Wyoming Mineral Corporation

Exploration and Mining Division

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Division of Fuel Cycle & Material Safety
Washington, D.C. 20555

Attention: Mr. L. C. Rouse, Chief
Fuel Processing & Fabrication Branch

Subject: Revised Environmental Report, Docket 40-8502

Gentlemen:

The Wyoming Mineral Corporation transmitted to the Nuclear Regulatory Commission in January, 1976 an application for a license to receive, possess, use and transfer source material in the course of production-scaled uranium solution mining activities. That application was accompanied and supported by an Environmental Survey. Subsequent to the docketing of the application, dialogue, meetings and written communications with the NRC resulted in certain modifications regarding the Environmental Survey.

As suggested by the NRC, for the convenience of additional reviewers of the Environmental Survey, WMC has incorporated all amplifications and clarifications regarding the original Environmental Survey into a revised and retitled environmental report. Accordingly, pursuant to the intent of amended 10 CFR 51.40 which is effective August 4, 1977, transmitted herewith are fifteen (15) copies of our revised document which is titled "Environmental Report, Irigaray Project, Johnson County, Wyoming". We are retaining an additional eighty-five (85) copies for distribution to Federal, State and local officials as you direct.

We await your written instructions.

Sincerely,

W.A. Eisenbarth
Licensing Manager

WAE:BF

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ENVIRONMENTAL REPORT

IRIGARAY PROJECT
JOHNSON COUNTY, WYOMING

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ENVIRONMENTAL REPORT

IRIGARAY PROJECT

JOHNSON COUNTY, WYOMING

WYOMING MINERAL CORPORATION
LAKEWOOD, COLORADO

Wyoming Mineral Corporation

Exploration and Mining Division

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W A Eisenbarth

W. A. Eisenbarth
Licensing Manager

WAE:cs

ACKNOWLEDGEMENTS

This report was prepared by personnel of the Wyoming Mineral Corporation with the assistance of other Westinghouse Electric personnal and consultants. The following listing does not identify the Wyoming Mineral Corporation or Westinghouse personnel who participated as principal investigators or contributors since the list is too lengthy to properly include here. The efforts of these people, however, are greatly appreciated.

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SECTION 1.0

INTRODUCTION

1.1 THE APPLICANT

Wyoming Mineral Corporation (WMC), a wholly owned subsidiary of the Westinghouse Electric Corporation has been granted a license by the U.S. Nuclear Regulatory Commission to possess source material for insitu, solution mining test purposes (R & D program) in five separate areas in the states of Wyoming and South Dakota (SUA-1204). Testing operations at one such property, the Irigaray lease in Johnson County, Wyoming, have demonstrated that this property may be mined productively for uranium by using a solution mining extraction technique. Accordingly, WMC is requesting a full-production source-material license. This Environmental Report is submitted in support of that license application.

1.2 BACKGROUND

In 1967, the Wyoming Mineral Corporation was in partnership with Homestake Mining Company to explore for uranium. In 1974 the partnership ended and WMC initiated programs to develop the technique of solution mining for uranium recovery. In the following years test facilities were established first in Texas and Wyoming and in 1976 in Colorado. The Texas facilities evolved from test scale to production scaled operations at two locations; the Bruni plant near Bruni, Texas (250,000 lbs

U_3O_8/ year capacity) and the Lamprecht plant near Ray Point, Texas (500,000 lbs U_3O_8/year capacity). These two Texas facilities are expected to be operating at capacity in 1977.

It is on the basis of the experiences gained from the Texas operating facilities, the Wyoming test facilities and to a limited degree, the Colorado test facilities that WMC proposes the production activities as described in this Environmental Report.

SECTION 2.0

PROPOSED ACTIVITIES

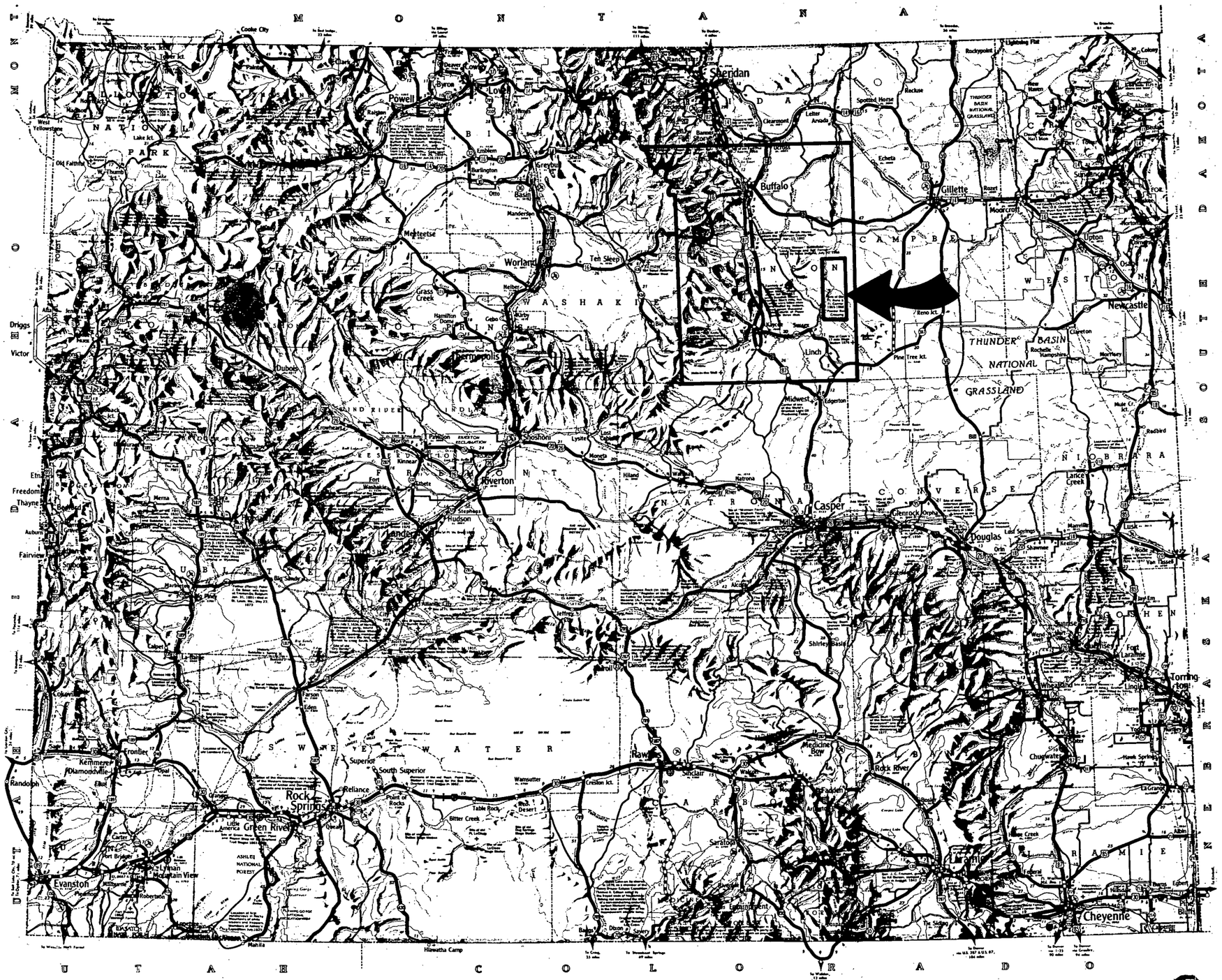
2.1 INTRODUCTION TO THE PROCESS

2.1.1 GENERAL

Wyoming Mineral Corporation proposes production-scale solution mining of uranium on the Irigaray Property in Johnson County, Wyoming, approximately 10 miles northeast of Sussex, Wyoming, (Figure 2-1). Operations within this area will affect approximately 1,000 acres of land within a lease and claim area of approximately 21,100 acres. Only one permanent dwelling lies within this mineral holdings area.

At the north end of the Property near the Irigaray Ranch, access to the lease property is limited to light-duty bridge which crosses the Powder River. Graded roads presently extend to the south and west boundaries of the property.

A second plant (or an expansion of the first) may be required at the Irigaray site since 500,000 lbs. per year is considered the minimum economical capacity of the project. Further, to mine the ore body at an efficient rate, a third and fourth plant may also be required if additional reserves of ore are discovered. Each additional plant is expected to mine on the average 25 - 50 acres per year.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Bitter Creek
Wamsutter
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Mahila
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Frontier
Diamondville
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Several extraction plants are planned, the first of which is scheduled for construction in the first quarter of 1978. The first production plant is proposed to be a 500,000 lb./yr. production module on a 5-acre site and will utilize production/injection wells covering approximately a 25 - 50 acre fenced production field per year. The solution mining technique leaches uranium ore insitu. Using the mineralized zone groundwater, reagents are added to reverse the natural uranium precipitation process. The resulting solution uranium bearing liquor is pumped from the mineralized zone to the processing plant to recover the uranium. After treatment, the injection solution is returned to the mineralized zone to recover additional uranium values. Each solution mining plant will be designed to produce up to 500,000 pounds of uranium concentrates per year, but flow rates, number of wells, and affected acreage will vary on a yearly basis since the production capacity of a plant is dependent on heads grade presented to the plant. Plant flow rates could range from 400 to 1600 gpm and well fields could vary in size from 200 to 1000 wells to maintain scheduled production.

Five to ten years is the normal life expectancy of a plant. Where possible, existing facilities and equipment will be moved to new locations while the decommissioned plant site is being reclaimed.

2.1.2 PROCESS COMPONENTS

The solution mining process consists of six major components: 1) the ore body; 2) well field; 3) lixiviant; 4) uranium recovery process; 5) waste treatment processes; and 6) aquifer restoration process. A brief discussion

of each is contained in the balance of this section.

2.1.2.1 THE ORE BODY

In general, uranium deposits amenable to solution mining are associated with relatively shallow aquifers (500 ft. subsurface) confined by non-porous shale or mud stone layers. Uranium was transported to this present location as soluble anionic complexes by the natural movement of oxygenated groundwaters. Uranium deposition occurred in areas where groundwater conditions changed from oxidizing to reducing. This produced a roll front deposit with uranium concentrated at the interface between the oxidized and reduced sandstones (Figure 2-2). This interface is commonally called the redox interface.

2.1.2.2 WELL FIELD

The well field provides the means by which leach solution (lixiviant) is circulated through the ore body to recover uranium. Thus, well field design determines the effectiveness of lixiviant circulation, confinement, and utilization. The principal considerations are: well spacing, injection/production well pattern, well completion method and number of wells (Figure 2-2 to 2-4). Well spacing is determined by the hydrologic characteristic of the formation which limit the rate and efficiency of lixiviant circulation. The injection/production well pattern is determined by the injectivity rates of the formation and the hydraulic sweep efficiency through the mineralized zone. The well completion method used determines the vertical confinement and vertical sweep efficiency of the lixiviant

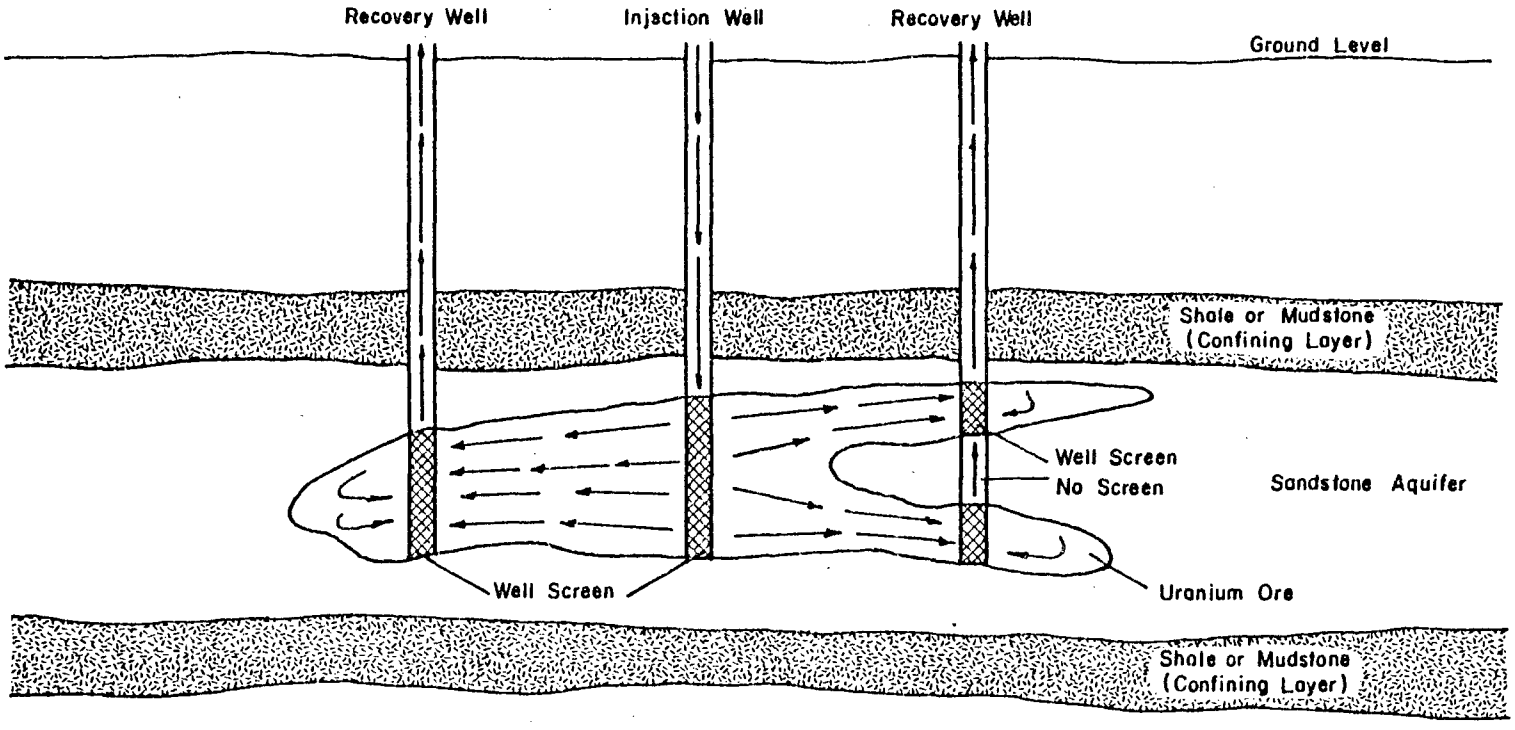


FIGURE 2-2: VERTICAL CROSS SECTION OF TYPICAL URANIUM ROLL FRONT DEPOSIT

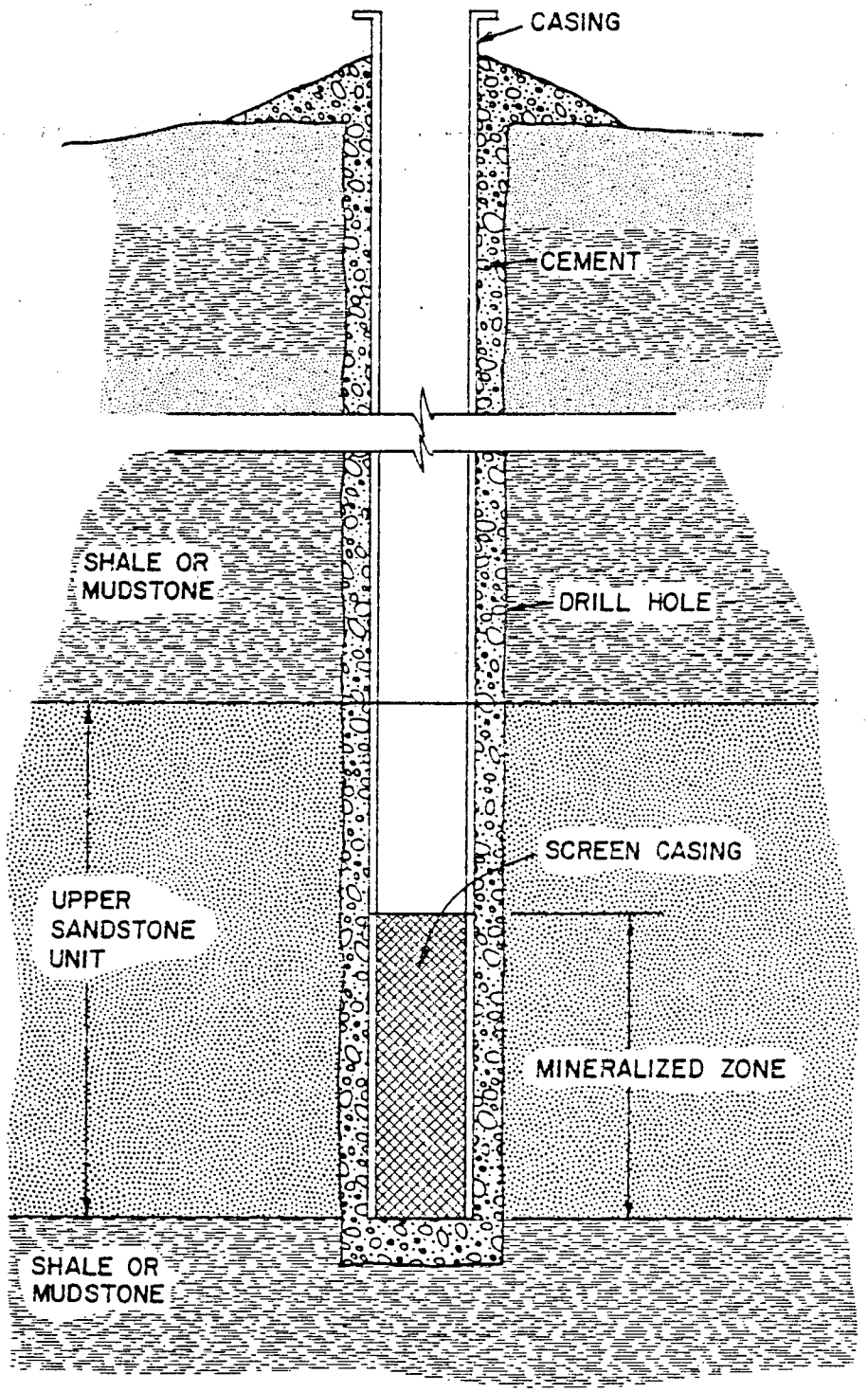


FIGURE 2-3: SOLUTION MINING WELL CONSTRUCTION DIAGRAM

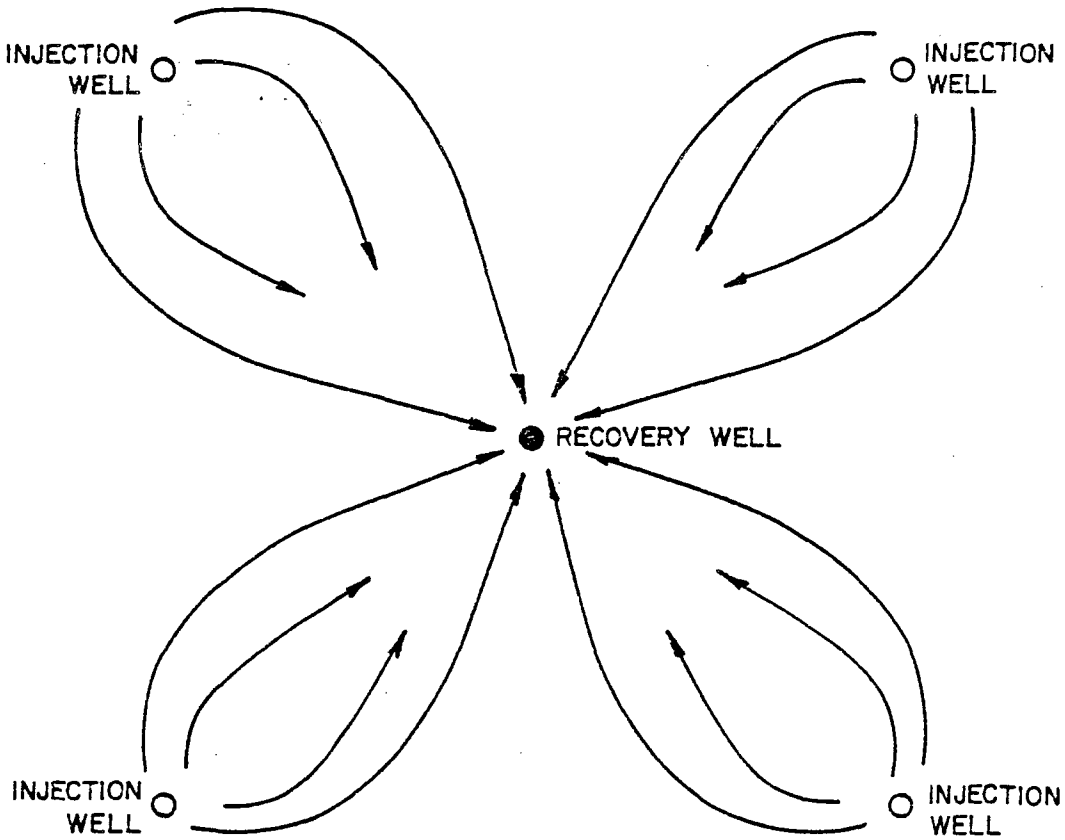


FIGURE 2-4: INDIVIDUAL PRODUCTION CELL FLOW PATTERN

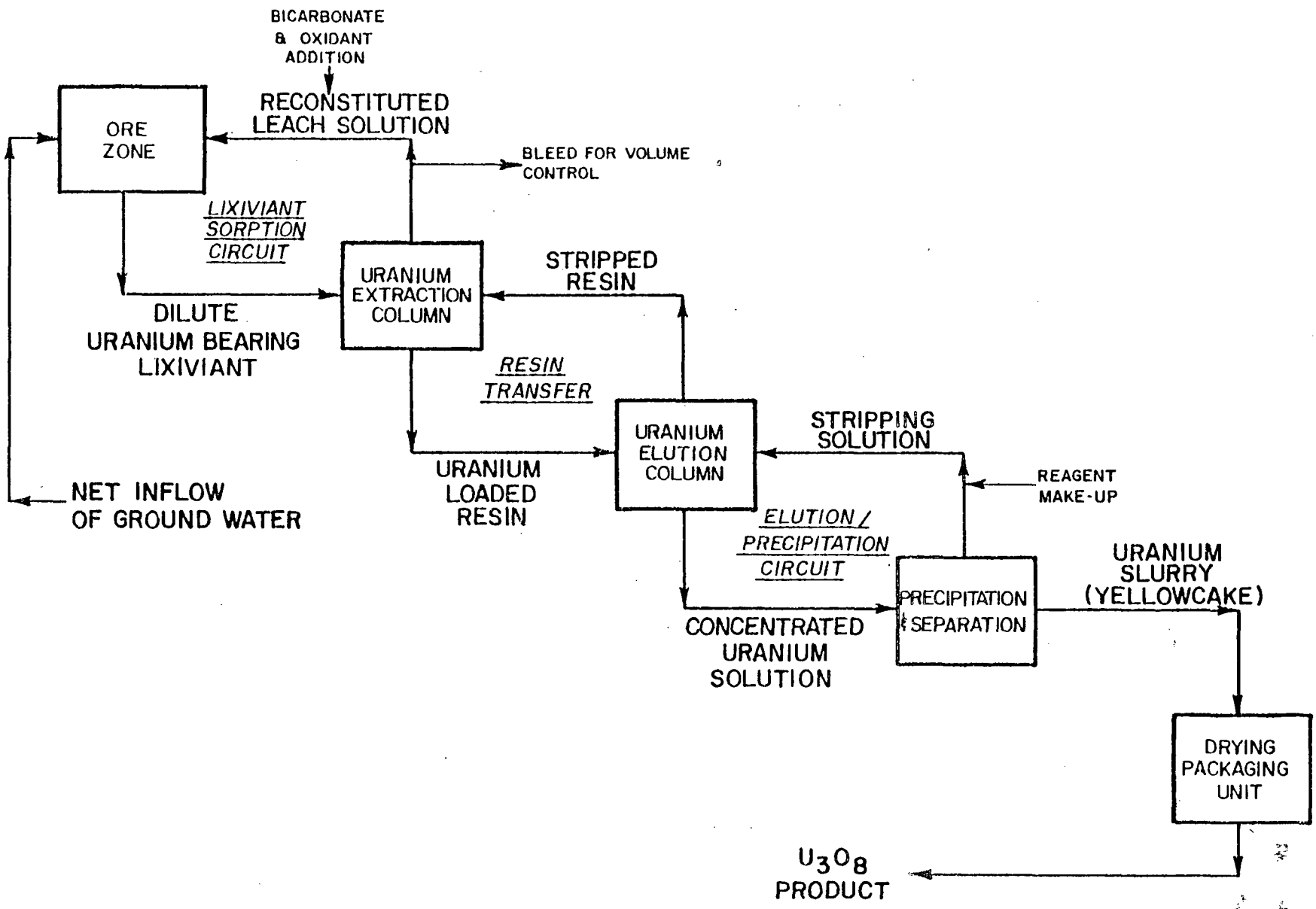
through the mineralized zone. Finally, the number of injection and production wells comprising a well field is established by the rate of mining and the geohydrologic characteristics of the aquifer.

2.1.2.3 LIXIVIANT

The lixiviant reverses the chemical conditions which led to uranium deposition and thus solubilizes uranium as it is circulated through the mineralized formation. It consists of groundwater fortified with an oxidant, and an anionic complexing agent. The oxidant converts uranium from the $^{+}4$ (reduced) to the $^{+}6$ (oxidized) valence state, making it amenable to complexation and solubilization. Typically, in alkaline leach solution mining a lixiviant composition of: 0.25 to 1.0 grams per litre (gpl) H_2O_2 and 1.0 to 5.0 gpl HCO_3 at a solution pH 7.5 to 8.5 is used.

2.1.2.4 URANIUM RECOVERY PROCESS

The uranium recovery process consists of three process circuits as depicted in Figure 2-5: a) lixiviant/sorption circuit, b) elution/precipitation circuit, and c) product drying/packaging unit. In the lixiviant/sorption circuit uranium is extracted from the recovered lixiviant. The lixiviant is then refortified and reinjected into the mineralized formation. Some provision for calcium control may also be incorporated to reduce the potential for calcium carbonate precipitation in the fortified lixiviant. The lixiviant/sorption circuit and elution/precipitation



WYOMING MINERAL CORPORATION	SOLUTION MINING PROCESS	DWN: N. Young	6/17/77	FIGURE 2-5	REV.
		CHKD:			
		SCALE:		SHEET OF	

circuits are interconnected by means of a resin transfer system only. In the elution/precipitation circuit uranium is chemically stripped from the resin and precipitated from solution. The uranium precipitate is then conveyed to the product drying/packaging unit where it is processed to obtain the final U_3O_8 product. The uranium free supernate is refortified and recycled through the elution/precipitation circuit.

2.1.2.5 WASTE TREATMENT PROCESSES

Liquid wastes are generated from three principal sources: a) well field over-pumping (i.e., production > injection) for the purpose of lixiviant confinement, b) process bleeds for the purpose of contaminant control and c) water treatment for the purpose of aquifer restoration. Over-pumped solution in part is utilized as make-up for process bleeds (i.e., to maintain process inventory). Over-pumping in excess of this amount will be impounded for waste concentration and water reclamation via reverse osmosis treatment or its equivalent. (See Section 9.1). A similar approach will be utilized to minimize consumptive water use during aquifer restoration. Concentrated waste streams of approximately 15,000 parts per million (ppm) of total dissolved solids (TDS) will be impounded and further concentrated by means of either natural or induced evaporation.

The principal sources of air emissions are the open surfaces of tanks (including waste ponds) and the product drying/packaging unit of the uranium recovery process. Process components will be covered to reduce air emissions, thus waste storage ponds are the principal source of

process emissions. Both particulate and gaseous emissions utilize spent resin wash water as the scrub solution. The spent scrub solution is impounded with other process wastes for further concentration via evaporation.

Most of the solid wastes are generated by the calcium control unit. (Alternative contaminant control methods, under evaluation, may be a source of additional solid wastes in the future). Solid wastes will be impounded and maintained under a liquid seal to minimize atmospheric dispersion, pending identification of permanent disposal methods. Waste disposal is discussed in Section 4.4.

2.1.2.6 AQUIFER RESTORATION PROCESS

After completion of mining, treatment methods will be implemented to restore water quality within the affected aquifer. The water quality which will be re-established, will be a function of pre-mining groundwater quality in the affected area and the use of the best known practical technology available. To accomplish aquifer restoration, it will be necessary to remove the soluble species and/or immobilize chemical species sorbed on the host solids during insitu mining. Additionally, it is desirable to process the removed water to concentrate the contained contaminants and recover a clean water fraction for reinjection into the original formation.

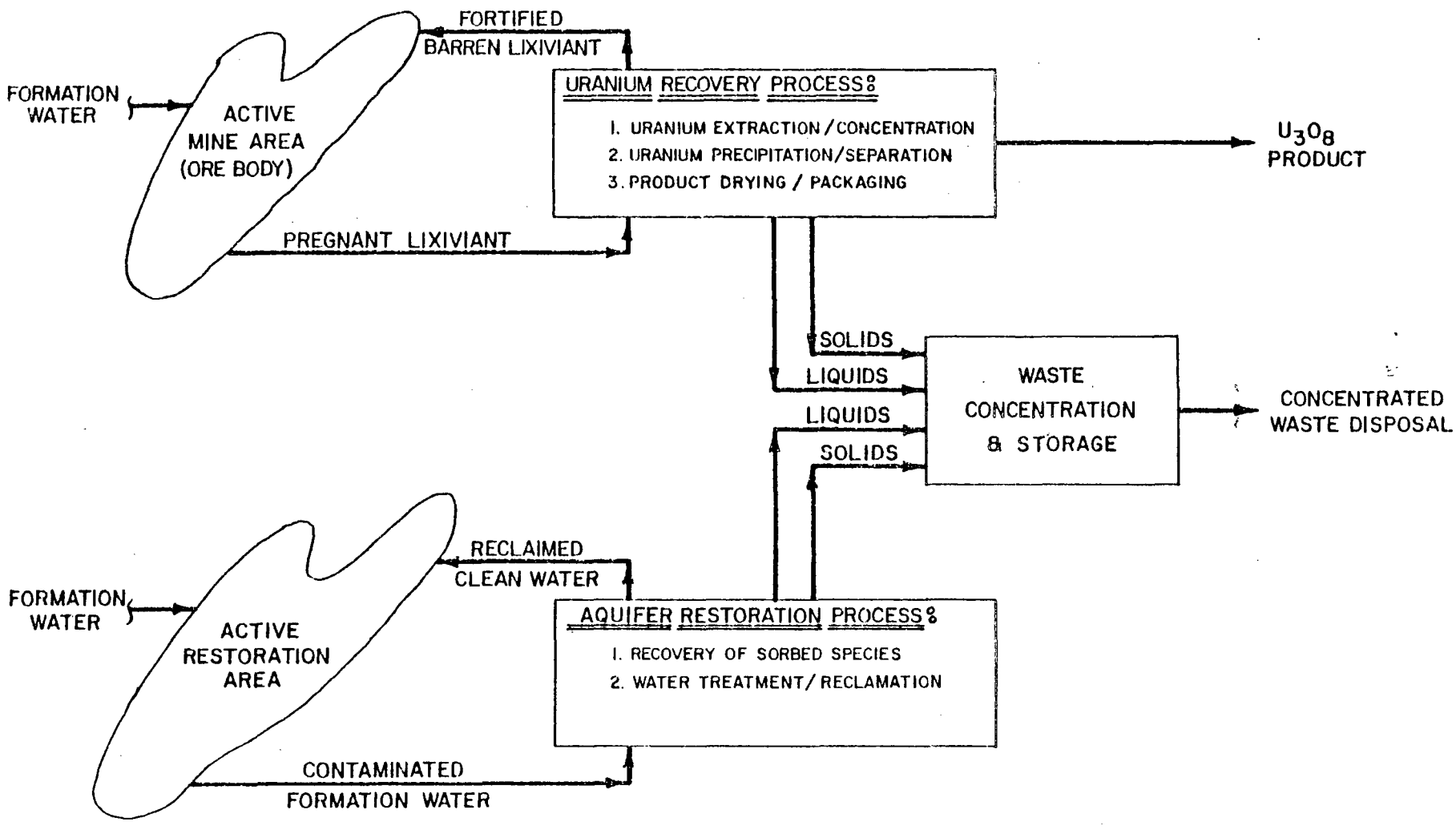
Development and field evaluation of restoration methods and processes are currently in progress at the proposed site. Restoration alternatives are

discussed in Section 9.0. Test results from other WMC solution mining operations are summarized in Appendix A.

The initial phase of restoration would involve selective contaminant removal from the recovered water via a combination of chemical precipitation and/or reverse osmosis treatment. The objective of this initial phase would be desorption and extraction or isolation of chemical species (principally NH_4^+) sorbed on the host solids during insitu mining. This may involve addition of a suitable eluting agent to the reinjected solution to improve the rate and/or extent of desorption. During the second phase of restoration the recovered water would be treated to reduce its total dissolved solids and trace metal content via reverse osmosis or an equivalent treatment process. The resultant concentrate fraction (10 to 20 percent) would be impounded and the clean water fraction (80 to 90 percent) may be returned to the mined aquifer.

2.1.3 RELATIONSHIP OF PROCESS COMPONENTS

The interrelationship of the major process components, described in the previous section is illustrated schematically in Figure 2-6. The rate of uranium recovery from any given mining area is dependent on characteristics of the ore body such as ore grade, permeability, localized concentration and the associated mineralogy. It is, therefore, not possible to accurately predict the time over which an area is completely mined out.



WYOMING MINERAL CORPORATION	RELATIONSHIP OF MAJOR PROCESS COMPONENTS	DWN: N. Young	6-23-77	FIGURE 2-6	REV.
		CHKD:			
		SCALE:		SHEET OF	

The criteria for when restoration should begin is dependent on the extent to which the mining is completed in a mine field. WMC may choose to operate certain smaller sections of any well field if, at the end of the useful life of the mine, these sections still show productive levels of uranium concentration. WMC will confine the leach solutions in the mined areas until the entire well field has been depleted. At that time restoration will be initiated and may proceed along the roll front following the mining operation. The procedure for such simultaneous mining and restoration operations is described in Section 9. In general, the procedure calls for restoration in a mined out area to be accomplished simultaneously to mining in a new area. A buffer zone between the two operations is necessary to assure that no hydrological interference will exist between the two operations.

2.2 ORE BODY CHARACTERISTICS

2.2.1 MINEROLOGY AND GEOCHEMISTRY

Roll type uranium mineralization at the Irigaray site is present in fluvial channel sands in the "Upper" and "Lower" sandstone units of the Wasatch formation. The "Upper" unit is the largest and most economically important. The channel sands trend to the north, which is also the direction of the regional dip and hydrologic gradient. The host environment of the upper unit consists of arkosic, fine to coarse grained, poorly sorted sands. The mineralization has been

stratigraphically confined by persistent layers of shales or mudstones. The top of mineralization is typically about 200 feet below the surface and the host averages near 100 feet in thickness. The calcite content of the host ranges from 1 to 3 percent, substantially lower than other WMC deposits.

Mineralization occurs along the margins of a large tongue of sand altered by oxidizing groundwater flow. This tongue measures some three miles in width near the center of the WMC property and extends from the southern boundary for a strike length of ten miles. Uranium deposition as uraninite and coffinite occurred where the groundwater encountered reducing conditions. Uranium is localized at the interface (roll front) between the oxidized and reduced sandstone. The oxidized zone is difficult to distinguish from the reduced zone; the sandstone on the oxidized side has a tan to yellowish green bleached color whereas the reduced portion is characterized by a gray color. Lack of strong red and brown coloration in oxidized material is due to the generally low pyrite content (less than 0.5 percent).

Tests of core samples indicate that porosity of the host sand ranges from 20 to 35 percent. The horizontal permeability ranges from 600 to 800 millidarcy whereas the vertical permeability averages between 400 and 600 millidarcy.

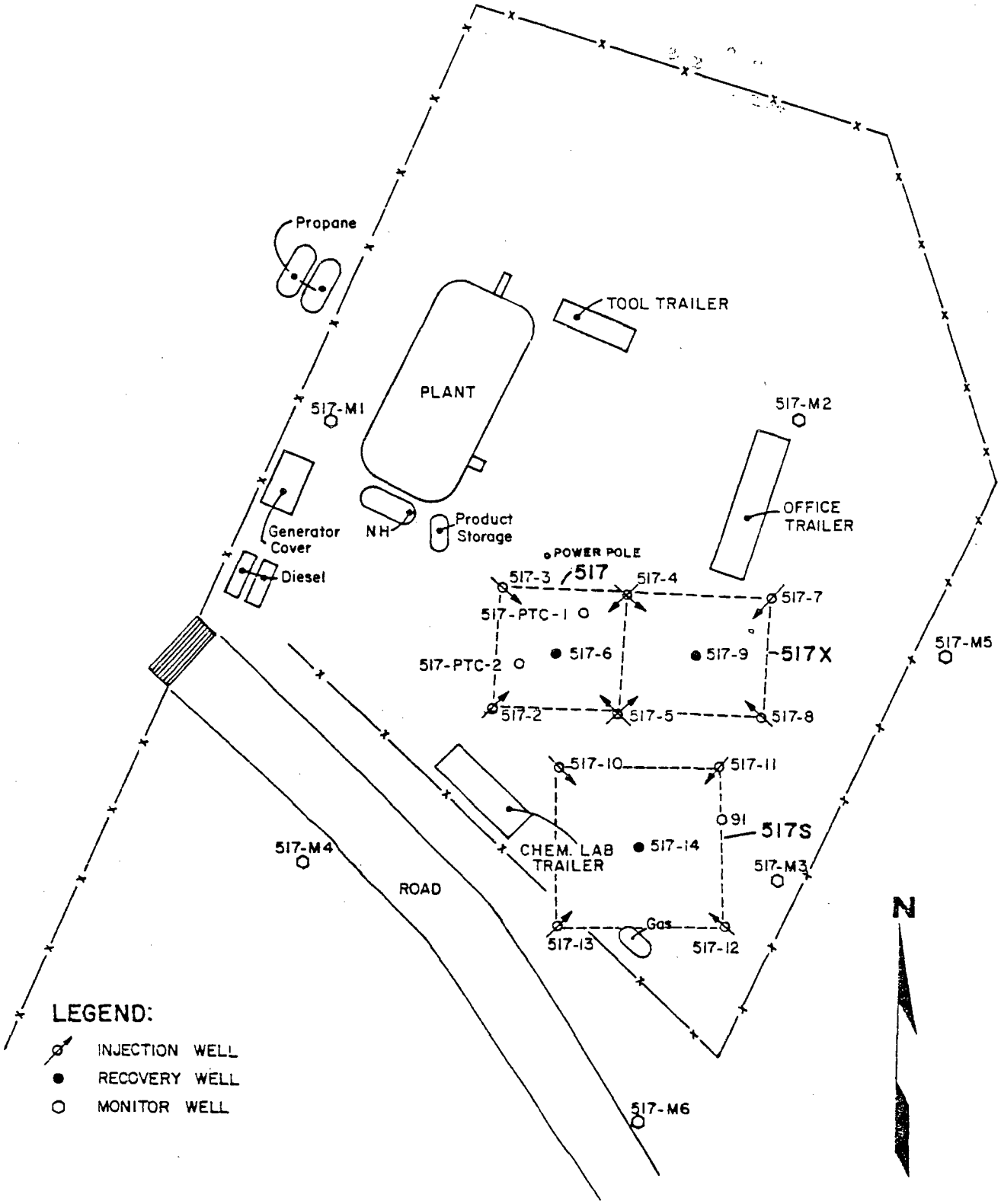
2.2.2 AMENABILITY TO INSITU MINING

Test work has been performed on the Irigaray deposit to determine amenability

and feasibility of recovering uranium by solution mining techniques. During the course of testing, data was collected on: 1) solution circulation rates as a function of well spacing, completion methods, and lixiviant composition; 2) produced solution characteristics as a function of lixiviant composition, and 3) sustained well field and process plant operation.

The first test period lasted for eleven months, beginning in November, 1975, and continuing until October, 1976. During this period, testing was conducted on three adjoining test patterns, designated 5I7 and 5I7X and 5I7S (see Figure 2-7).

All three of these test phases utilized a five-spot well pattern, with four injection wells symmetrically located about a central recovery well. The injection to recovery well spacing and well completion method were varied in each test phase. At each test pattern, an initial leach period of 75 to 100 days duration was followed by the cecession of chemical additions and circulation of residual lixiviant for approximately 20 days. During initial testing, various lixiviant compositions and concentrations were evaluated. Lixiviant circulation was continued without chemical addition during the second stage of testing to recover mobilized residual uranium. Results from the 5I7 test are shown in Table 2-1. The test data to date suggests that the well spacing (injection to production) best suited for the Irigaray deposit is near 40 feet. Because of limited injection flows and economic considerations, the adopted well configuration for the proposed plant and probably for future Irigaray mine sites is the seven spot pattern, i.e.; six injection wells arround a central recovery well.



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517 IRIGARY TEST LAYOUT JOHNSON COUNTY, WYOMING	DWN: JRV	6/29/76	FIGURE 2-7	REV BTP 3/22/77
	CHKD: AMB			
	SCALE: 1" = 50'		SHEET OF	

TABLE 2-1
RESULTS FROM 5I7 TEST

Test	Surface Area Test Site (ft^2)	Duration of Test (Days)	Approximate % U_3O_8 Recovered
5I7	1600	107	35%
5I7-X	2000	104	50%
5I7-S	3250	94	30% (approx)

Based on results from the 5I7 test, a pilot plant test is being performed to develop design criteria for a full-scale solution mining plant.

2.2.3 MINERALOGICAL CONDITIONS AND CHANGES INDUCED BY INSITU LEACH

2.2.3.1 MINERALOGICAL CONDITIONS

Mineralogical conditions of the host zone that must specifically be considered in the mining process are as follows:

1. In the sequence of uranium ore deposition, uranium is solubilized from a source area by slightly oxidized groundwater, transported in solution, and subsequently deposited as uraninite or coffinite as it interfaces with a reducing environment.
2. Vanadium is only slightly more concentrated in the mineralized zone (at the oxidized/reduced zone interface) as compared to the oxidized zone. It is transported as the anionic complex $(V_{10}O_{28})^{-6}$ in which vanadium is in the +5 valance.
3. The distribution pattern of arsenic is irregular but is generally more concentrated in the oxidized zone. This element is transported as the arsenate ion $(As\ O_4)^{-3}$.
4. Selenium is concentrated in the oxidized zone with uranium in the mineralized zone near the oxidation-reduction contact. This element is carried as $(Se\ O_3)^{-2}$ and deposited as native selenium or selenites.
5. Barium shows a tendancy to concentrate in the oxidized zone as opposed to the reduced or mineralized zones and is found in the form of barite, $BaSO_4$.
6. Iron content is equal in all zones.

2.2.3.2 POSSIBLE CHANGES

Possible changes in the solution mining process can take place as follows:

1. Uraninite and coffinite become oxidized to U^{+6} and are complexed to a soluble carbonate complex that is removed by the leaching solution.

2. Pyrite is partially replaced by hydroxy-oxide gels (limonite) during leaching.

3. The leaching solution mobilizes the calcium in the underground host material.

4. The leaching solution mobilizes selenium from the leached sands through the formation of the soluble ammonium selenate. Thus some of the mobilized selenium is removed from the ore zone.

5. Ammonia is retained in the leached zone as evidenced by post-test coring. Retention is through absorption and/or ion exchange of ammonium ions with alkali metal ions associated with the montmorillonite clay fraction of the sand matrix. Ammonia introduced into the aquifer via the leach solution could become oxidized to nitrite (NO_2^-) or nitrate ($NO_3^=$) ions.

6. Small amounts of radium from the host are mobilized during the leaching process.

In an ammonium bicarbonate system, 1.5 to 3.0 percent of the Ra 226 contained in the ore could be solubilized. This compares to .25 to .70 percent dissolution in an acid leach liquor. It will be noted that the relative abundance of Ra 226 mobilized in acidic and basic leach liquor during bench tests with mineralized core samples cited above are consistent with the ranges quoted by Merritt [1].

Range cited by Merritt:	$\frac{\text{Ra 226 in Basic Leach Soln.}}{\text{Ra 226 in Acidic Leach Soln.}}$	$\frac{2.25 + .75}{0.50 \pm .25}$	4.5
Observed ratio:	$\frac{\text{Ra 226 in Basic Leach Soln.}}{\text{Ra 226 in Acidic Leach Soln.}}$	$\frac{1750}{390}$	4.49

Based on data from WMC Texas operations, the feed and discharge conditions in Table 2-2 are typical of the Calcium precipitation process employed.

TABLE 2-2
FEED AND DISCHARGE COMPOSITIONS
TYPICAL OF CALCIUM PRECIPITATION PROCESS

	U_3O_8	Ca	Ra
Feed Composition	80 ± 5 ppm	189 ± 20 ppm	500 pCi/L
Discharged Supernatant	74 ± 5 ppm	11 ± 5 ppm	15 pCi/l
Discharged Precipitate	.010g/g $CaCO_3$	0.400 g/g $CaCO_3$	800pCi/g $CaCO_3$

Based on the recovered solution composition, it will be noted that the Ra 226/U ratio is 7,358 PCi of Ra 226/g U. If Ra 226 and U were in equilibrium in the mineralized host material, the Ra 226/U ratio would be 333,000 pCi of Ra 226/g U, which would imply that 2.2% of the contained Ra 226 in the mineralized host is solubilized by the lixiviant. The latter agrees well with the range cited by Merritt.[1]

2.3 WELL FIELD

2.3.1 DESCRIPTION

In the recovery of most mineral reserves, a "mine" is a relatively large surface excavation. In solution mining, the "mine" is a relatively small geographic area in which injection and production wells have been installed. This is called a "well field." A typical well field pattern in shown in Figure 2-8.

The well field is an array of wells designed to permit controlled lixiviant contact with the ore bearing strata beneath the ground. The wells are either injection wells through which the lixiviant is introduced to the ore or recovery wells from which the uranium-bearing liquor is produced. The field is usually installed in a regular geometric pattern but irregularities occur at the edges of the orebody.

The goals in the operation of a well field are as follows:

1. Confine solution flow to the well field cell.

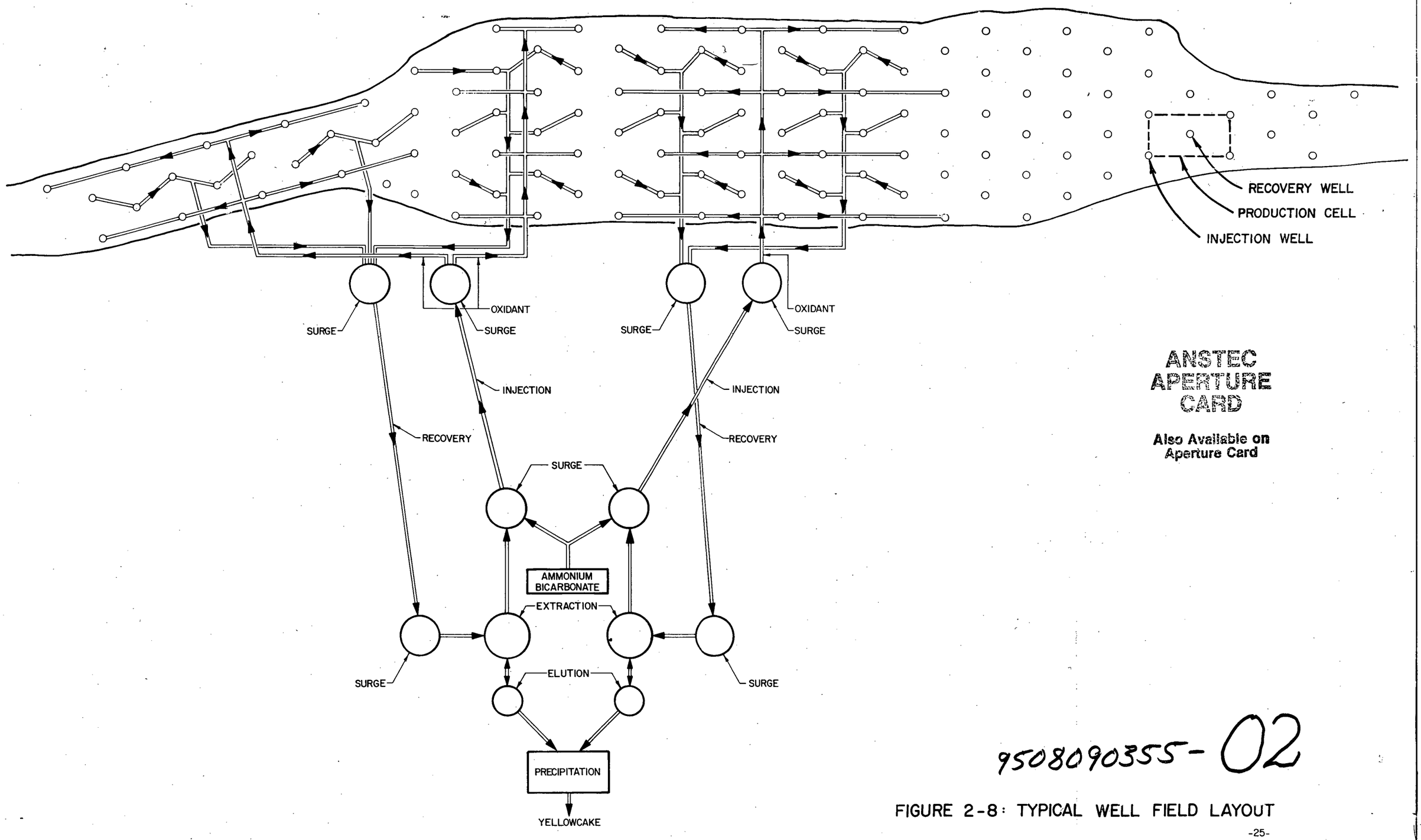

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FIGURE 2-8: TYPICAL WELL FIELD LAYOUT

2. Extract the maximum amount of uranium from a given well field cell.

3. Produce the uranium with a minimum amount of solution throughput, i.e., at the highest recovery solution grade.

4. Accomplish 1 & 2 with a minimum capital and operating cost.

2.3.2 WELL FIELD INSTALLATION

Within the limits of uranium mineralization, physical and geochemical characteristics are used to determine which portions of the ore body are mineable. These characteristics include uranium ore grade, equilibrium, permeability, porosity, and leachability. A number of drill holes are cored through the mineralized zone. The core is logged in detail and sampled for subsequent laboratory analysis to determine chemical U_3O_8, ratio of uranium to daughter products, permeability, porosity, and the various minerals and compounds. The data generated from core analysis, the ore grade calculated from the drill hole logs (factored for equilibrium conditions), physical properties observed during core logging, leach studies, and cost data, are used to determine the approximate mineable limits of the orebody.

The mineable ore body thus determined can then be divided into mining units which are subsequently divided into well fields which themselves are further divided into production cells. At Irigaray, the initial mining unit covers approximately two and one-half miles of the mineralized Upper Irigaray Sandstone (UISS) trend in Sections 4, 5, 9 and 16 of T45N, R77W. (See Figure 3.1). The analyses of close-spaced

drilling data established the reserves and will enable well fields to be installed with little additional development drilling. Subsequent development drilling programs then outline mining units to support successive extraction plants.

After the mining units are defined, a well field development plan is designed for a specific mining unit. The initial well fields are positioned on the best and most completely drilled portion of the mining unit. The well fields at Irigary will be designed to support approximately 125,000 lb. per year production each and will contain 10 to 15 cells. A total of 4 to 6 well fields will be utilized at any one time in a mining unit to maintain an annual production of 500,000 lbs. At Irigaray the injection rate is the main limiting factor in the determination of the number of wells per cell necessary to reach a specified plant capacity. The amount of U_3O_8 contained within a well field does not influence its recovery rate but only gives an indication of the length of time a well field can be mined.

The grouping of a production well and its contributing injection wells into a pattern describes the uranium production cell. As indicated above, a requisite number of cells comprise a well field. The type of pattern and the spacing of the wells is based on well completion costs, permeability, injection/recovery flow rates, and lixiviant/ore contact efficiency. As discussed earlier at Irigaray, the well spacing (injection to recovery) to be used initially is about 40 feet since this has been determined to be the longest spacing which can be used with confidence. Because of limited injection flows and economic considerations, the

adopted well configuration is the seven spot pattern, i.e., six injection wells surround a central recovery well. Changes in spacing and pattern may be necessary, depending on operating experience.

The well field is drilled to "straddle" the roll front. Rows of injection wells are drilled across the roll front perpendicular to its strike from the center out until cutoff grade material is reached on either side as evidenced by gamma logging of these holes. In this way, the lateral extent of the mineable ore is better defined. As rows of injection wells are completed, the recovery wells can then be drilled and completed to recover solution from the intervals in which solution will be injected. As the well field drilling is completed, the vertical extent of the mineable ore is defined and a final estimate of mineable pounds U_3O_8 is made.

2.3.3 WELL COMPLETION

The underground movement of injected fluids is controlled horizontally by the integrity of over and underlying shale. Vertical control is exercised by well completion techniques. (Figure 2-3). Because of the structural stability of the UISS, no expensive well screen is necessary and the mineralized interval is often left open. This is accomplished by setting casing to the top of a designated interval and cementing the outer annulus to prevent upward migration of solutions. PVC casing is used since it is relatively inexpensive and resistant to leach solutions.

In an injection well, the open hole interval is limited to the ore zones encountered in the hole. However, in a recovery well, the hole is open to

intervals determined by the upper and lower interval limits of adjacent injection wells. During well installation, a geologist is present at all times to make necessary correlations using all available data for important decisions regarding intervals to be made available to leach solutions since this is the main factor affecting ultimate produced solution grade and operation success. As the recovered solution from the cells reaches an uneconomic solution grade, the cells are shut off and new cells are brought on line. This process is repeated until the well field is mined.

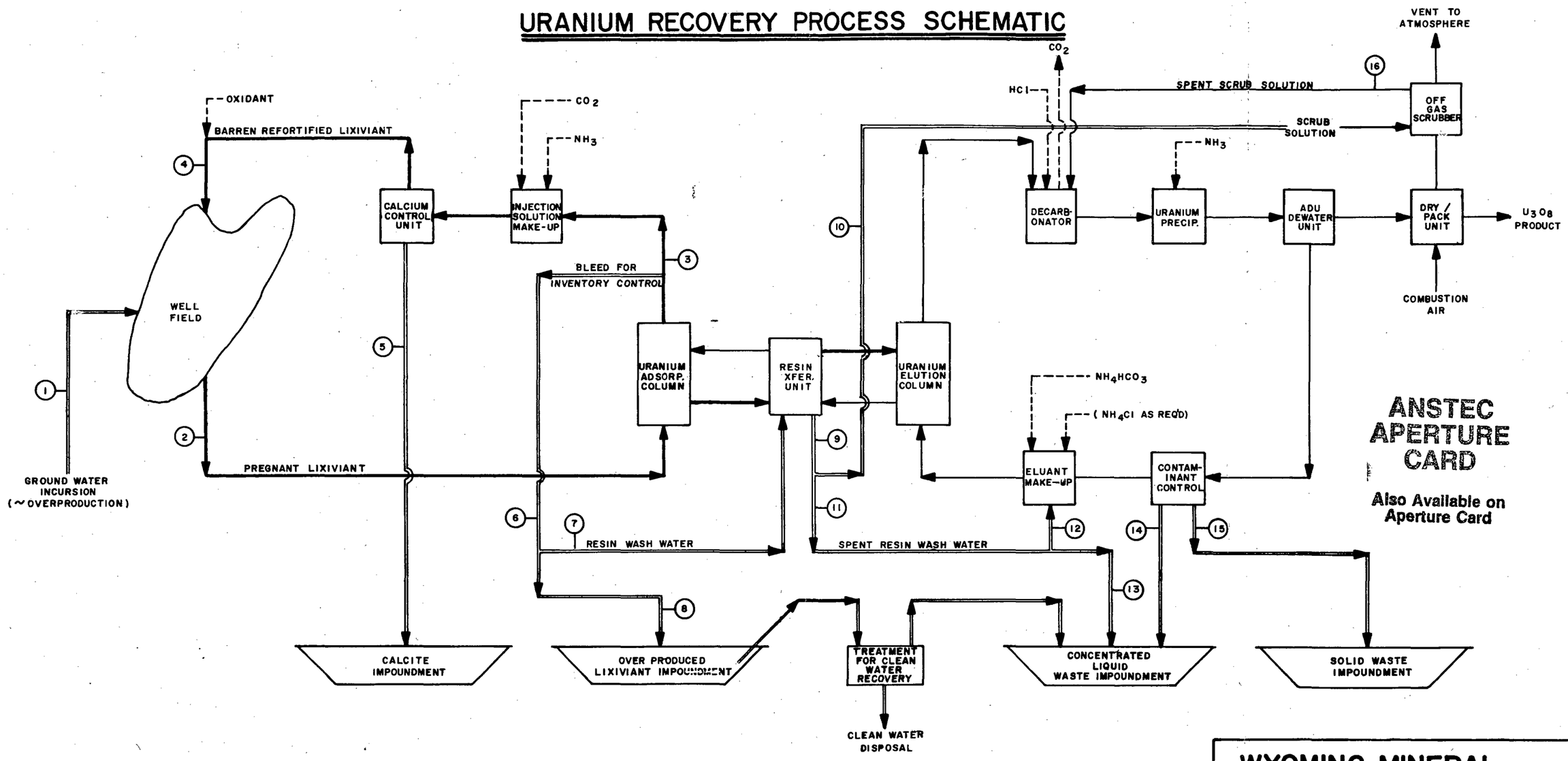
2.4 URANIUM RECOVERY PROCESS

The uranium recovery process consists of three process circuits: 1) lixiviant/sorption circuit, 2) elution precipitation circuit, and 3) product drying/packaging unit. The major process components comprising each process circuit and their function are depicted schematically in Figure 2-9. Table 2-3 indicates the principal locations and estimated magnitude of both chemical additions and process bleeds for the proposed 500,000 lbs/yr. installation.

2.4.1 PROCESS DESCRIPTION

In the lixiviant sorption circuit, uranium is stripped from the recovered lixiviant via an ion exchange process, employing a solid ion exchange resin. While the solution and resin are in contact, uranium ions are sorbed from solution by the resin, displacing anions (chloride) sorb on the resin during elution. The displaced anions (chloride) migrate in the opposite direction, i.e., from the resin into solution. The barren leach solution,

URANIUM RECOVERY PROCESS SCHEMATIC



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URANIUM RECOVERY PROCESS SCHEMATIC

DWN: J.D. Marcum	6/22/77	FIGURE 2-9	REV
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TABLE 2-3

ESTIMATED MAGNITUDE OF BOTH CHEMICAL ADDITION AND PROCESS BLEEDS FOR A 500,000 LBS/YR. INSTALLATION

Notes (Reference Figure 2-10 "Uranium Recovery Process"):

1) The calcium control unit may be incorporated in the process circuit either upstream or downstream (as depicted) of the uranium absorption column.

2) The proposed 500,000 lb/yr. Production Facility will consist of parallel 250,000 lb/yr. lixiviant/sorption circuits. A common Decarbonation/Precipitation circuit and Drying/Packaging Unit will service parallel Elution Columns.

3) Process components indicated in Dashed Outline are currently under evaluation and may be incorporated at a later date; but are not presently included in the planned facility.

4) Process Flows:

Stream No.	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16
Estimated Flow (gpm)	∿20	∿820	∿800	<800	<2.0	<18.0	<7.0	<11.0	<7.0	<2.0	<5.0	<3.5	<1.5	<3.0	<1.5	<1.0

Location	Injection Solution Make-up			Decarbonation/ Precipitation Circuit		Eluant Make-up		Dry/Pack Unit Scrubber		
Reagent	CO_2	NH_3	H_2O_2	HCl	NH_3	NH_4HCO_3	NH_4Cl	Fuel (Propane)	Cumbus-tion Air	Vent to Atmosphere
Estimated Use (lbs/hr)	75-225	40-120	75-250	25-70	5-20	35-100	75-200	20-60	< 6,700	< 7,250

leaving the ion exchange unit, is then refortified with hydrogen peroxide and ammonium bicarbonate and reinjected into the mineralized formation to repeat the leach cycle. Some provision for calcium control is generally incorporated since the recovered lixiviant is generally saturated with respect to calcium carbonate. Such provision may be either upstream or downstream of the ion exchange process for uranium removal and serves to reduce the potential for calcium carbonate precipitation in the fortified lixiviant.

Periodically a fixed quantity of uranium loaded resin is transferred from the sorption circuit to the elution circuit and a like quantity of eluted resin is transferred in the opposite direction. Thus, the resin transfer system and incorporated wash provisions limit chemical communication between the sorption and elution circuits.

In the elution/precipitation circuit the sorbed uranium complex is first stripped from the resin with an ammonium chloride eluant ($\sim$ 1 to 2 $\underline{M}$ NH_4Cl). While the solution and resin are in contact, the eluting anion (Cl^-) is sorbed from solution by the resin displacing the previously sorbed uranium complex. The elution process serves the dual purpose of stripping uranium from the resin and concentrating it in solution, i.e., the uranium concentration of the pregnant eluant is $\sim$ 40 to 60 times greater than that of the pregnant lixiviant. The pH of the pregnant eluant is then adjusted to $\sim$ 1.5 to 3 with hydrochloric acid to destroy residual carbonate species. Next the solution pH is adjusted between 5.0 and 8.0 with ammonia to precipitate the uranium present as ammonium diuranate. The resulting slurry is then separated into a uranium barren liquid fraction and a

uranium rich slurry fraction (∿ 20% solids content in a thickener). The liquid fraction is fortified with ammonium bicarbonate and ammonium chloride, if necessary, to restore the chloride ion strength (∿ 1 to 2M), then recycled through the elution/precipitation circuit.

2.4.2 WATER REQUIREMENTS/TREATMENT

It is estimated that approximately a 10 acre production field will be initially required to start the planned operation and that two (2) to three (3) such fields would be required each year to maintain production at 500,000 lbs/year.

Worst case estimates of the water volumes affected (contaminated portion and consumed portion) in a solution mining operation of this scale are summarized in (Table 2-4) along with the bases used in arriving at the estimates presented. The estimates presented are based on experience to date under normal conditions. It is noted that the largest volume of contaminated water generated by the solution mining process is the residual lixiviant left in the mined formation after mining is terminated prior to aquifer restoration. The consumptive use of water associated with aquifer restoration is strongly dependent on the type and extent of host/lixiviant interaction and the method of restoration. This subject is therefore independently addressed in Section 9.1.6.

The primary source of process effluent water (∿ 20 gpm) is associated with over production from the well field to insure lixiviant confinement within

TABLE 2-4
ESTIMATED VOLUMES OF PROCESS WASTES AND EFFLUENTS

Estimated Volumes of Process Wastes and Effluents (in acre feet/year) Associated with 500,000 lb/yr. Solution Mining Production Facility Excluding Aquifer Restoration

		Acre Feet Per Year
1.	Residual lixiviant left in the mined formation prior to commencement of aquifer restoration (Basis: 30 acres mined per year, with an average contained volume of 85,000 cu. ft. and a mean porosity of ∿ 25% plus a 33% contingency for flow expansion throughout the well field).	164.1
2.	Over production of the well field (Basis: 2.5% of design production rate of 500,000 lb/yr. facility.	32.2
3.	Well cleaning to maintain injection flows (Basis: 30 acres land on 7 spot configuration, 40 ft. spacings with 1500 gallons/well twice a month required to accomplish cleaning).	23.0
4.	Resin wash water for contaminant control (Basis: Field test data indicates a bleed of ∿ 7.0 gpm is required for control or ∿ 10.5 acre feet/yr.).	Included in Item 2
5.	Eluant bleed for contaminant control (Basis: Field test data indicates a bleed of ∿ 4.5 gpm will be required).	Included in Item 2
6.	Plant and well field sanitary water use (Basis: estimated consumption rate of ∿ 2,000 gpd)	2.1*
7.	Monitor well sampling (Basis: withdrawal of ∿ 200 gallons/well is necessary to obtain a representative sample and 50 wells sampled twice-monthly).	.9
	Total Affected Volume from Extraction Operations	72.5 acre feet per year
	Total Required Pond Capacity during Operations (Items 2, 3, 4, 5 and 7)	18.3 acre feet per year

*Goes to Sanitary Waste Field

the mine boundaries. In so far as possible this volume would be minimized by maintenance of balanced flow operation. The second major source of process effluent water (∿ 9 - 14 gpm) is associated with routine injection well cleaning to maintain necessary lixiviant flows. Present treatment to clean the injection well bore includes the withdrawal of ∿ 10 well bore volumes to remove residuals from the formation and well prior to resuming injection. Because of the waste volumes generated alternative well cleaning methods are being investigated and implemented as practical. The third and fourth major source of process effluent water are the spent resin wash water (∿ 7.0 gpm) and eluant circuit bleed (∿ 4.5 gpm) respectively. Alternative methods of contaminant control are under investigation in an effort to reduce both waste sources. It should be noted, however, that neither source represents a primary consumption of water unless over production from the well field can be maintained at less than ∿ 0.6 percent since over produced solution could be successively used for resin wash water and eluant make-up prior to being wasted. The remaining process water requirements (i.e., sanitary use and monitor well sampling) total approximately one gallon per minute.

The estimated worst case total process bleed from the planned solution mining operation would be 56.1 acre feet per year. As noted, this is exclusive of aquifer restoration and sanitary water treatment. This process waste water will be impounded in either lined or unlined ponds and concentrated via natural and/or induced evaporation. Total ponding requirements are independently discussed in Section 4.4.

2.4.3 AIR EMISSIONS

Air emissions from the proposed solution mining process originate from three principal sources: a) the uranium recovery process area, b) the calcium removal unit, and c) waste ponds utilized for both solid (calcite) and liquid waste storage. Generally the emissions from all three sources are the result of either natural or induced evaporative losses. To reduce losses to atmosphere within the uranium recovery process area, all process components are covered wherever practical and ventilation rates are maintained at levels necessary to insure safe working conditions. The principal air emissions are associated with two sources in the recovery process area: the calcium removal unit and the product drying/packaging unit. The drying/packaging unit air sources are of three types: 1) by-products of combustion (1.0×10^6 BTU product drying unit), 2) volatized solution residuals ($\sim$ .75 to 1.25 lbs. of barren eluant/lb. of ADU feed) and 3) U_3O_8 fines generated on product drying. The blended off gas is scrubbed with a high intensity venturi scrubber to remove contaminants prior to discharge to the atmosphere.

In serving the dual function of liquid waste storage and concentration, the waste storage ponds are a source of air emissions, primarily ammonia, carbon dioxide and ammonium chloride vapors. The mean composition of stored waste and the magnitude of air emissions will be determined by the equilibrium established between the prevailing evaporation rate, the feed rate and composition of solution being impounded. Particulate emissions from impoundment areas will be minimized via maintenance of a liquid seal on pond contents during operation.

Table 2-5 contains a summary of the estimated emissions from each of the indicated sources. Air emissions associated with treatment of contaminated formation water to accomplish aquifer restoration are not included in this summary (see Section 9.1.7). The cited estimates are based on prevailing source composition and ambient temperature and an assumed mean evaporation of $\sim$ 26 inches per year. Emissions from waste storage ponds are cited per acre of pond surface.

2.4.4 SOLID WASTES

Solid wastes are generated from three principal sources in the solution mining process: 1) the calcium control unit, 2) supplemental contaminant control incorporated in the elution/precipitation circuit of the recovery process, and 3) liquid waste concentration via evaporation during impoundment. Additional solid wastes are produced in conjunction with the water treatment methods utilized to accomplish aquifer restoration. The latter are generally similar to the solid wastes produced in the uranium recovery process and would be similarly managed.

Calcite ($CaCO_3$), which is removed prior to injection of the refortified lixiviant, is the principal solid waste produced in the solution mining process. The concentration of contaminants co-precipitated with calcite depend somewhat on the process location (either prior to uranium extraction or prior to lixiviant reinjection) at which control is implemented. The precipitated calcite may contain as much as 1 to 2 wt. % U_3O_8 and from 500 to 1200 pCi of Ra 226 per gram, which corresponds to approximately 95% removal of the Ra 226 mobilized by the lixiviant. It is estimated

TABLE 2-5
ESTIMATED AIR EMISSIONS

Source:	Emissions Rate (lbs./yr.)				
	NH_3	CO_2	NH_4Cl	U_3O_8	H_2O
1) Uranium Recovery Process Facility (excluding the calcium control unit and waste storage ponds).	$4\text{-}6 \times 10^3$	$1\text{-}2 \times 10^6$	$20\text{-}35 \times 10^3$	7-900	?
2) Calcium control unit (basis: 1,000 ft.^{2} of exposed solution surface containing a 0.75 gpl NH_4^+, 1.5 gpl Total CO_3 and 0.75 gpl Cl^-).	$1.5\text{-}2.5 \times 10^3$	$4\text{-}6 \times 10^3$	40-60	--	$250\text{-}300 \times 10^3$
3) Calcite storage pond (basis: complete evaporation of 2.04 gal/min. of supernate containing 0.75 gpl NH_4^+, 1.5 gpl Total CO_3, and 0.75 gpl Cl^-).	$2.5\text{-}3.5 \times 10^3$	$9\text{-}10 \times 10^3$	$9.5\text{-}10.5 \times 10^3$	--	$<900 \times 10^3$
4) Liquid Waste Storage Ponds (basis: 1 acre of exposed solution surface containing $\sim$ 7.0 gpl NH_4^+, $\sim$ 1.0 gpl Total $CO_3^=$, and $\sim$ 16 gpl Cl^-)	$12\text{-}14 \times 10^3$*	$9\text{-}10 \times 10^3$*	$35\text{-}40 \times 10^3$*		$<12 \times 10^6$*

*Note: Releases per acre of surface.

that less than approximately 2.8 pounds of calcite will be produced per pound of U_3O_8 recovered. The produced calcite (< 800 tons/yr.) would be impounded in a waste pond and maintained under a liquid seal to minimize atmospheric dispersion, pending identification of a permanent method for disposal. (See Section 4.4.1.1).

The second source of solid wastes is associated with supplemental contaminant control methods incorporated in the elution precipitation circuit of the process. However, present indications are that two contaminants, sulfate and vanadium, may have to be controlled to maintain uranium extraction and/or product quality. Wastes generated in this process would also be contained pending identification of a permanent method for disposal.

If necessary, sulfate levels in the eluant circuit would be controlled via precipitation of barium sulfate (estimated production < 800 tons/year). The recovered barium sulfate would be isolated via impoundment, also pending identification of a permanent method for disposal. If necessary, vanadium control would be exercised via sorption from the eluant of activated carbon. Although regeneration and reuse of the activated carbon sorbent is planned, disposal and replacement frequency and quantity are yet to be resolved by planned field tests, and will impact the method of disposal finally adopted. As an interim measure, spent carbon would be drummed and stored.

The third source of solid wastes are assorted precipitation compounds produced via evaporative concentration of impounded waste solutions. Such precipitation products are expected to be an assortment of alkali chloride, carbonate and sulfate salts. The rate and quantity of solids produced are

unknown at present, therefore, they would be impounded under a liquid seal to minimize atmospheric dispersion until solution mining operations were concluded. At such time an approved method of stabilization or disposal would be implemented in conjunction with site reclamation.

2.5 OPERATING PLANS AND SCHEDULES

2.5.1 WELL FIELD INSTALLATION

Well field drilling for the production plant well field is proposed to begin during the summer of 1977. By the time the plant is started, approximately 30 acres of well field drilling would be complete. The approximate areas of drilling/mining activity for each year are shown in Figure 2-10. The drilling is scheduled to stay approximately 4 to 5 months ahead of the mining program.

2.5.2 PLANT CONSTRUCTION

Plant start-up is anticipated in early July of 1978 which requires final construction to begin in January 1978.

2.5.3 MINING OPERATION

Anticipated progress of the mining operation by year is shown in Figure 2-10 as areas outlined by solid lines. The general mining plan will be to start at the existing test well field in Section 9 and

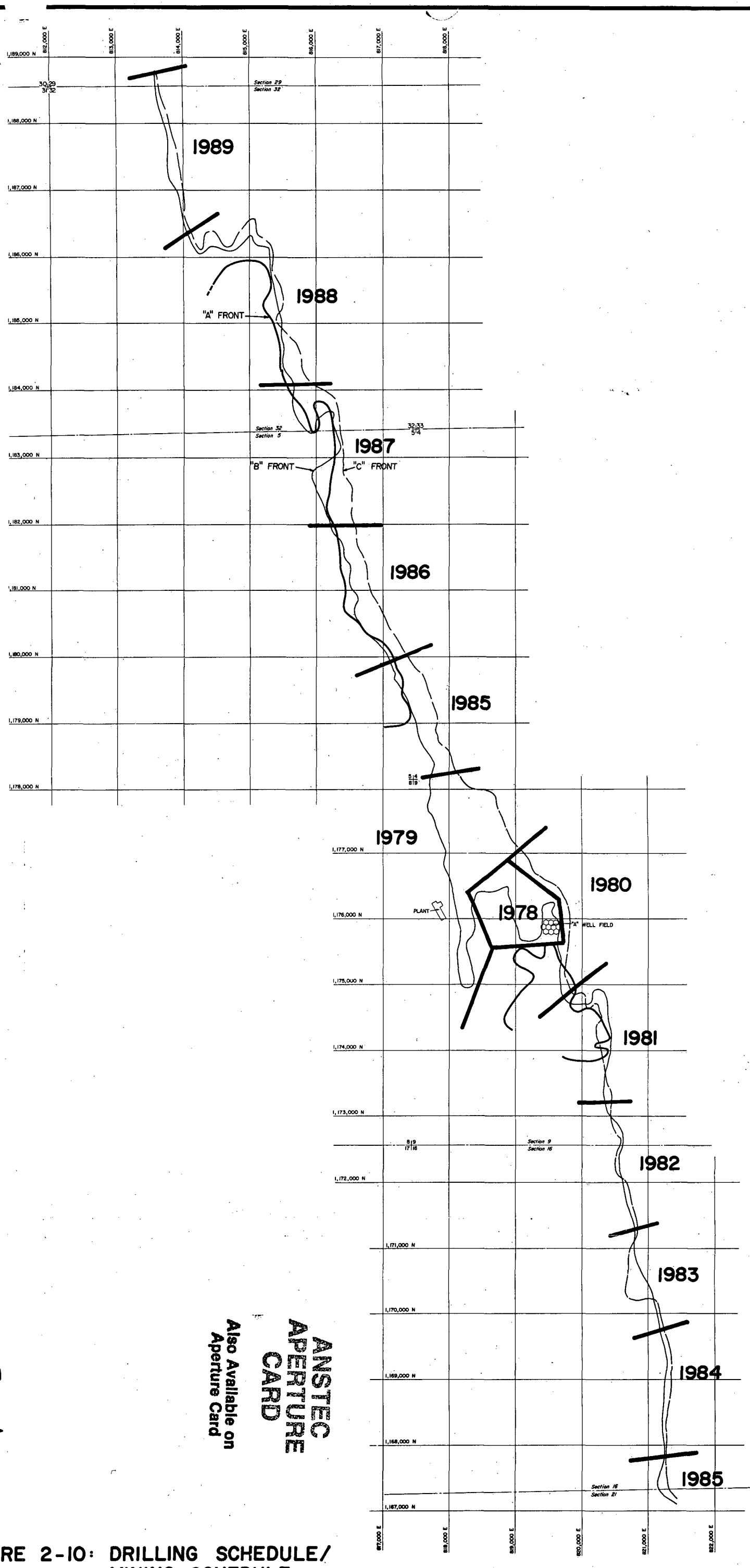

FIGURE 2-10: DRILLING SCHEDULE/ MINING SCHEDULE

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follow the front toward Section 4. On the south side of Willow Creek the well field will then switch to another front in the same confined aquifer and progress southward through Sections 9 and 16. Mining activity will then resume on the north side of Willow Creek and follow all the fronts northward through Sections 4, 5 and 32. Mining will probably be continued south of Section 16 and north of Section 32, but the solutions may be processed in plants at different locations.

Progress of drilling and mining activities is dependent on the mineralization encountered, topographical constraints, and the processing operation. The schedule shown in Figure 2-10 is based on preliminary drilling data and is subject to change.

2.5.4 SITE RESTORATION

As soon as the first mining areas have been mined out and the operating area has moved far enough to prevent interference, restoration of the mined-out areas will begin. Restoration is specifically addressed in Section 9.

SECTION 3.0

THE SITE

3.1 LOCATION AND LAYOUT

The proposed uranium solution mining operation is located in Johnson County, Wyoming (see Figure 2-1). Known as the Irigaray Property, this mining area represents a portion of the Powder River Basin in northeast Wyoming. The Property consists of approximately 28 square miles within Townships 45, 46, 47 North, Ranges 77 and 78 West. (Figure 3-1).

The region is one of physiographic diversity, including such features as the Bighorn Mountains (8,000 to 10,000 feet msl) to the west and the Black Hills of South Dakota (4,500 to 6,000 feet msl) to the east, separated by the broad Powder River Basin. The Powder River Basin is composed of hilly-to-rugged uplands, wide rolling valleys and badlands. Elevations range from 4,200 to 4,700 feet. The Laramie Range and the Hartville Uplift close the Basin to the south, and to the north the Basin gradually terminates in Montana.

3.1.1 PROPERTY STATUS

The Irigaray Property may be divided into four classes, based on mineral and surface ownership. These classes are:

1. Fee surface and minerals;
2. Fee surface and federal minerals;
3. Federal surface and minerals;
4. State surface and minerals.

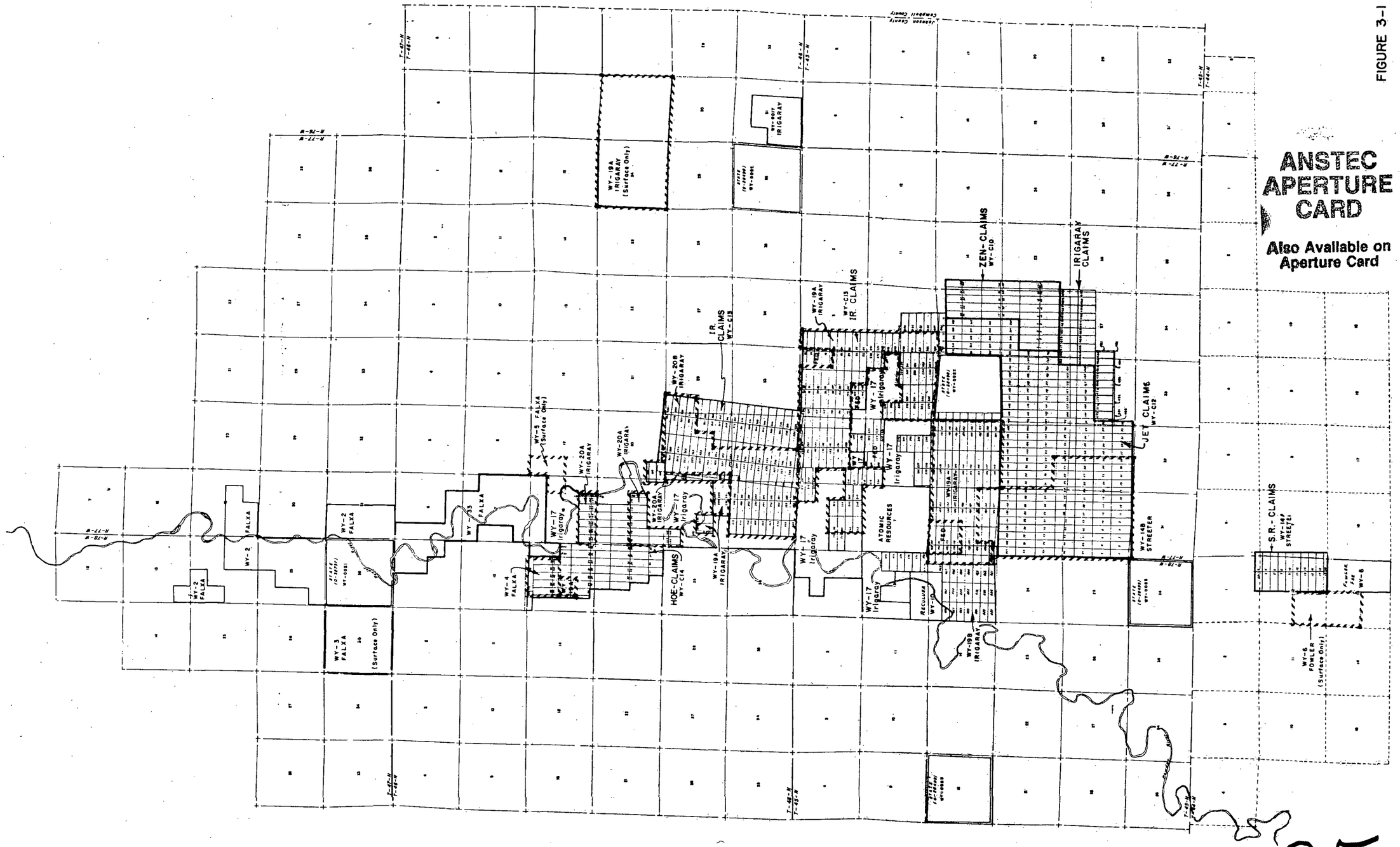

FIGURE 3-1

HOE - IRIGARAY AREA OWNERSHIP MAP

WYOMING MINERAL CORPORATION CODY, WYOMING

DWG. NO.

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There are several sections in which WMC holds only surface rights since the mining claims on those sections have been relinquished.

The Hoe-Irigaray Area Ownership Map (Figure 3-1) outlines and identifies the types of ownership. Fee surface and mineral areas are identified by the lease number and the owner's name. Fee surface and Federal mineral areas are those with mining claims which carry a lease number and the owner's name. Federal surface and mineral areas are those of mining claims labeled with only the claim name or "Fed." State lands are identified by "State" and the lease number. Section 7, T. 45N., R. 77W., is held by Atomic Resources and is not part of the Irigaray Property.

3.1.2 EXPLORATION AND MINING HISTORY

The first discovery of uranium ore in the Powder River Basin was made in 1951 by J. D. Love of the United States Geological Survey. Commercial production began in 1953, but was limited due to the small size of the deposits. Exploration during the late 1950's and early 1960's was effectively limited to the vicinity of near-surface deposits previously discovered by the Atomic Energy Commission (AEC) allocations program.

3.2 POPULATION, REGIONAL DEMOGRAPHY, AND LAND USE

3.2.1 REGIONAL COMMUNITY PROFILE

The production facility work force of 40 to 60 permanent, full-time workers

will be drawn from WMC employees in the Buffalo, Wyoming area. Thus, impacts to the social systems of the local communities should be minimal.

3.2.1.1 SOCIAL SERVICES

Buffalo is approximately 43 miles northwest of the project site, and is the county seat of Johnson County. The majority of current WMC employees reside there. Buffalo had a 1970 population of about 3400 compared to about 5600 for the county (see Table 3-1). In 1976 these figures were 4200 for Buffalo compared to about 5300 for the county.[1] The population density for the county is 1.29 people per square mile.

The local government is based on the Mayor-Council system, which administers the 850 acres within the city limits. A police force of 7 serve Buffalo, and those areas outside the city are protected by the County Sheriff's Office. Thirty-three percent of the city's streets are paved, and 50% of these have sidewalks. A 17-man volunteer fire department serves areas within 1-mile of the city limits.

3.2.1.2 HOUSING

There are 1,403 housing units in Buffalo, with home ownership at 79%; home vacancy stands at 8%. There is no government housing in Buffalo. The estimated cost of a new, 3-bedroom home of approximately 1,100 square feet with unfinished basement and 1-car garage, is approximately

TABLE 3-1
RANCH AND TOWN POPULATIONS NEAR IRIGARAY PROPERTY

Ranch or Town	Distance from Site	Population
Reculusa Ranch	4.1 (miles)	8-10
Irigaray Ranch	4.4	6
ZL Bar Ranch	5.6	12
Falxa Camp	5.7	2
Urruty Ranch	7.2	4- 5
Sussex	15.0	30
Linch	20.0	300
Kaycee	28.0	272
Buffalo	42.0	3,394
Gillette	42.0	7,194

TABLE 3-2
JOHNSON COUNTY POPULATION BY AGE

Age Class	%
18 or less	9.5
19-30	16.0
31-40	15.1
41-50	22.0
51-60	17.5
61+	19.5

TABLE 3-3
EDUCATION LEVEL OF JOHNSON COUNTY RESIDENTS

Level Attained	% of Population
Grade School	10.0
Less than H.S.	17.9
H.S. Graduate	40.7
1-2 yr. College	13.1
Technical College	3.2
3-4 yr. College	2.0
College Graduate	10.9
Graduate Degree	2.3

$40,000. Yearly taxes on such a house are about $300. The average monthly rental on a 3-bedroom home in the community is $200.

The distribution of the Johnson County Population by age class is summarized in Table 3-2.[1]

3.2.1.3 EDUCATION

Buffalo has a high school and an elementary school, with enrollments at 410 and 680 respectively. The ratio of students to teachers is 18.8, and the total expenditure per student was about $1,300 in 1976. The local public library has holdings of about 20,000 volumes. The education level of Johnson County residents is summarized in Table 3-3.[1]

3.2.1.4 LABOR FORCE

Buffalo has a combined labor force of 2,810 workers, of which 1,913 (68%) are male and 897 (32%) are females. The unemployment rate is 2.8% for the total work force; 2.7% for males, and 3.2% for females. Statistics on the distribution of the Buffalo labor force are shown in Table 3-4.[1]

Average weekly wage rates for the state and county for the period January to March 1975, are summarized in Table 3-5.

TABLE 3-4

DISTRIBUTION OF LABOR FORCE

Agr., Forestry & Fisheries	- ---
Contract Construction	- 236
Trans., Comm. Utilities	- 85
Finance, Ins. Real Estate	- 55
Service with Local Govt.	- 218
Mining	- 205
Manufacturing	- 96
Whsl. Tr.	- 11
Retail Tr.	- 365
Fed. Govt.	- 35
Railroads	- 0
Agric.	- 640
Non-agric.	- 720
Other	- 144
Total	2,810

TABLE 3-5
AVERAGE WEEKLY WAGE RATES

Industry Group	Avg. Wkly. Wage Wyo.	County
Agr., Forestry, Fish	$103.98	$ --
Mining	261.50	240.87
Contract Const.	244.65	243.49
Manufacturing	200.23	148.86
Transportation	207.31	--
Communications	203.67	188.06
Elec., Gas & Sant. Ser.	259.94	--
Wholesale Trade	213.24	166.95
Retail Trade	--	88.61
Finance, Ins., R. Estate	156.02	156.26
Service	108.92	--
Government	164.61	96.16

Per Capita Income: $4,934

3.2.1.5 EMPLOYMENT

Traditionally, agriculture has been the principal source of employment in Johnson County. However, with energy development, employment associated with the mining, construction, transportation, communication and the utilities sectors has increased in importance, while that of agriculture has diminished.

3.2.1.6 POPULATION GROWTH

Population growth in the Powder River Basin generally has been extremely slow since the 1940's. Historically, the Basin has been a rural, sparsely populated region with a static and, in some cases, declining population that is characterized by small towns. Oil booms caused rapid, temporary population increases in the 1940's and 50's but from 1960 to 1970 five of the eight Powder River counties experienced population decreases (see Table 3-6). Seven of the eight counties experienced emigration, although the region grew slightly due to a natural increase in population (see Table 3-7). The Johnson County population presently is categorized as urban (see Table 3-8).

There is a small number of permanent inhabitants located on a few scattered ranch headquarters near the WMC test sites. The ranch headquarters within a five-mile radius of the site and the populations of the town nearest the test site are given in Table 3-1.

TABLE 3-6
POPULATION AND PERCENTAGE CHANGE IN POPULATION
BY COUNTY 1940 - 1970

County	1940 Pop.	% Change 1930-40	1950 Pop.	% Change 1940-50	1960 Pop.	% Change 1950-60	1970 Pop.	% Change 1960-70
Campbell	6,048	-10.0	4,839	-20.0	5,861	21.1	12,957	121.1
Converse	6,631	- 7.2	5,933	-10.5	6,366	7.3	5,938	-6.7
Crook	5,463	2.4	4,738	-13.3	4,691	-1.0	4,535	-3.3
Johnson	4,980	3.4	4,707	- 5.5	5,475	16.3	5,587	2.0
Natrona	23,858	-1.7	31,437	31.8	49,623	57.8	51,264	3.3
Niobrara	5,988	26.8	4,701	-21.5	3,750	-20.2	2,924	-22.0
Sheridan	19,255	14.1	20,185	4.8	18,989	-5.9	17,852	-6.0
Weston	4,958	6.1	6,733	35.8	7,929	17.8	6,307	-20.5
TOTAL	77,181	3.5	83,273	7.9	102,684	23.3	107,364	4.6

TABLE 3-7
ESTIMATES OF COMPONENTS OF POPULATION CHANGE BY COUNTY
1950 - 1970

	1950-1960			1960-1970		
County	Population Change[a]	Natural Increase[b]	Net Migration	Population Change[a]	Natural Increase[b]	Net Migration
Campbell	1,022	822	200	7,096	1,226	5,870
Converse	433	906	-473	-428	458	-886
Crook	-47	671	-718	-156	597	-753
Johnson	768	824	-56	112	412	-300
Natrona	18,186	8,737	9,449	1,641	6,389	-4,748
Niobrara	-951	536	-1,487	-826	205	-1,031
Sheridan	-1,196	2,102	-3,298	-1,137	530	-1,667
Weston	1,196	1,750	-554	-1,622	990	-2,612
TOTAL	17,019	16,348	3,063	4,680	10,807	-6,127

[a]Population change is based on census figures obtained on April 1 of the census years 1950, 1960 and 1970.

[b]Natural increase (resident births minus resident deaths) is based on calendar years 1950-1959 and 1960-1969).

TABLE 3-8
PERCENT URBAN AND RURAL POPULATION BY COUNTY
1970

COUNTY	% RURAL NON-FARM	% RURAL FARM	% URBAN	MAJOR TOWNS & CITIES NAME & POPULATION
Campbell	30.4	14.1	55.5	Gillette 7,194
Converse	42.6	15.1	42.3	Douglas 2,677 Glenrock 1,515
Crook	73.7	26.3	0.0	Sundance 1,056 Moorcroft 981 Hulett 318
Johnson	21.9	14.7	63.4	Buffalo 3,394 Kaycee 272
Natrona	21.0	2.1	76.9	Casper 39,361 Mills 1,724 Evansville 832
Niobrara	74.8	25.2	0.0	Lusk 1,495 Manville 92
Sheridan	28.3	10.9	60.8	Sheridan 10,856 Dayton 396 Ranchester 208
Weston	35.4	11.9	52.7	Newcastle 3,432 Upton 987

3.2.1.7 HEALTH SERVICES

Buffalo is served by 5 physicians and 3 dentists. Johnson County Memorial Hospital has a capacity of 24 beds, and an occupancy rate of 66%.

3.2.1.8 UTILITIES

The Buffalo municipal water system has a source capacity of 5 million gallons per day, a storage capacity of 5.5 million gallons per day and a transmission capacity of 6.5 million gallons per day. Treatment is by chlorination and the peak demand has been 2.8 million gallons per day. Sanitary wastes are handled by a sewage treatment lagoon and a sanitary land fill.

Natural gas is supplied by the Montana-Dakota Utilities Co. Electric power is provided by Pacific Power & Light Co.

3.2.1.9 TAX STRUCTURE

The total assessed evaluation for Johnson County is $42,957,195 of which $4,231,289 (9.8%) lies within the city of Buffalo. The ratio of assessed valuation to true 1975 value is 20%. Industrial property bears 44.5%, and residential property bears 55.5% of the tax burden of the city. The distribution of the tax levy for the city, county, and the school district for 1970, 1974 and 1975 is summarized in Table 3-9.

TABLE 3-9
TAX LEVY

Tax Levy (Mills)	1970	1974	1975
City	7.7	17.6	17.09
County	29.5	9.5	12.56
School	18.3	40.6	41.10
Totals	55.76	68.5	70.76

The bonded indebtedness of the city is $113,000 and $140,000 for the school district. The total revenues collected in 1975 by the county was $2,387,437, and $299,389 by the city of Buffalo.

3.2.2 LAND USE

One major resource consideration is land and resource ownership. In the Powder River Basin, private surface holdings account for 68.5 percent, federal holdings for 22.9 percent and state holdings for 8.6 percent. Federal subsurface rights, however, extend to 42.6 percent, the state accounts for 8.7 percent and the remaining 48.7 percent is in private hands.

Cattle and sheep ranching utilize 89 percent of the total area in the Powder River Basin. Forest land comprises 9 percent of the Basin and consists primarily of coniferous trees, except at low elevation. Urban areas comprise only 2 percent of the area.

Most of the land is used for grazing and primarily consists of short grass, interspersed with sagebrush cover, that is suitable for year-round grazing. A large percentage of forage crops is raised to supplement livestock feed. The major cash crop is wheat, which typifies Great Plains agriculture.

Production of mineral resources has been a significant factor in the economy of the Powder River Basin since before 1900. Coal production began in 1891,

oil and gas in 1906 and uranium activity in the mid-1950's. While the presence of several other minerals is known, only bentonite is a major contributor to the economy.

3.3 REGIONAL HISTORIC, SCENIC, CULTURAL AND NATURAL LANDMARKS

Consultation with the National Registry of Historic Places and the National Registry of Natural Landmarks established the presence of one historic marker, Fort Reno (Appendix B), within six miles of the Irigaray sites. The State Historic Preservation Officer has indicated that only one new nomination for classification, Reno Cantonment (Appendix B), has been made within 10 miles of the Irigaray Property.

Currently there are no archaeological digs within 50 miles of the Property (Appendix C). The very nature of the solution mining method will result in very little, if any, disturbance of possible archaeological sites. Wyoming state archaeologists will be consulted for guidance if site operations uncover an archaeological site.

3.4 GEOLOGY, MINERAL RESOURCES, SEISMICITY

3.4.1 GENERAL GEOLOGY

The Irigary site is a part of the Great Plains Physiographic Province, which is characterized by broad river plains and low plateaus on stratified sedimentary rocks. The site is located on the west flank of the Powder River Basin which is a structural and topographic basin bounded on the

west by the Bighorn Mountains and on the east by the Black Hills of South Dakota. As much as 18,000 feet of sedimentary rock are present in the deepest part of the basin.[2] A generalized geologic column for the west side of the Powder River Basin is contained in Table 3-10.

The Wasatch Formation outcrops throughout the Irigaray property and consists of interbedded sandstones, shales, and coal. In the site area the Wasatch Formation is part of a west plunging area which results in a dip to the northwest of about 1-2°.

Figure 3-2 is a detailed geologic column of the Irigaray property. Surficial materials consist of alluvium, and interbedded siltstones, claystones, shales and discontinuous sands which extend to a depth of from 60 to 480 feet. Beneath these strata are two thin coal seams separated by two to three feet of shale. The upper seam is one to two feet thick and the lower seam is two or three feet thick. Beneath the coal seams are about 10 feet of claystone. The Upper Irigaray Sandstone (UISS mining unit) occurs underneath the coal and is an arkosic sandstone approximately 120 feet thick, with interbedded shales. The upper Irigaray Sandstone is confined by the claystone above and 60 feet of claystone beneath (Figures 3-3, 3-4, 3-5, 3-6, and 3-7).

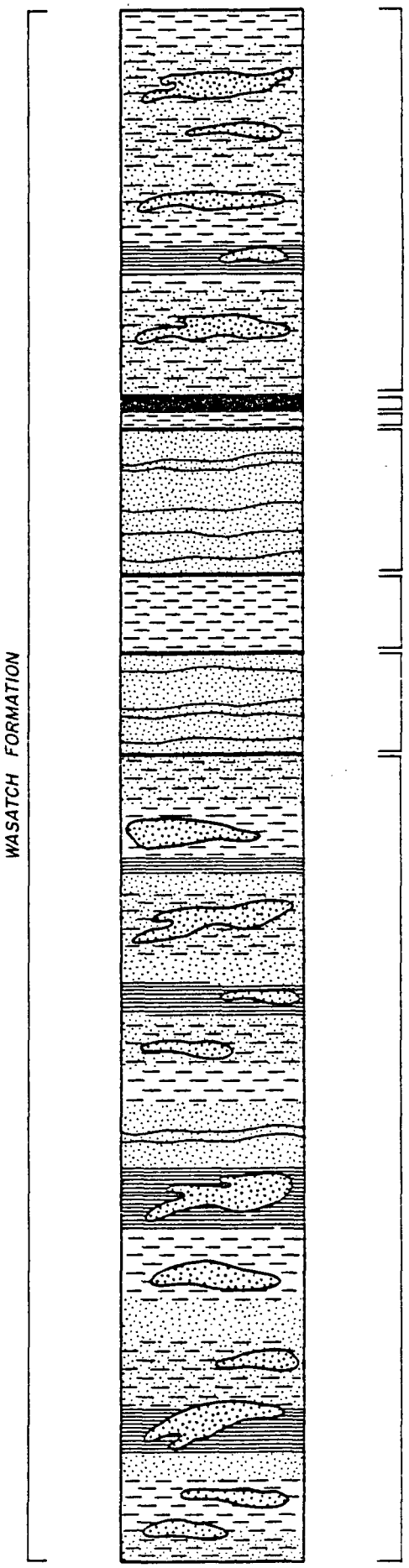
In the northern section of the area (T45N, R77W, Section 18, 19, 30) the Lower Irigaray Sandstone is found beneath the claystone and consists of sandstone with interbedded shales. This unit is about 80 feet thick;

TABLE 3-10
GENERALIZED GEOLOGIC COLUMN-WEST SIDE OF POWDER RIVER BASIN

GEOLOGIC UNIT	LITHOLOGY	THICKNESS (ft.)
Alluvium	unconsolidated silt, sand, and gravel	<50
Landslide	rock debris	---
Windblown Sand	unconsolidated sand and silt	<50
Glacial Deposits	sand, gravel and boulders	---
Arikee Formation	sandstone	600
White River Formation	claystone and siltstone	560
Wasatch Formation	lenticular sandstone and interbedded shale and coal	1,575
Fort Union Formation	sandstone and interbedded shale	2,270-3,450
Lance Formation	sandstone and interbedded sandy shale and claystone	500-3,000
Lewis Shale	shale	200-470
Mesaverde Formation	sandstone, shale	700-900
Cody Shale	shale, siltstone and sandstone	3,000-3,600
Frontier Formation	sandstone and interbedded shale	500-830

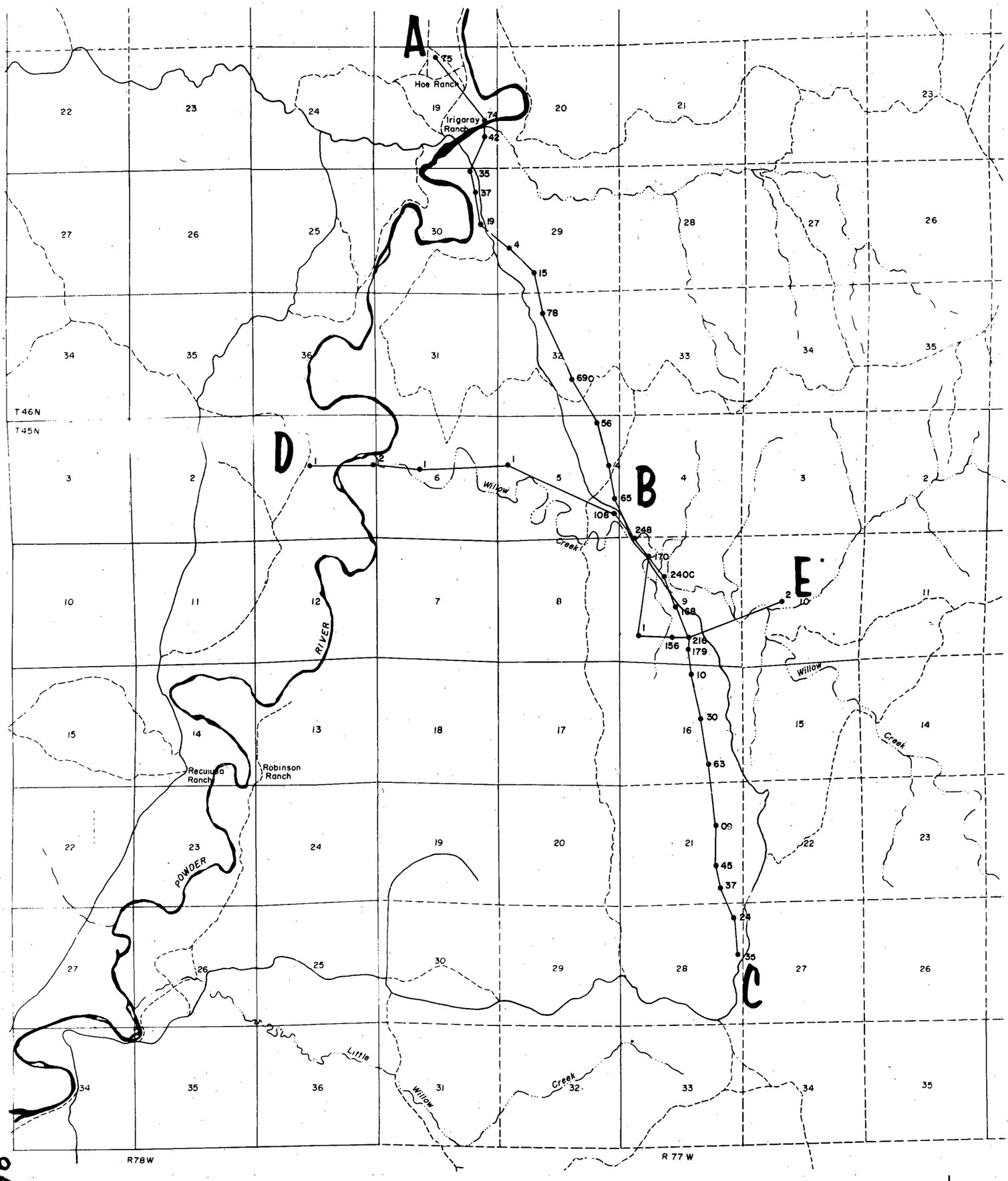
TABLE 3-10
GENERALIZED GEOLOGIC COLUMN-WEST SIDE OF POWDER RIVER BASIN

GEOLOGIC UNIT	LITHOLOGY	THICKNESS (ft.)
Mowry Shale	siliceous shale	150-250
Thermopilis Shale	shale	200
Cloverly Formation	shale and siltstone	140-150
Morrison Formation	claystone	20-220
Sundance Formation	shale and interbedded sandstond	280-350
Gypsum Spring Formation	gypsum, claystone, and limestone	145-185
Chugwater	siltstone, sandstone, and shale	700-800
Goose Egg Formation	interbedded shale, gypsum, and limestone	180-350
Tensleep Sandstone	sandstone	275-350
Amsden Formation	sandstone, shale, dolomite, and limestone	250-300
Madison Limestone	dolomite and limestone	550-670
Bighorn Dolomite	sandstone and dolomite	150-430
Callatin Formation Gros Ventre	limestone, shale and conglomerate	0-600
Flathead Sandstone	sandstone	260-340
Igneous and Metamorphic Rocks	granite, gneiss, and schist	---



Detailed Geologic Column
Irigaray Site

FIGURE 3-2



1 1/2 0 1 MILE

WYOMING

LEGEND

INTERMITTENT STREAMS

UNIMPROVED ROADS

LIGHT DUTY ROAD, HARD OR IMPROVED SURFACE.

N

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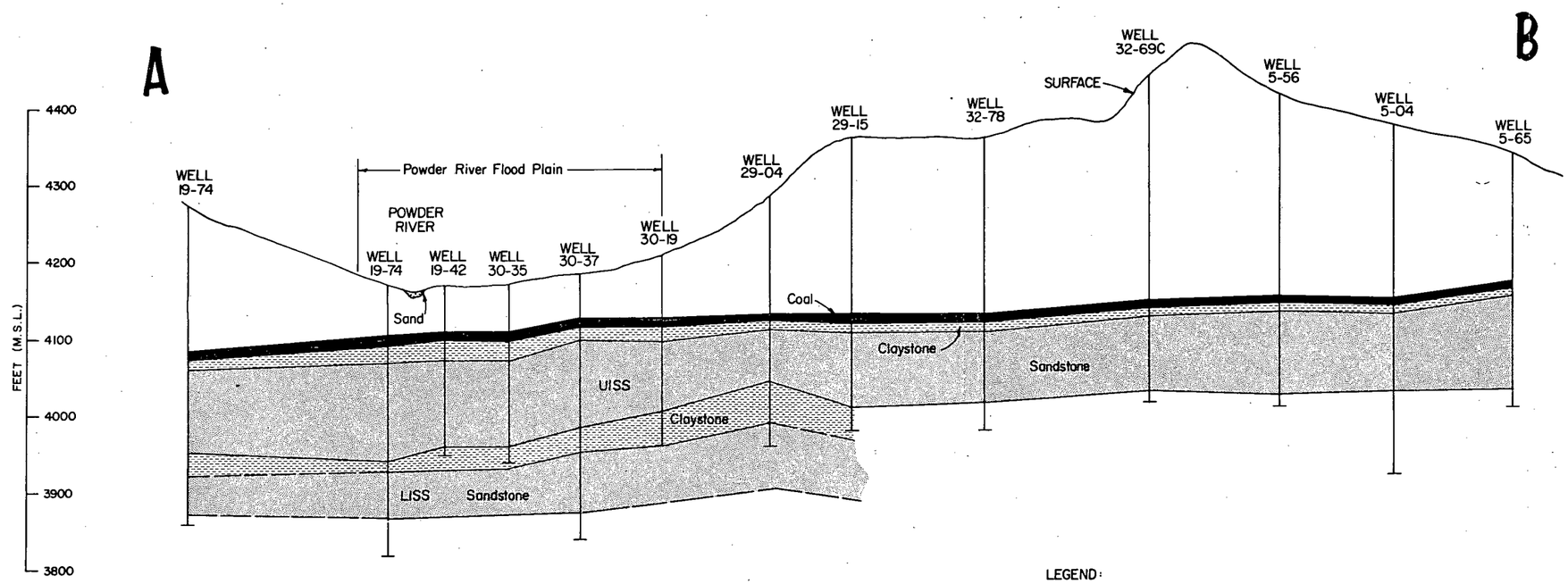
FIGURE 3-3: LOCATION OF GEOLOGIC CROSS SECTIONS, IRIGARAY SITE



LEGEND:

- Sandstone (with some interbedded shales)
- Coal and Shale
- Claystone
- Claystones, siltstone, shales & discontinuous sands
- Sand (alluvial)
- UISS Upper Irigaray Sandstone
- LISS Lower Irigaray Sandstone
- 29-15 Well number

0' 1000' 2000'
Horizontal Scale

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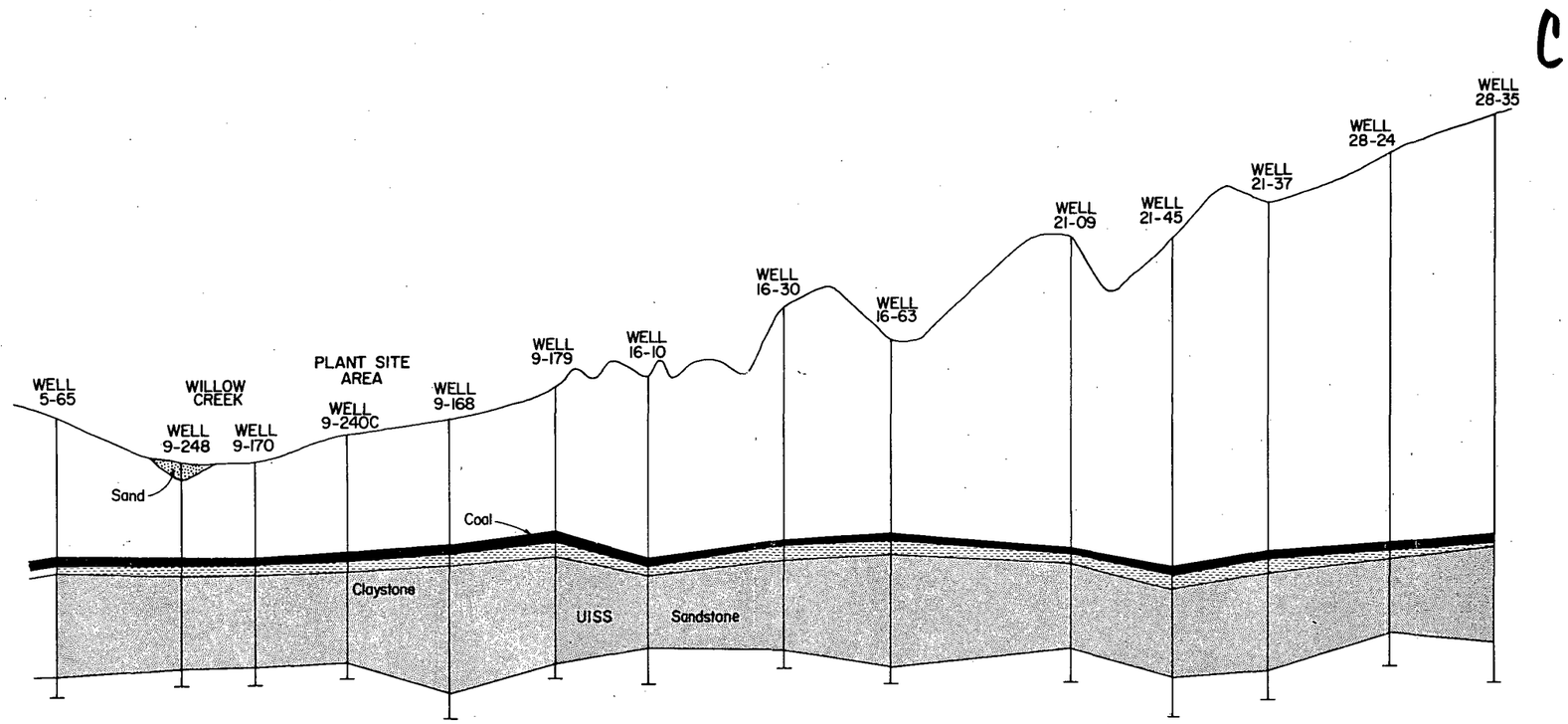
GEOLOGIC CROSS SECTION A-B, IRIGARAY SITE

FIGURE 3-4



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LEGEND:

- Sandstone (with some interbedded shales)
- Coal and Shale
- Claystone
- Claystones, siltstone, shales & discontinuous sands
- Sand (alluvial)
- UISS Upper Irigaray Sandstone
- 9-170 Well number

0' 1000' 2000'
Horizontal Scale

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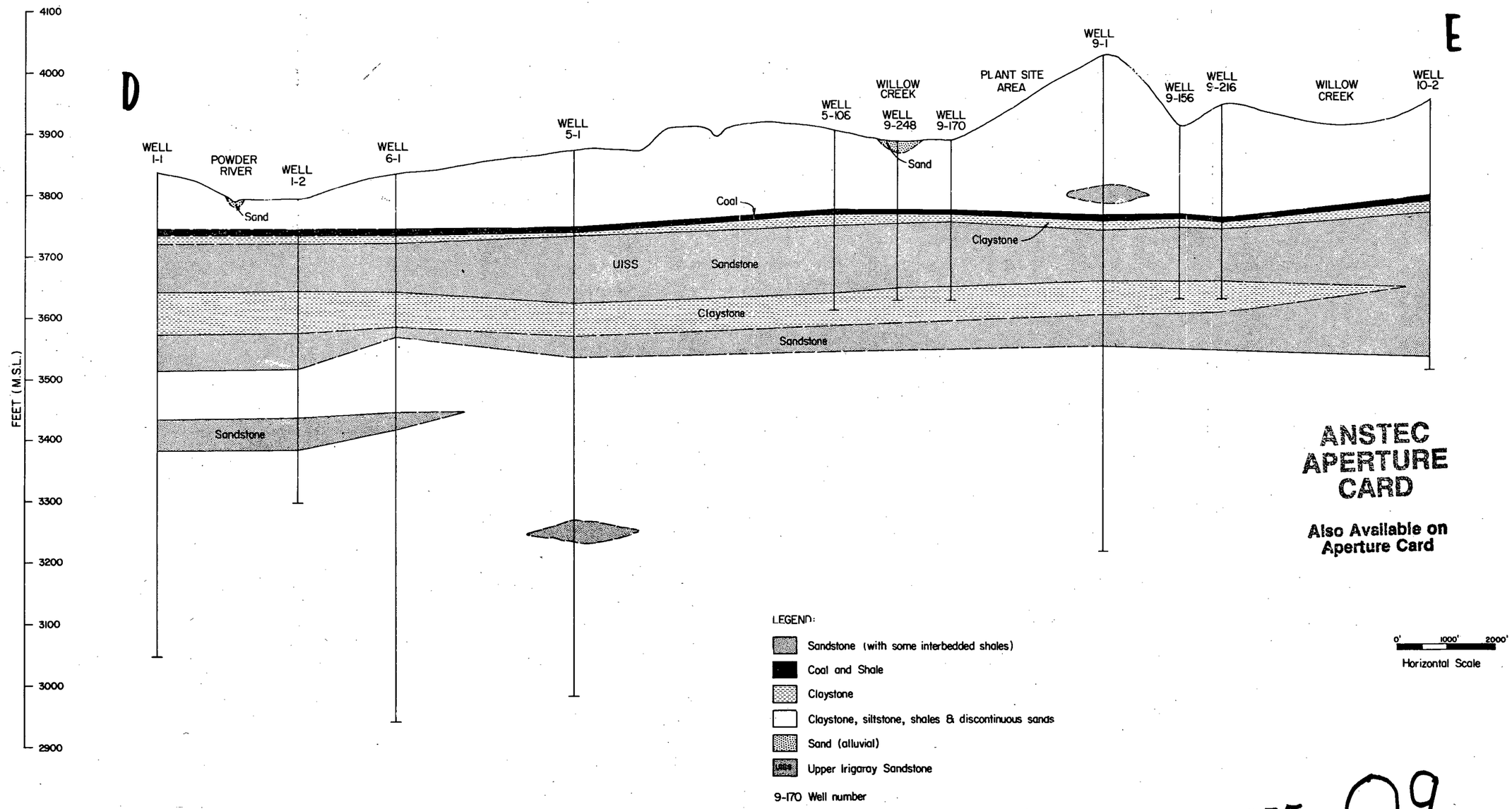
GEOLOGIC CROSS SECTION B-C, IRIGARAY SITE

FIGURE 3-5



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GEOLOGIC CROSS SECTION D-E, IRIGARAY SITE

FIGURE 3-6

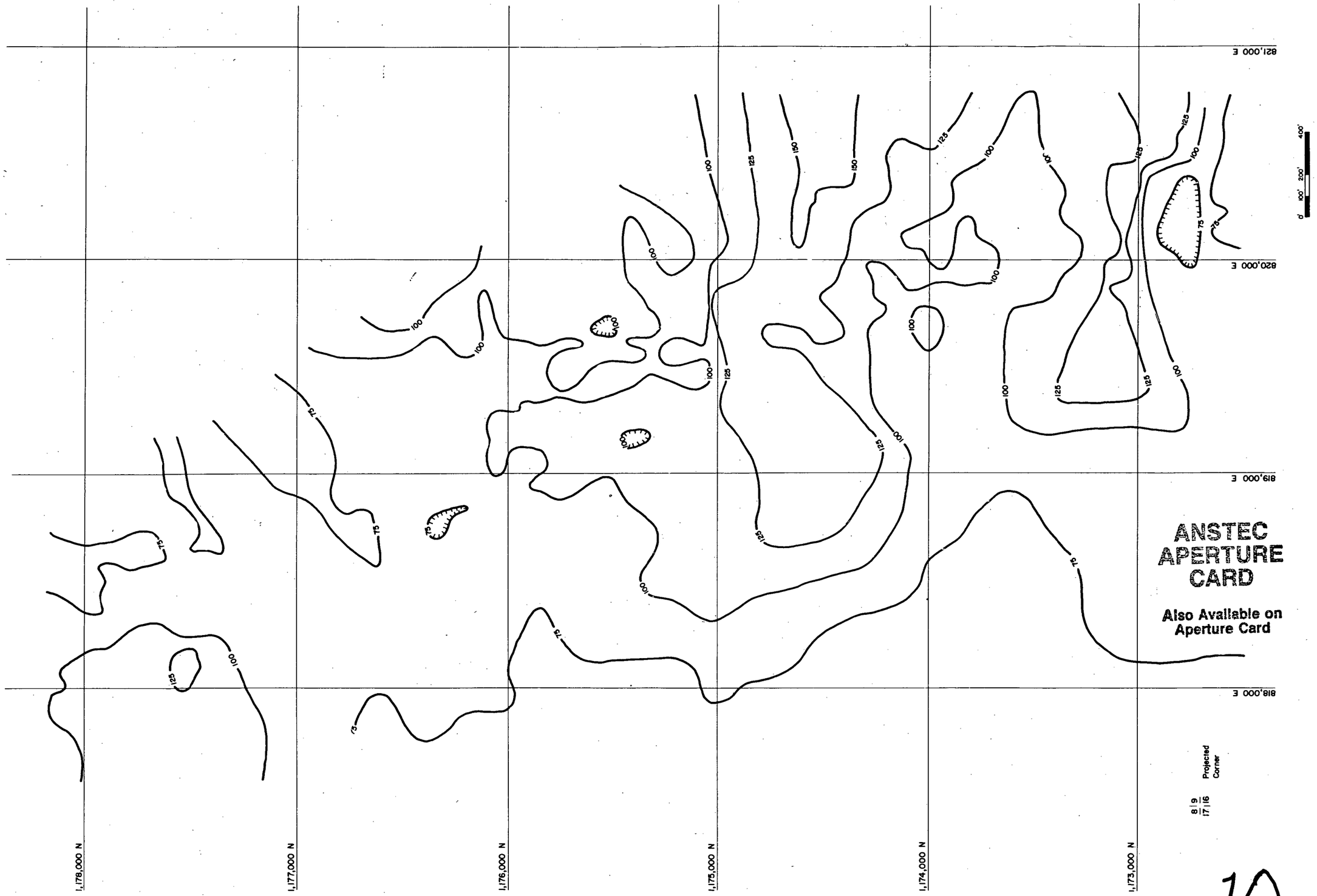

FIGURE 3-7: ISOPACH MAP OF UPPER IRIGARAY SANDSTONE

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however, it is not presently known if this unit extends into the southern part of the mining area. To date drilling beneath the Lower Irigaray Sandstone has only shown discontinuous sands interbedded with siltstones, claystones and shales.

3.4.2 MINERAL RESOURCES

Two thin coal seams lie approximately twenty feet above the ore bearing Upper Irigaray Sandstone (UISS) which is 200-300 feet below the surface. The upper seam is one to two feet thick, and the lower is two to three feet thick. The seams are separated by two to three feet of shale. The coal is classified as lignite and contains a large amount of ash. WMC believes that the coal is presently uneconomical to recover, and that any future use and recovery of the coal will not be affected by solution mining. Exploration drilling in the area seldom reaches 800 feet deep; however, wells to that depth indicate that no other coal is present. Oil exploration indicates there are deeper coal seams. However, they are not considered economically mineable at this time and will not be affected by solution mining activities.

Petroleum production and exploration are being carried out in the Sussex, Shannon, Frontier, and Muddy Formation -- all of Cretaceous Age. No unresolveable conflicts will arise between development of uranium and petroleum operations. Surface casing is set in the petroleum wells to approximately 1,000 feet, which is 600-700 feet deeper than the lower boundary of the UISS. Since the potential uranium ore deposit is only 400 to 800 feet wide and there is some flexibility in the location of an oil well, it should

be possible to resolve any problems that may be encountered on surface use. Conflicts can be resolved by adjustments in casing and cementing programs, well locations and timing.

3.4.3 SEISMOLOGY

While there is no reliable method for predicting the location and severity of an earthquake, the seismographic record of the area within 100 miles of the WMC Irigaray plant sites indicates that the region is one of low seismic activity. Data suggest that within 100 miles of the sites (Appendix D), an earthquake of magnitude 5.0 to 6.0 (Modified Mercalli Intensity Scale) should occur about once every 200 years.

The conclusions which may be drawn are that the WMC sites in the Powder River Basin should experience only occasional detectable ground motion and that there is minimal risk such motion could produce structural damage.

3.5 GROUNDWATER

3.5.1 REGIONAL GROUNDWATER HYDROLOGY

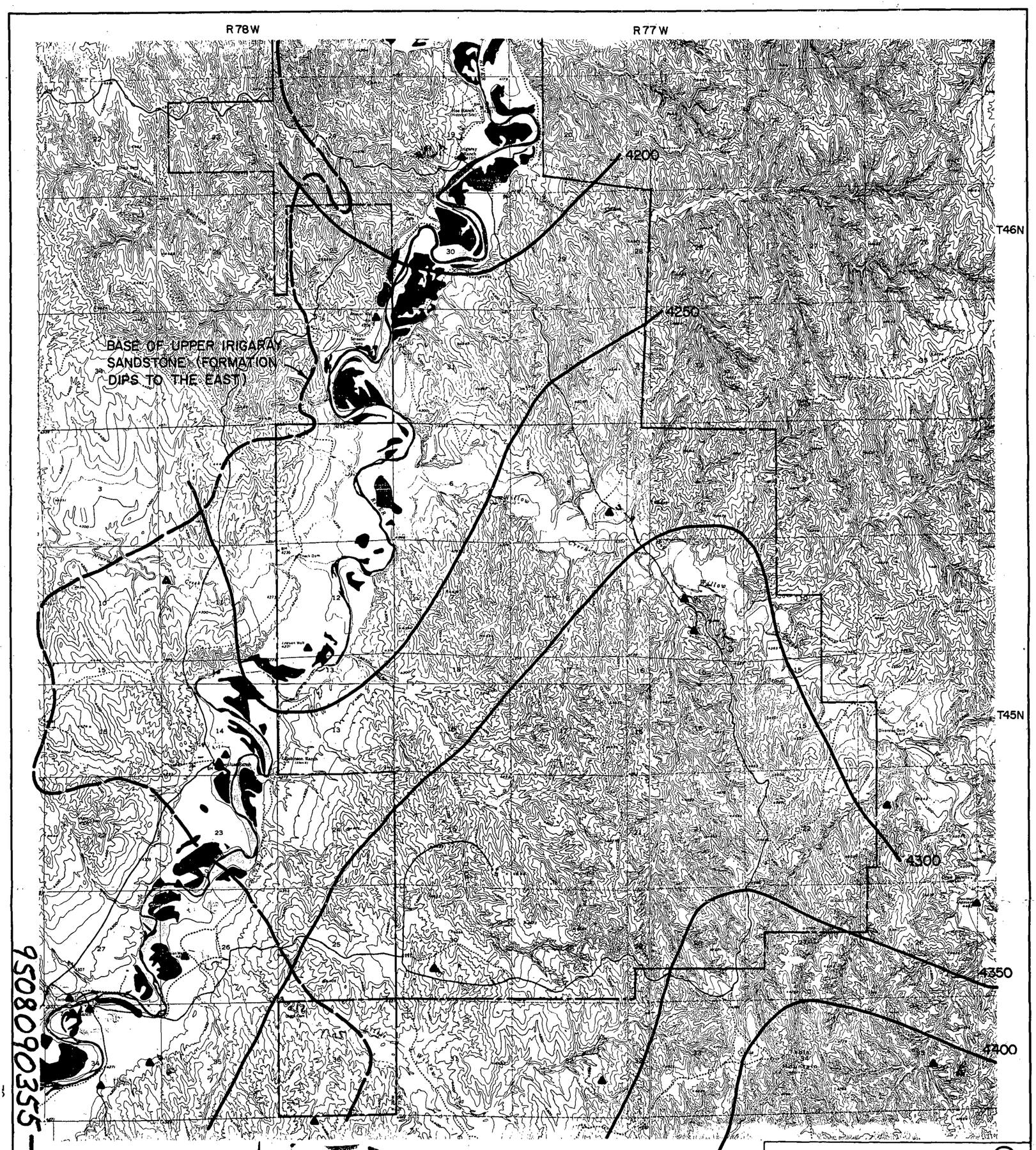
The Wasatch Formation outcrops throughout the Irigaray properties and consists of interbedded sandstones, shales and coal (Section 3.4). Sandstone beds in the Wasatch Formation supply water to many domestic and stock wells in the Powder River Structural Basin. In addition, some of the thicker coal beds in the basin have yielded water to wells (probably through interconnecting networks of fractures and joints).[3]

Water well yields in the Powder River Basin can be expected to range from 10 to 50 gallons per minute (gpm) in the northern part of the basin to 500 gpm or more in the southern part of the basin. One well near Gillette had a specific capacity of about 4 gpm per foot of drawdown. Seven wells on the Buffalo Ranch (T44N, R72W) had specific capacities ranging from 5 to 14 gpm per foot of drawdown.

In the Powder River Basin, groundwater dissolved solids range from less than 200 to more than 8,000 milligrams per liter (mg/l), but commonly range between 500 and 1,500 mg/l. Water mineralization decreases in the general southward direction. The most apparent constituents in the water are sodium sulfate and sodium bicarbonate.[3] No relation of dissolved solids to depth is discernible.

The water table for the Wasatch Formation is relatively shallow in the western part of the basin. In general, the depth to water in the Wasatch increases in the eastward direction because the upper part of the formation is dissected and drained by many deep narrow valleys. Wells on ridges and divides may penetrate several tens of feet of nearly dry strata before tapping a water-bearing bed. Due to the irregularity of the terrain and the discontinuity of aquifers, it is difficult to predict the depth at which water can be obtained.[2]

A regional piezometric surface map of the Wasatch formation was constructed for the Irigaray mine area (see Figure 3-8). The piezometric contours are based on water level readings taken by WMC in



WYOMING MINERAL CORPORATION

ELEVATION CONTOUR MAP OF PIEZOMETRIC SURFACE, WASATCH FORMATION, IRIGARAY, WYOMING

DWN: JRV
CHKD:
APRD:
SCALE: 1" = 4,500 ~

FIGURE 3-8

SHEET OF

REV

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1974. The groundwater is flowing in a northwesterly direction across the mine site area.

The regional groundwater gradient is estimated to be about 0.005 ft/ft from the Table Mountain area toward the Irigaray Ranch. The velocity of groundwater movement is estimated to be approximately 5 to 8 feet per year. The following equation and data was used in the estimation.

$$V = \frac{48.8K\ i}{\phi}$$

V = velocity of groundwater movement (feet/year)

K = hydraulic conductivity (average about 7 gpd/ft^2 across mine sites)

i = hydraulic gradient (0.005 ft/ft)

ϕ = effective porosity (0.234)

3.5.2 SITE SPECIFIC GROUNDWATER HYDROLOGY

Three pump tests were conducted at the general Irigary mine area (Figure 3-9). These sites are the Irigaray test field, proposed production field and a third area used for hydrologic testing (Area II) respectively. The following subsections present the various geohydrologic aspects of these sites.

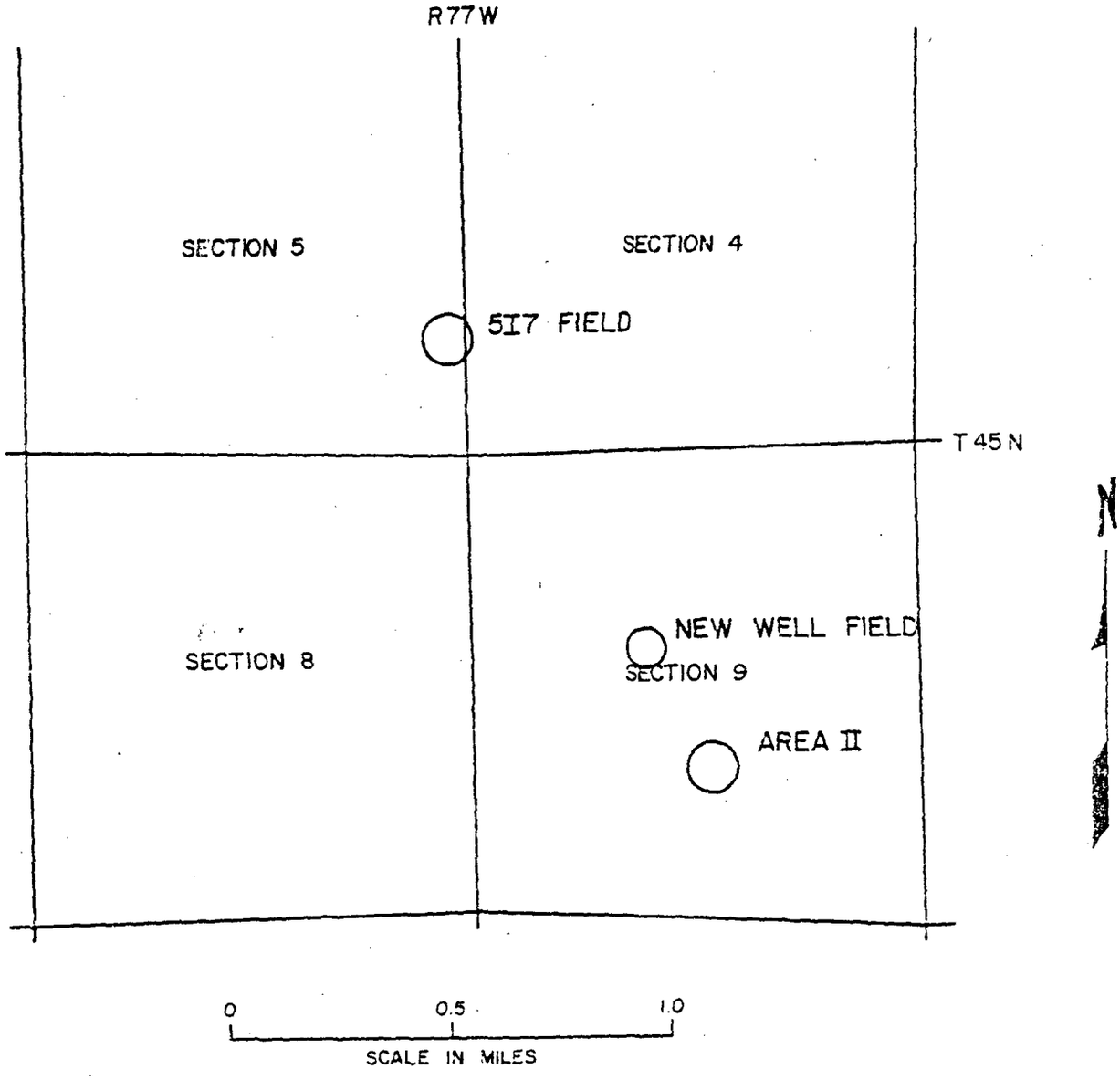


FIGURE 3-9
LOCATION MAP OF PUMP TEST SITES

3.5.2.1 IRIGARAY TEST FIELD

A pump test was performed in November 1975 at the Irigaray test field. The test consisted of a 19-hour drawdown test with one pumping well and eight observation wells (Figure 3-10). The test was conducted at a constant pumping rate of 15 gpm. The thickness of the upper Irigaray sand was 120 feet. The pumped well was screened from 225 feet to 285 feet and penetrated 50% of the aquifer. In the analysis no partial penetration corrections were made because the correction is relatively small, compared to the total drawdown at wells. The drawdown in the pumping well at the end of the test was 49 feet and yielded a specific capacity figure of about 0.3 gpm per foot of drawdown. The well efficiency was estimated to be 70%. Transmissivity values from observation wells ranged from 1030 to 1410 gpd/ft. Storage coefficient value ranged from 1.85×10^{-4} to 7.44×10^{-5}. An analysis of the anisotropy of the aquifer yielded a major and minor hydraulic conductivity of 11.6 and 6.7 gpd/ft^2 respectively. The direction of major hydraulic conductivity is estimated at N 35° W.

Based on groundwater level monitoring data conducted during June through October 1976, water levels at observation wells generally fluctuate less than ten feet, with high levels during June and low levels in October. The hydraulic gradient across the Irigaray field averages about 0.033 ft. per foot toward the west to northwest.

3.5.2.2 PROPOSED PRODUCTION SITE

A pump test was performed in February 1977 at the proposed production

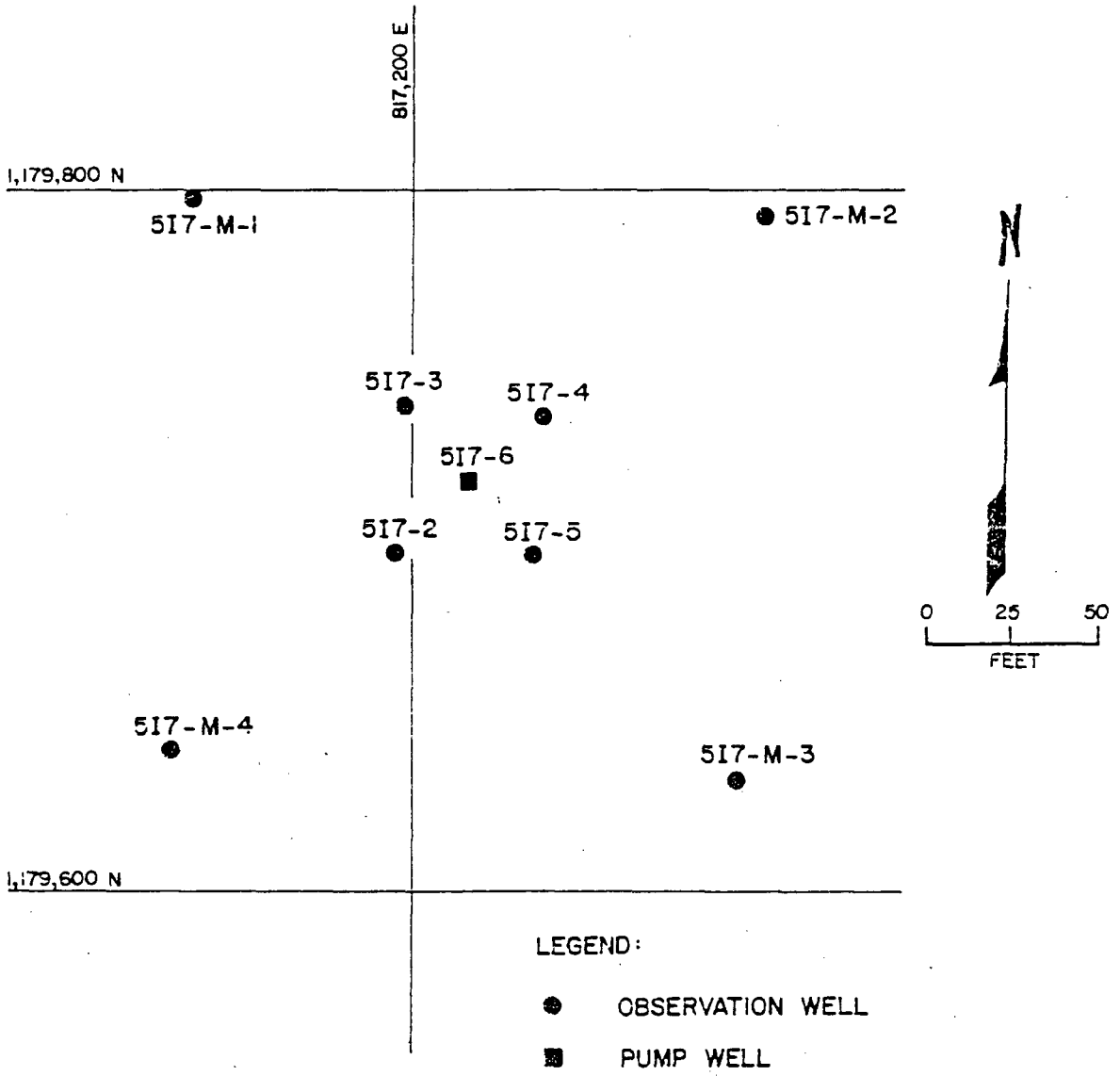


FIGURE 3-10
LOCATION OF WELLS USED IN 5I7 FIELD PUMP TEST

area. The test consisted of a 15-hour drawdown test with one pumping well and four observation wells (Figure 3-11). The test was conducted at a constant pumping rate of approximately 10 gpm. The wells used in the pumping test only partially penetrated the full thickness of the aquifer. Therefore, the flow lines in the aquifer were influenced by the vertical flow component. The Hantush method was used to calculate the correction of drawdown and the Jacob method was applied to determine the values of storage coefficient and transmissivity. The results of the analyses are listed in Table 3-11. The hydraulic gradient measured in November 1976 indicated a value of about 0.009 ft. per ft. due west.

3.5.2.3 AREA II

A pump test was performed in August 1975 at Area II. The test consisted of a 27-hour drawdown test with one pumping well and two observation wells (Figure 3-12). The test was conducted at a constant pumping rate of approximately 20 gpm. The drawdown in the pumped well at the end of test was about 100 feet which yields a specific capacity of about 0.2 gpm per foot of drawdown. The well efficiency was estimated to be 50%. The Jacobs method was used in the aquifer analyses and the results are listed in Table 3-12.

3.6 SURFACE WATER

The only surface water flowing through the mining area is the Powder River, which flows north. There are no other perennial surface waters in close

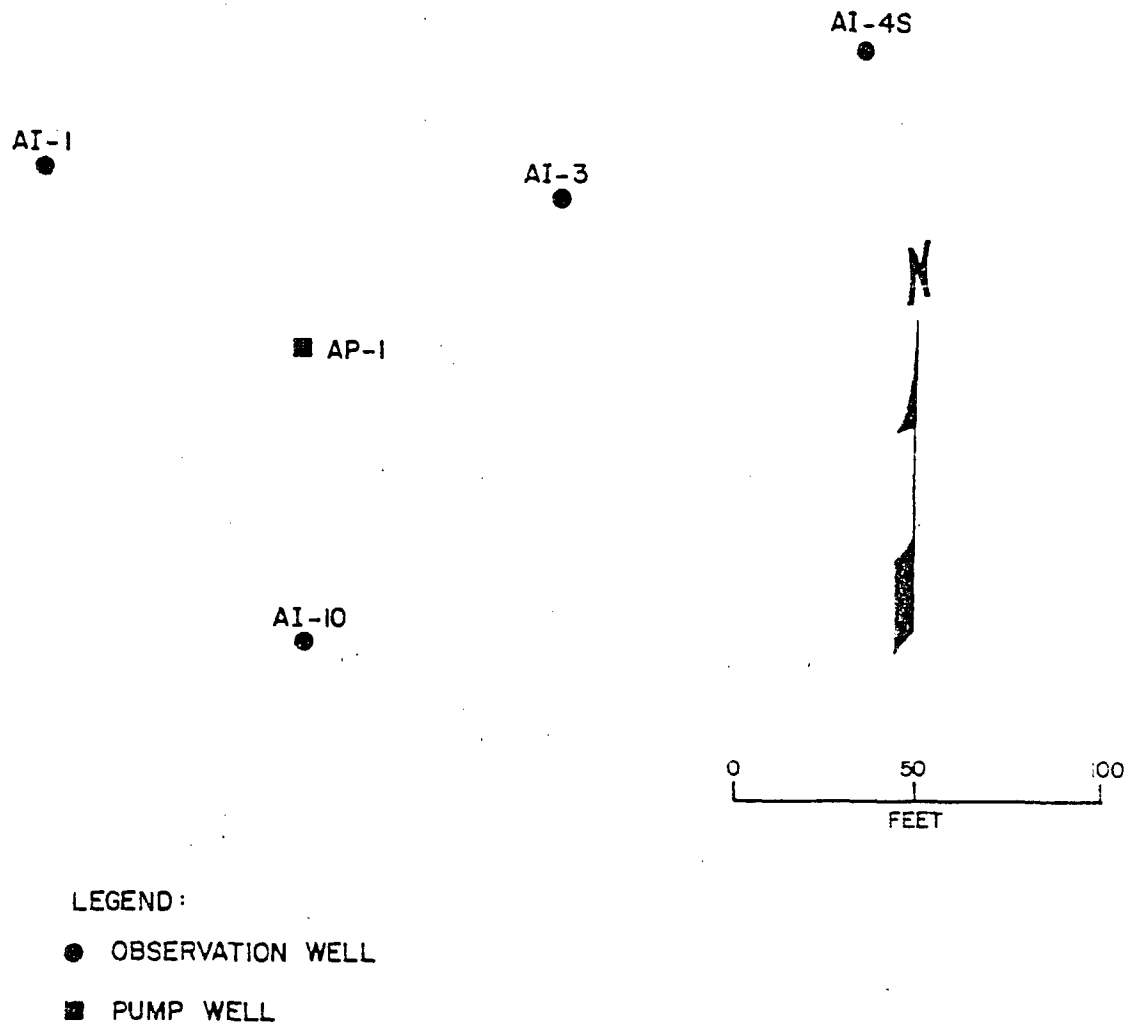


FIGURE 3-11
PROPOSED PRODUCTION SITE PUMP TEST WELLS

TABLE 3-11
RESULTS OF FEBRUARY, 1977, PUMP TEST

Well No.	Transmissivity (gpd/ft.)	Storage Coefficient
AI-1	373	1.0×10^{-5}
AI-3	460	5.0×10^{-5}
AI-4S	770	2.6×10^{-4}
AI-10	400	1.0×10^{-5}

TABLE 3-12
RESULTS OF AUGUST 1975 PUMP TEST AREA II

Well No.	Transmissivity gpd/ft.	Hydraulic Conductivity gpd/ft^2	Storage Coefficient
9I2-1	925	7.71	--
9I2-2	1035	8.63	3.6×10^{-5}
9I2-4	1100	9.17	6.7×10^{-5}

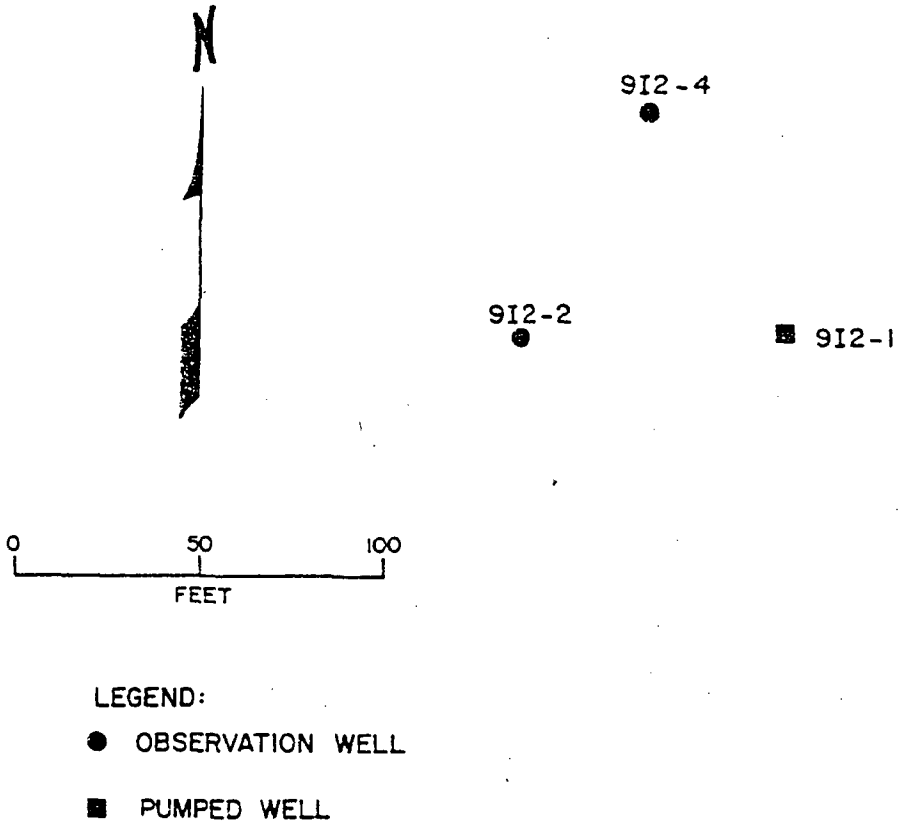


FIGURE 3-12
LOCATION OF WELLS USED IN AREA II PUMP TEST

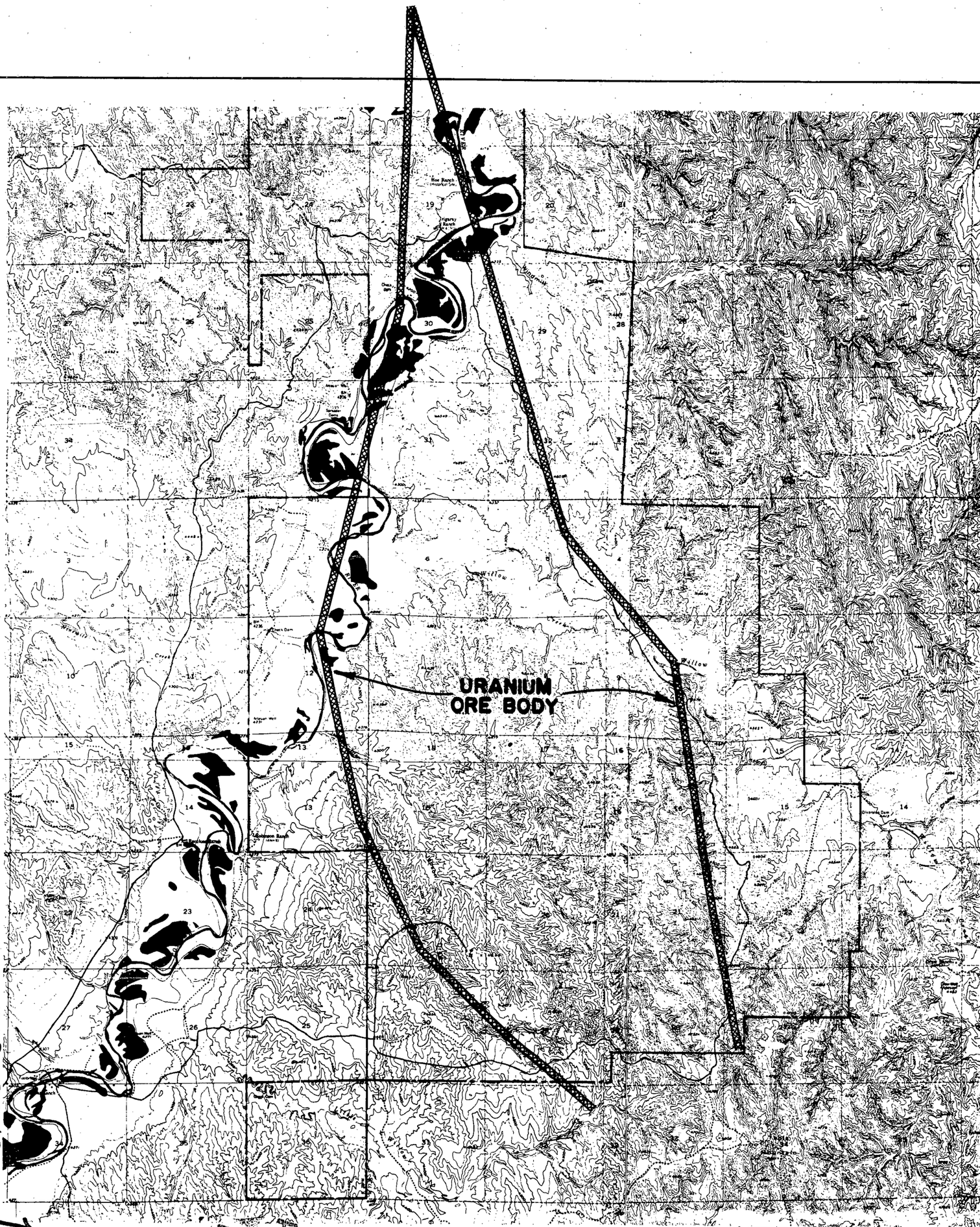
proximity to the proposed activity.

The major agricultural use of surface water in the mining areas is for sheep and cattle. There is no irrigation farming within the area.

Flooding has occurred in several areas of the Powder River Basin due to snowmelt, but these few recorded cases took place more than 50 miles north and south of the mining area.

The WMC uranium deposit crosses the Powder River in the northernmost part of the mining area, as shown in Figure 3-13. The solution mining technique will allow the mining of all the uranium close to the river without interfering with the natural flow. Chemical quality for the Powder River is shown on Figure 3-14. The stream gauging stations for the Powder River Basin are located and identified by station number in Table 3-13. There are no gauging stations on Willow Creek since it is an intermittant stream. Table 3-14 lists data for Powder River up and downstream from the proposed site.

The chemical quality of the river changes continuously, with most changes being related to the amount and source of water in the stream at any particular time. During periods of high flow, most of the streamflow is from snowmelt and/or precipitation. During periods of low flow, most of the streamflow is water that has entered the stream from the groundwater reservoir. This water generally has a higher mineral content than sur-



SCALE 1:24000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

WYOMING

WYOMING MINERAL CORPORATION		
IRIGARAY ORE BODY		
DWN:	FIGURE 3-13	REV
CHKD:		
APRD:		
SCALE:	SHEET OF	

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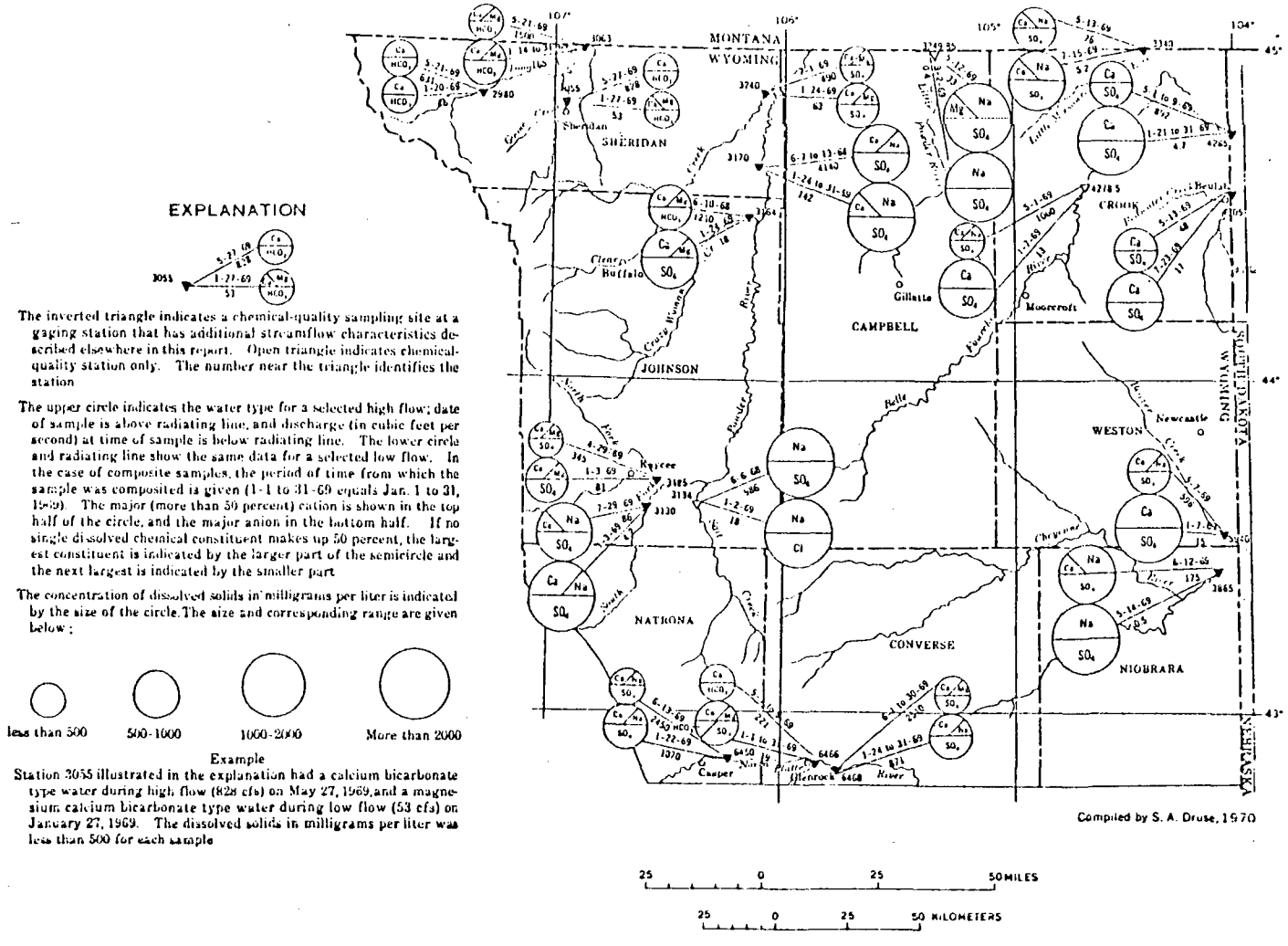


Figure 3-14: Quality of Water Stations and Selected Chemical Analyses

TABLE 3-13
STREAM GAUGING STATIONS

STATION NO.	DESCRIPTION	DRAINAGE AREA (SQ. MILE)	DISCHARGE (CFS) RANGE	AVERAGE	MAXIMUM INSTANTANEOUS
3095	Middle Fork Powder River near Kaycee	450	46.8 - 105	67.4	1,610
3164	Crazy Woman Creek at upper station near Arvada	945	14.6 - 80.3	not determined	15,800
3125	Powder River near Kaycee	980	57.7 - 217	126	5,230
3130	South Fork Powder River near Kaycee	1,150	15.5 - 109	37.6	35,500

TABLE 3-14
WATER QUALITY DATA FOR THE POWDER RIVER,
UPSTREAM AND DOWNSTREAM FROM WMC IRIGARAY PLANT SITE

Analysis	Unit	Upstream	Downstream
As	ppb	5.0	6.5
Ba	ppm	0.30	0.33
B	ppm	0.71	0.60
Cd	ppb	7.0	7.0
Cr	ppb	14.	36.
Cu	ppb	12.	28.
Mn	ppm	0.05	0.27
Hg	ppb	0.40	0.27
Ni	ppb	30.	52.
Se	ppb	<5.	<5.
Ag	ppb	6.	<5.
Zn	ppb	0.03	0.09
Pd	ppb	42.	62.
TDS	ppm	2090.	2110.
Ra 226	pCi/l	0.9 ± 0.5	1.0 ± 0.5
Gross Alpha	pCi/l	19 ± 7	13 ± 6
Gross Beta	pCi/l	46 ± 17	42 ± 17

face runoff because it has been in contact with soil and rock for a longer period of time and has accumulated larger amounts of dissolved minerals.

Willow Creek is the only major intermittent stream flowing through the mining area, but is normally dry. Flood frequency of the creek can be calculated from Figures 3-15, 3-16, and 3-17. Using Figure 3-15, the Willow Creek drainage area is estimated to total approximately 96 square miles and is located in Flood-Frequency Region E, Hydrologic Area 9. In Figure 3-16, the curve for Hydrologic Area 9 results in a mean annual flood rate of 680 cfs, which corresponds to the 96-square-mile drainage area. In Figure 3-17, the flood-frequency curve for Region E gives a discharge ratio of 8.8 for a 50-year recurrence interval. Applying these figures, the estimated discharge of a flood with a 2 percent $\frac{1}{50}$ x 100 chance of occurring once every 50 years is: 680 x 8.8 = 5,944 cfs.

A flash flood of approximately 6,000 cfs would temporarily stop transportation on the dirt road traversing the mining area.

3.7 METEOROLOGY & CLIMATE

The Powder River Basin is representative of a cold, dry (semi-arid) climate, with a cold, dry winter and hot, dry summer Appendix E). While the annual temperature averages about 44.6^{o}F, temperature extremes range between -40°F, -30°F and 70°F in winter to 5°F, 10°F and 100°F to 105°F in summer.

EXPLANATION

3170
▲ 0.045

Active (1967) stream-gaging station

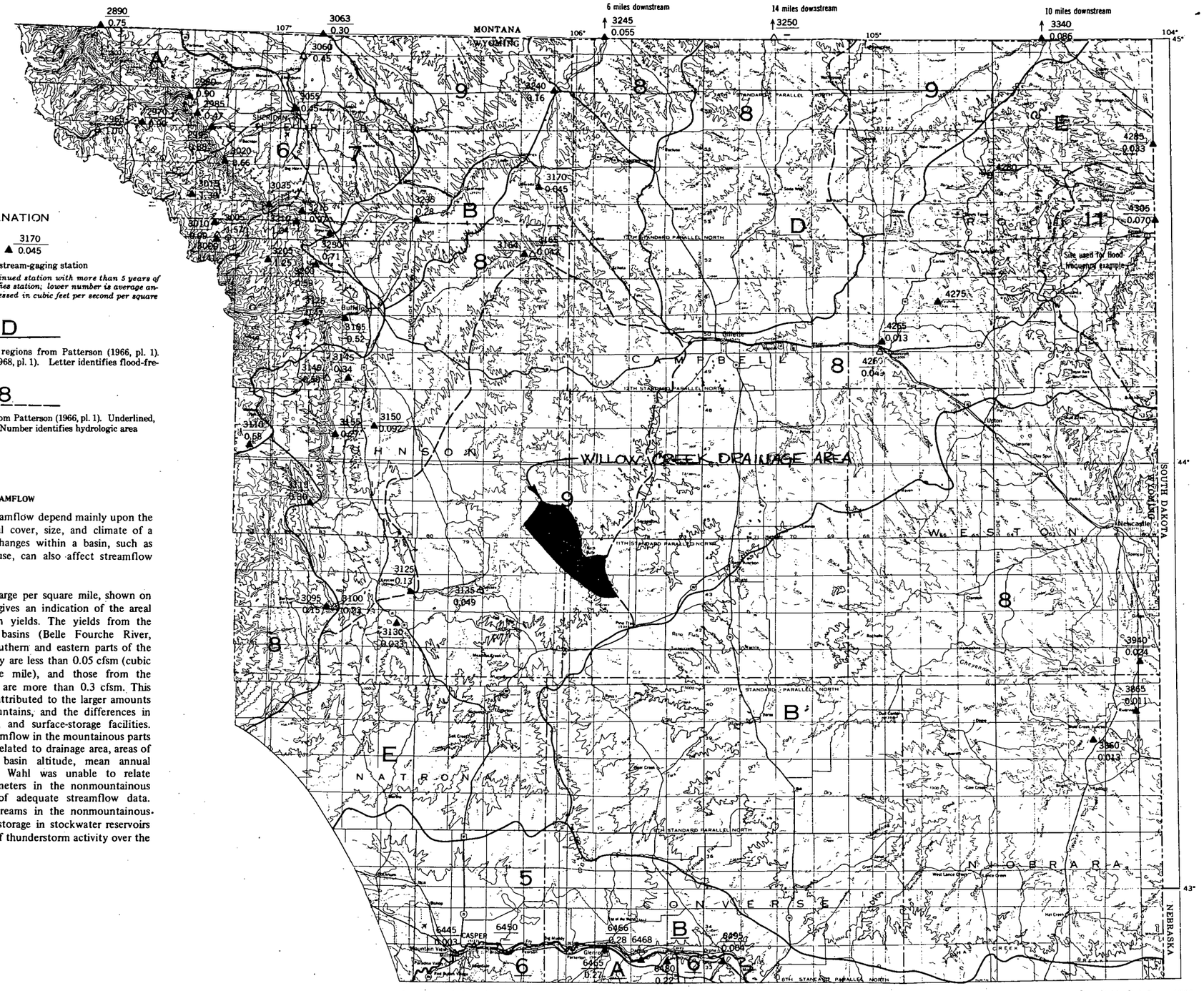
Open triangle indicates discontinued station with more than 5 years of record. Upper number identifies station; lower number is average annual runoff at the station expressed in cubic feet per second per square mile of drainage area

D

Boundary of flood-frequency regions from Patterson (1966, pl. 1). Underlined, from Matthai (1968, pl. 1). Letter identifies flood-frequency region

8

Boundary of hydrologic areas from Patterson (1966, pl. 1). Underlined, from Matthai (1968, pl. 1). Number identifies hydrologic area



Base from U.S. Geological Survey 1:500,000, 1967

Compiled by S. A. Druse, 1969

SCALE 1:750 000

10 0 10 20 30 40 MILES

10 0 10 20 30 40 50 60 KILOMETERS

CONTOUR INTERVAL 500 FEET
DATUM IS MEAN SEA LEVEL

FIGURE 3-15

STREAM-GAGING STATIONS, MEAN ANNUAL DISCHARGE, FLOOD FREQUENCY REGIONS, AND HYDROLOGIC AREAS

STREAMFLOW

The characteristics of streamflow depend mainly upon the geology, topography, vegetal cover, size, and climate of a drainage basin. Manmade changes within a basin, such as dams and change of land use, can also affect streamflow characteristics.

The average rate of discharge per square mile, shown on the map for each station, gives an indication of the areal variability of drainage basin yields. The yields from the nonmountainous drainage basins (Belle Fourche River, Cheyenne River, and the southern and eastern parts of the Powder River Basin) generally are less than 0.05 cfsm (cubic feet per second per square mile), and those from the mountain stations generally are more than 0.3 cfsm. This difference can generally be attributed to the larger amounts of precipitation in the mountains, and the differences in storm patterns, topography, and surface-storage facilities. Wahl (1970) found that streamflow in the mountainous parts of Wyoming is significantly related to drainage area, areas of lakes and ponds, mean basin altitude, mean annual precipitation, and latitude. Wahl was unable to relate streamflow to similar parameters in the nonmountainous parts because of a lack of adequate streamflow data. However, discharge from streams in the nonmountainous areas is greatly affected by storage in stockwater reservoirs and by the variable pattern of thunderstorm activity over the area.

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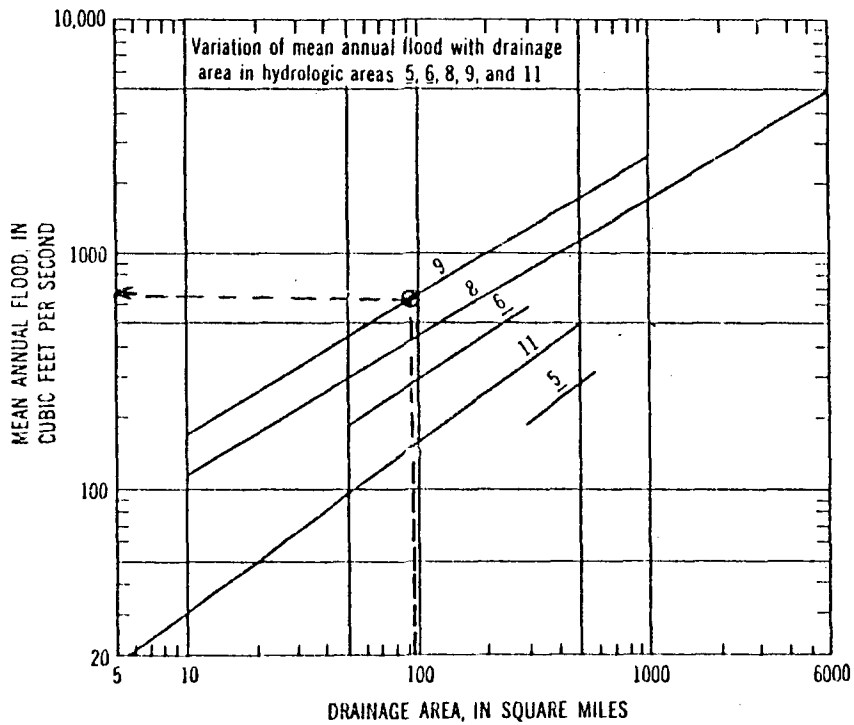
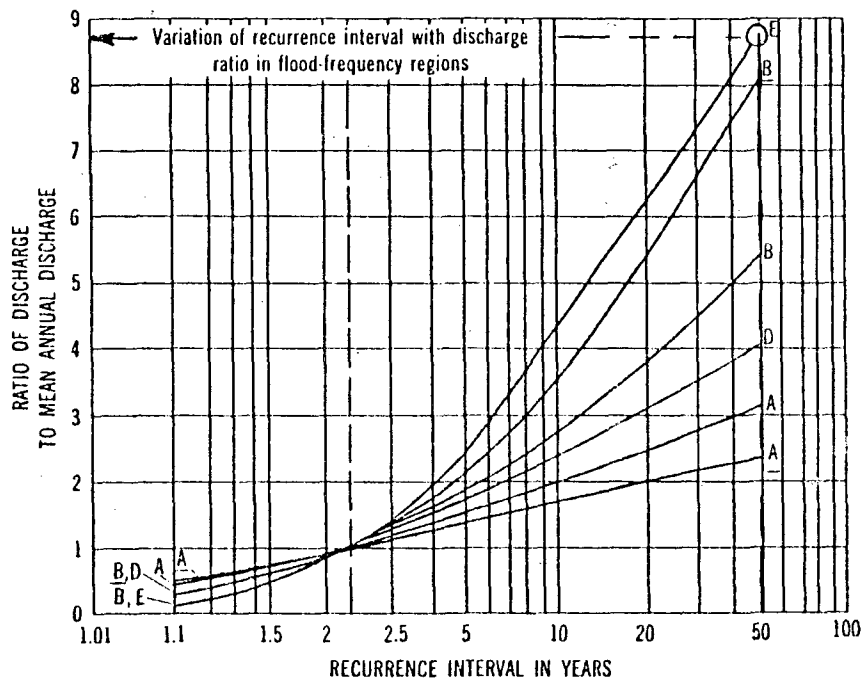




GRAPHS USED IN COMPUTING FLOOD FREQUENCY

FIGURE 3 - 16

FIGURE 3 - 17

Normal annual precipitation is between 11 and 16 inches. Spring is the season of maximum precipitation and, coupled with its transitional nature (rain versus snow, etc.), creates a period of transportation difficulty. Wide fluctuations exist in the seasonal and diurnal temperatures (ambient). Summer extremes produce temeratures above 100°F; the winter produces minimums in excess of -25°F. Precipitation varies between 7 and 19 inches with a mean of 12 inches per year (10 year average).

Prevailing winds are westerly, with average velocities between 8 and 13 mph; however, winds of 75 mph have been recorded. Winter winds are normally higher than summer winds, and this creates a significant wind-chill effect. A wind rose (Figure 3-18) for Sheridan, Wyoming is enclosed representing wind data correlatable with site data presently being collected.

3.8 ECOLOGY

3.8.1 VEGETATION

The vegetation cover of the Irigary site is characteristic of mid and short grass prairie. Carrying capacity and productivity vary, depending on aspect, slope, soil type, temperature, precipitation and grazing pressure. Specific range site classifications are supplied in Appendix F.

Vegetation in the study area consists of a series of intergradating sagebrush and sagebrush-grass associations. A compilation of the major

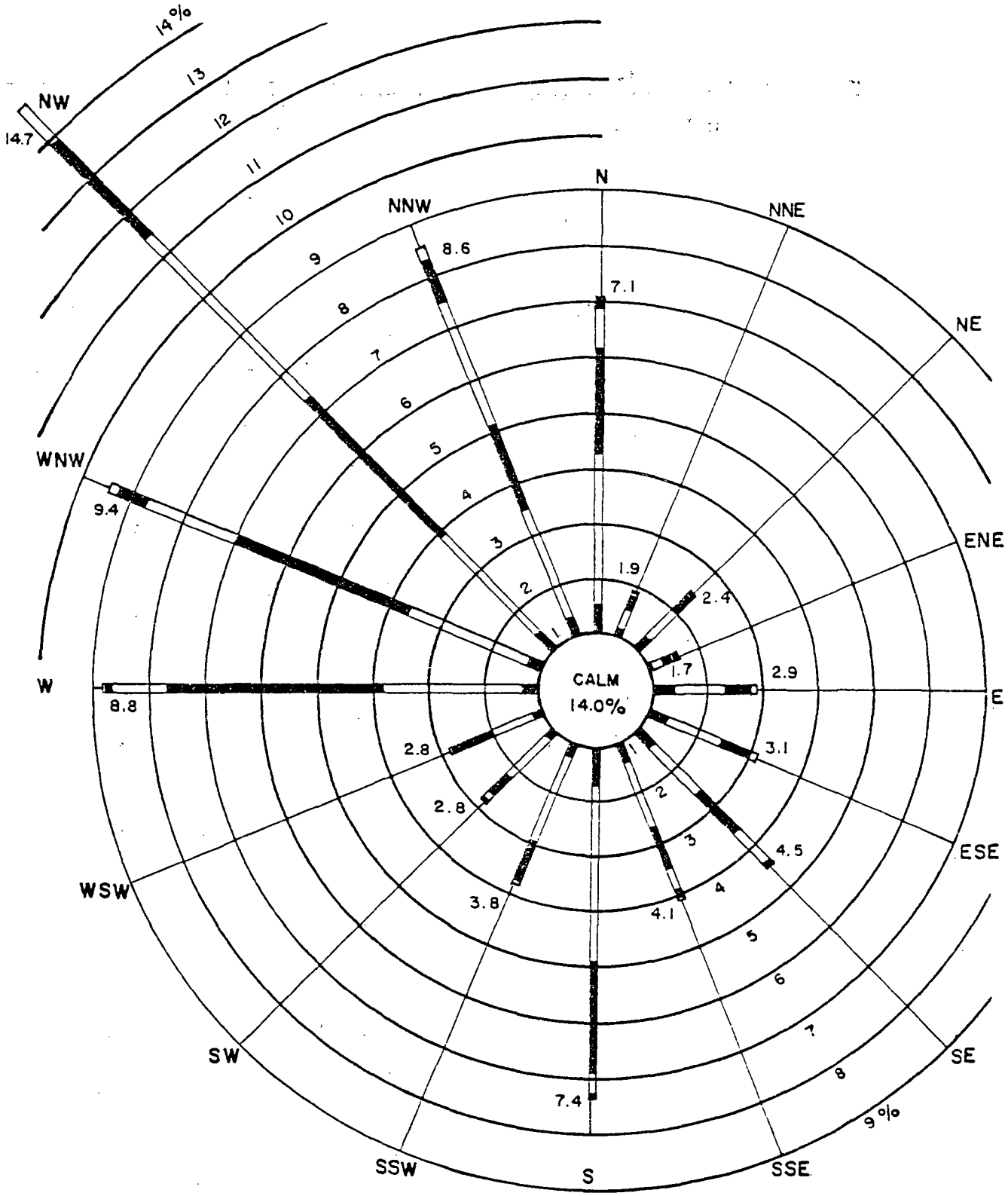
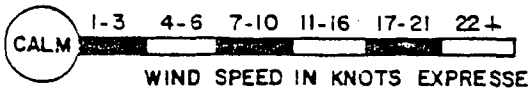


FIGURE 3-18: ANNUAL WIND ROSE - SHERIDAN, WYO.



WIND SPEED IN KNOTS EXPRESSED AS A PERCENTAGE OF LENGTH OF GRAPHIC BAR

PERCENT RINGS ARE A PERCENTAGE OF DIRECTIONAL WIND FLOW FOR A TWO YEAR PERIOD (JAN 1975 - DEC 1976)

plant species observed is found in Table 3-15. Vegetation within the study area is consistent with that found on eastern short-grass prairies of Wyoming except for big sagebrush (Artemisia tridentata), which is more abundant in the project area. Vegetative cover of the study area varied greatly. Three 10 hectare plots were sampled by a stratified sampling technique. Average cover was 57 percent and ranged from 0 to 78 percent.

There is no commercially merchantable timber within the study area. Trees are generally confined to areas along the Powder River and Willow Creek where water is available. The plains cottonwood (Populus sargentii) is the dominant tree cover. Some stands of willow (Salix sp.) are also present in bottom areas.

3.8.2 GRAZING AND PRODUCTIVITY

The Bureau of Land Management District Office in Buffalo, Wyoming has cumulative grazing records for the Irigaray area. The average yearly acreage required to provide one animal unit month (AUM) is 9 acres. Assuming a total area of distribution of 1,000 acres over the 10-year life of the mine, the proposed operation will displace approximately 11 AUM's per year of activity. Areas of active mining, facility buildings, and evaporation ponds will be fenced to exclude livestock. After mining, affected areas will be revegetated and returned to agricultural land use.

3.8.3 WILDLIFE

3.8.3.1 BIG GAME

Table 3-15: Major plant species observed within T44N, R77W.

Species	Common Name
Agropyron smithii	Western Wheat Grass
Alopecurus carolinianus	Caroloina Foxtail
Artemisia cana	Silver Sagebrush
Artemisia pedatifida	Birdfoot Sagewort
Artemisia tridentata	Big Sagebrush
Atriplex argentea	Tumbling Sagebrush
Bouteloua gracilis	Blue Grama Grass
Bromus tectorum	Cheatgrass Brome
Carex douglasii	Douglas Sedge
Carex filifloria	Threadleaf Sedge
Chrysothamnus visicidiflorus	Rabbitbrush
Distichlis spicata	Inland Saltgrass
Eleocharis acicularis	Slender Spikerush
Eriogonum annuum	Wild Buckwheat
Eriogonum ovalifolium	Cushion Buckwheat
Franceria discolor	Skeleton-leaf Bursage
Hordeum jubatum	Foxtail Barley
Koeleria cristata	Prairie Junegrass
Opuntia polyacantha	Plains Prickly Pear
Poa ampla	Big Bluegrass
Poa pratensis	Kentucky Bluegrass
Populus sargentii	Plains Poplar
Salix Sp.	Willow
Salsola kali	Russian Thistle
Stipa comata	Needle and Thread Grass
Yucca glauca	Soapweed

The most prominent big game animal of the Powder River Basin is the pronghorn antelope. The Wyoming Game and Fish Commission (WGFC) antelope distribution maps[4] list the entire area of proposed operations as "year long" habitat for antelope. This classification is defined as a "geographic area occupied by all or a portion of the population for the entire year." This habitat type extends from Interstate 25 on the west to approximately the Range 77-76W boundary on the east, and from Interstate 90 on the north to the Township 41-42N boundary on the south. An area of "W/Y combination" habitat occurs approximately 6 miles east of the site. This range may support antelope in either during "winter" (November - May), or "year long".[5]

During ecological field studies (November, 1974 to April, 1975), an average of 75 antelope were sighted per day of investigation. About 17 bucks were sighted per 100 does (Appendix G).

The area of activity is in the approximate center of WGFC Pumpkin Buttes Management Area, No. 23. Herd composition studies for the years 1969-1972, and 1974-1976 are summarized in Table 3-16.[6] Antelope counts are usually made between July 15 and August 15. These data indicate that natural recruitment (as evidenced by fawns per 100 does) decreased slightly from 1969 to 1976, while bucks per 100 does has remained relatively constant.

WMC activities will exclude antelope from the site proper, and some secondary displacement may occur in the immediate area of operations.

Mule deer numbers sighted during the field work numbered from 7 to 22

TABLE 3-16
SUMMARY OF ANTELOPE HERD COMPOSITION STUDIES, 23-PUMPKIN BUTTES MANAGEMENT AREA

YEAR	BUCKS NO.	BUCKS %	DOES NO.	DOES %	FAWNS NO.	FAWNS %	TOTAL CLASS.	BUCKS/DOES/FAWNS	FAWNS PER 100 ADULTS
1969	70	9%	331	41%	412	51%	813	21 / 100 / 124	103
1970	142	16%	351	39%	412	46%	905	40 / 100 / 117	84
1971	120	17%	282	41%	287	42%	689	43 / 100 / 100	71
1972	297	16%	875	46%	730	38%	1,902	34 / 100 / 83	64
1973	No classification								
1974	276	16%	685	41%	701	42%	1,653	39 / 100 / 102	74
1975	237	17%	571	41%	581	42%	1,389	42 / 100 / 102	72
1976	125	17%	311	43%	282	39%	718	40 / 100 / 91	65

individuals, with an average of about 10 per day sighted. Deer are usually restricted to the areas along the Powder River and Willow Creek, and in sagebrush draws. Mule deer are also an important big game species.

The Irigaray Site is located in Management Unit 19 for mule deer as designated by WGFC. Riparian areas and sagebrush draws provide habitat for mule deer in this region. WGFC classification counts for 1972-1973, and 1975-1976 are shown in Table 3-17.[6] These counts are usually made between December 1 and January 10.

3.8.3.2 SMALL GAME

The primary small game species of the project areas are cottontail rabbits and sage grouse. These species receive moderate hunting pressure in the fall. The migratory morning dove also receives seasonal hunting pressure.

Sage grouse density has been estimated by the Wyoming Game and Fish Department at about 2 birds per square mile. Sage grouse are dependent on grasses and forbes (especially in spring and summer) and a water supply. The operations of the project should not infringe on areas of critical habitat.

Migratory waterfowl use the Powder River and its tributaries; and the stock watering ponds of the area. Sufficient nesting habitat is lacking, however.

TABLE 3-17
POST-SEASON MULE DEER CLASSIFICATION SUMMARY, AREA 19

YEAR	BUCKS NO.	BUCKS %	DOES NO.	DOES %	FAWNS NO.	FAWNS %	TOTAL CLASS.	BUCKS/DOES/FAWNS	FAWNS PER 100 ADULTS
1972	14	5%	145	48%	140	48%	299	10 / 100 / 88	88
1973	No classification								
1974	No classification								
1975	28	9%	133	43%	152	49%	313	21 / 100 / 144	94
1976	9	8%	59	56%	38	36%	106	15 / 100 / 64	55

3.8.3.3 NON-GAME

A total of 92 species of mammals was observed on the study site. Peromyscus spp. represented 91% of the 217 rodents captured. No prairie dogs were sighted on the project area.

Signs of mammalian predators observed on the site included coyote, badger, long-tailed weasels, red foxes, and bobcat. Raptors were represented by 7 species of hawks, 2 species of owls, and the turkey vulture. A complete list of birds observed appears in Appendix G.

3.8.3.4 THREATENED AND ENDANGERED SPECIES

No animals listed by the Fish and Wildlife Service as "Threatened or Endangered" (Bur. Nat. Aff. Sec. 17.11(h), March 3, 1977) were observed in the project area. There is potential habitat for black-footed ferrets in the Powder River Basin area in or near prairie dog towns. The absence of prairie dogs on the Irigaray site makes the presence of ferrets there highly unlikely.

3.9 RADIOLOGICAL BASELINES OF SOIL AND VEGETATION

Representative pre-production samples of soil and vegetation were collected from the immediate site environment in November, 1976. Analysis is indicated in Table 3-18.

TABLE 3-18
NOVEMBER 1976 RADIOLOGICAL BASELINES

	Det.	Gross α	Gross β	Ra 226	U_3O_8	Air Dry Loss	Ash 550°C
	Est.	pCi/g	pCi/g	pCi/g	%	%	%
IRSI-1 (1)	1	4.8±3.8	46±15	1.0±1.5	<0.0003	<0.4	
IRSI-2 (2)	2	24±8	19±16	0.6±1.2	<0.0003	<0.1	
IRV-1 (3)	3	1.3±2.6	18±14	0.34±0.47	<0.0001	<2	34
IRV-2 (4)	4	1.9±2.8	43±15	0.46±0.63	<0.0001	<4	42

KEY

(1) IRSI-1 = Soil sample taken just off dirt road adjacent to test site well field.
(2) IRSI-2 = Soil sample taken approximately 50 yards NE from center of production plant construction site.
(3) IRV-1 = Vegetation taken as IRSI-1 above.
(4) IRV-2 = Vegetation taken as IRSI-2 above.

SECTION 4.0

WELL FIELD AND PROCESS

4.1 WELL FIELD

4.1.1 SPECIFIC LOCATION

The Irigaray Project lies in Sections 4, 5, 9, and 16 of T45N, R77W and in Section 32 of T46N, R77W. The initial well field, field A, and the next planned well fields B, C, D, and E are shown in Figure 4-1. The subsequent well fields will be laid out straddling the roll fronts as described in Section 2.5.

4.1.2 GEOLOGIC CHARACTERISTICS

See Section 3.4.

4.1.3 WELL FIELD GROUNDWATER CHARACTERISTICS

Water quality data established to date for individual wells at the Irigaray mine site is illustrated in Table 4-1 for three basic zones; the production zone, the trend zone and the monitor well zone. A preliminary summary description of the characteristics of the water found in the aquifer at the Irigaray mine site is found in Table 4-2. The water contains approximately 350 to 400 ppm total dissolved solids, the majority of which is sodium sulfate.

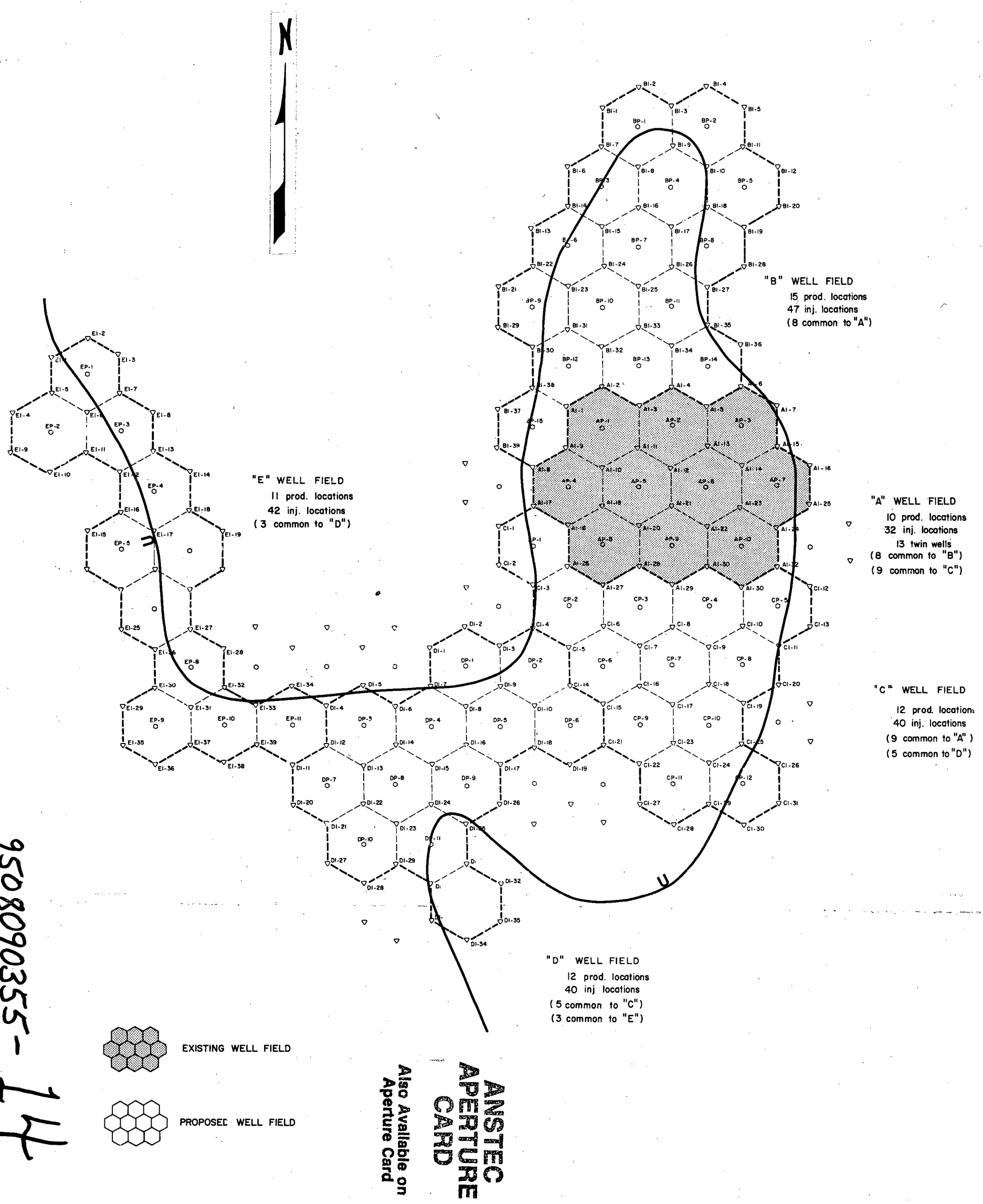


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FIGURE 4-1: WELL FIELD LOCATIONS

TABLE 4-1

Individual Well Water Quality Data
Irigaray, Wyoming

	Trend Well Zone					Production Well Zone				Monitor Well Zone				
	T1	T2	T3	T5	T6	P3	P4	P5	P10	M1	M2	M3	M4	M5
NH_4	<.2	0.24±.07	<.2	<.2	<.2	0.18±0.05	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.24±.07
As	0.01±.001	0.01±.002	<.01	.01	<.010	0.10±0.01	.09±.01	<.01	<.010	<.010	.010	.01±.002	.01±.01	.01±.00
Ba	0.01±.0004	0.02±.003	<.01	.02	.01	0.01±3.2	.02±.01	0.03±0.01	.02±.004	.02±.01	.02±.01	.02±.02	.02±.01	.04±.02
HCO_3	89.5±10.0	9.1±4.8	66.8±5.5	67.4±14.6	80.3±5.4	80.70±12.16	90.5±18.6	38.3±27.9	86.1±11.0	42.1±57.2	68.2±27.0	92.1±3.9	44.3±40.2	72.5±21
B	0.05±.01	0.02±0.01	0.05±0.01	.05±.01	.05±.01	0.12±0.07	.10±.02	0.10±0.03	.10±.04	.06±.02	.07±.02	.06±.01	.05±.02	.05±.02
Cd	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Ca	7.0±0.8	1.9±0.74	5.2±0.9	5.1±1.3	6.7±.3	7.88±1.15	10.5±2.4	2.8±1.77	7.5±1.0	3.4±2.5	3.0±1.7	4.5±.9	3.8±3.0	6.5±.9
CO_3	4.1±3.5	17.0±15.8	9.5±8.6	11.2±5.9	6.9±7.0	5.93±6.90	5.3±4.9	19.4±8.29	4.2±5.5	18.8±5.7	4.0±11.2	6.1±6.8	14.0±7.7	4.1±6.0
Cl	11.4±1.1	12.1±1.5	12.2±1.3	13.2±1.9	12.7±1.5	11.62±1.84	9.7±4.8	11.94±1.83	12.5±2.1	17.0±7.2	12.5±1.0	12.1±1.3	12.4±1.4	17.6±9.
Cr	<.002	<.002	.002±.001	<.002	<.002	<.002	<.002		.004 .004	<.002	<.002	<.002	<.002	.003±.0
Cond	647±45.6	647±51	624±68	595±30.4	620±60	613±6.5	613±56.7	618±16.7	589±10.3	665±74	624±28	571±25	607±41	610±25
Cu	.005±.001	.006±.002	.08±0.14	<.005	<.005	<.005	.01±.002	.006±.002	<.005	.006±.002	<.005	<.005	<.005	.01±.00
F	.25±.05	0.24±.03	.29±.05	.31±.04	.25±.03	.38±.20	.33±.02	0.28±.02	.29±.03	0.23±.04	0.29±.01	.28±.04	.23±.01	.22±.03
Gross A	38.7±39.0	1.7±11.0	5.2±4.3	4.3±3.9	5.3±7.4	1496±462	6341±3353	122.4±139.2	389±202	4.0±4.3	2.9±3.4	19.4±14.2	3.5±5.5	4.4±6.5
Gross B	69.1±101.3	107.3±167.1	100.4±137.3	81.2±114.8	39.8±85.1	493.3±477.3	1644±1621	117.8±208.4	143.6±185.8	65.9±104.8	63.2±123.8	66.6±126.0	80.4±160.0	102.0±1
$CaCO_3$	90.3±1.5	95.4±5.4	81.3±2.1	91.3±2.2	93.1±4.9	93.9±2.8	102.2±3.6	88.9±4.9	93.9±2.8	97.9±5.4	107.9±13.0	93.7±6.4	87.1±2.5	96.2±12
Fe	0.15±0.08	0.13±.07	0.21±0.12	.12±.10	.10±.02	.30±.22	.21±.25	0.18±0.11	1.05±.73	0.19±0.11	.12±.05	.12±.06	.09±.08	.38±.32
Pb	<.002	.003±.003	<.002	.004±.002	.02±.04	.006±.003	<.002	<.002	.004±.003	.01±.02	.003±.002	.01±.004	.003±.002	.004±.0
Mg	1.01±0.11	0.2±.08	0.39±0.08	.51±.16	.72±.03	.80±0	1.0±.14	0.14±0.08	1.00±.14	.27±.23	.38±.17	.51±.12	.33±.27	.48±.26
Mn	<.025	<.025	<.025	<.025	<.025	<.025	<.025	<.025	.03±.01	<.025	<.025	<.025	<.025	<.025
Hg	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002	<.0002
Mo	<.02	<.02	<.02	<.02	<.02	<.02	.02±.01	<.02	<.02	.03±.01	<.02	<.02	<.02	<.02
Ni	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.2	<.2	<.2	<.2	<.2	<.2
NO_3	0.54±0.14	0.35±0.10	0.32±0.14	.91±1.35	.40±.07	.40±.10	0.58±0.10	0.32±0.09	.38±.08	.55±.19	.57±.25	.53±.27	.42±.14	.78±.65
NO_2	0.29±0.24	<.02	0.13±0.22	.11±.18	.31±.21	.08±.12	<.02	<.02	.08±.11	<.02	.03±.02	.13±.23	.04±.03	<.02
pH	8.71±0.16	10.22±0.97	9.04±0.45	9.13±0.45	8.78±.28	8.65±0.27	8.79±0.26	9.94±0.43	8.59±0.35	9.80±1.00	9.31±.74	8.69±.31	9.51±.81	8.31±1.
K	1.6±0.2	5.6±1.00	2.1±0.3	1.9±0.1	1.7±0.1	2.3±.2	2.2±.3	4.3±0.89	1.9±0.3	3.9±1.6	2.0±.40	2.0±.9	2.3±.6	2.5±2.2
Ra 226	12.1±12.0	3.0±1.8	.8±.8	2.61±1.7	0.4±0.2	57.3±15.0	144.3±56.	23.5±3.0	28±8.4	6.8±7.4	.7±.7	1.4±.9	.3±.3	1.6±3.1
Se	<.010	<.010	<.01	<.01	<.01	.060±.08	0.73±0.84	.088±.090	.027±.03	.02±.01	.02±.01	<.010	<.010	<.010
Si	2.74±1.63	3.63±0.43	3.70±0.23	3.50±0.21	3.54±0.30	3.81±.06	4.38±0.17	3.61±0.38	3.54±.20	3.75±.06	3.86±.46	3.54±.41	3.73±.42	3.55±0.
Ag	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Na	129±5.8	128±5.3	126±3.4	121±6.5	129±5.3	128.5±3.9	131±9.4	127.5±2.1	125.0±4.2	130±2.2	127.8±4.4	119.2±4.5	123±2.4	121.0±2
SO_4	182±8.2	209±28.3	181.2±3.3	169.5±10.1	187.6±6.7	193.3±6.2	204.8±4.1	207±23.4	188.0±6.2	173.3±41.2	167.0±6.7	160.1±2.9	188±14.5	173.3±8
TDS	355±25.8	340±32	356±20.4	356±36.3	362.4±29.2	376±15.1	399.5±25.7	340±23.8	382±23.2	393±8.8	361±22.6	333±24.3	330±24.3	364±26
Th 230	0.2±.1	0.15±0.17	0.3±0.2	0.2±0.1	.5±.4	1.0±.42	9.0±14.7	0.2±0.2	3.3±3.3	0.9±1.6	.1±.09	.23±.45	.1	.08±.05
V	<.05	<.05	<.05	<.05	<.05	.06±.02	.34±.15	0.10±0.01	.06±.01	<.05	<.05	<.05	<.05	<.05
U_3O_8	0.03±.05	0.02±0.02	0.02±0.01	.02±.01	.01±.01	3.85±0.88	13.57±3.79	0.39±0.12	1.16±0.33	.05±.02	.05±.04	.10±.08	.04±.04	.02±.00
Zn	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	.02±.01	.02±.01	.02±.01	.02±.01

Table represent mean values with estimate of standard deviation with N=5. Samples taken from 11/9/76 to 2/24/77.

< indicates all data below detectable limits.

All data reported as ppm or mg/l (Ra 226 and Th 230 as pCi/l).

TABLE 4-2
PRELIMINARY WATER VALUES FOR 100 GPM IRIGARAY TEST SITE*

ppm/mgl	WATER IN MINERALIZED ZONE	TREND WELLS ZONE (1st Ring) Approx. 200 Dist.	MONITOR WELLS ZONE (2nd Ring) Approx. 450'-700' Dist.
NH_4	<.2	<.2	<.2
As	<.01	<.01	<.01
Ba	.033	.014	.02
HCO_3	74.02	62.59	63.89
B	.1	.04	.058
Cd	<.002	<.002	<.002
Cu	.006	.006	.005
CO_3	8.68	9.72	12.02
Cl	11.42	12.31	14.62
Cr	<.002	<.002	<.002
Cond.	6.08×10^2	6.25×10^2	6.11×10^2
Ca	7.15	5.17	4.16
F	.30	.26	.23
$CaCO_3$	94.7	90.28	96.56
Fe	.43	.14	.18
Pb	.003	.002	.005
Mg	1.04	.56	.39
Mn	<.025	<.025	<.025
Hg	<.0002	<.0002	<.0002
Mo	<.02	<.02	<.02
Ni	<.2	<.2	<.2
NO_3	.41	.39	.54
pH	8.98	9.36	9.39
K	2.66	2.57	2.81
Se	.62	.01	.01
Ag	.002	.002	.002
Na	128.31	124.58	124.10
Si	3,82	3,52	3.68
SO_4	198.25	185.06	172.72
TDS	374.25	358.53	362.20
V	.138	.05	.05
U_3O_8	4.73	.04	.06
Zn	.02	.02	.02
Th-230	3.35 ± 1.2	0.2 ± 0.4	0.2 ± 0.4
Ra-226 pCi/l	63.25 ± 8	3.4 ± 1.1	1.4 ± 0.7

*Values represent average of 4 to 5 wells only, sampled four times over a 30-day period for each zone. Baseline will be well specific and include seasonal variability. Baseline has not yet been determined.

In relation to the peripheral zones the mineralized zone is higher in Bicarbonate, Calcium, Iron, Magnesium, Radium, Selenium Sulfate, Thorium, Vanadium and Uranium. The presence of many of these parameters would classify this water zone as non potable. Conversely, the mineralized zone contains less Carbonate and Chloride and exits at a lower pH.

The trend and monitor wells, located outside the zone of mineralization at varying distances, with the trend wells no greater than 200 feet from mineralization and monitor wells no greater than 1000 feet are very similar in water characteristics except that in general, carbonate levels and pH appear to be greater in the monitor well zone but still higher than the mineralized zone. Chloride, Calcium, Sulfate and Radium are higher in the trend wells and decrease in value from the mineralized zone to the monitor well zone.

4.1.4 WELL COMPLETION

All wells are drilled using a standard exploration-type water drill rig. Both injection and production wells are normally 4", but 2", 5" and 6" wells have been used. The description given applies to both injection and production wells. The wells are drilled with a conventional bit and organic drilling mud. The viscosity and weight of the mud are carefully controlled to provide proper drilling conditions and to avoid migration of the drilling fluid into the surrounding rock. Once the hole is drilled to the expected bottom of the

mineralization the hole is logged (gamma, resistivity, self potential) to determine the exact location of the mineralization and what level(s) open or screened holes are needed. The well is then reamed to accept casing. Based on the results of the logging, the casing length is calculated and the bottom of the casing is assembled with a plastic plug (cap), cement basket, and a section with weep holes.

When the casing is assembled with centralizers and placed in the hole, water is circulated through the casing and into the annulus to remove wall cake in the vicinity of the cement basket. Cement is then pumped into the casing, through weep holes, and into the annulus above the cement basket. Water is used to force most of the cement out of the casing and bring the cement level in the annulus to the surface. The well is then shut-in, checked for leaks, and the cement allowed to harden.

Once the cement has hardened, the cement remaining in the casing is drilled out along with the plastic plug. The part of the well below the casing is then cleaned by circulating water. Following circulation, the well is 'produced' and steam cleaned. Underreaming is used when injectivity is not acceptable.

A cap is put on the injection well so that fluid can be injected into the open interval. Recovery wells are equipped with a downhole pump suspended on a 1" pipe which brings recovered solution to the surface.

4.1.5 INJECTION FLOWS AND PRESSURES AND PRODUCTION FLOWS

Due to the permeability of the mineralized formation in the Irigaray area (Section 3.5) injection flows of 4 to 5 gpm per well at a pressure of 50 - 120 psi are expected. These flow and pressure ranges are based on test plant experience but localized variations in the ore body might increase or decrease them. Other factors, such as hole interval, blinding of the injection well bore, and quality of well completion, impact on the maximum injectivity and the flow/pressure relationship. Injection pressure is mechanically limited so as not to exceed the fracturing pressure of the formation (about 140 psi).

Production rates from recovery wells are expected to range from 8 to 10 gpm. This is based upon the fact that injection is the limiting factor and that in an area of contiguous seven--spots the injection well to production well ratio approaches 2 to 1. The production wells will be run at a flow to balance the injection wells in that particular cell, which may be up to 25 or 30 gpm in an individual seven--spot. With a continuous field, however, the production flow will be in the previously mentioned lower range.

4.2 LIXIVIANT CHEMISTRY

4.2.1 ALTERNATIVES AVAILABLE

There are two major considerations related to selection of a lixiviant for uranium solution mining. First, it must be capable of oxidizing

uranium from the U^{+4} to U^{+6} valance and forming a soluble uranium complex which can be recovered. Second, reaction with the gangue minerals present in the formation, (such as calcite, clays, feldspars, zeolites, pyrites and carbonaceous materials) should be minimal. Both chemical and sorption, either physical or chemical, reactions may occur between the lixiviant and solid host. The consequences of such reactions are alteration of lixiviant composition and/or mobilization of contaminants, which impede aquifer resoration. The two complexing agents most commonly used for uranium solution mining are sulfate ion in the acid leach system, and bicarbonate ion in the neutral or alkaline leach system.

4.2.1.1 ACIDIC LEACH

Better recoveries (85 - 95%) can generally be obtained by the stronger action of the sulfuric acid leach, and oxidation is easily accomplished with a variety of chemical oxidants. However, for insitu applications, the acid leach system tends to be reagent limited due to attack and breakdown of the gangue minerals associated with the uranium deposit. In addition, leaching essentially stops when the solution pH increases above 2 and the uranium sulfate complex hydrolizes and precipitates if the pH increases above 4. This results in the formation of precipitation fronts as the injected acid is consumed and the solution pH rises.

4.2.1.2 BASIC LEACH

Overall, extractions with a bicarbonate lixiviant are generally less

(60 to 70%) than obtainable with sulfuric acid. However, the uranium carbonate complex is stable over a wide pH range (∿ 6 to 10) which includes the natural pH of the aquifer. Although precipitation and absorption fronts may still form, particularly in the high pH range, the influence of chemical front formation on complexed uranium solubility is less critical than with the acid process.

In general, the host minerals are inert to attack by the bicarbonate ion. However, core samples tend to exhibit ion exchange capacity for both anions and cations introduced in the leach solution, generally with a stronger potential for cation exchange. Thus, cations sorbed on the solid phase during leaching will tend to desorb during and after restoration unless they are chemically removed or stabilized.

4.2.1.3 COMPARISON OF ACIDIC AND BASIC LIXIVIANTS

Results of a bench scale comparison of acidic (sulfuric acid) and basic (ammonium bicarbonate) lixiviants are presented in Table 4-3. Although the core samples used in this test were not from Wyoming, the results are indicative of the relative amounts of host mineral attack and trace element mobilization characteristics of the two lixiviants. In both cases, a 24 hour agitation leach of 200 gms of ore with 600 ml of lixiviant was conducted. The spent lixiviant was then filtered to remove residual solids and evaporated to dryness. Trace element analyses of the dissolved solids fraction are presented in terms of both wt. % of total dissolved solids and equivalent concentration in solution. It should be noted that differences in the

TABLE 4-3
COMPARISON OF LIXIVIANTS

	Basic	Acidic
Composition:	8 gpl NH_4HCO_3 + 1 gpl H_2O_2	5 gpl H_2SO_4 + 0.1 gpl $NaClO_3$
TDS Content of Spent Lixiviant	1.0 gms.	7.8 gms.

Trace Element (1)	Wt.% in Evap. Solids	Calc'd. ppm in Lixiviant	Wt.% in Evap. Solids	Calc'd. ppm in Lixiviant
As(2)				
Cu	0.009	0.04	0.026	1.0
Zn	.023	.1	.11	4.3
Pb	.036	.2	.018	.7
Se	.32	1.6		
Fe	.11	.6	.65	25.4
Ni	.011	.06	.016	.6
Sr	.30	1.5	.096	3.7
Zr	.17	.9	.084	3.3
Co			.066	0.2
Cr	.014	.07	.012	.15
Mo	.18	.9		
Mn			.031	1.2
V			.026	1.0
Ra^{226}	3200 pCi	1750 pCi/l	780 pCi	390 pCi/l

Notes: (1) All analyses except Ra^{226} by x-ray fluorescence.

(2) Although not reported here, results of other analyses indicate that Arsenic would be $\leq$ .05 ppm.

trace element content of the dissolved solids, i.e., in terms of wt. %, are variable due to the significant difference (∿ 8 fold) in the TDS content of the two lixiviants. However, with the exception of a Ra^{226} significantly greater trace element mobilization and host mineral attack occurred with the acid lixiviant.

4.2.2 PROPOSED LIXIVIANTS

The considerations outlined above have led to selection of a bicarbonate lixiviant for the proposed solution mining operation. A lixiviant composition of 1 to 5 gpl. of bicarbonate ion and a solution pH similar to that of the host aquifer is planned. Either hydrogen peroxide at 0.25 to 1.00 gpl or dissolved oxygen at 0.10 to 0.75 gpl would be used as the oxidant. Both have the advantage of minimal contaminant addition to the host aquifer.

For the present, it is planned to use ammonium bicarbonate to maintain the indicated bicarbonate strength, since this is the only lixiviant which has been field tested to date. However, due to the observed cation exchange between the lixiviant and host solids, which results in ammonium sorption and calcium mobilization, alternate bicarbonate lixiviants are being evaluated with the objective of reducing the overall cost of solution mining. The results of planned lab and field test work may lead to adoption of an alternative bicarbonate salt to maintain lixiviant bicarbonate strength.

4.3 PROCESS PLANT

4.3.1 IRIGARAY PROCESS BUILDING - APPEARANCE AND CONSTRUCTION

The Irigaray Plant Building facility will house a 500,000 pound per year process plant. The site and core building have been designed to permit expansion to a 1,000,000 pound facility either by replication of the currently planned process system or by the use of satellite systems.

The process building covers 24,000 square feet and is 300 feet long, 80 feet wide and 20 feet high except for a raised section which is 40 feet high, 80 feet wide and 40 feet long. This raised section will accomodate the ion exchange columns which process the pregnant liquor from the process wells.

The building is a standard steel structural framed unit, covered with prepainted steel skin sheets of 24 guage with fiberglass insulated walls and ceilings. The floors are a minimum of 6 inches of reinforced treated concrete with central drain and sump systems to reclaim all plant liquids used in processing, washing, etc. The structure is designed to be expandable to accomodate modifications or process changes during the plant life. As the ore body is mined, new floors and foundations can be prepared and the skid mounted process units and the building moved to other locations in the mining area.

Attached to the process building is a combined office, warehouse and analytical laboratory of 4,800 square feet, measuring 80 feet long, 60

feet wide and 12 feet high. The building's steel framing and skin are identical in specification to the process building. The floors are reinforced concrete. Interior walls are of fire grade drywall with plywood paneling surface.

Septic systems have been built to state approved plans for the process building to handle normal human wastes and the chemical laboratory wastes. Power is supplied by Rural Electrification Administration (R.E.A.) on specially built power lines to meet service requirements. Water is supplied by on site wells drilled specifically to supply plant and process water. The process building is heated by propane space heaters to provide sufficient heat to eliminate equipment freezing. The office, warehouse and laboratories are served by a central heat and air conditioning unit to provide the required temperature levels to maintain comfort.

4.3.2 PROCESS CIRCUIT

See Section 2.4.1.

4.4 WASTES AND EFFLUENTS

4.4.1 SOLID WASTES AND EFFLUENTS

Solid waste will be generated through three principal processes. See Section 2.4.4.

4.4.1.1 CALCITE AND SUPPLEMENTAL CONTAMINANT CONTROL

The estimated quantity of calcite produced is shown in Figure 4-2. Based on test data, the expected Ca/U_3O_8 ratio in recovered solution at Irigaray will be approximately 2.

As the calcite is removed from the process streams, it will be temporarily stored in a lined settling pond. The calcite will be kept under a liquid layer and not available for atmospheric dispersion.

The method of temporary storage of process wastes in lined ponds will be implemented and maintained pending the 1978 conclusions of the NRC final generic environmental impact statement on uranium milling regarding tailings management procedures, at which time a final disposal system will be proposed by WMC for the Irigaray project. In the interim the following disposal alternatives are continuing to be studied:

(1) Transportation to a conventional uranium mill for further processing to remove the remaining contained uranium. The calcite would then be treated as mill waste.

(2) Construction of on-site tailing ponds.

(3) Shipment to a licensed off-site burial grounds.

Of these alternatives WMC proposes that alternative 2 will most probably be a long term action since insitu uranium process wastes are at least comparable to, and on the average, less toxic than

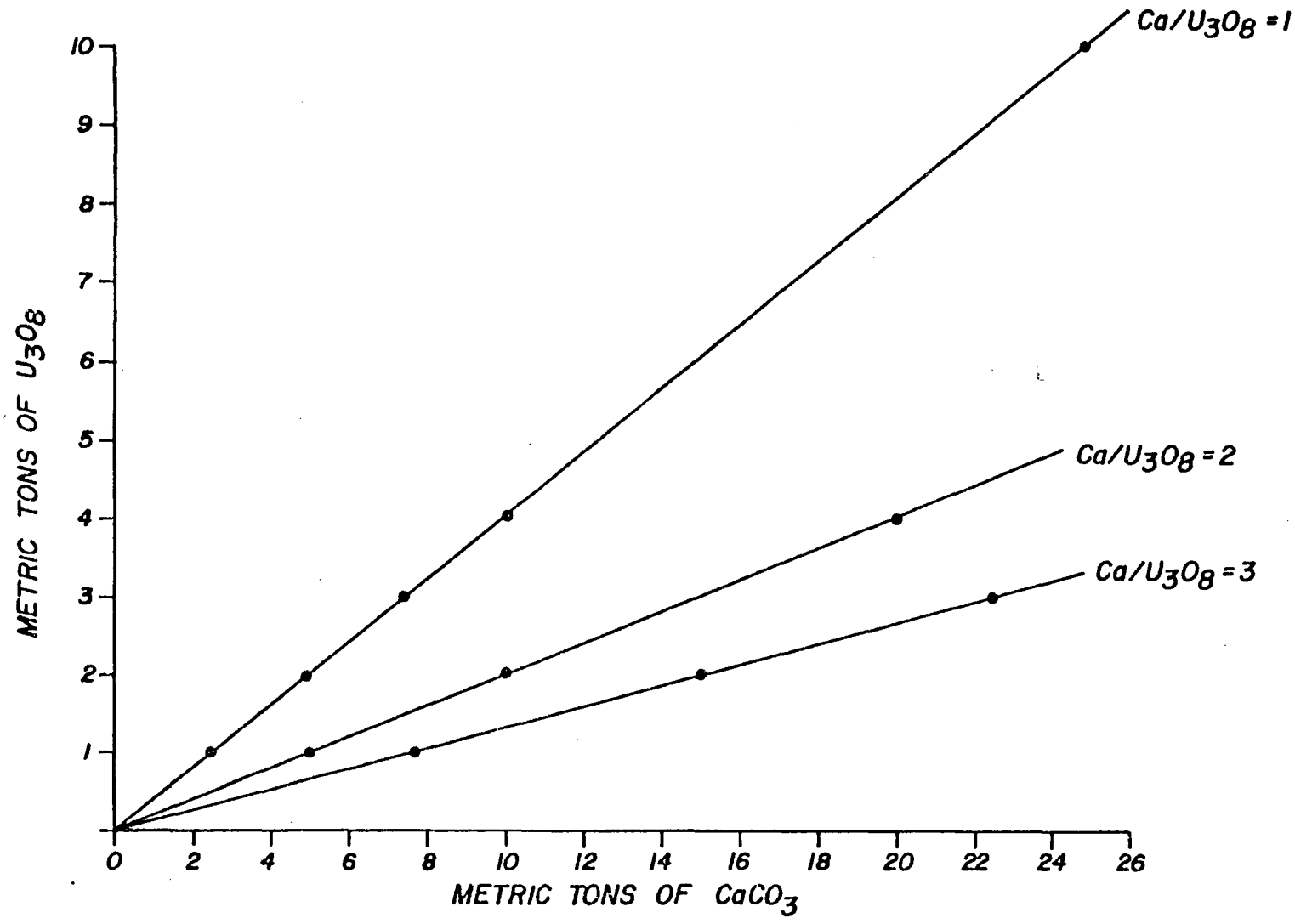


FIGURE 4-2: QUANTITY OF CALCITE PRODUCED

standard uranium mill tailings. Accordingly, a mill tailing pond system as described below is under evaluation for formal presentation to the NRC in 1978 following the expected conclusions of the generic statement referred to above.

4.4.1.2 ALTERNATIVE UNDER DETAILED EVALUATION

A tailing impoundment in an existing natural basin may be proposed in a centrally located area (centrally located to expected mine sites). The impoundment would be constructed of sufficient size to hold the lifetime output of the project. The bottom will be scarified, covered with clay and recompacted so as to reduce seepage. The water from the tailings pond, to the extent practicable, will be recycled and treated for subsequent reinjection to the mine zone. All surface water will be routed around the impoundment area. The entire area will be fenced. Prior to reclamation, blowing sands and dust which might impact offsite areas will be stabilized by use of chemicals or other methods. The tailings in a given area will be allowed to dry out sufficiently to move equipment over the pile and then cap with a layer of clay. Reclamation will be staged, with the initial efforts beginning as soon as an area has reached sufficient depth and dryness. Five and a half feet of overburden will be placed on top of the dried tailings, the pile will be contoured and shaped. Soil amendments (e.g., fertilizer, organic matter) will be added as necessary. The area will be revegetated with appropriate plant species. Following reclamation, a monitoring and maintenance program will be established to ensure stability.

4.4.1.3 SOLIDS FROM AQUIFER RESTORATION

Chemicals separated by conventional water purification techniques, and further concentrated by evaporation will be generated in the restoration program. Figure 4-3 shows the quantity of solid waste per million gallons of contaminated leach liquor containing varying quantities of total dissolved solids.

Solid waste of this type will be contaminated primarily with Radium 226 and Thorium 230. Based on data from other operations, the estimated contamination levels will be approximately 10 pCi Ra 226/gram and 1000 pCi Thorium 230/gram.

Waste from this source will be stored on site in a slurry or paste form and will be disposed of using methods similar to those described in Section 2.4.4.

4.4.2 GASEOUS WASTES AND EFFLUENTS

See Section 2.4.3.

4.4.3 LIQUID WASTES AND EFFLUENTS

See Section 2.4.2.

4.4.4 DISPOSAL OF CONTAMINATED PLANT EQUIPMENT

The WMC process does not use equipment such as wooden thickener tanks

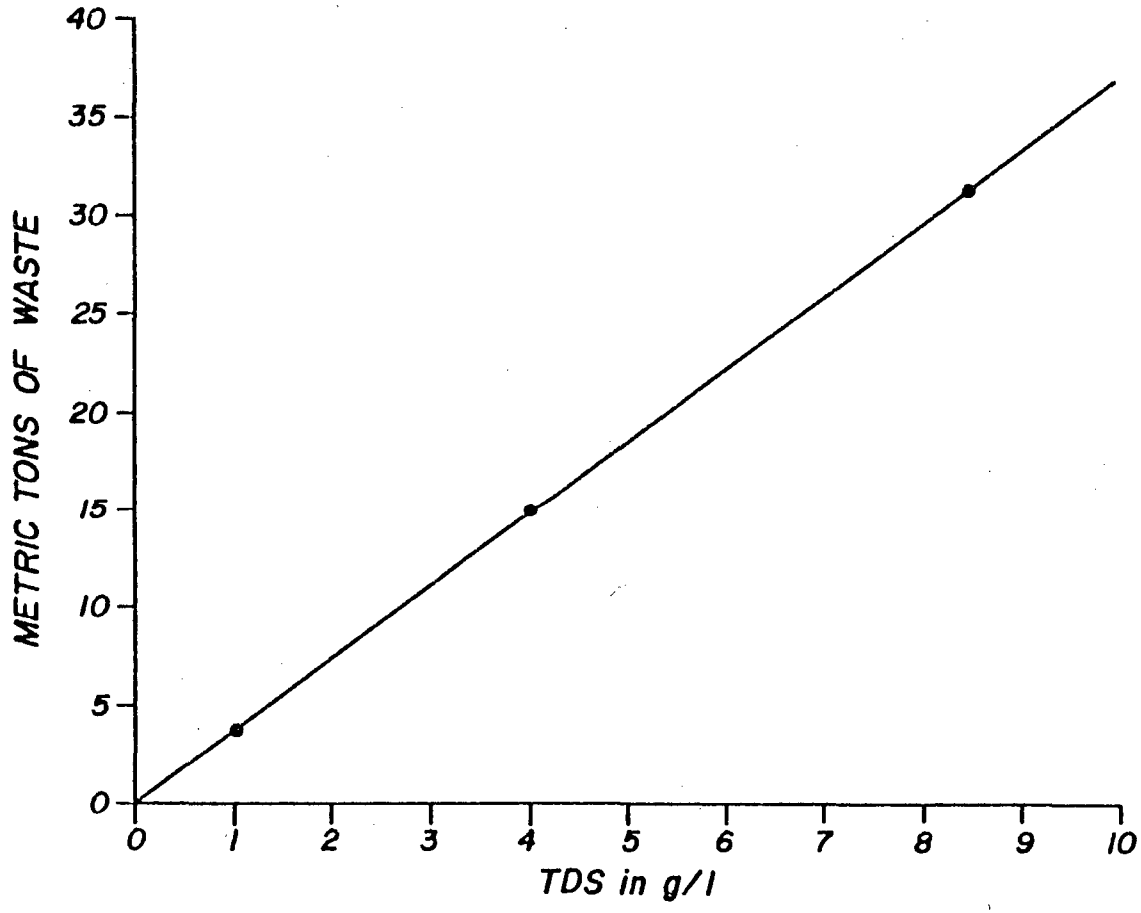


FIGURE 4-3: SOLID WASTE / MILLON GALLONS

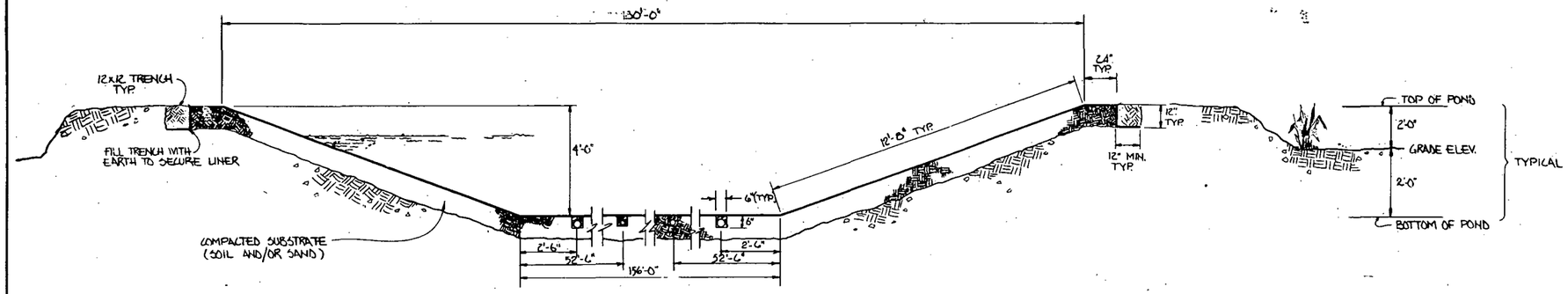
which could become contaminated with radium. Rather, the plant is constructed almost entirely of plastic, fiberglass and stainless steel, all of which can be cleaned of contamination and removed from the site at the end of mining activities.

4.4.5 CONTROL OF WASTES

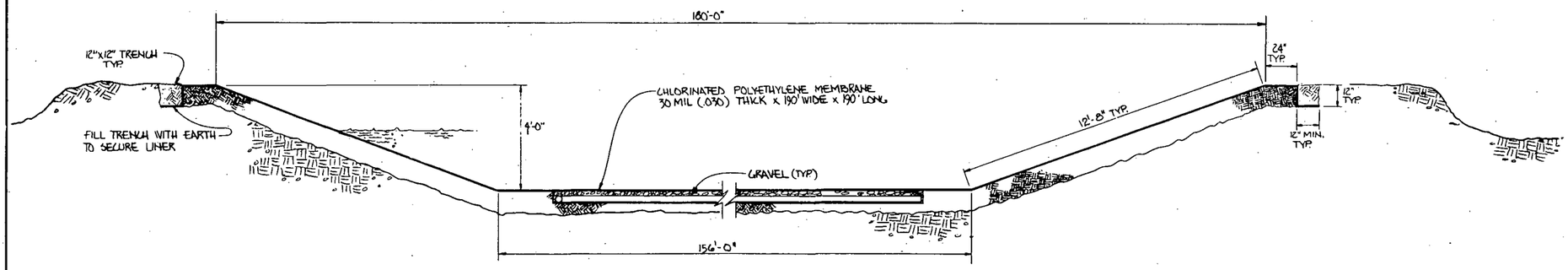
Process wastes and effluents will be stored in lined ponds on the site. The ponds will be retangular, earthen-bermed and lined with a plastic liner to prevent seepage. Each pond will be equipped with a leak detection system and will be periodically checked and sampled. In addition to waste storage, the ponds will be used for evaporation to reduce the volume of the contained waste. Ponds will be constructed and operated in such a manner that should a leak occur, the leaking pond could be safely evacuated into an adjacent pond while liner repairs were effected.

A typical pond detail is enclosed as Figure 4-4. The location of ponds is tentative pending soil and stability studies. Their tentative use and description is as follows:

1. Calcite Storage; 80' x 150' x 10' depth, 3:1 slope on sides, volume with 2' freeboard = 3.35 acre-feet.
2. Recovery Surge; 150' x 150' x 10' deep, 3:1 slope on sides, volume with 2' freeboard = 5.60 acre-feet.
3. High TDS Bleed; 300' x 135' x 10' deep, 3:1 slope on sides, volume with 2' freeboard = 9.49 acre feet.
4. Low TDS Bleed; 300' x 360' x 10' deep, 3:1 slope on sides, volume with 2' freeboard = 16.28 acre-feet.



SECTION A-A



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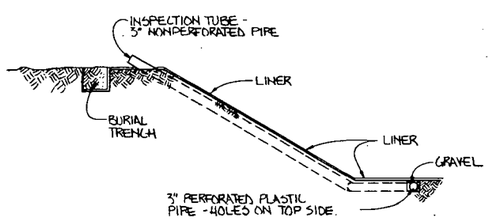

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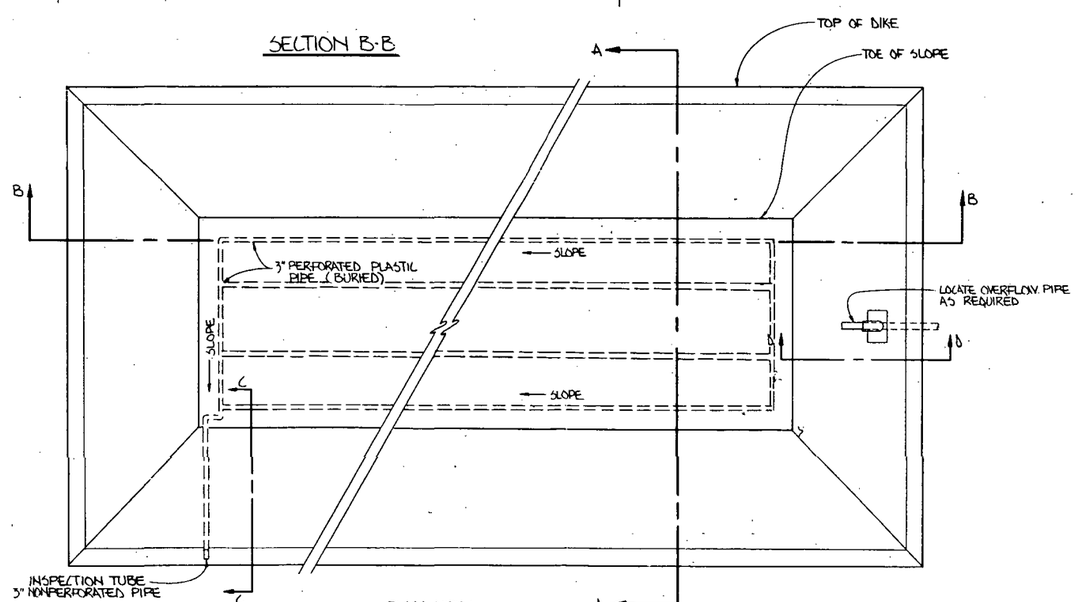
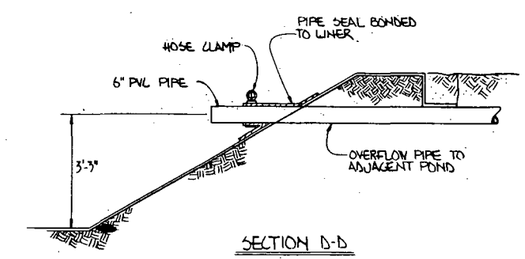


PLAN VIEW



SECTION D-D

ANSTEC APERTURE CARD

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WYOMING MINERAL CORPORATION			
POND DETAIL			
DWN: DJC	11-26-75	FIGURE 4-4	REV
CHKD: R.S.K.	11-26-75		
APRD: R.S. Ryan	11-26-75		
SCALE: NTS		SHEET OF	

5. Restoration; above ponds plus additional if needed; 150' x 200; x 10' deep each, 3:1 slope on sides, volume with 2' freeboard = 7.19 acre-feet/each.

SECTION 5.0

NON-RADIOLOGICAL IMPACTS

5.1 SITE AND PROCESS FACILITY PREPARATION

Many roads and trails traverse the area of proposed activity at the Irigaray site. In some instances these roads and trails, will be upgraded for short-term use. Maximum total road work (single lane dirt or gravel) would be approximately 50 miles over the length of operations. These roads will be bonded with the state and reclaimed as required. Operating crews will be approximately 10 persons per shift, and WMC will provide multi-passenger vehicles to and from the site. This will minimize noise, dust and ecological impacts.

Soil loss from the well field and associated roads was estimated at 0.2 tons per acre per year using the universal soil loss equation (Table 5-1). This means that approximately 0.01 inch of soil per acre per year would be lost from an active well field.[1,2]

The same method indicates that the present estimated average annual soil loss in the area is 0.14 tons per acre per year.[3,4] Assuming a total disturbance of about 100 acres at any one time, approximately 20 tons of soil would be lost per year of operation: fourteen tons per year would be a normal loss, the additional six tons related to WMC activity.

TABLE 5-1
UNIVERSAL SOIL LOSS EQUATION

The Universal Soil Loss Equation is: A = RKLSCP

Where:

A = the computed soil loss per unit area.

R = the rainfall factor, is the number of erosion index units in a normal year's rain. The erosion index is a measure of the erosive force of a specific rainfall.

K = the soil-erodibility factor, is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow, on a 9 percent slope 72.6 feet long.

L = the slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6-foot length on the same soil type and gradient.

S = the slope-gradient factor, is the ratio of soil loss from the field gradient to that from a 9 percent slope.

C = the cropping-management factor is the ratio of soil loss from a field with specified cropping and management to that from the fallow condition on which the factor K is evaluated.

P = the erosion-control practice factor is the ratio of soil loss with contouring, strip-cropping or terracing to that with straight-row farming, up-and-down slope.

When A = 20 the following values apply:

R = 50

K = 0.28

LS= 15.9

C = 0.10

P = 0.9

In view of the vast drainage basin of the Powder River and Willow Creek upstream from the plant site, the amounts of sediment contributed by mining operations to these water courses would probably be indistinguishable from natural variations, in sediment loads.

5.2 RESOURCES COMMITTED

5.2.1 LAND USE

Approximately 100 acres will be used annually over the ten year lifetime of the Irigaray mining operation. As mining ceases the area will be reclaimed and revegetated (Section 9.2) and returned to its previous agricultural land use as described.

There are no areas of known natural, cultural, scenic or historic value on the Irigaray site (Section 3.3). Currently there are no archaeological digs within 50 miles of the proposed mining site. The insitu mining method would have little impact on possible archaeological sites.

There are two thin (1 - 3 feet) coal seams above the Irigaray sandstone from which the uranium will be leached. The insitu mining method should not interfere with future coal mining or extraction of any other fuel and non-fuel minerals in the area.

5.2.2 ECOLOGY

The implementation of the proposed action will temporarily commit a total

of approximately 1000 acres over the life of the project. However, as stated earlier only about 100 acres will be disturbed at any one time. For the purposes of impact assessment, it should be assumed that the entire vegetative resources on the affected areas will be subsequently replaced by a new (but not necessarily different) plant community following revegetation. The use of the site for solution mining will temporarily remove approximately 11 AUM's per year of operation (Section 3.8.2).

Big and small game animals will be excluded from the area during operations, but impacts should be minimal due to the relatively small areas involved. No known migration routes or areas of critical habitat will be affected.

Small mammals on the affected areas will incur some direct losses due to the project operations. Animals remaining on the site during mining will either adapt to the altered environment, move to adjacent areas, or be lost. The carrying capacity of the surrounding habitat will determine the success of the emigrants.

5.2.3 SOCIOECONOMIC

The operating crew will consist of approximately 40 - 60 persons, most of whom will reside locally, and several visiting engineers. There is available housing in Buffalo to accommodate any personnel relocations. The available social services could accommodate any influx of population without any anticipated hardship to local residents (Section 10.2).

5.2.4 WATER RESOURCES

Water needs for mining operations will originate from the local groundwater source (the Wasatch Formation) for which applicable permits will be obtained. The maximum water requirements for all mining and plant operations are about 222.3 acre feet per year (Section 2.4.2). From data presented in Section 3.5, Groundwater Hydrology, withdrawal of such quantities of water from the local aquifer is possible without adversely affecting other users of the same aquifer.

The mineralogical changes induced by the insitu mining process as described in Section 4.2.2, during operation and after it, could have an effect on the water quality of the local aquifer. Existing wells in the vicinity of the proposed mining areas were surveyed in the course of this study (Section 3.5.1). Data obtained from this survey and from a literature survey indicate that water quality varies from well to well. In general, however, water quality of most wells is good. Precautions taken during mining, the extensive monitoring of water quality within the mining zone and outside this zone prior to and during mining (Sections 7.1 and 7.2) and the proposed restoration program (Section 9.1) should minimize the potential impacts and mitigate them.

Effluents from the Irigaray facility will be routed into lined evaporation waste ponds where the water will evaporate. No liquid wastes will be discharged into surface water bodies. No overflow will be allowed and the solids will accumulate until mining ceases and the ponds will be reclaimed and revegetated (Section 9.2). No impact to the local groundwater quality

from seepage from these ponds is anticipated. The proposed sewage facility that will accommodate a maximum of 60 persons should not affect the local surface or groundwater quality.

In addition to the groundwater monitoring program, the only perennial stream in the area, the Powder River, will be monitored as well. This river is mainly used for sheep and cattle watering and its water quality should be maintained for this use. Water quality of this river varies greatly seasonally. Surface water runoff during high flow seasons improves the water quality while during low flow periods when groundwater discharge comprises most of the flow, water quality decreases. Mining at Irigaray should not have a direct effect on this river.

5.2.5 AIR RESOURCES

The mining operation at the Irigaray site will not require the use of large volumes of atmospheric air for cooling or other process needs. Thus, the impact on local meteorological conditions near the site are insignificant. Meteoroligical data is currently being obtained for the area with a site weather station. Impact on air quality due to plant air emission result from several sources as described in Section 2.4.3. Of primary significance is the possibility of ammonia emission from various parts of the plant. The plant design includes adequate ventilation systems to reduce all possible in-plant ammonia concentrations to levels well below those required for occupational health regulations. Emissions external to the plant will have no impact on

the regional air quality due to the low emission rate and the large amount of atmospheric dispersion that will result at the nearest population impact area. The ammonia diuranate (ADU) drying and packaging plant will have a self-contained air scrubbing system which will reduce the particulate emissions to levels below discharge requirements as well as remove chemical gases such as ammonia by means of a high intensity venturi scrubber. By product gases from the combustion heating system in the ADU air heating system will be low ($1.0 \times 10_6$ BTU rated capacity) and should leave no adverse impact on local or regional air quality.

Radiological impact on air quality has been found to be insignificant at other solution mining operations. Monitoring systems designed to sample air quality for radon and/or radon daughters and long-half life particulates associated with drying and packaging process will be implemented. No adverse radiological impact on air quality is anticipated.

SECTION 6.0

RADIOLOGICAL ENVIRONMENTAL IMPACTS OF PROCESS FACILITY AND WELL FIELD OPERATION

6.1 RADIOLOGICAL EFFLUENT SOURCES

Under routine operating conditions, only two sources of radiological effluent are possible. (Radiological waste is addressed in Section 4.4).

(1) Release of Radon-222 gas from production surge tanks and ponds, and

(2) Loss of product through scrubber stack (primarily U_3O_8).

Small quantities of Radon-222 gas can be released from locations where solutions are exposed to the atmosphere. It is not anticipated that sufficient quantities of Radon gas will be released to constitute significant environmental impact. Surge tanks will be vented to ensure that occupational exposure limits for Radon or it's daughter products are not exceeded.

The primary radiological effluent (see Section 2.4.3) is the release of U_3O_8 to the atmosphere from the dryer/scrubber stack.

6.2 EXPOSURE PATHWAYS

There will be a small release of U_3O_8 from the scrubber stack (Table 2-5). Through dispersion in the atmosphere, radionuclides can be

deposited in soil, vegetation, and surface waters. The particulate removal system which has been selected minimizes potential environmental effluent and maximizes product containment. The radionuclides that may be released to the environment will be quantified by the environmental survey described in Section 7.2.1.

6.3 RADIOLOGICAL ENVIRONMENTAL MONITORING

During the initial year of dryer operation, quarterly environmental samples of soil, vegetation, and surface water will be collected at 4 different compass locations approximately 1 mile from the scrubber stack and at the nearest residence. These samples will be analyzed for U_3O_8 and Radium-226. Baseline samples will be collected at these stations before dryer start-up. When sufficient data are collected to indicate that this procedure is unnecessary, it may be modified or terminated.

6.4 ENVIRONMENTAL IMPACT ON MAN

6.4.1 SUMMARY OF ANNUAL EXTERNAL RADIATION DOSES (OCCUPATIONAL)

Survey data as shown in Tables 6-1 and 6-2 indicate that exposure of personnel to external radiation is minimal. Due to the leach characteristics of the WMC Solution Mining Process, the majority of gamma emitting daughter products remain undergound within the ore body itself. Radium-226, which co-precipitates with calcium, is the primary

TABLE 6-1
SUMMARY, 1976 - PERSONNEL DOSIMETRY RESULTS, BRUNI, TEXAS

Total number of individuals monitored for entire period	= 22
Total accumulated whole body exposure above background	= 70 mR
Average whole body exposure	= 3.2 mR/year/man
Total accumulated skin exposure	= 160 mR
Average skin exposure	= 7.2 mR/man/year
Present occupational (whole body) exposure limit (10CFR, P20)	= 5000 mR/man/year

TABLE 6-2
AREA MONITOR RESULTS, PERIOD 10/1/76 THROUGH 1/20/77, BRUNI, TEXAS*

Badge Number	Location	Exposure Rate
2735-1003	Outer surface of conduit at clarifier feed approximately 4' from clarifier junction	9.18 mR/wk
2735-1007	On post, approximately 12-14" above ground surface, 3'-4' from clarifier underflow pond	4.63 mR/wk

* These stations consistently record the highest exposure potential as they are located near the primary external exposure source, i.e., calcium removal (radium-226).

gamma source. The occupational monitoring data in Tables 6-1 and 6-2 represents personnel and area monitoring results (dosimetry) from the WMC Bruni production site, Webb County, Texas, (as reported by Eberline Instrument Corporation, Santa Fe, New Mexico).

This data demonstrates that the direct external radiation dose contribution to the general environs from radioactive material on site is therefore minimal.

6.4.2 INTERNAL DOSE COMMITMENTS

As indicated in Section 6.1, the primary source of radionuclide release will be the source of scrubber exhaust stack. First year and maximum 50-year dose commitment to man are calculated at the site boundary and at the nearest residence. The dispersion model used is from Turner's Workbook of Atmospheric Dispersion Estimates.[1] The dose commitment model used is that suggested by ICRP publications #2 and #10.[2] [3] The following assumptions were made.

(1) Average annual wind speed = 13 mph.

(2) Most probable stability class = Pasquill 3 (C) Actual frequency =0.65, Assumed frequency = 1.00.

(3) Stack height is 35 feet above ground (10.6 meters).

(4) Distance from exhaust stack to nearest residence (Irigaray Ranch) is 4.1 miles (6.6 km).

(5) Distance from exhaust stack to site boundary fence is 350 ft. (.1 km).

(6) Wind direction is 100% from stack to point of interest (worst case).

(7) Most probable wind direction at the site is from the NW; frequency =0.147 (normal conditions).

(8) Frequency of the wind direction from the stack to the nearest residence (Irigaray Ranch) =0.117 (SSE + SE + ESE) (normal conditions).

The results of these calculations (Tables 6-3, 6-4, 6-5 and 6-6) are summarized in Table 6-7 and 6-8 and demonstrate that for worst case and normal case conditions the internal dose commitments from the facility will be minimal.

TABLE 6-3
WORST CASE CALCULATIONS FOR DOSE COMMITMENTS AT SITE BOUNDARY

1. <u>50-Year Dose Commitment</u>

Using the ICRP model an annual maximum dose rate is calculated below for a 50 year dose commitment (lung).

$$D_R = \frac{F\ \varepsilon\ T_E}{m}\ (1 - \frac{e0.693t}{T_E})\ \times\ 5.7 \times 10'' \times Ca$$

Where:

D_R = Maximum annual dose rate; rem/yr

F = Fractional intake by injestion or inhalation which goes to organ of interest = 0.125 for U_{nat} in lung

ε = Effective absorbed energy/disintegration of a radionuclide = 43 mev for U_{nat} in lung

T_E = Effective half life = 380 days for U_{nat} in lung

m = Mass of organ of interest = 1,000 grams for lung

t = Time after continuous intake is initiated. For maximum dose rate, taken to be 50 years or 1.825×10^4 days 5.7 x 10" - Conversion factor; Mev/gram to rem

Ca = Concentration at site boundary calculated above = 1.04×10^{-12} µCi/ml

Yielding:

D_R = 1.2 rem/yr maximum after 50 years

50 year dose commitment at maximum dose rate = 60 rem

2. <u>First Year Dose Commitment</u>

All parameters as above except t = 1 year = 365 days

D_R = .59 rem for first year

TABLE 6-4
WORST CASE CALCULATIONS FOR DOSE COMMITMENTS
AT NEAREST RESIDENCE

1. 50-Year Dose Commitment

Using the ICRP model an annual maximum dose rate is calculated below for a 50 year dose commitment (lung).

$$D_R = \frac{F\ \varepsilon\ T_E}{m} \left(1 - \frac{e0.693t}{T_E}\right) \times 5.7 \times 10" \times Ca$$

Where:

D_R = Maximum annual dose rate; rem/yr

F = Fractional intake by injestion or inhalation which goes to organ of interest = 0.125 for U_{nat} in lung

ε = Effective absorbed energy/disintegration of a radionuclide = 43 mev for U_{nat} in lung

T_E = Effective half life = 380 days for U_{nat} in lung

m = Mass of organ of interest = 1,000 grams for lung

t = Time after continuous intake is initiated. For maximum dose rate, taken to be 50 years or 1.825×10^4 days 5.7 x 10" - Conversion factor; Mev/gram to rem

Ca = Concentration at nearest residence calculated above = 1.35×10^{-15} µCi/ml

Yielding:

$D_R = 1.54 \times 10^{-3}$ rem/yr (= 1.54mR) maximum after 50 years

50 year dose commitment at maximum dose rate = 7.73×10^{-2} rem

2. First Year Dose Commitment

All parameters as above except t = 1 year = 365 days

$D_R = 7.6 \times 10^{-4}$ = .76 mR for first year

TABLE 6-5
NORMAL CASE CALCULATIONS FOR DOSE COMMITMENTS AT SITE BOUNDARY

1. 50 Year Dose Commitment

All parameters are as they appear in Table 6-4 except

$Ca = 1.53 \times 10^{-13}$ μCi/ml

Yielding:

D_R = .17 rem/yr maximum after 50 years

50 year dose commitment at maximum dose rate = 8.5 rem

2. First Year Dose Commitment

All parameters are as they appear in Table 6-4 except t = 365 days and $Ca = 1.53 \times 10^{-13}$ μCi/ml

Yielding:

D_R = .08 rem = 800 m Rem for first year

TABLE 6-6

NORMAL CASE CONDITIONS FOR DOSE COMMITMENTS AT NEAREST RESIDENCE

1. 50 Year Dose Commitment

All parameters are as they appear in Table 6-5 except

$Ca = 1.58 \times 10^{-16}$ μCi/ml

Yielding:

$D_R = 1.8 \times 10^{-4}$ rem/yr maximum after 50 years

50 year dose commitment at maximum dose rate $= 9.0 \times 10^{-3}$ rem

2. First Year Dose Commitment

All parameters are as they appear in Table 6-5 except t = 365 days

and $Ca = 1.58 \times 10^{-16}$ μCi/ml

Yielding:

D_R = .0094 rem = 9.4 m Rem for first year

TABLE 6-7
SUMMARY OF DOSE COMMITMENTS

	Maximum Annual Dose Rate
Worst Case	
Site Boundary (50 years)	1.2 rem/yr
Site Boundary (1 year)	0.59 rem/yr
Nearest Residence (50 years)	0.0015 rem/yr
Nearest Residence (1 year)	0.00076 rem/yr
Normal Case	
Site Boundary (50 years)	0.17 rem/yr
Site Boundary (1 year)	0.08 rem/yr
Nearest Residence (50 years)	0.00018 rem/yr
Nearest Residence (1 year)	0.00 rem/yr

TABLE 6-8
50 YEAR DOSE COMMITMENTS AT MAXIMUM RATE

	Dose
Site Boundary (worst case)	60 rem
Site Boundary (normal case)	0.077 rem
Nearest Residence (worst case)	8.5 rem
Nearest Residence (normal case)	0.009 rem

SECTION 7.0

EFFLUENT AND ENVIRONMENTAL MONITORING PROGRAMS

7.1 PREOPERATIONAL MONITORING PROGRAMS

7.1.1 GROUNDWATER

In order to assure control of solution mining, groundwater quality and its natural variability must be established prior to mining operations. To achieve this end, WMC uses existing wells (or data) as well as new wells such as injection, production, or monitor wells to collect water samples for analysis and water quality baseline determinations. If baseline has already been established for a region or mine site in close proximity to a new mine site, the data may be used as the baseline provided it is checked for local variability prior to new test work.

Since water in the mineralized zone often reflects values in water quality different from water peripheral to the mineralized zone, WMC gathers data from areas in and adjacent to the uranium roll front deposit. Samples for environment determination are taken from 1) mineralized zone, 2) trend zone, and 3) monitor zone. Water samples are taken in the presence of state and federal water quality personnel at their option and divided equally between the state or federal personnal and WMC. Physical or chemical parameters of Groundwater Baseline Assays are shown in Table 7-1.

7.1.2 SURFACE WATER

If mining or test operations are in close proximity to surface water

TABLE 7-1
PHYSICAL OR CHEMICAL PARAMETERS OF GROUNDWATER BASELINE ASSAYS

Ammonia (as NH_4)	Gross Alpha and Beta	Potassium
Arsenic	Hardness (as $CaCO_3$)	Radium-226
Barium	Iron	Selenium
Bicarbonate (HCO_3)	Lead	Silica
Boron	Magnesium	Silver
Cadmium	Manganese	Sodium
Calcium	Mercury	Sulfate
Carbonate (as CO_3)	Molybdenum	TDS
Chloride	Nickel	Thorium 230
Chronium Hexavalent	Nitrate (NO_3^-)	Vanadium
Conductivity	Nitrite (NO_2^-)	Uranium (U_3O_8)
Copper	pH	Zinc
Fluoride		

flow or in close proximity to natural drainage that may discharge to surface water flow, baselines will be established consistent with Table 7-1. Sampling will include intermittent streams but this data will not be considered as baseline.

7.1.3 HYDROLOGIC MODEL

A fluid flow model is used by WMC to study the subsurface flow pattern resulting from the simultaneous operations of injection and production wells. The input data consists of the aquifer characteristics obtained from hydrology tests and the well field pattern.

In this computer model, the hypothetical tracer particles are initially distributed evenly around the circumference of each injection well and are released at the time injection begins. The particles then migrate following the computed streamlines of the subsurface flow (Figure 7-1). The program provides the option of four plots; 1) tracer particle plot (Figure 7-1); 2) head change distribution; 3) velocity vector plot and 4) velocity magnitude contour map.

7.1.4 AIR

In areas remote from National Weather Service First Order Stations, meteorological monitoring is accomplished by using a Meteorology Research Inc., or equivalent mechanical weather station, which continuously monitors wind speed and direction, temperature, and relative humidity and precipitation. Charts are changed monthly. The station is located on a tripod and placed at a suitable location where the station is not affected by neighboring

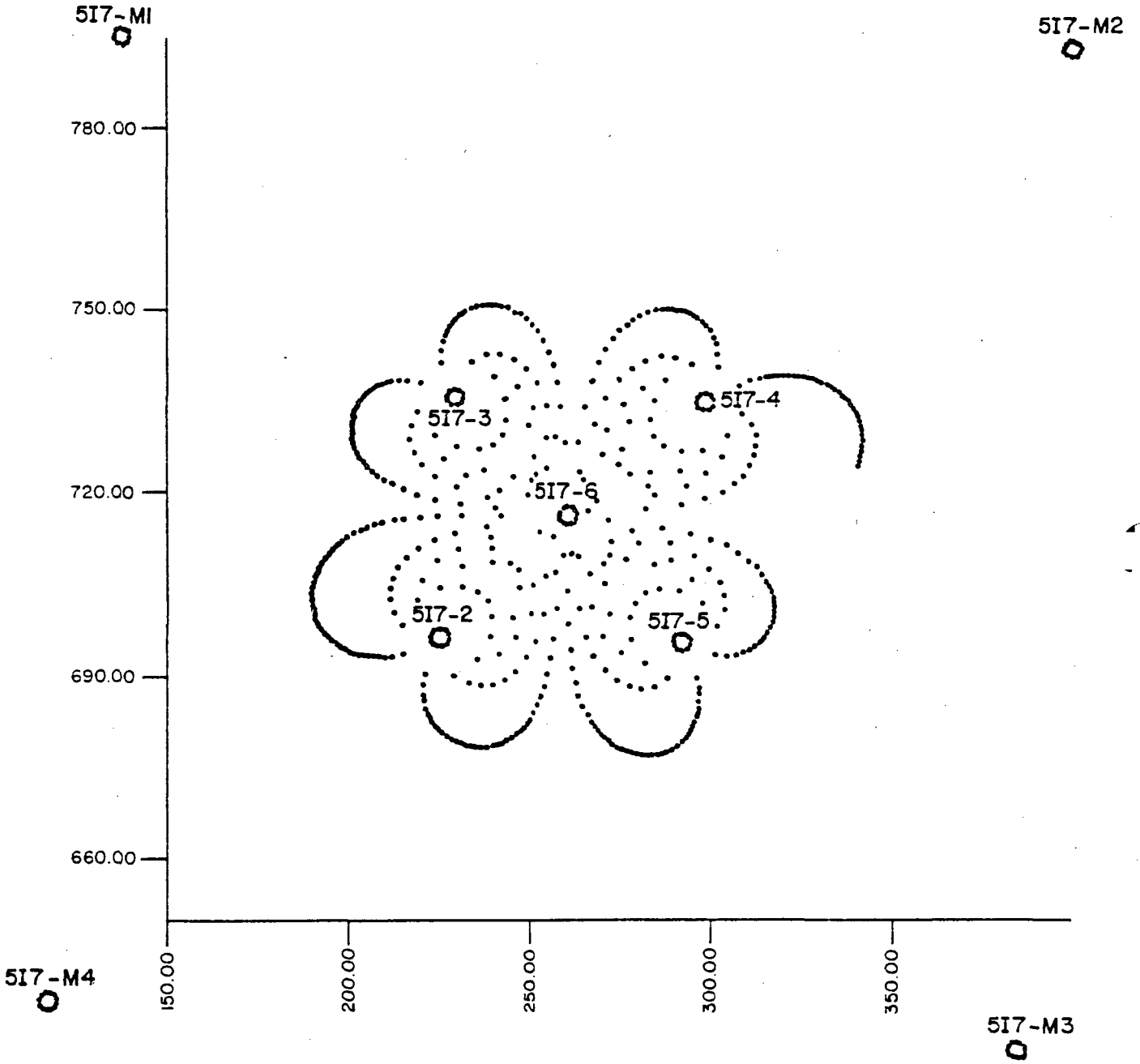


FIGURE 7-1: TRACER PARTICLE PLOT - IRIGARAY 5I7 WELL FIELD

structures or topography. Baseline data is accumulated for a minimum of one year and then correlated with the nearest stations of record. WMC is also presently collecting data on barometric pressure changes and evaporation rates.

Additional data on atmosphere monitoring is found in Section 6.6.

7.1.5 GEOLOGY AND SOILS

Geologic and soil information is obtained prior to plant operation from literature surveys and exploration activities. This data is used for formulating mine plans as well as for pond and septic system designs.

7.1.6 RADIOLOGICAL SURVEYS (Section 7.2.1).

7.2 PROPOSED OPERATION MONITORING PROGRAMS

7.2.1 RADIOLOGICAL MONITORING

7.2.1.1 AREA MONITORING

At least annually, air, soil, vegetation and surface water samples shall be taken from representative areas in the immediate unrestricted environment and analyzed for long-half life radionuclide content (natural uranium, radium 226). If/when sufficient data are collected to demonstrate this procedure unnecessary, it may be modified or terminated.

7.2.1.2 PLANT MONITORING

Radiation levels at WMC uranium extraction facilities shall be established by TLD (Thermoluminescent Dosimetry) monitors, exchanged and analyzed quarterly. The monitor may be either personnel badges and/or area badges.

Air samples will be collected and analyzed for radon 222 and recorded in micro curies per milliliter of air. In addition air samples will be taken for particulate radionuclides.

Selected working surfaces shall be surveyed with a portable alpha detection system, to help ensure that internal exposers potentials are maintained as low as is reasonably achievable.

7.2.2 CHEMICAL EFFLUENT MONITORING

All chemical effluents are discharged to ponds. Section 4.4.5 discusses pond monitoring.

7.2.3 METEOROLOGICAL MONITORING (See Section 7.1.3).

7.2.4 WELL FIELD MONITORING

Monitor wells are designed to serve a two-fold function. They define an area of solution mining containment which, after mining, is the area

designated for restoration. In addition, they represent the surveillance mode by which corrective action and reporting procedures are initiated in the event of leachate migration. Well Field monitoring is accomplished through the use of both trend and monitor wells.

7.2.4.1 TREND WELLS

Trend wells will be drilled within the monitor well ring and will be located no further than 200 feet from the well field. These wells are for production control but will be sampled along with monitor wells. (Section 7.2.4.6). Value changes in the trend will not signal corrective action but rather will initiate a production evaluation to determine cause. Adjustment action will then take place.

7.2.4.2 MONITOR WELLS

Monitor wells will be placed no closer than 400 feet from the limit of mineralization and no further than 1000 feet from the well field.

7.2.4.3 CRITERIA FOR TREND AND MONITOR WELL LOCATION

In order to avoid natural contamination or variability within the mine zone, and in order to minimize environmental impact, monitor and trend wells shall be placed in accordance with the following criteria:

(1) Away from higher mineralization grades;

(2) Away from roll fronts or other subsurface features that may influence surveillance;

(3) Use existing WMC wells that may be suitable for monitoring purposes;

(4) Consistent with test and production needs such as contruction, ponding, storage areas, future field work;

(5) Near existing trails or roads to avoid road construction.

7.2.4.4 WELL SCREENING AND PUMP LOCATION

Monitor and trend wells will be screened, perforated, or open holed for the full thickness of the sand. Pumps will be set above the screen or perforation but not more than 50 feet above the screen. The setting depth of the pump will become the standard for all samples pumped from that well.

7.2.4.5 SHALLOW AND DEEP MONITOR WELLS

Each well field will have at least one shallow and deep monitor well. These wells must screen a minimum of five feet of the aquifer or dry formation immediately above/below the confining mudstone or shale which overlays/underlays the mineralized formation. These wells will be placed within the well field and sampled and assayed in accordance with Section 7.2.4.6.

7.2.4.6 MONITOR WELL SAMPLING

Monitor and trend wells shall be sampled bi-weekly (every 2 weeks) and assayed for at least pH, water depth, conductivity, and one lead indicator of leachate, (i.e., an ion that will be first evidenced in a

migration). The present lead indicator for monitoring is chloride.

Wells shall be pumped for two bore displacements before a sample is taken upon commencement of operations and then for one bore displacement before a sample is taken during operations. Sample will be placed in a one-liter container and returned to the plant lab for analysis.

7.2.4.7 UPPER CONTROL LEVEL

An Upper Control Level (UCL) for each monitor and trend well will be specifield based on baseline determination. If assays exceed the UCL, a second set of samples will be immediately taken from the specified well. If the exceeding values are encountered again then sampling for that well will be every third day. When the second set of monitor well samples indicates an anomaly, the appropriate state agency shall be notified by the next working day.

If high and unexplained values for monitor wells persist for two weeks (a total of six samples) then corrective action procedures will be instituted until values are brought below the UCL.

7.2.4.8 RECORD KEEPING AND REPORTING

The monitor and trend well sampling, data collection and its availability on site is the responsibility of the mine site Licensing Engineer. It will also be his responsibility to transmit the monitor well data in a timely fashion to the main office (Denver) for Data Processing. All officially transmitted monitor well records will be prepared at the main office and returned to the

sites for reporting requirements and site accumulative records. Reporting will be annual unless otherwise specified.

7.2.4.9 POST-MINING MONITORING

After mining or test completion, monitor wells will be sampled semi-annually (preferrably spring and fall) until restoration has begun. After restoration has been completed, the field will be sampled at the end of a one-year period to verify restoration. Sampling will be the same as that referenced in Section 7.2.4.6.

7.2.4.10 CORRECTIVE ACTION PROCEDURES

Under normal operating conditions a small bleed stream is taken at the plant which is partially conveyed to a waste water pond. This provides for a net inflow into the well field aiding in well field control. However, in the event of migration, the plant supervisor will have several methods to choose from in containing and correcting a migration of leach solution. The principle ones are overpumping, reordering the pumping balance of the well field, reducing or stopping injection, ceasing both injection and recovery pumping, injecting solution of reduced concentrations, establishing a water fence, or the beginning of restoration procedures. These methods may be applied locally to a few wells within a cell, to the entire cell, to several cells or to the entire well field as the situation dictates. Current methods are as follows:

(1) <u>Overpumping</u>

This method involves adjusting pumping so that the rate of flow into the injection wells is exceeded by the flow from the

recovery wells. The net result is a general inward movement of native water.

(2) Reordering

This is a variation of overpumping in that different ratios are applied to different areas in the well field. Hence, the inward movement of native water may be emphasized at one point or another. Reordering may further include direct pumping from one part of the field to another.

(3) Reducing Injection

This is the second way to adjust the ratio of recovery flow to injection flow. At the same time it reduces the amount of leach solutions introduced into the production zone in the vicinity of the wells concerned.

(4) Ceasing Pumping

This method stops both the injection and recovery flows. Exclusive of the effects of natural forces (e.g., natural migration of groundwater) which are orders of magnitude less, this should arrest the further migration of leach solution beyond the established boundaries.

(5) Beginning Restoration

This step can be utilized when all other efforts have failed to halt the migration of leach solution beyond the farthest allowable limits.

7.2.4.11 IMPLEMENTATION

When six consecutive samples from a monitor well are found to have exceeded the upper control level (Section 7.2.4.7), a selected operational procedure described above can be implemented, depending on the particular circumstances involved. Records will be maintained of all actions taken.

7.2.4.12 WASTE WATER CONTROL

All waste water produced for excursion control from the production zone

will be conveyed to waste water ponds for treatment and disposition. (See Section 4.4.5).

7.3 INDUSTRIAL SAFETY PROGRAM

7.3.1 ORGANIZATION

Each production site has the mechanism for implementing corporate policies and procedures and thereby solving site specific safety problems. Safety objectives are accomplished via a site safety technician, site safety policy committee and a headquarters based Radiation Protection Officer and Safety Engineer.

7.3.2 GENERAL PROGRAM

Due to the type and design of the mining and milling process, chances for serious accidents are reduced in comparison to other types of mining operations. For example, solution mining extracts uranium without involving the usual open pit or underground mining hazards. Virtually no heavy equipment such as large trucks, shovels and dozers, is needed at the mine site, and the Plant does not utilize conveyors, ball mills or other heavy equipment. The major items of moving or rotating plant equipment are direct-drive pumps and small submerged agitators. The 1976 injury frequency rate (per million man hours) for all WMC mining operations was less than half that of the surface operations rate for the same period as reported by MESA.

It is the Wyoming Mineral Corporation policy to take all practical steps to eliminate or reduce exposure of employees to accidental injury, or to conditions adversely affecting their health while on the job. The specific objectives of the WMC industrial safety program are as follows:

(1) Identify possible safety hazards of the process at the design stage and implement procedures during operations.

(2) Instruct employees on safe operation, hazardous material handling and emergency procedures.

(3) Modify safety practices and procedures as dictated by need.

(4) Implement operating system emergency procedures to address potential hazards.

7.3.3 CLASSIFICATION OF INDUSTRIAL SAFETY HAZARDS

7.3.3.1 ELECTRICAL

Only trained and qualified personnel will repair and hook up electrical equipment and instrumentation. The major electrical equipment in both the mine (well fields) and processing facility will be pumps--such as submersible well pumps, stationary water-circulation pumps and reagent feed pumps--as well as transformers, electrically operated switches, gauges, valves, agitators and recording devices (e.g., pH meters).

7.3.3.2 MECHANICAL

Possible major mechanical equipment items in the mine and plant are:

1) small continuous steel-belt dryer for drying uranium precipitate (fully covered), 2) front-end loader, 3) agitators in precipitation tanks, 4) truck-mounted, water-well drill rigs, 5) road scraper, and 6) trucks.

This equipment will be operated only by experienced operators. All recommended OSHA and MESA regulations will be followed in use and maintenance of this equipment.

7.3.3.3 CHEMICAL

The chemical reagents used in the insitu leaching process are potentially dangerous to operating personnel if allowed to contact the skin or if the vapor is inhaled while in concentrated form. These reagents are stored on site in metal or fiberglass tanks recommended by the chemical manufacturers. WMC will continuously monitor air samples to conform to NRC and MESA standards. The chemical reagents stored on site are carbon dioxide (gas), hydrogen peroxide (50%) (liquid), anhydrous ammonia (liquid), hydrochloric acid (50%), ammonium chloride (solid), ammonium bicarbonate (solid).

7.3.3.4 ENVIRONMENTAL

There are potential hazards in operating a solution mining plant during a Wyoming winter. The company will maintain the necessary snow-removal equipment for field operations to insure that roads to and from mine

sites are safe. In the event of a blizzard, the plant can shut down for short periods.

In warm weather the danger of poisonous snakes in the well fields is a definite possibility, particularly at night. Outside lighting will be provided for night operations, and standard first aid procedures will be implemented in the event of snake bites.

In readiness for all emergencies, a list of the closest hospitals, clinics and doctors will be maintained at each plant site. If a serious emergency occurs, commercial helicopter service is available to evacuate a patient to the nearest hospital. Additionally, modified vehicles outfitted as ambulances and one vehicle for fighting grass fires will be maintained on site at all times. Personnel will be adequately trained in first aid administration and fire fighting techniques. Appropriate equipment will be maintained at the site.

7.3.3.5 FLOOD AND SEISMIC HAZARDS

Plant failure from serious flood or earthquakes is an extremely remote possibility due to the plant's structural mobility and the site location in an area of low seismic activity.

SECTION 8.0

ENVIRONMENTAL EFFECTS OF ACCIDENTS

8.1 WELL FIELD EXCURSION

If a significant change is recognized in the monitor well parameter values (value exceeding the UCL) to indicate that the leaching chemicals are migrating from the well field, WMC will undertake action as described in Section 7.2.4.

8.2 FAILURE TO RECOVER FROM A PRODUCTION WELL

Should a production well fail to recover as a result of plugging or power failure, flow meters routinely read every 2 hours would indicate same. Assuming a worst case flow rate of 20 gpm, and no portion of the solution is recovered by another cell, this would result in the temporary loss of 1200 gallons of solution. Although the solution might migrate beyond that cell, it would remain within the mining unit. Upon correction of the situation and reinstitution of pumping, over recovery would occur.

8.3 TRUNK LINE RUPTURE

Piping will be used for trunk lines at the Irigaray facility. Industrial experience indicates that the probability of rupture is small. In "An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants"[1] it is estimated from industrial experience that the pipe failure probability for pipes less than three inches in diameter ranges from 3×10^{-11}/hr

to 5 x 10^{-6}/hr. For pipes greater than three inches in diameter the failure probability ranged from 3 x 10^{-12}/hr to 5 x 10^{-6}/hr. If low flow alarms are used, the rupture would be brought to the immediate attention of the operators. If the rupture is not identified by visual inspection (well fields are under constant surveillance), or if low flow alarms are not used, indication would not be evident until a recovery tank drawdown had occurred, perhaps as long as 60 minutes. A worst case loss would be of the order of 12,000 gallons. Immediately upon indication that the above situation exists, operating personnel would cease plant flow. As much spilled solution as possible would be recovered via tank truck and pump and placed into an evaporation pond.

8.4 FAILURE OF WELL CASING

Should a leak develop in the casing of a production well to an upper aquifer, water would be drawn from the upper aquifer into the production well and no solution from the production zone will contaminate the upper aquifer.

Should a leak develop in the casing of an injection well, the leak will be detected by either monitor wells or by pressure drop in the injection well. A break which results in a further leak, will be quickly detected by pressure drop in the injection flow line or, by visual inspection. Since well fields are under surveillance, any surface leak would be quickly detected by inspection.

A subsurface leak to another aquifer would be identified by monitor well samples. The amount of aquifer contaminated will be a function of the distance from the injection well to a monitor well in that aquifer and the thickness of the aquifer. Deep and shallow aquifer monitor wells will exist within the well field. The time required for indication of failure would be a function of the distance between the leak and a monitor well. For worst case, the width of the well field would be considered.

Before a well field is placed into production, ground water is circulated through a well field to check for leaks. Leaks are likely to be more a function of failure in well completion than degradation during production.

Leaks identified during pre-production circulation will be plugged. Therefore, the likelihood of such accidents occurring during production are remote.

Should a leak occur in a well, the well will be permanently plugged or repaired. Initial aquifer cleanup involves containment by stopping the leak and water removal to clean up the contaminated portion of the aquifer. Several mechanisms can be employed for containing and correcting an excursion of leach solution; overpumping, re-establish the balance of the well field, reducing or stopping injection, cease pumping injection solutions of reduced concentrations, or establishing a water fence. These procedures may be applied locally to a few wells within a cell, to an entire cell, to several cells or to the entire well field as the situation dictates.

8.5 LEAKAGE THROUGH UNMAPPED EXPLORATION HOLES

Prior to injection of chemicals the well field is purged with water. Any communication between aquifers or with the surface through old exploration holes would be indicated at this time. Holes which appear would be plugged. Therefore this situation could not exist during production phases of operations.

8.6 RUPTURE OF STORAGE TANK

Storage tanks are of fiberglass construction and are diked or bermed to contain a minimum of twice the tank capacity should a rupture occur. (Maximum individual tank capacity = 12,000 gallons). Yellow cake slurry storage tank leaks can be recovered via sump pump. If a leak or rupture occurs in a tank, readily accessible inlet shut off valves would be closed and pumps turned off to minimize additional fluid loss. The rupture would be repaired and the affected area washed down.

Pond leaks can be detected by visual inspection, depth gauges, and underground leak detection systems.

If a leak occurs, the fluid in the pond will be pumped to another pond. If the leak contaminates an aquifer, the contaminating fluid will be pumped out and placed into an evaporation pond.

8.8 TRANSPORTATION ACCIDENTS

This section provides a general analysis of the potential environmental impact resulting from the shipment of chemical and radioactive materials to and from the WMC site. The materials considered in this analysis include toxic chemicals and radioactive materials. Non-radioactive chemical materials such as bulk tank-truck shipments of anhydrous ammonia, hydrogen peroxide, hydrochloric acid and carbon dioxide (gas) solutions are made to the site. The frequency of these shipments will be less than three per month for the site. These materials are all shipped in accordance with state and federal regulations.

Most shipments of radioactive materials move in routine commerce via Department of Transportation approved carriers. Therefore, shipments and packaging are subject to the requirements of 49CFR173 and the Nuclear Regulatory Commission. Data on the transportation of radioactive materials to and from nuclear power plants indicates that the probability of a truck accident occurring in transport is very small: about one for each million vehicle miles.[2] However, should an accident occur, it would be rare if all the drums in the shipment broke or if the uranium oxide spread over a large area. Should a spill occur on land, the uranium oxide could be scooped up and recovered along with any contaminated soil.

All material is shipped in DOT approved containers. In the event that a package of low specific activity material (uranium oxide) were in an accident, the low specific activity and the negligible external radiation levels associated with the materials limit the radiological impact.

8.9 NATURAL PHENOMENA

An earthquake of magnitude 5.0 to 6.0 (Modified Mercali Intensity Scale) may occur about once every 20 years. (See Section 3.4). The consequences of a magnitude 6.0 earthquake on site operations would be minimal. Other than movement of small unattached objects, furniture, and possible cracking of weak plaster and masonry, no significant effect on operations would be expected.

An earthquake of magnitude 6.0 to 7.0 (Modified Mercali Intensity Scale) may occur once every 200 years. Although the probability of such an event is rare, worst case consequences at magnitude 7.0 could result in rupture of pipelines or tanks causing fluid leaks. In such an event, plant flows would be shut off to minimize the amount of solution lost. Tanks and similar equipment containing hazardous materials will be diked to contain the solutions should a leak occur. Recoverable spilled solutions will be returned to the process or to evaporation ponds.

8.10 EXPLOSIONS AND FIRE

The potential for explosion and/or fires at the Irigaray plant has been minimized by the extensive use of non-combustible materials.

The bulk of the plant construction and equipment are made of metal, fiberglass, PVC, or concrete. Sources of fire are therefore limited to waste receptacles, electrical equipment and fuel storage tanks. An adequate supply of properly serviced and appropriate portable fire extinguishers

will be maintained at the site at all times. Personnel will be adequately trained in fire prevention and fire fighting techniques to limit and confine any fire which does occur. All electrical equipment will be properly wired and grounded in accordance with the National Electric Safety Code (ANSI C2). Fuel storage tanks will be properly labeled (contacts, "No Smoking", etc.) and will be diked or bermed.

Hydrogen peroxide storage tanks are designed with a pressure release vent to prevent the buildup of pressure within the vessel should unexpected oxidation occur (excessive heat, combustible in contact with contents, etc.).

The only other explosive source on site is the ammonia (NH_3) gas storage tank which is maintained in open air. Should this tank rupture releasing the contents, concentration of NH_3 in the vicinity of the tank would not be expected to remain within the explosive limits of the gas, i.e., 16% - 25% in air. The concentration at the tank rupture would be close to 100% and the gas would be diluted and dispersed very rapidly.

SECTION 9.0

RESTORATION AND RECLAMATION

9.1 WELL FIELD RESOTRATION

After mining, the affected aquifer(s) will be returned to appropriate water quality standards. The parts of the aquifer that have been contacted by the lixiviant will require the following two basic restoration actions; 1) pore volume waters containing leach solution will be removed and replaced with water of acceptable quality, and 2) certain chemical elements or compounds which have sorbed or reacted with the mineral content of the aquifer will be removed or rendered insoluble.

Pre-mining groundwater quality was determined during baseline studies (Section 7.2.4). Criteria based on the baseline water quality and its potential use will be used, to determine the level of water quality to which the aquifer will be restored. This determination of restoration water quality guidelines will be made in consort with the appropriate regulatory agencies.

9.2 RESTORATION CONSIDERATIONS

The introduction of leach solutions into the underground aquifer produces changes in both the aquifer water chemistry and the oxidation state of the host. Since the leach chemistry is chosen to extract uranium (a metallic element), it is to be expected that other elements in the ore

may also be mobilized. Both the introduction of leach chemicals and the leaching of other ions from the ore thus give rise to potential contamination in the aquifer. (Section 2.2.2). The leach solution mixes with and replaces the existing aquifer water in the ore zone. The residual lixiviant, together with the leached ore, constitutes the contaminated region.

The procedure for restoring the contaminated region will consist of removal and treatment of the affected waters, reinjection of the removed water after treatment to an appropriate water quality, and host sand stabilization. The method of aboveground water treatment to be used will be dependent upon the type and amounts of dissolved ionic species in the native groundwater and the ionic species introduced or mobilized through the introduction of leach solutions. During the course of reinjection, reagents for removal of residual lixiviant from the aquifer or those chemicals that mobilize species by underground precipitation may be introduced. Such chemicals would, if needed to meet final restoration target value, be removed from the aquifer prior to cessation of the restoration operation.

9.3 RESOTRATION PROCESS ALTERNATIVES

Upon termination of mining in a given area several techniques are available in restoring the aquifer to some agreed upon water quality. These methods fall into three general classifications, total water removal; water removal, clean-up and recycle; and insitu restoration.

Total water removal methods are those which pump the contaminated water from the aquifer and allow cleaner groundwater to flow into the affected area. In water removal, clean-up and recycle methods contaminated water is pumped to the surface, cleaned up, and re-injected into the aquifer. Insitu restoration methods rely on the injection of chemicals into the underground that produce the desired water clean-up. The applicable methods that can be applied to effect the desired restoration are outlined in Table 9-1 and will be further detailed in the following discussion.

9.3.1 TOTAL WATER REMOVAL METHODS

In total water removal, contaminated water is pumped from the aquifer and surrounding groundwater is allowed to flow into the leach ore zone to sweep the contaminants from the aquifer. The removed water is not reinjected into the ore zone aquifer. Methods of total water removal include solar evaporation, deep well injection, spray or flood irrigation, and conventional evaporation with steam venting.

These methods have some distinct advantages in terms of overall process simplicity, cost and established technology. They do, however, have the disadvantage that water is removed from the affected aquifer and, after treatment is released on the surface or evaporated. The volume of water that will have to be removed to reduce the chemical species that have sorbed on the clays in the ore body may be prohibitively large both in terms of cost and the time over which restoration is to be accomplished.

TABLE 9-1
METHODS FOR GROUNDWATER TREATMENT

Total Water Removal	Recycling of Clean Water
a. Solar Evaporation from Ponds	a. Reverse Osmosis
b. Conventional Evaporation	b. Electrodialysis
c. Flood Irrigation	c. Ion Exchange
d. Deep Disposal Wells	d. Conventional Evaporation with Water Recycle
	e. Ultrafiltration
	f. Chemical Precipitation
	g. Ammonia Air Stripping

9.3.1.1 SOLAR EVAPORATION FROM PONDS

Pond evaporation can be utilized to reduce the volumes of process waste water or to completely evaporate contaminated waste to a more readily solid form. The usefulness of the method depends on the amount of water, the pond area and the annual evaporation rate. A study of the annual evaporation rate of the Irigaray area shows that conditions are highly favorable for solar evaporation. The waste remaining after evaporation would be either shipped off-site to an approved burial site or stabilized using an approved technique.

9.3.1.2 CONVENTIONAL EVAPORATION

Conventional evaporation is a proven technique for water purification. Selection of the type of evaporator (multi-stage flash, single affect, multi-effect, etc.) and the heating system (electrical, oil, natural gas, coal) would be determined by conditions in the area in which it would be installed. Conventional evaporation would yield maximum volume reduction and minimum waste volume for final disposal. Major disadvantages of conventional evaporation are the high capital cost and high energy consumption.

9.3.1.3 FLOOD IRRIGATION

The chemicals used in WMC solution mining (ammonium bicarbonate) have useful value as fertilizers. The treatment of the leach solution to remove specific ions which are not desirable would be followed by transfer of the solutions to an agricultural area for use as fertilizer and a source of water.

9.3.2 WATER REMOVAL, CLEAN-UP AND RECYCLE

In water removal, clean-up and recycle, contaminated water is pumped from the aquifer, treated aboveground and is then reinjected into the aquifer from which is was pumped. In a sense this method is quite similar to the original solution mining procedure in that contaminant species are removed from the groundwater and concentrated aboveground. The main environmental advantage of this process is that the method minimizes water use, since most of the water is reinjected into the aquifer.

Aboveground techniques for cleaning up the groundwater prior to reinjection are highly dependent on the type and amount of contaminants that must be removed. Examples of treatment techniques include chemical precipitation, reverse osmosis, electrodialysis, ion exchange, evaporation, and aeration. Since the spectrum of contaminants that can be found in typical well field waters is diverse, a combination of the above methods may be necessary to restore the aquifer to the desired conditions in an economical fashion.

Water treatment-recycle is done in several stages much as is solution mining for uranium removal. The same pumping configuration is used to remove and reinject water into the aquifer. Thus, localized regions (specific cells or sets of cells) of the field are restored in a hydraulically balanced system. Different areas of the well field (cells) can be operated for different periods of time and for specific ion removal problems. If a series of cells in the field were found to exhibit a high level of any particular contaminant, that series of cells may

receive a larger number of volume displacements than would a cell region of low concentration. As contaminated water is removed from the aquifer it can be treated for specific contaminant removal and injected into the aquifer. Chemical constituents specifically designed to enhance the removal of certain sorbed species such as ammonia may be added to the water to increase the rate of aquifer restoration.

Specific equipment or unit operations useful, in part or in combination, in a process for implementation of the water recycle technique are reverse osmosis, electrodialysis, ion exchange, conventional evaporation with water recycle, ultrafiltration, chemical precipitation, and air stripping of ammonia. Osmosis operates on the principle that concentrated and dilute solutions separated by a semi-permeable membrane will tend to equilibrate by allowing solvent to flow from dilute to concentrated solution. In reverse osmosis, this flow is reversed by hydraulic pressure. The solvent progressively moves from concentrated to dilute solutions, thus allowing progressive separation of impurities and purified solvent.

For groundwater restoration of solution mining leachates, reverse osmosis has promise as an effective method for volume reductions. One of the major advantages of reverse osmosis is that no other chemicals are introduced into the system. However, large volumes of concentrated waste would have to be disposed of. Use of a secondary technique to handle the concentrates (conventional evaporation, precipitation, etc.) is being studied.

Electrodialysis is a commercially viable process for treating brackish waters. The system reduces the electrolyte content of a given feed solution by transferring ions through selective anion and cation membranes under the influence of an electrical potential difference. The process is most applicable for waters having TDS levels less than 10,000 ppm and preferrably less than 5000 ppm. Its drawbacks include membrane fouling due to insoluable material precipitation. As such, it is therefore limited (as is reverse osmosis) in its concentration capacity unless feed pre-treatment is performed. For feed solutions with high salt contents (e.g., 10,000 ppm TDS) the method becomes very expensive from a power consumption view point.

Ion exchange has been used in commercial water treatment very successfully. The typical ion exchange mechanism involves the exchange of the impurity species with an anion or cation form of a water insoluble resin. The impurities then must be treated by a secondary technique such as conventional evaporation to put them into a form suitable for solidification and subsequent disposal.

Conventional evaporation with water recycle is identical to conventional evaporation with the addition of a condenser to recover the vaporized water. The condensed, purified water would then be injected into the aquifer.

Ultrafiltration is another of the membrane separation processes such as reverse osmosis and electrodialysis. In ultrafiltration a membrane allows passage of water molecules but impedes passage of molecules having a molecular weight of about 100 or higher, depending upon the type of

membrane used. Ultrafiltration can be made somewhat selective by the proper choice of the membrane. The major disadvantage of ultrafiltration is possible fouling and plugging of the membrane with insoluble salts.

Chemical precipitation of specific impurities is a widely used technique in the mineral industry. The removal of Ra-226 by chemical precipitation with barium is used in many uranium milling operations. The technique to be used for a specific ion is determined by the concentration of the ion, the composition of the leach solution and the specific chemical characteristics of the ion.

Ammonia removal from aqueous solutions is most easily accomplished by the process of air stripping. The solution is pH adjusted and passed through a stripping tower through which a large volume air stream also passes. The high pH of the solution forces the ionic ammonium ion (NH_4^+) to convert to dissolved ammonia gas (NH_3) which can be removed from the water by the flowing air stream.

9.3.3 INSITU RESORATION METHODS

Another possible technique for groundwater restoration is the insitu method. This is a method whereby the underground aquifer is treated to produce the desired water quality without above ground treatment. This technique may be practical for those species that can be stabilized underground by precipitation or other techniques. However, it can only partly restore the aquifer since the method cannot effectively remove dissolved species such as ammonia and chloride.

A combination of chemical injection techniques together with water removal and treatment appears to be the most viable approach for the currently used ammonium bicarbonate leach chemistry restoration. WMC is performing both laboratory as well as field studies to identify the most applicable technique for the Irigaray solution mining site. A restoration demonstration test at Irigaray is now is progress and is described in Section 9.4.

9.4 RESTORATION PROCESS FIELD DEMONSTRATION

A restoration demonstration program is in progress using the Irigaray 5I7 R&D test field.

The objectives of the Irigaray restoration program are, to study the equilibration of an evacuated mine zone as a function of time, to determine the number of displacements required to reach acceptable levels of water quality, and to test above groundwater purification techniques. The demonstration is being carried out in three distinct phases, each designed to develop aquifer response data to the restoration process used. These three phases are groundwater sweeping, clean water recycle, and chemical restoration.

The first phase of the test consists of removing groundwater from the mine zone (aquifer). This removed water is being ponded. Surrounding water is thereby allowed to replace the removed volume. Removal, displacement and ponding will be repeated several times. Analysis will be made throughout this entire process to determine the removal rate of

specific water quality parameters. Ponds have been constructed to receive the pumped solution and a water treatment plant has been designed and built to treat the removed water to acceptable water quality standards. The water purification technique that will be employed is reverse osmosis (RO) followed by selective absorption of trace species such as ammonia if needed. It is anticipated that the RO treatment system can restore the water to baseline standards. The ground water sweeping tests will be confined to one seventh of the total 5I7 test field. It is anticipated that the 5I7 test area will be a part of future mining zones and, thus, restoration of the entire site is not warranted at this time. The selective portion of the test site will be isolated hydraulically and pumped to allow groundwater to sweep into a previously mined zone. The present water quality in the aquifer compared to previously determined post-mining water quality is shown in Table 9-2. Approximately 400,000 gal. of water will be removed from the area and treated with the RO water clean-up system. The groundwater sweeping tests should be completed by the 3rd quarter 1977.

Treated RO permeate of water quality comparable to or better than baseline quality will be reinjected into the aquifer in a controlled 5-spot pattern to observe the response of the aquifer to the flow of clean water through a previously mined zone. The same treatment plant that was built for clean-up of the groundwater sweep solutions will be used to conduct this study.

If, after the aquifer has been swept of its dissolved water contaminants, it still appears that traces of residual leach chemicals (such as NH_4^+)

TABLE 9-2
COMPARISON OF PRE-MINING WATER AND PRE-RESTORATION MINE WATER QUALITY
IRIGARAY TEST SITE 5I7

Analysis	Unit	Pre-Mining Groundwater Quality	Pre-Restoration Production Zone Values
As	ppm	<.0025	.021
Ba	ppm	.12	.069
B	ppm	.16	.283
Cd	ppm	<.005	.014
Cr	ppm	.0135	.002
Cu	ppm	.019	.220
Mn	ppm	.12	.97
Hg	ppm	.0028	<.0002
Ni	ppm	.018	.218
Se	ppm	.013	1.75
Ag	ppm	<.005	.015
Zn	ppm	.003	.22
TDS	mg/l	793.	1324.
Pb	ppm	.0035	.110
U_3O_8	ppm	.098	24.4
NH_3	ppm	<1.0	235.
HCO_3	mg/l	139.	805.
Cl^-	ppm	10.75	524.
Gross Alpha	pCi/l	168.±11.	22,815.±296.
Gross Beta	pCi/l	164.±19.	21,043.±441.
Ra 226	pCi/l	26.8±5.2	371.±5.6

remain in the aquifer, a chemical restoration test will be performed. Chemical restoration is a technique whereby certain inoccuous ions such as Ca^{++} or Mg^{++} are added to the recycle water in the initial stages of restoration to enhance the removal of ammonia from the clay fractions in the ore. Laboratory column studies have demonstrated that this technique increases the rate of the ammonia removal. These added constituents will replace the absorbed NH_4^+ on the clays and render it soluble in the revived mine water so that it can be removed.

The process to be used will involve the injection of Ca^{++} ions as either the compound $CaCl_2$ or $Ca(OH)_2$ or a combination of these compounds. The higher levels of calcium will desorb the NH_4^+ from the clays and replace Ca^{++} that was removed from the clays during the initial phases of mining. This returns the clays to their original state and assists in the rate at which NH_4^+ is removed from the clays. After the majority of the NH_4^+ has been removed from the clays the RO treatment plant will be utilized to remove any higher levels of TDS that may have been introduced during mining and the initial phases of the restoration. The small amount of Ca^{++} or NH_4^+ that remain after this treatment, can be stabilized by the introduction of carbonate into the water which will precipitate the residual Ca^{++} as $CaCO_3$ and will allow the small amount of residual NH_4^+ to be reabsorbed by the clays, thus rendering it insoluble in the groundwater. The chemical restoration tests, if the first phases of the Irigaray restoration demonstration warrant them, will be done during August to September and should be completed by the end of October, 1977.

9.5 RESTORATION PLANS FOR THE IRIGARAY SITE

Restoration will be conducted as a follow-up to the mining operation at the Irigaray site. The concept of restoring a mined area while mining is proceeding in another area poses both operational and hydrologic constraints on each of the operations. The untested concept of sequential restoration is being evaluated for use at the Irigaray site. This concept is described below.

9.5.1 SEQUENTIAL RESTORATION

As mining proceeds along a uranium roll front, the well field patterns that are developed are usually elongated and follow the area of mineralization. As the mining units are depleted of uranium, new mining units are brought into operation and the depleted ones are removed from production. Since leach solution may still remain in the uranium depleted unit, it is proposed that this solution be pumped out and injected into the new mining unit, while the (uncontaminated) aquifer water in the new mining unit is pumped into the depleted unit.

As restoration and mining proceed along the roll front, a buffer zone where no mining is taking place would be needed between the mining and restoration area so that no hydraulic coupling of the two operations could occur. When the majority of leach solution has been pumped from the area undergoing restoration, the restoration process of water removal, treatment and clean water reinjection will be initiated until the depleted area has been completely restored. This sequential restoration method using a buffer area between a mined out field and a new mine

field will continue as more new mine fields are brought into service and the old mining fields are depleted. The final steps in restoration of such a sequence of mine units would be the restoration of the last two mining units to close out the entire mine field.

9.5.2 IRIGARAY RESTORATION PROCESS DESCRIPTION

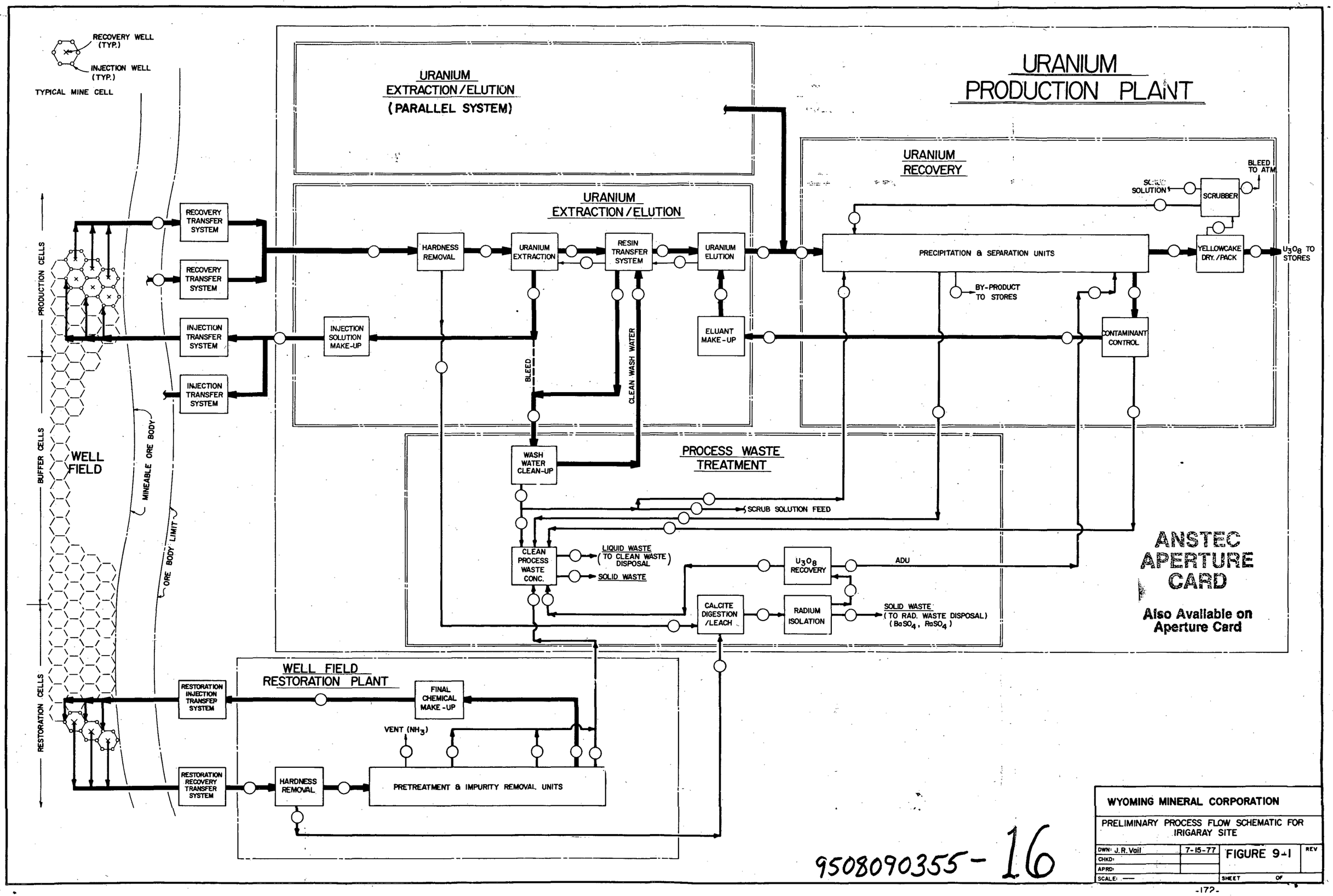
The objectives of the mine field restoration process will be to: 1) recover residual mining solutions from the mined zones of the aquifer which contain environmentally unacceptable dissolved constituents, 2) remove and concentrate the undesirable constituents, 3) recover a significant fraction of the processed water for reinjection; in order to restore acceptable water quality in the aquifer, 4) return the host sand to chemical equilibrium with the restored aquifer.

Although the final detailed flowsheet for the restoration process is contingent upon the results of restoration demonstration testing, (see 9.5.1) a general process description of a restoration process follows. (See Figure 9-1).

9.5.2.1 RESTORATION PROCESS SYSTEM

A recovery transfer system will perform a similar function for restoration as it does for uranium mining, i.e., transfers recovered solution to the restoration plant for treatment.

The recovered solution may require removal of hardness chemicals such as calcium and magnesium prior to further processing. The principle


RECOVERY WELL (TYP.)
INJECTION WELL (TYP.)
TYPICAL MINE CELL
PRODUCTION CELLS
BUFFER CELLS
RESTORATION CELLS
WELL FIELD
MINEABLE ORE BODY
ORE BODY LIMIT
RECOVERY TRANSFER SYSTEM
RECOVERY TRANSFER SYSTEM
INJECTION TRANSFER SYSTEM
INJECTION TRANSFER SYSTEM
URANIUM EXTRACTION/ELUTION (PARALLEL SYSTEM)
URANIUM EXTRACTION/ELUTION
HARDNESS REMOVAL
URANIUM EXTRACTION
RESIN TRANSFER SYSTEM
URANIUM ELUTION
INJECTION SOLUTION MAKE-UP
BLEED
CLEAN WASH WATER
ELUANT MAKE-UP
URANIUM PRODUCTION PLANT
URANIUM RECOVERY
SCRUBBER
BLEED TO ATM.
SOLUTION
PRECIPITATION & SEPARATION UNITS
YELLOWCAKE DRY./PACK
U_3O_8 TO STORES
BY-PRODUCT TO STORES
CONTAMINANT CONTROL
PROCESS WASTE TREATMENT
WASH WATER CLEAN-UP
SCRUB SOLUTION FEED
CLEAN PROCESS WASTE CONC.
LIQUID WASTE (TO CLEAN WASTE DISPOSAL)
SOLID WASTE
U_3O_8 RECOVERY
ADU
CALCITE DIGESTION /LEACH
RADIUM ISOLATION
SOLID WASTE (TO RAD. WASTE DISPOSAL) ($BaSO_4$, $RaSO_4$)
WELL FIELD RESTORATION PLANT
RESTORATION INJECTION TRANSFER SYSTEM
FINAL CHEMICAL MAKE-UP
VENT (NH_3)
RESTORATION RECOVERY TRANSFER SYSTEM
HARDNESS REMOVAL
PRETREATMENT & IMPURITY REMOVAL UNITS
ANSTEC APERTURE CARD
Also Available on Aperture Card
WYOMING MINERAL CORPORATION
PRELIMINARY PROCESS FLOW SCHEMATIC FOR IRIGARAY SITE
DWN: J.R. Vail
7-15-77
CHKD:
APRD:
SCALE: —
FIGURE 9-1
REV
SHEET OF
9508090355-16

technique to be employed in hardness removal will be cold-lime softening. Following hardness removal the overflow solution will be further treated for removal of remaining impurities. The primary contaminants to be removed are ammonia and total dissolved solids (TDS).

To accomplish this treatment the solution will be fed to a reverse osmosis (RO) unit. The unit will be operated so as to maximize clean water production (i.e., with a total dissolved solids content comparable to baseline water quality); thereby minimizing waste solution volume. The RO permeate solution is then fed to a final chemical treatment unit and, following verification analysis, the treated solution will be transferred to the well field for injection as in the mining operation.

9.5.2.2 ALTERNATIVES TO PROPOSED RESTORATION PROCESS

Alternatives to the above described process are being studied in both laboratory as well as field tests. (Section 9.4). In all cases however, after the ore zone aquifer has been restored to a defined water quality, potential hazards of any residual contaminants are not envisioned since this is the criteria for final process selection. Naturally occurring species that had been temporarily mobilized from the host mineralization would either have been removed from the mine zone aquifer by the water treatment process or would have stabilized by reprecipitation in the ore zone. Species that are specifically introduced in the leach solutions include hydrogen peroxide (which decomposes to form water and dissolved oxygen), bicarbonate (which is removed by the water treatment process

and will also stabilize naturally in the host) and ammonium ions. The latter would be removed both from the aquifer water as well as from the absorbing clays in the restoration process. Any residuals should not be deleterious to the future uses of the water. Small traces of leachate chemicals that might remain after restoration is complete would be rendered stable by the natural buffering capacity of the ore as water slowly percolates from the mined area through the host.

9.6 RESTORATION PROCESS WATER VOLUMES

During the restoration, process solutions are pumped from mined areas and processed in an aboveground treatment plant for purification. The clean treated water is reinjected into the aquifer. However, a small bleed stream containing the removed contaminants is wasted. The volumetric impact of such a process or the total waste volumes generated is dependent on the mining rate and the aerial extent of the mine zone. The calculations of affected aquifer and restoration waste volume assume the following:

1. The yearly mining rate would incorporate approximately 30 acres.
2. The well field is elongated along the roll front.
3. A 10% boundary sweep at the edge of a mine field.
4. A 10% vertical spread in the affected aquifer.

The following information on the well field is used:

Mine Area - 30 acres

To = Thickness of mined ore body = 20'

Θ = Porosity = 0.25

A_A = Affected Aerial Extent ≈ 50.0 acres

T_A = Affected thickness of mined ore body = 24'

Calculation of the affected volume, V_A, per year can then be made.

$$V_A = A_A \, \Theta \, T_A$$

$$\frac{\text{Affected Volume}}{\text{year}} = (30.)\ (24)\ (0.25)$$

$$= 180 \text{ acre feet/year}$$

Estimating treatment of the affected aquifer by five times to produce the desired water quality, with a bleed volume, V_B, of 15% that is wasted. The volume from the restoration process, V_R would be:

$$V_R = V_A \, N_A \, V_B$$

where N_A = number of aquifer volumes pumped

$$V_R = (180 \text{ acre feet})\ (5)\ (0.15)$$

$$V_R = 135 \text{ acre feet/year}$$

These restoration process waste waters will be ponded for further volume reduction by evaporation. The composition these wastes consist primarily of NH_4^+, Na^+, Cl^-, $SO_4^=$ as a saline brine pH ∿ 6, TDS 15,000 with minor quantities of Ca^{++}, Mg^{++} and the trace contaminants removed from the processed aquifer waters. Uranium concentrations of 10-500 ppm and Ra-226 concentrations of 100-1000 pCi/l are anticipated.

9.7 RECLAMATION

The post-mining land use goal is to return the area to agricultural grazing and wildlife habitat. The reclamation program will be designed to produce a stable plant cover to achieve that goal.

Surface reclamation generally involves three interrelated components: 1) the physical modification of land forms to produce a suitable topography, 2) the establishment of selected plant species (revegetation), and 3) monitoring of the success of the revegetative efforts until soil stability and vegetative productivity are achieved.

Reclamation at the Irigaray site will be directed toward the well field, the various storage ponds, and the plant site(s).

Reclamation of the well field will be by sections, as fields are mined out. Individual injection and production wells will be plugged and sealed below the surface, and the area surrounding the plugged wells will be filled with soil. These areas will then be seeded to Soil Conservation Service recommendation and fertilized and irrigated, if necessary. The fences which excluded livestock from the well field during mining will be left in place until a stable plant cover is established.

Reclamation techniques for the process and waste ponds on the site may vary depending on the materials contained by each. The relatively small, lined ponds will (except for the restoration holding pond) contain solid

materials of sufficient radioactivity to require disposition as discussed in Section 4.0. The pond will be backfilled with the materials which were originally excavated for dikes and achieve a slight crown. Such areas will then be revegetated with a seed mixture and application rate appropriate for the specific site. Irrigation and fertilization will be performed, as necessary.

The larger pond will not require removal of the accumulated solids due to the relatively low concentrations of radioactive and noxious elements stored therein.

When mining operations cease, the liquid portion of process and waste ponds will evaporate. After complete evaporation, contaminants will be bulldozed to the edge of the pond. The remains will be covered with overburden to a depth of approximately six feet, and with topsoil sufficient to support vegetation. Six feet of cover should eliminate any problems with direct gamma radiation doses, and reduce emissions of Radon 222.

The resulting surface will be revegetated to a stable plant cover consistent with the post-mining land use goal.

The diversion ditches constructed prior to the use of the ponding areas, will be maintained to protect the area from surface water erosion.

Fences around the final disposal ponds will be maintained and posted to prevent ingress by both human land users and livestock until it is determined that surface radiation levels are safe for unrestricted grazing, and until a stable vegetative cover is established.

Post reclamation monitoring will include radiation monitoring, and periodic checks on the success of the revegetated surface.

Plant close-out procedures will return the site to a condition compatible with present and future uses and will mitigate as much as practicable any adverse environmental impacts that may have occurred. Upon completion of operations, any structures which are not compatible with the post-mining land use goal will be decommissioned and the surface reclaimed.

9.8 RECLAMATION COSTS

Reclamation of the disturbed area will proceed at a rate commensurate with mining. Recurrent costs each year will occur for topsoil handling and grading, plant materials and seed, cement for well plugging, and labor to implement the reclamation efforts. In addition, at the end of the project (approximately 10 years) the plant will be decommissioned, and the plant site(s) area reclaimed. The costs of the various reclamation activities are summarized in Table 9.3. Costs of decommissioning the plant are shown in Table 9.4.

TABLE 9-3
ESTIMATED COSTS OF RECLAMATION OF IRIGARAY PROJECT
(Based on a Well Field Area of 30 Acres)

ITEM	
Topsoil Handling and Grading	60 hours at $32.00/hr. or $1920
Seed/Seedlings	$600
Cement for Well Plugging	$66/well, 25 well/acre $49,500/30 acres/year
Labor	Approximately 6.5 man-months = $7200
TOTAL:	$59,220/30 acres/year or approximately $2000/acre/year

TABLE 9-4
ESTIMATED COSTS OF PLANT AND POND DECOMMISSIONING, IRIGARAY PROJECT

CASE I Salvage only, Building and concrete burial on site

Gravel and concrete removal and burial	$11,500
Structure demolition and burial	7,500
Removal of 3 miles of power lines	2,500
Special handling equipment	2,500
Land contouring	6,000
Topsoid and seeding (ponds)	500
TOTAL	$30,500

CASE II Salvage only, off-site burial

Concrete and gravel removal	$ 9,500
Hauling and off-site burial	12,000
Structure demolition	5,000
Structure hauling and off-site burial	5,000
Equipment rental special handling	2,500
Removal of 3 miles of power lines	2,500
Land contouring	6,000
Topsoil and seeding (ponds)	500
TOTAL	$42,500

SECTION 10.0

SOCIOECONOMIC EFFECTS OF CONSTRUCTION AND OPERATION

10.1 GENERAL NEED FOR URANIUM

The general need for uranium has already been identified in licensing of nuclear power reactors.[1] In the nuclear reactor evaluation process the benefits of the energy produced are weighted against all the related environmental costs of uranium production. These incremental impacts are considered with the remainder of the fuel cycle and are justified in terms of the benefits of energy generation. (Also see Section 11.3).

10.2 BENEFITS/COSTS

10.2.1 DIRECT BENEFITS

The direct benefits of the Irigaray Project are in the value of the uranium oxide produced. Assuming an annual output of 500,000 pounds of U_3O_8, a current spot market price of $40 per pound, and a discount rate of ten percent, the estimated present worth market value of the Irigaray Project output taken over a ten year life is $112,049,000.

The value of the uranium oxide produced can also be viewed in terms of the physical contribution the Irigaray Project will make to existing production in Johnson County to Wyoming and to the United States as a whole. Department of Economic Planning and Development data

show that eight counties account for about 80 percent of the total assessed mineral valuation in Wyoming. They are Campbell, Park, Natrona, Sweetwater, Fremount, Converse, Hot Springs and Carbon counties. All others, including Johnson County account for the remaining 20%. Further, on the basis of latest Wyoming Department of Revenue/ Sales and Use Tax data, the percent collection of Sales and Use Taxes for Johnson County were approximately 1.5% of the total for Wyoming. Therefore, since there are no other uranium producing operations in Johnson County the Irigaray project will in the future, contribute significantly to the overall value and mineral portion of the tax category for Johnson County. On a state or national basis, the project's contribution will be significant, but not as dramatic as its effect at the county level. (See Section 11.3)

Table 10-1 summarizes the estimated unearned income that will be generated by the Irigaray Project during 1978 - 1988. This table is also based on the assumptions outlined in the preceeding paragraph. All amounts presented in the table are in 1977 dollars. The present value of the total estimated unearned income resulting from implementation of the Irigaray Project is $42,815,000.

10.2.2 SOCIAL EFFECTS

The proposed project is located approximately 40 miles southeast of Buffalo, Wyoming and the majority of the employees will reside in that community. The majority of these workers will be drawn from WMC employees already in the Buffalo area. (Section 3.2.1).

TABLE 10-1
ESTIMATED UNEARNED INCOME RESULTING FROM IMPLEMENTATION
OF THE IRIGARAY PROJECT, 1978 - 1988

Type of Unearned Income	Amount
Direct Taxes (Corporate)	
Federal Income (10 years)	$10,337,000
State Mineral Severance (10 years)	1,463,000
Local Production (10 years)	1,597,000
Local Property (10 years)	702,000
State Sales (Initial Procurement)	150,000
Indirect Taxes (Wages, salaries, procurement)	
Project Construction (450,000 x .35)	158,000
Plant Labor (8,291,000 x .35)	2,902,000
Construction Induced Services (450,000 x .25 x .35)	40,000
Permanent Induced Services (8,291,500 x 1.5 x .35)	4,353,000
Initial Capital Procurement (5,450,000 x .35)	1,908,000
Operating Materials (46,864,000 x .35)	16,403,000
Land Purchase-Mineral Royalties	
Mineral Royalties (10 years)	2,802,000
Total Unearned Income	$42,815,000*

*Table is based on several assumptions detailed in accompanying text. All amounts are in 1977 dollars; assumed discount rate of 10 percent.

The facility will employ a total of approximately 40 to 60 people, of which a maximum of about 30 to 40 would be on site at any one time during the day. WMC will provide multipassenger vehicles to transport each crew from the Buffalo area to the site and return to Buffalo. This will reduce significantly the environmental impacts to road surface and air resources due to fugitive dust and exhaust emissions.

As stated in Section 3.2.1, the 1976 populations of Johnson County and Buffalo were 5,300 and 4,200, respectively. The vacancy rate of the 1403 housing units of 8% indicates that approximately 112 housing units are currently available in Buffalo. If the entire work force of 40 - 60 people were to be newcomers to the area, the existing housing and social services should not be greatly affected. However, as stated above, most of the workers already reside in the Buffalo area, and thus, any additional residents should be undistinguishable from the normal population fluctuations of the community. The problems usually associated with large scale energy developments should not occur. The construction of larger and/or additional plants will not greatly increase the total number of employees.

10.2.3 DIRECT COSTS

Internal costs are those occuring to Wyoming Mineral Corporation over the development of the life of the Irigaray Project. Full production operating experiences for insitu mines are in the early phases of the learning curve. Accordingly, the 1977 discounted present value of internal costs may be categorized in the range of approximately 72 to

82 million dollars (Table 10-2) for the 10 year life of the project. The ranges incorporate uncertainties that are expected to arise due to developmental work etc., as the mine expands.

10.2.4 EXTERNAL COSTS

Average annual per capita social costs over the period 1977 - 1987 for Johnson County on the basis of the presence of the Irigaray Project would be insignificant (see Section 10.2.2); i.e., community and service function would not be materially affected since total population would not significantly increase.

The environmental costs of the proposed facility are primarily in the areas of surface impact and groundwater quality. Surface impacts are not significant since no overburden is removed and redressing would be a matter of well plugging and revegetation only (Section 9.2). Overall groundwater impact is not materially different from that of conventional mining/milling methods regarding water consumptive use under the worst case assumption that all affected groundwaters would be totally removed from the mine aquifer. However, these worst case assumptions of water consumptive use will be further mitigated by groundwater restoration programs; the major one being removal of affected water, treatment and reinjection of clean water to the mined aquifer.

TABLE 10-2
1977 PRESENT VALUE OF INTERNAL COSTS (10 YEAR BASIS)

Total investment (labor, capital);	7,200,000
Major annual direct tax payments (federal income, state mineral severance, local property and production);	14,099,000
Royalty payments;	2,802,000
Operating Materials;	40,000,000 to 48,000,000
Plant Labor	7,500,000 to 8,500,000
Total Direct Costs	71,601,000 to 80,601,000

10.3 BENEFIT/COST SUMMARY

The preceding benefit and cost sections of the socio-economic portion of this report contain assessments of the benefits and costs associated with the implementation of the Irigaray Project.

In the way of a summary this proposed facility will employ a maximum of only 60 permanent workers with a slightly larger number being used during construction. The facility will affect at the outset only 30 acres of land per year with a maximum possible affect of 100 acres prior to reclamation per year being disturbed at any one time. As discussed, the dollar benefit to Johnson County and Wyoming is significant with attendent social costs being negligible. On a national basis the contribution of the 500,000 pounds per year uranium toward the energy shortage is significant (Section 11.3). Environmental costs are at the worst case less than those anticipated by conventional mining due to insignificant surface impacts with a significant potential for reducing water consumptive use by groundwater restoration techniques. Therefore, a significantly favorable benefit/cost is indicated.

SECTION 11.0

ALTERNATIVES

Throughout the planning of the proposed project, alternatives were investigated and evaluated, including environmental and practical considerations. The following paragraphs provide the rationale for the decision-making that led to the proposed plant for the Irigaray Project.

11.1 NO ACTION

If the decision were made to take no action at the Irigaray Project, uranium solution mining and processing would not be initiated. The short-range and long-range effects of the "no action" alternative are considered below.

A short-range effect of no action at the Irigaray Project would be the elimination of approximately 40 to 60 employment opportunities for workers residing (primarily) in Buffalo, Wyoming (Section 3.2.1). Additional revenue resulting from an expansion of the local economic base would not be generated. Lessors of mineral rights would not accrue royalty benefits from uranium production. However, the present physical and biological environments of the project site would remain essentially unchanged.

If development of the project was not accomplished, significant quantities of uranium, known to be present, would be left in place

and not recovered for use. To replace the resources foregone by this alternative, other comparable quantities of uranium would be required to meet national needs (Section 11.3).

The current energy crisis and the uncertain future of fossil fuels make nuclear fuel a key source of energy for the near future. Several significant facts have emerged from the present energy crisis. Our current way of life is dependent on a constant supply of energy, and the energy crisis has dramatized the importance of energy supplies to a free world security. The recent oil embargo underscored this fact and emphasized the need to develop domestic energy supplies. The United States presently depends on imports of fossil fuels from existing foreign sources; however, various political considerations preclude U.S. control over these imports. This and the constantly increasing use of energy points out the importance of developing domestic energy sources. No action would, therefore, result in a failure to utilize a valuable natural resource to meet energy requirements.

11.2 MINING METHODS

11.2.1 OPEN-PIT MINING

Open-pit mining is most effective where ore bodies are near the surface and where there is ample suitable location for disposal of overburden. The earth surrounding the ore body is removed to expose the ore. As the ore is mined at depth, the overburden is removed, creating a depression or pit. The ultimate limit of the depth of an open-pit mine is due to economic considerations.

Open-pit mining on the Irigaray property is not feasable due to the depth of much of the mineralized zone and to the economics of resource recovery by this method. Open-pit mining would require many times more employees, for a similar annual production with the attendent increased impacts for local social service delivery systems. Also, significant biological and physical impacts would be incurred by a much larger area. The major limiting factor effecting the economics of open-pit mining is the large amount of overburden that would be removed, and the relatively low grade of the ore.

11.2.2 UNDERGROUND MINING

Underground mining requires a relatively high grade ore overlaid by structurally stable strata. Resource recovery by this method varies, but averages about 80%. The nature of the strata at the Irigaray site and the ore grade make underground mining economically impractical at this time. While the environmental impacts of the mining operation itself are less than for open-pit, the facilities required for processing are essentially the same.

11.2.3 SOLUTION MINING

Solution mining involves the drilling (from the surface) of injection and recovery wells into the ore body. An acidic or alkaline solution is pumped down the injection wells into the ore-bearing strata. This solution dissolves the uranium minerals. The uranium-containing leach solution is then recovered by pumping it to the surface through the recovery wells. The contamination of the aquifers is the primary

environmental risk. Uranium deposits, which are small, isolated and too deep to be mined economically by other methods, may be recovered by insitu leaching under the following general conditions:

(1) The ore is generally horizontal and is overlain and underlain by relatively impermeable stratum.

(2) The ore is in a saturated stratum below the static water table.

(3) The fluid transmissivity and storage capability of the ore-bearing sandstone and the mineralogy of the ore are known.

(4) A maximum recovery of the leach solution is possible.

The mineralized zone in the Upper Irigaray Sandstone is amenable to solution mining and the economics dictate that this resource recovery technique be utilized. Surface impacts are minimal, compared to open-pit and underground methods. The protection of ground water aquifers is maintained by restoration programs during and following mining.

11.3 ENERGY SOURCES

The use of uranium for generating electric power is relatively new. Coal was the first fuel used in quantity for electrical power generation. Coal use was reduced because of the ready availability and low price of oil and natural gas, which are cleaner burning than coal. Uranium fuel is cleaner (chemically) than oil or gas, and at present is less expensive on a thermal basis than all other fuels used to generate electric power. The following discussion concerns the relative availability of fuels for power generation over the next 10 to 15 years,

since availability will be the key factor in the choice of fuel to be used. In 1975, the U.S. consumed about 71 q of energy (1 q = 10^{15} Btu). Of this total, 20 q consisted of electric energy. An estimated 8.6% of this electric energy was generated using nuclear fuels, but within ten years the percentage is expected to increase to 26% of the total consumed energy.

Coal produced 59% of the electric energy generated by combustion of fossil fuel in 1975; the percentages for oil and gas were 20 and 21, respectively. Use of oil and gas to generate electric power has decreased about ten percent over the last three years, due to high oil prices and gas unavailability.

Information available to date indicates that coal and uranium must be used to generate an increasing share of future U.S. energy needs, because of decreasing supplies of oil and gas available for electric power generation. The U.S. does not have sufficient oil and gas reserves to insure long-run supply but coal and uranium resources are adequate for foreseeable needs. Currently rising prices for oil and gas are a reflection of increasing competition for these two resources which will be severely depleted in the next few decades.

Approximately 250 tons of U_3O_8 per year are required for a 1000-MW nuclear plant operating at a plant factor of 80%. Annual western coal (low sulfur) requirements for an equivalent 1000-MW coal plant would be more than 3,000,000 tons, or the load capacity of at least one unittrain (100 cars of 100 tons each) per day of plant operation.

The United States currently produces and consumes more uranium than the rest of the free world. The USA produced 11,600 tons of U_3O_8 in 1975 and has known reserves of uranium (January 1976), of an estimated 640,000 tons. Current projections are for domestic consumption to double by 1977 and to expand at an annual rate of 11 percent until 1985. The current energy crisis may be expected to accelerate increases in demand[1]. Reserves in the United States account for 32 percent of the established free world reserves and amount to 21 years supply at present rates of mine production. Most of the U.S. uranium reserves occur in deep, relatively low grade deposits and hence will be expensive to produce. A long-term shortage may develop for low-cost uranium in the U.S. By comparison the yearly potential production of U_3O_8 from the Irigaray Project (500,000 lbs) represents about 2.2 percent of the total yearly United States production for 1975. At present the economically recoverable reserves of uranium at Irigaray is estimated at 13 - 15 million pounds.

A variety of energy sources could be considered as substitutes for the uranium to be produced by the Irigaray Project. The relative advantages and disadvantages of the various alternative energy sources and the future importance of each are difficult to assess. It is unlikely that a single definite choice will be made between potential energy sources. Each will have a role to play; some may make major contributions to our energy supplies, while others may be subordinated to lesser roles. Some alternatives may be developed rapidly; others may evolve more slowly perhaps to make a more important contribution at a later date. Predictions made on the basis of present knowledge of the relative roles of

these potential alternatives and their respective or combined environmental impacts are highly subjective, and include judgments as to future trends in such variables as the direction and pace of technological development, the identification of usable resources, the rate of natural economic growth, and change in life styles. Technology and life style are inseparable, and it is difficult to independently analyze one or the other for the results to be meaningful.

SECTION 12.0

ENVIRONMENTAL APPROVALS AND CONSULTATIONS

12.1 ENVIRONMENTAL APPROVALS

Permits and licenses needed for the Irigaray Project are:

(1) Source Material License - U.S. Nuclear Regulatory Commission

(2) Permit to Mine - Land Quality Division, Wyoming Department of Environmental Quality (WDEQ)

(3) License to Mine - Land Quality Division, WDEQ

(4) Permit to Construct; Waste Treatment Facility (Sewage) - Water Quality Division, WDEQ

(5) Permit to Construct; Waste Treatment Facility (Evaporation Ponds) - Water Quality Division, WDEQ

(6) NPDES Discharge Permit - Water Quality Division, WDEQ

(7) Permit to Discharge - Air Quality Division, WDEQ

(8) Waste Collection, Storage and Disposal - Solid Waste Management, WDEQ

(9) Permit to Appropriate Groundwater - State Engineer

(10) Permit to Appropriate Surface Water - State Engineer

(11) Permit for Water Diversion - State Engineer

(12) Tailings Dam Design Approval - State Engineer

(13) Public Water System - Environmental Protection Agency

In addition to the permits and licenses listed above, and the inspections afforded same, WMC will be registered with the Wyoming Department of Health and Social Services and subject to inspection by the Wyoming State Mine Inspector.

12.2 CONSULTATIONS

WMC has had meetings with the Wyoming Department of Environmental Quality, Land and Water Quality Divisions, and the State Department of Health and Social Services for consultation on methods of environmental monitoring and control; and with the Wyoming Game and Fish Commission regarding ecological studies on the project area.

SECTION 13.0

GLOSSARY

(Uranium Insitu Mining)

ADU - Ammonium diuranate or yellowcake. Approximate chemcial composition is given as $UO_2 (OH)_2 \cdot (2 \quad X) H_2O \cdot x NH_4^+$ salt. ADU is not the oxide form of uranium, i.e., U_3O_8 (triuranium octa - oxide).

BASELINE - The environmental condition that existed prior to mining as determined by physical or chemical parameters and their natural variability.

CORRECTIVE ACTION - The implementation of those methods available to the mine operators for control of lixiviant migration or excursion.

EFFLUENT - A liquid, solid or gaseous substance discharged or emerging from a process. A form of waste since it has no further use.

ELUANT - The solution which removes (elutes) uranium from ion exchange resin.

MIGRATION (EXCURSION) - The movement of lixiviant out of a mine zone as evidenced by movement past a monitor well. Measurement is by an increase of selected parameters above their established upper control limit.

HEADS GRADE - The uranium content of recovered lixiviant normally expressed in parts per million.

INJECTION WELL - A well used to inject leach solution by gravity flow or pressure into an ore body.

INSITU - As applied to mining or restoration, the host sand in its original or natural position.

LIXIVIANT - Leach solution pumped underground to uranium.

MINE (OR MINE ZONE) - The area from which uranium is extracted including related buildings and structures. In the solution mining of uranium it would include the ore body and all associated surface areas and related well fields, process equipment and buildings.

MINE FIELD - Refers to the well field areas and affected surface associated with solution mining. Term is often used interchangeably with well field.

MINING UNIT - A segment or portion of an ore body capable of economically supporting mineral extraction; the mineable limits of an ore body which would normally include several production fields.

MONITOR WELL - A surveillance well located along the periphery of a well field normally 400 feet from the ore boundary and used to indicate containment or excursion of lixiviant. When the upper control level of a monitor well is exceeded, corrective action takes place. After mining the monitor wells define the area for restoration.

MONITOR WELL ZONE - The area of possible monitor well location - normally a zone at least 400 feet from mineralization but not more than 1000 feet from the well field. This zone is normally outside the limits of mineralization.

ORE BODY - The mineralized portion of the sanstone formation where uranium is found in various grades and concentrations; this includes only the portions of the mineral deposit that can be worked economically.

PRODUCTION CELL - The grouping of injection wells about a recovery or production well arranged in various configurations and varying in number.

PRODUCTION FIELD (ZONE) - Mine/well fields actively being used for production purposes. The production field normally consists of two or more well fields.

PRODUCTION MODULE - A process plant which is modularized for ease of installation and removal and which is capable of handling a given production flow and output.

PRODUCTION WELL (RECOVERY WELL) - It is the well from which lixiviant is recovered for conveyance to a process plant. Normally this is a term used to mean recovery well.

RECLAMATION - The returning of the surface environment to acceptable conditions. Reclamation normally includes equipment removal, well plugging, surface contouring, and reseeding, etc.

RESTORATION - The returning of the aquifer and affected water to acceptable levels using the best practicable technology currently available.

ROLL FRONT - Uranium deposition localized as a roll or interface (redox) separating an oxidized interior from a reduced exterior. The reduced side of this interface is significantly enriched in uranium.

TREND WELL (ZONE) - Surveillance wells for production control located within the mining unit but not more than 200 feet from a well field. These wells are located between the well field and the monitor wells.

UPPER CONTROL LIMIT (UCL) - A corrective action level to maintain containment within a well field. Initially the UCL is defined at $\bar{x}+ 2.75$ s of individual monitor well baselines. As the UCL values are exceeded corrective action is initiated and continued until migration is brought under control.

WASTE - Solids or liquids (contaminants) from solution mining or other processes of no further value and subject to no additional processing. Wastes are normally stored for concentration and disposal. Some effluent streams may be waste streams.

WELL FIELD - A well field is composed of several (production) cells and capable of supplying a given feed to a process plant. Well fields vary in size and number of cells. Normally two or more well fields would define a production field. This term is often used interchangeably with mine field.

SECTION 14.0

REFERENCES

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APPENDICES

APPENDIX A

GROUNDWATER RESTORATION DEMONSTRATION PROGRAMS

APPENDIX A

GROUNDWATER RESTORATION DEMONSTRATION PROGRAMS

WMC has insitu production operations in Texas in addition to test operations in Wyoming and Colorado. On the basis of the operating and test experience in these locations the Irigaray extraction plant design is being finalized. These tests provide the design criteria for the Irigaray groundwater restoration demonstration program as discussed in Section 9 of this ER. The results of restoration demonstration tests in Texas and Colorado are summarized below.

TEXAS

WMC has insitu operating experience in Texas at two locations: the Bruni plant north of Bruni, and the Lamprecht plant near Ray Point. The Bruni Plant Restoration Demonstration Program was started in 1976, and Phase III, Water Clean-up and Recycle is nearing completion.

There is a definite clean-up trend during the course of applying the restoration technique to a mined aquifer (Figure 1). A dashed line indicates a model of the data obtained to date. The mined groundwater TDS has been reduced to within 10% of the baseline levels except for ammonia. The final phase of the program is designed to evaluate processes to further reduce residual ammonia left in the formation by the use of a calcium based chemistry.

The overall objective of the program is to demonstrate the technical feasibility of post-mining groundwater restoration. The objectives

BRUNI RESTORATION DEMONSTRATION

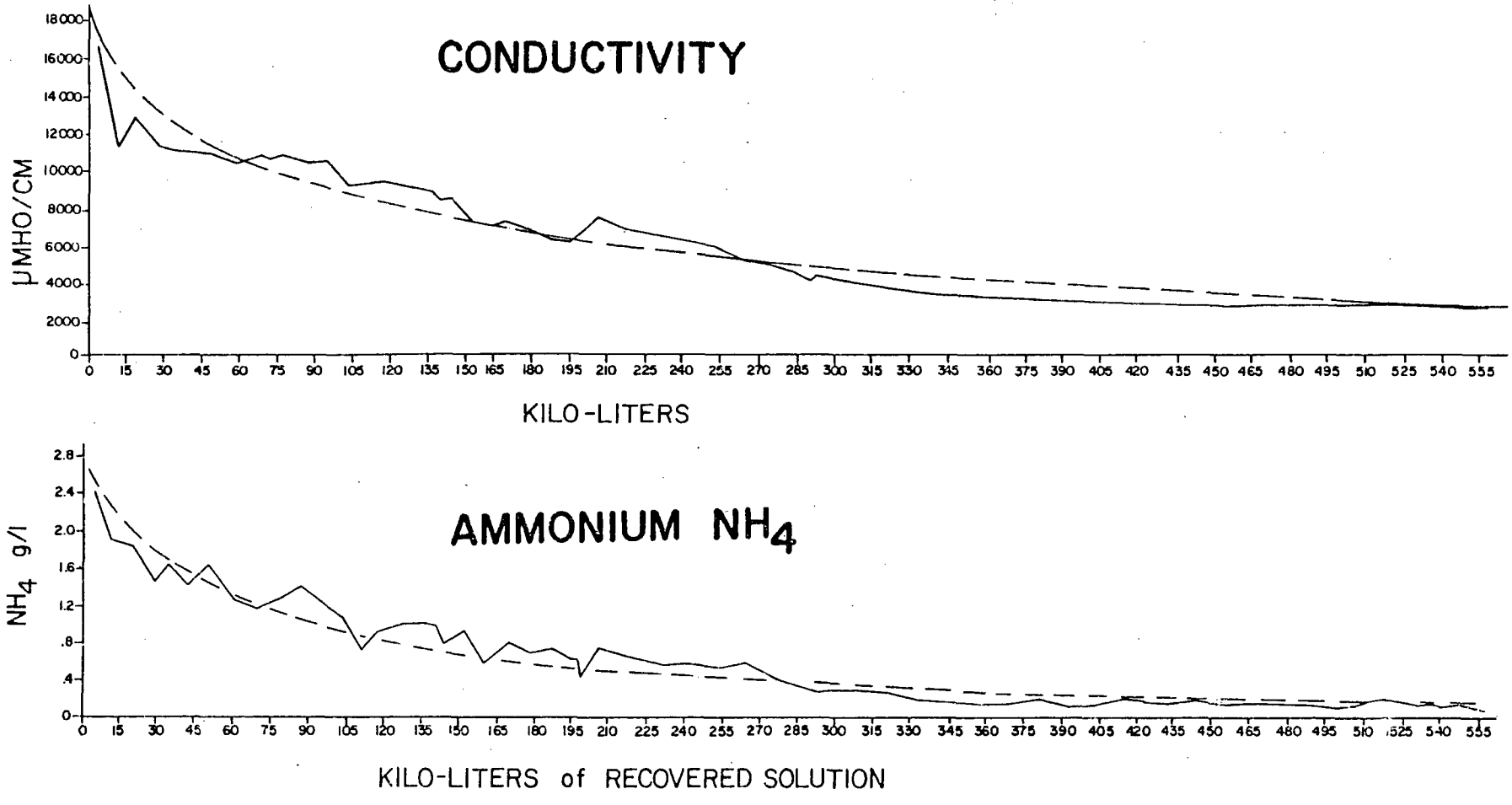

FIGURE 1

of the test were:

(1) Evaluate the effectiveness of groundwater sweeping.

a. Dissolved ion removal

b. NH_4 + removal

(2) Determine the effectiveness of water treatment and recycle methods.

(3) Develop and evaluate methods to chemically restore groundwater, if needed.

This field test involved the drilling of a two- hole test area in an unmined area of the well field and leaching the area using plant lixiviant solutions. The test was evaluated based on the three restoration methods discussed in Section 9 of this ER.

Major features of the test were:

(1) Leaching the 2-hole test pattern.

(2) Evaluation of the response of the aquifer to groundwater sweeping.

(3) Build and operate a water treatment plant.

(4) Operate the leach field in a closed loop clean water recycle mode.

(5) Evaluate effectiveness of water sweeping techniques; design and operate chemical treatment system, if needed.

(6) Monitor the test pattern to confirm aquifer stability.

Following the design and construction of the test wells and the establishment of baseline water quality, a test plant was built to treat

the water removed from the test field. This demonstration test was performed in the following sequence of operations.

Phase I - Well field leaching

Phase II - Groundwater sweeping (after leaching was terminated)

Phase III - Water Treatment and Recycle

Phase IV - Chemical restoration treatment (if needed)

Although the detailed methodologies and processes of the demonstration program are proprietary the conclusions are not. Initial post-mining water quality had a conductivity level of approximately 16,000 μmho/cm and an ammonium level of approximately 2.4 grams per litre. A trend indicating a reduction in ammonia levels, is shown on Figure 1. Average baseline water quality values (prior to test) for these two parameters were approximately 2500 μmhos of conductivity and approximately 1 ppm ammonium. Results from Phase III show a somewhat more rapid reduction of TDS and NH_4 + concentrations than was evidenced in Phase II. Trace element analyses are not yet completed.

COLORADO

The Colorado groundwater restoration demonstration test was designed around a single well "slug" test as opposed to the two-hole test pattern used in Texas. The test outline is as follows:

(1) A single well was completed and baseline water quality samples collected.

(2) 4000 gallons of lixiviant were injected into the test well.

(3) After 24 hours the first recovery solution was removed.

(4) Three successive recoveries were made at 24-hour intervals.

(5) A final recovery was made after 30 days of "soak" time.

(6) Recovered solutions were stored in pools for sampling and water treatment purification testing by various techniques.

The primary purpose of the test was to study site specific effects of water displacements through a mined zone. This test also supplemented the Texas work to demonstrate that clean reinjectable water can be obtained by conventionally available water treatment processes. The conclusion of the Colorado tests were that the mine water generated by the WMC insitu technique could be restored to acceptable levels for reinjection using reverse osmosis units together with activated carbon filtration.

The results were encouraging: simple water displacement returned the mined aquifer water quality essentially to baseline conditions. TDS was restored to near baseline conditions with the exception of carbonate which remained about 20% above the baseline. Ammonia levels were reduced from 1000 ppm to less than 30 ppm. Thorium - 230 and radium - 226 levels were reduced to baseline conditions. The levels remained constant over a thirty-day period and no substantial changes in the water quality were observed. Most trace elements were reduced to baseline conditions or showed no significant change throughout the restoration test. Slight changes were observed in vanadium, phosphate, silica and selenium. No significant water quality degredation resulted due to changes in these trace species.

APPENDIX B

REGIONAL HISTORIC, SCENIC, CULTURAL AND NATIONAL LANDMARKS

THE STATE OF WYOMING

ED HERSCHLER
GOVERNOR

Wyoming Recreation Commission

604 EAST 25TH STREET CHEYENNE, WYOMING 82002

PAUL H. WESTEDT
Director
777-7695

COMMISSION
OFFICERS
ALBERT PILCH
PRESIDENT
1800 Morse Lee
Evanston 82930
JACK D. OSMOND,
VICE PRESIDENT
P.O. Box 216
Thayne 83127
DUANE REDMAN
TREASURER
Dubois 82513
MEMBERS
REGNALD BAFFORD
P.O. Box 625
Lusk 82225
FLOYD BARTLING
P.O. Box 172
Douglas 82633
LYLE BENTZEN
1001 Pioneer Road
Sheridan 82801
MRS. ROBERT FRISBY
2007 Newton Avenue
Cody 82414
MARVIN HARSHMAN
1507 West Spruce
Rawlins 82301
BILL NATION
2221 Van Lennen Avenue
Cheyenne 82001

October 3, 1975

Mr. Alan D. Luck, Licensing Engineer
Westinghouse Electric Corporation
3900 S. Wadsworth Boulevard
Lakewood, CO 80235

Dear Mr. Luck:

The enclosed lists, subject to frequent additions, show places in Johnson County and Carbon County, Wyoming which are either already enrolled in the National Register of Historic Places or are considered probable subjects for future enrollment therein. In either case, enrolled or likely candidates for future enrollment, they are accorded identical protection under the National Historic Preservation Act, The National Environmental Policy Act and E.O. 11593.

If we can be of further service to you please do not hesitate to ask us.

Sincerely,

Paul H. Westedt, Director
and SHPO

Ned Frost

by Ned Frost, Chief
Historic Division

PHW:NF/lml

ran to Fort Laramie, then north to Rawhide Buttes and Running Water. It served as a main artery to the Black Hills goldfields. Rawhide Springs, between the two stage stations, possessed water and grass in quantity and so became a favorite camping spot along the trail. The Cheyenne-Black Hills Stage Company carried mail to the Black Hills, and numerous robberies of gold and mail by armed desperadoes occurred along the route. The coming of the railroad brought an influx of settlers, but it meant the end of the stage line. Today the Running Water Station is marked only by stone ruins, but the Rawhide Buttes Station still stands and is used as a ranch.
Municipal/private

HOT SPRINGS COUNTY
Thermopolis vicinity
WOODRUFF CABIN SITE
26 miles northwest of Thermopolis, 18 miles west on County Route 0900 from the intersection with Wyo. 120
1871

The cabin of John Dwight Woodruff was the first recorded white man's dwelling in the Big Horn basin, the entire northwestern corner of Wyoming. Only the cabin site remains today, marked by a rock and mortar monument. From pictures it has been estimated that the cabin measured 12 feet wide by 20 feet long, was constructed of logs, and covered with several inches of dirt on the roof to absorb moisture. Woodruff used the cabin in the winter, spring, and early summer as a headquarters while trapping and prospecting. He eventually introduced both sheep and cattle into the area, and the cabin may have served as a ranch house. Woodruff sold his cabin in the early 1880's, and buildings of the Embar Ranch presently form a semicircle around the cabin site.
State

JOHNSON COUNTY
Story vicinity
FORT PHIL KEARNY AND ASSOCIATED SITES
On secondary road west of U.S. 87
1866

In and around Fort Phil Kearny the Sioux Indians fought successfully to prevent invasion of their hunting grounds by prospectors and wagon trains bound for the Montana gold fields. From 1866 to 1868 the fort was held under virtual siege as the focus of the Red Cloud War, which resulted in relinquishment of military control of the area and the abandonment of the Bozeman Trail. The natural setting of Fort Phil Kearny has suffered comparatively little encroachment. In 1938 a peeled-log reproduction of an officers' quarters and a seven-foot slab stockade were erected here.
Multiple public/private
NHL

JOHNSON COUNTY
Sussex vicinity
FORT RENO
SE 1/4 SE 1/4 NW 1/4 sec. 33, T. 45 N., R. 78 W.
1865–1868

Fort Reno, established in August, 1865, as Fort Connor, was situated on the left bank of the Powder River. It was one of three forts (Fort Phil Kearny and Fort C. F. Smith) constructed by the Army to protect travelers along the Bozeman Trail. The Bozeman Trail ran along the eastern base of the Big Horn Mountains before turning east to Virginia City, and portions of it ran through a sacred hunting ground of the Sioux. A cottonwood stockade contained the quartermaster's and the commissary storehouses. Outside were two barracks, two officers' quarters, a post hospital, shops, teamsters' quarters, and two sutler's buildings. The fort was renamed (November, 1865) for General Jesse L. Reno, and in 1868 it was abandoned and later burned.
State

LARAMIE COUNTY
Cheyenne
ST. MARK'S EPISCOPAL CHURCH
1908 Central Avenue
1886–1888, Henry M. Congdon

St. Mark's Episcopal Church is the second structure of that name erected in Cheyenne. The first St. Mark's was built in 1868. The need for larger facilities caused the parish to embark upon a building program in the 1880's. The exterior is stone with pointed-arch windows and massive buttresses. Eleven of Wyoming's 26 governors have been members of St. Mark's congregation.
Private

LARAMIE COUNTY
Cheyenne
WYOMING GOVERNOR'S MANSION
300 E. 21st Street
1904

The Wyoming Governor's Mansion is a Georgian Revival brick house which originally contained a large drawing room and dining room, five bedrooms and a bath on the second floor, and three bedrooms and a bath on the third floor. Extensive interior remodeling was done in 1937. The Wyoming Executive Mansion has the distinction of being the first in the nation to have been occupied by a woman, Nellie Tayloe Ross, governor from 1925 to 1927.
State

LARAMIE COUNTY
Cheyenne vicinity
FRANCIS E. WARREN AIR FORCE BASE
Bounds against the west side of Cheyenne, the two are roughly separated by Int. 25

The present Air Force base was established in 1867 as Fort David A. Russell. In 1930, upon the death in office of Senator Francis E. Warren, the post was renamed in his honor. Originally the federal government used Fort Russell, located at the eastern base of the Rocky Mountains, to protect the transcontinental railroad which ran through nearby Cheyenne. When the Indian wars were over, Fort Russell was considered important enough to be made a permanent post by the War Department (1885). In 1906 it was enlarged to brigade size, and in 1947 the name was changed a second time to Francis E. Warren Air Force Base. It is presently under the control of the Strategic Air Command. All buildings reflect the growth and changing role of the post. Most are red brick.
Federal

LINCOLN COUNTY
La Barge vicinity
NAMES HILL
On the Green River, 5 miles south of La Barge and just west of U.S. 189
19th century

Names Hill on the Green River is one of three places (Register Cliff on the North Platte and Independence Rock on the Sweetwater) along the Oregon-California Trail where emigrants carved their names or left messages and greetings for those following. In 1844 Jim Bridger, famous trapper and mountain man, left his name here. The earliest dated name is 1822, which is earlier than any dated inscription at either of the other two locations. Names Hill was a popular camping spot for westward moving emigrants.
State

NATRONA COUNTY
Casper vicinity
INDEPENDENCE ROCK
60 miles southwest of Casper on Wyo. 220

Called "the great registry of the desert," Independence Rock was a well-known natural landmark on the Oregon Trail. This oblong mass, over 1900 feet long and 850 feet wide, lies near the Sweetwater

JOHNSON COUNTY

ASTORIAN ROUTE (HUNT PARTY).

BOZEMAN TRAIL.

CLARKE RANCH. Sec. 2, T52N, R83W.

CLOUD PEAK. T51N, R86W.

CRAZY WOMAN BATTLEFIELD. T48N, R80W.

DeSMET MONUMENT. Sec. 18, T52N, R82W.

DULL KNIFE BATTLEFIELD. Sec. 16, T45N, R83W.

FORT McKINNEY. 3 miles west of Buffalo on U.S. 16.

FORT PHIL KEARNY. Sec. 26, T53N, R83W.

FORT RENO. Sec. 33, T45N, R78W.

FREWEN CASTLE SITE. 4 miles below Kaycee on Powder River.

HOLE-IN-THE-WALL. 12 miles west of Kaycee on Barnum Road.

HORTON RANCH. Sec. 19, T52N, R83W.

LITTLE MEDICINE WHEEL. Sec. 16, T45N, R85W.

PHILLIPS MONUMENT. Sec. 26, T53N, R83W.

PORTUGUESE HOUSES. 10.5 miles east of Kaycee on County Road 1002.

RENO CANTONMENT. Sec. 17, T44N, R78W.

T A RANCH. 13 miles south of Buffalo.

TRABING TRADING POST. Buffalo.

APPENDIX C

AN EARLY MIDDLE PERIOD BISON KILL IN THE POWDER RIVER BASIN OF WYOMING

SITE 48 SH312:

AN EARLY MIDDLE PERIOD BISON KILL IN THE POWDER RIVER BASIN OF WYOMING

by

George C. Frison

Abstract

Site 48SH312 is part of an Early Middle Period complex in which as least part of the economy was oriented toward small-scale trapping of bison, utilizing the natural badland topography of the Powder River Basin. Further work is necessary to determine more of the economy as well as temporal and spatial aspects of the complex.

Introduction

This report is the third in a series that deals with complex of which little is as yet known. During the summer of 1961, the Sheridan Chapter of the Wyoming Archaeological Society excavated part of a bison kill (24PR5) in Powder River County, Montana just over the Wyoming line (Fig. 1). The evidence of the kill was a layer of bison bone in the profile of an arroyo bank, covered by about two and one half feet of sterile clay. Artifacts included a number of projectile points of a rather distinctive type and a few of what may have been butchering tools. A single large skull from the site was described by C. Bertrand Schultz of the University of Nebraska as "an intermediate form between Bison Bison and Bison antiquus," Bentzen 1961.

The following summer the same organization excavated in a similar bison kill (48SH311) further south in Wyoming (Fig. 1). Here the sterile overburden was nine feet in depth and again the layer of bison bone appeared in the profile of an arroyo bank. The same distinctive type of projectile point appeared with a few worked flakes that may be butchering tools. No identification of the species of bison involved was made but it was thought by the investigators to be Bison bison (Bentzen 1962).

Radiocarbon dates from the two sites were rather disparate. The Montana site yielded a date of 2500± 125 years B.C. and the Wyoming site 650± 200 years B. C. If correct, these dates suggest a rather long duration for this particular complex in the area. Both dates were from Isotopes Inc.

Site 48SH312

During the summer of 1966, the writer was asked by the Wyoming Archaeological Society to direct excavations in a similar bison kill along the Powder River, in the same general area as the other two sites mentioned above. The University of Illinois has their summer geology school in this area and Dr. John Mann, a geomorphologist of that institution expressed a keen interest in the site and provided the geological report that follows the archaeological report.

The Powder River Basin is drained by the Powder River which is a slow, meaandering stream that empties into the Yellowstone River further north in Montana. The Powder River Basin is a typical badland country with

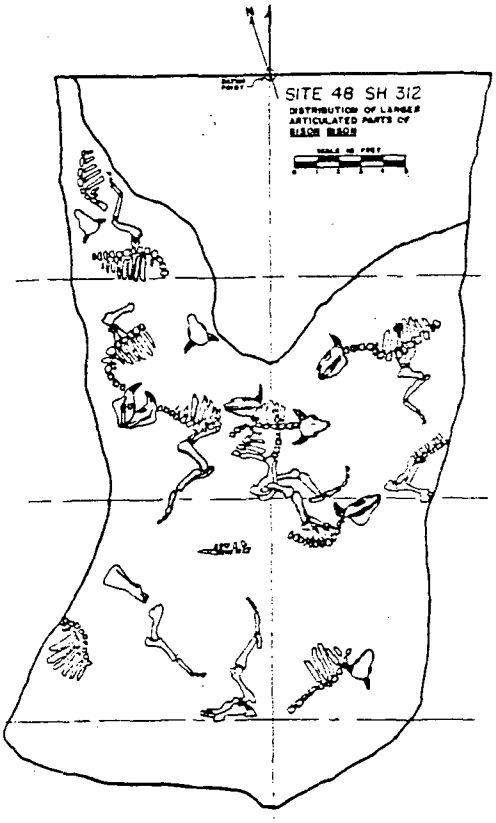

Figure 2. Map of archeological site 48SH312.

moderate erosional relief and the site area is highly dissected by arroyos that drain directly into Powder River a short distance away (Fig. 1). Site 48SH312 lies at an elevation of approximately 3850 feet in an area known as the Quarter Circle Hills (44° 47' N Lat, 106° 07' W Long). Bison bone appeared in the profile of an arroyo bank about 25 feet above the bottom of the trough and covered by as much as 11 feet of sterile clay (Fig. 4a). A contour map of the site area appears in the geological report immediately following. The nature of the site area and the overburden itself which was a very tough, hardgumbo clay ruled out the efficient use of power equipment. Shovels and other hand tools were relatively ineffective and the problem was solved rather uniquely and successfully. One of the members of the Wyoming Archaeological Society was an expert with blasting powder and was able to remove the sterile overburden to within a foot or so of the bone level without any damage to the latter and with a minimum cost in time and effort. Disposal of the dirt was no problem due to the location of the site above the bottom of the arroyo (Fig. 4b).

Exposure of the bone level revealed part of the bottom of what was at one time a larger bison trap. Remaining were parts of at least 12 bison in various stages of articulation (Figs. 2 and 5b). According to Dr. Paul McGrew, vertebrate paleontologist at the University of Wyoming, they are probably Bison bison. The animals were killed by placing projectile points in effective locations, usually fairly high and forward in the rib cage and in two instances, in the vertebrate column itself. The projectile points were relatively large and were probably dart points (Fig. 3). A

total of 25 complete and broken projectile points was recovered of which 16 were found in rib cages or the vertebral column. One carcass contained four points; three contained two; and six contained one. The projectile points vary from those which could almost be classified as stemmed (Fig. 3k) to side-notched (Fig. 3d) but a clustering occurs around a corner-notched type. Blade edges are usually convex although some are straight (Fig. 3f) but range to those with a definite base notch (Fig. 3a, i). The projectile point sample is rather small for any meaningful statistical analysis although none of the attributes suggests multi-modal tendencies. Of the total number, 20 are metamorphosed shale, three are quartzite and two are of chert. Two (Fig. 3p, q) suggest use other than as projectile and may have functioned, perhpas secondarily, as butchering tools or in other contexts.

The soil matrix differed somewhat at the bone level allowing the use of conventional hand excavation tools. The condition and distribution of the bones leaves little evidence of any patterned butchering process as in Late Prehistoric sites in the same area (Frison 1965). Instead it would appear that the butchers were taking whatever was easiest to obtain from each carcass. Front quarters were especially ignored although the meat could have been stripped from the bones to a large extent before they were abandoned. Most rear portions of the carcasses were mising entirely suggesting some preference for the hind quarters. Rib cages and the associated parts of vertebral columns and the forelegs resting directly on the ground were usually quite well preserved in a normal larticulated position suggesesting little in the way of disturbance after they were abandoned. Other disturbance of

bones may have been partially due to predators. It is believed however, that the bones were covered a short time after the kill.

Brain cavities were intact on eight skulls which were preserved to an extent that such an observation could be made and on five of these the mandibles and hyoid bones were still in their original positions suggesting that the tongues were not especially desired items of food, contrary to Late Prehistoric Period hunters who considered the tongue a special delicacy. Four complete sets of articulated caudal vertebrae suggest they were not saving all of the hides or employed a skinning process whereby the tail was left with the carcass which seems unlikely. Very few of the larger bones that contain any significant amount of grease or marrow were broken which may reflect a disregard for this food source, which was of considerable importance in later time periods, or it may imply that more animals were killed than were needed or could be thoroughly utilized.

In spite of the fact that foetal bones and the bones of calves or very young animals were entirely lacking, the question of the time of year of the kill remains open. The foetus could have been a desired food item as in Late Prehistoric times and if so they were probably removed. Young calves if present, could have been especially desired and removed to a different part of the site for butchering. As will be explained later, only part of the total site area remains and the presence or absence of certain bones or animals in certain age groups cannot be stated with any certainty.

Butchering tools at the site were lacking with the exception of the two points described above, yet the evidence suggests that a certain amount of butchering must have occurred. Flakes recovered at the site offer evidence of butchering activity that appears reasonable within limits of what might be expected. A total of 106 unworked flakes were recovered, all of which were quite small (total wt. 29 grams). None appeared to be the result of tool manufacture but at least 47 were retouch flakes that were removed from tools in resharpening. All were from tools that were plano-convex in transverse cross section and may have been what can best be described as side scrapers. Retouch from at least seven tools were recovered and a soft hammer percussion technique is indicated by rather broad flakes with distinct overhangs remaining on the bulbar face (Fig. 5a). The striking platforms are flat, none are faceted which suggests that they were part of the inner flake face of a tool such as a side scraper. Working edges of the retouch flakes demonstrate very small use flakes and sometimes a definite scalar retouch (Bordes 1961:26) all suggesting hard usage.

One bone artifact was recovered from the site. This was a needle (Fig. 3r) ground from a sliver of unidentified bone. It has a sharp point on both ends and the entire surface has a polish that covers most of the grinding resulting from manufacture.

Geological Considerations

A complete report on the geology of the site and the area follows this archaeological report and only a few brief comments need be made here. In the first place, it was impossible to expalin the location of the bison bones with

respect to the present topography of the immediate site area. Obviously the explanation is to be found in a reconstruction of the site area as it was at the time of the actual bison kill. At this time the bone level was the bottom of the arroyo. A few feet north of this, in the headward direction, was a perpendicular wall that formed as the result of headward erosion in alternating hard and soft strata. The sides of the arroyo were steep, forming a natural trap estimated by the goelogist, Dr Mann, to have been about 35 meters wide. A small remnant of the trap was discovered on the side of the arroyo opposite the excavated area, confirming Dr. Mann's independent conclusions. Down the arroyo from the trap, the sides gradually became less steep until a point was reached where it was simple matter to cross the arroyo. This was where the animals had to enter. The pattern of headward erosion in arroyo development is repeated continually over the entire Powder River Basin and in many instances offers the same favorable conditions for animal traps. It is of some interest to note that directly below the site today there is a configuration, produced by a recent cycle of erosion, that from all appearances would serve quite well as a bison trap.

After the animals were killed, there was a rapid deposition of debris over the remains and subsequent to this there was erosion that deepened the arroyo. This deepening action destroyed a major part of the original trap and left the remaining portion of the bison bone level high in the bank. No radiocarbon date from the site is yet available but Dr. Mann suggests a date of 3500 to 4000 years before present or somewhere between 1500 and 2000 B.C. which fits well within the range of radiocarbon dates of the sites excavated in 1961 and 1962.

Conclusions

The evidence to date suggests that 48SH312 represents an Early Middle Period (Mulloy 1958:208-209) bison kill that is part of a complex presently known as the Powder River Basin area of northern Wyoming and southeastern Montana. Further investigation may extend this complex to adjacent areas. To date there is no evidence of occupation immediately preceeding the Early Middle Period or during the Altithermal Period and the site may represent the first people to move back into the area after the Paleo-Indian hunters of which there is evidence at the Agate Basin Site (Roberts 1951), the Brewster Site (Agogino and Frankforter 1960), and other unreported locations.

How much the bison contributed to the economy of these people is as yet unknown. It is possible and, indeed, quite likely that they may have depended on vegetable foods to a considerable extent especially at certain times of the year. There is as yet, no evidence to prove or disprove that they may have been drying or in some other way preserving some of the meat from the bison for future use. The site area does produce sandstone slab milling stones and manos believed to indicate an Early Middle Period manifestation. The bison hunting may have been nothing more than a single phase in the lives of people oriented at other times toward vegetable gathering or hunting of small anaimals much as the evidence at the neaby McKean Site suggests (Mulloy 1954:440). One thing certain is that they were able to utilize the features offered by the natural topography of the country to trap bison and control the animals to the extent of killing them by placing projectile points in vital spots with remarkable regularity. The type of

operation indicated undoubtedly dealt with small numbers of bison and was not to be compared with the later bison drives where large numbers were driven over cliffs or into pounds. This Early Middle Period type of operation would not require the amount of communal cooperation necessary for the drives executed during the later periods. It would appear that four or five males or an extended family group would have been able to carry out an operation as suggested by the Powder River Site. It might be considered as an extension of individual or small group hunting where a small herd of animals could be stampeded into an arroyo and a man or two on each side could drive some or all of the animals headward until the walls became so steep that escape was impossible. When the animals reached the perpendicular wall at the end of the trap it would have been a simple matter to kill them. Successful traps were undoubtedly used again and again. It is difficult to conceive of any form of gate or plug for the downward opening, considering the lack of timber in the area, unless some sort of an obstacle possibly of hides sewn together was used. Wild animals are reluctant to push their way through an obstacle they are unable to see through. It would have been easy and effective for a man on each side of the arroyo to hold one end of such a contrivance and bring it along behind the animals as they headed up the arroyo toward the trap. An obstacle such as this is usually quite effective although it would not stop the animals if they were crowded or forced into it.

Still lacking is a good explanation of butchering and meat-handling techniques. It would appear that one of the most important and as yet unknown quantities of this adaptation to the Powder River Basin at this time period concerns the purposes for which the bison were killed with respect to immed-

iate or future needs. The evidence from 48SH312, which is admittedly very incomplete, suggests killing the animals for immediate food needs. Obviously if the entire bison trap remained, it might have been possible to extract more information of this nature. It is important to find a campsite or area where the meat was further handled after being killed. Comparison of bone remains in the two areas should provide useful information. There must have been a campsite close by as it is difficult to conceive of these people moving any large amount of meat long distances. They were probably small groups and the campsites of a temporary nature depending upon the random movements of the bison. Under these circumstances the camp would be unlikely to appear as a large concentration of cultural material. Even if found in the profiles of arroyos, the camp would be more difficult to see than the bison bone level typical of a kill site. Much of this is speculative but the writer has reports of other similar bison kills in the area which may eventually produce the evidence for a more complete description of this complex.

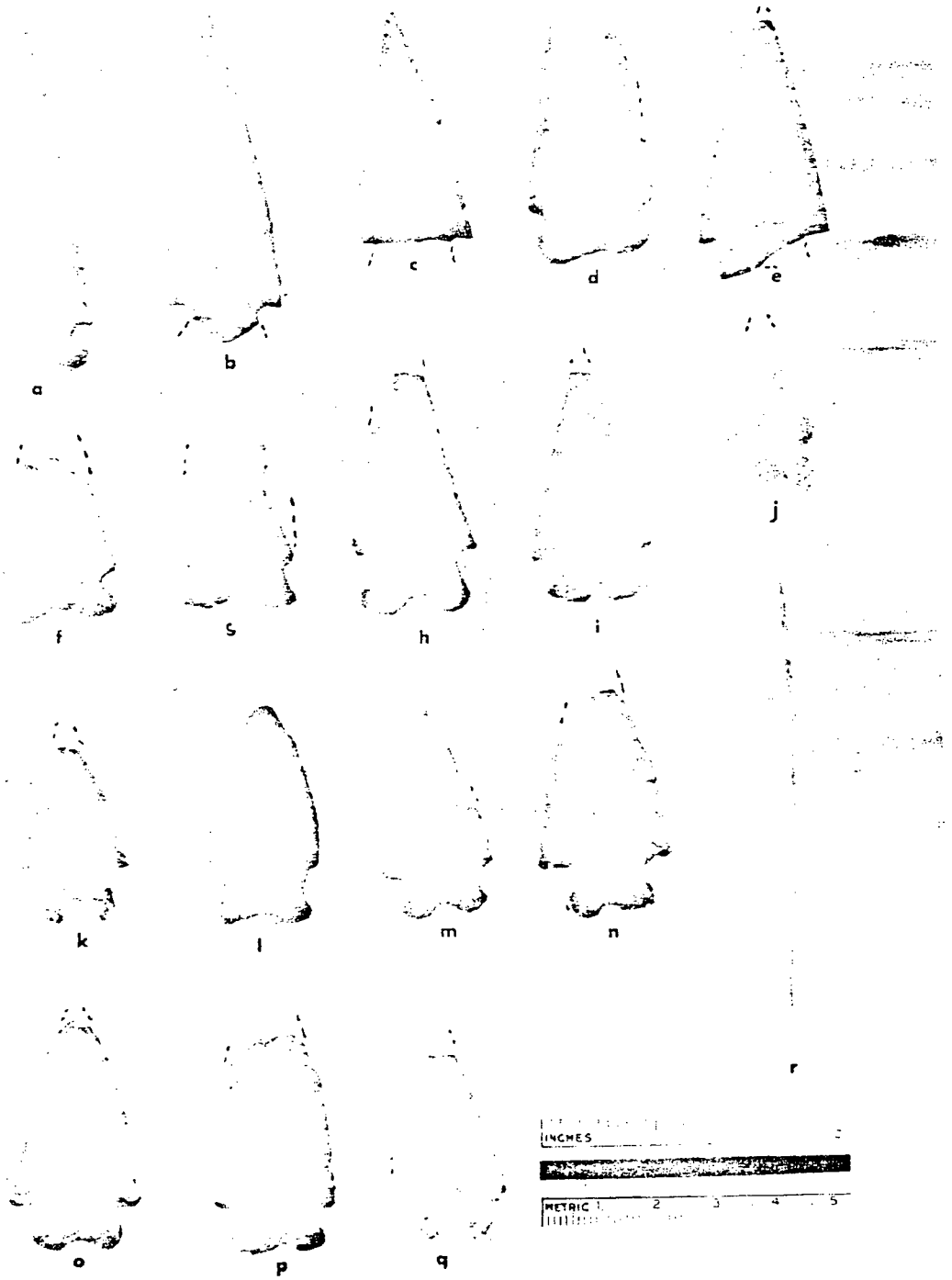

Figure 3. Projectile points(a-q), and bone needle(r) from site 48SH312.

Study Area Number Two:
A Descriptive Analysis

Roughly speaking, Area Two comprises the northwestern quarter of Wyoming. It is bordered on the north by the Montana-Wyoming state line and on the west by the Idaho-Wyoming state line. Area Two extends east to include the west face of the Bighorn Mountains. The southern section of this area includes the Owl Creek Mountains and the Wind River Range. From the northern section of the Wind River Range Area Two runs in a southwesterly direction to the Idaho border.

In protohistoric and historic times Area Two was occupied either permanently or intrusively by the Northwestern Plains groups listed for Area One with Crow, Shoshoni, and Arapaho being the most evident. In addition, the Rocky Mountain region in the western part of this area at one time contained Salishan-speaking groups similar to Kutenai, Flathead, Nez Perce, Kalispel and Coeur d'Alene groups now living farther west in the Plateau region. Intertribal warfare, the aquisition of firearms and the horse, smallpox, and the westward movement of white settlement have all had effects on cultural makeup of Area Two in historic times.

Some of the first systematic work on the archaeology of Area Two was done in the 1930's by the Work Projects Administration. This was later followed by survey and excavation work in the 1940's through 1960's by River Basin Surveys, Smithsonian Institution. In addition to these programs, the University of Wyoming and other institutions have conducted research within this area. Much of the information contained within this report has also come from private individuals concerned with the prehistory of Wyoming.

A Sampling of Sites From Study Area Two (Figure 1 and Table 1)

The Paleo-Indian Period

1. Mummy Cave, 48 PA 201.

Mummy Cave is a well stratified site which contains approximately thirty-three feet of cultural material. The middle levels of this site are quite important because they contain some of the first evidence for occupation in Wyoming during the Altithermal Period.

2. The Horner Site, 48 PA 29.

The Horner Site appears to have been a butchering area for nearly 200 bison, all apparently killed within a few weeks of each other. Associated with these faunal remains were projectile points and other tools of the Cody Complex.

3. 48 PA 26.

Mammoth bones are reported to have come from this site. Investigators have found traces of charcoal and a few tools. A full report on this site has never been written.

4. Bottleneck Cave, 48 BH 206.

This now flooded shelter in the northern part of Wyoming contained a series of occupations ranging from Early to Late Period cultures. A number of fire pits found during excavations at the site have provided many carbon-14 dates.

5. Medicine Lodge Creek, 48 BH 499.

This is a deeply stratified site containing approximately sixty cultural levels ranging in age from historic times to 10,000 years old.

Medicine Lodge Creek is a site which contains much information pertaining to many aspects of cultural development in the Bighorn Basin. Work on this site is continuing.

6. Hanson Site #1.

Surface collection on this site has yielded projectile points from the end of the Paleo-Indian Period.

7. Hanson Site #2.

The Hanson Site is a recently discovered area. Test excavations by the University of Wyoming have found several Folsom points as well as many other tools. More work is planned for this very important site.

8. The Worland Mammoth Site.

Initial excavations at this site have yielded a Clovis component in association with several mammoth and other fauna. Analysis of the material recovered is presently being undertaken at the University of Wyoming.

Paleo-Indian sites within Area Two are still quite rare in comparison with the number of sites from other periods of prehistory. In recent years, however, both professional archaeologists and concerned amateurs have made finds which demonstrate the great potential for more discoveries of sites from this time period.

One interesting area of study on the Northwestern Plains is concerned with the peoples and cultures of the very late Early Prehistoric Period (Husted 1969; Frison 1973a). The Bighorn Basin and adjacent areas

have provided much of the information about this period of time and will undoubtly supply more in the future.

The Altithermal Period

No Altithermal sites are listed for Area Two in this report. This is not due to an abscence of Altithermal occupation in the area. Instead, it is because important Altithermal sites within Area Two contain earlier cultural components and have therefore been listed in the Paleo-Indian section. Two highly important occurences of Altithermal cultural material are at Mummy Cave (48 PA 201) and Medicine Lodge Creek (48 BH 499). The mountain and break areas of northwestern Wyoming should in the future yield important data concerning this puzzling hot-dry period.

The Middle Prehistoric Period

9. Obsidian Cliff.

This site has been rather arbitrarily assigned to the Middle Period. The obsidian from this area in Yellowstone Park was quite likely used by earlier peoples and it is known to have been utilized through late prehistoric times. Material thought to have come from this site has been found as far east as Hopewellian villages along the Mississippi River.

10. Dead Indian, 48 PA 55.

Excavation at this site revealed a large Middle Prehistoric Period occupation containing many varieties of projectile points.

11. Rabbit Bone Cave, 48 PA 202.

Rabbit Bone Cave is a rock shelter containing Late Middle Period

artifacts and many small animal bones. The site was reported as being completely excavated.

12. The Medicine Wheel, 48 BH 302.

The age, origin and function of this structure are not entirely known at the present time. As originally described it consisted of two concentric circles of rock joined together by twenty-six rock lines or "spokes" radiating from the smaller circle. Within and around the wheel were six U-shaped structures. Similar rock alignments have been found as far north as Alberta.

13. Leigh Cave, 48 WA 304.

An Early Middle Period site with artifacts similar to the desert cultures farther to the southwest. The material at this site compares with the level at Mummy Cave dated at about 4500 years ago.

14. Spring Creek Cave, 48 WA 1.

This site is a dry cave in the Bighorn Basin near Tensleep. It contains a culture-bearing stratum of the Late Middle Period. The aridity of the cave has preserved many perishable items including coiled basketry, mats, pieces of leather and atlatl fragments.

15. Wedding of the Waters Cave, 48 HO 301.

This site contains nearly three feet of stratified material divided into four levels of occupation.

The dry cave sites within Area Two have provided much valuable information about the Middle Prehistoric Period. Many such sites have

undoubtedly been looted over the years, but those which have been excavated in a consciencious and scientific manner have given unique insight into the Middle Period by providing perishable materials. These and other Middle Prehistoric sites from Area Two indicate that many changes had taken place by this time in the prehistory of North America.

The Late Prehistoric Period

16. The Blue Stone Site, 48 PA 552.

This high altitude site derives its name from the blueish-green stones found in the area. This material is believed by some to be the rock from which some Indians made beads before the introduction of European trade beads.

17. 48 TE 301.

48 TE 301 lies high in the Tetons and has been classified by many who have seen it as a vision quest structure.

18. The Marques earthern pot.

This flat-bottomed Intermountain pottery vessel was discovered on the North Fork of the Shoshoni River. It closely resembles other vessels found in the area which are made from steatite.

19. The "Sioux Trail", 48 BH 204.

This interesting feature runs from northern Wyoming into Montana. It is believed to be the ruts left by many travois poles traveling over the same ground. Associated with the trail is a series of rock cairns.

20. The Crooked Creek Site, 48 BH 211.

This open-air site consisted of twenty-four stone circles, scattered lithics and a few sherds of pottery. Excavations indicated no subsurface deposits.

21. 48 BH 7

A site similar to Crooked Creek but smaller in size.

21. Canyon Creek Butte Site, 48 WA 306.

This is a stone circle site with associated pottery.

23. Dinwoody Cave and Campsite.

Both of these sites appear to be Late Period occupations of an area now within the Wind River Indian Reservation. Numerous examples of pictographs and petroglyphs are also found in this area.

24. Sheep kill area.

Two rather unique sites have recently been found in the mountainous areas of Area Two. They are animal procurement areas at which large numbers of mountain sheep were killed and butchered. Little work has been done on these sites and they may prove to be quite important.

Many Late Prehistoric Period archaeological sites have been located in this study area. Only a small number of them have been mentioned here. Much work remains to be done with the material from this time period. Area Two has contributed much knowledge about the use and distribution of certain Late Period pottery types found in Wyoming.

TABLE 1

SOME RADIOCARBON DATES FROM
STUDY AREA TWO

Period	Site	Radiocarbon Dates
Late	Mummy Cave, CL #2	A.D. 1594
	Mummy Cave, CL #3	A.D. 734
	Bottleneck Cave, Occ V	A.D. 440
Middle	Mummy Cave, CL #4	87 B.C.
	Wedding of the Waters, Level II	330 B.C.
	Bottleneck Cave, Occ. IV	1870 B.C.
	Dead Indian	2450 B.C.
	Mummy Cave, CL #9	2455 B.C.
Altithermal	Mummy Cave, CL #19	3850 B.C.
	Mummy Cave, CL #21	5190 B.C.
Early	Medicine Lodge Creek	6370 B.C.
	Bottleneck Cave, Occ. I	6320 B.C.
	Horner	6500 B.C.
	Medicine Lodge Creek	7410 B.C.
	Bottleneck Cave	7280 B.C.

Concluding Remarks on Study Area Two

The above report hopefully gives some indication of the archaeological resources present in Area Two. There is no way, of course, to predict exactly how many more sites remain to be discovered or to say what their importance will be. It can safely be stated, however, that a great many archaeological sites remain undiscovered in this area and that any portion of it has the potential for producing a highly significant site. The limited amount of survey work that has been done within Area Two amply demonstrates this fact.

A well planned and systematic archaeological survey of an area to be disturbed by construction work is the most efficient and accurate way to predict its archaeological potential. Such a survey not only finds sites which merit excavation; it also collects information on sites which would not be excavated but whose surfaces manifestations can provide valuable information.

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APPENDIX D

SEISMICITY EVALUATION OF THE IRIGARAY PROPERTY

SEISMICITY EVALUATION

Introduction. Earthquakes occur with the greatest frequency and severity along the margins of the dozen or so lithospheric plates which make up the crust of the earth. The North American continent is part of one such plate, but the nearest plate margin to the Powder River Basin is the San Andreas Fault in California. Earthquakes occurring there are sufficiently distant to produce negligible effects in this area. Plate interiors are far from aseismic, however, and the Rocky Mountain region, for example, is tectonically quite active.

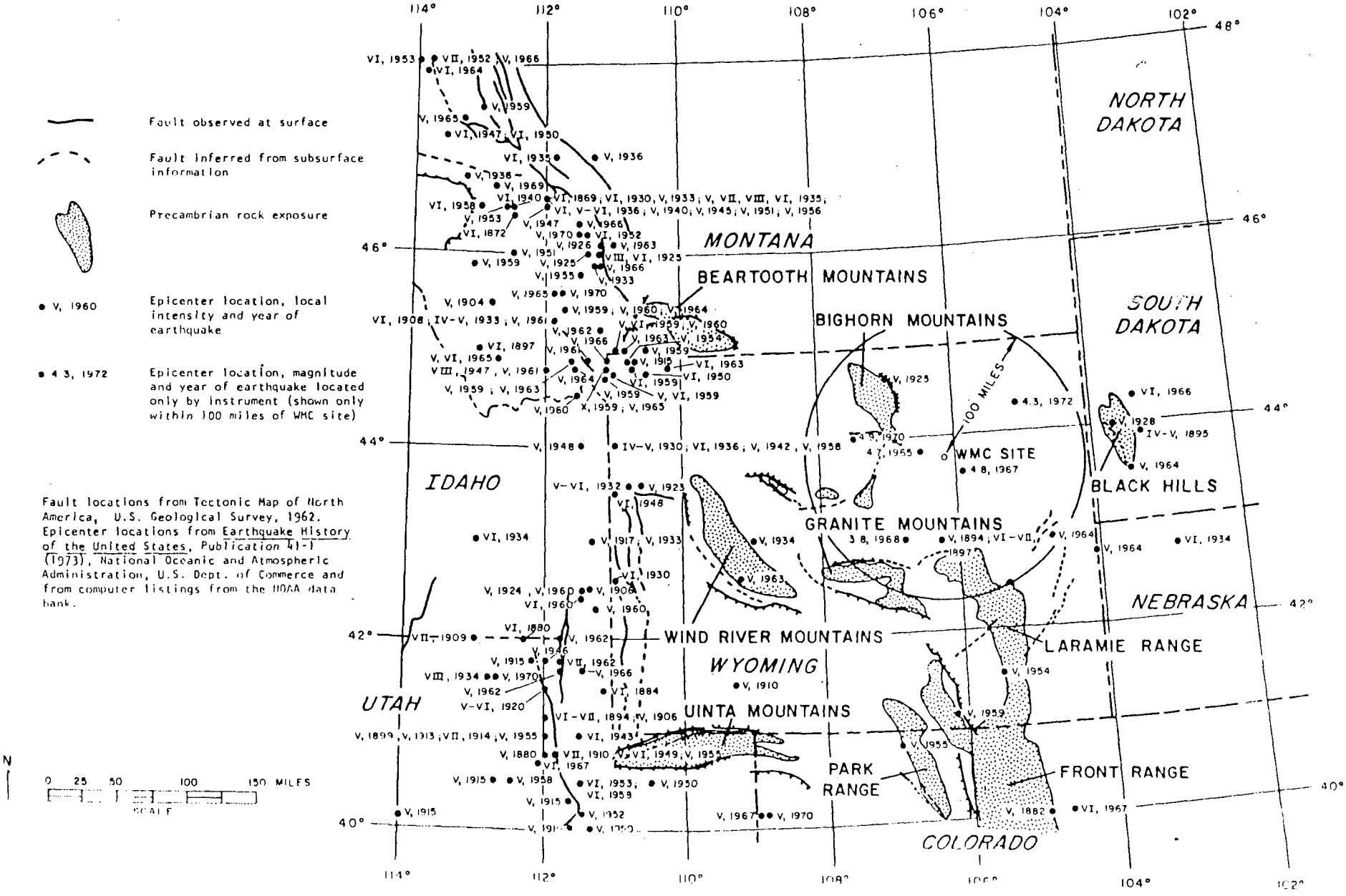
At the present time there is no reliable method for predicting the location and severity of an earthquake, although promising techniques are being developed by the National Center for Earthquake Research in California, whose main concern is in making such predictions for earthquakes on and near the San Andreas Fault. For other regions the most satisfactory approach to the prediction problem is to investigate the seismic history of the area and, using the assumption that the area will continue to behave in much the same way as before, to make predictions of seismic risk based on statistical considerations.

This is the technique used in the construction of the seismic risk map for the United States (U.S. Dept. of Commerce, 1973) which shows the Powder River Basin as part of a large region including much of central and eastern United States where only minor earthquake damage may be expected. This report will focus in detail on the Powder River Basin and surrounding region in an attempt to make some quantitative estimates of earthquake effects expectable at the Wyoming Mineral Corporation (WMC) site in the basin.

Local and Regional Seismicity. The seismicity map (Figure 1) shows the locations, dates and intensities (Modified Mercalli Intensity Scale, see Table 1) for all earthquakes felt since the region was extensively settled in the late 1800's. Earthquakes too small to be felt but large enough to be recorded on seismographs are shown if they occurred within 100 miles of the WMC site. A network of seismic recording stations dense enough to locate such small earthquakes accurately has been in existence for only about ten years, which is why there are none shown prior to 1965.

The map indicates that the Powder River Basin is an area of low seismic activity. Within a 100-mile radius of the site only four earthquakes strong enough to be felt have occurred during the last seventy years. Of these four, only the 1897 quake of intensity VII near Casper, Wyoming, was severe enough to cause damage. The only building suffering significant damage (cracks in outer walls) was not well built, and this quake may be better described as intensity VI.

Within the same 100 mile radius, only five earthquakes of magnitude 4.9 or less have been instrumentally recorded since 1965. Since earthquakes of a given magnitude occur roughly ten times more frequently than earthquakes of one magnitude greater (Richter, 1958), this is further evidence for low seismic activity in this area. These figures suggest that, within 100 miles of the site, an earthquake of magnitude 5.0 to 6.0 should occur about once every 20 years, and one with magnitude 6.0 to 7.0 about once every 200 years. The above analysis is weakened by the small number of observations upon which to base such a statistical estimate and by the fact that some earthquakes in the range 4.0 to 5.0 may not have been accurately located, but it does at least approximate the variation of frequency with magnitude. A similar estimate


Fault observed at surface
Fault inferred from subsurface information
Precambrian rock exposure
V, 1960 Epicenter location, local intensity and year of earthquake
4.3, 1972 Epicenter location, magnitude and year of earthquake located only by instrument (shown only within 100 miles of WMC site)
Fault locations from Tectonic Map of North America, U.S. Geological Survey, 1962. Epicenter locations from Earthquake History of the United States, Publication 41-1 (1973), National Oceanic and Atmospheric Administration, U.S. Dept. of Commerce and from computer listings from the NOAA data bank.
N
0 25 50 100 150 MILES
SCALE
114°
112°
110°
108°
106°
104°
102°
48°
46°
44°
42°
40°
NORTH DAKOTA
MONTANA
SOUTH DAKOTA
BEARTOOTH MOUNTAINS
BIGHORN MOUNTAINS
100 MILES
WMC SITE
BLACK HILLS
IDAHO
GRANITE MOUNTAINS
NEBRASKA
WIND RIVER MOUNTAINS
LARAMIE RANGE
WYOMING
UTAH
UINTA MOUNTAINS
PARK RANGE
FRONT RANGE
COLORADO

of frequency vs. intensity (which would be a better predictor of expected damage) is not as easily made, but the evidence from small earthquakes in the area supports the conclusion that very little damage is expected in the region from local earthquakes because a) they are relatively small and b) they do not occur often.

The WMC site is located about 200 miles from the closest approach of a belt of frequent and severe seismic activity within the northern Rocky Mountains (see Figure 1). The Hebgen Lake earthquake of August, 1959, lies within this belt and is the closest major earthquake to the site (about 250 miles distant) recorded in historic times. Vibrational effects near the epicenter indicated an intensity of about VIII, but very local non-vibrational effects (faulting and landslides) correspond to intensities of IX and X (Steinbrugge and Cloud, 1962). The effects propagated more effectively toward the northwest where intensities of V were reported 400 miles from the epicenter; toward the WMC site to the southeast intensities were IV and lower less than 200 miles from the epicenter.

This earthquake was not felt in the Southern Powder River Basin, but another one of similar local intensity could easily produce significant ground motion at the site. Therefore a seismicity evaluation for the site must be concerned with two separate problems -- the effects produced by major earthquakes at distances of about 200 miles and those produced by the smaller earthquakes which occur quite close to the site. The next section is concerned with establishing quantitative limits for expected ground motions resulting from earthquakes in each of these source areas.

Seismic Risk. The amount of damage produced by an earthquake is roughly dependent on the magnitude of the ground accelerations. Other important

variables are frequency and duration of wave motion, since some buildings may resonate strongly at certain frequencies or be poorly damped so that small accelerations can cause dangerous shaking if continued for a few seconds. But acceleration is the most important variable, as is indicated by the impirical relationship between intensity (I) and acceleration (a) (Båth, 1973).

$$\log a = \frac{I}{3} - \frac{1}{2}$$

The problem can then be stated as follows: if an earthquake of a certain intensity occurs at a certain distance from the site, what will be the peak acceleration (or intensity) produced at the site? A precise answer is not possible, since it depends on the nature of the earthquake source, the focal depth, the travel path to the site area and the local geology of the site. An estimate is provided by recent observations of surface waves (Page et al., 1972), which show that the accelerations decay approximately as the square of the distance from the epicenter beyond a central region within which the accelerations are fairly constant. The radius of the central region ranges from about 6 miles (magnitude 5) to about 30 miles (magnitude 8).

First we consider the effects of a hypothetical earthquake in the Rocky Mountain belt. A reasonable upper limit would be an earthquake of intensity X occurring 200 miles from the site. This would produce peak accelerations of about 0.7 g (1g = 980 cm/sec^2) in the epicentral region, but the WMC site would experience peak accelerations of only .016g corresponding to a local intensity of V.

The largest earthquake occurring in historic times within 100 miles of the site was the VI or VII Casper earthquake in 1897. Casper is about 60 miles from the site, but because of the low population density at that time we cannot be

certain that the epicenter was accurately located. We will assume that an earthquake of intensity VII might occur 17 miles from the site, the distance of the magnitude 4.8 event in 1967. Such a hypothetical earthquake would produce local peak accelerations of .068g, but peak accelerations at the site would be reduced to about 0.23g (intensity V-VI).

The hypothetical local and distant earthquakes produce roughly similar accelerations at the site. The surface wave characteristics would be different, however, because of dispersion and preferential attenuation of high frequency waves. The surface wave train from a distant event would be of lower frequency and longer duration than that from a local earthquake and would have greater effect on large, poorly damped structures.

It is not the purpose of this report to consider the effects of the above accelerations on different structures, but some general comments may be made. Ordinary structures not designed to be resistant begin to suffer damage when accelerations reach about 0.1g (Richter, 1958). Accelerations calculated above do not reach a quarter of this value. An intensity VII earthquake occurring right at the site would produce 0.07g accelerations which might cause slight damage, but the probability of this is vanishingly small considering the seismic history of the region. Accelerations below the surface of the ground would be even lower because surface wave amplitudes generally decrease with depth.

The time factor is also important. Earthquakes the size of the hypothetical events considered above have occurred in their respective areas only once in the last 100 years. The conclusion which may be drawn from the available data is that the WMC site in the Powder River Basin should only occasionally experience detectable ground motions and that there is very little risk that such motion could produce structural damage.

TABLE 1

MODIFIED MERCALLI INTENSITY SCALE

I. Not felt except by a very few under specially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day, felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.

V. Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage <u>negligible</u> in buildings of good design and construction; slight to moderate in well-built ordinary structures; <u>considerable</u> in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars.

VIII. Damage <u>slight</u> in specially designed structures; <u>considerable</u> in ordinary, substantial buildings, with partial collapse; <u>great</u> in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed.

IX. Damage <u>considerable</u> in specially designed structures; well-designed frame structures thrown out of plumb; <u>great</u> in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with their foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage <u>total</u>. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into air.

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APPENDIX E

THE CLIMATE AND WEATHER OF THE POWDER RIVER BASIN, WYOMING

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THE CLIMATE AND WEATHER OF THE POWDER RIVER BASIN, WYOMING

Purpose: The purpose of this report is to survey the weather and climate of the Powder River Basin, Wyoming, (Plate 1) and its effect on the Uranium Operations of Westinghouse Electric Corporation, as well as to provide a basis for environmental reports. Data was drawn from three National Weather Service stations peripheral to the study area and substantiated with data (1970-1974) from eight cooperative stations within the region. On September 3, 1975, Westinghouse established its own recording facilities near the area of operation.

Location: The South Central Powder River Basin study area is an area of approximately 4100 square miles located in East Central Wyoming (Johnson County) and is bordered by such towns as Buffalo, Kaycee, Midwest, Reno, and Gillette. Elevation varies from approximately 4200 to 4600 feet.

Climate: Climate and weather differ only in the extent of time. Both are expressed by the same elements, that is, solar energy, temperature, humidity--precipitation and wind. Other factors would be altitude, distribution of land and water, mountain barriers, pressure cells, air masses, atmospheric disturbances, and so on.

Using these factors as standard climatic criteria, the Powder River Basin of Wyoming represents a Cold, Dry (Semiarid) Climate, the boundaries being fixed by rainfall values more than by temperatures. In that the Dry Climates are defined as regions

where evaporation exceeds precipitation, a standard formula for determination would be:

$$R = 1/2\ T - 1/4\ PW \quad (1)$$

where R = Rainfall
T = Temperature
PW = Percent precipitation Winter half of year

The boundary separating Steppe (Semiarid) from Desert (Arid) would be:

$$R = \frac{1/2\ T - 1/4\ PW}{2}$$

Powder River Basin: Since Semiarid climates are based primarily on precipitation and evaporation criteria, it should be noted that the normal annual precipitation of the study area varies between 11 and 16 inches (Plate 2). This compares to a normal annual evaporation (Pans) of 58 to 60 inches. Most stations appear to have a double maximum of precipitation, namely Spring as the primary maximum and Fall as a secondary. Normal precipitation of the wettest month (April or May) is 2.1 inches. Average length of the "wet" season is 2 to 4 months with a possible deviation of 20 to 25% in precipitation occurrance. Normal daily precipitation is .3 inches, yet a 24 hour maximum of 3 inches has been recorded. Hailstorms do occur, but are usually restricted to June.

The normal date for the first snowfall is within the first week of October, and it should be noted that a substantial proportion of

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(1) After Patton

precipitation (30%) will occur as snow. In fact, 50 to 60 inches would represent the normal annual snowfall. Snow cover (1 inch) will last 80 to 100 days.

Yearly mean temperature for the Powder River Basin study area is 44.6°F, but since this is a cold climate with a short hot summer, temperature extremes and ranges are notable. In January the daily range of temperatures is about 25°, varying between a normal daily minimum of 10° and a maximum of 35° whereas in July the range is about 30° (50° vs 80°F).

Extremes can be startling. Temperatures in the 70°'s have been recorded in the Wyoming Winter, but the study area has also recorded low temperatures of -30 and -40°F. Summers also have their extremes, as is seen by a Wyoming Summer low between 5 and 10°F, and a high in the Study Area of 100 to 103°F.

Frost reaches a 50% probability by the third week of October and a 75% probability by the first week of November. Winter (daily normal temperature of 32°) can be said to begin by the third week of November. With 49% of the year's cold degree days occurring in the three months of Winter, frost penetration can be quite deep. In the study area the average depth of penetration is 30 to 35 inches whereas the State as a whole has recorded extreme frost depths of 60 inches.

Latitude dictates Wyoming's position in the Westerly Wind Belt (Plate 3), which, in turn, determines the path of pressure systems through this region. There is a frequency of cyclonic and anti-cyclonic movement along several paths that influence the Study Area

(Plate 4). Surface wind flow relative to these atmospheric disturbances can be noted in Plate 5 where prevailing winds fluctuate between Northwest and Southwest. Average velocities are between 8 and 13 miles per hour, with Winter wind velocities higher than those in Summer.

Like many Rocky Mountain East slope sites this area is subject to chinook winds representing a sudden outbreak of warm air in Winter. Winter temperatures can rise from below 0 degrees to 40 - 50 degrees F within an hour or two. In reality, it is a maritime polar front warmed as it descends the higher elevations and brings, on the average, a 30 degree temperature change.

In the course of a year, humidity can have a range of 91 percent from high to low, but a normal monthly fluctuation is best seen in the table below for Casper. High humidity values occur in the early morning and late evening hours while the lower percentage values would be registered midday.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
% Range	10	14	26	26	43	45	47	45	40	47	14	9
% High	71	72	76	80	83	76	73	68	73	73	73	69
% Low	61	58	50	54	40	31	26	23	33	26	59	60

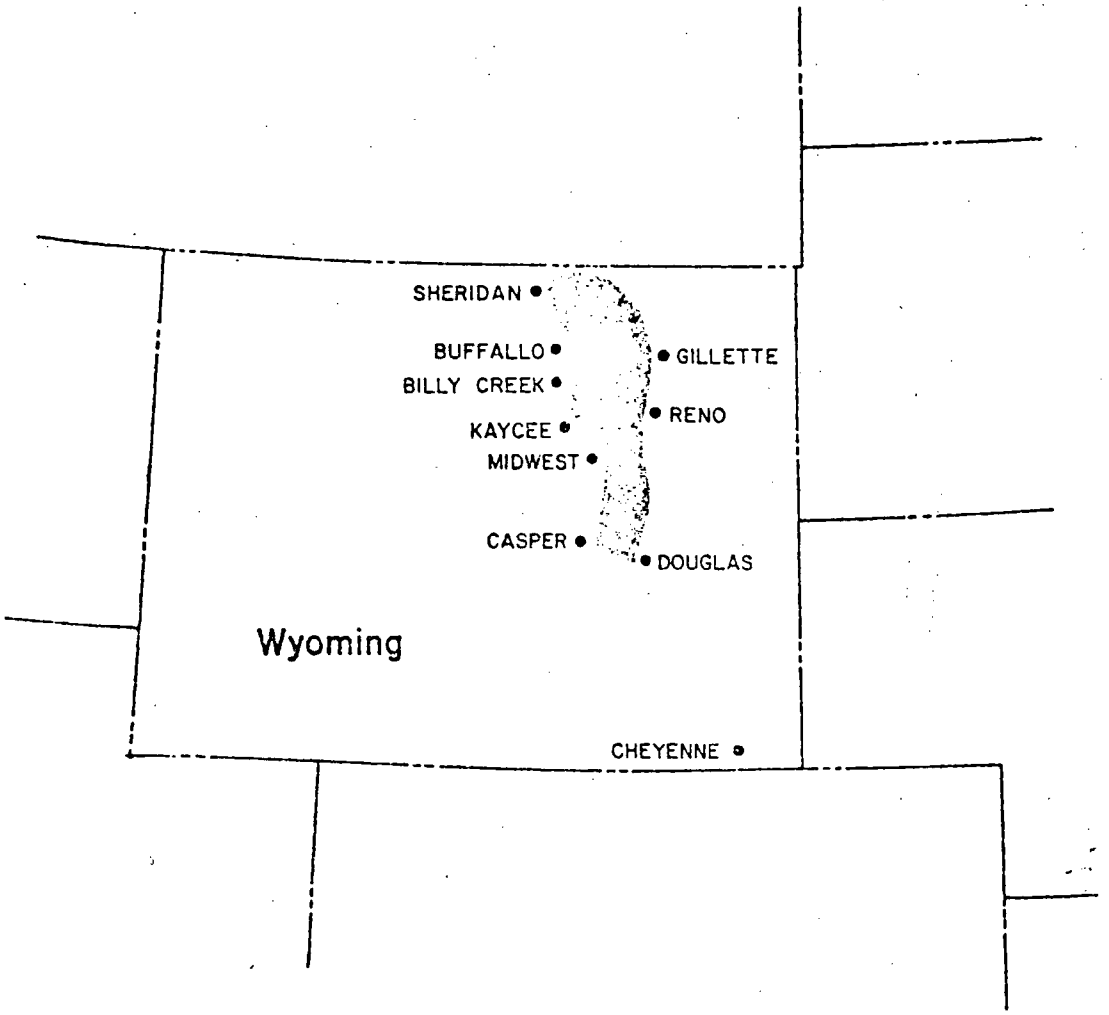
Conclusions: The Powder River Basin experiences a cold, dry Winter and a hot, dry Summer. While this climate may appear to have a high energy quotation for human activity, its extremes must be weighed. Winder winds may average 15 mph and temperatures may fall to the -30, -40 range creating a wind chill factor of consequence (Plate 6).

Winters are long and cold necessitating sufficient insulation, heating, and proper orientation to the prevailing westerly winds. Lines and cables should be buried sufficient depths so as not to be affected by the normal three foot frost penetration.

The Spring Season is the time of maximum precipitation, and due to the transitional nature of the season, can produce an alternate occurrance of rain or snow creating difficult working conditions.

Summers are primarily influenced by High Pressure Cells and, with the exception of thunderstorms, would represent a time of stable atmospheric conditions. Winters are cyclonic in nature, and stability becomes more tenuous and less predictable. Fall conditions would closely follow Spring.

Humidity values are normal and lie in the 30 to 70 percent range of comfort and, other than causing some Winter conditions to be less tolerable, present no major problems to the area.



WYOMING MINERAL CORPORATION

LOCATION OF POWDER RIVER BASIN STUDY AREA	DWN: JRB	9-9-75	PLATE I	REV
	CHK: ADL	9-10-75		
	SCALE: ——— NAS		SHEET OF	

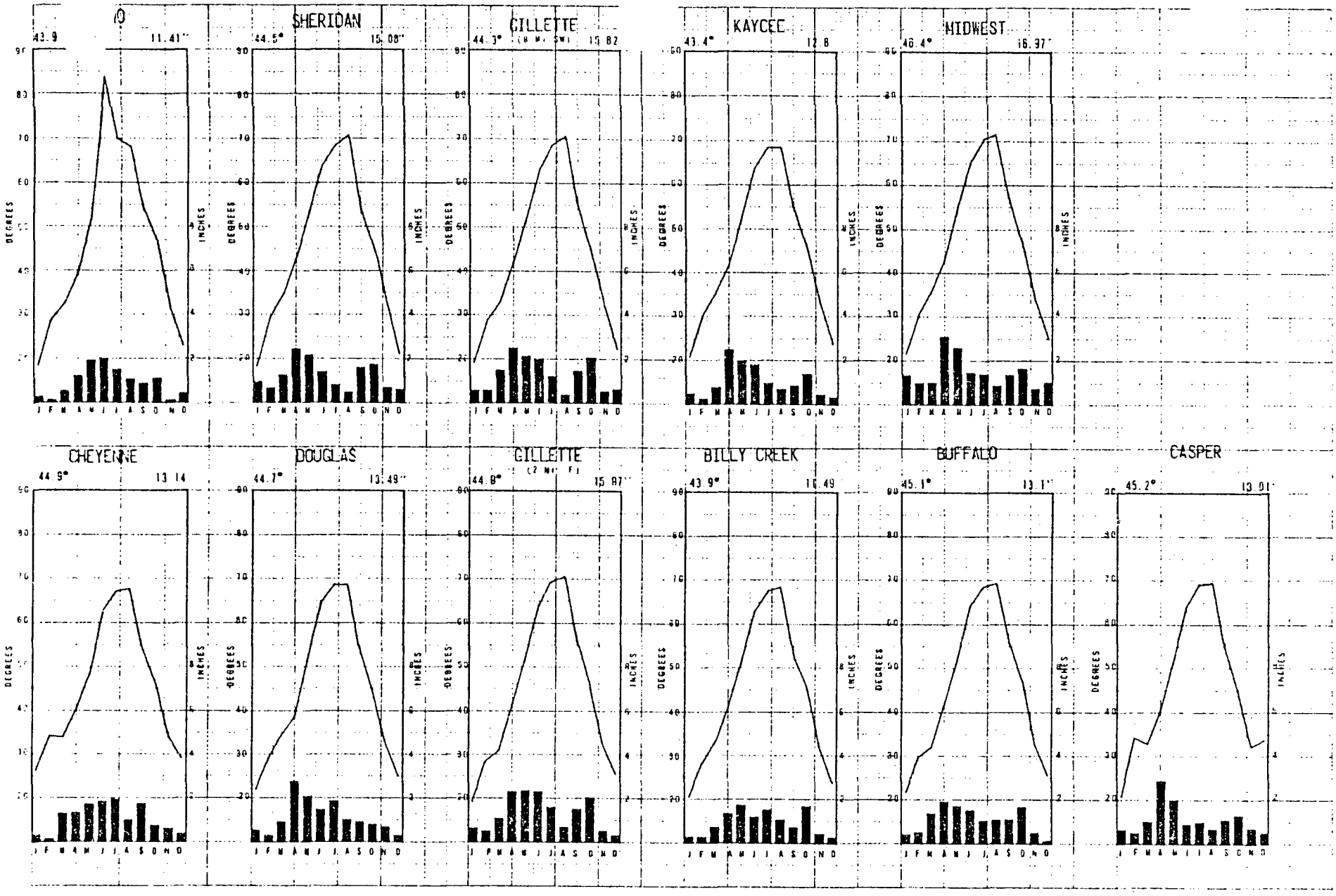
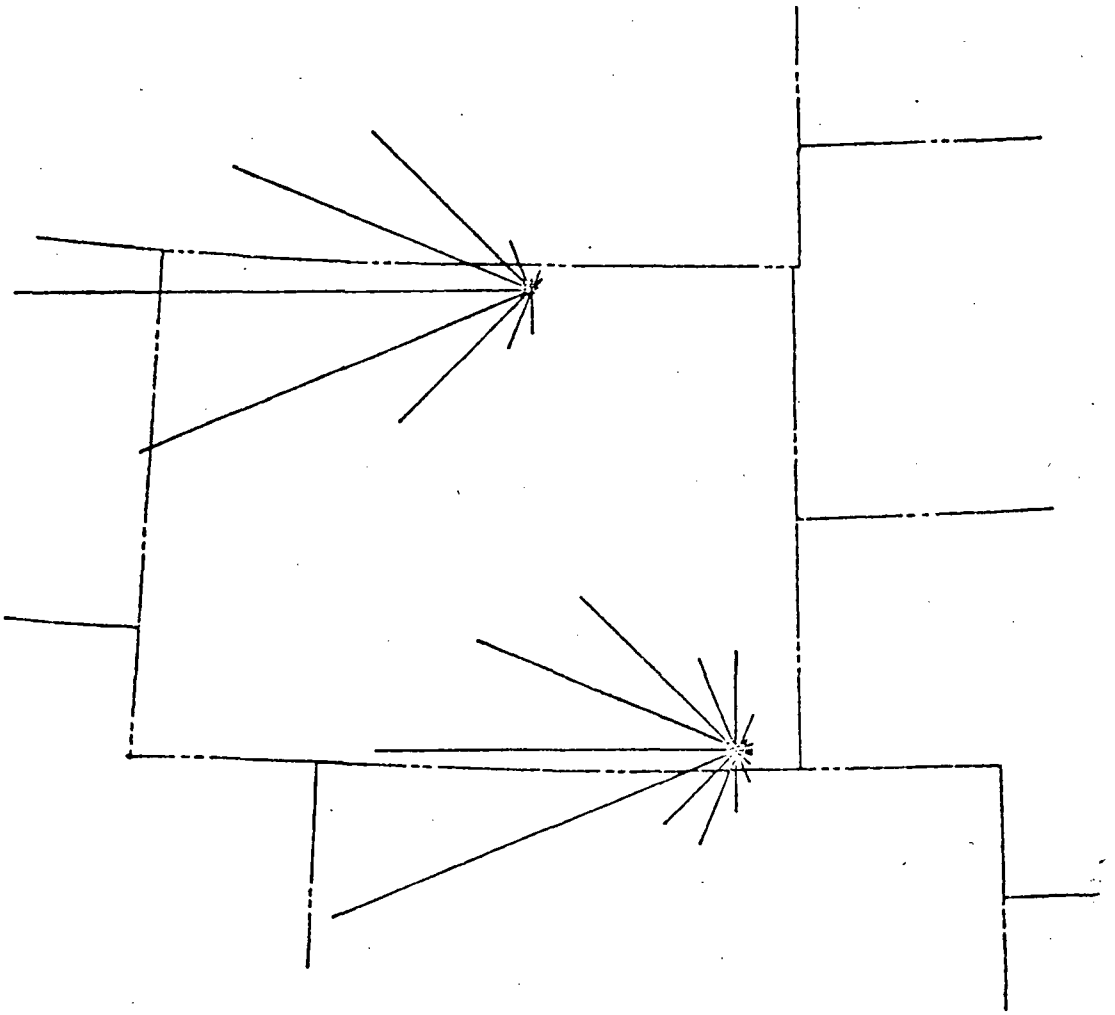

SHERIDAN
43.9
11.41"
44.5°
15.08"
GILLETTE
44.3°
15.82
KAYCEE
43.4°
12.8
MIDWEST
46.4°
16.97"
CHEYENNE
44.9°
13.14
DOUGLAS
44.7°
13.49"
GILLETTE
44.8°
15.87"
BILLY CREEK
43.9°
16.49
BUFFALO
45.1°
13.1"
CASPER
45.2°
13.01"
DEGREES
INCHES
J F M A M J J A S O N D

PLATE 2



0 10 20

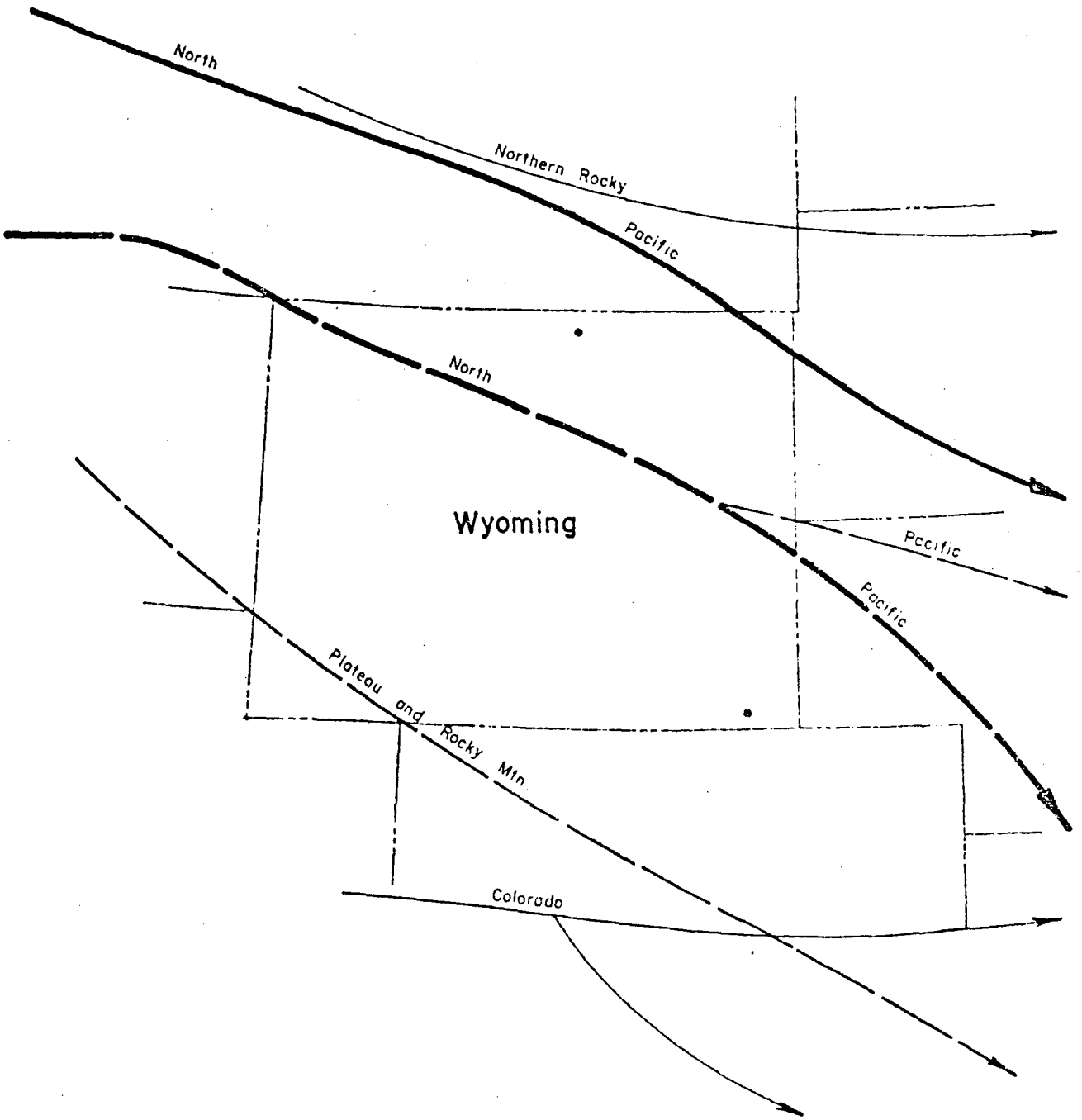
DIRECTIONAL OCCURANCE (%)

8000 METER ALTITUDE

AFTER VISHER

WYOMING MINERAL CORPORATION

HIGH ALTITUDE SUMMER WIND FLOW SHERIDAN AND CHEYENNE, WYO.	DWN: JRB	9-9-75	PLATE 3	REV
	CHKD: ADL	9-10-75		
	SCALE: ——		SHEET OF	



CYCLONIC PATHS

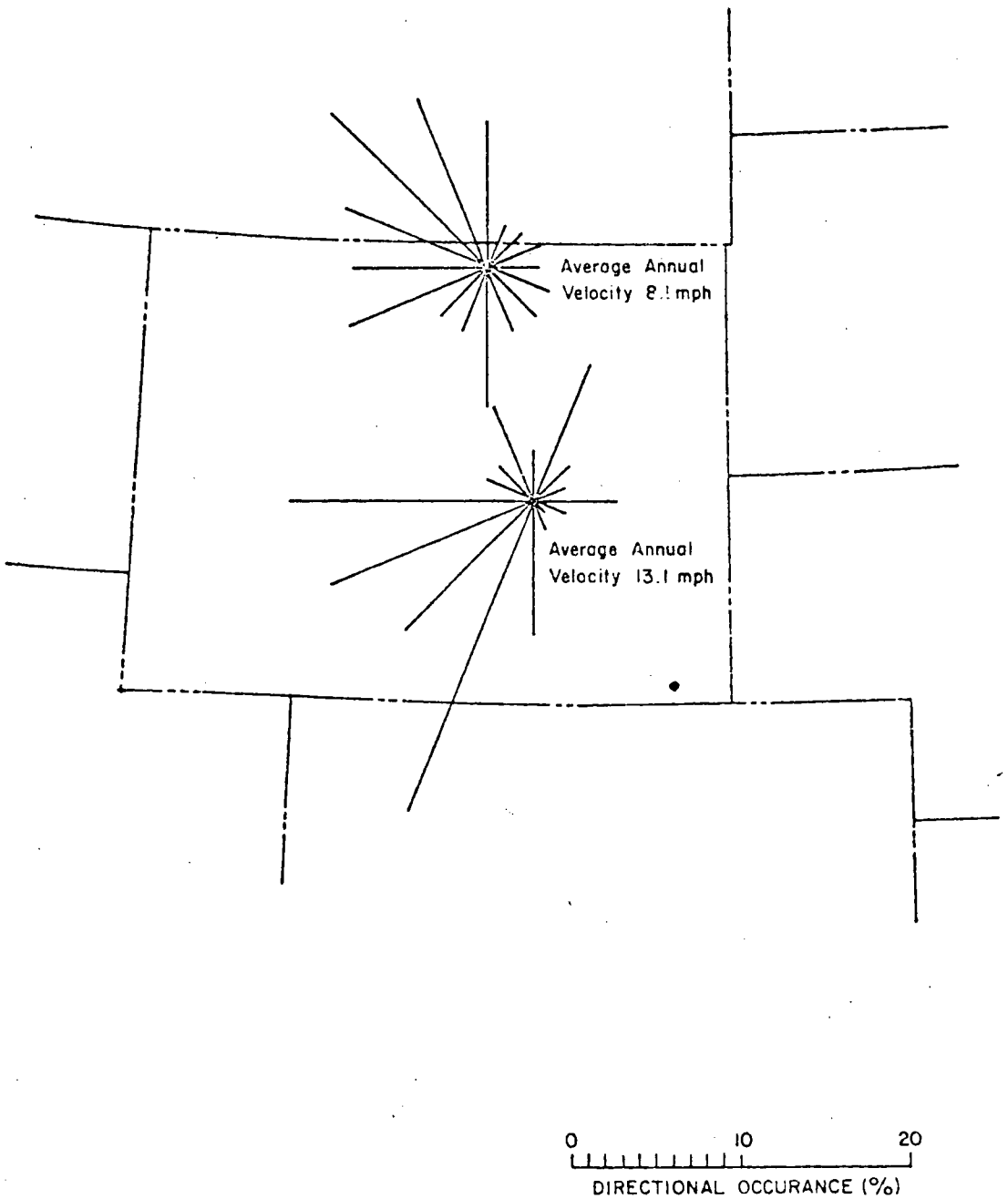
ANTICYCLONIC PATHS

LINE WIDTHS INDICATE FREQUENCY

AFTER GOODE

WYOMING MINERAL CORPORATION

AVERAGE CYCLONIC & ANTICYCLONIC PATHS ACROSS WYOMING	DWN: JRB	9-9-75	PLATE 4	REV
	CHKD: HOL	9-10-75		
	SCALE: —		SHEET OF	



WIND ROSE FOR THE
16 CARDINAL DIRECTIONS

WYOMING MINERAL CORPORATION

ANNUAL SURFACE WIND FLOW at SHERIDAN AND CASPER, WYO.	DWN: JRB 9-9-75	PLATE 5	REV
	CHKD: 9-10-75		
	SCALE:	SHEET OF	

WIND CHILL TABLE [a]

mph	Dry bulb temperature (°F)																
	35	30	25	20	15	10	05	0	-05	-10	-15	-20	-25	-30	-35	-40	-45
	equivalent temperature [b] of wind chill index (°F)																
calm	35	30	25	20	15	10	05	0	-05	-10	-15	-20	-25	-30	-35	-40	-45
5	33	27	21	16	12	7	1	-6	-11	-15	-20	-26	-31	-35	-41	-47	-54
10	21	16	9	2	-2	-9	-15	-22	-27	-31	-38	-45	-52	-58	-64	-70	-77
15	16	11	1	-6	-11	-16	-25	-33	-40	-45	-51	-60	-65	-70	-78	-85	-90
20	12	3	-4	-9	-17	-24	-32	-40	-46	-52	-60	-68	-76	-81	-88	-96	-103
25	7	0	-7	-15	-22	-29	-37	-45	-52	-58	-67	-75	-83	-89	-96	-104	-112
30	5	-2	-11	-18	-26	-33	-41	-49	-56	-63	-70	-78	-87	-94	-101	-109	-117
35	3	-4	-15	-20	-27	-35	-43	-52	-60	-67	-72	-83	-90	-98	-105	-113	-123
40	1	-4	-15	-22	-29	-36	-45	-54	-62	-69	-76	-87	-94	-101	-107	-116	-128
45	1	-6	-17	-24	-31	-38	-46	-54	-63	-70	-78	-87	-94	-101	-108	-118	-128
50	0	-7	-17	-24	-31	-38	-47	-56	-63	-70	-79	-88	-96	-103	-110	-120	-128

cold

very cold

bitterly cold

extreme cold

[a] Wind speeds greater than 40 mph have little additional chilling effect.

[b] Equivalent in cooling power of exposed flesh under calm condition.

CURVES SHOW RATES OF COOLING (kilogram calories per square meter per hour) FOR DIFFERENT COMBINATIONS OF TEMPERATURE AND WIND SPEED. WHEN THE DRY CONVECTIVE COOLING RATE IS LESS THAN THE RATE OF BODY HEAT PRODUCTION, EXCESS HEAT IS REMOVED BY EVAPORATION OF PERSPIRATION. UNDER CONDITIONS OF BRIGHT SUNSHINE COOLING IS REDUCED. THE TERMS DENOTING RELATIVE COMFORT ARE BASED ON INDIVIDUALS AT REST.

AFTER GATES

WYOMING MINERAL CORPORATION			
WIND CHILL FACTOR			
DWN: JRB	9-9-75	PLATE 6	REV
CHKD	9-9-75		
APRD:			
SCALE:		SHEET OF	

THE CLIMATE AND WEATHER OF THE POWDER RIVER BASIN, WYOMING

Prepared by: Alan D. Luck

Data Compiled by: Woodrow R. McKee

Loren W. Grace

Date: September 9, 1975

PRECIPITATION DATA FOR FIVE YEAR PERIOD 1970 to 1974

		Precipitation													
		Monthly		Greatest Monthly		Lowest Monthly		Snowfall (Snow and Ice Pellets)							
								Avg	Number of Days			Greatest Monthly		Lowest Monthly	
ation	Mo	Avg Amnt	Nrml Amnt	Amnt	Year	Amnt	Year	Mthly Amnt	.10or more	.50or more	1.00or more	Amnt	Year	Amnt	Year
lly	Jan	0.33	-	1.00	1972	0.06	1971	5.2	0.8	0	0	13.6	1972	1.1	1970
Creek*	Feb	0.30	-	1.26	1971	0.01	1973	3.7	0.6	0.4	0	8.3	1971	0.8	1973
	Mar	0.75	-	1.05	1971	0.42	1974	8.6	2.4	0.2	0	13.0	1970	5.8	1974
	Apr	1.37	-	2.65	1971	0.95	1972	6.2	4.8	0.6	0	10.7	1970	1.6	1974
	May	1.78	-	3.08	1970	0.71	1973	T	4.6	0.6	0.2	1.7	1973	0	1971-
	Jun	1.21	-	1.61	1972	0.84	1971	T	3.2	0.6	0.2	T	1973	0	1970-
	Jul	1.55	-	3.30	1973	0.58	1974	0	4.2	0.4	0.2	0	-	0	-
	Aug	1.08	-	2.64	1974	0	1970	0	3.0	0.6	0	0	-	0	-
	Sep	0.75	-	1.92	1973	0.28	1974	1.0	2.0	0.4	0	3.1	1970	0	1971
	Oct	1.68	-	3.30	1971	0.47	1970	6.1	3.6	1.4	0	6.5	1973	0.5	1974
	Nov	0.42	-	0.65	1973	0.20	1974	5.2	0.8	0.2	0	9.8	1971	2.1	1974
	Dec	0.27	-	0.43	1970	0.16	1971	4.2	0.8	0	0	7.0	1970	2.6	1974
	Yrly	11.49		3.30	10/71+	0	8/70	40.2				13.6	1/72	0	6/70-
Buffalo*	Jan	0.42	-	0.53	1974	0.34	1971	4.5	2.0	0	0	-	-	-	-
	Feb	0.52	-	0.97	1971	0.07	1974	6.5	1.5	0	0	17.5	1972	0	1974
	Mar	1.39	-	1.89	1971	0.58	1974	9.4	5.0	0.6	0.2	23.5	1971	1.0	1973
	Apr	1.91	-	2.95	1973	0.92	1972	2.2	4.2	1.0	0.2	4.5	1973	T	1974
	May	1.73	-	2.98	1970	0.64	1973	0.4	3.6	0.8	0.4	2.0	1973	0	1971-
	Jun	1.55	-	2.52	1972	0.58	1974	0	3.6	0.6	0	0	-	0	-
	Jul	1.04	-	2.38	1973	0.15	1974	0	3.0	0.6	0.2	0	-	0	-
	Aug	1.07	-	2.90	1972	T	1970	0	1.8	0.4	0	0	-	0	-
	Sep	1.14	-	2.65	1973	0.47	1971	T	4.0	0.4	0.2	T	1973	0	-
	Oct	1.64	-	3.58	1971	0.37	1970	2.0	4.0	1.2	0.4	6.6	1971	0	1974
	Nov	0.52	-	0.92	1973	0.27	1974	9.0	1.8	0	0	14.0	1973	6.0	1971
	Dec	0.17	-	0.38	1971	0.02	1971	3.3	0.8	0	0	9.0	1970	1.0	1972-
	Yrly	13.10		2.98	5/70	T	8/70	37.3				23.5	3/71		
sper	Jan	0.62	0.56	0.99	1972	0.19	1971	11.1	2.0	0.2	0	19.2	1972	3.7	1971
WSO	Feb	0.49	0.59	0.80	1971	0.27	1970	8.5	2.2	0	0	11.3	1973	4.8	1970
AP	Mar	1.00	1.03	1.53	1970	0.37	1974	14.0	3.4	0	0	22.3	1970	7.5	1974
	Apr	2.84	1.69	3.92	1974	1.44	1972	24.9	6.2	2.0	0.8	56.3	1973	10.9	1970
	May	2.00	2.03	5.59	1971	0.62	1974	1.5	5.0	0.8	0.6	2.2	1971	0	1972
	Jun	0.86	1.25	2.03	1970	0.17	1971	T	2.0	0.4	0.2	T	1970	0	-
	Jul	0.98	1.00	2.26	1973	0.11	1971	0	2.8	0.4	0.2	0	-	0	-
	Aug	0.63	0.72	1.52	1972	0.11	1971	0	1.6	0.4	0	0	-	0	-
	Sep	1.09	0.90	3.28	1973	0.21	1970	1.7	1.4	0.6	0.2	5.1	1974	T	1973
	Oct	1.31	0.84	2.04	1972	0.60	1973	8.2	4.2	0.2	0	11.2	1970	1.2	1974
	Nov	0.71	0.71	1.01	1970	0.46	1974	9.5	2.6	0.2	0	13.2	1973	7.4	1970
	Dec	0.48	0.48	0.89	1970	0.22	1974	8.1	1.2	0	0	11.9	1970	4.7	1971
	Yrly	13.01	11.80	5.59	5/71	0.11	7/71+	87.5				56.3	4/73		

*Ocnl Month of Data Msg.
+Also Other Dates.

PRECIPITATION DATA FOR FIVE YEAR PERIOD 1970 to 1974

		Precipitation													
		Monthly		Greatest Monthly		Lowest Monthly		Snowfall (Snow and Ice Pellets)							
								Avg	Number of Days			Greatest Monthly		Lowest Monthly	
ation	Mo	Avg Amnt	Nrml Amnt	Amnt	Year	Amnt	Year	Mthly Amnt	.10or more	.50or more	1.00or more	Amnt	Year	Amnt	Year
eyenne	Jan	0.34	0.52	0.51	1971	0.10	1970	5.4	1.2	0	0	8.6	1971	1.2	1970
WSO	Feb	0.16	1.56	0.62	1971	0.02	1972	2.5	0.2	0	0	9.3	1971	0.4	1972
AP	Mar	1.26	1.21	1,85	1973	0.79	1972	17.7	4.8	0.4	0	27.0	1973	10.6	1972
	Apr	1.34	1.88	2.81	1971	0.50	1974	10.1	4.8	0.4	0	13.0	1971	8.0	1974
	May	1.74	2.52	3.13	1970	0.11	1974	0.5	4.8	0.6	0.2	1.2	1973	0	1971+
	Jun	1.82	2.11	2.81	1974	0.97	1971	T	3.8	0.8	0.4	T	1970	0	1971+
	Jul	1.93	1.82	5.01	1973	0.82	1970	0	3.6	0.8	0.2	0	-	0	-
	Aug	0.99	1.44	1.83	1972	0.14	1970	0	3.2	0.2	0	0	-	0	-
	Sep	1.78	1.10	4.52	1973	0.50	1974	1.9	3.0	1.2	0.2	7.4	1971	T	1970+
	Oct	0.77	0.83	1.30	1970	0.06	1973	5.2	2.8	0	0	11.0	1970	0.5	1973
	Nov	0.62	0.62	1.29	1970	0.05	1971	6.8	1.8	0.2	0	17.4	1973	0.9	1971
	Dec	0.39	0.45	1.06	1973	0.07	1971	5.9	3.0	0.4	0	13.9	1973	4.7	1971
	Yrly	13.14	16.06	4.52	9/73	0.02	2/72	56.0				27.0	3/73		
uglas	Jan	0.55	-	1.15	1972	0.12	1973	9.7	1.8	0	0	19.9	1972	2.7	1973
WSO	Feb	0.31	-	1.19	1971	0.08	1973	9.3	2.2	0	0	18.6	1971	3.2	1973
	Mar	0.87	-	1.29	1970	0.20	1974	15.4	2.8	0	0	27.0	1973	10.6	1972
	Apr	2.76	-	5.85	1971	1.46	1974	20.2	6.0	1.6	0.4	40.5	1973	12.0	1974
	May	2.07	-	5.08	1971	0.23	1974	1.8	6.2	1.2	0.2	7.0	1970	0	1973
	Jun	1.45	-	3.04	1970	0.58	1973	2.2	0.6	0.6	-	0	-	0	-
	Jul	1.84	-	4.61	1973	0.26	1974	0	2.8	0.6	0.4	0	-	0	-
	Aug	1.00	-	3.25	1972	0.13	1970	0	2.2	0.6	0.2	0	-	0	-
	Sep	0.88	-	1.51	1971	0.61	1970	1.8	1.4	0.3	0	4.5	1974	0	1973
	Oct	0.81	-	1.11	1971	0.12	1973	7.4	2.4	0.4	0	15.2	1971	T	1973+
	Nov	0.67	-	1.29	1970	0.22	1974	6.1	2.4	0.2	0	11.9	1971	3.7	1972
	Dec	0.28	-	0.46	1970	0.07	1971	5.5	0.6	0	0	10.0	1970	1.0	1971
	Yrly	13.49		5.85	4/71	0.07	12/71	79.4				40.5	4/73		
illette	Jan	0.62	0.63	0.90	1974	0.35	1973	8.7	2.4	0	0	13.0	1974	8.5	1970
Mi E*	Feb	0.51	0.50	1.19	1971	0.08	1973	9.3	2.2	0	0	18.6	1971	3.2	1973
	Mar	1.06	1.06	1.62	1970	0.58	1974	12.5	3.2	0.6	0	25.8	1970	1.7	1973
	Apr	2.30	1.66	3.24	1973	1.34	1972	10.1	5.0	1.2	0.4	23.5	1973	6.3	1971
	May	2.36	2.22	4.33	1970	1.04	1973	1.8	6.2	1.2	0.2	7.0	1970	0	1973
	Jun	2.30	2.58	3.34	1972	1.17	1974	0	4.6	1.4	0.6	0	-	0	-
	Jul	1.60	1.24	2.64	1973	0.48	1971	0	2.6	1.0	0.4	0	-	0	-
	Aug	0.70	0.95	1.44	1974	0.23	1970	0	2.2	0.4	0	0	-	0	-
	Sep	1.56	1.09	2.35	1973	0.77	1974	1.8	3.8	0.8	0.2	3.5	1970	0	1974
	Oct	2.04	0.71	3.06	1973	0.70	1970	10.5	3.6	1.4	0.8	21.5	1971	1.2	1974
	Nov	0.57	0.75	0.84	1971	0.23	1972	5.4	2.0	0	0	10.4	1971	0.9	1972
	Dec	0.35	0.61	0.74	1973	0.38	1971	8.9	2.0	0	0	14.4	1972	5.3	1971
	Yrly	15.97	14.00	4.33	5/70	0.08	2/73	69.0				25.8	3/70		

* Ocnl Month of Data Msg.
\+ Also Other Dates.

PRECIPITATION DATA FOR FIVE YEAR PERIOD 1970 to 1974

		Precipitation													
		Monthly		Greatest Monthly		Lowest Monthly		Snowfall (Snow and Ice Pellets)							
								Avg	Number of Days			Greatest Monthly		Lowest Monthly	
tion	Mo	Avg Amnt	Nrml Amnt	Amnt	Year	Amnt	Year	Mthly Amnt	.10or more	.50or more	1.00or more	Amnt	Year	Amnt	Year
llette	Jan	0.62	-	0.90	1974	0.35	1973	8.7	2.4	0	0	14.3	1972	5.5	1973
Mi	Feb	0.61	-	1.46	1971	0.16	1973	8.2	2.6	0	0	19.1	1971	2.0	1974
SW*	Mar	1.51	-	1.93	1970	0.81	1974	13.9	5.0	0.8	0	22.9	1970	6.1	1974
	Apr	2.52	-	4.63	1974	1.45	1970	14.4	6.2	1.4	0.6	41.0	1974	5.2	1972
	May	2.16	-	3.85	1971	0.51	1973	0.9	5.6	1.0	0.2	3.0	1970	T	1971+
	Jun	2.00	-	2.63	1971	0.59	1974	0	4.4	1.0	0.2	0	-	0	-
	Jul	1.23	-	2.20	1973	0.41	1971	0	3.0	0.4	0.2	0	-	0	-
	Aug	0.42	-	1.47	1972	T	1970	0	0.6	0.2	0	0	-	0	-
	Sep	1.47	-	2.65	1973	0.73	1972	2.2	4.0	0.5	0.3	8.0	1970	T	1971+
	Oct	2.05	-	3.61	1971	0.77	1970	10.2	4.0	1.2	0.8	29.0	1971	T	1974
	Nov	0.58	-	0.93	1971	0.31	1974	5.3	1.6	0	0	9.0	1970	8.7	1971
	Dec	0.65	-	0.78	1970	0.53	1971	8.2	2.8	0	0	10.6	1970	5.5	1974
	Yrly	15.82		4.63	4/74	T	8/70	72.0				41.0	4/74		
ycee*	Jan	0.54	-	1.28	1972	0.06	1971	6.4	2.0	0.2	0	15.3	1972	0.8	1971
	Feb	0.27	-	0.36	1974	0.17	1973	3.0	0.8	0	0	5.0	1974	1.8	1972
	Mar	0.82	-	1.75	1972	0.36	1974	7.4	2.6	0.2	0	11.0	1970	2.4	1974
	Apr	2.51	-	4.62	1973	1.05	1972	11.9	5.4	1.4	0.6	43.3	1973	2.3	1974
	May	1.98	-	3.84	1971	0.76	1973	1.0	4.8	1.0	0.6	1.0	1973	0	-
	Jun	1.80	-	3.39	1972	0.71	1971	0	4.2	1.0	0.4	0	-	0	-
	Jul	1.02	-	2.71	1973	0.27	1971	0	2.8	0.4	0	0	-	0	-
	Aug	0.76	-	1.47	1972	0.10	1970	0	1.8	0.6	0	0	-	0	-
	Sep	0.88	-	1.82	1973	0.30	1974	5.5	1.4	0.4	0	4.0	1974	0	1973
	Oct	1.41	-	2.38	1971	0.38	1970	4.0	3.6	1.0	0.2	9.5	1971	T	1974
	Nov	0.45	-	0.59	1970	0.31	1972	3.4	1.8	0	0	7.0	1971	T	1972
	Dec	0.37	-	0.45	1973	0.20	1971	4.7	1.4	0	0	6.3	1970	2.4	1971
	Yrly	12.81		4.62	4/73	0.06	1/71	47.3				15.3	1/72		
idwest	Jan	1.38	0.55	4.03	1972	0.33	1970	9.9	2.2	1.0	0.2	24.5	1972	6.5	1970+
Mi SW*	Feb	1.01	0.55	1.74	1974	0.28	1972	8.0	2.5	0.8	0.3	11.5	1970	3.0	1972
	Mar	1.03	1.01	1.47	1970	0.50	1973	8.1	3.0	0.6	0.2	15.0	1970	3.3	1974
	Apr	3.17	1.72	5.43	1973	1.48	1970	13.3	5.0	2.4	0.8	39.8	1973	1.0	1974
	May	2.31	2.21	3.67	1971	0.61	1973	T	5.8	1.8	0.2	T	1970	0	-
	Jun	1.46	1.74	2.85	1972	0.43	1971	0	3.6	1.2	0.2	0	-	0	-
	Jul	1.40	1.19	3.17	1973	0	1971	0	3.0	1.0	0.2	0	-	0	-
	Aug	0.88	0.80	2.64	1972	0.04	1970	0	2.0	0.8	0.2	0	-	0	-
	Sep	1.19	0.93	3.19	1973	0.11	1974	0.1	2.6	0.8	0.4	0.3	1970	-	-
	Oct	1.33	0.90	2.59	1971	0.15	1970	4.1	2.3	0.8	0.3	11.0	1971	0.3	1974
	Nov	0.77	0.72	1.46	1973	0.44	1974	7.7	2.2	0.2	0.2	11.6	1973	5.3	1974
	Dec	1.04	0.52	2.51	1973	0.47	1972	8.9	2.2	0.4	0.2	19.8	1973	3.0	1971
	Yrly	16.97	12.84	5.43	4/73	0	7/71	60.1				39.8	4/73		

* Ocnl Month of Data Msg.
\+ Also Other Dates.

PRECIPITATION DATA FOR FIVE YEAR PERIOD 1970 to 1974

		Precipitation													
		Monthly		Greatest Monthly		Lowest Monthly		Snowfall (Snow and Ice Pellets)							
								Avg Mthly Amnt	Number of Days			Greatest Monthly		Lowest Monthly	
tion	Mo	Avg Amnt	Nrml Amnt	Amnt	Year	Amnt	Year		.10or more	.50or more	1.00or more	Amnt	Year	Amnt	Year
eno*	Jan	0.34	-	0.73	1974	0.03	1971	4.6	1.0	0	0	8.0	1974	0.3	1971
	Feb	0.16	-	0.43	1971	0.04	1970	1.0	0.4	0	0	4.3	1971	T	1970+
	Mar	0.59	-	1.20	1970	T	1974	4.7	1.8	0.2	0	10.0	1973	0.7	1974
	Apr	1.22	-	1.24	1972	1.19	1970	7.3	4.0	0.7	0.7	13.0	1972	4.0	1971
	May	1.96	-	3.88	1971	0.37	1973	T	4.6	1.4	0.4	T	1970+	0	1974
	Jun	1.99	-	3.53	1972	0.84	1973	0	3.3	1.4	0.4	T	1973	0	-
	Jul	1.49	-	2.92	1970	1.10	1974	0	2.8	0.8	0.4	0	-	0	-
	Aug	1.04	-	2.24	1972	0.16	1974	0	0.8	0.4	-	0	-	0	-
	Sep	0.85	-	1.00	1971	0.62	1970	T	1.3	0.3	0	T	1971	-	-
	Oct	1.14	-	1.31	1974	0.97	1972	8.3	2.0	1.0	0.3	14.0	1971	T	1974
	Nov	0.16	-	0.40	1970	0.01	1974	0.3	0.5	0	0	0.5	1972	T	1974
	Dec	0.47	-	-	-	-	-	5.4	-	-	-	-	-	-	-
	Yrly	11.41		3.88	5/71	T	3/74	31.6				14.0	10/71		
eridan	Jan	0.99	0.69	1.79	1972	0.35	1973	14.0	5.2	0.2	0	25.1	1972	7.8	1973
WSO	Feb	0.68	0.74	1.17	1971	0.39	1973	10.0	2.6	0	0	15.7	1971	6.8	1974
AP	Mar	1.25	1.42	2.31	1970	0.62	1971	13.7	4.0	0	0	26.1	1970	7.5	1971
	Apr	2.43	4.05	4.05	1973	1.02	1972	13.5	6.4	1.4	0.2	37.5	1973	5.2	1971
	May	2.19	2.57	5.20	1970	0.51	1973	0.8	5.0	1.2	0	2.0	1970	T	1971+
	Jun	1.41	2.57	2.21	1973	0.28	1971	0	2.8	0.6	0.2	0	-	0	-
	Jul	0.84	1.19	1.62	1972	0.21	1971	0	2.8	0	0	0	-	0	-
	Aug	0.53	0.90	0.96	1972	T	1970	0	1.8	0	0	0	-	0	-
	Sep	1.60	1.17	2.79	1973	0.90	1971	3.3	4.6	0.6	0.2	9.5	1971	T	1970+
	Oct	1.78	1.13	3.16	1971	0.81	1973	4.0	1.0	0.2	0	14.8	1971	0.9	1970
	Nov	0.76	0.80	1.43	1970	0.32	1972	7.6	2.6	0	0	11.7	1973	1.4	1972
	Dec	0.62	0.62	0.90	1972	0.24	1974	10.0	2.0	0	0	15.6	1972	4.7	1974
	Yrly	15.08	17.85	5.20	5/70	T	8/70	76.9				37.5	4/73		
	Jan														
	Feb														
	Mar														
	Apr														
	May														
	Jun														
	Jul														
	Aug														
	Sep														
	Oct														
	Nov														
	Dec														
	Yrly														

* Ccnl Month of Data Msg.
\+ Also Other Dates

RELATIVE HUMIDITY AND WIND DATA FOR PERIOD 1970 to 1974

		Relative Humidity								Wind			
		5 Year Average 1970-1974				Years 1970-1974				Fastest Mile 1970-1974			Monthl Avg
tion	Mo	05M	11M	17M	23M	Max	Date	Min	Date	Dir	Vel	Date	
sper	Jan	71	61	66	71	100	1970+	24	1971	27/21	51	72,74	17.4
WSO	Feb	72	58	57	58	100	1972	16	1970	27	43	1972	15.6
AP	Mar	76	57	50	73	100	1970+	10	1970	21	55	1974	14.3
	Apr	80	54	50	75	100	1970+	9	1971	26	40	1970	13.4
	May	83	46	40	73	100	1970+	9	1970+	26	46	1973	11.5
	Jun	76	36	31	64	100	1970+	6	1974	27	38	1971	11.1
	Jul	73	33	26	57	100	1970+	6	1974	21/25	52	73,74	10.1
	Aug	68	31	23	52	100	1972	6	1970	27	36	1973	9.5
	Sep	73	41	33	64	100	1970+	5	1973	36	40	1972	11.4
	Oct	73	50	26	68	100	1971+	6	1972	28	38	1970	12.1
	Nov	73	59	61	70	100	1970+	13	1974	25	49	1970	14.2
	Dec	69	60	62	69	100	1970+	21	1974	21	73	1973	16.5
	Yrly	74	49	41	66	100	+	5	9/73	21	73	12/73	13.1
eyenne	Jan	53	44	47	53	88	1970+	11	1972	W	61	1972	18.7
WSO	Feb	55	38	40	55	91	1973	11	1970	NW	56	1971	15.2
AP	Mar	61	46	46	60	100	1973	9	1972	NW	75	1972	15.1
	Apr	61	42	42	60	96	1972	9	1974	NW	50	1972	15.6
	May	66	37	38	62	96	1970	9	1970	W	56	1973	12.9
	Jun	64	34	35	58	93	1971	9	1974	NW	55	1973	11.3
	Jul	68	34	37	61	100	1970	7	1973	SW	47	1970	10.0
	Aug	65	32	33	57	100	1972	8	1974	NW	40	1971	9.9
	Sep	62	38	38	60	96	1972+	9	1974	W	50	1974	11.0
	Oct	61	38	40	60	100	1971	9	1972	NW	69	1970	11.5
	Nov	61	45	50	60	92	1970	8	1971	W	62	1970	13.2
	Dec	55	43	48	56	96	1971	6	1972	W/NW	50	70,71	14.8
	Yrly	61	39	41	59	100	+	6	12/72	NW	75	3/72	13.3
heridan	Jan	66	59	62	67	100	1973	13	1970	SW	52	1974	8.1
WSO	Feb	69	56	56	69	96	1970+	15	1974	NW	47	1970	7.8
AP	Mar	71	53	49	67	100	1970	14	1971	SW	57	1974	9.1
	Apr	71	51	46	66	100	1973	11	1971	NW	43	1971	9.9
	May	73	46	45	69	96	1970	14	1972	NW	51	1974	9.0
	Jun	75	42	40	69	100	1972	14	1974	SW	46	1970	7.9
	Jul	71	35	32	47	100	1970+	10	1971	NW/SW	40	70,72	7.3
	Aug	66	32	28	53	96	1972+	8	1970	NW	59	1973	7.2
	Sep	72	44	40	76	100	1972+	9	1971+	NW	43	1970	7.6
	Oct	71	50	48	69	100	1971	11	1970	NW	38	1970	7.6
	Nov	75	60	64	74	100	1971+	16	1972	SW	50	1970	6.9
	Dec	70	60	63	68	100	1971	15	1973	SW	56	1970	9.1
	Yrly	71	49	48	66	100	+	8	8/70	NW	59	8/73	8.1

+ Also Other Dates

TEMPERATURE DATA FOR FIVE YEAR PERIOD 1970 to 1974

Station	Mo	Monthly Avg Max	Monthly Avg Min	Monthly Avg	Monthly Norm	Monthly Hiest	Monthly Date	Monthly Loest	Monthly Date	Mo Avg Diurnal Chg	Avg Deg Days	Avg No of Days Max 90°& Abv	Avg No of Days Max 32°& Blw	Avg No of Days Min 32°& Blw	Avg No of Days Min 0°& Blw
Silly	Jan	33.6	7.4	20.5	-	66	19/74	-28	19/72	26.2	1376	0	13.2	29.4	11.2
Creek*	Feb	41.3	15.1	28.2	-	65	28/72	-19	2/72	26.2	1011	0	5.0	27.2	2.0
	Mar	46.8	19.7	33.3	-	74	10/72	- 7	2/71	27.1	976	0	4.4	27.6	1.2
	Apr	53.6	27.5	40.6	-	79	24/74	0	8/73	26.1	724	0	0.4	22.8	0.2
	May	65.5	36.9	51.2	-	86	17/72	23	16/74+	28.6	420	0	0	9.2	0
	Jun	78.3	47.5	62.9	-	99	27/70	27	18/73	30.8	121	4.2	0	0.8	0
	Jul	83.8	51.6	67.7	-	99	10/73+	35	4/72+	32.2	38	8.2	0	0	0
	Aug	84.3	52.1	68.2	-	99	12/72	37	25/71	32.2	37	9.4	0	0	0
	Sep	65.7	39.6	52.7	-	93	2/71	18	26/72	26.1	315	0	0	6.2	0
	Oct	59.7	31.1	45.4	-	84	2/74	2	30/71+	28.6	601	0	1.0	17.2	0
	Nov	44.9	19.6	32.2	-	69	10/73	-12	23/70	25.3	975	0	3.4	28.0	1.0
	Dec	36.8	10.8	23.8	-	62	1/73	-30	8/72	26.0	1272	0	10.4	30.2	5.4
	Yrly	57.9	29.9	43.9		99	6/70	-30	12/72	28.0	7866				
Buffalo*	Jan	36.0	6.7	21.4	-	64	17/74	-24	19/74	29.3	1349	0	11.0	30.3	11.0
	Feb	43.5	15.2	29.4	-	63	10/71+	-20	2/72	28.3	997	0	4.5	27.3	3.0
	Mar	45.4	18.6	32.0	-	76	10/72	-15	1/71	26.8	1017	0	4.2	29.4	3.0
	Apr	53.7	29.7	41.7	-	79	24/74	8	8/73	24.0	691	0	0.5	18.8	0
	May	67.7	37.9	52.8	-	88	31/73	13	13/70	29.8	372	0	0	5.6	0
	Jun	80.0	48.0	64.0	-	102	27/70	32	1/70	32.0	104	4.6	0	0.2	0
	Jul	85.6	51.1	68.4	-	101	6/73	36	2/70	34.5	33	11.8	0	0	0
	Aug	86.1	52.2	69.2	-	100	8/70	38	21/74	33.9	18	11.8	0	0	0
	Sep	72.5	39.7	56.1	-	92	11/71	20	17/71	32.8	272	0.8	0	5.6	0
	Oct	62.5	32.0	47.3	-	85	4/70	7	31/72	30.5	543	0	0.2	15.8	0
	Nov	45.4	20.8	33.1	-	66	12/73	- 8	23/70	24.6	951	0	2.8	27.0	0.4
	Dec	38.8	11.7	25.3	-	64	1/73	-10	24/70	27.1	1227	0	8.5	30.8	5.0
	Yrly	59.8	30.3	45.1		102	6/70	-24	1/74	29.5	7574				
Jasper	Jan	31.2	10.5	20.8	23.4	60	30/71	-40	14/72	20.7	1364	0	14.8	28.2	8.0
WSO	Feb	38.3	16.9	34.6	26.3	61	28/72	-17	2/72	21.4	1048	0	8.0	27.0	2.2
AP	Mar	45.0	21.6	33.1	32.1	70	10/72	- 6	2/71	23.4	973	0	4.4	27.2	1.2
	Apr	52.0	28.5	40.2	43.1	75	24/72	4	9/73	23.5	735	0	0.6	21.6	0
	May	65.9	37.3	51.6	53.1	85	31/72	26	2/72+	28.6	409	0	0	7.4	0
	Jun	80.2	47.7	64.0	63.1	101	27/70	32	1/74	32.5	97	4.0	0	0.2	0
	Jul	85.8	52.1	69.0	71.7	99	3/72+	30	4/72	33.7	29	10.6	0	0	0
	Aug	86.4	52.3	69.3	72.5	98	12/72	40	31/74+	34.1	21	10.4	0	0	0
	Sep	70.3	39.6	55.0	59.7	90	11/71+	24	18/71	30.7	308	0.4	0	6.2	0
	Oct	58.6	31.5	45.0	48.3	81	10/71	- 3	30/71	27.1	611	0	1.2	14.6	0
	Nov	42.2	23.1	32.7	33.6	58	24/70	- 6	28/71	19.1	962	0	4.4	25.0	1.0
	Dec	52.6	14.5	33.6	27.3	61	1/73	-27	5/72	38.1	1278	0	15.2	28.8	4.4
	Yrly	59.0	31.3	45.2	46.2	101	6/70	-40	1/72	27.7	7835				

*Cooperative stations observe only 24 hr precip amounts and only 24 hr max and min temps.
Ocnl months of data msg.
+ Also Other Dates.

TEMPERATURE DATA FOR FIVE YEAR PERIOD 1970 to 1974

tation	Mo	Monthly Avg Max	Monthly Avg Min	Monthly Avg	Monthly Norm	Monthly Hiest	Monthly Date	Monthly Loest	Monthly Date	Mo Avg Diur-nal Chg	Avg Deg Days	Avg No of Days Max 90°& Abv	Avg No of Days Max 32°& Blw	Avg No of Days Min 32°& Blw	Avg No of Days Min 0°& Blw
eyenne	Jan	36.5	16.1	26.3	25.4	62	16/74	-19	4/72	20.4	1193	0	10.2	25.8	6.6
WSO	Feb	42.3	17.7	34.2	27.3	64	28/72	-14	7/71	24.6	951	0	5.6	26.8	1.4
AP	Mar	43.1	25.0	33.9	32.4	70	10/72	0	1/71	18.1	958	0	4.8	26.4	0.2
	Apr	51.5	29.2	40.4	42.6	75	25/74	9	9/73	22.3	732	0	1.6	21.0	0
	May	65.5	31.1	48.3	52.9	84	28/74+	25	1/70	34.4	349	0	0	3.2	0
	Jun	76.2	49.5	62.9	63.0	93	27/70	35	3/73	26.7	112	1.4	0	0	0
	Jul	80.7	53.3	67.0	70.0	98	6/73	41	30/71	27.4	31	3.2	0	0	0
	Aug	81.5	53.5	67.5	69.7	92	13/70+	40	25/72	28.0	29	2.6	0	0	0
	Sep	67.6	41.9	54.8	58.6	87	1/70	24	8/71	25.7	308	0	0.2	3.4	0
	Oct	57.8	34.9	46.4	47.5	79	4/70	10	29/71	22.9	591	0	1.0	12.6	0
	Nov	44.9	23.9	34.4	34.2	70	14/71	- 2	29/72	21.0	910	0	3.8	25.4	0.4
	Dec	37.6	16.4	27.0	29.5	64	1/73	-24	5/72	21.2	1170	0	10.0	28.2	3.2
	Yrly	57.1	32.7	44.9	46.1	98	7/73	-24	12/72	24.4	7334				
ouglas	Jan	35.6	8.6	22.1	-	64	15/73	-38	4/72	27.0	1324	0	10.6	27.8	10.6
WSO	Feb	42.8	15.7	29.3	-	62	28/72	-16	7/71	27.1	1001	0	4.8	27.4	3.8
	Mar	47.8	21.0	34.4	-	72	30/71	- 8	20/70	26.8	941	0	3.2	27.8	1.2
	Apr	51.4	26.3	38.9	-	79	24/74	- 5	3/70+	25.1	778	0	1.6	23.6	0.4
	May	66.7	37.3	52.0	-	85	31/72	23	2/70	29.4	392	0	0	7.8	0
	Jun	80.7	47.9	64.3	-	98	27/70	33	13/70	32.8	85	2.8	0.4	0	0
	Jul	85.3	52.3	68.8	-	101	30/72	34	4/72	33.0	31	8.2	1.2	0	0
	Aug	86.0	51.6	68.8	-	97	12/72	37	2/74	34.4	16	10.4	0	0	0
	Sep	70.4	38.5	54.5	-	93	2/71	22	19/71+	31.9	332	0.8	0	8.8	0
	Oct	61.0	29.0	45.0	-	83	4/70	- 6	30/71	32.0	612	0	1.2	20.0	0.4
	Nov	45.6	20.7	33.2	-	68	12/73	- 9	23/70	24.9	948	0	3.2	26.0	1.6
	Dec	38.6	10.6	25.1	-	67	1/73	-27	10/72	28.0	1246	0	8.2	29.0	7.4
	Yrly	59.3	30.0	44.7	-	101	7/72	-38	1/72	29.3	7706				
llette	Jan	29.6	8.9	19.3	21.9	58	16/74	-26	26/72	20.7	1414	0	14.0	28.8	10.0
2 Mi E*	Feb	39.5	17.4	28.5	24.6	61	28/72	-22	7/71	22.1	1024	0	6.6	27.4	2.4
	Mar	45.3	22.3	31.1	31.1	75	10/72	- 3	12/70	23.0	963	0	5.0	27.8	0.8
	Apr	53.3	29.8	41.6	42.8	79	24/74	5	9/73	23.5	696	0	1.0	19.6	0
	May	65.6	38.9	52.3	53.1	84	17/72+	27	1/70	26.7	390	0	0	5.4	0
	Jun	78.8	49.0	63.9	61.6	100	27/70	33	13/70	29.8	105	4.6	0	0	0
	Jul	85.9	52.5	69.2	71.9	104	6/73	36	4/72	33.4	30	11.0	0	0	0
	Aug	87.2	52.8	70.2	70.2	104	12/72	38	24/71	34.4	25	15.0	0	0	0
	Sep	71.2	40.8	56.0	59.7	95	2/71	20	26/72	30.4	284	1.8	0	6.0	0
	Oct	59.7	32.2	46.0	48.4	85	1/73	- 3	30/71	27.5	580	0	1.2	15.0	0
	Nov	43.0	22.6	32.8	33.2	67	11/71	- 6	22/70	20.4	960	0	4.6	26.4	0
	Dec	38.9	12.2	25.6	26.5	64	1/73	-28	9/72	26.7	1295	0	13.6	23.4	5.6
	Yrly	58.2	31.6	44.9	45.4	104	7/73	-28	12/72	26.6	7766				

*See note on first page.
+Also Other Dates.

TEMPERATURE DATA FOR FIVE YEAR PERIOD 1970 to 1974

Station	Mo	Monthly Avg Max	Monthly Avg Min	Monthly Avg	Monthly Norm	Monthly Hiest	Monthly Date	Monthly Loest	Monthly Date	Mo Avg Diur-nal Chg	Avg Deg Days	Avg No of Days Max 90°& Abv	Avg No of Days Max 32°& Blw	Avg No of Days Min 32°& Blw	Avg No of Days Min 0°& Blw
illette	Jan	29.6	8.9	19.3	-	58	16/74	-26	4/73	20.7	1414	0	14.0	28.8	10.0
8 Mi SW	Feb	39.9	17.4	28.7	-	61	28/72	-19	7/71	22.5	1017	0	6.2	27.4	2.0
	Mar	45.1	20.8	33.0	-	75	10/72	- 6	12/70	24.3	986	0	5.0	22.6	1.4
	Apr	52.1	28.3	42.3	-	79	24/74	4	9/73	23.8	737	0	1.4	21.2	0
	May	65.2	37.6	51.4	-	84	17/72	23	14/74	27.6	415	0	0	7.2	0
	Jun	78.4	48.2	63.3	-	99	26/74	30	1/74	30.2	114	3.2	0	0.8	0
	Jul	84.4	52.1	68.3	-	101	6/73	37	4/72+	32.3	37	8.4	0	0	0
	Aug	87.4	53.7	70.6	-	101	12/72	41	25/72	33.7	17	14.0	0	0	0
	Sep	70.0	41.0	55.5	-	92	11/71+	20	26/72	29.0	302	0.1	0	6.0	0
	Oct	59.2	32.4	45.8	-	85	4/70	-11	30/71	26.8	590	0	1.0	15.6	0.2
	Nov	43.0	22.3	32.7	-	65	12/71	-10	23/70	20.7	963	0	5.0	25.2	0.8
	Dec	33.7	11.7	22.7	-	64	1/73	-31	8/72+	22.0	1035	0	14.2	29.4	6.6
	Yrly	57.3	31.2	44.3		101	7/73+	-31	12/72+	26.1	7627				
Kaycee*	Jan	35.5	5.6	20.6	-	68	16/74	-30	14/72	29.9	1373	0	10.6	30.6	11.2
	Feb	44.7	15.3	30.0	-	63	28/72	-20	2/72	29.4	979	0	3.6	27.6	3.0
	Mar	49.8	20.6	35.2	-	73	22/72+	- 7	11/70	29.2	917	0	2.0	27.8	1.4
	Apr	55.3	27.9	41.6	-	78	25/74+	3	8/73	27.4	694	0	0.2	22.0	0
	May	67.9	36.6	52.3	-	87	17/72	21	2/72	31.3	388	0	0	8.4	0
	Jun	81.1	46.5	63.8	-	102	27/70	31	1/70	34.6	98	6.0	0	1.0	0
	Jul	87.0	50.4	68.7	-	97	16/71	31	4/72	36.6	24	14.0	0	0	0
	Aug	87.2	50.2	68.7	-	101	12/72	40	24/71	37.0	22	13.6	0	0	0
	Sep	72.7	37.6	55.2	-	95	1/70	18	26/72	35.1	298	0.6	0	10.0	0
	Oct	62.3	28.8	45.6	-	84	1/73	5	29/71	33.5	598	0	0.8	20.8	0
	Nov	47.0	19.7	33.4	-	68	12/73+	-10	23/70	27.3	941	0	2.0	28.4	0.8
	Dec	39.0	8.8	23.9	-	63	1/73	-31	6/72	30.2	1268	0	7.6	30.6	8.2
	Yrly	60.8	25.9	43.4		102	6/70	-31	12/72	34.9	7600				
idwest	Jan	33.2	9.8	21.5	24.1	57	24/70	-31	13/72	23.4	1343	0	12.6	28.4	9.4
1 Mi SW*	Feb	43.8	17.6	30.7	27.3	64	28/72	-15	7/71	26.2	962	0	3.0	27.0	2.2
	Mar	49.4	22.7	36.0	34.1	73	22/72+	- 4	20/74	26.7	890	0	2.4	26.4	0.6
	Apr	55.3	30.2	42.8	45.0	80	26/74	8	10/73	25.1	653	0	0.8	19.8	0
	May	69.2	38.9	54.1	54.9	86	17/72	25	1/72	30.3	334	0	0	4.0	0
	Jun	81.8	49.0	65.4	64.4	102	28/70+	34	3/73	32.8	79	6.2	0	0	0
	Jul	88.0	53.1	70.6	72.4	106	12/73	33	4/72	34.9	17	16.4	0	0	0
	Aug	89.6	53.5	71.6	71.2	100	12/72	38	21/74	36.1	17	16.0	0	0	0
	Sep	74.1	40.5	57.3	61.1	95	1/70	20	26/72	33.6	251	1.6	0	6.0	0
	Oct	63.6	32.0	47.8	49.8	84	5/70	- 2	30/71	31.6	552	0	1.5	17.3	0.3
	Nov	45.5	23.2	34.8	34.8	66	12/73	- 4	29/72	22.3	912	0	1.8	24.4	0.6
	Dec	36.5	14.0	25.3	28.2	63	1/73	-27	6/72	22.5	1226	0	9.6	29.2	4.2
	Yrly	60.8	32.0	46.4	47.3	106	7/73	-31	1/72	28.8	7236				

*See note on first page.
+Also Other Dates.

TEMPERATURE DATA FOR FIVE YEAR PERIOD 1970 to 1974

tation	Mo	Monthly Avg Max	Monthly Avg Min	Monthly Avg	Monthly Norm	Monthly Hiest	Monthly Date	Monthly Loest	Monthly Date	Mo Avg Diur-nal Chg	Avg Deg Days	Avg No of Days Max 90°& Abv	Avg No of Days Max 32°& Blw	Avg No of Days Min 32°& Blw	Avg No of Days Min 0°& Blw
ɜno*	Jan	30.9	5.8	18.3	-	60	27/70	-28	8/70	25.1	1434	0	12.5	29.5	10.0
	Feb	39.5	17.5	28.5	-	58	17/70	-14	7/71	22.0	1031	0	3.0	26.5	1.0
	Mar	44.9	20.2	32.6	-	72	10/72	- 2	12/70	24.7	1006	0	4.4	26.7	0.8
	Apr	50.5	28.3	39.4	-	75	10/71	10	1/70	22.0	763	0	1.3	25.0	1.6
	May	65.6	36.9	51.3	-	82	17/70	24	2/73	28.7	425	0	1.0	7.0	0
	Jun	78.9	48.2	83.6	-	97	27/71	32	18/73+	30.7	103	4.0	0	0.6	0
	Jul	85.7	54.4	70.1	-	100	11/73	34	1/70	31.3	16	11.0	0	0	0
	Aug	81.6	50.7	68.2	-	103	28/71	-	-	30.9	57	-	0	0	0
	Sep	69.5	39.4	54.5	-	91	2/71	19	26/72+	30.1	321	0.5	0	0.6	0
	Oct	61.6	32.7	47.2	-	83	4/70	2	30/71	28.9	546	0	0.4	-	0
	Nov	42.1	21.5	31.8	-	64	12/73	- 4	23/70	20.6	989	0	5.3	26.0	0
	Dec	34.1	12.2	23.2	-	-	-	-	-	21.9	1288	-	-	-	-
	Yrly	57.1	30.7	43.9		103	8/71+	-28	1/70	26.4	7979				
Sheridan	Jan	30.1	6.6	18.3	21.3	70	15/74	-28	8/73	23.5	1436	0	14.6	29.8	11.2
WSO	Feb	41.1	16.9	29.0	23.8	62	28/72+	-17	2/72	24.2	1009	0	6.4	27.4	2.2
AP	Mar	46.9	22.2	34.4	30.2	75	10/72	- 2	11/70+	24.7	937	0	3.8	25.8	0.8
	Apr	54.8	29.8	42.3	43.6	80	25/74+	1	9/73	25.0	674	0	0.4	19.4	0
	May	66.3	39.0	52.7	54.6	88	17/72	26	16/74	27.3	379	0	0	5.0	0
	Jun	79.0	48.2	63.6	61.9	100	19/74+	32	1/74	30.8	104	3.8	0	0.2	0
	Jul	85.0	51.5	68.3	71.3	99	13/72	35	29/71	33.5	38	9.0	0	0	0
	Aug	89.9	51.8	70.9	69.5	100	14/71	38	21/74+	38.1	27	13.8	0	0	0
	Sep	70.0	39.2	54.6	58.8	96	11/71	21	26/72	30.8	316	0.6	0	6.8	0
	Oct	59.8	30.8	45.3	47.8	87	4/70	1	29/71	29.0	608	0	0.8	17.8	0
	Nov	44.7	20.3	32.5	33.4	71	12/70	- 8	23/70	24.4	968	0	3.8	29.0	1.2
	Dec	34.5	8.6	21.6	26.3	70	1/73	-30	8/72+	25.9	1339	0	12.0	30.8	5.0
	Yrly	58.5	30.4	44.5	45.2	100	6/74+	-28	1/73	28.1	7835				
	Jan														
	Feb														
	Mar														
	Apr														
	May														
	Jun														
	Jul														
	Aug														
	Sep														
	Oct														
	Nov														
	Dec														
	Yrly														

*See note on first page.
+Also Other Dates.

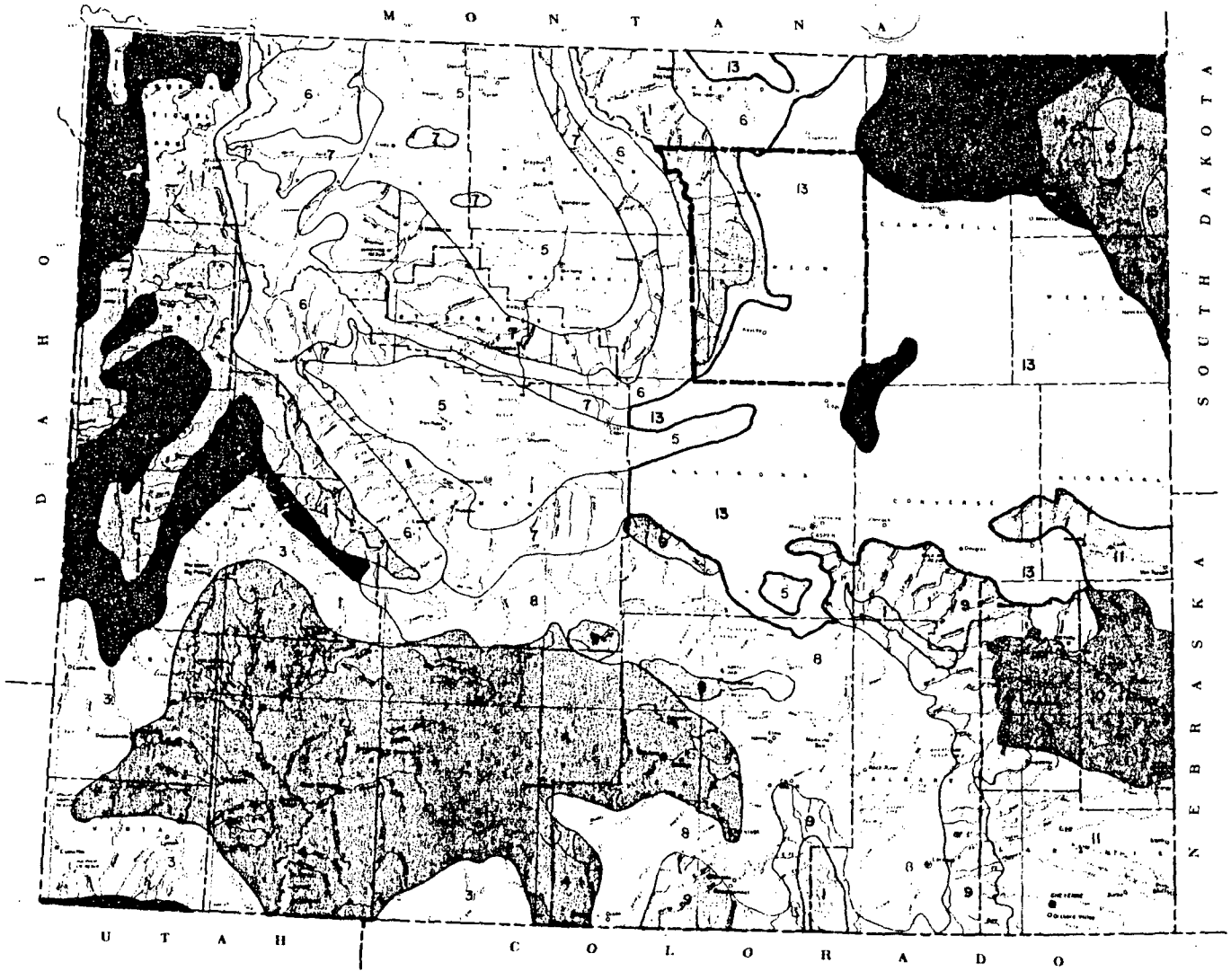
APPENDIX F

NATURAL VEGETATION OF THE POWDER RIVER BASIN, WYOMING

U. S. DEPARTMENT OF AGRICULTURE

WYOMING

SOIL CONSERVATION SERVICE



NATURAL VEGETATION

1 — PRECIPITATION ZONE 20 INCHES PLUS MOUNTAINS

WOODLAND SPECIES: Lodgepole pine, Douglas fir, alpine fir, aspen.

GRASSLAND SPECIES: Bluebunch wheatgrass, Columbia needlegrass, spike fescue, oneseed danthonia grass, black sagebrush, big sagebrush, serviceberry and numerous forbs.

2 — PRECIPITATION ZONE 15 TO 19 INCHES FOOTHILLS AND MOUNTAINS WEST

WOODLAND SPECIES: Lodgepole pine, timber pine, aspen.

GRASSLAND SPECIES: Thickspike wheatgrass, Idaho fescue, bluebunch wheatgrass, canby bluegrass, big sagebrush, antelope bitterbrush, mountain mahogany and forbs.

3 — PRECIPITATION ZONE 10 TO 14 INCHES FOOTHILLS AND BASINS WEST

WOODLAND SPECIES: Cottonwood on lowland sites and juniper on rocky ridges.

GRASSLAND SPECIES: Thickspike wheatgrass, Letterman needlegrass, Sandberg bluegrass, bluebunch wheatgrass, Indian ricegrass, big sagebrush, low rabbitbrush, winterfat.

4 — PRECIPITATION ZONE 7 TO 9 GREEN RIVER AND GREAT DIVIDE BASIN

WOODLAND SPECIES: Cottonwood on lowlands and juniper on hillsides.

GRASSLAND SPECIES: Thickspike wheatgrass, Indian ricegrass, bluebunch wheatgrass, Sandberg bluegrass, big sagebrush, Gardner saltbush, winterfat.

5 — PRECIPITATION ZONE 5 TO 9 INCHES BIG HORN AND WIND RIVER BASINS

WOODLAND SPECIES: Cottonwood and Russian olive along drainages.

GRASSLAND SPECIES: Gardner saltbush, bud sagebrush, shadscale, Indian ricegrass, western wheatgrass, needleandthread grass, bottlebrush squirreltail, Sandberg bluegrass.

6 — PRECIPITATION ZONE 15 TO 19 INCHES FOOTHILLS AND MOUNTAINS EAST

WOODLAND SPECIES: Alpine fir, Douglas fir, lodgepole pine, ponderosa pine, aspen.

GRASSLAND SPECIES: Idaho fescue, Columbia needlegrass, bluebunch wheatgrass, spike fescue, mountain brome, western wheatgrass, big sagebrush.

7 — PRECIPITATION ZONE 10 TO 14 INCHES FOOTHILLS AND BASINS EAST

WOODLAND SPECIES: Cottonwood, willow, boxelder on lowland site and juniper, timber pine on rocky ridges.

GRASSLAND SPECIES: Bluebunch wheatgrass, western wheatgrass, blue grama, prairie junegrass, Sandberg bluegrass, big sagebrush, black sagebrush, silver sagebrush.

8 — PRECIPITATION ZONE 10 TO 14 INCHES HIGH PLAINS SOUTHEAST

WOODLAND SPECIES: Cottonwood on lowland sites.

GRASSLAND SPECIES: Thickspike wheatgrass, bluebunch wheatgrass, needleandthread grass, Indian ricegrass, Sandberg bluegrass, low rabbitbrush, big sagebrush.

9 — PRECIPITATION ZONE 15 TO 19 INCHES FOOTHILLS AND MOUNTAINS SOUTHEAST

WOODLAND SPECIES: Blue spruce, lodgepole pine, ponderosa pine.

GRASSLAND SPECIES: Bluebunch wheatgrass, western wheatgrass, needleandthread grass, Idaho fescue, antelope bitterbrush, black sagebrush.

10 — PRECIPITATION ZONE 12 TO 14 INCHES SOUTHERN PLAINS

WOODLAND SPECIES: Cottonwood on lowland sites.

GRASSLAND SPECIES: Needleandthread grass, western wheatgrass, prairie sandreed grass, blue grama grass, sand sagebrush, fringed sagewort.

11 — PRECIPITATION ZONE 15 TO 17 INCHES SOUTHERN PLAINS

WOODLAND SPECIES: Cottonwood on lowland sites.

GRASSLAND SPECIES: Prairie sandreed grass, blue grama grass, needleandthread grass, little bluestem grass, sand sagebrush, fringed sagewort.

12 — PRECIPITATION ZONE 15 TO 17 INCHES NORTHERN PLAINS

WOODLAND SPECIES: Ponderosa pine, juniper, cottonwood.

GRASSLAND SPECIES: Western wheatgrass, green needlegrass, little bluestem, prairie sandreed grass, needleandthread grass, big sagebrush, low rabbitbrush, greasewood.

13 — PRECIPITATION ZONE 10 TO 14 INCHES NORTHERN PLAINS

WOODLAND SPECIES: Cottonwood on lowland sites.

GRASSLAND SPECIES: Western wheatgrass, blue grama grass, needleandthread grass, prairie sandreed grass, big sagebrush, greasewood.

14 — PRECIPITATION ZONE 15 TO 19 INCHES BLACK HILLS

WOODLAND SPECIES: Ponderosa pine, [illegible]

GRASSLAND SPECIES: Western wheatgrass, bluebunch grass, little bluestem grass, needleandthread grass, [illegible] grass, [illegible] bluegrass, chokecherry, [illegible]

15 — PRECIPITATION ZONE 20 TO 24 INCHES BLACK HILLS

WOODLAND SPECIES: Douglas fir, [illegible]

GRASSLAND SPECIES: Timber oatgrass, Idaho fescue, [illegible] kentucky bluegrass.

NATURAL VEGETATION

WYOMING

APRIL 1973

10 0 10 20 30 40 50 60 MILES

SCALE 1:2,750,000

USGS National Atlas 1:1,000,000 Albers Equal-Area projection (1967) used as source or base map and adapted for SCS use.

M7-E-22902-N

TECHNICIAN GUIDE TO RANGE SITES AND RANGE CONDITION WITH INITIAL STOCKING RATE
Key Climax Plants and Others That Invade

WYOMING
FOOTHILLS &
BASINS WEST
10"-14" P.Z.

KEY CLIMAX PLANTS — MAXIMUM PERCENTAGES IN CLIMAX BY RANGE SITE

DECREASERS	INCREASERS	WL	Sb	SS	LL	SL	Ov	CyO	Sa	Sy	Ly	Cy	DC	SLy	CU	Sw Sy	Sw Ly	Sw Cy	SwB	SwI	SU	Gr	Ig	VS	Sh
Alkali sacaton	Inland saltgrass			10		15																			
Basin wildrye	Low sedges & rushes	15	15	10	5	5	5	5	10	10	5	5		5	5	10	10	5	5	10		10	5	5	
Bluebunch wheatgrass	Mat muhly		5	10	5	5	5																		
Canby bluegrass	Plains reedgrass									5	5	5	d	d	d	d	d	d	d	d					
Indian ricegrass	Prairie junegrass				5		5	5	5	5	5	5	5	5	5	5	5	5	5	5		5	5	5	
Letterman needlegrass	Rhizomatous wheatgrasses		10	d	25	d	30	40	d	25	30	d	d	d	10	d	d	d	d	d	d	d	d	d	d
Mannagrasses	Sandberg bluegrass				5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5		10	5	10	
Mutton bluegrass	*Perennial forbs	10	10	5	10	5	10	10	10	5	5	5	5	10	5	10	10	5	5	10	5	10	10	10	5
Needleandthread	Big sagebrush				5		10	5	10	15	20	10		20	10	5	10		10	5			5	5	
Nuttall alkaligrass	Black sagebrush														15				5	10		5	10	5	
Slender wheatgrass	Chokecherry		5		5		5																		
Spike fescue	Cottonwood		5		10																				
Squirreltail	Greasewood			10		25															5				
Reedgrasses	Greenmolly summercypress																								10
Tall sedges	Juniper										Inv					Inv	Inv		50					10	
Tufted hairgrass	Low sagebrush						5	5				5	20					10							
Perennial forbs	Rabbitbrushes		5	5	10	5	5	5	5	10	5	5	5	5	5	5	5	5		5		5	5	5	
Bitterbrush	Shrubby cinquefoil		10																						
Gardners saltbush	Silver sagebrush				5		5																		
Mt. mahogany	Skunkbush				5	5										5	5			5		5		5	
Serviceberry	Snowberry				5		5	5						5											
	Roses	5	5		5																				
	Willows	10	10		5																				
	Winterfat								d	d	d	d	d	d	d	d	d	15		d	15	d		d	d
Total / Increasers allowed toward condition class		40	40	40	50	45	55	55	40	40	50	35	35	35	35	35	35	35	65	35	20	35	40	45	15

Range Condition	/ Original Vegetation	Initial Stocking Rates By Site (AUMs/Acre)																							
Excellent	76 - 100	3.00	2.00	1.50	0.60	0.50	0.60	0.60	0.04	0.40	0.40	0.40	0.30	0.30	0.30	0.20	0.20	0.20	0.15	0.17	0.20	0.15	0.12	0.15	0.10
Good	51 - 75	2.50	1.50	1.20	0.50	0.40	0.50	0.50	0.30	0.33	0.33	0.33	0.25	0.25	0.25	0.17	0.17	0.17	0.12	0.14	0.20	0.12	0.09	0.12	0.07
Fair	26 - 50	1.50	1.00	0.80	0.25	0.15	0.25	0.25	0.20	0.20	0.20	0.20	0.15	0.15	0.15	0.10	0.10	0.10	0.05	0.07	0.12	0.05	0.04	0.05	0.04
Poor	0 - 25	1.00	0.60	0.40	0.15	0.10	0.15	0.15	0.10	0.10	0.10	0.10	0.07	0.07	0.07	0.05	0.05	0.05	0.03	0.04	0.08	0.03	0.02	0.03	0.02

Legend:
* - Count no more than 5% of any one species unless listed separately
Blanks - Not important
d - decreaser; all allowed
5, 10, etc. - Increaser; percent found in climax
Inv. - Invader on site
Decreaser Column - These plants are decreasers on all sites on which they are found.

INVADERS
All annuals
All exotics
Broom snakeweed
Curlycup gumweed
Foxtail barley
Thistles
Cactus
Common dandelion
Goatsbeard
Plantains
Knapweeds

WL - Wetland
Sb - Subirrigated
SS - Saline Subirrigated
LL - Lowland
SL - Saline Lowland
Ov - Overflow
CyO - Clayey Overflow
Sa - Sands

Sy - Sandy
Ly - Loamy
Cy - Clayey
DC - Dense Clay
SLy - Steep Loamy
CU - Coarse Upland
SwSy - Shallow Sandy
SwLy - Shallow Loamy

SwCy - Shallow Clayey
SwB - Shallow Breaks
SwI - Shallow Igneous
SU - Saline Upland
Gr - Gravelly
Ig - Igneous
VS - Very Shallow
Sh - Shale

CLIMATE

Land Resource areas (34) and (46). Foothills and Basins West of Continental Divide in Wyoming -- 10" - 14" Precipitation Zone.

a. The precipitation pattern shows a fairly even distribution through the year with an average of 10" to 14". The wettest part of the year is from mid April to mid June and the driest is July and September. This area has fewer thunderstorms and less moisture per storm in late spring and summer than does the eastern parts of Wyoming. Extremes of recorded precipitation vary from zero to over 5" in a month.

   Sunshine is quite abundant in the area with but few days in the year without some sunshine. It is estimated that sunshine averages about 65% of possible on an annual basis, ranging from about 50 - 55% in the winter and spring to about 75 - 80% in the summer and fall.

b. Prevailing winds are from the west and southwest. Velocities are generally light to moderate but high winds are common at times during the fall, winter, and spring months.

c. The area is subject to wide ranges of temperature -- both seasonal and day-to-night. Only deep cold air masses from Canada which move due south reach the area because of the blocking effect of the Wind River Mountains to the north and east. However, these occasional cold air masses cause some of the coldest extremes. The cool climate is primarily due to the high elevation. Because of the high, thin, dry air, nighttime radiation cooling can produce freezing temperatures any month of the year.

   Growth of the native plants begins about April 15 and continues to about July 15. Fall green-up will usually occur if moisture is available and continue to late October or early November.

Legend:

Decreasers listed on each Technical Range Site Description are rated according to their relative importance on that site. The following is the presence rating index:

(1) Always present, more than 50 percent of total annual yield.
(2) Always present, 25 to 49 percent of total annual yield.
(3) Generally present, 10 to 24 percent of total annual yield.
(4) Frequently present, less than 10 percent of total annual yield.
(5) Occasionally present, less than 5 percent of total annual yield.

LEGEND

Decreasers listed on each Technical Range Site Description are rated according to their relative importance on that site. Following is the presence rating index:

1 - Always present; more than 50 percent of total annual yield

2 - Always present; 25 percent to 49 percent of total annual yield

3 - Generally present; 10 percent to 24 percent of total annual yield

4 - Frequently present; less than 10 percent of total annual yield

5 - Occasionally present; less than 5 percent of total annual yield

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Wetland (WL) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached climatic description)

Growth of native plants may continue on this site throughout the summer and fall, depending primarily on temperature.

3. Topography and Elevation:

This site will usually occur on level or gently sloping land near springs, seeps or sloughs. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site consist of poorly drained soils with water tables above the surface for part, but not all, of the growing season. They are usually on nearly level to slightly depressed areas with poor surface drainage. In some places the surface layers have a high content of organic matter. The subsoils are usually mottled or gleyed.

b. The soils in this site may include one or more of the following Taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants that can withstand long periods of submission in water.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Common reedgrass	- 5	Baltic rush	- 5
Nebraska sedge	- 2	Inland sedge	- 10
Northern reedgrass	- 3		
Tall mannagrass	- 4	Forbs:	- 10
Tufted hairgrass	- 3	Arrowgrass	
		Elephant head	
Blue-eyedgrass	- 5	Horsetails	
Waterleaf	- 5	Iris	
		Water hemlock	
		Woody plants:	
		Roses	- 5
		Willows	- 10

The increasers make up approximately 40% of the vegetation. As the condition deteriorates, willows become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 5000 lbs. per acre air dry, but varies from 4000 lbs. in less favorable years to 6000 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area: (34)(46) Foothills & Basin West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Subirrigated (Sb) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached climatic description)

Growth of native plants may continue on this site throughout the summer and fall, depending primarily on temperature.

3. Topography and Elevation:

This site will usually occur on nearly level land along perennial or intermittent streams and near seeps, springs or sloughs. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site have a non-saline and/or non-alkaline water table near the surface for most of the growing season. The surface soil is usually deep and has a high content of organic matter. These soils usually have mottling or gleying within 20" to 40" of the surface.

b. The soils in this site may include one or more of the following Taxonomic units:

c. Complete soil series descriptions are available in the soil-survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants that can benefit from high water tables.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Basin wildrye	- 2	Baltic rush	- 5
Nebraska sedge	- 4	Inland sedge	- 10
Northern reedgrass	- 5	Mat muhly	- 5
Slender wheatgrass	- 4	Western wheatgrass	- 10
Tall mannagrass	- 5		
Tufted hairgrass	- 3	Forbs:	- 10
		American licorice	
		Asters	
		Buttercups	
		Fleabane	
Clovers	- 5	Goldenpea	
		Iris	
Violets	- 5	Milkvetch	
		Pointvetch	
		Poverty weed	
Waterleaf	- 5	Western yarrow	
		Woody plants:	
		Chokecherry	- 5
		Cottonwood	- 5
		Rubber rabbitbrush	- 5
		Roses	- 5
		Shrubby cinquefoil	- 10
		Willows	- 10

The increasers make up approximately 40% of the vegetation. As the condition deteriorates, willows, rabbitbrush, and low growing sedges become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 3700 lbs. per acre air dry, but varies from 3000 lbs. in less favorable years to 4300 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Saline Subirrigated (SS) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached climatic description)

Growth of the native plants may continue on this site throughout the summer and fall, depending primarily on temperature.

3. Topography and Elevation:

This site will usually occur on nearly level land along perennial or intermittent streams and near seeps, springs or sloughs. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site are moderately to strongly saline and/or alkaline and have a water table near the surface for most of the growing season. Salt crusts are commonly found on ridges and mounds during dry periods. These soils may have mottling or gleying within 20" to 40" of the surface.

b. The soils in this site may include one or more of the following Taxonomic units:

SALINE SUBIRRIGATED

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants that can tolerate high saline and/or alkaline conditions and a high water table.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Alkali bluegrass	- 4	Alkali muhly	- 10
Alkali sacaton	- 1	Inland saltgrass	- 10
Basin wildrye	- 3	Inland sedge	- 10
Nebraska sedge	- 5		
		Forbs:	- 5
Nuttall alkaligrass	- 3	Arrowgrass	
		Horsetails	
		Milkvetch	
Western wheatgrass	- 4	Pointvetch	
		Poverty weed	
		Woody plants:	
		Greasewood	- 10
		Rubber rabbitbrush	- 3

The increasers make up approximately 40% of the vegetation. As the condition deteriorates, Greasewood, Inland saltgrass and alkali muhly become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 3000 lbs. per acre air dry, but varies from 2500 lbs. in less favorable years to 3400 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Lowland (LL) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached climatic description)

3. Topography and Elevation:

This site will usually occur on gently sloping land along perennial or intermittent streams. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site are moderately well drained and have a water table usually below 3 feet which provides beneficial water to woody plants but not to the majority of the forbs or grasses. Mottling usually occurs within 30" to 60" of the surface.

b. The soils in this site may include one or more of the following taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax community is characterized by a high percentage of woody plants which can take advantage of the deep water table.

Decreasers (Relative Importance)	
Basin wildrye	- 3
Bluebunch wheatgrass	- 5
Bottlebrush squirreltail	- 4
Canby bluegrass	- 3
Indian ricegrass	- 5
Letterman needlegrass	- 3
Mutton bluegrass	- 5
Needleandthread	- 2
Spike fescue	- 5
Slender wheatgrass	- 4
Clovers	- 5
Penstemons	- 5
Violets	- 5

Increasers (Max. % Found in Climax)	
Mat muhly	- 5
Needleleaf sedge	- 5
Prairie junegrass	- 5
Sandberg bluegrass	- 5
Thickspike wheatgrass	- 25
Forbs:	- 10
Asters	
Eriogonum	
Fleabane	
Goldenpea	
Gromwell	
Phlox	
pussytoes	
Scarlet globemallow	
Scurfpea	
Western yarrow	
Woody Plants:	
Big sagebrush	- 5
Boxelder,	- 3
Chokecherry	- 5
Cottonwood	- 10
Dogwood	- 3
Low rabbitbrush	- 5
Roses	- 5
Rubber rabbitbrush	- 5
Silver buffaloberry	- 3
Silver sagebrush	- 5
Skunkbush	- 3
Snowberry	- 3
Willows	- 5

The increasers make up approximately 50% of the vegetation. As the condition deteriorates, woody plants become even more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 2300 lbs. per acre air dry, but varies from 1600 lbs. in less favorable years to 3000 lbs. in more favorable years.

6. Specific Site Location:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants which can tolerate high saline and/or alkaline conditions and by woody plants which can take advantage of the deep water table.

Decreasers (Relative Importance)		Increasers (Max % Found in Climax)	
Alkali bluegrass	- 5	Alkali muhly	- 5
Alkali sacaton	- 2	Inland saltgrass	- 15
Basin wildrye	- 3	Inland sedge	- 5
Bluebunch wheatgrass	- 4	Sandberg bluegrass	- 5
Bottlebrush squirreltail	- 4		
Indian ricegrass	- 5	Forbs:	- 5
Nuttall alkaligrass	- 4	Milkvetch	
Western wheatgrass	- 3	Pointvetch	
		Poverty weed	
		Woody Plants:	
Four-wing saltbush	- 5	Greasewood	- 25
Gardner saltbush	- 5	Rubber rabbitbrush	- 5
Winterfat	- 5	Skunkbush	- 5

The increasers make up approximately 45% of the vegetation. As the condition deteriorates, Greasewood becomes more dominant.

Approximate total annual yield of this site in excellent condition is 1800 lbs. per acre air dry, but varies from 1200 lbs. in less favorable years to 2500 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills and Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Overflow (OV) 10"-14" P.Z.
Foothills and Basins West of Continental Divide.

2. Climate: (See attached climatic description)

3. Topography and Elevation:

This site will usually occur on gently sloping land along intermittent streams and draws. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site vary in texture from sandy loams through light silty clay loams. These soils occur in playa areas or along stream courses which receive periodic overflow from adjacent slopes.

b. The soils in this site may include one or more of the following taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is characterized by plants which can take advantage of periodic flooding and are able to withstand short periods of submersion.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Basin wildrye	- 3	Mat muhly	- 5
Bluebunch wheatgrass	- 5	Needleleaf sedge	- 5
Bottlebrush squirreltail	- 4	Prairie junegrass	- 5
		Sandberg bluegrass	- 5
Canby bluegrass	- 3	Western wheatgrass	- 30
Indian ricegrass	- 5	Forbs:	- 10
		American licorice	
Letterman needlegrass	- 3	Aster	
		Buttercup	
Mutton bluegrass	- 4	Eriogonum	
Needleandthread	- 3	Fleabane	
		Goldenpea	
Slender wheatgrass	- 3	Larkspur	
		Lupine	
Spike fescue	- 5	Milkvetch	
		Paintbrush	
		Pointvetch	
		Pussytoes	
		Phlox	
Clovers	- 5	Scarlet globemallow	
Bluebells	- 5	Toadflax	
Groundsel	- 5	Western yarrow	
Penstemon	- 5		
Violet	- 5	Woody plants:	
		Big sagebrush	- 10
		Chokecherry	- 5
		Low rabbitbrush	- 5
		Low sagebrush	- 5
Serviceberry	- 5	Silver sagebrush	- 5
		Snowberry	- 5

The increasers make up approximately 55% of the vegetation. As the condition deteriorates, sagebrush, rabbitbrush and Western wheatgrass become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 1800 lbs. per acre air dry, but varies from 1200 lbs. in less favorable years to 2200 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Clayey Overflow (CYO) 10"-14" P.Z. Foothills & Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur on gently sloping land along intermittent streams and draws. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site vary in texture from the finer portions of silty clay loams through sandy clay loams and clay loams. These soils occur in playa areas or along stream courses which receive periodic overflow from adjacent slopes.

b. The soils in this site may include one or more of the following Taxonomic units:

CLAYEY OVERFLOW

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is characterized by plants which can grow on heavy soils and take advantage of periodic flooding with short periods of submersion.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Basin wildrye	- 3	Needleleaf sedge	- 5
Bottlebrush squirreltail	- 4	Prairie junegrass	- 5
Canby bluegrass	- 3	Sandberg bluegrass	- 5
Indian ricegrass	- 5	Western wheatgrass	- 40
Letterman needlegrass	- 4		
Mutton bluegrass	- 4	Forbs:	- 10
Slender wheatgrass	- 4	Agoseris	
		American bistort	
Bluebells	- 5	Aster	
Clovers	- 5	Biscuit root	
Groundsel	- 5	Buttercup	
Penstemon	- 5	Cerastium	
		Eriogonum	
		Fleabane	
		Golden pea	
		Hawksbeard	
		Milkvetch	
		Onions	
		Paintbrush	
		Phlox	
		Pointvetch	
		Pussytoes	
		Starwort	
		Western yarrow	
		Woody Plants:	
		Big sagebrush	- 5
		Low sagebrush	- 5
		Low rabbitbrush	- 5
		Snowberry	- 5

The increasers make up approximately 55% of the vegetation. As the condition deteriorates, the woody plants and western wheatgrass become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 1800 lbs. per acre air dry, but varies from 1200 lbs. in less favorable years to 2200 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Clayey Overflow (CYO) 10"-14" P.Z. Foothills & Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur on gently sloping land along intermittent streams and draws. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site vary in texture from the finer portions of silty clay loams through sandy clay loams and clay loams. These soils occur in playa areas or along stream courses which receive periodic overflow from adjacent slopes.

b. The soils in this site may include one or more of the following Taxonomic units:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Sands (Sa) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in an upland position on rolling to very rough topography. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site are coarse textured loamy sand to sand soils usually occurring in an upland position and sometimes as dunes. The soils may be light or dark colored, greater then 20 inches deep with rapid permeability.

b. The soils in this site may include one or more of the following Taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants which prefer highly permeable soils and plants which can exist on unstable, shifting soils.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Bluebunch wheatgrass	- 4	Needleleaf sedge	- 10
Bottlebrush squirreltail	- 3	Prairie junegrass	- 5
Canby bluegrass	- 5	Sandberg bluegrass	- 5
Indian ricegrass	- 3	Sand dropseed	- 5
Needleandthread	- 2		
Thickspike wheatgrass	- 2	Forbs:	- 10
		Asters	
		Biscuit root	
		Buttercup	
		Death Camas	
		Dock	
Bluebells	- 5	Eriogonum	
Clovers	- 5	Fleabane	
Penstemon	- 5	Fringed sagewort	
		Milkvetch	
		Pointvetch	
		Paintbrushes	
		Phlox	
Bitterbrush	- 5	Pussytoes	
Four-wing saltbush	- 5	Sagebrush gilia	
Winterfat	- 5	Sandwort	
		Toadflax	
		Western yarrow	
		Woody Plants:	
		Big sagebrush	- 10
		Low rabbitbrush	- 5
		Silver sagebrush	- 3

The increasers make up approximately 40% of the vegetation. As the condition deteriorates, the woody species become more dominant and annuals invade.

Approximate total annual yield of this site in excellent condition in an average year is 1400 lbs. per acre air dry, but varies from 900 lbs. in less favorable years to 1700 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Sandy (Sy) 10"-14" P.Z. Foothills & Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in an upland position on relatively flat to moderately sloping land. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site are fine sandy loams, sandy loams or loamy sands at least 20 inches deep. They may be light or dark colored in this precipitation zone.

b. The soils in this site may include one or more of the following Taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is characterized by plants which prefer a light to moderately light textured soil with medium permeability.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Bluebunch wheatgrass	- 3	Needleleaf sedge	- 10
Bottlebrush squirreltail	- 3	Plains reedgrass	- 5
		Prairie junegrass	- 5
Canby bluegrass	- 3	Thickspike wheatgrass	- 25
		Sandberg bluegrass	- 5
Indian ricegrass	- 3	Sand dropseed	- 3
Letterman needlegrass	- 4		
Mutton bluegrass	- 4	Forbs:	- 5
		Aster	
		Cerastium	
Needleandthread	- 2	Death camas	
		Eriogonum	
Spike fescue	- 4	Fleabane	
		Hawksbeard	
		Milkvetch	
Bluebell	- 5	Paintbrush	
Clovers	- 5	Pointvetch	
		Phacelia	
		Phlox	
Groundsel	- 5	Primroses	
		Sagebrush gilia	
Penstemon	- 5	Starwort	
		Toadflax	
		Western yarrow	
Bitterbrush	- 5		
Winterfat	- 5	Woody Plants:	
		Big sagebrush	- 15
		Low rabbitbrush	- 10

The increasers make up approximately 40% of the vegetation. As the condition deteriorates, big sagebrush becomes more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 1200 lbs. per acre air dry, but varies from 700 lbs. in less favorable years to 1500 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Loamy (Ly) 10"-14" P.Z.
Foothills and Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in an upland position on relatively flat to moderately sloping land. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site may be light or dark colored in this precipitation zone and exceed 20 inches in depth. Textures range from very fine sandy loams through clay loams. Permeability is moderate to moderately slow.

b. The soils in this site may include one or more of the following taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is characterized by a variety of plants which prefer a medium textured soil with moderate permeability.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Bluebunch wheatgrass	- 3	Needleleaf sedge	- 5
Bottlebrush squirreltail	- 4	Plains reedgrass	- 5
Canby bluegrass	- 3	Prairie junegrass	- 5
		Thickspike wheatgrass	- 30
Indian ricegrass	- 4	Sandberg bluegrass	- 5
Letterman needlegrass	- 3		
Mutton bluegrass	- 4	Forbs:	- 5
Needleandthread	- 3	Agoseris	
Spike fescue	- 4	American licorice	
		Asters	
Clovers	- 5	Biscuit root	
Groundsels	- 5	Buttercups	
Penstemon	- 5	Cerastium	
Violet	- 5	Common commandra	
		Eriogonums	
Serviceberry	- 5	Fleabane	
Winterfat	- 5	Fringed sagewort	
		Gromwell	
		Hawksbeard	
		Larkspur	
		Lupine	
		Milkvetch	
		Paintbrush	
		Pointvetch	
		Phacelia	
		Phlox	
		Pussytoes	
		Scarlet globemallow	
		Sagebrush gilia	
		Toadflax	
		Western yarrow	
		Woody Plants:	
		Big sagebrush	- 20
		Low rabbitbrush	- 5

The increasers make up approximately 50% of the vegetation. As the condition deteriorates, Big sagebrush becomes more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 1200 lbs. per acre air dry, but varies from 700 lbs. in less favorable years to 1500 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Clayey (Cy) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached climatic description)

3. Topography and Elevation:

This site can occur in a lowland or upland position on relatively flat to gently sloping land. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site are at least 20 inches deep with texture ranging from silty clay through the finer sandy and silty clay loams and clays which do not develop severe cracks or become extremely hard when dry or very sticky when wet. Permeability is moderately slow to slow.

b. The soils in this site may include one or more of the following taxonomic units:

CLAYEY

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants which prefer a heavy textured soil with slow permeability.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Bottlebrush squirreltail	- 4	Needleleaf sedge	- 5
Canby bluegrass	- 5	Plains reedgrass	- 5
		Prairie junegrass	- 5
Indian ricegrass	- 4	Sandberg bluegrass	- 5
Letterman needlegrass	- 4		
Mutton bluegrass	- 3	Forbs:	- 5
		Aster	
		Biscuit root	
Needleandthread	- 5	Cerastium	
		Common commandra	
Spike fescue	- 5	Death camas	
Thickspike wheatgrass	- 2	Eriogonums	
American vetch	- 5	Hawksbeard	
Bluebells	- 5	Milkvetch	
Clovers	- 5	Pointvetch	
Penstemon	- 5	Pussytoes	
Violets	- 5	Onions	
		Phlox	
		Sagebrush gilia	
		Starwort	
Winterfat	- 5	Scarlet globemallow	
		Woody Plants:	
		Big sagebrush	- 10
		Low rabbitbrush	- 5
		Low sagebrush	- 5

The increasers make up approximately 35% of the vegetation. As the condition deteriorates, woody plants, forbs and thickspike wheatgrass become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 1100 lbs. per acre air dry, but varies from 600 lbs. in less favorable years to 1400 lbs. in more favorable years.

6. Specific Site Location:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants which can survive in extremely heavy soil which develops large cracks when dry.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Bottlebrush squirreltail	- 4	Prairie junegrass	- 5
Canby bluegrass	- 5	Sandberg bluegrass	- 5
Indian ricegrass	- 5		
		Forbs:	- 5
Mutton bluegrass	- 4	Asters	
		Biscuit root	
Needleandthread	- 5	Common commandra	
Plains reedgrass	- 5	Eriogonums	
Western wheatgrass	- 1	Fleabane	
		Milkvetch	
		Onion	
		Phlox	
Winterfat	- 5	Pointvetch	
		Pussytoes	
		Primrose	
		Scarlet globemallow	
		Western yarrow	
		Woody Plants:	
		Low rabbitbrush	- 5
		Low sagebrush	- 20

The increasers make up approximately 35% of the vegetation. As the condition deteriorates, woody plants and increasing forbs become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 700 lbs. per acre air dry, but varies from 450 lbs. in less favorable years to 1000 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Steep Loamy (SLy) 10"-14" P.Z. Foothills & Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in an upland position on moderately to steeply sloping land. Generally on north and east facing slopes. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site exceed 20 inches in depth and occur on slopes in excess of 30% and usually on north and east facing slopes. The textures range from very fine sandy loams through light clay loams.

b. The soils in this site may include one or more of the following taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is characterized by plants which can take advantage of cool temperatures and relatively moist conditions which occur on steep north and east facing slopes.

Decreasers (Relative Importance)		Increasers (Max. % Found in climax)	
Basin wildrye	- 4	Needleleaf sedge	- 5
Bluebunch wheatgrass	- 3	Prairie junegrass	- 5
		Sandberg bluegrass	- 5
Bottlebrush squirreltail	- 4		
Canby bluegrass	- 4	Forbs:	- 10
Indian ricegrass	- 4	Agoseris	
		American licorice	
		Asters	
Letterman needlegrass	- 3	Buttercup	
		Cerastium	
Mutton bluegrass	- 4	Common commandra	
		Eriogonum	
Needleandthread	- 4	Fleabane	
Plains reedgrass	- 5	Gromwell	
Spike fescue	- 3	Hawksbeard	
		Larkspur	
Thickspike wheatgrass	- 2	Lupine	
		Milkvetch	
Bluebells	- 5	Paintbrush	
Clovers	- 5	Phacelia	
		Pointvetch	
		Phlox	
Penstemon	- 5	Pussytoes	
		Scarlet globemallow	
Violets	- 5	Sagebrush gilia	
		Toadflax	
Mt. mahogany	- 4	Western yarrow	
Serviceberry	- 3		
Winterfat	- 5	Woody Plants:	
		Big sagebrush	- 20
		Low rabbitbrush	- 5
		Snowberry	- 5

The increasers make up approximately 35% of the vegetation. As the condition deteriorates, woody plants become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 1200 lbs. per acre air dry, but varies from 900 lbs. in less favorable years to 1600 lbs. in more favorable years.

6. Specific Site Location:

APPENDIX G

REPORT OF VERTEBRATE FAUNA SUSSEX SITE

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Coarse Upland (CU) 10"-14" P.Z. Foothills & Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in an upland position on gentle slopes but may occur on all slopes and in all positions. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site contain at least 40%-50% by volume of coarse fragments in the first 20 inches of soils, but this does allow plant roots to penetrate to at least 20 inches in most places. These cobbly, stony and/or bouldery soils occur as terraces, fan terraces or glacial moraines. Permeability is moderate to rapid.

b. The soils in this site may include one or more of the following taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is characterized by plants which can do well in very cobbly, somewhat drouthy soils.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Basin wildrye	- 5	Needleleaf sedge	- 5
Bluebunch wheatgrass	- 2	Prairie junegrass	- 5
		Sandberg bluegrass	- 5
Bottlebrush squirreltail	- 3	Thickspike wheatgrass	- 10
Canby bluegrass	- 4		
		Forbs:	- 5
Indian ricegrass	- 4	Asters	
		Biscuit root	
Letterman needlegrass	- 3	Buttercup	
		Eriogonum	
Mutton bluegrass	- 4	Fleabane	
		Lupine	
Needleandthread	- 3	Milkvetch	
Plains reedgrass	- 5	Paintbrush	
Spike fescue	- 5	Phacelia	
		Phlox	
		Pointvetch	
		Pussytoes	
Clovers	- 5	Sagebrush gilia	
Penstemon	- 5	Toadflax	
		Western yarrow	
Bitterbrush	- 4		
Winterfat	- 5	Woody Plants:	
		Big sagebrush	- 10
		Black sagebrush	- 15
		Low rabbitbrush	- 5

The increasers make up approximately 35% of the vegetation. As the condition deteriorates, woody plants become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 1000 lbs. per acre air dry, but varies from 600 lbs. in less favorable years to 1400 lbs. in more favorable year.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Shallow Clayey (SwCy) 10"-14" P.Z. Foothills & Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in an upland position, but can be found on all slopes and positions. Most commonly found on south and west facing slopes. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site are silty clays or heavier, 10 inches to 20 inches in depth, usually over a clay shale bedrock. This site may also include some deep gravelly and/or cobbly soils on south and west facing slopes which react like shallow soils. Permeability is slow to very slow and runoff is rapid.

b. The soils in this site may include one or more of the following taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants which can grow with restricted root depth and under drouthy conditions.

Decreasers (Relative Importance)		Increasers (Max. % Found in climax)	
Bluebunch wheatgrass	- 3	Needleleaf sedge	- 10
Bottlebrush squirreltail	- 4	Prairie junegrass	- 5
Canby bluegrass	- 5	Sandberg bluegrass	- 5
Indian ricegrass	- 4		
		Forbs:	- 10
Letterman needlegrass	- 4	Asters	
		Cerastium	
Mutton bluegrass	- 5	Common commandra	
		Eriogonum	
Needleandthread	- 4	Fleabane	
Plains reedgrass	- 5	Goldenweed	
Thickspike wheatgrass	- 3	Hawksbeard	
		Milkvetch	
		Paintbrush	
		Pointvetch	
		Phlox	
		Phacelia	
		Nailwort	
Bluebells	- 5	Sagebrush gilia	
Clovers	- 5	Toadflax	
		Western yarrow	
Penstemon	- 5		
		Woody Plants:	
		Big sagebrush	- 10
Bitterbrush	- 5	Low rabbitbrush	- 5
Winterfat	- 5	Skunkbush	- 5

The increasers make up approximately 35% of the vegetation. As the condition deteriorates, increasing forbs become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 900 lbs. per acre air dry, but varies from 700 lbs. in less favorable years to 1200 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Shallow Sandy (SwSy) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in an upland position, but can be found on all slopes and positions. Most commonly found on south and west facing slopes. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site are fine sandy loams or coarser. Soil depths range from about 10 inches to 20 inches over all kinds of bedrock except igneous or volcanic. Bedrock is commonly sandstones or sandy shales. This site may also include some deep gravelly and/or cobbly soils on south and west facing slopes which react like shallow soils. Permeability is moderate to rapid.

b. The soils in this site may include one or more of the following taxonomic units:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Shallow Loamy (SwLy) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site willusually occur in an upland position, but can be found on all slopes and positions. Most commonly found on south and west facing slopes. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site range in texture from very fine sandy loams to clay loams. Soil depths range from about 10 inches to 20 inches over all kinds of bedrock except igneous or volcanic. Bedrock is commonly limestones, siltstone or shales. This site may also include some deep gravelly and/or cobbly soils on south and west facing slopes which reacts like shallow soils. Permeability is moderate to moderately slow.

b. The soils in this site may include one or more of the following Taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants which can grow with restricted root depth and under drouthy conditions.

Decreasers (Relative Importance)		Increasers (Max.% Found in Climax)	
Bluebunch wheatgrass	- 3	Needleleaf sedge	- 10
		Prairie junegrass	- 5
Bottlebrush squirreltail	- 4	Sandberg bluegrass	- 5
Canby bluegrass	- 5		
		Forbs:	- 10
Indian ricegrass	- 3	Asters	
		Cerastium	
Letterman needlegrass	- 5	Common commandra	
		Eriogonum	
Mutton bluegrass	- 5	Fleabane	
		Hawksbeard	
Needleandthread	- 4	Goldenweed	
Plains reedgrass	- 5	Milkvetch	
Thickspike wheatgrass	- 4	Paintbrush	
		Pointvetch	
Clovers	- 5	Phlox	
Penstemons	- 5	Nailwort	
		Sagebrush gilia	
Violet	- 5	Toadflax	
		Western yarrow	
Bitterbrush	- 5		
Winterfat	- 5	Woody Plants:	
		Big sagebrush	- 5
		Low rabbitbrush	- 5
		Skunkbush	- 5

The increasers make up approximately 35% of the vegetation. As the condition deteriorates, increasing forbs become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 900 lbs. per acre air dry, but varies from 700 lbs. in less favorable years to 1200 lbs. in more favorable years.

6. Specific Site Location:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants which can grow in heavy soils with restricted root depth and under drouthy conditions.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Bottlebrush squirreltail	- 4	Needleleaf sedge	- 5
Canby bluegrass	- 5	Prairie junegrass	- 5
		Sandberg bluegrass	- 5
Indian ricegrass	- 4		
		Forbs:	- 5
Mutton bluegrass	- 4	Asters	
		Biscuit root	
Needleandthread	- 5	Docks	
		Eriogonum	
Plains reedgrass	- 5	Fleabane	
		Milkvetch	
Western wheatgrass	- 2	Onion	
		Phlox	
		Pointvetch	
		Primrose	
		Pussytoes	
		Western yarrow	
Gardners saltbush	- 5		
		Woody Plants:	
		Greenmolly sunmercypress	- 3
		Low rabbitbrush	- 5
		Low sagebrush	- 10
		Winterfat	- 15

The increasers make up approximately 35% of the vegetation. As the condition deteriorates, increasing forbs and low sagebrush become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 750 lbs. per acre air dry, but varies from 500 lbs. in less favorable years to 1000 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Shallow Breaks (SWB) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site is usually found in an upland position on gently sloping to very steep topography. Can be found on all exposures, but primarily on south and west facing slopes. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site can be light or dark colored, usually less than 20 inches to sedimentary bedrock which usually develops large cracks and crevices where Juniper can utilize moisture. Included in this site are small areas of bedrock outcrop, very shallow, moderately deep and deep soils. The majority of the soils range from sandy loams to sandy clay loams. Gravel, cobble, stone or angular fragments of sedimentary rock may occur on the surface or throughout the soil. Permeability is moderate to rapid.

b. The soils in this site may include one or more of the following Taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by Juniper and other plants which can grow on shallow, drouthy soils and take advantage of the cracks and crevices in the bedrock.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Bluebunch wheatgrass	- 2	Needleleaf sedge	- 5
Bottlebrush squirreltail	- 5	Prairie junegrass	- 5
Canby bluegrass	- 4	Sandberg bluegrass	- 5
Indian ricegrass	- 4		
		Forbs:	- 5
Letterman needlegrass	- 5	Asters	
		Eriogonum	
		Fleabane	
Mutton bluegrass	- 5	Goldenweed	
Needleandthread	- 4	Milkvetch	
Plains reedgrass	- 5	Onion	
Thickspike wheatgrass	- 4	Paintbrush	
		Phacelia	
		Phlox	
		Pointvetch	
Clovers	- 5	Pussytoes	
Penstemon	- 5	Scarlet globemallow	
		Stonecrop	
		Western yarrow	
Bitterbrush	- 5		
		Woody Plants:	
		Big sagebrush	- 10
		Black sagebrush	- 5
		Juniper	- 50
		Low rabbitbrush	- 3

The increasers make up approximately 65% of the vegetation. As the condition deteriorates, juniper and big sagebrush become even more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 1200 lbs. per acre air dry, but varies from 900 lbs. in less favorable years to 1400 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Shallow Igneous (SwI) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site is usually found in an upland position, but can occur on all slopes and in all positions. The elevation ranges from 7000 feet to 8000 feet.

4. Soils:

a. The soils of this site are medium to fine textured, ranging in depth from about 10 inches to 20 inches over igneous or volcanic bedrock. This site may also include some deep gravelly and/or cobbly soils on south and west facing slopes which react like shallow soils. Permeability is moderate to rapid depending on texture.

b. The soils in this site may include one or more of the following taxonomic units:

SHALLOW IGNEOUS

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is characterized by plants which can grow with restricted root depth, with drouthy conditions, and neutral to acid soils.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Bluebunch wheatgrass	- 4	Needleleaf sedge	- 10
Bottlebrush squirreltail	- 4	Prairie junegrass	- 5
		Sandberg bluegrass	- 5
Canby bluegrass	- 5		
		Forbs:	- 10
Indian ricegrass	- 4	Asters	
		Eriogonum	
Letterman needlegrass	- 4	Fleabane	
Mutton bluegrass	- 5	Goldenweed	
		Hawksbeard	
Needleandthread	- 4	Milkvetch	
		Paintbrush	
Plains reedgrass	- 5	Pointvetch	
		Phlox	
Thickspike wheatgrass	- 2	Pussytoes	
		Nailwort	
		Sagebrush gilia	
		Stonecrop	
Bluebells	- 5	Toadflax	
Clovers	- 5	Western yarrow	
		Woody Plants:	
		Big sagebrush	- 5
Bitterbrush	- 4	Black sagebrush	- 10
Mt. Mahogany	- 4	Low rabbitbrush	- 5
Winterfat	- 5	Skunk bush	- 5

The increasers make up approximately 35% of the vegetation. As the condition deteriorates, increasing forbs and black sagebrush become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 900 lbs. per acre air dry, but varies from 700 lbs. in less favorable years to 1200 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Saline Upland (SU) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in a lowland position, but can occur on all slopes and in all positions. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site may be light or dark colored and usually exceed 20 inches in depth. The topsoil has a high salt content and/or exchangeable sodium content. Permeability is moderate to slow.

b. The soils in this site may include one or more of the following taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is characterized by plants which are highly salt tolerant and can withstand drouthy conditions.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Alkali sacaton	- 5	Sandberg bluegrass	- 3
Bottlebrush squirreltail	- 3	Forbs:	- 5
Indian ricegrass	- 3	Asters	
		Death camas	
Needleandthread	- 5	Eriogonum	
		Fleabane	
Western wheatgrass	- 3	Milkvetch	
		Princes plume	
		Phlox	
Gardners saltbush	- 2	Pointvetch	
		Primrose	
		Pussytoes	
		Woody Plants:	
		Greasewood	- 5
		Winterfat	- 15

The increasers make up approximately 20% of the vegetation. As the condition deteriorates, the grasses and Gardners saltbush decrease and annuals invade.

Approximate total annual yield of this site in excellent condition in an average year is 600 lbs. per acre air dry, but varies from 400 lbs. in less favorable years to 750 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & P
West of Continental Di

Location

Date March, 1969

1. Range Site Name: Gravelly (Gr) 10"-14" P.Z.
Foothills and Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will normally occur along terrace breaks or along perennial or intermittent streams. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site are very gravelly, usually of sandy or loamy textures. The coarse fragments are up to 3 inches in diameter, cover 50% to 75% of the surface and usually make up 40% to 50% by volume of the first 20 inches of soil. These soils are relatively unstable and permeability is rapid to very rapid.

b. The soils in this site may include one or more of the following taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by shallow rooted plants and plants which can exist on an unstable, drouthy soil.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Bluebunch wheatgrass	- 2	Needleleaf sedge	- 10
Bottlebrush squirreltail	- 4	Prairie junegrass	- 5
Canby bluegrass	- 5	Sandberg bluegrass	- 10
Indian ricegrass	- 3		
		Forbs:	- 10
Letterman needlegrass	- 5	Aster	
		Buttercup	
Mutton bluegrass	- 5	Eriogonum	
		Fleabane	
		Fringed sagewort	
Needleandthread	- 3	Golden pea	
Thickspike wheatgrass	- 4	Golden weed	
		Hawksbeard	
		Milkvetch	
Clovers	- 5	Nailwort	
Penstemon	- 5	Paintbrush	
Violet	- 5	Phlox	
		Pointvetch	
		Pussytoes	
		Sagebrush gilia	
Winterfat	- 5	Sandwort	
		Stonecrop	
		Western yarrow	
		Woody Plants:	
		Black sagebrush	- 5
		Low rabbitbrush	- 5
		Skunkbush	- 5

The increasers make up approximately 35% of the vegetation. As the condition deteriorates, increasing forbs become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 450 lbs. per acre air dry, but varies from 300 lbs. in less favorable years to 650 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Igneous (Ig) 10"-14" P.Z. Foothills & Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in an upland position on steep slopes. The elevation ranges from 7000 feet to 8000 feet.

4. Soils:

a. The soils of this site are usually less than 10 inches in depth over igneous or volcanic bedrock. Some pockets of deep soil and areas of exposed bedrock will be included in this site. Permeability is moderate to rapid.

b. The soils in this site may include one or more of the following Taxonomic units:

IGNEOUS

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants which can survive with severe soil depth limitations, drouthy conditions and neutral to acid soils.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Bluebunch wheatgrass	- 2	Needleleaf sedge	- 5
Bottlebrush squirreltail	- 4	Prairie junegrass	- 5
Canby bluegrass	- 5	Sandberg bluegrass	- 5
Indian ricegrass	- 4		
		Forbs:	- 10
Letterman needlegrass	- 5	Asters	
		Eriogonums	
Mutton bluegrass	- 5	Fleabane	
Needleandthread	- 5	Goldenweed	
		Hawksbeard	
		Milkvetch	
Thickspike wheatgrass	- 4	Paintbrush	
		Pointvetch	
		Phlox	
		Nailwort	
Clovers	- 5	Pussytoes	
		Sagebrush gilia	
		Stonecrop	
Penstemon	- 5	Toadflax	
Violet	- 5	Western yarrow	
		Woody Plants:	
		Big sagebrush	- 5
Bitterbrush	- 5	Black sagebrush	- 10
Mountain mahogany	- 4	Low rabbitbrush	- 5

The increasers make up approximately 40% of the vegetation. As the condition deteriorates, increasing forbs become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 450 lbs. per acre air dry, but varies from 250 lbs. in less favorable years to 600 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Very Shallow (VS) 10"-14" P.Z. Foothills and Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in an upland position on steep slopes, but may occur in all positions and on all slopes. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site are generally less than 10 inches deep, but this site will include areas of exposed bedrock and pockets of deep soil. Bedrock includes all kinds except igneous and soft clay shales. Permeability is variable and runoff is usually high.

b. The soils in this site may include one or more of the following taxonomic units:

VERY SHALLOW

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants which can survive with severe soil depth limitations and under drouthy conditions.

Decreasers (Relative Importance)		Increasers (Max. / Found in Climax)	
Bluebunch wheatgrass	- 2	Needleleaf sedge	- 5
		Prairie junegrass	- 5
Bottlebrush squirreltail	- 4	Sandberg bluegrass	- 10
Canby bluegrass	- 5	Threeawn	- 3
		Forbs:	- 10
Indian ricegrass	- 4	Aster	
Letterman needlegrass	- 5	Biscuit root	
		Eriogonum	
Mutton bluegrass	- 5	Fleabane	
Needleandthread	- 5	Goldenweed	
Thickspike wheatgrass	- 4	Paintbrush	
		Phlox	
		Pointvetch	
Clovers	- 5	Milkvetch	
Penstemon	- 5	Pussytoes	
Violet	- 5	Sagebrush gilia	
		Sageworts	
		Scarlet globemallow	
		Stonecrop	
Bitterbrush	- 5	Toadflax	
Mountain mahogany	- 3	Western yarrow	
Winterfat	- 5		
		Woody Plants:	
		Big sagebrush	- 5
		Black sagebrush	- 5
		Low rabbitbrush	- 5
		Skunkbush	- 5
		Juniper	- 10

The increasers make up approximately 45% of the vegetation. As the condition deteriorates, increasing forbs and Sandberg bluegrass become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 450 lbs. per acre air dry, but varies from 250 lbs. in less favorable years to 600 lbs. in more favorable years.

6. Specific Site Location:

RANGE SITE DESCRIPTION WYOMING

Land Resource Area (34)(46) Foothills & Basins West of Continental Divide

Location

Date March, 1969

1. Range Site Name: Shale (Sh) 10"-14" P.Z.
Foothills and Basins West of Continental Divide.

2. Climate: (See attached Climatic Description)

3. Topography and Elevation:

This site will usually occur in an upland position on moderately to steeply sloping land. The elevation ranges from 6200 feet to 8000 feet with most of the area being above 7000 feet.

4. Soils:

a. The soils of this site are generally less than 10 inches deep with many outcrops of clay shale bedrock. These clay shales are usually salty in various degrees. Runoff is rapid and erosion is often severe.

b. The soils in this site may include one or more of the following Taxonomic units:

c. Complete soil series descriptions are available in the soil survey descriptive legend.

5. Climax Vegetation:

The climax plant community is dominated by plants which can tolerate the normally high salt content and extremely shallow soils.

Decreasers (Relative Importance)		Increasers (Max. % Found in Climax)	
Alkali sacaton	- 5		
Bottlebrush squirreltail	- 4	Forbs:	- 5
		Aster	
Indian ricegrass	- 4	Biscuit root	
Western wheatgrass	- 3	Docks	
		Fleabane	
Penstemon	- 5	Onion	
		Milkvetch	
		Phlox	
Gardners saltbush	- 4	Pointvetch	
Winterfat	- 5	Princes plume	
		Primrose	
		Scarlet globemallow	
		Woody Plants:	
		Greenmolly summercypress	- 10

The increasers make up approximately 15% of the vegetation. As the condition deteriorates, the grasses and Gardners saltbush decrease and Greenmolly summercypress and invading annuals become more dominant.

Approximate total annual yield of this site in excellent condition in an average year is 300 lbs. per acre air dry, but varies from 200 lbs. in less favorable years to 400 lbs. in more favorable years.

6. Specific Site Location:

May, 1975

To: Wyoming Mineral Corporation
From: Dr. Jack C. Turner, Environmental Consultant
Subject: Report of Vertebrate Fauna, N. E. Sussex Site

INTRODUCTION

This report is concerned with a survey of the terrestrial vertebrate animals living within the sphere of influence of the proposed Wyoming Mineral Corporation mining site. The area is located in southeast Johnson County, Wyoming, in T44N, R77W approximately 11 miles NE of Sussex and 5 miles E of the Powder River.

Field studies commenced late November and extended through the middle of April. A total of 13 field days (10-15 hrs/day) were spent at 3 different time intervals during the study period. Field investigations were conducted from two to four consecutive days each visit to the study area.

I wish to acknowledge the cooperation of the Wyoming Game and Fish for certain information provided.

Scientific nomenclature and other terminology is according to the following authorities:

Long, C. A., 1965. The Mammals of Wyoming. University of Kansas Publication, Museum of Natural History 14(18): 493-758.

American Ornithologist Union, 1957. Check-list of North American Birds. 5th Edition, and A.O.U. 1973. Thirty-second supplement to the American Ornithologist Union Check-list of North American Birds, Auk, 90:411-419.

Baxter, G. T., 1947. The Amphibians and Reptiles of Wyoming. Wyoming Wildlife, August and October.

Field Procedure

Transect trapping for rodents was done in the township. Transects were 300 meters long with two museum special traps set at 10 meter intervals. Each transect was trapped for two consecutive 24 hour periods for a total of 120 trap-nights per transect. Twelve transects consisting of 1440 trap-nights were trapped during the study period. Traps were baited with a mixture of peanut-butter, rolled oats, bacon grease and velveeta cheese. Transects were dispersed throughout the study area, most of which were placed into the specialized habitats of the study area. These areas included: ravine bottoms, rocky outcroppings, areas in which big sagebrush (*Artemisia tridentata*) predominated and areas of grass prairie.

General observations were made for all vertebrates on the study area. The study area was traversed on foot at least once each visit. Animal sign, feces, tracks, calls or songs, skeletal remains, burrows, etc., were taken as evidence of a species' presence as well as actual sightings of the animals.

RESULTS

Small Mammals

Twenty-two species of mammals belonging to ten families (five orders) were found to occur within the study area (Table 1). Rodents comprised the most abundant group present, being represented by five families and eleven species. The deer mouse (*Peromyscus maniculatus*) was the most frequent rodent captured and was trapped in all habitat types, rocky areas being slightly preferred. A total of 197 *Peromyscus* sp. were captured in all transects, representing 91 percent of the total (217) rodents captured. *Peromyscus* sp. comprised a major fraction of the rodent biomass.

Table 1. Taxonomic listing of mammals occurring within T44N, R77W (excluding bats).

Species	Common Name
Order: Insectivora	
Family: Soricidae	
Sorex vagrans vagrans	Vagrant Shrew
Order: Lagomorpha	
Family: Leporidae	
Sylvilagus auduboni baileyi	Desert Cottontail
Sylvilagus nuttali grangeri	Nuttal's Cottontail
Lepus townsendi campanius	White-tailed Jackrabbit
Order: Rodentia	
Family: Sciuridae	
Spermophilus tridecemlineatus pallidus	Thirteen-lined Ground Squirrel
Family: Geomyidae	
Thomomys talpoides bullatus	Northern Pocket Gopher
Family: Heteromyidae	
Perognathus fasciatus olivaceogriseus	Olive-backed Pocket Mouse
Dipodomys ordi terrosus	Ord's Kangaroo Rat
Family: Cricetidae	
Reithrodontomys megalotis dychei	Plains Harvest Mouse
Peromyscus maniculatus nebrascensis	Deer Mouse
Onyschomus leucogaster missouriensis	Northern Grasshopper Mouse
Neotoma cinerea orolestes	Bushy-tailed Wood Rat
Microtus ochrogaster haydeni	Prairie Vole
Family: Erethizontidae	
Erethizon dorsatum bruneri	Porcupine
Order: Carnivore	
Family: Canidae	
Canis latrans latrans	Coyote
Vulpes vulpes regalis	Red Fox
Family: Mustelidae	
Mustela frenata nevadensis	Long-tailed Weasel
Taxidea taxus taxus	Badger
Mephitis mephitis hudsonica	Striped Skunk
Family: Felidae	
Lynx rufus pallescens	Bobcat
Order: Artiodactyla	
Family: Cervidae	
Odocoileus hemionus hemionus	Mule Deer
Family: Antilocapridae	
Antilocapra americana americana	Pronghorn

Rabbits were abundant within the study area. The desert cottontail (*Sylvilagus auduboni baileyi*) and Nuttal's cottontail (*Sylvilagus nuttali grangeri*) were sympatric, however, the desert cottontail was more abundant preferring ravines. The Nuttal's cottontail was sparsely distributed in open flat lands and in the sagebrush plant community. Jackrabbits (*Lepus townsendi campanius*) occur primarily within sagebrush cover.

Pocket gophers (*Thomomys talpoides bulbatus*) were evidenced by their mound building activity. They are widely distributed over the grass land habitat of the study area.

The skeletal remains of a porcupine (*Erethizon dordatum bruneri*) was found on a dirt road within the study area. It is doubtful a viable population of these animals exists within the study area due to the lack of suitable habitat. Perhaps single individuals migrate into the area on a random basis.

Several mammalian predators have been observed. Coyotes (*Canis latrans latrans*) and badger (*Taxidea taxus taxus*) were frequently observed as was sign of their activity. The striped skunk (*Mephitis mephitis hudsonica*) was also abundant, especially in riparian habitats. Two long-tailed weasels (*Mustela frenata nevadensis*) were trapped in association with riparian habitat. Additionally, several active burrows were found with sign identified as red fox (*Vulpes vulpes regalis*). Tracks and feces of a medium sized felid, probably those of a bobcat (*Lynx rufus pallescens*) were observed around several rocky outcropings.

Large Mammals

Pronghorn (*Antilocapra americana americana*) were the most conspicuous component of the mammalian biota. They were distributed through the entire

study area, being concentrated in areas of sagebrush habitat. Numbers of individuals observed ranged from 32 to 142 individuals per day with an average of 75 individuals per day. The average sex ratio was 6 females per male.

Mule deer (*Odocoileus hemionus hemionus*) populations were varied. Numbers of individuals observed ranged from 7 to 22 individuals per day with an average of 10 individuals per day. Most deer occurred in groups of 1 to 5 individuals. Deer were associated with riparian habitat and at the heads of draws in sagebrush habitat.

Birds

Twenty-seven species of birds representing 13 families were observed within the study area (Table 2). Seven species of waterfowl (Anatidae) were observed, however, they were migratory. No resident waterfowl was observed. Similarly, seven species of hawks (Accipitridae) were observed, only one golden eagle (*Aquila chrysaetos*) appeared to be resident. Two great horned owls (*Bubo virginianus*) were observed in a small cluster of cottonwood trees (*Populus sargentii*) in a ravine bottom.

Although few sage grouse (*Centrocercus unophasianus*) were observed, their droppings occurred over much of the study area. No strutting grounds were found. Meadowlarks (*Sturnell neglecta*) and horned larks (*Eremophila alpestris*) were the most widespread and abundant birds on the study area.

Ectothermic Vertebrates

Owing to season and lateness of spring snows no observations were made of frogs, toads or reptiles as they had yet to emerge. Amphibians and reptiles which may occur in the study area according to Baxter (1947)

Table 2. Birds observed within T44N, R77W from December to May.

Species	Common Name
Family: Anatidae	
Branta canadensis	Canada Goose
Anas platyrhynchos	Mallard
Anas acuta	Pintail
Anas strepera	Gadwall
Anas discord	Blue-winged Teal
Anas cyanoptera	Cinnamon Teal
Oxyra jamaicensis	Ruddy Duck
Family: Cathartidae	
Cathartes aura	Turkey Vulture
Family: Accipitridae	
Accipiter gentilis	Cooper's Hawk
Circus cyaneus	Marsh Hawk
Buteo lagopus	Rough-legged Hawk
Buteo regalis	Ferruginous Hawk
Buteo jamaicensis	Red-tailed Hawk
Aquila chrysaetos	Golden Eagle
Falco sparverius	Sparrow Hawk
Family: Strigidae	
Bubo virginianus	Great Horned Owl
Asio flammeus	Short-eared Owl
Family: Tetronidae	
Centrocercus unophasianus	Sage Grouse
Family: Rallidae	
Fulica americana	American Coot
Family: Caprimulgidae	
Chordelles minor	Common Night Hawk
Family: Picidae	
Colaptes auratus cafer	Red-shafted Flicker
Family: Alaudidae	
Eremophila alpestris	Horned Lark
Family: Corvidae	
Corvus brachyrhynchos	Crow
Family: Fringillidae	
Calamospiza melanocorys	Lark Bunting
Pooecetes graminens	Vesper Sparrow
Family: Icteridae	
Sturnella neglecta	Meadowlark
Family: Mimidae	
Oreoscoptes Montanus	Sage Thrasher

are included in Table 3.

Vegetation

There is no commercially merchantable timber within the study area. Few trees are evident and are generally confined to ravine bottoms where at least semipermanent water is available. The plains cottonwood (*Populus sargentii*) is the dominant tree cover although sparsely distributed. Some stands of willow (*Salix* sp.) also exist in riparian situations which are minimal within the study area.

Vegetative cover of the entire study area consists of a series of interdigitating sagebrush and sagebrush-grass complexes. A compilation of the major plant species observed is found in Table 4. Vegetation observed within the study area is consistent with that found on eastern short-grass prairies of Wyoming with the possible exception of big sagebrush (*Artemisia tridentata*) being more abundant than on most grassland areas.

Area of vegetative cover varied greatly over the study area. The average cover was 57 percent based three 10 ha. plots sampled by a stratified sampling technique. Cover ranged from 0 percent to a maximum of 78 percent.

Climate

A continental climate prevails over the study area. Few days during the year are without insolation. Wide fluctuations exist in the seasonal and diurnal temperatures (ambient). Summer extremes produce temperatures above 100°F; the winter produces minimums in excess of -25°F. Precipitation varies between 7 and 19 inches with a mean of 12 inches per year (10 year average.

Table 3. Reptiles and amphibians which may occur within T44N, R77W (after Baxter, 1947).

Species	Common Name
Reptiles	
Phrynosoma douglassi	Eastern Short Horned Lizard
Sceloporus undulatus	Northern Prairie Lizard
Pituophis melanoleucus	Common Bull Snake
Crotalus viridis	Prairie Rattlesnake
Heterodon nasicus	Western Hognose Snake
Coluber constrictor	Blue Racer
Thamnophis ordinoides	Wandering Garter Snake
Thamnophis radix	Plains Garter Snake
Thamnophis sirtalis	Red-sided Garter Snake
Amphibians	
Pseudacris nigrita	Swamp Cricket Frog
Rana pipiens	Leopard Frog
Scaphiopus bombifroms	Central Plains Spadefoot Toad
Bufo woodhousii	Rocky Mountain Toad

Table 4. Major plant species observed within T44N, R77W.

Species	Common Name
Agropyron smithii	Western Wheat Grass
Alopecurus carolinianus	Carolina Foxtail
Artemisia cana	Silver Sagebrush
Artemisia pedatifida	Birdfoot Sagewort
Artemisia tridentata	Big Sagebrush
Atriplex argentea	Tumbling Sagebrush
Bouteloua gracilis	Blue Grama Grass
Bromus tectorum	Cheatgrass Brome
Carex douglasii	Douglas Sedge
Carex filifloria	Threadleaf Sedge
Chrysothaminus viscidiflorus	Rabbitbrush
Distichlis spicata	Inland Saltgrass
Eleocharis acicularis	Slender Spikerush
Eriogronum annuum	Wild Buckwheat
Eriogonum ovalifolium	Cushion Buckwheat
Franceria discolor	Skeleton-leaf Bursage
Hordeum jubatum	Foxtail Barley
Koeleria cristata	Prairie Junegrass
Opuntia polyacantha	Plains Prickly Pear
Poa ampla	Big Bluegrass
Poa pratensis	Kentucky Bluegrass
Populus sargentii	Plains Poplar
Salix sp.	Willow
Salsola kali	Russian Thistle
Stipa comata	Needle and Thread Grass
Yucca glauca	Soapweed

DISCUSSION AND SUMMARY

The study area is within the Powder River faunal subdivision of the Great Plains Faunal Area. Much of the study area is of the Transitional Life Zone with an interdispersion of the Sonoran Life Zone. The fauna observed is consistent with that expected on the basis of the habitat and cover availability.

Vegetation is primarily that of a grassland prairie with a big sagebrush intrusion, the condition of which varies with season and the availability of moisture.

Bird populations probably increase as would diversity with the onset of spring. Passerine birds would probably be the majority of the breeding bird population with meadowlarks and horned larks being the most abundant. Due to the lack of suitable habitat, waterfowl and most raptors would not breed within the study area. However, the rodent and rabbit population would probably support several hawks, owls and/or eagles.

Sage grouse may also occupy the study area in greater numbers than observed. Sign (droppings) indicate sage grouse to be dispersed over much of the study area.

There is an abundant rodent and small mammal population. The diversity of which is probably greater than measured due to prevailing winter conditions during this study.

Deer and pronghorn are abundant within the study area and contribute to both the aesthetic and recreation considerations of the available land resources. Although the use of the area by deer is perhaps seasonal, winter range is the most important aspect of deer habitat. Pronghorn use of the area is year-around, although pronghorn herds wander on and off the study area in their daily movements.

Relative to the type and magnitude of the proposed mining operation, the fauna will be effected to a greater or lesser degree. Any activity will serve to displace some component of the vertebrate fauna. Exploitation of the resources will alter the present environment by actual removal of vegetation and subsequent loss of animal populations from the construction(s) sites, through loss of habitat by construction of transportation systems and through the various impacts of mining personnel in their activities, both job related and personal.

Bird populations will be effected to the extent of surface disturbance. Since most birds require vegetation for nesting activity and minimal human encroachment, breeding populations will diminish with proximity to mining activities. Probably least effected will be ground nesting species, such as the meadowlark and horned lark, whose nesting specificity is less rigorous than most other passerine species as well as being more abundant. Again, however, man's activities can greatly (adversely) effect fledging success.

Sage grouse will be adversely effected by removal of sagebrush by the loss of cover and food. Without adequate cover for the precocious chicks, survival will diminish within the sphere of influence of mining activity. The sage grouse will probably be eliminated.

Rodent populations will be altered with an increase in man's activities. The deer mouse and thirteen-lined ground squirrel will probably be least effected owing to their high reproductive rates and relative high abundance. Possibly, mining activities could serve to increase their populations. Other rodent populations will be displaced to the extent they are restricted to a particular habitat which is being altered. In some circumstances, components

of the rodent fauna will be extirpated. This will negatively influence the raptor diversity and abundance.

Rabbits are a conspicuous component of the grassland-sagebrush habitat. Jackrabbits are intolerant of human encroachment. Additionally, hunting pressure (year-around) will increase with increased access to the area, potentially eliminating this species very quickly. Cottontail rabbits would be less adversely effected due to seasonal hunting pressure. Although sensitive to habitat changes, cottontails appear to be more adaptive and tolerant of man and his activities than do the hares.

Carnivores are effected by availability of food and, as such, tend to be wide ranging and opportunistic in feeding behavior. The effect of reduced prey items will diminish predator population, but such reductions should be less obvious with the over-all effect on carnivores being less. This assumes that predators would not be totally reduced from increased hunting and trapping pressure as a result of increased access and human population.

Big game species, pronghorn and mule deer, are intolerant of man and his activities. Such species will move away from disturbances into neighboring habitat until spacial limitations restrict such movements. With increased growth of mining operations, the subsequent influx of people and the continued removal of suitable big game habitat, pronghorn and mule deer populations could be greatly reduced. Additionally, the influx of people not only provide a harassment factor but also contribute to an increased demand for game species. The accumulative impact can serve to diminish game populations, possibly to extirpation. Such impact could be reduced through habitat rehabilitation and game management activities.

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