UNITED STATES NUCLEAR REGULATORY COMMISSION

ENVIRONMENTAL ASSESSMENT

BY THE

URANIUM RECOVERY FIELD OFFICE

IN CONSIDERATION OF THE ISSUANCE OF

SOURCE MATERIAL LICENSE FOR

WYOMING FUEL COMPANY

CROW BUTTE ISL PROJECT, DAWES COUNTY, NEBRASKA

DOCKET NO. 40-8829

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SUMMARY

This Environmental Assessment was prepared by the staff of the U.S. Nuclear Regulatory Commission (NRC) and issued by the Commission's Uranium Recovery Field Office, Region IV.

1. This action is administrative.

2. The proposed action is the issuance of Source Material and Byproduct Material License SUA-1441 to Wyoming Fuel Company (WFC) for implementation of Crow Butte In Situ Leach Research and Development Project, Docket No. 40-8829, in accordance with the company's statement in its application and accompanying environmental report.

   The proposed project consists of solution extraction (in situ leaching) operations involving uranium ore deposits within the Wyoming Fuel Company, Crow Butte ISL Project site in Dawes County, Nebraska. Research and development activities will include a 100 gallons per minute (gpm) process plant, two small evaporation ponds and two (5) five-spot wellfield patterns within .83 acres (.34 hectares) for the requested authorization. The project has an estimated lifetime of about 24 to 48 months for extraction and restoration operations.

3. Summary of environmental impacts and adverse effects:

   a. The site has historically been used for livestock grazing. The R&D solution extraction project will encompass approximately 6.7 acres (2.7 hectares) on the land surface with less than 1 acre (.42 hectares) subject to intense activity. Less than 1 acre of ground water will be involved in the operation. All disturbed surface areas will be reclaimed and returned to a condition suitable for their original use, livestock grazing.

   b. The long-term effects of the research and development project on ground-water use are expected to be minimal. Ground water in the ore zone within the immediate area of the well pattern is expected to temporarily contain increased concentrations of radioactive and toxic elements during the operation of all wellfields. The restoration goal will be to return this water to baseline conditions on an indicator-by-indicator basis. Surface water will not be affected by normal operations.

c. There are no discharges of liquid effluents from the Crow Butte ISL Project site authorized by the proposed license. Atmospheric effluents are expected to be within acceptable limits, and the effects will be insignificant.

4. The action that the Commission is considering is the issuance of a source material license pursuant to Title 10, Code of Federal Regulations, Part 40. The alternatives available are to issue the license, with the appropriate conditions or to deny the application and not issue the license. The selection of either alternative is based on a consideration of a number of factors related to protection of health, safety, and the environment.

5. This Environmental Assessment will be made available to the public and to government agencies in October 1984.

6 From the analyses and evaluations made in this appraisal, it is proposed that, if a source material license is issued, it contain the following conditions:

(1) Authorized Place of Use: N½SE¼, Section 19, T31N, R51W, Dawes County, Nebraska, approximately 4.5 road miles (7.3 Km) southeast of Crawford and 70 road miles (112.7 Km) north of Scottsbluff.

(2. Authorized Use: For uranium recovery from pregnant lixiviant in accordance with statements, representations, and conditions contained in the licensee's February 11, 1983 Report, enclosed with License Application Form NRC-2, Sections 2.1, 3.1, 3.2, 3.3, 5.1-5.6, 5.7, and 6.0, and in supplements dated July 12, 1983, August 1983, October 1983, October 27, 1983 and April 16, 1984. Wherever the word "will" is used in the licensee's submittals, it shall denote a requirement. Notwithstanding the above, the following conditions shall override any conflicting statements contained in the licensee's application and supplements.

(3) Variation from the sodium bicarbonate-carbonate leach solution with either hydrogen peroxide or oxygen added as proposed by the licensee is prohibited.

(4) The baseline water quality data submitted by the licensee to the NRC and shown in Appendix A of this Environmental Assessment shall be used to establish upper control limits and restoration criteria. Additional preoperational data is needed

to obtain a minimum of three (3) samples for baseline determination in monitoring wells PM-2, 3, 5, 8, 9, 10, and 11, and all proposed production wells in wellfield No. 1 and No. 2 with exception of PT-2, 7, 8, and 9. These wells shall be sampled and analyzed for the chemical indicators given in Appendix A-1A of this EA. The results shall be provided to the USNRC, Uranium Recovery Field Office, as an attachment to the proposed UCL's required in License Condition (8).

(5) The NRC has reviewed and approved the licensee's preliminary restoration plan as discussed in Section 6.1 of their February 11, 1983 Source Material License application. At least ninety (90) days prior to termination of mining activities, the licensee shall submit the specific plan for ground-water quality restoration at the test site including a description of restoration methods, a list of water quality indicators for which the composite restoration stream and representative injection and recovery well water samples are to be analyzed and projected schedule of activity. The licensee shall notify the NRC within thirty (30) days of any subsequent changes in the restoration method. Injection of additional chemical agents is prohibited.

Restoration of the production aquifer ground water and any other ground waters that may be affected by mining operations shall be initiated within sixty (60) days after solution mining operations have been terminated. The goal of restoration shall be to return the ground-water quality, on an indicator-by-indicator basis, to baseline for each monitoring, injection and recovery well. The licensee shall provide written notification to NRC, Uranium Recovery Field Office, that restoration activities are being initiated.

During restoration operations, the licensee shall sample and analyze the composite restoration stream every other week. Sampling and analysis of representative injection or recovery wells in the wellfields shall be done on a monthly basis to monitor differences in the restoration progress within the wellfield. Sampling and analysis of all monitor wells shall continue on a routine operational basis as defined in Condition (7).

(6) The post-restoration monitoring plan shall consist of water sampling and analysis of all production wells, as well as any monitor wells affected by mining operations, for the full suite

of baseline indicators as shown in Appendix A-1A of this EA on a monthly basis for a minimum of six months to document stabilization of the ground-water quality.

(7) Monitor wells PM-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 shall be used for ground water quality monitoring during solution mining operations and during ground-water restoration. The NRC shall require that the excursion indicators for these wells include the following: chloride, conductivity, sulfate, alkalinity and sodium. These wells shall be sampled and analyzed for the excursion indicators biweekly. Water level elevations in these wells shall also be measured, prior to sampling, once every two (2) weeks. Once per quarter, a set of samples from all monitor wells, including the private wells within one (1) km of the restricted area boundary, shall be analyzed for the full suite of baseline indicators as shown in Appendix A-1A of this EA. Results shall be reported graphically and in tabular form in the quarterly reports required in Condition (23).

(8) Upper Control Limit (UCL) criteria to be applied to monitor wells to determine when action must be taken to control excursions during mining shall be based upon the premining baseline water quality data collection outlined in Condition (4). Proposed upper control limits for the excursion indicators listed in Condition (7) shall be submitted to the NRC prior to injection of lixiviant. NRC approval of the UCL's shall be in the form of a license amendment. The upper control limit for each excursion indicator shall be defined, on a well-by-well basis, as the maximum representative baseline water quality value plus 20%.

If two UCL values are exceeded in a well, or if one UCL value is exceeded by 20% of the UCL, the licensee shall take another water sample within twenty-four (24) hours and analyze it for at least the five (5) excursion indicators listed in Condition (7) above. If the second sample does not indicate violation of the UCL's, a third sample shall be taken within fourty-eight (48) hours from the first sample. If neither the second or third sample indicate violation of the UCL's, the first sample shall be considered in error. If the second or third sample indicates a violation of the UCL's, the well in question shall be placed in excursion status. An excursion is confirmed if two or more UCL values are exceeded or if one UCL value is exceeded by 20% of the UCL or more. Corrective

action to mitigate the situation shall be initiated by the licensee when an excursion is confirmed and the NRC shall be notified by telephone within twenty-four (24) hours and within five (5) days in writing from the time the confirmation sample was taken. Corrective actions shall be maintained until the excursion is concluded. In addition to corrective actions, monitoring shall be intensified; sampling frequency and analysis of excursion status wells shall be at least once every seven (7) days for the five (5) indicators listed in Condition (7) above, as long as those wells are on excursion status. An excursion is considered concluded when the concentrations of excursion indicators are below the concentration levels defining an excursion for three (3) consecutive one-week samples.

If corrective actions have not been effective within sixty (60) days of excursion confirmation, the injection of lixiviant shall be terminated in the wellfield on excursion. Resumption of injection at the wellfield shall require NRC approval in the form of a license amendment.

(9) A formal report of events describing the corrective actions taken and detailed graphs and tables of all sample analyses shall be maintained during excursions as described in Condition (8) above to document actions and the ensuing results. This report along with pre-excursion and post-excursion data obtained from the analysis of at least two separate samples taken before and after an excursion, shall be submitted to the NRC as part of the routine quarterly reports required in Condition (23).

(10) Baseline water level elevations for each monitor well shall be defined and submitted to the NRC prior to injection of lixiviant. In addition, prior to injection of lixiviant in the wellfields, the applicant shall circulate ground water through the system to stabilize water levels. The licensee will provide for NRC approval, sufficient data to show water levels have been stabilized. Upon NRC approval of water level stabilization the licensee will monitor water levels in the monitoring wells prior to sampling in accordance with License Condition (7).

Net flow rates for the wellfields shall be recorded whenever monitor well water levels are measured; barometric pressure at the site or vicinity and its effect on water levels shall also be

recorded. Hydrologic monitoring shall continue as described in this condition until restoration of the ore zone begins. An evaluation of the net flow balance, along with water level data, in graphical and tabular form, shall be submitted in a separate section of each quarterly report, as described in Condition (23) below, until the monitoring is discontinued.

(11) The site of the waste storage ponds shall be that site investigated in the report entitled, "Soils Engineering Report, Wyoming Fuel Company, Crow Butte Project, Pilot Test Pond Area," by Fisher, Harden and Fisher, dated December 1982.

(12) The licensee shall construct, operate and maintain the waste pond system in accordance with the statements, drawings, conclusions, specifications and recommendations in the licensee's October 1983 response to questions on Section 4.2 of their license application. Any waste disposal technique other than the waste storage ponds, as described above, will require prior NRC approval by license amendment.

(13) The licensee shall notify the Uranium Recovery Field Office, USNRC, Denver, Colorado, at least three (3) weeks prior to the completion of construction of the ponds to provide adequate time for on-site inspections by the NRC. The licensee shall also submit a report detailing the construction methods, construction controls, quality assurance programs, and testing methods that were actually utilized in the construction of the ponds and the installation of the leak detection system and liner. This report shall also provide locations of field tests and all test results obtained during construction and as-built drawings showing details of construction of the various components of the pond.

(14) The licensee shall at all times maintain sufficient reserve capacity in the evaporation pond system to enable the transfer of the contents of a pond to other ponds in the event of a leak. In the event of a leak and subsequent transfer of liquid, the freeboard requirements outlined in the licensee's responses to NRC questions on Section 4.2 of the application dated October 1983, shall be discontinued while the liner is being repaired.

(15) The volume of discharges to the evaporation ponds shall be recorded. In addition, quarterly grab samples of the discharge shall be analyzed for calcium, chloride, bicarbonate,

sodium, uranium, radium-226, sulfate and TDS. These analyses shall be reported in the quarterly report.

(16) The licensee shall perform daily visual inspections of all evaporation pond embankments, daily measurements and recording of pond freeboard and daily checks of the leak detection system. Any fluid detected in the standpipes of the pond leak detection system shall be analyzed for calcium, chloride, alkalinity, sodium, uranium, sulfate, and TDS. Should analyses indicate that the pond is leaking, the NRC, Uranium Recovery Field Office, shall be notified by telephone within forty-eight (48) hours of verification and the pond level shall be lowered by transferring its contents into the other cell so that repairs can be made. Water quality samples taken at the standpipe shall be analyzed for at least chloride and TDS at least once every seven (7) days during the leak period and once every seven (7) days for at least two weeks following repairs, if any liquid is detected in the standpipes. Additionally, water samples collected at the standpipe shall be analyzed for all eight (8) parameters above at least once per month during the leak period.

A written report shall be filed with the NRC, Uranium Recovery Field Office, within thirty (30) days of first notifying the NRC that a leak exists. This report shall include all available analytical data and shall describe the action taken to stop the leak and the results of that action.

(17) The licensee shall immediately notify the Uranium Recovery Field Office, P.O. Box 25325, Denver, Colorado 80225, by telephone within fourty-eight (48) hours, of any failure of an evaporation pond, any break or rupture of any pipeline, or any similar failure of any other fluid or material conduit or storage facility which results in an uncontrolled release of radioactive materials, or of any unusual conditions which if not corrected could lead to such a failure. Such notification shall be followed, within seven (7) days, by submittal of a written report detailing the conditions leading to the failure or potential failure, corrective actions taken, and results achieved. This requirement is in addition to the requirements of 10 CFR Part 20.

(18) Final disposition of radioactive solid process and evaporation pond residues (byproduct material) shall be at a licensed radioactive waste disposal site.

(19) The uranium recovery plant shall be operated at a maximum flow rate of one-hundred (100) gallons per minute.

(20) Further treatment of the yellowcake slurry such as heat or vacuum drying is prohibited.

(21) The licensee shall conduct mechanical well integrity tests on each injection or recovery well before each well is put into service. The mechanical well integrity tests shall be conducted in accordance with the Nebraska Department of Environmental Control (DEC) permit. If any well casing failing the integrity test cannot be repaired or corrected, the well shall be plugged and abandoned in accordance with the Nebraska DEC permit. The results of the well integrity tests shall be submitted to the NRC prior to wellfield operation and injection of lixiviant.

(22) Flow rates on each injection and recovery well and manifold pressures on the entire system shall be measured at least once per day and recorded on a daily operational log. During wellfield operations, injection pressures shall not exceed the integrity test pressure at the injection well heads.

(23) A quarterly report shall be submitted to the NRC, Uranium Recovery Field Office, that summarizes the status of the R&D in situ test program, with supporting analytical data and evaluations regarding important environmental aspects of the operations such as water quality and water level data, lixiviant migration control, waste generation volumes, volumes and representative chemical analyses of injected lixiviant and pregnant solution produced. The quarterly report shall also contain the production data for the R&D facility. For the first two quarters, the operational data sheets, including such data as flow rates, chemical balance and injection pressures shall be included as an attachment to the quarterly report. The remaining quarterly reports will summarize the operational data, with the operational data sheets maintained on site. The Nebraska DEC Mining Monitoring Report (Figure 3.3.05) can be utilized as part of the quarterly report for the operational data. The quarterly report shall include all data on environmental monitoring as well as ground-water data. All water quality and water level data shall be presented in tabular and graphical form, with a written summary explaining what the data show.

(24) Any surface discharge of liquids is prohibited.

(25) This license shall not be terminated until the NRC has determined that all site reclamation, decommissioning, and wellfield restoration have met all applicable standards and regulations.

(26) All sampling and monitoring data, calibration records, reports on audits, inspections, and other analyses, training records, and safety meeting minutes, as well as any subsequent reviews, investigations, and corrective actions, shall be documented. Unless otherwise specified in the U.S. Nuclear Regulatory Commission regulations, all such documentation shall be maintained for a period of at least five (5) years.

(27) The licensee shall notify , in writing, the U.S. Nuclear Regulatory Commission, Uranium Recovery Field Office, P.O. Box 25325, Denver, Colorado 80225, at least six (6) weeks prior to commencing mining operations so that an NRC inspection may be conducted to review the licensee's development and implementation of administrative and operating procedures and monitoring programs.

(28) The licensee shall perform monthly surveys for natural uranium in the restricted area with the exception that they shall be increased to weekly for any area meeting the requirements of an "airborne radioactivity area" as described in 10 CFR Part 20.203(d), and an investigation of the cause of any high levels shall be made. Records shall be maintained of these investigations and results be furnished to the NRC in the quarterly reports described under License Condition (23).

The licensee shall perform monthly surveys for radon or radon progeny in the restricted area inhabited by workers with the exception that radon or radon progeny surveys shall be increased to weekly if the radon or radon progeny concentrations are found to exceed 8 pCi/l or 0.08 WL (Working Levels), respectively. Such weekly sampling shall be maintained until four (4) consecutive weekly samples exhibit less than 8 pCi/l or 0.08 WL. The licensee shall also be required to monitor on a monthly basis radon concentrations at and near the site boundary. Prior to commencing operations and within sixty (60) days of the issuance of this license, the licensee shall submit to the Uranium Recovery Field Office, for NRC review and approval in the form of a license amendment,

the designated locations for surveys of airborne natural uranium and radon or radon progeny.

The calculation of internal exposure to radon, radon progeny, or natural uranium shall be based on a Time Weighted Exposure (TWE) calculation incorporating a consideration of both occupancy times and average airborne working levels or activity concentrations. If occupancy times are established as an average for each category of worker, the licensee shall also, by means of a semiannual time study, determine the basis upon which average occupancy periods are established.

If any worker reaches or exceeds 25 percent of the maximum permissible exposure limits as specified in 10 CFR Part 20 based upon a calculated TWE for the week or the calendar quarter, dependent on the solubility of the material, the Health Physics Technician (HPT) shall initiate an investigation of the employee's work record and exposure history to identify the source of the exposure.

Necessary corrective measures shall be taken to ensure reduction of future exposures to as low as is reasonably achievable. Records shall be maintained of these investigations and results furnished to the NRC in the quarterly reports described in License Condition (23).

(29) Any changes in the process flow sheet, illustrated and described in Figure 3.1-6 of the license application dated February 11, 1983, shall require the approval of the Corporate Radiation Safety Officer (CRSO) and shall be submitted to the U.S. Nuclear Regulatory Commission, Uranium Recovery Field Office, for prior approval in the form of a license amendment.

(30) Release of equipment, materials, or packages from the restricted area shall be in accordance with "Annex C - Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of License for Byproduct, Source, or Special Nuclear Material," dated November 1976.

(31) All radiation monitoring, sampling, and detection equipment shall be recalibrated after each repair and as recommended by the manufacturer or at least semiannually, whichever is more frequent. In addition, all radiation survey instruments shall

be operationally checked with a radiation source before each use.

(32) The licensee is hereby exempted from the requirements of Section 20.203(e)(2) of 10 CFR 20 for posting areas within the facility, provided that all entrances to the restricted area are conspicuously posted with the words, "CAUTION - ANY AREA OR ROOM WITHIN THIS FACILITY MAY CONTAIN RADIOACTIVE MATERIAL."

(33) The licensee shall maintain a quality assurance program for all sampling and analyses performed as part of the in-plant radiation safety, ground-water and environmental monitoring programs that includes all of the recommended elements of a quality assurance program specified in USNRC Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Stream and the Environment." In addition, prior to commencing operations and within ninety (90) days of issuance of this license, the licensee shall submit to the USNRC, Uranium Recovery Field Office, for approval in the form of a license amendment, complete specifications for this quality assurance program.

(34) Prior to operation of wellfield No. 1, the licensee shall submit for NRC review and approval the location of two observation wells to be used to observe restoration along peripheral streamlines and contaminant transport outward along a path midway between production wells. The observation wells will be at least four (4) inches in diameter and screened over the same interval as the production wells. Baseline water quality data for the observation wells will be collected and analyzed in accordance with the requirements of License Condition (4). During restoration the licensee shall sample the observation wells every other week for the first four months and monthly thereafter. These observations well samples shall be analyzed for a minimum of conductivity, pH, alkalinity, sodium, sulfate, chloride. If restoration monitoring of these observation wells indicates that restoration has not been achieved at the completion of the proposed restoration program, the licensee will be required to drill additional wells and design a new pumping-injection scheme to restore the aquifer. The NRC will review and approve the location of the new wells and the new pumping and injection scheme prior to implementation.

(35) The NRC has reviewed and concurred with the Nebraska Department of Environmental Control's surety cost estimate for restoration of the Crow Butte site. The licensee shall maintain a surety to cover all ground-water restoration and all reclamation and decommissioning, including the cost of offsite disposal of radioactive solid process or evaporation pond residues and a decontamination survey. Surety arrangements covering the cost of restoration of Crow Butte ISL Site and the costs of decontamination, decommissing, and reclamation of above-grade facilities shall be provided by Nebraska DEC Bond. The licensee will submit to the NRC a copy of the surety bond prior to beginning operations. At least ninety (90) days prior to the expiration date of existing Nebraska DEC Bond or of any subsequent sureties, or any revision to existing surety arrangements, the licensee shall submit a copy of the proposed new surety or revision, and supporting documentation providing a detailed basis for the covered restoration, reclamation and decommissioning costs, to the NRC, Uranium Recovery Field Office, for review and approval. Surety arrangements shall be updated at least annually to account for inflation.

7. The position of the NRC is as follows:

Solution extraction of uranium is a developing technology. Uncertainties regarding environmental impacts, particularly with respect to ground-water contamination and the effectiveness of ground-water restoration techniques, have been recognized. Testing and data collection in a research and development project is proposed by the applicant to reduce the uncertainties. The scope of an R&D facility is sufficiently limited in size to enable continued development of solution mining technology without significant environmental risk.

1. INTRODUCTION

1.1 Background

Wyoming Fuel Company applied to the NRC for an NRC Source Material and Byproduct Material License to construct and operate an in situ leach uranium extraction and recovery facility in Dawes County, Nebraska. The project, known as the Crow Butte ISL Project, is a research and development (R&D) project designed to develop the environmental parameters and operating characteristics expected for a full-scale commercial operation.

The Crow Butte ISL Project R&D site consists of about 6.7 acres (2.7 hectares) situated in west central Dawes County, Nebraska, approximately 4.5 miles (7.3 km) southeast of Crawford and 70 miles (112.7 km) north of Scottsbluff (Figure 1.1.01). Wyoming Fuel Company controls the uranium mineral rights underlying these lands.

Wyoming Fuel Company proposes to extract uranium contained in the basal sandstone member of the Chadron Formation from a wellfield less than one (1) acre (.4 hectares) in size. The basal Chadron is a 40-foot (12 m) thick unit lying at a depth of approximately 620 feet (189 m). During the extraction process, an aqueous solution of sodium bicarbonate and an oxidizing agent (hydrogen peroxide or oxygen) will be injected into, and then recovered from, the uraniferous basal sandstone member through two (2) five-spot well patterns. Each five-spot pattern will consist of four (4) injection wells surrounding a central recovery well.

The process plant will be designed to operate at a maximum capacity of 100 gpm (378 l/min), but will be initially operated well below this level.

Wyoming Fuel Company has stated in an amendment to their application dated October 27, 1983, that the ultimate restoration goal is to return ground-water quality to baseline using the best practical technology.

1.2 Proposed Action

By Form NRC-2 to the U.S. Nuclear Regulatory Commission (NRC) dated February 11, 1983, Wyoming Fuel Company requested a license to receive, possess, use, and transfer source material and byproduct material in the course of research and development work associated with in situ extraction of uranium at their Crow Butte ISL Project site in Dawes County, Nebraska.

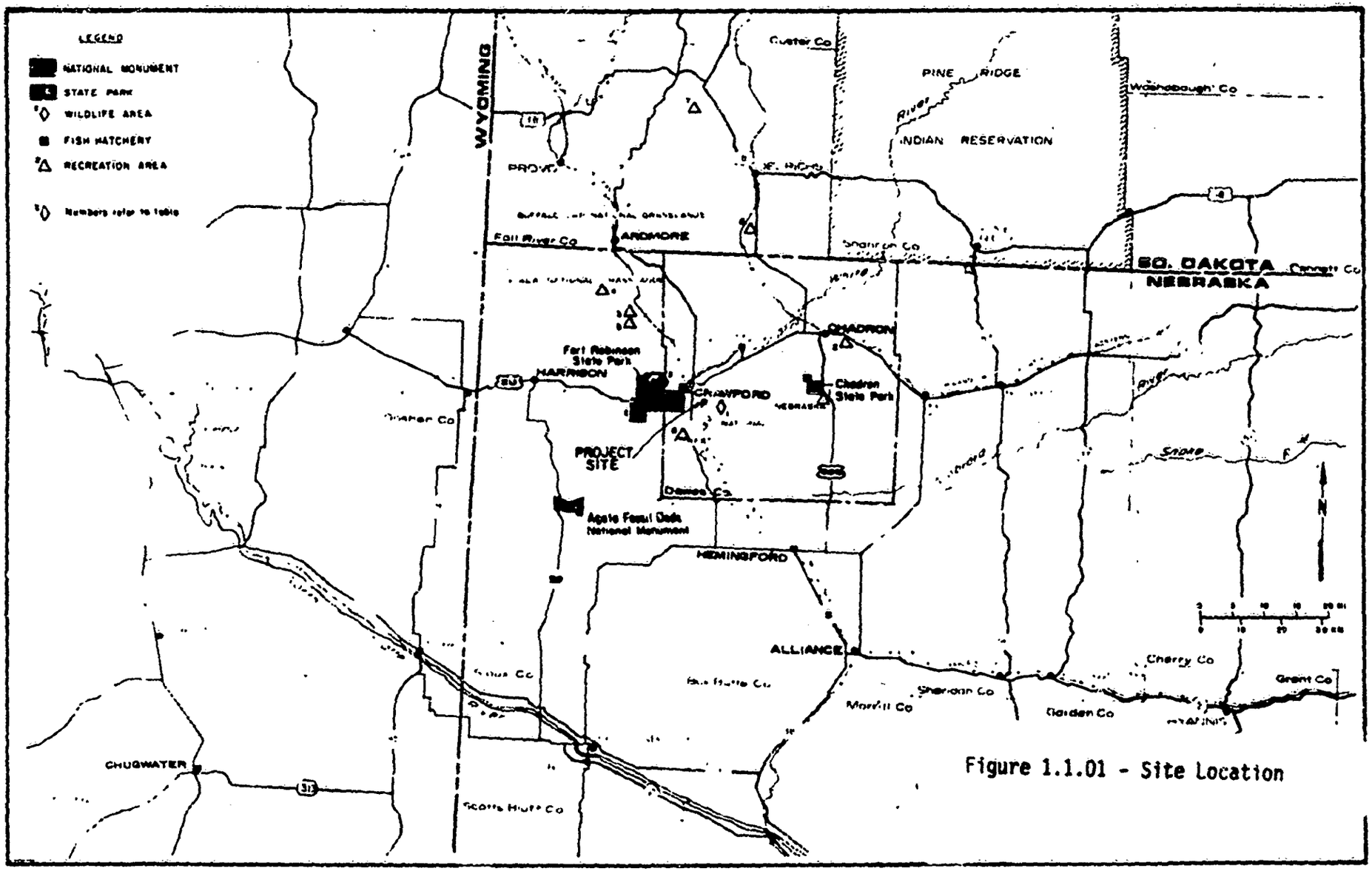


Figure 1.1.01 - Site Location

The purpose of their proposal is:

- To evaluate the feasibility of different well spacings in the in situ extraction of uranium from the Chadron Formation.
- To develop site-specific restoration methods which suit both environmental and economic needs.
- To test potential leach chemistries which could be used in a commercial operation.

This Environmental Assessment (EA) discusses the environmental and safety aspects of the application proposal. The proposed action would be to grant a license to Wyoming Fuel Company.

1.3 Review Scope

1.3.1 Federal and State Authorities

Under 10 CFR Part 40, a NRC license is required in order to "...receive, possess, use, transfer...any source material..." (i.e., uranium and/or thorium in any form, or ores containing 0.05% or more by weight of those substances). In addition, the Uranium Mill Tailing Radiation Control Act of 1978 (UMTRCA) requires persons who conduct uranium source material operations to obtain a byproduct material license to own, use, or possess tailings and wastes generated by the operation (including aboveground wastes from in situ operations). This environmental assessment has been prepared under Title 10, CFR Part 51. In accordance with 10 CFR Part 51, an EA serves to (a) briefly provide sufficient evidence and analysis for determining whether to prepare an environmental impact statement or a finding of no significant impact, (b) aid the NRC's compliance with NEPA when no environmental impact statement is necessary, and (c) facilitate preparation of an environmental impact statement when one is necessary. Should the NRC issue a finding of no significant impact, then a license would ordinarily be issued, everything else being equal. The proposed action is for a source material and byproduct material license for WFC's proposed research and development facility only. Should such a license be issued and should the R&D facility be successfully operated and restored, it is reasonable to assume that WFC would want to develop a commercial operation. In such an event, a new licensing request would have to be

made to the NRC requiring a new indepth environmental evaluation in accordance with NEPA before the license could be issued.

The State of Nebraska Department of Environmental Control administers and implements the State's rules and regulations. Wyoming Fuel Company has applied for and will be required to receive a permit from the State of Nebraska prior to operation of the proposed facility.

1.3.2 Basis of NRC Review

An impact appraisal for the licensing has been performed by Region IV, Uranium Recovery Field Office of the NRC. This report documents that appraisal. The staff has performed the appraisal of environmental and safety considerations associated with the proposed license in accordance with Title 10, Code of Federal Regulations (10 CFR Part 51, Licensing and Regulatory Policy and Procedures for Environmental Protection).

In conducting this appraisal, the staff considered the following:

- Environmental information submitted by the applicant to the NRC dated February 11, 1983 to support the application for a license;
- Information supplied in discussions with the State of Nebraska Department of Environmental Control relating to state permitting actions;
- Site visit by NRC staff on July 7, 1983;
- Additional information submitted by the applicant, dated July 12, 1983, August 1983, October 1983, October 27, 1983 and April 16, 1984.
- Information derived from professional papers, journals and text books; U.S. NRC Regulations and Regulatory Guides; as well as other Federal, State and local agencies, and independent consultants (Appendix E).

2. SITE DESCRIPTION

2.1 Location and Land Use

The proposed R&D license area is located in Dawes County, Nebraska, approximately 4.5 miles (7.3 km) southeast of Crawford and 70 miles (112.7 km) north of Scottsbluff (Figure 1.1-01).

The land at the proposed test site area and in the vicinity has historically been used for cattle and sheep grazing. The cultivated lands adjacent to the permit area are primarily used for production of winter wheat, alfalfa, and oats. Wyoming Fuel Company (WFC) holds claims or lease-hold interests of the surface and use rights along with uranium mineral rights within the proposed license area. After mining, he land will be reclaimed and returned to its original use as livestock grazing land.

The total surface area of the project site is approximately 6.7 acres (2.7 hectares). Total area of the wellfield will be .83 acres (.34 hectares). The total surface disturbance at the project site will be less than 1 acre. The solar evaporation ponds will represent the major part of the disturbed area. The access road, parking lot, storage tanks, pipelines, storage building, and wellfield area will account for a lesser amount of disturbance.

2.2 Geology and Hydrogeology of the Ore Body

2.2.1 Geologic and Hydrogeologic Setting

The R&D site is located in northwest Nebraska, approximately 4.5 miles (7 3 km) southeast of Crawford, in the N/2 SE/4 of Section 19, Township 31 North, Range 51 West, Dawes County, Nebraska (Figure 2.2.1-01). The topography consists of low rolling hills of the Missouri Plateau dominated by the north facing cuesta scarp known as the Pine Ridge located south and west of the site. Relief along the escarpment reaches a maximum of 700-800 feet south of Crawford and diminishes east and west of that point. The average relief is between 300-400 feet (91.4-121.9 m). The Pine Ridge serves to divide the Great Plains into two subdivisions, the High Plains south of the ridge and the "unglaciated Missouri Plateau" north of the ridge. Two major watersheds, Hat Creek and White River, drain the area north of the Pine Ridge. The proposed site lies within the White River watershed. The White River heads in east-central Sioux County and drains an area of 600 square miles.

The major structural feature of Dawes and northern Sioux Counties is the Chadron Dome or Arch (Figures 2.2.1-02 and 2.2.1-03), which is surficially expressed in northeastern Dawes County. The Chadron Arch is the most prominent stuctural expression in northwest Nebraska. The anticlinal feature strikes roughly northwest-southeast along the northeastern boundary of Dawes County, but much of the structure is buried by rather flat lying Miocene aged rock. The Black Hills lie just 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 features presently observed in the area today.

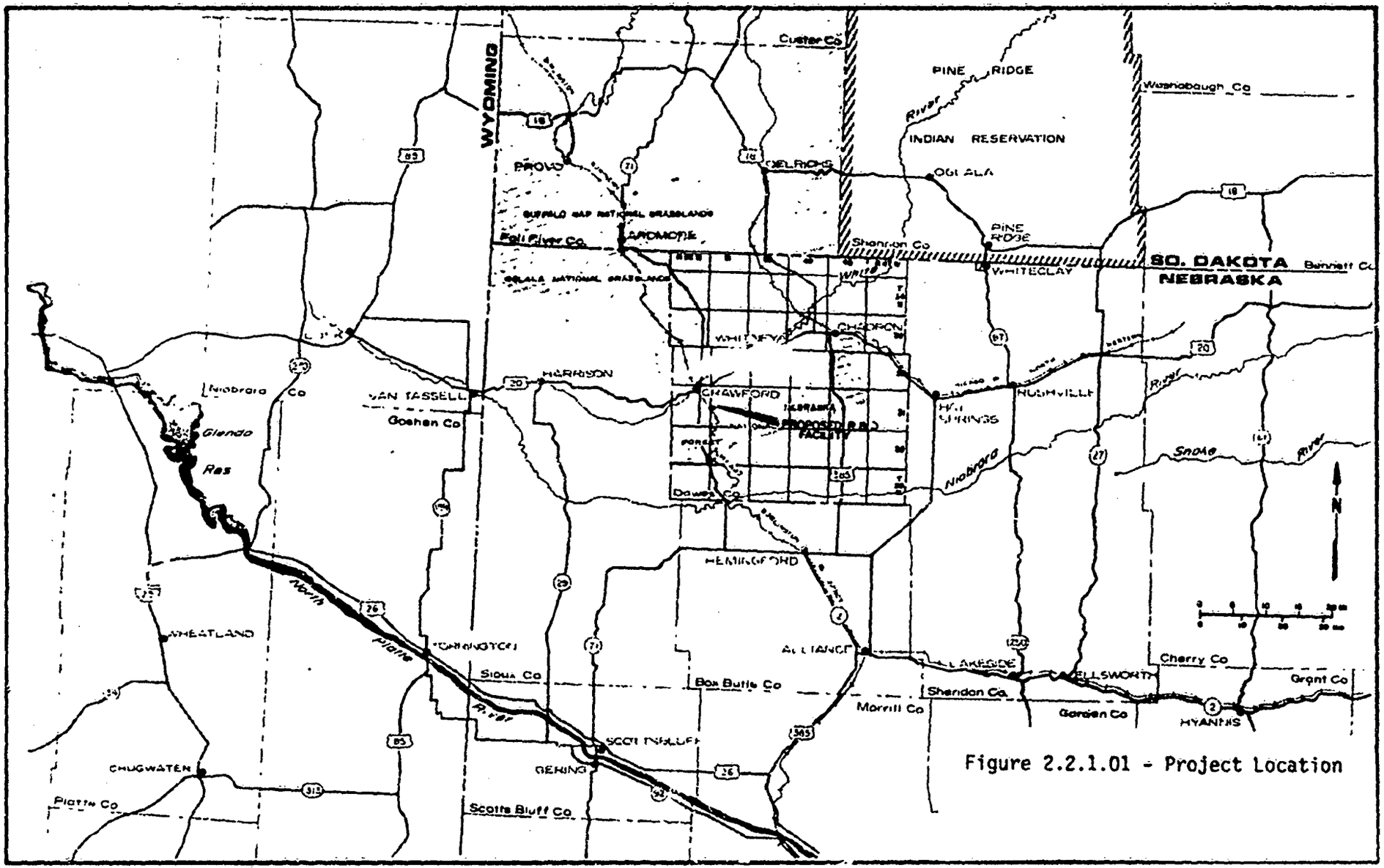
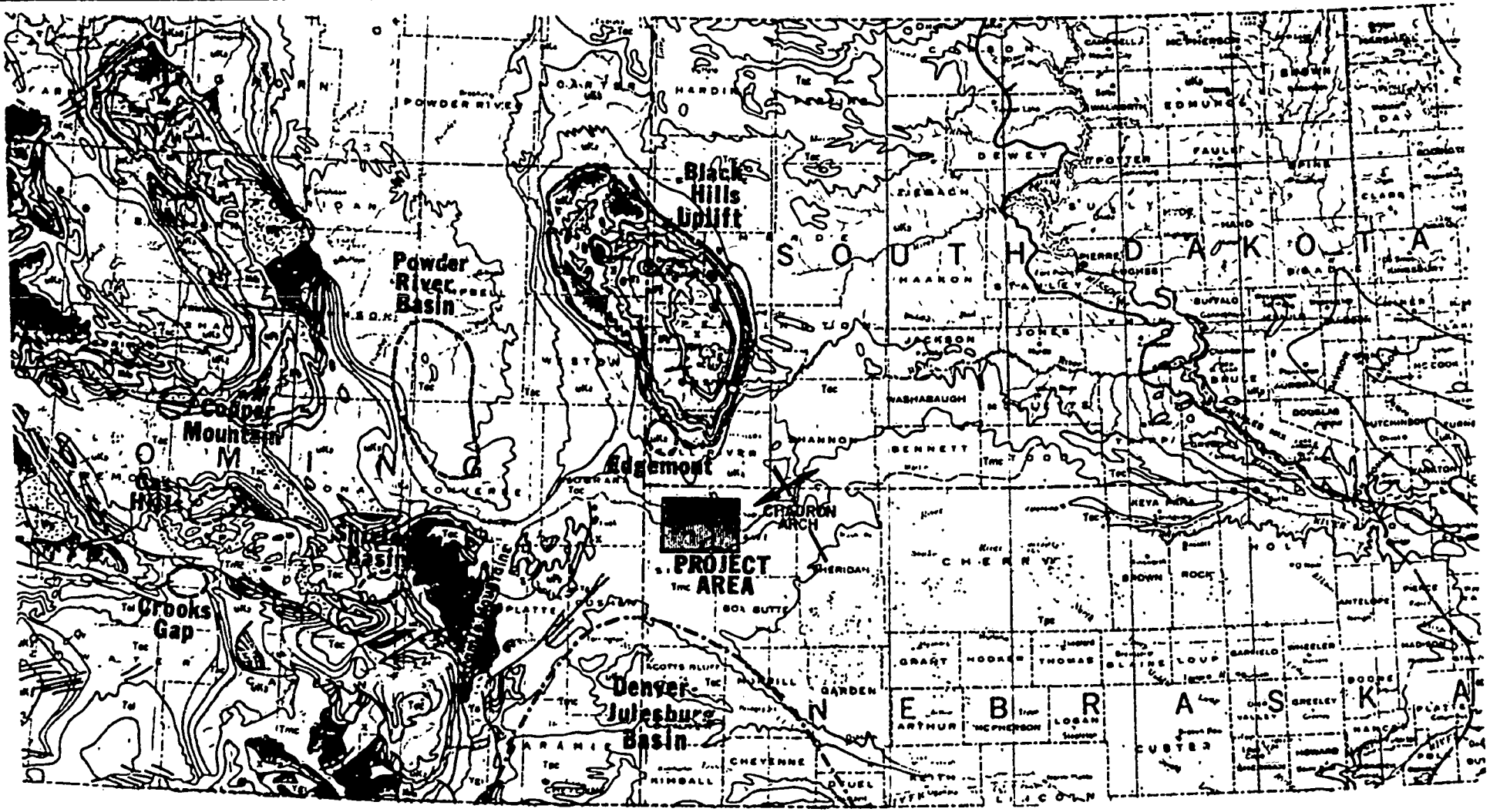


Figure 2.2.1.01 - Project Location



LEGEND

Uranium Districts

Structural Feature

Tpc Pliocene continental deposits includes Ogallala Formation

Tmc Miocene continental deposits includes Arikaree Group

Toc Oligocene continental deposits includes Chadron and Brule Formations

uK3 Upper Cretaceous Taylor Group includes Pierre Shale

Scale

1"=Approx.63mi.

N

Printed from
GEOLOGIC MAP of the UNITED STATES
1974

Figure 2.2.1.02 -

Regional Geologic Map

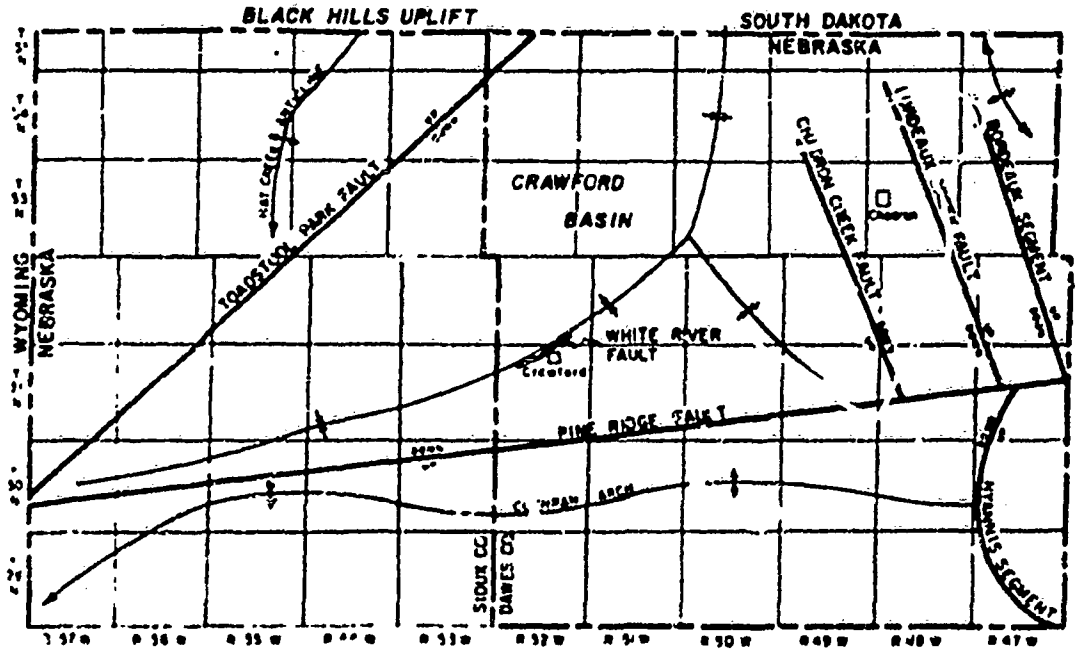


Figure 2.2.1.03 - Structural Geology

Within the site area, the southerly dip of the Mesozoic, Paleozoic, and to a lesser extent, the Tertiary beds, are directly related to uplift as late as Late Pliocene in the Black Hills.

The Crow Butte ore body lies in what has been named the Crawford Basin, as defined by detailed studies of pre-Tertiary subsurfaces in western Nebraska using primarily deep well information (DeGraw,1969). The Crawford Basin is defined as being a triangular asymmetrical basin bounded by the Chadron Arch (as previously discussed) and Bordeaux fault to the northeast and east, the Toadstool Park Fault to the northwest, and the Pine Ridge Fault and the Cochran Arch to the south. Structurally, it may be thought of as a pre-Miocene graben downthrown several hundred feet, although there are several structural highs recognized within the basin. The synclinal axis of the Crawford Basin trends approximately east-west and plunges to the west. The inner portion of the basin is characterized by a rather sharp paleotopographic change in the Pierre shale with dramatic increase in the thickness of the basal Chadron sandstone. To the east the plunging syncline is sharply truncated.

The Toadstool Park Fault, where it outcrops northwest of Crawford, strikes N 45° E and dips southeast at about 80°. The fault is normal with the southeastern side downdropped with a throw of 64 feet. Subsurface data from Sioux County indicates a total displacement of 600-800 feet. To the southwest, the fault is covered by Miocene deposits of the Arikaree Group which cap the Pine Ridge Escarpment. The Bordeaux Fault is a subsurface feature along the western flank of the Chadron Arch. DeGraw (1969) estimated a throw of 300-1200 feet on the western downthrown side of the fault. The strike of the Bordeaux Fault is approximately N 20°W. The pre-Miocene Cochran Arch trends east-west through Sioux and Dawes Counties and runs south of and parallel to the Pine Ridge Fault. The arch is best developed in Sioux county, where structural relief is perhaps 200-400 feet.

Sedimentary strata within the Crawford Basin range in age from late Cretaceous through Tertiary (Figure 2.2.1-04). Pleistocene alluvial and colluvial material are abundant along the north slope of the Pine Ridge. The Pierre Shale of late Cretaceous age is the oldest formation encountered in the site area. In general, the Pierre is a widespread unit of dark gray to black marine shale with a number of included bentonite seams in its upper portion. In Dawes County, deep oil tests have indicated thicknesses of 1200-1500 feet. Aeral exposure and subsequent erosion greatly reduced the vertical thickness of the Pierre prior to Oligocene sedimentation. Consequently, the top of the present day Pierre contact marks a major unconformity and exhibits a

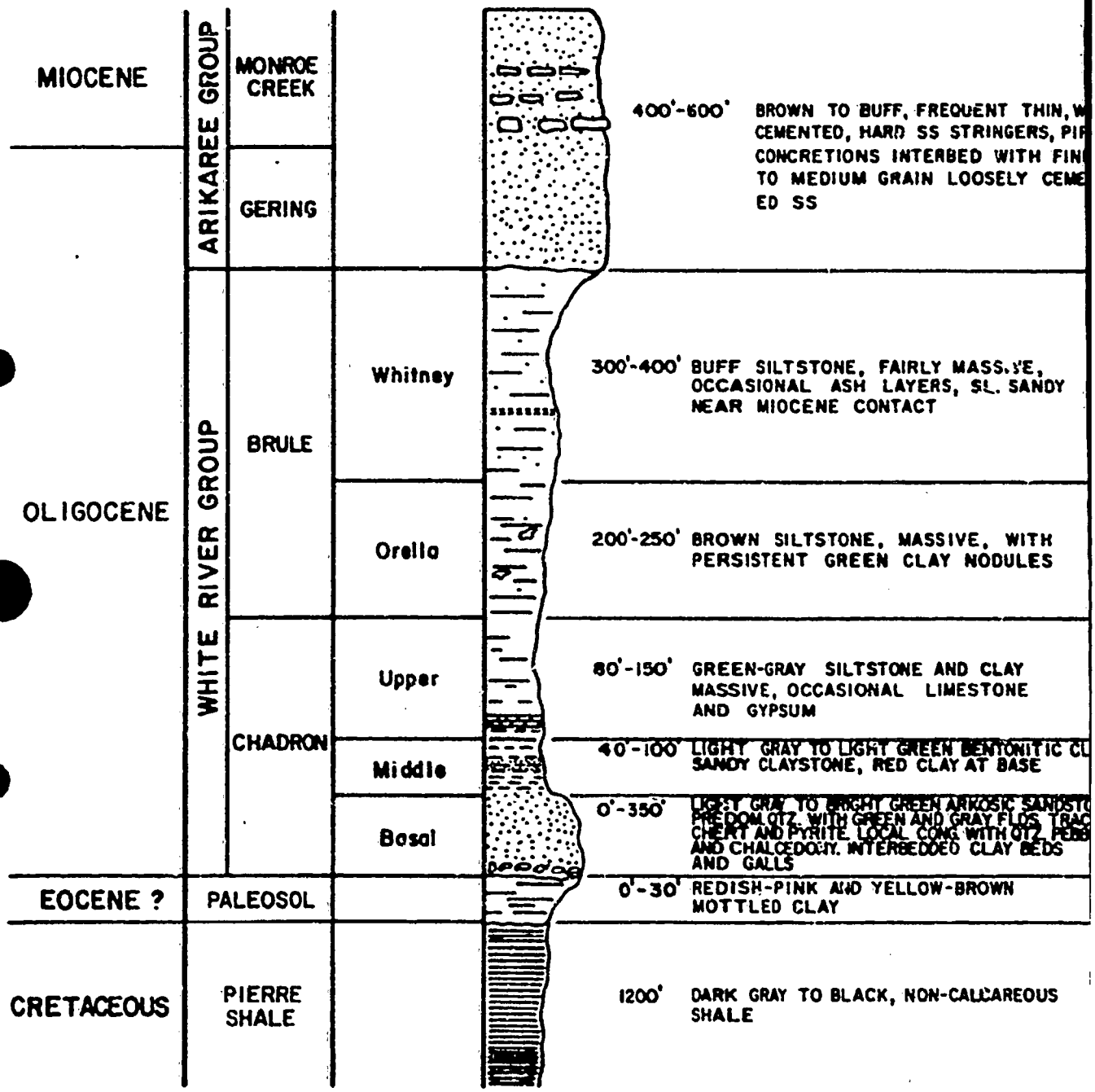


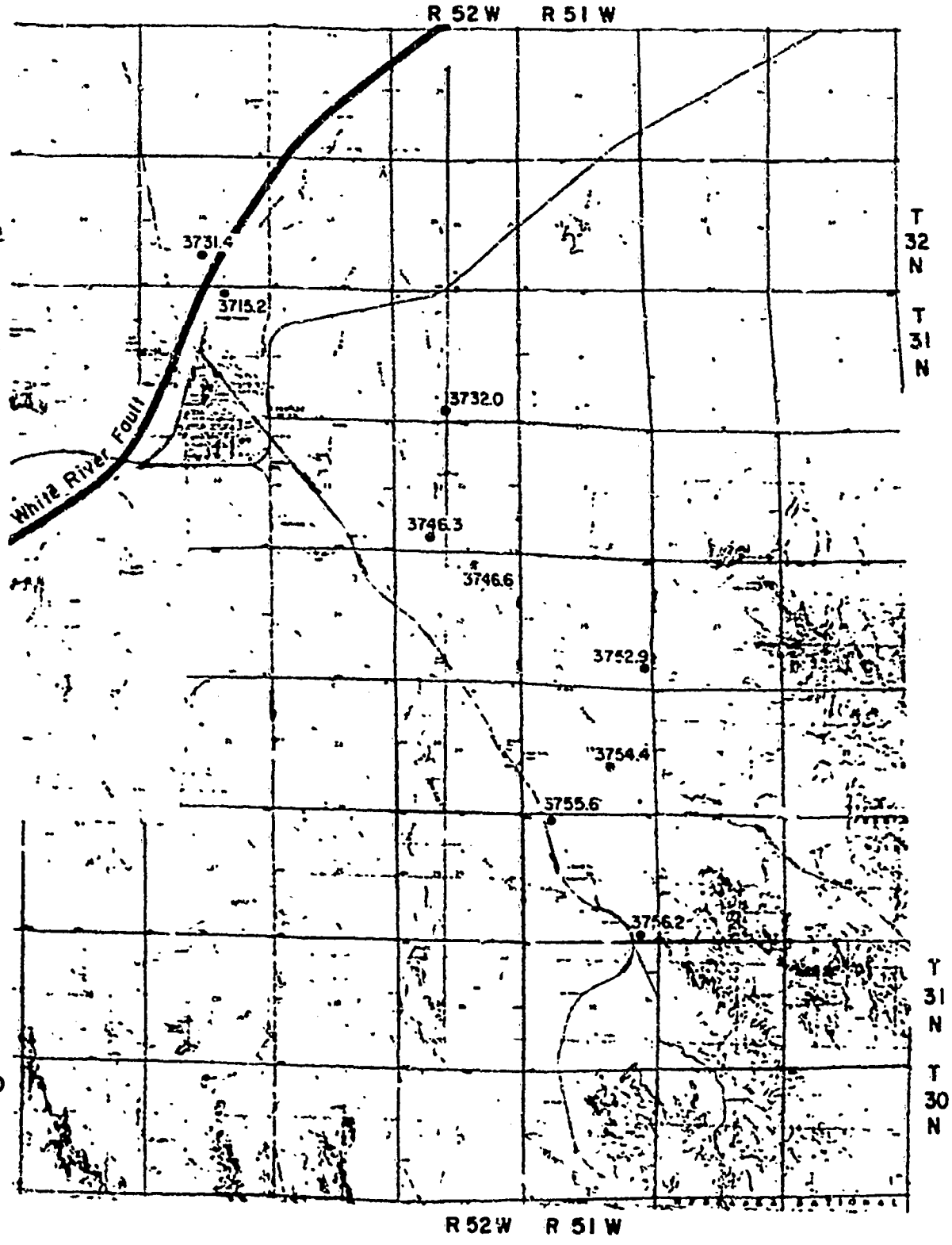
Figure 2.2.1.04 - Stratigraphic Column

paleotopography with considerable relief. 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. This Paleosol was scoured away during the deposition of the overlying basal Chadron sandstone and is non-existent within the site area. The Pierre is essentially impermeable, to the degree that in areas of outcropping Pierre, water for domestic and agricultural needs is piped in from wells from other formations. Surface expression of the Pierre Shale occurs north of the White River Fault and northeast of Crawford. The Pierre Shale is not considered to contain aquifers of any importance in this region Because of its nonpermeable nature it also serves as an aquiclude preventing vertical migration of water.

The White River Group is Oligocene in age and consists of the Chadron and Brule Formations. The Chadron is the oldest Tertiary formation of record in northwest Nebraska. It lies with marked unconformity on top of the Pierre shale. The Chadron Formation is comprised of three distinct members. The Basal Sandstone is the depositional product of a large, vigorous braided stream system which occurred during early Oligocene Regionally, the Basal Sandstone thickness ranges from 0 to 350 feet, but in the site area the vertical thickness is 40 feet. In the site area, the Basal Chadron is a coarse grained arkosic sandstone with frequent interbedded thin clay and silt lenses. The clay and silt lenses represent flood plain or low velocity deposits which normally occur during fluvial sedimentation. X-ray diffraction of the Basal Chadron have identified the following clay minerals. kaolinite, illite, smectite and expandable mixed illite-smectite. The basal Chadron sandstone is the host member of the Crow Butte uranium ore deposit and the only aquifer in the Chadron Formation The Nebraska Department of Environmental Control classifies the basal Chadron aquifer as an underground source of drinking water.

The Basal Chadron aquifer is artesian and wells from the White River fault to about 3000 m south may be free flowing at the surface. The direction of ground-water migration in the area is north toward the fault (Figure 2.2.1-05).

The Middle Chadron Member represents a distinct and rapid facies change from the underlying basal sandstone. The lower portion of the Middle Chadron is characterized by a brick red clay. This grades upward into light to medium green clay with dispersed very fine sand grains. The lower red clay is frequently interbedded with gray-white bentonitic clay. The Middle Chadron Member has been observed in virtually all drill holes along the mineral trend but is less likely to occur in drill holes outside the Basal Sandstone channels. Thickness of the Middle Chadron averages 65 feet throughout the site area.



3742.1 Water Level - MSL (feet)
Measured 9/82 to 9/83 (avg.)

Scale 1:72,000
1" = 6000'

0 2000 4000 6000 8000 10,000 Feet

0 1/2 1 2 Miles

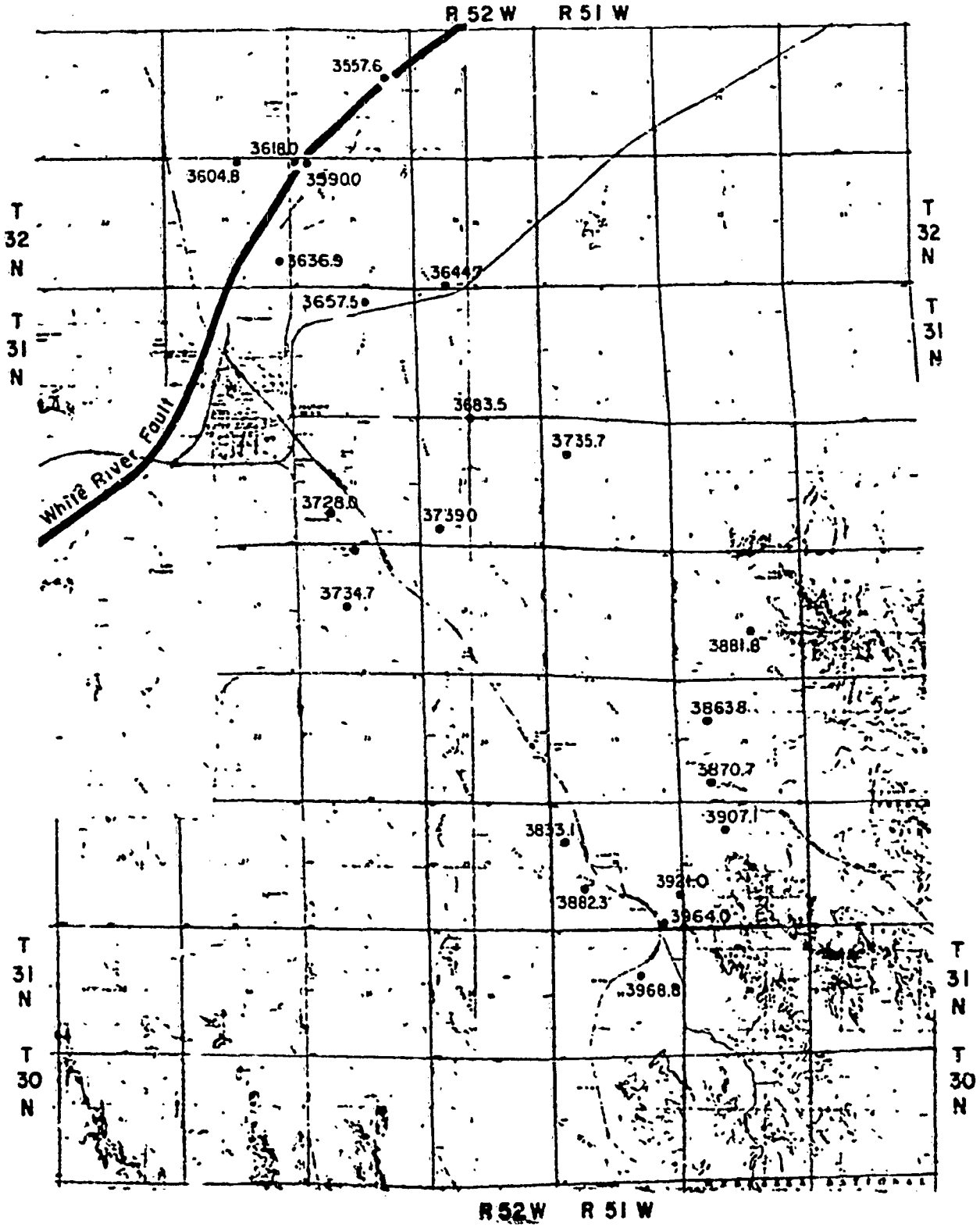
N

Figure 2.2.1.05 - Water Level Map: Chadron Formation

The Upper Chadron consists of massive claystones and siltstones. These range in color from a dark blue-green to greenish-brown. The sequence of green siltstones and mudstones is generally considered fluvial channel and flood plain deposits with limited lacustrine and eolian material present. Well developed sand channels are rarely encountered in test holes, and have very limited lateral extent when observed. The Upper Chadron averages 150 feet thick within the site area.

The Brule Formation lies conformably on top of the Chadron Formation and with the Chadron comprises the White River Group. The Brule has been subdivided into two separate members. the Orella and the Whitney. The Orella lies directly on the Chadron Formation. An approximate Brule-Chadron contact can be detected in drill hole cuttings but not usually in geophysical logs. The Orella is composed of buff to brown siltstones, with persistent spotty green nodules as it grades into the green clays of the Chadron. The Whitney Member of the Brule is comprised of fairly massive buff to brown siltstones, in part probably eolian in origin. Several volcanic ash horizons have been reported in outcrops. The Whitney Member frequently becomes coarser grained upward near the Miocene contact. Some moderate to well defined channel sands can be observed in both drill holes and in outcrops. These Upper Brule channels are limited in lateral extent and continuity but may occasionally be water saturated in the otherwise generally impermeable Brule. Within the site area these sand units are encountered in the upper 250 feet of the drill holes.

Regionally and locally, this is an important aquifer, producing sufficient quantities of water with low total dissolved solids, to be used for domestic and agricultural purposes. Locally, the direction of flow in the Brule aquifer is to the north-northwest (Figure 2.2.1-06). No regional water level maps are available for the Chadron or individual Brule aquifers The hydraulic head of the lower Chadron aquifer recorded at PT-7 is 1144.27 m msl, while the Brule aquifer is 1172.50 m msl. A hydrostatic head of 28.23 m would prevent upward migration of leach fluids or Chadron aquifer water under normal conditions (Table 2.2.1-01). A hydrologic cross-section of the Crow Butte site is shown on Figures 2.2.1-07 and 2.2.1-08.



•3742.1 Water Level - MSL (feet)
Measured 1/P2 to 7/P3 (avg.)

Scale 1:72,000
1" = 6000'

0 2000 4000 6000 8000 10,000 Feet

0 1/2 1 2 Miles

N

Figure 2.2.1.06 - Water Level Map: Brule Formation

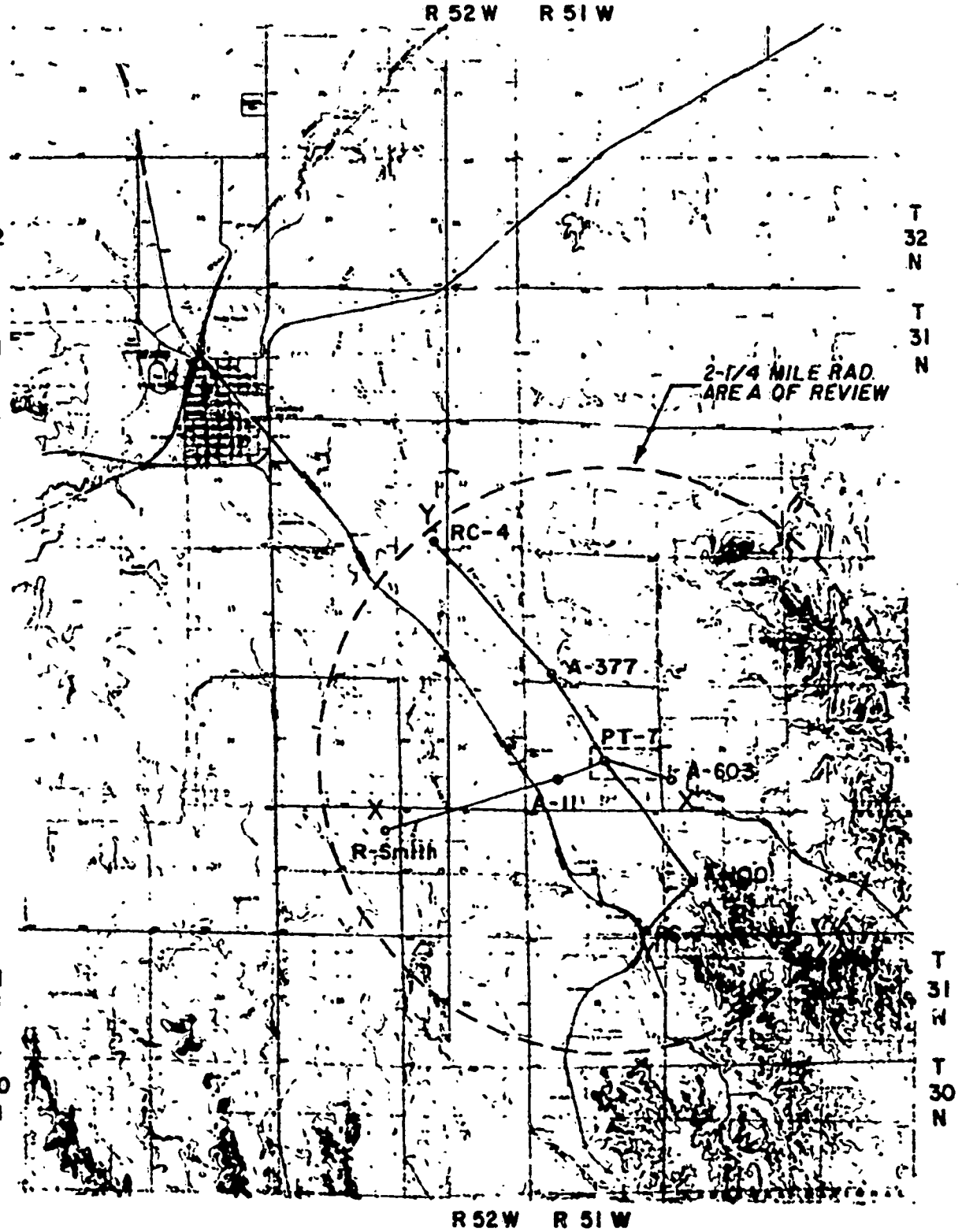


Figure 2.2.1.07 - Hydrologic Cross-Section Location Map

Scale 1:72,000
1" = 6000'

0 2000 4000 6000 8000 10,000 Feet

0 1/2 1 2 Miles

N

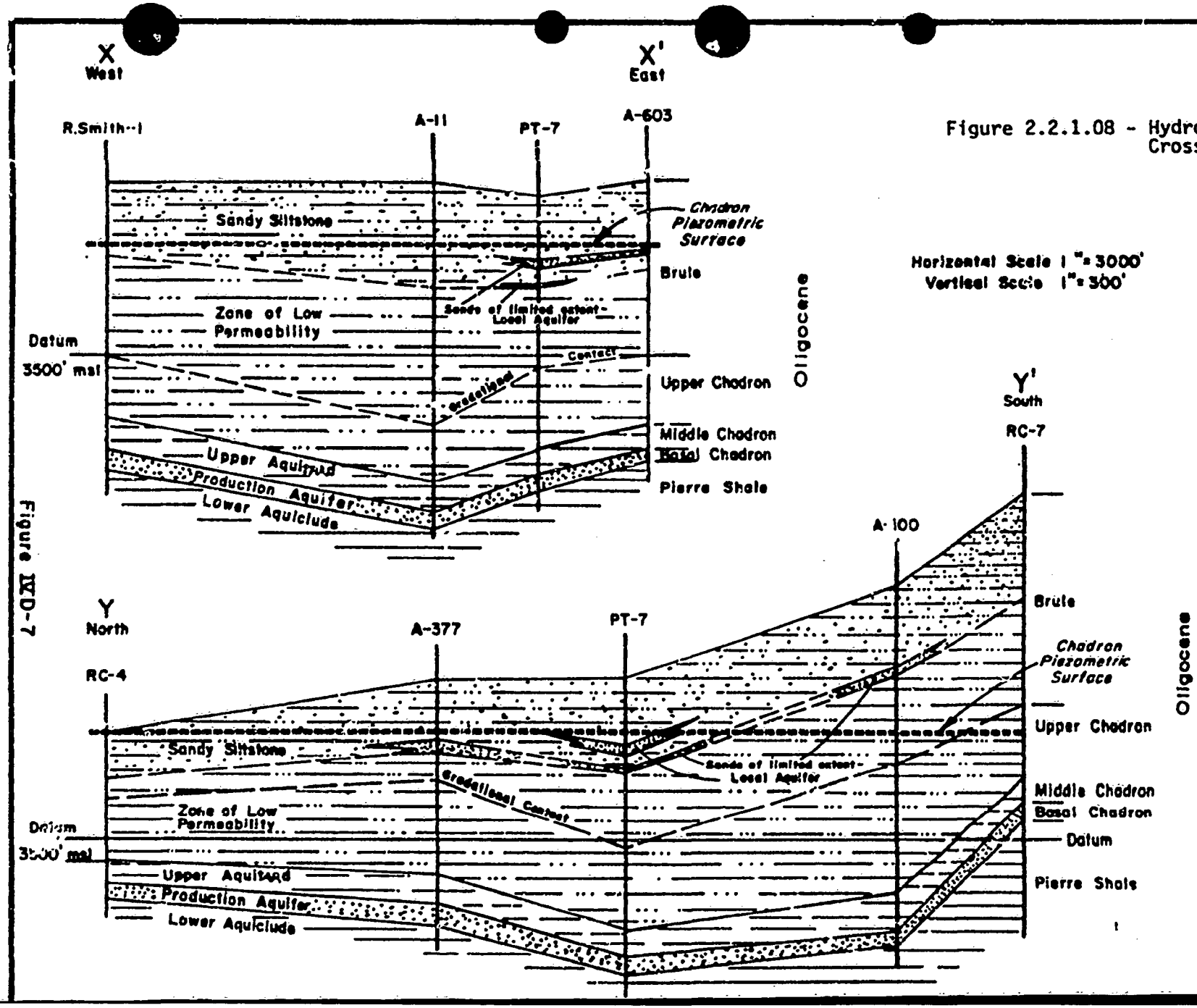


Figure 2.2.1.08 - Hydrologic Cross-Section

Figure XXD-7

Table 2.2.1-01
STATIC WATER LEVEL
IN THE CROW BUTTE R&D PROJECT AREA

Well No.	Aquifer	Water Level Elevation* (meters-msl)
PM-1	Chadron	1144.0
PM-4	Chadron	1143.35
PM-6	Brule	1171.50
PM-7	Brule	1172.24
PT-2	Chadron	1144.39
PT-7	Chadron	1144.27
PT-8	Chadron	1144.02
PT-9	Chadron	1144.40

* Measured January 10, 1983

2.2.2 Pump Test

The pump test designed by the applicant for the Crow Butte site consisted of PT-7 as the production zone pump test well, PT-9, 2, and 8 as the production zone pump test monitoring wells, PM-1 and PM-4 as production zone monitoring wells and PM-6 and PM-7 as upper aquifer monitoring wells (Figure 2.2.2-01). The wells used for the pump test were located so that they could be incorporated into the proposed pilot wellfield. The pump test wells were partially penetrating being completed in the lower 4.5-6.0 m (15-20 ft) of the Basal Chadron (Table 2.2.2-01). The center well of the pattern, PT-7, was equipped with a 7-½ hp submersible pump, and each of the observations wells, PT-9, 2, and 8, were equipped with electric water level indicators. Pumping began at 7:15 a.m. on November 16, 1982, and concluded at 10:00 a.m. on November 18, 1982; a period of 50.75 hours. The average flow rate for the test was 90 l/min (23.8 gpm). Water level measurements were taken at 1, 2, and 5 minutes, than at 5 minutes for the first 30 minutes of the test with regularly increasing intervals to 6 hours after 24 hours of elapsed time.

The objectives of the pump test for the Crow Butte site were:

1. Determine specific hydraulic properties of the production aquifer (e.g., permeability, transmissivity, and storativity).

2. Evaluate ore zone confinement.

3. Determine the coefficient of leakage through the upper and lower confining beds and evaluate the impact of such leakage on mining and restoration.

Appendix B provides the detailed discussion of the NRC staff's independent analysis and final position on the applicant's pump test and Appendix B-IV also provides a peer review of the NRC staff's independent analysis. As a result of this worst-case type of analysis, the NRC staff has concluded that the ore zone is adequately confined and that effects of leakage from the upper aquitard would not significantly affect wellfield operations, providing the water levels are stabilized during the initial phase of wellfield operations. Therefore, the staff recommends that ground water be circulated through both wellfields to stabilize water levels before lixiviant is introduced into the formation. This will be included as a license condition. In addition, the NRC staff analysis concluded that the low velocities and long flow paths associated with the streamlines for wellfield No. 1 may pose problems for restoration. Accordingly, the applicant was requested to provide additional information or modify the proposed pattern to allow restoration

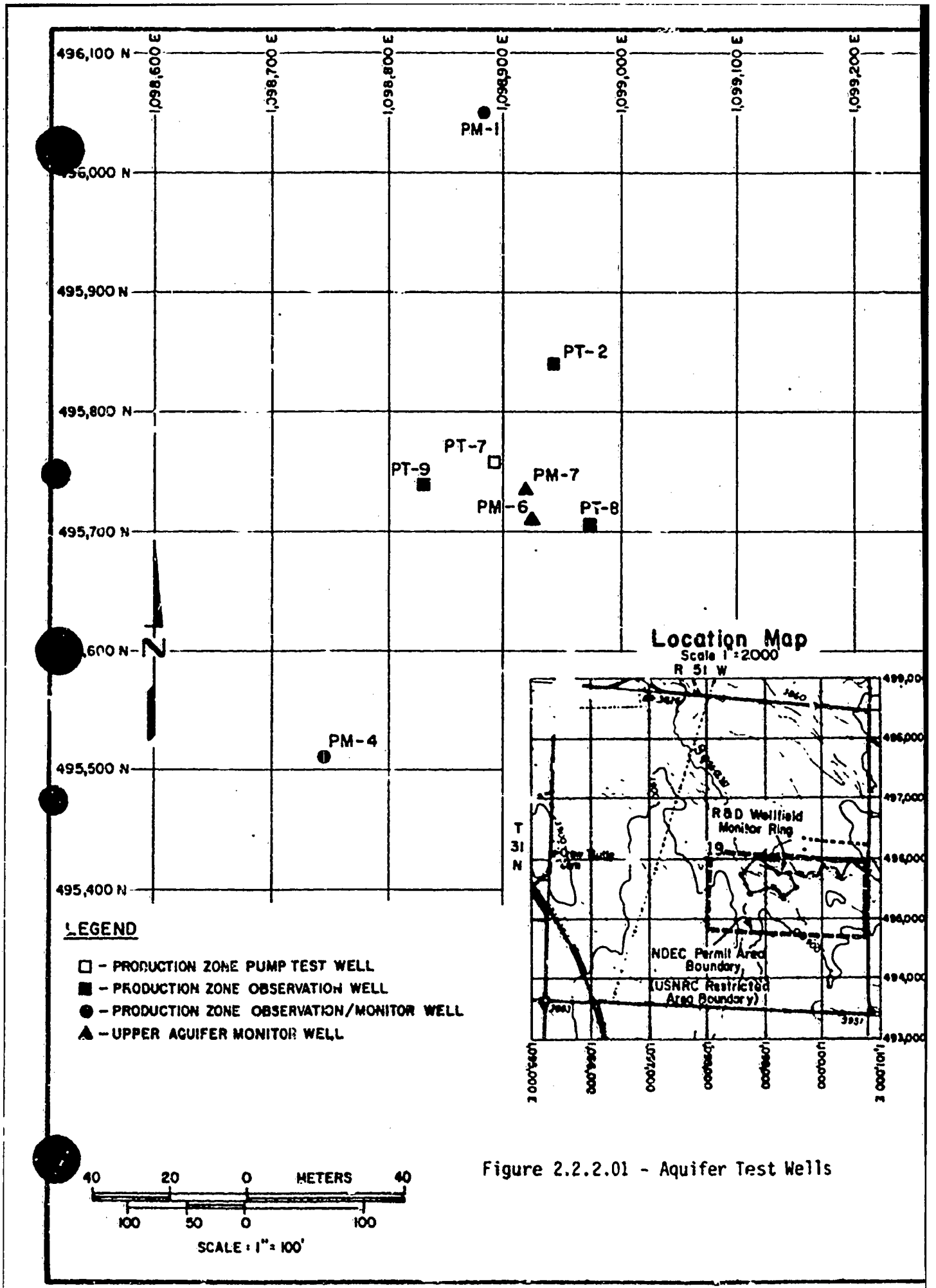


Figure 2.2.2.01 - Aquifer Test Wells

Table 2.2.1-01
R&D PROJECT AREA
PUMP TEST WELL COMPLETION DATA

Well Pumping No. (ft)	Total Depth (ft)	Centralizer Depths (ft)	Basket Depth (ft)	Screen Interval (ft)	Distance To Well
PM-1	674.5	640, 540, 440, 340, 240, 160, 120, 60, Top	645	649.5-669.5	293
PM-4	674.5	10, 40, 80, 115, 215, 315, 415, 5.5, 615	637	641.5-646.5 654.5-669.5	293
PM-6	217.5	0, 60, 140, 180	193	196-211	55
PM-7	129.5	0, 40, 80	85	89.5-94.5 99.5-104.5 109-114 119.5-124.5	35
PT-2	655.5	10, 60, 80, 119, 219, 319, 419, 519, 619	641	641-656	93
PT-7	672.5	20, 80, 120, 230 330, 430, 530, 630	648	649-664	0
PT-8	674.5	630, 530, 430, 330, 230, 130, 70, 30, 8	650	653-668	93
PT-9	680.5	10, 50, 90, 140, 240, 340, 440, 540, 640	656	659-674	66

within an acceptable time frame. The applicant provided the additional information in a report by Canonie Engineers dated April 1984. Based on staff review of the Canonie Engineers Report as discussed in Appendix B, the NRC staff will require that two observation wells be installed to monitor restoration in the peripheral regions of wellfield No. 1.

2.2.3 Baseline Water Quality

At the proposed test site, ground water occurs in the basal Chadron and upper Brule aquifers. Wyoming Fuel Company (WFC) has sampled each of these aquifers to determine baseline water quality (Appendix A). WFC has proposed continued monitoring of these wells before, during and after the proposed leaching test and to monitor those wells within a 1-mile radius during and after the leaching test. The following table describes each well sampled to date, for baseline ground water quality data and its role during operation.

WFC has submitted baseline water quality data from the Basal Chadron and Brule aquifers (see Appendix A). On an indicator by indicator basis, the sample mean and standard deviations have been calculated for the pilot well field (see Section 3.7.1). WFC has screened the data for outliers. Outliers have been marked by an asterisk in the tables and have not been included in the calculations.

There are two water wells in close proximity to the proposed test site, both located in the Brule aquifer. One well (25) is located .3 miles (.5 km) from the proposed restricted area boundary and the other well (17) is approximately .15 miles (.25 km). Baseline water quality data has been obtained for these wells. Due to the great thickness of the aquitard between the ore zone aquifer and the Brule aquifer and the fact that the piezometric head in the Brule is greater than in the Basal Chadron aquifer which would cause movement of water to Chadron from the Brule, the water quality of these wells would be unaffected. Water quality sampling will continue at these private wells on a quarterly basis.

Based on data submitted by WFC, the baseline water quality of the basal Chadron aquifer has been defined by the Nebraska Department of Environmental Control as an underground source of drinking water. Wells PT2, PT7, PT8, and PT9 show mean radium-226 concentrations in the range of 215.4 picocuries per liter. These wells are completed only

Table 2.2.3.01 Ground-water baseline sampling points

Well no.	Aquifer	Well Type
Regional		
13	Brule	Stock
17	Brule	Domestic, Stock
25	Brule	Domestic, Stock
26	Brule	Domestic, Stock
27	Brule	Livestock
57	Brule	Domestic, Stock
62	Chadron	Baseline
63	Brule	Baseline
66	Brule	Baseline
RA-2	Brule	Baseline
RB-3	Brule	Baseline
RC-3	Chadron	Baseline
RC-4	Chadron	Baseline
RC-5	Chadron	Baseline
RC-6	Chadron	Baseline
RC-7	Chadron	Baseline
PM-1	Chadron	Monitoring
PM-4	Chadron	Monitoring
PM-6	Brule	Monitoring
PM-7	Brule	Monitoring
PT-2	Chadron	Injection/Recovery
PT-7	Chadron	Injection/Recovery
PT-8	Chadron	Injection/Recovery
PT-9	Chadron	Injection/Recovery

in the lower portion of the ore zone where uranium is present in leachable quantities. Other wells in the basal Chadron, many of which are open to the full thickness of the ore zone, show a maximum radium-226 concentration of 9.9 picocuries per liter. Obviously, dilution and distance from the ore bearing sands are the primary factor causing these differences. Because the proposed injection/recovery wells will only be open to the lower portion of the ore zone and the baseline water quality will be based, in part, on the data from wells PT2, PT7, PT8, and PT9, and not on the data from the outlying monitoring wells, there should be no problem defining baseline water quality within the wellfield proper. In addition, the NRC staff will require water quality sampling to be done on all injection/recovery wells to be constructed. A minimum of three (3) samples shall be obtained and analyzed for the full suite of water quality indicators (Appendix A-1A) for all recovery and injection wells. These data shall be submitted to the NRC to be used in conjunction with data from wells PT2, PT7, PT8, and PT9, to determine baseline water quality within the proposed wellfield area. This will be included as a license condition.

3. PROCESS DESCRIPTION

3.1 In Situ Leaching Process

In situ leaching of uranium is a new addition to the list of conventional mining methods currently used to extract uranium. Basically, the in situ leaching method involves: (1) the injection of a leach solution (lixiviant) into a uranium-bearing ore body to oxidize the uranium, (2) the mobilization by complexing the uranium, and (3) surface recovery of the solution bearing the uranium complex via recovery wells. Uranium is then separated from the leach solution by conventional milling unit methods (ion exchange).

There can be many environmental advantages to in situ leaching of uranium. Conventional extraction methods can produce a significant impact on the environment. If hydrogeologic conditions are favorable, the impacts from solution mining are much less. The greatest impact of the in situ leach extraction method is to the ore zone ground-water quality which, in most instances, can be restored to baseline quality, premining quality use, or potential use category. Compared with the conventional uranium mining and milling operations, in situ leaching will also permit economical recovery of currently unrecoverable, deep, low-grade sandstone uranium deposits. The extent to which in situ mining can be conducted is limited in that the ore zone conditions must be suitable for containing and controlling leach solutions during the mining process (conditions described in Section 3.2).

3.2 The Ore Body

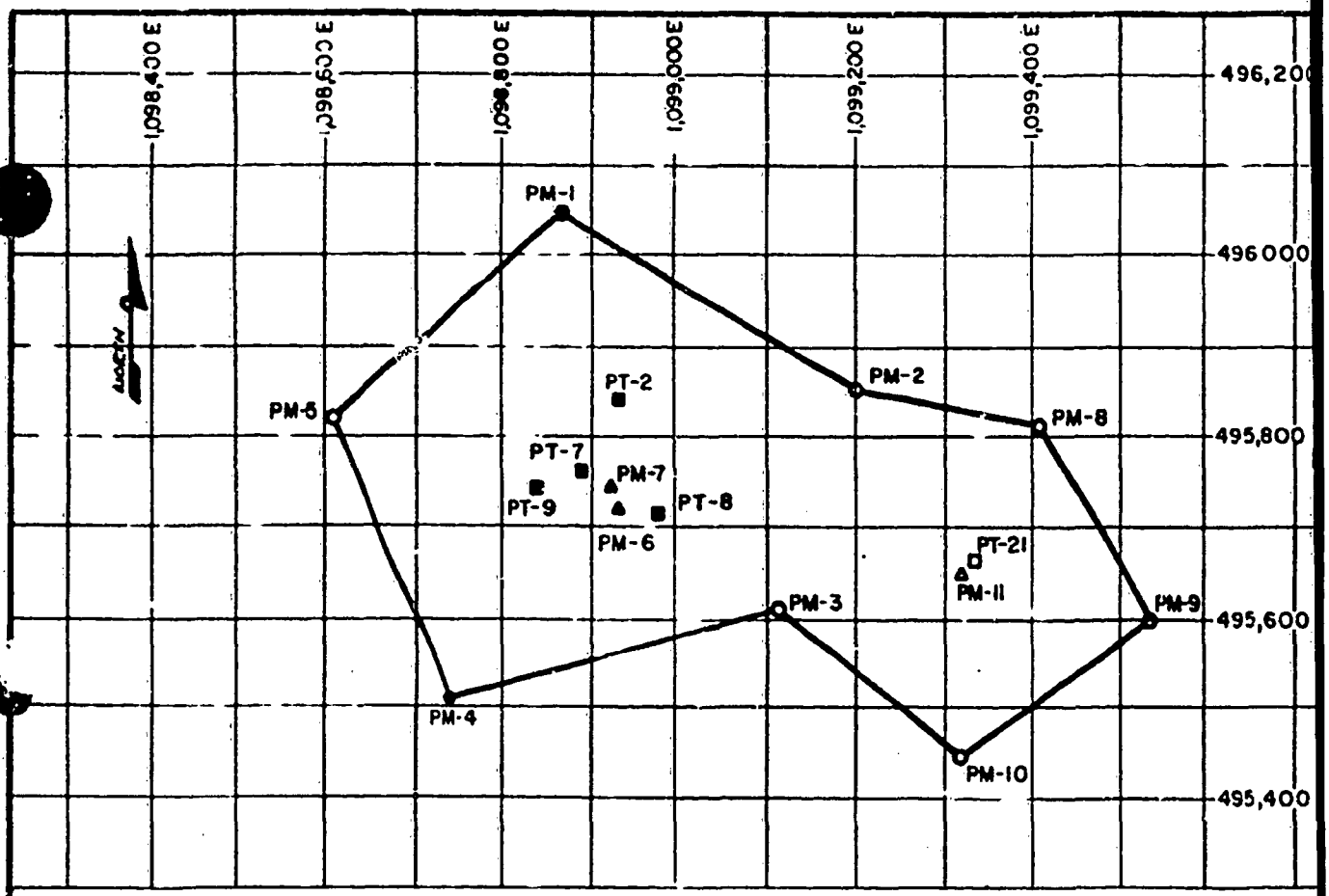
At the proposed Crow Butte ISL site, the Basal Chadron contains a roll front uranium deposit which is generally associated with fluvial sandstones and conglomerates. The mineral in the ore is concentrated by uranium-rich, oxidized ground water moving down the hydrologic gradient into a reducing environment. The interface is referred to as the oxidizing front. The physical shape of an ore roll (ore zone) is dependent on the local permeability of the matrix material and its continuity and distribution in the geologic unit. Such ore bodies are prevalent in most of the established uranium mining districts in the western United States. In situ leaching, however, can be conducted only on those ore deposits that meet certain criteria. These generally include: (1) the ore deposit must be located in a saturated zone,(2) the ore deposit must be confined both above and below by low permeability zones,(3) the ore deposit must have adequate permeability, and (4) the ore deposit must be amenable to chemical leaching.

The ore of the Basal Chadron at the Crow Butte ISL site appears to have been deposited as described above and appears to have the characteristics necessary to allow in situ leaching of uranium. The aquifer pumping test indicates the ore zone is saturated, permeability is adequate, and the ore zone is adequately confined. The capacity of the aquitards to confine lixiviant movement to the ore zone and the reaction of the deposit to chemical leaching will be further verified during the R&D testing, as discussed in Section 5.

3.3 Wellfield Design and Operation

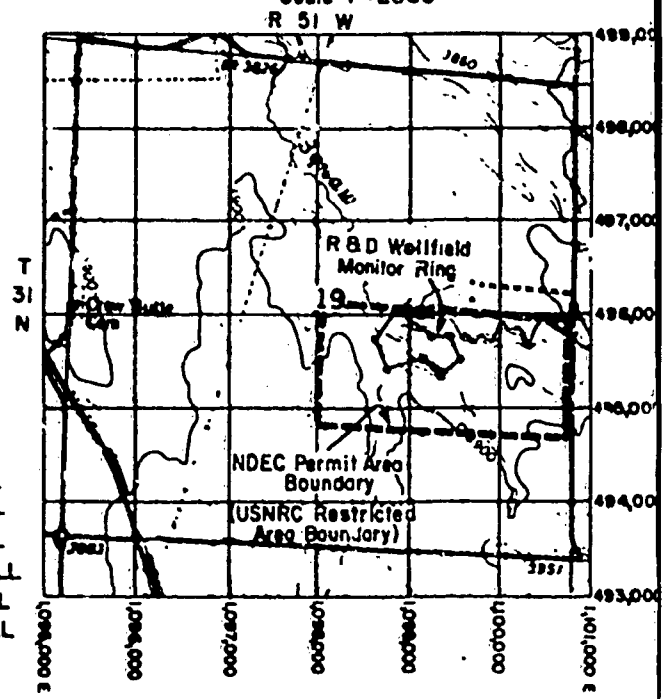
The operation of the pilot plant and wellfield, comprising 6.7 acres (2.7 ha), will commence upon completion of construction. Within this area, two wellfields will be constructed on a smaller area not to exceed one (1) acre (.42 ha) and tested consecutively. The exact dimensions of the wellfield will vary, based on conditions encountered in the field. WFC has proposed a smaller five-spot pattern with four injection wells on a 35 x 35-foot (10.7m) square spacing with a single production well in the center as wellfield No. 2. The larger pattern proposed consists of four injection wells on the corners of a 132 x 132-foot (40.2 m) square with a center production well (Figure 3.3-01) and is referred to as wellfield No. 1.

WFC proposes to use wellfield No. 2 to investigate the leaching response of the formation over a complete leaching cycle, including ore recovery and restoration. Wellfield No. 1 will be used to investigate the effects



Location Map

Scale 1" = 2000'



LEGEND

- ● - PRODUCTION ZONE MONITOR WELL - BASELINE WELL
- ○ - PRODUCTION ZONE MONITOR WELL - PROPOSED WELL
- ▲ - UPPER AQUIFIER MONITOR WELL - BASELINE WELL
- ■ - PRODUCTION ZONE PUMP TEST WELL - BASELINE WELL
- △ - UPPER AQUIFIER MONITOR WELL - PROPOSED WELL
- □ - PRODUCTION ZONE WELL - PROPOSED BASELINE WELL

50 25 0 50 METERS

200 100 0 200 FEET

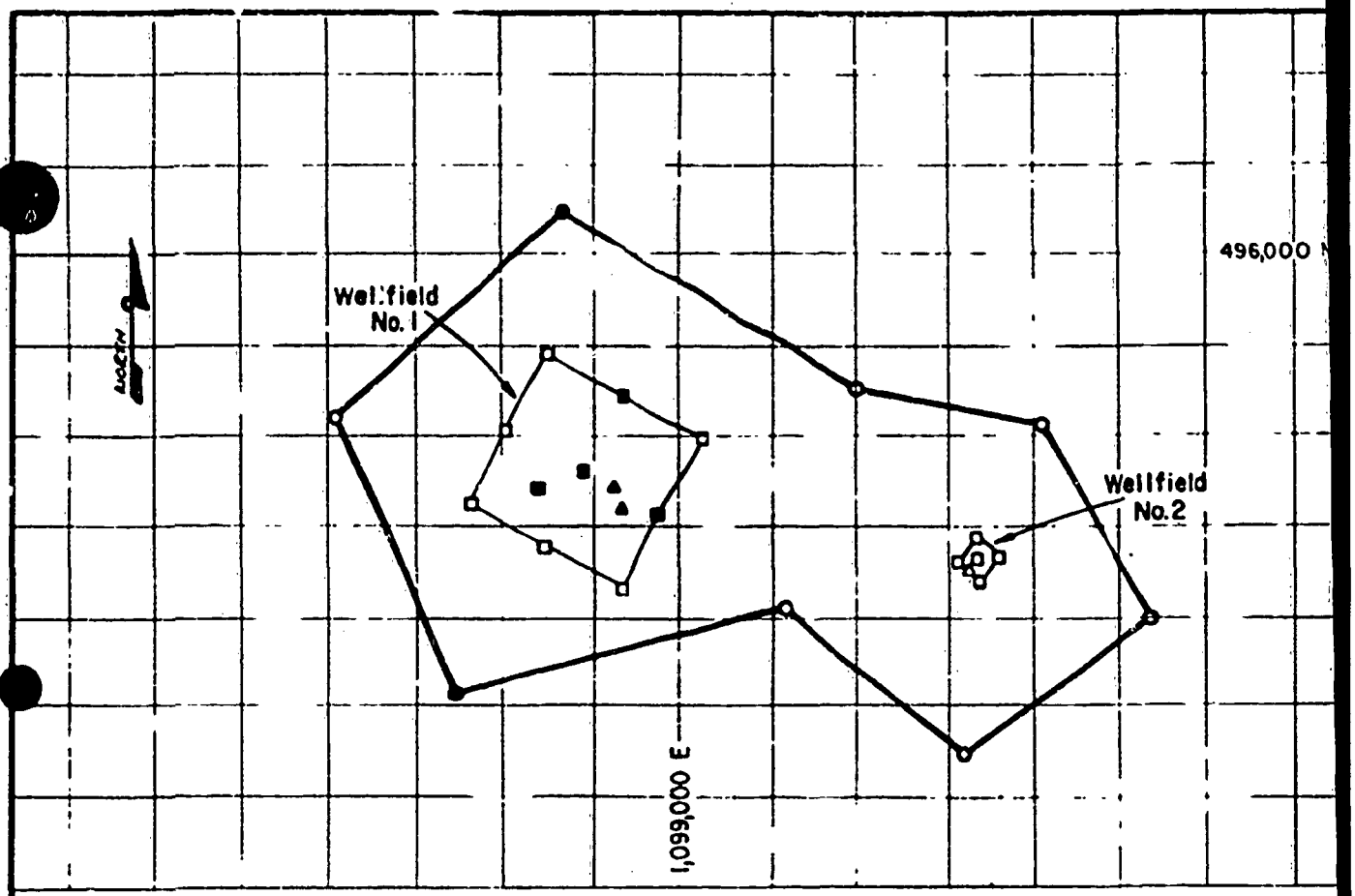
SCALE: 1" = 200"

Figure 3.3.01 - Well Field Patterns

of different well spacings on ore recovery. Although initially designated as either injection or recovery wells, all pattern wells will be capable of functioning for either purpose throughout the test. Monitor wells open to the Basal Chadron have been constructed and are located as shown on Figure 3.3-02. Monitor wells open to the Brule aquifer above the Basal Chadron have also been completed and are also shown on Figure 3.3-02. Baseline water quality data will be obtained for all monitor wells (Appendix A). Additional water quality information shall be required for those injection/recovery wells to be completed as indicated in Section 2.2.3.

During operation of the facility, as part of the quarterly reporting requirement, WFC will be required to provide the facility's operating data. For the first two quarters, all operational data will be reported including flow rates, chemical balance and injection pressures. During the remaining quarters, the operational data will be summarized in the quarterly report. The detailed operations data will be maintained on site. The Nebraska DEC Mining Monitoring Report (Figure 3.3.05) may be used to fulfill this requirement.

WFC will be required to perform casing integrity tests on the pattern wells before any injection or recovery well is put into service. All wells are to be tested at a pressure which simulates the maximum anticipated operating pressure of the well. If no more than a 10% drop in pressure occurs after at least 20 minutes of testing, the well casing will be determined to be mechanically sound. During operation, wellhead pressures shall not exceed the well integrity test pressure. WFC has proposed that in the event a given well fails the casing integrity test, and if the well cannot be repaired, the well will be plugged and abandoned as required by the Nebraska Department of Environmental Control (NDEC) permit. WFC will have available on site the results of all well completion reports (Figure 3.3.03) and mechanical integrity tests (Figure 3.3-04). In addition, the NRC will be notified when all wells which initially failed the tests have been either repaired or plugged. The above reporting requirements and data submittal will be included as license conditions.



Begin Construction	4/2/84
Start-up Wellfields 1 and 2	8/6/84
Begin Restoration Wellfield 2 (continue leaching Wellfield 1)	2/4/85
Complete Restoration Wellfield 2	7/8/85
Begin Restoration Wellfield 1 (based on no commercial operation)	7/8/85
Complete Restoration Wellfield 1	8/1/86

- ● - PRODUCTION ZONE MONITOR WELL - BASELINE WELL
- ○ - PRODUCTION ZONE MONITOR WELL - PROPOSED WELL
- ▲ - UPPER AQUIFIER MONITOR WELL - BASELINE WELL
- ■ - PRODUCTION ZONE PUMP TEST WELL - BASELINE WELL
- △ - UPPER AQUIFIER MONITOR WELL - PROPOSED WELL
- □ - PRODUCTION ZONE WELL - PROPOSED BASELINE WELL

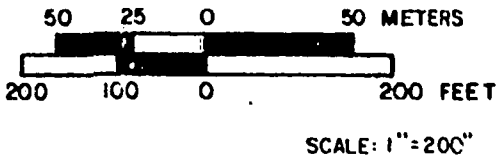


Figure 3.3.02 - Baseline Well Locations

NEBRASKA DEPARTMENT OF ENVIRONMENTAL CONTROL

WELL COMPLETION REPORT

FOR AGENCY USE

APPLICATION NUMBER

Company: _____ Project: _____

Type of Well: Production/Injection _____ Monitor _____ Well No.: _____

Ground Elevation: _____ Well Head Elevation: _____

Drilling Contractor: _____

Driller: _____

Mud Products: _____

Amount: _____

Bit Size: _____ Date Drilling Began: _____

Date Drilling Completed: _____ Depth Drilled: _____

Completed Formation: _____

Casing Diameter: _____ Casing Type: _____

Casing Depth: _____ Basket Depth: _____

Packer Type: _____ Packer Depth: _____

Centralizer Depth(s): _____

Screen Size: _____ Gravel Size: _____

Screened Interval(s): _____

Upper boundary of Completed Formation: _____

Lower boundary of Completed Formation: _____

Cement Contractor: _____ Operator: _____

Estimated Cement Volume: _____ Cement Volume, used: _____

Cement Weight: _____ Water Amount: _____

Cement Type or Class: _____ Additives: _____

Cement Circulated to Surface: Yes _____ No _____ Density of Fluid: _____

Logging Contractor: _____

Operator: _____

Unit No.: _____ Probe No.: _____

Log Type: _____

Well Deviation: _____

White-Yellow: DEC Pink: Your records

Describe any drilling problems, drilling time, lost circulation, casing difficulties, cementing, crooked hole, junk in hole, etc.:

This report was filled out by _____

Representing _____

Date _____

CERTIFICATION:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this form and all its attachment and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further I certify awareness that there are significant penalties for submitting false information, including the possibility of a fine and imprisonment.

By _____
Printed name of person signing

_____
Title

_____
Date

By _____
Signature

White-Yellow: DEC

Pink: Your records

NEBRASKA DEPARTMENT OF ENVIRONMENTAL CONTROL

CASING INTEGRITY TEST REPORT

Company: _____ Permit No: _____

Project: _____ Well No.: _____

Casing Type: _____ Diameter: _____

Hole Depth: _____ Casing Depth: _____

Screened Interval(s): _____

Depth of Test Packer(s): _____

Test Duration: _____ (minutes)

REMARKS: _____

Time	Elapsed Time (min)	Pressure (PSIG)

Time	Elapsed Time (min)	Pressu (PSI(

White-Yellow: DEC

Pink: Your records

Cementing Record (List type of test, log, etc. to determine proper cement job):

_____

_____

_____

_____

_____

Test performed by: _____ Date: _____

This report was filled out by: _____

Representing: _____ _____ Date: _____

CERTIFICATION:

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this application and all attachments and that, based on inquiry of those individuals immediately responsible for obtaining information, I believe the information is true, accurate, and complete. Further, I certify awareness that there are significant penalties for submitting false information, including the possibility of a fine and imprisonment.

By _____
Printed name of person signing

_____
Title

_____
Date

By _____
Signature

White-Yellow: DEC Pink: Your records

NEBR[illegible] DEPARTMENT OF ENVIRONMENTAL CONTROL
MINING MONIT[illegible]NG REPORT

Submit to: DEC [illegible]/E
P. O. Box 94877
Lincoln, NE 68509

PARAMETERS		WELL/MANIFOLD NUMBERS												
	MIN.													
	AVE.													
	MAX.													
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White-Yellow: DEC Pink: Your records

NEBRASKA DEPARTMENT OF ENVIRONMENTAL CONTROL

MINING MONITORING REPORT

Month: _____ Year: _____

Total volume or water level for reporting period: _____

Quality of injected fluid (Discuss any significant change in constituents or concentration of the injected fluid):

OPERATING CONDITIONS:

1. Have any operational problems occurred during this reporting period? _____

2. Has any well maintenance (repairs, workovers, etc.) been performed during this period? _____

3. Has any significant change occurred in any of the monitored parameters which might indicate a leak or other failure of any well? _____

If the answer to any of the above is yes, describe below:

I CERTIFY UNDER PENALTY OF LAW THAT I HAVE PERSONALLY EXAMINED AND AM FAMILIAR WITH THE INFORMATION SUBMITTED IN THIS APPLICATION AND ALL ATTACHMENTS AND THAT, BASED ON INQUIRY OF THOSE INDIVIDUALS IMMEDIATELY RESPONSIBLE FOR OBTAINING INFORMATION, I BELIEVE THE INFORMATION IS TRUE, ACCURATE, AND COMPLETE. FURTHER, I CERTIFY AWARENESS THAT THERE ARE SIGNIFICANT PENALTIES FOR SUBMITTING FALSE INFORMATION, INCLUDING THE POSSIBILITY OF A FINE AND IMPRISONMENT.

_____ _____

SIGNATURE/DATE NAME/TITLE (PRINTED)

White/Yellow: DEC Pink: Your records

3.4 Lixiviant Chemistry

The leach solution or lixiviant to be used for dissolution and recovery of uranium at the R&D site, as proposed by WFC, will be an aqueous solution of bicarbonate and carbonate as the complexing anion. The cations will be sodium. Oxidation will be provided by adding oxygen and/or hydrogen peroxide. Use of any other lixiviant is prohibited. This has been included as a license condition.

Several variations on the lixiviant chemistry are possible. WFC is proposing to use sodium bicarbonate as lixiviant for their operation. In general, the choice of lixiviant is between acidic or alkaline lixiviants. At a site where the ground water is carbonate, as at the Crow Butte ISL site, an alkaline lixiviant will mobilize fewer hazardous elements from the ore body than an acidic lixiviant.

Ammonia carbonate could have been proposed rather than sodium carbonate; however, ammonia tends to exchange with calcium on the clays causing precipitation of calcium sulfate which could cause plugging of the leaching channels (making restoration difficult) and may break down into carcinogenic nitrites. Therefore, because of the potential detrimental environmental impacts, ammonia carbonate is not as desirable as sodium carbonate.

A form of permeability loss can be associated with the injection of sodium carbonte lixiviants involving the adsorption of hydrated sodium ions onto montmorillonitic clays. The permeability loss results from clogging of pore space by clay swelling and subsequent migration of dissociated clay particles. Problems associated with clay swelling tend to increase with increasing cation concentration and ph. To minimize permeability loss, one should start at a low sodium concentration and near nuetral ph and gradually increase these parameters. The phenomena of refloculation is not significant at the concentrations anticipated for the Crow Butte project.

Potassium carbonate has been investigated as an alternative lixiviant, but with the present financial state and competitiveness of the uranium market, the use of potassium is not cost effective.

3.5 Uranium Recovery Process

The uranium recovery process involves three primary steps: (1) uranium adsorption; (2) resin elution; (3) precipitation of uranium. The following discussion provides more detail.

Uranium solubilized and recovered as a carbonate complex initially will be produced from the wellfields and be directed at a flow rate equal to, or less than, the maximum design plant capacity of 100 gpm (78l/min) to the ion exchange circuit (either a fluidized bed system, or a fixed bed system).

The uranium loaded on the ion exchange resin will then be stripped through an elution process.

The elution stream will consist of NaCl plus Na_2CO_3 . The uranium anion complexes on the resin are displaced by chloride anions. The chloride anions are then exchanged in the second step by HCO_3/CO_3 ions in a sodium carbonate/bicarbonate rinse. This subsequent chloride control circuit for $NaCl/Na_2CO_3$ elution is designed to reduce as much as possible the introduction of chloride anions back into the leach field.

The uranium-rich eluant in the precipitation tank will be acidized with hydrochloric acid to attain a pH of 2.0, or less. Under these conditions, the uranyl-carbonate complexes will be destroyed and CO_2 will be released. Hydrogen peroxide will than be added to the solution to precipitate uranyl-peroxide slurry. Further treatment of the yellowcake slurry wuch as heat or vacuum drying is prohibited. The thickened uranium slurry will be shipped to a licensed mill or converting facility in a slurry form. A schematic flow diagram of the process circuit is shown in Figure 3.5.01.

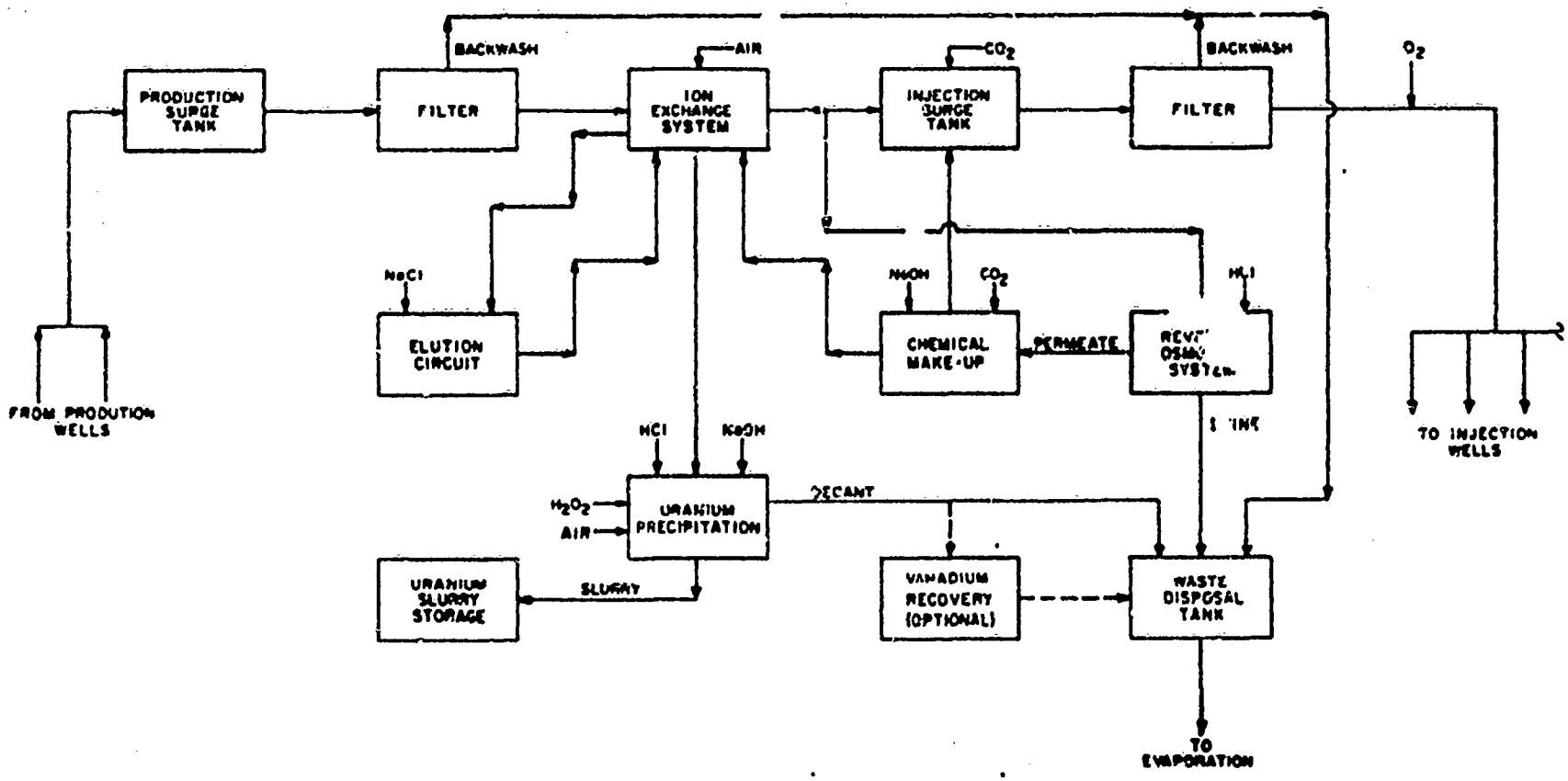

Figure 3.5.01 - Process Circuit Flow Chart

3.6 Description of Process Plant and Support Facilities, Ponds, and Wastes

3.6.1 The Process Plant and Support Facilities

The processing equipment (process tanks, ion exchange columns, piping systems and pumps, electrical equipment) will be housed in a 40-ft by 100-ft (12 by 30 m) building. All tanks containing yellowcake slurry will be placed in a curbed section of the plant. The floor will be sloped toward a collection sump and will be sealed by a chemical resistant coating. Lab, lunch room, locker rooms, and office space will be provided in trailers on the northwest side of the building. A parking lot will be located at the west side of the buildings near the office area.

Additional surface installations, besides the plant itself, will consist of fuel storage tanks, the evaporation pond system, and storage tanks for gaseous process chemicals. All shower, sink, and lavatory effluent wastes will be disposed of in a septic system and leach field in accordance with the Nebraska Department of Environmental Control Regulations Trash and garbage will be collected in suitable receptacles and hauled away for disposal at an approved location. Chemical laboratory effluents will be discharged into the evaporation ponds. A sheep-tight fence will be erected around the entire test area. Access to the site will be possible on an existing road, which will be further improved by grading and gravel topping. The road is included in the permit area. Power will be supplied commercially.

Squaw Creek cuts across the northeastern corner of the proposed permit area. Erosion control procedures will be utilized as necessary to mitigate any excess surface erosion. Baseline surface water quality samples have been obtained from both upstream and downstream of the project site (Apppendix A).

3.6.2 Solar Evaporation Ponds

While evaluating the feasibility of alternate waste disposal techniques, two of four waste storage (evaporation) ponds, each approximately 0.5 acres (.2 ha) in size, will be initially constructed for temporary disposal of liquid process waters at a location 300 feet (91.4 m) southeast of the plant area. The two ponds will provide adequate waste capacity for the operation of the plant during the leaching phase and for restoration of wellfield No. 2. The applicant will either install two additional waste ponds or an alternate system depending on the results of an analysis of alternative waste disposal techniques. The installation of the two additional evaporation ponds or the alternative waste disposal technique will be required prior to WFC's operation of wellfield No. 1. Any waste disposal technique other than the waste storage ponds will require NRC review and approval by license amendment

The two ponds proposed will have a total depth of 15 feet (4.6 m) and a maximum operating pool depth of 8.1 feet (2.5 m). An emergency volume from the 8.1 to 14-foot (2.5-4.3 m) levels is to be retained in the event of excessive precipitation and/or the need to empty one pond for liner repairs. The minimum design freeboard is therefore 1.0 foot (.3 m). Table 3.6.2.01 provides the individual pond capacities.

The ponds will be partially excavated below existing grade, with approximately 23,000 cubic yards (17,585 m^3) of soil being excavated, and partially constructed above grade, with approximately 12,000 cubic yards (9,175 m^3) of compacted fill being placed in perimeter embankments. The embankments, constructed of suitable silty fine sand material excavated from the pond interior, will have a crest width of 10 feet (3.04 m) and interior and exterior side slopes of 2 horizontal to 1 vertical.

The staff has reviewed the applicant's embankment design and earthwork specifications and finds that the applicant's soil investigation, selection of soil parameters, and analysis of embankment stability have been performed in accordance with guidance presented in "Staff Branch Position on Explorations for Design and Evaluation of Uranium Mill Tailings Retention Systems," and Regulatory Guide 3.11, "Design, Construction and Inspection of Embankment Retention Systems for Uranium Mills," Furthermore, the applicant's proposed earthwork specifications (soil excavation, fill placement, compaction, soil testing, gradations, etc.) are found to be acceptable and in accordance with standard engineering practice.

Each pond will be lined with a 36-mil reinforced Hypalon liner. The liners will be underlain by a leak detection system consisting of perforated PVC collector pipes placed in shallow trenches that are cut into the subgrade and lined with 20-mil PVC. The pipes will be wrapped with filter cloth, and the trenches will be backfilled with a clean, well-graded sand. A 6-inch thick bedding layer of the clean sand will be placed directly beneath the pond liners to ensure a more permeable zone to direct any seepage to the leak detection system. The collector pipes will drain to a standpipe (one for each pond) that will serve as the point for monitoring any seepage.

The applicant has stated that testing of the leak detection system will be performed prior to placement of the liner. Water flow (to simulate leaks) will be introduced into the subgrade layer and travel times to the standpipe will be recorded to confirm the applicant's analytical estimates.

To prevent surface water runoff from entering the evaporation ponds, a Hypalon-lined diversion ditch will be constructed on the southwest side

Table 3.6.3.01

POND CAPACITIES

Description	Depth	Individual Cell Capacity	Total of 4 Cell Capacity
Operating Pool	0 to 2.5 m (0 to 8.1 ft)	2,838,750 l (750,000 gal)	11,355,000 l (3,000,000 gal)
Emergency Volume	2.5 to 4.3 m (8.1 to 14 ft)	3,889,260 l (1,027,540 gal)	15,557,040 l (4,110,160 gal)
Freeboard Volume	4.3 to 4.6 m (14 to 15 ft)	847,540 l (223,920 gal)	3,390,160 l (895,680 gal)
TOTALS		7,575,550 l (2,001,460 gal)	30,302,200 l (8,005,850 gal)

(upstream) of the ponds. The ditch is designed to carry the runoff resulting from the Probable Maximum Precipitation (PMP). Based on the staff's review of the applicant's hydrologic calculations, it appears that the peak flow in the ditch was underestimated. The staff's calculations indicate that the peak flow will be about 40 cubic feet per second (cfs) (1.13 m^3/sec), rather than 20 cfs (.57 m^3/sec). However, the staff's independent capacity computations indicate that the ditch is large enough to convey 40 cfs (1.13 m^3/sec), and therefore, as designed, meets the criteria outlined in Staff Technical Position WM-8201, "Hydrologic Design Criteria for Tailings Retention Systems."

The applicant analyzed the effects of flooding in the dry wash to the northeast of the ponds to determine if severe flooding on that stream could possibly erode the toe of the pond embankments. The Probable Maximum Flood (PMF) and resulting velocities were computed by the applicant; the applicant concluded that the embankment toe was sufficiently above and far enough away from the flood flows. The staff's independent analyses indicated that the applicant did not conservatively estimate the magnitude and velocity associated with an occurrence of a PMF in the dry wash. The staff has concluded that a peak flow of about 5,000 cfs (141.6 m^3/sec) and a peak velocity of about 16 feet/second (4.9 m/sec) should have been used for design purposes. However, based on further independent analysis, the staff concludes that the toe of the pond will not be affected even by floods as large as the PMF. The applicant has indicated that the intermittent drainageway in the vicinity of the ponds should be straightened to improve hydraulic characteristics and to help prevent possible erosion toward the ponds. The staff agrees with this recommendation, since the lateral channel migration during a major flood will be reduced by such measures.

Based on staff review and independent analyses of the licensee's submittal, the staff concludes that the pond and liner designs meet applicable criteria outlined in 1) Regulatory Guide 3.11, "Design, Construction and Inspection of Embankment Retention Systems for Uranium Mills," 2) Staff Branch Position on Explorations for Design and Evaluations of Uranium Mill Tailings Retention Systems, 3) WM-8201, "Hydrologic Design Criteria for Tailings Retention Systems," and 4) WM-8101, "Design, Installation, and Operation of Natural and Synthetic Liners at Uranium Recovery Facilities." With regard to the design criteria for the diversion ditch, liner, leak detection system, geotechnical engineering aspects, and the quality assurance program, the staff concludes that adequate designs and specifications have been provided.

3.6.3 The Wastes

Based on information submitted by WFC, operation of the process plant will produce a series of liquid wastes which can be categorized into the following types:

Elution Bleed

A periodic bleed from the elution circuit to the evaporation ponds is necessary to maintain the proper chemistry of the eluant.

Filter Backwash

A backwash type of filter will be used to screen out possible particles before injection The backwash liquid will go to the evaporation ponds.

Reverse Osmosis Brine

A Reverse Osmosis (RO) (or similar water treatment unit) facility will be provided. The installation of this unit will greatly reduce the volume of waste solution going to the evaporation pond. Thus, the evaporation ponds need not be oversized.

Because this project is a research and development operation, the composition of the process wastes may vary as efforts are made to improve the process.

No solid wastes will be produced during this project except for residues from the solar evaporation ponds.

3.7 Ground-water Restoration, Reclamation, and Decommissioning

3.7.1 Ground-water Restoration

Restoration is defined as the returning of affected ground water, on an indicator-by-indicator basis, to its baseline condition or to a condition consistent with its premining use (or potential use) upon completion of leaching activities. Baseline condition, or baseline, as used in this document, refers to the level of constituents in the natural ground water or surface water prior to facility operations. Because the levels of constituents vary in nature, baseline for each well or surface sampling location is the mean value for each constituent as determined from repeated sampling at each location (see Section 2.2.3). Restoration is intended to reduce the concentration of contaminants remaining in the ground water to acceptable levels. In addition, to demonstrate the feasibility of restoration for larger scale operations, the restoration goal for a research and development project should be baseline water quality.

In order to more clearly illustrate the potential effect of the proposed facility operation and restoration on the Chadron aquifer, the NRC staff performed a worst case analysis For this analysis, it was assumed that the facility was in full production, the plant was shutdown and no restoration was subsequently performed. It should be pointed out that NRC requires a licensee have a surety bond (in this case, held by the state) with sufficient funds to have an outside contractor take over restoration and decommissioning of an abandoned site. Therefore, the assumed worst case would not occur and any actual case would be significantly better.

The computer program utilized in this worst case analysis is a ground-water transport model which uses only dispersion to model the peak concentration and transport time of a contaminant at a specified point. This model does not consider other natural processes such as adsorption, or chemical interactions with surrounding formations that also occur and may remove contaminants from the ground water or retard the travel time of contaminants. Therefore, not only is the worst case conservative, but the modeling is also conservative. By taking only dispersion into consideration, the concentration of a single parameter can be modeled and can be used to proportionally determine the concentrations of all other parameters.

The NRC staff modeled two specific cases. In each case, the contaminant modeled was Ra-226, the point at which the peak concentration was determined was the site boundary (130 m from wellfield No. 2 and 106 m from wellfield No. 1), and the source concentration (the maximum concentration at the wellfield at the time of abandonment) was 10,000 pCi/l. Past experience indicates that Ra-226 values at operating facilities are usually below 5,000 pCi/l. Therefore, the use of 10,000 pCi/l of Ra-226 is an additional conservatism. In the first case modeled only wellfield No. 2 (the small pattern) was simulated assuming operation to peak production and then shutdown with no restoration. As a result of this analysis, the concentration of Ra-226 takes approximately 80 years to reach the site boundary, and is within natural baseline values.

In the second case, the combined effects of both wellfields at peak production was modeled assuming no restoration. The peak concentration and transport time was determined at a point 106 m north of wellfied No. 1 at the site boundary. As a result of this analysis, the Ra-226 concentrations contributed by wellfield no. 2 were shown to be background and therefore had no effect on the analysis. As a result of abandonment of wellfield No. 1, at the site boundary the concentration of Ra-226 reached the site boundary after approximately 60 years and was

approximately 55% of the source concentration. Concentrations of Ra-226 do not exceed background outside the site boundary for approximately 30 years after cessation of operation. Therefore, even under these worst case conditions, there is more than adequate time for restoration operations to be completed before any contaminants could migrate off site. Sufficient funds would be available for the restoration and subsequent decommissioning from the required surety bond.

As stated previously, the goal of restoration is to return ground water, for each indicator, to its baseline value. However, it is recognized that this is not always possible for every parameter. Should this be the case, it is NRC's position that the ground water should not be degraded from its pre-mining water use. For the Chadron aquifer, the Nebraska DEQ has classified it as an underground source of drinking water. Therefore, the NRC will require that if it is not possible to restore ground water to its baseline quality, then the water use category should not be degraded. Should the licensee sucessfully demonstrate that the ground water cannot be restored to these standards, using best practical technology, an assessment will be made of the impact of the remaining contaminants in the aquifer. This assessment will be to determine the risk to public health and safety and the environment. If the impact is determined to be of relatively low risk, the NRC will release the licensee from his license when decommissioning is complete. If the risk is determined to be unacceptably high, the site would remain under license, continued monitoring and mitigating actions would be required, and public use of the site would be restricted. The modeling discussed above demonstrates that sufficient time is avialable to perform mitigating actions and that contaminant concentrations will be reduced to acceptable levels before reaching the site boundary.

WFC has proposed, as the ultimate restoration goal, restoring the ground-water quality to baseline conditions. The method for determining ground-water quality baseline is discussed in Section 2.2.3.

WFC, in their preliminary restoration plan, proposes to use reverse osmosis or similar surface treatment and a ground-water sweep as the initial method of restoration. Ground-water sweeping involves pumping of contaminated water from the mineralized zone. This causes surrounding, uncontaminated ground-water to flow to the affected area. WFC estimated that about 6.27 pore volumes (26.3 million gallons) would have to be pumped for a complete rinsing. The contaminated water from the sweep will be treated by reverse osmosis and the concentrated brine will be disposed of in the solar evaporation ponds.

In summary, the restoration methods proposed by WFC involve: (1) reverse osmosis or similar treatment of contaminated ground water with reinjection of the purified water, and (2) ground-water sweep. Restoration will be terminated when restoration targets (criteria) have been met.

The restoration methodology as proposed in the preliminary restoration plan by WFC has been reviewed by NRC staff and found to be acceptable. Because this is a research and development operation and therefore, specific restoration methodologies may be modified based on data obtained during the mining phase of the operation, WFC shall be required to submit a specific plan for ground-water quality restoration at least ninety (90) days prior to termination of mining activities. Included with this plan shall be a description of restoration methods and a projected schedule of activity. This shall be included as a license condition.

After the Nebraska Department of Environmental Control (NDEC) and the U.S. Nuclear Regulatory Commission have reviewed the restoration water quality data (subsequent to post restoration water quality monitoring) and determined that restoration is complete, ground-water restoration shall be deemed completed.

3.7.2 Reclamation and Decommissioning

As proposed by WFC, subsequent to the completion of ground-water restoration or at termination of commercial production, the wellfield areas will be reclaimed. All wells will be plugged in accordance with the requirement of the Nebraska Department of Environmental Control. The exception to this will be if the land owner requests that one or more wells to remain open with State approval.

After completion of all leaching, ground-water restoration activities, and well plugging, WFC shall decommission the recovery facilities and reclaim all land affected by leach operations. The land will be disked and reseeded. WFC has proposed a plan for dismantling plant buildings and equipment, reclamation of the pond area, reclamation of roads, ultimate disposal of chemical and radionuclide wastes, and final site (land) reclamation. The proposed plan depends on whether the site is abandoned after the research and development test or a future commercial facility is developed at the site. If a decision is made not to proceed with a commercial production plant, the test site shall be cleared and returned as close as possible to original conditions. Solid wastes from the evaporation ponds shall be assayed, packaged accordingly, and transported to a licensed radioactive waste disposal site. If a commercial

plant is erected on an enlarged Crow Butte ISL area, WFC will consider using existing facilities as part of that commercial operation. Thus, the reclamation of the test site would be delayed in accordance with the commercial plan.

The reclamation and decommissioning plan proposed by WFC, if the Crow Butte site is to be abandoned is as follows:

Dismantling of Plant Building and Equipment

If the test plant is abandoned, the plant will be checked for radioactive contamination prior to dismantling. Decontamination will be attempted by washing, and the wash water will be transferred to the evaporation ponds. Any equipment or material that cannot be decontaminated will be stored separately for final disposal at a licensed site.

Samples from the concrete foundation will be assayed for chemical contamination, especially for water soluble and toxic compounds. Plant equipment, such as piping, tanks and pumps, will be decontaminated as necessary and salvaged as far as possible.

Chemically and radiometrically decontaminated materials or nonradioactive materials including concrete foundations will be set aside for disposal by burial. All material will be checked before burial for soluble compounds and for possible long-term decay processes to prevent ground-water pollution. Uncontaminated material will be buried in the evaporation ponds.

Reclamation of Roads

The temporary roads and parking lots will be reclaimed by removing the gravel base and oil contaminated subsoil (if any) and by deep disking of compacted areas. The road bed materials will be buried in the evaporation ponds.

Reclamation of the Pond Area

If the operation is closed down after restoration, pond cleaning will be done in sequence. Any remaining liquids will be transferred to tank trucks of suitable construction and shipped to an approved disposal site. Bottom sludge can then be loaded into tank trucks or placed in lined drums for disposal at approved sites. The pond liners will then be cleaned. If after cleaning the liners meet the limitations for surface contamination, they will be cut up and placed in the bottom of the

ponds. If contamination limits are exceeded, the liners will be placed in trucks and hauled to an approved disposal site.

Leakage monitoring devices will be removed, but gravel or sand bedding may remain in place underneath the ponds if uncontaminated. Dike material will be leveled to blend with the adjacent topography.

Topsoil from the topsoil storage area will be spread evenly to cover the landscaped pond area. The area will be checked for compaction prior to reseeding, and compacted spots will be disked as required.

In case of site abandonment without a commercial operation to follow the leach test, remains of plant buildings, plant installations, cement foundations, parking lot gravel, etc. will be buried in the evaporation ponds.

Reclamation of the Site

The test site will be landscaped and then reseeded following Soil Conservation Service recommendations so that the land can be returned to its original use of livestock grazing. All areas with the original topsoil stripped or damaged will be covered with material from the topsoil storage. It is intended that the topsoil thickness and thickness distribution after reclamation be as near as possible to the conditions found before topsoil stripping. Special consideration will be given to erosion control during the maturation of the reseeded vegetation cover. The reseeded areas will be fenced for a period of one to two years to keep livestock off until the vegetation can sustain itself. The landowner and NDEC will be contacted prior to opening the area for livestock.

Reclamation Schedule

Assuming project termination, reclamation will begin immediately upon the completion of successful restoration and stabilization of the ground water.

3.7.3 Surety Requirements

WFC submitted cost estimates for reclamation and decommissioning of the Crow Butte R&D facility as the basis for their required surety bond. The applicants' breakdown included labor, materials, laboratory and processing costs for ground-water restoration, facility decommissioning, land reclamation, and waste disposal for a total bond estimate of $736,950. The proposed bond estimate for the Crow Butte R&D facility was reviewed by the Nebraska Department of Environmental Control

(NDEC) and increased by fifteen percent (15%) due to inflation and lack of consideration of contingency actions. The NDEC has approved a bond estimate of $847,792 for WFC. The state of Nebraska will hold the bond on this facility. The NRC staff has also reviewed WFC's proposed bond estimate and concurs with NDEC's 15% cost increase for a total bond estimate of $847,792 for the Crow Butte R&D facility. The staff shall require by license condition that the applicant submit to the NRC a copy of the surety bond, or other acceptable financial instrument, for reclamation and decommissioning costs of the facility. The bond shall be renewed annually in order to allow readjustment of the bond total value due to changing conditions, inflation, and other similar consideration.

4. EVALUATION OF ENVIRONMENTAL IMPACTS

4.1 Introduction

In situ leaching of uranium is a relatively new and developing technology. The major human health and environmental concerns with this technique of mining are the potential impacts of mining on ground-water quality, the impacts of evaporation pond leakage (if it were to occur), radiological impacts, and disposal of wastes.

4.2 Ground-water Impacts

4.2.1 Excursions

An excursion is defined as the exceedance of pre-specified concentrations of indicators at a specific well. Excursion indicators are normal constituents of the ground water and are selected as early indicators that conditions may be changing that could result in lixiviant not being contained in the area of operations. Based on the geochemical conditions at the site and the proposed operation, several indicators are selected. For each indicator at each monitor well, an Upper Control Limit (UCL) is established as the maximum baseline concentration plus 20 percent. This procedure for establishing UCLs has evolved from past experience with R&D and commercial insitu leach facilities. It is intended to represent, without rigorous statistical analysis, a process control value (or UCL) that can be used to indicate that the leaching process may not be confined to the area of operations. Due to limited baseline data available at each well and the natural variations of the constituents in the ground water, two indicators must exceed their respective UCLs before any excursion is declared. This is to prevent unnecessary false alarms. If only one indicator exceeds its UCL, it must exceed it by more than 20 percent before an excursion would be declared.

Excursions of contaminated ground water in a wellfield can be due to such things as improper balances between injection/recovery rates, undetected high permeability strata or geological faults, improperly abandoned exploration drill holes, discontinuity and unsuitability of the confining units to prevent movement of lixiviant out of the ore zone, cracked well casings and faulty well construction, and hydrofracturing of the ore zone or surrounding units. Based on the information previously discussed and operational controls to be implemented, none of the above are expected to be a problem. However, it is recognized that one of the purposes of a R&D project such as the one proposed is to determine the operational and other factors that may cause excursions, and to determine the best methods to control them. Past experience from other R&D leaching projects and commercial scale in situ leach projects indicates that if proper steps are taken in monitoring and operating a wellfield, excursions, if they occur, can be controlled and damage to the environment minimized.

Though past experience cannot accurately predict the future, there are two reasons to conclude that if any excursions do occur at the Crow Butte ISL Project site, they can be controlled with minimal impacts.

(1) For an R&D operation, the size of the wellfields and the expected quantity of contaminating fluid injected into the ore zone (both variables relate to the potential to mitigate excursions) are very small, when compared to full-scale operations. Excursions have been effectively controlled in large, full-scale operations by increasing the negative potentiometric pressure in the wellfield. It is expected that excursions, if they occur, can be controlled at WFC's R&D wellfields in the same manner.

(2) The monitoring program at the Crow Butte ISL wellfields, as described in Sections 5.1.1 and 5.1.2, monitors not only water quality in the ore zone and adjacent aquifers to detect excursions, but also the potentiometric pressure of the adjacent aquifers. This will provide early detection of any lateral and vertical excursions. Mitigating measures can then be taken before the excursions get out of control.

4.2.2 Aquifer Depletion

Depletion of the basal Chadron aquifer due to operation and restoration of the Crow Butte R&D facility was considered as part of the NRC review of WFC's application. Using the applicant's proposed pumping and injection rates for the mining and restoration of wellfield No. 1, the NRC staff conservatively assumed these values would be applied to both

wellfields simultaneously. In actuality, WFC has not proposed to mine and restore both wellfields at the same time, but in a staggered fashion. During both operations and restoration, WFC has proposed to overpump the basal Chadron aquifer (i.e., pump more out than injected) in order to maintain a negative wellfield pressure. During mining, WFC will overpump by 2%, restoration (stage A) 25% and restoration (stage B) 2%. Negative wellfield pressure assures that the flow in the basal Chadron aquifer will be toward the pumping well, thereby keeping the lixiviant within the site area. The NRC staff analysis of aquifer depletion indicated that the maximum drawdown due to simultaneous operation of both wellfields was during stage A restoration. At the end of 60 days of stage A restoration, the water level at the site boundary would be drawn down approximately 7.74 feet. Wells beyond the boundary would be affected even less. At the end of 305 days of stage B restoration, the aquifer would have recovered so that the drawdown at the site boundary was less than approximately one-half a foot. At the termination of all restoration activities at the proposed site, the basal Chadron aquifer will recover to the original water level. Based on this analysis, the NRC staff had concluded that no permanent depletion of the basal Chadron aquifer will occur as a result of the proposed Crow Butte project.

4.2.3 Evaporation Pond Seepage and Spills

Accidental leaks from the evaporation ponds could, if uncontrolled, contaminate shallow aquifers and locally degrade ground-water quality. The proposed installation of an impermeable synthetic bottom liner in the solar evaporation ponds at the Crow Butte ISL Project site should eliminate such seepage. Furthermore, if a pond leak developed, the monitoring program described in Section 5.1.3 should allow for early detection and repair of the leak, thereby minimizing the quantity of leakage. Based on the use of an impermeable pond liner and the leak monitoring and repair program, the staff concludes that the impact of pond leaks on ground-water quality will be minimal.

Spills from the evaporation ponds resulting from dike failure could result in unacceptable contamination of surface and ground waters. Because the pond embankments and the minimum acceptable freeboard from the top of the berms to the ponds' free water surfaces have been designed based on U.S. Nuclear Regulatory Commission Regulatory Guide No. 3.11, spills from the evaporation ponds are unlikely.

4.2.4 Restoration of Ground Water

Ground-water restoration will include treatment (by reverse osmosis and ground-water sweep) to remove contaminants from ore zone water and any other zones contaminated by lixiviant migration with subsequent reinjection of the treated ground water. Past experience has shown that restoration of ground water to baseline conditions is feasible. The staff concludes that WFC's proposed preliminary ground-water restoration plan, as described in Section 3.7.1, is suitable, and that the ground-water quality impacts of in situ operations at the Crow Butte ISL R&D test site will be minimal. WFC shall be required, by conditions of the source material license, to notify the NRC of any subsequent changes in the proposed restoration methods. If any changes in the proposed restoration methods are considered to be beyond the scope of the source material license and/or have the potential for any adverse impacts beyond those evaluated in this environmental assessment, NRC approval in the form of a license amendment shall be required.

4.3 Radiological Impacts

4.3.1 Introduction

The primary sources of radiological impact to the environment in the vicinity of the proposed Crow Butte pilot plant are naturally occurring cosmic and terrestrial radiation and naturally occurring radon-222. The average annual total-body dose rate from natural background radiation to the population in the site vicinity is estimated to be about 153 millirems. Diagnostic medical procedures result in an average dose of 75 millirems per year.

This section describes the results of the staff's analysis of the project-contributed incremental radiological effects on the environment in the vicinity of the Crow Butte R&D site. Exposure pathways are discussed, as are the estimated radiological impacts resulting from the estimated emissions from facility operations. The impacts to nearby individuals are estimated. Finally, consideration is given to the potential radiation exposures of project employees and of biota other than man.

Because the proposed operations at the Crow Butte facility do not involve displacement of ore from the ore body or drying and packaging of the yellowcake product, there will be no routine particulate emissions from the facility. This analysis has considered the effects of releases of gaseous radon-222, which is the only projected routine radioactive release. The estimated annual release of radon-222 due to the proposed activities will be 145 Ci, which was computed based on the calculational methods presented in Appendix C, and the models, data and assumptions discussed in Appendix D.

4.3.2 Offsite Impacts

4.3.2.1 Exposure Pathways

Estimates of the dose commitments to man are based on the proposed plant design, characteristics of the site environs, and the exposure pathways to man. Only exposure pathways resulting from gaseous radon-222 releases to the atmosphere are considered in this analysis. There will be no surface discharge of radioactive fluids, and radioactive materials liberated underground during the leaching process will be confined.

Because there is expected to be no particulate release and radon-222 should be the only gaseous radionuclide to be released from the Crow Butte facilities, the environmental exposure pathways of primary concern are the inhalation of radioactive materials (radon and its decay daughters) in the air and the external exposure to radon daughter radionuclides in the air and on the ground. The ingestion of contaminated food products (meat, milk and vegetables) are less significant contributors to dose.

4.3.2.2 Radiation dose commitments to individuals

The estimated radiation dose at a reference point depends on the distance and direction of the point with respect to each of the sources, as well as the wind directional frequency toward the receptor from each of the sources. Doses are higher at locations downwind from the plant. (Prevailing winds in the site vicinity are bimodal toward the WNW and the ESE sectors, as shown in Table D.2.) As radon is transported offsite, its daughters grow, which potentially results in higher dose commitments farther from the plant until the radioactive plume is further diluted by dispersion.

The closest residence to the Crow Butte site is 0.7 km (0.4 mile) east of the plant. In addition, the town of Crawford is 7.5 km (4.7 miles) northwest of the plant. Estimated annual dose commitments to individuals at these locations are shown in Table 4.11. For dose estimates at the above locations, it was conservatively assumed that vegetables, milk and meat consumed by the residents were produced locally. Dose estimates are based on assumptions described in Section C.4 of Appendix C.

4.3.2.3 Evaluation of compliance with regulatory limits

Calculated 50-year dose commitments for the maximally exposed individual are only small fractions of the current NRC limits for radiation exposure in unrestricted areas (10 CFR Part 20 "Standards for Protection Against Radiation"). Table 4.12 provides a comparison of calculated air concentrations compared with limits established by the NRC for public protection. Dose commitments to the nearest residents are not compared with the limits specified in the EPA's "Radiation Protection Standards for Normal Operations of the Uranium Fuel Cycle" (40 CFR Part 190), because these limits do not apply to radon-222 or its radioactive daughters.

As indicated in Table 4.12, projected radioactivity concentrations near the project site fall well below NRC limits. To ensure that offsite concentrations are maintained below permissible limits, the staff will require the applicant to monitor radon concentrations at and near the site boundary. This will be included as a license condition.

Table 4.11 Annual Dose Commitments to Individuals from Radioactive Releases from the Crow Butte Project

Location	Exposure pathway	Dose (millirem per year) Whole Body	Bone	Lungs	Bronchial Epithelium[a]
Nearest residence[b] 0.7 Km E	Inhalation	8.86E-7[c]	2.76E-5	7.45E-6	1.22E+1
	External ground	1.83E-3	1.83E-3	1.83E-3	1.83E-3
	External cloud	6.97E-3	6.97E-3	6.97E-3	6.97E-3
	Ingestion[d]				
	Veg	1.75E-5	4.36E-4	1.75E-5	1.75E-5
	Meat	3.20E-6	7.95E-5	3.20E-6	3.20E-6
	Milk	8.97E-7	2.23E-5	8.97E-7	8.97E-7
	Total	8.82E-3	9.37E-3	8.83E-3	1.22E+1
Town of Crawford 7.5 km NW	Inhalation	1.30E-6	4.03E-5	1.09E-5	8.78E-2
	External ground	1.98E-5	1.98E-5	1.98E-5	1.98E-5
	External cloud	5.33E-4	5.33E-4	5.33E-4	5.33E-4
	Ingestion[d]				
	Veg	1.75E-5	4.36E-4	1.75E-5	1.75E-5
	Meat	3.20E-6	7.95E-5	3.20E-6	3.20E-6
	Milk	8.97E-7	2.23E-5	8.97E-7	8.97E-7
	Total	5.76E-4	1.13E-3	5.85E-4	8.84E-2
Natural background		1.53E+2	1.88E+2	1.54E+2	5.60E+2

a Doses to the bronchial epithelium result from the inhalation of short-lived radioactive daughters of radon-222.

b Location of a Wyoming Fuel Co. airborne effluent monitoring station.

c Read as 8.86×10^{-7}.

d Vegetable, meat and milk ingestion doses result from ingestion of comestibles produced 10 km West of the pilot plant.

Table 4.12 Comparison of Air Concentrations During Solution Mining Operations with 10 CFR Part 20 Limits for Unrestricted Areas

	Total Air Concentrations (pCi/m^3)			
	Pb-210	Bi-210	Po-210	WL-Concentration[a]
10 CFR 20 limit[b]	4.00	2.00E-2[c]	7.00	3.33E-2
Rest. Area bdry 0.3 km W	5.61E-8	7.62E-12	9.92E-17	1.42E-4
Fraction of limit	1.40E-8	3.81E-14	1.42E-17	4.26E-3
Rest. vs. area bdry 0.3 km S	4.48E-8	5.85E-12	7.07E-17	1.18E-4
Fraction of limit	1.12E-8	2.92E-14	1.01E-17	3.56E-3

a WL denotes "working level." A one-WL concentration is defined to be any combination of air concentrations of the short-lived Rn-222 daughters. Po-218, Pb-214, Bi-214, and Po-214 that, in one liter of air, will yield a total of 1.3×10^5 MeV of alpha-particle energy in their complete decay to Pb-210. Predicted values given for outdoor air are those calculated on the basis of actual ingrowth from released Rn-222.

b Values given are from 10 CFR Part 20, Appendix B, Table II, column I.

c Read as 2.00×10^2 or 200.

Worker inhalation of radon and its daughters is the primary potential exposure condition. The ventilation system in the recovery plant and the small-scale nature of an R&D pilot plant will minimize this type of exposure, and employee exposures should not exceed 10% of the annual Part 20 limit specified by the NRC (according to a study of comparable employee exposures at existing uranium mills).

Exposure to external radiation is expected to be far below the maximum limits permitted by NRC regulations because of the nature of the material and the operations. However, the applicant will be required to perform periodic gamma radiation surveys to ensure that in-plant radium buildup does not result in excessive radiation exposure (see Safety Evaluation Report). This shall be included as a license condition.

4.3.2.4 Radiological impact on biota other than man

Although no guidelines concerning acceptable limits of radiation exposure have been established for the protection of species other than man, it is generally agreed that the limits for humans are also conservative for other species. Doses from gaseous effluents to terrestrial biota (such as birds and mammals) are quite similar to those calculated for man and arise from the same dispersion pathways and considerations. Because the effluents of the facility will be monitored and maintained within safe radiological protection limits for man, no adverse radiological impact is expected for resident animals.

4.3.2.5 Summary

An independent assessment of the radiological impacts of the Wyoming Fuel Company pilot plant project was conducted by the staff. The maximum dose to individuals would be 12.2 millirems/year to the bronchial epithelium, which is approximately 2% of the estimated dose to individuals from natural background radiation.. This dose estimate represents the annual dose commitment during operation of the facility. After mining has been completed and the site has been fully reclaimed and restored, no further radiological impacts are expected to occur.

4.3.3 In-Plant Safety

WFC shall establish and conduct an in-plant radiation safety program. The NRC staff is requiring a program that contains the basic elements required for, and found to be effective at, other source material extraction operations to assure that exposures are kept as low as reasonably achievable (ALARA). The scope of the program has been geared to account for the small size of the proposed R&D project. In general, the program will include the following:

(1) Airborne and surface contamination sampling and monitoring;

(2) Personnel exposure monitoring;

(3) Qualified management of the safety program and training of personnel;

(4) Written radiation protection procedures; and

(5) Periodic audits by highly qualified outside parties and frequent inspections to assure the program is being conducted in a manner consistent with the ALARA philosophy.

The staff considers the program of in-plant safety sufficient to protect in-plant personnel by keeping radiation doses as low as reasonably achievable. The staff evaluation of this program and the associated license conditions are contained in a Safety Evaluation Report.

4.4 Waste Disposal

The NRC has taken the position in regulations on uranium milling (10 CFR 40, Appendix A, Criterion 2) that the small volume of wastes generated at in situ operations should preferably be disposed of at existing tailings disposal sites or other licensed radioactive burial grounds to avoid proliferation of waste sites. Therefore, the NRC shall require by license condition that solid wastes generated at the Crow Butte ISL Project site shall be disposed of at an existing licensed radioactive waste disposal site.

4.5 Socioeconomic Effects

4.5.1 Work Force

The estimated work force necessary for the Crow Butte project is shown in Table 4.5.01.

Table 4.5.01 Estimated Work Force

Period	Hired Locally (Crawford)	Hired Sioux-Dawes County	Hired Outside 50-Miles	Total Work Force
Construction	10	10	5	25
Operation	10	4	3	17
Post-Operation	4	2	1	8

According to the applicant, the construction period of the R&D facility will require the largest work force. This period will last approximately three months. During operations, the work force will be reduced to seventeen. The reductions will result from contractors hired to complete the construction of plant building, wellfield, and solar evaporation ponds. The operational time for the R&D facility will be approximately one year. In the event the R&D facility is unsuccessful, it is estimated that eight workers will be required to totally decommission the site. Based on this work force, following is a discussion of the possible impacts on the local economy, roads, jobs, housing, schools, transient population and energy costs.

4.5.2 Local Economy

During the construction phase, the local economy would be moderately stimulated both by the local purchase of goods, materials and services directly related to the construction activities and by local spending of wages by construction and service workers and their families. This moderate stimulation would result from fifteen additional workers into the Crawford area, eight of which would be temporary (see Table 4.5.01). Since the construction phase is estimated at three months, it is doubtful these eight workers will rent or purchase housing, rather they will either commute or stay in motels in the Crawford or Chadron area.

The operational phase will require a work force of seventeen employees. Ten of these workers will be hired locally and seven will be hired regionally (see Table 4.5.01). Since this represents a reduction in eight workers from the construction period, there would be a slight drop in purchase of goods and services. However, these workers would be considered permanent and would again moderately stimulate the local economy through the purchase of goods and services.

Post operational decommissioning will only require eight workers. This reduction would result in a reduction in the purchase of goods and

services, as well as the sale of housing required by workers during construction and operation.

The NRC staff considers the overall impact on the local economy resulting from these phases of the R&D facility to be positive. New employment will result in moderate stimulation of the local economy through increased purchase of goods and services.

4.5.3 Roads

Truck traffic will be increased slightly through delivery of the necessary equipment and supplies for constructing the R&D facility. This will be a temporary impact and no significant road damage will be associated with this activity. Once constructed, the plant will receive normal deliveries from vendors and travel to the site by workers. If the facility is decommissioned, truck traffic will again be slightly increased resulting from hauling of equipment from the site.

4.5.4 Jobs

Construction will require twenty-five workers; seventeen workers during operations, and eight workers during post operation.

Additional jobs will result in a positive impact on the Crawford area. As previously discussed, wages earned by workers will moderately stimulate the local economy as well as the regional economy. The additional jobs offered by WFC should not stress existing facilities or services since only seven additional workers are expected to be permanent during the R&D operation. The remaining ten will already have resided in the Crawford area.

4.5.5 Housing

According to the applicant, although rental property is scarce, a May 1982 listing of property revealed nine houses, one rooming house and two parcels of land were up for sale. Housing will be no problem with the limited influx of workers expected to result from the R&D operations. There will be no need for temporary housing (i.e., trailer camps) during the construction, operation or post operation of the R&D facility.

4.5.6 Schools

The Crawford High School and grade school is presently under capacity. Total enrollment in these two schools is 274. The grade school currently has a student to teacher ratio of 16 to 17/1; while the high school has a ratio of 10 to 1. No historical maximum enrollment was given for the

grade school; however, it was estimated that the high school historical maximum enrollment was over 200 pupils (present enrollment is 142).

Outside the Crawford school 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 must pay tuition if they elect to go to the Crawford schools for grades one through eight. A tuition is paid to the Crawford High School by the individual rural school districts for each student enrolled. In the seven rural districts which Crawford high school is drawing from, there are an estimated 100 pupils in these lower grades.

Families moving into the Crawford district as a result of the R&D operations should not stress the current school system, since it is presently under capacity. It was estimated that at least 30 additional pupils could be accomodated easily. Using the factor of 2.3 children/family and an estimated 7 new families, 16 additional children will be entering the school system.

4.5.7 Energy Costs

No increase in energy costs will be associated with construction and operation of the R&D facility. Wyoming Fuel Company will be paying the cost for upgrading the power lines for operation of the R&D facility. This upgrade will provide more dependable power and better access to the rural areas surrounding the R&D facility.

4.5.8 Summary

Although conventional (open pit and underground) mining methods and milling processes have relatively high manpower requirements, the proposed R&D Crow Butte project does not. Due to the local unemployments rates, the majority of the project related employment opportunities will probably be filled by workers from the local labor pool. Because few in-migrants will be needed, population-induced impacts should be limited. Consequently, the NRC staff considers the socioeconomic impacts associated with the project to be minimal.

4.6 Transportation

Shipment of yellowcake: Because the applicant will ship yellowcake as slurry, the yellowcake dryer and associated emissions are eliminated. The slurry will be bulk loaded in a type-B tank truck or in approved drums for shipment. The staff estimates that approximately three tank truck shipments will be required as a result of operation of the R&D

facility. The yellowcake slurry will be shipped for further processing to the Kerr-McGee Nuclear Corporation hexafluoride plant in Gore, Oklahoma.

From published accident statistics, the probability of a truck accident ranges from 1.0×10^{-6} to 1.6×10^{-6} per kilometer(1.6×10^{-6} to 2.6×10^{-6} per mile). Truck accident statistics include three categories of traffic accidents: collision, noncollision, and other events.

Collisions involve interactions of the transport vehicle with other objects, whether moving vehicles or fixed objects. Noncollisions occur when the transport vehicle leaves the transport path or deviates from normal operation in some way, such as by rolling over on its top and/or side. Accidents classified as other events include injuries suffered by persons when in a vehicle, when falling from a venicle, or when being thrown against a standing vehicle; vehicle theft; and fires occurring on a standing vehicle. The probability of a truck shipment of yellowcake slurry from the Crow Butte site being involved in an accident of any type ranges from .003 to .005. The low probability of an accident makes this a statiscally insignificant event.

5. MONITORING

5.1 Ground Water

5.1.1 Water-Quality Monitoring

Water-quality monitoring shall be done during the operational (leaching), restoration and post-restoration phases of the project. The following discussion describes WFC's proposed monitoring plans and any modifications required by the NRC.

Operational Monitoring

There are ten monitor wells which will be sampled on a routine basis during extraction operations. There are eight (8) monitor wells in the production zone (PM-1, 2, 3, 4, 5, 8, 9, 10), and three (3) in the upper aquifer (PM-6, 7, 11). These are shown in Figure 2.2.1.07.

The NRC staff shall require by license condition that excursion indicators to include conductivity, chloride, sodium, sulfate and alkalinity During extraction operations NRC has proposed that a water sample from each monitor well be collected and analyzed once every two (2) weeks for conductivity, chloride, sodium, sulfate and alkalinity. An excursion would be assumed if any two excursion indicators in any monitor well exceed their respective upper control limits or a single

excursion indicator exceeds the upper control limit by 20%. The upper control limits for each excursion indicator shall be defined, on a well-by-well basis as the maximum baseline water quality value plus 20%.

If two UCL values are exceeded in a well or if a single UCL value is exceeded by 20% of the UCL, the licensee shall take a verification sample within twenty four (24) hours after results of the first analyses are received. If the second sample does not indicate exceedance of the UCL's, a third sample will be taken fourty-eight (48) hours after the first sample. If neither the second or third sample indicate exceedance of the UCL's, the first sample shall be considered in error. If the second or third sample indicates a violation, the well(s) in question will be placed on excursion status.

Corrective action will be initiated and the NRC, Uranium Recovery Field Office, will be notified by telephone within twenty-four (24) hours and in writing within five (5) days. The sample frequency for the affected well(s) will be increased to once every seven days for the excursion indicators previously listed, until the excursion is concluded. A formal report on the condition of the excursion will be filed with the NRC with the quarterly report. If corrective actions have not been effective within 60 days since the first excursion verification, injection of lixiviant within the wellfield or excursion shall be terminated until such time as the problem is solved and aquifer clean-up is complete.

Because monitor wells PM-2, 3, 5, 8, 9, 10, and 11 and production wells in wellfield No. 1 and No. 2 with exception of PT 2, 7, 8, and 9, will be constructed at a later date and because WFC plans additional baseline data acquisition, WFC has proposed submitting final upper control limits to the NRC for review and approval prior to commencement of injection into the ore zone. The UCLs for each member of the excursion indicator set, for each monitor well, will be established using the baseline water quality data for the individual monitor wells.

Quality Assurance (QA) Programs will be maintained by the Radiation Safety Officer of WFC who is reporting directly to the President. All QA programs will be conducted according to the Regulatory Guide 4.15 "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment." Standard QA procedures will be maintained through the operational phase. In accordance with Regulatory Guide 4.15, all outside labs will be required to file QA documents with WFC, prior to contract finalization.

In-house labs will be placed under the same QA requirements with audits, inspections, etc. as the outside labs, again following Regulatory Guide 4.15 requirements.

All lab work will be performed using Standard Methods as required by EPA and the Clean Water Act. Certifications and qualifications will be on file with WFC as part of the QA program.

5.1.2 Water-Level Monitoring

Changes in potentiometric levels in the ore zone aquifer monitor wells could give early warnings of potential excursions. However, water level changes must be regarded very cautiously, since they may be associated with numerous other phenomena including regional or barometric changes. Because of the variability of this data, while the NRC will require water level measurements to be taken during sampling of wells and reported quarterly, water level measurements will not used to define excursions.

5.1.2 Evaporation Pond Leak Detection

WFC has proposed inspecting the leak detection system sumps (standpipes) on a daily basis during operations. If water is detected in the inspection sump, chemical assays will be used to confirm the source of the water. The chemical assay will be for calcium, chloride, alkalinity, sodium, uranium, sulfate and TDS. The detection of any liquid within the leak detection system will be reported to the NRC within forty-eight (48) hours. All assay results will be reported in writing as soon as they are available. If a leak is confirmed, the damaged pond will be emptied immediately by transferring the solution to the other pond so that remedial actions can be made. This shall be included as a license condition.

5.2 Environmental Monitoring

WFC has performed a surface radiological monitoring program. Their program consisted of a series of direct gamma measurements at locations on the Crow Butte ISL Project site. In addition, soil samples were taken and analyzed for natural uranium and Ra-226. Vegetation was sampled and analyzed for Ra-226, Po-210, Pb-210, Th-230, and Total U. The specific operational surface radiation monitoring program proposed by WFC is shown on Table 5.2.01. Non-radiological monitoring to be conducted by WFC is shown on Table 5.2-02.

There will be no drying of yellowcake at the Crow Butte ISL Project site. Further treatment of the yellowcake slurry, such as heat or vacuum drying, will be prohibited by license condition. Should the applicant later request some form of yellowcake drying, it would require prior approval of the NRC in the form of a license amendment. This would also necessitate modification of the operational surface radiological environmental monitoring program.

TABLE 5.2-01
RADIOLOGICAL OPERATIONAL
MONITORING PROGRAM
CROW BUTTE R&D PROJECT

Type of Sample	Sample Collection				Sample Analysis	
	Number	Location	Method	Frequency	Frequency	Type of Analysis
AIR						
Particulates						
	Three	Nearest residences same as preoperational and near the town of Crawford	Continuous low volume air sampler with glass fiber filter	One week per month	Quarterly composite of filters according to location	Natural Uranium Th-230, Ra-226, Pb-210
	One	Control location same as preoperational	same	same	same	same
Radon	Four	Same as air particulates	Grab[1]	Monthly	Each sample	Rn-222
WATER						
Ground Water						
	One from each water supply well	Within 1 km of R&D restricted area boundary	Grab	Quarterly	Each sample	Total:Natural Uranium, Ra-226

[1] A grab sample shall consist of at least three(3) separate forty-eight(48) hour composite samples during a period of one(1) month.

Radiological Operational Monitoring Program (Cont'd)

Type of Sample	Sample Collection				Sample Analysis	
	Number	Location	Method	Frequency	Frequency	Type of Analysis
Surface Water						
	Two from Squaw Creek	One up-stream, one down-steam of restricted area	Grab	Quarterly	Each sample	Total:Natural Uranium, Ra-226
SOIL						
	One each	Air sampling stations	Grab (top 5 cm)	At completion of R&D operations	Each sample	Natural Uranium, Ra-226
SEDIMENT						
	Two from Squaw Creek	One up-stream, one down-stream of restricted area	Grab	Semiannually	Each sample	Natural Uranium, Ra-226
VEGETATION						
	Four	Air sampling stations	Composite of dominate vegetation present	At completion of R&D operations	Each sample	Natural Uranium, Th-230, Ra-226, Pb-210, Po-210
DIRECT RADIATION						
	One each	Plant site, well field, evaporation ponds, air sampling stations	Dosimeter	Quarterly	Quarterly	Gamma exposure rate μR/hr using a continuous integrating device

TABLE 5.2-02
NONRADIOLOGICAL OPERATIONAL MONITORING PROGRAM
CROW BUTTE R&D PROJECT

Type of Sample	Sample Collection				Sample Analysis	
	Number	Location	Method	Frequency	Frequency	Type of Analysis
Ground Water						
	One each	Production zone monitor wells	Grab	Two-week intervals	Within 24 hours	Excursion indicators: conductivity chloride, uranium
	One each	Upper aquifer monitor well	Grab	Two-week intervals	Within 24 hours	Excursion indicators: conductivity chloride, uranium
Water Levels	One each	Proudciton zone monitor well	Electric line	Immediately prior to sampling	Within 24 hours	Table, graph
	One each	Upper aquifer monitor well	Electric line	Immediately prior to sampling	Within 24 hours	Table, graph
Pond Level	One each	Evaporation ponds	Observation	Weekly	Weekly	Tabular
Pond Leak Detection System	One each	Evaporation ponds	Check for presence of liquid	Daily	Daily	Tabular
			Grab sample if liquid is present	Weekly	Within 24 hours	Leak indicators: conductivity, chloride, vanadium

6. ALTERNATIVES

6.1 Introduction

The action that the Commission is considering is the issuance of a source material license pursuant to Title 10, Code of Federal Regulations, Part 40. The alternatives available to the Commission are:

Issue the license, with appropriate conditions.

Deny the application and not issue the license.

The selection of either alternative is based on a consideration of a number of factors related to protection of health, safety, and the environment Section 40.32 of 10 CFR 40 states that an application for a specific license will be approved if, among other things:

The application is for a purpose authorized by the Atomic Energy Act;

The applicant is qualified by reason of training and experience to use the source material for the purpose requested in such a manner as to protect health and minimize danger to life or property;

The applicant's proposed equipment, facilities and procedures are adequate to protect health and minimize danger to life or property; and

The issuance of the license will not be inimical to the common defense and security or to the health and safety of the public.

If the Commission finds, based on its evaluation of the application, that these stipulations are met, its only choice is to issue the license, provided a finding of no significant environmental impact is also made.

If a finding of significant environmental impact is made, the Commission must conclude, after weighing the environmental, economic, technical and other benefits against environmental costs, that the action called for is the issuance of the proposed license. In this latter case, the additional step involves only the two basic alternatives, issuance of the license or denial of the application.

6.2 No License Alternative

The NRC can choose not to license the Crow Butte R&D ISL Project. The NRC would make this decision on an evaluation of environmental and

public health and safety considerations as required by NRC regulations. If the license application meets all applicable regulatory requirements, the NRC would have no basis for denial of the license.

Sandra L. Wastler, Project Manager
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Region IV

Approved: for
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Appendix A

Baseline Water Quality Data

A-1

A-1A Water Quality Indicators
A-1B EPA and NDEC Ground-Water Quality Criteria and Standards

A-1A

Baseline Water-Quality Indicators to be Determined During Permining Data Collection

Physical Indicators		
Specific Conductivity[1]	Appearance (e.g., color)	Total Dissolved Solids[3]
Temperature[2]	Alkalinity	
pH[1]	Odor	

Common Constituents		
Ammonia	Chloride	Potassium
Bicarbonate	Magnesium	Sodium
Calcium	Nitrate	Sulfate
Carbonate	Nitrite	

Trace and Minor Elements		
Arsenic	Copper	Mercury
Boron	Fluoride	Molybdenum
Barium	Iron	Nickel
Cadmium	Lead	Selenium
Chromium	Manganese	Silica
		Vanadium
		Zinc

Radionuclides	
Radium-226	Uranium

1 Field and laboratory determination.
2 Field only.
3 Laboratory only.

A-1B

COMPARISON OF GROUND-WATER QUALITY CRITERIA AND STANDARDS

Stds.[d] Drinking Parameter	USEPA[a] NDEC MCL	Quality Criteria for Water: Drinking	Irrigation	Livestock	USEPA for Water
Calcium (mg/l)					
Magnesium (mg/l)					
Sodium (mg/l)					
Potassium (mg/l)					
Carbonate (mg/l)					
Bicarbonate (mg/l)					
Sulfate (mg/l)		250[b]			250
Chloride (mg/l)		250[b]			250
Ammonia-N (mg/l)		0.5[b]			
Nitrate-N (mg/l)		1.0[b]		10.0[b]	
Nitrate-N (mg/l)	10.0	10.0[bc]		100.0(NO_2+NO_3)[b]	10.0
Fluoride (mg/l)	2.4	1.4-2.4[b] (temp.depen.)	1.0[b]	2.0[b]	1.4-2.4 (temp.depen.)
Silica (mg/l)					
TDS-180°C (mg/l)				3000[b]	500
Conductivity-Field (umhos)					
Conductivity-Lab (umhos)					
Conductivity-Dilute (umhos)					
Alkalinity (mg/l)					
pH-Field					
pH-Lab	6.5-8.5	5.0-9.0[bc]	4.5-9.0[b]		6.5-8.5
Aluminum (mg/l)					
Arsenic (mg/l)	0.05	0.05[c]	0.1[bc]	0.2[b]	0.05
Barium (mg/l)	1.0	1.0[bc]			1.0
Cadmium (mg/l)	0.01	0.01[bc]	0.01[b]	0.05[b]	0.01
Chromium (mg/l)	0.05	0.05[bc]	0.1[b]	1.0[b]	0.05
Cobalt (mg/l)					
Copper (mg/l)	1.0	1.0[bc]	0.2[b]	0.5[b]	1.0
Iron (mg/l)	1.0	0.3[bc]	5.0[b]		0.3
Lead (mg/l)	0.05	0.05[bc]	5.0[b]	0.1[b]	0.05
Manganese (mg/l)	0.2	0.05[bc]	0.2[b]		0.05
Mercury (mg/l)	0.002	0.002[bc]		0.01[b]	0.002
Molybdenum (mg/l)					
Nickel (mg/l)			0.2[b]		
Selenium (mg/l)	0.01	0.01[bc]	0.02[b]	0.05[b]	0.01
Vanadium (mg/l)			0.1[b]	0.1[b]	
Zinc (mg/l)	5.0	5.0[bc]	2.0[b]	25[b]	5.0
Boron (mg/l)			0.75[c]	5.0[b]	
Uranium (ug/l)					
Radium-226 (pCi/l)	5.0[f]	5.0[f]	5.0[f]	5.0[f]	5.0[f]

Footnotes to Comparison Ground-Water Quality
Criteria and Standards Table

a Maximum contaminant levels as presented in Chapter 4 of Title 118, Ground Water Protection Standards, Nebraska Department of Environmental Control.

b Levels based on recommendations from Water Quality Criteria, 1972, EPA-R3-73-003, March, 1972.

c Levels based on Quality Criteria for Water, July, 1976. USEPA Stock No. 005-001-01049-4.

d Levels based on CFR 40, Parts 100 to 149, Revised as of July 1, 1982.

e Uranyl ion based on Water Quality criteria USEPA 1968 edition.

f Radium-226 + Radium-228 = 5 pCi/l

A-2

Baseline Water Quality

CROW B[illegible] PROJECT
WATER QUALITY

Well Number: RA-2
Well Type: BASELINE WELL
Formation: BRULE

Surface Elevation: 3744.9 ft MSL
Well Depth: 26.9 ft
Distance From Wellfield: 11,900 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 07/22/82 NRL	09/29/82 NRL	01/20/83 NRL	04/04/83 CORE	07/19/83 CORE	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)		67	73	74	73	71	67	74	72
Magnesium (mg/l)		5.1	10	9.7	9.5	8.4	8.4	10.0	9.3
Sodium (mg/l)		41	36	38	39	34	34	41	38
Potassium (mg/l)		11	11	11	10.3	10.3	10.3	11.0	10.7
Carbonate (mg/l)		<2	<2	14	<1	<1	<1	14	4
Bicarbonate (mg/l)		330	320	320	364	312.0	312	364	329
Sulfate (mg/l)	250	19	14	12	11	16	11	19	14
Chloride (mg/l)	250	5	6	5	5.9	6.1	5.0	6.1	5.6
Ammonia-N (mg/l)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	2.4	0.01	1.5	1.0	2.1	0.01	2.4	1.40
Fluoride (mg/l)	1.4-2.4	0.9	0.7	0.8	1.09	0.9	0.7	1.1	0.9
Silica (mg/l)		56	57	54	53	57	53	57	55
TDS-180°C (mg/l)	500	370	380	350	384	372	350	384	371
Conductivity - Field (umhos)		370	540	430	480	350	350	540	434
Conductivity - Lab (umhos)		568	541	541	550	540	540	568	548
Conductivity - Dilute (umhos)		617	575	616	580	570	570	617	592
Alkalinity (mg/l)		270	260	290	303	265	260	303	278
pH - Field		7.8	6.9	7.1	7.05	7.10	6.9	7.8	7.2
pH - Lab		7.6	7.4	8.4	6.89	7.50	6.9	8.4	7.6
Aluminum (mg/l)		<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	0.005	0.007	0.009	<0.01		0.005	<0.01	<0.008
Barium (mg/l)	1	0.3	0.2	<0.1	<0.1		<0.1	0.3	0.2
Cadmium (mg/l)	0.01	<0.001	<0.001	<0.001	<0.01		<0.001	<0.01	<0.003
Chromium (mg/l)	0.05	0.001	<0.001	<0.001			<0.001	0.001	0.001
Cobalt (mg/l)		<0.001	<0.001	<0.001	<0.05		<0.001	<0.05	<0.013
Copper (mg/l)	1	<0.001	0.003	0.004	<0.01		<0.001	<0.01	<0.005
Iron (mg/l)	0.3	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05
Lead (mg/l)	0.05	<0.005	0.005	0.005	<0.01		<0.005	<0.01	<0.006
Manganese (mg/l)	0.05	<0.10	<0.1	<0.1	<0.01		<0.01	<0.10	<0.08
Mercury (mg/l)	0.002	<0.0001	<0.0001	0.0001	0.0003		<0.0001	0.0003	0.0002
Molybdenum (mg/l)		<0.002	0.014	0.004	<0.1		<0.002	<0.1	<0.03
Nickel (mg/l)		<0.002	<0.002	<0.002	<0.05		<0.002	<0.05	<0.014
Selenium (mg/l)	0.01	<0.002	<0.002	<0.002	<0.01		<0.002	<0.01	<0.004
Vanadium (mg/l)		0.012	0.010	0.012	<0.1		0.010	<0.1	<0.03
Zinc (mg/l)	5	0.19	0.180	0.18	0.08		0.08	0.19	0.157
Boron (mg/l)		0.6	0.5	<0.5	0.15		0.15	0.6	0.44
Uranium (µg/l)		16	14	21	9	5	5	21	13.
Radium 226 (pCi/l)	5	0.8±0.1	0.5±0.1	18.3±0.4*	0.4±0.2	0.4±0.2	0.4	0.8	0.53
Temperature (°C)		12	11	10	8	10	8	12	10
Water Level (ft) MSL		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CROW BUT[illegible] [illegible]JECT
WATER Q[illegible]TY

Well Number: RB-3
Well Type: BASELINE WELL
Formation: BRULE

Surface Elevation: 4040.2 ft MSL
Well Depth: 115.2 ft
Distance From Wellfield: 7,300 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 08/01/82 NRL	09/30/82 NRL	01/21/83 NRL	04/05/83 CORE	07/20/83 CORE	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)		38	37	30	33	29	29	38	33
Magnesium (mg/l)		5.1	4.8	3.7	4.3	3.4	3.4	5.1	4.3
Sodium (mg/l)		14	21	18	15	24	14	24	18
Potassium (mg/l)		6.1	6.9	8.5	6.8	8.0	6.1	8.5	7.3
Carbonate (mg/l)		<2	<2	<2	<1	<1	<1	<2	<2
Bicarbonate (mg/l)		180	180	160	137	154.0	137	180	162
Sulfate (mg/l)	250	7	<5	7	<5	6.1	<5	7	6.0
Chloride (mg/l)	250	2	4	<2	1.9	5.5	1.9	5.5	3.4
Ammonia-N (mg/l)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrite-N (mg/l)		0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Nitrate-N (mg/l)	10	0.48	<0.01*	0.50	0.5	0.4	0.4	0.50	0.47
Fluoride (mg/l)	1.4-2.4	0.3	0.3	0.3	0.42	0.4	0.3	0.4	0.3
Silica (mg/l)		61	62	60	52	62	52	62	59
TDS-180°C (mg/l)	500	230	290	190	196	227	190	290	227
Conductivity - Field (umhos)		230	350*	210	240	240	210	240	230
Conductivity - Lab (umhos)		290	282	246	180	280	180	290	256
Conductivity - Dilute (umhos)		303	295	266	190	290	190	303	269
Alkalinity (mg/l)		150	140	130	96	137	96	150	131
pH - Field		7.65	8.2	8.1	7.6	7.85	7.6	8.2	7.9
pH - Lab		7.9	8.3	8.2	6.46	7.68	6.5	8.3	7.7
Aluminum (mg/l)		<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	<0.002	0.002	0.002	<0.01		<0.002	<0.01	<0.004
Barium (mg/l)	1	0.2	0.2	<0.1	0.2		<0.1	0.2	0.2
Cadmium (mg/l)	0.01	<0.001	<0.001	<0.001	<0.01		<0.001	<0.01	<0.003
Chromium (mg/l)	0.05	0.001	0.001	<0.001			<0.001	0.001	0.001
Cobalt (mg/l)		<0.001	<0.001	<0.001	<0.05		<0.001	<0.05	<0.013
Copper (mg/l)	1	0.001	0.001	0.001	<0.01		0.001	<0.01	<0.003
Iron (mg/l)	0.3	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05
Lead (mg/l)	0.05	<0.005	0.005	<0.005	<0.01		<0.005	<0.01	<0.006
Manganese (mg/l)	0.05	<0.10	<0.1	<0.1	<0.01		<0.01	<0.10	<0.08
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0001	<.0003		<0.0001	<.0003	<0.0002
Molybdenum (mg/l)		<0.002	0.007	<0.002	<0.1		<0.002	<0.1	<0.03
Nickel (mg/l)		<0.002	0.002	<0.002	<0.05		<0.002	<0.05	<0.014
Selenium (mg/l)	0.01	<0.002	<0.002	<0.002	<0.01		<0.002	<0.01	<0.004
Vanadium (mg/l)		0.007	0.001	0.006	<0.1		0.001	<0.1	<0.03
Zinc (mg/l)	5	0.064	0.008	0.005	0.02		0.005	0.064	0.024
Boron (mg/l)		<0.5	0.5	<0.5	0.09		0.09	0.5	0.40
Uranium (µg/l)		6	6	7	<1	<1	<1	7	4.
Radium 226 (pCi/l)	5	0.4±0.1	0.1±0.1	1.1±0.1	0.0±0.1	3.4±3.4	0.1	3.4	1.3
Temperature (°C)		15	13	13	15	17	13	17	15
Water Level (ft) MSL		0.0	1961.2	1963.8	1969.7	1964.1	1961.2	1969.7	1964.8

WHITE PROJECT
WATER QUALITY

Well Number: RC-3
Well Type: BASELINE WELL
Formation: CHADRON

Surface Elevation: 1707.9 ft MSL
Well Depth: 270.0 ft
Distance From Wellfield: 15,300 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 07/21/82 NRL	09/29/82 NRL	01/20/83 NRL	04/05/83 NRL	04/05/83 CORE	07/21/83 CORE
Calcium (mg/l)		16	19	15	16	16	16
Magnesium (mg/l)		2.5	2.9	2.5	2.6	2.8	2.35
Sodium (mg/l)		390	370	350	370	380	370
Potassium (mg/l)		8.4	8.1	8.5	7.8	8.3	7.8
Carbonate (mg/l)		<2	<2	9	<2	<1	<1
Bicarbonate (mg/l)		390	400	370	380	384	371.0
Sulfate (mg/l)	250	340	340	320	320	320	313
Chloride (mg/l)	250	180	170	160	170	138	170
Ammonia-N (mg/l)		0.38	0.43	0.26	0.37	0.53	0.37
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	0.02	<0.01	0.02	<0.01	<0.1	<0.1
Fluoride (mg/l)	1.4-2.4	0.6	0.5	0.6	0.6	0.92	0.6
Silica (mg/l)		10	10	10	11	170*	11
TDS-180°C (mg/l)	500	1100	1100	1000	1000	1256	1121
Conductivity - Field (umhos)		1600	1700	1500	1650	1650	1450
Conductivity - Lab (umhos)		1810	1790	1680	1770	1750	1820
Conductivity - Dilute (umhos)		2060	1980	1980	2030	1800	2000
Alkalinity (mg/l)		320	320	320	320	327	317
pH - Field		8.2	7.65	7.7	7.8	7.8	7.75
pH - Lab		8.0	7.9	8.5	8.0	7.66	8.00
Aluminum (mg/l)		<0.1	<0.1	<0.1	<0.1	<0.1	
Arsenic (mg/l)	0.05	<0.002	<0.002	<0.002	<0.001	0.01	
Barium (mg/l)	1	<0.1	<0.1	<0.1	<0.1	0.2	
Cadmium (mg/l)	0.01	<0.001	<0.001	<0.001	<0.001	<0.01	
Chromium (mg/l)	0.05	0.001	0.001	<0.001	<0.001		
Cobalt (mg/l)		<0.001	<0.001	<0.001	<0.001	<0.05	
Copper (mg/l)	1	<0.001	0.003	0.003	0.002	<0.01	
Iron (mg/l)	0.3	<0.05	<0.05	<0.05	<0.05	<0.05	
Lead (mg/l)	0.05	<0.005	0.005	<0.005	<0.005	<0.01	
Manganese (mg/l)	0.05	<0.10	<0.1	<0.1	<0.1	<0.01	
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<.0003	
Molybdenum (mg/l)		<0.002	<0.002	<0.002	<0.002	<0.1	
Nickel (mg/l)		<0.002	0.002	<0.002	<0.002	<0.05	
Selenium (mg/l)	0.01	<0.002	<0.002	<0.002	<0.002	<0.01	
Vanadium (mg/l)		0.007	0.001	0.002	0.004	<0.1	
Zinc (mg/l)	5	<0.002	0.020	0.005	0.006	<0.01	
Boron (mg/l)		1.1	0.8	0.9	0.9	0.94	
Uranium (µg/l)		5	2	6	4	<1	<1
Radium 226 (pCi/l)	5	1.7±0.1	0.6±0.1	2.0±0.1	1.5±0.1	0.7±0.2	0.8±0.2
Temperature (°C)		15	14	11	8.0	8.0	14
Water Level (ft) MSL		--	3733.5	3733.5	3731.2	3731.2	3741.2

CHOW[illegible] PROJECT
WA[illegible] QUALITY

Well Number: RC-3

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)			15	19	16
Magnesium (mg/l)			2.3	2.9	2.6
Sodium (mg/l)			350	390	372
Potassium (mg/l)			7.8	8.5	8.1
Carbonate (mg/l)			<1	9	3
Bicarbonate (mg/l)			370	400	383
Sulfate (mg/l)	250		313	340	326
Chloride (mg/l)	250		138	180	165
Ammonia-N (mg/l)			0.26	0.53	0.39
Nitrite-N (mg/l)			<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10		<0.01	<0.1	<0.04
Fluoride (mg/l)	1.4-2.4		0.5	0.9	0.6
Silica (mg/l)			10	11	11
TDS-180°C (mg/l)	500		1000	1256	1096
Conductivity - Field (umhos)			1450	1700	1592
Conductivity - Lab (umhos)			1680	1820	1770
Conductivity - Dilute (umhos)			1800	2060	1975
Alkalinity (mg/l)			317	327	321
pH - Field			7.7	8.2	7.8
pH - Lab			7.7	8.5	8.0
Aluminum (mg/l)			<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05		<0.001	0.01	0.001
Barium (mg/l)	1		<0.1	0.2	0.1
Cadmium (mg/l)	0.01		<0.001	<0.01	<0.003
Chromium (mg/l)	0.05		<0.001	0.001	0.001
Cobalt (mg/l)			<0.001	<0.05	<0.011
Copper (mg/l)	1		<0.001	<0.01	<0.004
Iron (mg/l)	0.3		<0.05	<0.05	<0.05
Lead (mg/l)	0.05		<0.005	<0.01	<0.006
Manganese (mg/l)	0.05		<0.01	<0.10	<0.08
Mercury (mg/l)	0.002		<0.0001	<.0003	<0.0001
Molybdenum (mg/l)			<0.002	<0.1	<0.07
Nickel (mg/l)			<0.002	<0.05	<0.012
Selenium (mg/l)	0.01		<0.002	<0.01	<0.004
Vanadium (mg/l)			0.001	<0.1	<0.02
Zinc (mg/l)	5		<0.002	0.020	0.009
Boron (mg/l)			0.8	1.1	0.93
Uranium (µg/l)			<1	6	3.
Radium 226 (pCi/l)	5		0.6	2.0	1.2
Temperature (°C)			8	15	12
Water Level (ft) MSL			3731.2	3711.5	3712.1

CROW [illegible] PROJECT
WAT[illegible]ALITY

Well Number: RC-4
Well Type: BASELINE WELL
Formation: CHADRON

Surface Elevation: 3746.2 ft MSL
Well Depth: 159.9 ft
Distance From Wellfield: 11,800 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 07/22/82 NRL	09/30/82 NRL	01/20/83 NRL	04/04/83 CORE	07/20/83 CORE	MINIUM	MAXIMUM	AVERAGE
Calcium (mg/l)		17	18	16	17	17	16	18	17
Magnesium (mg/l)		3.7	4.2	3.7	4.3	3.3	3.3	4.3	3.8
Sodium (mg/l)		390	380	380	400	380	380	400	386
Potassium (mg/l)		9.3	8.9	9.0	9.1	9.4	8.9	9.4	9.1
Carbonate (mg/l)		<2	<2	<2	<1	<1	<1	<2	<2
Bicarbonate (mg/l)		400	410	400	395	386.0	386	410	398
Sulfate (mg/l)	250	350	340	340	325	316	316	350	334
Chloride (mg/l)	250	170	160	160	152	169	152	170	162
Ammonia-N (mg/l)		0.18	0.45	0.29	0.30	0.28	0.18	0.45	0.30
Nitrite-N (mg/l)		<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.02	0.01
Nitrate-N (mg/l)	10	0.02	<0.01	0.09	0.2	<0.1	<0.01	0.2	0.08
Fluoride (mg/l)	1.4-2.4	0.6	0.5	0.6	0.92	0.7	0.5	0.9	0.7
Silica (mg/l)		10	10	10	340*	12	10	10	10.5
TDS-180°C (mg/l)	500	1100	1100	1100	1108	1150	1100	1150	1112
Conductivity - Field (umhos)		1440	1875	1600	1700	1650	1440	1875	1653
Conductivity - Lab (umhos)		1870	1810	1690	1550	1850	1550	1870	1754
Conductivity - Dilute (umhos)		2080	2020	2020	1600*	1980	1980	2080	2025
Alkalinity (mg/l)		330	330	330	331	332	330	332	331
pH - Field		8.3	7.8	8.0	7.85	7.55	7.6	8.3	7.9
pH - Lab		8.1	8.2	8.3	7.82	8.08	7.8	8.3	8.1
Aluminum (mg/l)		<0.1	0.1	<0.1	<0.1		<0.1	0.1	0.1
Arsenic (mg/l)	0.05	<0.002	<0.002	0.002	<0.01		<0.002	<0.01	<0.004
Barium (mg/l)	1	<0.1	0.1	<0.1	<0.1		<0.1	0.1	0.1
Cadmium (mg/l)	0.01	<0.001	<0.001	<0.001	<0.01		<0.001	<0.01	<0.003
Chromium (mg/l)	0.05	0.001	<0.001	<0.001			<0.001	0.001	0.001
Cobalt (mg/l)		<0.001	<0.001	<0.001	<0.05		<0.001	<0.05	<0.013
Copper (mg/l)	1	<0.001	0.001	0.003	<0.01		<0.001	<0.01	<0.004
Iron (mg/l)	0.3	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05
Lead (mg/l)	0.05	<0.005	0.005	<0.005	<0.01		<0.005	<0.01	<0.006
Manganese (mg/l)	0.05	<0.10	<0.1	<0.1	<0.01		<0.01	<0.10	<0.08
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0001	0.0003		<0.0001	0.0003	0.0002
Molybdenum (mg/l)		0.018	0.028	0.033	<0.1		0.018	<0.1	<0.04
Nickel (mg/l)		<0.002	<0.002	<0.002	<0.05		<0.002	<0.05	<0.014
Selenium (mg/l)	0.01	<0.002	<0.002	<0.002	<0.01		<0.002	<0.01	<0.004
Vanadium (mg/l)		0.007	0.001	0.005	<0.1		0.001	<0.1	<0.03
Zinc (mg/l)	5	0.11	0.059	0.015	<0.01		<0.01	0.11	0.040
Boron (mg/l)		1.2	0.9	0.9	0.93		0.9	1.2	0.98
Uranium (µg/l)		65	870	2400	2000	217	65	2400	1110
Radium 226 (pCi/l)	5	235±5	430±10	619±13	432±4.9	341±3.4	235	619	411.
Temperature (°C)		17	15	15	13	17	13	17	15
Water Level (ft) MSL		0.0	0.0	1746.2	1746.2	1746.2	1746.2	1746.2	1746.2

CROW BUTTE PROJECT
WATER QUALITY

Well Number: RC-5
Well Type: BASELINE WELL
Formation: CHADRON

Surface Elevation: 3903.4 ft MSL
Well Depth: 594.8 ft
Distance From Wellfield: 3,900 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 07/22/82 NRL	09/30/82 NRL	01/21/83 NRL	04/05/83 CORE	07/19/83 CORE	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)		19	18	18	18	20	18	20	19
Magnesium (mg/l)		3.2	3.0	3.2	3.0	3.0	3.0	3.2	3.1
Sodium (mg/l)		390	370	390	380	380	370	390	382
Potassium (mg/l)		11	10	10	10	10.1	10.0	11.0	10.2
Carbonate (mg/l)		<2	2	12	<1	<1	<1	12	4
Bicarbonate (mg/l)		370	350	350	363	363.0	350	370	359
Sulfate (mg/l)	250	370	360	360	352	346	346	370	358
Chloride (mg/l)	250	180	190	180	174	175	174	190	180
Ammonia-N (mg/l)		0.19	0.35	0.26	0.29	0.29	0.19	0.35	0.28
Nitrite-N (mg/l)		<0.01	<0.01	0.03	<0.01	0.03	<0.01	0.03	0.02
Nitrate-N (mg/l)	10	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.1	<0.05
Fluoride (mg/l)	1.4-2.4	0.6	0.5	0.6	0.87	0.7	0.5	0.9	0.7
Silica (mg/l)		13	13	10	13	13	10	13	12
TDS-180°C (mg/l)	500	1100	1100	1100	1136	1142	1100	1142	1116
Conductivity - Field (umhos)		1520	1900	1700	1850	1750	1520	1900	1744
Conductivity - Lab (umhos)		1870	1850	1730	1800	1830	1730	1870	1816
Conductivity - Dilute (umhos)		2140	2050	2050	1850	1980	1850	2140	2014
Alkalinity (mg/l)		310	290	310	306	309	290	310	305
pH - Field		8.25	8.2	7.9	7.95	7.60	7.6	8.3	8.0
pH - Lab		8.1	8.4	8.7	7.98	8.00	8.0	8.7	8.2
Aluminum (mg/l)		<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	<0.002	<0.002	<0.002	<0.01		<0.002	<0.01	<0.004
Barium (mg/l)	1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1
Cadmium (mg/l)	0.01	<0.001	<0.001	<0.001	<0.01		<0.001	<0.01	<0.003
Chromium (mg/l)	0.05	0.001	<0.001	<0.001			<0.001	0.001	0.001
Cobalt (mg/l)		<0.001	0.001	<0.001	<0.05		<0.001	<0.05	<0.013
Copper (mg/l)	1	<0.001	0.003	0.003	<0.01		<0.001	<0.01	<0.004
Iron (mg/l)	0.3	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05
Lead (mg/l)	0.05	<0.005	0.010	<0.005	<0.01		<0.005	0.010	0.008
Manganese (mg/l)	0.05	<0.10	<0.1	<0.1	<0.01		<0.01	<0.10	<0.08
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0001	<.0003		<0.0001	<.0003	<0.0007
Molybdenum (mg/l)		0.005	0.006	0.010	<0.1		0.005	<0.1	<0.03
Nickel (mg/l)		<0.002	<0.002	<0.002	<0.05		<0.002	<0.05	<0.014
Selenium (mg/l)	0.01	<0.002	<0.002	<0.002	<0.01		<0.002	<0.01	<0.004
Vanadium (mg/l)		0.007	0.001	0.002	<0.1		0.001	<0.1	<0.03
Zinc (mg/l)	5	0.016	0.012	0.010	0.01		0.010	0.016	0.012
Boron (mg/l)		0.9	1.0	0.5	0.98		0.5	1.0	0.85
Uranium (µg/l)		3	6	<2	<1	<1	<1	6	3.
Radium 226 (pCi/l)	5	3.8±0.1	3.0±0.1	3.3±0.1	3.5±0.4	3.3±0.4	3.0	3.8	3.4
Temperature (°C)		18	15	17	15	19	15	19	17
Water Level (ft) MSL		1751.5	1751.5	1752.8	1752.8	1752.8	1752.8	1751.5	1751.1

CROW [illegible] PROJECT
WATER QUALITY

Well Number: RC-6
Well Type: BASELINE WELL
Formation: CHADRON

Surface Elevation: 3945.1 ft MSL
Well Depth: 692.0 ft
Distance From Wellfield: 3,200 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 07/22/82 NRL	09/28/82 NRL	01/24/83 NRL	04/05/83 CORE	07/20/83 CORE	MINIUM	MAXIMUM	AVERAGE
Calcium (mg/l)		35	38	30	41	37	30	41	36
Magnesium (mg/l)		6.8	7.2	6.2	6.3	5.9	5.9	7.2	6.5
Sodium (mg/l)		400	440	390	410	380	380	440	404
Potassium (mg/l)		14	18	16	14	13	13	18	15
Carbonate (mg/l)		<2	5	<2	<1	<1	<1	5	2
Bicarbonate (mg/l)		330	310	320	316	334.0	310	340	326
Sulfate (mg/l)	250	470	460	430	436	418	418	470	443
Chloride (mg/l)	250	190	250	220	207	192	190	250	212
Ammonia-N (mg/l)		0.31	0.58	0.30	0.34	0.30	0.30	0.58	0.37
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	0.01	0.03	0.08	<0.1	<0.1	0.01	<0.1	<0.06
Fluoride (mg/l)	1.4-2.4	0.7	0.6	0.7	0.71	0.7	0.6	0.7	0.7
Silica (mg/l)		18	16	16	34*	16	16	18	16.[illegible]
TDS-180°C (mg/l)	500	1200	1300	1200	1304	1273	1200	1304	1255
Conductivity - Field (umhos)		1600	2200	1600	2600	2100	1600	2600	2020
Conductivity - Lab (umhos)		2020	1800	1970	1970	2280	1800	2280	2008
Conductivity - Dilute (umhos)		2160	2460	2360	2000	2580	2000	2580	2312
Alkalinity (mg/l)		270	250	280	278	285	250	285	273
pH - Field		8.0	8.6	8.1	8.45	7.65	7.7	8.6	8.2
pH - Lab		8.0	8.4	8.2	7.83	8.02	7.8	8.4	8.1
Aluminum (mg/l)		<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	0.008	0.005	0.005	<0.01		0.005	<0.01	<0.007
Barium (mg/l)	1	<0.1	0.1	<0.1	<0.1		<0.1	0.1	0.1
Cadmium (mg/l)	0.01	0.001	<0.001	<0.001	<0.01		<0.001	<0.01	<0.003
Chromium (mg/l)	0.05	0.001	<0.001	0.004			<0.001	0.004	0.002
Cobalt (mg/l)		<0.001	<0.001	0.001	<0.05		<0.001	<0.05	<0.013
Copper (mg/l)	1	0.002	0.002	0.002	<0.01		0.002	<0.01	<0.004
Iron (mg/l)	0.3	<0.05	<0.05	0.50	<0.05		<0.05	0.50	0.16
Lead (mg/l)	0.05	<0.005	0.010	<0.005	<0.01		<0.005	0.010	0.008
Manganese (mg/l)	0.05	<0.10	<0.1	<0.1	<0.01		<0.01	<0.10	<0.08
Mercury (mg/l)	0.002	<0.0001	0.0001	<0.0001	0.0003		<0.0001	0.0003	0.0002
Molybdenum (mg/l)		0.019	0.032	0.023	<0.1		0.019	<0.1	<0.04
Nickel (mg/l)		<0.002	0.002	<0.002	<0.05		<0.002	<0.05	<0.014
Selenium (mg/l)	0.01	<0.002	<0.002	<0.002	<0.01		<0.002	<0.01	<0.004
Vanadium (mg/l)		0.008	0.002	0.006	<0.1		0.002	<0.1	<0.03
Zinc (mg/l)	5	0.096	0.030	0.009	<0.01		0.009	0.096	0.036
Boron (mg/l)		1.1	0.7	0.9	0.98		0.7	1.1	0.92
Uranium (µg/l)		6	3	2	<1	<1	<1	6	3.
Radium 226 (pCi/l)	5	9.9±0.2	0.4±0.1	0.2±0.1	0.2±0.1	0.6±0.2	0.2	9.9	2.1
Temperature (°C)		19	16	11	17	22	11	22	17
Water Level (ft) MSL		1755.8	1755.1	1757.1	1755.8	1755.1	1755.1	1757.1	1755.8

DRAFT

CROW BU[illegible] PROJECT
WATER QUALITY

Well Number: RC-7
Well Type: BASELINE WELL
Formation: CHADRON

Surface Elevation: 4038.9 ft MSL
Well Depth: 717.9 ft
Distance From Wellfield: 7,300 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 07/21/82 NRL	09/28/82 NRL	01/20/83 NRL	04/05/83 CORE	07/20/83 CORE	MINIUM	MAXIMUM	AVERAGE
Calcium (mg/l)		19	25	18	13	20	13	25	19
Magnesium (mg/l)		3.1	3.5	3.0	2.18	2.9	2.2	3.5	2.9
Sodium (mg/l)		360	350	350	340	350	340	360	350
Potassium (mg/l)		11	11	11	10.8	10.1	10.1	11.0	10.8
Carbonate (mg/l)		<2	<2	9	<1	<1	<1	9	3
Bicarbonate (mg/l)		360	340	340	308	350.0	308	360	340
Sulfate (mg/l)	250	330	310	310	286	304	286	330	308
Chloride (mg/l)	250	170	180	160	172	167	160	180	170
Ammonia-N (mg/l)		0.37	0.45	0.43	<0.05	0.25	<0.05	0.45	0.31
Nitrite-N (mg/l)		0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01
Nitrate-N (mg/l)	10	0.02	0.01	<0.01	0.3	0.2	<0.01	0.3	0.11
Fluoride (mg/l)	1.4-2.4	0.8	0.7	0.8	0.82	0.7	0.7	0.8	0.8
Silica (mg/l)	-	15	16	14	30 *	15	14	16	15.0
TDS-180°C (mg/l)	500	1000	1100	990	1044	1075	990	1100	1042
Conductivity - Field (umhos)		1650	1700	1550	1600	1800	1550	1800	1660
Conductivity - Lab (umhos)		1720	1610	1580	1500	1750	1500	1750	1632
Conductivity - Dilute (umhos)		1940	1850	1860	1490	1860	1490	1940	1800
Alkalinity (mg/l)		290	280	300	267	297	267	300	287
pH - Field		8.5	8.2	8.0	8.05	7.70	7.7	8.5	8.1
pH - Lab		8.0	8.3	8.5	7.91	8.02	7.9	8.5	8.1
Aluminum (mg/l)		<0.1	0.6	<0.1	<0.1		<0.1	0.6	0.2
Arsenic (mg/l)	0.05	<0.002	0.002	<0.002	<0.01		<0.002	<0.01	<0.004
Barium (mg/l)	1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1
Cadmium (mg/l)	0.01	<0.001	<0.001	<0.001	<0.01		<0.001	<0.01	<0.003
Chromium (mg/l)	0.05	0.001	0.001	<0.001			<0.001	0.001	0.001
Cobalt (mg/l)		<0.001	<0.001	<0.001	<0.05		<0.001	<0.05	<0.013
Copper (mg/l)	1	<0.001	0.003	0.003	<0.01		<0.001	<0.01	<0.004
Iron (mg/l)	0.3	<0.05	0.31*	<0.05	<0.05		<0.05	0.05	0.05
Lead (mg/l)	0.05	<0.005	0.010	<0.005	<0.01		<0.005	0.010	0.008
Manganese (mg/l)	0.05	<0.10	<0.1	<0.1	<0.01		<0.01	<0.10	<0.08
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0001	<.0003		<0.0001	<.0003	<0.0002
Molybdenum (mg/l)		0.018	0.017	0.022	<0.1		0.017	<0.1	<0.04
Nickel (mg/l)		<0.002	<0.002	<0.002	<0.05		<0.002	<0.05	<0.014
Selenium (mg/l)	0.01	<0.002	<0.002	<0.002	<0.01		<0.002	<0.01	<0.004
Vanadium (mg/l)		0.007	0.003	0.002	<0.1		0.002	<0.1	<0.03
Zinc (mg/l)	5	0.004	0.038	0.010	0.02		0.004	0.038	0.018
Boron (mg/l)		1.3	0.9	0.9	0.91		0.9	1.3	1.00
Uranium (µg/l)		3	1	3	<1	<1	<1	3	2.
Radium 226 (pCi/l)	5	0.8±0.1	0.4±0.1	2.1±0.1	0.5±0.2	0.6±0.2	0.4	2.1	0.9
Temperature (°C)		19	13	17	15	22	15	22	18
Water Level (ft) MSL		1755.8	1756.7	1756.1	1756.4	1756.1	1755.8	1756.7	1756.4

CRO[illegible] & PRODUCT
W[illegible] QUALITY

Well Number: PT-2
Well Type: BASELINE
Formation: CHADRON

Surface Elevation: 3865.0 ft MSL
Well Depth: 665.1 ft
Distance From Wellfield: 0 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 12/03/82 JORDAN	01/18/83 NRL	04/12/83 CORE	07/18/83 CORE	07/18/83 CORE-A
Calcium (mg/l)		15	12	11	7.7	7.8
Magnesium (mg/l)		3.6	3.0	2.5	2.05	2.06
Sodium (mg/l)		406	390	420	400	400
Potassium (mg/l)		16	15	17	18	18
Carbonate (mg/l)		5	14	<1	<1	<1
Bicarbonate (mg/l)		368	350	353	338.0	337.0
Sulfate (mg/l)	250	355	370	343	339	344
Chloride (mg/l)	250	188	200	205	221	216
Ammonia-N (mg/l)		0.52	0.40	0.38	0.34	0.33
Nitrite-N (mg/l)		<0.01	<0.01	0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	0.05	<0.01	<0.1	0.1	0.1
Fluoride (mg/l)	1.4-2.4	0.66	0.6	0.7	0.6	0.5
Silica (mg/l)		11	13	15	15	16
TDS-180°C (mg/l)	500	1220	1100	1184	1193	1185
Conductivity - Field (umhos)		2100	1900	2000	2000	2000
Conductivity - Lab (umhos)		1830	1800	1675	2000	2000
Conductivity - Dilute (umhos)		2190	2110	2027	2210	2210
Alkalinity (mg/l)		310	310	303	287	290
pH - Field		8.25	8.35	8.4	8.30	8.30
pH - Lab		8.42	8.6	8.30	8.19	8.15
Aluminum (mg/l)			<0.1	<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	.006	0.004	<0.01	<0.005	<0.005
Barium (mg/l)	1	0.09	<0.1	<0.1	<0.1	<0.1
Cadmium (mg/l)	0.01	<0.0001	<0.001	<0.01	<0.001	<0.001
Chromium (mg/l)	0.05	<0.001	<0.001		<0.005	<0.005
Cobalt (mg/l)			<0.001	<0.05	<0.005	<0.005
Copper (mg/l)	1	0.003	0.004	<0.01	<0.01	<0.01
Iron (mg/l)	0.3	0.02	<0.05	<0.05	<0.03	<0.03
Lead (mg/l)	0.05	<0.001	<0.005	<0.01	<0.005	<0.005
Manganese (mg/l)	0.05	0.007	<0.1	<0.01	<0.005	<0.005
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0003	<0.0002	<0.0002
Molybdenum (mg/l)		0.02	0.024	<0.1	<0.01	<0.01
Nickel (mg/l)		<0.01	<0.002	<0.05	<0.01	<0.01
Selenium (mg/l)	0.01	<0.001	<0.002	<0.01	0.001	0.001
Vanadium (mg/l)		0.01	0.027	<0.1	<0.01	<0.01
Zinc (mg/l)	5	0.010	<0.005	<0.01	0.01	0.01
Boron (mg/l)		1.0	0.9	0.93	0.77	0.81
Uranium (µg/l)		933	770	660	417	404
Radium 226 (pCi/l)	5	136±1	68.1±1.4	54.9±1.5	37.1±1.1	42.8±1.3
Temperature (°C)		10	19	16	20	20
Water Level (ft) MSL		3754.1	3753.1	3754.4	3754.1	3754.1

CROW [illegible] PROJECT
WATER QUALITY

Well Number: PT-2

Date Sampled Lab Name	EPA Standards and Criteria	SAMPLE RESULTS	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)			7.7	15.0	10.2
Magnesium (mg/l)			2.0	3.6	2.5
Sodium (mg/l)			390	420	403
Potassium (mg/l)			15	18	17
Carbonate (mg/l)			<1	14	4
Bicarbonate (mg/l)			337	368	347
Sulfate (mg/l)	250		339	370	349
Chloride (mg/l)	250		188	221	208
Ammonia-N (mg/l)			0.33	0.52	0.39
Nitrite-N (mg/l)			<0.01	0.01	0.01
Nitrate-N (mg/l)	10		<0.01	0.1	0.08
Fluoride (mg/l)	1.4-2.4		0.5	0.7	0.6
Silica (mg/l)			11	16	14
TDS-180°C (mg/l)	500		1100	1220	1178
Conductivity - Field (umhos)			1900	2100	2000
Conductivity - Lab (umhos)			1675	2000	1884
Conductivity - Dilute (umhos)			2027	2210	2160
Alkalinity (mg/l)			287	310	298
pH - Field			8.3	8.4	8.3
pH - Lab			8.1	8.6	8.3
Aluminum (mg/l)			<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05		0.004	<0.01	<0.006
Barium (mg/l)	1		0.09	<0.1	<0.10
Cadmium (mg/l)	0.01		<0.0001	<0.01	<0.003
Chromium (mg/l)	0.05		<0.001	<0.005	<0.003
Cobalt (mg/l)			<0.001	<0.05	<0.015
Copper (mg/l)	1		0.003	<0.01	<0.007
Iron (mg/l)	0.3		0.02	<0.05	<0.04
Lead (mg/l)	0.05		<0.001	<0.01	<0.005
Manganese (mg/l)	0.05		<0.005	<0.1	<0.03
Mercury (mg/l)	0.002		<0.0001	<0.0003	<0.0007
Molybdenum (mg/l)			<0.01	<0.1	<0.03
Nickel (mg/l)			<0.002	<0.05	<0.016
Selenium (mg/l)	0.01		<0.001	<0.01	<0.003
Vanadium (mg/l)			<0.01	<0.1	<0.03
Zinc (mg/l)	5		<0.005	0.010	0.009
Boron (mg/l)			0.77	1.0	0.88
Uranium (µg/l)			404	933	600.
Radium 226 (pCi/l)	5		37.1	136	62.7
Temperature (°C)			10	20	18
Water Level (ft) MSL			3753.1	3754.4	3754.1

CRO[illegible] PROJECT
QUALITY

Well Number: PT-7
Well Type: BASELINE
Formation: CHADRON

Surface Elevation: 3868.3 ft MSL
Well Depth: 672.3 ft
Distance From Wellfield: 0 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 12/03/82 CORE	12/03/82 JORDAN	01/18/83 NRL	04/11/83 NRL	04/11/83 CORE	07/18/83 CORE
Calcium (mg/l)		16	17	15	15	15	20
Magnesium (mg/l)		4.1	4.0	3.9	3.9	3.6	3.50
Sodium (mg/l)		412	402	400	410	400	370
Potassium (mg/l)		10.3	12	10	12	10.6	13
Carbonate (mg/l)		9.5	0	2	<2	<1	<1
Bicarbonate (mg/l)		377	383	380	390	373	345.0
Sulfate (mg/l)	250	348	355	370	360	355	337
Chloride (mg/l)	250	166	186	180	170	178.1	185
Ammonia-N (mg/l)		0.31	0.51	0.36	0.30	0.41	0.30
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	0.01	<0.01
Nitrate-N (mg/l)	10	<0.1	0.04	<0.01	<0.01	<0.1	<0.1
Fluoride (mg/l)	1.4-2.4	0.7	0.63	0.6	0.6	0.7	0.5
Silica (mg/l)		15	14	14	14	15	16
TDS-180°C (mg/l)	500	1180	1220	1100	1100	1134	1127
Conductivity - Field (umhos)		2150	2150	1850	1950	1950	2000
Conductivity - Lab (umhos)		1740	1810	1790	1880	1510*	1800
Conductivity - Dilute (umhos)		1760	2170	2120	2160	2022	1980
Alkalinity (mg/l)		337	314	310	320	320	300
pH - Field		8.15	8.15	7.95	7.7	7.7	8.45
pH - Lab		8.39	8.10	8.4	8.1	7.81	8.22
Aluminum (mg/l)				<0.1	<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	<0.01	0.001	<0.002	<0.001	<0.01	<0.005
Barium (mg/l)	1	<0.1	0.04	<0.1	<0.1	<0.1	<0.1
Cadmium (mg/l)	0.01	<0.01	0.004	<0.001	<0.001	<0.01	<0.001
Chromium (mg/l)	0.[illegible]	<0.01	<0.001	0.003	<0.001		<0.005
Cobalt (mg/l)				<0.001	<0.001	<0.05	<0.005
Copper (mg/l)	1	<0.01	0.004	0.005	0.003	<0.01	<0.01
Iron (mg/l)	0.3	<0.05	0.01	<0.05	<0.05	0.14	0.03
Lead (mg/l)	0.05	<0.01	<0.001	<0.005	<0.005	<0.01	<0.005
Manganese (mg/l)	0.05	<0.01	0.008	<0.1	<0.1	<0.01	<0.005
Mercury (mg/l)	0.002	<0.0003	<0.0001	<0.0001	<0.0001	<0.0003	<0.0002
Molybdenum (mg/l)		<0.1	0.02	0.022	0.023	<0.1	0.01
Nickel (mg/l)		<0.05	<0.01	<0.002	<0.002	<0.05	<0.01
Selenium (mg/l)	0.01	<0.01	<0.001	<0.002	<0.002	<0.01	<0.001
Vanadium (mg/l)			<0.01	0.004	0.006	<0.1	0.02
Zinc (mg/l)	5	0.06	0.017	0.015	0.013	<0.01	0.01
Boron (mg/l)		0.96	1.1	0.9	<0.5	0.95	0.79
Uranium (µg/l)		110	119	85	68	64	600*
Radium 226 (pCi/l)	5		79±1	280±6	103±3	266±3.0	84.7±1.7
Temperature (°C)		19	19	19	17	17	23
Water Level (ft) MSL		3751.1	3754.1	3754.1	3754.1	3751.1	3751.4

CROW BUTTE RESOURCES
WATER QUALITY

Well Number: PP-7

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)			15	20	16
Magnesium (mg/l)			3.5	4.1	3.8
Sodium (mg/l)			370	412	399
Potassium (mg/l)			10.0	13.0	11.3
Carbonate (mg/l)			<1	9.5	3.1
Bicarbonate (mg/l)			345	390	375
Sulfate (mg/l)	250		337	370	354
Chloride (mg/l)	250		166.0	186.0	177.5
Ammonia-N (mg/l)			0.30	0.51	0.37
Nitrite-N (mg/l)			<0.01	0.01	0.01
Nitrate-N (mg/l)	10		<0.01	<0.1	<0.06
Fluoride (mg/l)	1.4-2.4		0.5	0.7	0.6
Silica (mg/l)			14	16	15
TDS-180°C (mg/l)	500		1100	1220	1144
Conductivity - Field (umhos)			1850	2150	2008
Conductivity - Lab (umhos)			1740	1880	1804
Conductivity - Dilute (umhos)			1760	2170	2035
Alkalinity (mg/l)			300	337	317
pH - Field			7.7	8.4	8.0
pH - Lab			7.8	8.4	8.2
Aluminum (mg/l)			<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05		<0.001	<0.01	<0.005
Barium (mg/l)	1		0.04	<0.1	<0.09
Cadmium (mg/l)	0.01		<0.001	<0.01	<0.005
Chromium (mg/l)	0.05		<0.001	<0.01	<0.004
Cobalt (mg/l)			<0.001	<0.05	<0.014
Copper (mg/l)	1		0.003	<0.01	<0.007
Iron (mg/l)	0.3		0.01	0.14	0.06
Lead (mg/l)	0.05		<0.001	<0.01	<0.006
Manganese (mg/l)	0.05		<0.005	<0.1	<0.04
Mercury (mg/l)	0.002		<0.0001	<0.0003	<0.0002
Molybdenum (mg/l)			0.01	<0.1	<0.05
Nickel (mg/l)			<0.002	<0.05	<0.021
Selenium (mg/l)	0.01		<0.001	<0.01	<0.004
Vanadium (mg/l)			0.004	<0.1	<0.03
Zinc (mg/l)	5		<0.01	0.06	0.021
Boron (mg/l)			<0.5	1.1	0.87
Uranium (µg/l)			64	119	89.2
Radium 226 (pCi/l)	5		84.7	379	222.5
Temperature (°C)			17	21	19
Water Level (ft) MSL			3754.1	3754.4	3754.1

CROW BUTT[illegible]JECT
WATER [illegible]Y

Well Number: PT-8
Well Type: BASELINE
Formation: CHADRON

Surface Elevation: 3869.9 ft MSL
Well Depth: 674.2 ft
Distance From Wellfield: 0 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 12/03/82 JORDAN	01/18/83 NRL	04/11/83 CORE	07/18/83 CORE	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)		20	17	15	15	15	20	17
Magnesium (mg/l)		3.6	3.3	2.5	2.18	2.2	3.6	2.9
Sodium (mg/l)		389	400	390	380	380	400	390
Potassium (mg/l)		17	13	12	11	11	17	13
Carbonate (mg/l)		5	14	<1	<1	<1	14	5
Bicarbonate (mg/l)		368	350	364	354.0	350	368	359
Sulfate (mg/l)	250	341	360	345	347	341	360	348
Chloride (mg/l)	250	180	180	175.9	178	175.9	180.0	178.5
Ammonia-N (mg/l)		0.54	0.38	0.45	0.33	0.33	0.54	0.43
Nitrite-N (mg/l)		0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01
Nitrate-N (mg/l)	10	0.03	0.04	<0.1	<0.1	0.03	<0.1	<0.07
Fluoride (mg/l)	1.4-2.4	0.60	0.6	0.7	0.5	0.5	0.7	0.6
Silica (mg/l)		16	15	18	19	15	19	17
TDS-180°C (mg/l)	500	1190	1100	1170	1120	1100	1190	1145
Conductivity - Field (umhos)		2100	1850	1850	1950	1850	2100	1938
Conductivity - Lab (umhos)		1740	1750	1510	1900	1510	1900	1725
Conductivity - Dilute (umhos)		2090	2050	1992	2110	1992	2110	2061
Alkalini (mg/l)		310	310	309	302	302	310	308
pH - Fiel		8.50	8.45	8.25	8.45	8.2	8.5	8.4
pH - Lab		8.44	8.6	8.15	8.14	8.1	8.6	8.3
Aluminum (mg/l)			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	0.005	<0.002	<0.01	<0.005	<0.002	<0.01	<0.006
Barium (mg/l)	1	0.11	<0.1	<0.1	<0.1	<0.1	0.11	0.10
Cadmium (mg/l)	0.01	0.0001	<0.001	<0.01	<0.001	0.0001	<0.01	<0.003
Chromium (mg/l)	0.05	<0.001	<0.001		<0.005	<0.001	<0.005	<0.002
Cobalt (mg/l)			<0.001	<0.05	<0.005	<0.001	<0.05	<0.019
Copper (mg/l)	1	0.007	0.005	<0.01	<0.01	0.005	<0.01	<0.008
Iron (mg/l)	0.3	0.01	<0.05	0.11	<0.03	0.01	0.11	0.05
Lead (mg/l)	0.05	<0.001	<0.005	<0.01	<0.005	<0.001	<0.01	<0.005
Manganese (mg/l)	0.05	0.001	<0.1	<0.01	<0.005	0.001	<0.1	<0.03
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0003	<0.0002	<0.0001	<0.0003	<0.0002
Molybdenum (mg/l)		0.03	0.021	<0.1	<0.01	<0.01	<0.1	<0.04
Nickel (mg/l)		<0.01	<0.002	<0.05	<0.01	<0.002	<0.05	<0.018
Selenium (mg/l)	0.01	<0.001	<0.002	<0.01	0.001	<0.001	<0.01	<0.004
Vanadium (mg/l)		<0.01	0.012	<0.1	<0.01	<0.01	<0.1	<0.03
Zinc (mg/l)	5	0.027	0.005	0.01	<0.01	0.005	0.027	0.013
Boron (mg/l)		0.97	0.8	0.92	0.88	0.8	0.97	0.89
Uranium (µg/l)		322	290	225	209	209	322	262.
Radium 226 (pCi/l)	5	151±1	89.2±1.8	115±2.3	116±2.0	89.2	151	117.8
Temperature (°C)		19	19	17	22	17	22	19
Water Level (ft; MSL		3754.4	3753.8	3754.4	3754.1	3753.8	3754.4	3754.1

CROW BU[illegible] WATER [illegible]TY

Well Number: PF-9
Well Type: BASELINE
Formation: CHADRON

Surface Elevation: 3868.6 ft MSL
Well Depth: 600.2 ft
Distance From Wellfield: 0 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 12/03/82 JORDAN	01/18/83 NRL	04/11/83 CORE	07/18/83 CORE	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)		17	15	14	12	12	17	15
Magnesium (mg/l)		2.8	2.5	2.0	1.57	1.5	2.8	2.2
Sodium (mg/l)		408	390	420	400	390	420	405
Potassium (mg/l)		13	13	12	15	12	15	13
Carbonate (mg/l)		23	17	<1	<1	<1	23	11
Bicarbonate (mg/l)		353	350	379	365.0	350	379	362
Sulfate (mg/l)	250	355	350	353	367	350	367	356
Chloride (mg/l)	250	190	180	184.8	190	180.0	190.0	186.2
Ammonia-N (mg/l)		0.82	0.40	0.45	0.41	0.40	0.82	0.52
Nitrite-N (mg/l)		<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01
Nitrate-N (mg/l)	10	<0.01	<0.01	<0.1	0.1	<0.01	0.1	0.06
Fluoride (mg/l)	1.4-2.4	0.69	0.7	0.7	0.6	0.6	0.7	0.7
Silica (mg/l)		13	14	21	17	13	21	16
TDS-180°C (mg/l)	500	1240	1200	1162	1156	1156	1240	1190
Conductivity - Field (umhos)		2200	1950	2000	2200	1950	2200	2088
Conductivity - Lab (umhos)		1900	1820	1590	1970	1590	1970	1820
Conductivity - Dilute (umhos)		2240	2130	2093	2180	2093	2240	2161
Alkalinity (mg/l)		327	320	323	310	310	327	320
pH - Field		8.7	8.7	8.50	8.89	8.5	8.9	8.7
pH - Lab		8.82	8.8	8.41	8.29	8.3	8.8	8.6
Aluminum (mg/l)			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	0.014	0.007	<0.01	<0.005	<0.005	0.014	0.009
Barium (mg/l)	1	0.10	<0.1	<0.1	<0.1	<0.1	0.10	0.10
Cadmium (mg/l)	0.01	<0.0001	<0.001	<0.01	<0.001	<0.0001	<0.01	<0.003
Chromium (mg/l)	0.05	<0.001	<0.001		<0.005	<0.001	<0.005	<0.002
Cobalt (mg/l)			<0.001	<0.05	<0.005	<0.001	<0.05	<0.019
Copper (mg/l)	1	0.004	0.005	<0.01	<0.01	0.004	<0.01	<0.007
Iron (mg/l)	0.3	0.02	<0.05	<0.05	<0.03	0.02	<0.05	<0.04
Lead (mg/l)	0.05	<0.001	<0.005	0.02	<0.005	<0.001	0.02	0.008
Manganese (mg/l)	0.05	0.008	<0.1	<0.01	<0.005	<0.005	<0.1	<0.03
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0003	<0.0002	<0.0001	<0.0003	<0.0002
Molybdenum (mg/l)		0.05	0.075	<0.1	<0.01	<0.01	<0.1	<0.06
Nickel (mg/l)		<0.01	<0.002	<0.05	<0.01	<0.002	<0.05	<0.018
Selenium (mg/l)	0.01	<0.001	<0.002	<0.01	<0.001	<0.001	<0.01	<0.004
Vanadium (mg/l)		0.03	0.025	<0.1	0.03	0.025	<0.1	<0.05
Zinc (mg/l)	5	0.008	<0.005	0.04	<0.01	<0.005	0.04	0.016
Boron (mg/l)		0.99	0.7	0.96	0.86	0.7	0.99	0.88
Uranium (µg/l)		441	390	305	275	275	441	353.
Radium 226 (pCi/l)	5	602±2	207±5	491±4.5	369±3.2	207	602	417
Temperature (°C)		19	19	17	20	17	20	19
Water Level (ft) MSL		3755.1	3753.5	3752.8	3754.4	3752.8	3755.1	3754.1

CROW [illegible] PROJECT
WATER QUALITY

Well Number: PM-1
Well Type: BASELINE
Formation: CHADRON

Surface Elevation: 3877.2 ft MSL
Well Depth: 674.2 ft
Distance From Wellfield: 293 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 12/03/82 JORDAN	01/19/83 NRL	04/12/83 CORE	07/18/83 CORE	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)		17	13	12	14	12	17	14
Magnesium (mg/l)		2.9	2.2	1.9	2.17	1.9	2.9	2.3
Sodium (mg/l)		417	410	440	410	410	440	419
Potassium (mg/l)		13	16	18	17	13	18	16
Carbonate (mg/l)		13	12	<1	<1	[illegible]	13	7
Bicarbonate (mg/l)		368	370	376	374.0	368	376	372
Sulfate (mg/l)	250	358	380	361	365	358	380	366
Chloride (mg/l)	250	208	210	215.1	199	199.0	215.1	204.0
Ammonia-N (mg/l)		0.48	0.28	0.39	0.25	0.25	0.48	0.35
Nitrite-N (mg/l)		0.02	<0.01	0.01	<0.01	<0.01	0.02	0.01
Nitrate-N (mg/l)	10	<0.01	<0.01	<0.1	<0.1	<0.01	<0.1	<0.06
Fluoride (mg/l)	1.4-2.4	0.67	0.6	0.7	0.8	0.6	0.8	0.7
Silica (mg/l)		15	14	14	16	14	16	15
TDS-180°C (mg/l)	500	1260	1200	1226	1199	1199	1260	1221
Conductivity - Field (umhos)		2250	2000	2050	1800	1800	2250	2025
Conductivity - Lab (umhos)		1940	1930	1825	1970	1925	1970	1916
Conductivity - Dilute (umhos)		2300	2260	2179	2170	2170	2300	2227
Alkalinity (mg/l)		324	330	320	321	320	330	324
pH - Field		8.50	8.60	8.55	8.40	8.4	8.6	8.5
pH - Lab		8.61	8.7	8.42	8.25	8.3	8.7	8.5
Aluminum (mg/l)			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	0.001	<0.002	<0.01	<0.005	0.001	<0.01	<0.005
Barium (mg/l)	1	0.05	<0.1	<0.1	<0.1	0.05	<0.1	<0.09
Cadmium (mg/l)	0.01	<0.0001	<0.001	<0.01	<0.001	<0.0001	<0.01	<0.003
Chromium (mg/l)	0.05	<0.001	<0.001		<0.005	<0.001	<0.005	<0.002
Cobalt (mg/l)			<0.001	<0.05	<0.005	<0.001	<0.05	<0.019
Copper (mg/l)	1	0.005	0.005	<0.01	<0.01	0.005	<0.01	<0.008
Iron (mg/l)	0.3	0.02	<0.05	<0.05	<0.03	0.02	<0.05	<0.04
Lead (mg/l)	0.05	<0.001	<0.005	<0.01	<0.005	<0.001	<0.01	<0.005
Manganese (mg/l)	0.05	0.004	<0.1	<0.01	<0.005	0.004	<0.1	<0.03
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0003	<0.0002	<0.0001	<0.0001	<0.0002
Molybdenum (mg/l)		0.02	0.024	<0.1	<0.01	<0.01	<0.1	<0.04
Nickel (mg/l)		<0.01	<0.002	<0.05	<0.01	<0.002	<0.05	<0.019
Selenium (mg/l)	0.01	<0.001	<0.002	<0.01	<0.001	<0.001	<0.01	<0.004
Vanadium (mg/l)		<0.01	0.006	<0.1	<0.01	0.006	<0.1	<0.03
Zinc (mg/l)	5	0.12	<0.005	<0.01	<0.01	<0.005	0.12	0.036
Boron (mg/l)		0.99	0.8	0.96	0.85	0.8	0.99	0.90
Uranium (µg/l)		85	81	54	33	33	85	61.
Radium 226 (pCi/l)	5	90±1	47.6±1.0	43.4±1.4	50.7±1.5	41.4	99	60.2
Temperature (°C)		17	19	16	20	16	20	19

CROW [illegible] PROJECT
WATER QUALITY

Well Number: PM-4
Well Type: BASELINE
Formation: CHADRON

Surface Elevation: 3862.4 ft MSL
Well Depth: 674.2 ft
Distance From Wellfield: 293 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 12/03/82 JORDAN	01/19/83 NRL	04/12/83 CORE	07/1[illegible]/83 CORE	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)		16	14	15	14	14	16	15
Magnesium (mg/l)		3.5	3.3	3.1	3.50	3.1	3.5	3.4
Sodium (mg/l)		408	390	410	390	390	410	400
Potassium (mg/l)		11	11	10.2	11	10.2	11.0	10.8
Carbonate (mg/l)		0	14	<1	<1	<1	14	5
Bicarbonate (mg/l)		386	360	379	370.0	360	386	374
Sulfate (mg/l)	250	359	370	358	360	358	370	362
Chloride (mg/l)	250	187	170	170.3	186	170.0	187.0	178.3
Ammonia-N (mg/l)		0.49	0.46	0.37	0.30	0.30	0.49	0.41
Nitrite-N (mg/l)		<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01
Nitrate-N (mg/l)	10	0.02	<0.01	<0.1	<0.1	<0.01	<0.1	<0.06
Fluoride (mg/l)	1.4-2.4	0.66	0.6	0.7	0.4	0.4	0.7	0.6
Silica (mg/l)		18	14	16	16	14	18	16
TDS-180°C (mg/l)	500	1250	1100	1106	1209	1100	1250	1166
Conductivity - Field (umhos)		2100	1900	1950	1800	1800	2100	1938
Conductivity - Lab (umhos)		1820	1790	1599	1880	1599	1880	1772
Conductivity - Dilute (umhos)		2190	2110	2013	2050	2013	2190	2091
Alkalinity (mg/l)		316	320	322	317	316	322	319
pH - Field		8.2	8.10	7.95	8.15	7.9	8.2	8.1
pH - Lab		8.26	8.6	8.05	8.09	8.1	8.6	8.3
Aluminum (mg/l)			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	0.001	<0.002	<0.01	<0.005	0.001	<0.01	<0.005
Barium (mg/l)	1	0.03	<0.1	<0.1	<0.1	0.03	<0.1	<0.08
Cadmium (mg/l)	0.01	<0.0001	<0.001	<0.01	<0.001	<0.0001	<0.01	<0.003
Chromium (mg/l)	0.05	<0.001	<0.001		<0.005	<0.001	<0.005	<0.002
Cobalt (mg/l)			<0.001	<0.05	<0.005	<0.001	<0.05	<0.019
Copper (mg/l)	1	0.004	0.004	<0.01	<0.01	0.004	<0.01	<0.007
Iron (mg/l)	0.3	0.03	<0.05	<0.05	0.03	0.03	<0.05	<0.04
Lead (mg/l)	0.05	<0.001	<0.005	<0.01	<0.005	<0.001	<0.01	<0.005
Manganese (mg/l)	0.05	0.014	<0.1	<0.01	0.010	<0.01	<0.1	<0.03
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0003	<0.0002	<0.0001	<0.0003	<0.0002
Molybdenum (mg/l)		0.02	0.023	<0.1	<0.01	<0.01	<0.1	<0.04
Nickel (mg/l)		<0.01	<0.002	<0.05	<0.01	<0.002	<0.05	<0.019
Selenium (mg/l)	0.01	<0.001	<0.002	<0.01	<0.001	<0.001	<0.01	<0.004
Vanadium (mg/l)		0.02	0.003	<0.1	<0.01	0.003	<0.1	<0.03
Zinc (mg/l)	5	0.019	0.005	<0.01	<0.01	0.005	0.019	0.011
Boron (mg/l)		1.0	0.5	1.00	0.87	0.5	1.0	0.84
Uranium (µg/l)		36	29	12	19	12	36	24.
Radium 226 (pCi/l)	5	71±1	51.4±1.1	35.1±1.2	60.0±1.4	35.1	71	54.4
Temperature (°C)		20	21	17	22	17	22	20
Water Level (ft) [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CROW[illegible]TE PROJECT
WATER QUALITY

Well Number: PM-6
Well Type: BASELINE
Formation: BRULE

Surface Elevation: 3869.6 ft MSL
Well Depth: 217.5 ft
Distance From Wellfield: 0 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 12/21/82 CORE	12/21/82 JORDAN	01/18/83 NRL	04/12/83 NRL	04/12/83 CORE	07/18/83 CORE
Calcium (mg/l)		4.3	4.4	3.2	2.8	2.5	2.59
Magnesium (mg/l)		0.23	0.05	0.17	0.13	0.14	0.20
Sodium (mg/l)		100	100	98	97	97	97
Potassium (mg/l)		9.5	10	9.0	8.7	8.2	8.3
Carbonate (mg/l)		11.90	11	14	19	<1	<1
Bicarbonate (mg/l)		205	200	190	180	202	201.0
Sulfate (mg/l)	250	40	38	38	38	38	44
Chloride (mg/l)	250	4.6	9	8	12	12.3	12
Ammonia-N (mg/l)		<0.05	0.13	<0.05	<0.05	<0.05	<0.05
Nitrite-N (mg/l)		0.01	<0.01	0.22*	0.01	0.02	0.01
Nitrate-N (mg/l)	10	1.5	0.46	0.77	<0.01	0.9	1.4
Fluoride (mg/l)	1.4-2.4	0.5	0.44	0.5	0.4	0.6	0.4
Silica (mg/l)		67	69	63	63	63	66
TDS-180°C (mg/l)	500	306	363	330	310	342	316
Conductivity - Field (umhos)				380	390	390	390
Conductivity - Lab (umhos)		430	466	431	456	425	460
Conductivity - Dilute (umhos)		430	488	467	492	466	480
Alkalinity (mg/l)		195	182	180	180	176	175
pH - Field		8.5	8.5	8.95	8.9	8.9	8.85
pH - Lab		8.52	8.78	8.7	8.9	8.47	8.23
Aluminum (mg/l)				<0.1	<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	0.01	0.009	0.008	0.008	<0.01	<0.005
Barium (mg/l)	1	<0.1	0.01	<0.1	<0.1	<0.1	<0.1
Cadmium (mg/l)	0.01	<0.01	<0.0001	<0.001	<0.001	<0.01	<0.001
Chromium (mg/l)	0.05	<0.01	0.003	0.005	0.002		<0.005
Cobalt (mg/l)				<0.001	<0.001	<0.05	<0.005
Copper (mg/l)	1	<0.01	0.006	0.004	0.004	<0.01	0.02
Iron (mg/l)	0.3	0.09	<0.01	<0.05	<0.05	<0.05	<0.03
Lead (mg/l)	0.05	<0.01	<0.001	0.005	<0.005	<0.01	<0.005
Manganese (mg/l)	0.05	<0.01	<0.001	<0.1	<0.1	<0.01	<0.005
Mercury (mg/l)	0.002	<0.0003	<0.0001	0.0002	<0.0001	<0.0003	<0.0002
Molybdenum (mg/l)		<0.1	<0.01	0.003	0.002	<0.1	<0.01
Nickel (mg/l)		<0.05	<0.01	<0.002	<0.002	<0.05	<0.01
Selenium (mg/l)	0.01	<0.01	<0.001	<0.002	0.002	<0.01	0.002
Vanadium (mg/l)			<0.01	0.007	0.007	<0.1	<0.01
Zinc (mg/l)	5	0.70	0.270	0.12	0.20	0.22	0.06
Boron (mg/l)		0.32	<0.01	0.8	<0.5	0.14	0.11
Uranium (µg/l)		12	7	11	7	4	<1
Radium 226 (pCi/l)	5		1.0±0.1	9.1±0.2	6.2±0.3	1.6±0.3	1.1±0.2
Temperature (°C)		14	14	11	10	10	11

CROW [illegible] PROJECT
WATER QUALITY

Well Number: PM-6

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)		2.5	4.4	3.3
Magnesium (mg/l)		0.1	0.2	0.2
Sodium (mg/l)		97	100	98
Potassium (mg/l)		8.2	10.0	8.9
Carbonate (mg/l)		<1	19	9.65
Bicarbonate (mg/l)		180	205	196
Sulfate (mg/l)	250	38	44	39
Chloride (mg/l)	250	4.6	12.3	9.7
Ammonia-N (mg/l)		<0.05	0.13	0.06
Nitrite-N (mg/l)		<0.01	0.02	0.01
Nitrate-N (mg/l)	10	<0.01	1.5	0.84
Fluoride (mg/l)	1.4-2.4	0.4	0.6	0.5
Silica (mg/l)		63	69	65
TDS-180°C (mg/l)	500	306	363	328
Conductivity - Field (umhos)		380	390	388
Conductivity - Lab (umhos)		425	466	445
Conductivity - Dilute (umhos)		430	492	471
Alkalinity (mg/l)		175	195	181
pH - Field		8.5	8.9	8.8
pH - Lab		8.2	8.9	8.5
Aluminum (mg/l)		<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	<0.005	0.01	0.008
Barium (mg/l)	1	0.01	<0.1	<0.09
Cadmium (mg/l)	0.01	<0.0001	<0.01	<0.004
Chromium (mg/l)	0.05	0.002	<0.01	<0.005
Cobalt (mg/l)		<0.001	<0.05	<0.014
Copper (mg/l)	1	0.004	0.02	0.009
Iron (mg/l)	0.3	<0.01	0.09	0.05
Lead (mg/l)	0.05	<0.001	<0.01	<0.006
Manganese (mg/l)	0.05	<0.001	<0.1	<0.04
Mercury (mg/l)	0.002	<0.0001	<0.0003	<0.0002
Molybdenum (mg/l)		0.002	<0.1	<0.04
Nickel (mg/l)		<0.002	<0.05	<0.021
Selenium (mg/l)	0.01	<0.001	<0.01	<0.005
Vanadium (mg/l)		0.007	<0.1	<0.03
Zinc (mg/l)	5	0.06	0.70	0.262
Boron (mg/l)		<0.01	0.8	0.31
Uranium (µg/l)		<1	12	7.
Radium 226 (pCi/l)	5	1.0	9.1	3.8
Temperature (°C)	-	10	14	13
Water Level (ft) MSL		3844.0	3846.0	3845.3

DRAFT

CHO[illegible] E PROJECT
W[illegible] QUALITY

Well Number: PM-7
Well Type: BASELINE
Formation: BRULE

Surface Elevation: 3869.0 ft MSL
Well Depth: 129.6 ft
Distance From Wellfield: 0 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 12/21/82 JORDAN	01/18/83 NRL	04/11/83 CORE	07/18/83 CORE	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)		15	16	22	16	15	22	17
Magnesium (mg/l)		0.43	0.44	0.29	0.13	0.1	0.4	0.3
Sodium (mg/l)		64	68	68	67	64	68	67
Potassium (mg/l)		20	18	20	18	18	20	19
Carbonate (mg/l)		14	7	<1	<1	<1	14	6
Bicarbonate (mg/l)		187	200	219	216.0	187	219	206
Sulfate (mg/l)	250	8	7	5.3	9.6	5.3	9.6	7.5
Chloride (mg/l)	250	10	18	5.6	9.1	5.6	18.0	10.7
Ammonia-N (mg/l)		0.07	<0.05	<0.05	<0.05	<0.05	0.07	0.05
Nitrite-N (mg/l)		0.02	0.21	0.06	0.19	0.02	0.21	0.12
Nitrate-N (mg/l)	10	0.73	2.0	2.9	4.4	0.73	4.4	2.51
Fluoride (mg/l)	1.4-2.4	0.27	0.2	0.4	0.3	0.2	0.4	0.3
Silica (mg/l)		59	54	56	57	54	59	57
TDS-180°C (mg/l)	500	301	280	354	291	280	354	304
Conductivity - Field (umhos)			330	350	340	330	350	340
Conductivity - Lab (umhos)		396	375	365	390	365	396	382
Conductivity - Dilute (umhos)		416	410	416	430	410	430	419
Alkalinity (mg/l)		177	180	186	188	177	188	183
pH - Field		8.65	9.05	8.95	9.50	8.6	9.5	9.0
pH - Lab		8.88	8.5	8.29	8.30	8.3	8.9	8.5
Aluminum (mg/l)			0.1	<0.1	<0.1	<0.1	0.1	0.1
Arsenic (mg/l)	0.05	<0.001	<0.002	<0.01	<0.005	<0.001	<0.01	<0.005
Barium (mg/l)	1	0.07	<0.1	<0.1	<0.1	0.07	<0.1	<0.09
Cadmium (mg/l)	0.01	<0.0001	<0.001	<0.01	<0.001	<0.0001	<0.01	<0.003
Chromium (mg/l)	0.05	0.007	0.010		<0.005	<0.005	0.010	0.007
Cobalt (mg/l)			<0.001	<0.05	<0.005	<0.001	<0.05	<0.019
Copper (mg/l)	1	0.011	0.002	<0.01	0.01	0.002	0.011	0.008
Iron (mg/l)	0.3	0.02	<0.05	<0.05	<0.03	0.02	<0.05	<0.04
Lead (mg/l)	0.05	<0.001	<0.005	<0.01	<0.005	<0.001	<0.01	<0.005
Manganese (mg/l)	0.05	<0.001	<0.1	<0.01	<0.005	<0.001	<0.1	<0.03
Mercury (mg/l)	0.002	<0.0001	0.0001	<0.0003	<0.0002	<0.0001	<0.0003	<0.0002
Molybdenum (mg/l)		<0.01	<0.002	<0.1	<0.01	<0.002	<0.1	<0.03
Nickel (mg/l)		<0.01	<0.002	<0.05	<0.01	<0.002	<0.05	<0.018
Selenium (mg/l)	0.01	<0.001	<0.002	<0.01	<0.001	<0.001	<0.01	<0.004
Vanadium (mg/l)		<0.01	0.003	<0.1	<0.01	0.003	<0.1	<0.03
Zinc (mg/l)	5	0.011	0.010	<0.01	<0.01	<0.01	0.011	0.010
Boron (mg/l)		<0.01	<0.5	0.20	0.09	<0.01	<0.5	<0.20
Uranium (µg/l)		25	27	14	8	8	27	19
Radium 226 (pCi/l)	5	1.1±0.1	9.0±0.2	0.7±0.1	0.8±0.2	0.7	9.0	2.9
Temperature (°C)		14	12	9	13	9	14	12
Water Level (ft) MSL		--	3845.7	3846.0	3846.6	3845.7	3846.6	3846.0

CROW[illegible] PROJECT
WA[illegible]UALITY

Well Number: WELL 17
Well Type: BASELINE WELL
Formation: BRULE

Surface Elevation: 3910.0 ft MSL
Well Depth: 80.1 ft
Distance From Wellfield: 3,000 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 10/29/81 NRL	01/28/82 NRL	04/28/82 NRL	07/13/82 NRL	10/05/82 NRL	04/08/83 CORE	07/06/83 CORE
Calcium (mg/l)		59	57	60	61	60	57	61
Magnesium (mg/l)		7.7	8.0	8.0	8.0	9.0	7.7	8.0
Sodium (mg/l)		17	18	19	17	18	17	17
Potassium (mg/l)		4.8	4.0	4.7	4.5	4.6	4.3	4.7
Carbonate (mg/l)		<2	<2	<2	<2	<2	<1	<1
Bicarbonate (mg/l)		250	240	240	240	250	249	243.0
Sulfate (mg/l)	250	10	13	12	10	11	8.6	12
Chloride (mg/l)	250	4	2	3	4	3	4.5	4.21
Ammonia-N (mg/l)				0.30			<0.05	
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	1.3	1.2	1.2	1.3	1.2	3.4*	0.8
Fluoride (mg/l)	1.4-2.4	0.8	0.6	0.7	0.6	0.6	0.6	0.6
Silica (mg/l)		59	62	61	59	59	54	62
TDS-180°C (mg/l)	500	310	260	280	330	320	322	294
Conductivity - Field (umhos)		160*	270	365	370	350	360	360
Conductivity - Lab (umhos)		422	393	409	412	404	445	405
Conductivity - Dilute (umhos)				451	450	448	435	450
Alkalinity (mg/l)				200	200	210	214	209
pH - Field		7.5	6.81	7.45	7.1	6.9	6.9	7.25
pH - Lab		7.8	7.4	7.9	7.4	7.6	7.94	7.52
Aluminum (mg/l)				<0.1				
Arsenic (mg/l)	0.05			0.003				
Barium (mg/l)	1			0.2				
Cadmium (mg/l)	0.01			<0.001				
Chromium (mg/l)	0.05			<0.001				
Cobalt (mg/l)				<0.001				
Copper (mg/l)	1			0.002				
Iron (mg/l)	0.3	<0.05		<0.05				
Lead (mg/l)	0.05			<0.005				
Manganese (mg/l)	0.05			<0.1				
Mercury (mg/l)	0.002			<0.0001				
Molybdenum (mg/l)				0.002				
Nickel (mg/l)				<0.002				
Selenium (mg/l)	0.01			<0.002				
Vanadium (mg/l)				0.005				
Zinc (mg/l)	5			0.024				
Boron (mg/l)				<0.5				
Uranium (µg/l)		4	4	2	8	4	<1	<1
Radium 226 (pCi/l)	5	0.1±0.1	0.1±0.1	0.4±0.1	0.1±0.1	0.6±0.1	0.2±0.1	2.3±0.1
Temperature (°C)		17	11	9	11	[illegible]	15	14
Water Level (ft) MSL		3863.4	3865.0	3862.7	3863.4	3863.7	3864.7	3862.7

CROW B[illegible] ROJECT
WATE[illegible]ITY

Well Number: WELL 17

Date Sampled Lab Name	EPA Standards and Criteria	SAMPLE RESULTS	MINIUM	MAXIMUM	AVERAGE
Calcium (mg/l)			57	61	59
Magnesium (mg/l)			7.7	9.0	8.1
Sodium (mg/l)			17	19	18
Potassium (mg/l)			4.0	4.8	4.5
Carbonate (mg/l)			<1	<2	<2
Bicarbonate (mg/l)			240	250	245
Sulfate (mg/l)	250		8.6	13	10.9
Chloride (mg/l)	250		2.0	4.5	3.5
Ammonia-N (mg/l)			<0.05	0.30	0.18
Nitrite-N (mg/l)			<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10		0.8	1.3	1.2
Fluoride (mg/l)	1.4-2.4		0.6	0.8	0.6
Silica (mg/l)			54	62	59
TDS-180°C (mg/l)	500		260	330	302
Conductivity - Field (umhos)			270	370	345.[illegible]
Conductivity - Lab (umhos)			393	445	413
Conductivity - Dilute (umhos)			435	451	447
Alkalinity (mg/l)			200	214	207
pH - Field			6.8	7.5	7.1
pH - Lab			7.4	7.9	7.7
Aluminum (mg/l)			<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05		0.003	0.003	0.003
Barium (mg/l)	1		0.2	0.2	0.2
Cadmium (mg/l)	0.01		<0.001	<0.001	<0.001
Chromium (mg/l)	0.05		<0.001	<0.001	<0.001
Cobalt (mg/l)			<0.001	<0.001	<0.001
Copper (mg/l)	1		0.002	0.002	0.002
Iron (mg/l)	0.3		<0.05	<0.05	<0.05
Lead (mg/l)	0.05		<0.005	<0.005	<0.005
Manganese (mg/l)	0.05		<0.1	<0.1	<0.1
Mercury (mg/l)	0.002		<0.0001	<0.0001	<0.0001
Molybdenum (mg/l)			0.002	0.002	0.002
Nickel (mg/l)			<0.002	<0.002	<0.002
Selenium (mg/l)	0.01		<0.002	<0.002	<0.002
Vanadium (mg/l)			0.005	0.005	0.005
Zinc (mg/l)	5		0.024	0.024	0.024
Boron (mg/l)			<0.5	<0.5	<0.5
Uranium (µg/l)			<1	8	3.
Radium 226 (pCi/l)	5		<0.1	2.3	0.5
Temperature (°C)			9	17	13
Water Level (ft) MSL			3862.7	3865.0	3863.7

CROW BUT[illegible] [illegible]DIT
WATER[illegible]TY

Well Number: WELL 25
Well Type: BASELINE WELL
Formation: BRULE

Surface Elevation: 3904.7 ft MSL
Well Depth: 75.1 ft
Distance From Wellfield: 3,000 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 10/29/81 NRL	01/28/82 NRL	04/28/82 NRL	04/28/82 JORDAN	07/13/82 NRL	10/04/82 NRL	04/08/83 CORE	07/05/83 CORE
Calcium (mg/l)		74	73	78	75	77	79	75	70
Magnesium (mg/l)		9.9	10.0	11	10	10	12	10.1	10.2
Sodium (mg/l)		13	14	14	13	13	16	13	13
Potassium (mg/l)		4.8	4.4	4.7	4.7	4.6	5.1	4.4	4.6
Carbonate (mg/l)		<2	<2	<2	0	<2	<2	<1	<1
Bicarbonate (mg/l)		290	290	290	287	290	300	291	270.0
Sulfate (mg/l)	250	9	7	7	8	7	7	5.8	5
Chloride (mg/l)	250	5	4	5	7	3	5	5.6	9.9
Ammonia-N (mg/l)				0.05	0.08			<0.05	<0.05
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	3.8	3.8	4.6	4.0	3.9	4.5	6.4	2.3
Fluoride (mg/l)	1.4-2.4	0.8	0.6	0.7	0.71	0.6	0.6	0.6	0.7
Silica (mg/l)		55	55	54	52	54	52	50	59
TDS-180°C (mg/l)	500	340	310	340	332	350	370	356	325
Conductivity - Field (umhos)		418	290	390	390	460	430	380	400
Conductivity - Lab (umhos)		488	470	496	475	493	492	538	500
Conductivity - Dilute (umhos)				546	494	541	546	499	510
Alkalinity (mg/l)				230	235	240	240	246	233
pH - Field		7.4	6.9	7.3	7.3	7.0	6.6	6.85	7.15
pH - Lab		7.6	7.1	7.8	7.44	7.6	7.4	7.99	7.03
Aluminum (mg/l)				<0.1	0.07				
Arsenic (mg/l)	0.05			0.003	0.005				
Barium (mg/l)	1			0.1	0.03				
Cadmium (mg/l)	0.01			<0.001	<0.0001				
Chromium (mg/l)	0.05			<0.001	<0.001				
Cobalt (mg/l)				<0.001	<0.01				
Copper (mg/l)	1			0.004	0.007				
Iron (mg/l)	0.3	<0.05		<0.05	0.02				
Lead (mg/l)	0.05			<0.005	<0.001				
Manganese (mg/l)	0.05			<0.1	0.005				
Mercury (mg/l)	0.002			<0.0001	<0.0001				
Molybdenum (mg/l)				0.002	<0.01				
Nickel (mg/l)				<0.002	<0.01				
Selenium (mg/l)	0.01			<0.002	<0.001				
Vanadium (mg/l)				0.013	0.01				
Zinc (mg/l)	5			0.026	0.25				
Boron (mg/l)				<0.5	0.02				
Uranium (µg/l)		5	5	3	5	6	5	2	3
Radium 226 (pCi/l)	5	0.1±0.1	0.1±0.1	0.3±0.1	0.1±0.1	0.1±0.1	0.4±0.1	0.2±0.1	0.2±0.1
Temperature (°C)		10	7	4	4	16	14	8	13
Water Level (ft) MSL		3869.0	3869.9	3870.9	3870.9	3869.6	3870.6	3859.8	3871.6

CROW[illegible] PROJECT
WAT[illegible] QUALITY

Well Number: WELL 25

Date Sampled Lab Name	EPA Standards and Criteria	SAMPLE RESULTS	MINIUM	MAXIMUM	AVERAGE
p-					
Calcium (mg/l)			70	79	75
Magnesium (mg/l)			9.9	12.0	10.4
Sodium (mg/l)			13	16	14
Potassium (mg/l)			4.4	5.1	4.7
Carbonate (mg/l)			<1	<2	<2
Bicarbonate (mg/l)			270	300	289
Sulfate (mg/l)	250		5	9	7.0
Chloride (mg/l)	250		3.0	9.9	5.6
Ammonia-N (mg/l)			<0.05	0.08	0.06
Nitrite-N (mg/l)			<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10		2.3	6.4	4.2
Fluoride (mg/l)	1.4-2.4		0.6	0.8	0.7
Silica (mg/l)			50	59	54
TDS-180°C (mg/l)	500		310	370	340
Conductivity - Field (umhos)			290	460	395
Conductivity - Lab (umhos)			470	538	494
Conductivity - Dilute (umhos)			494	546	523
Alkalinity (mg/l)			230	246	237
pH - Field			6.6	7.4	7.1
pH - Lab			7.0	8.0	7.5
Aluminum (mg/l)			0.07	<0.1	<0.09
Arsenic (mg/l)	0.05		0.003	0.005	0.004
Barium (mg/l)	1		0.03	0.1	0.06
Cadmium (mg/l)	0.01		<0.0001	<0.001	<0.0006
Chromium (mg/l)	0.05		<0.001	<0.001	<0.001
Cobalt (mg/l)			<0.001	<0.01	<0.006
Copper (mg/l)	1		0.004	0.007	0.006
Iron (mg/l)	0.3		0.02	<0.05	<0.04
Lead (mg/l)	0.05		<0.001	<0.005	<0.003
Manganese (mg/l)	0.05		0.005	<0.1	<0.05
Mercury (mg/l)	0.002		<0.0001	<0.0001	<0.0001
Molybdenum (mg/l)			0.002	<0.01	<0.006
Nickel (mg/l)			<0.002	<0.01	<0.006
Selenium (mg/l)	0.01		<0.001	<0.002	<0.002
Vanadium (mg/l)			0.01	0.013	0.012
Zinc (mg/l)	5		0.026	0.25	0.138
Boron (mg/l)			0.02	<0.5	<0.26
Uranium (µg/l)			2	6	4.
Radium 226 (pCi/l)	5		0.1	0.4	0.2
Temperature (°C)			4	16	10
Water Level (ft) MSL			3859.8	3871.6	3869.0

C[illegible]TE PROJECT
[illegible] QUALITY

Well Number: WELL 26
Well Type: BASELINE WELL
Formation: BRULE

Surface Elevation: 3820.1 ft MSL
Well Depth: 80.1 ft
Distance From Wellfield: 3,700 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 10/29/81 NRL	01/28/82 NRL	04/28/82 NRL	07/14/82 NRL	10/05/82 NRL	04/08/83 CORE	07/05,83 CORE
Calcium (mg/l)		120	120	110	110	120	115	120
Magnesium (mg/l)		15	15	14	14	19	14	15
Sodium (mg/l)		15	15	15	14	15	15	16
Potassium (mg/l)		6.9	5.7	6.5	6.3	6.9	6.0	6.7
Carbonate (mg/l)		<2	<2	<2	<2	<2	<1	<1
Bicarbonate (mg/l)		340	360	350	350	330	363	370.0
Sulfate (mg/l)	250	28	21	21	21	36	17	28
Chloride (mg/l)	250	33	33	24	28	38	22.4	38
Ammonia-N (mg/l)				0.14			<0.05	
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	11.0	13.0	11	10	12	10.6	15.7
Fluoride (mg/l)	1.4-2.4	0.8	0.6	0.7	0.6	0.6	0.6	0.6
Silica (mg/l)		46	51	51	49	48	47	55
TDS-180°C (mg/l)	500	500	480	470	490	550	500	510
Conductivity - Field (umhos)		700	510	700	700	700	700	725
Conductivity - Lab (umhos)		751	740	720	699	802	780	770
Conductivity - Dilute (umhos)				810	779	926	789	880
Alkalinity (mg/l)				290	290	270	303	316
pH - Field		7.3	6.80	7.2	6.9	6.9	6.9	7.0
pH - Lab		7.5	7.0	7.8	7.3	7.2	7.82	7.85
Aluminum (mg/l)				<0.1				
Arsenic (mg/l)	0.05			0.003				
Barium (mg/l)	1			0.3				
Cadmium (mg/l)	0.01			<0.001				
Chromium (mg/l)	0.05			<0.001				
Cobalt (mg/l)				<0.001				
Copper (mg/l)	1			0.007				
Iron (mg/l)	0.3	0.05		<0.05				
Lead (mg/l)	0.05			<0.005				
Manganese (mg/l)	0.05			<0.1				
Mercury (mg/l)	0.002			<0.0001				
Molybdenum (mg/l)				0.002				
Nickel (mg/l)				<0.002				
Selenium (mg/l)	0.01			<0.002				
Vanadium (mg/l)				0.007				
Zinc (mg/l)	5			0.046				
Boron (mg/l)				<0.5				
Uranium (µg/l)		7	7	3	6	8	3	3
Radium 226 (pCi/l)	5	0.2±0.1	0.2±0.1	0.3±0.1	0.2±0.1	0.4±0.1	0.3±0.1	0.3±0.1
Temperature (°C)		13	11	9	15	13	11	13
Water Level (ft) MSL		N/A	N/A	N/A	N/A	N/A	N/A	N/A

Well Number: WELL 26

Date Sampled Lab Name	EPA Standards and Criteria	SAMPLE RESULTS	MINIUM	MAXIMUM	AVERAGE
Calcium (mg/l)			110	120	116
Magnesium (mg/l)			14	19	15
Sodium (mg/l)			14	16	15
Potassium (mg/l)			5.7	6.9	6.4
Carbonate (mg/l)			<1	<2	<2
Bicarbonate (mg/l)			330	370	352
Sulfate (mg/l)	250		17	36	25
Chloride (mg/l)	250		22.4	38.0	30.9
Ammonia-N (mg/l)			<0.05	0.14	0.09
Nitrite-N (mg/l)			<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10		10	15.7	11.9
Fluoride (mg/l)	1.4-2.4		0.6	0.8	0.6
Silica (mg/l)			46	55	50
TDS-180°C (mg/l)	500		470	550	500
Conductivity - Field (umhos)			510	725	676
Conductivity - Lab (umhos)			699	802	752
Conductivity - Dilute (umhos)			779	926	837
Alkalinity (mg/l)			270	316	294
pH - Field			6.8	7.3	7.0
pH - Lab			7.0	7.8	7.5
Aluminum (mg/l)			<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05		0.003	0.003	0.003
Barium (mg/l)	1		0.3	0.3	0.3
Cadmium (mg/l)	0.01		<0.001	<0.001	<0.001
Chromium (mg/l)	0.05		<0.001	<0.001	<0.001
Cobalt (mg/l)			<0.001	<0.001	<0.001
Copper (mg/l)	1		0.007	0.007	0.007
Iron (mg/l)	0.3		<0.05	0.05	0.05
Lead (mg/l)	0.05		<0.005	<0.005	<0.005
Manganese (mg/l)	0.05		<0.1	<0.1	<0.1
Mercury (mg/l)	0.002		<0.0001	<0.0001	<0.0001
Molybdenum (mg/l)			0.002	0.002	0.002
Nickel (mg/l)			<0.002	<0.002	<0.002
Selenium (mg/l)	0.01		<0.002	<0.002	<0.002
Vanadium (mg/l)			0.007	0.007	0.007
Zinc (mg/l)	5		0.046	0.046	0.046
Boron (mg/l)			<0.5	<0.5	<0.5
Uranium (µg/l)			3	8	5.
Radium 226 (pCi/l)	5		0.2	0.4	0.3
Temperature (°C)			9	15	12
Water Level (ft) MSL			N/A	N/A	N/A

CRO[illegible] : PROJECT
W[illegible]UALITY

Well Number: WELL 27
Well Type: BASELINE WELL
Formation: BRULE

Surface Elevation: 3849.9 ft MSL
Well Depth: 30.1 ft
Distance From Wellfield: 2,400 ft

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS 05/08/82 NRL	04/08/83 CORE	07/05/83 CORE	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)			69	71	69	71	70
Magnesium (mg/l)			9.0	9.1	9.0	9.1	9.1
Sodium (mg/l)			16	16	16	16	16
Potassium (mg/l)			4.7	5.4	4.7	5.4	5.1
Carbonate (mg/l)			<1	<1	<1	<1	<1
Bicarbonate (mg/l)			277	260.0	260	277	269
Sulfate (mg/l)	250		10	18	10	18	14
Chloride (mg/l)	250		10.1	7.4	7.4	10.1	8.8
Ammonia-N (mg/l)			0.12	<0.05	<0.05	0.12	0.09
Nitrite-N (mg/l)			<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10		2.8	0.8	0.8	2.8	1.8
Fluoride (mg/l)	1.4-2.4		0.6	0.7	0.6	0.7	0.7
Silica (mg/l)			52	59	52	59	56
TDS-180°C (mg/l)	500		330	336	330	336	333
Conductivity - Field (umhos)		380	395	372	372	395	382
Conductivity - Lab (umhos)			474	480	474	480	477
Conductivity - Dilute (umhos)			445	515	445	515	480
Alkalinity (mg/l)			239	228	228	239	234
pH - Field		7.4	7.1	7.20	7.1	7.4	7.2
pH - Lab			8.18	7.45	7.4	8.2	7.8
Aluminum (mg/l)							
Arsenic (mg/l)	0.05						
Barium (mg/l)	1						
Cadmium (mg/l)	0.01						
Chromium (mg/l)	0.05						
Cobalt (mg/l)							
Copper (mg/l)	1						
Iron (mg/l)	0.3						
Lead (mg/l)	0.05						
Manganese (mg/l)	0.05						
Mercury (mg/l)	0.002						
Molybdenum (mg/l)							
Nickel (mg/l)							
Selenium (mg/l)	0.01						
Vanadium (mg/l)							
Zinc (mg/l)	5						
Boron (mg/l)							
Uranium (µg/l)		4	<1	3	<1	4	3.
Radium 226 (pCi/l)	5	0.3±0.1	0.3±0.1	0.3±0.1	0.3	0.3	0.3
Temperature (°C)		9	9	11	9	11	10
Water Level (ft) MSL		--	--	--	--	--	--

UTTE PROJECT
R QUALITY

Well Number: WELL 57
Well Type: BASELINE WELL
Formation: BRULE

Surface Elevation: 3800.1 ft MSL
Well Depth: 24.9 ft
Distance From Wellfield: 5,700 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 10/29/81 NRL	01/29/82 NRL	04/28/82 NRL	10/04/82 NRL	04/09/83 CORE	07/05/83 CORE
Calcium (mg/l)		64	62	65	64	63	63
Magnesium (mg/l)		7.4	7.6	7.6	8.5	7.3	8.2
Sodium (mg/l)		17	17	17	17	17	20
Potassium (mg/l)		6.5	5.6	6.1	5.8	5.4	6.6
Carbonate (mg/l)		<2	<2	<2	<2	<1	<1
Bicarbonate (mg/l)		260	260	260	310	257	254.0
Sulfate (mg/l)	250	11	16	5	7	7.0	10
Chloride (mg/l)	250	4	<2	2	3	2.2	5.6
Ammonia-N (mg/l)				0.05		<0.05	
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	2.1	2.2	2.2	2.0	2.6	6.0*
Fluoride (mg/l)	1.4-2.4	0.6	0.5	0.6	0.5	0.5	0.6
Silica (mg/l)		54	56	59	58	56	62
TDS-180°C (mg/l)	500	310	320	310	340	294	330
Conductivity - Field (umhos)		362	315	400	370	250	420
Conductivity - Lab (umhos)		430	415	427	424	458	490
Conductivity - Dilute (umhos)				468	468	457	500
Alkalinity (mg/l)				210	260	236	217
pH - Field		7.6	6.89	7.6	6.95	7.25	7.35
pH - Lab		7.6	7.2	8.0	7.4	8.12	7.52
Aluminum (mg/l)				<0.1			
Arsenic (mg/l)	0.05			0.002			
Barium (mg/l)	1			0.2			
Cadmium (mg/l)	0.01			<0.001			
Chromium (mg/l)	0.05			<0.001			
Cobalt (mg/l)				<0.001			
Copper (mg/l)	1			0.001			
Iron (mg/l)	0.3	<0.05		<0.05			
Lead (mg/l)	0.05			<0.005			
Manganese (mg/l)	0.05			<0.1			
Mercury (mg/l)	0.002			0.0002			
Molybdenum (mg/l)				<0.002			
Nickel (mg/l)				<0.002			
Selenium (mg/l)	0.01			<0.002			
Vanadium (mg/l)				0.006			
Zinc (mg/l)	5			0.44			
Boron (mg/l)				<0.5			
Uranium (µg/l)		7	7	7	7	1	7
Radium 226 (pCi/l)	5	0.4±0.1	0.3±0.1	0.4±0.1	0.8±0.1	0.4±0.1	0.2±0.1
Temperature (°C)		9	11	9	13	10	12
Water Level (ft) MSL		N/A	N/A	N/A	N/A	N/A	N/A

CROMERTE PROJECT
WATER QUALITY

Well Number: WELL 57

Date Sampled Lab Name	EPA Standards and Criteria	SAMPLE RESULTS	MINIUM	MAXIMUM	AVERAGE
Calcium (mg/l)			62	65	64
Magnesium (mg/l)			7.3	8.5	7.8
Sodium (mg/l)			17	20	18
Potassium (mg/l)			5.4	6.6	6.0
Carbonate (mg/l)			<1	<2	<2
Bicarbonate (mg/l)			254	310	267
Sulfate (mg/l)	250		5	16	9.3
Chloride (mg/l)	250		2.0	5.6	3.4
Ammonia-N (mg/l)			<0.05	0.05	0.05
Nitrite-N (mg/l)			<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10		2.0	2.6	2.2
Fluoride (mg/l)	1.4-2.4		0.5	0.6	0.6
Silica (mg/l)			54	62	58
TDS-180°C (mg/l)	500		294	340	317
Conductivity - Field (umhos)			250	420	353
Conductivity - Lab (umhos)			415	490	441
Conductivity - Dilute (umhos)			457	500	473
Alkalinity (mg/l)			210	260	231
pH - Field			6.9	7.6	7.3
pH - Lab			7.2	8.1	7.6
Aluminum (mg/l)			<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05		0.002	0.002	0.002
Barium (mg/l)	1		0.2	0.2	0.2
Cadmium (mg/l)	0.01		<0.001	<0.001	<0.001
Chromium (mg/l)	0.05		<0.001	<0.001	<0.001
Cobalt (mg/l)			<0.001	<0.001	<0.001
Copper (mg/l)	1		0.001	0.001	0.001
Iron (mg/l)	0.3		<0.05	<0.05	<0.05
Lead (mg/l)	0.05		<0.005	<0.005	<0.005
Manganese (mg/l)	0.05		<0.1	<0.1	<0.1
Mercury (mg/l)	0.002		0.0002	0.0002	0.0002
Molybdenum (mg/l)			<0.002	<0.002	<0.002
Nickel (mg/l)			<0.002	<0.002	<0.002
Selenium (mg/l)	0.01		<0.002	<0.002	<0.002
Vanadium (mg/l)			0.006	0.006	0.006
Zinc (mg/l)	5		0.44	0.44	0.44
Boron (mg/l)			<0.5	<0.5	<0.5
Uranium (µg/l)			1	7	6.
Radium 226 (pCi/l)	5		0.2	0.8	0.4
Temperature (°C)			9	13	11
Water Level (ft) MSL			N/A	N/A	N/A

CROW BU[illegible] JECT
WATER [illegible]Y

Well Number: WELL 62
Well Type: BASELINE WELL
Formation: CHADRON

Surface Elevation: 3780.0 ft MSL
Well Depth: 469.8 ft
Distance From Wellfield: 9,700 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 10/30/81 NRL	01/28/82 NRL	04/27/82 NRL	04/27/82 JORDAN	07/13/82 NRL	10/04/82 NRL	04/08/83 CORE	07/05/83 CORE
Calcium (mg/l)		12	15	15	15	16	16	14	17
Magnesium (mg/l)		3.0	3.7	3.[illegible]	3.4	3.7	4.3	3.3	3.5
Sodium (mg/l)		400	380	390	396	380	400	390	400
Potassium (mg/l)		9.2	9.5	9.8	14	10	11	8.6	10.0
Carbonate (mg/l)		<2	<2	<2	0	<2	<2	2	<1
Bicarbonate (mg/l)		430	390	390	382	400	390	385	384.0
Sulfate (mg/l)	250	350	340	360	338	360	370	343	339
Chloride (mg/l)	250	200	180	180	186	150	170	169.2	177
Ammonia-N (mg/l)				0.44	0.44			0.25	0.20
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	0.03	<0.01	0.02	0.07	0.03	0.04	<0.1	0.1
Fluoride (mg/l)	1.4-2.4	0.9	0.6	0.6	0.69	0.6	0.6	0.8	0.6
Silica (mg/l)		8.8	11	12	11	11	11	11	12
TDS-180°C (mg/l)	500	1200	1100	1100	1200	1200	1200	1156	1162
Conductivity - Field (umhos)		1750	1400*	1700	1700	1650	1600	1700	1600
Conductivity - Lab (umhos)		1870	17[illegible]0	1900	1870	1890	1800	1900	1860
Conductivity - Dilute (umhos)				2140	2090	2180	2100	2002	2120
Alkalinity (mg/l)				320	313	330	320	328	331
pH - Field		8.4	7.46	7.75	7.75	7.8	7.65	7.85	7.95
pH - Lab		8.3	7.9	8.0	8.13	7.8	8.1	8.34	8.03
Aluminum (mg/l)				<0.1	0.07				
Arsenic (mg/l)	0.05			<0.002	<0.001				
Barium (mg/l)	1			<0.1	0.04				
Cadmium (mg/l)	0.01			<0.001	<0.0001				
Chromium (mg/l)	0.05			<0.001	<0.001				
Cobalt (mg/l)				<0.001	<0.01				
Copper (mg/l)	1			0.001	0.004				
Iron (mg/l)	0.3	0.85		<0.05	0.03				
Lead (mg/l)	0.05			<0.005	<0.001				
Manganese (mg/l)	0.05			<0.1	0.013				
Mercury (mg/l)	0.002			0.0003	0.0004				
Molybdenum (mg/l)				0.022	<0.01				
Nickel (mg/l)				<0.002	<0.01				
Selenium (mg/l)	0.01			<0.002	<0.001				
Vanadium (mg/l)				0.006	<0.01				
Zinc (mg/l)	5			0.11	0.11				
Boron (mg/l)				1.2	0.73				
Uranium (µg/l)		17	27	33	31	31	20	21	16
Radium 226 (pCi/l)	5	15.2±0.3	18.0±0.4	13.8±0.5	17.1±1	5.9±0.2*	16.9±0.5	14.2±0.8	16.0±1
Temperature (°C)		6	13	11	11	13	12	10	14
Water Level (ft) MSL		3743.6	3744.6	3744.6	3744.6	3744.3	3744.9	3743.3	3743.0

CROW BUTTE PROJECT
WATER QUALITY

Well Number: WELL 62

	EPA Standards and Criteria	SAMPLE RESULTS	MINIUM	MAXIMUM	AVERAGE
Date Sampled					
Lab Name					
Calcium (mg/l)			12	17	15
Magnesium (mg/l)			3.0	4.3	3.5
Sodium (mg/l)			380	400	392
Potassium (mg/l)			8.6	14.0	10.3
Carbonate (mg/l)			<1	2	2
Bicarbonate (mg/l)			380	430	393
Sulfate (mg/l)	250		338	370	350
Chloride (mg/l)	250		150.0	200.0	176.5
Ammonia-N (mg/l)			0.20	0.44	0.33
Nitrite-N (mg/l)			<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10		<0.01	0.1	0.05
Fluoride (mg/l)	1.4-2.4		0.6	0.9	0.7
Silica (mg/l)			8.8	12.0	11.0
TDS-180°C (mg/l)	500		1100	1200	1165
Conductivity - Field (umhos)			1600	1750	1683.3
Conductivity - Lab (umhos)			1790	1900	1860
Conductivity - Dilute (umhos)			2002	2180	2105
Alkalinity (mg/l)			313	331	324
pH - Field			7.5	8.4	7.8
pH - Lab			7.8	8.3	8.1
Aluminum (mg/l)			0.07	<0.1	<0.09
Arsenic (mg/l)	0.05		<0.001	<0.002	<0.002
Barium (mg/l)	1		0.04	<0.1	<0.07
Cadmium (mg/l)	0.01		<0.0001	<0.001	<0.0006
Chromium (mg/l)	0.05		<0.001	<0.001	<0.001
Cobalt (mg/l)			<0.001	<0.01	<0.006
Copper (mg/l)	1		0.001	0.004	0.003
Iron (mg/l)	0.3		0.03	0.85	0.31
Lead (mg/l)	0.05		<0.001	<0.005	<0.003
Manganese (mg/l)	0.05		0.013	<0.1	<0.06
Mercury (mg/l)	0.002		0.0003	0.0004	0.0004
Molybdenum (mg/l)			<0.01	0.022	0.016
Nickel (mg/l)			<0.002	<0.01	<0.006
Selenium (mg/l)	0.01		<0.001	<0.002	<0.002
Vanadium (mg/l)			0.006	<0.01	<0.008
Zinc (mg/l)	5		0.11	0.11	0.11
Boron (mg/l)			0.73	1.2	0.97
Uranium (µg/l)			16	33	25.
Radium 226 (pCi/l)	5		13.8	18.0	15.9
Temperature (°C)			6	14	11
Water Level (ft) MSL			3743.0	3744.9	3744.3

CHO[illegible]E PROJECT
W[illegible] QUALITY

Well Number: WELL 63
Well Type: BASELINE WELL
Formation: BRULE

Surface Elevation: 3780.0 ft MSL
Well Depth: NA ft
Distance From Wellfield: 9,900 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 10/29/81 NRL	01/29/82 NRL	04/28/82 NRL	07/13/82 NRL	10/04/82 NRL	04/08/83 CORE
Calcium (mg/l)		67	65	68	69	67	64
Magnesium (mg/l)		7.3	7.6	7.4	7.4	8.4	7.0
Sodium (mg/l)		22	23	23	24	23	22
Potassium (mg/l)		8.6	8.1	8.7	8.7	8.5	7.6
Carbonate (mg/l)		<2	<2	<2	<2	<2	<1
Bicarbonate (mg/l)		280	280	280	290	270	274
Sulfate (mg/l)	250	18	15	7	12	11	<10
Chloride (mg/l)	250	5	4	4	5	4	3.4
Ammonia-N (mg/l)				0.05			<0.05
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	1.9	2.0	2.0	1.9	1.9	2.3
Fluoride (mg/l)	1.4-2.4	0.6	0.5	0.6	0.5	0.5	0.5
Silica (mg/l)		57	60	60	59	58	54
TDS-180°C (mg/l)	500	340	330	340	360	390	304
Conductivity - Field (umhos)		410	335*	420	420	405	390
Conductivity - Lab (umhos)		479	467	489	471	453	499
Conductivity - Dilute (umhos)				529	530	507	496
Alkalinity (mg/l)				230	230	220	242
pH - Field		6.9	6.8	7.4	7.3	6.80	7.25
pH - Lab		7.7	7.2	7.5	7.3	7.4	7.72
Aluminum (mg/l)				<0.1			
Arsenic (mg/l)	0.05			0.003			
Barium (mg/l)	1			0.2			
Cadmium (mg/l)	0.01			<0.001			
Chromium (mg/l)	0.05			<0.001			
Cobalt (mg/l)				<0.001			
Copper (mg/l)	1			0.002			
Iron (mg/l)	0.3	<0.05		<0.05			
Lead (mg/l)	0.05			<0.005			
Manganese (mg/l)	0.05			<0.1			
Mercury (mg/l)	0.002			0.0001			
Molybdenum (mg/l)				<0.002			
Nickel (mg/l)				<0.002			
Selenium (mg/l)	0.01			0.002			
Vanadium (mg/l)				0.006			
Zinc (mg/l)	5			0.054			
Boron (mg/l)				<0.5			
Uranium (µg/l)		11	11	11	13	10	5
Radium 226 (pCi/l)	5	0.3±0.1	0.3±0.1	0.5±0.1	0.8±0.1	0.0±0.2	0.4±0.2
Temperature (°C)		10	9	8	13	13	8
Water Level (ft) MSL		--	--	--	--	--	--

CHOW BUTTE PROJECT
WATER QUALITY

Well Number: WELL 63

Date Sampled / Lab Name	EPA Standards and Criteria	SAMPLE RESULTS	MINIUM	MAXIMUM	AVERAGE
Calcium (mg/l)			64	69	67
Magnesium (mg/l)			7.0	8.4	7.5
Sodium (mg/l)			22	24	23
Potassium (mg/l)			7.6	8.7	8.4
Carbonate (mg/l)			<1	<2	<2
Bicarbonate (mg/l)			270	280	277
Sulfate (mg/l)	250		7	15	11
Chloride (mg/l)	250		3.4	5.0	4.2
Ammonia-N (mg/l)			<0.05	0.05	0.05
Nitrite-N (mg/l)			<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10		1.9	2.3	2.0
Fluoride (mg/l)	1.4-2.4		0.5	0.6	0.5
Silica (mg/l)			54	60	58
TDS-180°C (mg/l)	500		304	390	344
Conductivity - Field (umhos)			390	420	409
Conductivity - Lab (umhos)			453	499	476
Conductivity - Dilute (umhos)			496	530	516
Alkalinity (mg/l)			220	242	231
pH - Field			6.8	7.4	7.1
pH - Lab			7.2	7.7	7.5
Aluminum (mg/l)			<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05		0.003	0.003	0.003
Barium (mg/l)	1		0.2	0.2	0.2
Cadmium (mg/l)	0.01		<0.001	<0.001	<0.001
Chromium (mg/l)	0.05		<0.001	<0.001	<0.001
Cobalt (mg/l)			<0.001	<0.001	<0.001
Copper (mg/l)	1		0.002	0.002	0.002
Iron (mg/l)	0.3		<0.05	<0.05	<0.05
Lead (mg/l)	0.05		<0.005	<0.005	<0.005
Manganese (mg/l)	0.05		<0.1	<0.1	<0.1
Mercury (mg/l)	0.002		0.0001	0.0001	0.0001
Molybdenum (mg/l)			<0.002	<0.002	<0.002
Nickel (mg/l)			<0.002	<0.002	<0.002
Selenium (mg/l)	0.01		0.002	0.002	0.002
Vanadium (mg/l)			0.006	0.006	0.006
Zinc (mg/l)	5		0.054	0.054	0.054
Boron (mg/l)			<0.5	<0.5	<0.5
Uranium (µg/l)			5	13	10.
Radium 226 (pCi/l)	5		0.3	0.8	0.5
Temperature (°C)			8	13	10
Water Level (ft) MSL			--	--	--

BUTTE PROJECT
TER QUALITY

Well Number: WELL 66
Well Type: BASELINE WELL
Formation: BRULE

Surface Elevation: 3704.9 ft MSL
Well Depth: 60.0 ft
Distance From Wellfield: 15,000 ft

Date Sampled / Lab Name	EPA Standards and Criteria	Sample Results 10/29/81 NRL	01/28/82 NRL	04/27/82 NRL	07/13/82 NRL	10/04/82 NRL	04/07/83 CONE
Calcium (mg/l)		99	88	97	87	100	99
Magnesium (mg/l)		12	11	12	12	15	12
Sodium (mg/l)		55	53	53	53	52	56
Potassium (mg/l)		14	12	13	14	14	12
Carbonate (mg/l)		<2	<2	<2	<2	<2	<1
Bicarbonate (mg/l)		440	410	410	430	420	423
Sulfate (mg/l)	250	30	35	31	30	26	29
Chloride (mg/l)	250	17	17	22	19	23	20.2
Ammonia-N (mg/l)				0.08			<0.05
Nitrite-N (mg/l)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	6.5	5.3	4.1	4.2	9.2	8.7
Fluoride (mg/l)	1.4-2.4	0.7	0.6	0.6	0.6	0.5	0.6
Silica (mg/l)		59	61	60	58	58	55
TDS-180°C (mg/l)	500	540	480	530	540	570	498
Conductivity - Field (umhos)		320	560	600	700	700	750
Conductivity - Lab (umhos)		800	735	767	728	787	822
Conductivity - Dilute (umhos)				893	806	915	852
Alkalinity (mg/l)				340	350	340	362
pH - Field		7.5	7.03	7.40	7.0	6.55	6.85
pH - Lab		7.6	7.3	7.7	7.3	7.3	7.61
Aluminum (mg/l)				<0.1			
Arsenic (mg/l)	0.05			0.005			
Barium (mg/l)	1			<0.1			
Cadmium (mg/l)	0.01			0.002			
Chromium (mg/l)	0.05			<0.001			
Cobalt (mg/l)				<0.001			
Copper (mg/l)	1			0.006			
Iron (mg/l)	0.3	<0.05		<0.05			
Lead (mg/l)	0.05			0.020			
Manganese (mg/l)	0.05			<0.1			
Mercury (mg/l)	0.002			0.0009			
Molybdenum (mg/l)				0.004			
Nickel (mg/l)				<0.002			
Selenium (mg/l)	0.01			<0.002			
Vanadium (mg/l)				0.016			
Zinc (mg/l)	5			5.2			
Boron (mg/l)				0.5			
Uranium (µg/l)		31	28	31	31	27	26
Radium 226 (pCi/l)	5	0.4±0.1	0.3±0.1	0.6±0.2	0.3±0.1	0.9±0.2	0.3±0.2
Temperature (°C)		11	9	3	12	12	8
Water Level (ft) MSL		3684.9	3685.9	3685.5	3686.2	3684.9	--

CHOW BE[illegible] PROJECT
WATER QUALITY

Well Number: WELL 66

SAMPLE RESULTS

Date Sampled / Lab Name	EPA Standards and Criteria	MINIMUM	MAXIMUM	AVERAGE
Calcium (mg/l)		87	100	95
Magnesium (mg/l)		11	15	12
Sodium (mg/l)		52	56	54
Potassium (mg/l)		12	14	13
Carbonate (mg/l)		<1	<2	<2
Bicarbonate (mg/l)		410	440	422
Sulfate (mg/l)	250	26	35	30
Chloride (mg/l)	250	17.0	23.0	19.7
Ammonia-N (mg/l)		<0.05	0.08	0.06
Nitrite-N (mg/l)		<0.01	<0.01	<0.01
Nitrate-N (mg/l)	10	4.1	9.2	6.3
Fluoride (mg/l)	1.4-2.4	0.5	0.7	0.6
Silica (mg/l)		55	61	59
TDS-180°C (mg/l)	500	480	570	526
Conductivity - Field (umhos)		320	750	605
Conductivity - Lab (umhos)		728	822	773
Conductivity - Dilute (umhos)		806	915	867
Alkalinity (mg/l)		340	362	348
pH - Field		6.7	7.5	7.1
pH - Lab		7.3	7.7	7.5
Aluminum (mg/l)		<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	0.005	0.005	0.005
Barium (mg/l)	1	<0.1	<0.1	<0.1
Cadmium (mg/l)	0.01	0.002	0.002	0.002
Chromium (mg/l)	0.05	<0.001	<0.001	<0.001
Cobalt (mg/l)		<0.001	<0.001	<0.001
Copper (mg/l)	1	0.006	0.006	0.006
Iron (mg/l)	0.3	<0.05	<0.05	<0.05
Lead (mg/l)	0.05	0.020	0.020	0.020
Manganese (mg/l)	0.05	<0.1	<0.1	<0.1
Mercury (mg/l)	0.002	0.0009	0.0009	0.0009
Molybdenum (mg/l)		0.004	0.004	0.004
Nickel (mg/l)		<0.002	<0.002	<0.002
Selenium (mg/l)	0.01	<0.002	<0.002	<0.002
Vanadium (mg/l)		0.016	0.016	0.016
Zinc (mg/l)	5	5.2	5.2	5.2
Boron (mg/l)		0.5	0.5	0.5
Uranium (µg/l)		26	31	29.
Radium 226 (pCi/l)	5	0.3	0.9	0.5
Temperature (°C)		3	12	9
Water Level (ft) MSL		3684.9	3686.2	3685.5

TABLE 1
CROW BUTTE WATER QUALITY - PILOT WELL FIELD #1

DATE SAMPLED	12/03/82				01/18/83				04/11/83			
WELL NO.	PT-2	PT-7	PT-8	PT-9	PT-2	PT-7	PT-8	PT-9	PT-2	PT-7	PT-8	PT-9
LABORATORY		JORDAN				NRL				CORE		
CALCIUM <Mg/l>	15	17	20	17	12	15	17	15	11	15	15	14
MAGNESIUM <Mg/l>	3.6	4	3.6	2.8	3	3.9	3.3	2.5	2.5	3.6	2.5	2
SODIUM <Mg/l>	406	402	389	408	390	400	400	390	420	400	370	420
POTASSIUM <Mg/l>	16	12	17	13	15	10	13	13	17	10.6	12	12
CARBONATE <Mg/l>	5	0	5	23	14	2	14	17	<1	<1	<1	<1
BICARBONATE <Mg/l>	368	383	363	353	350	380	350	350	353	373	364	379
SULFATE <Mg/l>	355	355	341	355	370	370	360	350	343	355	345	353
CHLORIDE <Mg/l>	188	186	180	190	200	180	180	180	205	178.1	175.9	184.8
AMMONIA-N <Mg/l>	0.52	0.51	0.54	0.82	0.4	0.36	0.38	0.4	0.38	0.41	0.45	0.45
NITRITE-N <Mg/l>	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01
NITRATE-N <Mg/l>	0.05	0.04	0.03	<0.01	<0.01	<0.01	0.04	<0.01	<0.1	<0.1	<0.1	<0.1
FLUORIDE <Mg/l>	0.66	0.63	0.6	0.69	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7
SILICA <Mg/l>	11	14	16	13	13	14	15	14	19	22	24	37
TDS-180 C	1220	1220	1190	1240	1100	1100	1100	1200	1184	1134	1170	1162
K-LAB <umhos>	1830	1810	1740	1900	1800	1790	1750	1820	1675	*1510	*1510	*1590
pH-LAB	8.42	8.1	8.44	8.82	8.6	8.4	8.6	8.8	8.3	7.81	8.15	8.41
ARSENIC <Mg/l>	0.006	0.001	0.005	0.014	0.004	<0.002	<0.002	0.007	<0.01	<0.01	<0.01	<0.01
BARIUM <Mg/l>	0.09	0.04	0.11	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CADMIUM <Mg/l>	<0.0001	0.0004	0.0001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01
CHROMIUM <Mg/l>	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	a	a	a	a
COPPER <Mg/l>	0.003	0.004	0.007	0.004	0.004	0.005	0.005	0.005	<0.01	<0.01	<0.01	<0.01
IRON <Mg/l>	0.02	0.01	0.01	0.02	<0.05	<0.05	<0.05	<0.05	<0.05	0.14	0.11	<0.05
LEAD <Mg/l>	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01	0.02
MANGANESE <Mg/l>	0.007	0.008	0.006	0.008	<0.1	<0.1	<0.1	<0.1	<0.01	<0.01	<0.01	<0.01
MERCURY <Mg/l>	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0003	<0.0003	<0.0003	<0.0003
MOLYBDENUM <Mg/l>	0.02	0.02	0.03	0.05	0.024	0.022	0.021	0.075	<0.1	<0.1	<0.1	<0.1
NICKEL <Mg/l>	<0.01	<0.01	<0.01	<0.01	<0.002	<0.002	<0.002	<0.002	<0.05	<0.05	<0.05	<0.05
SELENIUM <Mg/l>	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.002	<0.002	<0.01	<0.01	<0.1	<0.01
VANADIUM <Mg/l>	0.01	<0.01	<0.01	0.03	0.027	0.004	0.012	0.025	<0.1	<0.1	<0.1	<0.1
ZINC <Mg/l>	0.01	0.017	0.027	0.008	<0.005	0.015	0.005	<0.005	<0.01	<0.01	0.01	0.04
BORON <Mg/l>	1	1.1	0.97	0.99	0.9	0.9	0.8	0.7	0.93	0.95	0.92	0.96
URANIUM <Mg/l>	0.933	0.119	0.322	0.441	0.77	0.085	0.29	0.39	0.66	0.075	0.265	0.36
RADIUM-226 <pCi/l>	136	379	151	602	68.1	280	89.2	207	54.9	266	115	491

a - CHROMIUM NOT RUN IN THIS SAMPLE SET, CALCULATIONS BASED ON A SAMPLE SIZE OF TWELVE.

* - DENOTES OUTLIER (NOT USED IN CALCULATIONS)

07/18/03				RANGE		MEAN	STANDARD DEVIATION
PT-2	PT-7 CORE	PT-8	PT-9	MINIMUM	MAXIMUM		
7.7	20	15	12	7.7	20	14.85625	>3.1618<
2.05	3.5	2.18	1.57	1.57	4	2.9125	>0.7545<
400	370	380	400	370	420	397.8125	>13.034<
18	13	11	15	10	18	13.6	>2.4494<
<1	<1	<1	<1	0	23	5.5	>7.2479<
338	345	354	365	338	383	360.8125	>13.565<
339	337	347	367	337	370	352.625	>10.461<
221	185	178	190	175.9	221	187.6125	>11.975<
0.34	0.3	0.33	0.41	0.3	0.82	0.4375	>0.1227<
<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	>0.0000<
0.1	<0.1	<0.1	0.1	0.01	0.1	0.0625	>0.0404<
0.6	0.5	0.5	0.6	0.5	0.7	0.63	>0.0674<
15	16	19	17	11	37	17.4375	>6.2393<
1193	1127	1120	1156	1100	1240	1163.5	>46.082<
2000	1800	1900	1970	1675	2000	>1829.6<	>91.616<
8.19	8.22	8.14	8.29	7.81	8.82	>8.3556<	>0.2650<
<0.005	<0.005	<0.005	<0.005	0.001	0.014	>0.0063<	>0.0035<
<0.1	<0.1	<0.1	<0.1	0.04	0.11	0.09625	>0.0154<
<0.001	<0.001	<0.001	<0.001	0.0001	0.01	>0.0030<	>0.0041<
<0.005	<0.005	<0.005	<0.005	0.001	0.005	0.0025	>0.0019<
<0.01	<0.01	<0.01	<0.01	0.003	0.01	>0.0073<	>0.0028<
<0.03	0.03	<0.03	<0.03	0.01	0.14	0.045625	>0.0346<
<0.005	<0.005	<0.005	<0.005	0.001	0.02	0.005875	>0.0048<
<0.005	<0.005	<0.005	<0.005	0.005	0.1	>0.0305<	>0.0414<
<0.0002	<0.0002	<0.0002	<0.0002	0.0001	0.0003	0.000175	>0.0000<
<0.01	0.01	<0.01	<0.01	0.01	0.1	0.043875	>0.0373<
<0.01	<0.01	<0.01	<0.01	0.002	0.05	0.018	>0.0193<
0.001	<0.001	0.001	<0.001	0.001	0.1	0.009125	>0.0244<
<0.01	0.02	<0.01	0.03	0.004	0.1	0.037375	>0.0381<
0.01	0.01	<0.01	<0.01	0.005	0.04	0.012625	>0.0090<
0.81	0.79	0.88	0.86	0.7	1.1	0.90375	>0.0974<
0.5	0.72	0.25	0.33	0.075	0.933	0.406875	>0.2518<
37.1	84.7	116	369	37.1	602	215.375	>168.37<

PAW BUTTE PROJECT
SURFACE WATER BASELINE WATER QUALITY

Location Number: S-1 Sample Type: STREAM
Distance From Wellfield: 1980 m Water System: SHAW CREEK

	EPA Standard	SAMPLE RESULTS				MINIMUM	MAXIMUM	AVERAGE
Date Sampled		02/25/82	04/19/82	07/03/82	10/05/82			
Lab Name		NRL	NRL	NRL	NRL			
Calcium (mg/l)		64	65	64	61	61	65	64
Magnesium (mg/l)		9.7	9.4	9.8	9.5	9.4	9.8	9.6
Sodium (mg/l)		12	12	13	12	12	13	12
Potassium (mg/l)		3.4	3.5	3.8	3.7	3.4	3.8	3.6
Carbonate (mg/l)		<2	<2	<2	<2	<2	<2	<2
Bicarbonate (mg/l)		270	270	260	270	260	270	268
Sulfate (mg/l)	250	<5	<5	8	5	5	8	7
Chloride (mg/l)	250	<2	<2	3	2	2	3	3
Ammonia-N (mg/l)		<0.05		<0.05		<0.05	<0.05	<0.05
Nitrite-N (mg/l)		<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.01
Nitrate-N (mg/l)	10	0.57	0.33	0.10	0.17	0.10	0.57	0.29
Fluoride (mg/l)	1.4-2.4	0.6	0.6	0.5	0.5	0.5	0.6	0.6
Silica (mg/l)		53	52	55	51	51	55	53
TDS-180°C (mg/l)	500	280	270	290	320	270	320	290
Conductivity - Field (umhos)		420	360	390	330	330	420	350
Conductivity - Lab (umhos)		421	425	424	391	391	425	415
Conductivity - Dilute (umhos)		465	451	466	439	439	466	455
Alkalinity (mg/l)		210	210	220	220	210	220	215
pH - Field		7.71	7.30	8.3	7.8	7.3	8.3	7.8
pH - Lab		7.7	7.6	8.1	8.1	7.6	8.1	7.9
Aluminum (mg/l)		<0.1		<0.1		<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	0.002		0.004		0.002	0.004	0.003
Barium (mg/l)	1	0.1		0.1		0.1	0.1	0.1
Cadmium (mg/l)	0.01	<0.001		<0.001		<0.001	<0.001	<0.001
Chromium (mg/l)	0.05	<0.001		<0.001		<0.001	<0.001	<0.001
Cobalt (mg/l)				<0.001		<0.001	<0.001	<0.001
Copper (mg/l)	1	<0.001		0.001		<0.001	0.001	0.001
Iron (mg/l)	0.3	0.05		<0.05		<0.05	0.05	0.05
Lead (mg/l)	0.05	<0.005		<0.005		<0.005	<0.005	<0.005
Manganese (mg/l)	0.05	<0.1		<0.1		<0.1	<0.1	<0.1
Mercury (mg/l)	0.002	<0.0001		<0.0001		<0.0001	<0.0001	<0.0001
Molybdenum (mg/l)		<0.002		<0.002		<0.002	<0.002	<0.002
Nickel (mg/l)		<0.002		<0.002		<0.002	<0.002	<0.002
Selenium (mg/l)	0.01	<0.002		<0.002		<0.002	<0.002	<0.002
Vanadium (mg/l)		0.005		0.006		0.005	0.006	0.006
Zinc (mg/l)	5	<0.002		0.004		<0.002	0.004	0.003
Boron (mg/l)		<0.5		<0.5		<0.5	<0.5	<0.5
Uranium (mg/l)		1	4	5		1	5	3.
Radium 226 (pCi/l)	5	0.4	0.3	0.4		0.3	0.4	0.4
Dissolved Oxygen (ppm)		12.0	11.9	8.5	10.5	8.5	12.0	10.7
Temperature (°C)		1	5	23	10	1	23	10

CROW BUTTE PROJECT
SURFACE WATER BASELINE WATER QUALITY

Location Number: S-2 Sample Type: STREAM
Distance From Wellfield: 6725 m Water System: SAWAW CREEK

	EPA Standards	SAMPLE RESULTS				MINIMUM	MAXIMUM	AVERAGE
Date Sampled		02/25/82	04/19/82	07/08/82	10/05/82			
Lab Name		NPL	NPL	NPL	NPL			
Calcium (mg/l)		64	64	53	58	53	64	60
Magnesium (mg/l)		9.5	9.4	9.2	9.1	9.1	9.5	9.3
Sodium (mg/l)		12	12	14	12	12	14	13
Potassium (mg/l)		3.5	4.0	4.0	4.3	3.5	4.3	4.0
Carbonate (mg/l)		<2	<2	<2	<2	<2	<2	<2
Bicarbonate (mg/l)		280	250	220	250	220	280	250
Sulfate (mg/l)	250	11	<5	10	<5	10	11	11
Chloride (mg/l)	250	<2	<2	2	2	2	2	2
Ammonia-N (mg/l)		<0.05		<0.05		<0.05	<0.05	<0.05
Nitrite-N (mg/l)		<0.01	0.02	<0.01	<0.01	<0.01	0.02	0.01
Nitrate-N (mg/l)	10	0.62	0.26	<0.01	<0.01	<0.01	0.62	0.22
Fluoride (mg/l)	1.4-2.4	0.6	0.6	0.5	0.5	0.5	0.6	0.6
Silica (mg/l)		53	51	50	48	48	53	51
TDS-180°C (mg/l)	500	300	240	260	280	240	300	270
Conductivity - Field (umhos)		430	390	350	300	300	430	368
Conductivity - Lab (umhos)		439	424	362	370	362	439	399
Conductivity - Dilute (umhos)		483	447	396	413	396	483	435
Alkalinity (mg/l)		230	200	180	200	180	230	203
pH - Field		7.78	7.73	7.5	7.85	7.5	7.8	7.7
pH - Lab		7.8	7.8	8.1	8.1	7.8	8.1	8.0
Aluminum (mg/l)		<0.1		0.1		<0.1	0.1	0.1
Arsenic (mg/l)	0.05	0.002		0.004		0.002	0.004	0.003
Barium (mg/l)	1	0.2		0.1		0.1	0.2	0.2
Cadmium (mg/l)	0.01	<0.001		<0.001		<0.001	<0.001	<0.001
Chromium (mg/l)	0.05	<0.001		<0.001		<0.001	<0.001	<0.001
Cobalt (mg/l)				<0.001		<0.001	<0.001	<0.001
Copper (mg/l)	1	<0.001		0.001		<0.001	0.001	0.001
Iron (mg/l)	0.3	0.05		<0.05		<0.05	0.05	0.05
Lead (mg/l)	0.05	<0.005		<0.005		<0.005	<0.005	<0.005
Manganese (mg/l)	0.05	<0.1		<0.1		<0.1	<0.1	<0.1
Mercury (mg/l)	0.002	<0.0001		<0.0001		<0.0001	<0.0001	<0.0001
Molybdenum (mg/l)		<0.002		<0.002		<0.002	<0.002	<0.002
Nickel (mg/l)		<0.002		<0.002		<0.002	<0.002	<0.002
Selenium (mg/l)	0.01	<0.002		<0.002		<0.002	<0.002	<0.002
Vanadium (mg/l)		0.004		0.006		0.004	0.006	0.005
Zinc (mg/l)	5	<0.002		0.002		<0.002	0.002	0.002
Boron (mg/l)		<0.5		0.6		<0.5	0.6	0.6
Uranium (mg/l)		2	2	4		2	4	3.
Radium 226 (pCi/l)	5	0.4	0.1	0.4		0.1	0.4	0.3
Dissolved Oxygen (ppm)		12.1	12.4	9.6	10.6	9.8	12.4	11.2
Temperature (°C)		1	7	24	10	1	24	11

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CROW BUTTE PROJECT
SURFACE WATER BASELINE WATER QUALITY

Location Number: S-3
Distance From Wellfield: 610 m

Sample Type: STREAM
Water System: SQUAW CREEK

	EPA Standard:	SAMPLE RESULTS				MINIMUM	MAXIMUM	AVERAGE
Date Sampled		02/25/82	04/19/82	07/08/82	10/05/82			
Lab Name		NRL		NRL	NRL			
Calcium (mg/l)		65	66	49	57	49	66	59
Magnesium (mg/l)		9.7	9.6	9.0	9.4	9.0	9.7	9.4
Sodium (mg/l)		12	13	14	13	12	14	13
Potassium (mg/l)		4.0	4.5	4.0	4.5	4.0	4.5	4.3
Carbonate (mg/l)		<2	<2	<2	<2	<2	<2	<2
Bicarbonate (mg/l)		270	270	220	240	220	270	250
Sulfate (mg/l)	250	5	<5	8	<5	5	8	7
Chloride (mg/l)	250	<2	<2	3	2	2	3	3
Ammonia-N (mg/l)		<0.05		<0.05		<0.05	<0.05	<0.05
Nitrite-N (mg/l)		<0.01	0.02	<0.01	<0.01	<0.01	0.02	0.01
Nitrate-N (mg/l)	10	2.4	0.21	<0.01	0.09	<0.01	2.4	0.68
Fluoride (mg/l)	1.4-2.4	0.6	0.6	0.5	0.5	0.5	0.6	0.6
Silica (mg/l)		51	48	44	48	44	51	49
TDS-180°C (mg/l)	500	290	280	260	280	260	290	278
Conductivity - Field (umhos)		430	390	340	385	305	430	365
Conductivity - Lab (umhos)		427	432	358	367	358	432	396
Conductivity - Dilute (umhos)		470	453	391	413	391	470	434
Alkalinity (mg/l)		220	210	180	200	180	220	203
pH - Field		7.82	7.80	8.4	7.8	7.8	8.4	8.0
pH - Lab		7.7	7.6	8.3	8.1	7.6	8.3	7.9
Aluminum (mg/l)		<0.1		<0.1		<0.1	<0.1	<0.1
Arsenic (mg/l)	0.05	0.002		0.004		0.002	0.004	0.003
Barium (mg/l)	1	0.2		0.1		0.1	0.2	0.2
Cadmium (mg/l)	0.01	<0.001		<0.001		<0.001	<0.001	<0.001
Chromium (mg/l)	0.05	<0.001		<0.001		<0.001	<0.001	<0.001
Cobalt (mg/l)				<0.001		<0.001	<0.001	<0.001
Copper (mg/l)	1	<0.001		0.001		<0.001	0.001	0.001
Iron (mg/l)	0.3	0.05		<0.05		<0.05	0.05	0.05
Lead (mg/l)	0.05	<0.005		<0.005		<0.005	<0.005	<0.005
Manganese (mg/l)	0.05	<0.1		<0.1		<0.1	<0.1	<0.1
Mercury (mg/l)	0.002	<0.0001		<0.0001		<0.0001	<0.0001	<0.0001
Molybdenum (mg/l)		0.002		<0.002		<0.002	0.002	0.002
Nickel (mg/l)		<0.002		<0.002		<0.002	<0.002	<0.002
Selenium (mg/l)	0.01	<0.002		<0.002		<0.002	<0.002	<0.002
Vanadium (mg/l)		0.005		0.005		0.005	0.005	0.005
Zinc (mg/l)	5	<0.002		0.002		<0.002	0.002	0.002
Boron (mg/l)		<0.5		0.5		<0.5	0.5	0.5
Uranium (µg/l)		12	4	4		4	12	7.
Radium 226 (pCi/l)	5	0.3	0.2	0.4		0.2	0.4	0.3
Dissolved Oxygen (ppm)		12.1	11.2	8.8	10.9	8.8	12.1	10.8
Temperature (°C)		1	8	25	11	1	25	11

CROW BUTTE PROJECT
SURFACE WATER BASELINE WATER QUALITY

Location Number: W-2
Distance From Wellfield: 8305 m

Sample Type: RIVER
Water System: WHITE RIVER

	EPA Standards	SAMPLE RESULTS				MINIMUM	MAXIMUM	AVERAGE
Date Sampled		02/25/82	04/21/82	07/09/82	10/05/82			
Lab Name		NRL	NRL	NRL	NRL			
Calcium (mg/l)		55	56	57	52	52	57	55
Magnesium (mg/l)		8.0	7.7	7.8	7.8	7.7	8.0	7.8
Sodium (mg/l)		17	16	20	18	16	20	18
Potassium (mg/l)		6.5	6.8	7.7	7.9	6.5	7.9	7.2
Carbonate (mg/l)		<2	<2	<2	<2	<2	<2	<2
Bicarbonate (mg/l)		230	230	240	230	230	240	233
Sulfate (mg/l)	250	12	<5	13	16	12	16	14
Chloride (mg/l)	250	4	4	6	6	4	6	5
Ammonia-N (mg/l)		<0.05		<0.05		<0.05	<0.05	<0.05
Nitrite-N (mg/l)		0.01	<0.01	0.01	0.40	<0.01	0.40	0.11
Nitrate-N (mg/l)	10	2.1	0.62	0.46	0.40	0.40	2.1	0.90
Fluoride (mg/l)	1.4-2.4	0.5	0.6	0.4	0.4	0.4	0.6	0.5
Silica (mg/l)		56	54	54	52	52	56	54
TDS-180°C (mg/l)	500	260	230	300	270	230	300	270
Conductivity - Field (umhos)		370	350	390	320	320	390	363
Conductivity - Lab (umhos)		394	413	420	377	377	420	401
Conductivity - Dilute (umhos)		436	431	459	422	422	459	437
Alkalinity (mg/l)		190	200	200	190	190	200	195
pH - Field		7.50	7.72	8.2	8.25	7.5	8.3	7.9
pH - Lab		7.5	7.7	7.9	8.2	7.5	8.2	7.8
Aluminum (mg/l)		<0.1		0.1		<0.1	0.1	0.1
Arsenic (mg/l)	0.05	0.002		0.004		0.002	0.004	0.003
Barium (mg/l)	1	0.2		<0.1		<0.1	0.2	0.2
Cadmium (mg/l)	0.01	<0.001		<0.001		<0.001	<0.001	<0.001
Chromium (mg/l)	0.05	<0.001		<0.001		<0.001	<0.001	<0.001
Cobalt (mg/l)				<0.001		<0.001	<0.001	<0.001
Copper (mg/l)	1	<0.001		0.002		<0.001	0.002	0.002
Iron (mg/l)	0.3	0.05		<0.05		<0.05	0.05	0.05
Lead (mg/l)	0.05	<0.005		<0.005		<0.005	<0.005	<0.005
Manganese (mg/l)	0.05	<0.1		<0.1		<0.1	<0.1	<0.1
Mercury (mg/l)	0.002	<0.0001		<0.0001		<0.0001	<0.0001	<0.0001
Molybdenum (mg/l)		<0.002		<0.002		<0.002	<0.002	<0.002
Nickel (mg/l)		<0.002		<0.002		<0.002	<0.002	<0.002
Selenium (mg/l)	0.01	<0.002		<0.002		<0.002	<0.002	<0.002
Vanadium (mg/l)		0.007		0.010		0.007	0.010	0.009
Zinc (mg/l)	5	<0.002		0.016		<0.002	0.016	0.009
Boron (mg/l)		<0.5		0.5		<0.5	0.5	0.5
Uranium (Mg/l)		1	7	6		1	7	5
Radium 226 (pCi/l)	5	3.0	0.4	0.5		0.4	3.0	1.3
Dissolved Oxygen (ppm)		12.1	13.9	9.1	10.4	9.1	13.9	11.4
Temperature (°C)		3	6	19	11	3	19	10

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5TH, 10TH AND 20TH LINE PROGRAMMED ACCEPTED

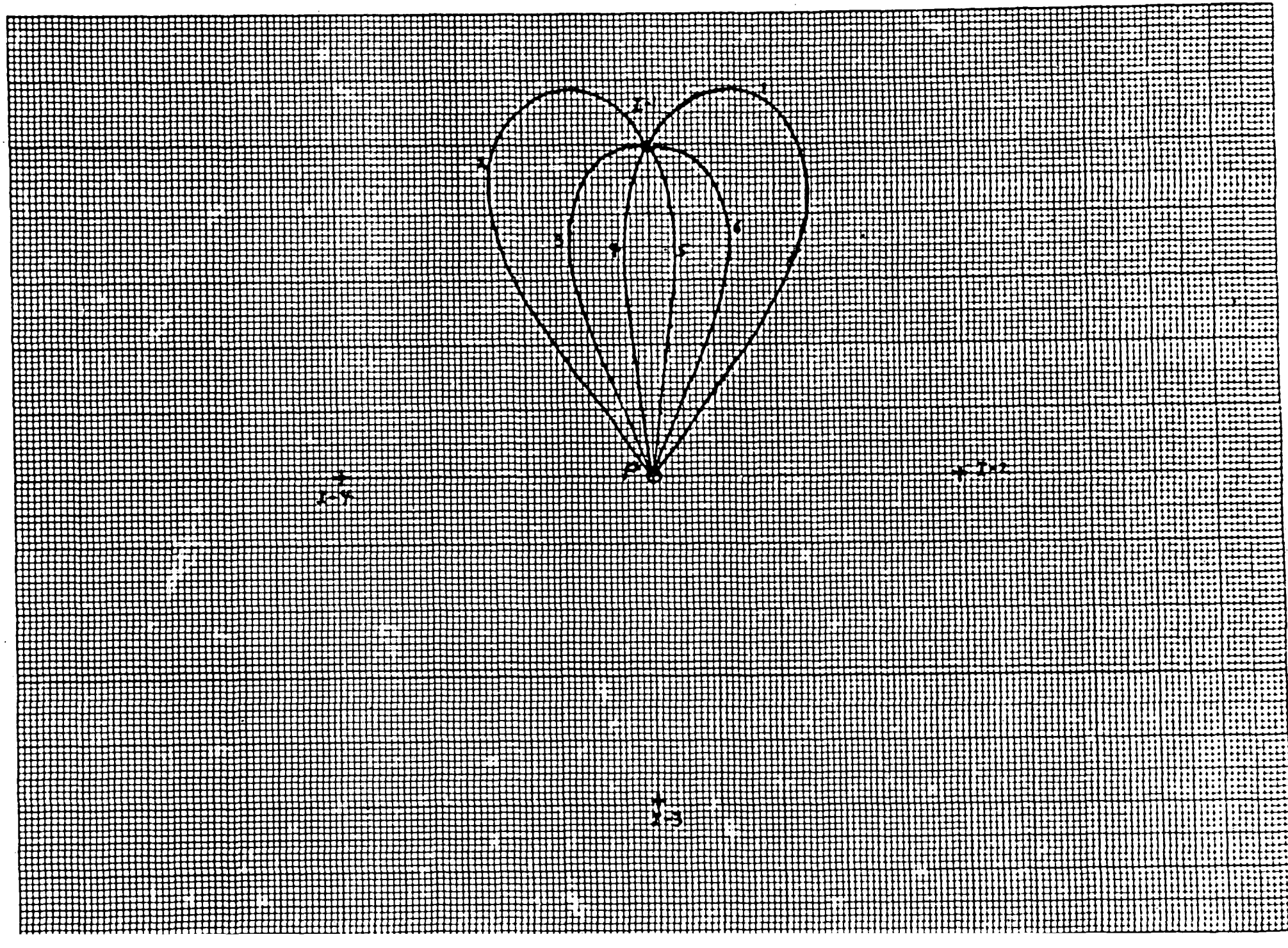

Figure 1

Table 2. Steady-State Simulation of Fluid Flow in Pattern 2

Parameter	Non-Leaky Aquifer	$K_v'/b' = 3.98 \times 10^{-5}$ day^{-1}
Streamline Arrival Times (hr):		
Streamline 1	2339.7	2342.6
Streamline 2	2330.8	2333.8
Streamline 3	661.0	661.2
Streamline 4	453.6	453.7
Streamline 5	453.5	453.5
Streamline 6	661.3	661.4
Areal Sweep (ft^2):		
Streamline 1	4036.2	4041.0
Streamline 2	4026.1	4024.5
Streamline 3	1133.4	1133.4
Streamline 4	773.0	773.1
Streamline 5	772.6	772.9
Streamline 6	1133.5	1135.2
Total for Quadrant	11874.8	11880.1
h at Production Well (ft):	-16.32	-16.53
h at Injection Well (ft):	2.95	2.74
Percentage of Injected Fluid Recovered after 8000 hrs. of Operation:	85.6	85.6
Vertical Velocity through Aquitard at Injection Well (cm/yr):	--	3.76

permeability, computed from the geometric mean transmissivity is approximately 3.4 darcys. Therefore, the aquifer is characterized by extremely high permeability and very low compressibility. It is underlain by an aquiclude and overlain by an aquitard of low permeability and high compressibility. These conclusions are consistant with geologic reports, geophysical logs, lithology of core samples from borehole C6C, and pump test data.

Analysis of pump test data indicates that leakage accounted for approximately 57.5% of the total volume of water pumped during the 2.09-day pump test. During the pump test, no water was injected into the aquifer, and the water recovered from the pumping well originated from only two sources: 1) storage within the aquifer and 2) storage within the aquitard. Since the compressibility of the aquitard is several orders of magnitude greater than that of the aquifer, it is reasonable to expect a high volume of leakage.

During an in situ leaching operation, injection wells supply fluid to the host aquifer. The fluid recovered from the production well is derived from three sources. 1) storage within the aquifer (after water levels stabilize, changes in storage occur predominently outside the well field), 2) leakage (from aquitard storage and/or recharge source); and 3) injection wells. Computer simulations indicate that leakage would have negligible effects on the proposed ISL pumping-injection schemes. The primary explanation for the modeling results is that the extremely high aquifer permeability provides excellent hydraulic connection between the production well and the four injection wells. Most of the fluid recovered is supplied by the injection wells. Other contributing factors include a low value of K_v/b and the fact that the change in hydraulic head within the aquifer is small.

CONCLUSIONS AND RECOMMENDATIONS

1. The NRC staff analyses demonstrate that leakage due to water released from aquitard storage is high. The effects of this type of leakage probably would be significant during the initial phase of well field operation. After water levels stabilize and the effects of aquitard storage diminish, leakage would not affect well field operations significantly. Therefore, we recommend that ground water be circulated through the system to stabilize water levels before lixiviant is introduced into the formation. This requirement shall be included as a license condition.

2. Effects of leakage on a multiple well system involving both recovery and injection can be minimized by maintaining aquifer permeability.

The fact that leakage effects for simulated ISL operations were negligible is due largely to the high permeability of the aquifer. Severe reductions in the permeability of the Basal Chadron would produce increases in leakage that may affect significantly the operation of the ISL well field. Typical problems associated with severe reductions in aquifer permeability include increased movement of contaminants into the aquitard and loss of control of fluid flow due to channeling and leakage.

To minimize problems associated with permeability loss, Wyoming Fuels Company must carefully select solutions which will minimize expansion of clays and precipitation. To assure the careful selection of solutions, the NRC staff will require Wyoming Fuels Company to explain the effects of proposed solution chemistries (specifically pH, Na^+, Ca^{++}, $CO_3^=$, and HCO_3^-) on clay swelling and calcite precipitation. Particular attention should be given to ion exchange and precipitation reactions that may occur at the interface of solutions of different composition.

3. The low velocities and long flow paths associated with exterior streamlines in Wellfield No. 1 may pose potential problems for aquifer restoration. During the proposed period of restoration, contaminants on the periphery of the pattern may not be entirely removed due to extremely low fluid velocities and long flow paths. This problem is particularly severe for species retarded by adsorption. Accordingly, the applicant will be requested to provide additional information or modify the proposed pattern to allow restoration within an acceptable time frame. Possible modifications include reduction in well spacing, incorporation of additional wells, and modifications to the pumping-injection scheme.

Additional Information on the Restoration of Wellfield No. 1 in Response to Conclusion No. 3 above.

In response to conclusion No. 3, Wyoming Fuel Corporation submitted a report April 1984, prepared by Canonie Engineers, entitled "Mining and Aquifer Restoration Scheme, Crow Butte ISL Uranium Project, Crawford, Nebraska." The report proposes a restoration program which addresses the NRC's concerns regarding wellfield No. 1. This restoration scheme incorporates injection of restored water in a central injection well (the production well of the leaching phase) and overproduction from four exterior wells (injection wells of the leaching phase). Computer simulations presented in this report show that at least one pore volume

of restored water would displace lixiviant along peripheral streamlines and that restoration would be achieved within the allotted time frame.

Although the assumptions and procedures of the Canonie report appear to be reasonable, the NRC staff believes that the conclusion may be overly optimistic. There are two concerns associated with the proposed restoration scheme which are paramount:

- that restoration along peripheral streamlines cannot be achieved with one pore volume displacement; and
- that contaminants transported outward along a path midway between production wells may not be recovered by the production wells.

To address these concerns, the NRC will require that two observation wells be installed to monitor restoration in the peripheral regions of wellfield No. 1. The locations of these wells should be proposed by Wyoming Fuel and approved by the NRC. The wells should be 4 inches in diameter and screened over the same interval as the pumping and injection wells. Monitoring of these wells should be bi-weekly for first 4 months of restoration and monthly thereafter. Baseline data for these wells should be collected in the same manner as the baseline data for other wells. Monitoring and baseline analyses must include conductivity, pH, total CO_3, Na^+, $SO_4^=$, cl^-, U, and Ra-226. If restoration monitoring of these observation wells indicates that restoration has not been achieved at the completion of the proposed restoration program, WFC will be required to drill additional wells and modify the pumping-injection scheme to restore the aquifer. These requirements will be included as a license condition.

Appendix B-I

Unsteady-State Radial Flow in an Isotropic Leaky Artesian Aquifer with Fully Penetrating Wells with Water Released from Storage in Aquitard.

The hydraulic model from which the Modified Hantush (1964) approach is derived comprises an artesian aquifer overlain by an aquitard and underlain by an aquiclude. Overlying the aquitard is a source of recharge which enables the head at the upper boundary of the aquitard to remain constant throughout the pump test. The aquifer is isotropic, infinite in a real extent, and homogeneous with respect to thickness and composition. The pumping well completely penetrates the aquifer and flow in the aquifer is horizontal and radial. The flow lines within the aquitard are vertical and are refracted at a right angle as they cross the aquitard-aquifer interface. Before pumping begins, the hydraulic heads within the aquifer, aquitard, and recharge source are equal. During the pumping test, the hydraulic head within the aquifer decreases while the head at the recharge source (upper boundary of the aquitard) remains constant ($h(b',t) = h_o$). The resultant gradient within the aquitard induces the flow which constitutes leakage. This flow can originate from the recharge source or from storage within the aquitard.

During the early stages of the pump test, the discharge of the pumping well is supplied entirely from storage within the aquifer and aquitard. No water is withdrawn from the recharge source during this period. As the pump test proceeds, the effects of storage diminish and leakage derived from the recharge source becomes significant. Water levels within the aquifer and aquitard eventually will stabilize when the total discharge of the pumping well is derived from leakage. When the hydraulic heads within the aquifer and aquitard no longer change with time, the system is considered to be at steady-state and no water is released from storage within aquifer or aquitard. At steady-state, all leakage is due to flow through the aquitard and is derived from the recharge source.

Detailed explanations of the governing equations for all stages of the pumping test (early, late, and steady-state) are presented by Hantush (1964) and Walton (1970). Only the equations pertinent to this analysis are provided here. For early times, when all leakage is derived from storage within the aquitard, the drawdown within the aquifer can be calculated by

$$s = 15.3187 \frac{Q}{T} W(u,\chi)$$

where $u = \frac{r^2 S}{T}$,

$$\lambda = \frac{r}{4}\sqrt{\frac{K_v' S_s'}{T S}},$$

$$W(u,\lambda) = \int_{u}^{\infty} \frac{e^{-y}}{y} \operatorname{erfc} \frac{t\sqrt{u}}{\sqrt{y(y-u)}}\, dy,$$

and erfc(x) is the complimentary error function defined by

$$\operatorname{erfc}(x) = 1 - \operatorname{erf}(x) = 1 - \frac{2}{\sqrt{\pi}} \int_{0}^{x} e^{-y}\, dy.$$

At steady-state, when all leakage occurs as flow from the recharge source, the drawdown within the aquifer can be calculated by

$$s = 30.6373 \frac{Q}{T} K_o\left(\frac{r}{B}\right)$$

where $\frac{r}{B} = r\sqrt{(K_v'/b')/T}$

Appendix B-II

Water Released from Storage in an Aquitard Due to One-Dimensional Consolidation

In D'Appolonia's analysis, leakage was assumed to be derived entirely from aquitard storage and was approximated from an equation derived from Terzaghi's Theory of one-dimensional consolidation. This theory, as it is presented by Freeze and Cherry (1979), considers two cases. One case is defined as a compressible aquitard of thickness b' situated between two incompressible aquifers. All three layers have initial hydraulic heads of h_o. At time t_o, the heads at both aquitard boundaries are reduced instantaneously (step function) to $h_o - h$ and the hydraulic head profile within the aquitard begins to diminish gradually with time. One-dimensional flow through the aquitard can be described by

$$\frac{\partial^2 h}{\partial z^2} = 0.01075 \frac{1}{Cv} \frac{\partial h}{\partial t}$$

where $h(z,o) = h_o$
$h(o,t) = h_o - h$
$h(b',t) = h_o - h$

The second case is defined as a compressible aquitard underlain by an incompressible aquifer and overlain by an aquiclude. In this case, water released from storage in the aquitard drains into only one aquifer. The flow equation for this case is the same as that of the first case. However, a Neumann boundary ($\frac{\partial h}{\partial z} = 0$) is used for the upper boundary in lieu of a Dirichlet boundary.

The solution to the flow equation provides a vertical profile of hydraulic head within the aquitard as a function of time. The volume of water released from aquitard storage can be described by

$$V_L = 8051.96\ A \int_0^{b'} S_s s'(z,t)\ dz$$

In computing the volume of water released from aquitard storage, D'Appolonia used an equation which is derived from Terzaghi's theory of one-dimensional consolidation and reported by Scott (1963). This equation, rewritten to conform to the units of this report and to describe the manner in which it was used, is

$$V_L = 2.8406\ A_i S_i \frac{2\ k_v'}{\sqrt{\pi\ C_v}}\ t$$

where N = number of concentric regions in the approximation.

Appendix B-III

Definition of Variables used in Equations

A = Area through which leakage occurs (acres)
C_v = Coefficient of consolidation (cm^2/sec)
$K_o(x)$ = Zero order hyperbolic Bessel function of x (fraction)
K_1 = Hydraulic conductivity of aquifer (ft/day)
K_v = Vertical hydraulic conductivity of aquitard (ft/day)
Q = Discharge of pumping well (gpm)
Q_L = Recharge rate due to leakage (gpm)
Q_s = Rate at which water is released from storage in aquifer (gpm)
S = Storage coefficient of aquifer (fraction)
S' = Storage coefficient of aquitard (fraction)
S_s = Specific storage of aquifer (ft^{-1})
S_s' = Specific storage of aquitard (ft^{-1})
T = Transmissivity of aquifer (ft^2/day)
V = Volume of fluid pumped (gal)
V_L = Volume of fluid supplied by leakage (gal)
V_s = Volume of fluid released from storage in aquifer (gal)
b = Thickness of aquifer (ft)
b' = Thickness of aquitard (ft)
erfc(x) = Complimentary error function of x (fraction)
g = Acceleration of gravity = 981 cm/sec^2
r = Distance from pumping well to observation well (ft)
$\bar{\beta}$ = Leakage term under steady-state conditions (fraction)
s = Drawdown in aquifer (ft)
t = Time (days)
α = Compressibility of aquifer (m^2/N)
α' = Compressibility of aquitard (m^2/N)
β = Compressibility of water = 4.4×10^{-10} m^2/N
ϕ = Porosity (fraction)
ρ = Density of water = 1.0 g/cc
χ = Same as used by Hantush (1964)(fraction)

Appendix B-IV
Technical Peer Review of the NRC Pump Test Analysis

Appendix B

Pump Test Analysis

On February 11, 1983, Wyoming Fuel Company (WFC) submitted an application for a R&D Source Material License for the proposed Crow Butte in situ leach (ISL) project. As part of this application, WFC provided an analysis of the aquifer pump test conducted at the proposed site.

WFC utilized the Theis non-equilibrium method and the Jacob straight line method to analyze the Crow Butte pump test data and to estimate transmissivity and storativity of the Basal Chadron aquifer. Potential leakage from the underlying Pierre Shale aquitard and the overlying Middle Chadron, Upper Chadron and Brule aquitards to the ore-bearing Basal Chadron aquifer was not analyzed by the applicant as requested by the NRC staff during a preapplication review of their proposed pump test design. WFC's method of evaluating the pump test data did not lend itself to the analysis of leakage. The applicant matched the pump test data to the Theis type curve by ignoring the early time drawdown data and force fitting the late time drawdown data. Using late time drawdown data results in over-estimates of transmissivity of the Basal Chadron aquifer because the Theis solution does not account for water supplied to the aquifer by leakage from the aquitards. Matching the Theis curve to the early time drawdown data can yield reasonable estimates of aquifer properties, but no information about leakage.

The NRC staff performed an independent analysis of the pump test data by utilizing the Hantush (1960) modified method. The Hantush modified method accounts for additional water supplied to the aquifer by compression of the aquitards and leakage from overlying and/or underlying aquifers, and allows use of all the pump test data to provide estimates of transmissivity and storativity of the aquifer that are much more reliable than values estimated by the Theis or Jacob techniques as used by the applicant. This evaluation showed that 1) WFC overestimated transmissivity, 2) leakage from storage was occurring from one or both aquitards, and 3) leakage may effect mining, excursion control, and restoration.

The NRC staff in a July 6, 1983 meeting requested that the applicant reanalyze the pump test data and outlined additional information to be provided as a result of the reanalysis. The applicant responded by reanalyzing the pump test data for the four observation wells PT8, PM1, PT2 and PM4; well PT7 is the pumping well. The applicant reanalyzed all four of the drawdown curves but continued to use the Theis curve matching technique which assumes that no leakage occurs. The applicant altered his original analysis by obtaining two matches and two match points for each curve. The matches for each curve are

for the early time drawdown data and for the late time drawdown data. The applicant asserted that this approach was valid because the later portions of the drawdown curves fall below the Theis curves due to variations in thickness of the aquifer. The applicant noted that the thickness of the aquifer at pumping well PT7 is 41 feet and that the thickness of the aquifer at observation well PT2 is 32 feet, which indicates that the aquifer is thinning between the pumping well and the observation well. However, the effect of thinning of the aquifer between the pumping well and the observation well should be to make the field data drawdown curve for the observation well rise above the Theis curve during the late portion of the pump test, and this does not occur in the field data curve. The drawdown data for well PT2 fell below the Theis curve as would a curve for a leaky aquifer. Consequently, it is not reasonable to explain the deviation of the field data curve from the Theis curve by variations in thickness of the aquifer.

The applicant also asser in their report that permeability varied within the basal Chadron aquifer and that variation in permeability may cause the drawdown curves for the observation wells to fall below the Theis curve, giving the appearance of a leaky aquifer. The applicant bases this assertion on the fact that "core logs of both holes reveal a marked change in the grain size and sorting of the material comprising the aquifer." In theory, increases in permeability in the direction from the pumping well to an observation well would cause the observation well drawdown data to give the appearance of a leaky aquifer. In this case, that explanation would require that permeability increase in all directions from pumping well PT7 because the drawdown curves in all four observation wells fall below the Theis curve. The NRC staff does not expect this to be the case since this sould not occur under the conditions that controlled deposition of the formation.

At this point in the review, the NRC staff was of the opinion that one must misinterpret the data base to discount the interpretation that the observation well drawdown curves fall below the Theis curve because of leakage from storage in the Middle Chadron.

The applicant's revised approach for analyzing the data using two matches of the Theis curve to the observation well drawdown curves yielded a range of transmissivity values for the Basal Chadron aquifer of 2116 to 3986 gal/day/ft. The Theis curve, when matched with early drawdown data, provides a reasonable estimate of the transmissivity because the effect of leakage is less pronounced at early time. The transmissivity value of 2116 gal/day/ft obtained by the applicant from

early time drawdown data compares well with the NRC's estimate based on the Hantush modified method, which assumes leakage.

In response to NRC staff concern over leakage from the confining beds, the applicant provided information on the competence of the confining units. The NRC staff evaluated the laboratory analyses by which the applicant calculated the properties of the Pierre Shale and the red clay and gray clay units in the Middle Chadron. The method (Tarzaghi's theory of one dimensional consolidation) employed by the applicant is used widely in the field of soil mechanics to analyze consolidation and calculate settling. The applicant states that "The two units of particular interest are the red clay which is a 10 to 25 foot thick bed immediately overlying the Chadron aquifer and the 1200 foot thick Pierre Shale." The applicant's analysis calculates the hydraulic properties of the red clay layer based on laboratory tests of a single core.

The NRC staff's concern regarding the applicant's analysis is two fold: first in placing emphasis on a laboratory method over that of the pump test method, and second in the interpretation of geophysical logs. The NRC staff considers the laboratory analysis a corroborative tool, not a primary method of analysis when a pump test has been conducted. This is because experience has shown that laboratory analysis does not often reflect actual field values. With regard to the interpretation of geophysical logs, the staff recognizes that the Basal Chadron is immediately overlain by a red clay layer, but the definition on the geophysical logs of site boreholes and the depositional history of the layer indicate that the thickness of this unit is variable. In combination with the significance of the interpretation of the pump test, the aforementioned factors indicate that the contact between the Basal Chadron aquifer and the Middle Chadron is gradational. The existance of a sandy layer in the Middle Chadron may very well be a source of leakage.

Based on the above analysis, it was the NRC's position that the only technically sound interpretation of the pump test data for the Crow Butte site was that of a leaky aquifer, where water is leaking into the Basal Chadron aquifer from storage within the confining beds of the Middle Chadron. Therefore, NRC staff instructed WFC to re-evaluate its position on the issue of leakage and either provide us with a sound technical basis to show that it is not occurring or accept the fact that leakage may be occurring and modify as appropriate their mining, monitoring and restoration plans.

As a result, WFC reanalyzed the pump test data to take into account leakage from storage from the upper aquitard. This reanalysis was submitted in October 1983. The applicant used the consolidation theory by Scott (1968) to calculate the amount of water derived from leakage during the 2.09-day pump test. The method was based on the laboratory testing of one core sample. As a result of the analysis, WFC concluded that the volume of water released from the storage in the upper aquitard during the pump test was approximately 1000 gallons, or 1.4% of the total water produced during the pump test.

The NRC staff review of WFC's October 1983 reanalysis did not disagree with the methodology used by WFC as it applies to the analysis of a single core hole. However, the NRC staff did not agree that a single borehole is adequate to define such values as the hydraulic conductivity of the aquitard. The NRC staff position was that the value of hydraulic conductivity should be derived directly from the pump test to provide a value representative of the pump test's area of influence. The biggest problem in estimating the amount of leakage from storage is the fact that while the hydraulic conductivity (K_v) of the aquitard can be determined directly from the pump test, the specific storage (S_s) has to be estimated. Therefore, the NRC staff independently reanalyzed the pump test data assuming a worst-case approach and using a unique methodology in order to determine a technically defensible estimate of leakage from aquitard storage as discussed in detail below.

NRC Staff Final Pump Test Evaluation

Uranium at the Crow Butte site exists in the lower 15 to 20 feet of the Basal member of the Chadron Formation. The Basal Chadron Member is a clean, coarse-grained, poorly-sorted sandstone with frequent interbedded, thin lenses of silt and clay. Occasionally, the lower portion comprises a very coarse-grained and very poorly-sorted conglomerate (Witzel 1974, Wyoming Fuels Company 1983). However, this basal conglomerate layer does not appear to be present within the R&D project area.

The thickness of the Basal Chadron within the pump test area averages 38 ft (arithmetic mean from logs of pump test wells) and ranges from 30 to 44 ft. Regional variation in thickness is considerably greater. Geophysical logs of wells within the R&D project area and pump test data suggest that the Basal Chadron Member is continuous throughout the R&D project area, but highly variable with respect to thickness and composition.

About 1200 to 1500 feet of massive, dark gray to black marine shale comprising the Pierre Formation underlie the host aquifer. This formation constitutes the lower confining bed for the host aquifer. The contact between the Chadron Formation and the Pierre Shale marks a maj unconformity and displays a distinctive pattern on geophysical logs. ional geologic data and geophysical logs indicate that the Pierre is homogeneous and continuous throughout the R&D project red

The vertical hydraulic conductivity of a sample of the Pierre Shale at borehole location C6C (approximately 500 ft. from the pumping well) is 9.6×10^{-8} ft/day (D'Appolonia, 1983). Although the formation hydraulic conductivity may be somewhat higher, it is reasonable to assume that it is insignificant relative to the aquifer hydraulic conductivity of 9.42 ft/day (geometric mean from pump test analysis). Due to the homogeneous composition of the Pierre Shale, the hydraulic conductivity within the pump test area is probably similar to the hydraulic conductivity at borehole location C6C. For the purpose of this analysis, the Pierre Shale is considered to act as an aquiclude.

Approximately 400 feet of clays, claystones, and siltstones overlie the host aquifer. Stratigraphically, these sediments comprise the Middle Chadron, Upper Chadron, and Lower Brule (Orella Member) Formations These fine-grained sediments provide upper confinement for the host aquifer and separate it from the water-bearing sands of the Whitney Member of the Brule Formation (DeGraw, 1969; Witzel, 1974; Wyoming Fuels Company, 1983). Pump test data indicate that this upper confining layer (or some portion of it) acts as a highly compressible aquitard. However, the complex stratigraphy of this layer makes it difficult to define the thickness of the aquitard.

Core samples of the Middle Chadron at borehole location C6C indicate three distinct layers defined as the Red Clay (lower), the Sandy Claystone (middle), and the Grey Claystone (upper). Thicknesses within the pump test area were determined from geophysical logs and are 15 ft, 25 ft, and 30 ft for the lower, middle, and upper layers, respectively. Permeability tests performed by Core Laboratories indicate that the Red Clay has a hydraulic conductivity which is less than 0.3% of that of the overlying Sandy Claystone (D'Appolonia, 1983). This suggests that the upper confinement of the host aquifer may be controlled by the Red Clay.

Several assumptions are inherent in D'Appolonia's 1983 analysis:

1. The average hydraulic conductivity of the aquitard system is dominated by the least permeable unit, the Red Clay.

2. During the period of the pump test, transient pore pressure changes induced by pumping did not propogate through the Red Clay into the overlying Sandy Claystone.

3. The Red Clay unit constitutes the aquitard for the hydrologic system in the analysis.

4. $b' = 15$ ft (thickness of Red Clay) (all variables are defined in Appendix B-III)

5. $K_v' = 7.8 \times 10^{-7}$ ft/day

6. $S_s' = 4.4 \times 10^{-6}$ ft^{-1} (computed from $C_v = 1.9 \times 10^{-3}$ cm^2/sec)

For all practical purposes, these assumptions can be considered valid only if the hydraulic properties of the core samples collected at borehole location C6C are representative of the aquitard within the area of the pump test. However, there are numerous reasons for questioning this fundamental assumption.

1. The sampling location C6C is approximately 500 ft. from the pumping well. Considering the variability in geophysical logs within the R&D project area, it is conceivable that the composition of the Middle Chadron within the pumping test area may be very different from the composition at the sampling location.

2 One sample (from the Red Clay) cannot reflect the heterogeneities of the aquitard.

3. Common limitations of laboratory testing of clays for permeability may result in considerable error. These limitations include the effects of expansive clays, partial saturation, entrapped air, and sample compression on permeability.

4. The specific storage of the Red Clay (4.4×10^{-6} ft^{-1}) is only slightly greater than the specific storage of the aquifer (4.2×10^{-6} ft^{-1}). The specific storage of a dense clay should range from approximately 3×10^{-5} to 3×10^{-3} ft^{-1} (Freeze and Cherry, 1979).

Comparison of Laboratory and Pump Test Analyses

Because the pump test did not utilize any piezometers in the aquitard, and the duration of the pump test was not long enough to nullify the effects of aquitard storage, it is impossible to determine the hydraulic parameters (K_v and S_s) of the aquitard from pump test data alone. Consequently, it is not possible to use K_v and S_s as a basis for comparing laboratory and pump test data. However, the product $K_v S_s$, which can be determined from both laboratory and pump test data, provides an excellent means of comparison. The values of $K_v S_s$ computed from the leakage term (Appendix B-I) are:

Well No.	$K_v' S_s'$ (day^{-1})
PM-1	2.95×10^{-9}
PM-4	1.76×10^{-8}
PT-2	6.18×10^{-8}
PT-8	3.76×10^{-7}
Geometric Mean	3.32×10^{-8}

The value of $K_v' S_s'$ for the core sample collected at borehole location C6C can be determined from laboratory values of hydraulic conductivity and coefficient of consolidation. The coefficient of [illegible]ion for clay is defined as

$$C_v = 3.53 \times 10^{-3} \frac{k_v'}{\rho g \alpha} \qquad \text{(Freeze and Cherry, 1979)} \quad (1)$$

In addition, it can be shown that

$$S_s' = 3.048 \; \rho g \alpha \qquad \text{(Domenico, 1972)} \quad (2)$$

Consequently,

$$K_v' S_s' = 0.011 \, (K_v')^2 / C_v = 3.52 \times 10^{-12} \; day^{-1} \quad (3)$$

Because the laboratory product lies outside the product range for the pump test and is almost 4 orders of magnitude less than the geometric mean for the pump test, it is reasonable to conclude that the hydraulic

characteristics of the Red Clay collected at borehole location C6C are not representative of the aquitard within the pump test area. Therefore, no values for b', K_v' or S_s can be assumed when analyzing leakage.

Due to the hyperbolic relation of K_v' to S_s', the minimum technically defensible hydraulic conductivity of the aquitard can be estimated from a value of S_s which can be considered an upper limit for any geologic material. The maximum compressibility for a clay, the most compressible material, is approximately 10^{-6} m^2/N (Freeze and Cherry, 1979). It is unlikely that the compressibility of the aquitard will exceed this value. A maximum S_s of 3.0×10^{-3} is computed from Equation 2. This value produces a minimum aquitard hydraulic conductivity of approximately 1.1×10^{-5} ft/day, indicating that the aquitard is probably more than 10 times as permeable as the value calculated for the Red Clay in the D'Appolonia report. Therefore, the effect of leakage on an ISL operation may be considerably greater than the effect anticipated by D'Appolonia.

In approximating the volume of water released from aquitard storage, D'Appolonia used an equation which is derived from Terzaghi's theory of one-dimensional consolidation and reported by Scott (1963). The substitution of the right side of Equation 3 into the leakage equation in Appendix II yields an equation which expresses the volume of leakage as a function of $K_v'S_s'$. In this way, the method used by D'Appolonia can be expressed by

$$V_L = \sum_{i=1}^{N} 8051.96\ A_i S_i \sqrt{K_v' S_s' t} \qquad (4)$$

where N = number of concentric regions in the approximation used by D'Appolonia (1983)

The estimated volume of leakage induced by the pump test, as determined by D'Appolonia, is too small for three reasons:

1. Considerable error may result from discretizing the system into concentric regions. A good approximation would require more regions extending far beyond the 4000 ft radius used by D'Appolonia.

2. The boundary conditions inherent in Terzaghi's theory are different from the Hantush boundary conditions used in creating the distance-drawdown curve.

3. The laboratory values of $K_v'S_s'$ used by D'Appolonia (1983) in computing leakage differ from the pump test values of K_vS_s used in creating the distance-drawdown curve by several orders of magnitude. Since two completely different values of K_vS_s are used in the same calculation, mass is not conserved (i.e., $V \neq V_L + V_S$).

In analyzing leakage induced by the pump test, the NRC staff used exact solutions provided by Hantush (1964) and values of S and K_vS_s derived from the pump test. No individual values are assumed for b', K_v, or S_s. The exact solution for the total volume of water released from aquitard storage during the pump test is

$$V_L = 1440.0\ Qt\ [1 - \frac{2}{\sqrt{\eta \pi t}} + \frac{1}{\eta t}\ (1 - \exp(\eta t)\mathrm{erfc}(\sqrt{\eta t}))] \qquad (5)$$

where $\eta = K_v'S_s'/S^2$

Substituting the geometric means of $K_v'S_s'$ and S into Equation 5 yields approximately 57.5% leakage over 2.09 days. D'Appolonia's estimate was 1.4% of the total volume pumped.

Up to this point, this analysis has been concerned with leakage during the relatively short period of the pump test. During this period, the hydraulic pressures in the aquifer and aquitard change significantly with time, and leakage is derived entirely from storage in the aquitard. To determine the effects of leakage on ISL operations, the behavior of the aquitard as water levels stabilize and the hydrologic system approaches steady-state must be considered. At steady-state, the effects of storage are absent and leakage is a function of K_v/b.

It is evident from the steady-state equations in Appendix I that a maximum value of K_v/b will produce maximum leakage. A maximum value of K_v/b can be computed from two equations:

The solution to the Modified Hantush leakage equation

$$K_v'S_s' = 3.32 \times 10^{-8} \qquad (7)$$

and the limiting criterion for determining the applicability of the Modified Hantush approach:

$$t \leq 0.1\ S_s'(b')^2/K_v' \qquad (8)$$

The solution to these equations,

$$K'_v/b' \leq \sqrt{3.32 \times 10^{-9}/t}\ , \qquad (9)$$

provides a maximum K'_v/b' for which the Modified Hantush approach is valid.

The maximum effects of leakage on ISL operations can be simulated with the ISL-50 Hydrology Model (Schmidt, 1980), which generates streamlines (flow paths) resulting from stresses imposed by injection and production. Simulations were performed for two five-spot patterns proposed by Wyoming Fuels Company. Pertinent aquifer/aquitard characteristics and wellfield specifications used in the simulations are provided in the following table:

Wellfield No. 2 well spacing	: 24.7 ft	(distance between production well and injection well for 35 X 35 pattern proposed by WFC)
Wellfield No. 1 well spacing	: 93.5 ft	(distance between production well and injection well in 132 X 132 pattern proposed by WFC)
Injection rate per well	: 12.25 gpm	(proposed by WFC)
Production rate	: 50.00 gpm	(proposed by WFC)
T	: 358.1 ft^2/day	(geometric mean)
b	: 38 ft	(arithmetic mean)
Maximum K'_v/b'	: 3.98×10^{-5} day^{-1}	(Equation 9)
Aquifer Porosity	: 0.25	(estimated for clean, poorly-sorted sand)
Aquitard Porosity	: 0.45	(estimated for clay)

Two simulations were performed for each five-spot pattern proposed. The first simulation assumes a non-leaky aquifer, while the second simulation models the effects of maximum leakage ($K_v/b = 3.98 \times 10^{-5}$ day^{-1}). The flow pattern for each injection well is represented by six streamlines. Since anisotropy and baseline ground-water flow are not considered by this analysis, the flow lines for a square five-spot pattern are symmetric and only one quadrant needs to be analyzed. Figure 1 illustrates the relative position of wells and the orientation of streamlines in the quadrant analyzed.

Tables 1 and 2 summarize the results of the computer simulations and depict the effect of leakage on the proposed wellfields. The arrival times and areal sweeps of streamlines are indicators of the system's

ability to contain excursions whereas the drawdowns at pumping and injection wells can be used to estimate the vertical movement of solutions through the aquitard. Streamline arrival times also can be used to estimate the time required to restore the aquifer. The percentage of injected fluid recovered from the pumping well indicates the pattern's efficiency with respect to the recovery of fluids from the aquifer.

The results of computer modeling indicate that maximum leakage has essentially no effect on the operation of Wellfield No. 2 and only a minor effect on Wellfield No. 1. The vertical fluid velocity at the injection well is small, indicating adequate vertical confinement of contaminants. However, extremely long arrival times for exterior streamlines in Wellfield No. 1 indicate that restoration of Wellfield No. 1 may not be possible within the time frame proposed by Wyoming Fuels Company. Additional wells, or other modifications to the proposed pumping-injection scheme possibly could allow restoration within the proposed time frame.

Before any conclusions can be made regarding leakage to the Basal Chadron Aquifer, the hydraulic behavior of the aquifer must be understood. Since the specific storage of the aquifer can be derived from the time-drawdown curves (geometric mean of 4.15×10^{-6} ft^{-1}), the compressibility of the aquifer can be calculated from the equation

$$S_s = 3.048 \quad g(\alpha + \beta) \text{ (Freeze and Cherry, 1979)} \qquad (10)$$

The compressibility of the host aquifer within the pump test area is 1.28×10^{-9} m^2/N assuming an aquifer porosity of 0.25. The aquifer

Table 1. Steady-State Simulation of Fluid Flow in Pattern 1

Parameter	Non-Leaky Aquifer	$K'_v/b' = 3.98 \times 10^{-5}$ day^{-1}
Streamline Arrival Times (hr):		
Streamline 1	185.0	185.0
Streamline 2	184.3	184.3
Streamline 3	49.1	49.1
Streamline 4	31.8	31.8
Streamline 5	31.7	31.7
Streamline 6	49.1	49.1
Areal Sweep (ft^2):		
Streamline 1	320.0	320.0
Streamline 2	318.6	318.6
Streamline 3	84.0	84.0
Streamline 4	53.6	53.6
Streamline 5	53.6	53.6
Streamline 6	84.0	84.0
Total for Quadrant	913.7	913.7
h at Production Well (ft):	-10.74	-10.95
h at Injection Well (ft):	1.54	1.33
Percentage of Injected Fluid Recovered after 8000 hrs of Operation:	98.9	98.9
Vertical Velocity through Aquitard at Injection Well (cm/yr):	--	1.82

Appendix C

RADON RELEASES FROM IN SITU OPERATIONS

This appendix describes the assumptions, data, and equations used to estimate the annual radon-222 released from the solution-mining and restoration processes. The parameters used in the radon release calculations were based on the data submitted by the applicant. The principal parameters are listed below:

Average area to be mined per year, km^2	.00405
Average production flow rate, gpm (lpm)	100 (378)
Average restoration flow rate, gpm (lpm)	50 (189)
Operating days per year	365
Formation porosity, %	28
Average ore thickness, m	1.5
Rock density, g/cm^3	1.92
Residence time for production solution, d	7
Equilibrium value for radon for 7 d, %	72
Residence time for restoration solution, d	7
Equilibrium value for radon for 7 d, %	72

The staff assumed that the two cells would be leached at a 100 gpm rate for 26 weeks. Then for a period of 22 weeks, one cell would be leached at a production rate of 50 gpm, while the other would be restored at a 50 gpm rate. For the final 56 weeks, the remaining leached cell would be restored at a rate of 50 gpm. These assumptions in conjunction with the above parameter values, were used to calculate the radon releases from the pilot plant.

C.1 RADON RELEASE FROM OPERATION

For uranium-238 in equilibrium with all its daughters, an ore-body concentration of 1012 pCi/g of radon is estimated for an average ore grade of 0.36%. One cubic meter of ore contains

$$1.92\ g/cm^3 \times (1 - 0.28) \times 1012\ pCi/g \times 1 \times 10^{-12}\ Ci/pCi$$
$$\times\ 10^6\ cm^3/m^3 = 1.40 \times 10^{-3}\ Ci/m^3$$

The radon activity in the pore water is based on an emanation coefficient of 0.20 of radon into the ore pore space (28% of the ore). Thus, the pore water contains:

$$\frac{1.40 \times 10\text{-}3\ Ci/m^3}{0.28} \times 0.20 = 1.0 \times 10^{-3}\ Ci/m^3$$

of radon at equilibrium. The radon release from a production flow of 378 lpm (100 gpm) is calculated as

$$378 \text{ lpm} \times 10^{-3} \text{ m/l} \times 1440 \text{ min/d} \times 365 \text{ d/year} \times 1.0$$

$$\times 10^{-3} \text{ Ci/m}^3 = 198.7 \text{ Ci/year},$$

where 365 d/year is the number of davs of annual operation.

For the pregnant leach solution, it is estimated that approxiamtely 72% of the radon-222 remains undecayed at the time the leach solution is depressurized by release into the production fluid surge tanks before processing for uranium removal. The annual radon release per mining unit is then calculated to be

$$198.7 \text{ Ci/year} \times 0.72 = 143 \text{ Ci/year}.$$

In addition to the release of radon from the production solution, it is estimated that one pore volume of non-production water will be removed as the R&D cells are put into service. The radon release from a non-productive source resulting from this start-up procedures is as follows:

$$.00405 \text{ km}^2\text{/year} \times 10^6\text{m}^2\text{/km}^2 \times 1.5 \text{ m} \times 0.28 \times 1.0 \times 10^{-3} \text{ Ci/m}^3$$

$$= 1.7 \text{ Ci/year},$$

where 1.5 m is the average thickness of the ore bodies and 0.28 is the assumed formation porosity.

The above calculations are based on operations for a year. As discussed earlier, the leaching/restoration scenario varies over the 2-year period of consideration. In Section C.4 of this appendix, adjustments will be made to account for the proposed schedule of operations.

The total release of radon from mining operations is:

Start-up solution	1.7 Ci/year
Production	143 Ci/year
Total	144.7 Ci/year

C.2 RADON RELEASE FROM RESTORATION

As mentioned in Section C.1, restoration will start 23 weeks after the pilot plant will be put into operation. The pumping rate will be 50 gpm

for each cell throughout the restoration period. Assuming an annual basis for restoration, the radon release is calculated to be:

$$189 \text{ lpm} \times 10^{-3} \text{ m}^3/\text{l} \times 1440 \text{ min/d} \times 365 \text{ d/year} \times 1.0 \times 10^{-3} \text{ Ci/m}^3$$

$$\times 0.72 = 72 \text{ Ci/year},$$

where 0.72 is the estimated degree of radon equilibrium.

In addition it is assumed that one pore volume of solution will be removed before restoration begins. The total release of radon from restoration procedures is:

Start-up solution	1.7 Ci/year
Restoration solution	72 Ci/year
Total from restoration	73.7 Ci/year

C.3 RADON RELEASED FROM THE EVAPORATION PONDS

Radium solids are not leached in sufficient quantities to produce significant amounts of radon in the waste liquids; therefore, radon emis[illegible] from the pond areas is negligible.

C.4 SU[illegible] AR

The radon annual release rate based on the first 22 weeks of operation is 144.6 Ci/year as calculated in Section C.1. During the next 26 weeks the leaching rate is halved, then the radon corresponding to this is also halved, or 72 Ci/year. Also during this time, restoration is being performed at 50 gpm, which was estimated to produce 72 Ci/year for a total radon release of 144.6 Ci/year corresponding to the next 26 weeks of operation. For this reason, the staff has modeled this pilot plant to release 145 Ci/year for the duration of R&D operations. This estimate will account for variations in restoration times for the smaller cell.

Appendix D

DETAILED BASIS FOR RADIOLOGICAL ASSESSMENT

The staff's radiological impacts assessment is based on site-specific data provided by the applicant (Table D.1) and on the models, data, and assumptions discussed in "Calculational Models for Estimating Radioactive Materials Resulting from Uranium Milling Operations," (Regulatory Guide 3.5.1, March 1982). The prediction of offsite air concentrations of radioactive materials is based on joint relative frequency data gathered from the National Weather Service Station at Scottsbluff, Nebraska, over the period 1967 through 1971 (Table D.2).

Table D.1. Parameters and conditions used in the radiological assessment of the solution-mining project

Parameter	Value
Average ore grade (U_3O_8), %	0.36
Ore activity, pCi/g	1012
Average production flow rate, L/min (gpm)	378 (100)
Average restoration flow rate, L/min (gpm)	189 (50)
Stack effluent height, m	7
Mixing height (annual average), m	522
Land use and grazing of cattle	
Hectarage required to graze one animal unit (450 kg) for one month (AUM), ha	0.66
Fraction of year spent grazing locally, %	42
Fraction of stored feed grown locally, %	100

TABLE D.2

ANNUAL FREQUENCY DISTRIBUTION

Stability Class: A

Number of Occurrences: 126

Station: Scottsbluff NE

Period of Record: 1967-1971

Direction	Speed(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Total
N	0.000201	0.000068	0.000000	0.000000	0.000000	0.000000	0.000270
NNE	0.000066	0.000068	0.000000	0.000000	0.000000	0.000000	0.000135
NE	0.000334	0.000205	0.000000	0.000000	0.000000	0.000000	0.000539
ENE	0.000133	0.000137	0.000000	0.000000	0.000000	0.000000	0.000270
E	0.000268	0.000137	0.000000	0.000000	0.000000	0.000000	0.000405
ESE	0.000268	0.000137	0.000000	0.000000	0.000000	0.000000	0.000405
SE	0.000334	0.000205	0.000000	0.000000	0.000000	0.000000	0.000539
SSE	0.000265	0.000274	0.000000	0.000000	0.000000	0.000000	0.000539
S	0.000464	0.000479	0.000000	0.000000	0.000000	0.000000	0.000944
SSW	0.000201	0.000068	0.000000	0.000000	0.000000	0.000000	0.000270
SW	0.000201	0.000068	0.000000	0.000000	0.000000	0.000000	0.000270
WSW	0.000464	0.000479	0.000000	0.000000	0.000000	0.000000	0.000944
W	0.000531	0.000548	0.000000	0.000000	0.000000	0.000000	0.001079
WNW	0.000803	0.000411	0.000000	0.000000	0.000000	0.000000	0.001214
NW	0.000334	0.000205	0.000000	0.000000	0.000000	0.000000	0.000539
NNW	0.000201	0.000068	0.000000	0.000000	0.000000	0.000000	0.000270
TOTAL	0.005068	0.003562	0.000000	0.000000	0.000000	0.000000	

Stability Class: B

Number of Occurrences: 668

Station: Scottsbluff NE

Period of Record: 1967-1971

Direction	Speed(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Total
N	0.000347	0.001096	0.000616	0.000000	0.000000	0.000000	0.002060
NNE	0.000140	0.000822	0.000274	0.000000	0.000000	0.000000	0.001236
NE	0.000553	0.000890	0.000205	0.000000	0.000000	0.000000	0.001649
ENE	0.000301	0.000822	0.000479	0.000000	0.000000	0.000000	0.001602
E	0.000531	0.001233	0.001164	0.000000	0.000000	0.000000	0.002928
ESE	0.000795	0.001370	0.001096	0.000000	0.000000	0.000000	0.003261
SE	0.000771	0.001233	0.001507	0.000000	0.000000	0.000000	0.003511
SSE	0.000588	0.001096	0.001301	0.000000	0.000000	0.000000	0.002985
S	0.000808	0.001918	0.000822	0.000000	0.000000	0.000000	0.003548
SSW	0.000438	0.000685	0.000685	0.000000	0.000000	0.000000	0.001807
SW	0.000404	0.000959	0.000342	0.000000	0.000000	0.000000	0.001705
WSW	0.000404	0.000959	0.000616	0.000000	0.000000	0.000000	0.001979
W	0.001052	0.002877	0.001781	0.000000	0.000000	0.000000	0.005709
WNW	0.001107	0.002260	0.001918	0.000000	0.000000	0.000000	0.005285
NW	0.000853	0.001712	0.001370	0.000000	0.000000	0.000000	0.003935
NNW	0.000634	0.001370	0.000548	0.000000	0.000000	0.000000	0.002552
TOTAL	0.009726	0.021301	0.014726	0.000000	0.000000	0.000000	

Stability Class: C

Number of Occurrences: 1403

Station: Scottsbluff NE

Period of Record: 1967-1971

Direction	Speed(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Total
N	0.000238	0.000822	0.001370	0.000274	0.000000	0.000000	0.002703
NNE	0.000112	0.000342	0.000822	0.000137	0.000000	0.000000	0.001413
NE	0.000162	0.000822	0.001575	0.000000	0.000068	0.000000	0.002628
ENE	0.000169	0.000890	0.001164	0.000205	0.000000	0.000000	0.002429
E	0.000187	0.001781	0.004110	0.000616	0.000000	0.000000	0.006694
ESE	0.000280	0.002671	0.007260	0.000685	0.000000	0.000000	0.010897
SE	0.000346	0.001849	0.005548	0.001096	0.000000	0.000000	0.008839
SSE	0.000137	0.001301	0.003493	0.001096	0.000068	0.000000	0.006096
S	0.000317	0.001575	0.003904	0.000890	0.000000	0.000000	0.006687
SSW	0.000043	0.000411	0.001096	0.000137	0.000000	0.000000	0.001687
SW	0.000162	0.000822	0.000685	0.000137	0.000000	0.000000	0.001806
WSW	0.000093	0.000890	0.001233	0.000137	0.000000	0.000000	0.002354
W	0.000425	0.002603	0.006027	0.001096	0.000274	0.000137	0.010562
WNW	0.000500	0.004041	0.008425	0.001438	0.000137	0.000068	0.014610
NW	0.000525	0.003562	0.005616	0.001370	0.000274	0.000000	0.011347
NNW	0.000483	0.001712	0.002260	0.000616	0.000205	0.000068	0.005346
TOTAL	0.004178	0.026096	0.054589	0.009931	0.001027	0.000274	

Stability Class: C

Number of Occurrences: 1403

Station: Scottsbluff NE

Period of Record: 1967-1971

Direction	Speed(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Total
N	0.000238	0.000822	0.001370	0.000274	0.000000	0.000000	0.002703
NNE	0.000112	0.000342	0.000822	0.000137	0.000000	0.000000	0.001413
NE	0.000162	0.000822	0.001575	0.000000	0.000068	0.000000	0.002628
ENE	0.000169	0.000890	0.001164	0.000205	0.000000	0.000000	0.002429
E	0.000187	0.001781	0.004110	0.000616	0.000000	0.000000	0.006694
ESE	0.000280	0.002671	0.007260	0.000685	0.000000	0.000000	0.010897
SE	0.000346	0.001849	0.005548	0.001096	0.000000	0.000000	0.008839
SSE	0.000137	0.001301	0.003493	0.001096	0.000068	0.000000	0.006096
S	0.000317	0.001575	0.003904	0.000890	0.000000	0.000000	0.006687
SSW	0.000043	0.000411	0.001096	0.000137	0.000000	0.000000	0.001687
SW	0.000162	0.000822	0.000685	0.000137	0.000000	0.000000	0.001806
WSW	0.000093	0.000890	0.001233	0.000137	0.000000	0.000000	0.002354
W	0.000425	0.002603	0.006027	0.001096	0.000274	0.000137	0.010562
WNW	0.000500	0.004041	0.008425	0.001438	0.000137	0.000068	0.014610
NW	0.000525	0.003562	0.005616	0.001370	0.000274	0.000000	0.011347
NNW	0.000483	0.001712	0.002260	0.000616	0.000205	0.000068	0.005346
TOTAL	0.004178	0.026096	0.054589	0.009931	0.001027	0.000274	

Stability Class: D

Number of Occurrences: 3863

Station: Scottsbluff NE

Period of Record: 1967-1971

Direction	Speed(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Total
N	0.000202	0.002260	0.003562	0.008562	0.003699	0.000959	0.019243
NNE	0.000104	0.000548	0.002123	0.002877	0.000411	0.000342	0.006405
NE	0.000110	0.001918	0.001438	0.002945	0.000685	0.000137	0.007233
ENE	0.000127	0.000959	0.001438	0.002877	0.000685	0.000274	0.006360
E	0.000312	0.001644	0.003836	0.005753	0.000479	0.000000	0.012024
ESE	0.000214	0.002466	0.007945	0.013014	0.002329	0.000000	0.025967
SE	0.000210	0.002397	0.005274	0.012877	0.003425	0.000274	0.024457
SSE	0.000196	0.000890	0.001918	0.007603	0.001918	0.000205	0.012730
S	0.000086	0.001507	0.002671	0.005068	0.001507	0.000137	0.010977
SSW	0.000108	0.000616	0.000616	0.001438	0.000274	0.000000	0.003053
SW	0.000016	0.000274	0.000548	0.000822	0.000137	0.000000	0.001797
WSW	0.000067	0.001164	0.000890	0.001301	0.000548	0.000137	0.004108
W	0.000071	0.001233	0.004521	0.010205	0.007397	0.003425	0.026852
WNW	0.000234	0.002808	0.008014	0.020616	0.010000	0.005000	0.046672
NW	0.000259	0.001986	0.006644	0.011986	0.008562	0.004726	0.034163
NNW	0.000151	0.001370	0.003014	0.008219	0.006575	0.003219	0.022548
TOTAL	0.002466	0.024041	0.054452	0.116164	0.048630	0.018836	

Stability Class: E

Number of Occurrences: 4127

Station: Scottsbluff NE

Period of Record: 1967-1971

Direction	Speed(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Total
N	0.001105	0.002055	0.007397	0.007123	0.001918	0.000479	0.020078
NNE	0.000354	0.001301	0.004247	0.004315	0.000822	0.000411	0.011450
NE	0.000333	0.001849	0.004452	0.003630	0.001301	0.000137	0.011703
ENE	0.000149	0.000753	0.004795	0.004315	0.000890	0.000205	0.011108
E	0.000497	0.001986	0.014521	0.007671	0.000205	0.000000	0.024880
ESE	0.000346	0.001986	0.017945	0.020479	0.002534	0.000000	0.043291
SE	0.000299	0.001507	0.009795	0.011438	0.001986	0.000068	0.025093
SSE	0.000170	0.000959	0.002329	0.002466	0.000548	0.000000	0.006471
S	0.000088	0.000[illegible]90	0.002329	0.001712	0.000411	0.000068	0.005499
SSW	0.000102	0.000274	0.001233	0.000342	0.000274	0.000137	0.002363
SW	0.000116	0.000411	0.000753	0.000479	0.000000	0.000000	0.001760
WSW	0.000157	0.000068	0.001027	0.001164	0.000342	0.000068	0.002828
W	0.000374	0.001507	0.006233	0.010890	0.004521	0.001507	0.025032
WNW	0.000661	0.002123	0.012055	0.016712	0.005205	0.002260	0.039017
NW	0.000456	0.001575	0.009452	0.014247	0.005205	0.001575	0.032511
NNW	0.000340	0.001164	0.005548	0.007808	0.003288	0.001438	0.019587
TOTAL	0.005548	0.020411	0.1040109	0.114794	0.029452	0.008356	

Stability Class: F

Number of Occurrences: 4413

Station: Scottsbluff NE

Period of Record: 1967-1971

Direction	Speed(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	>21	Total
N	0.004483	0.015958	0.007945	0.000000	0.000000	0.000000	0.028387
NNE	0.002725	0.008973	0.003493	0.000000	0.000000	0.000000	0.015191
NE	0.003660	0.009246	0.003562	0.000000	0.000000	0.000000	0.016468
ENE	0.001541	0.007740	0.002945	0.000000	0.000000	0.000000	0.012226
E	0.005654	0.022055	0.016986	0.000000	0.000000	0.000000	0.044695
ESE	0.003083	0.017260	0.019795	0.000000	0.000000	0.000000	0.040137
SE	0.001670	0.007672	0.004384	0.000000	0.000000	0.000000	0.013724
SSE	0.000930	0.004178	0.002260	0.000000	0.000000	0.000000	0.007368
S	0.002037	0.005822	0.001644	0.000000	0.000000	0.000000	0.009503
SSW	0.000735	0.001369	0.001164	0.000000	0.000000	0.000000	0.003269
SW	0.000754	0.002055	0.000274	0.000000	0.000000	0.000000	0.003083
WSW	0.000694	0.003219	0.000616	0.000000	0.000000	0.000000	0.004529
W	0.002530	0.007192	0.005000	0.000000	0.000000	0.000000	0.014722
WNW	0.003003	0.014315	0.014795	0.000000	0.000000	0.000000	0.032113
NW	0.003137	0.014658	0.013356	0.000000	0.000000	0.000000	0.031151
NNW	0.004187	0.013493	0.008014	0.000000	0.000000	0.000000	0.025694
TOTAL	0.040822	0.155205	0.106233	0.000000	0.000000	0.000000	

Appendix E

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Appendix E

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United States Department of the Interior

GEOLOGICAL SURVEY
BOX 25046 M.S. 404
DENVER FEDERAL CENTER
DENVER, COLORADO 80225

IN REPLY
REFER TO

June 26, 1984

Mr. Edward Hawkins
Uranium Recovery Field Office
U.S. Nuclear Regulatory Commission
P.O. Box 25325
Denver, CO 80225

Dear Mr. Hawkins:

I have reviewed all of the material you provided on the aquifer tests at the Crow Butte in-situ leaching project. My principal conclusions are as follows:

The drawdown data show no evidence of leakage sufficient to distort the shape of the cone of depression or affect the transient response of the observation wells. In other words, at the short radial distances involved, values of β are less than 0.01 (probably much less).

Superimposing the log-log time-drawdown data for all four observation wells on a common r^2/t base (a so-called "mass plot") demonstrates the late-time convergence of all data plots. The absence of an r-dependent separation of the drawdown curves confirms the lack of measurable leakage. The general appearance of the mass plot strongly suggests an influence of partial penetration. The anomalously small drawdown values obtained during the first 15 minutes of pumping also may be attributable to sluggish, inadequately developed observation wells. Data presented in the several reports do not permit a thorough evaluation of these possibilities.

The apparent shaliness of parts of the Basal Chadron aquifer indicates that the often quoted "r>2b" criterion for immunity from partial penetration effects is not applicable. This criterion is based on an assumption of an isotropic aquifer. More rigorously, the criterion may be expressed as

$$ar > 1.5b$$

where a is a measure of vertical-horizontal anistropy, defined as being equal to $\sqrt{K_z/K_r}$; r is the radial distance from pumped well to observation well; b is the aquifer thickness; K_z and K_r are the hydraulic conductivities in the vertical and horizontal (radial) directions,

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respectively. If $K_r \geq 2.5\ K_z$, the closer observation wells may show partial penetration effects; if $K_r \geq 25\ K_z$, the more distant wells may be affected. The shaliness of the Basal Chadron, as suggested by the electric logs and graphic logs, is certainly sufficient to produce an overall $K_r:K_z$ ratio greater than 2.5, and probably greater than 25.

Distortions in the shape of a log-log time-drawdown plot (relative to the Theis curve) that are attributable to partial penetration or sluggish observation-well response, become less significant with time. Therefore, it is justifiable to place some credence in a solution based on a selective "late-data" curve match, if an internally consistent and geologically reasonable result is obtained. On this basis, transmissivity and storage are estimated as follows:

$$T = 480\ ft^2/day$$
$$S = 7 \times 10^{-5}$$

If β at $r = 293$ ft is less than 0.01, as indicated by the drawdown data, then

$$0.5\ r \sqrt{\frac{(K'S_s')^*}{TS}} = \beta < 0.01$$

where $(K'S_s')^*$ is the average of the products of vertical hydraulic conductivity and specific storage for the upper and lower confining beds.

Thus

$$(K'S_s')^* < 4 \times 10^{-6} TS/r^2$$

$$(K'S_s')^* < 1.6 \times 10^{-6} day^{-1}$$

Then if S_s' is assumed to be $5 \times 10^{-6} ft^{-1}$, K' will be less than 3×10^{-5} ft/day. This assumed value for S_s' is supported by the results of the consolidation test on a sample of middle Chadron clay (620.0-620.8 ft below land surface). The elastic compressibility during unloading from 389 to 69 psi is about $9 \times 10^{-6} in^2/lb$, which about $4 \times 10^{-6} ft^{-1}$ in terms of the skeletal component of elastic specific storage (S'_{ske}).

It is essential to note that the elastic (rebound) value of compressibility, as calculated from a consolidation test, must be used for any computations addressing transient aquitard leakage during pumping. Values of compression index and consolidation coefficient (C_v) commonly provided as test results are based on the "virgin" compression characteristics obtained after test pressures have been increased to values substantially greater than the maximum past in-situ stress (preconsolidation stress). For overconsolidated Tertiary aquifers, estimates of compressibility and specific storage based on nonrecoverable virgin compression will typically be 10 to 100 times too large. A large body of laboratory and in-situ test data demonstrates that the value of aquitard specific storage at stresses less than the preconsolidation stress typically ranges from $2 \times 10^{-6} ft^{-1}$ to $2 \times 10^{-5} ft^{-1}$. Much larger values attributed to Domenico and Miflin (1965), Johnson, et al (1968),

Freeze and Cherry (1979) are based on virgin compressibilities and are seriously misleading, except in situations where large drawdowns cause effective stresses to exceed the preconsolidation stress.

For the 620.0-620.8 ft sample, the laboratory value of C_v of 0.18 ft^2/day, in conjunction with the rebound value of specific storage of 4×10^{-6} ft^{-1}, produces the following estimate of vertical hydraulic conductivity:

$$K'_f = C_v S_s' = (.18)(4 \times 10^{-6}) = 7.2 \times 10^{-7} \text{ft/day}$$

This compares very favorably with the measured permeability reported for the 615.8 - 616.0 ft sample, which is 2.6×10^{-4} millidarcys, or about 7.0×10^{-7} ft/day.

Thus, two independent laboratory procedures on two different samples of the Red Clay yield essentially identical values of K'_v, and a $K'_v S'_s$ that will not support a β value larger than $1. \times 10^{-3}$. The pumping test and laboratory results are, therefore, in agreement. Although it is always prudent to consider the possible nonrepresentativeness of laboratory data from a limited number of cores, there is nothing in the pumping test data to support a specific challange of these lab results.

The Hantush criterion for determining the duration of "early time" may be used to estimate the time required for the first detectable pressure response to pumping to propagate to the top of the Red Clay, as follows:

$$t = 0.05 b'^2 \, S_s'/K'_v$$

$$= (.05)(20^2)(4 \times 10^{-6})/7 \times 10^{-7}$$

$$= 114 \text{ days}$$

Your staff report is based on sound principles, but is quantitatively wide of the mark, primarily as a result of relying on a leaky aquifer solution that is not supported by the data. It should be noted that the concept represented by your equation 9 is very difficult to apply in practice, because it usually is difficult to determine the time at which drawdown data first begin to depart from a given β curve (the end of "early time").

I am not able to comment on the mechanics of the ISL simulation modeling. However, even when using a leakance (K'_v/b') that probably is 3 orders of magnitude too large, your results indicate that aquitard leakage is not a significant concern. Thus, the conflicts among the several interpretations of the pumping test and laboratory data are apparently largely academic.

You will find a large number of marginal comments, queries, rough calculations, etc. on the various reports and memoranda that you provided me. Most of these represent my first-pass reactions and notes to myself as I attempted to get a handle on the problem. In a few instances, they may be inconsistent with the conclusions summarized above, in which case, ignore them.

I am also enclosing, for your general information, copies of some field and laboratory-determined properties of late Cenozoic sediments.

Should any of my conclusions appear unclear or inadequately explained to you or your staff, please call; if we can't resolve the problems over the phone, I will be pleased to meet with you and go over the data in detail.

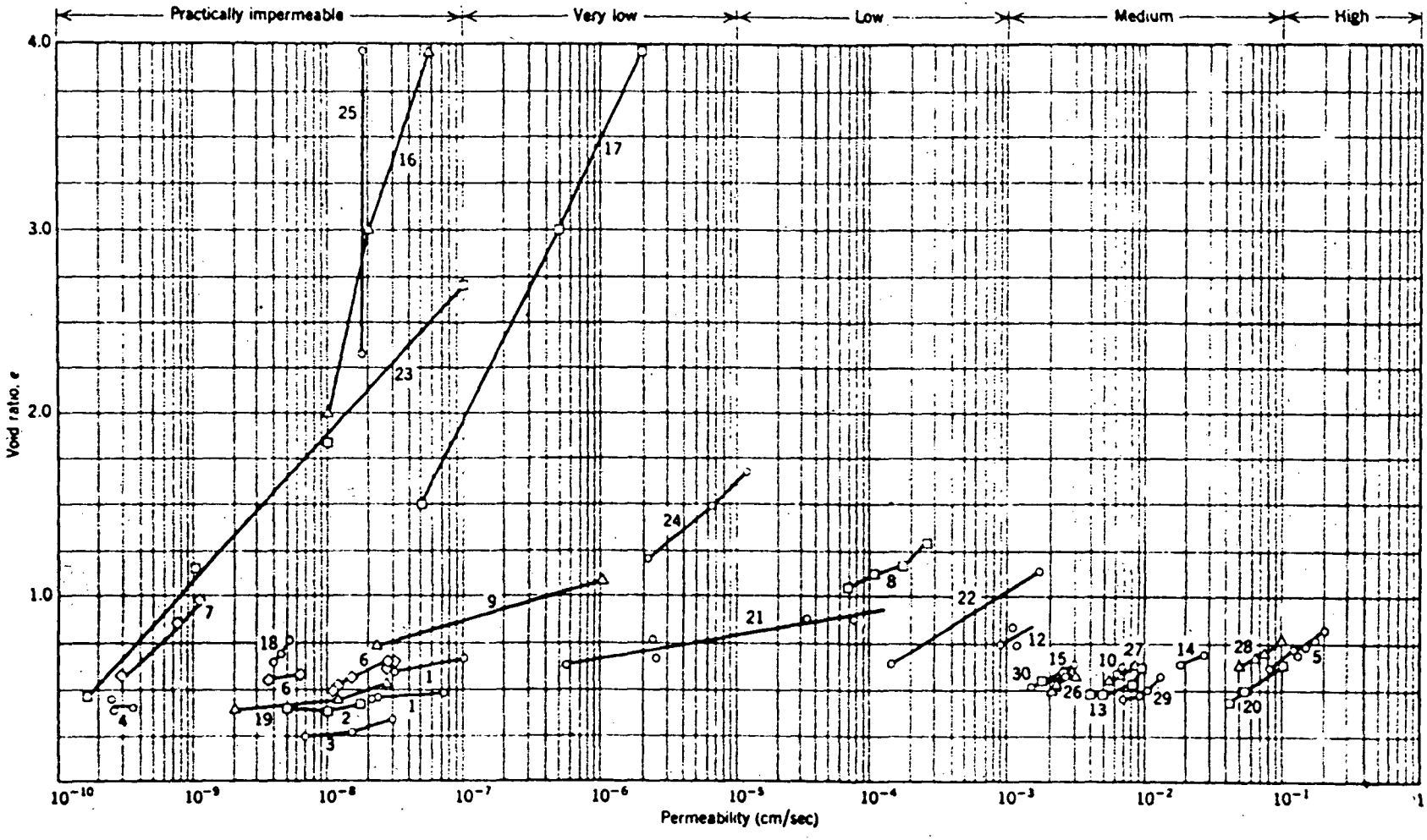
Sincerely,

Francis S. Riley

F. S. Riley, Chief
Subsidence Research Project

ps

enclosures



Soil Identification Code

1 Compacted caliche
2 Compacted caliche
3 Silty sand
4 Sandy clay
5 Beach sand
6 Compacted Boston blue clay
7 Vicksburg buckshot clay
8 Sandy clay
9 Silt—Boston
10 Ottawa sand
11 Sand—Gaspee Point
12 Sand—Franklin Falls
13 Sand—Scituate
14 Sand—Plum Island
15 Sand—Fort Peck
16 Silt—Boston
17 Silt—Boston
18 Loess
19 Lean clay
20 Sand—Union Falls
21 Silt—North Carolina
22 Sand from dike
23 Sodium—Boston blue clay
24 Calcium kaolinite
25 Sodium montmorillonite
26-30 Sand (dam filter)

Fig. 19.5 Permeability test data.

Table 4.--Computer simulation of aquifer-system compaction

Monitoring site	Monitored thickness of compacting sediments			Recoverable (elastic) storage parameters of the compacting confined aquifer system											
				Component due to skeletal compressibility						Total (skeletal plus water compressibility) storage					
				Average specific storage			Storage coefficients			Average specific storage			Storage coefficients		
Well or site number	Aggregate aquifer thickness	Aggregate aquitard thickness	Total monitored thickness	Aquifers	Aquitards	Aquitard model	Aquifers	Aquitards	Aquifer system	Aquifers	Aquitards	Aquifer system	Aquifers	Aquitards	Aquifer system
	Σb (feet)	$\Sigma b'$ (feet)	b^* (feet)	S_{ske} ($feet^{-1}$)	S'_{ske} ($feet^{-1}$)	S^h_{ske} ($feet^{-1}$)	S_{ke} (Dimensionless)	S'_{ke} (Dimensionless)	S^*_{ke} (Dimensionless)	S_s ($feet^{-1}$)	S'_s ($feet^{-1}$)	S^*_s ($feet^{-1}$)	S (Dimensionless)	S' (Dimensionless)	S^* (Dimensionless)
14/13-11D3,6	304	274	578		6.53×10^{-6}	7.01×10^{-6}	1.31×10^{-4}	1.79×10^{-3}	1.92×10^{-3}		7.10×10^{-6}	3.86×10^{-6}	2.83×10^{-4}	1.95×10^{-3}	2.23×10^{-3}
16/15-34N4	421	876	1,297		1.98×10^{-6}	2.19×10^{-6}	1.81×10^{-4}	1.74×10^{-3}	1.92×10^{-3}		2.56×10^{-6}	2.03×10^{-6}	3.92×10^{-4}	2.24×10^{-3}	2.63×10^{-3}
18/19-20P2	263	154	[1]417		6.76×10^{-6}	7.50×10^{-6}	1.13×10^{-4}	1.04×10^{-3}	1.15×10^{-3}		7.34×10^{-6}	3.29×10^{-6}	2.45×10^{-4}	1.13×10^{-3}	1.37×10^{-3}
19/16-23P2	636	1,324	1,960		1.81×10^{-6}	2.01×10^{-6}	2.73×10^{-4}	2.39×10^{-3}	2.66×10^{-3}		2.38×10^{-6}	1.91×10^{-6}	5.92×10^{-4}	3.15×10^{-3}	3.74×10^{-3}
20/18-11Q1	232	388	620		3.74×10^{-6}	3.99×10^{-6}	1.00×10^{-4}	1.45×10^{-3}	1.55×10^{-3}		4.31×10^{-6}	3.04×10^{-6}	2.16×10^{-4}	1.67×10^{-3}	1.89×10^{-3}
23/25-16N1,3	127	278	405	0.43×10^{-6}	4.41×10^{-6}	4.60×10^{-6}	$.546\times10^{-4}$	1.22×10^{-3}	1.28×10^{-3}	0.93×10^{-6}	4.98×10^{-6}	3.70×10^{-6}	1.18×10^{-4}	1.38×10^{-3}	1.50×10^{-3}
11N/21W-3B1	303	367	670		3.64×10^{-6}	3.99×10^{-6}	1.30×10^{-4}	1.34×10^{-3}	1.47×10^{-3}		4.21×10^{-6}	2.73×10^{-6}	2.82×10^{-4}	1.54×10^{-3}	1.83×10^{-3}

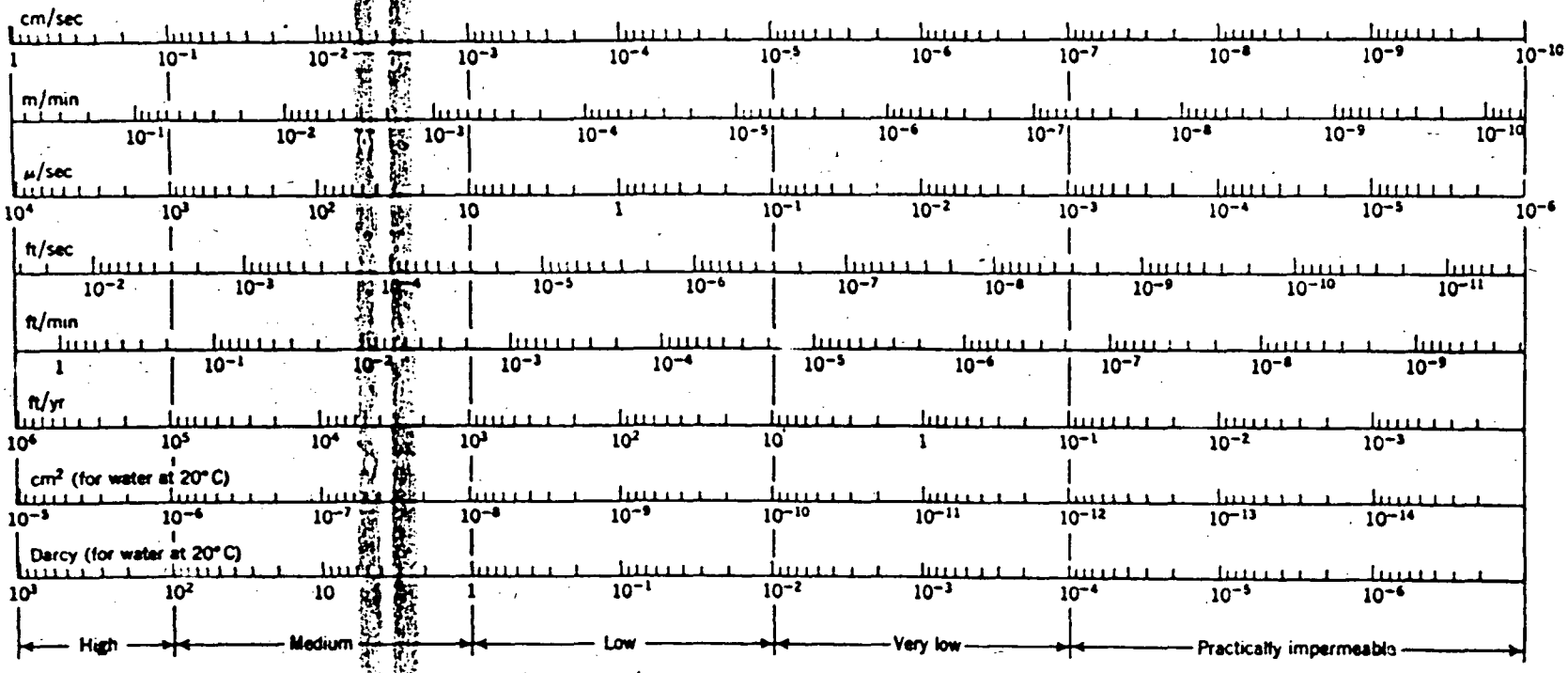
[1] Poland and others (1975) and the present authors have interpreted the thickness of compacting sediment at this site to be 347 feet.

These are in-situ values derived from direct measurement of the transient response (compaction and expansion) to pore-pressure changes in the confined alluvial aquifer systems of the San Joaquin Valley, Calif. Computer simulation was used to sort out the various components (aquifer/aquitard, elastic/inelastic) contributing to the total thickness changes recorded by the bore-hole extensometers.

Nonrecoverable (virgin) Aquitard storage parameters		Ratio of virgin to elastic specific storage for the aquitards	Vertical hydraulic conductivity of the aquitards	Time constants for characteristic aquitard		Depth to water at which nonrecoverable compaction would begin during a cycle of renewed drawdown		
				Elastic	Virgin	Predicted 1974 High	Predicted 1974 Low	Observed 1976-77
Skeletal specific storage S'_{skv_1} (feet^{-1})	Skeletal storage coefficient S'_{kv} (Dimensionless)	S'_{skv}/S'_s (Dimensionless)	K' (feet/year)	τ_e (years)	τ_v (years)	(feet)	(feet)	(feet)
4.3×10^{-4}	0.12	61	7.7×10^{-4}	0.67	40	348	426	≤330
2.4×10^{-4}	.21	94	5.2×10^{-4}	.44	42	377	520	415
6.7×10^{-4}	.10	91	7.0×10^{-4}	2.2	215	154	163	160
3.0×10^{-4}	.40	126	0.2×10^{-4}	10.7	1,350	361	509	520
1.4×10^{-4}	.05	32	1.2×10^{-4}	4.3	140	0	240	310
2.3×10^{-4}	.06	46	$30.\times10^{-4}$	.11	5	164	220	180
2.5×10^{-4}	.09	59	3.0×10^{-4}	1.3	75	33	392	<360

Table 1.--Preliminary tabulation of consolidation characteristics for samples from Texas City-Seabrook Subsidence Study

Laboratory sample number	Depth (ft)	Field number	Location	Calculated field effective stress p psi	Vertical hydraulic conductivity at p K_v' m/day	Inelastic specific storage at p S_{si}' ft^{-1}	Elastic specific storage at p S_{se}' ft^{-1}	Void ratio at p e	Coefficient of consolidation at (K_v'/S_{si}') C_v ft^2/day
73TEX188	163- 164	1	Texas City	80.0	9.73×10^{-7}	(4.9×10^{-4}) 3.29×10^{-4}	(7.4×10^{-5}) 8.02×10^{-5}	(.62) 0.636	(6.5×10^{-3}) 9.71×10^{-3}
73TEX189	256- 257	2	Texas City	136.	1.72×10^{-6}	1.21×10^{-4}	9.01×10^{-5}	0.636	4.66×10^{-2}
73TEX190	423- 424	3	Texas City	215.	2.09×10^{-6}	(1.55×10^{-4}) 1.48×10^{-4}	(2.0×10^{-5}) 2.65×10^{-5}	0.881	(4.4×10^{-2}) 4.63×10^{-2}
73TEX191	512- 513	4	Texas City	271.	7.00×10^{-7}	(1.05×10^{-4}) 1.12×10^{-4}	(2.2×10^{-5}) 2.53×10^{-5}	0.565	(2.2×10^{-2}) 2.05×10^{-2}
73TEX192	619- 620	5	Texas City	306.	2.77×10^{-7}	(5.4×10^{-5}) 5.69×10^{-5}	(3.3×10^{-5}) 3.40×10^{-5}	0.701	(1.7×10^{-2}) 1.60×10^{-2}
73TEX193	700- 701	6	Texas City	342.	1.76×10^{-7}	(1.1×10^{-4}) 1.22×10^{-4}	(2.1×10^{-5}) 2.20×10^{-5}	0.501	(5.2×10^{-3}) 4.73×10^{-3}
73TEX194	978- 979	1	Seabrook	507.	(2.10×10^{-7}) 1.72×10^{-7}	4.04×10^{-5}	(5.7×10^{-6}) 6.33×10^{-6}	0.323	(1.7×10^{-2}) 1.40×10^{-2}
73TEX195	1022-1023	2	Seabrook	512.	3.98×10^{-6}	5.39×10^{-5}	(3.3×10^{-6}) 3.68×10^{-6}	0.525	2.42×10^{-1}
73TEX196	1058-1059	3	Seabrook	527.	(5.55×10^{-7}) 5.47×10^{-7}	(2.45×10^{-5}) 2.61×10^{-5}	(4.4×10^{-6}) 4.68×10^{-6}	0.456	(7.4×10^{-2}) 6.88×10^{-2}
73TEX197	1249-1250	4	Seabrook	611.	3.66×10^{-7}	(1.15×10^{-4})? 1.10×10^{-4}	1.11×10^{-6}	(.75) 0.763	(1.0×10^{-2}) 1.09×10^{-2}
73TEX198	1339-1340	5	Seabrook	650.	(2.36×10^{-7}) 2.32×10^{-7}	(2.55×10^{-5}) 1.96×10^{-5}	(2.8×10^{-6}) 2.86×10^{-6}	(.42) 0.410	(3.0×10^{-2}) 3.88×10^{-2}



*For water at 20°C

To convert from cm/sec to:	m/min	μ/sec	ft/sec	ft/min	ft/yr	cm²*	Darcy*
Multiply by:	0.600	10^4	0.0328	1.968	1.034×10^6	1.031×10^{-5}	1.045×10^3

Fig. 19.6 Permeability conversion chart.