DRAFT
ENVIRONMENTAL STATEMENT

PROPOSED 20-YEAR PLAN OF MINING AND RECLAMATION, WESTMORELAND RESOURCES TRACT III, CROW INDIAN CEDED AREA, MONTANA

U.S. DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

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DIRECTOR

SUMMARY

Draft Environmental Statement
Department of the Interior, U.S. Geological Survey

1. Type of Action:

(X) Administrative ( ) Legislative

2. Description of Action:

Approval of a 20-year plan for strip mining of 190.6 million tons of coal for shipment from Montana and reclamation of the site, Westmoreland Resources Lease 1420-0252-4088, Crow Indian Ceded Area, Bighorn County, Montana. Coal ownership is by the Crow Tribe of Indians except for that in Sec. 36 which is owned by the State of Montana. Plan proposes extension eastward of presently approved Absaloka Mine in Sec. 25 and 26, T.1 N., R.37 E., into privately owned land in Sec. 24 and 25, and State owned land in Sec. 36, T.1 N., R.37 E., and privately owned land in Sec. 19, 30, and 31, T.1 N., R.38 E. The plan would ultimately cover 2151 acres in the lease area known as Tract III.

3. Summary of Environmental Impacts

(a) The existing land surface, vegetation, and all aquifers above the base of the Robinson Coal in the proposed mine area will be destroyed.

(b) Wildlife habitats will be disrupted until disturbed areas are revegetated and human intrusions terminated.

(c) Ground and surface water quantity and quality, livestock grazing, scenic views and open space qualities will be degraded and restricted until revegetation is successfully completed.

(d) Dust and noise will be increased locally until recontouring and revegetation is successfully completed.

(e) Livestock and wildlife forage will be reduced until revegetation is successful.

(f) Employment for the Crow Indians and other citizens of Bighorn County will be increased.

(g) Tax and royalty income for the Crow Tribe, the State of Montana, and Bighorn County will be increased.

4. Alternatives Considered:

(a) Approve mining plan.

(b) Approve mining plan after modification.

(c) Reject mining plan.

(d) Prevent further development of the lease.

(e) Mine coal only on State owned land.

5. Review and Coordination:

Environmental Protection Agency
Federal Energy Administration
Energy Research and Development Administration
Federal Power Commission
Department of the Army (Corps of Engineers)
Department of Health, Education and Welfare
Department of Labor
Clearing Houses for the States of Montana, Wyoming, North Dakota, South Dakota, Minnesota, Iowa, Wisconsin, and Illinois
Crow Tribal Council
Department of Commerce
Interstate Commerce Commission
Department of Transportation
Department of Interior
- Bureau of Land Management
- Bureau of Indian Affairs
- Bureau of Outdoor Recreation
- Fish and Wildlife Service
- Bureau of Reclamation
- Bureau of Mines
- National Park Service
- Mining Enforcement and Safety Administration

6. Date Made Available to CEQ and public:

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I. DESCRIPTION OF THE PROPOSAL

A. Introduction

Westmoreland Resources was the successful bidder on prospecting permits sold by the Crow Tribe of Indians at a competitive sale in 1970. The permit areas were located in what is known as the Ceded Area, north of the Crow Reservation. This area was ceded to the United States Government by the Congressional Act of April 27, 1904 (33 Stat. 352) and subsequently opened for settlement. The Indians then living on the land were either alloted the land or reimbursed for it if they moved to the Reservation.

After about 54 years on the market, the Congress by Act of May 19, 1958 (72 Stat. 121), restored to Tribal ownership all of the vacant and undisposed ceded land. These lands resumed trust status and the mineral rights were reinstated to the Crow Indians. The coal rights had been retained by the U.S. Government when the land in the Ceded Area was patented to the settlers, and these rights were also returned to Crow Tribal ownership by the Act of 1958. Coal rights in the Ceded area total about 150,000 acres and are held in trust for the Crow Indians and administered for the Secretary of Interior by the Bureau of Indian Affairs.

Surface ownership in the more than 1.1 million acres in the Ceded Area includes approximately 9000 acres of Tribal land, 17,000 acres of alloted land, 45,000 acres of State land, and over 1,000,000 acres of private fee land.

The existing Absaloka mine of Westmoreland Resources on Tract III began operations in 1974 under an approved mining plan covering 770 acres of which 360 acres was for plant and railroad facilities and the remainder for active mine operations. The initial mining operations and projected environmental impacts were described in "Final Environmental Statement FES 74-8" (U.S. Bureau of Indian Affairs, 1974).

Sebsequent to the approval of the mining and reclamation plan by the Secretary of Interior and the start of mining by Westmoreland, litigation related to the operation was initiated by local residents. As a result of this legal action, an opinion was handed down by the 9th U.S. Court of Appeals on June 19, 1975, and a U.S. District Court order for the District of Montana, Billings

Division, dated January 20, 1976 was issued. These in part held that the Secretary of the Interiors approval of two Crow Indian coal leases with Westmoreland, covering approximately 30,876 acres constituted a "Major Federal Action" requiring a comprehensive environmental impact statement as well as impact statements for each separate subsequent mining plan (Cady vs Morton, CV-74-12-B16).

To bring the Department of Interior into compliance, a draft environmental impact statement covering the Westmoreland leases was prepared under leadership of the Bureau of Indian Affairs and filed with The Council on Environmental Quality (CEQ) on August 17, 1976. This statement was prepared under the leadership of the U.S. Geological Survey for the 20-year mining plan. The leasewide impact statement will serve as the primary documentary basis upon which the Secretary of the Interior under the Court's order must reconsider his approval of the leases. Action cannot be taken by the Secretary on Westmorelands 20-year mining and reclamation plan until the leasing issue has been decided.

B. Purpose

Westmoreland Resources submitted a 20-year mining and reclamation plan covering an area of 2151 acres on its Tract III Crow coal lease on Sarpy Creek, Montana to the Department of the Interior on September 30, 1975. The purpose of the new plan was to permit the expansion of the existing Absaloka Mine to other areas of the lease. This expansion is necessary to permit existing contracts for coal (77 million tons) to be filled.

The description of methods and equipment to be used in the mine as presented in this section is adapted from Westmoreland Resources Mining and Reclamation Plan (1975 p).

C. Site Location

The proposed mine area is located on Tract III of the lease in the southeast portion of T.1 N., R.37 E. and the southwest portion of T.1 N., R.38 E., east of Sarpy Creek in Big Horn County, Montana. The area lies entirely in the Crow Ceded Area and is adjacent to the north boundary of the Crow Reservation. Access to the lease area is by County road 384 from Hardin, Montana, which lies about 26 miles west. A gravel road also connects the area with Hysham, Montana, about 30 miles to the north. Figure 1 shows the location of the mine area in relation to its surroundings.

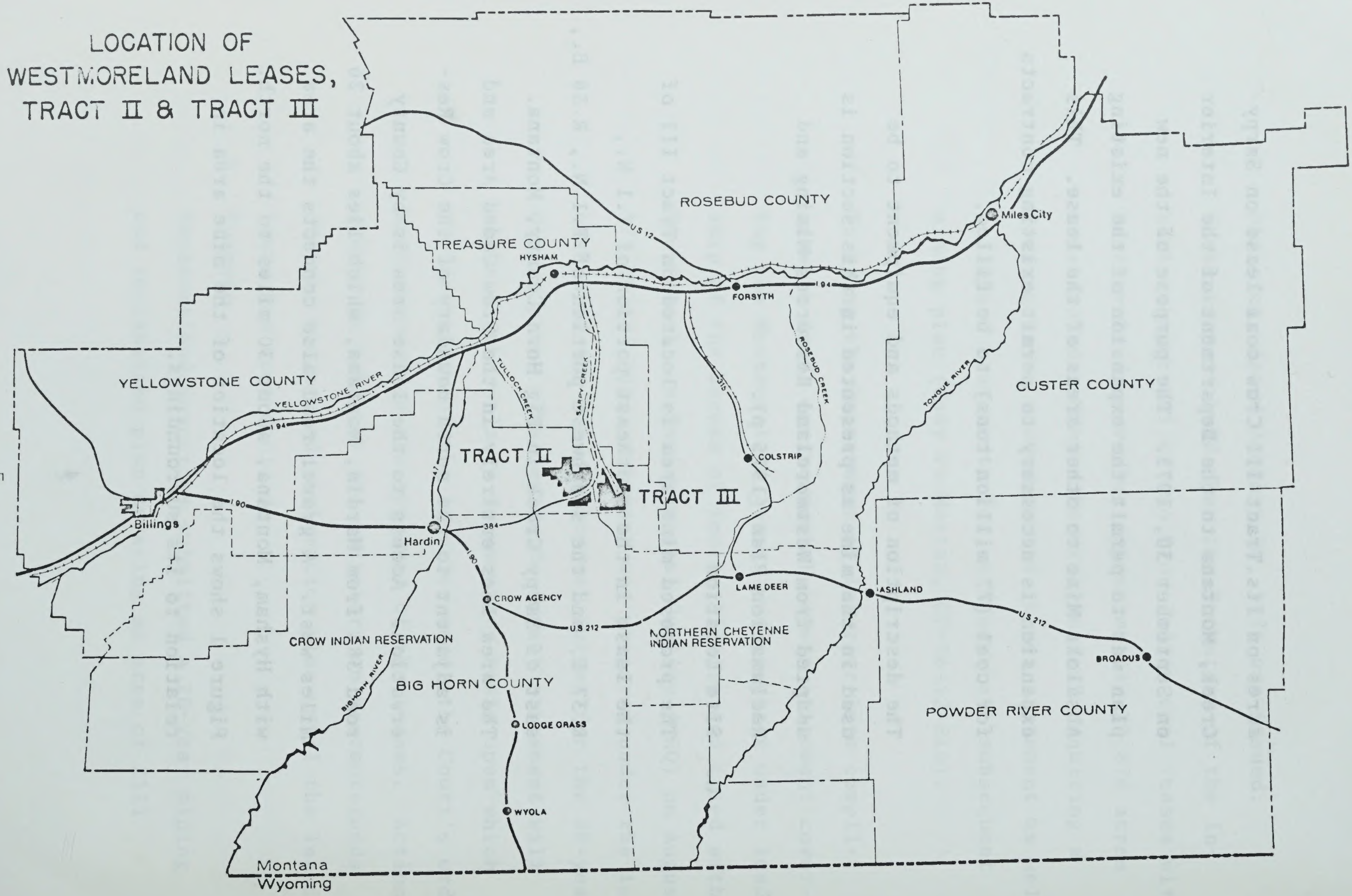

LOCATION OF
WESTMORELAND LEASES,
TRACT II & TRACT III
ROSEBUD COUNTY
TREASURE COUNTY
HYSHAM
FORSYTH
Miles City
YELLOWSTONE COUNTY
YELLOWSTONE RIVER
CUSTER COUNTY
TONGUE RIVER
TULLOCK CREEK
SARPY CREEK
ROSEBUD CREEK
COLSTRIP
TRACT II
TRACT III
Billings
Hardin
CROW AGENCY
LAME DEER
ASHLAND
BROADUS
NORTHERN CHEYENNE
INDIAN RESERVATION
CROW INDIAN RESERVATION
BIG HORN COUNTY
BIGHORN RIVER
LODGE GRASS
WYOLA
POWDER RIVER COUNTY
Montana
Wyoming
US 12
US 212
I 94
I 90
Source : Mountain West
Research Inc.

Figure 1.

D. Permit and Lease Terms

Exploration of the Tract III area began in 1970. In June 1972, the Crow Tribe leased the rights to the coal to Westmoreland Resources.

Controversy subsequently arose between the lease parties, and in November 1974, an amended coal mining lease was signed. By the amended lease, Westmoreland agreed to pay a bonus of $500,000 and advance royalty of $628,000, a royalty of the greater of 25 cents per ton or 6 percent of the mine price on coal shipped during 1974 and 1975, the greater of 30 cents per ton or 6 percent of the mine price on coal shipped during 1976 and 1977, and the greater of 35 cents per ton or 6 percent of the mine price on all coal shipped in 1978 or afterwards, to a maximum of 77 million tons, mined and shipped under contracts existing at the time of the agreement. Westmoreland further agreed to pay the greater of 40 cents per ton or 8 percent of the mine price on the balance of coal covered by the lease. Minimum royalties are payable only until the end of the "development period" which is approximately 1987. Westmoreland agreed, in addition, to mine coal at the rate of 10 million tons per year by 1982, subject to certain stipulations. Although no specific plans have been developed, a production rate of 15 million tons by approximately 1987 is stipulated in the amended Tract III lease. The additional 5 million tons plus continuation of the 10 million ton rate is expected to come from the alternate areas shown in Figure 6 (page).

By the original and amended leases, Westmoreland agreed to reclaim the land. The operator is bound not to pollute surface or ground water, to landscape the spoils and replace the topsoil on and reseed the disturbed areas, and to minimize air pollution. Copies of the lease are on file in the offices of the Area Mining Supervisor, U.S. Geological Survey, and the Bureau of Indian Affairs in Billings, Montana.

E. Description of the Coal

Two major coalbeds and two smaller stray beds underlie the proposed mining area and are recoverable by current strip mining technology. The coal lies within the Tongue River Member of the Tertiary age Fort Union Formation. The Tongue River is composed of interbedded light-colored clays and shales, and tan massive sandstones, as well as the coal.

The Rosebud-McKay coal seam is 30 to 35 feet thick and lies under 70 to 135 feet of sandstone and shale overburden. Sandstone and shale interburden 50 to 100 feet thick separates the Rosebud-McKay seam from the underlying Robinson seam which ranges from 17 to 23 feet in thickness. Two unnamed stray seams occur in the area. Both are continuous except where burned and reach a maximum of 5 feet in thickness.

The S-1 seam lies 20 to 30 feet above the Rosebud-McKay and the S-2, 5 to 10 feet below (Figure 2).

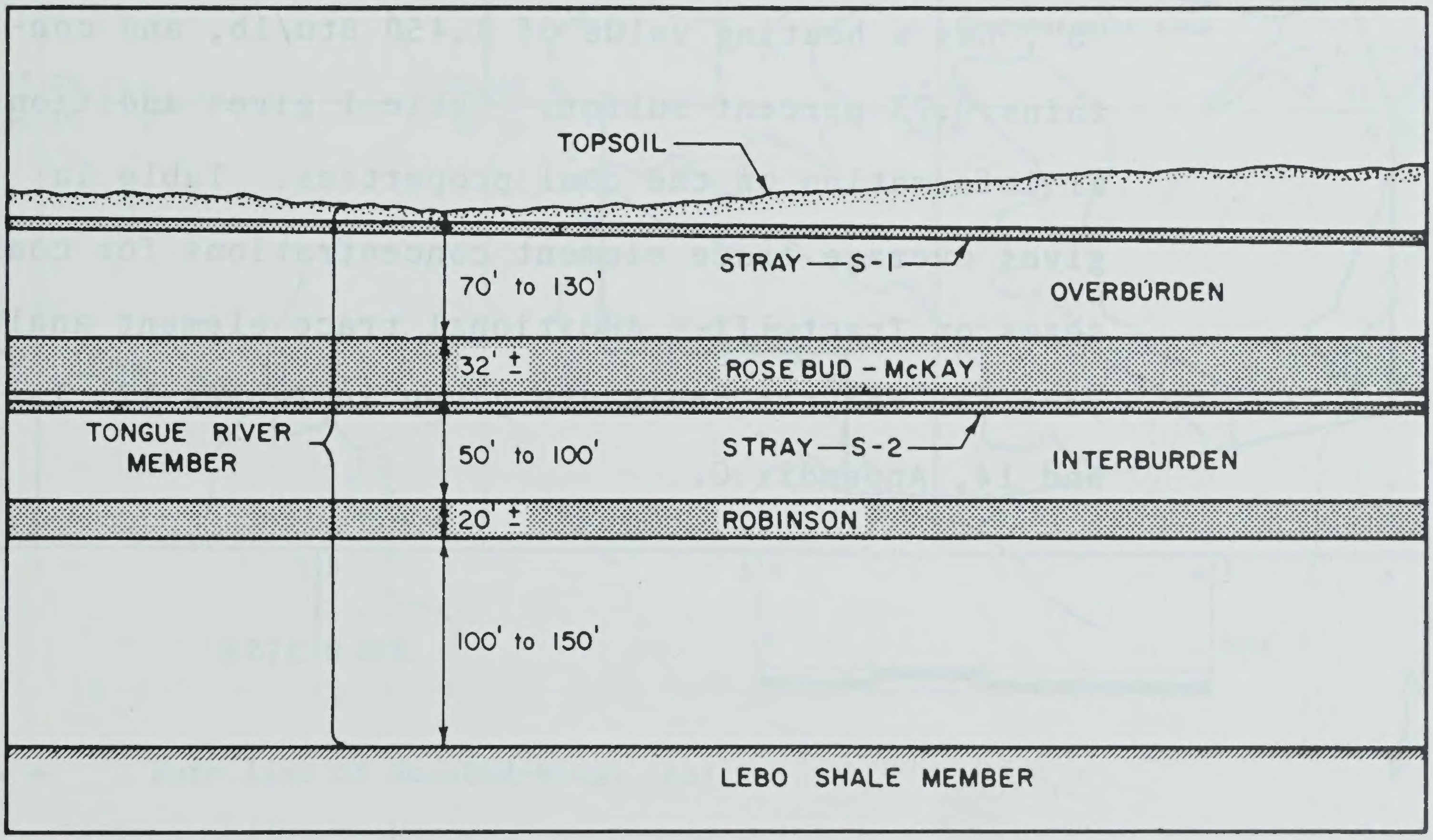
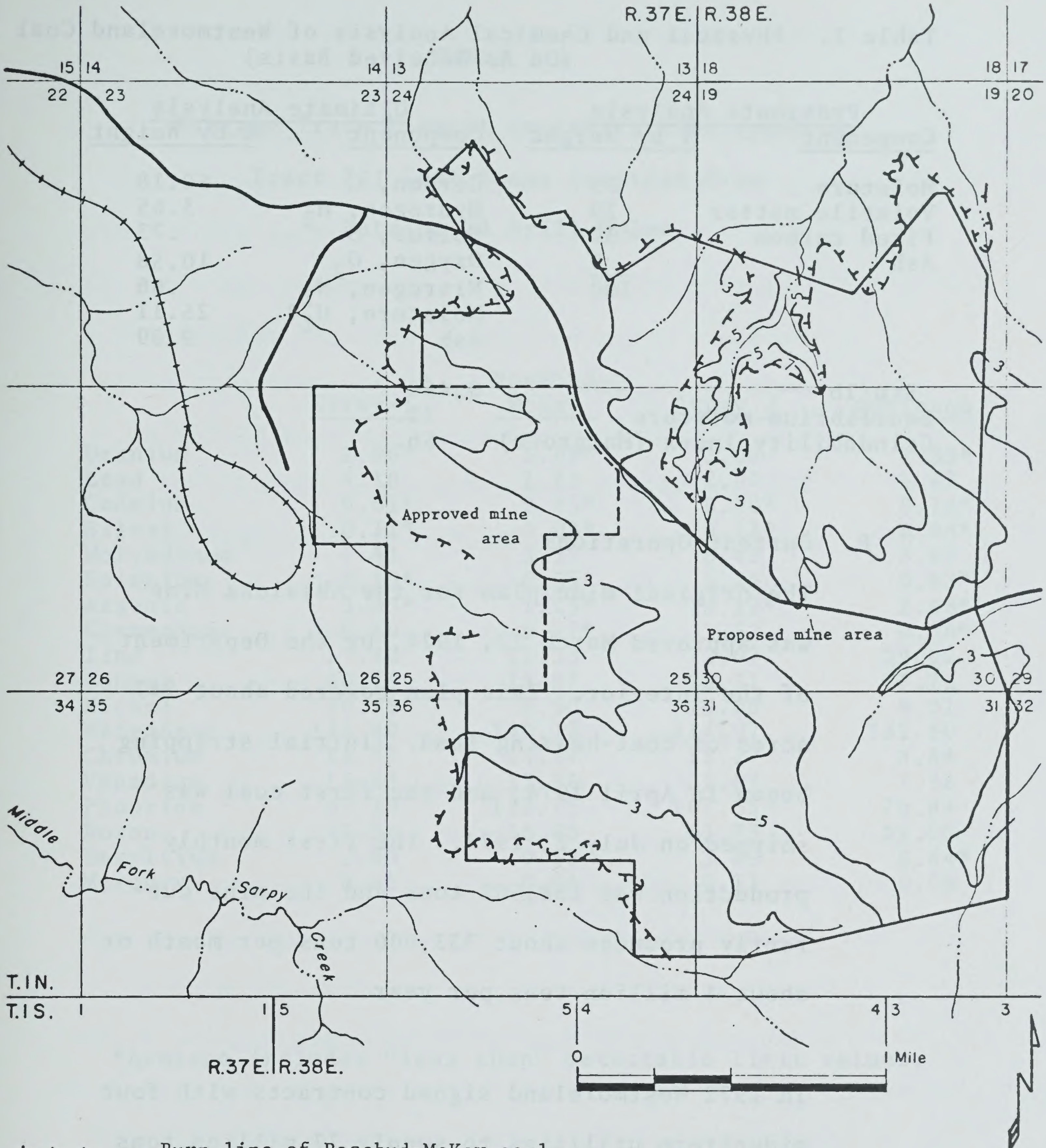


Figure 2. Geologic cross section of lower strata in the Fort Union Formation.

The in place mining ratio, which is the cubic yards of overburden which must be excavated to uncover 1 ton of coal, ranges up to 7 in the proposed mine area (Figure 3).

Westmoreland's analysis of data from its exploratory drilling program indicates that 850 million tons of minable coal underlie the entire Tract III, of which about 600 million tons is recoverable under current economic conditions. The proposed mining plan envisions the extraction of 190,600,000 tons by 1997. The coal is classed as subbituminous "B", has a heating value of 8,450 Btu/lb, and contains 0.73 percent sulfur. Table 1 gives additional information on the coal properties. Table 1a gives average trace element concentrations for coal seams on Tract III. Additional trace element analyses for for the coals are given in Tables 12, 13, and 14, Appendix C.



Burn line of Rosebud-McKay coal.

Contours showing in-place mining ratio which is the ratio at non-marketable material in cubic yards to coal in place in tons.

Figure 3. In-place mining ratio of proposed mine area. Adapted from Westmoreland Resources, 1975 p, Exhibit 8.

Table 1. Physical and Chemical Analysis of Westmoreland Coal (On As-Received Basis)

Proximate Analysis		Ultimate Analysis	
Component	% by Weight	Component	% by Weight
Moisture	25	Carbon, C	50.18
Volatile matter	29	Hydrogen, H_2	3.65
Fixed carbon	37	Sulfur, S	.73
Ash	9	Oxygen, O_2	10.58
	100	Nitrogen, N_2	.66
		Moisture, H_2O	25.11
		Ash	9.09

Btu/lb	8,450
Equilibrium moisture	23.
Grindability index (Hargrove)	56.

F. Current Operations

The original mine plan for the Absaloka Mine was approved March 22, 1974, by the Department of the Interior. This plan covered about 247 acres of coal-bearing land. Initial stripping began in April 1974, and the first coal was shipped on July 1, 1974. The first monthly production was 134,502 tons and the mine currently produces about 333,000 tons per month or about 4 million tons per year.

In 1972 Westmoreland signed contracts with four midwestern utilities to supply 77 million tons of low sulfur coal over a 20-year period. One additional midwestern utility now receives Westmoreland coal and test shipments have been sent to two others.

TABLE 1 a

Average Trace Element Concentrations (ppm) in Tract III Coal Seams Compiled from Data on 18 Drill Holes

	Stray-1	Rosebud-McKay	Stray 2	Robinson
Uranium	1.96*	1.69*	2.00	1.39*
Lead	4.18	1.83	2.97	1.47
Cadmium	0.61*	0.83*	0.40*	0.72*
Silver	0.11*	0.08*	0.13*	0.08*
Molybdenum	5.81	3.37	5.43	3.80
Selenium	2.19*	0.55*	1.26	0.63*
Arsenic	3.03*	1.15*	19.19*	1.05*
Germanium	0.50	0.17*	1.32	0.30*
Zinc	17.45	51.33	72.07	29.01
Copper	20.75	18.87	22.31	17.72
Nickel	19.95	8.50	10.06	6.91
Manganese	111.80	149.13	114.07	131.60
Chromium	15.77	14.37	18.27	8.84
Vanadium	15.03	15.34	22.97	7.58
Flourine	67.10	119.73	167.53	76.84
Boron	43.30	36.43	63.73	31.90
Beryllium	2.89	0.58	3.89	0.44*
Mercury	0.06	0.06	0.13	0.06

*Average includes "less than" detectable limit values.

A 75-cubic yard capacity dragline uncovers the coal and 18-cubic yard capacity front-end loaders load the coal into 120-ton coal haulers. To date (June 1976) about 250 acres have been disturbed by mining and topsoil removal activities. About 78 acres have been completely regraded, 43 acres of which have been topsoiled and seeded. Seeding of the remaining 35 acres is planned in the fall of 1976; additional regrading behind the active pit is in progress. The current pit is shown on Figure 5. As the mine expansion will use the same mining procedures as are currently employed, these procedures are discussed in section I and are not covered here. A general description of the mine is in the December 1975 issue of Coal Age magazine (Vol. 80, No. 13).

In addition to obtaining approval from the Interior Department, Westmoreland must obtain each year a surface mining permit from the Montana Department of State Lands in order to mine as the surface to be mined is not owned by the Crow Tribe and is thus under State jurisdiction. This permit requires the posting of a reclamation bond based on the actual costs of rehabilitation covering all land it plans to disturb each year. Approvals from the Department of Interior and Department of State Lands are not conditional one upon the other. They are independent approvals, and Westmoreland must have both to mine Indian coal on the Crow Ceded Area.

Westmoreland has obtained a State permit approving expansion of mining onto 231 acres of State land and coal in the proposed mine area. This permit and the acreage approved will allow one year of mining at which time a new State permit will be required.

G. Surface Facilities and Equipment

The existing plant layout of the Absaloka mine is shown in Figure 4. The present plant facilities are adequate to handle production from the proposed mine area and will be used without additions. Coal from the mine is dumped into the truck dump and run through the primary crusher. The crushed coal is transported by conveyor to the secondary crusher where it is reduced to minus 2-inch size. From here, a conveyor takes it to the loading point where it can

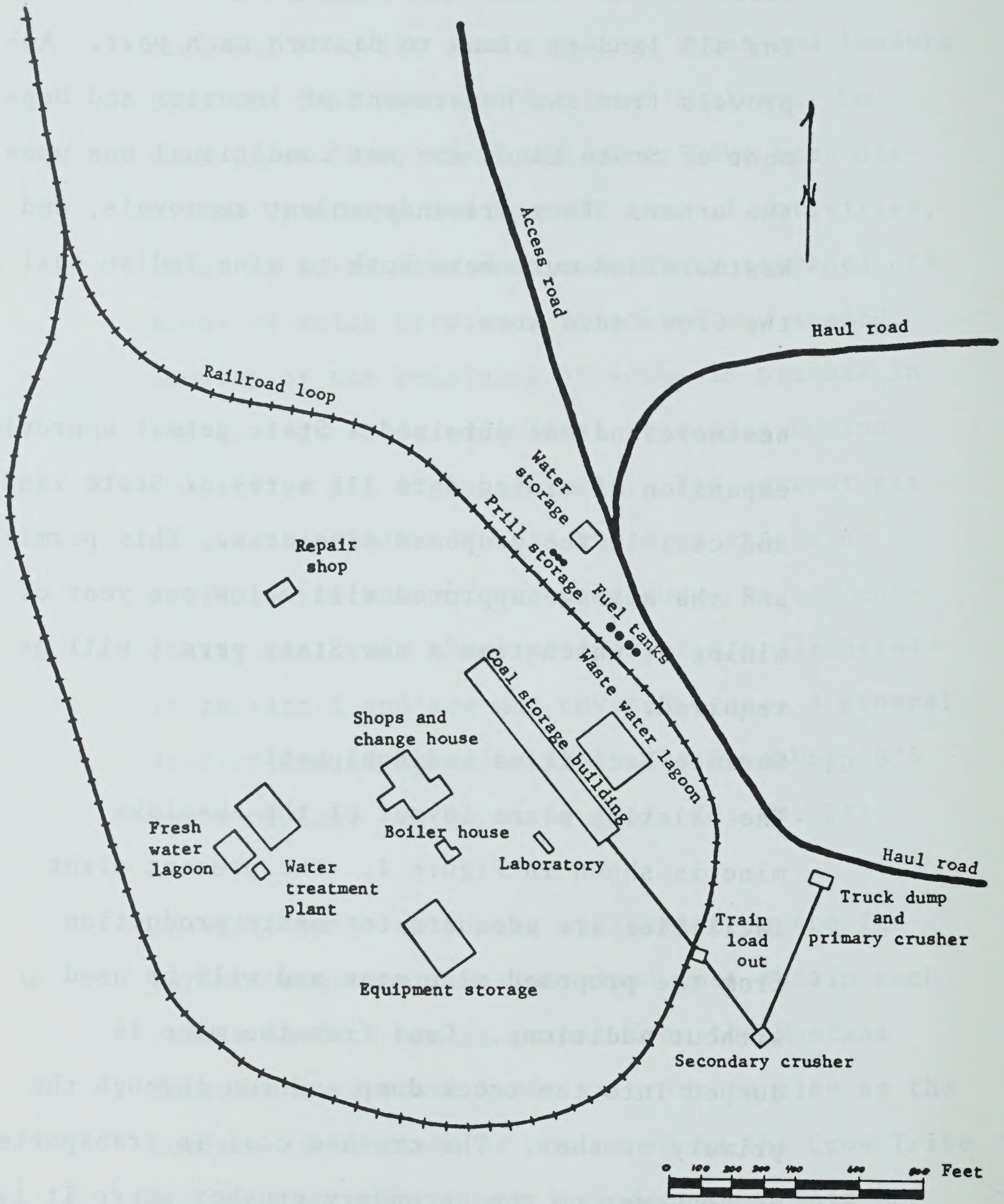


Figure 4. Mine plant layout.

be directly loaded into railroad cars or transported by another conveyor to the coal storage building (a 700-foot long covered storage area of 50,000-ton capacity). Another conveyor transports the coal from this storage building back to the loading point. Other structures in the plant site include an office, shops, and change houses, boiler house, equipment storage, repair shop, water treatment plant, water tanks, fuel tanks, and ammonium nitrate storage. Three hundred and sixty acres were approved for the present plant site. To date, the actual area disturbed by plant construction and related activities is 104 acres, plus 57 acres for access and haul roads. The existing coal processing system can handle 14 million tons per year. Capacity can be increased to 19 million tons per year by upgrading the conveyors, adding a secondary crusher, and enlarging the storage barn.

The mine currently uses the following major equipment:

1 - 75-cubic yard dragline
2 - 18-cubic yard front-end loaders
4 - 120-ton bottom dump trucks
1 - Overburden drill (electric)
1 - Coal drill (diesel)
4 - Motor scrapers
5 - Bulldozers
1 - Grader

Power is delivered to the mine by a 69 kv transmission line and distributed to equipment by overhead lines and ground cables. Water for plant use and sprinkling of haulroads comes from a deep well at the plant site. A part of the water is treated to make it potable. Water used for dust control receives only primary treatment to lower the dissolved solids concentration. A sewage treatment plant and lagoon treats all domestic wastewater from the plant. Current peak water use in the summer is 60,000 gallons per day.

Two haulroads connect the pit with the plant site. These roads are about 80 feet wide and surfaced with scoria. Water wagons are used to control dust.

H. Mining Plan

The new mining plan would extend the existing Sarpy Creek mine to areas of the lease to the south, east, and north of the existing operation (Figure 5). The existing pit would be lengthened and future cuts would run from the northern limits of the mine area toward the southeast. Later cuts would be oriented north-south and would eventually extend the full width of the mine area. The cuts would progress from west to east. The mine area on the north, south,

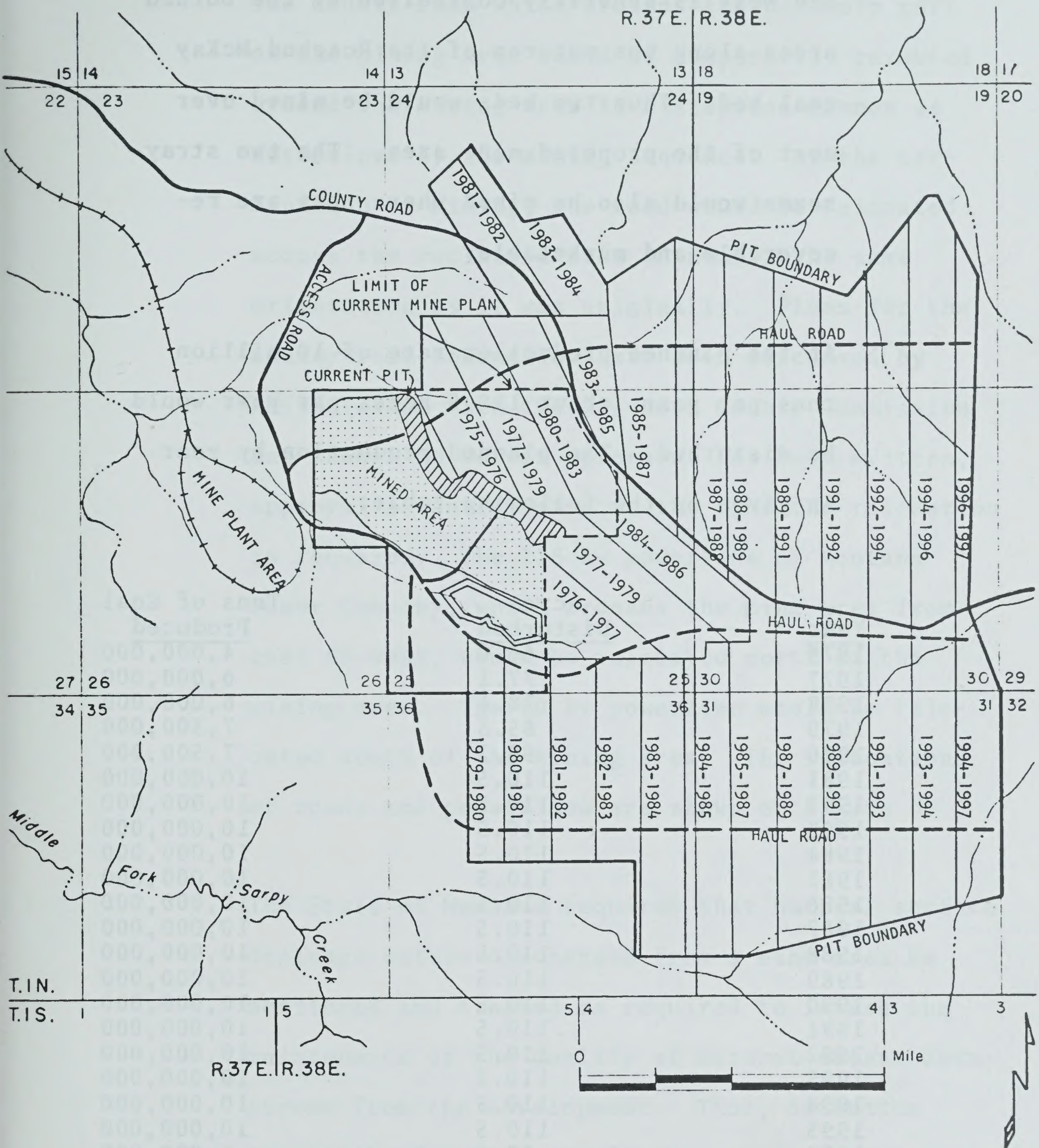


Figure 5. Mining sequence in proposed mine area. Lines show edge of every fifth cut. Dates are approximate. Adapted from Westmoreland Resources, 1975 p, Exhibit 3.

and west is generally controlled by the burned areas along the outcrop of the Rosebud-McKay coal bed. Thus two beds would be mined over most of the proposed mine area. The two stray seams would also be mined where they are recoverable and marketable.

At the planned production rate of 10 million tons per year, about 110.5 acres per year would be disturbed. The planned production by year is given on the following table:

Year	Acres Disturbed	Tons of Coal Produced
1976	66.0	4,000,000
1977	77.1	6,000,000
1978	78.4	6,000,000
1979	85.3	7,500,000
1980	90.2	7,500,000
1981	110.5	10,000,000
1982	110.5	10,000,000
1983	110.5	10,000,000
1984	110.5	10,000,000
1985	110.5	10,000,000
1986	110.5	10,000,000
1987	110.5	10,000,000
1988	110.5	10,000,000
1989	110.5	10,000,000
1990	110.5	10,000,000
1991	110.5	10,000,000
1992	110.5	10,000,000
1993	110.5	10,000,000
1994	110.5	10,000,000
1995	110.5	10,000,000
1996	57.6	6,000,000
1997	38.9	3,600,000
Total	2,151.0	190,600,000

The county road which crosses the northern part of the mining area would be temporarily rerouted around the mining area in a stepwise manner as determined by the mining sequence. At the termination of mining, the road would be relocated across the reclaimed area in nearly the same orientation as it was originally. Plans for the county road relocation have been discussed by Westmoreland with the Big Horn County Commission and though no formal agreement has been written, approval is anticipated at the time the relocation is required. The 115 kv powerline of Montana Power Company, which crosses the mine area from east to west, would be relocated north of the mining area. The 69 kv powerline would be relocated south of the mining area. The relocations of roads and powerlines are shown on Figure 6.

The State of Montana requires that natural surface drainage waters discharged from a mine area be monitored and treated as required to insure the maintenance of the quality of natural waters downstream from the development. Thus, detention facilities for mine runoff are necessary to meet

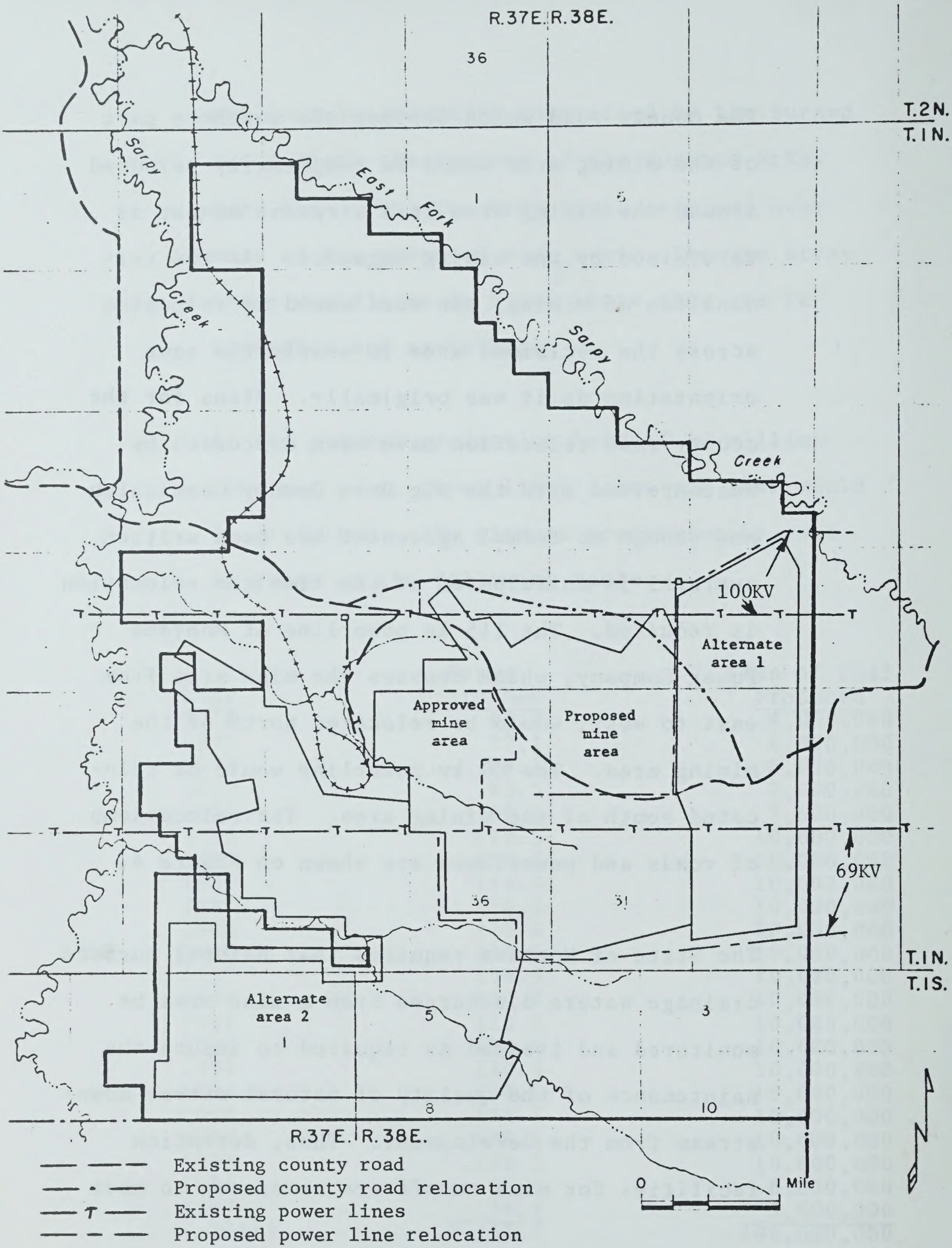
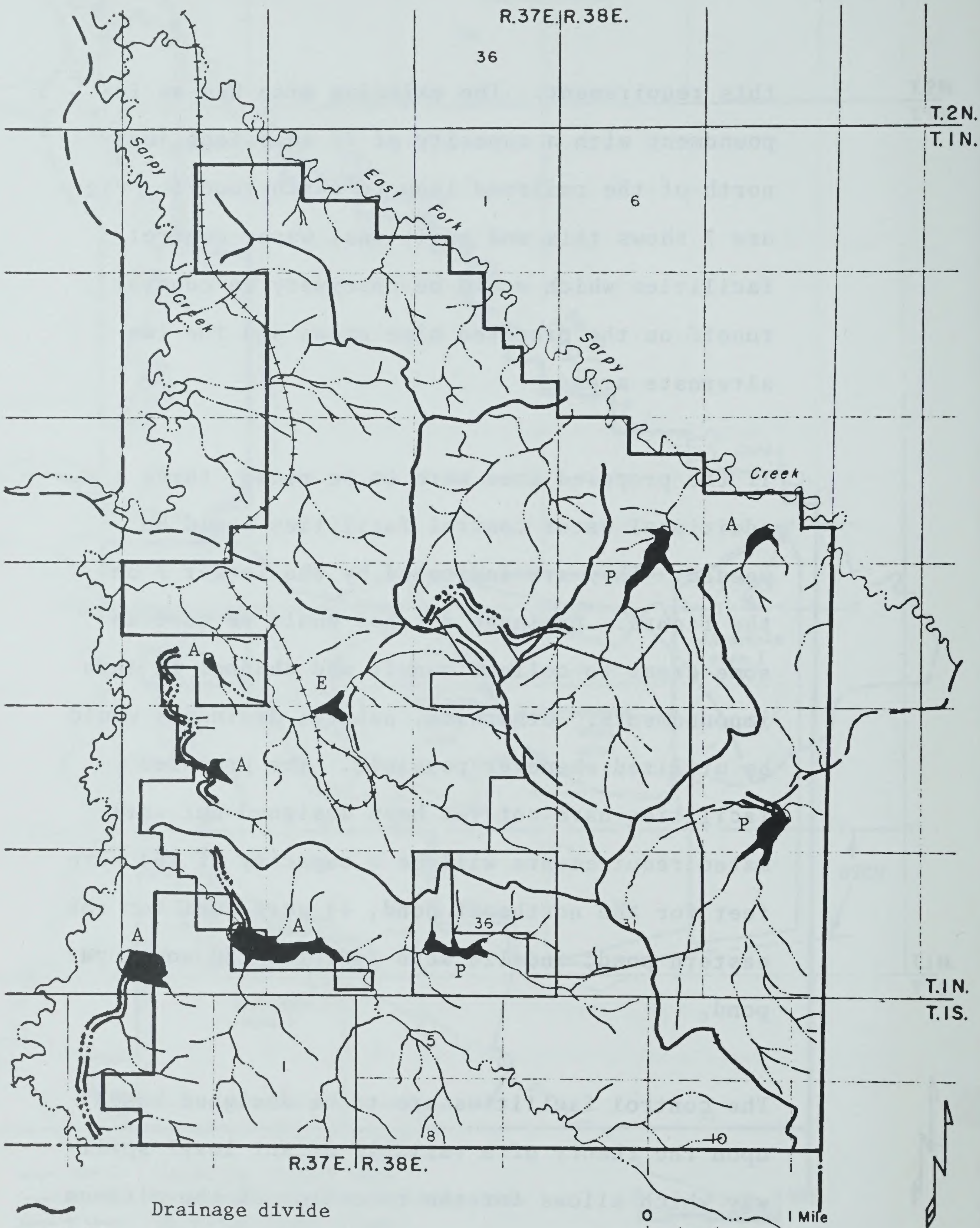


Figure 6. Alternate mine areas areas and proposed relocation of roads and power lines.

this requirement. The existing mine has an impoundment with a capacity of 77 acre feet just north of the railroad loop to catch runoff. Figure 7 shows this and additional water control facilities which would be necessary to control runoff on the proposed mine areas and the two alternate areas.

If the proposed area were to be mined, three additional water control facilities would be needed. They are indicated by the letter P on the figure. Drainage ditches would be used in some areas to collect runoff and channel it into impoundments. Otherwise, natural drainages would be utilized whenever possible. The proposed facilities have not yet been designed but estimated requirements will be a capacity of 164 acre feet for the northeast pond, 44 acre feet for the eastern pond; and 128 acre feet for the southern pond.

The control facilities are to be designed based upon the theory of a variable decant level spillway which allows for the retention of the minimum amount of water at any time for the settling of



Drainage divide

Artificial watercourse

Dam and settling pond.
P-For proposed mine plan
A-For alternate areas
E-Existing

34

Figure 7. Surface drainage and water control facilities.

suspended sediment loads. All facilities will have the capacity to store runoff from a 10-year frequency storm of 24 hour duration. Spillways will accomodate a 100-year storm of 6 hours duration. All impoundments will be designed to meet MESA standards. Typical dams would have a 2.5 to 1 (horizontal to vertical) minimum upstream slope and a 20-foot minimum width roadway, and on the downstream side a minimum slope of 2:1. Vegetation would be used to control erosion. The freeboard on the dams would be a minimum of 5 feet. The dams will be constructed of local earth materials of low permeability when compacted with internal blanket drains installed on the downstream side as required.

I. Proposed Mining Procedures

Westmoreland Resources would excavate the coal by area strip mining. First the topsoil suitable for use in reclamation is removed and stockpiled or redistributed on regraded spoils by a fleet of scraper-type earthmovers. Overburden is drilled with electric-powered, track-mounted rotary drills which make 9-to-15-inch blastholes whose pattern and spacing are dictated by the physical characteristics of the overburden material. The holes are loaded with detonators and an explosive consisting of 94 percent ammonium nitrate and 6 percent fuel oil. The explosive charges are then detonated in a predetermined fashion designed both to efficiently fragment the rock and to minimize damaging ground vibrations.

A large walking dragline removes overburden above the uppermost minable seam of coal, which may be the stray S-1 or the Rosebud-McKay. The overburden is placed into a previously mined area, or onto the ground surface in the case of an initial cut. The dragline removes the stray S-1 where appropriate and places it on the unmined area adjacent to its position to be hauled to the processing facilities, then removes additional overburden to the top of the Rosebud-McKay seam and places the overburden with the previously displaced material. The top of the Rosebud-McKay is cleaned by bulldozers. The coal is then drilled and blasted in much the same manner as the overburden.

Rubber-tire front-end loaders then load the coal into bottom-dump trucks to be hauled to the processing plant.

Bulldozers and scrapers uncover the stray S-2 seam, which is removed and hauled by truck to the processing plant. The interburden overlying the Robinson is drilled, blasted, removed by a dragline, and placed on previously emplaced spoils. The Robinson is then drilled, blasted, and removed. The cycle then repeats in a new cut, and the new spoils are placed in the old cut. Figure 8 is a generalized cross section through the pit showing spoil placement.

To increase the production at the mine, one additional dragline would be obtained. This machine would have a 110-cubic yard bucket and would be erected during 1977 and 1978. Additional equipment to be obtained is listed below:

Equipment Type	Number of Units
Bulldozers	7-10
Scrapers	4-6
Overburden drills	1
Coal drills	1
Front-end loaders	4-6
Haulage trucks	4-6

J. Reclamation Plan

Westmoreland Resources would fully comply with all applicable laws and regulations relating to the reclamation of mined land. The operator

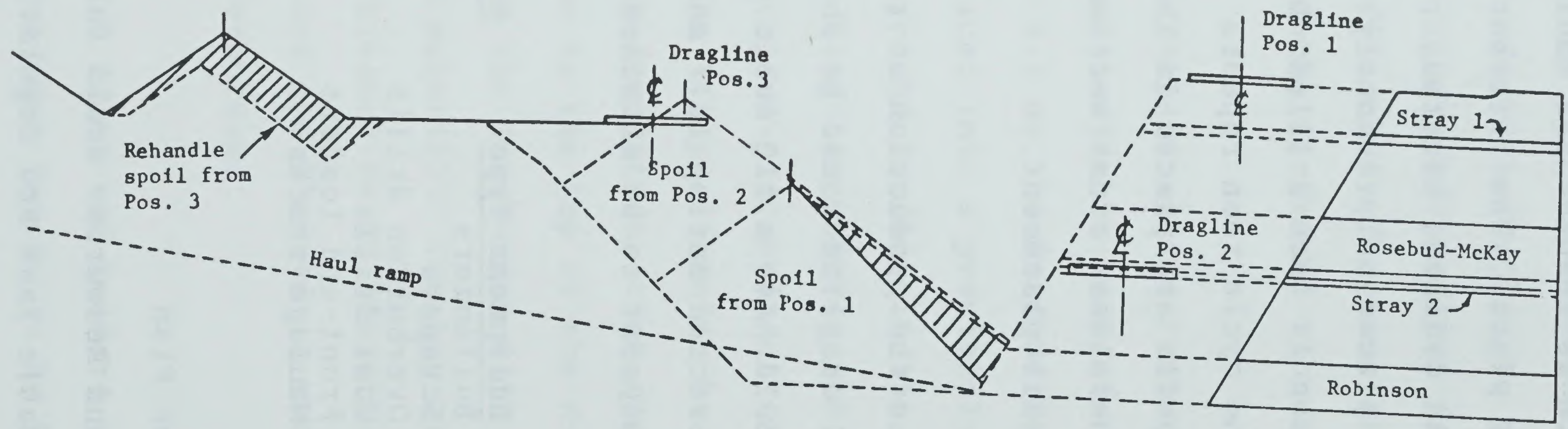


Figure 8. Generalized cross-section through mine pit.

also anticipates that regulations will change as knowledge of reclamation procedures increases.

Reclamation of mined lands begins before mining activity when topsoil is removed. Soil borings and tests indicate the depth of material suitable for plant growth, and all such soil will be removed. Wherever possible, the newly removed topsoil will be transported directly to recontoured spoils to prevent degradation of the soil and multiple handling. Otherwise, the topsoil will be stockpiled and seeded to retard erosion.

The spoil piles are reformed concurrently with the mining operation at a distance of two piles from the working area. Earthmoving equipment reduces the spoil piles to slopes of 5:1 or less, and will leave the landscape free of water impoundments. At the conclusion of all mining operations, the final highwall will be regraded to a 3:1 slope.

Westmoreland Resources expects to sample and test the spoils prior to the application of topsoil.

Parameters to be investigated include pH, conductivity, exchangeable sodium percentage, particle size distribution, and selected trace elements where drill core testing has indicated possible problems. Toxic or otherwise unsuitable spoils will be adequately buried with other material.

The operator will adequately prepare the spoil surface prior to application of topsoil. Such preparation normally includes discing to roughen the surface and relieve compaction. Topsoil is to be rotated directly onto fresh spoils whenever possible, and will be emplaced in fall or early spring to facilitate seeding and take advantage of seasonal moisture.

Westmoreland Resources will analyze the topsoil for nitrogen, phosphorus, and potassium in order to calculate fertilizer requirements. The topsoil surface will be disced prior to seeding. The seeds will be planted by drill seeding or broadcasting.

As soon after emplacement of topsoil as possible in the fall or spring, seed mixtures of native and introduced grasses, forbs and legumes as recommended or approved by the Montana Department of State Lands will be utilized. The following is the currently utilized seed mixture recommended by Mr. J. A. Olsen, Soil Scientist, Soil Conservation Service, who is currently working with the Reclamation Division of MDSL:

Western Wheatgrass	4 lbs/acre
Bluebunch or Whitmar Beardless Wheatgrass	3 lbs/acre
Side-oats grama	2 lbs/acre
Little Bluestem	1 lb/acre
Green Needle grass	3 lbs/acre
Blue grama	1 lb/acre
Thickspike Wheatgrass	2 lbs/acre
Four-wing Saltbush	Trace
Hard Fescue	1 lb/acre
Kentucky Bluegrass	2 lbs/acre
Pubscent Wheatgrass	1 lb/acre
Yellow Sweetclover	2 lbs/acre
Eskci Sainfoin	1 lb/acre
Total	23 lbs/acre

Trees and shrubs will be selectively planted. It is anticipated that the best ecological situation for shrub plantings may be along drainageways, while ponderosa pine plantings may be best suited to upper north facing slopes. The planting of woody plants will require considerable experimentation since it is anticipated that the uniformly deep topsoil gives herbaceous plants the competitive advantage.

Since fresh topsoil will be used where possible, plant growth from living roots, rhizomes, and seeds is expected to provide an important genetically adapted source of revegation.

Vegetation sampling will be conducted annually in reclaimed areas so that the progress of revegetation can be quantatively evaluated. Parameters to be measured include canopy coverage, height growth, herbage yield, and percent of survival (woody species). This information will provide a basis for comparing different reclamation treatments so that in future work the most successful procedures can be utilized.

The operator would regrade the spoil to the approximate original surface configuration. Reclamation will necessarily entail the reestablishment of a drainage pattern in the mined area. The anticipated configuration of reclaimed land and the new drainage pattern are shown in Figure 9. The spoil contours are matched with the natural contours at the boundary of the mined area. The drainages on the reclaimed land are less contorted than similar natural drainages, but nevertheless are adequate for the area. The artificial

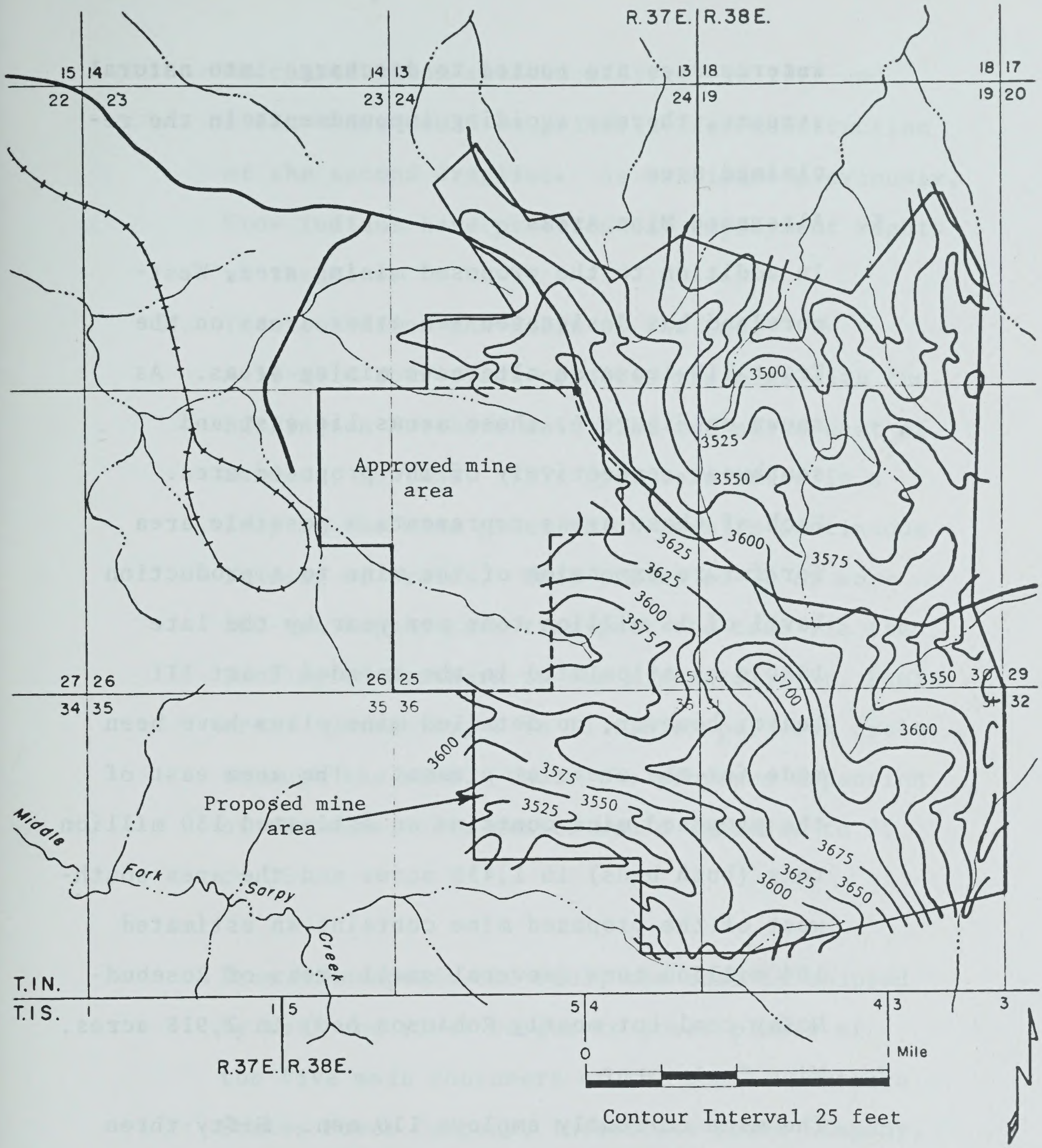


Figure 9. Estimated post-mining topography of the proposed mine area. Adapted from Westmoreland Resources, 1975 p, Exhibit 15.

watercourses are routed to discharge into natural streams, thereby avoiding impoundments in the reclaimed area.

K. Alternate Mine Areas

In addition to the proposed mining area, Westmoreland has designated two other areas on the Tract III lease as alternate mining areas. As shown on Figure 6, these areas lie east and southwest respectively of the proposed area. Each of these areas represents a possible area for future expansion of the mine to a production level of 15 million tons per year by the late 1980's as stipulated in the amended Tract III lease; however, no detailed mine plans have been made for the areas at present. The area east of the proposed mine contains an estimated 130 million tons (both beds) in 1,439 acres and the area southwest of the proposed mine contains an estimated 104 million tons (several small areas of Rosebud-McKay coal but mostly Robinson bed) in 2,918 acres.

L. Mine Employment

The mine currently employs 110 men. Fifty-three of these employees are members of the Crow Tribe. This figure would rise to 210 men by 1981 when the full 10-million-tons-per-year production is reached. In addition, 50 men would be employed on construction-related activity in 1977 and 1978. This would be primarily for construction of the second dragline. As mentioned previously, Crow Indians have preferential employment rights at the mine.

M. Transportation and Sales of the Coal

A 36-mile spur track connects the mine with the Burlington Northern main line two miles west of Sanders, Montana. This spur terminates in a loop at the mine plant which permits continuous loading of trains. Unit trains of 70 or more 100-ton hopper cars transport the coal via the Burlington Northern to the Minneapolis-St. Paul area. Currently, 9 to 11 trains per week cycle through the mine. Under the proposed expansion of the mine, this number would increase to 20 to 25.

From Minneapolis-St. Paul, the coal is shipped by rail and river barges to power plants of the five main consumers of the coal: Northern States Power Company, Interstate Power Company, Dairyland Power Cooperative, Wisconsin Power and Light Company, and Central Illinois Light Company. Westmoreland has 20-year contracts to deliver a total of 77 million tons to these five utilities.

Test shipments have been sent to Detroit Edison and United Power Cooperative. All the coal is currently used for electric power generation. The following table shows the power stations presently receiving Westmoreland coal:

Power Company	Station	Location	Mode of Delivery
Northern States Power Company (1,900,000 tons)	Riverside	Minneapolis, Minn.	rail
	Highbridge	Minneapolis, Minn.	rail
	Sherburne	No. of Minneapolis	rail
	Black Dog	So. of Minneapolis	barge
	King	St. Croix River	barge
Central Illinois Light Company (1,000,000 tons)	Edwards	Summer, Illinois	rail
	Wallace	Peoria, Illinois	rail
Interstate Power Company (300,000 tons)	Dubuque	Dubuque, Iowa	barge
	Kapp	Clinton, Iowa	barge
	Fox Lake	Minneapolis, Minn.	rail
Wisconsin Power and Light Co. (300,000 tons)	Genoa	Genoa, Wisconsin	barge
Dairyland Power Cooperative (500,000 tons)	Alma	Alma, Wisconsin	barge

II. DESCRIPTION OF THE ENVIRONMENT

A. Description of the area

The area of Westmoreland Resources Tract III proposed for mining encompases about 2151 acres located in parts of Sections 24, 25, and 36, T.1 N., R.37 E, and Sections 19, 30, and 31, T.1 N., R.38 E., Big Horn County, Montana. The area adjoins on the east the presently operating mine and facilities in Section 25 and 26, T.1 N., R.37 E.

The proposed mine site lies astride a ridge that is the divide between the valley of Sarpy Creek on the west, East Fork Sarpy Creek on the northeast, and Middle Fork Sarpy Creek on the southwest. The highest parts of the ridge are about 300 feet above the bordering valleys with the land sloping toward the valleys and in general direction west of north. The land is gently rolling with frequent groves of ponderosa pine interspersed with open rangeland and fields used for dryland grain crops.

Access to the area is by County road 384 from Hardin, Montana, about 26 miles to the west (20 miles pave, 6 miles gravel), and from Hysham about 30 miles to the north by gravel road. The county road from Hardin passes through the proposed mine area and serves farms and ranches to the east.

A spur line of the Burlington Northern Railroad running southward about 36 miles from a main line near Sanders, Montana, serves the presently operating mine. The spur terminates in a loading loop in Section 26, about one mile west of the proposed mine area.

B. Climate

Data Sources

Meteorlogical data from three stations are presented herein as a best estimate of long-term meteorological conditions at the Sarpy Creek site. These include the Billings airport (Logan Field), located 75 miles west of the Project area; the Miles City Municipal Airport, located 65 miles northeast of the project area; and the cooperative weather station at Colstrip, located 15 miles east-northeast of the project area. Additionally, evaporation data from Terry, located about 105 miles northeast of the project area,have been included. Short-term recent data from Colstrip were used to the extent possible because of the proximity of Colstrip to the Sarpy Creek area and the similarities between the two locations with regard to elevation, surrounding terrain, and general airshed characteristics.

Also included are summaries of data collected at the Sarpy Creek project area. However, due to the short collection period, the data were not used extensively for developing conclusions regarding the climate of the Sarpy Creek area. Appendix A contains descriptions of the monitoring program in operation in the Tract III area.

Total Precipitation

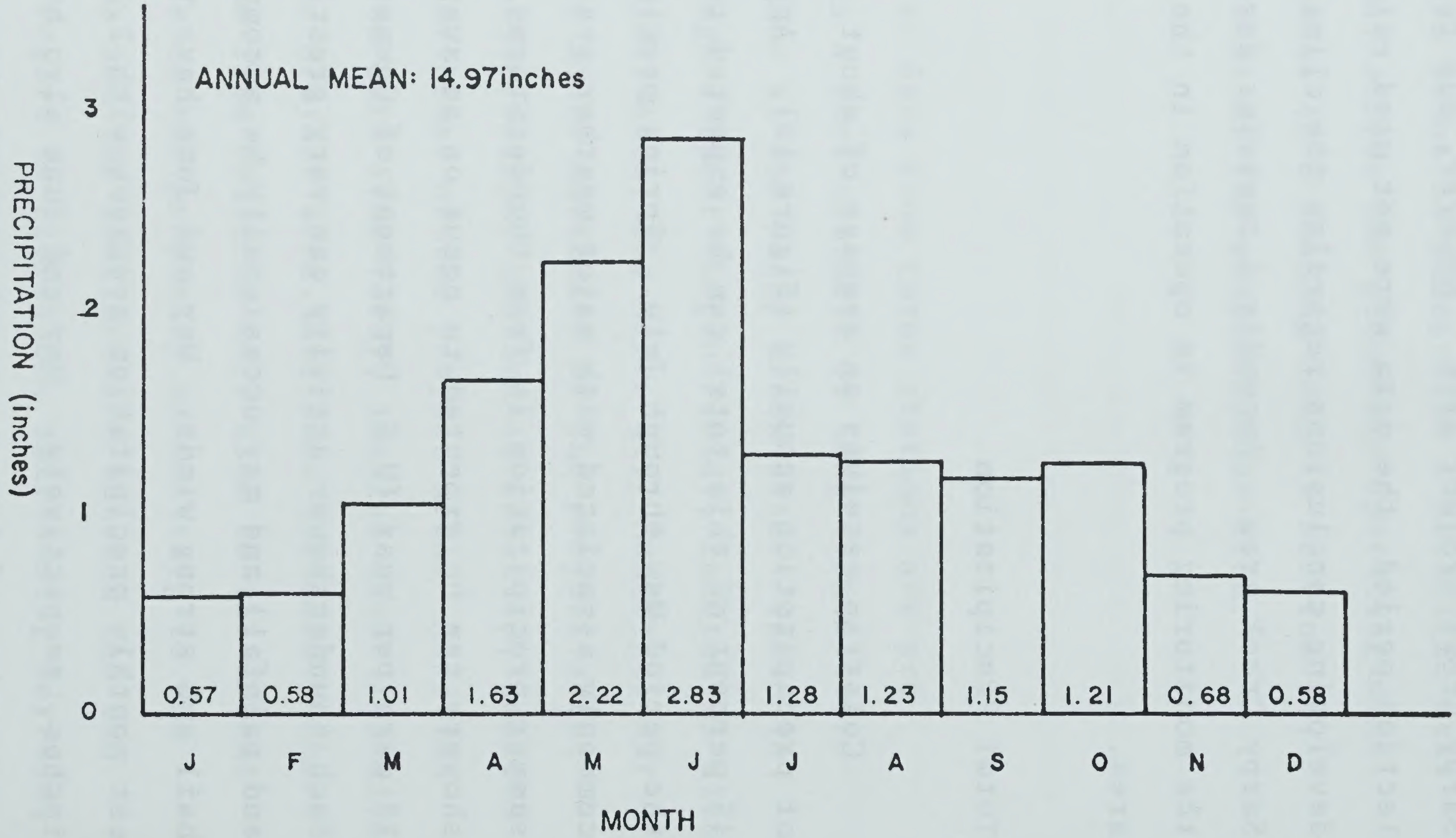
Colstrip receives an average of about 15.0 inches of precipitation annually (Figure 10). Approximately 45 percent of this total can be expected to fall during the period May through July. Spring precipitation is commonly associated with major weather systems while summer precipitation is from thunderstorms. Thundershowers can be expected to occur on an average of about 30 days per year (U.S. Department of Commerce, 1974 b). Such thundershower activity can vary greatly in extent and rainfall and may occasionally be accompanied by hail and strong winds. May and June have the two highest monthly precipitation averages with 2.22 and 2.83 inches, respectively. May and June also have the highest mean number of days on which precipitation totals amounting to 0.10 inch or more are likely to occur (Table 1, Appendix A). Twenty-four hour precipitation totals of

FIGURE 10

MEAN MONTHLY TOTAL PRECIPITATION[a]

COLSTRIP, MONTANA[a]

(FROM U.S. DEPARTMENT OF COMMERCE, 1965)



[a] BASED ON RECORDS FROM 32-34 YEARS PRIOR TO AND INCLUDING 1960

0.50 inch or more are typically more numerous in June than in any other month. In fall, thundershower activity occurs less frequently, and general rain or snow systems of Pacific or arctic origin become the dominant storm feature (U.S. Department of Commerce, 1965).

On-site total precipitation data that were collected from April 16, 1975, through November 30, 1975, in the Sarpy Creek area are summarized in Table 2, Appendix A. This table shows the total daily precipitation for the period of record as well as the monthly totals. The total for the 7 1/2 months of record was 12.21 inches.

The National Oceanographic and Atmospheric Administration (NOAA) has calculated the estimated return periods for various precipitation events. Representative data for the Sarpy Creek area are presented in Table 3, Appendix A.

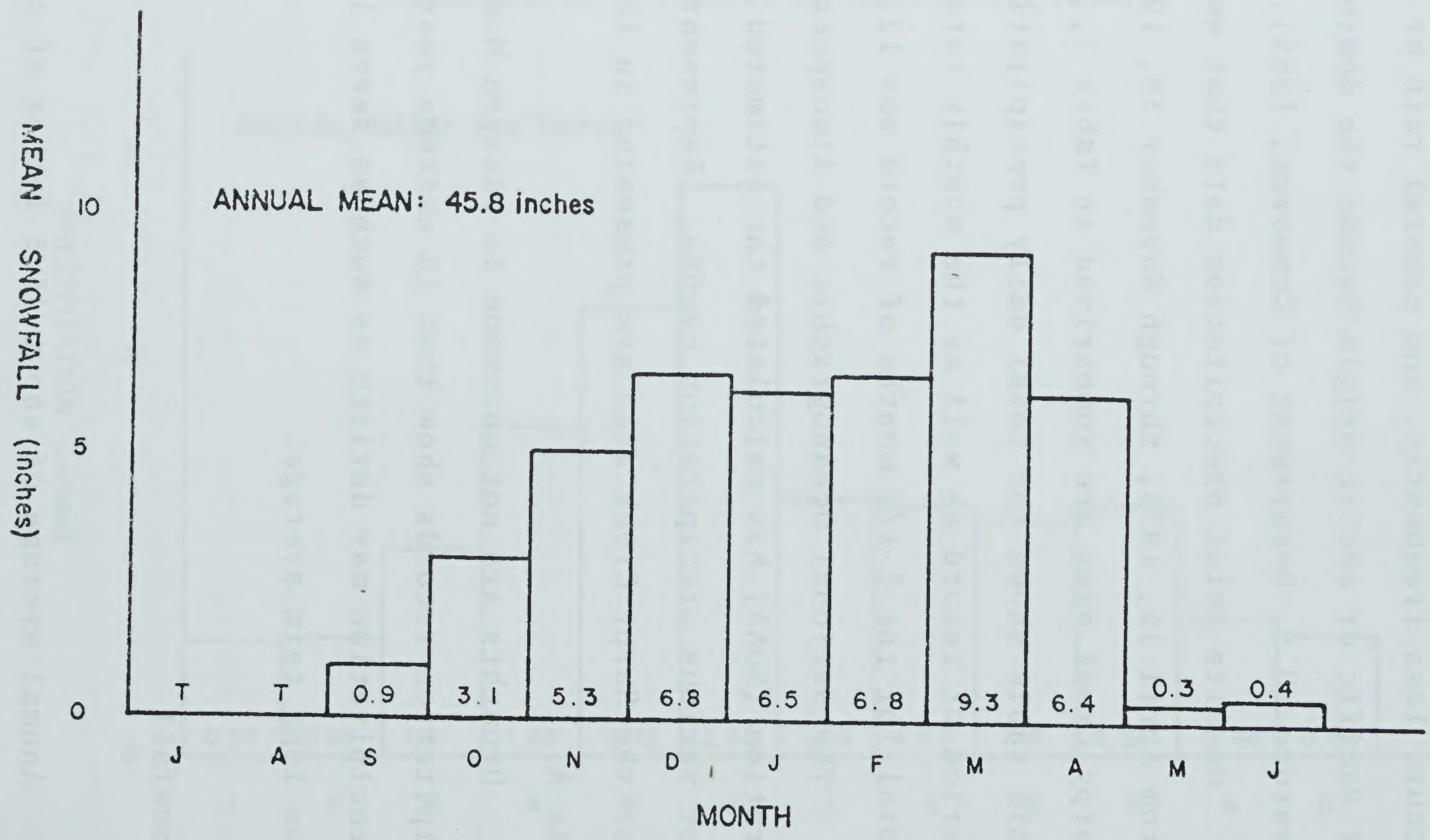
Droughts are not uncommon in eastern Montana. Precipitation records show that in extreme years, annual precipitation may deviate as much as seven inches from the long term average.

Snowfall

Annual average of about 45.8 inches of snow was recorded at Colstrip during a 26-29 year period prior to and including 1960 (Figure 11). March has the highest

FIGURE 11

MEAN MONTHLY SNOWFALL
COLSTRIP, MONTANA[a]
(FROM U.S. DEPARTMENT OF COMMERCE, 1965)



[a] BASED ON RECORDS FROM 26-29 YEARS PRIOR TO AND INCLUDING 1960

average snowfall, 9.3 inches, followed in order by February, December, January, and April with averages of 6.4 to 6.8 inches (U.S. Department of Commerce, 1965).

Storms of either Pacific or arctic origin can bring snow to eastern Montana. Pacific storms tend to deposit only light amounts of snow because they lose much moisture in their passage over the Cascade and Rocky Mountain ranges. The exception is when a low pressure distrubance passes eastward through Wyoming, thus creating upslope conditions in eastern Montana, which may result in moderate to heavy snowfall.

Arctic storms from the north are not uncommon in winter. However, because of their continental origin, they also tend to deposit only light amounts of snow except in local areas on the north, northeast, and east slopes of mountain ranges where the upslope effect is greatest. Despite the typically light amounts of snowfall associated with these polar outbreaks, strong northerly or northeasterly winds are likely to cause blizzard conditions with moderate to severe drifting and blowing snow.

Measurable amounts of snow have been recorded at Colstrip as early as September and as late as June. Snow does not ordinarily accumulate to great depths due to occasional periods of thawing weather throughout the winter.

No extreme snowfall data were found for Colstrip. However, at Billings the maximum 24-hour snowfall recorded during 39 years prior to and including 1973 was 23.7 inches in April, 1955, and the maximum monthly total was 42.3 inches in the same month. In general, snowfall is heavier at Billings than in the Sarpy Creek area and hence, these maximum figures should not be considered as necessarily representative of the area (U.S. Department of Commerce, 1974 a).

Evaporation

Evaporation data from Terry are presented in Table 4, Appendix A. These data, based on 5-10 years of records through 1960, indicate than an average of about 40 total inches of evaporation can be expected during the months of May through September. Evaporation data are obtained from exposed pans of water and, therefore, data are not available from October through April because of frequent periods of below-freezing weather (U.S. Department of Commerce, 1965).

On-site evaporation data collected at the Absaloka Mine are presented in Table 5, Appendix A, which lists the weekly and cumulative evaporation amounts for the period of April 25, 1975, through November 7, 1975. A total of about 23.8 inches of evaporation was recorded at the site during the four-month period.

Sky Cover

Sky cover data for the Billings area is presented in Table 6, Appendix A. These data indicate that cloudy days are most likely to occur in winter, whereas clear to partly cloudy days are most common in summer and early fall (U.S. Department of Commerce, 1974 a).

Incoming Solar Radiation

Weekly solar radiation data collected at the Sarpy Creek site are presented in Table 7, Appendix A. As would be expected, the highest figures tended to occur during June and July when days were relatively long and daytime cloudiness was minimal. The lower figures are indicative of shorter days or periods of increased cloudiness.

Fog

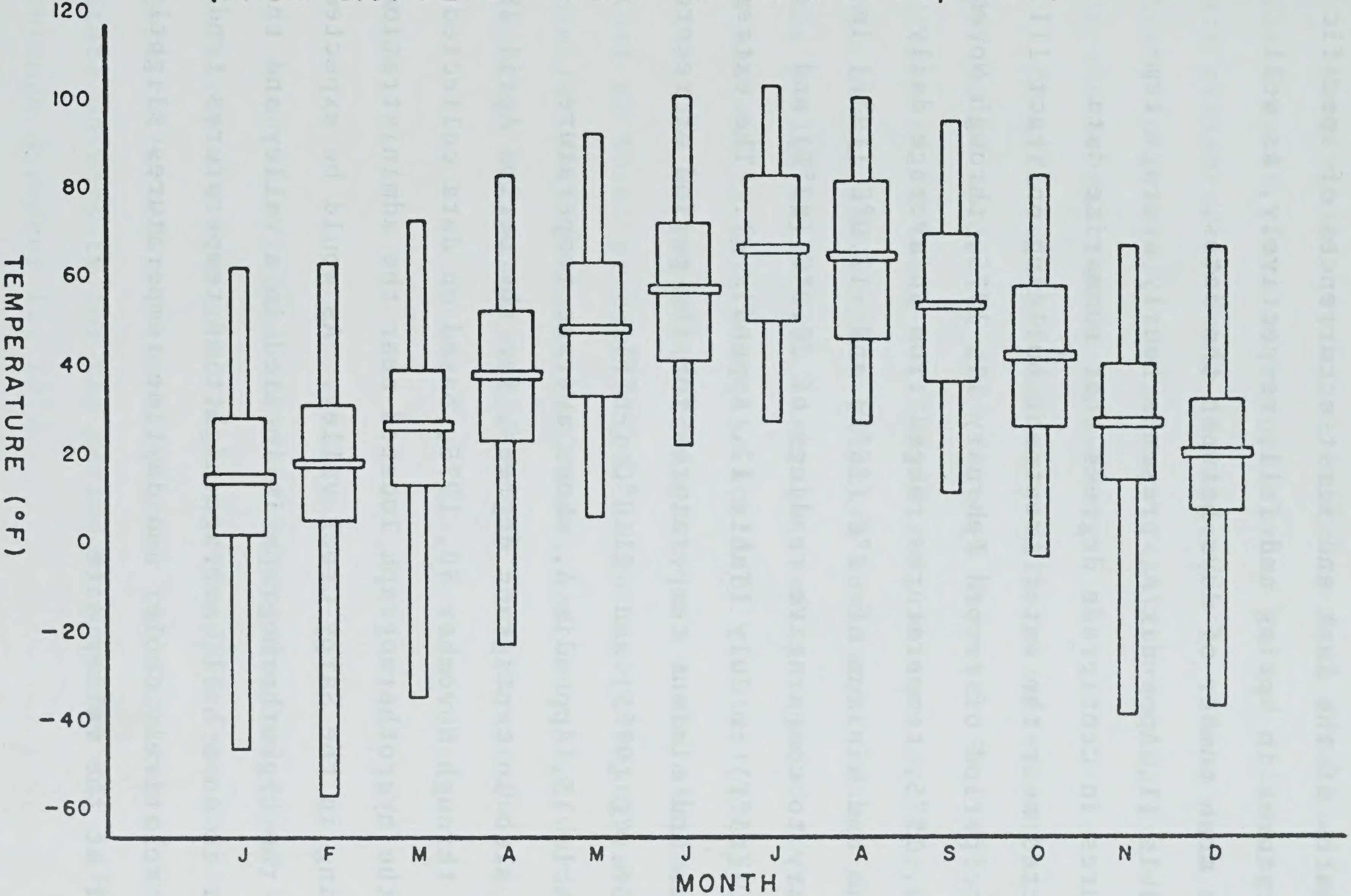
Heavy fog that reduced visibility to 1/4 mile or less is rather uncommon in most of eastern Montana. Data from Billings and Miles City show that heavy fog occurs on an average of less than 20 days per year at each location (Table 8, Appendix A).

Temperature

Temperature data from Colstrip are presented in Figure 12, which is diagramed to show the mean daily maximum and minimum, and extreme high and low temperatures for each month. All data are based on records from a 28-29 year period prior to and including 1960. This diagram shows that temperatures at Colstrip ranged, during the period of record, from as low as -50°F to as high as 110°F. July and August are typically the warmest months, averaging 17 to 14 days, respectively, when the temperature reaches or exceeds 90°F (Table 9, Appendix A). The daily maximum can be expected to reach or exceed 90°F on an average of about 39 days per year. The temperature can be expected to drop to 32°F or lower nearly every day in December, January, and February and on an average of about 181 days per year (U.S. Department of Commerce, 1965).

FIGURE 12

MONTHLY MEANS AND EXTREMES IN TEMPERATURE
COLSTRIP, MONTANA[a]
(FROM U.S. DEPARTMENT OF COMMERCE, 1965)



	J	F	M	A	M	J	J	A	S	O	N	D
MAXIMUM	69	70	80	90	99	108	110	107	102	90	74	74
MEAN MAX.	34.6	37.5	45.5	59.4	70.3	78.5	90.2	88.5	77.1	64.6	47.2	39.1
MEAN	21.5	24.6	32.6	44.8	55.1	63.5	72.7	70.5	59.8	48.6	34.3	26.6
MEAN MIN.	8.5	11.8	19.8	30.2	39.7	48.3	54.9	52.5	42.6	32.6	21.3	14.2
MINIMUM	-40	-50	-28	-16	13	29	34	34	18	4	-32	-30

[a] BASED ON RECORDS FROM 28-29 YEARS PRIOR TO AND INCLUDING 1960

Freeze data from both Billings and Miles City are presented in Table 10, Appendix A. This table shows the mean dates of the last and first occurrences of specific temperatures in spring and fall, respectively, as well as the mean number of days between the dates.

Table 11, Appendix A, presents hourly average temperatures in centigrade degrees that summarize data collected near the water treatment building on Tract III. For the period of record February 11, 1975, through November 30, 1975, temperatures ranged from an average daily maximum and minimum of -2°C (28°F) and -12.0°C (10°F) in February to comparative readings of 28.0°C (82°F) and 17.5°C (63°F) in July (Table 12, Appendix A). The extreme maximum and minimum temperatures for the period of record were 36.0°C (97°F) and -21.0°C (-6°F).

Table 13, Appendix A, shows average temperature data, also in centigrade degrees, for the period April 19, 1975, through November 30, 1975, based on data collected from the hygrothermograph located near the administration building in the Sarpy Creek valley. As would be expected, since the hygrothermograph is located in a valley and the sensor is on a hill, average nighttime temperatures tend to be relatively cooler and daytime temperatures slightly warmer at the valley site.

Relative Humidity

Mean monthly relative humidity data from Billings, based on 14 years of records prior to and including 1973, are presented in Table 14, Appendix A. These data show that, in general, the average relative humidity is highest in winter and lowest in summer.

On-site relative humidity data collected during the period of April 19, 1975 through November 30, 1975, are presented in Table 15, Appendix A, which lists the average hourly and monthly relative humidity readings for the period of record. Average readings tended to reach a maximum in May, also the month of greatest precipitation, and decrease toward August in a trend similar to that of total precipitation. Nighttime readings were similar during April, May, June, and July, but daytime readings decreased significantly from May to July.

Wind

Wind data from a 307-foot meteorological tower at Colstrip are presented herein. The data from Colstrip were collected and compiled under the auspices of Montana State University for the period of November 12, 1971, through November 11, 1972.

The data from Colstrip indicate that winds 307 feet above the ground blow more often from the northwest than any other quadrant (Figure 13). Westerly through northwesterly winds prevail during all months of the year except August, September, and October during which southeasterly winds were most prevalent. Average monthly wind speeds ranged from 9.4 miles per hour in November to 15.6 miles per hour in March with an annual average of 12.1 miles per hour (Environmental Systems, 1973).

Wind direction, frequency, and average speed data collected near the water treatment building at the Absaloka mine are summarized in Tables 16 and 17, Appendix A, respectively. In general, the highest percentage frequencies of wind direction occurred with winds out of the south-southeast through west-northwest, although the single most common direction varied from month to month. Average wind speeds also varied greatly by direction from month to month, although for the period of record, as a whole, the highest average wind speeds were associated with winds out of the west through northwest. The average wind speed for the entire period was 8.3 miles per hour.

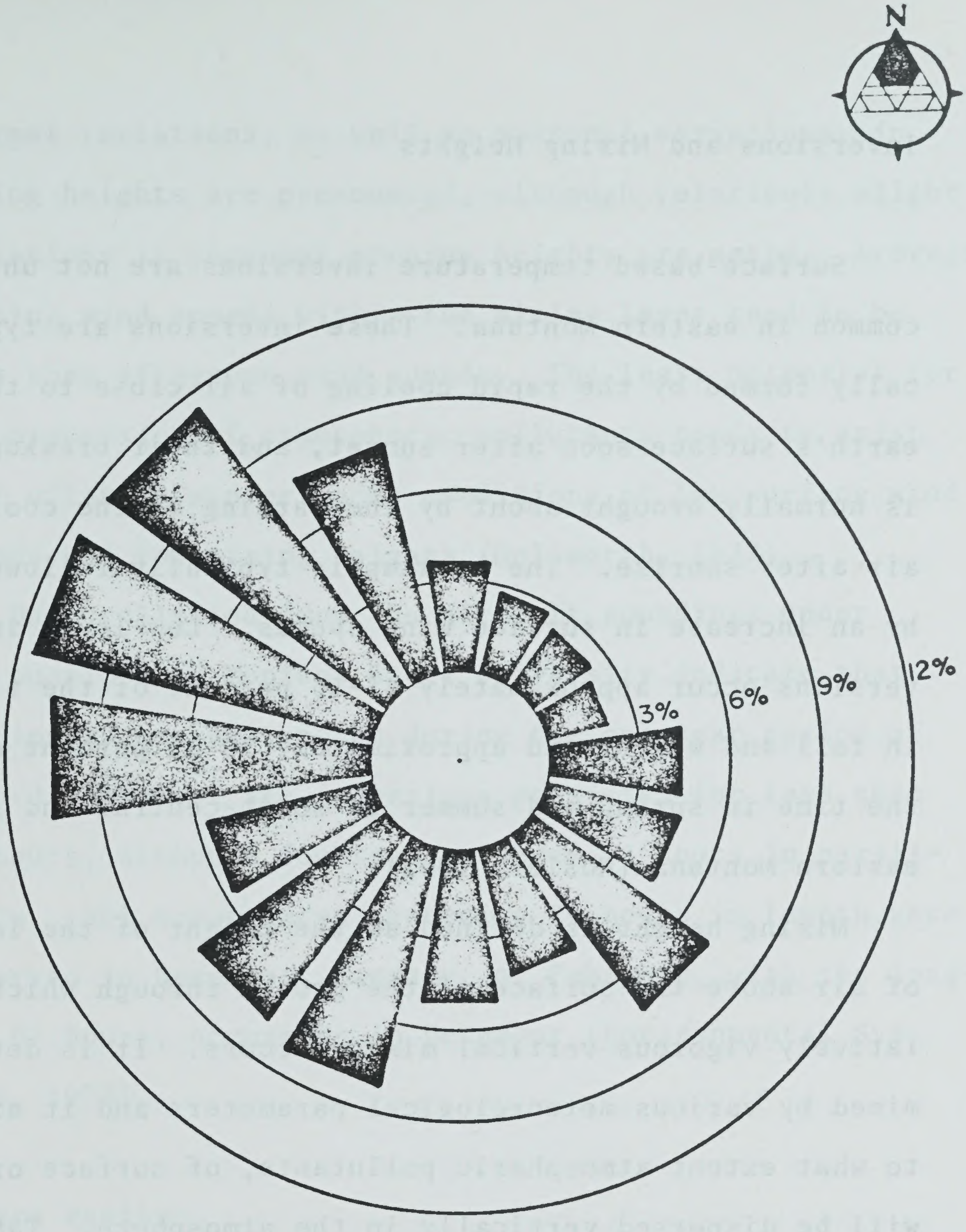


FIGURE 13

ANNUAL PERCENT FREQUENCY
OF SURFACE WIND DIRECTION

ALL STABILITY CLASSES

COLSTRIP, MONTANA
NOVEMBER 12, 1971 - NOVEMBER 11, 1972

(FROM ENVIRONMENTAL SYSTEMS, 1973)

Inversions and Mixing Heights

Surface-based temperature inversions are not uncommon in eastern Montana. These inversions are typically formed by the rapid cooling of air close to the earth's surface soon after sunset, and their breakup is normally brought about by the warming of the cool air after sunrise. The breakup is typically followed by an increase in surface wing speeds. Low-level inversions occur approximately 45-50 percent of the time in fall and winter and approximately 30-35 percent of the time in spring and summer in south-central and southeastern Montana (Hosler, 1961).

Mixing height is defined as the height of the layer of air above the surface of the ground through which relatively vigorous vertical mixing occurs. It is determined by various meteorological parameters and it affects to what extent atmospheric pollutants, of surface origin, will be dispersed vertically in the atmosphere. Table 18, Appendix A, presents a summary of mixing depths data collected from aircraft soundings taken above the Colstrip area by Montana State University personnel from November 12, 1971, through November 11, 1972. Table 19, Appendix A, presents data related to mixing heights in southeastern Montana as determined by Holzworth (1972). The diurnal variations, as well as seasonal variations, in mixing heights are pronounced, although relatively slight variations in seasonal morning heights are noted. Average morning wind speeds within the mixing layer tend to be less than afternoon wind speeds. The least potential for the dispersion of atmospheric pollutants tends to exist most often in winter under conditions of low surface wind speeds and low mixing heights (Holzworth, 1972).

Data collected from the aircraft soundings under the auspices of Montana State University indicate that 215 inversions were noted during the one-year period of record. Most of the inversions persisted for less than 24 hours, although fourteen exceeded 24 hours in persistence. All occurrences exceeding 24 hours in length were observed in December, January, or February, with the longest 67 hours, occurring in December (Environmental Systems, 1973).

Severe Weather

During the 54-year period from 1916-1969, 103 tornadoes were reported in Montana, mostly in the eastern third of the state and mostly in open country. Damage from these storms totaled about $1,750,000. The incidence of tornadoes is limited almost entirely to late spring and summer (Cordell, 1971).

Thom (1963) has developed a method whereby using the number of tornadoes observed in a 1° latitude by 1° longitude area during some ten-year period, one can estimate the point probability of occurrence of a tornado within the specified area, as well as an associated recurrence interval. During the period 1963-1972, four tornadoes were reported in Treasure County, two in Big Horn County, and none in Rosebud County. Therefore, conservatively assuming the occurrence of four tornadoes during the ten-year period of record in a one-degree square centered on the project area, it can be expected that the probablility of occurrence of a tornado at any given point is about 3.4×10^{-4}. The recurrence interval should be about 3000 years (Environmental Systems, 1973).

Thom (1968) also has developed a method for determining the mean recurrence interval for high winds as measured 30 feet above the ground. The results of this analysis for the southeastern region of Montana are presented in Table 20, Appendix A. Local high winds associated with thunderstorm activity are not uncommon in spring and summer.

Hailstorms are typically the most common and damaging form of severe weather in Montana. Limited mainly to July and August, hailstorms cause crop and property damage amounting to about $5 million annually (Cordell, 1971).

Because Montana is sufficiently distant from any sources of tropical moisture, the probability of occcurrence of a tropical storm is virtually zero. However, moisture of tropical origin may occasionally affect the area, especially in late spring and summer.

Blizzards which are a relatively common occurrence in Montana in winter bring high winds, extreme cold temperatures, and varying amounts of snow to the high plains of eastern Montana. Blizzard conditions seldom last longer than two to four days. However, even when blizzard conditions end, strong surface winds may create ground blizzards for an extended period of time. Nightime surface temperatures may drop to 30° to 50°F below zero following the passage of such storms. The combination of severe drifting and frigid temperatures can cause hardship for both humans and animals (U.S. Department of Commerce, 1974 b).

Ice storms may occur when rain falls from a warm layer of air through a shallow layer of cold air and freezes upon contact with objects on the ground. The frequency of such an occurrence is about three to six times per year. The thickness of accumulated ice on any surface can be expected not to exceed 1/4 inch (Environmental Systems, 1973).

Diffusion Climatology

The National Climatic Center in Asheville, North Carolina has computer processed and reformatted surface wind data from both Billings and Miles City for the period of January, 1967 through December, 1971, into seasonal and annual summaries of frequency and relative frequency distributions by direction and Pasquill stability class. Tables 21 and 22, Appendix A, present the total annual relative frequency distributions for both locations. Analysis of surface wind data according to atmospheric stability is typically based upon the parameters of sky conditions, wind speed, season, time of day, net radiation, and isolation. The Pasquill stability classes are coded as follows:

A-Extremely unstable
B-Moderately unstable
C-Slightly unstable
D-Neutral
E-Slightly stable
F-Moderately stable

This coding system defines each category as follows:
a) Unstable conditions (classes A, B, and C) occur when

layers of air close to the ground undergo warming with associated low wind speeds; b) Stable conditions (classes E and F) occur when the layers of air close to the ground undergo cooling with associated low wind speeds; c) Drainage winds occur under E and F stability conditions; and d) Neutral conditions (class D) occur with cloudy and/or high wind speeds.

From the data presented in Tables 21 and 22, it is seen that at Billings and Miles City, respectively, neutral conditions prevailed about 64 to 57 percent of the time, unstable conditions a total of about 14 to 15 percent of the time, and stable conditions a total of about 21.5 and 28.5 percent of the time. All of these data are based on three-hourly observations made at Logan Field in Billings and Miles City Municipal Airport from January, 1967 through December, 1971. Annual average wind speeds associated with the stability classes are presented in Table 23, Appendix A.

II. C. Air Quality

Air quality data were collected in the vicinity of Colstrip in 1972 by the Montana State Department of Health. A summary of average 24-hour levels of particulates and SO_3 (sulfate) and monthly dustfall amounts are presented in Table 24, Appendix A.

Total suspended particulates data collected in the Sarpy Creek area are presented in Table 25, Appendix A. Station No. 1 was the temporary location of a high-volume air sampler atop the roof of the water treatment building on Tract III from February 17, 1975, through April 7, 1975. Data at this station were collected from 1300 MST through 1300 MST of the following day in approximate conformity with the EPA's Standard Sampling Schedule for 1975.

In mid-April, 1975, Station No. 1 was relocated about 100 feet south of the water treatment building and a new high-volume air sampler installed. Also, a high-volume air sampler was installed about 300 feet east-northeast of the secondary crusher (Station No. 2). This sampler was installed to obtain representative background particulates level resulting from the mine operation near the coal processing equipment.

On April 24, 1975, dustfall canisters were installed on Tract III in two locations. A third canister (Station 3) was installed approximately five miles WNW of the mine site on June 20, 1975, for the purpose of obtaining data on background levels of settleable particulates. Monthly data from these three sites are presented in Table 26, Appendix A. The higher quantity of particulates that occur in the latter sampling periods is partially due to the growth of algae in the canister.

Federal primary and secondary Total Suspended Particulate standards and the Montana Standard for 24-hour samples are 260, 150, and 200 micrograms per cubic meter (ug/m^3), respectively. The Montana standard of 200 ug/m^3 is not to be exceeded more than one percent of days a year (i.e. 3.7 days per year). Stations 1 and 2 may be considered one station since Station 2 represents a relocation of the sampler of only about 100 feet from the Station 1 location. This station is within the mine property and is generally upwind of mine operations. During the period of record, the Federal secondary 24-hour standard was exceeded only once with a reading of 205 micrograms/m^3 on 7-29-75. Station 3 was established to obtain data on suspended particulates near the coal processing equipment. As expected, suspended particulates levels were quite high on several occasions. Probable sources include the primary crusher, secondary crusher and nearby roads. The Tract II location (Station 4) was established to measure suspended particulate levels at a location removed from mine operations. Standards were not exceeded during the period of record, with values ranging from 7 to 37 micrograms/m^3.

Data on settleable particulates (dustfall) are difficult to interpret. Sites 1 and 2 were about 1.5 mi. ENE and 0.5 mi. south of the mine site, respectively. The range at Station No. 1 was from approximately 3 to 70 tons per square mile per month; at Station No. 2 the range was from somewhat less than 4 tons to nearly 91 tons per square mile per month. Station No. 3 was removed from and upwind (about 5 miles WNW) of the mine site, and was established to obtain data on background levels of settleable particulates. Values at Station No. 3 ranged from a little more than 2 tons to approximately 121 tons per square mile per month; the highest values were recorded at this location. Although interpretation is difficult due to the problem of algal growth in the canisters, the data suggest that background levels of settleable particulates in the area are quite high. Probable sources include agriculture and gravel roads.

Westmoreland Resources will be required to meet Federal and State Air Quality Standards. These standards are presented in Tables 27 and 28, Appendix A.

D. Sound

To adequately describe sound quality an ambient sound survey was conducted by Westmoreland Resources (1975 n) at four locations adjacent to Tract III. These locations are listed below and were selected to reflect the present sound climates on the site, at noise sensitive land use areas, and along the railroad spur line which is used by unit trains to transport coal from the Tract III mine site. The numbers are those used in the studies by Westmoreland Resources (1975 n).

Location 2	Sarpy Creek valley west of present mine.
Location 3	Near east boundary of Tract III along county road.
Location 4	North of Tract III, along railroad spur line in Sarpy Creek valley.
Location 5	Southwest boundary of Tract III.

The ambient sound survey was conducted at the above locations during the period July 26 to August 2, 1975. Sound level recordings were made on typical weekdays and weekends during daytime (0700-1800), evening

(1800-2200) and nighttime (2200-0700) periods. The daytime and evening periods from 0700 to 2200 hours and nighttime periods from 2200 to 0700 hours are in accordance with the daytime and nighttime periods defined by the U.S. Environmental Protection Agency. A description of the instrumentation, method of data acquisition and analysis of the ambient sound survey is presented in Appendix B.

To assess the sound levels radiating offsite due to mining operations, the survey included monitoring sound levels of various mining equipment at the currently operating mine area on Tract III. Sound level monitoring of unit train passbys on the rail spur line also was conducted.

The range of sound pressures that can be heard by humans is very large. This range varies from two ten-thousand-millionths (2×10^{-10}) of an atmosphere for sounds barely audible to humans to two thousandths (2×10^{-3}) of an atmosphere for sounds which are so loud as to be painful. The decibel notation system is used to present sound levels over this wide physical range. Essentially, the decibel system compresses this range to a workable range using logarithms. It is defined as:

$$\text{Sound pressure in decibels (dB)} = 20 \, \text{Log}_{10} \left(\frac{P}{P_o}\right)$$

Where P_o is a reference sound pressure required for a minimum sensation of hearing. Zero decibels is assigned to this minimum level and 140 decibels to sound which is painful. Thus a range of more than one million is expressed on a scale of zero to 140. P is the measured sound pressure.

The human ear does not perceive sounds at low frequencies in the same manner as those at higher frequencies. Sound of equal intensity at low frequency do not seem as loud as those at higher frequencies. The A-weighting network is provided in sound analysis systems to simulate the human ear. A-weighted sound levels are expressed in units of dBA. These levels in dBA are used by the engineer to evaluate hearing damage risk (OSHA) or community annoyance impact. These values are also used in federal, state and local noise ordinances.

Sound is not constant in time. Statistical analysis is used to describe the temporal distribution of sound and to compute single number descriptors for the time-varying sound. This report contains the statistical A-weighted sound levels:

L_{90} - This is the sound level exceeded 90 percent of the time during the measurement period and is often used to represent the "residual" sound level.

L_{50} - This is the sound level exceeded 50 percent of the time during the measurement period and is used to represent the "median" sound level.

L_{10} - This is the sound level exceeded 10 percent of the time during the measurement period and is often used to represent the "intrusive" sound level.

L_{eq} - This is the equivalent steady sound level which provides an equal amount of acoustic energy as the time varying sound.

L_d - Equivalent sound level, L_{eq}, for the daytime period (0700-2200) only.

L_n - Equivalent sound level, L_{eq}, for the nighttime period (2200-0700) only.

L_{dn} - Equivalent day/night sound level, defined as:

$$L_{dn} = 10 \text{ Log}_{10} \left[15 \times 10^{Ld/10} + 9 \times 10^{(Ln + 10)} /10/24\right]$$

NOTE: A 10 dB correction factor is added to the nighttime equivalent sound level.

A summary of ambient sound survey results for the data collected at the four monitoring locations mentioned above is presented in Table 1, Appendix B. This table contains the statistical A-weighted sound level

L_{90}, L_{50}, L_{10} and L_{eq} for each measurement period, and L_d, L_n and L_{dn} at each measurement location for both weekdays and weekends. These data represent the background ambient sound levels of the existing environment at and near the Tract III area. They were made during periods when there were no uncharacteristic activities on the site and thus, do not contain any intrusive sounds.

A summary of the average background ambient daytime (L_{d_o}), nighttime (L_{n_o}), and day/night equivalent sound levels (L_{dn_o}) which includes the present mining activity are given below.

Average Background Ambient Sound Levels in dB

Location	L_{d_o}	L_{n_o}	L_{dn_o}
2	43	43	49
3	38	32	40
4	40	39	46
5	50	41	50

Locations 2 and 5 are noise sensitive locations immediately adjacent to Tract III mining area. Sound levels at these locations are contributed to by mining activities and local traffic.

Location 3 is a noise sensitive location a considerable distance from the mining activities, such that the contribution of noise from equipment to the background ambient sound levels is less significant, the major sound sources being local activities and traffic.

Location 4 is located about 130 feet from the railroad spur line and about 270 feet from Sarpy Creek Road north of Tract III. Background ambient sound level data at this location were taken when there was no traffic on the railroad spur line and thus do not contain near field train passby noise. Sound levels are mostly due to traffic on Sarpy Creek road. During late evenings, when the background ambient sound levels are low, noise from trains traveling on the railroad trunk line near Hysham are noticeable.

Sound Sources Related to Existing Mine Operations

At the Tract III surface mining operation the following pieces of mobile equipment are in use:

1 - dragline

3 - 18-yard front end loaders

4 - 100-ton trucks

4 - tractors

1 - water wagon

1 - coal drill

3-4- scrapers

1- overburden drill

Much of this equipment is often operated simultaneously but non-continuously. To estimate the sound level radiating offsite during mining, sound level data were obtained for this equipment while it was in operation. In addition to these mobile sound sources, sound level data were obtained for stationary sound sources such as the primary crusher, secondary crusher, conveyor belt and coal cars being loaded. A summary of these data is presented in Table 2, Appendix B, which contains the statistical A-weighted sound level measured for the above mentioned mining equipment. Sound data for the mobile equipment represent near field sound radiated from the equipment while operating in their noisiest modes.

It is estimated that at the full production level of the proposed mine area the equipment sound level contribution at 1000 feet from the center of mining operations will be about 65 dB. Equivalent sound level contribution at 1000 feet from the center of the coal preparation facilities is estimated to be about 52 dB.

Trains operating between the mine area to the railroad trunk line near Hysham constitute another sound source. Sound level recordings were made during train passbys approximately 130 feet from the train at Location 4. Two sets of data were obtained, one of an empty train entering the mine area and another of a loaded train leaving the mine area. A-weighted sound level time history of train passby for empty and load conditions are shown on Figures 1 and 2, Appendix B, respectively.

The measurements of the existing railroad operations on Tract III indicate that maximum A-weighted sound levels at 130 feet from a passing loaded and empty train may reach 84 dBA and 85 dBA respectively. These passbys are of about a two-minute duration. The energy average of this sound (L_{eq}) at 130 feet for the passing loaded and empty train is 73 dB and 78 dB respectively. At a distance of 1000 feet the two-minute intrusions to background ambient sound produce an estimated daytime and nighttime equivalent sound level contribution of 48 dB (L_d) and 46 dB (L_n).

Noise resulting from the use of explosives for breaking up overburden and coal seams to facilitate their removal constitutes an impulsive sound source. During normal operation of the existing mine the frequency of blasting is about four times a week. Blasting will increase to 8-10 times per week at the 10 million ton production level. The overpressure created from blasting depends on many criteria, several which are variable. The more important ones include the following:

1. Amount of explosive detonated
2. Depth of explosion

3. Characteristics of overlying material
4. Meteorological conditions such as temperature inversion, wind direction and gradient and humidity.
5. Topography and vegetative cover
6. Distance from explosion

Measurements for these types of blasts indicated that the impulse noise levels produced might be as high as 91 dB at 1000 feet.

The overpressure created from blasting and its acoustical impact on people has been extensively studied by the U.S. Department of the Army (1). With a knowledge of the above criteria, the estimated impact of overpressures at the site can be computed.

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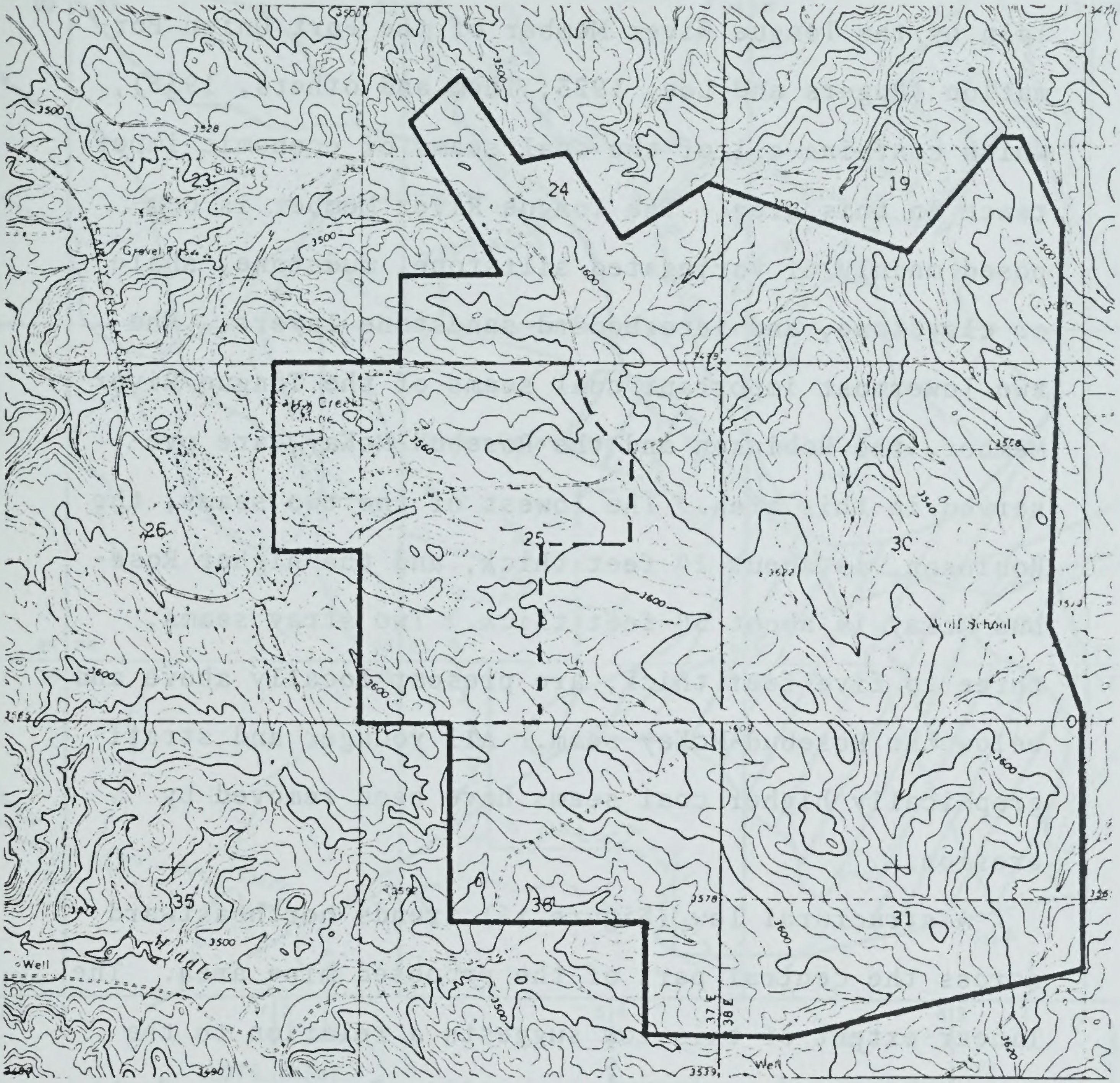
(1) "Predicting Community Response to Blast Noise" CERL Technical Report E-17, December, 1973.

E. Physiography and topography

Sarpy Creek, a northward-flowing tributary of the Yellowstone River, drains the area newly proposed for mining by Westmoreland Resources. Most of the proposed new area lies between 3,350 and 3,746 feet in altitude along a divide between the northwest-flowing East Fork and Middle Fork of Sarpy Creek, immediately east of the area presently being mined. The divide trends northwest from the southeast corner to the northwest corner of the proposed area. At the north edge of the area, a tributary of the East Fork has entrenched to about 3,410 feet above sea level, and at the south edge a tributary of the Middle Fork has entrenched to about 3,470 feet above sea level. Slopes generally are gentle and rounded, but locally are broken by sandstone ledges or cliffs. A topographic contour map of the present topography of the proposed mine area is shown on Figure 14.

Ponderosa pine crowns the higher hills along the divide crest and cover much of the headward area of a main tributary of the East Fork of Sarpy Creek, on the north side of the divide. Most of the rest of the proposed area north of the county road is hayfield. South of the county road it is mostly wheatfield or distrubed grassland (Westmoreland Resources, 1975 o, plate 2.3.1-2).



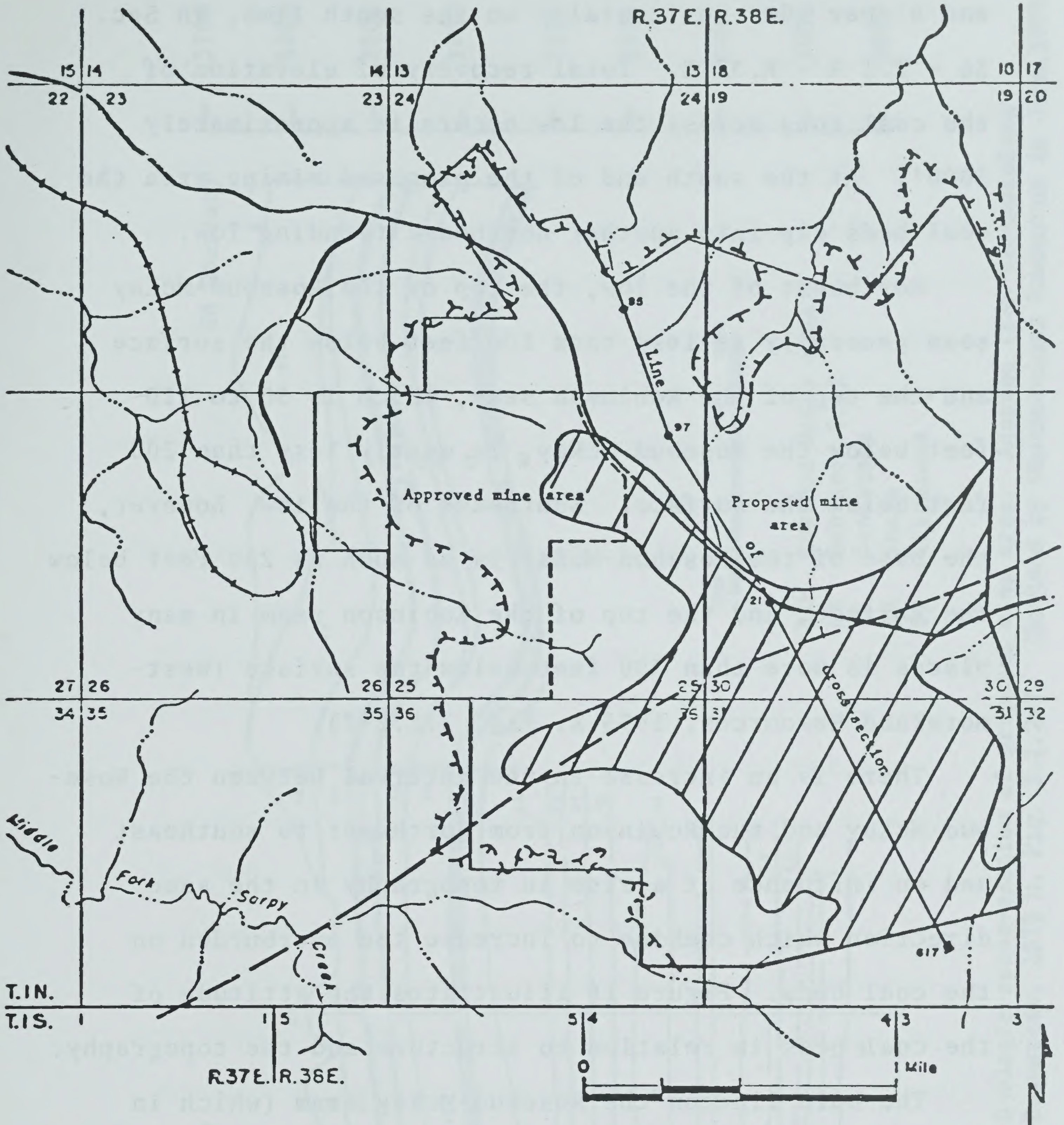
Contour Interval 20 feet

Figure 14. Pre-mining topography of proposed mine site and vicinity.

F. Geology

The entire area newly proposed for mining is underlain by the Tongue River Member of the Fort Union Formation (Rogers and Lee, 1923; Thom and others, 1935), which contains all of the coal seams of economic importance in this area. The Tongue River Member is composed mainly of variegated siltstone, mudstone, shale or claystone, and interbedded sandstone layers. The two lowermost important coal seams of the Tongue River Member, the Robinson and the Rosebud-McKay, are preserved in this area. The lowest of the two seams, the Robinson, is about 20 feet thick, and the higher Rosebud-McKay is about 30 feet thick. Two stray seams, three to five feet thick, are present locally above and below the Rosebud-McKay seam. All younger and stratigraphically higher coal seams have been removed by erosion.

A structural low (Figure 15) trends northeastward across the central part of the proposed mine area. The linear extent of this low suggests a relation to the dominant regional northeast trending fracture or fault pattern but no break in the coal beds can be demonstrated from the drilling done to the present time. Maximum structural decrease in elevation of the coal beds into the low is 10' per 100' horizontally on the north limb



Burn line of Rosebud-McKay coal.

Structural Low

Area where top of Robinson coal is more than 200 feet in depth.

Figure 15. Critical geologic aspects of the proposed mine area.

and 6' per 100' horizontally on the south limb, in Sec. 36 - T.1 N - R.37 E. Total recovery of elevation of the coal tops across the low occurs in approximately 3000'. At the south end of the proposed mining area the coal beds dip into another northeast trending low.

Northwest of the low, the top of the Rosebud-McKay seam generally is less than 100 feet below the surface and the top of the Robinson seam, which is 50 to 120 feet below the Rosebud-McKay, is mostly less than 200 feet below the surface. Southeast of the low, however, the base of the Rosebud-McKay is as much as 250 feet below the surface, and the top of the Robinson seam in many places is more than 300 feet below the surface (Westmoreland Resources, 1975 k, fig. 2.2.2-7).

There is an increase in the interval between the Rosebud-McKay and the Robinson from northwest to southeast and an influence of a rise in topography in the same direction which combine to increase the overburden on the coal beds. Figure 16 illustrates the attitude of the coal beds in relation to structure and the topography.

The burn line on the Rosebud-McKay seam (which in large part has determined the northern and southwestern boundaries of the proposed area) is mostly west of the proposed area, and intrudes along the north edge only along the valley walls of the major tributary of the

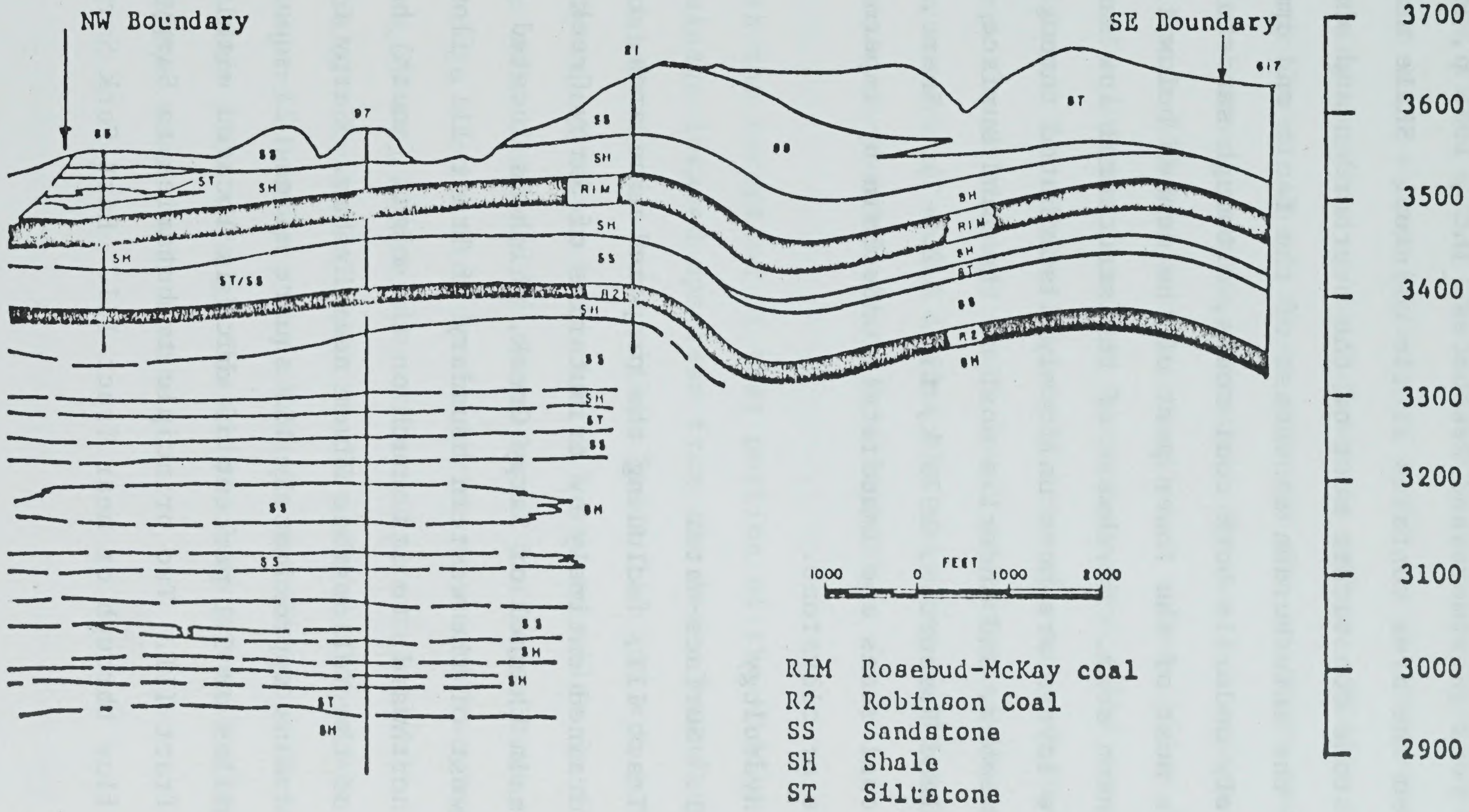


Figure 16. Geologic cross-section of proposed mine area. Adapted from Westmoreland Resources, 1975 h, Fig. 2.2.2-7. (Revised by Westmoreland Resources in June,1976)

East Fork (Westmoreland Resources, Inc., 1975 p, Exhibit 8), so the area contains little clinker. Shale and siltstone constitute most of the overburden and about half the interburden southeast of the fault and immediately underlie both coal seams, although sandstone forms most of the lower part of the member below the Robinson seam. Northwest of the structural low sandstone layers are more uniformly distributed throughout the member, and underlie most of the land surface (Westmoreland Resources, 1975 k, fig. 2.2.2-7). There, too, the coal seams are immediately underlain by impermeable shale or claystone.

G. Hydrology

1. Surface-Water

Tract III, including the proposed mine area, is drained entirely by tributaries of Sarpy Creek. The main channel of Sarpy Creek, which is located just west of the western boundary of Tract III, flows northward, to its mouth on the right (south) bank of the Yellowstone River near Hysham. Sarpy Creek drains approximately 453 square miles, 23 square miles or 5.1 percent of which is located within Tract III. Two principle tributaries to Sarpy Creek flow through or near Tract III. East Fork Sarpy

Creek flows along the northeast boundary and drains about 10.3 square miles via small local drainages varying in size up to 2.5 square miles. Middle Fork Sarpy Creek, which flows through the southern and southwestern portion, directly drains 5.5 square miles of Tract III and an additional 6.0 square miles located upstream from the lease boundary. The remainder of Tract III drains directly into the main channel of Sarpy Creek through small local tributaries including the watershed which drains the existing Westmoreland Resources Absaloka Mine development.

With the exception of that portion of the Middle Fork drainage located upstream from the lease boundary all local drainages head within Tract III and are generally equal to or less than 2.5 square miles in size. The main channels of these local drainages have average slopes from basin divide to mouth ranging from 80 to 120 feet per mile and are relatively straight in their upper reaches where slopes are steeper. However, the channels meander considerably as they flow through the wider, less steeply sloping valleys near their mouths.

Although stock ponds exist in several of the small local drainages their sizes do not impose significant regulation to surface flow. Only in the west-central portion of Tract III (Sec. 25 and 26, T.1 N., R.37 E.) has significant development and regulation of streamflow taken place. This development, Westmoreland Resources Absaloka Mine complex, is located in a single 2.4 square mile watershed which drains into a water control facility formed by the embankment of the Burlington Northern Railroad spur. The 77 acre-foot detention pond is used primarily for sediment and water quality control and affords complete regulation of surface runoff from the mine complex. Releases from this impoundment, which must meet State and Federal water quality standards, flow about 2.3 miles downstream before emptying into Sarpy Creek.

All stream channels located in local drainages within Tract III flow only intermittently as a result of runoff from excess precipitation and snowmelt. Some spring flow has been observed in the upper reaches of some of these small watersheds but is generally very small, contributes little to the overall flow, and is normally lost to evapotranspiration or infiltrates to the water table before it travels any great distance. Sustained flow has been observed, however, in channels draining larger watersheds at locations within or adjacent to Tract III. These streams include Sarpy Creek and two of its major tributaries, East and Middle Forks, respectively.

Data concerning the occurrence of surface water in the project area is limited and includes only data that has been collected since the latter part of 1973. The U.S. Geological Survey began monitoring flow in Sarpy Creek near its mouth in September 1973. In March 1975, Westmoreland Resources began collecting data at five sites on or near Tract III. These sites included two on Sarpy Creek, two on East Fork Sarpy Creek, and one on Middle Fork Sarpy Creek. Location of these sites are indicated on Figure 17, and pertinent information on the site is given in Table 2. Although no long-term surface water data have been collected in the project area, several larger streams in the vicinity have been monitored for many years. These include stations on the Bighorn, Little Bighorn, Tongue and Yellowstone Rivers in Montana and Wyoming.

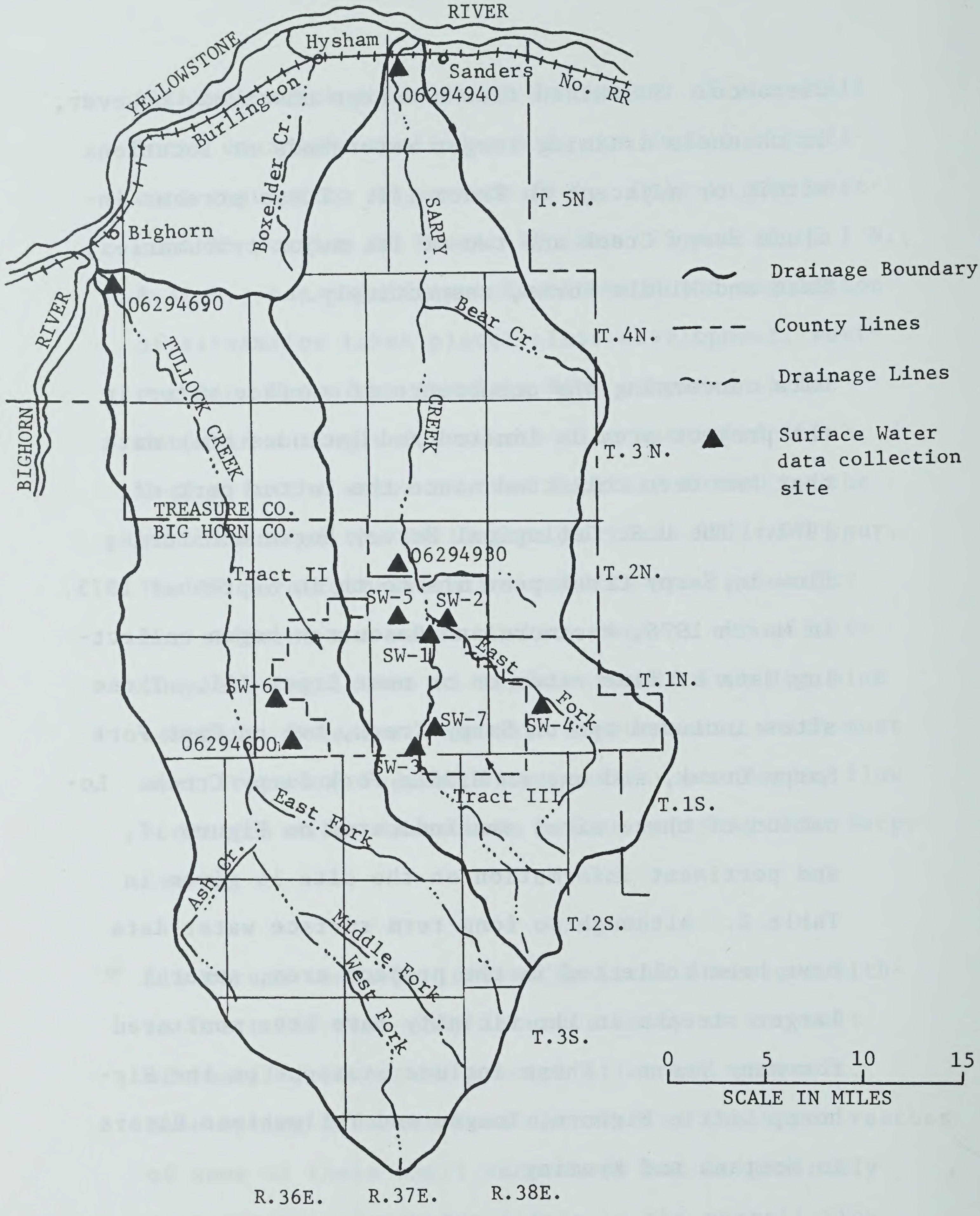


Figure 17. Map of Tullock and Sarpy Creek basins showing location of surface-water data collection sites. Modified from U.S. Bureau of Indian Affairs, 1974.

Table 2.-- List of surfaoe-water data oollection sites in the Tullock and Sarpy Creek basins.

Site ident.[a]	Stream name	Type of record	Operated by	Drainage area, in sq. mi.	Record began	Remarks
06294600	Tullock Creek trib. near Hardin	(csg)	U.S. Geol. Sur.	8.63	10/73	
06294690	Tullock Creek near Bighorn	(c)	do	446	8/74	1975 W.Y. records not available
06294930	Sarpy Creek trib. near Coalstrip	(csg)	do	4.44	10/73	
06294940	Sarpy Creek near Hysham	(c)	do	453	9/73	1975 W.Y. records not available
SW-1	Sarpy Creek above mouth of East Fork	(sg/csg)	Westmoreland Resources	76.3	3/75	
SW-2	East Fork Sarpy Creek near mouth	(c)	do	80.7	do	
SW-3	Sarpy Creek above mouth of Middle Fork	(sg/csg)	do	35.9	do	no stage-disoharge relation
SW-4	East Sarpy Creek at county road	(c)	do	55.8	do	
SW-5	Pleasant Creek	(sg)	do	7.8	do	
SW-6	Cabin Creek	do	do	6.7	do	no stage-discharge relation
SW-7	Middle Fork Sarpy Creek near mouth	do	do	11.8	do	do

a - see map (figure /7) for location; csg - annual peak flows from orest stage gage readings; c - flows from record of continuous stage; sg - periodic flows from stage readings (staff gage); sg/osg - periodio flows from staff gage readings and peak flows from crest stage gage readings.

Based on analysis of all data available and using methods discussed in Appendix C, the estimated annual unit runoff from Tract III is approximately 0.5 inches (about 27 acre feet per square mile). This is an average value and may vary by as much as 50 percent.

Base-line studies conducted by Westmoreland Resources during the period from March through November, 1975, indicate that surface-water flow in most drainages located within the project area ceases by midsummer. However, continued flow was observed on East Fork Sarpy Creek at Site 4 and Middle Fork Sarpy Creek at Site 7. Flow on East Fork Sarpy Creek at Site 2 ceased on or about August 1, indicating that the intervening channel between Sites 4 and 2 is a losing reach wherein water is lost to evapotranspiration and through the channel bottom to the water table. This condition is apparently typical of most channels within the project area. The flows in upper East Fork and in the Middle Fork, Sites 4 and 7, respectively, are apparently derived from springs and ground-water discharge. Records of stream flow at sites on and near Tract III are given in Appendix C, Tables 2, 3, 4, and 5.

Data concerning the occurrence of flood peaks and volumes is also very limited in the project area. Numerous studies involving aerial analysis of observed peak flows at locations within the Upper Missouri Basin have been conducted at various times during the last few years. These studies attempt to describe peak flows at unmeasured sites through use of regression equations which describe peak discharges for various recurrence intervals in terms of certain basin and channel characteristics. These techniques are discussed further and the equations derived are given in Appendix C, Table 1. Using these equations, unit peak discharges can be estimated at ungaged sites. For example, the peak flow for a flood in the project area with an expected recurrence interval of 10-years is estimated to be about 22 cubic feet per second per square mile on drainages between 2 and 5 square miles in size. A graph showing the estimated peak discharges for various recurrence intervals on major streams in the project area are shown in Figure 18.

Water use in the project area is limited to the watering of livestock and wildlife, for irrigation of small gardens, and to a lesser degree for domestic purposes. In the Sarpy Creek basin there are

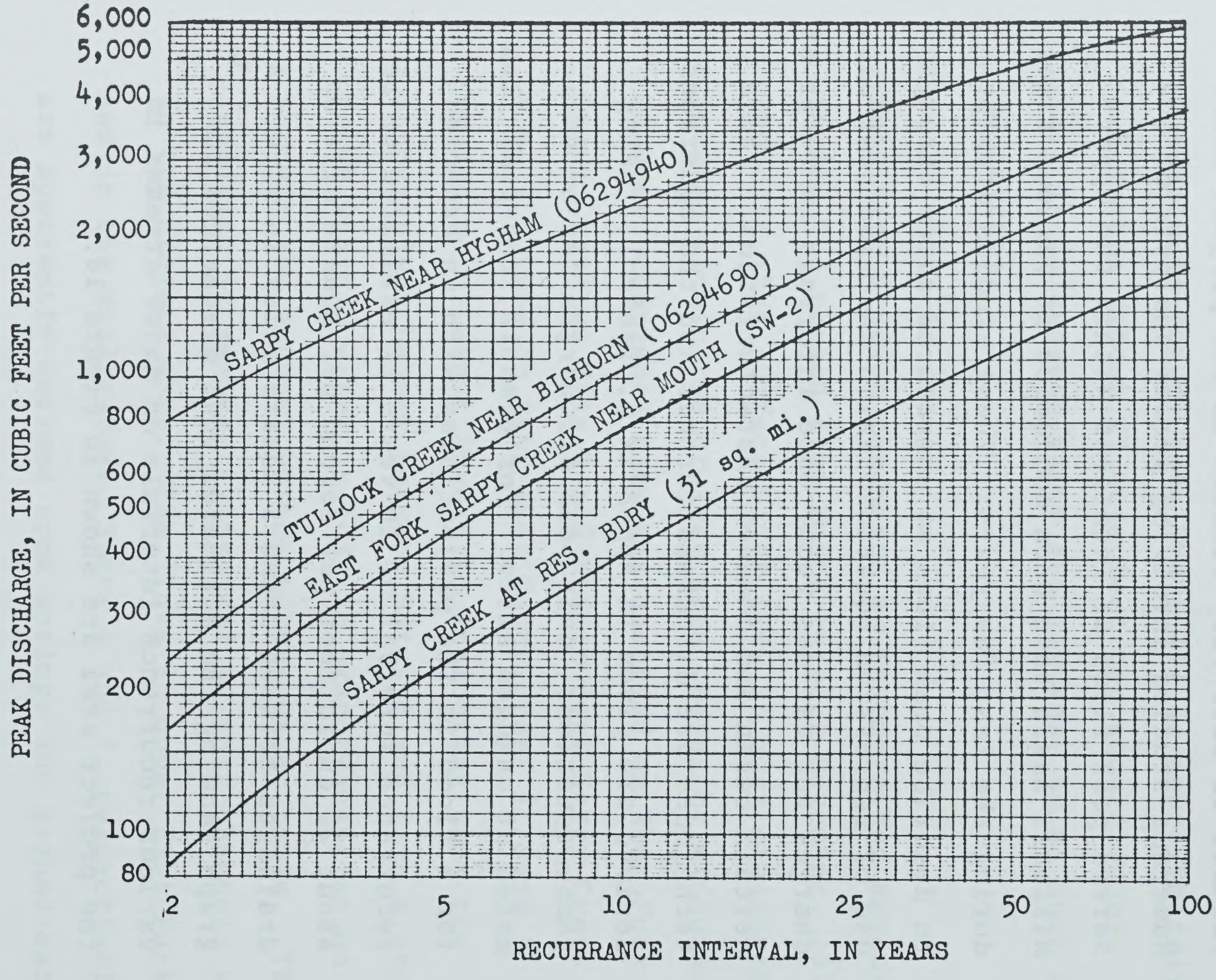


Figure 18 .-- Flood magnitudes and recurrance intervals for selected sites in the Sarpy and Tullock Creek drainages.

53 water rights appropriations totaling 740 cubic feet per second. In the vicinity of Tract III there are 13 appropriations that require a total 193 cubic feet per second. Irrigation water rights of record on Sarpy Creek and tributaries are given in Appendix C, Table 6.

It is apparent that the surface water supplies in Sarpy Creek have been overappropriated as the natural flow comprised only a small portion of the total appropriations (U.S. Bureau of Indian Affairs, 1974, p. 80).

Surface-Water Quality

Background:

Surface water in the Tract III area is characterized by intermittent streams, springs, and small ponds. Major streams are Sarpy Creek, which flows along the western boundary of the tract, and East Fork Sarpy Creek which flows northwest along the northern boundary of the tract. Middle Fork Sarpy Creek flows northwest from the southern part of the tract to Sarpy Creek. In addition, a second important tributary flows northwest to Sarpy Creek from the central portion of Tract III.

There are no long-term historical data available on the water quality of the major streams of the area. Recent data (last 4 years) have become available in a sporadic manner, as interest has developed in the regional coal resources. Published data are still few, however, and do not cover the entire project area in a systematic manner.

The natural water quality of a stream is primarily a result of the dissolved inorganic and organic material in the water. The water of a stream consists of a baseflow component from ground water that infiltrates into the stream and a direct runoff component which enters the drainage basin during precipitation events. At various times of the year, either or both of these components may dominate the character of a stream. For instance, during summer and early fall when little or no precipitation has occurred, the ground water component dominates the flow of the stream. Water from the ground water component has had a long residence time in consolidated and unconsolidated material of the ground water reservoir. Thus its dissolved solids content is relatively high; however the streamflow, due to base flow only, is relatively low. During and after a rainfall, the direct runoff component enters the drainage basin and the streamflow increases rapidly. The runoff component has had no residence time in the ground-water reservoir, but it has had extensive contact with the soil and vegetation as the water moves over the surface of the drainage basin. Thus, the dissolved solids content of the stream is considerably higher than that of the direct precipitation, yet less than it would be during base flow conditions. In general, therefore, the concentration of chemical constituents in a stream tends to be inversely related to streamflow.

A few other generalizations should be noted. In early spring, runoff from snow melt within the basin is relatively low in dissolved solids because the water reflects the composition of the freshly melted snow. This runoff dilutes the baseflow of the stream and often results in a moderate to low flow condition with low dissolved solids. On the other hand, at the beginning of a rainfall event and shortly thereafter, the runoff moving into the stream usually carries a relatively high dissolved solids concentration initially. That is, the sudden increase in water may tend to flush an area of readily dissolved material and initially increase the dissolved solids content of the runoff, and hence the stream, rather abruptly. Thereafter, the stream quality may return to the generalized case of high-flow, moderate to low dissolved solids content.

The chemical composition of a stream is influenced by other natural factors in addition to the ground water and surface runoff components. Other natural factors include reactions of stream water with mineral solids in the streambed and in suspension, reactions among solutes, losses of water by evaporation and transpiration, and effects of natural organic material and aquatic organisms (Hem, 1970). The effects of land use and water use by man are superimposed on the natural chemical composition of a stream and may modify the general observations described above. The Sarpy Creek basin has been used for many years for grazing and cropland which probably affected stream water quality to an unknown degree.

The surface coal mine located in Sections 25 and 26, T.1 N., R.37 E., is the only industrial development in the area. Current facilities include the operating mine, coal-haul roads and staging areas, coal preparation and storage facilities, a railroad spur and loading loop, various access roads, modified internal drainage system and a sediment detention pond. The excavations from the mine and subsequent replacement of spoil material have modified the surface water characteristics of this part of Tract III. Although water quality monitoring near the mine site to date has not detected adverse effects, the regional effect on the quality of surface water due to mining activities in the area has not yet been determined. Discussion of the water-quality characteristics of the areas affected by the mine will follow in subsequent sections.

Chemical quality and sediment sampling stations established by the USGS are located on the Bighorn and Tongue Rivers. Water-quality data are also available for selected stations on Rosebud Creek and Armells Creek, to the east of the project area. The data available for these rivers and streams are characteristic of surface water quality of southeastern Montana but are not directly transferable to the specific creeks of the project area.

Quality of streams in the project area can be generalized from recent data on Sarpy Creek and its major tributary, East Fork Sarpy Creek. According to U.S. Bureau of Indian Affairs, 1974, a sampling program was initiated in Sarpy Creek and East Fork Sarpy Creek in October 1972 by B. C. Research of Vancouver, British Columbia. Tables 7 and 8, Appendix C, give locations and analytical results for selected sites in October 1972, April and July 1973. U.S. Bureau of Indian Affairs, 1974, p. 82, states that "The B. C. Research report concluded that in Sarpy Creek the surface 'Waters were alkaline (pH 7.9-8.4), highly colored, slightly turbid, very hard, and high in dissolved solids, indicating a high concentration of dissolved salts. Probably because of low flow, suspended solids were only moderatly high."

U.S. Bureau of Indian Affairs, 1975, p. 129 states that consultants to Westmoreland Resources have monitored chemical quality of Sarpy and East Fork Sarpy Creeks since October 1972. The report described the water as predominantly magnesium and calcium sulfate type and containing 2,000 to 4,000 mg/l of dissolved solids, depending on the time of year and amount of runoff present; pH ranges from 7.9 to 8.4. Van Voast and Hedges, 1974, provide chemical analyses of water in the area of Westmoreland Resources' coal reserves. Table 9, Appendix C shows these data. Samples were taken in the summers of

1972 and 1973 at several ground-water wells, springs, and stream sites located in and around Tract III. USGS began collecting water-quality data on a monthly basis at Sarpy creek near Hysham, Montana, in December 1974. Provisional data available are given in Appendix C, Table 10.

Data on other streams near Tract III are few. Some data on Tullock Creek, west of the project area, are given in Table 11, Appendix C. Selected analyses are shown for winter and spring months of 1974 at an up-stream and downstream station on Tullock and Sarpy Creeks. In general, the specific conductivity, calculated dissolved solids, calcium, magnesium, bicarbonate, and sulfate concentrations are higher for Sarpy Creek. Results of trace metals analyzed for both creeks are about the same. Laboratory turbidity and total suspended solids are noticeably higher for the Tullock Creek stations.

Tables 12, 13, and 14, Appendix C lists concentrations of trace elements of coals in the project area. Metals which are water soluble at the atmospheric temperature and pressure of exposed mining cuts may be found in water seepage or water that might accumulate in present mine pits in the project area. To date, water seepage into the existing mine pit has been negligible.

No data are available on the chemical quality of water which may accumulate in the mine pits of Tract III.

However, water accumulates in the mine pits in sec. 27 of the Big Sky Mine, near Colstrip, Montana (U.S. Department of the Interior, 1974, p. 91). Water seepage from truncated aquifers on the highwall and surface run-off during rainstorms accumulates on the floor of the pit. Table 15, Appendix C gives chemical analyses of water from the Big Sky Mine strip pit. Similarly high concentrations of dissolved solids, nitrogen species, and metals may be expected in any waters accumulating in mine pits of the project area.

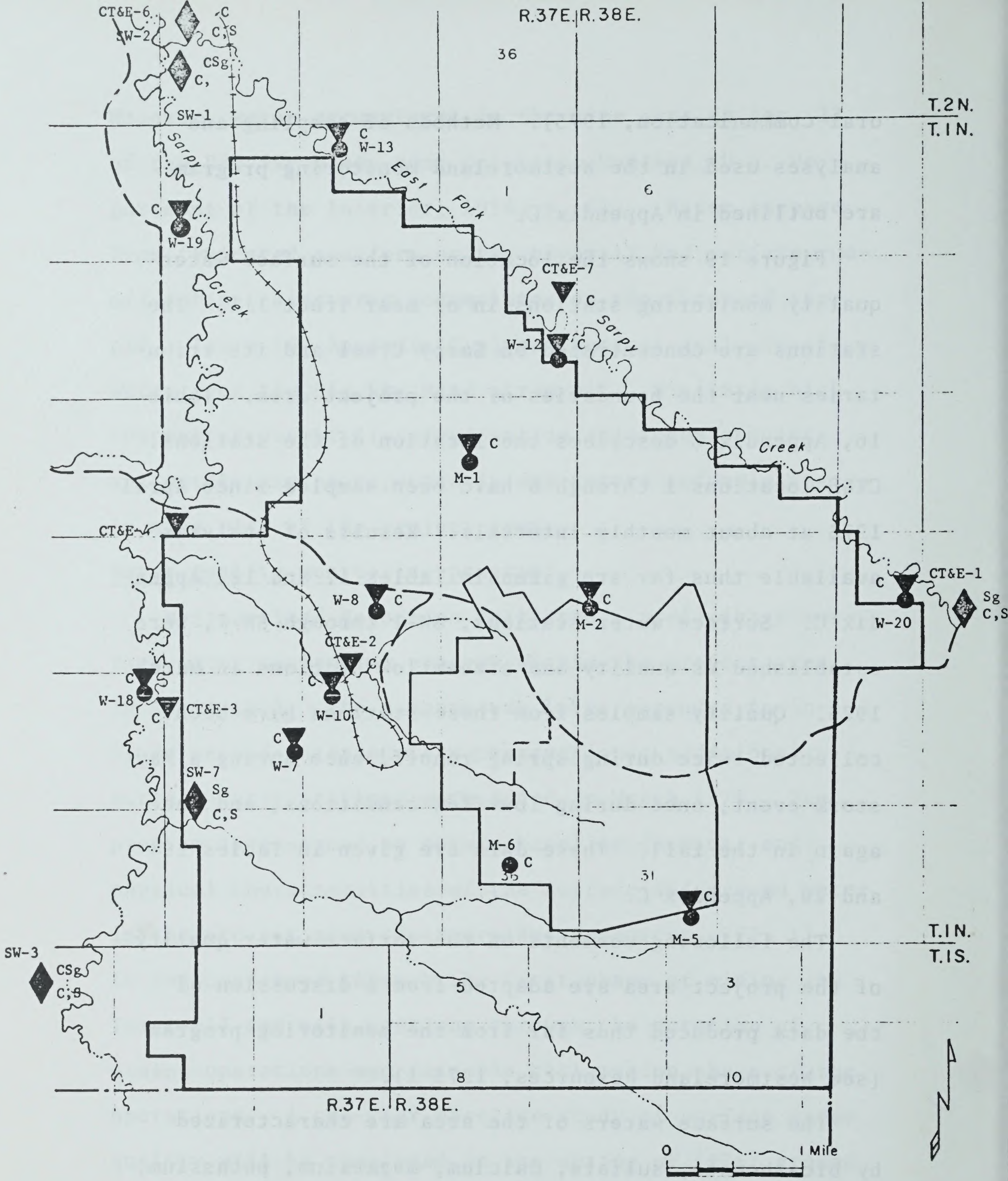
Water quality monitoring program:

Westmoreland Resources initiated a preliminary surface water monitoring program within the project area in April 1973. The program was later expanded to include ground-water quality observations; additional surface water stations were added in March 1975. The program is designed to obtain baseline chemical and physical characteristics of the surface and ground water in the project area (Westmoreland Resources, 1975 1). It has continued through the first phase of mining in Tract III and will continue through the duration of mining operations and into the reclamation phase of the operations. A one-year baseline study of surface water quality will be completed in the spring of 1976; ground water quality baseline studies will continue until late summer, 1976. (David W. Simpson, Westmoreland Resources, oral communication, 1975). Methods of sampling and analyses used in the Westmoreland monitoring program are outlined in Appendix C.

Figure 19 shows the location of the surface water-quality monitoring stations in or near Tract III. The stations are concentrated on Sarpy Creek and its tributaries near the boundaries of the project area. Table 16, Appendix C describes the location of the stations. CT&E locations 1 through 8 have been sampled since April 1973 at about monthly intervals. Results of analysis available thus far are given in Tables 17 and 18, Appendix C. Surface water stations, SW-1 through SW-7, were established as quality and streamflow stations in March 1975. Quality samples from these stations have been collected twice during spring runoff, once during a May storm event, once during low-flow conditions, and once again in the fall. These data are given in Tables 19 and 20, Appendix C.

The following comments on the surface water quality of the project area are adapted from a discussion of the data produced thus far from the monitoring program (see Westmoreland Resources, 1975 1).

The surface waters of the area are characterized by bicarbonate, sulfate, calcium, magnesium, potassium, and sodium. These ions comprise the bulk of the dissolved-solids concentrations.



KEY

Surface water monitoring stations	
CT&E-1	Commercial Testing and Engineering station
SW-1	Surface water station
▼ C	Water quality station-chemical
▼ S	Water quality station-sediment
▲ C	Water quanity station-continuous record
▲ Sg	Water quantity station-staff gage
▲ Csg	Water quantity station-crest stage gage

Ground water monitoring wells	
W-1	Westmoreland well
M-1	Mont. Bureau of Mines and Geology well
●	Observation well
▼●	Chemical quality observation well

Figure 19. Locations of surface and ground water monitoring stations; Tract III. Adapted from Westmoreland Resources, 1975 1.

Spring melt runoff: Analysis of surface waters sampled on March 21, 1975, indicate most of the flow consisted of snowmelt water. Relatively low sulfate, bicarbonate and dissolved solids concentrations were noted at most stations, except at SW-7 (Middle Fork Sarpy Creek) where concentrations of the above major constituents were considerably higher than those of the other five stations. Subsequent sampling of spring melt runoff was made about 24 days later, on April 13, 1975. Significantly higher dissolved solids and major ion concentrations were noted at all locations. Westmoreland Resources, 1975 1, p. 46, states that the higher dissolved solids concentrations indicate an increased contribution of water from the shallow ground-water system during the April sampling period. Trace metals concentrations were at relatively low values or near the limit of detection. Aluminum values for samples obtained on March 21, 1975, are suspect and probably resulted from inadequate filtration prior to being acidified for preservation (Westmoreland Resources, 1975 1, p. 2.2.3-46).

Storm runoff: Results of sampling during a storm event in May 1975 indicated that concentrations of the major constituents increased from those of the spring runoff event in April, except at SW-3 (upper Sarpy Creek). The concentrations of major constituents at this station indicated consistently low values compared to the other stations sampled during the spring runoff period, as well as during the storm event. Westmoreland Resources, 1975 1, p. 47 suggests that much of the flow at SW-3 consisted of direct runoff, with only minor contributions from ground water. In Sarpy Creek at SW-1 and East Fork Sarpy Creek at SW-2 and SW-4, the concentrations of calcium, magnesium and sodium increased during the storm runoff. Of the trace metals analyzed, only boron and strontium showed relatively high concentrations during storm events.

Low flow: The streams which remained flowing in July and August, 1975, exhibited high dissolved solids content. Average values over 3,000 mg/l were present in Sarpy and East Fork Sarpy Creeks during the low-flow period. Figure 20 shows the average low-flow concentrations of dissolved solids, bicarbonate, and sulfate for the CT&E stations along Sarpy Creek, during 1973 and 1974 (Westmoreland Resources, 1975 1). Concentrations of dissolved solids and sulfate increase in a downstream direction. Westmoreland Resources, 1975 1, suggests this observation could be the result of ground-water contribution to the creek and/or concentration of dissolved solids through evaporation of its waters. The reference concludes that evapotranspiration is mainly responsible for the increased concentrations because

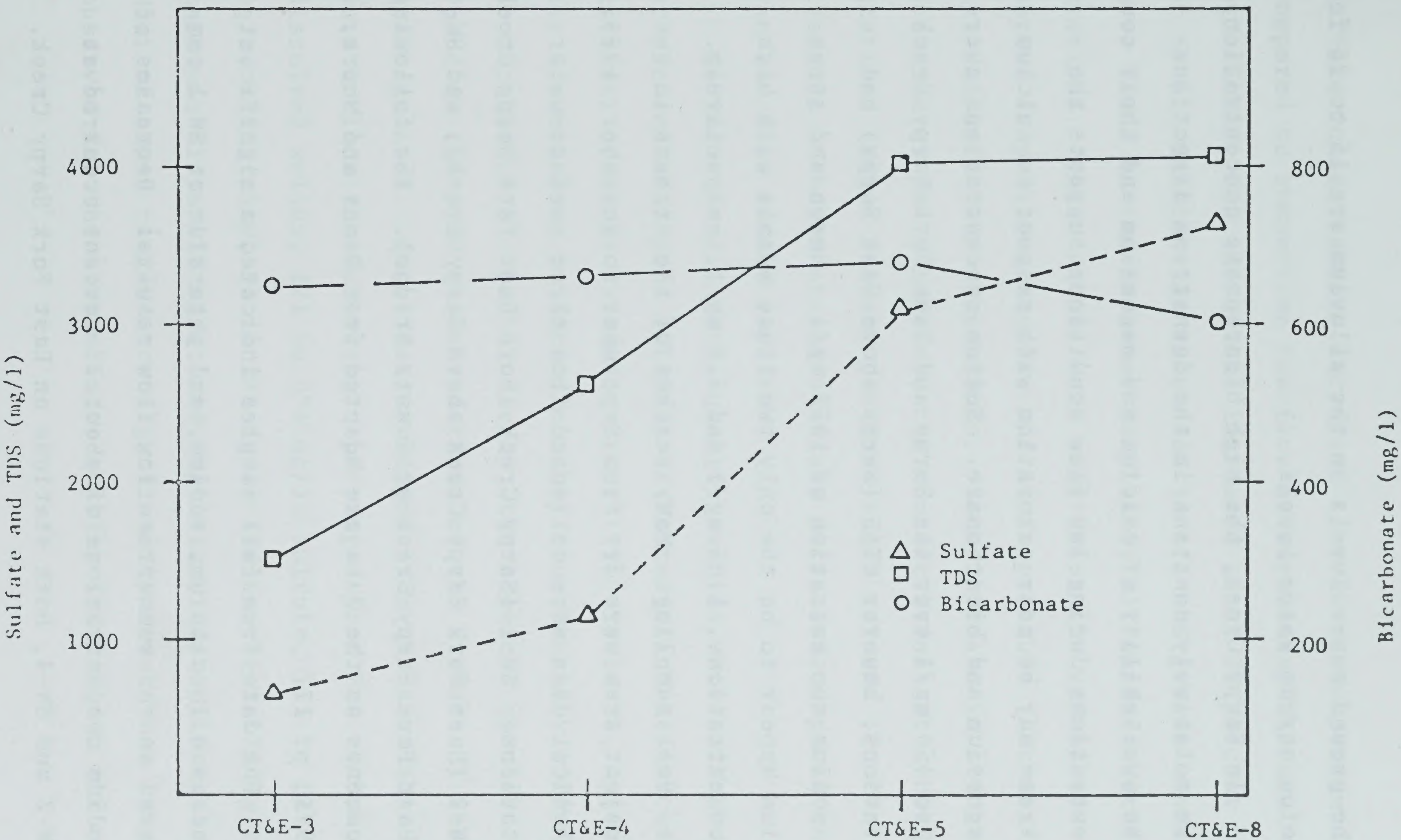


FIGURE 20

LEVELS OF SULFATE, BICARBONATE AND TOTAL DISSOLVED SOLIDS (TDS) ALONG SARPY CREEK

From Westmoreland Resources, 1975 1, Fig. 2.2.3-10.

the ground water levels in the alluvium are 15 to 25 feet below stream water levels.

In Sarpy Creek, the high bicarbonate concentrations are relatively constant in the downstream direction. The availability of calcium and magnesium and their concentrations during low-flow conditions suggests the stream may be near saturation with respect to calcium, magnesium and bicarbonate. Sodium concentrations averaged 450 mg/l over the Sarpy and East Fork Sarpy Creek stations; however CT&E (Sarpy above East Sarpy) had a sodium concentration of 1077 mg/l. Boron and strontium appear to be the only two trace metals with high concentrations, 1.03 mg/l and 5.2 mg/l, respectively.

Fall sampling: Many reaches of the streams in the project area were dry from September to November, 1975. Chemical data were collected from three surface-water stations: SW-1 (Sarpy Creek above East Fork Sarpy Creek), SW-2 (East Fork Sarpy Creek above Sarpy Creek), and SW-4 (East Fork Sarpy Creek at County Bridge). The following comments on the data are adapted from Dames and Moore, 1975, p. 17.

The data from fall samples indicated a significant increase in calcium, sodium, and potassium at SW-1 compared to the summertime low-flow results. Decreases of sodium concentrations of about 25 percent occurred at SW-2 and SW-4, both stations on East Fork Sarpy Creek.

Sulfate concentrations decreased from 20 to 30 percent compared to summertime low-flow measurements, whereas bicarbonate concentrations increased about 50 percent at SW-1. Substantial increases in oil and grease content were found in the November samples at all surface water stations. These values were many times the values reported in previous months, and it is probable that analytical error was responsible. Some increase in strontium occurred at SW-1; however, the concentrations at other stations ranged between previous known values. Concentrations of boron at all stations decreased compared to the low-flow summer results.

Sediment Pond: Water-quality samples were collected at the sediment pond (CT&E-2) of Westmoreland Resources internal drainage system on Tract III. Table 21, Appendix C shows data collected monthly from February 1974 to October 1975. Qualitatively, the chemical species found in the pond resembled those of the streams of the drainage area. Quantitative ranges from the available data include the following: pH ranged from 7.4 to 8.6; dissolved solids, 221 to 974 mg/l; sulfate, 125 to 617 mg/l; alkalinity, 84 to 270 mg/l; sodium, 41 to 73 mg/l; calcium, 81 to 123 mg/l; and magnesium, 60 to 110 mg/l. Most of these ranges were significantly lower than ranges observed for the stream water-quality stations in the project area; however, there were no significant differences in trace element concentrations.

On July 22 and October 1, 1975, samples were collected at the inlet to the sediment pond, as well as in the pond at station CT&E-2. The concentrations of most major chemical constituents were greater at the inlet station than at the pond station; however, no significant differences in trace metal concentrations were noted.

Summary

The following summary is adapted from Westmoreland Resources, 1975 1, p. 49-50. Sarpy and East Fork Sarpy Creeks have highest concentrations of most constituents measured. Sodium is the dominant cation and sulfate the dominant anion for both creeks, and the two creeks exhibit similar ratios of sodium and sulfate. Concentrations of magnesium are generally slightly less than sodium, and calcium is usually about one-third that of sodium. Sulfate concentrations are at least twice that of bicarbonate. The proportions of anions and cations observed are similar to the proportions in the groundwater ion relationship of the Robinson Coal.

The pH of the streams of the area ranges from 7.4 to 8.7, with one value as low as 7.0 and one as high as 9.1. The pH and alkalinity data indicate that all streams have natural alkaline sources.

The chemical analyses of water from SW-3 (upper Sarpy Creek) suggest direct surface runoff was the major water source on the days sampled, with little or no ground-water contribution in evidence.

Results of water analyses from SW-7 (Middle Fork Sarpy Creek) obtained during the spring and low-flow periods show bicarbonate to be the predominant anion, and calcium and magnesium to be the predominant cations. The proportions of anions and cations from SW-7 are similar to the proportions observed in ground water from the Rosebud-McKay Coal and indicate the latter may be the major ground-water source to Middle Fork Sarpy Creek. Of the six springs observed in this valley, four discharge from the Rosebud-McKay Coal and associated clinker zones.

The observation of relatively high concentrations of strontium in the surface water after spring melt and in the ground water of the area substantiates the effect of ground water on the quality of water present in most surface waters in and around the project area. (Westmoreland Resources, 1975 1, p. 50).

Qualitatively, the chemical constituents found in the sediment pond at station CT&E-2 resemble those found in the natural streams of the area. Ranges of concentrations, however, are lower at the pond station than at most stream stations. The few data available for the pond inlet indicate that the concentrations at the inlet resemble the concentrations found at most other surface-water stations.

Sediment

Tract III is located on a highly dissected plateau on which the regional surface water discharge is northward to the Yellowstone River. The land is susceptible to natural erosion. Surface runoff is the primary agent of erosion in the project area and is the principal vehicle for transport of eroded material, which is primarily suspended sediment. The major streams of the area and their many intermittent tributaries erode the land surface of Tract III and transport sediment from the small drainage basins of the project area. Sediment yield from a given drainage basin is dependent upon such factors as: geology of the area, nature of the soils, vegetation cover, topography, climate and local meteorology, amount and frequency of runoff, and use of the land. Sediment yield from the drainage basins of Tract III have not been measured.

Sediment sampling stations have been maintained by USGS on the Bighorn, Little Bighorn, and Tongue Rivers; however, records of sediment yields from these stations would not be applicable to Sarpy Creek or its tributaries

(U.S Bureau of Indian Affairs, 1974). There are, however, several studies of sediment yield over wider areas similar to the project area which suggest a general range in yield that may be expected from the Sarpy Creek drainage area (U.S. Bureau of Indian Affairs, 1974). A sediment delivery of 0.08 to 0.19 acre-feet per square mile per year is estimated for the basins of the project area (Westmoreland Resources, 1975 1). Land uses such as lumbering, mining, and overgrazing are examples of activities in the project area which could increase the estimate.

Suspended-sediment concentrations at selected stations on the Bighorn and Yellowstone Rivers during the period 1965 to 1973 are given in Appendix C, Table 22. Suspended-sediment concentrations vary widely in response to flow. The Montana Department of Natural Resources and Conservation, 1974, reports that suspended-sediment concentrations in the Yellowstone River are commonly less than 50 mg/l during low-flow periods and over 900 mg/l during high-flow periods.

Limited suspended-sediment data from two stations on Sarpy Creek have been taken periodically by USGS. (See Appendix C, Table 23).

Westmoreland Resources, 1975 1, also provides some data on suspended-sediment concentration from streams of the project area. Data from surface water stations

SW-1 through SW-7 are shown in Appendix C, Table 24. Thirty-eight samples were taken under various flow conditions from March to May 1975. All but one of the surface water stations is located in the Sarpy Creek basin. Thus, the sediment data are essentially representative of the Sarpy Creek basin over a short period of time. Continued monitoring of suspended-sediment concentrations, which is part of the overall water quality monitoring program in Tract III, should provide definitive data for the estimation of sediment yield from the streams of the project area.

Westmoreland Resources presently operates a strip mine in Tract III. Mine drainage facilities include an internal drainage system for diversion of runoff from the mining area to a sediment detention dam and settling pond. Some runoff is diverted around the mining area and to the settling pond. Water accumulating within the mine pit is pumped to the internal drainage system. The settling pond is used to minimize sediment concentrations in runoff leaving the mining property and entering the natural drainage. In addition, the water quality of the pond discharge is monitored before it enters the natural drainage system of the project area.

Westmoreland Resources discharges to their sediment pond an average of 0.012 million gallons per day (0.019 cfs) of waters for which dissolved and suspended solids loadings average 0.03 tons per day and 0.001 tons per day, respectively. Other select chemical parameter loadings are presented in Montana Department of Resources and Conservation, 1974, p. 341 (Westmoreland Resources, 1975 1, p. 17).

Existing Water Pollution Sources

Low level pollution sources within the project area include organic contributions from plants and domestic and wild animals (living and dead) and inorganic contribution from the weathering and erosion of soils, unconsolidated material, and rocks of the area. There is little or no contribution from domestic wastes in the general project area. Algal growth, decaying vegetation and occasional intensive growth of water plants tend to alter the water quality of stock ponds and ponded areas of streams (U.S. Bureau of Indian Affairs, 1975, p. 136).

The major man-made water pollution source in the project area is probably from agriculture. Tillage and overgrazing contribute uncontrolled sediment to streams. The use of fertilizer and biocides in farming constitutes another pollution source. Cattle congregating around water sources also contributes to biological degradation. The surface coal mine located on Tract III is the only industrial development in the area and is a potential pollution source. Alkaline mine drainage waters characterized by high dissolved solids concentrations and high concentrations of suspended sediment are typical potential pollutants. Miscellaneous sources of relatively low levels may be residues of biocides, wastewater from domestic and industrial sources, by-products of material buried in sanitary landfills, and organic residues dispersed by heavy machinery, vehicles, and railroad equipment.

2. Ground-Water

Methods of monitoring ground-water employed by Westmoreland Resources.

Background data that has been collected on the ground water system in the area include an inventory of springs and existing wells, their location and identification of source, and the drilling of new wells for monitoring purposes. Data was collected on yield, use, and chemical quality, well depths and depth to water in the wells (Figures 21 and 22, Tables 25 through 28, Appendix C).

A number of wells were drilled, cased and sealed by packers to measure the potentiometric heads in the overburden, the coals, the interburden, and the 50 to 150 foot thick section below the Robinson coal.

The groups of observation wells consist of two to three wells drilled at a location. The wells were cased and sealed so as to sample specific stratigraphic horizons for changes in water quality and potentiometric head and thus provide a basis for determining local and regional effects of mining on ground water. The location of these wells is shown on Figure 21 and the results of chemical analysis are given in a subsequent section. Water levels have been measured monthly on a continuing basis and samples have been collected from the wells annually for chemical analysis. In order to determine hydrologic characteristics of the units sampled, pumping and packer tests were made to determine transmissivity and lateral permeability. Vertical permeability was determined by laboratory methods for a number of core samples.

Geophysical logs were made of the wells and include gamma ray, spontaneous potential, resistivity, velocity (continuous or three dimensional), neutron, density, caliper and temperature logs (Westmoreland Resources, 1975 1, Appendix, F.P.4).

Occurrence and quantity

Ground water occurs in a number of aquifers which underlie the proposed mining area in Tract III of the ceded area. These aquifers are parts of local, intermediate and regional flow systems. The water occurs in intergranular openings in both consolidated and unconsolidated rocks and in joints, fractures, and solution

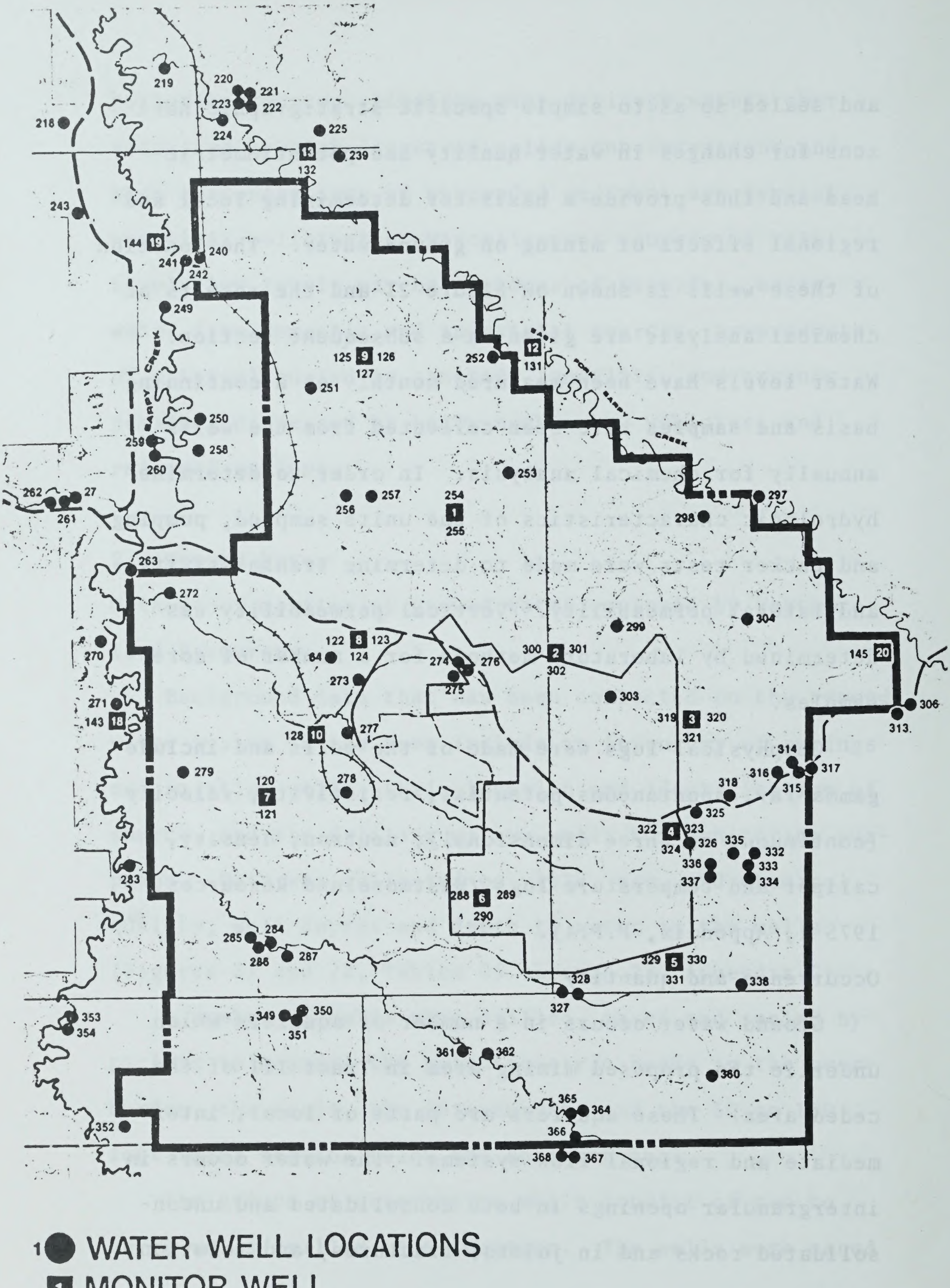


Figure 21. Location of water wells and monitor wells in Tract III. Adapted from Westmoreland Resources, 1975 1, Plate 2.2.3-3.

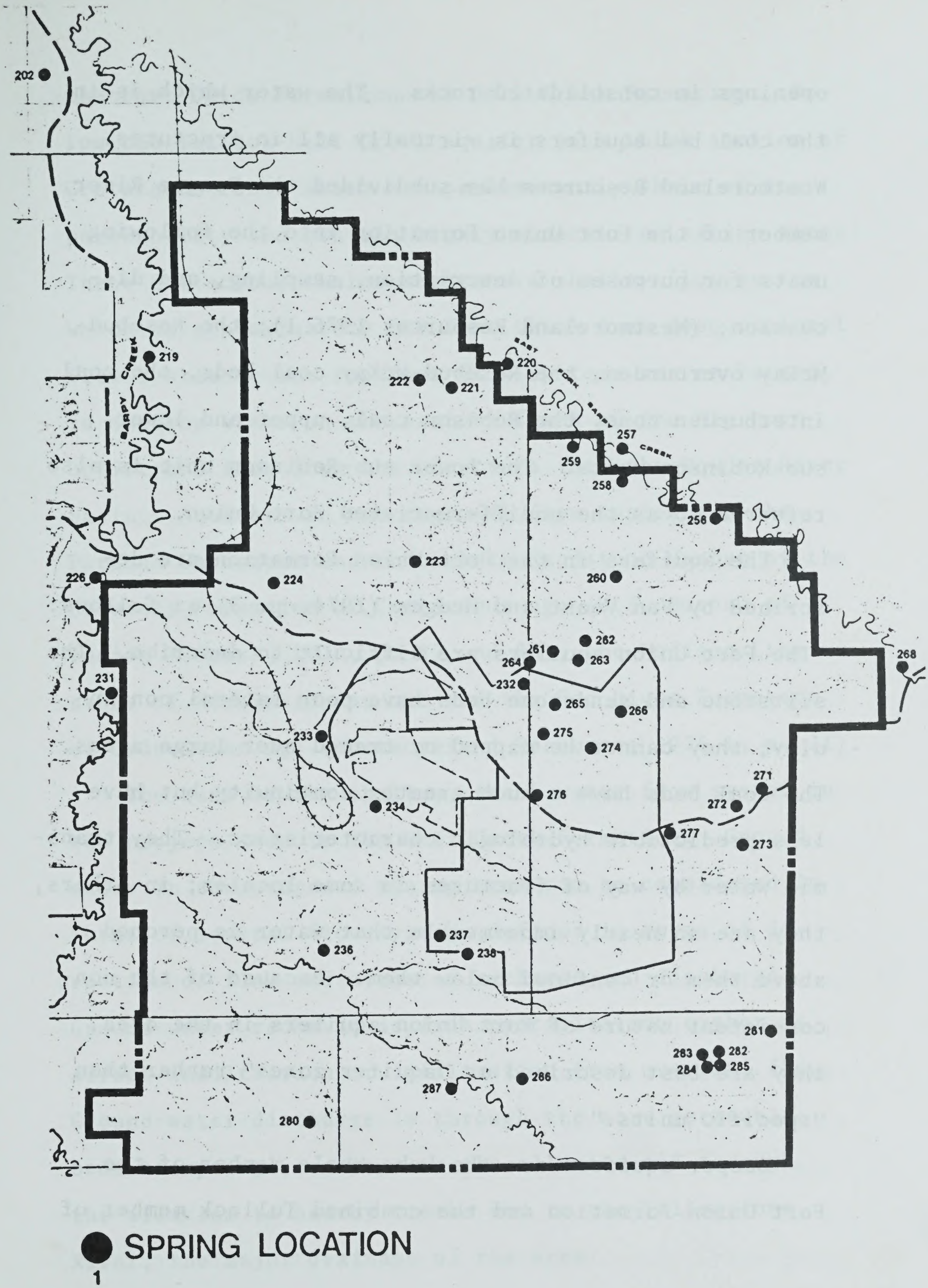


Figure 22. Location of springs in Tract III. Adapted from Westmoreland Resources, 1975 1, Plate 2.2.3-2.

openings in consolidated rocks. The water which is in the coal bed aquifers is virtually all in fractures. Westmoreland Resources has subdivided the Tongue River member of the Fort Union Formation into the following units for purposes of description, sampling, and discussion; (Westmoreland Resources 1975 1); the Rosebud-McKay overburden, the Rosebud-McKay coal beds, the coal interburden zone, the Robison coal, upper and lower sub-Robinson units. The lower sub-Robinson unit is also referred to as the undifferentiated Fort Union.

The aquifers in the Fort Union Formation are described by Van Voast and Hedges (1974, p. 3) as follows: "The Fort Union aquifers are difficult to describe. The siltstone and sandstone beds have poor lateral continuity; they cannot be mapped or traced over large areas. The coal beds have a much greater continuity but have less predictible hydrologic characteristics. They transmit water by way of fractures in some locales; in others, they are so nearly impermeable that water is perched above them or confined below them. Because of the nonconsistent nature of Fort Union aquifers in the area, they are best described as "aquifer zones" rather than "specific units."

Deeper aquifers are the Lebo Shale member of the Fort Union Formation and the combined Tullock member of the Fort Union Formation and Hell Creek Formation. Below the Tullock-Hell Creek aquifer is a thick section of Cretaceous rocks which are predominantly shale of low permeability and contain highly mineralized saline water. These Cretaceous shales separate a shallow flow system which is approximately 600 feet thick from deep regional flow systems. The regional flow systems are recharged in outcrop areas on the eastern flank of the Big Horn uplift and flow down the structure into the Powder River basin. Aquifers in the regional flow system are the Parkman Sandstone and the Lakota Sandstone Member of the Cloverly Formation of Cretaceous age (U.S. Bureau of Indian Affairs, 1974, p. 87 and 88), the Madison Limestone of Mississippian age and the Red River Formation of Ordovician age (Westmoreland Resources 1975 1, p. 21).

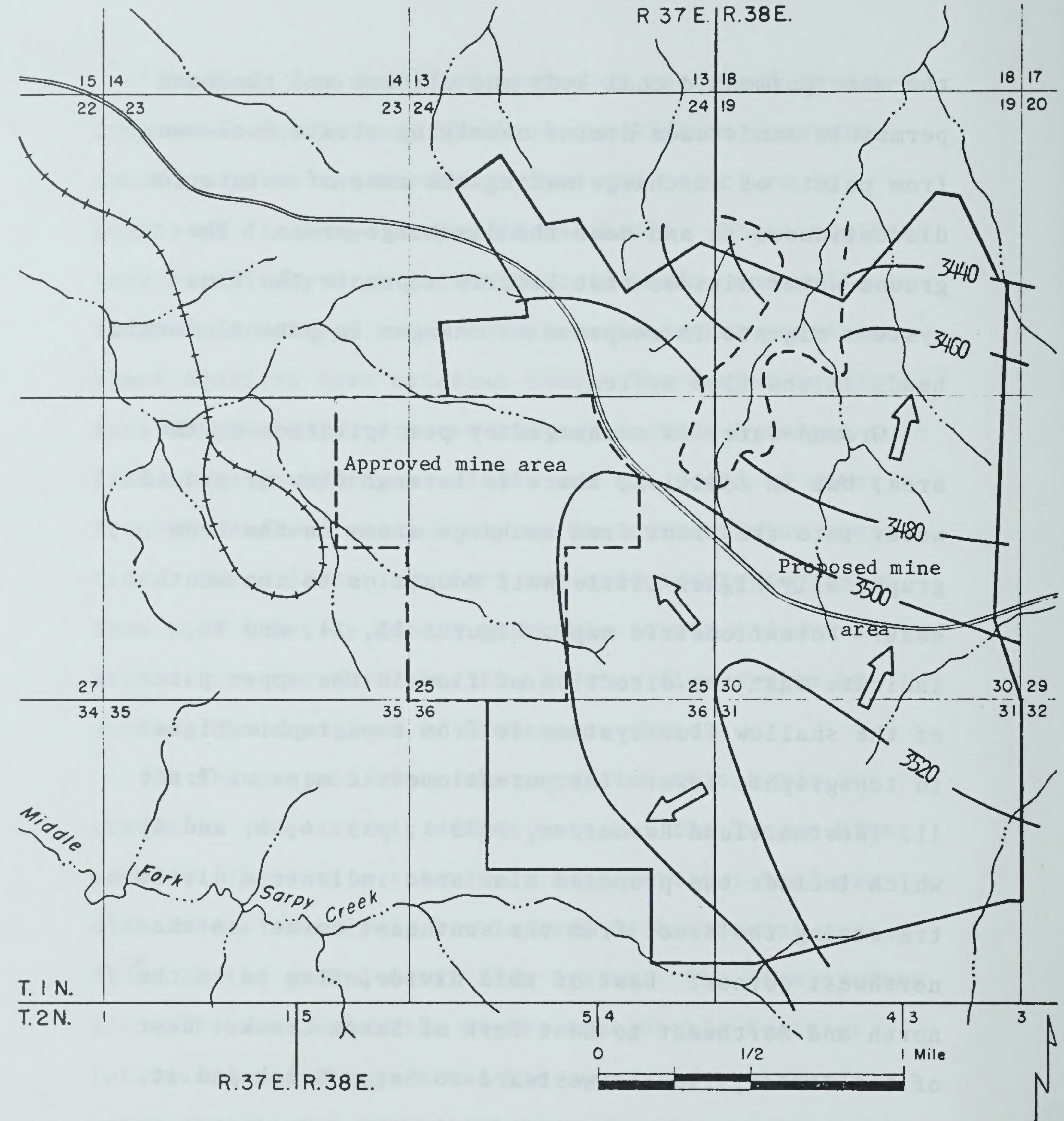
The base of the shallow, fresh water flow system in the project area is the Hell Creek Formation. Ground water in the proposed mining area can be considered in terms of several flow systems defined in terms of direction of flow and areas of recharge and discharge. Ground-water recharge is from precipitation either as direct infiltration or infiltration from overland flow. Ground-water discharge is through the more permeable beds to springs, seepage to the alluvium and through the alluvium to nearby creeks and to the Yellowstone River, the major drainage of the area.

The deep regional flow system is recharged in outcrop areas on the east flank of the Bighorn Mountains and flow is to the northeast down the structure to points of discharge deeper in the basin. These aquifers have relatively high potentiometric heads, and wells located in valleys or at low elevations that penetrate these aquifers have artesian flow. The deeper aquifers have calcium sulfate water and may contain hydrogen sulfide although hydrogen sulfide was not found in water from the Madison well supplying the current mine operation. These deeper aquifers are effectively separated from each other by poorly permeable strata and are separated from the shallower fresh water flow system by several thousand feet of Cretaceous shale.

In the project area, the potentiometric heads decrease in successively deeper units of the Tongue River member. There is a relatively high vertical head gradient and a relatively low lateral or horizontal gradient in the ground-water flow system. The flow systems are continuous under the higher topographic features but towards discharge areas are separated by groundwater divides and near discharge areas become discontinuous where there is lateral flow through units having relatively high horizontal permeability in comparison to the relatively low vertical permeability of underlying rock. The comparative rapid lateral flow through the more permeable coal beds and clinker and the more permeable sandstones drains overlying strata back away from points of discharge making the zone of saturation discontinuous in and near the discharge areas. The ground-water divides that locally separate the flow systems migrate in response to changes in potentiometric heads in the flow system.

Ground-water is recharged by precipitation on the area; but in addition, there is lateral flow of ground water into the tract from recharge areas in the topographically higher Little Wolf Mountains to the southeast. Potentiometric maps, Figures 23, 24, and 25, indicate that the direction of flow in the upper parts of the shallow flow systems is from topographic highs to topographic lows. The potentiometric maps of Tract III (Westmoreland Resources, 1975 1, pls. 4, 5, and 6) which include the proposed mine area indicate a divide traversing the tract from the southeast corner to the northwest corner. East of this divide, flow is to the north and northeast to East Fork of Sarpy Creek. West of the divide, flow is westward to Sarpy Creek and its tributaries.

Flow through the upper part of the shallow system discharges to springs and seeps at the base of the coal beds and clinker and more permeable sandstone units. The system discharges to the alluvium and either to the

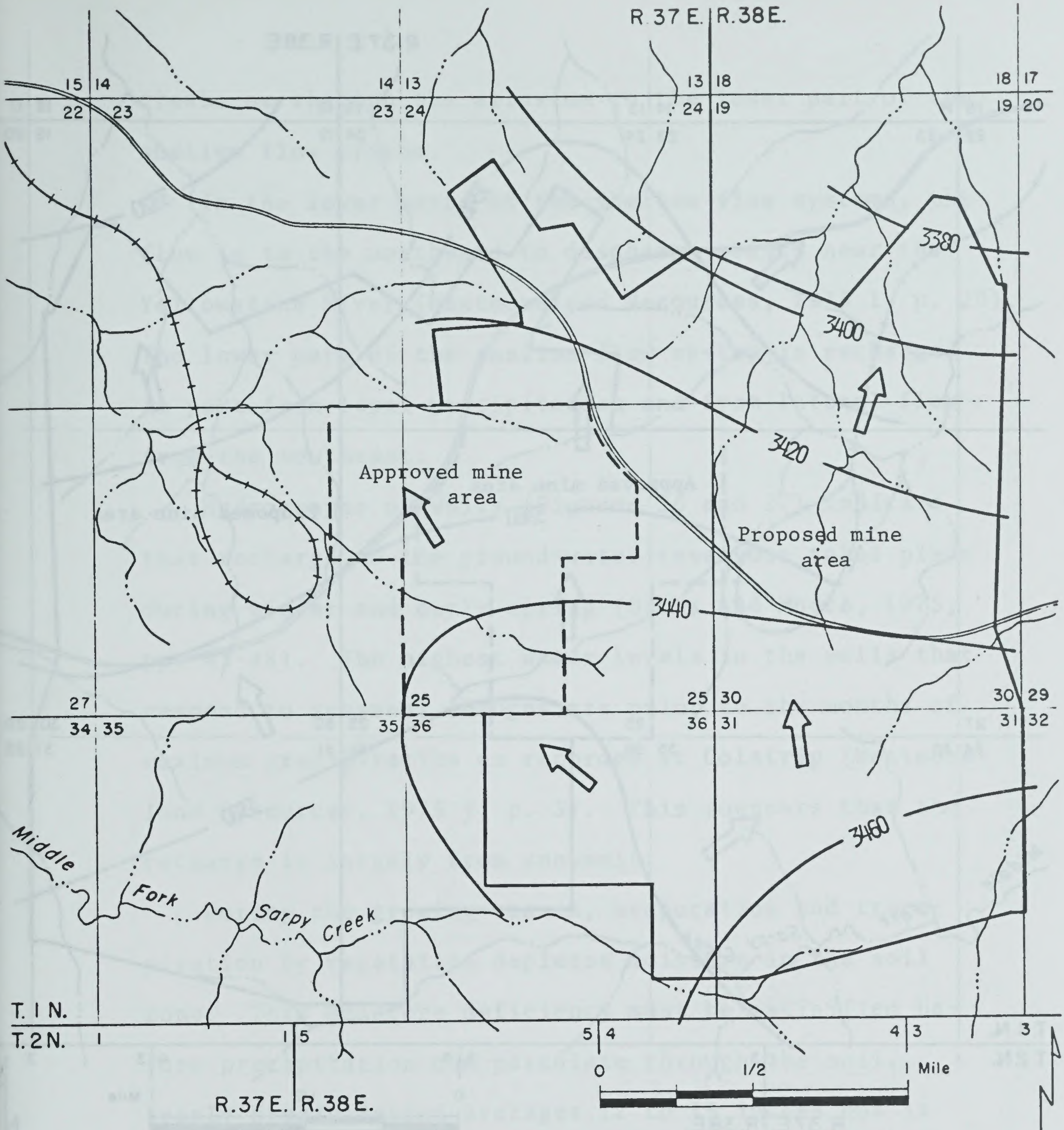


General direction of ground-water movement.

3500 — Contour on piezometric surface. Elevations in feet above mean sea level. Contour interval 20 feet.

Burn line of the Rosebud-McKay coal.

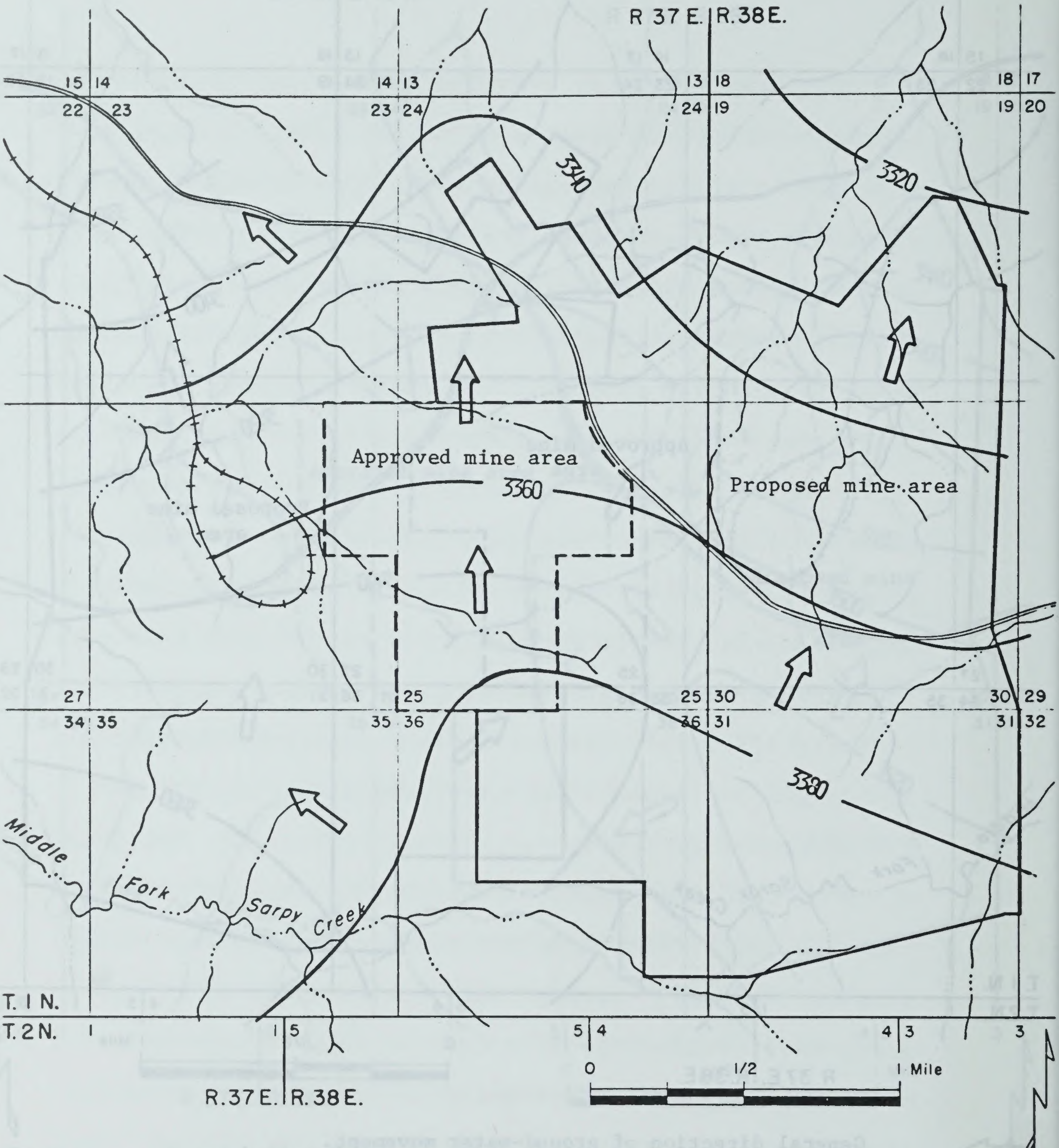
Figure 23. Generalized contours on the potentiometric surface of the Rosebud-McKay coal in the proposed mine area. Adapted from Westmoreland Resources, 1975 1, Plate 2.2.2-4.



General direction of ground-water movement.

—3400— Contour on piezometric surface. Elevations in feet above mean sea level. Contour interval 20 feet.

Figure 24. Generalized contours on the potentiometric surface of the Robinson coal in the proposed mine area. Adapted from Westmoreland Resources, 1975 1, Plate 2.2.2.5.



General direction of ground-water movement.

—3380— Contour on piezometric surface. Elevations in feet above mean sea level. Contour interval 20 feet.

Figure 25. Generalized contours on the potentiometric surface of the upper Sub-Robinson unit. Adapted from Westmoreland Resources, 1975 1, Plate 2.2.3.6.

creeks or through the alluvium to the lower part of the shallow flow system.

In the lower parts of the shallow flow systems, the flow is to the northward to discharge points near the Yellowstone River (Westmoreland Resources, 1975 1, p. 20). The lower part of the shallow flow system is recharged in part from local precipitation and from lateral flow from the southeast.

Hydrographs of wells (Figures 26 and 27) indicate that recharge to the ground-water reservoir takes place during winter and early spring (Dames and Moore, 1975, pp. 43-48). The highest water levels in the wells that respond to seasonal changes are prior to the months of maximum precipitation as recorded at Colstrip (Westmoreland Resources, 1975 j, p. 5). This suggests that the recharge is largely from snowmelt.

During the growing season, evaporation and transpiration by vegetation depletes moisture in the soil zone. This moisture deficiency must be satisified before precipitation can percolate through the soil. Yearly precipitation averages 12 to 15 inches but is very unequally distributed in that 45 percent of the annual precipitation occurs in one-quarter of the year-April, May, and June-whereas 32 percent of the annual precipitation falls from July to the end of October (Westmoreland Resources, 1975 j, p. 5). The small

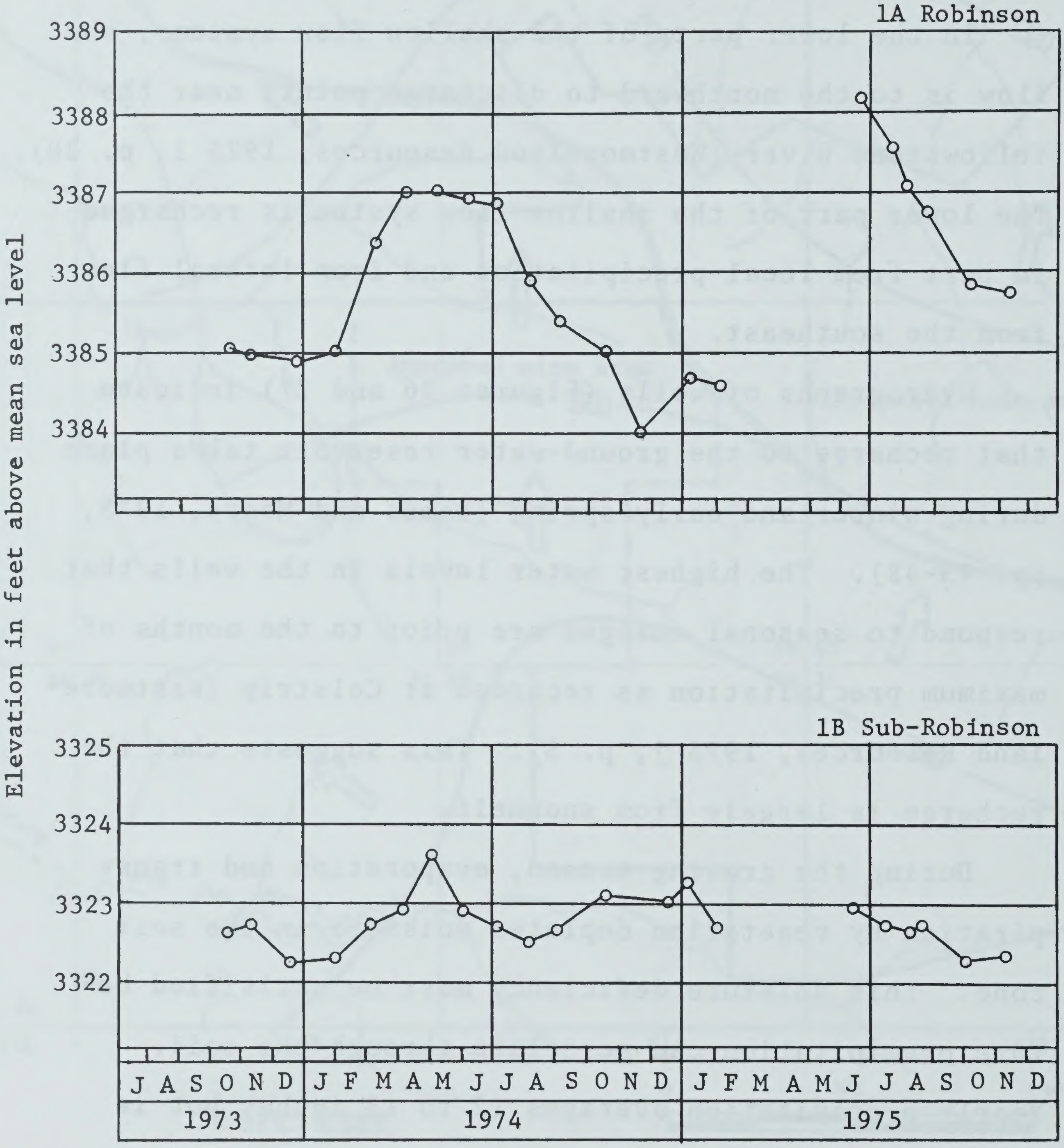


Figure 26. Hydrographs of wells 1A and 1B.

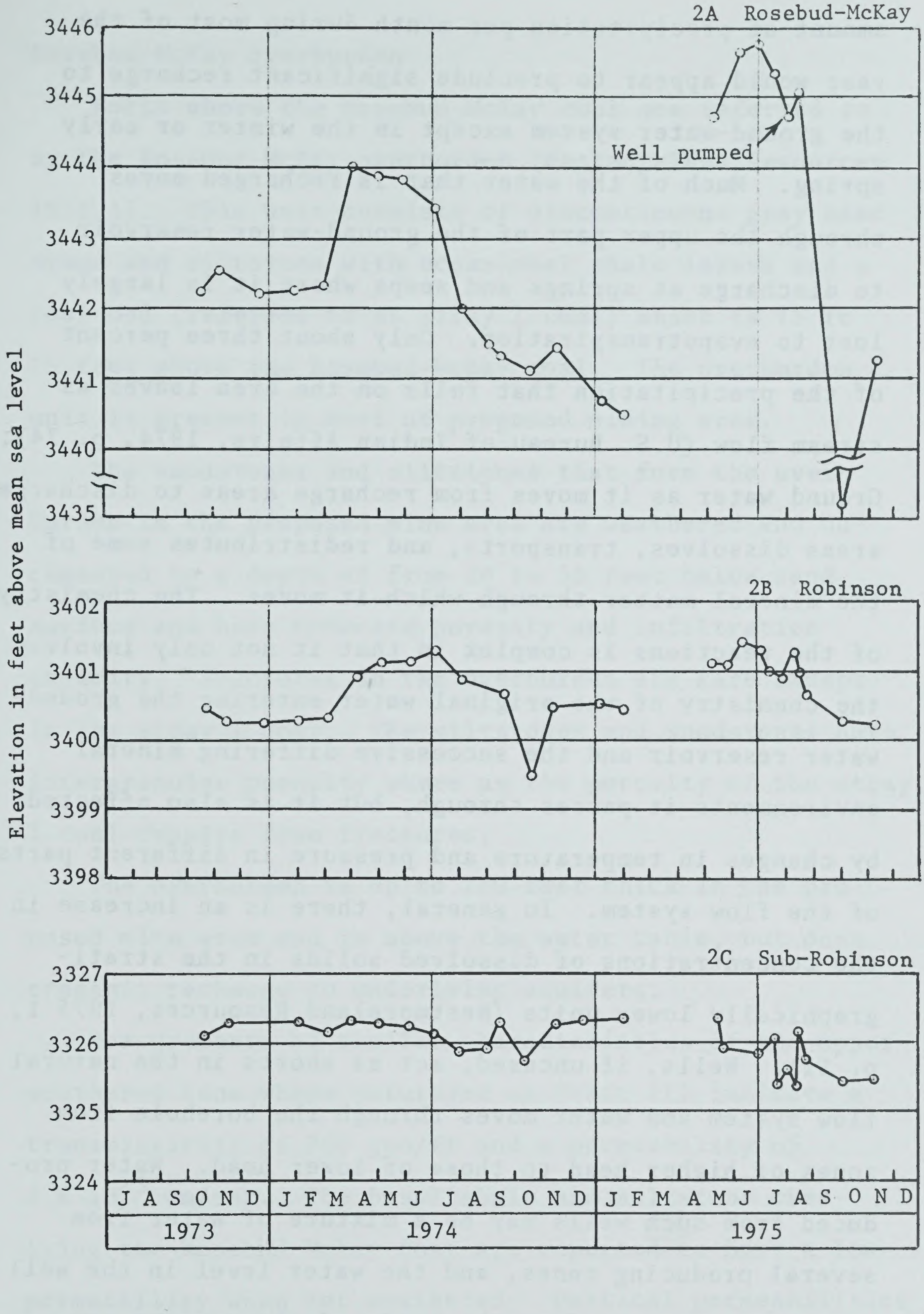


Figure 27. Hydrographs of wells 2A, 2B, and 2C.

amount of precipitation per month during most of the year would appear to preclude significant recharge to the ground-water system except in the winter or early spring. Much of the water that is recharged moves through the upper part of the ground-water reservoir to discharge at springs and seeps where it is largely lost to evapotranspiration. Only about three percent of the precipitation that falls on the area leaves as stream flow (U.S. Bureau of Indian Affairs, 1974, p. 74). Ground water as it moves from recharge areas to discharge areas dissolves, transports, and redistributes some of the mineral matter through which it moves. The chemistry of the reactions is complex in that it not only involves the chemistry of the original water entering the ground-water reservoir and the successive differing mineral environments it passes through, but it is also affected by changes in temperature and pressure in different parts of the flow system. In general, there is an increase in the concentrations of dissolved solids in the stratigraphically lower units (Westmoreland Resources, 1975 1, p. 51). Wells, if uncased, act as shorts in the natural flow system and water moves through the borehole from zones of higher head to those of lower head. Water produced from such wells may be a mixture of water from several producing zones, and the water level in the well may be a composite from the heads of the various producing zones.

Rosebud-McKay overburden

Rocks above the Rosebud-McKay coal are referred to as the Rosebud-McKay overburden (Westmoreland Resources 1975 1). This unit consists of discontinuous gray sandstone and siltstone with occasional shale layers and a coal bed (referred to as stray 1 coal) which is 15 to 75 feet above the Rosebud-McKay coal. The overburden unit is present in most of proposed mining area.

The sandstones and siltstones that form the overburden in the proposed mine area are weathered and uncemented to a depth of from 20 to 50 feet below land surface and have moderate porosity and infiltration capacity. Fractures in the overburden are rare except in the stray 1 coal. The siltstones and sandstones have intergranular porosity where as the porosity of the stray 1 coal results from fractures.

The overburden is up to 100 feet thick in the proposed mine area and is above the water table, but does transmit recharge to underlying aquifers.

Measurements of aquifer characteristics of the upper weathered zone where saturated on Tract III indicate a transmissivity of 700 gpd/ft and a permeability of 2×10^{-3} cm/sec. The basal shale and siltstone overlying the Rosebud-McKay coal are reported to have a low permeability when not weathered. Vertical permeabilities determined from cores in siltstone and shale are 9×10^{-9}

cm/sec and 2 x 10^{-9} cm/sec respectively (Table 29, Appendix C). Pumping tests indicate a transmissivity of 17 gpd/ft and a permeability 1 x 10^{-4} cm/sec for the stray 1 coal at Well 4A (Westmoreland Resources, 1975 1, p. 30).

Recharge of the overburden unit is from precipitation on the area and from lateral flow from the southeast. Hydrographs of wells 4A and 5A (Dames and Moore, 1975, p. 46 and 47) indicate a seasonal response to precipitation. Discharge from the overburden unit is to springs and downward to recharge deeper aquifers.

Rosebud-McKay coal

The Rosebud-McKay coal is present over most of the proposed mine area. It consists of 25 to 35 feet of cleated coal and includes a shale bed or parting. The fractures in the coal are partially saturated with ground water. Hydrographs made from water level measurements in observation wells (Figure 26 and Dames and Moore, 1975) indicate a seasonal response of the potentiometric surfaces at wells in the northern and central parts of Tract III and a subdued response in the southern part of the Tract where much of the recharge to the coal may be from lateral flow from the southeast.

Ground water occurs in fractures in the coal, and pumping tests on six wells in Tract III indicates a range of transmissibility of from one to 35 gpd/ft and a range of permeability from 1 x 10^{-6} cm/sec to 4 x 10^{-5} cm/sec (Westmoreland Resources, 1975 1, p. 61).

Recharge to the Rosebud-McKay coal is from vertical leakage through overlying beds, infiltration into clinker and hence to the coal and from lateral flow from the southeast. Water discharges from the coal to springs and seeps along the base of the coal where it crops out or to clinker and thence to springs, and vertically to recharge deeper aquifers. The potentiometric head in the Rosebud-McKay coal is lower than that in the overburden and higher than that in the interburden and Robinson coal.

Coal interburden zone

The coal interburden zone is between the Rosebud-McKay and the Robinson coals and consists of from 50 to 120 feet of discontinuous sandstones, siltstones, and shales and the stray 2 coal. In the western part of the proposed mine area, the interburden is 50 to 90 feet thick and is composed primarily of siltstone and some shale. In the eastern and southeastern part of Tract III, the interburden is 100 to 120 feet thick and contains more coarse clastics, predominantly sandstone. The sandstones and siltstones have intergranular porosity, and the stray 2 coal has porosity as a consequence of fracturing. Where exposed, the weathering and cementation of the interburden is variable, and infiltration capacities are similar to those of the Rosebud-McKay overburden.

Field and laboratory measurements indicate an upper 20 to 30 foot zone of low permeability composed of shale, siltstone and the stray 2 coal. Three core samples from this zone have vertical permeabilities ranging from 3×10^{-8} cm/sec to 7×10^{-9} cm/sec. (Table 29, Appendix C). The rest of the interburden is lithologically more varied than the upper part. The potentiometric head in the interburden is lower than that in the Rosebud-McKay coal and higher than that in the Robinson coal.

In Tract III, recharge is from vertical flow from the overlying coal and lateral flow from the southeast of the Tract. Discharge from the interburden is mainly to the Robinson coal. Unsaturated zones exist near and in some instances to considerable distances from valley walls as a result of the low permeability of the interburden and the relatively high horizontal permeabilities of the Rosebud-McKay and Robinson coals.

Robinson coal

The Robinson coal is a 20 to 25 foot thick cleated coal having low to moderate fracture permeability. The Robinson is present over most of Tract III and all of the proposed mine area. Near areas where it crops out and the coal has been weathered and in places burned, it has increased permeability. Fractures in the Robinson are saturated through most of the proposed mine area.

Observation wells have been drilled at nine locations in Tract III. Pumping tests indicate transmissivity ranges from 2 to 20 gpd/ft and permeability from 2 x 10^{-6} cm/sec to 5 x 10^{-5} cm/sec. The potentiometric head in the Robinson is lower than that of the interburden and higher than those in the sub-Robinson units.

Ground water in the Robinson coal is recharged by vertical and lateral flow in the proposed mine area in Tract III. Discharge is to springs at the base of the outcrop of the coal, and there is some vertical flow downward to recharge the sub-Robinson units.

Sub-Robinson units

Westmoreland Resources, for purposes of their baseline study, have investigated what are referred to as an upper sub-Robinson unit and a lower sub-Robinson unit. The upper sub-Robinson unit extends to approximately 100 feet below the base of the coal and consists of an upper zone of low permeability of predominantly silts and shales underlying the Robinson coal and a lower more clastic unit of sandstone and siltstone. Borehole packer tests of the shales, siltstones, and the sandstone beds of the upper zone indicate a range of horizontal permeability of from less than 5 x 10^{-8} cm/sec to 2 x 10^{-5} cm/sec

(Westmoreland Resources, 1975 1, p. 38). The more clastic lower zone consists of 60 to 90 feet of fine to medium grained poorly cemented friable sandstone interlayered with some better cemented beds. Transmissivities calculated from pumping tests indicate a range of 20 to 90 gpd/ft and permeabilities of from 2×10^{-6} cm/sec to 4×10^{-4} cm/sec. Borehole packer tests indicate a wider range in horizontal permeabilities in this zone. The permeabilities ranged from 4×10^{-8} cm/sec in interlayered siltstone and well cemented sandstone to 6×10^{-5} cm/sec in poorly cemented, fine-grained sandstone (Westmoreland Resources, 1975 1, p. 38). Vertical permeabilities determined from two core samples were 1×10^{-4} cm/sec and 4×10^{-4} cm/sec (Table 29, Appendix C).

Potentiometric head in the sub-Robinson is below that in the Robinson coal and is below the base of the coal. The upper part of the sub-Robinson may be dry or partially saturated in the vicinity of discharge areas where vertical recharge to the unit has been short circuited as a result of the comparatively high permeability of the overlying Robinson coal where the gound water is moving laterally to discharge at springs at the base of the coal. Throughout most of the area, there is hydrologic continuity between the sub-Robinson and the other aquifers.

The sub-Robinson units are recharged vertically from the overlying coal from lateral flow from the southeast. Discharge is to springs, the alluvium, and to deeper aquifers.

Underlying the upper sub-Robinson unit is a 80 to 250 foot thick unit composed of interlayered sandstone, siltstone, and shale. These rocks are referred to as the lower sub-Robinson (Westmoreland Resources, 1975 1, p. 41), or the Fort Union undifferentiated. Most of the domestic and stock wells in the area are completed in this unit and are 50 to 300 feet deep (Westmoreland Resources, 1975 1, p. 43) and generally yield less than 10 gpm (U.S. Bureau of Indian Affairs, 1974, p. 87).

Recharge to this unit is vertically from overlaying rocks and laterally from the southeast (Westmoreland Resources, 1975 1, p. 42). Discharge is to springs, where the unit crops out, to lower aquifers and upward to overlying aquifers depending on location in the flow system.

Deeper Aquifers

Deeper aquifers that do not crop out in the proposed mine area are little used as a source of ground water within a radius of 50 miles of the area (Westmoreland Resources, 1975 1, p. 22). Of the 156 wells inventoried in the project and for which the source of their yield zones could be identified, only 6 were from below the undifferentiated Fort Union aquifer, and 5 of these were presumably in the Tullock-Hell Creek aquifer one to several miles west of Tract II and about nine miles west of the proposed mine area. In the project area, Westmoreland drilled three test holes from 90 to 180 feet into the Tullock member in an attempt to develop an adequate water supply for the mining operation. An insufficient supply of water was obtained from this drilling program (U.S. Bureau of Indian Affairs, 1974, p. 87). The other deep well tapping aquifers below the Fort Union undifferentiated aquifer is Westmoreland's 7,977-foot deep well to the Madison Limestone which has a potentiometric head of 175 feet above ground surface. A 9,336-foot deep well at Colstrip, Montana, 20 miles northeast of the project area, produces from the Madison Limestone and the Red River Formation and has a potentiometric head 460 feet above ground surface. (Westmoreland Resources, 1975 1, p. 20 and 21).

Aquifers below the Tongue River that probably discharge northward to the Yellowstone River are the Lebo shale aquifer and the Tullock-Hell Creek aquifer. The Lebo shale member of the Fort Union Formation includes few water-bearing sandstone beds, and the contained water is normally too highly mineralized to be usable for either stock or domestic supplies (U.S. Bureau of Indian Affairs, 1975, p. 131). The transmissivity of the Hell Creek Formation in the southern Powder River area is reported to be 1,500 to 4,700 gpd/ft, and a storage coefficient of 4 x 10^{-4} was estimated (U.S. Bureau of Indian Affairs, 1974, p. 88). Deeper aquifers belonging to the regional flow system from the Big Horn Mountains to the Powder River basin that are mentioned in the literature for nearby areas are: The Parkman Sandstone (U.S. Bureau of Indian Affairs, 1974, p. 88), The Cloverly Formation-particularly, its basal conglomeratic sandstone unit, The Amsden Formation, The Madison Limestone, and the Red River Formation (Westmoreland Resources, 1975, p. 21 and 22).

Throughout Big Horn County, the Cloverly Formation is reported to yield moderate to large quantities of water to wells tapping its basal sandstone, and the potentiometric head of this unit is reported to be above ground surface southeast and southwest of the project area (Westmoreland Resources, 1975 1, p. 21).

The Amsden and Madison aquifers are the result of solution of the carbonate rock. A well in the Amsden Formation in Big Horn County indicated that the Amsden had a relatively high yield potential (U.S. Bureau of Reclamation, 1972, p. 54). Hydrologic characteristics of the deeper aquifers are given in the following table from Hurlbut, Kersich, and McCullough, 1972.

TABLE 3 Pumping Test Results

Aquifer		Coefficient of Transmissibility - gpd/ft	Storage Coefficient
Parkman sandstone	T.3 S., R.35 E., Sec. 18	6,000	--
	T.6 S., R.35 E., Sec. 13	20,000	5×10^{-4}
Cloverly Formation	T.6 S., R.35 E., Sec. 21	3,000	--
Madison Limestone	T.9 S., R.53 E., Sec. 22	90,000	--

Quantity and use of water

Typical domestic and stock wells in the area yield generally less than 10 gallons per minute from the Tongue River, Lebo shale, and Tullock members of the Fort Union Formation. Transmissivity values for the Fort Union derived from pumping tests in other areas indicate a range of from 500 to 1,000 gpd/ft, and the storage coefficient is estimated to be 1×10^{-4} (U.S. Bureau of Indian Affairs, 1974, p. 88). Transmissivity and permeability values of the monitoring wells are given in Table 30, Appendix C. Maximum spring flow in the project area from the Rosebud-McKay and Robinson coal beds is between 0.5 and 5 gpm (Westmoreland Resources, 1975 1, p. 44). It is estimated that 90 percent of the total ground-water consumption in the project area and surrounding vicinity is for supplying livestock, based on information provided by land owners. Westmoreland plans to use 90,000 to 250,000 gpd for housekeeping and sanitary purposes. Sprinkling of roads to control dust will be done in the drier parts of the year and will consume most of the water pumped. The actuual amount needed to control dust will depend on the degree of development and the length of the haulage roads. The present source of this water is the well drilled to the Madison Limestone.

Ground-water Quality

Background

There are no long term historical data available on the quality of the ground water resources specifically within Tract III. Only recently (last 4 years) have preliminary studies been made of the ground water quality of the project area as interest has developed in the regional coal resources.

The major man-made characteristic of the project area is the surface coal mine located in Sections 25 and 26, T.1 N., R.37 E., of Tract III. The excavations from the mine and subsequent replacement of spoil material modify the ground-water characteristics of this part of Tract III. The resultant local and regional effect on the quality of ground water due to the mining activities has not yet been determined. Discussion of the water-quality characteristics of the areas affected by the mine will follow in subsequent discussion.

The following comments on the general quality of ground water of the area are taken from U.S. Department of the Interior, 1974:

Chemical quality of ground water depends upon the physical and chemical characteristics of the aquifer, the time the water resides in the aquifer, and the route through which the water travels. Water from clinkered material is often of good quality because its source is usually from recent rainfall and snowmelt. The clinkered material is normally fratured and the fracture system results in a relatively high permeability. The concentration of the dissolved solids of this water is low, and likely to contain ions of magnesium, calcium, and sulfate (Hopkins, 1973). This water is termed "hard water", in reference to its soap consumption. Locally, water contains magnesium sulfate (epsom salt) at concentrations which may make it unsatisfactory for human consumption but acceptable for household use.

Water from the slope wash and alluvium deposits also contains magnesium, calcium and sulfate and is termed "hard". Dissolved solids concentrations of this water are usually higher than water from the clinker deposits. Some slope wash springs contain excessive magnesium sulfate.

Chemical composition of ground water in sandstone and coal bed aquifers in the Tongue River Member depends primarily on the depth at which the aquifer is tapped. The quality varies according to the characteristics of the aquifer intersected. The sandy beds of the Lebo Shale member contain water too highly mineralized to be used for domestic or stock supplies (U.S. Department of the Interior, 1974).

U.S. Bureau of Indian Affairs, 1974, cites the following data:

1) notes on the quality of ground water in the aquifers of the Sarpy Creek drainage basin (see Appendix C, Table 31).

2) selected chemical analyses of wells and springs on Westmoreland Resources Tract III (see Appendix C, Table 32). These data are from analyses of water samples collected by the Montana Bureau of Mines and Geology.

U.S. Bureau of Indian Affairs, 1974, p. 89-90, provides the following generalities from the above data:

(1) With one exception, all analyses indicate that the water is extremely high in hardness; the lowest hardness is from a well in the Lebo shale-Tullock member aquifer.

(2) Varied water quality is present in the alluvium along the major water courses.

(3) Water quality in the Rosebud-McKay overburden and coal seam aquifers is characterized by high calcium and magnesium concentrations in the forms of calcium sulfate and magnesium sulfate.

(4) High sodium as sodium sulfate and sodium bicarbonate is present in water from the Robinson coal seam aquifer.

(5) Water in the Lebo shale-Tullock member aquifer is high in sodium sulfate and sodium bicarbonate. The sodium-adsorption-ratio of this water is generally excessive.

(6) Lowest dissolved solids occur in the Rosebud-McKay aquifer; the highest occur in the alluvium and Lebo-Tullock aquifers.

(7) Iron is found in the ground water, probably associated with sulfur as iron sulfide.

(8) Specific quality of ground water in many of the deeper aquifers underlying Tract III is unknown. It is probable that the Parkman sandstone and Cloverly Formation contain slightly brackish water, characterized by predominant concentrations of sodium bicarbonate and sodium sulfate. The high salinity and sodium precludes the use of this water for agricultural purposes.

(9) The Madison Limestone aquifer contains ground water of fair to poor chemical quality for potable use. Calcium sulfate is the principal constituent. Although this water has a high salinity, it may be utilized for agricultural purposes on soils of good permeability. Domestic users may require acclimation to minimize cathartic effects.

(10) Relatively high ground-water temperatures may be found in these deeper aquifers. Concentrations of iron and hydrogen sulfide may also be present although hydrogen sulfide has not been detected in water from the Madison well supplying the present mine.

(11) Ground water from the shallower aquifer formations is used mainly for domestic and agricultural purposes in the Sarpy Creek drainage.

Van Voast and Hedges, 1974, studied the ground-water quality of aquifers in Tract III. Their objectives were to determine the pre-mining hydrologic conditions in the area, and to establish an observation well system around the area of operations of the Westmoreland Resources mine. Data presented by this study includes: 1) chemical analyses of a number of wells and springs in the area of Westmoreland Resources coal reserves (See Appendix C, Table 33); 2) well data for the Sarpy Creek area near the Westmoreland coal reserves (See Appendix C, Table 26); 3) spring data for the Sarpy Creek area near the Westmoreland Resources coal reserves (See Appendix C, Table 28).

A network of observation wells was established around the periphery of the proposed mine area in Tract III during the summer of 1973. The wells were drilled to different depth and completed to different aquifers. A list of the observation wells is given in Appendix C,

Table 34. Chemical analyses of water sampled from each well in 1974 and 1975 are shown in Appendix C, Table 35.

Results of this preliminary study showed the chemical characteristics of the ground water are diverse, depending on well depth, aquifer, and position in the flow system. Dissolved solids concentrations ranged from 400 to 5,000 mg/l, with a few samples of greater concentration. Laboratory pH values all exceeded 7, with most ranging between 8 and 9. The chemistry of the ground water in the area was not closely related to specific locales or aquifer zones. These workers found water of different types in the Rosebud-McKay zone without any apparent areal pattern. Sodium was noted to be the predominant cation in waters of the Robinson and sub-Robinson zones, and magnesium was found as the predominant cation in waters in the stratigraphically higher zones. No fixed relationship was observed for the predominant anions, sulfate and bicarbonate.

Present Monitoring of the Project Area

In addition to the ground-water monitoring network established by Montana Bureau of Mines and Geology (Van Voast and Hedges, 1974), Westmoreland Resources has also initiated a ground-water monitoring program in Tract III. The program is designed to obtain baseline chemical and physical characteristics of the ground-water in the project area. (Westmoreland Resources, 1975 1). This network includes a selected number of the 43 observation wells within and around the project area. (See Figure 19).

Observation wells located in the Rosebud-McKay overburden and coal, Robinson coal, and the upper sub-Robinson unit were sampled during the summer and fall of 1974 and 1975. Wells in valley alluvium were sampled in the summer and fall of 1975. The chemical analyses produced thus far are given in Appendix C, Tables 36, 37, and 38. From these data, Westmoreland Resources, 1975 1, provides the following comments on the description of the ground water of the mining area during July and October 1974 and August 1975.

(1) Dissolved solids and evaporated solids concentrations range from 75 mg/l in the Rosebud-McKay overurden to 2,700 mg/l in the Robinson coal, indicating increasing concentrations with depth. Likewise, in general, the lowest concentrations of sulfate (about 130 mg/l to 500 mg/l) occur in the stratigraphically high zones on Tract III, the Rosebud-McKay Coal and overburden.

(2) Bicarbonate was the predominant anion in water from the Rosebud-McKay Coal. Both bicarbonate and sulfate were the major anions in water from the Robinson coal. Sulfate was the predominant

anion from the upper Sub-Robinson unit. Low levels of chlorides and nitrates were detected in ground water from all aquifers sampled.

(3) Calcium, magnesium, and sodium concentrations from waters of the Rosebud-McKay Coal showed no apparent areal pattern. Sodium was the predominant cation found in water from the Robinson and sub-Robinson zones. Minor levels of potassium (usually less than 10 mg/l) were detected in all ground water samples.

(4) Three alluvial wells were sampled; two on Sarpy and one on East Fork Sarpy Creeks. The water quality was similar in all wells, with magnesium and sodium concentrations slightly higher than calcium. Evaporated solids ranged from 1,315 mg/l to 1,691 mg/l and sulfate concentrations ranged from 617 mg/l to 788 mg/l.

(5) All ground-water samples collected were alkaline with pH ranging from 7.3 to 9.0. This is attributed to the high bicarbonate and sulfate concentrations in the samples. Strontium was the only trace element found in relatively high concentrations; concentrations ranged from 0.8 mg/l to 11.8 mg/l, with a 3.5 mg/l average for all aquifers sampled. Boron concentrations ranged from 0.04 mg/l to 0.85 mg/l, with an average of 0.35 mg/l for all samples.

Dames and Moore, 1975, p. 19 and 20, provides comments on the monitoring wells sampled in October and November 1975. There was a general increase in the concentration of most major constituents in wells 1A(ROB), 1B(SR), and 2A(RMC), the Robinson Coal, sub-Robinson Zone, and Rosebud-McKay Coal, respectively, since the summer of 1975. Sulfate concentrations decreased in wells 6A(RMC) and 6B(ROB); however, there was a 300 percent increase in sulfate concentration of well 8B(ROB). It appears that most published data are still too infrequent to detect any strong quantitative trends or changes in the water quality of the above wells.

Strontium concentrations from the samples taken in fall 1975 range from 0.42 to 18.79 mg/l (average of 5.5 mg/l), showing a 60 percent increase over those reported in the summer of 1975.

Sulfate concentrations in alluvial wells along East Fork Sarpy Creek increased significantly downstream from well 20 to 13. On August 11, the upstream well (20) provided a sulfate concentration of 788 mg/l; wells 12 and 13 produced sulfate concentrations of 1007 mg/l and 1492 mg/l, respectively, on July 8. (Dames and Moore, 1975, p. 19). A similar increase was noted in sulfate concentration in the downstream direction of the surface waters of Sarpy and East Fork Sarpy Creeks.

In the future, Westmoreland Resources will concentrate ground-water monitoring efforts in wells immediately adjacent to the Tract III mining operations. Water-level measurements in Tract III wells will be made monthly and water-quality analyses annually or semi-annually. The wells to be sampled include the following: Montana Bureau of Mines and Geology wells 1, 2, 4, and 6; Dames and Moore 7 and 8, and alluvium well 10. As test wells are excavated, other wells will be utilized with new wells drilled if necessary. A one-year baseline study of the ground-water quality will be completed in the late summer of 1976. (David W. Simpson, Westmoreland Resources, written communication, 1976).

H. Soils

A soil survey of Tract III and the proposed mine area was made by Westmoreland Resources in 1975. The area was mapped at a scale of 1 inch=400 feet, following the tentative "Soils and Overburden Guidlines (1975)" issued by the Reclamation Division, Montana State Department of State Lands. These guidelines follow the mining permit application requirements that must be met pursuant to the Montana Strip Mining and Reclamation Act. The survey delineated the soil complexes on slopes over 20 percent, and each separate soil was delineated. The survey also combined slope phases that are important only for agriculture interpretations which eliminated some of the soil units that would normally be mapped. The methods of soil sampling and analysis used in the survey are given in Appendix C.

The soils in the area proposed for mining are formed from the Fort Union Formation. The landscape is characterized by rolling hills which are steeply dissected by intermittent drainages that are tributary to Sarpy and East Fork Sarpy Creeks. Outcrops of reddish baked shale occur along the knolls and esarpments overlooking the valleys. The Fort Union Formation is composed of stratified layers of sandstone, siltstone, and shale that weather to form loamy and clay loam soils. The soils range in depth from shallow (10 inches) to deep (60 inches). The deep soils are found primarily in the narrow alluvial valleys, with the shallow soils formed on the knolls and steep escarpments common to the area. The smoother lands in the uplands usually weather to form moderately deep soils (20 to 36 inches) and are sometimes used for agriculture.

Nine soil mapping units were recognized on the proposed mine area. Table 4 lists the soils mapping units including the soil type, slope, suitability as topsoil, and depth of the soil. The areal distribution of the soils on the proposed mine area is shown on Figure 28.

The following is a narrative description of the soils of the proposed mine area as adopted from Westmoreland Resources, 1975 m. A more detailed description of the soils is given in Appendix D.

Fort Collins Loam: This soil type consists of deep, sloping, well-drained soils on fans and in shallow drainageways. Slopes range from 2 to 8 percent. Soil depth ranges from 5 to 8 feet; being deepest along the stream channels. Typically, the A horizon is dark brown loam about 3 inches thick. The B horizon is grayish brown clay loam about 7 inches thick. The C horizon is light yellowish brown loam in the upper part and weakly stratified loam, fine sandy loam, and sandy loam in the lower part and extends beyond 60 inches. On the 4 to 8 percent

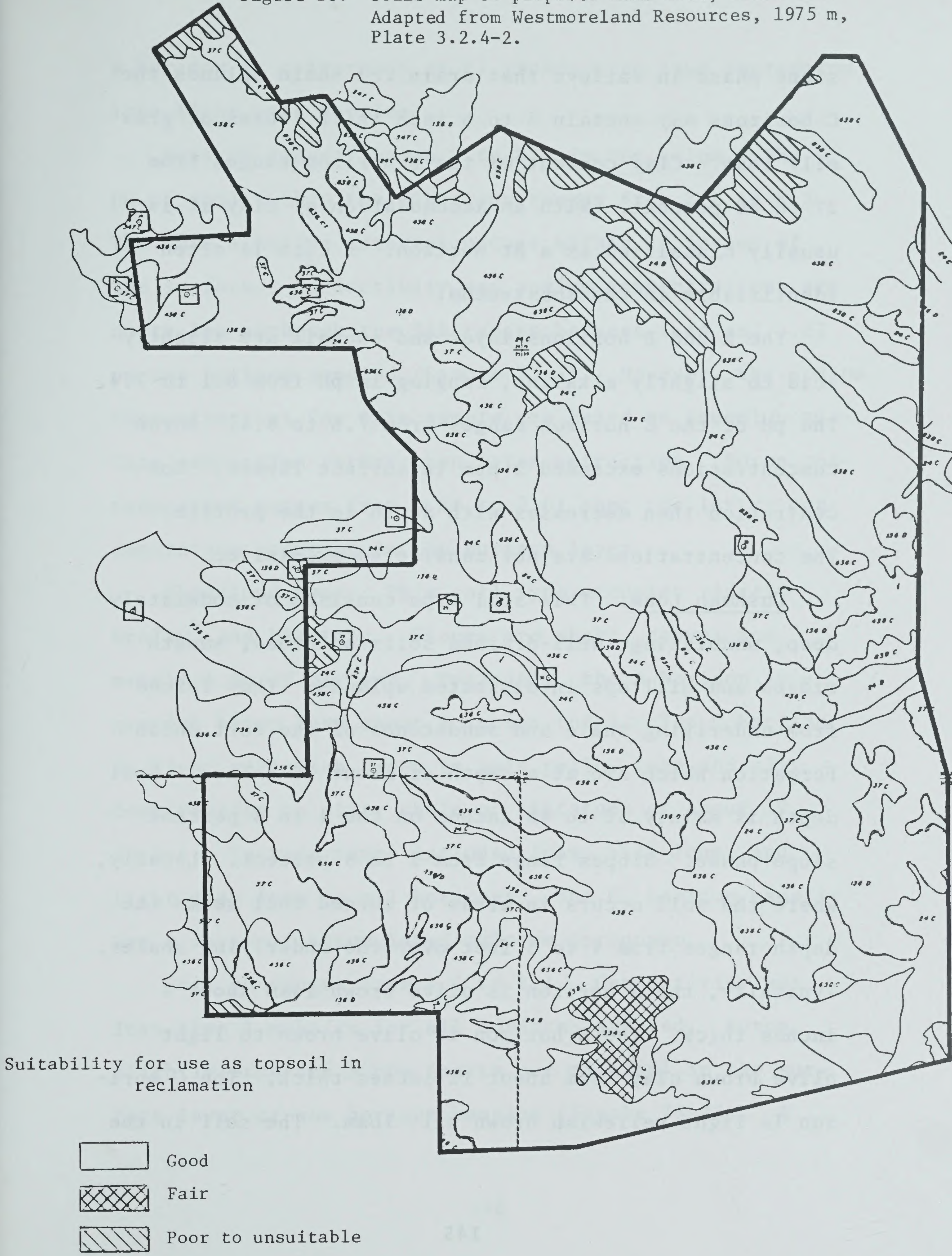
TABLE 4

Soil Mapping Units on Proposed Mine Area

Mapping Unit	Soil Type	Slope (Percent)	Suitability for Topsoiling	Depth of Topsoil
24B	Ft. Collins loam	2-4	Good	60 inches or to bedrock
24C	Ft. Collins loam	4-8	Good	60 inches or to bedrock
37C	Cushman loam	4-8	Good	30 inches or to bedrock
136D	Thedalund loam	8-25	Good	24 inches or to bedrock
334C	Midway silty clay loam	4-15	Fair	12 inches
438C	Nelson fine sandy loam	2-15	Good	30 inches or to bedrock
636C	Thedalund loam	4-8	Good	20 inches or to bedrock
736D	Thedalund-Wibaux	8-15	Poor to unsuitable	Not suitable
838C	Alice fine sandy loam	4-15	Good	60 inches or to bedrock

From Westmoreland Resources, 1975 m.

Figure 28. Soils map of proposed mine area, Tract III. Adapted from Westmoreland Resources, 1975 m, Plate 3.2.4-2.



slope phase in valleys that drain red shale uplands the C horizons may contain 3 to 6 inch thick lenses of gravelly loam. Clay content of the B horizon ranges from 27 to 40 percent. With an accumulation of clay it is usually classified as a Bt horizon. A C_2ca is often identifiable in the substratum.

The A and B horizons layer and subsoil are slightly acid to slightly alkaline, ranging in pH from 6.1 to 7.4. The pH of the C horizon ranges from 7.6 to 8.4. Boron concentrations exceeded 2 ppm in surface layers. Concentration then decreases with depth in the profile. The concentrations are not considered excessive.

Cushman Loam: This soil type consists of moderately deep, undulating, well-drained soils on broad, smooth ridges and hilltops in dissected uplands. They formed from underlying shale and sandstones of the Fort Union Formation which are at a depth of about 38 inches. Soil depth is mainly 30 to 48 inches on the 4 to 8 percent slope phase. Slopes range from 2 to 8 percent. Locally, where the soil occurs in areas of burned coal seams the depth ranges from 4 to 5 feet over the underlying shales. Typically, the A horizon is olive brown loam about 3 inches thick. The B horizon is olive brown to light olive brown clay loam about 12 inches thick. The C horizon is light yellowish brown silt loam. The soil in the

B horizon is calcareous at 11 inches with lime segregated into light gray mottles.

Soil pH ranges from 6.9 to 8.1 in the solum. The pH of soil within the C horizon ranges from 7.6 to 8.5. The more alkaline material occurs within 13 inches of the surface. Conductivity and sodium concentrations are quite low although the SAR ranges between 1.44 and 3.52 on one horizon sampled (Sample 73-3). However, the sodium concentrations for this sample are based on ammonium acetate extraction rather than water extraction. Boron concentration ranges from 0.34 to 2.01 ppm; the latter concentration occuring in the surface layer.

Thedalund Loam: This soil type occupies ridges, knolls, and hilltops. Slopes are short, convex and mainly 4 to 25 percent. Typically, the A horizon is grayish brown loam about 4 inches thick. The C horizon is light yellowish brown to pale yellow loam and silt loam resting on platy shale or siltstone at about 20 inches. Texture range included loam, silt loam, and light clay loam in all horizons. The C_2 horizon usually has a layer of accumulated calcium carbonate.

Soil pH ranges from 7.1 to 8.1. Conductivity was less than 1 mmho/cm for all horizons sampled. Boron slightly exceeded 3 ppm (parts per million) in the surface layer of one horizon sampled (Sample 75-23). A

3 ppm concentration of boron is considered excessive or toxic to growth of some plants.

Midway Silty Clay Loam: This soil type consists of shallow, sloping to steep, and undulating to hilly, well-drained soils on sedimentary plains. Slopes range from 4 to 15 percent. These soils formed in place from materials weathered from silty clay loam and silty clay shale. Typically, the A horizon is characteristically grayish brown silty clay loam about 3 inches thick. The underlying material is pale olive, heavy silty clay loam containing partly weathered shale chips and rests on shale at about 20 inches. Included in the mapping with this soil are 1.8 to 1.4 acre inclusions of Thedalund loam and Nelson fine sandy loam.

Soil pH of the Midway ranges from 7.4 to 8.2 with the more alkaline material being in the C horizon below the 10-inch depth. One C horizon sampled (Sample 75-34) had high concentrations of calcium, magnesium and sodium ions at the 10 to 18 inch depth. The SAR was 2.25 and 5.2 at the 6 to 10 inch and 10 to 18 inch depths, respectively. Boron concentration in the 10 to 18 inch depth was 2.12 ppm.

Nelson Fine Sandy Loam: This soil occurs on smooth hills, ridges, and shallow swales separating major drainageways where sandstone is the underlying rock. Slopes are constant and range from mainly 2 to 15 percent. Soil depth varies between 20 and 45 inches, being least on the narrow ridges and where slopes exceed 10 percent. Typically, the A horizon is grayish brown sandy loam about 5 inches thick. The B horizon is grayish brown, heavy sandy loam about 7 inches thick. The C horizon is light yellowish brown grading to white sandy loam resting on soft sandstone at about 34 inches.

Soil pH ranges from 7.0 to 8.5 and usually increases with soil depth. Conductivity is less than 1 mmho/cm. Typically, the sodium adsorption ratio (SAR) is less than one. However, one horizon (measured between 7 and 13 inches) sampled in 1973 (Sample 73-2) had a SAR value of 8.2. Sodium concentration was determined using ammonium acetate extraction on this sample rather than the saturation extract. Consequently, the relationship of sodium to the SAR is not available. Boron concentrations are not high enough to be toxic.

Thedalund-Wibaux Complex: The 8 to 15 percent slopes phase is characterized by about 55 percent Thedalund loam and about 45 percent Wibaux gravelly and channery loam on red shale uplands in the survey area of Tract III. Neither soil has a fixed or predictable position on the landscape. The red color of the Wibaux soil and the abundance of red baked shale and sandstone rock fragments identify the Wibaux soil from the grayish brown Thedalund. Fused rock boulders and sandstone ledges outcrop at random on the steepest hillsides. Some Spearman loam is included in the mapping. These are in the heads of small drainageways and on the footslopes below rock ledges.

The 15 to 35 percent slopes phase is characterized by about 50 percent Thedalund loam and about 50 percent Wibaux gravelly loam. Channery and stony loam occupies the steep uplands where burned coal beds have colored the rocks red. The soils occur in no predictable pattern but the red color and flat shale fragments covering the surface identify the Wibaux soil. Fused rock boulders and slaty shale outcrops are scattered throughout the Wibaux soil. These soils have profiles that contain more rock fragments than the ones described for laboratory analysis.

Soil depth ranges from 14 to 33 inches. Soil pH ranges from 7.1 to 7.6 which would classify this complex as neutral to slightly alkaline soils. Conductivity ranges from 2.1 to 12.7 mmhos/cm. The highest conductivity occurred in depth range of 6 to 21 inches for one profile. The same depth range also contain high concentration of calcium, magnesium and sodium. This profile also had a 12.4 ppm boron which would be highly toxic to plant growth. High salinity and boron are not characteristic of the Thedalund or Wibaux soils and contamination of the soil sample tested or analytical error is suspected.

Alice Sandy Loam: This soil type consists of deep, sloping to moderately steep, well-drained soils on foot-slopes, alluvial fans and valley bottoms. Slopes range from 4 to 15 percent. This soil type is formed in sandy alluvium from calcerous sandstone. Typically, the A horizon is dark grayish brown sandy loam and ranges from 4 to 12 inches thick. The B horizon is brown to yellowish brown sandy clay loam with a clay content range between 12 and 25 percent in the B. The C horizon is pale brown to light yellowish brown sandy loam to 60 or more inches.

Soil pH ranges from 6.6 to 7.4 in the A and B horizons, and from 8.0 to 8.4 in the C horizon which occurs at about 30 inches. Sodium concentrations are less than 1 meq/l (milli-equivalent per liter) in the A or B horizons but increases to greater than 1 meq/l in the C horizon.

The average depth of soils on the proposed mine area is about 34 inches. Chemical limitations of the soils, especially salinity, boron, and alkalinity, would affect their suitability for topsoiling. No such limitations have been identified although a few samples have elevated values of salinity and/or boron in lower horizons.

In addition to the soil survey, the Colorado School of Mines Research Institute (1975 a) under contract to Westmoreland Resources, prepared an evaluation of the overburden and interburden characteristics of Tract III and of the proposed mine area. The objective of this study was to evaluate overburden and interburden materials occurring on Tract III for their suitability as a subsoil in the reclamation program. As the properties of these materials will be highly significant when used as subsoil material during reclamation, the CSMRI summary related to the proposed mine area is presented in its entirety in Appendix D.

The studies by the Colorado School of Mines Research Institute (CSMRI) indicate that the pH values of the overburden range from 3.8 to 9.5, but most values fall within the range of 7.2 to 8.5. Values below 7.0 were rare and generally associated with carbonaceous material. Only one 4-foot interval in the overburden of the proposed mine site had a pH below 4.5.

Saline material was found in the northwestern part of the proposed mine area. Average soluble salt electrical conductivity ranged from 4.1 to 7.8 mmhos/cm. Soluble salt concentrations of these magnitudes may restrict growth of salt intolerant plants but were rarely found below a depth of 25 feet and would normally be deeply buried.

Only three overburden intervals within the proposed mine area were alkali. Averaged overburden sodium adsorption ratio (SAR) values are low, ranging from 0.9 to

7.1. Alkali intervals are commonly found in the interburden and SAR values range as high as 51. Additional studies were made for Westmoreland by CSMRI to determine if SAR levels in the interburden of some test holes posed a hazard to revegetation. CSMRI compared SAR and exchanged sodium percentage (ESP) values on a number of samples and found that the relationship between these analyses in surface soils did not hold for drill hole material. In surface soils, ESP and SAR are functionally related and SAR was used to derive ESP which is a more complicated analytical procedure. Westmoreland is now using the ESP analytical procedure on overburden analyses.

Limited clay minerology studies were also made by CSMRI to determine if interburden clays were expanding lattice type (montmorillinite). Expanding lattice clays in combination with high exchangeable sodium results in high dispersion and low water permeability characteristic of alkali soils. The majority of the interburden clays were non-expanding (kaolinite) with about 10 percent being montmorillinite. A copy of the CSMRI report on SAR-ESP and clay minerology is included in Appendix C.

In essentially all overburden and interburden on the proposed mine site, the concentration of nitrogen is insufficient to satisfy plant requirements. Analysis for other macronutrients included phosphorus, potassium, magnesium, sulfur, and calcium. Except for phosphorus, the concentrations of these macronutrients were generally adequate for plant needs. Plant micronutrients were generally present in concentrations adequate for plant requirements.

Concentrations of DTPA extractable zinc in the overburden and interburden were above the level generally found in surface soils and ranged from 52 to 200 parts per million (ppm). The occurrence of high zinc levels was erratic and did not correlate between drill holes. To investigate possible contamination of samples, drilling and sample handling procedures were reviewed. It was found that the joint compound used on the drill pipe contained 50 percent zinc, and was a likely source of contamination. A report by CSMRI evaluating the source of zinc contamination is included in Appendix D.

Except for three interburden samples from one drill hole, the boron concentration of overburden and interburden samples tested was less than 6 ppm and appears to be within the range considered nontoxic for many plant species used in revegetation.

The concentrations of total mercury, available selenium, and DTPA extractable cadmium, lead, and nickel were all within the ranges viewed as normal and nontoxic for surface soils. Quantitative analyses for total lead, cadmium, fluoride, and arsenic were made for some of the overburden and interburden in the proposed mine area and semiquantitative spectrographic scans were made for other intervals. Trace element concentrations were within the ranges considered normal and nontoxic for surface soils.

Water retention capacity determined for samples from all but five of the drill holes in the proposed mine area indicate that, with rare exceptions, water retention capacity of the overburden and interburden should not restrict plant growth. Plant growth testing under greenhouse conditions and with fertilizer applied indicated that with few exceptions, the intervals tested were capable of supporting normal plant growth.

I. Vegegation

The vegetative community in the area covered by the proposed mine plan consists of a mixture of native grass-lands, an interesting variety of shrub communities, a moderate amount of cultivated and improved lands, a small amount of previously cultivated land in various stages of revegetation, and a mixture of commercial and non-commer-cial ponderosa pine communities with a varied understory of grass, forbs and shrubs. Ponderosa pine predominates on well-drained soils derived from clinker or sandstone material, and reaches its best development on north and east facing slopes where moisture conditions are most favorable. The various plant communities are fairly evenly distributed throughout the proposed mine area. The size and location of the proposed mine area is such as to make the variation slight and fairly random. There are no known areas within the proposed mine area that are vegetatively unique in character.

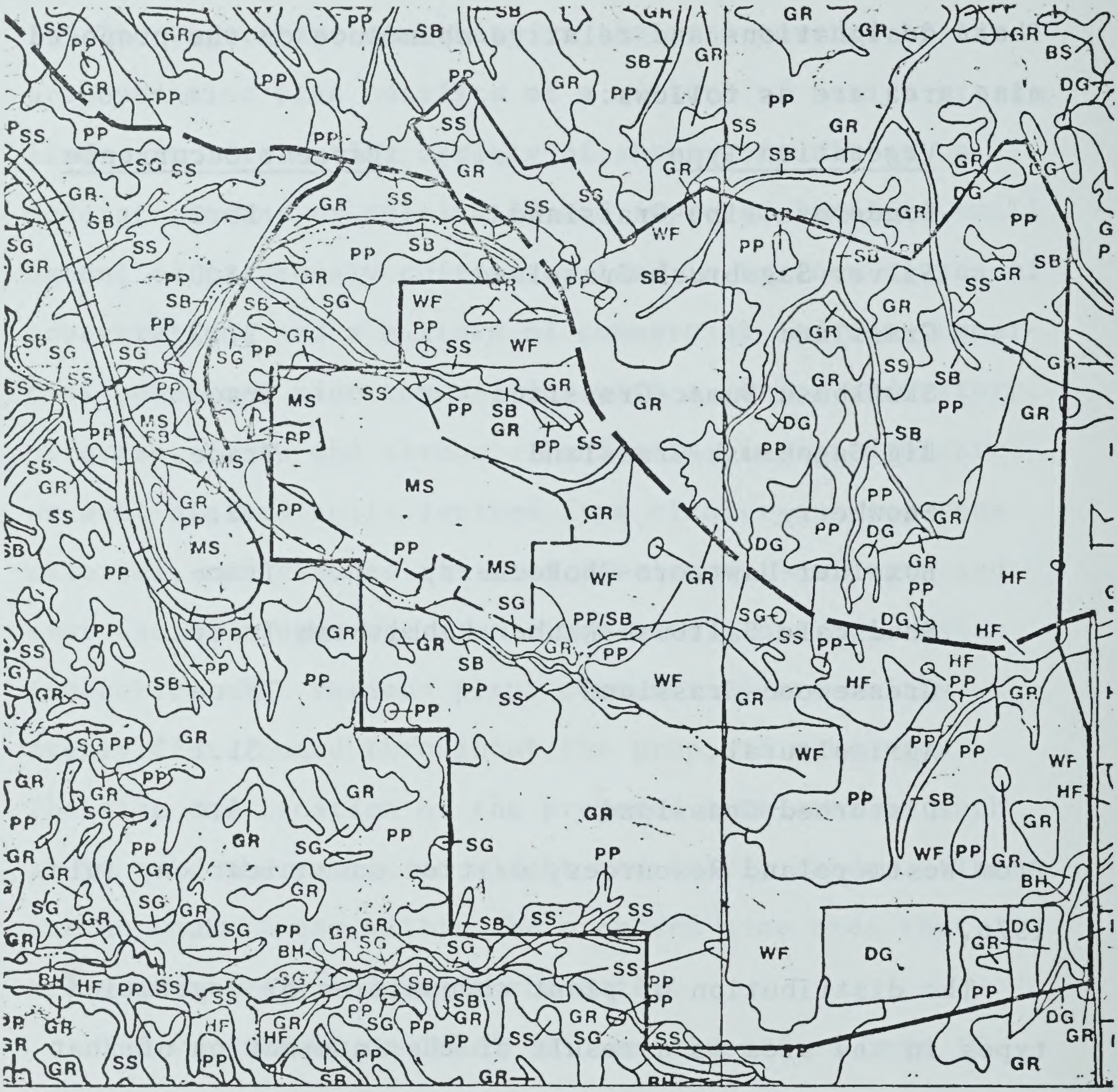
The vegetation on Tract III was classified into 15 vegetation types most or all of which are presumably present on the proposed mine area. There were nine naturally occurring types, two agricultural types, and four disturbance-related types. The distribution of the vegetation types on and adjacent to the proposed mine area is shown on Figure 29. A list of plant species observed in the area is given in Table 1, Appendix D. Their designations and relative abundance on the proposed mine area are as follows:

Vegetation Type	Percent Occurrence
Ponderosa Pine-Grassland	29.2
Silver Sagebrush-Grassland	3.0
Grassland	27.5
Skunkbush Sumac-Grassland	Trace
Big Sagebrush-Grassland	Trace
Snowberry	2.7
Boxelder-Hawthorn-Chokecherry	Trace
Shadscale Saltbush-Rubber Rabbitbush	Trace
Greasewood-Grassland	Trace
Agricultural	31.1
Disturbed Grassland	5.4

From Westmoreland Resources, written communication, July 1976.

The distribution of plant communities or vegetation types in the area is a result of the interaction of that plant community with its physical environment and in some cases the history of past disturbance.

A discussion of the plant communities, including their relation to the physical environment, influences of past disturbance and species composition, is presented in the following paragraphs.



EXPLANATION

GR - Grassland	PP - Ponderosa Pine-Grassland
BS - Big Sagebrush-Grassland	HF - Hayfield
SS - Silver Sagebrush-Grassland	WF - Wheatfield
SG - Skunkbush Sumac-Grassland	DG - Disturbed Grassland
BG - Box Elder - Hawthorn - Chokecherry	MS - Mine Site
SB - Snowberry	SR - Shadscale-Rabbitbrush

Figure 29. Vegetation types on proposed mine area. Adapted from Westmoreland Resources, 1975 o, Plate 2.3.1-2.

Woodland Communities

Ponderosa Pine - grassland type (Pinus ponderosa-grass): This vegetation type was the most predominant and the only woodland community on the area. About 23.7 percent of Tract III was covered by this type. Typically, the Ponderosa Pine-grassland type occurred on upper slopes and ridges with shallow well-drained soils throughout the area and extended into lower elevations along drainage bottoms with cobble soils. Normally, this type was associated with the Thedalund-Wibaux Complex or Thedalund-Wibaux stony loam soils.

One subtype of the Ponderosa Pine-grassland type is the Ponderosa Pine-Juniper type. This type comprised a relatively small acreage on Tract III. Because of the relatively small area of this type on the area and because of its great similarity to the Ponderosa Pine-grassland type, this subtype was combined with the Ponderosa Pine-grassland type. The juniper species are the Rocky Mountain Juniper (Juniperus scopulorum) and Creeping Juniper (Juniperus horizontalis). Grass species associated with both vegetation types included Bluebunch Wheatgrass (Agropyron spicatum), Idaho Fescue (Festuca Idahoensis), Slender Wheatgrass (Agropyron trachycaulum), Side-Oats Grama (Bouteloua curtipendula) and Bluegrass (Poa sp.).

The density of the pine overstory varied from approximately 111 to 1381 trees per acre on Tract III, generally reaching greatest density on north facing slopes. Ages of trees sampled ranged from 17 to older than 106 years on Tract III. The diameter at breast height (DBH) of trees on Tract III was approximately 6 inches. The understory of the Ponderosa Pine-grassland type also varied. Open stands had a greater understory than closed stands.

Grassland and Grassland-Shrub Communities

The grassland community differs from the grassland-shrub community in that the major portion of the grassland vegetation consists of grasses and forb species, whereas, in grassland-shrub communities a predominant woody shrub species is present. These communities are composed of numerous plant community types. Particular communities and dominant species within the communities depend upon topography, soils and past history of disturbance.

Grassland type: The grassland vegetation of this south central Montana area is of note because it is within the region where the bunch grass prairie of the northwest and short grass prairie of the Great Plains meet. These grasslands intermingle along a wide zone as a result of variations in soils, micro-climate and broken topographic relief (Wright and Wright, 1948). The Tract III lease is located within this zone.

Wright and Wright (1948) studied several grassland types of south central Montana. Because their results parallel the observations made on the lease area, a brief comparison follows. They classified five grassland types. Listed from most mesophytic (medium moisture) to most xerophytic (arid) they are: 1) Idaho Fescue type; 2) Bluebunch Wheatgrass type; 3) Bluebunch Wheatgrass-Needleleaf Sedge (*Carex filifolia*) Blue Grama (*Bouteloua gracilis*) type; 4) Blue Grama-Needle-and-Thread-Junegrass (*Koeleria cristata*); 5) Blue Grama-Needle-and-Thread type. Type 1 occurred in regions of well-drained soils with favorable moisture conditions. On the project area, the Idaho Fescue type grassland occurred mainly on north facing slopes with deep soils. Wright and Wright (1948) found that type 2 grassland occurred on spring moist sites with reduced grazing. On the lease area this type occupied sites of shallower soils in areas protected from grazing. Wright and Wright (1948) demonstrated that the type 3 grassland dominated on sandier soils. This type, however, was uncommon on the lease area. The type 4 grassland was the most common grassland type. According to Wright and Wright (1948), this type was found on the heavier textured soils throughout the Hardin-Billings area which includes the lease area. Type 5 grassland occupied extremely dry sites (Wright and Wright, 1948).

On the lease area, this type was present on extreme south and west facing slopes with sandy soils. The grassland type occurred on about 28.4 percent of Tract III. Grass species associated with this type included Western Wheatgrass, Bluebunch Wheatgrass, Side-oats Grama, Blue Grama, Sandberg Bluegrass (Poa sandbergii), Needle-and-Thread, Green Needlegrass (Stipa viridula), Little Bluestem (Andropogon scoparius), Junegrass, and Prairie Sandreed, Red Three-awn (Aristida longiseta), and Idaho Fescue.

Silver Sagebrush-grassland type (Artemisia cana-grass): This vegetation type comprised 9.7 percent of Tract III. It occurred on relatively level terrain, usually along drainage bottoms of the Thedalund-Nelson or Thedalund-Wibaux Complex soils. Silver Sagebrush was the dominant shrub of this type. Houston (1961) studied the distributions of Big Sagebrush and Silver Sagebrush types near Miles City, Montana. He noted that two types were greatly influenced by edaphic and grazing effects. Big Sagebrush type was favored under heavy grazing on upland soils while light grazing favored Silver Sagebrush type on upland soils. Heavier textured terrace soils were unfavorable to both regardless of grazing pressure.

Common Forb species of this type included Yarrow (Achillea millefolium), Golden Aster (Chrysopsis villosa), Silverleaf Scurfpea (Psoralea agrophylla), Chickweed

(Cerastium arvense), Aster (Aster sp.) and Prairie Coneflower (Ratibida columnifera). Common grasses included Green Needlegrass, Idaho Fescue, Japanese Brome (Bromus japonica) and Western Wheatgrass.

Skunkbush Sumac-grassland type (Rhus trilobata-grass): The Skunkbush Sumac-grassland type covered approximately 10.8 percent of Tract III. This type occurred on relatively dry, steep, west and south facing slopes of the Thedalund-Wibaux Stony Loam or Thedalund-Nelson Complex soil types. On level terrain this type occupied areas with reddish-colored scoria outcrops. Skunkbush Sumac was the dominant shrub; however, Prairie Rose (Rosa Arkansana) and Western Snowberry (Symphoricarpos occidentalis) sometimes co-dominated. Common grasses of this type included Needle-and-Thread, Prairie Sandreed, Side-oats Grama, and Cheatgrass (Bromus tectorum). Forb species were not as prevalent in this type as in other types. However, common forbs species included False-taragon Sagewort (Artemisia draunculus), Low Ragweed (Ambrosia artemisifolia), and Rush Skeletonweed (Lygodesmia juncea).

Big Sagebrush-grassland type (Artemisia tridentata-grass): The Big Sagebrush-grassland type comprised about 5.0 percent of Tract III. It was associated with the Thedalund and Nunn series as well as the Thedalund-Midway Complex soils. As previously mentioned, Big Sagebrush was shown to increase in dominance under heavy grazing pressure on the upland soils near Miles City, Montana (Houston, 1961).

Co-dominant grass species within this type included Western Wheatgrass, Side-oats Grama, Blue Grama and Sandberg Bluegrass. Common forbs included Fringed Sagewort (*Artemisia frigida*), Slimflowered Scurfpea (*Psoralea tenuiflora*), and Yarrow. Broom Snakeweed (*Gutierrezia sarothae*), a shrub, was also common.

Shadscale Saltbush-Rubber Rabbitbrush type (*Atriplex con fertifolia-Chrysothamnus nauseosus*): This type occurred only on Tract III. Ecological Consulting Service (ECS, 1974) studied this type and called it Caprock Gumbo Knob Type. They stated (p. 33):

> "This type occupied only 0.3 percent of Tract III and was found at the northern end, and more extensively in the southeast corner of the study area where it was interspersed with the Ponderosa Pine type....This type was typically found on extremely severe sites with steep slopes and possible localized alkaline conditions. It appeared to function as a persistent subclimax or rather stable edaphic variant to the regional climax, using the terminology of Oosting (1956). The Midway-Thedalund soil complex was most closely associated with this vegetation type."

Referring to the ground cover, they stated (p. 33):

"This type generally had a very sparse ground surface cover with very little litter. Bluebunch Wheatgrass and Indian Ricegrass (Oryzopsis hymenoides) are the prevalent grass species. Eriogonum (Eriogonum multiceps) and Nuttail Goldenweed (Haplopappus nuttallii) are the most abundant forbs, while Rubber Rabbitbrush (Chrysothamnus nauseosus) and Prairie Rose are the common shrubs."

Greasewood-grassland type (Sarcobatus vermiculatus-grass): This type only occurred on Tract III. Concerning this type, ECS (1974) stated (p. 35):

"A very small acreage of this type exists at the northern end of Tract III....It has been heavily grazed by domestic livestock, and the shrub overstory and grassland understory appear depleted. In Sarpy Creek, this type appears to be confined to, or associated with, the alluvial soils of the Sarpy Creek floodplain. No field analysis of this limited habitat type was conducted during the course of this study."

Shrub Thicket Communities

Two shrub thicket communities occurred on the area, the Snowberry type and the Boxelder-Hawthorn-Chokecherry type. Both communities occurred as dense stands along moist drainage bottoms but occupied different sites along the moisture gradient. The Snowberry type occupied upland areas while lower more mesic areas were dominated by Boxelder-Hawthorn-Chokecherry type. Dominance of species within these communities is variable and dependent upon moisture conditions.

Snowberry type (Symphoricarpos occidentalis): This vegetation type occurred on about 5.3 percent of Tract III. The Snowberry type occurred in areas where moisture persists through the summer as a result of large accumulations of snow in the valley bottoms during the winter or overflow conditions. The dominant shrub, Western Snowberry, formed large oval stands with numerous stems present. This habit may indicate that the species was clonal at these locations. At the edge of the stand, Snowberry intergraded with the surrounding grassland. Few other plant species inhabited the dense thicket formed by the Snowberry; however, Kentucky Bluegrass (Poa pratensis) was one of the more prevalent grasses encountered and Yarrow was the common forb.

Boxelder-Hawthorn-Chokecherry type (Acer negundo-Crataegus succulenta - Prunus virginiana): This vegetation type covered approximately 2.5 percent of Tract III. It occurred in narrow strips adjacent to permanent creeks and seasonally moist gully bottoms. A tree overstory of Boxelder was most common usually with an association of the shrub-like trees, Succulent Hawthorn and Chokecherry.

In addition, Green Ash (Fraximus pennsylvanica) commonly occurred with these species (ECS, 1974). Other associated shrubs included Prairie Rose, (Rosa arkansana) and Western Snowberry. The predominant grass species included Kentucky Bluegrass and Western Wheatgrass.

Agricultural types: The agricultural types comprised 11.9 percent of Tract III. Predominant crop plants included Alfalfa (Medicago sativa), Wheat (Triticum aestivum) and Barley (hordeum distichon). Figure 29 distinguishes two agricultural types, hay fields and wheat fields. Hay fields included alfalfa and native grass hay fields while wheat fields included fallowed fields and all small-grain fields.

Disturbed Area types: Disturbed areas were non-agricultural areas where practices of man, other than cattle grazing, have greatly altered the native communities. The vegetation at these sites exhibited various seral stages of plant succession toward the original climax state. On Tract III, several stands of Ponderosa Pine were commercially logged, thus altering the composition of this dominant species. Roadways throughout the lease area, both for railroad and highway traffic have altered the nature of the immediate and adjacent vegetation. On Tract III, the coal mine spoils and handling site have resulted in removal of the native vegetation on approximately 1.5 percent of the tract.

J. Fish and Wildlife

Numerous studies of fish and wildlife have been conducted on Tract III since 1972 and are continuing today as mining proceeds in the approved mine area. Westmoreland Resources has contracted work from B. C. Research, Ecological Consulting Service, Dames and Moore Consultants and Montana State University to research the wildlife and fish of the area. The Montana Department of Fish and Game has made area-wide wildlife and fishery studies on the Sarpy Creek Basin.

Tract III supports large numbers and a wide variety of wild animals. Due to the lack of large quantities of water, the fish populations in the area are minimal.

1. Mammals of the area

A total of 54 species of mammals have been listed (Table 1, Appendix E) that occur or may occur on Tract III. Table 2, Appendix E lists some habitat and food requirements of these mammals.

Those mammals classified as big game animals that occur on the area are the mule deer, _Odocoileus hemionus_, the white-tailed deer, _Odocoileus virginianus_, and the pronghorn or antelope, _Antilocapra americana_.

Mule deer are the most numerous of the three species on Tract III. Their greatest concentrations are located in the central to northern and extreme south-eastern and south-western portions of Tract III (Westmoreland Resources, 1975 o, Figure 2.3-2). These concentrations coincide with timbered areas on the lease (Ecological Consulting Service, 1974). A total of 559 mule deer sightings were made on Tract III from January to December, 1975 (Westmoreland 1975 o, and Dames and Moore, 1975). The greatest number sighted during one time period was 43. This number gives a minimum population density of 0.86 deer/square mile (Westmoreland Resources, 1975 o).

The composition of the mule deer herd on Tract III appears to differ with that of surrounding areas (Table 3, Appendix E). Fawn production and/or survival is low resulting in a lower fawn per 100 doe ratio. The number of bucks per 100 does was generally higher than that in surrounding areas except during the 1975 survey (Westmoreland Resources, 1975 o).

The ponderosa pine-grassland association is the most used habitat type by mule deer on Tract III (Table 4, Appendix E). Escape cover, resting, and bedding are probably its chief functions. Secondary habitat use was varied depending upon the time of the year (Tables 5 and 6, Appendix E). Silver Sagebrush grasslands were used most heavily during the spring months; agricultural lands were utilized in late winter, early spring and late summer; skunkbush-grasslands use occurred during the summer and fall; creek bottom, snowberry coulee, grassland and big sagebrush-grassland habitat types were used in spotted fashion throughout the year. Food availability undoubtedly dictates the habitat preferred by mule deer and thus accounts for their distribution.

"Known foods of mule deer include so many plants that it is not practical to list them all. Palatability is a relative factor, varying with local availability. Within one association a plant may rate high, whereas the same species occurring in a different association may be only lightly used (Taylor, 1965)." Foods of mule deer on the lease would be equally difficult to ascertain without intensive studies. Plants that are probably used in the mule deers diet are listed in Table 7, Appendix E.

Economically, the mule deer in Montana is very important. Thousands of sportsmen hunt deer each year and they provide a large portion of the Fish and Game Department's annual income to conserve all of Montanas' wild species.

White-tailed deer are the least numerous big game animal on Tract III. Most individuals were observed in the east-central portion of the area. A total of 65 white-tails were observed on Tract III from January-December, 1975.

Dames and Moore (1975) reported a doe/fawn ratio of 60:100 for white-tails. On the basis of their finding, the population structure would be: 60 fawns/100 does; 45 fawns/100 adults; 33 bucks/100 does; 17.2 percent bucks-51.7 percent does-31.0 percent fawns. This small sample (15 does, 5 bucks, 9 fawns) is probably not enough to make a valid estimate for the population but is the only information available. White-tail numbers appear to be increasing throughout southeastern Montana (Martin, 1975).

White-tails were observed in only five habitat types: sprouted wheat fields, ponderosa pine-grasslands, grasslands, creek bottoms, and alfalfa hay (Westmoreland Resources 1975 o, and Dames and Moore, 1975). Ponderosa pine and creek bottom associations are probably the most important habitat types to these deer for cover, food and bedding, due to their secretive nature.

Foods of the white-tailed deer are numerous. Taylor (1965) suggests that it would be easier to list the plant species that are not eaten than to name those that are. Table 7, Appendix E, lists the plant species available from the lease that may be utilized. Most white-tail studies have been conducted on eastern populations; very little information on Montana white-tailed deer is available.

The Sarpy Creek Basin, including Tract III, is a relatively poor area for antelope production (Martin, 1975). For the period January-December, 1975, observations of antelope on Tract III totaled 169. The highest single count totaled 14 individuals (Westmoreland Resources, 1975 o). Observations were made during April-September and November. Habitat is apparently not suitable during the winter months to support the herd. Martin (1975) states that large areas of relatively flat land, covered with sagebrush, are necessary for good antelope range.

The fawn per female ratio is low in comparison to some Montana areas. Westmoreland (1975 o) reported a ratio of 36:100 on Tract III for 1974 and stated that a fawn:doe ratio of 30-40:100 could be expected in the Sarpy Creek area. Early 1975 counts were too low to estimate the fawn to doe ratio but for the period of July-December it was 24:100 (Dames and Moore, 1975). Martin (1975) reported a decline in the fawn:doe ratio from 58.6:100 to 38.4:100 in the Sarpy Basin during 1974. These data indicate that fawn production per survival is near the levels of adjoining areas.

Antelope sighting occurred on grasslands 71 percent of the time (Table 8, Appendix E). Other habitat types were relatively unimportant for antelope use.

Pronghorns consume a wide variety of plant foods. A portion of those that are available on Tract III are listed in Table 7, Appendix E.

Coyotes are numerous on the lease. Much emphasis has been placed on this member of the dog family because of its predatory nature, large numbers, and presently high fur values. Coyotes are highly adaptable to their surroundings and have survived and prospered through every concerted effort to reduce their numbers.

Coyotes may be found in all habitat types especially when they are hunting. They require terrain that provides cover for resting, bedding, and escape. Observations on Tract III were made in ponderosa pine-grassland (7 sightings), silver sagebrush-grassland (9 sightings), grassland (14 sightings), creek bottom (9 sightings), alfalfa hay (8 sightings), big sagebrush-grassland (1 sighting), skunkbush grassland (1 sighting), and snowberry coulee (1 sighting).

Foods of the coyote are mostly animal, however studies have shown that around 2 percent of their diet may be vegetable (Martin, et. al, 1961). They are blamed for depredations on large numbers of domestic stock, birds, and wild game animals. Their chief source of food is small mammals, birds and carrion.

Other predators observed on the project area include the Striped Skunk, Raccoon, and Bobcat. The only furbearer observed near the project area was the Muskrat although Beaver reportedly occur in Sarpy Creek.

Medium sized mammals observed on the project area included Desert Cottontail Rabbits, White-tailed Jackrabbits, and Red Squirrels. Evidence of Porcupine exists in the area but they were not observed. One small Black-tailed Prairie Dog town is present near the southeast corner of Tract III, but none have been observed on the proposed mine area.

A total of eight species of rodents have been identified from traps sampling representative habitats in the project area. Included were Deer Mouse, Western Harvest Mouse, Prairie Vole, Least Chipmunk, Olive-backed Pocket Mouse, Northern Grasshopper Mouse, Thirteen-lined Ground Squirrel, and Montane Vole. Evidence indicated that the Northern Pocket Gopher inhabits the area but none were observed.

The most abundant and widely distributed rodent species in all habitats was Deer Mouse. The Western Harvest Mouse was the second most widely distributed species but was most abundant in Ponderosa Pine.

A listing of food habits and habitat preference of the mammals is given in Table 2, Appendix E.

2. Birds of the area

A list of 236 species of birds that occur or potentially occur on or near Tract III is included in Table 9, Appendix E. This listing is revised from Westmoreland Resources data (1975 o). Species observed on the project area are indicated as well as those species that are of special interest in Montana. Information on food habits and habitats of family groups, sub-family groups and individual species is provided in Table 10, Appendix E.

Sharp-tailed grouse are common on the lease. Information obtained by researchers on this important game bird is provided in Table 11, Appendix E.

Martin (1975) located a total of 16 shart-tail leks in the Sarpy Creek Basin; most were found on or just north of the lease. He observed 203 male birds on these grounds. By using the same formula (4 x number of male grouse) that Westmoreland researchers used to determine the grouse population on Tract III, there would be about 812 shart-tailed grouse in Martin's Sarpy Creek Basin study area.

One sharp-tail lek has been observed in the proposed mine area. When observed in 1975, this lek had 14 dominant males corresponding to an estimated spring population of 56 birds.

Sage grouse were not located on Tract III. This area is probably not good sage grouse habitat as they require extensive sagebrush plains. Martin (1975) located three sage grouse leks, all north of the lease. He stated that the 11.7 males per lek was an indicator of poor sage grouse habitat as the average for southeastern Montana is 43.2 sage grouse males per lek.

Ring-necked pheasants are one of the most visible birds on Tract III. The cover provided by Sarpy Creek and East Fork of Sarpy Creek along with the associated agricultural and grazing land produces good habitat for pheasants. Information compiled by researchers on the Sarpy Creek ring-necked pheasant population is presented in Table 12, Appendix E.

Although no population estimates are made, the crowing count routes are indicators, from year to year, of the stability of ring-necked pheasant populations. Lower Sarpy Creek undoubtedly contains the highest ring-necked pheasant populations of the area. The population on Tract III is comparable to the average for all of Sarpy Creek and much higher than the population in surrounding drainages.

Agricultural areas are important to the ring-necks of the lease for feeding. It is probable that counts were higher on alfalfa hay and grasslands due to the better visibility in these two habitat types. The amount of available creek bottom habitat is probably the limiting factor with the pheasant populations of the lease.

Merriam's wild turkeys that are present on Tract III are probably the result of stocking two tom and fifteen hen turkeys in 1957 (Martin, 1975). Table 13, Appendix E is a summary of Merriam's turkey data from Sarpy Creek.

The ponderosa pine-grassland, alfalfa hay, and silver sagebrush-grassland ranked highest in preferred habit type usage. No population estimates were made. Several flocks of 20 or more birds were observed.

Four species of ducks (mallard, green-winged teal, blue-winged teal, shoveler) were observed on Tract III. Other species probably use the area for resting and feeding during migrations. Lack of adequate aquatic habitat probably limits their use of the area. Nesting has been recorded in the vicinity and one mallard brood was hatched on an East Fork of Sarpy impoundment (Westmoreland, 1975 o).

Raptors observed on the lease were: great horned owl, saw-whet owl, golden eagle, sparrow hawk, prairie falcon, rough-legged hawk, red-tailed hawk, Swainson's hawk, and marsh hawk (Westmoreland, 1975 0, and Dames and Moore, 1975). No raptor nests have been reported on the lease, although with the exception of the rough-legged hawk all of the species listed may nest in the area.

Table 14, Appendix E is a summary of the data collected on the birds of Tract III. Species previously mentioned are included in this table.

3. Reptiles and Amphibians

Reptiles and amphibians that occur or potentially occur on or near Tract III are listed in Table 15, Appendix E. Notes on habitat and food requirements are given in Table 16, Appendix E. No species considered as endangered or threatened occur on the area.

4. Aquatic environment of the area

Tract III is drained by Sarpy Creek on the west and East Fork of Sarpy Creek on the east. These two streams roughly form the west and north boundaries of Tract III. All streams of this area are intermittent including Sarpy Creek. Thirty-five springs have been located (Westmoreland Resources, 1975 o, Plate 2.2.3-2).

Researchers at the Cooperative Fishery Research Unit, Montana State University, Bozeman, have conducted an aquatic resources study on Sarpy Creek for Westmoreland Resources (Dames and Moore, 1975). Fish species, aquatic invertebrates, bottom material composition, and streamside vegetation were studied in the lease area and downstream to the Yellowstone River.

Bottom composition (Table 17, Appendix E), in Sarpy Creek is primarily classified as muck. This condition is explained by the abundance of plant material and the sluggish current found in the stream (Dames and Moore, 1975). Fiberous peat and detritus, both of organic nature, were second and third in occurrence in the stream.

Twenty-six families of aquatic invertebrates were classified from bottom samples taken from Sarpy Creek. These families are listed in Table 18, Appendix E. The upper sections of Sarpy Creek and East Fork of Sarpy Creek are dominated by species that prefer soft, muddy substrates and slow-moving waters.

Ten species of fish that were identified from the Sarpy drainage are listed in Table 19, Appendix E. Habitat and food requirements are listed in Table 20, Appendix E. Three species, the lake chub, fathead minnow, and white sucker were observed in the lease area. The remainder of the fish species collected were found below the lease in lower Sarpy Creek with the majority of them being taken near its confluence with the Yellowstone River. The sauger was the only Montana game fish collected from Sarpy Creek.

Endangered and threatened species

Endangered species that could potentially occur in the area are the peregrine falcon, whooping crane and the black-footed ferret. None of these has been observed on the Tract III lease, and it is highly unlikely that any would occur there due to the lack of suitable habitats. The peregrine falcon and whooping crane would occur only as migrants, and the black-footed ferret is normally associated with prairie dogs, which except for a very small colony southeast of the mining plan area are not present on the lease. The prairie falcon, a threatened species, has been observed in the area. The prairie falcon requires steep, precipitous terrain for nesting, and it is unlikely that suitable nesting sites would be affected by mining.

Nine species of mammals and 30 species of birds (Table 11) that occur or may occur on the lease are listed as priority management species by the Montana Department of Fish and Game (Westmoreland Resources, 1975 o). Mining and related activities may have special significance where these species are concerned. A number of these species have been observed in the area of the leases:

Desert Cottontail - The desert cottontail is common along major creek bottoms and other shrub habitats. It may be adversely affected by mining of upland drainageways having suitable habitat, but planting of shrubs should create suitable habitat in reclaimed areas.

Black-Tailed Prairie Dog - One small colony of about 20 animals is present on Tract III, but is not included in the mining plan area.

Golden Eagle - No steep precipitous areas used by the golden eagle for nesting will be affected.

Prairie Falcon - (see above, first paragraph of the section).

Yellow-billed Cuckoo - The yellow-billed cuckoo is peripheral in Montana, is common over most of the country, and in the lease area is most likely to occur along Sarpy and East Fork Sarpy Creeks. Mining of wooded and brush habitats in upland areas could adversely effect this species in the lease area, although such habitats should eventually develop on reclaimed areas.

Western Kingbird - The western kingbird is common in the area during the nesting season. It's primary habitat needs are met along drainageways where trees and shrubbery provide nesting habitat. Like the yellow-billed cuckoo, it may be adversely affected until suitable habitat develops on reclaimed areas, although significant areas of suitable habitat will not be affected.

Based on available information regarding endangered and threatened plant species, adverse effects are not expected since none of the species so identified are likely to exist on areas to be affected by mining.

K. Non-coal mineral and mining activity

There is no present or past history of mining activity other than coal in the proposed or alternate mining areas.

L. Land Use

There are approximately 785 acres of land in the proposed mine area that is or has been cultivated. Some land is also used for roads, power transmission lines, and dwellings. The remainder of the area, about 1365 acres, is used for grazing. Within the grazing area there are scattered stands of Ponderosa pine occupying about 625 acres. All of the proposed mine area is utilized to some extent as habitat for a wide variety of wildlife.

The farmland is used for the production of small grains and alfalfa. The alfalfa is commonly harvested for seed, which helps support the livestock industry of the area. Table 2, Appendix D shows the average yields, value, and price for various crops grown in Big Horn County in 1972 and 1973. Present land use on Tract III and the proposed mine area is shown on Figure 30.

In 1975, about 785 acres within the proposed mine area were used for dry cropland or had been cultivated previously. The 1975 value of dry cropland in the area has been estimated at $200 to $350 per acre and net income from dryland agriculture is estimated to be about $30.33 per acre per year. Thus, the dry cropland on the proposed mine area might be expected to produce income of $23,809 per year.

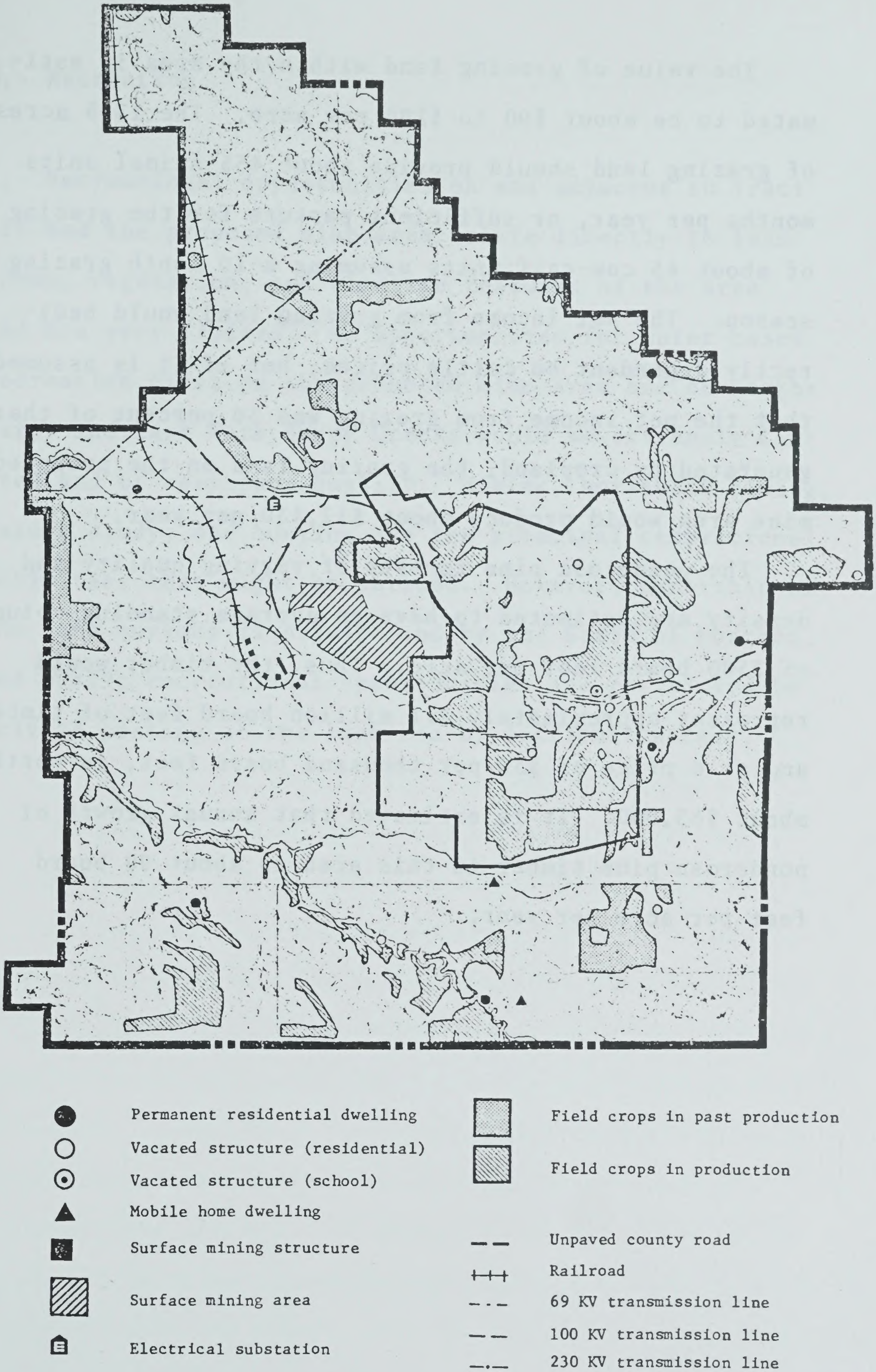


Figure 30. Land use in Tract III and the proposed mine area. Adapted from Westmoreland Resources, 1975 b, Plate 2.1.1-3.

The value of grazing land within the area is estimated to be about $90 to $100 per acre. The 1365 acres of grazing land should provide about 455 animal units months per year, or sufficient pasture for the grazing of about 45 cow-calf units assuming a 10 month grazing season. The net income from grazing land would bedirectly dependent on cattle prices, but if it is assumed that the net income from grazing was 30 percent of that generated by cropland, the grazing land on the proposed mine area would produce about $12,430 per year.

The ponderosa pine forests of varying quality and density are estimated to have an average standing volume of 3300 board feet per acre. Thus, the timber would represent approximately 2.1 million board feet of timber and at a price of $30 per thousand board feet, is worth about $63,000. It is estimated that annual growth of ponderosa pine timber in this area is about 90 board feet per acre per year.

M. Recreation

Recreational opportunities on and adjacent to Tract III and the proposed mine area relate directly to land forms, vegetation, and wildlife features of the area and are very limited. No opportunities for water-based recreation exist on the proposed mine area and on nearby Sarpy and East Fork Sarpy Creeks would be extremely limited and of very poor quality. Hiking, horseback riding, nature study, and hunting are the principal recreational activities that might be pursued. However, ownership of the land surface is private and by the State of Montana, and public recreational opportunities are restricted by private posting of the land and by difficult access.

N. Culture

The population of Big Horn County, in which the Westmoreland leases are located, has been relatively stable over the past 40 years at approximately 10,000 persons. Treasure County, lying approximately north of the lease site had only 1,069 persons in 1970 and has experienced a steady decline since 1930. The Indians in Big Horn County have, on the other hand, had a continuous population growth since 1940. The U.S. Census of Population indicated an Indian population of 3,917 (primarily Crow members) in Big Horn County in 1970 while the tribal estimates based on enrollment statistics would indicate a higher Crow resident population at somewhat over 4,000.

The Sarpy Census Division population was 215 in 1970, down from 246 in 1960. Of the 215, only 16 were Indian. The Sarpy Division encompasses the proposed mine area and is divided almost equally between the reservation (the extreme northeastern corner of the Crow Reservation) and the Ceded Area (the southeastern part of the Crow Ceded Area).

The culture of the people, both Indian and non-Indian, in the region of the proposed Westmoreland coal mining site is highly influenced by generations of living in close association with nature. It is the often expressed opinion that among both races, the local people have developed a way of life and a system of values, that reveres land and open space.

The culture of the Crow Indians and the heritage of their people is more accurately described below by a tribal member.

> "The Crows are of Siouan origin but had broken away from their ancestral group (Hidatsa) and settled along the valleys of the Yellowstone and Big Horn long before the coming of the white man. This tribe was originally called Absarokee which means 'Children of the large beaked bird', probably the raven.
>
> "The Absarokee Tribe evolved through several stages of cultural development. The early ancestors who lived in the eastern forests practiced agriculture and achieved a fairly high level of civilization. As they were pushed westward, they gradually became more and more dependent upon the hunt. By the time of their settlement on the plains, their agricultural pursuits were limited to the planting of corn and squash. Soon after their separation from the main Tribe (probably somewhere in what is now North and South Dakota), the Absarokee abandoned agricultural ways and became a nomadic people."

Early dependence on the land has influenced the cultural values of the Crow Nation. "Personal gain and the accumulation of private wealth has little prestige value in the Crow Communities."

Religion also has an influence on a people's culture. The old time Crow Indians recognized a supreme being whom they called "First Maker" but did not worship it directly. They sought its benevolence and favor through the worship and devotion to various animals and objects of nature which were regarded as possessing supernatural powers given them by the "First Maker." Although virtually all Crow Indians are now heavily influenced by the Christian religion, elements of their old time beliefs in nature still prevail.

While the culture of the non-Indians in the area has seemed to vary greatly from that of the Crows, it developed many similar traits. The basic love for land dominates the life of both groups.

O. Scenic-visual resources

The concept of treating scenic values as a social and economic resource is gaining acceptance, but is complicated by the intangible nature of these resources and the subjectivity associated with their identification and interpretation. The visual environment accounts for a substantial part of the perceived environment, and the visual landscape has become a valuable tool in monitoring the degree to which man is adapting advanced technology to his environment.

People perceive the visual landscape differently, and there is little agreement on what is most scenic or most aesthetically pleasing. However, general principles which help to define what constitutes scenic resources have been, and continue to be developed and refined.

In general, the landscape is perceived as the interaction of topographic relief, geologic formations, vegetational coverage, water features, and the influences of man-made structures and land use. The Sarpy Creek Basin, including the proposed mine area, consists primarily of rolling hills and deeply dissected plateaus and valleys. From a visual perspective, most of the land appears as a continuous mass characterized by subtle colors, contours, and open space, rather than as distinctly separate land forms. Within the proposed mine area and adjacent lands, the visually perceived characteristics are largely a function of the drainage network, vegetational coverage, rock outcroppings, and areas of steep terrain and related valleys.

In addition to these natural features, various types of land uses and structures are found with and adjacent to the proposed mine area and Tract III. These land use features can have a positive, negative, or neutral visual influence on the adjacent landscape depending on their visual compatibility with the natural landscape elements and the integrity of the setting. In general, positive influences are created by structures having distinct cultural or architectural integrity while negative scenic influences are related to such uses as industrial facilities and utility corridors.

Westmoreland Resources (1975 g) conducted an inventory of the scenic resources that identified the dominant visual features of the landscape on and adjacent to its leases. The dominant visual landscape was classified within the following categories:

- Steep slopes (30 percent and above)
- Sandstone outcrops
- Drainages and creeks
- Vegetation
  - Riparian vegetation
  - Ponderosa pines

Grasslands

Shrubs and grasslands

Agriculture

Structures of cultural/visual interest

Scenic modifications

- Sarpy Creek mine
- Transmission lines
- Railroad
- Trailer courts

For the puropses of their study, Westmoreland Resources evaluated the scenic resources of their leases and compared them in two regional contexts in an effort to provide a broad frame of reference for assessing the scenic value of the leases. The first region was geographic in nature and defined by a one day travel distance from the leases. The second region was defined by the physiographic characteristics associated with the region adjacent to the leases.

The geographic regional context was chosen in order to relate the scenic values of the leases to other areas potentially available for aesthetic appreciation by residents within a one day traveling distance. The second regional context focused on the scenic quality of the leases in relation to lands within a similar physiographic region.

The visual landscape associated with the Westmoreland leases, including the proposed mine area would be described by most viewers as aesthetically pleasing. The primary landscape features determining the scenic character of the area are steep-sloping terrain, exposed colored soils, sandstone outcroppings on ridges and valley walls, scattered ponderosa pines that follow numerous ridges and slopes, riparian vegetation that creates interesting patterns along meandering creeks and drainages, open grasslands, grassland-shrub communities, agricultural areas, and several old log and wood buildings.

The scenic amenities of this type of landscape is typical of large portions of eastern Montana. In comparison, the area is neither unique nor significantly representative of the scenery associated with this part of eastern Montana. In comparison to other landscapes within a one day travel distance, the proposed mine area and adjacent terrain represent neither the most scenic or least scenic of landscapes.

P. Archeological Sites

Prior to 1972, there was little archeological work done in the upper Sarpy Creek area of Tract III including the proposed mine area. In 1972, an intensive survey of about 3000 acres within Tract III was conducted for Westmoreland Resources (Fredlund, L.B., and Fredlund, D.E., 1974). Additional surveys were completed on both Tracts II and III for Westmoreland Resources in the summer of 1975 (Westmoreland Resources, 1975 i). Ten sites were located and studied in 1972, and 34 additional sites were found on Tract III during the surveys of 1975.

The types of sites found in the area included open occupation sites, observation sites, quarry sites, rock art sites, stone ring sites, rock cairns, and chipping stations. Kill or butchering sites are not common in the area but do occur occasionally although none were found during the Westmoreland survey.

Prehistoric peoples undoubtedly used the entire area for various activities but no archeologic sites were found within the boundaries of the proposed mine area. This might be explained in part by lack of permanent water on or close to the area and the fact that the coal underlying the site has not burned. With no burned coal to produce clinker (porcelanite) which was the most common material for making tools, this important activity would not have been convenient on the proposed mine area.

Q. Historical Sites

The history of the Sarpy Creek area prior to homesteading is very sketchy. With few exceptions, records are lacking, and there is some confusion over the location of historic sites.

One early use of the area involved large-scale cattle ranching. The Kendrick Cattle Company, based on Tullock Creek, utilized lands in the study area for winter range, probably beginning soon after the cession of Crow Tribal holdings along the northern border of the reservation.

In 1904, a congressional act ratified an agreement between the Federal government and the Crow Tribe that ceded the northern part of the reservation back to the government for settlement by homesteaders. Indians living on these lands were given the choice of retaining individual lands and receiving allotments for them, or of moving to the reservation proper and receiving compensation for the land and any improvements.

The July 18, 1912 issue of the Hysham Echo reported that the Sarpy area had been opened up for settlement. Some people like John and Leonard Luther had come there at least a year earlier. The earliest patent date for any of the properties in the study area is 1914.

From 1907-1943, Sarpy had its own post office. In the latter year the post office was moved to McRea, where it survived for another decade.

Big Horn County was organized January 20, 1913. As a result of a fall hunting trip by editor Sherman of the Hysham Echo, there is a good description of the people and countryside in the Sarpy area for that year: Sherman observed that the chief industry was stock raising, chiefly horses and cattle, and that most ranch buildings were of the log type (still much in evidence at various sites in the primary study area).

He also noted that although farming was relatively unimportant, there were numerous small fields of oats and corn. This, he thought, indicated the relative richness of the land, which that summer had yielded a rancher at the mouth of the East Fork some 50 bushels of corn to the acre, and another from North Beaver the same in oats. It was the writer's opinion that winter wheat and small grain farming could become an attractive enterprise if it were not for the tremendous distance to a suitable market-an observation which was later borne out when improved transportation and high wartime prices encouraged many Sarpy Creek residents to raise these crops.

Most homesteading in the primary study area occurred during the 1920's in a poor economic climate. When many of these latecomers failed during the droughts of the 1930's, the established families were able to acquire more than their original homestead lands. It was at this time that representatives of the Government tried to encourage all residents to move to the moister climates of the Pacific Northwest; however, many settlers like Bud Redding elected to stay. It is probably significant that most of those who remained had come to the area prior to the 1920's; they, in short, had chosen the area on its merits, and not simply because it was some of the last free land available.

From the 1930's to the present, the consolidation of holdings by individuals has continued. Coupled with modern farming and ranching methods and better transportation, this process has brought the primary study area to the relative prosperity it has enjoyed in recent years.

Westmoreland Resources (1975 h) conducted a survey of historic resources of Tracts II and III and the surrounding area. Many sites of historic interest associated with the white mans settlement of the region and the wars with the Indians are present in the area. However, on Tract III and the proposed mine area there are no sites that are included in the National Register of Historic Places or the Montana State Historic Sites Inventory. Six sites on the proposed mine area have been identified as being of possible local historic interest although for most people visiting the area they would perhaps be considered more as a scenic resource. These generally are dilapidated old homesteads. The names and locations of the sites, all in T.1 N., R.38 E., are listed below:

Dychman Ranch-SE¼SE¼, Sec.30

Second Sarpy School-NW¼SE¼, Sec.30

Jesse Wolf Place-SE¼NW¼, Sec.30

Old Homestead-NW¼SW¼, Sec.30

Charles Hite Place-E½SW¼, Sec.19

Roil Roberts Place-NW¼, Sec.31

It is unlikely that any of these sites would be eligible for inclusion on National or Montana registers of historic places.

R. Socio-economic conditions

Todays Communities

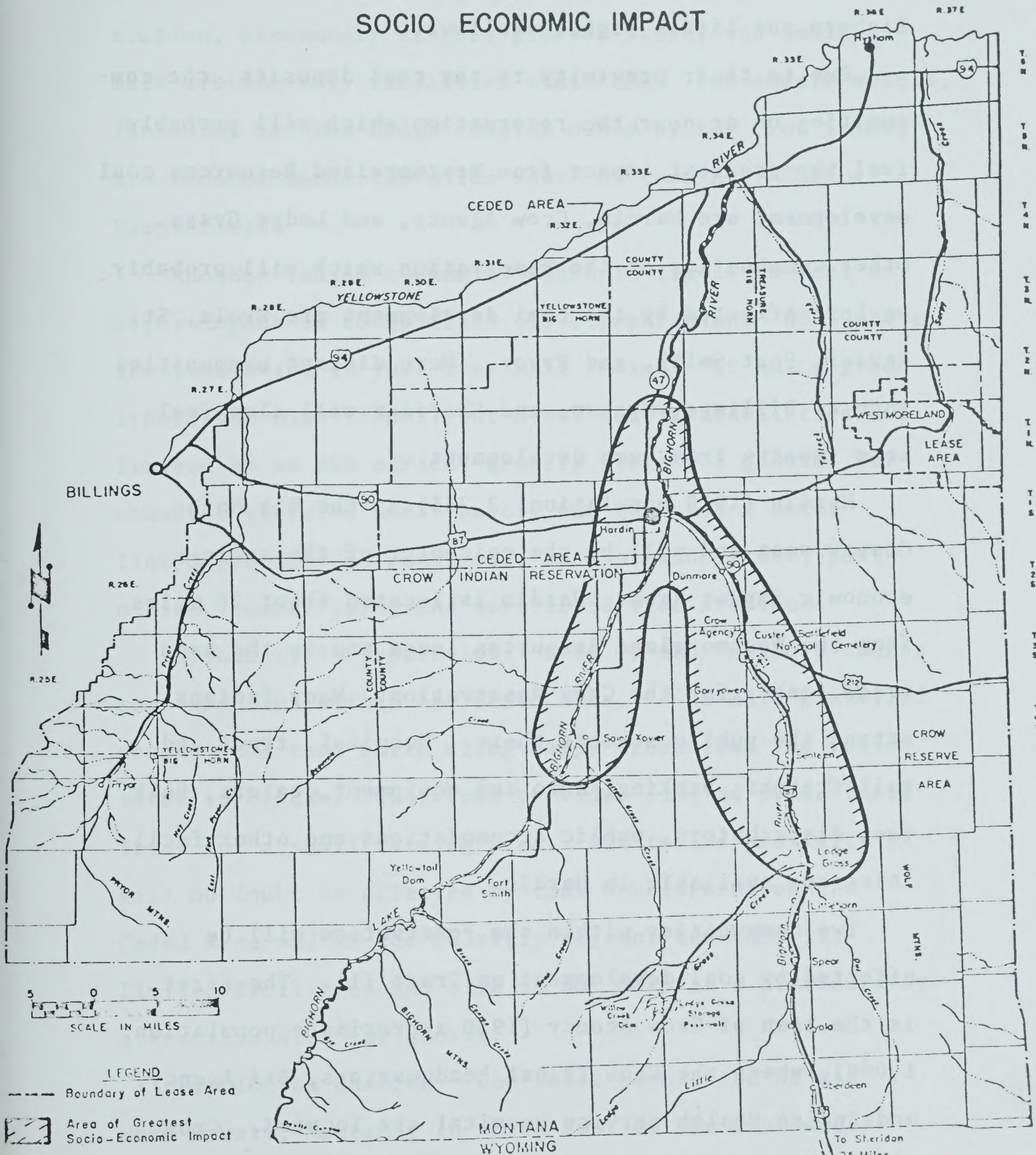
At present the study area (hereafter referred to as the impact area) is rural with a population mix of Indian and Anglo. Big Horn County, in which the major portion of the reservation lies, was 38.9 percent Indian in 1970, and the Crow Reservation proper was 56.1 percent Indian. Although this is an agricultural area, the Indians do not participate to a large extent in the agricultural economy, and a high percentage of their land is leased to non-Indian operators.

The Crow Reservation lies 27 miles north of Sheridan, Wyoming, and extends northerly and westerly to about 5 miles east of Billings, Montana. These two cities (with 1970 populations of 10,856 and 71,197, respectively) provide many services not available in Big Horn County. Billings is the major regional trade center and provides full medical and other services for a large section of southeastern Montana and northern Wyoming.

The reservation population, both Indian and non-Indian, lives mainly in the small towns and valleys. Although many Indians live on their own land, not many are engaged in farming and ranching, the main occupations of the white population. As shown on Figure 31, the geographic areas

FIGURE 31

CROW RESERVATION AND CEDED AREA
SHOWING AREA OF GREATEST
SOCIO ECONOMIC IMPACT



which are presently most populous and which are most likely to feel the major impacts of development are the Bighorn and Little Bighorn valleys.

Due to their proximity to the coal deposits, the communities on or near the reservation which will probably feel the greatest impact from Westmoreland Resources coal development are Hardin, Crow Agency, and Lodge Grass. Other communities on the reservation which will probably be less affected by the coal development are Wyola, St. Xavier, Fort Smith, and Pryor. More distant communities such as Billings, Hysham, and Sheridan will also feel some impacts from such development.

Hardin (1970 population: 2,733) is the Big Horn County seat and will be the epicenter of the socio-economic impact area. Hardin is located about 26 miles from the Westmoreland Resources lease and is the main trade center for the Crow Reservation. Many Indians attend the public schools there. Hospital, truck and rail freight, banking, auto and equipment dealers, bulk fuel distributors, public accomodations and other facilities are available in Hardin.

Two communities within the reservation will be affected by coal development on Tract III. The first is the town of Crow Agency (1970 approximate population: 1,000), where the Crow Tribal headquarters, BIA Agency, and Indian Health Service Hospital are located. Crow

Agency is a predominantly Indian community with most of the non-Indians being government employees. A service station, elementary school, grocery store, and small cafe are the only facilities available. Two modern motels, including the Sun Lodge complex owned by the Crow Tribe, are located about two miles south of town near Custer Battlefield.

Another Indian community which is likely to feel a major impact is Lodge Grass (1970 population: 806) where the population is just over half Indian. It has a grade school and high school, but other service facilities are limited to an REA office, grocery stores, a general merchandise store, a small hotel, two garages, a cafe, liquid propane gas suppliers, an appliance store, post office, lumber yard, and several service stations.

Hysham (1970 population: 373) is the Treasure County seat and lies within the Ceded Area. A 35 mile gravelled county road runs north along Sarpy Creek from the lease sites to Hysham. This town provides limited trade facilities for a small farming area. Due to its proximity it will no doubt be affected by coal development on the Ceded Area and in the Colstrip region; however, its limited facilities and size do not make it a particularly attractive area for growth.

Population Changes - The total population of Big Horn County, Montana, in which most of the coal areas are located, has remained at about 10,000 over the past 40 years. The 1970 U.S. Census reports a population of 10,057.

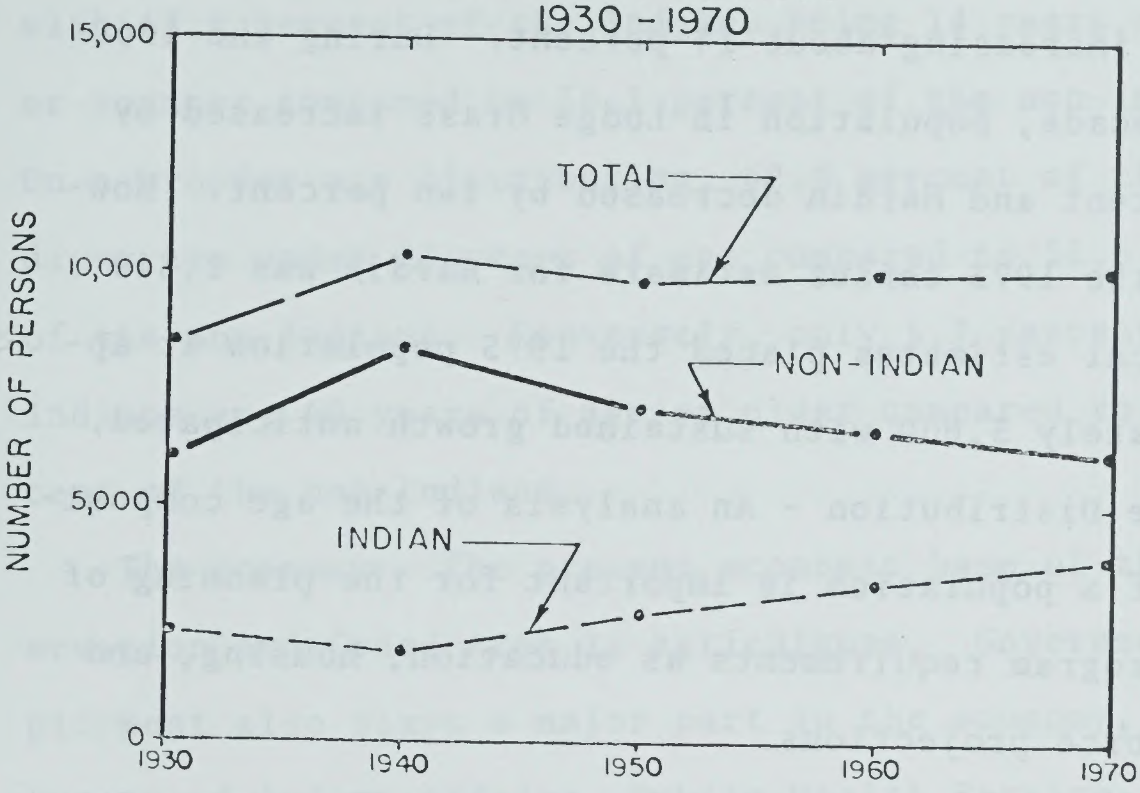
Census figures indicate a Crow population of 3,161 living within the boundaries of the Crow Reservation, or approximately 81 percent of the total Big Horn County Indian population. Outside the reservation boundaries, the towns of Hardin and Busby contain most of the country's remaining Indian population. The Crow Ceded Area also has about 100 Indian residents.

The non-Indian population in Big Horn County has declined from 8,433 in 1940 to 6,140 in 1970 (-27.1 percent) following an increase during the 1930-1940 decade. On the other hand, the Indian population has shown significant increases during every decade since 1940. The Indian population increased from 3,334 to 3,731 (+11.9 percent) during the 1960-70 decade, while the non-Indian population decreased from 6,673 to 6,149 (-8.0 percent) during the same period. 1/ Population change over the past 40 years

1/ Tribal estimates based on enrollment statistics for 1974 indicate a higher Crow resident population at somewhere over 4,000.

are shown graphically in Figure 32. In 1970, the Indian

FIGURE 32
POPULATION TRENDS
BIG HORN COUNTY
1930 - 1970



SOURCE : U.S. Census.

population in Big Horn County was 38.9 percent of the total population. If the present trends continue, Big Horn County will have a population evenly divided between Indian and non-Indian in 10 or 15 years.

Table 5 shows population trends for two of the principal towns in the impact area.

Table 5. Major Population Changes 1940-70

	1940	1950	1960	1970
Lodge Grass	839	536	687	806
Hardin	1,886	2,306	2,789	2,733

Source: U.S. Census

Both Lodge Grass and Hardin remained relatively stable in population over the 1940-1970 period, with Lodge Grass decreasing by less than one percent and Hardin increasing about 14 percent. During the 1960-1970 decade, population in Lodge Grass increased by 17 percent and Hardin decreased by two percent. However, the 1973 census estimate for Hardin was 2,849 and local estimates placed the 1975 population at approximately 3,000 with sustained growth anticipated.

Age Distribution - An analysis of the age composition of a population is important for the planning of such program requirements as education, housing, and work force projections.

Population numbers and percentage composition by age groupings of the Indian people on the reservation compared to the non-Indian people in Big Horn County is shown in Table 6.

Table 6. Age Distribution

Age	Indian On Reservation		Non-Indian Big Horn County	
	number	percent	number	percent
0 - 14	1,378	43.6	1,848	30.1
15 - 29	819	25.9	1,314	21.4
30 - 44	468	14.8	1,019	16.6
45 - 59	316	10.0	1,112	18.1
60 - 75	139	4.4	620	10.1
75+	41	1.3	227	3.7
Total	3,161	100.0	6,140	100.0

Source: U.S. Census

By and large, both the Indian and non-Indian population are quite young. However, the Indian population is significantly younger compared to the non-Indian, with 43.6 percent of the Indians being 14 years of age or younger compared to 30.1 percent of the non-Indians. On a broader age distribution, 69.5 percent of the Indians are under 30 years of age compared to 51.5 percent of the non-Indians. Conversely, only 5.7 percent of the Indians are 60 years of age or older compared to 13.8 percent of the non-Indians.

The Economy - The present economic base of the Reservation and Ceded Area is agriculgure. Government employment also plays a major part in the economy, with Bureau of Indian Affairs, Public Health Service, National Park Service and Bureau of Reclamation having payrolls within the reservation. Other Federal, County, City and Tribal entities provide payrolls on and adjacent to the reservation. By comparison the present industrial payroll of the area is insignificant.

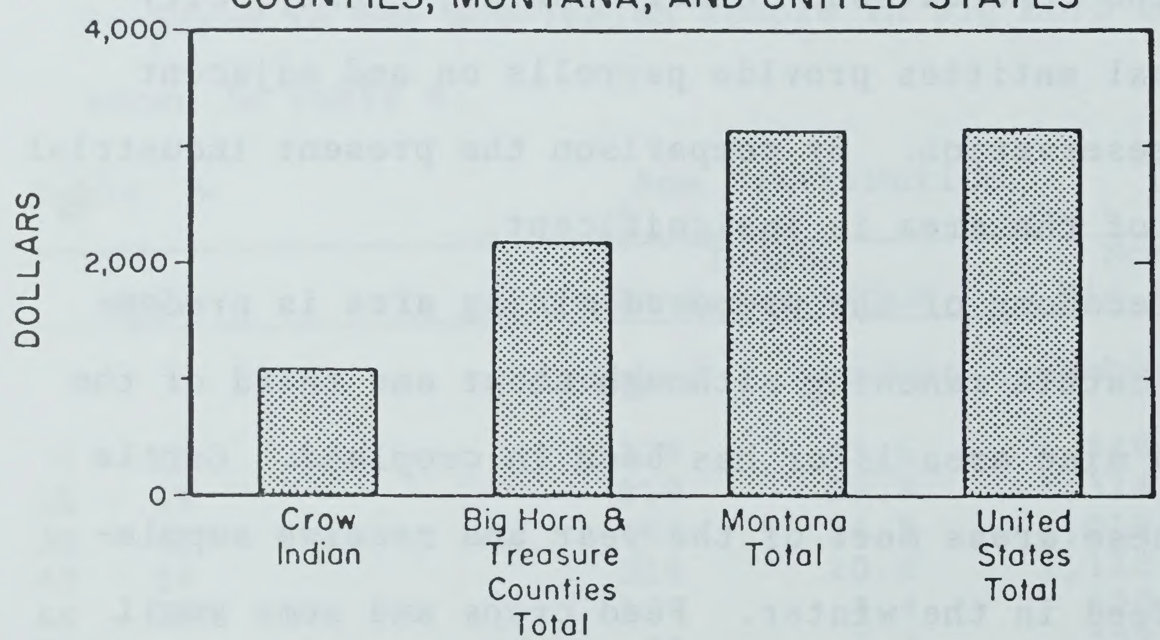
The economy of the proposed mining area is predominantly cattle ranching although about one third of the proposed mine area is or has been in cropland. Cattle graze these areas most of the year and receive supplemental feed in the winter. Feed crops and some small grain cash crops are grown where the soils are suitable.

Income - With agriculture dominating the economy, the census data indicates family income for Big Horn County was made up of $12,824,500 from wages and salaries (including wages for farm hands), $3,561,300 from farm self-employment, and $1,206,900 from non-farm self-employment. Family income in the Sarpy Census Division in Big Horn County, a census division typical of the Westmoreland Resources lease area, consisted of $486,200 from wages and salaries (including wages for farm hands), and $307,700 from farm self-employment.

Income, expressed on a per capita basis, is shown graphically in Figure 33.

FIGURE 33

PER CAPITA INCOME
CROW INDIAN, BIG HORN AND TREASURE COUNTIES, MONTANA, AND UNITED STATES



Source: U.S. Census

Income levels of Big Horn and Treasure County residents are lower than those of Montana or the nation, while the income of the Indians on the Crow Reservation is substantially lower still.

Another indication of income is a comparison of poverty levels. According to the 1970 U.S. Census poverty index, 39.4 percent of resident Crow Indian families are in poverty. By comparison, 21.4 percent of all families in Big Horn County and 10.4 percent for all of Montana are below the poverty level. The on-reservation median family income for the Crow Indians in 1969 was $5,260 compared to $8,210 for the white families on the reservation. 1/

1/ The nation-wide poverty threshold for a farm family of four headed by a male was $3,197, while for a family of 6.16 (the average size of Crow families in poverty) the index was approximately $4,500.

Labor Force and Employment - Table 7 shows that in 1970, of 1,686 Indians and 4,814 whites age 16 years or older, 38.9 percent of the Indians and 58.3 percent of the whites were in the labor force. There were 340 males and 690 female Indians not in the labor force, and 432 white males and 1,577 white females in the same category. For census analyses, the labor force is defined as those 16 years old or older employed or actively seeking work.

Table 7. Labor Force and Employment 16 Years Old and Older 1970 - On Reservation and Hardin

	Indian	Non-Indian
16 Years Old and Older		
Male	780	2,382
Female	906	2,432
	1,686	4,814
Total Labor Force	656	2,805
Percent total population in labor force	38.9	58.3
Population not in Labor Force		
Male	340	432
Female	690	1,577
	1,030	2,009
Employed		
Male	385	1,886
Female	201	826
Unemployed		
Male	55	64
Female	15	29
Unemployment Rate		
Male	12.5	3.3
Female	6.9	3.4

Source: U.S. Census

Many of those not in the labor force are 65 years old or older, are housewives, or are students. If bona fide employment opportunities existed, a considerable number of those not presently in the labor force probably would accept work. The actual number would depend upon training conditions, wages, working conditions, and living conditions, among other factors (Westmoreland Resources, 1975 c).

The March, 1975, BIA Labor Force Report on the Crow Reservation, using somewhat different definitions, reports an Indian labor force of 1,506. This is more than twice that reported by the U.S. Census. Employment rates according to this BIA study, were 925 (61.0 percent) while unemployment rates were 581 unemployed (39.0 percent). Of the unemployed, 581 Indians (22.0 percent) were actively seeking work. Over the past 10 years, the BIA Labor Force Reports have repeatedly shown the unemployment of the Crows to be as high as 40 percent with approximately one-half of these actively seeking work.

Income, Mobility, and Employment Characteristics of Crow Employees of Westmoreland Resources - At present Crow Indians occupy about 40 percent of all jobs (administrative and mining) at the Absaloka mine. Of the jobs directly involved in mining such as dragline operators, truck drivers, etc., Crows occupy about 50 percent of the employment. Of 101 seasonal and full-time workers at the mine as of August, 1975, 39 were members of the Crow Tribe. An additional 14 were related to Crows, generally as spouses of tribal members.

The annual average earnings of $20,111 for full-time Crow workers places this group in the upper two percent of Crow earners. These calculations imply that the Crow tribal members working at the mine earn a total of about one million dollars, and this figure could be higher since it is doubtful that over-time income has been adequately accounted for. The 53 comprise nearly 6 percent of the total eligible male workers on the Crow Reservation (903) and just under 10 percent of the employed male Crows on the reservation (550).

The Crow mine workers seem to be exceptional not only in their earnings but in work experience as well. All of them, with the exception of a summer employee who was a college student, were steadily employed before obtaining employment at the mine. They average nearly 11 years of formal schooling (ranging from 6 to 13 years) and their average age is 35 years.

The majority of Crow workers at the Westmoreland Mine currently reside in either Crow Agency or Hardin and only five changed their place of residence after obtaining jobs at the mine. Only one of the five came from outside Montana (a college student who works summers only). The 16 Crows who do not live in Crow Agency or Hardin are scattered in six residential areas (Garryowen, Lodge Grass, Pryor, rural Hardin, Kirby, and Sarpy Creek). Commuting distances for these workers (except the single Sarpy Creek resident) are substantial, and Morrison-Knudsen reimburses all employees for travel expenses. Hardin workers travel at least 60 round-trip miles daily and those living in Crow Agency travel about 80 miles. Although commuting distances are lengthy, workers expressed satisfaction with present wages and most of them resigned from full-time jobs nearer their residences in order to have substantially higher incomes at the mine (Westmoreland Resources, 1975 f).

Non-Indian-Crow related employees (these are also members of the Crow Tribe) are concentrated in Hardin (8 of 11). The remaining three are in Crow Agency or Lodge Grass. Only one of these workers, who had previously resided in Billings, changed his place of residence to be closer to the mine. Indian-Crow related workers, only two of whom work at the mine, did not relocate for their mine jobs. One of these lives in Hardin and one in Crow Agency.

In summary, only 11 percent of the Crow tribal members employed at the mine (6 of 53) changed their place of residence and only three of the six moved from communities off the reservation to be nearer their place of work.

The non-Indian employees at the mine exhibit a much different profile in present and previous residential patterns from the Crow tribal members. The overwhelming majority of non-Indian workers reside in Hardin (85 percent); this compares with 23 percent of the Crow and Crow-related workers who live in Hardin. Furthermore, 31 non-Indian workers, or 57 percent, changed their place of residence to work at the mine. This compares with only 11 percent of the Crow tribal members who moved to another location.

Of the non-Indians who moved, 15 were Montana residents (32 percent of non-Indian) and 16 came from outside the state (34 percent). Thus 66 percent (31 of 47) of the non-Indian workers moved into Hardin or nearby communities to work at the mine. This compares with only three Crow tribal members who moved from off-reservation communities to be closer to their jobs.

The statement is frequently made that Indians are lax in adhering to regular work schedules and that absenteeism and tardiness are common characteristics of Indian labor. However, the Crow Indians employed at the Absaloka Mine generally do not exhibit these characteristics.

The Morrison-Knudsen personnel office reported that absenteeism among mine workers does not exceed three percent. Company records on tardiness and absenteeism do not distinguish between members of the Crow Tribe (Crow and Crow-related workers) and others; however, personnel officers do not believe Crow tribal members are absent in frequencies exceeding those of other workers (Roberta Vanderslooth, Morrison-Knudsen Co., Inc., personal communication, August, 1975).

The turnover rate at the mine is about two percent per year, which is relatively low (Vanderslooth, personal communication, August, 1975). The Crow and Crow-related mine workers are primarily men who had good work records before securing employment at the Sarpy Creek mine and have apparently continued these work habits.

Labor Force Participation Rates - One of the most important demographic characteristics of any population is the extent to which the residents will participate in the labor force. This concept is referred to as the labor force participation rate, and it measures the number of employed persons and unemployed persons seeking work as a percentage of the population of working age: employed persons plus persons actively seeking work divided by total population of working age. This provides a reasonably accurate measure of the potential labor force and hereafter will be referred to as such. If the participation rate increases, the potential labor force increases proportionately.

Figure 34 shows three sets of participation rates for both the male and female residents of the impact area. Rates* for 1970 for Crow and non-Crow residents are shown, as the projected rates for the U.S. population at large in 1990. The U.S. rates provide a standard of comparison and it can be seen clearly that only the Anglo males of the impact area participate in the labor force to about the same extent as their U.S. counterparts. The pattern of participation for crow males and for Crow and Anglo females are substantially lower than national rates. It is well known that persons drop out of the labor force (i.e. no longer "actively seek" employment) if over an extended period, they are unsuccessful in finding a job. However, this behavior leaves open the possibility that if employment opportunities improve, persons will rejoin the labor force; that is, the participation rate tends to be positively associated with employment opportunities. As coal development activity increases in the impact area, it would be unrealistic to assume that the participation rates of area residents will remain at their low 1970 levels.

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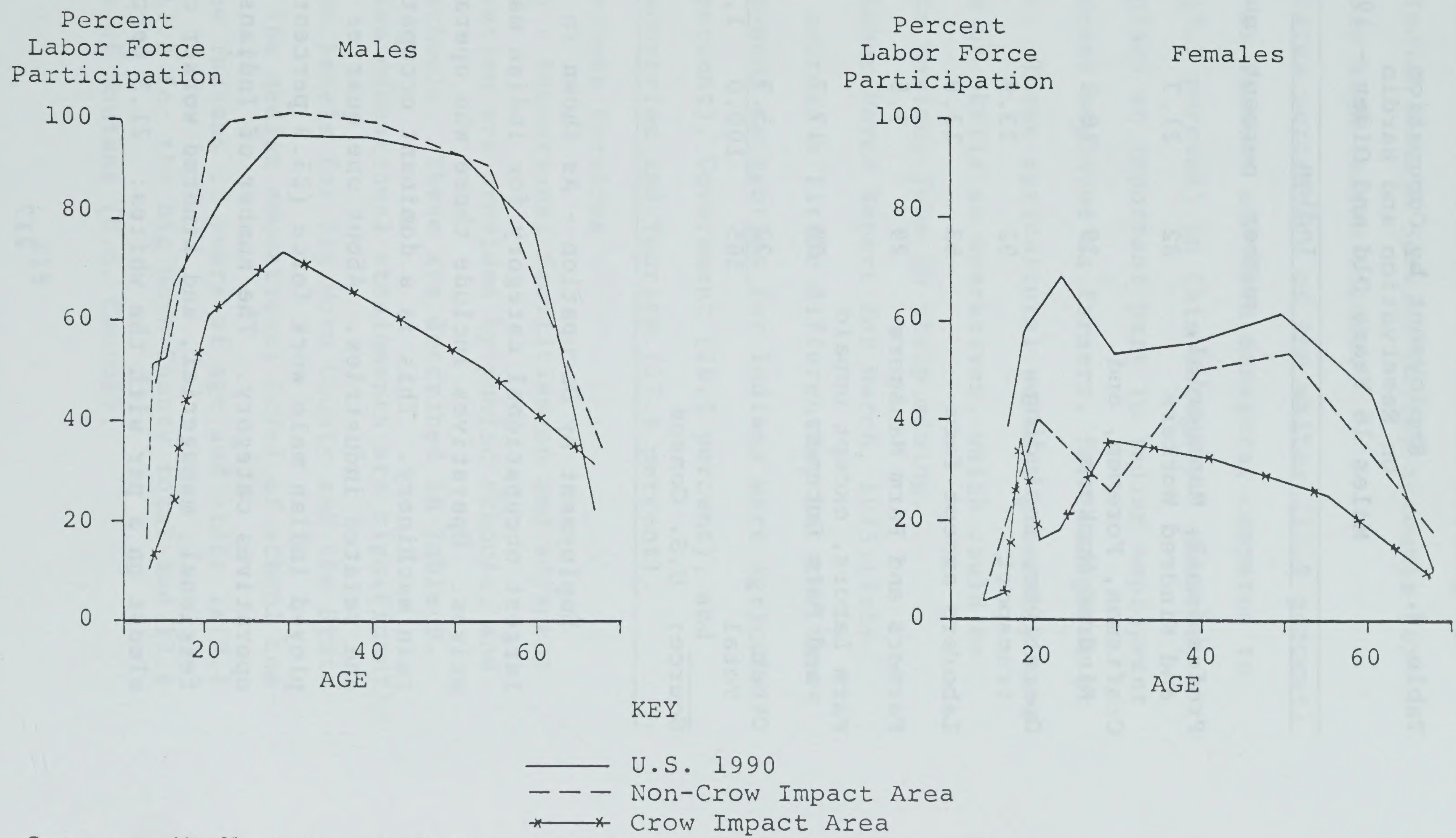
*These rates are from the 1970 Census except that they have been smoothed to eliminate obvious errors on the Census tapes (e.g. labor force exceeding the population), or where there is behavior that on a priori grounds did not make sense, (i.e. even if it did exist in 1970, it would not be expected to continue in the future even under an assumption of no change in participation behaviour). Of the total 36 data points, 8 were adjusted. These are explained in detail in TR, pp. 26-34.

FIGURE 34
1970 LABOR FORCE PARTICIPATION RATE
BIG HORN COUNTY IMPACT AREA
COMPARED WITH U.S. 1990



Source: Mt West Research Inc. Feb. 1970.

Table 8. Employment by Occupation
On Reservation and Hardin
Males 16 Years Old and Older - 1970

	Indian		Non-Indian	
	number	percent	number	percent
Professional, Managerial, and Kindred Workers	82	21.3	431	22.9
Craftsmen, Foremen, and Kindred Workers	39	10.1	307	16.3
Operatives, including transport	92	23.9	176	9.3
Laborers except farm	53	13.8	100	5.3
Farmers and Farm Managers	29	7.5	431	22.8
Farm Labors, except unpaid and Farm Foremen	68	17.7	188	10.0
Other	22	5.7	253	13.4
Total	385	100.0	1,886	100.0

Source: U.S. Census

Employment by Occupation - As shown in Table 8, the largest occupational category for Indian males is operatives. Operatives include those who operate and maintain machinery. This is a dominant occupation in coal and related industries. About one quarter of the employed Indian male work force (23.9 percent) is in the operatives category. The number of Indians in the professional, managerial, and kindred worker category is almost on a par with the whites: 21.3 percent compared with 22.8 percent. The number of Indians working for the BIA and Indian Health Service partly accounts for this relatively high Indian figure.

Quite a large percentage of the whites (22.8 percent) are employed as farmers and farm managers, compared to the Indians (7.5 percent) in this category. However, agriculture plays an important part in Indian employment with 25.2 percent employed as farmers, farm managers, or farm laborers. These agricultural workers generally have a broad range of skills as operatives, which could be transferred to various jobs in strip mining.

The BIA Labor Force Report for March, 1973 lists occupational sectors a little differently, but the three highest employment categories for Indians were Agricultural (31.5 percent), Government (26.5 percent), and Commercial Industries and Tourism (17.6 percent).

Public and Private Services -

Education - Educational facilities on and adjacent to the reservation are provided by public schools, and two private schools. These are described in Table 9.

Crow Indian educational attainments are significantly lower than the levels for Big Horn County and the State of Montana. The median educational level of school completed by Crow Indians 25 years of age and older is 9.4 compared to 11.8 for the Big Horn County total and 12.4 for the State of Montana (U.S. Census).

Table 9. Big Horn County Schools In The Impact Area

District	School	Grades	Enrollment 74-75	# Classrooms Capacity	Condition	# Teachers
Elementary						
2	Pryor	K-8	75	7 (also gym, lunch room, kitchen, and office)/150*	Adequate, brick, 10 years old	5
16	Community	1-6	32	2 and large multi purpose room/40	Adequate, about 8 years old	2
17H	Hardin Primary	K-3	302	17/30	Adequate	17**
17H	Hardin Intermediate	4-6	299	12/280	Adequate	16
17H	Crow Agency	K-6	233	14/225	Adequate	15
17H	Fort Smith	K-6	62	6/120	Good	6
17K	Big Bend Creek	1-8	18	11/20	Adequate	1
27	Lodge Grass	K-8	230	0/190	Adequate	22
29	Wyola	K-8	100	4 and 2 portable units/130*	Adequate, 19 years old	8 1/2
Junior and Senior High						
17H	Hardin	7-8	283	13/225	Inadequate	15**
1	Hardin	9-12	522	6/55		24**
2	Lodge Grass	9-12	230	/180	Poor	12
3	Pryor	9-12	48	5/125	Temporary building	6 1/2
Total			2,434			

*Average based on requirements in Standards for Accredition of Montana Schools as amended by the Board of Public Education, April 10, 1973.
*Shared with other local schools.
Sources: Big Horn County School Superintendent, Superintendent of Elementary District 17H and High School District and Superintendent of Elementary District 27 and High School District 2; personal communications, August, 1975.

The Hardin, Lodge Grass and Wyola schools listed in Table 9 have 1,736 students or 81 percent of all students in the county. All of the schools are open to both Indian and non-Indian students, with all four schools having a high representation from both groups. These schools, located near the coal lease area, are expected to be impacted by population changes associated with coal development.

Housing - The housing inventory on and adjacent to the Crow Reservation is presented in Table 10. Housing needs in the coal impacted area are presently acute, with an estimated 800 housing units required for Indians

Table 10. Number of Housing Units - Indian and Non-Indian Crow Indian Reservation, 1970

	Indian	Non-Indian	Vacant	TOTAL Number
On Reservation				
Owner occupied	427	411		848
Renter occupied	99	341		440
Vacant	--	--	169	169
Total	536	752	169	1,457
Adjacent to Reservation				
Owner occupied	18	978		996
Renter occupied	36	467		503
Vacant	--	--	97	97
Total	54	1,445	97	1,596
On and Adjacent to Reservation				
Owner occupied	455	1,389		1,844
Renter occupied	135	808		943
Vacant	--	--	266	266
Total	590	2,197	266	3,053

Source: U.S. Census

alone. Mobile homes are presently filling much of the housing gap in all communities of the county.

Public Assistance - In 1974 the Big Horn County Welfare Department had a seven-member staff, including two social workers, one full-time and one part-time homemaker was responsible for meeting the needs of Big Horn County and the Crow Reservation. The Big Horn Economic Development Corporation has helped with welfare-related problems on the Reservation by sponsoring local business development and job training. The local Tri-County Legal Aid Service has also provided services helpful to many low income people.

The Big Horn County Welfare Department handles all categories of welfare for the Crow Reservation except general assistance and child welfare (both of which are handled by the BIA Welfare Office). In Big Horn County, total welfare disbursements increased about five percent between 1960 and 1970, due to increased medical assistance, foster care, and BIA general assistance. The major increase was in medical assistance which utilized funds previously allotted to other categories. County social workers spend much of their time on Indian cases. In addition, two full-time extension agents and legal service aides serve both the Crow and Northern Cheyenne Reservations, with offices located at Crow Agency and Lame Deer. Also, operating on both reservations, the Big Horn

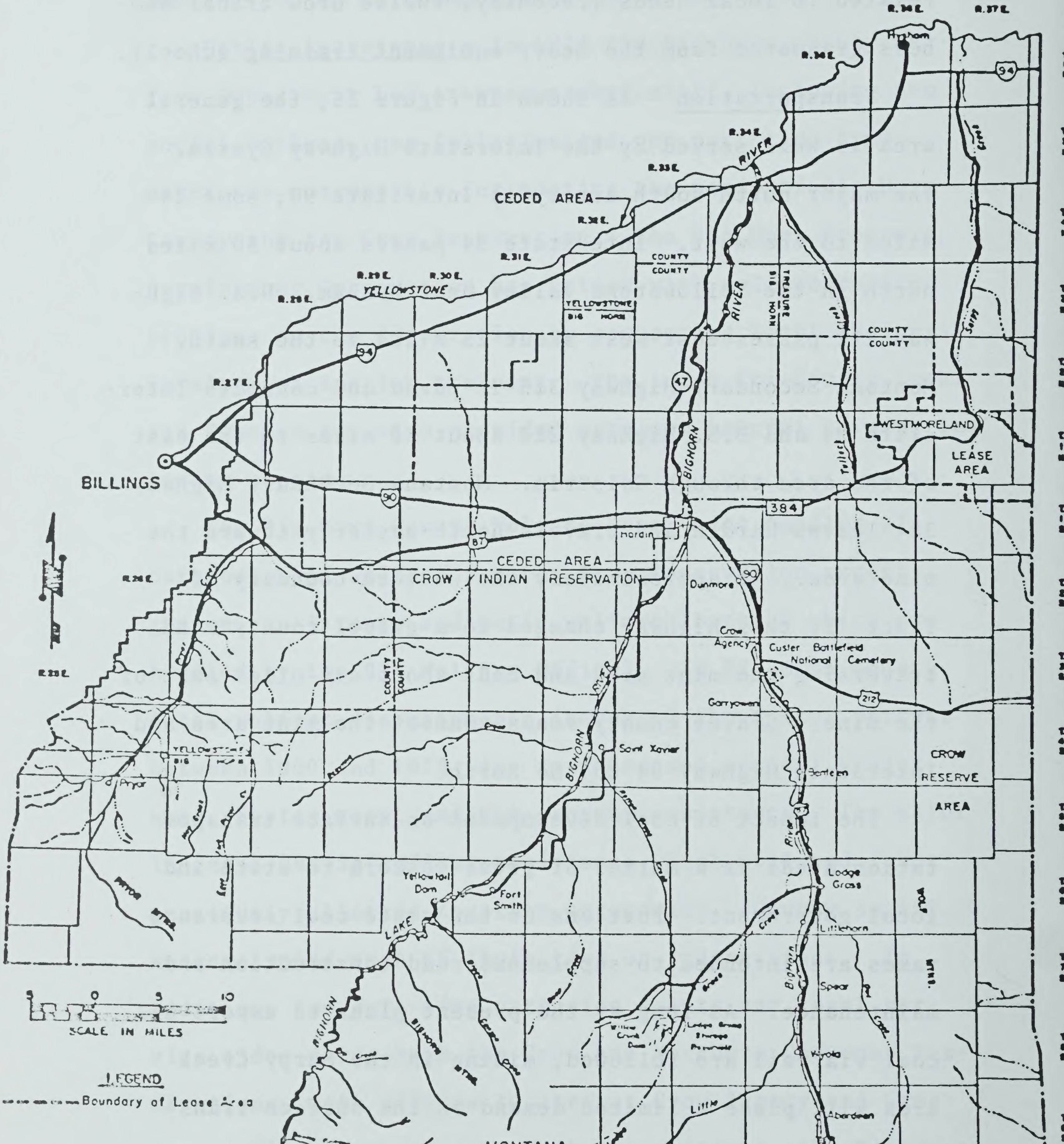
Economic Development Corporation emphasized job training related to local needs (recently, twelve Crow tribal members graduated from the heavy equipment training school).

Transportation - As shown in Figure 35, the general area is well served by the Interstate Highway System. The major north-south artery is Interstate 90, some 24 miles to the west. Interstate 94 passes about 30 miles north in the Yellowstone valley near Hysham. U.S. Highway 212 passes east-west about 25 miles to the south. Montana Secondary Highway 315 is paved and connects Interstate 94 and U.S. Highway 212 about 30 miles to the east of the area through Colstrip. Montana Secondary Highway 384 leaves Hardin and travels north-easterly toward the mine area. At approximately the western boundary of Tract II, this highway changes to a gravel county road traversing the mine area and ends about six miles east of the mine. Gravel county roads connect the mine area and Interstate Highway 94 to the north.

The impact of coal development on surface transportation needs is a matter of great concern to state and local government. Portions of the state coal severance taxes are intended to supplement road construction and maintenance. As long as the present plans to export all coal via rail are followed, mining in the Sarpy Creek area will place a limited demand on the surface transportation net of the area.

Figure 35

CROW RESERVATION REGION TRANSPORTATION NET



Present State Highway Department construction plans affecting the area are:

1. Paving of County Road 384 would extend to Spring Creek junction and northward to the Big Horn-Treasure County line.
2. Pave County Road 415 from the Treasure County line northward to Hysham, a distance of about 25 miles.
3. Upgrade and improve the roads from Crow Agency to Busby and from Lame Deer to Colstrip in 1976-77.
4. While the extension of the county road from the mine area project to Colstrip is recognized as a logical project, it is not yet in the planning phase.

The nearest major railroad is the main line of the Burlington Northern, 36 miles to the north at Sanders, Montana. A branch line along Sarpy Creek serves the mine, terminating in a loop at the present coal handling facilities. A branch line to Sheridan, Wyoming lies 27 miles to the west; a spur extends from Forsyth to Colstrip, 23 miles to the east. Present rail facilities are adequate to serve development of Tract III.

Excellent commercial air service is available in Billings, about 80 road miles from the mine. Small aircraft can land and obtain services in the surrounding communities of Hardin, Hysham, and Forsyth. There is an unpaved airstrip at Colstrip, which may be upgraded if coal generating units 3 and 4 are built. No air service is planned for the Sarpy Creek mine site.

Communications - Major media for mass communication coverage in the Billings and Hardin areas of southeastern Montana include radio, television and newspaper. Billings has 12 television channels which are available on cable T.V. to regional subscribers. Major regional newspapers include the Billings Gazette and the Great Falls Tribune. Local newspapers are the Hardin Herald, and the Crow Tribe's weekly, Kotta Hi Lik. For the interest of resources-conscious citizens in southeastern Montana, the Montana Department of Natural Resources, the U.S. Department of the Interior and the U.S. Department of Agriculture offer general and technical publications from time to time. Pamphlets and other media from various federal and state agencies are available in Billings, Hardin and Crow Agency. The Crow Indian Tribe's Office of Coal Research, and the Tribal Council, headquartered at Crow Agency, offer publications and a weekly radio program on coal and other resources development. Internal communications at the Westmoreland mine consist of a base station and several mobile unit radios in Westmoreland Resources vehicles.

Law and Order - Law and order on the Crow Reservation is maintained by the BIA and the Crow Tribe. This includes an agency special officer, a criminal investigator and a captain of police, all employed by the BIA. Eight additional police officers hired by the Crow Tribe serve the various Indian communities. The Crow Tribe also employs six support personnel including judicial, detention rehabilitation and administrative specialists and provides appropriate facilities for such activities.

At the Crow Tribal Council meeting of January 31, 1976, a resolution adopting a new Crow Law and Order Code was approved. The code extends tribal jurisdiction to most acitvities on the Crow Reservation and establishes tribal law enforcement and judicial systems. The code is presently undergoing review by the Secretary of Interior. The code will not apply to the Ceded Area.

Big Horn County has a sheriff and three deputies, as well as a jail at the county seat. Hardin, which employs a city police chief and four police officers, maintains a city jail. Finally, the town of Lodge Grass has a city marshal and a small detention cell.

Health Services - The Crow Reservation's health facilities for Indians are centered at Crow Agency, where a 35-bed hospital complete with a staff of five physicians is operated by the Indian Health Service.

Health facilities include a full array of in-patient and out-patient services, including nursing, laboratory, pharmacy and dental facilities and staff.

A 16-bed hospital with a 35-bed nursing home wing is located in Hardin. It has a full nursing and technical staff. Hardin has two resident physicians and a third on a National Health Service contract. Hardin also has one dentist and visiting services of two optometrists.

Billings, Montana, has two large hospitals and a very extensive medical staff, including doctors of medicine in essentially all specialties. Sheridan, Wyoming, also has extensive medical facilities, including a Veterans Administration hospital, and serves the southern portion of the impact area.

Municipal Services - In Big Horn County the major municipal water system is located at Hardin and is presently at its limit of capacity. Plans are underway to supplement the present 500,000 gallons storage capacity for treated water with an additional tank of the same size, addition of the new tank would provide the city with adequate storage capability for present demands. At present the water treatment plant is capable of supplying two million gallons daily and its present daily use is approaching this limit. The Hardin sewage disposal system, a two cell lagoon, covers a total of 12 acres and is also operating at capacity. Solid waste disposal provisions are adequate in Hardin, but land-fill dumping locations are needed for residents of rural areas. Several of the small towns are having sewer and water problems.

At Crow Agnecy the sewer and water system operated by BIA has reached full-capacity. Any significant population increase will require extensive expansion of the system. The municipal sewer and water system at Lodge Grass is adequate for immediate needs; but here again, any significant growth will demand expansion of the system. St. Xavier has no water or sewer system, depending upon individual wells and septic tanks or privies. This is also the case with the entire rural area up and down the Big Horn and Little Bighorn valleys. Hardin and Crow Agency have adequate land fill facilities which are used by the surrounding rural communities. Lodge Grass and St. Xavier have dumps with minimal fill and coverage capabilities.

Business Services - Hardin provides a central, full convenience shopping center for the coal resource area with seven food stores, six motels, one hotel, and seven automotive and implement dealers. The other communities on the reservation have minimal trade and shopping facilities and are essentially limited to food and gasoline outlets.

Billings, Montana, is the major off-reservation trade center and is capable of providing the full array of service facilities required for mine development and anticipated population increases. Sheridan, Wyoming, as well as Forsyth and Hysham, provide limited business services to the impacted area.

Utilities - Electric power and natural gas are provided by three companies. The Montana Power Company and Big Horn Electric Cooperative provide electric service to the reservation area. Six power transmission lines with voltages from 69-KV to 230-KV cross the area and are owned by Montana Power Company, the U.S. Bureau of Reclamation and the Rural Electric Association. Three wood-poled transmission lines (230-KV, 100-KV, and 69-KV) pass through Tracts II and III, and an additional high voltage line from Colstrip to Broadview is presently being constructed by Montana Power Company approximately six miles north of the Tracts.

Montana-Dakota Utilities Company provides natural gas to the area with its twelve-inch Worland-to-Cabin Creek line passing near Hardin. A three-inch lateral serves Crow Agency, with the remainder of the reservation area being without natural gas service.

Land Use Planning Program - Organized community planning activities pursuant to state enabling legislation

(Section 11, Chapter 38, revised Codes of Montana) have been carried on in Big Horn County for over five years. 1/ In early 1969 the city of Hardin passed a resolution setting up a planning board, and a short time later the County Commission included the county area immediately surrounding Hardin in the planning program. Accordingly, the Hardin Planning Board is officially designated the Hardin-Big Horn City-County Planning Board, and its jurisdiction extends south and east to the Crow Indian Reservation, north from the city limits two miles, and three miles west of the city limits. A comprehensive planning document was prepared for Hardin in 1972, and a capital improvements study was completed in 1974.

Big Horn County Planning Board - In anticipation of the prospects of massive coal development in or near Big Horn County, the county commission formed a county planning board in early 1973. The jurisdiction of this board, designated the Big Horn County Planning Board, includes the town of Lodge Grass and that portion of the county

1/ Comprehensive Plan, Big Horn County Planning Board Jurisdictional Area 1974-75, prepared by Intermountain Planning Inc., Billings, Montana.

exclusive of the Hardin-Big Horn City-County Planning Board jurisdiction as well as portions of the two Indian reservations.

The goals and objectives of the Bighorn County Planning Board include:

1. Attaining the best possible living and working environment in the planning area.
2. Promoting the wise use of Big Horn County's economic resources in a manner which will co-exist with present elements of the county's economy.
3. Developing the best possible system of public facilities and utilities commensurate with county growth.

At the present time very limited progress has been made in developing this concept of integrating the Indian and non-Indian jurisdictions into a workable whole. As indicated, the town of Lodge Grass in the Little Big Horn Valley has been involved in the planning process of the Big Horn County Planning Board.

To date, the planning board has not opened an office or employed a resident planner, although it has utilized consultant services. A good deal of background information has been gained, a capital improvements study is continuing, and discussion between representatives of non-Indian and Indian interests on plan coordination has taken place.

Big Horn County, including the town of Lodge Grass, adopted a subdivision ordinance in May 1974. This ordinance prohibits a developer from recording a plat which does not conform to the State law and local ordinances. It requires the developer to go far beyond the mere alignment of roads and location of easements. The developer now must include adequate public space for light, air, and recreation; provide sanitary facilities, and avoid congestion.

Big Horn Area Planning Organization - Because of the need for area-wide and intergovernmental coordination, an area planning organization was also instituted and designated the Big Horn Area Planning Organization, or Big Horn APO. The APO was joined by the city of Hardin, the town of Lodge Grass, and Big Horn County. It is intended that this APO will be the nucleus of a much larger area planning program to include the Indian reservations and thus provide a forum for discussion of common problems and coordination of their solution.

Mid-Yellowstone Areawide Planning Organization - Water quality planning for Big Horn, Carbon, Stillwater, Sweet Grass and Yellowstone Counties is being coordinated by the Mid-Yellowstone Areawide Planning Organization (MYAPO), headquartered in Billings.

The MYAPO was designated in the autumn of 1975 to administer funds provided by Section 208 (Areawide Waste Treatment Management) of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500). The MYAPO has indicated (Oral Communication, February 12, 1976) that they hope to enter into a contract which would allow the Crow tribe to do their own planning for water quality within the reservation area. MYAPO would provide funds for the tribe to subcontract the services of a consultant to conduct the assessments of pollution sources and develop the necessary management strategies. The MYAPO has also issued a Request For Proposals (RFP) for assessment of non-point pollution sources in the several counties and development of management strategies, with some $5,000 being designated for a review of the literature concerning water pollution from strip mines. No further assessment studies are planned concerning this problem, due to the abundance of existing research projects studying mine pollution. No responses have been received on the RFP as of February 12, 1976.

<u>Crow Tribal Codes and Ordinances</u> - On January 31, 1976 the Crow Tribe adopted by resolution a Land Use Zoning Ordinance for the entire reservation. The ordinance states that the Crow Tribe has sole regulatory power within the boundaries of the Crow Reservation on the use of lands, the height and size of buildings, open

spaces, and density of population. The resolution also provides other criteria for the unified development of facilities such as roadways, utilities, parks and waste disposal.

On the same date the Tribe adopted by resolution an Environmental Health and Sanitation Ordinance which provides similar powers to the Tribe on all aspects of community activity which have an influence on health and sanitation.

Implementation procedures for these Crow Ordinances are now being developed. Their effectiveness will be highly dependent on the degree of co-operation which is maintained with adjoining jurisdictions.

In summary, a limited though significant beginning in effective land use planning and control has been made. Much more intensive planning processes and appropriate institutional structures need to be developed. This will call for a massive effort requiring a maximum of cooperation including significant financial contributions from appropriate tribal, state, county, city and other local governmental units as well as the appropriate federal agencies.

At the January 31, 1976, Tribal Council meeting, the tribe also adopted, "an Ordinance creating a method for the Taxation of coal by the Crow Tribe, and known as the

Crow Tribal Taxation Code". This authorized the Crow Tribe to levy a license tax of 25 percent of the contract sales price of all coal produced on the Crow Reservation and Ceded Area. The Taxation Code is subject to approval by the Secretary of the Interior and has been submitted for legal review.

III ENVIRONMENTAL IMPACT OF THE PROPOSAL

A. Air Quality

If mining on the proposed mine area is approved some deterioration of air quality beyond that caused by the present mine operation can be expected, especially in the vicinity of the mine operation and downwind from it. Operation of heavy mining equipment and the fugitive dust it creates even with the planned road watering program can be expected to be the most serious factor causing air-quality deterioration although other activities associated with the operation will also contribute. As the mining operation expands from the present production level of 4 million tons per year to 10 million, the number of pieces of heavy equipment can be expected to approximately double. An increase in the number of workshifts with less equipment is also a possibility and would affect the time distribution of pollutant generation, but the overall effect would probably be about the same. Increased exhaust emissions from the increased numbers of mining equipment can also be expected.

Increased use of the coal crushing and handling equipment and more loadings of unit trains will also add to an increase in dust generation. Although much of this equipment is covered to prevent fugitive dust, some leakage can be expected.

Based on the results of a study conducted in the early 1970's under the auspices of the U.S. Environmental Protection Agency (U.S. EPA, 1973) the average particulate loading at a typical road construction site was estimated to be one to two tons per acre per month during all phases of activity. Actual rates of emission due to relocation of the county road will be dependent on the rate of construction, number and type of construction vehicles involved, time of year, etc.

Emission rates of various effluents from light-duty gasoline-powered trucks, and heavy duty diesel-powered gasoline-powered construction equipment have been determined by the U.S. EPA (1976). Based on these emission rates and on the numbers of major equipment required, it is estimated that approximately 50 grams per second of nitrogen oxides (the most abundant gaseous emission by far from heavy-duty diesel-powered vehicles) would be emitted to the atmosphere at a production rate of 10 million tons per year. This amount is not considered to result in a serious adverse impact on the air quality of the site vicinity, because of numerous individual sources which are spread out over several thousand acres.

In general, dust loading that results from local traffic on unpaved roads is not expected to be a major problem during late fall, winter, and early spring. During that time of year ground conditions (that is, snow, ice, frozen soil, etc.) should result in relatively low loading rates. However, during the remainder of the year, and particularly in late summer and early fall, traffic volume and roadway conditions will be conducive to relatively high particulate loading rates. The EPA study on fugitive dust (U.S. EPA, 1973) concluded that the effect of vehicular travel on dust loading to the atmosphere amounts to 5-10 pounds per vehicle-mile for standard vehicles, assuming a vehicular speed of 30 miles per hour. It was empirically determined that, on the average, 58 percent of the particulate loading was due to vehicle dust plumes and 42 percent was due to wind erosion. For heavy-duty vehicles the impact under the same conditions would be greater. It is estimated that a total of 325,000 vehicle miles are traveled annually on Tract III during present coal development of 4 million tons per year. At this rate, and based on a 10 pounds per vehicle-mile dust loading factor, the potential exists for about 1625 tons of dust loading to occur annually at this mine development level. This potential would increase to approximately 4,000 tons annually at the proposed production level of 10 million tons per year. However, the unpaved roads at the mine site will be heavily sprinkled with water during times the roadways are susceptible to considerable dust generation. Thus, sprinkling of roadways will significantly reduce this impact.

Fugitive dust will also be generated during many other mining activities besides vehicular traffic, e.g., blasting, coal preparation, coal loading and transportation, stockpiling, reclamation, etc. Accurate estimates of dust loading to the atmosphere as result of these activities cannot be made since definitive data on many of the factors involved are not available and/or are highly variable, e.g., soil types and moisture content, length of material exposure, ability to reclaim disturbed areas and micro-climate data. It should also be recognized that the indirect effect of wind erosion on disturbed materials contributes significantly to dust loading of the atmosphere, and that other sources of fugitive dust, such as vehicular traffic on county and private roads and agricultural activities, are present in the area. Settled particulates (dustfall) averaged approximately 33 tons/mile^2/month adjacent to the present mine site during late July to late August, 1975, and only about 4/tons/mile^2/month from late April to late May, 1975. However, dustfall at a Tract II site removed from and upwind of the mine operation was 120 tons/mile^2/month during the July-August period (Data are not available at this location for the April-May period).

The period in which dust loading of the atmosphere is most susceptible is from midsummer through midfall (July to November). Based on limited on-site data, fugitive dust created at the site during this period will most often be carried in an eastward direction from its source.

The large majority of fugitive dust created as result of the mining activities will settle out within a relatively short distance of its source. Based on results of recent studies, approximately 80 percent of fugitive dust created by tracked-vehicles settles out within a few hundred yards of its source (Viletto and Ohman, 1972). For dust particles less than two microns in diameter travel distance is much greater and they may be carried by air currents for several miles or further.

After mining operations have ceased and reclamation has been completed, it is expected that the only impact on the air quality resulting from previous operations will be some particulate loading from wind erosion effects on roadways and similar areas used for vehicular activity.

B. Sound

Increased use of heavy equipment, larger and more frequent blasts, increased vehiclular traffic, longer operating periods for coal crushing and handling facilities, and more unit trains associated with maximum coal prodution on the proposed mine area will increase ambient sound levels near the mine. The magnitude of the increase probably will not be proportional to the increased noise generating activity. Although much of the noise generating equipment is operated simultaneously it is not operated continuously. At full production level, much of the equipment and activity generating noise will be dispersed over a much larger area than at the present mining operation.

Strip mining operations, which include bench construction, stripping, removal of overburden and interburden, mining of coal and reclamation will occur simultaneously. The active mining area will be limited to a long narrow pit adjoining the reclamation area. The mining equipment will be distributed throughout the bench, pit and reclamation areas. At large distances the noise radiating from the combined mining operations will appear to radiate as a point sources.

It is estimated that the equipment sound level contribution at 1,000 feet from the center of mining operations at a production rate of 10 million tons per year will be 63 dB.

Blasting will be required during the removal of the overburden. It is estimated that there will be two blasts daily. The overpressure created from these blasts depends greatly on the weight of explosives detonated and on meteorological conditions. Measurements for these types of blasts indicated that the impulse noise levels produced might be as high as 91 dB at 1,000 feet. This overpressure level exists for a very short duration and thus does not provide hearing damage risk and only minimal annoyance. An impulse noise level of less than 140 dB is acceptable by OSHA standards (Federal Register, 20 May 1967).

It is estimated that the present equivalent sound level contribution at 1,000 feet from the center of the coal preparation facility is 52 dB and would be present for a longer period at the full production level.

By 1981, when coal production reaches 10 million tons per year, it is estimated that there will be three train movements per day leaving the coal preparation facility. Measurements of the existing railroad operations at Tract III indicate that the maximum sound level at 130 feet from the passing of a loaded and empty train may reach 84 dBA (A weighted sound levels) and 85 dBA, respectively

(Westmoreland Resources, 1975 n). These passbys are for about a two-minute duration. The energy average of this sound, L_{eg}, at 130 feet for the passing of loaded and empty trains is 73 dB and 78 dB, respectively.

The greatest impact from increased noise will probably be felt by the workers in the mine and near the coal handling and loading facilities. Increased noise associated with increased access road and railroad traffic will be noticed by residents near these facilities.

C. Physiography and topography

Strip mining operations necessarily alter the physiography and topography of an area. All of the existing land surface in the mine area will be destroyed, and the lithologic structures that create variety and stability in the landscape will lose structural identity by blasting, overburden removal, and grading operations during the rehabilitation process.

These operations will alter the mechanical and chemical characteristics of the spoil materials. Relatively dense sedimentary rock will be transformed into broken and pulverized loose spoils, and the pore space ratio, density, and unit weight of the material will be changed. The exact dimensions of these transformations have not been defined, although research is beginning on this topic. The net reduction in volume due to removal of 20 to 50 feet of coal will probably be about 10 to 30 percent in most places. However, pulverization of overburden will tend to increase its pore space; the resulting increase in volume will tend to compensate for the missing coal volume. Increase in pore space of replaced spoils is estimated to produce about 15 percent dilation. This would approximately offset the volume lost due to removal of material from the coal seams in some areas. Immediately following replacement and grading, the main topographic effect will generally be a somewhat lower land surface where volumetric increases are not sufficient to compensate for the volume of coal removed. Over time, the emplace loose spoils material will settle and compact, further reducing the volume of material and decreasing the elevation. Again, the extent of spoils settlement and its resulting impacts on rebuilt surface features is not known at this time.

Because slopes in regraded areas will not exceed 20 percent (except final highwall reductions), the post-mining landscape will be smoother than now exists. Drainage patterns will be reestablished in the recontouring process, although gradients are expected to be decreased somewhat. The major stream channels of Sarpy Creek and East Fork Sarpy Creek will not be directly affected by mining operations.

D. Geology

The geologic character of the mine area will be totally altered by the mining operation. Instead of a layered sequence of rock materials of different hardness and permeability, the area will be reduced to a mixed mass of broken rock totally different from the layered sequence. The replaced spoil will have greater porosity and may have greater permeability than the original layered rocks, and if so will be more uniform in its transmissivity in all directions. Infiltration will be increased, and runoff correspondingly decreased. The mass likely will consolidate and settle with time, as a result of saturation and disaggregation, and permeability ultimately may be reduced.

E. Hydrology

1. Surface Water

The proposed mining plan as submitted by Westmoreland Resources would affect the upstream portions of several small local drainages that are tributary to Sarpy Creek, East Fork Sarpy Creek, and Middle Fork Sarpy Creek. Included is that portion of the drainage located above the present Absaloka Mine. The downstream portions of these drainages are to be protected by existing or proposed water control facilities (detention ponds) which will be located immediately downstream from boundaries of the proposed mine area (Figure 7). All detention structures will meet regulations of the Mining Enforcement and Safety Administration (MESA) and will be designed to contain a 10-year runoff event. For more extreme events, each structure will have a gated-standpipe and an ungated emergency spillway.

The primary impacts to surface-water resources in the area of the proposed mining operation will be to the availability of surface-water to the present downstream users. Primarily, these impacts will consist of the depletions of surface runoff originating from excess precipitation and snowmelt. The depletions will be caused by the following: 1) interception of runoff in the mine pit, 2) interception by reclaimed areas where runoff will infiltrate and be lost to either the ground-water table or to evapotranspiration, 3) surface evaporation from detention ponds, and 4) consumptive use of water for road maintenance and dust control. The exact amount of depletions which will occur at any particular time are difficult to determine but will depend on the rate at which mining operations progress, in particular the number and size of local drainages isolated by the downstream water control facilities.

Another affect of the water control facilities (detention ponds) will be to reduce flood peaks resulting from runoff from intense precipitation or rapid snowmelt in the basins above the detention ponds. All runoff will be retained behind the structures thus reducing the chance of flooding in downstream channels and would be released at a later date. Only in extreme cases when runoff exceeds the capacity of these impoundments will downstream flooding occur. If these structures are breached or destroyed, extremely large peaks will occur immediately downstream. Although such an event is unlikely, should it occur the larger receiving streams will probably be at flood stage and the peak caused by a failed detention dam would not be noticeable a short distance downstream.

The extraction of coal seams and the associated over- and interburden will result in disturbing ground-water aquifers and will have the effect of reducing springflow in adjacent watersheds during the period of mining, particularly the contributions of flow to the East and Middle Forks of Sarpy Creek. These aspects will be further discussed in the section under ground water.

The over-all impact on the surface-water resources - the amount of depletion of surface runoff available to downstream users - will be related to the rate of production of the proposed mining operations. As development progresses, each tributary drainage basin effected will be isolated from the over-all drainage systems of Sarpy Creek by impoundment structures. Hence, the amount of local drainage effected will not increase progressively and proportionately with the amount of surface area disturbed by mining operations, but will increase step-wise as operations affect each separate local drainage. However, the number of local drainages affected at any one time will be related to the rate or level of production. The effect of this isolation could result in the depletion of surface-water runoff by as much as 50 percent as long as the dams are in place. Although water will be released from these impoundments it will not be available for downstream use until such releases can meet Federal and State water pollution control regulations. In the meantime considerable depletion of those resources will take place due to evaporation from pond surfaces, consumptive use, and infiltration to the ground-water table.

The proposed mining plan calls for the continuation of mining operations in an easterly or upstream direction from the present mine development, all of which is located in the local drainage presently isolated by the existing water control facility. These operations affect about 2.4 square miles of drainage tributary to Sarpy Creek. About 1979 operations will cross the drainage divide into a local drainage tributary to Middle Fork Sarpy Creek. The associated water control facility will isolate about 1.5 square miles tributary to Middle Fork, about 0.8 square miles of which is located inside the proposed mine area. As mining operations progress eastward, they will cross the drainage divide between Sarpy Creek and East Fork Sarpy Creek, thus effecting the headwaters of three tributaries to East Fork totaling about 3.5 square miles, 2.0 square miles of which are located in the proposed mine area. At that time, maximum isolation of 7.4 square miles of local drainages including the present mine site from the overall drainage system of Sarpy Creek will have occured and will continue until further operations are planned and approved.

The maximum overall reduction of flow in Sarpy Creek as a result of the present and proposed mining operations is not expected to be significant. If it is assumed that runoff from the affected areas is directly proportional to its area, the runoff depletion attributable to the project can be estimated. The total area of the Sarpy Creek basin is about 453 square miles, and the area above the confluence of East Fork Sarpy Creek is about 156 square miles. The drainage area affected by present and proposed mining is about 7.4 square miles. Thus, if the long term average runoff from the basin is 0.5 inch (26 acre feet) per square mile and assuming all other factors are equal (e.g., soils, terrain, vegetative cover, land use, climate, etc.) and that mining will result in a 50 percent depletion of runoff; the reduction in streamflow would be about 96 acre feet per year. This would represent a reduction in streamflow of 4.7 percent at the confluence of East Fork Sarpy Creeks and 1.6 percent at the mouth of Sarpy Creek.

2. Ground Water

The ground-water reservoir above the base of the Robinson Coal will be destroyed by mining and, as a consequence, gradients in the ground-water flow system will be changed in adjacent areas, changing both the direction and amount of ground-water flow with a consequent relocation of discharge areas. In general, the effect of mining will steepen gradients south of the proposed mine area and diminish gradients north of the area.

The overburden and Rosebud-McKay coal near its clinker outcrop and in structurally high areas is commonly drained and removal of these rocks by mining should have minimal impact. Owing to the lenticular nature of the interburden, the amount of water level lowering in this unit is difficult to predict but the unit will be drained adjacent to the mine pit. At the Decker mine in southeastern Montana which has been in operation since 1972, water levels have declined as much as 10 feet within 1-1/2 miles down gradient of the active mine. Upgradient from the mine water level declines have been less. As the rocks above the Robinson Coal outcrop along Sarpy and East Fork Sarpy Creeks in the northern part of Tract III, the effect of water level declines will not extend beyond the creeks. Drainage into the present mine has not occurred to date and only one monitoring well appears to have been affected by a water level decline of about five feet.

Adverse effects on existing domestic and stock wells will be limited to those finished in aquifers above the base of the Robinson Coal. Most existing wells in the area are finished in the sub-Robinson unit and these aquifers are expected to be little affected by mining on the proposed mine area. After mining, if suitable water cannot be obtained from shallow aquifers in the reclaimed area; wells to the sub-Robinson unit could be drilled.

The porosity and lateral and vertical permeability of the replaced spoil is an unknown factor; however, the spoil can be considered as a conglomerate having a higher porosity and possibly a higher permeability than the original rock. If the replaced material acts as a uniform uncemented conglomerate having appreciable higher permeability than the original rock, much of the lateral flow into the mine and later to the reclaimed area will drain out through springs on the southern part of Tract III. On the north end of Tract III, the effect of lower gradients would be to decrease flow both through the rock and from springs.

When the mine area is reclaimed, a ground-water reservoir would develop having perhaps different dishcarge points than originally; and if the permeability of the replaced spoil is materially larger than the original rock, it can be expected that springs would react faster to changes in potentiometric head in the system. Flow would be greater in the winter and spring and less in the summer than originally.

Dust control will require an average production over the 20-year project life of about 75,000 gallons of water per day (Bureau of Indian Affairs, 1974, p. 123). During summer months, production for all purposes will range from 90,000 gpd at the beginning of the project to 250,000 gallons at the end. Much of this water will be consumed by evaporation in the effort to control dust by sprinkling haulage roads. The water will be and is currently produced from the Madison Limestone. This water is high in dissolved solids, particularly, calcium sulfate. However, the

Madison well water received primary treatment with permanganate to precipitate dissolved solids before use in dust control. The dissolved solids not so removed will be left in the new environment as the water used there evaporates.

The Madison Limestone is a regional aquifer believed to contain an extremely large volume of water in storage. Although withdrawals will lower the head in the Madison for some distance around the well, the depletion in storage would not be significant on a regional basis and water levels should recover in a short time when withdrawals cease.

Rapid movement of water into and through reclaimed areas may change the quality of the ground water in that it is moving through a very different environment than it originally had. In the Colstrip, Montana, area, highly alkaline mine drainage contributions to surface-water supplies has occurred (U.S. Bureau of Indian Affairs, 1974, p. 121). It would seem that similar conditions could develop in the proposed mine area and cause problems in surface-water quality. The quality of the groundwater, except in and near the mine, would be less affected in that water moving from the mined area into the groundwater flow systems would tend to come to equilibrium with that environment and may not be much different than it is at present. Exceptions would be where more permeable zones rapidly transmit the water to wells or springs.

Blasting may have some very local effect on the groundwater system by creating new fractures in the rock, particularly the coal bed aquifers (U.S. Bureau of Indian Affairs, 1974, p. 124).

3. Water Quality

The proposed mining operation on Tract III will have some adverse effect upon the quality of surface and ground waters within and adjacent to the mine site. Potential water pollutants can be in a chemical form (e.g., acid or alkaline mine drainage) or a physical form (e.g., sediment) or a combination of both. Surface water quality is expected to be somewhat affected both physically and chemically, and ground water, chemically. The main factors which have the potential to cause these effects include the following:

1. Mine drainage
2. Leaching of distrubed materials
3. Increased sediment erosion
4. Drainage from wastewater and solid waste
5. Dust control
6. Biocide usage

With proper mining and reclamation operation none of these factors is expected to result in major degradation of surface or ground-water quality. A brief discussion concerning how and to what degree each of these factors may effect quality follows.

Mine Drainage

Acid-mine drainage is a major source of pollution from strip mining operations in the eastern United States, however, it is not considered a major problem in most eastern Montana coal fields (Environmental Quality Council, 1972). The U.S. Bureau of Indian Affairs (1974, p. 120) suggested that acid mine drainage problems will not occur in the Westmoreland Resources mines on Tract III due to the natural conditions at the site. These include:

1. A relatively low sulfur content (about 0.73 percent) is found in the Rosebud-McKay and Robinson coal beds.
2. The alkaline ground water of the coal beds has a pH range between 7 and 9 and, therefore, would aid in the neutralization of any acid conditions.
3. The unleached overburden material has a highly alkaline pH.

Although pumping of seepage water has not been necessary in the present mine, it is expected that water will have to be pumped from the proposed mine in order to mine efficiently, thus decreasing the contact time between the standing water and the coal seams or coal residue of the pit. Observations by people experienced in coal mining operations of eastern Montana (U.S. Bureau of Indian Affairs, 1972, p. 120-121) also confirm the lack of an acid mine drainage problem in this area. Thus, acid mine drainage problems are not expected from future mining operations in Tract III and indeed, there is no evidence that acid mine drainages is a problem in the present Westmoreland mine on Tract III. (David Simpson, Westmoreland Resources, oral communications, 1975; Westmoreland Resources, 1975).

There is expected to be some alkaline mine drainage occurring on Tract III since waters of relatively high alkalinity and dissolved solids content are common and can be expected to flow over and through strip mined and reclaimed areas. Based on overburden analysis data, pH of surface runoff is not likely to exceed 9.0, the upper limit under EAP regulations. Although some overburden and interburden intervals that will be exposed exceed a pH of 8.9, most fall in the range of 7.5 to 8.5. Although the potential exists for mixing of alkaline mine drainage waters containing possible high concentrations of dissolved solids with the surface and ground waters, adequate mitigating measures can substantially reduce the probability of adverse effects from such water. By means of an adequate internal drainage system, mine waters can be diverted to detention or holding ponds where a reduction of alkalinity concentration may take place by precipitation of calcium carbonate. Such a system is used on Tract III for the existing Westmoreland Resources mine and is planned for the proposed mine.

The alkalinity of water draining from the present mine on Tract III (collected at the intake to the sediment detention pond) ranges from about 500 to 600 milligrams per liter (Dames & Moore, 1975, p. 25). These alkalinities are similar to and often less than the alkalinity of surface and ground waters adjacent to and within Tract III. Analyses conducted on samples collected from the sediment pond indicate overall reductions of alkalinity, bicarbonate, calcium, and magnesium of more than 50 percent from input concentrations. This indicates that use of detention ponds and an adequate internal drainage system at the Westmoreland Resources mine has significantly reduced the alkalinity of mine drainage water. Thus, alkaline mine drainage is not expected to cause an adverse deterioration of surface or ground waters in the site area with use of adequate mitigating measures during the mining operations.

Some alkaline water will drain into the overburden and spoils material and eventually enter the shallow aquifer system. In doing so, the water will probably become enriched in dissolved solids through leaching of soluble materials in route. This could only affect the quality of water in the Robinson Coal outside of the lease area, as higher aquifers outcrop along the valley walls of Sarpy and East Fork Sarpy Creeks in the direction of ground-water movement. However, some alkaline recharge to the alluvium of the valleys would be possible from spring flow. The general aspects and effects that are expected to result from this process are discussed in the following section.

Leaching of Disturbed Material

Several aspects of surface mining (e.g., excavation of overburden and coal, stockpiling of soil and spoilbanks, and placement of overburden and soil into the mine pit) provide numerous opportunities for fresh porous material to be exposed to the atmosphere, precipitation, and water draining into the pit. The spoils material contains minerals which possess various degrees of solubility in water. As surface water percolates downward and ground water migrates laterally through stockpiled material and spoils, leaching of soluble salts will occur. The resultant water is expected to be alkaline, contain higher concentrations of dissolved solids, (including sulfates, bicarbonates and the alkaline earth metals), and to contain trace metals common to the overburden and mined coal seams. The amount of increase of dissolved constituents depend in part upon the leachability of the distrubed material.

Overburden analyses can be used to infer leachate composition. Based on saturation extract analyses, average conductivity for material from all test holes on Tract III was 3.0 mmhos/cm; SAR averaged 6.0; and the pH for most intervals ranged from 7.5 to 8.5. Trace metals concentrations cannot be inferred as analytical data are based on DTPA extraction. Owing to alkaline pH, water solubility for most metals is negligible. Molybdenum and selenium are soluble at high pH but the concentration of these metals is very low. The average hot water solubility of boron is 1.5 ppm and might possibly reflect maximum concentration in leachate.

As the leachate water moves down gradient through the disturbed material, it will come in contact with the existing aquifers in the undisturbed ground water system. As this water moves further down gradient, it will mix with other ground waters and improve somewhat in quality through dilution. Where ground water discharges at springs immediately adjacent to the mined area, the water will essentially be undiluted and it is expected to be of somewhat poorer quality than existing spring water. Where such discharge occurs into surface waters, the resulting overall quality of the surface water that receives ground water which has passed through the mine spoils is not expected to be measurably degraded because the existing surface water quality is generally poorer than that of most of the local ground water, except during periods of moderate to high surface flow. Possible exceptions to this may be for tributary streams that receive most of their water during the low flow from springs discharging from the base of the Robinson Coal or higher.

There is expected to be little or no adverse effect to the water quality of aquifers beneath the Robinson Coal as result of the mining operation as these will not be disturbed.

The quality of ground-water samples obtained from spoils material of active surface coal mines within south-eastern Montana indicates that these waters may or may not be more chemically diverse and different from mine effluent (drainage) waters and waters from undisturbed aquifers. Samples from the Decker mine contain much more sulfate and dissolved solids than other local water, more calcium, magnesium, potassium and manganese, and about the same amounts of fluoride, bicarbonate, silica, chloride, nitrate and iron (Van Voast and Hedges, 1975). However, results of analyses on ground waters from spoils material of the Rosebud Mine at Colstrip, Montana indicate these waters have similar chemical characteristics to waters in the adjacent unmined area (Van Voast and others, 1974). Principal constituents in all waters analyzed from the spoils were calcium, magnesium, and sulfate. Analyses results indicate that waters entering the mine area are not changed in their chemical type, but, if anything, the existing principal constituents in solution are increased. This relationship for the Rosebud Mine area (which also is expected to pertain to the Tract III area) is compatible with the assumption that the quality of ground water is determined by the minerals available for dissolution, and these minerals are more available for dissolution in the spoils material than they are in the undisturbed strata.

Increased Sediment Erosion

Erosion and sedimentation are natural processes occurring everywhere on the land surface. Surface mining activities accelerate these processes by the removal of ground cover, decreasing the strength of the overburden during excavation and the alteration of the natural topography.

By the use of mitigating measures, however, sediment discharge to the natural drainage systems outside of the project area in response to most runoff events can be controlled. Westmoreland Resources plans to use natural drainage systems within the mining area and sediment detention ponds on tributaries draining the mining area to regulate sediment discharge. The detention structures will be capable of capturing and containing runoff volumes equal to or less than 10-year precipitation event. Sediment laden runoff waters will be retained in the detention pond until sufficient clarification of the water occurs through settlement before it is released. For larger runoff events, releases must be made during the event resulting in a portion of the sediment load being passed downstream.

In general, the amount of sediment generated from a watershed is directly proportional to its area. Thus, by comparing the relative sizes of contributing areas within a watershed, the proportion of sediment attributed by each can be approximated. Therefore, using the watershed areas previously mentioned and assuming all other factors being equal, the 2151 acre mining plan would would yield about 0.7 percent of the natural sediment generated within the Sarpy Creek watershed.

Meaningful estimates of the potential increase in sediment load from areas disturbed by mining are not possible owing to the nature of the mining and reclamation plan and the many variables that affect sediment generation. On a conservative basis, potential sediment load from disturbed areas could be double the natural sediment loads draining from the area. However, the area would never be 100 percent disturbed by mining, and planned detention ponds would retain sediment generated by most runoff events. Thus, the impact of sediment production downstream from the mine area could be minimal and might be less than under natural conditions.

During periods of extreme runoff volume, precipitation exceeding a 10-year event, it is estimated that the sediment load contribution from the project area will be somewhat greater than what would occur naturally. However, the importance of such an increased sediment contribution in itself is not expected to cause a major impact because of the relatively small area involved (3.4 mi^2) in the mining operation compared to the overall drainage basin areas. During such an event, the receiving streams would be in flood with large sediment loads and it is doubtful that the increased load from the mine area would be detectable using current sediment sampling techniques.

Water impounded in sediment detention ponds is often of poor quality, not only because of high sediment content, but also due to its chemical and biological composition. Biological degradation may be characterized by excessive phytoplankton, zooplankton, and bacterial growths occurring primarily during the warmest months of the year. Because the water accumulates from various parts of the internal drainage system of a mine, it may contain a low concentration of a variety of organic constituents (oils, greases, etc.) from various forms of industrial wastes, plankton nutrients such as nitrogen, phosphorus, carbon, and silica, and accumulations of trace metals, as well as the inorganic constituents. Although it is unlikely to happen, premature release of this water to the natural drainage system could adversely impact surface and groundwater quality in local downstream drainageways.

<u>Wastewater and Solid Wastes</u>

Domestic or industrial liquid wastes generated within the mining area present a potential waste pollution problem. Currently, domestic waste water is channeled to an approved evaporation lagoon at the existing Westmoreland mine. This facility would continue to serve the proposed mine area. There is not expected to be any discharge of inadequately treated domestic or industrial wastes to surface or ground-water resources of Tract III.

Various forms of solid wastes may accumulate throughout the area of mining operations. Such wastes will be disposed of in a sanitary landfill or other approved disposal facility within the mining area. The use of a sanitary landfill includes careful selection of a site, control of the dispersion of the leachate, and proper operational procedures. No significant adverse effects are expected to result from solid waste disposal within the mine area.

Dust Control

Frequent sprinkling will be conducted to control dust on roads in the mining area. Well water from the Madison Limestone aquifer will be used for this purpose and it contains moderately high concentrations of dissolved mineral salts. Currently, this water receives primary treatment to decrease dissolved solids concentrations prior to use for dust control. These salts (predominately calcium sulfate) can become concentrated on the roadways and later redistributed and transported out of the area through wind blown dust, water runoff, or percolation into the local groundwater system. The main effect of the salts would be to increase the salinity of the topsoil adjacent to the roads, which may somewhat inhibit plant growth.

Biocides

Excessive use of herbicides or pesticides in and around the mining area could cause some degradation to the water quality of the project area. Much of these chemicals would eventually be absorbed by clay and silt particles in the soil. Only a very minor fraction would be available for transport by surface runoff. At the present mine, Westmoreland Resources does not use biocides and does not not anticipate the use of biocides on the proposed mine site.

Use of Fertilizers

During the reclamation phase of post-mining operations, it may be necessary to apply fertilizer to regraded spoil material or to topsoil. Depending on the amount applied and the time of year it is applied, soluble chemical compounds in fertilizer which is distributed on reclaimed mine lands could be partially washed from the land surface into constructed or natural drainage and/or leached by percolation of water. This could result in a distribution of chemical nutrients to sediment ponds and eventually to the upper reaches of the major creeks near the project area.

F. Soils

The existing soils on the 2151 acres to be surface mined will be destroyed, in the sense that they will no longer exist as stratified, developed soils. In handling, the root zone (A and B horizons) will be randomly mixed, and in many instances the lower-lying substrata material (C horizon) will also become mixed with the upper horizons. When mining and reclamation are completed, the resulting physical and chemical properties of respread soil materials will be significantly different from the present soils.

Soils that must be stockpiled for future use in reclamation although they will be seeded to control erosion may become biologically sterile at depth, requiring inoculation with fresh topsoil. Some soil microorganisms can become dormant and will survive stockpiling, but the extent of this adaptation within the soil micro-community is unknown. In general the chemical, biological and physical properties of the natural soil will be disrupted and changed to an unknown degree by stockpiling.

Excavation and regrading of overburden and interburden materials will result in drastically altered subsoil properties. In the mining process, materials of deepest origin generally are placed at the top of the spoil piles, although in excavating to the Robinson seam, a substantial amount of rehandled overburden will be mixed with the interburden (Figure 8).

Based on analytical data from drill holes, regraded spoils will be alkaline, possible with some areas highly alkaline (pH > 8.9). High pH should not be detrimental to the growth of plant species used in reclamation. Regraded spoils in some cases may be slightly saline, but the degree of salinity should not be detrimental.

Materials originating near the Robinson coal seam may be slightly to moderately sodic, and it is expected that regraded spoils in some areas will be sodic. High levels of exchangeable sodium in combination with expanding lattice clays can result in impaired water penetration, root penetration and aeration. Serious sodium problems are not anticipated because sodic conditions generally are limited in occurrence and clays are predominantly kaolinitic. Addition of sufficient topsoil should mitigate potential sodium problems by placing a suitable plant growth medium at the surface, but exposure of sodic materials by erosion of topsoil may eventually result in surface materials not conducive to plant growth.

It is possible that in some areas of regraded spoil slightly elevated levels of boron may occur. Water soluble boron in concentrations above 5-10 ppm is toxic to vegetation. If adequate fill is placed on areas high in boron prior to topsoiling, problems should not occur.

Some test holes indicated strata with higher than normal levels of zinc and lead. It is unlikely the levels observed would pose hazards to revegetation or to livestock (Colorado School of Mines Research Institute, 1975).

Regraded spoils may in many cases be high in clay. High clay levels may restrict water penetration and result in erosion. Addition of a sufficient layer of topsoil to absorb water during high rainfall periods should prevent possible erosion problems related to clay subsoils.

Overburden and interburden materials in the project area, although highly infertile, are expected to be reclaimable, particularly since topsoil will be redistributed (Colorado School of Mines Research Institute, 1975). Localized adverse conditions are not expected to be serious and will be adequately mitigated by the redistribution of topsoil or if necessary, addition of fill prior to topsoiling. If revegetation is not sufficiently rapid to control erosion, however, erosion of topsoils may result in exposure of spoil materials which would be difficult to revegetate, particularly on steeper slopes.

As a result of disturbance by mining, some soil will be lost from the mine area. Removal of plant growth and excavation of soil and overburden will create favorable conditions for erosion by wind and water.

Wind action is nearly constant in the region, and clay and silt-sized particles loosened by blasting, digging, and grading will easily become airborne. Soil particles will also be transported off-site by surface water runoff. Soil erosion and deposition will be increased where soil permeability and infiltration are reduced by compaction and cementation. Any steep slopes left from mining excavations will be very susceptable to water erosion.

Soils in the immediate vicinity of haul roads and processing facilities as well as a long railroad line may be adversely affected by settling of coal dust.

G. Vegetation

All vegetation on the proposed mine site will be completely destroyed by strip mining operations. In addition, construction of roads, mine service facilities, and coal handling and storage facilities has and will remove small areas of vegetation. The actual rate and sequence of the destruction of vegetation is governed by the progress of the actual mining operation. On the proposed mine area, this will begin at the rate of 66 acres per year and increase annually until 110.5 acres will be disturbed annually as the mine reaches full production from 1981 until 1995. Acreage disturbed would then taper off sharply during the remaining two years of operation. This will result in a total of 2151 acres of vegetation being destroyed over the 20-year life of the mine.

The topographic features and soil characteristics of the reclaimed lands will be sufficiently altered to preclude eventual re-establishment of the pre-existing plant communities. Some exchange of plant species with the surrounding areas can be expected, but the extent cannot be predicted. Westmoreland Resources' plan to redistribute topsoil transported directly from unmined areas will aid in introducing native species to reclaimed areas as a result of rhizomes, roots and seeds contained in the soil.

Invasion of reclaimed lands by native species from other seed sources may also eventually occur. To what extent native species will become re-established and the time factors involved are not known.

The potential of the reclamation program to successfully rehabilitate the lands affected by surface mining, in the long term, can only be speculated upon at this time. Likewise, the ability of the reclaimed lands to sustain any particular land use over a long period of time is speculation at this time. The most probable outcome will be the transformation of 2151 acres of mixed grasslands and agricultural lands (interspersed with brush and timber) into a predominately open, rolling grassland dominated by species which can survive and reproduce on disturbed, significantly altered land. Over time, species mix will change as ecological processes of selection and succession occur.

The potential for revegetation of mined lands appears to be relatively good. Precipitation is approximately 15 inches annually, with the majority occurring during the growing season. Adequate topsoil is available to provide a suitable plant growth medium to a depth exceeding 18 inches. Topsoil suitability is not limited by chemical characteristics, although some series contain sufficient clay that erosion due to excessive runoff may be a problem.

Problems with blowing of topsoil have not yet occurred at the existing mine (David W. Simpson, Westmoreland Resources, Personal communication). Long term success of revegetation is not known, but short term results at the Absaloka mine and at Colstrip, 20 miles to the east, are encouraging. Westmoreland Resources has seedings dating back to 1973, but the oldest mined land revegetation plantings using a primarily native seed mix were seeded in the spring of 1975. It will be several years before the success of these plantings can be fully evaluated, although germination and plant establishment appear to have been good (David W. Simpson, Westmoreland Resources, Personal communication).

Operation of the dragline and other heavy equipment used in mining, as well as bare spoil piles and other exposed soil, will cause dust pollution during certain times of the year. The effects of the dust may extend to areas of vegetation not scheduled for mining when dust control procedures are made ineffective by climatic conditions or operator failure. Small amounts of vegetation will be lost to this effect.

Vegetation adjacent to roads, railroads and coal processing and handling facilities will be stressed by exposure to road and coal dust settling on plants owing to increased traffic and activity in these areas.

The construction and relocation of power lines will result in the loss of vegetation from grubbing and leaning operations. There will also be changes in plant composition where forests or brush canopies are opened for power line or road construction.

The continuing disruption of land use patterns brought about by the ever-moving mining operations may result in localized areas of overgrazing by livestock or wildlife. When confined to areas that will be mined this will be no additional impact.

Wildfire occurrence in adjacent rangeland and timber communities undoubtedly will increase over pre-mining conditions. Man caused fire starts will increase due to increased activity in and around the mining area. Without prompt response to fire outbreaks, the potential exists for increased impact on vegetation adjacent to the mining activity.

H. Fish and Wildlife

Wildlife habitat will be lost wherever strip mining, road building, soil stockpiling, building construction, or any other disturbance requiring removal of plant material and/or reshaping of the surface occurs.

Reclamation following mining should allow mined-out areas to be suitable for some fish and wildlife production. Approximately two years after the surface is stripped, reclamation should begin to return the land to a useful state. Following completion of reclamation techniques, it is estimated that a minimum five year time lag will occur before the land can resume its former productivity (Westmoreland Resources, 1975). Development of trees and shrubs to provide habitat diversity will require considerably more time, possibly 5-20 years at a minimum. Therefore, although as much as 773.5 acres will be involved in mining and reclamation activities, wildlife habitat values will be diminished on a larger acreage due to time required for development of woody plant communities.

Most wild animal species are mobile enough to escape the mine area and will flee as equipment destroys their habitat. Sedentary or slow moving aquatic, and burrowing species will probably be destroyed by the mining operation. Those animals that are able to flee will probably encounter increased predation and stiff competition for food and shelter as they are forced into neighboring territories already occupied by other animals.

All increased human activity will have an adverse effect on wildlife in the area. For example, increased traffic in the area will require new roads and more fencing. New roads and heavier traffic will increase the dangers to wild species from road kills, dust pollution, and hunter-caused mortality (both legal and illegal). Danger due to accidental fires will also increase.

Fences do not generally restrict the movement of animals, with the exception of the pronghorn (antelope). The pronghorn prefers to crawl under rather than hurdling fences. The range of these animals is thus effectively reduced by sheep-proof fences. Fencing also poses the danger of entanglement to both deer and antelope. Westmoreland Resources does not plan to use sheep tight fencing and antelope movement should not be restricted.

Higher noise levels from roads, rail lines and mining activities will have adverse effects on some species of wildlife. Acceptance of noise levels by a few species will come in time, although periodic intrusive noises (blasting, train whistles, etc) may cause local disturbances.

If disruption of shallow aquifers results in the loss of seeps and springs, the lack of water availability may decrease carrying capacity or result in population redistribution of some species.

Reclamation will alter the availability of habitats in such a manner that some species of wildlife will not be able to become established due to the absence of essential requirements for survival. Carrying capacity for some species may be decreased, while other species may become more numerous as hibitat changes favor their needs. The eventual long term changes in carrying capacity due to mining and reclamation are difficult to project because the degree of reclamation success is speculative, and because relationships between animal populations and their habitats are complex and poorly understood for many species.

The area probably will be less attractive to mule deer since mining and reclamation will result in a smoother topography than now exists, and the suitability of reclaimed soils for ponderosa pine, the habitat type most utilized by mule deer in the project area is questionable. This effect may be offset somewhat by the establishment of species utilized by deer as food, provided adequate cover develops or is retained in adjacent unmined areas. White-tailed deer are most closely associated with creek bottoms, so effects on this species are expected to be minimal. Utilization of uplands probably will be decreased, however, unless reclamation techniques succeed in establishing suitable cover.

The creation of a relatively smooth, rolling topography covered primarily by grassland probably will be attractive to pronghorn as summer range. Utility as winter range will depend primarily on whether or not sagebrush becomes established in reclaimed areas.

The coyote is extremely adaptable, and it is unlikely that the coyote numbers will be substantially affected.

Small mammals, particularly deer mice, should inhabit reclaimed areas in numbers comparable to those present in unmined areas.

Effects on sharptail grouse are difficult to predict. Mining will result in the elimination of at least one dancing ground, which based on 1975 spring population levels, corresponds to an estimated 56 birds. Opinions vary as to whether or not dancing grounds can be reestablished on mined and reclaimed areas. The critical factor may be whether or not other habitat requirements, such as nesting and winter cover, can be established. If these requirements are met, it is possible that new dancing grounds may become established and the long term effects may be neutral or positive. Otherwise, sharptails may not inhabit reclaimed areas.

Ring-necked pheasants should not be adversely affected since critical creek bottom habitats along Sarpy and East

Fork Sarpy Creeks will not be mined. Upland areas contain limited areas of suitable winter cover, and the birds are present during the breeding season when males are territorial. Reclaimed areas should be utilized by pheasants, particularly if suitable cover and agricultural land uses result.

Small numbers of waterfowl may be affected due to mining of limited amounts of aquatic habitat, primarily stock ponds. Significant degradation of Sarpy and East Fork Sarpy Creeks also would adversely affect waterfowl but such degradation is not expected. However, creation of aquatic habitats by construction of sediment ponds and other impoundments if approved by regulatory agencies may benefit waterfowl and other types of water birds.

Some species of raptors may be adversely affected for a comsiderable period of time due to loss of nesting habitat. This is particularly true of the great horned owl, red-tailed hawk and Swainson's hawk, which utilize trees as nesting sites. The sparrow hawk, a cavity nester, may also decrease in numbers due to losses of rock ledges and dead trees. Rock ledges cannot be replaced after mining, but it is unlikely that nesting sites of prairie falcons and golden eagles would be affected since these birds prefer rugged, precipitous terrain that is not present in the mine plan area. Because reclaimed areas are expected to support suitable populations of prey species, long term adverse effects on birds of prey are not expected.

Songbird populations are expected to be substantially affected in the short and long term. Woodland species such as the black-capped chickadee, red-headed woodpecker, mourning dove and others are expected to decrease in numbers until suitable haibtat becomes re-established. If reclaimed areas consist primarily of rolling grassland, these areas should be attractive to grassland species such as the western meadwolark. Elimination of rock ledges probably will prevent habitation of reclaimed areas by species dependent of these habitats, such as cliff swallows. A number of species use rock ledges and cavities for nesting, and will be adversely affected.

If reclamation does not succeed in the long term, or if post mining levels of productivity are substantially reduced, long term adverse effects on virturally all species of wildlife in the project area can be expected.

Wherever any disturbance results in disruption of stream flow or watershed patterns, aquatic life will suffer either by elimination or degradation of the habitat.

Water pollution from leachates, fuel spills, and sediment-laden runoff could eventually enter the streams of the area and cause damage to aquatic life downstream from the lease. Availability of surface water for preservation of habitat values may be greatly affected. Significantly reduced flows would tend to eliminate aquatic life from affected stream reaches. Alteration of runoff cycles may disrupt behavior and reproductive success, and may force fish and other aquatic creatures to move further downstream, where water is available in suitable quantities, although alterations of sufficient magnitude to substantially affect stream flow are not expected.

Fish species of recreational importance should not be affected. Use of Sarpy Creek by the sauger, the only sport fish captured in fishery surveys is limited to areas near the confluence of Sarpy Creek with the Yellowstone River. Adverse effects on aquatic habitats for downstream of the lease are not expected.

I. Mineral depletion

Mining of the area proposed will result in the depletion of approximately 190.6 million tons of coal with a total heating value of about 1.6×10^{12} BTU.

The increased traffic loads on the existing roads, and the construction of new roads necessary for the mining operation, will require the use of large quantities of gravel and clinker for road construction material. Gravel is available locally only in limited amounts, but extensive amounts of clinker of variable quality is available in the tract area and will be used as necessary. The clinker present within the area to be mined which is not utilized will be lost, since if it is not used during mining or before, it will be incorporated into the replaced spoil.

Mining of the area will not affect possible future exploration for oil and gas, since if present, these are found at far greater depths than will be mined.

Mining and transportation of coal will require the use of other fossil fuels. Currently, energy requirements to mine 1 million tons of coal include approximately 150,000 gallons of diesel fuel and 5,250,000 kwh of electrical power. Shipping this coal (and train return assuming a 1600 mile round trip) requires an estimated 2,000,000 gallons of diesel fuel. Based on conversion factors of 125,400 BTU gal for diesel fuel and 10,000 BTU to generate 1 kwh of electricity, the energy required to mine and ship 1 million tons of coal is equivalent to approximately 322,110,000,000 BTU, or 1.91 percent of the energy contained in the coal itself at 8450 BTU/lb.

J. Land Use

Westmoreland Resources currently controls all of the surface within the proposed 20 year mining plan area with the exception of the southern half of Section 31, T.1 N, R.38 E. Acquisition of surface control has been accomplished through land purchases from non-Indian land owners. Surface lands owned by Westmoreland Resources are to be offered for purchase to the Crow Tribe upon completion of mining and rehabilitation. Should the Crow Tribe elect to purchase these lands it is assumed they would be offered to Crow Indians for grazing and farming purposes where appropriate.

Successful rehabilitation of the mined lands will provide the Crow Tribe with lands suitable for livestock grazing. However, if reclamation is not successful and the land requires additional care such as frequent fertilization, the tribe will be forced to furnish monies and resources in order to try to sustain grazing or other agricultural uses. Lands adjoining the mined areas and primarily in non-Indian ownership would also suffer if reclamation is unsuccessful. Reduced surface water run-off, increased siltation of streams, and blowing dust would be a few of the potential problems in such an event.

Although the area to be mined is large, the area actually involved in mining at any one time will be relatively small due to reclamation activities following closely behind mining. Assuming a two-year lag between the onset of mining and the beginning of revegetation activities, and a minimum five-year period before revegetated lands can be utilized for agricultural purposes, about 773.5 acres would be involved in mining and reclamation at any one time at a peak production level of 10 million ton annually.

In 1975, approximately 785 acres within the proposed mine area were utilized for dry cropland, or had been previously cultivated. The 1975 value of dry cropland in the area has been estimated at $200 to $350 per acre (Westmoreland Resources, 1975 b). Income forgone when dryland agricultural land is mined is estimated to be $30.33 per acre per year (Big Horn County Situation Statement Emphasizing Agriculture, 1972; U.S. Department of Agriculture, Committees for Rural Development, 1972), although this figure is highly dependent on market fluctuations and other factors. Therefore, foregone income from mined agricultural lands is expected to be that corresponding to 1000 acres for a period of seven years, or about $167,000.

Lands in the valleys of Sarpy and East Sarpy Creeks adjacent to the leases are irrigable, but are not presently under irrigation. Because mining will not extend into these valleys, effects on irrigable lands will be neglibible.

Immigration due to increased employment provided by mining is expected to be concentrated in Hardin. Expansion of Hardin will encroach on irrigated cropland in the Big Horn River Valley. On the average, it is expected that construction of each new single family dwelling will result in the loss of about 1/4 acre of irrigated cropland.

Grazing on native or reseeded grasslands and woodlands comprises the largest current usage of Tract III; over 90 percent of the total area is used for grazing. About 1365 acres of the proposed mine area are currently used for grazing. This corresponds to approximately 455 AUM's (animal unit months) per year, or sufficient acreage for the grazing of about 45 cow-calf units assuming a 10 month grazing season. Assuming that mined lands can be returned to grazing at equal capacity 7 years after mining, which may or may not be the case, a grazing capacity of about 315 cow-calf units will be forgone over the life of the proposed 20-year mining plan. The average value of grazing land in the area is $90-$100 per acre. Cattle prices vary considerably and it is difficult to present valid figures for the net income represented. If the income generated by grazing land is 30 percent of that generated by cropland as is implied by relative land values, then the foregone income from 1365 acres over seven years would be about $87,000.

It should also be noted that livestock reservoirs and fences will be removed. These will have to be replaced before grazing can be effectively implemented and range management practices utilized.

Species of plants suited to highly disturbed sites will become established and may distribute noxious weed species on reclaimed lands. Special practices to eliminate these opportunistic species may be required, although as desirable plant communities become established the undesirable species should lose out due to limited ability to compete for water, nutrients, and light.

The impacts of coal mining on the timber resource will be of two types: the effect on the area disturbed by mining, and the effect on surrounding forest communities. The impact of removing the forest cover will be longlasting.

Eventually coal mining activities (including stripping, construction of roads, processing and handling facilities) will completely destroy all vegetation in the areas they occupy. Ponderosa pine forest of varying quality and density is present on about 29 percent (625 acres) of the proposed mining plan area. These stands have an estimated average standing volume of 3300 board feet per acre. Therefore, mining will require the harvest of approximately 2.1 million board feet of ponderosa pine timber which at a price of $30.00 per thousand board feet, is worth about $63,000. Westmoreland Resources has stated that every effort will be made to utilize timber resources from areas to be mined. However, if markets cannot be found, this resource will be lost when the timber is cleared in preparation for mining.

Stripmined forest land requires a number of years to return to its former use. Sawlog production on non-mined sites in the area presently requires a growing period of 80 to 120 years. After tree seedling establishment it will take approximately 40 years for the reclaimed area to achieve a forest-like appearance.

As evidenced by existent plant communities, aspect (direction of slope) has a profound effect on vegetation development and distribution on the project area. For example, environmental conditions on south facing slopes are generally too severe for forest communities to become established. Microclimatic changes will occur in the area due to removal of existent vegetation and significant changes in land forms during reclamation. Loss of suitable microclimates for tree growth may hamper reforestation efforts on even the best previously forested sites. Microclimatic alternation has hampered reforestation efforts on many clearcuts and burned over lands in the Northern Rocky Mountains, and these sites are only moderately altered in comparison with stripmined land.

Wildfire occurrence in surrounding forest communities will undoubtedly increase over pre-mining conditions.

Man-caused fire starts will increase due to increased activity in and around the mining area. These fires should not pose a great threat, since heavy equipment is available at the present mine site to construct fire lines.

Tree residue resulting from logging and mining operations could result in an environment conducive to insect population build-up. Mountain pine beetle (Dendroctonous ponderosa) is of primary concern in this type of timber stands and is presently destroying a considerable volume of commercial timber in the Wolf Mountains on the Crow Indian Reservation. Proper disposal of slash material will be necessary.

Because reclamation techniques may result in soil conditions not suitable for the growth of ponderosa pine, the timber production potential of mined areas may be permanently lost. If this occurred, the estimated loss in timber production on the approximately 625 acres of forest land involved would be about 56,250 board feet per year assuming 90 board feet per acre of annual growth. At a price of $30.00 per thousand board feet, this would represent an annual income value of about $1700.

It is unlikely that mined lands would be suitable for home construction and residential land use due to instability of the loosened spoil material. Lineal land uses (roads, powerlines etc.) will require temporary relocation as the mining operation progresses, but should not be affected in the long term.

K. Recreation

As recreational use of the proposed mine site is very limited at present owing to lack of facilities and restricted access, the impact of development of the site on recreation will be limited. Owing to the inherent hazards to visitors of a strip mining operation, access to the area will of necessity be restricted during the life of the mine. Use of the outlying areas of Tract III for present recreational uses should not be affected. Based on the high interest the public has shown in visiting coal mining operations, it is likely that sightseeing will increase and be the major recreational activity for the leasehold, in terms of visitor days, during the life of the mine.

As reclamation of the site proceeds and it is again available for use, the subdued topography, changed vegetation, and more homogeneous appearance of the area may make it less desirable for the limited recreational activities now possible.

Increased employment as mine production increases, if filled by newcomers to the area, would increase the demand for local recreational opportunities. As the anticipated immigration of workers as a result of development of the proposed mine site is not large, little impact would be noticed on recreational facilities now available in the general area.

L. Transportation and use of the coal

Shipment of coal from Sarpy Creek by rail will result in increased rail traffic. The number of trains leaving Sarpy Creek will be proportional to coal production, with an average of at least three trains per day expected at a production level of 10 million tons annually. Considering returning empty trains, this amounts to six train passbys per day along the Sarpy Creek railroad spur from Sarpy Creek to Sanders, Montana, and assuming eastward shipment of all coal, along the Burlington Northern main line to the upper mid-west. It is difficult to quantify transportation related impacts with certainty since it is not now known where all ultimate markets will be. However, annoyance due to train passby noise and increased traffic congestion at rail crossings will certainly occur along the railroad lines involved. Soils and plant communities along rail lines may be adversely affected by coal dust blowing from railroad cars.

Further shipment of coal by barge would increase barge traffic on portions of the Mississippi River, although interference with existing commercial navigation should not occur (Bureau of Indian Affairs, 1974, p. 130). However, increased conflict with recreational use of the river may result. The environmental consequences of coal shipment by barge are discussed in the Pigs Eye Terminal Environmental Impact Statement (Department of the Army, Corps of Engineers, St. Paul District, July 3, 1973).

Air quality impacts of burning Sarpy Creek coal will vary depending on the situation. Where existing power plants now burning high sulfur mid-western or eastern coal convert to coal from the Tract III lease, beneficial impacts on air quality would occur since sulfur dioxide emissions would be reduced substantially. Emissions from plants currently burning western coal would remain essentially unchanged in the event of conversion to Sarpy Creek coal.

New plants utilizing Westmoreland Resources coal will be required to take measures to reduce sulfur emissions. Federal Air Standards (Bureau of National Affairs, 1975) limit allowable surfur dioxide emissions to 1.2 lbs. per million BTU. The average analysis of the coal in the lease area corresponds to about 1.73 lbs. SO_2 per million BTU but which would be much closer to the allowable limit if the two stray seams were excluded. It should also be noted that recent testing conducted by consultants at Westmoreland's direction indicated that 87.5 percent of the sulfur in the coal was emitted. If the test was conducted in a modern boiler designed for this coal the precentage emitted would be expected to decrease. Alternative methods of reducing SO2 emissions include the installation of stack gas scrubbers, blending of fuels and fuel cleaning. It is probable that current research will result in more advanced methods of sulfur removal and/or coal burning to reduce sulfur emissions.

Air quality impacts to be expected from the burning of Sarpy Creek coal in any particular plant depend upon a multitude of factors including design, meteorological conditions and surrounding topography. Northern States Power Company (1976) presents detailed air quality data for its proposed SHERCO Units 3 and 4 in Sherburne County, Minnesota, which will utilize coal from Sarpy Creek. These units will have stack gas scrubbers, and in no case are allowable class II significant deterioration increments expected to be exceeded or even approached (Northern States Power, 1976 pp. 4.2-41, 42).

The fate of trace elements in the burning of coal has been identified as a potential environmental problem. Trace element concentrations in the coal seams are presented in Table 1b. Trace elements contained in coal are largely associated with the mineral portion and are predominantly carried with the bottom ash and fly ash. However some elements may be volatilized to varying degrees at combustion temperatures and emitted in the flue gas. For most elements, the majority will be retained in the scrubber slurry, presumably contained largely in the fly ash. Therefore, possible effects of trace elements on water quality, soils, plants and animals must be considered in fly ash or scrubber slurry disposal. For many elements, notably mercury, chlorine and molybdenum, significant quantities were present in the flue gas and hence would be introduced to the atmosphere. Northern States Power (1976) calculated ground level concentrations of trace elements that will be present in the vicinity of the proposed SHERCO Units 3 and 4, and concluded that a hazard to human health does not exist by comparing these values to threshold limit values at which harmful effects will occur to a human occupationally exposed over a long period of time.

Effects of trace elements on soils and the terrestrial food chain are more difficult to assess. Factors to be considered include the amounts involved, soil pH effects on chemical mobility, rainfall leaching effects, land use, interactions between elements, and the potential for toxic effects on plants or animals. Research on the fate of trace elements in biological systems is just beginning, and many questions remain unanswered. Because terrestrial inputs in any case would be quite small, adverse effects are extremely unlikely, although accumulations in surface soils over long periods of time could occur. Because analysis of the coals has not indicated abnormally high trace element concentrations, the environmental implications probably are not significant compared to those which would result from burning coal from other sources.

M. Risk of accidents

Industry related

The risk of fatal and disabling accidents to the employees in any industrial operation depends on many factors other than the physical hazards of the work. The experience, motivation, and training of employees as well as management commitment to safety can have a great effect on accident rates. Underground coal mining remains the most hazardous occupation in terms of fatalities and disabling accidents; however, the risks in surface coal mining are much smaller and are comparable to risks in the construction industries. The following statistics compare accident rates for surface and underground coal mining in the western United States for 1974, and include shops and crushing facilities:

Accidents Per Million Tons of Coal Mined

1974

Type of Mining	Disabling*	Fatal
Underground	47.4	0.20
Surface	3.0	0.083

Source: Mining Enforcement and Safety Administration

*Includes all lost-time accidents

The incidence of fatal accidents in underground mining was over three times the rate in surface mining while the incidence of disabling accidents was almost 16 times greater in underground mines. Machinery caused most fatalities in surface mining. In Montana for the first nine months of 1975, there was no fatal accidents, and the nonfatal rate was 0.89 per million tons mined in surface mines.

The railroad would pose some risk of accients, but this risk should be fairly low because the trains are loaded continuously and remotely, and the train is not broken nor switched in normal loading. Personnel are protected in the engine cab or crewcar of the train. The only exposure from switching operations would be in placing equipment or supply cars on the siding.

Population related

Probably the greatest risk to mine employees would be commuting to and from the mine site. Based on 1974 figures from the Montana State Highway Department and assuming that most of the proposed 210 employees would commute from Hardin, there would be an estimated risk of 1 fatal accident every 5 years and 5 to 6 injuries per year for the next few years.

N. Culture

The increase in local income from mine employment and from increased economic activity in the secondary economic sectors, together with the influx of a few workers to fill the critical skill positions, will almost certainly change the local rural culture to a slight to moderate extent. The change, of course, need not be considered negative but some extent of change is inevitable when an industrial economic sector is superimposed upon an agrarian economy. The extent and effect of the cultural change depends to a large degree on the manner in which the Crow Tribe uses or distributes the Tribal income derived from coal royalties. Other influencing factors on the cultural change are the location of the secondary services and the new residences. If these are located at or near the mining site in the rural setting, they will have a substantial effect on the existing culture; if, on the other hand, they are located at existing population centers, the effect on the local culture will be much less severe.

The location of the secondary services and new residential areas at existing population centers, Hardin for example, will have an impact on the utility, public service, and transportation systems to these towns and cities.

Sewer, water, street, and utility requirements will increase.

Displacement of ranchers living in the mining area will be minimal. In purchasing the surface rights, Westmoreland has included an agreement permitting the ranchers to continue the grazing use of the land until mining takes place. As part of the terms of the amended lease for Tract III, the Crow Tribe has the first right to purchase the reclaimed land after mining.

O. Scenic-visual resources

Existing scenic and visual resources now existing on the proposed mine site would be destroyed as mining progresses across the area. The varicolored rolling hills, stream valleys, rock outcrops, and vegetation patterns of the basically rural site will be removed by mining. In their place, the viewer would see the long deep scar of the mine pit and long parallel ridges of the predominately gray spoil piles until these are regraded and revegetated. The heavy, noisy, mobile equipment, the giant draglines, haul roads, coal handling facilities, plant facilities, and railroad during the life of the mine will be aesthetically displeasing to most people accustomed to a quiet rural setting. However, in so isolated a location, few visitors will stumble on to the site unexpectedly, and most will be coming to specifically visit the mine.

Reclaimed area behind the mining front will lack the scenic variety that existed on the undisturbed area. Although probably not visually offensive to most viewers, the reclaimed land may lack the scenic appeal that previously existed.

P. Archeological and Historical Sites

Westmoreland Resources studies of archeological and historical resources of their leases have been filed with the State Historical Preservation Officer. When approved, that officer will submit the studies to the National Council of Historical Preservation for their approval. Copies of these approvals will be included in the final environmental impact statement if available.

There are no known archeologic sites within the boundaries of the proposed mine area. Thus, there would be no impact on archeological values unless undiscovered sites are present that would be found during mining operation and not properly evaluated.

All sites of historical interest on the proposed mine area will be destroyed as mining progresses across the area. None of the sites are currently on or eligible for inclusion on State or National Historic Registers.

Q. Socio-Economic Impacts 1/

In presenting the socio-economic impacts of the proposed Westmoreland Resource mining plan it will be assumed that no other significant Crow coal development is to take place during the period between 1976 and 1997. This will enable the reader to obtain a clearer picture of the socio-economic impact of the Sarpy Creek development since it will separate it from impacts of other probable Crow coal development. The analysis also assumes that the Crow labor force participation rate will be at a maximum during the period of major impact and that this participation will remain constant throughout the life of the mine.

Dètailed discussion of the impacts of other combinations of Crow labor force participation rates and levels of Crow coal development are presented in "Draft Environmental Statement; Crow Ceded Area Coal Lease, Tracts II and III Westmoreland Resources", hereafter referred to as the lease-wide statement.

1/ All data presented is abstracted or derived from Mountain West Inc., Phoenix, Arizona, reports: Economic Impact Assessment Summary Report, Feb. 1976; Technical Report (unprinted) and Westmoreland Resources, 1975 f.

Employment Impacts

Employment impacts are illustrated in Figure 36 which shows the anticipated levels of employment generated by the implementation of the Westmoreland Resources Sarpy Creek twenty-year mining plan.

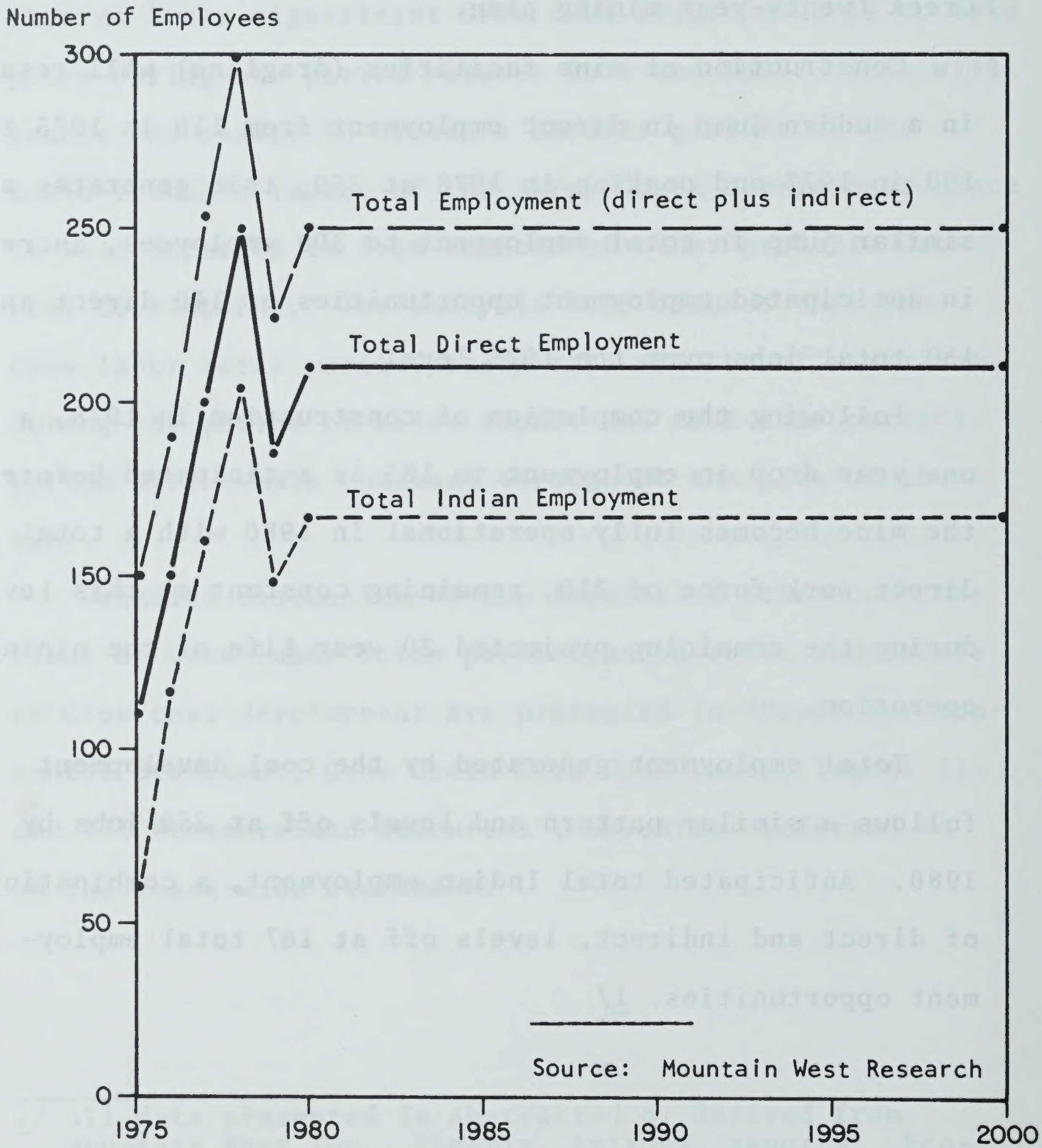
Construction of mine facilities (dragline) will result in a sudden jump in direct employment from 110 in 1975 to 190 in 1977 and peaking in 1978 at 250, this generates a similar jump in total employment to 300 employees, increases in anticipated employment opportunities of 140 direct and 150 total jobs over the 1975 level.

Following the completion of construction in 1978, a one year drop in employment to 185 is anticipated before the mine becomes fully operational in 1980 with a total direct work force of 210, remaining constant at this level during the remaining projected 20 year life of the mining operation.

Total employment generated by the coal development follows a similar pattern and levels off at 250 jobs by 1980. Anticipated total Indian employment, a combination of direct and indirect, levels off at 167 total employment opportunities. 1/

1/ For numerical details see Tables 1 and 2, Appendix F.

Figure 36 Employment Impacts 1975-2000
Big Horn County Impact Area
Westmoreland Resources Mining Plan



Income Impacts 1/

Income impacts attributable to Westmorelands 20-year mining plan will be derived from: (1) increased non-agricultural wage income, (2) royalty payments and (3) expenditures by Westmoreland Resources directly linked to their coal mining operation.

Increased non-agricultural wage income will be presented as (1) wage income from direct employment in the mining operation and, (2) total wage income from employment in services generated by the mining operations. Direct wage employment in current mining operations is expected to exceed $2,805,000 in 1976. With the advent of construction associated with mine expansion this is expected to increase by $935,000 in 1977 to a total of $3,739,000. In 1978, payroll for construction and operation is expected to total $4,862,000. In 1979, with completion of construction and with mine employment not yet at a maximum, the total payroll is expected to be decreased to

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1/ All in constant 1976 prices. For numerical details see Table 3, Appendix F.

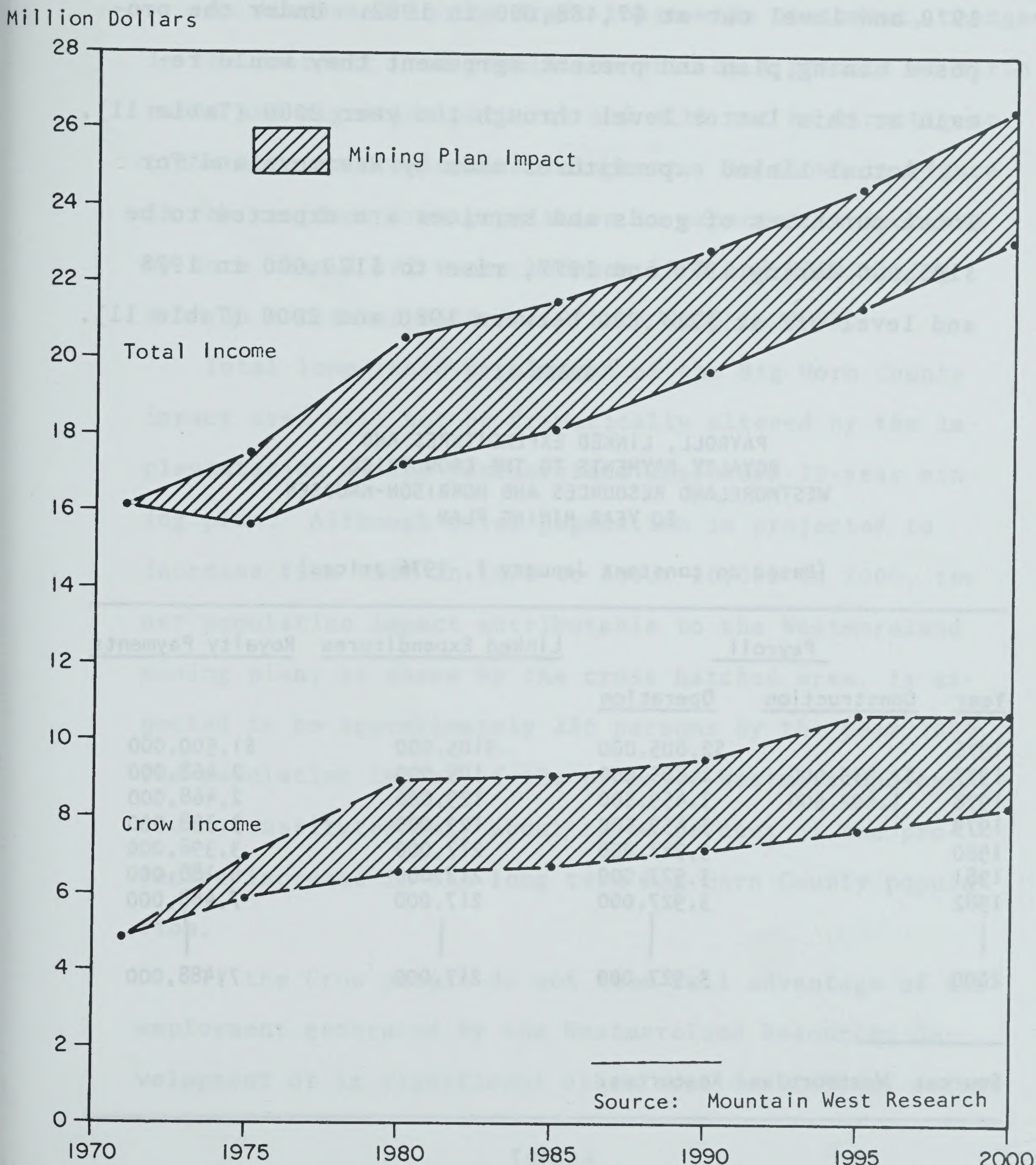
$3,459,500. Upon reaching maximum production, the mine operational payroll is expected to reach $3,927,000 and remain at that level throughout the 20-year mining period. Projected total non-agricultural wage income for the impact area is shown in Figure 37.

The lower line for both Indian and total income is the base line representing the projected level of non-agricultural income without any coal development. The upper line shows the level with Westmoreland development with the cross-hatched area indicating the actual income impact.

Without any coal development, annual Indian non-agricultural wage income would grow at a fairly constant rate from about $4,827,000 in 1971 to an estimated $8,292,000 in 2000. With Westmoreland's 20-year plan development, it would more than double between 1971 and 1985 rising from $4,827,000 to an estimated $9,113,000 in 1985. It would then further increase at a slower rate to an estimated $10,727,000 by the year 2000.

Without any coal development, total non-agricultural wage income would, after a slight decline by 1975, gradually increase an estimated $16,149,000 to approximately $23,178,000 in the year 2000. With Westmoreland's 20-year plan development it would rise rapidly from the 1971 level to an estimated $20,546,000 by 1980 and then continue a

Figure 37 Non-Agricultural Wage Income Impacts 1971-2000
Big Horn County Impact Area
Westmoreland Resource Mining Plan



gradual increase to an estimated $26,563,000 by the year 2000.

Royalty payments to the Tribe are expected to increase from approximately $1,500,000 in 1976 to $3,398,000 in 1979 and level out at $7,488,000 in 1982. Under the proposed mining plan and present agreement they would remain at this latter level through the year 2000 (Table 11).

Actual linked expenditures made by Westmoreland for local purchases of goods and services are expected to be $105,000 during 1976 and 1977, rise to $129,000 in 1978 and level off at $217,000 between 1980 and 2000 (Table 11).

TABLE 11

PAYROLL, LINKED EXPENDITURES AND
ROYALTY PAYMENTS TO THE CROW TRIBE
WESTMORELAND RESOURCES AND MORRISON-KNUDSEN
20 YEAR MINING PLAN

(Based on constant January 1, 1976 prices)

	Payroll		Linked Expenditures	Royalty Payments
Year	Construction	Operation		
1976		$2,805,000	$105,000	$1,500,000
1977	$ 935,000	2,805,000	105,000	2,468,000
1978	1,402,500	3,459,500	129,000	2,468,000
1979		3,459,500	129,000	3,398,000
1980		3,927,000	217,000	3,398,000
1981		3,927,000	217,000	6,188,000
1982		3,927,000	217,000	7,488,000
|		|	|	|
2000		3,927,000	217,000	7,488,000

Source: Westmoreland Resources.

Population Impacts

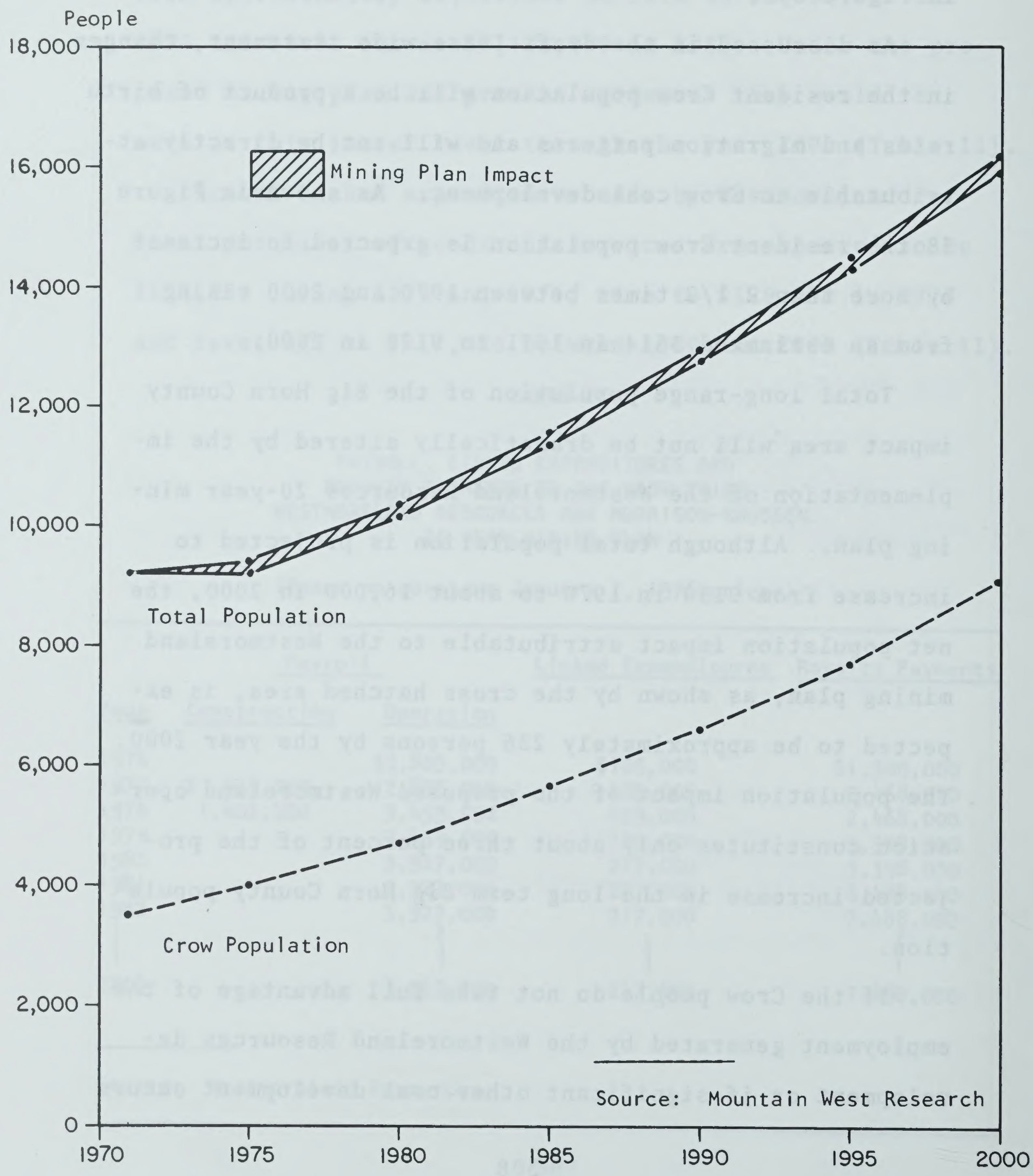
Long term population impacts resulting from the Westmoreland Resources Sarpy Creek coal development are shown in Figure 38.

As discussed in the draft lease-wide statement, changes in the resident Crow population will be a product of birth rates and migration patterns and will not be directly attributable to Crow coal development. As shown in Figure 38 the resident Crow population is expected to increase by more than 2 1/2 times between 1970 and 2000 rising from an estiamted 3514 in 1971 to 9120 in 2000.

Total long-range population of the Big Horn County impact area will not be dramatically altered by the implementation of the Westmoreland Resources 20-year mining plan. Although total population is projected to increase from 9180 in 1970 to about 16,000 in 2000, the net population impact attributable to the Westmoreland mining plan, as shown by the cross hatched area, is expected to be approximately 236 persons by the year 2000. The population impact of the proposed Westmoreland operation constitutes only about three percent of the projected increase in the long term Big Horn County population.

If the Crow people do not take full advantage of the employment generated by the Westmoreland Resources development or if significant other coal development occurs

Figure 38 Population Impacts 1971-2000
Big Horn County Impact Area
Westmoreland Resources Mining Plan



simultaneously, the population impacts would be much more significant. These alternatives are discussed in detail in the lease-wide draft statement.

Population Related Impacts

Population related impacts attributable to the Westmoreland Resources development will be felt in Big Horn County in direct proportion to the increase in population generated by this development.

The city of Hardin and its immediate off-reservation environs will be the only area which will have any measurable impact on its service facilities. It is estimated that in this area there will be an increase of something like 15 to 20 households with a total population increase of less than 200 attributable to the development of the mining plan. 1/

1/ In a related analysis Mountain West Research shows no measurable impact for the Hardin area through 1981.

Since the projected Crow population increases are independent of coal development, the projected population impacts attributable to the planned Westmoreland Resources 20-year operation on the predominately Crow communities would be so minor as to be immeasurable. There will be a need for significant increase in various types of services in these communities which must be met, but they will not be attributable to the planned Westmoreland Resources operation. This fact must be kept in mind to gain proper perspective on impact assessment.

The projected increases in population even without coal development will call for increased educational, health, public safety, municipal and other services. If a lower Indian employment level or a higher level of coal production occurs in the impact area, the impacts may be intense. Such impacts are discussed at length in the lease-wide statement which takes variables into account.

As implied by the peak of employment during the constriction phase (about 75 persons) there may be short term population increase in the impact area, creating a temporary shortage of housing and some other facilities. However it is anticipated that at least half of the non-Crow construction workers will commute from outside of the impact area thus, short term impact should not be critical.

Public Revenue Impacts

Public revenue impacts will be very positive. As detailed in Table 12, Westmoreland Resources and Morrison-Knudson anticipates that by 1979 they will be paying well over 10 million dollars annually to the state of Montana in severance and resource indemnity taxes and after 1982 well over 21 million dollars annually.

TABLE 12
TAXES
WESTMORELAND RESOURCES AND MORRISON-KNUDSON
Mining Plan
(Based on constant January 1, 1976 prices)

	State		County	
Year	Severance	Resource Indemnity	Proceeds	Property
1976	$ 4,508,000	$ 48,000	$ 888,000	$ 437,000
1977	7,858,000	72,000	1,798,000	905,000
1978	7,858,000	72,000	1,798,000	905,000
1979	10,371,000	90,000	2,481,000	1,638,000
1980	10,371,000	90,000	2,481,000	1,638,000
1981	17,908,000	144,000	4,528,000	1,638,000
1982	21,258,000	168,000	5,438,000	1,638,000
1997	21,258,000	168,000	5,438,000	1,638,000

Source: Westmoreland Resources.

Big Horn County will also receive significant revevenue benefits from the operation of the mine. If the plan proceeds on schedule, revenues to the county will total over 1.3 million dollars in 1976 from proceeds and property taxes and over 7 million dollars by 1982.

Cultural Change

Inherent in the continually urbanizing environment that prevails in the impact area is a relatively rapid cultural change. The degree of social stress experienced as a result of this change will be in direct proportion to the rate of coal and other development and the involvement of the Crow people and other impact area residents in the development.

For those Crow people who take industrial type employment for the first time, the cultural change is likely to be dramatic. New concepts of social priority and new avenues for financial support are likely to significantly modify the cultural environment of not only the employee but that of his kin and significant others. If sufficient numbers in any community are exposed to such experiences, the likely result will be significant cultural changes influencing the entire community.

The subject of cultural change under differing levels of Crow coal production are discussed in detail in the lease-wide statement.

Inter-group Relationship

In view of the relatively little population impact associated with the planned development and since this will be concentrated in the immediate Hardin area, there is little indication that any significant change in inter-group or intercultural relationships can be attributable to the Westmoreland Resources Sarpy Creek development. In an urbanizing environment, such as that which is continually occurring on the Crow Reservation and Big Horn County, increases in inter-group and inter-cultural stress are to be expected without the influence of significant Crow coal development. However, any change that occurs will be almost entirely a result of other factors and events than the development of the Westmoreland Resources Sarpy Creek mining plan. This development will make its small contribution to change in inter-group relationships but to consider it a major factor would be to underrate present trends and situations.

For a discussion on the probable inter-group relationships impacts under alternative levels of coal development and Crow employment participation rates the reader is referred to the lease-wide statement.

In summary, if no other significant Crow coal development takes place and if Crow Indians take maximum advantage of employment opportunities, there will be no serious impact on population related services attributable to the proposed Westmoreland 20-year mining plan. This applies to both government and private sector services such as health care, public assistance, education, law and order, water and waste disposal services, housing, shopping and other community facilities and services.

IV MITIGATING MEASURES INCLUDED IN THE PROPOSED ACTION

A. Environmental controls and legislation

The Crow Indian mining leases, Federal and State legislation, and Crow Tribal codes all contain provisions that when enforced will provide mitigation of most environmental impacts. These provisions are discussed in detail in the Draft Environmental Statement, Crow Ceded Area Coal Lease Tracts II and III, Westmoreland Resources, (U.S. Bureau of Indian Affairs, 1976), and the reader is referred to that publication for details.

B. Lessee's reclamation plan

In Section I the Westmoreland reclamation plan was described in detail. As with any plan, its success will depend partly on Westmoreland's commitment to proper reclamation including a willingness to adopt additional measures, should the original plan require changes.

The plan includes the following important provisions:

1. All topsoil and other soil horizons determined by tests to be capable of sustaining vegetation will be removed from the overburden prior to stripping.
2. Spoils will be graded to a rolling topography with no more than a 5 to 1 (11 degree) slope. The final highwall will be graded to not more than 3 to 1 (19 degrees). Grading of spoils will be kept up to two piles back from the active pit.
3. Overburden will be sampled for toxic material, and any such material will be buried deep enough to protect vegetation.
4. The regraded surface will not contain any water impoundments without prior arrangement with State agencies.
5. To the extent possible, topsoil would be replaced directly on regraded spoils without stockpiling

or double handling. Current practice is to place an average of 24 inches of topsoil on regraded spoils.

6. When possible, topsoiling will be done in fall or early spring so that planting can be done immediately to take advantage of early season moisture.
7. Reclamation progress would be monitored and results incorporated into future work.

This plan contains all of the requirements of the Montana Strip Mine and Reclamation Act as well as those of 30 CFR 211.40 although these are not now applicable to Indian lands. The regulations and technology concerning mined land reclamation can be expected to change with time. Westmoreland recognizes that this plan is tentative and may require changes.

C. Air Pollution Control

All activities associated with construction and operation of the proposed mine area must comply with appropriate Federal and State air quality standards. These Federal and State laws and regulations include:

(1) Federal Clean Air Act, as amended in 1970; 42USC., 1857.

(2) National Primary and Secondary Air Quality and Air Pollution Control, Vol. 36 #21 Part 2 CFR 1971.

(3) State of Montana, Air Pollution Act: Title 69, Chapter 39, sections 14-25, RCM 1947.

Dust will comprise the greatest amount of pollutants and therefore will receive the most extensive control measures. A dust reduction program accomplished by graveling, patrolling, and watering of roads is in effect at the present mine and will be continued. Dust control measures incorporating latest technology are included in the design of crushers, conveyors, and loading facilities in operation at the present mine and their use will be continued. Vehicles and equipment are equipped with factory installed pollution control devices as required by EPA.

Federal and industrial fire prevention campaigns are in use at the presently operating mine and will be continued to minimize the frequency of coal, forest, and rangeland fires. Firefighting equipment and trained operators are presently available on the site.

Stripped and stored topsoil will be subject to immediate revegetation which will reduce air pollution from dust from this source. Spoil banks will be recontoured, topsoiled, and planted to control erosion and dust as soon as practical after mining but will usually lag two spoil rows behind the mining operation.

D. Noise Control

Much of the noise associated with strip mining is that generated by heavy vehicles of various types in use, blasting, coal crushing and handling, and unit trains in transit. The main effects of noise will be felt by the workers in the mine and coal handling facilities.

Westmoreland Resources present and proposed mining operations must comply with the Federal noise regulations established pursuant to Sections 6(a) and 8(g) of P.L. 91-596, The Occupational Safety and Health Act of 1970, and specifically the noise exposure regulations set forth in 29 CFR 1910.95. Workpersons in areas subject to high noise levels will be required to wear ear plugs.

E. Water Quality

Because any disturbance of the land surface will alter the environment in the vicinity of the disturbance, pre-mining planning is a necessary prerequisite to any environmentally sound surface mining operation. The proposed mining plan, Tract III, is a planning document which addresses many probable environmental impacts. In addition, the coal mining lease for Tract III specifies that the Lessee agrees to preserve and protect the natural environmental conditions on the land covered by the lease, or land affected by its mining operation, and to take corrective actions within the scope of normal stream pollution control practices. Thus, the Lessee is obligated to mitigate adverse envirinmental impacts and can do so through the utilization of proven techniques. For instance, if proper planning, modern mine practices, and current pollution control measures are employed, most adverse environmental effects of surface coal mining can be minimized. With regard to water quality, it is not only important to minimize impacts on water quality in the vicinity of the mine; it is of primary importance to minimize or negate any water quality problems downstream and "down aquifer" from the mining operation. Furthermore, by complying fully to all applicable State and

Federal water pollution control and reclamation regulations, the mining company can utilize a variety of mitigating measures.

Mine Drainage

Acid-mine drainage is not a serious problem in eastern Montana, and recent as well as past experience with mine operations on and near Tract III have verified this observation. Alkaline mine drainage problems should be expected; however, certain preventive measures can be taken to mitigate their impacts on the local area and downstream from Tract III.

The proposed mining plan states that the company will develop water control facilities to assure the quality of natural surface drainage waters as required by the Montana Strip Mining and Reclamation Act and EPA Standards. These facilities would be constructed to intercept all runoff waters originating from areas being mined and would include sediment detention ponds. Figure 7 shows the location of the proposed water control facilities within and around the proposed mine area. This plan includes an internal drainage system for each sub-basin which is mined. That is, the remaining unmodified natural drainage system and additional constructed drainage would be designed to divert runoff away from the mining area and away from access to local aquifers, spoil banks, open pits, large cleared areas for staging or processing operations, and coal-haul roads. In addition, any dilute waters from direct precipitation or snowmelt which the internal drainage system can collect (e.g., via small collection ponds, runoff from undisturbed areas, etc) would aid in the dilution of mine drainage water collected throughout the mine area. Also, in order to prevent the accumulation of standing water within a mine pit due to seepage, runoff or direct precipitation, any water accumulating in a mine pit will be pumped to the internal drainage system. An internal drainage system similar to that described above is presently in use at the Westmoreland mine on Tract III. (David W. Simpson, Westmoreland Resources, oral communication, 1975).

In the event that alkaline mine drainage problems are so severe that the water from the internal drainage system cannot be released to natural surface drainage, a facility for chemical treatment to neutralize alkaline mine drainage water would be provided by the mining company. Although neutralization will decrease pH and reduce alkalinity, the resulting water may still contain high levels of sulfates and dissolved solids. Water from internal drainage would not be released to the natural drainage system unless it meets current water-quality standards of the appropriate State and Federal agencies. Dilution of alkaline mine drainage water appears to be one of the best treatments for mitigating its impact. Experience to date at the operating mine has shown that dissolved solids decrease substantially in the detention pond from levels present in the inflow.

Control of Leaching

The control of leaching is intimately connected to the prevention of mine drainage water problems. The most effective control is the proper use of mining and reclamation techniques. The mining and reclamation techniques to be used in the proposed mine area are described in the Proposed Mining Plan, Tract III. Reclamation of spoil bank material by contouring, replacement of topsoil and revegetation of overburden and diversion of surface runoff around active mine areas will help to prevent the percolation of water through freshly disturbed and exposed materials. To minimize the production of leachate, one must prevent access by water to freshly disturbed material in spoil banks above the pits, in the open pits, and in the overburden material replaced in the mine pit after completion of mining. Leachate which enters surface-water systems within the mine area will be routed to the internal drainage system with the expectation it can be diluted and released in a controlled manner to the natural drainage system. The reclamation techniques and internal drainage system mentioned above are currently in use at the Westmoreland mine on Tract III and are to be employed in the proposed mine area, as stated in the Proposed Mining Plan.

Sediment

Siltation from surface mining in flat to rolling terrain is less acute than from mining operations in mountainous regions (Grim and Hill, 1974). Nevertheless, the control of erosion and sedimentation on the topography which is characteristic of Tract III is intimately linked to the prevention of mine drainage in the project area. The most positive controls consist of proper pre-mining planning and the use of improved mining practices and modern reclamation techniques. These plans are described in the Proposed Mining Plan for Tract III. All earth-moving activities can be planned such that the minimum amount of disturbed area will be exposed for a minimum amount of time. This can be accomplished by excavating and mining an area in stages, with progressive backfilling and reclamation as mining progresses. Similar plans are given in the Proposed Mining Plan, Tract III.

Specific mitigating measures that can be taken during and after mining include the design of properly contoured spoil banks; prompt revegetation; controlled use of the disturbed surface after revegetation; properly designed and constructed coal-haul roads; construction of an internal drainage system along roads and expansive staging and processing areas; and the use of sediment detention ponds.

The internal drainage system established within and around the mining area to control mine drainage water will also serve as a suspended sediment control. Suspended sediment will be channeled to sediment detention basins and settling ponds as described in the Proposed Mining Plan and shown in Figure 7. A sediment pond can minimize high suspended sediment concentrations in runoff emanating from mining areas. An internal drainage system for sediment control and a sediment detention pond similar to that described above, are presently in use at the Westmoreland mine on Tract III.

Sediment detention basins are utilized for the collection and retention of eroded material before it reaches the natural streams of the project area. In addition, by retaining storm water, sediment basins may be used to reduce peak flows during heavy rainstorms and potential flood conditions. The Proposed Mining Plan states that in accordance with MESA regulations, the detention ponds will retain a storm of 24 hours duration with a recurrence interval of 10 years. Emergency spillways will allow for a 100-year frequency storm of 6 hours duration.

Water in the settling basins will be monitored for chemical and biological quality as well as for concentration of suspended sediment. Water would be released only when its chemical, biological, and suspended sediment content are within established State and Federal limits, and when its quality would not degrade the natural surface water drainage of the area or adversely affect local ground-water resources susceptible to recharge. The water of the sediment detention pond presently in use on Tract III is monitored as part of the water quality monitoring network at the operating Westmoreland mine on Tract III.

Periodic dredging of accumulated material from sediment ponds will ensure the maintenance of their designed capacities. The Proposed Mining Plan states that upon completion of mining, the landscape will be left free of water impoundments unless prior approval is obtained from appropriate State agencies. Subject to State approval and future modification of their mining plan, Westmoreland Resources intends to leave water detention facilities in place for use as stock water ponds, wildlife habitat improvement, and possible future use of water for irrigation.

Water Quality Monitoring

A water-quality monitoring network has been established within the present, actively mined area of Tract III, peripheral to the mining area, and at key downstream locations and outlying aquifers. The network was established in 1973 before mining operations began in order to observe the baseline, pre-mining condition of the area's surface- and ground-water quality. The monitoring network will continue throughout all phases of mining operations. The monitoring program provides the water-quality information required by the Montana Strip Mining and Reclamation Act. The proposed mine area is located within the area presently covered by water-quality monitoring network. Additional quality stations would be added to the network to comply with State regulations regarding the quality of water discharged from new mining areas.

A ground water monitoring program has also been established on Tract III by the Montana Bureau of Mines and Geology. (Van Voast and Hedges, 1974). The network was established in 1973 and has been used to determine the general, pre-mining, hydrologic conditions of the ground-water system in Tract III and the conditions around the immediate area of operations of the present Westmoreland Resources mine. The observation network will continue to monitor the ground-water quality in the area during any subsequent mining operations and after reclamation operations have been completed. The program objective is to determine long-term water level trends and quality changes (if any) of local and regional aquifer systems as a result of mining activities.

Biocides

Westmoreland Resources does not anticipate the use of biocides in the proposed mine area. If any such compounds are used and if of a persistent nature, water quality monitoring programs will be modified appropriately.

Use of Fertilizer

Fertilizer may be applied to the reclaimed surfaces. As outlined in the proposed mining plan, fertilizer requirements will be determined after top soil analyses have been made and after consultation with the Montana Department of State Lands. From past experience, little or no adverse impact is expected.

Blasting

Although the effects of blasting can disrupt the flow of ground water to aquifers or produce fissures for the entry of contaminated waters, recent developments in blasting matrerials and methods have minimized some problems (Grim and Hill, 1974). Blasting associated with strip mining at Colstrip, Montana, has not contributed to any documented degradation of water quality (U.S. Dept. of the Interior, 1974).

F. Waste management

Through the general provisions of the Coal Mining Lease, the Lessee is obligated to mitigate adverse environmental impacts. This can be accomplished through the utilization of acceptable techniques and by the compliance with State and Federal laws.

Domestic liquid wastes generated within the project area are routed to an approved sewage lagoon at the present facilities and the practice will continue on the proposed mine area. The water quality of any effluent discharged to watercourses of the area must comply fully with Local, State, and Federal pollution control standards.

Industrial liquid wastes, such as excess, contaminated, or finished fuels, lubricants, solvents or other organic liquids, are transported from the site for disposal. Proper safeguards would be maintained to prevent the dispersal of organic liquids to surface-or ground-water resources of the project area.

Combustible solids wastes at the present mining operation are burned at an approved site. Non-combustible solid wastes are buried in the mine pit. These operations would continue on the proposed mine area.

All potential waste management, as well as water-quality problems, must be addressed in full compliance with all State and Federal regulations. The regulations include, but are not limited to, the following:

1) Federal Water Pollution Control Act of 1956 (70 Stat. 498).
2) Amendments of 1961 to the above Act (75 Stat. 204; PL 87-88).
3) Water Quality Act of 1965 (75 Stat. 903; PL 89-234).
4) Amendments of 1972 to the Federal Water Pollution Control Act of 1956 (89 Stat. 816).
5) 33 U.S.C. 44 - Codes for the Federal Water Pollution Control Act as amended.
6) State of Montana Senate Bill 94 (The Montana Strip Mining and Reclamation Act).

G. Fish and Wildlife

Westmoreland Resources (1975 a) has outlined some of the measures that will be taken during reclamation to lessen the impact of strip mining on Tract III that will be of benefit to wild species of animals.

1. "All reclamation and revegetation procedures will be conducted in compliance with the Montana Strip Mining Reclamation Act (Chapter 325), pursuant rules and regulations, and guidelines issued by the Montana Department of State Lands, as well as applicable federal regulations."
2. All suitable topsoil will be removed and either stockpiled or spread directly on recontoured lands to a uniform eight-inch depth. Stockpiled topsoil will be seeded to prevent erosion. These procedures will be beneficial in speeding the process of revegetation and thus re-establishing wildlife habitat. Erosion control will help eliminate downstream pollution of water that would effect aquatic life.
3. High walls resulting from mine cuts will be reduced to a slope of not greater than three units horizontal to one unit vertical. This will help stop erosion and lessen the hazard of injury or death to wildlife by falling.

4. Seeds of native and introduced grasses, forbs and legumes will be sewn on recontoured lands. Trees and shrubs will be planted. The recommended seed mixture is given elsewhere in this statement. Planting of trees and shrubs will aid in restoring wildlife habitat values.
5. Sampling of vegetation will be conducted on an annual basis to determine the success of reclamation.
6. An earthfill dam, with 77 acre-feet capacity, has been constructed to detain rainfall runoff, ground water seep, plant washdown and water encountered and pumped from the presently operating mine. Sediment accumulated will be removed and used in reclamation or if not suitable, buried in the mine pit. Rip-rap is used to retard erosion. Additional water control facilities will be added as necessary when mining operations proceed across drainage divides.
7. Roads are sprinkled with water to retard suspended dust particles.

H. Monitoring Plans

The success of planning and implementation of a program for mitigation of environmental damage will be dependent on a monitoring program whereby environmental changes can be detected and evaluated. Westmoreland Resources (written communication, January 2, 1976) plans to continue a monitoring program upon completion of baseline studies on Tract III in the areas of wildlife, vegetation, aquatic biology, hydrology, meteorology, and air quality. Present plans discussed below are subject to revision if required to conform with State of Montana mining regulations.

A program of wildlife monitoring was initiated on Tract III in January 1975 following completion of baseline studies. For big game species, aerial surveys are conducted on a monthly basis. Survey of ring-necked pheasants and sharptail grouse are conducted in the spring. Observations of predators, raptors, game birds, and other species are recorded as observations are made. Habitat use by each species is analyzed seasonally, and it is planned that as mining progresses, assessing wildlife use of reclaimed areas will be a primary objective. Small mammal trapping studies are conducted annually on reclaimed and unmined areas. It is planned that as reclamation progresses, songbird surveys also will be conducted in reclaimed areas. It is expected that this program will be continued during the life of mining and reclamation activities with modifications to the program to address changing situations.

Vegetation in reclaimed areas is sampled annually to monitor the progress of revegetation. Ground cover and above ground production of herbaceous species will be measured and compared to corresponding parameters of unmined areas. Percent survival of trees and shrubs also will be measured. It is anticipated that over the long term this information will be useful in evaluating various reclamation treatments.

Surface water flow measurement stations were established on Sarpy and East Fork Sarpy Creeks adjacent to Tract III for baseline studies of surface water hydrology. Measurement of surface water flows will continue. Two continuous recording stations on East Fork Sarpy Creek operated by AMAX Coal Company presumably will remain operational. The Westmoreland system consists of a network of staff gauges and crest stage gauges to measure flows above and below discharge points.

Surface water samples are collected monthly at sampling stations for chemical analysis. Analyses performed include the following:

Acidity	Settable solids
Alkalinity	Evaporated solids
Alkalinity ($CaCO_3$)	Total suspended solids
Flouride	Oil and grease
Sulfate	pH
Total iron	Temperature
Dissolved iron	Turbidity

This program will continue, although sampling locations may be modified to meet changing conditions. In addition, analyses for metals, including trace metals, will be made quarterly.

Ground-water monitoring will concentrate on those monitoring wells immediately adjacent to the mine operation. Water level measurements will be made monthly and water quality analyses will be made semiannually or annually or as required or approved by the Montana Department of State Lands. As monitoring well sites are mined out, other wells will be monitored with new wells installed if necessary.

Weather stations currently in operation at the existing water treatment plant and the administration office located adjacent to Tract III in the NE¼ Sec. 21, T.1 N., R.37 E., will be operated indefinitely. When baseline air quality studies are completed, the two high volume air samplers will be moved to locations suitable for monitoring air quality downwind of the mine site. Operation will continue on a six-day cycle. Dustfall jar locations will be modified according to prevailing wind directions determined by the baseline studies. A minimum of four locations around the mine site are planned with additional stations located downwind from the mine.

I. Scenic-visual resources

Both Federal regulations and the Montana Strip Mining and Reclamation Act require that strip mined land be returned to a condition as near as possible to that which existed before mining. The reclamation program planned for the proposed mine area by Westmoreland Resources will conform to Montana state laws and if successful will restore many scenic and visual amenities to the land.

The spoil piles will be recontoured to a topographic configuration as near as possible to that present before mining. New surface drainages will be established as near as possible to those present before mining. Topsoil removed ahead of the mining front will, when possible, be placed immediately on recontoured spoils material and seeded with a mixture of native and introduced grasses, forbs, and shrubs. Planting of trees native to the area in favorable locations is also planned. Immediate placement of topsoil is expected to re-establish many native species from seeds and roots.

As mining is completed, all roads, utilities, and mine facilities will be removed and the land reclaimed. Although the reclaimed mine site will be visually quite different from adjacent unmined land it should not be aesthetically displeasing to most people.

J. Archeological and Historical Sites

Although there are no known archeological sites on the proposed mine area, it is possible that unrecognized sites are present. Machine operators assigned to topsoil removal are instructed to be alert for artifacts. If such sites are discovered during soil removal operations ahead of the mining front, work would stop at the site and a qualified archeologist would be contacted to document and evaluate the site and excavate if the evaluation so warranted.

All sites of historical interest on the proposed mine area have been studied and recorded as a part of the historical record of the area.

K. Safety

The Sarpy Creek mine is subject to Federal safety laws with standards covering every aspect of mining. The laws require training of miners, procedural and equipment safeguards, health standards, and frequent, detailed inspections to enforce standards by personnel of the Mining Enforcement and Safety Administration (MESA).

The mine operator, Morrison-Knudsen Co., employs a full-time safety director. Mine inspections are made on a near daily basis. All new mine employees, at the time of their employment, are required to read the Morrison-Knudsen Co. safety handbook. All mine employees are required to attend weekly safety meetings lasting about one half hour that are related to day to day operations. More formal safety meetings are held quarterly with keynote speakers and safety films. Special safety training meetings are held for affected employees when new equipment or techniques are introduced into the operation. All employees assigned duties in fire fighting and/or first aid are required to update these skills at annual training courses. These procedures would be continued in the enlarged operation of the proposed mine area.

Railroad safety is the responsibility of the Federal Railroad Administration, which has standards covering track construction and maintenance, car and locomotive maintenance, and operating rules. The Treasury Department regulates the transportation and storage of explosives. The mine has an ambulance to transport injured workers to the hospital in Hardin or Billings.

V ADVERSE IMPACTS THAT CANNOT BE AVOIDED IF THE PROPOSAL IS IMPLEMENTED

A. Air Quality

The generation of fugitive dust by heavy mining equipment, coal handling facilities, and vehicles cannot be completely eliminated even with the best control programs and thus will contribute to degraded air quality, particularly in the vicinity of the proposed mine and for some distance downwind from the mine. The potential dust loading from vehicle activity associated with the production level of 10 million tons per year is estimated to be 4000 tons annually. However, the sprinkling of unpaved roads in the mine area will greatly reduce this impact. The same would be true for exhaust and particulate emissions by heavy mining equipment, support vehicles, and unit trains serving the mine. It is estimated that about 50 grams per second of nitrogen oxides, the most abundant gaseous emissions, from heavy duty diesel power vehicles, would be emitted to the atmosphere at a production rate of 10 million tons per year. Vehicular traffic of employees and businesses serving the proposed mine will also contribute to air quality degradation from exhaust emissions and dust along access roads.

Fugitive dust from two rows of bare spoil piles which will be exposed to wind action during the life of the mine is unavoidable as these areas are generally not accessible for dust control by sprinkling. Reclaimed and seeded land on which vegetation is not yet established will also be a source of dust. Accurate estimates of dust loading to the atmosphere as a result of these activities cannot be made since definitive data on many of the factors involved are not available and are highly variable.

Some damage to vegetation from dust along access roads, the railroad spur line, and adjacent to the proposed mine is unavoidable. The extent of damage will be dependent on the frequency of precipitation that will wash the dust from plants.

B. Noise

An increase in near field noise levels in the mine area will be unavoidable as output from the mine is increased to the planned full production level and additional heavy mining equipment is put into use. More frequent blasting, start up warning at the plant, and back-up signals will be the most noticeable intrusive noises. Noise of the coal and overburden drills, two operating draglines, scrapers, loaders, and coal hauling trucks will all add to increased noise levels and will last for longer periods during each working day. Longer operation periods for the coal crushers, conveyors, and loading equipment will add to the noise. Noise levels from these activities are estimated to be 63dB at 1000 feet from the center of mining activity, impulse noise levels of about 91dB at 1000 feet from two blasts per day, and equivalent sound levels of about 52dB at a distance of 1000 feet from the coal handling facilities.

Three unit trains per day transporting coal from the mine will result in more frequent noise along the railroad right of way from the mine site to the trains destination. Experience at the present mine indicates that the maximum sound level at 130 feet from the passing of a loaded and empty train may reach 84dBA and 85dBA respetively. These passbys are for about a two-minute duration.

C. Physiography and topography

Mining in the newly proposed mining area will destroy the existing diversity of the landscape that lends character to this land. The ledges and cliffs and caprocks that create this diversity also provide protective cover for some small and medium-sized mammals and will be lost. Although the post mining topography will be similar to that before mining, some lowering of the land surface due to removal of the coal is unavoidable.

D. Geology

The primary impact on the geologic character of the region is the depletion of the natural fuel resource and of clinker used for road surfacing. The loss of continuity of beds caused by the excavation and mixing of the rock undoubtedly will eliminate some local bodies of ground water, but the lensing character of the sandstone beds now limits their productivity as aquifers. The increased porosity of the replaced spoil will increase infiltration and reduce runoff, which will alter slightly the hydrologic balance of the area. Increased surface area of rock materials, resulting from breakage, and increased infiltration likely will cause greater leaching of salts from the rocks. These dissolved salts likely will be confined largely to the area of excavation initially, and, as the excavated area becomes saturated, will be transmitted to adjoining permeable rocks where the concentrations of salines may become greater. Because of the limited potential for future use of near-surface ground water, this is not considered a serious impact.

E. Hydrology

Surface Water

The most prominent adverse impacts to surface-water resources resulting from mining operations will be those to the quality and quantity of surface-water supplies. Substantial depletions of surface-water runoff from the proposed mine site will result from evaporation from ponded surfaces, consumtive use, and infiltration to the ground-water table. These depletions can conceivably amount to as much as 50 percent of the total runoff which would have been expected with unaltered surface conditions. As about five square miles on and adjacent to the proposed mine area will be affected by detention ponds, surface water depletion could be about 65 acre feet per year or about 1.1 percent of the runoff from the Sarpy Creek basin. Subsequent to the completion of mining operations, surface-water supplies originating from local watersheds could conceivably return to near pre-mining conditions. However, depletions which take place during mining operations are in fact irretrievable. It is unlikely however that such supplies will return to equal conditions due primarily to the altered land surfaces which will facilitate greater infiltration rates and, thus reduce the amount of unit runoff.

Ground Water

The ground-water reservoir above the base of the Robinson Coal in the area mined will be destroyed. The replaced spoil will have different hydrological characteristics than the original rock and may have a tendency to transmit water more rapidly to discharge. Gradients in the ground-water reservoir adjacent to the mine area will be altered as will flow paths. Current spring flow from the coals will be affected. Pumpage of large quantities of water for dust control will locally lower the head in the Madison Limestone-the source of the water used for dust control.

Water Quality

Water quality will be degraded to some degree in and around the area of mining operations on Tract III. The degree of degradation will depend on such factors as the number and size of operations, the location of the excavation activities, the mining practices used, and the pollution control practices employed.

With the removal of overburden, interburden, and coal, certain local aquifers will be permanently lost. Removal of the aquifers, pumping of mine drainage water from open pits, and subsequent replacement of aquifers with unconsolidated overburden will alter the local ground-water flow patterns within and around the mined area. A change in quality of local shallow aquifers may result due to the leaching of surface water through freshly replaced overburden, seepage of water between contacts of replaced overburden and undisturbed material, and a change in the drainage pattern of runoff on the land surface of the replaced overburden. Local springs and wells within Tract III which are located near mining excavations may experience some change in water quality during mining and after reclamation. The degree of degradation would not be expected to be severe or long lasting.

A general degradation of surface water quality in the mined area during operations can be expected. Construction and mining excavations will disrupt natural drainage boundaries. Disturbed natural surface drainages and internal constructed drainage will exhibit the characteristics of alkaline mine drainage. The resultant physical and chemical composition of mine drainage water flowing from mine pits, over, through (leaching) and around spoil banks, and over mine staging areas and coal-haul roads will be found in sediment detention ponds. In spite of monitoring and control, this water may cause some degree of degradation of the quality of creeks to which it discharges, depending on the extent of mining, the quantity of runoff, and the flow conditions. Chemical and sediment inputs to local creeks may cause concentrations of water-quality constituents to be higher than what are presently observed. Exceptionally high chemical and sediment inputs may occur during periods of extreme flooding conditions if the capacity of the internal drainage system and the capacity of the sediment detention ponds are exceeded. Conditions under which this might occur are:

1) The occurrence of high intensity thunderstorms over the mining area.

2) The presence of extensive unreclaimed or denuded spoil banks susceptible to considerable erosion by runoff during periods of excessive precipitation.

3) The accidental release of water from sediment detention ponds.

4) The designed capacities of the sediment ponds have been decreased by sediment loading which was not removed.

5) The designed capacities of the sediment ponds are less than required by an actual flood event.

The potentially high chemical concentrations entering a creek during a period of high flow or flood, however, may be mitigated by the dilution factor of the high flow. Light suspended sediment fractions (e.g. coal fines) might be transported far downstream from their source; however, they would be relatively chemically inert.

The use of sanitary landfills and sewage treatment facilities in or around mining areas of Tract III may leave a permenent long-term impact. However, if the sites were selected properly, and adequate operation and control of the site has been enforced, no serious after effects should be observed.

The new operations in the proposed mine area would essentially be a continuation of the operations started in 1974. Initially this should mitigate any increase in degree of severity of adverse impacts to Tract III.

However, expansion of facilities and roads over a larger area is proposed. The gradual increase in coal production after 1976 and the projected sharp increase of production in 1980 after the construction of a second dragline, mean an increase in the rate of expansion of mining operations in the proposed mining area. With two drag lines working simultaneously, the degree of severity of adverse impacts may be increased as the scale of the operation increases.

It is impossible to guarantee that adverse effects on water quality by the mining of coal can be completely eliminated. However, it is realistic to expect that the degradation of water quality can be greatly reduced. In general, pollution problems associated with western coal mining are not well characterized (Grim and Hill, 1974). With regard to the project area under consideration, the experiences being gained from prevention and control of adverse effects on water quality in the operating mine in the approved mine area of Tract III can be transferred readily to any future operations in the proposed mining area.

F. Soils

Destruction of 2151 acres of soils as they now exist on the proposed mine area during the life of the mining operation is unavoidable. Although the soils will when possible be immediately placed on recontoured spoils, the removal and handling process will thoroughly mix the soils and soil structure as it now exists will be destroyed. Surplus soil that will be stockpiled until needed will suffer some deterioration in its properties.

Some loss of topsoil during handling is unavoidable. Other losses will occur by erosion of the placed and stored topsoil until such time as vegetation is established that will control the action of wind and water.

Replacement of natural subsoils with spoil material could be an adverse impact as adverse physical or chemical problems may be present. Erosion of replaced soil materials could expose these spoils which lack adequate plant nutrients and may be too clayey for seedling establishment.

G. Vegetation

Destruction of all vegetative cover which includes about 775 acres of agricultural crops, 1365 acres of grass, and 625 acres of timber, is unavoidable in the areas that will be mined. The degree of impact will depend upon the rapidity of revegetation including restoration of partial tree cover on the area.

Also unavoidable is the loss of income that would have been generated from the vegetation if mining did not take place. This loss is estimated to be $167,000 for agricultural crops, $87,000 of grazing income, and $1,700 for tree growth that would take place.

Changes in soils and other physical features of the environment are altered by strip mining in such a way that it may permanently preclude the re-establishment of pre-mining climax vegetation communities. Many species of plants are extremely slow in reinvading a site that has been disturbed. There will therefore very probably be a change in the composition of the plant cover on disturbed areas.

H. Fish and Wildlife

Numerous adverse impacts on fish and wildlife are unavoidable as the mining of Tract III coal proceeds. These impacts will be felt by wild populations both on the lease as mining destroys their habitat and off the lease as activities related to mining occur. Food, shelter, and breeding grounds will be lost.

Building of transportation routes will destroy wildlife habitat and increase noise levels, promote increased dust pollution, increase road deaths of animals and make some wild species more susceptible to hunter losses (both legal and illegal).

Fences along roadways and the active mine area alter normal movement patterns of deer and antelope and will increase the probability of injury or death by entanglement.

Removal of coal by strip mining will completely destroy all wildlife habitat on the proposed mine area. Mobile species will probably escape the area but more sedentary animals (burrowing and slow moving forms) will be lost during blasting and excavation. Competition will increase in outlying areas as escaping mammals and birds invade niches occupied by resident species. Traditional breeding grounds for grouse will be lost and are probably not replaceable. There is one lek present within the proposed mine area that had 14 dominant males present in 1975. This would represent an estimated spring population of about 56 birds. Water-shed flow patterns will be at least temporarily lost. Springs and seeps in the area will be eliminated. To the extent not mitigaged, pollution of the air and water will be caused by blasting, earth moving equipment, vehicular traffic, exhaust emissions, oil and fuel spills and other means which will have effects on the quality of the environment of wild species. Noise levels will increase and have a potential disruptive effect on wildlife behavior. Mine-cuts (high walls) may be dangerous to animals wandering in the area.

Post mining habitats resulting from reclamation will differ in carrying capacity for many species, and some species may not be able to meet their habitat needs. Populations of some species will decrease, while others may not inhabit reclaimed areas.

I. Depletion of natural resources

Other than coal and clinker use for road surfacing, there will be no depeltion of local mineral resources as a result of the mining operation. The Tongue River Member of the Fort Union Formation here contains no other minerals of potential economic value. The ultimate recovery of petroleum, if present, will not be affected by the mining operation.

The consumption of other fossil fuels for mining, transport of coal, and reclamation activities is unavoidable. Current estimates of requirements for mining one million tons of coal include 150,000 gallons of diesel fuel and 5,250,000 kwh of electrical power. Shipping of this coal and return of the train requires an estimated 2 million gallons of diesel fuel.

J. Land Use

Disruption of all present land uses on the proposed mine area during the life of the mine is unavoidable. Curtailment of present land uses will take place at approximately the same rate as mining progresses across the site. All agricultural activity in the mining and reclamation areas will cease, dwelling and other structures will be destroyed, and roads and power lines will have to be relocated.

Although only 500 to 600 acres of land will be unavailable for use at any given time at the full production level of the mine, reclaimed areas may not be suitable for present land uses. Roads will be re-established in the reclaimed area. Many species of wildlife will return but some species formerly using the area may find it unsuitable. Owing to expected instability of the reclaimed spoils, building of structures, especially large structures, may not be feasible without pilings driven to undisturbed strata for support.

K. Recreation

Complete disruption of the limited recreational opportunities now available in the proposed mine area is unavoidable as mining and reclamation activity move across the site. It is not likely that the reclaimed site when again available for use will have the same appeal for recreational activities as the pre-mining surface with its varied topography, colors, and vegetation communities.

L. Transportation

Transportation routes, both road and rail, are already established to the operating Westmoreland mine. The unavoidable impacts related to transportation will be those associated with road relocations on the proposed mine site and increased road and rail traffic.

Relocation of the county road crossing the proposed mine site in stages as mining encroaches on the present site will result in dust and sediment production until the road is graveled and cuts are stabilized with vegetation. This activity will also cause some inconvenience to local residents who must use the road.

Increased traffic on all roads serving the mine will increase the potential for vehicular accidents and road deaths of wildlife crossing the roads. The increase in the number of unit trains serving the mine will also increase the potential for accidents throughout the rail route and will add to noise and air pollution along the right of way.

M. Scenic-visual resources

Radical alteration of the scenic and visual resources of the proposed mine area is unavoidable as mining and reclamation activities take place. The existing scenic amenities which would be aesthetically pleasing to most viewers will by nature of strip mining be destroyed. The reclaimed and revegetated site will lack the variety in color, topographic features, rock outcrops, and vegetation patterns now present on the site. Although not visulally displeasing, the reclaimed site will lack the scenic values that it now has for most people.

N. Archeological and Historical Sites

Ultimate destruction of any undiscovered archeological sites is unavoidable if the proposed mine area is developed. The sites will not be available for future study after mining and reclamation.

VI THE RELATIONSHIP BETWEEN SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

Westmoreland Resources proposes over a period of 20 years to mine from the proposed mine site in Tract III of the Crow Ceded Area about 190,600,000 tons of low sulfer subbituminous coal. The proposed mine area covers 2151 acres of which 314 acres with an estimated 31,867,000 tons of coal in place is owned by the State of Montana. The remainder of the surface area is in private ownership with the underlying coal reserves the property of the Crow Indian Tribe.

The proposed action represents a planned use of land in the Crow Ceded Area that would result in the beneficial use of the areas coal reserves for electric power generation in the midwest, and insure that the land was promptly returned to a condition suitable for resumption of use as rangeland and wildlife habitat. The proposed action would also provide employment opportunities and royalty income for the Crow Tribe.

Projected mining rates call for mining 4 million tons in 1976, 6 million tons in 1977 and 1978, with the addition of a second dragline 7.5 million in 1979 and 1980, reaching full production level of 10 million tons per year in 1981 through 1995, with production dropping sharply in 1996 and 1997 within the proposed mine area as the coal reserves are depleted. At the full production level, about 110.5 acres of land per year will be disturbed by mining. Reclamation of the mined land would follow two spoil piles behind the mining front and once underway, about the same acreage would be reclaimed each year as was disturbed by mining. The reclaimed and revegetated areas would not be available for grazing for a probable minimum of five years to allow the vegetation to become firmly established.

The short term effects of mining on the physical and biological environment will be mostly confined to the years of active mining plus a probable two years following mining for final reclamation of the site. Most visible of the effects will be the displacement of overburden into long steep spoil banks that will contrast sharply with the color and topography of the surrounding area. Mining will also result in the short term introduction into a relatively undistrubed area of roads, power lines, increased road and rail traffic, and the noise of blasting and heavy machinery at work.

The impoundment of tributaries draining the mine site, the lowering of the water table near the mine pit, stripping of vegetation and topsoil ahead of mining and displacement of wildlife would be less visible but would be short term effects.

Most impacts resulting from the short-term use of the area will be largely unnoticed by regional inhabitants and the public. The population of the proposed mine area is very sparse and its location remote from principal highways will preclude public notice of the activity except for increased road and railroad use.

The impacts resulting from the short-term use of the environment would be minimized to the greatest extent possible consistent with well designed mining and reclamation practices. Westmoreland Resources is committed to a comprehensive reclamation program as required by stipulations of the lease with the Crow Indian Tribe and Federal and State laws and regulations. The reclamation program previously described and conducted concurrently with extraction of the coal would return the topography to a configuration similar to that prior to mining, but more subdued and blended into the unmined areas adjoining the mine site. Pre-mining drainages would be returned to near their present courses and new tributary drainage systems established. Vegetation compatible with range and wildlife use would be re-established.

The preceding indicates that the short-term use of the proposed mine site for extraction of coal should ultimately result in returning the land to a similar or possibly greater degree of productivity as rangeland. The suitability of reclaimed lands for agriculture is a significant issue. As the topography will be smoother than before mining, the area probably will be more suitable for agriculture, provided productivity is not decreased by soil characteristics. Its suitability for wildlife habitat will be dependent on the successful re-establishment of suitable plant communities. Although the appearance of the land would be permanently changed, its attractiveness should not be greatly diminished. However, other potential long-term land uses such as by heavy industry, for housing development, or transportation routes, may be impaired by the inherent instability of the reclaimed spoils.

Loss of the shallow aquifers in the proposed mine site would be permanent and it is not known if the replaced spoils would function as a source of ground-water supply. Water levels lowered in adjacent areas by mining should recover in time. Little use was made of the shallow aquifers of the site prior to mining, but they would not be available for productive use if desired.

The possible introduction of vegetation more desirable as forage than the native vegetation could, without adequate management, result in over-grazing when cattle are introduced to the reclaimed mine site. This would result in erosion and encroachment of undesirable plant species with untimate degradation of the land and its long-term productivity.

Improved road access to the remote mine site could result in more intensive use of the area. More intensive use could improve the productivity of the area for agricultural and rangeland recreational uses, but without adequate management could be detrimental to long-term productivity.

VII IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

A. Coal

Westmoreland Resources mining operation is planned to reach a maximum production level of 10 million tons per year in 1981. The planned production levels will result in a cumulative production of 190.6 million tons. With losses of about 13 percent, this will exhaust the known reserves of about 219 million tons of coal in the area newly proposed for mining by 1997.

B. Other minerals

An undetermined quantity of local clinker material will be used for road surfacing during the life of the mine. This material and the clinker resources of the mine site not so used will be irretrievably committed.

C. Aquifers

All aquifers in the proposed mine area above the base of the Robinson coal bed will be destroyed during mining and irretrievably lost to future use. The aquifers include the Robinson coal, the interburden, the Rosebud-McKay coal, and in parts of the area the overburden. Adjacent parts of these aquifers will be affected by lowered water levels during the 20-year life of the mine, but the change will not be permanent.

All aquifers above the Robinson coal and the Robinson in the northern part of the area outcrop in the valleys of Sarpy and East Fork Sarpy creeks, and lowered water levels cannot extend beyond these areas. Five existing wells and 10 springs will be destroyed by mining and as many as 24 wells and 12 springs could be affected by lowered water levels.

D. Soils

The soils now existing on the 2151 acres of the proposed mine area will no longer exist after mining. A whole new sequence of soil formation factors will be activated as the land is reclaimed. The climate is the only factor which will not be altered. The reclamation program will be starting with a new parent material, topography, and biological organisms may have to be introduced and it will take a very long time to develop a new soil. The use of topsoil and fertilizers will speed this process but it will take time to develop soil structure, permeability, and aeration which is essential for optimum plant growth.

Also irretrievably lost will be the income produced from the soils of the site estimated as $255,700 during the life of the mine.

E. Vegetation

All existing vegetation on the proposed mine area will be forever lost if mining is approved. The reshaping of the land, topsoil mixing and displacement, and subsoil disturbance and alteration during reclamation may preclude the re-establishment of exact premining native plant communities. However, many native species will be present.

Also foregone will be the income from grazing use and timber growth, estimated as $87,000 and $1,700 respectively, that could have been generated if mining did not take place.

F. Fish and Wildlife

Little is known of the long-term effect that habitat destruction and reclamation will have on the wild species on Tract III. Certainly, critical habitat needs such as timber and brush will be destroyed and may not be successfully replaced.

Grouse dancing grounds are special areas to these birds and used year after year. Only one sharp-tail lek is known on the proposed mine area. Destruction of this dancing ground may result in the permanent loss of as many as 56 grouse.

As many as 10 seeps and springs may be destroyed and as many as 12 may be affected during the life of the mine and result in the loss of habitat to numerous small birds, mammals, reptiles and amphibians. Loss of these areas as watering places would cause shifts in the ranges of other wild species.

G. Archeological and Historical Values

Any archeological sites not discovered during mining operations and historic sites now present on the proposed mine area will be irretrievably lost if the area is mined and will no longer be available for future study or enjoyment.

H. Energy, fuels, and materials

The extraction and transportation of coal and the reclamation of disturbed areas will require the use of electrical power, liquid fuels in the form of diesel fuel and gasoline, explosives, and structural and repair materials for the facilities and equipment used in mining. Experience at the present mine has shown that to mine one million tons of coal requires about 150,000 gallons of diesel fuel and 5,250,000 kwh of electrical energy. Shipment of the coal to present markets and return of the unit train requires an estimated 2,000,000 gallons of diesel fuel. Estimates of the requirements for gasoline and expolsives are not available. The electrical energy, fuels, and explosives used are irretrievably committed and would not be available for other uses. Much of the equipment and material used in mining can be salvaged for future use, but materials such as concrete, road materials, and chemicals would not be recoverable and thus irreversibly lost to future uses.

I. Human resources

During the construction of the proposed new dragline, a maximum of about 50 persons would be employed during the period 1977 through 1978. At maximum production level of the mine, about 210 persons would be employed, about 100 more than in the present operation. In addition, many people not employed in mining but providing short term services would be needed throughout the life of the mining and reclamation operation and their services so expended would not be available for other productive endeavors.

VIII ALTERNATIVE TO THE PROPOSED ACTION

A. Introduction

In the discussion that follows, the alternatives discussed relate specifically to the consideration of the approval of Westmoreland Resources 20-year mining plan for Tract III as submitted. Other relevant alternatives that are related to taking action on the proposed ultimate development of the leases of both Tracts II and III are considered in the EIS being prepared by the Bureau of Indian Affairs (1976). Prior to his consideration of this proposed plan, the Secretary of Interior must, under the orders of the 9th USCA decision in Cady vs Morton, first reconsider his previous approval of the lease itself.

The Department of Interior in considering the Westmoreland Resources proposed plan of mining and reclamation of Crow Indian coal lands on Tract III will have several courses of action. These actions could include approval of the mine plan as submitted, require modification of the plan, reject the plan, or prevent further development on the lease beyond that which has already been approved and is currently being mined. Any alternatives adopted that would place restrictions on Westmoreland Resources over and above the lease terms would most probably result in legal action against the lessors or the Secretary of the Interior, whichever imposed such restrictions.

In considering any alternative to the mining of Crow Indian coal, it should be born in mind that the primary purpose of leasing the coal in the Ceded Area was to provide income and employment opportunities to the Crow Tribe.

B. Approval of the mining plan as submitted

The approval of the mining plan as submitted would carry with it the stipulations set forth in the lease and mining plan and as required by regulations to insure the plan would be adhered to. The impacts associated with this alternative would be as previously described.

C. Approve mining plan after modification

Another alternative would be to require changes in the proposed mining and reclamation plan before the plan would be approved, or as conditions of Secretarial approval. Changes could be made in the configuration of the proposed mine area, the requirements and procedures for reclamation, and mining procedures.

1. Configuration of the proposed mine area

The proposed mine area has been selected to obtain the maximum recovery of a non-renewable fuel resource consistent with reclamation of the land and protection of other resources. Restriction of the size or shape of the area to be mined or relocation of the mine area to another part of the lease; as briefly discussed in Part I, Section K, might reduce the environmental impacts in the presently proposed area but would result in the transfer of most of those impacts elsewhere with differences in impact that would likely be negligible.

2. Stipulations and procedures for reclamation

The reclamation plan as submitted has been designed to comply with existing Federal and State laws and regulations and to the terms of the lease. The plan calls for a high level of reclamation and it is questionable that exceeding the present plans would result in significant environmental benefit. Westmoreland Resources has accepted the fact that technology and regulations regarding reclamation are constantly changing and is prepared to adapt to changes that will improve reclamation success.

Less stringent reclamation plans would result in greater environmental impacts to the land and people. These could include less vegetation on reclaimed land, pollution of ground and surface water, permanent disruption of drainage patterns, serious erosion, aesthetic damage, and generally hazardous conditions, depending on the requirements reduced. At a lower level of reclamation, mining costs would be reduced and resulting reductions in the price of coal could be passed on to consumers.

3. <u>Mining procedures</u>

Different procedures could be required for removing topsoil, overburden, and coal if the procedures as proposed were considered technically inadequate, or to result in unacceptable environmental consequences, or unsafe operating conditions. The methods proposed in the mining plan are those currently in use at the existing Absaloka mine. These procedures are used at other large strip mines in the west and are generally accepted as being the most technically and economically feasible for this type of operation.

Any major changes in the proposed procedures that would require additional rehandling of spoils, different mining equipment, or increased complexity of operation for the reasons of improved reclamation, greater coal recovery, or protection of other resources would probably result in lower production rates and higher production costs without any significant further reduction in environmental impacts as described and evaluated in this statement.

4. <u>Production rates</u>

Under terms of the lease and existing regulations, the Secretary of Interior lacks the authority to regulate production per se from the leasehold. However, on environmental or other adequate grounds within his trust responsibility to the Crow Tribe, some degree of controlled production rates could be effected.

The proposed mining plan calls for a production rate of 10 million tons per year by 1981. Five million tons per year are needed to satisfy existing contracts. Sale of the remaining five million tons is being negotiated.

A lower mining rate would result in less land being disturbed, and thus a lesser environmental impact each year. However, to produce the same total amount of coal from the lease, the duration of impact would be extended. Less production would also mean reduced employment and royalty income to the Crow Tribe and less tax revenue generated annually. Reducing production would conflict with minimum production requirements of the amended Tract III lease with the Crow Tribe.

Increasing the rate of production would result in an accelerated rate of land disturbance, higher employment levels, additional vehicle and rail traffic in the area, and an acceleration in the rate of environmental impacts previously discussed. There would also be larger royalty payments to the Crow Tribe, higher payrolls, and increased tax revenues if production was increased. The total duration of impacts would be shortened accordingly.

D. Reject the mining plan

If the mining plan was found to be totally unacceptable, there would be no environmental impact on the proposed mine area and a new plan would be required or alternate sources of coal found to meet contractural obligations. The plan as submitted is based on established practice at the Sarpy Creek Mine and at other surface coal mines in the west.

If the plan were rejected, Westmoreland Resources would have to prepare a new plan. This would entail considerable time and expense to the company and the Government as a new impact statement would be required for a new mine plan under the decisions of the USCA decision in Cady vs Morton.

If mining on the leasehold were rejected by the Secretary, such action would also deprive the Crow Tribe of projected royalty income and employment opportunities until an acceptable mine plan was developed and activated for mining of the Crow-owned coal under this lease.

E. Prevent further development of the lease

The granting of the lease entails the right to mine the coal under an approved mining and reclamation plan. Any alternative that prevented further development on the lease would require revocation of or changes in the lease. This would probably result in legal action by the lessee to recover damages. Coal production would end as soon as the currently approved mine area was exhausted. There would be no further adverse environmental impacts on the area following that expiration. However, it is likely that the coal production foregone would be supplied by some other surface mines in Montana or Wyoming and the general environmental impacts of such operations would be simply transferred to another area. Depending on many factors, these impacts could be lesser or greater than would occur on the proposed mine area.

This action would in the near future also deprive the Crow Tribe of the royalty income and employment opportunities associated with the proposed mine expansion.

F. Mine coal only on State-owned land

As 314 acres within the proposed mine area underlain by 31,867,000 tons of coal is a part of a State-owned section, mining of the State land only is an alternative to development of the proposed Crow leasing and mining area. Mining on State land would not require approval by the Department of the Interior but would require approvals by the appropriate State agencies. Mining of the State land only would permit Westmoreland Resources to meet its contractural obligations for an undetermined but comparatively short period but would deprive the Crow Tribe of all royalty income and could negate the company committment on employment of Indians.

Environmental impacts of mining the State land would be essentially the same as those previously discussed for the proposed mine area.

IX CONSULTATION AND COORDINATION WITH OTHERS

Guidlines

Pursuant to NEPA, the Council on Environmental Quality (CEQ) issued guidelines to Federal Agencies for preparation of environmental impact statements. (Federal Register, 38(147), August 1, 1973). Provisions for review of proposals and for public comments on environmental impact statements are a part of these guidelines.

In accordance with these guidelines, this environmental impact statement will be submitted for review by the general public and a wide spectrum of governmental agencies, and revised accordingly in response to these reviews. This action is in response to CEQ guidelines which, in part, require that Federal agencies shall:

(1) Provide for circulation of draft environmental statements to other Federal, State, and local agencies and for their availability to the public in accordance with the provisions of these guidelines.

(2) Consider the comments of the agencies and the public; and

(3) Issue final environmental impact statements responsive to the comments received. (CER 138(147) Section 1500.2.b).

Consultation in the Preparation of this EIS

Task Force

The U.S. Geological Survey, Department of Interior, was the lead agency for the preparation of this draft statement. The Geological Survey provided a project leader and the same personnel that had been assembled for the preparation of the Westmoreland lease EIS (U.S. Bureau of Indian Affairs, 1976) also contributed to this statement. Members of the task force included appropriate discipline specialists from several offices of the Geological Survey, the Billings area office of the Bureau of Indian Affairs, the Fish and Wildlife Service, and representatives of the Crow Tribe of Indians.

State Agencies

The Montana Department of State Lands provided early input and coordination into the planning of this statement. The Montana Department of Highways submitted date pertaining to future road improvement and reconstruction plans. The Montana State Air Quality Bureau supplied air quality information and consultation on air quality standards.

Consultants

Representatives of Westmoreland Resources provided consultation on company plans, and extensive use was made of consultants reports of environmental baseline studies prepared for that company.

Review of Statement

This statement will be circulated to other Federal, State and local agencies, and shall be available to the public for comment. Copies for general public inspection and review will be available in appropriate Geological Survey and Bureau of Indian Affairs offices to be announced in the "Notice of Availability" in the Federal Register at the time of release of the Document.

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APPENDIX A

Data on Climate and Air Quality

TABLES

METEOROLOGY AND AIR QUALITY

MONITORING PROGRAM

On February 11, 1975, the meteorology and air quality monitoring program at Sarpy Creek was initiated with the installation of a battery-operated, self-contained mechanical weather station adjacent to and a high-volume air sampler atop the water treatment building on Tract III. In addition to samples of total suspended particulates collected by the high-volume sampler, the mechanical weather station recorded continuous wind direction, wind speed (wind run), and temperature data. Specifications for the mechanical weather station and high-volume air sampler are presented in Tables H-1 and H-2. The mechanical weather station was mounted atop a 30-foot pole on a small rise of ground approximately 100 feet south of the water treatment building; the high-volume air sampler was mounted on the roof of the water treatment building.

On April 14, 1975, the mechanical weather station was removed and on April 18, it was replaced by individual wind direction, wind speed, and temperature sensors wired to a single signal translator and separate recorders located within the water treatment building. Specifications of these sensors, translator, and recorders are included in Table H-3. Also, the high-volume air sampler was removed from the roof of the water treatment building and two new samplers were installed, one approximately 300 feet east-northeast of the secondary crusher and the other near the base of the pole on which the meteorological sensors were mounted.

After the installation of the meteorological sensors was complete, a small impoundment near the pole was filled with relatively hot water as part of the water treatment process. Because water temperatures in the pond were significantly high, it was decided that to ensure the continued collection of quality, data, the sensors should be moved to another location. Therefore, on May 20, 1975, the sensors were removed and mounted atop a 40-foot pole, located about 300 feet south-southeast of the water treatment building, which is their current location. The high-volume sampler, however, was left at its original location near the base of the 30-foot pole.

On April 18 and 19, 1975, additional meteorological monitoring equipment were installed about 100 feet east-northeast of the administration building. Included were an evaporation pan, a hygrothermograph, maximum-minimum thermometers, a recording rain and snow gage, and a recording pyrhelimoter. On May 21, 1975, a microbaragraph was also installed at that site. The specifications of all of these instruments are listed in Table H-2.

On April 24, 1975, dustfall canisters were set out at two locations on Tract III (Plate 2.2.1-1). To expand the dustfall sampling, a third dustfall canister was installed on Tract II on June 23, 1975 (Plate 2.2.1-1).

All equipment was calibrated or checked for accuracy at installation and also after approximately three months of operation. Data collected from the instruments are summarized in Sections 2.2.1.2 and 2.2.1.3.

Data Reduction Techniques

All hourly wind direction, wind speed, temperature, relative humidity, and precipitation data were copied onto computer keypunching forms. After being keypunched the data were then loaded for computer storage and subsequent analysis as described below.

Wind Direction

All wind direction data were abstracted from strip-charts according to sector. Consequently, all data were segregated into the sixteen cardinal directions. The direction assigned to any given hour was the direction deemed most persistent during each preceding hour; a "variable" direction classification was assigned to any hour during which a variation of more than 180 degrees occurred.

Wind Speed

Wind speed (wind run) data from the mechanical weather station that was at the site from February 11, 1975, through April 14, 1975, were abstracted to the nearest 0.1 mile per hour. Qualitative analysis of the TechEcology Met Set 3 data, collected from April 18, 1975, through August 31, 1975, did not allow the abstraction of wind speed data to the nearest 0.1 mile per hour, but rather whole miles per hour. Therefore, although wind speed averages are presented to the nearest 0.1 mile per hour, resolution of the data beyond one whole mile per hour is a factor attributable mainly to the analysis process. The average wind speed for any given hour was determined from data recorded during each preceding hour.

Temperature

Temperature data from the mechanical weather station were abstracted to the nearest whole Fahrenheit degree with the reading at 30 minutes before any given hour being recorded as best representative of each preceding hour; hygrothermograph temperature data were abstracted on the hour to the nearest 0.5°F; and the Met Set 3 data were abstracted at 30 minutes before each recorded hour to the nearest 0.5°C. All Fahrenheit data were then converted to Centrigrade degrees, the result being that all on-site temperature data are presented herein to the nearest 0.5°C.

Relative Humidity

All relative humidity data were abstracted on the hour and analyzed to the nearest whole percent.

Solar Radiation

To obtain solar radiation data from the weekly records a chart constant for each chart was determined. This constant was then multiplied by the area under the trace on the chart with the product representing incoming solar radiation in gram-calories per square centimeter.

Evaporation

Weekly evaporation data were determined from measurements of evaporation from an exposed pan of water using a graduated hook gage.

Precipitation

Precipitation data were abstracted from weekly charts to the nearest 0.1 inch according to hourly events. These data were then summed by computer to provide daily totals.

Total Suspended Particulates

High-volume air sampler filters were initially weighed, prior to exposure in the field, in Dames & Moore's Denver office. After being used in a sampler each filter was returned to Denver for final weighing. The difference between the initial and final weights, the sampling time, and the flow rate were used in the following equation to determine total suspended particulates densities:

$$\text{Density}\left(\frac{\text{gm}}{\text{m}^3}\right) = \frac{\text{weight (gm)}}{\text{Time (hrs.)} \times 60\left(\frac{\text{min.}}{\text{hour}}\right) \times \text{flow rate}\left(\frac{\text{ft}^3}{\text{min.}}\right) \times 0.02832\left(\frac{\text{m}^3}{\text{ft}}\right)}$$

Also, a multiplicative factor of 0.88 was applied to the results of the equation above to allow for changes in air flow characteristics due to increased elevation above sea level. This factor was obtained from the following equation:

$$\text{Flow Rate}_2 = \text{Flow Rate}_1 \times K \times \sqrt{\frac{P_1}{P_2}}$$

Where Flow Rate_1 = Flow rate under standard temperature and pressure conditions

Flow Rate_2 = Flow rate at 3500' elevation, based on standard conditions

P_1 = Pressure under standard conditions

P_2 = Average pressure at 3500' elevation

K = Constant, determined from calibration data

Solution of this equation indicated that Flow Rate_2 = Flow Rate_2 X 1.13, or, when Flow Rate_2 was substituted for the flow rate in the previous equation the result was the same as multiplying the entire equation by 0.88.

Dustfall

Dustfall samples were shipped to Corning Laboratories, Inc., Cedar Falls, Iowa, where they were analyzed according to American Society for Testing Materials (ASTM) Designation D1739-70.

TABLE 1

MEAN NUMBER OF DAYS WITH PRECIPITATION
≥0.10 OR ≥0.50 INCH[a]
COLSTRIP, MONTANA

	J	F	M	A	M	J	J	A	S	O	N	D	Yr
≥0.10 Inch	1	2	2	5	6	6	2	4	2	2	3	2	37
(Years of record)	7	7	7	7	7	7	7	7	7	7	7	7	
≥0.50	0	0	*	1	1	2	1	1	*	*	*	*	6
(Years of record)	10	10	10	10	10	10	10	10	10	9	10	10	

* Less than one-half day

a From U. S. Department of Commerce, 1965

TABLE 2

TOTAL PRECIPITATION (INCHES)
SARPY CREEK AREA

DAY OF MONTH	1975 APR	MAY	JUN	JUL	AUG
1		0.	0.	0.	0.
2		0.	0.	0.	0.
3		0.	.01	0.	0.
4		0.	0.	.05	0.
5		.33	0.	.02	0.
6		1.06	.04	0.	0.
7		.03	.01	.30	0.
8		.05	1.02	0.	0.
9		.03	.04	0.	0.
10		.17	0.	.01	0.
11		0.	0.	0.	0.
12		0.	0.	0.	0.
13		0.	.03	0.	0.
14		0.	0.	0.	.04
15		0.	.01	0.	.28
16	0.	.10	.06	0.	0.
17	0.	0.	.01	.36	.16
18	.15	0.	.20	0.	0.
19	.24	.67	.06	0.	0.
20	.03	.15	.03	0.	0.
21	.03	.06	.57	0.	0.
22	.07	.06	.01	.03	0.
23	.19	0.	.01	0.	0.
24	0.	.18	0.	0.	0.
25	.02	.07	0.	0.	.04
26	.21	0.	.12	0.	0.
27	0.	0.	0.	0.	0.
28	.38	0.	0.	0.	0.
29	.60	0.	0.	.02	0.
30	.20	0.	0.	.01	0.
31	0.	.36	0.	.39	0.
TOTAL	1.92	3.32	2.23	1.19	.52

TABLE 2

TOTAL PRECIPITATION (INCHES)
SARPY CREEK AREA
(1975)

DAY OF MONTH	Month (1975)		
	SEPT	OCT	NOV
1	0.	0.	0.
2	.15	0.	0.
3	0.	0.	0.
4	0.	0.	0.
5	0.	0.	0.
6	0.	0.	0.
7	0.	0.	0.
8	0.	0.	0.
9	0.	0.	0.
10	0.	0.	.11
11	0.	0.	0.
12	0.	.02	0.
13	0.	.03	0.
14	0.	.22	0.
15	0.	0.	0.
16	0.	0.	.06
17	.19	0.	.08
18	0.	0.	.24
19	0.	0.	0.
20	0.	.15	0.
21	0.	.46	0.
22	0.	.18	0.
23	0.	0.	.02
24	0.	0.	.59
25	0.	0.	.11
26	0.	0.	.02
27	0.	0.	.02
28	0.	0.	.30
29	0.	0.	.04
30	0.	0.	.04
31	0.	0.	0.
TOTAL	.34	1.06	1.63

TABLE 3

ESTIMATED RETURN PERIOD FOR SPECIFIED PRECIPITATION EVENTS[a] FOR SARPY CREEK AREA

6-Hour Precipitation (inches)	24-Hour Precipitation (inches)	Return Period (years)
1.0	1.4	2
1.3	2.0	5
1.6	2.4	10
2.0	3.0	25
2.2	3.4	50
2.4	3.8	100

[a]U. S. Department of Commerce, 1973

TABLE 4

MEAN EVAPORATION (INCHES)[a]
TERRY, MONTANA

	J	F	M	A	M	J	J	A	S	O	N	D	Yr
Mean Evaporation	(-)	(-)	(-)	(-)	8.51	9.93	10.91	9.59	5.99	(-)	(-)	(-)	(-)
Years of Record					5	7	9	9	10				

[a] U. S. Department of Commerce, 1965

TABLE 5

EVAPORATION DATA
SARPY CREEK AREA

Week Ending	Weekly Evaporation (Inches)	Cumulative Evaporation (Inches)
5/2/75	0.76	0.76
5/9/75	-0.22	0.54
5/16/75	1.06	1.60
5/23/75	0.02	1.62
5/30/75	1.36	2.98
6/6/75	1.40	4.38
6/13/75	0.11	4.49
6/20/75	0.54	5.03
6/27/75	1.21	6.24
7/4/75	2.42[a]	8.66
7/11/75	1.52[a]	10.18
7/18/75	2.05	12.23
7/25/75	2.09	14.32
8/1/75	1.46[a]	15.78
8/8/75	2.37	18.15
8/15/75	1.80	19.95
8/22/75	1.73	21.68
8/29/75	2.14	23.82

[a] Estimate

TABLE 5

EVAPORATION DATA
SARPY CREEK AREA

Week Ending	Weekly Evaporation (Inches)	Cumulative Evaporation (Inches) (from week ending 5/2/75)
9/5/75	1.62	25.44
9/12/75	2.28	27.72
9/19/75	1.04	28.76
9/26/75	1.01	29.77
10/3/75	1.03	30.80
10/10/75	0.35	31.15
10/17/75	0.04	31.19
10/24/75	-0.45	30.74
10/31/75	0.31	31.05
11/7/75	0.64	31.69

TABLE 6

SKY COVER DATA[a]
BILLINGS, MONTANA

	Percent of Possible Sunshine	Mean Sky Cover Sunrise to Sunset[b]	Sunrise to Sunset: Clear Days	Sunrise to Sunset: Partly Cloudy Days	Sunrise to Sunset: Cloudy Days
J	48	7.1	5	8	18
F	54	7.1	4	8	16
M	61	7.1	4	9	18
A	58	7.1	4	9	17
M	61	6.5	6	11	14
J	64	5.9	7	12	11
J	78	4.0	15	12	4
A	77	4.1	14	12	5
S	67	5.3	10	10	10
O	61	5.7	9	10	12
N	46	6.9	5	9	16
D	46	6.8	6	9	16
Yr.	62	6.1	89	119	157

[a]Based on records from 34 years prior to and including 1973

[b]Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover.

TABLE 7

INCOMING SOLAR RADIATION
SARPY CREEK AREA

Week Ending	Incoming Solar Radiation (gram-calories/cm^2)
4/25/75	2570
5/2/75	3188
5/9/75	3216
5/16/75	4595
5/23/75	3233
5/30/75	4683
6/6/75	4428
6/13/75	4147
6/20/75	3488
6/27/75	5228
7/4/75	4868
7/11/75	4727
7/18/75	5166
7/25/75	4885
8/1/75	4718
8/8/75	3753
8/15/75	3445
8/22/75	3753
8/29/75	3911

TABLE 7

INCOMING SOLAR RADIATION
SARPY CREEK AREA

Week Ending	Incoming Solar Radiation (gram-calories/cm^2)
9/5/75	4033
9/12/75	3691
9/19/75	3155
9/26/75	3164
10/3/75	Incomplete data*
10/10/75	Incomplete data*
10/17/75	2698
10/24/75	1380
10/31/75	1230
11/7/75	1582
11/14/75	1485
11/21/75	923
11/28/75	817

*Instrument clock being winterized

TABLE 8

MEAN NUMBER OF DAYS WITH HEAVY FOG[a]

	J	F	M	A	M	J	J	A	S	O	N	D	Yr
Billings[b]	1	2	2	3	1	1	*	*	1	2	2	2	18
Miles City[c]	1	2	1	1	1	*	*	*	1	1	1	2	10

* Less than one-half day

[a] From U. S. Department of Commerce, 1974A and 1974B
[b] Based on records from 26 years prior to and including 1973
[c] Based on records from 21 years prior to and including 1973

TABLE 9

MEAN NUMBER OF DAYS WITH TEMPERATURE
$\geq 90^oF$ OR $\leq 32^oF$[a]
COLSTRIP, MONTANA

	J	F	M	A	M	J	J	A	S	O	N	D	Yr
$\geq 90^oF$	0	0	0	0	1	3	17	14	4	*	0	0	39
Years of Record	10	10	10	10	10	10	10	10	10	10	10	10	10
$\leq 32^oF$	30	27	28	20	5	*	0	0	3	15	24	29	181
Years of Record	10	10	10	9	10	10	10	10	9	7	7	10	

* Less than one-half day

a From U. S. Department of Commerce, 1965

TABLE 10

FREEZE DATA[a]

	Freeze Threshold Temperature	Mean Date Of Last Spring Occurrence	Mean Date Of First Fall Occurrence	Mean Number Of Days Between Dates
Billings	32	5/15	9/24	132
	28	4/29	10/9	163
	24	4/17	10/18	185
	20	4/9	11/1	206
	16	3/29	11/12	228
Miles City	32	5/5	10/3	150
	28	4/24	10/11	170
	24	4/13	10/22	191
	20	4/5	11/2	211
	16	3/30	11/12	226

Based on records from 1921-1950

[a] From Cordell, 1971

TABLE 11

MEAN TEMPERATURES (°C)
(40-foot Pole Near Water Treatment Building)
SARPY CREEK AREA

1975

LOCAL TIME (MST)	FEB	MAR	APR	MAY	JUN	JUL	AUG	PERIOD OF RECORD
100	-8.0	-5.5	-1.0	8.5	13.0	19.5	18.0	6.5
200	-8.0	-6.0	-1.5	8.0	12.5	19.0	17.5	6.0
300	-8.5	-6.5	-2.0	7.5	11.5	18.5	16.5	5.5
400	-8.5	-6.5	-2.0	7.0	11.5	18.0	16.0	5.5
500	-8.5	-6.5	-2.0	7.0	11.5	18.0	15.5	5.0
600	-8.5	-7.0	-2.5	6.5	11.5	17.5	15.0	5.0
700	-8.5	-7.0	-2.0	7.5	12.0	18.5	15.5	5.0
800	-8.0	-6.5	-1.0	9.0	13.0	20.0	17.0	6.5
900	-7.0	-5.0	.5	10.0	14.0	21.0	18.5	8.0
1000	-4.5	-3.5	1.5	11.0	15.0	22.5	20.0	9.5
1100	-3.0	-2.5	2.5	11.5	16.0	24.0	21.5	10.5
1200	-2.5	-1.5	3.5	12.5	16.5	25.5	22.5	11.5
1300	-2.0	-1.0	4.0	13.0	17.0	26.0	23.5	12.0
1400	-2.0	-.5	4.0	14.0	17.5	26.5	24.5	12.5
1500	-2.5	-.5	4.5	14.5	18.5	27.0	24.5	13.0
1600	-3.5	-.5	4.5	14.5	18.5	27.5	25.0	13.0
1700	-4.0	-1.0	4.5	14.5	19.0	27.5	24.5	12.5
1800	-5.0	-1.5	4.0	14.0	19.0	27.0	24.5	12.0
1900	-6.0	-2.5	3.5	13.5	18.0	26.0	23.5	11.0
2000	-7.0	-4.0	2.0	12.0	17.0	25.0	22.0	10.0
2100	-7.5	-4.5	1.0	11.0	16.0	23.0	20.5	9.0
2200	-7.5	-5.0	.5	10.5	15.5	22.0	19.5	8.0
2300	-7.5	-5.5	0.	10.0	14.5	21.0	19.0	7.5
2400	-8.0	-6.0	-.5	9.5	14.0	20.0	19.0	7.0
AVERAGE	-6.0	-4.0	1.0	10.5	15.0	22.5	20.0	9.0

TABLE 11

MEAN TEMPERATURES (^{o}C)
(40-foot Pole Near Water Treatment Building)
SARPY CREEK AREA
(1975)

LOCAL TIME (MST)	Month SEP	OCT	NOV	QUARTERLY AVERAGES
0100	13.0	7.0	-1.5	6.2
0200	12.5	6.5	-1.5	5.8
0300	12.0	6.5	-1.5	5.7
0400	11.5	6.0	-1.5	5.3
0500	11.0	5.5	-1.5	5.0
0600	10.5	5.5	-2.0	4.7
0700	10.0	5.5	-1.5	4.7
0800	11.0	5.5	-.5	5.3
0900	13.0	7.0	0.	6.7
1000	15.0	8.0	1.0	8.0
1100	16.5	9.5	2.0	9.3
1200	17.5	10.5	2.5	10.2
1300	18.5	11.5	3.0	11.0
1400	19.0	11.5	3.0	11.2
1500	20.0	11.5	3.0	11.5
1600	20.0	11.5	2.5	11.3
1700	19.5	11.5	1.5	10.8
1800	19.5	10.5	.5	10.2
1900	18.0	9.5	.5	9.3
2000	16.5	9.0	0.	8.5
2100	15.5	8.5	-.5	7.8
2200	15.0	8.0	-1.0	7.3
2300	14.0	7.5	-1.0	6.8
2400	13.5	7.0	-2.0	6.2
AVERAGE	15.1	8.4	0.2	7.9

TABLE 12

MEAN DAILY AND MONTHLY TEMPERATURE DATA (°C)
(40-foot Pole Near Water Treatment Building)
SARPY CREEK AREA

1975

MONTH	DAILY MAXIMUM	DAILY MINIMUM	DAILY AVERAGE	MONTHLY MAXIMUM	MONTHLY MINIMUM
FEB	-2.0	-12.0	-7.0	8.5	-21.0
MAR	.5	-8.0	-3.5	11.0	-18.0
APR	5.0	-3.5	.5	20.0	-13.5
MAY	15.0	5.5	10.0	28.0	-.5
JUN	19.0	10.0	14.5	24.0	5.0
JUL	28.0	17.5	23.0	36.0	12.0
AUG	25.5	14.0	20.0	33.0	8.5
PERIOD OF RECORD	13.5	4.0	9.0	36.0	-21.0

TABLE 12

MEAN DAILY AND MONTHLY TEMPERATURE DATA (°C)
(40-foot Pole Near Water Treatment Building)
SARPY CREEK AREA
(1975)

MONTH	DAILY MAXIMUM	DAILY MINIMUM	DAILY AVERAGE	MONTHLY MAXIMUM	MONTHLY MINIMUM
Sep	20.5	9.5	15.0	29.0	1.0
Oct	12.5	4.0	8.5	28.0	-4.0
Nov	4.5	-3.5	0.5	24.0	-22.0
Quarterly Averages	12.5	3.0	8.0	29.0	-22.0

TABLE 13

MEAN TEMPERATURES (°C)
(Hygrothermograph Near Administration Building)
SARPY CREEK AREA

1975

LOCAL TIME (MST)	MONTH APR	MAY	JUN	JUL	AUG	PERIOD OF RECORD
100	4.5	5.5	9.5	16.5	14.5	11.0
200	3.5	5.0	9.0	15.5	13.5	10.0
300	3.0	4.5	8.5	15.5	12.5	9.5
400	2.5	4.0	8.0	14.5	12.0	9.0
500	2.5	4.0	8.0	14.5	11.5	9.0
600	3.0	5.5	10.0	16.5	12.0	10.5
700	4.0	8.0	13.0	19.5	15.0	13.0
800	5.0	10.0	14.5	21.5	18.0	15.5
900	7.5	11.5	16.0	24.0	21.0	17.0
1000	8.5	13.0	17.0	25.5	22.5	18.5
1100	9.5	13.5	18.0	27.0	24.0	20.0
1200	10.0	13.0	18.5	27.5	25.0	20.5
1300	11.0	14.0	19.5	28.5	26.0	21.0
1400	11.0	14.0	19.5	29.0	26.0	21.5
1500	11.0	14.0	19.5	29.0	26.5	21.5
1600	11.5	14.0	19.5	29.0	25.5	21.0
1700	11.5	13.5	19.0	28.0	25.0	20.5
1800	10.5	12.5	18.0	26.5	23.5	19.5
1900	9.0	11.0	16.5	24.5	21.0	17.5
2000	7.0	9.0	14.5	22.0	19.5	15.5
2100	6.0	8.0	13.0	19.0	17.5	13.5
2200	5.0	7.0	12.0	17.5	16.0	12.5
2300	4.5	6.5	11.5	16.5	15.5	12.0
2400	4.5	6.0	10.5	16.0	15.0	11.0
AVERAGE	7.0	9.5	14.5	22.0	19.0	15.5

TABLE 13

MEAN TEMPERATURES (°C)
(Hygrothermograph Near Administration Building)
SARPY CREEK AREA
(1975)

LOCAL TIME (MST)	Month SEP	OCT	NOV	QUARTERLY AVERAGES
0100	7.0	2.0	-3.0	2.0
0200	6.5	2.0	-3.5	1.7
0300	5.5	1.5	-3.5	1.2
0400	5.0	1.0	-3.0	1.0
0500	5.0	0.5	-3.5	0.7
0600	5.0	0.5	-3.0	0.8
0700	9.0	1.0	-2.0	2.7
0800	13.5	2.5	0.0	5.3
0900	17.0	5.0	2.0	8.0
1000	18.0	7.0	4.0	9.7
1100	20.0	9.0	5.0	11.3
1200	20.5	10.0	5.5	12.0
1300	21.5	10.5	6.0	12.7
1400	22.0	10.0	5.5	12.5
1500	22.0	10.0	5.0	12.3
1600	21.5	9.5	3.5	11.5
1700	20.0	8.0	1.0	9.7
1800	17.0	6.5	-0.5	7.7
1900	14.0	5.0	-1.5	5.8
2000	12.0	4.0	-1.0	5.0
2100	10.0	3.5	-2.0	3.8
2200	9.0	3.5	-2.5	3.3
2300	8.0	3.5	-3.0	2.8
2400	7.5	3.0	-3.0	2.5
AVERAGE	13.2	5.0	0.1	6.1

TABLE 14

MEAN RELATIVE HUMIDITY (PERCENT)[a]
BILLINGS, MONTANA

	Local Time			
	0500	1100	1700	2300
J	65	61	58	64
F	67	59	53	64
M	68	53	46	62
A	69	51	43	60
M	70	48	42	60
J	73	48	42	61
J	63	39	30	49
A	59	39	29	45
S	68	51	41	57
O	63	49	42	56
N	67	59	55	63
D	65	61	58	64
Yr	67	51	45	59

Based on records from 14 years prior to and including 1973

[a] From U. S. Department of Commerce, 1974A

TABLE 15

MEAN RELATIVE HUMIDITY (PERCENT)
SARPY CREEK AREA

1975

LOCAL TIME (MST)	MONTH APR	MAY	JUN	JUL	AUG	PERIOD OF RECORD
100	75	76	76	73	63	73
200	77	80	78	74	62	75
300	79	81	79	75	67	77
400	80	82	81	79	70	79
500	78	85	78	80	72	79
600	80	83	71	70	72	75
700	75	70	55	56	62	62
800	65	61	48	51	53	54
900	56	53	43	43	40	46
1000	51	45	41	38	36	41
1100	47	41	37	34	35	38
1200	43	40	36	32	32	36
1300	41	46	33	29	29	35
1400	38	42	33	28	28	33
1500	37	41	34	27	28	33
1600	37	43	35	28	30	34
1700	38	45	36	31	33	36
1800	42	47	39	34	37	40
1900	45	52	44	38	43	44
2000	56	59	53	50	48	53
2100	67	66	62	62	55	62
2200	75	72	67	69	61	68
2300	77	75	70	73	61	71
2400	77	74	73	72	61	71
AVERAGE	60	61	54	50	47	54

TABLE 15

MEAN RELATIVE HUMIDITY (PERCENT)
SARPY CREEK AREA
(1975)

LOCAL TIME (MST)	Month SEP	OCT	NOV	QUARTERLY AVERAGES
0100	68	69	79	72
0200	69	74	77	73
0300	72	77	73	74
0400	76	79	69	75
0500	76	75	74	75
0600	78	78	74	77
0700	66	73	76	72
0800	51	71	68	63
0900	40	68	54	54
1000	36	53	47	45
1100	33	48	42	41
1200	30	44	43	39
1300	28	43	43	38
1400	27	45	45	39
1500	27	48	45	40
1600	28	49	46	41
1700	29	53	49	44
1800	35	57	58	50
1900	42	63	64	56
2000	49	71	57	59
2100	58	71	57	62
2200	63	68	66	66
2300	65	72	73	70
2400	65	71	77	71
AVERAGE	50	63	61	58

TABLE 16

PERCENTAGE FREQUENCY OF WIND DIRECTION
SARPY CREEK AREA

DIRECTION IN SECTORS	1975 MONTH FEB	MAR	APR	MAY	JUN	JUL	AUG	PERIOD OF RECORD
NNE	1.0	4.8	2.7	4.8	6.1	3.4	4.4	4.2
NE	2.9	7.7	1.3	2.0	1.3	4.8	3.7	3.4
ENE	3.2	6.1	3.9	4.7	5.3	5.8	6.3	5.1
E	8.7	8.0	5.9	7.1	5.3	5.1	8.7	7.0
ESE	4.8	6.6	6.4	6.3	2.5	4.8	6.8	5.6
SE	8.1	2.3	3.0	5.5	5.9	6.5	7.4	5.1
SSE	17.1	7.2	5.7	6.7	9.2	12.0	6.3	8.2
S	11.6	5.8	6.9	5.0	6.4	10.6	2.4	6.3
SSW	13.2	6.6	8.9	7.5	5.0	15.4	4.8	7.8
SW	10.3	4.1	4.2	6.4	6.1	8.6	4.6	5.8
WSW	6.5	14.5	6.2	9.4	7.7	8.2	5.2	8.6
W	6.8	7.0	14.1	9.0	4.1	1.0	4.1	7.1
WNW	.3	5.0	14.9	4.3	10.2	1.7	4.1	6.5
NW	0.	2.1	6.2	4.3	6.3	1.0	3.5	3.8
NNW	0.	4.8	1.2	7.5	6.7	1.4	4.4	4.4
N	1.3	4.8	2.9	5.5	7.7	1.0	6.3	4.8
VARIABLE	4.2	2.6	5.7	4.0	4.2	8.6	17.2	6.3
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 16

PERCENTAGE FREQUENCY OF WIND DIRECTION
SARPY CREEK AREA
(1975)

DIRECTION IN SECTORS	Month SEP	OCT	NOV	QUARTERLY AVERAGES
NNE	4.3	5.9	1.7	4.0
NE	2.4	1.7	.7	1.6
ENE	2.1	2.8	.3	1.7
E	3.9	1.0	1.8	2.2
ESE	7.1	2.6	2.9	4.2
SE	5.2	2.7	3.5	3.8
SSE	10.3	10.6	15.7	12.2
S	6.3	11.2	13.1	10.2
SSW	5.4	9.7	11.1	8.7
SW	3.4	7.7	7.9	6.3
WSW	2.8	7.1	5.5	5.1
W	6.6	8.0	5.2	6.6
WNW	8.4	8.1	8.7	8.4
NW	8.7	4.9	6.3	6.6
NNW	10.1	5.5	9.3	8.3
N	7.8	7.0	4.9	6.6
Light and Variable	5.2	3.5	1.4	3.4

TABLE 17

MEAN WIND SPEEDS (MPH)
SARPY CREEK AREA

DIRECTION IN SECTORS	FEB	MAR	APR	MAY	JUN	JUL	AUG	PERIOD OF RECORD
	1975 MONTH							
NNE	2.8	8.0	6.8	15.9	9.6	5.6	7.1	9.1
NE	4.1	9.7	5.3	13.2	5.0	5.7	6.3	8.0
ENE	5.1	5.7	8.2	12.9	6.5	6.7	7.1	7.2
E	5.5	5.3	6.7	13.5	11.5	6.1	5.9	7.7
ESE	6.1	5.7	12.4	7.8	6.7	7.3	4.9	7.5
SE	6.0	5.5	10.1	7.0	7.4	5.1	5.6	6.6
SSE	6.8	6.6	9.8	7.2	6.8	5.6	4.6	6.8
S	7.9	9.2	10.7	6.8	5.9	6.6	5.5	7.8
SSW	10.4	10.5	9.6	6.2	7.7	6.1	6.3	8.4
SW	13.6	10.6	10.7	10.0	6.5	5.7	8.6	9.4
WSW	11.0	11.6	9.2	9.6	6.2	5.5	7.8	9.3
W	9.7	9.2	11.8	13.0	6.8	8.0	12.0	10.7
WNW	1.0	6.3	16.8	6.9	8.9	5.2	10.6	11.2
NW	999.0	5.1	18.7	10.0	8.9	3.3	6.0	10.9
NNW	999.0	7.3	13.1	10.1	8.7	4.0	7.5	8.6
N	4.8	6.8	7.5	15.0	7.3	3.3	8.8	8.7
VARIABLE	2.7	3.5	8.3	4.8	4.1	4.2	4.6	4.9
AVERAGE	8.0	8.1	11.4	9.8	7.5	5.7	6.6	8.3

TABLE 17

MEAN WIND SPEEDS (MPH)
SARPY CREEK AREA
(1975)

DIRECTION IN SECTORS	Month SEP	OCT	NOV	QUARTERLY AVERAGES
NNE	8.0	7.7	5.3	7.0
NE	6.0	6.1	4.6	5.6
ENE	4.3	5.1	2.5	4.0
E	6.5	3.9	7.0	5.8
ESE	4.9	4.7	5.8	5.1
SE	4.1	4.9	4.4	4.5
SSE	4.0	5.5	4.5	4.7
S	4.5	6.6	5.5	5.5
SSW	4.6	6.3	5.3	5.4
SW	5.1	6.2	5.0	5.4
WSW	6.1	7.3	5.7	6.4
W	9.3	8.0	7.5	8.3
WNW	7.5	9.5	8.2	8.4
NW	10.3	8.1	8.3	8.9
NNW	8.0	5.0	6.5	6.5
N	5.9	7.0	5.7	6.2
Light and Variable	4.3	2.4	2.1	2.9
AVERAGE	6.1	6.1	5.5	5.9

TABLE 18

MID-AFTERNOON MIXING DEPTHS
AT COLSTRIP[a]

Season	Mixing Depth (feet)		
	Maximum[b]	Mean	Minimum
Winter	6770	3800	0
Spring	6770	6030	3800
Summer	6770	6490	5640
Fall	6770	5620	2210
Mean	(-)	5250	(-)

[a]Environmental Systems, 1973
[b]Maximum height of aircraft

TABLE 19

ESTIMATED AVERAGE MIXING HEIGHTS AND WIND SPEEDS IN MIXING LAYERS IN SOUTHEASTERN MONTANA[a]

	Winter		Spring		Summer		Autumn		Annual	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Mixing Heights (meters)	300	900	400	2000	300	2800	300	1600	325	1825
Wind Speeds (mph)	11	15	13	18	10	15	10	16	11	16

[a] Holzworth, 1972

TABLE 20

MEAN RECURRENCE INTERVALS FOR EXTREME WINDS[a]
SOUTHEASTERN MONTANA

Wind Speed (mph)	Mean Recurrence Interval (years)
60	2
70	10
80	25
90	100

[a] Thom, 1968

TABLE 21

TOTAL RELATIVE FREQUENCY
DISTRIBUTION OF SURFACE WINDS[a]
BY STABILITY CLASS[b]
BILLINGS, MONTANA

Direction	A	B	C	D	E	F
N	0.0	0.1	0.4	4.5	1.5	1.2
NNE	0.0	0.2	0.3	3.9	0.8	0.5
NE	0.0	0.2	0.6	5.6	0.7	0.5
ENE	0.0	0.3	0.8	3.2	0.5	0.5
E	0.0	0.4	0.7	1.4	0.6	0.4
ESE	0.0	0.2	0.4	0.6	0.4	0.2
SE	0.0	0.2	0.3	0.6	0.5	0.2
SSE	0.0	0.3	0.4	0.5	0.3	0.3
S	0.1	0.5	1.0	1.1	0.7	0.7
SSW	0.0	0.4	1.0	2.1	1.1	0.5
SW	0.0	0.3	1.9	10.0	3.2	0.5
WSW	0.0	0.3	1.0	13.9	1.8	0.5
W	0.0	0.1	0.3	4.2	0.7	0.2
WNW	0.0	0.1	0.2	4.4	0.5	0.2
NW	0.0	0.1	0.3	5.2	0.6	0.3
NNW	0.0	0.1	0.3	3.0	0.5	0.4
TOTAL	0.1	3.8	9.9	64.2	14.4	7.1
Total number of observations	50	587	1491	9399	2106	1054

[a] National Weather Service data, 1/67-12/71
[b] Calms have been statistically distributed according to the frequency of low wind speed occurrences

TABLE 22

TOTAL RELATIVE FREQUENCY
DISTRIBUTION OF SURFACE WINDS[a]
BY STABILITY CLASS[b]
MILES CITY, MONTANA

Direction	A	B	C	D	E	F
N	0.0	0.2	0.4	4.7	0.8	0.3
NNE	0.0	0.1	0.3	3.4	0.9	0.4
NE	0.0	0.1	0.4	3.6	1.0	0.5
ENE	0.0	0.1	0.5	2.7	0.7	0.6
E	0.0	0.2	0.5	1.6	0.5	0.6
ESE	0.0	0.2	0.5	1.0	0.3	0.4
SE	0.0	0.5	1.0	2.9	1.1	0.9
SSE	0.0	0.5	1.6	4.4	3.0	1.4
S	0.1	0.6	1.4	3.3	2.7	2.3
SSW	0.0	0.1	0.5	0.8	0.5	0.5
SW	0.0	0.3	0.4	1.0	0.4	0.4
WSW	0.0	0.2	0.6	2.3	0.6	0.4
W	0.0	0.3	0.8	5.1	1.3	0.8
WNW	0.1	0.2	0.6	5.3	1.4	0.6
NW	0.0	0.2	0.6	8.4	1.2	0.8
NNW	0.0	0.1	0.5	6.2	0.6	0.4
TOTAL	0.2	3.9	10.6	56.7	17.0	11.3
Total Number of observations	133	651	1603	8376	2496	2064

[a] National Weather Service data, 1/67-12/71

[b] Calms have been statistically distributed according to the frequency of low wind speed occurrences.

TABLE 23

MEAN ANNUAL WIND SPEED
BY STABILITY CLASS[a]
BILLINGS, AND MILES CITY, MONTANA
(1/67-12/71)

Stability Class	Mean Wind Speed (mph) Billings	Miles City
A	4.8	4.7
B	6.6	6.9
C	8.7	8.7
D	12.0	12.3
E	8.2	8.4
F	5.6	5.9

[a]National Weather Service Data, 1/67-12/71.

TABLE 24

SUMMARY OF AIR QUALITY
BACKGROUND AROUND COLSTRIP SITE[a]

Station	Particulates ($ug/m^3/day$)	Dustfall ($tons/mi^2/month$)	SO_3 ($mg/100cm^2/day$)
Colstrip 4.5 SSE	35.5	9.6	0.05
Forsyth	68.6	18.3	0.09
Miles City	71.5	24.0	0.08
Broadus	39.7	45.2	0.09
Hardin	58.4	9.8	0.10
Lame Deer	(-)	10.7	0.06

[a] Environmental Systems, 1973

TABLE 25

TOTAL SUSPENDED PARTICULATES
SARPY CREEK AREA

Date (1975)	TSP ($\mu g/m^3$) High-Volume Air Sampler Station #1	TSP ($\mu g/m^3$) High-Volume Air Sampler Station #2	TSP ($\mu g/m^3$) High-Volume Air Sampler Station #3
2/17-2/18	(-)	(-)	(-)
2/18-2/19	6	(-)	(-)
2/23-2/24	7	(-)	(-)
3/1-3/2	22	(-)	(-)
3/7-3/8	36	(-)	(-)
3/13-3/14	27	(-)	(-)
3/19-3/20	74	(-)	(-)
3/25-3/26	61	(-)	(-)
3/31-4/1	(-)	(-)	(-)
4/6-4/7	6	(-)	(-)
4/12	(-)	(-)	(-)
4/18	(-)	(-)	(-)
4/24	(-)	18	34
4/30	(-)	3	25
5/6	(-)	17	44
5/12	(-)	39	(-)
5/18	(-)	17	47
5/24	(-)	25	38
5/30	(-)	42	235
6/5	(-)	40	(-)
6/11	(-)	20	131
6/17	(-)	27	86
6/23	(-)	35	207
6/29	(-)	34	82
7/5	(-)	(-)	61
7/11	(-)	76	(-)
7/17	(-)	31	82
7/23	(-)	108	(-)
7/29	(-)	205	1,182
8/4	(-)	46	323
8/10	(-)	92	178
8/16	(-)	40	94
8/22	(-)	(-)	(-)
8/28	(-)	82	302

TABLE 25

TOTAL SUSPENDED PARTICULATES
SARPY CREEK AREA
(1975)

Date	TSP ($\mu g/m^3$) High-Volume Air Sampler Station #2	TSP ($\mu g/m^3$) High-Volume Air Sampler Station #4
9/3/75	73	
9/9/75	(-)	
9/15/75	63	
9/21/75	22	
9/27/75	24	37[a]
10/3/75	26	21
10/9/75	27	16
10/15/75	14	12
10/21/75	19	7
10/27/75	12	11
11/2/75	11	8
11/9/75[b]	16	17
11/14/75	(-)	18
11/20/75	29	7
11/26/75	11	8

[a]First date of data collection at new location of Station #3 on Tract II

[b]Sampling date out of sequence

(-) Missing data

TABLE 26

SETTLEABLE PARTICULATES (DUSTFALL)
SARPY CREEK AREA

Data Collection Period	Settleable Particulates[a] (tons/mile²/month) Sampling Station #1	Sampling Station #2	Sampling Station #3
4/24/75-5/23/75	4.157	3.734	(-)
5/23/75-6/20/75	7.609	8.157	(-)
6/20/75-7/21/75	4.691	20.500[b]	17.884
7/21/75-8/19/75	26.135	40.222	120.699

a Much of the settleable particulates measured were attributable to the presence of algae in the samples

b Estimate

TABLE 26

SETTLEABLE PARTICULATES (DUSTFALL)
SARPY CREEK AREA

Data Collection Period	Settleable Particulates (tons/mile^2/month) Sampling Station #1	Sampling Station #2	Sampling Station #3
8/19/75 - 9/18/75	70.153	90.547	85.527
9/18/75 - 10/17/75	2.949	8.126	16.048

FEDERAL AND STATE AIR QUALITY STANDARDS

The Federal and State of Montana air quality standards are contained in Tables 27 and 28, respectively.

TABLE 27

FEDERAL PRIMARY AND SECONDARY AIR QUALITY STANDARDS[a]

Pollutant	Averaging Time	Federal Primary Standard	Federal Secondary Standard
Nitrogen dioxide[e]	Annual Average	0.05 ppm[b] (100 $\mu g/m^3$)[c]	0.05 ppm (100 $\mu g/m^3$)
Sulfur Dioxide	Annual Average	0.03 ppm (80 $\mu g/m^3$)	(-)
	24 Hour	0.14 ppm (365 $\mu g/m^3$)	(-)
	3 Hour	(-)	0.05 ppm (1300 $\mu g/m^3$)
Suspended Particulate	Annual Geometric Mean	75 $\mu g/m^3$	60 $\mu g/m^3$
	24 Hour	260 $\mu g/m^3$	150 $\mu g/m^3$
Hydrocarbons (corrected for methane)	3 Hour 6-9 a.m.	0.24 ppm[f] (160 $\mu g/m^3$)	0.24 ppm (160 $\mu g/m^3$)
Photochemical Oxidants	1 Hour	0.08 ppm (160 $\mu g/m^3$)	0.08 ppm (160 $\mu g/m^3$)
Carbon Monoxide	8 Hour	9 ppm (10 mg/m^3)[d]	9 ppm (10 mg/m^3)
	1 Hour	35 ppm (40 mg/m^3)	35 ppm (40 mg/m^3)

All standards except annual average are not to be exceeded more than once a year.

[a] From The Bureau of National Affairs, 1975
[b] ppm = parts per million
[c] $\mu g/m^3$ = micrograms per cubic meter
[d] mg/m^3 = milligrams per cubic meter
[e] Nitrogen dioxide is the only one of the nitrogen oxides considered in the ambient standards.
[f] Maximum 3-hour concentration between 6-9 a.m.

TABLE 28

STATE OF MONTANA AMBIENT AIR QUALITY STANDARDS[a]

Pollutants	Standards (Maximum permissible concentrations)
Sulfur dioxide	0.02 ppm, maximum annual average 0.10 ppm, 24-hour average, not to be exceeded over 1 percent of the days in any 3-month period 0.25 ppm not to be exceeded for more than 1 hour in any 4 consecutive days
Reactive sulfur (sulfation)	0.25 milligrams sulfur trioxide per 100 square centimeters per day, maximum annual average 0.50 milligram sulfur trioxide per 100 square centimeters per day, maximum for any 1-month period
Suspended sulfate	4 micrograms per cubic meter of air, maximum allowable annual average 12 micrograms per cubic meter of air, not to be exceeded over 1 percent of the time
Sulfuric acid mist	4 micrograms per cubic meter of air, maximum allowable annual average 12 micrograms per cubic meter of air, not to be exceeded over 1 percent of the time 30 micrograms per cubic meter of air, hourly average, not to be exceeded over 1 percent of the time
Hydrogen sulfide	0.03 ppm, 1/2-hour average, not to be exceeded more than twice in any 5 consecutive days 0.05 ppm, 1/2-hour average, not to be exceeded over twice a year

[a] From The Bureau of National Affairs, 1975

TABLE 28

Pollutants	Standards (Maximum permissible concentrations)
Total suspended	75 micrograms per cubic meter of air, annual geometric mean 200 micrograms per cubic meter of air, not to be exceeded more than 1 percent of days a year
Settle particulate (dustfall)	15 tons per square mile per month, 3-month average in residential areas 30 tons per square mile per month, 3-month average in heavy industrial areas
Lead	5.0 micrograms per cubic meter of air, 30-day average
Beryllium	0.01 micrograms per cubic meter of air, 30-day average
Fluorides, total (as HF) in air	1 part per billion parts of air, 24-hour average
Fluorides (as F) in forage for animal consumption - dry weight basis	35 parts per million
Fluorides (gaseous)	0.3 micrograms per square centimeter per 28 days

APPENDIX B

Data on Sound

DATA ACQUISITION AND ANALYSIS

This section describes the instrumentation, data acquisition and analysis of the ambient sound survey conducted at the proposed mine site.

The data acquisition system consisted of a General Radio omnidirectional one-inch electret condenser microphone with windscreen, a General Radio Type 1933 Sound Level Meter and Octave Band Analyzer, and a Nagra 4.2L single track magnetic tape recorder. The General Radio Type 1933 Sound Level Meter and Octave Band Analyzer were used as a linear amplifier and step attenuator. Ambient sound was recorded on Scotch 177 magnetic tape.

The above system was calibrated before each recording by means of a reference signal at 1000 Hertz of 114 dB generated by a General Radio Type 1562A Sound Level Calibrator.

The microphone was mounted on a tripod four feet above the ground surface and at least ten feet from any sizable sound reflecting surfaces in order to avoid major interference with sound propagation.

Most recordings of the background ambient sound were 15 minutes in length. However, if a large number of intrusions, such as aircraft over-flights or wind induced system overloads, occurred, the measurement period was extended.

Meteorological parameters such as wet bulb and dry bulb temperature, barometric pressure, and wind speed and direction were noted during each recording period. If high relative humidity (over 90%) or excessive wind speed (over 12 miles per hour) occurred during the measurement period, the recording session was terminated. The tape recorded data were returned to the acoustic laboratory at Dames & Moore for analysis, using a General Radio Real-Time Analyzer and a Digital Equipment Corporation mini-computer shown schematically in Figure G-55.

During the recording sessions, any unusual intrusions, such as wind pop over the microphone or clipping due to overloads, were noted by the engineer monitoring the signal input to the tape. Such intrusions are not characteristic of the acoustic environment, and are deleted during the analysis phase. Each sample tape is used to obtain a cumulative distribution of A-weighted sound levels.

Sound level recordings were made at the near field of various mining equipment. Sound level recordings of coal car passbys were also obtained. From these recordings, one-third octave band sound pressure level spectra and A-weighted sound levels of the major noise sources during the operation of the coal mine were obtained.

TABLE 1 Sheet 1 of 4

SUMMARY OF AMBIENT SOUND LEVELS

Weekdays

Location		Daytime (0700-1800)		Evening (1800-2200)		Nighttime (2200-0700)		
2		7/30/75	1735	7/31/75	1940	7/31/75	0315	
	L_{90}	40		37		43		
	L_{50}	42		39		45		
	L_{10}	44		44		46		
	L_{eq}	43.2		41.6		44.6		
	L_d							42.8
	L_n							44.6
	L_{dn}							40.8
3		7/30/75	1120	7/31/75	2040	7/30/75	2345	
	L_{90}	35		31		30		
	L_{50}	37		31		32		
	L_{10}	39		40		35		
	L_{eq}	38.3		37.6		33.6		
	L_d							31.1
	L_n							33.6
	L_{dn}							41.0

TABLE 1

Weekdays

Location		Daytime (0700-1800)	Evening (1800-2200)	Nighttime (2200-0700)	
4		7/30/75 1344	7/31/75 2140	7/31/75 0105	
	L_{90}	29	29	36	
	L_{50}	32	30	39	
	L_{10}	40	32	42	
	L_{eq}	35.0	30.7	40.1	
	L_d				34.2
	L_n				40.1
	L_{dn}				46.0
5		7/31/75 1440	7/30/75 1845	7/31/75 0220	
	L_{90}	41	51	41	
	L_{50}	44	52	42	
	L_{10}	50	54	43	
	L_{eq}	50.4	52.5	42.2	
	L_d				51.1
	L_n				42.2
	L_{dn}				51.5

TABLE 1

Weekends

Location		Daytime (0700-1800)		Evening (1800-2200)		Nighttime (2200-0700)	
2		7/26/75	0940	8/2/75	2130	8/2/75	0050
	L_{90}	42		43		25	
	L_{50}	44		45		26	
	L_{10}	46		48		27	
	L_{eq}	44.2		46.1		26.4	
	L_d						44.8
	L_n						26.4
	L_{dn}						43.1
3		8/2/75	1420	8/2/75	2000	8/2/75	0145
	L_{90}	35		35		23	
	L_{50}	39		36		24	
	L_{10}	47		39		26	
	L_{eq}	43.2		37.4		25.2	
	L_d						42.2
	L_n						25.2
	L_{dn}						40.7

TABLE 1 Sheet 4 of 4

Weekends

Location		Daytime (0700-1800)		Evening (1800-2200)		Nighttime (2200-0700)		
4		8/2/75	1540	8/2/75	2300	8/2/75	0305	
	L_{90}	35		33		24		
	L_{50}	39		34		25		
	L_{10}	47		37		26		
	L_{eq}	46.1		36.9		25.1		
	L_d							44.9
	L_n							25.1
	L_{dn}							43.2
5		8/2/75	1730	8/2/75	2103	8/2/75	0020	
	L_{90}	39		41		23		
	L_{50}	43		42		23		
	L_{10}	48		42		25		
	L_{eq}	44.7		41.7		26.7		
	L_d							44.1
	L_n							26.7
	L_{dn}							42.5

TABLE 2

A-WEIGHTED SOUND LEVELS FROM OPERATION MOBILE AND STATIONARY MINE EQUIPMENT

	Equipment	Distance[a]	Sound Level in dBA
1.	Dragline	100 ft	74
2.	Two Front End Loaders	55 ft	71
	And 100-Ton Truck	75	71
3.	100-Ton Truck (Loaded Traveling at about 12 mph	30 ft	80
4.	100-Ton Truck (Unloaded) Traveling at about 20 mph	30 ft	77
5.	Tractor	100 ft	72
6.	Water Wagon Traveling at 10-12 mph	30 ft	75
7.	Coal Drill Rig	30 ft	90
8.	Scraper Traveling at about 15 mph	20 ft	81
9.	Overburden Drill Rig	40 ft	65
10.	Primary Coal Crusher	50 ft	57
11.	Secondary Coal Crusher	50 ft	73
12.	Conveyor Belt	50 ft	63
13.	Loading of Coal Cars	50 ft	78

[a]Distance in feet from sound source that measurement was obtained.

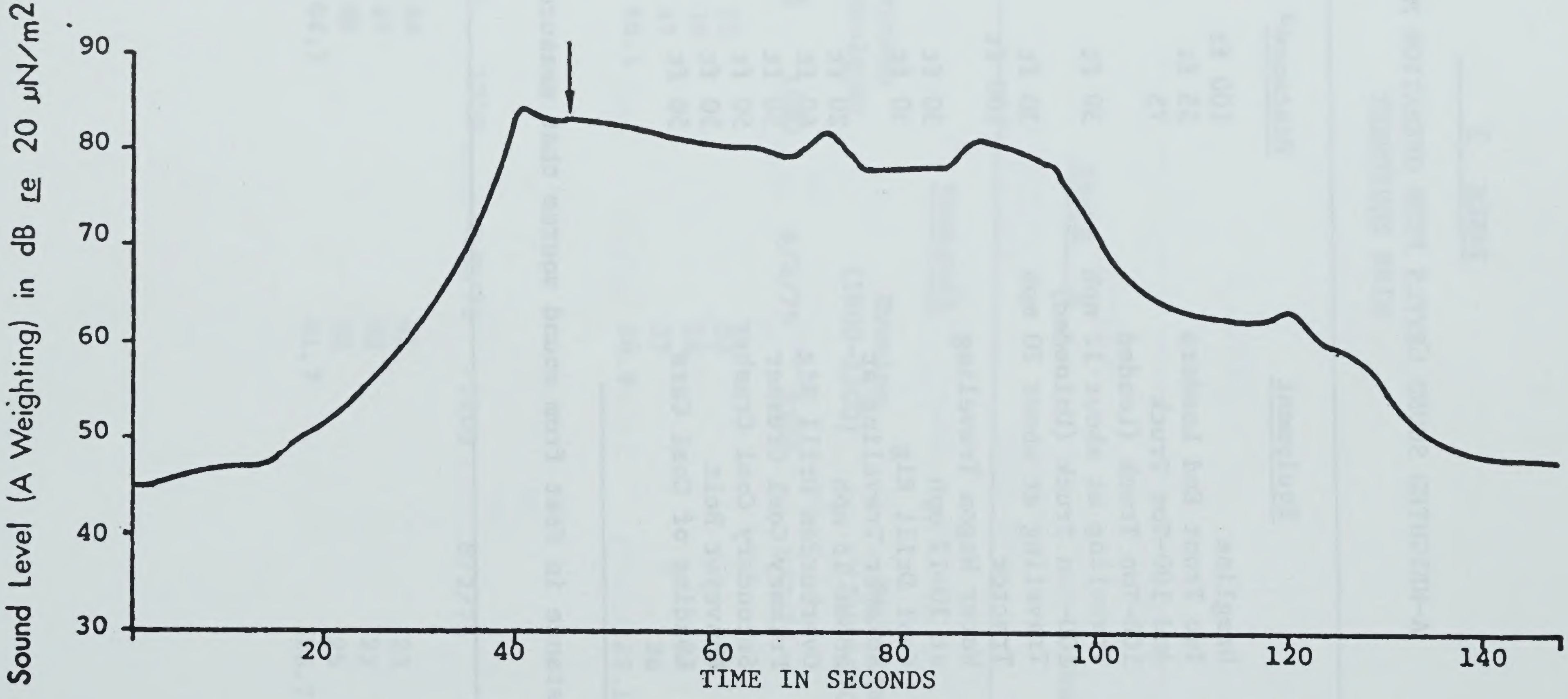

FIGURE 1

A-WEIGHTED SOUND LEVEL TIME HISTORY OF TRAIN (EMPTY) PASSBY AS MEASURED AT 130 FEET FROM TRAIN

Note: One-third octave band sound pressure level spectrum at the position of the pointer is presented in Appendix G, Figure G-52.

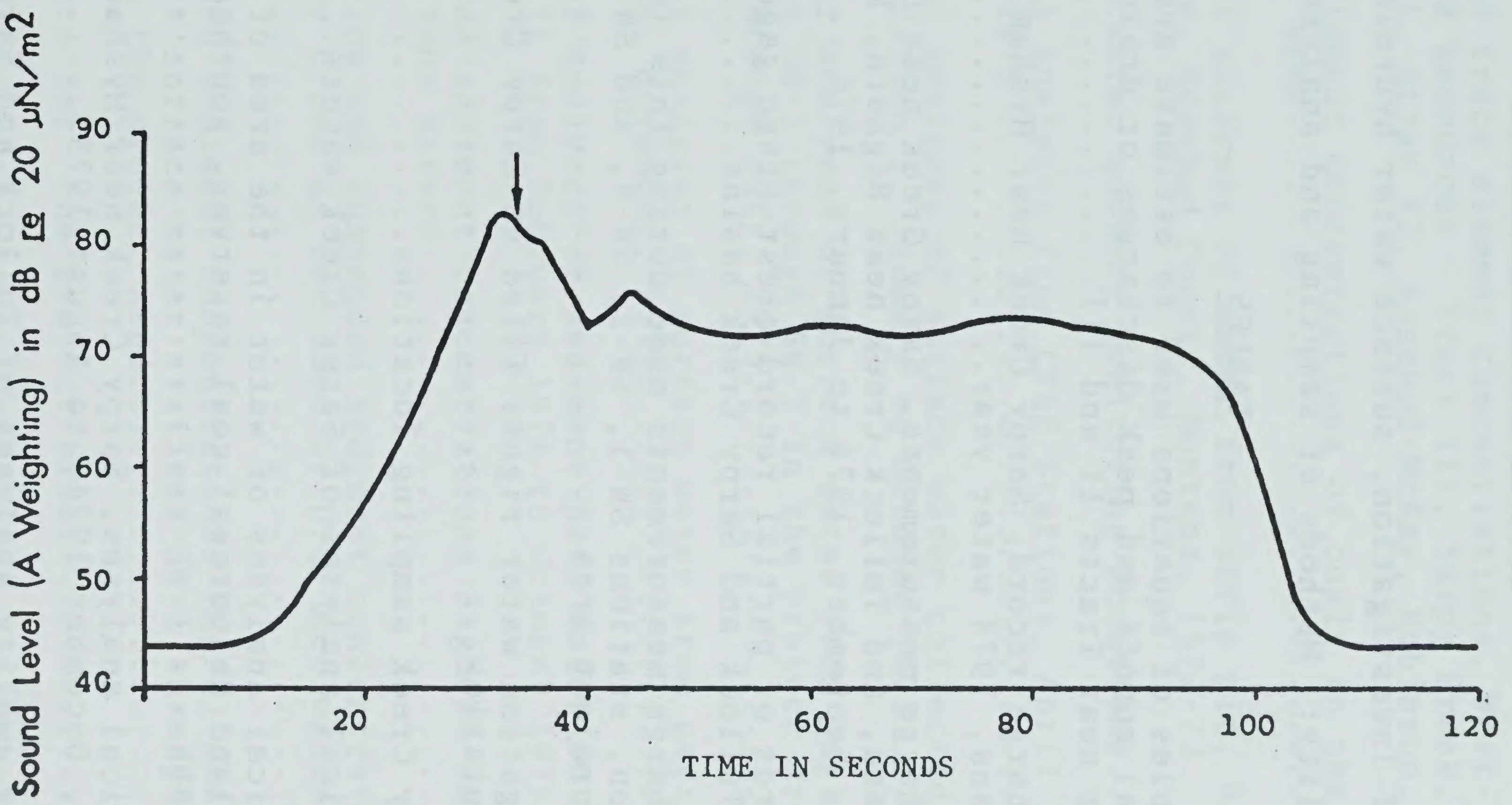

FIGURE 2

A-WEIGHTED SOUND LEVEL TIME HISTORY OF TRAIN PASSBY (LOADED) AS MEASURED AT 130 FEET FROM TRAIN

Note: One-third octave band sound pressure level spectrum at the position of the pointer is presented in Appendix G, Figure G-53.

APPENDIX C

Data on Water Resources

TABLES

Appendix C

METHOD OF INVESTIGATION

Surface-water hydrology.

Numerous published and unpublished reports and studies were reviewed and data therefrom analyzed prior to and during preparation of the surface-water hydrology portion of this environmental statement. The published reports consisted of: 1) Previously prepared environmental statements for coal development in the immediate area of the Crow Ceded Area, 2) The Environmental Baseline Studies for Crow Indian Coal Leases prepared by Westmoreland Resources, and 3) Reports of the U.S. Geological Survey and private consulting firms. Sources of existing unpublished data were the U.S. Geological Survey, Water Resources Division, Billings, Montana, for the 1974, 1975 streamflow data on Tullock and Sarpy Creeks and the U.S. Geological Survey, Water Resources Division, for unpublished studies which describe techniques of estimating streamflow and peak discharges in streams of Montana and the Upper Missouri River basin.

There exists several varied techniques with which flow characteristics in ungaged watersheds can be estimated. These techniques were used to estimate mean runoff and peak discharges within the project area due to the fact that no long-term surface-water data are available in the immediate area. These techniques are discussed in the various referenced material, hence will not be described in detail in this statement. In that several techniques for estimating mean annual flows were available, none were allowed to stand by themselves. Hence, the various techniques were used to compute estimated values; extreme values were disregarded and the remainder averaged. The result of the computations should yield a reasonable estimate of actual conditions. The same approach was used for determining peak discharges from drainage areas located within the project area.

The technique most widely used in recent years has been to relate certain flow characteristics to specific basin and meteorologic parameters and hence describe the characteristics through use of derived equations. Particular basin and meteorological parameters include drainage area size, main channel length and slope, and probable recurrances of certain rainfall intensities. Also, in recent years significant results have been obtained by relating flow characteristics to channel dimensions, in particular the widths and depths of the active channel and depositional bars both of which are identifiable and measurable features of stream channels. These particular characteristics of stream channel geometry are more adequately described in the references Moore (1968, 1974), Hedman, Moore, and Hejl (1974), and Hedman and Kastner (1974). The use of regression techniques and resulting equations to describe various flow characteristics has proved quite successful and has become a useful tool to the environmentalist to estimate flow characteristics in areas where little or no data are available. One of the byproducts of regression analyses are certain statistics which measure the reliability of the resulting regression equations. One such statistic is the standard error of estimate. Normally expressed as a percentage, the standard error indicates the limit above and below the computed value wherein lie two-thirds of the points used to derive the subsequent equation. Listed in Appendix C, Table 1 are some of the equations used to describe certain flow characteristics within the project area, along with the standard error of estimate for each equation and the referenced material from which the equations were obtained.

Appendix C

Water Quality: Methods of Sampling and Analyses

Methods of sampling and analyses of all constituents reported in the Westmoreland Resources monitoring program are given in Westmoreland Resources, 1975 (1), Appendix F, p. F-6 and F-7 and are quoted below:

"Most measurements of temperature, specific conductance, and dissolved oxygen, and some pH measurements were made in the field at the time of sample collection, using portable field instrumentation. Suspended sediment samples were collected by a hand-held, standard, suspended sediment collector (depth-integrating suspended-sediment wading-type hand sampler, U.S. DH-48).

Methods and materials used for sample collection, sample preservation, and analysis were generally those described in Standard Methods for the Examination of Water and Wastewater, Thirteenth Edition, 1971, and also those recommended in U.S. EPA Manual EPA-625-16-74-003, Methods for Chemical Analysis of Water and Wastewater (1971). The following table gives the parameters and method of laboratory analysis of samples collected during 1975. Determination of the suspended sediment constant weight was done by a qualified commercial testing laboratory in accordance with procedures recommended by the U.S. Geological Survey Laboratory at Worland, Wyoming (H. Fabricius and S. Druse, personal communication, 1975).

ANALYTICAL METHODS FOR SAMPLES OF SURFACE AND GROUND WATER

Parameter	Analytical Technique
Bicarbonate Carbonate Hydroxide Alkalinity	"Standard Methods" 13th edition, #102, Potentiometric method
Chloride	"Standard Methods" 13th edition, #112A Argentometric method
Nitrate	"Standard Methods" 13th edition, #133, Phenoldisulfonic method (Cadmium reduction method, tentative)
Nitrite	Sulfanilamide-N-(1-naphthy 1)-ethylenediamine dihydrochloride method
Fluoride	Specific Ion Electrode, Orion
Ortho phosphate	Potassium antimonyl tartate-ammonium molybdate-ascorbic method, EPA
TDS and evaporated solids	Evaporation method
Hardness Non-carbonate Hardness Carbonate Hardness	Calculation
Oil and Grease	"Standard Methods" 13th edition, #137, Frion Extraction method
SAR	Calculation
Acidity	"Standard Methods" 13th edition, #101, Phenolphthalein acidity at boiling point
Calcium Magnesium Sodium	Atomic Absorption Spectrophotometer and Plasma Emission Spectrometer
Potassium	Atomic Absorption Spectrophotometer
Mercury	Cold Vapor
Selenium, arsenic	Gaseous Hydride method
Iron, Manganese, Aluminum, Zinc, Chromium, Nickel, Molybdenum, Copper, Cadmium, Strontium, Lead, Vanadium, Boron	Plasma Emission Spectrometer
COD	"Standard Methods" 13th edition, #220
BOD	"Standard Methods" 13th edition, #219
TSS	"Standard Methods" 13th edition, #224C
Turbidity	Hach Turbidimeter
pH	pH meter
Total Coliform	5 tube or M-coliform agar
Fecal Coliform	mfc agar or EC broth
Sulfate	"Standard Methods" 13th edition, Gravimetric method with ignition of residue, #156A

Table 1.-- Examples of equations used to estimate average annual runoff and peak discharges on drainages in or near Tracts II & III.

a. Average annual runoff, Q_a, in acre-feet

1. $Q_a = 37.9 L^{1.47}$, Se = 53 (1/)

2. $Q_a = 77.0 W_{ac}^{1.587}$, Se = 47.7 (2/)

3. $Q_a = 95.8 W_{ac}^{1.455} D_{ac}^{0.497}$, Se = 43.6 (2/)

4. $Q_a = 196 W_{db}^{1.531}$, Se = 33.5 (2/)

5. $Q_a = 52.3 A^{1.08} P_{24,2}^{-2.918}$, Se = 71.4 (2/)

b. Peak discharge, Q_n, in cubic feet persecond (n = recurrance interval, in years)

1. $Q_2 = 58.5 A^{0.449} S^{-0.466} P_{24,2}^{2.40}$, Se = 100 (1/)

2. $Q_2 = 5.01 W_{ac}^{1.497}$, Se = 56.9 (3/)

3. $Q_2 = 6.94 W_{db}^{1.537}$, Se = 52.0 (3/)

4. $Q_2 = 9.91 A^{0.940} P_{24,2}^{-3.931}$, Se = 88.5 (3/)

5. $Q_{10} = 367 S^{-0.365} L^{0.767}$, Se = 88 (1/)

6. $Q_{10} = 47.0 W_{ac}^{1.212}$, Se = 30.0 (3/)

7. $Q_{10} = 82.7 W_{db}^{1.137}$, Se = 48.8 (3/)

8. $Q_{10} = 57.4 A^{0.718} P_{24,2}^{-1.969}$, Se = 84.2 (3/)

9. $Q_{50} = 198 W_{ac}^{1.027}$, Se = 37.6 (3/)

10. $Q_{50} = 390 W_{db}^{0.892}$, Se = 64.2 (3/)

11. $Q_{50} = 121 A^{0.575}$, Se = 83.6 (3/)

Table 1.-- continued

12. $Q_{100} = 333\ W_{ac}^{0.959}$, Se = 44.2 (3/)

13. $Q_{100} = 307\ W_{ac}^{1.07}\ D_{ac}^{-0.467}$, Se = 37.8 (3/)

14. $Q_{100} = 683\ W_{db}^{0.804}$, Se = 71.6 (3/)

15. $Q_{100} = 224\ A^{0.529}$, Se = 84.0 (3/)

Footnotes - 1/ from Boner and Buswell, 1970, region B; 2/ from Hedman and Kastner, 1974, region A; 3/ from Hedman and Kastner, 1974, region 1.

where L = length of main channel, in miles; W_{ac} = width of active channel, in feet; D_{ac} = depth of active channel, in feet; W_{db} = width between channel bars, in feet; A = drainage area, in square miles; S = main channel slope, in feet per mile; $P_{24,2}$ = rainfall, in inches, having probable recurrance interval of 2 years; Se = average standard error of estimate, in percent.

Table 2

YELLOWSTONE RIVER BASIN

06294940 Sarpy Creek near Hysham, Mt.

LOCATION.--Lat 46°14'12", long 107°08'03", in SE¼SE¼ sec.30, T.6 N., R.37 E., Treasure County, on left bank 100 ft (30 m) upstream from bridge on FAS Route 415, 0.8 mi (1.3 km) upstream from Hysham Canal, and 5.5 mi (8.8 km) southeast of Hysham.

DRAINAGE AREA.--453 mi^2 (1,173 km^2).

PERIOD OF RECORD.--September 1973 to current year.

GAGE.--Water-stage recorder. Altitude of gage is 2,680 ft (817 m), from topographic map.

EXTREMES.--September 1973: No flow during period.

Water year 1974: Maximum discharge, 36 ft^3/s (1.02 m^3/s) June 10, gage height, 5.88 ft (1.792 m); maximum gage height, 7.06 ft (2.152 m) Jan. 18 (backwater from ice); no flow for many days.

REMARKS.--Records fair except those for winter period, which are poor. Diversions for irrigation of about 870 acres (352 m^2) above station.

DISCHARGE, IN CUBIC FEET PER SECOND, SEPTEMBER 1973

TOTAL	0
MEAN	0
MAX	0
MIN	0
RUNOFF IN ACRE-FEET	0

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1		0	.10	.10	4.3	6.4	1.2	3.8	4.6	.40		
2		0	.10	.10	4.5	6.4	1.4	3.3	3.9	.30		
3		0	.10	.10	4.0	7.7	.94	2.7	3.6	.76		
4		0	.10	.10	3.0	9.8	.76	2.7	3.2	.80		
5		0	.10	.10	2.8	8.7	.60	2.7	2.8	.64		
6		0	.10	.10	2.5	9.1	.56	2.5	2.9	.44		
7		0	.10	.10	3.0	9.2	2.6	2.4	3.9	.44		
8		0	.10	.10	3.5	6.3	2.7	2.2	9.1	.34		
9		0	.10	.10	4.0	11	2.7	2.5	11	.26		
10		0	.10	0	4.5	7.7	1.1	2.0	32	.19		
11		0	.10	0	5.0	5.7	1.4	1.7	22	.15		
12		0	.10	0	7.0	5.9	5.2	1.5	15	.09		
13		0	.10	0	17	5.9	6.1	1.8	12	.08		
14		0	.10	.10	16	5.2	6.1	2.5	11	.04		
15		0	.10	1.0	15	5.0	6.0	2.0	9.4	.03		
16		0	.10	10	19	3.4	5.6	2.2	8.0	.03		
17		0	.10	12	17	2.8	3.2	2.8	6.7	.03		
18		0	.10	15	15	3.2	2.5	1.9	6.8	.02		
19		0	.10	25	15	3.5	1.9	1.8	5.3	.02		
20		0	.10	20	13	4.1	1.7	6.4	4.2	.02		
21		0	.10	15	11	4.7	1.6	5.9	3.1	.01		
22		0	.10	20	10	5.3	1.5	6.7	2.9	0		
23		0	.10	18	8.8	6.8	3.0	7.4	2.4	0		
24		.10	.10	15	8.1	6.4	3.8	5.0	2.0	0		
25		.10	.10	13	8.0	5.4	3.5	4.1	1.9	0		
26		.10	.10	10	7.8	4.6	3.6	2.9	1.8	0		
27		.10	.10	8.0	7.7	4.6	4.0	2.7	.94	0		
28		.10	.10	6.5	7.0	2.5	3.9	2.8	.68	0		
29		.10	.10	5.5	------	1.5	5.7	3.0	.58	0		
30		.10	.10	4.5	------	1.4	4.0	5.7	.52	0		
31		------	.10	4.0	------	1.4	------	4.0	------	0		------
TOTAL	0	.70	3.10	203.50	243.5	171.6	88.86	101.6	194.20	5.09	0	0
MEAN	0	.023	.10	6.56	8.70	5.54	2.96	3.28	6.47	.16	0	0
MAX	0	.10	.10	25	19	11	6.1	7.4	32	.80	0	0
MIN	0	0	.10	0	2.5	1.4	.56	1.5	.52	0	0	0
AC-FT	0	1.4	6.1	404	483	340	176	202	385	10	0	0

WTR YR 1974 TOTAL 1,012.15 MEAN 2.77 MAX 32 MIN 0 AC-FT 2,010

PEAK DISCHARGE (BASE, 100 CFS).--No peaks above base.

NOTE.--Stage-discharge relation affected by ice Nov. 24 to Feb. 19.

(From U.S. Geological Survey, 1974)

Table 3.--Discharge Measurements, Sarpy Creek near Hysham, Montana, and Tullock Creek near Bighorn, Montana, September, 1974 to January, 1976.[a]

Sarpy Creek near Hysham, Montana (06294940)

Date	Discharge (cfs)	Date	Discharge (cfs)
Sept. 23, 1974	0.0	Feb. 26	178.0
Oct. 18	0.0	Mar. 3	387.0
Nov. 1	0.0	Apr. 1	15.5
Nov. 6	0.0	June 2	11.4
Dec. 3	0.28	July 9	3.4
Jan. 6, 1975	0.58	Aug. 12	0.25
Jan. 19	193.0	Sept. 9	0.0
Jan. 20	392.0	Sept. 13	0.0
Jan. 22	160.0	Oct. 14	.02
Jan. 24	57.6	Nov. 4	.62
Feb. 3	5.37	Dec. 1	.77
		Jan. 13, 1976	1.41

Tullock Creek near Bighorn, Montana (06294690)

Date	Discharge (cfs)	Date	Discharge (cfs)
Aug. 12, 1974	0.0	Mar. 3	1160.0
Sept. 12	0.0	Mar. 4	403.0
Oct. 18	0.0	Mar. 17	49.4
Oct. 22	0.0	Apr. 23	28.5
Nov. 1	1.86	May 10	69.1
Nov. 8	.11	June 11	9.54
Dec. 3	0.49	July 14	12.6
Jan. 6, 1975	0.82	Aug. 19	0.92
Jan. 10	672.0	Aug. 27	.33
Jan. 19	527.0	Sept. 13	.28
Jan. 23	203.0	Oct. 29	.32
Jan. 28	43.9	Nov. 18	1.40
Feb. 26	30.1	Jan. 15, 1976	3.10

[a] Provisional data subject to change. Data from U.S. Geological Survey, Water Resources Division, Billings, Montana.

Table 4 .-- Records of partial record crest-stage gages in the Tullock and Sarpy Creek basins.

Sarpy Creek tributary near Colstrip, Mt. (06294930)

Location.--Lat 45°54'54", long 107°07'57", in SW¼SW¼ sec. 16, T. 2 N., R.37 E., Treasure County, at culvert on county road, 0.1 mi (0.2 km) north of the Treasure and Big Horn county line, 25 mi (40 km) west of Colstrip.
Drainage area.--4.44 mi^2 (11.5 km^2).
Records available.--October 1973 to current year.
Gage.--Crest-stage gage installed Oct. 30, 1973. Altitude of gage is 3,120 ft (951 m), from topographic map.
Annual maximum data.--

Water year	Date	Gage height (ft)	Discharge (cfs)
1972	--	4.33	194
1973	--	1.27	6
1974	--	--	(c)
1975	April 15, 1975	2.27	20

Tullock Creek tributary near Hardin, Mt. (06294600)

Location.--Lat 45°47'52", long 107°15'40", in NW¼NW¼ sec. 33, T.1 N., R.36 E., Big Horn County, at culvert on State Highway 384, 18 mi (30 km) northeast of Hardin.
Drainage area.--8.63 mi^2 (22.4 km^2).
Records available.--October 1973 to current year.
Gage.--Crest-stage gage installed Oct. 30, 1973. Altitude of gage is 3,180 ft (969 m), from topographic map.
Annual maximum data.--

Water year	Date	Gage height (ft)	Discharge (cfs)
1973	--	2.12	95
1974	June 8, 1974	1.75	Not determined
1975	April 15, 1975	2.34	100

TABLE 5

DISCHARGE MEASUREMENTS MADE DURING THIS INVESTIGATION, STATIONS SW-1, SW-2, SW-4, AND SW-5, IN THE PROJECT AREA

Date	Discharge (cfs)			
	SW-1	SW-2	SW-4	SW-5
March 4, 1975				1.5
5, 1975				1.0
7, 1975	14.4	10.1	2.8	0.6
8, 1975	15.9	12.7	2.2	
9, 1975	10.7	4.0	1.4	0.5
10, 1975	9.4	5.6		0.5
11, 1975			1.7	
12, 1975			1.3	
13, 1975		6.0		0.8
14, 1975	1.6	4.3	1.8	
15, 1975		68.3		
17, 1975	39.6		24.2	0.6
18, 1975	19.4	63.9	26.2	
19, 1975	30.4	78.1	19.7	0.4
20, 1975	20.0	72.4	10.6	0.4
21, 1975				0.4
24, 1975		7.5	1.0	0.4
25, 1975		7.4	1.0	0.4
26, 1975	0.8	6.5	1.0	0.5
27, 1975	1.0	6.3	1.0	
28, 1975	1.0			
30, 1975	1.0	3.8	1.2	0.6
31, 1975	0.7	3.8	1.0	
April 1, 1975	0.7	3.3	1.0	
2, 1975	0.7	3.1	1.5	0.3
3, 1975	0.8	3.7	9.3	0.4
4, 1975	0.8	8.3	5.4	0.3
5, 1975	0.8	3.5	2.2	0.2
7, 1975	0.8	6.7	1.2	0.2
9, 1975	0.8	3.4	1.1	
10, 1975	0.7	8.6	1.0	
11, 1975	0.7	5.7	1.0	0.4
12, 1975	0.7	6.1	1.0	
13, 1975	0.8	7.8	1.1	0.4
14, 1975	1.4	16.2	5.4	
15, 1975	1.1	43.8	3.6	0.4
16, 1975	2.3	40.1	1.5	0.4

TABLE 5

Date	Discharge (cfs) SW-1	SW-2	SW-4	SW-5
April 17, 1975	1.4	31.2	1.2	0.4
18, 1975	1.0	11.4	1.2	0.4
19, 1975	0.8	10.6		
21, 1975	0.7	6.2	1.0	0.1
22, 1975	0.7	5.3	1.0	0.3
25, 1975	0.6	4.8	1.0	0.3
30, 1975	1.2	8.9	1.2	0.9
May 1, 1975	1.3			
2, 1975				0.4
6, 1975	1.1	10.2		
7, 1975	1.7	2.3	2.0	0.5
8, 1975	1.9	21.2	1.1	
9, 1975	1.7	10.6	1.1	0.5
15, 1975	0.7	4.4	1.0	0.5
23, 1975	0.7	4.8	1.0	0.5
29, 1975	0.5	2.8	0.8	0.5
June 4, 1975	0.4	2.0	0.7	0.5
12, 1975	0.4	2.4	0.8	0.5
18, 1975	0.4	1.5	0.9	0.5
26, 1975	0.4	1.5	0.8	0.5
July 11, 1975	0.2	0.7	0.4	0.5
17, 1975	0.1	0.5	0.3	0.5
21, 1975	dry	dry	0.2	0.5
August 8, 1975	dry	dry	0.1	0.4
15, 1975	dry	dry	0.2	0.5
20, 1975	dry	dry	0.3	0.5
October 11, 1975	Standing water, no flow	dry	0.4	0.6
November 13, 1975	Standing water, no flow[a]	0.7[b]	0.6	0.7

[a]Frozen

[b]Frozen, flow beneath ice

(From Westmoreland Resources, 1975.1)

TABLE 6

IRRIGATION WATER RIGHTS FILED ON SARPY CREEK AND TRIBUTARIES
(SOMERS, 1973 SCHEDULE A)

SCHEDULE A
IRRIGATION WATER RIGHTS FILED ON
SARPY CREEK AND TRIBUTARIES

BOOK	PAGE	APPROPRIATOR	LAND DESCRIPTION	WATERCOURSE	DATE OF APPRO.	CFS	REMARKS
BIG HORN COUNTY TWP 1S RG 37E							
Misc 1	282	Oscar E. Secrest	2 Lots 3,4,5,6, $W\frac{1}{2}$ Lot 2, $S\frac{1}{2}NW$ $W\frac{1}{2}SWNE$	W.Fk. Sarpy Cr.	5/1/16	5.00	
BIG HORN COUNTY TWP 1N RG 37E							
Misc 25.	93	J.R. Haynie	12 $NE\frac{1}{4}$ land in	Franklin Coulee	7/19/55	5.00	Also in T. 1N - R. 38E
Misc 36	122	Eva R. Miller, Exect.	16 $N\frac{1}{2}$	Spring Creek	6/26/61	30.00	
Misc .1	160	Hurbert Nichols	2 $N\frac{1}{2}NW$	East Fork Sarpy Cr.	9/19/14	20.00	Also in T. 2N - R. 37E
BIG HORN COUNTY TWP 1N RG 38E							
WR A	164	Michael Barrett	Land in	E. Sarpy Creek	4/12/94	37.50	RBWRI-87
Misc 1	98	Elizabeth Clark	26 $E\frac{1}{2}NW$	Sarpy Creek	12/13/13	10.00	
Misc A-T	526	Mrs. Frank Clark	26 $N\frac{1}{2}$	Sarpy Creek	5/1/11	10.00	RB2-228
Misc A-T	533	Mrs. Frank Clark	26 $NW\frac{1}{4}$	Sarpy Creek	6/15/11	25.00	RB2-247
Misc A-T	455	W. G. Cooley	14 $S\frac{1}{2}NW$, $N\frac{1}{2}SW$, $W\frac{1}{2}SESE$, SW, SESE	East Sarpy Creek	12/20/06	8.00	RB1-539
Misc 25	93	J. R. Haynie	7 $SE\frac{1}{4}$	Franklin Coulee	7/19/55	5.00	Also in T. 1N - R. 37E

TABLE 6

SCHEDULE A
IRRIGATION WATER RIGHTS FILED ON
SARPY CREEK AND TRIBUTARIES

BOOK	PAGE	APPROPRIATOR	LAND DESCRIPTION	WATERCOURSE	DATE OF APPRO.	CFS	REMARKS
BIG HORN COUNTY TWP 1N RG 38E							
Misc 1	596	B. F. Hertzler	22 SE¼ 23	E. Fk. Sarpy Creek	8/9/19	10.00	
Misc A-T	452	Morgan L. Howell		East Sarpy Creek	9/24/06	7.50	RB1-533
BIG HORN COUNTY TWP 2N RG 37E							
Misc 1	160	Hubert Nichols	35 SWSW	E. Fk. Sarpy Creek	9/19/14	20.00	Also in T. 1N - R. 37E
TREASURE COUNTY TWP 3N RG 37E							
1	40	C. R. Dick	3 E½E½	Sarpy Creek	1/24/08	12.50	RBWRI-610
1	192	J. C. Gamble	9	Unnamed Coulee	10/1/27	5.00	
1	195	W. R. Nichols, etal	29	Rainwater Coulee	7/15/49	5.00	
1	196	W. R. Nichols, etal	32	Cox Coulee	7/15/49	5.00	
1	191	Otto J. Peterson	2	South Beaver Creek	6/20/46	5.00	Alsq·in T. 4N - R. 37E
TREASURE COUNTY TWP 4N RG 37E							
1	178	C. H. Lowry	33 SE¼	Sarpy Creek	3/1/40	7.50	
1	18	R. I. Lyon	3 Lot 4-5 4 Lot 8-9	Sarpy Creek	8/6/06	5.00	BHWRI-491

TABLE 6

SCHEDULE A
IRRIGATION WATER RIGHTS FILED ON
SARPY CREEK AND TRIBUTARIES

BOOK	PAGE	APPROPRIATOR	LAND DESCRIPTION	WATERCOURSE	DATE OF APPRO.	CFS	REMARKS
TREASURE COUNTY TWP 4N RG 37E							
1	191	Otto J. Peterson	34	S. Beaver Creek	6/20/46	5.00	Also in T. 3N - R. 37E
1	188	William R.E. Plummer	28 S½SE¼ 33 NE¼	Unnamed Coulee	8/12/46	20.00	
1	189	William R.E. Plummer	27 W½SW¼	Unnamed Coulee	8/12/46	15.00	
1	190	William R. E. Plummer	22 W½SW¼	Unnamed Coulee	8/12/46	15.00	
1	243	J. D. Romine	10-11-12-13	E. Bear Creek	6/10/42	15.00	
Misc12	294	J. D. Romine	10-11-12-13	E. Bear Creek	6/10/42 7/7/51	15.00	
1	17	William M. Selvidge	9 E½E½	Sarpy Creek	7/23/06	5.00	RBWRI-489
TREASURE COUNTY TWP 5N RG 37E							
1	61	Ezra Cleaver	17 SESW	Unnamed Coulee	9/22/09	5.00	RBWR2-87
1	115	Bert T. Coleman	22 W½, S½NE¼, SE¼	Corral Creek	10/30/12	25.00	RBWR2-372
1	76	C. L. Criswell	8 SESW 17 E½NW¼,NESW	Koskie Creek	10/19/10	25.00	RBWR2-186

TABLE 6

SCHEDULE A
IRRIGATION WATER RIGHTS FILED ON
SARPY CREEK AND TRIBUTARIES

BOOK	PAGE	APPROPRIATOR	LAND DESCRIPTION	WATERCOURSE	DATE OF APPRO.	CFS	REMARKS
TREASURE COUNTY TWP 5N RG 37E							
1	93	Geo. Criswell	8 $W\frac{1}{2}SE\frac{1}{4}$, SWNE 17 NWNE	Sarpy Creek	8/7/11	.289	RBWR2-259
1	33	Loyd Criswell, etal	8 $W\frac{1}{2}SE\frac{1}{4}$, SESW, SWNE 17 $E\frac{1}{2}NW\frac{1}{4}$, NESW, NWNE	Sarpy Creek	9/17/07	50.00	RBWR1-577
1	181	Leo Ferguson	20 $S\frac{1}{2}SE\frac{1}{4}$ 21 $S\frac{1}{2}S\frac{1}{2}$	Sarpy Creek	3/1/42	5.00	
1	116	Henry vander Pauwert	29 SE portion	Unnamed Creek	11/11/12	10.00	RBWR2-374
1	114	John vander Pauwert	30	Unnamed Creek	11/1/12	20.00	RBWR2-371
1	111	John vander Pauwert, etal	30	Unnamed Creek	11/1/12	20.00	RBWR2-369
1	152	Roy C. Sweetser	5 NWNW 6 NENE	Sarpy Creek	6/2/19	3.00	Also in T. 6N - R. 37E

TABLE 6

SCHEDULE A
IRRIGATION WATER RIGHTS FILED ON
SARPY CREEK AND TRIBUTARIES

OOK	PAGE	APPROPRIATOR	LAND DESCRIPTION	WATERCOURSE	DATE OF APPRO.	CFS	REMARKS
TREASURE COUNTY TWP 6N RG 37E							
1	28	W. H. Armstrong, etal		Yellowstone River	4/17/07	500.00	RBWR1-556 Also in T. 6N-R. 36-38-39E T. 7N-R. 36-37-38-39E
1	139	Bradbrook-Saunders Lbr. & Hdwe Co.	7 E½SW¼, W½SE¼ 18 E½NW¼, W½NE¼	Sarpy Creek	6/22/18	100.00	RBWR3-3
1	235	Norris E. Cole, etal	23 NENE	Deveny Coulee	1951	5.00	
1	237	Norris E. Cole, etal	25 NWNW	Deveny Coulee	1950	5.00	
1	239	Norris E. Cole, etal	13 NWNW	Coles Coulee	1950	5.00	
1	81	John E. Collins	30 SWSE 31 NWNE	Unnamed Coulee	10/8/10	.173	RBWR2-197
1	44	Chas. L. Crum	7 W½NE¼, E½NW¼	Sarpy Creek	6/9/08	25.00	RBWR2-5
1	69	Daniel Deveny	10 SWSE	Springs & Un.Coulee	4/19/10	.011	RBWR2-137
1	173	Ray Garverich	30 W½SE¼, E½SW¼ 31 W½NE¼	Sarpy Creek	3/5/38	40.00	

TABLE 6

SCHEDULE A
IRRIGATION WATER RIGHTS FILED ON
SARPY CREEK AND TRIBUTARIES

OK	PAGE	APPROPRIATOR	LAND DESCRIPTION	WATERCOURSE	DATE OF APPRO.	CFS	REMARKS
TREASURE COUNTY TWP 6N RG 37E							
1	174	Ray Garverich	30 N½SE¼, NESW, E½NW¼, W½NE¼	Sarpy Creek	3/5/38	40.00	
1	143	Edward Kimball	19 E½, E½SW¼	Sarpy Creek	3/12/19	10.00	RBWR3-12
1	68	C. W. Lyndes	31 E½NE¼	Butte Creek	4/1/10	5.00	RBWR2-124
TREASURE COUNTY TWP 6N RG 37E							
1	152	Roy C. Sweetser	31 E½SE¼ 32 W½SW¼	Sarpy Creek	6/2/19	3.00	Also in T. 5N - R. 37E
1	39	John M. Vail	30 W½NE¼, NWNE	Sarpy Creek	2/15/08	7.50	RBWR1-603
1	80	John M. Vail	30 W½NE¼	Unnamed Creek	10/28/10	.289	RBWR2-196
1	150	John M. Vail	30 SWSE 31 NWSE	Sarpy Creek	5/29/19	2.00	
1	151	John M. Vail	30 W½NE¼, NWSE, NESW	Sarpy Creek	5/29/19	2.00	

Table 7 Sarpy Creek Sampling Locations

Sample Description	Location	Remarks
East Sarpy	Below East Sarpy Bridge	Water hole contained fish (cyprinids and suckers)
Main Sarpy No. 1	300 ft. above confluence of Main and East Sarpy Creek	Water sampled from pool, no surface flow at this point.
Main Sarpy No. 2	Above old ranch head-quarters, NE¼NE¼, section 28, T. 1 N., R. 37 E.	Creek not running; sample taken from pool.

From U.S. Bureau of Indian Affairs, 1974, p. 82

Table 8 Chemical Analyses of Sarpy Creek Waters

Parameter	East Sarpy	Main Sarpy No. 1	Main Sarpy No. 2	Recommended U.S.P.H.S. Drinking Water Standards
pH	8.4 (8.3) 1/ ((8.2))	8.1 (8.3) ((8.0))	7.9 (8.1) ((8.2))	- - -
Color (units)	30 (40) ((40))	30 (50) ((40))	90 (45) ((30))	15
Turbidity	2.2 (17.0) ((3.7))	0.45 (8.5) ((7.6))	7 (3.9) ((3.9))	5
Hardness as $CaCO_3$ (mg/l)	1,125 (1,387) ((1,632))	1,835 (1,187) ((1,854))	1,095 (1,040) ((1,668))	- - -
Specific conductance (mmhos/cm)	2,433 (3,300) ((4,080))	4,493 (2,900) ((4,880))	2,433 (2,400) ((4,350))	- - -
Total solids (mg/l)	- - - (3,236) ((4,318))	4,453 (2,540) ((5,068))	2,048 (2,050) ((4,376))	- - -
Dissolved solids (mg/l)	2,260 (3,032) ((3,755))	4,523 (2,350) ((4,518))	2,025 (1,920) ((3,918))	1,000 2/
Suspended solids (mg/l)	- - - (36) ((5))	20 (4) ((11))	23 (4) ((3))	- - -

1/ Values in parentheses are for samples collected on April 27, 1973; values in double parentheses are for samples collected on July 17, 1973.

2/ Maximum concentration desirable. 500 mg/l recommended.

From U.S. Bureau of Indian Affairs, 1974, p. 83

Table 9 - Chemical analyses of water in the area of Westmoreland Resources' coal reserves, southeastern Montana.

Location	Depth(feet)	Date of Collection	Silica(SiO_2)	Iron(Fe)	Manganese(Mn)	Calcium(Ca)	Magnesium(Mg)	Sodium(Na)	Potassium(K)	Bicarbonate(HCO_3)	Carbonate(CO_3)	Hydroxide(OH)	Alkalinity as $CaCO_3$	Sulfate(SO_4)	Chloride(Cl)	Flouride(F)	Nitrate(NO_3)	Dissolved Solids (calc.)	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate	Sodium Adsorption Ratio	Specific Conductance (micromhos at 25° C.)	pH(laboratory)	Temperature(° C.)	Collecting Agency	Aquifer[a]
2N. 36E. 14ABBB	Spring	7-09-73	5.8	.00	.00	7.9	54	57	3.1	64	144	0	532	60	8.8	.3	.0	404.9	247	0	1.6	568	10.22	31.5	MBMG	
2N. 36E. 23AADB		7-09-73	8.8	.00	.00	7.9	10.8	143	2.5	299	34	0	375	63	2.6	.5	.2	571.6	65	0	7.8	689	8.80	11.0	MBMG	
2N. 36E. 36DDAC	Spring	7-10-73	3.9	.00	.01	25	396	245	14.5	391	58	0	513	1670	17.0	.0	2.0	2825.1	513	1220	2.6	3160	8.74		MBMG	
2N. 37E. 20ABDC	90	6-26-73	7.6	.00	.00	5.4	3.8	704	3.1	805	34	0	773	782	13.8	1.3	.3	2361.4	32	0	54.5	2640	8.73	11	MBMG	SubRb
2N. 37E. 27DCBA	100	10-5-73	12.4	.00	.00	59	44	500	5.6	358	19	0	358	1022	10.6	.3	5.8	2036.9	329	0	12.0	2710	8.57	11	MBMG	SubRb
2N. 37E. 28BDDD	Stream	7-17-72	12	.30	.08	81	118	152	9.6	414	0	0	340	644	10.9	.3	.0	1442.4	340	354	2.5	1660	7.93	21.9	MBMG	
2N. 37E. 31CCCB	60	7-05-73	14	.00	.00	40	105	163	5.0	437	0	0	358	525	6.2	.2	.3	1295.6	358	183	3.1	1544	8.17	22.0	MBMG	SubRb
2N. 37E. 32BBBB	100	7-09-73	12.2	.00	.03	87	304	267	10.5	618	0	0	507	1448	17.8	.2	3.3	2768.3	507	985	3.0	1970	8.11	9.5	MBMG	SubRb
2N. 37E. 34DABD	70	6-22-73	10.3	.01	.00	81	121	843	11.5	264	0	0	216	2276	13.9	.3	3.1	3622.8	216	489	13.9	3390	8.12	13.0	MBMG	SubRb
2N. 38E. 16ADAC	Spring	7-09-73	10.5	.00	.00	110	218	128	7.1	520	0	0	426	1004	14.7	.2	.0	2011.8	426	759	1.6	2274	8.02	23.0	MBMG	RbC
2N. 38E. 18ABBB	70	6-26-73	11.8	.00	.01	89	131	97	5.3	417	0	0	342	557	12.0	.2	21.3	1342.2	342	425	1.5	1522	8.17	9.0	MBMG	SubRb
2N. 38E. 19ACDA	Spring	7- -73	14.6	.00	.01	434	403	357	33.0	366	0	0	300	3060	4.6	.3	.1	4671.8	300	2453	3.0	4440	7.77		MBMG	SubRb
2N. 38E. 20BDCA	160	7- -73	1.7	.00	.00	11.[illegible]	57	525	6.5	365	18	0	358	1062	7.7	.1	.8	2054.4	268	0	1.7	2600	8.49	10.0	MBMG	SubRb
2N. 38E. 22BBAB		7-02-73	15.7	.00	.00	25	126	64	4.3	405	0	0	332	385	4.7	.1	3.1	1032.7	332	257	1.2	1232	8.27	10.0	MBMG	SubRb
2N. 38E. 30AABD	Spring	7-09-73	14.9	.00	.00	36	45	11	1.2	295	0	0	242	53	1.9	.2	.7	458.6	242	33	0.3	534	8.12	18.0	MBMG	R-McCl
2N. 38E. 30BCCC	Spring	10-05-73	12.7	.00	.00	34	64	27	2.7	302	14	0	295	80	4.8	.2	14.4	546.8	295	35	0.7	680	8.61	11.0	MBMG	R-McCl
2N. 38E. 32ABDB	114	7-10-73	13.8	.00	.03	127	231	232	8.2	542	0	0	444	1306	8.8	.0	2.3	2468.5	444	831	2.8	2710	7.93	14.0	MBMG	R-McCl
1N. 36E. 01BACA		7-09-73	13.2	.00	.01	32	16.5	105	7.1	401	0	0	329	652	6.5	.0	.6	1383.1	329	443	1.7	1640	8.18	12.5	MBMG	
1N. 36E. 19BB		8-01-72	7	.00	.02	[illegible]	10.9	910	2.9	459	0	0	376	1628	13.8	.4	4.8	3067.7	121	0	35.9	3430	8.30	11.0	MBMG	
1N. 37E. 02BAAA		6-22-73	8.1	.02	.00	99	122	576	11.6	276	0	0	226	1736	12.1	.1	6.0	2846.4	226	528	9.2	3414	8.06	11.0	MBMG	SubRb
1N. 37E. 03C	Stream	7-21-73	0	.00	.01	75	306	386	19.1	581	41	0	613	1662	15.5	.2	10.0	3096.4	613	858	4.4	3390	8.53	20.5	MBMG	

Analyses by Montana Bureau of Mines and Geology water laboratory, Butte
Concentrations in milligrams per liter

[a]/Aquifer: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

From Van Voast and Hedges, 1974, Table 1

Table 9 - (continued)

Location	Depth	Date of Collection	Silica(SiO2)	Iron(Fe)	Manganese(Mn)	Calcium(Ca)	Magnesium(Mg)	Sodium(Na)	Potassium(K)	Bicarbonate(HCO3)	Carbonate(CO3)	Hydroxide(OH)	Alkalinity as CaCO3	Sulfate(SO4)	Chloride(Cl)	Flouride(F)	Nitrate(NO3)	Dissolved Solids (calc.)	Hardness as CaCO3: Carbonate	Hardness as CaCO3: Noncarbonate	Sodium Adsorption Ratio	Specific Conductance (micromhos at 25° C.)	pH(laboratory)	Temperature(° C.)	Collecting Agency	Aquifer[a]
1N. 37E. 32BCDA	Spring	8-02-73	22.6	.00	.00	31	47	24	7.5	329	0	0	270	57	4.1	.9	2.8	526.2	260	4	0.6	598	8.21		MBMG	RbC
1N. 37E. 33AAAB	130	7-02-73	19.4	.00	.20	79	178	219	13.0	536	22	0	512	918	10.0	.2	.6	1995.2	512	429	3.1	2270	8.00	9	MBMG	SubRb
1N. 37E. 34DAAC		9-06-73	10.7	.00	.11	120	146	1043	13.9	343	15	0	331	2780	16.2	.2	17.4	4505.2	331	575	15.1	5130	8.44	10.0	MBMG	SubRb
1N. 37E. 35CBCB		8-11-72	21.4	.00	.01	44	99	55	6.0	278	2	0	236	390	4.3	.3	1.6	902.9	236	290	1.0	1089	8.39	10.0	MBMG	Al
1N. 37E. 36BDCA	Spring	7-29-72	17.0	.00	.00	4.9	78	35	3.8	283	19	0	296	146	4.6	.0	.3	592.0	296	43	0.8	743	8.82	13.0	MBMG	R-McC
1N. 38E. 08ADBD	146	8-27-73	2.4	.00	.00	3.1	1.1	650	4.0	138	15	0	162	1224	12.6	.4	2.3	2052.9	12	0	81.0	2780	8.78	10.0	MBMG	SubRb
1N. 38E. 15BBDA	Spring	8-13-73	1.6	.00	.00	47	65	580	8.9	553	10	0	486	1120	8.8	.2	6.0	2400.6	389	0	12.8	2830	8.30	27	MBMG	SubRb
1N. 38E. 17ADDD	113	8-27-73	4.8	.00	.00	37	32	65	4.8	183	0	0	150	216	2.3	.2	.9	546.1	150	75	1.9	712	7.71	11.0	MBMG	SubRb
1N. 38E. 19BCDC	Spring	8-11-72	9.6	.02	.01	51	166	97	2.3	327	8	0	296	700	9.5	.2	.7	1372.3	296	528	1.5	1580	8.47	9.0	MBMG	R-McCl
1N. 38E. 19CABA	Spring	8-28-73	15.2	.00	.00	69	124	107	4.9	376	0	0	308	563	7.8	.2	5.1	1271.9	308	381	1.8	1460	8.16	11.0	MBMG	R-McCl
1N. 38E. 19CBBC	Spring	7-31-72	16.0	.02	.00	195	142	61	10.6	471	0	0	386	783	10.3	.3	1.1	1689.9	386	686	0.8	1790	7.96	15.0	MBMG	R-McCl
1N. 38E. 19CCAC	Spring	8-11-72	20.1	.05	.02	225	159	48	16.3	339	0	0	278	1002	8.0	.5	2.2	1820.4	278	942	0.6	1950	8.28	22.0	MBMG	R-McCl
1N. 38E. 19CDDB	115	7-31-72	2.0	.02	.02	14.0	30	242	2.6	360	5	0	311	360	4.2	.3	.0	1020.0	162	0	8.3	1210	8.44	11.0	MBMG	RbC
1N. 38E. 19DCDB	Spring	7-31-72	17.0	.00	.00	13.9	87	22	5.3	409	15	0	385	78	6.0	.2	1.7	659.4	385	25	0.5	734	8.58	20.0	MBMG	R-McC
1N. 38E. 22CADD	Stream	6-29-73	15.4	.02	.01	105	276	395	11.9	579	0	0	475	1736	5.8	.2	:0	3124.4	475	944	4.6	3425	8.12		MBMG	
1N. 38E. 22CCCC1	40	7-18-72	8.0	3.08	.39	31	106	235	4.8	439	0	0	360	767	10.7	.3	.0	1655.3	360	283	4.0	1960	7.94	6.0	MBMG	
1N. 38E. 23BBBD	120	7-03-73	9.9	.00	.00	65	114	288	7.3	187	0	0	154	1070	7.2	.0	1.7	1750.0	154	483	5.0	2170	8.07	12.0	MBMG	SubRb
1N. 38E. 26DBAA	140	7-07-73	9.4	.00	.01	120	49	493	7.9	253	0	0	207	1292	7.1	.0	3.7	2235.4	207	295	9.6	2777	8.25	11.5	MBMG	SubRb
1N. 38E. 28AAAA1		7-18-72	9.0	.09	.02	11.1	2.0	530	2.4	337	0	0	276	880	9.8	.4	.3	1782.1	36	0	38.4	2290	8.05	13.0	MBMG	
1N. 38E. 28AAAA2	200	6-29-73	12.8	.00	.00	11.2	1.7	556	2.4	324	4	0	279	944	9.4	.3	1.0	1867.0	35	0	40.9	2310	8.39	12.5	MBMG	SubRb
1N. 38E. 29ADCC	20	7-31-72	11.0	.00	.08	44	125	22	3.6	548	3	0	459	196	8.5	.2	4.7	965.7	459	173	.4	1050	8.32	12.5	MBMG	R-McO
1N. 38E. 29ADCA1		7-21-72	11	.67	.04	50	88	26	2.7	395	0	0	324	160	32.0	.1	21.5	787.7	324	169	.5	925	8.06	10.0	MBMG	R-McC
1N. 38E. 29ADCA2	100	7-21-72	10.0	.05	.10	57	70	22	2.9	431	0	0	353	120	7.8	.2	3.0	723.8	353	82	.5	816	8.07	13.5	MBMG	R-McC

Analyses by Montana Bureau of Mines and Geology water laboratory, Butte
Concentrations in milligrams per liter

[a] Aquifer: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

Table 9 - (continued)

Location	Depth(feet)	Date of Collection	Silica(SiO_2)	Iron(Fe)	Manganese(Mn)	Calcium(Ca)	Magnesium(Mg)	Sodium(Na)	Potassium(K)	Bicarbonate(HCO_3)	Carbonate(CO_3)	Hydroxide(OH)	Alkalinity as $CaCO_3$	Sulfate(SO_4)	Chloride(Cl)	Flouride(F)	Nitrate(NO_3)	Dissolved Solids (calc.)	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate	Sodium Adsorption Ratio	Specific Conductance (micromhos at 25° C.)	pH(laboratory)	Temperature(° C.)	Collecting Agency	Aquifer[a]
1N. 37E. 06ACAD	50	7-09-73	12.1	.01	.00	4.4	188	227	5.9	383	76	0	567	830	6.5	.0	.3	1733.6	567	234	3.5	2074	9.00		MBMG	SubRb
1N. 37E. 13CCAD	Spring	7-29-72	24.1	.05	.01	188	95	62	14.5	222	0	0	182	650	6.9	1.3	11.0	1225.4	182	556	1.0	1450	7.87	10.5	MBMG	R-McCl
1N. 37E. 14ACCC	130	7-20-72	12.1	.62	.13	162	132	142	6.2	454	0	0	372	820	8.5	.5	1.8	1729.8	372	578	2.0	2000	7.65	10.5	MBMG	SubRb
1N. 37E. 15BAAD		7-10-72	13	7.00	.15	47	45	700	6.7	416	7	0	364	1440	11.7	.3	.7	2694.5	305	0	17.5	3340	8.54	10.0	MBMG	SubRb
1N. 37E. 15BBCA	140	7-20-72	9	.05	.02	6.3	1.6	564	1.8	679	16	0	611	635	6.1	.3	.0	1919.2	22	0	52.3	2320	8.70	14.1	MBMG	SubRb
1N. 37E. 15C	Stream	7-21-73	17.2	.02	.02	78	515	644	29.6	1288	139	0	1522	2422	26	.3	30.0	5015.7	1522	835	5.8	4950	8.70	23	MBMG	
1N. 37E. 16ACCC		7-02-73	11.9	.00	.05	25	42	512	5.2	434	0	0	356	934	7.0	.3	2.0	1973.2	238	0	14.5	2400	8.30	12.0	MBMG	SubRb
1N. 37E. 20BADC	Spring	4-02-73	22.8	.00	.00	55	26	24	7.3	291	0	0	239	56	2.5	.5	2.4	487.0	239	3	.7	516	8.17	1.3	MBMG	R-McCl
1N. 37E. 20ABCA		7-27-73	15.4	.00	.03	101	139	137	5.8	490	0	0	402	720	5.8	.1	.0	1613.6	402	429	2.1	1835	7.71	11.0	MBMG	
1N. 37E. 21ACDD	30	8-13-72	26.8	.02	.00	51	183	207	11.5	419	0	0	343	943	17.0	.2	.5	1859.0	343	551	3.0	2080	8.20	8.0	MBMG	Al
1N. 37E. 22BBAD		7-20-72	11.0	1.80	.15	76	42	415	5.4	443	0	0	363	859	6.1	.4	.0	1860.0	362	0	9.5	2230	8.20	9.5	MBMG	SubRb
1N. 37E. CBCC	Spring	8-13-72	2.1	.00	.00	58	210	338	19	795	0	0	652	1041	18.1	.2	5.4	2486.5	652	372	4.6	2590	8.08	26.0	MBMG	Al
1N. 37E. 23DBCD	80	7-20-72	12	10.80	.16	122	112	120	4.3	406	0	0	333	676	9.5	.3	.0	1473.0	333	437	1.9	1690	7.79	12.0	MBMG	RbC
1N. 37E. 24CACC	8	7-29-72	11	.00	.00	65	66	22	1.8	444	0	0	364	97	7.1	.4	2.6	716.4	364	72	.5	810	8.23	12.0	MBMG	R-McO
1N. 37E. 25BCAC	*	73	5.8	.00	.14	88	64	409	12.8	441	29	0	459	926	11.3	.5	1.9	1988.8	459	23	8.1	2300	8.64		MBMG	RbC
1N. 37E. 26AADA	*	73	6.4	.00	.01	41	107	447	9.9	365	15	0	348	1126	12.4	.4	1.9	2131.2	348	200	8.4	2540	8.44		MBMG	RbC
1N. 37E. 26ABBB	Spring	7-17-72	32	2.70	.10	117	105	73	8.5	457	0	0	375	499	8.1	.8	.0	1303.6	375	353	1.2	1400	8.16	17.0	MBMG	RbC
1N. 37E. 26ABBC	123	7-17-72	12.1		.20	45	61	73	8.2	293	0	0	240	345	5.3	1.0	21.5	904.4	240	126	1.7	941	7.85	10.0	MBMG	SubRb
1N. 37E. 26CAAA	7977	10-11-73	48.5	.65	.13	317	54	52.4	48.6	103	0	0	84	1049	27	4.2	.5	1705.6	84	921	.7	1926	8.05	62	MBMG	Mission Canyon
1N. 37E. 26DAAB	Spring	7-17-72	41	.90	.81	72	72	46	18	381	0	0	312	257	8.6	1.2	7.5	906.1	312	168	.9	1010	7.95	19.0	MBMG	R-McCl
1N. 37E. 26	*		5.4	.05	.01	9.0	16.2	451	4.6	525	14	0	477	595	12.6	1.5	.7	1634.5	90	0	20.8	2050	8.63		MBMG	SubRb
1N. 37E. 27BDCB	30	8-13-72	9.6	.00	.01	52	59	458	6.3	265	0	0	218	1103	8.4	.3	1.4	1964.2	218	160	10.3	2430	8.30	11.0	MBMG	SubRb
1N. 37E. 28D	Stream	7-21-73	14.1	.02	.01	54	125	224	15.2	431	32	0	460	702	13.0	.2	13.0	1623.6	460	199	3.8	1870	8.40	15.2	MBMG	

* Uncased test hole

Analyses by Montana Bureau of Mines and Geology water laboratory, Butte
Concentrations in milligrams per liter

[a] Aquifer: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

Table 9 - (continued)

Location	Depth	Date of Collection	Silica(SiO_2)	Iron(Fe)	Manganese(Mn)	Calcium(Ca)	Magnesium(Mg)	Sodium(Na)	Potassium(K)	Bicarbonate(HCO_3)	Carbonate(CO_3)	Hydroxide(OH)	Alkalinity as $CaCO_3$	Sulfate(SO_4)	Chloride(Cl)	Flouride(F)	Nitrate(NO_3)	Dissolved Solids (calc.)	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate	Sodium Adsorption Ratio	Specific Conductance (micromhos at 25° C.)	pH(laboratory)	Temperature(° C.)	Collecting Agency	Aquifer[a]
1N. 38E. 29ADDA	20	7-31-72	9.0	.00	.01	80	146	81	3.0	486	0	0	398	540	10.3	.3	2.5	1357.5	398	410	1.2	1520	7.95	8.0	MBMG	R-McO
1N. 38E. 29CABD	45	8-11-72	134	.00	.00	49	80	21	1.8	336	0	0	275	152	28	.1	31	832.2	275	179	.4	834	8.16	8.2	MBMG	R-McC
1N. 38E. 29DBBB	Spring	8-11-72	4.8	.03	.01	75	138	48	10.1	668	0	0	548	291	11.1	.2	2.8	1249.0	548	215	.8	1340	8.21	20.5	MBMG	R-McO
1N. 38E. 29DBCC	Spring	8-11-72	6.4	.00	.00	131	222	89	10.4	691	0	0	566	830	11.9	.2	7.0	1998.4	566	687	1.1	2060	8.22	22.0	MBMG	R-McO
1N. 38E. 30BBBA	Spring	8-11-72	42.2	.03	.01	198	150	36	29.8	372	0	0	305	870	15.5	.5	6.8	1720.1	305	808	.5	1880	7.62	24.0	MBMG	
1N. 38E. 30DADD		7-30-72	11	.00	.00	55	130	51	2.6	272	0	0	223	273	69	.0	220	1083.3	223	457	.9	1360	8.21	7.4	MBMG	R-McC
1N. 38E. 30DADD	Spring	7-30-72	11	.00	.02	24	73	49	2.7	444	10	0	397	76	1.7	.1	3.6	695.1	365	0	1.1	742	8.54		MBMG	
1N. 38E. 30DDBD	50	7-30-72	11	.00	.00	25	68	23	2.3	357	0	0	293	86	3.7	.1	4.9	581.3	293	56	.5	657	8.21	9.2	MBMG	R-McC
1N. 38E. 31CCCC	165	1-24-73	15	.04	.13	245	106	39	2.7	644	0	0	528	568	8.0	.0	.4	1629.3	528	518	.5	1680	7.33		MBMG	RbC
1N. 38E. 31CCCD		8-12-72	13.4	.00	.01	45	43	244	3.4	420	5	0	360	445	3.6	.1	2.9	1225.2	290	0	6.2	1470	8.44	12.0	MBMG	
1N. 38E. 32BBAA	15	8-10-72	13.4	.00	.01	37	45	4	16	314	2	0	265	42	1.8	.2	1.8	477.8	265	16	.1	540	8.33	11.8	MBMG	Al
1N. 38E. 32BBBD		8-10-72	5.4	.00	.00	7.2	13.8	174	3.2	381	18	0	373	102	5.2	.1	1.5	711.9	76	0	8.7	909	8.81	12.4	MBMG	
1N. 38E. 32BBCA	225	8-10-72	6.4	.00	.03	51	28	480	4.3	346	6	0	305	951	5.0	.1	.7	1878.8	243	0	13.4	2290	8.45	13.5	MBMG	SubRb
1N. 38E. 36BACD		7-26-73	9.2	.05	.05	105	58	422	8.2	193	0	0	158	1216	6.9	.0	12.0	2031.1	158	344	8.2	2510	8.15		MBMG	
1N. 38E. 36BDAB	173	2-05-74	.0	.06	.00	4.4	43	40.3	3.5	155	17	0	184	117	7.8	.1	.1	388.9	184	8	1.3	501	8.97		MBMG	SubRb
1N. 39E. 31AAAC		7-17-73	12.1	.00	.03	55	149	238	10	334	0	0	274	948	4.2	.1	1.2	1751.9	274	487	3.8	2100	8.10	10.5	MBMG	RO
1S. 37E. 01BAAC	174	9-11-73	8.6	.00	.00	120	75	378	11.3	358	0	0	294	1090	8.2	.1	5.5	2055.7	294	318	6.7	2380	7.99	11.0	MBMG	SubRb
1S. 37E. 01BAAD$_1$	180	9-11-73	8.3	.00	.00	67	61	633	6	337	0	0	276	1476	15.5	.2	1.8	1605.3	276	145	13.4	3287	8.20	11.0	MBMG	SubRb
1S. 37E. 01DACC	Spring	10-09-73	1.3	.00	.00	65	47	19	10.4	193	0	0	158	239	4.8	.2	.0	580.0	158	197	.4	753	7.90	19.0	MBMG	R-McCl
1S. 37E. 03AABD$_2$		7-05-73	27.1	.00	.00	54	136	124	7.9	510	0	0	418	519	5.6	.3	.0	1384.3	418	287	2.0	1510	8.06	9.5	MBMG	
1S. 37E. 06CCBB		7-03-73	2.5	.00	.00	7.8	37	211	5.8	417	17	0	399	262	8.3	.0	2.0	970.4	173	0	7.0	1153	8.78	8.78	MBMG	
1S. 37E. 13BCDB		9-10-73	14.1	.01	.10	42	207	149	8.3	209	0	0	171	1100	5.9	.0	3.8	1739.2	171	805	2.1	2091	8.23	11.0	MBMG	

Analyses by Montana Bureau of Mines and Geology water laboratory, Butte
Concentrations in milligrams per liter

[a] Aquifer: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

Table 9 - (continued)

Location	Depth	Date of Collection	Silica(SiO_2)	Iron(Fe)	Manganese(Mn)	Calcium(Ca)	Magnesium(Mg)	Sodium(Na)	Potassium(K)	Bicarbonate(HCO_3)	Carbonate(CO_3)	Hydroxide(OH)	Alkalinity as $CaCO_3$	Sulfate(SO_4)	Chloride(Cl)	Flouride(F)	Nitrate(NO_3)	Dissolved Solids (calc.)	Carbonate	Noncarbonate	Sodium Adsorption Ratio	Specific Conductance (micromhos at 25° C.)	pH(laboratory	Temperature(° C.)	Collecting Agency	Aquifer[a]
1S.38E.02BBCB	Spring	8-10-72	2.1	.00	.00	50	119	180	4.7	397	0	0	325	652	6.0	.1	4.2	1415.3	325	298	3.2	1620	7.96	21.7	MBMG	
1S.38E.03ACDB	Spring	8-20-72	11	.03	.01	126	319	85	9.2	427	0	0	350	1383	18.2	.1	3.0	2381.9	350	1300	.9	2400	3.09	21.0	MBMG	R-McO
1S.38E.03CACC	180	6-27-73	2	.00	.00	25	51	22	3.2	284	1	0	237	84	2.4	.2	4.1	477.9	237	37	.6	578	8.35	11.5	MBMG	R-McO
1S.38E.03CACC	180	8-10-72	11	.00	.02	53	64	22	2.7	358	0	0	293	145	1.9	.1	1.1	659.1	293	105	.5	733	8.00	11.8	MBMG	R-McO
1S.38E.03DBAB	Spring	8-10-72	10	.02	.00	46	117	28	4.1	394	4	0	337	308	5.8	.1	3.0	920.6	337	266	.5	1040	8.32	26.0	MBMG	R-McO
1S.38E.03DBDB[1]	Spring	8-10-72	11	.02	.02	67	172	57	6.3	357	0	0	293	690	9.7	.2	3.7	1373.9	293	595	.8	1530	8.25	30.5	MBMG	R-McO
1S.38E.03DBDB[2]	Spring	8-10-72	18	.03	.22	137	154	31	29	579	0	0	475	510	9.2	.2	79	1547.0	475	510	.4	1620	7.25	26.0	MBMG	R-McO
1S.38E.09ACBB	120	7-18-72	13	2.10	.08	70	97	45	2.4	510	0	0	418	238	4.7	.1	.0	982.4	418	161	.8	1060	8.27	9.2	MBMG	R-McC
1S.38E.09BADD	80	7-18-72	15	1.20	.09	82	96	62	4.3	433	0	0	355	364	7.6	.0	.0	1065.6	355	249	1.1	1230	7.86	10.0	MBMG	R-McC
1S.38E.09BDDA	84	8-01-72	11	.00	.01	104	140	143	7.4	256	0	0	210	901	6.8	.0	2.9	1572.2	210	633	2.2	1780	8.04	10.0	MBMG	R-McC
1S.38E.09CAAA	98	8-01-72	16	.00	.02	90	65	182	4.3	517	0	0	424	441	4.1	.1	1.6	1321.4	424	69	3.6	1370	8.12	11.0	MBMG	SubRb
1S.38E.10CABA	Spring	8-12-72	17.4	.02	.01	78	269	129	6.2	303	0	0	248	1275	8.1	.0	1.3	2087.5	248	1076	1.6	2320	8.13	11.5	MBMG	R-McO
1S.38E.12BBDB	160	9-13-73	12.1	.00	.21	87	321	238	7.9	415	0	0	340	1630	.1	.0	1.1	2712.9	340	1223	2.6	2460	7.69	12.0	MBMG	SubRb
1S.38B.13CBDA		9-13-73	16.6	.02	.02	152	310	154	11.2	112	0	0	92	1872	5.4	.0	4.5	2637.5	92	1583	1.6	2955	7.58	11.0	MBMG	

Analyses by Montana Bureau of Mines and Geology water laboratory, Butte
Concentrations in milligrams per liter

[a] **Aquifer: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.**

06294940 - SARPY CREEK NEAR HYSHAM, MT.

WATER QUALITY DATA, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	TIME	INSTANTANEOUS DISCHARGE (CFS)	TEMPERATURE (DEG C)	DISSOLVED SILICA (SIO2) (MG/L)	DISSOLVED BORON (B) (UG/L)	DISSOLVED IRON (FE) (UG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)
DEC.												
03...	1300	.30	.5	9.5	510	60	110	130	600	14	853	0
JAN.												
06...	1315	.58	.0	12	340	40	95	87	430	8.0	780	0
19...	1500	193	1.0	6.5	160	410	18	8.0	27	11	89	0
FEB.												
03...	1520	5.3	.0	12	240	330	71	60	170	11	342	0
MAR.												
03...	1100	387	.0	7.7	110	250	20	10	14	7.4	95	0
APR.												
01...	1045	15	.0	9.1	200	30	88	95	240	9.9	425	0
MAY												
05...	1030	20	11.0	7.8	350	40	99	110	270	8.5	457	0
JUNE												
02...	0930	11	12.5	7.0	680	70	130	190	440	11	625	0
JULY												
09...	1710	3.4	23.0	1.6	620	150	87	150	460	10	498	30
AUG.												
12...	1150	.25	18.5	.8	430	20	59	92	430	9.7	548	13

Table 10.--Chemical analyses, Sarpy Creek near Hysham, Montana, December 1974 to August 1975. Data from U.S. Geological Survey, WRD, Billings, Montana

06294940 - SARPY CREEK NEAR HYSHAM, MT.

WATER QUALITY DATA, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	DIS-SOLVED SOLIDS (TONS PER AC-FT)	DIS-SOLVED SOLIDS (TONS PER DAY)	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	SODIUM AD-SORP-TION RATIO	ALKA-LINITY AS CACO3 (MG/L)	CARBON DIOXIDE (CO2) (MG/L)	BIO-CHEM-ICAL OXYGEN DEMAND 5 DAY (MG/L)
DEC.												
03...	1300	21	.5	2610	3.55	2.11	810	110	9.2	700	14	3.6
JAN.												
06...	900	14	.4	1930	2.62	3.02	600	0	7.7	640	31	1.2
19...	64	3.1	.1	182	.25	94.8	78	5	1.3	73	2.8	9.2
FEB.												
03...	490	8.6	.2	992	1.35	14.4	420	140	3.6	281	1.7	6.1
MAR.												
03...	40	3.5	.1	150	.20	157	91	13	.6	78	.5	12
APR.												
01...	770	11	.3	1430	1.94	59.8	610	260	4.2	349	8.6	1.2
MAY												
05...	840	12	.3	1570	2.14	85.8	700	330	4.4	375	4.6	2.1
JUNE												
02...	1400	15	.4	2500	3.40	77.0	1100	590	5.8	513	4.0	1.7
JULY												
09...	1300	15	.4	2300	3.13	21.1	830	380	6.9	458	3.6	1.4
AUG.												
12...	1000	16	.4	1890	2.57	1.28	530	55	8.2	471	2.9	1.4

06294940 - SARPY CREEK NEAR HYSHAM, MT.

WATER QUALITY DATA, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	TOTAL ORGANIC NITRO-GEN (N) (MG/L)	AMMONIA NITRO-GEN (N) (MG/L)	TOTAL KJEL-DAHL NITRO-GEN (N) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	TOTAL NITRO-GEN (N) (MG/L)	TOTAL PHOS-PHORUS (P) (MG/L)	AIR TEMPER-ATURE (DEG C)	TUR-BID-ITY (JTU)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	DIS-SOLVED OXYGEN (MG/L)	PER-CENT SATUR-ATION	PH (UNITS)
DEC.												
03...	.49	.03	.52	.04	.56	.05	5.5	3	37[illegible]0	8.0	61	8.0
JAN.												
06...	.40	.02	.42	.01	.43	.02	7.5	3	3710	8.9	67	7.6
19...	2.5	.23	2.7	.24	2.9	.46	9.0	30	288	11.0	85	7.7
FEB.												
03...	1.1	.08	1.2	.13	1.3	.06	-5.0	20	1420	10.4	79	8.5
MAR.												
03...	1.8	.34	2.1	.11	2.2	.35	3.0	100	215	11.0	83	8.5
APR.												
01...	.53	.11	.64	.11	.75	.02	-5.0	30	1750	10.7	80	7.9
MAY												
05...	.94	.06	1.0	.46	1.5	.11	8.0	48	2000	8.6	86	8.2
JUNE												
02...	.67	.01	.68	.00	.68	.07	24.5	40	3000	7.8	81	8.4
JULY												
09...	.46	.06	.52	.02	.54	.03	31.5	7	3150	8.4	108	8.4
AUG.												
12...	.66	.01	.67	.01	.68	.03	19.0	14	2340	8.4	99	8.5

06294940 - SARPY CREEK NEAR HYSHAM, MT.

WATER QUALITY DATA, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	TIME	TOTAL ALUM-INUM (AL) (UG/L)	TOTAL ARSENIC (AS) (UG/L)	TOTAL BERYL-LIUM (BE) (UG/L)	TOTAL CAD-MIUM (CD) (UG/L)	TOTAL CHRO-MIUM (CR) (UG/L)	TOTAL COPPER (CU) (UG/L)	TOTAL IRON (FE) (UG/L)
DEC.								
03...	1300	--	11	<10	<10	0	<10	250
JAN.								
06...	1315	--	0	10	20	0	90	140
19...	1500	--	8	<10	0	20	80	11000
APR.								
01...	1045	--	2	<10	10	1	<10	1900
JUNE								
02...	0930	1500	2	0	20	0	20	1900

06294940 - SARPY CREEK NEAR HYSHAM, MT.

WATER QUALITY DATA, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	TOTAL LEAD (PB) (UG/L)	TOTAL LITHIUM (LI) (UG/L)	TOTAL MAN-GANESE (MN) (UG/L)	TOTAL MERCURY (HG) (UG/L)	TOTAL MOLYB-DENUM (MO) (UG/L)	TOTAL NICKEL (NI) (UG/L)	TOTAL SELE-NIUM (SE) (UG/L)	TOTAL ZINC (ZN) (UG/L)
DEC.								
03...	<100	60	110	<.1	6	<50	0	--
JAN.								
06...	<100	40	20	.1	4	0	0	--
19...	100	10	240	.0	1	<50	0	--
APR.								
01...	<100	20	200	.3	1	<50	1	--
JUNE								
02...	<100	40	80	.0	1	50	0	50

06294940 - SARPY CREEK NEAR HYSHAM, MT.

WATER QUALITY DATA, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	TIME	DIS-SOLVED ALUM-INUM (AL) (UG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	DIS-SOLVED BARIUM (BA) (UG/L)	DIS-SOLVED BERYL-LIUM (BE) (UG/L)	DIS-SOLVED BISMUTH (BI) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	DIS-SOLVED CHRO-MIUM (CR) (UG/L)
DEC.								
03...	1300	0	2	60	<10	<16	1	<10

06294940 - SARPY CREEK NEAR HYSHAM, MT.

WATER QUALITY DATA, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	DIS-SOLVED COBALT (CO) (UG/L)	DIS-SOLVED COPPER (CU) (UG/L)	DIS-SOLVED GALLIUM (GA) (UG/L)	DIS-SOLVED GER-MANIUM (GE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	DIS-SOLVED LITHIUM (LI) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED MERCURY (HG) (UG/L)	DIS-SOLVED MOLYB-DENUM (MO) (UG/L)
DEC.									
03...	<16	3	<8	<16	1	80	130	<.1	<5

06294940 - SARPY CREEK NEAR HYSHAM, MT.

WATER QUALITY DATA, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	DIS-SOLVED NICKEL (NI) (UG/L)	DIS-SOLVED SILVER (AG) (UG/L)	DIS-SOLVED STRON-TIUM (SR) (UG/L)	DIS-SOLVED TIN (SN) (UG/L)	DIS-SOLVED TI-TANIUM (TI) (UG/L)	DIS-SOLVED VANA-DIUM (V) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)	DIS-SOLVED ZIR-CONIUM (ZR) (UG/L)
DEC.								
03...	1	<2	2500	<16	<11	<8.0	10	<35

06294940 - SARPY CREEK NEAR HYSHAM, MT.

WATER QUALITY DATA, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975

DATE	TIME	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED NATURAL URANIUM (U) (UG/L)	DISSOLVED RA-226 (RADON METHOD) (PC/L)	DISSOLVED GROSS ALPHA AS U-NAT. (UG/L)	DISSOLVED GROSS BETA AS SR90 /Y90 (PC/L)	DISSOLVED GROSS BETA AS CS-137 (PC/L)	TOTAL FILTRABLE RESIDUE (MG/L)	SUSPENDED GROSS ALPHA AS U-NAT. (UG/L)	SUSPENDED GROSS BETA AS SR90 /Y90 (PC/L)	SUSPENDED GROSS BETA AS CS-137 (PC/L)	TOTAL NONFILTRABLE RESIDUE (MG/L)
DEC. 03...	1300	.30	9.0	.04	38	20	23	2700	<.4	3.5	3.8	5

TABLE 11

WATER QUALITY ANALYSES OF TULLOCK AND SARPY CREEKS[a]

Sampling Site Designation	Sampling Site Location[a]	Dates Sampled	Flow (cfs)	Temperature (°C)	pH (S.U.)	Specific Conductance umhos/cm @ 25°	Calculated Dissolved Solids (mg/l)	Dissolved Oxygen DO (mg/l)	Biological Oxygen Demand BOD (mg/l)	Fecal Coliform (counts/100 ml)	Calcium Ca (mg/l)	Magnesium Mg (mg/l)	Sodium Na (mg/l)	Potassium K (mg/l)	Total Hardness $CaCO_3$ (mg/l)	Bicarbonate HCO_3 (mg/l)	Carbonate CO_3 (mg/l)	Alkalinity $CaCO_3$ (mg/l)	Sulfate SO_4 (mg/l)	Chloride Cl (mg/l)	Fluoride F (mg/l)	Nitrate NO_3 (mg/l)	Phosphate PO_4 (mg/l)	Iron Fe (mg/l)	Manganese Mn (mg/l)	Zinc Zn (mg/l)	Copper Cu (mg/l)	Cadmium Cd (mg/l)	Lead Pb (mg/l)	Arsenic As (mg/l)	Mercury Hg (mg/l)	Chromium Cr (mg/l)	Sodium Adsorption Ratio SAR	Laboratory Turbidity (JTU)	Total Suspended Solids TSS (mg/l)
Sarpy Creek below Westmoreland	01N 37E 16DA	1/18/74	25.9	0.0	7.01	283	187	11.1	>11.1	500	18.8	9.2	20		85	76	0	62	56	5.0	.05	1.3	0.92	22		0.01	<.01	<.01	<.01	<.01			0.9	82	190
		1/31/74	0.0	0.0	7.40	2584	2245	4.7	2.4	11	142	203	194		1188	640	0	525	1059	6.3		1.25	0.10	0.67	1.1	0.03	<.01	<.01	<.01	<.01		0.01	2.4	4	5.0
		3/19/74	1.0	1.0	8.00	2270	2041	10.5	4.1		120	177	196	12	1028	608	0	498	920	8.0	.27	0.0	<.03	0.60	0.11	<.01	0.02	<.001		<.01			2.7	8	6.0
E of Hysham	06N 37E 18AB	12/27/73	2.8	0.0	8.31	2395	2037	12.8	3.0	18	86	78	400		535	576	0	472	883	14.2	.43		0.01	0.31		0.01	<.01	<.01	<.01	<.01			7.3	5	6.0
	06N 37E 18AB	2/9/74	3.7	0.0	8.20	1793	1390	11.4	2.8	20	74	62	238		440	426	0	349	582	7.2		0.78	0.25	0.60		<.01	<.01	<.01	<.01		<.001		4.9	9	9.5
	06N 37E 18AB	4/17/74	3.2	10.5	8.34	2656	2269	10.4	2.7	29	91	129	385		758	556	0	456	1096	11.8													6.1	10	14.0
	06N 37E 18AB	6/11/74	30.2	16.7	8.12	2205	1849	8.1	6.3		107	68	325		630	329	25	311	962	12.5		0.06	0.06	3.0	0.17	0.02	<.01	<.001		0.002	<.001	0.01	5.6	51	159
Tullock Creek E of Hardin	01N 35E 36DD	1/31/74		0.0		1226	968	8.0	4.9	5	34	39	185		245	382	0	313	323	4.0		1.4	0.30	1.0	.08	0.01	<.01	<.01	<.01	<.01		0.01	5.1	35	
	01N 35E 36DD	3/6/74	24.2	0.0	8.05	1194	943	11.6	4.9	0	32	43	170		256	421	4	351	267	4.1		2.3	0.11	2.4		0.01	0.01		<.01	<.01	<.001	<.01	4.5	44	118
	01N 35E 36DD	6/11/74	25.5	17.2	8.48	1270	1027	8.5	4.4		41	62	184		359	454	51	469	230	4.5		.09	0.06	.78	.04	0.01	0.01	<.001			<.001			14	23.0
Tullock Creek near Bighorn	04N 34E 02AC	1/31/74	28	0.0	7.95	942	716	8.9	3.8	11	33	28	132		197	258	0	212					0.30	1.4	.05	0.01	0.01	<.01	<.01	<.01		<.01	4.1	31	50.0
	04N 34E 02AC	2/16/74	30.1	0.2	7.91	911	1005	10.7	3.4	0	37	37	200		245	412	5	346	312	0.4		1.5	0.14	1.4	.07	0.01	<.01	<.01			<.001		5.6	43	83.0
	04N 34E 02AC	3/17/74	7.8	11.5	8.41	1990	1618	9.8	3.1	34	57	56	338		374	528	16	459	612	10.0	.46	.04	0.03	1.6	.15	0.01	0.01	<.001		0.007			7.6	37	76.0
	04N 34E 02AC	6/11/74	36.8	17.1	8.31	2422	1971	7.7	5.8		77	52	450		405	572	72	589	735	13.5		.26	0.09	1.4	.53	0.02	<.01	<.001		0.001	<.002	0.02	9.7	245	892

[a]From Montana Department of Natural Resources and Conservation, 1974, Tables 10-25, 10-29.

TABLE 12

Tabulation of Some Selected Trace Element Concentrations in Coals taken from the Rosebud, Robinson and McKay Seams. Samples are Physical Composites of Five Core Holes Drilled in the Sarpy Creek Area, Big Horn County, near Hardin, Montana. Core Holes Drilled during period of December, 1970 to June, 1971. Concentrations are PPM Weight analysis by Spark Source Mass Spectrometry.

ELEMENT	Sample 72-10490 Rosebud Seam(1)	Sample 72-10491 McKay Seam(2)	Sample 72-10492 Robinson Seam(3)	Calculated Weighted Average
COBALT (Co)	3.60	0.35	1.20	1.85
CADMIUM (Cd)	1.80	0.53	0.69	1.06
VANADIUM (V)	7.70	5.80	5.80	6.51
NICKEL (Ni)	9.00	0.90	9.00	6.65
FLUORINE (F)	130.00	130.00	380.00	215.00
BERYLLIUM (Be)	0.70	2.00	2.00	1.52
MERCURY (Hg)	0.26	0.43	0.35	0.34
LEAD (Pb)	3.60	7.20	1.44	3.91
ARSENIC (As)	3.00	1.00	0.75	1.66
SELENIUM (Se)	0.08	0.30	0.08	0.14
ZINC (Zn)	22.00	33.00	13.00	22.15

(1) Total Footage 86.0' - Average Seam Thickness 17.2' (37.2%)
(2) Total Footage 67.0' - Average Seam Thickness 13.4' (29.0%)
(3) Total Footage 78.0' - Average Seam Thickness 15.6' (33.8%)

From U.S. Bureau of Indian Affairs, 1974, p. 248

Table 13 — Selected Trace Element Concentrations, Westmoreland Resources - Tract III, Sarpy Creek, Stray #1, Stray #2, Rosebud-McKay, Robinson. Hole No. 403, December, 1970.

	Stray Seam #1	Stray Seam #2	Rosebud-McKay Seam	Robinson Seam	Weighted Average
Cobalt (Co)	12	11	13	8.3	11.32
Cadmium (Cd)	0.43	0.87	2.1	2.1	1.95
Vanadium (V)	48	33	25	11	22.04
Nickel (Ni)	30	30	30	15	25.14
Fluorine (F)	330	340	510	340	436.58
Beryllium (Be)	14	18	1.8	3.7	3.92
Mercury (Hg)	0.03	0.26	0.14	0.07	0.12
Lead (Pb)	6.2	5.7	8.6	2.9	6.47
Arsenic (As)	3.3	20	3.3	0.65	3.38
Selenium (Se)	1.4	1.1	1.1	0.22	0.83
Zinc (Zn)	170	45	45	45	51.13

Table No. 3 — Hole No. 414

	Stray Seam #1	Stray Seam #2	Rosebud-McKay Seam	Robinson Seam	Weighted Average
Cobalt (Co)	11	11	11	5.6	9.39
Cadmium (Cd)	0.66	0.87	0.66	1.7	0.98
Vanadium (V)	22	44	83	11	55.60
Nickel (Ni)	150	15	30	15	31.11
Fluorine (F)	120	110	680	340	509.53
Beryllium (Be)	7.4	7.4	1.8	1.8	2.49
Mercury (Hg)	0.06	0.30	0.07	0.14	0.11
Lead (Pb)	29	14	5.7	2.9	6.71
Arsenic (As)	6.3	17	1.3	2.5	3.00
Selenium (Se)	11	1.8	0.56	0.73	1.27
Zinc (Zn)	22	67	45	22	38.39

Table No. 4 — Hole No. 12C

	Stray Seam #1	Stray Seam #2	Rosebud-McKay Seam	Robinson Seam	Weighted Average
Cobalt (Co)			1.5	1.3	1.43
Cadmium (Cd)			3.9	4.6	4.14
Vanadium (V)			11	11	11.00
Nickel (Ni)			21	21	21.00
Fluorine (F)			120	70	102.74
Beryllium (Be)			0.09	0.20	0.13
Mercury (Hg)			0.18	0.18	0.18
Lead (Pb)			5.4	5.4	5.40
Arsenic (As)			6.5	2.0	4.95
Selenium (Se)			1.4	1.4	1.40
Zinc (Zn)			200	200	200.00

From U.S. Bureau of Indian Affairs, 1974, p. 249

TABLE 14

TRACE ELEMENT CONCENTRATIONS OF COALS IN THE PROJECT AREA[a]

Trace Elements	S-1 Low	S-1 High	S-1 Average	S-2 Low	S-2 High	S-2 Average	R-1 Low	R-1 High	R-1 Average	R-2 Low	R-2 High	R-2 Average
Uranium	<.5	3.10	1.66	.5	1.20	.9	<.5	2.40	1.43	.5	1.60	.99
Thorium	1.80	4.90	3.2	1.7	6.7	4.0	1.40	7.30	3.64	1.50	3.70	2.72
Bismuth	.10	.97	.39	1.40	1.40	.47	.18	.66	.28	.10	<.73	.32
Lead	3.10	68.00	17.94	5.7	14.0	8.6	.70	8.6	3.30	1.40	3.0	2.36
Thallium	<.1	.41	.16	.70	.70	.23	.1	.65	.23	.12	.72	.25
Mercury	.03	.14	.07	.16	.30	.24	.06	.14	.082	.04	.10	.072
Tungsten	.42	8.20	3.50	.33	2.80	1.19	.8	2.0	1.21	.53	2.30	1.31
Tantalum	.16	4.00	1.29	.20	.20	.07	.12	3.30	.81	.14	3.30	.79
Hafnium	.20	1.20	.5	1.20	1.20	.4	.16	1.10	.48	.23	.38	.37
Lutetium	.04	.35	.17	.06	.06	.02	.05	.35	.16	.05	<.35	.15
Ytterbium	<.28	<2.00	.93	.39	.39	.13	<.23	<2.00	.91	.28	<2.0	.92
Thulium	.04	<.24	.11	.03	.03	.01	.03	<.24	.12	.04	<.24	.14
Erbium	.10	<.84	.38	.21	.21	.07	.07	<.84	.37	.07	<.84	.33
Holmium	.07	<.21	.12	.13	.13	.04	.08	.12	.12	.06	<.21	.11
Dysprosium	<.81	2.10	1.10	2.0	2.0	.67	<.81	2.40	1.04	.56	1.60	.76
Terbium	.03	<.16	.09	.09	.35	.15	.09	.16	.1	.03	<.16	.08
Gadolinium	.16	.48	.38	.14	.33	.16	.08	.48	.35	.08	<.48	.29
Europium	.12	.36	.24	.7	.48	.44	.15	<.36	.25	.07	<.36	.21
Samarium	.50	1.80	1.06	.78	6.30	3.43	.34	1.6	.81	.17	<.84	.55
Neodymium	3.00	20.00	12.18	2.50	30.0	15.83	5.40	11.0	8.12	2.60	25.0	8.82
Prascodymium	.61	3.20	2.16	1.6	4.0	2.23	.42	1.70	1.07	.46	1.70	1.04
Cerium	2.90	17.00	11.78	7.50	33.0	24.50	6.60	32.0	17.64	3.60	20.0	11.92
Lanthanum	1.00	8.60	3.50	1.50	34.0	23.17	1.40	17.0	5.52	.87	8.0	3.10
Barium	21.00	170.00	81.20	39.0	7800.0	2628.67	78.0	480.0	181.60	26.0	150.0	79.0
Cesium	.03	.32	.12	.4	3.0	1.4	.08	1.5	.54	.01	.70	.15
Iodine	.03	.87	.49	.03	.53	.21	.03	.57	.37	.04	.63	.3
Tellurium	<.03	.31	.11	<.13	<.13	.04	<.03	<.30	.12	<.03	.26	.01
Antimony	.19	.56	.34	.64	4.0	2.08	.11	1.60	.67	.35	.41	.15
Tin	.99	6.0	2.40	.75	2.0	1.58	.74	1.80	1.23	1.0	4.60	3.14
Cadmium	.43	1.60	.79	.87	1.20	.98	1.10	2.40	1.80	1.10	2.60	1.65
Silver	.04	.19	.09	.05	.19	.12	.05	.16	.09	.01	.12	.03
Molybdenum	.77	85.0	27.25	4.60	10.0	8.2	.85	8.60	4.87	2.0	8.60	4.24
Niobium	1.30	10.0	5.98	1.90	15.0	6.9	1.70	11.0	6.30	1.40	6.90	3.53
Zirconium	22.0	130.0	73.0	68.0	190.0	108.67	22.0	310.0	128.0	29.0	200.0	93.50

[a]Data based on analyses from five samples of each coal unit provided by Westmoreland Resources. Concentrations given in parts per million. Coal Units: S-1 - Stray 1 Coal; R-1 - Rosebud-McKay Coal; S-2 - Stray 2 Coal; R-2 - Robinson Coal.

From Westmoreland Resources, 1975 1, Appendix E, p. E-5, 6

TABLE 14

Trace Elements	S-1 Low	S-1 High	S-1 Average	S-2 Low	S-2 High	S-2 Average	R-1 Low	R-1 High	R-1 Average	R-2 Low	R-2 High	R-2 Average
Yttrium	1.50	20.0	10.24	15.0	19.0	16.33	1.80	19.0	10.50	4.20	19.0	8.06
Strontium	26.0	700.0	212.40	230.0	1400.0	943.33	.11	1200.0	497.02	280.0	1000.0	532.0
Rubidium	.27	12.0	4.65	2.0	71.0	30.00	.55	13.0	5.06	.09	.77	.39
Bromine	1.1	29.0	10.58	.43	13.0	4.75	.65	37.0	19.35	.54	28.0	13.37
Selenium	1.4	7.50	3.92	1.1	4.8	2.57	.22	4.40	1.30	.22	1.10	.43
Arsenic	3.3	22.0	8.46	17.0	68.0	35.0	$<$.43	3.3	1.77	$<$.43	$<$2.80	1.13
Germanium	.20	2.30	.93	2.0	2.5	2.17	.18	2.30	.7	.10	.25	.13
Gallium	1.30	7.0	3.46	2.0	19.0	13.33	.87	9.40	3.65	.80	9.40	2.95
Zinc	2.20	170.0	54.58	7.70	67.0	39.90	.41	45.0	13.70	.80	45.0	11.33
Copper	5.40	50.0	17.68	18.0	100.0	72.67	2.30	50.0	21.42	6.40	19.0	10.54
Nickel	.77	30.0	7.83	$<$4.30	30.0	16.43	.70	30.0	7.42	.90	15.0	4.31
Cobalt	.42	12.0	4.34	6.90	11.0	9.63	.90	13.0	3.62	.38	8.3	3.74
Manganese	42.0	410.0	198.40	250.0	810.0	490.0	20.0	400.0	202.0	230.0	630.0	344.0
Chromium	1.30	17.0	6.38	6.0	.78.0	54.0	1.80	15.0	6.36	1.40	7.8	3.72
Vanadium	1.70	48.0	16.78	33.0	75.0	50.67	5.40	35.0	18.48	3.0	13.0	7.33
Scandium	.20	5.70	4.16	3.50	3.50	1.17	.20	4.80	2.22	.20	2.50	1.39
Fluorine	33.0	330.0	139.20	310.0	1100.0	583.33	33.0	510.0	227.4	77.0	340.0	143.0
Boron	80.0	160.0	109.40	80.0	250.0	136.67	48.0	540.0	218.6	80.0	290.0	192.0
Beryllium	.51	14.0	7.92	7.4	20.0	15.13	.07	3.40	1.25	.12	4.10	1.53
Lithium	2.60	100.0	43.40	43.0	120.0	68.67	14.0	47.0	35.20	5.30	100.0	37.63

R-1, R-2, S-1, S-2: Palladium - $<$.10 ppm; Rhodium - $<$.10 ppm; Ruthenium - $<$.10 ppm

R-1, R-2, S-1, S-2: Palladium - $<$.1 ppm; Rhodium - $<$.1 ppm; Ruthenium - $<$.1 ppm

R-1, R-2, S-1, S-2: Gold - $<$.1 ppm; Platinum - $<$.1 ppm; Iridium - $<$.1 ppm; Osmium - $<$.1 ppm; Rhenium - $<$.1 ppm

R-1, R-2, S-1, S-2: Gold - $<$.10 ppm; Platinum - $<$.10 ppm; Iridium - $<$.10 ppm; Osmium - $<$.10 ppm; Rhenium - $<$.10 ppm

Table 15--Chemical Analyses of Water from Strip Pit, Big Sky Mine, Rosebud County, Montana, 1972-73.
[Analyses made by Peabody Coal Company]

Date of coll.	Disch., g.p.d.	Al, total ug/l	Al, diss. ug/l	Fe, total ug/l	Fe, diss. ug/l	Mn, total ug/l	Ca mg/l	Mg mg/l	Na mg/l	HCO_3 mg/l	Alkalinity as $CaCO_3$ mg/l	Sulfate SO_4 mg/l	Sulfate as S mg/l	Cl mg/l	F mg/l
1972															
1-31	1,000	600		305		82	183	22	19	24	282		605	4.9	0.8
2-29	2,000	660		640		140	37	28	180	909	184		5,250	9.3	.7
3-27		1,230		420		66	308	256	192	181	181		500	8.6	.1
5-10		280		70		25	266	272	155	359	359		550	6	.2
6-19		150		100		50	306	270	136	254	254		560	17	.2
8-2		300		130		35	183	292	183	277	217		575	13.5	.1
9-5		300		155		70	--	--	120	254	254		510	22	.2
10-6		300		600		730	262	282	14	611	611		500	2.8	.2
10-30	7,500	2,900		3,825		500	634	246	121	528	528		462	11.2	.3
1973															
1-29		200		250	--	240	222	248	119	--	424	1,440		13	.2
3-2		300		550	150	--	148	178	--	--	373	1,000		6.6	.2
4-2		5,300		--	85	--	254	127	--	--	498	1,160		--	.2
5-1		500	200	300	45	90	160	200	39	--	546	1,100		11	.2
5-31		750	250	715	135	60	181	227	159	--	395	720		35	.2
7-1		250	100	160	90	40	169	238	152	--	492	1,160		23	.7
7-31		300	100	105	85	50	170	200	118	--	321	1,070		17	.5
9-4		400	200	435	85	35	190	237	130	--	514	1,130		60	.3
9-29		300	300	85	85	80	180	262	140	--	562	970		27	.2
11-1		650	650	335	170	215	52	658	258	--	588	680		20	.3
12-6		700	550	590	115	355	185	281	170	--	606	1,000		15	.3

From U.S. Department of Interior, 1974, p. 92-94

Table 15--Chemical Analyses of Water from Strip Pit, Big Sky Mine, Rosebud County, Montana, 1972-73--Continued

[Analyses made by Peabody Coal Company]

Date of coll.	Br mg/l	NO_3 as N mg/l	Nitrogen ammonia as N mg/l	Nitrogen, organic as N mg/l	Nitrogen, kjeldahl as N mg/l	Nitrogen, total, as N mg/l	Diss. solids residue (Total) mg/l	Diss. solids, calc. mg/l	Susp. solids mg/l	Residue, volatile mg/l	Hardness as $CaCO_3$ mg/l	Acidity as $CaCO_3$ mg/l
1972												
1-31	2.5	0.6	--	0.56	0.56	1.17	3,150	2,960	191	4,490	1,750	--
2-29	--	9.8	--	2.24	2.24	12.09	3,450	3,450	0	586	1,880	--
3-27	.4	11.9	2.1	1.54	3.64	15.54	3,360	3,360	0	785	1,760	--
5-10	.1	1.4	0	.56	.56	1.99	3,410	3,200	211	758	1,780	--
6-19	.4	1.3	0	0	0	1.30	3,850	3,450	400	766	1,830	--
8-2	.1	.3	--	--	--	.25	2,930	2,800	127	500	1,670	--
9-5	.1	.2	<.1	6.3	6.4	6.56	3,020	2,710	311	758	1,560	32.5
10-6	.3	.3	1.2	.06	1.26	1.56	2,870	2,740	131	586	1,740	204
10-30	.2	20	3	.5	3.5	23.5	3,020	3,020	0	521	1,710	143
1973												
1-29	.2	.7	.5	7.9	8.4	9.1	2,470	2,470	0	346	--	75
3-2	--	--	--	--	--	--	1,920	1,920	0	--	--	51
4-2	--	--	--	--	--	--	--	--	50	--	--	177
5-1	.6	1.1	.4	.3	.7	1.8	2,480	2,250	233	387	1,440	216
5-31	.4	.5	.5	0	.5	1.0	2,630	2,590	41	526	1,320	146
7-1	.2	1.2	.6	.4	1.0	2.2	2,560	2,550	8	422	1,460	182
7-31	.2	8.6	.6	0	.6	9.2	2,470	2,460	8	644	1,260	200
9-4	.4	2.5	.2	--	--	--	2,460	2,440	18	427	1,430	249
9-29	.3	1.1	.3	.4	.7	1.8	2,720	2,720	5	471	1,540	244
11-1	.3	1.1	.2	.3	.5	1.6	2,550	2,510	36	395	2,240	201
12-6	.4	.7	.5	.8	1.3	2.0	2,850	2,820	29	391	1,750	268

Table 15--Chemical Analyses of Water from Strip Pit, Big Sky Mine, Rosebud County, Montana, 1972-73--Continued

[Analyses made by Peabody Coal Company]

Date of coll.	Sp. cond. micromhos at 25°C	pH	Temp. °F	Color Pt-Co scale	Turbidity J.T.U.	Chem. oxygen demand mg/1	Oil & grease mg/1	As ug/1	Cd ug/1	Cr ug/1	Cu ug/1	Pb ug/1	Hg ug/1	Ni ug/1	Se ug/1	Zn ug/1
1972																
1-31	3,100	7.3	34	4	22	9.9	0.1	12	15	18	16	118	--	175	--	31
2-29	3,100	7.5	35	4	35	20.4	0	6.0	11	3	27	210	--	140	0	18
3-27	3,000	7.2	46	5	14	4.0	--	1.4	0	5	10	0	--	110	--	42
5-10	2,800	7.4	54	8	.8	9.3	--	1.8	0	0	0	1.6	--	165	.5	18
6-19	3,000	7.3	67	4	2.3	9.5	2.9	0	0	0	30	0	--	120	--	23
8-2	3,600	7.3	72	6	3.2	4.9	--	0	0	1.3	7	34	--	180	--	0
9-5	2,800	7.4	74	4	2.5	10.2	--	26	1	0	10	6	--	10	--	155
10-6	2,800	7.6	58	6	8.1	1	0	0	0	0	10	0	0	245	--	60
10-30	2,000	7.7	42	5	110	8.4	--	36.4	0	1.2	10	19.5	.2	180	--	15
1973																
1-29	2,800	7.5	45	5	.9	0	0	--	56	21	10	65	.09	95	--	45
3-2	2,300	7.5	47	-	4.0	0	--	--	--	--	--	58.5	--	--	--	--
4-2	--	7.4	--	-	27	--	--	--	--	--	--	106	--	--	--	--
5-1	2,900	7.5	--	8	22	4	2.0	2	77	0	0	100	.25	88	--	71
5-31	3,000	7.6	--	5	5.7	3	--	1	71	15	0	118	.04	402	--	0
7-1	2,700	7.7	--	5	2.8	4	--	1	98	19	5	1,330	.08	264	--	122
7-31	2,200	7.7	--	5	.5	4	0	0	43	7	10	125	.38	379	--	0
9-4	2,700	7.6	--	5	4.0	0	--	0	74	16	0	39	.34	567	--	0
9-29	2,500	7.5	--	5	1	4	--	1	80	78	0	1,430	0	516	--	20
11-1	2,800	7.6	--	5	7.7	3	--	--	84	18	0	152	.20	772	--	0
12-6	2,900	7.4	--	5	12	8	0	3	98	22	30	148	.07	2,710	--	62

TABLE 16

SURFACE WATER QUALITY MONITORING LOCATIONS

Location	CT&E	SW
East Sarpy Creek at County Bridge	CT&E-1	SW-4
Sediment Pond	CT&E-2	
Upper Luther Buildings (Sarpy Creek)	CT&E-3	
Sarpy Creek at County Bridge	CT&E-4	
Sarpy Creek above Junction with East Fork Sarpy Creek	CT&E-5	SW-1
East Fork Sarpy Creek above Junction with Sarpy Creek	CT&E-6	SW-2
East Sarpy Creek-Section 12	CT&E-7	
Main Sarpy Creek above Pleasant Creek	CT&E-8	
Sarpy Creek on R. Thrower Property		SW-3
Pleasant Creek (North of Tract II)		SW-5
Plum Creek (West of Tract II)		SW-6
Middle Fork Sarpy Creek		SW-7
Sarpy Creek just above Junction with Spring Creek (Temporary station near SW-7		SW-7A

From Westmoreland Resources, 1975 1, Appendix F, p. F-90

TABLE 17

Chemical Analyses from CT & E Stations, April 1973 to May 1975

LOCATION (CT&E) No. 1 — CT&E - EAST SARPY CREEK AT COUNTY BRIDGE

ANALYSIS[a]		2-11-74	3- 5-74	4-10-74	5- 8-74	6-10-74	7- 9-74	8- 8-74	9- 9-74	10-23-74
Acidity to pH 8.2	(meq/l)			0.7	0.84	0.22	A	A	A	A
Alkalinity to pH 4.5	(meq/l)			10.8	9.4	9.60	8.8	7.8	3.8	2.6
Alkalinity ($CaCO_3$)		125	430		470	480	440	390	474	322
Ammonia (Nitrogen)		0.6	2.6							
Bicarbonate		150	525							
BOD, 5-day		4	2							
Bromide		A	A							
Carbonate		A	A							
COD		53	40							
Chloride		6	11							
Color	(Pt-Co Units)	150	45							
Coliform Bacteria, total		8	62							
Fluoride		0.1	0.8	0.5	0.28	0.29	0.80	1.00	0.70	0.95
Hardness, total ($CaCO_3$)		196	1060							
Nitrate (Nitrogen)		1.4	A							
Nitrite (Nitrogen)		A	A							
Nitrogen, total Kjeldahl		2.2	3.4							
Oil & Grease		1	<1	<1	<1	<1	2	3	4	1
pH		7.5	8.0	8.1	8.2	8.0	8.2	8.7	8.1	8.0
Phosphorus, total		<0.1	0.1							
Settleable Solids				14	17	A	22	606	<0.1[b]	<0.1[b]
Evaporated Solids, total	(105°C)	470	1970						3751	3841
Total Dissolved Solids		360	1852	2740	2700	2263	3206	3090		
Total Suspended Solids		104	7	21	21	9	23	613	6	15
Total Volatile Solids		102	360							
Specific Conductance	(umhos/cm@25°C)	541	2222							
Sulfate		166	1037	2383	1519	1234	1737	2202	1400	1950
Sulfide		A	A							
Temperature	(°C)	0	1	4	12	14	30	20	9	2.5
Turbidity	(JTU)	43	5.8	7.4	5.5	7.2	6.0	47	10	2
Aluminum	(PPB)	A	A							
Cadmium	(PPB)	1	<1							
Calcium		34	178							
Chromium, total	(PPB)	5	<5							
Copper	(PPB)	6	6							
Iron, total	(PPB)	0.79	0.127		0.10	0.32	0.47	5.85	0.50	2.05
Iron, dissolved				0.5	0.06	0.09	A	0.22	0.09	0.30
Magnesium		27	150							
Manganese	(PPB)	172	246							
Mercury	(PPB)	0.7	<.05							
Nickel	(PPB)	12	4							
Sodium		50	213							
Zinc	(PPB)	8	7							

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

A = Absent

From Westmoreland Resources, 1975 1, Appendix F, p. F-99 to 112

TABLE 17

LOCATION (CT&E) No. 1 — CT&E - EAST SARPY CREEK AT COUNTY BRIDGE

ANALYSIS[a]	Units	11-27-74	12-27-74	2-25-75	3-31-75	8-29-75
Acidity to pH 8.2	(meq/l)	A	A	.14	A	A
Alkalinity to pH 4.5	(meq/l)	38	30	1.00	9.43	11.47
Alkalinity ($CaCO_3$)		584	606	50	476	574
Ammonia (Nitrogen)						
Bicarbonate						
BOD, 5-day						
Bromide						
Carbonate						
COD						
Chloride						
Color	(Pt-Co Units)					
Coliform Bacteria, total						
Fluoride		0.74	.37	.15	.20	.39
Hardness, total ($CaCO_3$)						
Nitrate (Nitrogen)						
Nitrite (Nitrogen)						
Nitrogen, total Kjeldahl						
Oil & Grease		1	2	6		<5
pH		8.0	7.8	7.2	8.0	8.0
Phosphorus, total						
Settleable Solids		<0.1[b]	<0.1[b]	0.1[b]	<0.1[b]	<0.1[b]
Evaporated Solids, total	(105°C)	2564	2927	101	2263	2905
Total Dissolved Solids						
Total Suspended Solids		41	23	18	42	2
Total Volatile Solids						
Specific Conductance	(µmhos/cm@25°C)					
Sulfate		1500	1838	18	1531	1750
Sulfide						
Temperature	(°C)	0	0	0	0	16
Turbidity	(JTU)	2	2	27	10	<25
Aluminum	(PPB)					
Cadmium	(PPB)					
Calcium						
Chromium, total	(PPB)					
Copper	(PPB)					
Iron, total	(PPB)	0.7	.30	.1	1.5	.6
Iron, dissolved		0.12	A	A	A	A
Magnesium						
Manganese	(PPB)					
Mercury	(PPB)					
Nickel	(PPB)					
Sodium						
Zinc	(PPB)					

TABLE 17

LOCATION (CT&E) No. 3 — CT&E - UPPER LUTHER BUILDING

DATE		4-27-73	5-25-73	6-29-73	7-26-73	9-6-73	2-5-74	3-5-74	4-10-74	5-8-74
ANALYSIS[a]										
Acidity to pH 8.2	(meq/1)								0.9	1.28
Alkalinity to pH 4.5	(meq/1)								12.2	11.7
Alkalinity ($CaCO_3$)		530	645	560	610	140	310	495		585
Ammonia (Nitrogen)		<1	<1	<1	<1	0.3	<0.1	3.3		
Bicarbonate		500	763	610	744	170	380	605		
BOD, 5-day		14	3	23	10	11	36	5		
Bromide		A	A	A	A	A	A	A		
Carbonate		72	12	36	A	A	A	A		
COD		36	48	136	59	73	55	24		
Chloride		12	16	18	15	16	11	16		
Color	(Pt-Co Units)	40	50	75	65	75	140	35		
Coliform Bacteria, total	(per 100 ml)	A	95	1165	50	440	A	A		
Fluoride		0.6	0.9	0.6	0.2	0.5	0.2	0.8	0.8	0.26
Hardness, total ($CaCO_3$)		872	1102	754	1002	323	495	870		
Nitrate (Nitrogen)		<0.1	<0.1	<0.1	0.1	0.1	<0.1	0.9		
Nitrite (Nitrogen)		A	A	A	A	A	A	A		
Nitrogen, total Kjeldahl		<1	<1	13	<1	1.1	2.8	4.1		
Oil & Grease		0.5	<1	4	<1	1	2	1	2	1
pH		8.3	8.2	8.3	8.0	8.2	7.3	7.5	8.1	8.2
Phosphorus, total		0.1	<0.1	<0.1	<0.1	<0.1	0.3	0.7		
Settleable Solids									23	49
Evaporated Solids, total	(105°C)	1860	2150	2006	2108	824	1042	1640		
Total Dissolved Solids	(180°C)	1634	2096	1518	1960	720	881	1572	1896	1878
Total Suspended Solids		114	9	310	16	43	132	2	28	51
Total Volatile Solids		462	520	494	468	184.	196	292		
Specific Conductance	(µmhos/cm@25°C)	210	250	213	2380	901	1010	1960		
Sulfate		718	978	737	951	344	361	749	859	858
Sulfide		A	A	A	A	A	A	A		
Temperature	(°C)	8	12	17	15	12	A	1	4	
Turbidity	(JTU)	44	4.6	110	8.2	18	21	4.7	7.4	5.6
Aluminum	(PPB)	<10	<10	<10	<10	<10	A	A		
Cadmium	(PPB)	< 5	13	8	<2	<2	1	<1		
Calcium		104	140	65	90	44	75	123		
Chromium, total	(PPB)	<5	<5	<5	9	2	<5	<5		
Copper	(PPB)	8	<5	18	10	12	14	6		
Iron, total	(PPB)	25	35	75	65	50	267	70		0.37
Iron, dissolved									0.2	0.22
Magnesium		149	183	144	189	52	75	137		
Manganese	(PPB)	35	28	720	90	22	197	222		
Mercury	(PPB)	8	2	4	.5	3	0.5	3		
Nickel	(PPB)	16	12	6	6	5	8	3		
Sodium		194	268	275	284	90	95	197		
Zinc	(PPB)	23	<5	4	42	7	14	12		

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

A = Absent

TABLE 17

LOCATION (CT&E) NO. 3 — CT&E - UPPER LUTHER BUILDING

DATE		6-10-74	7- 9-74	8- 8-74	9- 9-74	12-27-74	2-25-75	3-31-75	5-29-75
ANALYSIS[a]									
Acidity to pH 8.2	(meq/l)	0.12	0.3	0	0	0	.12	.08	0
Alkalinity to pH 4.5	(meq/l)	8.60	5.9	15.4	13		2.16	9.39	11.91
Alkalinity ($CaCO_3$)		430	295	770	214		108	474	596
Ammonia (Nitrogen)									
Bicarbonate									
BOD, 5-day						N/A	N/A	N/A	N/A
Bromide									
Carbonate									
COD									
Chloride									
Color	(Pt-Co Units)								
Coliform Bacteria, total									
Fluoride		0.29	0.45	0.50	0.50	.48	.15	.07	.44
Hardness, total ($CaCO_3$)									
Nitrate (Nitrogen)									
Nitrite (Nitrogen)									
Nitrogen, total Kjeldahl									
Oil & Grease		1	<1	3	3	21	6	N/A	<5
pH		7.9	8.0	8.3	8.0	7.3	7.1	7.9	8.1
Phosphorus, total									
Settleable Solids		30	109	2333	0.3[b]	5.0[b]	0.1[b]	<0.1[b]	<0.1[b]
Evaporated Solids, total	(105°C)				914	5616	329	1619	1901
Total Dissolved Solids	(180°C)	1109	810	1338					
Total Suspended Solids		37	120	2443	2460	373	10	11	48
Total Volatile Solids									
Specific Conductance	(μmhos/cm@25°C)								
Sulfate		487	260	400	224	750	2.5	925	1075
Sulfide									
Temperature	(°C)	13	21	17	8	0	0	0	10
Turbidity	(JTU)	14	65	90	142	2500	92	5	<25
Aluminum	(PPB)								
Cadmium	(PPB)								
Calcium									
Chromium, total	(PPB)								
Copper	(PPB)								
Iron, total	(PPB)	1.15	1.52	11	1.8	3.4	1.2	.3	1
Iron, dissolved		0.06	0.13	0	0	.55	.05	.02	0
Magnesium									
Manganese	(PPB)								
Mercury	(PPB)								
Nickel	(PPB)								
Sodium									
Zinc	(PPB)								

TABLE 17

LOCATION (CT&E) No. 4 — CT&E - MAIN SARPY CREEK AT THE COUNTY BRIDGE

DATE		4-27-73	5-25-73	6-29-73	7-26-73	9- 6-73	2-11-74	3- 5-74	4-10-74	5- 8-74
ANALYSIS[a]										
Acidity to pH 8.2	(meq/1)								0.9	1.48
Alkalinity to pH 4.5	(meq/1)								11.6	12.6
Alkalinity ($CaCO_3$)		641	630	710	820	180	340	480		630
Ammonia (Nitrogen)		<1	<1	<1	<1	0.5	0.1	2.4		
Bicarbonate		641	769	695	537	220	415	585		
BOD, 5-day		5	2	4	52	16	4	2		
Bromide		A	A	A	A	A	A	A		
Carbonate		0	0	84	228	Trace	0	0		
COD		29	44	66	193	57	56	11		
Chloride		13	15	23	35	24	13	16		
Color	(Pt-Co Units)	45	70	80	90	45	110	25		
Coliform Bacteria, total		460	925	290	c	6000	0	0		
Fluoride		0.7	0.9	0.9	0.5	0.7	0.6	0.8	1.0	0.47
Hardness, total ($CaCO_3$)		1040	1335	1309	1740	1812	624	1004		
Nitrate (Nitrogen)		<0.1	<0.1	<0.1	4.3	<0.1	1.2	A		
Nitrite (Nitrogen)		A	A	A	A	A	A	A		
Nitrogen, total Kjeldahl		1	<1	1	9	1.0	2.9	5.0		
Oil & Grease		0.5	<1	<1	14	2	<1	<1	1	<1
pH		8.1	8.1	8.6	9.1	8.3	7.4	7.7	7.9	8.1
Phosphorus, total		0.1	<0.1	0.2	0.2	0.1	0.2	0.1		
Settleable Solids									14	15
Evaporated Solids, total	(105°C)	2050	2618	2704	4090	3548	1170	1772		
Total Dissolved Solids	(180°C)	1920	2494	2404	3778	3220	1130	1814	2242	2256
Total Suspended Solids		4	7	12	209	42	24	6	19	17
Total Volatile Solids		518	692	648	824	652	232	322		
Specific Conductance	(µmhos/cm@25°C)	2400	2900	2940	4000	3077	1235	2020		
Sulfate		925	1266	1249	2004	2024	535	827	281	1111
Sulfide		A	A	A	A	A	A	0		
Temperature	(°C)	9	14	23	19	14	0	1	4	18
Turbidity	(JTU)	3.9	5.3	6.6	62	11	14	7.6	7.3	8.5
Aluminum	(PPB)	<10	<10	<10	<10	<10	A	A		
Cadmium	(PPB)	< 5	12	12	< 2	< 2	<1	<1		
Calcium		112	120	75	30	290	87	129		
Chromium, total	(PPB)	<5	<5	8	12	7	<5	<5		
Copper	(PPB)	<5	9	12	10	8	8	8		
Iron, total	(PPB)	30	23	58	37	20	385	64		0.10
Iron, dissolved									0.4	0.09
Magnesium		185	252	273	405	264	99	166		
Manganese	(PPB)	29	9	54	147	120	880	271		
Mercury	(PPB)	1	4	5	0.1	1	0.3	4		
Nickel	(PPB)	24	14	20	9	7	12	4		
Sodium		214	291	337	558	235	134	164		
Zinc	(PPB)	11	<5	<4	30	82	9	20		

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

[c] Coliform too numerous to count

A = Absent

TABLE 17

LOCATION (CT&E) No. 4 — CT&E - MAIN SARPY CREEK AT THE COUNTY BRIDGE

DATE		6-10-74	7- 9-74	8- 8-74	10-23-74	11-27-74	12-27-74	2-25-74	3-31-75	5-29-75
ANALYSIS[a]										
Acidity to pH 8.2	(meq/1)	0.18	A	A	A	A	A	.24	.04	.08
Alkalinity to pH 4.5	(meq/1)	9.80	12.6	38.0	34	48	26	2.52	9.51	12.39
Alkalinity ($CaCO_3$)		490	630	1900	848	810	910	126	480	620
Ammonia (Nitrogen)										
Bicarbonate										
BOD, 5-day						N/A	N/A	N/A	N/A	N/A
Bromide										
Carbonate										
COD										
Chloride										
Color	(Pt-Co Units)									
Coliform Bacteria, total										
Fluoride		0.33	1.15	0.45	0.85	0.63	.67	.17	.10	.50
Hardness, total ($CaCO_3$)										
Nitrate (Nitrogen)										
Nitrite (Nitrogen)										
Nitrogen, total Kjeldahl										
Oil & Grease		2	1	7	1	2	3	8	N/A	<5
pH		7.9	8.2	8.6	8.1	8.1	7.6	7.1	7.7	8.0
Phosphorus, total										
Settleable Solids		9	9	36,844	0.1[b]	<0.1[b]	0.1[b]	0.1[b]	<0.1[b]	<0.1[b]
Evaporated Solids, total	(105°C)				4220	2360	2360	251	1661	2236
Total Dissolved Solids	(180°C)	1565	1843	4185						
Total Suspended Solids		11	21	36,850	22	9	19	21	7	9
Total Volatile Solids										
Specific Conductance	(µmhos/cm@25°C)									
Sulfate		796	718	601	1500	1125	1950	250	1000	1250
Sulfide										
Temperature	(°C)	17	31	19	5	0	0	0	0	16
Turbidity	(JTU)	4.5	8.0	1000+	2	2	2	180	10	<25
Aluminum	(PPB)									
Cadmium	(PPB)									
Calcium										
Chromium, total	(PPB)									
Copper	(PPB)									
Iron, total	(PPB)	0.28	0.91	14	1.15	1.4	.55	1.5	.5	.4
Iron, dissolved		0.17	0.17	0.17	0.56	0.28	.02	.07	.03	A
Magnesium										
Manganese	(PPB)									
Mercury	(PPB)									
Nickel	(PPB)									
Sodium										
Zinc	(PPB)									

TABLE 17

LOCATION (CT&E) No. 5 — CT&E - MAIN SARPY CREEK ABOVE JUNCTION WITH EAST FORK SARPY CREEK

ANALYSIS[a]		4-27-73	5-23-73	6-29-73	7-26-73	9-6-73	2-11-74	3-5-74	4-10-74	5-8-74
Acidity to pH 8.2	(meq/l)								0.9	1.38
Alkalinity to pH 4.5	(meq/l)								11.4	12.2
Alkalinity ($CaCO_3$)		510	620	599	640	500	455	485		610
Ammonia (Nitrogen)		<1	<1	<1	<1	0.4	0.4	3.2		
Bicarbonate		549	756	730	683	610	555	590		
BOD, 5-day		5	1	3	21	11	11	5		
Bromide		A	A	A	A	A	A	A		
Carbonate		36	A	A	48	A	A	A		
COD		30	36	36	53	39	52	16		
Chloride		16	20	25	26	24	20	18		
Color	(Pt-Co Units)	50	65	40	40	35	65	25		
Fluoride		0.8	0.9	1.0	0.5	0.8	0.8	1.1	0.8	0.42
Hardness, total ($CaCO_3$)		1187	1608	1854	1953	1607	624	1261		
Nitrate (Nitrogen)		<0.1	<0.1	<0.1	0.4	<0.1	2.5	A		
Nitrite (Nitrogen)		A	A	A	A	A	A	A		
Nitrogen, total Kjeldahl		1	1	1	4	2.1	2.3	4.6		
Oil & Grease		0.4	<1	<1	8	2	1	<1	<1	2
pH		8.3	8.2	8.0	8.3	8.2	7.7	7.8	8.2	8.1
Phosphorus, total		0.1	0.1	<0.1	0.1	0.1	<0.1	0.2		
Settleable Solids									17	9
Evaporated Solids, total	(105°C)	2540	3526	5068	6210	5008	2462	2550		
Total Dissolved Solids	(180°C)	2350	3254	4518	5462	4486	1494	2434	2890	3126
Total Suspended Solids		4	10	11	59	21	63	8	22	14
Total Volatile Solids		574	802	720	996	848	438	380		
Specific Conductance	(μmhos/cm@25°C)	290	370	488	5650	4762	2500	2632		
Sulfate		1169	1819	2790	3480	2716	1335	1395	1518	1772
Sulfide		0	A	A	A	A	A	A		
Temperature	(°C)	9	13	21	19	14	0	1	4	14
Turbidity	(JTU)	8.5	6.5	7.6	17	11	12	5.8	6.5	5.7
Aluminum	(PPB)	<10	<10	<10	<10	<10	A	A		
Cadmium	(PPB)	<5	7	14	<2	<2	<1	1		
Calcium		128	150	150	150	150	149	158		
Chromium, total	(PPB)	<5	<5	18	9	3	177	<5		
Copper	(PPB)	13	11	12	6	9	5	9		
Iron, total	(PPB)	20	27	4	54	<20	172	56		0.10
Iron, dissolved									0.2	0.08
Magnesium		211	300	360	384	300	188	211		
Manganese	(PPB)	41	13	610	311	690	414	169		
Mercury	(PPB)	2	4	4	<.1	2	0.4	7		
Nickel	(PPB)	18	18	12	6	4	10	5		
Sodium		258	429	773	1077	805	334	321		
Zinc	(PPB)	12	<5	8	6	8	9	17		

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

A = Absent

TABLE 17

LOCATION (CT&E) No. 5 — CT&E - MAIN SARPY CREEK ABOVE JUNCTION WITH EAST FORK SARPY CREEK

DATE		6-10-74	7- 9-74	8- 8-74	9- 9-74	10-23-74	11-27-72	12-27-74	2-25-75		3-31-75	5-29-75
ANALYSIS[a]												
Acidity to pH 8.2	(meq/1)	0.10	A	A	A	A	A	A	16	A	0.22	A
Alkalinity to pH 4.5	(meq/1)	8.60	11.8	12.6	5	32	40	28	2.8	8.91	9.18	11.43
Alkalinity ($CaCO_3$)		430	590	630	520	792	764	752	142	450	460	572
Ammonia (Nitrogen)												
Bicarbonate												
BOD, 5-day												
Bromide												
Carbonate												
COD												
Chloride												
Color	(Pt-Co Units)											
Fluoride		0.36	1.05	1.35	1.10	1.20	0.52	.67	.17	.20	0.5	.48
Hardness, total ($CaCO_3$)												
Nitrate (Nitrogen)												
Nitrite (Nitrogen)												
Nitrogen, total Kjeldahl												
Oil & Grease		<1	1	1	2.7	1	1	6	6		<1	<5
pH		8.1	8.3	8.2	8.2	8.0	7.9	7.7	7.6	7.8	7.6	8.1
Phosphorus, total												
Settleable Solids		74	8	92	<0.1[b]	0.4[b]	0.4[b]	0.1[b]	0.1[b]	<0.1[b]	11	<0.1[b]
Evaporated Solids, total	(105°C)				1442	5165.	6409.	6111	492	2068		2835
Total Dissolved Solids	(180°C)	2629	3960	5862							2176	
Total Suspended Solids		111	9	105	26	38	17	39	10	20	18	1
Total Volatile Solids												
Specific Conductance	(μmhos/cm@25°C)											
Sulfate		1445	2133	3687	224	1425	3150	3825	375	1125	1138	1688
Sulfide												
Temperature	(°C)	17	24	18	9	5	0	0	0	0		150
Turbidity	(JTU)	42	7.8	22	15	14	3	2	37	10	8.6	<25
Aluminum	(PPB)											
Cadmium	(PPB)											
Calcium												
Chromium, total	(PPB)											
Copper	(PPB)											
Iron, total	(PPB)	1.45	0.43	0.67	1.00	0.90	2.4	1.25	.75	.6	0.7	0.4
Iron, dissolved		0.09	0.03	0.32	0.43	0.25	0.60	.06	A.	.01	0.3	A
Magnesium												
Manganese	(PPB)											
Mercury	(PPB)											
Nickel	(PPB)											
Sodium												
Zinc	(PPB)											

TABLE 17

LOCATION (CT&E) No. 6 — CT&E - EAST FORK SARPY CREEK ABOVE JUNCTION WITH MAIN SARPY CREEK

DATE		4-27-73	5-25-73	6-27-73	7-26-73	9- 6-73	2-11-74	3- 5-74	4-10-74	5- 8-74
ANALYSIS[a]										
Acidity to pH 8.2	(meq/1)								0.6	0.94
Alkalinity to pH 4.5	(meq/1)								10.6	10.0
Alkalinity ($CaCO_3$)		485	560	500	596	500	405	435		500
Ammonia (Nitrogen)		1	1	1	1	0.2	1.3	2.3		
Bicarbonate		470	586	610	726	610	495	530		
BOD, 5-day		5	3	4	5	9	6	2		
Bromide		A	A	A	A	A	A	A		
Carbonate		60	48	A	A	A	A	A		
COD		29	36	32	17	21	70	20		
Chloride		11	16	19	19	84	9	15		
Color	(Pt-Co Units)	40	50	40	5	15	130	.25		
Fluoride		0.9	1.0	0.9	0.5	0.7	0.5	0.9	0.7	0.37
Hardness, total ($CaCO_3$)		1387	1781	1632	2029	1881	476	1253		
Nitrate (Nitrogen)		<0.1	<0.1	0.2	<0.1	<0.1	1.2	A		
Nitrite (Nitrogen)			A	A		A	A	A		
Nitrogen, total Kjeldahl		<1	<1	<1	<1	0.9	3.2	6		
Oil & Grease		0.5	<1	<1	1	1	<1	1	2	1
pH		8.3	8.4	8.2	7.5	8.0	7.6	7.8	8.2	8.3
Phosphorus, total		0.1	0.1	0.0	0.3	0.1	<0.1	<0.1		
Settleable Solids									A	54
Evaporated Solids, total	(105°C)	2701	4364	4318	5052	4631	886	2510		
Total Dissolved Solids		3032	3974	3755	5174	5078	774	2354	3154	3342
Total Suspended Solids		36	81	5	9	12	56	8	28	55
Total Volatile Solids		718	902	838	678	914	180	338		
Specific Conductance	(μmhos/cm@25°C)	330	420	408	5300	5181	1099	2632		
Sulfate		1626	781	2370	3210	2972	337	1434	1709	1984
Sulfide		A	A	A	A	A	A	A		
Temperature	(°C)	9	12	19	14	15	A	1	4	13
Turbidity	(JTU)	17	21	3.7	9.0	6.8	28	7.0	12	9
Aluminum	(PPB)	<10	<10	<10	<10	<10	A	A		
Cadmium	(PPB)	<5	8	16	<2	<2	<1	<1		
Calcium		164	180	135	210	190	59	178		
Chromium, total	(PPB)	<5	6	10	9	4	5	12		
Copper	(PPB)	14	14	16	5	<2	8	5		
Iron, total	(PPB)	35	26	64	38	20	445			370
Iron, dissolved									0.1	0.07
Magnesium		238	324	315	366	342	80	197		
Manganese	(PPB)	95	14	55	758	790	172	74		
Mercury	(PPB)	3	2	7	<.1	1	0.3	3		
Nickel	(PPB)	18	18	12	3	8	12	3		
Sodium		370	567	626	889	803	135	319		
Zinc	(PPB)	11	6	10	<5	<5	12	14		

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

A = Absent

TABLE 17

LOCATION (CT&E) No. 6 — CT&E - EAST FORK SARPY CREEK ABOVE JUNCTION WITH MAIN SARPY CREEK

DATE		6-10-74	7-9-74	8-8-74	9-9-74	10-23-74	11-27-74	12-27-74	2-25-75	3-31-75[c]		8-29-75
ANALYSIS[a]												
Acidity to pH 8.2	(meq/l)	0.30	A	0.16	A	A	A	A	.28	0.12	0	A
Alkalinity to pH 4.5	(meq/l)	8.80	9.2	12.2	11	26	40	26	2.21	9.02	8.91	11.35
Alkalinity ($CaCO_3$)		440	460	610	278	618	570	646	111	450	450	568
Ammonia (Nitrogen)												
Bicarbonate												
BOD, 5-day												
Bromide												
Carbonate												
COD												
Chloride												
Color	(Pt-Co Units)											
Fluoride		0.33	1.0	1.25	0.70	0.90	0.38	.48	.17	0.7	0.20	.44
Hardness, total ($CaCO_3$)												
Nitrate (Nitrogen)												
Nitrite (Nitrogen)												
Nitrogen, total Kjeldahl												
Oil & Grease		<1	<1	<1	2	1	3	3	7	2	A	14.4
pH		7.9	8.2	7.7	7.6	8.0	8.0	7.5	7.4	7.8	7.9	8.1
Phosphorus, total												
Settleable Solids		15	6	3	0.1[b]	0.1[b]	<0.1[b]	0.1[b]	<0.1[b]	7	<0.1[b]	<0.1[b]
Evaporated Solids, total	(105°C)				2395	5462	3700	5525	529		2753	3770
Total Dissolved Solids		1923	3608	5022						2904		
Total Suspended Solids		44	7	6	12	10	14	133	4	9	4	10
Total Volatile Solids												
Specific Conductance	(µmhos/cm@25°C)											
Sulfate		1091	2189	3134	680	2400	2400	3150	450	1687	1700	2083
Sulfide												
Temperature	(°C)	16	24	16	10	55	A	A	A		A	13
Turbidity	(JTU)	22	3.6	4.5	10	2	2	2	51	5.7	7	<25
Aluminum	(PPB)											
Cadmium	(PPB)											
Calcium												
Chromium, total	(PPB)											
Copper	(PPB)											
Iron, total	(PPB)	1.10	0.17	0.13	0.10	0.20	0.6	2.9	.25	0.6	0.2	.4
Iron, dissolved		0.17	A	0.09	A	0.05	0.09	.18	A	0.4	0.01	A
Magnesium												
Manganese	(PPB)											
Mercury	(PPB)											
Nickel	(PPB)											
Sodium												
Zinc	(PPB)											

[c] Analysis done by two laboratories for this date.

LOCATION (CT&E) No. 7 — CT&E - EAST SARPY CREEK - SECTION 12

DATE		2- 5-74	3- 5-74	4-10-74	5- 8-74	6-10-74	7- 9-74	8- 8-74	9- 9-74	10-23-74
ANALYSIS[a]										
Acidity to pH 8.2	(meq/1)			0.7'	0.84	0.04	A	A	A	A
Alkalinity to pH 4.5	(meq/1)			10.8	10.0	9.20	8.0	7.2	6	20
Alkalinity ($CaCO_3$)		475	490		500	460	400	360	372	478
Ammonia (Nitrogen)		<0.1	3.7							
Bicarbonate		580	600							
BOD, 5-day		7	3							
Bromide		A	A							
Carbonate		A	A							
COD		39	26							
Chloride		16	14							
Color	(Pt-Co Units)	65	25							
Coliform Bacteria, total		66	10							
Fluoride		1.3	0.9	0.5	0.34	0.28	0.85	0.90	0.75	0.85
Hardness, total ($CaCO_3$)		1176	1196							
Nitrate (Nitrogen)		1.3	A							
Nitrite (Nitrogen)		A	A							
Nitrogen, total Kjeldahl		1.4	1.2							
Oil & Grease		<1	1	<1	<1	1	1	1	2	1
pH		7.5	7.7	8.1	8.1	8.1	8.2	8.2	8.2	7.9
Phosphorus, total		0.2	<0.1							
Settleable Solids				8	11	1	0	10	<0.1[b]	<0.1[b]
Evaporated Solids, total	(105°C)	2546	2514						3232	3092
Total Dissolved Solids		2474	2352	2886	2948	2290	2675	3027		
Total Suspended Solids		13	15	30	15	22	12	12	50	12
Total Volatile Solids		454	396							
Specific Conductance	(μmhos/cm@25°C)	2632	2597							
Sulfate		1338	1317	1437	1661	1274	1677	1875	1952	1800
Sulfide		A	A							
Temperature	(°C)	0	1	4	14	18	30	19	11	8
Turbidity	(JTU)	10	6.9	8.5	5.7	8.0	7.2	5.0	10	2
Aluminum	(PPB)	A	A							
Cadmium	(PPB)	<1	<1							
Calcium		188	178							
Chromium, total	(PPB)	<5	<5							
Copper	(PPB)	14	7							
Iron, total	(PPB)	0.162	0.074		0.14	0.35	0.38	0.32	0.60	0.32
Iron, dissolved				0.3	0.09	0.06	0.09	0.27	0.07	0.16
Magnesium		172	183							
Manganese	(PPB)	540	238							
Mercury	(PPB)	0.5	<0.5							
Nickel	(PPB)	10	3							
Sodium		328	315							
Zinc	(PPB)	11	25							

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

A = Absent

TABLE 17

LOCATION (CT&E) No. 7		CT&E - EAST SARPY CREEK - SECTION 12				
DATE		11-27-74	12-27-74	2-25-75	3-31-75	5-29-75
ANALYSIS[a]						
Acidity to pH 8.2	(meq/1)	A	0	.14	0	0
Alkalinity to pH 4.5	(meq/1)	30	26	7.49	8.91	11.19
Alkalinity ($CaCO_3$)		572	604	375	450	560
Ammonia (Nitrogen)						
Bicarbonate						
BOD, 5-day		N/A	N/A	N/A	N/A	N/A
Bromide						
Carbonate						
COD						
Chloride						
Color	(Pt-Co Units)					
Coliform Bacteria, total						
Fluoride		1.41	.37	.32	.27	.44
Hardness, total ($CaCO_3$)						
Nitrate (Nitrogen)						
Nitrite (Nitrogen)						
Nitrogen, total Kjeldahl						
Oil & Grease		<1	3	7	N/A	<5
pH		7.9	7.7	8.2	7.9	8.0
Phosphorus, total						
Settleable Solids		<0.1[b]	<0.1[b]	0.1[b]	<0.1[b]	<0.1[b]
Evaporated Solids, total	(105°C)	3015	3431	1899	2540	3170
Total Dissolved Solids						
Total Suspended Solids		27	19	28	6	6
Total Volatile Solids						
Specific Conductance	(μmhos/cm@25°C)					
Sulfate		1650	1875	975	1450	1792
Sulfide						
Temperature	(°C)	0	0	0	0	12
Turbidity	(JTU)	2	2	52	8	<25
Aluminum	(PPB)					
Cadmium	(PPB)					
Calcium						
Chromium, total	(PPB)					
Copper	(PPB)					
Iron, total	(PPB)	0.4	.18	.05	.3	.3
Iron, dissolved		0.08	A	A	A	A
Magnesium						
Manganese	(PPB)					
Mercury	(PPB)					
Nickel	(PPB)					
Sodium						
Zinc	(PPB)					

TABLE 17

LOCATION (CT&E) No. 8 — CT&E - MAIN SARPY CREEK ABOVE PLEASANT CREEK

ANALYSIS[a]	Units	4-27-73	5-25-73	6-29-73	7-26-73	9- 6-73	2-11-74	3- 5-74	4-10-74	5- 8-74
Acidity to pH 8.2	(meq/1)								0.8	0.88
Alkalinity to pH 4.5	(meq/1)								10.8	10.2
Alkalinity ($CaCO_3$)		500	565	439	615	490	400	460		510
Ammonia (Nitrogen)		<1	<1	<1	<1	0.6	1.4	0.9		
Bicarbonate		464	653	535	750	600	490	560		
BOD, 5-day		5	2	2	2	3	4	2		
Bromide		A	A	A	A	A	A	A		
Carbonate		72	18	A	0	0	0	0		
COD		21	36	36	20	21	56	29		
Chloride		15	19	21	28	28	16	15		
Color	(Pt-Co Units)	35	45	30	20	10	65	25		
Fluoride		0.9	1.1	1.0	0.4	0.6	0.8	1.0	0.7	0.34
Hardness, total ($CaCO_3$)		1307	1805	1668	2151	1984	1076	1647		
Nitrate (Nitrogen)		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0		
Nitrite (Nitrogen)		A	A	A	A	A	A	A		
Nitrogen, total Kjeldahl		<1	<1	<1	<1	2.7	3.6	6.1		
Oil & Grease		0.4	<1	<1	<1	5	<1	<1	<1	2
pH		8.3	8.3	8.2	7.6	8.0	7.9	7.7	8.1	8.2
Phosphorus, total		0.1	0.1	A	0.2	<0.1	<0.1	0.1		
Settleable Solids									15	15
Evaporated Solids, total	(105°C)	2968	4314	4376	6152	6060	2904	2760		
Total Dissolved Solids		2808	3920	3918	5486	5668	2166	2586	2978	3402
Total Suspended Solids		10	30	3	6	6	106	20	22	20
Total Volatile Solids		646	948	704	938	878	526	538		
Specific Conductance	(μmhos/cm@25°C)	310	420	435	5700	5714	2632	2941		
Sulfate		1486	2300	2519	3480	3252	1300	1531	1734	2066
Sulfide		A	A	A	/	A	A	A		
Temperature	(°C)	11	73	21	17	13	A	1	4	14
Turbidity	(JTU)	10	4.8	3.9	6.0	6.4	160	12	9.7	4.9
Aluminum	(PPB)	<10	<10	<10	<10	<10	A	A		
Cadmium	(PPB)	<5	8	10	<2	<2	<1	<1		
Calcium		148	175	115	180	170	158	168		
Chromium, total	(PPB)	<5	<5	12	13	<2	13	5		
Copper	(PPB)	11	12	10	<2	3	8	9		
Iron, total	(PPB)	35	32	42	46	60	740	43		0.14
Iron, dissolved									0.1	0.07
Magnesium		228	333	336	414	378	166	299		
Manganese	(PPB)	39	9	74	439	1030	269	117		
Mercury	(PPB)	3	4	2	.1	2	0.3	0.6		
Nickel	(PPB)	25	23	20	4	5	10	4		
Sodium		350	542	653	976	890	322	195		
Zinc	(PPB)	13	<5	8	7	5	21	12		

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

A = Absent

TABLE 17

LOCATION (CT&E) No, 8 — CT&E - MAIN SARPY CREEK JUST ABOVE PLEASANT CREEK

DATE		6-10-74	7- 9-74	8- 8-74	9- 9-74	10-23-74	11-27-74	12-27-74	2-25-75	3-31-75	5-29-75
ANALYSIS[a]											
Acidity to pH 8.2	(meq/l)	0.08	A	0.32	0.2	A	A	A	.42	A	A
Alkalinity to pH 4.5	(meq/l)	9.20	9.6	12.2	7.5	22	30	26	1.7	8.63	11.67
Alkalinity ($CaCO_3$)		460	480	610	528	660	694	710	85	436	584
Ammonia (Nitrogen)											
Bicarbonate											
BOD, 5-day											
Bromide											
Carbonate											
COD											
Chloride											
Color	(Pt-Co Units)										
Fluoride		0.32	1.15	1.15	0.90	1.00	0.65	.48	.17	.20	.44
Hardness, total ($CaCO_3$)											
Nitrate (Nitrogen)											
Nitrite (Nitrogen)											
Nitrogen, total Kjeldahl											
Oil & Grease		<1	<1	<1	<1	<1	4	3	5		<5
pH		8.0	8.2	7.3	7.7	7.7	7.7	7.6	7.0	8.0	8.1
Phosphorus, total											
Settleable Solids		9	A	3	<0.1[b]	0.2[b]	<0.1[b]	0.1[b]	<0.1[b]	0.1[b]	<0.1[b]
Evaporated Solids, total	(105°C)				1690	5348	5833	6172	360	2607	3553
Total Dissolved Solids		2617	3595	5838							
Total Suspended Solids		33	3	4	13	9	33	39	19	29	3
Total Volatile Solids											
Specific Conductance	(μmhos/cm@25°C)										
Sulfate		1549	2285	3000	2560	2700	3900	3750	288	1531	2042
Sulfide		12	6.6	4.5	5	2	2	2	36	15	<25
Temperature	(°C)										
Turbidity	(JTU)										
Aluminum	(PPB)										
Cadmium	(PPB)										
Calcium											
Chromium, total	(PPB)										
Copper	(PPB)										
Iron, total	(PPB)	0.53	0.37	0.37	1.60	0.40	1.2	.65	.43	.6	.5
Iron, dissolved		0.09	0	0.04	0.08	0.08	0.24	.02	A	.03	A
Magnesium											
Manganese	(PPB)										
Mercury	(PPB)										
Nickel	(PPB)										
Sodium											
Zinc	(PPB)										

TABLE 18

CHEMICAL ANALYSES OF SURFACE WATER COLLECTED AT CT&E LOCATION 1, January to October 1975

Location CT&E No. 1							
Date	1/24/75	4/25/75	6/30/75	7/31/75	8/25/75	9/18/75	10/31/75
ANALYSIS[a]							
Acidity to pH 8.2 (meq/L)	0	0	0.08	0	0	0	0
Alkalinity to pH 4.5 (meq/L)	6	9.58	10.96	11.46	12.34	9.76	8.78
Alkalinity ($CaCO_3$)	100	484	549	574	618	488	439
Fluoride	.13	.25	.38	.40	.38	..39	..37
Oil and Grease	2	0.1	< 5	< 5	< 5	< 5	< 5
pH	7.8	8.0	8.1	8.0	8.2	8.0	8.1
Settleable Solids[b]	< .1	< .1	< .1	< .1	< .1	< .1	< .1
Total Suspended Solids	5	1	0	2	4	1	4
Sulfate	575	1225	1680	1870	1645	1462	1025
Temperature		7°C	19°C	22°C	21°C	9°C	8°C
Turbidity	8	15	< 25	< 25	< 25	< 25	< 25
Iron, Total	.20	.50	.4	.56	.48	.6	.70
Iron, Dissolved	.01	0	.2	.08	.12	0	.08

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

From Dames and Moore, 1975, p. 26-32

TABLE 18

CHEMICAL ANALYSES OF SURFACE WATER COLLECTED AT CT&E LOCATION 3

Location CT&E No. 3							
Date	1/24/75	4/25/75	6/30/75	7/31/75	8/25/75	9/18/75	10/31/75
ANALYSIS[a]							
Acidity to pH 8.2 (meq/L)	0	0	0	Dry	Dry	Dry	Dry
Alkalinity to pH 4.5 (meq/L)	4	10.42	9.52				
Alkalinity ($CaCO_3$)	94	526	476				
Fluoride	.12	.18	.40				
Oil and Grease	3	< 5	< 5				
pH	7.0	8.0	8.0				
Settleable Solids[b]	0.1	< .1	< .1				
Total Suspended Solids	13	7	14				
Sulfate	10	788	825				
Temperature		5°C	17°C				
Turbidity	38	19	< 25				
Iron, Total	1.1	.48	.7				
Iron, Dissolved	0.05	.13	0				

[a]Units reported in parts per million unless otherwise indicated

[b]Analysis reported in parts per thousand

TABLE 18

CHEMICAL ANALYSES OF SURFACE WATER COLLECTED AT CT&E LOCATION: 4

Location CT&E No. 4							
Date	1/24/75	4/25/75	6/30/75	7/31/75	8/25/75	9/18/75	10/31/75
ANALYSIS[a]							
Acidity to pH 8.2 (meq/L)	0	0	0	Dry	Dry	Dry	Dry
Alkalinity to pH 4.5 (meq/L)	8	10.57	11.56				
Alkalinity ($CaCO_3$)	92	534	579				
Fluoride	.13	.30	.50				
Oil and Grease	3	8	< 5				
pH	7.4	8.1	8.1				
Settleable Solids[b]	< .1	< .1	< .1				
Total Suspended Solids	7	3	2				
Sulfate	163	863	1073				
Temperature		4°C	22°C				
Turbidity	27	16	25				
Iron, Total	.07	.60	.4				
Iron, Dissolved	.01	.08	0				

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

TABLE 18

CHEMICAL ANALYSES OF SURFACE WATER COLLECTED AT CT&E LOCATION 5

Location CT&E No. 5							
Date	1/24/75	4/25/75	6/30/75	7/31/75	8/25/75	9/18/75	10/31/75
ANALYSIS[a]							
Acidity to pH 8.2 (meq/L)	0	0	.08	0	Dry	Dry	0
Alkalinity to pH 4.5 (meq/L)	6	10.77	9.73	10.54			11.86
Alkalinity ($CaCO_3$)	80	5.44	487	528			594
Fluoride	.12	.32	.4	.38			.42
Oil and Grease	2	5	< 5	< 5			< 5
pH	7.3	8.1	8.0	8.1			8.2
Settleable Solids[b]	.03	< .1	< .1	< .1			< .1
Total Suspended Solids	16	2	7	9			8
Sulfate	175	1275	1470	1562			1842
Temperature		4°C	22°C				
Turbidity	34	13	< 25	< 25			< 25
Iron, Total	.04	.40	.3	.4			.6
Iron, Dissolved	0	.10	0	C			.08

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

TABLE 18

CHEMICAL ANALYSES OF SURFACE WATER COLLECTED AT CT&E LOCATION 6

Location CT&E No. 6								
Date	1/24/75	4/25/75	5/29/75	6/30/75	7/31/75	8/31/75	9/18/75	10/31/75
ANALYSIS[a]								
Acidity to pH 8.2 (meq/L)	0	0	0	0	Dry	Dry	Dry	0
Alkalinity to pH 4.5 (meq/L)	6	10.30	11.47	10.96				12.64
Alkalinity ($CaCO_3$)	92	520	574	549				633
Fluoride	.12	.28	.39	.40				.38
Oil and Grease	1	< 5	< 5	< 5				< 5
pH	7.3	8.3	8.0	8.2				8.1
Settleable Solids[b]	0.2	< .1	1.1	0.1				< 0.1
Total Suspended Solids	2	3	2	7				8
Sulfate	225	1550	1750	1680				1817
Temperature		4°C	16°C	19°C				7°C
Turbidity	37	23	< 25	< 25				< 25
Iron, Total	0.04	.70	.6	.6				.48
Iron, Dissolved	0	.15	0	0				.06

[a]Units reported in parts per million unless otherwise indicated

[b]Analysis reported in parts per thousand

TABLE 18

CHEMICAL ANALYSES OF SURFACE WATER COLLECTED AT CT&E LOCATION 7

Location CT&E No. 7							
Date	1/24/75	4/25/75	6/30/75	7/31/75	8/25/75	9/18/75	10/31/75
ANALYSIS[a]							
Acidity to pH 8.2 (meq/L)	0	0	0	0	0	0	0
Alkalinity to pH 4.5 (meq/L)	10	10.06	10.02	12.45	11.63	10.74	9.75
Alkalinity ($CaCO_3$)	104	508	502	623	582	538	487
Fluoride	.13	.30	.40	.38	.44	.40	.39
Oil and Grease	2	7.2	< 5	< 5	< 5	< 5	< 5
pH	7.6	8.2	8.2	8.1	8.0	8.1	8.2
Settleable Solids[b]	< .1	< .1	< .1	< .1	< .1	< .1	< .1
Total Suspended Solids	17	2	1	1	2	3	2
Sulfate	478	1475	1874	1925	1876	2074	1934
Temperature		3°C	21°C	22°C	25°C	10°C	7°C
Turbidity	8	23	< 25	< 25	< 25	< 25	< 25
Iron, Total	0	.74	.6	.70	.65	.62	.58
Iron, Dissolved	0	0	.1	.08	1.2	0	1.0

[a]Units reported in parts per million unless otherwise indicated

[b]Analysis reported in parts per thousand

TABLE 18

CHEMICAL ANALYSES OF SURFACE WATER COLLECTED AT CT&E LOCATION 8

Location CT&E No. 8							
Date	1/24/75	4/25/75	6/30/75	7/31/75	8/25/75	9/18/75	10/31/75
ANALYSIS[a]							
Acidity to pH 8.2 (meq/L)	0	0	0	Dry	Dry	Dry	0
Alkalinity to pH 4.5 (meq/L)	8	10.06	11.08				9.76
Alkalinity ($CaCO_3$)	84	508	555				488
Fluoride	.13	.30	.41				.38
Oil and Grease	1	8.5	< 5				< 5
pH	7.5	7.9	8.0				8.2
Settleable Solids[b]	.2	< .1	< .1				< .1
Total Suspended Solids	11	9	3				4
Sulfate	275	1550	1890				1760
Temperature		7°C	20°C				7°C
Turbidity	35	20	< 25				< 25
Iron, Total	.01	.55	.2				.4
Iron, Dissolved	0	.08	0				.06

[a]Units reported in parts per million unless otherwise indicated

[b]Analysis reported in parts per thousand

TABLE 19

CHEMICAL ANALYSES OF SURFACE WATER FROM GAGING STATIONS SW-1 THROUGH SW-7 IN THE PROJECT AREA

LOCATION[a]		SW-1 SARPY CREEK JUST ABOVE JUNCTION WITH EAST FORK SARPY CREEK				
DATE		3-21-75	4-13-75	5-6-75	5-7-75	7-22-75
TIME		1230	1300	2240	0610	1235
STAFF GAGE LEVEL		-	11.50	11.63	11.73	Dry
TYPE		Spring Runoff	Spring Runoff	Storm	Storm	Low Flow
ANALYSIS						
Calcium		26.0	130	127.5	120.75	109.44
Magnesium		26	202	262.0	239.0	425.00
Sodium		19	261	227.0	217.25	597.95
Potassium		7	10	14.61	13.40	29.48
Iron (total)		0.41	0.09	0.20	0.20	0.36
Manganese		0.03	0.15			0.02
Aluminum		3.6	0.15	2.2	1.1	0.20
Silica		7.2	12.5			
Bicarbonate		344	547	329.04	610.20	1001.70
Carbonate		0	0	0.0	0.0	46.47
Hydroxide		0	0	0.0	0.0	0.0
Chloride		7	26	15.04	15.29	12.40
Sulfate		81	1212	1211	1045.1	2369.93
Nitrate (NO3+NO2)				1.23	16.61	1.64
Fluoride		0.15	0.32	0.28	0.26	0.23
Ortho Phosphate		0.12	<0.01	0.04	0.04	0.12
Field pH	(no units)	7.73				
Lab pH	(no units)	6.3	8.3	8.15	6.12	7.5
Field Temperature	(°C)	4.05	6.0	6.7	7.6	23
Field Conductivity[c]	(μmhos/cm, ambient)	273	1780	1850	1800	4190
Lab Conductivity[c]	(μmhos/cm@25°C)	380	2552	2300	2250	3950
Total Suspended Solids		48	4	10.6	30.8	23
Total Dissolved Solids		331	2808			
Evaporated Solids	(105°C)			2379.1	2297.1	3876.1
Carbonate Hardness ($CaCO_3$)				433.5	500	866.74
Non-Carbonate Hardness ($CaCO_3$)				299.33	792	1374.30
Total Hardness ($CaCO_3$)		170	1150	134.17	1291.99	2241.04
Total Alkalinity ($CaCO_3$)		318	430	433.5	500	866.74
Sodium Adsorption Ratio	(no units)	0.72	3.3	3.18	2.61	5.78
Acidity ($CaCO_3$)		0	0	3.75	6.25	0
Zinc		0.05	0.03			0.06
Chromium				[illegible]	0.04	<0.02
Selenium		0.002	0.002	0.3	<0.02	<0.05
Mercury		<0.001	<0.001	0.002	<0.002	<0.0006
Nickel		<0.01	<0.01	0.10	0.08	<0.01
Arsenic		<0.01	<0.01	0.25	<0.25	<0.1
Boron		0.02	<0.01	1.06	1.06	1.80
Copper		<0.01	0.02			0.05
Cadmium					0.002	0.003
Strontium		<0.01	<0.01	5.0	5.0	2.3
Lead		<0.01	<0.01	0.2	0.1	<0.05
Vanadium		<0.01	<0.01	8.5	<0.5	<1.0
Molybdenum		<0.01	<0.01	<0.008	<0.005	<0.2
Cyanide		<0.1	<0.1			
Beryllium		<0.01	<0.01			
SPECIFIC SURFACE WATER PARAMETERS						
Field Dissolved Oxygen		10.2	11.1	6.0	8.1	
COD		36	25	32.4	[d]	28.0
BOD		4.2	1.0	6.6	7.2	2110
Depletion %		-	-	25.29	27.91	
Turbidity (NTU)		136	47	16.0	16.0	
Oil & Grease		4	3	0.07	0.02	-
Total Coliform (/100 ml)		310	0	30	130	<1.0
Fecal Coliform (/100 ml)		20	0	190	70	<1.0
Ammonia Nitrogen as N		0.4	0.4			
Organic Nitrogen as N		0.3	0.5			

[a] Location shown on hydrologic monitoring plate

[b] All analyses reported in mg/l unless otherwise indicated

[c] Conductivity refers to specific conductance

[d] Insufficient amount of sample available

LOCATION[a]		SW7 EAST FORK SARPY CREEK ABOVE JUNCTION WITH SARPY CREEK				
DATE		3-21-75	4-13-75	5-6-75	5-8-75	7-22-75
TIME		1350	1530	2315	1200	0100
STAFF GAGE LEVEL			9.71	10.16	10.77	
TYPE		Spring Runoff	Spring Runoff	Storm	Storm	Low Flow
ANALYSIS[b]						
Calcium		35	141	157.5	162	151.28
Magnesium		35	181	275.0	245.75	399.0
Sodium		30	185	323.75	305	371.42
Potassium		6	10	15.5	15.96	20.408
Iron (total)		0.16	0.14	0.36	0.36	0.36
Manganese		0.13	0.27	0.019		<0.02
Aluminum		3.5	0.17	1.1	1.4	8.55
Silica		6.4	12.5			
Bicarbonate		244	431	561.38	571.76	973.70
Carbonate		0	0	0	4.8	7.74
Hydroxide		0	0	0.0	0.0	0
Chloride		0	8	30.58	0	4.65
Sulfate		292	2354	1591.1	1620.6	1934.54
Nitrate (NO3+NO2)		0.19	0.06	0.89	1.55	1.55
Fluoride		0.14	0.47	0.25	0.2	0.33
Ortho Phosphate		0.06	<0.01	0.05	0.04	0
Field pH	(no units)	7.26				
Lab pH	(no units)	7.8	8.3	8.16	8.35	8.4
Field Temperature	(°C)	4.0	3.6	9.0	11.0	25
Field Conductivity[c]	(µmhos/cm, ambient)	352	1670	2310.0	2400	4320
Lab Conductivity[c]	(µmhos/cm@25°C)	498	2532	2600	2800	—
Total Suspended Solids		216	4	528.8	21.6	3.0
Total Dissolved Solids		408	2448			
Evaporated Solids	(105°C)		-	1865.1	2982	4366.9
Carbonate Hardness ($CaCO_3$)			-	460.0	450	810.78
Non-Carbonate Hardness ($CaCO_3$)			-	50.6	1056.89	1212.03
Total Hardness ($CaCO_3$)		230	1099	434.55	1506.89	2022.81
Total Alkalinity ($CaCO_3$)		118	534	460.0	450.0	810.78
Sodium Adsorption Ratio	(no units)	1.09	3.7	3.41	3.43	3.53
Acidity ($CaCO_3$)		0	8	5	25.0	80.14
Zinc		0.05	0.04	0.09	0.02	0.05
Chromium					<0.02	<0.02
Selenium		0.003	0.003	1.0	0.3	<0.05
Mercury		<0.001	<0.001	0.002	<0.002	<0.0002
Nickel		<0.01	<0.01	0.05	0.01	<0.01
Arsenic		<0.01	<0.01	<0.25	<0.25	<0.1
Boron		<0.01	0.01	1.26	0.75	1.11
Copper		<0.01	0.05	0.01	0.02	0.06
Cadmium			-		<0.002	<0.001
Strontium		<0.01	<0.01	10	6.6	2.8
Lead		<0.01	<0.01	0.5	8.5	<0.05
Vanadium		<0.01	<0.01	<0.5	<0.5	<0.1
Molybdenum		<0.01	<0.01	<0.005	<0.005	<0.2
Cyanide		<0.01	<0.01		-	
Beryllium		<0.01	<0.01			
SPECIFIC SURFACE WATER PARAMETERS						
Field Dissolved Oxygen		10.6	11.3	8.4	8.6	
COD		43	29			46.8
BOD		3.0	8.0	7.6	8.7	
Depletion %				39.21	35.37	1.8
Turbidity (NTU)		172	64	24	16	0.01
Oil & Grease		2	3			12.3
Total Coliform (/100 ml)		1180	0	130	130	<1
Fecal Coliform (/100 ml)		30	0	1030	210	
Ammonia Nitrogen as N		0.4	0.3			
Organic Nitrogen as N		0.5	1.2			

LOCATION[a]		SW3 SARPY CREEK ON R. THROWER PROPERTY		
DATE		3-21-75	4-13-75	5-7-75
TIME		1945	1555	0200
STAFF GAGE LEVEL		9.03	8.33	
TYPE		Spring Runoff	Spring Runoff	Storm
ANALYSIS[b]				
Calcium		23	83	43
Magnesium		17	35	47.25
Sodium		10	123	67.25
Potassium		6	10	12.81
Iron (total)		0.37	0.15	0.41
Manganese		<.01	0.54	0.06
Aluminum		3.4	0.17	1.1
Silica		6.8	13.4	
Bicarbonate		117	485	364.29
Carbonate		0	0	0.0
Hydroxide		0	0	0.0
Chloride		8	14	83.72
Sulfate		46	376	92.0
Nitrate (NO3+NO2)		0.15	0.05	0.74
Fluoride		0.09	0.41	0.2
Ortho Phosphate		0.14	<0.01	0.09
Field pH	(no units)	7.75		
Lab pH	(no units)	7.8	8.3	7.84
Field Temperature	(°C)	4.5	8.5	
Field Conductivity[c]	(µmhos/cm, ambient)	164	990	
Lab Conductivity[c]	(µmhos/cm@25°C)	205	1400	750
Total Suspended Solids		74	3	34.7
Total Dissolved Solids		162	930	
Evaporated Solids	(105°C)			864.4
Carbonate Hardness ($CaCO_3$)		.	.	298.5
Non-Carbonate Hardness ($CaCO_3$)		-		10.26
Total Hardness ($CaCO_3$)		128	330	308.76
Total Alkalinity ($CaCO_3$)		96	376	298.5
Sodium Adsorption Ratio	(no units)	0.39	2.9	1.68
Acidity ($CaCO_3$)		0	0	3.75
Zinc		0.03	0.01	0.05
Chromium				
Selenium		0.003	0.002	0.3
Mercury		<0.001	<0.001	<0.002
Nickel		<0.01	<0.01	0.16
Arsenic		<0.01	<0.01	<0.25
Boron		<0.01	<0.01	0.14
Copper		<0.01	0.02	0.01
Cadmium				
Strontium		<0.01	<0.01	2.7
Lead		<0.01	<0.01	0.1
Vanadium		<0.01	<0.01	0.5
Molybdenum		<0.01	<0.01	<0.008
Cyanide		<0.01	<0.01	
Beryllium		<0.01	<0.01	
SPECIFIC SURFACE WATER PARAMETERS				
Field Dissolved Oxygen		9.1	10.9	
COD		29	29	39.6
BOD		4.4	2.3	8.4
Depletion %				32.94
Turbidity (NTU)		137	51	65.0
Oil & Grease		1	<1	
Total Coliform (/100 ml)		8	30	410
Fecal Coliform (/100 ml)		2	6	2100
Ammonia Nitrogen as N		0.4	0.9	
Organic Nitrogen as N		0.3	0.3	

TABLE 19

LOCATION[a]	SW-4 EAST FORK SARPY CREEK AT COUNTY BRIDGE				
DATE	3-21-73	4-13-73	5-7-73	5-7-73	7-22-73
TIME	1730	2140	0030	0723	0830
STAFF GAGE LEVEL	-	0.06	9.22	8.97	
TYPE	Spring Runoff	Spring Runoff	Storm	Storm	Low Flow
ANALYSIS[b]					
Calcium	39	242	225.5	134.50	123.21
Magnesium	18	277	250.0	200.23	316.32
Sodium	23	216	232.5	291.00	323.98
Potassium	6	8	23.3	21.7	20.400
Iron (total)	0.39	0.15	0.36	0.20	0.357
Manganese	0.09	0.32	0.14	0.16	0.00
Aluminum	3.9	0.17	2.2	0.98	0.327
Silica	6.3	14.5			
Bicarbonate	125	325	588.232	360.018	903.645
Carbonate	0	0	0.0	0.0	0
Hydroxide	0	0	0.0	0.0	0
Chloride	4	13	22.333	7.765	0.06
Sulfate	81		1212.2	2022.12	1313.33
Nitrate (NO3+NO2)	0.27	0.27	1.05	16.61	2.719
Fluoride	0.10	0.48	0.2	<0.2	0.39.
Ortho Phosphate	0.09	<0.01	0.02	0.01	0
Field pH (no units)	-	-	-		
Lab pH (no units)	7.7	8.3	8.11	8.06	8.0
Field Temperature (°C)	3.0	5.0	8.0	6.7	19
Field Conductivity[c] (µmhos/cm, ambient)	223	1330	1960	1590	3000
Lab Conductivity[c] (µmhos/cm@25°C)	300	2320	2350	2000	2610
Total Suspended Solids	34	33	28	13.2	15
Total Dissolved Solids	242	2116	-		
Evaporated Solids (105°C)			2773.50	2090.6	3095.8
Carbonate Hardness ($CaCO_3$)			482.0	295.0	740.46
Non-Carbonate Hardness ($CaCO_3$)			352.9	903.75	871.843
Total Hardness ($CaCO_3$)	151	1083	129.09	1198.73	1612.305
Total Alkalinity ($CaCO_3$)	102	406	482.0	295.0	740.46
Sodium Adsorption Ratio (no units)	0.82	2.9	3.16	2.66	3.31
Acidity ($CaCO_3$)	0	0	7.3	6.23	81.84
Zinc	<0.01	0.09	0.05	0.04	0.02
Chromium					
Selenium	0.003	0.002	0.3	<0.3	<0.05
Mercury	<0.001	<0.001	0.0016	<0.0016	<0.004
Nickel	<0.01	<0.01	0.07	0.03	0.01
Arsenic	<0.01	<0.01	0.25	<0.25	<0.1
Boron	<0.01	0.13	0.72	0.827	0.868
Copper	<0.01	0.02	0.01	0.02	0.02
Cadmium					
Strontium	<0.01	<0.01	20	8.0	1.9
Lead	<0.01	<0.01	0.2	0.2	<0.05
Vanadium	<0.01	<0.01	0.3	<0.3	<1.0
Molybdenum	<0.01	<0.01	<0.005	<0.005	<0.2
Cyanide	<0.01	<0.01			
Beryllium	<0.01	<0.01			
SPECIFIC SURFACE WATER PARAMETERS					
Field Dissolved Oxygen	10.7	10.2	8.8	8.2	
COD	30	23	18.0	39.8	4.0
BOD	3.7	2.6	8.8	6.3	19.2
Depletion %	-	-	25.39	24.14	
Turbidity (NTU)	120	73	20.0	2.2	1.0
Oil & Grease	1	<1			<1
Total Coliform (/100 ml)	60	0	70	240	390
Fecal Coliform (/100 ml)	36	0	300	370	110
Ammonia Nitrogen as N	0.4	0.3			
Organic Nitrogen as N	0.6	0.7			

LOCATION[a]		SW-3 PLEASANT CREEK			
DATE		3-21-75	4-13-75	5-7-75	7-22-75
TIME		1045	1010	1830	0925
STAFF GAGE LEVEL		2.22	2.22	2.25	
TYPE		Spring Runoff	Spring Runoff	Storm	
ANALYSIS[b]					
Calcium		99	73	89.50	100.00
Magnesium		258	143	287.50	354.08
Sodium		194	147	178.75	261.48
Potassium		8	7	15.72	16.51
Iron (total)		0.06	0.13	0.36	0.36
Manganese		0.12	0.11		<0.02
Aluminum		3.2	0.18	1.0	0.17
Silica		5.6	9.1		
Bicarbonate		681	408	600.44	1012.26
Carbonate		0	0	28.8	0
Hydroxide		0	0	0.0	0
Chloride		30	20	0.0	12.40
Sulfate		1199	751	1076.8	1371.30
Nitrate (NO3+NO2)		0.04	0.03	1.29	1.79
Fluoride		0.22	0.44	<0.2	0.25
Ortho Phosphate		<0.01	<0.01	0.05	0.02
Field pH	(no units)	-	-	-	
Lab pH	(no units)	8.2	8.3	8.57	8.1
Field Temperature	(°C)	5.3	2.6	13.5	21
Field Conductivity[c]	(µmhos/cm, ambient)	1820	1050	2240	2890
Lab Conductivity[c]	(µmhos/cm@25°C)	1950	1740	2400	2450
Total Suspended Solids		2	5	1.7	
Total Dissolved Solids		2460	1486		
Evaporated Solids	(105°C)	-		2251	3095.7
Carbonate Hardness ($CaCO_3$)		-		540.0	1709.09
Non-Carbonate Hardness ($CaCO_3$)		-		873.26	
Total Hardness ($CaCO_3$)		1308	769	1413.26	
Total Alkalinity ($CaCO_3$)		558	318	540.0	829.43
Sodium Adsorption Ratio	(no units)	2.33	2.3	2.26	2.75
Acidity ($CaCO_3$)		0	0	0	10.23
Zinc		<0.01	0.08	0.02	0.02
Chromium					<0.02
Selenium		0.007	0.002	0.3	<0.05
Mercury		0.002	<0.001	<0.0008	<0.0004
Nickel		<0.01	<0.01	0.07	<0.01
Arsenic		<0.01	<0.01	<0.25	<0.1
Boron		0.31	<0.01	1.02	1.35
Copper		<0.01	0.02	<0.01	0.05
Cadmium					<0.002
Strontium		<0.01	<0.01	7.00	1.8
Lead		<0.01	<0.01	0.2	0.09
Vanadium		<0.01	<0.01	<0.5	<1.0
Molybdenum		<0.01	<0.01	<0.005	<0.2
Cyanide		<0.1	<0.01		
Beryllium		<0.01	<0.01		
SPECIFIC SURFACE WATER PARAMETERS					
Field Dissolved Oxygen		12.4	12.2	9.3	
COD		10	14	39.6	16.0
BOD		0.8	2.6	11.1	21.8
Depletion %				42.53	
Turbidity (NTU)		12	39	2.3	8.0
Oil & Grease		2	1	8	0.06
Total Coliform (/100 ml)		<1	2	800	90
Fecal Coliform (/100 ml)		<1	0	140	<1.0
Ammonia Nitrogen as N		0.2	0.2		
Organic Nitrogen as N		1.3	0.6		

LOCATION[a]		SW-6 PLUM CREEK		
DATE		3-21-75	4-13-75	5-7-75
TIME		1025	1745	1950
STAFF GAGE LEVEL			9.56	
TYPE		Spring Runoff	Spring Runoff	Storm
ANALYSIS[b]				
Calcium		21.0	13	98.25
Magnesium		15	7	47.25
Sodium		16	15	34.75
Potassium		6	4	11.93
Iron (total)		0.12	0.82	0.36
Manganese		<0.01	0.06	0.50
Aluminum		2.8	0.51	0.99
Silica		7.2	12.0	
Bicarbonate		100	52	370.39
Carbonate		0	0	0
Hydroxide		0	0	0
Chloride		5	6	-3.00
Sulfate		57	45	211.06
Nitrate (NO3+NO2)		0.15	0.08	0.67
Fluoride		0.14	0.40	<0.2
Ortho Phosphate		0.07	0.09	0.1
Field pH	(no units)			
Lab pH	(no units)	7.8	7.7	7.83
Field Temperature	(°C)	1.7	4.0	
Field Conductivity[c]	(µhos/cm, ambient)	155	113	
Lab Conductivity[c]	(µmhos/cm@25°C)	235	203	930
Total Suspended Solids		131	507	2.7
Total Dissolved Solids		176	162	
Evaporated Solids	(105°C)	-		752.0
Carbonate Hardness ($CaCO_3$)		-		305.0
Non-Carbonate Hardness ($CaCO_3$)		-		141.24
Total Hardness ($CaCO_3$)		112	59	446.23
Total Alkalinity ($CaCO_3$)		82	38	305.0
Sodium Adsorption Ratio	(no units)	0.65	0.8	0.72
Acidity ($CaCO_3$)		0	0	25.0
Zinc		<0.01	0.05	0.04
Chromium				<0.05
Selenium		0.003	0.003	0.5
Mercury		<0.001	<0.001	<0.002
Nickel		<0.01	<0.01	<0.03
Arsenic		<0.01	<0.01	<0.25
Boron		<0.01	<0.01	0.25
Copper		<0.01	0.02	<0.01
Cadmium				<0.01
Strontium		<0.01	<0.01	2.4
Lead		<0.01	<0.01	0.2
Vanadium		<0.01	<0.01	0.5
Molybdenum		<0.01	<0.01	<0.009
Cyanide		<0.1	<0.1	
Beryllium		<0.01	<0.01	
SPECIFIC SURFACE WATER PARAMETERS				
Field Dissolved Oxygen		8.8	10.1	
COD		34	42	46.8
BOD		4.8	3.8	11.7
Depletion %				46.99
Turbidity (NTU)		233	480	21
Oil & Grease		1	2	
Total Coliform (/100 ml)		2340	0	320
Fecal Coliform (/100 ml)		20	6	5.
Ammonia Nitrogen as N		0.4	0.3	
Organic Nitrogen as N		0.6	1.1	

LOCATION[a]		SW-7 SPRING CREEK (TRACT 3)				
DATE		3-21-75	4-13-75	5-6-75	5-7-75	7-22-75
TIME		1945	1300	2310	0715	1015
STAFF GAGE LEVEL		-	11.79	11.80	11.77	Dry
TYPE		Spring Runoff	Spring Runoff	Storm	Storm	Low flow
ANALYSIS[b]						
Calcium		80	115	118.25	134.5	118.88
Magnesium		87	114	134.25	155.75	172.70
Sodium		43	66	58.25	58.25	70.92
Potassium		8	8	11.7	10.4	11.51
Iron (total)		0.56	0.11	0.2	0.50	0.34
Manganese		0.89	0.92	0.74	0.98	0.16
Aluminum		5.6	0.17	1.0	2.9	0.19
Silica		12.0	19.0			[illegible]
Bicarbonate		368	475	511.96	497.92	822.24
Carbonate		0	0	0	0	0
Hydroxide		0	0	0	0	0
Chloride		36	12	6.31	5.58	0
Sulfate		286	502	484.01	891.48	490.71
Nitrate (NO3+NO2)		0.12	0.04	7.88	18.34	1.55
Fluoride		0.23	0.89	0.36	0.4	0.64
Ortho Phosphate		0.02	0.02	0.03	0.03	0.05
Field pH	(no units)	7.40				
Lab pH	(no units)	7.2	8.3	7.72	7.61	7.9
Field Temperature	(°C)	4.0	12.8	6.80		19
Field Conductivity[c]	(µmhos/cm, ambient)	730	1180	1060		1460.0
Lab Conductivity[c]	(µmhos/cm@25°C)	805	1450	1300	1400	1220.0
Total Suspended Solids		12	6	12.7	15	3.0
Total Dissolved Solids		788	1172			
Evaporated Solids	(105°C)			1308	1254.3	1285.2
Carbonate Hardness ($CaCO_3$)				419.5	408.0	73.73
Non-Carbonate Hardness ($CaCO_3$)				165.5	587.94	334.8
Total Hardness ($CaCO_3$)		560	755	254.0	995.94	1008.53
Total Alkalinity ($CaCO_3$)		302	370	419.5	408.0	673.73
Sodium Adsorption Ratio	(no units)	0.79	1.0	1.07	0.81	0.97
Acidity ($CaCO_3$)		0	0	7.5	6.25	141.52
Zinc		<0.01	0.01	0.04	0.05	0.02
Chromium					<0.02	<0.02
Selenium		0.006	0.002	0.5	0.3	<0.05
Mercury		0.002	<0.001	<0.002	<0.002	<0.0004
Nickel		<0.01	<0.01	0.06	0.08	<0.01
Arsenic		<0.01	<0.01	<0.25	<0.25	<0.1
Boron		0.18	<0.01	1.38	1.0	1.35
Copper		<0.01	0.02	0.01	0.01	0.02
Cadmium					<0.002	<0.008
Strontium		<0.01	<0.01	5.5	5.0	1.2
Lead		<0.01	<0.01	0.2	0.2	<0.05
Vanadium		<0.01	<0.01	<0.5	<0.5	<1.0
Molybdenum		<0.01	<0.01	<0.005	<0.005	<0.2
Cyanide		<0.1	<0.01			
Beryllium		<0.01	<0.01			
SPECIFIC SURFACE WATER PARAMETERS						
Field Dissolved Oxygen		6.8	9.7	6.8		
COD		33	12	39.6	7.2	12.0
BOD		1.7	1.6	7.2	17.4	12.0
Depletion %				28.24	33.33	
Turbidity (NTU)		49	44	8.0	6.0	4.7
Oil & Grease		<1	<1			
Total Coliform (/100 ml)		12	2	100	10	240
Fecal Coliform (/100 ml)		2	0	100	30	90
Ammonia Nitrogen as N		0.3	0.2			
Organic Nitrogen as N		1.7	0.7			

LOCATION[a]		SW-3A SARPY CREEK JUST ABOVE JUNCTION WITH SPRING CREEK (TRACT 3)	
DATE		5-7-73	5-7-73
TIME		0243	0810
STAFF GAGE LEVEL		14.01	14.04
TYPE		Storm	Storm
ANALYSIS[b]			
Calcium		80.0	78.25
Magnesium		138.25	138.25
Sodium		137.0	125.0
Potassium		11.92	11.8
Iron (total)		0.36	0.2
Manganese		0.13	0.07
Aluminum		2.1	2.1
Silica			
Bicarbonate		332.71	344.30
Carbonate		0	0
Hydroxide		0	0
Chloride		7.77	10.43
Sulfate		333.5	334.63
Nitrate (NO3+NO2)		10.37	12.05
Fluoride		<0.2	<0.2
Ortho Phosphate		0.05	0.06
Field pH	(no units)		
Lab pH	(no units)	8.02	8.09
Field Temperature	(°C)		7.0
Field Conductivity[c]	(µmhos/cm, ambient)		1130
Lab Conductivity[c]	(µmhos/cm@25°C)	1500	1400
Total Suspended Solids		23.4	35.6
Total Dissolved Solids			
Evaporated Solids	(105°C)	1275.4	1286.3
Carbonate Hardness ($CaCO_3$)		436.5	446.0
Non-Carbonate Hardness ($CaCO_3$)		344.82	322.99
Total Hardness ($CaCO_3$)		781.33	768.99
Total Alkalinity ($CaCO_3$)		436.5	446.0
Sodium Adsorption Ratio	(no units)	2.29	1.98
Acidity ($CaCO_3$)		3.75	7.50
Zinc		0.05	0.04
Chromium			<0.02
Selenium		0.3	0.6
Mercury		<0.002	<0.002
Nickel		0.03	0.07
Arsenic		<0.25	<0.25
Boron		1.14	1.06
Copper		<0.10	0.10
Cadmium			
Strontium		5.1	4.7
Lead		0.1	0.1
Vanadium		<0.5	0.3
Molybdenum		<0.005	<0.005
Cyanide			
Beryllium			
SPECIFIC SURFACE WATER PARAMETERS			
Field Dissolved Oxygen		8.1	8.1
COD		43.2	75.6
BOD		7.5	8.1
Depletion %		28.74	31.03
Turbidity (NTU)		12.0	0.4
Oil & Grease			
Total Coliform (/100 ml)		90	60
Fecal Coliform (/100 ml)		210	80
Ammonia Nitrogen as N			
Organic Nitrogen as N			

TABLE 20

CHEMICAL ANALYSES OF SURFACE WATER FROM GAGING STATIONS,
November, 1975

LOCATION	SW-1	SW-2	SW-4	SW-5
DATE	11/13/75	11/13/75	11/13/75	11/13/75
TIME	5:00 pm	5:25 pm	6:25 pm	4:30 pm
STAFF GAGE LEVEL				
TYPE				
ANALYSIS[a]				
Calcium	222.19	228.57	156.38	71.43
Magnesium	288.78	316.07	338.27	355.61
Sodium	913.27	466.84	255.10	200.77
Potassium	54.40	36.20	16.72	13.08
Iron (total)	0.26	0.38	-0.05	0.11
Manganese	0.49	0.85	0.34	-0.02
Aluminum	0.23	0.16	0.16	0.05
Silica				
Bicarbonate	1999.02	1326.57	1229.55	1127.65
Carbonate				16.20
Hydroxide				
Chloride	26.79	11.66	8.19	15.13
Sulfate	1853.89	1902.28	1300.22	1103.89
Nitrate (NO3+NO2)	0.14	0.08	0.34	0.43
Fluoride	0.52	0.38	0.28	0.22
Ortho Phosphate	0.036	0.009	0.018	0.009
Field pH (no units)				
Lab pH (no units)	7.8	8.2	8.3	8.4
Field Temperature (°C)	3.0	1.0	3.5	2.0
Field Conductivity[c] (mhos/Cm, ambient	4000.0	2100.0	1700.0	1450.0
Lab Conductivity (mhos/cm@25°C)	6660.0	3640.0	2770.0	2500.0
Total Suspended Solids	25.12	5.01	15.18	5.79
Total Dissolved Solids				
Evaporated Solids (105oC)	7001.5	3684.8	2649.3	2242.9
Carbonate Hardness ($CaCO_3$)	1638.0	1087.0	1007.5	951.0
Non-Carbonate Hardness ($CaCO_3$)	124.1	792.7	781.0	695.6
Total Hardness ($CaCO_3$)	1762.1	1879.7	1788.5	1646.6
Total Alkalinity ($CaCO_3$)	1638.0	1087.0	1007.5	951.0
Sodium Adsorption Ratio (no units)	9.52	4.7	2.63	2.16
Acidity ($CaCO_3$)	0	0	0	0
Zinc	0.05	0.04	0.01	0.02
Chromium	-0.02	-0.02	-0.02	-0.02
Selenium	-0.005	-0.005	-0.005	-0.005
Mercury	-0.2	-0.2	-0.2	-0.2
Nickel	-0.2	-0.02	-0.02	-0.02
Arsenic	-0.02	-0.02	-0.02	-0.02
Boron		0.64	0.28	0.71
Copper	0.01	0.04	0.05	0.04
Cadmium	0.003	-0.002	-0.002	-0.002
Strontium	13.92	4.23	3.67	3.57
Lead	0.43	0.31	0.08	0.68
Vanadium	-1.0	-1.0	-1.0	-1.0
Molybdenum	0.20	0.16	0.17	0.13
Cyanide				
Beryllium				
SPECIFIC SURFACE WATER PARAMETERS				
Field Dissolved Oxygen				
COD	14.4	17.3	20.2	11.15
BOD	5.62	1.80	2.44	2.80
Depletion %				
Turbidity (WTU)	11.0	1.7	7.0	1.5
Oil & Grease	17.87	78.6	33.75	14.9
Total Coliform (/100 ml)		110	70	100
Fecal Coliform (/100 ml)		1	1	48
Amonia Nitrogen as N				
Organic Nigrogen as N				

[a] Units reported in parts per million unless otherwise indicated

From Dames and Moore, 1975, p.22

TABLE 21

CHEMICAL ANALYSES OF SEDIMENT POND WATER ON TRACT III from February 1974 to October 1975

Sheet 1 of 3

DATE		2/20/74	3/15/74	4/10/74	5/8/74	6/10/74	7/9/74	8/8/74	8/28/74	8/30/74	9/9/74
ANALYSIS[a]											
Acidity to pH 8.2		0.11	0.05	0.5	0.72	0.04	0	0			
Alkalinity to pH 4.5		3.6	3.3	5.2	4.6	4.00	4.6	4.8			5.8
Alkalinity ($CaCO_3$)		180	165		230	200	230	240			196
Bicarbonate											
BOD, 5-day					8	4	1	2	-1	-1	1
Bromide											
Carbonate											
COD											
Chloride		11									
Color											
Coliform Bacteria, total											
Fluoride		0.8	0.35	0.8	0.50	0.58	0.70	0.85			0.90
Hardness, total ($CACO_3$)											
Nitrate (nitrogen)											
Nitrite (nitrogen)											
Nitrogen, total Kjeldahl											
Oil & grease		2	2	-1	-1	-1	-1				-1
pH		7.4	7.8	8.1	8.3	7.8	8.1	8.4	8.2	8.1	8.4
Phosphorus, total											
Seattleable solids		11	6	6	4	69	25	5			-0.1[b]
Evaporated solids, total (105°C)											
Total dissolved solids (180°C)		724	498	904	916	778	933	950			1096
Total suspended solids		20	12	19	6	84	40	6			4
Total volatile solids											
Specific Conductance (μmhos/cm@25°C)											
Sulfate		361	248	407	414	420	448	480			340
Sulfide											
Temperature	(°C)										8
Turbidity	(JTU)		9.0	8.4	4.5	25	15	4			-5
Aluminum	(PPB)										
Cromium	(PPB)										
Calcium											
Chromium, total	(PPB)										
Copper	(PPB)										
Iron, total	(PPB)	0.20			0.14	1.10	0.62	0.13			0.20
Iron, dissolved		0.17	0.22	0.2	0.09	0.40	0	0.09			0.06
Magnesium		60									
Manganese	(PPB)										
Mercury	(PPB)										
Nickel	(PPB)										
Sodium		41									
Zinc	(PPB)										

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

From Dames and Moore, 1975, p. 23-25

TABLE 21

DATE	10/23/74	11/1/74	11/27/74	12/27/74	1/24/75	2/75	3/75	4/1/75	4/25/75	5/29/75
ANALYSIS[a]										
Acidity to pH 8.2	0		0	0	0	..16	.04	0.08		.04
Alkalinity to pH 4.5	16		6	12	4	2.56	2.34	2.38	4.28	.456
Alkalinity ($CaCO_3$)	270		202	242	84	128	118	120	216	228
Bicarbonate										
BOD, 5-day	5		0	1				2		
Bromide										
Carbonate										
COD										
Chloride										
Color										
Coliform Bacteria, total										
Fluoride	0.75		0.91	..67	.15	.25	.03	.05	.25	NA
Hardness, total ($CACO_3$)										
Nitrate (nitrogen)										
Nitrite (nitrogen)										
Nitrogen, total Kjeldahl										
Oil & grease	-1		2	-1.0	-1.0	9	5	1	9.0	< 5
pH	8.1	8.0	7.5	8.0	7.5	7.8	7.9	7.5	8.0	8.2
Phosphorus, total										
Seattleable solids	-0.1[b]	-0.1[b]	-0.1[b]	-0.1[b]	-0.1[b]	< .1	1	63	-0.1[b]	< .1
Evaporated solids, total (105°C)										
Total dissolved solids (180°C)		887	429	974	221			392	757	
Total suspended solids	8	19	4	14	7	.34	126	89	20	7
Total volatile solids										
Specific Conductance (μmhos/cm@25°C)										
Sulfate	575		325	538	125	250	156	154	363	NA
Sulfide										
Temperature (°C)	10		0	0	0	0	0		7	17
Turbidity (JTU)	2		2	1	142	141	45	48	19	< 25
Aluminum (PPB)										
Cromium (PPB)										
Calcium										
Chromium, total (PPB)										
Copper (PPB)										
Iron, total (PPB)	0.43		0.9	.75	0	1.40	2.1	0.2	..10	.30
Iron, dissolved	0.08		0.14	0	0	0	.04	0.1	0	0
Magnesium										
Manganese (PPB)										
Mercury (PPB)										
Nickel (PPB)										
Sodium										
Zinc (PPB)										

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

TABLE 21

DATE	6/30/75	7/22/75	7/31/75	8/25/75	9/18/75	10/1/75	10/31/75	Intake to Sediment Pond 7/22/75	Intake to Sediment Pond 10/1/75
ANALYSIS[a]									
Acidity to pH 8.2	0		.06	0	0		0		
Alkalinity to pH 4.5	4.34		4.06	4.60	4.56		4.24		
Alkalinity ($CaCO_3$)	217	220.27	203	230	228	251.5	212	597.68	493.5
Bicarbonate		4.004				226.99		11.954	468.38
BOD, 5-day									
Bromide									
Carbonate		0.402				9.00			3.30
COD									
Chloride		1.542				8.70		6.168	11.47
Color									
Coliform Bacteria, total									
Fluoride	.80	0.500	.55	.60	.45	0.68	.52	1.08	1.48
Hardness, total ($CACO_3$)		657.041				687.9			
Nitrate (nitrogen)		2.653				0.58		2.259	0.76
Nitrite (nitrogen)									
Nitrogen, total Kjeldahl									
Oil & grease	< 5		< 5	< 5	< 5		< 5		
pH	8.2	8.6	8.4	8.0	8.1	8.5	8.2	7.9	8.3
Phosphorus, total									
Seattleable solids	< .1		< .1	< .1	< .1		< .1		
Evaporated solids, total (105°C)		1011.5				110.8		1671.6	498
Total dissolved solids (180°C)									
Total suspended solids	3	18	9	4	7	104.6	6	4	7
Total volatile solids									
Specific Conductance (µmhos/cm@25°C)		1320.00				1700		1850.0	2500
Sulfate	124	514.704	210	176	183	616.67	156	742.634	923.65
Sulfide									
Temperature (°C)	13	25.25	19	13	17		10	23.5	25
Turbidity (JTU)	< 25		< 25	< 25	< 25		< 25		
Aluminum (PPB)		0.215				−0.10		0.353	0.39
Cromium (PPB)		0.031				−0.002		0.031	−0.002
Calcium		81.125				122.96		189.284	269.90
Chromium, total (PPB)	.2		.25	.15	.20	−0.02	.18	0.143	−0.02
Copper (PPB)	0	0.051	0	0	0	0.02	.06	0.01	0.02
Iron, total (PPB)		0.357				0.33		0.354	0.34
Iron, dissolved									
Magnesium		109.949				92.35		158.652	140.82
Manganese (PPB)		< 0.05				0.02		0.112	−0.02
Mercury (PPB)		< 0.4				−0.2		−0.4	−0.2
Nickel (PPB)		< 0.01				−0.02		−0.01	0.07
Sodium		47.449				72.76		93.367	82.65
Zinc (PPB)		0.061				0.06		0.061	0.07

[a] Units reported in parts per million unless otherwise indicated

[b] Analysis reported in parts per thousand

TABLE 22

SUSPENDED SEDIMENT CONCENTRATIONS,
BIGHORN AND YELLOWSTONE RIVERS[a]

1965-1973

Station Location	Suspended Sediment Concentration (mg/l)
Bighorn River at Bighorn, Montana	
maximum value	21,000
minimum value	42
average value	4,088
Yellowstone River near Sidney, Montana	
maximum value	15,500
minimum value	167
average value	2,308

[a]Data from Northern Great Plains Resource Program, 1975, p. 89

TABLE 23

STREAMFLOW AND SUSPENDED SEDIMENT CONCENTRATIONS ON SARPY CREEK AS RECORDED BY U.S. GEOLOGICAL SURVEY[a]

Station Location	Streamflow (cfs)	Total Suspended Sediment (mg/1)
Westmoreland		
1-18-74	25.9	190.0
1-31-74	0.0	5.0
3-19-74	1.0	6.0
Hysham		
12-27-73	2.8	6.0
2-9-74	3.7	9.5
4-17-74	3.2	14.0
6-11-74	30.2	159.0

[a]Data reported by Montana State Dept. of Natural Resources and Conservation, 1974.

From Westmoreland Resources, 1975 1, p. 2.2.3-59

TABLE 24

SUSPENDED SEDIMENT CONCENTRATIONS (MG/L) DETERMINED AT SURFACE WATER STATIONS SW-1 THROUGH SW-7 IN THE PROJECT AREA (TIME OF SAMPLING LISTED WITH CONCENTRATIONS IN PARENTHESES)

	Station Location[a]						
Date	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7
3-13-75		(14:00) 191.1				(17:45) 585.8	
3-14-75		(17:45) 461.7		(20:05) 423.4			
3-15-75		(14:00) 1593.9					
3-21-75	(01:45) 115.8	(16:20) 26.9	(17:00) 55.1	(18:10) 125.5			(20:03) 239.0
	(13:45) 212.9						
4-13-75	(13:15) 35.5		(16:00) 226.6	(11:35) 495.7	(10:00) 230.9		(15:20) 112.8
4-15-75				(13:30) 207.0			
5-6-75	(23:45) 405.2	(23:30) 2010.6					(23:00) 230.0
5-7-75	(01:45) 417.9	(01:50) 569.6	(03:25) 402.1	(00:30) 305.5	(18:30) 537.1	(18:57) 234.2	(01:00) 209.0
	(03:10) 700.5	(03:20) 460.5	(06:45) 209.7	(02:35) 559.8			(02:20) 199.5
	(06:00) 465.2	(05:45) 893.4		(04:20) 419.4			
	(16:10) 569.5	(16:00) 633.4		(07:25) 369.4			
5-8-75		(12:00) 596.5					

[a]All station locations are in the Sarpy Creek drainage basin except SW-6 which is in the Tullock Creek drainage basin.

From Westmoreland Resources, 1975 1, p. 2.2.3-60

TABLE 25

WELL DATA FOR THE PROJECT AREA

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (μmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
1	1N36E23	80		3150	5-75	1620	9.5	H,S	Tfu	4500
2	1N36E23	80		3160		2040	12	S	Tfu	9000
3	1N36E14	80		3400				U	Tfu	
4	1N36E23	80		3430				S	Tfu	6000
5	1N36E14	100		3530		1450		S	Tfu	3600
6	1N36E14	130		3520		2040		S	Tfu	9000
7	1N36E2	130		3640				S	Tfu	6000

[a]Well number indexed to locations and shown on Plate 2.2.3-3. Information for numbers greater than 200 generally from Van Voast and Hedges, 1974.

[b]Whole numbers only--reported; whole numbers and tenths--measured.

[c]Estimated from U.S. Geological Survey 7.5 minute topographic maps. Reference in feet relative to mean sea level.

[d]Specific conductance measured in field unless otherwise noted (L indicates laboratory measurement) at 25°C.

[e]C - commercial or industrial; H - domestic; S - stock; U - unused; M - observation monitoring well.

[f]Source: Q - Quaternary alluvium or slope wash; Ttr1 - Tongue River member above Rosebud-McKay Coal; Ttr2 - Tongue River member between Rosebud-McKay Coal and Robinson Coal; Ttr3 - Tongue River member to about 100' below Robinson Coal; rmcl - Rosebud-McKay clinker; rmc - Rosebud McKay Coal; rcl - Robinson clinker; rc - Robinson Coal; Tfu - undifferentiated Fort Union formation; HC - Hell Creek formation; MC - Mission canyon member of the Madison formation.

[g]Information derived from landowners.

From Westmoreland Resources, 1975, Appendix F

TABLE 25

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (μmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
9	1N36E28	30		3190		1990	18	U	Q	
10	1N36E29	150	6	3150	5-75	1600	12.5	S	Tfu	9000
11	1N36E21	120	25.4	3360	5-75	1990	15		Tfu	6000
18	1N37E20	100		3630				S	Tfu	360
22	1N36E25	100		3430				S	Tfu	
25	1N36E36	200		3510				S	Tfu	3150
27	1N37E16	160		3300				C	Tfu	
28	2N36E17	60		3160		1350	13	H,S	Tfu	840
29	1N35E24	40		3110	5-75	1225	15	H,S	Q	600
30	1N35E24	≈500	Art	3090				S	HC	3200
32	1N36E18	80		3150				S	Tfu/HC	15000
33	1N36E17	80		3210				S	Tfu	15000
34	1N36E16	80		3285				S	Tfu/Q	15000
35	1N36E5	320		3420				S	Tfu/HC	15000
36	2N36E29	320		3260				S	Tfu/HC	15000
37	2N36E27	110		3195				S	Tfu	15000
38	2N36E22	280		3280				S	Tfu/HC	15000
40	2N36E32	100		3405				S	Tfu	4200
42	2N35E36	70		3025		2600	13	H,S	Q	3440
43	2N35E24	125		3010				H,S	Q/Tfu	1230
44	2N35E24	50		3020				S	Q	
45	2N36E16	150		3140				S	Tfu	
46	2N36E21	75		3200				S	Tfu	300
48	2N36E15	145		3295				S	Tfu	410
49	2N36E16			3120				S		
50	2N36E16			3110				S		
51	2N36E28			3240				S		
52	2N36E26			3340				S		

TABLE 25

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (μmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
53	1N36E19			3220				S		
54	1N36E30			3240						
55	1N36E28			3225						
56	1N36E34			3235						
57	1S36E2			3395						
58	1S36E10			3440						
59	1N36E31			3140						
60	2N38E15			3500						
61	2N38E8			3365						
62	2N37E9			3168						
63	2N37E17			3140						
64	1N37E23			3440						
65	1S38E8			3510						
66	1S38E18			3690						
67	1S38E13			3800						
68	1S38E24			3710						
69	1S38E15			3570						
70	1S37E9			3460						
71	1S36E23			3240						
72	2N38E20			3420						
73	1S35E6			3245						
100	1N38E22			3440						
101	1N38E22			3375						
102	1N38E17			3440						
103	1N38E17			3350						
104	1N38E8			3620						
105	2N38E34			3205						
106	2N38E15			3540						

TABLE 25

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (μmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
107	2N38E7			3300						
108	2N38E18			3300						
109	2N38E18			3280						
110	2N37E13			3280						
111	2N37E12			3300						
112	2N37E14			3245						
113	2N37E11			3240						
114	2N37E14			3220						
115	2N37E14			3180						
116	2N37E15			3240						
117	2N37E10			3240						
118	2N37E16			3110						
119	2N37E16			3170						
120	1N37E27DAAC	139	Dry	3520				M	Ttr3	
121	1N37E27DAAC	69	Dry	3520				M	rc	
122	1N37E23ACCA	282	197	3530	8/14/75	2120L	14	M	Ttr3	
123	1N37E23ACCA	88	130.5	3530	8/14/75	5100L	12.8	M	rc	
124	1N37E23ACCA	100	75	3530	8/14/75	1700L	12.8	M	rmc	
125	1N37E11DBAA	304	263	3530				M	Ttr3	
126	1N37E11DBAA	170		3530				M	rc	
127	1N37E11DBAA	83	82	3530				M	rmc	
128	1N37E26BABC	19.5	16	3420	8/19/75	1150L		M	Q	
129	1N36E2CCCC	212.5	219	3670				M	Ttr3	
130	1N36E2CCCC	127.5	123	3670				M	rc	
131	1N37E12ABD	60	25	3280				M	Q	
132	1N37E2BBA	40	15	3220				M	Q	
133	1N36E12CDAB	300	251	3665				M	Ttr3	
134	1N36E12CDAB	170	135	3670	8/14/75	2500L	14	M	Ttr2	

TABLE 25

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (µmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
135	1N36E12CDAB	68	68	3670				M	rmc	
136	1N37E18DABA	261	260	3635				M	Ttr3	
137	1N37E18ACDA	97	91	3570	8/12/75	2250L		M	Ttr3	
138	1N36E24DCCD	172	152	3650	8/13/75	2500L	17	M	Ttr3	
139	1N36E24DCCD	100	77	3650	8/13/75	4290L	18	M	rc	
140	1N37E29CBDA	250	235	3630				M	Tfu	
141	1N37E29CBDA	180	182	3630				M	Ttr3	
142	1N37E29CBDC	74.5	77	3630				M	rc	
143	1N37E21DDCC	50	23	3310	8/12/75	2460L	13	M	Q	
144	1N37E21DDCC	40	16.2	3210	8/12/75	2100L	14.8	M	Q	
145	1N38E21DAAB	80	30	3400	8/11/75	2500L	11.4	M	Q	
201	2N37E20ABDC	90	60	3170	6-73	2640L		S	Tfu	
202	2N37E21CAAC	30	15	3135		3040		H	Q	
203	2N37E21CADB			3390		2260		S	Q/Tfu	
204	2N37E22DBAB	60	22.4	3188	10-73			S	Tfu	
205	2N37E24CBCC	100	40	3342		3640		S	Tfu	
206	2N37E27DABB	440	300	3285				S	Tfu	
207	2N37E27DABC		44	3285				U	Tfu	
208	2N37E27DCBA	100	34.9	3247	10-73	2710L		S	Tfu	
209	2N37E28ACBC		50	3160					Tfu	
210	2N37E28ACCB1	50	12	3160				S	Tfu	
211	2N37E28ACCB2	80	23.6	3160	5-75	1990	15	H,S	Tfu	1410
212	2N37E28CADC			3178				S	Tfu	
213	2N37E29CADD	50	6	3180				S	Tfu	
214	2N37E31CBCD	30		3290	7-73	1670		S	Tfu	
215	2N37E31CBDB	30		3276	7-73	2670		S	Tfu	
216	2N37E31CCCB	60		3310	7-73	1544L		H	Tfu	

TABLE 25

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (μmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
217	2N37E32BBBB	100	70	3220	7-73	2970L		S	Tfu	
218	2N37E33DCBB		10	3208	10-73			S	Q	
219	2N37E34BCDA		65	3165		4860		S	Tfu	
220	2N37E34DABC	60	19.2	3210	9-73			U	Tfu	
221	2N37E34DABD	70		3218	6-73	4490L		H	Tfu	
222	2N37E34DACA	60	22.7	3210	9-73			S	Tfu	
223	2N37E34DACB	80	28.3	3220	9-73			U	Tfu	
224	2N37E34DCAB			3210		3760		H	Tfu	
225	2N37E35CDCB		75	3240				S	Tfu	
226	2N37E36CCCC			3282		2680L		S	Tfu	
227	2N38E20BDCA	160		3415	7-73	2600L		S	Tfu	
228	2N38E20DDCA	86	20	3450		3450		S	Tfu	
229	2N37E22BBAB			3500	7-73	1232L		S	Tiu	
230	2N38E24BCBA			3520		1290		S		
231	2N38E25CDDD		150	3620				S	rmc	
232	2N38E26AAAB	225	200	3655				S	Tfu	
233	2N38E26AABA	226	166.8	3659	10-73			S	rc	
234	2N38E28ABCB1			3490		3520		S		
235	2N38E28ABCB2			3490		2560		S		
236	2N38E30BDDD			3518				U		
237	2N38E32ABDB	114	84	3524	7-73	2710L		S	rmc	
238	2N38E36CDBD		60	3760				S	Ttrl	
239	1N37E02BAAA		24.9	3249	6-73	3414L		S	Tfu	
240	1N37E03CDAA	40	15	3212	8-73			S	Q/Tfu	
241	1N37E03CDAB1	90		3212	8-73			S	Tfu	
242	1N37E03CDAB2	87	12.4	3212	8-73	2010		S	Tfu	
243	1N37E04ACDB	75		3250				H	Tfu	

TABLE 25

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (μmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
244	1N37E06ACAD	50		3378		2074L		S	Tfu	
245	1N37E06BD	85							Tfu	
246	1N37E07DDDB	80		3400				S	Tfu	
247	1N37E08CCCC	130	60	3410				S	Tfu	
248	1N37E08CCDA	100		3380	6-72				Tfu	
249	1N37E10BBAD	400		3235		1760L			Tfu	
250	1N37E10CDDB	47		3235				S	Q/Tfu	
251	1N37E11CACB	164		3351				S	Tfu	
252	1N37E12DAAA			3292				H	Tfu	
253	1N37E13ACAB		36.5	3355				S		
254	1N37E13CABB1	72	24.4	3408	11-73			M	rc	
255	1N37E13CABB2	125	87.4	3408	11-73			M	Ttr3	
256	1N37E14ACCC	130	60	3395	7-72	2000L		S	Tfu	
257	1N37E14ACDC	50		3451				S	rmcl	
258	1N37E15BAAD		40	3280	7-72	3340L		S	Tfu	
259	1N37E15BBBA				6-73			H		
260	1N37E15BBCA	140	17	3274	7-72	2290		H	Tfu	
261	1N37E16ACCC	208		3325	7-72	2400L		C	Tfu	
262	1N37E16BDDC	68		3310	11-66				Tfu	
263	1N37E16DDDD			3272				S		
264	1N37E17DABD	200		3395				S	Tfu	
265	1N37E18AABA	130	60	3435	10-73	2090L		S	Tfu	
266	1N37E18BABC	132	65	3490	7-67			S	Tfu	
267	1N37E19DABD			3395						
268	1N37E20ABCA	200		3480	7-73	1835L		S	Tfu	
269	1N37E20CCBC			3432				S		
270	1N37E21ACDD	30	10	3289	8-72	2170		U	Q	
271	1N37E21DDCA	45		3357				S	rc	

TABLE 25

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (μmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
272	1N37E22BBAD			3300	7-72	2310		S	Tfu	
273	1N37E23DBCD	80	41	3450	7-72	1690L		S	rc	
274	1N37E24CACA	15		3540				S	rmc	
275	1N37E24CACC	8	6	3549	7-72	910		U	Ttrl	
276	1N37E24CADB	11	6.8	3550	10-73			U	Ttrl	
277	1N37E26ABBC	123	39.5	3419	7-72	941L		U	Tfu	
278	1N37E26CAAA	7977	+175	3545	10-73	1926L		U	MC	
279	1N37E27BDCB	30	8	3360	8-72	2430L		U	Tfu	
280	1N37E29DABB	200		3463		2820		S	Tfu	
281	1N37E31ADDB									
282	1N37E32DDCC	50		3398				S	Tfu	
283	1N37E33AAAB	130		3331	7-73	2270L		S	Tfu	
284	1N37E34DAAC		21.2	3380	9-73	5130L			Tfu	
285	1N37E34DABC1	80	28.3	3220	9-73			U	Tfu	
286	1N37E34DABC2	60	19.2	3210	9-73			U	Tfu	
287	1N37E35CBCB			3390	8-72	1390		S	Q	
288	1N37E36BDAD1	110	46.8	3545	11-73			M	rmc	
289	1N37E36BDAD2	196	108.7	3545	11-73			M	rc	
290	1N37E36BDAD3	288	160.4	3545	11-73			M	Ttr3	
291	1N38E04DCCA	140	53.7	3517	8-73			S	rmcl	
292	1N38E05CCCB			3398				S		
293	1N38E08ADBD	146	104.8	3455	8-73	2780L		S	Tfu	
294	1N38E10ADCA			3679				S	Ttrl	
295	1N38E11BBCB		24.7	3760	8-73	5040L		S	Ttrl	
296	1N38E13CDCC			3660				S	Ttrl	
297	1N38E17ADDD	113	63.5	3396	8-73	712L		S	Tfu	
298	1N38E17CBDA	190	78.5	3408	8-73			S	Tfu	

TABLE 25

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (μmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
299	1N38E19BCCC	160	24.5	3463				S	rmc	
300	1N38E19CBBB1	45	10.1	3450	11-73			M	rmc	
301	1N38E19CBBB2	125	50.6	3450	11-73			M	rc	
302	1N38E19CBBB3	232	124.7	3450	11-73			M	Ttr3	
303	1N38E19CDDB	115	36.7	3450	7-72	1440		U	rc	
304	1N38E20BDAC			3475				S		
305	1N38E22AADA	100		3395	5-71			S	rc	
306	1N38E22CCCC	30	5.3	3405	7-72	2240		S	Q	
307	1N38E23BBBD	120	65.4	3520	7-73	2170L		S	Tfu	
308	1N38E23CCDA	60	1.9	3465	8-73	3540L		S	rmcl	
309	1N38E24BBDD			3630				S	Ttrl	
310	1N38E25BBCA	80	3.5	3507	7-73	1720L		S	rmcl	
311	1N38E25CAAA	225		3515					Tfu	
312	1N38E26DBAA	140	8	3475	7-73	2777L		H	Tfu	
313	1N38E28AAAA	200	160	3410	6-73	2310L		H	Tfu	
314	1N38E29ADCA1			3473	7-72	925L		H	rmc	
315	1N38E29ADCA2	100	28	3482	7-72	816L		H	rmc	
316	1N38E29ADCC	20	0	3440	7-72	1260			Ttrl	
317	1N38E29ADDA	20		3440	7-72	1780		S	Ttrl	
318	1N38E29CABD	45		3510	8-72	834L			rmc	
319	1N38E30AAAD1	142	114.5	3565	11-73			M	rmc	
320	1N38E30AAAD2	215	162.3	3565	11-73			M	rc	
321	1N38E30AAAD3	290	182.9	3565	11-73			M	Ttr3	
322	1N38E30DDBB1	61	32.6	3550	7-72			M	Ttrl	
323	1N38E30DDBB2	111	46.3	3550	7-72	905		M	rmc	
324	1N38E30DDBB3	212	110.8	3550	11-73			M	rc	
325	1N38E30DADD			3508	7-72	1820			rmc	

TABLE 25

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (μmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
326	1N38E30DDBD	50	23.2	3528	7-72	921		U	rmc	
327	1N38E31CCCC	165	71.0	3534	1-73	1680L		H	rc	
328	1N38E31CCCD			3529	8-72	1575		H		
329	1N38E31DDBA1	63	29.6	3585	11-73			M	Ttrl	
330	1N38E31DDBA2	135	56	3585	11-73			M	rmc	
331	1N38E31DDBA3	267	110.6	3585	11-73			M	rc	
332	1N38E32BAAB			3500				S		
333	1N38E32BABC1	15		3490				S	Q	
334	1N38E32BABC2	15		3490				S	Q	
335	1N38E32BBAA	15	6	3490	8-72	719		S	Q	
336	1N38E32BBBD			3530	8-72	1032		S		
337	1N38E32BBCA	225		3530	8-72	2440		S	Tfu	
338	1N38E32CDCB	164	75.4	3620	8-72	958L		S	Ttrl	
339	1N38E34CDCC	120	8	3590	7-73	3180L			Ttrl	
340	1N38E35ACBD			3537	8-57	1840L		S		
341	1N38E36ADDD			3555	7-73	1580L				
342	1N38E36BACD1			3530				H		
343	1N38E36BACD2			3536	7-73	2510		H		
344	1N38E36BBCB	193	52.6	3540	7-73	2180L		S	rmc	
345	1N38E36BDAB	173	108	3520	2-74	501L		S	Tfu	
346	1N38E36BDBD			3510				S		
347	1N38E36CDBD	12	4	3519	10-73	4570L		S	Ttrl	
348	1N38E36CDCD			3548				S		
349	1S37E01BAAC	174	55.6	3494	9-73	2380L		U	Tfu	
350	1S37E01BAAD1	180		3501	9-73	3287L		S	Tfu	
351	1S37E01BAAD2	300	100	3509	9-73			H	Tfu	
352	1S37E02CCAD			3410		2050L		H		
353	1S37E03AABD1	60		3362				S	Q or Tfu	

TABLE 25

Well Number[a]	Well Location	Well Depth (feet)	Depth To Water[b] (feet)	Elevation[c]	Date Examined	Conductivity[d] (μmhos/cm)	Temperature (°C)	Water Use[e]	Water Source[f]	Consumption[g] (gal/day)
354	1S37E03AABD2			3362	7-73	1510L		H		
355	1S37E03CCCC			3402						
356	1S37E04ACBB			3431				S		
357	1S37E04ADDD			3431				S		
358	1S37E05DBCD	250		3530		1120L		S	Tfu	
359	1S37E06CCBB	80		3430	7-73	1153L		S		
360	1S38E03CACC	180	80	3652	6-73	578L		S	Ttrl	
361	1S38E05DBAD	83	57	3466				U	Tfu	
362	1S38E05DDB	44	14.3	3480				U	rc	
363	1S38E08CACC			3543				S		
364	1S38E09ACBB	120	15.3	3517	7-72	1060L		S	rmc	
365	1S38E09BADD	80		3505	7-72	1230L		H	rmc	
366	1S38E09BDDA	84	5.9	3508	7-72	1780L		S	rmc	
367	1S38E09CAAA	98		3518	7-72	1370L		S	Tfu	
368	1S38E09CAAB			3526				S		
369	1S38E11BCBC	180	74.6	3700	9-73			S	Tfu	
370	1S38E12BBDB	260	153.2	3651	9-73	2460L		S	Tfu	
371	1S38E12DDBD	210	139.1	3700	9-73				rmc	

Table 26. Well data for the Sarpy Creek area near the Westmoreland Resources coal reserves, southeastern Montana.

Well location	Well depth (feet)	Depth to water (feet)	Land-surface altitude (feet)	Date examined	Specific conductance of water (μmhos/cm)	Dissolved Solids (mg/l)	Water use	Water source
2N37E20ABDC	90	60	3170	6-73	2640L	2361	S	SubRb
2N37E21CAAC	30	15	3135		3040	2644E	H	Al
2N37E21CADB			3390		2260	1966E	S	Al or SubRb
2N37E22DBAB	60	22.4	3188	10-73			S	SubRb
2N37E24CBCC	100	40	3342		3640	3166	S	SubRb
2N37E27DABB	440	300	3285				S	SubRb
2N37E27DABC		44	3285				U	SubRb
2N37E27DCBA	100	34.9	3247	10-73	2710L	2037	S	SubRb
2N37E28ACBC		50	3160					SubRb
2N37E28ACCB1	50	12	3160				S	SubRb
2N37E28ACCB2	80	15	3160				H	SubRb
2N37E28CADC			3178				S	SubRb
2N37E29CADD	50	6	3180				S	SubRb
2N37E31CBCD	30		3290	7-73	1670	1452E	S	SubRb
2N37E31CBDB	30		3276	7-73	2670	2380E	S	SubRb
2N37E31CCCB	60		3310	7-73	1544L	1296	H	SubRb
2N37E32BBBB	100	70	3220	7-73	2970L	2768	S	SubRb
2N37E33DCBB		10	3208	10-73			S	Al
2N37E34BCDA		65	3165		4860	4228E	S	SubRb
2N37E34DABC	60	19.2	3210	9-73			U	SubRb
2N37E34DABD	70		3218	6-73	4490L	3623	H	SubRb
2N37E34DACA	60	22.7	3210	9-73			S	SubRb
2N37E34DACB	80	28.3	3220	9-73			U	SubRb
2N37E34DCAB			3210		3760	3271E	H	SubRb

EXPLANATION

Depth to water: Whole numbers only--reported; whole numbers and tenths--measured.
Land-surface altitude: Estimated from U.S. Geol. Survey $7\frac{1}{2}$ min. topog. maps; accurate to 10 feet.
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Dissolved solids: Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).

Water use: C, commercial; H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval. (M) denotes monitor well.

From Van Voast and Hedges, 1974, Table 2

Well location	Well depth (feet)	Depth to water (feet)	Land-surface altitude (feet)	Date examined	Specific conductance of water (µmhos/cm)	Dissolved Solids (mg/l)	Water use	Water source
2N37E 35CDCB		75	3240				S	SubRb
2N37E 36CCCC			3282		2680L	2385E	S	SubRb
2N38E 20BDCA	160		3415	7-73	2600L	2054	S	SubRb
2N38E 20DDCA	86	20	3450		3450	3001	S	SubRb
2N37E 22BBAB			3500	7-73	1232L	1033	S	SubRb
2N38E 24BCBA			3520		1290	1122E	S	
2N38E 25CDDD		150	3620				S	R-McC
2N38E 26AAAB	225	200	3655				S	SubRb
2N38E 26AABA	226	166.8	3659	10-73			S	RbC
2N38E 28ABCB1			3490		3520	3062E	S	
2N38E 28ABCB 2			3490		2560	2227E	S	
2N38E 30BDDD			3518				U	
2N38F 32ABDB	114	84	3524	7-73	2710L	2468	S	R-McC
2N38E 36CDBD		60	3760				S	R-McO
1N37E 02BAAA		24.9	3249	6-73	3414L	2846	S	SubRb
1N37E 03CDAA	40	15	3212	8-73			S	Al or SubRb
1N37E 03CDAB1	90		3212	8-73			S	SubRb
1N37E 03CDAB2	87	12.4	3212	8-73	2010	1748E	S	SubRb
1N37E 04ACDB	75		3250				H	SubRb
1N37E 06ACAD	50		3378		2074L	1734	S	SubRb
1N37E 06BD	85							SubRb
1N37E 07DDDB			3400				S	
1N37E 08CCCC	130	60	3410				S	SubRb

EXPLANATION

Depth to water: Whole numbers only--reported; whole numbers and tenths--measured.
Land-surface altitude: Estimated from U.S. Geol. Survey 7½ min. topog. maps; accurate to 10 feet.
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Dissolved solids; Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).
Water use: C, commercial; H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval. (M) denotes monitor well.

Well location	Well depth (feet)	Depth to water (feet)	Land-surface altitude (feet)	Date examined	Specific conductance of water (µmhos/cm)	Dissolved Solids (mg/l)	Water use	Water source
1N37E08CCDA	100		3380	6-72				SubRb
1N37E10BBAD	400		3235		1760L	1531		SubRb
1N37E10CDDB	47		3235				S	SubRb
1N37E11CACB	164		3351				S	SubRb
1N37E12DAAA			3292				H	SubRb
1N37E13ACAB		36.5	3355				S	
1N37E13CABB1	72	24.4	3408	11-73				RbC (M)
1N37E13CABB2	125	87.4	3408	11-73				SubRb(M)
1N37E14ACCC	130	60	3395	7-72	2000L	1740	S	SubRb
1N37E14ACDC	50		3451				S	R-McCl
1N37E15BAAD		40	3280	7-72	3340L	2695	S	SubRb
1N37E15BBBA				6-73			H	
1N37E15BBCA	140	17	3274	7-72	2290	1919	H	SubRb
1N37E16ACCC			3325	7-72	2400L	1973	C	SubRb
1N37E16BDDC	68		3310	11-66				SubRb
1N37E16DDDD			3272				S	
1N37E17DABD			3395				S	
1N37E18AABA	130	60	3435	10-73	2090L	1818	S	SubRb
1N37E18BABC	132	65	3490	7-67			S	SubRb
1N37E19DABD			3395					
1N37E20ABCA			3480	7-73	1835L	1613	S	
1N37E20CCBC			3432				S	
1N37E21ACDD	30	10	3289	8-72	2170	1859	U	Al
1N37E21DDCA	45		3357				S	RbC
1N37E22BBAD			3300	7-72	2310	1860	S	SubRb
1N37E23DBCD	80	41	3450	7-72	1690L	1473	S	RbC

EXPLANATION

Depth to water: Whole numbers only--reported; whole numbers and tenths--measured.
Land-surface altitude: Estimated from U.S. Geol. Survey 7½ min. topog. maps; accurate to 10 feet.
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Dissolved solids: Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).

Water use: C, commercial; H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval. (M) denotes monitor well.

Well location	Well depth (feet)	Depth to water (feet)	Land-surface altitude (feet)	Date examined	Specific conductance of water (µmhos/cm)	Dissolved Solids (mg/l)	Water use	Water source
1N37E24CACA	15		3540				S	R-Mc
1N37E24CACC	8	6	3549	7-72	910	716	U	R-McO
1N37E24CADB	11	6.8	3550	10-73			U	R-McO
1N37E26ABBC	123	39.5	3419	7-72	941L	904	U	SubRb
1N37E26CAAA	7977	+175	3545	10-73	1926L	1705	U	Mission Canyon
1N37E27BDCB	30	8	3360	8-72	2430L	1964	U	SubRb
1N37E29DABB	160		3463		2820	2453E	S	SubRb
1N37E31ADDB								
1N37E32DDCC	50		3398				S	SubRb
1N37E33AAAB	130		3331	7-73	2270L	1995	S	SubRb
1N37E34DAAC		21.2	3380	9-73	5130L	4505		SubRb
1N37E34DABC$_1$	80	28.3	3220	9-73			U	SubRb
1N37E34DABC$_2$	60	19.2	3210	9-73			U	
1N37E35CBCB			3390	8-72	1390	903	S	Al
1N37E36BDAD1	110	46.8	3545	11-73				R-McC (M)
1N37E36BDAD2	196	108.7	3545	11-73				RbC (M)
1N37E36BDAD3	288	160.4	3545	11-73				SubRb (M)
1N38E04DCCA	140	53.7	3517	8-73			S	R-McCl
1N38E05CCCB			3398				S	
1N38E08ADBD	146	104.8	3455	8-73	2780L	2053	S	SubRb
1N38E10ADCA			3679				S	R-McO
1N38E11BBCB		24.7	3760	3-73	5040L	4384	S	R-McO
1N38E13CDCC			3660				S	R-McO
1N38E17ADDD	113	63.5	3396	8-73	712L	546	S	SubRb
1N38E17CBDA	190	78.5	3408	8-73			S	SubRb
1N38E19BCCC	160	24.5	3463				S	R-McC

EXPLANATION

Depth to water: Whole numbers only--reported; whole numbers and tenths--measured.
Land-surface altitude: Estimated from U.S. Geol. Survey 7½ min. topog. maps; accurate to 10 feet.
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Dissolved solids; Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).
Water use: C. commercial; H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval. (M) denotes monitor well.

Well location	Well depth (feet)	Depth to water (feet)	Land-surface altitude (feet)	Date examined	Specific conductance of water (µmhos/cm)	Dissolved Solids (mg/l)	Water use	Water source
1N38E19CBBB1	[illegible]	10.1	3450	11-73				R-McC (M)
1N38E19CBBB2	[illegible]	50.6	3450	11-73				RbC (M)
1N38E19CBBB3	232	124.7	3450	11-73				SubRb (M)
1N38E19CDDB	115	36.7	3450	7-72	1440	1020	U	RbC
1N38E20BDAC			3475				S	
1N38E22AADA	100		3395	5-71			S	RbC
1N38E22CCCC	[illegible]	[illegible]	3405	7-72	2240	1655	S	Al
1N38E23BBBD	[illegible]	65.4	3520	7-73	2170L	1750	S	SubRb
1N38E23CCDA	[illegible]	[illegible]	3465	8-73	3540L	3079	S	R-McCl
1N38E24BBDD			3630				S	R-McO
1N38E25BBCA	80	[illegible]	3507	7-73	1720L	1496	S	R-McCl
1N38E25CAAA	225		3515					SubRb
1N38E26DBAA	140	8	3475	7-73	2777L	2235	H	SubRb
1N38E28AAAA	200	160	3410	6-73	2310L	1867	H	SubRb
1N38E29ADCA1			3473	7-72	925L	788	H	R-McC
1N38E29ADCA2	100	28	3482	7-72	816L	724	H	R-McC
1N38E29ADCC	20	9	3440	7-72	1260	966		R-McO
1N38E29ADDA	20		3440	7-72	1780	1358	S	R-McO
1N38E29CABD	45		3510	8-72	834L	832		R-McC
1N38E30AAAD1	142	114.5	3565	11-73				R-McC (M)
1N38E30AAAD2	215	162.3	3565	11-73				RbC (M)
1N38E30AAAD3	290	182.9	3565	11-73				SubRb(M)
1N38E30DDBB1	61	32.6	3550	7-72				R-McO (M)
1N38E30DDBB2	111	46.6	3550	7-72	905			R-McC (M)
1N38E30DDBB3	212	[illegible]	3550	11-73				RbC (M)
1N38E30DADD			3508	7-72	1820	1083		R-McC

EXPLANATION

Depth to water: Whole numbers only--reported; whole numbers and tenths--measured.
Land-surface altitude: Estimated from U.S. Geol. Survey 7½ min. topog. maps; accurate to 10 feet.
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Dissolved solids: Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).
Water use: C, commercial; H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval. (M) denotes monitor well.

Well location	Well depth (feet)	Depth to water (feet)	Land-surface altitude (feet)	Dat examined	Specific conductance of water (µmhos/cm)	Dissolved Solids (mg/l)	Water use	Water source
1N38E30DDBD	50	23.2	3528	7-72	921	581	U	R-McC
1N38E31CCCC	165	71.0	3534	1-73	1680L	1629	H	RbC
1N38E31CCCD			3529	8-72	1575	1225	H	
1N38E31DDBA1	63	29.6	3585	11-73				R-McO (M)
1N38E31DDBA2	135	56	3585	11-73				R-McC (M)
1N38E31DDBA3	267	110.6	3585	11-73				RbC (M)
1N38E32BAAB			3500				S	
1N38E32BABC1	15		3490				S	Al
1N38E32BABC2	15		3490				S	Al
1N38E32BBAA	15	6	3490	8-72	719	478	S	Al
1N38E32BBBD			3530	8-72	1032	712	S	
1N38E32BBCA	225		3530	8-72	2440	1878	S	SubRb
1N38E32CDCB	164	75.4	3620	8-72	958L	833	S	R-McO
1N38E34CDCC	120	8	3590	7-73	3180L	2766		R-McO
1N38E35ACBD			3537	8-57	1840L	1600	S	
1N38E36ADDD			3555	7-73	1580L	1374		
1N38E36BACD1			3530				H	
1N38E36BACD2			3536	7-73	2510	2031	H	
1N38E36BBCB	193	52.6	3540	7-73	2180L	1896	S	R-McC
1N38E36BDAB	173	108	3520	2-74	501L	389	S	SubRb
1N38E36BDBD			3510				S	
1N38E36CDBD	12	4	3519	10-73	4570L	3975	S	R-McO
1N38E36CDCD			3548				S	

EXPLANATION

Depth to water: Whole numbers only--reported; whole numbers and tenths--measured.
Land-surface altitude: Estimated from U.S. Geol. Survey $7\frac{1}{2}$ min. topog. maps; accurate to 10 feet.
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Dissolved solids; Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 $\pm$ .13) times specific conductance).
Water use: C, commercial; H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval. (M) denotes monitor well.

Well location	Well depth (feet)	Depth to water (feet)	Land-surface altitude (feet)	Date examined	Specific conductance of water (µmhos/cm)	Dissolved Solids (mg/l)	Water use	Water source
1S37E01BAAC	174	55.6	3494	9-73	2380L	2056	U	SubRb
1S37E01BAAD1	180		3501	9-73	3287L	2605	S	SubRb
1S37E01BAAD2	300	100	3509	9-73			H	SubRb
1S37E02CCAD			3410		2050L	1783E	H	
1S37E03AABD1	60		3362				S	Al or SubRb
1S37E03AABD2			3362	7-73	1510L	1384	H	
1S37E03CCCC			3402					
1S37E04ACBB			3431				S	
1S37E04ADDD			3431				S	
1S37E05DBCD			3530		1120L	974E	S	
1S37E06CCBB			3430	7-73	1153L	970	S	
1S38E03CACC	180	80	3652	6-73	578L	478	S	R-McO
1S38E05DBAD	83	57	3466				U	SubRb
1S38E05DDB	44	14.3	3480				U	RbC
1S38E08CACC			3543				S	
1S38E09ACBB	120	15.3	3517	7-72	1060L	981	S	R-McC
1S38E09BADD	80		3505	7-72	1230L	1066	H	R-McC
1S38E09BDDA	84	5.9	3508	7-72	1780L	1572	S	R-McC
1S38E09CAAA	98		3518	7-72	1370L	1321	S	SubRb
1S38E09CAAB			3526				S	
1S38E11BCBC	180	74.6	3600	9-73			S	SubRb
1S38E12BBDB	260	153.2	3651	9-73	2460L	2713	S	SubRb
1S38E12DDBD	210	139.1	3700	9-73				R-McC

EXPLANATION

Depth to water: Whole numbers only--reported; whole numbers and tenths--measured.
Land-surface altitude: Estimated from U.S. Geol. Survey $7\frac{1}{2}$ min. topog. maps; accurate to 10 feet.
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Dissolved solids; Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).

Water use: C. commercial; H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval. (M) denotes monitor well.

TABLE 27

SPRING DATA FOR THE PROJECT AREA

Spring Number[a]	Location	Water Source[b]	Land Owner	Elevation[c]	Estimated Flow (gpm)	Temperature (°C)	Specific Conductance (μmhos/cm)[d]	Use[e]
1	1N36E11DDC	Ttr3	G. Luther	3500	<0.5	8	510	S
2	1N36E14BBA	Tfu	G. Luther	3440	<0.1	20	875	S
3	1N36E14CCCC	Tfu	G. Luther	3390	~0.1	13	1175	S
4	1N36E10BBD	Tfu	G. Luther	3380	0	18	1225	U
5	1N36E10CDA	Tfu	G. Luther	3400	<0.1	15	1900	S
6	1N36E23DDB	Tfu	G. Luther	3480		25	1990	S
7	1N36E14DBC	Tfu	G. Luther	3435		24	835	S
8	1N36E13ABB	Ttr2	G. Luther	3590	0	23	2190	U
9	1N36E12CDC	Ttr2	G. Luther	3575	0	23	2650	U
11	2N36E17DDB		L. Hammond	3070	<0.1	17.5	2400	S
12	2N36E17BBD		L. Hammond	3040	<0.1	20	2800	U

[a]Spring number indexed to locations and shown on Plate 2.2.3-2. Information for numbers greater than 200 from Van Voast and Hedges, 1974.

[b]Source: Q - Quaternary alluvium or slope wash; Ttrl - Tongue River member above Rosebud-McKay Coal; Ttr2 - Tongue River member between Rosebud-McKay Coal and Robinson Coal; Ttr3 - Tongue River member to about 100' below Robinson Coal; rmcl - Rosebud-McKay clinker; rmc - Rosebud McKay Coal; rcl - Robinson clinker; rc - Robinson Coal; Tfu - undifferentiated Fort Union formation.

[c]Estimated from U.S. Geological Survey 7.5 minute topographic maps.

[d]Values shown are field measurements except as noted L, which are Laboratory measurements.

[e]S - stock, H - domestic, U - Unused.

From Westmoreland Resources, 1975, Appendix F

TABLE 27

Spring Number[a]	Location	Water Source[b]	Land Owner	Elevation[c]	Estimated Flow (gpm)	Temperature (°C)	Specific Conductance (μmhos/cm)[d]	Use[e]
13	2N36E17DDA		L. Hammond	3050	<0.1	18	1725	S
14	2N36E17CCA		L. Hammond	3050	<0.5	18	1750	S
15	2N36E17BBD		L. Hammond	3055	<0.5	21.5	1825	S
16	2N36E17DBD		L. Hammond	3045	0	23.5	2200	U
17	2N35E24ACB		C. Redding Jr.	2980	20	18	1850	S
18	2N35E24ADB		C. Redding Jr.	2980	20	18	1850	S
19	2N36E15BBC		C. Redding Jr.	3180	~8	17.5	1110	S
20	2N36E15AAC		C. Redding Jr.	3230	~5	18	1290	S
21	2N36E15CCA		C. Redding Jr.	3250	~3	14	449	S
22	2N36E20CBD		C. Redding Jr.	3190	<0.5	18	1590	S
25	1N36E17CDB		Kendrick	3180	<5	12	1375	S
26	1N36E8BAC	Tfu	Kendrick	3300	<1	16	3750	S
27	1N36E8BBC	Tfu	Kendrick	3300	<0.5	15	5590	U
28	1N36E17DDA		Kendrick	3210	<0.5	11.5	1500	U
29	1N36E9DCB	Tfu	Kendrick	3360	<0.3	14	2950	U
30	1N36E9DBA	Tfu	Kendrick	3460	<1	16	2850	S
31	1N36E9BBD	Tfu	Kendrick	3360	<0.5	9.5	1350	U
32	1N36E9AAB	Tfu	Kendrick	3375	~1.5	20	1850	S
33	1N36E5AAB		Kendrick	3380	0	22	2600	U
35	1N36E6DBA		Kendrick	3390	<1	8	5675	S
36	1N36E6BCD		Kendrick	3210	<0.1	21	3790	S
37	1N36E6ADD		Kendrick	3300	<0.5	17	10050	U
38	1N36E5DBA		Kendrick	3400	<1	20	3250	S
39	2N36E29ACC		Kendrick	3330	<0.01	21	12200	U

TABLE 27

Spring Number[a]	Location	Water Source[b]	Land Owner	Elevation[c]	Estimated Flow (gpm)	Temperature (°C)	Specific Conductance (μmhos/cm)[d]	Use[e]
40	2N36E32BCA		Kendrick	3340	<0.5	17.5	950	S
41	2N36E32ACA		Kendrick	3360	<1	20	1200	S
42	2N36E34BBB	Tfu	Kendrick	3280	0	23	2400	U
43	2N36E7CAC		Kendrick	2980	<1	21	3400	S
50	1S36E14ADC		Scott L&L	3275	<1			S
51	1S37E20DCB		Scott L&L	3450	<0.3	18.5	3900	U
52	1S36E3DAA		E. Miller	3280	<0.1	14.5	1400	S
53	1S36E2CDD		E. Miller	3390	<2	17	1390	S
54	2N36E2CCA		Davidson	3270	<1	27	1050	S
55	2N36E14CBA		Davidson	3295	<5	30	565	S
56	2N36E23CAA		Davidson	3315		29	480	S
57	2N36E22BCA		Davidson	3290	<0.5	32	1450	S
58	2N36E22DCD		Davidson	3260	<1	29	3000	S
59	2N36E13CCD		Davidson	3270		22	675	S
60	2N36E24ABA		R. Fly	3250		23	875	S
61	2N37E18CCC		Davidson	3220	<1	26	860	S
62	2N36E19DDC		Davidson	3250	<1	13	850	S
63	1N36E12BBD	Tfu	Davidson	3495		20	1250	S
64	2N36E25ABA	Tfu	R. Fly	3310	<1	23.5	2790	S
65	1N36E24BBA	Ttr2	E. Stark	3615	<0.5	27	3425	S
66	1N36E24AAD	Ttr2	E. Stark	3600	<0.1	26	2225	U
67	1N36E24BAA	rmcl	E. Stark	3680	<1.5	20	1000	
68	1N36E13AAA	rc	E. Stark	3490		16	2250	S
69	1N36E12DDD	Ttr2	Davidson	3470		20	1900	S
70	1N36E12CCD	Ttr3	Davidson	3520	<0.5	21	1600	S
71	1N36E13DAA	Ttr3	E. Stark	3560		22	2695	S

TABLE 27

Spring Number[a]	Location	Water Source[b]	Land Owner	Elevation[c]	Estimated Flow (gpm)	Temperature (°C)	Specific Conductance (μmhos/cm)[d]	Use[e]
72	1N36E12DDD	rc	E. Stark	3490		21	2900	S
73	1N37E18CCB	Ttr2	E. Stark	3540	1	12	1900	U
74	1N37E18DCB	Ttr2	E. Stark	3500	1	14	2050	U
75	1N37E18CCC	Ttr2	E. Stark	3590	1	21	1670	S
76	1N36E13DBA	Ttr2	E. Stark	3520	5	27	3220	S
77	1N36E12DDB	Tfu	Davidson	3480	1			
78	1N37E18ACA	rmc	E. Stark	3550	1			
79	1N37E8DAC	Ttr2	Davidson	3460	3	22	1500	S
80	1N37E8ACB	Ttr2	Davidson	3460	3	16.5	1650	S
81	2N36E25ADB	Tfu	R. Fly	3345	0.5	18.5	1410	S
82	1N37E32CCA	Ttr3	R. Thrower	3480-3490	4	17.5	1900	S
83	1N37E32CAA	Ttr2	R. Thrower	3540	3	19	590	S
84	1N36E25BAA	Ttr3	J. Romine	~3540				
85	1N36E25DDA	rc	J. Romine	~3550				
86	1N37E30BCB	rc	J. Romine	~3550				
87	1N37E19CCB	rc	J. Romine	~3600				
88	1N37E19CDB	rc	J. Romine	~3500				
89	1N37E20DDB	Ttr2	J. Romine	~3525				
91	1N37E20DBA	rc	J. Romine	~3450				
92	1N37E20DBA	rcl	J. Romine	~3490				H
93	1N36E29BAD	Ttr3	J. Romine	~3440				
94	1N37E29CDC	rc	J. Romine	~3570				
95	1N37E39DBD	Ttr2	J. Romine	~3580				
96	1N37E30CBD	Ttr2	J. Romine	~3550				
97	1N37E30CCD	Ttr2	J. Romine	~3630				
98	1N37E16BDCC	rc	J. Romine	~3310				
100	1N36E12CBC	Ttr3	G. Luther	3550	<0.5	15.5	1490	S

TABLE 27

Spring Number[a]	Location	Water Source[b]	Land Owner	Elevation[c]	Estimated Flow (gpm)	Temperature (°C)	Specific Conductance (µmhos/cm)[d]	Use
101	1N36E36BDB	Q	J. Romine	~3430				
102	1S36E5CCD	Tfu	J. Romine	~3530				
103	1N36E2ADB	rc	G. Luther	~3600				
104	1N36E11AAB	rc	G. Luther	~3550				
105	2N37E35CDBC	Tfu		~3250				
106	2N37E9BAC	Tfu		~3140				
200	2N37E23BBCD	Tfu		3204			3940	S
201	2N37E25DCAD	rmcl		3380			1940	S
202	2N37E33ACCD	Tfu		3210				
203	2N38E19ACDA	Tfu		3400			4440L	S
204	2N38E20CDCA	rc		3420				
205	2N38E20DAC	rc		3430				S
206	2N38E20DBAC	rc		3430			994	S
207	2N38E29ABBD	rmcl		3360				
208	2N38E30AABD	rmcl		3455	.9		534L	
209	2N38E30BBCA	rmcl		3480	2			S
210	2N38E30BCCC	rmcl		3495	.9		680L	S
211	2N38E30BDDD	rmcl		3498	2		683L	S
212	2N38E34ABBC	Ttrl		3630	1			S
213	2N38E35ACAD	Ttrl		3700				
214	2N38E36BBBD	Ttrl		3660				
215	2N38E36DCDC	Ttrl		3750	.5			S
216	1N37E07CCAA	rc		3500	4			S
217	1N37E07CCCD	rc		3500	4			S
218	1N37E07DBAC	rmcl		3480	4			S
219	1N37E10BDCB	Tfu		3230				S

TABLE 27

Spring Number[a]	Location	Water Source[b]	Land Owner	Elevation[c]	Estimated Flow (gpm)	Temperature (°C)	Specific Conductance (µmhos/cm)[d]	Use[e]
220	1N37E12ADCD	Tfu		3280				S
221	1N37E12CADA	rmcl		3430	1			S
222	1N37E12CBAD	rc		3365	1			S
223	1N37E13CCAD	rmcl		3430			1450L	
224	1N37E14CCDC	rmcl		3420				
226	1N37E16DDDD	Tfu		3290				
229	1N37E19CDDA	Tfu		3560	3			S
230	1N37E20BADC	rmcl		3530			516L	H
231	1N37E22CBCC	Q		3290			2740	
232	1N37E24DADD	Ttrl		3470	.5			
233	1N37E26ABBB	rc		3425			1400L	
234	1N37E26DAAB	rmcl		3467			1010L	
235	1N37E32BCDA	rc		3538	.5		598L	S
236	1N37E35DBBB	rc		3435				
237	1N37E36BDCA	rmc		3497			743L	S
238	1N37E36DBBB	Q		3477				S
239	1N38E02DAAC	Ttrl		3922				
240	1N38E03AACC	Ttrl		3703				
241	1N38E03ACDC	Ttrl		3660			4820L	S
242	1N38E03DBAA	Ttrl		3680				
243	1N38E05ACDD	rmc		3470	.1			S
244	1N38E05CACB	rmc		3440	1			S
245	1N38E08ADBC	rmc		3450	.1			S
246	1N38E10BBDC	Ttrl		3544	1		2050L	S
247	1N38E11CCDD	Ttrl		3660				S
248	1N38E11DBBC	Ttrl		3750	.1		5840L	S
249	1N38E12CDCA	Ttrl		3855				

TABLE 27

Spring Number[a]	Location	Water Source[b]	Land Owner	Elevation[c]	Estimated Flow (gpm)	Temperature (°C)	Specific Conductance (μmhos/cm)[d]	Use
250	1N38E13AADA	Ttrl		3930	5		1860L	S
251	1N38E13BABB	Ttrl		3820				
252	1N38E13BCBA	Ttrl		3750				
253	1N38E15BBDA	Tfu		3460	.1		2830L	S
254	1N38E15BCCD	rmc		3425			7320L	S
255	1N38E15DAAD	Ttrl		3527				
256	1N38E17CAA	Q		3330	4			S
257	1N38E18ABAB	rc		3300				S
258	1N38E18ACAB	rc		3300				
259	1N38E18BABB	rc		3300				
260	1N38E18DCCD	Q		3360	1			S
261	1N38E19BCDC	rmcl		3440	1		1580L	S
262	1N38E19BDDB	Q		3392				S
263	1N38E19CABA	Q		3405			1460L	
264	1N38E19CBBC	Ttrl		3455			1750	
265	1N38E19CCAC	rmcl		3445			1999	S
266	1N38E19DCBD	Ttrl		3468			734L	S
267	1N38E22CADD	Q		3400	.5		3425L	S
268	1N38E22CBAC	rmcl		3385	.5			S
269	1N38E24ADBA	Ttrl		3710				S
270	1N38E26CABA	Q		3463				U
271	1N38E29ACDC	Ttrl		3460				
272	1N38E29DBBB	Ttrl		3470			1340L	S
273	1N38E29DBCC	Ttrl		3465			2060L	S
274	1N38E30BADB	Ttrl		3460				S
275	1N38E30BBBA	rmcl		3465			1880L	S
276	1N38E30BCCC	Ttrl		3560				S

TABLE 27

Spring Number[a]	Location	Water Source[b]	Land Owner	Elevation[c]	Estimated Flow (gpm)	Temperature (°C)	Specific Conductance (μmhos/cm)[d]	Use[e]
277	1N38E30DADD	Ttrl		3520			742L	S
278	1N38E36BCCC	Ttrl		3510				
279	1N38E36CDAC	Ttrl		3519	.1			S
280	1S37E01DACC	rmcl		3560			753L	
281	1S38E02BBCB	Ttrl		3650			1620L	
282	1S38E03ACDB	Ttrl		3575			2400L	S
283	1S38E03DBAB	Ttrl		3592			1040L	
284	$1S38E03DBDB_2$	Ttrl		3625			1620L	
285	$1S38E03DBDB_1$	Ttrl		3615			1530L	
286	1S38E04C	rmc		3475				
287	1S38E05DDB	rmc		3480				
288	1S38E10CABA	Ttrl		3600			2320L	S
289	1S38E12BBAC	Ttrl		3650				

Table 28. Spring data for the Sarpy Creek area near the Westmoreland Resources coal reserves, southeastern Montana.

Location	Land-surface altitude (feet)	Dissolved Solids (mg/l)	Date examined	Specific conductance of water (µmhos/cm)	Flow	Water use	Water source
2N37E23BBCD	3204	3427E		3940		S	SubRb
2N37E25DCAD	3380	1687E		1940		S	R-McCl
2N37E33ACCD	3210						SubRb
2N38E19ACDA	3400	4672	7-73	4440L		S	SubRb
2N38E20CDCA	3420						RbC
2N38E20DAC	3430					S	RbC
2N38E20DBAC	3430	864E		994		S	RbC
2N38E29ABBD	3360						R-McCl
2N38E30AABD	3455	458	7-73	534L	.9		R-McCl
2N38E30BBCA	3480				2	S	R-McCl
2N38E30BCCC	3495	547	7-73	680L	.9	S	R-McCl
2N38E30BDDD	3498	594		683L	2	S	R-McCl
2N38E34ABBC	3630		7-73		1	S	R-McO
2N38E35ACAD	3700						R-McO
2N38E36BBBD	3660		7-73				R-McO
2N38E36DCDC	3750		7-73		.5	S	R-McO
1N37E07CCAA	3500				4	S	RbC
1N37E07CCCD	3500				4	S	RbC
1N37E07DBAC	3480				4	S	R-McCl
1N37E10BDCB	3230					S	SubRb
1N37E12ADCD	3280					S	SubRb

EXPLANATION

Land-surface altitude: Estimated from U.S. Geol. Survey 7½ min. topog. maps; accurate to 10 feet.
Dissolved solids: Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Flow: Estimated spring discharge (gallons per minute).
Water use: H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

From Van Voast and Hedges, 1974, Table 3

Location	Land-surface altitude (feet)	Dissolved Solids (mg/l)	Date examined	Specific conductance of water (µmhos/cm)	Flow	Water use	Water source
1N37E12CADA	3430				1	S	R-McCl
1N37E12CBAD	3365				1	S	RbC
1N37E13CCAD	3430	1225	7-72	1450L			R-McCl
1N37E14CCDC	3420		7-72				R-McCl
1N37E16BDCC	3310						RbC
1N37E16DDDD	3290		7-72				SubRb
1N37E18ACDA	3500				8	S	R-McCl
1N37E18BBBB	3472	1818		2090L		S	RbC
1N37E19CDDA	3660				3	S	SubRb
1N37E20BADC	3530	487	7-73	516L		H	R-McCl
1N37E22CBCC	3290	2486	8-72	2740			Al
1N37E24DADD	3470		7-72		.5		R-McO
1N37E26ABBB	3425	1304	7-72	1400L			RbC
1N37E26DAAB	3467	906	7-72	1010L			R-McCl
1N37E32BCDA	3538	526	8-73	598L	.5	S	RbC
1N37E35DBBB	3435						RbC
1N37E36BDCA	3497	592	7-72	743L		S	R-McC
1N37E36DBBB	3477		7-72			S	Al
1N38E02DAAC	3922						R-McO
1N38E03AACC	3703						R-McO
1N38E03ACDC	3660	4193	8-73	4820L		S	R-McO
1N38E03DBAA	3680						R-McO

EXPLANATION

Land-surface altitude: Estimated from U.S. Geol. Survey 7½ min. topog. maps; accurate to 10 feet.
Dissolved solids: Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Flow: Estimated spring discharge (gallons per minute).
Water use: H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

Location	Land-surface altitude (feet)	Dissolved Solids (mg/l)	Date examined	Specific conductance of water (µmhos/cm)	Flow	Water use	Water source
1N38E05ACDD	3470		8-73		.1	S	R-McC
1N38E05CACB	3440				1	S	R-McC
1N38E08ADBC	3450		8-73		.1	S	R-McC
1N38E10BBDC	3544	1783	8-73	2050L	1	S	R-McO
1N38E11CCDD	3660		8-73			S	R-McO
1N38E11DBBC	3750	5080	8-73	5840L	.1	S	R-McO
1N38E12CDCA	3855						R-McO
1N38E13AADA	3930	1618	8-73	1860L	5	S	R-McO
1N38E13BABB	3820						R-McO
1N38E13BCBA	3750						R-McO
1N38E15BBDA	3460	2401	8-73	2830L	.1	S	SubRb
1N38E15BCCD	3425	6368	8-73	7320L		S	R-McC
1N38E15DAAD	3527						R-McO
1N38E17CAA	3330		8-73		4	S	Al
1N38E18ABAB	3300		8-73			S	RbC
1N38E18ACAB	3300						RbC
1N38E18BABB	3300						RbC
1N38E18DCCD	3360		8-73		1	S	Al
1N38E19BCDC	3440	1372	8-73	1580L	1	S	R-McCl
1N38E19BDDB	3392		8-73			S	Al
1N38E19CABA	3405	1272	8-73	1460L			Al

EXPLANATION

Land-surface altitude: Estimated from U.S. Geol. Survey 7½ min. topog. maps; accurate to 10 feet.
Dissolved solids: Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Flow: Estimated spring discharge (gallons per minute).
Water use: H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

Location	Land-surface altitude (feet)	Dissolved Solids (mg/l)	Date examined	Specific conductance of water (µmhos/cm)	Flow	Water use	Water source
1N38E19CBBC	3455	1[illegible]90	7-72	1750			R-McO
1N38E19CCAC	3445	1820	8-72	1999		S	R-McCl
1N38E19DCDB	3468	659	7-72	734L		S	R-McC
1N38E22CADD	3400	3124	6-73	3425L	.5	S	Al
1N38E22CBAC	3385				.5	S	R-McCl
1N38E24ADBA	3710					S	R-McO
1N38E26CABA	3463		8-73			U	Al
1N38E29ACDC	3460						R-McO
1N38E29DBBB	3470	1249	8-72	1340L		S	R-McO
1N38E29DBCC	3465	1998	8-72	2060L		S	R-McO
1N38E30BADB	3460					S	R-McO
1N38E30BBBA	3465	1720	8-72	1880L		S	R-McCl
1N38E30BCCC	3560		7-72			S	R-McO
1N38E30DADD	3520	695	7-72	742L		S	R-McO
1N38E36BCCC	3510						R-McO
1N38E36CDAC	3519		7-73		1	S	R-McO
1S37E01DACC	3550	580	10-73	753L			R-McCl
1S38E02BBCB	3650	1415	8-72	1620L			R-McO
1S38E03ACDB	3575	2382	8-72	2400L		S	R-McO
1S38E03DBAB	3592	921	8-72	1040L			R-McO
1S38E03DBDB2	3625	1547	8-72	1620L			R-McO

EXPLANATION

Land-surface altitude: Estimated from U.S. Geol. Survey 7½ min. topog. maps; accurate to 10 feet.
Dissolved solids: Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).
Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).
Flow: Estimated spring discharge (gallons per minute).
Water use: H, domestic; S, stock; U, unused.
Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

Location	Land-surface altitude (feet)	Dissolved Solids (mg/l)	Date examined	Specific conductance of water (µmhos/cm)	Flow	Water use	Water source
1S38E03DBDB1	3615	1374	8-72	1530L			R-McO
1S38E04C	3475						R-McC
1S38E05DDB	3480						R-McC
1S38E10CABA	3600	2088	8-72	2320L		S	R-McO
1S38E12BBAC	3650						R-McO

EXPLANATION

Land-surface altitude: Estimated from U.S. Geol. Survey $7\frac{1}{2}$ min. topog. maps; accurate to 10 feet.

Dissolved solids: Milligrams per liter; laboratory calculations unless otherwise noted (E: estimated; equal to (.87 ± .13) times specific conductance).

Specific conductance: Micromhos per centimeter; field measurements unless otherwise noted (L: laboratory).

Flow: Estimated spring discharge (gallons per minute).

Water use: H, domestic; S, stock; U, unused.

Water source: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

TABLE 29

VERTICAL PERMEABILITY OF CORE SAMPLES

Geologic Unit	Lithology	Core Hole	Depth (feet)	Vertical Permeability (cm/sec)
Rosebud-McKay Overburden	siltstone	292C	≈ 51	1.8×10^{-9}
	siltstone	26	≈ 70	8.8×10^{-9}
Coal Interburden Zone	siltstone	292C	≈107	2.9×10^{-8}
	sandstone	292C	≈188	1.3×10^{-4}
	shale	619	≈ 97	6.5×10^{-8}
	shale	626	≈148	6.6×10^{-9}
Upper Sub-Robinson Units	sandstone	626	≈307	1.1×10^{-4}
	siltstone	627	≈121	2.8×10^{-8}
	sandstone	627	≈181	4.1×10^{-4}
	sandstone	627	≈182	3.9×10^{-4}
	sandstone	630	≈125	1.7×10^{-4}
	siltstone	630	≈164	1.4×10^{-9}
Lower Sub-Robinson Units	shale	619	≈269	1.5×10^{-8}

From Westmoreland Resources, 1975 1

TABLE 30

TRANSMISSIVITY$^{(T)}$ AND PERMEABILITY$^{(K)}$ OF GEOLOGIC UNITS TAPPED BY OBSERVATION WELLS IN THE PROJECT AREA

AQUIFER NAME-WELL NUMBER	GRAVEL INTERVAL (feet) FROM	TO	TESTED THICKNESS (feet)	PUMPING T (gpd/ft)	PUMPING K (cm/sec)	PUMPING LENGTH OF TEST (min.)	RECOVERY T (gpd/ft)	RECOVERY K (cm/sec)	RECOVERY LENGTH OF TEST (min.)	FALLING HEAD T (gpd/ft)	FALLING HEAD K (cm/sec)	FALLING HEAD LENGTH OF TEST (min.)
ALLUVIUM - 10	2	10	18			.75	1.1[a]	2.9×10^{-6}	15			
18	3	50	47	5280	5.3×10^{-3}	15	6815 11733	6.8×10^{-3} 1.2×10^{-1}	15			
19	3	40	37			15	1005 2640	1.3×10^{-3} 3.4×10^{-3}	15			
20	3	80	71			·15	6212	3.8×10^{-3}	15			
ROSEBUD-MCKAY OVERBURDEN												
4A	55	41	6			8	17	1.3×10^{-4}	15			
5A	46	63	17	634[b]	1.8×10^{-3}	180[b]	581	1.6×10^{-5}	31	725	2.0×10^{-3}	16
ROSEBUD-MCKAY COAL												
2A	15	45	30	14	2.2×10^{-5}	25	21	3.3×10^{-5}	60			
3A	112	142	30				4.6	7.2×10^{-6}	15			
4B	70	111	41	5	5.8×10^{-6}	130	9	1.0×10^{-5}	40	4.07	4.7×10^{-6}	55
5B	91	135	44	35[b]	3.8×10^{-5}	60[b]	3.1[x]	3.3×10^{-6}	17	44.5	4.8×10^{-5}	45
6A	10	110	40	1[b]	1.2×10^{-6}	40	3.5[x]	4.1×10^{-6}.	20	5.3	3.9×10^{-6}	45
8C	68	100	32			11	1.8[x]	2.1×10^{-6}	11	7.5 9.4	1.1×10^{-5} 1.4×10^{-5}	55
INTERBURDEN												
14B	131	110	39	7.3	8.8×10^{-6}	60	8	9.7×10^{-6}	60	28 36	3.4×10^{-5} 4.4×10^{-5}	60
ROBINSON COAL 1A	48	72	24	14	2.8×10^{-5}	120	21	4.1×10^{-5}	60			
2B	105	125	20	2.9[b]	6.8×10^{-6}	110[b]	2.3[a]	5.4×10^{-6}	10	3.9	9.2×10^{-6}	50
3B	195	215	20			15	1.4[x]	$3.\dot{3} \times 10^{-6}$	15			
4C	165	212	47			60	2.4 12.5	2.4×10^{-6} 1.3×10^{-5}	485	17.6	1.8×10^{-5}	60
5C	247	261	20	3[b]	7.1×10^{-6}	120[b]	4.1[a]	1.1×10^{-5}	33	2.2	5.2×10^{-6}	60
6B	175	196	21	13[b] 21	2.9×10^{-5} 4.7×10^{-5}	110[b] 120	8	1.8×10^{-5}	60	12	2.7×10^{-5}	60
8B	141	185	44			15	2.8[a]	3.0×10^{-6}	15	1.6	1.1×10^{-6}	75
15B	70	91	27			15	3.1[x]	5.4×10^{-6}	15			
16B	65	100	35			15	1.7[x]	2.3×10^{-6}	16	1.8	2.4×10^{-6}	46
SUB-ROBINSON												
1B	85	115	40	87	1.0×10^{-4}	110	56	6.6×10^{-5}	289			
2C	172	231	60	469 508	3.7×10^{-4} 4.0×10^{-4}	150[b] 690	131 633[b]	1.0×10^{-4} 5.0×10^{-4}	50 80[b]	62 324	7.3×10^{-5} 5.8×10^{-4}	20
3C	250	290	40			120	50	3.5×10^{-5}	48			
8A	236	280	44	21	2.3×10^{-5}	300	17	1.8×10^{-5}	120	22	2.4×10^{-5}	60
16A	141	112	31			265	32	4.9×10^{-5}	60	2.5 44	3.8×10^{-6} 6.7×10^{-5}	64
SUB SUB-ROBINSON												
9A	172	341	69							30 40	2.1×10^{-5} 2.7×10^{-5}	45

[x] Calculated using Q as the Recovery rate in gpm.

[b] Values given by Van Voast and Hedges, written communication, 1974.

From Westmoreland Resources, 1975 1

Table 31 Geologic Formations and Their Hydrologic Properties In the Sarpy Creek and Tullock Creek Drainages

System and Formation	Member	Approximate Thickness (feet)	Water Supply Capability
Quaternary			
Allvuium		Less than 60	Alluvium present along the major water courses is water-bearing and yields small quantities of water to wells and springs. Larger well yields may be obtainable where more extensive sand and gravel beds or lenses are present. Water quality is fair to poor and consists of calcium, magnesium and sodium sulfate and sodium bicarbonate types. The water is high in hardness.
Tertiary			
Fort Union	Tongue River	+ 1650 (approximately ± 300' present on Tract III)	Sandstone and coal beds are water-bearing. They yield small quantities of water to wells and springs. Water quality is fair to poor. Chemical constituents of the water ranges from calcium and magnesium sulfates, to that contained in the alluvium. The water is generally high in hardness.
	Lebo shale	± 100	Sandstone or coal beds may yield some water to wells although the formation is not considered to be an aquifer. Water is usually very poor in quality and is of the sodium bicarbonate and sodium sulfate types.
	Tullock	± 300	Sandstone beds furnish small (Tullock) to moderate (Hell Creek) supplies of water to wells. Water quality is fair to poor. Near the formation outcrop, calcium and magnesium sulfate and hardness prevail; while at greater depth sodium bicarbonate and sodium sulfate type water containing low hardness predominates.
Cretaceous			
Hell Creek		± 600	

From U.S. Bureau of Indian Affairs, 1974, p. 232-234

Table of Geologic Formations and Their Hydrologic Properties
In the Sarpy Creek and Tullock Creek Drainages

System and Formation	Member	Approximate Thickness (feet)	Water Supply Capability
Bearpaw shale		± 600	Relatively impermeable. Weathered part may contain some water, but probably the quantity would be small and the water highly mineralized.
Parkman sandstone		± 250	Wells that tap the basal sandstone yield adequate supplies of water: but toward the north, where mudstone is present, yields are smaller and the water is more mineralized.
Cody shale		± 2,600	Small supplies of mineralized water can be obtained from the weathered shale.
Frontier		± 250	Upper part may yield small amounts of water; lower part is not water-bearing.
Mowry shale		± 300	Possibly would yield small amounts of mineralized water.
Thermopolis shale		± 550	Nearly impermeable. Would yield little or no water to wells.
Cloverly		± 200	Yields moderate to large supplies of water to wells that tap the lower part of the formation. Water is under artesian pressure and wells in favorable topographic locations will flow. Water is mineralized but is suitable for stock, domestic, and limited irrigational use.
Jurassic			
Morrison		± 150	Yields small quantities of water to wells tapping the more permeable beds.
Ellis group		± 700	Possibly would yield small quantities of water to wells.

Table of Geologic Formatins and Their Hydrologic Properties
In the Sarpy Creek and Tullock Creek Drainages

System and Formation	Member	Approximate Thickness (feet)	Water Supply Capability
Triassic-Permian			
Chugwater		± 350	Relatively impermeable.
Pennsylvanian			
Tensleep sandstone		± 50	Yields moderate to large supplies of water to wells that tap thick sections of the formation.
Amsden		± 250	Large yields of water reportedly are obtained where rocks are brecciated or limestone is cavernous
Mississippian			
Madison limestone		± 700	Formation contains numerous caverns, open joints, and fissures, and is the most prolific water-bearing formation underlying the area. Water quality is unknown, but may be potable. Water probably high in calcium-sulfate and hardness.

(1) Range in water quantity may be defined as:

Small	-	0 - 25 gpm
Moderate	-	25 - 100 gpm
Large	-	+ 100 gpm

(2) Range in water quality may be defined by the following:

Good -	0 to 500 mg/l	of total dissolved solids
Fair -	500 to 1500 mg/l	of total dissolved solids
Poor -	> 1500 mg/l	of total dissolved solids

ALLUVIAL AQUIFER

Table 32 Chemical Quality of Water Data for Wells and Springs on Westmoreland Resources TRACT III

LOCATION	Calcium (mg/1)	Magnesium (mg/1)	Sodium (mg/1)	Iron (mg/1)	Bicarbonate (mg/1)	Sulfate (mg/1)	Total Hardness as $CaCO_3$ (mg/1)	Total Alkalinity as $CaCO_3$ (mg/1)	Dissolved solids (mg/1)	Conductance (mmhos/cm)	pH
WELLS											
IN-37E-21ACDD (LEBO?)	51	183	207	.02	419	943	894	343	1859	2080	7.35
IN-37E-26ABBC(RC?)	45	61	73	39.5	293	345	366	240	904	941	8.1
IN-37E-27BDCB	52	59	458	0	265	1103	377	218	1954	2430	7.4
IN-37E-35CBCB	44	99	55	0	278	390	526	236	903	1089	7.4
IN-38E-22CCC	81	106	235	3.1	439	767	643	360	1655	1960	7.6
IN-38E-29ADDA(RMOB?)	80	146	81	0	486	540	809	393	1358	1520	7.4
IN-38E-32BBAA(RMOB?)	37	45	4.2	0	314	42	281	265	478	540	7.3
SPRINGS											
IN-37E-22CBCC	58	210	338	0	795	1041	1024	652	2487	2590	8.5

From U.S. Bureau of Indian Affairs, 1974, 237-241

ROSEBUD - McKAY, CLINKER OR OVERBURDEN AQUIFERS

LOCATION	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Iron (mg/l)	Bicarbonate (mg/l)	Sulfate (mg/l)	Total Hardness as $CaCO_3$ (mg/l)	Total Alkalinity as $CaCO_3$ (mg/l)	Dissolved solids (mg/l)	Conductance (mmhos/cm)	pH
WELLS											
IN-37E-24CACC	65	66	22	0	444	97	436	364	716	810	7.35
IN-38E-29ADDA (Alluvium ?)	80	146	81	0	486	540	809	398	1358	1520	7.4
IN-38E-32BBAA (Alluvium ?)	37	45	4.2	0	314	42	281	265	478	540	7.3
IS-38E-03CACC	53	64	22	0	358	145	399	293	659	733	7.5
SPRINGS											
IN-38E-29DBBB	75	138	48	.03	668	291	763	548	1249	1340	8.4
IN-38E-29DBCC	131	222	89	0	691	830	1254	566	1998	2060	8.2
IN-38E-30BBBA	198	150	36	.03	372	870	1113	305	1720	1880	8.05
IN-38E-30DADD	24	73	49	0	444	76	365	397	695	742	7.4
IS-38E-03ACDB	126	319	85	.03	427	1383	1650	350	2382	2400	7.7
IS-38E-03DBAB	46	117	28	.02	394	308	604	337	921	1040	8.25
IS-38E-03DBDB	67	172	57	.02	357	690	887	293	1374	1530	8.35
IS-38E-03DBDB	137	154	31	.03	579	510	984	475	1547	1620	7.45

ROSEBUD-McKAY COAL BED AQUIFER

LOCATION	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Iron (mg/l)	Bicarbonate (mg/l)	Sulfate (mg/l)	Total Hardness as $CaCO_3$ (mg/l)	Total Alkalinity as $CaCO_3$ (mg/l)	Dissolved Solids (mg/l)	Conductance (mmhos/cm)	pH
WELLS											
IN-38E-29ADCA	57	70	22	.05	431	[illegible]	435	353	[illegible]	816	7.4
IN-38E-29CABD	49	80	21	0	336	152	454	275	[illegible]	834	7.1
IN-31F-30DDAD	55	130	51	0	272	273	680	223	1032	1360	7.3
IN-38E-30DDBD	25	68	23	0	357	86	349	293	581	657	---
IS-38E-09ACBB	70	97	45	2.1	510	238	579	418	982	1060	7.2
IS-38E-09BADD	82	96	62	1.2	433	364	604	355	1066	1230	7.1
IS-38E-09BDDA	104	140	143	0	256	901	943	210	1572	1780	7.15
IS-38E-09CAAA	90	54	182	0	517	441	493	424	1321	1370	7.3
SPRINGS											
IN-37E-13CCAD	138	95	62	.05	222	650	738	182	1225	1450	7.25
IN-37E-26DAAB	72	72	46	0.90	331	257	487	312	906	1010	8.7
IN-37E-36DDCA	5	78	35	0	283	146	339	296	592	743	7.25
IN-38E-19BCDC	51	166	97	.02	327	700	824	296	1372	1580	7.2
IN-38E-19CBBC	195	142	61	.02	471	733	1072	386	1690	1770	7.5
IN-38E-19CCAC	225	159	48	.05	339	1002	1220	278	1820	1950	7.3
IN-38E-19DCDB	19	87	22	0	409	78	410	385	659	734	7.9

ROBINSON COAL BED AQUIFER

LOCATION	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Iron (mg/l)	Bicarbonate (mg/l)	Sulfate (mg/l)	Total Hardness as $CaCO_3$ (mg/l)	Total Alkalinity as $CaCO_3$ (mg/l)	Dissolved solids (mg/l)	Conductance (mmhos/cm)	pH	SAR
WELLS												
IN-37E-23DBCD	122	112	120	10.8	406	676	770	333	1473	1690	7.6	< 10
IN-37E-26ABBC (Alluvium ?)	45	61	73	39.5	293	345	366	240	904	941	8.1	"
IN-38E-19CDDB	14	30	242	.02	360	360	162	311	1020	1210	9.4	"
IN-38E-31CCC	45	43	244	0	420	445	290	360	1225	1470	7.35	"
IN-38E-32BBCA	51	28	480	0	346	951	243	205	1879	2290	7.55	13.4
SPRINGS												
IN-37E-26ABBB	117	105	73	2.7	457	499	728	375	1304	1400	7.35	

LEBO SHALE OR UPPER TULLOCK MEMBER AQUIFER

LOCATION	Calcium (mg/1)	Magnesium (mg/1)	Sodium (mg/1)	Iron (mg/1)	Bicarbonate (mg/1)	Sulfate (mg/1)	Total Hardness as $CaCO_3$ (mg/1)	Total Alkalinity as $CaCO_3$ (mg/1)	Dissolved solids (mg/1)	Conductance (mmhos/cm)	pH	SAR
WELLS												
1N-37E-14ACCC	162	132	142	0.62	454	820	950	372	1739	2000	7.1	2.6
1N-37E-15BBCA	6	1.6	564	0.05	670	635	22	611	1919	2320	8.39	52.3
1N-37E-21ACDD(Alluvium)	51	183	207	0.02	419	943	894	343	1859	2080	7.25	3.1
1N-37E-22BBAD	76	415	415	1.8	443	859	362	363	1860	2230	7.6	9.5

MADISON LIMESTONE (MISSION CANYON) AQUIFER

LOCATION	Calcium (mg/1)	Magnesium (mg/1)	Sodium (mg/1)	Iron (mg/1)	Bicarbonate (mg/1)	Sulfate (mg/1)	Total Hardness as $CaCO_3$ (mg/1)	Total Alkalinity as $CaCO_3$ (mg/1)	Dissolved solids (mg/1)	Conductance (mmhos/cm)	pH	SAR
WELL												
1N-37E-26D	309	60	44	6.7	136	980	--	--	1540	--	6.6	0.4

Table 33 - Chemical analyses of water in the area of Westmoreland Resources' coal reserves, southeastern Montana.

Location	Depth(feet)	Date of Collection	Silica(SiO_2)	Iron(Fe)	Manganese(Mn)	Calcium(Ca)	Magnesium(Mg)	Sodium(Na)	Potassium(K)	Bicarbonate(HCO_3)	Carbonate(CO_3)	Hydroxide(OH)	Alkalinity as $CaCO_3$	Sulfate(SO_4)	Chloride(Cl)	Flouride(F)	Nitrate(NO_3)	Dissolved Solids (calc.)	Hardness as $CaCO_3$ Carbonate	Hardness as $CaCO_3$ Noncarbonate	Sodium Adsorption Ratio	Specific Conductance (micromhos at 25° C.)	pH(laboratory)	Temperature(° C.)	Collecting Agency	Aquifer[a]
2N.36E.14ABBB	Spring	7-09-73	5.8	.00	.00	7.9	54	57	3.1	64	144	0	532	60	8.8	.3	.0	404.9	247	0	1.6	568	10.22	31.5	MBMG	
2N.36E.23AADB		7-09-73	8.8	.00	.00	7.9	10.8	143	2.5	299	34	0	375	63	2.6	.5	.2	571.6	65	0	7.8	689	8.80	11.0	MBMG	
2N.36E.36DDAC	Spring	7-10-73	3.9	.00	.01	28	396	245	14.5	391	58	0	513	1670	17.0	.0	2.0	2825.1	513	1220	2.6	3160	8.74		MBMG	
2N.37E.26ABDC	90	6-26-73	7.6	.00	.00	6.4	3.8	704	3.1	805	34	0	773	782	13.8	1.3	.3	2361.4	32	0	54.5	2640	8.73	11	MBMG	SubRb
2N.37E.27DCBA	100	10-5-73	12.4	.00	.00	59	44	500	5.6	358	19	0	358	1022	10.6	.3	5.8	2036.9	329	0	12.0	2710	8.57	11	MBMG	SubRb
2N.37E.28BDDD	Stream	7-17-72	12	.30	.08	81	118	152	9.6	414	0	0	340	644	10.9	.3	.0	1442.4	340	354	2.5	1660	7.93	21.9	MBMG	
2N.37E.31CCCB	60	7-05-73	14	.00	.00	40	105	163	5.0	437	0	0	358	525	6.2	.2	.3	1295.6	358	183	3.1	1544	8.17	22.0	MBMG	SubRb
2N.37E.32BBBB	100	7-09-73	12.2	.00	.01	87	304	267	10.5	618	0	0	507	1448	17.8	.2	3.3	2768.3	507	985	3.0	1970	8.11	9.5	MBMG	SubRb
2N.37E.34DABD	70	6-22-73	10.3	.01	.00	81	121	843	11.5	264	0	0	216	2276	13.9	.3	3.1	3622.8	216	489	13.9	3390	8.12	13.0	MBMG	SubRb
2N.38E.16ADAC	Spring	7-09-73	10.5	.00	.00	110	218	128	7.1	520	0	0	426	1004	14.7	.2	.0	2011.8	426	759	1.6	2274	8.02	23.0	MBMG	RbC
2N.38E.18ABBB	70	6-26-73	11.8	.00	.01	89	131	97	5.3	417	0	0	342	557	12.0	.2	21.3	1342.2	342	425	1.5	1522	8.17	9.0	MBMG	SubRb
2N.38E.19ACDA	Spring	7- -73	14.6	.00	.01	434	403	357	33.0	366	0	0	300	3060	4.6	.3	.1	4671.8	300	2453	3.0	4440	7.77		MBMG	SubRb
2N.38E.20BDCA	160	7- -73	1.7	.00	.00	11.1	57	525	6.5	365	18	0	358	1062	7.7	.1	.8	2054.4	268	0	1.7	2600	8.49	10.0	MBMG	SubRb
2N.38E.22BBAB		7-02-73	15.7	.00	.00	25	126	64	4.3	405	0	0	332	385	4.7	.1	3.1	1032.7	332	257	1.2	1232	8.27	10.0	MBMG	SubRb
2N.38E.30AABD	Spring	7-09-73	14.9	.00	.00	36	45	11	1.2	295	0	0	242	53	1.9	.2	.7	458.6	242	33	0.3	534	8.12	18.0	MBMG	R-McCl
2N.38E.09CCCC	Spring	10-05-73	12.7	.00	.00	24	64	27	2.7	302	14	0	295	80	4.8	.2	14.4	546.8	295	35	0.7	680	8.61	11.0	MBMG	R-McCl
2N.38E.32ABDB	114	7-10-73	13.8	.00	.03	125	231	232	8.2	542	0	0	444	1306	8.8	.0	2.3	2468.5	444	831	2.8	2710	7.93	14.0	MBMG	R-McCl
1N.36E.03BACA		7-09-73	13.2	.00	.01	32	16.5	105	7.1	401	0	0	329	652	6.5	.0	.6	1383.1	329	443	1.7	1640	8.18	12.5	MBMG	
1N.36E.19BB		8-01-72	7	.00	.02	31	10.9	910	2.9	459	0	0	376	1628	13.8	.4	4.8	3067.7	121	0	35.9	3430	8.30	11.0	MBMG	
1N.37E.02BAAA		6-22-73	8.1	.02	.00	99	122	576	11.6	276	0	0	226	1736	12.1	.1	6.0	2846.4	226	528	9.2	3414	8.06	11.0	MBMG	SubRb
1N.37E.03C	Stream	7-21-73	0	.00	.01	75	306	386	19.1	581	41	0	613	1662	15.5	.2	10.0	3096.4	613	858	4.4	3390	8.53	20.5	MBMG	

Analyses by Montana Bureau of Mines and Geology water laboratory, Butte
Concentrations in milligrams per liter

[a]/Aquifer: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

From Van Voast and Hedges, 1974, Table 1

Table 33- (continued)

Location	Depth	Date of Collection	Silica(SiO_2)	Iron(Fe)	Manganese(Mn)	Calcium(Ca)	Magnesium(Mg)	Sodium(Na)	Potassium(K)	Bicarbonate(HCO_3)	Carbonate(CO_3)	Hydroxide(OH)	Alkalinity as $CaCO_3$	Sulfate(SO_4)	Chloride(Cl)	Flouride(F)	Nitrate(NO_3)	Dissolved Solids (calc.)	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate	Sodium Adsorption Ratio	Specific Conductance (micromhos at 25° C.)	pH(laboratory)	Temperature(° C.)	Collecting Agency	Aquifer[a]
1N.37E.32BCDA	Spring	8-02-73	22.6	.00	.00	31	47	24	7.5	329	0	0	270	57	4.1	.9	2.8	526.2	260	4	0.6	598	8.21		MBMG	RbC
1N.37E.33AAAB	130	7-02-73	19.4	.00	.20	79	178	219	13.0	536	22	0	512	918	10.0	.2	.6	1995.2	512	429	3.1	2270	8.00	9	MBMG	SubRb
1N.37E.34DAAC		9-06-73	10.7	.00	.11	120	146	1043	13.9	343	15	0	331	2780	16.2	.2	17.4	4505.2	331	575	15.1	5130	8.44	10.0	MBMG	SubRb
1N.37E.35CBCB		8-11-72	21.4	.00	.01	44	99	55	6.0	278	2	0	236	390	4.3	.3	1.6	902.9	236	290	1.0	1089	8.39	10.0	MBMG	Al
1N.37E.36BDCA	Spring	7-29-72	17.0	.00	.00	4.9	78	35	3.8	283	19	0	296	146	4.6	.0	.1	592.0	296	41	0.8	743	8.82	13.0	MBMG	R-McC
1N.38E.08ADBD	146	8-27-73	2.4	.00	.00	3.1	1.1	650	4.0	138	15	0	162	1224	12.6	.4	2.3	2052.9	12	0	81.0	2780	8.78	10.0	MBMG	SubRb
1N.38E.15BBDA	Spring	8-13-73	1.6	.00	.00	47	65	580	8.9	553	10	0	486	1120	8.8	.2	6.0	2400.6	389	0	12.8	2830	8.30	27	MBMG	SubRb
1N.38E.17ADDD	113	8-27-73	4.8	.00	.00	17	32	65	4.8	183	0	0	150	216	2.3	.2	.9	546.1	150	75	1.9	712	7.71	11.0	MBMG	SubRb
1N.38E.19BCDC	Spring	8-11-72	9.6	.02	.01	51	166	97	2.3	327	8	0	296	700	9.5	.2	.7	1372.3	296	528	1.5	1580	8.47	9.0	MBMG	R-McCl
1N.38E.19CABA	Spring	8-28-73	15.2	.00	.00	69	124	107	4.9	376	0	0	308	563	7.8	.2	5.1	1271.9	308	381	1.8	1460	8.16	11.0	MBMG	R-McCl
1N.38E.19CBBC	Spring	7-31-72	16.0	.02	.00	195	142	61	10.6	471	0	0	386	783	10.3	.3	1.1	1689.9	386	686	0.8	1790	7.96	15.0	MBMG	R-McCl
1N.38E.19CCAC	Spring	8-11-72	20.1	.05	.02	225	159	48	16.3	339	0	0	278	1002	8.0	.5	2.2	1820.4	278	942	0.6	1950	8.28	22.0	MBMG	R-McCl
1N.38E.19CDDB	115	7-31-72	2.0	.02	.02	14.0	30	242	2.6	360	5	0	311	360	4.2	.3	.0	1020.0	162	0	8.3	1210	8.44	11.0	MBMG	RbC
1N.38E.19DCDB	Spring	7-31-72	17.0	.00	.00	18.9	87	22	5.3	409	15	0	385	78	6.0	.2	1.7	659.4	385	25	0.5	734	8.58	20.0	MBMG	R-McC
1N.38E.22CADD	Stream	6-29-73	15.4	.02	.01	105	276	395	11.9	579	0	0	475	1736	5.8	.2	.0	3124.4	475	944	4.6	3425	8.12		MBMG	
1N.38E.22CCCC$_1$	30	7-18-72	8.0	3.08	.39	31	106	215	4.8	439	0	0	360	767	10.7	.3	.0	1655.3	360	283	4.0	1960	7.94	6.0	MBMG	
1N.38E.23BBBD	120	7-03-73	9.9	.00	.00	65	114	288	7.3	187	0	0	154	1070	7.2	.0	1.7	1750.0	154	483	5.0	2170	8.07	12.0	MBMG	SubRb
1N.38E.26DBAA	140	7-07-73	9.4	.00	.01	120	49	493	7.9	253	0	0	207	1292	7.1	.0	3.7	2235.4	207	295	9.6	2777	8.25	11.5	MBMG	SubRb
1N.38E.28AAAA$_1$		7-18-72	9.0	.09	.01	11.1	2.0	530	2.4	337	0	0	276	880	9.8	.4	.3	1782.1	36	0	38.4	2290	8.05	13.0	MBMG	
1N.38E.28AAAA$_2$	200	6-29-73	12.8	.00	.00	11.2	1.7	556	2.4	324	4	0	279	944	9.4	.3	1.0	1867.0	35	0	40.9	2310	8.39	12.5	MBMG	SubRb
1N.38E.29ADCC	20	7-31-72	11.0	.00	.08	44	125	22	3.6	548	3	0	459	196	8.5	.2	4.7	965.7	459	173	.4	1050	8.32	12.5	MBMG	R-McO
1N.38E.29ADCA$_1$		7-21-72	11	.67	.04	50	88	26	2.7	395	0	0	324	160	32.0	.1	21.5	787.7	324	169	.5	925	8.06	10.0	MBMG	R-McC
1N.38E.29ADCA$_2$	100	7-21-72	10.0	.05	.10	57	70	22	2.9	431	0	0	353	120	7.8	.2	3.0	723.8	353	82	.5	816	8.07	13.5	MBMG	R-McC

Analyses by Montana Bureau of Mines and Geology water laboratory, Butte
Concentrations in milligrams per liter

[a]/Aquifer: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

Table 33 (continued)

Location	Depth(feet)	Date of Collection	Silica(SiO_2)	Iron(Fe)	Manganese(Mn)	Calcium(Ca)	Magnesium(Mg)	Sodium(Na)	Potassium(K)	Bicarbonate(HCO_3)	Carbonate(CO_3)	Hydroxide(OH)	Alkalinity as $CaCO_3$	Sulfate(SO_4)	Chloride(Cl)	Flouride(F)	Nitrate(NO_3)	Dissolved Solids (calc.)	Hardness as $CaCO_3$ Carbonate	Hardness as $CaCO_3$ Noncarbonate	Sodium Adsorption Ratio	Specific Conductance (micromhos at 25° C.)	pH(laboratory)	Temperature(° C.)	Collecting Agency	Aquifer[a]
1N.37E.06ACAD	50	7-09-73	12.1	.01	.00	4.4	188	227	5.9	383	76	0	567	830	6.5	.0	.3	1733.6	567	234	3.5	2074	9.00		MBMG	SubRb
1N.37E.13CCAD	Spring	7-29-72	24.1	.05	.01	188	95	62	14.5	222	0	0	182	650	6.9	1.3	11.0	1225.4	182	556	1.0	1450	7.87	10.5	MBMG	R-McCl
1N.37E.14ACCC	130	7-20-72	12.1	.62	.13	162	132	142	6.2	454	0	0	372	820	8.5	.5	1.8	1729.8	372	578	2.0	2000	7.65	10.5	MBMG	SubRb
1N.37E.15BAAD		7-10-72	13	7.00	.15	47	45	700	6.7	416	7	0	364	1440	11.7	.3	.7	2694.5	305	0	17.5	3340	8.54	10.0	MBMG	SubRb
1N.37E.15BBCA	140	7-20-72	9	.05	.02	6.3	1.6	564	1.8	679	16	0	611	635	6.1	.3	.0	1919.2	22	0	52.3	2320	8.70	14.1	MBMG	SubRb
1N.37E.15C	Stream	7-21-73	17.2	.02	.02	78	515	644	29.6	1288	139	0	1522	2422	26	.3	30.0	5015.7	1522	835	5.8	4950	8.70	23	MBMG	
1N.37E.16ACCC		7-02-73	11.9	.00	.05	25	42	512	5.2	434	0	0	356	934	7.0	.3	2.0	1973.2	238	0	14.5	2400	8.30	12.0	MBMG	SubRb
1N.37E.20BADC	Spring	4-02-73	22.8	.00	.00	55	26	24	7.3	291	0	0	239	56	2.5	.5	2.4	487.0	239	3	.7	516	8.17	1.3	MBMG	R-McCl
1N.37E.20ABCA		7-27-73	15.4	.00	.03	101	139	137	5.8	490	0	0	402	720	5.8	.1	.0	1613.6	402	429	2.1	1835	7.71	11.0	MBMG	
1N.37E.21ACDD	30	8-13-72	26.8	.02	.00	51	183	207	11.5	419	0	0	343	943	17.0	.2	.5	1859.0	343	551	3.0	2080	8.20	8.0	MBMG	Al
1N.37E.22BBAD		7-20-72	11.0	1.80	.15	76	42	415	5.4	443	0	0	363	859	6.1	.4	.0	1860.0	362	0	9.5	2230	8.20	9.5	MBMG	SubRb
1N.37E.CBCC	Spring	8-13-72	2.1	.00	.00	58	210	338	19	795	0	0	652	1041	18.1	.2	5.4	2486.5	652	372	4.6	2590	8.08	26.0	MBMG	Al
1N.37E.23DBCD	80	7-20-72	12	10.80	.16	122	112	120	4.3	406	0	0	333	676	9.5	.3	.0	1473.0	333	437	1.9	1690	7.79	12.0	MBMG	RbC
1N.37E.24CACC	8	7-29-72	11	.00	.00	65	66	22	1.8	444	0	0	364	97	7.1	.4	2.6	716.4	364	72	.5	810	8.23	12.0	MBMG	R-McO
1N.37E.25BCAC	*	73	5.8	.00	.14	88	64	409	12.8	441	29	0	459	926	11.3	.5	1.9	1988.8	459	23	8.1	2300	8.64		MBMG	RbC
1N.37E.26AADA	*	73	6.4	.00	.01	41	107	447	9.9	365	15	0	348	1126	12.4	.4	1.9	2131.2	348	200	8.4	2540	8.44		MBMG	RbC
1N.37E.26ABBB	Spring	7-17-72	32	2.70	.10	117	105	73	8.5	457	0	0	375	499	8.1	.8	.0	1303.6	375	353	1.2	1400	8.16	17.0	MBMG	RbC
1N.37E.26ABBC	123	7-17-72	12.1		.20	45	61	73	8.2	293	0	0	240	345	5.3	1.0	21.5	904.4	240	126	1.7	941	7.85	10.0	MBMG	SubRb
1N.37E.26CAAA	7977	10-11-73	48.5	.65	.13	317	54	52.4	48.6	103	0	0	84	1049	27	4.2	.5	1705.6	84	921	.7	1926	8.05	62	MBMG	Mission Canyon
1N.37E.26DAAB	Spring	7-17-72	41	.90	.81	72	72	46	18	381	0	0	312	257	8.6	1.2	7.5	906.1	312	168	.9	1010	7.95	19.0	MBMG	R-McCl
1N.37E.26	*		5.4	.05	.01	9.0	16.2	451	4.6	525	14	0	477	595	12.6	1.5	.7	1634.5	90	0	20.8	2050	8.63		MBMG	SubRb
1N.37E.27BDCB	30	8-13-72	9.6	.00	.01	52	59	458	6.3	265	0	0	218	1103	8.4	.3	1.4	1964.2	218	160	10.3	2430	8.30	11.0	MBMG	SubRb
1N.37E.28D	Stream	7-21-73	14.1	.02	.01	54	125	224	15.2	431	32	0	460	702	13.0	.2	13.0	1623.6	460	199	3.8	1870	8.40	15.2	MBMG	

* Uncased test hole

Analyses by Montana Bureau of Mines and Geology water laboratory, Butte
Concentrations in milligrams per liter

a/ Aquifer: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

Table 33. (continued)

Location	Depth	Date of Collection	Silica(SiO_2)	Iron(Fe)	Manganese(Mn)	Calcium(Ca)	Magnesium(Mg)	Sodium(Na)	Potassium(K)	Bicarbonate(HCO_3)	Carbonate(CO_3)	Hydroxide(OH)	Alkalinity as $CaCO_3$	Sulfate(SO_4)	Chloride(Cl)	Flouride(F)	Nitrate(NO_3)	Dissolved Solids (calc.)	Hardness as $CaCO_3$ Carbonate	Hardness as $CaCO_3$ Noncarbonate	Sodium Adsorption Ratio	Specific Conductance (micromhos at 25° C.)	pH(laboratory)	Temperature(° C.)	Collecting Agency	Aquifer[a]
1N.38E.29ADDA	20	7-31-72	9.0	.00	.01	80	146	81	3.0	486	0	0	398	540	10.3	.3	2.5	1357.5	398	410	1.2	1520	7.95	8.0	MBMG	R-McO
1N.38E.29CABD	45	8-11-72	134	.00	.00	49	80	21	1.8	336	0	0	275	152	28	.1	31	832.2	275	179	.4	834	8.16	8.2	MBMG	R-McC
1N.38E.29DBBB	Spring	8-11-72	4.8	.03	.01	75	138	48	10.1	668	0	0	548	291	11.1	.2	2.8	1249.0	548	215	.8	1340	8.21	20.5	MBMG	R-McO
1N.38E.29DCCC	Spring	8-11-72	6.4	.00	.00	131	222	89	10.4	691	0	0	566	830	11.9	.2	7.0	1998.4	566	687	1.1	2060	8.22	22.0	MBMG	R-McO
1N.38E.30BBBA	Spring	8-11-72	42.2	.03	.01	198	150	36	29.8	372	0	0	305	870	15.5	.5	6.8	1720.1	305	808	.5	1880	7.62	24.0	MBMG	
1N.38E.30DADD		7-30-72	11	.00	.00	55	130	51	2.6	272	0	0	223	273	69	.0	220	1083.3	223	457	.9	1360	8.21	7.4	MBMG	R-McC
1N.38E.30DADD	Spring	7-30-72	11	.00	.02	24	73	49	2.7	444	10	0	397	76	1.7	.1	3.6	695.1	365	0	1.1	742	8.54		MBMG	
1N.38E.30DDBD	50	7-30-72	11	.00	.00	25	68	23	2.3	357	0	0	293	86	3.7	.1	4.9	581.3	293	56	.5	657	8.21	9.2	MBMG	R-McC
1N.38E.31CCCC	165	1-24-73	15	.04	.13	245	106	39	2.7	644	0	0	528	568	8.0	.0	.4	1629.3	528	518	.5	1680	7.33		MBMG	RbC
1N.38E.31CCCD		8-12-72	13.4	.00	.01	45	43	244	3.4	420	5	0	360	445	3.6	.1	2.9	1225.2	290	0	6.2	1470	8.44	12.0	MBMG	
1N.38E.32BBAA	15	8-10-72	13.4	.00	.01	37	45	4	16	314	2	0	265	42	1.8	.2	1.8	477.8	265	16	.1	540	8.33	11.8	MBMG	Al
1N.38E.32BBBD		8-10-72	5.4	.00	.00	7.2	13.8	174	3.2	381	18	0	373	102	5.2	.1	1.5	711.9	76	0	8.7	909	8.81	12.4	MBMG	
1N.38E.32BBCA	225	8-10-72	6.4	.00	.03	51	28	480	4.3	346	6	0	305	951	5.0	.1	.7	1878.8	243	0	13.4	2290	8.45	13.5	MBMG	SubRb
1N.38E.36BACD		7-26-73	9.2	.05	.05	105	58	422	8.2	193	0	0	158	1216	6.9	.0	12.0	2031.1	158	344	8.2	2510	8.15		MBMG	
1N.38E.36BDAB	173	2-05-74	.0	.06	.00	4.4	43	40.3	3.5	155	17	0	184	117	7.8	.1	.1	388.9	184	8	1.3	501	8.97		MBMG	SubRb
1N.39E.31AAAC		7-17-73	12.1	.00	.03	55	149	238	10	334	0	0	274	948	4.2	.1	1.2	1751.9	274	487	3.8	2100	8.10	10.5	MBMG	RO
1S.37E.01BAAC	174	9-11-73	8.6	.00	.00	120	75	378	11.3	358	0	0	294	1090	8.2	.1	5.5	2055.7	294	318	6.7	2380	7.99	11.0	MBMG	SubRb
1S.37E.01BAAD$_1$	180	9-11-73	8.3	.00	.00	67	61	633	6	337	0	0	276	1476	15.5	.2	1.8	1605.3	276	145	13.4	3287	8.20	11.0	MBMG	SubRb
1S.37E.01DACC	Spring	10-09-73	1.3	.00	.00	65	47	19	10.4	193	0	0	158	239	4.8	.2	.0	580.0	158	197	.4	753	7.90	19.0	MBMG	R-McCl
1S.37E.03AABD$_2$		7-05-73	27.1	.03	.00	54	136	124	7.9	510	0	0	418	519	5.6	.3	.0	1384.3	418	287	2.0	1510	8.06	9.5	MBMG	
1S.37E.06CCBB		7-03-73	2.5	.00	.00	7.8	37	211	5.8	417	17	0	399	262	8.3	.0	2.0	970.4	173	0	7.0	1153	8.78	8.78	MBMG	
1S.37E.13BCDB		9-10-73	14.1	.01	.10	42	207	149	8.3	209	0	0	171	1100	5.9	.0	3.8	1739.2	171	805	2.1	2091	8.23	11.0	MBMG	

Analyses by Montana Bureau of Mines and Geology water laboratory, Butte
Concentrations in milligrams per liter

[a] Aquifer: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

Table 33 - (continued)

Location	Depth	Date of Collection	Silica(SiO_2)	Iron(Fe)	Manganese(Mn)	Calcium(Ca)	Magnesium(Mg)	Sodium(Na)	Potassium(K)	Bicarbonate(HCO_3)	Carbonate(CO_3)	Hydroxide(OH)	Alkalinity as $CaCO_3$	Sulfate(SO_4)	Chloride(Cl)	Flouride(F)	Nitrate(NO_3)	Dissolved Solids (calc.)	Carbonate	Noncarbonate	Sodium Adsorption Ratio	Specific Conductance (micromhos at 25° C.)	pH(laboratory)	Temperature(° C.)	Collecting Agency	Aquifer[a]
1S.38E.02BBCB	Spring	8-10-72	2.1	.00	.00	50	119	180	4.7	397	0	0	325	652	6.0	.1	4.2	1415.3	325	298	3.2	1620	7.96	21.7	MBMG	
1S.38E.03ACDB	Spring	8-20-72	11	.03	.01	126	319	85	9.2	427	0	0	350	1383	18.2	.1	3.0	2381.9	350	1300	.9	2400	3.09	21.0	MBMG	R-McO
1S.38E.03CACC	180	6-27-73	2	.00	.00	25	51	22	3.2	284	0	0	237	84	2.4	.2	4.1	477.9	237	37	.6	578	8.35	11.5	MBMG	R-McO
1S.38E.03CACC	180	8-10-72	11	.00	.02	53	64	22	2.7	358	1	0	293	145	1.9	.1	1.1	659.1	293	105	.5	733	8.00	11.8	MBMG	R-McO
1S.38E.03DBAB	Spring	8-10-72	10	.02	.00	46	117	28	4.1	394	0	0	337	308	5.8	.1	3.0	920.6	337	266	.5	1040	8.32	26.0	MBMG	R-McO
1S.38E.03DBDB$_1$	Spring	8-10-72	11	.02	.02	67	172	57	6.3	357	4	0	293	690	9.7	.2	3.7	1373.9	293	595	.8	1530	8.25	30.5	MBMG	R-McO
1S.38E.03DBDB$_2$	Spring	8-10-72	18	.03	.22	137	154	31	29	579	0	0	475	510	9.2	.2	79	1547.0	475	510	.4	1620	7.25	26.0	MBMG	R-McO
1S.38E.09ACBB	120	7-18-72	13	2.10	.08	70	97	45	2.4	510	0	0	418	238	4.7	.1	.0	982.4	418	161	.8	1060	8.27	9.2	MBMG	R-McC
1S.38E.09BADD	80	7-18-72	15	1.20	.09	82	96	62	4.3	433	0	0	355	364	7.6	.0	.0	1065.6	355	249	1.1	1230	7.86	10.0	MBMG	R-McC
1S.38E.09BDDA	84	8-01-72	11	.00	.01	104	140	143	7.4	256	0	0	210	901	6.8	.0	2.9	1572.2	210	633	2.2	1780	8.04	10.0	MBMG	R-McC
1S.38E.09CAAA	98	8-01-72	16	.00	.02	90	65	182	4.3	517	0	0	424	441	4.1	.1	1.6	1321.4	424	69	3.6	1370	8.12	11.0	MBMG	SubRb
1S.38E.10CABA	Spring	8-12-72	17.4	.02	.01	78	269	129	6.2	303	0	0	248	1275	8.1	.0	1.3	2087.5	248	1076	1.6	2320	8.13	11.5	MBMG	R-McO
1S.38E.12BBDB	160	9-13-73	12.1	.00	.21	87	321	238	7.9	415	0	0	340	1630	.1	.0	1.1	2712.9	340	1223	2.6	2460	7.69	12.0	MBMG	SubRb
1S.38E.13CBDA		9-13-73	16.6	.02	.02	152	310	154	11.2	112	0	0	92	1872	5.4	.0	4.5	2637.5	92	1583	1.6	2955	7.58	11.0	MBMG	

Analyses by Montana Bureau of Mines and Geology water laboratory, Butte
Concentrations in milligrams per liter

[a] Aquifer: Coded sources--Al, Alluvium; R-McO, Rosebud-McKay overburden; R-McC, Rosebud-McKay coal; R-McCl, Rosebud-McKay clinker; RbC, Robinson coal; RbCl, Robinson clinker; SubRb, unspecified aquifers below strippable interval.

Table 34 - Observation wells near Westmoreland Resources' Tract 3 coal reserves, Sarpy Creek area, southeastern Montana.

Well location	Number	Surface altitude (feet)	Date drilled	Total depth (feet)	Perforated zone (feet)	Packer setting (feet)	Aquifer
1N. 37E. 13CABB	1-A	3408	8-31-73	72	48-68	48	Robinson Coal
1N. 37E. 13CABB	1-B	3408	8-30-73	125	105-125	85	Sub-Robinson
1N. 38E. 19CBBB	2-A	3450	8-23-73	45	25-40	15	Rosebud-McKay Coal
1N. 38E. 19CBBB	2-B	3450	8-21-73	125	105-125	105	Robinson Coal
1N. 38E. 19CBBB	2-C	3450	8-27-73	232	192-212	172	Sub-Robinson
1N. 38E. 29BBBD	3-A	3565	8-14-73	142	113-137	112	Rosebud-McKay Coal
1N. 38E. 29BBBD	3-B	3565	8-29-73	215	195-215	195	Robinson Coal
1N. 38E. 29BBBD	3-C	3565	8-15-73	290	270-285	250	Sub-Robinson
1N. 38E. 30DDBB	4-A	3550	7-17-73	61	56-61	55	Rosebud-McKay Overburden
1N. 38E. 30DDBB	4-B	3550	7-16-73	110	71-105	70	Rosebud-McKay Coal
1N. 38E. 30DDBB	4-C	3550	7-11-73	212	189-204	165	Robinson Coal
1N. 38E. 31DDBA	5-A	3585	8-07-73	63	46-61	45	Rosebud-McKay Overburden
1N. 38E. 31DDBA	5-B	3585	8-06-73	131	91-126	91	Rosebud-McKay Coal
1N. 38E. 31DDBA	5-C	3585	7-31-73	267	247-262	247	Robinson Coal
1N. 37E. 36BDAD	6-A	3545	7-25-73	110	70-110	70	Rosebud-McKay Coal
1N. 37E. 36BDAD	6-B	3545	8-09-73	196	176-196	175	Robinson Coal
1N. 37E. 36BDAD	6-C	3545	7-27-73	288	243-263	243	Sub-Robinson

(From Van Voast and Hedges, 1974, Table 4)

Table 35 Chemical analyses from wells near Westmoreland Resources Tract III coal reserves, Sarpy Creek area, southeastern Montana.

(From Van Voast and Hedges, 1974, Chemical analyses)

MONTANA BUREAU OF MINES AND GEOLOGY   BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 37E 13CABB
SAMPLE TYPE	WELL	LAB NO.	74-705
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	48 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	22.2
DATE ANALYZED	8-27-74	ALTITUDE OF SAMPLE POINT	3408
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH
REMARKS ROBINSON COAL WATER, STATE RESEARCH WELL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	96.	4.800	BICARBONATE(HCO3)	307.	5.039
MAGNESIUM (MG)	47.	3.893	CARBONATE (CO3)	7.	0.240
SODIUM (NA)	650.	28.275	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	8.5	0.218	CHLORIDE (CL)	9.4	0.266
TOT. IRON (FE)	.00	0.0	SULFATE (SO4)	1535.	31.957
MANGANESE (MN)	.01	0.000	NITRATE (NO3)	2.0	0.032
ALUMINUM (AL)			FLUORIDE (F)	.3	0.016
SILICA (SIO2)	10.9		PHOSPHATE (PO4)		
TOTAL CATIONS		37.185	TOTAL ANIONS		37.550

STANDARD DEVIATION OF CATION-ANION BALANCE 0.35 SIGMA

LABORATORY PH	8.51	CARBONATE HARDNESS AS CACO3	276
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	158
CALCULATED DISSOLVED SOLIDS	2674.7	TOTAL HARDNESS AS CACO3	434
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	276
SPECIFIC CONDUCTANCE IN MICROMHOS/CM AT 25 C	3248.0	LANGLIER SATURATION INDEX	
		RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	13.6	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) <.02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE   PERCENT REACTANCE VALUES

				CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
MEAS DSC	0.	CALC DSC	4459.									
ERROR DSC	0.0			13	10	76	1	1	85	13	1	0

ANALYST LAW   PROCESSING PROGRAM 72(REV5)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-705

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 37E 13CABB
SAMPLE TYPE	WELL	LAB NO.	74-706
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 1-B
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	105 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	86.3
DATE ANALYZED	8-22-74	ALTITUDE OF SAMPLE POINT	3408
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR WESTMORELAND TRACT 3 MBMG SMITH
REMARKS STATE RESEARCH WELL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	78.	3.888	BICARBONATE(HCO3)	389.	6.374
MAGNESIUM (MG)	64.	5.264	CARBONATE (CO3)	15.	0.512
SODIUM (NA)	535.	23.272	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	6.4	0.164	CHLORIDE (CL)	8.8	0.247
TOT. IRON (FE)	.01	0.001	SULFATE (SO4)	1194.	24.851
MANGANESE (MN)	.01	0.000	NITRATE (NO3)	1.6	0.026
ALUMINUM (AL)			FLUORIDE (F)	.1	0.005
SILICA (SIO2)	9.3		PHOSPHATE (PO4)		
TOTAL CATIONS		32.589	TOTAL ANIONS		32.015

STANDARD DEVIATION OF CATION-ANION BALANCE -0.95 SIGMA

LABORATORY PH	8.36	CARBONATE HARDNESS AS CACO3	370
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	89
CALCULATED DISSOLVED SOLIDS	2301.0	TOTAL HARDNESS AS CACO3	460
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	370
SPECIFIC CONDUCTANCE IN MICROMHOS/CM AT 25 C	2878.0	LANGLIER SATURATION INDEX	
		RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	10.9	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) .02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE
MEAS DSC 0. CALC DSC 3779.
ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
12	16	71	1	1	78	20	2	0

ANALYST LAW PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-706

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 19CBBB
SAMPLE TYPE	WELL	LAB NO.	74-707
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 2-A
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	25 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	7.6
DATE ANALYZED	8-27-74	ALTITUDE OF SAMPLE POINT	3450
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR WESTMORELAND TRACT 3 MBMG SMITH
REMARKS STATE RESEARCH WELL ROSEBUD MCKAY COAL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	116.	5.768	BICARBONATE(HCO3)	448.	7.342
MAGNESIUM (MG)	124.	10.218	CARBONATE (CO3)	0.	0.0
SODIUM (NA)	67.5	2.936	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	2.7	0.069	CHLORIDE (CL)	10.5	0.296
TOT. IRON (FE)	.00	0.0	SULFATE (SO4)	529.	11.018
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	7.9	0.127
ALUMINUM (AL)			FLUORIDE (F)	.3	0.016
SILICA (SIO2)	10.6		PHOSPHATE (PO4)		
		------			------
TOTAL CATIONS		18.991	TOTAL ANIONS		18.799

STANDARD DEVIATION OF CATION-ANION BALANCE -0.48 SIGMA

LABORATORY PH	8.04	CARBONATE HARDNESS AS CACO3	367
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	437
CALCULATED DISSOLVED SOLIDS	1316.5	TOTAL HARDNESS AS CACO3	805
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	367
SPECIFIC CONDUCTANCE IN		LANGLIER SATURATION INDEX	
MICROMHOS/CM AT 25 C	1549.0	RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	1.0	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) .03

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE

MEAS DSC 0. CALC DSC 2091.

ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
30	54	15	0	2	59	39	0	1

ANALYST LAW PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-707

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 19CBBB
SAMPLE TYPE	WELL	LAB NO.	74-708
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 2-8
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	105 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	49.8
DATE ANALYZED	8-28-74	ALTITUDE OF SAMPLE POINT	3450
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH
REMARKS STATE RESEARCH WELL ROBINSON COAL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	6.3	0.312	BICARBONATE(HCO3)	176.	2.887
MAGNESIUM (MG)	4.0	0.327	CARBONATE (CO3)	0.	0.0
SODIUM (NA)	108.5	4.720	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	2.7	0.069	CHLORIDE (CL)	4.2	0.120
TOT. IRON (FE)	1.46	0.078	SULFATE (SO4)	120.	2.507
MANGANESE (MN)	.02	0.001	NITRATE (NO3)	2.0	0.032
ALUMINUM (AL)			FLUORIDE (F)	.2	0.011
SILICA (SIO2)	19.5		PHOSPHATE (PO4)		
		------			------
TOTAL CATIONS		5.507	TOTAL ANIONS		5.557

STANDARD DEVIATION OF CATION-ANION BALANCE 0.26 SIGMA

LABORATORY PH	8.22	CARBONATE HARDNESS AS CACO3	32
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	0
CALCULATED DISSOLVED SOLIDS	445.4	TOTAL HARDNESS AS CACO3	32
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	145
SPECIFIC CONDUCTANCE IN MICROMHOS/CM AT 25 C	548.0	LANGLIER SATURATION INDEX	
		RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	8.3	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) <.02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE

MEAS DSC 0. CALC DSC 591.

ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
6	6	87	1	2	45	52	0	1

ANALYST LAW PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-708

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 19CBBB
SAMPLE TYPE	WELL	LAB NO.	74-709
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 2-C
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	192 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	124.9
DATE ANALYZED	8-29-74	ALTITUDE OF SAMPLE POINT	3450
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH
REMARKS STATE RESEARCH WELL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	32.	1.600	BICARBONATE(HCO3)	421.	6.902
MAGNESIUM (MG)	19.4	1.593	CARBONATE (CO3)	28.	0.928
SODIUM (NA)	500.	21.750	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	4.2	0.108	CHLORIDE (CL)	8.8	0.247
TOT. IRON (FE)	.00	0.0	SULFATE (SO4)	813.	16.922
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	1.8	0.029
ALUMINUM (AL)			FLUORIDE (F)	.2	0.011
SILICA (SIO2)	7.0		PHOSPHATE (PO4)		
TOTAL CATIONS		25.051	TOTAL ANIONS		25.039

STANDARD DEVIATION OF CATION-ANION BALANCE -0.02 SIGMA

LABORATORY PH	8.55	CARBONATE HARDNESS AS CACO3	160
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	0
CALCULATED DISSOLVED SOLIDS	1835.2	TOTAL HARDNESS AS CACO3	160
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	438
SPECIFIC CONDUCTANCE IN MICROMHOS/CM AT 25 C	2396.0	LANGLIER SATURATION INDEX	
		RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	17.2	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) <.02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE

MEAS DSC 0. CALC DSC 2883.

ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
6	6	87	0	1	68	28	4	0

ANALYST LAW

PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-709

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 29BBBD
SAMPLE TYPE	WELL	LAB NO.	74-710
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	113 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	114.4
DATE ANALYZED	8-30-74	ALTITUDE OF SAMPLE POINT	3565
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH
REMARKS STATE OBSERVATION WELL-ROSEBUD MCKAY COAL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	8.8	0.437	BICARBONATE(HCO3)	405.	6.630
MAGNESIUM (MG)	1.4	0.119	CARBONATE (CO3)	34.	1.136
SODIUM (NA)	268.	11.658	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	4.2	0.108	CHLORIDE (CL)	72.	2.042
TOT. IRON (FE)	.13	0.007	SULFATE (SO4)	129.	2.690
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	3.0	0.048
ALUMINUM (AL)			FLUORIDE (F)	.4	0.021
SILICA (SIO2)	13.5		PHOSPHATE (PO4)		
TOTAL CATIONS		12.329	TOTAL ANIONS		12.567

STANDARD DEVIATION OF CATION-ANION BALANCE 0.80 SIGMA

LABORATORY PH	8.74	CARBONATE HARDNESS AS CACO3	28
FIELD TEMPERATURE	54.0 F	NON-CARB. HARDNESS AS CACO3	0
CALCULATED DISSOLVED SOLIDS	939.7	TOTAL HARDNESS AS CACO3	28
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	446
SPECIFIC CONDUCTANCE IN MICROMHOS/CM AT 25 C	1214.0	LANGLIER SATURATION INDEX	
		RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	22.1	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

AA CALCIUM (CA)	8.76	AA MAGNESIUM (MG)	1.45
SPEC.COND., FIELD	2200.	LEAD (PB)	<.02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE

MEAS DSC 0. CALC DSC 1350.

ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
4	1	95	1	16	21	53	9	0

ANALYST LAW PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-710

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 29BBBD
SAMPLE TYPE	WELL	LAB NO.	74-711
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 3-B
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	195 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	155.8
DATE ANALYZED	8-27-74	ALTITUDE OF SAMPLE POINT	3565
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH

REMARKS STATE OBSERVATION WELL, ROBINSON COAL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	18.7	0.932	BICARBONATE(HCO3)	399.	6.542
MAGNESIUM (MG)	3.9	0.319	CARBONATE (CO3)	24.	0.800
SODIUM (NA)	296.	12.876	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	4.3	0.110	CHLORIDE (CL)	8.6	0.244
TOT. IRON (FE)	.00	0.0	SULFATE (SO4)	304.	6.325
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	.6	0.010
ALUMINUM (AL)			FLUORIDE (F)	.5	0.026
SILICA (SIO2)	7.9		PHOSPHATE (PO4)		
		------			------
TOTAL CATIONS		14.237	TOTAL ANIONS		13.947

STANDARD DEVIATION OF CATION-ANION BALANCE -0.89 SIGMA

LABORATORY PH	8.50	CARBONATE HARDNESS AS CACO3	62
FIELD TEMPERATURE	56.0 F	NON-CARB. HARDNESS AS CACO3	0
CALCULATED DISSOLVED SOLIDS	1067.5	TOTAL HARDNESS AS CACO3	62
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	407
SPECIFIC CONDUCTANCE IN		LANGLIER SATURATION INDEX	
MICROMHOS/CM AT 25 C	1390.0	RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	16.3	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

SPEC.COND., FIELD 2600. LEAD (PB) <.02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE

MEAS DSC 0. CALC DSC 1543.

ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
7	2	90	1	2	45	47	6	0

ANALYST LAW PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-711

MONTANA BUREAU OF MINES AND GEOLOGY   BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 30DDBB
SAMPLE TYPE	WELL	LAB NO.	74-712
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 4-
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	56 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	32.5
DATE ANALYZED	8-27-74	ALTITUDE OF SAMPLE POINT	3550
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH
REMARKS STATE OBSERVATION WELL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	31.	1.557	BICARBONATE(HCO3)	386.	6.326
MAGNESIUM (MG)	61.	5.002	CARBONATE (CO3)	7.	0.240
SODIUM (NA)	55.8	2.427	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	8.2	0.210	CHLORIDE (CL)	3.3	0.093
TOT. IRON (FE)	.00	0.0	SULFATE (SO4)	129.	2.694
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	2.9	0.047
ALUMINUM (AL)			FLUORIDE (F)	.1	0.005
SILICA (SIO2)	18.2		PHOSPHATE (PO4)		
		------			------
TOTAL CATIONS		9.196	TOTAL ANIONS		9.405

STANDARD DEVIATION OF CATION-ANION BALANCE 0.84 SIGMA

LABORATORY PH	8.51	CARBONATE HARDNESS AS CACO3	332
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	0
CALCULATED DISSOLVED SOLIDS	703.1	TOTAL HARDNESS AS CACO3	332
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	341
SPECIFIC CONDUCTANCE IN MICROMHOS/CM AT 25 C	878.6	LANGLIER SATURATION INDEX	
		RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	1.3	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

AA CALCIUM (CA) 31.2   AA MAGNESIUM (MG) 60.8
LEAD (PB) <.02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE
MEAS DSC 0. CALC DSC 954.
ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
17	54	26	2	1	29	67	3	0

ANALYST LAW   PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-712

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 30DDBB
SAMPLE TYPE	WELL	LAB NO.	74-713
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 4-B
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	71 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	45.2
DATE ANALYZED	8-28-74	ALTITUDE OF SAMPLE POINT	3550
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3

REMARKS STATE OBSERVATION WELL ROSEBUD MCKAY COAL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	19.2	C.960	BICARBONATE(HCO3)	103.	1.684
MAGNESIUM (MG)	8.0	0.655	CARBONATE (CO3)	0.	0.0
SODIUM (NA)	74.5	3.241	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	13.4	0.343	CHLORIDE (CL)	6.0	0.171
TOT. IRON (FE)	.00	0.0	SULFATE (SO4)	165.	3.431
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	3.6	0.058
ALUMINUM (AL)			FLUORIDE (F)	.2	0.011
SILICA (SIO2)	18.0		PHOSPHATE (PO4)		
		------			------
TOTAL CATIONS		5.198	TOTAL ANIONS		5.354

STANDARD DEVIATION OF CATION-ANION BALANCE 0.83 SIGMA

LABORATORY PH	8.05	CARBONATE HARDNESS AS CACO3	81
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	0
CALCULATED DISSOLVED SOLIDS	410.5	TOTAL HARDNESS AS CACO3	81
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	84
SPECIFIC CONDUCTANCE IN MICROMHOS/CM AT 25 C	548.6	LANGLIER SATURATION INDEX	
		RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	3.6	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) <.02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE

MEAS DSC 0. CALC DSC 609.

ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
18	13	62	7	3	64	32	0	1

ANALYST LAW PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-713

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 30DDBB
SAMPLE TYPE	WELL	LAB NO.	74-714
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 4-
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	189 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	111.0
DATE ANALYZED	8-29-74	ALTITUDE OF SAMPLE POINT	3550
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH

REMARKS STATE OBSERVATION WELL ROBINSON COAL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	21.	1.048	BICARBONATE(HCO3)	318.	5.207
MAGNESIUM (MG)	3.5	0.291	CARBONATE (CO3)	14.	0.464
SODIUM (NA)	455.	19.792	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	3.0	0.077	CHLORIDE (CL)	9.3	0.264
TOT. IRON (FE)	.00	0.0	SULFATE (SO4)	744.	15.494
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	4.8	0.077
ALUMINUM (AL)			FLUORIDE (F)	.2	0.011
SILICA (SIO2)	9.5		PHOSPHATE (PO4)		
TOTAL CATIONS		21.208	TOTAL ANIONS		21.516

STANDARD DEVIATION OF CATION-ANION BALANCE 0.70 SIGMA

LABORATORY PH	8.53	CARBONATE HARDNESS AS CACO3	66
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	0
CALCULATED DISSOLVED SOLIDS	1582.2	TOTAL HARDNESS AS CACO3	66
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	307
SPECIFIC CONDUCTANCE IN MICROMHOS/CM AT 25 C	2163.0	LANGLIER SATURATION INDEX	
		RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	24.2	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) .03

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE

MEAS DSC 0. CALC DSC 2481.

ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
5	1	93	0	1	72	24	2	0

ANALYST LAW PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-714

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 31DDBA
SAMPLE TYPE	WELL	LAB NO.	74-715
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 5-A
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	46 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	30.0
DATE ANALYZED	8-27-74	ALTITUDE OF SAMPLE POINT	3585
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH
REMARKS STATE OBSERVATION WELL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	105.	5.240	BICARBONATE(HCO3)	649.	10.637
MAGNESIUM (MG)	134.	11.006	CARBONATE (CO3)	0.	0.0
SODIUM (NA)	29.	1.261	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	4.2	0.108	CHLORIDE (CL)	11.0	0.312
TOT. IRON (FE)	.01	0.001	SULFATE (SO4)	329.	6.841
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	1.6	0.026
ALUMINUM (AL)			FLUORIDE (F)	.0	0.0
SILICA (SIO2)	19.3		PHOSPHATE (PO4)		
		------			------
TOTAL CATIONS		17.615	TOTAL ANIONS		17.816

STANDARD DEVIATION OF CATION-ANION BALANCE 0.53 SIGMA

LABORATORY PH	7.97	CARBONATE HARDNESS AS CACO3	532
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	287
CALCULATED DISSOLVED SOLIDS	1281.6	TOTAL HARDNESS AS CACO3	819
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	532
SPECIFIC CONDUCTANCE IN		LANGLIER SATURATION INDEX	
MICROMHOS/CM AT 25 C	1432.0	RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	0.4	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) <.02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE
MEAS DSC 0. CALC DSC 1849.
ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
30	62	7	1	2	38	60	0	0

PROCESSING PROGRAM 72(REV3)

ANALYST LAW

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-715

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 31DDBA
SAMPLE TYPE	WELL	LAB NO.	74-716
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 5-
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	91 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	53.3
DATE ANALYZED	8-27-74	ALTITUDE OF SAMPLE POINT	3585
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH

REMARKS STATE OBSERVATION WELL, ROSEBUD-MCKAY COAL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	19.2	0.956	BICARBONATE(HCO3)	399.	6.546
MAGNESIUM (MG)	11.2	0.918	CARBONATE (CO3)	15.	0.488
SODIUM (NA)	187.	8.134	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	3.5	0.090	CHLORIDE (CL)	4.1	0.117
TOT. IRON (FE)	.00	0.0	SULFATE (SO4)	145.	3.027
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	2.0	0.032
ALUMINUM (AL)			FLUORIDE (F)	.1	0.005
SILICA (SIO2)	8.1		PHOSPHATE (PO4)		
TOTAL CATIONS		10.098	TOTAL ANIONS		10.216

STANDARD DEVIATION OF CATION-ANION BALANCE 0.44 SIGMA

LABORATORY PH	8.52	CARBONATE HARDNESS AS CACO3	94
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	0
CALCULATED DISSOLVED SOLIDS	794.6	TOTAL HARDNESS AS CACO3	94
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	376
SPECIFIC CONDUCTANCE IN		LANGLIER SATURATION INDEX	
MICROMHOS/CM AT 25 C	969.7	RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	8.4	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) <.02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE

MEAS DSC 0. CALC DSC 1059.

ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
9	9	81	1	1	30	64	5	0

ANALYST LAW

PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-716

MONTANA BUREAU OF MINES AND GEOLOGY   BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 37E 36BDAD
SAMPLE TYPE	WELL	LAB NO.	74-718
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 6-A
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	70 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	45.2
DATE ANALYZED	8-27-74	ALTITUDE OF SAMPLE POINT	3545
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH
REMARKS STATE OBSERVATUON WELL ROSEBUD- MCKAY COAL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	52.	2.600	BICARBONATE(HCO3)	478.	7.842
MAGNESIUM (MG)	71.	5.809	CARBONATE (CO3)	0.	0.0
SODIUM (NA)	40.2	1.749	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	4.7	0.120	CHLORIDE (CL)	3.2	0.090
TOT. IRON (FE)	.00	0.0	SULFATE (SO4)	103.	2.140
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	1.5	0.024
ALUMINUM (AL)			FLUORIDE (F)	.0	0.0
SILICA (SIO2)	21.3		PHOSPHATE (PO4)		
		------			------
TOTAL CATIONS		10.278	TOTAL ANIONS		10.097

STANDARD DEVIATION OF CATION-ANION BALANCE -0.68 SIGMA

LABORATORY PH	8.16	CARBONATE HARDNESS AS CACO3	392
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	32
CALCULATED DISSOLVED SOLIDS	774.9	TOTAL HARDNESS AS CACO3	424
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	392
SPECIFIC CONDUCTANCE IN MICROMHOS/CM AT 25 C	900.2	LANGLIER SATURATION INDEX	
		RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	0.9	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) .03

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE

MEAS DSC 0. CALC DSC 1009.

ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
25	57	17	1	1	21	78	0	0

ANALYST LAW   PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-718

MONTANA BUREAU OF MINES AND GEOLOGY BUTTE, MONTANA 59701

WATER QUALITY ANALYSIS

STATE	MONTANA	COUNTY	BIGHORN
LATITUDE-LONGITUDE		LOCATION	01N 38E 36BDAD
SAMPLE TYPE	WELL	LAB NO.	74-719
GEOLOGICAL SOURCE		SAMPLE OR BOTTLE NO.	
DRAINAGE BASIN		AGENCY AND STATION CODE	MBMG 6-B
DATE SAMPLED	07-11-74	DEPTH WATER ENTERS WELL	176 FT
TIME SAMPLED		SWL ABOVE(+) OR BELOW GS	107.4
DATE ANALYZED	8-27-74	ALTITUDE OF SAMPLE POINT	3545
SAMPLE HANDLING	11	WATER FLOW RATE	
METHOD SAMPLED	BOTTLE	FLOW MEAS METHOD	
SANITARY CONDITION		PRINCIPAL USE OF WATER	UNUSED

PROJECT SARPY CR-WESTMORELAND TRACT 3 MBMG SMITH
REMARKS STATE OBSERVATION WELL ROBINSON COAL

PARAMETERS REPORTED IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	4.9	0.244	BICARBONATE(HCO3)	120.	1.967
MAGNESIUM (MG)	34.	2.777	CARBONATE (CO3)	16.	0.520
SODIUM (NA)	51.	2.218	HYDROXIDE (OH)	0.	0.000
POTASSIUM (K)	3.7	0.095	CHLORIDE (CL)	8.2	0.233
TOT. IRON (FE)	.00	0.0	SULFATE (SO4)	125.	2.598
MANGANESE (MN)	.00	0.0	NITRATE (NO3)	.4	0.006
ALUMINUM (AL)			FLUORIDE (F)	.1	0.005
SILICA (SIO2)	1.9		PHOSPHATE (PO4)		
		------			------
TOTAL CATIONS		5.334	TOTAL ANIONS		5.330

STANDARD DEVIATION OF CATION-ANION BALANCE -0.02 SIGMA

LABORATORY PH	9.03	CARBONATE HARDNESS AS CACO3	151
FIELD TEMPERATURE		NON-CARB. HARDNESS AS CACO3	3
CALCULATED DISSOLVED SOLIDS	364.4	TOTAL HARDNESS AS CACO3	154
EVAPORATED SOLIDS AT 105 C		TOTAL ALKALINITY AS CACO3	151
SPECIFIC CONDUCTANCE IN		LANGLIER SATURATION INDEX	
MICROMHOS/CM AT 25 C	517.7	RYSNAR STABILITY INDEX	
SODIUM ADSORPTION RATIO	1.8	TECH. CORROSION INDEX	

ADDITIONAL PARAMETERS

LEAD (PB) <.02

NOTE. PARAMETERS ARE TOTAL DISSOLVED UNLESS LABELED TR-TOTAL RECOVERABLE

DILUTE SPECIFIC CONDUCTANCE
MEAS DSC 0. CALC DSC 597.
ERROR DSC 0.0

PERCENT REACTANCE VALUES

CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
5	52	42	2	4	49	37	10	0

ANALYST LAW PROCESSING PROGRAM 72(REV3)

NOTE. IN CORRESPONDENCE RELATED TO THIS ANALYSIS REFER TO NUMBER 74-719

TABLE 36

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED MONITORING WELLS IN THE PROJECT AREA

WELL NUMBER		1A	1A	1B	1B
AQUIFER		ROB	ROB	SR	SR
DATE		7-11-74	8-12-75	7-11-74	8-12-75
METHOD SAMPLED		Bottle	Pumped	Bottle	Pumpad
WATER LEVEL[a]		22.2	22.07	86.3	86.62
ANALYSIS[b]					
Calcium		96	75.5	78	76.25
Magnesium		47	45.0	64	48.20
Sodium		650	597.7	535	480.67
Potassium		8.5	14.2	6.4	11.05
Iron (total)		<0.01	0.36	0.01	0.19
Manganese		0.01	0.04	0.01	0.02
Aluminum			0.18		0.20
Silica		10.9		9.3	0
Bicarbonate		307	488.40	389	
Carbonate		7	0	15	0
Hydroxide		0	0	0	0
Chloride		9.4	6.62	8.8	6.13
Sulfate		1535	1399.68	1194	1200.88
Nitrate[c]		2	0.37	1.6	0.56
Fluoride		0.3	<0.20	0.1	<0.20
Ortho Phosphate			.001		0.008
Lab pH	(no units)	8.51	8.1	8.36	7.7
Field Temperature	(°C)		12.5		13.0
Field Conductivity[d]	(μmhos/cm@ambient temp.)		2550.0		2220.0
Lab Conductivity[d]	(μmhos/cm@25°C)	3248.0	4050.0	2878.0	3500
Total Suspended Solids					
Total Dissolved Solids		2674.7	2480.2	2301.0	2180.4
Evaporated Solids	(105°C)				
Carbonate Hardness ($CaCO_3$)		276	378.30	370	395.64
Non-Carbonate Hardness ($CaCO_3$)		158	0	89	0
Total Hardness ($CaCO_3$)		434	378.30	460	395.64
Total Alkalinity ($CaCO_3$)		276	400.20	370	520.9
Sodium Adsorption Ratio	(no units)	13.6	13.45	10.9	10.60
Acidity ($CaCO_3$)			0		0
Zinc			0.01		0.04
Chromium			0.02		<0.02
Selenium			<0.05		<0.05
Mercury			0.0008		0.0006
Nickel			<0.05		<0.01
Arsenic			<0.10		<0.10
Boron			0.51		0.67
Copper			0.01		0.02
Cadmium			0.002		<0.002
Strontium			2.4		4.3
Lead		<0.2	<0.05	<0.02	<0.05
Vanadium			<0.5		<0.5
Molybdenum			<0.005		<0.005

[a] Water level measurement below ground surface

[b] Analyses reported as mg/l unless otherwise indicated

[c] Nitrate reported as NO3 for 1974 samples, (NO3+NO2) for those after 1974

[d] Conductivity refers to specific conductance

WELL NUMBER		2A	2A	2B	2B	2B	2C	2C	2C
AQUIFER		RMC	RMC	ROB	ROB	ROB	SR	SR	SR
DATE		7-11-74	8-12-75	7-11-74	10-29-74	8-12-75	/-11-74	10-25-74	8-12-75
METHOD SAMPLED		Bottle	Pumped	Bottle	Pumped	Pumped	Bottle	Pumped	Pumped
WATER LEVEL[a]		7.6	15.0	49.8	49.4	50.4	124.9	123.7	125.6
ANALYSIS[b]									
Calcium		116	109.40	6.3	3.3	124.12	32.0	25.0	88.83
Magnesium		124	145.61	4.0	0.6	178.56	19.4	13.3	26.17
Sodium		67.5	41.31	100.5	127	138.14	300.	350.	415.65
Potassium		2.7	2.73	2.7	2.5	11.13	4.2	3.6	2.95
Iron (total)		<0.01	<0.01	1.46	2.26	<0.01	<0.01	<0.01	<0.01
Manganese		<0.02	0.06	0.02	0.01	<0.02	<0.02	0.01	0.02
Aluminum			0.42			0.18			0.22
Silica		10.6		19.5	20.7		7.0	8.0	
Bicarbonate		648	720.28	176	186	680.37	421.	391.	492.98
Carbonate		0.0	0.0	0.0	0.0	0.0	28.	22.	0
Hydroxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Chloride		10.5	6.62	4.2	3.3	7.88	8.8	2.7	7.25
Sulfate		529	488.41	120	131	772.06	813.	927.	950.20
Nitrate[c]		7.9	0.67	2.0	4.8	0.79	1.8	1.4	0.30
Fluoride		0.3	0.20	0.2	0.2	<0.20	0.2	0.3	0.66
Ortho Phosphate			0.001			0.001			0.00
Lab pH	(no units)	8.04	7.4	8.22	8.05	8.0	8.55	8.56	8.3
Field Temperature	(°C)		12.1		14.0	14.0		13.0	15.0
Field Conductivity[d]	(µmhos/cm@ambient temp.)		1220.0		620	1780.0		2710.	1950.0
Lab Conductivity[d]	(µmhos/cm@25°C)	1549.0	1950.0	548.0	599.6	2700.0	2396.0	2519.0	2900.0
Total Suspended Solids									
Total Dissolved Solids		1316.5		645.4	481.5		1835.2	1943.7	
Evaporated Solids	(105°C)		1192.2			1624.4			1773.2
Carbonate Hardness ($CaCO_3$)		367	590.20	32	10	557.50	160.	116.	334.03
Non-Carbonate Hardness ($CaCO_3$)		437	287.10	0	0	491.00	0.0	0.0	0.00
Total Hardness ($CaCO_3$)		805	877.30	32	10	1048.50	160.	116.	334.03
Total Alkalinity ($CaCO_3$)		367	590.20	145	152	557.50	438.	393.	403.79
Sodium Adsorption Ratio	(no units)	1.0	0.61	8.3	17.0	2.13	17.2	22.2	9.96
Acidity ($CaCO_3$)		-	0.0			0.0			0.00
Zinc						0.240			
Chromium			< 0.02			< 0.02			< 0.02
Selenium			<0.05			<0.05			<0.05
Mercury			0.0006			0.0002			.0006
Nickel			<0.01			<0.05			<0.05
Arsenic			<0.1			<0.1			<0.1
Boron			0.43			0.27			0.43
Copper			<0.01			0.02			0.05
Cadmium			< 0.002			< 0.002			0.002
Strontium			2.0			1.9			2.7
Lead		0.03	0.04.	<0.02	<0.02	<0.05	<0.02	<0.02	<0.05
Vanadium			<0.5			<0.5			<0.5
Molybdenum			<0.005			<0.005			.03

WELL NUMBER		3A	3A	3B	3B	3C
AQUIFER		RMC	RMC	ROB	ROB	SR
DATE		7-11-74	8-11-75	7-11-74	8-11-75	8-11-75
METHOD SAMPLED		Bottle	Pumped	Bottle	Pumped	Pumped
WATER LEVEL[a]		114.4	115.10	155.8	156.02	224.46
ANALYSIS[b]						
Calcium		8.8	7.85	18.7	46.93	12.86
Magnesium		1.4	3.37	3.9	9.43	3.09
Sodium		268	224.91	296	480.87	445.48
Potassium		4.2	6.33	4.3	14.91	7.24
Iron (total)		0.13	< 0.01	< 0.01	0.54	< 0.01
Manganese		< 0.02	<0.02	< 0.02	0.02	<0.02
Aluminum			2.14	.	0.12	.0.34
Silica		13.5		7.9		
Bicarbonate		405	557.97	399	628.73	500.00
Carbonate		34	18.78	24	3.45	17.27
Hydroxide		0.0	0.00	0.00	0.0	0.0
Chloride		72	5.36	8.6	3.15	2.21
Sulfate		129	146.29	304	810.70	540.22
Nitrate[c]		3.0	1.19	0.6	0.70	0.86
Fluoride		0.4	0.22	0.5	0.64	0.27
Ortho Phosphate			0.001		0.00	0.001
Lab pH	(no units)	8.74	8.7	8.50	8.4	8.8
Field Temperature	(°C)	10.0	18.0	13.3	18.10	16.8
Field Conductivity[d]	(μmhos/cm@ambient temp.)		1320.0	2600.0	1770.0	1490.0
Lab Conductivity[d]	(μmhos/cm@25°C)	1214.0	1400.0	1390.0	2450.0	2200.0
Total Suspended Solids					147.0	
Total Dissolved Solids		939.7		1067.5		
Evaporated Solids	(105°C)		741.1			
Carbonate Hardness ($CaCO_3$)		28	46.28	62	157.84	
Non-Carbonate Hardness ($CaCO_3$)		0.0	0.00	0.00	0.00	
Total Hardness ($CaCO_3$)		28	46.28	62	157.84	
Total Alkalinity ($CaCO_3$)		446	488.45	407	357.05	438.40
Sodium Adsorption Ratio	(no units)	22.1	16.92	16.3	33.55	28.95
Acidity ($CaCO_3$)			0.00		0.00	0.00
Zinc			0.02		0.23	0.02
Chromium						< 0.02
Selenium			<0.05		<0.05	<0.05
Mercury			0.0004		0.0002	<0.0002
Nickel			<0.01		<0.05	<0.05
Arsenic			<0.1		<0.1	<0.1
Boron			.34		0.33	0.31
Copper			0.03		<0.01	0.03
Cadmium						< 0.002
Strontium			0.8		1.8	0.9
Lead		<0.02	<0.05	<0.02	<0.05	<0.05
Vanadium			<0.5		<0.5	<0.5
Molybdenum			0.005		00.01	0.04

TABLE 36

WELL NUMBER		4A	4A	4B	4B	4C	4C
AQUIFER		RMCO	RMCO	RMC	RMC	ROB	ROB
DATE		7-11-74	8-11-75	7-11-74	8-11-75	7-11-74	8-11-75
METHOD SAMPLED		Bottle	Pumped	Bottle	Pumped	Bottle	Pumped
WATER LEVEL[a]		32.5	33.10	45.2	37.86	111.0	111.31
ANALYSIS[b]							
Calcium		31.0	100.12	19.2	103.94	21.0	28.38
Magnesium		61.0	108.13	8.0	117.05	3.5	7.32
Sodium		55.8	56.49	74.5	35.29	455.0	497.01
Potassium		8.2	5.20	13.4	4.98	3.0	7.93
Iron (total)		<0.01	0.19	<0.01	0.19	<0.01	<0.01
Manganese		<0.02	<0.04	<0.02	0.04	<0.02	0.02
Aluminum			0.13		0.16		0.06
Silica		18.2		18.0		9.5	
Bicarbonate		386.0	1019.22	103.0	916.28	318.0	422.93
Carbonate		7.0	0.0	0.0	0.0	14.0	3.78
Hydroxide		000	0.0	0.0	0.0	0.0	0.0
Chloride		3.3	0.32	6.0	2.52	9.3	0.63
Sulfate		129.0	124.44	165.0	133.70	744.0	757.16
Nitrate[c]		2.9	1.15	3.5	1.15	4.8	1.13
Fluoride		0.1	<0.20	0.2	<0.20	0.2	0.26
Ortho Phosphate			0.001		0.001		
Lab pH	(no units)	8.51	7.8	8.05	7.9	8.53	8.4
Field Temperature	(°C)		16.0		14.5		15.50
Field Conductivity[d]	(µmhos/cm@ambient temp.)		920.0		970.0		1600.0
Lab Conductivity[d]	(µmhos/cm@25°C)	878.6	1300.0	548.6	1400.0	2163.0	2500.0
Total Suspended Solids							
Total Dissolved Solids		703.1		410.5		1582.2	
Evaporated Solids	(105°C)		636.2		689.8		1464.9
Carbonate Hardness ($CaCO_3$)		332.0	700.38	81.0	747.29	66.0	102.22
Non-Carbonate Hardness ($CaCO_3$)		0.0	0.00	0.0	0.0	0.0	0.00
Total Hardness ($CaCO_3$)		332.0	700.38	81.0	747.29	66.0	102.22
Total Alkalinity ($CaCO_3$)		341.0	835.15	84.0	750.79	307.0	346.55
Sodium Adsorption Ratio	(no units)	1.3	0.93	3.6	0.56	24.2	21.49
Acidity ($CaCO_3$)			0.00		0.00		0.00
Zinc			0.08		0.04		0.04
Chromium			<0.02		<0.02		<0.02
Selenium			<0.05		<0.05		<0.05
Mercury			0.00006		0.0004		<0.0002
Nickel			<0.01		<0.05		0.01
Arsenic			<0.1		<0.1		<0.1
Boron			0.19		0.22		0.20
Copper			0.01		0.02		0.01
Cadmium			<0.002		0.003		0.005
Strontium			3.6		4.0		1.8
Lead		<0.02	<0.05	<0.02	0.5	.03	0.05
Vanadium			<0.5		<0.5		<0.5
Molybdenum			<0.005		<0.005		0.01

WELL NUMBER		5A	5A	5A	6B	5B	5B	5C	5C	5C
AQUIFER		RMCO	RMCO	RMCO	RMCO	RMC	RMC	ROB	ROB	ROB
DATE		7-11-76	10-24-74	8-11-75	7-11-74	10-24-74	8-11-75	7-11-74	10-25-74	8-11-75
METHOD SAMPLED		Bottle	Pumped	Pumped	Bottle	Pumped	Pumped	Bottle	Pumped	Pumped
WATER LEVEL[a]		30.0	28.9	30.30	53.3	52.2	53.80	110.9	109.9	107.45
ANALYSIS[b]										
Calcium		105.0	45.0	130.34	19.2	12.2	31.30	44.0	41.0	99.30
Magnesium		134.0	119	160.44	11.2	8.0	9.79	39.0	29.0	34.94
Sodium		29.0	25.0	20.93	187.0	198.0	217.11	305.0	324.0	462.36
Potassium		4.2	3.6	3.17	3.5	3.7	5.87	4.2	5.8	20.4
Iron (total)		0.01	<0.01	<0.01	<0.01	<0.01	0.19	<0.01	0.01	<0.01
Manganese		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04
Aluminum				0.22			0.09			0.18
Silica		19.3	17.2		8.1	6.9		15.0	13.2	
Bicarbonate		649.0	422.0	904.56	399.0	408.0	430.09	363.0	354.0	385.63
Carbonate		0.0	0.0	0.0	15.0	5.0	2.76	14.0	24.0	3.43
Hydroxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chloride		11.0	6.4	2.21	4.1	2.9	0.0	7.3	4.1	4.42
Sulfate		329.0	283.0	243.90	145.0	132.0	128.55	411.0	556.0	1104.57
Nitrate[c]		1.6	1.8	0.22	2.0	1.1	1.14	2.6	1.4	0.16
Fluoride		0.0	0.0	<0.20	0.1	0.2	<0.20	0.1	0.2	0.54
Ortho Phosphate				0.002			0.0			0.001
Lab pH	(no units)	7.97	8.26	7.9	8.52	8.42	8.4	8.37	8.52	8.3
Field Temperature	(°C)		9.5	14.8		12.0	14.0		15.0	16.0
Field Conductivity[d]	(umhos/cm@ambient temp.)		1500.0	1010.0		990.0	770.0		1850.0	1850.0
Lab Conductivity[d]	(umhos/cm@25°C)	1432.0	1068.0	1600.0	969.7	933.1	1200.0	1742.0	1754.0	2800.0
Total Suspended Solids										
Total Dissolved Solids		1281.6	922.7		796.6	778.2		1407.5	1358.5	
Evaporated Solids	(105°C)			888.1			634.6			1779.8
Carbonate Hardness ($CaCO_3$)		532.0	344.0	741.20	94.0	63.0	121.41	274.0	222.0	321.75
Non-Carbonate Hardness ($CaCO_3$)		287.0	262.0	249.15	0.0	0.0	0.0	0.0	0.0	73.83
Total Hardness ($CaCO_3$)		819.0	608.0	990.35	94.0	63.0	121.41	274.0	222.0	395.58
Total Alkalinity ($CaCO_3$)		532.0	346.0	741.20	376.0	352.0	520.90	344.0	371.0	321.75
Sodium Adsorption Ratio	(no units)	0.4	0.6	0.29	0.6	10.8	8.67	8.0	9.5	8.44
Acidity ($CaCO_3$)				0.00			0.0			0.00
Zinc				0.04						0.05
Chromium				<0.02			<0.02			<0.02
Selenium				<0.05			<0.05			<0.05
Mercury				0.0002			0.0002			0.0004
Nickel				<0.05			<0.01			<0.05
Arsenic				<0.1			<0.1			<0.1
Boron				0.035			0.21			0.10
Copper				0.051			0.02			<0.01
Cadmium				<0.002			<0.002			<0.002
Strontium				2.0			1.8			2.3
Lead		<0.02	0.04	0.765	<0.02	<0.02	<0.05	<0.02	<0.02	<0.05
Vanadium				<0.5			<0.5			<0.5
Molybdenum				<0.005			0.005			<0.005

WELL NUMBER		6A	6A	6A	6B	6B	6B
AQUIFER		RMC	RMC	RMC	ROB	ROB	ROB
DATE		7-11-74	10-29-74	8-11-75	7-11-74	10-30-74	8-11-75
METHOD SAMPLED		Bottle	Pumped	Pumped	Bottle	Pumped	Pumped
WATER LEVEL[a]		43.2	66.7	47.28	107.4	106.3	103.36
ANALYSIS[b]							
Calcium		32.0	23.0	81.44	4.9	7.1	69.74
Magnesium		71.0	66.0	94.50	34.0	1.9	11.80
Sodium		40.2	43.6	34.03	31.0	380.0	346.12
Potassium		< 0.01	4.8	4.33	3.7	2.4	15.60
Iron (total)		< 0.02	< 0.01	<0.01	< 0.01	0.12	< 0.01
Manganese		0.00	0.16	0.11	< 0.02	< 0.02	<0.02
Aluminum				0.17	-		0.08
Silica		21.3	19.2	-	1.9	7.7	
Bicarbonate		478.0	381.0	703.32	120.0	378.0	420.67
Carbonate		0.0	0.0	0.0	16.0	28.0	13.26
Hydroxide		0.0	0.0	0.0	0.0	0.0	0.0
Chloride		3.2	3.3	0.95	8.2	6.5	3.78
Sulfate		103.0	95.0	113.45	125.0	664.0	675.08
Nitrate[c]		1.5	1.0	0.16	0.6	0.6	0.61
Fluoride		0.0	0.0	<0.20	0.1	0.6	0.70
Ortho Phosphate		-		0.001			
		-				-	
Lab pH	(no units)	8.16	8.23	8.2	9.03	8.75	8.5
Field Temperature	(°C)		16.0	15.2		13.0	17.5
Field Conductivity[d]	(μmhos/cm@ambient temp.)		950.0	800.0	-	1700.0	1400.0
Lab Conductivity[d]	(μmhos/cm@25°C)	900.2	730.2	1200.0	517.7	1660.0	1920.0
Total Suspended Solids							
Total Dissolved Solids		774.9	636.1		364.4	1276.5	
Evaporated Solids	(105°C)			664.30	-		1105.5
Carbonate Hardness ($CaCO_3$)		392.0	313.0	574.3	151.0	25.0	175.50
Non-Carbonate Hardness ($CaCO_3$)		32.0	19.0	11.55	3.0	0.0	0.0
Total Hardness ($CaCO_3$)		424.0	331.0	587.85	156.0	25.0	175.50
Total Alkalinity ($CaCO_3$)		392.0	313.0	576.30	151.0	403.0	346.80
Sodium Adsorption Ratio	(no units)	0.9	1.0	0.61	1.8	32.7	11.44
Acidity ($CaCO_3$)				0.0			0.00
Zinc				0.05			0.01
Chromium				< 0.02			< 0.02
Selenium				<0.05			<0.05
Mercury				0.0002			0.0002
Nickel				<0.05			<0.01
Arsenic				<0.1			<0.1
Boron				0.23			0.21
Copper				0.01			0.02
Cadmium				< 0.002			< 0.002
Strontium				2.3			1.9
Lead		0.08	<0.08	0.75	<0.08	<0.08	<0.05
Vanadium				<0.5			<0.5
Molybdenum				0.008			0.008

WELL NUMBER		8A	8B	8C
AQUIFER		SR	ROB	RMC
DATE		8-14-75	8-14-75	8-14-75
METHOD SAMPLED		Pumped	Pumped	Pumped
WATER LEVEL[a]		197.5	130.85	75.18
ANALYSIS[b]				
Calcium		228.68	306.77	176.23
Magnesium		56.58	1.73	124.15
Sodium		71.91	280.73	48.28
Potassium		42.94	46.36	24.94
Iron (total)		0.19	< 0.01	0.36
Manganese			<0.02	0.35
Aluminum		0.49	0.56	0.34
Silica				
Bicarbonate		322.98	0.0	584.63
Carbonate		0.0	479.40	0.0
Hydroxide		0.0	203.78	0.0
Chloride		16.35		9.87
Sulfate		819.54	339.46	489.19
Nitrate[c]		0.13	0.75	0.05
Fluoride		3.77	1.12	1.67
Ortho Phosphate		0.01	0.001	0.08
Lab pH	(no units)	7.3	13.0	7.5
Field Temperature	(°C)	14.0	12.8	12.8
Field Conductivity[d]	(μmhos/cm@ambient temp.)	1430.0	3600.0	1010.0
Lab Conductivity[d]	(μmhos/cm@25°C)	2120.0	5100.0	1700.0
Total Suspended Solids				
Total Dissolved Solids				-
Evaporated Solids	(105°C)	1635.6		1160.4
Carbonate Hardness ($CaCO_3$)		264.65	781.34	479.05
Non-Carbonate Hardness ($CaCO_3$)		501.77	0.0	481.19
Total Hardness ($CaCO_3$)		766.42	781.34	960.24
Total Alkalinity ($CaCO_3$)		264.65	1392.7	479.05
Sodium Adsorption Ratio	(no units)	1.01	4.39	0.68
Acidity ($CaCO_3$)		0.0	0.0	0.0
Zinc			0.11	0.08
Chromium		< 0.02	< 0.02	< 0.02
Selenium		<0.05	<0.05	<0.05
Mercury		0.0006	0.0010	0.0008
Nickel		0.05	<0.05	0.05
Arsenic		<0.1	<0.1	<0.1
Boron		0.36	0.10	0.17
Copper			0.01	0.07
Cadmium		< 0.002	0.002	< 0.002
Strontium		6.8	4.3	5.3
Lead		0.75	<0.05	0.51
Vanadium		<0.5	<0.5	<0.5
Molybdenum		.03	0.01	<0.005

WELL NUMBER		14B	15B	16A	16B
AQUIFER		INT	SR	SR	ROB
DATE		8-14-75	8-12-75	8-13-75	8-13-75
METHOD SAMPLED		Pumped	Pumped	Pumped	Pumped
WATER LEVEL[a]			91.13	152.27	78.04
ANALYSIS[b]					
Calcium		297.59	126.90	269.79	170.34
Magnesium		109.65	165.30	109.65	118.83
Sodium		59.16	168.77	59.42	462.32
Potassium		39.63	11.51	38.45	28.31
Iron (total)		0.54	< 0.01	<0.01	0.36
Manganese			<0.02	1.03	<0.02
Aluminum		0.52	0.28	0.50	0.47
Silica					
Bicarbonate		486.08	775.26	215.58	648.83
Carbonate		0.0	0.0	0.0	0.0
Hydroxide		0.0	0.0	0.0	0.0
Chloride		14.34	2.21	17.58	18.20
Sulfate		923.12	665.85	1087.10	138.19
Nitrate[c]		0.05	0.73	0.09	0.14
Fluoride		2.38	<0.20	1.38	0.62
Ortho Phosphate		0.02	0.0	0.001	0.001
Lab pH	(no units)	7.3	7.7	7.9	7.7
Field Temperature	(°C)	14.0		17.0	18.0
Field Conductivity[d]	(μmhos/cm@ambient temp.)	3760.0		1740.0	2600.0
Lab Conductivity[d]	(μmhos/cm@25°C)	2500.0	2250.0	2500.0	4290.0
Total Suspended Solids					
Total Dissolved Solids					
Evaporated Solids	(105°C)	2175.2	1469.3	1829.8	2653.7
Carbonate Hardness ($CaCO_3$)		398.30	635.25	176.65	331.67
Non-Carbonate Hardness ($CaCO_3$)		813.03	367.02	961.72	400.49
Total Hardness ($CaCO_3$)		1211.33	1002.27	1138.37	932.15
Total Alkalinity ($CaCO_3$)		398.3	635.25	176.65	331.67
Sodium Adsorption Ratio	(no units)	0.74	2.32	0.77	6.65
Acidity ($CaCO_3$)		0.0	0.0	0.0	0.0
Zinc		0.10	0.16	0.02	0.11
Chromium		< 0.02	< 0.02	< 0.02	< 0.02
Selenium		<0.05	<0.05	<0.05	<0.05
Mercury		0.0008	0.0016	0.0008	0.0006
Nickel		<0.05	<0.05	<0.01	<0.01
Arsenic		<0.1	<0.1	<0.1	<0.1
Boron		0.59	0.84	0.25	0.43
Copper		0.40	0.06	0.04	0.01
Cadmium		< 0.002	< 0.002	< 0.002	0.002
Strontium		11.8	2.9	7.2	6.3
Lead		<0.05	<0.05	0.76	<0.05
Vanadium		<0.5	<0.5	<0.5	<0.5
Molybdenum		0.015	0.005	0.01	<0.005

TABLE 36

WELL NUMBER		18	19	20	10
AQUIFER		AL	AL	AL	AL
DATE		8-12-75	8-12-75	8-11-75	8-19-75
METHOD SAMPLED		Pumped	Pumped	Pumped	Bailed
WATER LEVEL[a]		23.47	16.30	29.89	16.5
ANALYSIS[b]					
Calcium		109.40	69.11	121.48	107.375
Magnesium		150.20	131.12	206.97	57.23
Sodium		121.25	195.61	153.56	75.0
Potassium		12.63	10.83	9.49	10.62
Iron (total)		0.19	0.19	0.19	0.19
Manganese		<0.02	0.18		
Aluminum		0.23	0.27	0.09	0.37
Silica					
Bicarbonate		762.87	629.91	841.65	451.98
Carbonate		0.0	0.0	0.0	0
Hydroxide		0.0	0.0	0.0	0
Chloride		7.25	6.46	2.67	5.36
Sulfate		654.08	617.91	788.02	263.15
Nitrate[c]		1.44	0.155	1.20	0.18
Fluoride		0.20	<0.20	<0.20	1.08
Ortho Phosphate		0.0	0.002	0.001	0.001
Lab pH	(no units)	7.4	7.7	8.0	7.5
Field Temperature	(°C)	13.0	14.8	11.4	
Field Conductivity[d]	(µmhos/cm@ambient temp.)	1460.0	1400.0	1510.0	
Lab Conductivity[d]	(µmhos/cm@25°C)	2460.0	2100.0	2500.0	1150.0
Total Suspended Solids					369.9
Total Dissolved Solids					
Evaporated Solids	(105°C)	1691.0	1318.8	1647.3	914.3
Carbonate Hardness ($CaCO_3$)		625.10	516.50	689.65	370.35
Non-Carbonate Hardness ($CaCO_3$)		271.38	200.45	471.44	136.37
Total Hardness ($CaCO_3$)		896.48	716.95	1161.09	506.72
Total Alkalinity ($CaCO_3$)		625.10	516.50	689.65	370.35
Sodium Adsorption Ratio	(no units)	1.77	3.19	1.94	1.40
Acidity ($CaCO_3$)		0.0	0.0	0.0	0.0
Zinc		0.02	0.01		0.010
Chromium		< 0.02		< 0.02	< 0.02
Selenium		<0.05	<0.05	<0.05	< 0.05
Mercury		0.0002	0.0008	0.0002	0.008
Nickel		<0.05	<0.01	<0.01	0.08
Arsenic		<0.1	<0.1	<0.1	< 0.1
Boron		0.85	0.51	0.29	0.43
Copper		<0.01			< 0.02
Cadmium		< 0.002		0.002	< 0.002
Strontium		2.9	2.3	3.6	2.3
Lead		<0.05	0.05	0.76	0.20
Vanadium		<0.5	<0.5	<0.5	< 0.5
Molybdenum		<0.005	<0.005	<0.005	< 0.005

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED MONITORING WELLS IN THE PROJECT AREA
from October and November, 1975

WELL NUMBER		1A	1A	1B	1B
AQUIFER		ROB	ROB	SR	SR
DATE		10-1-75	11-12-75	10-1-75	11-12-75
METHOD SAMPLED					
WATER LEVEL[a]		23.15	23.20	86.71	86.63
ANALYSIS[b f]					
Calcium		61.73	51.02	81.12	71.43
Magnesium		38.78	30.61	92.35	91.50
Sodium		686.22	855.10	500.0	532.66
Potassium		9.95	13.08	8.37	11.06
Iron (total)		0.33	-0.05	0.20	0.26
Manganese		0.04	0.07	-0.02	-0.02
Aluminum		0.22	0.31	0.23	0.26
Silica					
Bicarbonate		536.53	665.73	689.14	823.77
Carbonate					
Hydroxide					
Chloride		6.37	6.93	5.80	0.63
Sulfate			1428.28	1125.53	1180.06
Nitrate[c]		-0.04	0.05	-0.04	0.10
Fluoride		0.24	-02.0	-0.20	-0.20
Ortho Phosphate		0.008	-0.001	0.001	0.012
Field pH	(no units)				
Lab pH	(no units)	8.0	8.1	7.7	7.9
Field Temperature	(°C)	13.1	10.8	13.6	11.8
Field Conductivity[d]	(µmhos/cm @ ambient temp.)	2600.0	2390	2300.0	2150.0
Lab Conductivity[d]	(µmhos/cm @ 25°C)	3700.0	3700	3220.0	3100.0
Total Suspended Solids		52.3	22.7	18.9	3.7
Total Dissolved Solids					
Evaporated Solids	(105°C)	608.0	2480.9	2313.0	2127.1
Carbonate Hardness	($CaCO_3$)	315.7	258.3	584.5	562.9
Non-Carbonate Hardness	($CaCO_3$)	0	0	0	0
Total Hardness	($CaCO_3$)	315.7	258.3	584.5	562.9
Total Alkalinity	($CaCO_3$)	559.0	545.5	718.0	675.0
Sodium Adsorption Ratio	(no units)	16.86	23.38	9.02	9.86
Acidity	($CaCO_3$)	0	0	0	0
Zinc		0.06	-0.01	0.09	0.01
Chromium		-0.02	-0.02	-0.02	0.02
Selenium		-0.005	-0.005	-0.005	-0.005
Mercury		-0.2	-0.2	-0.2	-0.2
Nickel		-0.02	0.02	-0.02	-0.02
Arsenic		-0.1	-0.02	-0.1	-0.02
Boron		0.493	0.19	0.873	0.43
Copper		0.04	-0.01	0.02	-0.01
Cadmium		-0.002	0.003	-0.002	0.002
Strontium		2.16	2.69	4.9	5.20
Lead		0.57	0.08	-0.02	0.22
Vanadium		-1.0	-1.0	-1.0	-1.0
Molybdenum		-0.10	0.04	-0.10	0.09

[a] Water level measurement below ground surface.

[b] Analyses reported as mg/l unless otherwise indicated.

[c] Nitrate reported as NO3 for 1974 samples, (NO3+NO2) for those after 1974.

[d] Conductivity refers to specific conductance.

[e] Duplicate analysis for quality control

[f] Minus sign indicates concentration less than stated detectable limits

From Dames and Moore, 1975, p. 33-41

TABLE 37

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED MONITORING WELLS IN THE PROJECT AREA

WELL NUMBER		2A	2A	2C	2C
AQUIFER		RMC	RMC	SR	SR
DATE		10-1-75	11-11-75	10-1-75	11-11-75
METHOD SAMPLED					
WATER LEVEL[a]		15.76	9.70	125.6	125.55
ANALYSIS[b] [f]					
Calcium		142.09		17.14	19.80
Magnesium		185.87		37.40	12.35
Sodium		87.65		561.22	572.45
Potassium		2.04	6.56	5.20	6.79
Iron (total)		0.12	-0.05	0.44	0.20
Manganese		0.02	0.04	-0.02	-0.02
Aluminum		0.31	0.18	0.16	0.02
Silica					
Bicarbonate		858.06	809.13	645.95	810.35
Carbonate		0			
Hydroxide		0			
Chloride		6.62	3.28	4.66	4.41
Sulfate		500.26	893.20	924.23	866.66
Nitrate[c]		0.53	0.20	-0.04	0.43
Fluoride		0.49	0.26	0.27	0.36
Ortho Phosphate		0.03	0.013	0.018	0.009
Field pH	(no units)				
Lab pH	(no units)	7.4	8.3	8.3	8.3
Field Temperature	(°C)	12.4	12.2	16.0	13
Field Conductivity[d]	(µmhos/cm @ ambient temp.)	1400.0	1900	2100.0	1940
Lab Conductivity[d]	(µmhos/cm @ 25°C)	1820.0	2100	2840.0	2120
Total Suspended Solids		971.2	3.4	33.1	4.0
Total Dissolved Solids					
Evaporated Solids	(105°C)	1191.0	1709.5	1733.0	1726.4
Carbonate Hardness	($CaCO_3$)	894.0	107.6	232.9	101.64
Non-Carbonate Hardness	($CaCO_3$)	227.9	0	0	0
Total Hardness	($CaCO_3$)	1121.9	107.6	232.9	101.64
Total Alkalinity	($CaCO_3$)	894.0	663.0	673.0	663.9
Sodium Adsorption Ratio	(no units)	1.14	23.92	24.40	24.89
Acidity	($CaCO_3$)	0	0	0	0
Zinc		0.08	-0.01	0.03	-0.01
Chromium		-0.02	-0.02	-0.02	-0.02
Selenium		-0.005	-0.005	-0.005	-0.005
Mercury		-0.2	-0.2	-0.2	-0.2
Nickel		-0.02	-0.02	-0.02	-0.02
Arsenic		-0.1	-0.02	-0.1	-0.02
Boron		0.349	0.25	0.566	0.34
Copper		-0.01	0.07	0.02	0.07
Cadmium		-0.002	-0.002	-0.002	0.003
Strontium		2.21	0.73	0.72	0.75
Lead		-0.02	0.63	0.12	0.08
Vanadium		-1.0	-1.0	-1.0	-1.0
Molybdenum		-0.10	-0.01	-0.10	0.07

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[a] Water level measurement below ground surface.

[b] Analyses reported as mg/l unless otherwise indicated.

[c] Nitrate reported as NO3 for 1974 samples, (NO3+NO2) for those after 1974.

[d] Conductivity refers to specific conductance.

[e] Duplicate analysis for quality control.

[f] Minus sign indicates concentration less than stated detectable limits

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED MONITORING WELLS IN THE PROJECT AREA

WELL NUMBER		4A	4A	4B	4B
AQUIFER		RMCO	RMCO	RMC	RMC
DATE		10-1-75	11-11-75	10-1-75	11-11-75
METHOD SAMPLED					
WATER LEVEL[a]		33.45	33.68	46.92	47.00
ANALYSIS[bf]					
Calcium		90.05	80.61	95.15	88.40
Magnesium		114.29	115.31	127.55	124.5
Sodium		58.16	48.27	41.02	47.19
Potassium		5.20	6.33	4.08	6.35
Iron (total)		0.77	0.41	0.20	0.20
Manganese		0.09	0.14	0.05	0.04
Aluminum		0.12	0.16	0.16	0.21
Silica					
Bicarbonate		914.69	1156.94	962.20	1255.18
Carbonate					
Hydroxide					
Chloride		5.04	4.54	5.42	3.91
Sulfate		147.48		114.77	129.54
Nitrate[c]		0.44	0.20	-0.04	0.12
Fluoride		-0.20	0.19	-0.20	-0.20
Ortho Phosphate		0.01	-0.001	0.015	0.001
Field pH	(no units)				
Lab pH	(no units)	7.5	7.3	7.9	7.4
Field Temperature	(°C)	16.0	9	13.8	10.6
Field Conductivity[d]	(µmhos/cm @ ambient temp.)	780.0	790	910.0	890
Lab Conductivity[d]	(µmhos/cm @ 25°C)	1260.0	920	1310.0	970
Total Suspended Solids		67.4	20.5	68.1	142.0
Total Dissolved Solids					740.5
Evaporated Solids	(105°C)	674.0	1328.3	813.0	740.5
Carbonate Hardness	($CaCO_3$)	697.6	682.5	764.0	
Non-Carbonate Hardness	($CaCO_3$)	0	0	0	
Total Hardness	($CaCO_3$)	697.6	682.5	764.0	1028.5
Total Alkalinity	($CaCO_3$)	953.0	948.0	1002.5	740.5
Sodium Adsorption Ratio	(no units)	0.96	0.81	0.64	0.76
Acidity	($CaCO_3$)	0	0	0	0
Zinc		0.08	0.06	0.02	0.05
Chromium		-0.02	-0.02	-0.02	-0.02
Selenium		-0.005	-0.005	-0.005	-0.005
Mercury		-0.2	-0.2	-0.2	-0.2
Nickel		-0.02	-0.02	-0.02	-0.02
Arsenic		-0.1	-0.02	-0.1	-0.02
Boron		0.077	0.07	0.134	0.04
Copper		0.01	0.08	0.03	0.02
Cadmium		-0.002	0.002	-0.002	0.003
Strontium		4.13	4.0	4.16	4.9
Lead		0.02	0.37	-0.02	0.17
Vanadium		-1.0	-1.0	-1.0	-1.0
Molybdenum		-0.10	0.02	-0.1	0.03

[a] Water level measurement below ground surface.

[b] Analyses reported as mg/l unless otherwise indicated.

[c] Nitrate reported as NO3 for 1974 samples, (NO3+NO2) for those after 1974.

[d] Conductivity refers to specific conductance.

[e] Duplicate analysis for quality control.

[f] Minus sign indicates concentration less than stated detectable limits

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED MONITORING WELLS IN THE PROJECT AREA

WELL NUMBER		4C	4C	6A	6A
AQUIFER		ROB	ROB	RMC	RMC
DATE		10-1-75	11-11-75	10-1-75	11-12-75
METHOD SAMPLED					
WATER LEVEL[a]		111.25	111.05	45.81	45.15
ANALYSIS[b] [f]					
Calcium		22.96	19.90	71.43	71.88
Magnesium		12.24	12.76	101.53	97.45
Sodium		486.22	422.19	70.92	39.16
Potassium		16.04	7.22	4.31	5.67
Iron (total)		0.77	0.10	0.44	-0.05
Manganese		-0.02	-0.02	0.13	0.11
Aluminum		0.02	0.11	0.23	0.02
Silica					
Bicarbonate		491.90	641.32	767.36	967.78
Carbonate		0		0	
Hydroxide		0		0	
Chloride		4.60	3.28	3.97	6.62
Sulfate		664.82	723.58		75.39
Nitrate[c]		-0.04	0.16	0.40	0.01
Fluoride		0.29	0.42	-0.20	-0.20
Ortho Phosphate		0.036	0.011	0.004	0.065
Field pH	(no units)				
Lab pH	(no units)	8.2	8.0	7.7	7.9
Field Temperature	(°C)	17.0	12	16.0	11.9
Field Conductivity[d]	(µmhos/cm @ ambient temp.)	1700.0	1510	780.0	700.0
Lab Conductivity[d]	(µmhos/cm @ 25°C)	2300.0	1600	1100.0	1050.0
Total Suspended Solids		34.8	16.0	54.3	41.2
Total Dissolved Solids					
Evaporated Solids	(105°C)	1524.0	1357.0	517.0	512.9
Carbonate Hardness	($CaCO_3$)	109.3	104.4	429.2	585.3
Non-Carbonate Hardness	($CaCO_3$)	0	0	0	0
Total Hardness	($CaCO_3$)	109.3	104.4	429.2	585.3
Total Alkalinity	($CaCO_3$)	512.5	525.5	799.5	793.0
Sodium Adsorption Ratio	(no units)	20.33	18.18	1.26	0.71
Acidity	($CaCO_3$)	0	0	0	0
Zinc		0.06	0.01	0.06	0.04
Chromium		-0.02	-0.02	-0.02	-0.02
Selenium		-0.005	-0.005	-0.005	-0.005
Mercury		-0.2	-0.2	-0.2	-0.2
Nickel		-0.02	0.02	0.02	-0.02
Arsenic		-0.1	-0.02	-0.1	-0.02
Boron		0.108	0.05	0.107	0.16
Copper		0.02	0.06	0.01	0.03
Cadmium		-0.002	0.015	-0.002	0.005
Strontium		0.92	1.15	3.54	3.81
Lead		-0.02	0.44	-0.02	0.64
Vanadium		-1.0	-1.0	-1.0	-1.0
Molybdenum		-0.10	0.01	-0.10	0.08

[a] Water level measurement below ground surface.

[b] Analyses reported as mg/l unless otherwise indicated.

[c] Nitrate reported as NO3 for 1974 samples, (NO3+NO2) for those after 1974.

[d] Conductivity refers to specific conductance.

[e]

[f] Duplicate analysis for quality control.

Minus sign indicates concentration less than stated detectable limits

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED MONITORING WELLS IN THE PROJECT AREA

WELL NUMBER		6B	8B	14B	14B[e]
AQUIFER		ROB	ROB	INT	INT
DATE		10-1-75	11-12-75	10-2-75	10-2-75
METHOD SAMPLED					
WATER LEVEL[a]		102.66	130.80	135.20	135.20
ANALYSIS[b f]					
Calcium		9.69	184.44		372.96
Magnesium		12.24	8.16		145.66
Sodium		330.36	261.74	84	77.76
Potassium		4.78	54.40	26	20.41
Iron (total)		0.44	0.28	3.70	0.55
Manganese		0.02	-0.02	1.61	1.84
Aluminum		0.19	0.31	-0.1	0.52
Silica				26.6	
Bicarbonate		508.69		485	671.38
Carbonate		27.0	84.90	0	0
Hydroxide		0	274.03	0	0
Chloride		4.41	34.67	15	10.72
Sulfate		403.14	973.28	1052	977.85
Nitrate[c]		-0.04	0.06	0.09	0.04
Fluoride		1.00	0.85	1.0	0.67
Ortho Phosphate		0.013	0.009	0.05	0.013
Field pH	(no units)				
Lab pH	(no units)	8.7	12.1	6.8	7.3
Field Temperature	(°C)		13.0	19	19
Field Conductivity[d]	(µmhos/cm @ ambient temp.)		3000.0	1975	1975
Lab Conductivity[d]	(µmhos/cm @ 25°C)	1950.0	3900.0	2231	2200
Total Suspended Solids		13.5	25.5		52.7
Total Dissolved Solids				1976	
Evaporated Solids	(105°C)	232.0	989.1		2239
Carbonate Hardness	($CaCO_3$)	76.5	501.1	398	699.5
Non-Carbonate Hardness	($CaCO_3$)	0	0	879	838.64
Total Hardness	($CaCO_3$)	76.5	501.1	1277	1538.1
Total Alkalinity	($CaCO_3$)	575.0	947.0	398	699.5
Sodium Adsorption Ratio	(no units)	16.51	5.13	1.02	0.86
Acidity	($CaCO_3$)	0	0	0	20.46
Zinc		0.06	0.05	0.19	0.06
Chromium		-0.002	-0.02	0.02	-0.02
Selenium		-0.005	-0.005	0.005	-0.005
Mercury		-0.2	-0.2	-0.001	-0.2
Nickel		-0.02	-0.02	0.02	-0.02
Arsenic		-0.1	-0.02	-0.01	-0.1
Boron		0.123	0.05	0.65	1.276
Copper		0.01	0.05	0.04	0.02
Cadmium		-0.002	0.002	0.007	-0.002
Strontium		0.42	4.04	15.40	11.62
Lead		0.05	0.13	0.09	-0.02
Vanadium		-1.0	-1.0	-0.5	-1.0
Molybdenum		-0.10	0.16	0.06	-0.1

[a] Water level measurement below ground surface.

[b] Analyses reported as mg/l unless otherwise indicated.

[c] Nitrate reported as NO3 for 1974 samples, (NO3+NO2) for those after 1974.

[d] Conductivity refers to specific conductance.

[e] Duplicate analysis for quality control.

f Minus sign indicates concentration less than stated detectable limits.

Table 37

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED MONITORING WELLS IN THE PROJECT AREA

WELL NUMBER		14B	14B[e]	16A	16A
AQUIFER					
DATE		11/12/75	11/12/75	10/1/75	11/25/75
METHOD SAMPLED					
WATER LEVEL[a]		135.32	135.32	152.24	157.45
ANALYSIS[b] [f]					
Calcium		283.67	245.66		
Magnesium					
Sodium		81.89	84.69		
Potassium		18.67	18.49	24.80	40.80
Iron (total)		4.29	3.72	1.99	7.94
Manganese		1.84	6.63	7.04	6.33
Aluminum		0.27	0.30	0.47	0.54
Silica					
Bicarbonate					
Carbonate					
Hydroxide					
Chloride		12.61	41.28	4.41	11.66
Sulfate		976.94	949.58		.
Nitrate[c]		0.15	0.09	0.22	0.08
Fluoride		0.26	0.40	-0.20	0.38
Ortho Phosphate		0.018	-0.001	0.005	0.009
Field pH	(no units)				
Lab pH	(no units)	7.8	7.5	7.4	7.3
Field Temperature	(°C)	14.0		19.0	13.0
Field Conductivity[d]	(μmhos/cm @ ambient temp.)	1900.0		3150.0	3100.0
Lab Conductivity[d]	(μmhos/cm @ 25°C)	2550.0	2500.0	3890.0	4310.0
Total Suspended Solids		41.1	57.9	612.6	272.0
Total Dissolved Solids					
Evaporated Solids	(105°C)	2247.1	2063.7	5120.0	3134.2
Carbonate Hardness	($CaCO_3$)	982.0	989.0	1119.0	1264.0
Non-Carbonate Hardness	($CaCO_3$)	728.5	632.4	946.7	1401.9
Total Hardness	($CaCO_3$)	1710.5	1621.4	2065.7	2665.9
Total Alkalinity	($CaCO_3$)	982.0	989.0	1119.0	1264.0
Sodium Adsorption Ratio	(no units)	0.87	0.93	1.38	1.50
Acidity	($CaCO_3$)	0	0	25.91	0
Zinc		0.04	0.04	0.06	0.07
Chromium		-0.02	-0.02	-0.02	-0.02
Selenium		-0.005	-0.005	-0.005	-0.005
Mercury		-0.2	-0.2	-0.2	-0.2
Nickel		-0.02	-0.02	-0.02	-0.02
Arsenic		-0.02	-0.02	-0.1	-0.02
Boron		1.10	1.12	0.636	1.14
Copper		-0.01	0.02	0	-0.01
Cadmium		0.002	0.002	-0.002	-0.002
Strontium		18.79	17.05	4.28	15.79
Lead		0.36	0.36	0.08	0.57
Vanadium		-1.0	-1.0	-0.10	2.3
Molybdenum		0.15	0.19	-0.10	0.16

[a] Water level measurement below ground surface.

[b] Analyses reported as mg/l unless otherwise indicated.

[c] Nitrate reported as NO3 for 1974 samples, (NO3+NO2) for those after 1974.

[d] Conductivity refers to specific conductance.

[e] Duplicate analysis for quality control.

[f] Minus sign indicates concentration less than stated detectable limits.

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED MONITORING WELLS IN THE PROJECT AREA

WELL NUMBER		16B	16B	18	18
AQUIFER		ROB	ROB	AL	AL
DATE		10/1/75	11/12/75	10-1-75	11-11-75
METHOD SAMPLED					
WATER LEVEL[a]		77.73	77.65	23.46	23.50
ANALYSIS[b] [f]					
Calcium		132.65		142.09	114.29
Magnesium		83.67		190.53	199.49
Sodium		505.10		161.53	139.29
Potassium		2.27	58.60	10.41	12.17
Iron (total)		0.44	5.38	0.20	0.26
Manganese		1.85	5.10	-0.02	0.05
Aluminum		0.29	0.77	0.31	0.26
Silica					
Bicarbonate		928.13	1288.13	827.35	1054.43
Carbonate				0	
Hydroxide				0	
Chloride		13.30	16.07	5.17	3.66
Sulfate				653.42	664.41
Nitrate[c]		0.22	0.09	0.40	0.15
Fluoride		0.94	0.70	0.24	-0.20
Ortho Phosphate		0.005	0.018	0.019	0.001
Field pH	(no units)				
Lab pH	(no units)	7.6	7.5	7.6	7.6
Field Temperature	(°C)	16.0	13.5	13.5	10.2
Field Conductivity[d]	(μmhos/cm[e] ambient temp.)	2580.0	2490	1440	1350
Lab Conductivity[d]	(μmhos/cm[e] 25°C)	3490.0	4000	2020	1520
Total Suspended Solids		664.0	1269	1124.8	366.0
Total Dissolved Solids					
Evaporated Solids	(105°C)	731.0	3685.3	1551	1478.1
Carbonate Hardness	($CaCO_3$)	681.5	1055.5	862.0	864.0
Non-Carbonate Hardness	($CaCO_3$)	0	1647.8	279.2	248.3
Total Hardness	($CaCO_3$)	681.5	2703.3	1141.2	1112.3
Total Alkalinity	($CaCO_3$)	967.0	1055.5	862.0	864.0
Sodium Adsorption Ratio	(no units)	8.45	1.64	2.08	1.82
Acidity	($CaCO_3$)	0	0	0	0
Zinc		0.06	0.04	0.08	-0.01
Chromium		-0.02	-0.02	-0.02	-0.02
Selenium		-0.005	-0.005	-0.005	-0.005
Mercury		-0.2	-0.2	-0.2	-0.2
Nickel		-0.02	0.80	-0.02	0.08
Arsenic		-0.1	-0.2	-0.1	-0.02
Boron		1.643	1.23	1.234	0.52
Copper		0.02	0.02	0.02	0.08
Cadmium		-0.002	0.002	-0.002	-0.002
Strontium		4.60	16.42	2.94	3.29
Lead		-0.02	0.44	-0.02	0.69
Vanadium		-1.0	2.6	-1.0	-1.0
Molybdenum		-0.10	0.12	-0.10	0.07

[a] Water level measurement below ground surface.

[b] Analyses reported as mg/l unless otherwise indicated.

[c] Nitrate reported as NO3 for 1974 samples, (NO3+NO2) for those after 1974.

[d] Conductivity refers to specific conductance.

[e] Duplicate analysis for quality control.

[f] Minus sign indicates concentration less than stated detectable limits.

Table 37

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED MONITORING WELLS IN THE PROJECT AREA

WELL NUMBER		20	20	Romine	Romine [e]
AQUIFER		AL	AL		
DATE		10-1-75	11-11-75	10-2-75	10-2-75
METHOD SAMPLED					
WATER LEVEL [a]		30.56	30.32	29.18	29.18
ANALYSIS [bf]					
Calcium		127.55	132.65		175.26
Magnesium		244.11	236.05	244	230.36
Sodium		133.16	127.04	170	156.63
Potassium		7.02	9.04	7	45.92
Iron (total)		1.55	1.22	1.65	0.77
Manganese		0.46	0.43	0.02	-0.02
Aluminum		0.24	0.11	-0.1	0.24
Silica				17.8	
Bicarbonate		906.53	1145.35		899.33
Carbonate		0		0	0
Hydroxide		0		0	0
Chloride		5.80	3.28	10	6.93
Sulfate		664.82	634.90	923	866.25
Nitrate [c]		-0.02	1.60	0.69	-0.04
Fluoride		0.26	0.29	0.2	0.22
Ortho Phosphate		0.011	0.001	-0.01	0.012
Field pH	(no units)				
Lab pH	(no units)	7.7	7.4	7.3	7.6
Field Temperature	(°C)	10.1	10		12
Field Conductivity [d]	(µmhos/cm @ ambient temp.)	1460	1420		1660
Lab Conductivity [d]	(µmhos/cm @ 25°C)	2300	1790	2258	2280
Total Suspended Solids		13	21.6		11.4
Total Dissolved Solids				1862	
Evaporated Solids	(105°C)	715	1451.2		1961
Carbonate Hardness	($CaCO_3$)	944.35	938.5	490	937.0
Non-Carbonate Hardness	($CaCO_3$)	384.02	372.4	577	451.6
Total Hardness	($CaCO_3$)	1328.37	1310.9	1067	1388.6
Total Alkalinity	($CaCO_3$)	944.35	938.5	490	937.0
Sodium Adsorption Ratio	(no units)	1.59	1.53	2.26	1.83
Acidity	($CaCO_3$)	0	0	0	0
Zinc		0.05	0.02	-0.01	0.07
Chromium		-0.02	-0.02	-0.02	-0.02
Selenium		-0.005	-0.005	-0.005	-0.005
Mercury		-0.2	-0.2	-0.001	-0.2
Nickel		-0.02	-0.02	-0.01	-0.02
Arsenic		-0.1	-0.02	-0.01	-0.1
Boron		0.255	0.11	0.74	1.055
Copper		-0.01	0.02	-0.01	0.01
Cadmium		-0.002	0.002	0.005	0.008
Strontium		3.68	3.89	5.90	4.09
Lead		0.02	0.31	0.05	-0.02
Vanadium		-1.0	-1.0	-0.5	-1.0
Molybdenum		-0.10	0.04	0.05	-0.1

[a] Water level measurement below ground surface.

[b] Analyses reported as mg/l unless otherwise indicated.

[c] Nitrate reported as NO3 for 1974 samples, (NO3+NO2) for those after 1974.

[d] Conductivity refers to specific conductance.

[e] Duplicate analysis for quality control.

[f] Minus sign indicates concentration less than stated detectable limits.

Table 37

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED MONITORING WELLS IN THE PROJECT AREA

WELL NUMBER		Romine[e]	Romine	Romine[e]
AQUIFER				
DATE		10-2-75	11-13-75	11-13-75
METHOD SAMPLED				
WATER LEVEL[a]		29.18		
ANALYSIS[bf]				
Calcium		127.55	137.24	156.12
Magnesium		230.61	255.10	248.72
Sodium		163.78	169.90	176.02
Potassium		8.59	11.94	12.17
Iron (total)		0.20	0.38	0.18
Manganese		-0.02	-0.02	-0.02
Aluminum		0.40	0.09	0.12
Silica				
Bicarbonate		900.77	1191.72	1181.96
Carbonate				
Hydroxide				
Chloride		7.12	6.30	5.04
Sulfate		799.21	849.54	890.82
Nitrate[c]		-0.04	0.15	0.49
Fluoride		0.26	0.23	0.22
Ortho Phosphate		0.006	0.041	0.009
Field pH	(no units)			
Lab pH	(no units)	7.6	8.0	8.1
Field Temperature	(°C)		10.0	11.5
Field Conductivity[d]	(μmhos/cm @ ambient temp.)		1600.0	1700.0
Lab Conductivity[d]	(μmhos/cm @ 25°C)	2250.0	2120.0	2160.0
Total Suspended Solids		31.3	6.4	5.5
Total Dissolved Solids				
Evaporated Solids	(105°C)	202.0	1950.4	1882.0
Carbonate Hardness	($CaCO_3$)	938.5	976.5	968.0
Non-Carbonate Hardness	($CaCO_3$)	331.85	422.7	452.1
Total Hardness	($CaCO_3$)	1270.0	1399.2	1420.1
Total Alkalinity	($CaCO_3$)	93.5	976.5	968.0
Sodium Adsorption Ratio	(no units)	2.0	1.98	1.51
Acidity	($CaCO_3$)	0	0	0
Zinc		0.05	0.06	0.06
Chromium		-0.02	-0.02	-0.02
Selenium		-0.005	-0.005	-0.005
Mercury		-0.2	-0.2	-0.2
Nickel		-0.02	-0.02	-0.02
Arsenic		-0.1	-0.02	-0.02
Boron		1.107	0.78	0.76
Copper		0.02	0.04	0.07
Cadmium		-0.002	-0.002	0.01
Strontium		3.99	4.59	4.82
Lead		0.08	0.49	0.08
Vanadium		-1.0	-1.0	-1.0
Molybdenum		-0.10	0.15	0.18

[a] Water level measurement below ground surface.

[b] Analyses reported as mg/l unless otherwise indicated.

[c] Nitrate reported as NO3 for 1974 samples, (NO3+NO2) for those after 1974.

[d] Conductivity refers to specific conductance.

[e] Minus sign indicates concentration less than stated detectable limits.

[f] Duplicate analysis for quality control.

TABLE 38

CHEMICAL ANALYSES OF GROUND WATER FROM EAST FORK SARPY CREEK ALLUVIAL WELLS NO. 12 and 13

July, 1975

WELL NUMBER	12	13
AQUIFER	AL	AL
DATE	7-8-75	7-8-75
METHOD SAMPLED	Pumped	Pumped
WATER LEVEL[a]	25.2	14.5
ANALYSIS[b]		
Calcium	173.47	170.66
Magnesium	194.56	226.28
Sodium	211.56	363.27
Potassium	11.26	12.64
Iron (total)	0.19	0.19
Manganese	0.31	<0.05
Aluminum	0.02	0.02
Bicarbonate	13.487 meq/L	11.552 meq/L
Carbonate	0	0
Hydroxide	0	0
Chloride	4.32	11.37
Sulfate	1007.43	1491.81
Nitrate[c]	1.84	1.42
Fluoride	0.385	0.394
Ortho Phosphate	0.009	0.008
Field pH (no units)	6.6	6.8
Lab pH (no units)	7.5	7.7
Field Temperature (°C)		
Field Conductivity[d] (μmhos/cm@ambient temp.)	1180.0	1240.0
Lab Conductivity[d] (μmhos/cm@25°C)	2380.0	2920.0
Total Suspended Solids	35520.8	4758.5
Total Dissolved Solids		
Evaporated Solids (105°C)	2110.0	2939.0
Carbonate Hardness ($CaCO_3$)	674.35	577.59
Non-Carbonate Hardness ($CaCO_3$)	560.71	780.41
Total Hardness ($CaCO_3$)	1235.06	1358.00
Total Alkalinity ($CaCO_3$)	674.35	577.59
Sodium Adsorption Ratio (no units)	1.854	4.288
Acidity ($CaCO_3$)	213.13	254.05
Zinc	0.05	0.03
Chromium	0.02	
Selenium	<0.05	<0.05
Mercury	< 0.4ppb	< 0.4
Nickel	0.08	< 0.01
Arsenic	< 0.1	< 0.1
Boron	0.802	0.878
Copper	0.21	0.15
Cadmium	0.03	0.03
Strontium	10.0	13.0
Lead	0.19	0.45
Vanadium	< 0.5	< 0.5
Molybdenum	0.005	0.005

[a] Water level measurement below gound surface
[b] Analyses reported as mg/L unless otherwise indicated
[c] Nitrate reported as NO3+NO2
[d] Conductivity refers to specific conductance

From Dames and Moore, 1975, p. 42

APPENDIX D

Data on Soils, Vegetation, and Land Use

TABLES

METHODS OF SOIL SAMPLING AND ANALYSIS

Sample Collection

Soil samples for laboratory analysis were collected from hand dug pits. Individual horizons, described and identified according to procedures outlined in Agriculture Handbook No. 18., Soil Survey Manual USDA, 1951, were sampled. Quart size samples were taken of each significant horizon from a vertical section of the pit. Horizons below 2 1/2 to 3 feet were sampled with a hand auger or mechanical soil probe to a maximum depth of 5 to 7 feet.

Soil profiles were selected to represent the central concept of the soil series within the survey area where ranges in characteristics were small. Where soil characteristics ranged broadly the profiles were selected to represent the extremes.

Sample Preparation

Soil samples were air dried and split into two samples, one for chemical analysis and the remaining half was kept for later use. Each sample was passed through a 9 mesh screen for mechanical analysis and 20 mesh screen for chemical analysis.

Chemical and Physical Analysis

The following determinations were carried out on horizon sample material after screen (9 and 20 mesh).

Chemical Determinations	Reference or Procedure
pH, water	American Society of Agronomy (ASA) Monograph No. 9, Methods of Soil Analysis, Method 60-3.4, p. 922-933, except that a 1 to 2 sample to water ratio is used.
Soluble Salts (conductivity)	American Society for Testing and Materials (ASTM), Publication STP479, p. 288-290, note that a 1 to 2 sample to water ratio is used.
Calcium, water soluble	APHA, AWWA, WPCF, Standard Methods for the Examination of Water and Wastewater, 13th Edition, Part 129, p. 210-215. A 1 to 2 water extract is analyzed.
Magnesium, water soluble	APHA, AWWA, WPCF, Standard Methods for the Examination of Water and Wastewater, 13th Edition, Part 129, p. 210-215. A 1 to 2 water extract is analyzed.
Sodium, water soluble	ASA Agronomy Monograph No. 9, method 62-3.3.2, p. 944-945, a 1 to 2 water extract is analyzed.
Sodium Adsorption Ratio (SAR)	U.S. Dept. of Agriculture, Agriculture Handbook No. 60, p. 26, Calculated from the equation: $SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$
Boron, water soluble	U.S. Department of Agriculture, Agriculture Handbook No. 60, p. 142.

Chemical and Physical Analysis-Continued

Chemical Determinations	Reference or Procedure
Particle size analysis	ASA Agronomy Monograph No. 9, Method 43-5, p. 562-566. A sedimentation-sieving procedure. The sample material is sieved to pass a 9 mesh (1.981 mm) screen and dispersed in water prior to analysis.
Saturation percentage	U.S. Department of Agriculture, Agriculture Handbook 60, p. 84, Method 2 or 3a.

DESCRIPTION OF SOIL MAPPING UNITS AND ASSOCIATED SERIES

ALICE SERIES

The Alice series consists of deep, sloping and moderately steep and rolling, well-drained soils on narrow footslopes, fans and valley bottoms. Slopes range from 4 to 15 percent. They formed in sandy alluvium from calcareous sandstone at elevations of 2900 to 3700 feet.

Vegetation is green sagewort, little bluestem, prairie sandreed, sideoats grama, blue grama, broom snakeweed, ragweed and eriogonum. Precipitation is 13 to 14 inches, mean annual soil temperature is 47 to 49 degrees F., and the frost free season is 115 to 125 days.

Typically, the surface layer is grayish brown fine sandy loam about 2 inches thick. The subsoil is grayish brown and light olive brown sandy loam about 10 inches thick. The substratum is light olive brown, light yellowish brown, and pale yellow sandy loam and loamy sand.

The soil has moderately rapid permeability and an effective rooting depth of 60 or more inches.

Most of these soils are used for range. Small areas are in dryland hay.

A typical profile of Alice sandy loam in grassland, 30 feet north and 10 feet west of power line pole 252 in the NW 1/4, NW 1/4 of Sec. 2, T. 1 S., R. 35E.

A — 0 to 2 inches, grayish brown (2.5Y 5/3) fine sandy loam, very dark grayish brown (2.5Y 3/2) moist; weak coarse crumb structure parting to single grain; soft, very friable, nonsticky and slightly plastic; many fine and very fine roots; clear smooth boundary. (2 to 6 inches thick)

B21 — 2 to 6 inches, grayish brown (2.5Y 5/2) sandy loam, very dark grayish brown (2.5Y 3/2) moist; moderate, coarse prismatic structure; slightly hard, friable, slightly sticky and slightly plastic; common fine roots; gradual wavy boundary.

B22 — 6 to 12 inches, light olive brown (2.5Y 5/3) sandy loam, olive brown (2.5Y 4/3) moist; slightly hard, friable, nonsticky and slightly plastic; common fine roots; gradual wavy boundary. (B2 horizon is 5 to 10 inches thick)

C1 — 12 to 17 inches, light olive brown (2.5Y 5/3) light sandy loam, olive brown (2.5Y 4/3) moist; massive, slightly hard, friable, nonsticky and slightly plastic; very slightly effervescent; a few very fine roots; clear smooth boundary.

C2 17 to 28 inches, light yellowish brown (2.5Y 6/3) light sandy loam, light olive brown (2.5Y 5/3) moist; massive; hard, friable, nonsticky and slightly plastic; slightly effervescent; a few fine, soft masses of lime; a few very fine roots; gradual wavy boundary.

C3 28 to 41 inches, light yellowish brown (2.5Y 6/3) light sandy loam, light olive brown (2.5Y 5/3) moist; massive; slightly hard, friable, nonsticky and slightly plastic; slightly effervescent; a few very fine roots; gradual wavy boundary.

C4 41 to 65 inches, pale yellow (2.5Y 7/3) heavy loamy sand, olive (2.5Y 5/3) moist; massive, slightly hard, very friable, nonsticky and slightly plastic; slightly effervescent.

The A horizon ranges in color from dark grayish brown to light olive brown. The texture is sandy loam or fine sandy loam. The B2 horizon thickness ranges from 5 to 10 inches. Clay content ranges between 12 and 18 percent. Segregated lime in the C horizons is in indistinct fine threads and soft masses.

Alice soils are associated with Nelson, Travessilla, and Thedalund soils. They have greater depth to sandstone than the Nelson soils and have greater depth to sandstone than the Travessilla soils. They are more sandy than the Thedalund soils.

<u>Alice fine sandy loam, 4 to 15 percent slopes</u> (<u>Ar</u>).

This soil is on footslopes, fans and valley bottoms in 20 to 30 acre size areas. Slopes are smooth and mainly 4 to 10 percent. Steeper slopes occur below the higher hills and the residual soils that border the deep valleys. Slope length is 200 to 400 feet. Included with this soil in mapping are small areas of Olney fine sandy loam on gently slopes of the larger fans. Also included is a 50 to 75 feet wide band of Glenberg fine sandy loam on 8 to 15 percent slopes below the sandstone ledges and outcrops that border the valley. The soil profile is the one described as typical for the series.

Runoff is slow, the wind erosion hazard is severe.

This soil is used for range and dry cropland.

(Capability Unit IIIe-3 Dryland; Sandy range site 10-14 inch precipitation zone; Windbreak Suitability Group 2M).

CUSHMAN SERIES

The Cushman series consists of moderately deep, undulating, well-drained soils on smooth ridges and hilltops in the sedimentary plains. The slopes range from 4 to 8 percent. They formed in place from underlying mixed shale and sandstone at elevations of 3100 to 3800 feet.

The vegetation is mainly needle-and-thread, big sage, western wheatgrass, and fringed sagewort. Annual precipitation is 12 to 14 inches, the mean annual soil temperature is 47 to 49 degrees F., the frost free season is 115 to 125 days.

Typically, the surface layer is brown loam about 5 inches thick. The subsoil is brown and light brownish gray clay loam and loam about 11 inches thick. The substratum is light gray loam. Shale and sandstone bedrock are at about 30 inches. The soil reaction is mildly alkaline throughout. The soil is noncalcareous to about 9 inches and moderately calcareous below this depth. Lime in the substratum is segregated into soft masses and nodules.

The soil has moderate permeability and an effective rooting depth of about 36 inches. Available water holding capacity is 5 to 6 inches.

These soils are used for range and for dry cropland.

A typical profile of Cushman loam in a crop field, 36 feet east of trail, 1000 feet north and 175 feet west of the S1/4 corner of Sec. 1, T. 1 S., R. 37 E.

Ap 0 to 5 inches, brown (10YR 5/3) loam, dark brown (10YR 3/3) moist; cloddy; hard, friable, very sticky and plastic; a few fine roots; abrupt smooth boundary.

B2t 5 to 10 inches, brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; moderate medium prismatic structure parting to moderate medium blocks; hard, firm, very sticky and plastic; thin patchy clay films on ped surfaces; a few very fine roots; clear wavy boundary.

B3 10 to 16 inches, light brownish gray (2.5Y 6/2) loam, grayish brown (2.5Y 5/2) moist; moderate medium prismatic structure, parting to moderate medium blocks; thin patchy clay films on ped surfaces; strongly effervescent, a few medium lime mottles and some film lime; a few very fine roots; clear wavy boundary.

C1ca 16 to 25 inches, light gray (2.5Y 7/2) loam, light olive brown (2.5Y 5/3) moist; weak angular blocky structure; hard, friable, sticky and plastic; strongly effervescent, common medium and coarse lime mottles; a few very fine roots; gradual wavy boundary.

C2 25 to 35 inches, light gray (2.5Y 7/2) loam, grayish brown (2.5Y 5/2) moist; massive; hard, friable, sticky and plastic; strongly effervescent, a few coarse lime mottles; clear wavy boundary.

R 30 to 40 inches, soft platy shale.

Depth to the shale and sandstone is 30 to 40 inches. The depth to the calcareous part of the soil is 9 to 11 inches. Clay content of the B2t is 27 to 33 percent. Lime segregations in the Cca horizon are few to common. Ap horizon color range is grayish brown to brown. The C horizon has color range of light yellowish brown to light gray.

Cushman soils are associated with Thedalund, Midway, and Renohill soils. They have a B2t horizon not present in the Thedalund soils and Renohill soils. They are less slayey than the Midway and Renohill soils.

Cushman loam, undulating (4 to 8 percent slopes)(Cz).

This undulating soil is on sedimentary plains. It occupies smooth ridges and hills on the broad divides between major stream valleys. The areas range from 10 to 50 acres in size. The soil has the profile described as typical for the series. Included with this soil in mapping are small areas of Heldt, Midway, and Thurlow soils.

The runoff is medium, the erosion hazard is moderate.

This soil is used for range and dry cropland.

(Capability Unit IIIe-3 Dryland; Silty range site 10-14 inch precipitation zone; Windbreak Suitability Group 3M).

FORT COLLINS SERIES

The Fort Collins series consists of deep, nearly level to sloping and rolling, well-drained soils on terraces and fans. Slopes range from 0 to 15 percent. They formed in loam and clay loam alluvium in stream valleys at elevations of 2850 to 3400 feet.

The vegetation is mainly blue grama, needle-and-thread, big sagebrush, and cheatgrass. The annual precipitation is 12 to 14 inches, the mean annual soil temperature is 47 to 49 degrees F., the frost free season is 115 to 125 days.

Typically, the surface layer is grayish brown loam about 4 inches thick. The subsoil is brown clay loam and loam about 7 inches thick. The substratum is light brownish gray loam to 60 or more inches.

These soils have moderate permeability and an effective rooting depth of 60 or more inches. Available water holding capacity is 9 to 11 inches.

These soils are used for irrigated and dry cropland and for range.

A typical profile of Fort Collins loam in grassland, 380 feet south and 710 feet east of the center of Sec. 12, T. 1 S., R. 34 E.

A — 0 to 3 inches, grayish brown (1Y 5/2) loam, dark grayish brown (1Y 4/2) moist; moderate, medium platy structure; soft, friable, nonsticky and nonplastic; clear smooth boundary. (2 to 4 inches thick)

AB — 3 to 4 inches, brown (1Y 5/3) loam, dark grayish brown (1Y 4/2) moist; moderate, medium platy structure; slightly hard, friable, slightly sticky and slightly plastic; clear smooth boundary. (0 to 2 inches thick)

B21t — 4 to 9 inches, brown (1Y 5/3) clay loam, dark brown (1Y 4/3) moist; moderate, medium prismatic structure parting to moderate medium blocks; hard, firm, sticky and slightly plastic; thin continuous clay films on ped surfaces; gradual wavy boundary.

B22t — 9 to 12 inches, brown (1Y 5/3) clay loam brown (1Y 4/3) moist; moderate, medium prismatic structure parting to moderate, medium blocks; hard, firm, slightly sticky and slightly plastic; thin patchy clay films on ped surfaces; gradual wavy boundary. (B2t 6 to 10 inches thick)

B3ca — 12 to 22 inches, grayish brown (1Y 5/2) loam, grayish brown (1Y 4/2) moist; weak, weak prismatic structure parting to weak medium blocks; hard, friable, slightly sticky and plastic; strongly effervescent; a few fine lime mottles. Clear wavy boundary. (6 to 10 inches thick)

C1 22 to 27 inches, light brownish gray (2.5Y 6/2) loam, light olive brown (2.5Y 5/3) moist; weak, coarse prismatic structure; hard, friable, slightly sticky and slightly plastic; strongly effervescent; a few medium and coarse lime mottles; gradual wavy boundary.

C2 27 to 33 inches, light brownish gray (2.5Y 6/2) loam, light olive brown (2.5Y 5/3) moist; massive; hard, friable, slightly sticky and slightly plastic; strongly effervescent; gradual wavy boundary.

C3 33 to 65 inches, light gray (2.5Y 7/2) loam, grading to silt loam below 53 inches; massive; strongly effervescent.

The depth to the calcareous soil ranges from 7 to 12 inches. Coarse fragment in the upper 24 inches of the profile range from 0 to 10 percent. Soil color hue is 10 YR to 5Y. The A horizon color range is light brownish gray and grayish brown. The B2t horizon color range is grayish brown to olive brown. The Cca horizon color range is grayish brown and olive. Segregated lime is in fine and medium soft masses, and threads. Stratification in the C horizon includes textures of fine sandy loam, clay loam, and silt loam.

Fort Collins soils are associated with Thurlow, McRae, and Hydro soils. They contain less clay than the Thurlow soils and more clay than the McRae soils. They lack the A2 and B & A horizons of the Hydro soils.

Fort Collins loam, 2 to 4 percent slopes (Fk).

This soil is on fans and terraces in river and intermittent stream valleys. The areas are 5 to 40 acres in size. The soil profile is the one described as typical for the series. In the areas of gravel terraces the soil may include strata of loamy and below 30 inches. Included with the soil in mapping are small spots of McRae and Thurlow soils.

The runoff is slow and the erosion hazard moderate.

This soil is used for irrigated and dry cropland and for range.

(Capability Unit IIIe-3, Dryland, IIe-1 Irrigated; Silty range site 10-14 inch precipitation zone; Windbreak Suitability Group 1).

Fort Collins loam, 4 to 8 percent slopes (Fm).

This soil is on footslopes, fans and terraces. It lies in 20 to 50 acre patches in the tributary drainageways to major stream valleys. Slope length ranges between 250 and 450 feet. The soil has a profile similar to the typical one described for the series. Included with this soil in mapping on the footslopes are narrow bands of McRae soils immediately below the residual soils of the valley rim.

The runoff is medium and the erosion hazard moderate.

This soil is used for dry and irrigated cropland and range.

(Capability Unit IIIe-3 Dryland, IIIe-1 Irrigated; Silty range site 10-14 inch precipitation zone; Windbreak Suitability Group 1).

MIDWAY SERIES

The Midway series consists of shallow, sloping to steep and undulating to hilly, well-drained soils on sedimentary plains. Slopes range from 2 to 35 percent. They formed in place in materials weathered from silty clay loam and silty clay shales at elevations of 3000 to 4000 feet.

The vegetation is sideoats grama, green needlegrass, big sage, skunkbush sumac, western wheatgrass and broom snakeweed. Annual precipitation is 12 to 14 inches, the mean annual soil temperature is 47 to 49 degrees F., the frost free season is 105 to 115 days.

Typically, the surface layer is light olive gray silty clay loam about 2 inches thick. The underlying material is olive gray silty clay loam underlain by shale at about 11 inches. Shale chips make up 30 percent of the volume in the lower substratum.

Permeability is slow and the effective rooting depth is about 15 inches. Available water holding capacity is 1 to 3 inches.

These soils are used for range. Small areas are used for dry cropland.

A typical profile of Midway silty clay loam in grassland, in bank of old road 110 feet south of new road, 1500 feet west and 50 feet north of the N 1/16 corner of Sec. 10 and 11, T. 1 S., R. 35 E.

A — 0 to 2 inches, light olive gray (5Y 6/2) light silty clay loam, olive gray (5Y 5/2) strong, very fine granular structure; hard, friable, sticky and plastic; common, fine roots; slightly effervescent; clear smooth boundary. (2 to 4 inches thick)

C1 — 2 to 5 inches, olive gray (5Y 5/2) silty clay loam olive gray (5Y 4/2) moist; moderate, thin platy structure; hard, firm, very sticky and plastic; many fine and micro roots; many micro pores; strongly effervescent; gradual wavy boundary.

C2 — 5 to 11 inches, olive gray (5Y 5/2) silty clay loam, olive gray (5Y 4/2) moist; weak, coarse blocky structure; hard, firm, very sticky and very plastic; 30 percent of volume in fine, partly weathered shale chips; common fine roots; common, fine and micro pores; strongly effervescent; diffuse wavy boundary.

C3 — 11 to 14 inches, platy shale containing root mats between horizontal fractures.

Depth to the shale beds ranges from 10 to 20 inches. Clay content throughout the soil ranges from 35 to 45 percent. The soil color hue is 2.5Y or 5Y. Texture of the A1 horizon is silty clay loam, clay loam or clay. The color range is light olive brown, light olive gray, and light brownish gray. Volume of shale chips in the C horizon ranges from 5 to 35 percent. Few to many gypsum crystals occur immediately above the shale bedrock in some pedons.

Midway soils are associated with Thedalund, Lismas, Renohill and Thurlow soils. They contain more clay than the loam Thedalund soils and less clay than the Lismas soils. They have less depth to shale than the Renohill soils, and they lack the B2t horizon of the deep Thurlow soils.

Midway silty clay loam, undulating (2 to 8 percent slopes)(Mu).

This soil is in narrow, irregular areas on smooth ridges between intermittent stream valleys. Slopes range in length between 100 and 250 feet. Slopes are mainly 5 to 8 percent but range downward to 2 percent. The soil profile is similar to the typical one described for the series. Included with this soil in mapping were areas of Renohill silty clay loam in the heads of drainageways and spots having concave, 2 to 4 percent slopes. A few spots with a gravelly silty clay loam surface are also included.

Surface runoff is medium, and the erosion hazard is moderate.

This soil is suited to dry cropland and range. Moisture conservation is an important practice in managing the cultivated soil.

(Capability Unit IVe-3 Dryland; Clayey range site 10-14 inch precipitation zone; Windbreak Suitability Group 3M).

Midway silty clay loam, rolling (8 to 15 percent slopes)(MVa).

This soil is on the drainage divides between major valleys. The areas consist of ridges and hills that separate the short tributary drainageways to the main valley. Where total relief is under 150 feet the soil extends from the valley floor to the top of the drainage divide. Where relief is greater than 150 feet, this soil lies above steeper Midway soils. The soil profile is similar to the typical one described for the series. Included with this soil in mapping were small areas of Heldt, Lohmiller and McRae soils. These soils are in drainageways, and on the narrow footslopes of the main valleys. Also included on the ridge crests were areas of Thedalund loam and Nelson sandy loam.

The surface runoff is rapid, and the erosion hazard is severe.

This soil is suited to range.

(Capability Unit VIe Dryland; Clayey range site 10-14 inch precipitation zone; Windbreak Suitability Group 3M).

NELSON SERIES

The Nelson series consists of moderately deep, undulating and rolling, well-drained soils on hills and ridges of sedimentary plains. Slopes are mainly 4 to 15 percent, but range downward to 2 percent and upward to 20 percent. They formed, in places, in materials weathered from calcareous, weakly consolidated sandstones at elevations of 3000 to 3800 feet.

The vegetation is mainly prairie sandreed, dryland sedges, silver sage, green sagewort, yucca and bluebunch wheatgrass. Annual precipitation is 13 to 14 inches, mean annual soil temperature is 48 to 50 degrees F., the frost free season is 115 to 125 days.

Typically, the surface layer is light olive brown and grayish brown fine sandy loam about 5 inches thick. The underlying material is light olive brown, light yellowish brown grading to pale yellow sandy loam resting on sandstone at about 29 inches.

Permeability is moderately rapid, the effective rooting depth is about 30 inches. Available water holding capacity is 3 to 5 inches.

These soils are used for range.

A typical profile of Nelson fine sandy loam, grassland, 9 percent slope, about 1100 feet south and 175 feet west of the center of Sec. 3, T. 1 S., R. 35 E.

A — 0 to 3 inches, light olive brown (2.5Y 5/3) fine sandy loam, dark grayish brown (2.5Y 4/2) moist; single grain structure breaking from a weak crust; soft, very friable, nonsticky and slightly plastic; clear smooth boundary.

AC — 3 to 5 inches, grayish brown (2.5Y 5/2) fine sandy loam, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure; soft, very friable, nonsticky and slightly plastic; clear smooth boundary.

C1 — 5 to 16 inches, light olive brown (2.5Y 5/3) sandy loam, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure; slightly hard, very friable, nonsticky and slightly plastic; slightly effervescent; diffuse boundary.

C2 — 16 to 21 inches, light yellowish brown (2.5Y 6/3) sandy loam, light olive brown (2.5Y 5/3) moist; massive; slightly hard, friable, nonsticky and slightly plastic; strongly effervescent; diffuse boundary.

C3 21 to 29 inches, pale yellow (5Y 7/3) sandy loam, pale olive (5Y 6/3) moist; massive with some evidence of platy of the rock structure; slightly hard, friable, nonsticky and slightly plastic; strongly effervescent; clear wavy boundary.

IIC 29 to 44 inches, pale yellow (5Y 7/3) sandstone, (5Y 6/3) moist; banded soft sandstone augered with moderate pressure; strongly calcareous.

Depth to the calcareous soil ranges from 0 to 6 inches. Depth to sandstone and loam shale ranges from 20 to 40 inches. Content of coarse fragments ranges from 0 to 15 percent. Color hue is 2.5Y or 10YR in the surface and upper part of the underlying material. The lower part of the underlying material has hue of 2.5Y or 5Y.

Nelson soils are associated with Alice, Tullock, and Thedalund soils. They have lighter colored surfaces and bedrock at shallower depths than the Alice soils. They have more clay than the Tullock soils and are more sandy than the Thedalund soils.

Nelson fine sandy loam, undulating (2 to 15 percent slopes)(Nd).

This undulating soil is on hills and ridges separating major drainageways in sandstone land. Slopes are smooth except for a few thin ledges and outcrops of sandstone on the steep sides of prominent ridges. Slopes are mainly 4 to 8 percent but range downward to 2 percent and upward to 15 percent. The soil has a profile like the typical one described for the series. Included with this soil in mapping are narrow 10 acre areas of Alice fine sandy loam on valley sides and bottoms.

The surface runoff is medium and the erosion hazard is moderate.

This soil is suited to range and limited dryland crops.

(Capability Unit IVe-3 Dryland; Sandy range site 10-14 inch precipitation zone; Windbreak Suitability Group 3M).

THEDALUND SERIES

The Thedalund series consists of moderately deep, undulating to very steep, well-drained soils on sedimentary plains. Slopes range from 4 to 90 percent. They formed in materials weathered in place from shale at elevations of 2800 to 3800 feet.

Vegetation is mainly western wheatgrass, needle-and-thread, sideoats grama, dryland sedges, and big sagebrush. Annual precipitation is 12 to 14 inches, mean annual soil temperature is 48 to 50 degrees F., the frost free season is 105 to 125 days.

Typically, the surface layer is grayish brown loam about 2 inches thick. The underlying material is olive brown light yellowish brown, and light gray loam resting on loam shale at about 28 inches. A few shale and sandstone fragments occur below 20 inches.

Permeability is moderate, the effective rooting depth is about 28 inches. The available water holding capacity is 4 to 5 inches.

These soils are used for range. Small areas included with deeper soils are in dry cropland.

A typical profile of Thedulund loam, grassland, 125 feet east of trail, 1610 feet north and 1400 feet east of the SW corner of Sec. 14 T. 1 S., R. 35 E.

A — 0 to 2 inches, grayish brown (2.5Y 5/2) loam, dark grayish brown (2.5Y 4/2) moist; weak, coarse crumb structure; slightly hard, very friable, slightly sticky and slightly plastic; slightly effervescent; common very fine roots; clear smooth boundary. (1 to 4 inches thick)

C1 — 2 to 8 inches, light olive brown (2.5Y 5/3) heavy loam, olive brown (2.5Y 4/3) moist; weak, coarse prismatic structure; hard, friable, slightly sticky and slightly plastic; slightly effervescent; a few fine threads and soft masses of lime; many very fine pores; common very fine roots; gradual wavy boundary.

C2 — 8 to 14 inches, light yellowish brown (2.5Y 6/3) heavy loam, olive brown (2.5Y 4/3) moist; weak, coarse prismatic structure; hard, friable, slightly sticky and plastic; strongly effervescent; a few fine soft masses of lime; common very fine pores and roots; gradual wavy boundary.

C3 — 14 to 22 inches, light yellowish brown (2.5Y 6/3) loam, light olive brown (2.5Y 5/3) moist; massive; slightly hard, friable, slightly sticky and plastic; strongly effervescent; common, fine, soft masses of lime; a few very fine roots; common very fine pores; gradual wavy boundary.

C4 22 to 28 inches, light gray (5Y 7/2) loam, olive (5Y 5/3) moist; very weak, coarse platy structure; slightly hard, friable, sticky and plastic; a few shale and sandstone chips; strongly effervescent; common, medium soft masses of lime; a few very fine roots; common very fine pores; diffuse boundary.

C5 28 to 37 inches, platy loam shale, hard when dry; a few very fine roots.

Some visible segregated calcium carbonate occurs at random in most profiles. The 10 to 40 inches section is loam, or light clay loam with clay ranging from 18 to 30 percent. Content of coarse fragments range from 0 to 20 percent. The A and upper C horizons have hues of 25.Y and 10YR. The lower C horizon has hue of 2.5Y and 5Y. Color range in the A horizon is grayish brown, brown and dark grayish brown. The lower C horizon has color range of light olive brown, light yellowish brown and pale olive.

Thedalund soils are associated with Midway, Cushman, and McRae soils. They contain less clay and have greater depth to shale than the Midway soils. They lack the B2t horizon on the Cushman soils and have less depth to bedrock than the McRae soils.

Thedalund loam, undulating (4 to 8 percent slopes) (Tg)

This soil is on narrow ridges between intermittent stream valley and on broad drainage divides at the heads of several shallow valleys. The areas occur in mixed shale and sandstone highlands. The soil profile is the typical one described for the series. Included with this soil in mapping are areas having very fine sandy loam surfaces.

The surface runoff is medium, and the erosion hazard is moderate.

This soil is suited to dryland crops and range.

(Capability Unit IIe-2 Dryland; Silty range site 10-14 inch precipitation zone; Windbreak Suitability Group 2M)

AN OVERVIEW OF THE OVERBURDEN AND INTERBURDEN CHARACTERISTICS OF THE PROPOSED 20-YEAR MINING PLAN AREA

The 20-year mining plan area is located near the center of Tract 3 and is approximately 2,550 acres in size. Westmoreland Resources is currently surface mining the northwestern section of the mining plan area. This overview of the 20-year mining plan area evaluates the overburden and interburden material from 21 drill holes (Figure 2) for their suitability for use as a subsoil in the reclamation program. Thirteen of these drill holes are located in the area of ongoing mining operations.

pH

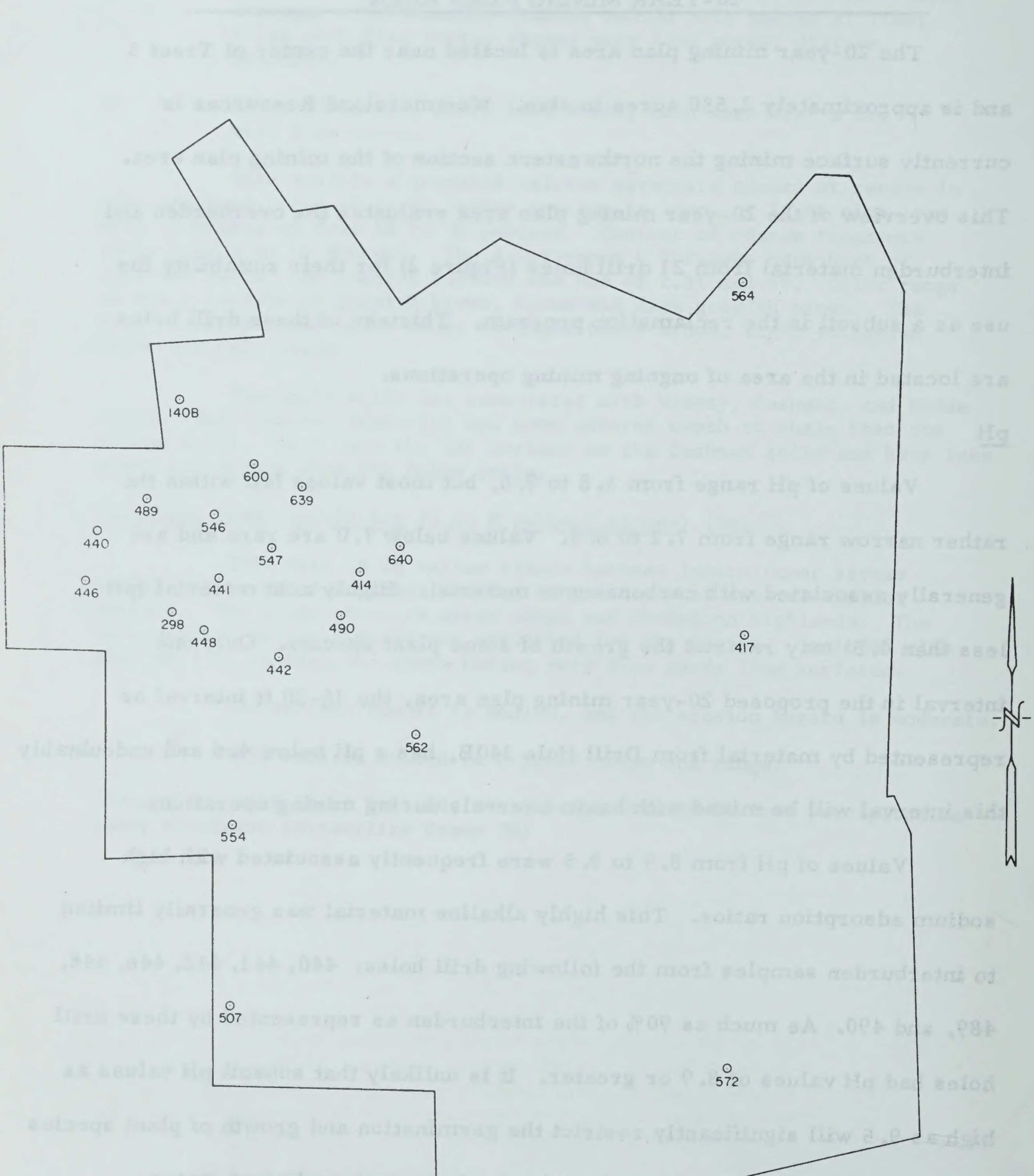
Values of pH range from 3.8 to 9.5, but most values fall within the rather narrow range from 7.2 to 8.5. Values below 7.0 are rare and are generally associated with carbonaceous material. Highly acid material (pH less than 4.5) may restrict the growth of some plant species. Only one interval in the proposed 20-year mining plan area, the 16-20 ft interval as represented by material from Drill Hole 140B, has a pH below 4.5 and undoubtably this interval will be mixed with basic intervals during mining operations.

Values of pH from 8.9 to 9.5 were frequently associated with high sodium adsorption ratios. This highly alkaline material was generally limited to interburden samples from the following drill holes: 440, 441, 442, 446, 448, 489, and 490. As much as 90% of the interburden as represented by these drill holes had pH values of 8.9 or greater. It is unlikely that subsoil pH values as high as 9.5 will significantly restrict the germination and growth of plant species generally used in revegetation of mining lands in western United States.

FIGURE
DRILL HOLE LOCATIONS FOR
OVERBURDEN AND INTERBURDEN SAMPLING

PROPOSED 20-YEAR MINING PLAN AREA

WESTMORELAND RESOURCES



In addition, these relatively high pH values indicate the presence of small amounts of sodium carbonate. Upon exposure to air, this compound is converted to bicarbonate, thus causing the pH to decrease.

SOLUBLE SALT CONCENTRATIONS

Saline material is commonly found in the northwestern part of the 20-year mining plan area. Potentially saline spoils (based on Tables 1 and 2) may occur in the area represented by the following drill holes:

Drill Hole Number	Averaged Soluble Salt Electrical Conductivity (mmhos/cm)
140B (Overburden)	4.9
414 (Overburden)	8.5
440 (Interburden)	4.1
446 (Overburden)	7.8
490 (Overburden)	4.4
547 (Overburden)	5.4
600 (Overburden)	5.1

With the exception of the interburden represented by Drill Hole 440, potentially saline spoils are limited to the overburden. Soluble salt concentrations of these magnitudes may restrict the growth of salt-intolerant plant species, but would not restrict the growth of salt-tolerant plants. Many plant species used in revegetation are considered salt tolerant. The application of nonsaline topsoil to spoil surfaces will considerably reduce any adverse impact of a saline subsoil. The movement of salts from a saline subsoil into the topsoil is possible. Application of a deep layer (approximately 2 ft) of topsoil to saline spoils should preclude significant amounts of soluble salts from moving into the topsoil.

Overburden and interburden may be combined during stripping and recontouring operations. The soluble-salt electrical conductivity of such a mixture is presented in Table 3. Potentially saline spoils appear to be limited to the following material:

Drill Hole Number	Averaged Soluble Salt Electrical Conductivity mmhos/cm
140B	4.5
414	6.6
446	5.0
547	4.4

This saline material should not hinder reclamation if salt-tolerant species are used for revegetation. With the exception of two highly saline intervals as represented by Drill Hole 414, individual intervals which are highly saline occur near the surface (from the surface to 25 ft in depth). During stripping operations, the upper portion of overburden may be deposited near the bottom of the spoil pile, and the lower portion of the overburden is likely to form the spoil surface. If this occurs, the highly saline intervals will be buried well below the plant-rooting zone.

SODIUM ADSORPTION RATIO

Only three overburden intervals (one from Drill Hole 489 and two from Drill Hole 639) are alkali, and it is likely that this alkali material will be dispersed during mining and recontouring. Averaged overburden SAR values (Table 1) are very low (from 0.9 to 7.1) and indicate that alkali overburden spoils are not probable.

TABLE 1

Averaged Values of Selected Characteristics for Overburden Material[a]

Drill Hole No.	Overburden Thickness ft	Soluble Salt Electrical Conductivity mmhos/cm	Sodium Adsorption Ratio	DTPA Extractable Zinc ppm	DTPA Extractable Nickel ppm	DTPA Extractable Lead ppm	Boron Water Soluble ppm	Clay Percent
73	132	2.0	4.9	4.6	0.7	1.8	0.4	28
140B	94	4.9	1.6	23.3	3.8	13.2	1.3	21
186	95	1.6	1.1	11.2	0.5	2.3	1.0	21
298	10	1.5	1.0(c)	12.5	(b)	(b)	3.3	25
324	65	0.6	0.9	10.3	0.7	0.8	0.2	19
341	60	4.4	6.5	11.5	1.4	2.4	3.3	26
352	50	4.7	1.7	2.9	0.7	2.4	1.4	30
391	88	1.0	1.6(c)	2.3	(b)	(b)	0.8	(b)
414	116	8.5	1.4(c)	4.4	(b)	(b)	0.8	(b)
417	35	1.3	1.6	3.6	0.4	2.6	1.8	37
440	88	3.1	2.2(c)	(b)	(b)	(b)	(b)	(b)
441	60	3.5	2.3(c)	1.7	1.8	12.6	0.9	19
442	61	2.6	1.0(c)	(b)	(b)	(b)	(b)	(b)
446	60	7.8	2.2(c)	8.7	(b)	(b)	1.4	29
448	31	2.7	1.0(c)	8.7	(b)	(b)	0.1	27
489	75	3.2	3.8(c)	12.7	2.4	14.4	1.5	24
490	73	4.4	2.6(c)	22.5	1.9	6.9	1.5	21
507	57	1.9	7.8(c)	15.5	2.0	9.2	1.9	19
546	68	3.7	2.6(c)	15.4	3.7	9.9	1.6	28
547	106	5.4	2.1(c)	19.2	2.0	6.8	1.2	20
554	73	2.1	4.7(c)	26.8	2.0	6.6	4.7	23
562	51	0.9	1.0	10.4	2.9	8.5	2.0	22
564	50	1.9	1.0	11.3	1.3	4.8	0.1	28
568	73	0.9	1.0	10.3	1.0	1.9	0.5	18
570	42	1.0	1.0	2.2	0.4	0.6	1.3	25
572	142	2.2	1.0	3.0	0.5	1.6	0.9	17
579	83	4.3	1.1	3.4	0.8	2.6	2.8	26
599	80	2.6	1.9	3.4	0.6	1.9	0.7	17
600	68	5.1	2.0	5.0	1.4	5.7	1.1	24
604	82	5.6	5.0	5.8	1.2	2.4	5.0	20
605	169	4.3	3.7	2.9	0.7	2.2	2.8	27
606	18	6.2	6.8	3.9	0.7	1.4	6.7	32
607	133	6.0	2.5	33.2	1.2	2.8	8.7	24
608	47	1.5	1.6	15.7	0.3	3.1	0.7	24
614	192	4.0	3.0	20.2	1.2	2.1	1.0	32
615	275	2.6	5.0	18.7	1.0	0.6	1.3	24
639	86	1.7	7.1	8.6	1.3	5.1	2.0	21
640	103	2.9	2.1	21.5	1.6	3.7	2.1	24

a/ Calculated from analyses on individual interval samples by the following equation:

$$\text{Value of Selected characteristic} = \Sigma\left[(\text{individual interval analysis})\left(\frac{\text{interval thickness}}{\text{overburden thickness}}\right)\right].$$

b/ Data not available.

c/ Calculated by USDA correlation from exchangeable sodium percentage:

$$ESP = \frac{100(-0.0126 + 0.01475\ SAR)}{1 + (-0.0126 + 0.01475\ SAR)}.$$

TABLE 2

Averaged Values of Selected Characteristics for Interburden Material[a, b]

Drill Hole No.	Interburden Thickness ft	Soluble Salt Electrical Conductivity mmhos/cm	Sodium Adsorption Ratio	DTPA Extractable Zinc ppm	DTPA Extractable Nickel ppm	DTPA Extractable Lead ppm	Boron Water Soluble ppm	Clay Percent
140B	54	3.9	6.9	68.4	5.0	10.5	1.0	32
186	66	3.7	17.2	47.8	1.4	3.7	0.3	37
298	51	2.5	6.6(d)	10.3	(c)	(c)	2.3	29
324	53	3.4	4.2	19.3	1.6	3.6	1.4	37
391	54	0.7	4.4(d)	8.8	(c)	(c)	1.9	(c)
414	59	3.1	15.1(d)	6.7	(c)	(c)	1.2	(c)
417	63	2.4	14.3	10.0	1.5	3.2	1.3	32
440	51	4.1	7.6(d)	(c)	(c)	(c)	(c)	(c)
441	59	3.2	12.0(d)	1.5	2.1	6.8	0.9	21
442	52	3.3	11.1(d)	(c)	(c)	(c)	(c)	(c)
446	50	1.6	7.3(d)	14.8	(c)	(c)	6.0	31
448	53	1.5	7.4(d)	15.7	(c)	(c)	4.0	28
489	57	2.9	13.0(d)	27.0	2.8	6.6	2.6	27
490	59	2.6	15.4(d)	53.9	3.2	5.9	2.4	28
507	57	2.9	8.7(d)	30.7	4.4	9.2	2.0	25
546	57	3.3	6.8(d)	16.8	3.3	6.4	1.3	26
547	54	2.6	7.7(d)	31.3	2.9	9.2	2.4	23
554	51	4.0	8.2(d)	59.3	4.0	6.9	1.8	31
562	63	1.9	6.5	22.5	5.0	7.7	1.5	31
564	53	2.9	4.7	22.2	1.4	3.3	0.1	31
568	63	2.8	5.2	28.2	1.5	2.8	0.6	31
570	42	2.6	4.1	11.7	1.2	2.5	0.6	19
572	82	2.1	3.2	2.5	1.0	3.2	1.1	29
600	66	2.7	3.8	4.8	1.8	3.3	1.6	15
606	64	2.7	8.0	18.4	1.4	2.6	2.5	28
608	81	3.6	29.1	21.0	0.7	3.5	0.6	26
614	92	4.3	13.9	73.8	1.9	4.6	1.4	26
615	87	1.7	13.5	12.3	1.5	4.7	0.4	18
639	64	3.2	18.5	12.8	2.5	3.8	1.3	22
640	63	2.5	25.7	7.9	1.8	3.9	0.3	22

a/ Calculated from analyses on individual interval samples by the following equation:

$$\text{Value of Selected Characteristic} = \Sigma \left[(\text{individual interval analysis}) \left(\frac{\text{interval thickness}}{\text{interburden thickness}} \right) \right].$$

b/ Interburden was not present for the material represented by drill holes 73, 341, 352, 579, 599, 604, 605, and 607.

c/ Data not available.

d/ Calculated by USDA correlation from exchangeable sodium percentage:

$$ESP = \frac{100(-0.0126 + 0.01475\ SAR)}{1 + (-0.0126 + 0.01475\ SAR)}$$

TABLE 3

Averaged Values of Selected Characteristics for Overburden Plus Interburden[(a, b)]

Drill Hole No.	Thickness ft	Soluble Salt Electrical Conductivity mmhos/cm	Sodium Adsorption Ratio	DTPA Extractable Zinc ppm	DTPA Extractable Nickel ppm	DTPA Extractable Lead ppm	Boron Water Soluble ppm	Clay Percent
140B	148	4.5	3.5	39.8	4.2	12.3	1.2	25
186	161	2.4	7.7	26.2	0.9	2.9	0.7	28
298	61	2.3	5.7(d)	10.7	(c)	(c)	2.5	28
324	118	1.9	2.4	14.3	1.1	2.1	0.7	27
391	142	0.9	2.6(d)	4.8	(c)	(c)	1.2	(c)
414	175	6.6	6.0(d)	5.2	(c)	(c)	0.9	(c)
417	98	2.0	9.7	7.7	1.1	3.0	1.5	33
440	139	3.4	4.2	(c)	(c)	(c)	(c)	(c)
441	119	3.3	7.1(d)	1.6	1.9	9.7	0.9	20
442	113	2.9	5.6(d)	(c)	(c)	(c)	(c)	(c)
446	110	5.0	4.5(d)	11.4	(c)	(c)	3.5	30
448	84	2.0	5.0(d)	13.1	(c)	(c)	2.5	28
489	132	3.1	7.8(d)	18.9	2.6	11.0	2.0	25
490	132	3.6	8.3(d)	36.6	2.5	6.5	1.9	24
507	114	2.4	8.3(d)	23.1	3.2	9.2	2.0	22
546	125	3.5	4.5(d)	16.0	3.5	8.3	1.5	27
547	160	4.4	4.0(d)	23.3	2.3	7.6	1.6	21
554	124	2.9	6.1(d)	40.2	2.8	6.3	3.5	26
562	114	1.5	4.1	17.2	4.1	8.1	1.7	27
564	103	2.4	2.9	16.9	1.4	4.0	0.1	29
568	136	1.8	2.9	18.6	1.2	2.3	0.6	24
570	84	2.0	2.9	8.0	0.9	1.8	0.9	21
572	224	2.2	1.8	2.8	0.7	2.1	1.0	21
600	134	3.9	2.9	4.9	1.6	4.5	1.3	20
608	128	4.0	19.0	19.1	0.5	3.3	0.6	26
614	284	4.1	6.5	37.5	1.4	2.9	1.1	30
615	362	2.4	7.1	17.2	1.1	1.6	2.4	22
639	150	2.3	12.0	10.4	1.8	4.5	1.7	21
640	166	2.8	11.1	16.3	1.7	3.8	1.4	23

a/ Calculated from analyses on individual interval samples by the following equation:

$$\text{Value of Selected Characteristic} = \Sigma\left[(\text{individual interval analysis})\left(\frac{\text{interval thickness}}{\text{overburden + interburden thickness}}\right)\right].$$

b/ Interburden was not present for the material represented by drill holes 73, 341, 352, 579, 599, 604, 605, and 607.

c/ Data not available.

d/ Calculated by USDA correlation from exchangeable sodium percentage:

$$ESP = \frac{100(-0.0126 + 0.01475\ SAR)}{1 + (-0.0126 + 0.01475\ SAR)} .$$

Alkali intervals are commonly found in the interburden, and SAR values range as high as 51. Areas in which stripped and recontoured interburden may be alkali (based on Table 2) are as follows:

Drill Hole Number	Averaged Interburden Sodium Adsorption Ratio
414	15.1
417	14.3
489	13.0
490	15.0
639	18.5
640	25.7

These alkali levels are generally low and do not represent a serious reclamation problem. The interburden material as represented by material from Drill Holes 639 and 640 is moderately alkali and may significantly reduce plant growth and water infiltration. However, application of a deep layer of nonalkali material to spoil surfaces and the use of sodium-tolerant plants in revegetation should produce favorable substrate conditions for revegetation of alkali spoils.

If overburden is combined with interburden, the nonalkali overburden will dilute the above-mentioned alkali interburden. The resulting mixture should not be alkali, as suggested in Table 3.

In the areas represented by 38% of the drill holes, alkali material is found within 10 feet of the Robinson coal seam. These drill holes are:

Drill Hole Number	Sodium Adsorption Ratio of Lowest 10 ft of Interburden
414	18
417	16
440	14
441	19
442	14
490	19
639	23
640	27

Stripping operations may deposit this material on the top of spoil piles. Recontouring may mix this alkali material with nonalkali material, but spoil surfaces may still be alkali. If this occurs, the previously-mentioned procedure of applying nonalkali material to spoil surfaces and of using sodium-tolerant species in revegetation should mitigate the undesirable effects of alkali subsoils.

PLANT NUTRIENTS

In essentially all overburden and interburden intervals in the proposed 20-year mining plan area, the concentration of nitrogen (nitrate plus ammonium) is insufficient to satisfy plant requirements for this macronutrient. The supply of plant-available nitrogen can be brought up to an adequate level by applying nitrogen fertilizer to spoil surfaces.

Overburden and interburden samples from approximately 90% of the drill holes in the mining plan area were analyzed for the macronutrients phosphorus, potassium, magnesium, sulfur, and calcium. Except for phosphorus, the concentrations of these macronutrients were generally adequate to ample for plant needs. Phosphorus was deficient in almost all intervals tested and the application of phosphorus fertilizers to spoil surfaces would be beneficial to plant growth.

Plant micronutrients are generally present in concentrations that are adequate to ample for plant requirements. Intervals deficient in micronutrients are limited to the material represented by material from Drill Holes 417, 564, 572, 639, and 640. The mixing that occurs during overburden and interburden stripping and recontouring should combine intervals with low concentrations of micronutrients with intervals containing abundant concentrations of micronutrients. However, overburden spoils from the area represented by material from Drill Hole 572 may be deficient in copper. Plants may be able to obtain sufficient copper from the topsoil that will be applied to spoil surfaces. If the topsoil fails to supply sufficient plant-available copper, supplemental forms of copper can be applied to the topsoil.

Concentrations of DTPA extractable zinc are above the level generally found in surface soils in the following intervals:

Drill Hole Number	Interval, ft	Zinc, ppm
140B	20-24	110
140B	82-89	61
140B	125-131	152
140B	140-150	135
140B	160-164	197
489	151-161	52
490	49-45	140
490	118-127	140
490	148-153	164
507	130-134	74
546	60-68	58
547	36-41	60
547	154-159	60
547	159-168	53
547	178-184	66
554	44-51	54
554	57-67	125
554	120-130	73
554	137-141	95
554	159-166	128
564	101-103	61
564	136-143	58
639	40-44	90
640	61-68	200

These zinc concentrations are not thought to be phytotoxic. High zinc concentrations can restrict plant uptake of iron, but the abundance of iron in overburden and interburden intervals should preclude this event. As previously mentioned, if plants absorb and accumulate relatively large amounts of zinc, this zinc-enriched vegetation may be beneficial to animal growth. Based on the data presented in Tables 1 and 2, high zinc concentrations of spoils appear likely in only three cases. Interburden spoils represented by material from Drill Holes 140B, 490, and 554 may be high in zinc, but such spoils should not create reclamation problems. If overburden and interburden are combined, the intervals high in zinc will be greatly diluted and the resulting spoils should have zinc concentrations within the range generally found for surface soils (Table 3).

Except for three interburden intervals from Drill Hole 446, the boron concentration of overburden and of interburden intervals in the proposed 20-year mining plan area is less than 6.0 ppm and appears to be within the range considered nontoxic for many plant species used in revegetation. In the material from Drill Hole 446, interburden intervals from 91 to 122 ft have boron concentrations ranging from 6.4 to 11.7 ppm. Westmoreland Resources investigated the procedures used in drilling this hole and reported that when these interburden intervals were bored, water was obtained for the drilling mud from a source which may have contained considerable boron. If contamination did not occur in this case, any problems due to high boron content could be solved by deep topsoiling of spoil surfaces and the use of boron-tolerant plants.

TRACE ELEMENTS

The concentrations of total mercury, available selenium, and DTPA extractable cadmium, lead, and nickel appear to be within the ranges reported in the literature and viewed as normal and nontoxic for surface soils. Lead is the only trace element found in the proposed 20-year mining plan area which approaches a level thought to be outside the range of normal soils. The 54-61 ft interval as represented by material from Drill Hole 489 had a DTPA extractable lead concentration of 41 ppm, and this represented the highest lead concentration on the proposed mining plan area. This lead concentration is within the range cited in the literature and is considered nontoxic to plants and to animals consuming plants growing on such soils. Spoils that may have lead concentrations greater than 10 ppm (Tables 1 and 2) are likely to occur from material represented by the following drill holes:

Drill Hole Number	Average Concentration of DTPA Extractable Lead, ppm
140B(Overburden)	10.5
140B(Interburden)	13.2
441(Interburden)	12.6
489(Interburden)	14.4

While these lead concentrations are higher than average values commonly cited for surface soils, they are still within the range considered normal for surface soils. Spoils from the area represented by the above-mentioned drill holes should create no reclamation problems either to plants or to grazing animals.

In addition to the previously mentioned trace elements, total lead, total nickel, total cadmium, total fluoride, and total arsenic were quantitatively determined for some of the overburden and interburden found in the proposed mining area. Semiquantitative spectrographic scans were made for many of the interval samples from the proposed mining area. Trace element concentrations determined by the above methods were within the ranges found in the literature and considered normal and nontoxic for surface soils.

PHYSICAL CHARACTERISTICS

Water-holding capacity was determined for all but five of the drill holes located in the proposed mining area. As previously mentioned, these data indicate that, with only rare exceptions, overburden and interburden materials have a retention capacity for water which should not restrict plant growth.

Spoils generated from coal removal in the proposed 20-year mining plan area should be of suitable texture for use as a subsoil. The overburden and interburden as represented by material from most drill holes have occasional intervals in which the clay content is slightly higher than 40%. The overburden as represented by material from Drill Holes 417 and 564 has several intervals in which the sand content is higher than 80%. The mixing that occurs during stripping and recontouring operations should disperse high-clay and high-sand intervals. It is unlikely that subsoil texture will have a significant influence on revegetation or on other reclamation activities.

PLANT-GROWTH TESTING

Plant-growth testing was conducted on all intervals as represented by the drill holes found in the proposed mining plan area except for that material as represented by material from Drill Holes 562, 572, 600, 639, and 640. As discussed in the overview of Tract 3, plant-growth testing demonstrated, with only a few exceptions, that the intervals tested were capable of supporting normal plant growth and seed-head development under greenhouse conditions and when fertilizers were applied to all interval samples. These greenhouse tests suggest that plants growing on revegetated areas will be able to complete their life cycle and that their growth will not be restricted by subsoil traits.

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March 11, 1976 CSMRI Project J60241

Mr. David Simpson
Environmental Administrator
Westmoreland Resources
P. O. Box 449
Hardin, Montana 59034

Dear Dave:

This letter is to report the results of analyses for exchangeable sodium percentage and the results of clay mineralogy studies on 10 selected burden interval samples from drill hole 640. These intervals included one immediately above the upper coal seam, the eight between the upper and lower coal seam, and one immediately below the lower coal seam.

Exchangeable Sodium Percentage Determinations

The results of chemical analyses used for calculation of exchangeable sodium percentage, the ESP values, and for comparison the previously determined SAR values for these interval samples are given in the attached Table 1. A comparison of the ESP values with the SAR values for these samples again indicates that ESP values are significantly less than the parallel SAR values for these strata. The SAR ranged from 1. 3 times the ESP value to 7. 6 times.

Clay Mineralogy

The results of the clay mineralogy study are given in the attached Tables 2, 3, and 4.

Kaolinite and montmorillonite were the only clay minerals found in these intervals by x-ray diffraction methods. However, an amorphous clay mineral phase not detectable by x-ray diffraction is probably present in several of the intervals. This indication is based on comparisons of clay mineral concentrations as estimated from the x-ray diffraction determinations with the corresponding cation exchange capacity values as given in Table 1, and taking into consideration the cation exchange capacity ranges reported in the literature for specific clay minerals. It is thought that this amorphous phase is an alteration product derived from crystalline montmorillonite which retains the capacity for cation exchange, but which does not contribute to swelling with addition of moisture. The intervals with the most definite indication of this amorphous phase are as follows: 104-108, 148-156, 166-174, and 231-238 ft. However, it may be present to some extent in the others as well.

You may note that the overall concentration of clay minerals as indicated by x-ray diffraction is for some intervals less, and for some intervals more than the percentage of minus 2 micron particles as determined by the hydrometer method. This appears to be due to combinations of factors including the probable presence of an amorphous clay mineral phase, the presence of nonclay minerals with particle sizes of less than 2 microns, and the presence of clay minerals with indicated particle sizes greater than 2 microns. The later two factors are probably the result of the expected less than complete separations obtained from the water suspensions of the sample materials.

A comparison of the data on estimated clay mineral concentrations with the corresponding exchangeable sodium percentages shows a somewhat rough trend of increasing ESP with increasing clay minerals concentration but the correlation would not be good enough to make any firm predictions of the level of one versus the other.

If you would like to discuss any aspects of this work, please give us a call.

Best regards,

Lawrence Tisdel
Project Manager
Environmental Technology Division

Maurice Pattengill
Mineralogist
Chemical Division

/laj
Attach.
cc: S. R. Olsen
R. Barth

TABLE 1

Determination of Exchangeable Sodium Percentage for Selected Burden Strata Intervals of Drill Hole 640

Sample No.	Interval, ft From	Interval, ft To	Sodium Water Soluble (milliequivalents/100 g)	Sodium NH_4 Acetate Soluble (milliequivalents/100 g)	Cation Exchange Capacity (milliequivalents/100 g)	Exchangeable Sodium Percentage	Previously Determined Sodium Absorption Ratio
369	104	108	1.51	2.00	29.7	1.6	7.9
370	148	156	1.72	4.41	16.1	16.7	31.3
371	156	166	0.75	0.95	3.12	6.4	17.4
372	166	174	0.79	0.66	7.33	<1.0	7.6
373	174	184	1.39	2.21	6.86	12.0	26.9
374	184	194	1.56	4.60	11.7	26.0	34.5
375	194	201	1.27	3.08	8.68	20.9	35.4
376	201	206	0.93	1.20	3.71	7.3	20.1
377	206	211	2.81	9.07	28.4	22.0	34.0
378	231	238	2.26	4.43	17.6	12.3	35.9

TABLE 2

Particle Size Analysis by Hydrometer Method

Drill Hole 640

Sample No.	Interval, ft From	Interval, ft To	Particle-Size Analysis, Wt. % +0.43mm	-0.043 mm+0.002 mm	-0.002 mm	Location
369	104	108	9.5	42.5	48.0	above upper coa seam
370	148	156	14.0	53.0	33.0	between upper and lower coal seams
371	156	166	70.0	17.5	12.5	"
372	166	174	30.5	22.5	8.0	"
373	174	184	40.0	40.0	20.0	"
374	184	194	22.0	52.5	25.5	"
375	194	201	25.0	52.5	22.5	"
376	201	206	60.0	27.0	13.0	"
377	206	211	80.0	33.0	47.0	immediately above lower coal seam
378	231	238	25.0	45.0	30.0	below lower coal seam

TABLE 3

Mineral Identification and Semiquantitative Concentration Estimates for -0.043 mm + 0.002 mm and -0.002 mm Fractions by X-Ray Diffraction[1]

Sample No. →	369	370	371	372	373	374	375	376	377	378
	-43µ + 2µ Fraction, Wt. %									
Quartz	50	55	15	15	20	45	30	15	40	45
Plagioclase	--[2]	3	2	2	5	5	5	5	--	--
k Feldspar	5	5	2	2	--	5	5	5	13	5
Calcite	--	--	--	2	5	5	5	5	tr	--
Dolomite	5	3	4	4	10	20	15	5	2	2
Sericite	20	17	12	15	15	10	15	10	15	24
Kaolinite	20	17	65	60	45	10	25	55	30	24
Montmorillonite	--	--	--	--	--	--	--	--	--	--
	-2µ Fraction, Wt. %									
Quartz	5	5	5	--	1	2	2	3	2	5
Sericite	40	30	25	20	9	3	3	20	10	25
Kaolinite	55	65	70	80	60	15	10	77	30	70
Montmorillonite[3]	--	--	--	--	30	80	85	--	58	--

1/ A 2-65° Cu two theta scan was run on a random mount of the -43µ+2µ fraction of each sample. An oriented mount was prepared from each of the two fractions of each sample and a diffractometer scan run from 2-30° Cu two theta; these mounts then being glycollated and scanned again to enhance definition of clay minerals.

2/ -- mineral not detected

3/ some montmorillonite may be present which has been altered by chemical action to an amorphous form not detectable by x-ray diffraction.

TABLE 4

Semi-Quantitative Estimates of Clay Mineral Concentrations in Selected Intervals of Drill Hole 640[1]

Sample No.	Interval, ft From	Interval, ft To	Kaolinite, %	Montmorillonite, %	Other, %
369	104	108	35	ND[2]	ND
370	148	156	30	ND	ND
371	156	166	20	ND	ND
372	166	174	20	ND	ND
373	174	184	30	6	ND
374	184	194	9	20	ND
375	194	201	15	19	ND
376	201	206	25	ND	ND
377	206	211	24	27	ND
378	231	238	32	ND	ND

1/ Based on data shown in Tables 2 and 3.

2/ ND = none detected by x-ray diffraction.

Colorado School of Mines Research Institute

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March 24, 1976 CSMRI Project J51252

Mr. David W. Simpson
Environmental Administrator
Westmoreland Resources
P. O. Box 449
Hardin, Montana 59034

Dear Dave:

The purpose of this letter is to present our findings on possible zinc contamination by a grease reported to be used in drilling operations. A sample of this grease was sent to CSMRI by Westmoreland Resources.

METHODS

The minus 9 mesh fraction of the 15-25 ft interval sample from Drill Hole 639 and the 83-86 ft interval sample from Drill Hole 640 were used as test materials. Both intervals had chemical and physical characteristics considered typical for overburden material. Two levels of grease contamination were used: 1% grease to 99% interval sample (by weight) and 5% grease to 95% interval sample. The grease and interval sample were carefully weighed, mixed, and ground to a minus 150 mesh. DTPA extractable zinc was determined using the standard method cited in our formal reports.

RESULTS

Chemical analysis of the overburden samples gave the following results:

Drill Hole No.	Interval, Ft From	Interval, Ft To	pH	DTPA Extractable Zinc, ppm 0% grease	1% grease	5% grease
639	15	25	8.2	<1.0	1180	1252
640	83	86	7.2	20.0	1520	17[illegible]0

DISCUSSION

Drilling grease could be a significant source of zinc contamination of interval samples. The DTPA extractable zinc values obtained at the 1% grease level were considerably higher than those values found in the interval samples previously tested by CSMRI. The amount of grease needed to give an extractable zinc concentration of 200, a value sometimes encountered in interval testing but rarely exceeded, would be quite small. Based on the experimental data, for a 1 foot section of 2 inch diameter core which weighs about 1500 g, only 2.2 g of grease would be needed to give a zinc value of 200 for this foot of core sample.

Increasing the amount of grease in the sample material by a factor of 5 increased the amount of DTPA extractable zinc by only 12%. The DTPA method was developed to determine the amount of plant-available zinc in soils. The average DTPA extractable zinc in soils is probably in the range of 5 to 15 ppm. Anomalous results may occur when materials with a very high concentration of zinc are analyzed by this method, possibly because the extracting solution may become saturated with zinc.

The pH value may influence the amount of extractable zinc from contaminated core samples. Slightly more zinc was extracted from the sample with a pH value of 7.2 than from the sample with a pH of 8.2. Research has shown that most heavy metals, including zinc, are more available at lower pH values than at higher pH values.

CONCLUSIONS

Based on the experimental data, the drilling grease could be a source of zinc contamination in overburden and interburden samples. Only small amounts of grease are necessary to give unusually high values of DTPA extractable zinc.

If you would like to discuss any aspects of this report, please feel free to contact us.

Sincerely,

Richard C. Barth
Senior Research Ecologist
Environmental Technology Division

APPROVED:

Lawrence C. Tisdel
Project Manager
Environmental Technology Division

TABLE 1

LIST OF PLANT SPECIES OBSERVED ON THE PROJECT AREA[a]

	Scientific Name	Common Name
TREES:	*Acer negundo*	Boxelder
	Fraxinus pennsylvanica	Green ash
	Juniperus horizontalis	Creeping juniper
	Juniperus scopulorum	Rocky Mountain juniper
	Pinus ponderosa	Ponderosa pine
	Populus deltoides	Plains cottonwood
	Salix sp.	Willow
	Ulmus americana	American elm
SHRUBS:	*Artemisia biennis*	Biennial sagewort
	Artemisia cana	Silver sagebrush
	Artemisia tridentata	Big sagebrush
	Atriplex confertifolia	Shadscale saltbush
	Atriplex nuttallii	Nuttall saltbush
	Chrysothammus nauseosus	Rubber rabbitbrush
	Crataegus succulenta	Fleshy hawthorn
	Eurotia lanata	Winterfat
	Gutierrezia sarothrae	Snake weed
	Oenothera serrulata	Shrubby evening primrose
	Prunus americana	Wild plum
	Prunus virginiana	Chokecherry
	Rhus trilobata	Skunkbush sumac
	Ribes aureum	Golden currant
	Ribes cereum	Squaw currant
	Ribes setosum	Redshoot gooseberry
	Rosa arkansana	Prairie rose
	Rosa sp.	Rose
	Shepherdia argentea	Buffaloberry
	Symphoricarpos occidentalis	Western snowberry
	Symphoricarpos sp.	Snowberry
GRASSES & GRASS-LIKE PLANTS:	*Agropyron cristatum*	Crested wheatgrass
	Agropyron smithii	Western wheatgrass
	Agropyron spicatum	Bluebunch wheatgrass
	Agropyron trachycaulum	Slender wheatgrass
	Andropogon gerardi	Big bluestem

[a]List of species obtained from observation of plants on Tract II and lists published by Ecological Consulting Service (1974a).

GRASSES & GRASS-LIKE PLANTS: (Cont'd)	Andropogon scoparius	Little bluestem
	Aristida longiseta	Red three-awn
	Bouteloua curtipendula	Side-oats grama
	Bouteloua gracilis	Blue grama
	Bromus inermis	Smooth brome
	Bromus japonicus	Japanese chess
	Bromus tectorum	Downy chess brome
	Calamovilfa longifolia	Prairie sandreed
	Carex filifolia	Needleleaf sedge
	Carex sp.	Sedge
	Carex viridula	Green sedge
	Distichlis stricta	Inland saltgrass
	Elymus canadensis	Canada wild-rye
	Festuca idahoensis	Idaho fescue
	Festuca octoflora	Six-week fescue
	Hordeum distichon	Barley
	Hordeum jubatum	Foxtail barley
	Koeleria cristata	Junegrass
	Muhlenbergia cuspidata	Plains muhly
	Oryzopsis hymenoides	Indian ricegrass
	Oryzopsis micrantha	Littleseed ricegrass
	Panicum virgatum	Switchgrass
	Phalaris arundinacea	Reed canary grass
	Poa ampla	Big bluegrass
	Poa canbyi	Canby bluegrass
	Poa pratensis	Kentucky bluegrass
	Poa scabrella	Pine bluegrass
	Poa secunda	Sandberg bluegrass
	Poa sp.	Bluegrass
	Scirpus olneyi	Rush
	Spartina gracilis	Alkali cordgrass
	Sporobolus airoides	Alkali dropseed
	Stipa comata	Needle-and-thread
	Stipa viridula	Green needlegrass
	Triticum aestivum	Winter wheat
	Typha latifolia	Common cattail
FORBS:	Achillea millefolium	Yarrow
	Agoseris glauca	Pale agoseris
	Alisum plantago-aquatica	American water-plantain
	Allium textile	Wild onion
	Alyssum alyssoides	Pale alyssum
	Amaranthus albus	White pigweed
	Amaranthus retroflexus	Redroot pigweed
	Ambrosia artemisifolia	Low ragweed
	Androsace septentrionalis	Northern androsace

Antennaria parvifolia	Small-leaf pussytoes
Antennaria rosea	Rose pussytoes
Apocynum androsaemifolium	Spreading dogbane
Arabis holboelii	Holboell rockcress
Arenaria hookeri	Hooker sandwort
Argemone intermedia	Prickly poppy
Artemisia dracunculus	False-tarragon sagewort
Artemisia frigida	Fringed sagewort
Artemisia ludoviciana	Cudweed sagewort
Ascelepias speciosa	Showy milkweed
Ascelepias verticillata	
Asclepias viridiflora	Green milkweed
Aster canescens	Hoary aster
Aster falcatus	
Aster occidentalis	Western aster
Aster sp.	Aster
Astragalus bisulcatus	Two-grooved milkvetch
Astragalus canadensis	Canada milkvetch
Astragalus cicer	Cicer milkvetch
Astragalus dasyglottis	Purple milkvetch
Astragalus gracilis	
Astragalus missouriensis	Missouri milkvetch
Astragalus purshii	Pursh loco
Astragalus spatulatus	Tufted milkvetch
Astragalus striatus	Prairie milkvetch
Astragalus sp.	Milkvetch
Bahia oppositifolia	Opposite-leaf bahia
Balsamorhiza sagittata	Arrowleaf balsamroot
Besseya wyomingensis	Kittentail
Brodiaea grandiflora	
Calochortus nuttallii	Mariposa lily
Camelina microcarpa	Littlepod false-flax
Campanula rotundifolia	Roundleaf harebell
Capsella bursa-pastoris	Shepherd's purse
Carduus nutans	Musk thistle
Castilleja sessiliflora	Indian paintbrush
Cerastium arvense	Field chickweed
Chaenactis douglasii	Douglas dusty maiden
Chenopodium album	Lamb's quarter
Chenopodium leptophyllum	Narrowleaf goosefoot
Chorispora tenella	
Chrysopsis villosa	Golden-aster
Cirsium undulatum	Wavyleaf thistle
Collinsia parviflora	Blue-eyed Mary
Collomia linearis	Narrow-leaved collomia
Comandra umbellata	Pale bastard toadflax
Convolvulus arvensis	Field bindweed
Corydylanthus ramosus	Bird's beak

Crepis accuminata	Tapertip hawksbeard
Cryptantha bradburiana	Miner's candle
Delphinium bicolor	Low larkspur
Descurainia pinnata	Pinnate tansy mustard
Draba nemorosa	Woods draba
Draba sp.	Draba
Echinaceae pallida	Purple coneflower
Epilobium paniculatum	Panicled willow-herb
Erigeron divergens	Spreading fleabane
Erigeron pumilus	
Erigeron strigosus	
Eriogonum annuum	Annual eriogonum
Eriogonum multiceps	
Erodium cicutarium	Alfilaria
Erysimum asperum	Plains wallflower
Euphorbia robusta	Robust spurge
Evoloulus nuttallianus	
Fragaria virginiana	Virginia strawberry
Fritillaria pudica	Yellow bell
Galium boreale	Northern bedstraw
Gaura coccinea	Scarlet gaura
Gaura parviflora	Small-flowered gaura
Geum triflorum	Prairie smoke
Gilia congesta	Densely flowered gilia
Glycyrrhiza lepidota	Wild licorice
Grindelia squarrosa	Curlcap gumweed
Hackelia floribunda	Many flowered stickseed
Haplopappus lanceolatus	Lance goldenweed
Haplopappus nuttallii	Nuttall goldenweed
Haplopappus spinulosus	Spiny goldenweed
Hedeoma drummondii	Drummond false pennyroyal
Helianthus annuus	Common sunflower
Helianthus petiolaris	Prairie sunflower
Hesperis matronalis	Rocket
Hymenopappus filifolius	Narrowleaf hymenopappus
Kochia scoparia	Kochia, summer cypress
Lactuca pulchella	Blue lettuce
Lactuca serriola	
Lappula echinata	European stick tight
Lappula redowskii	Western stick tight
Lepidium densiflorum	Prairie pepperweed
Lepidium perfoliatum	Clasping pepperweed
Lesquerella ludoviciana	Silver bladderpod
Leucocrinum montanum	Mountain star lily
Liatris punctata	Dotted blazingstar
Linanthus septentrionalis	
Linum perenne	Blue flax
Linum regidum	Stiffstem flax

Lithophragma parviflora	Small flower woodlandstar
Lithospermum arvense	Field gromwell
Lithospermum incisum	Narrowleaf gromwell
Lomatium sp.	
Lupinus lepidus	Pacific lupine
Lygodesmia juncea	Rush skeleton weed
Mamillaria vivipara	Pink pincushion cactus
Marrubium vulgare	Horehound
Medicago lupulina	Black medic
Medicago sativa	Alfalfa
Melilotus alba	White sweetclover
Melilotus officinalis	Yellow sweetclover
Mentha arvensis	Field mint
Mentzelia decapetala	Ten-petal blazing star
Mertensia lanceolata	Lanceleaf bluebell
Microseris cuspidata	
Microseris nutans	Nodding microseris
Monarda fistulosa	Horse mint
Oenothera biennis	Rydberg's evening primrose
Oenothera caespitosa	Tufted evening primrose
Oenothera nuttallii	Nuttall evening primrose
Opuntia polycantha	Plains pricklypear
Oxytropis lambertii	Pruple pointloco
Oxytropis sericea	White pointloco
Pedicularis apysoniana	
Penstemon albidus	White penstemon
Penstemon eriantherus	Fuzzytongue pensetmon
Penstemon nitidus	Waxleaf penstemon
Petalostemon candidum	White prairie-clover
Petalostemon purpureum	Purple prairie-clover
Phacelia hastata	Silverleaf phacelia
Phacelia linearis	Linear-leaf placelia
Phlox hoodii	Hoods phlox
Phlox kelseyi	Kelsey phlox
Physaria didymocarpa	Common twinpod
Plantago purshii	Woolly plantain
Potentilla gracilis	Northwest cinquefoil
Potentilla sp.	
Psoralea argophylla	Silverleaf scurfpea
Psoralea esculenta	Breadroot scurfpea
Psoralea tenuiflora	Slimflower scurfpea
Ranunculus glaverriumus	Sagebrush buttercup
Ratibida columnifera	Prairie coneflower
Rhus radicans	Poison ivy
Rumex crispus	Curl dock
Sagittaria cuneata	Arum-leaved arrowleaf
Salsola kali	Russian thistle

Senecio canus	Woolly groundsel
Senecio integerrimus	Lambstongue groundsel
Sisymbrium altissimum	Tumblemustard
Sisymbrium loeselii	Smallpod tumblemustard
Smilacina stellata	Starry false Solomon's seal
Solidago canadensis	Canada goldenrod
Solidago missouriensis	
Solidago mollis	Goldenrod
Solidago sp.	
Sphaeralcea coccinea	Scarlet globemallow
Taraxacum officinale	Common dandelion
Thermopsis rhombifolia	Prairie thermopsis
Thalaspi arvense	Fanweed
Townsendia hookeri	
Trandescantia occidentalis	Spiderwort
Tragopogon dubius	Common salsify
Urtica dioica	Stinging nettle
Vaccaria segetalis	Pink Cockle
Verbascum thapsus	Flannel mullein
Verbena bracteata	Bracted verbena
Vicia americana	American vetch
Viola nuttallii	Nuttall violet
Yucca glauca	Soapweed
Zigadenus venenosus	Meadow death camas

Table 2 YIELD PER ACRE, VALUE AND PRICE OF NON-IRRIGATED CROPS, 1972 and 1973

	1972 Yield Per Acre				1973 Yield Per Acre			
	Montana	Big Horn Co.	Price Per Bushel	Value Per Acre	Montana	Big Horn Co.	Price Per Bushel	Value Per Acre
Winter Wheat	26.6	34	1.87	50.49	26.3	26	4.30	114.01
Durum Wheat	31.5	29	1.86	58.59	21.9	22	5.65	124.37
Other Spring Wheat	25.7	22.5	1.90	49.40	20.6	20	4.15	87.20
Barley	36	33	1.22	45.75	28.4	28	2.20	66.00
Oats	45.5	46	.71	34.08	35	47	1.20	45.60
Hay (all)	1.22	1.49	32.00*	55.39	1.09	1.49	57.00*	95.39
Alfalfa Hay	1.41	1.70	N/A	N/A	1.26	1.90	N/A	N/A

*Price per ton baled N/A

Source: Montana Agricultural Statistics Vol. XV. County Statistics 1972 and 1973 Montana Department of Agriculture and Statistical Reporting Service - USDA December 1974.

APPENDIX E

Data on Fish and Wildlife

TABLES

TABLE 1

SPECIES OF MAMMALS OBSERVED OR POTENTIALLY OCCURRING IN THE VICINITY OF THE SARPY CREEK MINE, BIG HORN COUNTY, MONTANA

Order Insectivora - Insectivores	
Family Soricidae - Shrews	
Sorex cinereus	Masked Shrew
[a]*Sorex merriami*	Merriam's Shrew
Order Chiroptera - Bats	
Family Vespertilionidae - Vespertilionid Bats	
Myotis lucifugus	Little Brown Myotis
Myotis leibii	Small-footed Myotis
Lasionycteris noctivagans	Silver-haired Bat
Eptesicus fuscus	Big Brown Bat
[a]*Euderma maculatum*	Spotted Bat
[a]*Plecotus townsendii*	Townsend's Big-eared Bat
Order Lagomorpha - Lagomorphs	
Family Leporidae Hares and Rabbits	
[ab]*Sylvilagus audubonii*	Desert Cottontail
[b]*Lepus townsendii*	White-tailed Jack Rabbit
Order Rodentia - Rodents	
Family Sciuridae - Squirrels	
[b]*Eutamias minimus*	Least Chipmunk
[b]*Spermophilus tridecemlineatus*	Thirteen-lined Ground Squirrel
Spermophilus richardsonii	Richardson's Ground Squirrel

[a]Species of special interest or concern (Flath, 1975).
[b]Observed on Project area in 1975.

Family Sciuridae - Squirrels (continued)	
[ab]*Cynomys ludovicianus*	Black-tailed Prairie Dog
[b]*Tamiasciurus hudsonicus*	Red Squirrel
Family Geomyidae - Pocket Gophers	
[b]*Thomomys talpoides*	Northern Pocket Gopher
Family Heteromyidae - Heteromyids	
[b]*Perognathus fasciatus*	Olive-backed Pocket Mouse
Dipodomys ordii	Ord's Kangaroo Rat
Family Cricetidae - New World Rats and Mice	
[b]*Reithrodontomys megalotis*	Western Harvest Mouse
[b]*Peromyscus maniculatus*	Deer Mouse
Peromyscus leucopus	White-footed Mouse
[b]*Onychomys leucogaster*	Northern Grasshopper Mouse
Neotoma cinerea	Bushy-tailed Woodrat
Microtus pennsylvanicus	Meadow Vole
Microtus longicaudus	Long-tailed Vole
[b]*Microtus ochrogaster*	Prairie Vole
[a]*Lagurus curtatus*	Sagebrush Vole
Ondatra zibethicus	Muskrat
Family Zapodidae - Jumping Mice	
[a]*Zapus hudsonius*	Meadow Jumping Mouse
Family Erethizontidae - New World Porcupines	
[b]*Erethizon dorsatum*	Porcupine
Order Carnivora - Carnivores	
Family Canidae - Canids	
[b]*Canis latrans*	Coyote
Vulpes vulpes	Red Fox
[a]*Vulpes velox*	Swift Fox
Family Procyonidae - Procyonids	
[b]*Procyon lotor*	Raccoon

TABLE 1

Family Mustelidae - Mustelids	
Mustela erminea	Ermine
Mustela frenata	Long-tailed Weasel
[a]*Mustela nigripes*	Black-footed Ferret
Mustela vison	Mink
Taxidea taxus	Badger
[b]*Mephitis mephitis*	Striped Skunk
Family Felidae - Cats	
[b]*Lynx rufus*	Bobcat
Order Artiodactyla - Even-toed Ungulates	
Family Cervidae - Cervids	
[b]*Odocoileus hemionus*	Mule Deer
[b]*Odocoileus virginianus*	White-tailed Deer
Family Antilocapridae - Pronghorn	
[b]*Antilocapra americana*	Pronghorn

TABLE 1 ADDENDUM

Order Chiroptera-Bats	
Family Vespertilionidae	
Mytosis evotis	Long-eared bat
Mytosis yumanensis	Yuma bat
Mytosis volans	Long-legged bat
Lasivrus cinereus	Hoary bat
Lasivrus borealis	Red bat
Order Lagormorpha-Lagomorphs	
Family Leporidae-Hares and Rabbits	
Sylvilogus nutlalli	Mountain cottontail
Order Rodentia-Rodents	
Family Sciuridae-Squirrels	
Marmota flaviventris	Yellow-bellied Marmot
Family Muridae-Old World Rats and Mice	
Rattus Norvegicus	Norway rat
Mus musculus	House mouse
Family Costoridae-Beaver	
Castor canadensis	Beaver
Order Carnivora-Carnivores	
Family Mustilidae-Mustilids	
Spilogale grocilis	Western spotted skunk

TABLE 2.

Brief listing of some habitat and food requirements of mammals that occur or may occur on the Westmorland lease. Where family groups are similar in requirements the family will be treated as a group, otherwise individual species requirements are listed. Food habits and habitat requirements are taken from Martin, et. al. (1961) and Burt and Grossenheider (1964).

Name: Shrews-Family Soricidae

Habitat: Moist areas-forests, brushlands, open country (Masked); arid areas-sagebrush, bunchgrass (Merriams).

Foods: Earthworms, insects, snails, spiders, mice.

Misc.:

Name: Plainnose Bats-Vespertilionidae

Habitat: Nocturnal, free roaming in search of food. Occur in caves, tunnels, buildings, forests.

Foods: Insectivorous.

Misc.:

Name: Raccoon-Procyon lotor

Habitat: Dense or rocky areas near water.

Foods: Omnivorous. Frogs, crayfish, insects, fish, small mammals, alfalfa, corn, barley.

Misc.: May damage crops and poultry. Fur of value. Edible.

Name: Shorttail Weasel(Ermine)-Mustela erminea

Habitat: Areas of dense vegetative growth, near water. Mostly nocturnal.

Foods: Rabbits, rodents, snakes, frogs, fish, birds, eggs.

Misc.: Winter pelts are of value. Good mousers.

Name: Longtail Weasel-Mustela frenata

Habitat: All areas near water. Mostly nocturna.

Foods: Rabbits, rodents, snakes, frogs, fish, birds, eggs.

Misc.: Winter pelts are of value. Kills many rodents.

Name: Mink-Mustela vison

Habitat: Aquatic. Found near lakes, marshes, streams.

Foods: Rodents, snakes, crustaceans, frogs, birds, eggs.

Misc.: Valuable for their pelts.

Name: Badger-<u>Taxidea taxus</u>

Habitat: Open areas of grasslands and deserts. Mostly nocturnal.

Foods: Rodents, rabbits, insects, grouse, lizards.

Misc.:

Name: Striped Skunk-<u>Mephitis mephitis</u>

Habitat: Open country, mixed woods, brushland, prairie preferred. Mainly nocturnal.

Foods: Mostly animal. Insects, spiders, toads, frogs, lizards, mice, gophers, turtle eggs, birds, fleshy fruits, grasses.

Misc.:

Name: Coyote-<u>Canis latrans</u>

Habitat: No boundaries. Prefers areas where cover is readily available such as brush, boulders, ravines.

Foods: Wide variety of plants and animals. Small mammals to deer, sheep, fleshy fruits, carrion, etc.

Misc.: Valuable pelts during winter. Blamed for high mortality to domestic stock and wild populations.

Name: Red Fox-<u>Vulpes fulva</u>

Habitat: Brushy areas where escape cover is available, will hunt in open. Mostly nocturnal.

Foods: Mainly animal. Mice, other small rodents, rabbits, birds, frogs, insects, carrion, various fruits and berries.

Misc.: May cause damage to domestic and wild fowl. Pelt is valuable.

Name: Swift Fox-<u>Vulpes velox</u>

Habitat: Open areas; sandy, plains, low vegetation. Nocturnal.

Foods: Samll rodents, rabbits.

Misc.: Few in number in U.S.; of special concern to conservationists.

Name: Bobcat-<u>Lynx rufus</u>

Habitat: Areas where cover is available, (secretive). From deserts to mountains, rimrock areas are preferred.

Foods: Small mammals, birds, occasionally deer.

Misc.: Valued for its winter pelt.

Name: Blacktailed Prairie Dog-Cynomys ludovicianus

Habitat: High, dry, plains, and prairies. Live in communities called "towns".

Foods: Predominantly plants. Occasionally insects. Almost any green vegetation, wheatgrass, Russian thistle, fescue, bluegrass, grama, barley, saltbush, globe mallow, sunflower, plantain.

Misc:

Name: Red Squirrel-Tamiasciurus hudsonicus

Habitat: Pine or spruce forests.

Foods: Insects, young birds, eggs, fresh carrion, conifer seeds, fleshy fruits, nuts.

Misc.:

Name: Least Chipmunk-Eutamias minimus

Habitat: Sagebrush deserts, coniferous forests, mixed-hardwoods. Highly variable.

Foods: Insects (50% in warm months), seeds and fruits. Wheat, sedge, gooseberry, cinquefoil, ragweed, buffaloberry, dandelion, bromegrass, sunflower, sagebrush, goosefoot.

Misc:

Name: Thirteen-lined Ground Squirrel-Citellus tridecemlineatus

Habitat: Clear areas, deserts, plains.

Foods: Grasshoppers, other insects, mice, birds, carrion, ragweed, sunflower, clover, wheat, needlegrass, Russian thistle.

Misc:

Name: Richardsons Ground Squirrel-Citellus richardsoni

Habitat: Sagebrush, grasslands.

Foods: Grasshoppers, caterpillars, mice, birds, carrion, goosefoot, bluegrass, dandelion, sunflower, cinquefoil.

Misc.:

Name: Northern Pocket Gopher-Thomomys talpoides

Habitat: Subterranean in prairies, meadows, open pine forests, brushy areas.

Foods: Roots, bulbs, rootstocks, seeds, nuts; most plants that grow near the burrow.

Misc.: May cause damage to some crops. Cause problems with irrigation waters.

Name: Olive-backed (Wyoming) Pocket Mouse-Perognathus fasciatus

Habitat: Shortgrass prairies.

Foods: Locoweed, pigweed, fescue, saltbush, bromegrass, bindweed, sunflower, plantain, barley, Russian thistle, saltbush.

Misc.:

Name: Ord's Kangaroo Rat-Dipodomys ordii

Habitat: Plains, prairies on sandy soil.

Foods: Pigweed, saltbush, ragweed.

Misc.:

Name: Beaver-Castor canadensis

Habitat: Streams, rivers, lakes, marshes with trees and brush available for cutting.

Foods: Bark and wood, main diet. Willow, pine.

Misc.: Pelts valuable at times. May cause damage through dam building activities.

Name: Western Harvest Mouse-Reithrodontomys megalotis

Habitat: Grasslands, open deserts, weed patches, near water.

Foods: Insects and seeds.

Misc.:

Name: White-footed Mice-Peromyscus

Habitat: Well distributed in a wide variety of habitats.

Foods: Insects, snails, centipedes, small mammals, small birds, pine, Russian thistle, corn, sunflower, three-own.

Misc.: Includes: deer mouse and white-footed mouse.

Name: Northern Grasshopper Mouse-Onychomys leucogaster

Habitat: Open country, grass, sagebrush, sandy or gravelly soil.

Foods: Mainly animal. Insects, scorpions, mice, lizards, spiders, wheat, barley, needlegrass, Russian thistle.

Misc.:

Name: Bushy-tailed Woodrat-Neotoma cinerea

Habitat: High mountains, rimrocks, rockslides, pines.

Foods: Green vegetation, twigs, shoots, grasses.

Misc.:

Name: Voles-Microtus sp.

Habitat: Moist areas, streamside, swamps except prairie vole, which prefers open prairies, fence rows, dry places.

Foods: Grasses, sedges, seeds, grain, bark, insects, bulbs.

Misc.: May cause damage to trees by girdling. Includes: Meadow, long-tailed and prairie voles.

Name: Sagebrush Vole-Lagurus curtatus

Habitat: Sagebrush, loose soil.

Foods: Sagebrush and other green vegetation.

Misc.:

Name: Muskrat-Ondatia zibethica

Habitat: Rivers, lakes, ponds, marshes, ditches, swamps.

Foods: Mostly plants. Fish, mussels, insects, crayfish, snails, cattail, bullrush, pondweed, corn, willow, buttercup.

Misc.: Valuable for fur. May cause damage due to burrowing.

Name: Meadow Jumping Mouse-Zapus hudsonius

Habitat: Widespread habitat but feeds in low meadows.

Foods: Little known habits. Probably seeds, leaves, shoots, insects in available habitat.

Misc.:

Name: Porcupine-Erethizon dorsatum

Habitat: Forested areas but also areas with low brush.

Foods: Pine, clover, dandelion, sedge, goldenrod.

Misc.: Cause severe damage to trees in some areas.

Name: Desert Cottontail-Sylvilagus auduboni

Habitat: Open areas, grasslands, sagebrush, scattered forests.

Foods: Summer: herbaceous plants. Winter: twigs and bark. Plaintain, bluegrass, clover, goldenrod, strawberry, willow, wheat, corn, wild rose, elm, sagebrush, rush.

Misc: Very important game and food animal in much of the U.S. May cause damage to crops and orchards when in sufficient numbers.

Name: White-tailed Jack Rabbit

Habitat: Open, grassy or sagebrush plains.

Foods: Rabbitbush, sagebrush, and other plants.

Misc.: May cause some crop damage.

Name: Mule Deer-Odocoileus hemionus

Habitat: Coniferous forest, desert shrubs, chaparral, grasslands.

Foods: Sagebrush, fescue, bluegrass, bromegrass, needlegrass, wheatgrass, ricegrass, pine, snowberry, rabbitbush, willow, alfalfa, phlox, Russian thistle, pussytoes, rose, clover, corn, lichen.

Misc: Important game animal.

Name: White-tailed Deer-Odocoileus virginianus

Habitat: Brushy areas, forests, river bottoms.

Foods: Pine, wi-low, alfalfa, wheatgrass, rose, bluegrass, snowberry, pussytoes.

Misc.: Important game animal.

Name: Pronghorn (Antelope)-Antilocapra americana

Habitat: Open prairies and sagebrush plains.

Foods: Sagebrush, snowberry, wheatgrass, grama grass, saltbush, bromegrass, locoweed, thistle, ragweed.

Misc.: Important game animal.

Name:

Habitat:

Foods:

Misc.:

TABLE 3

Herd composition of Tract II and Tract III with comparison of other studies and other areas.

Mule Deer	Fawns/100 Does	Fawns/100 Adults	Bucks/100 Does	% Bucks	% Does	% Fawns
1975 Tract III (Aug-Dec)[1]	55.7	43.7	27.5	15.0	54.6	30.4
1974 Tract III (Winter)[2]	48	34	40	21.3	53.3	25.4
1973-74 Tract III (Dec-Feb)[3]	64	46	40	19.6	48.9	31.5
1973-74 Sarpy Basin (Dec-Feb)[4]	81.8	54.5	27.3	13.1	47.8	39.1
1974 Sarpy Basin (Sept-Nov)[4]	76.9	59.3	29.8	14.4	48.4	37.2
1973 Sarpy Basin (Fall)[4]	85.7	62.1	38.1	17.0	44.7	38.3
1973 Region 7, MT[4]	88	65	35.3	15.8	44.8	39.4
1934-1950 Western U.S.[5]	81	62	30	14.2	47.4	38.4

1. Dames and Moore, 1975.
2. E.C.S., 1974.
3. Westmorland Resources, 1975o.
4. Martin, 1975.
5. Taylor, 1965.

TABLE 4

Percent of mule deer observation by habitat type for the period January-December 1975, on Tract III.

1.	Ponderosa Pine Grassland	35.8
2.	Creek Bottom	10.0
3.	Silver Sagebrush-Grassland	9.9
4.	Alfalfa Hay	9.1
5.	Fallow	9.1
6.	Skunkbush-Grassland	6.6
7.	Grassland	6.0
8.	Mature Wheat or Stubble	3.4
9.	Big Sagebrush-Grassland	2.5
10.	Snowberry Coulee	2.3
11.	Sprouted Wheat	2.0
12.	Reclaimed Spoils	1.3
13.	Disturbed Grasslands	0.9
14.	Ponderosa Pine-Juniper	0.5

TABLE 5

PERCENT OF MULE DEER OBSERVED USING EACH HABITAT TYPE ON TRACT III BY MONTH FOR PERIOD JANUARY TO JUNE 1975

Habitat Type	Percent of Mule Deer Observed						
	Jan. [a]37(16)	Feb. 10(04)	Mar. 61(27)	Apr. 62(27)	May 17(08)	Jun 42(18)	All 229(100)
Grassland	(-)	[b]20/10	08/13	06/10	(-)	10/09	07/09
Big Sagebrush-Grassland	[c]16	(-)	(-)	(-)	(-)	05/02	04/02
Silver Sagebrush-Grassland	(-)	(-)	02/06	13/17	35/35	19/21	10/14
Skunkbush-Grassland	(-)	0/30	0/15	(-)	0/03	12/14	02/09
Creek Bottom	25	0/20	(-)	(-)	0/12	02/02	04/02
Snowberry Coulee	(-)	(-)	0/02	0/10	(-)	0/02	0/04
Ponderosa Pine-Grassland	35	80/40	62/49	13/30	18/26	50/48	40/41
Ponderosa Pine-Juniper	08	(-)	(-)	(-)	(-)	(-)	01/0.7
Alfalfa Hay	(-)	(-)	(-)	40/19	18/09	02/02	13/07
Fallow	(-)	(-)	(-)	10/05	(-)	(-)	03/01
Sprouted Wheat	(-)	(-)	(-)	18/09	(-)	(-)	05/03
Mature Wheat or Stubble	16	(-)	16/08	(-)	(-)	(-)	06/04
Reclaimed Spoils	(-)	(-)	12/06	(-)	(-)	(-)	03/02
Disturbed Grassland	(-)	(-)	(-)	(-)	29/15	(-)	02/01
Roadways (with borrow pits)	(-)	(-)	0/01	(-)	(-)	(-)	0/0.2

[a] Number and (percent) of total observations.
[b] Percent of observations within habitat type/percent of observations including next habitat type.
[c] The next nearest habitat type was not recorded for January observations.

TABLE 6

PERCENT OF MULE DEER OBSERVED USING EACH HABITAT TYPE ON TRACT III BY MONTH FOR THE PERIOD JULY TO DECEMBER 15, 1975

	Percent of Mule Deer Observed						
Habitat Type	July [a]43(13)	Aug. 63(19)	Sept. 97(29)	Oct. 15(5)	Nov. 91(28)	Dec. 20(6)	All 329(100)
Grassland	[b]05/12	(-)	10/07	00/07	10/07	(-)	06/06
Big Sagebrush-Grassland	(-)	08/13	01/01	(-)	00/12	(-)	02/06
Silver Sagebrush-Grassland	02/08	02/11	04/19	47/23	21/22	00/30	10/18
Skunkbush-Grassland	12/20	03/18	12/13	27/13	10/05	00/20	10/13
Creek Bottom	14/07	06/03	25/17	00/23	13/08	(-)	14/10
Snowberry Coulee	14/08	00/07	03/02	13/07	02/01	(-)	04/03
Ponderosa Pine-Grassland	49/41	81/44	18/26	00/20	00/02	100/50	33/26
Alfalfa Hay	05/05	00/01	20/10	07/03	00/04	(-)	07/05
Fallow	(-)	(-)	05/03	(-)	44/39	(-)	14/12
Mature Wheat or Stubble	(-)	(-)	02/01	07/03	(-)	(-)	01/tr[c]
Roadways (with borrow pits)	(-)	(-)	00/01	(-)	(-)	(-)	00/tr
Pond	(-)	00/02	(-)	(-)	(-)	(-)	00/tr
Strip Mine	(-)	(-)	00/02	(-)	(-)	(-)	00/tr

[a]Number and (percent) of total observations.
[b]Percent of observations within habitat type/percent of observations including next nearest habitat type.
[c]tr = trace; a value less than 0.5%.

TABLE 7

Partial listing of foods of the mule deer, white-tailed deer and pronghorn. Species listed are included as flora of Tract III. From Westmorland Resources, 1975o.

MULE DEER

Sagebrush	Pussytoes	Ricegrass	Paintbrush
Snowberry	Clover	Rabbitbrush	Sedge
Sunflower	Pine	Alfalfa	Evening Primrose
Wild Rose	Fescus	Phlox	Mustard
Willow	Brome	Russian Thistle	Wild-rye
Chokecherry	Needlegrass	Gramma	Gooseberry
Bluegrass	Wheatgrass	Lupine	Sumac
Juniper	Lilly	Saltbush	Winter fat

WHITE-TAILED DEER

Sumac	Chokecherry	Snowberry
Willow	Pussytoes	Wheatgrass
Hawthorn	Sedge	Alfalfa
Elm	Three-own	Chokecherry
Pine	Rose	Juniper
Goldenrod	Bluegrass	Many grasses

PRONGHORN

Sagebrush	Rabbitbrush	Saltbush
Gramma grass	Wheatgrass	Prickly pear
Phlox	Alfalfa	Russian Thistle
Spurge	Peusteman	Evening Primrose
Snowberry	Rose	Globe Mallow
Milkweed	Sweet Clover	Brome grass
Locoweed	Pigweed	Ragweed

Source: Westmorland Resources, 1975o
Taylor, 1965
Martin, et. al., 1961

TABLE 8

Habitat type use by antelope* on Tract III from January to December 1975.

Habitat Type	Percent observed in habitat type
Grassland	71.0
Big Sagebrush-Grassland	7.1
Silver Sagebrush/Grassland	7.1
Grass Hay	5.3
Fallow	3.6
Ponderosa Pine-Grassland	3.0
Alfalfa Hay	2.4

* 169 observations.

Source: Westmorland (1975o) and Dames and Moore 1975.

TABLE 9

SPECIES OF BIRDS OBSERVED OR POTENTIALLY OCCURRING IN THE VICINITY OF THE SARPY CREEK MINE, BIG HORN COUNTY, MONTANA

Scientific Name	Status[z]	Common Name
Order Gaviiformes - Loons		
Family Gavidae - Loons		
Gavia immer	M	Common Loon
Order Podicipediformes - Grebes		
Family Podicipedidae - Grebes		
Podiceps auritus	M	Horned Grebe
Podiceps nigricollis	S	Eared Grebe
Aechmophorus occidentalis	S	Western Grebe
Podilymbus podiceps	S	Pied-billed Grebe
Order Pelecaniformes - Tropicbirds, Boobys, and Cormorants		
Family Pelecanidae - Pelicans		
Pelecanus erythrorhynchos	M	White Pelican
Family Phalacrocoracidae - Cormorants		
Phalacrocorax auritus	S	Double-crested Cormorant
Order Ciconiiformes - Herons, Egrets, Bitterns, Ibises, Spoonbills, and Flamingos		
Family Ardeidae - Herons and Bitterns		
Ardea herodias	R	Great Blue Heron
Nycticorax nycticorax	S	Black-crowned Night Heron
Botaurus lentiginosus	S	American Bittern

[z]Status symbols: M = Migrant; R = Resident; S = Summer Resident; W = Winter Resident.

Order Anseriformes - Swans, Geese, and Ducks		
Family Anatidae - Swans, Geese, and Ducks		
Branta canadensis	S	Canada Goose
Anser albifrons	M	White-fronted Goose
Chen caerulescens	M	Snow Goose
[a]Anas platyrhynchos	S	Mallard
Anas strepera	S	Gadwall
Anas acuta	S	Pintail
[a]Anas crecca	S	Green-winged Teal
[a]Anas discors	S	Blue-winged Teal
Anas cyanoptera	S	Cinnamon Teal
Anas americana	S	American Wigeon
[a]Anas clypeata	S	Shoveler
Aythya americana	S	Redhead
Aythya collaris	M	Ring-necked Duck
Aythya valisineria	S	Canvasback
Aythya marila	M	Greater Scaup
Aythya affinis	S	Lesser Scaup
Bucephala clangula	W	Common Goldeneye
Bucephala albeola	M	Bufflehead
Oxyura jamaicensis	M	Ruddy Duck
Lophodytes cucullatus	S	Hooded Merganser
Mergus merganser	S	Common Merganser
Mergus serrator	S	Red-breasted Merganser
Order Falconiformes - Vultures, Hawks, Kites, Falcons, and Eagles		
Family Cathartidae - American Vultures		
Cathartes aura	S	Turkey Vulture
Family Accipitridae - Kites, Hawks, Eagles, and Harriers		
[b]Accipiter gentilis	W	Goshawk
[b]Accipiter striatus	S	Sharp-shinned Hawk
[b]Accipiter cooperii	S	Cooper's Hawk
[a]Buteo jamaicensis	S	Red-tailed Hawk
[a]Buteo swainsoni	S	Swainson's Hawk

[a]Observed on Project area in 1975.
[b]Highest management priority (Flath, 1975).

Family Accipitridae - Kites, Hawks, Eagles, and Harriers (continued)

[a] Buteo lagopus	W	Rough-legged Hawk
Buteo regalis	R	Ferruginous Hawk
[ab] Aquila chrysaetos	R	Golden Eagle
[b] Haliaeetus leucocephalus	W	Bald Eagle
[ab] Circus cyaneus	S	Marsh Hawk

Family Pandionidae - Ospreys

[b] Pandion haliaetus	S	Osprey

Family Falconidae - Caracaras and Falcons

[ab] Falco mexicanus	S	Prairie Falcon
[b] Falco peregrinus	M	Peregrine Falcon
[b] Falco columbarius	S	Pigeon Hawk
[a] Falco sparverius	S	Sparrow Hawk

Order Galliformes - Grouse, Pheasants, Ptarmigans, Prairie Chickens, Quail, and Turkeys

Family Tetraonidae - Grouse and Ptarmigan

[a] Pedioecetes phasianellus	R	Sharp-tailed Grouse
Centrocercus urophasianus	R	Sage Grouse

Family Phasianidae - Quail, Pheasants, and Partridge

[a] Phasianus colchicus	R	Ring-necked Pheasant
[a] Perdix perdix	R	Gray Partridge

Family Meleagrididae - Turkeys

[a] Meleagris gallopavo	R	Turkey

Order Gruiformes - Cranes, Rails, and Allies

Family Gruidae - Cranes

Grus canadensis	S	Sandhill Crane

Family Rallidae - Rails, Gallinules, and Coots

Porzana carolina	S	Sora
Coturnicops noveboracensis	M	Yellow Rail
[a] Fulica americana	S	American Coot

Order Charadriiformes - Shorebirds, Gulls, and Allies

Family Charadriidae - Plovers, Turnstones, and Surfbirds

Charadrius semipalmatus	M	Semipalmated Plover
[a] Charadrius vociferus	R	Killdeer
[b] Charadrius montanus	S	Mountain Plover
Pluvialis squatarola	M	Black-bellied Plover

Family Scolopacidae - Woodcock, Snipe, and Sandpipers

[a] Capella gallinago	S	Common Snipe
Numenius americanus	S	Long-billed Curlew
[a] Bartramia longicauda	S	Upland Plover
[a] Actitis macularia	S	Spotted Sandpiper
Tringa solitaria	M	Solitary Sandpiper
Tringa melanoleuca	M	Greater Yellowlegs
Tringa flavipes	M	Lesser Yellowlegs
Catoptrophorus semipalmatus	S	Willet
Calidris melanotos	M	Pectoral Sandpiper
Calidris fuscicollis	M	White-rumped Sandpiper
Calidris bairdii	M	Baird's Sandpiper
Calidris minutilla	M	Least Sandpiper
[c] Calidris pusilla	M	Semipalmated Sandpiper
[c] Calidris mauri	M	Western Sandpiper
[c] Calidris alba	M	Sanderling
[a] Limnodromus scolopaceus	M	Long-billed Dowitcher
Micropalama himantopus	M	Stilt Sandpiper
Tryngites subruficollis	M	Buff-breasted Sandpiper
Limosa fedoa	M	Marbled Godwit
Limosa haemastica	M	Hudsonian Godwit

Family Recurvirostridae - Avocets and Stilts

Recurvirostra americana	S	American Avocet

[c] Third highest management priority (Flath, 1975).

Family Phalaropodidae - Phalaropes		
Steganopus tricolor	S	Wilson's Phalarope
Family Laridae - Gulls and Terns		
[b]*Larus argentatus*	M	Herring Gull
Larus californicus	M	California Gull
Larus delawarensis	S	Ring-billed Gull
Larus pipixcan	M	Franklin's Gull
[c]*Larus philadelphia*	M	Bonaparte's Gull
Sterna forsteri	M	Forster's Tern
[c]*Hydroprogne caspia*	M	Caspian Tern
Chlidonias niger	S	Black Tern
Order Columbiformes - Pigeons and Doves		
Family Columbidae - Pigeons and Doves		
[a]*Columba livia*	R	Rock Dove
[a]*Zenaida macroura*	S	Mourning Dove
Order Cuculiformes - Cuckoos, Roadrunners, and Anis		
Family Cuculidae - Cuckoos, Roadrunners, and Anis		
[ad]*Coccyzus americanus*	S	Yellow-billed Cuckoo
Coccyzus erythropthalmus	S	Black-billed Cuckoo
Order Strigiformes - Owls		
Family Strigidae - Typical Owls		
[b]*Otus asio*	R	Screech Owl
[a]*Bubo virginianus*	R	Great Horned Owl
[b]*Speotyto cunicularia*	R	Burrowing Owl
Strix varia	R	Barred Owl
[b]*Asio otus*	R	Long-eared Owl
Asio flammeus	R	Short-eared Owl
[b]*Aegolius acadicus*	R	Saw-whet Owl

[d]Fourth highest management priority (Flath, 1975).
[e]Second highest management priority (Flath, 1975).

Order Caprimulgiformes - Goatsuckers

Family Caprimulgidae - Goatsuckers

Phalaenoptilus nuttallii	S	Poor-will
[a]*Chordeiles minor*	S	Common Nighthawk

Order Apodiformes - Swifts and Hummingbirds

Family Apodidae - Swifts

Aeronautes saxatalis	S	White-throated Swift

Order Coraciiformes - Kingfishers

Family Alcedinidae - Kingfishers

[a]*Megaceryle alcyon*	S	Belted Kingfisher

Order Piciformes - Woodpeckers, Flickers, and Sapsuckers

Family Picidae - Woodpeckers, Flickers, and Sapsuckers

[a]*Colaptes auratus*	S	Common Flicker
[a]*Melanerpes erythrocephalus*	S	Red-headed Woodpecker
Sphyrapicus varius	S	Yellow-bellied Sapsucker
[b]*Sphyrapicus thyroideus*	S	Williamson's Sapsucker
[a]*Dendrocopos villosus*	R	Hairy Woodpecker
Dendrocopos pubescens	R	Downy Woodpecker

Order Passeriformes - Perching Birds

Family Tyrannidae - Tyrant Flycatchers

[a]*Tyrannus tyrannus*	S	Eastern Kingbird
[ab]*Tyrannus verticalis*	S	Western Kingbird
Sayornis phoebe	M	Eastern Phoebe
[a]*Sayornis saya*	S	Say's Phoebe
Empidonax traillii	S	Willow Flycatcher
Empidonax minimus	S	Least Flycatcher
Empidonax difficilis	S	Western Flycatcher
[a]*Contopus sordidulus*	S	Western Wood Pewee
Nuttallornis borealis	S	Olive-sided Flycatcher

Family Alaudidae - Larks		
Eremophila alpestris	R	Horned Lark
Family Hirundinidae - Swallows		
[a]Tachycineta thalassina	S	Violet-green Swallow
[a]Riparia riparia	S	Bank Swallow
[a]Stelgidopteryx ruficollis	S	Rough-winged Swallow
[a]Hirundo rustica	S	Barn Swallow
[a]Petrochelidon pyrrhonota	S	Cliff Swallow
[e]Progne subis	S	Purple Martin
Family Corvidae - Jays, Magpies, and Crows		
Perisoreus canadensis	R	Gray Jay
[a]Pica pica	R	Black-billed Magpie
[a]Corvus brachyrhynchos	R	Common Crow
[a]Gymnorhinus cyanocephalus	R	Pinyon Jay
Nucifraga columbiana	R	Clark's Nutcracker
Family Paridae - Chickadees, Titmice, Verdins, and Bushtits		
[a]Parus atricapillus	R	Black-capped Chickadee
Family Sittidae - Nuthatches		
[a]Sitta carolinensis	R	White-breasted Nuthatch
[a]Sitta canadensis	R	Red-breasted Nuthatch
Family Certhiidae - Creepers		
Certhia familiaris	S	Brown Creeper
Family Troglodytidae - Wrens		
[a]Troglodytes aedon	S	House Wren
Telmatodytes palustris	M	Long-billed Marsh Wren
Salpinctes obsoletus	S	Rock Wren
Family Mimidae - Mockingbirds and Thrashers		
Dumetella carolinensis	S	Catbird
[a]Toxostoma rufum	S	Brown Thrasher
Oreoscoptes montanus	S	Sage Thrasher

Family Turdidae - Thrushes, Solitaires, and Bluebirds

[a]Turdus migratorius	S	American Robin
Hylocichla mustelina	S	Wood Thrush
Catharus ustulatus	S	Swainson's Thrush
Catharus minimus	M	Gray-cheeked Thrush
Catharus fuscescens	S	Veery
[b]Sialia sialis	S	Eastern Bluebird
[a]Sialia currucoides	R	Mountain Bluebird
Myadestes townsendi	R	Townsend's Solitaire

Family Sylviidae - Arctic Warblers, Kinglets, Gnatcatchers

Regulus satrapa	M	Golden-crowned Kinglet
Regulus calenpula	M	Ruby-crowned Kinglet

Family Motacillidae - Wagtails and Pipits

Anthus spinoletta	M	Water Pipit
Anthus spragueii	M	Sprague's Pipit

Family Bombycillidae - Waxwings

Bombycilla garrulus	W	Bohemian Waxwing
Bombycilla cedrorum	S	Cedar Waxwing

Family Laniidae - Shrikes

Lanius excubitor	W	Northern Shrike
[a]Lanius ludovicianus	S	Loggerhead Shrike

Family Sturnidae - Starlings

[a]Sturnus vulgaris	R	Starling

Family Vireonidae - Vireos

[a]Vireo solitarius	S	Solitary Vireo
Vireo olivaceus	S	Red-eyed Vireo
Vireo gilvus	S	Warbling Vireo

Family Parulidae - Wood Warblers

[d]Mniotilta varia	M	Black-and-white Warbler
[b]Vermivora peregrina	M	Tennessee Warbler

Family Parulidae - Wood Warblers (Continued)

Vermivora celata	S	Orange-crowned Warbler
[a]*Dendroica petechia*	S	Yellow Warbler
Dendroica magnolia	M	Magnolia Warbler
[a]*Dendroica coronata*	M	Yellow-rumped Warbler
Dendroica townsendi	M	Townsend's Warbler
Dendroica virens	M	Black-throated Green Warbler
Dendroica pensylvanica	M	Chestnut-sided Warbler
Dendroica striata	M	Blackpoll Warbler
Dendroica palmarum	M	Palm Warbler
Seiurus aurocapillus	S	Ovenbird
Seiurus noveboracensis	M	Northern Waterthrush
Oporornis tolmiei	S	MacGillivray's Warbler
Geothylpis trichas	S	Yellowthroat
Icteria virens	S	Yellow-breasted Chat
[a]*Wilsonia pusilla*	S	Wilson's Warbler
Setophaga ruticilla	S	American Redstart

Family Ploceidae - Weaver Finches

[a]*Passer domesticus*	R	House Sparrow

Family Icteridae - Meadowlarks, Blackbirds, and Orioles

Dolichonyx oryzivorus	S	Bobolink
[a]*Sturnella neglecta*	S	Western Meadowlark
Xanthocephalus xanthocephalus	S	Yellow-headed Blackbird
[a]*Agelaius phoeniceus*	R	Red-winged Blackbird
[b]*Icterus spurius*	S	Orchard Oriole
[a]*Icterus galbula*	S	Northern Oriole
[a]*Euphagus cyanocephalus*	R	Brewer's Blackbird
[a]*Quiscalus quiscula*	S	Common Grackle
[a]*Molothrus ater*	S	Brown-headed Cowbird

Family Thraupidae - Tanagers

Piranga ludoviciana	S	Western Tanager

Family Fringillidae - Grosbeaks, Sparrows, Finches, and Buntings

Passerina amoena	S	Lazuli Bunting
[b]*Spiza americana*	S	Dickcissel
Hesperiphona vespertina	R	Evening Grosbeak

Family Fringillidae - Grosbeaks, Sparrows, Finches, and Buntings (continued)

Carpodacus purpureus	M	Purple Finch
Carpodacus mexicanus	R	House Finch
Pinicola enucleator	R	Pine Grosbeak
Leucosticte tephrocotis	W	Gray-crowned Rosy Finch
Leucosticte atrata	R	Black Rosy Finch
Acanthis flammea	W	Common Redpoll
[a]Spinus pinus	R	Pine Siskin
[a]Spinus tristis	S	American Goldfinch
[a]Loxia curvirostra	R	Red Crossbill
Chlorura chlorura	S	Green-tailed Towhee
[a]Pipilo erythrophthalmus	S	Rufous-sided Towhee
[a]Calamospiza melanocorys	S	Lark Bunting
[a]Passerculus sandwichensis	S	Savannah Sparrow
Ammodramus savannarum	S	Grasshopper Sparrow
Ammodramus bairdii	M	Baird's Sparrow
Ammospiza caudacuta	S	Sharp-tailed Sparrow
[a]Pooecetes gramineus	S	Vesper Sparrow
[a]Chondestes grammacus	S	Lark Sparrow
Junco hyemalis	W	Dark-eyed Junco
Spizella arborea	W	Tree Sparrow
[a]Spizella passerina	S	Chipping Sparrow
Spizella pallida	S	Clay-colored Sparrow
[a]Spizella breweri	S	Brewer's Sparrow
[e]Spizella pusilla	S	Field Sparrow
Zonotrichia querula	M	Harris's Sparrow
Zonotrichia leucophrys	R	White-crowned Sparrow
Zonotrichia albicollis	M	White-throated Sparrow
Passerella iliaca	S	Fox Sparrow
Melospiza lincolnii	S	Lincoln's Sparrow
Melospiza melodia	R	Song Sparrow
Calcarius mccownii	S	McCown's Longspur
Calcarius lapponicus	W	Lapland Longspur
Calcarius pictus	M	Smith's longspur
Calcarius ornatus	S	Chestnut-collared Longspur
Plectrophenax nivalis	M	Snow Bunting

TABLE 9. ADDENDUM

Order Strigiformes-Owls	
Family Strigidae-Typical Owls	
Nyctea scandioca	Snowy Owl
Order Apodiformes-Swifts and Hummingbirds	
Family Trochilidae-Hummingbirds	
Archilochus colubris	Ruby-throated hummingbird
Archilochus alexandri	Black-chinned hummingbird
Selasphorus rufus	Rufous hummingbird
Order Passeriformes-Perching Birds	
Family Cinclidae-Dippers	
Cinclus mexicanus	Dipper (Water Ouzel)

TABLE 10

List of bird families, sub-families, and species that occur or may occur on Westmorland Resources Sarpy Creek lease with notes on habitat and food habits.

Sources: Peterson, 1961
Martin, Tim, and Nelson, 1961

Name: Common Loon, Gavia immer

Habitat: Conniferous lakes

Foods: Fish, mollusks, frogs, insects

Misc.: Feeds on fish species considered undesirable.

Name: Grebes-Family Podicipediformes

Habitat: Lakes, ponds, streams and marshes

Foods: Fish, aquatic insects, mollusks and crustaceans. Also eat their own feathers.

Misc.: As with the loons, undesirable fish species are a major portion of their diet.

Name: White Pelican, Pelecanus erythrorhynches

Habitat: Lakes and marshed

Foods: Fish and some crustaceans

Misc.: More than 90% of fish diet is undesirable species.

Name: Double-crested Cormorant-Phalacrocorax auritus

Habitat: Lakes and rivers

Foods: Fish and crustaceans

Misc.: Beneficial by removing undesirable fish species.

Name: Herons and Bitterns-Family Arderdae

Habitat: Marshes, swamps, streams, ditches, ponds-anywhere that food and water are available.

Foods: Fish, crustaceans, amphibians, mice, shrews, snakes and turtles.

Misc.: Generally beneficial through removal of undesirable species. May cause damage at fish hatcheries.

Name: Geese-Subfamily Anserinae

Habitat: Lakes, rivers, marshes, prairies and grainfields.

Foods: Pondweed (1), saltgrass (1), bullrush (1), wheat (2) brome grass (3), wild barley (3)

Misc.: Sought after by sportsmen and bird-watchers alike. Cause some damage to crops when concentrations are high enough.

Name: Surface-feeding ducks-Subfamily Anatinae

Habitat: Lakes, ponds, rivers, marshes, grainfields, irrigated lands, and prairies
Foods: Pondweed (1), bullrush (1), spikerush (1), muslegrass (1), corn (1), sedge (1), wheat and algae
Misc.: Prized by sportsmen.

Name: Diving ducks-Subfamily Aythyinae

Habitat: Lakes, marshes, and rivers

Foods: Pondweed (1), bullrush, algae, saltgrass, sedge, waterweed, aquatic insects (adult and larvae), crustaceans, mollusk and fish.
Misc: Goldeneye and bufflehead feed mostly on animal life.

Name: Stiff-tailed Ducks-Subfamily Oxyurinae

Habitat: Lakes, marshes, and ponds

Foods: Pondweed, bullrush, sedge, aquatic grasses, aquatic insects, mollusks and crustaceans.
Misc.: The ruddy duck, Oxyura jamaicensis is the only species of this subfamily found in Montana.

Name: Mergansers-Subfamily Merginae

Habitat: Wooded lakes, lakes, ponds, and rivers

Foods: Fish (major diet), crayfish, shrimps, frogs, insects, and mollusks.
Misc.: Fish eating habits cause some damage to game fish population.

Name: American Vultures-Family Cathartidae

Habitat: Usually seen airborne, perched, or feeding on gournd.

Foods: Carrion

Misc.: Turkey vulture, Cathartes aura is only Montana species. Very beneficial.

Name: Bird Hawks-Subfamily Accipitrinae

Habitat: Forests, river gorges and wooded areas.

Foods: Mostly other birds including domestic fowl and game birds, some rodents.
Misc.: All members are of Genus Accipiter. Habit of preying on important birds has given this group a bad reputation.

Name: Buzzard Hawks-Subfamily Buteoninae

Habitat: Open country, woodlands, mountains, deserts.

Foods: Rodents, rabbits, snakes, lizards and small birds. Swainsons feed on insects commonly.

Misc.: Swainsons migrates south in winter. Mostly beneficial habits however, red-tailed may become problem with poultry.

Name: Harriers-Subfamily Circinae

Habitat: Marshes, fields and prairies.

Foods: Rodents, reptiles, amphibians and birds.

Misc.: Marsh hawk is the representive in this subfamily.

Name: Ospreys-Family Pandionidae

Habitat: Rivers and lakes. Nests normally in high open places, sometimes on ground.

Foods: Fish

Misc.: Only hawk that dives into water for fish.

Name: Falcons-Subfamily Falconinae

Habitat: Wide-ranging, nearly cosmopolitan.

Foods: Birds, rodents, insects.

Misc.: Three species discussed in text.

Name: Hungarian or Gray Partridge-Perdix perdix

Habitat: Open farmland, grainfields. Nests in grass-lined hollow in grass or brush.

Foods: Wheat (1), barley (1), brome grass (2), alfalfa (3) clover (3), sunflower (3), and insects.

Misc.: Introduced species. Important game bird.

Name: Sandhill Crane-Grus canadensis

Habitat: Prairies, grainfields, marshes and mountain meadows. Nests in marshes on ground.

Foods: Mostly domestic crops (corn, wheat, oats), and grasses, also insects, small mammals (rodents), amphibians and snails.

Misc.: Hunted in some areas for meat. Relative of the endangered whooping crane.

Name: Rails and Coots-Family Rallidae

Habitat: Ponds, lakes, marshes. Rails build grass cup in marshy areas for nesting. Coots nest in reeds or vegetation rafts on ponds and lakes.
Foods: Pondweed, bullrush, algae, duckweed, saltgrass, insects, crustaceans, small fish and mollusks.
Misc: Coot is second only to the mallard and pintail in population numbers.

Name: Plovers-Family Charadriidae

Habitat: Shorelines, grasslands, plains, mudflats and open marshes. Nests are usually made on open, bare ground.
Foods: Insects, crustaceans, mollusks. Killdeer feed on insects for major portion of their diet.
Misc.: Semiplalmated plover occurs as migrant only.

Name: Snipe, Sandpiper-Family Scolopacidae (partial)

Habitat: Rangeland (curlew, plover), streamside, lake shores, ponds, marshes, wet meadows. Most nest in small ground depressions of natural material (rock, tundra, leaves)
Foods: Insects, crustaceans, mollusks, worms.
Misc.: Includes: long-billed curlew, upland plover, spotted, solitary Bairds', least, western and buff-breasted sandpipers, greater and lesser yellow legs, willet, sanderling.

Name: Snipe, Sandpiper-Family Scolopacidae (partial)

Habitat: Marshes, ditches, streamsides, bogs, meadows, mudflats, prairie pools; nests in shallwo depressions on ground.
Foods: These birds feed on plants more than the above group. Insects, crustaceans, mollusks, worms, clover, sunflower, sedge, cattail, pondweed, bullrush.
Misc: Includes: common snipe, pectoral, white-rumped, semipalmated and stilt sand pipers, long-billed dowitcher, and the marbled and Hudsonian godwits.

Name: American Avocet, <u>Recurvirostra americana</u>
Habitat: Marshes, mudflats, alkaline lakes, ponds. Nest in depression in the ground.
Foods: Mostly animal: Insects, crustaceans, mollusks, worms, pondweed bullrush, algae.
Misc.:

Name: Wilson's Phalarope- <u>Steganopus tricolor</u>

Habitat: Shallow lakes, marshes, pools, shores, mudflats. Nest in grass-lined hollows in meadows.
Foods: Plankton, aquatic insects, water fleas, snails.

Misc.: Distinguished from sandpipers by swimming rapidly in a tight circle while feeding.

Name: Gulls-Subfamily Larinae

Habitat: Lakes, farmlands, cities, piers, refuge dumps, rivers, marshes. Nest in colonies (usually) on ground (isolated areas)
Foods: Garbage, fish, mollusks, bird eggs, insects, algae, pondweed, gooseberry, wheat, oats, duckweed.
Misc.: Beneficial birds through their scavaging and insectiverous food habits.

Name: Terns-Subfamily Sterninae

Habitat: Marshes and lakes. Nests are built near water on ground, nets of aquatic vegetation, muskrat houses.
Foods: Small fish, aquatic insects.

Misc.:

Name: Rock Dove (Domestic Pigeon), Columbia livia

Habitat: Cosmopolitan. Nests in buildings, bridges, cliffs, etc.

Foods: Seeds, grain, fruits, insects.

Misc.:

Name: Cuckoos-Family Cuculidae

Habitat: Areas of thick brush; rivers, forests, willowgroves. Nest in low trees or bushes.
Foods: Insectivorious; caterpillars main food.
Misc.:

Name: Owls-Family Strigidae

Habitat: May be found in most habit types due to their free-roaming nature. Nests found on ground, in trees, tree cavities, cliffs, rodent burrows.
Foods: Variety of animals depending on size of owl (rabbits, mice, frogs, birds, squirrels, crayfish and insects.
Misc: Beneficial to man due to their food habits.

Name: Goatsuckers-Family Caprimulgidae

Habitat: Generally open areas, sparse brush. Eggs laid on bare ground or flat roofs.
Foods: Insectivorous.

Misc.: Nocturnal.

Name: Swifts-Family Apodidae

Habitat: Seen in flight almost anywhere.

Foods: Insectivorous.

Misc.: Chimney and Voux's swift probably are migratory only.

Name: Hummingbirds-Family Trochilidae

Habitat: Flowering plants, gardens, wooded areas, rivergroves, and meadows. Nests are usually a cup-like of soft material in a shrub or tree.

Foods: Flower nectar, insects, fruit juice and tree sap. May be attracted to feeder with colored water and sugar.

Misc: Plants utilized (partial) garden flowers, sage, larkspur, bindweed, phlox, rose, milkweed, gooseberry, current and evening primrose.

Name: Belted Kingfisher-Megaceryle alcyon

Habitat: Near water; rivers, ponds, lakes and marshes. Nest in burrow of river bank or sand bank.

Foods: Fish is main diet but also crayfish, frogs and lizards.

Misc.:

Name: Woodpeckers-Family Picidae

Habitat: May be found in or near any wooded area, in town, around buildings.

Foods: Various insects during summer months. All but hairy and downy migrate during winter and their diet consists of about 50% plant material including poison ivy, sumac, corn, pine.

Name: Tyrant Flycatchers-Family Tyrannidae

Habitat: Prefer mostly open country, farmyards, roadsides, scattered trees except Trails flycatcher, western wood pewee, and Olive-sided flycatcher.

Foods: Mostly insects captured during flight except for king birds and phoebes which consume a small portion of plant foods.

Name: Horned Lark-Eremophila alpestris

Habitat: Open areas such as plains, deserts, fields, airports, golf courses. Nest in grass lined depression in ground.

Foods: Pigweed, goosefoot, ragweed, sedge, corn, wheat, sunflower, saltbush, chickweed, shepherds-purse, gromwell, Russian Thistle and dropseed.

Name: Swallows-Family Hirundinidae

Habitat: Widespread; found in towns, near water, fields, canyons, wooded areas, etc. Barn and Cliff swallow build nests, remainder use holes in banks, trees and crevices.
Foods: Insectivorous, capture food on the wing.
Misc.:

Name: Gray Jay-<u>Perisoreus canadensis</u>

Habitat: Coniferous forests. Nests are feather-lined bowls.

Foods: Omniverous.

Misc.: Also called camp robbers.

Name: Black-billed Magpie-<u>Pica pica</u>

Habitat: Free-ranging, may be found in most areas of N.E. United States. Prefers areas of moderate to dense cover.
Foods: Omniverous, will feed on berries, seeds, carrion, insects, etc.
Misc.: Good scavanger.

Name: Common Crow-<u>Corvus brachyrhynchos</u>

Habitat: Woodlands, farm lands, river groves and shores. Wherever food may be found.
Foods: Omniverous, grasshoppers, scarab beetles, carrion, ground beetles, caterpillars, crustaceans, amphibians, reptiles, corn, whea and sunflower.
Misc: May be destructive to crops and other bird populations.

Name: Pinyon Jay-<u>Gymnorhinus cyanocephala</u>

Habitat: Found in or near pinon pines, junipers or sage. Build nests in colony.
Foods: Insects, pinon and pine seeds, wheat, corn and barley.

Misc.: Large numbers of these birds feed together.

Name: Clark Nutcracker-<u>Nucifraga columbiana</u>

Habitat: Found in mountainous areas.

Foods: Pine seeds are major diet, also insects, wheat, corn, oats and barley.
Misc.:

Name: Black-capped Chickadee-<u>Parus atricapillus</u>

Habitat: Mixed woodlands, willow groves. Nest in cavity of tree or stump.

Foods: Primarily use animal foods. Eggs of insects and spiders, insects, spiders, pine, poison ivy, sunflower and ragweed.

Misc.:

Name: Nuthatches-Family Sittidae

Habitat: Conifer forests, mixed forests, river groves and bushy areas Nest in tree cavity.

Foods: Beetles, weevils, ants, spiders, moths, caterpillars-also pine wheat and oats.

Misc.:

Name: Brown Creeper-<u>Certhia familiaris</u>

Habitat: Forest groves. Nest behind loose bark.

Foods: Insects and spiders found on trees, some pine and corn.

Misc.:

Name: Dipper (water ouzel)-<u>Cinclus mexicanus</u>

Habitat: Near water, usually fast flowing stream. Construct nest of moss along stream bank.

Foods: Mainly aquatic insects, snails, moths, fish eggs and small fish.

Misc.: Able to walk on bottom of fast flowing stream in search of food.

Name: Wrens-Family Troglodytidae

Habitat: House Wren-thickets, open woods, brush; Long-billed-marshes; Rock Wren-rocky areas of plains to high mountains.

Foods: Animal matter such as insects and spiders.

Misc.:

Name: Trashers and Catbirds-Family Mimidae

Habitat: Brushy areas. Nests are a twig bowl placed in brush.

Foods: Insects such as ants, beetles, grasshoppers, caterpillars; also spiders, frogs, lizards, buffaloberry, gooseberry, strawberry and corn.

Name: Robin-Turdus migratorius (F. Turdidae)

Habitat: Open areas anywhere. Likes towns and short grass. Nests mud-grass bowl in trees.

Foods: Caterpillars, beetles, earthworms, currant and wheat.

Misc.: One of our most familiar birds.

Name: Thrushes-Family Turdidae (partial)

Habitat: Prefer areas with heavy vegetation growth (thickets, forests, etc). Nests are usually small cups of leaves, grass and/or twigs.

Foods: Insects, spiders, snails, earthworms, crayfish, pine, gooseberry, sumac, rose and strawberry

Misc.:

Name: Bluebirds-Family Turdidae (partial)

Habitat: Prefer open country with scattered trees. Nests are usually in hollow of tree, cliff, stump or birdbox.

Foods: Insects, spiders, snails, centipedes, poison ivy and sumac.

Misc.:

Name: Kinglets-Family Sylviidae

Habitat: Conifers and other densly wooded areas. Nest of moss in conifers.

Foods: Insects (wasps, flies, beetles, plant lice).

Misc.:

Name: Pipits-Family Motacilladae

Habitat: Plains and short-grass prairies. Nest of grass on ground.

Foods: Insects, spiders, millipedes, crustaceans. Small quantities of grasses are also utilized.

Misc.: Water Pipit is migratory only.

Name: Bohemian Waxwing-Bombycilla garrula

Habitat: Forests and muskeg. Nest of moss and twigs in conifer.

Foods: Fleshy fruits (hawthorn, cherry, apple, strawberry) account for most of diet, also supplemented by insects.

Misc.:

Name: Cedar Waxwing-<u>Bombycilla</u> <u>cedrorum</u>

Habitat: Open woodlands, fruiting trees, orchards. Nest composed of grass and twigs on branch.
Foods: Same as Bohemian Waxwing

Misc.:

Name: Shrikes-Family Laniidae

Habitat: Semi-open to open country with lookout post available. Nests are well lined cups (bulky) on branch.
Foods: Almost entirely animal life. Large insects, other birds, small rodents, reptiles.
Misc.: Includes: Loggerhead and Northern Shrikes. Have a habit of hanging prey on thorns, cactus spines, or barbed wire.

Name: Starlings-Family Sturnidae

Habitat: Open areas; fields, farm yards, ranches, sparse tree groves. Nests in holes of trees, buildings, etc.
Foods: Insects and various fruited plants.

Misc.: Introduced species. Usually considered a nuisance because of its gregarious nature.

Name: Vireos-Family Vireonidae

Habitat: Mixed forests, shade trees, groves. Nests are baskets hung from branch.
Foods: Main diet consists of insects, spiders, snails. Also various berries.
Misc.:

Name: Wood Warblers-Family Parvlidae

Habitat: Most prefer dense conifer forests but some utilize wet areas of streams and marshes. Nests are usually grass or moss cups in low branches or on ground.
Foods: Mainly insectivorous. Consume caterpillars, beetles, wasps, ants, flies, true bugs, plant lice, bees, cankerworms, locusts; also spiders.
Misc.:

Name: House (English) Sparrow-<u>Passer</u> <u>domesticus</u>

Habitat: Cities, towns, farms. Nest of various twigs, grass, and strings woven into bulky mass
Foods: Mostly plants. Corn, oats, wheat, ragweed, elm, sunflower, insects.
Misc.: Introduced species. Sometime damage crops.

Name: Meadowlarks, Blackbirds, Orioles-Family Icteridae (partial-see below)
Habitat: Open fields, hay meadows, prairies, plains. Nests are in grassy bowls on ground.
Foods: 50% animals: insects, spiders, centipedes, ants, sunflower, wheat.
Misc.: Includes: bobolink and western meadowlark.

Name: Family Icteridae (partial)

Habitat: Fresh marshes, tules, swamps-forages in open areas. Nest of woven plant fibers suspended above water in tules.
Foods: 50% plants: insects, snails, crustaceans, spiders, oats, corn, ragweed, wheat, sunflower, dandelion.
Misc.: Includes: yellow-headed and red-winged blackbirds.

Name: Family Icteridae (partial)

Habitat: Orchards, farms, towns, shade trees, open woods, lake-shores, parks. Nests are grass-lined pouches suspended from trees or a cup on ground (Brewers blackbird).
Foods: Mostly animal: insects, spiders, snails, corn, oats, wheat, sunflower, dandelion, berries.
Misc: Includes: Brewer's blackbird, Orchard and Northern (Baltimore) Orioles.
Name: Family Icteridae (partial)

Habitat: Croplands, towns, streamsides, stockyards, farms. Cow-birds lay their eggs in other birds nests. Grackles build nest in trees, reeds, hollows.
Foods: 50/50. Insects, spiders, myriapods, crustaceans, worms, snails, toads, mice, bird eggs, ragweed, oats, wheat, corn, sunflower.
Misc: Includes: common grackle and brown-headed cowbird.
Name: Western Tanager-Piranga ludoviciana

Habitat: Open conifer or mixed forest. Nest in shallow bowl of oak, pine, or fir.
Foods: Insects plus fruits of various trees.

Misc.:

Name: Grosbeaks-Family Fringillidae (partial)

Habitat: Conifer forests. Nests are loose, low cups in conifers.

Foods: Mostly seed and fruits, also insects, spiders.

Misc.: Includes: evening and pine grosbeaks.

Name: Buntings-Family Fringillidae (partial)

Habitat: Sagebrush, brushy slopes, streamsides. Nests are loosly-formed cups in brush.
Foods: Insects, seeds of weeds, grasses.

Misc.: Includes: lazuli bunting.

Name: Dickcissel-Family Fringillidae (partial)

Habitat: Roadsides, field, meadows, other open areas. Nests in low bush.
Foods: 50% animal matter. Insects, bristlegrass, oats, wheat, corn.
Misc.:

Name: Finches-Family Fringillidae (partial)

Habitat: Mountains and woodlands except for house finch which may inhabit towns, ranches, open woods, canyons and deserts.
Foods: Near 100% plant foods-buds, fruit, seeds. Elm, ragweed, aspen, poison ivy, mullein, mustard, pigweed, chickweed, sedge, oats, wheat; aphids, caterpillars and others.
Misc: Includes: purple, house, gray-crowned rosy, black rosy finches, and pine siskin.
Name: Goldfinches-Family Fringillidae (partial)

Habitat: Rivergroves, willows, orchards, roadsides. Nest is a felt cup in a tree.
Foods: Near 100% plant except spring. Aphids, caterpillars, ragweed, thistle, shepards-purse, goosefoot, sunflower, dandelion, golden rod, chickweed, evening primrose, cane flower, pine, elm.
Misc: Includes: American (common) goldfinch.
Name: Crossbills-Family Fringillidae (partial)

Habitat: Conifer forests and groves. Nest is a flat cup in a conifer.
Foods: Near 100% plants except in summer months. Spiders, insects, pine (66%), ragweed, other conifers.
Misc.: Includes: Red Crossbill.

Name: Towhees-Family Fringillidae (partial)

Habitat: Dry mountain brush, chaparral, sage, open pines, city shrubs. Nests are on the ground or low in bush.
Foods: Spiders, insects, pigweed, dandelion, ricegrass, corn, sedge, strawberry, chickweed.
Misc.: Includes: Green-tailed and rufous-sided towhees.

Name: Lark Bunting-Family Fringillidae (partial)

Habitat: Plains and prairies. Nest on ground.

Foods: Mostly animal. Grasshoppers (50% +), beetles and weevils (second), other insects, needlegrass, pigweed, oats, dropseed, gromwell, goosefoot.

Misc.:

Name: Sparrows-Family Fringillidae (partial)

Habitat: Large group; may be present in most habitat types.

Foods: Large variety of invertebrates and plant materials.

Misc.: Includes: Savannah, grasshopper, Baird's, sharp-tailed, vesper, lark, tree, chipping, clay-colored, Brewer's, field, Harris's, white-crowned, white-throated, fox, Lincoln's, and song sparrows.

Name: Juncos-Family Fringillidae (partial)

Habitat: Conifers and mixed forests. Nest on ground.

Foods: Caterpillars, beetles, ants (choice animal foods), other insects, spiders, ragweed, dropseed, pigweed, goosefoot, wheat, sedge.

Misc:

Name: Longspurs-Family Fringillidae (partial)

Habitat: Open areas; plains, prairies, airports, fields. Nest on ground.

Foods: Insects, spiders, sunflower, wheat, goosefoot, grama, needlegrass, ragweed, sedge, dropseed, clover, bullrush, three-own, pigweed.

Misc: Includes: McCown's, lapbird, Smith's, and chestnut-collared longspurs.

Name: Snow Bunting-Family Fringillidae (partial)

Habitat: Prairies, fields, shores. Nest on ground.

Foods: Mostly plants. Fly larvae, true bugs, sand fleas, ragweed, pigweed, goosefoot, sedge, buttercut, dropseed, wheat, fescue, bullrush.

Misc:

Name:

Habitat:

Foods:

Misc.:

TABLE 11

Summary of data collected by researchers on the sharp-tailed grouse of Tract III.

Sharp-tailed grouse observation	272
Population estimate	404
Density	8.1/sq. mile
Leks (dancing grounds)	8 (101 males)

Food habits, Tract III, Fall:

1973-	Prairie rose hips Skunkbush sumac berries	79 percent by volume
	Common dandelion leaves	14 percent by volume
1974*-	Grasshoppers, other animal matter	79 percent by volume
	Prairie rose hips Skunkbush sumac berries Snowberry berries	16.1 percent by volume

*1974 collection was made earlier and may account for insect use.

Habitat type preference. Percentage use of birds observed during January-December, 1975.

1.	Grassland	24
2.	Silver sagebrush-grassland	17
3.	Roadways (with burrow pits)	13.5
4.	Pasture	9.5
5.	Mature wheat or stubble	9.5
6.	Alfalfa hay	8
7.	Big sagebrush-grassland	6
8.	Skunkbush-grassland	4.5
9.	Disturbed grassland	4
10.	Ponderosa pine-grassland	2.5
11.	Creek bottom	.5
12.	Grass hay	.5
13.	Fallow	.5
14.	Tall shelter belt	.5

Source: Westmorland, 1975o, and Dames and Moore, 1975.

TABLE 12

Summary of ring-necked pheasant data from Sarpy Creek, Bighorn and Treasure Counties, Montana.

	Other Areas	Tract III
Pheasants observed:		305
Ring-necked pheasant crowing count route results: (calls/2 minute stop)[2]		
Sarpy Creek route, 1974		9.7
Sarpy Creek route, 1975		9.6
E. Fork Sarpy Creek route, 1974		10.3
E. Fork Sarpy Creek route, 1975		11.5
Sarpy Basin study area, 1975[2]	13.3	
Lower Sarpy Creek, 1975[2]	27.7	
Lower Sarpy Creek, seven prior years[2]	23.4	
Surrounding drainages[2]	4.7	

Habitat preference of ring-necked pheasants observed on Tract III, January-June, 1975.[1]

Percent observations within habitat type		Percent observations including next habitat type	
49	Alfalfa hay	27	Alfalfa hay
17	Grassland	27	Creek bottom
13	Silver sagebrush-grassland	16	Silver sagebrush-grassland
6	Creek bottom	5	Roadways
6	Pasture	5	Residential
4	Roadways	4	Big sagebrush-grassland

1. Westmorland Resources, 1975o.
2. Martin, 1975.

TABLE 13

Summary of data collected on the Merriam's turkey on Sarpy Creek, Bighorn and Treasure Counties, Montana.

	Tract III
Turkeys observations (1-12-75):	173

Habitat preference by percentage of observations on Tract III.

Within each habitat type		Including next nearest habitat type	
Ponderosa pine-grassland	40.0	Ponderosa pine-grassland	43.6
Alfalfa hay	27.8	Silversage-grassland	13.9
Roadways	11.6	Alfalfa hay	13.9
Silversage-grassland	11.0	Creek bottom	6.4
Residential	8.7	Disturbed grassland	6.1
Grasslands	.6	Roadways	5.8
Skunkbush-grassland	.6	Residential	4.3
		Snowberry coulee	3.2
		Mature wheat or stubble	1.4
		Skunkbush-grassland	1.2
		Grassland	.3

TABLE 14

Summary of data of bird species collected from Sarpy Creek, Bighorn County, Montana.

Species potentially occurring	237
Species observed	73
Species that may nest in area	162
Species known to nest in area	13
Resident species	41
Species of special interest	30

From Westmorland Resources, 1975o and Dames and Moore, 1975.

TABLE 15 Sheet 1 of 2

SPECIES OF AMPHIBIANS AND REPTILES OBSERVED
OR POSSIBLY OCCURRING ON THE PROJECT AREA
NEAR SARPY CREEK, BIG HORN COUNTY, MONTANA

Species	Common Name
Order Caudata - Salamanders	
Family Ambystomatidae - Mole Salamander	
Ambystoma tigrinum	Tiger Salamander
Order Salientia - Frogs and Toads	
Family Pelobatidae - Spadefoot Toads	
Scaphiopus bombifrons	Spadefoot Toad
Family Bufonidae - True Toads	
[a]*Bufo woodhousei*	Woodhouse's Toad
Bufo cognatus	Great Plains Toad
Family Ranidae - True Frogs	
[a]*Rana pipiens*	Leopard Frog
Family Hylidae - Tree Frogs	
Pseudacris triseriata	Chorus Frog
Order Testudines - Turtles	
Family Chelydridae - Snapping, Musk, and Mud Turtles	
Chelydra serpentina	Snapping Turtles
Family Testudinidae - Water and Box turtles, Tortoises and Allies	
[a]*Chrysemys picta*	Painted Turtles
Family Trionychidae - Softshell Turtles	
Trionyx spiniferus	Spiny Softshell

TABLE 15 Sheet 2 of 2

Species	Common Name
Order Squamata - Lizards and Snakes	
Family Iguanidae - Iguanids	
Sceloporus graciosus	Sagebrush Lizard
Phrynosoma douglassi	Short-Horned Lizard
Family Colubridae - Colubrids	
Heterodon nasicus	Western Hognose Snake
[a]Coluber constrictor	Racer
Pituophis melanoleucus	Gopher Snake
Lampropeltis triangulum	Milk Snake
Thamnophis sirtalis	Common Garter Snake
Thamnophis elegans	Western Terrestrial Garter Snake
Thamnophis radix	Plains Garter Snake
Family Viperidae - Vipers and Pit Vipers	
[a]Crotalus viridis viridis	Prairie Rattlesnake

[a]Observed on Project Area

TABLE 16

Notes on habitat and food habits of amphibians and reptiles that occur or may oc cur on or near Westmorland Resources Sarpy Creek lease.

Sources: Stebbins, Robert C., 1966
Martin, Tim, and Nelson, 1961

Name: Tiger Salamander-Ambystoma tigrinum

Habitat: Adults terrestrial, larvae aquatic. Adults usually not seen except during breeding season. Range from high mountains to plains.
Foods: Worms, insects, carrion.
Misc.:

Name: Spadefoot Toad (plains)-Scaphiopus bombifrons

Habitat: Areas of low rainfall; plains, hills and river bottoms. Burrows in spil. Uses both temporary and permanent water.
Foods: Tadpoles, sometimes cannibalistic, insects.

Misc.:

Name: True Toads-Family Bufonidae

Habitat: Woodhouse's-wide variety. Great Plains-prairies and deserts.
Foods: Invertebrates.

Misc.: Includes: Woodhouse's and Great Plains toads.

Name: Leopard Frog-Rana pipiens

Habitat: Most widely distributed amphibian in North America.

Foods: Invertebrates.

Misc.:

Name: Chorus Frog-Pseudacris triseriata

Habitat: Quiet pools of lakes and marshes.

Foods: Invertebrates.

Misc.:

Name: Snapping Turtle-Chelydra serpentina

Habitat: Lakes, ponds, marshes, slow rivers and streams. Prefers areas of dense aquatic vegetation.
Foods: Crayfish, snails, insects, fish, frogs, salamanders, reptiles, birds, mammals and aquatic plants.
Misc.:

Name: Painted Turtle-Chrysemys picta

Habitat: Quiet waters of lakes, marshes, rivers, streams. Prefer aquatic vegetation-mud bottoms.

Foods: Aquatic plants, insects, spiders, earthworms, mollusks, crayfish, fish, frogs, tadpoles, carrion.

Misc.:

Name: Spiny Softshell-Trionyx spiniferus

Habitat: Quiet water of rivers, ponds, canals. Likes mud bottoms.

Foods: Earthworms, snails, crayfish, insects, fish, frogs, tadpoles, aquatic plants, carrion.

Misc.:

Name: Sagebrush Lizard-Sceloporus graciosus

Habitat: Sagebrush areas; also forests and river bottoms where open areas and sunlight are available.

Foods: Insects, spiders, mites, scorpions, snails.

Misc.:

Name: Short-Horned Lizard-Phrynosoma douglassi

Habitat: Plains to mountains. Live-bearer.

Foods: Mainly ants.

Misc.:

Name: Western Hognose Snake-Heterodon nacicus

Habitat: Sandy, gravelly prairies, farmlands and flood plains.

Foods: Toads, frogs, salamanders, lizards.

Misc.:

Name: Racer-Coluber constrictor

Habitat: Open areas; meadows, prairies, thin brush, forest glades.

Foods: Lizards, frogs, small mammals, insects.

Misc.:

Name: Gopher Snake-Pituophis melanoleucus

Habitat: Nation wide-most habitat types.

Foods: Rodents, rabbits, birds, eggs, lizards.

Misc.:

Name: Milk Snake-Lampropeltis triangulum

Habitat: Widely distributed in U.S. in most habitat types. Secretive.

Foods: Snakes, lizards, mice, birds, eggs.

Misc.:

Name: Common Garter Snake-Thamnophis radix

Habitat: Most widely distributed U.S. reptile. Found in most habitat tupes but usually near water.

Foods: Fish, toads, frogs, dadpoles, salamanders, birds, small mammals, earthworms, slugs, leeches. Live-bearer.

Misc.:

Name: Western Terrestrial Garter Snake-Thamnophis elegans

Habitat: Grassland, brushland, woodland, forest. May frequent water.

Foods: Fish, toads, frogs, tadpoles, salamanders, birds, small mammals, earthworms, slugs, leeches, lizards, snakes. Live-bearer.

Misc:

Name: Plains Garter Snake-Thamnophis radix

Habitat: Wet prairies and farmland, also pinon-juniper types. Live-bearer.

Foods: Fish, toads, frogs, tadpoles, earthworms, insects, carrion.

Misc.:

Name: Prairie Rattlesnake-Crotalus viridis viridis

Habitat: Many habitat types; avoids deserts. Rock outcrops, talus, rocky stream courses and ledges. Live-bearing.

Foods: Small mammals, birds, lizards, frogs.

Misc.:

TABLE 17

Bottom composition (percentage) of Sarpy Creek, Bighorn and Treasure Counties, Montana.*

Material	All Sampling Stations	In Lease Area
Muck	47.9	52.7
Fiberous Peat	23.1	30.8
Detritus	11.2	12.0
Rock	12.1	4.4
Pulpy Peat	5.8	0.2

*Source: Dames and Moore, 1975.

TABLE 18

Aquatic invertebrates collected on Sarpy Creek, Treasure and Bighorn Counties, Montana.

Family	Common Name	Order
Sphaeridae		Eulamellibranchia
Hirudidae		Arhynchobdellida
Talitridae		Amphipoda
Gerridae	Water Striders	Hemiptera
Corixidae	Water Boatmen	Hemiptera
Dytiscidae	Predaceous Diving Beetles	Coleoptera
Hydrophilidae	Water Scavenger Beetles	Coleoptera
Elmidae	Riffle Beetles	Coleoptera
Haliplidae	Crawling Water Beetles	Coleoptera
Aeshnidae	Darners	Odonata
Livellulidae	Common Skimmers	Odonata
Coenagrionidae	Narrow-winged Danselflies	Odonata
Limnephilidae	Northern Caddisflies	Trichoptera
Hydropsychidae	Net-spinning Caddisflies	Trichoptera
Leptoceridae	Long horned Caddisflies	Trichoptera
Phryganeidae	Large Caddisflies	Trichoptera
Chironomidae	Midges	Diptera
Tabanidae	Horse and Deer Flies	Diptera
Ceratopogonidae	Biting Midges	Diptera
Simuliidae	Black Flies	Diptera
Tipulidae	Crane Flies	Diptera
Sciomyzidae	Marsh Flies	Diptera
Stratiomyidae	Soldier Flies	Diptera
Caenidae	Mayflies	Ephemeroptera
Baetidae	Mayflies	Ephemeroptera
Polymitarcidae	Mayflies	Ephemeroptera

Sources: Borror and White, 1970.
Dames and Moore, 1975.

TABLE 19

Common Name	Species	Family
Goldeye	Hiodon alosoides	Hiodontidae
Carp	Cyprinus carpio	Cyprinidae
Golden Shiner	Notemigonus crysoleucas	Cyprinidae
Flathead Chub	Hybopsis gracilis	Cyprinidae
Lake Chub	Covesius plumbeus	Cyprinidae
Emerald Shiner	Notropis atherinoides	Cyprinidae
Plains Minnow	Hybognathus placitus	Cyprinidae
Fathead Minnow	Pimephales promelas	Cyprinidae
Longnose Dace	Rhinichthys cataractae	Cyprinidae
River Carpsucker	Carpoides carpio	Catostomidae
Shorthead Redhorse	Moxostoma macrolepidotum	Catostomidae
Longnose Sucker	Catostomus catostomus	Catostomidae
White Sucker	Catostomus commersoni	Catostomidae
Mountain Sucker	Catostomus platyrhynchus	Catostomidae
Black Bullhead	Ictalvras melas	Ictalvridae
Green Sunfish	Lepomis cyanellus	Centrarchidae
Sauger	Stizostedion canadense	Percidae

Source: Dames and Moore, 1975.
Brown, 1971.

TABLE 20

List of the species of fish that occur in Sarpy Creek with notes on habitat and food requirements.

References: Dames and Moore, 1975.
Brown, 1971.

Name: Goldeye-Hiodon alosoides

Habitat: Montana native. Generally found in large turbid rivers, lakes, and marshes.
Foods: Mostly insects, also crustaceans, mollusks, small fish. Whatever is available at the time.
Misc.: Goldeye are consumed both fresh and smoked; have good fighting qualities; are not considered a game fish. Some commercial fishing in state.

Name: Carp-Cyprinus carpio

Habitat: Introduced species. Prefer warmer, shallow water of lakes and streams. Withstand turbid and polluted waters.
Foods: Omnivorous. Feed on large variety of plants and aquatic animals as the opportunity arises.
Misc.: Non-game fish. Some commercial value. Good fighter on light fishing tackle. Generally disliked.

Name: Golden Shiner-Notemigonus crysoleucas

Habitat: Montana native (eastern); introduced as forage fish in other areas. Prefers clear quiet waters of rivers and ponds, likes heavy weed growth.
Foods: Crustaceans, snails, zooplankton, aquatic insects, terrestrial insects, mollusks, felamentous algae.
Misc: Important as a forage and bait fish over much of its range.

Name: Flathead Chub-Hybopsis gracilis

Habitat: Montana native. Turbid, quiet waters of streams and rivers.

Foods: Predaceous, opportunistic feeders. Most aquatic insects and occasional terrestrial forms that occur in their vicinity.
Misc.: Probably are important forage fish for predaceous game fishes. Little value to man except as bait fish.

Name: Lake Chub-Covesius plumbeus

Habitat: Montana native. Rare in large streams; prefers small streams; sometimes found in lakes.
Foods: Terrestrial and aquatic insects, zooplankton, algae, other fish.
Misc.: Probably an important food source for predaceous game fishes.

Name: Emerald Shiner-Notropis atherinoides

Habitat: Montana native. Prefers open water of lakes and rivers, avoids vegetation.
Foods: Zooplankton, terrestrial and aquatic insects, microcrustaceans, algae, diatoms.
Misc.: Importand as a food source for predatory species.

Name: Plains Minnow-Hybognathus placitus

Habitat: Montana native. Large, quiet rivers, weedy areas.

Foods: Feeds on bottom ooze. Algae, minute animals.

Misc.: Food source for predatory species.

Name: Fathead Minnow-Pimephales promelas

Habitat: Montana native. Hardy fish, can survive in numerous habitats. Lakes, streams, swamps.

Foods: Algae, debritus, insect larvae, zooplankton.

Misc.: Good forage fish.

Name: Longnose Dace-Rhinichthys cataractae

Habitat: Montana native. Wide distribution. Swift, cold streams to warm muddy lakes and ponds.

Foods: Bottom feeder. Aquatic insect larvae, fish eggs, algae.

Misc.: Important forage fish.

Name: River Carpsucker-Carpoides carpio

Habitat: Montana native. Warmer lakes, streams and rivers, brackish waters.

Foods: Algae, diatoms, desmids, crustaceans, mollusks, rotifers, aquatic insect larvae.

Misc.:

Name: Shorthead Redhorse-Moxostoma macrolepidotum

Habitat: Montana native. Streams and rivers, swift, shallow water, clean rocky bottom.

Foods: Aquatic insects, crustaceans, diatoms, worms, mollusks.

Misc.: Fair food fish.

Name: Longnose Sucker-Catostomus catostomus

Habitat: Montana native. Prefers clear lakes, streams and rivers but found in warmer, more turbid waters.

Foods: Aquatic invertebrates and plants.

Misc.: Provide forage for predatory species. Flesh sometimes eaten by man.

Name: White Sucker-Catostomus commerson

Habitat: Wide-spread in all habitat types except very cold, very fast water.

Foods: Aquatic invertebrates and plants.

Misc.: Provide forage for predatory species. Flesh sometimes eaten by man.

Name: Mountain Sucker-Catostomus platyrhynchus

Habitat: Streams and rivers. Seldom in lakes.

Foods: Diatoms, other algae, higher plants, dysterous larvae.

Misc.: May be important as a forage fish.

Name: Black Bullhead-Ictalurus melas

Habitat: Probably introduced species. Shallow ponds, lakes and backwaters of streams. Tolerant of poor quality water.

Foods: Omnivorous. Aquatic insects, fish, crayfish, worms, snails, aquatic plants, carrion.

Misc.: Considered good sport fish and food fish in some areas.

Name: Green Sunfish-Lepomis cyanellus

Habitat: Probably introduced species. Inhabits wide variety of habitats. Likes backwater of streams.

Foods: Insects, mollusks, crustaceans, small fish.

Misc.: Not a good sportfish except for young anglers. Provides forage for predators.

Name: Sauger-Stizostedion canadense

Habitat: Montana native. Prefer large lakes and rivers that are turbid.

Foods: Small fish (any species), crayfish, aquatic insects.

Misc.: Prized game fish.

Name:

Habitat:

Foods:

Misc.:

APPENDIX F

Data on Socio-Economics

TABLES

Page

TABLE 1

POPULATION AND EMPLOYMENT ANALYSIS:
CONVERGING LABOR FORCE PARTICIPATION RATE

Baseline - No Crow Coal Development

	Population			Labor Force			Employment			Unemployment Rate		Population Change: Anglo				Population Change: Crow			Impact Area
Year	Anglo	Crow	Total	Anglo	Crow	Total	Anglo	Crow	Total	Anglo	Crow	Births	Deaths	Migration	Total Change	Births	Deaths	Total Change	Total Change
1971	5666	3514	9180	2431	795	3226	2316	755	3071	4.7	5.0	94	51	0	43	141	34	107	150
1972	5709	3626	9335	2457	851	3308	2250	809	3059	8.4	5.0	96	52	0	44	147	35	112	155
1973	5442	3743	9186	2351	906	3257	2148	861	3009	8.6	5.0	98	53	-312	-267	154	36	117	-150
1974	5144	3868	9012	2220	964	3184	2014	912	2927	9.3	5.4	92	52	-338	-298	162	38	124	-174
1975	5178	4002	9181	2253	1030	3283	2034	919	2953	9.7	10.7	86	52	0	34	174	39	135	169
1976	5215	4142	9357	2284	1099	3383	2054	927	2981	10.1	15.6	90	53	0	37	181	41	140	176
1977	5255	4287	9542	2327	1172	3499	2081	953	3035	10.6	18.6	94	54	0	40	188	42	145	185
1978	5299	4438	9737	2361	1246	3607	2122	965	3086	10.1	22.6	99	55	0	44	194	43	151	195
1979	5347	4599	9945	2391	1327	3718	2150	974	3124	10.1	26.6	103	56	0	48	205	45	161	209
1980	5398	4762	10160	2424	1408	3832	2180	984	3163	10.1	30.1	108	56	0	51	209	46	163	214
1981	5452	4934	10385	2459	1488	3947	2204	975	3180	10.3	34.5	112	58	0	54	219	47	172	226
1982	5509	5112	10621	2491	1566	4057	2236	986	3222	10.3	37.0	115	58	0	57	226	48	178	235
1983	5566	5292	10859	2511	1642	4153	2268	996	3264	9.7	39.3	118	60	0	58	230	49	180	238
1984	5626	5475	11101	2529	1721	4250	2297	1007	3304	9.2	41.5	120	61	0	59	233	50	183	242
1985	5684	5659	11343	2552	1794	4346	2327	1017	3344	8.8	43.3	120	61	0	58	235	52	184	242
1986	5741	5845	11586	2578	1874	4452	2357	1028	3385	8.6	45.2	120	63	0	58	238	53	186	243
1987	5798	6038	11835	2597	1965	4563	2387	1038	3425	8.1	47.2	120	63	0	56	247	54	193	249
1988	5853	6232	12084	2619	2060	4679	2418	1049	3467	7.7	49.1	119	64	0	55	250	55	194	249
1989	5906	6426	12332	2640	2173	4813	2448	1060	3508	7.3	51.2	118	64	0	53	251	57	194	247
1990	6140	6622	12763	2741	2244	4986	2504	1078	3582	8.7	52.0	116	65	184	234	255	58	197	431
1991	6193	6821	13014	2762	2324	5086	2534	1089	3623	8.2	53.1	119	66	0	52	258	59	198	251
1992	6244	7027	13271	2790	2411	5201	2565	1100	3665	8.1	54.4	117	66	0	51	267	61	206	257
1993	6292	7246	13538	2814	2506	5320	2598	1112	3710	7.7	55.6	115	67	0	49	281	63	219	267
1994	6510	7476	13986	2914	2603	5517	2656	1131	3787	8.8	56.5	113	67	171	218	295	65	230	448
1995	6557	7719	14277	2951	2703	5654	2692	1144	3836	8.7	57.7	116	68	0	48	310	66	243	291
1996	6604	7976	14580	2986	2809	5794	2730	1157	3886	8.6	58.8	115	68	0	47	325	69	256	303
1997	6651	8242	14893	3029	2921	5951	2769	1170	3939	8.6	59.9	115	68	0	46	338	71	266	313
1998	6697	8522	15219	3065	3034	6099	2810	1184	3995	8.3	61.0	115	68	0	46	353	74	280	326
1999	6744	8814	15558	3110	3153	6263	2853	1199	4053	8.2	62.0	116	69	0	47	369	76	293	340
2000	6782	9120	15912	3147	3271	6418	2897	1215	4112	7.9	62.9	117	69	0	48	384	78	305	353

Source: Mountain West Research, Inc., January, 1976.

TABLE 2

POPULATION AND EMPLOYMENT ANALYSIS: CONVERGING LABOR FORCE PARTICIPATION RATE WITH WESTMORELANDS 20 YEAR MINING PLAN

	Population			Labor Force			Employment			Unemployment Rate		Population Change: Anglo				Population Change: Crow			Impact Area	Change from Baseline				
Year	Anglo	Crow	Total	Anglo	Crow	Total	Anglo	Crow	Total	Anglo	Crow	Births	Deaths	Migration	Total Change	Births	Deaths	Total Change	Total Change	Δ Basic Emp	Δ Total Emp	Δ Pop	ΔTE/ΔBE	ΔPOP/ΔBE
1971	5666	3514	9180	2431	795	3226	2316	755	3071	4.7	5.0	94	51	0	43	141	34	107	150	0	0	0	--	--
1972	5709	3626	9335	2457	851	3308	2250	809	3059	8.4	5.0	96	52	0	44	147	35	112	155	0	0	0	--	--
1973	6423	3743	10167	2815	906	3721	2661	861	3521	5.5	5.0	98	53	669	714	154	36	117	831	337	512	981	1.52	2.91
1974	6300	3868	10168	2771	964	3735	2504	916	3420	9.6	5.0	109	56	-176	-123	162	38	124	1	286	493	1156	1.72	4.04
1975	5410	4002	9413	2372	1030	3402	2126	978	3104	10.4	5.0	108	56	-942	-890	174	39	135	-755	110	151	232	1.37	2.11
1976	5444	4142	9586	2405	1099	3504	2128	1044	3171	11.5	5.0	87	54	0	34	181	41	140	173	150	190	229	1.27	1.53
1977	5480	4287	9767	2444	1172	3616	2162	1113	3275	11.6	5.0	92	55	0	36	188	42	145	181	200	240	225	1.20	1.13
1978	5521	4438	9959	2484	1246	3729	2217	1169	3386	10.7	6.1	97	56	0	41	194	43	151	191	260	300	222	1.15	.85
1979	5565	4599	10164	2519	1327	3846	2226	1122	3348	11.6	15.4	101	57	0	45	205	45	161	205	185	224	219	1.21	1.18
1980	5614	4762	10376	2555	1408	3963	2261	1151	3412	11.5	18.3	106	58	0	49	209	46	163	212	210	249	216	1.19	1.03
1981	5666	4934	10600	2593	1488	4081	2286	1142	3428	11.9	23.3	111	59	0	52	219	47	172	224	210	248	215	1.18	1.02
1982	5722	5112	10834	2630	1566	4195	2317	1153	3470	11.9	26.4	116	60	0	56	226	48	178	234	210	248	213	1.18	1.01
1983	5779	5292	11072	2654	1642	4296	2349	1163	3512	11.5	29.1	119	61	0	58	230	49	180	238	210	248	213	1.18	1.01
1984	5840	5475	11315	2676	1721	4396	2378	1174	3552	11.1	31.8	122	62	0	60	233	50	183	243	210	248	214	1.18	1.02
1985	5899	5659	11558	2702	1794	4496	2408	1184	3593	10.9	34.0	123	63	0	60	235	52	184	243	210	249	215	1.19	1.02
1986	5959	5845	11804	2731	1874	4605	2439	1195	3633	10.7	36.3	125	65	0	60	238	53	186	246	210	248	218	1.18	1.04
1987	6018	6038	12056	2754	1965	4719	2469	1206	3675	10.3	38.7	125	66	0	59	247	54	193	252	210	250	221	1.19	1.05
1988	6077	6232	12308	2777	2060	4837	2500	1216	3717	10.0	40.9	125	67	0	58	250	55	194	252	210	250	224	1.19	1.07
1989	6134	6426	12560	2799	2173	4972	2532	1227	3759	9.6	43.5	124	67	0	57	251	57	194	251	210	251	228	1.20	1.09
1990	6189	6622	12811	2807	2244	5051	2563	1238	3801	8.7	44.8	122	68	0	55	255	58	197	251	210	219	48	1.04	.23
1991	6241	6821	13062	2822	2324	5146	2593	1249	3842	8.1	46.3	121	68	0	53	258	59	198	251	210	219	48	1.04	.23
1992	6292	7027	13319	2844	2411	5254	2624	1260	3884	7.7	47.7	119	68	0	51	267	61	206	257	210	219	48	1.04	.23
1993	6514	7246	13760	2941	2506	5447	2681	1279	3960	8.9	49.0	117	69	174	222	281	63	219	441	210	250	222	1.19	1.06
1994	6563	7476	14039	2958	2603	5561	2716	1291	4007	8.2	50.4	119	70	0	49	295	65	230	279	210	220	53	1.05	.25
1995	6609	7719	14328	2987	2703	5690	2752	1304	4055	7.9	51.8	117	71	0	46	310	66	243	289	210	219	51	1.04	.24
1996	6654	7976	14629	3015	2809	5823	2789	1316	4105	7.5	53.1	115	71	0	45	325	69	256	301	210	219	49	1.04	.23
1997	6697	8242	14939	3053	2921	5975	2828	1330	4158	7.4	54.5	114	71	0	43	338	71	266	310	210	219	46	1.04	.22
1998	6936	8522	15457	3174	3034	6208	2895	1353	4247	8.8	55.4	114	71	196	239	353	74	280	518	210	252	238	1.20	1.13
1999	6982	8814	15796	3216	3153	6369	2938	1367	4305	8.7	56.6	118	72	0	46	369	76	293	339	210	252	238	1.20	1.13
2000	7029	9120	16148	3249	3271	6520	2982	1383	4364	8.2	57.7	119	72	0	47	384	78	305	352	210	252	236	1.20	1.12

Source: Mountain West Research, Inc., January, 1976.

TABLE 3

Non-Agricultural Wage Income Impacts
Big Horn County Impact
Westmoreland 20 Year Mining Plan
Annual Income Levels

	With No Crow Coal Development		With Westmoreland		Change Relative to Baseline	
	Crow Income	Total Income	Crow Income	Total Income	Crow Income	Total Incor
1971	4827.1	16148.5	4827.1	16148.5	0	0
72	5193.4	16131.0	5193.4	16131.0	0	0
73	5507.6	15865.0	7059.6	21969.5	1552.0	6104.5
74	5857.4	15446.2	7341.3	20966.2	1483.9	5520.0
75	5920.8	15634.7	6998.1	17535.4	1077.3	1900.7
76	5987.2	15847.5	7698.1	18315.9	1710.9	2468.4
77	6338.6	16426.8	8631.4	19627.9	2292.8	3201.1
78	6419.3	16719.3	9402.3	20822.4	2983.0	4103.0
79	6501.3	16981.3	8624.7	19951.8	2123.4	2970.5
1980	6553.6	17205.8	8968.5	20546.3	2414.9	3337.5
81	6350.9	17125.4	8778.1	20444.8	2427.2	3319.4
82	6438.8	17357.4	8862.4	20712.0	2423.6	3354.6
83	6531.7	17637.9	8952.1	21005.2	2420.4	3367.3
84	6621.4	17929.1	9032.7	21263.0	2411.3	3333.9
85	6702.0	18179.3	9113.0	21521.3	2411.0	3342.0
86	6782.3	18437.6	9205.1	21797.9	2422.8	3360.3
87	6874.4	18724.5	9298.0	22079.1	2423.6	3354.6
88	6967.3	19003.0	9387.9	22358.7	2420.6	3355.7
89	7048.6	19253.9	9476.9	22645.4	2428.3	3391.5
1990	7189.9	19732.1	9565.1	22908.7	2375.2	3176.6
91	7278.1	19998.6	9634.4	23168.4	2356.3	3169.8
92	7367.1	20269.3	9722.8	23442.6	2355.7	3173.3
93	7464.8	20590.5	9880.6	23930.4	2415.8	3339.9
94	7628.6	21063.9	9981.3	24241.8	2352.7	3177.9
95	7722.3	21392.5	10075.0	24555.0	2352.7	3162.5
96	7825.4	21705.7	10178.1	24875.8	2352.7	3170.1
97	7935.5	22066.2	10288.2	25208.4	2352.7	3142.2
98	8064.2	22431.3	10469.2	25790.1	2405.0	3358.8
99	8171.3	22779.6	10591.9	26171.0	2420.6	3391.4
2000	8291.6	23178.4	10726.9	26563.6	2435.3	3385.2

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DATE LOANED	BORROWER