CROW BUTTE URANIUM PROJECT

Dawes County, Nebraska

Application for Renewal of USNRC Radioactive Source Materials License SUA-1534

Submitted to:
United States Nuclear Regulatory Commission
Denver, Colorado

December 1995

Submitted by:
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1. PROPOSED ACTIVITIES

1.1 LICENSING ACTION REQUESTED

This application is made by Crow Butte Resources Inc. (CBR) for renewal of the United States Nuclear Regulatory Commission (USNRC) Radioactive Source Materials License SUA-1534 concerning uranium in-situ leach mining operations located in Dawes County, Nebraska.

This renewal application has been prepared using suggested guidelines and standard formats from both state and federal agencies. The application is presented primarily in the USNRC format of Regulatory Guide No. 3.46.

1.2 CROW BUTTE PROJECT BACKGROUND

The original development of what is now the Crow Butte Project was done by Wyoming Fuel Corporation, who constructed a Research and Development Facility in 1986. The project was subsequently acquired and operated by Ferret Exploration Company of Nebraska until May 1994, when the name was changed to Crow Butte Resources. This change was only a name change and not an ownership change.

The Research and Development Facility was located in N/2 SE/4 of Section 19, T 31 N, R 51 W. 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 One of Commercial Operations.

The production wellfield is located within the permit area as shown in Figure 1.3-1. The process plant is located in Section 19, Township 31 North, Range 51 West, Dawes County, Nebraska. The permit area is approximately 2,800 acres and the surface area affected over the estimated life of the project is approximately 500 acres.

1.3 SITE LOCATION AND DESCRIPTION

The location of the Crow Butte Project Area is in Sections 11, 12 and 13 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 plant site is situated approximately 4.0 miles southeast of the City of Crawford. Figure 2.1 shows the general location of the facility and Figure 2.2 shows the Project Site. (See Section 2.0)

Figure 1.3-1: Permit Area Boundary

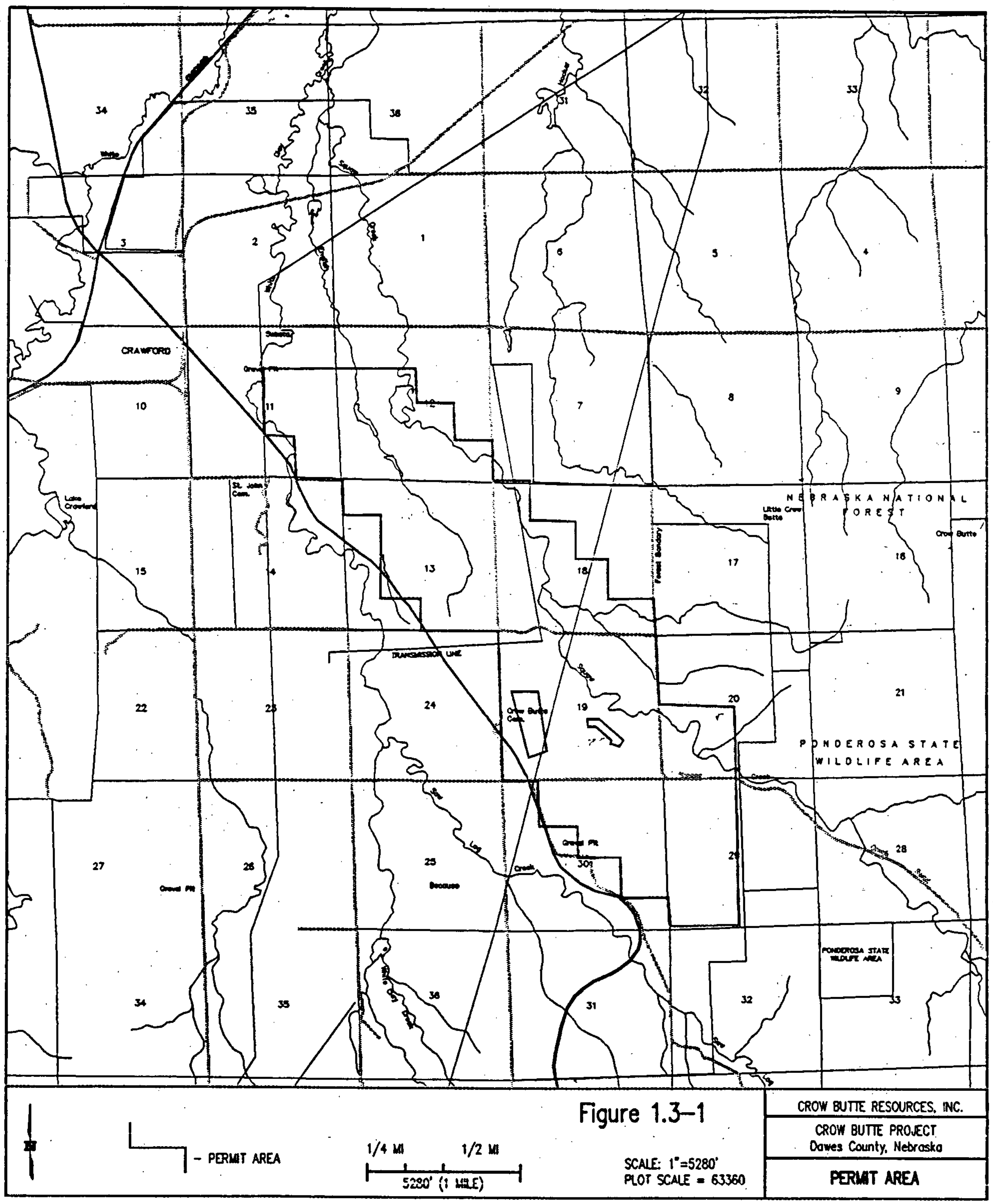


Table 1.3-1 shows the land ownership for the Crow Butte Project. Approximately 90% of all minerals leased in Dawes County are on private lands. No Indian lands are present within a 5 mile radius of the project site.

Table 1.3-1: Land Ownership

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

1.4 OREBODY DESCRIPTION

Uranium is recovered by in-situ leaching from the Basal Chadron Sandstone at a depth which varies from 400 feet to 800 feet over the permit area. 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% U_3O_8, with an average grade estimated at 0.26% equivalent U_3O_8 and 0.31% chemical U_3O_8.

1.5 SOLUTION MINING METHOD AND RECOVERY PROCESS

The in-situ leaching 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 bicarbonate and oxygen;
- Elution of the uranium complexes from the resin;
- Drying and packaging of the uranium.

The current extraction plant is operating at a capacity of 3,500 gallons per minute, excluding any restoration flow. Crow Butte Resources has proposed to increase the permitted flow from 3,500 gpm to 5,000 gpm. Two options are being evaluated to accomplish this increase. These options are discussed further in Section 3.

- Expand the ion exchange processing capacity in the existing plant. The additional production flow would result from either adding additional wellfields or operating production wells longer.

- Maintain the flow at the existing process facility at 2,500 to more than 3,500 gpm and construct a satellite plant. The satellite plant would have a capacity of 2,500 gpm and utilize pressurized downflow IX columns for uranium separation. Loaded IX resin or eluate from this satellite would be transported to the main plant for further processing.

1.6 OPERATING SCHEDULES

Sufficient reserves have been estimated to allow mining operations to continue for between 10 and 25 years. Status of the current mine unit operations is shown in Table 1.6-1.

Table 1.6-1: Mine Unit Status

Mine Unit	Production Initiated	Current Status
Mine Unit 1	April 1991	Restoration
Mine Unit 2	March 1992	Production
Mine Unit 3	January 1993	Production
Mine Unit 4	March 1994	Production
Mine Unit 5	January 1996 Planned	Development

Mining schedules have been completed for the first ten years of the project. Additional mine unit development plans are submitted approximately one year prior to the planned commencement of new mining operations.

1.7 EFFLUENT CONTROL SYSTEMS

1.7.1 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 which 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.

1.7.2 Liquid and Solid Waste

There are currently three waste water disposal options for the Crow Butte Project: evaporation from the 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 land applied.

- **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 well.

- **Aquifer restoration** - Following mining operations, restoration of the affected aquifer commences which results in the production of waste water. The restoration waste is primarily brine from the reverse osmosis unit, which is sent to the waste disposal system. The permeate is either reinjected into the wellfield or sent to the waste disposal system.

Domestic liquid waste is disposed of in an approved septic system.

Solid wastes generated at the site consist of spent resin, resin fines, empty reagent containers, miscellaneous pipe and fittings, and domestic waste. These wastes are classified as contaminated or non-contaminated waste according to their survey results. Contaminated waste which cannot be decontaminated are stored until they 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.

1.7.3 Contaminated Equipment

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

1.8 GROUNDWATER RESTORATION

Restoration activities will be carried out at the Crow Butte site 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 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 homogonize 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.

1.9 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 NRC Regulatory Guidelines will be followed as required.

1.10 SURETY ARRANGEMENTS

Crow Butte Resources maintains a NRC-approved financial surety arrangement consistent with 10 CFR 40, Appendix A, Criterion 9 to cover the estimated costs of reclamation activities. Crow Butte maintains an irrevocable Letter of Credit No. 74504 issued by First Bank N.A. during 1995 in favor of the State of Nebraska in the present amount of $5,543,958.

2. SITE CHARACTERISTICS

2.1 SITE LOCATION AND LAYOUT

The location of the Crow Butte project is in Sections 11, 12 and 13 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 2.1-1 shows the general location of the site.

Figure 2.1-2 shows the general project site layout, process building area, R&D facility, and commercial evaporation ponds. These facilities are located in Section 19 of Township 31 North, Range 51 West. Figure 2.1-3 shows the outline of the various areas referred to in this application.

Figure 2.1-1: Project Location

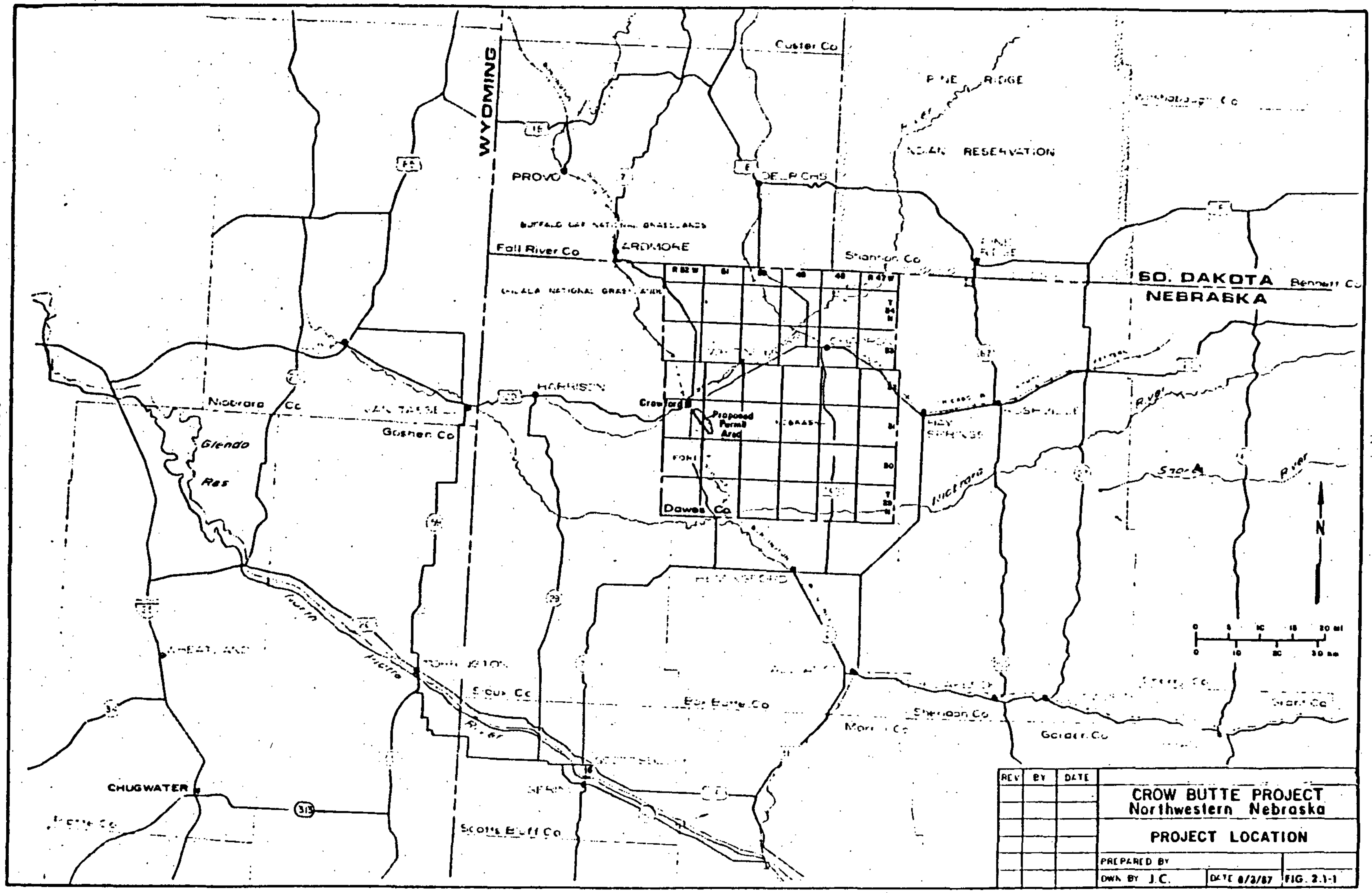


Figure 2.1-2: Site Layout

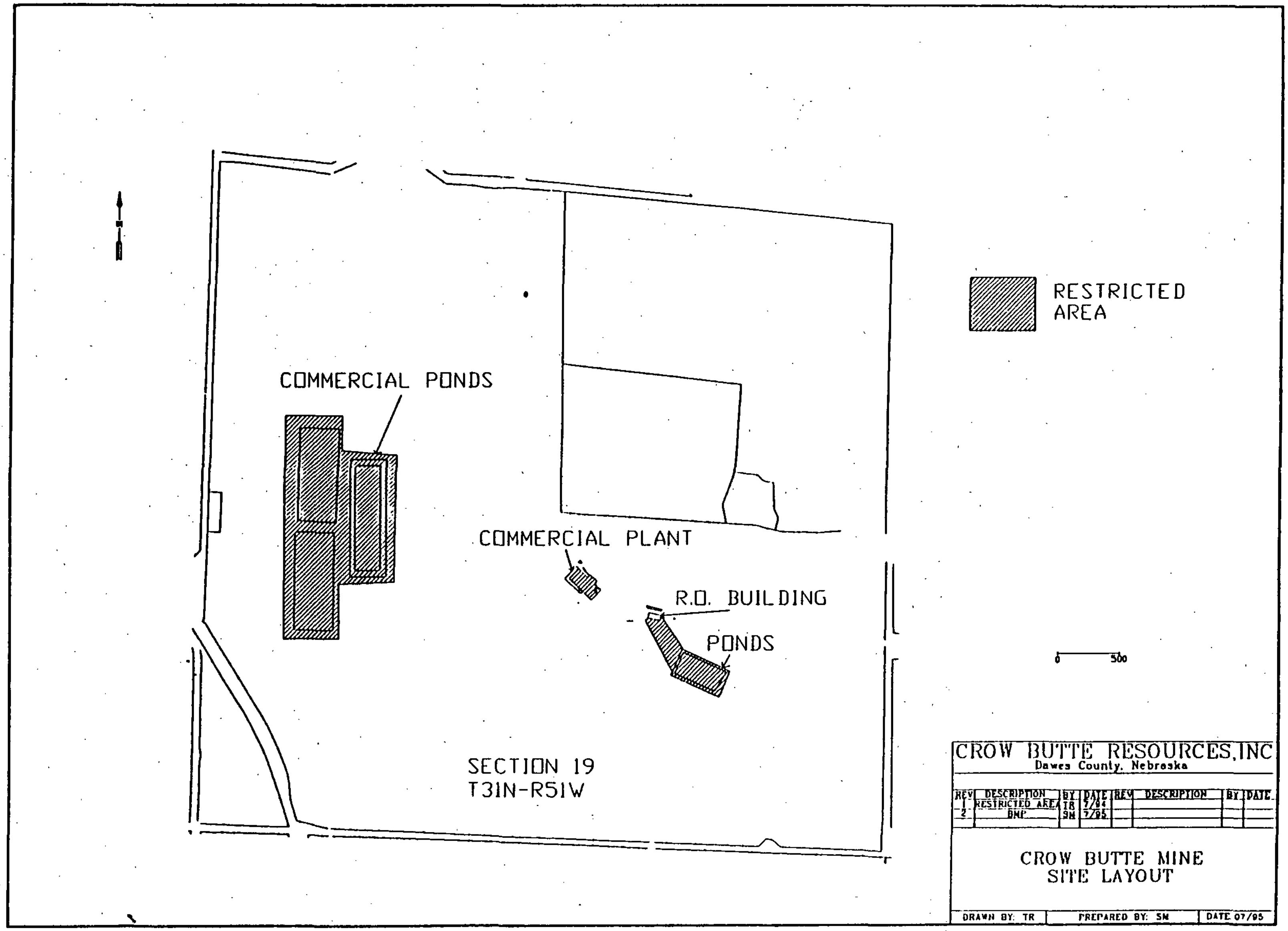
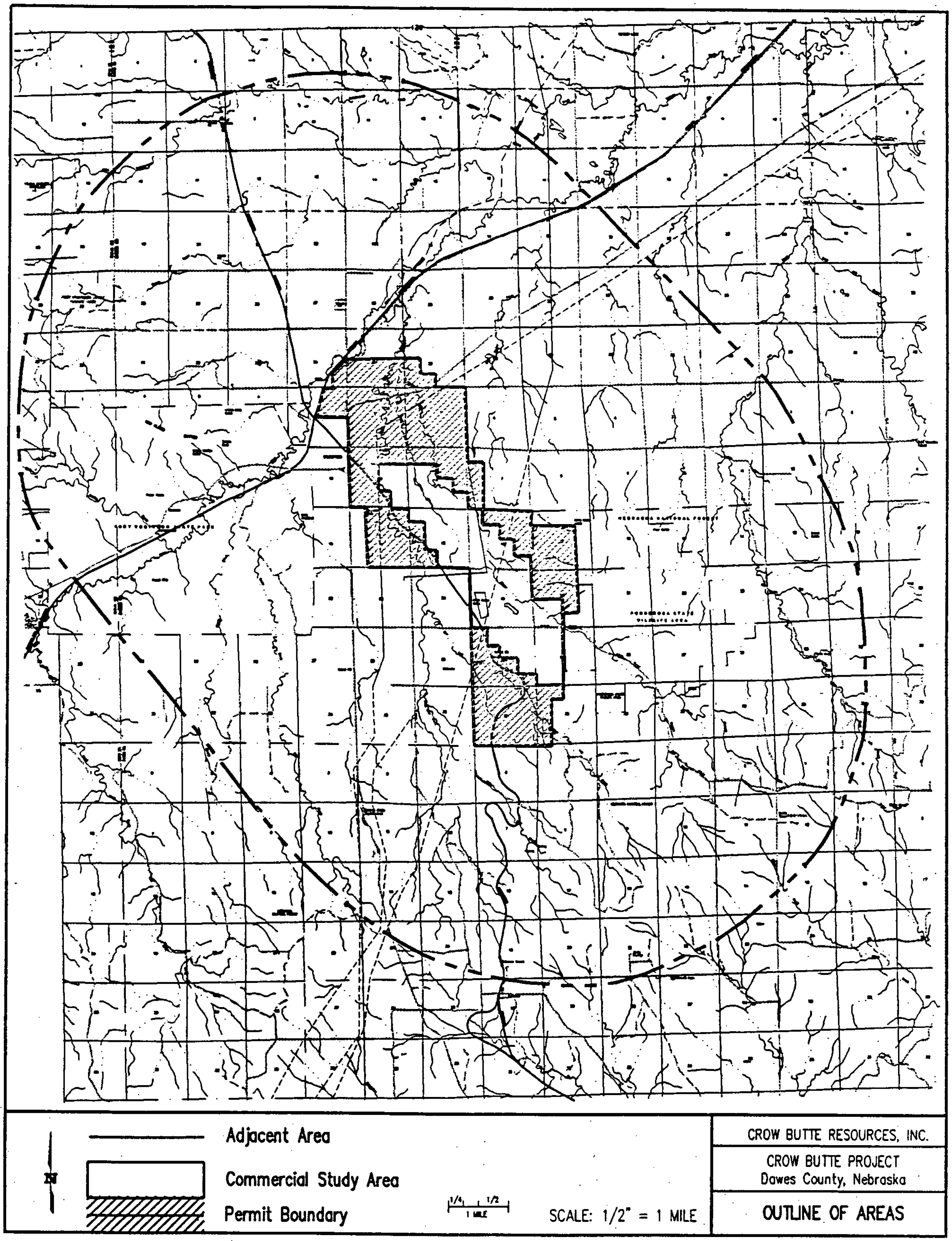


Figure 2.1-3: Outline of Areas



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 developed over a 9-month period in 1982 as part of the Research and Development (R&D) permit application. 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 useful information. These 1982 data were verified in 1987 through additional data collection and review, personal communications, and a site reconnaissance. The land and water use information included in this section considers the area within an 8-km (5 mile) radius of the center point of the commercial permit area. Population distribution characteristics were updated in 1995 as well.

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 71 provides access to the project area from points north and south of Crawford. U.S. Highway 20 provides access to Crawford and the project area from points east and west.

Approximately 4 percent of the area within an 8-km (5 mile) radius of the project site 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 commercial permit area, is livestock raising. An annual average of 56,833 cattle valued at approximately $21.35 million were 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 (see 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 snd 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 project site.

2.2.3 LAND USES WITHIN THE 8-KM PROJECT SITE AREA

For the land use data inventory, the Crow Butte project study area is defined as all lands within an 8-km (5 mile) radius of the proposed project's designated centerpoint. Because the commercial facilities are an expansion of the existing R&D facilities, the same centerpoint was used as that in the R&D permit application. Figure 2.2-2 shows the land within the project area. Table 2.2-1 presents a detailed breakdown of land use by sector while Table 2.2-3 presents the land uses by percentages and square kilometers. This breakdown is the same as that presented in 1982 since area land use has not changed since (Dawes County, City of Crawford, 1987). Land use categories and definitions are developed from both U.S. Geological Survey and U.S. Office of Surface Mining land use definitions (Table 2.2-4).

The information presented for the project site area is based on information gathered from recent local and state publications, USGS quadrangle map sheets, a Dawes County U.S. Soil Conservation survey, and telephone interviews with various knowledgeable officials. The information was verified during an on-site field investigation conducted in early May, 1982 and again in 1987.

Figure 2.2-1: Recreational Facilities Location Map

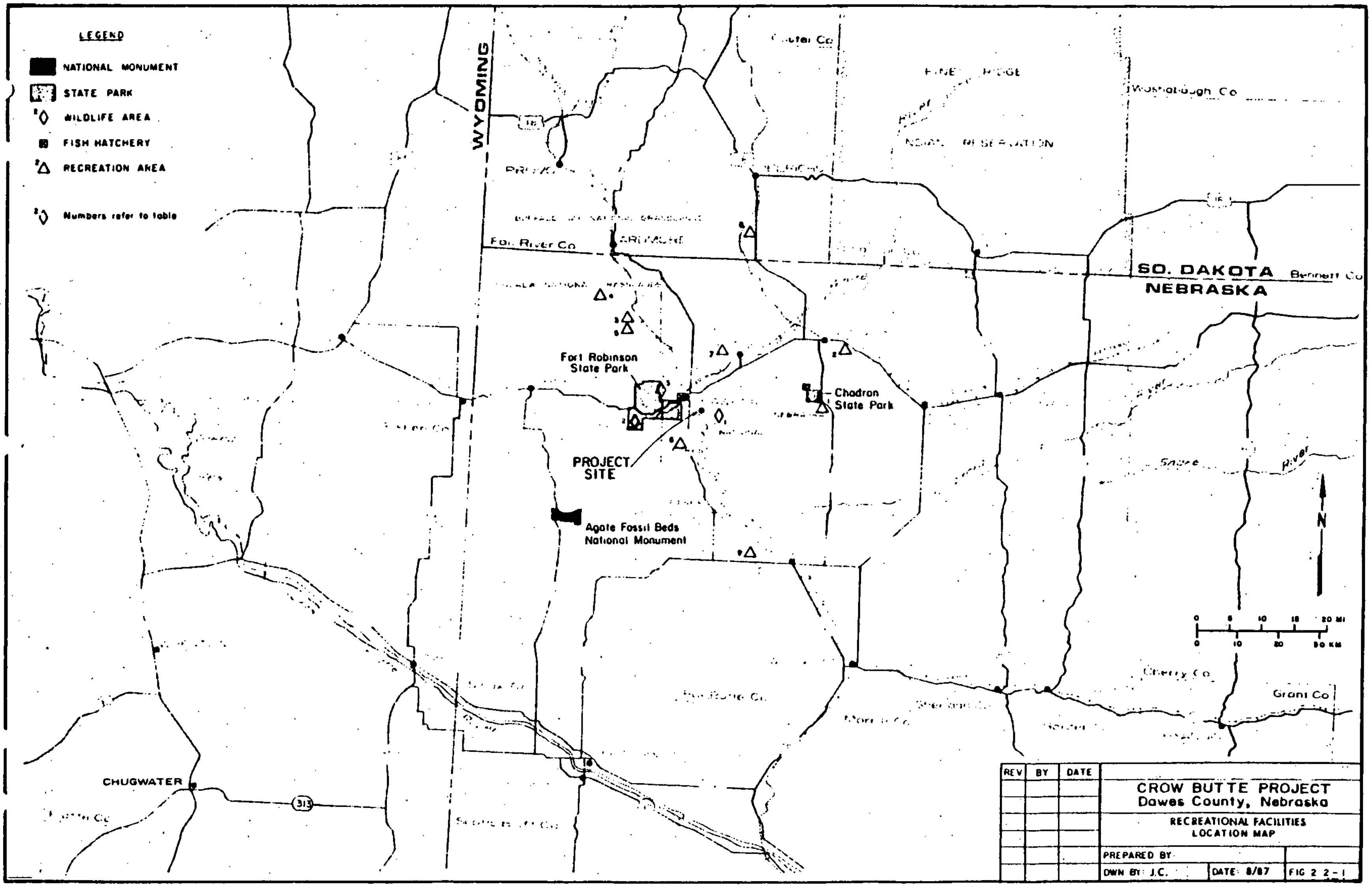


Table 2.2-1: Recreational Facilities Within 50 Miles of the Crow Butte Area

NUMBER [1]	NAME OF RECREATIONAL FACILITY	DISTANCE FROM SITE (miles)
1	Red Cloud Picnic Area	19.0
2	Museum of the Fur Trade	24.0
3	Toadstool Park	18.0
4	Warbonnet Battlefield	24.0
5	Hudson-Meng Bison Hill Site	17.0
6	Cochran State Wayside Area	5.0
7	Whitney Lake	10.0
8	Pioneer Roadside Park	28.0
9	Box Butte Reservoir	24.0
1 (Wildlife)	Ponderosa Wildlife Area	2.0
2 (Wildlife)	Petreson Wildlife Area	11.0
3 (Wildlife)	Soldier Creek Management Unit	7.0
	Agate Fossil Beds National Monument	27.0

[1] Refers to numbers and symbols shown on Figure 2.2-1.

Source: Nebraska Department of Roads, 1981.
South Dakota Division of Tourism, 1981

Agriculture

Several of the soil types found on the Crow Butte project area are classified as prime farmland (Dixon, 1982). However, in Dawes County soils are classified by the U.S. Soil Conservation Service (SCS) as prime only if irrigated. According to 1978, 1979 and 1980 Nebraska State Agricultural Statistics, only 2% of Dawes County land is irrigated, and about 18% of that irrigated acreage is harvested cropland acreage. The remainder of the irrigated land is used for pasture, habitat, or rangeland (Nebraska Crop and Livestock Reporting Service, 1980; 1981). Applying these same percentages to the Crow Butte 8-km (5 mile) area approximately 994 acres of the land is irrigated, of which 179 acres can be classified as harvested cropland. However, a review of Figure 2.2-2 would indicate that the actual irrigated acreage is less than the county average. All of the irrigated lands within the study area occur in the north and northwest sectors where aqueducts flow from the White River to the south and west.

Table 2.2-5 through Table 2.2-8 show agricultural productivity within the 8-km (5 mile) radius as well as Dawes County. Winter wheat and hay are the major crops grown on croplands within the study area. Most of these crops are used for livestock feed while the remaining crops are commercially sold. The livestock inventory found within the study area is similar to the rest of Dawes County, with cattle accounting for over 80% of all livestock.

Habitat

As defined in Table 2.2-4 these lands are 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 area. Deer and turkey hunting is permitted within the Ponderosa State Wildlife area.

Residential

According to 1980 USGS quad sheets and on-site field investigations, 73 occupied dwelling units are located in the rural area of the Crow Butte 8-km (5 mile) (see Table 2.2-9). Interviews with local citizens were conducted in 1982 within a 10-km (6.2 mile) radius to find actul rural population counts. The average persons per household estimate for the known rural household were then used to estimate the population of the remaining households located in the 10-km (6.2 mile) radius. As a result, an estimated 181 persons reside within the rural portions of the 8-km (5 mile) project radius. An additional 1,100 persons reside in Crawford, approximately 6.5 km (4 miles)

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CROW BUTTE PROJECT
LAND USE MAP"

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Figure 2.2-2: Land Use Map

Table 2.2-2: Land Use of the Crow Butte 8-km Radius, By Sector and Category (in acres)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Subtotal
Cropland																	
0-1.8	70.9	64.8	76.8	110.8	86.5	*	33.4	--	--	30.4	73.3	89.7	64.8	8.2	57.4	27.1	802.1
1.8-3.6	323.7	90.2	17.8	8.3	5.5	--	--	--	74.5	64.8	233.0	276.4	267.8	166.6	292.0	246.9	2067.5
3.6-5.4	308.9	522.5	380.7	87.2	--	--	42.5	5.6	20.8	358.8	240.6	457.2	503.6	523.7	235.1	367.1	4054.3
5.4-7.2	334.0	824.8	636.6	123.9	--	98.2	130.4	151.6	--	164.4	--	384.9	148.0	70.8	495.8	552.9	4116.3
7.2-8.0	297.1	442.9	247.1	238.8	--	172.1	131.1	0	--	1	.2	313.8	43.1	--	156.7	178.3	2224.2
Subtotal	**1334.6**	**1945.2**	**1359.0**	**577.0**	**92.0**	**273.3**	**337.4**	**157.2**	**95.3**	**618.4**	**547.1**	**1522.0**	**1027.3**	**769.3**	**1237.0**	**1372.3**	**13264.4**
Commercial/Services																	
0-1.8												--		--	--	--	--
1.8-3.6												--		--	--	--	--
3.6-5.4												2.8		0.9	13.4	--	17.5
5.4-7.2												--			103.1	--	103.1
7.2-8.0												--		--	7.4	5.4	12.8
Subtotal												**2.8**		**0.9**	**124.3**	**5.4**	**133.4**
Forested Land																	
0-1.8	0.9	--	--	2.7	0.9	10.8	5.3	8.6	--	0.9	*	0.9	1.8	3.6	9.4	11.4	57.2
1.8-3.6	--	58.9	230.4	361.4	--	--	104.5	304.5	53.0	10.8	--	--	4.5	--	--	7.2	1135.2
3.6-5.4	--	--	35.7	169.9	53.9	--	512.6	556.7	472.7	31.5	11.1	--	--	--	13.8	3.6	1861.5
5.4-7.2	--	--	15.7	237.7	579.9	717.7	675.5	567.8	804.5	392.2	370.2	27.7	--	--	8.4	30.8	4428.1
7.2-8.0	6.4	--	.9	82.8	411.8	377.4	176.0	360.0	394.3	501.7	284.5	30.4	--	--	33.0	36.9	2696.1
Subtotal	**7.3**	**58.9**	**282.7**	**854.5**	**1046.5**	**1105.9**	**1473.9**	**1797.6**	**1724.5**	**937.1**	**665.8**	**59.0**	**6.3**	**3.6**	**64.6**	**89.9**	**10178.1**
Habitat																	
0-1.8				--	25.1	57.8	15.8	--							--		98.7
1.8-3.6				67.9	466.0	471.5	361.6	1.8							--		1368.8
3.6-5.4				241.7	716.6	656.9	102.5	1.9							--		1719.6
5.4-7.2				--	160.1	103.7	--	--							3.7		267.1
7.2-8.0				--	--	--	--	--							1.8		1.8
Subtotal				**309.6**	**1367.8**	**1289.9**	**479.9**	**3.7**							**5.5**		**3456.4**

Table 2.2-2: Land Use of the Crow Butte 8-km Radius, By Sector and Category (in acres)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Subtotal
Industrial																	
0-1.8															--		--
1.8-3.6															--		--
3.6-5.4															--		--
5.4-7.2															13.9		13.9
7.2-8.0															--		--
Subtotal															**13.9**		**13.9**
Mines, Quarries, or Gravel Pits																	
0-1.8										3.6		--	3.6	*	5.7		12.9
1.8-3.6										--		--	--	--	--		--
3.6-5.4										--		0.9	--	--	6.4		7.3
5.4-7.2										--		--	--	--	--		--
7.2-8.0										--		--	--	--	--		--
Subtotal										**3.6**		**0.9**	**3.6**	*	**12.1**		**20.2**
Pastureland																	
0-1.8	85.3	92.4	80.4	35.6	44.6	88.5	102.7	148.5	157.2	122.3	83.8	66.6	87.0	145.4	84.7	118.7	1543.7
1.8-3.6	147.7	320.4	148.6	33.9	--	--	3.6	83.5	344.0	395.9	233.0	195.0	199.3	304.9	176.7	217.4	2803.9
3.6-5.4	477.1	263.6	365.1	287.2	15.5	98.5	93.3	94.2	234.5	395.7	531.4	325.0	282.4	261.4	508.7	129.7	4363.3
5.4-7.2	752.6	273.7	448.1	656.8	145.4	28.5	294.5	221.0	29.2	440.0	717.9	687.7	158.1	122.9	118.8	758.3	5853.5
7.2-8.0	279.5	147.0	347.9	268.8	41.1	5.6	246.6	--	--	--	243.8	246.3	174.1	--	121.6	377.0	2584.3
Subtotal	**1742.2**	**1097.1**	**1390.1**	**1282.3**	**246.6**	**221.1**	**740.7**	**632.2**	**764.9**	**1353.9**	**1809.9**	**1520.6**	**900.9**	**834.6**	**1010.5**	**1601.1**	**17148.7**
Rangeland																	
0-1.8		--	--	--	--	--	--	--	--	--	--						--
1.8-3.6		1.8	74.7	--	--	--	1.8	81.6	--	--	--						159.9
3.6-5.4		--	--	--	--	30.7	35.1	127.7	58.0	--	--						251.5
5.4-7.2		--	--	82.0	215.0	152.3	--	160.0	266.6	103.8	6.6						986.3
7.2-8.0		--	--	--	137.5	31.4	36.7	144.6	192.9	84.1	61.9						689.1
Subtotal		**1.8**	**74.7**	**82.0**	**352.5**	**214.4**	**73.6**	**513.9**	**517.5**	**178.9**	**68.5**						**2086.8**

Table 2.2-2: Land Use of the Crow Butte 8-km Radius, By Sector and Category (in acres)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Subtotal
Recreational																	
0-1.8		--				--					--		--	--	--	--	--
1.8-3.6		--				--					--		--	--	--	--	--
3.6-5.4		--				--					--		--	--	--	--	--
5.4-7.2		--				--					6.6		794.2	890.0	127.2		1818.0
7.2-8.0		1.8				0.9					--		382.9	594.5	256.1		1236.2
Subtotal		**1.8**				**0.9**					**6.6**		**1177.1**	**1484.5**	**383.3**		**3054.2**
Urban Residential																	
0-1.8															--		--
1.8-3.6															--		--
3.6-5.4															--		--
5.4-7.2															229.4		229.4
7.2-8.0															9.2		9.2
Subtotal															**238.6**		**238.6**
Water																	
0-1.8	--	--									--			--	--	--	--
1.8-3.6	--	--									5.6			--	2.8	--	8.4
3.6-5.4	--	--									2.8			--	8.3	18.8	29.9
5.4-7.2	13.8	1.8									--			16.8	--	12.7	45.1
7.2-8.0	7.4	-0-									--			--	--	2.3	9.7
Subtotal	**21.2**	**1.8**									**8.4**			**16.8**	**11.1**	**33.8**	**93.1**

Table 2.2-2: Land Use of the Crow Butte 8-km Radius, By Sector and Category (in acres)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Subtotal
All Land Uses[a]																	
C	1334.6	1945.2	1359.0	577.0	92.0	273.3	337.4	157.2	95.3	618.4	547.1	1522.0	1027.3	769.3	1237.0	1372.3	13264.4
C/S	--	--	--	--	--	--	--	--	--	--	--	2.8	--	0.9	124.3	5.4	133.4
F	7.3	58.9	282.7	854.5	1046.5	1105.9	1473.9	1797.6	1724.5	937.1	665.8	59.0	6.3	3.6	64.6	89.9	10178.1
H	--	--	--	309.6	1367.8	1289.9	479.9	3.7	--	--	--	--	--	--	5.5	--	3456.4
I	--	--	--	--	--												
M	--	--	--	--	--												
P	1742.2	1097.1	1390.1	1282.3	246.6	221.1	740.7	632.2	764.9	1353.9	1809.9	1520.6	900.9	834.6	1010.5	1601.1	17148.7
R	--	1.8	74.7	82.0	352.5	214.4	73.6	513.9	517.5	187.9	68.5	--	--	--	--	--	2086.8
RC	--	1.8	--	--	--	0.9	--	--	--	--	6.6	--	1177.1	1484.5	383.3	--	3054.2
UR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	238.6	--	238.6
W	21.2	1.8	--	--	--	--	--	--	--	--	8.4	--	--	16.8	11.1	33.8	93.1
Total[b]	**3105.3**	**3106.6**	**3106.5**	**3105.4**	**3105.4**	**3105.5**	**3105.5**	**3104.6**	**3102.2**	**3100.9**	**3106.3**	**3105.3**	**3115.2**	**3109.7**	**3100.9**	**3102.5**	**49687.8**

Notes:

* Less than one-tenth of one acre.

a See Table 4.6-5 for land-use definitions.

b Calculations used in this table for each of the 22-1/2% compass points:

0-1.8 km = 157.158 acres
1.8-3.6 km = 471.747 acres
3.6-5.4 km = 786.038 acres
5.4-7.2 km = 1,100.354 acres
7.2-8.0 km = 590.407 acres
Total 8 km = 3,105.431 acres

c Actual area of the 8-km radius is equal to 49,682.7 acres. However, multiplying the total acreage used for each compass point (3105.43) by 16 equals 49,686.9 acres. Differences between this total as well as other subtotals due to rounding.

Table 2.2-3: Land Use Within the Crow Butte Study Area (8-km radius)

Category	Acres	km^2	% of Total Area
Cropland (C)	13,264.4	53.7	26.7
Commercial and Services (C/S)	133.4	0.5	0.2
Forested Land (F)	10,178.1	41.1	20.5
Industrial (I)	13.9	0.1	< 0.1
Mines, Quarries, or Gravel Pits (M)	20.2	0.1	< 0.1
Pastureland (P)	17,148.7	69.5	34.6
Rangeland (R)	2,086.8	8.4	4.2
Recreational (RC)	3,054.2	12.3	6.1
Urban Residential (UR)	238.6	1.0	0.5
Water (W)	93.1	0.4	0.2
Total	49,687.8	201.1	100.0

Table 2.2-4: Crow Butte Study Area Land and Water Use Definitions

Croplands (C):	Harvested cropland, including grasslands cut for hay: cultivated summer-fallow and idle cropland.
Commercial and Services (C/S):	Those areas 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 product 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	Residential land uses range from high density, represented by multi-family units, to low density, where houses are on lots of more than one acre. these areas are found in and around Crawford and Ft. Robinson. Areas of sparse residential land use, such as

Table 2.2-4: Crow Butte Study Area Land and Water Use Definitions

	farmsteads, will be included in categories to which they are related.
Water (W):	Areas of land mass that persistently are water covered.
Recreational (RC):	Land used for public or private leisure-time use, 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.

Sources: U.S.G.S., 1976; U.S. Department of Interior, 1979.

from the site centerpoint (U.S.Bureau of the Census, 1982). Two dwelling units are within 1-km (0.62 miles) and another five dwelling units are within 2km (1.24 miles) of the centerpoint of the proposed permit site.

Commercial and Services

Retail and commercial establishments are located in both Crawford and Fort Robinson. The four largest establishments include the Crawford Community Hospital, the Ponderosa Villa Nursing Home, livestock sale barn and railroad.

Industrial/Mine

Eight gravel pits are found within the 8-km (5 mile) radius of the Crow Butte study area (see Figure 2.2-2). Most of the pits are inactive, although a few are mined periodically for local road construction purposes. Besides Crow Butte Resources, Conoco, Amoco Minerals, Sante Fe Mining, and Union Carbide have also drilled exploratory testing holes in the area. Other industrial facilities within the 8-km (5 mile) radius include the railroad station and maintenance yard at the City of Crawford.

Recreational

The Ponderosa State Wildlife area, located less than 2 miles from the Crow Butte study area, is open to the public for hunting. Although no park sites in the Nebraska State Forest are found within the 8-km (5 mile) study area, the area is open for hiking and camping. The Cochran State Wayside Area, located 7-km (4.3 miles) southwest of the site, is a primitive camping area with 2 campsites, hiking trails, and scenic views. A small portion of Fort Robinson State Park is within 8-km of the site. Urban recreational facilities in the project area include a golf course and city park in Crawford.

Aesthetics

The Crow Butte project area has varied land form and color variation. Crow Butte provides a backdrop along south and west approaches to the site. Ponderosa pines and mixed evergreens are seen while approaching from north of the project site. As the project area has been used historically for grazing, it is unlikely that any undisturbed area exists within the site boundary. Human influence is evidenced by scattered farmhouses and some fencing, and the existing R&D and commercial facility.

Transportation and Utilities

Nebraska Highway 2 and U.S. Highway 20 converge in Crawford. 1980 average daily traffic counts range between 625-825 on Nebraska Highway 2

Table 2.2-5: Agricultural Yields (kg/km^2) for Croplands in Dawes County, 1978-1980 Average

		Planted Acres	Harvested		Production		Yield
			Acres	km^2	Bu/Tons	Kgs	Kgs/km^2
Corn							
	for grain (bu)		2,333	9.44	229,867	5,838,622	618,498
	for silage (tons)		767	3.10	9,650	8,754,287	2,823,964
	other		67	.27	843	765,696	2,823,964[c]
	Subtotal	3,233[b]	3,167	12.81	240,360	15,358,605	1,198,954.3
Sorghum for Grain (bu)	100	100	0.40	3,750	92,250	238,125	
Oats (bu)	7,033	4,367	17.67	162,800	2,360,600	133,593	
Barley (bu)	1,500	1,333	5.39	53,300	1,161,940	215,573	
Rye (bu)	467	233	0.94	5,367	136,322	145,023	
All hay[d] (tons)	69,967	69,967	283.15	100,453	91,128,953	321,840	
Wheat (bu)	53,167	47,334	191.56	1,506,000	40,963,200	213,840	
Total	135,467	126,501	511.94	----	151,204,870	295,356.6	
Irrigated	n/a	3,067	12.41	----	----	----	

Notes:
- n/a- not available
- a 1 acre = 0.0040469 km2
- b Total for grain, silage and forage or pastured.
- c Used the same kgs/km2 as corn for silage.
- d Includes wild and tame alfalfa.

Table 2.2-6: Potential Agricultural Production for Cropland in the Crow Butte 8-km Study Radius

	Percent of Total Planted [a]	Total Cropland (acres)	Percent of Planted/ Harvested [a]	Harvested (acres)	Harvested (km^2) [b]	County Yield (kgs/km^2)	Production 8-km Radius (kgs)
Corn	2.39	317.0	97.96	310.5	1.26	1,198,954	1,510,682
Sorghum	0.07	9.3	100.00	9.3	0.04	238,125	11,906
Oats	5.20	689.7	62.09	428.2	1.73	133,593	231,116
Barley	1.11	147.2	86.67	127.6	0.52	215,573	112,098
Rye	0.35	46.4	49.89	23.1	0.09	145,023	13,052
Hay	51.55	6,837.8	100.00	6,837.8	27.67	321,840	8,905,313
Wheat	39.33	5,216.9	89.03	4,644.6	18.80	213,840	4,041,576
Total	100.0	13,264.4	93.34	12,381.1	50.11	(295,864)c	14,825,743

Notes:
- a Same as Dawes County.
- b 1 acre = .0040469 km2.
- c Average yield for all crops harvested in the 8-km project radius.

Table 2.2-7: Livestock Inventory, Dawes County January 1980- 3 Year Average

	Number	% of Total	Animial Units [a]	
			Pounds	% of
All Cattle, except dairy	56,510	82.1	56,510	97.2
Dairy cattle	323	0.5	323	0.5
Hogs	5,100	7.4	1,122	1.9
Sheep	843	1.2	169	0.3
Chickens[b]	6,050	8.8	31	0.1
Total animals	68,826	100.0	58,155	100.0
Milk production (000's lb)	3,400			
Egg production (000's lb)	1,250			

Notes: [a] Animal unit conversions:

1 cow	=	1,000 lbs.
1 hog	=	220 lbs.
1 sheep	=	200 lbs.
1 chicken	=	5 lbs.
1 animal unit	=	1,000 lbs.

[b] Chickens on farms December 1 of previous year.

Source: Nebraska Crop and Livestock Reporting Service, 1980; 1981.

Table 2.2-8: Estimated Annual Yields for Native Grassland (Rangeland) and Improved Pastureland for the Crow Butte 8-km Project Site Area

	Total Land Use	Total Yield		Potential Animial Units[c]	
		Acres	Tons[a]	Kgs.[b]	Per Month[d]
Rangeland	2,086.8	1,043.4	946,552	1,043	5,215
Pastureland	17,148.7	25,723.1	23,335,482	13,719	68,595
Total	19,235.5	26,766.5	24,282,034	14,762	73,810

Notes:

a Yield for rangeland is .5 tons/acre, yield for improved pasture is 1.5 tons/acre.

b 1 ton = 907.18 kg.

c 1 animal unit = 1,000 lbs.

d 1 acre of rangeland supports .5 animal units in a month (aum); 1 acre of improved pasture supports .8 aum.

e Grazing season in Dawes County lasts approximately 5 months.

Source: D. Huls, 1982. Dawes County Agricultural Extension agent.

Table 2.2-9: Residence Count and Distance (8-km Radius of Crow Butte Project Centerpoint)

Sector	Structure Count[a]	Nearest Residence (km)	Nearest Vegatable Garden (km)	Nearest Project Boundary
N	2	5.7		2.4
NNE	1	4.0		2.0
NE	3	4.3		2.5
ENE	6	.6	.6	2.1
E	0	--		2.1
ESE	5	.6		1.4
SE	1	4.5		2.9
SSE	1	4.5		2.9
S	3	3.8		4.0
SSW	2	5.0		2.3
SW	3	1.6		1.5
WSW	3	3.1		1.3
W	3	2.5		1.3
WNW	38[b]	4.4		1.3
NW	608[b]	3.1		5.4
NNW	10	1.1	1.1	2.4

Notes: a Residences.

b U.S. Census Bureau reported 621 housing units within the City of Crawford. As with the Sectorial population, housing units for Crawford are allocated as 5% for the WNW sector and 95% for the NW sector.

Sources: USGS, 1980; EH&A, 1982; U.S. Dept. of Commerce, 1981.

and between 1,190-1,225 on U.S. Highway 20 within the project area (Nebraska Department of Roads, 1981). Although unpaved, Squaw Creek Road provides access to the Crow Butte site. A Burlington Northern Railroad runs in a northwesterly direction approximately 1.2-km (0.75 miles) west of the site. Several transmission lines traverse the project area, including one less than 1-km west of the designated centerpoint.

Other

Three cemeteries are within the site area, one within 2km of the site centerpoint. Several radio towers and one school are also located in the area.

2.2.4 WATER USES WITHIN THE 8-KM STUDY AREA

The Crow Butte project 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 is used to support agricultural production, wildlife habitat, and both warm and cold-water fish. Within 10-km (6.2 miles) of the project, the White River, upstream from the project, supplies drinking water to the citizens of Crawford. In 1981, average daily usage ranged from a low of 199 gallons per day per person (gpd) in February to a high of 508 gpd 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,are also located within a 10-km (6.2 mile) radius.

Groundwater in the 8km (5 mile) study area is supplied by either the Brule or Chadron Formations (Williams,1982). A water well survey conducted by Wyoming Fuel Company indicates that most of the groundwater pumped from 123 wells surveyed within 2-1/4 miles (3.62 km) of the proposed commercial study area is used either to water livestock or for domestic purposes. A spring, located at Fort Robinson State Park, produces an average of 972,000 gpd (Storbeck, 1987).

Future water use within an 8-km radius of the project site will likely be a continuation of present use. It is unlikely that any additional irrigation development will occur due to the shortage of existing water.

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 Crow Butte commercial operations. Data were obtained through the 1980 and 1990 U.S. Census of Population and discussions with state and local agency personnel.

2.3.1 DEMOGRAPHY

Regional Population.

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

Historical and current population trends in the project 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 over a 17.0 percent population increase, largely occurring in the latter half of the 1970s. The 1985 population estimate shows continued but slower growth for the county.

All of the Nebraska counties comprising the project area experienced slight growth or actual population decline between 1960 and 1980 and population decline between 1980 and 1990. Chadron is located approximately 40-km (25 miles) northeast of the project site with a 1990 population of 5,588. The community of Crawford, within 10-km (6.3 miles) of the site, had a 1990 population of 1,115. Sheridan, Sioux and Morrill Counties experienced overall population losses between 1960 and 1980, although the small communities of Hay Springs and Rushville increased slightly in the latter half of the 1970s. 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.

Scottsbluff County experienced gradual population growth over the two decade period from 1960 to 1980. Scottsbluff County showed a slight

Table 2.3-1: Historical and Current Population Change for Counties and Town Within 80 KM of the Crow Butte Project Site, 1960-1990

State / County / City	Population						Average Annual % Change				
	1960	1970	1977	1980	1985	1990	1960/ 1970	1970/ 1977	1977/ 1980	1980/ 1985	1980/ 1990
Nebraska											
Dawes	9,536	9,761	8,890	9,609	9,400	9,021	.23	-1.33	2.63	-0.42	-0.22
Chadron	5,079	5,921	5,049	5,933		5,588	1.55	-2.25	5.53		-0.58
Crawford	1,588	1,291	1,254	1,315		1,115	-2.05	-0.41	1.60		-1.11
Box Butte	11,688	10,094	11,202	13,696	14,400	13,130	-1.46	1.50	6.93	1.04	-0.41
Alliance	7,845	6,862	7,997	9,869		9,765	-1.33	2.21	7.26		-0.11
Hemingford	904	734	801	1,023		953	-2.06	1.26	8.50		-0.68
Scottbluff	33,809	36,432	37,510	38,344	37,900	36,025	0.75	0.42	0.74	-0.22	-0.60
Scottsbluff	13,377	14,507	13,813	14,156		13,711	0.81	-0.70	0.82		-0.31
Sheridan	9,049	7,285	7,464	7,544	7,600	6,750	-2.15	0.35	0.36	0.16	-1.05
Hay Springs	823	682	627	794		693	-1.86	-1.19	8.19		-1.27
Rushville	1,228	1,137	1,192	1,217		1,127	-0.77	0.68	0.69		-0.74
Sioux	2,575	2,034	1,925	1,845	1,800	1,549	-0.24	-0.78	-1.40	-1.62	-1.60
Harrison	448	377	384	361		241	-1.71	0.26	-2.04		-1.94
Morrill	7,057	5,813	6,200	6,085	5,100	5,423	-1.92	0.93	-0.62	-0.64	-1.09
South Dakota											
Fall River	10,688	7,505	8,344	8,439	7,800	7,353	-3.47	1.53	0.38	-1.52	-1.29
Hot Springs	4,943	4,434	4,759	4,742		4,325	-1.08	1.02	-0.12		-0.88
Oelrichs	132	94	145	124		138	-3.34	6.39	-5.08		-0.48
Ardmore	73	14	17	16		NA	-15.22	2.81	-2.00		--
Shannon	6,000	8,198	8,494	11,323	11,700	9,902	3.17	0.51	10.06	0.60	-1.25
Wyoming											
Goshen	11,941	10,885	12,139	12,040	12,600	12,373	-0.92	1.57	-0.27	0.94	0.28
Niobrara	3,750	2,924	2,953	2,924	3,200	2,499	-2.46	0.14	-0.33	1.64	-1.45
Lusk	1,890	1,495	1,710	1,650		1,504	-2.32	1.94	-1.18		-0.88

Sources: U.S. Bureau of the Census, 1972a, 1972b, 1972c, 1979, 1981, 1986, 1990a, 1990b, 1990c.

Table 2.3-2: Population by Age and Sex for Counties Within the 80-km Radius of the Crow Butte Project Area, 1990

State County Nebraska	Age	Male	Female	Total	Total % Breakdown
Box Butte	Under 5	590	476	1,066	8.1
	5 - 18	1,720	1,624	3,344	25.5
	19 - 34	1,337	1,407	2,744	20.9
	35 - 64	2,128	2,090	4,218	32.1
	65+	703	1,055	1,758	13.4
	Total	6,478	6,652	13,130	100.0
Dawes	Under 5	336	261	597	6.6
	5 - 18	1,023	920	1,943	21.5
	19 - 34	1,253	1,228	2,481	27.5
	35 - 64	1,274	1,314	2,588	28.7
	65+	547	865	1,412	15.7
	Total	4,433	4,588	9,021	100.0
Scottsbluff	Under 5	1,315	1,225	2,540	7.1
	5 - 18	4,106	3,980	8,086	22.4
	19 - 34	3,536	3,768	7,304	20.3
	35 - 64	5,936	6,344	12,280	34.1
	65+	2,410	3,405	5,815	16.1
	Total	17,303	18,722	36,025	100.0
Sheridan	Under 5	214	191	405	6.0
	5 - 18	800	756	1,556	23.0
	19 - 34	558	557	1,115	16.5
	35 - 64	1,127	1,146	2,273	33.7
	65+	586	815	1,401	20.8
	Total	3,285	3,465	6,750	100.0

Table 2.3-2: Population by Age and Sex for Counties Within the 80-km Radius of the Crow Butte Project Area, 1990

State County	Age	Male	Female	Total	Total % Breakdown
Sioux	Under 5	61	39	100	6.5
	5 - 18	169	164	333	21.5
	19 - 34	130	126	256	16.5
	35 - 64	303	306	609	39.3
	65+	114	137	251	16.2
	Total	777	772	1,549	100.0
Morrill	Under 5	204	197	401	7.4
	5 - 18	626	543	1,169	21.6
	19 - 34	484	460	944	17.4
	35 - 64	947	942	1,889	34.8
	65+	424	596	1,020	18.8
	Total	2,685	2,738	5,423	100.0
South Dakota					
Fall River	Under 5	195	181	376	5.1
	5 - 18	733	760	1,493	20.3
	19 - 34	557	573	1,130	15.4
	35 - 64	1,582	1,245	2,827	38.4
	65+	741	786	1,527	20.8
	Total	3,808	3,545	7,353	100.0
Shannon	Under 5	742	649	1,391	14.0
	5 - 18	1,691	1,588	3,279	33.1
	19 - 34	1,189	1,167	2,356	23.8
	35 - 64	1,153	1,197	2,350	23.7
	65+	246	280	526	5.3
	Total	5,021	4,881	9,902	100.0

Table 2.3-2: Population by Age and Sex for Counties Within the 80-km Radius of the Crow Butte Project Area, 1990

State County	Age	Male	Female	Total	Total % Breakdown
Wyoming					
Goshen	Under 5	414	430	844	6.8
	5 - 18	1,458	1,374	2,832	22.9
	19 - 34	1,251	1,333	2,584	20.9
	35 - 64	2,041	2,074	4,115	33.3
	65+	826	1,172	1,998	16.1
	Total	5,990	6,383	12,373	100.0
Niobrara	Under 5	81	75	156	6.2
	5 - 18	235	245	480	19.2
	19 - 34	210	268	478	19.1
	35 - 64	432	475	907	36.3
	65+	193	285	478	19.1
	Total	1,151	1,348	2,499	99.9
Total	Under 5	4,152	3,724	7,876	7.6
	5 - 18	12,561	11,954	24,515	23.6
	19 - 34	10,505	10,887	21,392	20.6
	35 - 64	16,923	17,133	34,056	32.7
	65+	6,790	9,396	16,186	15.6
	Total	50,931	53,094	104,025	100.0

Source: U.S. Bureau of the Census, 1981a, 1981b, 1981c, 1990a, 1990b, 1990c.

Table 2.3-3: Population Projections for Counties Within an 80-km Radius of the Crow Butte Project Area, 1980-2020

County	Projected[1]	Census 1990	2000	2010
Box Butte	9,529	13,130	13,200	13,102
Dawes	10,218	9,021	9,124	9,190
Scottsbluff	42,695	36,025	36,576	36,337
Sheridan	6,811	6,750	6,354	6,110
Sioux	1,950	1,549	1,406	1,274
Morrill	6,077	5,423	5,027	4,659
Fall River	12,485	7,353	6,673	6,447
Shannon	7,724	9,902	11,550	13,192
Goshen	13,632	12,373	12,650	--
Niobrara	3,148	2,499	2,590	--

Notes: [1]Projected 1990 population from 1980 Census.

Sources: University of South Dakota, Bureau of Business Research, 1981.
South Dakota State Data Center, 1995.
University of Nebraska-Lincoln, Bureau of Business Research, 1981, 1995.
Wyoming Department of Administration and Fiscal Control, 1981, 1995.
U.S. Census Bureau, 1986, 1990.

decrease in population between 1980 and 1985, and again between 1985 and 1990. The 1990 population of the county is 36,025, of which 13,711 is found in the City of Scottsbluff, located beyond the 80-km area.

The two South Dakota counties in the 80-km study area include Fall River and Shannon. Fall River County declined by more than 2,000 persons between 1960 and 1980, with a gradual upturn evident by 1975. By 1985, the upturn had reversed, and by 1990 the population declined by 12.9 percent from 1980. Shannon County, on the other hand, grew by 5,323 persons since 1960 to over 11,300 by 1980. Most of the increase occurred between 1977 and 1980. Shannon County population continued to increase through 1985 while Fall River County continued its decline. However, by 1990, population had decreased by 15.4 percent from the 1985 high point of 11,700 to 9,902 in 1990. Only the very southern portions of both counties are included within 80-km of the project area.

Population Characteristics.

1990 population by age and sex for counties within 80-km of the Crow Butte project area is shown in Table 2.3-2. Overall, 68.8 percent of the population in the region are over 18 years of age. Fall River and Niobrara counties reported the highest percentage of persons over 18 with 74.6 percent. About 7.6 percent of the population were less than five years old in 1990. Shannon County reported the youngest population, with 14.0 percent less than five years old and nearly half (47.1 percent) 18 years of age and under. Females slightly outnumbered males in all, with 50.7 percent female to 49.3 percent male.

In 1990 nearly 85 percent of the ten county population were classified as white. Indians and persons of Hispanic origin comprised 11.0 percent and 8 percent, respectively, of the total population. Nearly 80 percent of the Indians were Sioux living on the Pine Ridge Reservation in Shannon County, South Dakota.

Population Projections.

The projected population for selected years by county within the 80-km radius of the proposed Crow Butte Project is shown in Table 2.3-3. Actual versus projected populations for 1990, prepared from 1980 Census data, are either too high or too low for counties in Nebraska and South Dakota. Box Butte and Shannon Counties reported higher 1990 population census counts than those projected, while the remaining counties reported lower population counts than the project numbers. The declines in oil and gas production in the area may not have been accounted for in these projections, thus causing the discrepancies.

Seasonal Population and Visitors.

In 1981, approximately 376,997 people visited Fort Robinson State Park. This number represents a 28.8 percent increase from 1980 and over a 100 percent increase from 1978 total visitors to the park. Fort Robinson officials estimated that total visitors to the park in 1986 should at least equal that of 1981 (Rotherham, 1982; Foster, 1982). The majority of these visitors are Nebraskan families, staying between 3 to 40 days. In 1994, 359,278 people visited the park, a decrease of nearly 5 percent from 1981 (Plooster, 1995).

The Trooper National Recreation Trail within the Nebraska National Forest recorded 1,800 visitor days in 1980 (Foster, 1982). Visitor statistics are not recorded for the Ponderosa Wildlife Area. However, some idea of the number visiting these areas can be assessed through the number of hunting permits issues. Most hunters and hikers visit the Ponderosa Wildlife Area and surrounding Nebraska National Forest during the spring and fall turkey season and fall deer season. On the opening day of turkey season, approximately 20 hunters are allowed into the area. This daily number eventually falls to between 5 and 8 hunters. For the opening day of deer season, approximately 40-50 hunters are permitted to hunt the area. This number also drops as the season progresses (Lemmons, 1982 and 1987).

One source of seasonal population in this region is Chadron State College, located approximately 35 km (21.6 miles) from the site. During the 1982 spring semester, 2,000 students were officially enrolled at the college (Datson, 1982). In Fall 1986, total enrollment was 2,240 with 1,600 at the Chadron campus (Schmiedt, 1987). In the 1994 fall semester, a total of 3,296 students were enrolled at the college (Taylor, 1995).

Schools.

The Crawford High School and grade school are presently under capacity. Total enrollment in these two schools as of Fall 1995 is 147 in the high school and 130 in the elementary school with maximum capacities of 545 and 185, respectively (Crawford High School, 1995; Crawford Elementary School, 1995). Current enrollment numbers are comparable to annual enrollments since 1987 for both schools. The grade school currently has a student to teacher ratio of 20 to 1; while the high school has a ratio of 14 to 1. No historical high was given for the grade school. However, it was estimated that the high school historical high was over 200 pupils (present enrollment is 147).

Outside the Crawford district are a number of rural school districts supporting grades one through eight. These are generally one-room school houses. Students living in these rural districts may pay tuition if they elect to go to the

Crawford schools for grades one through eight. There is no tuition for high school. In seven rural districts from which Crawford High School draws, there are an estimated 100 pupils in the lower grades.

Families moving into the Crawford district as a result of the proposed commercial operations would not stress the current school system, since it is presently under capacity. It is estimated that at least 30 new pupils could be handled easily. Using a factor of 2.3 children/family and an estimated 9 new families, the resulting 21 children could be accommodated.

Sectorial Population.

Existing population as determined for the original analysis in CBR 1987 for the 80-km radius was estimated for 16 compass sectors, by annual rings of 1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 70 and 80-km from the site (a total of 208 sectors). Subtotals by sector and compass points as well as the total population are shown in Table 2.3-4.

Population within the 10-km Radius

Population within the 10-km radius was estimated using the following techniques:

- 1980 U.S. Census of Population estimates of 1,315 for the City of Crawford was used to estimate urban population within the 10-km (6.2 mile) radius.

- The radius was drawn on a 1980 USGS Quad map (1"=2,000'); the locations of houses indicated on the map were then compared with an aerial photograph of the 10-km radius area.

- A "windshield survey" of the area was conducted to check each rural house for occupancy. Obviously abandoned homes were excluded resulting in a total of 102 occupied rural housing units.

- To estimate the number of rural residents, local citizens were interviewed. Actual persons per household estimates were used if the persons interviewed agreed on the number of residents in a household.

- The average persons per household for all known rural households in the 10-km (6.2 mile) radius was then used to estimate the population of the remaining occupied households located in the 10-km radius. 245 persons were identified in this manner.

Table 2.3-4: 1980 Population Within an 80-km (50 mile) Radius of the Crow Butte Project Site [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	15	39	65	95	145	178	210	242	989
NNE	0	0	0	0	1	2	111	65	92	142	185	400	365	1,363
NE	0	0	0	0	1	6	39	65	91	124	290	488	572	1,676
ENE	4	0	0	0	0	10	39	65	5,982	157	232	647	3,077	10,213
E	0	0	0	0	0	0	39	65	91	140	1,047	302	1,563	3,247
ESE	2	2*	3	0	0	5	39	65	91	125	249	302	348	1,231
SE	0	0	0	4*	4*	13	39	65	142	238	301	338	364	1,508
SSE	0	0	0	0	6	1*	39	94	91	1,367	301	354	10,290	12,543
S	0	0	0	0	0	10	39	110	192	243	283	299	1,186	2,362
SSW	0	1	0	0	0	5	39	58	64	67	76	89	1,077	1,476
SW	0	2*	4	0	0	4*	28	35	49	61	76	89	157	505
WSW	0	0	0	2*	0	13*	24	35	49	61	84	242	354	864
W	0	0	6*	0	0	6	39	35	49	422	300	199	239	1,295
WNW	0	0	0	0	2	84*[bc]	23	35	49	61	79	106	127	565
NW	0	2	0	2*	0	1,308[b]	28	35	49	63	119	191	187	1,984

Table 2.3-4: 1980 Population Within an 80-km (50 mile) Radius of the Crow Butte Project Site [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
NNW	0	2	2*	0	5	21*	21	54	61	146	178	209	381	1,080
Total	6	9	15	8	19	1,503	625	946	7,237	3,562	3,978	4,465	20,529	42,902

[a] An actual head count was conducted for the population living within 10-km of the mine site. These figures were supplemented by interviews with local people and 1980 census data for Dawes County and the City of Crawford. Current population living between 10-80 km of the mine site were estimated using 1980 census data. See Sec. 2.3.1.5 for a detailed description of EH&A's methodology.

[b] WNW sector includes 5% of the 1980 Crawford population; NW sector includes 95% of the 1980 Crawford population.

[c] Total persons residing at Ft. Robinson State Park.

* The average persons per household for known rural residences within the 10-km radius was used to estimate the population of the remaining households located within the 10-km radius.

- Rural and urban populations were added together resulting in a total estimated population of 1,560 within the 10-km radius.

Population between the 10-km and the 80-km Radii

The 1980 population found in between a 10-km and an 80-km radius of the site was determined as follows:

- 1980 U.S. Census of population estimates for cities and counties in Nebraska, South Dakota and Wyoming were used to arrive at total urban population.

- City population and areas (sq. mi.) were subtracted from their respective county population and area to determine the population density of the non-urban areas within each county.

- Non-urban densities were multiplied by the number of square miles of area of each county in each of the 112 sectors to estimate 1980 non-urban population.

- The population of cities within each sector was added to the rural population of that sector to get total 1980 population for each sector.

2.3.2 LOCAL SOCIO-ECONOMIC CHARACTERISTICS

Major Economic Sectors.

In 1994, average annual unemployment rates in Dawes, Box Butte, and Scottsbluff counties decreased from the February 1987 rates. Table 2.3-5 summarizes unemployment rates and employment in the Nebraska project area counties. As of February 1987, the Dawes/Box Butte County area as well as the large Scottsbluff area to the southwest exhibited unemployment rates ranging from 4.8 percent in Dawes County to 9.3 percent in Scottsbluff County. Unemployment rates increased between the submission of the R&D application in 1982 and 1987. In 1994, unemployment levels declined from February 1987 levels. The annual average 1994 unemployment rates in Dawes, Box Butte, and Scottsbluff counties were 3.3 percent, 3.8 percent, and 4.2 percent, respectively. These rates were a little higher than the state-wide (unadjusted) rate of 2.9 percent.

The major economic sectors in the project area have changed little in recent years, although individual sectors have shifted in their relative proportion in the overall economy. The area continues its dependence on trades,

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

	Dawes	Box Butte	Scottsbluff
Labor Force	4,490	6,156	18,333
Unemployment	149	235	778
Unemployment Rate	3.3	3.8	4.2
Employment	4,341	5,921	17,555
Non-Farm Employment Total	3,479	5,446	15,539
Manufacturing	165	402	1,771
Non-Manufacturing	3,314	5,044	13,768
Construction & Mining	136	80	642
Transportation, Communication & Utilities	216	1,909	871
Trade	952	1,106	4,967
Retail	824	840	3,918
Wholesale	128	265	1,049
Financial, Insurance & Real Estate	77	215	787
Services	548	779	3,549
Government	1,384	955	2,952
Federal	144	65	188
State	721	67	469
Local	519	824	2,294

government and services. Economic activities in the Crawford area include farming, ranching, cattle feed lots, tourism, and retail sales.

In Dawes, Box Butte and Scottsbluff counties, agriculture accounts for approximately 20, 8 and 11 percent of total employment, respectively. In Dawes County, government makes up 40 percent of total non-farm employment followed by trade (27%), service (16%), and transportation (6%). Construction and mining account for 4 percent. In Scottsbluff County, trade and services compose the greatest part of non-farm employment (30% and 22%) respectively) with government (19%) and manufacturing (14%) also important.

Housing.

Between 1970 and 1980, total housing units increased by 17 percent in Dawes County from 3,388 to 3,965 units. By 1990, total housing units decreased by 1.4 percent to 3,909 units. Chadron, the largest community in Dawes County (1990 population of 5,588) and within 40-km (25 miles) of the project site, experienced a 25 percent increase in housing stock between 1970 and 1980. By 1990, there were 2,333 housing units in Chadron and 576 units in Crawford. Alliance, in Box Butte County (approximately 72-km (45 miles) from the project site), with a 1980 population of 9,869, exhibited a 54 percent growth in total housing units between 1970 and 1980. In 1990, there were 4,108 housing units in Box Butte County (U.S. Department of Commerce, Bureau of the Census, 1981a, 1990d).

In 1990, Dawes and Box Butte counties had homeowner vacancy rates of 3.8 and 1.5 percent, respectively. Rental vacancy rates were 12.5 percent in Dawes County and 14.9 percent in Box Butte County (U.S. Department of Commerce, 1990a).

According to a local Crawford realtor, rental property in Crawford is scarce. However, an October 1995 listing of property for sale revealed ten houses and eight lots. Five of the lots are located on the outskirts of town, and do not have utility hookups. Housing prices ranged from $12,000 to $62,500. Recent sales of parcels of land ranged in price from $74 to $600 per acre, depending on the location of the parcels (Suchor, 1995).

High interest rates and high tax rates were the major deterrents for potential home buyers in the project area in the past. Current deterrents are economic uncertainty and unemployment. Recent interest rates on most home mortgages have ranged from 7 to 11 percent.

The purchase of homes by Crow Butte employees would provide the City with ad valorem property taxes. The City of Crawford levies taxes at a dollar per hundred of valuation, with taxes on a $50,000 property of approximately $1,475/year as of 1994 (Suchor, 1995).

2.3.3 EVALUATION OF SOCIO-ECONOMIC IMPACTS OF THE CURRENT OPERATION

The preliminary evaluation of socio-economic impacts of the commercial facility was completed in 1987 as reported in the original license application. The preliminary evaluation was divided into two phases--construction and operation. The evaluation concluded that the construction phase would result in a moderate impact to the local economy, resulting from the purchases of goods and services directly related to construction activities. Impacts to community services such as roads, housing, schools and energy costs would be minor or non-existent and temporary.

Since the inception of the operational phase, the overall effect of the current commercial facility operations on the local and regional economy has been beneficial. Purchases of goods and services by the mine and mine employees contribute directly to the economy. Local, state, and the federal governments benefit from taxes paid by the mine and its employees. Indirect impacts are also beneficial, resulting from the circulation and recirculation of direct payments through the economy. These economic effects further stimulate the economy, resulting in the creation of additional jobs. Beneficial impacts to the local and regional economy provided by the current operation would continue for the life of mine, estimated to be an additional ten years as of January 1, 1996.

The current mine operation has not resulted in any significant impact to the community infrastructure (including schools, roads, water and sewage facilities, law enforcement, medical facilities, and any other public facility) in the town of Crawford or in Dawes County. The mine employs a workforce of 50-55 people, including contractors. This is a small workforce relative to the community of 1,115 people in Crawford and the additional 7,906 people in Dawes County. It does not place any significant additional demand on community services or local housing availability.

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

Identification and assessment of cultural resources within the Crow Butte In-Situ Uranium Mining project have involved two separate field investigations. The Research and Development (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 Commercial Study Area (CSA) lands during April and May 1987 by the Nebraska State Historical Society.

This section presents a summary of 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 study area and that no National Register 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 on project lands. Registered National Historic Landmarks representing military and Native American reservation period use of the study area are located near the proposed Crow Butte project.

Intensive (100% coverage) pedestrian inspection of the R&D area (in 1982) and the full CSA survey unit (in 1987) resulted in identification of twenty-one newly recorded resource locations (Table 2.4-1 and Figure 2.4-1). Included are eight sites representing Native American components, twelve Euroamerican locations, and a buried bone deposit of undetermined cultural association.

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 (m^2)	Field Investigation
1982				
25DW111 (Harvey Homestead ?)	surface; glass, ceramic, metal; bone debris; Euroamerican; 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); Euroamerican late 19th/early 20 century	broad terrace; Squaw Creek	6,000	survey, sketch plan, photographs
25DW113 (Fiandt Homestead ?)	Surface/buried; glass, ceramic, metal, wood, leather debris (25-40 cm S.D.); 4 depressions; Euroamerican; 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; Euroamerican; late 19th century	small rise on upper slope	900	survey, sketch map
	surface; chipped stone flaking debris;	terrace slope; Squaw		survey, sketch map,

**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
25DW116	unassigned Native American	Creek	2	photographs
25DW117 (Fleming Homestead?)	surface; windmill, cistern, stock tank complex; Euroamerican (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, controlled bank profile/collection, sketch map, photographs
FN-3	Crow Butte Cemetery; Euroamerican; 1880-1971	level ridge top	2,700	survey, sketch plan, photographs
1987				
25DW191 (Dougherty/Smith)	surface/buried; outbuilding; 2 depressions; farm machinery; Euroamerican; late 19th century	foot of Pine Ridge colluvial slope	50,000	survey, sketch map, photographs
25DW192 (Stetson/Roby)	surface/buried; glass and metal debris; 2 depressions, 2 foundations; Euroamerican; late 19th century	top and slope of small knoll overlooking Squaw Creek tributary	1,000	survey, sketch map, uncontrolled surface collection, photographs

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
25DE196	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; 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
25DW199 (Crawford Ice House)	surface/buried; foundation, pond; Euroamerican; 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); Euroamerican 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); Euroamerican; early 20th century to present	broad terrace, Squaw Creek	25,000	survey, sketch plan, photographs

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 have 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.

2.5 METEOROLOGY

2.5.1 INTRODUCTION

This section describes the meteorological conditions in the region surrounding the Crow Butte project. The data presented in this section were used to determine the effect of the local climate on the proposed commercial operation and will also be used to evaluate the continuation of the project. The joint frequency data will 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 Climatological Summary from Chadron, Nebraska and an on-site monitoring station located near the Crow Butte Facility. The Climatological Summary from Chadron covers 30 years of observation from 1941 through 1970. From April 1982 through April 1984, a monitoring station on the Crow Butte Project site monitored temperature, precipitation, evaporation, and wind speed and direction. Data are also included from the National Weather Service Stations at Scottsbluff, Nebraska and Rapid City, South Dakota.

The Crow Butte Project is located in Dawes County. This county is located in the north central portion of the Nebraska panhandle and its northern border is shared 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 to the west and the Black Hills 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 area is generally drier than the rest of the panhandle.

Precipitation during the winter months averages about 1.0 cm (0.39 in) per month generally occurring as light snow. Cold spells persist for only a few days ending with the advance of warmer air from the west or southwest. Occasionally there are winters with persistently cold temperatures and heavy snow.

Precipitation increases in the spring, with March usually posting the greatest monthly snowfall. The snow and gentle rains gradually change to showers and thundershowers as June approaches. The high temperatures increase to not quite 27°C (81°F) in April and temperatures above 32°C (90°F) have been recorded as early as May.

Thunderstorms produce most of the precipitation during the summer months. In severe storms, hail and damaging winds can be problems but tornadoes are rare. The warmest month of the year is July with an average high temperature of 32°C (90°F) and an average low temperature of 15°C (59°F). Several times during the summer months, temperatures can be expected to climb above 38°C (100°F).

Precipitation becomes light again during the fall months. High temperatures drop to around 29°C (84°F) in September and by the beginning of October they only reach to near 21°C (70°F). Increasing cloudiness and falling temperatures best characterize November. Early snows have been reported in September and by the end of November most of the precipitation is in the form of snow.

The following data were taken from the Climatological Summary for Chadron, Nebraska prepared by U.S. Department of Commerce (USDC, 1971) and the on-site monitoring station. The Climatological Survey data were collected at the Chadron Airport, latitude 42° 50' north, longitude 103° 05' west with a ground elevation of 1006 m (3300 ft) above mean sea level. The airport is located 7.2 km (4.5 miles) west of Chadron, 29 km (18.0 miles) east of Crawford, and 31 km (19.3 miles) east-northeast of the license area. The period of record for this data is 30 years, from 1941 through 1970. The on-site monitoring data have been collected from May 1982 through April 1984.

2.5.2 TEMPERATURE

Table 2.5-1 shows the mean daily maximum and minimum temperatures as well as the mean monthly temperatures. The months November through March all have mean daily minimum temperatures below freezing with January the coldest month with a mean daily minimum temperature of -12.4°C (9.7°F). December, January and February all have monthly mean temperatures below freezing. The warmest months are July and August with mean daily maximum temperatures above 31°C (87°F). The mean yearly temperature is 8.7°C (47.7°F).

The temperature extremes for the period of record are given in Table 2.5-1 along with the year of occurrence. Four months, June through September, recorded temperatures in excess of 37.8°C (100°F). Only July and August did not have recorded low temperatures below freezing. Five months, November through March, had recorded low temperatures below -17.8°C (0°F). The lowest temperature for the period of record was -33.9°C (-29°F) in January 1949 but the lowest temperature on record was -35°C (-31.0°F) occurring on February 8, 1936. The warmest temperature during the period of record was

43.3°C (109.9°F) in July 1954 while the record high temperature was 43.9°C (111°F) on August 25, 1926.

Table 2.5-2 lists the mean number of days per month with temperatures above or below selected values. There are an average of 44 days per year with maximum temperatures exceeding 32.2°C (90°F) and 37 days per year when the maximum temperature will not exceed 0°C (32°F). On almost 50 percent of the days in a given year, the temperature will fall to 0°C (32°F) or below and on an average 19 of those days the temperature will go below -17.8°C (0°F).

The average date of the last 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 in length (USDA, 1981). These are average values and the exact occurrence of freezing temperatures is dependent on exposure.

2.5.3 PRECIPITATION

Precipitation in the region is generally light with the greatest occurrences in the spring and summer. Table 2.5-3 lists the monthly precipitation totals for the period of record. June has the greatest precipitation with a mean of 8.43 cm (3.31 in). The driest months are November through February, when average monthly precipitation is about 1.0 cm (0.393 in). The mean yearly precipitation is 39.52 cm (15.55 in).

Also listed in Table 2.5-3 are the maximum 24-hour precipitation events. The maximum 24-hour rainfall of 8.08 cm (3.18 in) was recorded on June 21-22, 1947. The greatest monthly accumulation was 26.37 cm (10.38 in) recorded during June 1947. The greatest annual precipitation was 80.54 cm (31.71 in) in 1915 while the driest year on record was 1956 when only 26.82 cm (10.56 in) of precipitation fell.

The mean and extreme snowfalls for the period of record are listed in Table 2.5-3. The mean annual snowfall is 105.16 cm (41.40 in). July and August are the only two months without a reported snowfall. The maximum mean monthly snowfall is in March and is reported to be 20.57 cm (8.10 in). The maximum monthly snowfall is 151.38 cm (59.60 in) recorded in January 1949, while the greatest June snowfall is 3.05 cm (1.20 in). The largest 24-hour total snowfall is 67.82 cm (26.70 in) recorded in January 1949.

Precipitation data from Scottsbluff, Nebraska, located 98 km (60.9 mi) south of the license area and from Rapid City, South Dakota 158 km (98.2 mi) north of the license area indicate that precipitation in excess of 0.03 cm (.01 in) can

Table 2.5-1: Mean and Minimum Temperature Data for Chadron, NE (1941 to 1970)

Month	Mean Daily Maximum (°C)	Mean Daily Minimum (°C)	Mean Monthly (°C)	Record High		Record Low	
				°C	Year	°C	Year
Jan.	2.4	-12.4	-5.0	18.3	1965	-33.9	1949
Feb.	5.0	-9.8	-2.4	23.3	1962	-31.7	1962
Mar.	8.1	-6.7	0.7	29.4	1946	-28.9	1948
Apr.	15.4	0.1	7.8	32.2	1962	-17.2	1968
May	10.7	5.8	13.3	36.7	1969	-8.9	1954
June	26.2	10.9	18.6	40.0	1961	-3.3	1969
July	31.9	14.7	23.3	43.3	1954	3.3	1945
Aug.	31.6	13.8	22.7	40.6	1959	1.7	1942
Sept.	25.3	7.3	16.3	39.4	1959	-7.2	1942
Oct.	18.8	0.9	9.9	35.0	1947	-14.4	1952
Nov.	9.7	-5.8	1.9	25.0	1965	-27.8	1959
Dec.	4.1	-10.3	-3.1	21.7	1941	-33.3	1968
Year	16.6	0.7	8.7	43.3	July 1954	-33.9	Jan. 1949

Table 2.5-2: Temperature Occurrences for Chadron, NE (From 1941 to 1970)

Month	Mean Number of Days with Maximum Temperatures		Mean Number of Days with Minimum Temperatures	
	> 32.2°C	< 9°C	< 0°C	< -17.8°C
Jan.	0	11	31	8
Feb.	0	7	28	4
Mar.	0	6	28	2
Apr.	0.5	1	15	0
May	1	<0.5	4	0
June	5	0	<0.5	0
July	16	0	0	0
Aug.	16	0	0	0
Sept.	5	0	2	0
Oct.	<0.5	<0.5	15	0
Nov.	0	3	27	1
Dec.	0	9	30	4
Year	44	37	180	19

Table 2.5-3: Mean and Maximum Precipitation Data for Chadron, NE (1941 to 1970)

Month	Water Equivalent		Snow Fall		
	Mean (cm)	Maximum 24-hour (cm)	Mean (cm)	Maximum Monthly (cm)	Maximum 24-hour (cm)
Jan.	1.04	2.72	18.80	151.38	67.82
Feb.	0.94	1.24	15.75	59.69	26.16
Mar.	1.78	2.21	20.75	53.85	22.86
Apr.	4.24	5.51	13.97	49.28	25.40
May	7.57	5.46	2.79	23.62	17.78
June	8.43	8.08	<1.27	3.05	3.05
July	5.49	4.95	0.00	0.00	0.00
Aug.	2.46	3.63	0.00	0.00	0.00
Sept.	3.38	5.89	1.27	25.40	25.40
Oct.	2.11	3.94	3.81	24.64	18.29
Nov.	1.09	2.84	12.70	65.79	20.57
Dec.	0.99	1.27	15.49	46.99	15.24
Year	39.52	8.08	105.16	151.38	67.82

Table 2.5-4: Percent Relative Humidity Data (From 1941 to 1970)

Month	0500 Hours		1100 Hours		1700 Hours		2300 Hours	
	NE[a]	SD[b]	NE	SD	NE	SD	NE	SD
Jan.	74	68	59	60	60	64	72	68
Feb.	74	72	53	61	50	63	70	72
Mar.	75	74	49	56	44	55	68	72
Apr.	76	73	46	49	40	46	66	68
May	77	75	45	49	41	46	67	70
June	78	76	43	51	39	48	67	73
July	79	72	42	45	37	40	66	65
Aug.	80	69	44	41	38	36	67	60
Sep.	78	66	42	40	36	38	66	59
Oct.	74	64	42	40	39	44	64	60
Nov.	75	67	52	51	51	58	68	66
Dec.	74	68	55	59	57	65	70	68
Year	76	70	48	50	44	50	68	67
Period of Record	16	30	16	30	16	30	16	30

[a]Scottsbluff, NE
[b]Rapid City, SD

be expected on an average of 85 and 96 days per year, respectively (NOAA, 1980a, 1980b). These data are listed in Table 2.5-4. Also given in this table are the mean number of days on which thunderstorms may occur. The annual occurrences range from 44 in Scottsbluff to 15 in Rapid City. In the more severe thunderstorms, high winds and possibly hail can be expected to occur. Tornadoes are a rare occurrence. 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 4.8×10^{-4}. A tornado in intensity Category I has a rotational speed of 134 m/s and a translational speed of 26 m/s.

2.5.4 HUMIDITY

Relative percent humidities at the Scottsbluff and Rapid city weather stations are given in Table 2.5-4. The humidities at 0500, 1100, 1700, and 2300 hours are 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. From Table 2.5-4 it can be seen that these humidity differences are slight and the humidity at the license is expected to be similar to these locations.

2.5.5 WINDS

Figure 2.5-1 and Figure 2.5-2 are the windroses for Scottsbluff, Nebraska and Rapid City, South Dakota respectively. These figures do 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 both locations is from the southwest.

2.5.6 LOCAL METEOROLOGICAL STATION

Local terrain will have a significant influence on the wind patterns in a given area. Because of this, a meteorological station was installed on the project site. This station was capable of measuring wind speed, direction, and the standard deviation of the wind direction. From this information joint frequency data was compiled. Figure 2.5-3: Windrose for Crow Butte Site exhibits the windrose that were identified for the site and Table 2.5-5 shows the frequency of winds by direction and speed for the six stability classes. Table 2.5-6 shows the annual relative joint frequency distribution.

Precipitation was also recorded at the station with a heated tipping bucket rain gauge. Evaporation was measured using a 48" evaporation pan and an evaporation gauge with analog output. The air temperature was also recorded using a precision linear thermistor and fan aspirated radiation shoed. All 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.

2.5.7 REFERENCES

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Table 2.5-5: Frequency of Winds

FREQUENCY OF WINDS BY DIRECTION AND SPEED
FOR STABILITY CLASS A
DATA RECORDED FROM MAY 1982 THROUGH APRIL 1984
CROW BUTTE - NEBRASKA

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	12.35	4.9
NNE	2.51	8.74	2.95	0.11	0.00	0.00	14.32	4.6
NE	1.64	8.52	1.31	0.00	0.00	0.00	11.48	4.5
ENE	0.66	4.37	0.55	0.00	0.00	0.00	5.57	4.4
E	1.20	1.97	0.77	0.00	0.00	0.00	3.93	4.4
ESE	0.33	0.87	0.22	0.00	0.00	0.00	1.42	4.0
SE	0.98	1.75	1.64	0.00	0.00	0.00	4.37	5.1
SSE	0.44	2.51	1.64	0.11	0.00	0.00	4.70	5.3
S	0.98	3.72	1.53	0.00	0.00	0.00	6.23	5.0
SSW	0.55	1.97	2.08	0.22	0.00	0.00	4.81	6.0
SW	0.77	3.72	1.53	0.00	0.00	0.00	6.01	5.0
WSW	0.66	2.08	1.53	0.00	0.00	0.00	4.26	5.3
W	0.66	1.75	1.75	0.11	0.00	0.00	4.26	5.5
WNW	0.77	1.42	0.98	0.44	0.00	0.00	3.61	5.7
NW	0.66	2.30	1.53	0.11	0.00	0.00	4.59	5.5
NNW	1.53	3.93	1.86	0.44	0.00	0.00	7.76	5.3
ALL	15.30	58.25	24.48	1.64	0.00	0.00	99.67	5.0

Calm (less than one knot) = 0.3%
Period mean wind speed = 5.0 knots
Percent occurrence for A stability class 5.6%

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Table 2.5-5 (cont)

**FREQUENCY OF WINDS BY DIRECTION AND SPEED
FOR STABILITY CLASS B
DATA RECORDED FROM MAY 1982 THROUGH APRIL 1984
CROW BUTTE - NEBRASKA**

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	6.4
NNE	1.34	3.52	3.77	0.34	0.00	0.00	8.97	5.7
NE	0.92	5.28	5.45	0.50	0.00	0.00	12.15	6.0
ENE	0.84	1.76	2.85	0.25	0.00	0.00	5.70	6.0
E	0.17	0.84	0.75	0.08	0.00	0.00	1.84	6.0
ESE	0.59	0.59	1.09	0.00	0.00	0.00	2.26	5.8
SE	0.08	1.26	2.26	0.25	0.00	0.00	3.86	6.9
SSE	0.67	1.17	2.43	0.50	0.00	0.00	4.78	6.5
S	1.09	1.01	4.02	0.92	0.00	0.00	7.04	7.0
SSW	1.01	2.01	2.26	0.75	0.00	0.00	6.04	6.3
SW	0.92	3.19	2.51	0.59	0.00	0.00	7.21	6.1
WSW	0.59	2.01	2.60	0.84	0.08	0.00	6.12	6.9
W	0.42	1.34	2.35	0.42	0.08	0.00	4.61	7.2
WNW	0.67	1.09	2.10	0.34	0.00	0.00	4.19	6.6
NW	0.25	1.09	4.02	1.09	0.08	0.00	6.54	7.8
NNW	0.42	1.51	4.95	1.68	0.08	0.00	8.63	7.8
ALL	10.98	30.34	48.95	9.22	0.34	0.00	99.83	6.6

Calm (less than one knot) = 0.2%
Period mean wind speed = 6.5 knots
Percent occurrence for B stability class 7.4%

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Table 2.5-5 (cont)

FREQUENCY OF WINDS BY DIRECTION AND SPEED
FOR STABILITY CLASS C
DATA RECORDED FROM MAY 1982 THROUGH APRIL 1984
CROW BUTTE - NEBRASKA

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	5.69	6.7
NNE	0.63	2.62	2.90	0.85	0.00	0.00	7.00	6.6
NE	0.91	2.28	5.69	1.20	0.00	0.00	10.08	7.0
ENE	0.46	1.03	2.96	0.97	0.00	0.00	5.41	7.3
E	0.00	0.57	0.74	0.28	0.00	0.00	1.59	7.6
ESE	0.23	0.34	0.91	0.23	0.00	0.00	1.71	7.0
SE	0.17	0.68	1.82	0.74	0.00	0.00	3.42	7.7
SSE	0.46	0.74	2.22	1.48	0.00	0.00	4.90	8.0
S	0.97	1.65	5.30	2.28	0.00	0.00	10.19	7.7
SSW	1.14	3.02	3.93	0.97	0.00	0.00	9.05	6.6
SW	1.03	3.36	4.67	1.14	0.11	0.00	10.31	6.8
WSW	0.97	3.02	3.59	1.14	0.06	0.06	8.83	6.8
W	0.11	0.91	1.99	1.03	0.11	0.00	4.16	8.4
WNW	0.17	0.51	1.03	1.25	0.06	0.00	3.02	9.1
NW	0.40	0.74	3.70	2.22	0.06	0.00	7.12	8.7
NNW	0.40	1.42	3.42	2.11	0.00	0.00	7.35	8.2
ALL	8.77	24.43	47.55	18.62	0.40	0.06	99.83	7.4

Calm (less than one knot) = 0.2%
Period mean wind speed = 7.4 knots
Percent occurrence for C stability class 10.8%

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Table 2.5-5 (cont)

FREQUENCY OF WINDS BY DIRECTION AND SPEED
FOR STABILITY CLASS D
DATA RECORDED FROM MAY 1982 THROUGH APRIL 1984
CROW BUTTE - NEBRASKA

SPEED CLASS INTERVALS(KNOTS)

DIRECTION	1,<3	3,<6	6,<10	10,<16	16,<21	>21	ALL	S[illegible]
N	0.17	0.52	1.14	0.83	0.20	0.02	2.88	9.[illegible]
NNE	0.16	1.12	2.34	2.90	0.89	0.19	7.59	10.7
NE	0.13	1.53	2.55	2.72	0.46	0.08	7.46	9.8
ENE	0.04	0.47	0.79	0.50	0.06	0.00	1.86	8.3
E	0.02	0.06	0.28	0.22	0.04	0.00	0.61	9.5
ESE	0.01	0.25	0.35	0.13	0.00	0.00	0.74	7.4
SE	0.06	0.42	0.71	0.52	0.18	0.01	1.90	9.5
SSE	0.13	1.78	1.50	2.60	1.21	0.34	7.56	11.1
S	0.34	1.67	3.58	7.77	3.57	0.58	17.51	12.4
SSW	0.22	1.37	3.82	3.60	0.76	0.12	9.89	10.0
SW	0.17	2.11	5.80	3.80	0.29	0.02	12.20	8.8
WSW	0.17	0.61	2.28	2.74	0.54	0.16	6.50	10.7
W	0.10	0.20	0.64	1.03	0.47	0.19	2.63	12.5
WNW	0.05	0.17	0.91	1.39	0.66	0.28	3.46	13.2
NW	0.05	0.31	1.60	5.13	2.68	1.55	11.32	15.0
NNW	0.04	0.49	1.80	2.34	0.90	0.20	5.78	11.9
ALL	1.84	13.08	30.10	38.22	12.90	3.75	99.89	11.2

Calm (less than one knot) = 0.1%
Period mean wind speed = 11.2 knots
Percent occurrence for D stability class 51.3%

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Table 2.5-5 (cont)

**FREQUENCY OF WINDS BY DIRECTION AND SPEED
FOR STABILITY CLASS E
DATA RECORDED FROM MAY 1982 THROUGH APRIL 1984
CROW BUTTE - NEBRASKA**

	SPEED CLASS INTERVALS(KNOTS)							
DIRECTION	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	4.6
NNE	0.97	2.80	1.82	0.00	0.00	0.00	5.59	5.2
NE	0.97	3.32	1.90	0.08	0.00	0.00	6.28	5.1
ENE	0.45	1.26	0.73	0.00	0.00	0.00	2.43	5.1
E	0.16	0.73	0.20	0.00	0.00	0.00	1.09	4.7
ESE	0.28	0.65	0.45	0.00	0.00	0.00	1.38	4.8
SE	0.49	1.82	0.85	0.12	0.00	0.00	3.28	5.1
SSE	1.70	7.62	1.05	0.08	0.00	0.00	10.45	4.4
S	2.23	11.06	4.34	0.16	0.00	0.00	17.79	5.0
SSW	2.11	10.53	2.80	0.04	0.00	0.00	15.48	4.7
SW	1.78	8.18	5.67	0.12	0.04	0.00	15.80	5.5
WSW	1.05	2.88	2.47	0.04	0.00	0.00	6.44	5.4
W	0.65	0.97	0.36	0.04	0.00	0.00	2.03	4.3
WNW	0.36	0.97	0.81	0.00	0.00	0.00	2.15	5.5
NW	0.45	1.18	0.85	0.20	0.00	0.00	2.67	5.7
NNW	0.61	1.34	0.49	0.00	0.00	0.00	2.43	4.5
ALL	15.11	58.23	25.45	0.93	0.04	0.00	99.76	5.0

Calm (less than one knot) = 0.2%
Period mean wind speed = 5.0 knots
Percent occurrence for E stability class 15.2%

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Table 2.5-5 (cont)

FREQUENCY OF WINDS BY DIRECTION AND SPEED
FOR STABILITY CLASS F
DATA RECORDED FROM MAY 1982 THROUGH APRIL 1984
CROW BUTTE - NEBRASKA

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	4.96	2.8
NNE	1.65	1.33	0.00	0.00	0.00	0.00	2.99	3.0
NE	0.95	1.40	0.00	0.00	0.00	0.00	2.35	3.1
ENE	1.40	0.76	0.00	0.00	0.00	0.00	2.16	2.8
E	1.27	0.44	0.00	0.00	0.00	0.00	1.72	2.8
ESE	1.78	1.02	0.00	0.00	0.00	0.00	2.80	2.6
SE	1.72	1.78	0.00	0.00	0.00	0.00	3.49	3.0
SSE	3.75	4.76	0.00	0.00	0.00	0.00	8.51	3.1
S	7.50	12.07	0.00	0.00	0.00	0.00	19.57	3.3
SSW	7.24	13.15	0.00	0.00	0.00	0.00	20.39	3.3
SW	6.48	8.01	0.00	0.00	0.00	0.00	14.49	3.2
WSW	2.73	2.60	0.00	0.00	0.00	0.00	5.34	3.0
W	1.78	1.46	0.00	0.00	0.00	0.00	3.24	2.9
WNW	0.83	0.95	0.00	0.00	0.00	0.00	1.78	3.0
NW	1.33	1.21	0.00	0.00	0.00	0.00	2.54	3.0
NNW	1.33	0.51	0.00	0.00	0.00	0.00	1.84	2.5
ALL	45.04	53.11	0.00	0.00	0.00	0.00	98.16	3.1

Calm (less than one knot) = 1.8%
Period mean wind speed = 3.1 knots
Percent occurrence for F stability class 9.7%

ENECOTECH INC.
SBWIND(3.2) 1/ 5/84

Table 2.5-5 (cont)

**FREQUENCY OF WINDS BY DIRECTION AND SPEED
FOR STABILITY CLASS ALL
DATA RECORDED FROM MAY 1982 THROUGH APRIL 1984
CROW BUTTE - NEBRASKA**

SPEED CLASS INTERVALS(KNOTS)

DIRECTION	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	6.5
NNE	0.70	2.16	2.24	1.61	0.46	0.10	7.26	8.2
NE	0.57	2.54	2.69	1.57	0.23	0.04	7.64	7.7
ENE	0.37	0.99	1.08	0.38	0.03	0.00	2.85	6.5
E	0.24	0.42	0.35	0.15	0.02	0.00	1.18	6.2
ESE	0.31	0.46	0.44	0.09	0.00	0.00	1.29	5.5
SE	0.35	0.93	0.95	0.38	0.09	0.01	2.71	7.0
SSE	0.81	2.84	1.44	1.55	0.62	0.17	7.44	8.2
S	1.48	4.17	3.45	4.33	1.83	0.30	15.55	9.3
SSW	1.36	4.17	3.09	2.03	0.39	0.06	11.10	7.2
SW	1.21	3.91	4.62	2.13	0.17	0.01	12.05	7.1
WSW	0.70	1.60	2.21	1.60	0.29	0.09	6.48	8.2
W	0.40	0.69	0.87	0.68	0.26	0.10	3.00	8.9
WNW	0.27	0.54	0.91	0.90	0.35	0.14	3.11	10.2
NW	0.32	0.75	1.73	2.99	1.39	0.79	7.97	12.8
NNW	0.40	0.99	1.84	1.58	0.47	0.10	5.38	9.5
ALL	10.23	28.87	29.43	22.53	6.69	1.93	99.68	8.4

Calm (less than one knot) = 0.3%
Period mean wind speed = 8.4 knots
Percent occurrence for ALL stability classes 100.0%

ENECOTECH INC.
SBWIND(3.2) 1/ 5/84

Table 2.5-6: Joint Frequency Distribution

.00056	.00488	.00148	.00006	.00000	.00000	JFD FOR CROW BUTTE
.00142	.00495	.00167	.00006	.00000	.00000	DATE(SEWIND3.2) 1/ 6/84
.00093	.00482	.00074	.00000	.00000	.00000	
.00037	.00247	.00031	.00000	.00000	.00000	
.00068	.00111	.00043	.00000	.00000	.00000	
.00019	.00049	.00012	.00000	.00000	.00000	
.00056	.00099	.00093	.00000	.00000	.00000	
.00025	.00142	.00093	.00006	.00000	.00000	
.00056	.00210	.00087	.00000	.00000	.00000	
.00031	.00111	.00117	.00012	.00000	.00000	
.00043	.00210	.00087	.00000	.00000	.00000	
.00037	.00117	.00087	.00000	.00000	.00000	
.00037	.00099	.00099	.00006	.00000	.00000	
.00043	.00080	.00056	.00025	.00000	.00000	
.00037	.00130	.00087	.00006	.00000	.00000	
.00087	.00223	.00105	.00025	.00000	.00000	
.00074	.00198	.00408	.00049	.00000	.00000	B START
.00099	.00260	.00278	.00025	.00000	.00000	
.00068	.00389	.00402	.00037	.00000	.00000	
.00062	.00130	.00210	.00019	.00000	.00000	
.00012	.00062	.00056	.00006	.00000	.00000	
.00043	.00043	.00080	.00000	.00000	.00000	
.00006	.00093	.00167	.00019	.00000	.00000	
.00049	.00087	.00179	.00037	.00000	.00000	
.00080	.00074	.00297	.00068	.00000	.00000	
.00074	.00148	.00167	.00056	.00000	.00000	
.00068	.00235	.00185	.00043	.00000	.00000	
.00043	.00148	.00192	.00062	.00006	.00000	
.00031	.00099	.00173	.00031	.00006	.00000	
.00049	.00080	.00155	.00025	.00000	.00000	
.00019	.00080	.00297	.00080	.00006	.00000	
.00031	.00111	.00365	.00124	.00006	.00000	
.00080	.00167	.00291	.00080	.00000	.00000	C START
.00068	.00284	.00315	.00093	.00000	.00000	
.00099	.00247	.00618	.00130	.00000	.00000	
.00049	.00111	.00321	.00105	.00000	.00000	
.00000	.00062	.00080	.00031	.00000	.00000	
.00025	.00037	.00099	.00025	.00000	.00000	
.00019	.00074	.00198	.00080	.00000	.00000	
.00049	.00080	.00241	.00161	.00000	.00000	
.00105	.00179	.00575	.00247	.00000	.00000	
.00124	.00328	.00427	.00105	.00000	.00000	
.00111	.00365	.00507	.00124	.00012	.00000	
.00105	.00328	.00389	.00124	.00006	.00006	
.00012	.00099	.00216	.00111	.00012	.00000	
.00019	.00056	.00111	.00136	.00006	.00000	
.00043	.00080	.00402	.00241	.00006	.00000	
.00043	.00155	.00371	.00229	.00000	.00000	

Table 2.5-6 (cont)

.00087	.00266	.00587	.00427	.00105	.00012	D START
.00080	.00575	.01205	.01490	.00457	.00099	
.00068	.00785	.01311	.01397	.00235	.00043	
.00019	.00241	.00408	.00260	.00031	.00000	
.00012	.00031	.00142	.00111	.00019	.00000	
.00006	.00130	.00179	.00068	.00000	.00000	
.00031	.00216	.00365	.00266	.00093	.00006	
.00068	.00915	.00773	.01335	.00624	.00173	
.00173	.00859	.01842	.04000	.01836	.00297	
.00111	.00705	.01966	.01854	.00389	.00062	
.00087	.01088	.02986	.01953	.00148	.00012	
.00087	.00315	.01175	.01409	.00278	.00080	
.00049	.00105	.00328	.00532	.00241	.00099	
.00025	.00087	.00470	.00717	.00340	.00142	
.00025	.00161	.00822	.02640	.01379	.00797	
.00019	.00253	.00927	.01205	.00464	.00105	
.00130	.00445	.00099	.00006	.00000	.00000	E START
.00148	.00427	.00278	.00000	.00000	.00000	
.00148	.00507	.00291	.00012	.00000	.00000	
.00068	.00192	.00111	.00000	.00000	.00000	
.00025	.00111	.00031	.00000	.00000	.00000	
.00043	.00099	.00068	.00000	.00000	.00000	
.00074	.00278	.00130	.00019	.00000	.00000	
.00260	.01162	.00161	.00012	.00000	.00000	
.00340	.01688	.00661	.00025	.00000	.00000	
.00321	.01607	.00427	.00006	.00000	.00000	
.00272	.01249	.00865	.00019	.00006	.00000	
.00161	.00439	.00377	.00006	.00000	.00000	
.00099	.00148	.00056	.00006	.00000	.00000	
.00056	.00148	.00124	.00000	.00000	.00000	
.00068	.00179	.00130	.00031	.00000	.00000	
.00093	.00204	.00074	.00000	.00000	.00000	
.00321	.00161	.00000	.00000	.00000	.00000	F START
.00161	.00130	.00000	.00000	.00000	.00000	
.00093	.00136	.00000	.00000	.00000	.00000	
.00136	.00074	.00000	.00000	.00000	.00000	
.00124	.00043	.00000	.00000	.00000	.00000	
.00173	.00099	.00000	.00000	.00000	.00000	
.00167	.00173	.00000	.00000	.00000	.00000	
.00365	.00464	.00000	.00000	.00000	.00000	
.00729	.01175	.00000	.00000	.00000	.00000	
.00705	.01280	.00000	.00000	.00000	.00000	
.00631	.00779	.00000	.00000	.00000	.00000	
.00266	.00253	.00000	.00000	.00000	.00000	
.00173	.00142	.00000	.00000	.00000	.00000	
.00080	.00093	.00000	.00000	.00000	.00000	
.00130	.00117	.00000	.00000	.00000	.00000	
.00130	.00049	.00000	.00000	.00000	.00000	

Figure 2.5-1: Windrose for Scottsbluff, Nebraska

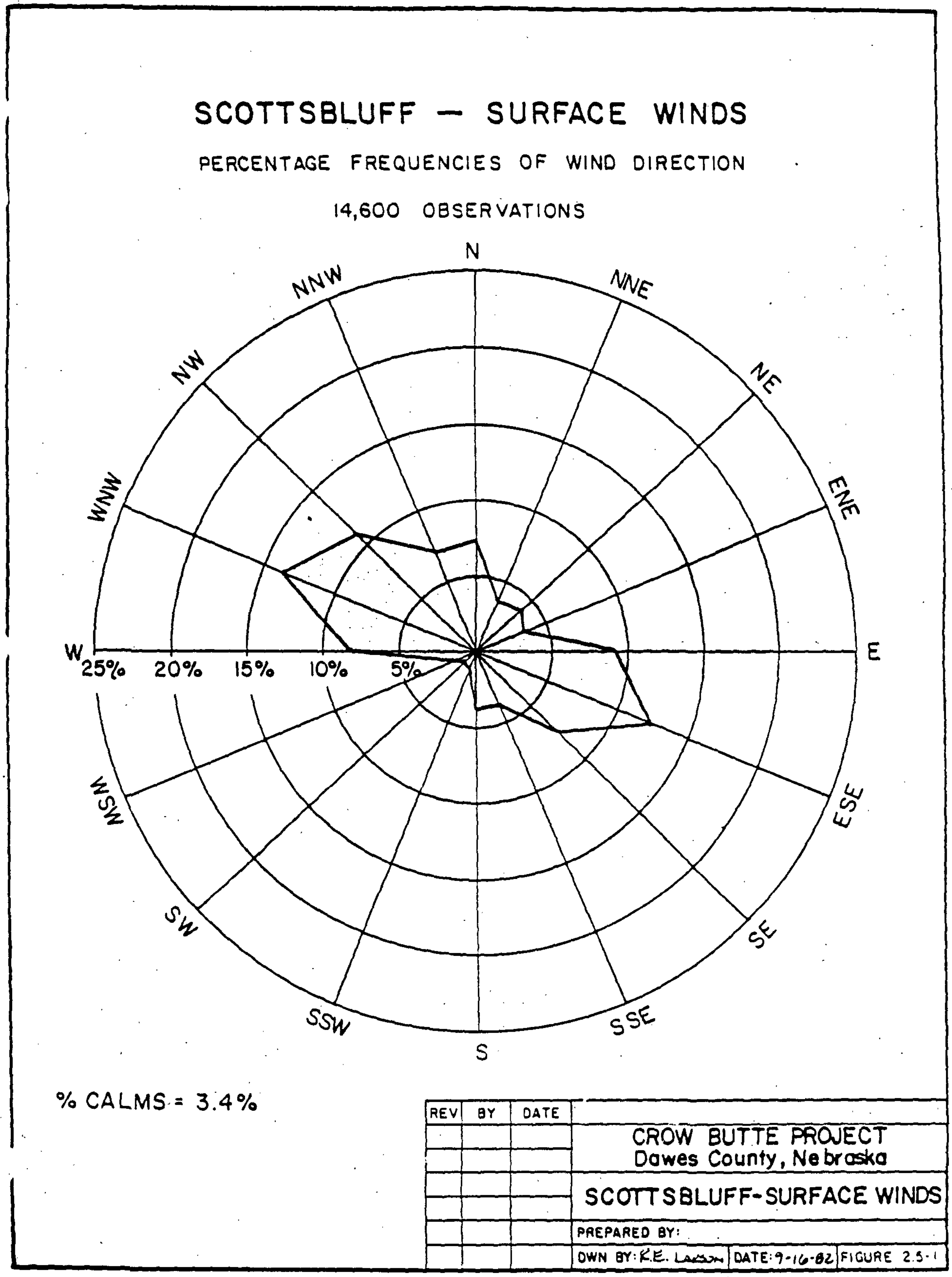
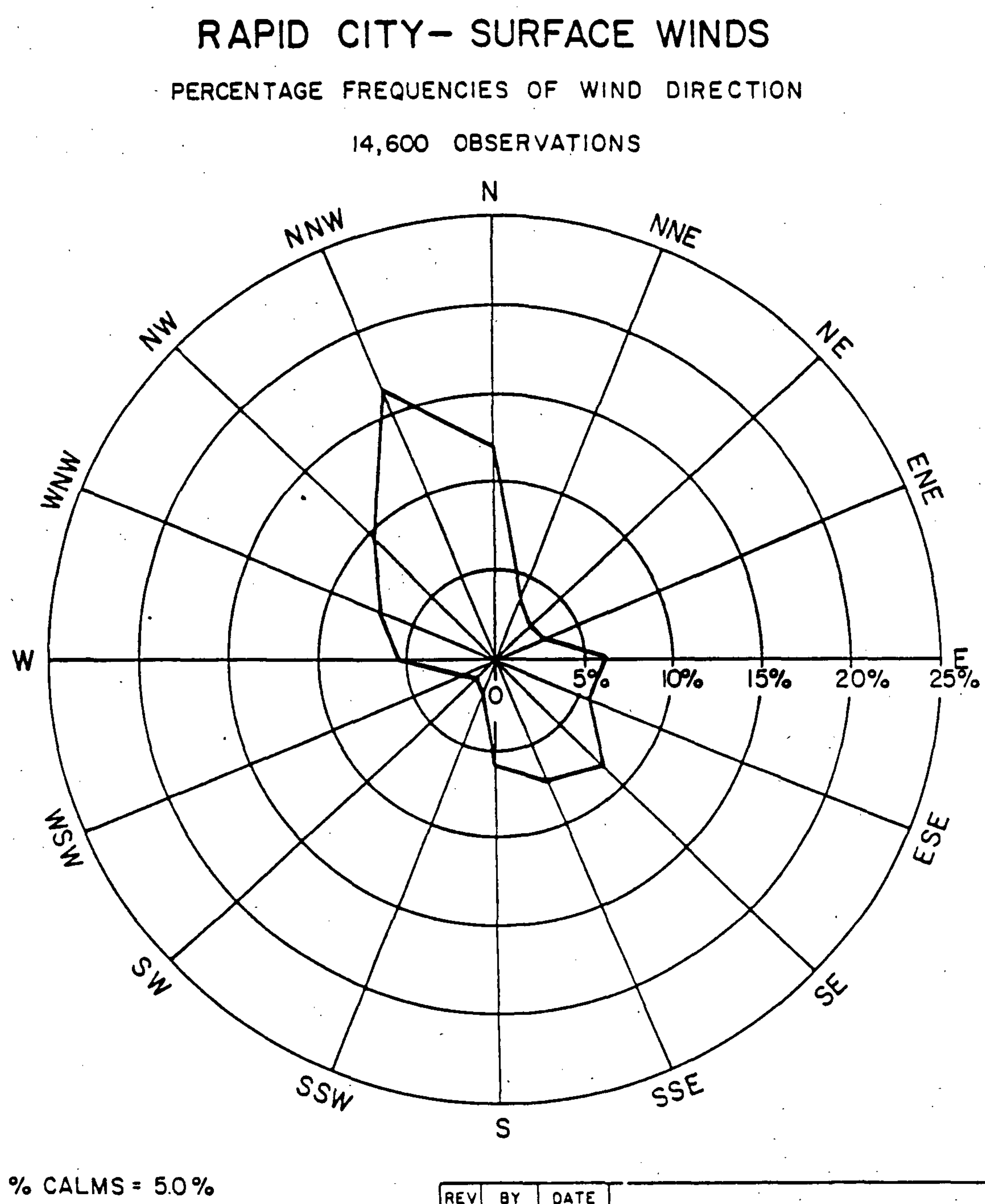
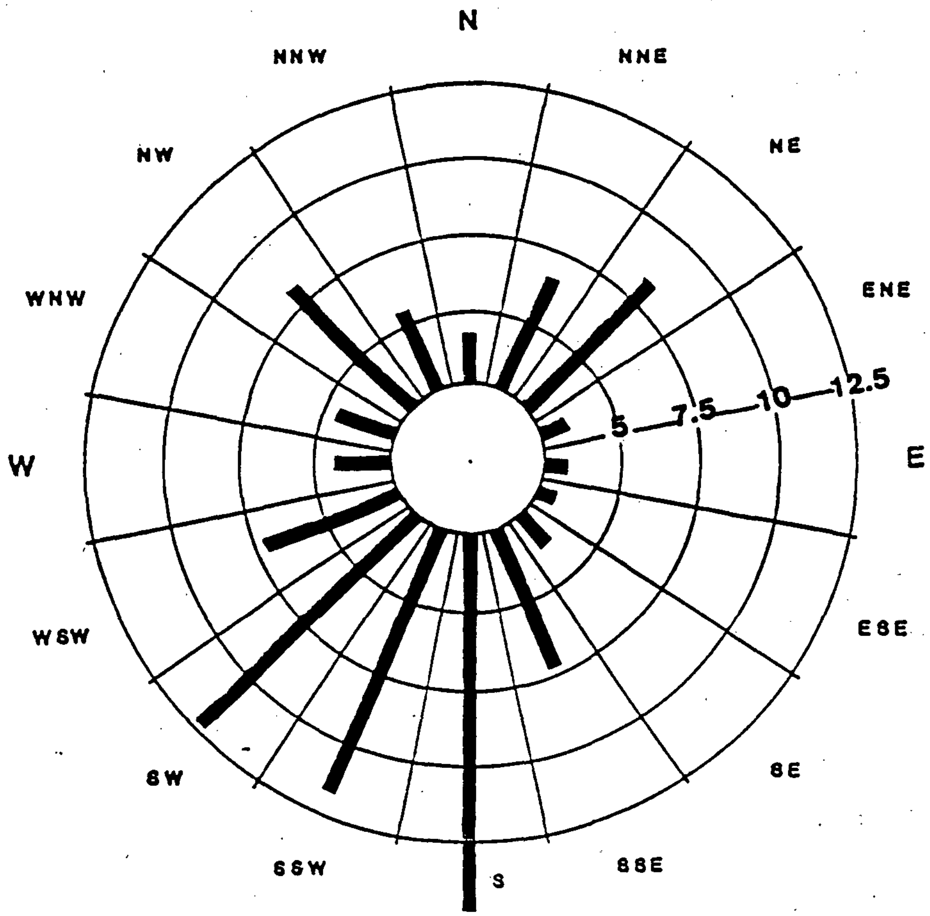


Figure 2.5-2: Windrose for Rapid City, South Dakota



REV	BY	DATE	
			CROW BUTTE PROJECT Dawes County, Nebraska
			RAPID CITY- SURFACE WINDS
			PREPARED BY:
			DWN BY: R.E. Larson DATE: 9-16-86 FIGURE 2.5-2

Figure 2.5-3: Windrose for Crow Butte Site



UNITS IN PERCENT

ENECOTECH
Denver, Colorado

PROJECT CROW BUTTE, NEBRASKA

PERCENT OCCURRENCES BY DIRECTION
CROW BUTTE, NEBRASKA
MAY 1982 THROUGH APRIL 1984

FILE NO. 153-001 DATE JULY 1987 FIGURE NO. 2.5-3

2.6 GEOLOGY AND SEISMOLOGY

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 proposed 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.

General Stratigraphy

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

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, 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 ppm.

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

Figure 2.6-1: Geologic Map

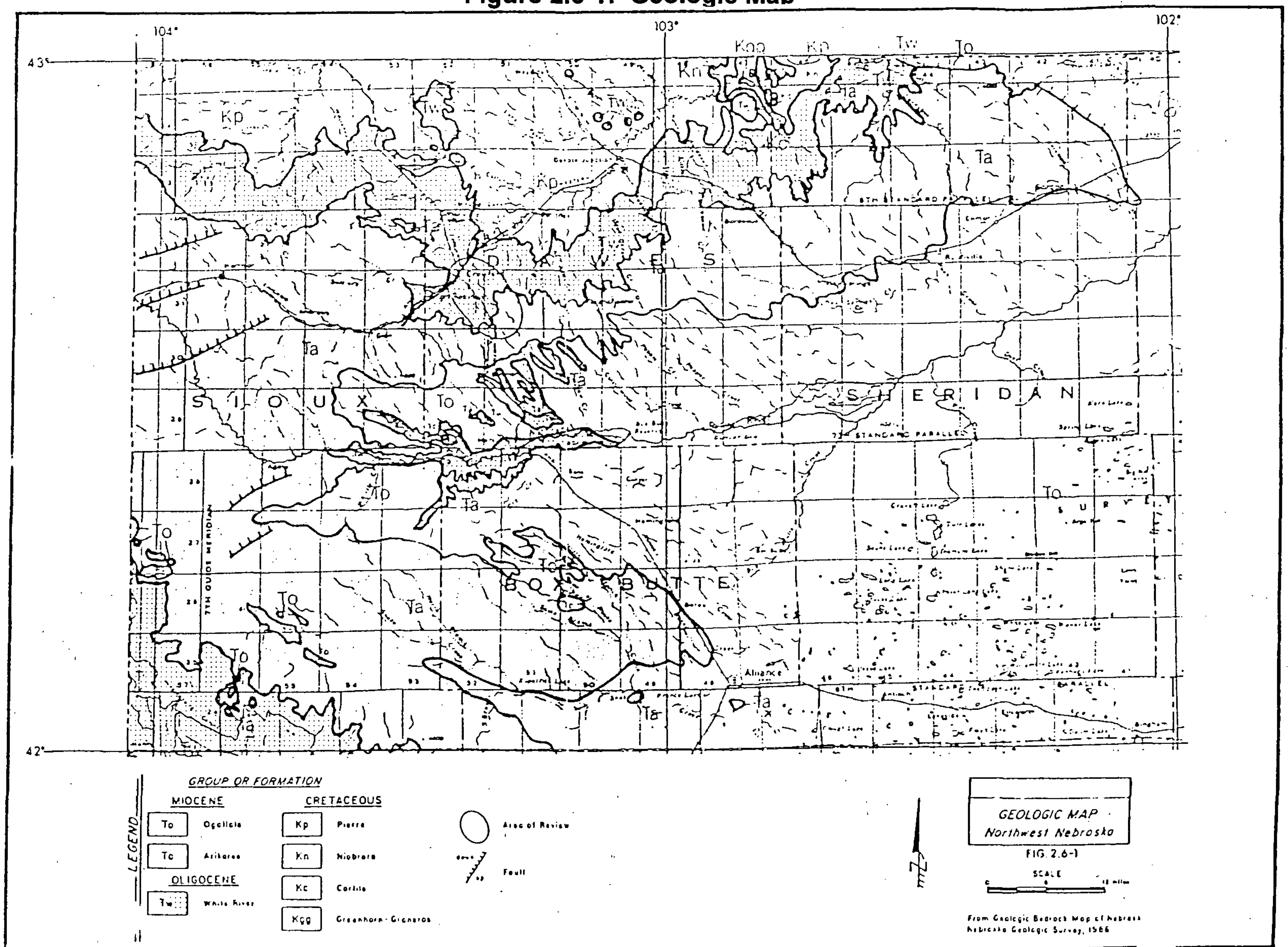


Table 2.6-1: General Stratigraphic Chart for Northwest Nebraska

System	Series	Formation or Group	Rock Types	Thickness
Miocene		Ogallala	SS, Slt	1560*
		Arikaree	SS, Slt	1070*
Oligocene		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/ Cherokee	Ls, Sh	130
	Atoka	Upper/Lower	Ls, Sh	200
Mississippian	Lower	Lower	Ls, Sh	30
Pre-Cambrian			Granite	

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

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 Quarternary alluvium overlying the Pierre Shale. The bottom few tens of feet in those wells provide storage. It is recognized in this report that (Spalding, 1982, p.18) "In very shallow wells (a few tens of feet) significant amounts of water utilized may be contained in the thin Quarternary 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 by Marvin Carlson on 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 Quarternary 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.

<u>White River Group</u>

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

<u>Chadron Formation</u>

The Chadron is the oldest 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.

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 which trends from west to east across northwest Nebraska.

Gering Formation

The MioceneGering 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, l938, in Witzel, l974, 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.

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 which 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.

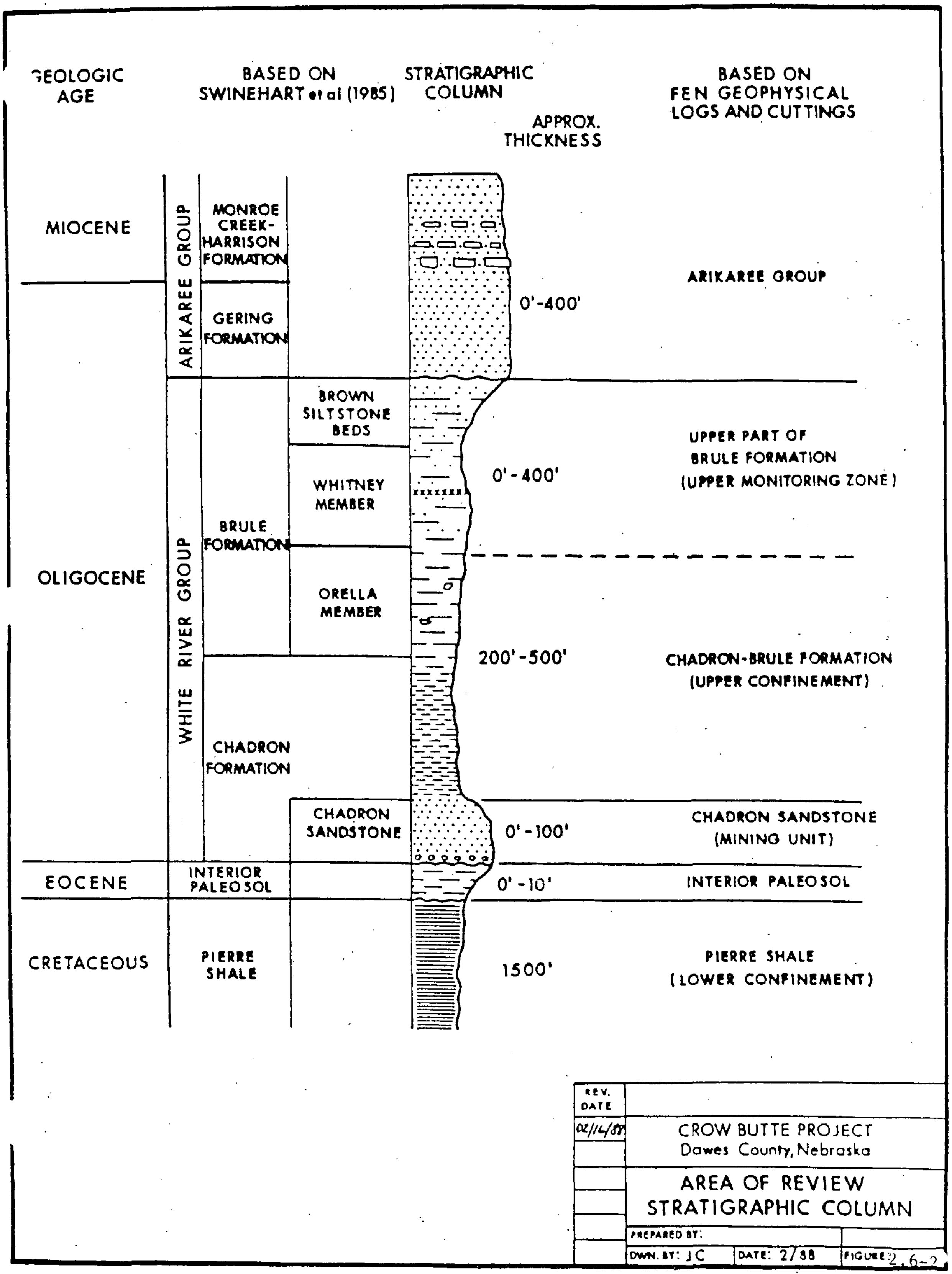
2.6.2 AREA OF REVIEW GEOLOGY

Introduction

An Area of Review Stratigraphic Column 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 seven 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). One northwest-southeast cross section is included to show the continuity of the geology (Figure 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 which are the most important consideration in a solution mining project. These sections demonstrate the continuity of the Chadron

Figure 2.6-2: Area of Review, Stratigraphic Column



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).

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 2.6-3 to Figure 2.6-11). The Pierre Shale is the confining bed below the Chadron Sandstone which is the host for uranium mineralization (Figure 2.6-3 to Figure 2.6-11). 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.

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 2.0×10^{-9} 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.

Chadron Sandstone - Mining Unit

The Chadron Sandstone is generally present at the base of the Chadron Formation and is a 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.

Figure 2.6-3: Cross Section Location

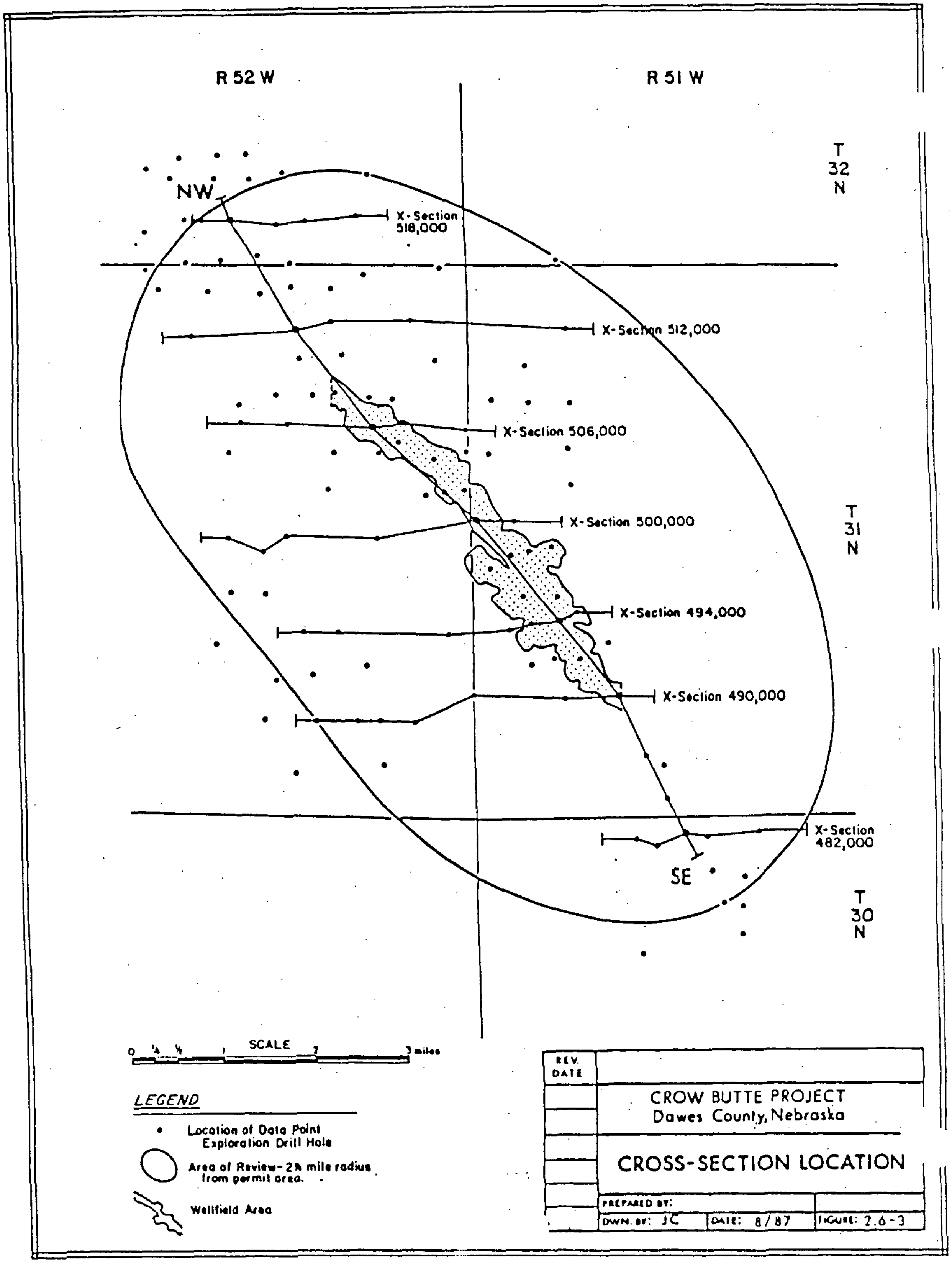


Figure 2.6-4: Cross Section 518,000 E-W

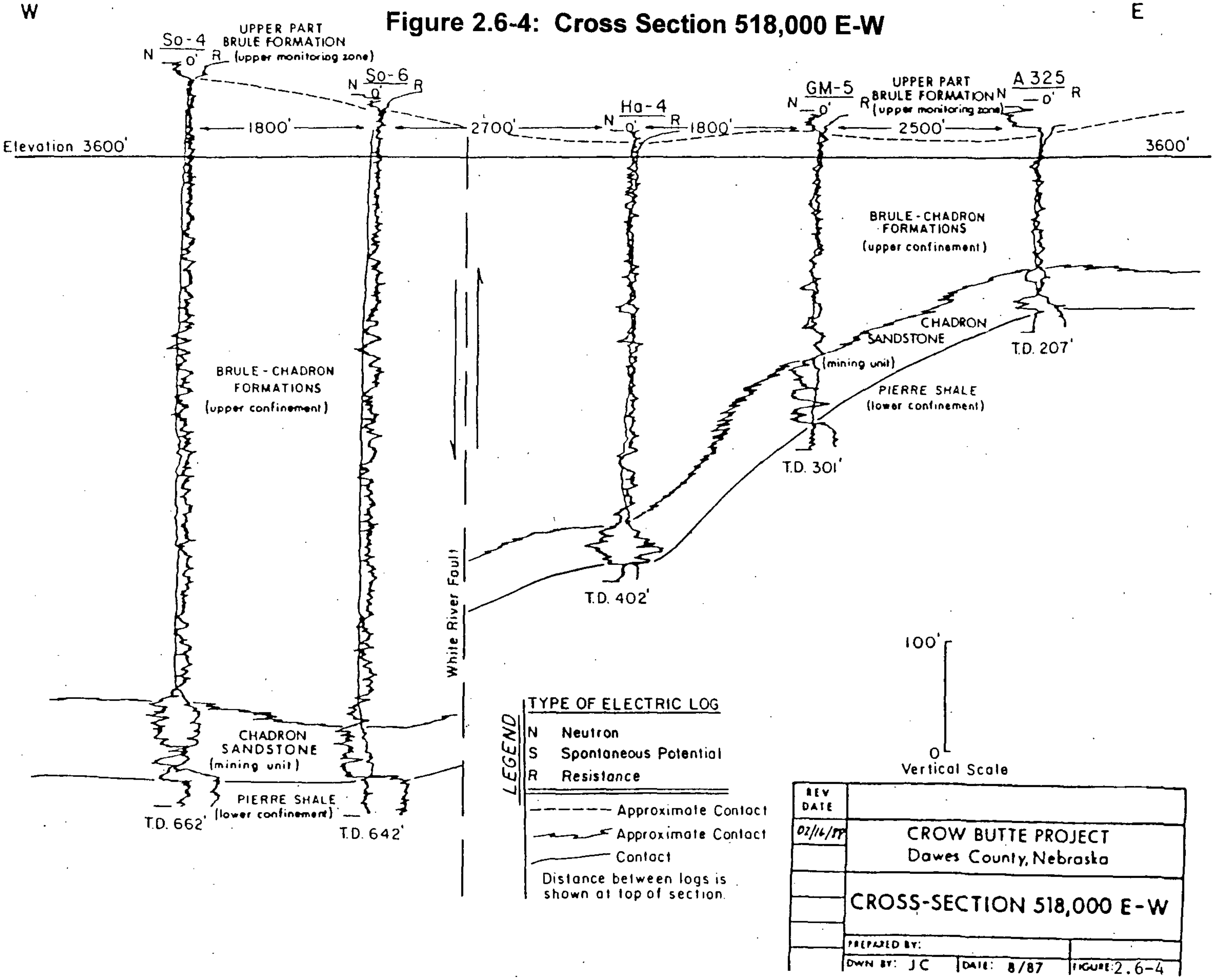


Figure 2.6-5: Cross Section 512,000 E-W

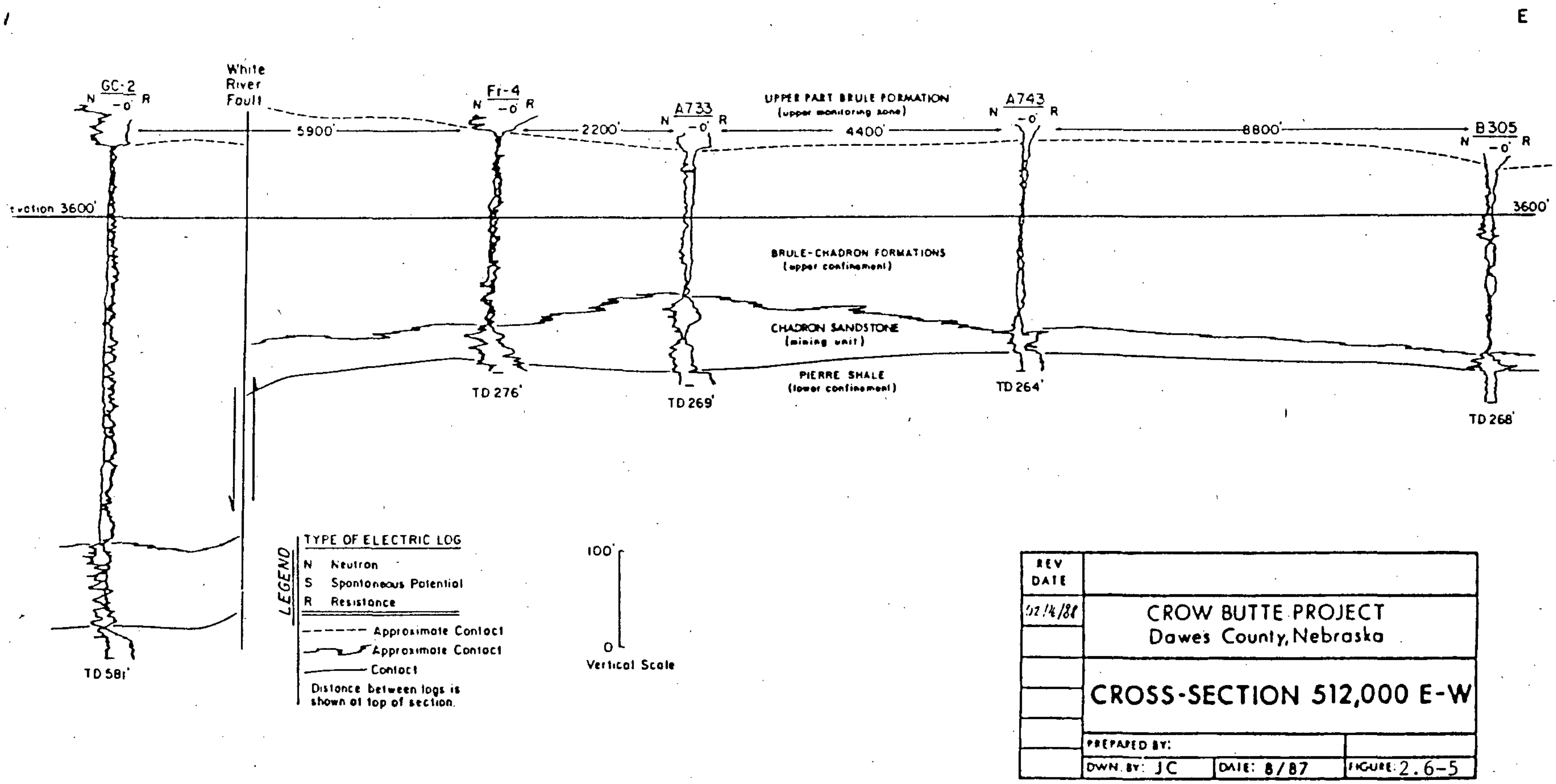


Figure 2.6-6: Cross Section 506,000 E-W

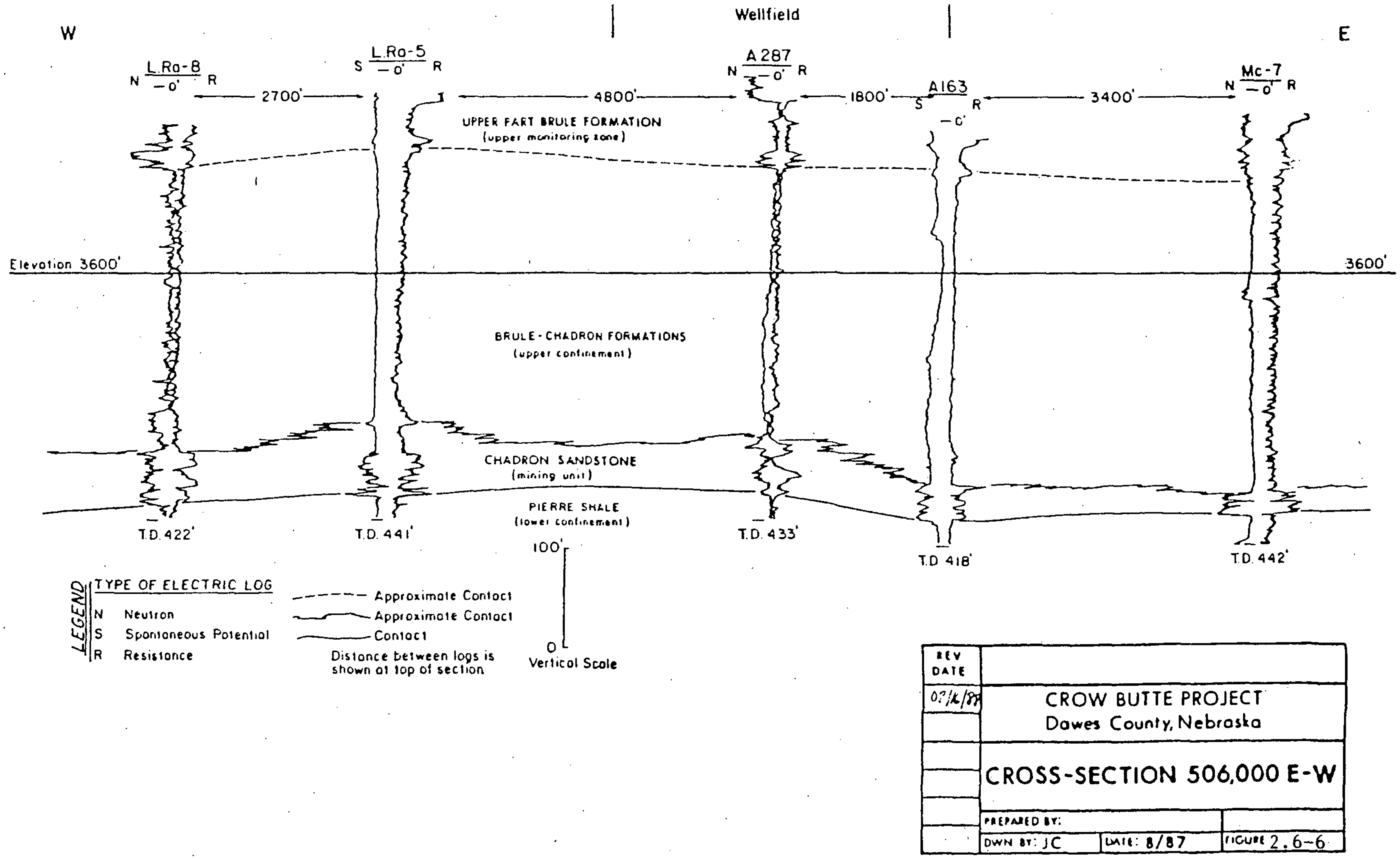


Figure 2.6-7: Cross Section 500,000 E-W

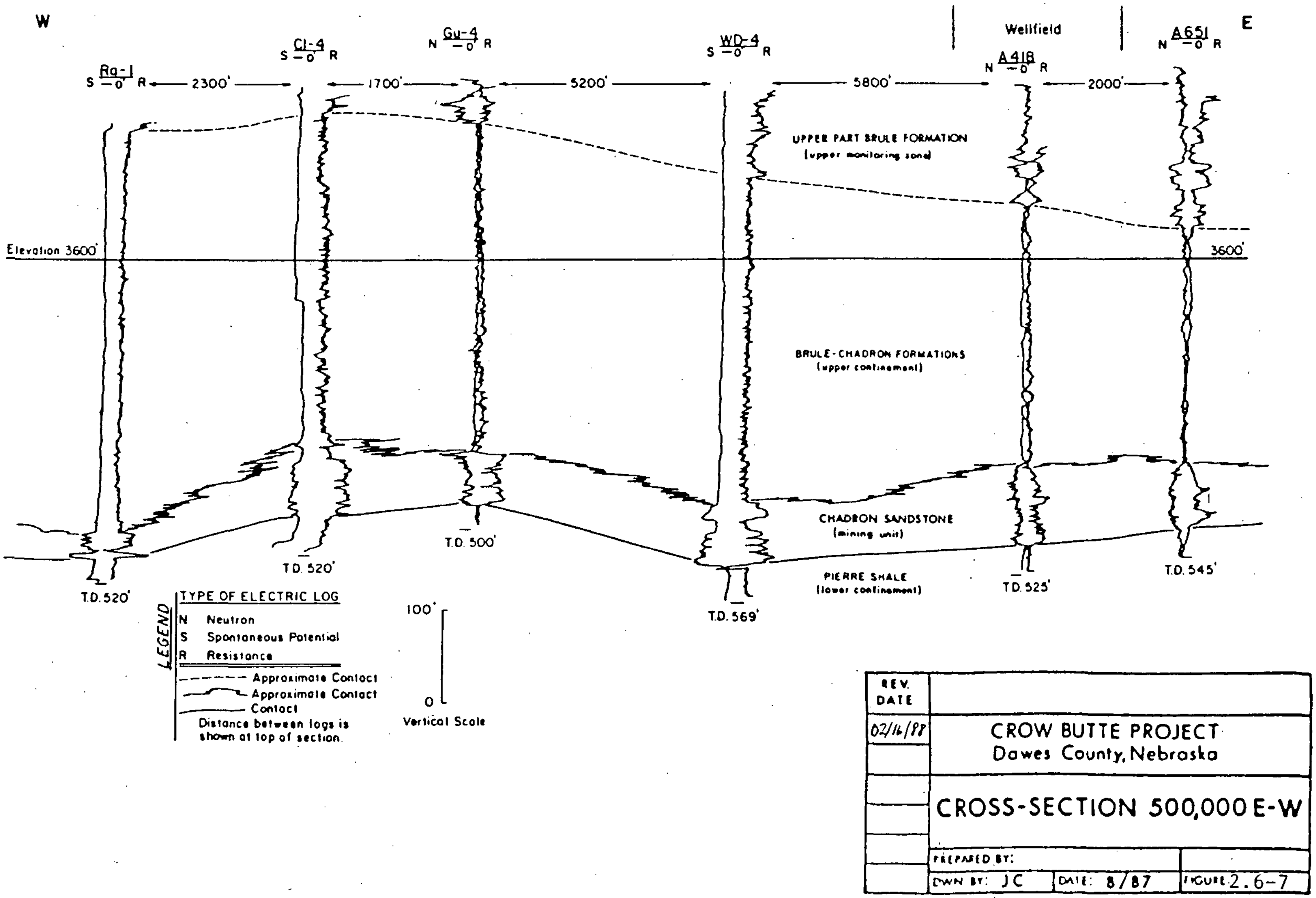


Figure 2.6-8: Cross Section 494,000 E-W

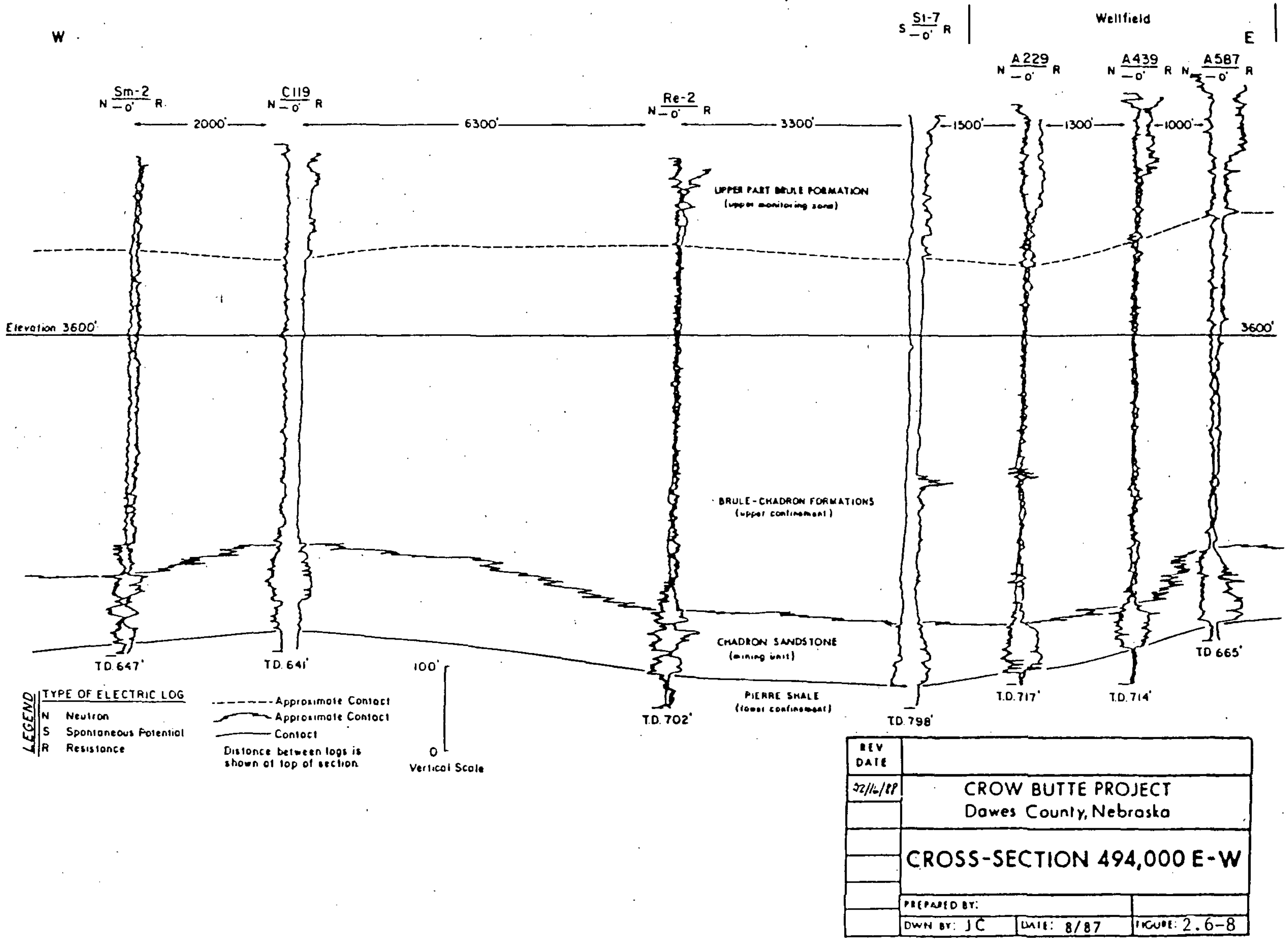


Figure 2.6-9: Cross Section 490,000 E-W

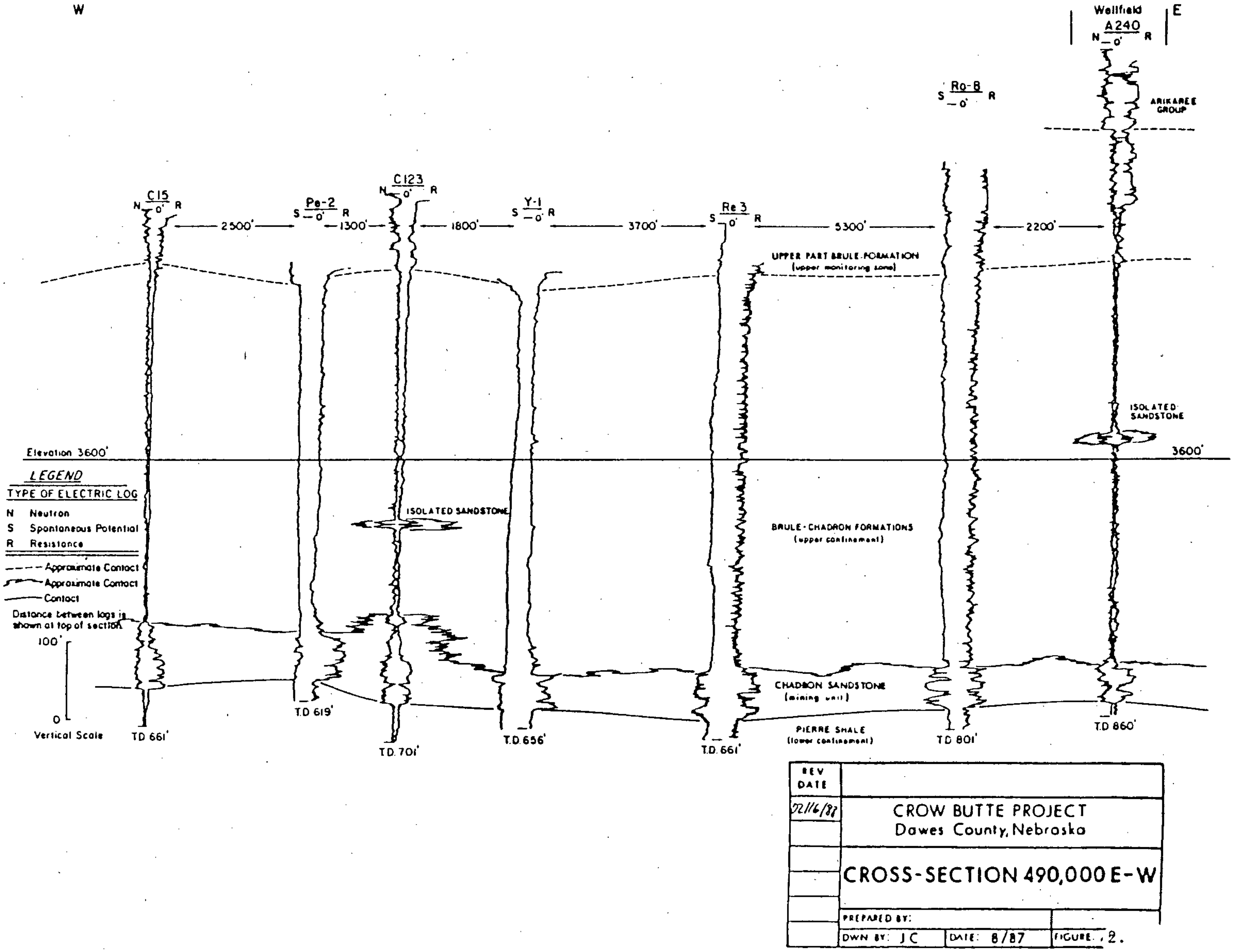
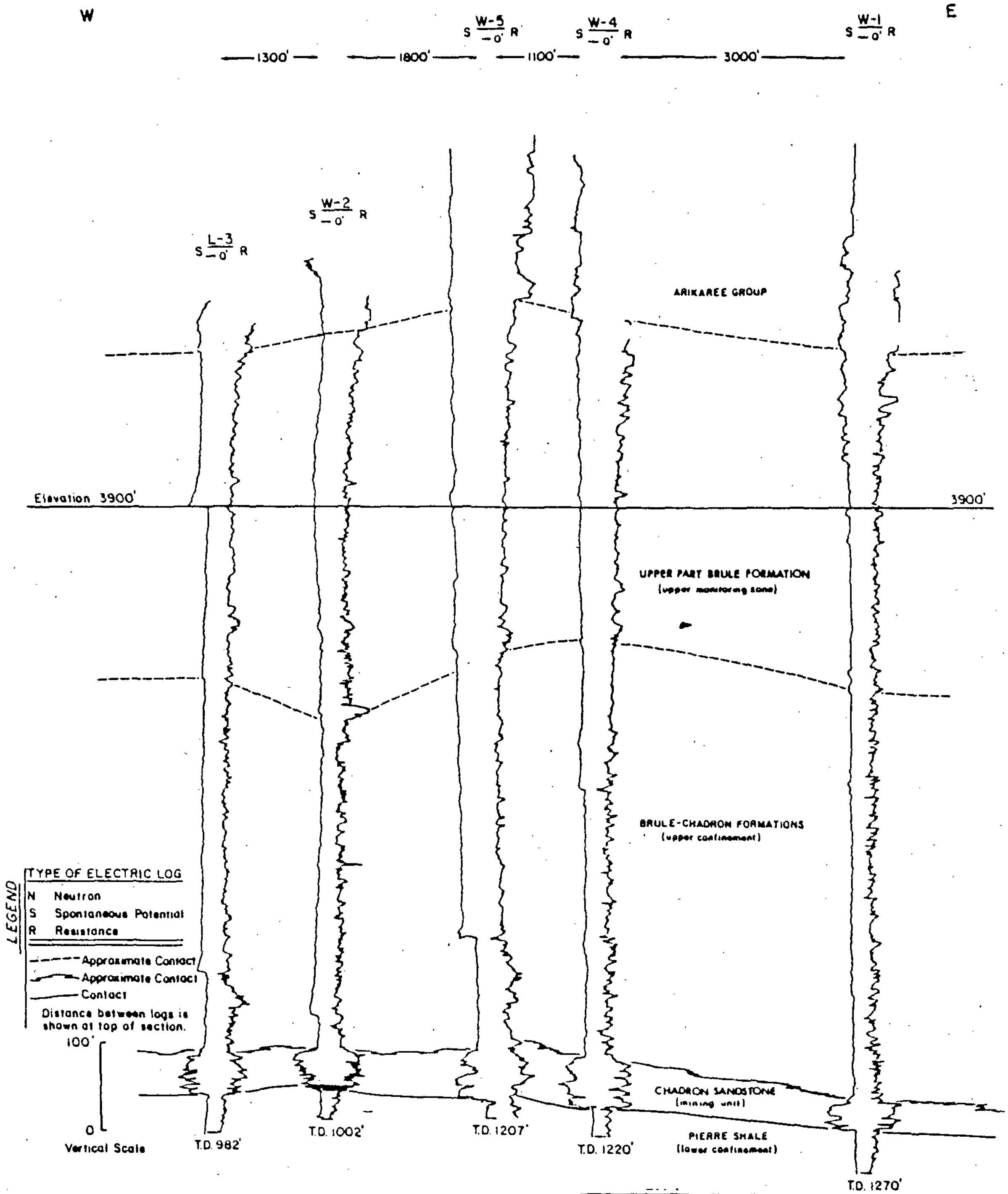
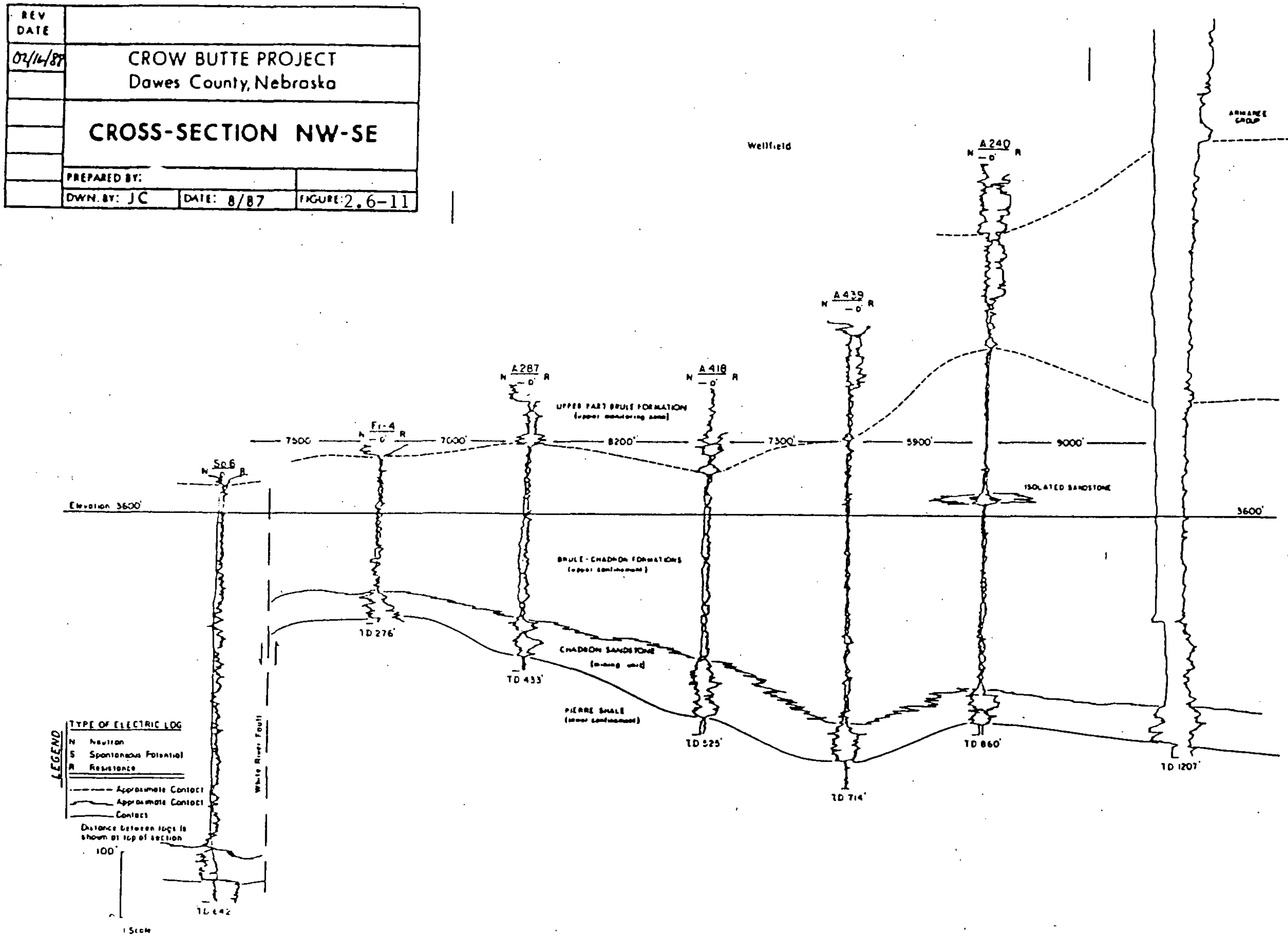


Figure 2.6-10: Cross Section 482,000 E-W



REV DATE	
02/16/89	CROW BUTTE PROJECT Dawes County, Nebraska
	CROSS-SECTION 482,000 W-E
	PREPARED BY:
	DWN. BY: JC | DATE: 8/87 | FIGURE 2.6-10

Figure 2.6-11: Cross Section NW-SE



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 a 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 a very fine to fine grained, well sorted, poorly cemented sandstone.

Thin section examination of the Chadron Sandstone reveals its composition to be 50% monocrystalline quartz, 30 to 40% 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% 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 which normally occur during fluvial sedimentation. Within the permit 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.

<u>Chadron-Brule Formations, Upper Confinement</u>

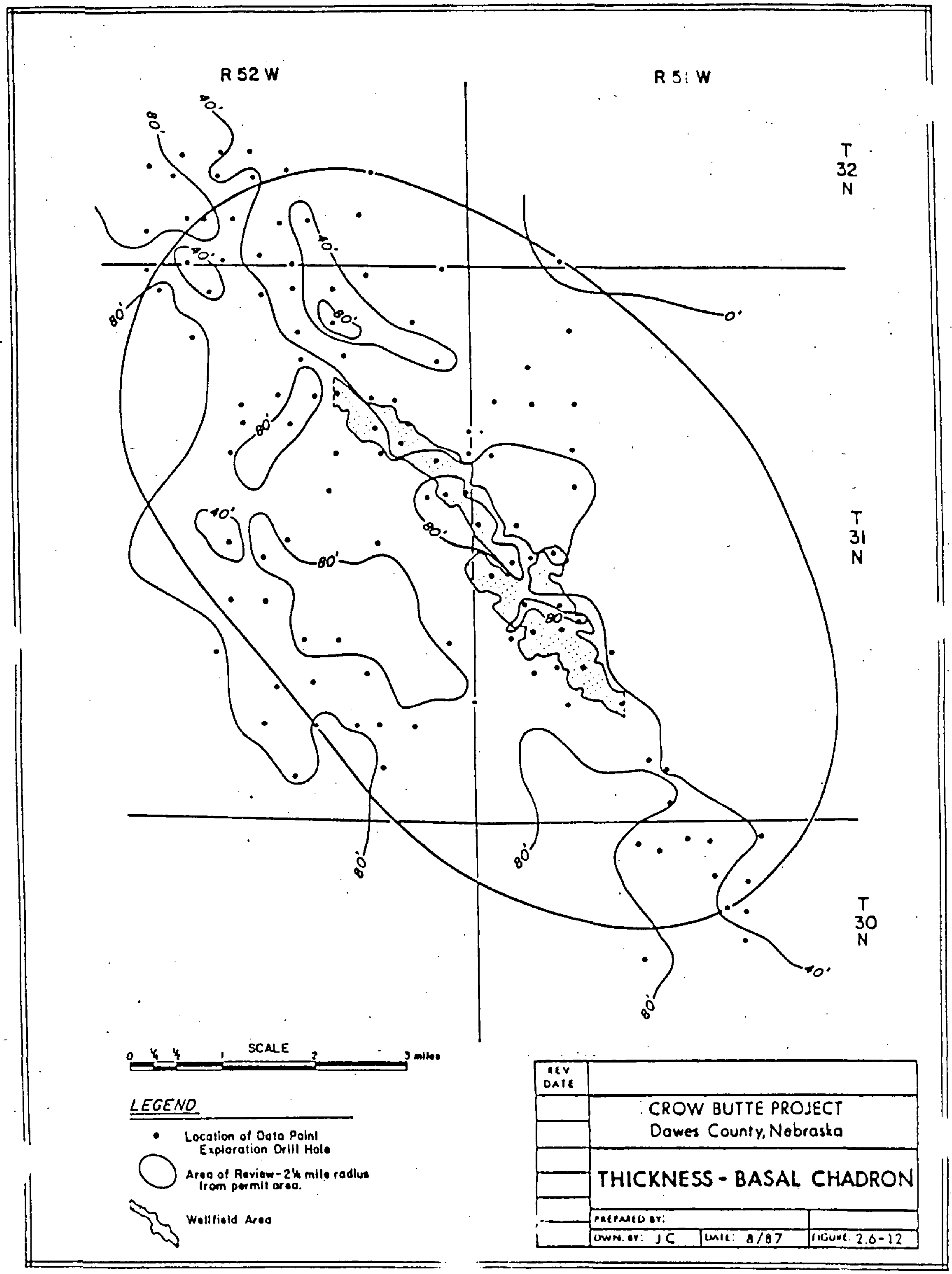
The upper part of the Chadron Formation and the Brule Formation are the upper confinement overlying the Chadron Sandstone. This is observable by the epigenetic occurrence of the uranium mineralization, which is strictly confined to the Chadron Sandstone. The upper part of the Chadron represents a distinct and rapid facies change from the underlying sandstone unit. The upper part of the Chadron Formation is a light green-gray bentonitic clay grading downward to green and frequently red clay. X-ray diffraction analyses of the red clay indicate that it is primarily comprised of montmorillonite and calcite (Table 2.6-2). This portion of the Chadron often contains gray-white bentonitic clay interbeds. The light green-gray "sticky" clay of the Chadron serves as an excellent marker bed in drill cuttings and has been observed in virtually all drill holes within the Area of Review. In 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

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

Number in parentheses is number of core samples.

Figure 2.6-12: Thickness- Basal Chadron



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.

Upper Part of the Brule Formation - Upper Monitoring Unit

The upper part of the Brule Formation is primarily buff to brown siltstones which 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).

Area of Review Structure

The structure of the Area of Review is illustrated on Figure 2.6-13. Elevation contours on top of the Cretaceous Pierre Shale, base of the Tertiary Chadron Formation illustrate the structure. The current 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 which occurred after the deposition of the Chadron Formation. Regionally and within the Area of Review, the White River Group, Chadron and Brule Formations dip gently south at about 1/2 to 1 degree. The White River Fault is present along the northwest margin of the Area of Review and is dated as post-Oligocene since it cuts both the Chadron and Brule Formations. The fault has a total vertical displacement of 200 to 400 feet with the upthrown side on the south. The White River Fault is about 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 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 effect the confinement of the Chadron Sandstone based on hydrologic testing in the area.

A synclinal feature trends east-west through the Area of Review and plunges west. 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.

Discussion of Confining Strata

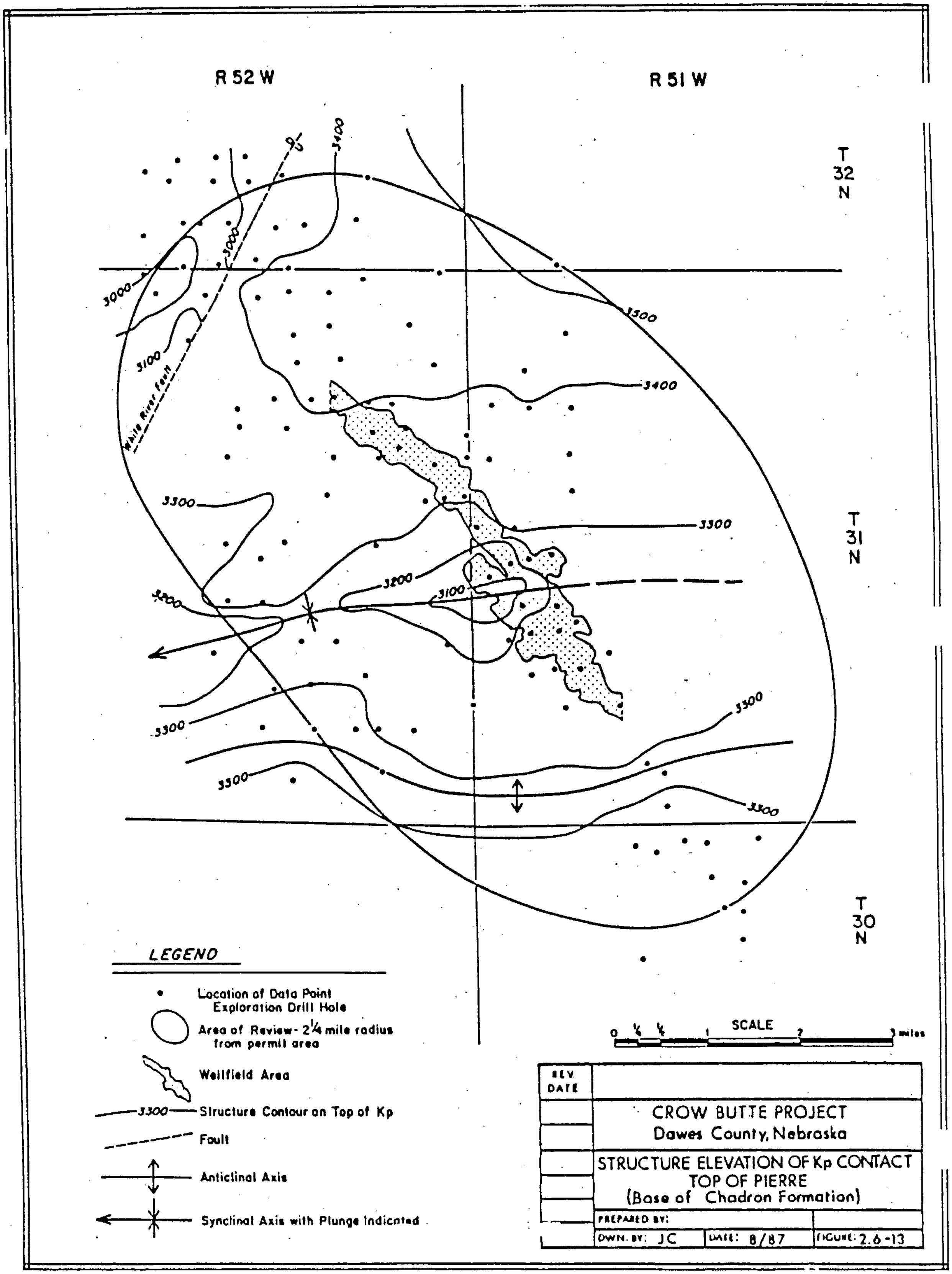
The Crow Butte ore body represents a situation favorable for in-situ mining of uranium. The lower confining bed is the Pierre Shale and is over 1,000 feet in thickness. The Pierre Shale is a thick, homogenous black shale with very low permeability and is one of the most laterally extensive formations 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 an 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).

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



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). Stratigraphyically 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 Project 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 which 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.

Although the project 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 2.1-1 illustrates earthquake epicenters in Nebraska (Burchett, 1979). The location of the Chadron and Cambridge Arches are shown on this map. The earthquakes which 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.

2.6.4 REFERENCES

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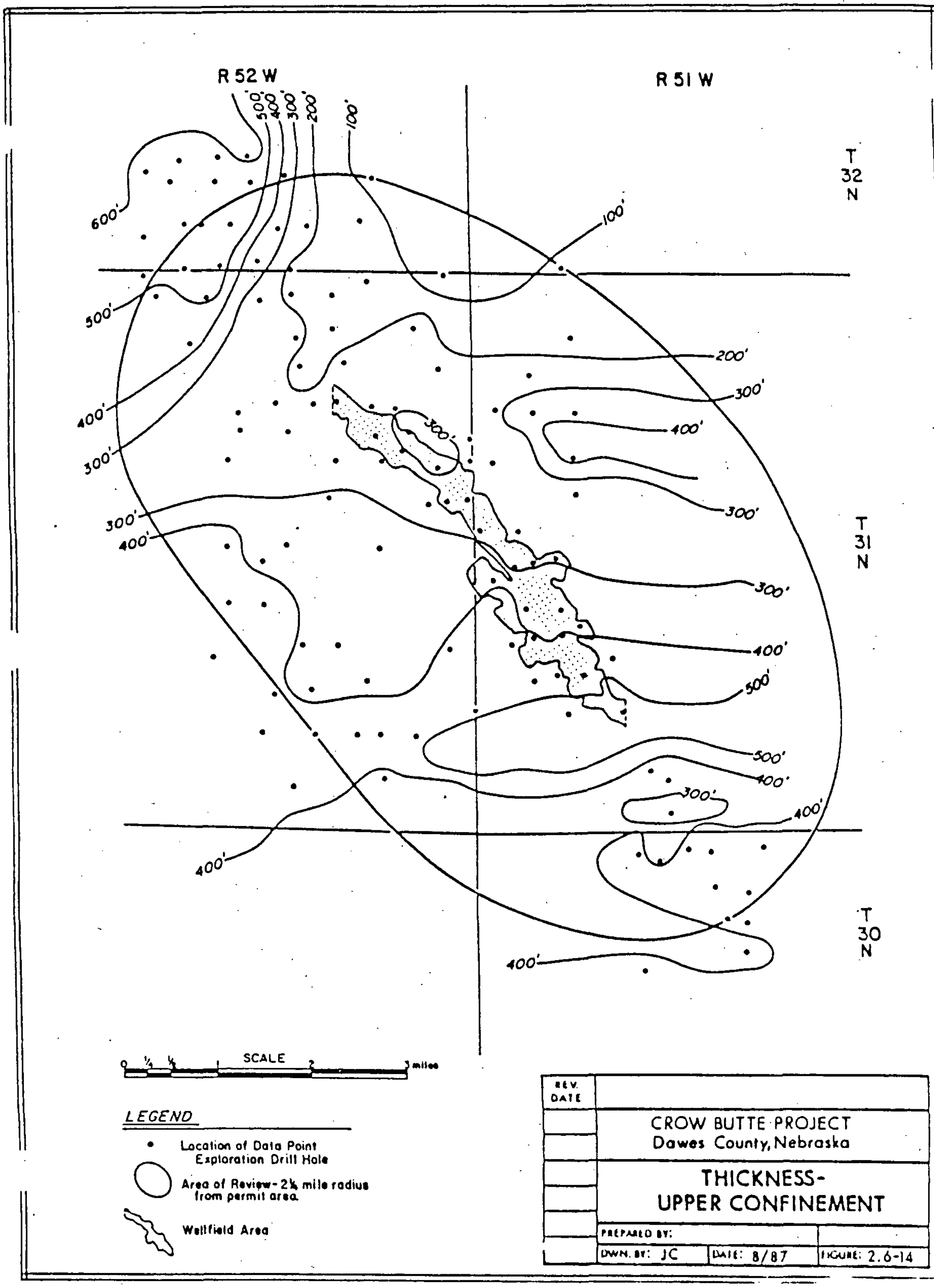
Oil and Gas Logs in the Area of Review

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

Figure 2.6-14: Thickness- Upper Confinement



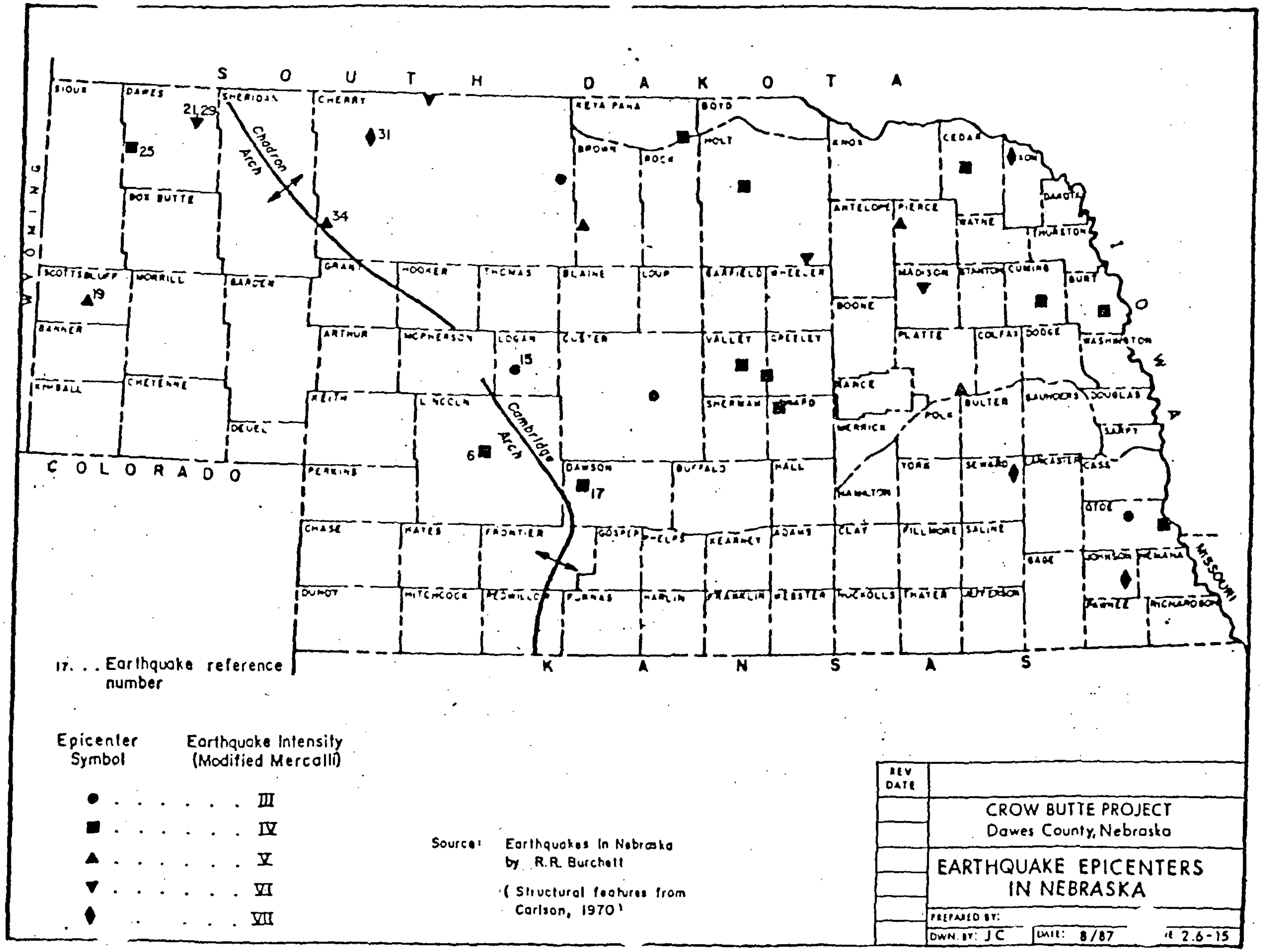

SOUTH DAKOTA
WYOMING
COLORADO
KANSAS
IOWA
MISSOURI
Chadron Arch
Cambridge Arch
17. . . Earthquake reference number
Epicenter Symbol
Earthquake Intensity (Modified Mercalli)
● III
■ IV
▲ V
▼ VI
♦ VII
Source: Earthquakes in Nebraska by R.R. Burchett
(Structural features from Carlson, 1970)
REV DATE
CROW BUTTE PROJECT
Dawes County, Nebraska
EARTHQUAKE EPICENTERS IN NEBRASKA
PREPARED BY:
DWN. BY: JC
DATE: 8/87
2.6-15

Table 2.6-3: Earthquakes in Nebraska

Map Ref.	Date	Central Standard Time	Locality	Latitude Degrees North	Longitude Degrees West	Modified Mercalli (MM) Intensity	Source
6	March 17, 1884	14:00	North Platte	41.133	100.750	IV	A
15	Dec 1916	-----	Stapleton	41.550	100.476	II-III	A
17	Sept. 24, 1924	05:00	Gothenburg	40.950	100.133	IV	A
19	Aug. 8, 1933	-----	Scottsbluff	41.867	103.667	IV-V	A
21	July 30, 1934	01:20	Chadron	42.850	103.000	VI	A
25	March 24, 1938	07:11	Fort Robinson	42.683	103.417	IV	A
29	March 9, 1963	09:25	Chadron	42.860	103.000	II-III	A
31	March 28, 1964	19:21	Merriman	42.800	101.667	VII	A
34	May 7, 1978	10:06	SW Cherry County	42.340	101.930	V	C

Source: A = Docekal, 1970
B = National Earthquake Information Service

2.7 HYDROLOGY

2.7.1 SURFACE WATER

The Crow Butte permit area lies 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.

Eight surface water impoundments occur within or near the commercial restricted area boundaries.

Location.

The Crow Butte permit area lies 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 spring-fed.

Squaw Creek is one of the southern tributaries of the White River. This creek heads in the Pine Ridge southeast of the permit 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 on a month to month and yearly basis.

Squaw Creek enters the commercial permit area on the southeast corner, travels through the entire length of permit 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 Crow Butte Permit Area with respect to the Squaw Creek and English Creek watercourses and the location of the restricted area and the commercial evaporation ponds.

Stream Flow

Flow rates were measured on Squaw Creek and these data and the methodology used is found in Section 2.9.

Table 2.7-1 shows the mean monthly discharge of the White River as compared to the mean monthly precipitation over several years (NOAA, 1981). These extended data show that a loose 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. For the period of 1931 to 1980 the average normal annual mean discharge at the White River Station at Crawford was 20.1 cfs (0.57 cms) with a standard deviation of 2.8 cfs (0.08 cms). The maximum was 29.7 cfs (0.84 cms) and minimum 16.6 cfs (0.47 cms). Peak rainfall at Harrison and Scottsbluff, Nebraska occurs in May and June (NOAA, 1976 and 1980). This is typically true for the Crawford area also.

Surface Water Impoundments

Eight surface water impoundments are located near or within the boundaries of the commercial permit area. Figure 2.9-1 (See Section 2.9) shows the location 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 permit area while impoundments I-3 through I-6 are inside the permit 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. Samples of impoundments I-1 through I-8 were collected and handled as described in Section 2.9.

Water Quality

Samples were collected from Squaw Creek and all surface bodies of water within the commercial permit area. This schedule was begun in 1982 and continued into 1987 for specified locations. The data and sampling methodology are found in Section 2.9.

Figure 2.7-1: English Creek and Squaw Creek Watercourses

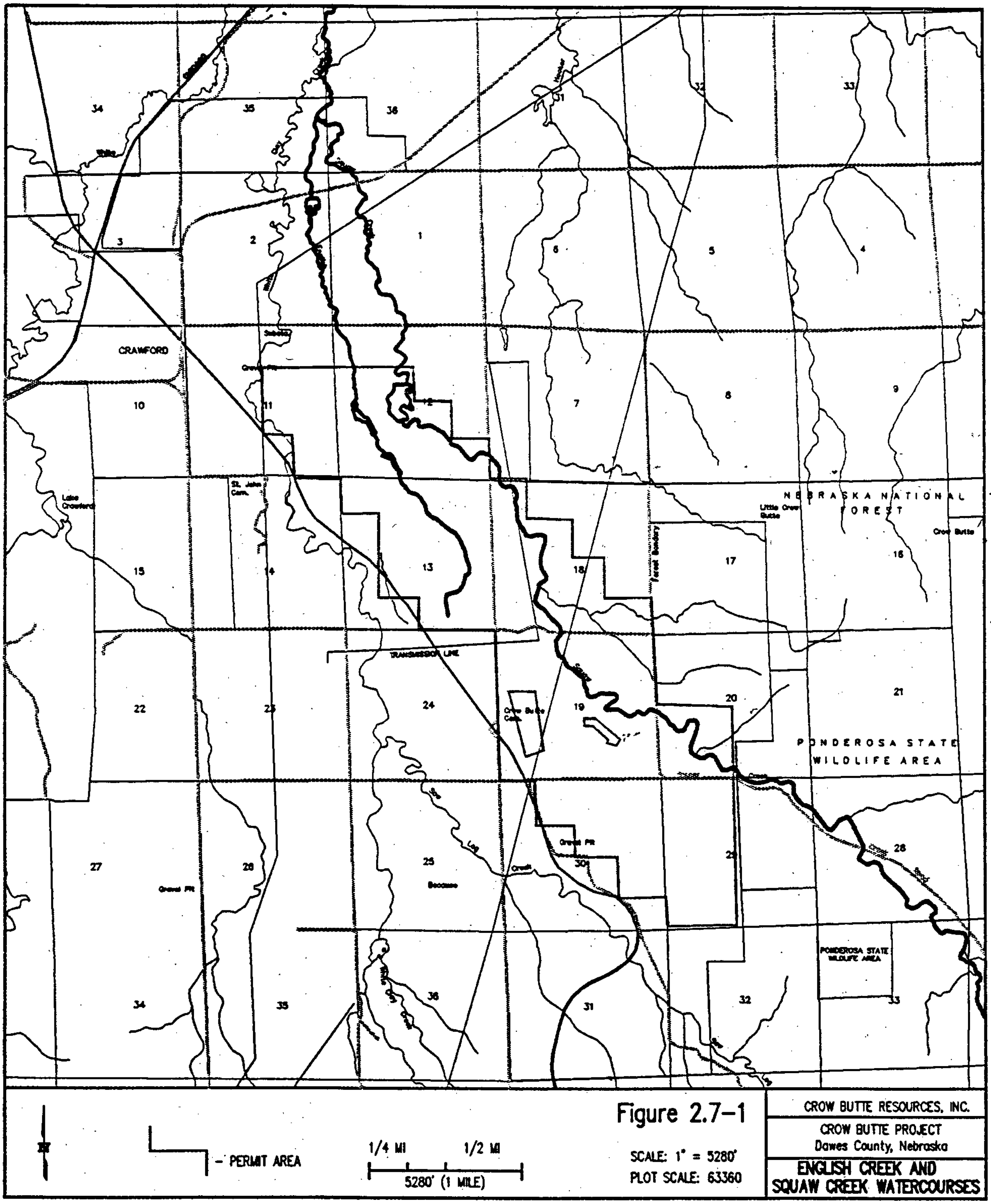


Table 2.7-1: Comparison of Mean Monthly Precipitation With Normal Mean Monthly Discharge of the White River at Crawford, Nebraska

Month	Mean Precipitation [1]		Mean Discharge [2]	
	Inches	(cm)	Inches	(cm)
January	0.41	1.04	21.0	0.59
February	0.37	0.94	23.4	0.66
March	0.70	1.78	27.2	0.77
April	1.67	4.24	25.3	0.72
May	2.98	7.57	25.3	0.72
June	3.32	8.43	22.2	0.63
July	2.16	5.49	15.4	0.44
August	0.97	2.46	12.6	0.36
September	1.33	3.38	13.3	0.38
October	0.83	2.11	16.6	0.47
November	0.43	1.09	19.4	0.55
December	0.39	0.99	20.2	0.57

1 U.S. Department of Commerce, 1982, Period of Record 1941-1970.
2 U.S. Department of the Interior, 1981, Period of Record 1931-1980.

2.7.2 GROUNDWATER

With regard to the Crow Butte Project, two groundwater sources are of interest in the Crawford and Crow Butte area. These are the local Brule sands and the Chadron aquifer. The Chadron aquifer contains the uranium mineralization of interest to this project. This section describes the regional and local hydrology of the groundwater, including physical and chemical characteristics.

An aquifer test was performed in the R&D wellfield in November, 1982. A second aquifer test was performed in June, 1987 at a site which is approximately 2800 feet north of the R&D wellfield. The purpose of these two tests was to determine the hydrogeologic characteristics of the Chadron aquifer. The following discussion includes the results of these tests and the conclusions which can be drawn concerning transmissivities, storage coefficients, vertical permeability of the confining layers and boundary conditions.

Regional Hydrology

A map prepared by Souders and Freethey (1975) indicates that the water table configuration in the region trends north-northeast. No published regional water level maps are available for the Chadron aquifer or the local Brule sands.

Water level data have been gathered from existing and specifically drilled wells throughout the Crawford-Crow Butte area for the local Brule sands and the Chadron aquifer. Maps showing the piezometric surfaces are included as Figure 2.7-2 and Figure 2.7-3 for these two aquifers. The direction of flow in the local Brule sands appears to be to the north-northwest. However, the extreme variation in the piezometric surface from the Pine Ridge to the White River (south to north) would indicate separate, hydraulically isolated Brule sands.

The Chadron aquifer is artesian (confined) and wells completed in it may flow to the surface near the White River Fault and to about 1.5 miles south of the fault. The direction of groundwater migration in that area is north-northwest. Farther to the south, the piezometric surface is almost flat.

Commercial Area Hydrology

The hydrogeologic system within and surrounding the Crow Butte commercial permit area is essentially the same as found regionally. The outcropping

Figure 2.7-2: Water Level Map- Brule Formation

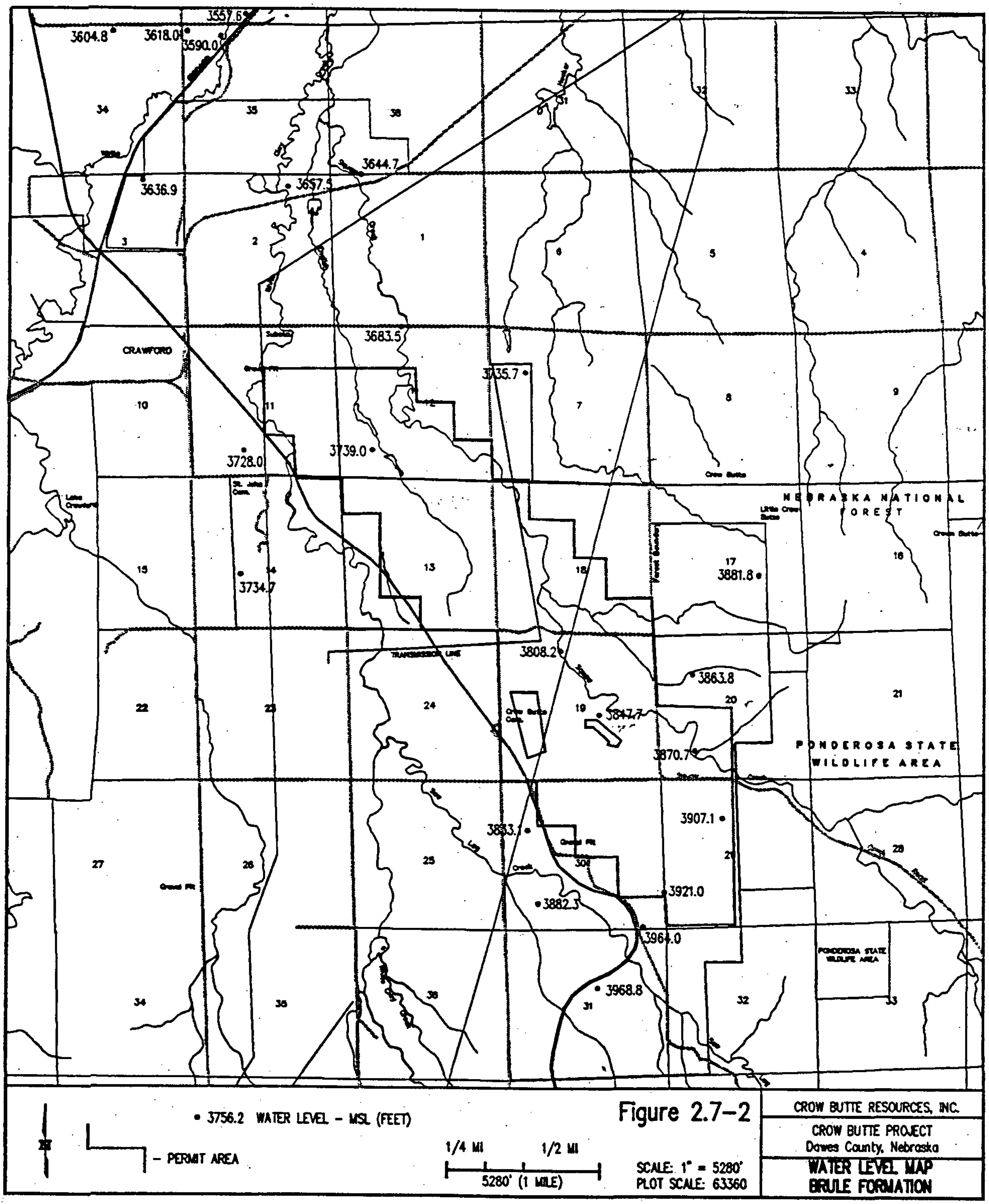
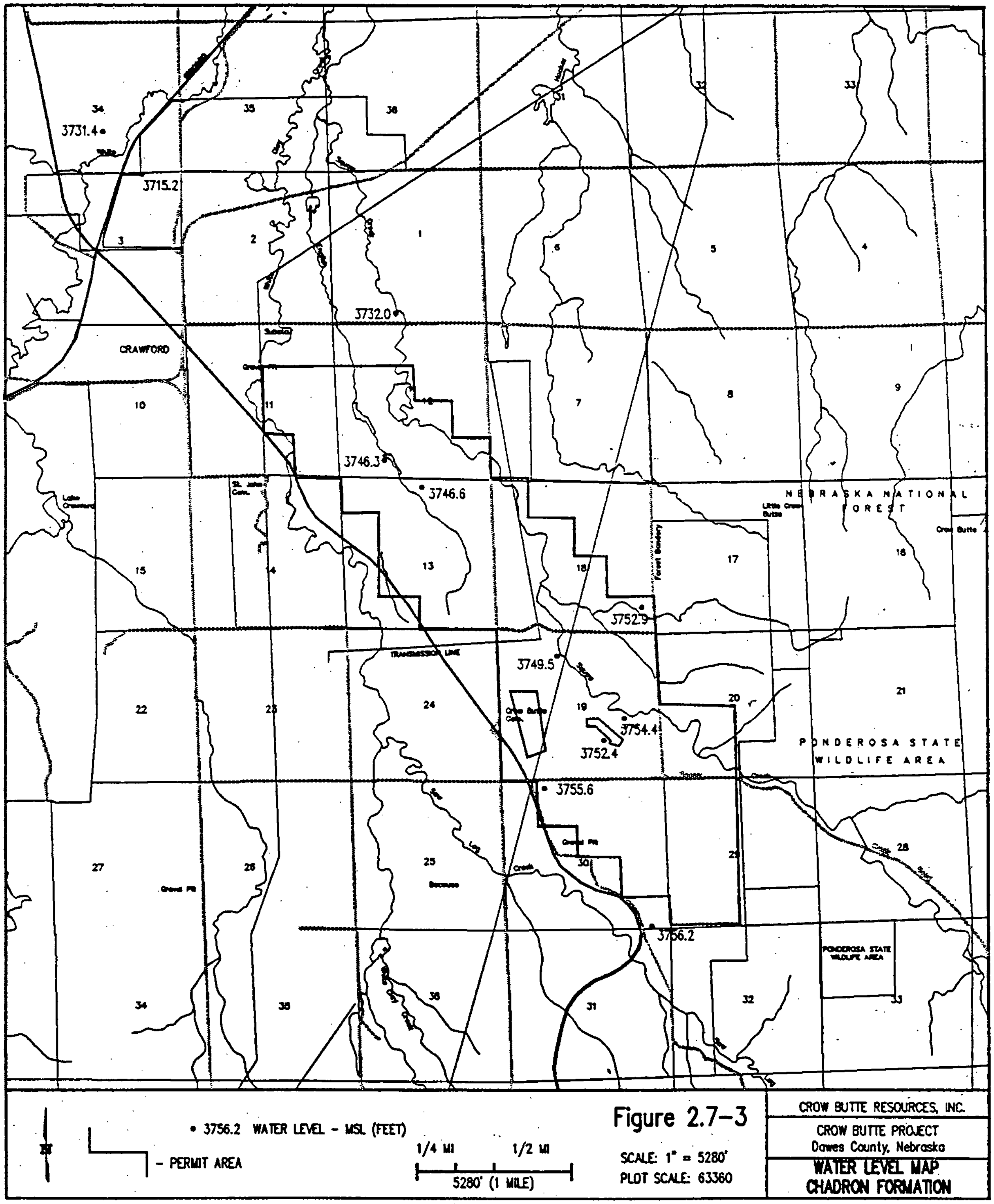


Figure 2.7-3: Water Level Map- Chadron Formation



Brule Formation is underlain by the Chadron Formation and Pierre Shale. Figure 2.7-4 and Figure 2.7-5 are cross-sectional representations of these strata indicating their hydrologic properties. These cross sections are based on lithologic descriptions and geophysical logs from exploration drilling, core samples and baseline wells. Figure 2.7-6 shows the location of these sections.

The Basal Chadron Sand, 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 mean a strata capable of transmitting only minor amounts of fluid either vertically or horizontally. Typical values for the permeability of "aquicludes" are in the range of 10^{-4} to 10^{-5} darcys for vertical and horizontal permeabilities (Todd, 1980). The measured vertical permeabilities of the aquicludes are shown in Table 2.7-4 and Table 2.7-7.

In the upper part of the Brule Formation, sandstones and sandy siltstones are present which locally may be water bearing. 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 1.0 foot (0.30 m) and range from 0.7 feet (0.21 m) to 2.4 feet (0.73 m). 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.

Water Quality

A monitoring program was conducted to establish baseline groundwater and surface water quality conditions on the commercial permit area and surrounding areas. A detailed description of this program and all data is found in Section 2.9.

2.7.3 AQUIFER TESTING

To evaluate the hydraulic properties of the uranium bearing sand and the confining strata within the permit area, an aquifer testing program was conducted. The aquifer testing program consisted of two aquifer tests. The first test was conducted within the R&D wellfield in November, 1982. The second test was conducted in June, 1987 at a site located approximately 2800 feet north of the first test.

Figure 2.7-4: NW-SE Hydrostratigraphic Cross Section

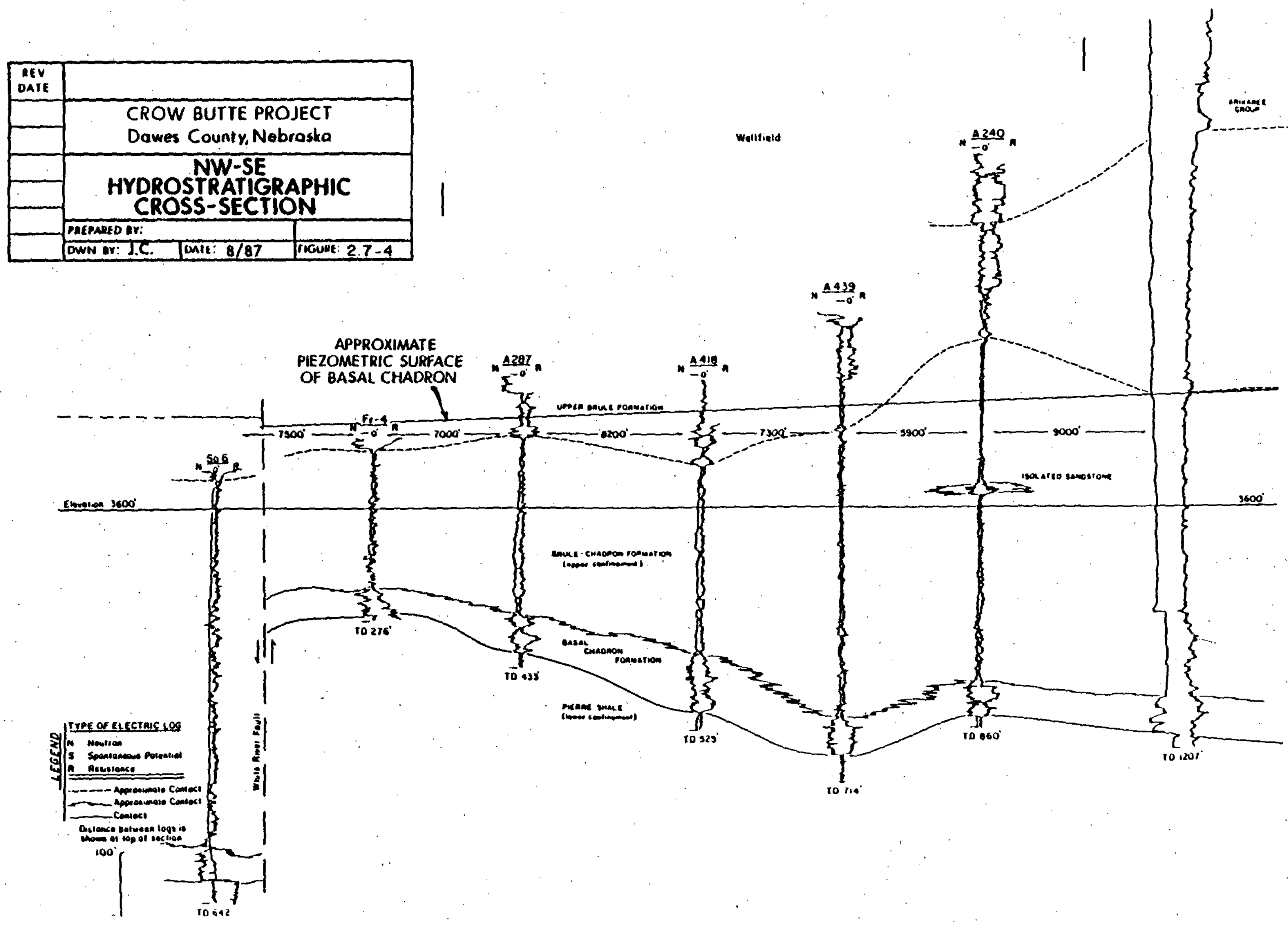


Figure 2.7-5: E-W Hydrostratigraphic Cross Section

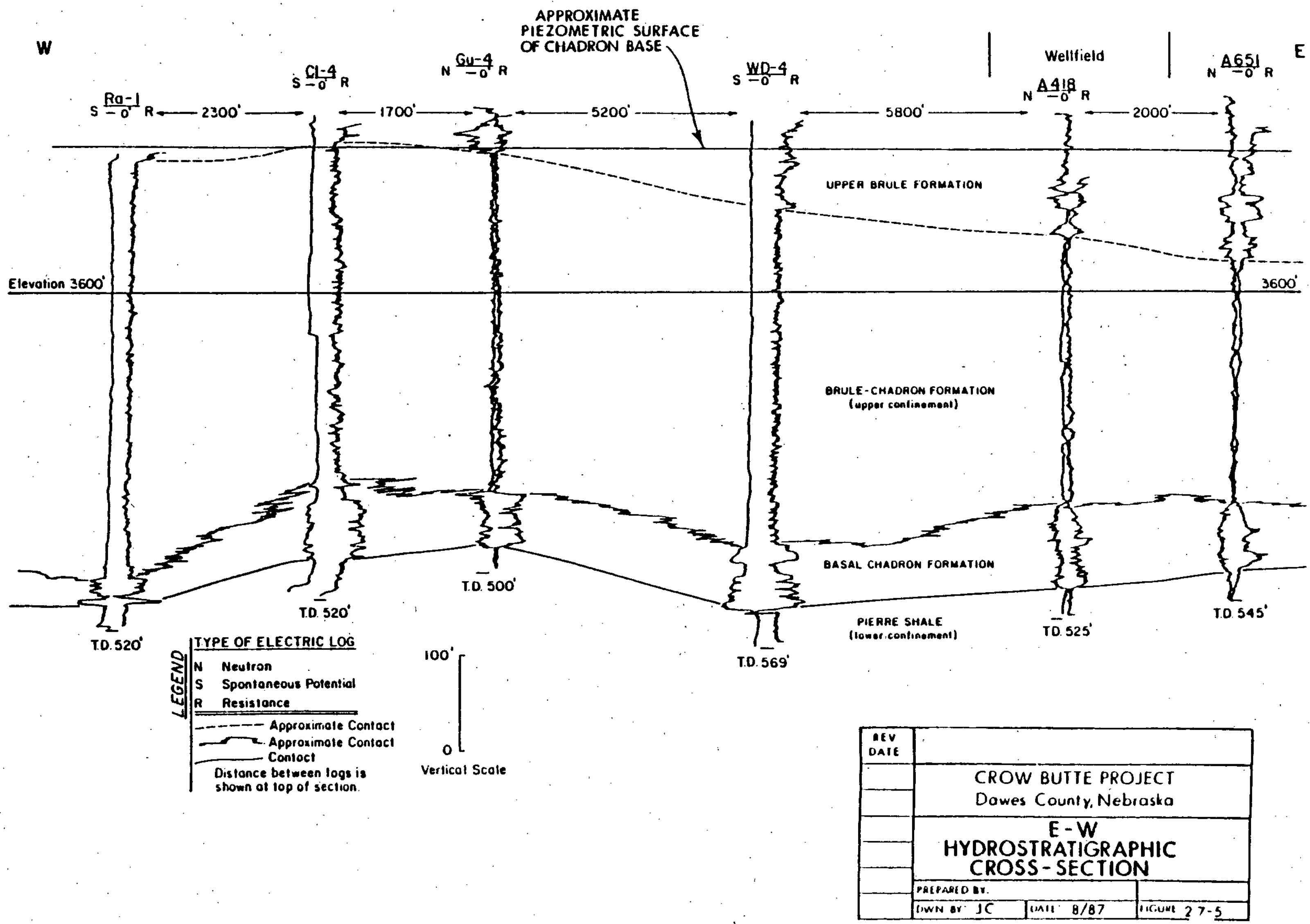
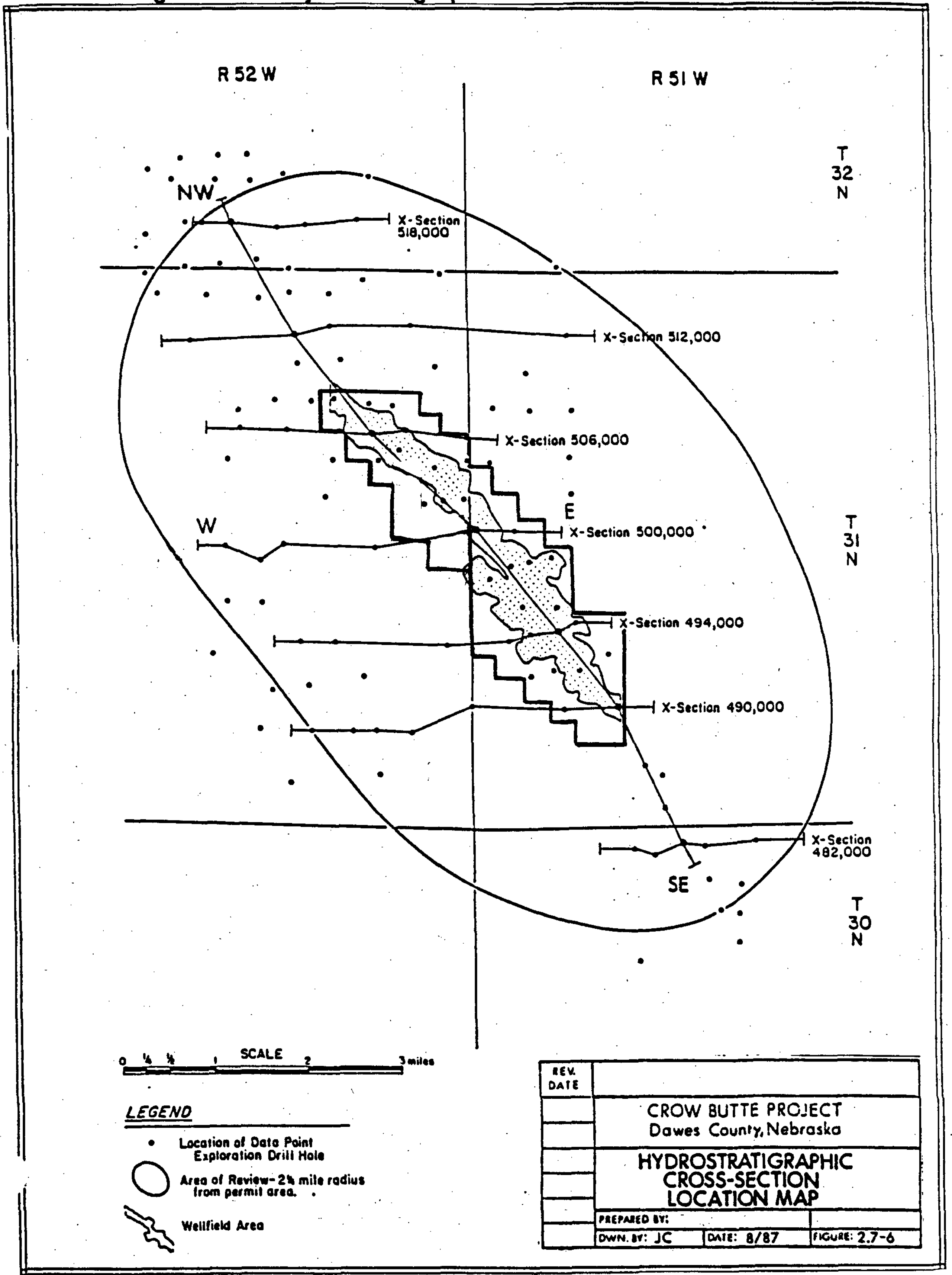


Figure 2.7-6: Hydrostratigraphic Cross Section Location Map



First Aquifer Test

The first multiple-well aquifer test 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 in four production zone observation wells and two shallow Brule monitor wells were measured.

Aquifer Response to Pumping

The data from the first aquifer test were analyzed by five different methods. The results of these five 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 as determined from the five analytical methods, ranged from 2453 gpd/ft (327 ft^2/day) to 3863 gpd/ft (516 ft^2/day). The average thickness of the aquifer at the test site is about 40 feet. Therefore, the average hydraulic conductivity ranges from about 61 gpd/ft^2 (8.2 ft/day) to about 97 gpd/ft^2 (13 ft/day). The average coefficient of storage, as determined from the five analysis, ranged from 9.66×10^{-5} to 1.75×10^{-4}. The azimuth and magnitude of the major axis of transmissivity are about 2° and 3000 gpd/ft (401 ft^2/day). The azimuth and magnitude of the minor axis of transmissivity are about 92° and 2169 gpd/ft (290 ft^2/day). Evidence from the test show that the Basal Chadron Sandstone is not hydraulically connected to the overlying aquifer in the Brule Sand.

Integrity of Confinement

The 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 aquifer-test pumping. 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 is 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, is about 7.8×10^{-7} ft/day (2.8×10^{-10} cm/sec), and that of the underlying confining layer is about 9.6×10^{-8} ft/day (3.4×10^{-11} cm/sec). Confining layers with vertical hydraulic conductivies 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 most graphically by the hydraulic resistance factor, c. The hydraulic resistance of the overlying aquiclude is about 53,000 years and that of the underlying aquiclude is about 34,000,000 years. The times needed for a water molecule to travel through the entire thicknesses of the aquicludes, assuming a porosity of 22 percent, under unit gradient (one foot of head loss per foot of movement in the direction of flow) are about 12,000 years for the overlying aquiclude and about 7,500,000 years for the underlying aquiclude.

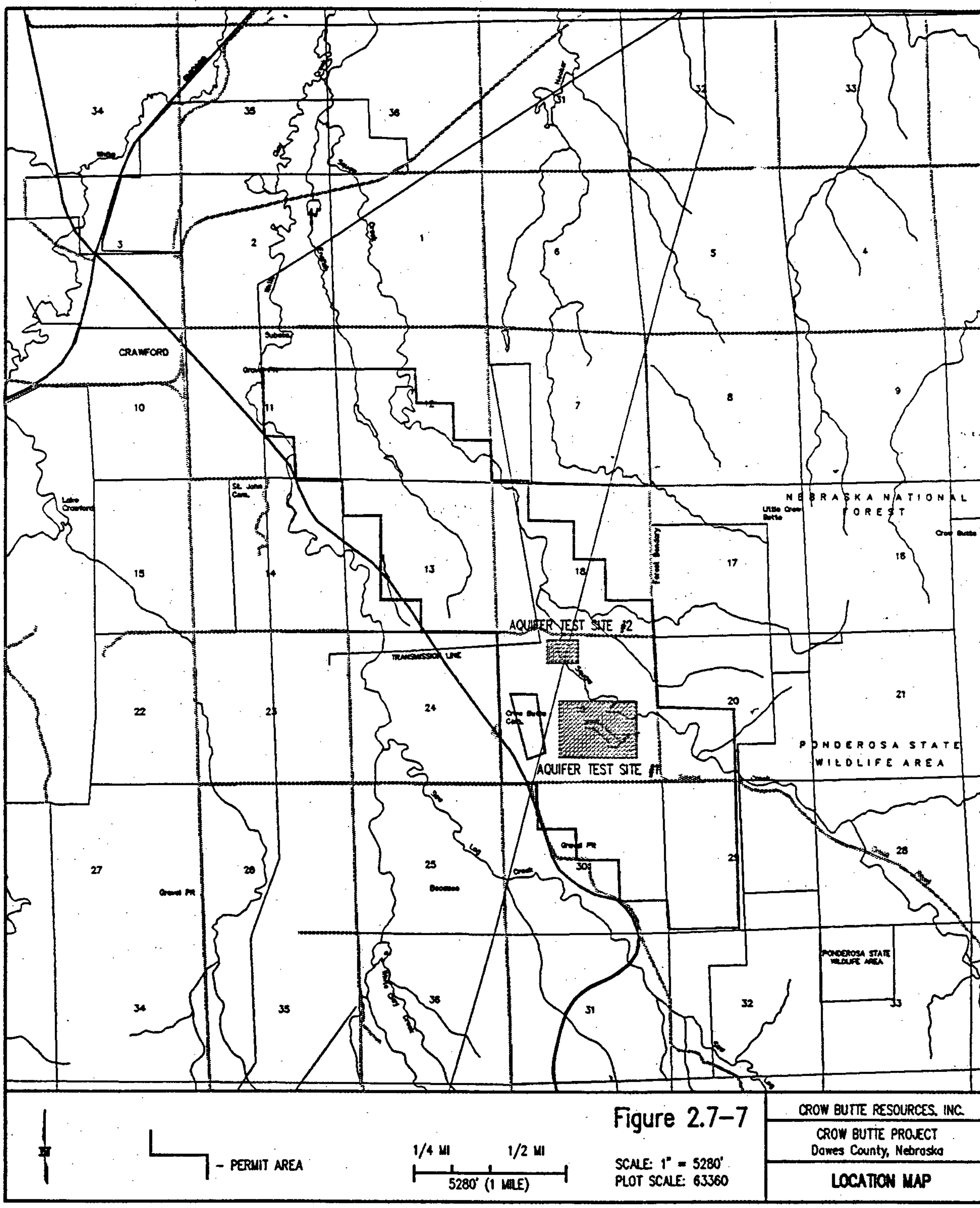
Movement of Groundwater

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 one foot per 2500 feet. Using a directional hydraulic conductivity of 10 ft/day, a gradient of $4X10^{-4}$ 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 $0.16ft^3$/day per unit width of the aquifer.

Second Aquifer Test

A second multiple-well aquifer test was performed in the mineralized area near the northern boundary of Section 19. This test was part of a hydrogeologic investigation of the commercial permit area north of the R&D site. This investigation consisted of: (1) a review of exisiting geologic and hydrogeologic data; (2) design of an appropriate aquifer test; (3) design and construction of an appropriate well array for the aquifer test; (4) laboratory testing of core samples from confining layers; (5) conducting the aquifer test, (6) analyzing the aquifer test data, and (7) interpreting the results. This hydrogeologic investigation was structured to address environmental and operational questions pertinent to ISL uranium mining at the site. Specifically, the requirements outlined by the Nuclear Regulatory Commission (NRC) in Regulatory Guide 3.46, Section 2.7.1 and Draft Staff Technical Position Paper WM-8203, Section 3.1.2. Therefore, this 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 and the overlying aquifer. The aquifer test site is located near the north boundary of Section 19, T 31 N, R51 W, Dawes County, Nebraska. This site is approximately 2800 feet north of the R & D site (Figure 2.7-7).

Figure 2.7-7: Location Map



Site Hydrostratigraphy

The uranium-bearing aquifer is formed by a 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). Regionally, the thickness of the Basal Sandstone ranges from 0 to 350 feet. Exploration drilling in the vicinity of the test site shows that the average thickness of Basal Sandstone is approximately 40 feet. At the test site, the Basal Sandstone is approximately 550 to 600 feet below ground surface. The Chadron Formation lies with marked unconformity on top of the Pierre Shale.

The Pierre Shale of late Cretaceous age forms the underlying confining layer for the Basal Chadron Sandstone. The Pierre is a wide-spread dark-gray to black marine shale which is essentially impermeable. Regionally, the Pierre Shale is up to 5000 feet thick. In Dawes County, deep oil test holes have encountered thicknesses of 1200 to 1500 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. At the test site, the overlying confining layer is approximately 315 to 325 feet thick.

Purpose of Investigation

The purpose of this hydrogeologic investigation was to accurately characterize the hydrogeologic regime of the commercial permit area north of the R&D site as it pertains to ISL uranium mining. The specific objectives of this investigation were to:

- confirm confinement of the ore-bearing aquifer,
- determine the transmissivity,hydraulic conductivity, and storativity of the ore-bearing aquifer,
- determine the azimuth and magnitude of the major and minor axes of transmissivity in the ore-bearing aquifer,
- use the Neuman-Witherspoon Method to determine the vertical hydraulic conductivity under in situ conditions, of the confining layers which overlie and underlie the ore-bearing aquifer.

In addition to its use in the commercial permit application, the information gathered during this investigation may be used for:

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

2.7.3.1 AQUIFER TESTING PROGRAM

The aquifer test program was designed to quantify the hydrogeologic parameters recommended by the NRC in Regulatory Guide 3.46, Section 2.7.1, and Draft Staff Technical Position Paper WM-8203. Specifically, this test was designed to allow analysis of the confining layers by the Neuman/Witherspoon Method (1972) which is currently considered by the NRC to be the most applicable to aquifer-aquitard systems commonly associated with uranium deposits.

Configuration of Well Array

The well array used for the aquifer test consisted of five wells and two high-sensitivity piezometers configured as shown in Figure 2.7-8. All of the wells and piezometers used to perform this test were constructed during April and May, 1987 specifically for use in this test. The location and completion details of these wells and piezometers are shown in Table 2.7-2 and Table 2.7-3. 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). These wells were screened through the entire thickness of the aquifer (fully penetrating), (Figure 2.7-9). The three observation wells were located in an equiangular arrangement around the central pumping well (Figure 2.7-8). 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 (Figure 2.7-9). Well BMW-1 is also screened through the entire thickness of the aquifer (fully penetrating). This well was used to monitor the water level in the first overlying sand during the aquifer test.

Two small-diameter, high-sensitivity piezometers (UCP-1, LCP-1) were completed in the confining layers which overlie and underlie the ore-bearing aquifer (Figure 2.7-9). These piezometers provided the data to calculate the vertical hydraulic conductivities of these confining layers under in-situ field conditions.

Well Construction and Completion Techniques

All well and piezometer boreholes were drilled with a conventional rotary drill rig using a bentonite based drilling fluid. The borehole was drilled to the appropriate depth and was geophysically logged. The log suite consisted of a gamma log, a resistivity log, a neutron log and a deviation survey. The geophysical logs were then used to determine the exact completion interval of each well or piezometer.

The pumping, observation and monitor wells were completed by a single stage or integral completion method. Figure 2.7-10 is a schematic of this completion method. This method consisted of drilling a nominal 8-inch borehole to the desired depth. Next, a string of 4.5-inch diameter Yelomine casing with the desired length of screen attached to the lower end was placed in the hole. A cement basket was attached to the blank casing just above the screen to exclude cement from the screen interval during cementing. The cement was then pumped down the inside of the casing to a plug set just below the cement basket. The cement passed out through weep holes in the casing above the cement basket and was directed by the cement basket back to the surface through the annulus between the casing and the drill hole. After the cement had cured sufficiently, the residual cement and plug were drilled out. The completed wells were then developed by air-lifting. The confining layer piezometers were cased with two-inch I.D.Yelomine casing and a porous stone tip. The porous stone tip was two feet long, 1.5 inches in diameter, with 50 micron pores. These piezometers were grouted through a tremie line from the top of the completion interval to ground surface with cement slurry. The cement was excluded from the completion interval by an inflatable packer. Figure 2.7-11 is a generalized diagram of the drilling and completion procedures for the piezometers. The completed piezometers were then cleaned and developed by inserting a one-inch pipe to the bottom of the piezometer and circulating clean water. During the construction of the confining layer piezometers, cores were cut from the completion intervals. These cores were sealed in nitrogen purged containers made of PVC pipe to preserve in situ moisture content and to prevent oxidation during transportation to the testing laboratory.

Standard consolidation tests were performed on samples of these cores to determine the coefficient of consolidation, c_v, compression index, C_c, coefficient of compressibility, a_v ,and vertical hydraulic conductivity, k_v, of the

Figure 2.7-8: Aquifer Test Well Array

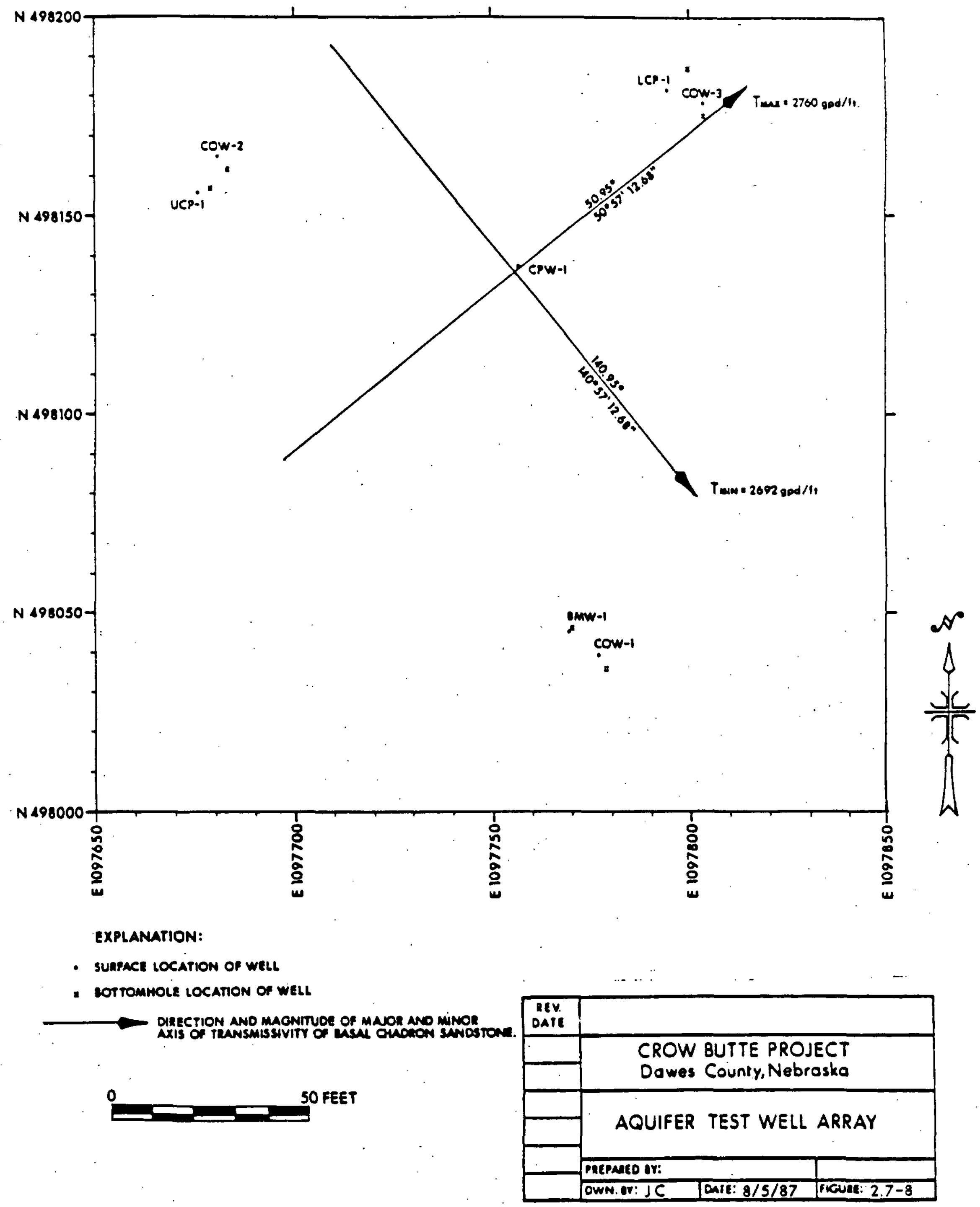


Table 2.7-2: Well Locations

Well	Surface Coordinates (ft) E	Surface Coordinates (ft) N	Deviation (ft) E	Deviation (ft) N	Bottom-hole Coordinates (ft) E	Bottom-hole Coordinates (ft) N	Ground Surface Elevation (ft)	Top of Casing Elevation (ft)
CPW-1	1,097,757.20	498,137.28	-.64	-1.02	1,097,756.56	498,136.26	3837.55	3838.75
COW-1	1,097,774.33	498,039.39	+3.02	-2.62	1,097,777.35	498,036.77	3840.21	3842.25
COW-2	1,097,681.13	498,164.90	+1.89	-2.33	1,097,683.02	498,162.57	3833.61	3835.57
COW-3	1,097,803.23	498,177.05	-.19	-1.39	1,097,803.04	498,175.66	3840.40	3842.36
BMW-1	1,097,768.97	498,045.32	+1.63	+.76	1,097,770.60	498,046.08	3839.85	3841.82
UCP-1	1,097,676.19	498,156.47	+2.33	+.58	1,097,678.52	498,157.05	3834.16	3836.82
LCP-1	1,097,794.73	498,181.79	+4.41	+6.07	1,097,799.14	498,187.86	3840.02	3840.98

Table 2.7-3: Well Completion Details

Well	Open Interval Depth (ft)	Completion Stratum	Casing Size ID (in)	Total Depth (ft)	From CPW-1 Distance	From CPW-1 Azimuth	Elevation of Piezometric Surface in feet above MSL
CPW-1	572-612	Basal Chadron	4.5	617	----	----	3749.3
COW-1	585-625	Basal Chadron	4.5	630	101.64	168.20°	3749.4
COW-2	565-610	Basal Chadron	4.5	615	78.10	289.69°	3749.3
COW-3	575-615	Basal Chadron	4.5	620	60.93	49.71°	3749.4
BMW-1	235-260	Upper Aquifer	4.5	265	91.27	171.15°	3808.0
UCP-1	555-557	Upper Aquiclude	2.0	557	80.76	284.92°	3750.7
LCP-1	618-620	Lower Aquiclude	2.0	620	66.90	39.53°	3748.8

Figure 2.7-9: Schematic of Well Completion Intervals

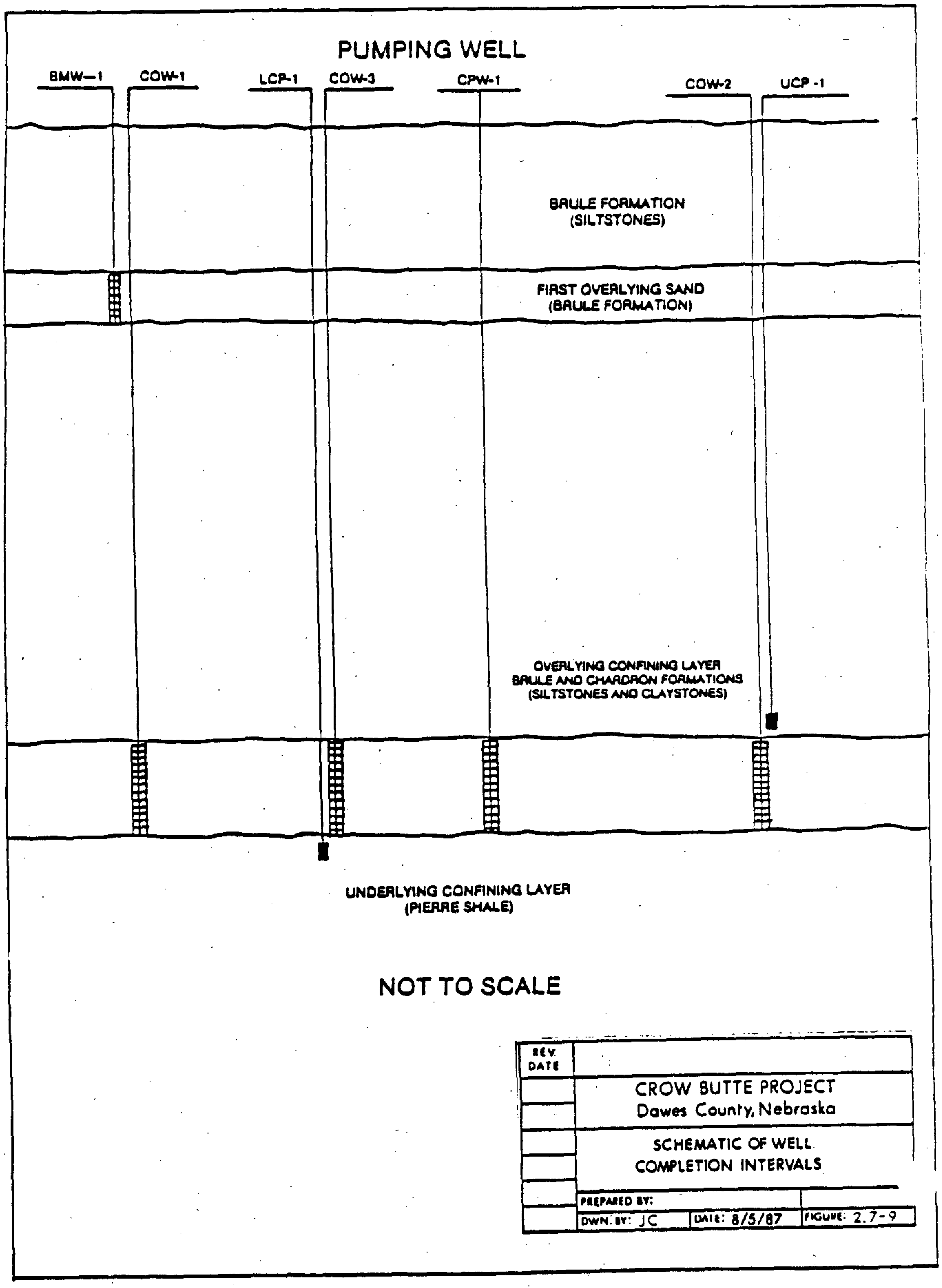


Figure 2.7-10: Schematic of Integral Completion Method for Pumping, Observation and Monitor Wells

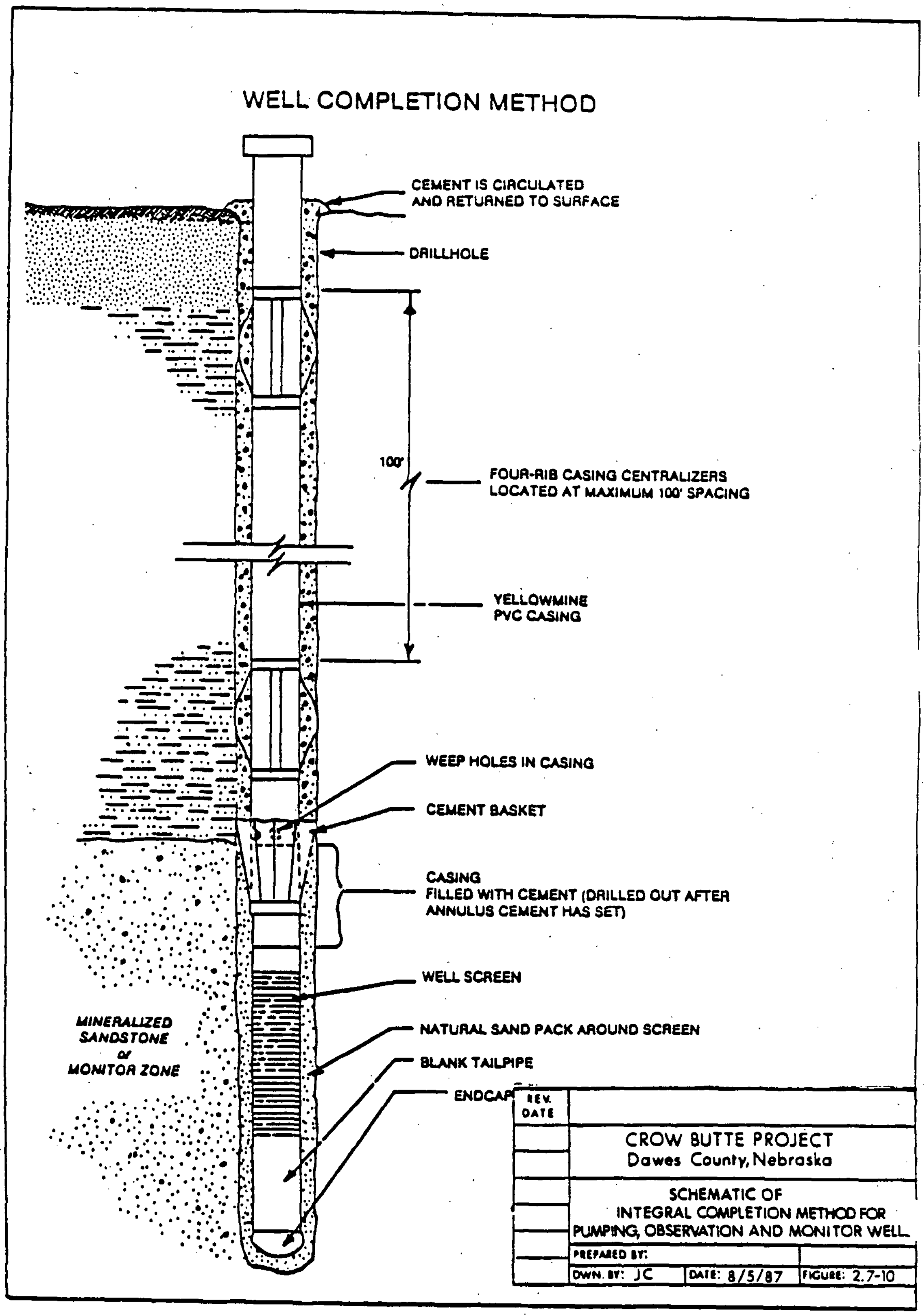
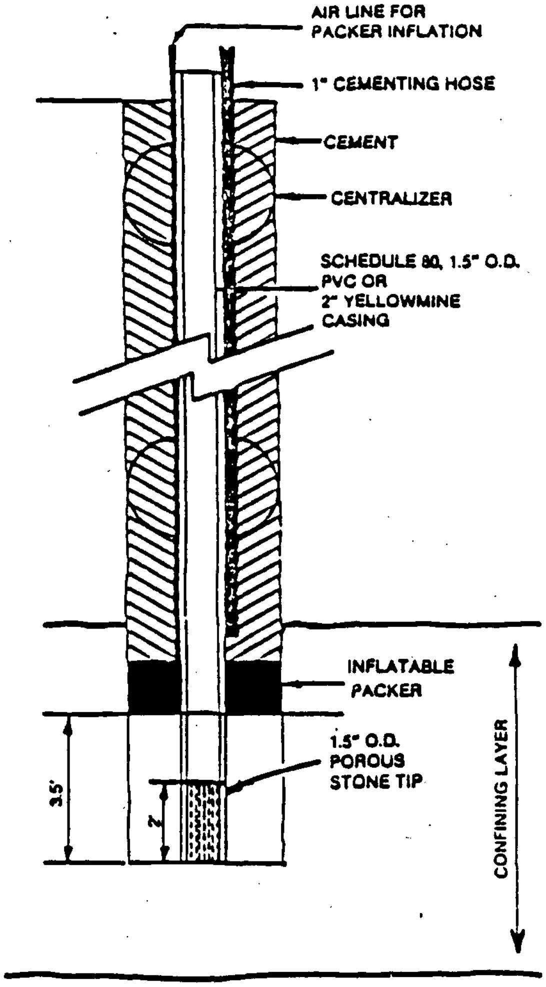


Figure 2.7-11: Schematic of Completion Method for Confining Layer Piezometers

DRILLING AND COMPLETION PROCEDURES



1. Drill pilot hole to top of completion interval.
2. Core (2" minimum diameter) through completion interval.
3. Run geophysical logs.
4. Set casing with an inflatable packer at top of completion interval. Porous stone piezometer will be used in the completion interval.
5. Inflate the packer.
6. Cement the annulus through 1" cementing line and shut the well in.
7. Top off annulus with cement after setting has occurred.

SCHEMATIC
NOT TO SCALE

REV. DATE	
	CROW BUTTE PROJECT Dawes County, Nebraska
	SCHEMATIC OF COMPLETION METHOD FOR CONFINING LAYER PIEZOMETERS
	PREPARED BY:
	DWN. BY: JC / DATE: 8/5/87 / FIGURE: 2.7-11

Table 2.7-4: Results of Consolidation Tests of Confining Layer Core Samples

Borehole	Depth (ft)	Lithology	Porosity	Coefficient of Consolidation (cm^2/sec)	Compression Index	Coefficient of Compress-ability (cm^2/g)	Vertical Hydraulic Conductivity[1] (cm/sec)
UCP-1	546.5	red clay	.341	6.65×10^{-5}	2.75×10^{-2}	4.46×10^{-7}	2.22×10^{-11}
UCP-1	550.6	red clay	.328	1.13×10^{-4}	2.69×10^{-2}	4.37×10^{-7}	3.78×10^{-11}
UCP-1	555.6	red clay	.284	1.78×10^{-4}	1.94×10^{-2}	3.15×10^{-7}	4.46×10^{-11}
UCP-1	Average		.318	1.19×10^{-4}	2.46×10^{-2}	3.99×10^{-7}	3.49×10^{-11}
LCP-1	617.0	shale	.317	1.04×10^{-4}	2.28×10^{-2}	3.70×10^{-7}	2.89×10^{-11}
LCP-1	621.8	shale	.333	9.10×10^{-5}	4.04×10^{-2}	6.56×10^{-7}	4.36×10^{-11}
LCP-1	Average		.325	9.70×10^{-5}	3.16×10^{-2}	5.13×10^{-7}	3.63×10^{-11}

1 Calculated for 600 psi effective overburden pressure from consolidation test data.

confining layers (Table 2.7-4). Laboratory determination of these parameters allowed calculation of the specific storage of the confining layers and their vertical hydraulic conductivity.

Pre-Test Monitoring

Construction and development of the five wells and two piezometers in the well array was completed on May 28, 1987. For the next 33 days, the well array was allowed to stabilize. During this time, the water levels in all the wells and piezometers and the barometric pressure were measured and recorded daily. These data were used to ensure that the wells and piezometers had reached a true static water level.

Aquifer Test Equipment and Instrumentation

During the aquifer test, the pumped well (CPW-1) was equipped with a 7.5 HP submersible pump which was set at a depth of about 500 feet. A two-inch I.D. discharge pipe conveyed the pumped water to the surface. Electrical power for the pump was supplied by a diesel-powered portable generator which ran continuously throughout the pumping phase of the test. A one-inch diaphragm valve was used to control the discharge rate. Two Haliburton meters which measured both flow rate and volume were installed in the discharge line to measure instantaneous discharge rate and cumulative discharge volume. Only one meter was used at any one time, keeping the second in reserve as a backup.

The discharge line extended about 400 feet from the wellhead to prevent discharged water from leaking downward and recharging the shallow overlying aquifer. The three Chadron observation wells (COW-1, COW-2, and COW-3), the overlying monitor well (BMW-1),and the two confining layer piezometers (UCP-1 and LCP-1) were equipped with electronic pressure transducers. These six pressure transducers were connected to a computer-controlled datalogger which automatically recorded the water levels in each well at specified time intervals. A seventh electronic pressure transducer was used to measure barometric pressure which was also recorded by the data-logger each time the water levels were recorded.

Aquifer Test

The pumping phase of the aquifer test began at 12:47 on June 30, 1987 and concluded at approximately 12:47 on July 3, 1987. Thus, the length of the pumping phase of the test was 4322 minutes, or about 72 hours. Just prior to the start of the pumping, static water levels of all the wells were measured and recorded (Table 2.7-5). The recovery phase of the test began at 12:47

Table 2.7-5: Static Water Levels

Well	Static Water Level (ft above MSL)
CPW-1	----[1]
COW-1	3749.5
COW-2	3749.5
COW-3	3749.5
BMW-1	3808.2
UCP-1	3751.3
LCP-1	3749.4

Notes: [1] Could not measure water level because pump was in well.

on July 3, 1987 and concluded at 13:17 on July 6, 1987, which is a period of 4350 minutes, or 72.5 hours.

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 insure 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. Therefore, the aquifer was under confined conditions throughout the test. No equipment failures or interruptions occurred during the aquifer test. However, barometric pressure did vary considerably during the six-day test as the result of the passage of a low pressure system and a cold front with associated thunderstorms and subsequent high pressure.

2.7.3.2 ANALYSIS OF DATA

Analytical Methods

To accomplish the goals of this investigation, the following methods of analysis were used:

- 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.

From a practical viewpoint, the field conditions at the test site met all the assumptions and conditions necessary for these analytical methods to be applicable and valid.

Results of Analysis

Basal Chadron Sandstone

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 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 lower transmissivity values calculated from the recovery data are probably the result of the variation in the storage coefficient during pumping and recovery. In theory, the storage coefficient is assumed to be constant during both the pumping and the recovery phases of an aquifer test. This assumption is true if the aquifer is perfectly elastic. In practice, however, a confined aquifer is usually not perfectly elastic. Therefore, it will not rebound vertically during recovery of water levels (recovery of pressure) at the same rate that it consolidates or compresses when pressure is decreased during the preceeding pumping. Therefore, the storage coefficient will vary and is likely to be larger during pumping than during the subsequent recovery (Jacob, 1963). Thus, transmissivity values calculated from pumping data are commonly larger than those calculated from recovery data.

The average thickness of the aquifer at the test site is 40 feet. Therefore, the hydraulic conductivities calculated from the drawdown data ranges from about 67 gpd/ft^2 (8.96 ft/day) to about 70 gpd/ft^2 (9.34 ft/day). The hydraulic conductivities calculated from the recovery data ranged from about 65 gpd/ft^2

(8.7 ft/day) to about 66 gpd/ft^2 (8.89 ft/day) Table 2.7-6 summarizes the results of the analysis of the aquifer test data.

The Hantush Method For Anisotropic aquifers 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) (Figure 2.7-8). The minor axis of transmissivity has an azimuth of about 141° and a magnitude of 2692 gpd/ft 360 ft^2/day.

<u>Overlying and Underlying Confining Layers</u>

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 that accompanied the passage of a low pressure system and a cold front which confirmed that it was indeed functioning properly because UCP-1 did not respond to pumping, it was not possible to use the water level data from UCP-1 to calculate the hydraulic properties of the upper confining layer using the Neuman-Witherspoon Method. Therefore, laboratory data from the consolidation tests of core samples from UCP-1 were used to calculate the hydraulic properties of the overlying confining layer.

Results of the laboratory consolidation test data from three core samples of UCP-1 are shown earlier in Table 2.7-4. 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. Analysis of drill cuttings and geophysical logs of UCP-1 and exploration holes in the vicinity of the test site show that the lithology of the strata between the red clay and the overlying Brule aquifer (Upper Chadron and Lower Brule Formations) is similar to the red clay. Therefore, it is reasonable to assume that the hydraulic characteristics of these strata are similar to those of the red clay. 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, I979) is about 830,200 years for the red clay and 8,994,000 years for the entire confining layer. The average porosity of the overlying confining layer calculated from the consolidation test data is 31.8%, therefore, the travel time through the red clay portion of the upper confining layer would be about 264,000 years and that of the entire upper confining layer would be about 2,860,000 years under unit gradient.

Table 2.7-6: Summary of Aquifer Test Data Analysis

Jacob Method (Drawdown)

Well	T (gpd/ft)	T (ft^2/day)	S	K (gpd/ft^2)	K (ft/day)
COW-1	2682	359	8.65×10^{-5}	67	8.98
COW-2	2687	359	1.14×10^{-4}	67	8.98
COW-3	2795	374	9.73×10^{-5}	70	9.35
Average	2721	364	9.93×10^{-5}	68	9.10

Theis Method (Drawdown)

Well	T (gpd/ft)	T (ft^2/day)	S	K (gpd/ft^2)	K (ft/day)
COW-1	2730	365	8.44×10^{-5}	68	9.13
COW-2	2733	365	1.11×10^{-4}	68	9.13
COW-3	2724	364	1.31×10^{-4}	68	9.10
Average	2729	365	1.09×10^{-4}	68	9.12

Theis Recovery Method

Well	T (gpd/ft)	T (ft^2/day)	S	K (gpd/ft^2)	K (ft/day)
COW-1	2659	355		66	8.88
COW-2	2626	351		66	8.78
COW-3	2604	348		65	8.70
Average	2630	351		66	8.79

Average of Jacob and Theis Methods (Drawdown) [1]

Well	T (gpd/ft)	T (ft^2/day)	S	K (gpd/ft^2)	K (ft/day)
COW-1	2706	362	8.55×10^{-5}	68	9.05
COW-2	2710	362	1.13×10^{-4}	68	9.05
COW-3	2760	364	1.14×10^{-4}	69	9.23
Average	2725	364	1.04×10^{-4}	68	9.11

Notes: [1] Used in anisotropy calculations.

Table 2.7-7 summarizes the confining layer properties determined by laboratory and field methods as part of this investigation.

The underlying confining layer piezometer (LCP-1) responded to the same rapid changes in barometric pressure which were measured in overlying confining layer piezometer. However, LCP-1 also showed a trend toward a very small amount of drawdown (.06 feet) during the aquifer test.

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 (10-11 cm/sec), no drawdown was anticipated in LCP-1 during the test. For this reason, it is suspected that the small amount of drawdown observed in LCP-1 is the result of annular leakage between the borehole and the packer which was set to hydraulically isolate the piezometer tip from the overlying Basal Chadron Sandstone. If the packer did not completely seal the borehole above the piezometer tip, the piezometer would be affected by the pressure drop in the pumped aquifer which would be transmitted by the annulus leaks. Thus, the response of the piezometer would be the result of borehole-packer annulus leaks. If this were the case, the Neuman-Witherspoon analysis of the piezometer water levels would only serve to quantify the vertical leakage or hydraulic conductivity of the packer and borehole seal, not the vertical hydraulic conductivity of the underlying confining layer. Recognizing that this problem may exist, a Neuman-Witherspoon analysis was made of the water level data from LCP-1.

Results of the laboratory consolidation test data from two core samples from LCP-1 are shown earlier in Table 2.7-4. 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 tothe 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 1200 feet thick in the vicinity of the aquifer test site. Therefore, the calculated hydraulic resistance, c, using field measured vertical hydraulic conductivity, is about 799,300 years. The calculated hydraulic resistance using the vertical hydraulic conductivity calculated from the laboratory consolidation tests is about 31,929,000 years. The average porosity of the Pierre Shale calculated from the consolidation test data is 32.5%. Therefore, the travel time through the Pierre Shale would be about 259,770 years using field determined vertical hydraulic conductivity

Table 2.7-7: Summary of Confining Layer Properties

Parameters	Red Clay (UCP-1)	Pierre Shale (LCP-1)
Coefficient of compressibility, a_v (cm^2/g)	3.99×10^{-7}	5.13×10^{-7}
Specific storage, S_s', (cm^{-1})	3.08×10^{-7}	2.78×10^{-7}
Diffusivity, (cm^2/sec)	1.13×10^{-4}	5.22×10^{-3}
Vertical hydraulic conductivity, K_v', (cm/sec)		
Lab Data	3.49×10^{-11}	3.63×10^{-11}
Field Data	-----	1.45×10^{-9}
Hydraulic resistance, c, (years)		
Lab Data	830,200 [1]	31,929,000
Field Data	-----	799,300
Porosity (percent)	31.8	32.5
Travel time (years)		
Lab Data	264,000 [2]	259,700
Field Data	-----	10,377,000

Notes:

1 Red clay member only - total overlying confining layer = 8,994,000.

2 Red clay member only - total overlying confining layer = 2,860,000.

and about 10,377,000 years using laboratory determined vertical hydraulic conductivity under unit gradient.

Overlying Aquifer

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 which confirmed that it was functioning properly. 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, no further analysis was made of the test data from BMW-1.

2.7.3.3 INTERPRETATION OF DATA

Aquifer Response to Pumping

The results of this investigation show that the Basal Chadron Sandstone, which is the ore-bearing aquifer at the Crow Butte site, 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 (9.10ft/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 piezometric surface of the Basal Chadron Sandstone is approximately 495 feet above the top of the aquifer. 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 fact plus the fact that BMW-1 did not respond to pumping from the Basal Chadron Sandstone, are evidence that the Basal Chadron Sandstone is confined and that it is not hydraulically connected to the overlying aquifer.

Integrity of Confinement

Confined aquifers may receive small amounts of water through vertical recharge from the confining layers. Even confining layers formed of very low permeability may yield small amounts of water if the hydraulic gradient in the aquifer-aquitard system is favorable. The aquitards 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 feet 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 3.49×10^{-11} cm/sec., and that of the underlying confining layer is about 1.45×10^{-9} to 3.63×10^{-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 most graphically by the hydraulic resistance, c. The calculated hydraulic resistance of the entire thickness of the overlying aquiclude is about 8,994,000 years and that of the underlying aquiclude is between 799,300 years and 31,900,000 years. The times needed for a given water molecule to travel through the entire thicknesses of the aquicludes under unit gradient (one foot of head loss per foot of movement in the direction of flow) are about 2,860,000 years for the upper aquiclude and about 260,000 years to 10,377,000 years for the lower. Because the gradients would be much smaller during mining, actual travel times would be much longer than those stated above.

Movement of Groundwater

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 1275 feet. Using a directional hydraulic conductivity of 9.11 ft/day, a gradient 7.84×10^{-4} and a porosity of 29 percent, the average pore velocity across this part of the commercial study area is about 9.00 ft/year. The groundwater flux across the test site was computed to be about .29 ft^3/day per unit width of the aquifer. (Darcy, 1856).

Extent of Investigated Area

Using the Cooper-Jacob Distance-Drawdown Method (Cooper and Jacob, 1946), the radius of influence of the aquifer test in the Basal Chadron Sandstone was calculated to be about 5000 feet. Therefore, the area investigated and characterized by this test is approximately 1803 acres.

Soils

The Crow Butte Commercial Project Area is located in the semiarid western portion of Dawes County. To the south lies the Pine Ridge, an area of rough steep terrain dissected by steep drainage ways. Vegetative cover there is typically mixed grass and Ponderosa pine trees. Width of the Pine Ridge ranges from 3.2 kilometers to 8 kilometers and from 150 to 305 meters in height from base to crest. South of the Pine Ridge is the Niobrara River drainage basin. The Crow Butte site is situated in the White River watershed along the Squaw Creek tributary. The terrain is gently rolling to hilly.

For the proposed project, an investigation was made of the local soils. Existing Soil Conservation Service literature was consulted, and field sampling for radionuclide, physical and chemical properties was conducted.

The Soil Conservation Service was contacted regarding available soils data for the Crow Butte site. In response, they provided a document containing a comprehensive soils survey which had recently been performed. The following soils descriptions and classifications were extracted from a publication entitled Soil Survey of Dawes County, Nebraska published in 1977 by the U.S. Dept. of Agriculture, Soil Conservation Service and the University of Nebraska, Conservation and Survey Division.

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 outcrops in the Crow Butte project area and at lower elevations. As this material weathered, it produced the Epping, Kadoka, Deota, Schamber and Mitchell soils. 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 in colluvial and alluvial materials.

The regional area between the Pine Ridge to the south, the White River to the north and town of Crawford to the north-west is comprised of two major soil associations. The Kadoka-Keith-Mitchell association contains "deep,, nearly level to steep, well drained silty soils that formed in loess and in material weathered from siltstones, on uplands and foot slopes". Typically this association consists of undulating to rolling uplands that are dissected by many spring-fed creeks. Areas of this association are mostly west of the restricted area.

The Busher-Tassel-Vetal association is described as "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 drainageways. 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.

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

The soils shown in Figure 2.7-12 for the commercial area were initially identified and boundaries drawn on aerial photographs by the Soil Conservation Service. The mapping units on aerial photographs are closely equivalent to the soil phases. The Soil Legend for the various units is found in Table 2.7-8.

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 gives 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".

Soils Mapping Unit Descriptions

The following section discusses those soils which occur within Section 19 of the Crow Butte Permit Area.

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

This soil is on uplands, occurring in areas up to 81 ha (200 ac) 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 8 to 18 cm (3 to 7 in) 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 18 to 61 cm (7 to 20 in) in thickness and is neutral to mildly alkaline. The AC horizon is from 20 to 53 cm (8 to 21 in) thick. It is fine sandy loam or loamy very fine sand. Lower horizons become progressively more coarse 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 40.5 ha (100 ac) in size. The group is comprised 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 18 cm (7 in) thick in places. Bedrock occurs at depths of 51 to 91 cm (20 to 36 in) in certain areas. Small areas of outcropping sandstone are also included.

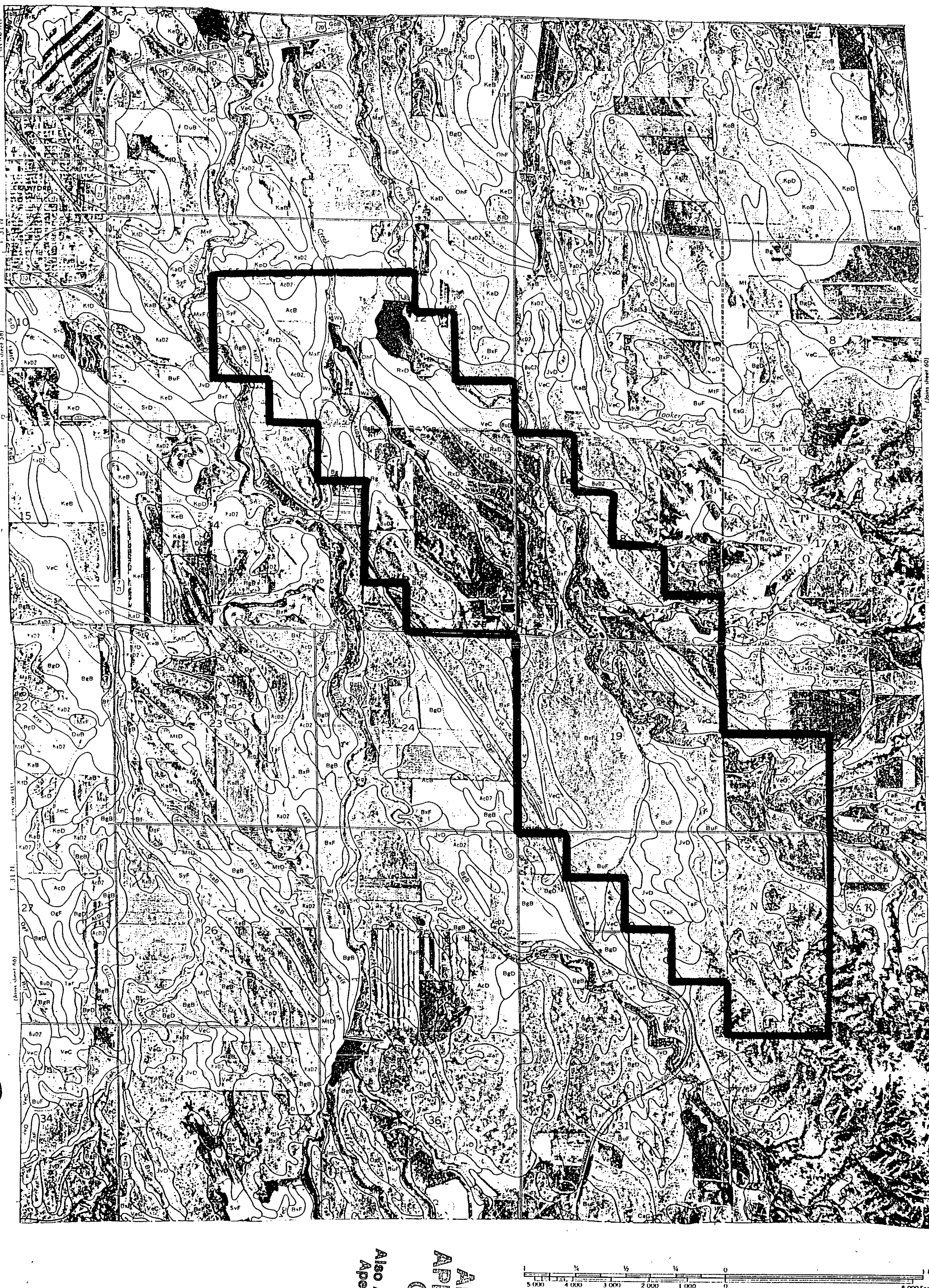
This mapping area may be vegetated in native grass, used for grazing or cut for hay. Cultivation is not suitable as serious soil blowing and water erosion may occur if cover is removed. Runoff is medium. Classification of Busher soil is sandy range site and Tassel soil is shallow limy range site.

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 121 ha (300 ac) 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 33 cm (13 in) thick underlain by a transitiona llayer 18 cm (7 in) thick. The A horizon ranges from 36 to 102 cm (14 to 20 in), and the AC horizon from 20 to 51 cm (8 to 20 in) 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

Figure 2.7-12: Soils Map- Commercial Permit Area



Permit Area Boundary

9601300331-03

Table 2.7-8: Soil Legend

The first capital letter is the initial one 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.

Symbol	Name	Symbol	Name
AcB	Alliance silt loam, 1 to 3 percent slopes	Ky	Kyle silty clay, 0 to 1 percent slopes.
AcD	Alliance silt loam, 3 to 9 percent slopes	KyC	Kyle silty clay, 1 to 5 percent slopes.
AcD2	Alliance silt loam, 3 to 9 percent slopes eroded	Kz	Kyle-Slickspots complex, 0 to 2 percent slopes.
B3	Badland	La	Las Animas soils, 0 to 2 percent slopes
Bc	Bankard loamy fine sand, 0 to 2 percent slopes	Lo	Loamy alluvial land
Bd	Bankard loamy fine sand, wet variant, 0 to 2 percent slopes	MnC	Minnequa silty clay loam, 1 to 5 percent slopes
Bf	Breaks-Alluvial land complex	MnD	Minnequa silty clay loam, 5 to 12 percent slopes
Bg	Bridget silt loam, 0 to 1 percent slopes	Mt	Mitchell silt loam, 0 to 1 percent slopes.
BgB	Bridget silt loam, 1 to 3 percent slopes.	MtC	Mitchell silt loam, 1 to 5 percent slopes.
BgD	Bridget silt loam, 3 to 9 percent slopes.	MtD	Mitchell silt loam, 5 to 9 percent slopes.

Table 2.7-8: Soil Legend

The first capital letter is the initial one 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.

Symbol	Name	Symbol	Name
BgF	Bridget silt loam, 9 to 20 percent slopes.	MtF	Mitchell silt loam, 9 to 20 percenr slopes.
Bh	Buffington silty clay, 0 to 1 percent slopes.	MnF	Mitchell-Epping silt loams, 3 to 30 percent slopes.
Bn	Bufton silty clay loam, 0 to 1 percent slopes	NrB	Norrest silty clay loam, 1 to 3 percent slopes
BnB	Bufton sily clay loam, 1 to 3 percent slopes.	NrD	Nottest silty clay loams, 3 to 9 percent slopes.
BnD	Bufton silty clay loam, 3 to 9 percent slopes.	NrF	Norrest silty clay loams, 9 to 20 percent slopes.
BnF	Bufton silty clay loam, 9 to 20 percent slopes.	OgF	Oglala loam. 9 to 30 percent slopes
BoD	Bufton-Slickspots complex, 0 to 9 percent slopes.	OhF	Oglala-Canyon loams, 9 to 20 percent slopes.
BuC	Busher loamy very fine sand, 1 to 5 percent slopes.	OrF	Oretta silty clay loam, 3 to 30 percent slopes.
BuC2	Bushy loamy very fine sand, 1 to 5 percent slopes, eroded.	OsG	Oretta-Badland complex, 3 to 50 percent slopes.
BuD	Busher loamy very fine sand, 5 to 9 percent slopes.	PeG	Penrose-Shale outcrop complex, 10 to 50 percent slopes.

Table 2.7-8: Soil Legend

The first capital letter is the initial one 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.

Symbol	Name	Symbol	Name
BuD2	Busher loamy very fine sand, 5 to 9 percent slopes eroded.	PmF	Penrose and Minnequa complex, 10 to 50 percent slopes.
BuF	Busher loamy very fine sand, 5 to 20 percent slopes.	PrC	Pierre silty clay, 1 to 5 percent slopes
BxF	Busher and Tassel loamy very fine sands, 5 to 20 percent slopes.	PrF	Pierre silty clay, 5 to 30 percent slopes.
CaG	Canyon-Bridget Rock outcrop association steep	PsD	Pierre-Slickspots complex, 3 to 9 percent slopes.
CcF	Canyon soils, 3 to 30 percent slope	RhB	Richfield silt loam, 1 to 3 percetn slopes.
CcG	Canyon soils, 30 to 50 percent slope	RoG	Rock Outcrop-Canyon complex, 30 to 60 percent slopes.
Cf	Clayey alluvial land	RsB	Rosebud silt loam, 1 to 3 percent slopes.
DuB	Duroc very fine sandy loam, 1 to 3 percent slopes.	RxD	Rosebud-Canyon loams, 3 to 9 percent slopes.
EpF	Epping silt loam, 3 to 30 percent slopes.	Sa	Saline-Alkali land
EsG	Epping-Badland complex, 3 to 50 percent slopes.	SbF	Samsil silty clay, 3 to 30 percent slopes.

Table 2.7-8: Soil Legend

The first capital letter is the initial one 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.

Symbol	Name	Symbol	Name
GbD	Glenberg loamy very fine sand, 0 to 3 percent slopes	ShG	Samsil-SHale outcrop complex, 9 to 50 percent slopes.
GoB	Glenberg laomy very fine sand occasionally flooded. 0 to 3 percent slopes.	Sn	Sandy alluvial loam
Gr	Gravelly alluvial land	SrC	Sarben fine sandy loam, 1 to 5 percent slopes.
HaB	Haverson silt loam. 0 to 3 percent slopes.	SrD	Sarben fine sandy loam, 5 to 9 percent slopes.
HbB	Haverson silt loam, occasionally flooded, 0 to 3 percent slopes.	SrF	Sarben fine sandy loam, 9 to 30 percent slopes.
HcB	Haverson silty clay loam, occasionally flooded, 0 to 3 percent slopes.	SvF	Sarben and Vetal loamy very fine sands, 9 to 30 percent slopes.
JmC	Jayem loamy very fine sand, 0 to 5 percent slopes.	SyF	Schamber soils, 3 to 30 percent slopes.
JmD	Jayem loamy very fine sand, 5 to 9 percent slopes.	TaF	Tassel soils, 3 to 30 percent slopes.
JvD	Jayem and Vetal loamy very fine sands, 5 to 9 percent slopes.	Tr	Trapp silt loam, 0 to 1 percent slopes.

Table 2.7-8: Soil Legend

The first capital letter is the initial one 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.

Symbol	Name	Symbol	Name
KaB	Kadoka silt loam, deep variant, 1 to 3 percent slopes.	TrB	Trapp silt loam, 1 to 3 percent slopes.
KaD	Kadoka silt loam, deep variant, 3 to 9 percent slopes.	Ts	Trapp silt loam, saline-alkali, 0 to 2 percent slopes.
KaD2	Kadoka silt loam, deep variant, 3 to 9 percent slopes eroded.	UsF	Ulysses silt loam, 9 to 20 percent slopes.
KeB	Keith silt loam, 1 to 3 percent slopes.	VaB	Valent and Dwyer loamy fine sands, 0 to 3 percent slopes.
KeD	Keith silt loam, 3 to 9 percent slopes.	VaF	Valent and Dwyer loamy fine sands, 3 to 17 percent slopes.
KfD	Keith and Ulysses silt loam, 3 to 9 percent slopes.	VeC	Vetal and Bayard soils, 1 to 5 percent slopes.
KoB	Keota silt loam, 1 to 3 percent slopes.	Wx	Wet alluvial land
KpD	Keota-Epping silt loams, 3 to 0 percent slopes.		

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 102 cm (40 in.). 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 3 m (10 ft) 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 121 ha (300 ac) 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 15 cm (6 in) thick but ranges from 8 to 25 cm (3 to 10 in) in thickness. Underlying material, C horizon, is fine sandy loam, with no AC horizon development present. Lime may occur at a depth of 61 cm (24 in). Vetal soils occur swales and on lower portions of foot slopes. The Vetal soils are typical being deep and well-drained. The A horizon may be up to 79 cm (31 in) thick with lime occasionally at less than 61 cm (24 in) depth.

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 as 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 121 ha (300 ac) 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 18 cm (7 in) thick and in other areas silty material is below a depth of 0.6 m (2 ft). 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 upon 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 which occurs on these soils is influenced by the moderately rapid to rapid permeability of the soils. A typical climax plant community is about 50 percent a mixture of decreaser plants such as sand bluestem, little bluestem, and prairie junegrass. The remaining 50 percent is perennial grass, forbs and shrubs. The principal increaser are blue grama, threadleaf sedge, prairie sandreed, needleandthread, sand dropseed, western wheatgrass, fringed sagewort and small soapweed. A site in poor condition will commonly have blue grama, threadleaf sage, sand dropseed and western ragweed.

2.7.4 REFERENCES

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Oil and Gas Logs in 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 51 West
Roby No. 1, Section 31, Township 31 North, Range 51 West
Soester No. 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

2.8 ECOLOGY

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 NRC's permit application guide (NRC, 1982).

The information presented in this section includes a summary of findings of the baseline studies conducted in 1982 including information gathered in 1987 and 1995. This section also describes what affects the commercial operation has had on the biological resources. The data base complies with federal and state requirements for commercial relicense applications and is sufficient to assess the probable impacts of continuing the project.

2.8.2 BASELINE DATA

The Terrestrial and Aquatic Ecology sections below summarize the results of the 1982 baseline data, including 1987 and 1995 information. For more detailed descriptions of the data, please refer to the Crow Butte Uranium Project Application and Supporting Environmental Report for NRC 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).

2.8.2.1 TERRESTRIAL ECOLOGY

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 immediate environs. Additional investigations were conducted within an 80-km (50-mi) Outer Area (OA) centered on Section 19, drawing primarily upon published sources of information.

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 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.

Vegetation

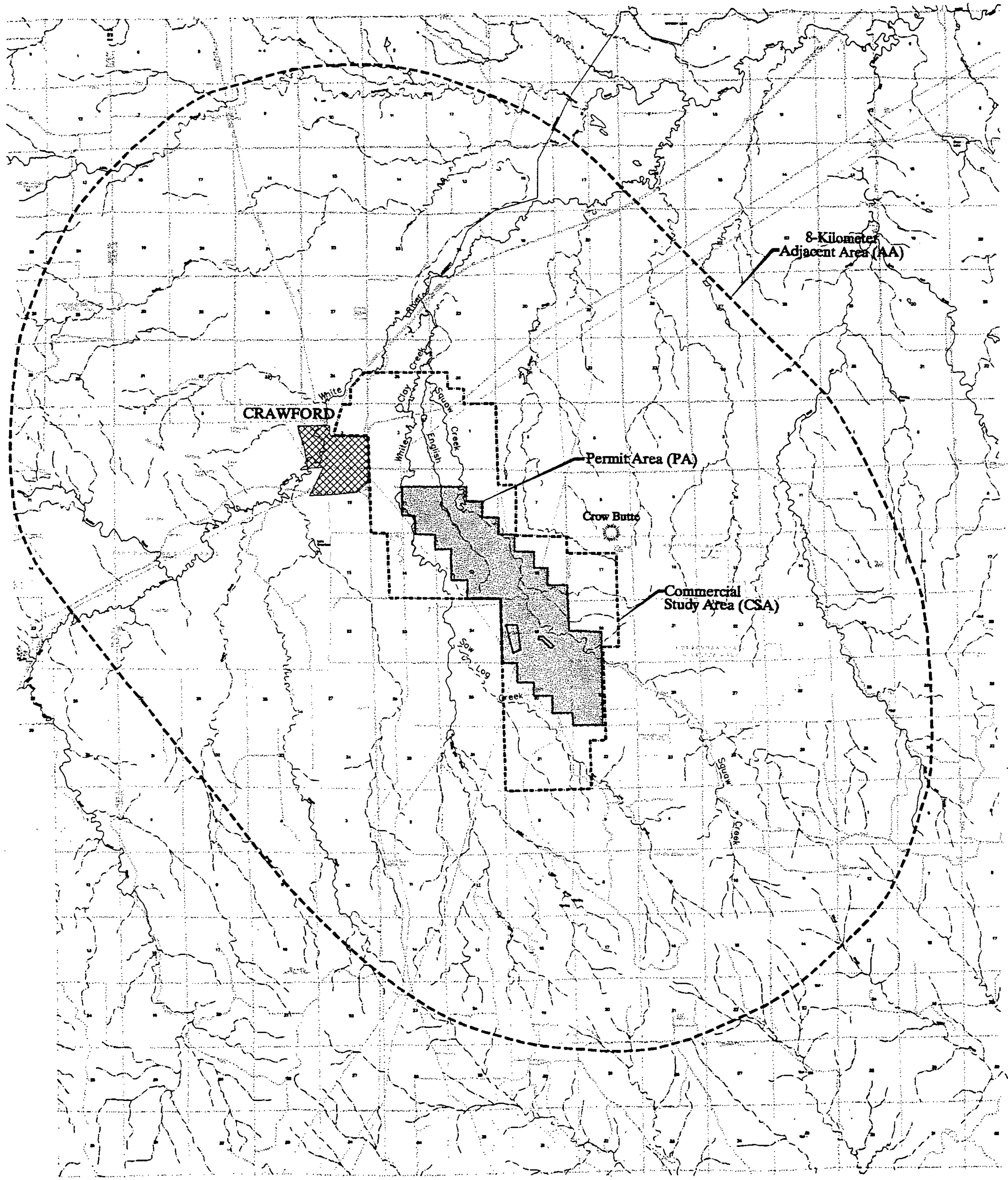
According to the Great Plains Flora Association (1977), about 1,020 species of plants should be expected to occur within 80-km of the CSA. The Chadron State College herbarium contains 468 species from Dawes County. During the baseline study between March and Mid-July, 1982, more than 400 species of plant were collected within the study area (CSA and AA). Of that number, 163 species were recorded within a specific Section 19 study. (See Table 2.8-1.

Study Area Vegetation Habitat Types

A vegetation classification system (Table 2.8-2) was derived for the study area, sufficient to include the flora within the 80-km OA, with particular reference to generating a system useful in identifying faunal habitat affinities (Figure 2.8-2). 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 WFC (1983).

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 outlined briefly below:



LEGEND

- Permit Area (PA)
- Commercial Study Area (CSA)
- Adjacent Area (AA)

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N

0 2 4

Scale (mi.)

GREYSTONE®

ECOLOGICAL STUDY AREA

CROW BUTTE PROJECT
Dawes County, Nebraska

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

- **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 exotic 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 exotics. Species that are conspicuously successful 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.

Threatened, Endangered, or Sensitive Plant Species

No plant species of state or federal concern has been found or are known to occur within the study area. Additionally, Van Bruggen (1977) points out that the Black Hills/Pine Ridge region is not an area where endemics occur. No endemics were found in the 1982 surveys and it is doubtful any are present in the study area.

Mammals

Thirty-six species of wild mammals were documented within the study area, and another 28 species, mostly bats, insectivores and small rodents, are deemed likely to occur (Table 2.8-4).

Big Game Mammals

Mule deer are distributed primarily along the foothills and escarpments, ranging outward into cultivated land (its preferred habitat type during the 1982 survey). White-tailed deer were distributed more widely than mule deer and were recorded in a greater range of habitat types. Most commonly used habitats, however, were the Deciduous Woodland Types.

Table 2.8-1: Plant Species List

Common Name	Scientific Name
TREES	
Box elder	*Acer negundo*
Green ash	*Fraxinus pennsylvanica*
Ponderosa pine	*Pinus ponderosa*
Plains cottonwood	*Populus deltoides*
Wild plum	*Prunus americana*
Coyote willow	*Salix exigua*
Siberian elm	*Ulmus pumila*
American elm	*Ulmus americana*
SHRUBS	
Western sagebrush	*Artemisia campestris*
Fringed sagebrush	*Artemisia frigida*
Broom snakeweed	*Gutierrezia sarothrae*
Chokecherry	*Prunus virginiana*
Aromatic sumac	*Rhus aromatica*
Buffalo currant	*Ribes odoratum*
Prickly wild rose	*Rosa acicularis*
Western wild rose	*Rosa woodsii*
Prairie wild rose	*Rosa arkansana*
Western snowberry	*Symphoricarpos occidentalis*
FORBS	
Primrose	
Yarrow	*Achillea millefolium*
False dandelion	*Agoseris glauca*
White wild onion	*Allium textile*
Tumbleweed amaranth	*Amaranthus graecizans*
Rough pigweed	*Amaranthus retroflexus*
Western rocky jasmine	*Androsace occidentalis*
Pasque-flower	*Anemone patens*
Rose pussytoes	*Antennaria rosea*
Hemp dogbane	*Apocynum cannabinum*

Table 2.8-1: Plant Species List

Common Name	Scientific Name
Rockcress	*Arabis holboellii*
Hooker sandwort	*Arenaria hookeri*
Prickle poppy	*Argemone polyanthemos*
White sage	*Artemisa ludoviciana*
Showy milkweed	*Asclepias speciosa*
Missouri milkvetch	*Astragalus missouriensis*
Slender milkvetch	*Astragalus gracilis*
Charlock	*Brassica kaber*
Mariposa lily	*Calochortus nuttalii*
Harebell	*Campanula rotundifolia*
Shepherd's purse	*Capsella bursa-pastoris*
Prairie chickweed	*Cerastium arvense*
Gremont goosefoot	*Chenopodium fremontii*
Lamb's quarters	*Chenopodium album*
Maple-leaved goosefoot	*Chenopodium leptophyllum*
Blue mustard	*Chorispora tenella*
Golden aster	*Chrysopsis villosa*
Bull thistle	*Cirsium vulgare*
Wavyleaf thistle	*Cirsium undulatum*
Western clematis	*Clematis ligusticifolia*
Rocky mountain beeplant	*Cleome serrulata*
Bastard toadflax	*Comandra umbellata*
Hedge bindweed	*Convolvulus sepium*
Field bindweed	*Convolvulus arvensis*
Golden corydalis	*Corydalis aurea*
Hawk's-beard	*Crepis runcinata*
Texas croton	*Croton texensis*
James' cryptantha	*Cryptantha jamesii*
Tansy mustard	*Descurainia pinnata*
Flixweed	*Descurainia sophia*
White whitlowwort	*Draba reptans*
Smooth horsetail	*Equisetum laevigatum*

Table 2.8-1: Plant Species List

Common Name	Scientific Name
Purple coneflower	*Echinacea angustifolia*
Low fleabane	*Erigeron pumilus*
Bushy wallflower	*Erysimum repandum*
Western wallflower	*Erysimum asperum*
Leafy spurge	*Euphorbia esula*
Catchweed bedstraw	*Galium aparine*
Scarlet gaura	*Gaura coccinea*
Curly-top gumweed	*Grindelia squarrosa*
Common sunflower	*Helianthus annuus*
Plains sunflower	*Helianthus petiolaris*
Common Hop	*Humulus lupulus*
Kochia	*Kochia scoparia*
Low stickseed	*Lappula redowskii*
Bladderpod	*Lesquerella ludoviciana*
Mountain lily	*Leucocrinum montanum*
Blue Flax	*Linum perenne*
Stiffstem flax	*Linum rigidum*
Narrow-leaved puccoon	*Lithospermum incisum*
Wild parsely	*Lomatium nutallii*
Silvery lupine	*Lupinus argenteus*
Skeleton-weed	*Lygodesmia juncea*
Common mallow	*Malva rotundifolia*
Alfalfa	*Medicago sativa*
Yellow lucerne	*Medicago flacata*
Yellow sweetclover	*Melilotus officinalis*
White sweetclover	*Melilotus alba*
Field mint	*Mentha arvensis*
Spotted beebalm	*Monarda pectinata*
Gumbo lily	*Oenothera caespitosa*
White-stemmed evening	*Oenothera nuttallii*
Purple locoweed	*Oxytropis lambertii*

Table 2.8-1: Plant Species List

Common Name	Scientific Name
James nailwort	*Paronychia jamesii*
Woodbine	*Parthenocissus vitacea*
Large beartongue	*Penstemon grandiflorus*
Narrow beartongue	*Penstemon angustifolia*
Smooth beartongue	*Penstemon glaber*
White beartongue	*Penstemon albidus*
Moss phlox	*Phlox andicola*
Buckhorn	*Plantago patagonica*
White milkwort	*Polygala alba*
Wild buckwheat	*Polygonum convolvulus*
Bushy knotweed	*Polygonum ramosissimum*
Breadrood scurf pea	*Psoralea esculenta*
Lemon scurf pea	*Psoralea lanceolata*
Silver-leaf scurf pea	*Psoralea agrophylla*
Early wood buttercup	*Ranunculus abortivus*
Prairie coneflower	*Ratibida columnifera*
Black-eyed susan	*Rudbeckia hirta*
Russian thistle	*Salsola iberica*
Prairie ragwort	*Senecio plattensis*
Tumbling mustard	*Sisymbrium altissimum*
Blue-eyed grass	*Sisyrinchium montanum*
Spikenard	*Smilacina stellata*
Buffalobur	*Solanum rostratum*
Red false mallow	*Sphaeralcea coccinea*
Common chickweed	*Stellaria media*
Dandelion	*Taraxacum officinale*
Purple meadowrue	*Thalictrum dasycarpum*
Pennycress	*Thlaspi arvense*
Easter daisy	*Townsendia exscapa*
Poison ivy	*Toxicodendron rydbergii*
Prairie spiderwort	*Tradescantia occidentalis*
Goatsbeard	*Tragopogon dubius*

Table 2.8-1: Plant Species List

Common Name	Scientific Name
Puncturevine	*Tribulus terrestris*
Stinging nettle	*Urtica dioica*
Common mullein	*Verbascum thapsus*
American vetch	*Vicia americana*
Canada violet	*Viola canadensis*
Yellow prairie violet	*Viola nuttallii*
Death camass	*Zigadenus venenosus*
GRASSES	
Intermediate wheatgrass	*Agropyron intermedium*
Crested wheatgrass	*Agropyron cristatum*
Smoothcrested wheatgrass	*Agropyron pectiniforme*
Western wheatgrass	*Agropyron smithii*
Little bluestem	*Andropogon scoparius*
Red threeawn	*Aristada longiseta*
Blue grama	*Bouteloua gracilis*
Cheatgrass	*Bromus tectorum*
Japanese brome	*Bromus japonicus*
Smooth brome	*Bromus inermis*
Buffalo-grass	*Buchloe dactyloides*
Wooly-headed sedge	*Carex lanuginosa*
Bottlebrush sedge	*Carex hystericina*
Thread-leaved sedge	*Carex filifolia*
Nebrasla sedge	*Carex nebraskensis*
Ross' sedge	*Carex rossii*
Field sandbur	*Cenchrus longispinus*
Canada wild rye	*Elymus canadensis*
Six-weeks fescue	*Festuca octoflora*
Little barley	*Hordeum pusillum*
Foxtail barley	*Hordeum jubatum*
Baltic rush	*Juncus balticus*
Junegrass	*Koeleria pyramidata*

Table 2.8-1: Plant Species List

Common Name	Scientific Name
Indian ricegrass	*Oryzopsis hymenoides*
Witchgrass	*Panicum capillare*
Sandberg bluegrass	*Poa sandbergii (=P. secunda)*
Canada bluegrass	*Poa compressa*
Kentucky bluegrass	*Poa pratensis*
Green foxtail	*Sertaria viridis*
Yellowtail foxtail	*Sertaria glauca*
Squirreltail	*Sitanion hystrix*
Green needlegrass	*Stipa viridula*
Needle-and-thread	*Stipa comata*
Annual wheatgrass	*Triticum aestivum*
Wheatgrass	*Wheatgrass*
SUCCULENTS	
Pincushion cactus	*Coryphantha vivipara*
Brittle prickly pear	*Opuntia fragilis*
Yucca	*Yucca glauca*

Table 2.8-2: Habitat Classification System

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
- 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

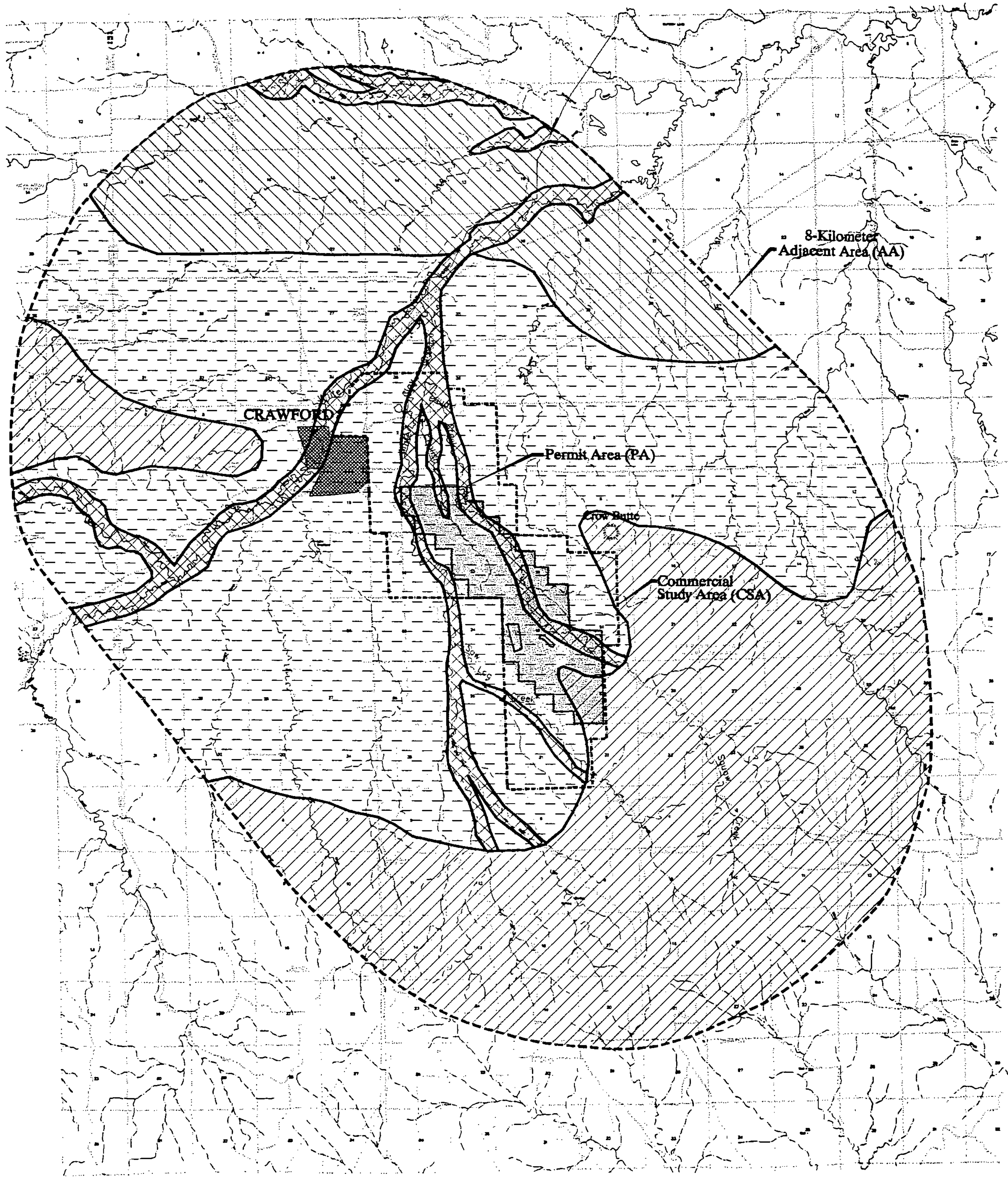
200 - Xerophytic Shrublands
- 211 - Big Sagebrush

Table 2.8-2: Habitat Classification System

	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
	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

Table 2.8-3: Commercial Study Area 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**



LEGEND

- Permit Area (PA)
- Commercial Study Area (CSA)
- Adjacent Area (AA)
- Shortgrass Prairie
- Mixed Grass Prairie (Short/Mid-Grass)
- Deciduous Woodland
- Coniferous Woodland

9601300331-05

N

0 2 4

Scale (mi.)

GREYSTONE®

MAJOR VEGETATION TYPES-BIOMES (Potential Vegetation)

CROW BUTTE PROJECT
Dawes County, Nebraska

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

Pronghorn in the study area are divided into three separate populations (WFC, 1983). However, none of the populations extend into the CSA.

Elk have been expanding their range to include Pine Ridge south of the project area and have been moving westward in the Nebraska National Forest toward the project area (Suetsuga, Lemmons, 1987). The project area could be used sporadically by elk for feeding, but it would not be classified as home territory (Prochazka, 1987). Elk have also been seen more frequently north of the project area between Crawford and Harrison.

Carnivores

The most commonly observed carnivore on the study area was the feral house cat, occurring widely and in an estimated ratio of five cats per wild carnivore observed. Coyotes, red foxes, and long-tailed weasels range widely throughout the study area in low numbers. Bobcats, Badgers, and striped skunks also occur in the study area, but less commonly. Black-footed ferret and swift fox are described in the Threatened, Endangered, and Sensitive Mammals section.

Small Mammals

Small mammal trapping was conducted during the spring of 1982. The most abundant and widespread species was the deer mouse (WFC, 1983). Other species captured included white-footed mouse 13 lined ground squirrel, and meadow mole.

Muskrats were recorded commonly along watercourses and occur in all permanent impoundments. Beaver are located in the White River Basin and have been introduced into Squaw Creek since 1982. Porcupines and fox squirrels are common, ranging throughout the study area. White-tailed and black-tailed jackrabbits range over the study area. Additionally, Eastern cottontails are common within the study area.

Domestic Mammals

Domestic ungulates 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).

Table 2.8-4: Mammal Species List

Order/Common Name	Scientific Name	Status[1]	Status[2]	Status[3]
CARNIVORES				
Carnivora				
Raccoon	*Procyon lotor*	D	CA	C
Long-tailed weasel	*Mustela frenata*	D	CA	U
Mink	*Mustela vison*	D	AA	U
Black-footed ferret	*Mustela nigripes*	E	OA	F
Badger	*Taxidea taxus*	D	AA	U
Spotted skunk	*Spilogale putorius*	E	AA	U
Striped skunk	*Mephitis mephitis*	D	CA	C
Coyote	*Canis latrans*	D	CA	U
Swift fox	*Vulpes velox*	R	AA	S
Red fox	*Vulpes fulva*	D	CA	U
Bobcat	*Lynx rufus*	D	AA	U
Mountain lion	*Felis concolor*	R	OA	U
BIG GAME MAMMALS				
Artiodactyla				
Mule deer	*Odocoileus hemionus*	D	CA	C
White-tailed deer	*Odocoileus virginianus*	D	CA	C
Pronghorn	*Antilocapra americana*	D	AA	C
Elk	*Cervus elaphus*	D	AA	U
Bighorn sheep	*Ovis canadensis*	D	AA	U
Bison	*Bison bison*	D	AA	U
Moose	*Alces alces*	R	OA	U
Mule deer/White-tailed deer hybrid	*O. hemionus x virginianus*	D	AA	U
SMALL MAMMALS				
Chiroptera				
Keen myotis	*Myotis keeni*	E	CA	U
Little brown myotis	*Myotis lucifugus*	E	CA	C
Fringed myotis	*Myotis thysanodes*	E	CA	C
Long-eared myotis	*Myotis evotis*	E	CA	U
Long-legged myotis	*Myotis volans*	E	CA	U

Table 2.8-4: Mammal Species List

Order/Common Name	Scientific Name	Status[1]	Status[2]	Status[3]
Small-footed myotis	*Myotis subulatus*	E	CA	U
Silver-haired bat	*Lasionycteris noctivagans*	E	CA	U
Red bat	*Lasiurus borealis*	E	AA	U
Big brown bat	*Eptesicus fuscus*	E	CA	C
Hoary bat	*Lasiurus cinereus*	E	CA	U
Western big-eared bat	*Plecotus townsendi*	E	AA	U
Insectivora				
Masked shrew	*Sorex cinereus*	E	CA	U
Dwarf shrew	*Sorex nanus*	E	CA	U
Merriam shrew	*Sorex merriami*	E	AA	U
Least shrew	*Cryptotis parva*	E	CA	U
Eastern mole	*Scalopus aquaticus*	D	CA	U
Lagomorpha				
White-tailed jackrabbit	*Lepus townsendi*	D	CA	C
Black-tailed jackrabbit	*Lepus californicus*	D	CA	U
Eastern cottontail	*Sylvilagus floridanus*	D	CA	C
Desert cottontail	*Sylvilagus auduboni*	D	AA	U
Rodentia				
Black-tailed prairie dog	*Cynomys ludovicianus*	D	CA	U
Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*	D	CA	C
Spotted ground squirrel	*Citellus spilosoma*	D	OA	U
Least chipmunk	*Eutamias minimus*	D	AA	U
Eastern fox squirrel	*Sciurus niger*	D	CA	C
Northern pocket squirrel	*Thomomys talpoides*	D	CA	C

Table 2.8-4: Mammal Species List

Order/Common Name	Scientific Name	Status[1]	Status[2]	Status[3]
Plains pocket gopher	*Geomys bursarius*	E	CA	U
Wyoming pocket mouse	*Perognathus fasciatus*	E	CA	U
Plains pocket mouse	*Perognathus flavescens*	E	CA	U
Silky pocket mouse	*Perognathus flavus*	E	CA	U
Hispid pocket mouse	*Perognathus hispidus*	E	CA	U
Ord kangaroo rat	*Dipodomys ordii*	D	CA	C
Beaver	*Castor canadensis*	D	AA	U
Plains harvest mouse	*Reithrodontomys montanus*	E	CA	U
Western harvest mouse	*Reithrodontomys megalotis*	E	CA	U
White-footed mouse	*Peromyscus leucopus*	D	CA	C
Deer mouse	*Peromyscus maniculatus*	D	CA	A
Northern grasshopper mouse	*Onychomys leucogaster*	E	CA	U
Eastern woodrat	*Neotoma floridana*	E	AA	U
Bushy-tailed woodrat	*Neotoma cinerea*	E	AA	U
Brown rat	*Rattus norvegicus*	E	CA	U
House mouse	*Mus musculus*	D	CA	C
Meadow vole	*Microtus pennsylvanicus*	D	CA	C
Prairie vole	*Microtus ochrogaster*	D	CA	U
Muskrat	*Ondatra zibethicus*	D	CA	C
Meadow jumping mouse	*Zapus hudsonicus*	D	CA	U
Porcupine	*Erethizon dorsatum*	D	CA	C

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).

[2] Distribution:
AA Within the 8-km Adjacent Area Boundary.
CA Within the Commercial Study Area Boundary.
OA Within the 80-km Outer Area Boundary.

[3]Abundance:
A Abundant.
C Common.
F Federally-listed Rare, Threatened, or Endangered.
O Occasional, Accidental, or Rare in study area.
S State-listed Rare, Threatened, or Endangered.
U Uncommon.

Threatened, Endangered, and Sensitive Mammals

Threatened and Endangered mammals that may occur in the region include the black-footed ferret (federal and state listed as endangered) and the swift fox (listed as state endangered). The black-footed ferret was last observed in Nebraska north of the study area in 1959 (USFS, 1978). Its principal prey, the prairie dog, is uncommon on the study area. The two colonies found in the AA and the single prairie dog (no colony) found in the CSA (Figure 2.8-3) are probably insufficient to sustain a viable ferret population (WFC, 1983). Because no prairie dog colonies were found within the CSA, there is no chance of black-footed ferrets occurring there.

Approximately 40 sightings of swift fox have been documented in northwest Nebraska by Nebraska Game and Parks since the late 1970's. Most of these sightings have occurred west of Fort Robinson Sate Park. However, there were two confirmed and one probable sighting of swift fox within the 5-mile radius of the AA. These sightings were in the shortgrass prairie west of the CSA in habitat typical of the species. The closest sighting occurred just west of the CSA near Highway 2 in 1986. No sightings have occurred on the CSA and although the swift fox could use the CSA as a hunting area, the amount of cultivated land and poor condition of the range would most likely preclude the swift fox from inhabiting the CSA. Swift foxes might be expected to occur in low numbers anywhere within the grassland habitat in the region.

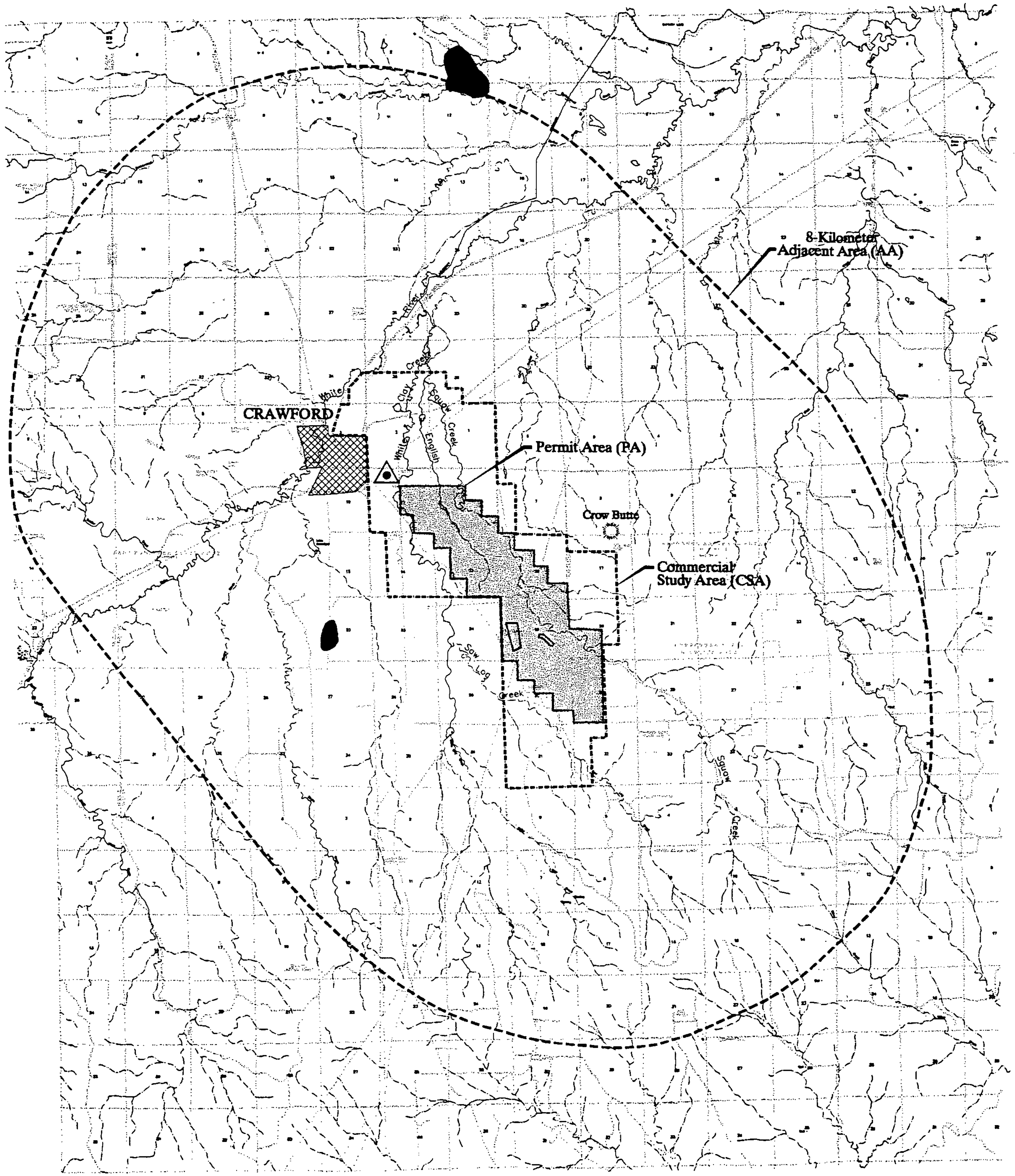
Birds

According to published sources (Johnsgard, 1979; USFS, 1981), 302 species of birds have been reported within 80-km of the study area. During the 1982 study, 201 species were documented within the study area (Table 2.8-5).

Upland Game Birds

Turkey is the most popular game bird in the region and is widely distributed within the study area (WFC, 1983). However, the species is not native to the Pine Ridge area, and the current population is semi-domesticated and requires supplemental feeding in winter. Although the species does not regularly occur on the CSA, it may occur in proportion to the amount of supplemental winter feeding offered by local landowners.

Pheasants are common within the study area, with about half the 1982 observations recorded in the CSA. The total CSA pheasant population was estimated at 180 birds in the spring of 1982. Sharp-tailed grouse are also common within the study area, with about 10 percent found in the CSA.



LEGEND

- Permit Area (PA)
- Commercial Study Area (CSA)
- Adjacent Area (AA)
- Prairie Dog Colony
- Single Prairie Dog Observation

9601300331-06

N

0 2 4

Scale (mi.)

GREYSTONE®

LOCATION OF PRAIRIE DOG COLONIES

CROW BUTTE PROJECT
Dawes County, Nebraska

Scale: 1"=2 miles	Date: 10/95	Figure 2.8-3

Waterfowl

Ground surveys for waterfowl were initiated in March 1982 and were conducted weekly until the end of June. Twenty-four species were observed during the survey, 19 of which were found in CSA (Table 2.8-5). The mallard was the most commonly observed species of waterfowl while the snow goose and hooded merganser were the least commonly observed.

Impoundments and wetlands were the most important habitat types used in the study area. The area of waterfowl concentration within the CSA included impoundment I-6 (See Figure 2.8-5 in the Aquatics Section), where 18 of the 19 species were observed (WFC, 1983). The waterfowl concentration areas within the AA included impoundment M-1 and Class II, III, and V wetlands north and northwest of this impoundment.

Raptors

Several raptor species (Table 2.8-5) were documented on the study area, a reflection of the diversity in habitat types and the existence of many suitable nesting sites such as trees and cliff sites. Raptor nesting locations identified in 1982 are presented in Figure 2.8-4. Golden eagles are permanent residents of the area, ranging over most of the study area in a variety of habitats. The presence of five active golden eagle nesting territories on the study area suggests that the species is near saturation density in the area. Bald eagles are discussed in the Threatened, Endangered, and Sensitive Birds section.

Red-tailed hawks, kestrels, Northern harriers, prairie falcons, turkey vultures, and great horned owls are common permanent residents of the study area and within CSA. Rough-legged hawks are common winter residents of the CSA, occurring on the study area until early April (WFC, 1983).

Ferruginous hawks, merlins, goshawks, Cooper's hawks, sharp-shinned hawks, burrowing owls, barn owls, short-eared owls, screech owls, saw-whet owls, and gyrfalcons are uncommon, but do occur in the study area with most also within the CSA (WFC, 1983).

Other Bird Species

During the 1982 ecology survey, a bird population transect study was conducted (WFC, 1983). The most abundant bird was the red crossbill. Other common birds (densities of more than one per ha) were the redwing blackbird, blackcapped chickadee, mourning dove, rufous-sided towhee, yellow warbler, house wren, violet-green swallow and pine siskin (Table 2.8-5).

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
GAVIIFORMES					
Common loon	*Gavia immer*	R	OA	O	m
Arctic loon	*Gavia arctica*	R	OA	O	m
PODICIPEDIFORMES					
Red-necked grebe	*Podiceps grisegena*	R	OA	O	m
Horned grebe	*Podiceps auritus*	D	AA	U	m
Eared grebe	*Podiceps caspicus*	D	CA	U	sv
Western grebe	*Aechmophorus occidentalis*	D	CA	U	sv
Pied-billed grebe	*Podilymbus podiceps*				
PELECANIFORMES					
White pelican**	*Pelicanus erythrorhynchos*	D	AA	U	sr
Double-crested cormorant**	*Phalacrocorax auritus*	D	CA	U	sr
CICONIFORMES					
Great blue heron	*Ardea herodias*	D	CA	U	sr
Green heron	*Butorides virescens*	R	OA	O	m
Cattle egret	*Bubulcus ibis*	R	OA	O	m
Great egret	*Casmerodius albus*	R	OA	O	m
Snowy egret	*Leucophoyx thula*	R	OA	O	m
Black-crowned night heron**	*Nycticorax nycticorax*	D	CA	U	sr
Yellow-crowned night heron	*Nyctanassa violacea*	R	OA	O	m
American bittern**	*Botaurus lentiginosus*	D	AA	U	sr
White-faced ibis	*Plegadia chihi*	R	OA	O	m
ANSERIFORMES					
Whistling swan	*Olor columbianus*	R	OA	O	m
Trumpeter swan	*Olor buccinator*	D	AA	O	m
Canada goose	*Branta canadensis*	D	CA	U	pr
Brant	*Branta bernicla*	R	OA	U	pr
White-fronted goose	*Anser albifrons*	D	AA	U	m
Snow goose	*Chen hyperborea*	D	CA	U	m
Mallard*	*Anas plantyrhynchos*	D	CA	C	pr

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
Black duck	*Anas rubripes*	R	OA	O	m
Gadwall**	*Anas strepera*	D	CA	C	sr
Pintail**	*Anas acuta*	D	CA	C	sr
Green-winged teal**	*Anas carolinensis*	D	CA	U	sr
Blue-winged teal**	*Anas discors*	D	CA	C	sr
Cinnamon Teal	*Anas cyanoptera*	D	CA	U	sr**
American Wigeon	*Mareca americana*	D	CA	U	sr**
Northern Shoveler	*Spatula clypeata*	D	CA	C	sr**
Wood Duck	*Aix sponsa*	D	CA	U	sv**
Redhead	*Aythya americana*	D	CA	U	sv
Ring-necked Duck	*Aythya collaris*	D	AA	U	m
Canvasback	*Aythya valisineria*	D	AA	U	m
Lesser Scaup	*Aythya affinis*	D	CA	C	m
Common Goldeneye	*Bucephala clangula*	D	CA	U	m
Barrow's Goldeneye	*Bucephala islandica*	R	OA	O	wv
Bufflehead	*Bucephala albeola*	D	CA	C	m
Oldsquaw	*Clangula hyemalis*	R	OA	U	m
White-winged Scoter	*Melanitta deglandi*	R	OA	U	m
Surf Scoter	*Melanitta perspicillata*	R	OA	U	m
Black Scoter	*Oidemia nigra*	R	OA	U	m
Ruddy Duck	*Oxyura jamaicensis*	D	CA	C	sr**
Hooded merganser	*Lophodytes cucullatus*	D	CA	U	m
Common Merganser	*Mergus merganser*	D	CA	U	m
Red-breasted merganser	*Mergus serrator*	R	OA	O	m
FALCONIFORMES					
Turkey Vulture	*Cathartes aura*	D	CA	U	sr**
Goshawk	*Accipiter gentilis*	D	CA	U	wv
Sharped-shinned Hawk	*Accipiter striatis*	D	AA	U	pr**
Cooper's Hawk	*Accipiter cooperi*	D	AA	U	pr*
Red-tailed Hawk	*Buteo jamaicensis*				
(Light Phase)	"	D	CA	C	sr*
(Dark Phase)	"	D	AA	U	m

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
Red-shouldered Hawk	*Buteo lineatus*	R	OA	O	m
Broad-winged Hawk	*Buteo platypterus*	R	OA	O	m
Swainson's Hawk	*Buteo swainsoni*	R	OA	U	sr**
Rough-legged Hawk	*Buteo lagopus*	D	CA	C	wv
Ferruginous Hawk	*Buteo regalis*	D	AA	U	sr*
Golden Eagle	*Aquila chrysaetos*	D	CA	C	pr*
Bald Eagles	*Haliaeetus leucocephalus*	D	CA	F	wv
Northern Harrier	*Circus cyaneus*	D	CA	C	pr**
Osprey	*Pandion haliaetus*	R	AA	O	sv
Gyrfalcon	*Falco rusticolus*	D	AA	U	m
Pairie Falcon	*Falco mexicanus*	D	CA	C	pr**
Peregrine Falcon	*Falco peregrinus*	R	OA	F	m
Merlin	*Falco columbarius*	D	AA	U	pr**
American Kestrel	*Falco sparverius*	D	CA	A	pr*
GALLIFORMES					
Sharp-tailed grouse*	*Pedioecetes phasianellus*	D	CA	C	pr
Bobwhite	*Colinus virginianus*	R	OA	O	pr
Ring-necked pheasant*	*Phasianus colchicus*	D	CA	C	pr
Turkey*	*Meleagris gallopavo*	D	AA	C	pr
Gray partridge**	*Perdix perdix*	D	AA	O	pr
GRUIFORMES					
Sandhill crane	*Grus canadensis*	D	OA	U	m
Virginia rail**	*Rallus limicola*	D	AA	U	sr
Sora rail**	*Porzana carolina*	D	CA	U	sr
American coot**	*Fulica americana*	D	CA	C	sr
CHARADRIIFORMES					
Semipalmated plover	*Charadrius semipalmatus*	R	OA	U	m
Piping plover	*Charadrius melodus*	R	OA	U	m
Snowy plover	*Charadrius alexandrinus*	R	OA	O	m
Killdeer*	*Charadrius vociferus*	D	CA	C	sr
American golden plover	*Pluvialis dominica*	R	OA	U	m

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
Black-bellied plover	*Squatarola squatarola*	D	AA	U	m
Marbled godwit	*Lemosa fedoa*	D	AA	U	m
Whimbrel	*Numenius phaeopus*	R	OA	O	m
Long-billed curlew**	*Numenius americanus*	D	AA	U	sr
Upland sandpiper**	*Bartramia longicauda*	D	AA	U	sr
Greater yellowlegs	*Totanus melanoleucus*	D	CA	C	m
Lesser yellowlegs	*Totanus flavipes*	D	CA	C	m
Solitary sandpiper	*Tringa solitaria*	D	CA	U	m
Willet**	*Catoptrophorus semipalmatus*	D	CA	U	sr
Spotted sandpiper**	*Actitis macularia*	D	CA	C	sr
Common snipe*	*Capella gallinago*	D	CA	C	pr
Short-billed dowitcher	*Limnodromus griseus*	R	OA	U	m
Long-billed dowitcher	*Limnodromus scolopaceus*	D	AA	C	m
Red knot	*Calidris canutus*	R	OA	O	m
Sanderling	*Calidris alba*	D	AA	U	m
Semipalmated sandpiper	*Ereunetes pusillus*	D	AA	U	m
Western sandpiper	*Ereunetes mauri*	R	OA	U	m
Least sandpiper	*Eriola minutilla*	D	CA	U	m
White-rumped sandpiper	*Eriola fuscicollis*	R	OA	U	m
Baird's sandpiper	*Eriola bairdii*	D	AA	C	m
Pectoral sandpiper	*Eriola melanotos*	R	OA	U	m
Stilt sandpiper	*Micropalama himantopus*	D	AA	C	m
CHARADRIIFORMES					
Buff-breasted sandpiper	*Tryngites subrufficollis*	R	OA	U	m
American avocet**	*Recurvirostra americana*	D	AA	V	sr
Wilson's phalarope**	*Steganopus tricolor*	D	CA	V	sr

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
Northern phalarope	*Lobipes lobatus*	D	AA	U	m
Parasitic jaeger	*Stercorarius parasiticus*	R	OA	I	m
Herring gull	*Larus argentatus*	R	OA	U	m
California gull	*Larus californicus*	R	OA	U	m
Ring-billed gull	*Larus delawarensis*	D	CA	C	sv
Black-headed gull	*Larus ridibundus*	R	OA	O	m
Franklin's gull	*Larus pipixcan*	D	AA	C	sv
Bonaparte's gull	*Larus philadelphia*	R	OA	U	m
Forster's Tern	*Sterna forsteri*	D	AA	U	sv
Common tern	*Sterna hirundo*	R	OA	O	m
Least (Least interior) Tern	*Sterna albifrons*	R	OA	S	m
Black tern**	*Chlidonias niger*	D	AA	U	sr
COLUMBIFORMES					
Mourning dove*	*Zenaidura macroura*	D	CA	A	sr
Rock dove*	*Columba livia*	D	CA	C	pr
CUCULIFORMES					
Yellow-billed cuckoo**	*Coccyzus americanus*	D	CA	A	sr
Black-billed cuckoo**	*Coccyzus erythropthalmus*	D	CA	U	sr
STRIGIFORMES					
Barn owl**	*Tyto alba*	D	AA	U	pr
Screech owl**	*Otus asio*	D	AA	U	pr
Great horned owl*	*Bubo virginianus*	D	CA	C	pr
Snowy owl	*Nyctea scandiaca*	R	OA	U	wv
Burrowing owl*	*Speotyto cunicularia*	D	AA	U	sr
Barred owl	*Strix varia*	R	OA	O	pr
Long-eared owl	*Asio otus*	R	OA	U	pr
Short-eared owl**	*Asio flammeus*	D	CA	U	pr
Saw-whet owl**	*Aegolius acadicus*	D	AA	U	pr
CAPRIMULGIFORMES					
Common poor-will**	*Phalaenoptilus*	D	AA	U	sr

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
	nuttallii				
Common nighthawk**	*Chordeiles minor*	D	CA	C	sr
APODIFORMES					
Chimney swift**	*Chaetura pelagica*	D	AA	U	sr
White-throated swift**	*Aeronautes saxatalis*	D	AA	U	sr
Broad-tailed hummingbird	*Selasphorus platycercus*	R	OA	O	m
Rufous hummingbird	*Selasphorus rufus*	R	OA	O	m
CORACIIFORMES					
Belted kingfisher**	*Megaceryle alcyon*	D	CA	U	sr
PICIFORMES					
Common flicker*	*Colaptes auratus*	D	CA	C	pr
Red-bellied woodpecker	*Centurus carolinus*	R	OA	O	sr
Red-headed woodpecker*	*Melanerpes erythrocephalus*	D	CA	C	sr
Lewis' woodpecker**	*Asyndesmus lewis*	D	AA	U	sr
Yellow-bellied sapsucker	*Sphyrapicus varius*	R	OA	U	m
Hairy woodpecker**	*Dendrocopos villosus*	D	CA	C	pr
Downy woodpecker**	*Dendrocopos pubescens*	D	CA	C	pr
PASSERIFORMES					
Eastern kingbird*	*Tyrannus tyrannus*	D	CA	C	sr
Western kingbird*	*Tyrannus verticalis*	D	CA	C	sr
Cassin's kingbird	*Tyrannus vociferans*	R	OA	U	sv
Scissor-tailed flycatcher	*Muscivora forfic*	R	OA	O	m
Great crested flycatcher**	*Myiarchus crinitus*	D	CA	U	sr
Eastern phoebe**	*Sayornis phoebe*	D	AA	U	sr
Say's phoebe**	*Sayornis saya*	D	CA	U	sr
Black phoebe	*Sayornis nigricans*	D	AA	O	m
Willow flycatcher**	*Empidonax traillii*	D	AA	U	sr
Least flycatcher	*Empidonax minimus*	D	AA	U	m
Hammond's flycatcher	*Empidonax hammondii*	R	OA	O	m

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
Western flycatcher	*Empidonax difficilis*	R	OA	O	m
Eastern pewee**	*Contopus virens*	D	AA	U	sr
Western pewee*	*Contopus sordidulus*	D	CA	C	sr
Olive-sided flycatcher	*Nuttalornis borealis*	R	OA	U	m
Horned lark*	*Eremophila alpestris*	D	CA	C	pr
Violet-green swallow**	*Tachycineta thallassina*	D	CA	U	sr
Tree swallow**	*Iridoprocne bicolor*	D	CA	U	sr
Bank swallow*	*Riparia riparia*	D	CA	C	sr
Rough-winged swallow**	*Stelgidopteryx ruficollis*	D	CA	C	sr
Barn swallow*	*Hirundo rustica*	D	CA	C	sr
Cliff swallow*	*Petrochelidon pyrrhonota*	D	CA	C	sr
Purple martin	*Progne subis*	R	OA	O	m
Gray jay	*Perisoreus canadensis*	R	OA	O	wv
Blue jay**	*Cyanocitta cristata*	R	CA	C	pr
Stellar's jay	*Cyanocitta stelleri*	R	OA	O	wv
Black-billed magpie*	*Pica pica*	D	CA	C	pr
American crow*	*Corvus branchyrhynchos*	D	CA	C	pr
Pinyon Jay**	*Gymnorhinus cyanocephalus*	D	CA	C	pr
Clark's nutcracker	*Nucifraga columbiana*	R	OA	O	wv
Black-capped chickadee**	*Parus atricapillus*	D	CA	C	pr
Tufted titmouse	*Parus bicolor*	R	OA	O	m
White-breasted nuthatch**	*Sitta carolinensis*	D	CA	C	pr
Red-breasted nuthatch**	*Sitta canadensis*	D	CA	C	pr
Pygmy nuthatch**	*Sitta pygmaea*	D	AA	C	pr
Brown creeper**	*Certha familiaris*	D	AA	U	pr
Dipper	*Cinclus mexicanus*	R	R	U	wv

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
Northern house wren**	*Troglodytes aedon*	D	CA	C	sr
Winter wren	*Troglodytes troglodytes*	R	OA	U	wv
Bewick's wren	*Thryomanes bewickii*	R	OA	O	m
Carolina wren	*Thryothorus ludovicianus*	R	OA	O	m
Marsh wren**	*Telmatodytes palustris*	D	AA	U	sr
Canyon wren	*Catherpes mexicanus*	R	OA	O	wv
Rock wren**	*Salpinctes obsoletus*	D	AA	U	sr
Mockingbird	*Mimus polyglottos*	R	OA	U	sv
Gray catbird**	*Dumetella carolinensis*	D	CA	C	sr
Brown thrasher**	*Toxostoma rufum*	D	CA	C	sr
Sage thrasher	*Orescoptes montanus*	R	OA	U	sv
American robin*	*Turdus migratorius*	D	CA	C	sr
Wood thrush	*Hylocichla mustelina*	D	AA	U	m
Hermit thrush	*Hylocichla guttata*	D	AA	U	m
Swainson's thrush	*Hylocichla ustalata*	D	CA	C	m
Gray-cheeked thrush	*Hylocichla ustalata*	D	CA	C	m
Veery	*Hylocichla fuscenscens*	D	CA	U	m
Eastern bluebird	*Sialia sialis*	R	OA	U	sv
Mountain bluebird**	*Sialia currucoides*	D	CA	C	sr
Townsend's solitaire**	*Myadestes townsendi*	D	AA	U	pr
Blue-gray gnatcatcher	*Polioptila caerulea*	R	OA	O	m
Golden-crowned kinglet	*Rugulus satrapa*	R	OA	U	m
Ruby-crowned kinglet	*Rugulus calendula*	D	AA	U	m
Water pipit	*Anthus spinoletta*	D	AA	C	m
Bohemian waxwing	*Bombycilla garrulus*	D	CA	C	wv
Ceder Waxwing**	*Bombycilla cedrorum*	D	PA	C	sr
Northern shrike	*Lanius excubitor*	D	CA	U	wv
Loggerhead shrike**	*Lanius ludovicianus*	D	CA	U	sr

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
European starling*	*Sturnus vulgaris*	D	CA	C	pr
White-eyed vireo	*Vireo griseus*	R	OA	O	m
Bell's vireo**	*Vireo bellii*	D	AA	U	sr
Yellow-throated vireo	*Vireo flavifrons*	R	OA	O	m
Solitary vireo	*Vireo solitarius*	R	OA	U	sv
Red-eyed vireo**	*Vireo olivaceus*	D	CA	C	sr
Philadelphia vireo	*Vireo philadelphicus*	R	OA	O	m
Warbling vireo**	*Vireo gilvus*	D	CA	C	sr
Black and white warbler	*Mniotilta varia*	D	AA	U	m
Prothonotary warbler	*Protonotaria citrea*	R	OA	O	m
Tennessee warbler	*Vermivora peregrina*	D	AA	U	m
Orange-crowned warbler	*Vermivora celata*	D	CA	U	m
Nashville warbler	*Vermivora ruficapilla*	D	AA	U	m
Northern Parula	*Parula americana*	R	OA	U	m
Yellow warbler**	*Dendroica petechia*	D	CA	C	sr
Magnolia warbler	*Dendroica magnolia*	R	OA	U	m
Cape May warbler	*Dendroica tigrina*	R	OA	U	m
Yellow-rumped warbler	*Dendroica coronata*				
(Audubon race)**	*Dendroica coronata*	D	CA	C	sr
(Myrtle race)	*Dendroica coronata*	D	CA	U	m
Townsend's warbler	*Dendroica townsendi*	R	OA	U	m
Black-throated green warbler	*Dendroica virens*	R	OA	O	m
Cerulean warbler	*Dendroica cerulea*	R	OA	O	m
Blackburnian warbler	*Dendroica fusca*	R	OA	U	m
Chestnut-sided warbler	*Dendroica pensylvanica*	R	OA	U	m
Blackpoll warbler	*Dendroica striata*	D	AA	U	m
Palm warbler	*Dendroica palmarum*	R	OA	U	m
Ovenbird**	*Seiurus aurocapillus*	D	AA	U	sr
Northern waterthrush	*Seiurus noveboracensis*	D	CA	U	m

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
PARULIDAE					
Mourning warbler	*Oporornis philadelphia*	R	OA	O	m
MacCillivray's warbler	*Oporornis tolmiei*	R	OA	U	m
Common yellowthroat**	*Geothlypis trichas*	D	CA	C	sr
Yellow-breasted chat**	*Icteria virens*	D	CA	C	sr
Hooded warbler	*Wilsonia citrina*	R	OA	O	m
Wilson's warbler	*Wilsonia pusilla*	D	AA	C	m
American redstart**	*Setophaga ruticilla*	D	RA	C	sr
House sparrow*	*Passer domesticus*	D	CA	C	pr
Bobolink**	*Dolichonyx oryzivorus*	D	CA	U	sr
Eastern meadowlark**	*Sturnella magna*	D	AA	U	sr
Western meadowlark*	*Sturnella neglecta*	D	CA	C	sr
Yellow-headed blackbird**	*Xanthocephalus xanthocephalus*	D	CA	U	sr
Red-winged blackbird*	*Agelaius phoeniceus*	D	CA	C	sr
Orchard oriole**	*Icterus spurius*	D	CA	C	sr
Northern (Bullock) oriole**	*Icterus galbula*	D	CA	U	sr
Rusty blackbird	*Euphagus carolinus*	R	OA	U	m
Brewer's blackbird**	*Euphagus cyanocephalus*	D	CA	U	sr
Common grackle**	*Quiscalus quiscula*	D	CA	C	sr
Brown-headed cowbird**	*Molothrus ater*	D	CA	C	sr
Western tanager**	*Piranga ludoviciana*	D	CA	U	sr
Scarlet tanager	*Piranga olivacea*	R	OA	O	m
Cardinal	*Richmondena cardinalis*	R	OA	O	pr
Rose-breasted grosbeak	*Pheucticus ludovicianus*	R	OA	U	m
Blue grosbeak**	*Guiraca caerulea*	D	CA	U	sr
Indigo bunting**	*Passerina cyanea*	D	CA	U	sr

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
Lazuli bunting**	*Passerina amoena*	D	CA	C	sr
Indigo x lazuli hybrid**	*P. cyanea x amoena*	D	CA	U	sr
FRINGILLIDAE					
Dickcissel	*Spiza americana*	R	OA	U	sv
Evening grosbeak	*Herperiphona vespertina*	D	AA	C	wv
Purple finch	*Carpodacus purpureus*	R	OA	U	m
Cassin's finch	*Carpodacus cassinii*	R	OA	U	m
House finch	*Carpodacus mexicanus*	D	CA	U	m
Pine grosbeak	*Pinicola enucleator*	R	OA	O	wv
Gray-crowned rosy finch	*Leucosticte tephrocotis*	R	OA	U	wv
Common redpoll	*Acanthis flammea*	R	OA	U	wv
Pine siskin**	*Spinus pinus*	D	CA	C	pr
American goldfinch**	*Spinus tristis*	D	CA	C	pr
Red crossbill**	*Loxia curvirostra*	D	AA	A	pr
White-winged crossbill	*Loxia leucoptera*	R	OA	O	wv
Green-tailed towhee	*Chlorura chlorura*	R	OA	O	m
Rufous-sided towhee**	*Pipilo erythrophthalmus*	D	CA	C	sr
Lark bunting**	*Calamospiza melanocoryx*	D	CA	C	sr
Savannah sparrow	*Passerculus sandwichensis*	D	CA	C	m
Grasshopper sparrow	*Ammodramus savannarum*	D	AA	U	m
Vesper sparrow**	*Pooecetes gramineus*	D	CA	U	sr
Lark sparrow*	*Chondestes grammacus*	D	CA	C	sr
Black-throated sparrow	*Amphispiza bilineata*	R	OA	O	m
Dark-eyed junco	*Junco hyemalis*				
(White-winged race)**	*Junco hyemalis*	D	CA	C	pr
(Slate-colored race)	*Junco hyemalis*	D	CA	C	wv

Table 2.8-5: Bird Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]	Status[4]
(Oregon race)	*Junco hyemalis*	D	CA	C	wv
(Gray-headed race)	*Junco hyemalis*	D	AA	U	m
Tree sparrow	*Spizella arborea*	D	CA	C	wv
Chipping sparrow**	*Spizella passerina*	D	CA	C	sr
Clay-colored sparrow**	*Spizella pallida*	D	CA	C	sr
Brewer's sparrow**	*Spizella breweri*	D	AA	U	sr
Field sparrow	*Spizella pusilla*	R	OA	U	m
Harris' sparrow	*Zonotrichia querula*	R	OA	U	m
White-crowned sparrow	*Zonotrichia leucophrys*	D	CA	C	m
White-throated sparrow	*Zonotrichia albicollis*	R	OA	U	m
Fox sparrow	*Passerella iliaca*	R	OA	O	m
Lincoln's sparrow	*Melospiza lincolnii*	D	AA	U	m
Swamp sparrow	*Melospiza georgiana*	R	OA	O	m
Song sparrow	*Melospiza melodia*	D	CA	C	wv
McCown's longspur**	*Rhynchophanes mccownii*	D	AA	U	sr
Lapland longspur	*Calcarius lapponicus*	D	AA	C	m
Chestnut-collared longspur**	*Calcarius ornatus*	D	AA	U	sr
Snow bunting	*Plectyrophenax nivalis*	D	AA	C	wv

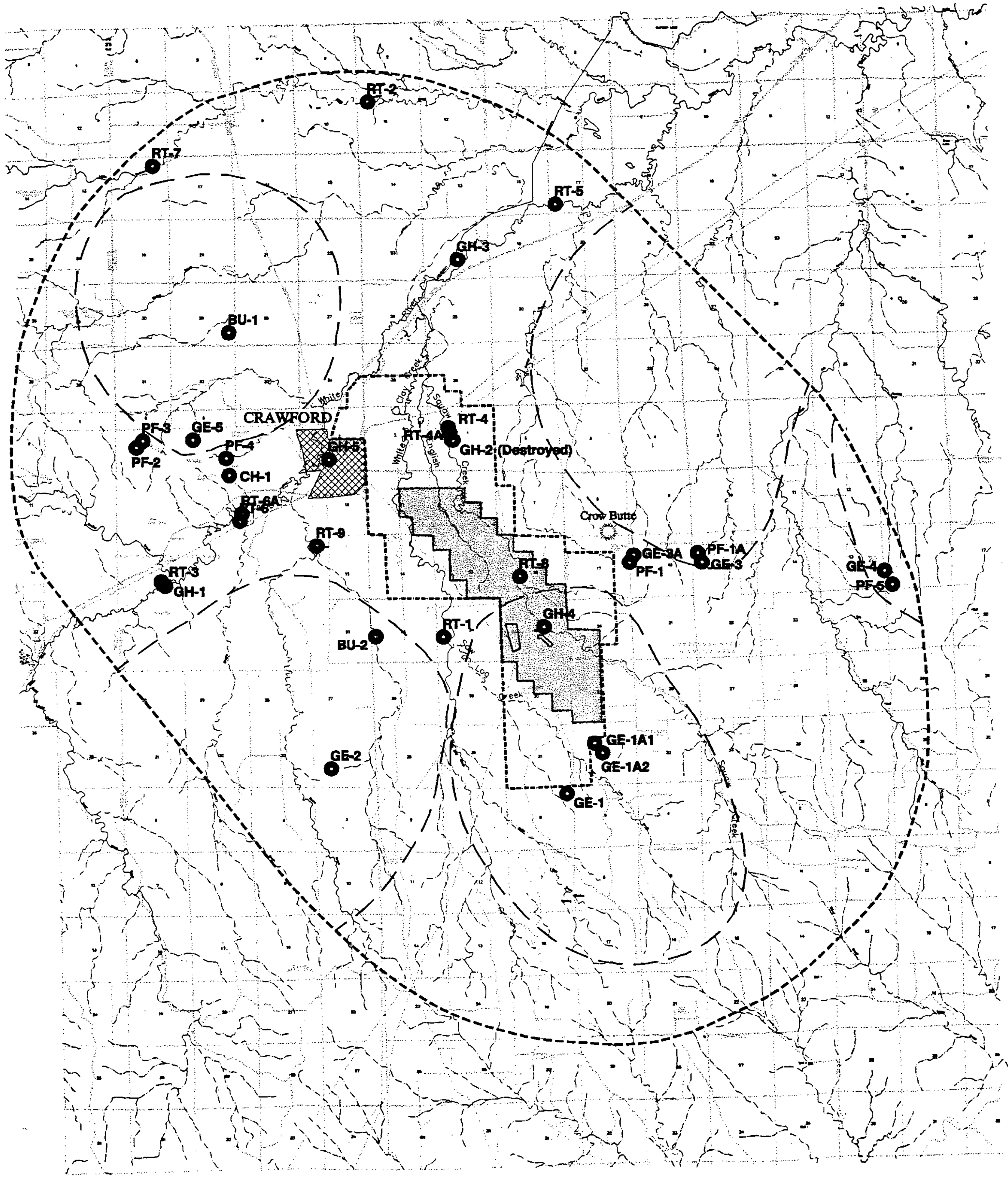
Notes:

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).

2 Distribution:
- AA Within the 8-km Adjacent Area Boundary.
- CA Within the Commercial Study Area Boundary.
- OA Within the 80-km Outer Area Boundary.

3 Abundance:
- A Abundant.
- C Common.
- F Federally-listed Rare, Threatened, or Endangered.
- O Occasional, Accidental, or Rare in study area.
- S State-listed Rare, Threatened, or Endangered.

	U	Uncommon.
4	Migratory Status	
	pr	Permanent Resident.
	sr	Summer Resident.
	sv	Summer Visitor,
	wv	Winter Visitor.
	m	Migrant.
*	confirmed breeder	
**	suspected breeder	



LEGEND

- GE — Golden Eagle (Primary)
- GE — Golden Eagle (Alternative)
- RT — Red-Tailed Hawk
- CH — Cooper's Hawk
- GH — Great Horned Owl
- BU — Burrowing Owl
- PF — Prairie Falcon
- Estimated Limits of Golden Eagle Territory

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N

0 2 4
Scale (mi.)

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RAPTOR NEST LOCATIONS

CROW BUTTE PROJECT
Dawes County, Nebraska

Scale: 1"=2 miles	Date: 10/95	Figure 2.8-4

Threatened, Endangered, and Sensitive Birds

Threatened, endangered, or sensitive bird species that may occur in the region include whooping crane, bald eagle, peregrine falcon, and mountain plover (Anschutz, 1995; Twedt 1995). Whooping cranes (federal and state listed as endangered) use shallow, sparsely vegetated streams and wetlands for roosting and feeding sites during migration. The species migrate through Nebraska between October 1 and December 1 in the fall, and March 15 and May 15 in the spring. Whooping cranes were not observed in the study area during the 1982 survey. However, sightings have been confirmed outside the study area within Dawes County, on wetlands near Whitney, Nebraska (Anschutz, 1995).

Bald eagles (federally listed as threatened, state as endangered) use mature riparian timber near streams and lakes. The species is sparsely scattered across Dawes County during migration (November 1 to April 1). Bald eagles were observed at several locations on the study area in winter and early spring of 1982. Lock (1974) reported that the species is an uncommon winter resident and migrant, with its primary winter distribution lying along rivers 100-km to the east. Bald eagles do not nest on the area, and neither critical habitat nor regular roosting sites are present on the CSA.

Peregrine falcons (federal and state listed as endangered) generally are associated with wetlands and open areas such as cropland and grassland. Most observations in Nebraska are in spring (late April to early May) and fall (September to October) migration periods (Anschutz, 1995). No peregrine falcon was observed within the study area during the 1982 survey.

Mountain plover (listed as state threatened) prefer expansive, arid short grass prarie with a high proportion of bare ground. Prarie dog towns are characteristic of this ideal habitat, and thus can be closely associated with mountain plovers. Although no mountain plovers were observed during the 1982 survey, the limited information available suggests the rarely occur as a summer resident in the Nebraska Panhandle and its potential habitat includes the Crow Butte Project area (Twedt, 1995).

Reptiles and Amphibians

Of 25 species of reptiles and amphibians recorded for the region, 13 were documented within the study area during the investigation (Table 2.8-6). Woodhouse's toad, Great Plains toad, and plains spadefoot were the toads observed. Documented frogs included the boreal chorus frog, leopard frog, and bullfrogs. The two turtles observed were the snapping turtle and painted turtle. Bullsnake, plains garter snake, common garter snake, and racer were

Table 2.8-6: Reptile and Amphibian Species List

Common Name	Scientific Name	Status[1]	Status[2]	Status[3]
Tiger salamander	*Ambystoma tigrinum*	E	CA	C
Plains spadefoot	*Scaphiopus bombifrons*	D	AA	C
Woodhouse's toad	*Bufo woodhousei*	D	CA	C
Great Plains toad	*Bufo cognatus*	D	CA	C
Boreal chorus frog	*Pseudacris triseriata*	D	CA	C
Leopard frog	*Rana pipiens*	D	CA	C
Bullfrog	*Ran catesbeiana*	D	CA	C
Snapping turtle	*Chelydra serpentina*	D	CA	C
Western box turtle	*Terrepene ornata*	E	CA	U
Painted turtle	*Chrysemys picta*	D	CA	U
Spiny softshell	*Trionyx spiniferus*	E	AA	U
Lesser earless lizard	*Holbrookia maculata*	E	AA	U
Eastern fence lizard	*Sceloporus undulatus*	E	AA	U
Short-horned lizard	*Phrynosoma douglassi*	E	CA	U
Great Plains skink	*Eumeces obsoletus*	E	CA	U
Many-lined skink	*Eumeces multivirgatus*	E	CA	U
Six-lined racerunner	*Cnemidophorus sexlineatus*	E	CA	U
Western hognose snake	*Heterodon nascicus*	E	CA	U
Racer	*Coluber constrictor*	D	AA	U
Bullsnake	*Pituophis melanoleucus*	D	CA	C
Milk snake	*Lampropeltis triangulum*	E	CA	U
Common water snake	*Natrix spipedon*	E	OA	U
Common garter snake	*Thamnophis sirtalis*	D	CA	U
Plains garter snake	*Thamnophis radix*	D	CA	C
Prairie rattlesnake	*Crotalus viridis*	R	CA	U

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).

[2] Distribution:
- AA Within the 8-km Adjacent Area Boundary.

CA Within the Commercial Study Area Boundary.
OA Within the 80-km Outer Area Boundary.
[3] Abundance:
A Abundant.
C Common.
F Federally-listed Rare, Threatened, or Endangered.
O Occasional, Accidental, or Rare in study area.
S State-listed Rare, Threatened, or Endangered.
U Uncommon.

the snakes found. No Threatened, Endangered, or Sensitive Reptile or Amphibian occurs within the study area.

2.8.2.2 AQUATIC ECOLOGY

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 WFC (1983).

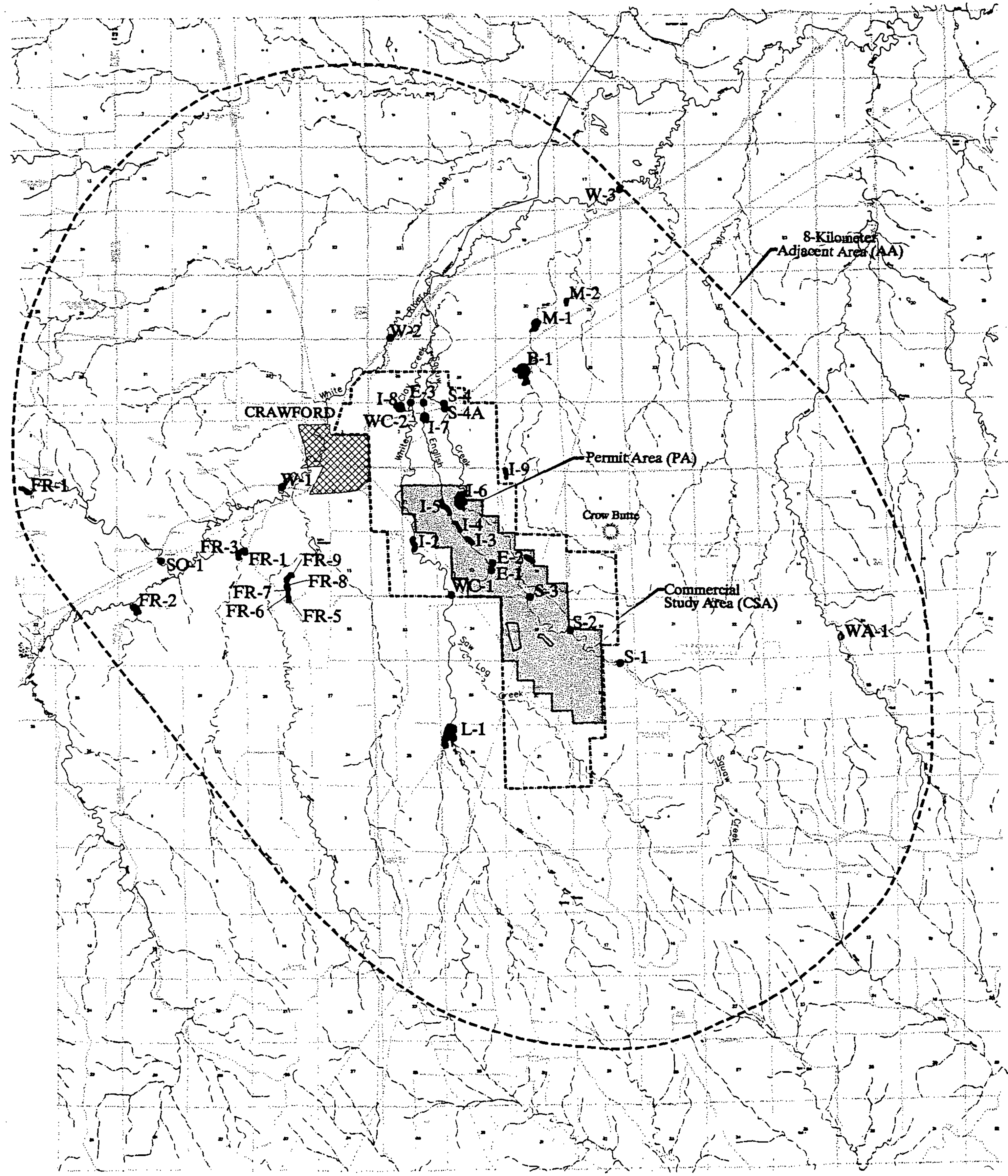
Aquatic Study Area Description

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 (Table 2.8-5). 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 has 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



LEGEND

- Permit Area (PA)
- Commercial Study Area (CSA)
- Adjacent Area (AA)

SAMPLING SITE KEY

B	Britton
E	English Creek
FR	Fort Robinson
I	Impoundment
L	Lux
M	Mansfield
S	Squaw Creek
SO	Soldier Creek
W	White River
WA	West Ash Creek
WC	White Clay Creek

9601300331-08

N

0 2 4

Scale (mi.)

GREYSTONE®

AQUATIC SAMPLING SITE LOCATIONS

CROW BUTTE PROJECT
Dawes County, Nebraska

Scale: 1"=2 miles | Date: 10/95 | **Figure 2.8-5** 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.

- 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.

<u>Methods</u>

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.

Fish

Fourteen species of fish were collected from the CSA streams and impoundments (Table 2.8-7). 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 2.8-8). 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.

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%, simulidae - 20%, oligochaeta - 19%, and ceratopogonidae - 15%. 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 2.8-9. 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 2.8-10. *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.

2.8.3 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.

2.8.3.1 TERRESTRIAL ECOLOGY

No Threatened or Endangered plant species occur on or near any area of project disturbance. No wetlands have been affected as a result of operations.

Table 2.8-7: Fish Species List

Family/Common Name	Scientific Name	Status[1]	Status[2]	Status[3]
CATOSTOMIDAE				
River sucker	*Carpiodes carpio*	R	OA	
Longnose sucker	*Catostomus catostomus*	R	OA	
White sucker	*Catostomus commersoni*	D	CA	C
CENTRARCHIDAE				
Green sunfish	*Lepomis cyanellus*	D	CA	C
Bluegill	*Lepomis macrochirus*	D	OA	C
Smallmouth bass	*Micropterus dolomieui*	R	OA	
Largemouth bass	*Micropterus salmoides*	D	OA	C
Black crappie	*Pomoxis nigromaculatus*	D	OA	C
CYPRINIDAE				
Carp	*Cyprinus carpio*	D	OA	C
Plains minnow	*Hybognathus placitus*	D	CA	O
Flathead chub	*Hybopsis gracilis*	R	OA	
Common shiner	*Notropis cornutus*	R	OA	
Golden shiner	*Notemigonus crysoleucas*	D	CA	C
Red shiner	*Notropis lutrensis*	R	OA	
Sand shiner	*Notropis stramineus*	D	CA	U
Flathead minnow	*Pimephales promelas*	D	AA	C
Longnose dace	*Rhinichthys cataractae*	D	AA	C
Creek chub	*Semotilus atromaculatus*	D	CA	C
CYPRINODONTIDAE				
Plains topminnow	*Fundulus sciadicus*	D	CA	O
ESOCIDAE				
Northern pike	*Esox lucius*	R	OA	
HIODONTIDAE				
Goldeye	*Hiodon alosoides*	R	OA	
ICTALURIDAE				
Black bullhead	*Ictalurus melas*	D	CA	U
Channel catfish	*Ictalurus punctatus*	R	OA	
Stonecat	*Noturus flavus*	R	OA	

Table 2.8-7: Fish Species List

Family/Common Name	Scientific Name	Status[1]	Status[2]	Status[3]
PERCICHTHYIDAE				
White bass	*Morone chrysops*	D	OA	C
PERCIDAE				
Walleye	*Stizostedion vitreum*	D	OA	C
SALMONIDAE				
Rainbow trout	*Oncorhynchus mykiss*	D	AA	C
Brown trout	*Salmo trutta*	D	AA	C
Brook trout	*Salvelinus fontinalis*	D	AA	O

<u>Notes</u>

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).

2 Distribution:
- AA Within the 8-km Adjacent Area Boundary.
- CA Within the Commercial Study Area Boundary.
- OA Within the 80-km Outer Area Boundary.

3 Abundance:
- A Abundant.
- C Common.
- F Federally-listed Rare, Threatened, or Endangered.
- O Occasional, Accidental, or Rare in study area.
- S State-listed Rare, Threatened, or Endangered.
- U Uncommon.

Table 2.8-8: Relative Abundance (Percent Occurrence) of Fish Collected at Each Sampling Location (1982)

FISH SPECIES	STREAMS								IMPOUNDMENTS								
	E-3	S-1	S-2 S-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									

FISH SPECIES	STREAMS								IMPOUNDMENTS								
	E-3	S-1	S-2 S-3	S-4	WC-1	WC-2	W-1	W-2	1	2	3	4	5	6	7	8	9
ICTALURIDAE																	
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

Table 2.8-9: 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./m^2)																					
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	1343 2	14698	2480	459		965	184	7578
Ō	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
Ō	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

	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
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 2.8-10: Diatom Proportional Counts (Percent Occurrence) and Occurrence of Other Algae by Sampling Location. Data are From Samples Collected in 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

	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
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		

No black-footed ferrets have been affected because no prairie dog colonies have been affected by the project. There have been no project-related impacts to big game or big game hunting. CBR does not preclude landowners from hunting on their property and big game habitat has not been significantly reduced. Carnivores (including the swift fox) have not been affected by the project because there has been no reduction in suitable prey species.

There are no known project-related impacts to raptors (including bald eagles and peregrine falcons) in the area because there was little to no reduction in the prey base and no project-related disturbance of identified nests. No waterfowl have been affected by the project because none of the identified waterfowl concentration areas have been directly disturbed. No impacts to whooping cranes or mountain plovers are expected because critical habitat for these species dies not occur within the CSA.

2.8.3.2 AQUATIC ECOLOGY

Aquatic resources have been affected by the project twice during the R&D and commercial project operations. Impacts resulted from two accidental releases that entered Squaw Creek, one in 1992 and one in 1993. The 1992 release was minor, with only an estimated 50 gallons of mining fluid entering the creek. The 1993 release was larger, and may have caused short-term impacts to Squaw Creek aquatic biota before dilution at the downstream impoundment (I-6). Considerable dilution occurred during the spill as a result of melting snow. Because of the 1993 accident, CBR constructed berms and containment dams to prevent any possible future accident from entering Squaw Creek. Furthermore, an Incident Response Plan was developed in 1993 (RTG, 1993) to reduce the chance of another release to aquatic resources.

2.8.4 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.

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 (1985-87) and the commercial preoperational data which were collected from 1985 through 1987, are also presented in this section.

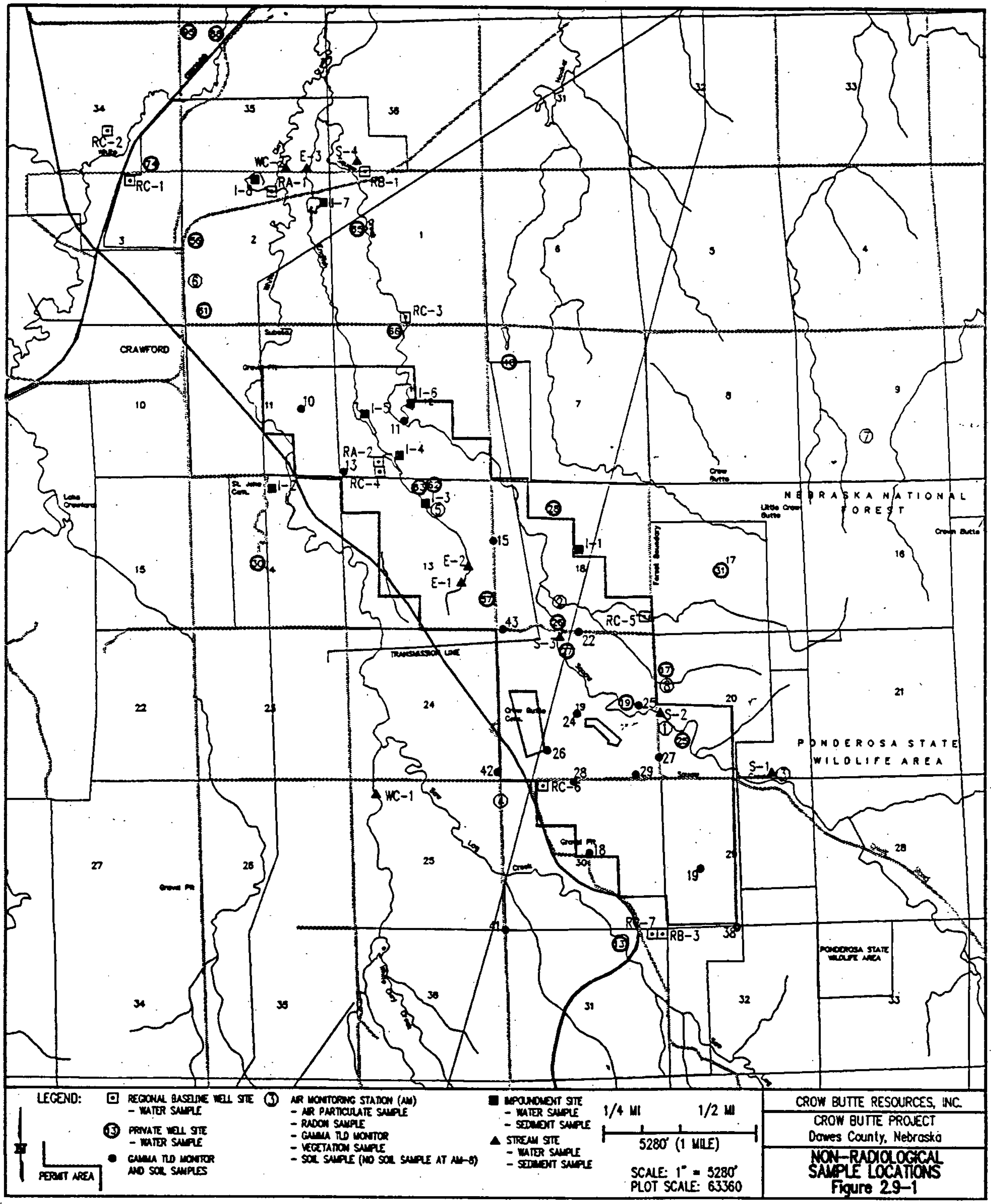
The nonradiological monitoring program was adapted from the monitoring recommended in U.S. NRC Regulatory Guide 4.14 to provide companion data to the Crow Butte preoperational radiological monitoring program described in Section 2.10 of this report. Site specific data have been collected from monitor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

2.9.1 GROUNDWATER

Investigations of the groundwater quality and usage for the Commercial Permit Area was 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.

Figure 2.9-1: Preoperational Nonradiological Sampling Points



Existing hydrologic studies were then compared with these findings. A thorough discussion of the groundwater hydrology is found in Section 2.7.1 of this document.

Water samples were taken from selected representative wells within the commercial permit 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 2.9-2 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 locations of these wells are listed in Table 2.9-3. Four are completed in the Brule Formation and seven in the Chadron Sandstone (production zone).

Sample collection and preservation were performed using standard EPA 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. EPA-600/4-82-029) are added to the samples and samples are transported to the lab for analysis. A summary of these results on the eleven baseline wells drilled by WFC is given in Table 2.9-4.

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

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						
Ground Water						
	One from each water supply well	All wells within 1 km of restricted are boundary	Grab	3 Times	Each Sample	Complete Table 5.7-8 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 5.7-8 list once; common ions only other quarters
Surface Water						
	One from each pond or impoundment		Grab	Once	Once	Complete Table 5.7-8 list
	Two from Squaw Creek	One up-stream, one down stream of restricted area	Grab	Quarterly	Quarterly	Complete Table 5.7-8 list once; common ions only other quarters

Table 2.9-1: Non-Radiological Preoperational Monitoring Program

Sample Collection					Sample Analysis	
Type of sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
	Two from White Clay Creek	Upstream and down stream of Commercial Permit area.	Grab	Four Times	Quarterly	Complete Table 5.7-8 list once; common ions other quarters
	Two from English Creek	Upstream and down stream of Commercial Permit Area	Grab	Four Times	Quarterly	Complete Table 5.7-8 once; common ions other quarters
	Two from Squaw Creek	One upstream and one down stream of restricted area	Grab	Quarterly	Quarterly	Suspended sedi-
Water Levels						
	One from each monitor well, baseline well, and selected private wells	Surrounding and within wellfield	Electric line	Monthly	Monthly	Map
Flow						
	Two from Squaw Creek	One upstream and one down stream of restricted area	Flow	Monthly through 1982; then	Monthly	Tabular

Table 2.9-1: Non-Radiological Preoperational Monitoring Program

Sample Collection					Sample Analysis	
Type of sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
				quarterly		
SOILS						
Surface						
	One each	Six locations in Section 19	Grab	Once	Once	Arsenic, Selenium
	One each	Nine locations in Commercial Permit Area	Grab	Once	Once	Arsenic, Selenium
	One each	Seven Locations In restricted area	Grab	Once	Once	Vanadium

Table 2.9-2: Private Wells Sampled Within and Around the Commercial 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

Table 2.9-3: 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

monitor wells used during mining. Table 2.9-5 lists the depth and geologic unit for each baseline well.

2.9.3 WATER LEVELS

Monthly water level measurements were made on 23 representative wells within the commercial permit 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 Crow Butte 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 individualtaking the readings. Values were then corrected to mean sea level (msl). Selected results are presented in Figure 2.9-3 and 2.9-4 and all results listed in Tables 2.9-6 and 2.9-7.

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 commercial permit area during preoperational smapling. Table 2.9-1 outlines the preoperational sampling schedule and the parameters for analysis. This schedule was begun in 1982 and continued.

Squaw Creek passes through the Crow Butte commercial permit 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 2.9-8. Average Squaw

Table 2.9-4: Aquifer Water Quality Summary

	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).

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

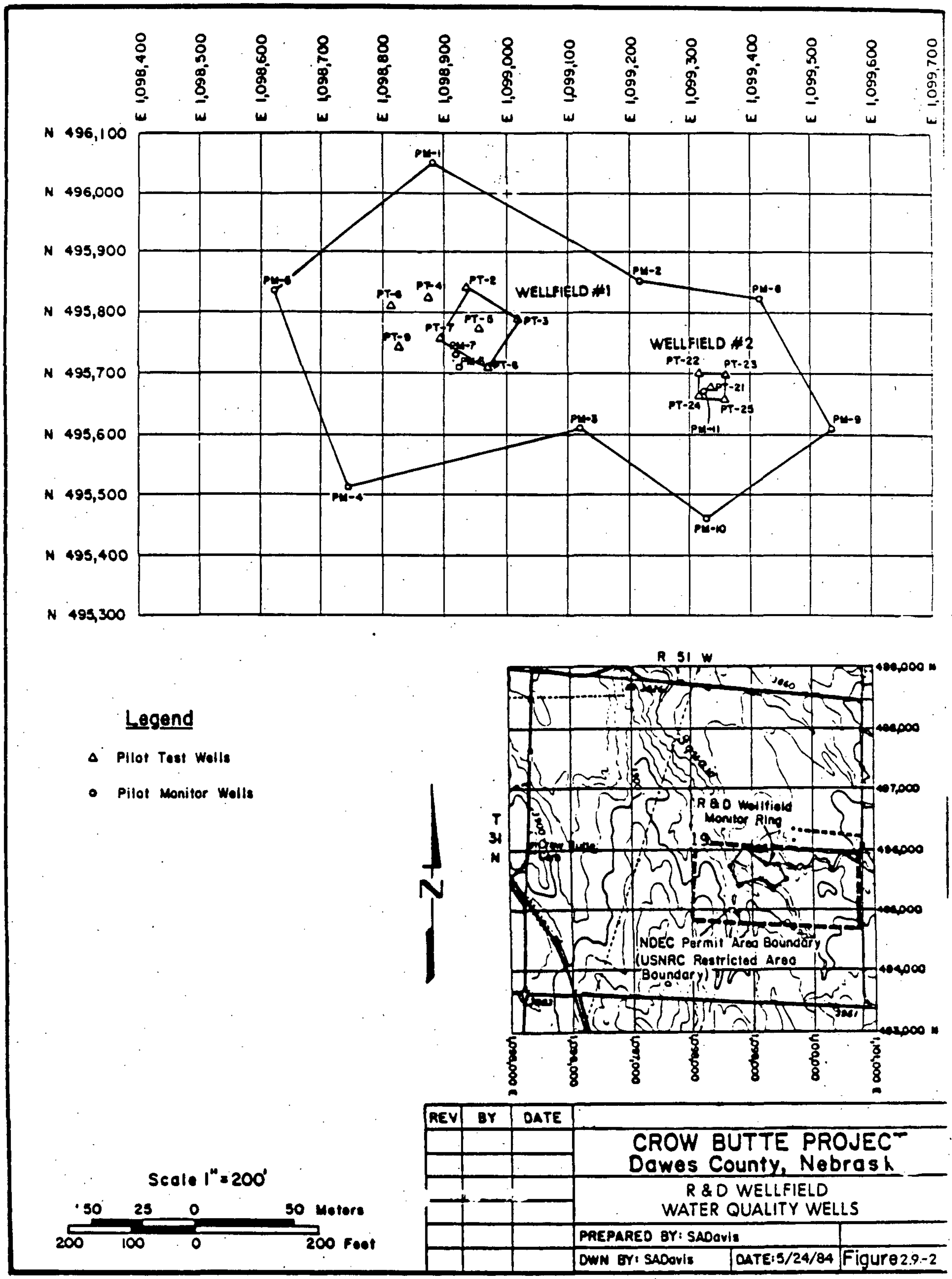


Table 2.9-5: Water Quality Wells Used for Preoperational and Operational Data

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

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.

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

Eight impoundments are located within the commercial permit area of review; 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 2.10.

2.9.5 STREAM FLOW

Squaw Creek flows through the Crow Butte commercial permit area from east to northwest. The flowrate 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 commercial permit 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 number 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 2.9-9 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.

2.9.6 SOILS

Soils samples were collected to determine baseline concentrations of selected elements in the different soils types. Nine samples were collected in the Commercial Permit 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 will be 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 these companion compounds will also 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.

Samples from the Permit Area and the specific samples from Section 19 (Figure 2.9-5) 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 Tables 2.9-10 and 2.9-11. As can be seen from the data in Table 2.9-10 the arsenic concentration ranges from 0.59 mg/g to 3.30 ug/g and the selenium concentration ranges from <0.01 ug/g to 0.06 ug/g. There does not appear to be any relationship between the soils type and the levels of these elements. The vanadium analysis shown in Table 2.9-11 indicate that the vanadium levels in the restricted area are very consistent with a range of 22 to 29 ug/g.

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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U.S. Nuclear Regulatory Commission, Staff Technical Position Paper, Ground Water Monitoring at Uranium In-Situ Solution Mines, WM-8102, December, 1981.

Figure 2.9-3: Seasonal Water Level Fluctuations

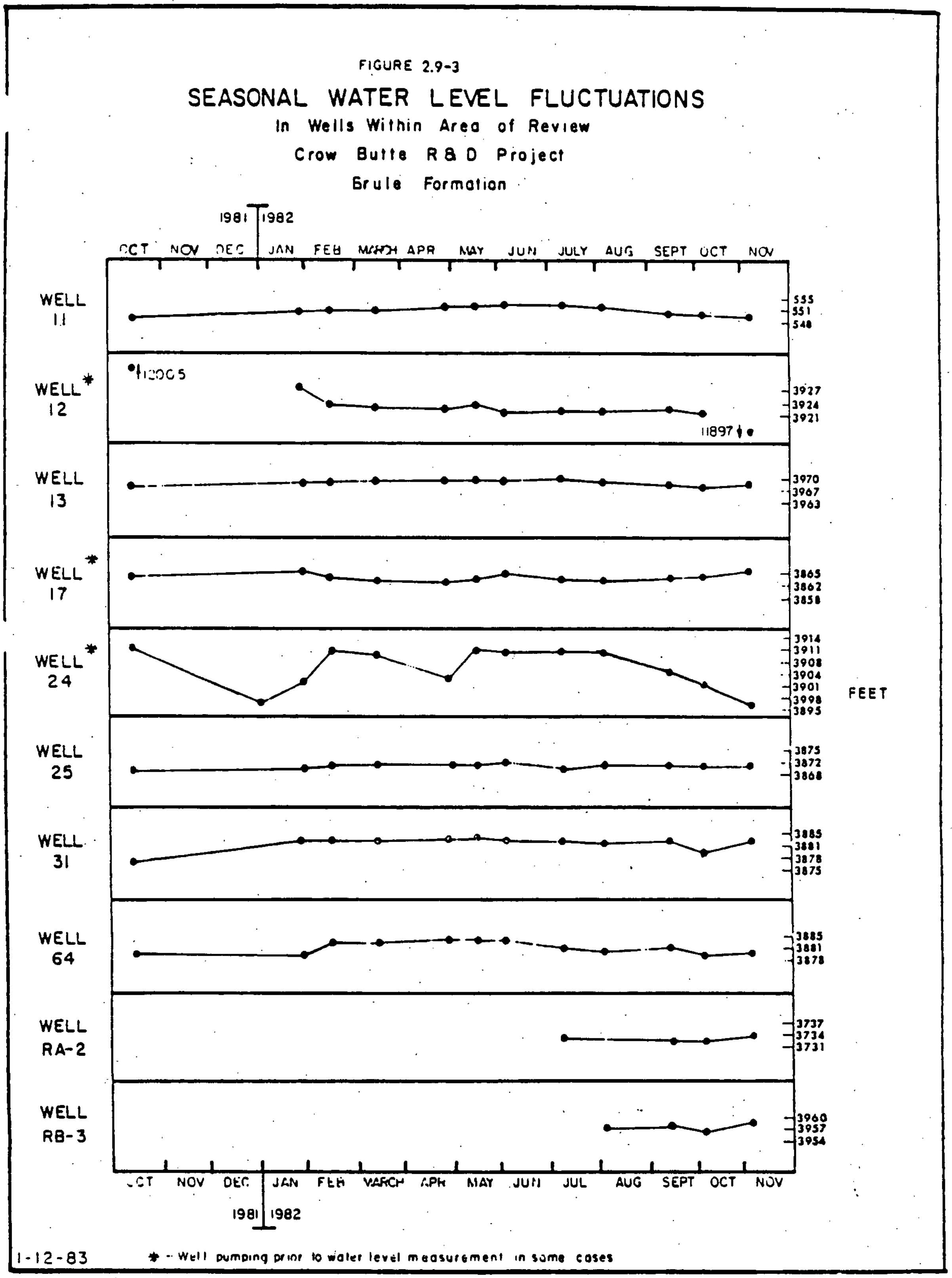


Figure 2.9-4: Seasonal Water Level Fluctuations

FIGURE 2.9-4

SEASONAL WATER LEVEL FLUCTUATIONS

In Wells Within Area of Review

Crow Butte R & D Project

Chadron Formation

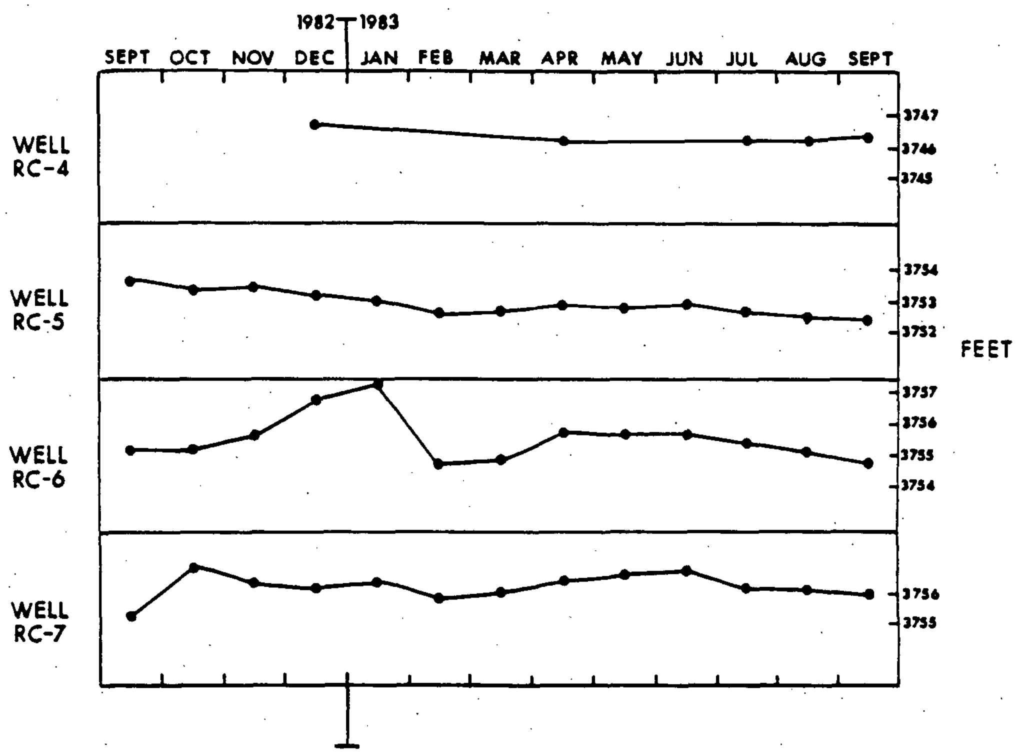


Table 2.9-6: Brule Water Levels
(in feet above mean sea level)

Well	1982 Jan	Feb	Mar	April	May	June	July	August	Sept	Oct	Nov	Dec	1993 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 Sept	Oct	Nov	Dec	1983 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

Table 2.9-7: Chadron Water Levels

	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.

Table 2.9-8: Suspended Sediment in Flowing Waters 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

Results given as Total Suspended Solids in mg/l.

Table 2.9-9: 1982 Stream Discharge Rates
(m^3/sec)

Station	Feb.	Mar.	Apr.	May	June	July	August	Sept.	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

Figure 2.9-5: Stream Discharge Rates

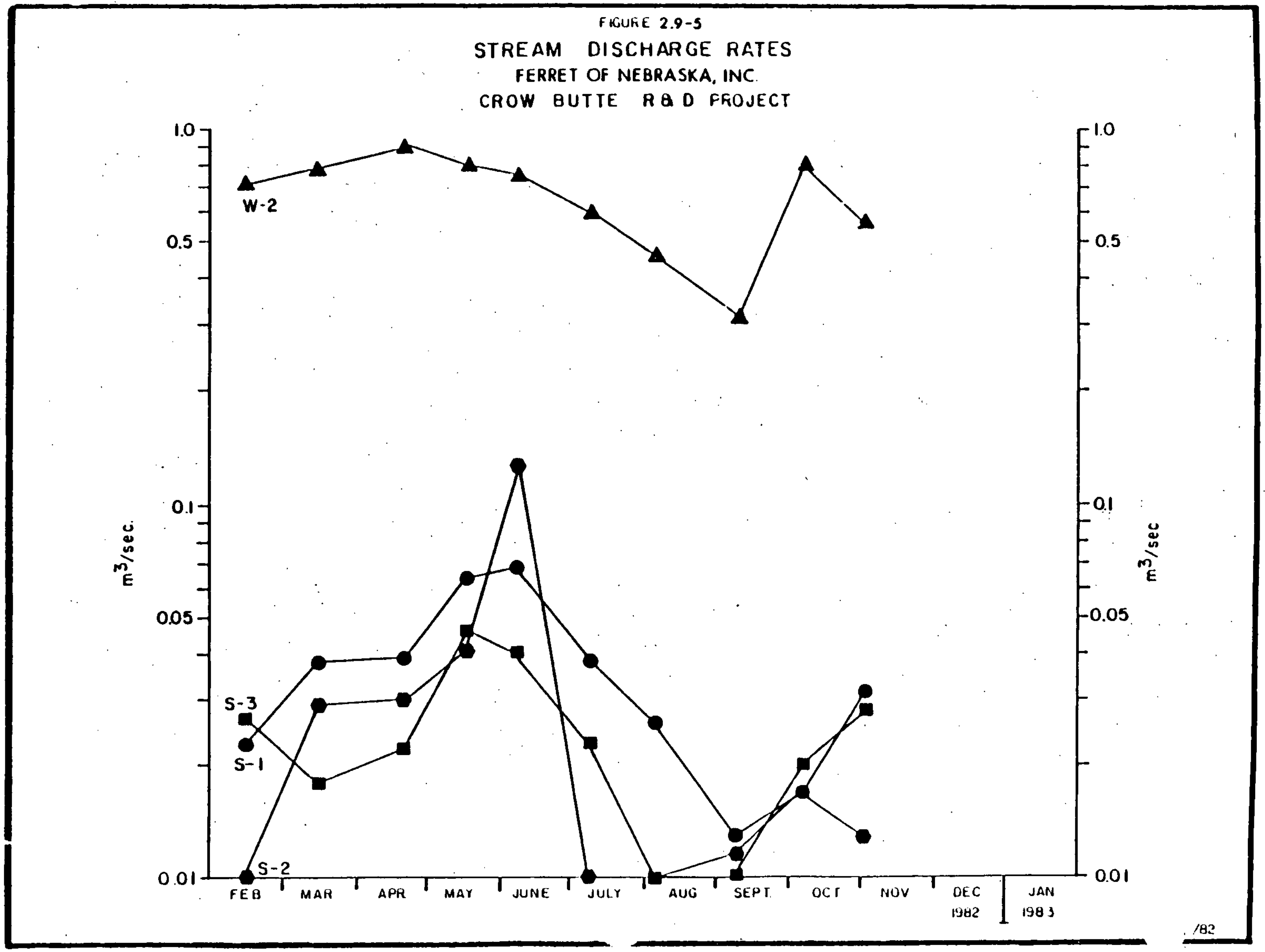


Figure 2.9-6: Soil Sample Location

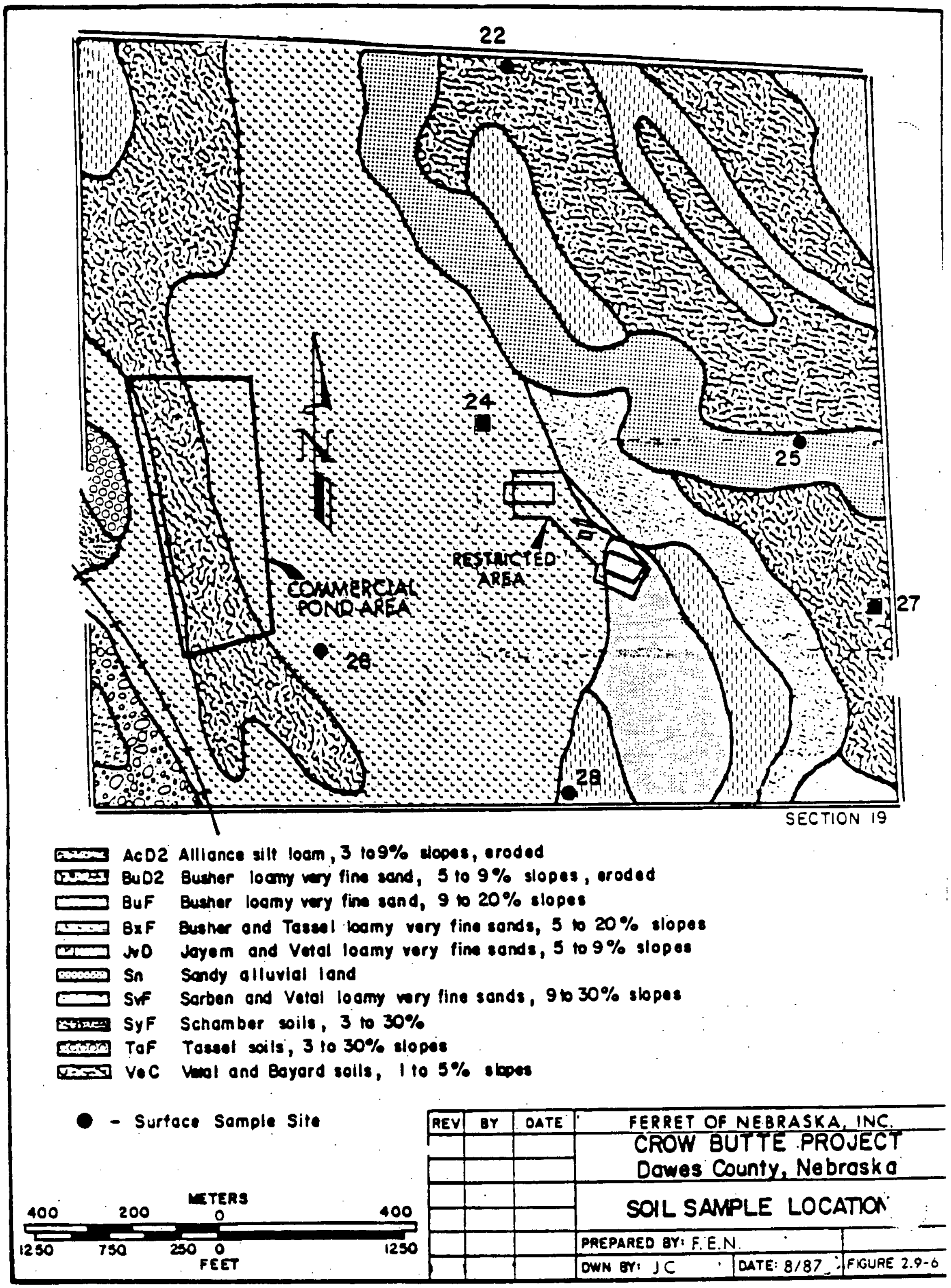


Figure 2.9-7: Soil Sample Sites in Restricted Area

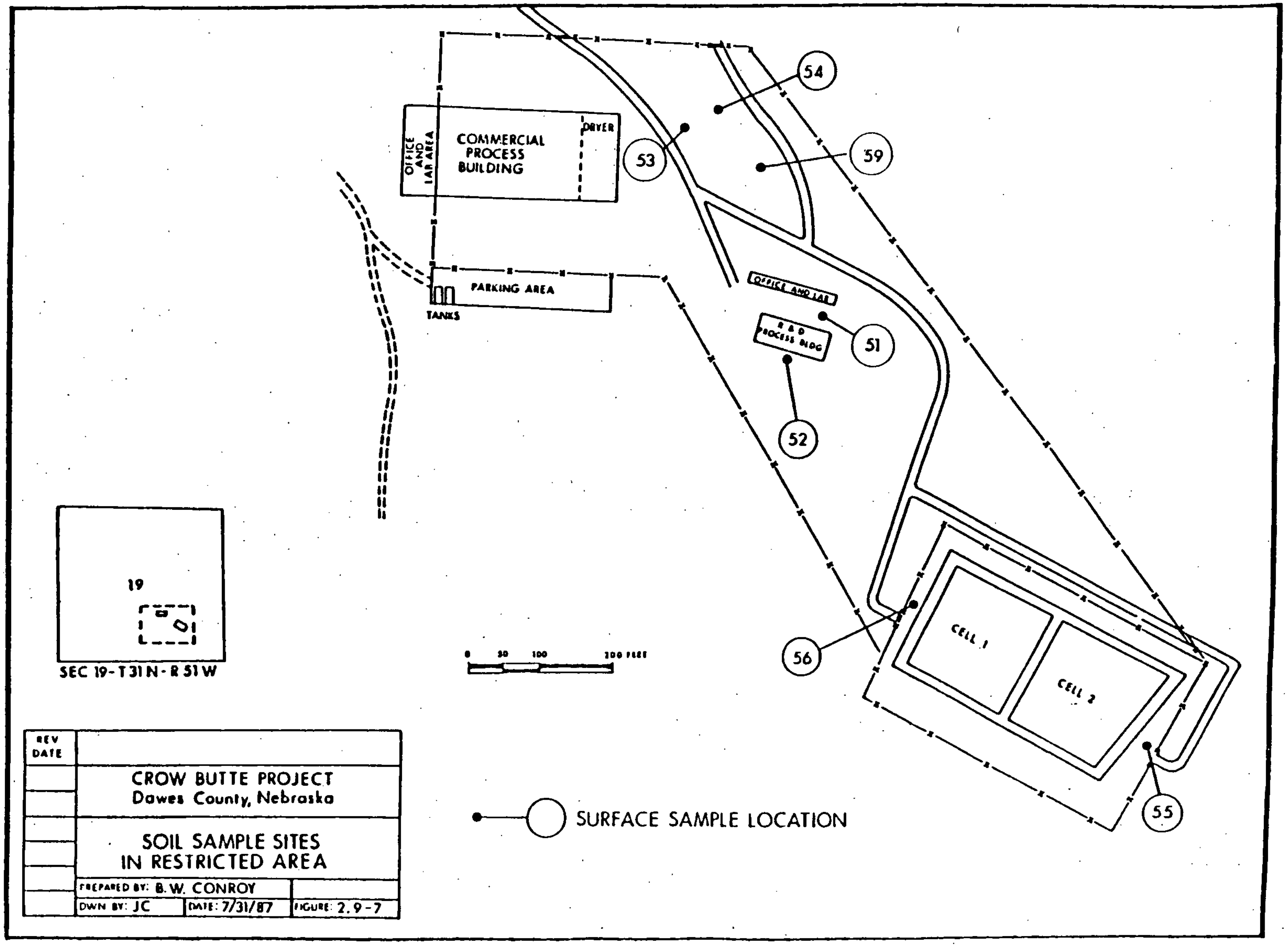


Table 2.9-10: Soils Analysis Results
Commercial Permit Area and Section 19

Sample Site	Soils Map Unit	Sample Date	Arsenic (ug/g)	Selenium (ug/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 2.9-11: Soils Analysis Results in Restriced Area

Sample Site	Sample Date	Vanadium (ug/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

2.10 BACKGROUND RADIOLOGICAL CHARACTERISTICS

2.10.1 INTRODUCTION

This section contains a description of the environmental sampling program that Crow Butte Resources Inc, (CBR) used to assess radiological background conditions of the area in the vicinity of the Crow Butte Project. The results of this program, in conjunction with an operational monitoring program, will be used to determine the effects on the environment, if any, of the Crow Butte Project. Over a period in excess of four years, samples were collected and analyzed for the concentration of radionuclides in the pre-mining environment. This program includes sample data collected through the second quarter of 1986. Environmental monitoring will continue through mining and restoration. The program includes samples of the air, groundwater, surface water, soils, sediments, vegetation, and fish. The pre-mining data indicate that the existing concentrations of the radionuclides are in the range reported in similar studies. The only anomalies reported were elevated radium-226 levels in some groundwater samples. This increase in radium-226 is to be expected in groundwater from mineralized strata containing uranium.

In order to determine background radiological conditions in the immediate area of the Crow Butte CSA, CBR initiated an environmental sampling program in the fourth quarter of 1981. This program was designed to meet the criteria outlined in the USNRC Regulatory Guide 4.14, Radiological Effluent and Environmental Monitoring at Uranium Mills (1980). Lower limits of detection for the program described below are equivalent to those specified in USNRC Regulatory Guide 4.14. An air sampling program was initiated in April 1982. This program evaluated the background concentration of various airborne radionuclides including ambient radon-222 levels. Gamma dosimeters were also distributed through the area in April 1982. Sampling of private wells began in October 1981 and by April 1982, selected area wells were sampled on a quarterly basis.

Soils in the region have been sampled for the concentration of natural uranium and radium-226. Soils in the immediate area of the proposed plant, ponds and wellfield have also been sampled. Surface water in Squaw Creek was collected at two locations on a quarterly basis. Samples of sediments from the creek were also obtained at these two locations. Water and sediment samples were taken from several area impoundments. Samples of fish were obtained from Squaw Creek and selected impoundments. Vegetation samples have been collected near the air monitoring stations. In June 1983, samples of area crops were also collected.

Table 2.10-1: Radiological Preoperational Monitoring Program

Sample Collection					Sample Analysis	
Type of sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
Air						
Particulates						
	Four	Nearest residences with highest airborne radionuclide concentration in each of the two prevailing wind direction and near the town of Crawford	Continious low volume air sampler with glass fiber filter	One week or more per month	Quarterly composite of filters according to location	Natural uranium, Th-230, Ra-226, Pb-210
	Three	Additional sites were sampled due to uncertainty in wind data	Same	Same	Same	Same
	One	Control location least prevailing wind direction	Same	Same	Same	Same
Radon Gas						
	Eight	Same locations as air particulates	Grab[1,2]	Monthly	Each sample	Rn-222

Table 2.10-1: Radiological Preoperational Monitoring Program

Sample Collection					Sample Analysis	
Type of sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
Water						
Ground Water	One from each water supply well	All wells within 1 km of restricted area boundary	Grab	Three to establish baseline	Each sample	Natural uranium, Th-230, Ra-226, P-210, Po-210
	One from each	Selected regional wells	Grab	Three to establish baseline	Each sample	Natural uranium, Th-230, Ra-226, P-210, Po-210
	One from each DEQ baseline and monitor well	As required by DEC	Grab	Three to establish baseline	Each sample	Natural uranium, Ra-226
Surface Water	One from each body of water	All large permanent impoundments with 2 $^{1}/_{4}$ mile radius of wellfield	Grab	Semi-annually for one year	Each sample	Natural uranium, Th-230, Ra-226, P-210, Po-210
	Two from Squaw Creek	One upstream, one down stream of restricted area	Grab	Quarterly	Each sample	Natural uranium, Th-230, Ra-226, Pb-210, Po-210

Table 2.10-1: Radiological Preoperational Monitoring Program

	Sample Collection				Sample Analysis	
Type of sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
	Two from Squaw Creek	One upstream, one down stream of restricted area	Grab	Two to establish baseline	Each sample	Natural uranium, Th-230, Ra-226, Pb-210, Po-210
Sediment						
	One from each body of water	From each permanent impoundment within a 2 1/4 mile radius of the wellfield	Grab	Once	Each sample	Natural uranium, Th-230, Ra-226, Pb-210, Po-210
	Two from Squaw Creek	One upstream, one down stream of restricted area	Grab	Semi-annually	Each sample	Natural uranium, Th-230, Ra-226, Pb-210, Po-210
Soil						
Surface	Three	Plant site before topsoil removal	Grab (top 5 cm)	Once	Each sample	Natural uranium, Ra-226
	Two	Plant site after topsoil removal	Grab (top 5 cm)	Once	Each sample	Natural uranbium, Ra-226

Table 2.10-1: Radiological Preoperational Monitoring Program

Sample Collection					Sample Analysis	
Type of sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
	Three	Wellfield	Grab (top 5 cm)	Once	Each sample	Natural uranium, Ra-226
	Three	Restricted area	Grab (top 5 cm)	Once	Each sample	Natural uranium, Ra-226
	One each	Air sampling stations	Grab	Once	Each sample	Natural uranium, Ra-226
	One each	42 locations in commercial permit area	Grab (top 5 cm)	Once	Each sample	Natural uranium, Ra-226
Subsurface						
	One	Plant site	One third meter composites to a total depth of one meter	Once	Each sample	Natural uranium, Ra-226
	Two	Wellfield	Same	Same	Same	Same
	One each	Evaporation ponds (after excavation at deepest point)	Composite core sample to two meters	Once	Each sample	Natural uranium, Ra-226

Table 2.10-1: Radiological Preoperational Monitoring Program

Sample Collection					Sample Analysis	
Type of sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
Vegetation						
	One each	Operational air sampling stations	Composite of dominent vegetation present	Once during grazing season (82, 83, 84)	Each sample	Natural uranium, Th-230, Ra-226, Pb-210, Po-210
	One each	NE of wellfield	Composite of dominant vegetation present	Once during grazing season (June or July 1987)	Each sample	Natural uranium, Th-230, Ra-226, Pb-210, Po-210
	One each	Wellfield, plant site	Composite of dominant vegetation present	Once during grazing season (83, 84)	Each sample	Natural uranium, Th-230, Ra-226, Pb-210, Po-210
Fish						
	Each significant body of water	Fish from each body of water if a significant pathway to man exists	Grab	Once	Each sample	Natural uranium, Th-230, Ra-226, Pb-210, Po-210

Table 2.10-1: Radiological Preoperational Monitoring Program

Sample Collection					Sample Analysis	
Type of sample	**Number**	**Location**	**Method**	**Frequency**	**Frequency**	**Type of Analysis**
Direct Radiation						
	One each	Air sampling stations and selecetd area locations	Dosimeter	Continuous	Quarterly	Gamma exposure - continuous integrating device
		Closely spaced grid through wellfield, evaporation ponds and plant areas	Grab	Once	Once	Gamma exposure using properly calibrated NaI scintillometer

Table 2.9-1 summarizes the preoperational radiological monitoring program implemented at Crow Butte. Figure 2.10-1, is a map of the region surrounding the in situ uranium project showing the locations of the various sample sites.

2.10.2 AIR SAMPLING PROGRAM

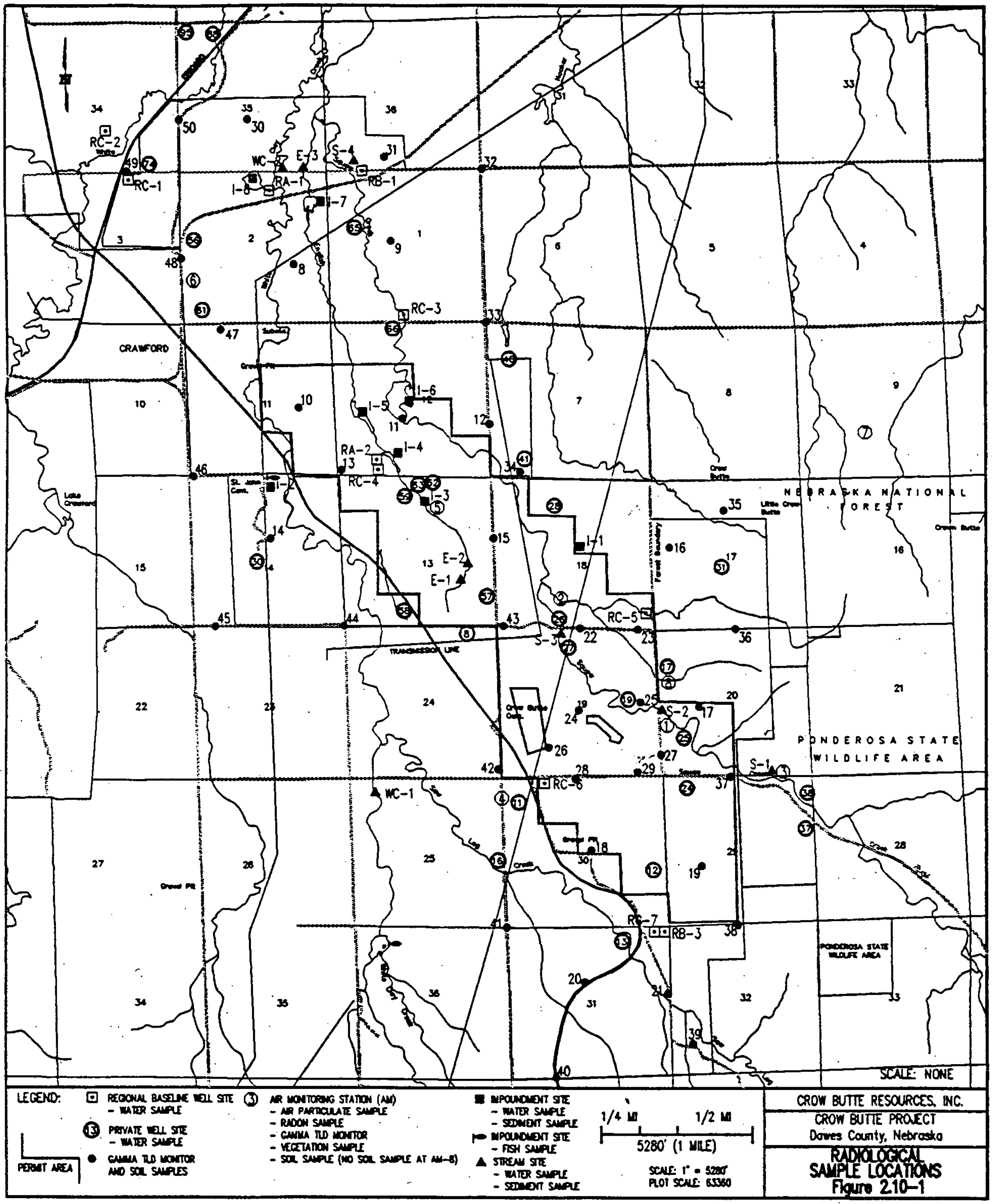
The original locations of the air sampling stations were based on wind data obtained from Scottsbluff, Nebraska. The air sampling stations were used during the preoperational and operational phases of the Crow Butte R&D are shown in Figure 2.10-1. AM-1, AM-2, AM-6 and AM-7 were used as operational monitoring sites during the Crow Butte R&D and AM-3, AM-4 and AM-5 were used for preoperational monitoring only.

From April 1982 to 1984, wind data were collected from a meteorological station installed at the Crow Butte site. The site specific wind data are found in Section 2.5, Meteorology. Based on the site specific wind data an additional monitoring station (AM-8) was added in March of 1987. This station is also shown in Figure 2.10-1.

CBR has collected data continuously at AM-1, AM-2, AM-6 and AM-7 from 1982 to the present, although monitoring at AM-7 was halted in 1990. Preoperational data from AM-3, AM-4 and AM-5 were collected in 1982 and 1983 and have been included in this report for completeness. CBR restarted sampling at AM-3, AM-4 and AM-5 in March of 1987 in order to obtain additional preoperational data. In 1987, an air monitoring station (AM-8) was installed in the direction of the prevailing wind. The data from this station are also included.

The four primary stations (AM-1, AM-2, AM-6, AM-7) are identical and consist of an instrument shelter standing approximately 1.5 m (5 ft) above ground level. A Regulated Air Sampler is housed in the shelter. The inlet to the sampler is fitted with a 47 mm filter holder and glass fiber filters are used. These filters remove 99.9% of the particles larger than 0.3 micron. The samplers operated continuously each month with filter changes on a weekly basis through 1983. Samplers operated continuously one or two weeks each month from 1984 to present. The flow rates are recorded during each filter change and adjusted to a flow indicator reading of 20-60 lpm. The filters are composited according to location and analyzed on a quarterly basis. The samplers are calibrated semiannually. Calibration is accomplished using a mass flowmeter that is certified and calibrated with standards traceable to the National Bureau of Standards (NBS).

Figure 2.10-1: Preoperational Radiological Sampling Locations



Radon-222 was also measured at the four primary air monitoring stations. Radon-222 samples were also collected at AM-3, 4 and 5 through March 1983.

The air sample was collected using a radon sampler. This system is a single-pump, single-bag sampler designed to collect a composite ambient air sample over a preselected time interval. Particulates are removed by an inline 37 mm diameter, 5 micron filter. The sample bag is made of Tedlar and has a 30 liter volume. The system is housed in a 226 liter plastic drum.

This unit is used to collect three consecutive composite air samples per month at each air monitoring station. The three samples represent two 48-hour and one 72-hour composite sample. The air in the sample gas is analyzed by CBR personnel for the concentration of radon-222 by using a Lucas cell and a SAC-R5 scintillation detector with an MS-3 scaler. As of July 1987, CBR changed the method of measuring environmental radon gas concentration to the track etch cup method.

As was stated earlier, air sampling has taken place since the beginning of the second quarter of 1982. Research & Development operations did not begin until the third quarter, 1986; therefore, the air monitoring results through the second quarter, 1986 are included as preoperational. The means and standard deviations for radiometric air particulate concentrations from the second quarter 1982 through the first quarter 1987 for AM-1, 2, 6 and 7 are given in Table 2.10-2. Table 2.10-2 also illustrates the results for AM-3, 4 and 5 for the first year of monitoring during which these stations operated. Approximately 2000 m^3 of air was sampled during each sampling period. The analyses were performed by a commercial laboratory. The filters from each of the monitoring stations were analyzed for the concentration of natural uranium, thorium-230, radium-226 and lead-210. From these analyses and the total volume of air sampled, the concentration in air is calculated and listed in Table 2.10-2 as uCi/ml of air.

Comparing the concentrations given in this table to those reported by the National Council on Radiation Protection (NCRP45, 1985), these values are consistent with reported background concentrations. As can also be seen from this table, the concentrations of radionuclides vary considerably at any given location and between locations. This variability, according to NCRP-45, is not unusual and has been demonstrated at other locations. For example, the maximum uranium concentration reported for Anaconda's Rhode Ranch Project in South Texas is 3.0×10^{-16} uCi/ml, while in Wyoming at Conoco's Sand Rock Mill Project, the concentration of uranium was reported to average 20.3×10^{-16} uCi/ml (Texas Department of Health, 1982; USNRC, 1982).

Also included in Table 2.10-2 are the values listed in 10 CFR Part 20, Appendix B, Table II. These values represent the maximum offsite concentration of the

Table 2.10-2: Average Results of the Air Particulate Survey Crow Butte Project

Station Location	Natural Uranium (uCi/ml)x10 $^{-16}$	Thorium-230 (uCi/ml)x10 $^{-16}$	Radium-226 (uCi/ml)x10 $^{-16}$	Lead-210 (uCi/ml)x10 $^{-16}$
AM-1 [1]	10.2 ± 13.9	8.1 ± 7.5	2.0 ± 1.2	147.2 ± 89.3
AM-2 [1]	18.6 ± 23.9	2.8 ± 5.5	2.3 ± 1.1	146.1 ± 4.3
AM-3 [2]	2.8 ± 1.7	13.6 ± 15.8	4.1 ± 5.3	120.4 ± 40.5
AM-4 [2]	2.3 ± 1.7	11.6 ± 17.5	2.4 ± 1.1	282.5 ± 334.0
AM-5 [2]	14.5 ± 32.9	15.2 ± 29.0	1.9 ± 1.1	215.8 ± 95.1
AM-6 [1]	1.7 ± 1.5	8.4 ± 7.1	1.8 ± 0.8	147.9 ± 69.6
AM-7 [1]	3.7 ± 2.9	6.0 ± 2.5	2.4 ± 2.3	164.7 ± 73.6
AM-8 [3]	76.1	20.0 ± 8.0	5.8 ± 2.9	160.0 ± 30
10 CFR 20 Appendix B Table II	50,000	800	30,000	40,000

Notes:
1 Time period is 2nd quarter 1982 through first quarter 1987.
2 Time period is 2nd quarter 1982 through 1st quarter 1983.
3 Time period is 2nd quarter 1987.

various radionuclides and are given for the insoluble fraction since it is generally more restrictive than the limits for the soluble fraction. These limits are applicable after consideration of naturally occurring background concentrations. The background concentrations measured at the Crow Butte Project generally range from 1 percent of the thorium-230 limit to less than 0.01 percent of the uranium limit and radium-226 limit.

The results of the radon sampling are present in Table 2.10-3. This table gives the mean and standard deviations for the concentration of radon in air that were obtained at the four primary air monitoring stations for forty-five months preceding the start-up of the R&D operations. The data for AM-3, 4 and 5 represent nine months of the monitoring program. Data for each month consisted of three samples collected and analyzed during the month.

The average values for the forty-five month period were quite consistent for all seven monitoring stations with mean values ranging from 0.18 to 0.20 x 10^{-9} uCi/ml. AM-7, the background location, averaged 0.20 x 10^{-9} uCi/ml. Values for radon-222 near the area of the proposed Sand Rock Mill Project in Campbell County, Wyoming have been reported to range from 0.01 x 10^{-9} to 0.81 x 10^{-9} uCi/ml (USNRC, 1982). Average values ranging from 0.15 x 10^{-9} to 0.20 x 10^{-9} uCi/ml of radon-222 have been measured in the region of the Rhode Ranch Project in South Texas (Texas Dept. of Health, 1982). The outdoor levels of radon-222 vary widely and have been reported to range from 0.04 x 10-9 to 2.0 x 10-9 uCi/ml (USNRC, 1979A, USEPA, 1979). The limit for radon-222 stated in Table II of Appendix B, 10 CFR Part 20 is 3 x 10^{-9} uCi/ml. This limit is for unrestricted locations and is applied after correction for the background radon-222 concentration.

Table 2.10-4 lists the radon-222 and air particulate concentrations during the R&D operation. There is no statistical difference (a = 0.05) between the mean concentration values of radon-222 before and during the operations. With only two quarters of data for the airborne particulate concentrations, statistical differences can only be evaluated based on comparing the individual quarterly results with the mean concentrations prior to operation. The statistical differences which exist consistently include increased radium-226 concentrations at AM-1, and below average concentrations of thorium-230 at AM-7. Other differences which exist between the concentrations prior to and during R&D operations, however, were not consistent. Given the large standard errors associated with air particulate concentrations and the minimal data available for air particulate concentrations during operation, statistical comparisons are probably inappropriate.

Table 2.10-3: Average Ambient Radon-222 Concentration Crow Butte Project

Air Monitor Station Number	Radon Concentration x 10^{-19} uCi/ml
AM-1	0.19 ± 0.14
AM-2	0.19 ± 0.11
AM-3	0.20 ± 0.13
AM-4	0.19 ± .011
AM-5	0.20 ± 0.11
AM-6	0.18 ± 0.13
AM-7	0.20 ± 0.14

Time Periods

AM-1, AM-2, AM-6, AM-7	Samples from 2nd quarter 1982 through 4th quarter of 1985.
AM-3, AM-4, AM-5	Sample taken from 2nd quarter 1982 through 4th quarter 1982.

Table 2.10-4: Average Air Particulate and Radon-222 Concentrations During R&D Operations Crow Butte Project

Air Monitor Station	Radon-222[1] x 10^{-9} µCi/ml		Natural Uranium[2] x 10^{-16} µC/ml	Th-230[2] x 10^{-16} µCi/ml	Ra-226[2] x 10^{-16} µCi/ml	Pb-210[2] x 10^{-16} µCi/ml
AM-1	0.20 ± 0.18	4th 1986	< 1.0	< 0.9	6.9 ± 4.3	280 ± 70
		1st 1987	34.0	< 1.0	15.1 ± 2.2	162 ± 160
AM-2	0.21 ± 0.14	4th 1986	4.4	0.9	2.6 ± 3.4	220 ± 50
		1st 1987	1.9	5.4 ± 1.32	2.9 ± 1.8	140 ± 20
AM-6	0.20 ± 0.27	4th 1986	< 1.0	54.0 ± 26.0	22.6 ± 6.1	230 ± 70
		1st 1987	1.9	9.8 ± 5.4	3.8 ± 2.1	160 ± 30
AM-7	0.35 ± 0.50	4th 1986	< 1.0	< 0.9	< 0.8	180 ± 60
		1st 1987	1.9	< 1.0	2.2 ± 1.8	160 ± 20

Notes:
1 Monthly samples from August 1986 through March 1987.
2 4th quarter 1986 and 1st quarter 1987; air volume sampled greater than 2000 m^3.

2.10.3 WATER SAMPLING PROGRAM

Ground Water

In the area around the Crow Butte site, 20 private water wells were used to determine the concentrations of various radionuclides in the groundwater. The locations of these wells are shown in Figure 2.10-1. Samples from these wells were analyzed for radionuclides. This section will be limited to the results of the radiometric analyses.

The sampling program began in October 1981 when a few wells were sampled. By May 1982, all wells within one kilometer of the commercial permit area had been sampled for radionuclides at least once. The analyses of these wells are shown in Table 2.10-5. The samples were collected at a discharge point closest to the well and preserved following EPA Guidelines. The samples were not filtered and the results represent the concentration of the total radionuclides. The primary analytical laboratories were Core Laboratories, Inc. in Denver, Colorado and Energy Laboratories in Casper, Wyoming. Some of the analyses for uranium and radium-226 were performed by Natural Resources Laboratory in Denver, Colorado. Duplicate analyses were performed on sample splits by Jordan Laboratories in Corpus Christi, Texas.

Table 2.10-6 contains the results of the analyses on all wells sampled from 1981 to 1986 for the concentration of natural uranium and radium-226. Some of these wells were also included in Table 2.10-5. The locations of these wells are shown in Figure 2.10-1. The results of the analyses indicate concentrations of the radionuclides are within the expected ranges for naturally occurring background concentrations.

In addition to the thirty private wells that were sampled, eleven additional wells were drilled by CBR. These wells were screened in specific formations, four wells being completed in the Brule and seven wells in the Chadron. These wells were sampled from late July 1982 through October 1985 and analyzed for the concentration of uranium and radium-226. The results of the sampling for these wells are shown in Table 2.10-7.

In addition to these regional baseline wells and the area private wells, samples have been collected from eleven monitor wells for a minimum of four samples. The mean uranium concentration is 22.1 ± 12 uCi/ml x 10^{-9}, with a mean radium-226 concentration of 51.2 ± 80.6 x 10^{-9} uCi/ml. Table 2.10-8 lists the means and standard deviations for the individual monitor wells.

**Table 2.10-5: Results of the Radiometric Analysis of Area Water Wells
Crow Butte Project**

Well Number	Sample Date	U-Nat x 10 $^{-9}$ μCi/ml	Th-230 x 10 $^{-9}$ μCi/ml	Ra-226 x 10 $^{-9}$ μCi/ml	Pb-210 x 10 $^{-9}$ μCu/ml	Po-210 x 10 $^{-9}$ μCi/ml
8	5/10/82	14	0.1 ± 0.3	0.3 ± 0.1	0.7 ± 0.7	0.1 ± 0.2
11	5/4/82	5	0.3 ± 0.5	0.3 ± 0.1	0.0 ± 0.7	0.5 ± 0.4
12	5/10/82	2	0.7 ± 0.54	0.2 ± 0.1	0.6 ± 0.8	0.2 ± 0.2
13	4/29/82	5	0.0 ± 0.2	0.1 ± 0.1	0.2 ± 0.7	0.5 ± 0.3
16	5/4/82	5	0.5 ± 0.6	0.3 ± 0.1	0.0 ± 0.8	0.3 ± 0.2
17	4/28/.82	1	0.1 ± 0.6	0.4 ± 0.1	0.4 ± 0.6	0.1 ± 0.3
	7/13/82	6	0.0 ± 0.8	0.1 ± 0.1	0.0 ± 3.5	0.4 ± 0.3
	10/5/82	4	---	0.6 ± 0.1	0.0 ± 1.8	0.1 ± 0.1
24	5/8/82	2	0.2 ± 0.4	0.3 ± 0.1	0.0 ± 0.7	0.0 ± 0.1
25	4/28/82	2	0.0 ± 0.3	0.3 ± 0.1	0.5 ± 0.6	0.6 ± 0.3
	4/28/82	3	-0.4 ± 2.7	0.1 ± 0.1	-1.5 ± -2.3	-0.02 ± 0.2
	7/13/82	4	0.3 ± 1.0	0.1 ± 0.1	0.9 ± 3.6	1.4 ± 1.0
	10/4/82	5	---	0.4 ± 0.1	0.0 ± 1.6	0.3 ± 0.4
26	4/28/82	2	0.6 ± 0.5	0.1 ± 0.1	0.0 ± 0.6	0.2 ± 0.2
	7/14/82	4	0.0 ± 0.8	0.2 ± 0.1	0.0 ± 3.2	0.3 ± 0.9
	10/5/82	8	---	0.4 ± 0.1	0.0 ± 1.6	1.3 ± 1.2
27	5/8/82	3	0.4 ± 0.4	0.3 ± 0.1	0.4 ± 0.7	0.4 ± 0.3
	7/14/82	4	0.6 ± 1.0	0.2 ± 0.1	0.0 ± 3.4	0.0 ± 0.5
	10/5/82	3	---	0.5 ± 0.2	0.0 ± 1.7	0.6 ± 0.5
28	5/8/82	3	0.1 ± 0.4	0.5 ± 0.1	0.7 ± 0.7	0.3 ± 0.2
31	5/6/82	3	0.0 ± 0.3	0.1 ± 0.1	0.0 ± 1.0	0.2 ± 0.2
37	5/4/82	4	0.2 ± 0.4	0.3 ± 0.1	0.0 ± 0.7	0.5 ± 0.3
38	5/4/82	6	0.4 ± 0.6	0.2 ± 0.1	0.0 ± 0.7	0.3 ± 0.5

Table 2.10-5: Results of the Radiometric Analysis of Area Water Wells Crow Butte Project

Well Number	Sample Date	U-Nat x 10^{-9} µCi/ml	Th-230 x 10^{-9} µCi/ml	Ra-226 x 10^{-9} µCi/ml	Pb-210 x 10^{-9} µCu/ml	Po-210 x 10^{-9} µCi/ml
41	5/6/82	2	0.7 ± 0.5	0.4 ± 0.1	0.0 ± 0.8	0.5 ± 0.4
57	4/28/82	5	0.8 ± 0.7	0.4 ± 0.1	0.9 ± 0.7	0.3 ± 0.3
58	5/4/82	10	0.5 ± 0.4	0.5 ± 0.1	0.0 ± 0.7	0.5 ± 0.5
59	5/4/82	26	1.0 ± 0.6	0.2 ± 0.1	0.4 ± 0.9	0.6 ± 0.3
62 *	4/27/82	22	0.4 ± 0.5	13.8 ± 0.6	10.6 ± 1.3	0.8 ± 0.4
	4/27/82	21	0.7 ± 1.7	17 ± 1.0	22 ± 4.0	0.9 ± 0.3
63	4/28/82	8	0.1 ± 0.5	0.5 ± 0.1	0.1± 0.7	0.5 ± 0.3

Notes: See Figure 2.10-1 for well locations.
* Chadron formation. All other wells are in the Brule Formation.

Table 2.10-6: Average Results of Uranium and Radium-226 Analysis of Area Water Wells

Well Number	Formation	Dates	Natural Uranium x 10^{-9} μCi/ml	Radium-226 x 10^{-9} μCi/ml
13	Brule	1/82 - 7/85	5.01 ± 2.20	0.26 ± 0.28
17	Brule	10/81 - 10/86	2.44 ± 2.17	0.43 ± 0.55
19	Brule	7/85 - 10/85	2.37 ± 1.42	0.45 ± 0.35
25	Brule	10/81 - 10/86	3.05 ± 2.30	0.45 ± 0.53
26	Brule	10/81 - 10/86	3.66 ± 2.10	0.64 ± 0.98
27	Brule	10/81 - 10/86	3.10 ± 2.78	0.54 ± 0.71
30	Brule	1/82 - 10/85	10.56 ± 3.15	0.54 ± 0.23
40	Brule	1/82 - 7/85	3.11 ± 1.49	0.36 ± 0.23
56	Brule	10/81 - 7/85	12.19 ± 3.66	0.29 ± 0.22
57	Brule	10/81 - 4/86	4.4 ± 2.78	1.2 ± 2.9
61	Chadron	10/81 - 7/85	0.95 ± 0.34	3.3 ± 0.85
62	Chadron	10/81 - 7/85	16.42 ± 4.47	13.98 ± 3.9
63	Brule	10/81 - 7/85	7.38 ± 3.72	0.44 ± 0.22
65	Chadron	10/81 - 7/85	1.29 ± 0.98	19.29 ± 3.68
66	Brule	10/81 - 7/85	18.90 ± 6.57	0.58 ± 0.64
74	Brule	10/81 - 7/85	6.97 ± 1.96	0.42 ± 0.19
88	Brule	1/82 - 7/85	11.58 ± 3.99	0.46 ± 0.26
95	Brule	1/82 - 7/85	15.64 ± 2.78	0.53 ± 0.35

These values will be used to establish the actual background concentrations of the radionuclides in the zone to be mined.

The concentration of uranium in the wells completed in the Brule Formation (Table 2.10-5, Table 2.10-6, Table 2.10-8, Table 2.10-9) ranges from 1 x 10^{-9} to 26 x 10^{-9} uCi/ml, while the Chadron wells vary between 0.95 x 10^{-9} and 426 x10^{-9} uCi/ml. A study of uranium concentrations in groundwater was conducted in southcentral Nebraska on the north side of the Platte River. This study found uranium concentrations ranging from 0.3 x 10^{-9} to 380 x 10^{-9} uCi/ml with an average of 54 x 10^{-9} uCi/ml. The source of this uranium was concluded to be from upgradient irrigated croplands (Spalding, 1981).

In another study performed on groundwater in Southeastern Harding County, South Dakota, the uranium concentrations were reported to range from 0.7 x 10^{-9} to 15 x 10^{-9} uCi/ml (Struempler, 1980). This area of South Dakota has been studied due to the potential for uranium deposits in the region. Groundwater samples collected in the Brule Formation in northwestern Nebraska and analyzed for uranium concentrations average 12 x 10^{-9} uCi/ml, while samples from wells completed in the Chadron Formation averaged 32 x 10^{-9} uCi/ml (Struempler, 1979).

The analyses of the baseline wells completed in the Brule display the fairly low concentrations of uranium and radium-226 that are typical of the Brule Formation. Some baseline wells completed in the Chadron Formation have radionuclide concentrations that are low, while the other wells have elevated concentrations of uranium and radium-226. An explanation for these elevated levels is that these wells were completed in or near the mineralized zone of the Chadron Formation. The Chadron is known to be mineralized and is the formation from which the uranium will be extracted and therefore, these elevated levels are not unexpected. As can be seen from the data presented, radium-226 concentrations in the Chadron Formation can be extremely high. In the R&D wellfield, values exceeding 1000 x 10^{-9} uCi/ml are present.

<u>Surface Water</u>

Surface waters in the region surrounding the Crow Butte Project have been sampled as part of the preoperational radiological monitoring program. Eight impoundments have been incorporated into the program. These impoundments are labels I-1 through I-8 on the topographic map (Figure 2.10-1). There are no impoundments located within the restricted area boundary.

The impoundments were sampled semiannually for one year. The samples were collected in June, 1982 and January, 1983. Samples collected in June,

Table 2.10-7: Average Radiometric Analysis of Regional Baseline Wells Crow Butte Project

Well Number	Formation	Natural Uranium x 10^{-9} μCu/ml	Radium-226 x 10^{-9} μCi/ml
RA-1	Brule	4.2 ± 3.5	6.9 ± 2.1
RA-2	Brule	9.8 ± 3.3	2.1 ± 5.38
RB-1	Brule	2.0 ± 3.1	1.9 ± 1.4
RB-3	Brule	3.4 ± 2.2	2.6 ± 4.7
RC-1	Chadron	1.5 ± 0.9	0.8 ± 0.6
RC-2	Chadron	1.8 ± 1.2	1.4 ± 1.4
RC-3	Chadron	2.1 ± 1.7	1.2 ± 0.8
RC-4	Chadron	425 ± 597.7	366 ± 120
RC-5	Chadron	1.42 ± 1.2	4.3 ± 2.1
RC-6	Chadron	1.8 ± 1.4	2.3 ± 4.3
RC-7	Chadron	2.2 ± 2.1	1.1 ± 0.8

Table 2.10-8: Average Uranium and Radium-226 in R&D Monitor Wells Crow Butte Project

Well Number	Formation	Date	Natural Uranium x 10^{-9} μCi/ml	Radium-226 x 10^{-9} μCi/ml
PM-1	Chadron	12/82 - 10/86	33.2 ± 14.2	84.0 ± 49.3
PM-2	Chadron	11/85 - 10/86	17.9 ± 9.4	5.2 ± 2.3
PM-3	Chadron	11/85 - 10/86	25.1 ± 10.6	12.6 ± 6.3
PM-4	Chadron	12/82 - 10/86	13.5 ± 5.9	60.1 ± 20.0
PM-5	Chadron	11/85 - 10/86	35.5 ± 28.2	27.9 ± 44.5
PM-6	Brule	12/82 - 10/86	4.4 ± 2.3	2.4 ± 2.7
PM-7	Brule	1/83 - 10/86	15.2 ± 7.0	1.8 ± 2.6
PM-8	Chadron	11/85 - 10/86	25.5 ± 10.6	60.2 ± 19.9
PM-9	Chadron	11/85 - 10/86	44.6 ± 17.5	34.8 ± 10.3
PM-10	Chadron	11/85 - 10/86	18.5 ± 7.11	19.7 ± 6.5
PM-11	Brule	11/85 - 10/86	10.0 ± 9.1	4.9 ± 5.2

1982 were analyzed for the concentration of natural uranium, thorium-230, radium-226, lead-210 and polonium-210. The samples were not filtered and the results of the analysis represent the combination of both the dissolved and suspended concentrations. A commercial laboratory performed the analyses. The samples collected in January, 1983 were analyzed for uranium and radium-226.

The results of the analyses for the two sets of samples are shown Table 2.10-9. All the impoundments appear to have similar concentrations of radionuclides. Uranium varied from 2.7×10^{-9} to 7.1×10^{-9} uCi/ml, while radium varied from 0.03×10^{-9} to 0.8×10^{-9} uCi/ml. All of the values are within ranges considered as natural background. Concentrations of uranium in impoundments near the Anaconda Rhode Ranch Project, in South Texas, have been reported to vary between $<1.2 \times 10^{-9}$ and 4.6×10^{-9} uCi/ml, while radium-226 ranged from 0.0×10^{-9} to a maximum of 1.4×10^{-9} uCi/ml (Texas Department of Health, 1982).

A small stream, Squaw Creek, passes north of the Crow Butte restricted area. This stream eventually enters the White River downstream of Crawford. In the preoperational radiological monitoring program, four sample sites (2 primary S-2, S-3) were designated on Squaw Creek. These sites are shown in Figure 2.10-1. Site S-2 is located on Squaw Creek as it enters the restricted area and S-3 is downstream from the restricted area. Site S-1 is located southeast of the Permit Area and Site S-4 is located north of the Permit Area.

Samples were collected from these locations on a quarterly basis beginning in February 1982. The first samples from S-2 were analyzed for the concentrations of total uranium, thorium-230 and radium-226. Additionally, on a semiannual basis, the downstream sample was analyzed for lead-210 and polonium-210. Core Laboratories in Denver performed a majority of these analyses. Samples from S-1 and S-4 were analyzed for uranium and radium-226 only.

Samples were also taken from White Clay Creek which flows near the Permit Area over the time period of 4/82 to 10/85 and analyzed for uranium and radium-226. These samples are designated as WC-1 and WC-2 on Figure 2.10-1.

The results obtained on samples collected from February 1982 are listed in Table 2.10-10. The upstream (S-2) and downstream (S-3) samples were consistent within a given sampling period, but varied between quarterly samples. The differences in stream flowrate at various sampling times may have resulted in these perturbations. The results displayed in Table 2.10-10 are consistent with concentrations normally considered as naturally occurring.

Table 2.10-9: Average Radiometric Analysis of Water Samples From Surface Water Impoundments Crow Butte Project

Sample Location	Natural Uranium x 10^{-9} µCi/ml	Thorium-230 x 10^{-9} µCi/ml	Radium-226 x 10^{-9} µCi/ml	Lead-210 x 10^{-9} µCi/ml	Polonium-210 x 10^{-9} µCi/ml
I-1	2.7	1.4 ± 0.8	0.6	0.2 ± 0.9	0.8 ± 0.6
I-2	6.4 ± 1.4	2.3 ± 0.7	0.3	0.3 ± 0.6	0.9 ± 1.0
I-3	4.4 ± 3.4	1.5 ± 0.6	0.8 ± 0.3	1.0 ± 1.0	2.0 ± 1.2
I-4	6.1 ± 0.95	3.8 ± 1.7	0.45 ± 0.21	0.6 ± 1.3	0.3 ± 0.6
I-5	4.7 ± 0.95	2.7 ± 1.1	0.65 ± 0.2	0.1 ± 0.9	0.0 ± 0.3
I-6	4.1 ± 1.4	2.0 ± 1.3	0.5 ± 0.2	1.8 ± 1.4	0.2 ± 0.4
I-7	6.4 ± 1.4	---	0.6 ± 0.0	---	---
I-8	7.1 ± 1.4	---	0.6 ± 0.1	---	---

Table 2.10-10: Average Radiometric Analysis of Water Samples From Squaw Creek Crow Butte Project

Sample Location	Sample Period	U-Nat x 10^{-9} µCi/ml	Th-230 x 10^{-9} µCi/ml	Ra-226 x 10^{-9} µCi/ml	Pb-210 x 10^{-9} µCu/ml	Po-210 x 10^{-9} µCi/ml
S-1	2/82 - 10/85	2.5 ± 2.4	---	0.5 ± 0.95	---	---
S-2	2/82 - 1/87	2.8 ± 3.5	2.0 ± 1.7	0.6 ± 0.8	---	---
S-3	2/82 - 1/87	8.3 ± 24.1	0.6 ± 0.2	0.4 ± 0.4	0.7 ± 0.5	0.3 ± 0.1
S-4	4/82 - 7/84	3.1 ± 1.7	---	0.4 ± 0.3	---	---
WC-1	4/82 - 10/85	5.9 ± 2.9		0.4 ± 0.2		
WC-2	4/82 - 10/85	6.1 ± 4.2		0.3 ± 0.1		

Squaw Creek empties into the White River and samples collected from the White River show average uranium concentrations of between 2.5 x 10^{-9} and 7.8 x 10^{-9} uCi/ml and average radium concentrations between 0.3 x 10^{-9} and 1.0 x 10^{-9} uCi/ml.

Uranium concentrations in the Platte River in southcentral Nebraska have been reported to average 16 x 10^{-9} uCi/ml (Spalding, 1981). The Brazos River in central Texas has been reported to have uranium concentrations between 0.4 x 10^{-9} and 1.8 x 10^{-9} uCi/ml (Spalding and Exner, 1976). In the study of the Brazos River, the source of uranium was identified as the phosphate fertilizers used in the region. This source of uranium was also identified as contributing to a uranium concentration of 1.3 x 10^{-9} uCi/ml found in the Navasota River and an average of 0.66 x 10^{-9} uCi/ml in the Little Brazos, both located in central Texas (Spalding and Sackett, 1972).

2.10.4 SOIL SAMPLING PROGRAM

Samples of the soils in and nearby the Commercial Permit Area have been collected. The samples were collected in July 1982 at 50 locations in the Commercial Permit Area and vicinity. The locations are shown in Figure 2.10-1. The samples were all surface samples, collected to a depth of 5 centimeters. Two of the sites, Nos. 24 and 27, also serve as subsurface sites. One-third meter composite samples to a total depth of one meter were collected at each of the two locations. Once collected, the samples were bagged and sent to a commercial lab for analysis. The concentrations of uranium and radium-226 were determined as well as the concentrations of the various metals. Only the radiometric analyses will be presented in this section. The nonradiometric analyses are discussed in Section 2.9.

The results of the surface soil sampling program are presented in Table 2.10-11 and the subsurface soil sample results are in Table 2.10-12. The uranium concentration varied from 0.36 x 10^{-6} to 6.7 x 10^{-6} uCi/g, while radium-226 ranged between 0.1 x 10^{-6} and 2.0 x 10^{-6} uCi/g. The radionuclide concentrations are found to be homogeneous through the first meter of soil. Also included in Table 2.10-11 are the results of the surface soil samples collected at the air monitoring stations. These results appear similar to the samples collected in the area with the exception of the uranium concentration in the sample collected at AM-6 (Sample Location 6). This uranium value is slightly higher than the other samples. A possible explanation for this anomaly is that AM-6 is located very close to the compacted dirt driveway of a local motel and that the surface sample may have included a substantial contribution from the roadbed material. This value for uranium is still considered low and at this time, there does not appear to be a need for resampling AM-6.

Table 2.10-11: Radionuclides in Surface Soils From Commercial Permit Area and Vicinity

Sample Location [1]	Date	Natural Uranium x 10^{-6} µCi/g	Radium-226 x 10^{-6} µCi/g
1	7/24/82	1.4	1.1 ± 0.2
2	7/24/82	0.75	1.4 ± 0.3
3	7/24/82	0.68	0.9 ± 0.3
4	7/24/82	0.83	1.4 ± 0.3
5	7/24/82	5.2	1.4 ± 0.3
6	7/24/82	6.7	0.9 ± 0.2
7	7/24/82	1.4	2.0 ± 0.4
8	7/24/82	1.1	1.3 ± 0.3
9	7/24/82	2.0	1.2 ± 0.3
10	7/24/82	0.51	1.6 ± 0.3
11	7/24/82	1.2	1.6 ± 0.3
12	7/24/82	1.8	1.2 ± 0.2
13	7/24/82	1.9	1.2 ± 0.2
14	7/24/82	2.3	1.2 ± 0.2
15	7/24/82	1.6	1.3 ± 0.2
16	7/24/82	1.3	1.4 ± 0.2
17	7/24/82	2.4	1.5 ± 0.3
18	7/24/82	1.8	1.3 ± 0.3
19	7/24/82	1.5	0.7 ± 0.2
20	7/24/82	1.9	0.8 ± 0.2
21	7/24/82	3.2	1.6 ± 0.3
22	7/24/82	3.3	1.3 ± 0.2
23	7/24/82	1.3	1.2 ± 0.2
24	7/24/82	0.36	1.4 ± 0.3
25	7/24/82	1.6	0.9 ± 0.2
26	7/24/82	1.2	0.8 ± 0.2
27	7/24/82	1.7	0.9 ± 0.2
28	7/24/82	0.38	0.7 ± 0.2
29	7/24/82	1.2	1.2 ± 0.2
30	7/24/82	0.65	1.0 ± 0.2
31	7/24/82	1.2	0.7 ± 0.2
32	7/24/82	1.2	0.5 ± 0.2
33	7/24/82	1.4	0.9 ± 0.3
34	7/24/82	1.2	1.3 ± 0.3

Table 2.10-11: Radionuclides in Surface Soils From Commercial Permit Area and Vicinity

Sample Location [1]	Date	Natural Uranium x 10^{-6} μCi/g	Radium-226 x 10^{-6} μCi/g
35	7/24/82	0.86	1.0 ± 0.2
36	7/24/82	1.1	0.7 ± 0.2
37	7/24/82	1.2	0.8 ± 0.3
38	7/24/82	1.7	1.0 ± 0.2
39	7/24/82	1.5	1.0 ± 0.2
40	7/24/82	1.1	0.5 ± 0.1
41	7/24/82	0.59	0.8 ± 0.2
42	7/24/82	0.81	0.7 ± 0.2
43	7/24/82	1.5	0.9 ± 0.2
44	7/24/82	1.7	1.0 ± 0.3
45	7/24/82	1.8	1.3 ± 0.3
46	7/24/82	1.6	0.8 ± 0.2
47	7/24/82	1.7	0.4 ± 0.2
48	7/24/82	1.1	0.4 ± 0.2
49	7/24/82	2.4	0.9 ± 0.2
50	7/24/82	1.5	0.8 ± 0.2

Notes: [1] Samples 1 - 7 taken from air monitoring stations.
Samples 8 - 50 taken from sites shown in Figure 2.10-1

Table 2.10-12: Radiometric Analysis of Subsurface Soil Samples in Section 19- Crow Butte Project

Sample Location	Depth	Natural Uranium x 10^{-6} μCi/g	Radium-226 x 10^{-6} μCi/g
24	0 - 0.33 m	1.2	0.4 ± 0.1
24	0.34 - 0.66 m	1.2	0.3 ± 0.1
24	0.67 - 1.0 m	1.2	0.2 ± 0.1
27	0 - 0.33 m	1.2	0.2 ± 0.1
27	0.34 - 0.66 m	0.6	0.1 ± 0.1
27	0.67 - 1.0 m	0.6	0.2 ± 0.1

The concentration of uranium in sandstones has been reported to be between 0.3×10^{-6} and 0.4×10^{-6} uCi/g (Eisenbud, 1973, Eicholz, 1976). In Campbell County, Wyoming near Conoco's proposed Sand Rock Mill Project, the results of the surface soil sampling showed radium-226 in the range of 0.1×10^{-6} to 1.8×10^{-6} uCi/g and the highest concentration of uranium was reported to be 5.1×10^{-6} uCi/g (USNRC, 1982). Soil samples collected around Ray Point and Falls City, Texas had a reported average radium-226 concentration of 0.9×10^{-6} uCi/g with a range of 0.5×10^{-6} to 1.4×10^{-6} uCi/g (USNRC, 1979a).

In addition to the 50 surface samples collected in the Commercial Permit Area and vicinity, nine surface samples were collected within the Crow Butte restricted area boundary. The locations of the samples in the Crow Butte proposed commercial restricted area are shown in Figure 2.10-2. Of the nine surface sample sites, five sites were chosen for subsurface sampling - one subsurface site in each R&D wellfield and one in the plant area. These subsurface sites were sampled to a depth of one meter with composite samples prepared at one third meter intervals. When the R&D ponds were excavated, one sample was collected from the lowest point in each pond. This samples was a composite sample to a total depth of 60 centimeters below pond bottom.

All of the samples collected within the restricted area boundary were analyzed for the concentration of natural uranium and radium-226. All the samples were collected in December 1982 with the exception of the subsurface samples from the pond bottoms and the surface samples in the plant area after topsoil removal. The results of the analyses are contained in Table 2.10-13. The radionuclide concentrations are consistent with those obtained from samples collected in Section 19 and presented in Table 2.10-11 and Table 2.10-12.

2.10.5 SEDIMENT SAMPLING PROGRAM

Sediments in selected impoundments and Squaw Creek have been sampled as part of the preoperational radiological sampling program. These sediments were analyzed for the concentration of natural uranium, Th-230, Ra-226, Pb-210 and Po-210. Sediments from Squaw Creek were sampled semiannually. The sediment sampling began in May 1982 and continued through April 1986. The location for the sampling was the same as for the water samples. Site S-2 is upstream from the R&D restricted area while S-3 is downstream of the restricted area. The results from the analysis of the sediments collected from May 1982 through October 1986 are listed in Table 2.10-14.

Figure 2.10-2: Soil Sample Sites in Restricted Area

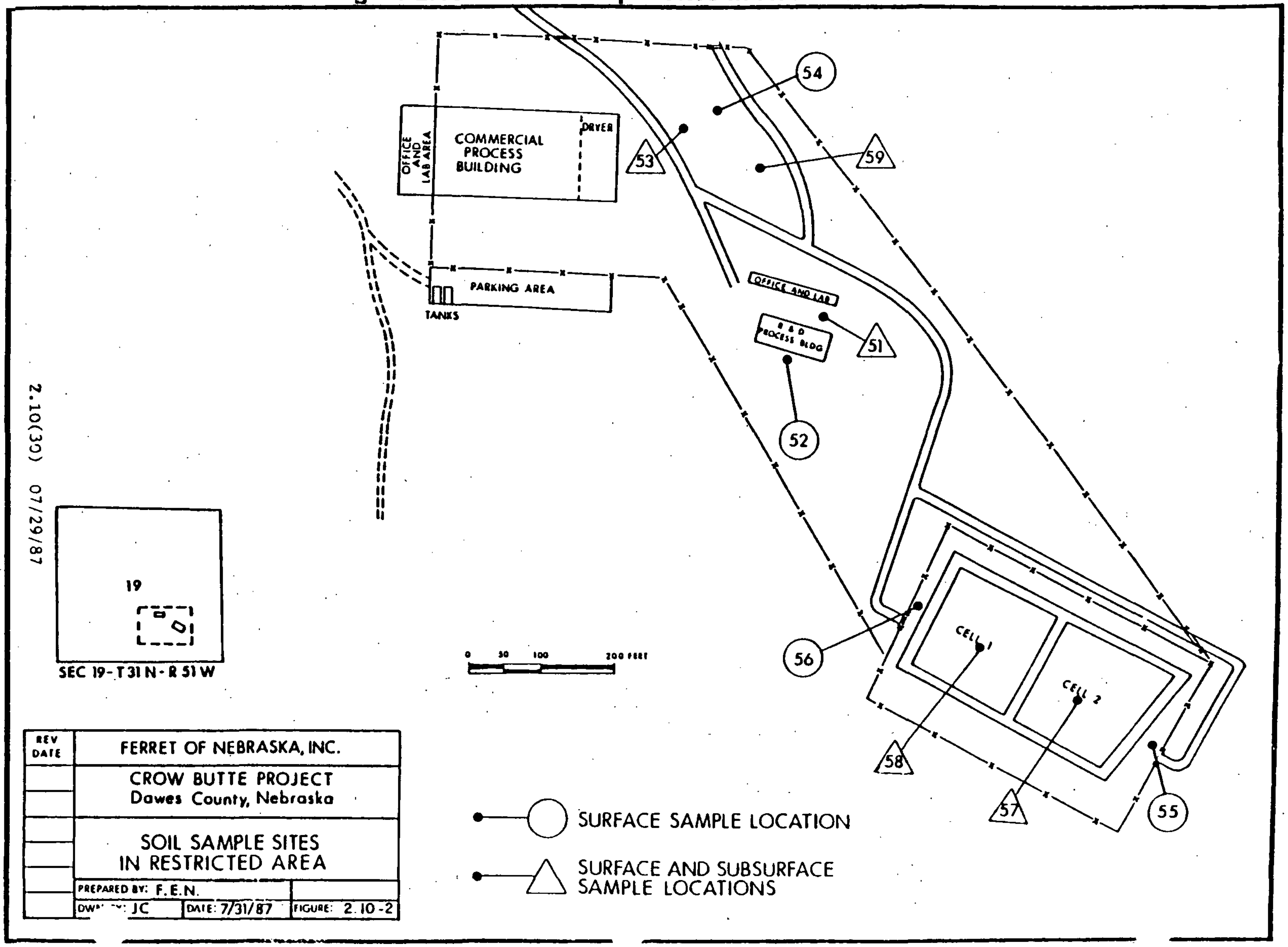


Table 2.10-13: Radiometric Analysis of Soil Samples Within the Crow Butte Restricted Area Boundary

Sample Location	Depth	Natural Uranium x 10^{-6} μCi/g	Radium-226 x 10^{-6} μCi/g
51	Surface	1.2	0.1 ± 0.1
51	0 - 0.33 m	1.8	0.3 ± 0.1
51	0.34 - 0.66 m	1.2	0.1 ± 0.1
51	0.67 - 1.0 m	1.2	0.2 ± 0.1
52	Surface	1.2	0.1 ± 0.1
53	Surface	1.8	0.0 ± 0.1
53	0 - 0.33 m	0.6	0.1 ± 0.1
53	0.34 - 0.66 m	0.6	0.1 ± 0.1
53	0.67 - 1.0 m	1.2	0.2 ± 0.1
54	Surface	4.2	0.1 ± 0.1
55	Surface	1.2	0.4 ± 0.1
56	Surface	1.2	0.1 ± 0.1
57	0 - 0.23 m	1.5	1.0 ± 0.2
57	0.23 - 0.44 m	1.3	1.1 ± 0.2
57	0.44 - 0.60 m	1.3	1.5 ± 0.3
58	0 - 0.27 m	1.5	1.5 ± 0.3
58	0.27 - 0.46 m	1.8	1.3 ± 0.3
58	0.46 -0.60 m	1.5	1.4 ± 0.3
59	Surface	1.2	0.2 ± 0.1
59	0 - 0.33 m	1.8	0.1 ± 0.1
59	0.34 - 0.66 m	1.2	0.1 ± 0.1
59	0.67 - 1.0 m	1.8	0.2 ± 0.2

Table 2.10-14: Average Radiometric Analysis of Sediment Samples From Squaw Creek
Crow Butte Project

Sample Location	Sample Period	U-Nat x 10^{-9} μCi/ml	Th-230 x 10^{-9} μCi/ml	Ra-226 x 10^{-9} μCi/ml	Pb-210 x 10^{-9} μCu/ml	Po-210 x 10^{-9} μCi/ml
S-2	5/82 - 10/86	4.9 ± 9.43	2.4 ± 4.6	0.9 ± 1.1	0.4 ± 0.3	1.0 ± 0.5
S-3	5/82 - 10/86	2.5 ± 4.2	2.2 ± 40	0.8 ± 0.5	0.3 ± 0.4	0.5 ± 0.2

The radionuclide concentrations in the sediments at the two sites are very similar and are less than the maximums reported by the NRC (1982). Sediment samples collected near the Sand Rock Mill Project in Wyoming has reported maximum values of $13x10^{-6}$ uCi/g for uranium, $3.5x10^{-6}$ uCi/g for radium-226, $3.4x10^{-6}$ uCi/g for thorium-230 and $22x10^{-6}$ uCi/g for lead-210 (USNRC, 1982). Sediments from impoundments near Anaconda's proposed Rhode Ranch Project in south Texas had maximum uranium concentrations of 11x10-6 uCi/g and radium-226 concentrations ranged from 0.1x10-6 to $1.2x10^{-6}$ uCi/g with an average of $0.5x10^{-6}$ uCi/g (Texas Department of Health, 1982).

Eight impoundments, I-1 through I-8 also had sediment samples collected in December of 1982 and January of 1983. The results of the analyses of these samples are presented in Table 2.10-15. The concentrations of radionuclides in these sediments are similar to those reported for sediments from Squaw Creek.

2.10.6 VEGETATION SAMPLING PROGRAM

As part of the preoperational radiological monitoring program vegetation samples were collected at the four primary air monitoring stations (AM-1, AM-2, AM-6, AM-7) and in the proposed R&D wellfield area. These samples were collected from June 1982 through July 1984 and analyzed for the concentrations of natural uranium,m Th-230, Ra-226, Pb-210 and Po-210. Samples were also taken at air monitoring stations AM-3, AM-4 and AM-5 in June of 1982 and in the pasture in the prevailing wind direction in 1987.

The results of the analyses are presented in Table 2.10-16. The vegetation sample at each air monitoring station was a composite sample of the vegetation present in proportion to occurrence. Table 2.10-17 lists the vegetation species that were composited at each location. The results of the analyses are typical of naturally occurring concentrations. Vegetation samples collected in the vicinity of the proposed Rhode Ranch Mill in south Texas had a range in the Ra-226 concentrations from $10x10^{-6}$ to $700x10^{-6}$ uCi/kg while the concentration of Pb-210 ranged from $500x10^{-6}$ to $1080x10^{-6}$ uCi/kg (Texas Department of Health, 1982). Vegetation collected in Campbell County, Wyoming had maximum uranium concentrations of $140x10^{-6}$ uCi/kg, $52x10^{-6}$ uCi/kg of Ra-226, $93x10^{-6}$ uCi/kg of Th-230, $3200x10^{-6}$ uCi/kg of Pb-210 and $410x10^{-6}$ uCi/kg of Po-210 (USNRC, 1982). The concentrations reported for Campbell County were considered normal background levels. The uranium concentration in pine tree branches has been reported to be $3.1x10^{-6}$ uCi/kg, $11x10^{-6}$ uCi/kg in grapes, $180x10^{-6}$ uCi/kg in celery leaves and $270x10^{-6}$ uCi/kg in garlic (Eichholz, 1976).

Table 2.10-15: Radiometric Analysis of Sediment Samples From Area Impoundments

Sample Location	Sample Period	U-Nat x 10^{-9} µCi/ml	Th-230 x 10^{-9} µCi/ml	Ra-226 x 10^{-9} µCi/ml	Pb-210 x 10^{-9} µCu/ml	Po-210 x 10^{-9} µCi/ml
I-1	12/15/82	0.6	2.8 ± 4.5	0.2 ± 0.1	1.1 ± 0.9	0.8 ± 0.3
I-2	1/7/83	1.8	0.8 ± 0.4	1.2 ± 0.2	1.8 ± 0.8	0.6 ± 0.5
I-3	12/15/82	1.2	0.0 ± 2.4	0.3 ± 0.1	0.7 ± 0.9	0.8 ± 0.3
I-4	12/15/82	1.2	3.2 ± 1.5	0.4 ± 0.1	1.0 ± 1.0	0.4 ± 0.3
I-5	1/7/83	1.2	1.0 ± 0.6	1.0 ± 0.2	1.7 ± 0.8	0.6 ± 0.4
I-6	1/7/83	1.2	1.0 ± 0.6	0.8 ± 0.1	3.7 ± 0.9	0.1 ± 0.2
I-7	1/7/83	1.8	1.1 ± 0.4	1.1 ± 0.1	2.4 ± 0.9	0.4 ± 0.3

Table 2.10-16: Average Concentration of Radionuclides in Vegetation- Crow Butte Project

Sample Location	U-Nat x 10^{-9} µCi/ml	Th-230 x 10^{-9} µCi/ml	Ra-226 x 10^{-9} µCi/ml	Pb-210 x 10^{-9} µCu/ml	Po-210 x 10^{-9} µCi/ml
AM-1	144 ± 206	4 ± 7	11 ± 18	28 ± 25	18 ± 15
AM-2	17 ± 22	8 ± 14	12 ± 20	19 ± 21	40 ± 61
AM-3 *	90	11 ± 8	32 ± 4	26 ± 12	26 ± 9
AM-4 *	6	14 ± 16	51 ± 6	30 ± 18	20 ± 6
AM-5 *	30	19 ± 15	41 ± 5	27 ± 14	20 ± 7
AM-6	22 ± 11	8 ± 10	16 ± 22	203 ± 316	101 ± 147
AM-7	87 ± 112	4 ± 6	10 ± 16	46 ± 39	31 ± 26
Wellfield Area	151 ± 139	1 ± 1	1 ± 1	297 ± 515	307 ± 510
Pasture Sample *	6	48 ± 4	28 ± 3	16 ± 4	0.7

Notes: * Data reresents a single sample.
Wellfield area sample taken in the R&D wellfield. Pasture sample was taken in June of 1987 NE of the restricted area in the direction of the prevailing wind.

Table 2.10-17: Vegetation Used in Radiological Composite Sample Crow Butte Project

Species	Sample Location AM-1	AM-2	AM-6	AM-7
Crested Wheatgrass (Agropyron cristatum)			X	
Intermediate Wheatgrass (Agropyron intermedium)	X	X		X
Western Wheatgrass (Agropyron smithii)	X			X
Blue Grama (Boutelous gracilis)				X
Smooth Brome (Bromus inermis)	X		X	
Japanese Brome (Bromus japonicus)		X		
Brome (Bromus tectorum)	X	X	X	X
Buffalo Grass (Buchloe dactyloides)				X
Sixweeks Fescue (Festuca octoflora)	X	X		X
Yellow Sweetclover (Melitotus officinalis)		X		
Little Barley		X		
Kentucky Bluegrass (Poa pratensis)			X	
Needlegrass (Stipa comata)	X			X
Needlegrass (Stipa viridula)				X

2.10.7 FISH SAMPLING PROGRAM

As part of the preoperational radiological sampling program, fish were collected from several area impoundments for radiological analyses. Impoundments designated I-2, I-5 and I-6 possessed a significant fish population and were sampled while impoundments I-1, I-3 and I-4 did not have a sufficient fish population to justify sampling. Additionally impoundment L-1 was sampled. This impoundment is in a different watershed than the Crow Butte commercial restricted area and as a result it should not be influenced by the commercial plant operation. In addition to these impoundments, two larger impoundments, Johnson Lake and Whitney Lake were sampled.

The fish samples were collected during the fourth week of June 1982. The collection methods used were electric shocking and netting. The fish were composited in the following order of preference; 1) game and food fish, 2) marginal game fish and 3) forage fish. After collection the fish were eviscerated and the internal organs discarded. The samples were bagged and transported to Core Laboratories in Denver, Colorado for analysis. The samples were analyzed for the concentration of natural uranium, Th-230, Ra-226, Pb-210 and Po-210.

Table 2.10-18 contains the results of the analysis. Table 2.10-19 lists the species that were included in each composite sample. The samples appear to have similar concentrations with uranium exhibiting the greatest variability. These values are considered background concentrations. For example samples of fish collected in south Texas near Anaconda's proposed Rhode Ranch Mill were determined to have lead-210 concentrations between 20×10^{-6} to 120×10^{-6} uCi/kg and a maximum polonium-210 concentration of 400×10^{-6} uCi/kg (Texas Department of Health, 1982). Samples of fish collected from Lake Corpus Christi located north of the city of Corpus Christi, Texas were reported to contain radium-226 concentrations ranging from 70×10^{-6} to 580×10^{-6} uCi/kg. Thorium-230 values ranged from 10×10^{-6} to 30×10^{-6} uCi/kg, in the same samples while radium-226 was reported to vary between 10×10^{-6} and 80×10^{-6} uCi/kg (Texas Department of Health, 1981).

2.10.8 DIRECT GAMMA RADIATION

As part of the preoperational monitoring program the gamma radiation in the environment around the Crow Butte R&D Project area was measured. This was accomplished using thermoluminescence dosimetry (TLD). Lithium fluoride chips were used and housed in rugged containers to provide

Table 2.10-18: Radiometric Analysis of Fish Samples From Area Impoundment Crow Butte Project

Sample Location	Date	U-Nat x 10^{-9} µCi/ml	Th-230 x 10^{-9} µCi/ml	Ra-226 x 10^{-9} µCi/ml	Pb-210 x 10^{-9} µCu/ml	Po-210 x 10^{-9} µCi/ml
I-2	6/26/82	30	51.3 ± 19.7	38.7 ± 5.2	183.6 ± 19.9	145.3 ± 21.2
I-5	6/23/82	60	17.2 ± 18.6	32.8 ± 4.8	91.9 ± 15.6	71.4 ± 12.9
I-6	6/26/82	120	51.8 ± 22.0	44.7 ± 6.1	64.9 ± 19.0	56.1 ± 14.1
L-1	6/25/85	42	8.4 ± 6.0	23.3 ± 2.7	76.7 ± 8.8	34.0 ± 8.5
Johnson Lake	6/24/82	18	38.8 ± 16.2	37.3 ± 4.3	195.3 ± 20.5	178.2 ± 23.9
Whitney Lake	6/27/82	24	34.4 ± 15.5	39.0 ± 4.8	59.8 ± 18.5	53.2 ± 13.8

Table 2.10-19: Species of Fish Used for Radiological Composite Sample- Crow Butte Project

Species	L-1	I-2	I-5	I-6	Whitney Lake	Johnson Lake
Brown Trout	X					
Rainbow Trout	X					
Brook Trout	X			X		
Largmouth Bass						X
White Bass					X	
Bluegill						X
Green Sunfish		X	X			
Black Crappie					X	
White Sucker		X				
Creek Chub		X				
Fathead Minnow			X	X		
Golden Shiner			X	X		
Longnose Dace				X		

protection from the weather. A total of five chips are located in each container. The containers or monitors are placed at predetermined locations approximately one meter above ground level. They are exchanged with new monitors on a quarterly basis and the exposed monitors are returned to Eberline Instrument Corporation for processing. The results are reported by Eberline in mRem per week. These devices provide an integrated exposure for the period between annealing and processing. A control monitor is stored in a lead shield during the environmental exposure period.

A total of fifty locations in the Commercial Permit Area were chosen for placement of the gamma TLD monitors. These locations are shown on the topographic map (Figure 2.10-1). These fifty include, 43 monitors located in and nearby the Permit Area and 7 TLD's; one at each of the air monitoring stations. The monitors were initially placed in service during the second quarter of 1982 and remained in place through April, 1983. The average results for five quarters are listed in Table 2.10-20. The data show a range from 1.50 to 1.84 mRem per week.

In addition to the environmental gamma monitors, the background gamma radiation in the plant, and pond areas was measured with a Mount Sopris SC-132 scintillometer. This instrument was calibrated on July 17, 1985 and the gamma survey was performed during the summer of 1985. The areas included in the gamma surveys were the proposed R&D evaporation ponds and plant area. The grid was approximately at fifty foot intervals.

The data obtained from the survey in the plant and pond areas are listed in Table 2.10-21 and in Table 2.10-22 respectively. The data in the tables correspond to instrument readings obtained at the intersection of the transects, while holding the scintillator at approximately one meter above ground level. In both tables the numerical axis corresponds to east-west direction with the numbers increasing to the east and the lettered axis corresponding to the north-south direction with the letter A representing the southernmost boundary. In the plant area 20 readings were obtained ranging from a low value of 0.01 mR/hr to a high of 0.014 mR/hr. The average reading was 0.012 mR/hr with a standard deviation of 0.0011 mR/hr. The results appear to be randomly occurring through the survey area and no attempt was made to contour the results. Survey for the pond area resulted in 45 readings with an average of 0.013 mR/hr and a standard deviation of 0.0008 mR/hr. Again the individual readings seemed to be randomly distributed and contouring of the results was not applicable.

The average of the TLD gamma monitors was 1.69 + 0.07 mRem per week which, assuming a relative biological efficiency of unity, corresponds to 0.010 mR/hr. The average background gamma level in the Western Great Plains

Table 2.10-20: Results of Gamma TLD Dosimeters Crow Butte Project

Location	Average Gamma (mRem/week)	Location	Average Gamma (mRem/week)
AM-1	1.65	26	1.57
AM-2	1.71	27	1.65
AM-3	1.72	28	1.75
AM-4	1.60	29	1.74
AM-5	1.84	30	1.57
AM-6	1.72	31	1.59
AM-7	1.71	32	1.64
8	1.71	33	1.59
9	1.67	34	1.72
10	1.70	35	1.78
11	1.66	36	1.61
12	1.69	37	1.75
13	1.72	38	1.83
14	1.72	39	1.73
15	1.50	40	1.77
16	1.72	41	1.68
17	1.73	42	1.54
18	1.72	43	1.63
19	1.79	44	1.70
20	1.72	45	1.75
21	1.67	46	1.69
22	1.72	47	1.68
23	1.70	48	1.72
24	1.78	49	1.75
25	1.69	50	1.68

Table 2.10-21: R&D Plant Pad Taken From NE Corner Straight South and N 75° W in an Approximate 50 Foot Grid (micro R/hr)

N-S E-W	A	B	C	D
1	10.0	12.6	12.0	13.8
2	10.2	13.2	11.0	12.6
3	12.0	10.6	12.0	12.0
4	11.0	10.2	11.8	13.0
5	12.0	11.0	13.0	12.2

Table 2.10-22: R&D Evaporation Ponds Taken From NW Berm Stake at Compass Reading Readings of S 55°W and S 55°E in an Approximate 50 Foot Grid (micro R/hr)

N-S	A	B	C	D	E
E-W					
1	12.0	13.0	13.0	12.0	12.2
2	12.2	12.4	14.2	13.0	12.4
3	12.2	12.4	15.0	12.8	14.0
4	13.0	12.4	14.2	12.2	12.0
5	11.0	13.0	12.4	13.0	13.8
6	12.0	11.8	13.0	12.2	13.0
7	12.0	11.8	12.4	13.0	11.8
8	12.2	12.6	12.4	14.0	12.6
9	12.0	12.0	11.8	13.0	13.2

has been reported to be 0.014 mR/hr (USNRC, 1979b), which corresponds well to the results obtained with the TLD gamma monitors. The results obtained during the gamma survey with a scintillation detector were consistent with the TLD gamma measurements.

2.10.9 REFERENCES

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3. DESCRIPTION OF FACILITY

The current Crow Butte in-situ leach (ISL) facility is capable of processing in excess of 3,500 gallons per minute (gpm) of leach solution. This 3,500 gpm flow does not include the restoration flow. Crow Butte Resources is proposing to increase the permitted flow to 5,000 gallons per minute, excluding restoration flow. Two cases are presented to accomplish this increase, and will be discussed in more detail later in this section.

Both the current facility as well as any proposed additions utilize 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

3.1 SOLUTION MINING PROCESS AND EQUIPMENT

3.1.1 ORE BODY

The ore body is in the Basal Chadron Sandstone at a depth which ranges from 400 to 800 feet. The overall width of mineralization in this area ranges from 1000 feet to 5000 feet. 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.

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. The well construction method are not necessarily described in the order of their preferred use. Any of the methods is appropriate for monitor wells.

Method No. 1, Figure 3.1 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 air lifting or pumping.

Method No. 2, shown in Figure 3.2, 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 air lifting or pumping. Minor variations from these procedures may be used as conditions require.

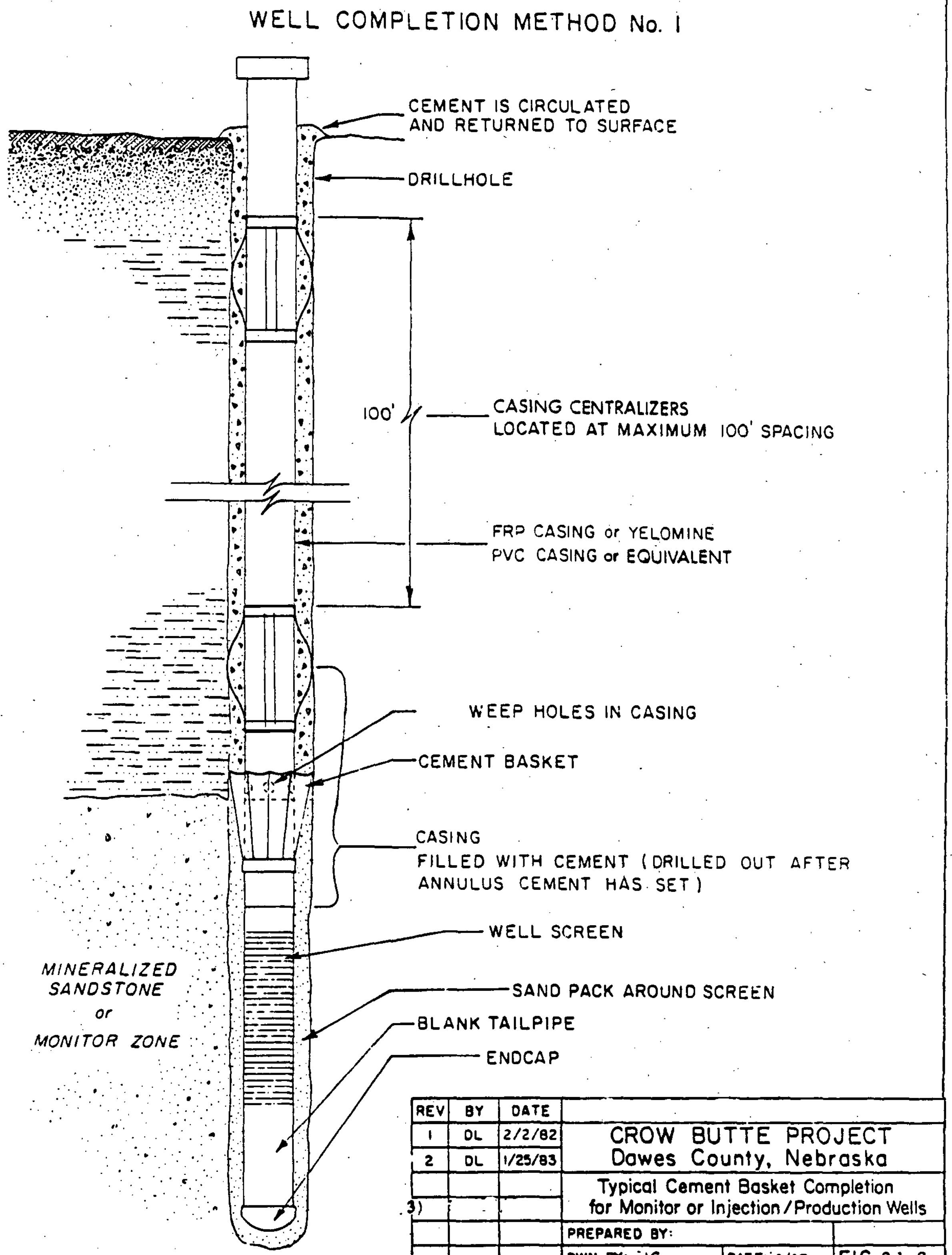
Method Number 3 as shown in Figure 3.3 is similar to methods one and two. The casing is cemented in place the entire length, and , after the cement grout has cured, the casing and grout are cut away to expose the interval to be mined or monitored. A screen is then telescoped into the open interval.

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

Prior to leach solution injection, field testing of injection and recovery wells is performed to demonstrate the mechanical integrity of the well casing. This testing is performed using pressure-packer tests. The following procedure is followed:

- The well is tested after the cement plug at the bottom of the casing has been drilled out. 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. Alternatively, a well cap can be used at the wellhead. A bottom packer is inflated and the casing pressurized to 125 percent of the maximum operating pressure.

Figure 3.1-1: Well Completion Method One



REV	BY	DATE	
1	DL	2/2/82	CROW BUTTE PROJECT Dawes County, Nebraska
2	DL	1/25/83	
			Typical Cement Basket Completion for Monitor or Injection/Production Wells
3)			
			PREPARED BY:
			DWN BY: JC — DATE: 8/87 — FIG. 3.1-2

Figure 3.1-2: Well Completion Method Two

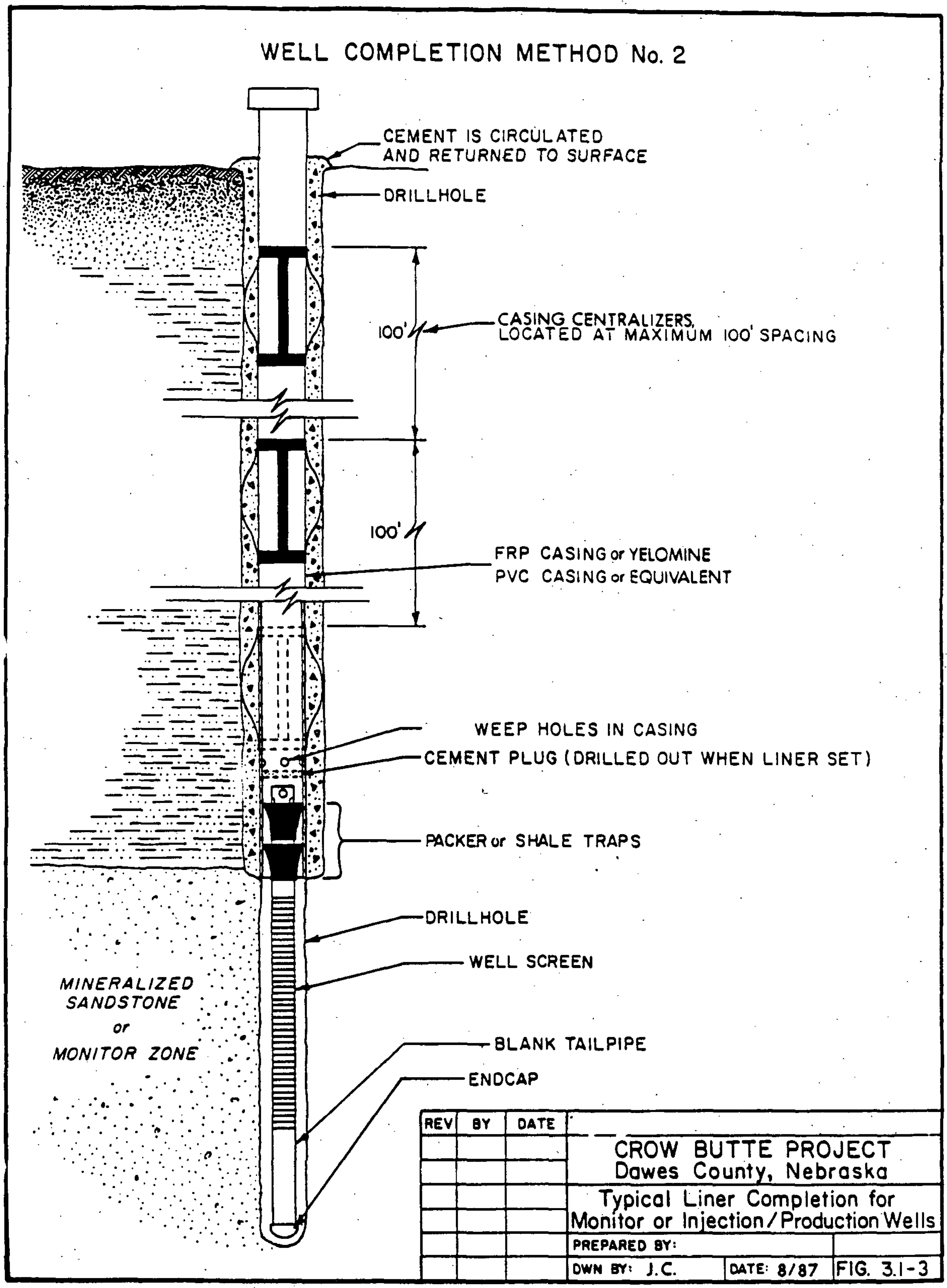
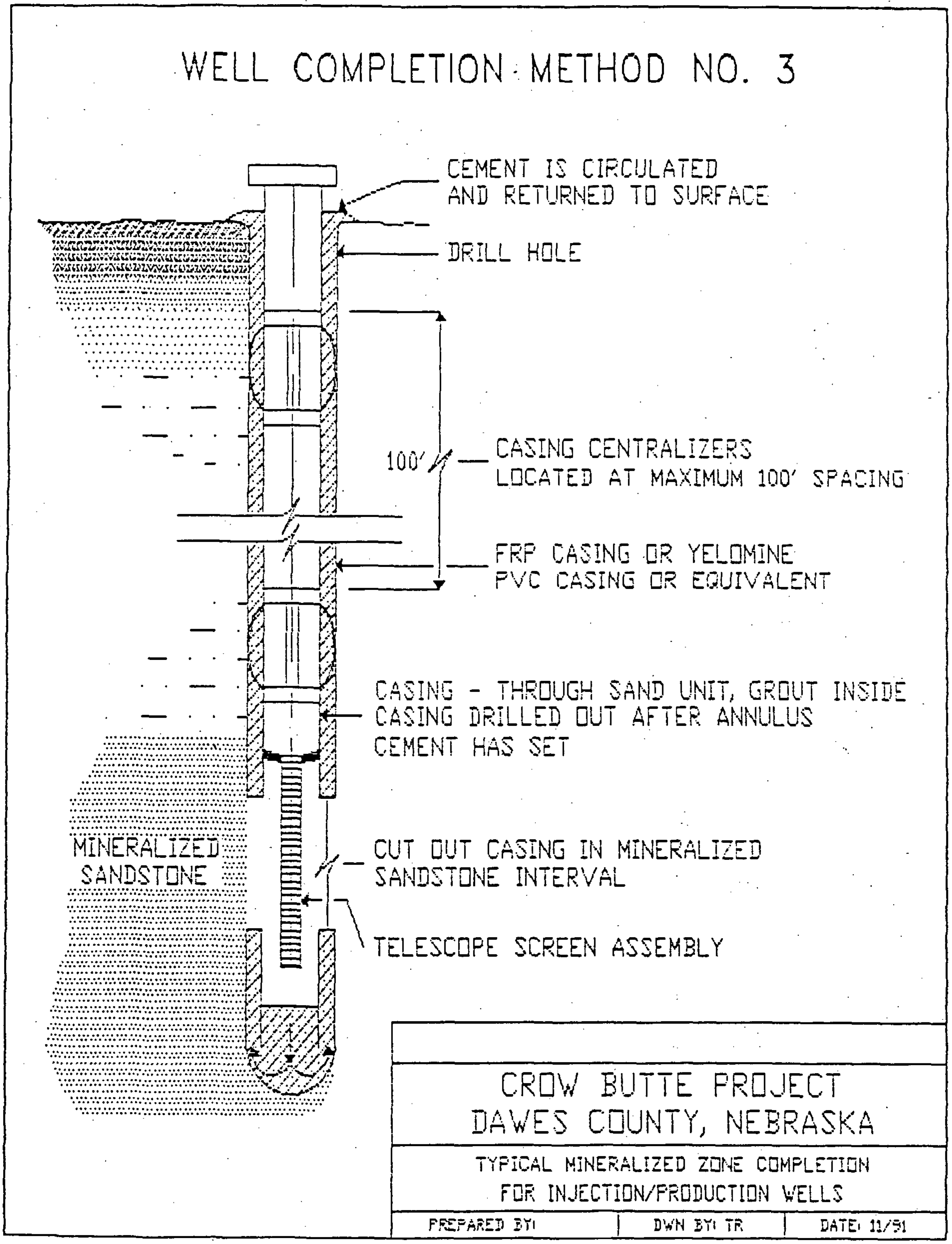


Figure 3.1-3: Well Completion Method Three



On occasion, several attempts may be necessary to obtain a satisfactory result.

- The well is then "closed in" and the pressure maintained for a minimum of twenty minutes.
- If more than ten percent of the pressure is lost during this time period, the well is deemed unacceptable for use as an injection well.

An alternative method of integrity testing for an operational well can be used. This test involves installing a well cap and pressuring the well with air to force the water column down the casing to a level where the pressure is at a minimum equal to 125 percent of the maximum operating pressure. After the well is pressurized and sealed, the pressure is monitored for ten minutes. If more than ten percent of the pressure is lost during this period the well is deemed unacceptable for use as an injection well.

Testing is also done on wells that have been serviced. This testing generally consists of electrical logging.

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. Crow Butte Resources maintains all integrity testing records on site for regulatory review.

3.1.3 WELLFIELD OPERATION

Table 3.1-1 shows the history of mining operations to date. The current mining schedule is shown in Table 3.1.2. This schedule covers the first ten years of the project. A map of the mine units and water well withdrawal points is given in Figure 3.1-4. A typical wellfield layout is shown in Figure 3.1-5. A wellfield is generally a repeated five or seven spot design, with the spacing between injection wells ranging from forty to one hundred feet. Other well designs include alternating single line drives.

Each mine unit contains a number of wellfield houses where injection and recovery solutions from the process building are distributed to the individual wells. Table 3.1-3 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 which are monitored in the Control Room.

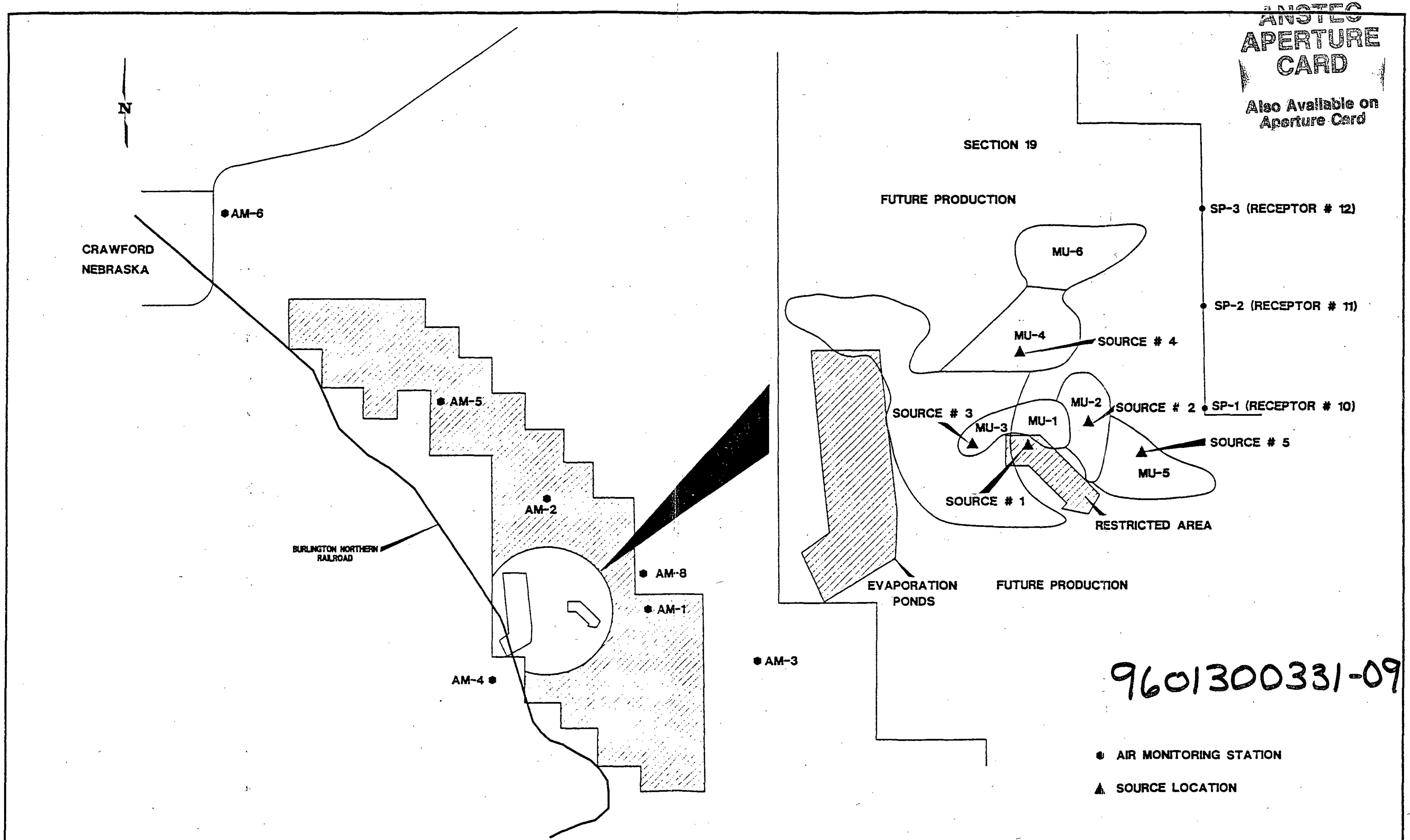
Table 3.1-1: Mine Unit Status

Mine Unit	Production Initiated	Current Status
Mine Unit 1	April 1991	Restoration
Mine Unit 2	March 1992	Production
Mine Unit 3	January 1993	Production
Mine Unit 4	March 1994	Production
Mine Unit 5	January 1996 Planned	Development

Table 3.1-2: Mine Schedule

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: All flow rates are in gallons per minute.



REVISIONS					
NO	DESCRIPTION	BY	DATE	CHK.	APPR.

DRAWING STATUS	BY	DATE
PRELIMINARY	/	
FOR COMMENT and/or APPROVAL	/	
APPROVED FOR CONSTRUCTION	/	
REVISED and APPROVED FOR CONSTRUCTION		

DRAWING IS NOT APPROVED FOR CONSTRUCTION UNLESS SIGNED AND DATED. ALL PRINTS ARE TO BE DESTROYED HAVING AN EARLIER DATE AND / OR REVISION NUMBER.

DRAWING INFORMATION	NAME	DATE
DESIGN BY	B. CONROY	11/19/92
DRAWN BY	J. PAGE	11/21/92
CHECKED BY		
SCALE	NONE	
PLOT DATE	11/23/92 PLOT SCALE 36=60000	

AIR MONITORING STATION LOCATIONS AND MILDOS-AREA SOURCE AND RECEPTOR LOCATIONS

PROJECT LOCATION: CRAWFORD, NEBRASKA | PROJECT NO.

RTG RESOURCE TECHNOLOGIES GROUP, INC.

CLIENT: FERRET EXPLORATION CO. OF NEBRASKA | REVISION NO. A | DRAWING NO. 101

Figure 3.1-4: Mine Unit Map

Figure 3.1-5: Typical Wellfield Layout

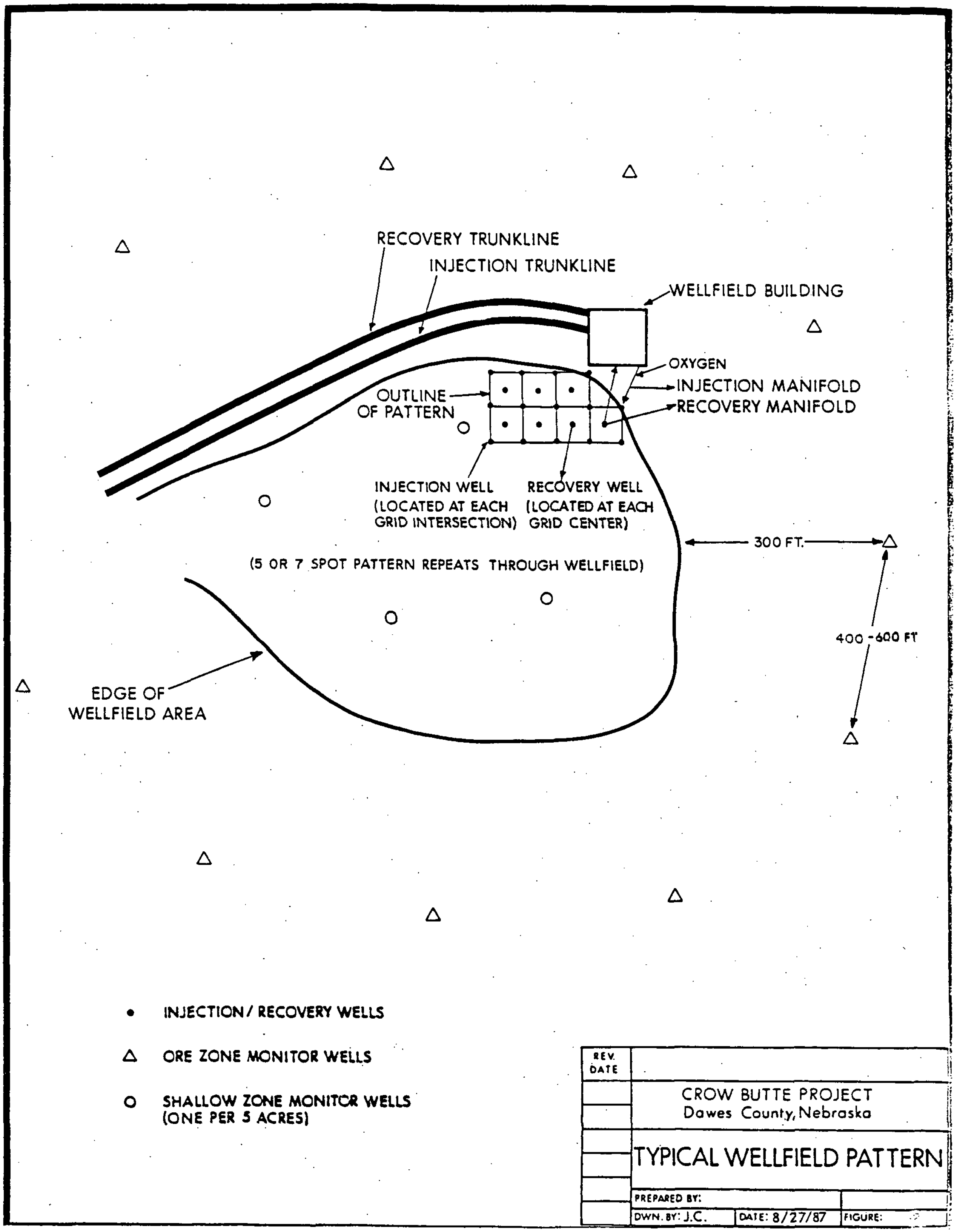


Table 3.1-3: Wellfield Houses by Mine Unit

Mine Unit	Wellfield Houses
Mine Unit 1	2
Mine Unit 2	3
Mine Unit 3	3
Mine Unit 4	5
Mine Unit 5	1 completed, total of 7 projected

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.

Monitor wells have been placed in the Chadron Sand and in the first significant water bearing Brule sand above the Chadron sand. All monitor wells are 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 prior to the initiation of mining operations.

Computations have indicated that the minimum pressure that could initiate hydraulic fracture is 0.63 psi/ft of well depth. The injection pressure is limited to less than 0.63 psi/ft of well depth to prevent fracturing the formation. The 0.63 psi/ft of well depth limit provides a factor of safety to avoid fracturing the formation at the depths and peizometric surfaces encountered in the vicinity of the wellfield. Injection pressures also do not exceed the pressure at which the well was integrity tested, less the safety factor.

3.1.4 URANIUM RECOVERY PROCESS

Sodium and carbonate species along with an oxidizer (oxygen or hydrogen peroxide is added to the formation water in the injection stream for dissolution of uranium. Uranium dissolution is a process involving an oxidation step and a dissolution step. The reactions representing these steps at a neutral or slighly alkaline pH are:

Oxidation: $UO_2 + H_2O_2 \text{ --> } UO_3 + H_2O$

$UO_{2\,(solid)} + {}^1/_2\, O_{2\,(in\ solution)} \text{ --> } UO_{3\,(at\ solid\ surface)}$

Dissolution: $UO_3 + 2\ HCO_3^{-1} \text{ ---> } UO_2(CO_3)_2^{-2} + H_2O$

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

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.

In addition to the carbonate complexing agent, an oxidant is added to the injection solution to carry out the oxidation reaction shown above. Although several oxidants could be used, the common choices are hydrogen peroxide (H_2O_2) or gaseous oxygen (O_2). Both of these oxidants revert to naturally occurring substances.

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

1. Loading of uranium complexes onto an ion exchange resin;
2. Reconstitution of the leach solution by addition of bicarbonate and oxygen;
3. Elution of uranium complexes from the resin;
4. Precipitation of uranium.

The process flow sheet for the above steps is shown in Figure 3.1-6.

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:

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

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

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

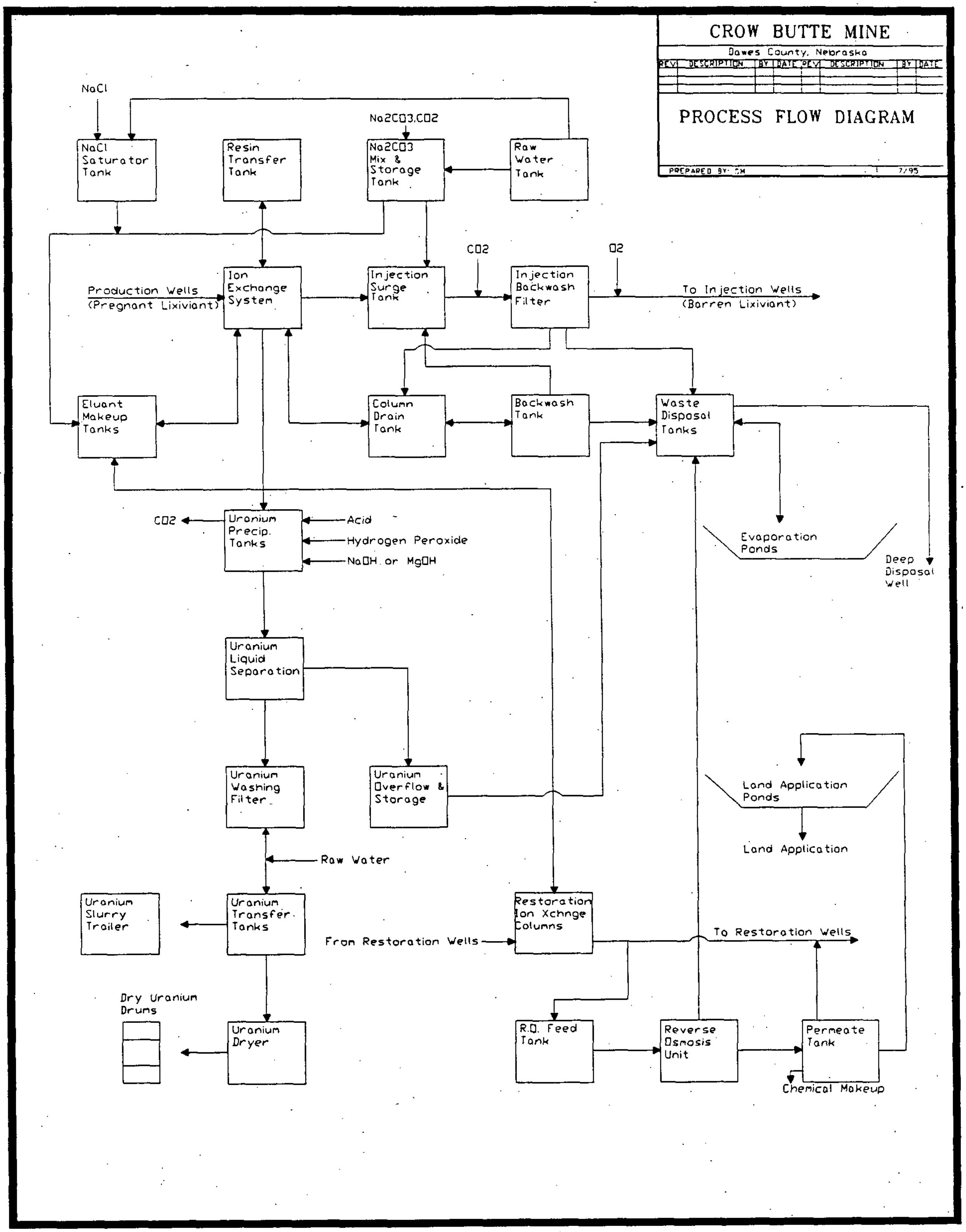
As shown in the reaction, loading of the uranium complex results in simultaneous displacement of chloride, bicarbonate or sulfate ions.

The now barren leach solution passes from the IX columns to a barren lixiviant surge tank. At this point, the solution is refortified with sodium and carbonate chemicals as required and pumped to the wellfield for reinjection into the formation.

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:

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

Figure 3.1-6: Process Flow Sheet



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. 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.

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:

$$UO_2(CO_3)_3^{-4} + 6H^+ \text{--->} UO_2^{++} + 3\ CO_2\uparrow + 3H_2O$$

Hydrogen peroxide is then added to the solution to precipitate the uranium according to the following reaction:

$$UO_2^{++} + H_2O_2 + 2H_2O \text{-->} UO_4 \bullet 2H_2O + 2H^+$$

The precipitated uranyl peroxide slurry is pH adjusted, allowed to settle, and the clear solution decanted. The decant solution is either 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 using a vacuum belt filter. The solids discharge is either sent to the dryer for drying before shipping or is sent to storage for shipment as a slurry to a licensed milling or converting facility.

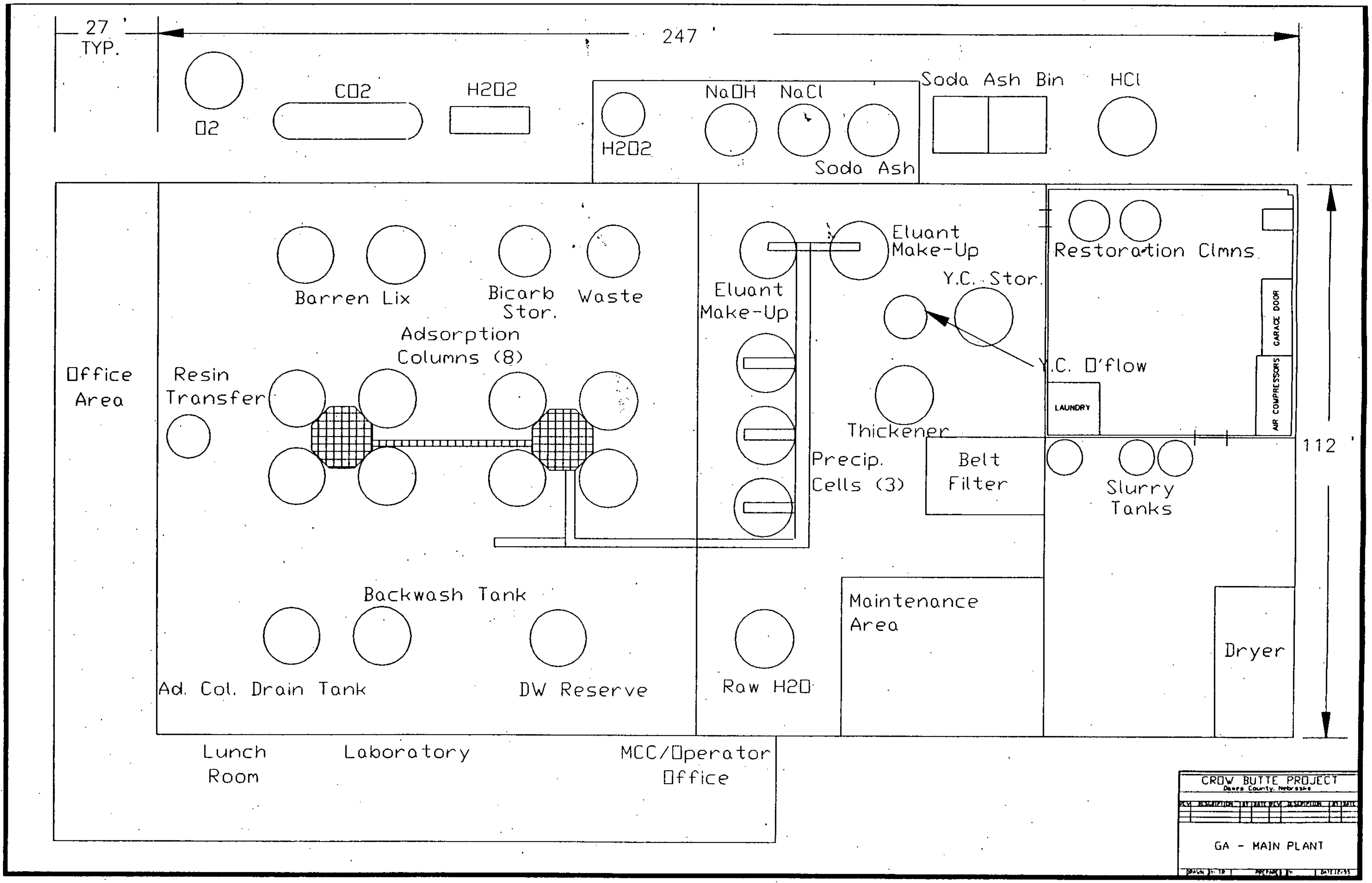
3.2 RECOVERY PLANT EQUIPMENT

3.2.1 EXISTING MAIN PROCESS PLANT

A general arrangement for the current main processing facility can be found in Figure 3.2-1. The recovery plant equipment can be placed in one of the following unit operations:

- Ion Exchange
- Filtration
- Lixiviant injection

Figure 3.2-1: General Arrangement- Main Processing Facility



- Elution/precipitation
- Dewatering/drying

The ion exchange system consists of two sets of four columns. These four columns are operated in a carousel configuration. The resin is eluted and rinsed in place. The uranium loading process is continuous but the elution process is operated on a batch process.

The injection filtration system consists of backwashable filters, with an option of installing polishing filters downstream.

The 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 type.

The elution/precipitation circuit consist of the barren eluant tanks and the acidizer/precipitator tanks. The barren eluant tanks and the precipitation tanks are constructed out of FRP. The eluant is pumped from the barren eluant tanks to the ion exchange column which 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 precipitated uranium (yellowcake) is dewatered and washed using a vacuum filter. The yellowcake can then either be shipped as a slurry for drying or converted at a licensed facility, or it is dried on site in a vacuum dryer. Yellowcake at the Crow Butte Facility is currently dried on site.

A discussion of the areas in the processing plant where fumes or gases are generated can be found in Section 7.3. Process tanks are vented for radon 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.

3.2.2 INCREASE IN PRODUCTION CAPACITY

As has been discussed, Crow Butte Resources desires to increase the permitted flow to 5,000 gallons per minute, and are evaluating two options of accomplishing this increase. While these options are discussed as distinct scenarios, in all likelihood the increase in production capacity would be a combination of the two cases discussed below.

Case 1

In Case 1, Crow Butte proposes to increase the flow by expanding the ion exchange processing capacity in the existing plant. The additional flow would come from additional wells or by operating production wells longer.

The increased ion exchange capacity would be provided by adding additional ion exchange columns to the existing processing facility or increasing the capacity of the existing IX columns. The IX columns would be pressurized downflow and would be operated with two columns in series. Each set of two columns would be capable of processing 500 to 750 gpm of process solutions. The IX columns would be installed in the existing warehouse area of the facility or in an adjacent building extension. The columns would be nominally eight feet in diameter, thus up to six columns could be installed in the existing warehouse area.

After the IX resin is loaded with uranium, the uranium will be stripped from the resin using the same eluant circuit presently used and described above. The pregnant eluant will then go to the existing yellowcake circuit, also described above, for precipitation, dewatering, and drying. The existing yellowcake circuit has adequate capacity to process up to 2,000,000 pounds of U_3O_8 per year. The process flow sheet for this expansion will remain the same as shown in Figure 3.1-6 except for the increase in IX capacity.

The additional flow will increase the volume of liquid waste generated at the Crow Butte facility. The volume of liquid waste generated at the Crow Butte Facility in 1993 was 9,159,000 gallons with an average flow of 2,740 gpm. The waste generation rate at Crow Butte in 1993 was 0.64% of the production flow. With an increase in average flow to 5,000 gpm, the volume of liquid waste expected would be 16,819,000 gallons per year. The existing evaporation pond capacity at the Crow Butte Site is approximately 40,000,000 gallons using the three commercial ponds and the two R&D ponds. Two additional commercial ponds are presently approved and if installed would increase the capacity to 74,000,000 gallons. In addition, the deep disposal well is in operation and has the potential of disposing of twenty to one hundred gallons per minute of liquid waste. When combined with the land application of waste as approved under an NPDES permit, the existing and proposed waste capacity at Crow Butte is adequate to store and dispose of the additional waste volume form the increased flow.

Case 2

In Case 2, Crow Butte proposes to maintain the flow at the existing process facility at 2,500 to 3,500 gpm and construct a satellite plant. This satellite facility would have a capacity of 2,500 gpm, and would utilize pressurized downflow IX columns for uranium separation. The satellite plant would contain eight to ten IX columns, operating with two columns in series. Each set of columns would be capable of processing 500 to 750 gpm of process solution. After the IX resin is loaded with uranium, it would be transferred to a resin trailer and transferred to the main process facility for elution of the uranium and subsequent precipitation, dewatering and drying. The process flow sheet and general arrangement for the satellite plant are shown in Figure 3.2-2 and Figure 3.2-3. The only additional equipment needed at the main process facility would be an elution tank. The existing elution feed tanks, uranium precipitation tanks, dewatering and drying equipment are adequate to process the uranium from the satellite plant.

The liquid waste generated at the satellite plant will be primarily the production bleed which is estimated at 0.5% of the production flow. At 2,500 gpm the volume of liquid waste is estimated at 6,570,000 gallons per year. Crow Butte Resources proposes to construct two evaporation ponds at the satellite facility with a combined capacity of 12,000,000 gallons. This capacity when combined with the deep disposal well and appropriate land application will provide adequate capacity for liquid waste disposal.

3.3 INSTRUMENTATION

The basic control system at the Crow Butte site is built around an Allen-Bradley PLC-5 6200 Series system. This system allows for extensive monitoring of all wellfield and recovery plant operations.

The Allen-Bradley system consists of a series on 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 UPS systems 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 which 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

Figure 3.3-2: Satellite Plant Process Flow Sheet

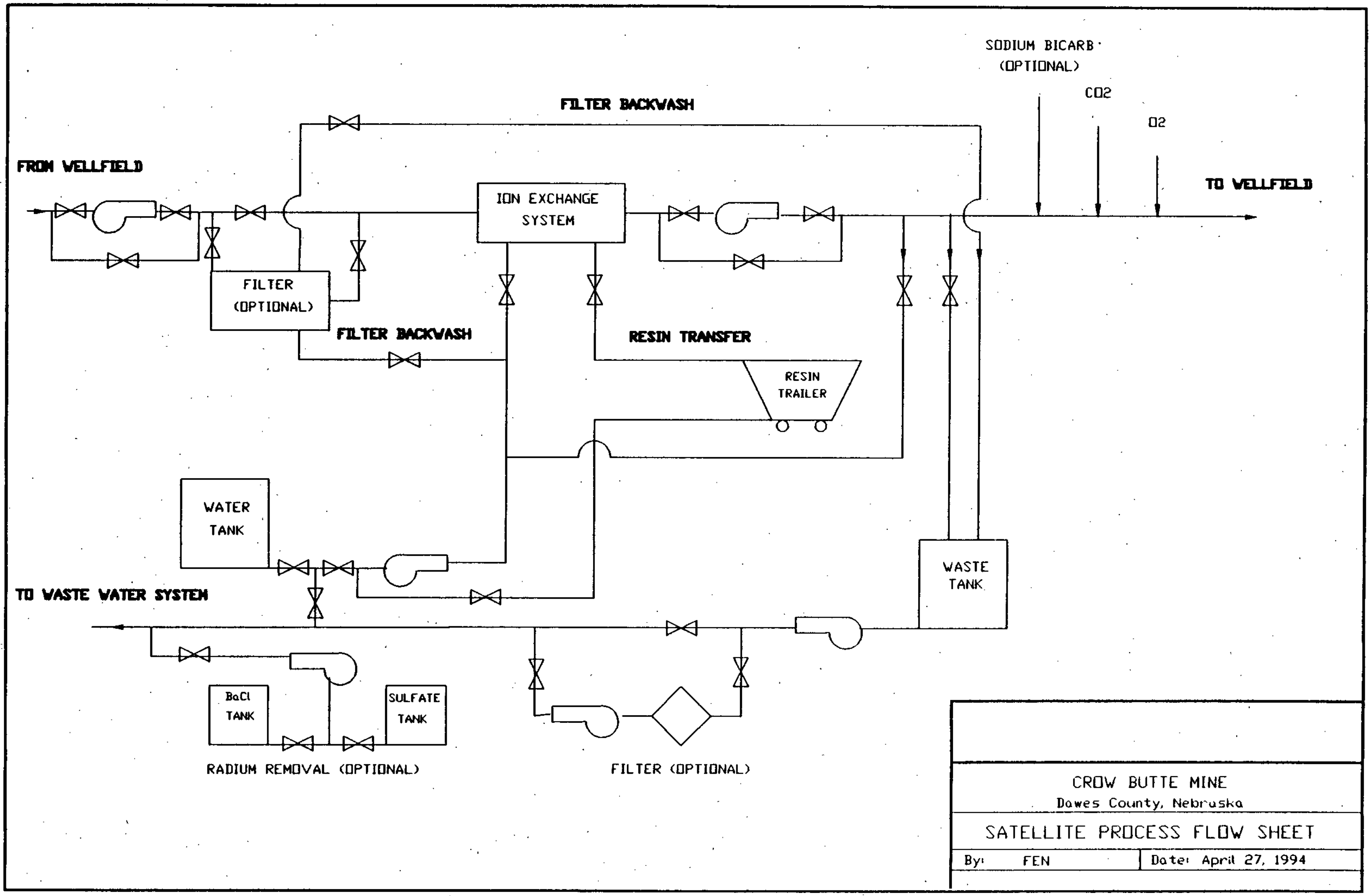
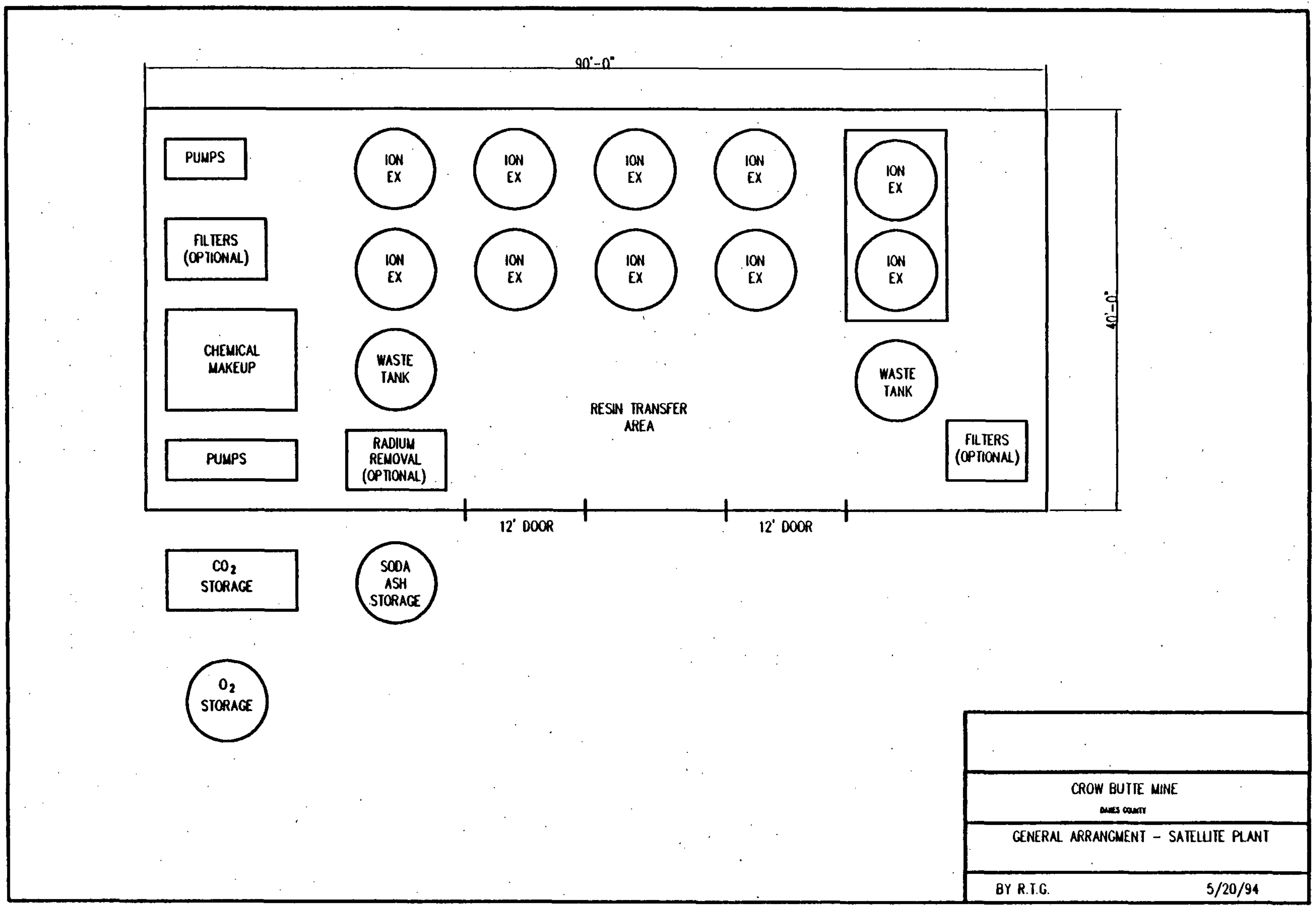


Figure 3.3-3: Satellite Plant General Arrangement



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 sized or equipped so that they are incapable of producing pressures high enough to exceed design pressure of the injection lines or the maximum pressure to be applied to the injection wells.

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.

4. EFFLUENT CONTROL SYSTEMS

4.1 GASEOUS AND AIRBORNE PARTICULATES

The only radioactive airborne effluent at the Crow Butte facility is radon-222 gas. 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.

The radon-222 is contained in the pregnant lixiviant which comes from the wellfield into the plant. The majority of the radon-222 is released in the recovery 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 which 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. 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 (see Section 5.0) to assure that concentration levels of radon and radon daughters is maintained ALARA.

The type of dryer utilized in the process facility is a vacuum dryer. With this dryer, the yellowcake is dried in a heating chamber that is maintained at negative pressure. Air flow 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. 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 air flow. 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, 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.

4.2 LIQUIDS AND SOLIDS

4.2.1 LIQUID WASTE

As a result of in-situ leach mining process, there are three sources of water that are collected on the site. Three methods of disposal are currently permitted: evaporation from the evaporation ponds, deep well injection, or land application. Water discharged via land application is treated as necessary to meet NPDES requirements.

These water sources include the following:

- **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 are 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 waste water. 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 waste water.

  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 waste water disposal system during this activity.

  Groundwater treatment activities involve the use of process equipment to lower the ion concentration of the groundwater in the affected mining area. A reverse osmosis (RO) unit will 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 waste water disposal system.

A final source of water is storm runoff, however it is not included in the above discussion as this water is not specifically collected and routed to a pond for disposal. 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.

The pond design, installation and operation criteria for the solar evaporation ponds are those found to be applicable in USNRC Regulatory Guide 3.11. 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 failure.

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 waste water. 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 parameters.

While there are a number of potential sources of pollution present at the Crow Butte facility, existing regulatory requirements from the NRC and Nebraska Department of Environmental Quality have established a framework that significantly reduces the possibility of such an occurrence. Extensive training of all personnel occurs on a regular basis, along with frequent inspections, and detailed Standard Operating Procedures. This training is verified by the NRC.

Potential sources of pollution include the following:

- **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 NRC standards, and are equipped with leak detection systems. Standard operating procedures 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 building**- 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 first. In addition, the flows through the pipe are at a relatively low pressure and can quickly be stopped, thus any release would not migrate far. Wellfield buildings are also equipped with wet alarms for early detection of leaks. Finally, containment berms are in place along Squaw Creek in the event of a wellfield spill in this area.

- **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 to the waters of the State. This could be as a result of 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** - 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, SOP's are in place to insure a rapid response to the situation.

Spills can take two forms within an in-situ 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.

- **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 from the process plant to the wellfield and back. These are generally classified as small releases.

  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 final operation. It is unlikely that a break would occur in a buried section of line because no additional stress is placed on the pipes. In addition, underground pipelines are protected from a major cause of potential failure - that of 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.

- **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 which may migrate away from the production area due to fluid pressure imbalance. This system has proven to function satisfactorily over many years of operating experience with in-situ mining.

  At the Crow Butte 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 facilities has shown that this monitoring system is effective in detecting leachate migration. 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 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 two hydrologic tests prior to mining. Results indicated that no leakage or communication exists between the mineralized zone and overlying aquifers. In addition, prior to start of production a well integrity test is performed on all injection/recovery wells. This requirement of the Nebraska Underground Injection Control Regulations insures that all wells are constructed properly and capable of maintaining pressure without leakage. Lastly, 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 previously described have been implemented to insure maximum competency of the synthetic liner and earthen embankments. The underdrain leak detection system allows sampling which would detect a leak. The pond soil foundation has a low ambient moisture due to its elevation, soil type and preparation, thus should the unlikely event occur of pond fluids seeping into the compacted subsoil, the liquid would be quickly absorbed and would not migrate. Pond monitor wells are also located donwstream 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. 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 effect the quality of Squaw Creek as the more sensitive areas of the stream are located upstream from 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 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, however, 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.

4.2.2 SOLID WASTE AND CONTAMINATED EQUIPMENT

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 contact surfaces waters, solid wastes should be swept up regularly and disposed of in trash containers. Any liquid waste that may enter the drain is routed through the sump to one of the solar evaporation ponds where it can be treated if necessary.

Solid waste generated at the site consists of spent resin, resin fines, empty reagent containers, miscellaneous pipe and fittings, and domestic trash. These wastes are classified as contaminated or non-contaminated waste according to their survey results with radioactive materials.

Solid waste is separated into two categories. The first category is waste which is non-contaminated 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 decontaminated.

The second category of solid waste includes all items not yet decontaminated or which cannot be decontaminated. These materials are stored until such a time as they can be decontaminated or they are shipped to a licensed waste disposal site or licensed mill tailings facility.

If decontamination is possible, records of the residual surface contamination are made prior to releasing the material for final disposal. Decontaminated materials have activity levels lower than those specified in the NRC "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". An area is maintained inside the restricted area boundary for storage of contaminated materials prior to their disposal.

Domestic liquid wastes from the restrooms and lunchrooms are disposed of in an approved septic system which 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.

Non-contaminated solid waste is collected on the site on a regular basis and disposed of in the nearest sanitary landfill.

5. OPERATIONS

Crow Butte Resources, Inc. (CBR) operates a commercial scale in-situ leach uranium mine (the Crow Butte Uranium Project) near Crawford, Nebraska. CBR maintains a headquarters in Denver, Colorado where site licensing actions originate. All CBR operations, including the Crow Butte Uranium 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 AND ADMINISTRATIVE PROCEDURES

The CBR organizational chart, as it pertains to the responsibility for radiation safety and environmental protection at the Crow Butte Uranium Project facility is given as Figure 5.1-1. 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. Specific responsibilities of the organization are provided below.

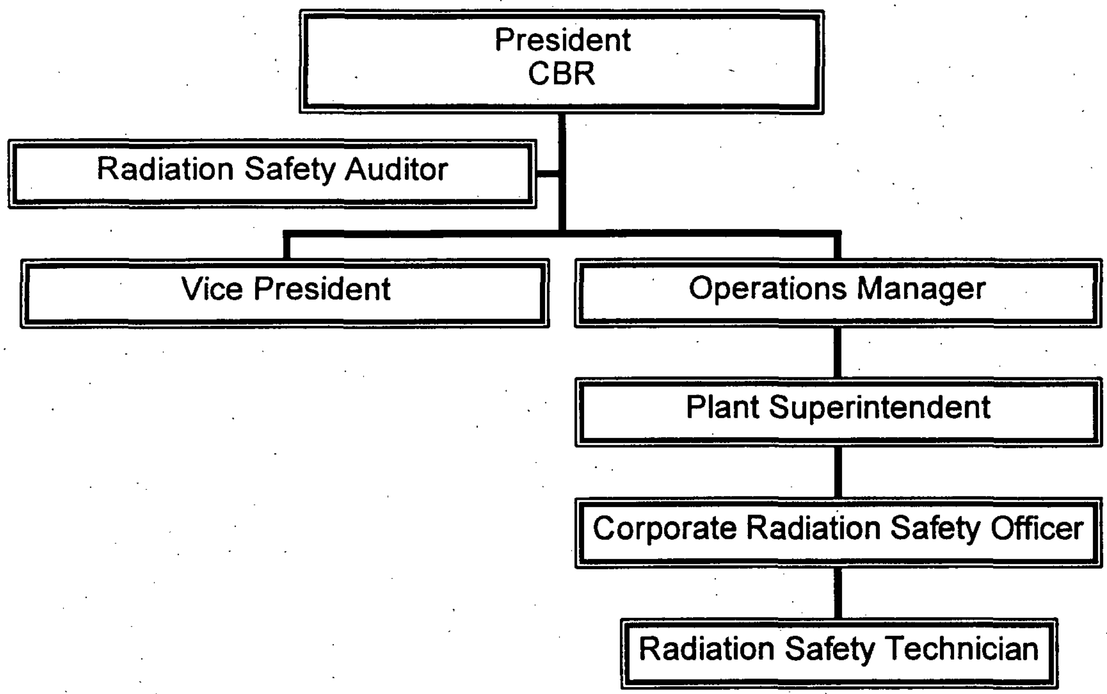
5.1.1 PRESIDENT

The overall responsibility for the radiation, environmental, and safety activities of the Crow Butte Facility rests with the President of CBR. In addition, the President of CBR is responsible for all Crow Butte commercial production facilities, reporting directly to the Board of Directors of CBR. The President is also responsible for license development and license modifications.

5.1.2 VICE PRESIDENT

The Vice President is directly responsible for all site administration and wellfield development and construction. The Vice President reports directly to the President. The Vice President will, in the absence or disability of the President, perform the duties of the President.

Figure 5.1-1: Crow Butte Resources Organizational Chart



5.1.3 OPERATIONS MANAGER

The Operations Manager is responsible for all uranium production activity at the project site. The Operations Manager is also responsible for implementing any safety and/or monitoring programs associated with operations, including yellowcake handling procedures. The Operations Manager is authorized to immediately implement any action to correct or prevent radiation safety hazards. The Operations Manager reports directly to the President.

5.1.4 PLANT SUPERINTENDENT

The Plant Superintendent has direct oversight of the facility operations including yellowcake handling procedures. The Plant Superintendent is responsible for carrying out any procedures or actions implemented by the Corporate Radiation Safety Officer (CRSO) or Operations Manager to correct or prevent radiation safety hazards. The Plant Superintendent supervises the CRSO to ensure that these programs are conducted in a manner consistent with regulatory requirements. The Plant Superintendent reports directly to the Operations Manager.

5.1.5 CORPORATE RADIATION SAFETY OFFICER

The CRSO is responsible for the development, administration and enforcement of all radiation safety programs. The CRSO 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 CRSO is responsible for the implementation of all on-site environmental and safety programs, including emergency procedures. The CRSO inspects facilities to verify compliance with all applicable requirements in the areas of radiological health and safety as well as industrial health and safety. The CRSO works closely with all supervisory personnel to insure that established programs are maintained. The CRSO is also responsible for the collection and interpretation of employee exposure related monitoring, including data from industrial safety and radiological safety. The CRSO makes recommendations to improve any and all safety related controls. The CRSO has no production related responsibilities.

5.1.6 HEALTH PHYSICS TECHNICIAN

The Health Physics Technician (HPT) assists the CRSO 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 CRSO.

5.1.7 RADIATION SAFETY AUDITOR

CBR may utilize an outside radiation protection auditing service to provide assurance that all radiation health protection procedures and license condition requirements are being conducted properly at the Crow Butte Uranium Project facility. Any outside service used for this purpose is qualified in radiation safety procedures as well as environmental aspects of solution mining operations.

5.2 MANAGEMENT CONTROL PROGRAM

5.2.1 OPERATING PROCEDURES

Written Standard Operating Procedures (SOPs) have been developed for all process activities, including those activities involving radioactive materials, for the Crow Butte Uranium Project facility. Where radioactive material handling is involved, pertinent radiation safety practices are incorporated into the SOP. Additionally, written SOPs have been developed for non-process activities including environmental monitoring, health physics procedures, emergency procedures, and general safety. Written SOPs have been developed, reviewed and approved by the appropriate supervisors including the CRSO. All written SOPs are reviewed for radiological protection aspects and approved by the CRSO prior to implementation. Additionally, the CRSO reviews all SOPs on an annual basis. Applicable current SOPs are referenced throughout this document. SOPs are revised as necessary to meet changing operational and regulatory requirements. Any revisions made to the SOPs are reviewed and approved by the CRSO and appropriate supervisor prior to implementation. Written SOPs are kept in the areas of the plant facility where they are used for easy access by employees.

For the performance of non-routine work or maintenance activities where the potential for radiation exposure exists and for which written operating procedures have not been prepared, a Radiation Work Permit (RWP) is required. The RWP specifies the necessary radiological safety precautions, equipment or specialized clothing, and radiological surveys required for performing the job. RWPs are issued by the CRSO or designee by way of specialized training.

5.2.2 SAFETY AND ENVIRONMENTAL REVIEW PANEL (SERP)

The existing Source Materials License SUA-1534 held by CBR for the Crow Butte Uranium Project is scheduled for renewal at the end of 1995. At this time, it is anticipated that CBR will request that the Nuclear Regulatory Commission consider issuance of a performance based license. If a performance based license is issued, one of the requirements is the development of a Safety and Environmental Review Panel (SERP). The SERP consists of a minimum of three individuals. One member of the SERP has expertise in management, one member has expertise in operations and/or construction, and one member is a radiation safety officer or equivalent. Other members of the SERP may be included as appropriate to address specific technical issues.

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 NRC license. As such, they are responsible for insuring that any such change results in no degradation in the essential safety or environmental commitments of the operator.

5.3 MANAGEMENT AUDIT AND INSPECTION PROGRAM

The following internal inspections, audits and reports are performed for the Crow Butte Uranium Project operations:

<u>Daily</u>

A daily walkthrough inspection of the plant is conducted by the CRSO, HPT or a qualified designated operator. The inspection entails a visual examination of compliance or other problems which are reviewed with the Plant Superintendent.

<u>Monthly</u>

The CRSO 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.

Quarterly

Quarterly inspections are performed of the evaporation ponds in accordance with the guidance contained in USNRC Regulatory Guide 3.11.1, "Operational Inspection and Surveillance of Embankment Retention Systems for Uranium Mill Tailings".

Annually

On an annual basis, an audit of the radiation protection and ALARA program is conducted in accordance with USNRC Regulatory Guide 8.31, "Information Relevant to Ensuring That Occupational Radiation Exposures at Uranium Mills Will Be As Low As Reasonably Achievable". A written report of the results submitted to corporate management. The auditor may be an outside radiation safety auditor as identified in Figure 5.1-1. The CRSO may accompany the auditor, but may not participate in the conclusions.

The annual ALARA audit report summarizes the following data:

1. Employee exposure records
2. Bioassay results
3. Inspection log entries and summary reports of mine and process inspections
4. Documented training program activities
5. Applicable safety meeting reports
6. Radiological survey and sampling data
7. Reports on any overexposure of workers
8. Operating procedures that were reviewed during this time period

The ALARA audit report specifically discusses the following:

1. Trends in personnel exposures
2. Proper use, maintenance and inspection of equipment used for exposure control

3. Recommendations on ways to further reduce personnel exposures from uranium and its daughters.

The ALARA audit report is submitted to and reviewed by the President and the CRSO. Implementation of the recommendations to further reduce employee exposures, or improvements to the ALARA program, are discussed with the ALARA auditor.

An audit of the Quality Assurance/Quality Control (QA/QC) program is also conducted on an annual basis. The audit is performed by an individual qualified in analytical and monitoring techniques who does not have direct responsibilities in the areas being audited. The results of the QA/QC audit are documented and reported to the President and the CRSO. The CRSO has the primary responsibility for the implementation of the QA/QC programs at the Crow Butte Uranium Project facilities.

5.4 QUALIFICATIONS

CBR project staff are highly experienced in the management of uranium development, mining and operations. The following minimum personnel specifications and qualifications are strictly adhered to.

The minimum qualifications for the Corporate Radiation Safety Officer (CRSO) are as follows:

- Education - A Bachelor's Degree or an Associate Degree in the physical sciences, industrial hygiene, environmental technology or engineering from an accredited college or university or an equivalent combination of training and relevant experience in uranium mill/solution mining radiation protection.

- Health Physics Experience - A minimum of 1 year of work experience relevant to uranium mill/solution mining operations in applied health physics, radiation protection, industrial hygiene or similar work.

- Specialized Training - A formalized, specialized course(s) in health physics specifically applicable to uranium milling/solution mining operations, of at least 4 weeks duration. The CRSO attends refresher training on uranium mill health physics every two years.

- Specialized Knowledge - The CRSO, through classroom training and on-the-job experience, possesses a thorough knowledge of the proper application and use of all health physics equipment used in the operation, the procedures used for radiological sampling and monitoring, methods used to calculate personnel exposures to uranium and its daughters, and a thorough undeHPTanding of the solution mining process and equipment used and how hazards are generated and controlled during the process.

The Health Physics Technician (HPT) will have one of the following combinations of education, training and experience:

1. Education - An associate degree or 2 years or more of study in the physical sciences, engineering or a health-related field, or high school diploma and a combination of experience and training.

   Training - At least a total of 4 weeks of generalized training in radiation health protection applicable to uranium mills/solution mining operations.

   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 uranium mill/solution mining operation.

2. Education - A high school diploma.

   Training - A total of at least 3 months of specialized training in radiation protection relevant to uranium mills of which up to 1 month may be on-the-job training.

   Experience - Two years of relevant work experience in applied radiation protection.

5.5 TRAINING

All site employees, and contracted personnel when present, at the Crow Butte Uranium Project are administered a training program based upon the CBR Radiation Safety Training Plan covering radioactive material handling and radiological emergency procedures. This training program is administered in keeping with standard radiological protection guidelines. The technical content of the training program is under the direction of the CRSO. Training is conducted by the CRSO or a qualified designee.

5.5.1 TRAINING PROGRAM CONTENT

Visitors

Visitors to the Crow Butte Uranium Project who have not received training are escorted by on site personnel properly trained and knowledgable about 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.

Contractors

Any contractors having work assignments at the facility are given appropriate training and safety instruction. Contract workers who will be performing work on heavily contaminated equipment receive the same training normally required of permanent workers.

Permanent Employees

The CBR Radiation Safety Training Program incorporates the following topics discussed in USNRC Regulatory Guide 8.31, "Information Relevant to Ensuring That Occupational Radiation Exposures at Uranium Mills Will Be As Low As Reasonably Achievable":

Fundamentals of health protection

- Using respirators when appropriate.
- Eating, drinking and smoking only in designated areas.
- Using proper methods for decontamination.

Facility-provided protection

- Cleanliness of working space.
- Safety designed features for process equipment.
- Ventilation systems and effluent controls.
- Standard operating procedures.
- 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.
- Personnel dosimetry.

Radiation protection regulations

- Regulatory authority of NRC, MSHA and state.
- Employee rights in 10 CFR Part 19.
- 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 done in the form of individualized on the job training. Retraining is done annually and documented. Every two months, all workers attend a general safety meeting.

5.5.2 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.

5.5.3 ON-THE-JOB TRAINING

HPT

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 Standard Operating Procedures.

5.5.4 REFRESHER TRAINING

Following initial radiation safety training, all permanent employees receive on-going radiation safety training as part of the routine bimonthly safety meetings. This on-going 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.

5.5.5 TRAINING RECORDS

Records of training are kept for a period of five years for all process employees.

5.6 SECURITY

The entrance to the Crow Butte Uranium Project site is a gravel road to the west of the facility. The entrance to the site is posted indicating that permission is required prior to entry. The gate on the access route can be locked. The plant site is within the fenced permit area and properly posted in accordance with 10 CFR § 20.1902 (e). The evaporation ponds are also fenced and posted. All visitors entering the restricted areas on the Crow Butte Uranium Project site are required to register at the main office and are not permitted inside the plant or wellfield areas without proper authorization. Inexperienced visitors are escorted unless they are frequent visitors who have been instructed regarding areas to be avoided.

The plant will normally operate 24 hours per day and 7 days per week, so CBR employees will normally be on-site except for occasional shutdowns. All plant personnel are instructed to immediately report any unauthorized persons to their supervisors. The supervisor will contact the reported unauthorized person and make sure that they have been authorized for entry. If the person is unauthorized, and has no business on the property, they will be escorted to the main entrance for departure.

5.7 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 Uranium Project facility. This corporate commitment to maintaining personnel exposures as low as reasonably achievable (ALARA) has been incorporated into the radiation safety controls and monitoring programs described in the following sections. This license renewal application contains the results of the radiological control program since 1990. Each area in this section describes the historical program and the results of monitoring since 1990.

Where the monitoring results indicate that the program should be modified, proposed changes in the program are also discussed.

5.7.1 EFFLUENT CONTROL TECHNIQUES

5.7.1.1 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 which 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. 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 which is exhausted outside the plant building through the plant stack.

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 5.7.3

5.7.1.2 LIQUID EFFLUENTS

The liquid effluents from the Crow Butte Uranium 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 are 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 waste water. 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 waste water.

  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 reverse osmosis (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 waste water 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 waste water by three methods:

- Evaporation from the evaporation ponds;
- Deep well injection; and
- Land application.

The design, installation 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." 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 waste water. 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.

Spill Contingency Plans

The CRSO is charged with the responsibility to develop and implement appropriate procedures to handle potential spills. Personnel representing the engineering and operations functions of the Crow Butte Uranium Project facility will assist the CRSO 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 classified as small releases.

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 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.

- **Transportation accidents** - Standard Operating Procedure P-18 provides the CBR emergency action plan for responding to a transportation accident involving a yellowcake shipment. The SOP provides instructions for proper packaging, documentation, driver emergency and accident response procedures and cleanup and recovery actions. Spill response is specifically addressed in SOP C-19, Significant Solution Spills.

- **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 which 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 Uranium 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 two hydrologic tests prior to mining. Results indicated that no leakage or communication exists between the mineralized zone and overlying aquifers. In addition, prior to start of production a well integrity test is performed on all injection/recovery wells. This requirement of the Nebraska Underground Injection Control Regulations insures that all wells are constructed properly and capable of maintaining pressure without leakage. Lastly, 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 which would detect a leak. The pond soil foundation has a low ambient moisture due to its elevation, soil type and preparation, thus should the unlikely event occur 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 effect 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 Uranium 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.

5.7.2 EXTERNAL RADIATION EXPOSURE MONITORING PROGRAM

5.7.2.1 GAMMA SURVEY

Program Description

External gamma radiation surveys have been performed routinely at the Crow Butte Uranium 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 mR/hr for worker occupied stations. An investigation is performed to determine the probable source and survey frequency for areas exceeding 5.0 mR/hr is increased to quarterly. Records were maintained of each investigation and the corrective action taken. If the results of a gamma survey identified 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).

External gamma surveys are performed with survey equipment which meets the following minimum specifications:

1. Range - Lowest range not to exceed 100 microRoentgens per hour (μR/hr) full-scale with the highest range to read at least 5 milliRoentgens per hour (mR/hr) full scale;

2. Battery operated and portable;

Examples of satisfactory instrumentation which meets these requirements are the Eberline Instruments Corporation Model ESP-1 with a HP-270 probe or equivalent. Gamma survey instruments were calibrated every six months and were operated in accordance with the manufacturer's recommendations. Instrument checks were performed each day that an instrument was used.

Historical Program Results

Routine gamma surveys have been performed as required at the Crow Butte Uranium Project. A Radiation Area has been established around the injection filter system since the beginning of commercial operations due to gamma levels above 5.0 mRem/hr. Engineering controls such as lead sheeting have been employed around the filters to maintain personnel exposures ALARA. Results of the gamma survey program are maintained at the Crow Butte Uranium Project site.

Proposed Gamma Survey Program

CBR proposes to institute the same gamma exposure monitoring program at the Crow Butte Uranium Project that has been performed to date with the following changes.

- Based upon operating experience, CBR proposes to perform gamma exposure rate surveys at the locations shown in Figure 5.7-1. CBR believes that these locations will provide accurate monitoring of plant radiological conditions.

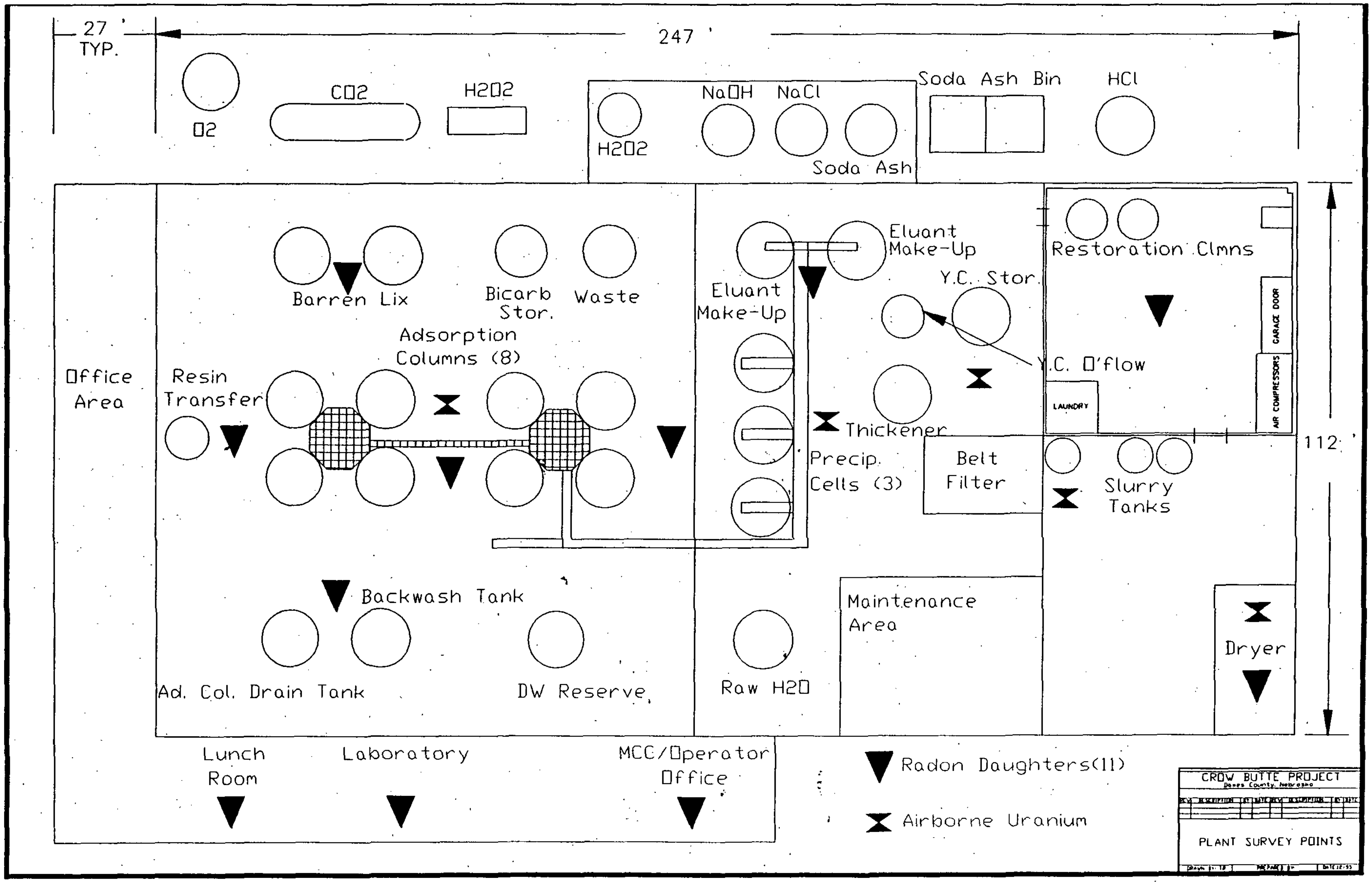
Gamma exposure rate surveys will be performed in accordance with the instructions currently contained in Standard Operating Procedure C-13, "Gamma Surveys". Gamma survey instruments will be checked each day of use in accordance with the manufacturer's instructions.

5.7.2.2 PERSONNEL DOSIMETRY

Program Description

All employees working in the process facility or wellfield operations who are assigned full-time to the Crow Butte Uranium Project facility have been issued Thermoluminescent Dosimeters (TLD) for determination of external gamma exposure since the beginning of commercial operations. TLDs have been provided by TMA Eberline which is accredited by NVLAP of the US Department of Commerce as required in 10 CFR § 20.1501. The TLDs have

Figure 5.7-1: Proposed Survey and Sampling Locations



a sensitivity of 1.0 mR and a range of 1 mR to 1000 R. TLDs are exchanged and read on a quarterly basis.

Historical Program Results

Table 5.7-1 contains a summary of the average and maximum annual exposure for all personnel at the Crow Butte Uranium Project facility since 1990. As can be seen in Table 5.7-1, the average annual exposures at the Crow Butte Uranium Project from 1990 to 1994 have been at or below 1% of the regulatory limit of 5.0 Rem. The maximum annual individual exposure in 1994 was well below 10% of the regulatory limit and indicate that exposures at the Crow Butte Uranium Project are maintained ALARA.

Proposed 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 10 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 Uranium Project facilities since 1987 have been well below 10 percent of the limit. CBR believes that it is not likely that any employee will exceed 10 percent of the regulatory limit. Although monitoring of external exposure may not be required in accordance with §20.1201(a), CBR proposes to continue to issue TLDs to all process employees and exchange them on a quarterly basis. CBR has discontinued TLD issuance to employees in other work categories who do not routinely enter the process plant.

Results from TLD monitoring will be used to determine individual Deep Dose Equivalent (DDE) for use in determining Total Effective Dose Equivalent (TEDE) in accordance with the instructions currently contained in Standard Operating Procedure C-15, "External Exposure".

Table 5.7-1: External Radiation Exposure Monitoring Results

EXPOSURE MONITORING PERIOD	AVERAGE ANNUAL EXPOSURE (mRem/yr)[2]	MAXIMUM INDIVIDUAL ANNUAL EXPOSURE[1] (mRem/yr)[2]
Calendar Year 1990	6.3	14
Calendar Year 1991	33.3	83
Calendar Year 1992	27.8	109
Calendar Year 1993	32.3	98
Calendar Year 1994	51.2	315

Notes:
1 Annual External Exposure Limit (10 CFR § 20.1201) = 5 rems

2 All data based upon results from Eberline Instrument Corporation; LLD = 10 mrems

5.7.3 IN-PLANT AIRBORNE RADIATION MONITORING PROGRAM

5.7.3.1 IN-PLANT 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 was performed routinely at Crow Butte Uranium Project through the use of area sampling and breathing zone sampling. The monitoring programs are described below.

Area Sampling

Area samples are collected monthly at the four specified sample locations in the plant. Additionally, samples are taken in the dryer room during dryer operations and for the issuance of an RWP. Area samples are taken in accordance with the instructions currently contained in SOP C-12, "Survey for Airborne Uranium". 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 limits of detection (LLD) for uranium in air. Samplers are calibrated every six months using a digital mass flowmeter.

Measurement of airborne uranium is performed by gross alpha counting of the air filters using an alpha scaler such as a Eberline MS-3 or equivalent. 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 was used. This is a conservative method because the gross alpha results include Uranium-238 and several of its daughters (notably Ra-226 and Th-230) which are alpha emitters. An action level of 25% of the MPC (DAC since 1994) for soluble natural uranium was established at the Crow Butte Uranium Project facilities. If an airborne uranium sample exceeded the MPC (DAC), an investigation was performed. The only area at the Crow Butte Uranium Project which has met the definition of an Airborne Radioactivity Area as contained in 10 CFR § 20.1003 is the dryer room during yellowcake packaging operations.

Breathing Zone Sampling

Breathing zone sampling is performed to determine individual exposure to airborne uranium during certain operations. Sampling was performed with an MSA pump or equivalent. The air filters were counted and compared to the MPC (DAC) using the same method described for area sampling. Air samplers were calibrated at least every six months.

Historical Program Results

Table 5.7-2 provides the results of monitoring for airborne uranium from the period of 1990 through 1994. The annual average and maximum monthly average airborne gross alpha activity for this period are reported. The increase in the average activity in 1994 is due to the influence of the sampling results from the dryer room. All activity levels were well below 25% of the MPC or DAC.

Proposed In-Plant Airborne Uranium Monitoring Program

CBR proposes to institute the same airborne uranium monitoring program at Crow Butte Uranium Project that has been performed to date with the following changes.

- Based upon operating experience, CBR proposes to perform air sampling at the locations shown in Figure 5.7-1 for the plant. CBR believes that these locations will provide accurate monitoring of plant radiological conditions.

Airborne sampling will be performed on a monthly basis in accordance with the instructions currently contained in Standard Operating Procedures C-12, "Survey for Airborne Uranium " and C-8, "Breathing Zone Samples." These Standard Operating 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 Standard Operating Procedure C-6, "Radon Daughter Measurement" for MSA type samplers and Standard Operating Procedure E-7, "Environmental Air Particulate Sampling".

Table 5.7-2: Inplant Airborne Uranium Monitoring Results

AIRBORNE URANIUM MONITORING PERIOD	ANNUAL AVERAGE AIRBORNE ACTIVITY μCi/ml gross α (% MPC, % DAC)[1,2]	MAXIMUM MONTHLY AVERAGE AIRBORNE ACTIVITY μCi/ml gross α (% MPC, %DAC)[1,2]
Calendar Year 1990 - RO Building (twelve months of sampling data)	4.3 E-13 (0.4% MPC)	3.2 E-12 (3.2% MPC)
Calendar Year 1990 - Commercial Plant (two months of sampling data)	1.56 E-13 (0.2% MPC)	1.78 E-13 (0.2% MPC)
Calendar Year 1991 - RO Building (two months of sampling data)	5.05 E-13 (0.5% MPC)	1.0 E-12 (1.0% MPC)
Calendar Year 1991 - Commercial Plant (twelve months of sampling data)	4.53 E-13 (0.5% MPC)	2.31 E-12 (2.3% MPC)
Calendar Year 1992	5.61 E-13 (0.6% MPC)	1.18 E-12 (1.2% MPC)
Calendar Year 1993	9.67 E-13 (1.0% MPC)	6.67 E-12 (6.7% MPC)
Calendar Year 1994 (includes dryer room sample results)	3.22 E-12 (0.6% DAC)	6.07 E-12 (1.2% DAC)

Notes:
1 Samples prior to January 1, 1994 compared to MPC where MPC = 1 E-10 μCi/ml (10 CFR §§ 20.1 - 20.601 App B) .
2 Samples after January 1, 1994 compared to the DAC where DAC=5 E-10 μCi/ml (10 CFR §§ 20.1001-2401 App B)

5.7.3.2 IN-PLANT RADON DAUGHTER SURVEYS

Program Description

Radon daughter surveys were conducted in the operating areas of the Crow Butte Uranium Project facilities on a monthly basis at the specified locations. Samples were 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 at least every six months.

Results of radon daughter sampling are expressed in Working Levels (WL) where one WL is defined as any combination of short-lived radon-222 daughters in one liter of air without regard to equilibrium that emit 1.3×10^5 MeV of alpha energy. The MPC 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% of the DAC or 0.08 WL. Radon daughter results in excess of the action level result in an investigation of the cause and an increase in the sampling frequency to weekly until the radon daughter levels did not exceed the action level for four consecutive weeks.

Historical Program Results

Table 5.7-3 provides the results of monitoring for radon daughters from the period of 1990 through 1994. The annual average and maximum values are presented. The data shows that the average radon daughter activity concentration at Crow Butte Uranium Project was consistently less than 25% of the regulatory limit.

Proposed In-Plant Radon Daughter Monitoring Program

CBR proposes to institute the same radon daughter monitoring program at Crow Butte Uranium Project that has been performed to date with the following changes.

- Based upon operating experience, CBR proposes to perform radon daughter sampling at the locations shown in Figure 5.7-1. CBR believes that these locations will provide accurate monitoring of plant radiological conditions.

Routine radon daughter monitoring will be performed on a monthly basis in accordance with the instructions currently contained in Standard Operating Procedure C-6, "Radon Daughter Measurement."

Table 5.7-3: Inplant Radon Daughter Monitoring Results

RADON DAUGHTER MONITORING PERIOD	ANNUAL AVERAGE RADON DAUGHTER ACTIVITY in WL (% MPC, % DAC)[1,2]	MAXIMUM MONTHLY AVERAGE RADON DAUGHTER ACTIVITY in WL (% MPC, %DAC)[1,2]
Calendar Year 1990 - RO Building (twelve months of sampling data)	0.015 (4.5% MPC)	0.022 (6.7% MPC)
Calendar Year 1990 - Commercial Plant (two months of sampling data)	0.008 (2.4% MPC)	0.009 (2.7% MPC)
Calendar Year 1991 - RO Building (two months of sampling data)	0.012 (3.6% MPC)	0.019 (5.8% MPC)
Calendar Year 1991 - Commercial Plant (twelve months of sampling data)	0.036 (11% MPC)	0.060 (18.2% MPC)
Calendar Year 1992	0.035 (10.7% MPC)	0.061 (18.5% MPC)
Calendar Year 1993	0.038 (11.8% MPC)	0.061 (18.5% MPC)
Calendar Year 1994	0.032 (9.6% DAC)	0.046 (13.9% DAC)

Notes:

1 Samples prior to January 1, 1994 compared to MPC where MPC=0.33 WL (10 CFR §§ 20.1 - 20.601 App B).

2 Samples after January 1, 1994 compared to the DAC where DAC= 0.33 WL (10 CFR §§ 20.1001-2401 App B)

Air sampler calibration will be performed in accordance with the instructions contained in Standard Operating Procedure C-6.

5.7.3.3 RESPIRATORY PROTECTION PROGRAM

Respiratory protective equipment has been 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 Crow Butte Uranium Project is in accordance with the procedures currently set forth in the following Standard Operating Procedures:

- Standard Operating Procedure R-1, "Respiratory Protection Program"
- Standard Operating Procedure R-2, "Respirator Selection"
- Standard Operating Procedure R-3, "Functional Fit Test: Positive pressure and Negative Pressure Test"
- Standard Operating Procedure R-4, "Respirator Facepiece Fit Testing"Standard Operating Procedure R-5, "Fit Test Exercises"
- Standard Operating Procedure R-6, "Maintenance, Cleaning, Disinfection, Decontamination and Storage of Respirators."

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 CRSO.

5.7.4 EXPOSURE CALCULATIONS

Employee internal exposure to airborne radioactive materials has been determined at the Crow Butte Uranium Project facility since commercial operations began in 1991. Since January 1, 1994 CBR has determined internal exposures based upon the requirements of 10 CFR § 20.1204. Prior to January 1, 1994, internal exposure was calculated using the MPC-Hour method based upon 10 CFR § 20.103. Following is a discussion of the exposure calculation methods and results.

5.7.4.1 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 Mills," Section 2. 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 that the worker is exposed to concentrations X_i (hr)
X_i	=	average concentration of uranium in breathing zone, µg/m^3, µCi/m^3
b	=	breathing rate, 1.2 m^3/hr
PF	=	the respirator protection factor, if applicable
n	=	the number of exposure periods during the week or quarter

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 is determined as follows:

Time of Exposure Determination

100% occupancy time is used to determine routine worker exposures. Exposures during non-routine work is always based upon actual time.

Airborne Uranium Activity Determination

Airborne uranium activity is determined from surveys performed as described in Section 5.7.3.1.

Historical Program Results

Table 5.7-4 summarizes internal exposure results at Crow Butte Uranium Project from airborne uranium. The data shows that internal exposure at Crow Butte Uranium Project has been maintained ALARA. The maximum individual internal exposure to airborne uranium during the period from 1990 through 1994 was less than 1% of the allowable regulatory limit.

Proposed Airborne Uranium Exposure Monitoring Program

CBR proposes to institute the same internal airborne uranium exposure calculation methods at Crow Butte Uranium Project that have been used to date and which are currently contained in Standard Operating Procedure C-16, "Internal Exposure Control and Calculations". Exposures to airborne uranium will be compared to the DAC for the "D" solubility class for natural uranium from appendix B of 10 CFR §§20.1001 - 20.2401 (5 E-10 μCi/ml) for all areas of the plant.

Table 5.7-4: Annual Airborne Uranium Exposure Results

AIRBORNE URANIUM EXPOSURE MONITORING PERIOD	AVERAGE AIRBORNE URANIUM EXPOSURE (µCi)[1]	MAXIMUM AIRBORNE URANIUM EXPOSURE (µCi)[1]
Calendar Year 1990	3.39×10^{-4}	6.08×10^{-4}
Calendar Year 1991	7.20×10^{-4}	1.38×10^{-3}
Calendar Year 1992	7.44×10^{-4}	1.59×10^{-3}
Calendar Year 1993	6.74×10^{-4}	1.26×10^{-3}
Calendar Year 1994	3.66×10^{-3}	9.03×10^{-3}

Notes: 1 The annual uranium intake limit for calendar years 1990 through 1991 was 0.252 µci based upon 10 CFR 20.103. In 1994, the annual limit on intake (ALI) was 1 µCi based upon "D" class natural uranium.

5.7.4.2 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 Mills," Section 2. The radon daughter intake is calculated using the following equation:

$$I_r = \frac{1}{170} \sum_{i=1}^{n} \frac{W_i \times t_i}{PF}$$

where:

I_r	=	radon daughter intake, working-level months
t_i	=	time that the worker is exposed to concentrations W_i (hr)
W_i	=	average number of working levels in the air near the worker's breathing zone during the time (t_i)
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 is determined as follows:

<u>Time of Exposure Determination</u>

100% occupancy time is used to determine routine worker exposure times. Exposures during non-routine work is always based upon actual time.

Radon Daughter Concentration Determination

Radon-222 daughter concentrations are determined from surveys performed as described in Section 0.

The working-level months for radon daughter exposure is calculated on Time Weighted Exposure (TWE) forms. The working-level months are totaled and entered onto each employee's Occupational Exposure Record.

Historical Program Results

Table 5.7-5 summarizes the results of radon daughter exposure calculations at Crow Butte Uranium Project since 1990. The data shows that internal exposure due to radon daughters at Crow Butte Uranium Project has been maintained ALARA. The maximum individual internal exposure to radon daughters during the period from 1990 through 1994 was 0.502 working-level months or approximately 12.5% of the allowable regulatory limit of 4 working-level months. The maximum annual average internal exposure to radon daughters was 0.258 working-level months which is approximately 6.5% of the regulatory limit.

Proposed Radon Daughter Exposure Monitoring Program

CBR proposes to institute the same internal radon daughter exposure calculation methods at Crow Butte Uranium Project that have been used to date and which are currently contained in Standard Operating Procedure C-16, "Internal Exposure Control and Calculations". 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).

Table 5.7-5: Annual Radon Daughter Exposure Results

RADON DAUGHTER EXPOSURE MONITORING PERIOD	AVERAGE INDIVIDUAL EXPOSURE (WORKING-LEVEL MONTHS)[1]	MAXIMUM INDIVIDUAL EXPOSURE (WORKING-LEVEL MONTHS)[1]
Calendar Year 1990	0.062	0.117
Calendar Year 1991	0.257	0.477
Calendar Year 1992	0.227	0.468
Calendar Year 1993	0.258	0.502
Calendar Year 1994	0.188	0.418

Notes:
1 The annual limit was 4 working-level months.

5.7.5 BIOASSAY PROGRAM

Program Description

CBR has implemented a urinalysis bioassay program at the Crow Butte Uranium Project facilities that meets the guidelines contained in USNRC Regulatory Guide 8.22, "Bioassay at Uranium Mills." The primary purpose of the program is to detect uranium intake in employees who are regularly exposed to uranium. The bioassay program consisted 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.

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 on a quarterly frequency. Workers who have the potential for exposure to dried yellowcake are sampled on a monthly basis. 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 μg/l.

3. Action levels for urinalysis are established based upon Table 1 in USNRC Regulatory Guide 8.22, "Bioassay at Uranium Mills."

Historical Program Results

Following is a summary of the results of the bioassay program since 1990.

1990

All bioassay samples were reported at less than the 5 μg/l detection limit.

1991

All bioassay samples were reported at less than the 5 μg/l detection limit.

1992

All bioassay samples were reported at less than the 5 μg/l detection limit.

1993

All bioassay samples were reported at less than the 5 μg/l detection limit.

1994

All bioassay samples were reported at or less 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 less than 5 μg/l.

Bioassay Quality Assurance Program Description and Historical Results

Elements of the Quality Assurance requirements for the Bioassay Program are based upon the guidelines contained in USNRC Regulatory Guide 8.22, "Bioassay in Uranium Mills". These elements included the following:

1. Each batch of samples submitted to the analytical laboratory is accompanied by two blind control samples. The control samples are from persons that have not been occupationally exposed and are spiked to a uranium concentration of 10 to 20 μg/l and 40 to 60 μg/l. The results of analysis for these samples are required to be within ± 30% of the spiked value. CBR has tracked the results of the blind spike analysis since 1990. All analytical results have fallen within the acceptable range.

2. The analytical laboratory spikes 10 to 30% 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%.

Proposed Bioassay Program

CBR proposes to continue to implement the Bioassay Program described in this section in accordance with the guidance contained in USNRC Regulatory Guide 8.22, "Bioassay in Uranium Mills" and with the instructions currently contained in Standard Operating Procedure C-10, "Bioassay Sampling."

5.7.6 CONTAMINATION CONTROL PROGRAM

CBRs contamination control program at Crow Butte Uranium Project consists of the following elements:

Surveys For Surface Contamination

CBR performs surveys for surface contamination in operating and clean areas of the Crow Butte Uranium Project facilities in accordance with the guidelines contained in USNRC Regulatory Guide 8.30, "Health Physics Surveys in Uranium Mills". Surveys for alpha contamination in clean areas such as lunch rooms, change rooms and offices are conducted weekly. An action level of 25% of the limits from USNRC Regulatory Guide 8.30 is used for clean areas.

Surveys For Contamination of Skin and Personal Clothing

Condition 32 of License SUA-1534 requires that all employees who do not shower prior to leaving the restricted area monitor themselves with an alpha survey instrument. 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 does not originate in yellowcake areas. All other items are surveyed as described in the next section.

As recommended in USNRC Regulatory Guide 8.30, "Health Physics Surveys in Uranium Mills", CBR conducts quarterly unannounced spot checks of personnel to verify the effectiveness of the surveys for personnel contamination. A spot check of the employees assigned to the mine site are conducted, 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.

Surveys of Equipment Prior to Release to an Unrestricted Area

Surveys of all items from the restricted areas with the exception of small, hand-carried items described above are performed by the CRSO, radiation safety staff or properly trained employees. The release limits are set by "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses For Byproduct or Source Materials", NRC, September 1984. Surveys are performed with the following equipment:

1. Portable alpha count rate meter, Eberline MS-3 or equivalent.

2. Portable GM survey meter with a beta/gamma probe with an end window thickness of not more than 7 mg/cm^2, Eberline Model ESP-1 with HP-270 probe or equivalent.

3. Swipes for removable contamination surveys as required.

Historical Program Results

The weekly contamination survey results indicate that the contamination control program at the Crow Butte Uranium 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 Uranium Project site.

Proposed Contamination Control Program

CBR proposes to implement the same contamination control program which is currently in use. The program has proven to be effective at controlling contamination of personnel and clean areas. The program will be implemented in accordance with the instructions currently contained in the following Standard Operating Procedures:

- Survey instruments will be calibrated and checked in accordance with the manufacturers instructions.

- Surveys for removable and fixed contamination will be performed in accordance with the instructions contained in Standard Operating Procedure C-3, "Surface Contamination Surveys."

- Surveys for alpha and beta/gamma contamination of items prior to release from restricted areas will be performed in accordance with the instructions contained in Standard Operating Procedure C-14, "Equipment Release and Disposal."

- Personnel monitoring will be performed in accordance with the instructions contained in Standard Operating Procedure C-17, "Entering and Leaving Restricted Areas."

5.7.7 AIRBORNE EFFLUENT AND ENVIRONMENTAL MONITORING PROGRAMS

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 Uranium 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 5.7-6 provides the sampling locations, types, frequency, methods and parameters for the Crow Butte Uranium Project facilities. CBR performs environmental sampling and gamma exposure monitoring as indicated in Table 5.7-6.

Radon

The radon gas effluent released to the environment is monitored at seven locations (AM-1 through AM-6 and AM-8). Monitoring is performed using Track-Etch radon cups provided by Landauer Corporation. The cups are exchanged on a quarterly basis. Standard Operating Procedure C-2, "Radon Sampling and Analysis" currently provides the instructions for radon gas monitoring. In addition to the manufacturer's Quality Assurance program, CBR exposes two duplicate radon Track Etch cups per quarter at locations AB-3 and AB-6. Table 5.7-7 contains the results of radon monitoring for the Crow Butte Uranium Project facility since 1991.
In addition to the environmental monitoring performed at the Crow Butte Uranium Project, release of radon from process operations is estimated and reported in the semi-annual reports required by 10 CFR § 40.65 and License SUA-1534 Condition Number 40. Table 5.7-8 contains annual calculated radon releases from the Crow Butte Uranium Project Facility since 1991.

Air Particulate

CBR performs low volume air particulate sampling at the seven environmental monitoring stations for two weeks per month during dryer operations. Filters are collected for two weeks and then composited for analysis on a quarterly basis. The results of air particulate sampling performed since 1991 are shown in Table 5.7-9.

Surface Soil

Surface soil has been sampled as described in Table 5.7-6. 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.

Subsurface Soil

Subsurface soil has been sampled at the plant as described in Table 5.7-6. Subsurface soil samples will be taken following conclusion of operations and will be compared to the results of the preoperational monitoring program.

Vegetation

Vegetation samples from Crow Butte Uranium Project were collected on an annual basis in animal grazing areas in the direction of the prevailing wind as described in Table 5.7-6. Sampling was normally performed during the summer months. The samples were collected using the following procedures:

- A minimum of one 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 Uranium Project facility is presented in Table 5.7-10.

Table 5.7-6: Radiological, Environmental, Operational Effluent Monitoring Program

		SAMPLE COLLECTION				SAMPLE ANALYSIS	
MONITORED CONSTITUENT	NO.	LOCATION	TYPE	FREQUENCY	METHOD	FREQUENCY	PARAMETER[1]
Air (Radon)	6	Nearest residences and in the prevalent wind direction	Continuous	Quarterly	Terradex Trac-Etch Type F1 Cups or equivalent	Quarterly	Rn-222
	1	Environmental control location near town of Crawford					
Air (Particulates)	7	Same locations as radon monitoring	Continuous	2 weeks per month when dryer is operating	Low volume air sampler with glass fiber filter	Each sample composited quarterly by location	Natural uranium, Ra-226,
Surface Soil	2	Plant site before topsoil removal	Grab (top 5 cm)	Once	Composite sample	Once	Natural uranium, Ra-226
	2	Plant site after topsoil removal	Grab (top 5 cm)	Once	Composite sample	Once	Same
	2	Evaporation ponds before excavation	Grab (top 5 cm)	Once	Composite sample	Once	Same
	7	Air sampling stations	Grab (top 5 cm)	Once	Composite sample	Once	Same
Subsurface Soil	1	Plant site	One-third meter composites to a total depth of 1 meter	Once	Composite sample	Once	Same

Table 5.7-6: Radiological, Environmental, Operational Effluent Monitoring Program

	SAMPLE COLLECTION					SAMPLE ANALYSIS	
MONITORED CONSTITUENT	NO.	LOCATION	TYPE	FREQUENCY	METHOD	FREQUENCY	PARAMETER[1]
Vegetation	1	Animal grazing area in direction of prevailing wind	Composite of dominant vegetation present	Three times during grazing season	Composite sample	Once	Natural uranium, Ra-226,
	7	Air sampling stations	Composite of dominant vegetation present	Once	Composite sample	Once (at completion of mining activities)	Natural uranium, Ra-226,
Direct Radiation	7	Air sampling stations	Continuous	Quarterly exchange of dosimeters	Continuous passive integrating dosimeters	Quarterly	External gamma ray exposure rate
Sediment	1	Each body of water	Grab	Annually	Grab	Annually	Natural uranium, Ra-226,

1 Reg. Guide 4.14 recommends analyses of natural uranium, Ra-226, Th-230, Pb-210 and Po-210. CBR submitted and received approval for analyses of natural uranium and Ra-226 only for the existing sampling program

Table 5.7-7: Ambient Radon Gas Monitoring Results (pCi\L)

	MONITORING LOCATION								
MONITORING PERIOD	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

Notes: All values are given in units of pCi/L.
Monitoring Locations AB-3 and AB-6 are co-located with stations AM-3 and AM-6.

Table 5.7-8: Radon Release to the Environment (Curies)

Year	1991	1992	1993	1994
First Quarter	0	325	600	753
Second Quarter	308	435	637	776
Startup	13	16	11	7
Semi-Annual Total	321	776	1248	1536
Third Quarter	334	527	673	793
Fourth Quarter	329	572	700	808
Startup	0	0	6	16
Semi-Annual Total	663	1099	1379	1617
Annual Total	984	1875	2627	3153

Table 5.7-9: Environmental Air Particulate Monitoring Results

Station	Period	U-Nat (10^{-16} µCi/ml)	Th-230 (10^{-16} µCi/ml)	Ra-226 (10^{-16} µCi/ml)	Pb-210 (10^{-16} µCi/ml)	Volume of Air Sampled M^3
AM-1	First Quarter, 1991	< 1.00	< 1.00	10.1	175	2810
AM-1	Second Quarter, 1991	< 1.00	< 1.00	2.17	91.2	2610
AM-1	Third Quarter, 1991	4.38	< 1.00	< 1.00	151	2590
AM-1	Fourth Quarter, 1991	9.61	< 1.00	9.98	45.5	2560
AM-1	First Quarter, 1992	< 1.00	< 1.00	1.46	300	2590
AM-1	Second Quarter, 1992	7.33	< 1.00	1.47	88.3	2590
AM-1	Third Quarter, 1992	None	None	None	None	None
AM-1	Fourth Quarter, 1992	None	None	None	None	None
AM-1	First Quarter, 1993	None	None	None	None	None
AM-1	Second Quarter, 1993	None	None	None	None	None
AM-1	Third Quarter, 1993	None	None	None	None	None
AM-1	Fourth Quarter, 1993	17.9	< 1.00	7.63	171	2120
AM-1	First Quarter, 1994	5.56	< 1.00	15.0	187	2220
AM-1	Second Quarter, 1994	5.73	< 1.00	11.9	134	2160
AM-1	Third Quarter, 1994	70.9	<1.00	8.87	193	2140
AM-1	Fourth Quarter, 1994	2.7	<1.00	< 1.00	200	2110
AM-2	First Quarter, 1991	< 1.00	< 1.00	< 1.00	224	2810
AM-2	Second Quarter, 1991	< 1.00	< 1.00	4.34	88.9	2610

Table 5.7-9: Environmental Air Particulate Monitoring Results

Station	Period	U-Nat (10^{-16} µCi/ml)	Th-230 (10^{-16} µCi/ml)	Ra-226 (10^{-16} µCi/ml)	Pb-210 (10^{-16} µCi/ml)	Volume of Air Sampled M^3
AM-2	Third Quarter, 1991	4.35	< 1.00	< 1.00	99.4	2600
AM-2	Fourth Quarter, 1991	4.81	< 1.00	< 1.00	71.8	2560
AM-2	First Quarter, 1992	2.19	< 1.00	< 1.00	246	2590
AM-2	Second Quarter, 1992	2.56	< 1.00	8.43	99.6	2590
AM-2	Third Quarter, 1992	None	None	None	None	None
AM-2	Fourth Quarter, 1992	None	None	None	None	None
AM-2	First Quarter, 1993	None	None	None	None	None
AM-2	Second Quarter, 1993	None	None	None	None	None
AM-2	Third Quarter, 1993	None	None	None	None	None
AM-2	Fourth Quarter, 1993	9.7	< 1.00	4.85	127	2150
AM-2	First Quarter, 1994	4.2	< 1.00	8.4	205	2260
AM-2	Second Quarter, 1994	6.65	< 1.00	8.42	105	2140
AM-2	Third Quarter, 1994	8.02	< 1.00	4.46	193	2130
AM-2	Fourth Quarter, 1994	5.1	< 1.00	< 1.00	210	2050
AM-3	First Quarter, 1991	< 1.00	< 1.00	< 1.00	266	2810
AM-3	Second Quarter, 1991	< 1.00	< 1.00	4.39	77.5	2580
AM-3	Third Quarter, 1991	58.2	< 1.00	< 1.00	137	2600
AM-3	Fourth Quarter, 1991	4.81	< 1.00	1.48	51.4	2560

Table 5.7-9: Environmental Air Particulate Monitoring Results

Station	Period	U-Nat (10^{-16} µCi/ml)	Th-230 (10^{-16} µCi/ml)	Ra-226 (10^{-16} µCi/ml)	Pb-210 (10^{-16} µCi/ml)	Volume of Air Sampled M^3
AM-3	First Quarter, 1992	2.19	< 1.00	2.92	141	2580
AM-3	Second Quarter, 1992	< 1.00	< 1.00	1.84	121	2590
AM-3	Third Quarter, 1992	None	None	None	None	None
AM-3	Fourth Quarter, 1992	None	None	None	None	None
AM-3	First Quarter, 1993	None	None	None	None	None
AM-3	Second Quarter, 1993	None	None	None	None	None
AM-3	Third Quarter, 1993	None	None	None	None	None
AM-3	Fourth Quarter, 1993	6.56	< 1.00	4.81	104	2170
AM-3	First Quarter, 1994	14.6	< 1.00	< 1.00	190	2280
AM-3	Second Quarter, 1994	7.45	< 1.00	6.57	129	2170
AM-3	Third Quarter, 1994	4.85	< 1.00	2.20	238	2160
AM-3	Fourth Quarter, 1994	< 1.00	< 1.00	< 1.00	162	2170
AM-4	First Quarter, 1991	< 1.00	< 1.00	4.78	275	2770
AM-4	Second Quarter, 1991	< 1.00	< 1.00	5.11	< 20	2590
AM-4	Third Quarter, 1991	< 1.00	< 1.00	< 1.00	167	2600
AM-4	Fourth Quarter, 1991	4.81	< 1.00	< 1.00	20.7	2560
AM-4	First Quarter, 1992	2.2	< 1.00	< 1.00	178	2580
AM-4	Second Quarter, 1992	< 1.00	< 1.00	< 1.00	63.2	2580

Table 5.7-9: Environmental Air Particulate Monitoring Results

Station	Period	U-Nat (10^{-16} µCi/ml)	Th-230 (10^{-16} µCi/ml)	Ra-226 (10^{-16} µCi/ml)	Pb-210 (10^{-16} µCi/ml)	Volume of Air Sampled M^3
AM-4	Third Quarter, 1992	None	None	None	None	None
AM-4	Fourth Quarter, 1992	None	None	None	None	None
AM-4	First Quarter, 1993	None	None	None	None	None
AM-4	Second Quarter, 1993	None	None	None	None	None
AM-4	Third Quarter, 1993	None	None	None	None	None
AM-4	Fourth Quarter, 1993	5.86	< 1.00	4.18	156	2270
AM-4	First Quarter, 1994	7.58	< 1.00	1.00	198	2380
AM-4	Second Quarter, 1994	5.79	< 1.00	12.5	114	2130
AM-4	Third Quarter, 1994	10.8	< 1.00	7.17	296	2120
AM-4	Fourth Quarter, 1994	2.67	< 1.00	< 1.00	233	2140
AM-5	First Quarter, 1991	67.7	< 1.00	< 1.00	277	2780
AM-5	Second Quarter, 1991	< 1.00	< 1.00	4.35	< 20	2610
AM-5	Third Quarter, 1991	< 1.00	< 1.00	3.63	160	2600
AM-5	Fourth Quarter, 1991	4.82	< 1.00	1.11	36.6	2560
AM-5	First Quarter, 1992	< 1.00	< 1.00	1.46	178	2590
AM-5	Second Quarter, 1992	2.56	< 1.00	9.52	127	2590
AM-5	Third Quarter, 1992	None	None	None	None	None
AM-5	Fourth Quarter, 1992	None	None	None	None	None

Table 5.7-9: Environmental Air Particulate Monitoring Results

Station	Period	U-Nat (10^{-16} µCi/ml)	Th-230 (10^{-16} µCi/ml)	Ra-226 (10^{-16} µCi/ml)	Pb-210 (10^{-16} µCi/ml)	Volume of Air Sampled M^3
AM-5	First Quarter, 1993	None	None	None	None	None
AM-5	Second Quarter, 1993	None	None	None	None	None
AM-5	Third Quarter, 1993	None	None	None	None	None
AM-5	Fourth Quarter, 1993	1	< 1.00	1.00	164	2290
AM-5	First Quarter, 1994	12.3	< 1.00	1.00	217	2400
AM-5	Second Quarter, 1994	3.1	< 1.00	12.8	161	2150
AM-5	Third Quarter, 1994	4.9	< 1.00	4.01	252	2130
AM-5	Fourth Quarter, 1994	2.69	< 1.00	1.00	235	2120
AM-6	First Quarter, 1991	23.5	< 1.00	6.12	275	2780
AM-6	Second Quarter, 1991	< 1.00	< 1.00	2.17	< 20	2610
AM-6	Third Quarter, 1991	8.72	< 1.00	< 1.00	129	2600
AM-6	Fourth Quarter, 1991	4.81	< 1.00	< 1.00	76.1	2560
AM-6	First Quarter, 1992	< 1.00	< 1.00	< 1.00	286	2590
AM-6	Second Quarter, 1992	< 1.00	< 1.00	4.02	103	2600
AM-6	Third Quarter, 1992	None	None	None	None	None
AM-6	Fourth Quarter, 1992	None	None	None	None	None
AM-6	First Quarter, 1993	None	None	None	None	None
AM-6	Second Quarter, 1993	None	None	None	None	None

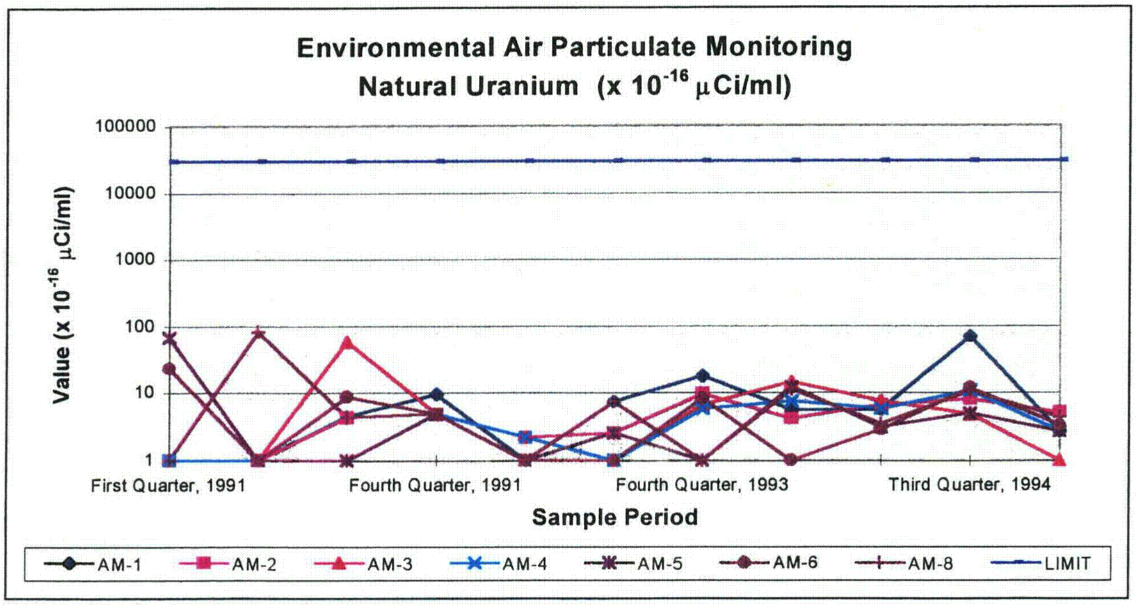
Table 5.7-9: Environmental Air Particulate Monitoring Results

Station	Period	U-Nat (10^{-16} µCi/ml)	Th-230 (10^{-16} µCi/ml)	Ra-226 (10^{-16} µCi/ml)	Pb-210 (10^{-16} µCi/ml)	Volume of Air Sampled M^3
AM-6	Third Quarter, 1993	None	None	None	None	None
AM-6	Fourth Quarter, 1993	8.27	< 1.00	6.10	146	2180
AM-6	First Quarter, 1994	< 1.00	< 1.00	2.49	173	2290
AM-6	Second Quarter, 1994	2.92	< 1.00	12.5	130	2280
AM-6	Third Quarter, 1994	11.9	< 1.00	2.54	233	2240
AM-6	Fourth Quarter, 1994	3.36	< 1.00	< 1.00	208	2270
AM-8	First Quarter, 1991	< 1.00	< 1.00	6.05	253	2810
AM-8	Second Quarter, 1991	82.5	< 1.00	3.62	< 20	2610
AM-8	Third Quarter, 1991	4.36	< 1.00	< 1.00	109	2600
AM-8	Fourth Quarter, 1991	4.82	< 1.00	1.48	43.4	2560
AM-8	First Quarter, 1992	< 1.00	< 1.00	4.38	290	2590
AM-8	Second Quarter, 1992	7.33	< 1.00	< 1.00	95.7	2590
AM-8	Third Quarter, 1992	None	None	None	None	None
AM-8	Fourth Quarter, 1992	None	None	None	None	None
AM-8	First Quarter, 1993	None	None	None	None	None
AM-8	Second Quarter, 1993	None	None	None	None	None
AM-8	Third Quarter, 1993	None	None	None	None	None
AM-8	Fourth Quarter, 1993	1.00	< 1.00	2.11	173	2250

Table 5.7-9: Environmental Air Particulate Monitoring Results

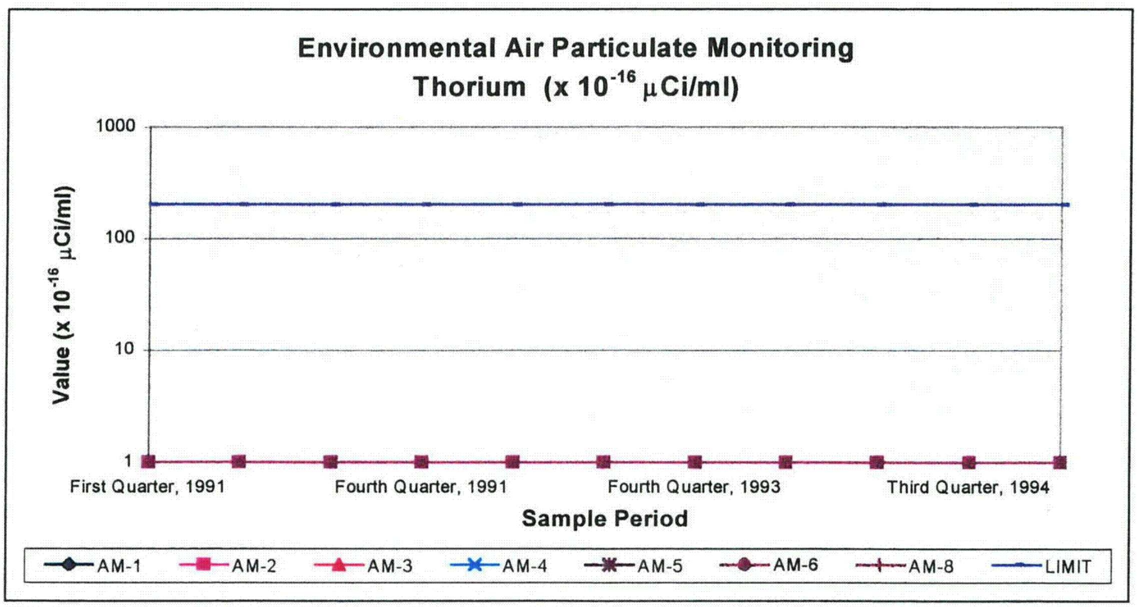
Station	Period	U-Nat (10^{-16} µCi/ml)	Th-230 (10^{-16} µCi/ml)	Ra-226 (10^{-16} µCi/ml)	Pb-210 (10^{-16} µCi/ml)	Volume of Air Sampled M^3
AM-8	First Quarter, 1994	11.3	< 1.00	33.9	147	2360
AM-8	Second Quarter, 1994	3.51	< 1.00	57.4	149	2170
AM-8	Third Quarter, 1994	10.6	< 1.00	4.85	317	2160
AM-8	Fourth Quarter, 1994	4.36	< 1.00	< 1.00	165	2180

Figure 5.7-2: Environmental Air Particulate Monitoring Trend Natural Uranium (x 10^{-16} μCi/ml)



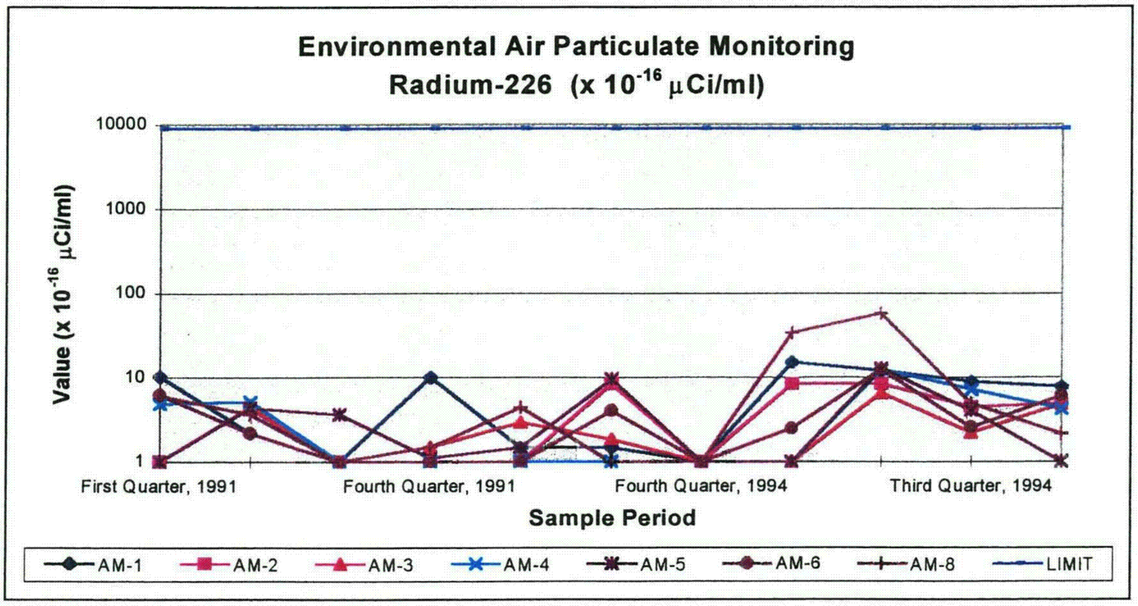
Appendix B to 10 CFR 20.1001 - 20.2401 Table 2 Effluent Concentration in Air Limit is 3.0 x 10^{-12} μCi/ml. This chart is presented on a log scale to accomodate this limit.

Figure 5.7-3: Environmental Air Particulate Monitoring Trend Thorium (x 10^{-16} μCi/ml)



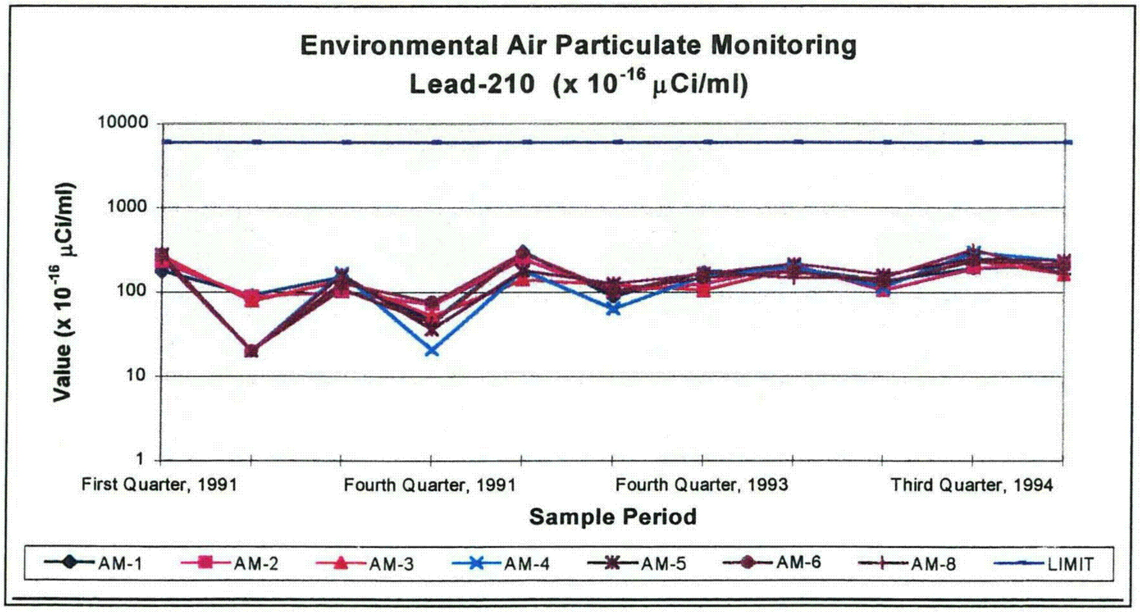
Appendix B to 10 CFR 20.1001 - 20.2401 Table 2 Effluent Concentration in Air Limit is 2.0 x 10^{-14} μCi/ml. This chart is presented on a log scale to accomodate this limit.

Figure 5.7-4: Environmental Air Particulate Monitoring Trend Radium-226 (x 10^{-16} μCi/ml)



Appendix B to 10 CFR 20.1001 - 20.2401 Table 2 Effluent Concentration in Air Limit is 9.0 x 10^{-13} μCi/ml. This chart is presented on a log scale to accomodate this limit.

Figure 5.7-5: Environmental Air Particulate Monitoring Lead-210 (x 10^{-16} μCi/ml)



Appendix B to 10 CFR 20.1001 - 20.2401 Table 2 Effluent Concentration in Air Limit is 6.0 x 10^{-13} μCi/ml. This chart is presented on a log scale to accomodate this limit.

Direct Radiation

Environmental gamma radiation levels are monitored continuously at the seven air quality monitoring stations. Gamma radiation is monitored through the use of thermoluminescent dosimeters (TLDs) obtained from Eberline Instrument Corporation. TLDs are exchanged on a quarterly basis. Results of the annual gamma radiation monitoring are shown in Table 5.7-11.

Sediment

Sediment in Squaw Creek is sampled at two locations on a semiannual basis for one year prior to any construction in the area. Samples have been taken as described in Table 5.7-6 annually. 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 5.7-12.

Proposed Airborne Effluent and Environmental Monitoring Program

CBR proposes to continue to implement the Airborne Effluent and Environmental Monitoring Program described in this section with the following proposed changes.

- CBR proposes to eliminate vegetation sampling in accordance with the provisions of USNRC Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills". Footnote (o) to Table 2 requires that "vegetation and forage sampling need be carried out only if dose calculations indicate that the ingestion pathway from grazing animals is a potentially significant exposure pathway..." defined as a pathway which would expose an individual to a dose in excess of 5% of the applicable radiation protection standard. This pathway was evaluated by MILDOS-Area and is discussed further in Section 7.3.

Table 5.7-10: Annual Vegetation Sampling Program Results

SAMPLE DATE	U-Natural uCi/kg	Ra-226 uCi/kg	Th-230 uCi/kg	Pb-210 uCi/kg	Po-210 uCi/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

Figure 5.7-6: Annual Vegetation Sampling Trend

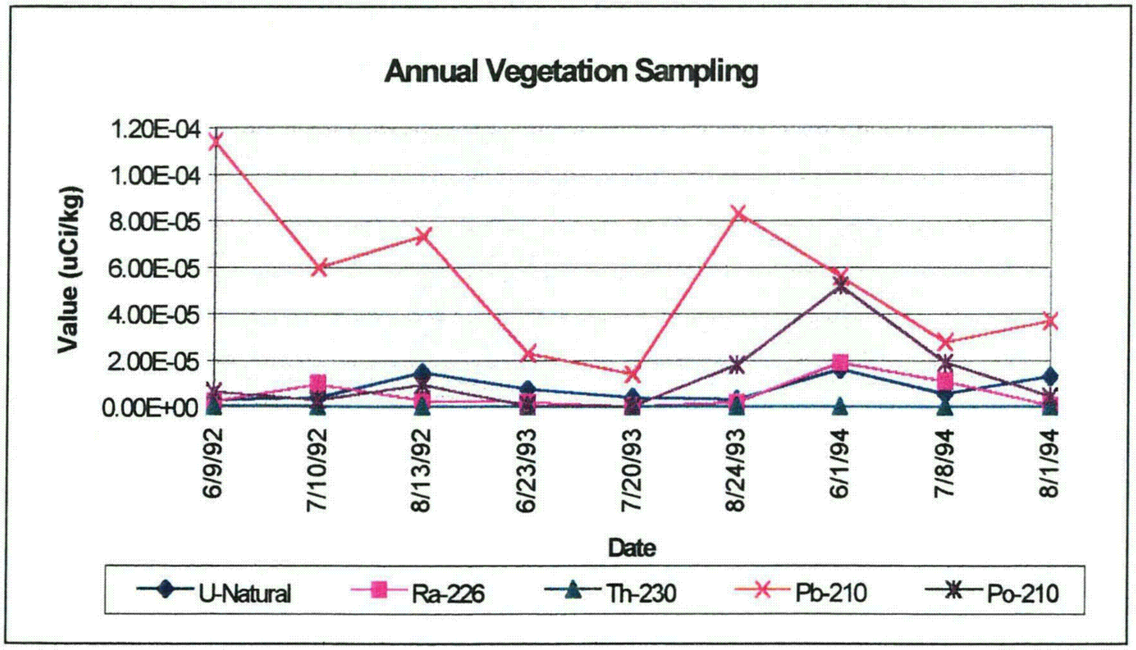


Table 5.7-11: TLD Area Monitoring Results (mRem)

DATE	1000	1001	1002	1003	1005	1006	1007	1008	1009	1010	1011	1012
	CONT	AM-1	AM-2	AM-6	R&D	WELL	WELL	AM-8	AM-3	AM-4	AM-5	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

Sample Locations:

1000:	Control
1005:	R&D Pond Gate
1006:	Wellfield
1007:	Wellfield
1012:	Commercial Pond Gate

Figure 5.7-7: Area TLD Monitoring Trend (mRem)

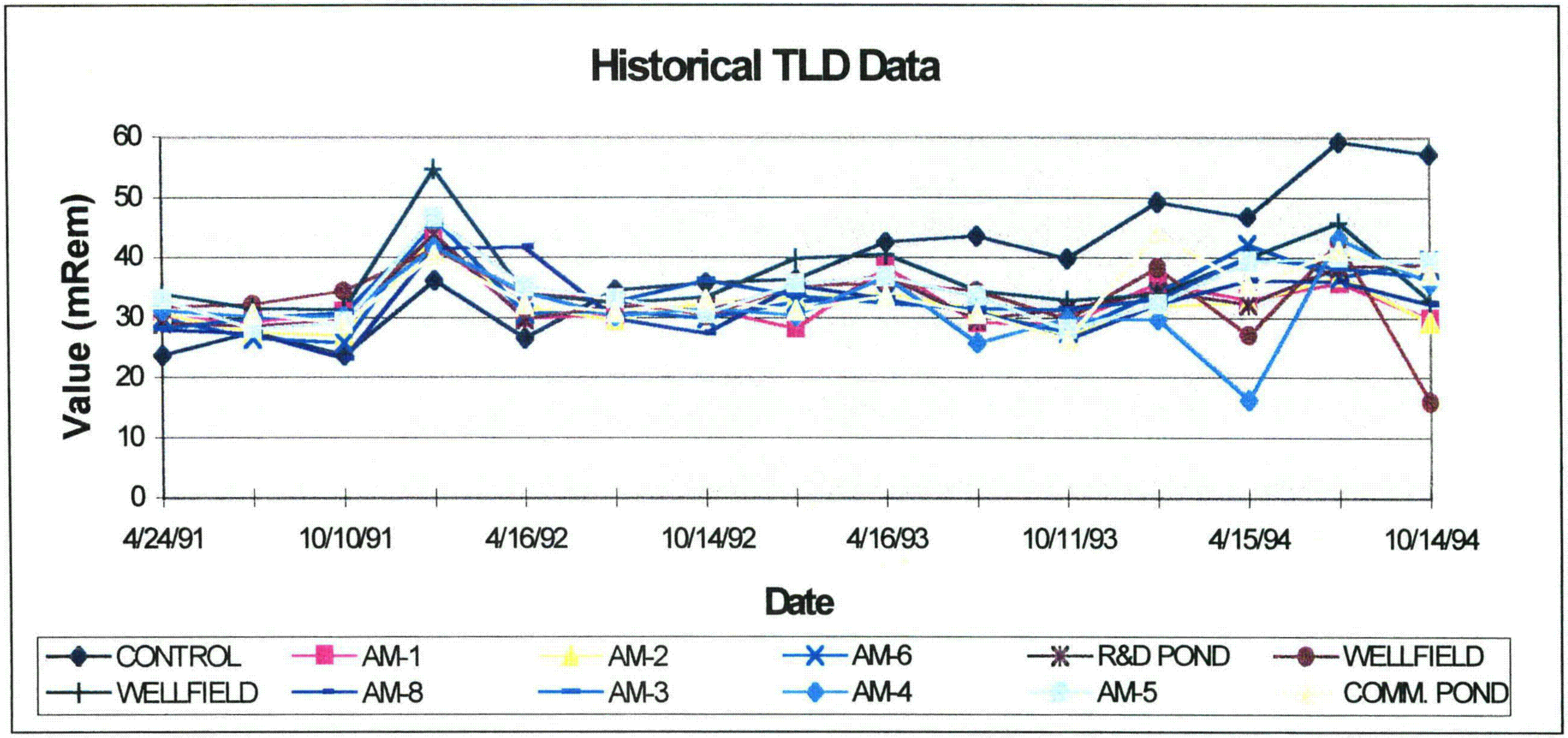


Table 5.7-12: Annual Sediment Sampling Results

Station	Date	U-Natural pCi/g	Radium-226 pCi/g	Th-230 pCi/g	Pb-210 pCi/g
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
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

Notes: No analysis done for Th-230 and Pb-210 in 1992.

Figure 5.7-8: Annual Sediment Sampling Trend- Location S-2

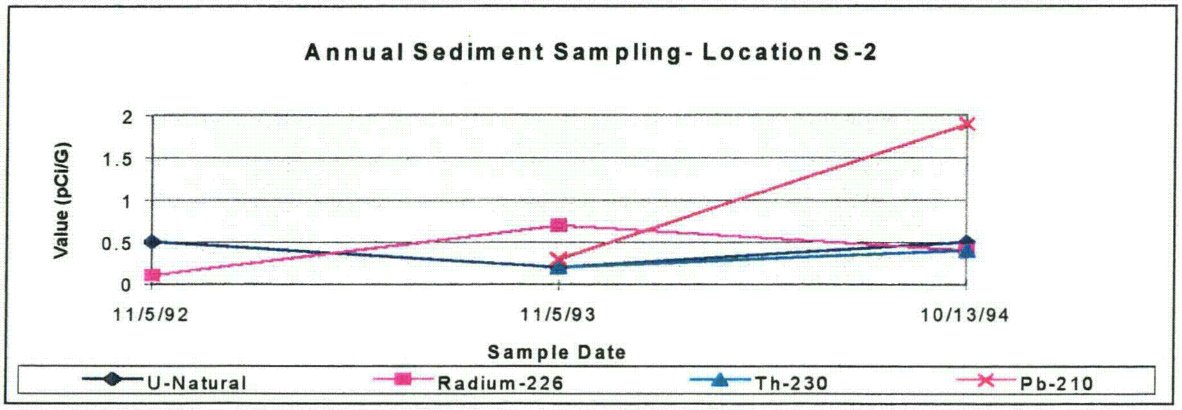
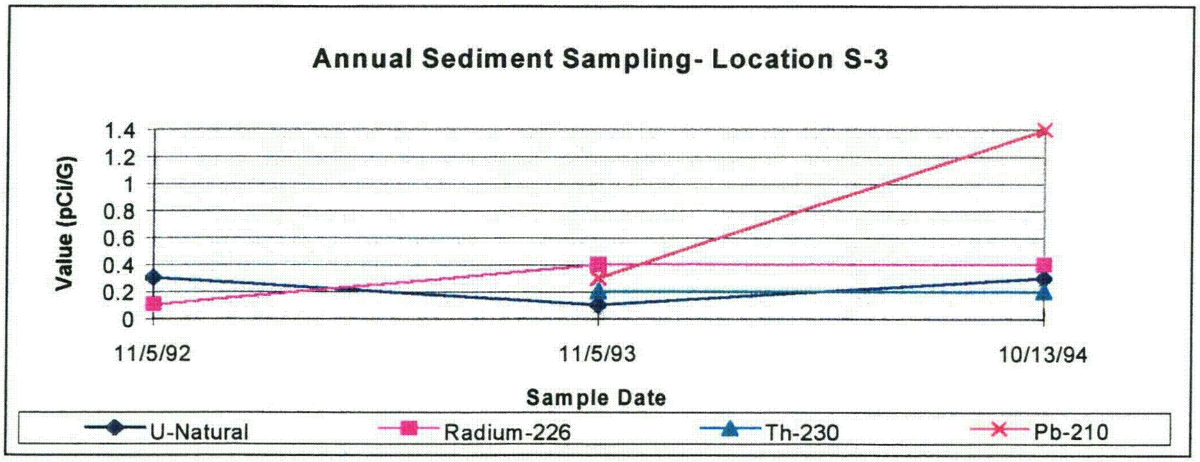


Figure 5.7-9: Annual Stream Sediment Sampling Trend- Location S-3



5.7.8 GROUNDWATER/SURFACE WATER MONITORING PROGRAM

Program Description

During operations at the Crow Butte Uranium 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, 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 Uranium Project can be found in Table 5.16.

5.7.8.1 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. The Pierre Shale below the ore zone is over 1200 feet thick and contains no water bearing strata. Therefore, it is not necessary to monitor any water bearing strata below the ore zone.

All private wells and surface waters within one kilometer of the restricted area boundary are sampled on a quarterly basis. Surface water samples are taken in accordance with the instructions contained in Standard Operating Procedure E-6, "Surface Water Sampling." Samples are analyzed for natural uranium and radium-226. The results of this sampling since 1991 for uranium is shown in Table 5.7-14 and for radium in Table 5.7-15.

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 appear stable and consistent with the anticipated quality of the area. After development, wells are sampled to obtain baseline water quality. For baseline sampling, a minimum of one casing displacement is evacuated prior to sample collections. Quarterly monitor well results are shown for uranium in Table 5.7-16 and for radium in Table 5.7-17 All monitor wells including ore zone and overlying monitor wells are sampled three times at two week intervals and analyzed for the baseline parameters shown in Table 5.7-18.

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 which would be indicative of a migration of lixiviant from the well field. The constituents chosen for indicators of lixiviant migration and for which UCLs are set are chloride, conductivity, sodium, sulfate 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 very 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. A minimum of one casing displacement is evacuated prior to collection of the sample. Upper control limits are set at 20% above the maximum baseline concentration for the excursion indicator.

Operational monitoring consists of sampling the monitor wells on a twice per month basis and analyzing the samples for the excursion indicators chloride, conductivity, sodium, sulfate and total alkalinity.

Excursion Verification and Corrective Action

During routine sampling, if two of the five 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. If neither the second or 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 is notified by telephone within 24 hours and notified in writing within seven (7) days.

If an excursion is verified, the following methods of corrective action are instituted (not necessarily in the order given; dependent upon 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 well field 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 one-week samples.

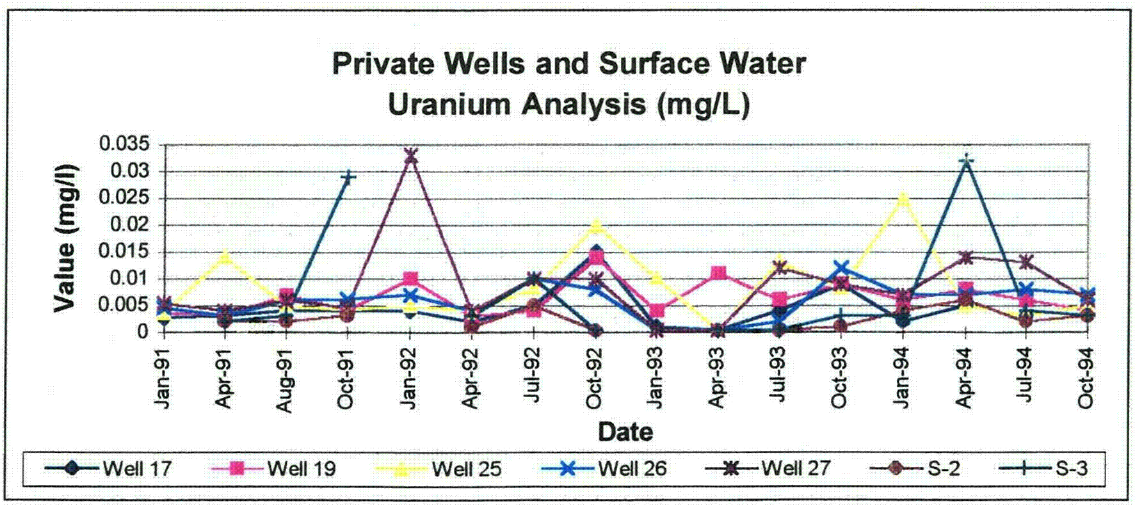
Table 5.7-13: Environmental Groundwater and Surface Water Monitoring Programs

	SAMPLE COLLECTION			SAMPLE ANALYSIS		
CONSTITUENT	LOCATION	TYPE	FREQUENCY	METHOD	FREQUENCY	PARAMETER
Groundwater	One from each water supply well within 1 km of area wellfield	Grab	Quarterly	Grab	Each sample	Natural uranium, Ra-226
	One from each monitor well in the wellfield	Grab	Quarterly	Grab	Each sample	Same
Surface Water	Two from each stream passing through the wellfield area: one upstream and one downstream.	Grab	Quarterly	Grab	Each sample	Natural uranium, Ra-226
	One from each body of water in wellfield area	Grab	Quarterly	Grab	Each sample	Same

Table 5.7-14: Private Wells and Surface Water Monitoring Results Uranium Analysis (mg/L)

Date	Well 17	Well 19	Well 25	Well 26	Well 27	S-2	S-3
Jan-91	0.0027	0.0036	0.0036	0.0045	0.0054		
Apr-91	0.003	0.003	0.014	0.003	0.004	0.002	0.002
Aug-91	0.0039	0.0069	0.0049	0.0059	0.0059	0.002	0.003
Oct-91	0.0041	0.0041	0.0041	0.0062	0.0047	0.0031	0.029
Jan-92	0.004	0.01	0.005	0.007	0.033		
Apr-92	0.002	0.003	0.004	0.004	0.004	0.001	0.003
Jul-92	0.005	0.004	0.008	0.01	0.01	0.005	0.01
Oct-92	0.015	0.014	0.02	0.008	0.01	< 0.0003	<0.0003
Jan-93	0.001	0.004	0.01	< 0.0003	< 0.0003		
Apr-93	< 0.0003	0.011	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003
Jul-93	0.004	0.006	0.013	0.002	0.012	< 0.0003	< 0.0003
Oct-93	0.009	0.009	0.008	0.012	0.009	0.001	0.003
Jan-94	0.002	0.006	0.025	0.007	0.007	0.004	0.003
Apr-94	0.005	0.008	0.005	0.007	0.014	0.006	0.032
Jul-94	0.003	0.006	0.003	0.008	0.013	0.002	0.004
Oct-94	0.005	0.004	0.005	0.007	0.006	0.003	0.003

Figure 5.7-10: Private Wells and Surface Water Trend-Uranium Analysis (mg/L)

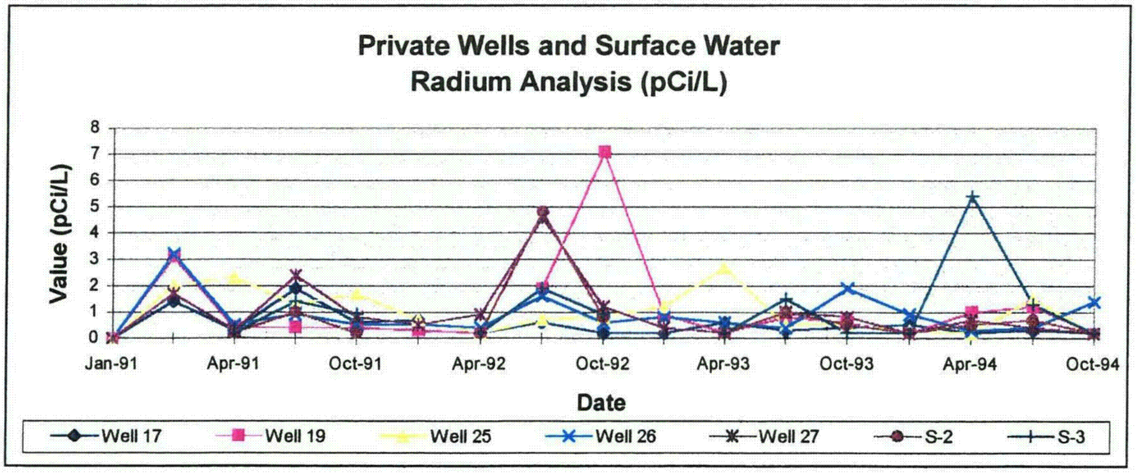


Note: Gaps in chart are due to missing data points.

Table 5.7-15: Private Wells and Surface Water Monitoring Results Radium Analysis (pCi/L)

Date	Well 17	Well 19	Well 25	Well 26	Well 27	S-2	S-3
Jan-91	1.4	3.1	2	3.2	1.7		
Apr-91	0.3	0.4	2.3	0.5	0.3	< 0.2	< 0.2
Aug-91	1.9	0.4	1.3	0.9	2.4	1	1.4
Oct-91	0.6	0.4	1.7	0.5	0.8	0.2	0.9
Jan-92	0.7	0.3	0.7	0.5	0.5		
Apr-92	< 0.2	< 0.2	< 0.2	0.4	0.9	< 0.2	< 0.2
Jul-92	0.6	1.9	0.7	1.6	4.6	4.8	1.9
Oct-92	< 0.2	7.1	0.8	0.6	1.2	0.8	0.9
Jan-93	< 0.2	0.9	1.2	0.8	0.4		
Apr-93	< 0.6	< 0.2	2.7	0.6	< 0.2	< 0.2	< 0.2
Jul-93	< 0.3	0.8	0.5	0.4	1	1	1.5
Oct-93	< 0.4	0.6	0.5	1.9	0.8	0.5	< 0.2
Jan-94	0.5	< 0.2	0.3	0.9	< 0.2	< 0.2	< 0.2
Apr-94	0.2	1	0.2	0.3	0.7	0.5	< 5.4
Jul-94	0.3	1.2	1.5	0.4	0.4	0.7	1.3
Oct-94	< 0.2	< 0.2	< 0.2	1.4	< 0.2	< 0.2	< 0.2

Figure 5.7-11: Private Wells and Surface Water Trend Radium Analysis (pCi/L)



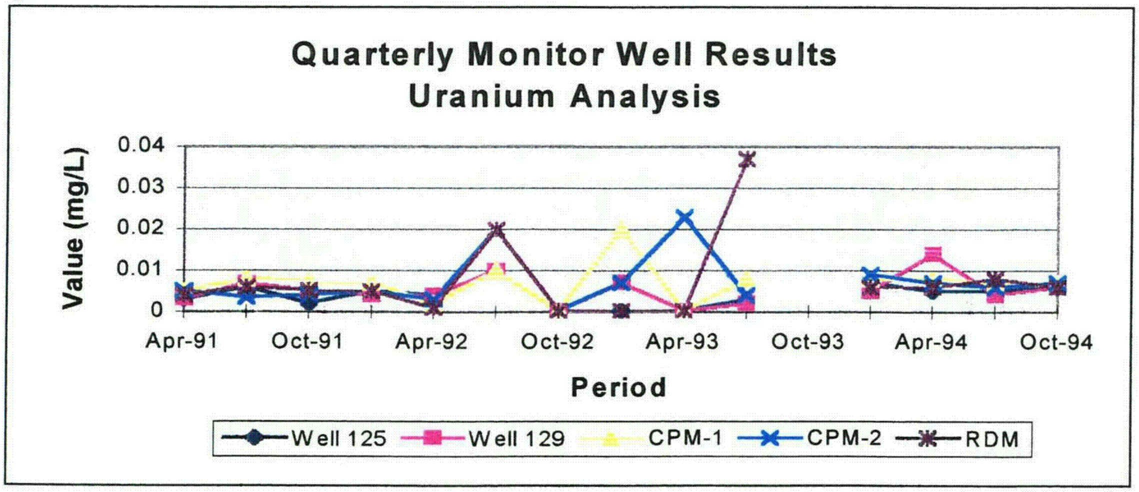
Note: Gaps in chart are due to missing data points.

Table 5.7-16: Quarterly Monitor Well Results
Uranium Analysis (mg/L)

Date	Well 125	Well 129	CPM-1	CPM-2	RDM
Apr-91	0.003	0.003	0.005	0.005	0.004
Aug-91	0.0059	0.0069	0.0079	0.0035	0.0059
Oct-91	0.0021	0.0052	0.0073	0.0041	0.0052
Jan-92	0.005	0.004	0.007	0.005	0.005
Apr-92	0.004	0.004	0.002	0.003	0.001
Jul-92	0.01	0.01	0.01	0.02	0.02
Oct-92	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003
Jan-93	< 0.0003	0.007	0.02	0.007	< 0.0003
Apr-93	< 0.0003	< 0.0003	< 0.0003	0.023	< 0.0003
Jul-93	0.003	0.002	0.008	0.004	0.037
Oct-93					
Jan-94	0.007	0.005	0.008	0.009	0.006
Apr-94	0.005	0.014	0.008	0.007	0.006
Jul-94	0.005	0.004	0.007	0.006	0.008
Oct-94	0.006	0.006	0.007	0.007	0.006

Notes: CPM-1 is the Commercial Pond No. 1 Monitor Well.
CPM-2 is the Commercial Pond No. 2 Monitor Well.
RDM is the Research and Development Pond Monitor Well.

Figure 5.7-12: Quarterly Monitor Well Trend
Uranium Analysis (mg/L)



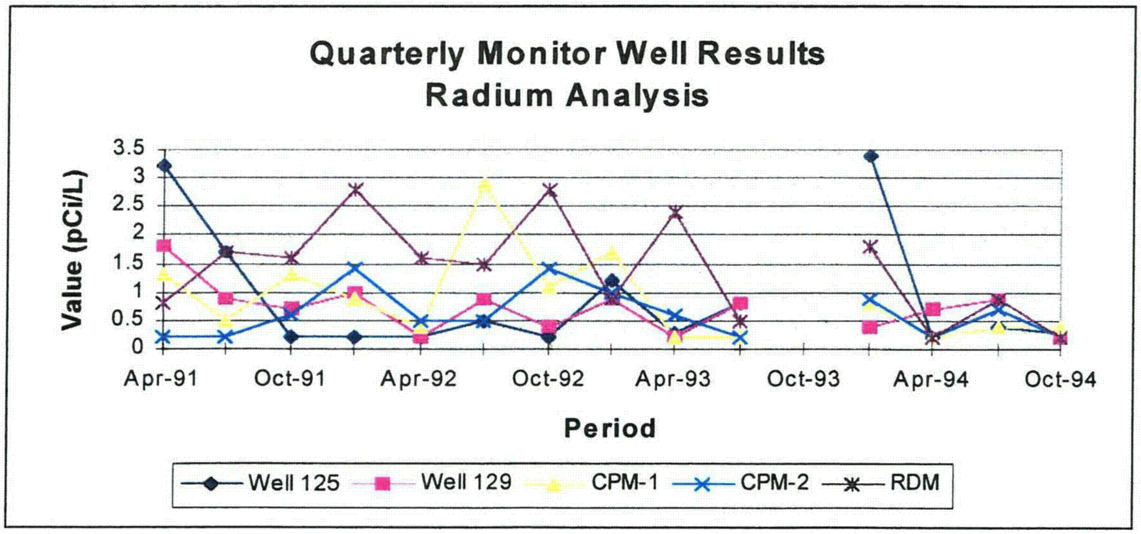
Note: Gaps in chart are due to missing data points.

**Table 5.7-17: Quarterly Monitor Well Results
Radium Analysis (pCi/L)**

Date	Well 125	Well 129	CPM-1	CPM-2	RDM
Apr-91	3.2	1.8	1.3	< 0.2	0.8
Aug-91	1.7	0.9	0.5	< 0.2	1.7
Oct-91	0.2	0.7	1.3	0.6	1.6
Jan-92	< 0.2	1	0.9	1.4	2.8
Apr-92	< 0.2	< 0.2	0.4	0.5	1.6
Jul-92	0.5	0.9	2.9	0.5	1.5
Nov-92	< 0.2	0.4	1.1	1.4	2.8
Jan-93	1.2	0.9	1.7	1	0.9
Apr-93	0.3	< 0.2	< 0.2	0.6	2.4
Jul-93	0.8	0.8	< 0.2	< 0.2	0.5
Oct-93					
Jan-94	3.4	0.4	0.8	0.9	1.8
Apr-94	< 0.2	0.7	< 0.2	< 0.2	0.2
Jul-94	0.4	0.9	0.4	0.7	0.9
Oct-94	0.3	< 0.2	0.4	< 0.2	< 0.2

Notes: CPM-1 is the Commercial Pond Monitor No. 1 Well.
CPM-2 is the Commercial Pond Monitor No. 2 Well.
RDM is the R&D Pond Monitor Well.

**Figure 5.7-13: Quarterly Monitor Well Trend
Radium Analysis (pCi/L)**



Note: Gaps in chart are due to missing data points.

Table 5.7-18: Baseline Water Quality Indicators

Physical Indicators

Specific Conductivity	Alkalinity	Total Dissolved Solids
Temperature	pH	

Common Constituents

Ammonia	Chloride	Silica
Bicarbonate	Magnesium	Sodium
Calcium	Nitrate	Sulfate
Carbonate	Nitrite	Potassium

Trace and Minor Elements

Arsenic	Fluoride	Nickel
Boron	Iron	Selenium
Barium	Lead	Vanadium
Cadmium	Manganese	Zinc
Chromium	Mercury	
Copper	Molybdenum	

Radionuclides

Radium-226	Uranium

5.7.8.3 SURFACE WATER MONITORING

The pre-operational water quality monitoring program assessed water quality and quantity for Squaw Creek. CBR samples two surface water locations for Squaw Creek. Samples from all locations are obtained quarterly. Surface water samples are analyzed for the parameters given in Table 5.7-18. Surface monitoring results are submitted in the semi-annual activity and monitoring reports submitted to NRC. A summary table of regional surface water monitoring results can be found in Table 5.7-14 and Table 5.7-15.

5.7.8.4 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 six (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 is notified by telephone within 48 hours of leak verification.
- The level of the leaking pond is lowered by transferring its contents into an adjacent pond. While lowering the water level in the pond, inspections of the liner are made to determine the cause and location of the leakage. The area of investigation first centers around the pond area specific for the particular standpipe which 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.

5.7.9 QUALITY ASSURANCE PROGRAM

A quality assurance program is in place at Crow Butte Uranium 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, duplicate sample programs 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 Standard Operating Procedures developed by CBR are a critical step to insuring that quality assurance objectives are met. Current SOP's 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.

7. Laboratory procedures.

5.7.10 MONITORING PROGRAM SUMMARY

Section 5.7 of this renewal application has reviewed the radiological monitoring data produced at Crow Butte Uranium Project for the years of 1990 through 1994. 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 5.7-19 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 Mills".

Table 5.7-19: 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 • Monthly radon daughter grab samples	• Weekly radon daughter grab samples • Monthly radon daughter grab samples • Monthly 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	• Annually	• Annually	• 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	• Detailed survey before	• Detailed survey before	• Once before release

Table 5.7-19: Radiological Monitoring Program Summary

Type of Survey	Type of Area	Current Frequency	Proposed Frequency	Reg. Guide 8.30 Recommended Frequency
	be contaminated	*release*	*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 upon administrative action level of 25% 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% process staff also conducted.

6. RESTORATION, RECLAMATION, AND DECOMMISSIONING

6.1 GROUNDWATER RESTORATION

Prior to discussing restoration methodologies, 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 Crow Butte uranium deposit is a roll front deposit in a fluvial sandstone. The deposit is very similar to those in the Wyoming basins such as Gas Hills, Shirley Basin and the Powder River Basin. The origin of the uranium in the deposit could be from within the host rock itself either from the feldspar or volcanic ash content of the Basal Chadron Sandstone. The source of the uranium could also be volcanic ash of the Middle Chadron Formation which overlays the Basal Chadron Sandstone. Regardless of the source of the uranium, it has been precipitated in several long sinuous roll fronts. The individual roll fronts are developed within subunits of the Basal Chadron Sandstone. The Basal 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 conditions probably resulted from H_2S and to a lesser degree from organic material 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 Basal Chadron Sandstone to oxidize the reduced uranium and to complex it with bicarbonates. The uranium bearing solution is then drawn through the mineralized portion of the sandstone between the clay beds towards recovery wells by pumping. 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 Basal 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 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. This represents the normal range of operating conditions for the Crow Butte Commercial Plant.

6.1.2.1 ION EXCHANGE

The main 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 Basal Chadron Sandstone and the ore, magnesium and potassium in solution have no impact. The limited solubility of calcium carbonate, 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 a 3.0 g/l total carbonate strength is 1.21 milliequivalents of calcium per 100 grams of ore. This equates roughly to 1/2 pound of calcium or about 1.2 pounds of calcium carbonate per ton of ore which could potentially be precipitated. 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 which can be exchanged. Somewhat less than this 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, one controls the lixiviant carbonate concentration and the lixiviant pH. 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 overproduction 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 a few 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 and 1 gram/liter carbonate in lixiviant, the equilibrium solubility of calcium will be 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 do illustrate the effect of carbonate concentration and pH on the equilibrium solubility of calcium.

The amount of calcium produced depends on the ion exchange which is taking place, while the precipitation of calcium is a function of the lixiviant chemistry, and the degree of supersaturation which 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 every in-situ leach operation 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 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% of the void space in that ton of ore.

Calcium may be removed from the system in the following ways: filters will be routinely backwashed to the ponds and periodically will be acid cleaned if necessary to remove precipitated calcium carbonate from the filter housing or filter media; the solution bleed taken to compensate for over production will also serve to eliminate some calcium form the system. Should precipitation of calcium carbonate at or near the wellbore of the wellfield wells become a problem, these wells are air lifted, surged, water jetted, or acidified as necessary 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 which has been identified is iron, which could probably precipitate as either the hydroxide or the carbonate, causing some fouling. Such fouling is usually evidenced by 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 Basal Chadron Sandstone, iron precipitation has not been a problem.

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, 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, a possible small increase in the cations associated with the silicious minerals. The hydrolysis reaction do not have a significant effect on operations.

6.1.2.4 OXIDATION

The oxidant consumers in the Basal Chadron Sandstone are hydrogen sulfide in the groundwater, uranium, vanadium, iron pyrite, and other trace and heavy metals. The impacts of these oxidant consumers on the operation of the plant would be to generally increase the oxidant consumption over that which would be required for uranium alone. The second effect would be to release iron and sulfate into solution from the oxidation of pyrite. A third effect would be to increase 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 upon its oxidation state. Any vanadium which is oxidized along with the uranium will be solubilized by the lixiviant, recovered with the uranium and could potentially contaminate the precipitated yellowcake product. The Crow Butte plant uses hydrogen peroxide precipitation of uranium in an effort 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 resulting in compounds such as polythionates which can foul ion exchange resins. In in-situ operations using 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 Crow Butte ore body at levels greater than 0.1 to .02%. Where present their effect is to increase the oxidant consumption and make uranium leaching a bit more difficult. On longer flow paths, organic material could potentially reprecipitate uranium, should all of the oxidant be consumed and conditions become reducing. Another potential impact of organics could be the coloring and fouling of leach solutions should the organics be mobilized. As the plant is operated in the pH range of 6.5 to 9.0, mobilization of the organics and coloring of the leach solution is avoided.

6.1.3 RESTORATION GOALS

The primary goal of the groundwater restoration program is to return groundwater affected by mining operations to baseline values on a mine unit average. A secondary goal is to return the groundwater to a quality consistent with premining use or uses. The restoration values set by the Nebraska Department of Environmental Quality are consistent with this secondary goal. Target restoration values for each mine unit have been specified by the (NDEQ) for groundwater restoration efforts. Prior to mining in each mine unit, baseline groundwater quality data is submitted. This data is established in each mine unit at the following minimal density:

- One production or injection well per four acres;
- One upper aquifer monitor well per five acres; and
- All perimeter monitor wells.

The baseline data support establishment of the upper control limits and restoration standards for each mine unit. Restoration criteria is established as the average plus two standard deviations for any parameter that exceeds the applicable drinking water standard. If a drinking water standard exists for a parameter, and baseline is below that standard, the drinking water standard is used to establish the restoration criteria. If there is no drinking water standard for an element, for example vanadium, the restoration criteria will be based on best practicable technology. The restoration criteria for the major cations (Ca, Mg, K) should allow for 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 criteria should allow for the total carbonate to be less than 50% of the TDS. The TDS restoration value is set at the average plus one standard deviation.

Target restoration values for Mine Units 1 through 5 are given in Table 6.1-1. NDEQ Permit Number NE0122611 requires that 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 6.1-2.

Crow Butte Resources 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. Crow Butte Resources 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.

The commercial groundwater restoration program consists of two stages, the restoration stage and the stabilization stage. The restoration stage consist of four activities:

- Groundwater transfer;
- Groundwater sweep;
- Groundwater treatment; and
- 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 for six months following successful completion of the restoration stage. Stabilization will begin once restoration activities have returned the average concentration of restoration parameters to acceptable levels. Following the stabilization phase, Crow Butte Resources will make a request to the appropriate regulatory agencies that the wellfield is restored.

6.1.4 RESTORATION STAGE

Restoration activities include four steps which are designed to optimize restoration equipment used in treating groundwater and to minimize the number of pore volumes circulated during the restoration stage. Crow Butte Resources will monitor the quality of selected wells during restoration to determine the efficiency of the operations and to determine if additional techniques are necessary.

Table 6.1-1: Target Restoration Values By Mine Unit

Parameter	Groundwater Standard	MU-1 Avg.	MU-1 Target	MU-2 Avg.	MU-2 Target	MU-3 Avg.	MU-3 Target	MU-4 Avg.	MU-4 Target	MU-5 Avg.	MU-5 Target
Ammonium	10.0	≤ 0.372	10.0	≤ 0.37	10.0	≤ 0.329	10.0	0.288	10.0	0.28	10.0
Arsenic	0.05	≤ 0.00214	0.05	≤ 0.001	0.05	≤ 0.001	0.05	≤ 0.00209	0.05	≤ 0.001	0.05
Barium	1.0	≤ 0.996	1.0	≤0.01	1.0	≤ 0.1	1.0	< 0.1	1.0	≤ 0.10	1.0
Cadmium	0.01	≤ 0.00644	0.01	≤0.01	0.01	≤ 0.01	0.01	< 0.01	0.01	≤ 0.01	0.01
Chloride	250.0	203.9	250.0	208.6	250.0	197.6	250.0	217.5	250.0	191.9	250.0
Copper	1.0	≤ 0.0249	1.0	≤0.013	1.0	≤ 0.0108	1.0	≤ 0.0114	1.0	≤ 0.01	1.0
Fluoride	4.0	0.686	4.0	0.67	4.0	0.719	4.0	0.745	4.0	0.64	4.0
Iron	0.3	≤ 0.0441	0.3	≤ 0.05	0.3	< 0.05	0.3	≤ 0.0504	0.3	≤ 0.05	0.3
Mercury	0.002	≤ 0.00067	0.002	≤ 0.001	0.002	< 0.001	0.002	< 0.001	0.002	< 0.001	0.002
Manganese	0.05	≤ 0.00122	0.05	≤0.01	0.05	≤ 0.01	0.05	≤ 0.01	0.05	≤ 0.01	0.05
Molybdenum	1.0	≤ 0.0689	1.0	≤ 0.073	1.0	< 0.1	1.0	< 0.1	1.0	≤ 0.10	1.0
Nickel	0.15	≤ 0.0340	0.15	≤0.05	0.15	< 0.05	0.15	< 0.05	0.15	≤ 0.05	0.15
Nitrate	10.0	≤ 0.050	10.0	≤0.039	10.0	≤0.0728	10.0	≤ 0.114	10.0	≤ 0.10	10.0
Lead	0.05	≤ 0.0315	0.05	≤ 0.05	0.05	< 0.05	0.05	< 0.05	0.05	< 0.05	0.05
Radium (pCi/L)	5.0	229.7	584.0	234.5	1058.0	165.0	611.0	154.0	496.0	166.0	535.00
Selenium	0.01	≤ 0.00323	0.01	≤0.001	0.01	≤ 0.00115	0.01	≤ 0.00244	0.01	≤ 0.002	0.01
Sodium	N/A	412		411		428		416.6	416.6	397.6	397.6
Sulfate	250.0	356.2	375.0	348.2	369.0	377.0	404.0	337.0	375.0	364.5	385.0
Uranium	5.0	0.0922	5.0	0.046	5.0	0.115	5.0	0.118	5.0	0.072	5.0
Vanadium	0.2	≤ 0.0663	0.2	≤ 0.1	0.2	< 0.1	0.2	≤ 0.0984	0.2	≤ 0.10	0.2
Zinc	5.0	≤ 0.0384	5.0	≤ 0.025	5.0	≤ 0.0131	5.0	≤ 0.0143	5.00	≤ 0.02	5.0
pH (Std. Units)	6.5-8.5	8.46	6.5-8.5	8.32	6.5-8.5	8.37	6.5-8.5	8.68	9.28	8.5	6.5-8.5
Calcium	N/A	12.5	125.0	13.4	134.0	13.3	133.0	11.2	112.0	12.6	126.0
Total Carbonate	N/A	351.2	585.0	362.0	585.0	377.0	592.0	374.0	610.0	373.0	590.0
Potassium	N/A	12.5	125.0	12.6	126.0	13.9	139.0	16.7	167.0	11.5	115.0
Magnesium	N/A	3.2	32.0	3.5	35.0	3.5	35.0	2.8	28.0	3.4	34.0
TDS	N/A	1170.2	1170.0	1170.4	1170.4	1183.0	1183.0	1221.0	1221.0	1179.0	1202.0

Table 6.1-2: 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	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	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	1154	942	1054	1144	1054	1174	1177	1182	1126	1144	1172	1083
K	32.7	26.3	30	30	27.2	31.3	30	31.3	32.7	30	30	28.6
CO_3	0	0	0	0	0	0	0	0	0	0	0	0
HCO_3	1099	900	972	981	1057	1086	1111	1207	1104	1170	1170	959
SO_4	1109	959	1115	1240	1031	1209	1119	1112	1134	1115	1115	1283
Cl	598	455	586	594	544	598	594	619	607	603	603	590
NH_4	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	< 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	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	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	25.7	18.2	35.3	24.7	33.3	34.3	26.4	31.6	28.3	33.2	30	22.2
TDS	3694	3121	3756	3851	3515	3899	3751	3886	3873	3820	3807	3765
Cond	5843	4841	5590	5964	5445	6012	5807	6025	5916	5819	5940	5819
$CaCO_3$	901	738	797	804	866	890	911	989	905	959	959	786
pH	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	< 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	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	< 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	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	< 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	< 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	< 0.01	< 0.01	0.05	< 0.01	0.02	< 0.01	< 0.01	< 1	< 0.01	< 0.01	< 0.01	< 0.01

Table 6.1-2: 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
Fe	< 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	< 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	0.02	0.11	0.05	0.04	0.14	0.15	0.08	0.06	0.06	0.02	< 0.01	0.16
Hg	< 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	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	< 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	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	1	0.1	0.38	1.15	1.12	1.18	1.03	1.24	1.29	1.23	1.56	0.28
Zn	< 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	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	370	126	329	1139	1113	1558	1258	1147	681	417	109	1182

6.1.4.1 GROUNDWATER TRANSFER

Prior to commencing restoration activities, the regulatory agencies will be notified that mining has ceased in a given mine unit and Crow Butte Resources will proceed to establish post mining water quality data for all of the required parameters listed in Table 6.1-1. The designated wells will be sampled and may be split with the NDEQ if requested.

During the groundwater transfer step, water may be transferred between the mine unit commencing restoration and a mine unit commencing operations. Baseline quality water from the mine unit starting production may be pumped and injected into the mine unit in restoration. The higher TDS water from the mine unit in restoration may be recovered and injected into the mine unit commencing production. The direct transfer of water will act to lower the TDS in the mine unit being restored by displacing water affected by mining with baseline quality water.

The goal of groundwater transfer 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. For the groundwater transfer to occur, a newly constructed mine unit must be ready to commence mining.

The advantage of using the groundwater transfer technique is that it reduces the amount of water that must be ultimately be sent to the waste disposal system during restoration activities.

6.1.4.2 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 water has lower ion concentrations that act to strip off the cations that have attached to the clays during mining. The plume of 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 is dependent upon the capacity of the waste water disposal system and the success of the groundwater transfer step in lowering TDS.

6.1.4.3 GROUNDWATER TREATMENT

Following the groundwater sweep step water is pumped from production wells to treatment equipment and then reinjected into the wellfield. Ion exchange and reverse osmosis treatment equipment is utilized during this stage as shown in Figure 6.1-1. Depending upon the final configuration of the main plant following the capacity increase to 5,000 gpm, the ion exchange step may utilize the existing fixed bed downflow columns located at the main plant, or may be relocated.

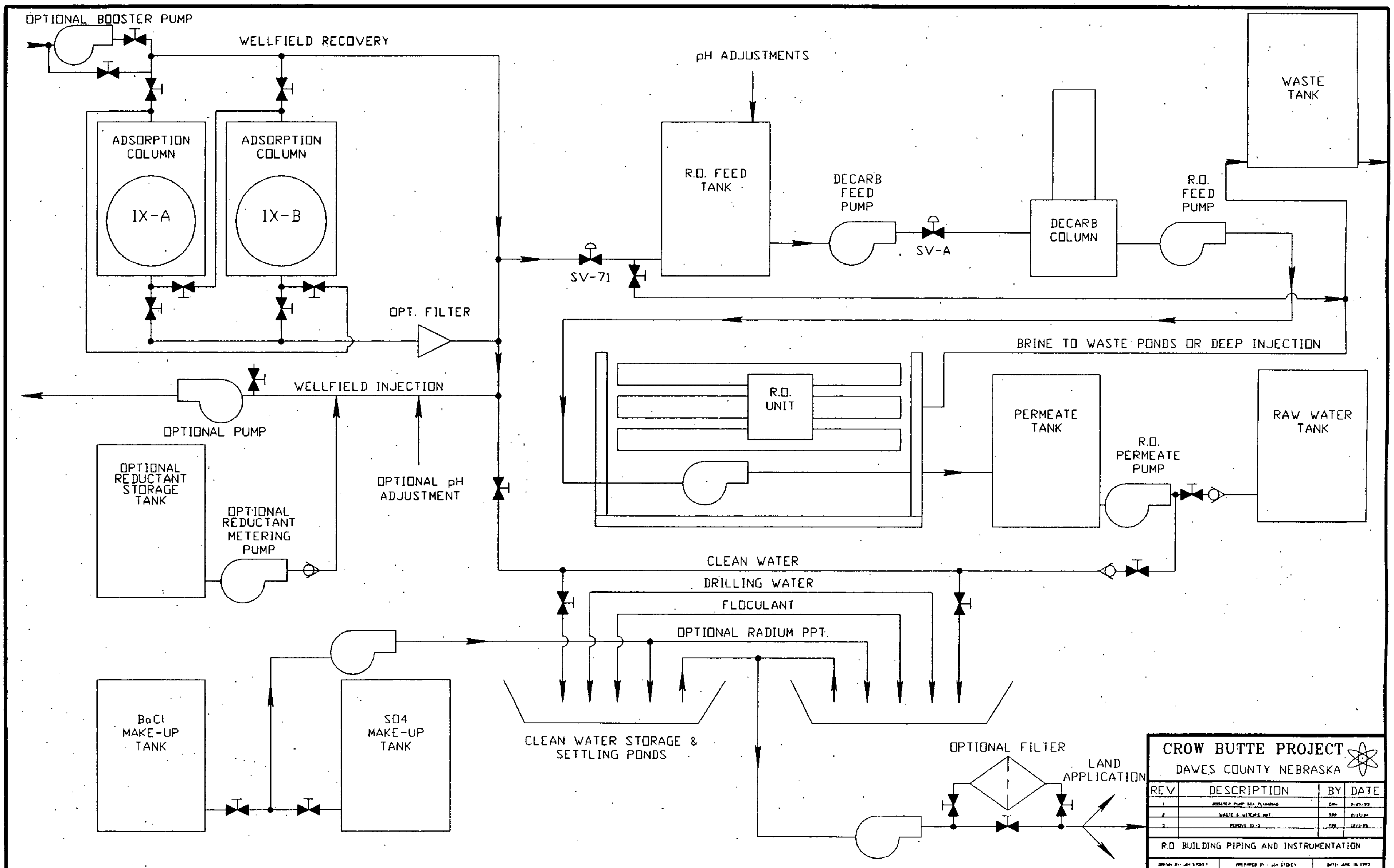
Water recovered from restoration containing a significant amount of uranium is passed through the ion exchange system. The ion exchange columns exchange the majority of the contained soluble uranium for chloride or sulfate. Once the solubilized uranium is removed, a small amount of reductant may be metered 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. The goal of reductant addition is to reduce those minerals that are solubilized by carbonate complexes to prevent build-up of dissolved solids which would increase the time required to complete restoration.

A portion of the restoration recovery water can be sent to the reverse osmosis unit. The use of a reverse osmosis unit has several effects:

- Reduces the total dissolved solids in the contaminated groundwater;
- Reduces the quantity of water that must be removed from the aquifer to meet restoration limits;
- Concentrates the dissolved contaminates in a smaller volume of brine to facilitate waste disposal; and
- Enhances the exchange of ions from the formation due to the large difference in ion concentration.

Before the water can be processed by the reverse osmosis unit, the soluble uranium must be removed by the ion exchange system. The water is then filtered, the pH lowered for decarbonation to prevent calcium carbonate plugging of the membranes, and then pressurized by a pump. The reverse osmosis unit contains membranes which 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 membrane. Table 6.1-3 shows typical 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

Figure 6-1: Restoration Process Schematic



sent to the waste disposal system. The twenty-five to forty percent of water that is rejected, referred to as the brine, contains the majority of dissolved salts that contaminate the groundwater and is sent for disposal in the wastewater system.

The sulfide reductant that may be added to the injection stream during this stage will 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. A comprehensive safety plan regarding reductant use will be implemented should it be utilized.

The number of pore volumes treated and re-injected during the groundwater treatment stage will depend on the efficiency of the reverse osmosis unit in removing total dissolved solids and the reductant in lowering the uranium and trace element concentrations.

6.1.5 STABILIZATION PHASE

Upon completion of restoration, a groundwater stabilization monitoring program will begin in which the restoration wells and any monitor wells on excursion status during the mining operations will be sampled and assayed. Sampling frequency will be one sample per month for a period of six months, and if all six samples show that restoration values for all wells are maintained during the stabilization period, restoration shall be deemed complete.

6.1.6 REPORTING

The initial step in the restoration process is to determine post-mining water quality in the mine unit by sampling all designated restoration wells for the required constituents listed in Table 6.1-1. These samples may be split with the NDEQ if required. Assay results will be submitted to both the NDEQ and the USNRC as required.

During the restoration process, Crow Butte Resources will perform daily, weekly, and monthly analysis as needed to track restoration progress. These analysis will be provided to NDEQ in Monthly Restoration Reports and the USNRC in the Semiannual Radiological Effluent and Environmental Monitoring Report. This information will also be included in the final restoration report.

Upon completion of restoration activities and prior to stabilization, all designated restoration wells in the mine unit will be sampled for the required constituents listed in Table 6.1-1. These samples may be split with NDEQ if

Table 6.1-3: Typical Membrane Rejection
Source: Osmonics, Inc.

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+

required. Assay results will be submitted to NDEQ and USNRC as required. If restoration activities have returned the wellfield average of restoration parameters to concentrations at or below those approved by the regulatory agencies, Crow Butte Resources will notify the regulatory agencies it is commencing the stabilization phase of restoration.

During stabilization all designated restoration wells will be sampled monthly for the required constituents listed in Table 6.1-1. At the end of a six month stabilization period Crow Butte Resources will compile all water quality data obtained during restoration and stabilization and submit a final report to the regulatory agencies. At that time, Crow Butte Resources would request that the mine unit be declared restored.

6.1.7 CURRENT RESTORATION STATUS

The approval of the Notice of Intent to Operate for Mine Unit 4 was received from the NDEQ on March 11, 1994. With the approval, active mining operations ceased in Mine Unit 1 and restoration was initiated. On March 23, 1994 the baseline restoration wells were sampled to establish the post mining water quality. The results of this sampling are given in Table 6.1-2.

Groundwater transfer was performed for the Mine Unit 1 restoration by transferring water between Mine Unit 1 and Mine Unit 4. Uranium recovery was accomplished through the two fixed bed downflow columns located in the main process plant. Some groundwater treatment utilizing the reverse osmosis unit located in the R&D building has also been initiated.

6.2 DECONTAMINATION AND DECOMMISSIONING

The following sections address the final decommissioning of process facilities, evaporation ponds, wellfields and equipment which will be used on the Crow Butte site. It discusses general procedures to be used, both 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. It 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:

- 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.

- Decontamination to meet unrestricted use criteria for release, sale or other non-restricted use by the landowners and others.

It is most likely that process buildings will be dismantled and moved to another location or to a permanent licensed disposal facility. Cement foundation pads and footing will be broken up and trucked to disposal site or a licensed facility if contaminated. The landowners, however, could request that a building or other structures be left on site for his use. In this case, the building will be decontaminated to meet unrestricted use criteria.

6.2.1.1.1 DISPOSAL AT A LICENSED FACILITY

If a piece of process equipment is to be moved to another licensed area 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 plastic lined 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.

- Plug and abandon all wells as detailed per Section 6.2.3.
- Radiological surveys and sampling of all facilities, process related equipment and materials presently 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.
- Decontamination of items to be released for unrestricted use to levels consistent with the requirements of U.S. Nuclear Regulatory Commission.
- Survey excavated areas for earthen contamination and remove same to a licensed disposal facility.
- Backfill and recontour all disturbed areas.
- Perform final site soil radiation background surveys.
- 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. Crow Butte Resources will, prior to final decommissioning of an area, submit to the USNRC and NDEQ a detailed plan for their review and approval.

6.2.1 PROCESS BUILDINGS AND EQUIPMENT

Prior to process plant decommissioning, a preliminary radiological survey will be conducted to identify any potential hazards. The survey will also support the development of procedures for dealing with such hazards prior to commencement of decommissioning activities. 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 below.

6.2.1.1 REMOVAL AND DISPOSAL ALTERNATIVES

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:

- All other miscellaneous contaminated material will be transported to a licensed disposal facility.

6.2.1.1.2 DISPOSAL TO UNRESTRICTED USE

If a piece of equipment 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. 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. Criteria to be used for release to unrestricted use will be USNRC's *"Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct or Source Materials, Uranium Recovery Field Office Region IV, Denver, Colorado, September 1984"*, or the most current standards for decontamination at that time.

If a process building is left on site for landowner unrestricted use, 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 sump 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.

6.2.2 EVAPORATION POND DECOMMISSIONING

6.2.2.1 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, treatment and disposal or transportation to another licensed facility or disposal site. The pond water from the later stages of groundwater restoration may be treatable to within discharge limits; if this can be accomplished, the water will be treated and discharged under an appropriate NPDES permit. Evaporation of the remaining water may be enhanced by use of sprinkler systems, etc.

6.2.2.2 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 dump trucks or drums and transported to a USNRC licensed disposal facility. All equipment and personnel working on sludge and liner removal will be checked prior to leaving the work area to prevent the tracking of sludge into uncontaminated locations.

6.2.2.3 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 limits defined in 10 CFR 40, Appendix A, will be removed.

Following the removal of all pond materials and the disposal of any contaminated soils, surface preparation will take place prior to reclamation. Pond surface reclamation will be performed in accordance with the surface reclamation plan, Section 6.3. An additional radiation background survey will be conducted on the recontoured area prior to topsoiling.

6.2.2.4 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 burial of contaminated wastes.

6.2.3 WELLFIELD DECOMMISSIONING

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, electrical conduit, well boxes, and wellhead equipment. All of the lines are above ground surface lines which will not require excavation for removal. Wellhead equipment such as valves, meters or control fixtures will be salvaged.
- Removal of buried well field piping.
- Wells will be plugged and abandoned according to the procedures described below.
- The well field area may be recontoured, if necessary, and a final background gamma survey conducted over the entire well field area to identify any contaminated earthen materials requiring removal to disposal.
- Final surface reclamation of the well field areas will be conducted according to the surface reclamation plan described in Section 6.3.

- All piping, boxes 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 releasable limits which will allow disposal at an unrestricted area landfill. Other materials which are contaminated will be acid washed or cleansed with other methods until they are releasable. If the equipment still does not meet releasable limits, it will be disposed of at a facility licensed to accept by-product material.

After the Crow Butte aquifer restoration and post-restoration stabilization has been completed and accepted in writing as successful by both the NDEQ and USNRC, the decommissioning of the mine unit wellfields will commence.

Wellfield decommissioning will be an independent ongoing operation throughout the mining sequence at the Crow Butte site. 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.

6.2.3.1 WELL PLUGGING AND ABANDONMENT

All wells no longer useful to continued mining or restoration operations will be abandoned. These include all injection and recovery 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 well which could be transferred to the landowner for domestic or livestock use.

The objective of the Crow Butte Resources 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.

The plugging method will be as follows:

- An approved abandonment mud (a mud-polymer mix) will be mixed in a cement unit and pumped down a hose, which is lowered to the bottom of the well casing using a reel.

- When the hose is removed, the casing is topped off and a cement plug placed on top.

- A hole is then dug around the well, and, at a minimum, the top three feet of casing removed.

- The hole is backfilled and the area revegetated.

Records of abandoned wells will be tabulated and reported to the appropriate agencies after decommissioning.

6.2.3.2 BURIED TRUNKLINES, PIPES AND EQUIPMENT

Buried process related piping such as injection and recovery lines will be removed from the production 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. If on site burial is an option in the future, lines may be disposed of on site according to conditions of the appropriate licenses/permits.

6.2.4 DECONTAMINATION

After all surface equipment is removed and all wells are properly plugged and abandoned, a gamma survey of the wellfield surfaces will be conducted. Any areas with elevated gamma readings which indicate radium-226 levels in excess of limits in 10 CFR 40, Appendix A, will be resurveyed. Soil samples will be collected from confirmed contaminated locations for the analysis of radium-226 and uranium. Based upon the soil sampling and additional gamma radiation readings, contaminated soil will be removed and transferred to a site licensed to accept by-product materials. Gamma survey results and soil sampling results will be submitted to the USNRC for their review, approval and opportunity to split soil samples. After approval of the soil contamination removal program, revegetation will commence.

The objective of site soil surveys during decommissioning will be to identify and remove to a licensed disposal facility any earthen materials which exceed EPA 40 CFR Part 192.32 standards or other applicable standards at the time of decommissioning. These standards presently require that radium concentrations in surface soils, averaged over areas of 100 square meters, do not exceed background levels by more than 5 pCi/g averaged over the first 15 cm below the surface and 15 pCi/g averaged over any 15 cm thick layer more than 15 cm below the surface.

Three general types of site soil surveys will be conducted on the site during decommissioning:

- Areas of potential surface contamination will be identified using a gross gamma survey on an adequately spaced grid.
- Spot checks of areas around the site of potentially contaminated areas.
- The final soil background survey on areas which have been prepared for surface reclamation using a grid spacing adequate for confirming clean up to applicable standards.

Contaminated soils which are removed from site surfaces will be transported to a licensed disposal site. The primary areas for potential soil contamination include well field surfaces, evaporation pond bottoms and berms, process building areas, storage yards and transportation routes over which product or contaminants have been moved.

6.2.5 DECOMMISSIONING HEALTH PHYSICS AND RADIATION SAFETY

The health physics and radiation safety program for decommissioning will document decommissioning processes and ensure that occupational radiation exposure levels are kept as low as reasonably achievable during decommissioning. The Radiation Safety Officer, Radiation Safety Technician or designee by way of specialized training, will be on site during any decommissioning activities where a potential radiation exposure hazard exists.

Health physics survey conducted during decommissioning will be guided by applicable sections of 10 CFR 20 and USNRC Regulatory Guide No. 8.30 entitled "*Health Physics Surveys in Uranium Mills*" or other applicable standards at the time.

6.2.6 EQUIPMENT AND MATERIAL SURVEYS

Any site equipment to be released for unrestricted use will be surveyed for alpha contamination and beta gamma as necessary to document levels for release, according to USNRC "*Guidelines for Decontamination of Facilities for Byproduct or Source Materials*", *Uranium Recovery Field Office Region IV, Denver, Colorado, September 1984*, or the most current standards for decontamination at that time.

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 and U.S. Nuclear Regulatory Commission Regulations (49 CFR 173.389)(10 CFR 71).

6.2.7 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.

6.3 SURFACE RECLAMATION

The following reclamation plan provides procedural techniques for surface reclamation of all disturbances contained in the Crow Butte Resources mine plan. Provided are reclamation procedures for the process plant facilities, evaporation ponds, wellfield production units, access and haul roads. Reclamation techniques and procedures for subsequent satellite facilities, additional ponds and wellfields will follow the same concepts as presented below. 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 include all activities which are anticipated to complete groundwater restoration, decontamination, decommissioning and surface reclamation of wellfield and satellite plant facilities installed to operate for one year of mining activity.

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 its premining condition. The reclaimed lands should therefore be capable of supporting livestock grazing and provided 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 through drainage patterns.

6.3.1 WELLFIELD RECLAMATION

Surface reclamation in the wellfield production units will vary in accordance with the development sequence, mining/reclamation time table. Final surface reclamation of each wellfield production units will be after approval of groundwater restoration stability and the completion of well abandonment and decommissioning activities specified in Section 6.2. Surface preparation will be accomplished as needed so as to blend any disturbed areas into the contour of the surrounding landscape. The seed bed will be prepared and reseeded with assistance from the U.S. Soil Conservation Service.

6.3.2 PROCESS FACILITIES RECLAMATION

Subsoils 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, push-cats 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. Backfill compacting will be accomplished by movement of the equipment over the fill area. 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. There will be no topsoil used for construction of any kind; topsoil will have been salvaged and stockpiled.

6.3.3 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 which 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 re-establishment of drainage patterns will be accomplished by returning the earthen materials moved during construction to their approximate original locations.

Drainage channels which have been modified by the mine plan for operational purposes such as road crossings will be re-established by removing fill materials, culverts and reshaping to as close to pre-operational conditions as practical. Surface drainage of disturbed areas which 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.

6.4 BONDING ASSESSMENT

6.4.1 BOND CALCULATIONS

Cost estimates for the purpose of bond calculations were made 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 calculation utilized in determining the bonding requirements for the Crow Butte Project are enclosed on Attachment 6.1.

6.4.2 FINAL SURETY ARRANGEMENTS

Crow Butte Resources maintains a NRC-approved financial surety arrangement consistent with 10 CFR 40, Appendix A, Criterion 9 to cover the estimated costs of reclamation activities. Crow Butte maintains an Irrevocable Letter of Credit No. 74504 issued by First Bank N.A. during 1995 in favor of the State of Nebraska in the present amount of $5,543,958.

ATTACHMENT 6.1

BASIS OF COSTS:

Costs used in the surety bond calculations are based on the following rationale:

1. Labor Rates: Labor rates are based on 1994 actual CBR labor for plant and wellfield operations including benefits and payroll taxes, plus 20% for contractors overhead and profit.

2. Disposal Costs: Disposal costs of byproduct material are based on a current disposal agreement held by CBR.

	Fee	Transport Cost	Total
Packaged Material	$10/cf	$2.35/cf	$12.35/cf
Soil, etc.	$30/cy	$64/cy	$94/cy

   Disposal of non-byproduct material will be at a licensed landfill per NDEQ permit. $10 load fee plus transport cost of $360/20 tons @ 30 miles.

3. Power Costs Based on actual 1994 power costs including demand factor, energy charge, taxes, and service fees, $0.05/Kw-hr.

4. Equipment Costs:

Equipment	Base(1) Rental Cost ($/hr)	Labor Cost ($/hr)	Oper. Cost ($/hr)	Fuel(2) Cost ($/hr)	Mob. &(3) Demob ($/hr)	Total ($/hr)
IT12 Loader	17	19	8	4	2	50
Shredder	11	--	--	incl.	incl.	11
Bulldozer (D8N)	77	19	17	12	2	127
Smeal	38	incl.	incl.	incl.	incl.	38
Mixing Unit	11	--	--	incl.	incl.	11

(1) From Nebraska Machinery rental rates for IT12 and D8N. Shredder and mixing units are estimates.
(2) From Caterpillar Handbook, Edition 19 fuel consumption using $1.00/gal for diesel cost.
(3) Based on $1.90/mile at 90 miles one way x 2 trips/176 hours.

A. GROUNDWATER RESTORATION

Restoration costs are based on restoring Mine Units (MU) 1, 2, 3, 4 and 5. MU-1, 2 and 3 are based on actual installed information. MU-4 is under construction and information as of 9/6/94 is used to predict the final mine unit size. MU-5 size is projected to be similar to MU-4.

Mine Unit	Thickness (ft)	No. Patterns	Pattern Size (ft^2)	Porosity	Pore Volume (gals)	Mine Unit Total Area (Acres)
MU-1	19.6	38	10,624	0.29	17,165,000	9.3
MU-2	16.3	52	9,800	0.29	18,018,500	11.7
MU-3	12.8	57	10,284	0.29	15,447,280	13.4
MU-4	13.0	96	11,200	0.29	30,320,210	24.7
MU-5	13.0	96	11,200	0.29	30,320,210	24.7

MU-1

1) Remove 3 pore volumes (PV) for halo recovery and transfer to ponds.
   - o Produce at 1,150 gpm with (36) 32 gpm downhole pumps (5 HP) and transfer to ponds with (2) 5 HP waste pumps.
   - o Total horsepower = 190 HP
   - o Time to do work:
     3 PV x 17,165,000 gal/PV x 1 min/1,150 gal x
     1 hour/60 min = 746 hours

   a. Power Cost:
   746 hours x 190 HP x .75 Kw/HP x $0.05/Kw-hr = $5,315

   b. Labor Cost:
   746 hours x 2 man-day/8 hours x $152/man-day = 28,348

   $33,663

   or $0.65/1000 gal

2) Treat 2 PV with R.O. and re-inject permeate using a 400 gpm R.O. unit.
   - o 2 PV x 17,165,000 gal/PV x 1 min/400 gal x 1 hr/60 min = 1,430 hours

   a. Power cost:

Downhole pump HP	
400 gpm/32 gpm/pump x 5 HP/pump	65 HP
Injection Pump	100 HP
R.O. System	
R.O. Unit pump	300 HP
Feed pump	25 HP
Decarbonator pump	15 HP
Permeate pump	50 HP
Waste pump	10 HP
	565 HP

   1,430 hrs x 565 HP x .75 Kw/HP x $0.05/Kw-hr = $30,300

   b. Chemical Cost: (from R&D restoration experience)
   Acid: $0.72/gal x 3.5 gal/hr x 1,430 hrs = $3,604
   Antiscalant: $29/gal x 0.26 gal/hr x 1,430 hrs = 10,782
   Cleaning Chemicals: $2.56/hr x 1,430 hrs = 3,661

   c. Labor Cost:
   1,430 hrs x 2 man-day/8 hours x $152/man-day = $54,340
   Total $102,687

   or $2.99/1,000 gal

3) Recirculate 3 PV with reductant @ 1,150 gpm.

   a. Power Cost:

(36) 5 HP downhole pumps =	180 HP
(1) Injection pump =	150 HP
Total HP	330 HP

   330 HP x 746 hrs x .75 Kw/HP x $0.05/Kw-hr = $ 9,232

   b. Chemical Cost:
   3 PV x 17,165,000 gal/PV x 1 lb Na_2S/1000 gal
   x $0.33/lb = 16,993

c. Labor Cost: (see above)	28,348		
Total		$54,573	
	or $1.06/1000 gal		

4) Treat 2 PV with R.O. and re-inject (same as above). $102,687
or $2.99/1000 gal

5) Spare parts, filters, consumables, etc.
for items 1-4 above are estimated to be $15,070/yr.
- o Time to do work is 4,352 hours/24 hours = 181 days (1/2 yr)
- a. $15,070/yr x 1/2 yrs = $7,535

6) Sampling and Monitoring.
- o Number of wells to be sampled are a minimum of 10 per mine unit or 1/acre plus any monitor wells on excursion.

a. Sample prior to restoration: 10 wells x $154/well (32 parameter suite) =	$1,540		
b. Phase I sampling (halo recovery): 10 wells x $36/well x (6 parameters) 1 month =	360		
c. Phase 2 sampling (2PV to R.O., 3 PV recirculation, 2 PV to R.O.): 10 wells x $154/well x 5 months =	7,700		
d. Phase 3 sampling (stabilization): 10 wells x $154/well x 6 months =	9,240		
e. Monitor well sampling: 14 wells x 2 samples/month x $36/well x 6 months =	6,048		
f. Other lab analysis (radon, urinalysis, etc): $738/month x 6 months =	4,428		
Total sampling and monitoring		$ 29,316	

7) Supervisory labor for restoration work (including 33% overhead factor)

a. (1) Engineer $5,725/month x 6 months =	$34,350		
b. (1) Radiation Technician $4,770/month x 6 months =	28,620		
(Operator wages included in above calculations)			
		$ 62,970	
MU-1 TOTAL			$393,431

MU-2

1) Remove 3 PV, halo recovery.
   - o 3 PV x 18,018,500 gal/PV x 1 min/1,150 gal x 1 hr/60 min = 784 hours
   - a. 3 PV x 18,018,500 gal/PV x $0.65/1000 gal = $35,136

2) Treat 2 PV with R.O. and inject permeate.
   - o 2 PV x 18,018,500 gal/PV x 1 min/400 gal x 1 hr/60 min = 1,502 hours
   - a. 2 PV x 18,018,500 gal/PV x $2.99/1000 gal = $107,751

3) Recirculate 3 PV with reductant.
   - o Time = 784 hours
   - a. 3PV x 18,018,500 gal/PV x $1.06/1000 gal = $57,299

4) Treat 2 PV with R.O. and inject permeate
   - o Time = 1,502 hours
   - a. 2 PV x 18,018,500 gal/PV x $2.99/1000 gal = $107,751

5) Spare parts, etc.
   - o Total time to do work = 1/2 yr
   - a. $15,070/yr x 1/2 yr = $7,535

6) Sampling and monitoring - 12 restoration wells plus 14 monitor wells.

a.	Sample prior to restoration: 12 wells x $154/well (32 parameter suite) =	$1,848	
b.	Phase I sampling (halo recovery): 12 wells x $36/well x (6 parameters) 1 month =	432	
c.	Phase 2 sampling (2PV to R.O., 3 PV recirculation, 2 PV to R.O.): 12 wells x $154/well x 6 months =	9,240	
d.	Phase 3 sampling (stabilization): 12 wells x $154/well x 6 months =	11,088	
e.	Monitor well sampling: 14 wells x 2 samples/month x $36/well x 6 months =	6,048	
f.	Other lab analysis (radon, urinalysis, etc) $738/month x 6 months =	4,428	
			$33,084

7) Supervisory Labor (same as MU-1). $62,970

MU-2 TOTAL $411,526

MU-3

1) Remove 3 PV, halo recovery
   - o Time to do work:
     3 PV x 15,447,280 gal/PV x 1 min/1,150 gpm x
     1 hr/60 min = 672 hours
   - a. Cost:
     3 PV x 15,447,280 gal/PV x $0.65/1000 gal = $30,122

2) Treat 2 PV with R.O. and inject permeate
   - o 2 PV x 15,447,280 gal/PV x 1 min/400 gal x
     1 hr/60 min = 1,287 hours
   - a. Cost:
     2 PV x 15,447,280 gal/PV x $2.99/1000 gal = $92,375

3) Recirculate 3 PV with reductant
   - o Time = 672 hours
   - a. Cost:
     3 PV x 15,447,280 gal/PV x $1.06/1000 gal = $49,122

4) Treat 2 PV with R.O. and inject permeate
   - o Time = 1,202 hours
   - a. Cost:
     2 PV x 15,447,280 gal/PV x $2.99/1000 gal = $92,375

5) Spare parts, etc.
   - o Time = 6 months
   - a. Cost:
     $15,070 x 1/2 = $7,535

6) Sampling and monitoring 18 restoration wells plus 14 monitor wells.

a.	18 wells x $154/well =	$2,772	
b.	18 wells x $36/well x 2 months =	1,296	
c.	18 wells x $154/well x 5 months =	13,860	
d.	18 wells x $154/well x 6 months =	16,632	
e.	14 wells x 2 samples/month x $36/well x 5 months =	5,040	
f.	Other lab: $738/month x 5 months =	3,690	
	Total		$43,290

7) Supervisory Labor (same as MU-1). $62,970

MU-3 TOTAL $377,789

MU-4 and 5

MU-4 and 5 are the same size. Calculations will be made for one MU and the total multiplied by 2.

1) Remove 3 PV, halo recovery
   - o Time to work:
     3 PV x 30,320,210 gal/PV x 1 min/1,150 gpm x
     1 hr/60 min = 1,318 hours
   - a. Cost:
     3 PV x 30,320,210 gal/PV x $0.65/1000 gal= $59,124

2) Treat 2 PV with R.O. and inject permeate
   - o 2 PV x 30,320,210 gal/PV x 1 min/400 gal x
     1 hr/60 min = 2,527 hours
   - a. Cost:
     2 PV x 30,320,210 gal/PV x $2.99/1000 gal= $181,315

3) Recirculate 3 PV with reductant
   - o Time = 1,318 hours
   - a. Cost:
     3 PV x 30,320,210 gal/PV x $1.06/1000 gal= $96,418

4) Treat 2 PV with R.O. and inject permeate
   - o Time = 2,527
   - a. Cost:
     2 PV x 30,320,210 x $2.99/1000 gal= $181,315

5) Spare parts, etc.
   - o Time = 2,527
   - a. Cost:
     15,070 x 11/12= $13,814

6) Sampling and monitoring 18 restoration wells plus 14 monitor wells.

a.	25 wells x 154/well=	$3,850	
b.	25 wells x 36/well x 2 months=	1,800	
c.	25 wells x 154/well x 9 months=	34,650	
d.	25 wells x 154/well x 6 months=	23,100	
e.	18 wells x 2 samples/month x 36/well x 11 months =	14,256	
f.	Other lab: $738/month x 11 months=	8,118	
			$85,774

7) Labor:

a. (1) Engineer: $5,725/month x 11 months=	$62,975		
b. (1) Radiation Technician: $4,770/month x 11 months (Operator wages included in above calculations)	52,470		
		$115.445	
MU-4 and 5 Total		2 x $733,205	$1,466,410
TOTAL MU-1, 2, 3, 4, 5 RESTORATION COST			$2,649,156

B. WELLFIELD RECLAMATION

Wellfield Reclamation costs are based on removing and disposing of the wellfield pipe at a licensed facility. The soil around the production wells will also be removed and disposed of at a licensed facility.

Mine Unit	2" Prod & Inj. Lines (ft)	1-1/4" Stinger (ft)	2" Prod. Downhole Pipe	Producers	Injectors
MU-1	30,000	43,200	15,200	38	72
MU-2	34,000	47,400	20,800	52	79
MU-3	39,520	57,400	22,800	57	95
MU-4	68,900	101,400	38,400	96	169
MU-5	68,900	101,400	38,400	96	169

Pipe Volumes:

Normal Pipe Size	Wall Thickness (inches)	Pipe O.D. (Inches)	Volume[1] per Foot (ft^3/ft)
2" Sch. 40 downhole	0.154	2.375	0.0074
1-1/4" Sch. 40 stinger	0.140	1.660	0.0044
2" SDR 13.5 inj. & prod.	0.14815	2.2963	0.0069
4" SDR 35	0.1143	4.2286	0.0103
6" Sch. 40 process pipe	0.280	6.5600	0.0384

MU-1

1) Removal/disposal of 2" production and injection lines. Piping is rated SDR 13.5 and constructed of HDPE.

o Two inch lines are buried 18-24" deep and can be pulled up with a loader. A two man crew should remove 450 ft per day. Two additional men will shred the pipe.

a.	Remove pipe: 30,000 ft x 2 man-days/450 ft x $152/man-day =	$20,267	
b.	Shred pipe: 30,000 ft x 2 man-days/450 ft x $152/man-day =	20,267	
c.	Equipment: o IT12 loader, $50/hr x 533 hours = o Shredder, $11/hr x 533 hours =	 26,650 5,863	
d.	Disposal: 30,000 ft x .0069 ft^3/ft x $12.35/$ft^3$ x 1.25(1) =	3,196	
			76,243
	or	$2.54/ft	

(1) 1.25 factor for void spaces.

2) Removal/disposal of downhole pipe. Downhole pipe is Sch. 40 PVC.

o From experience, 10 wells of downhole pipe can be removed each day with a 3 man crew and a smeal.

a.	Removal of downhole pipe 43,200 ft stinger x 3 man-days/6,000 ft x $152/man-day =	 3,283	
	15,200 ft prod. x 3 man-days/6,000 ft x $152/man-day =	 1,155	
b.	Shred pipe: 43,200 ft x 2 man-days/4,500 ft x $152/man-day =	 2,918	
	15,200 ft x 2 man-days/4,500 ft x $152/man-day =	 1,027	
c.	Equipment: Smeal: $38/hour x 78 hours = Shredder: $11/hour x 78 hours =	 2,964 858	
d.	Disposal: 43,200 ft x .0044 ft^3/ft x $12.35/$ft^3$ x 1.25 = 15,200 ft x .0074 ft^3/ft x $12.35/$ft^3$ x 1.25 =	 2,934 1,736	
			$16,875

or $0.28/ft (stinger pipe)
or $0.31/ft (2" production pipe)

3) Well Plugging.

o Assume 700 ft total depth/well average.

a. Materials:

Cement - 564 lbs x $78/ton =	$22
Bentonite - 45 lbs x $194/ton =	4
Salt - 33 lbs x $53/ton =	1
Well Cap	9

b. Labor:

2 hours/well x 1 day/8 hours x 2 man-days x $152/man-day =	76

c. Equipment:

Backhoe - 1/2 hour/well x $43/hour =	22	
Mixing Unit - 2 hours x $11/hour =	22	
	$156/well	
110 production and injection wells x $156/well =	$17,160	
11 monitor wells x $156/well =	1,716	
		$18,876

4) Wellfield surface area reclamation.

o Remove and dispose of contaminated soil around well, scarify and seed well locations

a. Remove and dispose of contaminated soil:

10 ft^3/well x 110 wells x 1 cy/27 ft^3 x $94/cy =	$3,830	
20 hours loader x $50/hour =	1,000	
20 man-hours x $152/8 hours =	380	

b. Recontour and seed

9.3 acres x $269/acre =	2,502	
		$7,712

5) Wellfield house dismantle and disposal.

o Dismantle wellfield house (10'x20'x10')

a. Labor:

2 man-days x $152/man-day	$304

b. Equipment (IT12):

2 hours x $45/hour =	100

c. Disposal at landfill

$370/load x 6,000 lbs/wellhouse x 1 load/40,000 lbs =	56		
Total per wellhouse	$460		
2 Wellhouses x $460/wellhouse =		$920	
MU-1 TOTAL			$120,626

MU-2

1)	Removal/disposal of 2" production and injection lines			
	a. 34,000 ft x $2.54/ft =		$86,360	
2)	Removal/disposal of downhole pipe			
	a. 47,400 ft stinger x $0.28/ft =		13,272	
	b. 20,800 ft production x $0.31/ft =		6,448	
3)	Well plugging			
	o 131 production and injection wells, 14 monitoring wells			
	a. 145 wells x $156/well =		22,620	
4)	Surface reclamation			
	a. Removal/disposal of contaminated soil 131 wells x $47/well =		6,157	
	b. Recontour, seed 11.7 acres x $269/acre =		3,147	
5)	Wellfield house dismantle/disposal			
	a. 3 wellfield houses x $460/wellfield house =		1,380	
	MU-2 TOTAL			$139,384

MU-3

1)	Removal/disposal of 2" production and injection lines			
	a. 39,520 ft x $2.54/ft =		$100,381	
2)	Removal/disposal of downhole pipe			
	a. 57,400 ft stinger x $0.28/ft =	$16,072		
	b. 22,800 ft production x $0.31/ft =	7,068		
			23,140	
3)	Well plugging			
	o (152 production and injection wells, 14 monitor wells)			
	a. 166 wells x $156/well =		25,896	
4)	Surface reclamation			
	a. Removal/disposal of contaminated soil 166 wells x $47/well =	7,802		
	b. Recontour, seed 13.4 acres x $269/acre =	3,605		
			11,407	
5)	Wellfield house dismantle/disposal			
	a. 4 wellfield houses x $460/wellfield house =		1,840	
	MU-3 Total			$162,664

MU-4 and 5

Calculate for MU-4 and multiply by 2 to get total.

1)	Removal/disposal of 2" production and injection lines			
	a. 68,900 ft x $2.54/ft=		$175,006	
2)	Removal/disposal of downhole pipe			
	a. 101,400 ft stinger x $0.28/ft=	28,392		
	b. 38,400 ft production x $0.31/ft=	11,904		
			40,296	
3)	Well plugging			
	o (265 production and injection wells, 18 monitor wells)			
	a. 283 wells x 156/well=		44,148	
4)	Surface reclamation			
	a. Removal/disposal of contaminated soil			
	283 wells x $47/well =	13,301		
	b. Recontour, seed			
	25 acres x $269/acre=	6,725		
			20,026	
5)	Wellfield house dismantle/disposal			
	a. 5 wellfield houses x $460/wellfield house+		2,300	
	MU-4 and 5 Total		2 x $281,776	563,552

TOTAL WELLFIELD RECLAMATION MU-1, 2, 3, 4 and 5 $986,226

C. COMMERCIAL PLANT RECLAMATION/DECOMMISSIONING

The plant interior components; tanks, pumps, steel structure, filters, piping and electrical components are from an in-situ plant that was moved from Texas to the Crow Butte site in 1988. The actual cost to perform this work, escalated to 1994 $'s, is used for bonding purposes with the breakdown of volumes of equipment and other structural items included.

1) Dismantle interior steel, tanks, pumps, filters, piping and electrical components (including labor, equipment, tools, etc.) The volume of components to be dismantled are detailed below:

   Interior structural steel - 75 tons
   Tanks - 34 each
   Pumps - 30 each
   Piping - 8,250 feet
   Filters - 4 each
   Dryer - 1 each
   Electrical boxes - 20 each (estimate)

   o $66,600 (1988$) x 148.0 (June 1994 CPI Index)/ 118.3 (1988 average CPI Index) = $83,320

2) Dismantle plant building (including office and lab area)

   o 146 tons of steel, siding, girts x $300 (1988 dismantle cost)/ton x 148.0/118.3 = $54,796

3) Decontaminate floor and walls of plant building: Plant floor area is 30,000 sf, 5,450 sf will be removed and disposed of, and 7,000 sf is in warehouse, shop and water tank areas which will not be contaminated. The remaining floor area is 17,530 sf. HCl will be sprayed on the floors and walls and recycled in the plant sumps for reuse until neutralized.

   Wall area is approximately 24,000 sf. Use 1 gal HCl/sf for wall area and 2 gal HCl/sf for floors.

   a. Material:
      Floors: 17,530 sf x 2 gal HCl/sf x $0.54/gal HCl = $18,932
      Walls: 24,000 sf x 1 gal HCl/sf x $0.54/gal HCl = 12,960
   b. Labor:
      2 men x 30 days x $152/man-day = $9,120
   c. HCl Disposal (to ponds):
      59,060 gal HCl x 5 HP/30 gpm x .75 Kw/HP x $0.05/Kw-hr= $370

d.	Decontamination equipment:			
	Sprayer pump	$500		
	Tank (on hand)			
	Recycle pump	500		
	Sprayer with hose	1,000		
			$2,000	$43,382

4) Dispose of concrete

- o Area which would be potentially contaminated and not decontaminated by HCl is 5,450 ft^2. The areas are in the trough drains, sumps, yellowcake dryer, belt filter, precipitation cells and eluant tanks. Average concrete thickness is 6".

a.	Disposal: $5{,}450\ ft^2 \times .5\ ft \times \$94/cy \times 1\ cy/27\ ft^3 =$	$9,487	
b.	Removal: $5{,}450\ ft^2 \times \$2.49/sf =$	$13,571	$23,058

5) Dismantle/dispose of tanks

- o There are 27 process tanks to be disposed of at an NRC licensed disposal facility. All of the tanks are fiberglass and will be cut up into pieces for disposal. Seven tanks are chemical storage tanks and will be disposed of at a licensed landfill.

a.	Labor: 34 tanks x 2 man-days/tank x $152/man-day =	10,336	
b.	Disposal: 27 tanks @ (14' dia x 14' high x 1/4" wall thickness) 27 tanks x 19.3 ft^3/tank x 1.20(1) x $12.35/ft=	7,723	
c.	Clean and haul chemical tanks: 7 chemical storage tanks will be disposed of in a licensed landfill (1) truckload $10 fee + $360 =	370	
	7 tanks x 1 man-day cleaning/tank x $152/man-day =	1,064	
d.	Equipment: Saws, scaffolding, tools, etc. =	5,381	
			$24,874

(1) void space factor

6) Dispose of pumps

- o 30 process pumps are in the commercial plant plus 78 downhole pumps. Plant pumps are approximately 5 ft^3 each, downhole pumps are 0.5 ft^3 each

a.	30 pumps x 5 ft^3/pump x $12.35/$ft^3$ =	$1,853	
b.	78 downhole pumps x 0.5 ft^3/pump x $12.35/$ft^3$ =	482	
			$2,335

7) Dispose of filters; (2) injection filters, (1) backwash filter and (1) yellowcake filter

a. 4 filters x 100 ft^3/filter x \$12.35/ft^3= \$4,940

8) Dispose of yellowcake dryer

o yellowcake dryer system is approximately 400 ft^3 in volume

a. 400 ft^3 x \$12.35/ft^3 = \$4,940

9) Dispose of piping

o There is a total of 8,250 ft of process piping in the plant with an average diameter of approximately 6". Of the 8,250 ft, roughly 50% is used for yellowcake process. The other pipe is for chemical make-up, raw and potable water.

a. NRC licensed disposal: 4,125 ft x 0.04 ft^3/ft x \$12.35/ft^3 x 1.25(1) =	\$2,547	
b. Landfill disposal: 1 load @ \$10 fee + \$360 =	370	
		\$2,917

(1) void space factor

10) Reclaim plant site

a. Dirtwork: 20,000 cy x 1 hour/700 cy x \$127/hour =	\$3,629	
b. Seed: 4 acres x \$269/acre =	1,076	
		\$4,705

11) Supervisory labor for plant reclamation

a. (1) Engineer \$5,725/month x 6 months =	\$34,350	
b. (1) Radiation Technician \$4,770/month x 6 months (operator wages included in above calculation) =	28,620	
		\$62,970

TOTAL COMMERCIAL PLANT RECLAMATION/DECOMMISSIONING \$312,237

D. R.O. BUILDING RECLAMATION/DECOMMISSIONING

Use a factor based on square footage of commercial plant for total reclamation/decommissioning of R.O. building

a. $312,237 x 5,000 ft^2/34,000 ft^2 =	$45,917
TOTAL R.O. BUILDING RECLAMATION/DECOMMISSIONING	$45,917

E. EVAPORATION POND RECLAMATION

Pond reclamation consists of removal and disposal of the pond liners, piping, and sludge to an NRC licensed disposal facility. The pond earthen embankments will be leveled, top soiled and seeded. The liner will be cut in sections and stacked for shipment.

1) Removal and disposal of pond liner systems

a. Five solar evaporation ponds at 250,000 ft^2/each at commercial plant Total thickness of liners is 100 mils. 5 ponds x 250,000 ft^2/pond x 0.00833 ft thick x 1.25(1) x \$12.35/ft^3 =	\$160,743	
b. Two solar evaporation ponds at R&D plant Total liner thickness is 36 mils. 2 ponds x 50,000 ft2 x 0.0030 ft thick x 1.25 x \$12.35/ft^3 =	\$4,631	
c. Labor for liner and pipe removal Cut and stack 40,000 ft^2/day with a four man crew.(5 ponds x 250,000 ft^2/pond + 2 ponds x 50,000 ft^2/pond) x 4 man-days/40,000 ft^2 x \$152/man-day =	\$20,520	
d. Equipment for liner and pipe removal Loader: 176 hours x \$50/hour =	\$8,800	
		\$194,694

(1) void space factor

2) Removal/Disposal of leak detection pipe, SDR 35 pipe.

a. Commercial pond pipe removal: 5 ponds x 2,100 ft of 4" pipe/pond x .010 ft^3/ft x 1.25 x \$12.35/ft^3 =	\$1,621	
b. R&D pond pipe removal: 2 ponds x 600 ft of 3" pipe/pond x .006 ft^3/ft x 1.25 x \$12.35/ft^3 =	111	
c. Pipe disposal: 24.60 ft^3 x \$12.35/ft^3 x 1.25 =	380	
		\$2,112

3) Removal/disposal of pond sludge.

o Pond sludge removal is based on removal of sludge in R&D ponds after operation and restoration.

a. Sludge disposal: 38 barrels x 55 gallons/barrel x 1 cf/7.48 gallons x 1 cy/27 cf = 10.4 cy Flow through R&D plant was 101,625,362 gallons, therefore,1 cy of sludge per 9,772,000 gallons processed. Total flow for 1991 to 1996 will be approximately 5,200,000,000 gallons 5,200,000,000 gallons x 1 cy/9,772,000 gallons x \$94/cy =	\$50,020

	b.	Labor: 532 cy x 3 man-days/25 cy x $152/man-day =	9,704	
	c.	Equipment (IT12): $50/hour x 100 hours =	5,000	
				$64,724
4)		Reclaim ponds.		
	o	Dirtwork volume per pond is approximately 60,000 cy/pond at commercial and 30,000 cy total at R&D based on post construction surveys.		
	o	Total earthwork volume is 330,000 cy.		
	o	Average dozing distance is 150 ft. A D8 will get 700 cy per hour(1).		
	a.	Dirtwork: 330,000 cy x 1 hour/700 cy x $127 (including operator)/hour =	$59,871	
	b.	Topsoil placement and seed: 30 acres x $269/acre =	8,070	
				$67,941
	(1)	Caterpillar Handbook, Edition 19		
5)		Supervisory labor for pond reclamation.		
	a.	(1) Engineer $5,725/month x 3 months =	$17,175	
	b.	(1) Radiation Technician $4,770/month x 3 months (operator wages included in above calculation) =	14,310	
				$31,485

TOTAL EVAPORATION POND RECLAMATION $360,956

F. MISCELLANEOUS SITE RECLAMATION

1)	Reclaim/seed main access road.		
	a. Road dirtwork:		
	4,000′ long x 25′ wide x 1′ deep x		
	1 cy/27 ft^3 = 3,704 cy		
	3,704 cy x 1 hour/200 cy x $127/hour =	$2,352	
	b. Seed roadway:		
	2.3 acres x $269/acre =	619	
			$2,971
2)	Remove/dispose of pipe from commercial plant to ponds and from commercial plant to R.O. building.		
	o Pond pipeline (2) at 2,000′ = 4,000 ft		
	o Pipe to R.O. (4) at 300" = 1,200 ft		
	o 5,200′ average size 4" Sch. 40		
	a. Disposal:		
	5,200 ft x .021 ft^2 x $12.35/$ft^3$ x 1.25 =	$1,686	
	b. Removal labor:		
	5,200 ft x 3 man-days/200 ft x $152/man-day =	11,856	
	c. Equipment:		
	o Loader:		
	5 days x $50/hour x 8 hours/day =	2,000	
	o Shredder:		
	5 days x $11/hour x 8 hours/day =	440	
			$15,982
3)	Remove electrical facilities.		
	a. Remove HV lines:		
	6,000 ft of HV line at $0.54/ft =	$3,240	
	b. Remove substations:	1,076	
			$4,316
4)	Supervisory Labor.		
	a. (1) Engineer		
	$5,725/month x 3 months =	$17,175	
	b. (1) Radiation Technician		
	$4,770/month x 3 months (Operator wages included in above calculations) =	14,310	
			$31,485

TOTAL MISCELLANEOUS SITE RECLAMATION $54,754

G. DEEP DISPOSAL WELL RECLAMATION

1. Plugging
   o Based on estimate in Deepwell Disposal Well Permit Application.

a. Cement:	Total Units	Unit Cost	Total Cost ($)	
300 Foot Bottom Plug (3750-3450) 70 sx. Class H + Halad 122 + CFR-9)	70	7.80	546	
200 Foot Bottom Plug (800'-600') 50 sx. Class H + Halad 122 + CFR-9	50	7.80	390	
200 Foot Bottom Plug (200'-surface) 50 sx. Class H + Halad 122 + CFR-9	50	7.80	390	
Pumping Charge	1	2500	2500	
				$3,826

b. Workover Rig	Total Units	Unit Cost	Total Cost ($)		
Daily Rig Cost	6	1500	9000		
Supervision	6	450	2700		
Miscellaneous Costs	1	2700	2700		
Subtotal Costs				$14,400	
					$18,226

2. Remove/dispose of surface facility

a. Pumps, piping, etc. removal on surface. 2 men x 10 days x $152/man-day+ $3,040

b. Dispose of equipment @ licensed disposal facility: 100 cf x $12.34/cf = 1,235

c. Dispose of building @ landfill:

	1 building x $460 =	460	
d.	Remove Piping: 700 ft x 2 man-days/450 ft x $152/man-day =	473	
e.	Equipment: o Loader $50/hr x 16 hrs =	800	
	o Shredder $11/hr x 16 hours =	176	
f.	Disposal of Pipe (4"): 700 ft x .0103 ft^3/ft x $12.35/$ft^3$ x 1.25 =	<u>112</u>	
			$6,296

3. Surface Reclamation:

a.	Recontour berm and containment area and seed: 2 acres x $269/acre =	538	
b.	Remove surface casing and dispose (top 10 feet)		
o	Loader $50/hr x 8 hours =	400	
o	Dispose @ Landfill 1 load x $460=	<u>460</u>	
			<u>$1,398</u>

TOTAL DEEP DISPOSAL WELL RECLAMATION <u>$25,920</u>

CROW BUTTE RESOURCES, INC.
CROW BUTTE IN-SITU MINE
09-22-94
1995 RESTORATION/RECLAMATION SURETY COST ESTIMATE

SUMMARY

A.	Groundwater Restoration	$2,649,156
B.	Wellfield Reclamation	986,226
C.	Commercial Plant Reclamation/Decommissioning	312,237
D.	R.O. Building Reclamation/Decommissioning	45,917
E.	Evaporation Pond Reclamation	360,956
F.	Miscellaneous Site Reclamation	54,754
G.	Deep Disposal Well Reclamation	25,920
	Subtotal	$4,435,166
H.	Contract Administration (10%)	443,517
I.	Contingency (15%)	665,275
	TOTAL	$5,543,958

7. ENVIRONMENTAL EFFECTS

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 which are used to ensure that the potential sources of land, water and air pollution are controlled and monitored are presented in Section 5.7, Radiation Safety Control 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 site.

7.1 ENVIRONMENTAL EFFECTS OF SITE PREPARATION AND CONSTRUCTION

Major facilities have already been constructed at the Crow Butte site. The site layout for the commercial operation 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.

- Three commercial solar evaporation ponds.

- Deep well injection building located north of the main process facility.

- Commercial wellfields. Wellfield development includes a number of wellfield houses for each mine unit.

- Access roads.

Future site construction may include the following:

- A satellite process facility and/or pumphouse located approximately one to three miles northwest of the existing process facility in response to the proposed increase in production capacity to 5,000 gpm. Initial estimates are that the satellite would be in the area of 5,000 square feet.

- Two solar evaporation ponds located in conjunction with the satellite facility. Two additional solar evaporation ponds adjacent to the commercial ponds.

- Expansion of the main process facility in response to the increase in production capacity to 5,000 gpm. Initial estimates are that this expansion may be in the area of 2,500 square feet.

- Additional access roads.

The total area impacted at any one time, not including access roads which 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 pumphouses scattered throughout the permit area, the facilities are confined to approximately 40 acres within Section 19, T31N, R51W, Dawes County, Nebraska.

Site preparation and construction activities included topsoil salvaging, pond excavation, building erection, road construction and completion of injection, production and monitor wells. Impacts that have resulted from this construction include:

- **Grazing**- the principal land use for the area is grazing. As a result, cattle are excluded from the areas that are under development or production at any given time. Exclusion of livestock from these areas is actually a direct benefit as the present range is rested, thus the carrying capacity is increased.

- **Vegetation**- vegetation removal from the construction areas has been an unavoidable impact, although it has been limited as much as possible. There were, however, no threatened or endangered plant species documented with the Permit Area. The vegetation in the permit area is dominated by disclimax flora with a low productivity. Considerable opportunity for floristic enhancement exists during revegetation. This vegetation removal is considered to be a short term impact with potential long term benefits through reclamation. Vegetation impacts on any future construction will be the same.

- **Wildlife**- there has been a minimal short term impact on wildlife species as a result of construction activities. There were no threatened or endangered mammals, birds, reptiles, amphibians, or fish in the

Permit Area. The Permit Area provides marginal habitat for big game (mule deer, white-tailed deer, and elk) while carnivores (red foxes, coyotes, raccoons, long tailed weasels, stripped skunks) only occur regularly in small numbers.

The nesting territory of raptors lies with the Permit Area. Impacts on these species are in direct proportion to a reduction in suitable prey. This has been minimal as a result of the relatively small disturbance.

The worst case scenario projected for the Crow Butte site consisted of the departure of wildlife as a result of normal construction activity. Section 2.8 discussed the ecology of the area and concluded that the impacts as a result of the mining operations to date have in fact been minimal.

- **Archeological Resources**- field investigation in 1982 and 1987 identified twenty one new archeological resource locations. These sites are represented by eight Native American components, twelve Euroamerican locations and a buried deposit of undetermined cultural association. Six of these sites are considered to be potentially eligible for the National Register of Historic Places 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.

- **Hydrology**- construction impacts have had a minimal impact on the local hydrological system. Some additional sediment had entered Squaw Creek from adjacent unnamed tributaries during earth moving activities, however, this condition was temporary.

- **Groundwater**- Well completion has not and will not adversely affect groundwater during the construction phase. Completion methods previously discussed in the application are designed to prevent commingling of aquifers and provide adequate mechanical integrity for use during the operational phase. Well clean-up will result in removing a small volume of water relative to the overall recharge capacity of the zone of well completion. No water users have been or will be impacted as a result of completion of wells.

Population- the effects of construction on the immediate population were another unavoidable impact, although a temporary one. Future construction activities may result in increased traffic to and from the construction site, noise from heavy equipment, minimal fugitive dust and a slight increase in the work force. Fugitive dust during construction activities will be controlled within the Permit Area by watering or applying a dust suppressant to roads as necessary.

- **Social and economic-** the social and economic impacts to the town of Crawford and surrounding areas during the construction of the original facility was slight given the relative small scale of activities. Any future construction activities will be even smaller in scope, thus there should once again be limited negative impacts.

7.2 ENVIRONMENTAL EFFECTS OF OPERATIONS

The major environmental concerns during the operation of the Crow Butte Commercial facility are air quality effects, land use and water quality impacts, ecological impacts, and radiological impacts.

7.2.1 AIR QUALITY EFFECTS

The impacts of operations at the Crow Butte site upon the air quality in the area are minimal. Some increase in suspended particulates from vehicular traffic on the access roads has occured, but the resulting impact on air quality has been minor. Fugitive dust is also released from vehicular traffic on access roads and within the wellfield areas, however, it has not affected air quality to date.

While some additional fugitive dust is released during construction of evaporation ponds, wellfields, and access roads, it is both localized as well as transient in nature. Some diesel emissions occur from drilling and construction equipment, however they are minor and of short duration.

Other operational activities have had impact 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 7.3.

7.2.2 LAND USE IMPACTS

The primary impact upon land use is the previously discussed impact on grazing land. Assuming that cattle are excluded from approximately 150 acres through the completion of restoration activities, there would be a loss of between 3.9 animal unit months (AUM) per year to 11.7 AUM per year. The 3.9 AUM per year is based on proper use as determined by field observations of presented range condition while 11.7 AUM per year is based on the present stocking rates used in the area. These impacts are considered temporary and reversible by returning the land to its former grazing use through post-mining surface reclamation.

7.2.3 IMPACTS TO WATER RESOURCES

Potential impacts to water resources from mining and restoration activities include:

- **Groundwater consumption**- the drawdown effects on the aquifer as a result of operations has been and is expected to remain minimal. This is discussed in greater detail in Section 7.4.3.

  Declines in groundwater quality- 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 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. Based upon operational results to date, none of the above are expected to occur during present and future operations.

  To date, no confirmed excursions have been seen, although this is not to say that an excursion will never occur. Past experience from other commercial scale in-situ leach projects has shown that when proper steps are taken in monitoring and operating a wellfield, excursions, if they do occur, can be controlled and serious impacts on the groundwater prevented.

  The long term impacts on groundwater quality should also be minimal, as restoration activities in the R&D wellfield as well as other in-situ facilities have been shown to be successful.

- **Impacts to surface water from construction and decommissioning activities**- normal construction activities within the wellfields, process plants, and along the pipeline courses and roads may slightly increase the sediment yield of the areas so disturbed. However, the relative size of these disturbances are 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.

- **Impacts to groundwater and surface water from accidents**-another potential impact during operations would be evaporation pond leakage or failure, or an uncontrolled release of process liquids due to a wellfield accident. In accordance with the NPDES permit issued to Crow Butte Resources, a Best Management Practices Plan has been developed and implemented that addresses these scenarios. In addition, there are a number of Standard Operating Procedures in place to carefully monitor any potential pollution source.

  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, catastrophic failure, as a result of overflow due to excess production or restoration flow, or due to the addition of rainwater or runoff.

  To mitigate the likelihood of pond failure, all ponds have been designed and built to NRC standards using impermeable synthetic liners. A leak detection system has also been installed, and all ponds 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. With respect to potential overflow of a pond, current standard operating procedures require that pond levels be closely monitored. Process flow to the ponds is 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.

  Other releases could occur as a result of the release of injection or recovery solutions from a wellfield building or associated piping. This is considered unlikely as all piping is PVC, high density polyethylene with butt welded joints or equivalent, and potential drainage is diked and bermed. All piping is leak tested prior to production flow. Process buildings are constructed with secondary containment, and a regular program of inspections and preventive maintenance is in place.

7.2.4 ECOLOGICAL IMPACTS

Principal impacts on terrestrial biota will be caused by disturbance of soils and vegetation during construction of facilities. The greatest effect created by this disturbance is the setting back of plant succession within the area of disturbance. As previously noted, there should be no threatened or endangered plant or wildlife species impacted due to construction or operations. To mitigate the potential for wildlife entering the pond area, a seven foot wildlife proof fence has been constructed around the ponds.

7.3 RADIOLOGICAL EFFECTS

Crow Butte Resources is proposing to increase production flow rate from 3500 gpm to 5000 gpm. The average restoration flow rate will also increase to 1000 gpm. The 5000 gpm of production flow rate may be processed at the existing plant, referred to as Case 1, or may be split between the existing facility and a satellite operation, referred to as Case 2. This will be discussed further in the Exposure Pathways section.

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.

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 (June 1989) are used to predict the ground level air concentration at various points in the environment. The ingrowth of radon daughters is important and their concentration in the soil, vegetation and animals 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 Crow Butte Project at 5000 gpm will be discussed briefly. A detailed presentation of the source terms is included as Attachment 7.3(A). 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 proposed project.

7.3.1 EXPOSURE PATHWAYS

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.

In Case 1 approximately 3500 gpm of the process solution is passed through upflow ion exchange columns which vent the majority of the Radon into the exhaust manifold. From these columns, the solution will is 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.

In Case 1, Crow Butte Resources is planning to use pressurized fixed bed downflow ion exchange columns to process the expanded flow requested. The flow capacity of the existing facility is nominally 3500 gpm and it would require additional downflow columns to increase the flow to 5000 gpm. These columns would be operated with 2 columns in series with either 2 or 3 sets in parallel. The columns would be nominally eight feet in diameter and can process 500 to 750 gpm.

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% of the radon contained in the process solutions will be vented to atmosphere.

In the source term calculation Crow Butte Resources has adjusted the Radon release value to show that all of the contained Radon in the 3500 gpm flow processed by upflow IX will be released to the environment and that 10% of the contained Radon found in the 1500 gpm flow processed by pressurized downflow IX columns will be released to the environment

In Case 2, Crow Butte Resources proposes to process 2500 gpm to 3500 gpm, using the existing upflow IX system and to process an additional 1500 to 2500 gpm using a pressurized downflow IX system that would operate as a satellite system. 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.

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.

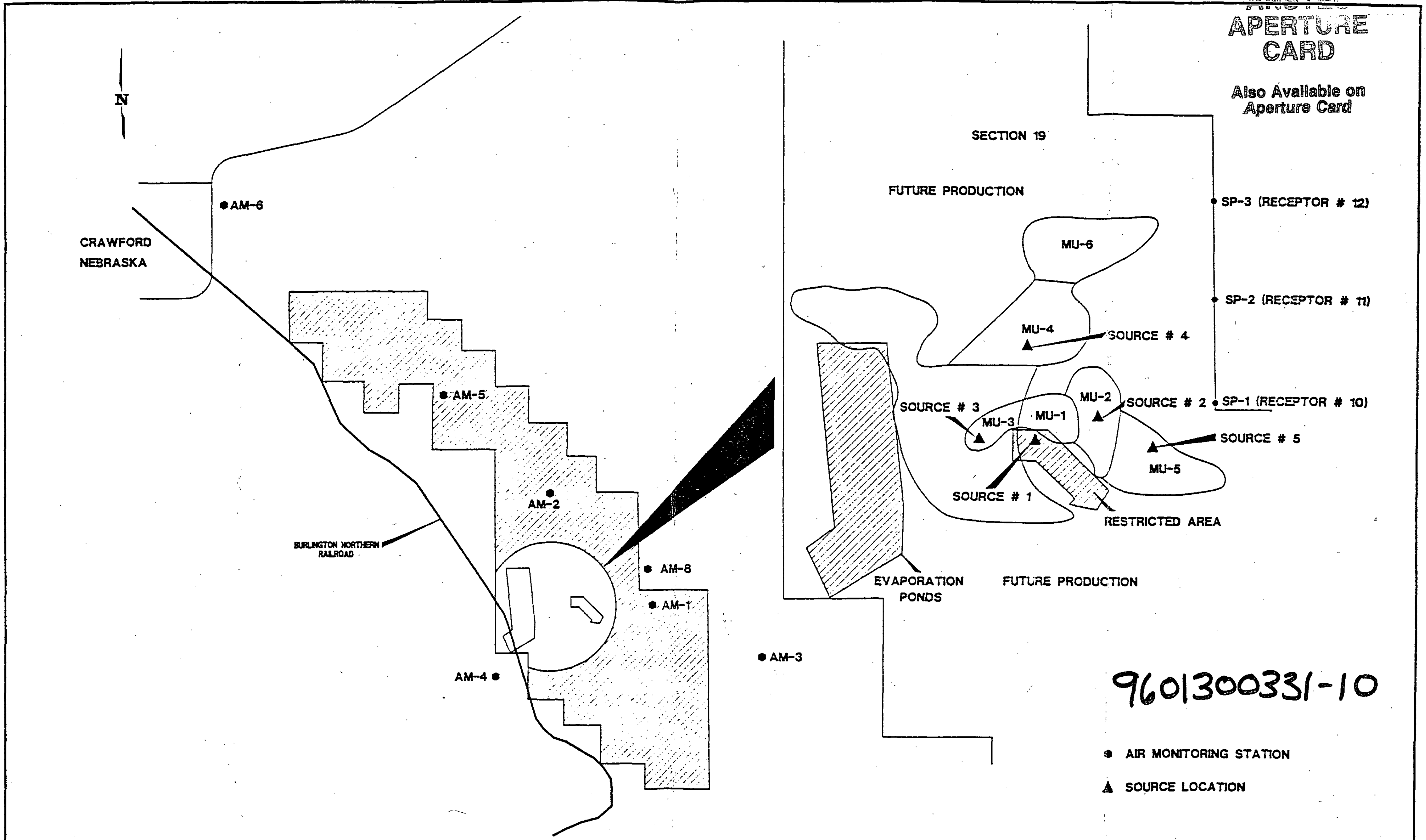
The injection wells will generally be closed and pressurized, but will be periodically vented. As stated earlier for purposes of this evaluation, it was estimated that 25% of the radon will be released in the wellfield. In Case 1 the 25% released from the wellfields was assumed to be released from MU-4, MU-5, and the Brott Wellfield with the restoration wellfield releases assumed to be evenly distributed over MU-1, MU-2 and MU-3. The locations of the sources and receptors for Case 1 are shown in Figure 7.3-1.

In Case 1 the remaining radon release was from the plant vent located 15.9 meters above the foundation of the facility. The above values were entered into the MILDOS code as the source terms.

In Case 2 the radon releases are as follows:

- Wellfield releases will be from MU-4, MU-5 and the Raben Wellfield for mining with releases from MU-1, MU-3, and MU-3 for restoration.
- Plant releases will be from the main process facility through the plant vent and from the satellite facility located in the McDowell Wellfield. The locations of the sources and receptors are in Figure 7.3-1, which is found later in this report. 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 Crow Butte Project. 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



REVISIONS	DRAWING STATUS	BY	DATE	DRAWING INFORMATION	NAME	DATE
	PRELIMINARY	/		DESIGN BY	B. CONROY	11/19/92
	FOR COMMENT AND/OR APPROVAL			DRAWN BY	J. PAGE	11/21/92
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	REVISED AND APPROVED FOR CONSTRUCTION			SCALE	NONE	
NO / DESCRIPTION / BY / CHK / APPR	DRAWING IS NOT APPROVED FOR CONSTRUCTION UNLESS SIGNED AND DATED. ALL PRINTS ARE TO BE DESTROYED HAVING AN EARLIER DATE AND / OR REVISION NUMBER.			PLOT DATE	11/23/92	PLOT SCALE 36=60000

AIR MONITORING STATION LOCATIONS AND MILDOS-AREA SOURCE AND RECEPTOR LOCATIONS

PROJECT LOCATION: CRAWFORD, NEBRASKA — PROJECT NO.

RESOURCE TECHNOLOGIES GROUP, INC.

CLIENT: FERRET EXPLORATION CO. OF NEBRASKA — REVISION NO. A — DRAWING NO. 101

Figure 7.3-1: Source and Receptor Locations Process Capacity Increase to 5,000 gpm 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 secondary pathway if fed to animals which are in turn consumed by man.

All of the above pathways are evaluated by MILDOS-Area.

7.3.2 EXPOSURES FROM WATER PATHWAYS

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

Three commercial evaporation ponds located approximately 2000 feet from the 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 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.

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

7.3.3 EXPOSURES FROM AIR PATHWAYS

The only source of radioactive emissions is radon released into the atmosphere through a vent system or from the wellfields. This release results 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 Crow Butte Project were 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.

Based on the site specific data and method of estimation of the source term presented in Attachment 7.3(A), the emission rate of Radon from the Crow Butte Project will be 4904 Ci/yr for Case 1 which consists of a flow of 3,500 gpm in the upflow ion exchange columns in the existing plant along with the proposed 1,500 gpm of flow treated in the pressurized down flow ion exchange columns.

The emission rate of Radon from the Crow Butte Project for Case 2 will be 4,284 Ci/yr. Case 2 consists of a flow of 2,500 gpm processed in the existing facility in upflow ion exchange columns and 2,500 gpm processed in pressurized downflow ion exchange columns located in a satellite plant approximately 10,000 feet from the existing facility.

In order to show compliance with the annual dose limit found in 10 CFR20.1301 Crow Butte Resources has demonstrated by calculation that the total effective dose equivalent (TEDE) to the individual most likely to receive the highest dose from the licensed operation is less than 100 mrem per year. This data for Case 1 and Case 2 are shown in Table 7.3-1 and Table 7.3-2. As can be seen from the data the dose to the most effected resident (Receptor 19) was 20.3% of the allowable limit for Case 1 and 14.3% of the allowable limit to the most effected resident (Receptor 19) for Case 2.

The applicant reviewed the Radon monitoring data obtained at the Crow Butte Site from June of 1992 through December of 1993 and these data are found in Table 7.3-3. These data show no significant increase in Radon concentration above background at any monitoring station. The data from the site monitoring show that the impact of the site on radon levels is minimal and the increase in flow should have little, if any, impact on the radon levels in the area.

7.3.4 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 contained in Table 7.3-4, where the dose to the bronchial epithelium is expressed in terms of person-rems. For comparison, the dose to the population within 80 km of the facility due to natural background radiation has been 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 7.3-4 and also combined with dose to the region within 80 km (50 mi) 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 7.3-4, 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 Crow Butte Project would be to increase the dose to the bronchial epithelium of the continental population by 0.00018 percent for Case 1 and 0.00016 percent for Case 2.

7.3.5 EXPOSURE TO FLORA AND FAUNA

The exposure to flora and fauna was evaluated in the Environmental Report submitted in September of 1987 and the doses were found to be negligible. The proposed increase in flow will have no measurable impact on dose to flora and fauna.

Table 7.3-1: Total Effective Dose Equivalent to Nearby Residents [1] Case 1 at 5000 gpm

Receptor	TEDE (mRem/yr)[1]
#6 (Town of Crawford)	0.43
#18 (Ehlers)	8.9
#19 (Gibbons)	20.3
#20 (Stetson)	13.1
#21 (Knode)	2.6
#22 (Brott)	10.5
#26 (McDowell)	1.8
#27 (Taggert)	2.1
#28 (Franey)	2.9
#29 (Bunch)	3.7
#30 (Dyer)	1.2

1 TEDE was identical for infant, child, teenager and adult.

Table 7.3-2: Total Effective Dose Equivalent to Nearest Residents [1]
Case 2 at 5000 gpm

Receptor	TEDE (mRem/yr) [1]
#6 (Town of Crawford)	0.34
#18 (Ehlers)	5.9
#19 (Gibbons)	14.3
#20 (Stetson)	10.3
#21 (Knode)	1.3
#22 (Brott)	1.8
#26 (McDowell)	1.1
#27 (Taggert)	1.3
#28 (Franey)	1.9
#29 (Bunch)	4.1
#30 (Dyer)	0.67

1 TEDE was identical for infant, child, teenager and adult.

Table 7.3-3: Ambient Radon Concentration
June 1992 - December 1993

Air Monitor Station Number	Average (pCi/L)	Standard Deviation (pCi/L)
AM-1	0.47	0.21
AM-2	0.60	0.29
AM-3	0.47	0.14
AM-4	0.58	0.25
AM-5	0.67	0.27
AM-6	0.47	0.19
AM-8	0.55	0.19
AB-3 (AM-3)	0.42	0.15
AB-6 (AM-6)	0.40	0.17

[1] AB-3 and AB-6 are duplicate track etch radon cups at Air Monitor stations No. AM-3 and AM-6.

Table 7.3-4: Dose to the Population Bronchial Epithelium From One Year's Operation at 5000 gpm

Criteria	Case 1 Dose (person rem/yr)	Case 2 Dose (person rem/yr)
Dose received by population within 80 km of the facility	39	34
Natural background by population within 80 km of the facility	24025	24025
Dose received by population beyond 80 km of the facility	275	240
Total continental dose	314	274
Natural background for the continental population	1.73×10^{8}	$1.73 \text{ X } 10^{8}$
Fraction increase in continental dose	$1.82 \text{ X } 10^{-6}$	1.58×10^{-6}

7.4 NON-RADIOLOGICAL EFFECTS

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 7.1 and Section 7.2 above. The environmental monitoring programs given in Section 5.7.8 are designed to quickly identify any adverse conditions that may result during operations. No long term irreversible effects are anticipated.

7.4.1 AIRBORNE EMISSIONS

Hydrochloric acid will constitute the main gaseous nonradiological effluent that is anticipated at Crow Butte. Hydrochloric acid that is kept on-site is stored in a tank twelve feet in diameter and eighteen 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% 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%.
- 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} ug/m^3 in the vicinity of the facility. The threshold limit for hydrogen chloride is 7,000 ug/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).

$$E = (0.81s) \frac{S}{30} \frac{365 - w}{w}$$

Where:

E = emission factor, lb / 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% 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.

7.4.2 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 revegatation 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.

7.4.3 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 5,000 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.

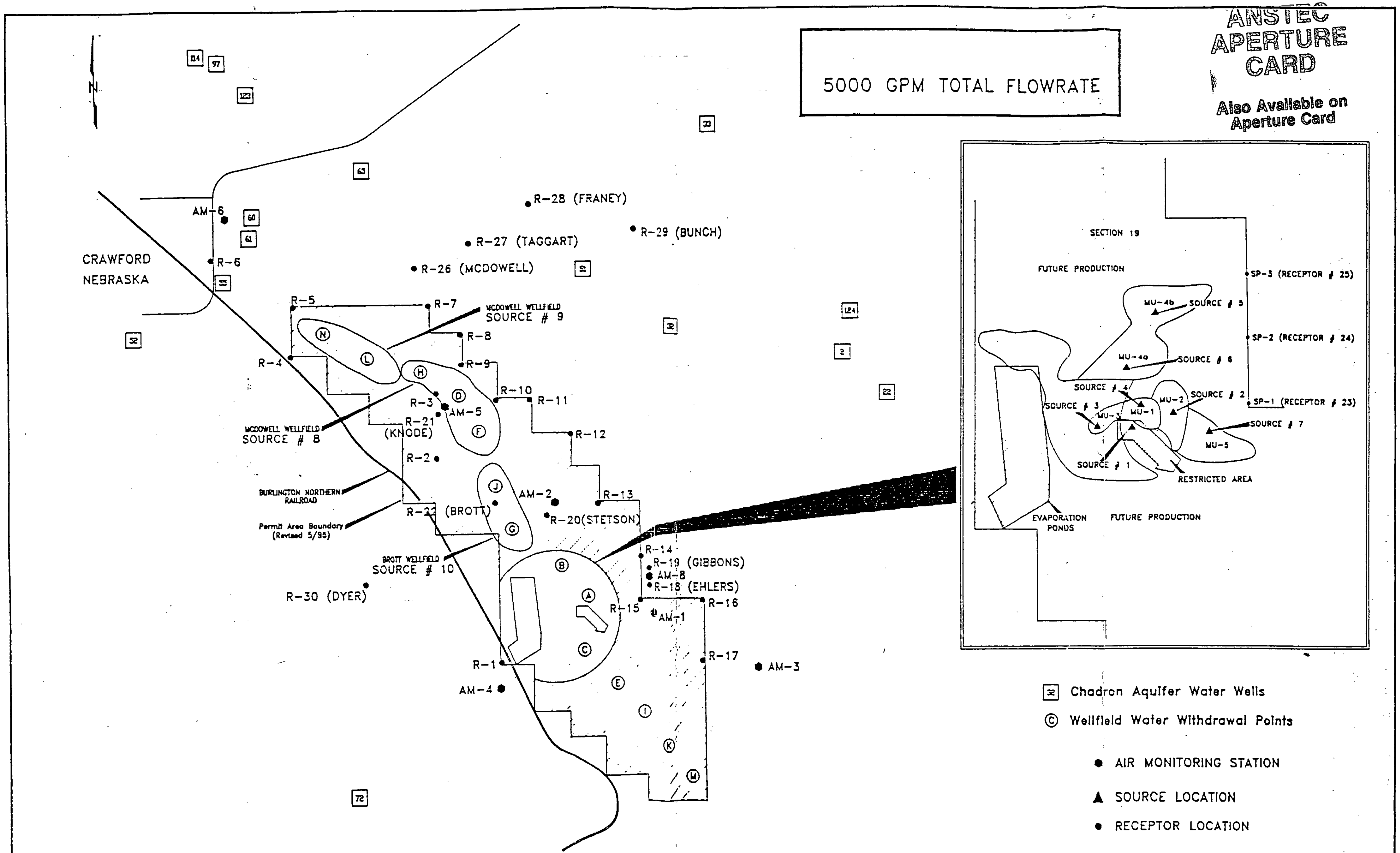
Since groundwater is injected as well as extracted in the ISL process, the flow rates of interest in gauging the impact are the net flows, or extraction minus injection. These net withdrawals and their timing were estimated from the generalized production schedule shown in Table 7.4-1. The net groundwater 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 permit area. (See Figure 7.4-1) 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 7.4-2. 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 7.4-2 provides an early and separate progression of the wellfield production away from the Crow Butte main 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.

The pressure drawdown calculations were made using the unsteady state Theis 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 project area.

Figure 7.4-2 through Figure 7.4-5 show the estimated drawdowns overtime for each of the Chadron Aquifer water wells (ww) outside of the Crow Butte permit area shown on Figure 7.4-1. 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 an equilibrium as a result of recharge of the surrounding aquifer.

Figure 7.4-1: Revised Wellfield Map Showing Withdrawal Points



REVISIONS
B Water Wells, Withdrawal Points, Permit Area

DRAWING STATUS: PRELIMINARY; FOR COMMENT and/or APPROVAL; APPROVED FOR CONSTRUCTION; REVISED AS APPROVED FOR CONSTRUCTION

DRAWING IS NOT APPROVED FOR CONSTRUCTION UNLESS SIGNED AND DATED. ALL PRINTS ARE TO BE DESTROYED HAVING AN EARLIER DATE AND / OR REVISION NUMBER.

AIR MONITORING STATION LOCATIONS AND MILDOS – AREA SOURCE AND RECEPTOR LOCATIONS

RESOURCE TECHNOLOGIES GROUP, INC.

Crow Butte Resources, Inc. | B | 101

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Table 7.4-1: 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	Figure 7.4-2	-23.4	530	-4.4%
22	-70 est.	400	Figure 7.4-2	-23.2	270	-8.6%
33	-20 est.	212	Figure 7.4-2	-22.1	132	-16.7%
124	-50 est.	520	Figure 7.4-2	-22.8	410	-5.6%
32	-39.8	400	Figure 7.4-3	-26.2	300	-8.7%
51	-30 est.	300	Figure 7.4-3	-26.8	210	-12.8%
72	-82.2	450	Figure 7.4-3	.25.5	308	-8.3%
52	4.62[3]	420	Figure 7.4-4	-24.7	365	-6.8%
55	-6.25[3]	320	Figure 7.4-4	-26.8	254	-10.5%
60	20 est.	312	Figure 7.4-4	-25.9	272	-9.5%
61	19.64[3]	280	Figure 7.4-4	-26.4	240	-11.0%
65	22.52[3]	260	Figure 7.4-4	-25.6	223	-11.5%
97	57.75[3]	380	Figure 7.4-5	-22.2	378	-5.9%
114	60 est.	470	Figure 7.4-5	-21.9	470	-4.7%
123	21.37[3]	280	Figure 7.4-5	-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

**Table 7.4-2: 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 7.3.1 (Revised)
All flow rates are in gallons per minute.

Figure 7.4-2: Crow Butte Project
Impact of Water Withdrawals

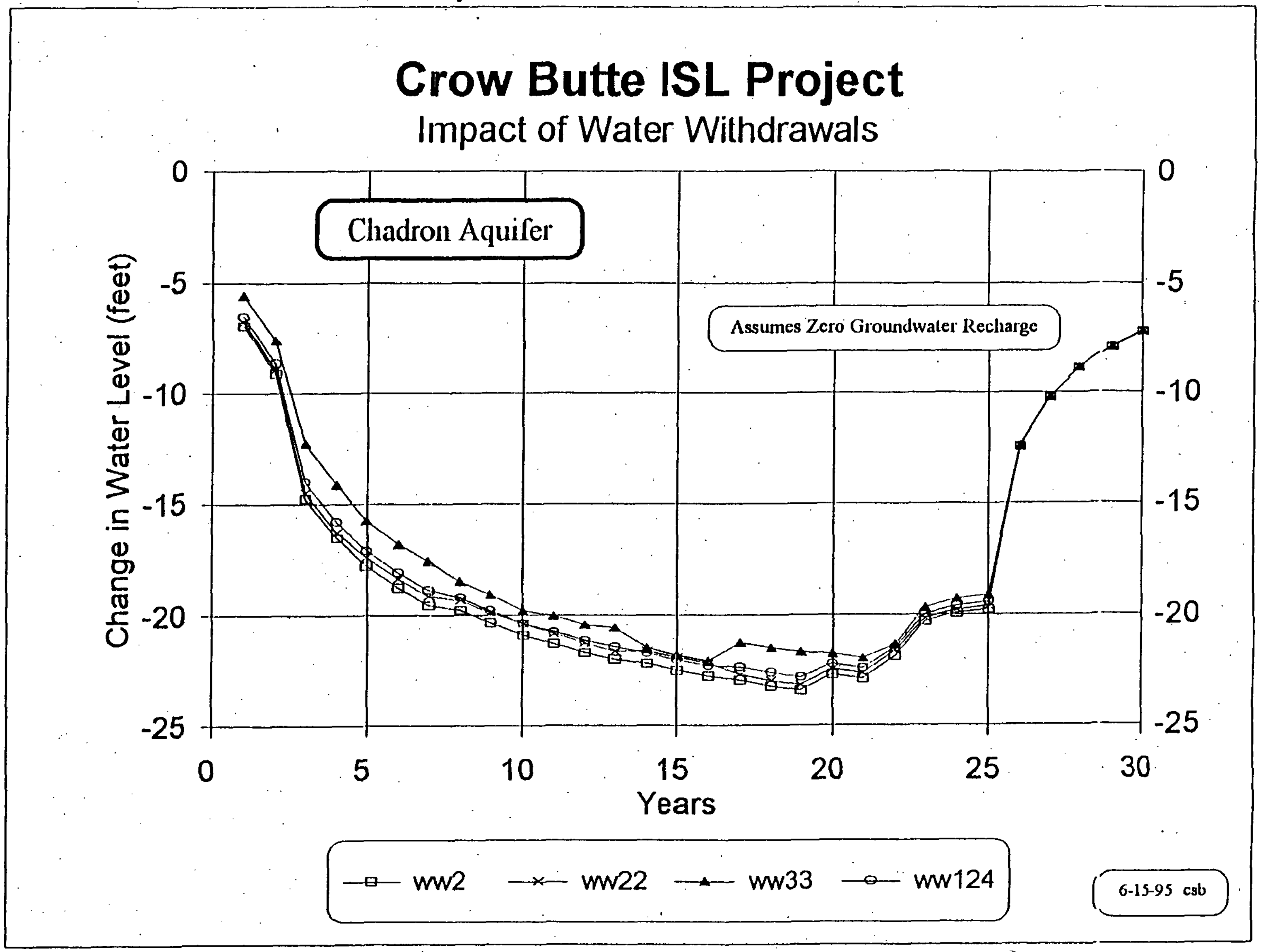

Figure 7.4-3: Crow Butte Project
Impact of Water Withdrawals

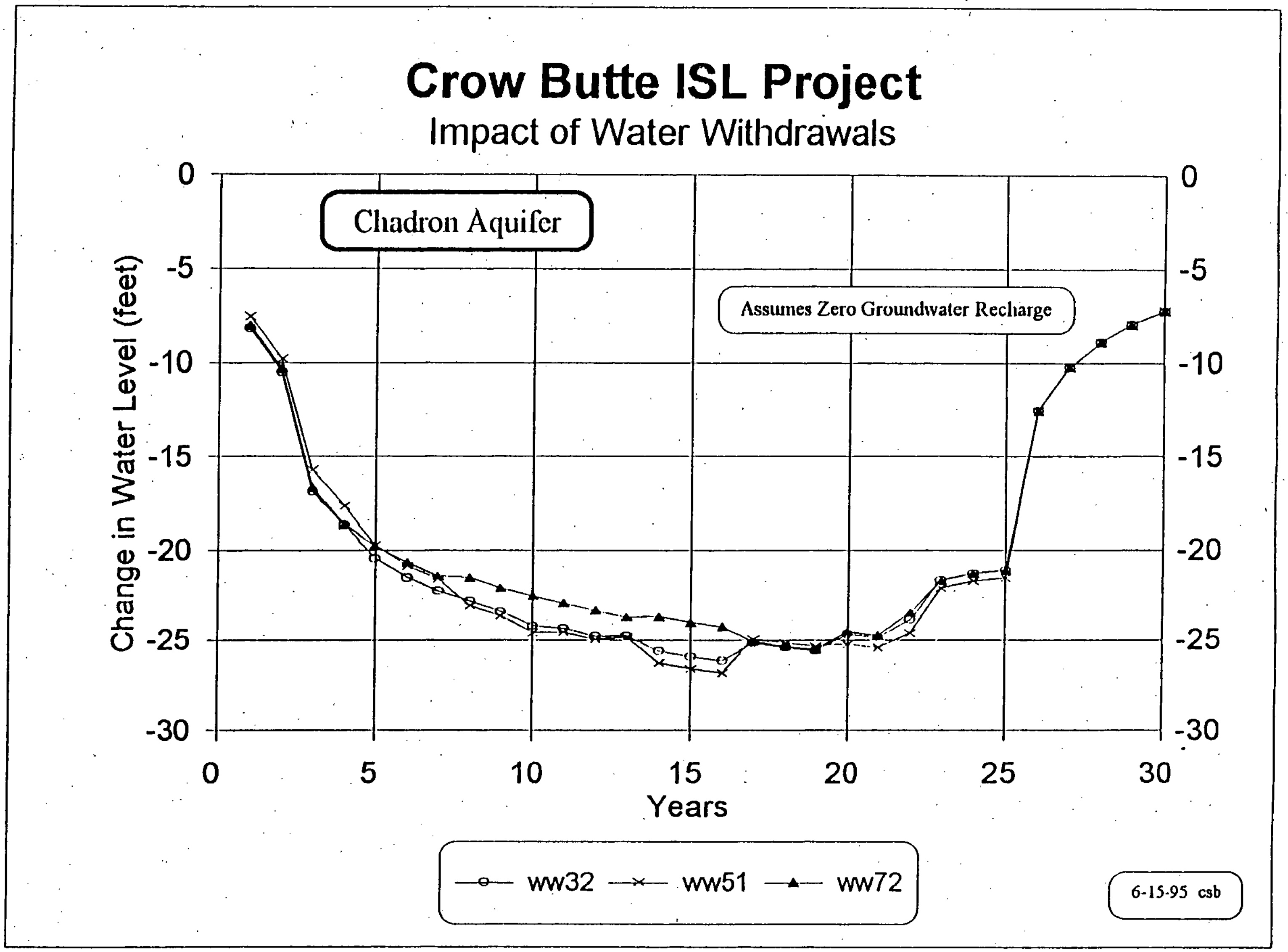

Figure 7.4-4: Crow Butte Project
Impact of Water Withdrawals

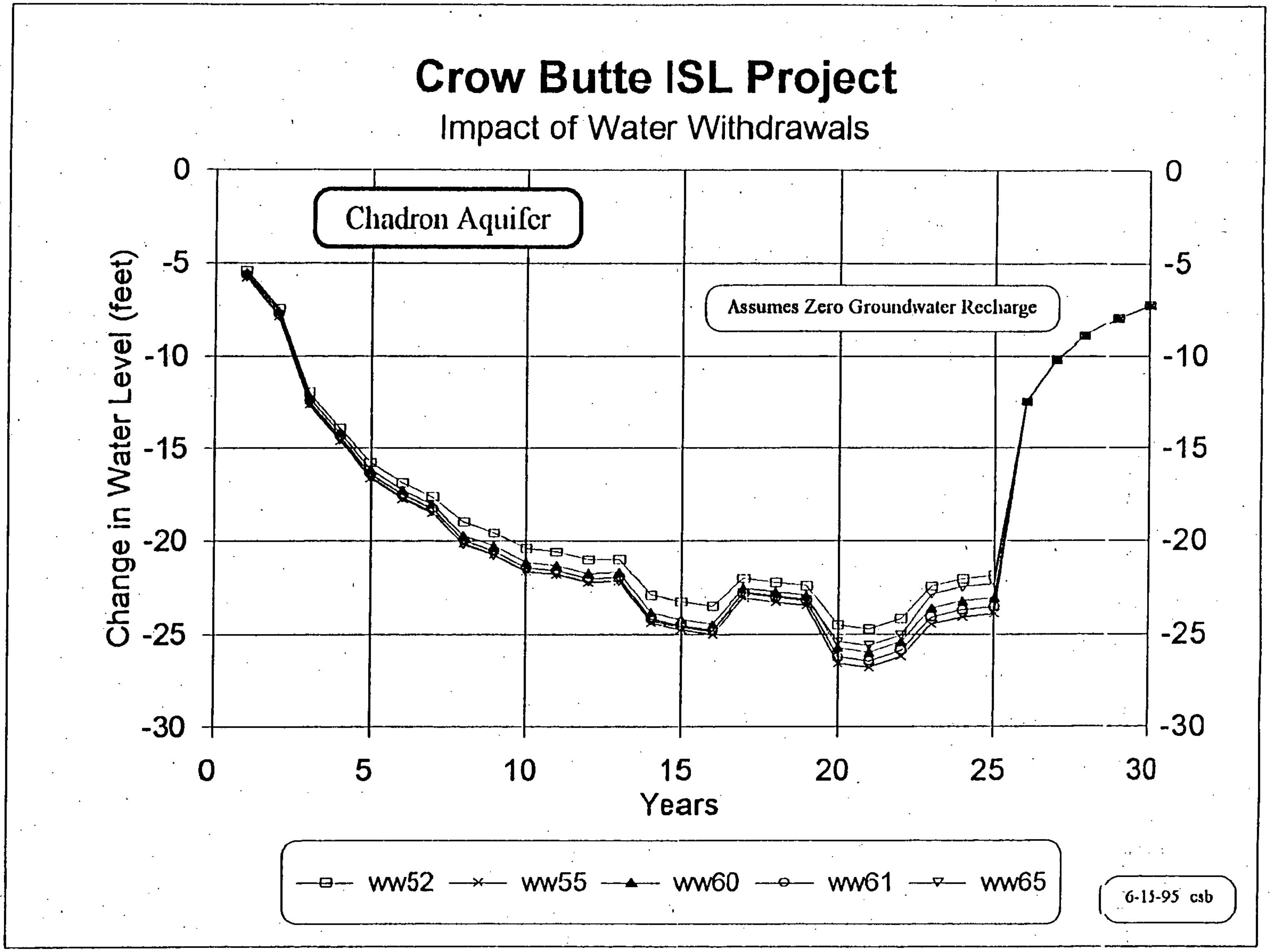

Figure 7.4-5: Crow Butte Project
Impact of Water Withdrawals

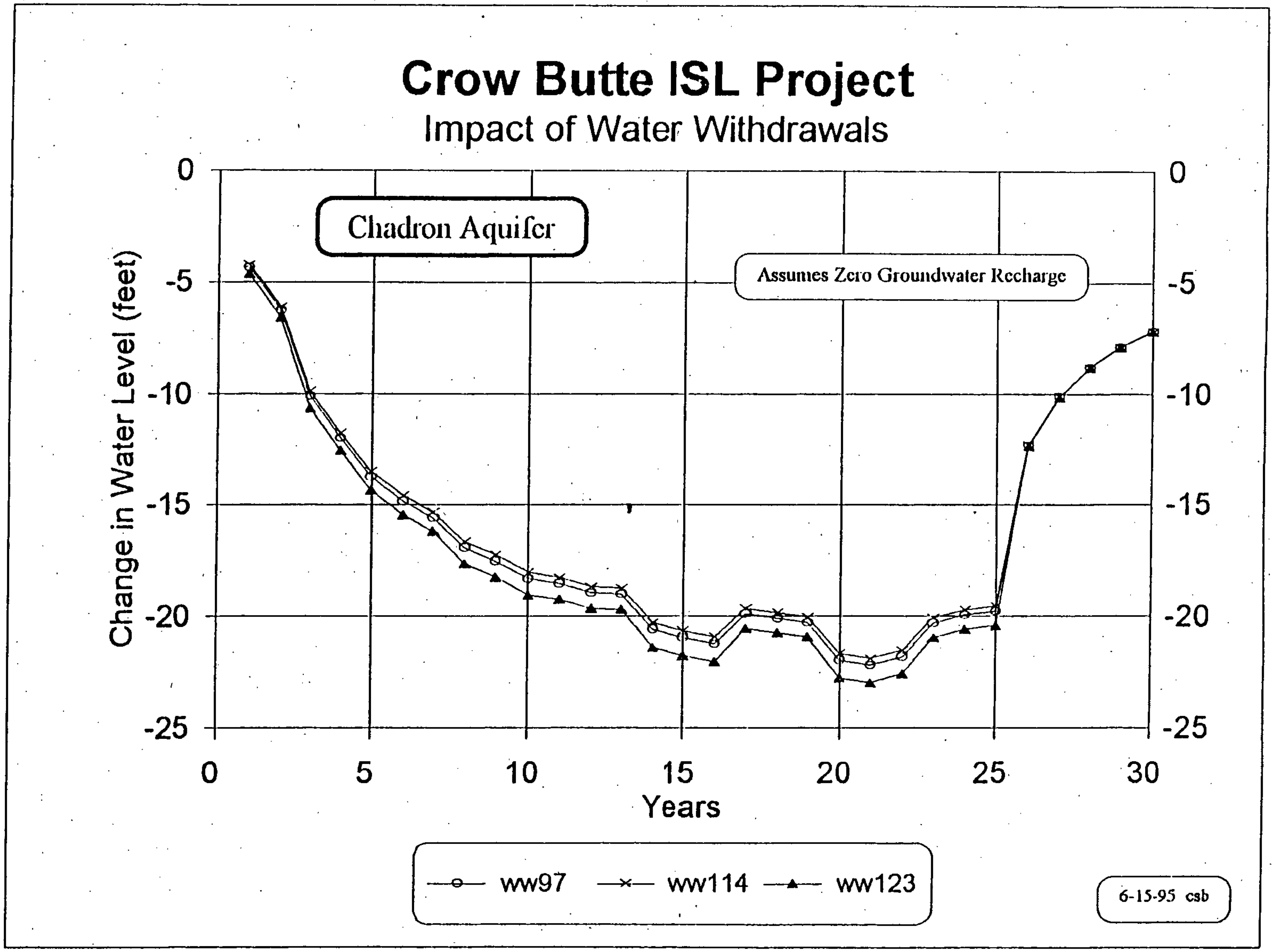

Table 7.4-1 shows the maximum projected drawdowns, without formation recharge, caused by Crow Butte mining operations to the surrounding Chadron water wells. It also includes an estimated maximum drawdown available in those water wells, assuming the wells were drilled to the bottom of the Chadron Aquifer, 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% to 16.7% with an average of 9.0%. 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 7.4-1. Comparing the predicted drawdowns in the Crawford area to the static levels of Table 7.4-1 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.

7.5 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.

7.5.1 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. Standard Operating Procedures are in place to respond to any spill that may occur.

7.5.2 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 which 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 have been diked and bermed to protect this water source.

7.5.3 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 a low ambient moisture, thus leaking solutions would not tend to migrate. Contingency plans are in place to address situations that may occur.

7.5.4 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 which 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 generally 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 5.7.8. 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.

7.5.5 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, this transfer vehicles would be operated by a Crow Butte employee.

7.5.5.1 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 5,000 gpm 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.

7.5.5.2 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 site being involved in an accident of any type in the Crawford area during a one year period is approximately 1%.

7.5.5.3 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.

7.5.5.4 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 Permit 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 are listed as follows:

- The resin, either loaded or eluted, will be shipped as "Exclusive Use Only". This will require the outside of each container or tank to be marked "Radioactive ' LSA", and placarded on four sides of the transport vehicle with "Radioactive" diamond signs.

- A bill of lading will be included for each shipment (including eluted resin). The bill of lading will indicate that a hazardous cargo is present. Other items identified shall be the shipping name, ID number of the shipped material, quantity of material, the estimated activity of the cargo, the transport index and the package identification number.

- Before each shipment of loaded, eluted resin or eluate, the exterior surfaces of the tanker will be surveyed for alpha contamination. In addition, gamma exposure rates will be obtained from the surface of the tanker and inside the cab of the tractor. All of the survey results will appear on the bill of lading.

- Crow Butte's emergency response plan for yellowcake and other transportation accidents to or from the Crow Butte site will be expanded to include an emergency resin transfer accident procedure. Personnel at both the satellite plant and the main process facility will receive training for responding to a resin transfer transportation accident.

Currently, Crow Butte Resources 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.

The worst case accident involving the resin transfer would involve the total wreckage of the transport truck and tanker trailer when carrying uranium laden resin, and where all of the tank contents were spilled. Because the uranium adheres to the resin, and the resin is in a wet condition during shipment, the radiological and environmental impacts of such a spill should be relatively minimal. The radiological or environmental impact of a similar accident with barren, eluted resin would be very minor. The primary environmental impact associated with either accident would be the salvage of soils impacted by the spill area and the subsequent damage to the topsoil and vegetation structure. Areas impacted by the removal of soil would be revegetated.

In the event of a transportation accident involving the resin transfer operation, Crow Butte Resources will institute its emergency response plan for transportation accidents. To minimize the impacts from such an accident, the following procedures will be followed:

- Each resin hauling truck will be equipped with a radio which can communicate with either the Crow Butte recovery facility or the satellite plant. In the event of an accident and spill, the driver can radio to both sites to obtain help.

- A check-in and check-out procedure will be instituted where the driver will call the receiving facility prior to departure from his location. If the resin shipment fails to appear within a set time, a crew would respond and search for this vehicle. This system will assure reasonably quick response time in the case that the driver is incapacitated in the accident.

- Each resin transport vehicle will be equipped with an emergency contingency package whereby the driver could use the contained equipment to begin containment of any spilled material.

- Both the satellite and main process facilities will be equipped with emergency response packages to quickly respond to a transportation accident.

- Personnel at both the satellite and main process facilities, as well as the designated truck drivers, will have specialized training to handle an emergency response to a transportation accident.

7.5.6 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.

ATTACHMENT 7.3(A)

Table 7-3(A)- 1: Site Specific Information Crow Butte Project

PARAMETER	VALUE
Average ore quality, U_3O_8, in ore body	0.27%
Ore radon-222 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	34 acres
Average thickness of body	5.0 feet
Average screened interval	15.1 feet
Average production flow rate	5000 gpm
Formation porosity	29%
Process recovery	95%
Leaching efficiency	60%
Rock density	1.89 g/cm^3
Restoration flow rate	1000 gpm
Production cell parameters	
Residence time	assume 7 days
Type of cell pattern	variable
Average cell area	10,000 ft^2
Average cell flow rate	121 lpm
Annual Rn-222 emission from production	4053 Ci/yr
Annual Rn-222 emission from restoration	851 Ci/yr
Source stack description (Radon)	plant vent
Stack height	15.9 m
Stack diameter	0.30 m
Stack exit velocity	38.7 m/sec

Table 7-3(A)- 2: Source and Receptor Coordinates Crow Butte Project

			Case 1	Case 2
Source	East (km)	North (km)	Rn-222 (Curies)	Rn-222 (Curies
1. Plant Vent	0	0	3270	2400
2. MU-1	-0.13	0.30	119	119
3. MU-2	0.06	0.27	119	119
4. MU-3	-0.30	0.16	119	119
5. MU-4a	-0.17	0.00	0	159
6. MU-4b	0.33	0.12	445	159
7. MU-5	-0.13	0.74	445	318
8. McDowell WF	1.55	2.80	0	445
9. Raben WF	2.93	3.53	0	445
10. Brott WF		-1.19	1.65	383

Table 7-3(A)- 3: Individual Receptor Location Data

Location	X (km)	Y (km)	Distance (km)
1. R1	-1.21	-0.44	1.28
2. R2	-1.95	1.95	2.76
3. R3	-1.89	2.71	3.31
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	4.44
8. R8	-1.99	3.60	4.11
9. R9	-1.57	3.23	3.59
10. R10	-1.16	2.80	3.04
11. R11	-1.78	2.77	3.30
12. R12	-0.30	2.35	2.37
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	1.35
17. R17	1.31	0.34	1.35
18. EHLERS	0.73	-0.06	0.73
19. GIBBONS	0.73	0.73	1.04
20. STETSON	-0.46	1.22	1.30
21. KNODE	-1.89	2.68	3.28
22. BROTT	-1.37	1.34	1.91
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	4.85
29. BUNCH	1.01	4.27	4.38
30. DYER	-2.44	0.55	2.50

Table 7-3(A)- 4: Calculation of Annual Radon Emissions
Crow Butte Project
Case 1 - 3500 gpm Upflow/1500 gpm Pressurized Downflow

1) To calculate radon release from leaching assuming that U-238 is in equilibrium with all its decay products:

Ci/m^3 = 761 pCi/g ore x 1.89 g/cm^3 x 0.2 x 0.71/0.29 x 10^{-6} = 7.04 x 10^{-4} Ci/m^3

Where:	0.2	=	Emanating Power
	0.71	=	1 - Porosity
	0.29	=	Porosity

The yearly release is then:

7.04 x 10^{-4} Ci/m^3 x 18925 lpm x (0.72) x 365 d/yr x 1.44 = 5042 Ci/yr

Where:	18925	=	liters per minute
	0.72	=	$1-e^{-(\lambda t)}$
		=	$1-e^{-(0.1812)(7d)}$
		=	$1-e^{-(0.28)}$
	1.44	=	constant

2) The radon release from start-up is given by:

7.04 x 10^{-4} Ci/m^3 x 34 acres x 4074 m^2/acre x 1.52 m x 0.29 = 43 Ci/yr

Where:	4074	=	m^2/acre
	1.52	=	Thickness of orebody in meters
	0.29	=	Porosity

The total release of radon from the start-up solution and production lixiviant solution is:

Start-up solution	43 Ci/yr
Production	5042 Ci/yr
	5085 Ci/yr

3) The radon release from restoration is given by:

7.04 x 10^{-4} Ci/m^3 x 3785 lpm x 365 d/yr x (0.99) x 1.44
= 1387 Ci/yr + 43 (start-up) = 1430 Ci/yr

Where:	3785	=	Restoration flow in liter per minute
	0.99	=	$1\text{-}e^{-(\lambda t)}$
		=	$1\text{-}e^{-(0.181)(35)}$
		=	0.99
	1.44	=	constant

The total release from this 34 acre in-situ mining operation is then:

Production	- 5042
Start-up	- 43
Restoration (Includes Start-up)	- 1430
	6515 Ci/yr

4) Actual Radon Release to the Environment

In Case 1 with 3500 gpm being processed by upflow ion exchange columns it is expected that all of the radon will be released to the environment and that 25% of the radon will be released in the wellfield and 75% will be released in the plant vent.

The 1500 gpm of flow being processed by pressurized downflow ion exchange columns will release only a small fraction of the contained radon to the environment. Only about 10% of the contained radon will be released during regeneration and venting. It is also expected that 25% of the radon will be released in the wellfield.

During restoration 1000 gpm of recovered water will be processed by pressurized downflow ion exchange (IX) columns. After IX treatment, 400 gpm will be treated by reverse osmosis (RO). Only a small fraction of the contained radon will be released during ion exchange and virtually all of the contained radon will be released during RO treatment. The actual release of the source term of 1430 Ci of radon/yr (including start-up) will be as follows:

- 25% of the 1430 Ci will be released in the wellfield - 358 Ci/yr
- 10% of the radon in the 600 gpm to be treated by pressurized IX (NOTE: All of the radon in the 400 gpm treated by IX-RO will be released).

The calculation follows:

$$1430\ \text{Ci/yr} - 358\ \text{Ci/yr (Wellfield loss)} \times \frac{600\ \text{gpm}}{1000\ \text{gpm}} \times 0.10 = 64\ \text{Ci/yr}$$

- 100% of the radon contained in the 400 gpm treated by RO - 429 Ci/yr

The calculation follows:

$$1430 \text{ Ci/yr} - 358 \text{ Ci/yr (Wellfield loss)} \times \frac{400 \text{ gpm}}{1000 \text{ gpm}} = 429 \text{ Ci/yr}$$

A summary of the actual Radon releases follow:

	Ci/yr Released
• 3500 gpm upflow	
Plant Vent	2666
Wellfield	889
• 1500 gpm Pressurized downflow	
Plant Vent	115
Wellfield	383
• 1000 gpm	
Restoration	851
TOTAL RADON RELEASE	4904 Ci/yr

Table 7-3(A)- 5: Calculation of Annual Radon Emissions
Crow Butte Project
Case 2 - 2500 gpm Upflow/2500 gpm Pressurized Downflow Satellite

1) To calculate radon release from leaching assuming that U-238 is in equilibrium with all its decay products:

Ci/m^3 = 761 pCi/g ore x 1.89 g/cm^3 x 0.2 x 0.71/0.29 x 10^{-6} = 7.04 x 10^{-4} Ci/m^3

Where:	0.2	=	Emanating Power
	0.71	=	1 - Porosity
	0.29	=	Porosity

The yearly release is then:

7.04 x 10^{-4} Ci/m^3 x 18925 lpm x (0.72) x 365 d/yr x 1.44 = 5042 Ci/yr

Where:	18925	=	liters per minute
	0.72	=	$1\text{-}e^{-(\lambda t)}$
		=	$1\text{-}e^{-(0.1812)(7d)}$
		=	$1\text{-}e^{-(0.28)}$
	1.44	=	constant

2) The radon release from start-up is given by:

7.04 x 10^{-4} Ci/m^3 x 34 acres x 4074 m^2/acre x 1.52 m x 0.29 = 43 Ci/yr

Where:	4074	=	m^2/acre
	1.52	=	Thickness of orebody in meters
	0.29	=	Porosity

The total release of radon from the start-up solution and production lixiviant solution is:

Start-up solution	43	Ci/yr
Production	<u>5042</u>	Ci/yr
	5085	Ci/yr

3) The radon release from restoration is given by:

7.04 x 10^{-4} Ci/m^3 x 3785 lpm x 365 d/yr x (0.99) x 1.44
= 1387 Ci/yr + 43 (start-up) = 1430 Ci/yr

Where:	3785	=	Restoration flow in liter per minute
	0.99	=	$1\text{-}e^{-(\lambda t)}$
		=	$1\text{-}e^{-(0.181)(35)}$
		=	0.99
	1.44	=	constant

The total release from this 34 acre in-situ mining operation is then:

Production	- 5042
Start-up	- 43
Restoration (Includes Start-up)	- 1430
	6515 Ci/yr

4) Actual Radon Release to the Environment

In Case 2 2500 gpm of the flow will be processed by upflow ion exchange columns in the existing plant. It is expected that all contained radon will be released to the environment and that 25% of the radon will be released in the wellfield and 75% will be released in the plant vent. The radon source terms from 2500 gpm will be 2512 Ci/yr from the recovered solution plus 22 Ci/yr from start-up for a total of 2543 Ci/yr. The wellfield release (25%) will be 636 Ci/yr and the plant vent release will be 1907 Ci/yr.

In Case 2 CBR will also have a 2500 gpm flow which will be processed in a satellite plant using pressurized downflow ion exchange columns. Because the columns are operated under pressure only a small amount of radon is released to the environment. The only release to the environment will occur when the resin is transferred to the trailer and during the venting that takes place when the resin is returned to the column after regeneration in the main process facility. The fraction of radon released is conservatively estimated at 10% of the contained radon. The total contained radon will be 2543 Ci/yr and the 10% release will be 254 Ci/yr and the 25% release from the wellfield will be 636 Ci/yr.

The radon release from restoration will be identical to the radon release calculated for Case 1.

A summary of the actual releases to the environment follows:

		Ci/yr Released
2500 gpm upflow		
	Plant Vent	1907 Ci/yr
	Wellfield	636 Ci/yr
2500 gpm Pressurized downflow		
	Plant Vent	254 Ci/yr
	Wellfield	636 Ci/yr
1000 gpm		
	Restoration	851 Ci/yr
TOTAL RADON RELEASE		4284 Ci/yr

Table 7-3(A)- 6: Miscellaneous Data

Fraction of year during which cattle graze locally	Est 33%
Fraction of cattle feed obtained by grazing	Est. 90%
Fraction of stored cattle feed grown locally	Est. 90%
Acreage required to graze 1 animal unit (450 kg) for one month (AUM)	3.5 ha
Length of growing season	4 mo/yr
Fraction of locally produced vegetables consumed locally	Est. 100%
Fraction of locally produced meat consumed locally	Est. 50%
Fraction of locally produced milk consumed locally	Est. 100%

8. ALTERNATIVES TO PROPOSED ACTION

8.1 SUMMARY OF CURRENT ACTIVITY

Crow Butte Resources currently operates the Crow Butte Project, a commercial in-situ uranium leach mining operation located 4 miles southeast of Crawford in Dawes County, Nebraska.

A Research and Development facility was operated in 1986 and 1987. Construction of the commercial process facility began in 1988, with production beginning in April of 1991. The total permit area is 2800 acres and the surface area to be affected by the commercial project will be approximately 500 acres. Facilities include the R&D facility, the commercial process facility and office building, solar evaporation ponds, parking, access roads and wellfields.

Commercial production at the Crow Butte site is expected to be from ten to over twenty years. Aquifer restoration and reclamation will be done concurrent with operations plus an additional three years at the end of the project for final decommissioning activities and surface reclamation.

Uranium is recovered by in-situ leaching from the Basal Chadron Sand at a depth of approximately 400 to 800 feet. The overall width on mineralization in the area ranges from less than 1000 feet to 5000 feet. The ore body ranges in grade from 0.05% to greater than 0.5% U_3O_8 with an average grade estimated at 0.26% equivalent U_3O_8 and 0.31% chemical U_3O_8. Production is currently in progress in Mine Units 2, 3, and 4. Mine Unit 5 is under development. Production has been completed in Mine Unit 1, and partial restoration has taken place.

The in-situ process consists of an oxidation step and a dissolution step. The oxidants utilized in the facility are hydrogen peroxide and gaseous oxygen. A sodium bicarbonate lixiviant is used for the dissolution step. The sodium bicarbonate lixiviant is used at a strength ranging from 0.5 to 5.0 g/l. The hydrogen peroxide or oxygen equivalent is used at a strength ranging from 0.01 to 1.5 g/l.

The uranium bearing solution resulting from the leaching of uranium underground is recovered from the wellfield and piped to the process facility for extraction. The plant process utilizes the following steps:

- Loading of uranium complexes onto an ion exchange resin.

- Reconstitution of the solution by the addition of sodium bicarbonate and oxygen;

- Elution of the uranium complexes from the resin using a sodium chloride/bicarbonate eluant and precipitation of uranium using H_2O_2 and a base;

- Drying and packaging of the uranium.

The current extraction plant is operating at a capacity of 3,500 gallons per minute, excluding any restoration flow. Maximum allowable throughput from the plant is currently 1,000,000 pounds of U_3O_8 per year. Crow Butte Resources has proposed to increase the permitted flow from 3,500 gpm to 5,000 gpm. They have also proposed to increase to maximum allowable throughput to 2,000,000 pounds of U_3O_8 per year.

The operation of the facility results in a number of effluent streams. Airborne effluents are limited to the release of radon-222 gas during the uranium recovery process. Liquid wastes are handled through either evaporation, deep well injection, or land application.

Groundwater restoration activities consist of four steps:

- Groundwater transfer.

- Groundwater sweep

- Groundwater treatment

- Aquifer recirculation

Groundwater restoration will take place concurrently with development and production activities. The goal of the groundwater restoration is to return the water quality of the affected zone to a chemical quality consistent with the quality level specified by the NDEC.

Following groundwater restoration activities, all injection and recovery wells will be reclaimed using appropriate abandonment procedures. In addition, a sequential land reclamation and revegetation program will be implemented on the site. This reclamation will be performed on all disturbed areas, including the plant, wellfields, ponds and roads.

Crow Butte Resources will maintain financial responsibility for groundwater restoration, plant decommissioning and surface reclamation. Currently, an irrevocable letter of credit is maintained based on the estimated costs of the aforementioned activities.

8.2 MINING ALTERNATIVES

Conventional surface or underground mining of the Crow Butte ore deposits 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 makes surface mining impractical. Surface mining is commonly undertaken on large, shallow (less than 300 feet) ore deposits. At the Crow Butte site, uranium is recovered from depths averaging 650 feet.

The physical characteristics of the deposit and overlying materials also make underground mining not feasible for the Crow Butte Project. In addition, the costs of mine development, including surface facilities, shaft, subsurface stations, ventilation system, and drifting would decrease the economic efficiency of this project.

Finally, and perhaps most importantly, as 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 process mining operation economically viable and perhaps the only economical method of mining uranium at this time.

Environmental and socioeconomic advantages of the in-situ leach mining method as compared with underground or open pit methods are:

- Minimal surface disturbance,
- Less solid waste production- no mill tailings,
- Less air pollution,
- Smaller radiological release to the environment- both short and long term,
- Ability to mine a lower grade of ore,
- A modest capital investment,
- Lower manpower requirements and less risk to personnel,
- Ability to return groundwater to pre-mining conditions.

8.3 PROCESS ALTERNATIVES

8.3.1 LIXIVIANT CHEMISTRY

Crow Butte is utilizing a sodium bicarbonate lixiviant which is an alkaline solution. Where the groundwater contains carbonate, as it does at Crow Butte, 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 Crow Butte R&D project and on commercial mining operations to date.

8.3.2 GROUNDWATER RESTORATION

The restoration of the R&D project at the Crow Butte site exhibited 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.

8.3.3 WASTE MANAGEMENT

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 NRC approved facility for disposal. Should a NRC licensed disposal facility not be available to Crow Butte Resources 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.

8.3.4 URANIUM RECOVERY PROCESS ALTERNATIVES

At present, there are no alternatives to the current uranium recovery process that have been shown to be more effective and economically feasible. However, even though the uranium recovery process, sodium bicarbonate lixiviant and current wellfield installation are the most suitable for the Crow Butte site, changes in the environmental, technical, economic and regulatory climate may necessitate changes within the solution mining alternative established at the Crow Butte Project. Should these changes become necessary, proper notification will be made to the regulatory agencies.

8.4 ALTERNATIVE TO NO LICENSING ACTION

If the NRC chooses to deny the renewal of License SUA-1534 for production on a commercial scale, Crow Butte would be forced to decommission and reclaim the site, leaving a valuable mineral unmined. This denial would also result in the loss of large investments incurred to date by Crow Butte Resources for the rights to and development of the site. As Crow Butte Resources currently has contracts for the sale of uranium for critical industries, the denial of the application will impair Crow Butte's ability to deliver on their contracts.

9. BENEFIT-COST ANALYSIS

9.1 GENERAL

The general need for 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. These minimal impacts are justified in terms of the benefits of energy generation, however, it is still appropriate to review the specific site-related benefits and costs of an individual fuel-cycle facility such as the Crow Butte Project.

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. It has been estimated that the combined total of federal, state and local taxes, as well as royalty payments will be approximately $110,000,000 over a twenty year project life. Against these monetary benefits are the monetary costs to the communities involved, such as those for new or expanded schools and other community services. Because of the small number of people who have needed to move into the community to support this project, the impact on the community in terms of expanded services has been minimal, and is expected to remain that way for the remainder of the project life. 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.

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 an constant U3O8 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 the R&D project has demonstrated that the restoration process can meet this criteria successfully.

The radiological impacts of the project are small, with all radioactive wastes being transported and disposed of off-site eventually. Radiological impacts to air and water are also minimal.

10. ENVIRONMENTAL APPROVALS AND CONSULTATIONS

As discussed in Section 1.0, this is a renewal application for Radioactive Source Materials License SUA-1534, originally submitted in September of 1987. All other required permits for the project have been obtained and maintained since that time. A summary of the relevant permits is given below:

Permit or License	Granting Authority
Source Materials License SUA-1534	USNRC
Underground Injection Control Permit	Nebraska DEQ
Permit to Construct Ponds	Nebraska DEQ
Aquifer Exemption	Nebraska DEQ/EPA
NPDES Surface Discharge Permit	Nebraska DEQ
Industrial Groundwater Permit	Nebraska Department of Water Resources
Class I UIC Disposal Well	Nebraska DEQ