	0.6	0.2	0.42	0.53	0.47	0.5	0.56	0.54	0.53	0.59	0.53	0.37
Ni (mg/L)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.12	0.12	0.12	< 0.05	< 0.05	< 0.05	< 0.05
Se (mg/L)	0.139	0.012	0.129	0.24	0.112	0.122	0.1	0.138	0.149	0.154	0.148	0.041
V (mg/L)	1	0.1	0.38	1.15	1.12	1.18	1.03	1.24	1.29	1.23	1.56	0.28
Zn (mg/L)	< 0.01	0.14	0.11	0.01	0.11	0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Radionuclides												
U (mg/L)	8.63	6.29	54.52	9.3	13.9	9.31	9.9	2.52	14.83	5.24	5.18	6.78
Ra-226 (pCi/l)	370	126	329	1139	1113	1558	1258	1147	681	417	109	1182

1994. Mine Unit 1 was successfully restored to the approved primary or secondary restoration standards for all parameters.

The commercial groundwater restoration program consists of two stages, the restoration stage and the stabilization stage. The restoration stage consists of four activities:

- Groundwater transfer
- Groundwater sweep
- Groundwater treatment
- Wellfield recirculation

A reductant may be added at anytime during the restoration stage to lower the oxidation potential of the mining zone. A sulfide or sulfite compound will be added to the injection stream in concentrations sufficient to reduce the mobilized species.

The stabilization stage consists of monitoring the restoration wells following successful completion of the restoration stage. Stabilization begins once restoration activities have returned the average concentration of restoration parameters to acceptable levels. Following the stabilization phase, CBR provides a restoration report to the appropriate regulatory agencies. A cone of depression (inward hydraulic gradient) is not maintained during stabilization.

During mining until the start of stabilization, a hydrologic bleed will be maintained within the perimeter monitor well ring to prevent lateral migration of mining lixiviant. If a proper hydrologic bleed is not maintained, it is possible for water with chemistry similar to that in **Table 2.7-18** column "Typical Water Quality During Mining at CSA" to begin migrating toward the monitor well ring. If mobile ions such as chloride and carbonate are detected at the monitor well ring, adjustments will be made to reverse the trend.

The maintenance of a hydrologic bleed and the close proximity of the monitor well ring, less than 300 feet from the mining patterns, will ensure there is negligible migration of mining fluid. Vertical migration of fluids is less of a concern than lateral migration due to the underlying and overlying aquitards. The ubiquitous Chadron Formation clays, which cap the Lower Chadron Formation ore body, have hydraulic conductivities on the order of 10^{-11} cm/sec as outlined in **Section 2.7.2.2** of this application. Likewise, the underlying Pierre Shale is over 1,200 feet thick and acts as a significant aquitard. The vastly different piezometric heads between the Lower and Middle Chadron as well as the results of the pumping test support the conclusion that the Lower Chadron is vertically isolated.

6.1.4.2 Restoration Process

Restoration activities include four steps that are designed to optimize restoration equipment used in treating groundwater and to minimize the number of pore volumes

circulated during the restoration stage. CBR will monitor the quality of selected wells during restoration to determine the efficiency of the operations and to determine if additional or alternate techniques are necessary.

The number of pore volumes that are displaced during groundwater restoration is as follows: three pore volumes through the IX treatment; six pore volumes through RO treatment; and two pore volumes of recirculation. There were nine pore volumes used for Mine Unit 1 at the current CBR operations. For the remainder of the mine units (Mine Units 2 through 11), 11 pore volumes will be used

The pore volumes (in gallons) affected by the extraction process within the commercial area ore body water bearing zone are as follows:

Pore Volume = Area x Thickness x Pore Space x Gallons per Cubic Foot					
Mine Unit	**Actual Area**	**Effected Thickness**	**Porosity Factor**	**Gallons per Cubic Foot**	**Pore Volume Gallons**
MU1	403,712	19..6	0.29	7.481	17,164,000
MU2	509,600	16.3	0.29	7.481	18,018,000
MU3	586,188	12.5	0.29	7.481	15,894,000
MU4	1,033,405	12.9	0.29	7.481	28,917,000
MU5	1,383,005	14.6	0.29	7.481	43,800,000
MU6	1,507,647	15.4	0.29	7.481	50,364,000
MU7	2,222,190	12.3	0.29	7.481	59,291,000
MU8	2,522,911	16.4	0.29	7.481	89,752,000
MU9	2,132,355	16.4	0.29	7.481	75,858,000
MU10*	3,610,000	18.0	0.29	7.481	140,955,000
MU11*	2,100,000	22.0	0.29	7.481	100,217,000
*Estimated					

Groundwater Transfer

During the groundwater transfer step, water may be transferred between the mine unit commencing restoration and a mine unit commencing mining operations. Baseline quality water from the mine unit starting mining may be pumped and injected into the mine unit in restoration. The higher TDS water from the mine unit in restoration is recovered and injected into the mine unit commencing mining. The direct transfer of water will act to lower the TDS in the mine unit being restored by displacing water affected by the mining with baseline quality water.

The goal of the groundwater transfer step is to blend the water in the two mine units until they become similar in conductivity. The recovered water may be passed through ion exchange columns and filtration during this step if suspended solids are sufficient in concentration to present a problem with blocking the injection well screens.

groundwater sweep or other activity will be utilized as the first step of restoration. The advantage of using the groundwater transfer technique is that it reduces the amount of water that must ultimately be sent to the wastewater disposal system during restoration activities.

Groundwater Sweep

During groundwater sweep, water is pumped without injection from the wellfield, causing an influx of baseline quality water from the perimeter of the mining unit, which sweeps the affected portion of the aquifer. The cleaner baseline quality water has lower ion concentrations that act to strip off the cations that have attached to the clays during mining. The affected water near the edge patterns of the wellfield is also drawn into the boundaries of the mine unit. The number of pore volumes transferred during groundwater sweep, if any, is dependent upon the presence of other active mine units along the mine unit boundary, the capacity of the wastewater disposal system, and the success of the groundwater transfer step in lowering TDS.

Groundwater Treatment

Following the groundwater sweep step, water will be pumped from production wells to treatment equipment and then re-injected into the wellfield. IX, RO, and/or Electro Dialysis Reversal (EDR) treatment equipment is generally used during this stage as shown on the generalized restoration flow sheet on **Figure 6.1-1**.

Water recovered from restoration that contains a significant amount of uranium is passed through the IX system. The IX columns exchange the majority of the contained soluble uranium for chloride or sulfate. Once the solubilized uranium is removed, a small amount of reductant may be metered into the restoration wellfield injection to reduce any pre-oxidized minerals. The concentration of reductant injected into the formation is determined by the concentration and type of trace elements encountered.

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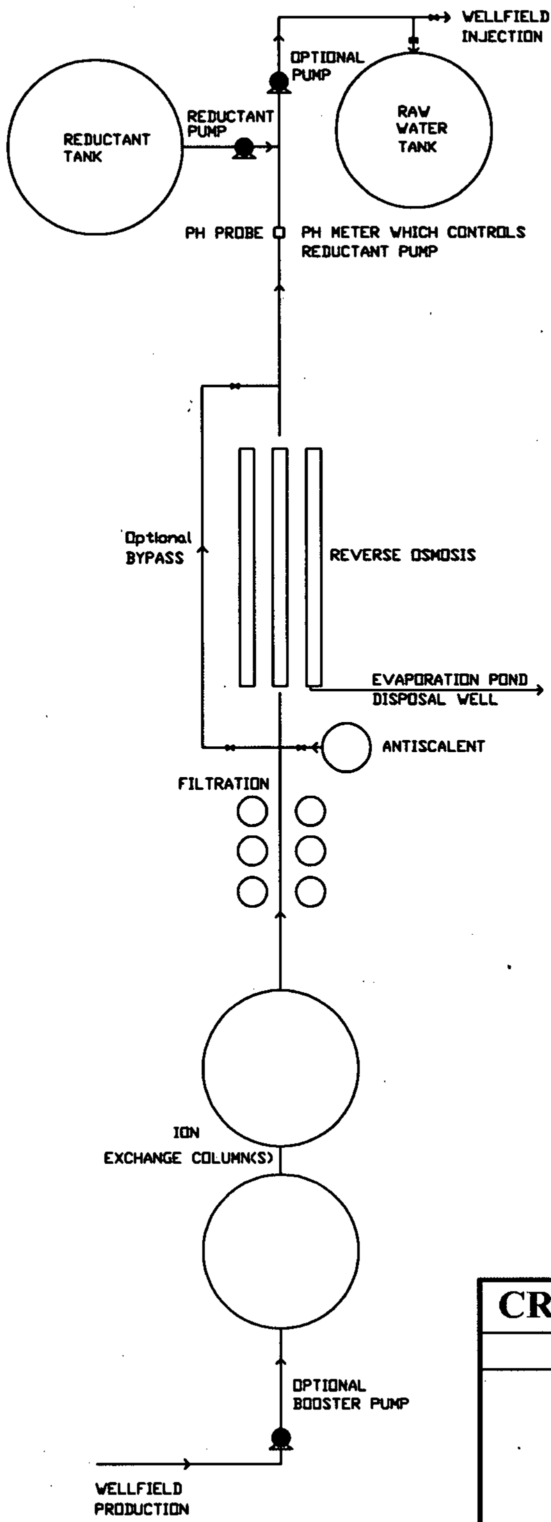
FIGURE 6.1-1
Restoration Process Flow Diagram



CROW BUTTE RESOURCES	
DAWES COUNTY, NEBRASKA	
Restoration Process Flow Diagram	
Prepared By : JD	
Drawn By: JD	Date: 3/30

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The concentration of reductant injected into the formation is determined by the concentration and type of trace elements encountered. The goal of reductant addition is to reduce those minerals that are solubilized by carbonate complexes to prevent the buildup of dissolved solids, which would increase the time for restoration to be completed.

A portion of the restoration recovery water can be sent to the reverse osmosis (RO) unit. The use of a RO unit 1) reduces the total dissolved solids in the contaminated groundwater, 2) reduces the quantity of water that must be removed from the aquifer to meet restoration limits, 3) concentrates the dissolved contaminates in a smaller volume of brine to facilitate waste disposal, and 4) enhances the exchange of ions from the formation due to the large difference in ion concentration.

Before the water can be processed by the RO, soluble uranium can be removed by the IX system. The RO unit contains membranes that pass about 60 to 75 percent of the water through, leaving 60 to 90 percent of the dissolved salts in the water that will not pass the membranes. **Table 6.1-13** shows typical RO manufacturers specification data for removal of ion constituents. The clean water, called "permeate", will be re-injected, sent to storage for use in the mining process, or to the wastewater disposal system. The 25 to 40 percent of water that is rejected, called "brine", contains the majority of dissolved salts that contaminate the groundwater and is sent for disposal in the waste system. Make-up water may be added to the wellfield injection stream to control the amount of "bleed" in the restoration areas.

The reductant (either biological or chemical) added to the injection stream during the groundwater treatment stage will scavenge any oxygen and reduce the oxidation-reduction potential (Eh) of the aquifer. During mining operations, certain trace elements are oxidized. By adding a reductant, the Eh of the aquifer is lowered, thereby decreasing the solubility of these elements. Hydrogen sulfide (H_2S), sodium sulfide (Na_2S), or a similar compound will be added as a reductant. CBR typically uses sodium sulfide due to the chemical safety issues associated with proper handling of hydrogen sulfide. A comprehensive safety plan regarding reductant use is implemented.

The number of pore volumes treated and re-injected during the groundwater treatment stage will depend on the efficiency of the RO in removing TDS and the reductant in lowering the uranium and trace element concentrations. Pore volumes being used at the current CBR site are discussed at the beginning of this section.

Another potential method for groundwater treatment within the wellfield is through bioremediation. Bioremediation entails adding an organic electron donor, such as cheese whey, to the aquifer to stimulate native bacteria. As the bacteria feed on the organic media they generate a reducing environment which in turn causes most metals in solution to precipitate back to their original state. The concentration of native bacteria colonies returns to normal levels once the organic media is consumed. Crow Butte Resources, Inc. will seek approval before initiating bioremediation. CBR is currently performing a bioremediation test in the north section of Mine Unit 4, Wellhouse 9. This test is

evaluating the effectiveness of in situ bioremediation by applying it to a field scale test in a small well pattern consisting of six (6) wells. The system was installed in December, 2008, and will operate for one year and then be evaluated. The nutrient being used is Emulsified Oil Substrate (EOS), a commercial product designed for enhancing groundwater bioremediation.

Table 6.1-13: Typical Reverse Osmosis Membrane Rejection

Name	Symbol	Percent Rejection
Cations		
Aluminum	Al^{+3}	99+
Ammonium	NH_4^{+1}	88-95
Cadmium	Cd^{+2}	96-98
Calcium	Ca^{+2}	96-98
Copper	Cu^{+2}	98-99
Hardness	Ca and Mg	96-98
Iron	Fe^{+2}	98-99
Magnesium	Mg^{+2}	96-98
Manganese	Mn^{+2}	98-99
Mercury	Hg^{+2}	96-98
Nickel	Ni^{+2}	98-99
Potassium	K^{+1}	94-96
Silver	Ag^{+1}	94-96
Sodium	Na^{+}	94-96
Strontium	Sr^{+2}	96-99
Zinc	Zn^{+2}	98-99
Anions		
Bicarbonate	HCO_3^{-1}	95-96
Borate	$B_4O_7^{-2}$	35-70
Bromide	Br^{-1}	94-96
Chloride	Cl^{-1}	94-95
Chromate	CrO_4^{-2}	90-98
Cyanide	CN^{-1}	90-95
Ferrocyanide	$Fe(CN)_6^{-3}$	99+
Fluoride	F^{-1}	94-96
Nitrate	NO_3^{-1}	95
Phosphate	PO_4^{-3}	99+
Silicate	SiO_2^{-1}	80-95
Sulfate	SO_4^{-2}	99+
Sulfite	SO_3^{-2}	98-99
Thiosulfate	$S_7O_3^{-2}$	99+

Source: Osmonics, Inc.

Wellfield Recirculation

At the completion of the Groundwater Treatment Stage, wellfield recirculation may be initiated. In order to homogenize the aquifer, pumping from the production wells and re-injecting the recovered solution into injection wells may be performed to blend solutions.

The sequence of the activities will be determined by CBR based on operating experience and waste water system capacity. Not all phases of the restoration stage will be used if deemed unnecessary by CBR.

Once the restoration activities are completed, CBR will sample the restoration wells and determine if the mining unit has achieved the restoration values, on a mine unit average basis. If so, CBR will notify the regulatory agencies that it is initiating the Stabilization Stage and will submit supporting documentation that the restoration parameters are at or below the restoration standards. If at the end of restoration activities the parameters are not at or below the approved values, CBR will either re-initiate certain steps of the restoration plan or submit documentation to the agencies that the best practical technology has been used in restoration. The documentation will include a justification for alternate parameter value(s) including available water quality data and a narrative of the restoration techniques used.

6.1.5 Groundwater Stabilization

Upon completion of restoration, a groundwater stabilization monitoring program will begin.in which the restoration wells and monitor wells will be sampled and analyzed for the restoration parameters listed in **Table 6.1-1**.

Although CBR's CSA Class III UIC Permit requires a minimum of a 6-month period for stability monitoring of a mine unit to demonstrate the success of restoration activities (stabilization), for purposes of this license, the specified ore zone monitoring wells will be sampled at a frequency of once each quarter. The monitoring on a quarter-year basis will continue until the data from the most recent four consecutive quarters indicate no statistically significant increasing trend for all constituents of concern at which point will be deemed complete, subject to approval.

Throughout restoration and stabilization, excursion monitoring, consistent with Section 5.8.8.2, will continue until NRC determines that groundwater stabilization has been demonstrated.

6.1.6 Groundwater Restoration Reporting

During the restoration process CBR will perform daily, weekly, and monthly analyses as needed to track restoration progress. These analyses will be summarized and discussed in the *Semiannual Radiological Effluent and Environmental Monitoring Report* submitted to USNRC. This information will also be included in the final report on restoration.

Upon completion of restoration activities and before stabilization, all designated restoration wells in the mine unit will be sampled for the constituents listed in **Table 6.1-1**. If restoration activities have returned the wellfield average of restoration parameters to concentrations at or below those approved by the USNRC and the NDEQ, CBR will proceed with the stabilization phase of restoration.

During stabilization, all designated restoration wells will be sampled in accordance with the respective agencies' sampling requirements for the constituents listed in **Table 6.1-1**. At the end of each agency's stabilization period, CBR will compile all water quality data obtained during restoration and stabilization and submit a final report. If the analytical results continue to meet the appropriate standards for the mine unit and do not exhibit significant increasing trends, CBR would request the mine unit be declared restored. Following agency approval, wellfield reclamation and plugging and abandonment of wells will be performed as described in Section 6.2.

6.2 PLANS FOR RECLAIMING DISTURBED LANDS

The following section addresses the final decommissioning methods of disturbed lands including wellfields, plant areas, evaporation ponds, and diversion ditches that will be used on the Crow Butte project sites. The section discusses general procedures to be used during final decommissioning as well as the decommissioning of a particular phase or production unit area.

Decommissioning of wellfields and process facilities, once their usefulness has been completed in an area, will be scheduled after agency approval of groundwater restoration and stability. Decommissioning will be accomplished in accordance with an approved decommissioning plan and the most current applicable NDEQ and USNRC rules and regulations, permit and license stipulations and amendments in effect at the time of the decommissioning activity.

The following is a list of general decommissioning activities:

- Plug and abandon all wells as detailed in **Section 6.2.4**.
- Determination of appropriate cleanup criteria for structures (**Section 6.3**) and soils (**Section 6.4**).
- Radiological surveys and sampling of all facilities, process related equipment and materials on site to determine their degree of contamination and identify the potential for personnel exposure during decommissioning.
- Removal from the site of all contaminated equipment and materials to an approved licensed facility for disposal or reuse, or relocation to an operational portion of the mining operation as discussed in **Section 6.3**.
- Decontamination of items to be released for unrestricted use to levels consistent with the requirements of USNRC.
- Survey excavated areas for contamination and remove contaminated materials to a licensed disposal facility.
- Perform final site soil radiation surveys.
- Backfill and recontour all disturbed areas.
- Establish permanent revegetation on all disturbed areas.

The following sections describe in general terms the planned decommissioning activities and procedures for the Crow Butte facilities. CBR will submit to the USNRC and NDEQ a detailed Decommissioning Plan for their review and approval at least 12 months before planned commencement of final decommissioning. As required by 10 CFR 40.36 (f), records of information important to decommissioning will be maintained in the office of the on-site RSO. Such information shall meet the criteria of 10 CFR 40.42 (g) (4) and (5).

6.2.1 General Surface Reclamation Procedures

The primary surface disturbances associated with solution mining are the sites containing the Central Processing Plant and associated facilities, Satellite Facilities, and evaporation ponds. Surface disturbances also occur during the well drilling program, pipeline installation, and road construction. These more superficial disturbances, however, involve relatively small areas or have short-term impacts.

The principal objective of the surface reclamation plan is to return disturbed lands to production compatible with the post mining land use of equal or better quality than the premining condition. For the License Area, the reclaimed lands should be capable of supporting livestock grazing and providing stable habitat for native wildlife species. Soils, vegetation, wildlife and radiological baseline data will be used as guidelines for the design, completion and evaluation of surface reclamation. Final surface reclamation will blend affected areas with adjacent undisturbed lands so as to re-establish original slope and topography and present a natural appearance. Surface reclamation efforts will strive to limit soil erosion by wind and water, sedimentation and re-establish natural trough drainage patterns.

The following sections provide procedural techniques for surface reclamation of all disturbances contained in the CBR mine plan. Provided are reclamation procedures for the facility sites, wellfield production units, evaporation ponds, and access and haul roads. Reclamation schedules for wellfield production units will be discussed separately because they are dependent upon the progress of mining and the successful completion of groundwater restoration. Cost estimates for bonding calculations are discussed in **Section 6.6** and include all activities that are anticipated to complete groundwater restoration, decontamination, decommissioning, and surface reclamation of wellfield and satellite plant facilities installed. These cost estimates are updated annually to cover work projected for the next year of mining activity.

6.2.1.1 Topsoil Handling and Replacement

In accordance with NDEQ requirements, topsoil is salvaged from building sites (including Satellite buildings) and pond areas. Conventional rubber-tired, scraper-type earth moving equipment is typically used to accomplish such topsoil salvage operations. The exact location of topsoil salvage operations is determined by wellfield pattern emplacement and designated wellfield access roads within the wellfields, which are determined during final wellfield construction activities.

As described in **Section 2.6**, topsoil thickness varies within the current License Area. Topsoil thickness is usually greatest in and along drainages where material has been deposited and deep soils have developed. Therefore, topsoil stripping depths may vary in depth, depending on location and the type of structure being constructed. In cases where it is necessary to strip topsoil in relatively large areas, such as a major road or building site, field mapping and Soil Conservation Service Soil Surveys will be utilized to determine approximate topsoil depths.

Salvaged topsoil is stored in designated topsoil stockpiles. These stockpiles are generally located on the leeward side of hills to minimize wind erosion. Stockpiles are not located in drainage channels. The perimeter of large topsoil stockpiles may be bermed to control sediment runoff. Topsoil stockpiles are seeded as soon as possible after construction with the permanent seed mix to promote stability and minimize erosion.

During mud pit excavation associated with well construction, exploration drilling and delineation drilling activities, topsoil is separated from subsoil with a backhoe. When use of the mud pit is complete, all subsoil is replaced and topsoil is applied. Mud pits generally remain open a short time. The success of revegetation efforts at the current site show that these procedures adequately protect topsoil and result in vigorous vegetation growth.

6.2.1.2 Contouring of Affected Areas

Due to the relatively minor nature of disturbances created by in-situ mining, there are only a few areas disturbed to the extent to which subsoil and geologic materials are removed, causing significant topographic changes that need backfilling and recontouring. Generally speaking, solar evaporation pond construction results in redistribution of sufficient amounts of subsurface materials, which requires replacement and contour blending during reclamation. The existing contours will only be interrupted in small, localized areas. Because approximate original contours will be achieved during final surface reclamation, no post mining contour maps have been included in this application.

Changes in the surface configuration caused by construction and installation of operating facilities will be only temporary, during the operating period. These changes will be caused by topsoil removal and storage along with the relocation of subsoil materials used for construction purposes. Restoration of the original land surface, which is consistent with the pre- and post-mining land use, the blending of affected areas with adjacent topography to approximate original contours and the reestablishment of drainage patterns will be accomplished by returning the earthen materials moved during construction to their approximate original locations.

Drainage channels that have been modified by the mine plan for operational purposes such as road crossings will be reestablished by removing fill materials, culverts and reshaping to as close to pre-operational conditions as practical. Surface drainage of disturbed areas that have been located on terrain with varying degrees of slope will be accomplished by final grading and contouring appropriate to each location so as to allow for controlled surface run off and eliminate depressions where water could accumulate.

6.2.1.3 Revegetation Practices

Revegetation practices are conducted in accordance with NDEQ requirements. During mining operations the topsoil stockpiles, and as much as practical of the disturbed wellfield and pond areas, will be seeded with vegetation to minimize wind and water erosion. After placement of topsoil and contouring for final reclamation, an area will

normally be seeded with a seed mixture developed in consultation with the Natural Resource Conservation Service as required by the NDEQ.

6.2.2 Process Facility Site Reclamation

Following removal of structures as discussed in **Section 6.3**, subsoil and stockpiled topsoil will be replaced on the disturbances from which they were removed during construction, within practical limits. Areas to be backfilled will be scarified or ripped prior to backfilling to create an uneven surface for application of backfill. This will provide a more cohesive surface to eliminate slipping and slumping. The less suitable subsoil and unsuitable topsoil, if any, will be backfilled first so as to place them in the deepest part of the excavation to be covered with more suitable reclamation materials. Subsoils will be replaced using paddle wheel scrapers, bulldozers or other appropriate equipment to transfer the earth from stockpile locations or areas of use and to spread it evenly on the ripped disturbances. Grader blades may be used to even the spread of backfill materials. Topsoil replacement will commence as soon as practical after a given disturbed surface has been prepared. Topsoil will be picked up from storage locations by paddle wheel scrapers or other appropriate equipment and distributed evenly over the disturbed areas. The final grading of topsoil materials will be done so as to establish adequate drainage and the final prepared surface will be left in a roughened condition.

6.2.3 Evaporation Pond Decommissioning

6.2.3.1 Disposal of Pond Water

The volume of water remaining in the lined evaporation ponds after restoration as well as its chemical and radiological characteristics will be considered to determine the most practical disposal program. Disposal options for the pond liquid include evaporation sprays, treatment and disposal in the deep well, or transportation to another licensed facility or disposal site. Currently, there are no plans for treating and discharging the pond water under an NPDES permit.

6.2.3.2 Pond Sludge and Sediments

Pond sludges and sediments will contain mining process chemicals and radionuclides. Wind blown sand grains and dust blown into the ponds during their active life also add to the bulk of sludges. This material will be contained within the pond bottom and kept in a dampened condition at all times, especially during handling and removal operation to prevent the spread of airborne contamination and potential worker exposure through inhalation. Dust abatement techniques will be used as necessary. The sludge will be removed from the ponds and loaded into roll off containers, dump trucks or drums and transported to a USNRC licensed disposal facility.

6.2.3.3 Disposal of Pond Liners and Leak Detection Systems

Pond liners will be kept washed down and intact as much as practical during sludge removal so as to confine sludges and sediments to the pond bottom. Pond liners will be

cut into strips and transported to a USNRC licensed disposal facility or will be decontaminated for release to an unrestricted area. After removal of the pond liners, the pond leak detection system piping will be removed. Materials involved in the leak detection system will be surveyed and released for unrestricted use if not contaminated or transported to a USNRC licensed facility for disposal. The earthen material in the pond bottom and leak detection system trenches will be surveyed for soil contamination. Any contaminated soil in excess of the cleanup criteria discussed in Section 6.4.1. will be removed and disposed at a USNRC licensed disposal facility.

Following the removal of all pond materials and the disposal of any contaminated soils, surface preparation will take place prior to reclamation.

6.2.3.4 On Site Burial

At the present time, on site burial of contaminants is not anticipated; however, depending upon the availability of a USNRC licensed disposal site at the time of decommissioning, on site burial may become a potential alternative. Should this occur, pond locations would be considered initially as the on site disposal locations for contaminated materials. Appropriate licensing with the regulatory agencies would be obtained prior to any on site disposal of contaminated wastes.

6.2.4 Wellfield Decommissioning

Surface reclamation in the wellfield production units will vary in accordance with the development sequence and the mining/reclamation timetable. Final surface reclamation of each wellfield production unit will be completed after approval of groundwater restoration stability and the completion of well abandonment activities discussed below. Surface preparation will be accomplished as needed so as to blend any disturbed areas into the contour of the surrounding landscape.

Wellfield decommissioning will consist of the following steps:

- The first step of the wellfield decommissioning process will involve the removal of surface equipment. Surface equipment primarily consists of the injection and production feed lines, wellhouses, electrical and control distribution systems, well boxes, and wellhead equipment. Wellhead equipment such as valves, meters or control fixtures will be salvaged.
- Removal of buried wellfield piping.
- Wells will be plugged and abandoned according to the procedures described below.
- The wellfield area may be recontoured, if necessary, and a final background gamma survey conducted over the entire wellfield area to identify any contaminated earthen materials requiring removal to disposal.

- Final revegetation of the wellfield areas will be conducted according to the revegetation plan.
- All piping, equipment, buildings, and wellhead equipment will be surveyed for contamination prior to release in accordance with the USNRC guidelines for decommissioning.

It is estimated that a significant portion of the equipment will meet release limits, which will allow disposal at an unrestricted area landfill. Other materials that are contaminated will be acid washed or decontaminated with other methods until they are releasable. If the equipment cannot be decontaminated to meet release limits, it will be disposed of at a USNRC licensed disposal facility.

Wellfield decommissioning will be an independent ongoing operation throughout the mining sequence at the License Area. Once a production unit has been mined out and groundwater restoration and stability have been accepted by the regulatory agencies, the wellfield will be scheduled for decommissioning and surface reclamation.

6.2.4.1 Well Plugging and Abandonment

All wells no longer useful to continue mining or restoration operations will be abandoned. These include all injection and production wells, monitor wells, and any other wells within the production unit used for the collection of hydrologic or water quality data or incidental monitoring purposes. The only known exception at this time may be a shallow well that could be transferred to the landowner for domestic or livestock use.

The objective of the Crow Butte well abandonment program is to seal and abandon all wells in such a manner as to assure the groundwater supply is protected and to eliminate any potential physical hazard.

Prior to abandoning a well, data are gathered (static water level, under-ream interval, casing depth) for use in a well abandonment spreadsheet that accounts for formation pressures, mining injection pressures, static water level, casing depth, materials used and weight of material used. Based on that information, adjustments can be made to the amount of bentonite chips to be used to plug the well screens, and also to calculate the minimum weight (lbs/gallon) of abandonment mud to be used to fill the hole to the surface and keep formation and mining pressures from allowing water to rise in the borehole. A prepackaged bentonite-filled tube currently is used for plugging the well screens. These tubes are placed into the screens by filling the well to the surface with water from a water truck, and then dropping the bentonite tubes down the well. The water is allowed to run while the tubes make their descent into the screens. The drill rig then trips drill pipe into the well and tags the bentonite to verify it has reached the targeted depths. The drill stem is raised approximately 10 feet and a Plug-gel abandonment mud is mixed. If the weight of the abandonment mud needs to be increased, an amount of barite may be added to increase the weight. Likewise, a drilling additive (Dris-pac) may be

added to improve the ability of the abandonment mud to carry the barite. In situations where it appears that the operating pressure and formation pressure are great enough to make it difficult to mix heavy mud, cement slurry may be substituted to fill the casing to the surface. All abandoned wells will remain above the surface until the wellfield is reclaimed. This allows for the continuation of monitoring and observation of the integrity of the abandonment fluid. If needed, additional abandonment fluids are added. The plugging method is approved by the NDEQ and is generally as summarized below:

- A mechanical plug may be placed above the screened interval.
- Thirty to fifty feet of coarse bentonite chips will be added to provide a grout seal.
- A plug gel or cement grout will be placed by tremie pipe from the chips to the top of the casing. The weight of the gel or grout plus the weight of the bentonite chips will be enough to exceed the local Chadron formation pressure plus the maximum injection pressure allowed (100 psi).
- The tremie pipe will be removed (when possible) and the casing will be filled to the surface.
- An approved hole plug will be installed.
- The well casing will be cut off below ground level, capped with cement, and the surface disturbance will be smoothed and contoured.
- The hole will be backfilled and the area revegetated.

Records of abandoned wells will be tabulated and reported to the appropriate agencies after decommissioning. CBR must submit a notarized affidavit to the NDEQ detailing the significant data and the procedure used in connection with each well plugged. The Nebraska Department of Natural Resources (NDNR) also requires filing a well abandonment notice for all registered wells.

6.2.4.2 Buried Trunklines, Pipes and Equipment

Buried process related piping such as injection and production lines will be removed from the mine unit undergoing decommissioning. Salvageable lines will be held for use in ongoing mining operations. Lines that are not reusable may either be assumed to be contaminated and disposed of at a licensed disposal site or may be surveyed and, if suitable for release to an unrestricted area, may be sent to a sanitary landfill.

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6.3 REMOVAL AND DISPOSAL OF STRUCTURES, WASTE MATERIALS, AND EQUIPMENT

CBR would submit a final, detailed decommissioning plan for structures and equipment to the NRC for review and approval at least 12 months before the planned commencement of decommissioning of such structures and equipment. This final decommissioning plan would describe structures and equipment to be decommissioned, planned decommissioning activities, methods that will be implemented to ensure protection of workers and the environment against radiation hazards, the planned final radiation survey, and provide an updated detailed cost estimate.

The procedures to be used for removing and disposing of structures, waste materials and equipment would meet the following criteria:

- A written program is in place to control residual contamination on structures and equipment.
- Measurements of radioactivity on the interior surface of pipes, drain lines, and duct work would be determined by conducting measurements at all traps and other appropriate access points, provided that such contamination is likely to be representative of contamination on the interior of the pipes, drain lines and ductwork.
- Any surfaces of premises, equipment, or scrap that would likely be contaminated, but are of such size, construction, or location as to make the surface inaccessible for purposes of measurement, would be presumed to be contaminated in excess of the limits.
- Prior to the release of structures for unrestricted use, a comprehensive radiation survey would be made to establish that contamination is within the limits specified in NRC *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material* (USNRC 1987) and NRC approval would be obtained.
- A contract between CBR and a waste disposal operator would be in place to dispose of 11e.(2) byproduct material.

6.3.1 Preliminary Radiological Surveys and Contamination Control

Prior to process plant decommissioning, a preliminary radiological survey will be conducted to characterize the levels of contamination on structures and equipment and to identify any potential hazards. The survey will support the development of procedures for dealing with such hazards prior to commencement of decommissioning activities. In general, the contamination control program used during mining operations (as discussed in **Section 5.8**) will be appropriate for use during decommissioning of structures.

Based on the results of the preliminary radiological surveys, gross decontamination techniques will be employed to remove loose contamination before decommissioning activities proceed. This gross decontamination will generally consist of washing all

accessible surfaces with high-pressure water. In areas where contamination is not readily removed by high-pressure water, a decontamination solution (e.g., dilute acid) may be used.

6.3.2 Removal of Process Buildings and Equipment

The majority of the process equipment in the process building will be reusable, as well as the building itself. Alternatives for the disposition of the building and equipment are discussed in this section.

All process or potentially contaminated equipment and materials at the process facility including tanks, filters, pumps, piping, etc., will be inventoried, listed and designated for one of the following removal alternatives:

- Removal to a new location within the Crow Butte site for further use or storage;
- Removal to another licensed facility for either use or permanent disposal; or
- Decontamination to meet unrestricted use criteria for release, sale or other non-restricted use by others.

It is most likely that process buildings will be decontaminated, dismantled and released for use at another location. If decontamination efforts were unsuccessful, the material would be sent to a permanent licensed disposal facility. Cement foundation pads and footings will be broken up and trucked to a licensed disposal site or properly licensed facility if contaminated.

6.3.2.1 Building Materials, Equipment and Piping to be Released for Unrestricted Use

Salvageable building materials, equipment, pipe and other materials to be released for unrestricted use will be surveyed for alpha contamination in accordance with license conditions contained in SUA-1534 and applicable USNRC guidance.

The CBR release limits for alpha radiation are as follows:

- Removable of 1,000 dpm/100 cm^2
- Average total of 5,000 dpm/100 cm^2 over an area no greater than one square meter
- Maximum total of 15,000 dpm/100 cm^2 over an area no greater than 100 cm^2

Monitoring for beta contamination is a current license requirement. This requirement has been eliminated in subsequent ANSI standards, including ANSI/HPS N13.12 (ANSI 1999). In addition, CBR has routinely made these measurements but has never found them limiting.

Decontamination of surfaces will comply with CBR's ALARA policy, to reduce surface contamination as far below the limits as practical.

Non-salvageable contaminated equipment, materials, and dismantled structural sections will be sent to an USNRC-licensed facility for disposal. In most cases, the byproduct material will be shipped as Low Specific Activity (LSA-I) material, UN2912, pursuant to 49 CFR 173.427.

6.3.2.2 Disposal at a Licensed Facility

If facilities or equipment are to be moved to a facility licensed for disposal of 11(e)2 byproduct material, the following procedures may be used.

- Flush inside of tanks, pumps, pipes, etc., with water or acid to reduce interior contamination as necessary for safe handling.
- The exterior surfaces of process equipment will be surveyed for contamination. If the surfaces are found to be contaminated the equipment will be washed down and decontaminated to permit safe handling.
- The equipment will be disassembled only to the degree necessary for transportation. All openings, pipe fittings, vents, etc., will be plugged or covered prior to moving equipment from the plant building.
- Equipment in the building, such as large tanks, may be transported on flatbed trailers. Smaller items, such as links of pipe and ducting material, may be placed in lined roll off containers or covered dump trucks or drummed in barrels for delivery to the receiving facility.
- Contaminated buried process trunk lines and sump drain lines will be excavated and removed for transportation to a licensed disposal facility.
- All other miscellaneous contaminated material will be transported to a licensed disposal facility.

6.3.2.3 Release for Unrestricted Use

If a piece of equipment or structure is to be released for unrestricted use, it will be appropriately surveyed before leaving the licensed area. Both interior and exterior surfaces will be surveyed to detect potential contamination. Radioactivity levels are determined on the interior surfaces of pipes, drain lines or duct work by making measurements in all traps and other appropriate access points, provided that contamination at these locations is expected to be representative of contamination on the interior of the pipes, drain lines or duct work. If the shape, size, or presence of inaccessible surfaces prevents an accurate and representative survey, the material will be assumed contaminated and properly disposed of. Appropriate decontamination procedures will be used to clean any contaminated areas and the equipment resurveyed and documentation of the final survey retained to show that unrestricted use criteria were met prior to releasing the equipment or materials from the site. The current release criteria are based on USNRC guidelines. The criteria used for release to unrestricted use

will be the appropriate USNRC guidelines at that time. Release surveys will be based on the release methods discussed in **Section 5.8**.

If a process building is left on site for unrestricted use by a landowner, the following basic decontamination procedures will be used. Actual corrective procedures will be determined by field requirements as defined by radiological surveys.

After the building has been emptied, the interior floors, ceiling and walls of the building and exterior surfaces at vent and stack locations will be checked for contamination. Any remaining removable contamination will be removed by washing. Areas where contamination was noted will be resurveyed to ensure removal of all contamination to appropriate levels.

Process floor sumps and drains will be washed out and decontaminated using water and, if necessary, acid solutions. If the appropriate decontamination levels cannot be achieved, it may be necessary to remove portions of the sump and floor to disposal.

Excavations necessary to remove trunklines or drains will be surveyed for contaminated earthen material. Earthen material that is found to be contaminated will be removed to a licensed disposal facility prior to backfilling the excavated areas.

The parking and storage areas around the building will be surveyed for surface contamination after all equipment has been removed.

Decontamination of these areas will be conducted as necessary to meet the standards for unrestricted use.

6.3.3 Waste Transportation and Disposal

Materials, equipment, and structures that cannot be decontaminated to meet the appropriate release criteria will be disposed of at a disposal site licensed by the USNRC or an Agreement State to receive 11(e)2 byproduct material. CBR currently maintains agreements with two such facilities located in the states of Utah and Wyoming for disposal of 11(e)2 byproduct materials generated by mining operations. A contract for disposal at a minimum of one facility will be maintained current as required in SUA-1534.

Transportation of all contaminated waste materials and equipment from the site to the approved licensed disposal facility or other licensed sites will be handled in accordance with the Department of Transportation (DOT) Hazardous Materials Regulations (49 CFR Part 173) and the USNRC transportation regulations (10 CFR 71).

6.4 METHODOLOGIES FOR CONDUCTING POST-RECLAMATION AND DECOMMISSIONING RADIOLOGICAL SURVEYS

6.4.1 Cleanup Criteria

Surface soils will be cleaned up in accordance with the requirements of 10 CFR Part 40, Appendix A, including a consideration of ALARA goals and the chemical toxicity of uranium.

The proposed limits and ALARA goals for cleanup of soils are summarized in **Table 6.4-1** and described below.

Table 6.4-1: Soil Cleanup Criteria and Goals

	Radium-226 (pCi/gm)		Natural Uranium (pCi/gm)	
Layer Depth	**Limit**	**Goal**	**Limit**	**Goal**
Surface (0-15 cm)	5	5	230	150
Subsurface (15 cm layers)	15	10	230	230

The existing radium-226 criterion in 10 CFR Part 40, Appendix A, was used to derive a dose criterion (Benchmark Approach) for the cleanup of byproduct materials. The Benchmark Dose was modeled using NRC's Residual Radioactivity (RESRAD) computer code. RESRAD Version 6.22 computer code was used to model the Crow Butte site and calculate the annual dose from the current radium cleanup standard. The results show that a concentration of 537 pCi/g for natural uranium in the top 15 cm layer of soil for the resident farmer scenario is equivalent to the Benchmark Dose derived from a concentration of 5 pCi/g of radium-226. The radium benchmark dose assessment modeling and assumptions, including outputs, are presented in Appendix B.

ALARA considerations require that an effort be made to reduce contaminants to as low as reasonably achievable levels. The ALARA goals are normally based on a cost-benefit analysis. For the cleanup of gamma-emitting radionuclides, the cost of cleanup becomes excessively high as soil concentrations and/or gamma emission rates become indistinguishable from background.

Cleanup of uranium mill sites has demonstrated that conservatively derived gamma action levels along with appropriate field survey and sampling procedures result in near background radium-226 concentrations for the site. In addition, the presence of a mixture of radium-226 and uranium will tend to drive the cleanup to even lower radium-226 concentrations. It is therefore believed that no specific ALARA goal is required for surface radium-226.

CBR proposes an ALARA goal of limiting the natural uranium concentration in the top 15 cm soil layer to 150 pCi/g, averaged over 100 m^2. According to the RESRAD runs shown in **Appendix B,** the ratio of radium-226 dose rate per pCi/g to the uranium dose

rate per pCi/g is 120. It is also shown by calculation that the ratio of radium-226 to uranium emission rates is 30. Therefore, if the action level for pure radium-226 results in cleanup of the site to less than 5 pCi/g, the action level should result in the cleanup of pure uranium to 30 times 5 or 150 pCi/g.

The uranium concentration should be limited to, at most, 230 pCi/g for all soil depths because of chemical toxicity concerns. Using the most conservative daily limit corresponding to the National Primary Drinking Water Standard, a soil limit of 230 pCi/g corresponds to the USEPA intake limit from drinking water with a uranium concentration of 0.06 mg/day.

CBR desires to reduce subsurface concentrations to a maximum of two-thirds of the proposed limit of 15 pCi/g radium-226. The subsurface uranium goal has not been reduced since it has not been demonstrated that these levels can be detected with readily available field instruments.

Section 2.5 of Appendix E to the Environmental Report supporting the license amendment application for the North Trend Expansion Area "Wellfield Decommissioning Plan for Crow Butte Uranium Project" demonstrates that spills of process solutions at the Crow Butte Uranium Project are not likely to contain substantial amounts of Thorium-230. CBR believes that developing soil cleanup criteria for Thorium-230 is not appropriate at this time. In the unlikely event that Thorium-230 is present in significant quantities, cleanup criteria will be developed using the Radium-226 benchmark approach and submitted to the NRC for approval prior to final site decommissioning.

6.4.2 Excavation Control Monitoring

CBR will use 17,900 cpm as its gamma action level, as determined with a Ludlum Model 44-10/2221 NaI detection system or equivalent held at 18 inches above ground surface. The gamma action level, defined as the gamma count rate corresponding to the soil cleanup criterion, will be used in the interpretation of the data. This action level will be used with caution, or until a new action level is developed.

Hand-held and GPS-based gamma surveys will be used to guide soil remediation efforts. Field personnel will monitor excavations with hand-held detection systems to guide the removal of contaminated material to the point where there is high probability that an area meets the cleanup criteria. Support will be provided by GPS-based gamma surveys periodically to more accurately assess the progress of excavation.

The 17,900 cpm action level was based on an evaluation of the correlation between gamma count rates and Ra-226 concentrations in soil using data from the few spill-related contaminated areas that existed at the main plant area. CBR believes that 17,900 cpm is a conservative value since the contaminated areas were small in size. The measured gamma emission rate per unit Ra-226 concentration from small areas is typically lower than that which would be measured using large areas, such as 100- m^2

area. Therefore, cleanup to 17,900 cpm should ensure that each 100- m^2 area meets the radium-226 soil cleanup standard.

Section 6.3 of Appendix E to the Environmental Report supporting the license amendment application for the North Trend Expansion Area "Wellfield Decommission Plan for Crow Butte Uranium Project" discusses the development of the 17,900 cpm action level. It does however allow for a revision of the number should it later be determined not appropriate.

6.4.3 Surface Soil Cleanup Verification and Sampling Plan

Cleanup of surface soils will be restricted to a few areas where there are known spills and, potentially, small spills near wellheads. Final GPS-based gamma surveys will be conducted in potentially contaminated areas, including 10 m buffer zones.

CBR will divide the area systematically into 100 m^2 grid blocks and sample all grid blocks containing gamma count rates exceeding the gamma action level. The samples will be five-point composites, and analyzed at an offsite laboratory for radium-226 and natural uranium.

CBR will sample the remaining grid blocks with average gamma count rates ranking in the top 10 percent.

If any grid blocks within the top 10 percent fail the cleanup criteria, CBR will sample the second ten percent of grid blocks. This will continue until all grid blocks pass within a 10 percent grouping. To meet the cleanup criterion, each of the sampled grid blocks must satisfy the following inequality,

$$\sum \frac{C_i}{Cc} < 1$$

where C_i is the concentration of the constituent and C_c is the concentration of the constituent that is equivalent to the Benchmark Dose.

CBR will remediate the grid blocks failing this inequality or propose alternatives consistent with Appendix A of 10 CFR 40.

After all sampled grids have met the inequality, an USEPA-recommended statistical test will be done to determine whether the mean of the equality defined above for all grid blocks is 1 or less at the 95 percent confidence level, using Equation 8-13 of draft NUREG/CR-5849 (USNRC 1992). If the mean of the sample concentrations is less than the criterion but the data fail the statistical test, CBR will follow procedures similar to those recommended in Section 8.6 of draft NUREG/CR-5849.

6.4.4 Subsurface Soil Cleanup Verification and Sampling Plan

For subsurfaces, CBR will adopt different survey and sample protocols, depending on the type and size of excavation. CBR will rely more on sampling and radium-226 and natural uranium analysis over surveying, to verify cleanup of subsurface excavations. The protocols are summarized in site procedures.

6.4.5 Temporary Ditches and Impoundments Cleanup Verification and Sampling Plan

CBR will adopt survey and sample protocols for temporary ditches and surface impoundments on a case-by-case basis. Ditches and impoundments can extend from the surface to the subsurface. For the purpose of decommissioning, the surfaces will be considered as part of adjacent soil surfaces. The subsurfaces will be surveyed and sampled systematically, based on their size and geometry. As with other subsurfaces, CBR will rely more on sampling and radium-226 and uranium analysis over surveying to verify cleanup of ditches and impoundments. Surveying is applicable in larger impoundments, however, wherein the effects of geometry are not as pronounced, particularly in areas not influenced by adjacent walls.

6.4.6 Quality Assurance

Verification soil samples will be sent to a commercial laboratory for analysis of radium-226 and natural uranium. The criteria that CBR will use to select the commercial laboratory will follow the guidance published in the Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP) (USNRC 2004). The commercial laboratory will adhere to a well-defined quality assurance program that addresses the laboratory's organization and management, personal qualifications, physical facilities, equipment and instrumentation, reference materials, measurement traceability and calibration, analytical method validation, SOPs, sample receipt, handing, storage, records, and appropriate licenses.

The analytical work performed by the commercial laboratory will adhere to CBR-defined Data Quality Objectives (DQOs). Part of the DQO process is specific analytical sensitivities required by CBR. The minimum sensitivity required for each sample will be 0.5 pCi/g dry weight for each analyte, with an estimated overall error of $\pm$ 0.5 pCi/g.

CBR will expect the reporting equivalent of an USEPA Contract Laboratory Program Level 3 data package from the commercial laboratory.

CBR will maintain a laboratory QA file that will include, at a minimum, the laboratory's Quality Assurance Manual (QAM) and audit reports.

6.5 DECOMMISSIONING HEALTH PHYSICS AND RADIATION SAFETY

The health physics and radiation safety program for decommissioning will ensure that occupational radiation exposure levels are kept as low as reasonably achievable during decommissioning. This program will ensure that contamination and any use of the premises, equipment or scrap will not result in an unacceptable risk to the health and safety of the public or the environment. The Radiation Safety Officer, Health Physics Technician or designee will be on site during any decommissioning activities where a potential radiation exposure hazard exists. In general, the radiation safety program discussed in **Section 5** will be used as the basis for development of the decommissioning health physics program. Health physics surveys conducted during decommissioning will be guided by applicable sections of Regulatory Guide 8.30 (USNRC 2002) or other applicable standards at the time.

6.5.1 Records and Reporting Procedures

At the conclusion of site decommissioning and surface reclamation, a report containing all applicable documentation will be submitted to the USNRC and NDEQ. Records of all contaminated materials transported to a licensed disposal site will be maintained for a period of five years or as otherwise required by applicable regulations at the time of decommissioning.

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6.6 FINANCIAL ASSURANCE

6.6.1 Bond Calculations

Cost estimates for the purpose of bond calculations are made annually for the Crow Butte Project site. The cost assessment includes groundwater restoration, decontamination and decommissioning and surface reclamation costs for all areas to be affected by the installation and operation of the proposed mine plan. The detailed calculations utilized in determining the bonding requirements for the Crow Butte Project are submitted annually.

6.6.2 Financial Surety Arrangements

CBR maintains an USNRC-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 (New York Branch) in favor of the State of Nebraska in the present (2007) amount of $22,980,913. The surety amount is revised annually in accordance with the requirements of SUA-1534.

6.6.3 References

American National Standards Institute (ANSI). 1999. ANSI/HPS N13.12, Surface and Volume Radioactivity Standards for Clearance.

Nebraska Department of Environmental Quality (NDEQ). 2006. Title 118 – Ground Water Quality Standards and Use Classification, March 27, 2006.

United States Nuclear Regulatory Commission (USNRC). 1992. NUREG/CR-5849, Manual for Conducting Radiological Surveys in Support of License Termination, Draft Report for Comment, June 1992.

United States Nuclear Regulatory Commission (USNRC). 1987. *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material.* Policy and Guidance Directive FC 83-23.

USNRC. 2002. Regulatory Guide No. 8.30, Health Physics Surveys in Uranium Recovery Facilities, May 2002.

Nuclear Regulatory Commission et al. (USNRC). 2004. Multi-Agency Radiological Laboratory Analytical Protocols Manual. NUREG 1576. July, 2004.

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7 ENVIRONMENTAL IMPACTS

The objective of the mining and environmental monitoring program is to conduct an operation that is economically viable and environmentally responsible. The environmental monitoring programs that are used to ensure that the potential sources of land, water and air pollution are controlled and monitored are presented in **Section 5.8**, Radiation Safety Controls and Monitoring.

This section discusses and describes the degree of unavoidable environmental impacts, the short and long-term impacts associated with operations and the consequences of possible accidents at the Crow Butte project.

Environmental impacts that have occurred since the approval of the Crow Butte Project 1997 LRA are summarized for well excursions and effluent releases as measured at groundwater monitoring, stream monitoring, air monitoring, and stream sediment sampling stations,

7.1 LAND USE IMPACTS

7.1.1 Land Surface Impacts

The primary surface disturbances associated with solution mining are the sites containing the processing plants and associated facilities including satellite facilities and evaporation ponds. Surface disturbances also occur during the well drilling program, pipeline installation, and road construction. These more superficial disturbances, however, involve relatively small areas or have short-term impacts.

Due to the relatively minor nature of disturbances created by in-situ mining, there are only a few areas disturbed to the extent to which subsoil and geologic materials are removed, causing significant topographic changes that need backfilling and recontouring. Generally speaking, solar evaporation pond construction results in redistribution of sufficient amounts of subsurface materials, which requires replacement and contour blending during reclamation. The existing contours have only been interrupted in small, localized areas. Because approximate original contours will be achieved during final surface reclamation, no post-mining contour maps have been included in this application.

Major facilities have already been constructed at the Crow Butte site. The site layout for the commercial operation and ancillary facilities **(Figure 2.1-2)** currently includes:

- The original Research and Development Process building housing the Reverse Osmosis unit to be utilized for groundwater restoration activities. This area also includes two wellfields, two solar evaporation ponds and access roads.
- A nominal 120' by 300' process building which is used for uranium extraction, precipitation, drying and packaging, offices, laboratories and change rooms.
- An office complex (75' x 75').

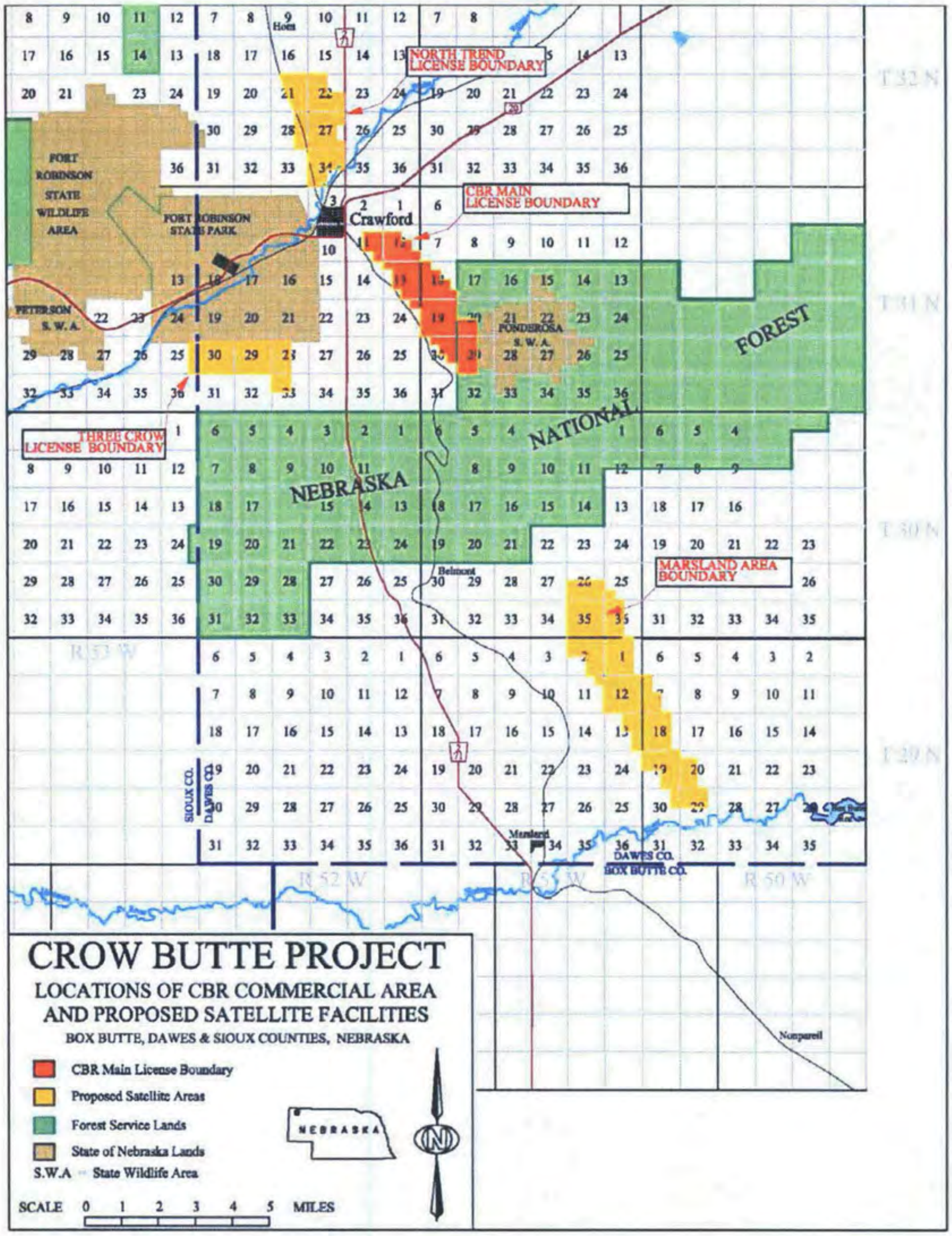
- A geology storage unit.
- Three commercial solar evaporation ponds.
- Deep well injection building located north of the main process facility.
- Maintenance, electrical and storage buildings located north of the main process facility.
- Drilling supply storage buildings.
- Commercial wellfields. Wellfield development includes a number of wellfield houses for each mine unit.
- Access roads.

CBR has identified three additional resource areas in the region near the Crow Butte Central Plant that could conceivably be developed as satellite facilities. CBR submitted a request on May 30, 2007, for an amendment to Source Material License SUA-1534 for the development of an additional uranium in-situ recovery mining resource referred to as the North Trend Expansion Area. Commercial production at the Crow Butte Project, including the proposed North Trend Expansion Area, is expected to extend over the next ten years with depletion of uranium reserves at both areas by 2017. Environmental impacts associated with the proposed North Trend Expansion Area are addressed in the above-referenced license amendment and are not addressed in this document.

A Notice of Intent dated March 4, 2009, was filed by CBR with the NRC advising of intent to file additional amendments to Source Material License SUA-1534 for the potential development of two additional development areas for use as satellite facilities to the current main CBR operating facilities. The proposed satellite facilities are referred to as the Three Crow Expansion Area (TCEA) and Marsland Expansion Area (MEA). Current plans are to submit a license amendment for the TCEA during the first quarter of 2010 and for the MEA during the third quarter 2012. CBR currently projects that development of these areas would be primarily intended to maintain production allowed under the current license as reserves in the current licensed area are depleted.

The proposed centerpoint of the NTEA satellite processing facilities would be located approximately 6 miles northwest of the centerpoint of the current license area processing facilities. The centerpoint of the TCEA satellite processing facilities would be located approximately 5 miles southwest of the centerpoint of the current license area processing facilities. The proposed centerpoint of the MEA satellite processing facility would be located approximately 12 miles southwest of the centerpoint of the current license area processing facilities The proposed satellite facilities locations in relation to the current license area and each other are shown in **Figure 7.1-1**.

Figure 7.1-1: Main Plant & Proposed Satellite Areas



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Future site construction of the current licensed resource area in the next one to two years, including the NTEA (subject to required NRC and NDEQ approvals) , may include the following:

- A satellite process facility and/or pumphouse that would be in the area of 5,000 square feet.
- Two solar evaporation ponds located in conjunction with the satellite facility.
- Additional access roads.

By License Amendment No. 22 dated November 30, 2007, expansion of the main process facility for an increase in production capacity from 5,000 gpm to 9,000 gpm was approved.

The total area impacted at any one time for the current License Area, not including access roads that will be reclaimed during the final stages of reclamation, is approximately 120 acres. All areas disturbed will be reclaimed either during the life of the mine or during final restoration and reclamation activities. Except for the wells, access roads, and possible satellite facility and/or pump houses scattered throughout the License Area, the facilities are confined to approximately 40 acres within Section 19, T31N, R51W, and Section 13, T31N, R52W, Dawes County, Nebraska.

Changes in the surface configuration caused by construction and installation of operating facilities will be only temporary, during the operating period. These changes are due to topsoil removal and storage along with the relocation of subsoil materials used for construction purposes.

These surface impacts are unavoidable and will last for the duration of the project until final decommissioning. Mitigation measures for land surface impacts are discussed in **Section 6.2.**

7.1.2 Land Use Impacts

The principal land use for the License Area and the 3.62 km (2.25 mile) review area is livestock grazing on rangeland. Rangeland accounted for 55.7 percent of the land use in the License Area and the review area as discussed in **Section 2.2.** The secondary land use within this area is cropland, primarily for wheat, although a small proportion is used for alfalfa. Cropland accounted for 29.9 percent of the land use in the Crow Butte License Area and the review.

Land use impacts have occurred from existing Crow Butte facilities such as site preparation and construction activities included topsoil salvaging, pond excavation, building erection, road construction and completion of injection, production and monitor wells.

The unavoidable impact of site preparation, construction, and operation are the exclusion of cattle and crop production from the areas that are under development. The exclusion of agricultural activities from active mining areas is an unavoidable impact that will last for the duration of the project. Pastureland accounts for 43 percent of the nearly 50,000-acre License Area and surrounding 3.6 km (2.25 mile buffer). Cropland accounts for 29 percent of the total area. **Figure 2.2-1** depicts the License Area containing existing permitted facilities, and the current land use types within the CSA, which includes the License Area and a surrounding 2-mile buffer area.

As a result of site preparation and construction, cattle production has been excluded from the areas that are under development. The total estimated area that has been impacted during the course of the project is the 120 acres associated with the plant and wellfields. As discussed in **Section 2.2**, livestock and livestock products had a value of $28.81 per acre, indicating that livestock production on rangeland within the impacted wellfield area has a potential value of more than $7,770.

As a result of site preparation and construction, crop production has been excluded from the areas that are under development. The total estimated cropland area that has been impacted during the course of the project is the 1,041.7 acres associated with the plant and wellfields. In 2001 Dawes County had 77,000 acres harvested for 123,800 tons of hay and 33,700 acres harvested for 1,198,700 bushels of winter wheat. These harvests resulted in yields of 1.6 tons of hay and 35.6 bushels of wheat per acre harvested. Based on these yields, the lost annual crop production in the License Area would be up to 1,666 tons of hay and up to 37,085 bushels of wheat.

These impacts are considered temporary and reversible by returning the land to its former grazing use through post-mining surface reclamation. Mitigation measures for the loss of agricultural production over the course of the project are discussed in **Section 6.2**.

7.2 TRANSPORTATION IMPACTS

7.2.1 Access Road Construction Impacts

As noted in **Section 2.2.3**, Nebraska Highway 2/71 and U.S. Highway 20 converge at Crawford. The Crow Butte Project site is about 4.0 miles southeast of the City of Crawford via the unpaved Squaw Creek Road. Nebraska Highway 2/71 provides access to the License Area from points north and south of Crawford. U.S. Highway 20 provides access to Crawford and the License Area from points east and west.

The Burlington Northern Santa Fe (BNSF) Railroad runs in a northwesterly direction approximately 0.75 miles west of the license area. The BNSF rail line along the western boundary is used for combining local "pusher" engines with southbound trains to assist them in climbing the Pine Ridge south of Crawford. This rail line accommodates a significant amount of rail traffic, primarily from the coal mines in northeastern Wyoming.

The DM&E Railroad runs in a northeasterly direction, and forms a portion of the southeast boundary of the License Area. The junction of the two railroads is about 0.50 miles south of the License Area.

The continued operations of the project will have no impact on railroad operations in the area.

Main access roads have been designed to allow safe access from public roads by employees, contractors, and delivery vehicles. The annual average traffic counts for 2004 ranged between 1,195 south of Crawford and 540 north of Crawford on Nebraska Highway 2, and 1,795 on U.S. Highway 20 north of the License Area (Nebraska Department of Roads 2007). Traffic associated with the operation of the current facility has not adversely impacted existing traffic, and this trend is expected to continue with future planned operations.

7.2.2 Transportation of Materials

Transportation of materials to and from the Crow Butte Central Plant is discussed in the following sections:

7.2.2.1 Shipments of Construction Materials, Process Chemicals, and Fuel from Suppliers to the Site

Shipments of maintenance materials, process chemicals, and fuel from suppliers will continue to be received at the Crow Butte Plant. These shipments will continue to generate some additional noise in the area as discussed in **Section 7.7**. Since the site access roads are surfaced with gravel, the shipments will continue to generate additional dust. Air quality impacts and mitigation are discussed in **Section 7.6**.

Based on the current production schedule and material balance, it is estimated that approximately 150 bulk chemical and fuel deliveries per year will be made to the Crow

Butte Main Plant. This averages about one truck per working day for delivery of fuel and chemicals throughout the operational life of the project. Types of deliveries include carbon dioxide, oxygen, soda ash, propane, hydrochloric acid, sodium hydroxide, hydrogen peroxide, and motor vehicle fuel.

Additionally, wellfield construction materials will be received periodically throughout the operational phase of the project. These shipments are expected to occur at a frequency of once per month.

7.2.2.2 Shipment of U_3O_3, Loaded Ion Exchange Resin and 11(e)2 By-Product Material, Yellowcake, Resin from the Site to a Licensed Disposal Facility

Low level radioactive waste or unusable equipment contaminated with 11(e)2 by-product material will continue to be generated during operations and will be transported to a licensed disposal site. Because of the low volume of radioactive 11(e)2 by-product material generated, these shipments will be infrequent (averaging two per year if using roll off containers).

Shipments of natural uranium (U_3O_3), Ion Exchange Resin loaded with U_3O_3 and 11(e)2 by-product material shipments will continue to be handled as Low Specific Activity (LSA) material. All shipments will comply with all applicable DOT and USNRC regulations governing the transportation of this material.

7.2.3 Impacts to Public Roads

The additional traffic generated by the continued operation of the proposed Crow Butte Project may result in degradation of public road surfaces. In particular, the additional traffic may adversely impact local gravel roads maintained by Dawes County. These impacts have been, and are expected to continue to be, minimal since the additional traffic is not significant in comparison with current traffic levels.

7.4 WATER RESOURCES IMPACTS

7.4.1 Surface Water Impacts of Construction and Decommissioning

When stormwater drains off a construction site, it typically carries sediment and other pollutants that can harm lakes, streams and wetlands. USEPA estimates that 20 to 150 tons of soil per acre is lost every year to stormwater runoff from construction sites. For this reason, stormwater runoff is controlled by National Pollutant Discharge Elimination System (NPDES) regulations.

Construction activities at the Crow Butte Project to date have had a minimal impact on the local hydrological system. CBR conducts construction activities under NDEQ permitting regulations for control of construction stormwater discharges contained in Title 119. CBR is required by NDEQ General Construction Stormwater NPDES Permit NER 100000 to implement procedures that control runoff and the deposition of sediment in surface water features during construction activities. These procedures are contained in SHEQMS Volume VI, *Environmental Manual,* and require active engineering measures, such as berms, and administrative measures, such as work activity sequencing to control runoff and sedimentation of surface water features. CBR must annually submit a construction plan for the coming year and obtain authorization from the NDEQ under the general permit.

The results of stream sediment sampling for most semiannual periods between 1998 and 2007 fall within the expected ranges, as shown in **Table 5.8-11** and **Figures 5.8-32** through **5.8-37**. In the second half of 2005, the concentrations of natural uranium in several English Creek samples were well above regional background levels. CBR has noted these elevated concentrations in the English Creek drainage during preoperational monitoring, which indicates that these levels are anomalous natural background concentrations.

7.4.2 Surface Water Impacts of Operations

7.4.2.1 Surface Water Impacts from Sedimentation

Protection of surface water from stormwater runoff during on-going wellfield construction related to operations is regulated by the NDEQ as discussed in **Section 7.4.1**.

7.4.2.2 Potential Surface Water Impacts from Accidents

Surface water quality could potentially be impacted by accidents such as an evaporation pond leakage or failure or an uncontrolled release of process liquids due to a wellfield accident. Section 7.4.3.3 discusses the operation of the ponds and measures to prevent and control wellfield spills. An additional measure to protect surface water is that wellfield areas are installed with dikes or berms to prevent spilled process solutions from entering surface water features. Process buildings are constructed with secondary containment, and a regular program of inspections and preventive maintenance is in

place. In addition to the administrative and engineering controls routinely implemented by CBR, it is expected that surface water impacts from potential accidents at the Crow Butte facilities will be minimal since there are no nearby surface water features.

7.4.3 Groundwater Impacts of Operations

Potential impacts to water resources from mining and restoration activities include the following.

7.4.3.1 Groundwater Consumption

As discussed in **Section 2.7**, a regional pump test has been conducted to assess the hydraulic characteristics of the Basal Chadron Sandstone, and overlying confining units. Pump tests are also performed for each mine unit to demonstrate hydraulic containment above the production zone, demonstrate communication between the production zone mining and exterior monitor wells, and to further evaluate the hydrologic properties of the Basal Chadron Sandstone.

A full and detailed analysis of the potential impacts of the mining operations at Crow Butte on surrounding water users have been provided in an Industrial Groundwater Use Permit application required by NDEQ. The permit application was submitted to NDEQ by Ferret of Nebraska, Inc. (predecessor to CBR) in 1991. The application states that water levels in the City of Crawford (approximately three miles northwest of the mining area) could potentially be impacted by approximately 20 feet by consumptive withdrawal of water from the Basal Chadron Sandstone during mining and restoration operations (based on a 20-year operational period).

A similar order of magnitude impact (drawdown) likely exists for the Crow Butte operations. No impact to other users of groundwater has been observed, nor is expected during future operations because: (1) there is no documented existing use of the Basal Chadron in the License Area; and, (2) the potentiometric head of the Basal Chadron Sandstone in the License Area ranges from approximately 40 to 200 feet below ground surface.

Because the Basal Chadron Sandstone (production zone) is a deep confined aquifer, no surface water impacts are expected. Further, the geologic and hydrologic data presented in **Sections 2.6** and **2.7**, respectively, demonstrate that (1) the occurrence of uranium mineralization is limited to the Basal Chadron Sandstone; and, (2) the Basal Chadron is isolated from underlying and overlying sands. Hence, the mining operations are expected to impact water quality only in the Basal Chadron Sandstone, and restoration operations will be conducted in the Basal Chadron following completion of mining.

Based on a bleed of 0.5 percent to 1.5 percent, which has been successfully applied in the current licensed area, the potential impact from consumptive use of groundwater is expected to be minimal. In this regard, the vast majority (e.g., on the order of 99 percent) of groundwater used in the mining process will be treated and re-injected. Potential

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Because the Basal Chadron Sandstone (production zone) is a deep confined aquifer, no surface water impacts are expected. Further, the geologic and hydrologic data presented in **Sections 2.6** and **2.7**, respectively, demonstrate that (1) the occurrence of uranium mineralization is limited to the Basal Chadron Sandstone; and, (2) the Basal Chadron is isolated from underlying and overlying sands. Hence, the mining operations are expected to impact water quality only in the Basal Chadron Sandstone, and restoration operations will be conducted in the Basal Chadron following completion of mining.

Based on a bleed of 0.5 percent to 1.5 percent, which has been successfully applied in the current licensed area, the potential impact from consumptive use of groundwater is expected to be minimal. In this regard, the vast majority (e.g., on the order of 99 percent) of groundwater used in the mining process will be treated and re-injected. Potential

impacts on groundwater quality due to consumptive use outside the license area are expected to be negligible.

Because of the uncertainty regarding the impact of the White River structural feature on groundwater flow in the Basal Chadron Sandstone, strict quantification of the mining impacts is difficult until more detailed information related to this feature is available.

To generally quantify the potential impact of drawdown due to mining and restoration operations, the following assumptions were used:

- Mining/restoration life: 20 years
- Average net consumptive use: 5112 gpm
- Location of pumping centroid: Center of Section 19
- Observation radius: 4 miles radially from centroid of pumping
- Formation transmissivity 330 ft^2/d
- Formation thickness 40 feet
- Formation hydraulic conductivity 9.0 ft/d
- Formation storativity 9.0×10^{-5}

The data was evaluated using a Theis semi-steady state analytical solution, which includes the following assumptions:

- The aquifer is confined and has apparent infinite extent;
- The aquifer is homogeneous and isotropic, and of uniform effective thickness over the area influenced by pumping;
- The piezometric surface is horizontal prior to pumping;
- The well is pumped at a constant rate;
- No recharge to the aquifer occurs;
- The pumping well is fully penetrating; and,
- Well diameter is small, so well storage is negligible.

Based on these assumptions and results from pumping tests, drawdown after 20 years of operation at a 4 mile radial distance from the centroid of pumping was calculated to be 23.6 feet. This amount of drawdown is approximately 4.5 percent of the available drawdown in the Basal Chadron Sandstone.

As discussed in **Section 5.8**, an extensive water-sampling program will be conducted prior to, during and following mining operations at the Crow Butte facility to identify any potential impacts to water resources of the area.

Water level measurements will be routinely performed in the production zone and overlying aquifer. Sudden changes in water levels within the production zone may indicate that the wellfield flow system is out of balance. Flow rates would be adjusted to correct this situation. Increases in water levels in the overlying aquifer may be an indication of fluid migration from the production zone. Adjustments to well flow rates or

complete shut down of individual wells may be required to correct this situation. Increases in water levels in the overlying aquifer may also be an indication of casing failure in a production, injection or monitor well. Isolation and shut down of individual wells can be used to determine the well causing the water level increases.

To ensure the leach solutions are contained within the designated area of the aquifer being mined, the production zone and overlying aquifer monitor wells will be sampled once every two weeks as discussed in **Section 5.8.**

These impacts are unavoidable aspects of solution mining. No mitigative measures have been identified.

7.4.3.2 Impacts on Groundwater Quality

Solution mining of a mineral deposit is accomplished by reversing the natural processes that deposited the uranium. The native formation waters in the ore zones in the Basal Chadron aquifer are not recommended for human consumption because of naturally high levels of dissolved radioactive materials (uranium and Ra-226). In addition to uranium, other metals will mobilize by the mining process. This process affects the mining zone, which must be exempted from Clean Water Act protections by the NDEQ and the USEPA under the aquifer exemption provisions of the State and Federal UIC regulations.

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

To date, there have been several confirmed horizontal excursions in the Chadron sandstone in the current license area. These excursions were quickly detected and recovered through overproduction in the immediate vicinity of the excursion. In all but one case, the reported vertical excursions were actually due to natural seasonal fluctuations in Brule groundwater quality and very stringent upper control limits (UCLs). In no case did the excursions threaten the water quality of an underground source of drinking water since the monitor wells are located well within the aquifer exemption area approved by the USEPA and the NDEQ. **Table 7.4-1** provides a summary of excursions reported for the License Area.

Table 7.4-1: Excursion Summary

Monitor Well ID	Date On Excursion	Date Off Excursion	Causal Factor(s)
CM6-6	July 1, 1999	September 23, 1999	Excursion of mining solutions
PR-15	January 13, 2000	March 23, 2000	Mine Unit 1 interior monitor well affected by adjacent groundwater restoration (unrelated to mining activities)
SM6-18	March 6, 2000	April 11, 2001	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
IJ-13	April 20, 2000		Mine Unit 1 interior monitor well affected by adjacent groundwater restoration (unrelated to mining activities)
SM7-23	April 27, 2000	January 13, 2004	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM6-28	May 25, 2000	June 22, 2000	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM6-13	May 25, 2000	July 20, 2000	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
SM6-12	September 8, 2000	November 20, 2000	Surface leak
SM6-13	March 1, 2001	April 12, 2001	Natural fluctuation of shallow groundwater quality (unrelated to mining activities)
CM5-11	September 10, 2002	May 6, 2003	Excursion of mining solutions
CM6-7	April 4, 2002	April 25, 2002	Excursion of mining solutions
PR-8	December 23, 2003		Mine Unit 1 interior monitor well affected by adjacent groundwater restoration (unrelated to mining activities)
CM5-19	May 2, 2005	July 26, 2005	Excursion of mining solutions
SM6-28	June 16, 2005	July 5, 2005	High water table due to heavy spring rains (unrelated to mining activities)
SM6-12	June 28, 2005	July 26, 2005	High water table due to heavy spring rains (unrelated to mining activities)
CM9-16	August 4, 2005	November 8, 2005	Excursion of mining solutions
CM8-21	January 18, 2006	April 7, 2006	Excursion of mining solutions
PR-15	September 26, 2006		See IJ-13 and PR-8

Notes:
Mitigative measures for impacts on groundwater quality are discussed in Section 5.3.

7.4.3.3 Potential Groundwater Impacts from Accidents

Groundwater quality could potentially be impacted during operations due to an accident such as evaporation pond leakage or failure, or an uncontrolled release of process liquids due to a wellfield accident. If there should be an uncontrolled pond leak or wellfield

accident, potential contamination of the shallow aquifer (Brule), as well as surrounding soil, could occur. This could occur as a result of a slow leak or a catastrophic failure, a shallow excursion, an overflow due to excess production or restoration flow, or due to the addition of excessive rainwater or runoff.

To mitigate the likelihood of pond failure, all ponds at Crow Butte have been designed and built to USNRC standards using impermeable synthetic liners. A leak detection system was also installed, and all ponds are inspected on a regular basis. In the event that a problem is detected, the contents of any given pond can be transferred to another pond while repairs are made. The pond design and operation is discussed in greater detail in **Section 4.2.**

Over the course of the current licensed operation, CBR has experienced several leaks associated with the inner pond liner on the commercial evaporation ponds. These small leaks are virtually unavoidable since the liners are exposed to the elements. In each case these leaks were quickly discovered during routine inspections, primarily due to a response in the underdrain system. Corrective actions included lowering the pond level and locating the leak to allow repairs. In none of these situations was the shallow groundwater affected since the outer pond liner functioned as designed and prevented a release of the pond contents. All pond leaks, causes, and corrective actions are reported to the USNRC and the NDEQ.

With respect to potential overflow of a pond, current SOPs require that pond levels be closely monitored as part of the daily inspection. Process flow to the ponds are minimal in comparison to the pond capacity, thus it can easily be diverted to another pond if necessary. In addition, sufficient freeboard is maintained on all ponds to allow for a significant addition of rainwater with no threat of overflow. Finally, the dikes and berms around the ponds channel runoff away from the ponds.

Another potential cause of groundwater impacts from accidents could be releases as a result of a spill of injection or production solutions from a wellfield building or associated piping. In order to control these types of releases, all piping is either PVC, high density polyethylene with butt welded joints, or equivalent. All piping is leak tested prior to production flow and following repairs or maintenance.

7.5 ECOLOGICAL RESOURCES IMPACTS

7.5.1 Effects of the Current Commercial Operation

Adverse impacts associated with development of the R&D operation and the current commercial operation included ground disturbing activities resulting from the construction of access roads, processing facility, active wells, and other project related needs. These disturbances have been less than 100 acres at any one time.

These disturbances have not significantly affected ecological resources because, as discussed in the baseline section, there is no critical habitat for any species within the CSA. Additionally, the small amount of project-disturbed land compared to the amount of similar habitat surrounding the area should not have affected populations of any species occurring there.

7.5.2 Impact Significance Criteria

The following criteria were used to determine the significance of construction and operation of the proposed project on wildlife and vegetation resources within the project area. These criteria were developed based on professional judgment, involvement in other USEPA projects throughout the West, and state and federal regulations.

- Removal of vegetation such that following reclamation, the disturbed area(s) would not have adequate cover (density) and species composition (diversity) to support pre-existing land uses, including wildlife habitat;
- Unauthorized discharge of dredged or fill materials into, or excavation of, waters of the U.S., including special aquatic sites, wetlands, and other areas subject to the Section 404 of the Clean Water Act, Executive Order 11988-flood plains, and Executive Order 11990 - wetlands and riparian zones;
- Reclamation is not accomplished in compliance with Executive Order 13112 (Invasive Species);
- Introduction and establishment of noxious or other undesirable invasive, non-native plant species to the degree that such establishment results in listed invasive, non-native species occupying any undisturbed rangeland outside of established disturbance areas or hampers successful revegetation of desirable species in disturbed areas;
- Whether or not a substantial increase in direct mortality of wildlife caused by road kills, harassment, or other causes would occur;
- Incidental take of a special-status species to the extent that such impact would threaten the viability of the local population;
- Whether or not an officially-designated critical wildlife habitat was eliminated, sustained a permanent reduction in size, or was otherwise rendered unsuitable;

- Whether or not any effect, direct or indirect, results in a long-term decline in recruitment and/or survival of a wildlife population; and
- Construction disturbance during the breeding season or impacts to reproductive success which could result in the incidental loss of fertile eggs or nestlings, or otherwise lead to nest abandonment in accordance with regulations prescribed by the Migratory Bird Treaty Act.

7.5.3 Vegetation

Direct impacts associated with project development and operations include the short-term loss of vegetation (modification of structure, species composition, and areal extent of cover types) from soil disturbance and grading. Potential indirect impacts include the short-term and long-term increased potential for non-native species invasion, establishment, and expansion; exposure of soils to accelerated erosion; shifts in species composition or changes in vegetative density; reduction of wildlife habitat; and changes in visual aesthetics. Vegetation removal and soil handling associated with the construction and installation of wellfields, pipelines, access roads, and satellite facilities would affect vegetation resources both directly and indirectly. However, because most project-related infrastructure will be constructed within cultivated agricultural fields, vegetation impacts will be negligible. If the mixed-grass prairie vegetation community were to be developed, direct impacts would include the short-term loss of vegetation (modification of structure, species composition, and areal extent of cover types). Indirect impacts would include the short-term and long-term increased potential for non-native species invasion, establishment, and expansion; exposure of soils to accelerated erosion; shifts in species composition or changes in vegetative density; reduction of wildlife habitat; reduction in livestock forage; and changes in visual aesthetics.

During the anticipated life of the project (15 to 18 years), an estimated 1,041.7 acres of cultivated agricultural fields would be affected by surface-disturbing production facilities. The likelihood of impact is greatest for the primary vegetation cover types of cultivated fields, which occupies 62 percent of the total impacted area. As stated above, clearing of mixed-grass prairie vegetation community types is not anticipated.

Construction activities, increased soil disturbance, and higher traffic volumes could stimulate the introduction and spread of undesirable and invasive, non-native species within the project area. Non-native species invasion and establishment has become an increasingly important result of previous and current disturbance in western states. These species often out-compete desirable species, including special-status species, rendering an area less productive as a source of forage for livestock and wildlife. Additionally, sites dominated by invasive, non-native species often have a different visual character that may negatively contrast with surrounding undisturbed vegetation. Currently, the project area is relatively free of noxious and other unwanted invasive, non-native species.

In general, the duration of effects on cultivated agricultural land and mixed-grass prairie vegetation are significantly different. Cropland areas can be readily returned to

production through fertilizer treatments and compaction relief. However, disturbed native prairie tracts require reclamation treatments and natural succession to return to predisturbance conditions of diversity (both species and structural). Reestablishment of mixed-grass prairie to predisturbance conditions would be influenced by climate (growing season, temperature, and precipitation patterns) and edaphic (physical, chemical, and biological) conditions in the soil.

Previously planted agricultural fields would be recontoured to approximate precontours and ripped to depths of 12 to 18 inches to relieve compaction. If mixed-grass prairie tracts were disturbed by surface activities, these areas would be completely reclaimed. Reclamation of mixed-grass prairie would generally include: (1) completing cleanup of the disturbed areas (wellfields and access roads); (2) restoring the disturbed areas to the approximate ground contour that existed before construction; (3) replacing topsoil, if removed, over all disturbed areas; (4) ripping disturbed areas to a depth of 12 to 18 inches; and (5) seeding recontoured areas with a locally adapted, certified weed-free seed mixture.

7.5.4 Surface Waters and Wetlands

Surface disturbances associated with the proposed facilities would not affect either Spring Creek or the White River. In addition, no wetlands have been identified within the project area. Therefore, impacts to wetlands and surface waters are not anticipated.

The Crow Butte License Area lies within the watershed of Squaw Creek and English Creek which are small tributaries to the major regional water course, the White River. Construction and operation impacts have had a minimal impact on the local hydrological system. Some additional sediment entered Squaw Creek from adjacent unnamed tributaries during construction earth moving activities of the Central Plant; however, this condition was temporary without any long-term impacts. The increased sediment load as a result of precipitation during construction, operations or reclamation should not significantly affect the quality of Squaw Creek since the more sensitive areas of the stream are located upstream from the point of entry of the tributary.

Although normal construction activities within the wellfields, process plant and along pipeline courses and roads may slightly increase the sediment yield of the areas disturbed, the relative size of such disturbances is minor compared to the size of the permitted areas and to the size of the watersheds. As wellfield decommissioning and reclamation activities will be on going throughout the life of the project, the area to be reclaimed at the conclusion of operations will be reduced, although a slight increase in sediment yields and total runoff can still be expected.

The results of stream sediment sampling for Squaw and English Creeks indicate that measured concentrations of radiological parameters (e.g., uranium) between 1998 and 2207 are consistent with preoperational monitoring, which indicates that these levels are anomalous natural background concentrations.

Wetlands and/or waterbodies (i.e., wet meadow, mixed prairie – riparian, wet meadow-riparian, deep marsh-riparian, riverine, and impoundment) make up only 3.17 percent (273.92 acres) of the habitat within the CSA. Although the potential for impacting such ecological systems is minor, efforts are made to avoid impacting such environments.

7.5.5 Wildlife and Fisheries

The effects on wildlife are associated with construction and operation of project facilities, which include displacement of some individuals of some wildlife species, loss of wildlife habitats, and an increase in the potential for collisions between wildlife and motor vehicles. Other potential effects include a rise in the potential for illegal kill, harassment, and disturbance of wildlife because of increased human presence primarily associated with increased vehicle traffic. The magnitude of impacts to wildlife resources would depend on a number of factors, including the time of year, type and duration of disturbance, and species of wildlife present.

7.5.6 Small Mammals and Birds

The direct disturbance of wildlife habitat in the project area likely would reduce the availability and effectiveness of habitat for a variety of common small mammals, birds, and their predators. The initial phases of surface disturbance and increased noise would result in some direct mortality to small mammals and would displace some bird species from disturbed areas. In addition, a slight increase in mortality from increased vehicle use of roads in the project area would be expected.

The temporary disturbances that occur during the construction period would tend to favor generalist wildlife species such as ground squirrels and horned larks, and would have more impact on specialist species such as western meadowlarks, lark buntings, and grasshopper sparrows. Overall, the long-term disturbance of 1,265 acres would have a low effect on common wildlife species. Songbirds that may be affected by the reduction in cultivated fields would be horned larks, sage sparrows, sage thrashers, and vesper sparrows. Although there is no way to accurately quantify these changes, the impact is likely to be low in the short term and be reduced over time as reclaimed areas begin to provide suitable habitats.

Because of the high reproductive potential of these species, they would rapidly repopulate reclaimed areas as habitats become suitable. Birds are highly mobile and would disperse into surrounding areas and utilize suitable habitats to the extent that they are available. The primary small mammals found on the project area include, but are not limited to, eastern cottontail, deer mice, thirteen-lined ground squirrel, white-footed mouse, meadow jumping mouse, and northern pocket mouse. The initial phases of surface disturbance would result in some direct mortality and displacement of small mammals from construction sites. Quantifying these changes is not possible because population data are lacking. However, the impact is likely to be low, and the high reproductive potential of these small mammals would enable populations to quickly repopulate the area once reclamation efforts are initiated.

7.5.7 Big Game Mammals

The principal wildlife impacts likely to be associated within the project area include: (1) a direct loss of certain wildlife habitat; (2) the displacement of some wildlife species; (3) an increase in the potential for collisions between wildlife and motor vehicles; and, (4) an increase in the potential for the illegal kill and harassment of wildlife.

In general, direct removal of habitat used by big game mammals is expected to be minimal, as the project area is predominantly used for agricultural production. Because a substantial proportion of the project area is used for seasonal crop production, only a small proportion of the available wildlife habitat in the project area would be affected. The capacity of the project area to support big game populations should remain essentially unchanged from current conditions.

In addition to the direct removal of habitat because of the development of wells and associated satellite facilities, disturbances from drilling activities and traffic would affect utilization of the habitat immediately adjacent to these areas; however, big game mammals are adaptable and may adjust to non-threatening, predictable human activity. It is envisioned that most big game mammal responses will consist of avoidance of areas proximal to the operational facilities, with most individuals carrying out normal activities of feeding and bedding within adjacent suitable habitats. In addition, the magnitude of displacement would decrease over time as: (1) the animals have more time to adjust to the operational circumstances; and, (2) the extent of the most intense activities such as drilling and road building diminishes and the wellfields are put into production. By the time the wellfields are under full production, construction will have ceased, and traffic and human activities in general would be greatly reduced. As a result, this impact would be minimal and it is unlikely that big game mammals would be significantly displaced under full field development. The level of big game mammal use of the project area is more likely to be determined by the quantity and quality of forage available.

The potential for vehicle collisions with big game mammals would increase as a result of increased vehicular traffic associated with the presence of construction crews and would continue (although at a reduced rate) throughout all phases of the wellfield operations. Development of new roads would allow greater access to more areas and may lead to an increased potential for poaching of big game animals; however, because of the proximity to Crawford and locations of farm residences in the project area, the incidence of vehicle collision impacts to big game mammals is anticipated to occur infrequently and no long-term adverse effects are expected.

Based on the foregoing, long-term adverse effects are not expected for any local big game mammal populations.

7.5.8 Upland Game Birds

The potential effects of the operation and maintenance of project facilities on upland game birds may include nest abandonment and reproductive failure caused by project-

related disturbance and increased noise. Other potential effects involve increased public access and subsequent human disturbance that could result from new construction and production activities.

7.5.8.1 Sharp-tailed Grouse

No sharp-tailed grouse leks are known to occur within the project area. However, noise related to drilling and production activities may affect sharp-tailed grouse utilization of leks or reproductive success. Reduction of noise levels in areas near leks would minimize this potential impact. If leks are found, surface disturbance should be avoided within 0.25 miles of leks. If disturbance within the buffer areas is avoided, no impacts are expected.

Areas with large tracts of mixed-grass prairie would provide the best quality nesting habitat. To protect sharp-tailed grouse nesting habitats, construction should be limited within a 1-mile radius of an active lek between March 1 and June 30. Significant impacts to leks and subsequent reproductive success are not expected if these guidelines are implemented.

7.5.9 Raptors

Potential impacts to raptors within the project area include: (1) nest desertions or reproductive failure as a result of project activities and increased public access; (2) temporary reductions in prey populations; and, (3) mortality associated with roads.

The primary potential impact to raptors from project activities is disturbance during nesting that might result in reproductive failure. To minimize this potential, construction would not be allowed during the critical nesting season (Feb. 1 - July 31, depending on species) within 0.5 mile of an active nest of listed or sensitive raptor species, and 0.25 mile (depending on species or line of sight) of an active nest of other raptor species. The nature of the restrictions, exclusion dates, and the protection radii would vary, depending on activity status of nests, species involved, and natural topographic barriers, and line-of-sight distances should be developed in coordination within the Nebraska Game and Parks Commission (NGPC) or the U.S. Fish and Wildlife Service (USFWS).

Nests not used in 1 year, may potentially be used in subsequent years. Subsequent development within close proximity to these nests may preclude use of the nest in following years. Therefore, protection of nests that may potentially be used in the future may require limiting construction within 300 meters (depending on species or line of sight) to minimize impacts. If "take" of an inactive nest were unavoidable, development of artificial nesting structures would mitigate for the loss of the nest. In some instances, during the production phase when human activity is reduced, raptors may actually nest on artificial above-ground structures. Based on the foregoing, significant impacts to raptor nesting activities are not expected.

The development of proposed wellfield and satellite facilities would disturb an estimated 1,265 acres of potential habitat for several species of small mammals that serve as prey

for raptors. This short-term impact would affect approximately 62 percent of the proposed license area, although this is not likely to limit raptor use within the project area. The small amount of short-term change in prey base populations created by construction is minimal in comparison to the overall status of the rodent and lagomorph populations. While prey populations on the project area would likely sustain some impact during the initial phase of the project, prey numbers would be expected to soon rebound to pre-disturbance levels following reclamation or active agricultural uses. Once reclaimed or in active agricultural uses, these areas would likely promote an increased density and biomass of small mammals that is comparable to those of undisturbed areas. For these reasons, implementation of the project is not expected to produce any appreciable long-term negative changes to the raptor prey base within the project area.

The creation of new roads would increase public access to areas within the project area. As use of the project area increases, the potential for encounters between raptors and humans would increase and could result in increased disturbance to nests and foraging areas. Closure of roads located near active raptor nests to public vehicle use would offset this potential impact. Some raptor species feed on road-killed carrion on and along the roads, while others (owls) may attempt to capture small rodents and insects that are illuminated in headlights. These raptor behaviors put them in the path of oncoming vehicles where they are in danger of being struck and killed. The potential for such collisions can be reduced by requiring drivers to follow all posted speed limits.

7.5.10 Fish and Macroinvertebrates

Suitable habitat for fish and macroinvertebrates exists within portions of Spring Creek and the White River. However, the construction, operation, and maintenance of the project are not expected to affect either of these habitats.

7.5.11 Threatened, Endangered and Candidate Species

The USFWS and NGPC have identified the following threatened, endangered and candidate species with the potential to occur in Dawes County: swift fox (state endangered), the bald eagle (state endangered), black-footed ferret (state/federal endangered), and whooping crane (state/federal endangered). However, as discussed in **Section 2.8**, the species with a reasonable possibility of occurring on or near the project site are the bald eagle and swift fox. The whooping crane, black-footed ferret and black-tailed prairie dog have not been observed on the project site.

7.5.11.1 Swift Fox (State Endangered)

The swift fox is closely associated with lagomorph populations, prairie dog colonies, ground squirrels, and other small mammals, which exist in varying densities and abundance throughout the License Area. High quality swift fox habitat is present in a grassland area immediately northwest of the project area, which would be expected to be a preferred habitat area over the existing License Area. Based on our analysis, the implementation of the project may affect the swift fox due to disturbance to habitats that

may support preferred swift fox prey species. This minor indirect effect is not expected to affect the individual health of the swift fox or the status of the local swift fox population because of the availability and suitability of other undisturbed habitats in the License Area and adjacent areas.

7.5.11.2 Bald Eagle (State Threatened)

Based on our analysis of the effects of project implementation and the current and potential status of this species in northwestern Nebraska, we conclude that the proposed alternative will have no adverse effect on the bald eagle. This analysis is based on lack of observed bald eagle nests in the project area, no documentation of winter concentration areas or winter nighttime roosts (Fritz 2004), and lack of open water in which most bald eagle populations tend to maintain a close association

7.5.11.3 Black-footed Ferret (Federal and State Endangered)

There have been no observations or reports of the black-footed ferret in the project area, nor have there been any confirmed populations of the ferret observed in the state of Nebraska since 1959 (USFWS 1978). Black-footed ferret populations coincide closely with colonies of prairie dogs on which the ferret depends for food and habitat. Prairie dog colonies required for a successful ferret population are not found within the License Area. Based on our analysis of the effects of project implementation and the current and potential status of this species in northwestern Nebraska, we conclude that the proposed alternative will have no adverse effect on the black-footed ferret.

7.5.11.4 Whooping Crane (Federal and State Endangered)

There is a limited availability of highly suitable whooping crane habitat within the License Area, with the majority of sitings within Nebraska occurring in the Platte Valley that is located a considerable distance away in central Nebraska. Therefore, any presence of whooping cranes within the License Area and surrounding area would be expected to be infrequent and transient. Based on our analysis of the effects of project implementation and the current and potential status of this species in northwestern Nebraska, we conclude that the proposed alternative will have no adverse effect on the whooping crane.

7.5.11.5 Reptiles, Amphibians, and Fish

No threatened or endangered reptiles, amphibians, or fish species have been recorded in the project area, and none are expected to occur.

7.5.12 Cumulative Impacts

Cumulative impacts to ecological resources are not anticipated, as no substantive impairment of ecological stability or diminishing of biological diversity is expected within the project area.

7.6 AIR QUALITY IMPACTS

Any construction activities (e.g., new wellfields and Central Plant improvements) at the Crow Butte Project would cause minimal effects on local air quality. Effects to air quality would be increased suspended particulates from vehicular traffic on unpaved roads, in addition to existing fugitive dust caused by wind erosion, and diesel emissions from heavy equipment. As needed, the application of water to unpaved roads reduces the amount of fugitive dust to levels equal to or less than the existing condition. Diesel emissions from heavy equipment during operations (e.g., maintenance and new wellfield construction/development) are expected to be short term only.

Although there are no ambient air quality monitoring data for these non-radiological pollutants in the License Area, PM_{10} concentrations have been measured in Rapid City, South Dakota and Badlands National Park in South Dakota. Both locations are geographically similar to the License Area.

The Rapid City data were collected at the National Guard Camp Armory site about 2 miles west of the city. This area is classified as suburban. The Badlands data were collected in an area classified as rural. Because of the degree of urbanization, the air quality at the License Area would probably fall somewhere between the air quality at these two locations. These data were obtained from the USEPA air quality monitoring database (USEPA 2007), and are presented in **Table 7.6-1.**

Table 7.6-1: PM_{10} Monitoring Summary (micrograms per cubic meter)

	Maximum 24-hr Average		Annual Average	
Year	Black Hills, SD	Rapid City, SD	Black Hills, SD	Rapid City, SD
1998	-	87.4	-	30.7
1999	-	116.9	-	28.2
2000	38.5	97.4	12.0	31.3
2001	47.9	81.5	12.6	34.6
2002	26.0	104.7	9.9	34.9
2003	74.4	91.8	16.3	36.2
2004	24.0	72.0	10.0	30.0
2005	40.0	94.00	9.0	27.0
2006	30.0	124.0	10.0	29.0

The National Ambient Air Quality Standards (NAAQS) for PM_{10} are 150 micrograms per cubic meter (24-hour average), and 50 micrograms per cubic meter (annual average). All counties within the 80-km radius of the project are in attainment of NAAQS.

There will be an increase in the total suspended particulates (TSP) in the region as a result of the License Area. This increase in TSP will be greatest during the site preparation phase of the satellite facility. Revegetation will be performed where possible to mitigate the problems associated with the resuspension of dust and dirt from disturbed

areas. All areas disturbed during construction are revegetated with the exception of plant pad areas, roads, and areas covered by the pond liners. Of these, the only significant source of TSP is dust emissions from unpaved roads. The amount of dust can be estimated from the following equation taken from "Supplement No. 8 For Compilation of Air Pollutant Emission Factors" (USEPA 1978).

$$E = (0.81s)\frac{S}{30}\frac{365 - w}{360}$$

Where:

E	=	emission factor, lb per vehicle-mile
s	=	silt content of road surface material, 40%
S	=	average vehicle speed
w	=	mean number of days with 0.01 inches or more of rainfall, 85

Using the values stated above, the emission factor is equal to 0.25 lb/vehicle-mile. The distance from the facility to Highway 71 is 3 miles away traveling due west and 4.5 miles through Crawford. Assuming 35 employees, a five workday week and a 33 percent increase to allow for additional traffic (deliveries, etc.), the total mileage on dirt roads is 1000 miles/week. This corresponds to a dust emission of 6.5 tons/year as a result of the increased traffic on dirt roads. Traffic counts made by the Nebraska Department of Roads in 1987 indicated that there were 119 daily trips on the County Road that employees would take to Crawford (4.5 miles) from the plant. This results in over 2,000 miles per week at the present time. If the increased dust should present a problem, either due to current operations or due to possible future expansions, the emissions can be reduced through appropriate control procedures such as the use of dust control chemicals on the road surface.

All of the airborne emissions presented above will have a minimal impact of the environment. At no time during the life of the project it is anticipated that the ambient air quality standard of the State of Nebraska will be exceeded.

Other operational activities may have impacts on surrounding air quality. The only atmospheric emission from the production and process facilities will be radon gas, which is discussed at length in **Section 7.12.2**.

7.7 NOISE IMPACTS

The main noise impacts of the current Crow Butte uranium in-situ operation were during construction of the main processing plant. Noise impacts at a distance of 2880 feet, the approximate location of the closest receptor from construction equipment located at the License Area, was calculated to be 49 dBA. Noise impacts were addressed in the 1998 LRA. The project area is bounded on the west by the Burlington Northern Santa Fe (BNSF) rail line. Therefore, the existing ambient noise in the immediate vicinity of the Project area is dominated by the trains on the BNSF rail line.

If a new satellite facility (e.g., North Trend Expansion Area) is constructed, then noise impacts would be comparable to those of the Central Plant construction. Noise impacts associated with the North Trend Satellite Plant are addressed in the North Trend application.

Construction associated with the current License Area has been, and will continue to be, minimal, e.g., heavy equipment used for periodic maintenance and construction of new wellfields. Such activities involve minimal equipment at any one time and are short-term impacts.

Noise sources during operation in the License Area have increased due to increased vehicle travel as increased numbers of employees traveling to and from Crawford for work at the Central Plant. In addition, there is some additional noise due to periodic truck deliveries an shipments associated with operations. Train usage has not increased as a result of operations. Processing equipment at the proposed satellite site would be minimal and is not expected to add to existing noise sources. Increases in noise levels due to operation are less than noise levels generated during construction. Therefore, noise levels during operation are expected to continue to be barely perceptible over the existing ambient noise that is dominated by vehicle noise from SH 2/71 and the BNSF railroad.

7.8 HISTORIC AND CULTURAL RESOURCES IMPACTS

As discussed in **Section 2.4**, an archaeological review area was surveyed for the presence of cultural resources that may be impacted by the Crow Butte Project. Field investigation in 1982 and 1987 identified twenty-one new archeological resource locations. These sites are represented by eight Native American components, twelve Euro-American locations and a buried deposit of undetermined cultural association. Six of these sites are considered to be potentially eligible for the NRHP and would warrant further investigation if they were ever to be directly impacted. These resources however, have been avoided and not directly impacted as a result of construction activities. Any further construction activities will avoid these identified resources and coordination will be maintained with the Nebraska State Historical Society.

7.9 VISUAL/SCENIC RESOURCES IMPACTS

7.9.1 Environmental Consequences

The visible surface structures constructed in the Crow Butte License Area include the processing plant, office buildings, wellhead covers, wellhouses, and electrical distribution lines.

Each wellhead cover consists of a weatherproof structure placed over each well. Each structure is approximately 3 feet high and 2 feet in diameter. Each well house consists of a small shed. The plant building is approximately 100 feet by 130 feet in size. Electric distribution lines connect wellhouses to existing electric distribution lines. The distribution poles are approximately 20 feet high. The poles are wooden so that their natural color harmonizes with the landscape.

7.9.1.1 Short-term Effects

Temporary and short-term effects to the rural character of the landscape occurred from well construction, well drilling, and associated construction of ancillary facilities, such as access roads and electric distribution lines. Once installation of facilities was complete, temporary disturbance areas were reclaimed to pre-construction conditions. Only permanent disturbances associated with operations and maintenance of the facilities have remained following post-construction restoration.

7.9.1.2 Long-term Effects

Long-term effects for the project have resulted from the addition of structures to the landscape, such as the plant, wellhouses, wellhead covers, and associated access roads and electric distribution lines. Effects from long-term activities occur over the production life of the project.

Project development has altered the physical setting and visual quality of portions of the landscape, which would affect the overall landscape to some degree. However, these effects have been subordinate in scale to the existing landscape as viewed from sensitive viewing areas, which consist primarily of a small number of residences located outside of the License Area. The existing rural/agricultural landscape has been retained, but has been modified with a noticeable, but minor, industrial component. Line and textural contrasts of the well houses, the plant, administration buildings, and associated access roads and distribution lines are not visible from sensitive viewing areas. This is due to the License Area being isolated from locations where there are viewers with a concern for scenic landscapes, including recreation areas, major transportation routes, and residential areas.

7.10 SOCIOECONOMIC IMPACTS

Monetary benefits accrue to the community from the presence of the Crow Butte Project. Against these monetary benefits are the monetary costs to the communities involved, such as those for new or expanded schools and other community services. While it is not possible to arrive at an exact numerical balance between these benefits and costs for any one community or for the project, because of the ability of the community and possibly the project to alter the benefits and costs, this section summarizes the expected incremental economic impacts from the continued operation of the Crow Butte Project.

7.10.1 Tax Revenues

Future tax revenues are dependent on uranium prices, which cannot be forecast with any accuracy; however, these taxes are also somewhat dependent on the number of pounds of uranium produced by CBR. To the extent that uranium prices remain at current levels (spot market of around $80 per pound U_3O_8 in mid-August 2007), the increased production from the satellite plants should contribute to higher tax revenues as well.

The present taxes are based on a relatively consistent production rate of 800,000 pounds per year. The additional production from the satellite plants should be about 600,000 pounds per year. This additional production will eventually be offset by declining production from the original plant; however, the incremental contribution to taxes would be on the order of $1.0 million to $1.2 million per year in combined taxes.

7.10.2 Temporary and Permanent Jobs

7.10.2.1 Projected Short-Term and Long-Term Staffing Levels

CBR expects that construction of future satellite plant(s) will provide approximately ten to fifteen temporary construction jobs for a period of up to one year for each satellite. It is likely that the majority of these jobs will be filled by skilled construction labor brought into the area by a construction contractor, although some positions could be filled by local hires. Permanent CBR employees will perform all other facility construction (e.g., wells and wellfields).

CBR actively pursues a policy of hiring and training local residents to fill all possible positions. Due to the technical skills required for some positions, a small percentage of the current mine staff (less than five percent) has been hired elsewhere and relocated to the area. Because of the small number of people who have needed to move into the area to support this project, the impact on the community in terms of expanded services has been minimal. CBR expects that the types of positions created by any future expansion will be filled with individuals from the local workforce and that there will be no significant impact on services and resources such as housing, schools, hospitals, recreational facilities, or other public facilities. In 2006, total unemployment in Dawes County was 137 individuals, or 2.9 percent of the total work force of 4,799. CBR expects that any new positions will be filled from this pool of available labor.

CBR projects that the current staffing level will increase by ten to twelve full-time CBR employees for each active satellite plant. These new employees will be needed for satellite plant and wellfield operator and maintenance positions. Contractor employees (i.e., drilling rigs) may also increase by four to seven employees depending on the desired production rate. The majority if not all of these new positions will be filled with local hires.

These additional positions should increase payroll by about $40,000 per month, or $400,000 to $480,000 per year.

7.10.3 Impact on the Local Economy

CBR actively supports the local economies through purchasing procedures that emphasize obtaining all possible supplies and services that are available in the local area. In 2006, these local purchases were estimated at $5,000,000. This level of business is expected to continue and should increase somewhat with the addition of expanded production from the satellite plant, although not in strict proportion to production. While there are some savings due to some fixed costs (Central Plant utilities for instance), there are additional expenses that are expected to be higher (wellfield development for the satellites is expected to be more expensive). Therefore, it can be estimated that the overall effect on local purchases will be proportional to the number of pounds produced. In addition, mineral royalty payments accrue to local landowners. This should translate to additional purchases of $3.65 to $4.35 million per year.

7.10.4 Economic Impact Summary

As discussed in this section, approval of this LRA would have a positive impact on the local economy as summarized in **Table 7.10-1.**

Table 7.10-1: Projected Economic Impact from Crow Butte License Area

	Estimated Economic Impact due to Crow Butte License Area
Employment	
Full Time Employees	+ 10 to 12
Full Time Contractor employees	+ 4 to 7
Part Time Employees and Short Term Contractors	+ 10 to 15 (Satellite Construction)
CBR Payroll	+ $400,000 to $480,000
Taxes	
Property Taxes	-
Sales and Use Taxes	-
Severance Taxes	-
Total Taxes	+ $1,000,000 to $1,200,000
Local Purchases	
Local Purchases, 2006	+ $3,650,000 to $4,350,000
Total Direct Economic Impacts	
	+ $5,050,000 to $6,030,000

7.11 ENVIRONMENTAL JUSTICE

The 2000 Census provides population characteristics for census tracts, which contain block groups that are further divided into blocks. The blocks are the smallest census area that contains the race characteristics of the population in Dawes County. The review area contains all or a portion of 68 blocks within Census Tract 9506. Block groups are the smallest census area that contains poverty level information. There is no poverty data for individual blocks within each block. There are three block groups that are located partially within the 2.25-mile review area; however, the block groups area includes most of the north portion of Dawes County.

The affected area selected for the Environmental Justice analysis includes the race characteristics of the population within the city of Crawford and the surrounding census tract blocks within the 3.62-km (2.25-mile) review area. The population with an annual income below the poverty level was determined from block group characteristics.

According to the 2000 Census, which is summarized in **Table 7.11-1**, the combined population of the city of Crawford and the surrounding census blocks within the review area was 1,265. Minority populations accounted for a small percentage of the total population. The majority of minority populations resided within Crawford.

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

The data in **Table 7.11-1** shows that minority populations in the affected blocks account for considerably smaller proportion of the total review area population than the proportion of minority populations at the state level. No concentrations of minority populations were identified as residing near the proposed project facilities, as residents nearest to the Crow Butte License Area are rural populations, while most of the minority population lives in Crawford. There has been no disproportionate impact to minority population from the construction and implementation of the Crow Butte Project.

With the exception of block group 3, the populations within the block groups have higher rates of people living below the poverty level than the state; however, lower income levels are characteristic of predominantly rural populations and small communities that serve as a local center of agricultural activity. No adverse environmental impacts would occur to the population within the review area from proposed project activities; therefore there would be no disproportionate adverse impact to populations living below the poverty level in these block groups.

Approval of this LRA may have a positive economic impact on the lower income and minority groups since the project will generate additional employment opportunities with compensation that compares favorably with other employment opportunities in the area.

Table 7.11-1: Race and Poverty Level Characteristics of the Population in the State of Nebraska, Dawes County, and the 2.25-mile Review Area

	Nebraska	Percent of Nebraska Pop.	Dawes County	Percent of Dawes County Pop.	Crawford City	Total Block Pop.	Crawford & Block Pop. (review area)	Percent of Crawford & Block Pop.	Block Group 1	Block Group 2	Block Group 3
Total Population	1,711,263	100.0	9,060	100.00	1,107	158	1,265	100.0	1,111	1,137	890
White alone	1,533,261	89.6	8,457	93.34	1,037	151	1,188	93.9		N/A	N/A
Black or African American	68,541	4.0	73	0.81	1	0	1	0.1	N/A	N/A	N/A
American Indian and Alaska Native	14,896	0.9	261	2.88	38	6	44	3.5	N/A	N/A	N/A
Asian alone	21,931	1.3	28	0.31	0	0	0	0.0	N/A	N/A	N/A
Native Hawaiian and Other Pacific Islander	836	0.0	5	0.06	0	0	0	0.0	N/A	N/A	N/A
Some other race	47,845	2.8	93	1.03	10	1	11	0.9	N/A	N/A	N/A
Two or more races	23,953	1.4	143	1.58	21	0	21	1.7	N/A	N/A	N/A
Hispanic or Latino	94,425	5.5	220	2.43	22	3	25	2.0	N/A	N/A	N/A
Percent below poverty level	9.4	N/A	17.1	N/A	14.4	N/A	N/A	N/A	21.3	14.0	8.3

N/A = Not Applicable
Source: Census 2000

7.12 PUBLIC AND OCCUPATIONAL HEALTH IMPACTS

7.12.1 Nonradiological Impacts

The in-situ solution mine is by design a self-contained mining circuit. Wastes generated by the facility are contained and eventually removed to disposal elsewhere. The potential non-radiological effects of the operation include the possibility of lixiviant excursion, evaporation pond leakage, and temporary disturbance of the land during site preparation, construction and operations. The effects of these possible occurrences are considered small as discussed in **Section 7**. The environmental monitoring programs given in **Section 5.8** are designed to quickly identify any adverse conditions that may result during operations. No long-term irreversible effects are anticipated.

7.12.1.1 Airborne Emissions

Hydrochloric acid is the main gaseous nonradiological effluent at Crow Butte. Hydrochloric acid that is kept on-site is stored in a tank twelve feet in diameter and ten feet tall. This tank is vented into a process tank to remove hydrogen chloride gas from the air passing from the vent. The only other possible gaseous effluent is carbon dioxide, which is also located on-site in a fifty-four ton tank. Very minor amounts of CO_2 could escape into the atmosphere when the tanks are charged.

To predict the concentration of hydrogen chloride in the region around the process facility, its rate of release must be estimated. The following assumptions were used in the estimate:

- Hydrogen chloride gas is emitted from the scrubber only during the process of filling the tank.
- The acid concentration is 32 percent with a temperature of 10° C (50° F) and a partial pressure of 11.8 mm Hg.
- One tank truck delivery is 1,497 kg (3,300 pounds) of acid and it requires one hour to fill the tank.
- The scrubber efficiency is 99 percent.
- Emissions occur from a scrubber vent 3.0 meters (9.8 feet) above the facility foundation. The vent has a diameter of 0.20 meters (8.0 inches) and a flow velocity of 0.2 meters/second (0.66 feet/second).

The estimate of hydrogen chloride gas released during tank filling process is 3.2 grams. Using this source term, atmospheric dispersion calculations, and the average meteorological condition, the highest concentration of hydrogen chloride is anticipated to be 2.5×10^{-2} $\mu g/m^3$ in the vicinity of the facility. The threshold limit for hydrogen chloride is 7,000 $\mu g/m^3$. This predicted concentration is very low and only occurs during the one hour required to fill the tank. It is estimated that this tank needs to be filled approximately 43 times per year. Even if the satellite process facility is built with a tank of similar

capacity, the effect of this emission on the region surrounding the Crow Butte site will be insignificant.

There will be an increase in the total suspended particulates (TSP) in the region as a result of the Crow Butte project. This increase in TSP was greatest during the site preparation phase of the commercial facility. Revegetation has been performed where possible to mitigate the problems associated with the resuspension of dust and dirt from disturbed areas. Should new facilities be built, another transient increase in TSP can be expected, but it will not be as great as that experienced during the original construction phase. All areas disturbed during construction are revegetated with the exception of plant pad areas, roads, and areas covered by the pond liners. Of these, the only significant source of TSP is dust emissions from unpaved roads. The amount of dust can be estimated from the following equation taken from *Supplement No. 8 For Compilation of Air Pollutant Emission Factors* (USEPA 1978).

$$E = (0.81s)\frac{S}{30}\frac{365-w}{365}$$

Where:

E	=	emission factor, lb per vehicle-mile
s	=	silt content of road surface material, 40%
S	=	average vehicle speed
w	=	mean number of days with 0.01 inches or more of rainfall, 85

Using the values stated above, the emission factor is equal to 0.25 lb/vehicle-mile. The distance from the facility to Highway 71 is 3 miles away traveling due west and 4.5 miles through Crawford. Assuming 35 employees, a five workday week and a 33 percent increase to allow for additional traffic (deliveries, etc.), the total mileage on dirt roads is 1000 miles/week. This corresponds to a dust emission of 6.5 tons/year as a result of the increased traffic on dirt roads. Traffic counts made by the Nebraska Department of Roads in 1987 indicated that there were 119 daily trips on the County Road that employees would take to Crawford (4.5 miles) from the plant. This results in over 2,000 miles per week at the present time. If the increased dust should present a problem, either due to current operations or due to possible future expansions, the emissions can be reduced through appropriate control procedures such as the use of dust control chemicals on the road surface.

All of the airborne emissions presented above will have a minimal impact of the environment. At no time during the life of the project it is anticipated that the ambient air quality standard of the State of Nebraska will be exceeded.

7.12.1.2 Sediment Load

At the present time, there is little chance that the sediment load may increase due to precipitation and runoff, as erosion control and revegetation has occurred where possible.

Should additional construction take place, there is a possibility that sediment load may increase in Squaw Creek. If rain, producing runoff, occurs during construction a small amount of the fill may be carried into the creek. In addition, site reclamation with backfilling of the ponds, grading the plant site, and replacing topsoil will also expose unsecured soil for suspension in runoff waters. The increased sediment load as a result of precipitation during construction or reclamation should not significantly affect the quality of Squaw Creek since the more sensitive areas of the stream are located upstream from the point of entry of the tributary.

7.12.1.3 Water Levels

The effects of the production and restoration phases of the project on water levels in the Chadron aquifers has been evaluated, both at current production levels as well as the proposed 9,000 gpm production level. The potential impact of the mining operations on water users of the Chadron Aquifer near the project site relates only to a decrease in formation pressure (drawdown) of the aquifer. The in-situ leach operations will not impact the quality of the groundwater available to the well user. It should be noted that private wells completed in the Chadron Aquifer are relatively rare and only a few are regularly used for domestic purposes. To assess the pressure decrease associated with the Crow Butte project, it is necessary to establish the total consumptive water use of the mining operations from the primary leaching to the groundwater restoration phase. The method of calculation will then incorporate individual flow rates, along with the timing and spatial position of those flow rates.

Since groundwater is injected as well as extracted in the ISL process, the flow rates of interest in gauging the impact are the net flows, or extraction minus injection. These net withdrawals and their timing were estimated from the generalized production schedule shown in **Table 7.12-1**. The net groundwater loss from the Chadron Aquifer will be around 105 gpm by year three. However, this overall net loss is small and is comparable to an industrial well or irrigation well pumping at this same rate.

Three years was used as a representative length of time for production, and then restoration, of a typical wellfield unit. Since distance weakens the effects of pressure transients (caused by water production) dramatically, it is important to allocate withdrawal points, for calculation purposes, throughout the expected production area, especially as the area increases in size. As a result, withdrawal points were considered centered in multiple wellfield units across the Crow Butte License Area (**Figure 7.12-1**). The base of this figure has been updated to reflect the withdrawal points discussed above and the water wells completed in the Chadron Aquifer nearest to the Crow Butte ISL project. Withdrawal points are noted with letters (A, B, C, etc.) and correlate to the same letters shown in **Table 7.12-1**. Since the density of the Chadron Aquifer wells increase northwest from the Crow Butte project area toward Crawford, the tentative wellfield production schedule shown in **Table 7.12-1** provides an early and separate progression of the wellfield production away from the Crow Butte Central Plant area toward the Crawford area. This will maximize the effect of withdrawals on the Crawford area wells and provide a more conservative estimate of impact.

Table 7.12-1: Production Restoration Schedule Flow Projections

Year	Production			Restoration			Total Net Withdrawal
	Flow	Withdrawal Point	Net Withdrawal	Flow	Withdrawal Point	Net Withdrawal	
1	4000	B	20.0	450	A	36	56.0
2	4500	B	22.5	500	A	40	62.5
3	5000	B	25.0	1000	A	80	105.0
4	5000	C,D	25.0	1000	A	80	105.0
5	5000	C,D	25.0	1000	B	80	105.0
6	5000	C,D	25.0	1000	B	80	105.0
7	5000	D,E	25.0	1000	B	80	105.0
8	5000	E,F	25.0	1000	C,D	80	105.0
9	5000	E,F	25.0	1000	C,D	80	105.0
10	5000	F,G	25.0	1000	C,D	80	105.0
11-20+	5000		25.0	1000		80	105.0
+1	0	0	0	1000		80	80.0
+2	0	0	0	1000		80	80.0
+3	0	0	0	1000		80	80.0
+4	0	0	0	1000		80	80.0

Note:

A, B, etc. refer to wellfield withdrawal points, see **Figure 7.12-1** (Revised). All flow rates are in gpm.

The pressure drawdown calculations were made using the unsteady state solution to the exponential integral describing radial flow in a confined aquifer. The Principal of Superposition was used in the calculations to allow flow rates to a particular location to vary, as they normally would during production and restoration (start, stop, restart, etc.). The formation flow parameters employed in the computer model were 2725 gpd/ft for transmissivity and 1.04×10^{-4} for storage coefficient and are considered representative of the pumping tests conducted at the Crow Butte License Area.

Figures 7.12-2 through **Figure 7.12-5** show the estimated drawdowns over time for each of the Chadron Aquifer water wells (ww) outside of the Crow Butte License Area shown on **Figure 7.12-1**. As shown, the changes in formation pressures vary according to timing and location of water well withdrawals, with maximum drawdowns in this case of 26-27 feet reached at different times depending upon the location of the water well. After this, the formation water pressures will rise again as consumptive water use is decreased, then altogether stopped. Recharge of the Chadron Aquifer was ignored in these calculations, which resulted in larger, more conservative drawdowns. However, it can be expected that sometime during the mining operation, the cone of influence resulting from the net withdrawals will reach equilibrium as a result of recharge of the surrounding aquifer.

Table 7.12-2 shows the maximum projected drawdowns, without formation recharge, caused by Crow Butte mining operations to the surrounding Chadron water wells. It also includes an estimated maximum drawdown available in those water wells, assuming the wells were drilled to the bottom of the Chadron Aquifer, a sand thickness of 60 feet, and drawdown to the top of the Chadron. The ratio of maximum drawdown to available drawdown is then shown as a percentage. That ratio varies from 4.4 percent to 16.7 percent with an average of 9.0 percent. Generally, the relative impact of the Crow Butte project on the Chadron water well users is small. Chadron water has limited use as a groundwater supply because of its generally poor quality and high radionuclide content. If a user has his pump set just below the level, he may have to lower the pump by up to 25 feet to accommodate the drawdown.

In the Crawford area, several Chadron Aquifer water wells flow at the surface as a result of the elevation represented by the formation water pressure being higher than the ground-surface elevation. These wells are noted as having a positive Static Water Level in **Table 7.12-2**. Comparing the predicted drawdowns in the Crawford area to the static levels of **Table 7.12-2** indicates that some of the wells may no longer be flowing after some time. However, the water level will remain near the ground surface and submersible pumps can be installed to accommodate the well user. Later, as consumptive water use from mining operations is stopped, the formation pressures should recover so that these wells will again be flowing.

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Figure 7.12-1: Location of Wellfield Withdrawal Points – Dawes County, Nebraska

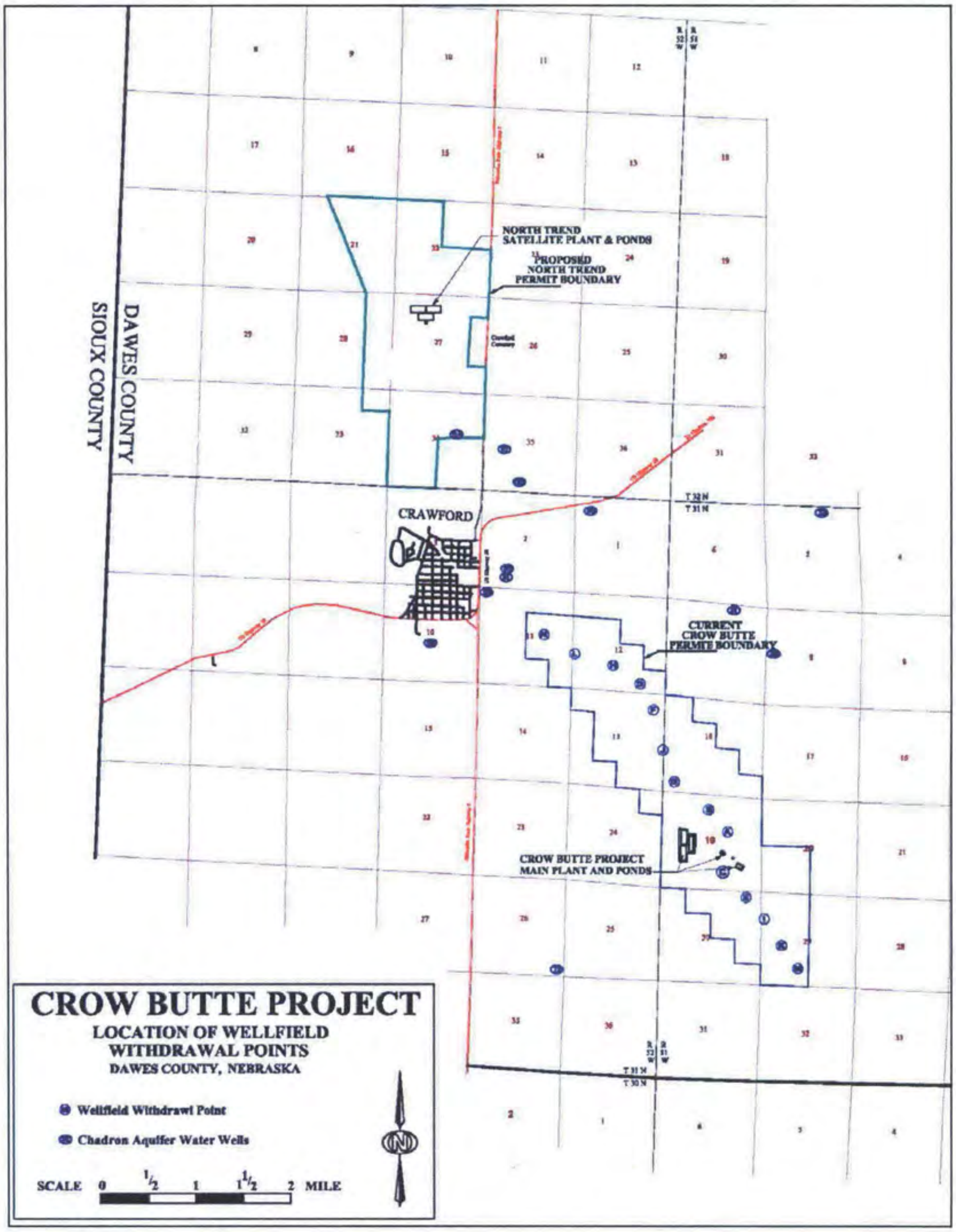

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Figure 7.12-2: Crow Butte Project Impact of Water Withdrawals

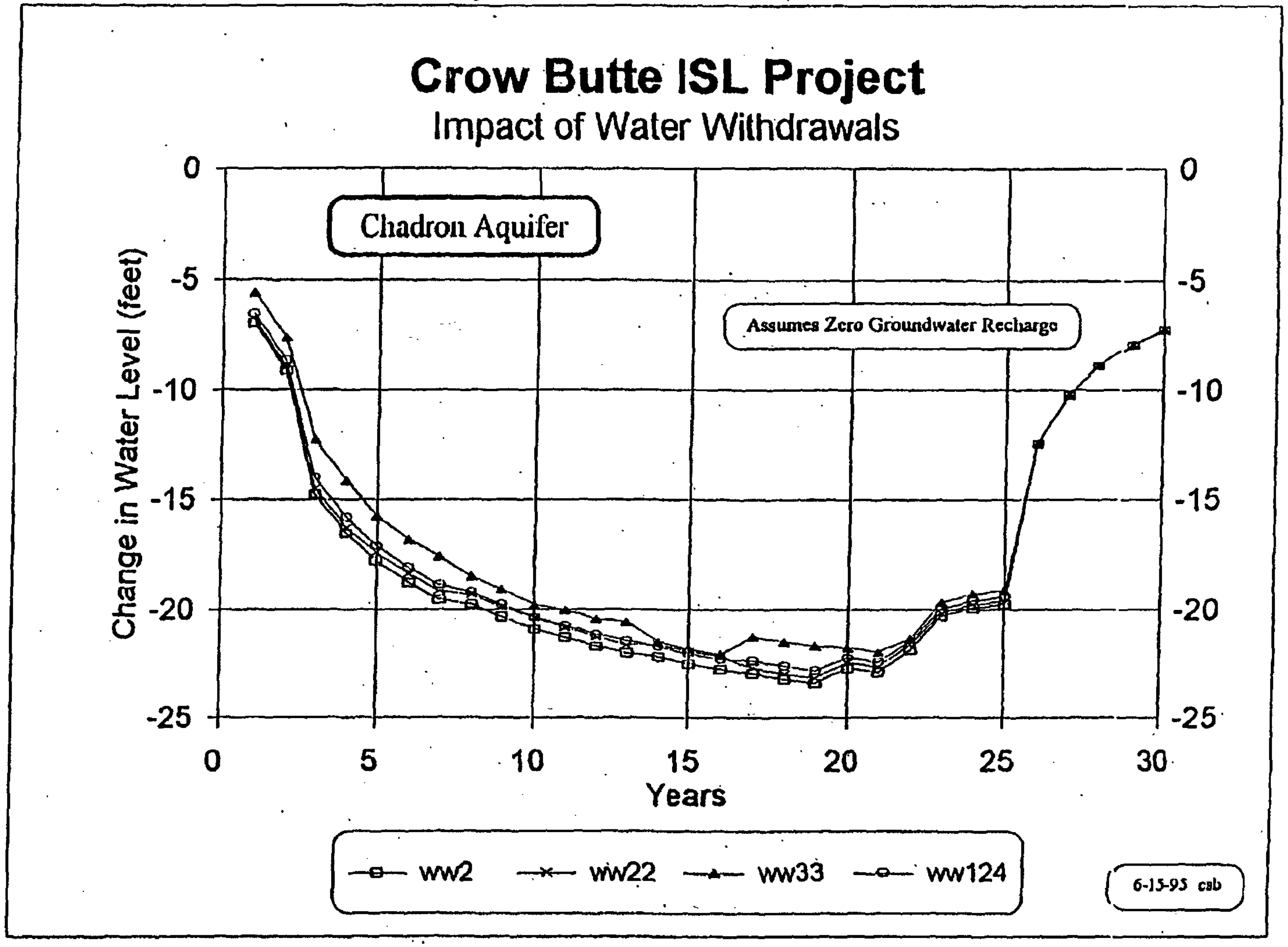


Figure 7.12-3: Crow Butte Project Impact of Water Withdrawals

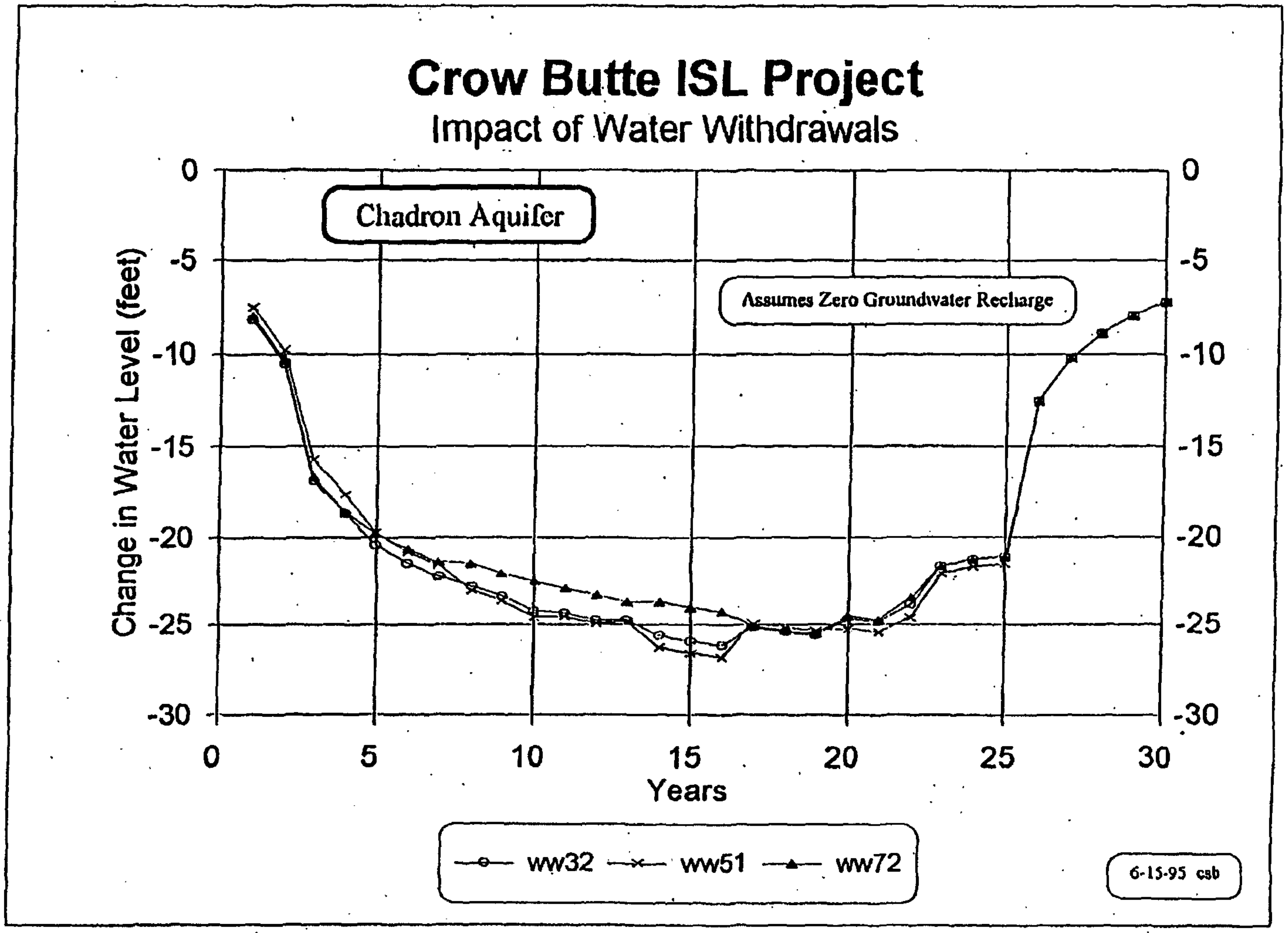


Figure 7.12-4: Crow Butte Project Impact of Water Withdrawals

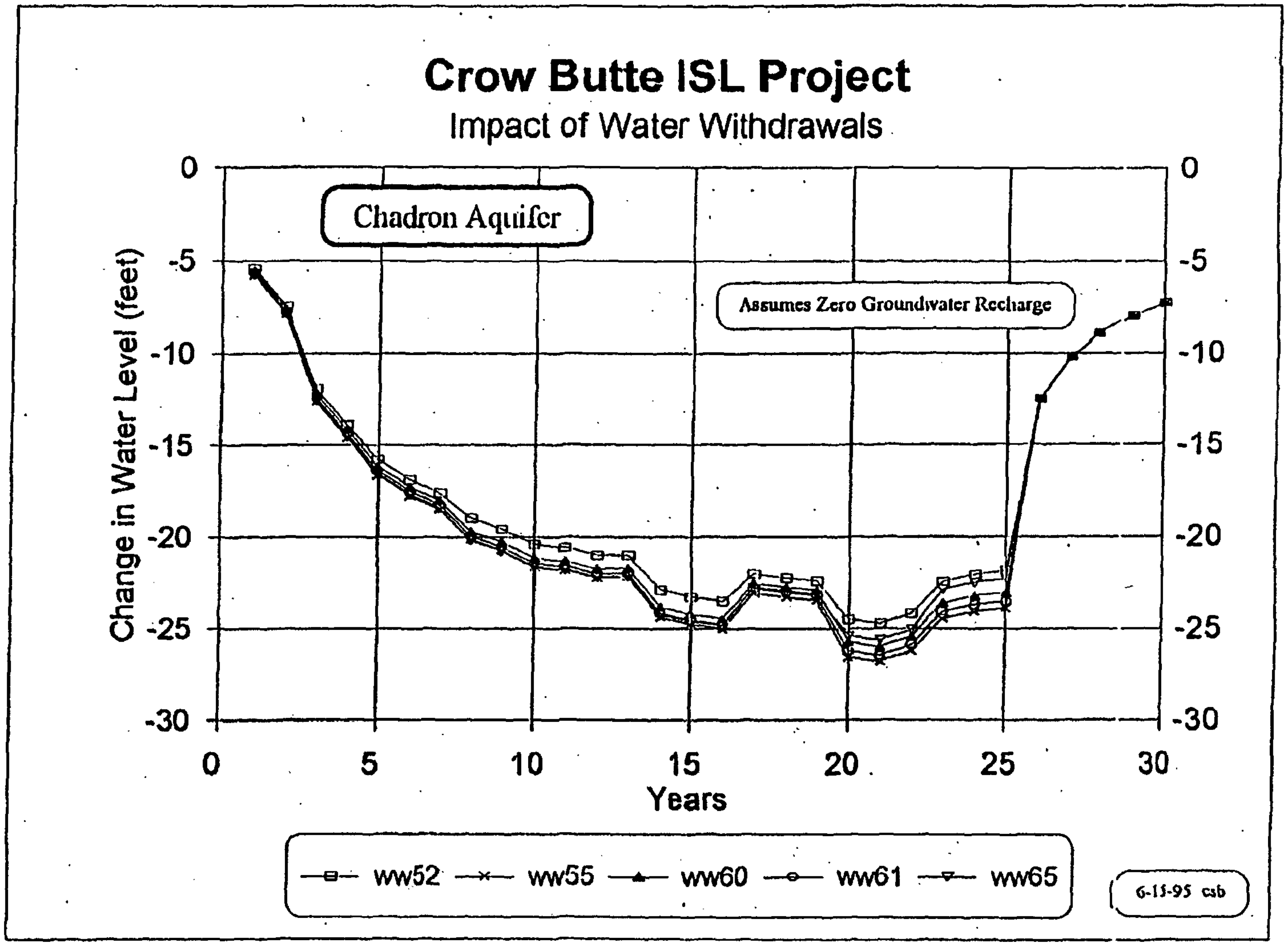


Figure 7.12-5: Crow Butte Project Impact of Water Withdrawals

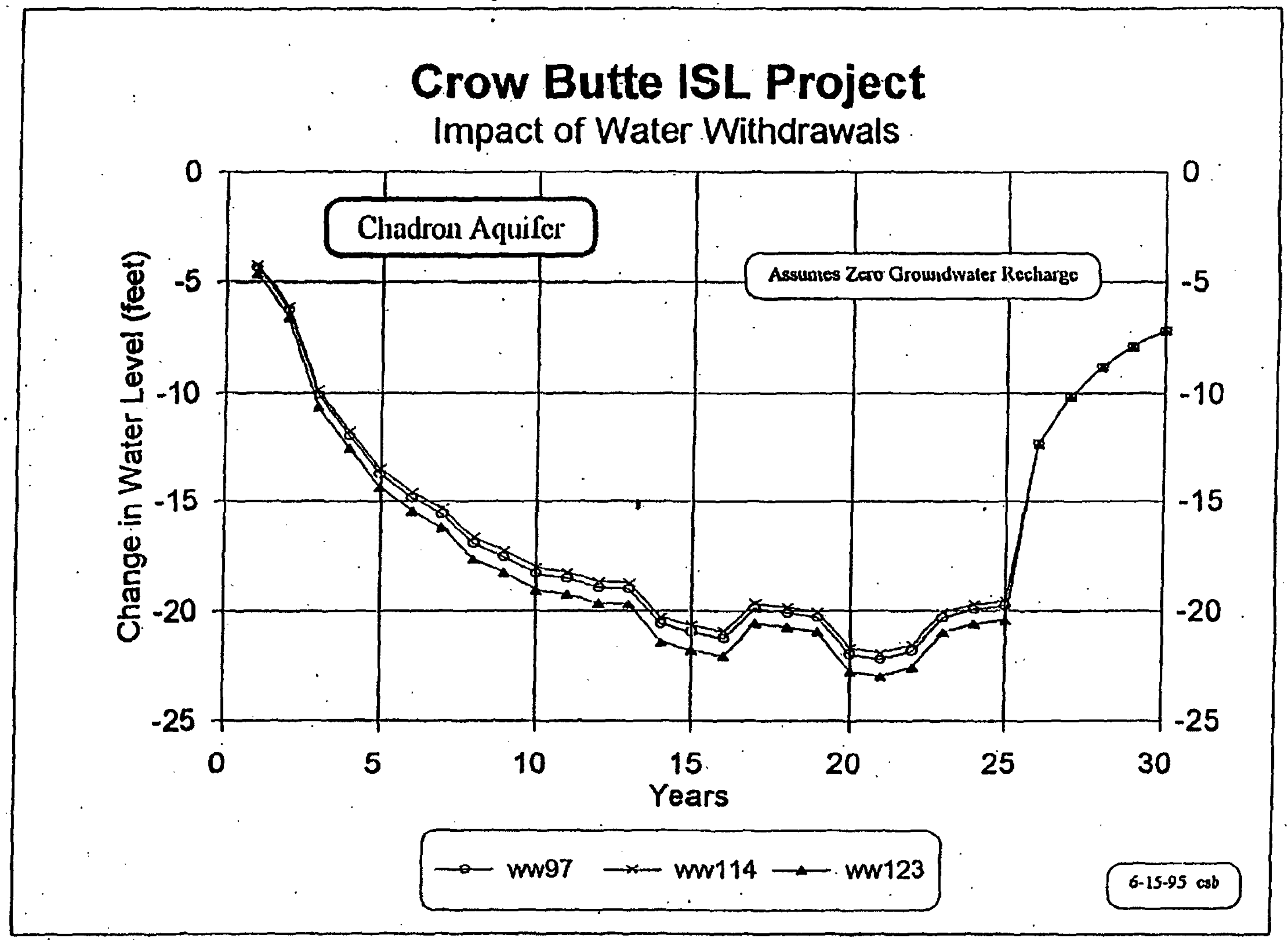


Table 7.12-2: Estimated Percent Reduction in Available Drawdown in Chadron Aquifer Water Wells as a Result of the Crow Butte ISL Operations

Water Well Number	Static Water Level (feet)[1]	Total Depth of Well (feet)	Figure Number: Drawdown vs. Time	Projected Maximum Drawdown (feet)	Maximum Available Drawdown (feet)[2]	Reduction of Available Drawdown (percent)
2	-60 est.	650	4.12-2	-23.4	530	-4.4
22	-70 est.	400	4.12-2	-23.2	270	-8.6
33	-20 est.	212	4.12-2	-22.1	132	-16.7
124	-50 est.	520	4.12-2	-22.8	410	-5.6
32	-39.8	400	4.12-3	-26.2	300	-8.7
51	-30 est.	300	4.12-3	-26.8	210	-12.8
72	-82.2	450	4.12-3	-25.5	308	-8.3
52	4.62[3]	420	4.12-4	-24.7	365	-6.8
55	-6.25[3]	320	4.12-4	-26.8	254	-10.5
60	20 est.	312	4.12-4	-25.9	272	-9.5
61	19.64[3]	280	4.12-4	-26.4	240	-11.0
65	22.52[3]	260	4.12-4	-25.6	223	-11.5
97	57.75[3]	380	4.12-5	-22.2	378	-5.9
114	60 est.	470	4.12-5	-21.9	470	-4.7
123	21.37[3]	280	4.12-5	-23.0	241	-9.5
					Average =	-9.0

[1] + = Above Ground Level; - = Below Ground Level

[2] To the Top of the Chadron Sandstone; assumes 60 feet sand thickness

[3] Measured 11/83

7.12.2 Radiological Impacts

An assessment of the radiological effects of the Crow Butte Project must consider the types of emissions, the potential pathways present, and an evaluation of the potential radiological hazards associated with the emission and pathways. Since the project is an in-situ operation, most of the particulate emission sources normally associated with a conventional mill will not be present. A vacuum dryer is in use at the commercial operation. The vacuum dryer works on the principle that gases or particulates released into the system are collected in a liquid condenser and there is no release of particulates. The effluent collection efficiency for this dryer system is, therefore 100 percent. The routine radioactive emission will therefore, be radon-222 (radon) gas.

For purposes of this section, the proposed Crow Butte North Trend Expansion Area (new satellite facility), is included in the assessment of the total project radiological impacts. Radiological impacts associated with the proposed satellite facility are discussed in detail in a separate license amendment submitted to the USNRC In June, 2007. The satellite facility will not have precipitation equipment, with the loaded ion exchange resin being transported to the Crow Butte Main Plant for regeneration and stripping. The only source of planned radioactive emissions from the satellite will be radon gas, which is dissolved in the leaching solution.

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

In order to assess the radiological effect of radon on the environment, an estimate of the quantity released during the operation must be made. Meteorological data and MILDOS-Area (Yuan et al. 1989) are used to predict the ground level air concentration at various points in the environment. The ingrowth of radon daughters is important and their concentration in the soil, vegetation and animals must be calculated. Finally, the impact on man from these concentrations of radionuclides in the environment must be determined.

In the following sections, the assumptions and methods used to arrive at an estimate of the radiological effects of the current Crow Butte Central Facility (average production flow rate of 9000 gpm) and the proposed North Trend Satellite Facility (average production flow rate of 4500 gpm) will be discussed briefly. The anticipated effects will be compared to naturally occurring background levels. This background radiation, arising from cosmic and terrestrial sources, as well as naturally occurring Radon, comprises the primary radiological impact to the environment in the region surrounding the Central Plant and proposed satellite facility.

7.12.3 Exposure Pathways

7.12.3.1 Crow Butte Main Plant

The Crow Butte Project is an in-situ facility with a vacuum dryer and the only source of radioactive emissions from the facility is radon gas. Radon gas is dissolved in the leaching solution and may be released as the solution is brought to the surface and processed in the plant. Unplanned emissions from the site are possible as a result of accidents and engineered structure failure but are not addressed in the MILDOS-Area modeling. A human exposure pathway diagram addressing planned and unplanned radiological emissions is presented in **Figure 7.12-6.**

Currently, CBR has a license amendment request pending to increase the annual plant throughput from 5,000 gpm, exclusive of restoration flow to 9,000 gpm exclusive of restoration flow (i.e., 1000 gpm). The license amendment was submitted on October 17, 2006 and the MILDOS-Area simulation included in this license amendment application reflects the requested flow increase. Approval of this increase in the annual plant throughout is expected in the near-term.

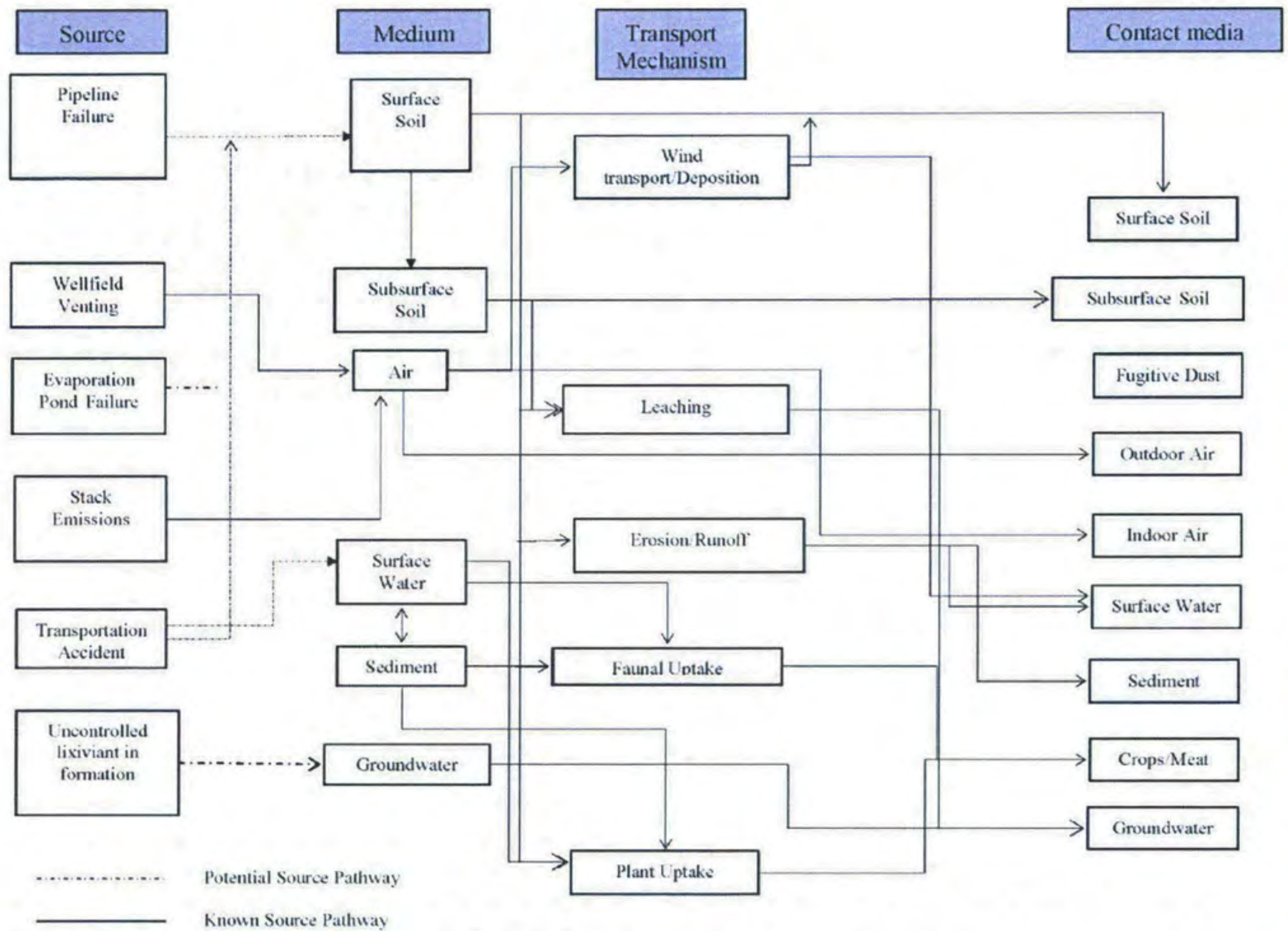
Approximately 5000 gpm of the process solution will be passed through upflow ion exchange columns which will vent the majority of the Radon into the exhaust manifold. From these columns, the solution will be transferred to an injection surge tank, where it will be refortified with chemicals before being pumped to the wellfield. This tank will be vented in a manner similar to the IX column and if any additional radon leaves the solution, it would be vented at this location.

Pressurized fixed bed downflow ion exchange columns will be used to process 4000 gpm of flow. The flow capacity of the existing facility is nominally 5000 gpm and it will require these additional downflow columns to increase the average production flow rate to 9000

With pressurized columns the radon will remain in solution and be returned to the formation and will not be released to the atmosphere. There will be minor releases of radon during the air blowdown prior to elution and during the filling of the columns after elution has been completed. The air blowdown and the gas released from the vent during column filling will be vented into the exhaust manifold and will be discharged via the main exhaust stack along with the radon from the upflow columns. It is estimated that less than 10 percent of the radon contained in the process solutions will be vented to atmosphere.

In the source term calculation CBR has adjusted the Radon release value to show that all of the contained Radon in the 5000 gpm flow processed by upflow IX will be released to the environment and that 10 percent of the contained Radon found in the 4000 gpm flow processed by pressurized downflow IX columns will be released to the environment during regeneration and venting.

Figure 7.12-6: Human Exposure Pathways for Known and Potential Sources from the Crow Butte License Area



Pathway

Contact media	Ingestion	Inhalation	Direct Exposure	Absorption
Surface Soil	X		X	
Subsurface Soil	X		X	
Fugitive Dust	X	X	X	X
Outdoor Air		X	X	
Indoor Air		X	X	
Surface Water	X			X
Sediment				
Crops/Meat	X			
Groundwater	X			

x Predominant Path (shaded cells)

7.12.3.2 Satellite Plant

The satellite plant would have 4500 gpm of production flow that would be processed by pressurized downflow ion exchange columns. The proposed satellite plant would consist of 8 to 10 pressurized downflow columns that would be operated with 2 columns in series and with either 4 or 5 sets of two operating in parallel. The columns will be nominally 8 feet in diameter and can process 500 to 750 gpm per set of two columns in series. Operation of these columns would only release a small fraction of the contained radon to the environment, with approximately 10 percent of the contained radon being released during resin transfer and venting.

After the IX resin is loaded the resin or eluate will be transferred to a trailer. It is anticipated that two resin or eluate shipments will be made per day. The trailer will transfer the resin or eluate to the main process facility for additional processing. The stripped and regenerated resin will be transferred to the trailer and returned to the satellite plant and be transferred into a process column.

The injection wells at the Central Plant and the proposed satellite facility will generally be closed and pressurized, but will be periodically vented. It was estimated that 25 percent of the radon will be released in the wellfields. The 25 percent released from the wellfields was assumed to be released from MU-4, MU-5, and the Raben Wellfield for mining with releases from MU-1, MU-2 and MU-3 for restoration.

In addition to releases from the wellfields, plant releases of radon will be from the main process facility through the plant vent and from the satellite facility (e.g., during resin transfer and venting) located in the McDowell Wellfield. The locations of the sources and receptors are in **Figure 7.12-7**. The height of the vent at the plant is 15.9 meters above the foundation of the facility.

The atmospheric emission of radon will lead to its presence in all quadrants of the region surrounding the current License Area and the proposed North Trend Satellite Facility. Due to the relatively short half-life of radon, the ingrowth of radon daughters during wind blown transportation must be considered. There exists an inhalation pathway as a result of the emission of radon gas. As the radon daughters' ingrow, deposition on the ground surface increases. A pathway also exists due to external radiation exposure arising from two sources. One source is radon and its daughters in the air, which is considered the cloud contribution. The other source is from radon daughters deposited on the ground, this source being termed the ground contribution.

A third pathway exists, which is the ingestion pathway. This results from direct foliar deposition and radionuclides in the soil being assimilated by the vegetation. The vegetation may represent a direct ingestion pathway to man if consumed, and a secondary pathway if fed to animals that are in turn consumed by man.

All of the above pathways are evaluated by MILDOS-Area.

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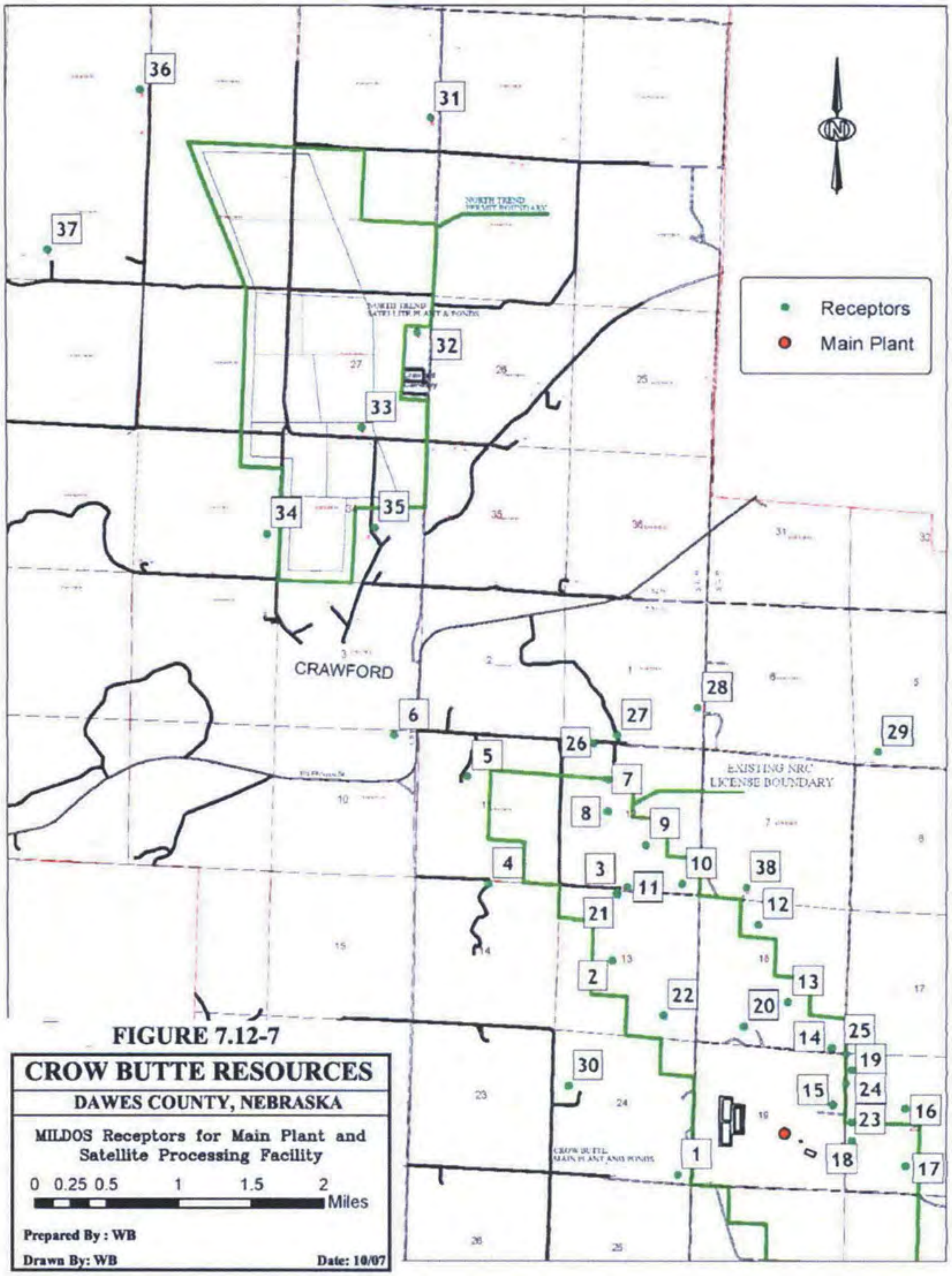
Figure 7.12-7: MILDOS Receptors for Main Plant and Satellite Processing Facility



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7.12.4 Exposures from Water Pathways

7.12.4.1 Main Plant

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

Three commercial evaporation ponds located approximately 2000 feet from the plant building have been constructed for commercial operation. There are also two R&D evaporation ponds located approximately 1,000 feet from the plant building. The R&D ponds have a 34-mil Hypalon liner and a leak detection system. The commercial evaporation ponds are lined with double impermeable synthetic liners. The ponds, therefore, are not considered a source of liquid radioactive effluents. There is a leak detection system installed to provide a warning if the liner develops a leak. The ponds, therefore, are not considered a source of liquid radioactive effluents. The use of ponds to manage liquid waste was discussed in further detail in **Section 4.**

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

The primary method of waste disposal at the Main Plant is by deep disposal well injection. The deep disposal well is completed at an approximate depth of 3,500 to 4,000 ft, isolated from any underground source of drinking water by approximately 2,500 feet of shale (Pierre and Graneros Shales). The well has been constructed under a Class I Underground Injection Control (UIC) Permit issued by the NDEQ and meets all requirements of the NDEQ UIC program. The use of a deep disposal well to manage liquid waste was discussed in further detail in **Section 4.**

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

7.12.4.2 Satellite Facility

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

The North Trend Satellite Facility will have evaporation ponds used to store waste solutions prior to deep well injection. The ponds will be double-lined with impermeable synthetic liners. A leak detection system will be installed to provide a warning if the liner develops a leak. The ponds, therefore, are not considered a source of liquid radioactive effluents. The use of ponds to manage liquid waste was discussed in further detail in **Section 4.**

The primary method of waste disposal at the North Trend Satellite Facility will be by deep disposal well injection. The deep disposal well will be completed at an approximate

depth of 3,500 to 4,000 ft, isolated from any underground source of drinking water by approximately 2,500 feet of shale (Pierre and Graneros Shales). The well will be constructed under a Class I Underground Injection Control (UIC) Permit issued by the NDEQ and will meet all requirements of the NDEQ UIC program. The use of a deep disposal well to manage liquid waste was discussed in further detail in **Section 4.**

The North Trend Satellite Facility will be located on a curbed concrete pad to prevent any liquids from entering the environment. Solutions used to wash down equipment will drain to a sump and be pumped to the ponds. The pad will be of sufficient size to contain the contents of the largest tank if it ruptures.

Since no routine liquid discharges of process water are expected from the North Trend Satellite Facility, there are no definable water-related pathways.

7.12.5 Exposures from Air Pathways

The only source of radioactive emissions is radon released into the atmosphere through a vent system or from the wellfields. As shown in **Figure 7.12-6**, atmospheric releases of radon can result in radiation exposure via three pathways; inhalation, ingestion, and external exposure. The total effective dose equivalent (TEDE) to nearby residents in the region around the main processing plant and satellite facility was estimated by using the computer simulation, MILDOS-Area. The joint frequency data compiled from a site-specific meteorological station were used to define the atmospheric conditions in the project area.

Currently, CBR has a license amendment request pending to increase the annual plant throughput from 5,000 gpm, exclusive of restoration flow to 9,000 gpm, exclusive of restoration flow. The license amendment was submitted on October 17, 2006 and the MILDOS-Area simulation included in this license amendment application reflects the requested flow increase. To show compliance with the annual dose limit found in 10 CFR § 20.1301, CBR has demonstrated by calculation that the TEDE to the individual most likely to receive the highest dose from the mining processing plant and the North Trend Satellite operation is less than 100 mREM/yr. The results of the MILDOS-Area simulation are presented in **Table 7.12-3**, which shows the estimated TEDE from operation of the main Crow Butte Plant and the North Trend Satellite Plant. The coordinates of all receptors are listed in **Table 7.12-4**. The source values and the locations of the sources are presented in **Table 7.12-5**. Receptor locations and appropriate identifiers are shown on **Figure 7.12-7**.

No TEDE limits were exceeded. An evaluation of the TEDE follows:

- The maximum TEDE was 31.7 mREM/yr at Receptor #15, which is located approximately 0.25 mile northeast of the Central Plant site.
- Receptor #31 (NT-1) is the closest resident in the downwind direction for the North Trend Satellite Plant. The estimated TEDE at this location was 5.8 mREM/yr.

Table 7.12-3: Estimated Total Effective Dose Equivalent (TEDE) to Receptors Near the Crow Butte Uranium Processing Facility

Receptor #	Description	Distance from Main Plant (km)	TEDE* (mREM/y)
1	R1	1.29	6.64
2	R2	2.76	4.82
3	R3	3.30	6.14
4	R4	4.36	1.92
5	R5	5.35	1.98
6	Crawford	6.25	1.65
7	R7	4.43	4.87
8	R8	4.11	5.16
9	R9	3.59	8.12
10	R10	3.03	16.0
11	R11	3.29	7.34
12	R12	2.37	17.7
13	R13	1.49	28.1
14	R14	1.10	28.3
15	R15	0.62	31.7
16	R16	1.34	9.48
17	R17	1.35	6.06
18	Ehlers	0.73	15.5
19	Gibbons	1.03	24.9
20	Stetson	1.30	19.9
21	Knode	3.28	6.09
22	Brott	1.92	16.2
23	SP1	0.75	18.1
24	SP2	0.89	26.2
25	SP3	1.13	24.8
26	McDowell	4.87	4.24
27	Taggart	4.83	4.87
28	Franey	4.86	6.55
29	Bunch	4.39	7.54
30	Dyer	2.50	3.27
31	NT-1	12.01	5.84
32	NT-2	9.83	3.41
33	NT-3	9.19	3.09
34	NT-4	8.87	2.14
35	NT-5	8.18	2.42
36	NT-6	13.7	1.63
37	NT-7	12.86	1.04
38	NT-8	2.79	15.9

*No differences in TEDE between age classes were observed.

Table 7.12-4: Individual Receptor Location Data

Location	X (km)	Y (km)	Distance (km)
1. R1	-1.21	-0.44	1.29
2. R2	-1.95	1.95	2.76
3. R3	-1.89	2.71	3.30
4. R4	-3.34	2.80	4.36
5. R5	-3.57	3.99	5.35
6. CRAWFORD	-4.39	4.45	6.25
7. R7	-1.99	3.96	4.43
8. R8	-1.99	3.60	4.11
9. R9	-1.57	3.23	3.59
10. R10	-1.16	2.80	3.03
11. R11	-1.78	2.77	3.29
12. R12	-0.30	2.35	2.35
13. R13	0.03	1.49	1.49
14. R14	0.51	0.98	1.10
15. R15	0.52	0.34	0.62
16. R16	1.31	0.30	1.34
17. R17	1.31	-0.34	1.35
18. EHLERS	0.73	-0.06	0.73
19. GIBBONS	0.73	0.73	1.03
20. STETSON	-0.46	1.22	1.30
21. KNODE	-1.89	2.68	3.28
22. BROTT	-1.37	1.34	1.92
23. SP 1	0.73	0.15	0.75
24. SP 2	0.67	0.58	0.89
25. SP 3	0.67	0.91	1.13
26. McDOWELL	-2.16	4.36	4.87
27. TAGGART	-1.89	4.45	4.83
28. FRANEY	-0.98	4.76	4.86
29. BUNCH	1.01	4.27	4.39
30. DYER	-2.44	0.55	2.50
31. NT-1	-3.97	11.33	12.01
32. NT-2	-4.12	8.93	9.83
33. NT-3	-4.75	7.87	9.19
34. NT-4	-5.82	6.69	8.87
35. NT-5	-4.61	6.76	8.18
36. NT-6	-7.20	11.65	13.70
37. NT-7	-8.25	9.86	12.86
38. NT-8	-0.44	2.76	2.79

Table 7.12-5: Source Coordinates for Crow Butte Project and North Trend Satellite

Source	East (km)	North (km)	Rn-222 (Curies)
1. Plant Vent	0.00	0.00	4603
2. Satellite Plant Vent	-5.30	9.60	342
3. MU-2-4 (restoration)	-0.30	0.16	350
4. MU-5	0.0	0.74	454
5. MU-6&8	1.92	-1.20	908
6. MU 7&9	0.00	-0.74	908
7. North Trend Wellfield	-5.30	9.60	1320

- The estimated TEDE at Receptor # 6, located on the east side of the town of Crawford, was 1.65 mREM/yr.
- The effect of the North Trend Satellite operation on the nearby residents of the existing Crow Butte facility is less than 1 mREM/yr.
- Since radon-222 is the only radionuclide emitted, public dose limits in 40 CFR 190 and the 10 mREM/yr constraint rule in 10 CFR §20.1101 are not applicable to the CBR facility.

Based on the site specific data (**Table 7.12-6**) and method of estimation of the source term presented in **Appendix A**, the modeled emission rate of Radon from the Crow Butte Project will be 7178 Ci/yr which consists of a flow of 5000 gpm in the upflow ion exchange columns in the existing plant along with the proposed 4000 gpm of flow treated in the pressurized downflow ion exchange columns.

Based on the site specific data (**Table 7.12-6**) and the method of estimation of the source term presented in **Appendix A**, the modeled annual emission rate of radon from the North Trend Satellite Facility is 1482 Ci/yr, which includes releases from ion exchange, production and restoration activities.

Additional discussions as to radon emissions from operations and restoration activities at the Central Plant and satellite facility are presented in **Section 5.8**.

Seven air monitoring stations are used to monitor radon gas effluent to the environment around the Crow Butte Plant. The applicant reviewed the Radon monitoring data obtained at these locations from 1991 through June of 2007 and these data are found in **Table 5.8-6** and **Figures 5.8-10** through **5.8-16.**

Sources 2 and 7 are from the proposed North Trend Satellite Facility operating at 4500 gpm using upflow IX columns and 500 gpm restoration flow using downflow IX and reverse osmosis. Resin from the North Trend Satellite is transferred to the Crow Butte processing facility for elution and precipitation.

All other sources are from the existing Crow Butte processing facility operating at 5000 gpm production flow using downflow IX columns, 4000 gpm production flow using pressurized upflow IX columns, and a 1000 gpm restoration flow using downflow IX and reverse osmosis.

Table 7.12-6: Site Specific Information Crow Butte Project and North Trend Expansion Area

Parameter	Value
Average ore quality, U_3O_8, in ore body	0.27 percent
Ore radon activity, assuming equilibrium with U-238	761 pCi/g
Operating days per year (plant factor)	365 days
Dimensions of ore body	
Area per year to be mined	20 acres
Average thickness of body	5 ft
Average screened interval	15.1 ft
Average production flow rate (Satellite Facility)	4500 gpm
Average production flow rate (Main Facility)	9000 gpm
Formation porosity	29 percent
Process recovery	95 percent
Leaching efficiency	60 percent
Rock density	1.89 g/cm^3
Restoration flow rate (Satellite Facility)	500 gpm
Restoration flow rate (Main Facility)	1000 gpm
Restoration Residence time	35 days
Production cell parameters	
Residence time	7 days
Type of cell pattern	variable
Average cell area	10,000 ft^2
Average cell flow rate	121 lpm
Source stack description (Main)	
Stack height	15.9 m
Stack diameter	0.30 m
Stack velocity	11 m/sec
Source stack description (Satellite)	
Stack height	10 m
Stack diameter	0.2
Stack velocity	10 m/sec

ft/ft^2 = feet/square feet
g/cm^3 = grams per cubic centimeter
gpm = gallons per minute
lpm = liters per minute
m = meter
m2/sce = meters squared per second
pCi/g = picoCuries per gram

The results of the area ambient radon 222 concentrations and radionuclide concentrations for each monitoring site, and for TLD monitors at each site, fall within the expected

ranges for all semi-annual reporting periods between the second half of 1998 through the first half of 2007 with the exception of results for the periods summarized below.

For the second half of 2003, the radon-222 results from three stations (AM-1, AM-2, and AM-8) were elevated above concentrations that are normally present. These sample locations are located along the eastern and northern boundaries of the License Area and Section 19. The cause of the elevated radon-222 concentrations is not known. Radon release levels from the Crow Butte project for the period are consistent with those since increased process flows were approved in 1998, so it does not appear that project releases are the source. CBR noted that there was no identifiable cause for these elevated concentrations from licensed operations. One possible cause for the anomalous results is sampling or analytical error. In order to monitor this possibility, CBR deployed duplicate monitors at the three stations for the second half of 2004 for comparison of results. Even those these spikes in 2003 were above normal concentrations at the environmental monitoring stations (generally less than 10 percent), the levels were well below levels considered protective of the public.

In the initial analytical results, the results from several stations were elevated and did not correlate well to the results from the duplicate monitors; therefore all monitors were reanalyzed. The results of the reanalysis resulted in changes in reported values ranging from 0 percent to over 120 percent. The variance in the reported values was likely due to a routine quarterly update of the background track density for manufacturing lots. The repeat analysis was performed after the background update and in all cases where the reanalysis resulted in a change, the reported values were lower and were consistent with historical concentrations. It is possible that a similar situation was the cause of the higher concentrations noted in the second half of 2003. CBR will continue to place duplicate monitors at six stations through 2005 to determine the accuracy of the monitoring method.

7.12.6 Population Dose

The annual population dose commitment to the population in the region within 80 km of the Crow Butte Project is also predicted by the MILDOS-Area code. The results are listed in **Table 7.12-7**, where the dose to the bronchial epithelium is expressed in person-rem. For comparison, the dose to the population within 80 km of the facility due to natural background radiation is included in the table. These figures are based on the 1980 population and average radiation doses reported for the Western Great Plains.

The atmospheric release of radon also results in a dose to the population on the North American continent. This continental dose is calculated by comparison with a previous calculation based on a 1 kilocurie release near Casper, Wyoming, during the year 1978. The results of these calculations are included in **Table 7.12-7** and also combined with dose to the region within 80 km of the facility to arrive at the total radiological effects of one year of operation at the Crow Butte Project.

For comparison of the values listed in **Table 7.12-7**, the dose to the continental population as a result of natural background radiation has been estimated. This estimate is

based on a North American population of 346 million and a dose to each person of 500 mREM/yr to the bronchial epithelium. The maximum radiological effect of the combined operation of the North Trend Satellite Plant and the Crow Butte Project would be to increase the dose to the bronchial epithelium of the continental population by 0.0023 percent.

Table 7.12-7: Dose to the Population Bronchial Epithelium and Increased Continental Dose from One Year's Operation at the Crow Butte Facility

Criteria	Dose (person-rem/yr)
Dose received by population within 80 km of the facility	171
Natural background by population within 80 km of the facility	24025
Dose received by population beyond 80 km of the facility	224
Total continental dose	394
Natural background for the continental population	$1.73 \times 10^{+8}$
Fraction increase in continental dose	2.27×10^{-6}

7.12.7 Exposure to Flora and Fauna

The exposure to flora and fauna was evaluated in Environmental Reports submitted in September of 1987 for the Central Plant, and in 2007 for the North Trend Satellite Plant, and the doses were found to be negligible. The proposed increase in process flow to 9,000 gpm at the Central Plant, and the addition of the North Trend Satellite Facility, is not expected to have any measurable impact on dose to flora and fauna.

7.13 WASTE MANAGEMENT IMPACTS

Liquid wastes generated from production and restoration activities are handled by one of three methods: solar evaporation ponds, deep well injection, or land application. All three methods are currently being employed at Crow Butte.

Alternative pond design and locations have been considered. The sites selected represent the best location considering proximity to the plant, size of drainage and suitable soils. The design is such that any seepage of toxic materials into the subsurface soils or hydrologic system would be prevented or minimized. The ponds have also been designed to protect the down-gradient are from surface flows and subsurface seepage in the event of dam failure.

All solid wastes are transported from the site for disposal. Non-contaminated waste is shipped to an approved sanitary landfill. Contaminated wastes are shipped to a USNRC approved facility for disposal. Should a USNRC licensed disposal facility not be available to CBR at the time of decommissioning, the alternative of on-site burial may be necessary. This alternative could incur long term monitoring requirements and more expensive reclamation costs; however, it may be the only alternative available to Crow Butte at that time.

7.14 EFFECTS OF ACCIDENTS

Accidents involving human safety associated with the in-situ uranium mining technology typically have far less severe consequences that accidents associated with underground and open pit mining methods. In-situ mining provides a higher level of safety for personnel and neighboring communities when compared to conventional mining methods or other energy related industries. Accidents that may occur would generally be quite minor when compared to other industries, such as an explosion at an oil refinery or chemical plant. Radiological accidents that might occur would typically manifest themselves slowly and are therefore easily detected and mitigated. The remote location of the facility and the low level of radioactivity associated with the process both decrease the potential hazard of an accident to the general public.

7.14.1 Tank Failure

Process fluids are contained in vessels and piping circuits within the process plant or in bermed outside storage tanks. The process plant has been designed to control and confine liquid spills should they occur. The plant building structure and concrete curb will contain the liquid spills from the leakage or rupture of a process vessel and will direct any spilled solution to a floor sump. The floor sump then pumps any spilled solutions back into the plant process circuit or to the waste disposal system.

All tanks inside the plant are constructed of fiberglass or steel. Instantaneous failure is thus highly unlikely. Tank failure would more likely occur as a small leak in the tank. In this case, the tank would be emptied to at least a level below the leaking area and repairs or replacement made as necessary. SOPs are in place to respond to any spill that may occur.

7.14.2 Pipe Failure

The rupture of a pipeline within the process plant is easily visible and can be repaired quickly. Spilled solution is contained and removed in the same fashion as for a tank failure.

The rupture of an injection or recovery line in a wellfield, or a trunkline between a wellfield and the process plant would result in either a release of barren or pregnant lixiviant solution that would contaminate the ground in the area of the break.

All piping from the plant, to and within the wellfield is buried for frost protection. Pipelines are constructed of PVC, high-density polyethylene with butt-welded joints or equivalent. All pipelines are pressure tested at operating pressures prior to final burial and production flow. As no additional stress is placed on a pipeline following burial, catastrophic failures are unlikely. The section of trunkline that flows under Squaw Creek has been double contained for additional safety.

Each wellfield has a number of wellfield houses, where injection and recovery lines are continuously monitored. Individual lines can each have high and low flow alarm limits

set. All set points and alarms are monitored in the control room via the computer system. In addition, each wellfield building has a "wet" alarm to detect the presence of any liquids that may be present.

Small occasional leaks at pipe joints and fittings in the wellfield house or at the wellheads may occur from time to time. Until remedied, these leaks may drip some solution into the underlying soil. After repair, the soil will be surveyed for contamination and removed as appropriate. Preventative maintenance programs are in place to preclude this type of spill to the extent possible. In the event of a catastrophic pipe failure, solutions released would still be minimal as the pressure in the lines is not that great. In addition, all drainage to Squaw Creek has been diked and bermed to protect this water source.

7.14.3 Pond Failure

An accident involving a leak in a solar evaporation pond is detectable either from the regular visual inspections or via the leak detection system. The inspection program consists of daily, weekly, monthly and quarterly inspections in conjunction with an annual technical evaluation of the pond system. Any time six inches or more of fluid is detected in the standpipes, it is analyzed for specific conductance. If the water quality is degraded beyond the action level, it is sampled again and analyzed for chloride, alkalinity, sodium, and sulfate.

In the event of a leak, the contents of any one pond can be transferred to the other ponds while repairs are made. Freeboard requirements may be waived during this period. Catastrophic failure of a berm is also unlikely given the design requirements of the pond and the freeboard that is maintained. The pond soil foundation is compacted and has low ambient moisture, thus leaking solutions would not tend to migrate. Contingency plans are in place to address situations that may occur.

7.14.4 Lixiviant Excursion

Mining fluids are normally maintained in the production aquifer within the immediate vicinity of the wellfield. The function of the encircling monitor well ring, which is installed prior to any production activity, is to detect any lixiviant that may migrate away from the production area due to fluid pressure imbalance. This system has been proven to function satisfactorily over many years of operating experience with in-situ mining.

For the Crow Butte Project, monitor wells are located no further than 300 feet from the wellfields and screened in the ore-bearing Chadron Aquifer. Additionally, monitor wells are placed in the first overlaying aquifer above each wellfield segment. Sampling on these wells occurs on a regular basis as described in **Section 5.8**. The total effect of close proximity of the monitor wells, low flow rate from the well patterns, and over-production of leach fluids (production bleed) makes the likelihood of an undetected excursion remote.

7.14.5 Transportation Accidents

Transportation of materials to and from Crow Butte can be classified as follows:

- Shipments of yellowcake
- Shipments of process chemicals or fuel from suppliers to the site.
- Shipment of radioactive waste from the site to a licensed disposal facility.
- If the satellite plant is built, shipments of uranium-laden resin from the satellite plant to the main process facility.
- If the satellite plant is built, shipments of barren eluted resin or eluate from the main processing facility back to the satellite plant.

Accidents involving these transportation occurrences are discussed below. It is assumed that all transports will be made with contracted vehicles and licensed drivers, with the exception of the on-site transfers between the satellite plant and main facility should the satellite be built. In all likelihood, these transfer vehicles would be operated by a Crow Butte employee.

7.14.5.1 Accidents Involving Yellowcake Shipments

Accidents involving yellowcake shipment can take two forms. The first would involve a shipment of dried yellowcake product being shipped from the Crow Butte facility after processing. The second would involve the shipment of uranium oxide or yellowcake slurry. The slurry could be enroute from Crow Butte to another facility for processing, or it could be a shipment being sent to Crow Butte for processing. Slurry would generally be shipped from Crow Butte only if the dryer were not operational. Regarding slurry shipments to Crow Butte, there are currently no contracts or plans that would anticipate such a situation.

The dried yellowcake that is produced at Crow Butte is generally packaged in fifty-five gallon 18 gauge drums holding an average of 364 kg (800 pounds), classified by the Department of Transportation as Type A packaging (49 CFR Parts 171-189 and 10 CFR Part 71). An average truck shipment contains approximately 55 drums, or 17.5 tons of yellowcake. At the current production levels, approximately two shipments per month are made. At the proposed production level, it is expected that approximately three to four shipments per month would be necessary. If it becomes necessary to transport slurry, it will be transported in either a trailer-mounted tank vessel or in lined drums.

All vehicles and shipments are surveyed prior to leaving the site. The driver is provided with copies of all documents in the shipping packet. The shipping packet contains current copies of the shipping papers containing an exclusive use statement, the bill of lading, the Form 741, the contamination survey results, copies of the emergency telephone numbers, the emergency procedures, a list of materials in the spill control kit, and the driver responsibility statement.

In the accident analysis of the Sand Rock Mill Project, a transportation accident involving yellowcake was assumed for which an environmental release fraction of 9 x 10^{-3} of fractional probability of occurrence was calculated. This represents the initial airborne material released at an accident site carried by a five meter/second (10 mph) wind for a twenty-four hour period. Assuming a population density of sixty-two people per square kilometer, a fifty-year dose commitment to the lungs in the general population was estimated at between 0.9 and 13 man-rem, depending upon the severity of the spill. This value was considered small when compared with the estimated fifty year integrated lung dose of 1427 man-rem from natural background (USNRC, 1982). The relatively low activity of the product combined with the low population density in Northwest Nebraska and Wyoming would produce even lower dose commitments than the above estimates in the event of an accident.

7.14.5.2 Accidents Involving Shipments of Process Chemicals

Based on the current production schedule and material balance, it is estimated that approximately 272 bulk chemical deliveries per year will be made to the site. This averages about one truck per working day for delivery of chemicals throughout the life of the project. The proposed increase in production capacity would increase this number somewhat. Types of deliveries include carbon dioxide, hydrochloric acid, sodium chloride, hydrogen peroxide, oxygen, and soda ash. Since no unusual or hazardous driving conditions are known to exist in the northwest part of Nebraska, the accident rate should be that of the overall chemical trucking industry. Based on published accident statistics the probability of a truck accident is in the range of 1.0 to 1.6 x 10^{-6}/km. (1.6 to 2.6 x 10^{-6}/mile). Truck accident statistics include three categories of events:

- **Collisions-** between the transport vehicle and other objects, whether moving vehicles or fixed objects.
- **Noncollisions-** accidents involving only one vehicle, such as when it leaves the road and rolls over.
- **Other events-** include personal injuries suffered on the vehicle, persons falling from or being thrown against a standing vehicle, cases of stolen vehicles, and fires occurring in a standing vehicle.

The likelihood of a truck shipment of chemicals or product from the Crow Butte Project being involved in an accident of any type in the Crawford area during a one-year period is approximately 1 percent.

7.14.5.3 Accidents Involving Radioactive Wastes

Low level radioactive solid byproduct material or unusable contaminated equipment generated during operations are transported to a licensed disposal site as needed. Because of the low levels of radioactive concentration involved, these shipments are considered to have minimal potential impact in the event of an accident. Emergency response procedures are the same as for yellowcake shipments.

7.14.5.4 Accidents Involving Resin Transfers

One of the potential impacts of a satellite plant is the transfer of the uranium-loaded resin or eluate from the satellite to the main process facility.

Resin will be transported to and from the Crow Butte satellite plant in a specially designed, low-profile, 400 cubic foot (3,000 gallon) capacity tanker trailer. It is currently anticipated that two loads of uranium laden resin will be transported to the Crow Butte recovery facility for elution, and two loads of barren eluted resin will be returned to the Crow Butte satellite plant on a daily basis. The transfer of resin between the two sites will occur on county and private roads within the License Area.

Resin or eluate shipments shall be treated similarly to yellowcake shipments in regards to Department of Transportation (DOT) and USNRC regulations. Shipments will be handled as Low Specific Activity (LSA) material, for both uranium laden and barren eluted resin. Pertinent procedures, which Crow Butte will follow for a resin shipment, including emergency procedures in the event of an accident, are discussed n detail in the North Trend Amendment Expansion Area Technical Report

Currently, CBR intends to treat the eluted resin the same as the uranium loaded resin. It is possible that the eluted resin may be clean enough to be transported as non-radioactive material, as defined by DOT regulations. Operating experience will aid in the determination of the most practical and efficient way of dealing with the shipment of barren resin. Regardless, compliance with all applicable DOT and USNRC regulations will be the primary determining factor.

7.14.6 Other Accidents

Other potential accidents involving non-radiological materials are associated with the various chemical and fuel storage tanks maintained outside the process facilities. Each of the liquid chemical storage tanks is located on curbed concrete pads to contain any spills. The oxygen and carbon dioxide, which are stored as liquefied gases, do not require a curbed concrete pad for containment since these chemicals will convert to gaseous form and vent to the atmosphere if a leak occurred. These tanks are stored away from the processing building and yellowcake storage area.

Accidents involving personnel are also a possibility, although with a small work force, not considered to be likely. Personnel are trained in safety and emergency procedures in accordance with Mine Safety and Health Administration regulations. Initial and refresher training include occupational safety, first aid, radiation safety and fire procedures.

8 ALTERNATIVES TO PROPOSED ACTION

8.1 NO-ACTION ALTERNATIVE

8.1.1 Summary of Current Activity

CBR currently operates the Crow Butte Project; a commercial ISL uranium mining operation located approximately 4.0 miles southeast of Crawford in Dawes County, Nebraska. Operation is allowed under USNRC Source Materials License SUA-1534.

An R&D facility was operated on the property in 1986 and 1987. Construction of the commercial process facility began in 1988, with production beginning in April of 1991. The total current License Area occupies 2,875 acres, and the surface area to be affected by the current commercial project will be approximately 1,265 acres. Facilities include the R&D facility, the commercial process facility and office building, solar evaporation ponds, parking, access roads, and wellfields.

In the current License Area, uranium is recovered by ISL from the Chadron Sandstone at a depth that varies from 400 feet to 800 feet. The overall width of the mineralized area varies from 1,000 feet to 5,000 feet. The ore body ranges in grade from less than 0.05 percent to greater than 0.5 percent U_3O_8, with an average grade estimated at 0.27 percent U_3O_8. Production is currently in progress in Mine Units 10 and 11. Groundwater restoration has been completed and received regulatory approval in Mine Unit 1. Groundwater restoration is currently underway in Mine Units 2 through 4.

The current extraction plant is operating with a licensed process flow rate of 5,000 gpm exclusive of restoration flow. Maximum allowable throughput from the plant under SUA-1534 is currently 2,000,000 pounds (lb) of U_3O_8 per year. On October 16, 2006, CBR submitted a request to the USNRC for a license amendment to increase the plant throughput from 5,000 to 9,000 gpm. USNRC approval is pending.

8.1.2 Impacts of the No-Action Alternative

The no-action alternative would allow CBR to continue mining operations in the current License Area until the USNRC formally denied the renewal of the license application. As long as CBR submits a source material renewal application to the USNRC at least thirty days before the expiration date of the existing license (February 28, 2008), the license would not expire until the USNRC determined the final disposition of the renewal application and advised CBR of its decision. If the license renewal was not approved by the USNRC, restoration and reclamation activities would then become the primary activities.

If renewal of the current source material license was not approved, all activities at the Crow Butte site that are not associated with groundwater restoration and decommissioning would be completed, resulting in the loss of a significant portion of the

total employment at the site. At the completion of decommissioning activities, all employment opportunities at the mine would be terminated.

In addition to the loss of significant employment opportunities in Crawford and Dawes Counties, the premature closing of the Crow Butte Project before commercially viable resources had been recovered would adversely affect the economic base of Dawes County. As discussed in further detail in **Section 7.10** and shown in **Table 8.1-1**, the Crow Butte Project currently provides a significant economic impact to the local Dawes County economy.

Table 8.1-1: Current Economic Impact of Crow Butte Project

	Current Crow Butte Operation Annual Economic Impact
Employment	
Full-Time Employees	52
Full-Time Contractor Employees	20
Part-Time Employees and Short Term Contractors	7
CBR Payroll, 2006	$3,400,000
Taxes	
Property Taxes	$627,000
Sales and Use Taxes	$238,000
Severance Taxes	$545,000
Total Taxes	$1,410,000
Local Purchases	
Local Purchases, 2006	$6,800,000
Total Direct Economic Impacts	
	$11,610,000

A decision to not renew SUA-1534 for mining in the Crow Butte License Area would leave a large resource unavailable for energy production supplies. In 2006, total domestic U.S. uranium production was approximately 4 million pounds U_3O_8, of which more than 700,000 pounds (or approximately 18 percent) were produced at the Crow Butte Project. During the same year, domestic U.S. uranium consumption was approximately 67 million pounds of U_3O_8 with approximately 16 percent supplied by domestic producers (EIA 2007). The Crow Butte Project represents an important source of domestic uranium supplies that are essential in providing a continuing source of fuel to power generation facilities. The current limited supplies of fuel for nuclear power plants may negatively impact the renewed and growing interest in nuclear energy in the U.S. and other nations (MIT 2007).

In addition to leaving a large deposit of valuable mineral resources untapped, a denial of this license renewal would result in the loss of a large investment in time and money made by CBR for the rights to and development of these valuable deposits. Denial of this license renewal would also have an adverse economic impact on the individuals who have surface leases with CBR and own the mineral rights within the License Area.

8.2 PROPOSED ACTION

With USNRC approval of Source Material License SUA-1534, CRB would continue to operate the Crow Butte Project ILR operation as discussed in **Section 5** of this LRA. Amendments to the license may be sought as needed in order to recover the uranium resources, for which CBR holds valid claims, in the most effective manner.

8.3 REASONABLE ALTERNATIVES

8.3.1 Process Alternatives

8.3.1.1 Lixiviant Chemistry

CBR is using a sodium bicarbonate lixiviant that is an alkaline solution. Where the groundwater contains carbonate, as it does at CBR, an alkaline lixiviant will mobilize fewer hazardous elements from the ore body and will require less chemical addition than an acidic lixiviant. Also, test results at other projects indicate only limited success with acidic lixiviants, while the sodium bicarbonate has proven highly successful on the CBR R&D project and on commercial mining operations to date. Alternate leach solutions include ammonium carbonate solutions and acidic leach solutions. These solutions have been used in solution mining programs in other locations; however, operators have experienced difficulty in restoring and stabilizing the aquifer. Therefore, these solutions were excluded from consideration.

8.3.1.2 Groundwater Restoration

The restoration of the R&D project, the successful completion of restoration in Mine Unit 1, and the current restoration activities in Mine Units 2 through 4 at the current License Area exhibit the effectiveness of the restoration methods, in which groundwater sweep, permeate/reductant injection, and aquifer recirculation restored the groundwater to pre-mining quality. No feasible alternative groundwater restoration method is currently available for the Crow Butte project. The USNRC and NDEQ consider the method currently employed as the BPT available.

8.3.1.3 Waste Management

Liquid wastes generated from production and restoration activities are handled by one of three methods: solar evaporation ponds, deep disposal well injection, or land application. All three methods are permitted at the current operation; however, only solar evaporation ponds and deep disposal have been implemented. The use of deep waste disposal wells in conjunction with storage/evaporation ponds to dispose of the high total dissolved solids (TDS) liquid wastes that primarily result from the yellowcake processing and drying facilities is considered the best alternative to dispose of these types of wastes.

All solid wastes are transported from the site for disposal. Non-contaminated waste is shipped to an approved sanitary landfill. Radioactive-contaminated wastes are shipped to an USNRC-approved facility for disposal. Should an USNRC (or Agreement State) licensed disposal facility not be available to CBR at the time of decommissioning, the alternative of on-site burial may be necessary. This alternative could incur long-term monitoring requirements and more expensive reclamation costs.

8.4 ALTERNATIVES CONSIDERED BUT ELIMINATED

Several mining alternatives were considered as a part of the alternatives analysis conducted by CBR for the original 1987 permit application. Due to the significant environmental impacts and cost associated with these mining alternatives, they were eliminated from further consideration.

8.4.1 Mining Alternatives

Underground and open pit mining represent the two currently available alternatives to solution mining for the uranium deposits within the License Area. Neither of these methods is economically viable for producing the Crow Butte reserves at this time. These alternative methods are not economically feasible for several reasons including the spatial characteristics of the mineral deposit and environmental factors. The depth of the deposit and subsequent overburden ratio make surface mining impractical. Surface mining is commonly undertaken on large, shallow (less than 300 feet) ore deposits. Within the License Area, uranium is recovered from depths ranging from 400 to 800 feet.

In addition, the physical characteristics of the deposit and the overlying materials make underground mining infeasible for the Crow Butte Project. The costs of mine development, including surface facilities, shaft, subsurface stations, ventilation systems, and drifting, would decrease the economic efficiency of the project.

From an environmental perspective, open pit mining or underground mining and the associated milling process involve higher risks to employees, the public, and the environment. Radiological exposure to the personnel in these processes is increased, not only from the mining process, but also from milling and the resultant mill tailings. The personnel injury rate is traditionally much higher in open pit and underground mines than has been the experience at ISL solution mining operations.

Both open pit and underground mining methods would require substantial de-watering to depress the potentiometric surface of the local aquifers to provide access to the ore. The groundwater does contain naturally high levels of radium-226 that would have to be removed prior to discharge, resulting in additional radioactive solids that would require disposal. For conventional mining, a mill tailings pond that could contain 5 to 10 million tons of solid tailings waste from the uranium mill would also be required. Reclaiming mill tailings ponds typically requires dewatering/treatment of contaminated fluids, extensive in-place reclamation, and long-term monitoring.

In a comparison of the overall impacts of ISL of uranium compared with conventional mining, an USNRC evaluation concluded that environmental and socioeconomic advantages of ISL include the following: U.S. Nuclear Regulatory Commission, *Draft Environmental Statement Related to the Operation of the Teton Project*, NUREG-0925, June 1982 Para. 2.3.5.

- Significantly less surface area is disturbed than in surface mining, and the degree of disruption is much lower.
- No mill tailings are produced, and the volume of solid wastes is reduced significantly. The gross quantity of solid wastes produced by ISL is generally less than 1 percent of that produced by conventional milling methods (more than 2,090 lbs of tailings usually result from processing each metric ton 2,200 lbs of ore).
- Because no ore and overburden stockpiles or tailings pile(s) are created, and the crushing and grinding ore-processing operations are not needed, the air pollution problems caused by windblown dusts from these sources are eliminated.
- The tailings produced by conventional mills contain essentially all of the radium-226 originally present in the ore. By comparison, less than 5 percent of the radium in an ore body is brought to the surface when ISL methods are used. Consequently, operating personnel are not exposed to the radionuclides present in and emanating from the ore and tailings, and the potential for radiation exposure is significantly lower than that associated with conventional mining and milling.
- By removing the solid wastes from the site to a licensed waste disposal site and otherwise restricting them from contaminating the surface and subsurface environment, the entire mine site can be returned to unrestricted use within a relatively short time.
- Solution mining results in significantly less water consumption than conventional mining and milling.
- The socioeconomic advantages of ISL include:
    - The ability to mine a lower grade ore,
    - A lower capital investment,
    - Less risk to the miner,
    - Shorter lead time before production begins, and
    - Lower manpower requirements.

Finally, and perhaps most importantly, because Crow Butte is now an established commercial solution mining site, there are no viable alternative mining methods at this time. The current market price of uranium makes an established solution mining operation the most economically viable method of mining uranium.

8.5 CUMULATIVE EFFECTS

8.5.1 Cumulative Radiological Impacts

The USNRC website provides the location of all fuel cycle facilities in the United States, including source material facilities (e.g., uranium mills). The website was reviewed to identify the location of fuel cycle facilities within an 80-km (50-mile) radius of the CBR ISL facility (USNRC 2007).

The CBR operation is currently the only nuclear fuel cycle facility located in the state of Nebraska. There are no other fuel cycle facilities (including conventional uranium mills and in situ recovery facilities) located within 80 km of the CBR License Area. The nearest uranium in-situ recovery plant is the Highland Mines/Smith Ranch facility in Campbell County, Wyoming, which is currently the only producing facility in Wyoming. This facility is located approximately 100 miles west-northwest of the CBR facility. The White Mesa Mill located in southeastern Utah is currently the only fully licensed, operating conventional uranium mill in the U.S.

Other fuel cycle facilities that are nearest the CBR facility, but well beyond the 80-km radius, include the following: Honeywell International, Inc. Uranium Hexafluoride Production (Conversion) Facility, Metropolis, Illinois (currently the only active conversion plant in U.S.); AREVA NP, Inc. Uranium Fuel Fabrication Facility, Richland, Washington; Louisiana Energy Services Gas Centrifuge Enrichment Facility (under construction), Hobbs, New Mexico; and the U.S. Enrichment Corporation Gas Centrifuge Enrichment Facility, in Paducah.

There are two operating nuclear reactors located in the state of Nebraska beyond the 80-km radius: Cooper Boiling Water Reactor, 23 miles south of Nebraska City; and the Ft. Calhoun Pressurizes Water Reactor, 19 miles north of Omaha, Nebraska.

Potential impacts associated with the cumulative impacts associated with other existing radiological sources are considered to be *de minimus*. This is due primarily to the fact there are no nuclear fuel cycle facilities located within a 80-km radius of the CBR facility, there have been no cumulative impacts observed during the operating life of the CBR facility (16 years), and the CBR facility has operated for approximately 16 years with no observable significant adverse impacts associated with its operations (e.g., environmental).

8.5.2 Future Development

CBR has identified several additional resource areas in the region near the Crow Butte Central Plant that could conceivably be developed as satellite facilities. CBR submitted a request on May 30, 2007 for an amendment to Source Material License SUA-1534 for the development of additional uranium ISL mining resources called the North Trend Expansion Area. The proposed development area would be located approximately 1.0 mile northwest of the current License Area and would be used as a satellite facility to the existing Central Plant. Commercial production at the Crow Butte Project, including the

proposed North Trend Expansion Area, is expected to extend over the next 10 years with depletion of uranium reserves at both areas by 2017.

Development of additional satellite facilities depends on further site investigations by CBR and the future of the uranium market. If conditions warrant, CBR may submit additional license amendment requests to permit development of these additional resources. However, CBR currently projects that development of these areas would be primarily intended to maintain production allowed under the current license as reserves in the current licensed area are depleted.

CBR believes that the only environmental impact from approval of the increased flow rate at the current operation would be a corresponding increase in the emission of radon-222 from the current operation. The amendment request estimated a 22 percent increase in the maximum public dose. CBR estimated that the maximum public dose would remain well below the public dose limit found in 10 CFR § 20.1301.

8.5.2.1 Other Fuel Cycle Facility Development

With the increase in worldwide demand for uranium, and the resulting increase in the price of uranium, additional fuel cycle facilities such as uranium milling (e.g., conventional uranium milling and in situ recovery facilities) are in the planning and development stages in the U.S., including Wyoming and South Dakota (USNRC 2007). The addition of any new fuel cycle facilities in close proximity to the CBR facility could result in cumulative impacts, with impacts depending upon the type of fuel cycle facilities. Any such future cumulative impacts associated with new fuel cycle facilities would have to be assessed once future plans for any such facilities are better understood.

Today, ISL has evolved to the point where it has been demonstrated to be both an economic and environmentally acceptable method for extracting uranium (IAEA 2005). The primary environmental consideration with ISL is typically the risk of groundwater contamination. Any future cumulative environmental impacts associated with ISL development in the area would be expected to be associated primarily with groundwater. Historically, groundwater contamination associated with ISL facilities using strict environmental controls, has been demonstrated to be controllable, safe and environmentally sound.

Cumulative impacts associated with local and regional socioeconomic issues would also be important considerations associated with significant future uranium development in the area of the existing CBR uranium operations.

8.6 COMPARISON OF THE PREDICTED ENVIRONMENTAL IMPACTS

Table 8.6-1 summarizes the environmental impacts for the no-action alternative, the preferred alternative, and the process alternatives discussed above. The predicted impacts for the mining alternatives are not included for comparison because these alternatives were rejected due to significant environmental and economic impacts. Environmental impacts are discussed in greater detail in **Section 7** of this LRA.

Table 8.6-1: Comparison of Predicted Environmental Impacts

			Process Alternatives	
Impacts of Operation	**No-Action Alternative**	**Preferred Alternative**	**Alternate Lixiviant Chemistry**	**Alternate Waste Management**
Land Surface Impacts	None	Minimal temporary impacts in wellfield areas; Significant surface and subsurface disturbance confined to a portion of the 30-acre satellite plant site.	Same as Preferred Alternative.	Same as Preferred Alternative. Potential additional impacts from land application of treated waste water.
Land Use Impacts	None	Loss of crop and cattle production in 1,310-acre impacted area for duration of project.	Same as Preferred Alternative.	Same as Preferred Alternative plus a potential long-term land use impact from on-site disposal of 11(e)2 byproduct material.
Transportation Impacts	None	Minimal impact on current traffic levels. Estimated additional heavy truck traffic of 500 trips per year; additional 6 to 8 VTPD light duty trucks.	Same as Preferred Alternative.	Same as Preferred Alternative.
Geology and Soil Impacts	None	None	None	None
Surface Water Impacts	None	None	None	None
Groundwater Impacts	None	Consumption of Chadron groundwater for control of mining solutions and restoration (estimated at 50 gpm average).	Same as Preferred Alternative. Increased difficulty with groundwater restoration and stabilization.	Same as Preferred Alternative.
Ecological Impacts	None	No substantive impairment of ecological stability or diminishing of biological diversity.	Same as Preferred Alternative.	Same as Preferred Alternative.

Table 8.6-1: Comparison of Predicted Environmental Impacts

Impacts of Operation	No-Action Alternative	Preferred Alternative	Process Alternatives: Alternate Lixiviant Chemistry	Process Alternatives: Alternate Waste Management
Air Quality Impacts	None	Additional 14.5 tons per year total dust emissions due to vehicle traffic on gravel roads.	Same as Preferred Alternative.	Same as Preferred Alternative.
Noise Impacts	None	Barely perceptible increase over background noise levels in the area.	Same as Preferred Alternative.	Same as Preferred Alternative.
Historic and Cultural Impacts	None	None	None	None
Visual/Scenic Impacts	None	Moderate impact; noticeable minor industrial component in sensitive viewing areas.	Same as Preferred Alternative.	Same as Preferred Alternative plus possible long-term visual and scenic impacts from on-site disposal cell for 11(e)2 byproduct material.
Socioeconomic Impacts	Eventual loss over the next 5 to 10 years of positive economic impact of $8.95M to the local area as reserves deplete in the current licensed operation.	Extension of the current annual direct economic impact of $8.95M plus the addition of between $5.05M and $6.03M annual direct economic impact to the local area.	Same as Preferred Alternative.	Same as Preferred Alternative.
Nonradiological Health Impacts	None	None	None	None
Radiological Health Impacts	None	12 percent increase in estimated maximum dose from additional radon gas released at Crow Butte.	Same as Preferred Alternative.	Same as Preferred Alternative.
Waste Management Impacts	None	Generation of additional liquid and solid waste for proper disposal.	Same as Preferred Alternative. Mobilization of additional hazardous elements in lixiviant requiring disposal.	Same as Preferred Alternative. Potential additional long-term impact from on-site disposal of 11(e)2 byproduct material.

Table 8.6-1: Comparison of Predicted Environmental Impacts

Impacts of Operation	No-Action Alternative	Preferred Alternative	Process Alternatives: Alternate Lixiviant Chemistry	Process Alternatives: Alternate Waste Management
Mineral Resource Recovery Impacts	Loss of a valuable domestic energy resource. CBR estimated reserves are under development but the current estimated recoverable resource is 2.0 million pounds with a current spot market value of $160 million.	Recovery and use of a domestic energy resource.	Same as Preferred Alternative.	Same as Preferred Alternative.

8.6.1 References

Energy Information Administration. 2005. *Uranium Market Annual Report.* [Web Page] Located at: http://www.eia.doe.gov/cneaf/nuclear/umar/umar.html. Accessed on February 22, 2007.

International Atomic Energy Agency (IAEA). 2005. *Guidebook on environmental impact assessment for in situ leach mining projects*, IAEA-TECDOC-1428. 170 pages.

United States Nuclear Regulatory Commission (USNRC). 2007. Locations of Fuel Cycle Facilities. [Web Page] Located at: http://www.nrc.gov/info-finder/materials/fuel-cycle/. Accessed on August 8, 2007.

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9 COST-BENEFIT ANALYSIS

9.1 GENERAL

The general need for production of uranium is assumed in the operation of nuclear power reactors. In reactor licensing evaluations, the benefits of the energy produced are weighed against environmental costs including a prorated share of the environmental costs of the uranium fuel cycle. The incremental impacts of typical mining and milling operation required for the fuel cycle are justified in terms of the benefits of energy generation to the society in general. However, the specific site-related benefits and costs of an individual fuel-cycle facility such as the Crow Butte Project must be reasonable as compared to that typical operation.

9.2 ECONOMIC IMPACTS

Monetary benefits accrue to the community from the presence of the Crow Butte Project, such as local expenditures of operating funds and the federal, state and local taxes paid by the project. Against these monetary benefits are the monetary costs to the communities involved, such as those for new or expanded schools and other community services. While it is not possible to arrive at an exact numerical balance between these benefits and costs for any one community, or for the project, because of the ability of the community and possibly the project to alter the benefits and costs, this section summarizes the economic impact of the project to date.

9.2.1 Tax Revenues

Table 9.2-1 summarizes the tax revenues from the Crow Butte Project.

Table 9.2-1: Tax Revenues for the Crow Butte Project

	2006	2005	2004	2003
Property Taxes	627,000	351,000	144,000	65,000
Sales and Use Taxes	238,000	185,000	161,000	153,000
Severance Taxes	545,000	338,000	180,000	73,000
Total	**1,410,000**	**874,000**	**485,000**	**291,000**

Future tax revenues are dependent on uranium prices which cannot be forecast with any accuracy; however, these taxes are also somewhat dependent on the number of pounds of uranium produced by CBR. To the extent that uranium prices remain at current levels (spot market of around $80 per pound U_3O_8 in mid-March 2007), the increased production from the satellite plants should contribute to higher tax revenues as well.

The present taxes are based on a relatively consistent production rate of 800,000 pounds per year. The contribution to taxes is on the order of $1.4 million per year.

9.2.2 Temporary and Permanent Jobs

9.2.2.1 Current Staffing Levels

CBR currently employs approximately 52 employees and 20 contractors on a full-time basis. Short-term contractors and part-time employees are also used for specific projects and/or during the summer months and may add up to 10 percent to the total staffing. This level of employment is significant to the local economies. The private employment in Dawes County in 2006 was 2,189 out of a total labor force of 3,401. Based on these statistics, CBR currently provides approximately 2.3 percent of the private employment in Dawes County. In 2006, CBR's total payroll was over $2,543,000. Of the total Dawes County wage and salary payments of $76,006,000 in 2006, the CBR payroll represented about 3.4 percent.

Total CBR payroll for the past four years was:

2003:	$2,102,000
2004:	$2,213,000
2005:	$2,382,000
2006:	$2,543,000

The average annual wage for all workers in Dawes County was $22,350 for 2006. By way of comparison, the average wage for CBR was about $51,000. Entry-level workers for CBR earn a minimum of $15.53 per hour or $32,300 per year, not including bonus or benefits.

9.2.2.2 Projected Short-Term and Long-Term Staffing Levels

CBR expects that construction of future satellite plant(s) will provide approximately ten to fifteen temporary construction jobs for a period of up to one year for each satellite. It is likely that the majority of these jobs will be filled by skilled construction labor brought into the area by a construction contractor, although some positions could be filled by local hires. Permanent CBR employees will perform all other facility construction (e.g., wells and wellfields).

CBR actively pursues a policy of hiring and training local residents to fill all possible positions. Due to the technical skills required for some positions, a small percentage of the current mine staff (less than five percent) have been hired elsewhere and relocated to the area. Because of the small number of people who have needed to move into the area to support this project, the impact on the community in terms of expanded services has been minimal. CBR expects that the types of positions required at the current facility and those that will be created by any future expansion will be filled with individuals from the local workforce and that there will be no significant impact on services and resources such as housing, schools, hospitals, recreational facilities, or other public facilities. In 2006, total unemployment in Dawes County was 137 individuals, or 2.9 percent of the total work force of 4,799. CBR expects that many new positions will be filled from this pool of available labor.

CBR projects that the current staffing level will increase by ten to twelve full-time CBR employees for each active satellite plant. These new employees will be needed for satellite plant and wellfield operator and maintenance positions. Contractor employees (i.e., drilling rigs) may also increase by four to seven employees depending on the desired production rate. The majority, if not all, of these new positions will be filled with local hires.

These additional positions should increase payroll by about $40,000 per month, or $400,000 to $480,000 per year.

9.2.3 Impact on the Local Economy

In addition to providing a significant number of well-paid jobs in the local communities of Crawford, Harrison, and Chadron, Nebraska, CBR actively supports the local economies through purchasing procedures that emphasize obtaining all possible supplies and services that are available in the local area.

Total CBR payments made to Nebraska businesses for the past four years were:

2003:	$3,602,000
2004:	$3,597,000
2005:	$4,570,000
2006:	$6,800,000

The vast majority of these purchases were made in Crawford and Dawes County.

This level of business is expected to continue and should increase somewhat with the addition of expanded production from the satellite plant, although not in strict proportion to production. While there are some savings due to some fixed costs (Central Plant utilities for instance), there are additional expenses that are expected to be higher (well-field development for the satellites is expected to be more expensive). Therefore, it can be assumed that the overall effect on local purchases will be proportional to the number of pounds produced. In addition, mineral royalty payments accrue to local landowners. This should translate to additional purchases of $3.65 to $4.35 million per year.

9.2.4 Economic Impact Summary

The Crow Butte Project currently provides a significant economic impact to the local Dawes County economy. Approval of this LRA would have a positive impact on the local economy as summarized in **Table 9.2-2.**

Table 9.2-2: Current Economic Impact of Crow Butte Project

	Current Crow Butte Operation
Employment	
Full Time Employees	60
Full Time Contractor employees	15
Part Time Employees and Short Term Contractors	7
CBR Payroll, 2006	$3,400,000
Taxes	
Property Taxes	$627,000
Sales and Use Taxes	$238,000
Severance Taxes	$545,000
Total Taxes	$1,410,000
Local Purchases	
Local Purchases, 2006	$6,800,000
TOTAL	**$11,610,000**

9.2.5 Short-Term External Costs

9.2.5.1 Housing Impacts

The available housing resources should be adequate to support the short-term needs during facility construction. According to the Nebraska Department of Economic Development, in 2000 a total of 492 housing units were vacant in Dawes County out of a total housing base of 4,004 units. Of the vacant units, 176 were available for rent. In addition to this availability of rental housing units, there are two small motels in Crawford that generally have vacancies and routinely provide units for itinerant workers such as railroad crews.

9.2.5.2 Noise and Congestion

No short-term increases in noise or congestion are anticipated at the current License Area; however, the addition of satellite facilities may increase the noise and congestion in the immediate vicinity during initial construction of the facility. This will include heavy truck and equipment traffic and access to the jobsite by construction workers. These impacts will be most noticeable to residents in the immediate vicinity of the facility and will be temporary in nature. The increase in noise should be considered in light of the project location, which is bounded on the west by the Burlington Northern Santa Fe rail line and on the east by Nebraska State Highway 2/71. The rail line along the western boundary is used for combining local "pusher" engines with south bound trains to assist them in climbing the Pine Ridge south of Crawford. As a result, there is a significant amount of noise generated by this activity including trains parked for extended periods. Dust from construction activities will be controlled using standard dust suppression techniques used in the construction industry.

9.2.5.3 Local Services

As previously noted, CBR actively recruits and trains local residents for positions at the mine. CBR expects that the majority of and open permanent positions would be filled with local hires. As a result of using the local workforce, the impact on local services should be minimal. In many cases these services (e.g., schools) are underutilized due to population trends in the area.

9.2.6 Long-Term External Costs

9.2.6.1 Housing and Services

Because of the small number of people who have needed to move into the area to support this project, the impact on the community in terms of expanded services has been minimal. CBR expects that any increase in long-term positions would be filled with individuals from the local workforce and that there will be no significant impact on services and resources such as housing, schools, hospitals, recreational facilities, or other public facilities. In 2006, total unemployment in Dawes County was 137 individuals, or

2.9 percent of the total work force of 4,799. CBR expects that any new positions would be filled from this pool of available labor.

9.2.6.2 Noise and Congestion

No long-term increases in noise or congestion are anticipated at the current License Area; however, the addition of satellite facilities may increase the noise and congestion in the immediate vicinity during initial construction of the facility. Most of this will consist of increased traffic from employees commuting to and from the work site and performing work in the wellfields. Some increase in heavy truck traffic will occur due to deliveries of process chemicals such as oxygen and the shipment of ion exchange resin from the satellite facility to the Central Processing facility. Delivery and ion exchange shipments should average two per day. These impacts will be most noticeable to residents in the immediate vicinity of the facility. As noted in **Section 9.2.5.2**, there is significant existing noise in the immediate area generated by the adjacent rail line and highway.

In the area around Crawford, the increased traffic will be unnoticeable due to the presence of U.S. Highway 20 and Nebraska Highway 2/71, which are both significant transport routes. The annual average 24-hour total and heavy vehicle count for U.S. Highway 20 at the eastern approach to Crawford for 2004 was 1,795 and 235, respectively. The limited additional traffic related to potential new satellite operations will not significantly affect these main routes.

9.2.6.3 Aesthetic Impacts

No additional aesthetic impacts are anticipated at the existing License Area; however, impacts to aesthetic resources resulting from the construction of new satellite facilities may occur. The potential visible surface structures at a satellite facility may include wellhead covers, wellhouses, electrical distribution lines, and one processing plant. The project would use existing and new roads to access each wellhouse and the satellite plant. Project development would alter the physical setting and visual quality of portions of the landscape, which would affect the overall landscape to some degree, as viewed from sensitive viewing areas. The proposed facilities would introduce new elements into the landscape and would alter the existing form, line, color, and texture, which characterize the existing landscape. The project would primarily affect croplands.

In foreground-middleground views, the satellite plant, wellhouses, and associated access road clearings would be the most obvious features of development. Clearings and access roads would be visible as light-tan exposed soils in geometrically-shaped areas with straight, linear edges that provide some textural and color contrasts with the surrounding cropland. The satellite plant, wellhouses, and wellhead covers would be painted to harmonize with the surrounding soil and vegetation cover. These facilities may be visible from area travel ways such as SH 2/71 and viewing areas such as the Crawford Cemetery, but would be subordinate to the rural landscape.

The electric distribution line poles would be an estimated 20 feet tall, and would be located throughout the project area to connect wellhouses with existing lines. The distribution lines are similar in appearance to those typical of the rural landscape, but would occur at a higher density than on adjacent lands. The lines would be obvious to viewers at the viewing areas, but would not change the rural character of the existing landscape.

Wellhead covers would be difficult to discern in the landscape from any sensitive viewing area. The form and textural contrast would be very weak because the relatively low profile (3 feet high) and small size of the facilities would disappear into the surrounding textures of soil and vegetation. Generally, color contrasts are most likely to be visible in foreground-middleground distance zone; however, the wellhead covers would be painted a tan color that would harmonize with the surrounding vegetation and soil colors. Therefore, contrast of line, form, texture, and color would be low. The facilities would not be noticeable to the casual observer. Wellhead covers would be visually subordinate to the landscape in foreground-middleground distance zone.

9.2.6.4 Land Access Restrictions

Property owners of land located within the immediate wellfield and plant boundaries will lose access and free use of these areas during mining and reclamation. The areas impacted are all used for agricultural purposes and the owners will lose the ability to use the areas for production purposes. Offsetting these land use restrictions are the surface lease and mineral royalty payments to the landowners.

9.3 THE BENEFIT COST SUMMARY

The benefit-cost summary for a fuel-cycle facility such as the Crow Butte Project involves comparing the societal benefit of a constant U_3O_8 supply (ultimately providing energy) against possible local environmental costs for which there is no directly-related compensation. For this project, there are basically three of these potentially uncompensated environmental costs:

- Groundwater impact
- Radiological impact
- Disturbance of the land

The groundwater impact is considered to be temporary in nature, as restoration activities will restore the groundwater to a pre-mining quality. The successful restoration of groundwater during the Research and Development (R&D) project and the commercial restoration of Mine Unit 1 have demonstrated that the restoration process can meet this criterion successfully.

The radiological impacts of the current and proposed project are small, with all radioactive wastes being transported and disposed of off-site. Radiological impacts to air and water are also minimal. Extensive on-going environmental monitoring of air, water, and vegetation has shown no appreciable impact to the environment from the Crow Butte Project.

The disturbance of the land for an ISL facility is quite small, especially when compared with conventional surface mining techniques. All of the disturbed land will be reclaimed after the project is decommissioned and will become available for previous uses.

9.4 SUMMARY

In considering the energy value of the U_3O_8 produced to U.S energy needs, the economic benefit to the local communities, the minimal radiological impacts, minimal disturbance of land, and mitigable nature of all other impacts, it is believed that the overall benefit-cost balance for the Crow Butte Project is favorable, and that issuing an license renewal for SUA-1534 is the appropriate regulatory action.

9.4.1 References

Nebraska Department of Economic Development. 2006. *Nebraska Databook*, December 2006. [Web Page] Located at: http://info.neded.org/stathand/isect10.htm.

Nebraska Department of Roads. Undated. *Traffic Flow Map of the State Highways, State of Nebraska*,. [Web Page] Located at: http://www.dor.state.ne.us/maps/Statewide%20Traffic%20Flow%20Maps/2004%20Statewide%20Traffic%20Flow%20Map.pdf.

U. S. Department of Labor, Bureau of Labor Statistics. 2007. as of March 5, 2007.

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10 ENVIRONMENTAL APPROVALS AND CONSULTATIONS

10.1 ENVIRONMENTAL APPROVALS FOR THE CURRENT LICENSED AREA

As discussed previously, this is an LRA for Radioactive Source Materials License SUA-1534, originally submitted in September of 1987 and renewed in 1997. All other required permits for the existing Crow Butte Project have been obtained and maintained since that time. A summary of the relevant permits and authorizations for the current License Area is given in **Table 10.1-1**.

Table 10.1-1: Environmental Approvals for the Current License Area

Issuing Agency	Permit Description
Nebraska Department of Environmental Quality PO Box 98922 Lincoln, Nebraska 68509-8922	Underground Injection Control Class III Authorization NE0122611 Approved: April 24, 1990
	Aquifer Exemption Approval Effective: March 23, 1984
	Underground Injection Control Class I Authorization NE0206369 Approved: September 9, 1994 Replaced: July 2, 2004
	Underground Injection Control Class I Authorization NE0210457 Approved: July 2, 2004
	National Pollutant Discharge Elimination System Permit NE0130613 Approved: September 30, 1994 Renewed: October 1, 2006
	Mineral Exploration Permit NE0209317 Approved: June 3, 2003 Replaced: July 16, 2007
	Mineral Exploration Permit NE0210679 Approved: July 16, 2007
	Evaporation Pond Design Approved: July 21, 1988
	Construction Stormwater NPDES General Permit NER100000 Authorization # NER105203 Approved: December 19, 2006
Nebraska Department of Natural Resources 301 Centennial Mall South Lincoln, Nebraska 68509-4676	Industrial Ground Water Permit I-2 Approved: August 7, 1991
Nebraska Department of Health and Human Services Regulation and Licensure PO Box 95007 Lincoln, Nebraska 68509-5007	Class IV Public Water Supply Permit NE3121024 Approved: April 12, 2002

Table 10.1-1: Environmental Approvals for the Current License Area

Issuing Agency	Permit Description
U.S. Nuclear Regulatory Commission Washington, DC 20555	Source Materials License SUA-1534 Issued: December 29, 1989 Renewed: February 28, 1998
U.S. Environmental Protection Agency 1200 Pennsylvania Ave, NW Washington, DC 20460	Aquifer Exemption Approval Effective: June 22, 1990

10.1.1 References

USNRC Regulatory Guide 3.11.1, *Operational Inspection and Surveillance of Embankment Retention Systems for Uranium Mill Tailings* (Revision 1, October 1980).