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BUREAU OF LAND MANAGEMENT

EMRIA REPORT No. 16

RECLAIMABILITY ANALYSIS OF THE EMERY COAL FIELD, EMERY COUNTY UTAH

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16. Abstract (Limit: 200 words)

As a multidisciplinary integration of field and archival data, to evaluate coal strip mining reclaimability in the Emery, Utah coal field, the initial effort consisted of collecting baseline data. These data covered the geology, overburden, hydrology, climate and vegetation of the area. Six new bore holes were drilled for overburden, ground water hydrology tests, and to obtain coal samples for analysis. Visual, cultural, and recreational resources appear modest when contrasted with the surrounding region. The land use potential is dominantly limited to range land which appears to be reclaimable after mining by the methods described. Site specific problems are a lack of available topsoil, coupled with a potential excess of boron, and general nutrient deficiency (Nitrogen, Potassium, Phosphorous) in the overburden. The top 40 to 60 feet of deeply weathered and leached overburden can generally be used with supplemental fertilization as a topsoil amendment. Rainfall is marginal for revegetation purposes. Use of fly ash (or bottom ash) from nearby power plants as both a geochemical soil supplement and mulch seems desirable. No significant groundwater connections with aquifers now in use is seen. A potential geochemical problem may arise by exposing the overburden to more rapid leaching. Sedimentation problems, as evaluated by a variety of techniques, do not appear significant.

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ENGLISH-METRIC CONVERSION FACTORS

To convert English unit	Multiply by	To obtain Metric unit
Inches (in)	2.54	Centimeters (cm).
Feet (ft)	3.048×10^{1}	Centimeters (cm).
	3.048×10^{-1}	Meters (m).
Miles (mi)	1.609	Kilometers (km).
Square feet (ft^2)	9.290×10^{-2}	Square meters (m^2).
Acres	4.047×10^{-1}	Hectares (ha).
	4.047×10^{-3}	Square kilometers (km^2).
Acre-feet (acre-ft)	1.233×10^{3}	Cubic meters (m^3).
	1.233×10^{-3}	Cubic hectometers (hm^3).
Cubic yards (yd^3)	7.646×10^{-1}	Cubic meters (m^3).
Pounds (lb)	4.536×10^{-1}	Kilograms (kg).
Short tons (tons)	9.072×10^{-1}	Metric tons (t).
Pounds per acre (lb/acre)	4.883	Kilograms per hectare (kg/ha).
Btu/lb	2.326	Kilojoules per kilogram (kJ/kg)
Gallons (gal)	3.785×10^{-3}	Cubic meters (m^3).
Gallons per minute (gal/min)	6.309×10^{-2}	Liters per second (L/s).
Degrees Fahrenheit (°F)	([1])	Degrees Celsius (°C).

[1] Temperature in °C = (temperature in °F − 32)/1.8.

Energy Minerals Rehabilitation Inventory and Analysis

EMRIA Report No. 16

Reclaimability Analysis of the Emery Coal Field Emery County, Utah

Prepared For

Bureau of Land Management

By

Geoscientific Systems
and Consulting

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ABSTRACT

This EMRIA study is a multidisciplinary integration of field and archival data, to meet the information needs of evaluating coal strip mining reclaimability in the Emery, Utah coal field. The initial effort consisted of collecting baseline data, on the geology, overburden, hydrology, climate and vegetation of the area. This effort was two-fold. First to compile a baseline set of data for the study area and its environ, and second to assess the site and region reclaimability with respect to a model mining plan. As part of the contracted effort, 6 new bore holes were drilled to evaluate overburden, serve as observation holes for ground water hydrology tests and to obtain coal samples for analysis. From the completed baseline study, the visual, cultural, and recreational resources of the Emery coal field are modest when contrasted with the surrounding region. The land use potential appears limited to range land and on a portion of the lands to the NW and North of the study site, limited agriculture. Evidently these values are reclaimable. Site specific problems identified in the study are a lack of available topsoil within the study area coupled with a potential excess of boron, and general nutrient deficiency (Nitrogen, Potassium, Phosphorous) in the overburden. This creates a need for special care in choice of overburden for amendment to insure revegetation success. The top 40 to 60 feet, deeply weathered and leached overburden can generally be used with supplemental fertilization as a topsoil amendment. Rainfall is marginal for revegetation purposes but may suffice if a 3 to 5 year window is chosen. However, sufficient surface water exists for modest irrigation of reclaimed lands, provided suitable arrangements are made. Use of fly ash (or bottom ash) from nearby power plants as both a geochemical soil supplement and mulch seems desirable. No significant groundwater connections with aquifers now in use is seen, but in view of the potential geochemical problem created by exposing the overburden to more rapid leaching, special concern to avoid deeper aquifer and runoff contamination is implied. Sedimentation problems, as evaluated by a variety of techniques, appear not to be a significant problem.

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INTRODUCTION

This EMRIA study is a multidisciplinary integration of field and archival data, to meet the information needs of evaluating coal strip mining reclaimability in the Emery, Utah coal field. The initial effort consisted of collecting baseline data on the geology, overburden, hydrology, climate and vegetation of the area. In this, objective support was drawn from a series of companion studies set up by the BLM but conducted by other groups. These may be briefly enumerated as follows:

1) Geologic and stratigraphic studies by Dr. Thomas Ryer of the USGS, Denver.
2) Coal analyses by Dr. Joseph Hatch of the USGS, Denver.
3) Hydrologic, and water quality studies by Greg Lines of the USGS, Salt Lake.
4) Field revegetation experiments on the site with native species by Dr. Neil Frischknecht and Robert Ferguson of the Forest Services Shrub Sciences Lab, Provo.
5) Greenhouse and geochemical tests on ground core (overburden) performed by Dr. Robert Heil of Colorado State University, Ft. Collins.

Unfortunately, with the exception of Ryer's work, these studies could give only late or incomplete results at this writing. We have made the effort to incorporate the best currently available data from each of these studies by interviewing the investigators, but would advise the reader to seek out the publications which should result from these studies as they become available, and carefully compare their results to those presented here. These later studies may alter some of the conclusions listed here. If so, this report should be amended at that time to reflect those changes.

As part of the contracted effort, 6 new bore holes were drilled to evaluate overburden, serve as observation holes for groundwater hydrology tests and to obtain coal samples for analysis. Due to problems encountered in the drilling, the number of holes was expanded to nine, (holes 2A, 3A, 4A) and the original program considerably lengthened. As a result, the overburden and greenhouse analyses were largely based on data from bore holes 3 through 6, with only supplemental investigations conducted on the latter bore holes.

New color and color IR vertical and oblique aerial photography was taken to record the vegetative cover, and control ground vegetation transect lines. These images were also used to evaluate soils, geology and small drainage features. Some question was raised from these studies as to the accuracy of the recently completed SCS 3rd order soil survey of the site. As a result it was decided to resurvey a portion of the site which included the revegetation test plots. This was contracted to Dr. Rudolph Ulrich. Significant changes in mapped soil units were noted in this area, although the companion revegetation experiment was evidently unable to use this more accurate mapping in their data reduction. Dr. Archie Smith of Utah was provided with coal core for evolved gas and coal analyses. His coal analyses are included, the evolved gas analyses are unavailable at this writing.

The balance of the effort was completed by GSC and consultant staff. This effort was two-fold. First to compile a baseline set of data for the study area and its environ, and second to assess the site and region reclaimability with respect to a model mining plan. Review, guidance, and assistance in planning and implementation was received from; Dick Jewell, Hydrologist and BLM COAR, at Price, Utah, Benton Tibbetts, Geologist, EMRIA Staff, and David Lyons, Contracting Officer for BLM, Denver. Figure 1 presents the location of the study area with respect to major cultural, topographic and drainage features. Figure 2 portrays the test site related to regional land ownership and management patterns. Figure 3 shows the study area's relationship to prior EMARS and other coal leases or nominations. Finally Figure 4 shows the existing pattern of land use for the area. The historical development of the area is summarized in the Historical/Cultural Resources section. Although early agrarian settlements opened up the area, coal and now coal fired power plants are the mainstay of the economy.

Summary of the Situation on the Emery Study Site

From the completed baseline study, the visual, cultural, and recreational resources of the Emery coal field are modest when contrasted with the surrounding region. The land use potential appears limited to range land and on a portion of the lands to the NW and North of the study site, limited agriculture. Evidently these values are reclaimable. The local economy would benefit from a coal mining development in the Emery field. The coal resource, which could be recovered by strip mining, has been estimated as 140 million tons, of good quality.

The study area upon which detailed investigations were conducted is reasonably typical of the Emery coal field at large and hence problems and approaches identified may be more generally applied.

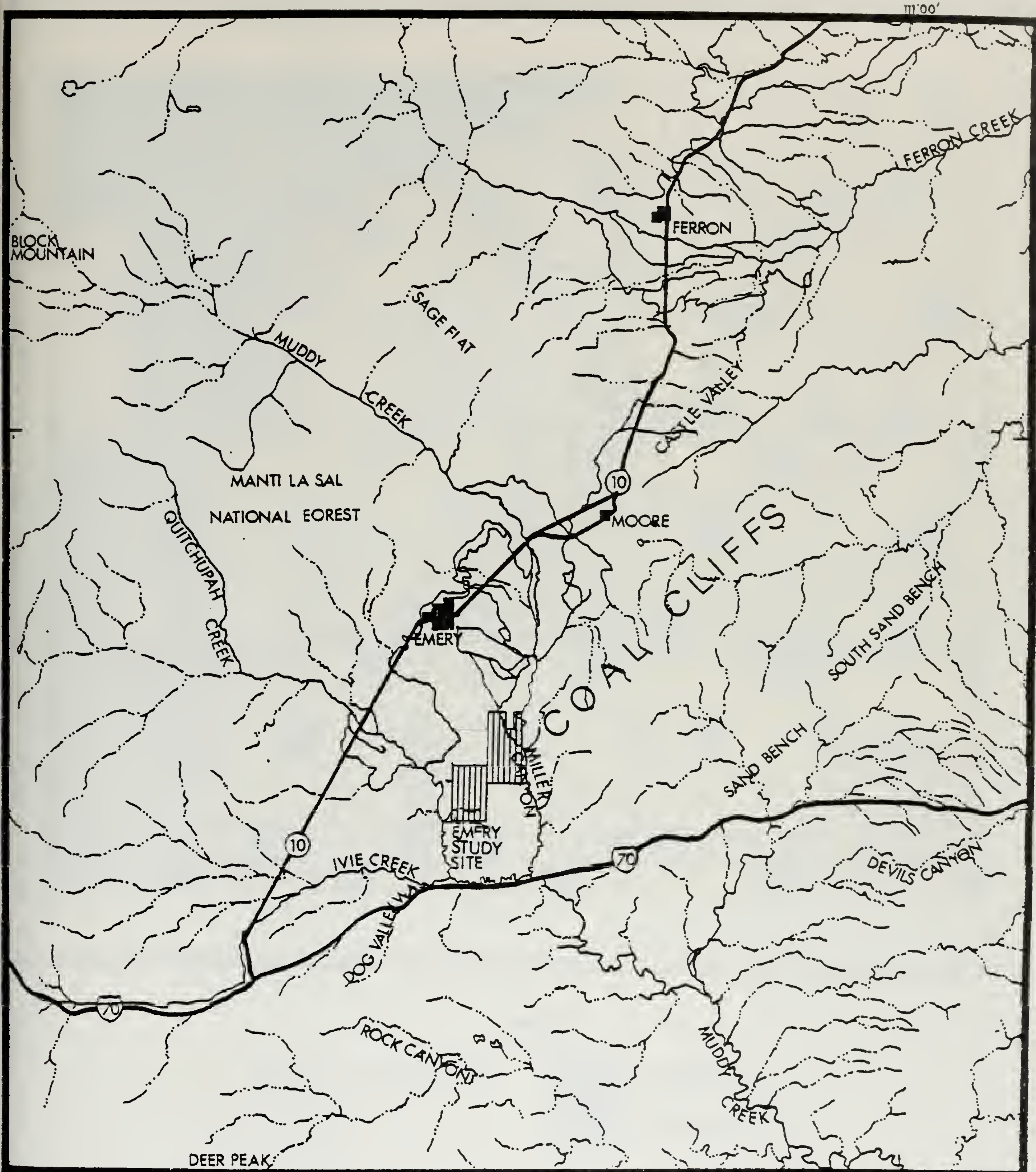

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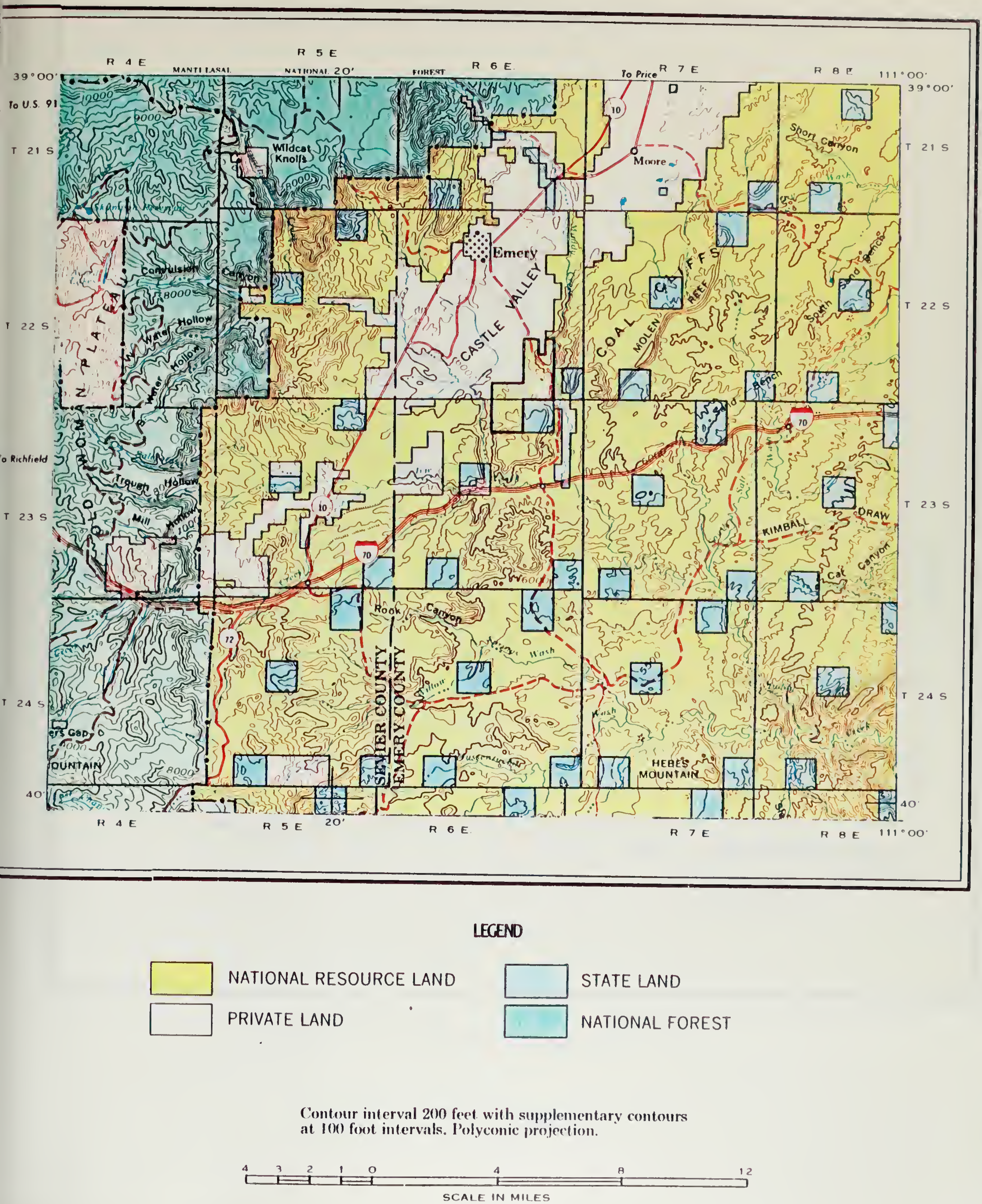
Figure 1. Study Area Location Map

Figure 2.

LAND OWNERSHIP AND PUBLIC MANAGEMENT



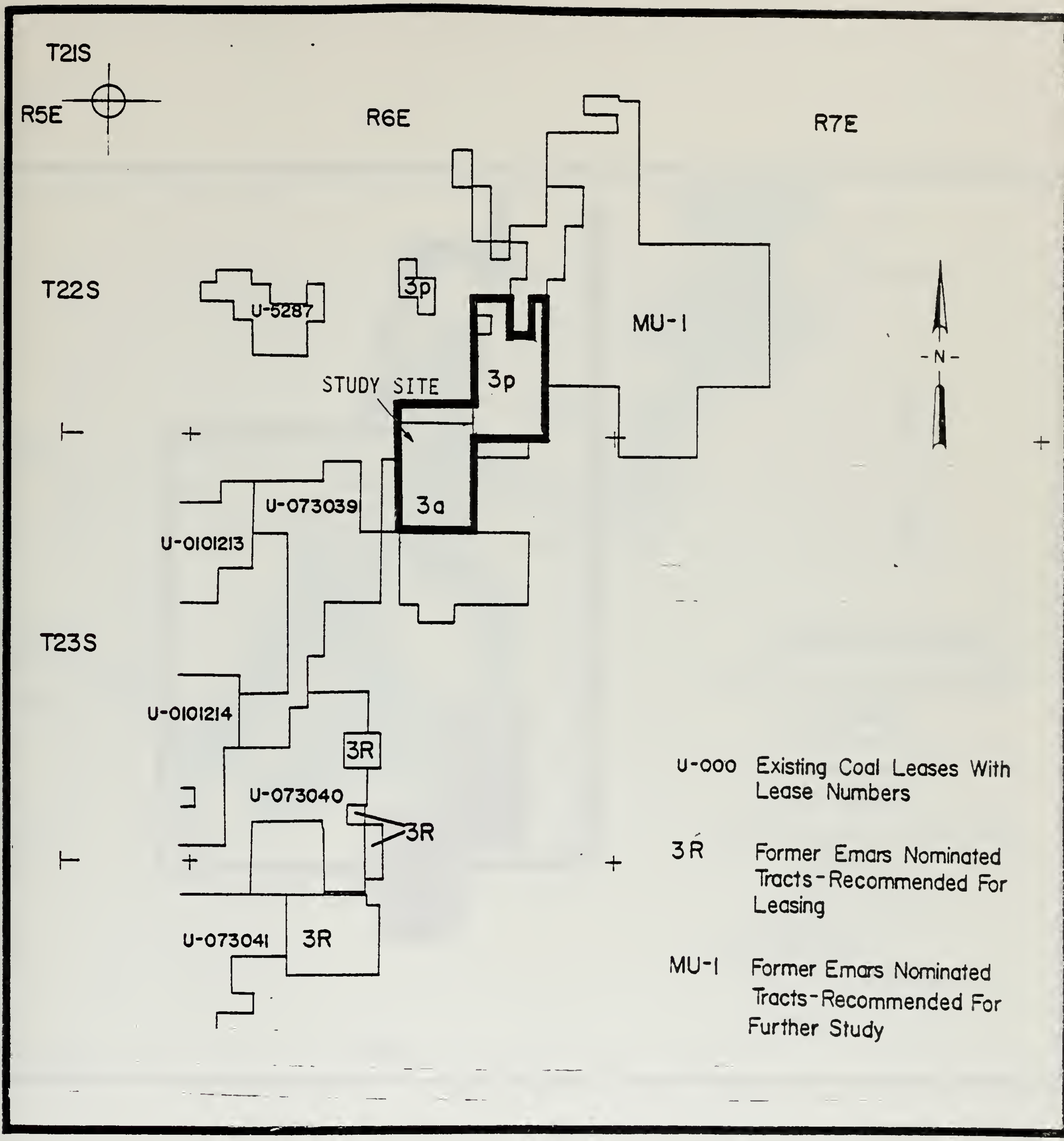


Figure 3. Coal Leasing in the Emery Field.

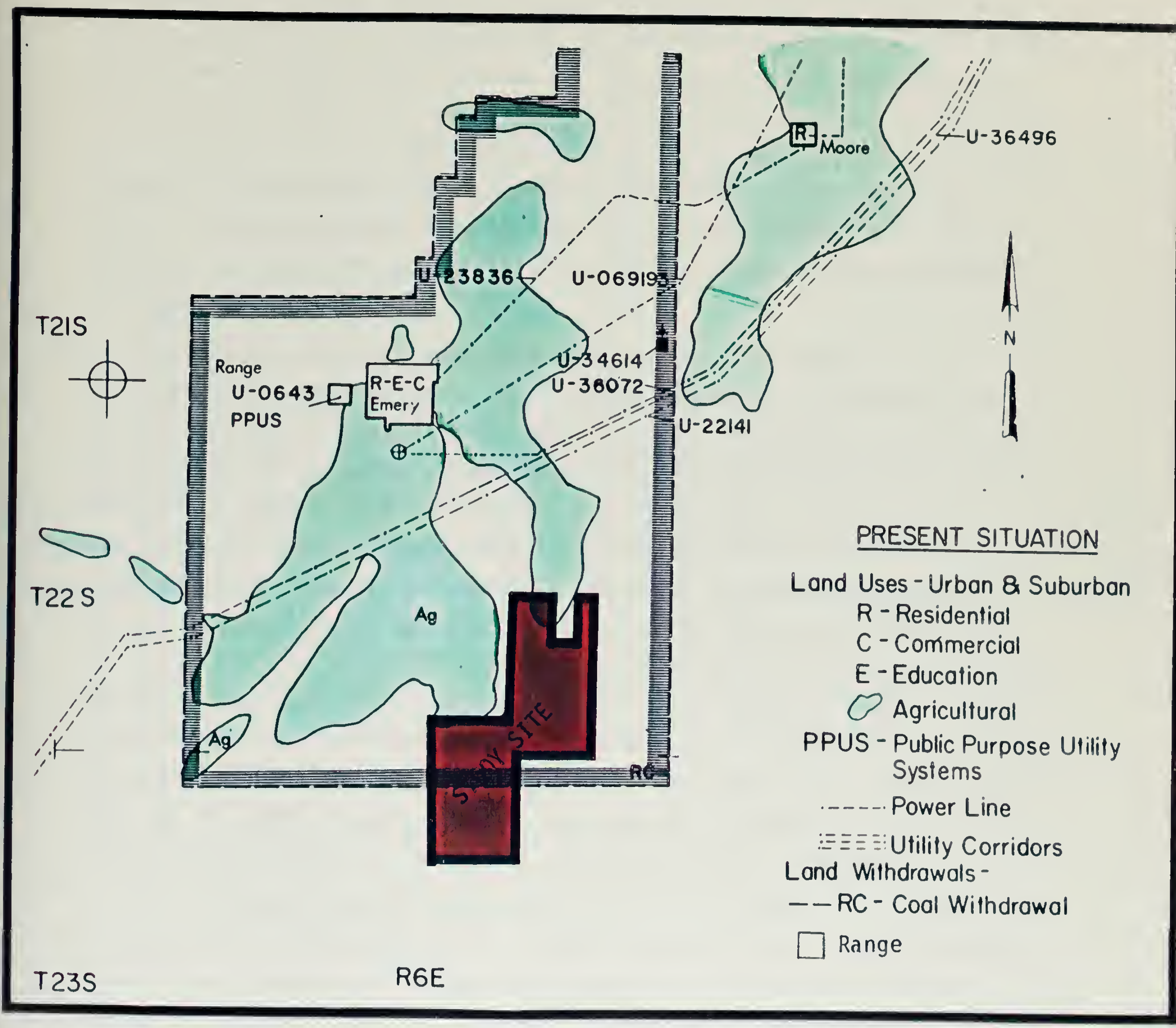


Figure 4. Present Land Use - Study Site

With respect to the Emery study site itself, the NW and SE portions of the site appear to meet criteria for stripping (100 to 200 depth to 20 foot coal seams). The northwestern area is the only part of the site containing the Blue Gate Shale (Persayo-Chipeta) soil derivatives. However, this appears to be the dominant soil type over the larger strippable resources which are more characteristic of the Emery coal field. But at least one of the defined strippable areas on the study site is representative of this "worst case" soil type. As a topsoil, the Blue Gate is nearly worthless, having the highest salinity and shrink swell potential, and lowest available moisture of all types represented. It may have some value in creating permeability barriers in site reconstruction if its salinity can be tolerated, but as a top soil it either requires amendment or disposal.

With regard to the drainage subbasin potentially disrupted by the stripping of the NW area, this would be the Miller Canyon drainage with an area within the study zone of 1195 acres. We note that continuation to the north of the presumed northern limit of recoverable coal would intercept Miller Creek, but mining in this area is unlikely. Miller Creek carries away irrigation water from the north and has been capturing small stream drainage as it erodes to the north and they change their channel geometry due to sediment filling. Diversion of these waters out of the coal pit by a bypass west to the town of Emery or a return to Miller Canyon further downstream, would be required. If the mine "makes" significant water this must be added to the diversion. If the first option is chosen, the Miller Canyon Creek would undoubtedly dry up in summer causing loss of the modest riparian habitat on the site. Perhaps mine water could be used to preserve this habitat if its quality were suitable.

This site would be most visible from the town of Emery. The average slopes are low to moderate here. However, here no significant streams are involved and prevention of wastes from entering Christiansen Wash by a series of sediment ponds is feasible. For the area the geochemical content of the sampled surface waters are not exceptional.

The second strippable area on the SE corner of the test site, involves the statistically more typical (for the study site) Castle Valley and Palisade soils. The revegetation tests conducted were essentially on these soils with minor areal exceptions. These experiments certified the soils as reclaimable even with admixture of shallow weathered overburden sandstone and some shales. In fact the bore hole geochemistry for bore holes 5 and 5A indicates the deeper overburden to be (unlike bore hole 3 to the north) a more acceptable soil supplement. But the extremely poor greenhouse results cast doubt on the use of the overburden as a supplement over all the site. In this region, conservation and storage of the topsoil is the obvious choice. The presence of a significant belt of Rock land over this site would require "stretching" this top soil over the Rock land area if mined and amending and blending with the nutrient poor, crushed shallow overburden; fly ash from the adjacent power plants or the less toxic deeper overburden suitable leached or crushed.

Evaluation of Toxic, Detrimental and Essential Elements in the Overburden

Several problems have yet to be resolved regarding the interpretation of the overburden geochemical data given by Heil and Deutsch (1979), Affolter et al., (1978) and the USGS (1979) water analyses. The latter did not include many of the elements reported by Heil and Deutsch and Affolter et al. The report by Affolter et al., (1978) did not analyze the siltstones and sandstones of the Ferron Formation. This probably does not constitute a serious problem in admixing sandstone in the formation of reconstituted subsoil or topsoil because trace element levels in siltstones and sandstones are generally lower than shales. Finally, the data reported by Heil and Deutsch represent those samples derived from crushed core bedrock samples. This material was not soil; fertilizer was added to the crushed rock for pot tests. Growth results indicate that salt tolerant native species perform less well than western wheatgrass, which seems unacceptable (Figure 5). GSC greenhouse tests on unfertilized overburden and the same seedstock were even more disappointing, as might be expected. But these backup tests do confirm Heil's results at least qualitatively. The problem of the cause of plant mortality is aggravated because similar pot tests by Heil from the Foidel Creek area did not produce as many deaths. GSC performed limited germination tests on the seed used and obtained 10 to 20% yields, hence poor germination does not account for the severity of these results. On review of the geochemical data, toxic concentrations do not appear either in the water, Ferron shale or crushed core samples. However, detrimental to toxic levels of boron (especially in the lower part of bore hole #6) and deficiencies of manganese, copper, and zinc may occur.

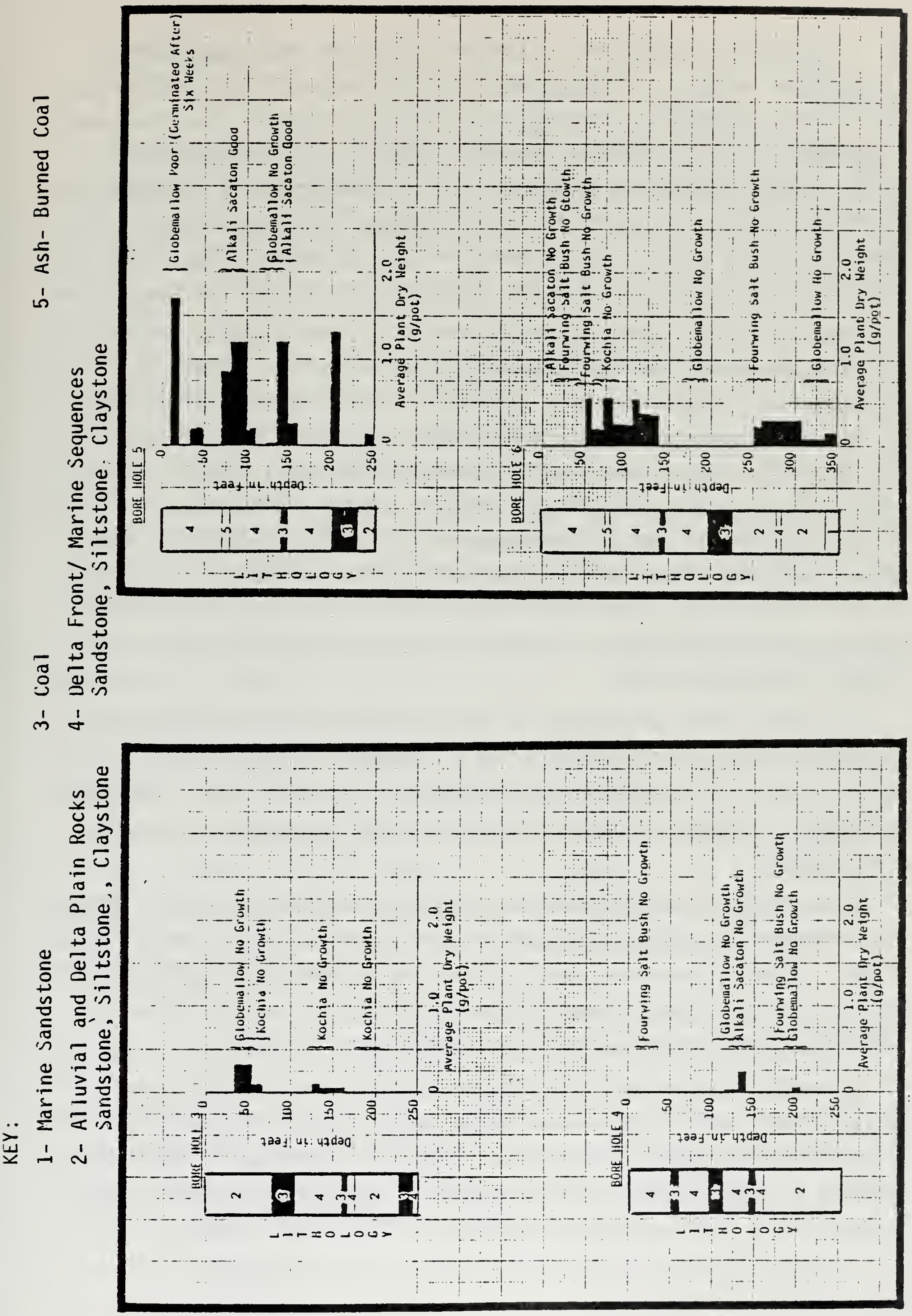


Figure 5. Greenhouse Comparison of Western Wheatgrass Growth Rates in Overburden.

Returning to the problems of admixed fertilizer added to crushed rock in pot tests, a possible concern is the lowering of pH by this fertilizer. Since Emery crushed rock (with the exception of pyritic and carbonaceous shale zones) are generally alkalic, a reduced pH would tend to mobilize whatever potentially toxic elements may be present. Under conditions of high pH, most toxic metals form insoluble carbonates and hydroxides. We recommend analysis of extractable toxic elements from leachates before and after addition of fertilizers.

Based on the evaluation of major, minor and trace elements, four possible overburden configurations might be considered. First, we recommend an adequate clay seal above the Ferron siltstones after the I coal seam is removed. A permeable coarse layer should be placed on top of this seal. Above this a reconstituted subsoil should be added. Finally, a thick-permeable topsoil layer is recommended if overburden must be used in the amendment. If boron is present, a slow growth rate would occur until sufficient leaching and removal of boron in the coarse rock substrate can take place. In the case of mobilized toxics, accelerated downward leaching may be achieved by addition of fertilizer to the topsoil

The second action does not involve a leach and lateral transport by a gravel substrate above the clay seal. Instead, dilution of the reconstituted overburden and topsoil by admixing either Ferron sandstone, Quaternary windblown sands, or fly ash from the nearby Emery Power Plant is suggested.

In addition to neutralizing power, fly ash, admixed with spoil, effects favorable physical changes of the mix, which improves plant growth (Doyle, 1976, p. 134). Since the density of the mix is reduced by admixture of the fly ash, the pore volume, moisture availability, and air capacity increase. These factors improve root penetration and depth.

If trucks hauling coal away from the strip mining area can return with fly ash loads from the power plant site, possibly low cost stockpiling of this product at the strip site would be achieved. The ashed samples of coal analyzed by the USGS (1979) suggest that nutrients are present which might enhance plant survival if fly ash is added.

The strippable coal resource to the west of the study site would potentially involve thicker alluvial soil sequences, which if a unitized development were involved, could be borrowed for the poor topsoil strippable regions on the plateau. Drainage from this site would be to the east into Quitchupah Creek. It is conceivable that the confined Ferron Sandstone aquifer, beneath this western part of the coal field, with artesian flow, could be impacted. For this area (off the study site) a more significant ground water disposal problem is implicit during mine dewatering. Also a potential hazard is possible to the municipal water supply of Emery by downward seepage into unsealed vertical joints. Extremely high iron contents were found in surface waters in the area. These may be taken to indicate the possible presence of other trace elements of greater concern which may be masked by the iron. The elimination of some small springs feeding into local creeks could result, but this is questionable considering the baseline data available. The removal of the necessary overburden should not effect the artesian pressure of the confined Ferron aquifer to the east.

As it now stands the study area has limited range/wildlife habitat/watershed value and possible recreational values. On the other hand, if the carrying capacity of the land could be increased as a result of an improved moisture retention capacity due to strip mining and shaping, then local long-term benefit may accrue in the process.

Secondly, for whatever reason, drought or loss of vegetative cover, springs and seeps from the plateau are now dried up. Thus a reasonable second objective would be to intercept a portion of the runoff in small basins after the mining by surface shaping and producing an increased infiltration surface zone.

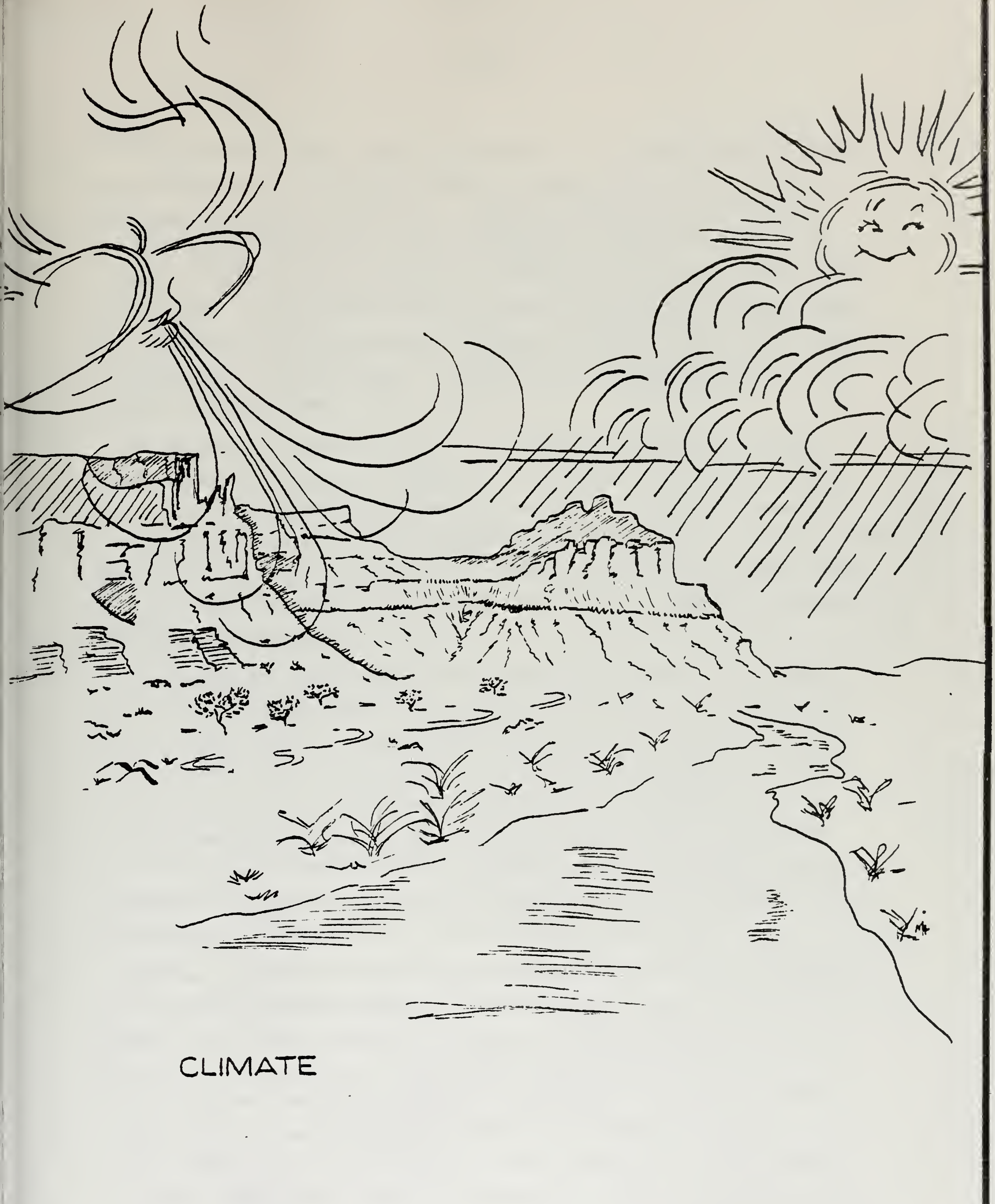
Thirdly, after the interruption of the existing stratigraphy by the mining process, a single ground water zone will develop above the floor of the coal mine. This increase in infiltration may serve to dilute near surface salinity and enhance vegetation and stock water supplies. On the other hand the altered chemical properties of the ground water may produce undesirable characteristics downslope. In the reclamation process a balance between these situations is needed.

Fourth, introduction of new grass, forbs and shrub species, native to the region but not how well represented on site could improve the ultimate range carrying capacity. The restored strip mined lands offer opportunity for such introduction free of competition.

Fifth, the existing wildlife in the area appears to be meager, evidently it would be possible to introduce a superior habitat for deer and elk, on the unmined sites by shaping small hills as cover with water nearby. Game could be introduced.

A sixth objective would be to provide superior flood control catchment basins as a by-product of the strip mining operation. As discussed in the strip mine model, a natural result of a mining operation is a final pit which may have inadequate fill. If this pit could be placed to catch excess runoff, it would protect the downslope surface construction, provide water for supplemental irrigation and avoid potential stream contamination by sediment or other runoff water geochemistry.

A seventh objective would be to isolate any toxic wastes from the ground and surface water supplies. Essentially we would wish to have a closed cycle system result in such areas with losses to evapotranspiration and input from precipitation. We would wish to avoid excess surface water entering such a zone, and infiltrating. Hence impoundments, barriers or surface coating with parafin or asphalt as is employed in water harvesting might be considered. Vertical fractures below the floor of such a disposal site must be sealed to avoid contaminating deeper aquifers.



CLIMATE

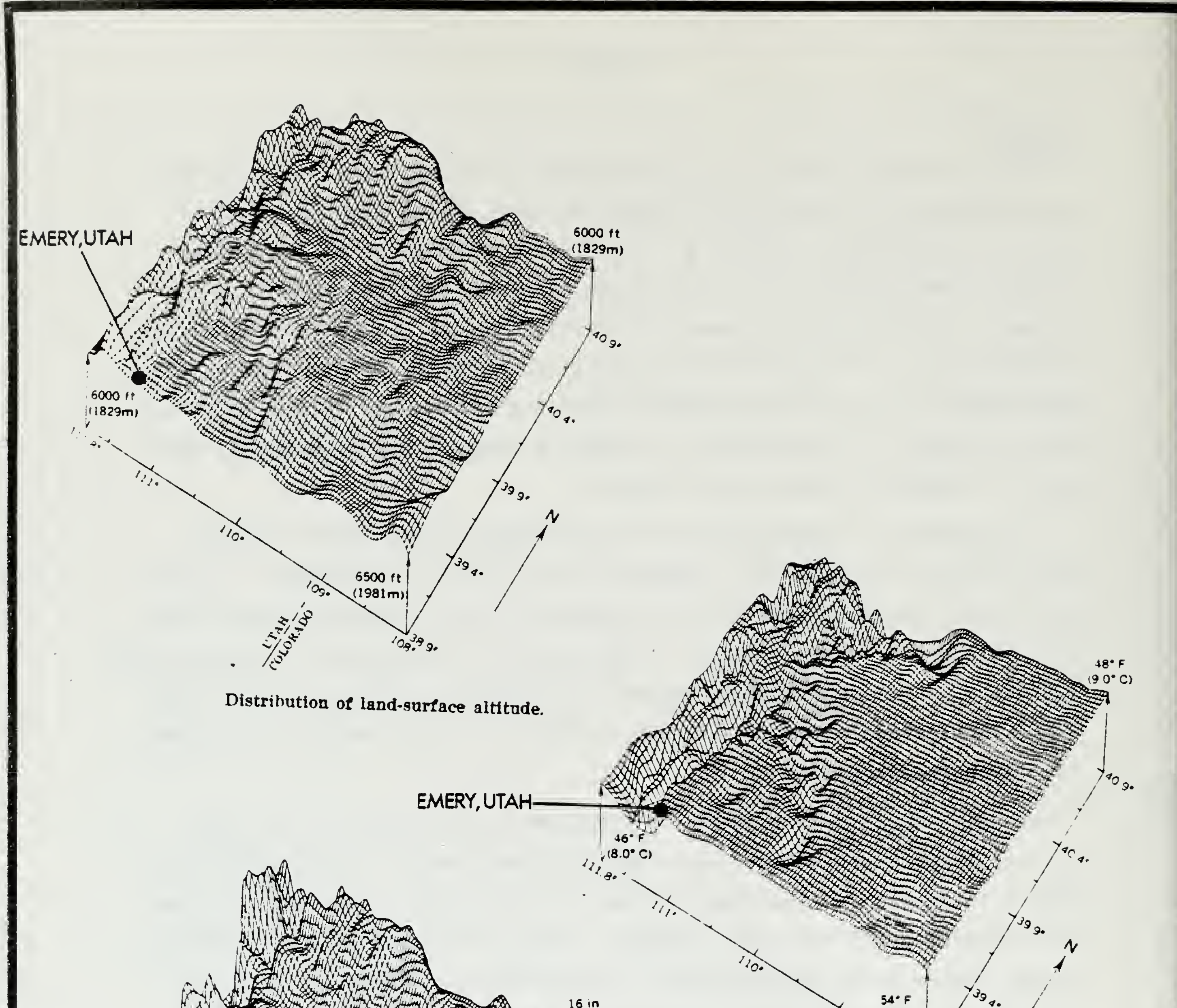
General

The Emery coal field lies at the eastern foot of the Wasatch Plateau, the northernmost of the high plateaus of Utah, as do several other of the Utah coal fields (Figure 6). At higher elevations of the Wasatch Plateau, over 11,000 feet, annual precipitation averages more than 30 inches, largely as winter snows which provide most of the streamflow and ground water. This precipitation depletes the moisture from the wintertime westerly flow, and the general downslope motion of this flow across Castle Valley, in which Emery lies, make winters rather dry there, with about 3 inches of winter precipitation.

In contrast, in summer moist air occasionally penetrates northward from the Sea of Cortez and, sometimes, from the Gulf of Mexico. As this flow rises northwestward from the Colorado River, convective showers and rare thunderstorms are formed, bringing most of the region's precipitation. But the stronger sunshine and warmer temperatures, although only around 70°F, increase evaporation and transpiration, so that most of the summer rain evaporates quickly.

Average annual precipitation around Emery coal field is less than 10 inches, with extensive areas receiving less than 8 inches, some less than 6 (Figure 7). The town of Emery at 6,220 feet elevation receives 7.55 inches annually on the average. Studies in other parts of western United States have suggested that revegetation of reworked land is unlikely when precipitation is less than 12 inches. Hence in the Emery coal field and in portions of the adjacent coal fields shown in Figure successful revegetation may require extensive irrigation, except in those few years when precipitation is almost double the average.

Weather conditions during the few years after mining and reclamation will determine whether topographic and vegetative restoration of surface mined lands in Emery county will succeed. Careful consideration should be given to eventual uses of the mined land, to avoid spending $5,000 an acre to restore land which then will be worth $55 an acre, as cited by Singer (1977). Newly reshaped terrain can be eroded by wind and rain before vegetation is established, if such is permitted by the sequence of weather conditions. While further weather cannot be predicted with sufficient precision to indicate the probable success of land reclamation and revegetation, probabilities can be extracted from records of the



Distribution of land-surface altitude.

Distribution of average annual temperature, 1941–70.

Distribution of average annual precipitation, 1941–70. Each vector base is equal to 9 in (229 mm).

Figure 6. Perspectives of Average Annual Precipitation and Temperature Related to Topography.

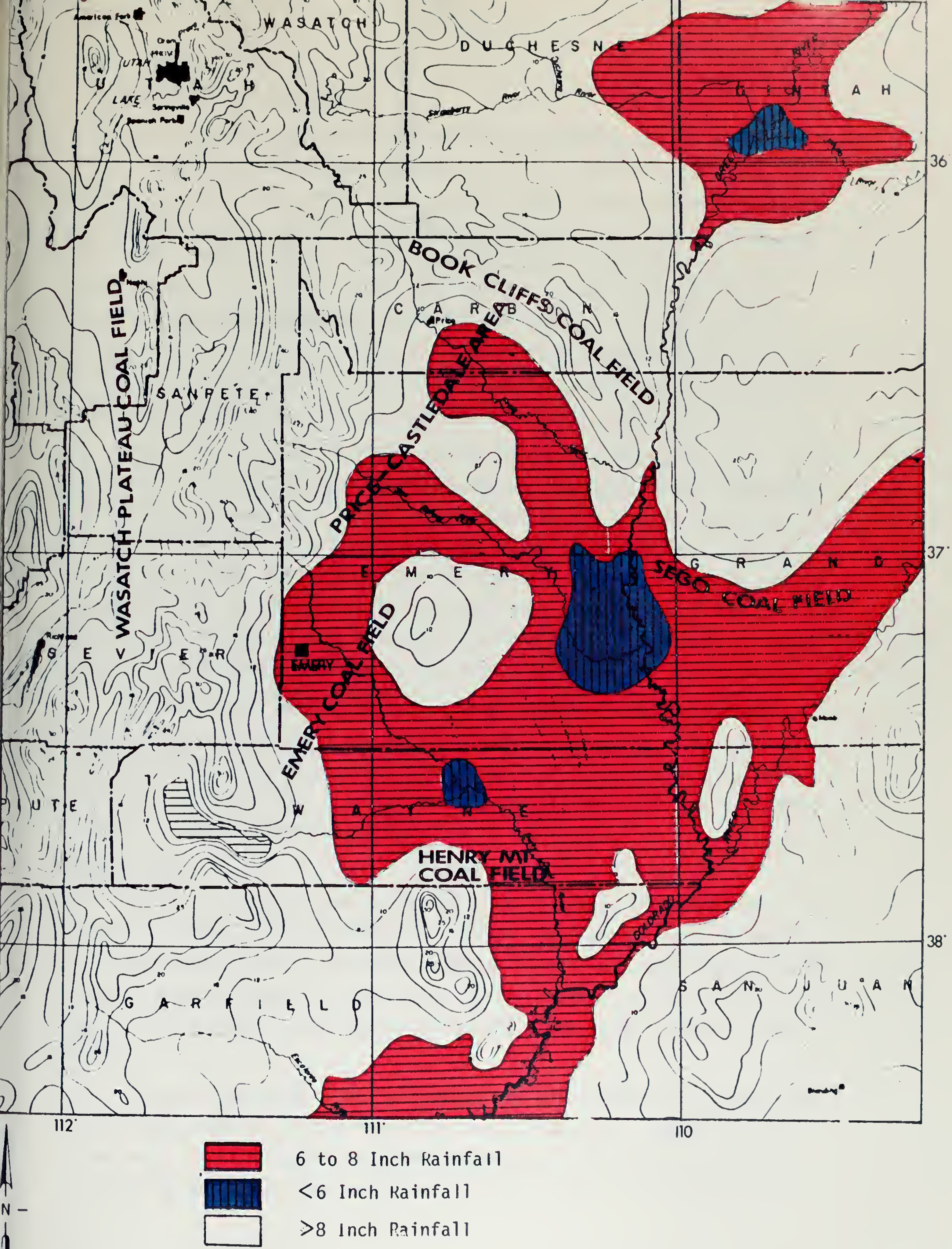


Figure 7. Normal Annual Precipitation (in inches)

past behavior of the weather.

Over the slightly rolling and partially dissected terrain of the Emery EMRIA study area, weather conditions vary naturally somewhat, from place to place, but perhaps less than the normal year-to-year variations at any one place. On the whole, Emery weather of past years, which constitutes climate, should be an adequate guide to conditions during the next decade or two in the Emery coal field. In fact, climate doesn't vary excessively throughout most of Castle Valley, in whose south end Emery lies, and indeed for tens of miles farther south, along the eastern foot of the high plateau. Conditions described here should be generally applicable to possible mining areas as far south as the Henry Mountains.

Fortunately, the Emery EMRIA site is only 3 to 6 miles SSE of the town of Emery, for which weather records obtained from 1901 to 1978 have been tabulated and summarized by the U.S. Weather Bureau and its successor, the Environmental Data Information Service. Other summaries have been compiled by various federal and state agencies. In addition, hourly records were obtained for ten months in 1972-1973 at a site two miles north of the EMRIA area. Detailed data from this site are given in Appendix 1 ; data from the town station are summarized here.

From 1901 until 1978, a series of five observers measured maximum and minimum temperatures, and rainfall amount, every day, with some interruptions. The station was moved only four times, to various residences a few blocks apart in the level townsite, and data from the four locations appear compatible.

Temperature

Temperatures experienced at Emery during 30 years, 1941-1970, are shown in Figure 8 (from Richardson, 1975). Mean temperatures by month for each recorded year are given in Table 1 , arranged into two half-years, beginning with October ("winter") and April ("summer"). This division more clearly reflects the nature of Emery's climate, and is used in all tables.

One index frequently used to characterize the climate of an area, mean annual temperature, can be misleading because two areas reporting the same mean annual temperature may actually have quite different climates. Thus temperature extremes as given in Tables 2 and 3 must also be con-

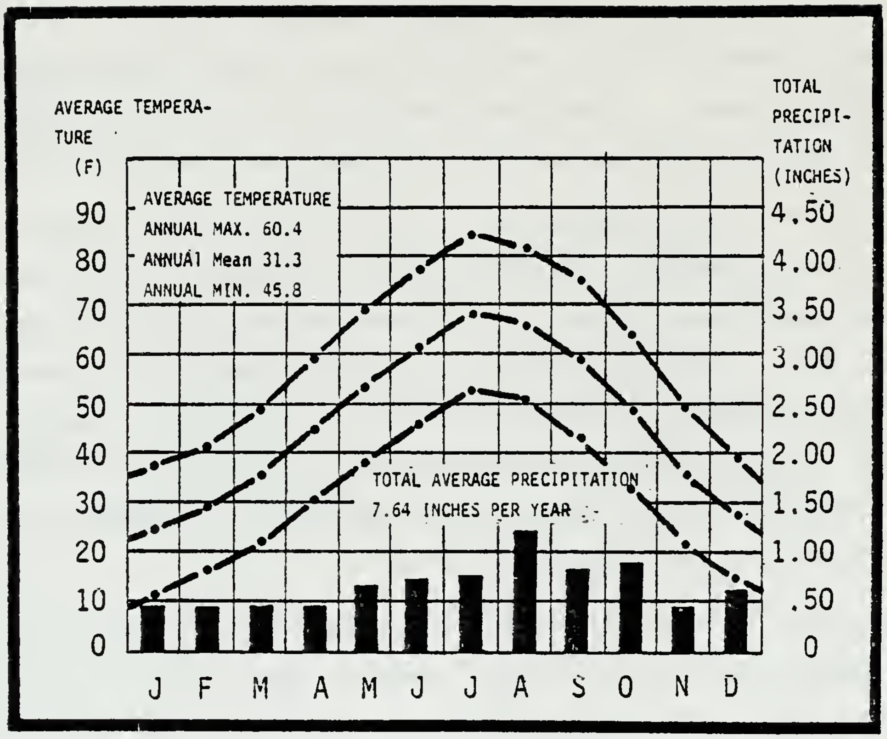


Figure 8. Emery Climatological Summary (Monthly Averages 1941-1970)

Table I.

Mean Temperature, by months, at EMERY UT (38°55 N, 111°15 W, 1893 m MSL)

	OCT	NOV	DEC	JAN	FEB	MAR	WINTR	APR	MAY	JUN	JUL	AUG	SEP	SUMMR	YEAR
1901-02	49.8	37.8	31.4	28.3	31.8	33.0	35.4	43.0	49.0	59.9	60.4	61.6	56.3	55.0	45.2
1902-03	44.8	34.8	24.6	26.2	19.2	35.1	30.8	40.8	47.4	58.7	62.8	65.0	52.6	54.6	42.7
1903-04	48.8	33.4	25.8	22.6	33.0	34.8	33.9	42/4	50.6	56.2	61.2	60.2	52.1	53.8	43.3
1904-05	39.0	33.6	22.4	24.2	25.6	36.4	30.2	41.0	45.3	57.4	59.4	62.3	—	—	—
1905-06	38.6	34.3	—	26.4	35.0	36.8	—	45.2	53.3	59.6	68.2	69.2	57.4	59.0	—
1906-07	49.0	34.1	31.6	25.5		43.6		49.0	51.9	56.5		67.0	56.6		
1907-08	53.4	41.4	30.3	27.9	30.5	43.5	37.8	51.1	54.2	59.0	69.8	65.2	56.4	59.3	48.6
1908-09	44.6	35.9	26.8	—	32.8	37.6	—	44.5	52.3	64.8	69.0	67.4	60.0	58.8	—
1909-10	53.1	44.3	17.8	21.8	26.3	45.4	34.8	50.6	54.0	62.6	67.8	66.3	56.8	59.7	47.2
1910-11	50.7	44.0	31.6	31.9	29.0	38.4	37.6	43.6	53.6	61.5	64.9	63.5	64.0	58.5	48.1
1911-12	39.4a	29.9		26.8	34.4	35.8		39.0	54.0	60.6	63.8	64.0	49.0	55.1	
1912-13	39.7	39.0		20.4	30.7	34.6		43.4	54.6	60.2	60.6	68.6	59.5	57.8	
1913-14	50.0	39.7	28.3	22.9	25.4	34.4	33.5	48.6	55.0	50.5	62.2	58.8	58.1	55.5	44.5
1914-15	49.0	36.6	26.0	22.7	22.2	31.7	31.4	45.8	46.5	54.3	63.4	62.2	50.4		
1915-16	50.6	42.0	27.8	20.4	28.4	39.8	34.8	48.0	53.0	61.8	65.7	62.3	58.0	58.2	46.5
1916-17	48.4	35.2	25.2	16.6	29.6	32.8	31.8	40.5	46.0	60.8	69.4	66.0	59.3	47.1	44.2
1917-18	47.1	45.2	34.6	26.8	29.2	38.0	36.8	44.3	52.8	66.2	65.8	64.0	57.3	58.6	47.7
1918-19	53.2	35.8	21.9	18.8	24.4	36.2	31.7	43.7	55.6	63.8	70.6	68.2	61.1	60.5	49.1
1919-20	45.0	37.2	24.9	26.6	33.3	34.6	33.7	38.2	56.1	63.0	67.8	66.4	62.0	58.9	46.3
1920-21	53.2	38.0	24.2	25.3	33.4	40.1	35.7	43.7	50.2	65.4	—	—	—	—	—
1921-22	—	—	31.0m	20.5	25.2	33.0	—	40.2	53.6	65.9	69.7	67.2	61.0	59.6	—
1922-23	48.4	34.6	30.8	31.4	25.6	34.5b	34.2	43.6	55.0	60.4	70.5	63.8	54.8	58.0	46.1
1923-24	43.2	36.2	25.1m	22.4a	34.2	31.0	32.0	44.6	56.4	65.9	69.5	66.8	55.7	59.8	47.0
1924-25	44.6	34.6	18.6	17.3	29.6	38.6	30.6	46.2	58.4	60.5	69.3	65.0	55.3	59.1	44.8
1925-26	46.4	32.4	30.0	55.4	32.0	38.8	34.2	48.8	54.4	65.4	68.0c	65.4	56.6	59.8	45.2
1926-27	48.8	37.0	23.6	27.4	31.4	35.6	34.0	44.2	52.5	63.0	68.6	63.4	56.4	58.0	44.3
1927-28	47.9	38.4	22.1	28.4a	30.5	39.8	34.5	41.7	55.6	60.4	68.6	65.3	59.0	58.4	46.4
1928-29	47.2	34.6	23.2	22.6	21.6	36.4	30.9	41.4	52.4	62.1	70.0e	67.2	56.0	58.2	44.6
1929-30	47.4	34.2	30.4	13.7	32.0	35.4	32.2	49.9	50.0	63.9	68.4	65.4	56.0	58.9	44.9
1930-31	44.4	33.3	24.7	25.2	33.3	34.8	32.7	47.3	53.8	65.0	73.0	67.9	59.9	61.1	45.9
1931-32	49.1	32.2	21.8	18.6	30.8	36.6	31.5	44.5	53.0	61.8	68.4	67.0	59.8	59.1	45.3
1932-33	47.3	37.4	18.3c	19.3	15.4	37.1	29.2	40.1	48.2	65.4	70.8	66.2	62.3	58.3	44.0
1933-34	53.0	39.6	30.6	29.8	37.4	45.0	39.2	49.7	60.0	60.9	71.8	68.9	59.4	61.3	45.5
1934-35	50.3	38.4	29.6	28.4a	32.2	34.4	35.6	43.0	49.4	64.6	68.6	66.6	59.9	58.7	47.2
1935-36	46.6	34.0	27.0	26.5	29.1	39.5	37.8	47.8	56.4	64.4	68.5	66.6	56.8	60.1	47.9
1936-37	45.3	35.8a	26.9	8.7	22.6	36.2	29.2	43.8	57.2	61.2	67.5	67.4	60.1	59.6	44.4
1937-38	49.7	38.6	30.8	29.1	30.6	35.5	35.7	45.6	51.9	62.6	66.1	67.1	59.4	58.3	47.2
1938-39	48.3	29.4	28.5a	24.0	15.8	36.4	30.4	48.5	55.4	60.4	68.6	67.1	58.3	59.3	45.1
1939-40	48.3	40.0	—	—	32.2	39.7	—	46.7	58.6	66.2	69.8	68.0	58.5	61.3	—
1940-41	49.1	32.5a	25.0	25.0	31.0	36.6	33.2	40.2	54.4	57.8	65.8	64.8	54.0	56.2	44.7

Table I (cont.)

Mean Temperature, by months, at EMERY UT (38°55 N, 111°15 W, 1893 m MSL)

	OCT	NOV	DEC	JAN	FEB	MAR	WINTR	APR	MAY	JUN	JUL	AUG	SEP	SUMMR	YEAR
1941-42	44.5	36.6	27.5	23.7	23.1	34.1	31.6	45.8	50.5	60.2	67.2	65.4	56.8	57.6	44.5
1942-43	49.0	36.8	31.8	28.6	32.9	36.9	36.0	50.2	52.0	58.7	66.9	65.2	59.8	58.8	47.4
1943-44	48.0	35.4	26.6	21.0b	24.0b	33.5	31.4	40.3d	51.8	57.2	65.4c	65.0	58.6	56.3	43.9
1944-45	49.0	33.4	29.4	28.5	31.3	33.2	34.1	38.0d	53.3i	55.6	60.1	64.8	55.6	55.6	44.9
1945-46	48.4	34.3	23.2	22.4	29.6	38.8	32.8	51.4	51.1	63.5	68.6	66.6	58.5	60.0	46.4
1946-47	42.8	31.6	31.2	25.1	33.9	40.0	34.1	44.0	56.8	57.0	67.0	64.1	61.2	58.9	46.5
1947-48	49.8	30.0	25.6	26.0	25.6	29.5	31.1	45.1	54.0	60.6	66.6	65.4	61.2	58.3	45.0
1948-49	47.7	31.1	25.3	15.8	18.4	36.5	29.1	48.3	52.6	60.0	67.5	65.3	60.3	59.1	44.1
1949-50	45.7	43.8	23.5	20.6	31.7	37.5	33.3	47.4	52.0	61.6	66.3	65.4	57.4	58.3	46.1
1950-51	54.5	40.1	34.4	27.2	29.8	36.2	37.0	47.3	53.6	59.3	70.3	64.7	59.4	59.1	48.1
1951-52	46.1	31.7	21.8	21.9	26.3	30.5	29.7	46.2	55.5	62.5	68.1	67.1	60.6	60.0	44.9
1952-53	54.0	32.1	24.8	30.5	30.9	39.2	35.2	43.7	48.9	63.2	70.2	64.4	61.4	58.6	46.9
1953-54	48.5	38.5	25.8	28.0	39.3	36.3	36.0	50.3	57.4	60.9	70.8	67.8	60.3	60.9	48.5
1954-55	51.0	40.7	24.3	20.9	18.9	34.4	31.7	42.9	53.7	60.7	68.9	67.3	61.3	59.2	45.5
1955-56	50.6	34.2	30.4	31.2	25.4	39.9	35.3	46.1	55.8	65.5	68.2	64.5	62.0	60.3	47.8
1956-57	49.1	31.6	44.7	20.9	32.6	38.7	36.8	43.4	50.0	62.1	67.3	65.2	57.8	57.7	47.2
1957-58	46.4	31.8	29.7	27.7	34.8	33.3	34.0	42.3	58.0	64.5	68.3	69.3	59.7	60.3	47.1
1958-59	50.0	37.1	35.3	27.6	30.8	37.5	36.4	46.5	52.2	66.6	70.4	67.0	—	—	—
1959-60	—	—	28.0	18.6	23.3	38.7	—	46.4	52.9	64.2	70.0	67.3	61.3	60.3	—
1960-61	47.7	35.4	27.4	26.1	32.0	36.0	34.1	44.4	53.6	66.6	69.3	67.7	52.8	59.1	46.6
1961-62	47.2	33.2	21.9	25.0	32.7	31.9	32.0	48.6	52.0	61.1	67.3	66.1	58.4	58.9	45.4
1962-63	49.1	38.9	28.4	17.6	—	32.9	—	40.5	56.4	59.0	68.3	65.2	59.4	58.2	—
1963-64	51.6	34.2	24.1	21.5	25.6	31.1	31.3	43.7	52.1E	60.1E	71.5E	66.2E	57.7E	58.5	44.9
1964-65	51.0	32.1	25.5	30.4	28.7	33.6	33.5	44.1m	50.3E	58.2E	67.7m	65.1m	53.5	56.5	45.0
1965-66	51.3m	39.6m	25.5	31.2	23.3	—	—	—	—	—	—	68.1	—	—	—
1966-67	—	—	24.4	24.5	—	—	—	—	51.9	58.0m	70.5	68.4	59.6	—	—
1967-68	52.0	38.7m	18.4	18.3	31.8	39.1	33.1	40.5m	50.5m	62.9	65.7	61.0	56.1	56.1	44.5
1968-69	49.1	35.0	21.0	27.8	24.0	30.4	41.2	45.9	58.5	59.6	69.4	70.2	61.4	60.8	47.0
1969-70	42.4	34.7	30.5	26.5	—	34.8	—	40.0	54.3	62.2	69.5	69.8	56.0	58.3	—
1970-71	42.8	34.3	25.6	26.0	28.1m	35.3m	32.0	44.1	51.5	—	—	68.3	56.0	—	—
1971-72	44.1	—	—	28.1	33.6	44.0	—	45.6	54.7	64.2	69.6	66.2	58.0	59.7	—
1972-73	43.9m	32.6m	—	16.9	—	—	—	—	—	—	—	70.0m	—	—	—
1973-74	—	—	27.1	17.1m	22.9	42.0	—	43.0	57.8	66.2	67.9	66.7	60.2	58.6	—
1974-75	49.6	35.1	25.6	24.2	28.5m	35.6	33.1	38.5	49.7	58.9	69.4m	65.5	58.9m	56.8	45.0
1975-76	46.9	33.8	27.9	24.6	34.4	34.2	33.6	43.6	55.4	61.3	70.9	65.2	59.4	59.3	46.5
1976-77	46.3	38.8	24.3	24.6	34.0	32.2	33.9	47.5	—	67.5	69.9	69.4	60.7	—	—
1977-78	49.7	37.3m	31.7m	25.7	27.1	—									

a, b, c, ... etc., indicate 1, 2, 3, ... 35c. days missing; m = unspecified number of days missing.
E = estimated value.

Table 2

Hottest Temperature of Each Month, 1960-1978, Emery Utah

	OCT	NOV	DEC	JAN	FEB	MAR	WINTR	APR	MAY	JUN	JUL	AUG	SEP	SUMMR
1960-61				52	55	61		74	81	--	98	98	80	--
1961-62	75	57	48	57	56	67	75	79	82	90	94	88	76	94
1962-63	76	71	60	51	--	64	--	71	82	87	92	85	65	92
1963-64	85	65	53	50	53	64	85	72	--	--	--	--	--	--
1964-65	81	63	58	53	55	59	81	--	78	84	89	89	79	89
1965-66	81	64	50	45	45	--	--	--	--	--	--	93	--	--
1966-67	--	--	53	52	--	--	--	--	86	91	92	91	87	92
1967-68	78	70	52	43	57	69	78	71	85	92	92	84	85	92
1968-69	79	68	58	58	48	69	79	77	85	86	98	95	85	98
1969-70	75	61	56	59	--	62	--	70	87	98	92	95	83	98
1970-71	76	61	51	65	59	73	76	72	78	--	--	91	88	--
1971-72	79	--	--	56	62	--	--	73	84	91	93	93	85	93
1972-73	77	56	--	39	--	--	--	--	--	--	--	93	--	--
1973-74	--	--	48	42	45	67	--	72	83	93	91	90	89	93
1974-75	79	62	47	59	58	59	79	65	80	87	91	90	86	91
1975-76	79	67	53	55	61	60	79	69	82	92	95	88	87	95
1976-77	75	68	50	53	62	61	75	77	84	88	91	92	90	91
1977-78	77	64	60	50	49									

Table 3

Coldest Temperature of Each Month, 1960-1978, Emery Utah

1960-61				- 2	6	9		19	28	--	47	47	24	--
1961-62	17	12	- 8	- 2	- 1	5	- 8	18	21	31	40	32	26	18
1962-63	25	10	-12	-20	--	4	--	11	27	33	44	39	43	11
1963-64	22	6	- 2	-11	- 2	5	-11	23	--	--	--	--	--	--
1964-65	20	2	0	3	1	4	0	23	22	34	45	40	23	22
1965-66	24	15	1	- 2	- 4	--	--	--	--	--	--	41	--	--
1966-67	--	--	1	- 1	--	--	--	--	12	37	47	45	31	--
1967-68	19	5	- 8	-10	2	13	-10	15	24	28	28	30	23	15
1968-69	18	3	- 7	- 6	- 4	1	- 7	24	31	37	41	46	34	24
1969-70	17	8	- 2	- 6	--	8	--	12	20	33	38	48	29	12
1970-71	13	10	3	-16	- 7	3	-16	14	25	--	--	45	23	--
1971-72	7	--	--	- 3	- 2	12	--	19	19	41	44	41	28	19
1972-73	--	13	--	- 9	--	--	--	--	--	--	--	42	--	--
1973-74	--	4	7	-13	- 3	18	-13	19	23	31	43	28	26	19
1974-75	24	9	- 4	- 5	2	5	- 5	13	23	32	45	41	32	13
1975-76	12	6	5	- 3	7	4	- 3	18	28	30	46	42	36	18
1976-77	16	- 5	3	- 4	10	6	- 5	16	28	41	47	42	29	16
1977-78	23	- 3	- 1	3	- 4									

sidered. Note in Table 3 the common occurrence of freezing conditions during the nominal summer growing season, which is masked by considering only the mean data.

The diurnal range (difference between the daytime maximum and the nighttime minimum) should be considered in assessing the climate of the region. In general, stations on mountain slopes, where air drainage is good, have a much smaller diurnal range than stations in valleys, including small mountain valleys, where air is more stagnant. Thus seasonal variation in mean daily (diurnal) range is greater for valley stations than for stations located on slopes.

"Growing degree days" (GDD) are an arithmetic accumulation of daily mean temperatures above a certain threshold temperature. They are a simple means of relating plant growth, development, and maturation to environmental air temperatures. Different species of plants have different base threshold temperatures below which theoretically they do not grow. At temperatures above this base or threshold value, the amount of plant growth is approximately proportional to the amount of heat or temperatures. Table 4 gives the number of degree days above 40° F and 50°F respectively, corresponding to the generally accepted values of the base temperature for important plants.

The growing degree day value for any day is easily obtained by subtracting the appropriate base or threshold temperature for the specific crop from the mean temperature. Thus, on a day with a maximum of 65° F and a minimum of 55° F, the mean temperature would be 60° F, which yields 10 degree days base 50, for a plant with 50° F threshold temperature. Actually the National Weather Service now uses a 50°- 86° F growing degree day, with all temperatures over 86° F counted as though they were 86° F, i.e. 36 GDD, base 50 would be calculated for an 86° F mean temperature day.

At Emery the frost-free or growing season is a little more than four months long (Richardson, 1975). On the average, temperatures have remained for:

132 days above 32° F, from May 21 to September 30;
166 days above 28° F, from April 30 to October 13;
187 days above 24° F, from April 21 to October 25;
212 days above 20° F, from April 6 to November 4;
236 days above 16° F, from March 22 to November 13.

Table 4. Growing Degree Days

Week Beginning	A. (40 F) Emery Mean	S.D.	B. (50 F) Emery Mean	S.D.
Mar 01	3	7	0	0
Mar 08	7	8	0	0
Mar 15	8	10	0	0
Mar 22	13	17	0	0
Mar 29	22	16	1	3
Apr 05	26	24	2	6
Apr 12	52	27	7	10
Apr 19	58	36	14	15
Apr 26	57	26	12	13
May 03	83	38	28	23
May 10	92	37	33	27
May 17	96	31	34	24
May 24	114	29	50	25
May 31	115	33	49	28
Jun 07	140	32	71	30
Jun 14	162	26	92	27
Jun 21	176	30	106	29
Jun 28	185	23	116	23
Jul 05	195	18	125	18
Jul 12	202	20	132	20
Jul 19	203	19	133	19
Jul 26	203	16	133	16
Aug 02	196	14	126	14
Aug 09	188	20	118	20
Aug 16	184	12	114	17
Aug 23	171	17	101	17
Aug 30	165	24	95	24
Sep 06	147	23	78	23
Sep 13	134	19	65	19
Sep 20	111	24	45	21
Sep 27	101	29	37	20
Oct 04	83	29	24	16
Oct 11	66	25	12	14
Oct 18	47	27	6	9
Oct 25	34	24	2	5
Nov 01	18	17	0	1
Nov 08	8	12	0	0
Nov 15	5	8	0	0
Nov 22	4	10	0	0
Nov 29	2	6	0	1
Dec 06	1	5	0	0
Dec 13	0	0	0	0
Dec 20	0	3	0	0
Dec 27	0	1	0	0
Jan 03	0	0	0	0
Jan 10	0	2	0	0
Jan 17	0	0	0	0
Jan 24	0	1	0	0
Jan 31	0	1	0	0
Feb 07	1	3	0	0
Feb 14	1	2	0	0
Feb 21	2	6	0	0
Totals =	3889	297	1961	214

The Emery coal field is slightly higher than the town, and therefore slightly colder. The various durations are one to two weeks shorter than those given for Emery.

Days of first and last occurrences of specified temperatures in spring and autumn are almost symmetrically distributed around their mean values, which are therefore also median values. That is, chances are even that the actual date in any given year will be earlier or later than the median. The probabilities that the differences between such last (or first) occurrences will differ by as much as the estimated number of days is indicated below (Jeppson et al., 1968):

Difference (Days):	1	3	5	7	9	11	13	16	21
Probability (%):	5	10	15	20	25	30	35	40	45

Thus the probability that a temperature of 38° F or colder will occur for the last time in spring no later than April 30-5 = April 25, is 50-15=35%; the probability that such last occurrence will be no later than May 5 is 65%. Likewise, the probability that 28° F or colder will occur in autumn 5 days or more before the median date of October 13 is 35%. The median length of the interval between last and first occurrences of 28° F or colder is 166 days, but the probability that it will be at least 10 days shorter, or 156 days, is 15 + 15 =30%, because actual dates in spring and autumn appear to be independent statistically. Thus the probabilities given above also apply to durations of various "frost-free" periods.

Precipitation

Mean annual precipitation for the region surrounding the Emery coal fields has been shown in Figure 2, emphasizing areas receiving less than 8 and less than 6 inches annually. This map is based on calendar year averages for the 30-year "normal" period, 1931-1960, when Emery received 7.27 inches. For various other periods, the Emery averages as tabulated and published by the Weather Bureau have been slightly greater (Table 5). But calendar year amounts have varied from 0.94 inches in 1902 to 13.56 in 1957, 13.78 in 1906, 14.83 in 1909, and 16.84 in 1941.

Seasonal precipitation is more significant than calendar year amounts. Most useful is division of the year into two halves, beginning with October ("winter") and April ("summer"). Monthly precipitation for the entire period of record at Emery is arranged in this way in Appendix 2.

The six-month "winter" receives only 39% of the year's precipitation, as shown by the following figures for the entire period, 1901-1978 (missing data in some years makes the annual total differ from the sum of the winter and summer averages):

	Winter	Summer	Year
Mean Precipitation	2.97	4.58	7.58
Standard Deviation	1.05	2.16	2.71
Coefficient of Variation	.35	.47	.36

The coefficient of variation (ratio of standard deviation to mean) is greatest in summer, indicating that precipitation is more variable then. Before 1930, winters were slightly wetter and summers slightly drier than in the following 38 years, as indicated in Figure 9, which shows the percentage frequency with which various seasonal totals have occurred.

No relation is apparent between the precipitation of one winter and that of the following summer season, as indicated by the scatter of the dots in Figure 10. A dry winter is just as likely to be followed by a wet summer as by a dry one. Nor is much relation shown between winter precipitation and snow accumulation at one of the two snow courses at the headwaters of Muddy Creek (Figure 11). Annual snow accumulations at both snow courses, as furnished by the Soil Conservation Service (Whaley and McWhirter, 1976) are given in Appendix 3. These water contents of the snowpack in late March indicate the water then will be available for irrigation during the "summer".

Extreme Probability Precipitation Events

Two tabulations of precipitation probability are presented in Appendices 4 and 5 . One gives the probability that various amounts of precipitation will not be exceeded during intervals of one week, two weeks, and three weeks of the standard Farmer's Year, beginning on March 1. The other indicates the probability of sequences of rainy days for three definitions of rainy day (.01, .05, and .10 inch) during one, two, and three-week periods of the same Farmer's Year. The one-week rainfall amount probabilities are shown in Figure 12.

Rainfall intensity is not great at Emery, the greatest daily catch in 78 years being only 2.60 inches in May of 1928. Greatest daily amounts in

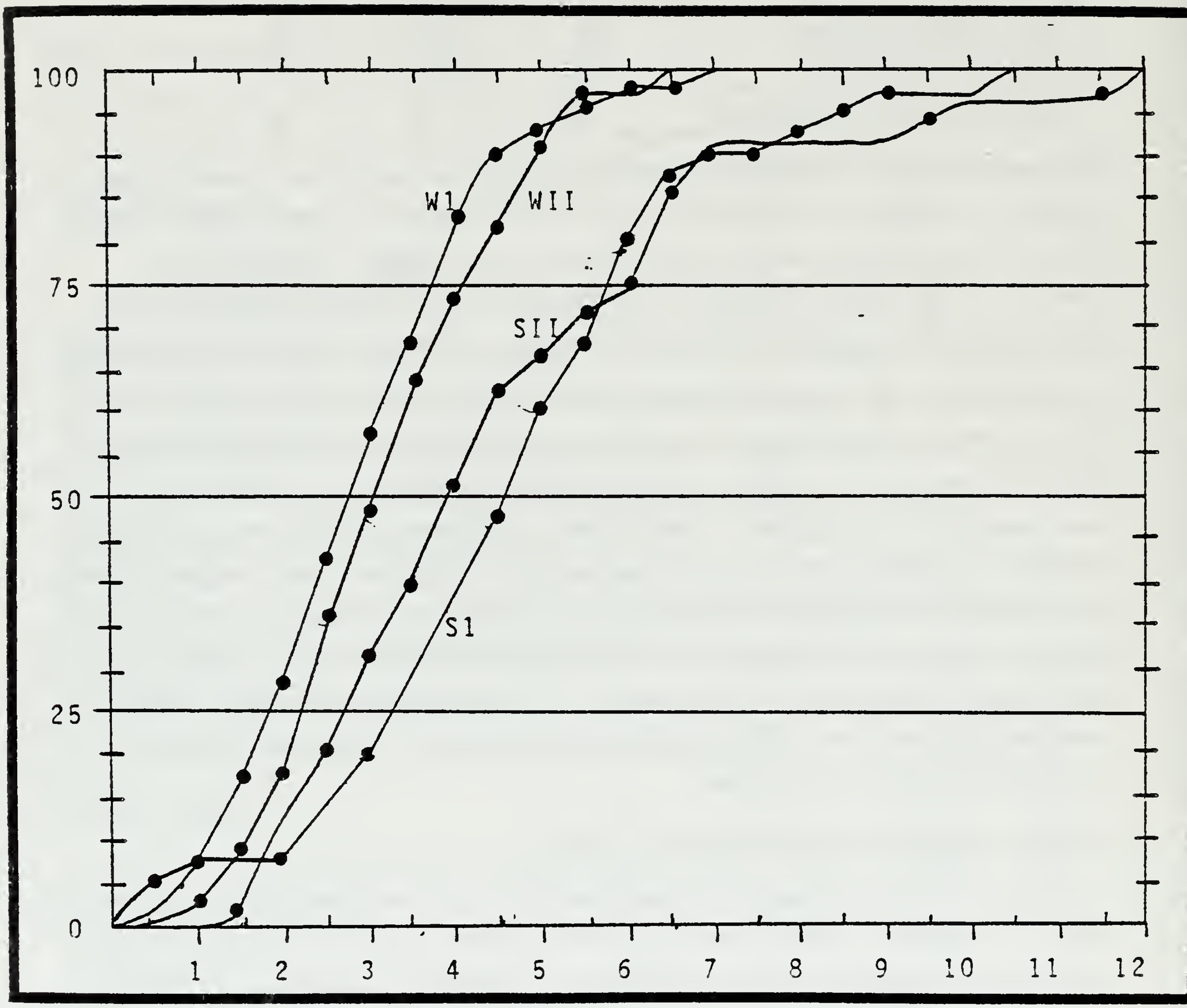


Figure 9. Cumulative Frequency of Seasonal Precipitation, Emery, Utah.

W= Winter (Oct. - Mar.)
S= Summer (Apr. - Sep.)
I= 1901 - 1941
II= 1941 - 1978

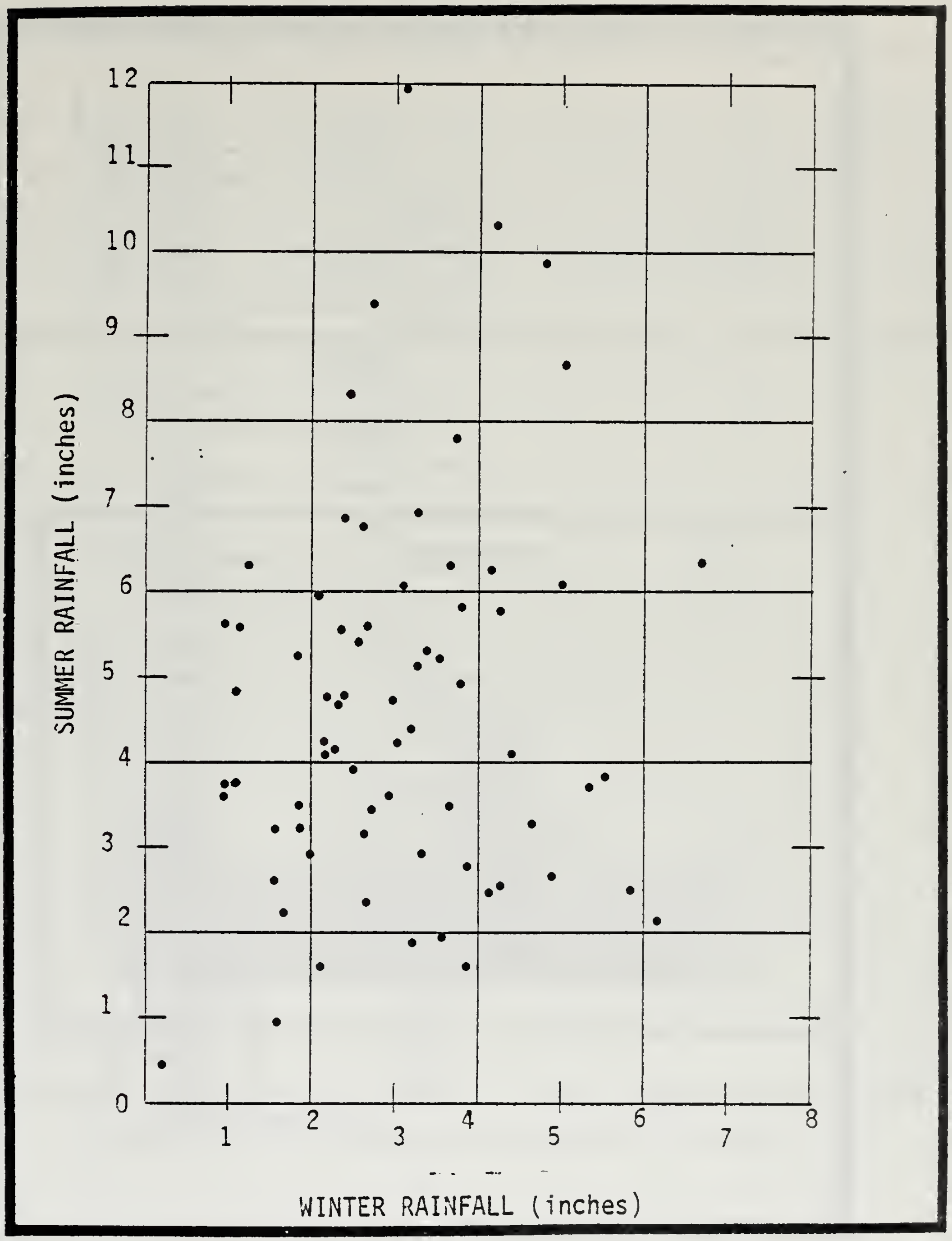


Figure 1Q Distribution Plot of Winter and Summer Precipitation.

Precipitation in Winter (Oct. - Mar.), Abscissa, and in following Summer (Apr. - Sep.) at Emery, Utah, 1901 to 1978 (1922, 1966, 1967 and 1976 missing).

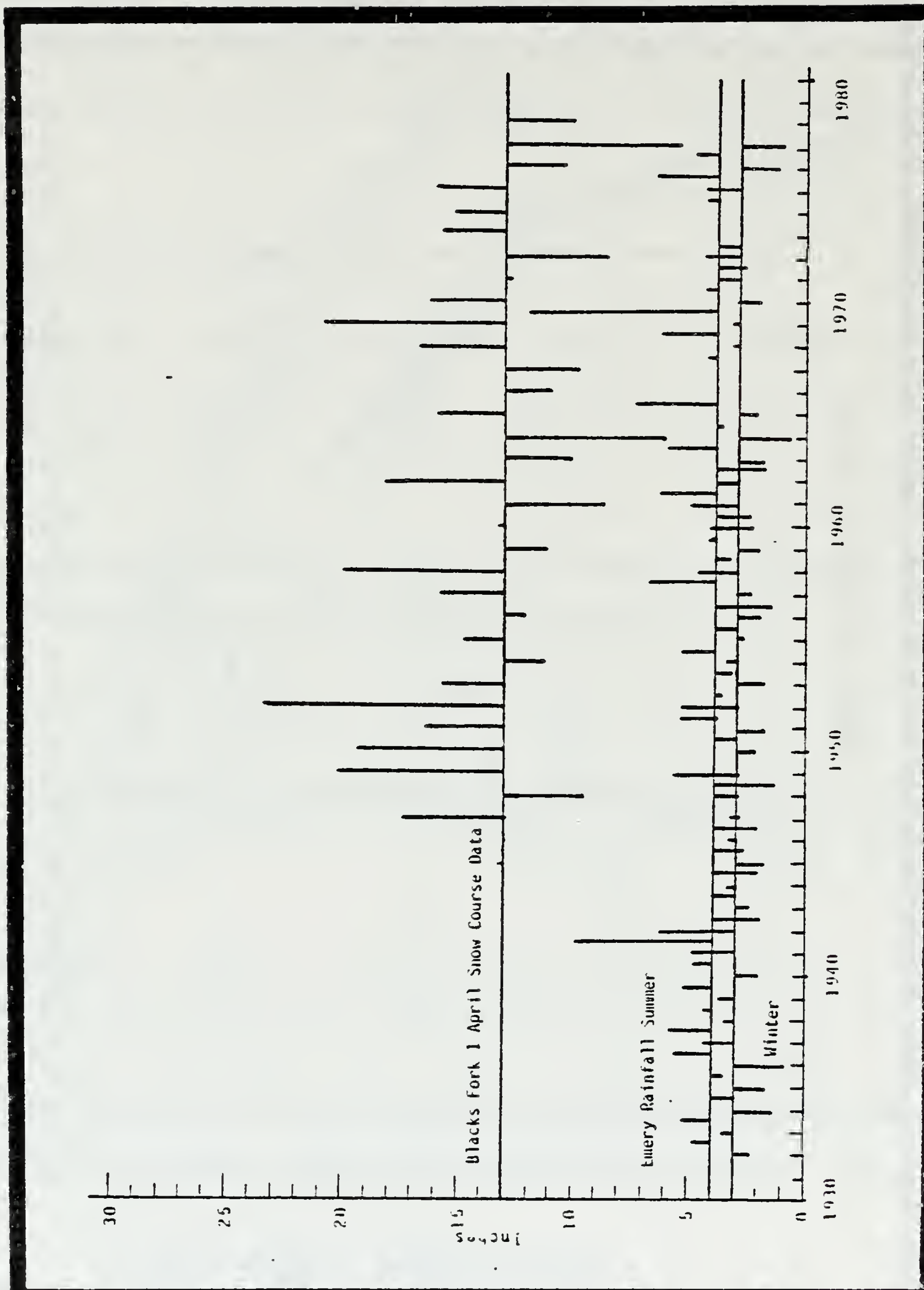


Figure 11 Emery Area Precipitation. (From 1930 to 1978)

Table 5

Mean Monthly Precipitation for Various Periods - Emery, Utah

Period	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Cum. Year
1901 - 20	.73	.35	.48	.52	.68	.42	.43	.54	.42	.87	1.22	1.13	7.81
1901 - 3-	.69	.32	.46	.47	.64	.45	.42	.62	.44	.83	1.23	1.07	7.81
1931 - 52	.80	.32	.58	.52	.38	.49	.37	.50	.54	.83	1.24	.72	7.29
1931 - 60	.89	.59	.50	.59	.47	.40	.40	.71	.41	.41	1.07	.83	7.27
1941 - 70	.86	.41	.57	.47	.42	.46	.43	.62	.71	.73	1.17	.79	7.64

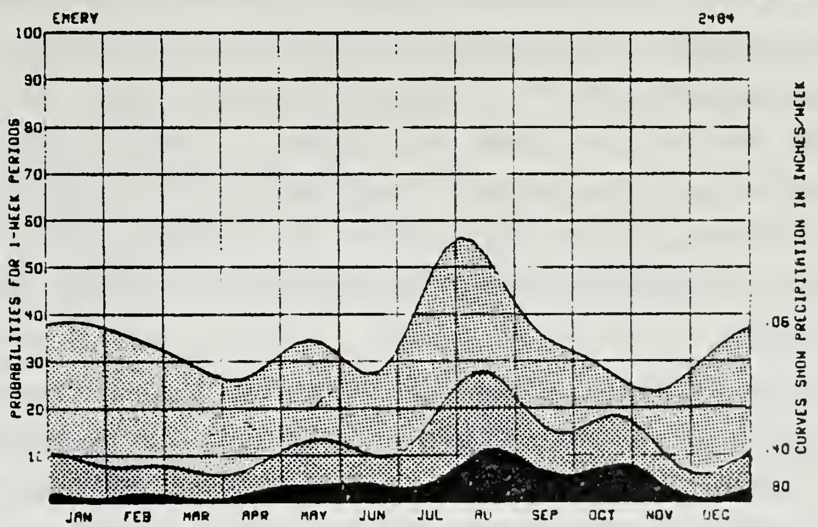


Figure 12. Precipitation Probability Graph (Jeppson et al., 1968).
(1 week rainfall)

inches for each month have been estimated by Richardson, (1975):

OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
2.07	1.03	0.70	0.83	0.72	1.22	1.25	2.60	1.40	2.13	2.16	1.69

"Probable maximum precipitation (PMP) estimates," defined as the estimated "upper limits of rainfall ... for use in hydrologic design" have been compiled for the Colorado River and Great Basin drainages by Hansen et al., (1977). Their procedure, allowing for both convergence ("synoptic") and orographic influences, yields the following estimates of the maximum precipitation in August, normally the wettest month, averaged over drainage areas of 10 and 418 square miles:

Duration	6	12	18	24	48	72	hours
10 square miles	4.8	6.5	7.8	8.7	11.3	12.6	inches
418 square miles	3.1	4.6	5.7	6.5	8.8	9.8	inches

The smaller area approximates the total Emery coal field under study, the larger one is the entire drainage of Muddy Creek above Interstate 70, a few miles downstream. Structures and excavations in the coal mining area should be designed for the 10 square mile data, except for those features along the Muddy which may be affected by the drainage from storms over the larger area. The average flow of Muddy Creek is about 36.6 cubic feet per second, the maximum, on May 10, 1952 was 3,340 ft^3/sec, or 94.6 m^3/sec. More details are given under the "Hydrology and Water Supply" section.

The other type of storm to consider is the "cloudburst", which releases rainfall of the order of an inch within an extremely short period (i.e. one hour). A USGS compilation in the general area of the Book Cliffs shows such storms occurring within a 30 year period (USGS Open-File Rept.) Recall again that Emery data for 78 years gives the greatest daily (24 hr.) rainfall as only 2.60 inches. This is much less than the PMP estimates given before. One such storm was evidently experienced in November, 1978, with a corresponding sediment catch in our trough type sediment traps as discussed in the sedimentation section. In any case we have simulated a one inch rainfall within a one-hour period for our rainfall simulation experiments, evaluating sedimentation problems.

Comparison With 100 Year Return Period Rainfalls

Miller et al., (1973) compared PMP estimates and 100 year - 24 hour rainfall values in the western United States. The 100 year return 24 hour data are heavily weighted by thunderstorm rain. The 100 year data range from 20 to 35% of the PMP, but do not, of course, apply to the same area as was computed for the PMP. If elected, the 100 year return rainfall values would be a less stringent design criteria.

Evapotranspiration Demand

Need for water to support revegetation efforts will primarily depend on evapotranspiration demand during the summer months. Normally 75% of the precipitation enters the soil, two-thirds of which is lost to evapotranspiration. Dominant recharge of aquifers and wetting of topsoils will hence occur due to snow melt. Although intense short duration summer storms are common, they would have little effect in supplying usable water to support plant growth. By reference to Figure 13, we can see that high losses for the area average precipitation can normally be anticipated. Reservoir design must also take these factors into account, by designing excess storage capacity to account for evaporative losses.

For revegetation water needs and surface water impoundment losses for irrigation, we need the evapotranspiration for the freeze-free season. Evapotranspiration for the freeze-free period does not follow the same pattern as that for the entire year. The available heat units become greater as one progresses from the mountain peaks down the slopes to the valley. The length of growing season also increases as one moves from the mountains to the foothills. However, in moving from the foothills on into the valley bottom, the growing season again becomes shorter due to accumulation of cold air drainage. As a result of the shortened growing season, the actual evapotranspiration for the freeze-free season will often be greater in the foothill regions than in the valley bottoms.

Monthly and annual values of potential evapotranspiration computed by the Thornthwaite method are given in Table 6. Standard deviations (SD) were calculated using the Ashcroft (1968) method. Monthly and annual standard deviations are also shown.

Table 6

Potential Evapotranspiration in Inches
(Thornthwaite Method-Calculated Yearly)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Amount	0.5	0.5	0.9	2.0	3.3	4.5	5.5	4.9	3.5	2.1	0.8	0.5	23.2
Standard Deviation	0.5	0.6	0.8	0.9	0.9	0.9	0.7	0.7	0.7	0.8	0.8	0.6	1.4

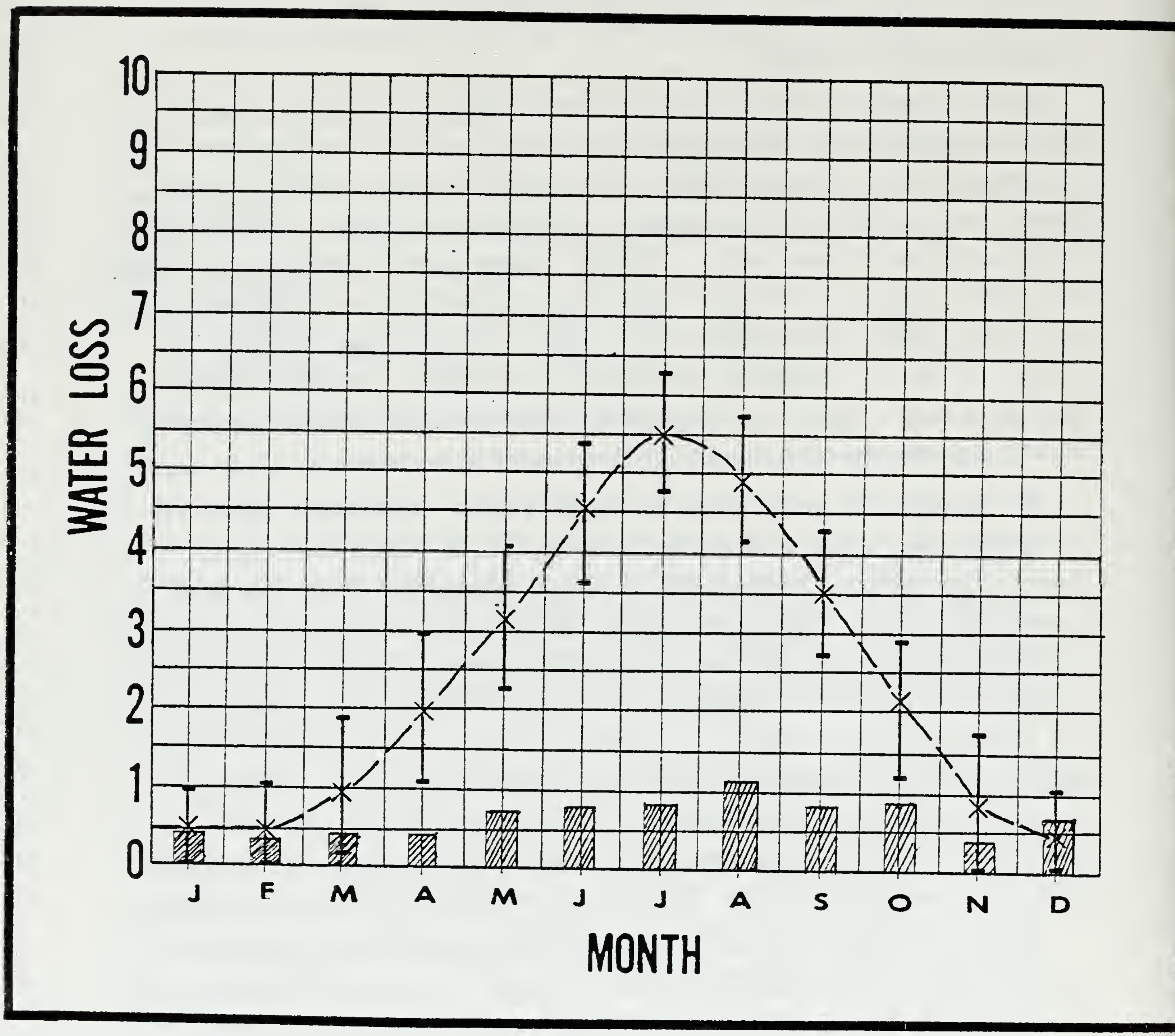


Figure 13. Evapotranspiration by Month - Emery, Utah

⊢X⊣ Standard Deviation

▨ Average Precipitation

Other weather-related factors may have adverse effects on revegetation of the Emery site. Low annual precipitation rates compounded with erratic distribution patterns and high summer storm intensities are not optimum conditions for seed germination and plant growth. On the Mancos Shale the effectiveness of the incoming precipitation is further reduced by the occurrence of shallow soils over much of the area and by relatively low soil moisture that could otherwise be utilized in seed germination, seedling establishment, and general plant growth. Dry, cold, windy winters may also result in relatively high percentages of winterkill among recently established vegetation (Figure 14, Figure 15).

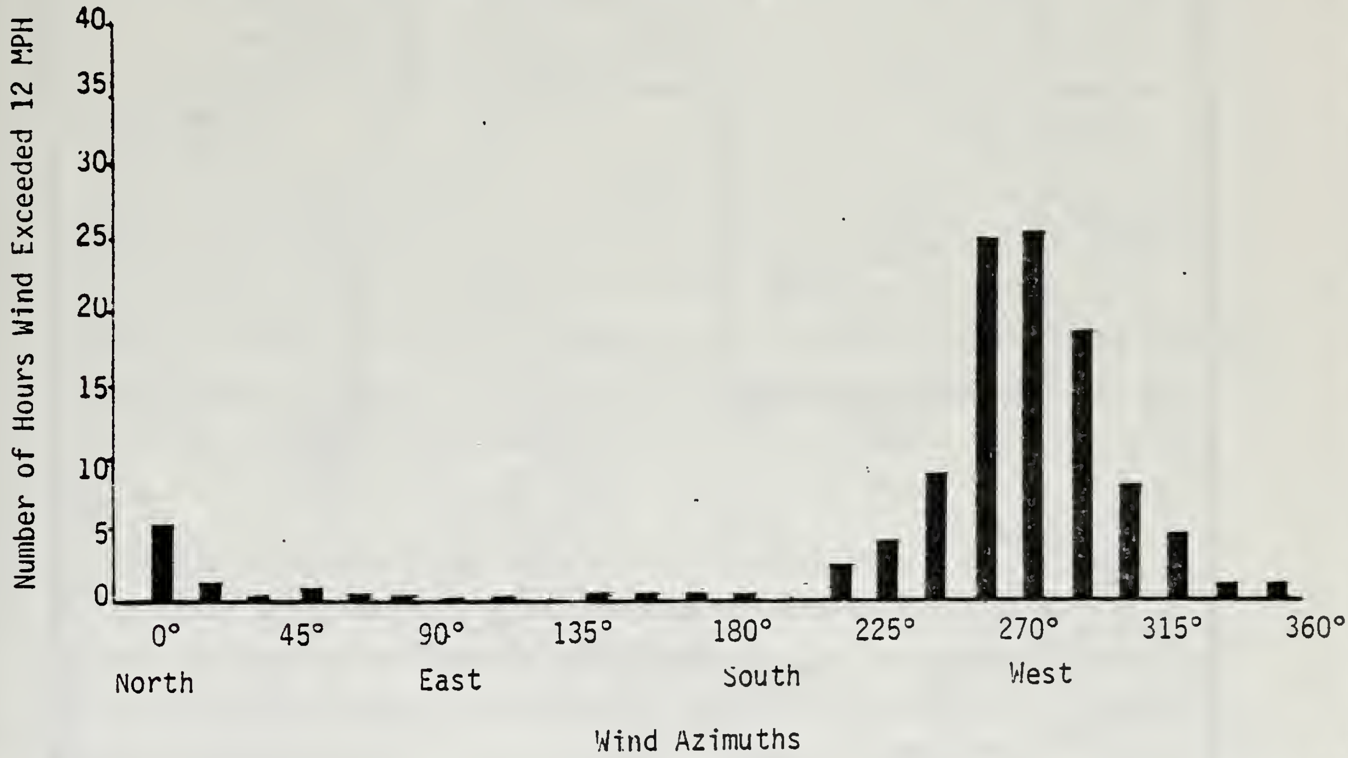


Figure 14 . Wind Erosion - Nine Month Average (November, 1972 thru July 1973)

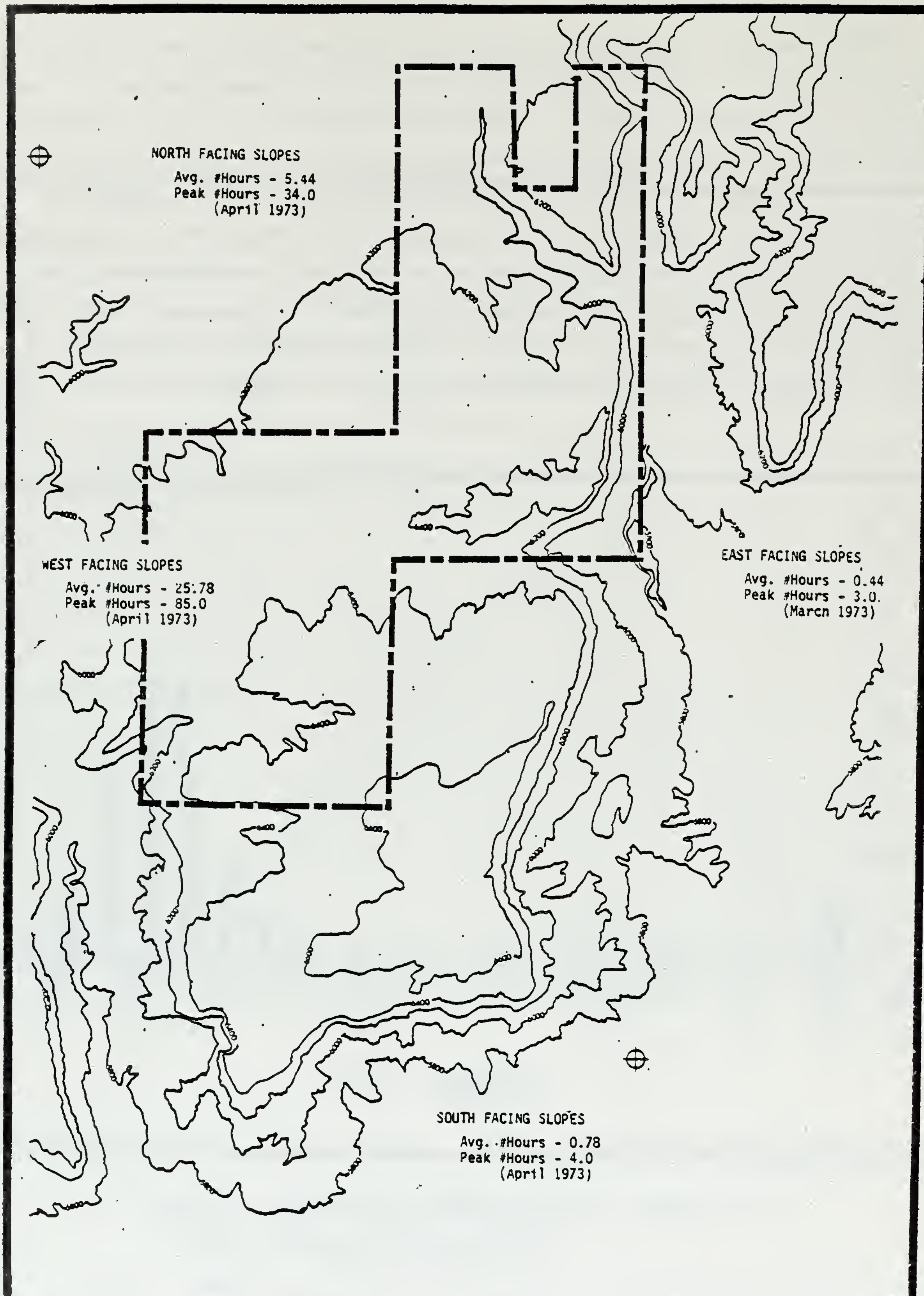


Figure 15. Relative Probability of Wind Erosion by Slope Exposure and Season. (Number Hours Wind Exceeded 12 MPH by Month)

South facing slopes at the study site will characteristically be subjected to more droughty conditions than slopes with northern aspects or exposures. These droughty conditions result primarily from the prevailing winds and from higher temperatures due to greater amounts of incoming solar radiation. Soil movement due to wind erosion may expose the tender roots of plant seedlings or bury the seedlings.

Emery on the east slope receives little winter precipitation. As the air comes in from the southeast, it rises over the Wasatch Plateau. Hence, summer storms account for a large share of the yearly precipitation in Emery.

The probability of receiving appreciable precipitation in a 7-day period is at or near its greatest in either May or October (during the closed low seasons) for all Utah stations. Precipitation probability graphs for Emery stations are shown in Figure 12. The precipitation levels plotted in Figure 12 are 0.06, 0.4 and 0.8 inches of weekley rainfall.

Peck and Williams (1961 and 1962) related precipitation to topography and atmospheric circulation. The normal annual precipitation (isohyetal) map for Emery is shown. The October through April precipitation is important in water storage as snowpack. The "growing season" precipitation is May through September. Precipitation-elevation relationships can be observed by comparing the isohyetal maps with the relief.

Summary

Climatic factors will normally have an adverse effect on revegetation of the study area and must be reckoned with. The most significant factors influencing reclamation techniques are the low precipitation, high wind velocities on some slope exposures, and the resulting high potential evapotranspiration rates over the growing season. Summer frosts with kill potential are not infrequent. The winter winds may also redistribute the snow leaving many areas bare which would permit winterkill of new vegetation. Soil movement caused by the wind damages vegetation by abrasive action and deflation around root systems. Because of greater amounts of incoming solar radiation, south facing slopes tend to be more droughty than north and east facing slopes. The result is an unfavorable environment for summer seed germination and plant growth. Late summer rainfall (August) may serve later grasses, but high evapotranspiration would require heavy summer rainfall (3/4 inches) to be useful.

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PHYSIOGRAPHY, RELIEF, & DRAINAGE

PHYSIOGRAPHY, RELIEF AND DRAINAGE

The Emery study area occupies the northwestern border of the canyon lands which are an extension of the Colorado Plateau and cover about half of the state of Utah (Gregory and Moore, 1931). This section borders the high plateaus of Utah. It lies within the Colorado Plateaus' physiographic province of the intermontane plateau (Dutton, 1880 and Fenneman, 1946). The western flank of the San Rafael Swell, where the strata dip generally 2° - 4° northwest, is eroded into a long line of southeast facing escarpments locally called the "Coal Cliffs" (see Figures 16 and 17

The study area generally occupies the gently sloping upland surface of a dissected questa on the southern margin of the Wasatch Plateau. The mesa, thus isolated, is a south facing extension of a main plateau underlying the entire Emery region. The elevations of the upland range from 6680 feet to about 6400 feet with a general northwesterly slope of 200 feet/mi. The valley bottoms, in the lowland, range from 5800 to 5600 feet in elevation. The mesa is underlain by gently dipping sedimentary beds, including the coal units, truncated by erosion along the main drainage streams (Austin and Skogerboe, 1970).

As shown in Figure 18, the main drainage in the area is the 3rd order Muddy Creek, flowing southward along the eastern escarpment of the mesa. Ivie Creek, a 2nd order tributary, flows eastward into Muddy Creek on the south, and 2nd order Quitchupah Creek flows southward into Ivie Creek on the west, isolating the mesa from the lowland. All the first-order tributaries are intermittent, draining the upland west and east into the Quitchupah and Muddy drainages. Nearly all of the 1st order basins on the upland surface drain westward into Quitchupah Creek. The main exception is Miller Canyon and its tributaries, eroding headward NW toward Emery, capturing the upland drainage, formerly tributary to Christiansen Wash and the Quitchupah drainage. The gradients of these streams are generally small, except locally where they cross the steep to vertical escarpments. On the upland, the tributaries are incised slightly and drop 200 to 360 feet per mile and range from 800 feet to 1100 feet per mile across the escarpment. The lowland Quitchupah and Muddy Creeks grade only 30 feet per mile. Tributaries to the main N-S drains merge

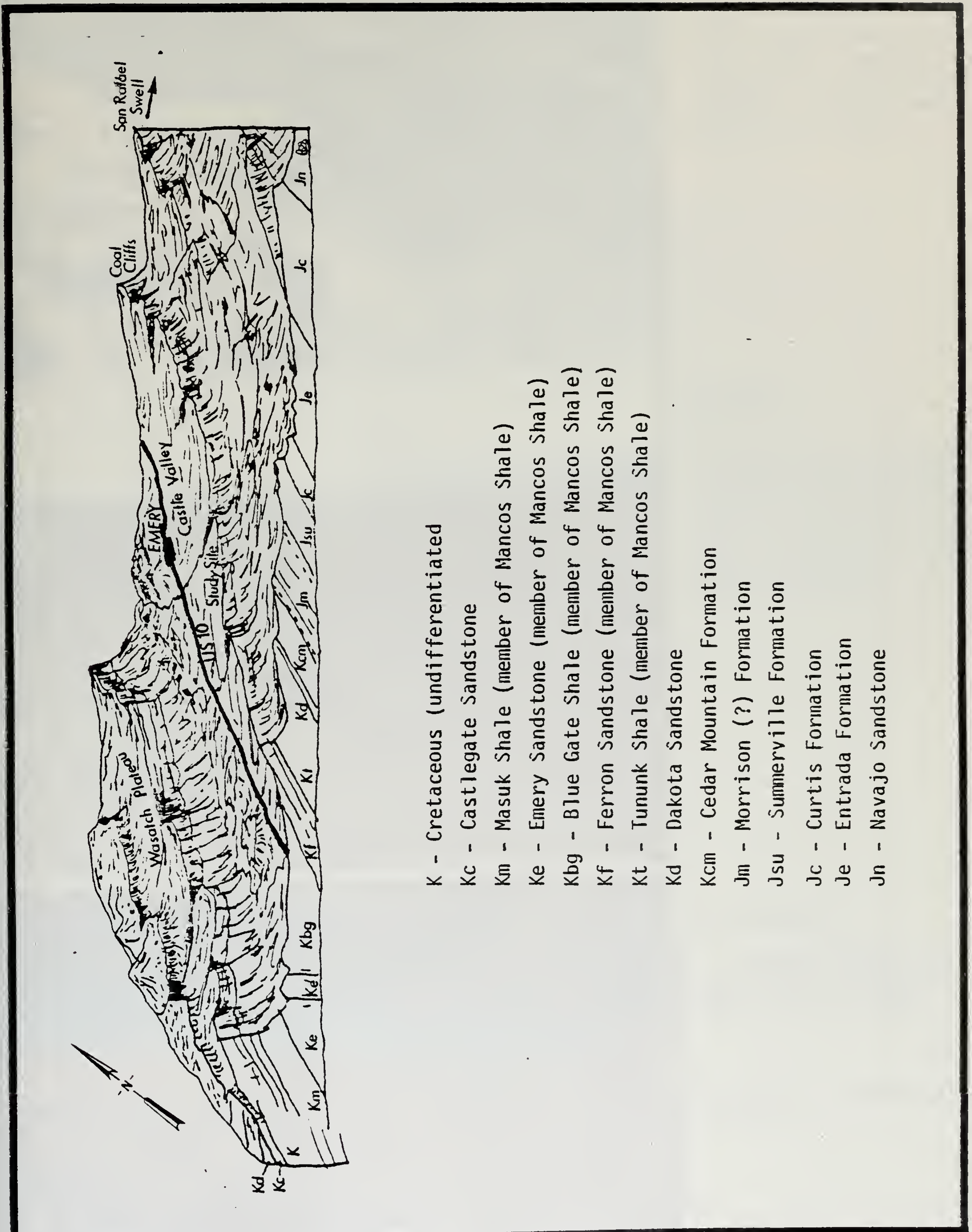
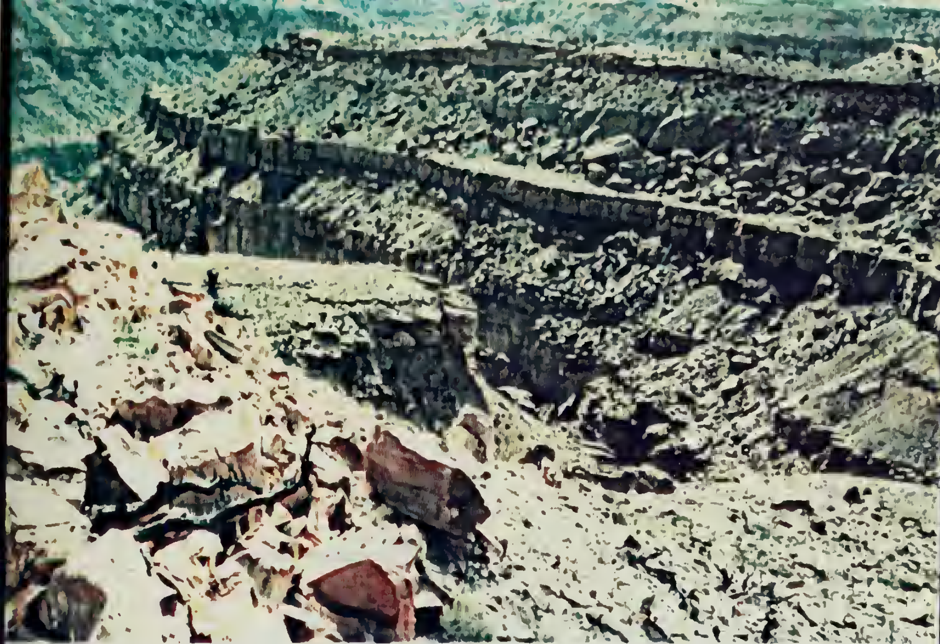


Figure 16. East-West Cross Section and Physiographic Diagram of Emery Coal Field and Surrounding Area.



Canyons

View west from top of study site, Quitchupah drainage at upper left corner. Showing cliff forming sandstone units and canyons, lower coal present in creek bottom (not visible); I-J Coal seam is burned in this area.

Plateaus

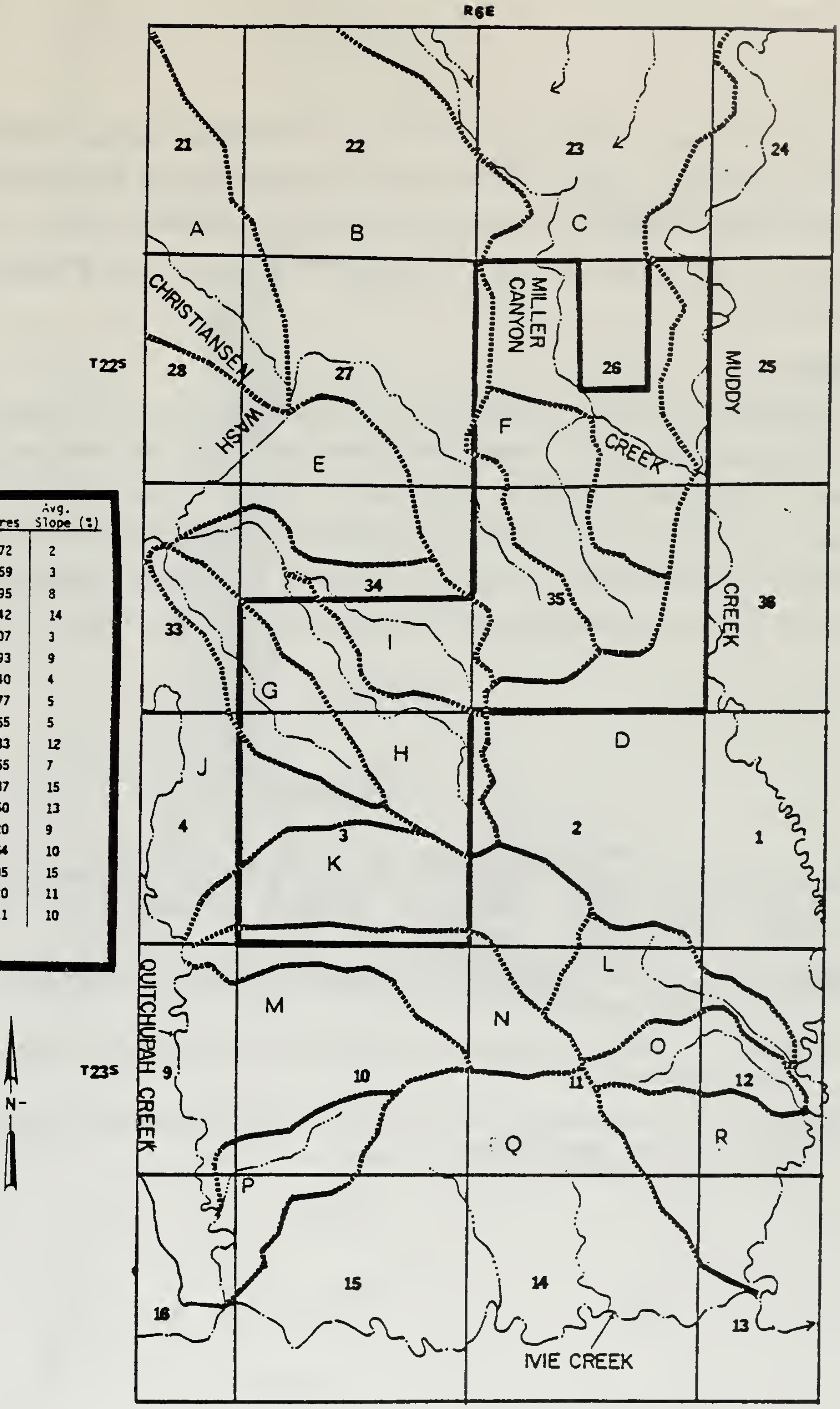
View SW across Quitchupah drainage showing plateau facing study area in background. Quitchupah flow is from right to left. Ivie Creek is visible in upper left hand corner

Muddy Creek

View west across the Muddy Creek drainage. Bear Gulch Mine at right.

Figure 17. Landscape Views

Basin	Acres	Avg. Slope (%)
A	372	2
B	1459	3
C	1195	8
D	2442	14
E	507	3
F	293	9
G	240	4
H	377	5
I	255	5
J	383	12
K	455	7
L	237	15
M	460	13
N	320	9
O	164	10
P	205	15
Q	1120	11
R	311	10



EMERY, UTAH

SMALL DRAINAGE BASINS

DRAINAGE DIVIDE
PERENNIAL STREAMS
INTERMITTENT STREAMS

0 — 8000 Feet
0 — 1 — 2 Miles

Figure 18

in the vicinity of Emery on the nearly horizontal upland surface. None of the perennial streams with their low gradient and mean dendritic channel pattern seems capable of carrying excessive sediment load. The intermittent upland channels are also meandering and of low gradient (see Figure 18).

Summary

Perennial streams are the Muddy, Quitchupah, and Ivie Creeks and Christiansen Wash. All have been known to go dry on occasion during summer. They are presently sustained at least in part by irrigation flows. The terrain consists of canyon lands and plateaus, which locally form the "Coal Cliffs". Locally, the area elevations range from 5600 feet on the valley bottoms to 6680 feet on the top of the plateaus.

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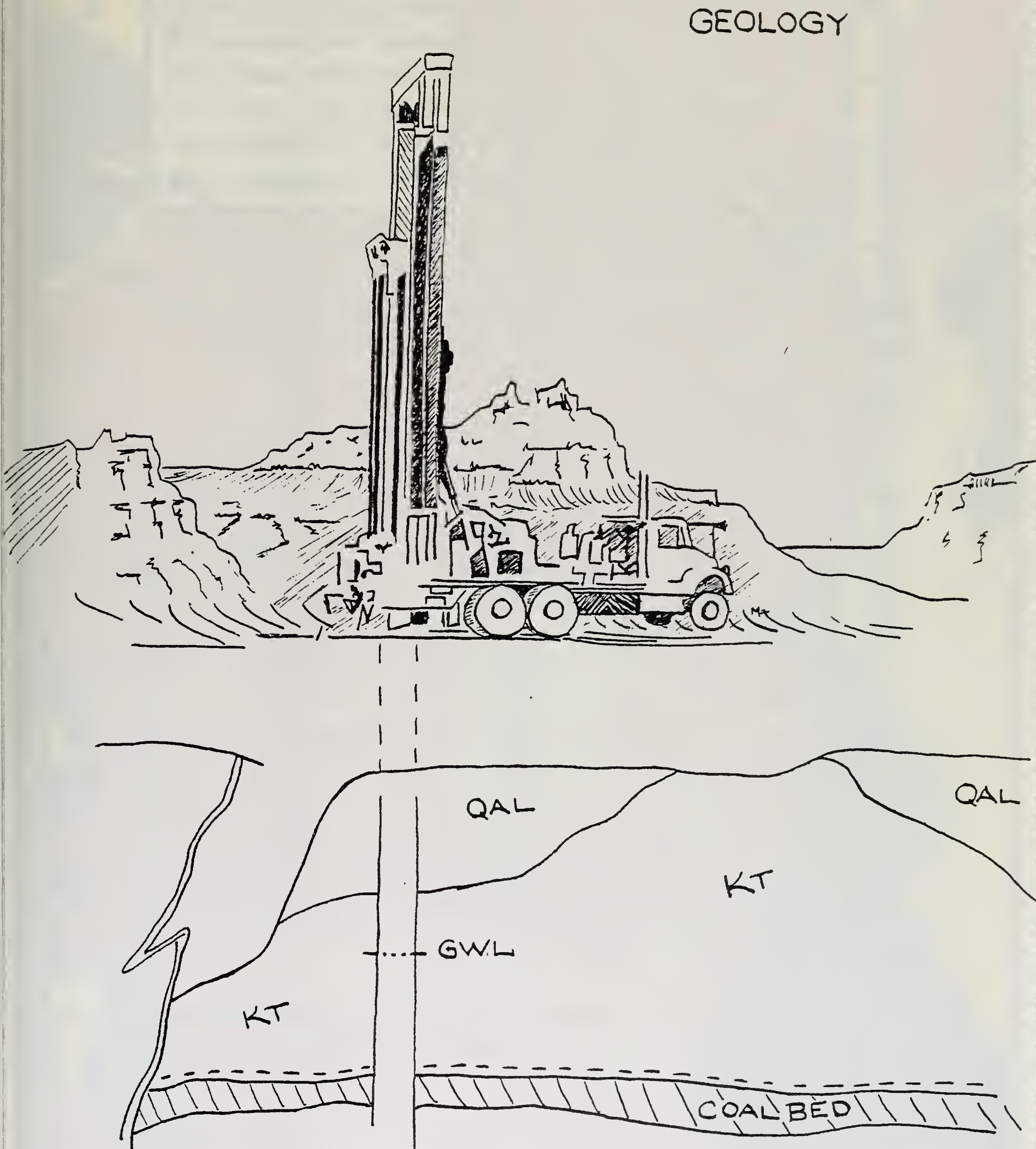


GEOLOGY
QAL
QAL
KT
GWL
KT
COAL BED

Regional Geologic Setting

The Emery coal field is located on an intermediate bench within the generally northwest dipping Upper Cretaceous marine strata. These units form an extension of the older rocks which make up the plateaus and canyon lands of central Utah (Figure 18). West of the Emery field, the steep eastward facing cliffs of the overlying westerly dipping Upper Cretaceous and Lower Tertiary sedimentary rocks mark the eastern edge of the Wasatch Plateau. East of the region the underlying Cretaceous and Jurasic sediments of the anticlinal San Rafael Swell dip westward beneath the study area, and form the lowlands and the lower benches to the east (Figure 19). The region has been described by Lupton (1916), Spieker (1925) and Doelling (1972).

Local Geologic Setting

The study area in the Emery coal field is entirely within the resistant cliff-forming Ferron Sandstone member of the Upper Cretaceous Mancos Shale (Figure 20). The Ferron crops out in a long line of northeast trending steep to nearly vertical cliffs, the Coal Cliffs, along the western edge of Muddy Creek, forming the middle bench between the Wasatch Plateau and the San Rafael Swell. Figures 21 and 22 (Ryer, 1979) give two fence diagram cross-sections of the area constructed from outcrop and bore hole data. The beds dip generally northwest 2-4 degrees and are locally exposed as a dip slope plateau by erosion of the overlying Blue Gate member. The Ferron Sandstone member averages 400 feet thick and is commonly divided into an upper and lower unit, but this simple division becomes unworkable northeast of the study area. The lower unit is characteristically continuous yellow-gray, fine to medium sandstone in tabular or sheet-like beds, commonly calcareous. The Ferron sandstone is marine, locally cross-bedded, and grades into the underlying Tununk Shale. It represents episodes of the retreat of the Cretaceous Sea to the northeast.

The upper unit is less continuous, commonly cross-bedded, with lenticular beds of fine to coarse sandstone, lenses and intercalated beds of shale, siltstone, and coal. The sands, shales and coals represent fluctuations of the non-marine coastal swamp environment at the edge of the Cretaceous Sea. All of the coal in the Emery area is in this unit. There is a minor

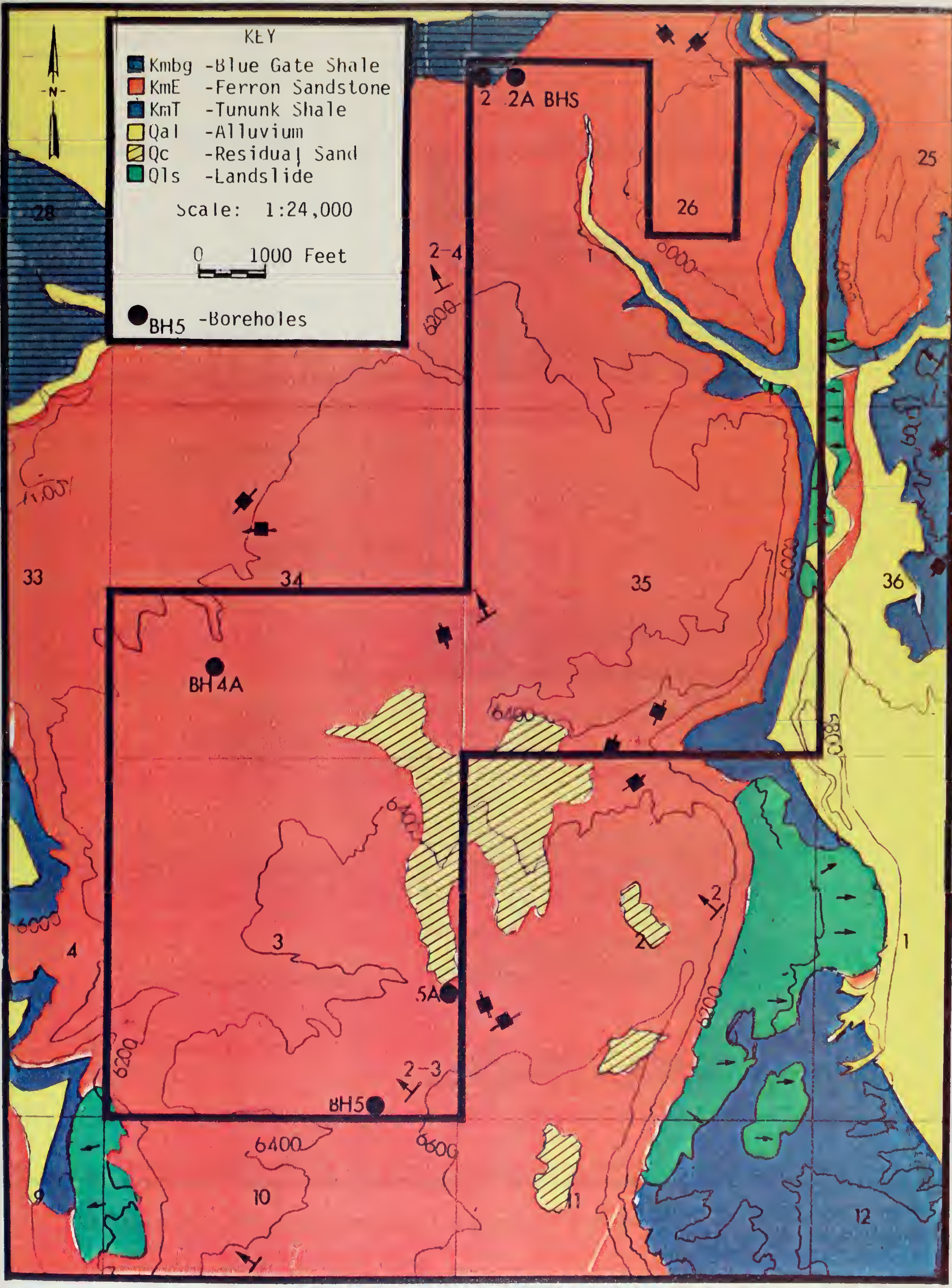


Figure 19. Geologic Map of Emery Test Site, Showing Bore Hole Locations.

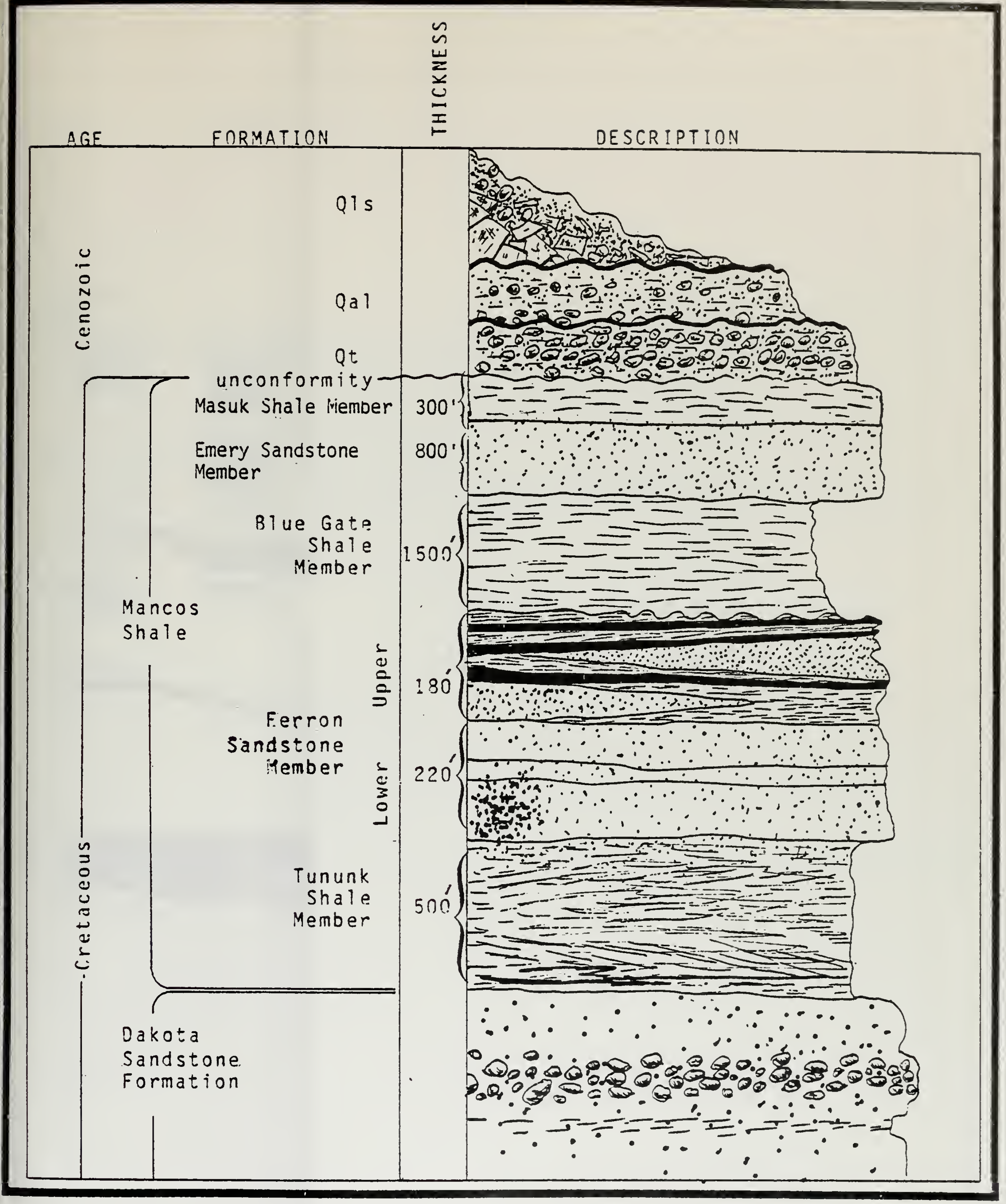
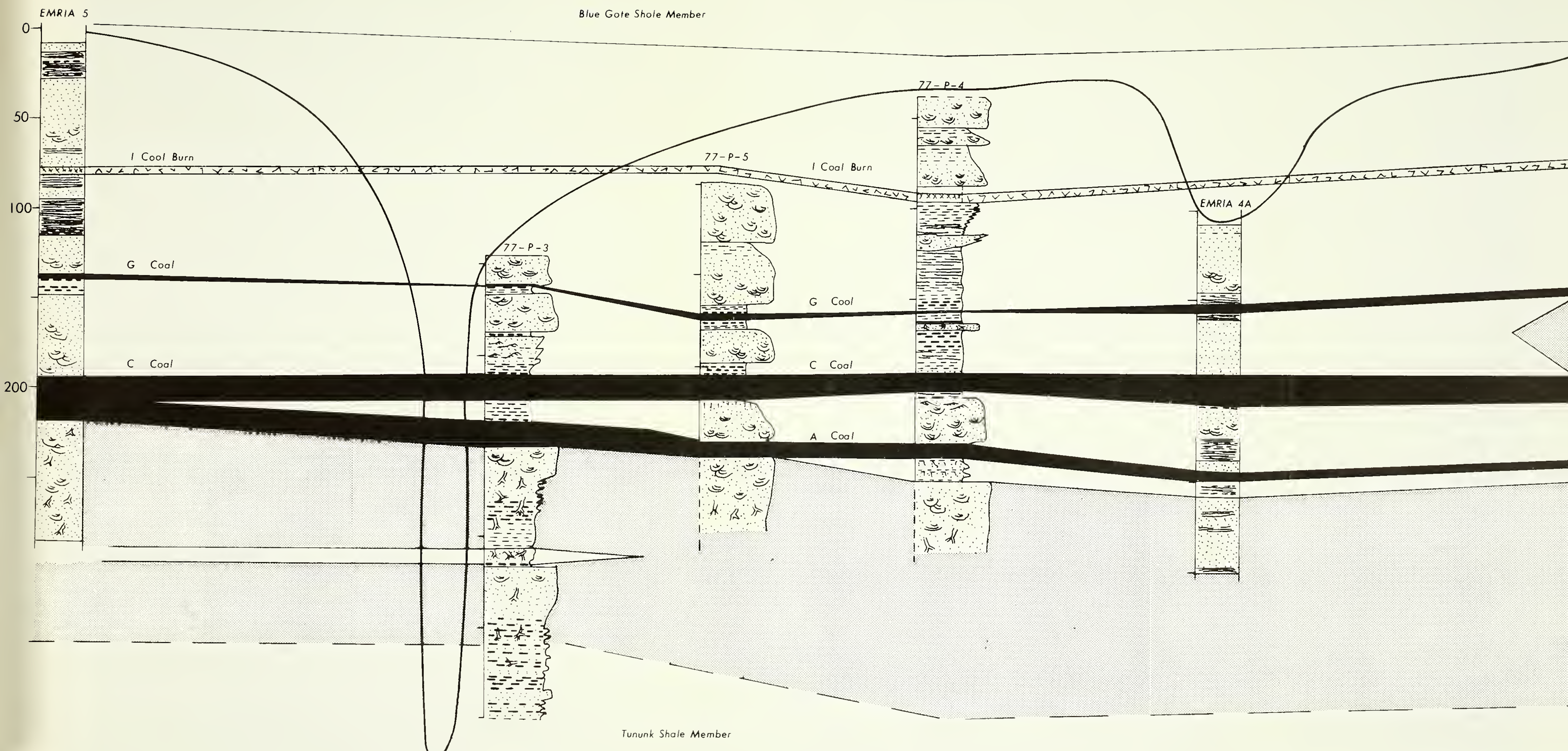


Figure 20 . Generalized Stratigraphic Column.


Alluvial and Delta Plain
rocks undivided: ss, sltst, clyst
lateral variation great. unpredictable,
particularly in alluvial rocks
Coal (identified according to letter scheme)
of Lupton, 1916
Ash (burned coal) - thickness exaggerated
Delta Front / Marine Sequences
laterally continuous, primarily ss,
minor sltst, clyst
EMRIA 5
EMRIA 5A
77-14
77-P-2
77-P-1
77-3
77-8
0
50
100
200
J Coal
I Coal
G Coal
G Coal Equiv
C Coal
A Coal
200
150
100
50
0
FEET
Miller Canyon
Present Erosional Surface
Along Line of Section (approx.)
0
1000
2000
3000
4000
FEET

Figure 21. -74-



EMRIA 5
Blue Gate Shale Member
0
50
100
200
77-P-4
77-P-5
I Coal Burn
I Coal Burn
EMRIA 4A
77-P-3
G Coal
G Coal
C Coal
C Coal
A Coal
Tununk Shale Member

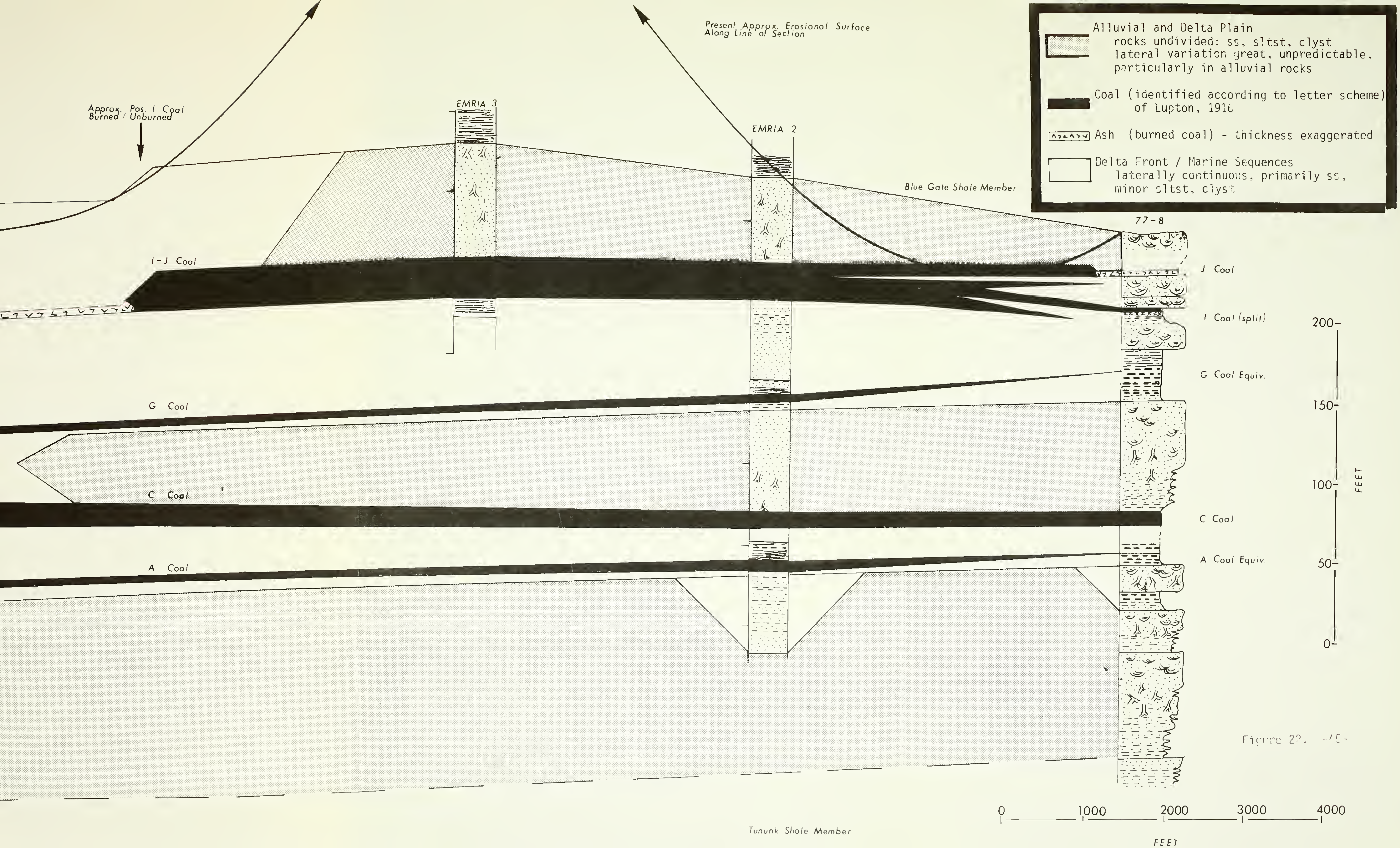

Alluvial and Delta Plain rocks undivided: ss, sltst, clyst lateral variation great, unpredictable, particularly in alluvial rocks
Coal (identified according to letter scheme) of Lupton, 1910
Ash (burned coal) - thickness exaggerated
Delta Front / Marine Sequences laterally continuous, primarily ss, minor sltst, clyst
Present Approx. Erosional Surface Along Line of Section
Approx. Pos. I Coal Burned / Unburned
EMRIA 3
EMRIA 2
77-8
Blue Gate Shale Member
I-J Coal
J Coal
I Coal (split)
G Coal
G Coal Equiv.
C Coal
C Coal
A Coal
A Coal Equiv.
200
150
100
50
0
FEET
0
1000
2000
3000
4000
FEET
Tununk Shale Member

Figure 22. -75-

amount of erosion of the contact, disconformable with the overlying Blue Gate Shale member. The underlying marine Tununk Shale member averages about 500 feet in thickness, is black or bluish-gray, and erodes easily, forming lowlands or slopes between more resistant units. The shale is locally silty and sandy in the upper and lower portions and grades into the overlying Ferron Sandstone. Near the lower boundary the shale is locally carbonaceous.

The overlying Blue Gate Shale member is a saline bluish-gray silty mudstone. This eroded to form the southern extension of Castle Valley. The unit exists as a veneer or as isolated outcrops throughout the study area, locally covering the underlying resistant Ferron Sandstone. The Blue Gate is distinguished in the field by its irregular "badland" erosion topography and the incompleteness of its vegetative cover.

Engineering Geology

The stripping of overburden to exploit the coal resources in the Emery study area is susceptable to one primary geologic hazard, the collapse of excavation benches in the vicinity of surface fractures. Based upon the large volumes of gas encountered in drilling near the burn zone, there are potential hazards in exposing trapped gas (methane) during stripping. Flooding by released groundwater apparently is a negligible hazard in the area.

Surface fractures are common and locally abundant in the area and derive from three sources: (a) the natural stress-fracturing of brittle surface rocks (Figure 23), (b) tension fields produced by subsidence of previously mined underground seams, which may be relieved along natural joint features as at the old Browning Mine (Figure 24), and (c) tension fields resulting from subsidence caused by subsurface burning of the coal (Figures 24 and 25). These collapse hazards are compounded by the regional physiography of steep cliffs and plateaus.

The engineering usefulness of the local lithologic materials is limited. Roads and level sites are easily graded into the soft or crumbly shale and sandstone, but there is no suitable aggregate source in the overburden. The sandstone readily weathers and decays to sand after only one season. During wet seasons the shale similarly weathers to a sticky mass. Figure 26 presents an analysis of the feasible angles of repose for various spoil slopes.

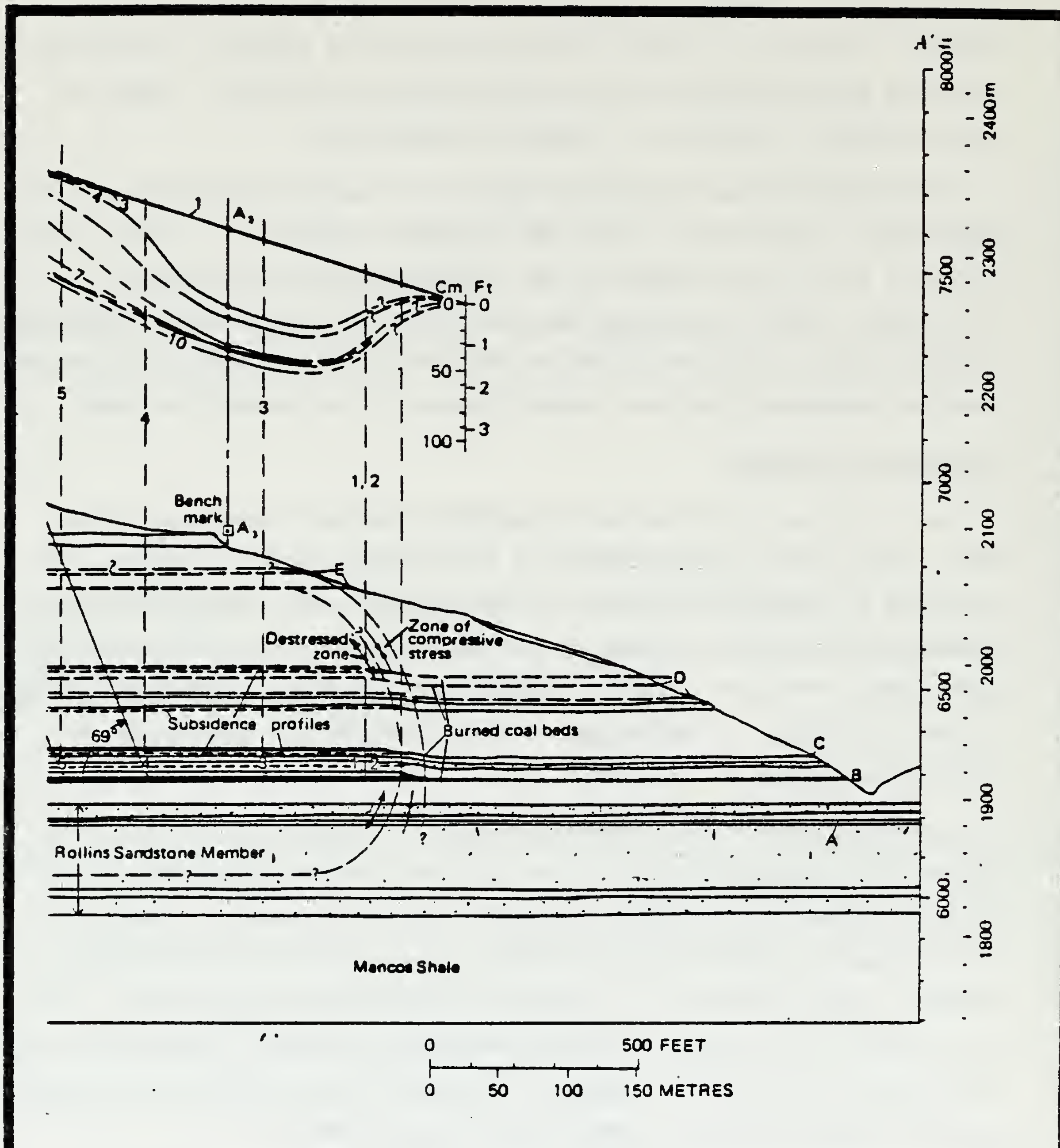


Figure 23. Stresses in Overburden Analogous to Emery Site Conditions. (Note Zone of Compressive Stress)

Figure 24 . Natural Fracturing of Ferron Sandstone Above Simulated Strip Mine Site on Christiansen Wash.

Figure 25 . Surface Jointing Cracks in Ferron Sandstone Over Subsidence Area.

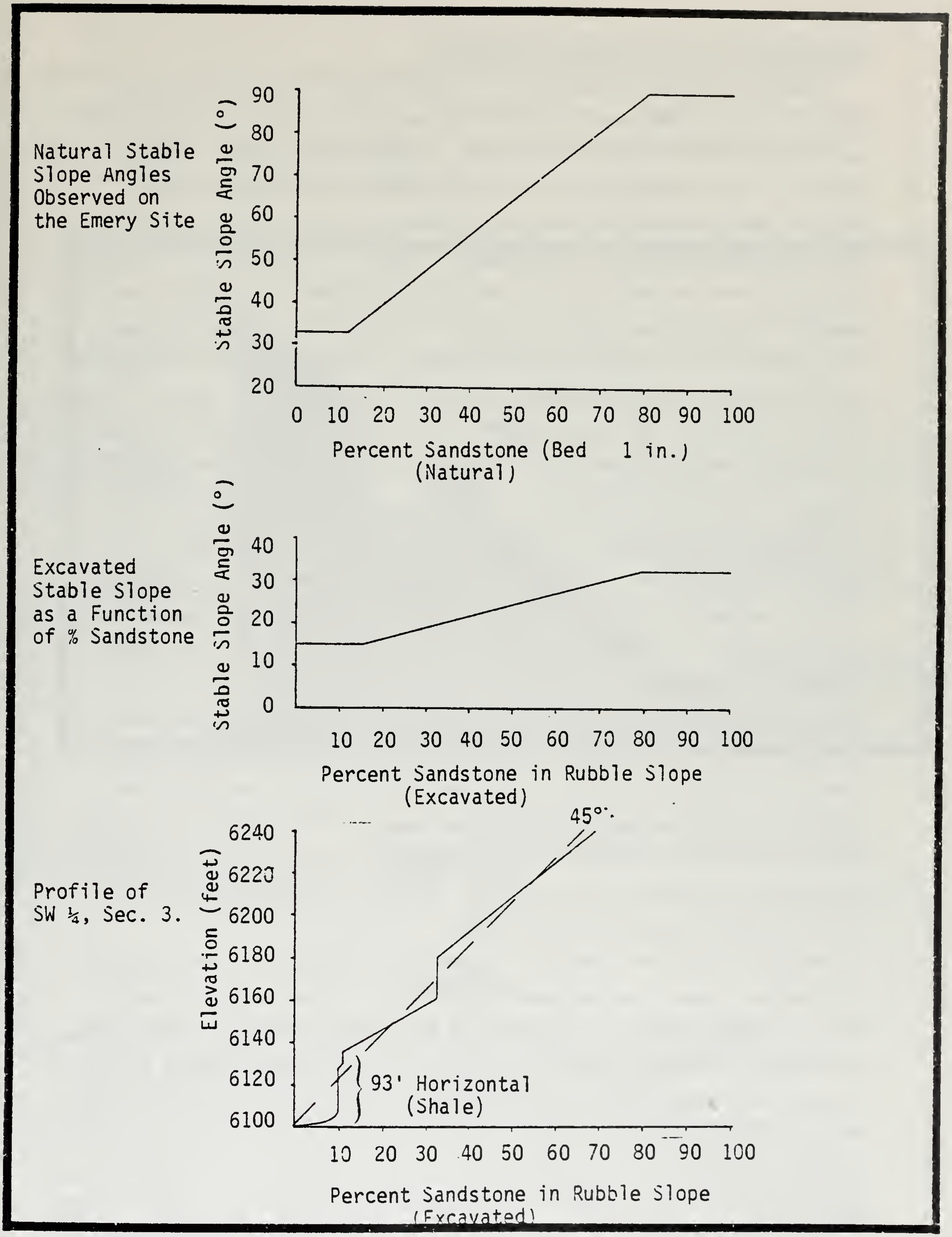


Figure 26. Slope Stability Consideration.

Landslides and Slope Failure Potential

A common practice in cut and fill operations is to divert water, such as in our case that derived from dewatering coal, to the spoil, so as to promote rapid infiltration. This avoids washing off of top soil, and formation of rills and gulleys, but might create a serious mass overloading problem (Figure 27). The result may vary from slow earth flows to rapid debris flows. In general, this practice should be avoided particularly where such a flow, if produced, would endanger right-of-way, block streams or canals and cause flooding. The production of undesirable geochemical leachates would also result, as discussed in the overburden section of this report. Seismic events could, of course, act as a trigger for such slides, or even rock falls of blocks already undermined or unstabilized by strip mine operations.

Summary

The Masuk Shale member is the uppermost member of the Mancos Formation. Together with the Emery Sandstone it forms the highest resistant benches on the west side of Castle Valley at the base of the Wasatch Plateau. The unit is 800 feet thick, light yellowish-gray and locally carbonaceous.

The Cenozoic deposits comprise Quaternary landslides, alluvium, and older remnant terraces. The alluvium and terrace deposits are crudely stratified, poorly sorted sands and gravels occupying the valley sides and bottoms, and in the lower valleys, serve as the perennial aquifer for the area. The landslide deposits are local accumulations of coarse to fine angular boulders and cobbles from the steep cliffs of the resistant strata.

The local structure consists of gentle tilting of all the strata 2-4 degrees toward the northwest conforming to the western flank of the San Rafael Swell on the east and the trend of the Wasatch Plateau on the west. A major fault system passes through the western margin of the area approximately corresponding to the eastern boundary of the Wasatch Plateau known as Joe's Valley fault zone, which is visible as a sharp vegetation break to the west in the cover satellite photo. It consists of an area 2 miles wide of north-south trending normal faults 75 miles long creating a line of narrow grabens downthrown approximately 2800 feet interrupting the regular attitude of the rocks. No faults directly affect the study site .

Figure 19 summarizes the existing landslide potential of the area (Qls). Coupled to this must be the concept of distress due to built up compressive stress from the coal burning subsidence. These areas too must be recognized. Finally the methane gas evolution evidently from the coal burning, must also be considered.

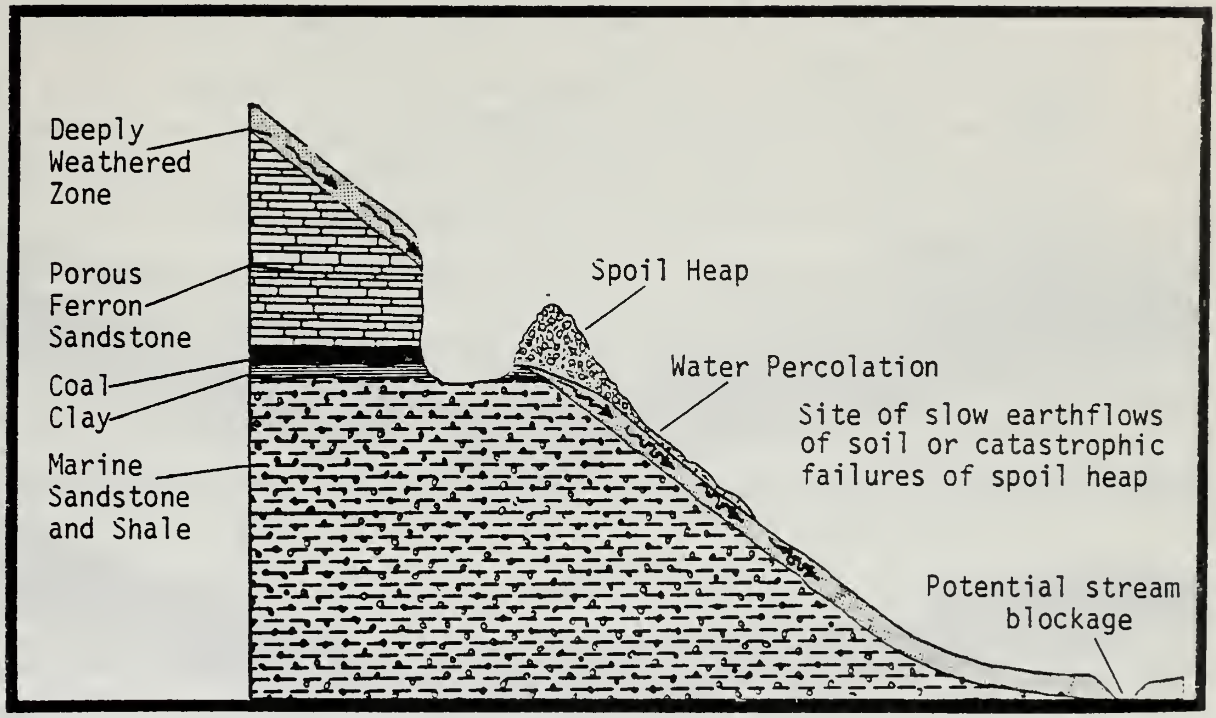


Figure 27 Potential Overloading and Water Percolation May Cause Slow Earthflows, Debris Slides, and Debris Flows.

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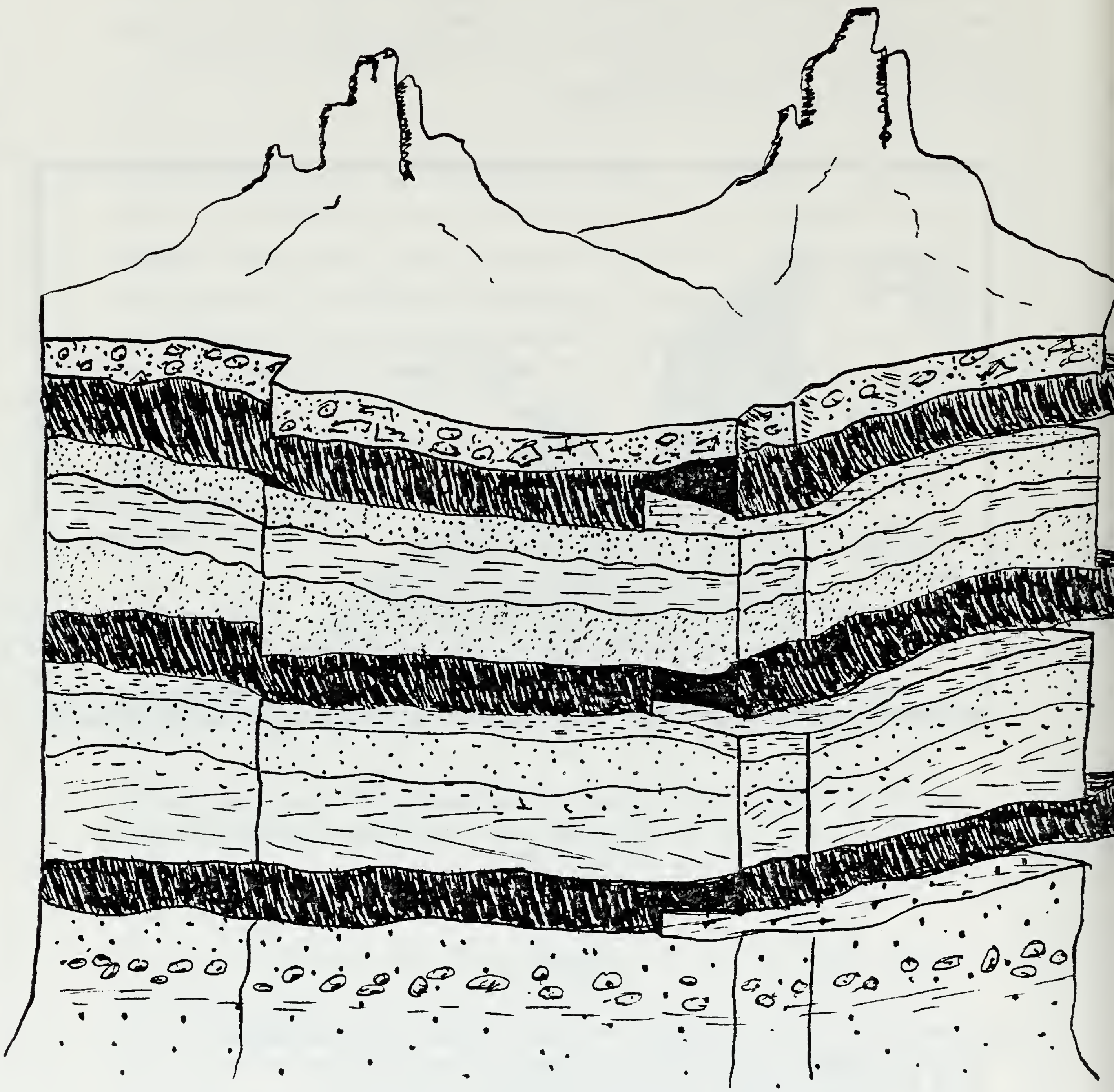


COAL RESOURCES

The Emery Coal Field

The Emery coal field has been estimated by Doelling (1977) to contain a minimum of 1.4 to 2 billion tons of coal (see Table 7). Of this, 45% is considered recoverable (630 to 900 million tons), and 140 million tons are considered strip-minable. As shown in Figure 28, the field lies east of the southern part of the Wasatch Plateau.

The field (Figure 28) is 25 miles long and 2 to 10 miles wide, tapering southward. The latitude of Emery township is the approximate northern limit of economic coal. The coal thins and disappears to the north, as shown in the fence diagram (Figure 22) the width of the field is limited by an erosional east escarpment and the Joe's Valley-Paradise fault zone to the west. Extreme dips on the coal beds are 2 to 12 degrees, but more generally dips range from 4 to 7 degrees. Jointing fractures are evidently the only impediment to mining.

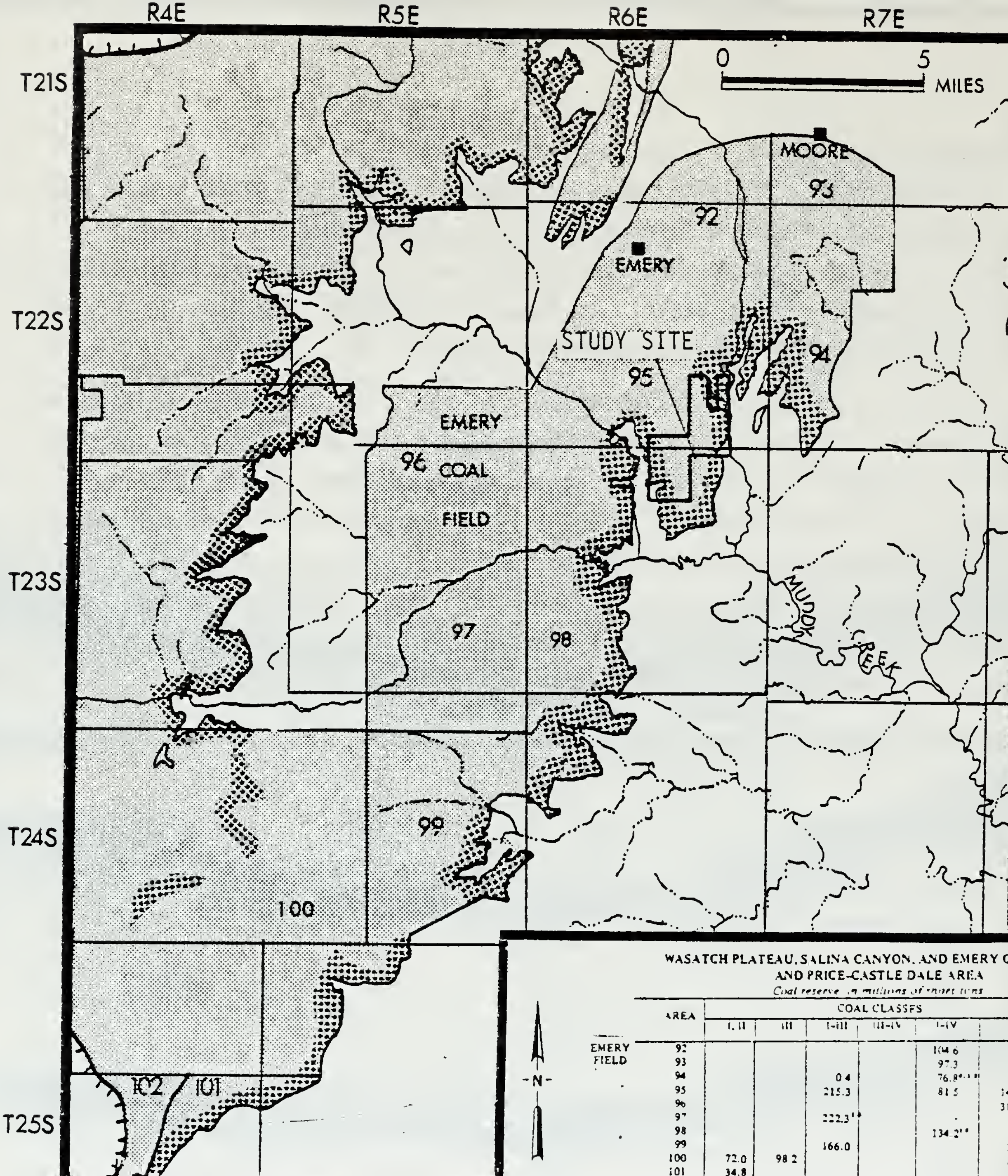
Table 7

Emery Field - Coal Seams

Emery Field Seams	Avg. Devel. Thickness	Max. Exposed Thickness
M bed (south)	4 to 6 feet	10. feet
K and L beds	thin	4.0
* J bed	4 to 10	12.0
I bed	5 to 10	13.0
H bed	thin	5.0
G bed	thin	2.0
F bed (east central)	5 to 7	7.5
D and E beds	thin	3.0
C bed (north)	5 to 8 feet	12.0
B bed	thin	2.0
A bed	4 to 12	13.0

*Locally, I and J beds are merged.

Coal not consumed at a local power plant, must be trucked 45 miles to Salina or northward 50 miles to Wellington to lines of the Denver & Rio Grande Western Railroad for out-of-state shipments. One producer has indicated plans for a 1,000,000 tons per year strip mine to serve midwest markets. Local power plants are projected to consume 9 to 10 million tons of coal annually from the Emery, southern Wasatch Plateau or Henry Mountains coal fields.



3,000-foot depth of potentially mineable coal

Coal, potentially mineable, reserve for area (28) shown in tables

Coal outcrop, dashed where concealed, uncertain, or approximately located, stippled pattern behind outcrop

WASATCH PLATEAU, SALINA CANYON, AND EMERY COAL FIELDS, AND PRICE-CASTLE DALE AREA

Coal reserve in millions of short tons

	AREA	COAL CLASSES						SUBTOTAL (BY AREA)
		I, II	III	I-III	III-IV	I-IV	IV	
EMERY FIELD	92					104.6		104.6
	93					97.3		97.3
	94			0.4		76.8[4,5,9]	1.0	78.2
	95			215.3		81.5	144.5	441.3
	96						381.6	381.6
	97			222.3[14]				222.3
	98					134.2[15]	0.2	134.4
	99			166.0			10.2	176.2
	100	72.0	98.2				19.8	190.0
	101	34.8						34.8
	102	Reserves not quantified, data lacking.						
SUBTOTALS, BY CLASS		106.8	98.2	604.0		494.4	557.3	
TOTAL, ALL CLASSES								1,860.7

[1] Coal bed lies under lake and is probably faulted.
[2] Coal occurs in a more complex geologic setting and is more deeply buried here than to the south, with coal of area generally north-dipping and faulted.
[3] Based on inference that coal is probably like that to the east in persistence, thickness, and tonnage.
[4] Includes some coal thinner than 4 feet.
[5] Some coal may not be minable.
[6] Probably more than 100 000 000 tons.
[7] May not be minable due to faults in area, and locally coal may be deeper than 3,000 feet.
[8] Average thickness is less than 4 feet over much of the area.
[9] Possibly should be classed as I-IV.
[10] Recent drill hole data indicates that this estimate may be too high.
[11] Chiefly classes II-IV.
[12] Plus noted unquantified amounts could possibly add 10-20 percent to the tabulated tonnage.
[13] This quantity may be slightly too low.
[14] Mainly class III.
[15] Includes some 3-foot thick coal.
[16] Coal nowhere exposed. Coal bed is at a much lower stratigraphic position than the minable coal farther west.
[17] Coal may or may not be present in minable quantities, but deep burial generally would preclude mining except perhaps between areas 103 and 106.

COAL CLASSES[1]

Class I — *Measured reserves* based on adequate exploration data; properly correlated; control no more than one-half mile apart.

Class II — *Indicated reserves* based on geologic measurement supplemented by limited drill-hole information and limited to 1½ miles from a control point.

Class III — *Inferred reserves* based on geologic inference and projection of the habit of the coal beyond 1½ miles from control points.

Class IV — *Potential reserves* based on geographic and geologic position with little surrounding data, includes coal covered by no more than 3,000 feet of overburden.

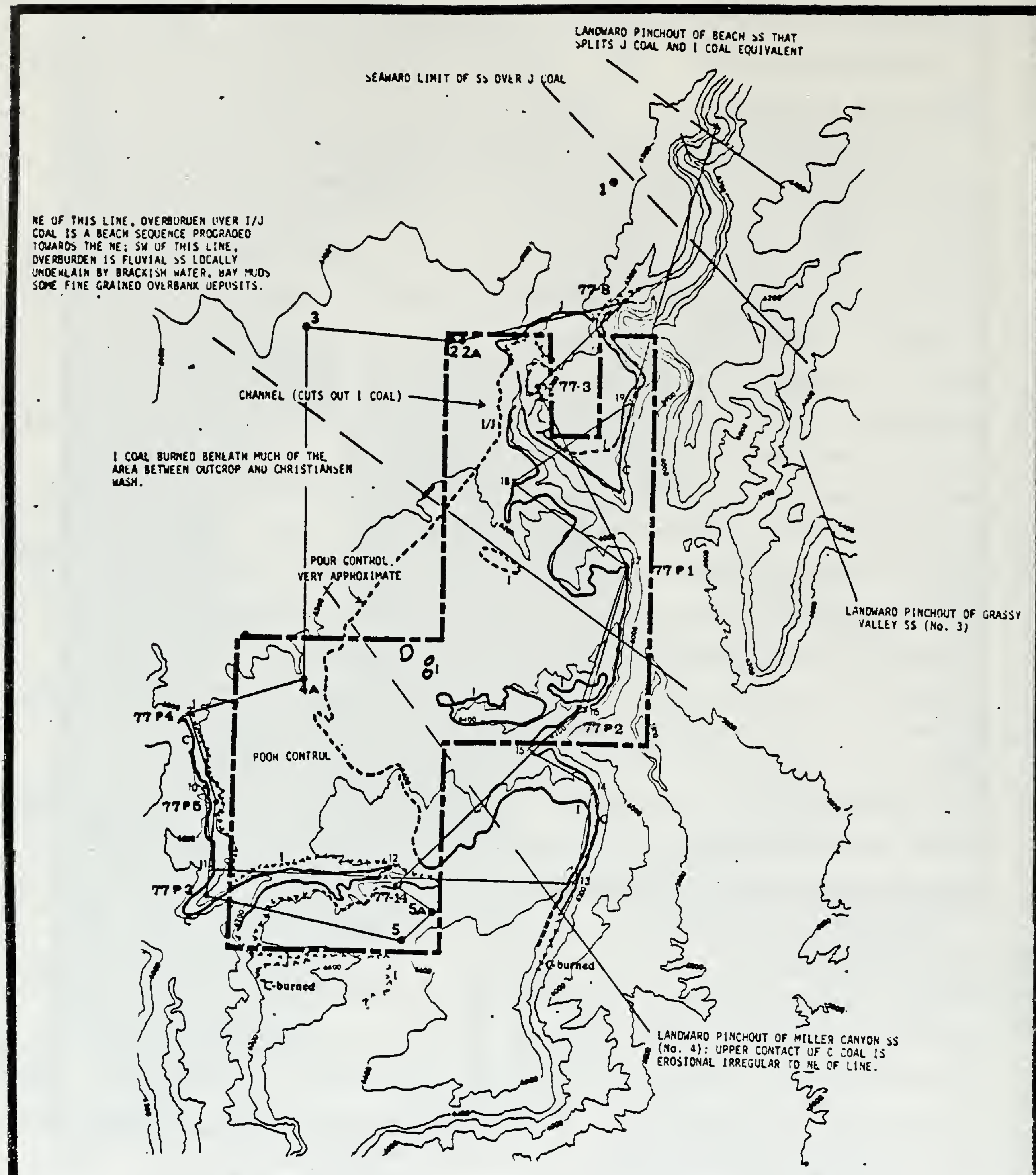
Most of the coal reserve is based on surface measurements which are not always as reliable as the drill. The reserve commonly is underestimated because surface measurements usually are smaller than thickness penetrated by drilling. Class I and II figures are combined in these reports, no attempt was made to separate the more reliable figure. The first three reserve classes constitute the principal reserve and more nearly reflect the current potential. The reserves include only coal beds that average 4 feet or greater thickness and are covered by less than 3,000 feet of overburden except where otherwise noted. Less than 50 percent of the total reserves are economically mineable.

[1] The division of coal into four classes generally follows that described by Doelling (1972c, p. 549).

Figure 28. Coal Resources Map (USGS 1979)

Study Site Resources

A recent update of the Emery coal field geographic distribution and reserve estimates are presented in Figure 28, adapted from the Central Utah EIS (USGS, 1978). From our own core data, the strippable coal resources on the study site are depicted in more detail in Figures 29 and 30 for 100 and 200 foot depth capabilities. They are considered a typical subset of a larger strippable resource lying to the NW in a belt oriented NE-SW. A three dimensional computer model of the coal resources is presented in Figures 31, 32, 33, and 34. This computer model was employed to depict the complexity of the coal resource, and treat the twin competing processes of erosion and underground coal fires which have removed a portion of the resources which would be inferred from a simple stratigraphic interpretation of the numerous outcrops. The figures present four aspect views of the coal resources on site with each of the significant coal layers depicted in relative correspondence to their actual thickness. The cells with residual coal are filled in colors corresponding to the coal layer they represent. Figure 35, is an isopach map of coal overburden. This gives the depth to strip, where coal is present. Both 100 and 200 foot overburden lines are presented on the coal distribution map based essentially on the I-J seam, but note that both the deeper C and A seams are recoverable as well under these ground rules. To the north, along the NW-SE line, indicated in Figure 29, along Miller Creek, the coal splits up and pinches out. This represents the practical limit of coal resources to the north from current data. Evidently these coals have a higher sulfur content as well (e.g. viz Table 8). The C coal pinches out to the north in the coal cliffs east of Muddy Canyon. To the south it thins markedly in the vicinity of Interstate 70, pinching out just north of the location of bore hole #6. Hence both A and C coals may be exploitable SE of the study area. In the region, maximum coal thickness occurs within a distance of about 6 miles landward of the pinch-out of the delta front sandstone units (Ryer, 1979). First and second delta cycles are evident in outcrops along the N. Quitchupah, followed by a layer of channel sands. In the northern part of Quitchupah Canyon, the A and C coals are separated by 20 ft. of channel sandstone, but at bore hole #5 the two coals merge in a fashion similar to the merging of the I-J seams to the north. The total coal analyses presently available from the USGS (Affolter, Hatch, Ryer, 1979) are for bore holes 1, 5, 2, and 2A.



KEY

- • Outcrop Locations
- —x— Fence Diagram Track
- ● Bore Holes
- —— Strippable Coal
- (I) Coal Layer =(letter)
- ········ Burned Coal
- ▬ ▬ ▬ EMRIA Site

Figure 29. Cross-Section and Bore Hole Location Map With Respect to Strippable Coal.

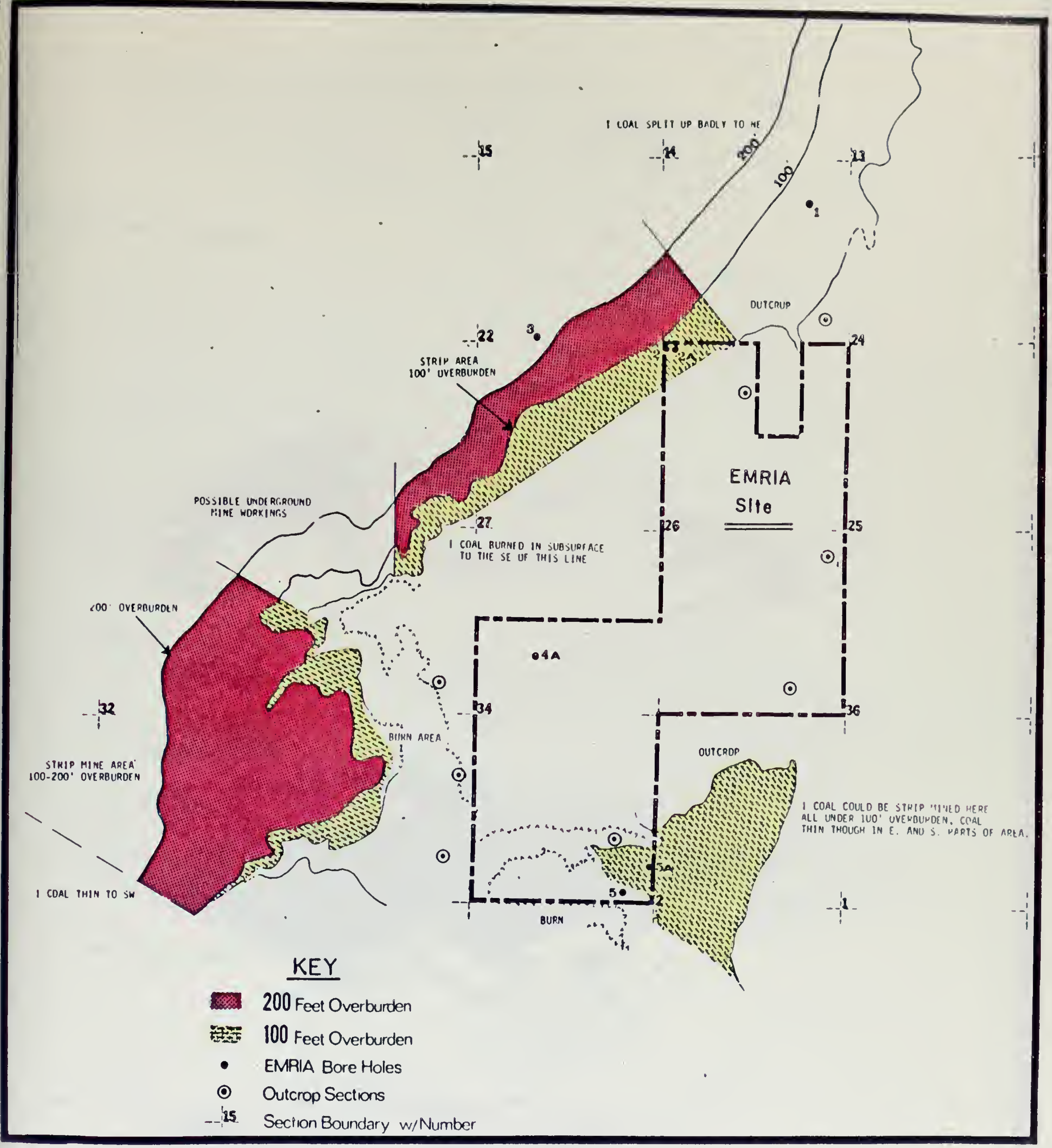


Figure 30. Strippable Coal and Burn Areas

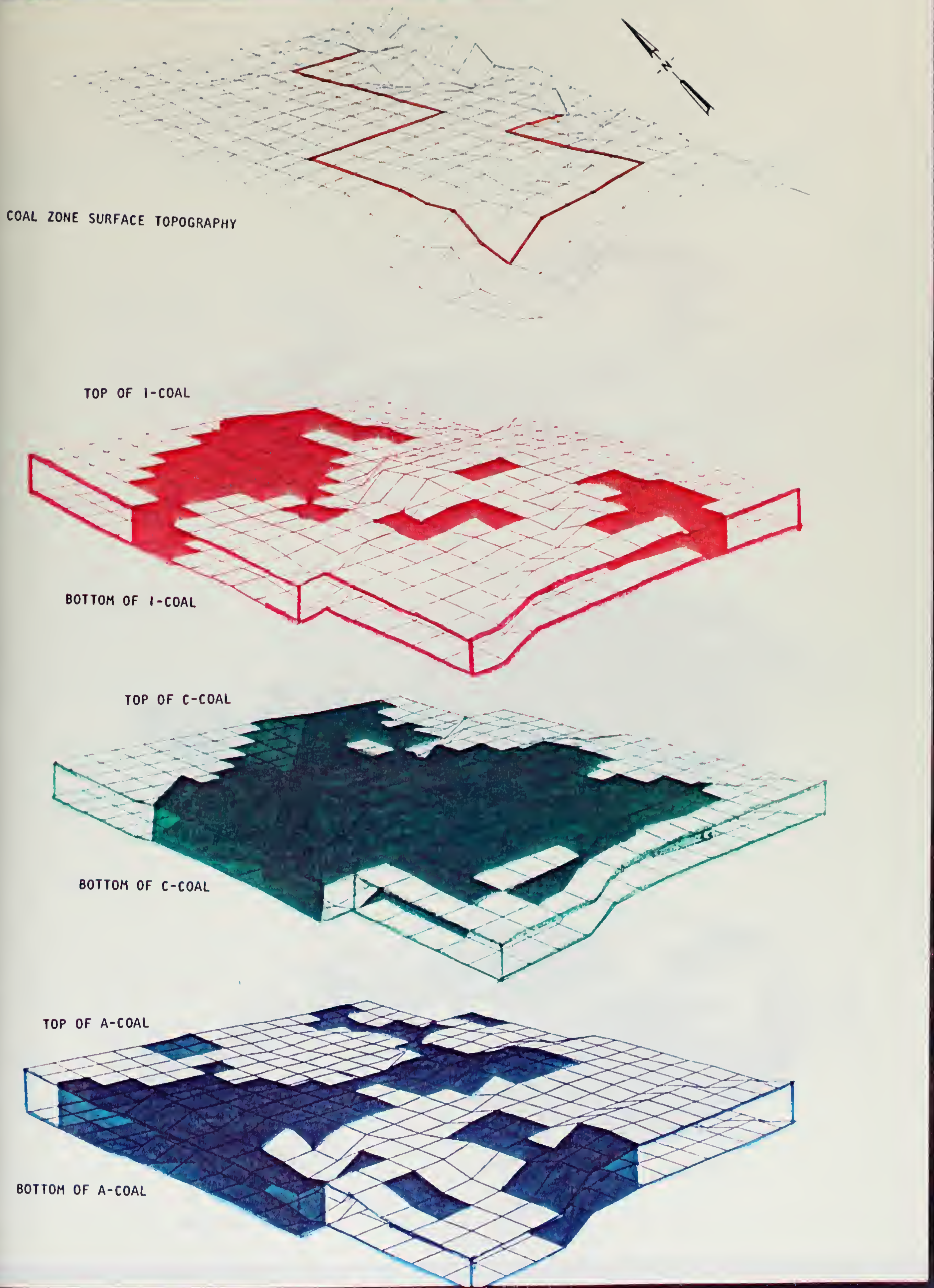


Figure 31. Perspective View Towards 45° Emery Study Site.

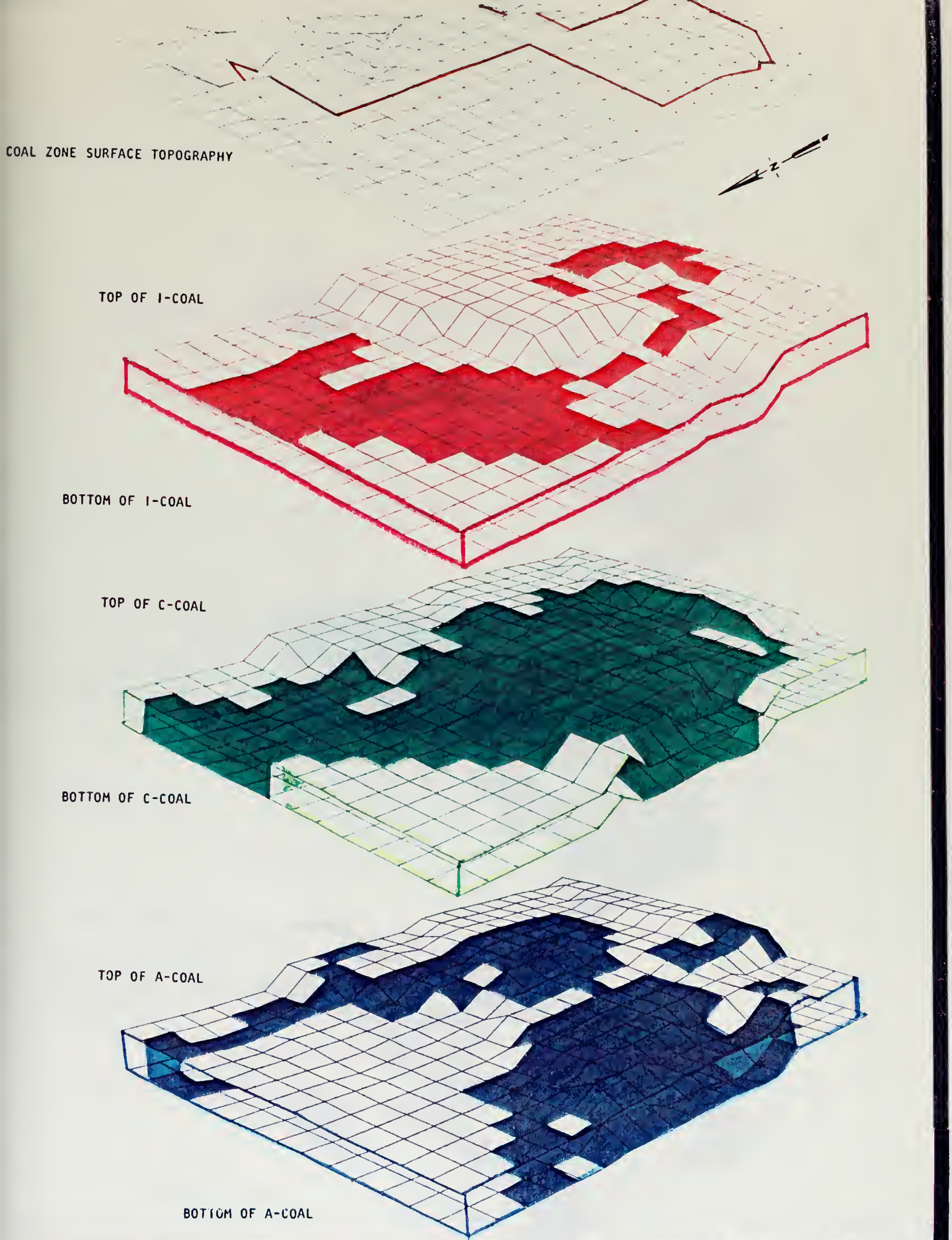


Figure 32. Perspective View Towards 135° Emery Study Site.

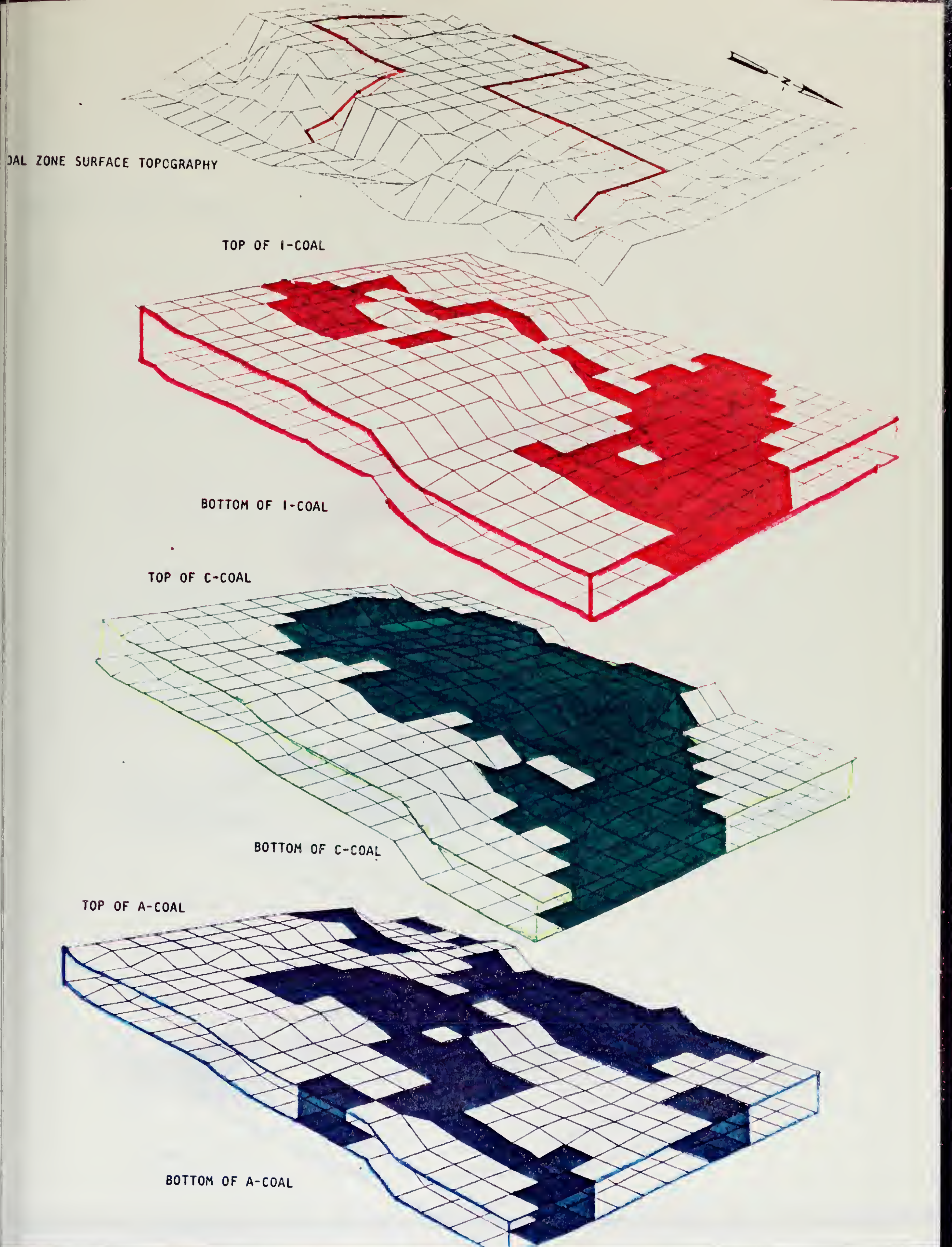


Figure 33. Perspective View Towards 225° Emery Study Site.

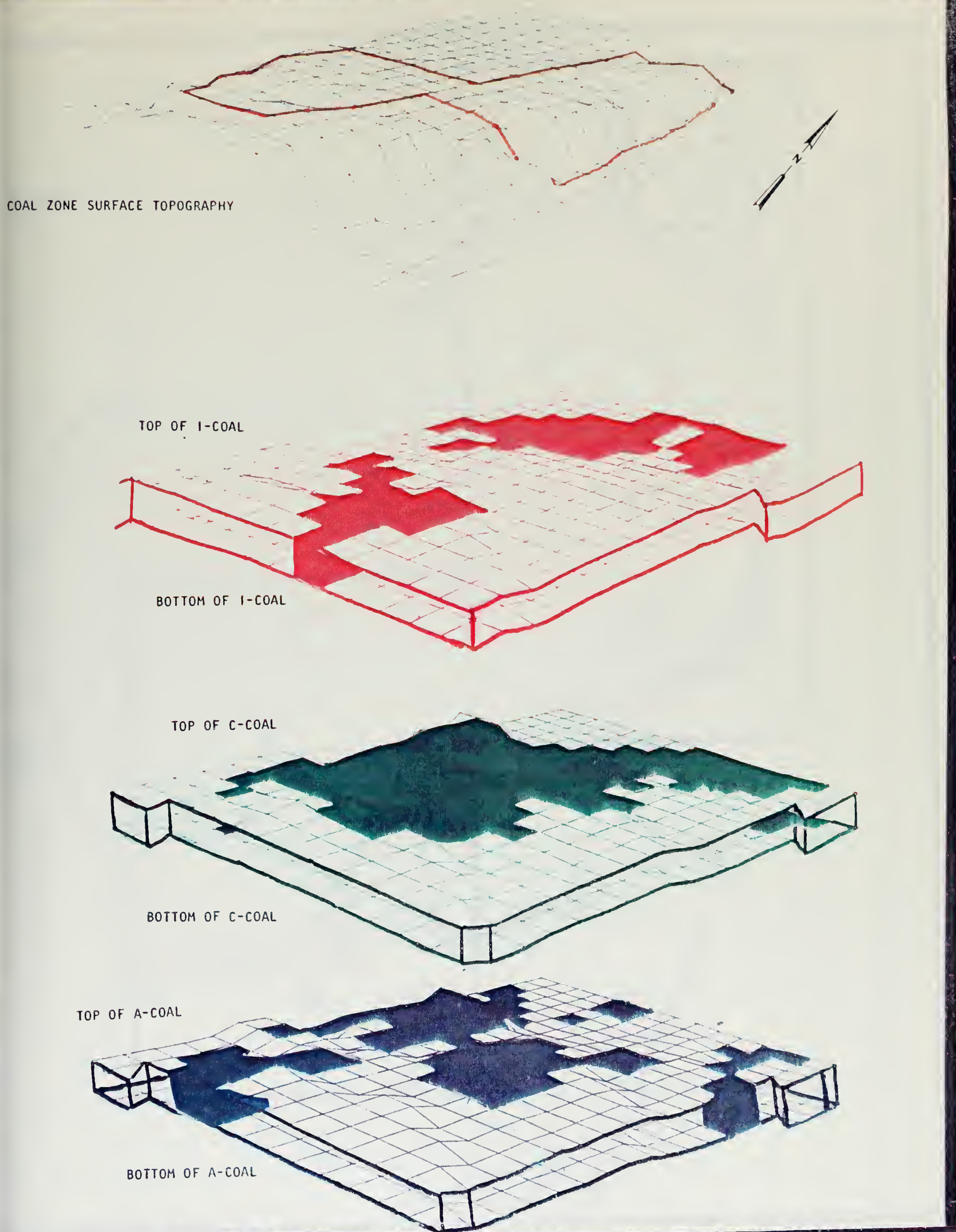


Figure 34. Perspective View Towards 315^0 Emery Study Site.

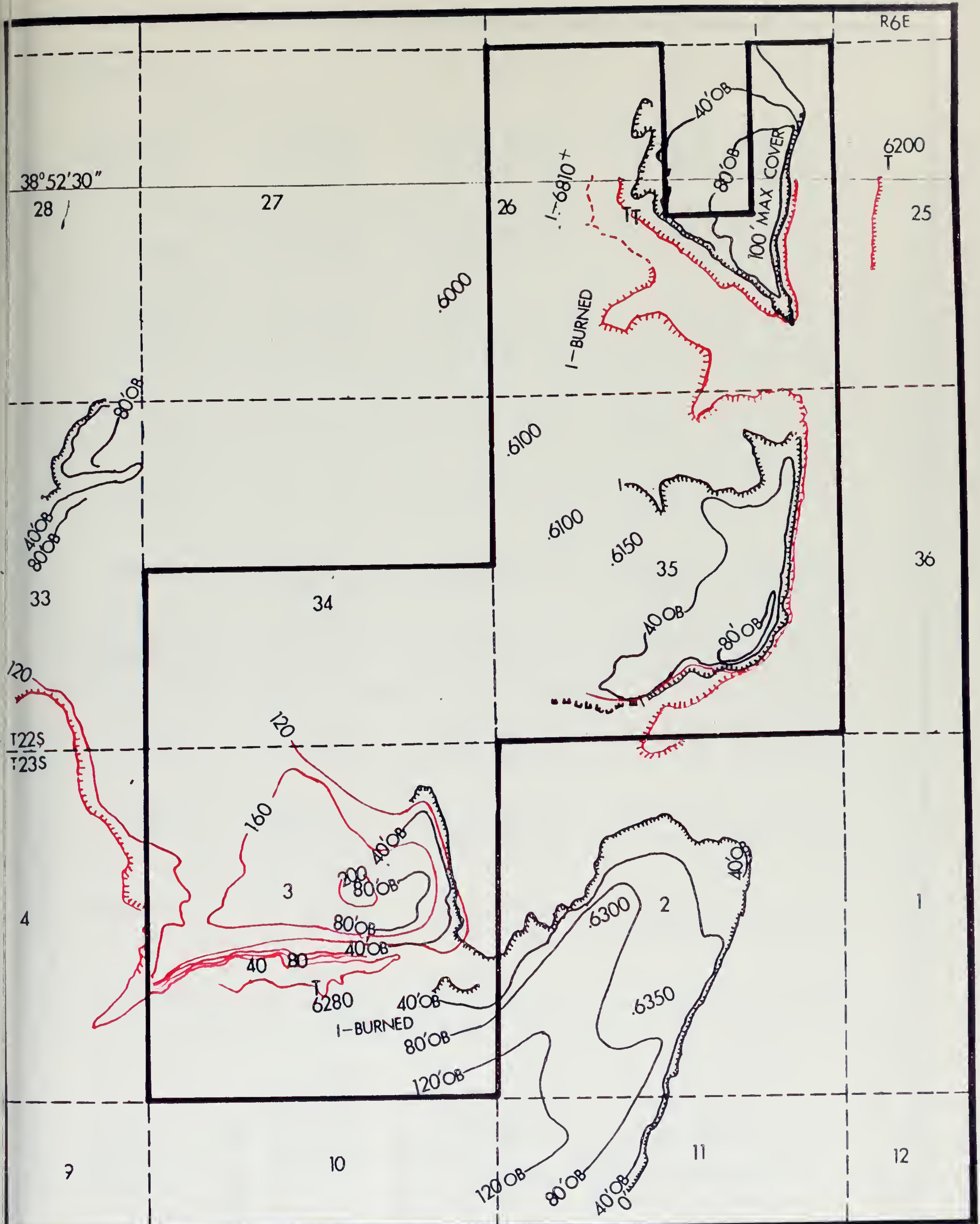


Figure 35. Strippable Coal Overburden Isopach Map (overburden depth in feet)

Table 8.

COAL ANALYSIS	Proximate				Ultimate Analysis						Heat Value BTU/lb.	Free Swelling Index
	Moisture	Volatiles	Carbon	Ash	Hydrogen	Carbon	Nitrogen	Sulfur	Oxygen	Ash		
Borehole 2A												
83.8 to 85.0 ft.	3.5	41.4	49.8	5.3	5.7	73.8	1.3	1.8*	12.0	5.3	13139	-
98.1 to 99.0 ft.	2.8	36.4	44.4	16.4	5.0	64.1	1.2	2.2*	11.2	16.4	11508	-
239.0 to 240.0 ft.	2.6	35.0	44.2	18.2	4.6	63.7	1.2	.7	11.6	18.2	11125	-
Borehole 4A												
53.2 to 56.8 ft.	3.6	39.4	40.2	16.8	5.1	62.5	1.1	3.6*	10.8	16.8	11164	1.5
93.9 to 99.5 ft.	3.8	36.1	39.6	20.5	4.8	58.9	1.0	2.1*	12.7	20.5	10527	1.0
101.2 to 108.7 ft.	4.0	37.2	43.8	15.0	5.1	64.3	1.1	.7	13.7	15.0	11394	1.0
144.0 to 149.0 ft.	3.7	40.2	46.8	9.3	5.5	70.0	1.2	1.0	13.0	9.3	12503	1.0
Borehole 5												
137.5 to 139.5 ft.	8.8	36.6	39.2	15.4	5.1	57.2	1.1	2.3*	18.9	15.4	10084	.0
199.5 to 202.3 ft.	4.1	38.8	44.1	13.0	5.2	65.9	1.1	.9	13.8	13.0	11710	1.0
204.0 to 208.3 ft.	4.5	37.9	42.0	15.6	5.1	63.3	1.1	.5	14.3	15.6	11206	1.0
208.5 to 211.8 ft.	5.4	37.7	45.6	11.3	5.2	66.9	1.2	.6	14.8	11.3	11799	1.0
212.9 to 215.7 ft.	5.1	38.3	45.2	11.4	5.3	66.8	1.2	.9	14.4	11.4	11720	1.0
216.0 to 219.0 ft.	3.9	38.2	43.3	14.6	5.2	65.6	1.1	.7	12.7	14.6	11613	1.0

*excessive sulfur value

Table 8. (cont.)

	Proximate				Ultimate Analysis							
	Moisture	Volatiles	Carbon	Ash	Hydrogen	Carbon	Nitrogen	Sulfur	Oxygen	Ash	Heat Value BTU/lb.	Free Swelling Index
Borehole 6												
54.2 to 56.9 ft.	5.8	39.4	41.8	13.0	5.2	62.2	1.2	3.4*	15.1	13.0	11128	0.5
80.9 to 81.9 ft.	5.0	35.0	32.1	27.9	4.6	50.3	1.1	3.9*	12.3	27.9	9006	0.5
109.3 to 110.7 ft.	6.1	37.6	44.8	11.5	5.4	65.4	1.3	.8	15.6	11.5	11458	0.5
111.3 to 114.5 ft.	6.0	39.4	47.9	6.7	5.5	67.3	1.3	.4	18.8	6.7	12250	0.5
114.5 to 117.7 ft.	6.7	40.3	48.0	5.0	5.7	69.9	1.3	.5	17.7	5.0	12426	0.5
118.7 to 123.2 ft.	5.7	37.6	43.8	12.9	5.2	63.4	1.1	.9	16.5	12.9	11266	0.5
205.7 to 206.8 ft.	5.2	40.3	47.9	6.6	5.7	68.6	1.3	1.4*	16.4	6.6	12299	0.5
243.0 to 243.7 ft.	5.0	40.7	46.9	7.4	5.6	68.1	1.3	1.9*	15.8	7.4	12191	0.5
286.3 to 293.3 ft.	5.1	38.5	45.0	11.4	5.4	65.7	1.4	.6	15.5	11.4	11684	0.5

*excessive sulfur value

Proximate Analysis - involves the determination of four constituents: (1) water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cakelike residue that burns at higher temperatures after volatile matter has been driven off.

Ultimate Analysis - involves the determination of carbon and hydrogen as found in the gaseous products of combustion, the determination of sulfur, nitrogen, and ash in the material as a whole, and the estimation of oxygen by difference.

The I coal may indicate a sulfur problem with peak values up to 6%, but more commonly 3-4% sulfur is found at the top of the I seam. To meet EPA standards ($<$ 1% sulfur) coal rinsing and blending may be required.

Summary

As shown in Table 8, 6 of the 13 coal beds are over 4 ft. thick. Seventy-six percent of the reserve is estimated to be under less than 1000' of cover (Doelling, 1977). The seams were given letter designations by Lupton (1916) ascending from A to M. The host formation is the Ferron Sandstone member of the Mancos Shale, which ranges in thickness from 300 to 900 feet, generally thickening north to south. The base of the unit is a massive cliff-forming sandstone 80 to 140 feet thick above which are delta plain beds containing the first sequence of coal beds A to F (Lower Group or Zone of Doelling, 1972). Of these, the A bed is more important economically to the south and the C bed to the north. Overlap occurs in the central part of the field, essentially at the southern end of the study area. Above the Lower Zone is an 80 to 200 foot interval that is mostly sandy containing the normally uneconomical F and G coal seams. The Upper Zone of Doelling (1972) contains beds H to M. The merged I and J beds are of greatest importance to our study, but are extensively burned on the site. The separation is minimal in many areas making one very thick seam (up to 25 feet). Overburden in the study area is shallow over these beds, permitting strip-mining of the I-J seam as noted. In this context, the A-C beds could be taken in conjunction as well. The uppermost M bed develops to economic thickness locally and in many areas could be taken by surface mining methods, but is eroded out on the study site.

Coal quality data are presented in Table 8 (Hatch, 1979). Most analyses, published and elsewhere, have been based on samples taken from mines operating in the I bed thus presenting some bias (e.g. Lupton, 1916; Doelling, 1972, 1977; USGS, 1978). Samples collected at outcrop would present an unrealistically low Btu/lb. estimate. An operating mine average is 12,000 Btu/lb. on an as-received basis. The coal samples taken in this study were somewhat lower; about 11,000 Btu/lb. Sulfur content of coals varies considerably from area to area and from seam to seam with an as-received range from 0.31 to 4.6% and most falling between 0.5 and 2.5%, but in some cases, as noted, exceeds accepted levels (i.e. 1.8 to 3.9%).

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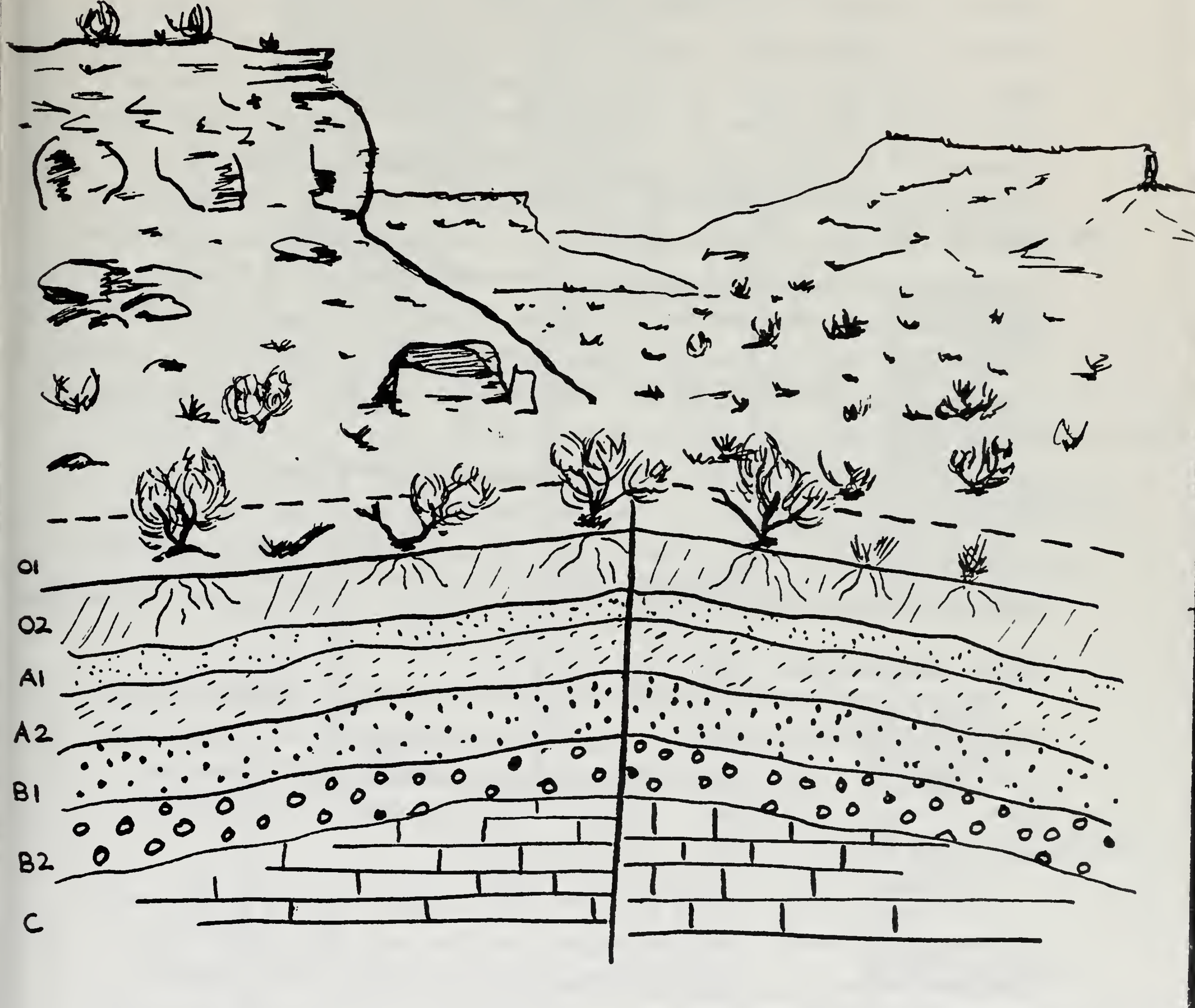


SOILS

Detailed mapping and descriptions of soils occurring on the study site have been provided by the Soil Conservation Service (SCS, 1954; 1978), and these data have been supplemented by field observations and analyses carried out during the current study. In general, soils of the area are shallow and subject to high salinity. Agricultural development is very limited and the most important type of land use is grazing, which takes place on most of the suitable terrain. Figure 36 shows soils as mapped by the SCS. Data from quantitative sampling of plant communities has been used to assess the relative fertility of the various units as indicated by percent vegetative cover. The floristic composition is discussed with each soil type. No extreme differences in floristic composition were noted between soil types, except for those soils which correspond to special landforms (e.g. Ry-Rock Land; Ml-Made Land). Species coverage values do vary with soil type, but the two basic vegetation types, Shadscale and Pinyon-Juniper, are found on most soils which have slopes less than 20%. Comparison of soil and vegetation maps reveals a close correspondence between units of the Castle Valley series and the Pinyon-Juniper vegetation type, which was used as an indicator of this substrate.

Mapping Unit Descriptions (Table 9 gives a summary of the physical attributes)

Castle Valley Series

The Castle Valley soils series consists of sloping to steep, shallow, calcareous, well-drained soils on upland benches and mesas. These soils have formed in material that weathered from sandstone and interbedded shale. Areas of these soils are generally surrounded by scarp faces of very steep Shaly Colluvial Land or Rock Land.

In a typical profile, the surface layer is brown loamy very fine sand. The subsoil is brown, very fine sandy loam that has lime at its base. Sandstone bedrock is at a depth of about 10-20 inches. Flat, angular fragments of sandstone make up 15 to 50 percent of the volume, with the highest percentage near bedrock.

Castle Valley (CeE2), extremely rocky, very fine sandy loam, is found on 0-20% eroded slopes. From 60-75% of this mapping unit is Castle Valley soil and the rest is rock outcrop. The Castle Valley soil is the model profile for the series. The texture of the surface layer is variable, because of deposition and removal of material by wind action. In places, as much as half of the original surface layer is gone.

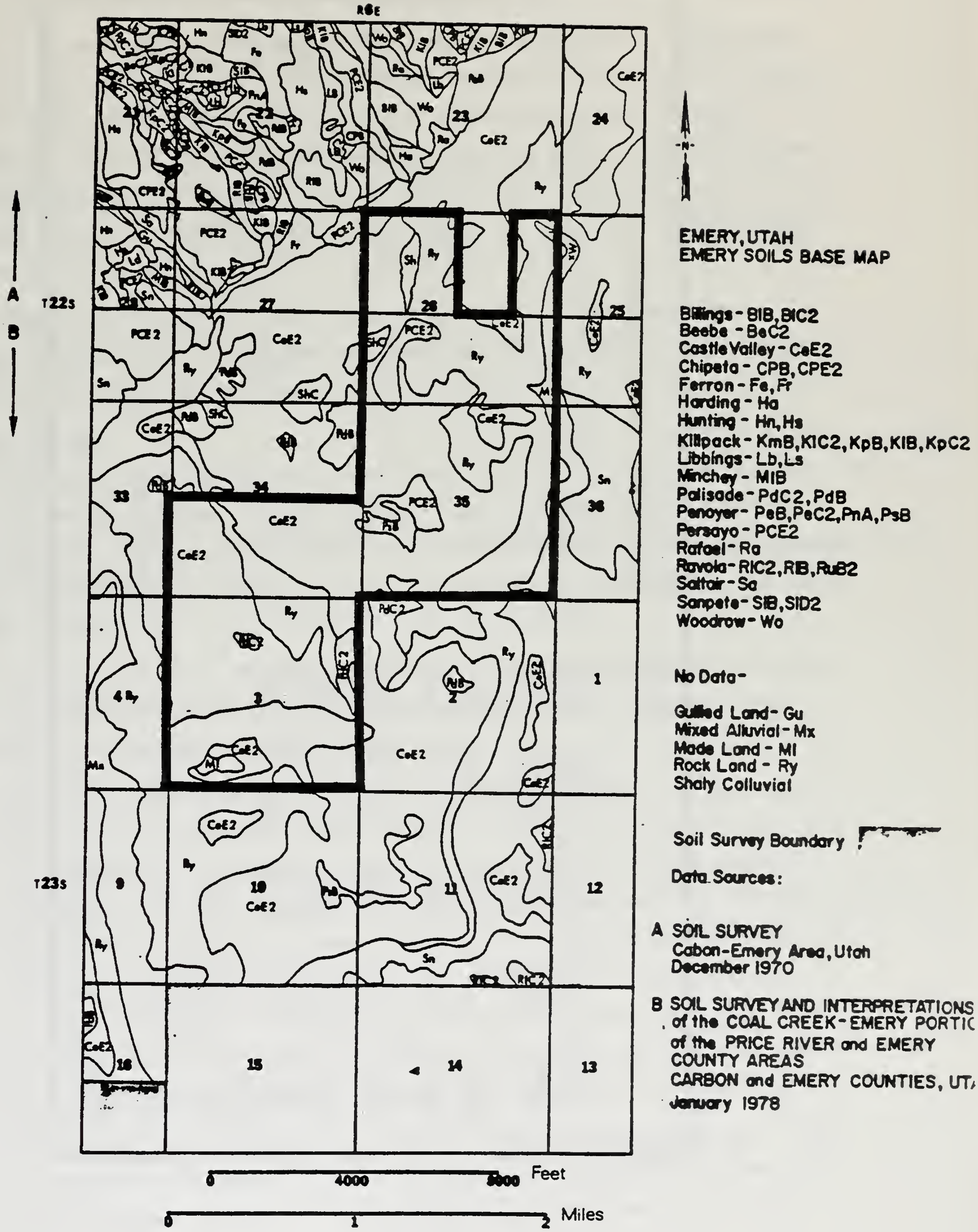


Figure 36. Emery, Utah - Emery Soils Base Map.

Table 9. Physical Soil Characteristics

Soil Legend	Texture	Permeability	Available Water Capacity	Soil Reaction	Salinity	Erosion Factors	Wind Erod. Group	Slope	Area on Site (acres)	Aver. Depth (in.)	Volume (acre ft.)
Penoyer (PsB)	L, VSFL	0.6-2.0	0.17-0.19	7.4-8.4	4	.43 5	4L	1-3%	25.53	48	102
	SICL	0.2-0.6	0.17-0.19	7.4-8.4	4	.43 5	4L				
	L, VSFL	0.6-2.0	0.17-0.19	7.4-8.4	4	.43					
Persayo (PCE2)	L, SICL	0.6-2.0	0.17-0.19	7.4-8.4	2-16	.49 1	4L	1-20%	.74.67	8	50
	WB	0.0-0.0	0.0 -0.0								
Chipeta (CBF2, CBF)	SICL, SIC	0.06-0.2	0.11-0.15	7.4-8.4.	8-16	.43 1	4L	3-30%	(not on site)		
Shaly Colluvial (ShC)	CB-VFSL	2.0-6.0	0.11-0.13	7.4-8.4	4	.37 2	8	3-6%	9.99	24	20
	CL	0.6-2.0	0.12-0.14	7.4-8.4	4	.43					
	CB-CL	0.6-2.0	0.12-0.14	7.9-9.0	4	.37					
Palisade (PdC2, PdB)	VFSL	0.6-2.0	0.15-0.17	7.9-8.4	2	.43 5	3				
	VFSL	0.6-2.0	0.15-0.17	7.9-9.0	2	.43		3-6%	31.73	60	158
	VFSL	2.0-6.0	0.14-0.16	8.5-9.0	2	.43		1-3%			
Castle Valley (CeE2)	GR-VFSL	2.0-6.0	0.8 -0.13	7.4-8.4	4	.37 1	8	0-20%	1217.24	8	815
Rock Land (Ry)	Coarse Fragments	Var	Var						779.60	2	130
Mixed Alluvial (Mx)	SI-CL	Var	Var			No Data Available			60.52	48	240
Man-Made Land (ML)	Var	Var	Var						11.64	0	0

Included in mapping were areas of soils having depths less than 10 inches over sandstone and other areas in which the soils are more than 20 inches thick.

Drainage is good, and permeability is moderately rapid. Roots penetrate to the sandstone and then spread horizontally. From 2 to 3 inches of available water is retained by this soil; depending on the depth to bedrock. Runoff is slow to medium except in areas of bare rock where the amount of runoff is high. The susceptibility to further erosion from wind and water is slight to high. Many areas of this unit contain deep ravines.

The Castle Valley soils are almost exclusively covered by Pinyon-Juniper woodland with a very sparse understory of shadscale, black sage, and indian ricegrass. Vegetative cover averages 25-30%.

Penoyer Series

The Penoyer soils series consists of well-drained, calcareous soils that are medium textured. These soils occupy medium to small areas of alluvial fans, flood plains, and alluvial plains on the bottoms of canyons. They have formed in alluvium, derived from sandstone, limestone, and basic igneous rocks.

In a typical profile, a surface layer of light brownish-gray, strongly calcareous loam about 9 inches thick is underlain by a layer of light brownish-gray loam and very fine sandy loam.

Penoyer soils are generally dry, unless snow covered or irrigated. The content of calcium carbonate ranges from 5 to 25%. Reaction ranges from mildly to moderately alkaline. Salinity ranges from slight to moderate. Clay mineralogy is mixed, but the clay fraction is dominantly montmorillonite. The texture of the A horizon ranges from very fine sandy loam to silty clay loam. The profile between 10 and 40 inches consists of light loam, silt loam, or very fine sandy loam with less than 18% clay and less than 15% coarser sand. All of the upper 40 inches is about the same color. Below a depth of 40 inches, the texture ranges from clay loam to sandy loam.

Penoyer (PsB), very fine sandy loam, is found on 1 to 3% slopes. This soil is similar to the model profile for the series, except for the surface layer texture. Penoyer is found in the southern portion of the survey area, near Ivie and Quitchupah Creeks.

Included in mapping were areas of shallow, fine sand over shale and sandstone.

Runoff is slow, and the susceptibility to wind erosion is moderate. Hummocks 6 to 12 inches high have formed in some areas. In places, head cutting is active and deep gulleys have formed.

This soil type is of limited extent on the site. It supports fairly diverse stands of grasses and shrubs, often with no single dominant species. Line transect data showed that black sage, shadscale, rabbit-brush and ephedra were the most important shrubs, while galleta and indian ricegrass formed most of the understory. Prickly pear cactus (Opuntia polycanthus) was found to have invaded certain areas of this soil type.

Persayo Series

Persayo series soils are calcareous, well-drained soils found on moderately fine textured, gently sloping to steep slopes. They form in residium weathered from shale hills. The associated vegetation is mainly galleta grass and shadscale.

In a typical profile, the surface layer is light brownish-gray loan about 1 inch thick. The underlying material is light brownish-gray loam and silty clay loam that contains a weak to moderate gypsum horizon. Shale bedrock is at a depth of about 12 inches.

As a rule, Persayo soils are dry. The part of the profile below 10 inches is silty clay loam that contains less than 35% clay. Weathered fragments of shale make up 5 to 70% of the material in this part of the profile. The shale fragment content increases with depth. All of the upper 20 inches has about the same color. In the C3cs horizon, the content of gypsum ranges from 0.5 to 10%. Gypsum crystals range from few to common.

Persayo soils occur with the Chipeta soils. The Persayo-Chipeta association (PCE2) is found on 1 to 20% eroded slopes. About 60% of this mapping unit is Persayo loam on 1 to 20% eroded slopes, and 40% is Chipeta silty clay loam occurring on 3 to 20% eroded slopes. These soils are intermingled and occur in no identifiable pattern. The Chipeta soil generally is on ridges.

The Persayo soil is the model profile for the series. This soil is well drained and has moderate permeability. Roots penetrate down to the shale, and then spread horizontally. This soil may take up 1 to 3 inches of available water, the amount depending on the depth to bedrock. Runoff is medium, and the susceptibility to erosion is moderate.

The soils in this mapping unit are used mainly for spring and fall range. Sheet erosion is active, and in many places shallow gulleys have cut down as far as the shale bedrock.

The Shadscale vegetation type is well developed on this soil type. Highest coverage values for _Atriplex confertifolia_ and _Hilaria jamesii_, the two main species in the type, were found on Persayo soils. A variety of other shrubs occur as sub-dominants including four-wing saltbush, kochia and cuneate saltbush.

Palisade Series

The Palisade series consists of deep, medium-textured, well-drained, nearly level soils deposited on mesas and benches. As a rule, the soil occurs on the lower parts of benches in medium to large areas. The Palisades series forms in alluvium and glacial outwash derived from calcareous sandstone mixed with shale and limestone. Palisade soils have strongly calcareous horizons throughout.

In a typical profile, the surface layer is pale-brown, limey, soft loamy fine sand about 3 inches thick. The underlying material is very pale brown and yellowish-brown very fine sandy loam, and it is strongly calcareous to moderately calcareous. Gravel and cobblestones may occur at depths between 2 and 5 feet.

The Palisade soils generally are dry. They have a mixed clay mineralogy. The part of the profile between 10 and 40 inches is very fine sandy loam or light loam that contains less than 18% and more than 15% sand coarses than very fine sand. In places gravel and cobblestones make up as much as 50%, by volume, of the lower one-third of this 30-inch section. The content of calcium carbonate in the limey horizons ranges from 15 to 40%. Below a depth of 40 inches, the texture ranges from very fine sandy loam to gravelly loamy sand.

Palisade (PdB), very fine sandy loam, is found on 1 to 3% slopes. The profile of this soil is the one described as typical of the series. Gravel and cobblestones are between depths of 2 and 5 feet in places.

Drainage is good and permeability is moderate. Root penetration is deep. About nine inches of water is retained by this soil, but only 4.5 to 5.5 inches is readily available to plants. Runoff is medium, and the susceptibility to erosion is moderate.

The Shadscale vegetation type is well developed on Palisade soils. The coverage of perennial plants averages 15-18% for samples taken from this substrate, with 12-15% of the cover accounted for by shadscale and galleta.

Palisade (PdC2), very fine sandy loam, is found on 3 to 6% eroded slopes. This soil is similar to the model profile for the series, except that it is steeper and more eroded. It occurs in small areas on benches.

Runoff is medium and the susceptibility to erosion is high. Although not observed on the Emery study site, some areas having this soil type are reported to develop gulleys 2 to 3 feet deep with a whitish calcareous subsoil exposed through erosion to 3-4 inches below the surface.

Ravola Series

The Ravola soils series are deep, medium textured, moderately permeable, and well drained. These soils occupy moderate to large areas on alluvial fans, on flood plains, and in narrow alluvial valleys, and formed in alluvium that washed from shale and sandstone.

In a typical profile, the surface layer is light brownish-gray, slightly hard, moderately calcareous loam about 9 inches thick. The underlying material is light brownish-gray, moderately to strongly calcareous loam that in places is weakly stratified with layers of sandy loam or clay loam.

Ravola loam (R1C2) is found on 1 to 3% eroded slopes. This soil is similar to Ravola loam found on 1 to 3% slopes, except for the steeper slope ranges and erosion. It occupies alluvial fans.

Runoff is rapid, and the susceptibility to erosion is high. Sheet erosion is active. In many areas, especially near the steep, nearly bare shale hills, gulleys are 4 to 8 feet deep and 100 to 400 feet apart.

Plants associated with this soil type are those adapted to extremely dry conditions, and are often the same species observed in rocky and craggy places, such as rabbitbrush, ephedra and occasionally species of yucca.

Sh Series

Shaly very fine sandy loam (ShC) is found on 3 to 6% slopes. This soil is similar to Castle Valley (CeE2) except that it is less rocky and the depth to bedrock is 20 to 40 inches. Slopes are 3 to 6%.

This is a moderately deep, well drained, moderately fine textured soil and is found on gently sloping upland benches. Sh soil has strongly calcareous horizons throughout.

In a typical profile, the surface layer is light brown, soft, cobbly very fine sandy loam about 6 inches thick. The subsoil is light yellowish-brown, hard clay loam about 14 inches thick. The substratum is limey, very hard, cobbly clay loam. Sandstone bedrock is at depths of 20 to 40 inches.

Drainage is good, and permeability is moderate. Roots penetrate to the sandstone and then spread horizontally. Estimated available water holding capacity is 4 to 6 inches depending on the depth to bedrock. The lowest elevation stands of juniper in the study area were observed on this soil type.

Shaly Colluvial Land (Sn), is a mixture of soil material, cobblestones, and fragments of rock which accumulated on moderately steep and steep slopes and at the bases of slopes, primarily as the result of gravity sliding. This colluvium is variable in thickness, and in some places it is as much as 3 feet thick over shale. As the shale on the slopes of the mesa and benches erodes away, this capping falls and rolls down the slope. From 20 to 40 percent of the surface is shale outcrops. Because of the steep slopes, the lack of precipitation to establish plants, and the unconsolidated nature of the colluvium, moderate to severe erosion is present.

Vegetative coverage is very low, with an average of less than 5%. Species found in these areas tend to be extremely xeric, such as ephedra, rabbitbrush, shadscale and occasionally pickleweed.

Rock Land (Ry)

Rock Land is a miscellaneous soil type having a surface 50 to 70% covered by stones, boulders and outcrops of shale and sandstone. Most of this land type is moderately to severely eroded. Any soil characteristics are almost obscured by the stones and boulders. The slopes are very steep to perpendicular, but typically they lie between 50 and 80%.

Included in mapping were gently sloping, deep fine sandy loam. Intermingled with the sandstone outcrops were inclusions of shallow fine sandy loams. Also included on some of the north-facing slopes were small areas of an unidentified soil.

This land type has almost no value for farming, although some areas have a sparse cover of grass, hardy shrubs, and juniper. This vegetation grows on all exposures, but it is dominant on north and west exposures. Small areas are accessible to livestock and wildlife, but most of the land type is too steep and rocky for grazing.

Made Land (Ml)

Made Land is a miscellaneous land type that consists of areas where the soil has been artificially moved. On the soil map the material was used to fill and cover crevices in the rock formation to extinguish fire in the underlying coal beds. These soils were shallow to sandstone or shale bedrock. The texture of the soil is very fine sandy loam or silty clay loam.

Most of the area has little or no vegetation and is presently of little value for grazing. Where the soil material is very fine sandy loam, the land can be revegetated. The places occurring on shale have silty clay loam texture, high salt content and are very difficult to revegetate. Below are soil attributes used in Figures 37 through 44 :

Figure 37 - Soil Salinity (mmohs/cm)= Measure of salt content
Figure 38 - Soil Reaction (pH)= Acid-Alkali nature of soil
Figure 39 - Permeability (in/hr)= Ability to absorb water
Figure 40 - Available Water Capacity (in)= Measure of water available to plants.
Figure 41 - Erosion (K) Factor = Susceptibility to erosion
Figure 42 - Erosion (T) Factor = Susceptibility to erosion
Figure 43 - Wind Erosion Group = Susceptibility to wind erosion
Figure 44 - Shrink Swell Potential = Factor determining bulk expansion or contraction on wetting

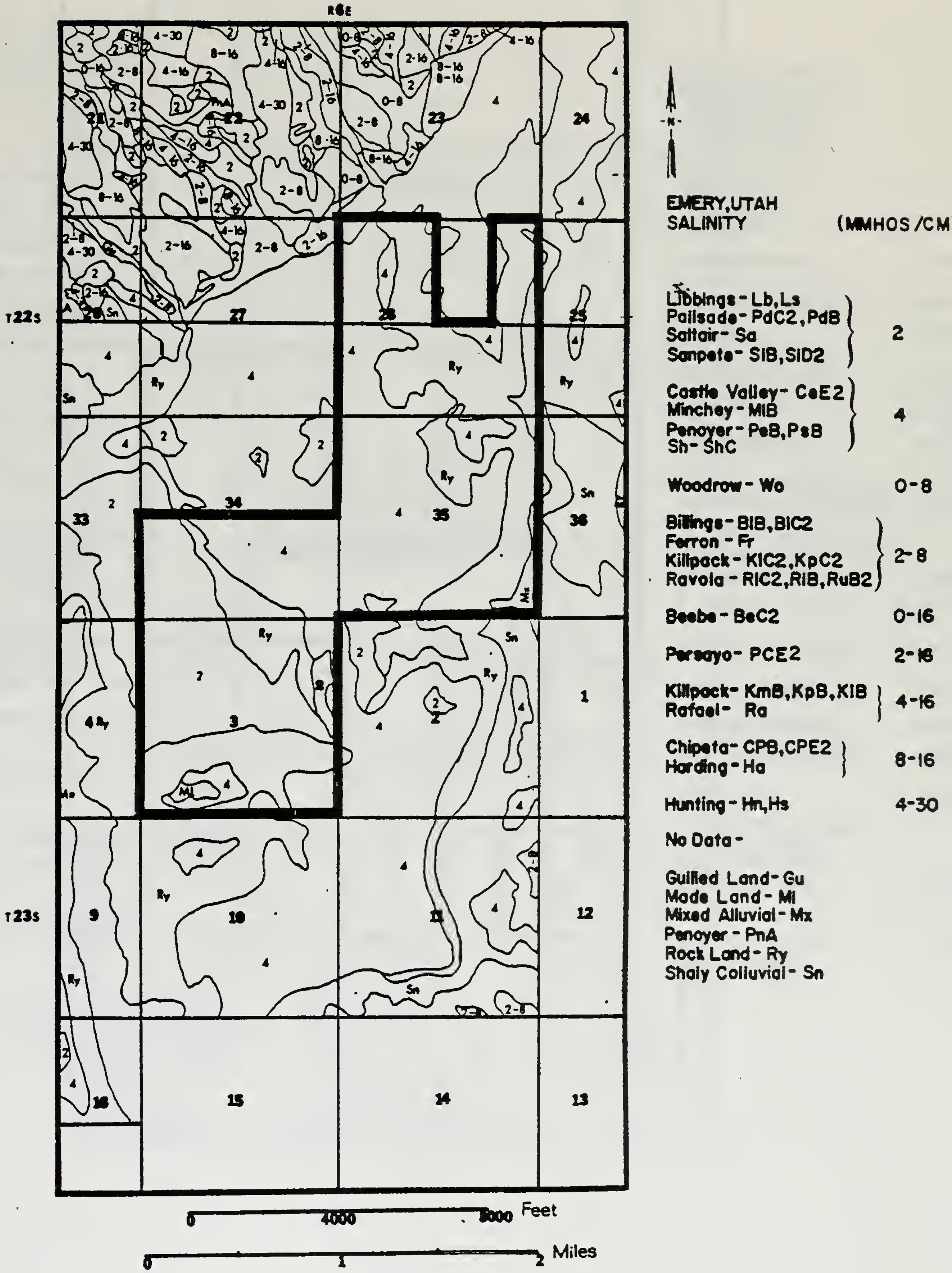


Figure 37. Emery, Utah - Salinity.

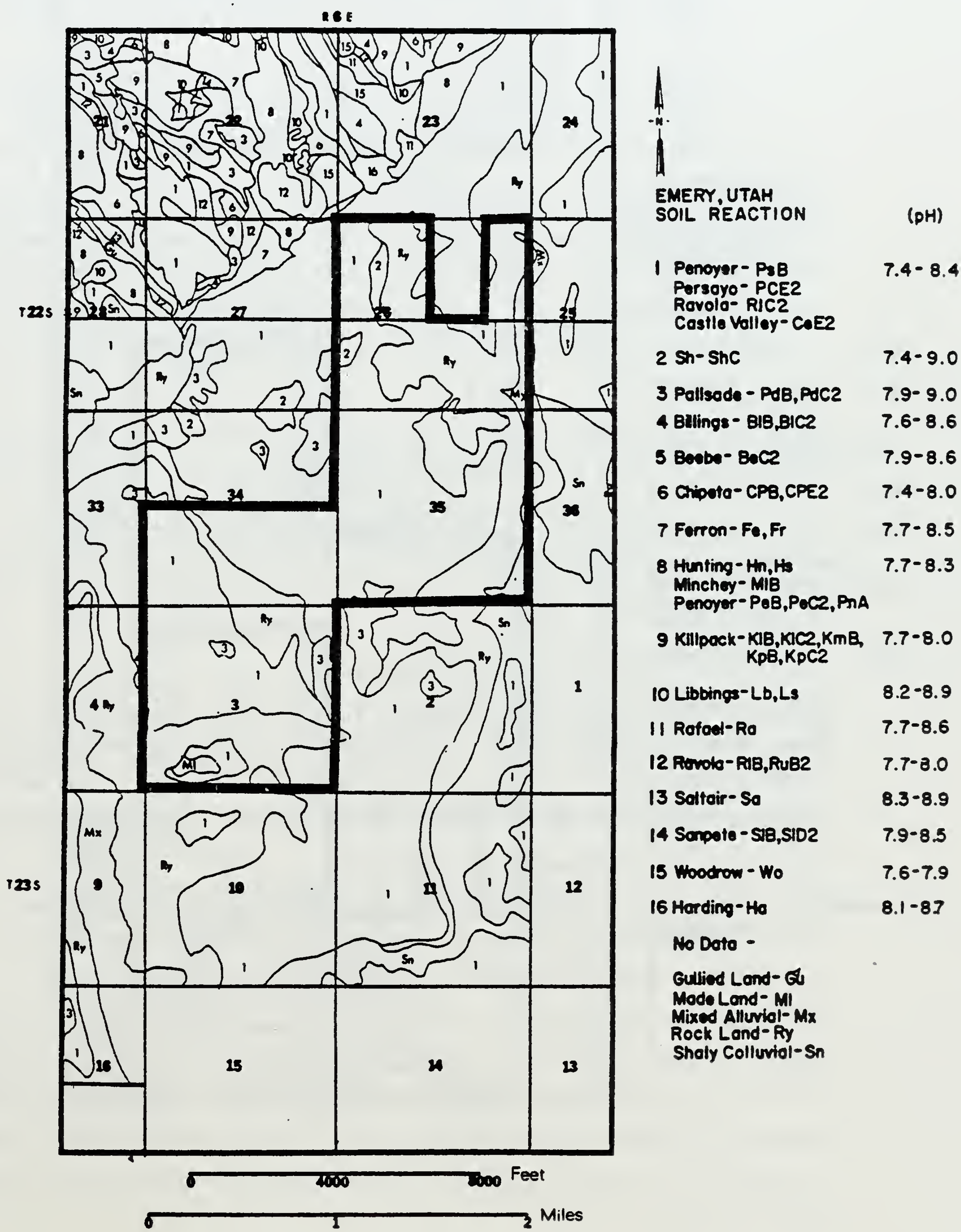


Figure 38. Emery, Utah Soil Reaction

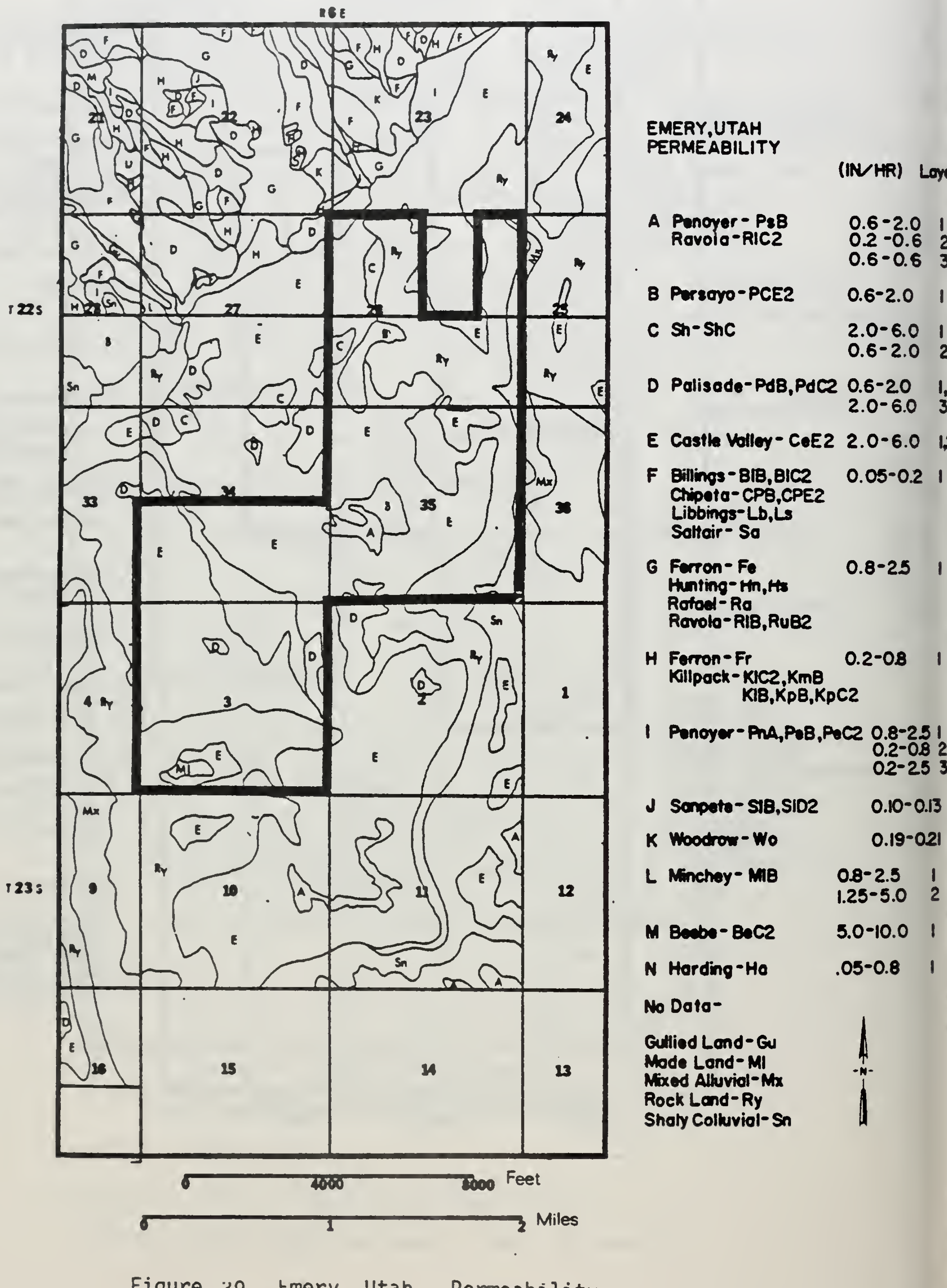
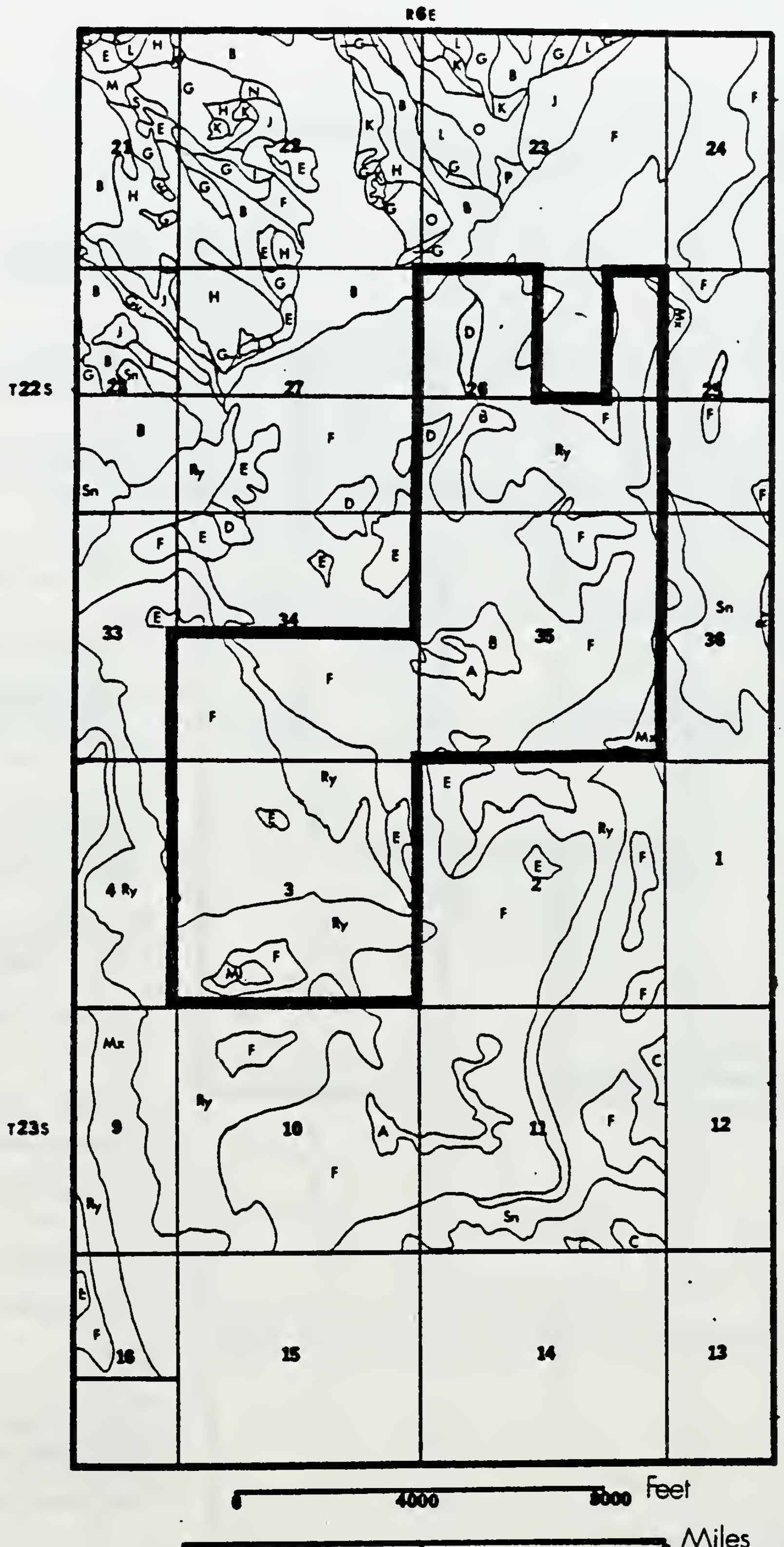


Figure 39. Emery, Utah - Permeability.



EMERY, UTAH
AVAILABLE WATER CAPACITY

			Layer
A	Penoyer-PsB	0.17-0.19	1,2,3
B	Persayo-PCE2	0.17-0.19	1
	Rafael-Ra	0.0-0.0	2,3
	Ravola-RIB,RuB2		
	Ferron-Fe,Fr		
	Hunting-Hn,Hs		
C	Ravola-RIC2	0.13-0.17	1,2,3
D	Sh-ShC	0.11-0.13	1
		0.12-0.14	2,3
E	Palisade-PdB,PdC2	0.15-0.17	1,2
		0.14-0.16	3
F	Castle Valley-CeE2	0.8-0.13	1
G	Kilpack-KIB,KIC2, KmB,KpB,KpC2	0.19-0.21	1
H	Chipeta-CPB,CPE2	0.15-0.17	1
I	Minchey-MIB	0.19-0.2	1
		0.06-0.09	2
J	Penoyer-PeB,PeC2, PnA	0.17-0.19	1,3
		0.19-0.21	2
K	Libbings-Lb,Ls	0.16-0.18	1
	Saltair-Sa		
L	Billings-BIB,BIC2	0.17-0.2	1
M	Beebe-BeC2	0.06-0.10	1
N	Sanpete-SIB,SID2	0.10-0.13	1
O	Woodrow-Wo	0.19-0.21	1
P	Harding-Ha	0.19-0.21	1
		0.16-0.18	2

No Data-

Gullied Land-Gu
Made Land-Ml
Mixed Alluvial-Mx
Rock Land-Ry
Shaly Colluvial-Sn

-N-

Figure 40. Emery, Utah Available Water Capacity.

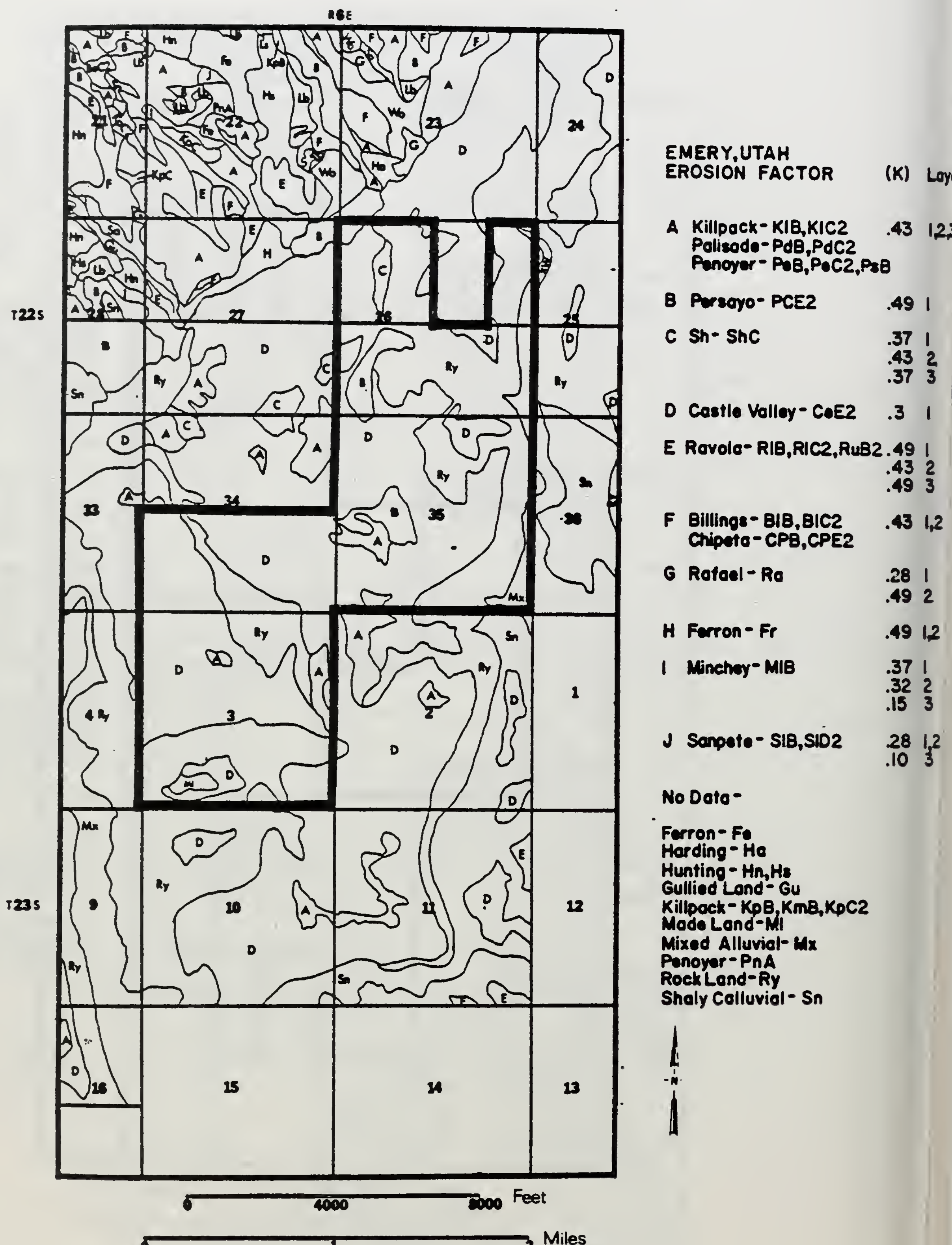


Figure 41. Emery, Utah Erosion Factor (K).

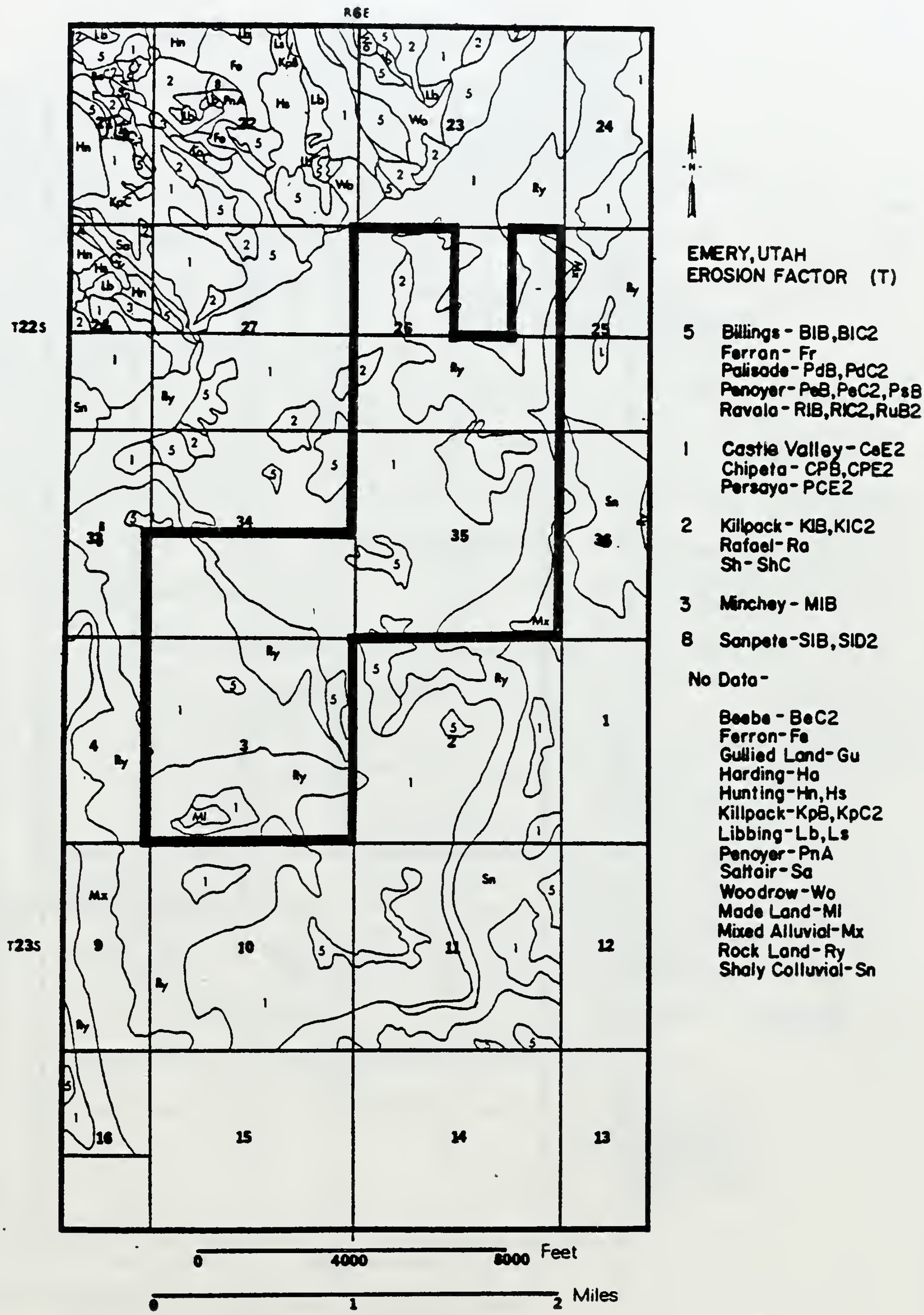


Figure 42. Emery, Utah Erosion Factor (T).

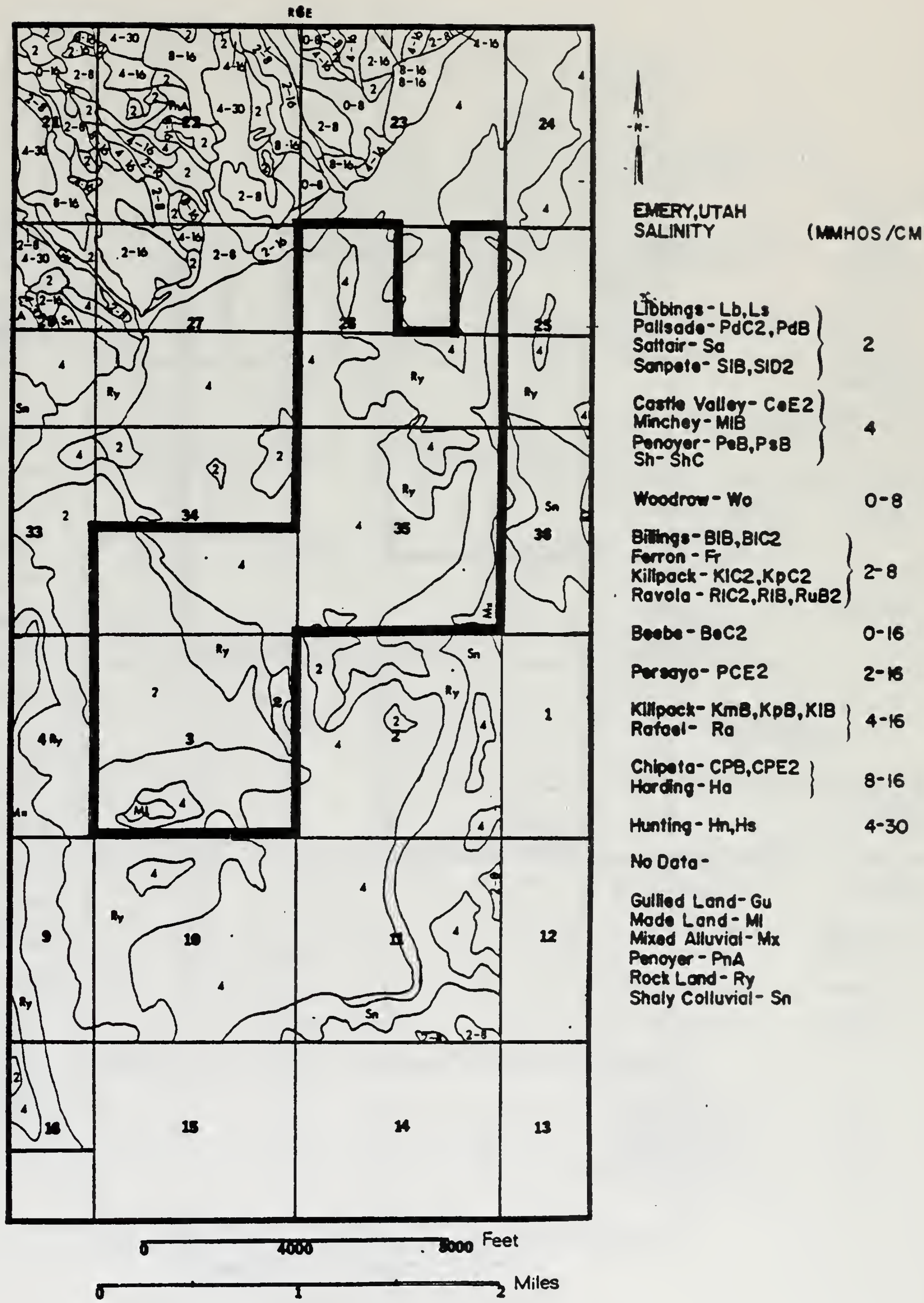


Figure 37. Emery, Utah - Salinity.

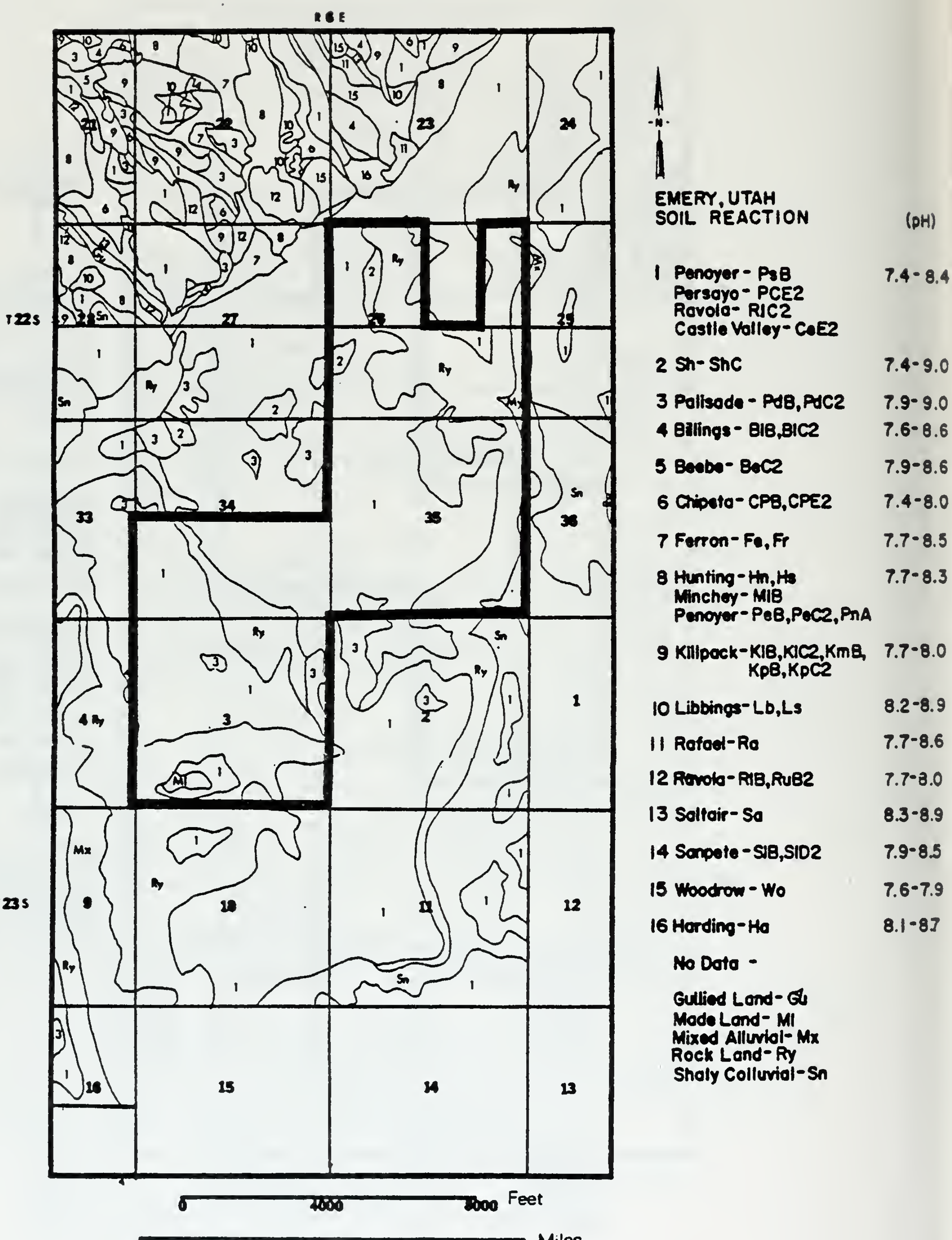


Figure 38. Emery, Utah Soil Reaction

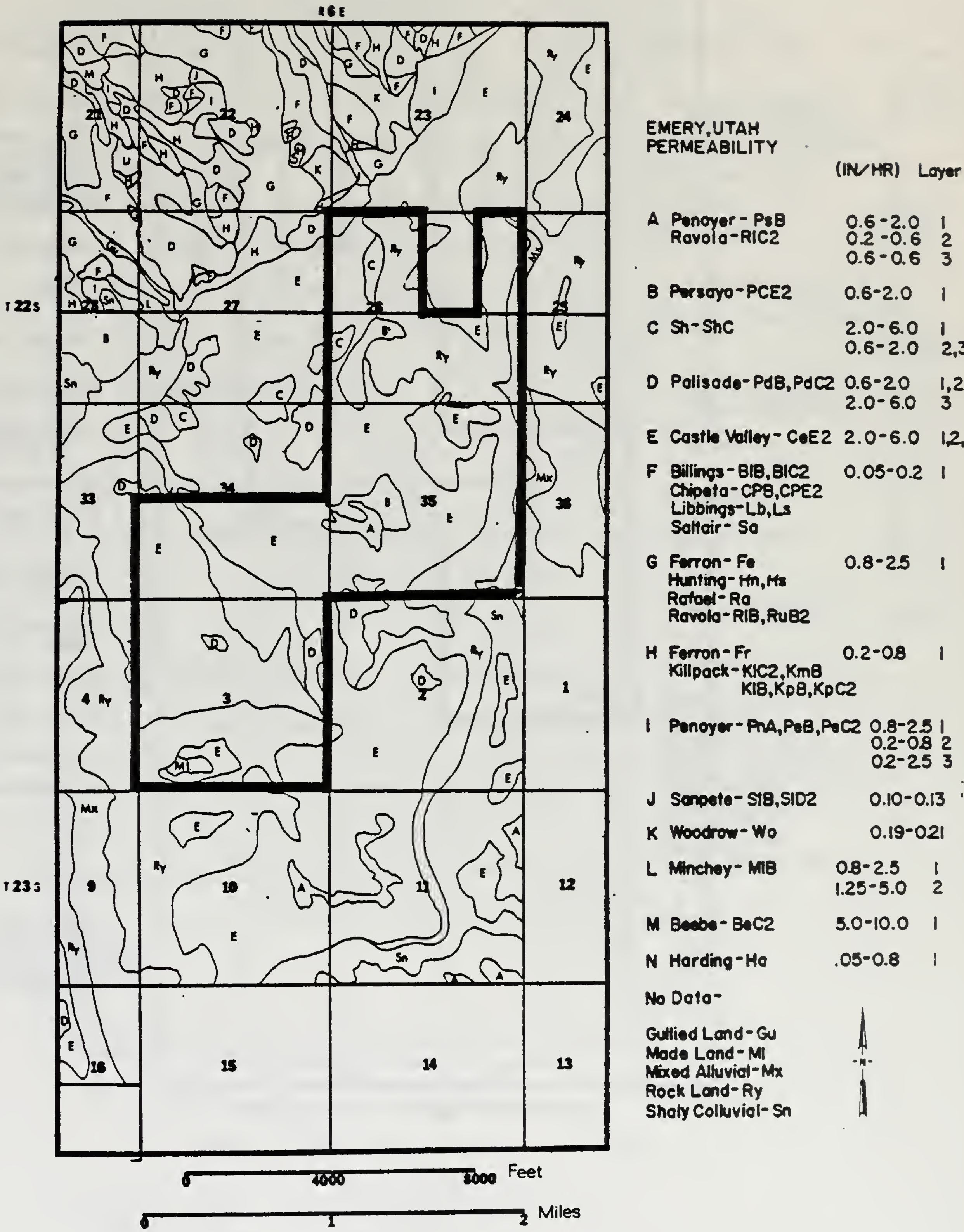


Figure 39. Emery, Utah - Permeability.

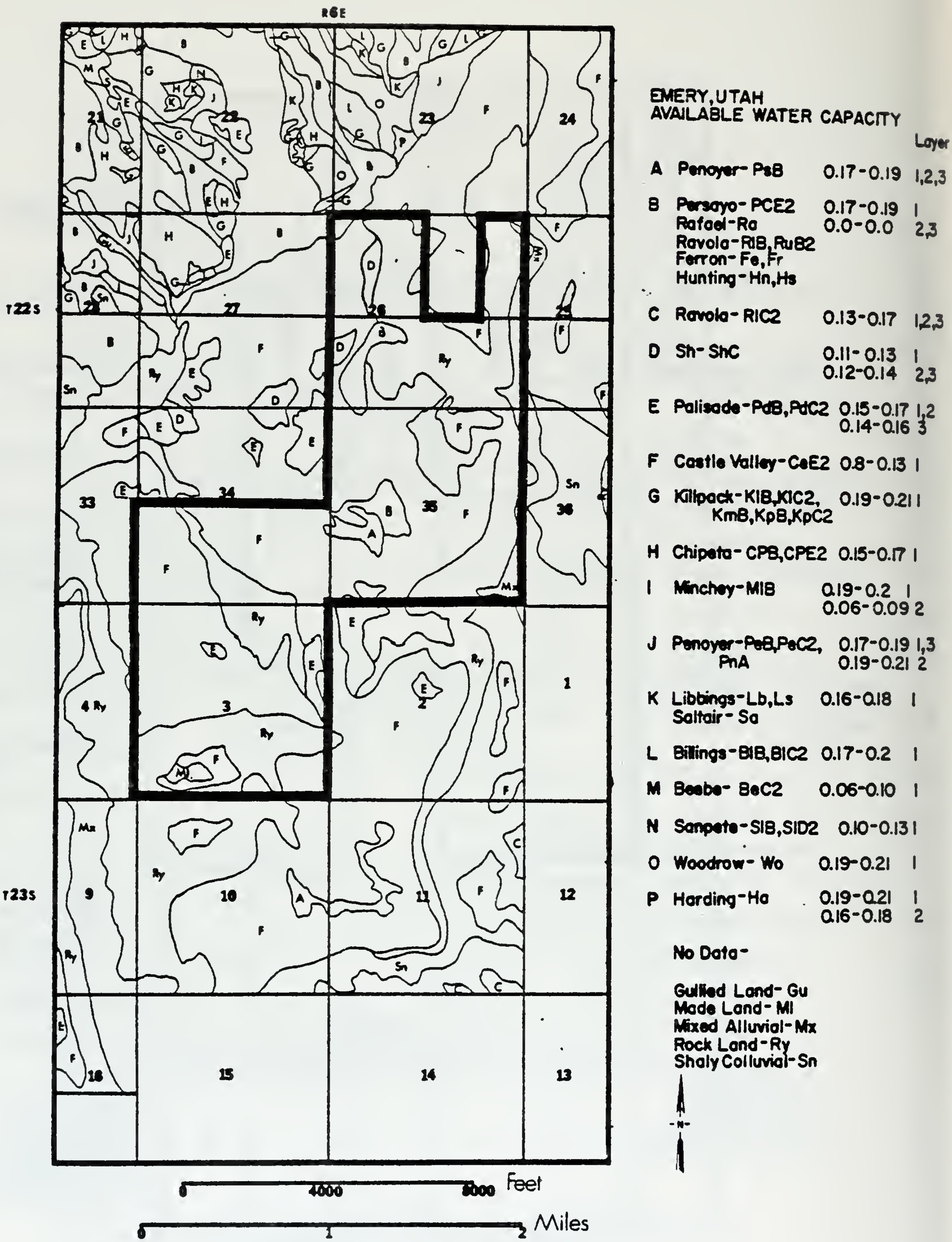


Figure 40. Emery, Utah Available Water Capacity.

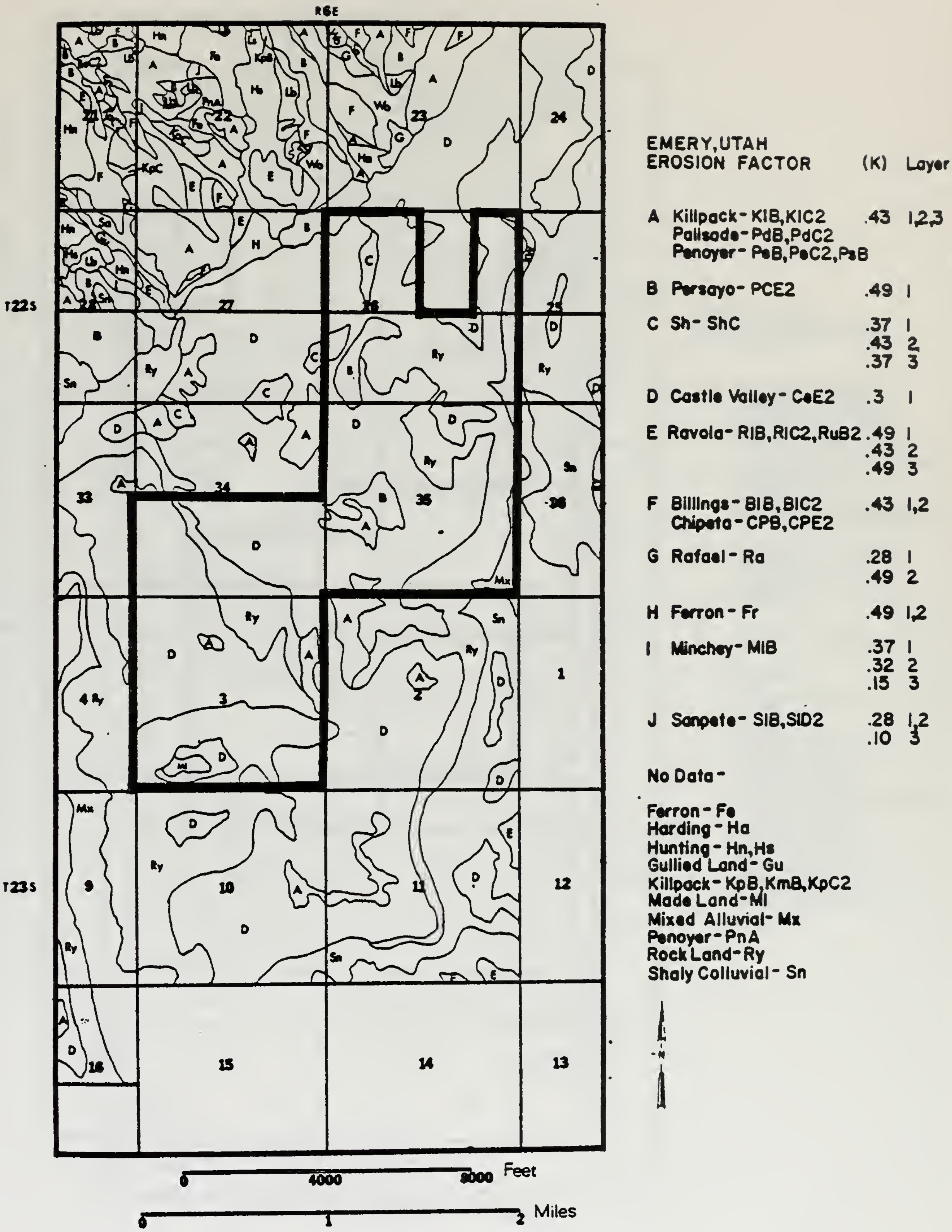


Figure 41. Emery, Utah Erosion Factor (K).

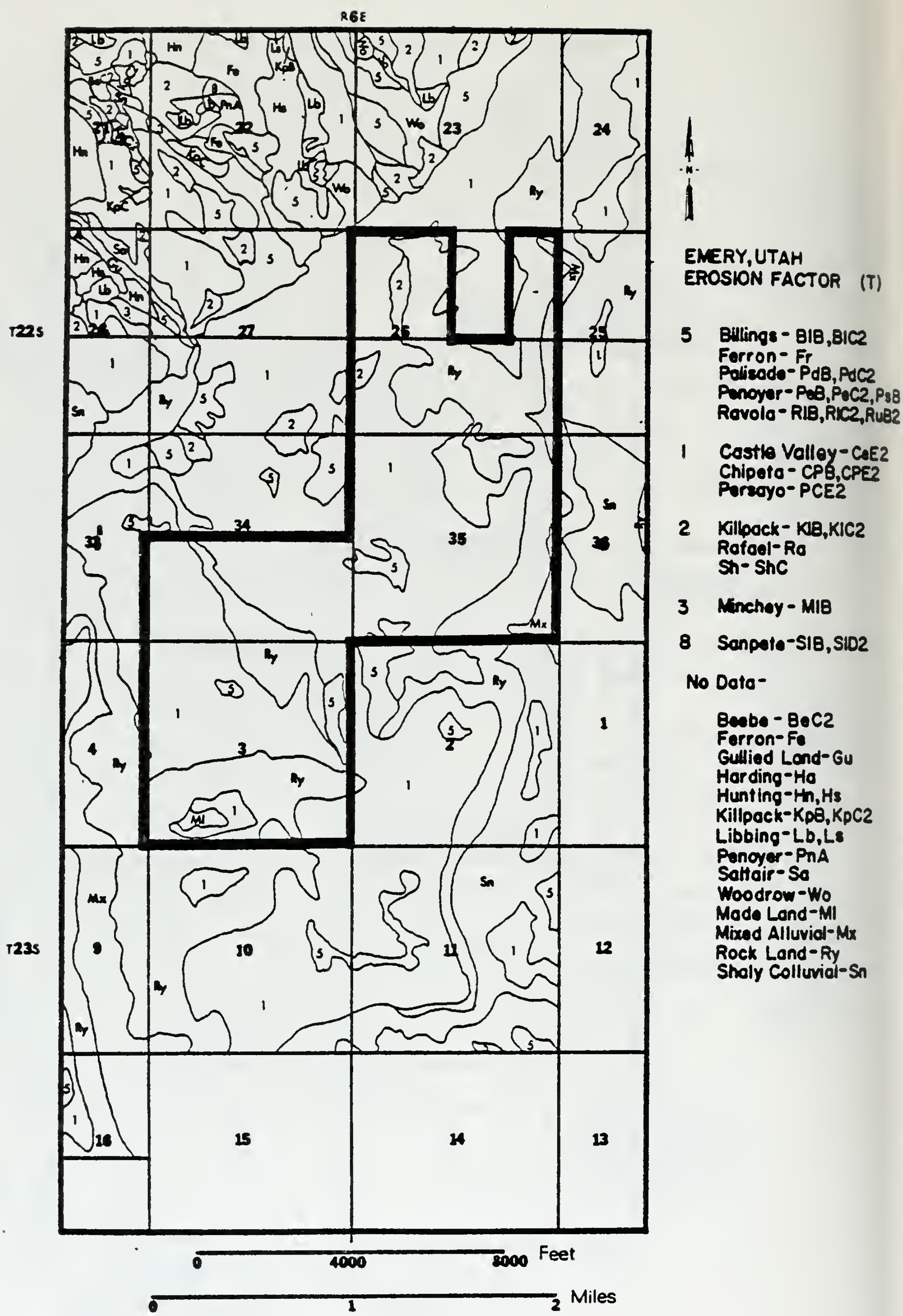


Figure 42. Emery, Utah Erosion Factor (T).

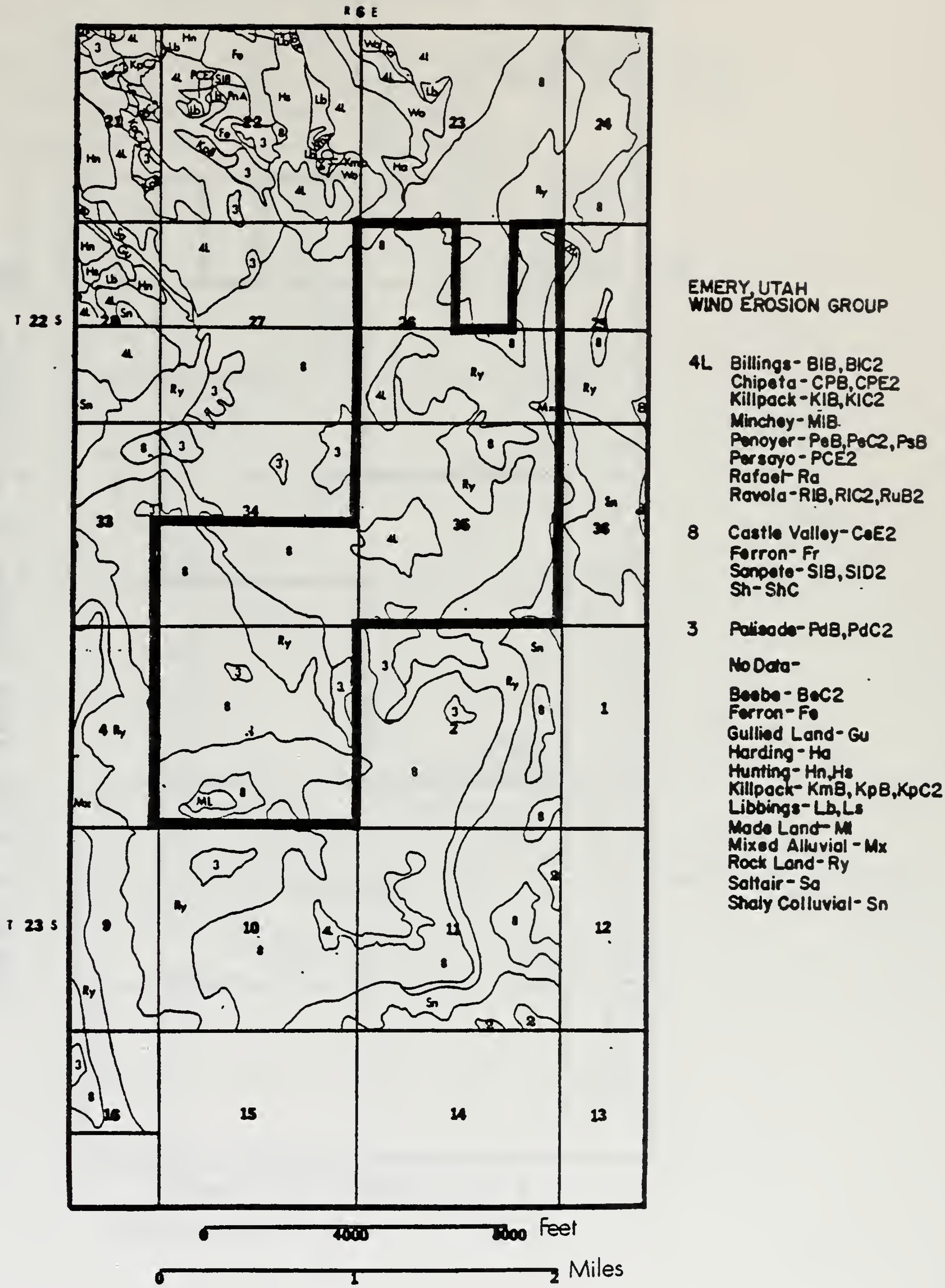


Figure 43. Emery, Utah - Wind Erosion Group.

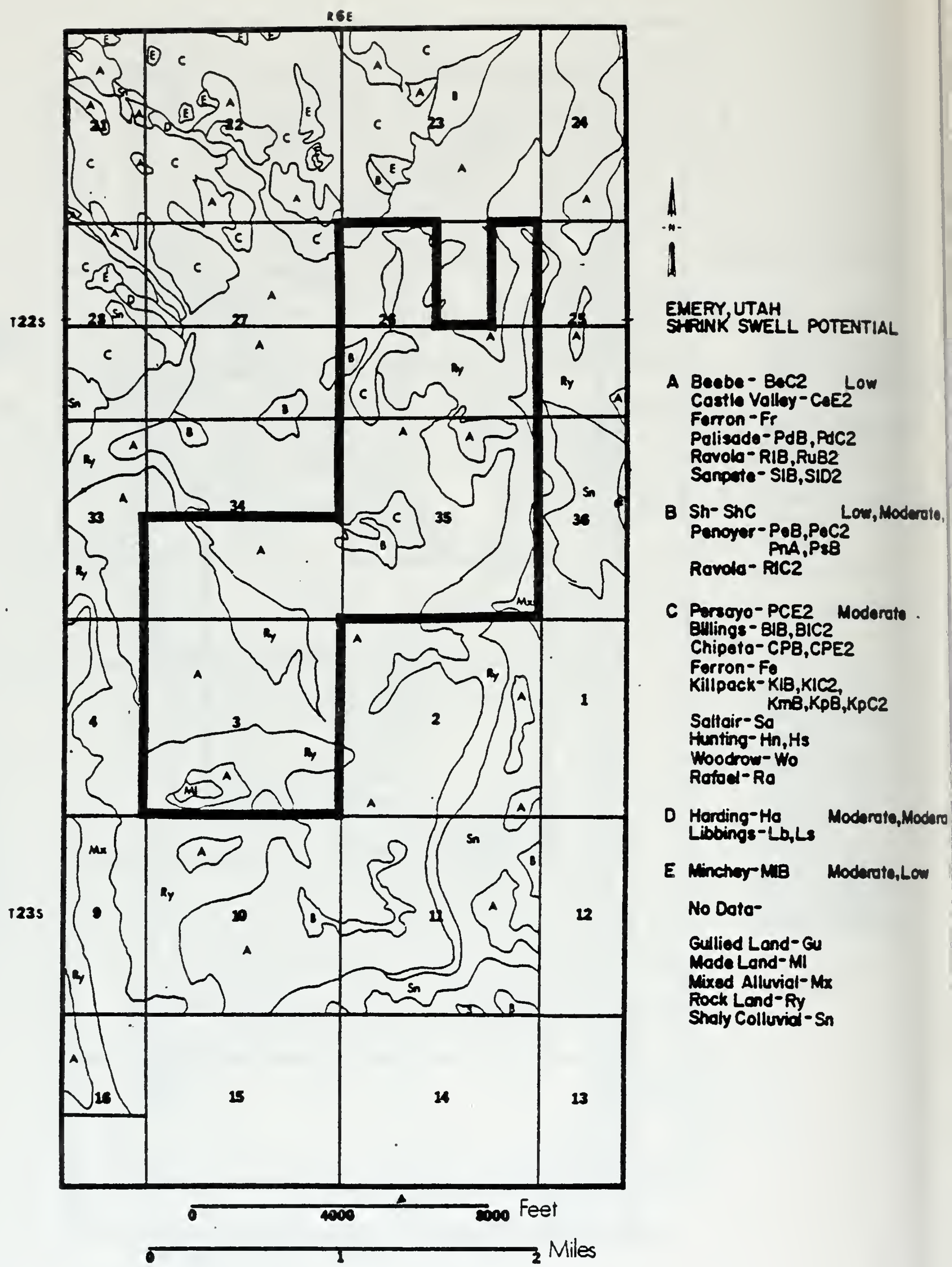


Figure 44. Emery, Utah Shrink Swell Potential

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Swenson, J.L., D.T. Erickson, K.M. Donaldson, J.J. Shiozaki, 1970; "Soil survey of Carbon-Emery area Utah, U.S. Soil Conservation Service, 77p.

Soil Conservation Service, 1978; "Soil survey and interpretation of the Coal Creek-Emery portion of the Price River and Emery County area- Carbon and Emery Counties, Utah, 129 p.

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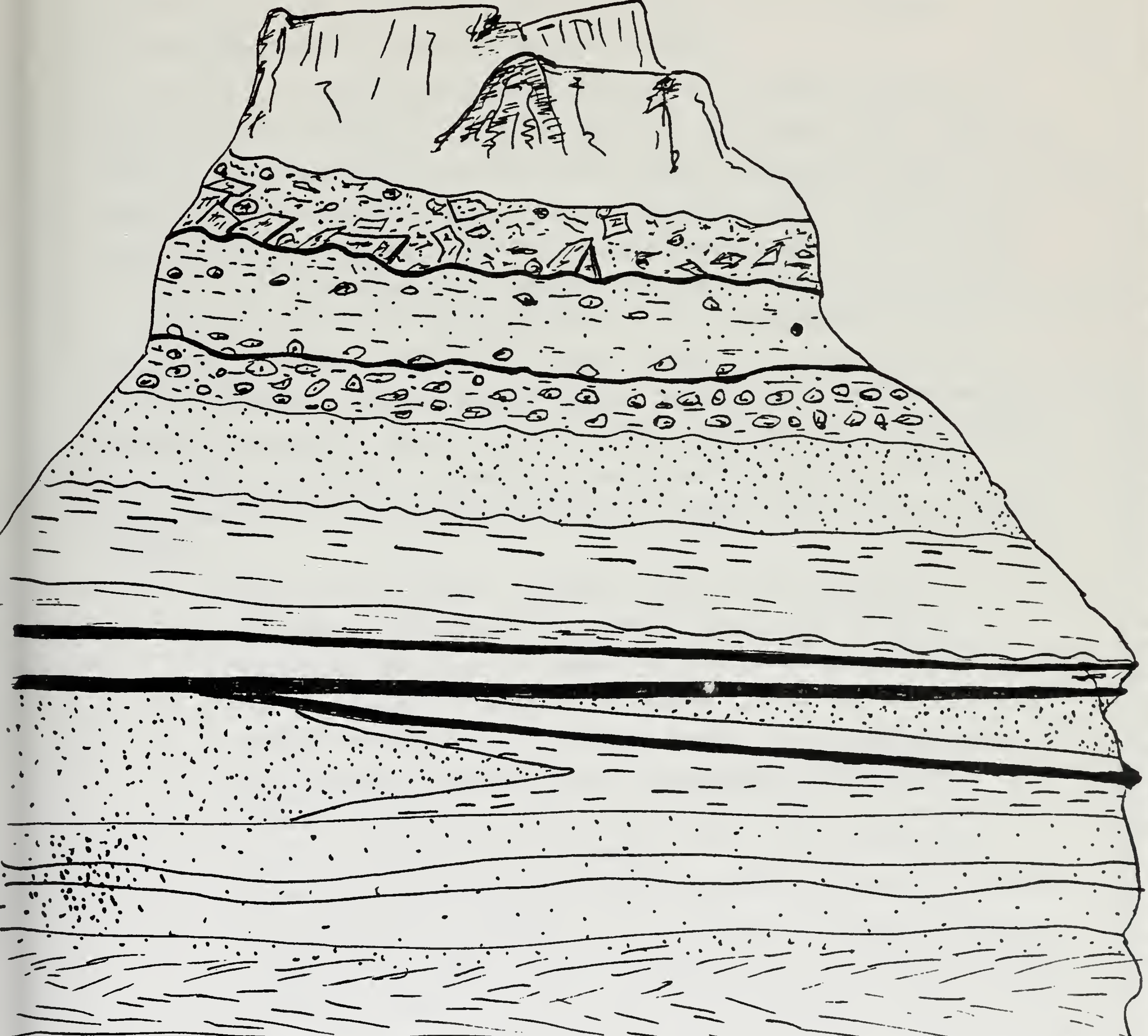


OVERBURDEN

OVERBURDEN

This section reviews the physical and chemical properties of the overburden in the test site area relative to their suitability as planting media (topsoil) and subsoil. Analytical techniques and procedures are given in Heil, 1979. The format of this section is a synthesis of the final report by Heil and Deutsch (1979) with data provided by the United States Geological Survey (1977) with emphasis on interpretations by Gough and Shacklette (1976).

Relative to extractable essential elements from crushed overburden materials from boreholes 2, 3, 4, 5, and 6, pH and textural data, (Heil and Deutsch, 1979) identify 77 problem identification categories (Figures 45 & 46) which fell into 42 problem area groups. Conclusions drawn from this study based on over 120 samples submitted from greenhouse tests are as follows:

Much of the overburden (55%) appears to be too saline for use as soil in an arid climate due to the potential for salt accumulation in the root zone. Materials with salinity above 4 mmho's were dismissed from initial greenhouse tests on these grounds. Another common characteristic was found to be high sodium absorbtion ratio. Samples with excess sodium were deemed unsuitable. In addition, many samples (40%) were found to have potentially limiting characteristics for one or more of the following reasons:

1. Nitrogen deficiency is common to nearly all materials.
2. Phosphorous deficiency is common to nearly all materials.
3. Potassium deficiency is common to a large percentage of materials.
4. Micronutrient deficiencies are common. Copper and zinc are most common and manganese to a lesser degree. It is important to note that the criteria used for evaluating micronutrient deficiencies are based on deficiencies associated with agronomic crops sensitive to these elements. Thus, the micronutrient interpretations must be considered somewhat arbitrary. Our main concern would be the effect of low copper in materials where Mo levels may be high. Data provided later in this report indicates that the Mo level is quite low in most materials. Overall, we suspect that micronutrients would not be a major fertility problem.
5. Texture has been identified as being a potential concern with a large number of materials. Low available water holding capacity and fertility would be the major problems associated with

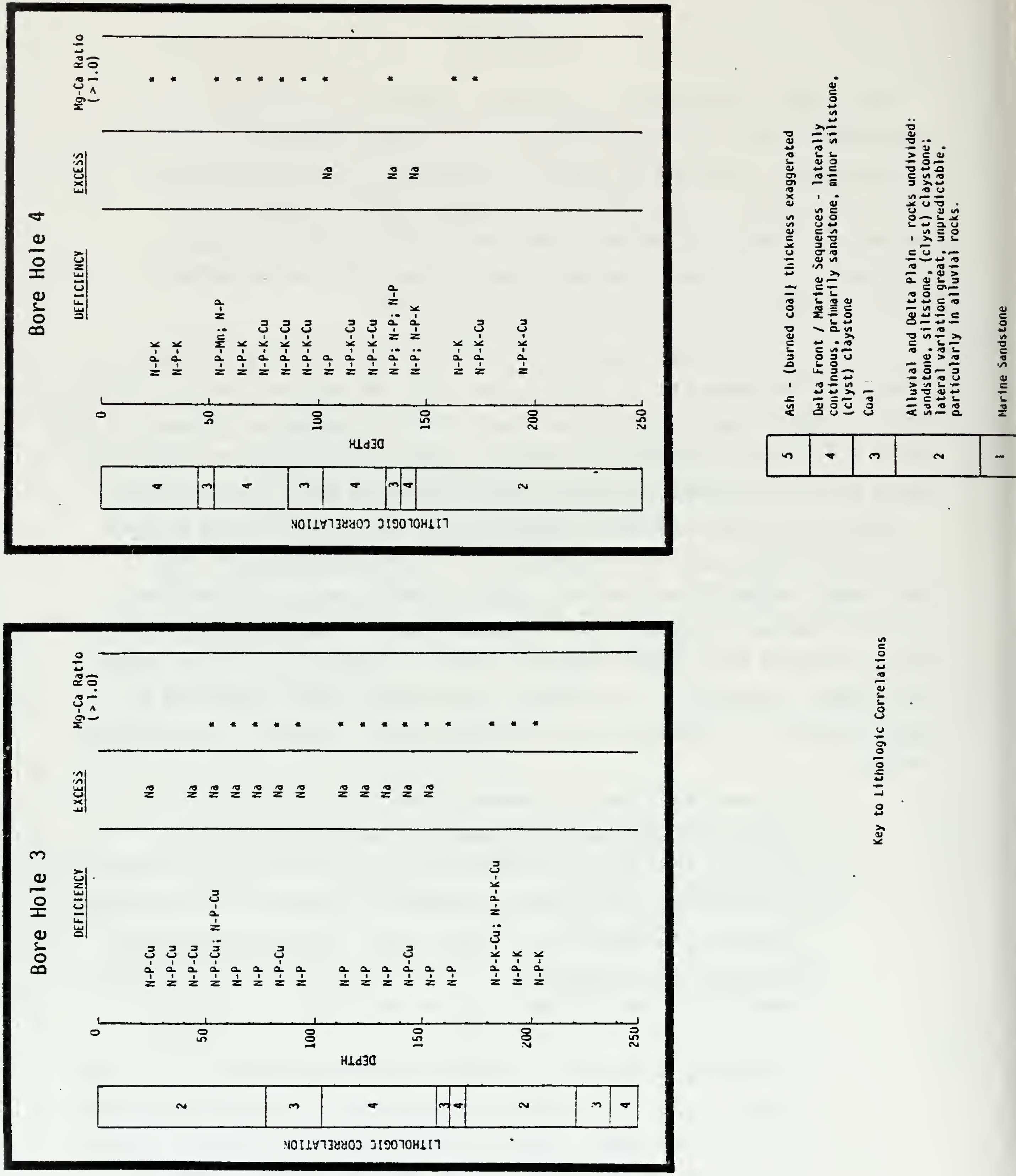


Figure 45. Overburden Growth Suitability in Bore Holes 3 and 4.

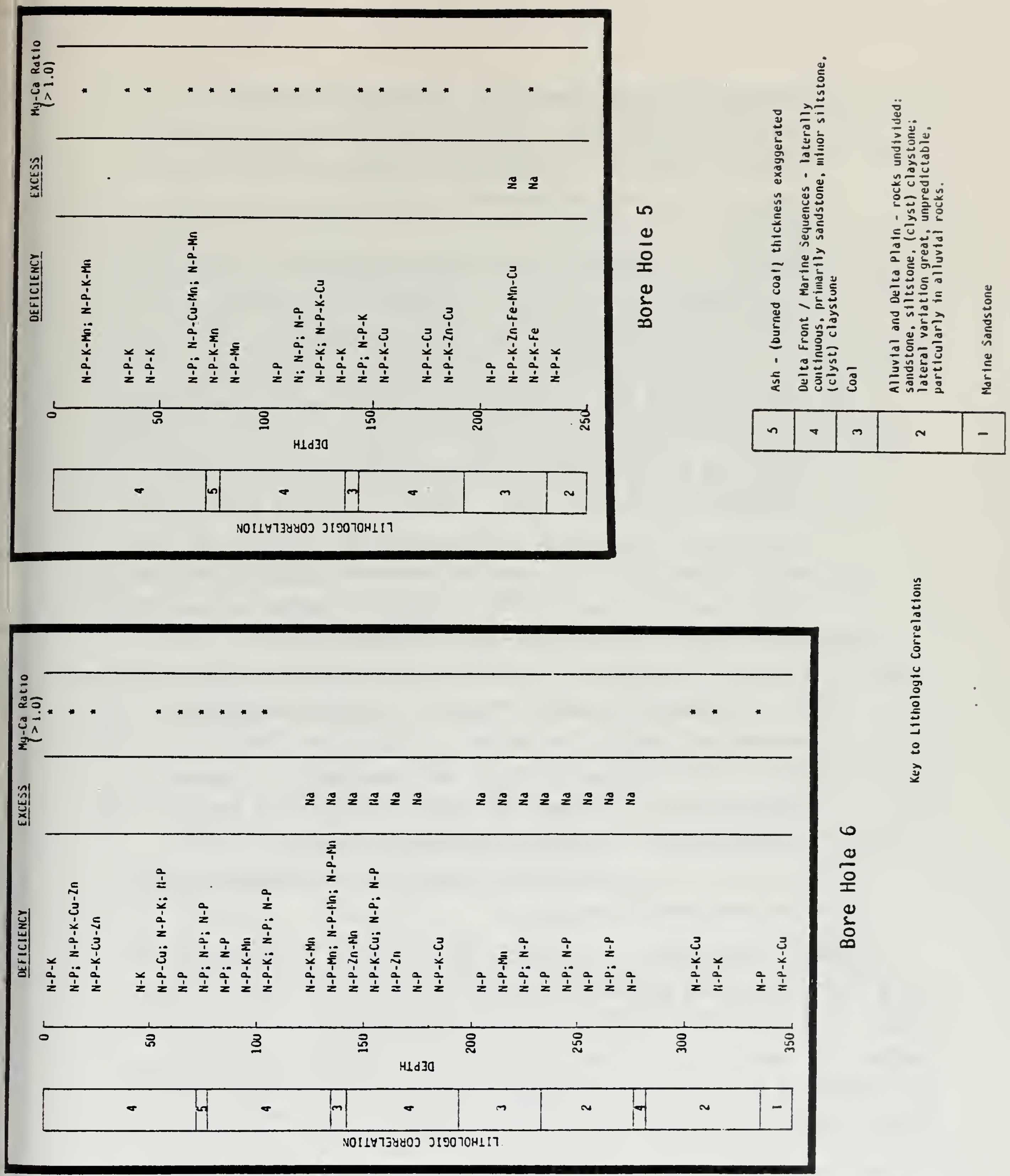


Figure 46. Overburden Growth Suitability in Bore Holes 5 and 6.

the coarse textured materials. High runoff potential and erosion would be major problems associated with the coarse textured materials. The high runoff potential is a concern both as it affects environmental quality as well as plant growth.

6. Salinity is a serious problem associated with many materials.
7. High sodium concentrations are common to many materials.
8. Excessive boron and selenium levels are common in many samples.
9. High arsenic and nickel concentrations in some samples.
10. Low pH must be considered as potentially limiting because of its relationship to heavy metal solubility. This is a concern both from an environmental and plant growth point of view.
11. Magnesium to calcium ratios. There is evidence that the productivity of some plants is decreased due to a high Mg to Ca ratio in the soil. As shown in the descriptions of the "Problem Identification Categories" in Figure 45, the Mg to Ca ratio in the saturation extract exceeds 1.0 in many materials. The effect of high Mg to Ca on plant growth appears to be a function of the interrelationship of several factors; namely total concentration of Mg and Ca in soil solution, pH of the soil, bicarbonate concentration, salinity and crop species. There is insufficient data available to evaluate this factor at this time, particularly as it relates to the study area.
12. Low cation exchange capacity (less than 5 meq/100gm) suggests low productivity potential.

In summary, deficiencies in nitrogen, phosphorous, potassium and possibly zinc, copper and manganese; sodium; salinity; low pH and texture appear to be the kinds of specific problems associated with the materials studied, in terms of plant growth suitability. The particular problem or combination of problems are defined for each of the "Problem Identification Categories" in Heil and Deutsch, 1979.

The discussion of the chemical and physical characteristics of the Emery core samples is based on the following three tables taken from Heil and Deutsch (1979):

Table A. DTPA-NH_4HCO_3 Extractable B, Pb, As, Se, Al, Ni, Mo, Cd, Sr, Zn, Fe, Mn, and Cu Materials from Bore Holes 3, 4, 5, and 6.

Table B. Geochemical Data for Total and Extractable As, Se, Cd, Cu, Ni, Zn, Mo, Mn, and Fe on Selected Materials.

Table C. Laboratory Characterization Data to Determine Plant Growth Suitability.

Extractable Zn, Cu, Mn, and Fe were determined using a DTPA* extract. All other elements shown were determined from an ammonium bicarbonate-DTPA extract. Data for the materials analyzed are shown on the basis of the "Problem Area Groups". We grouped the materials in this manner in an attempt to determine the relationship between the amounts of the elements considered in this portion of the study vs. the chemical and physical characteristics which were used in determining plant growth suitability. Mean concentration, range and standard deviations of the concentration of each element on the basis of "Problem Area Groups" are also given.

A summary of the extractable geochemical data shown in Appendix 8 gives the following important relationships:

1. The evaluation of materials with respect to effect of moderate to high acidity on the mobility of heavy metals in the environment is well supported by the extractable geochemical data. This factor was identified as a potential problem for materials in Groups 5, 12, 17, 18, 20, 21, 27, 28, 29, and 42. An examination of the data in Heil, 1979, indicates that the extractable Al, Zn, Ni Fe, Mn, and Cu are consistently higher in these groups as compared to materials with an alkaline environment.
2. In general, extractable Se, As and B were higher in the groups identified as having salinity problems. This only confirms our existing knowledge that these elements which usually accumulate as evaporites are often associated with deposits which contain relatively high levels of soluble salts.
3. Potential high Mo availability to plants or mobility in the environment normally is associated with highly alkaline environments. The extractable data indicate that Mo levels are relatively low and do not indicate any potential problem.
4. Standard deviations indicate that for most elements other than those already discussed, there appears to be no consistent relationship between the "Problem Area Groups" and the elements studied.

* DTPA = diethylenetriamine pentaacetic acid

5. In general, extractable Pb levels appear to be higher in materials with low pH. However, this relationship is not consistent. Pb levels appear to be as high or higher in some alkaline materials as compared to the low pH materials. The extractable Pb levels in some materials are higher than what have been reported as the mean total concentration for most soils (10.0 ppm) or geologic materials (5 to 20 ppm). Because of the apparent randomness in Pb concentration as a function of pH and other chemical characteristics, as well as the abnormally high levels in some materials, we must consider that either contamination or error in the analyses have affected the results. We are not sure that the Pb data reflect the real situation that exists. Further evaluations are required to resolve this problem. We suspect that with the method used, that high Al and high Fe may influence the determination of Pb. However, there is no direct evidence from the data that high Pb contents were always associated with high Al and Fe.

In summary, it is important to note that even though extractable chemical analyses data more closely approximate the actual soil solution condition than do total analyses, we must recognize the limitations of the former in terms of predictive capability. Several factors must be kept in mind are:

1. Very little data is available that correlates plant uptake with extractable levels of elements, particularly with regard to native species.
2. The extracant used in this study has a pH of 7.6, thus this effect on the extractability of elements from soil or overburden materials which are acid is not well documented.
3. Most methods, such as the method used in this part of the study, are still being investigated relative to the effects in interferences of various elements on one another and the resulting data.
4. Based on the above considerations, Heil and Deutsch (1979, p. 36) feel that the interpretations are valid. However, to interpret the data further would be risky and may lead to faulty conclusions.

Major Elements of Significance

Nitrogen (N)

Virtually all of the overburden tested were found to be low in nitrogen, as the range was from 5 - 50 lbs/acre (normally referenced to the upper 6 to 8 meters of topsoil). An overall nitrogen content of 40 lbs/acre would be the minimum recommended for reclamation (Goodman, 1973), and since part of the nitrogen in tested samples was not in a form directly used by plants, supplemental N will be needed. Although excessive nitrogen fertilization may not improve the growth of salt desert species, and may encourage noxious weeds which respond quickly to fertilizer (Goodman, 1973) passive soils levels of nitrogen must be raised to at least 40 lbs/acre.

Potassium (K) and Sodium (Na)

Potassium values are variable, with a range from 100 to 400 lbs/acre. Most materials with greater than 200 lbs/acre will have adequate K, unless the soils are excessively acidic or basic. Generally, plants have sufficient K where the pH is in the range of 5.0 - 7.0, but outside this range, plants may suffer from K deficiency (especially poor root development) regardless of the K content because of the preferential assimilation of calcium, which is often plentiful in the soils of arid areas (Heil, 1979). The problem of high alkali content as indicated by sodium is indicated by the number of rejected samples in the greenhouse tests due to salinity (including alkali salts) and SAR values (Table 10). The alkaline nature of local soils is one of the most adverse problems in the soil reconstitution/revegetation phase of this area.

In bore hole #3 the upper 171 feet are in shale where the saturated pH is 8 - 8.5. This excessive alkali content (shown in Figure 47) reaches about 4000 ppm. However, bore holes 4, 5, and 6 are not drilled in Blue Gate Shale. In the upper Ferron Sandstone of bore hole 3 at about 175 feet the delta plain facies are relatively high in alkalies in their upper members but show a decrease to less than 250 ppm. In all other bore holes, the low alkali content is shown in Figure 47. Bore hole #5 for all footage above the I coal seam is in alluvial and deltaic plain siltstones and sandstones. Here, the low alkali siltstones, which range from about 50 to about 500 ppm Na and K, would make an excellent soil dilutant to reduce

Sample Number	Electrical Cond.	SAR	Sample Number	Electrical Cond.	SAR
BH-3-18	11.6	32.2	BH-3-12	5.8	36.4
3-19	4.3	15.9	3-13	9.0	36.2
3-20	10.4	11.4	3-14	6.7	44.0
4-7	2.1	27.3	3-15	6.7	49.5
4-9	6.0	21.1	3-16	9.3	53.2
4-9B	8.9	18.3	3-17B	17.9	39.2
6-25	1.7	15.7	6-22	2.9	17.0
6-37	1.6	16.6	6-24	3.3	19.2
6-4	4.1	40.0	6-27	1.5	17.4
6-30	1.3	16.1	6-29	1.5	18.4
6-31	3.6	39.6	6-35	2.2	18.9
4-16	5.5	2.2	6-36	1.7	16.9
4-8	4.7	2.8	6-41	6.2	49.2
6-28	1.7	13.0	6 46	1.9	20.6
4-12	17.8	0.2	6-47	2.2	23.2
3-8	5.2	28.8	4-17	4.6	2.7
6-49	8.1	13.7	5-3	4.6	4.7
6-56	4.5	0.9	5-13	4.8	1.4
5-14A	4.2	0.9	5-14B	4.4	1.1
5-19	16.2	3.6	6-16	6.4	6.6
6 9	15.2	1.2	6-14	7.0	4.3
4-1	5.5	3.1	6-15	8.6	5.1
4-6	4.8	13.3	6-12	6.5	5.9
4-5	6.0	7.6	6 13	6.4	4.0
4-11	3.2	15.5	6-23	2.5	15.6
5-15	4.4	0.8	3-7	6.4	16.8
6-8	15.2	1.1	3-17	15.5	34.7
3-9	7.8	45.1	6-39	1.8	16.8
3-10	7.2	43.3	6-40	1.8	17.8
3-11	6.9	38.7	6-43	1.2	17.8
			6-45	2.0	27.4

Note: Criteria used for Evaluation:

Salinity

Electrical Conductivity - 0-4 mmho's - Suitable
Electrical Conductivity - 4-8 mmho's - Marginal
Electrical Conductivity - 8 or greater - Unsuitable

Sodium

SAR-0-12 - Suitable
12 or greater - Unsuitable

Table 10. Samples Eliminated from Greenhouse Study doe to Salinity and/or Sodium.

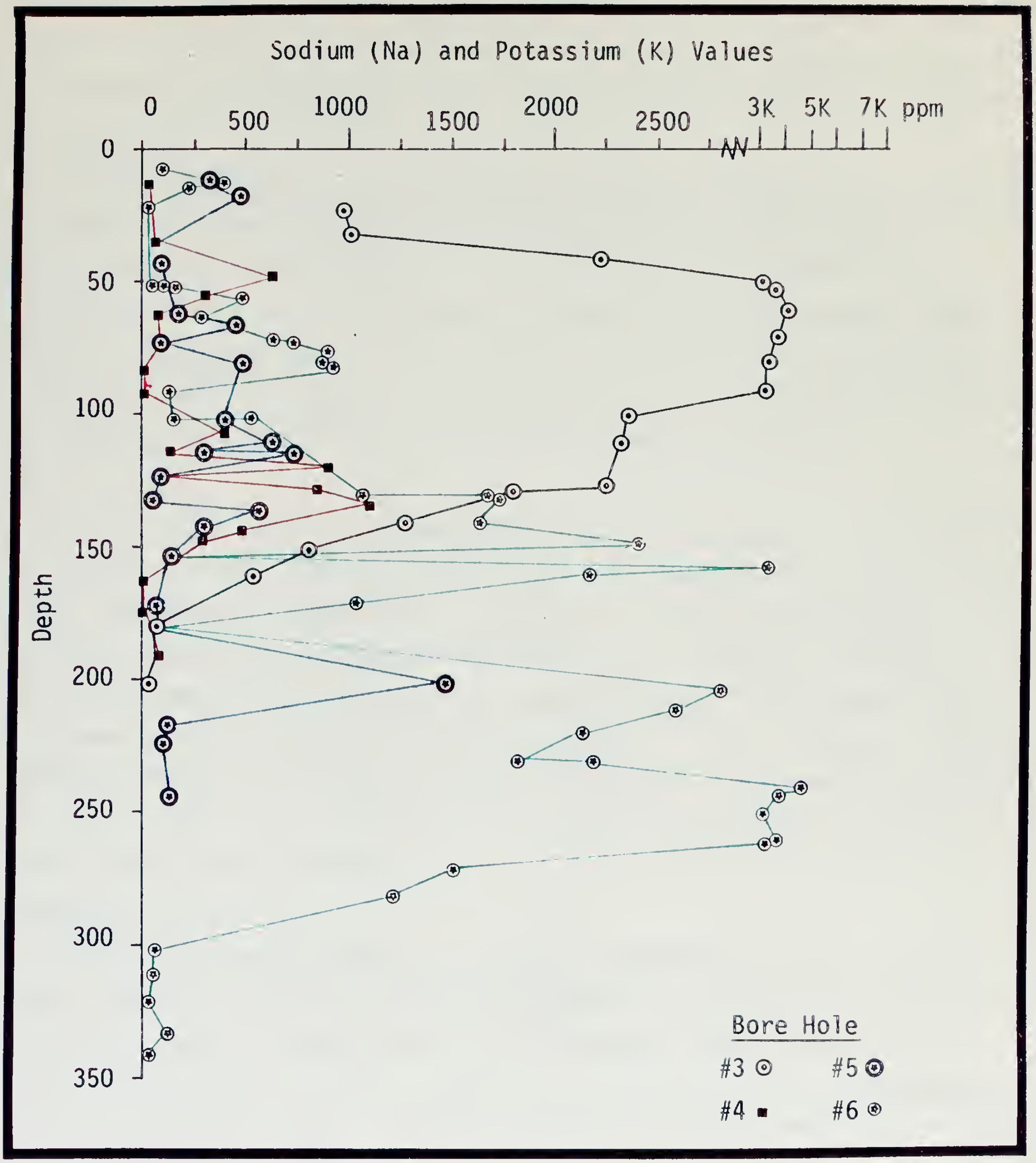


Figure 47. Total Alkalis in EMRIA Bore Hole Samples

alkali values. Bore hole #6 in its lower half (below 150 feet) shows sharp spikes in the total alkali content to levels approaching the Blue Gate Formation of bore hole #3. However, the depth at which these high alkali bore hole #6 levels exist precludes their incorporation into the reconstituted soil and subsoil. In all cases the thickest and purest sand units of the Ferron Sandstone show minimal potassium and sodium concentrations.

Calcium (Ca)

With the exception of a thin anomalous zone at 40 feet in bore hole #3, saturated extractable Ca is below 600 ppm which can be considered a deficiency. The average of Ca in Ferron shales also reflects this deficiency; the average is 2400 ppm, far below that of the average shale which is 22000 ppm. Bore #4A exhibits more variability with some saturated extractable Ca spikes at 125 feet and 195 feet due primarily to a high dolomite content reflected by corresponding magnesium spikes

Magnesium (Mg)

Mg is a major essential element for plants and animals. True toxicity is unknown. Ferron shales are relatively low compared to "average" shale (3600 ppm vs. 16000 ppm). The range of total Mg in 12 Ferron shales is from 1400 to 60000 ppm (Affolter et al., 1978). The range in NH_4 OAC extractable Mg in Emery core samples ranges from 32 ppm to 3630 ppm (sample 27 bore hole #5) with an average well below 1000 ppm. Heil's anomalous sample 27 (Figure 48), which is probably a volcanic ash horizon, is also unusual in its very high Ca, Zn and Cu concentrations and the highest CEC value (of 32.3).

Aluminum (Al)

Because overburden leachates (geologic formations and soil) in the Emery area have a high pH (with the exception of pyritic coal or coal associated shale), aluminum toxicity in plants, livestock and man is considered minimal since its solubility is less than 2 ppm at reasonable soil pH values over 4.9. (Aluminum solubility rises at very high pH values.)

Minor and Trace Elements

A review of the data provided by Heil and Deutsch (1979) indicates that of the minor and trace elements there is some concern with certain deficiencies of Cu, Mn and Zn and possible near toxic levels of B and Se in some samples. We detail the geochemistry of these elements below and provide data on other minor and trace elements of interest (As, Br, Cd, Cl,

Figure 48. Borehole 5 - Geochemical Anomalous Zone [in brackets], Sample 27 (Heil, 1979)

Footage:

195	7	COAL, blk, competent, tr marcasite on cleat surf, non-calc, brittle
196	6	SS, gry, non-calc, tite
196	10	COAL, as abv
197	7	COAL, shaley, dk gry, w/ COAL stringer @ 199' 7"
199	11	COAL, blk, pure, massive, tr marcasite on cleats, non-calc
201	6	COAL, dk gry, shaley, competent, non-calc trans to
202	8	MUDSTN, lgt cream-brn, incoh, non-calc, crumbly
204	2	Sharp contact, COAL, sft, slickensides, massive
206	4	End Box 20

			ppm				
	7. SAT	CEC	Ca	Mg	Na	Zn	Cu
Sample 27 Mudstone	67.6	32.3	5160	3630	1190	14.50	3.00

Cr, Co, F, I, Pb, Li, Hg, Ni, Tl, Sn, and V) in Appendix 8, bearing in mind that As and Ni are present in sufficiently high concentrations in some samples to warrant concern (Heil and Deutsch, 1979, p. 53).

Boron (B)

Although boron is essential in higher plants, the difference between ideal concentrations of boron in soils and toxic concentrations is only 1 or 2 ppm. Affolter's data for boron are for ashed coal samples and are therefore much higher than whole rock values. Water soluble extractions are best indicated in the water quality analyses (USGS, 1979). Most boron concentrations in the Emery area streams are below 0.5 ppm. For values above 0.75 ppm, in irrigation water, some sensitive crops may begin to show toxicity symptoms (Bradford, 1966). These high (>0.75 ppm) values of boron occur as follows:

Table 11.
Boron Content in USGS Water Samples

Sample	ppm Boron (B)
SRU 5-373 (D-20-8)	.890
(D-22-6) 29-DAC Consol. Mine Ceiling Sample #1	.850
(D-22-6) 30-BDA-1 Blue Gate Well #3	.870
(D-21-7) 4 AAC-1 Blue Gate Well #1	.780
(D-20-8) 22 CAA SRU 5, 413 Seismic Test	1.100
SRU 8-1061 Seismic Test Hole Miller Canyon	2.600
SRU 8-1037 Seismic Test Hole Miller Canyon	1.100

From multivariant cluster analysis of plant growth characteristics, Heil and Deutsch (1979) indicate that boron, salinity, and high alkalinity either alone or in combination caused death of plants in pot tests in cluster 4 and samples 5-19 in cluster 8. The depth interval represented in the sample 4-12 cluster 5 is 93' 6" to 94' 2" and in sample 5-19 is 143' 3" to 143' 9", both below the I coal seam. High (>0.75 ppm) extractable boron values are given in Table 10 and graphed in Figure 49.
The toxic level of boron for man is 5300 ppm.

Copper (Cu)

The element is mobile as copper chlorides, nitrates and sulfates. Toxicity to plants apparently occurs only near copper ore deposits.

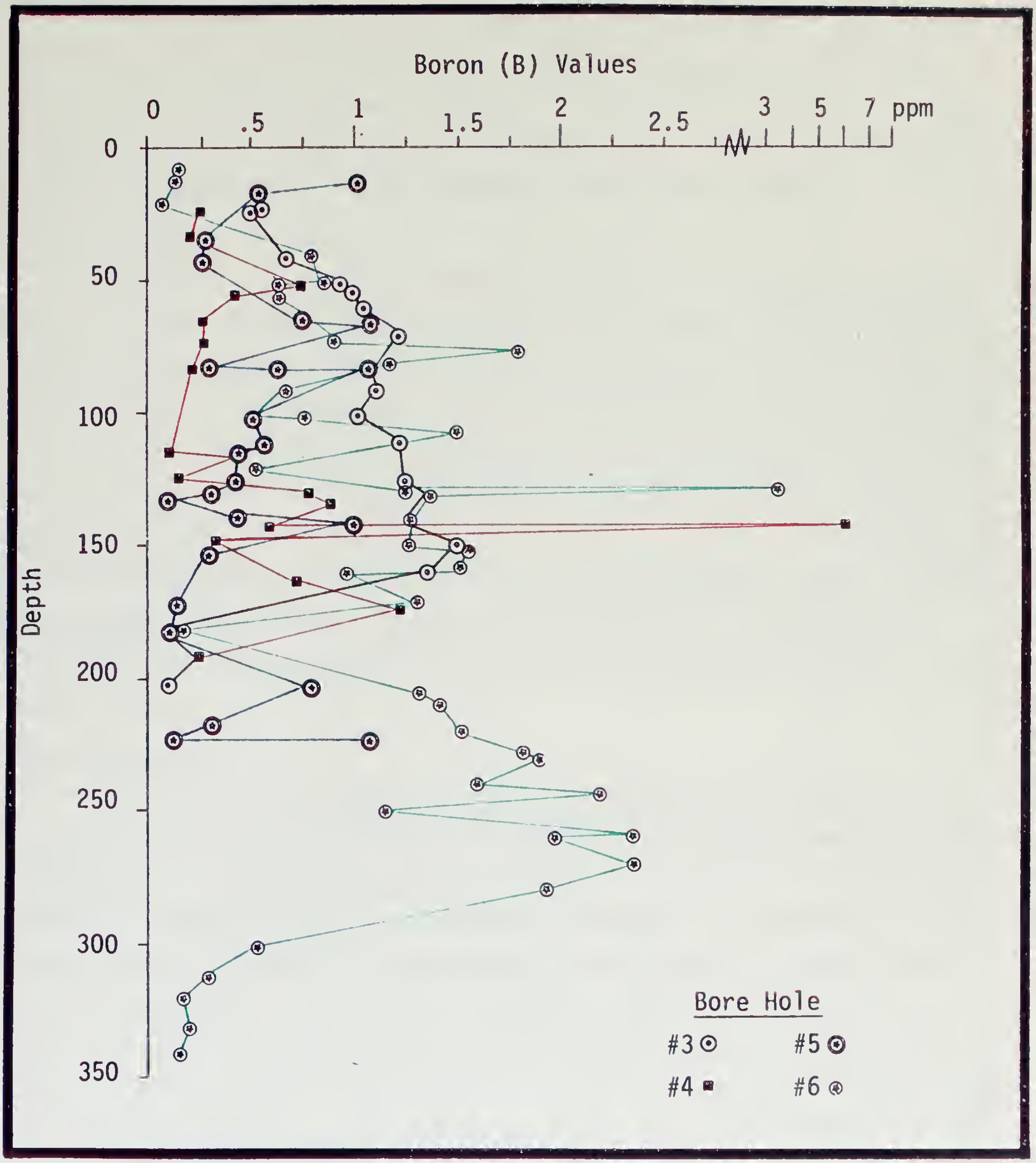


Figure 49. Boron (B) Values in EMRIA Bore Hole Samples

Copper present in herbicides and fungicides can cause adverse effects the concentration exceeds about 150 ppm in acid soil. An outstanding Cu anomaly exists in the upper part of a coal seam at a depth of 130' 11" to 131' 5" in bore hole #6 where a DTPA extract shows a Cu value of 15.7 ppm along with a major anomaly in Zn (21.8 ppm). Most extractable Cu values in cores are below 4 ppm. Heil and Deutsch (1979) cite a general extractable copper deficiency in the samples analyzed. Ashed Emery coal values (Affolter et al., 1978) range from 34 to 140 ppm Cu with an average above that of Wasatch Plateau coal samples.

Manganese (Mn)

As with Mg, Mn is also an essential element for plants and animals but in trace amounts. Only amounts of Mn in excess of about 450 ppm Mn (dry weight basis) in their tissues show toxicity. Extractable DTPA Mn in Emery bore hole samples are all below 21 ppm and most are under 5 ppm. Extractable Mn is therefore generally deficient in most of the crushed core samples analyzed by Heil and Deutsch (1979). Total Mn in Ferron pyritic shales (Affolter et al., 1978) ranges from 16 to 45 ppm with an average of 25, well below that of the "average" shale (66 ppm). A reciprocal relationship exists in the ashed coal from the Ferron Formation versus ashed coal from the Wasatch Plateau (18 versus 7, respectively).

Molybdenum (Mo)

Mo is not a toxic element to plants although above 5-6 ppm in dry forage for cattle and 10-12 ppm in dry forage for sheep, molybdenosis may occur. The problem could be a matter of concern in the Emery area since Mo is more available to plants at high pH. Extractable Mo (by the ammonium bicarbonate DTPA method) is well under 0.1 ppm for most bore hole samples; the maximum recorded by Heil being 0.82 ppm in bore hole #6 (51' 4" to 51' 7") in the upper level of a coal seam. The Emery area soils may be deficient in Mo since the minimum level in plants should be at least 0.1 ppm (Johnson, 1966). Mo is not reported in the USGS (1979) water analyses. Affolter et al., (1978) shows an average for 12 Ferron shales of 5 ppm (Table 12). Even the ashed coal averages from the Ferron Formation are equal to or less than 2 ppm Mo.

Table 12

Arithmetic Mean, Observed Range, Geometric Mean, and Geometric Deviation of Contents of 35 Elements in 12 Shale Samples from the Ferron Sandstone Member of the Mancos Shale, Emery Coal Field, Emery County, Utah.

Element	Arithmetic Mean	Observed Range		Geometric Mean	Geometric Deviation	Average Shale
		Minimum	Maximum			
			Percent			
Si	19	14	22	19	1.1	27
Al	11	6.2	16	10	1.4	8.0
Ca	.24	.09	.56	.22	1.6	2.2
Mg	.36	.14	.60	.32	1.6	1.6
Na	.13	.06	.46	.11	1.8	.96
K	.56	.27	1.5	.50	1.6	2.7
Fe	2.0	.56	4.2	1.5	2.0	4.7
Ti	.40	.22	.59	.38	1.3	.46
			Parts per Million			
As	8.5	0.4	54	2.9	4.6	13
B	70	50	100	70	1.3	100
Ba	150	50	500	150	1.9	580
Be	2	1.5 L	5	1.5	2.6	3
Co	3.8	.5	9.2	2.7	2.6	19
Cr	31	4.7	75	22	2.7	90
Cu	26	16 L	57	22	1.9	45
F	430	240	850	400	1.5	740
Ga	30	10	50	20	1.7	19
Hg	.32	.02	1.7	.13	3.9	.4
Li	88	47	170	80	1.6	92
Mn	27	16	45	25	1.5	66
Mo	5	5 L	10	5	1.6	850*
Nb	15	10 L	15	15	1.3	11
Ni	10	7 L	30	7	2.1	68
Pb	30	15 L	59	26	1.7	20
Sb	1.2	.2	2.3	.9	1.9	1.5
Sc	7	5 L	10	5	1.7	13
Se	3.1	2.0 L	4.6	2.9	1.4	.6
Sr	100	20	150	70	1.7	300
Th	23	10	47	20	1.7	12
U	11	2.2	31	8.8	2.0	3.7
V	50	15	100	50	1.8	130
Y	10	10 L	15	10	1.4	26
Yb	1	1 L	1.5	1	1.4	2.6
Zn	56	18	120	47	1.8	95
Zr	150	50	200	100	1.6	160

* This value appears to be in error

(For comparison, average shale contents are included (Turekian and Wedepahl, 1961). All values except geometric deviation are in percent or parts per million and are reported on a whole-shale basis. As, Co, Cr, F, Hg, Sb, Th, and U values used to calculate the statistics were determined directly on whole shale. All other values used were calculated from determinations made on shale ash. L, less than value shown.)

Selenium (Se)

The element causes health problems in animals both at low and high concentrations. At optimum concentration levels, Se is an essential element. In soil Se is made available to plants mostly as calcium selenate and organic selenium. Elemental Se and selenite, especially basic ferric selenite, are only slightly available to most plants. Concentrations in Se from shale bedrock to soil plants growing on this soil occur in the following concentration ranges in a known seleniferous area in Canada (Byers and Lakin, 1939):

Bedrock	0.3 to 3 ppm
Soil	0.1 to 6 ppm
Plants	3.0 to 4200 ppm

Selenium values in crushed core samples analyzed by Heil range from 0.06 to 4.7 ppm; values in Ferron shale range from 2 to 4.6 ppm with a comparable range in ashed coal (Affolter et al., 1978). Dissolved Se in stream water (USGS, 1979) is very low (0.004 to 0.06 ppm). *Atriplex canescens* (fourwing saltbush), used in experiments by Heil and Deutsch, is known to concentrate selenium and can accumulate to levels lethal to livestock (Kingsbury, 1964; Davis, 1972).

Zinc (Zn)

Zinc-rich soils, those with concentrations exceeding 1000 ppm, are distinguished by also having high Pb levels (of over 1000 pp,) but not Cd (Ernst, 1974 p. 3). In the Emery area, the Zn values are generally much lower and for many samples constitute a possible deficiency. However, in some pot tests, zinc levels are high (Heil and Deutsch, 1979) with a positive correlation with Cu. A maximum value (30 ppm) of extractable Zn occurs in the base of a carbonaceous shale (with calcite stringers) overlying a clean siltstone in bore hole #6 at a depth of 81' 6" to 81' 10". Paralelling Heil's observation that extractable soil Zn in most samples is relatively low, the total Zn content of 12 Ferron shales on the average (Table 11) is about half of that of the "average" shale (56 versus 95 ppm, respectively). This relationship is reversed in the coal samples of the Ferron Formation with respect to average Wasatch coal (15 versus 6.9 ppm, respectively). Only three determinations were made of dissolved Zn in stream waters by the USGS and these range from 0 to 0.01 ppm Zn (samples F, I and M of Figure 50).

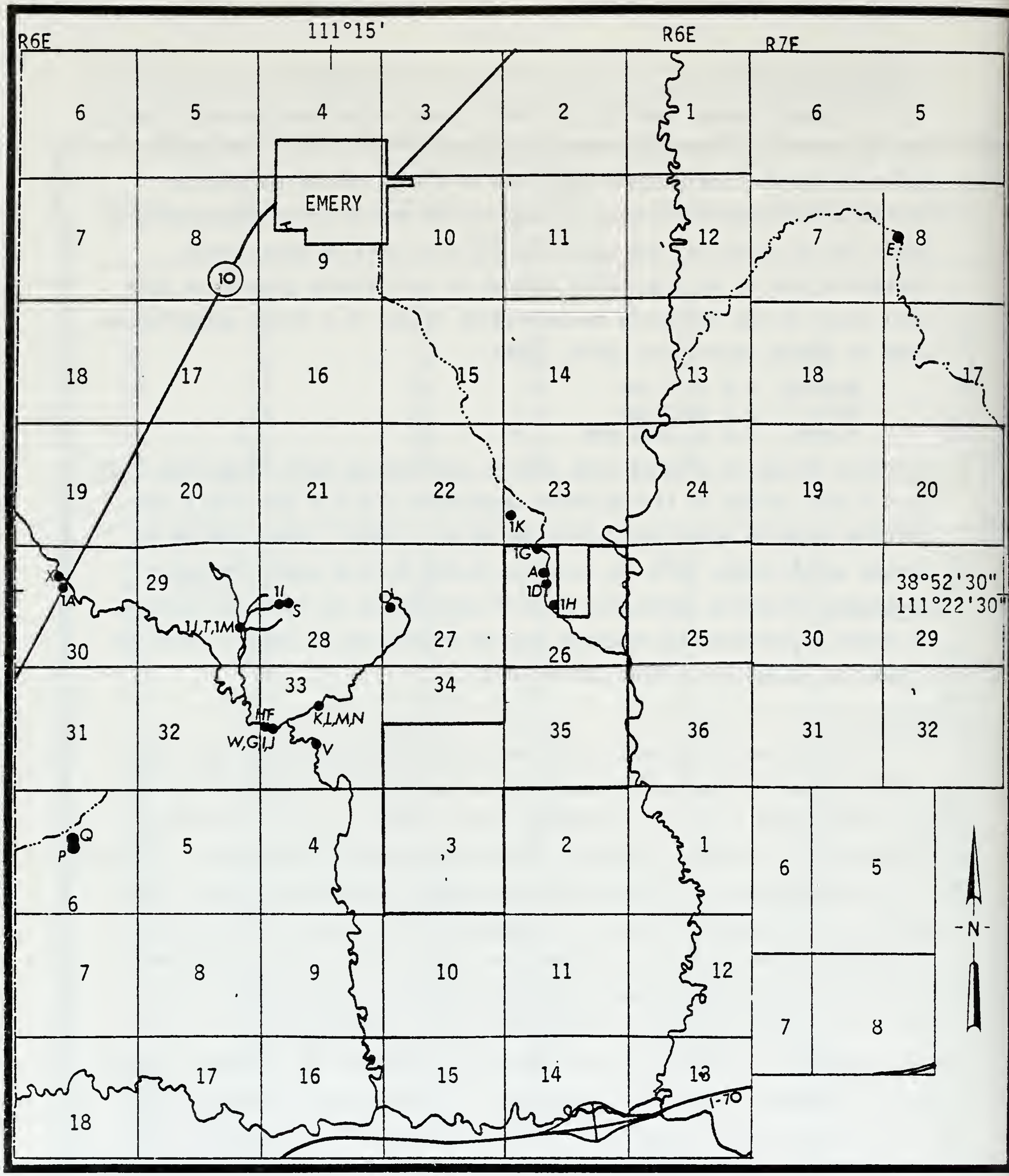


Figure 50. USGS Water Quality Sample Analysis Sites.
See Appendix 8 for reference to Sample Stations.

Summary of Toxic, Detrimental and Essential Elements in the Project Area

Several problems have yet to be resolved regarding the interpretation of the geochemical data based on the report by Heil and Deutsch (1979), Affolter et al., (1978) and the USGS (1979) water analyses. The latter did not include many of the elements reported by Heil and Deutsch (1979) and Affolter et al., (1978). The report by Affolter et al., (1978) did not analyze the siltstones and sandstones of the Ferron Formation. This probably does not constitute a serious problem in admixing sandstone in the formation of re-constituted subsoil or topsoil because trace element levels in siltstones and sandstones are generally lower than shales. Finally, the data reported by Heil and Deutsch represent those samples derived from crushed core bedrock samples. This material was not soil and fertilizer was added to the crushed rock for pot tests. Growth results for native species other than western wheatgrass were disappointing (Table 13). The problem of the cause of plant mortality is aggravated because similar pot tests by Heil from the Foidel Creek area did not produce as many deaths. On review of the geochemical data, we note from Table 14 that toxic concentrations either in the water, Ferron shale and crushed core samples are not present. However, detrimental to toxic levels of boron (especially in the lower part of bore hole #6) and deficiencies of manganese, copper, and zinc may occur.

Returning to the problems of admixed fertilizer added to crushed rock in pot tests, we are concerned with a lowering of pH by this fertilizer. Since Emery crushed rock (with the exception of pyritic and carbonaceous shale zones) are generally alkalic, a reduced pH would tend to mobilize whatever potentially toxic elements may be present. Under conditions of high pH, most toxic metals from insoluble carbonates and hydroxides. We recommend analysis of extractable toxic elements from leachates before and after addition of fertilizers.

Based on the evaluation of major, minor and trace elements, four possible overburden configurations might be considered. First (Figure 51), we recommend an adequate clay seal above the Ferron siltstones after the I coal seam is removed. A permeable coarse rock layer should be placed on top of this seal. Above this a reconstituted subsoil should be added.

Table 13

Growth Results Obtained in Greenhouse from Kochia, Fourwing Saltbush, Scarlet Globemallow and Alkali Sacaton. (after Heil and Deutsch, 1979 p. 67)

Greenhouse Pot No.	Species Grown	Western Wheatgrass Performance	Other Native Species Performance
8	Alkali sacaton	Good	Good
5	Globemallow	Good	Poor-germinated after 6 weeks
7	Fourwing salt brush	Good	No germination or growth
23	Kochia	Good	No germination or growth
25	Alkali sacaton	Poor	Poor germination and growth
26	Globemallow	Poor	No germination or growth
27	Fourwing salt brush	Poor	No germination or growth
28	Kochia	Poor	No germination or growth
29	Fourwing salt brush	No growth	No germination or growth
13	Globemallow	No growth	No germination or growth
17	Kochia	No growth	No germination or growth
15	Alkali sacaton	No growth	No germination or growth

Table 14

General Characteristics of Overburden
Major and Trace Element Content

Element	Essential: Acceptable Level	Essential: Possibly Too Low	Essential: Possibly Too High (detrimental to toxic)	Non-Essential: Acceptable for Plants	Non-Essential: Possibly Too High (detrimental to toxic)
Al				X	
As				X	
B			X		
Br	X				
Cd				X	
Cl	X				
Cr				X	
Co					
Cu		X			
F					
I					
Pb				X	
Li				X	
Mg		X			
Mn		X			
Hg					
Mo	X				
N		X			
Na			X		
Ni					X (?)
P		X			
K		--- Variable ---			
Se					X (?)
Tl				X	
Sn				X	
V				X	
Zn		X			

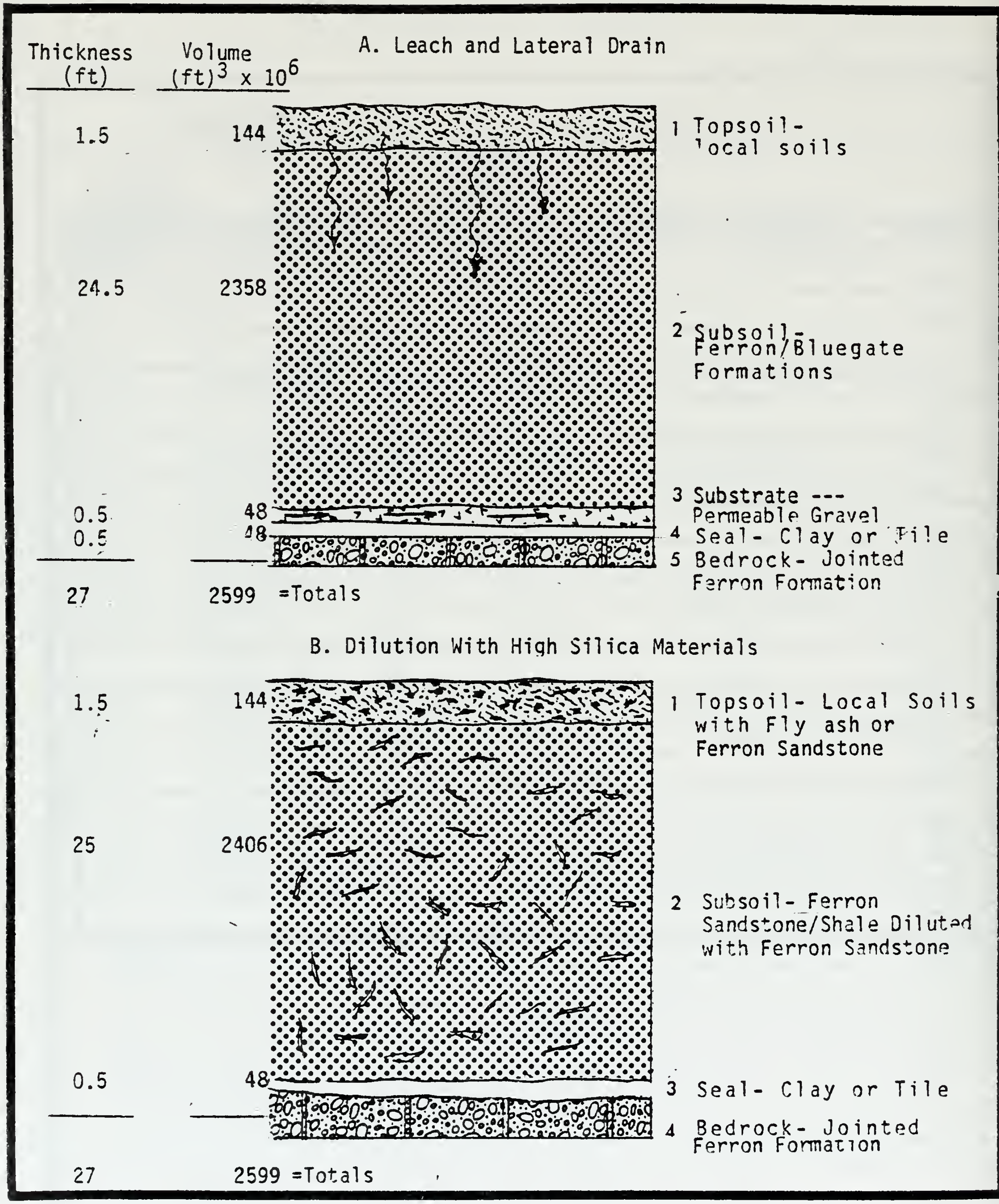


Figure 51. Alternate Overburden Configurations for Optimum Revegetation. Present Thickness of Weathered Zone (Based on Drilling Water Loss Logs) is 45-48 Feet.

Finally, a three foot topsoil layer is recommended. If boron is present, we will assume a slow growth rate until sufficient leaching and removal of boron in the coarse rock substrate can take place (Figure 51). In the case of mobilized toxics, accelerated downward leaching may be achieved by addition of fertilizer to the topsoil.

The second action does not involve a leach and lateral transport by a gravel substrate above the clay seal. Instead, we suggest dilution of the reconstituted overburden and topsoil by admixing either Ferron sandstone, Quaternary windblown sands (Qca of Figure 18), or fly ash (Figure 51). Fly ash admixture which must be quantitatively evaluated, would qualitatively provide the benefits shown in Table 15.

Table 15

Advantages of Fly Ash Soil Dilution

1. Dilute (lower) the alkali content
2. Increase the sulfur content and therefore
3. Lower the soil pH
4. Increase the calcium content
5. Possibly raise the zinc and copper contents
6. Dilute the boron content
7. Increase the soil moisture retentivity and soil/plant root moisture accessibility

The amount of fly ash generated by the Emery coal fired power plant is 780 tons/day. Most fly ash is mildly to moderately alkaline so that this waste product can substitute for limestone in strip mine spoils neutralization. The neutralizing capacity of fly ash derived from bituminous coal ranges from 15 to 200 tons of fly ash per ton of $CaCO_3$.

In addition to neutralizing power, fly ash, admixed with spoil, effects favorable physical changes of the mix, which improves plant growth (Doyle, 1976, p. 134) Since the density of the mix is reduced by admixture of the fly ash, the pore volume, moisture availability, and air capacity increase. These factors improve root penetration and depth.

If trucks hauling coal away from the strip mining area can return with fly ash loads from the power plant site, possibly low cost stockpiling of this product at the strip site would be achieved. The ashed samples of coal analyzed by the USGS (1979) suggest that nutrients are present which might enhance plant survival if fly ash is added to the spoil (Table 16). We suggest pot test on soil mixes with fly ash to quantify optimum mixtures.

Table 16

Chemical and Screen Analysis of Fly Ashes
(after Doyle, 1976, p. 133)

	Fly Ash 1	Fly Ash 2	Fly Ash 3
pH	11.40*	9.1 - 10.6	11.90
Bulk density, g/cc	1.12	0.93	1.15
Chemical analysis, wt pct			
Aluminum (Al_2O_3)	23.90	23.90	23.60
Silicon (SiO_2)	46.30	42.20	47.70
Iron (Fe_2O_3)	22.90	24.00	15.60
Phosphorous (P_2O_5)	.30	.20	.60
Titanium (TiO_2)	.90	.80	2.70
Calcium (CaO)	1.90	4.00	3.50
Magnesium (MgO)	.80	1.20	1.50
Potassium (K_2O)	2.20	2.20	2.20
Sodium (Na_2O)	.60	.60	1.90
Cobalt	.02	.02	ND**
Boron	.008	.02	ND
Manganese	.03	.05	ND
Copper	.02	.02	ND
Molybdenum	.007	NT***	ND
Carbon	5-7	12.4	1.54
Sulfur (total)	.24	.51	.34
Screen analysis, wt pct			
+60 mesh	2	2	1
-60+100 mesh	5	3	2
-100+150 mesh	4	4	2
-150+200 mesh	8	7	4
-200 mesh	81	84	91

*pH of fly ash used at site 1 was 11.4; when used the next year at site 2 the pH had dropped to the range of 4.4 to 9.5

**Not determined.

***Not detected.

Chemical and Physical Characteristics of Soil and Fly Ash

Sample	Organic Matter	pH	Effective $CaCo_3$	Available P	Exchange K	CEC	Bulk Density	Field Capacity	Texture Sand	Texture Silt	Texture Clay
	(percent)		(pounds/acre)	(pounds/acre)	(pounds/acre)	(meq/100 g)	(g/cc)	(percent)	(percent)	(percent)	(percent)
Soil A	1.7	4.8	7,500	50	257	12.7	1.18	20.6	28	72	0
Soil B	1.5	3.1	20,000+	190	93	14.1	1.19	27.5	22	74	4
Soil C	2.2	6.3	3,000	34	252	14.1	1.18	24.1	22	74	4
Fly ash	–	7.7	–	42	1,000+	–	1.48	17.0	46	52	2

A final advantage to the use of fly ash in soil dilution is to reduce permeability caused by overburden swelling.

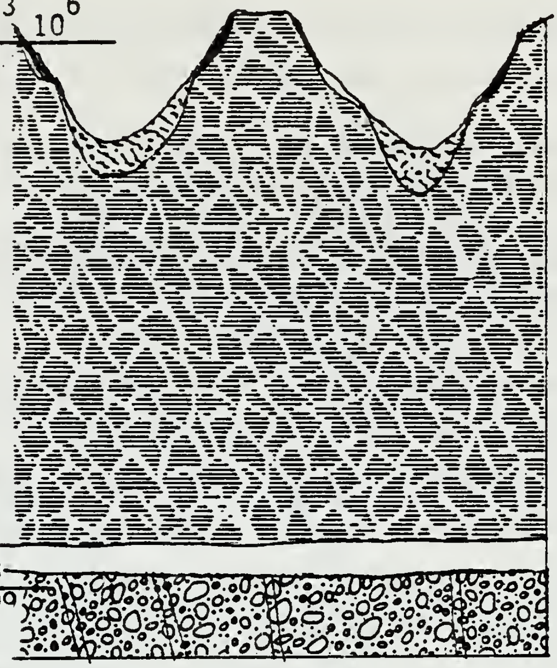
When large volumes of rock are dug up and subsequently replaced as fill, the new ground surface may be higher than the original surface depending on the thickness of coal removed. This phenomenon is called overburden swelling and may provide as much as a 20% increase in apparent volume of the fragmented rock. Thus if stripping occurs to 100 ft. depth, we might expect a 20 ft. overburden swell. This should be distinguished from ground swell due to the expansion of wetted clays (i.e. the soil shrink-swell potential in Figure 44). Overburden swelling is due to the fact that broken rock fragments cannot be packed as tightly as the original rock. As a result the replaced rock has a significant amount of void space filled with either air or water. Its permeability, or ability to transmit fluids, is likewise increased. The increased access of these weathering elements, coupled with the increased surface area of the rock exposed to them, allows leaching to occur at an advanced rate. Since harmful materials may be present in the Emery overburden rock, contamination of local streams, or shallow aquifers may result unless the formation is sealed.

In addition to leaching problems, the raised ground level and/or changed contour may pose revegetation problems, aesthetic conflicts, and instabilities. Differential settling may occur over some extended time. Drainage patterns can also be changed due to the presence of the overburden swell. Surface water runoff will decrease due to increased infiltration and ground water recharge. Fly ash dilution can minimize these problems.

The third overburden configuration (Figure 52) is that conceived by the Department of Energy's Pacific Northwest Laboratory, which uses water runoff for irrigation. The method eliminates the need for major recontouring of mining debris and the need for irrigation to maintain plant cover.

In research sponsored by DOE's Biomedical and Environmental Research Division, Dr. Ronald J. Sauer is studying the possibility of using the steep slopes of spoil piles to collect rainfall for growing marketable

C. Waterproof Slopes of Resulting Spoil Banks.



D. Sandwiching of Undesireable Materials.

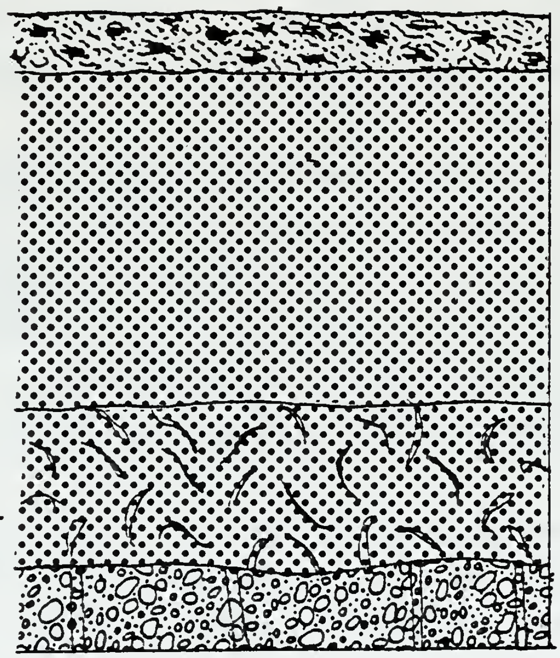


Figure 52. Alternate Overburden Configurations for Optimum Revegetation. Present Thickness of Weathered Zone (Based on Drilling Water Loss Logs) is 45-48 Feet. Concept C. after Sauer (1979), Concept D. after Hinkley (1979).

crops in arid regions.

The method requires minimal recontouring of the spoil banks, with only the tops and sides smothered. Soil spread in the narrow valleys between the banks is seeded with marketable crops, such as winter wheat or grapes. Irrigation is supplied by rainfall, which runs off the waterproofed slopes of the spoil and concentrates in the valleys.

In this way, three-fourths of the land collects moisture for cultivating the other fourth - an important step in arid areas where precipitation is scarce. One inch (25mm) of rainfall becomes 4 in. (100mm) of moisture in the cultivated valleys, offsetting the need for expensive irrigation systems.

A current research objective is to develop an effective, long-lasting, and economical slope treatment. Rubberized asphalt, a combination of ground-up tires and asphalt, is the best treatment tested so far, he notes. A paraffin wax treatment, sprayed on the hillside in a molten state, is also being studied.

Dr. Sauer is also considering treating slopes with salt. A demonstration site, located in Washington's arid Columbia Basin region, is composed mainly of sand and rock. However, in most strip-mining areas of the West, typical spoil has a high clay content. Salt cements clay particles together to produce a virtually waterproof surface. Dr. Sauer hopes to try this method in a new demonstration site being planned for the Black Mesa area of the Southwest.

The fourth alternative (Figure 52) is simply to sandwich the undesirable spoil in between a modified topsoil and a "clean" lower subsoil above accessable aquifers. In this case if the lower subsoil is admixed with fly ash (to reduce permeability and boron/alkali content) the requirement for a clay seal above the permeable Ferron sandstone units might not be neccessary (personal conversation, T. Hinkley, May 11, 1979).

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VEGETATION

Throughout the Central Utah Region, precipitation is the principal factor controlling the distribution of major vegetation types. Although the Emery study site lies at more than 6000' elevation, it lies in the rainshadow of the Fish Lake Mountains and receives only 7-8" annual precipitation. The severity of the arid climate is accentuated by the seasonal rainfall distribution, which peaks in July-August when air temperatures and evapotranspiration potential is at a maximum. Consequently, the precipitation is less available for use by plants. Another result of the arid conditions is high soil salinity which is produced by the upward migration of ground water towards the land surface where it evaporates, leaving salts in the upper soil horizons. Much of the area consists of tablelands with steep talus slopes and unweathered rock debris around the perimeter of the benches. Soils derived from such materials are juvenile and consist of very coarse, thin veneers where present, with little or no organic component. Thus, naturally occurring environmental conditions are very harsh. At the same time, it is these conditions which create the habitats to which the natural vegetation has become adapted. During the course of evolution, local plants and those which have migrated into the area have been constantly improving their survival potential by a variety of adaptations which allow them to survive here, where more mesic species cannot. Were conditions to change toward a more moist environment for several years, the present vegetation would be eliminated by the other species more suited to the new environment. The plant assemblage which appears to have the highest potential for rehabilitation of mined lands in the Emery area consists mainly of the same species occurring there naturally because of their preadaptation to local conditions. For example, Bleak et al., (1965) found that seeds from native grasses and shrubs collected on one site in the shadscale zone would perish when planted in another area of the shadscale zone, while endemic ecotypes reproduced successfully. Physinomic, physiologic and morphological characteristics have been found to vary greatly among several important shrubs, as is often the case with widespread species. Assessment of the present resource is prerequisite to outline of mining and rehabilitation objectives, and essential for development of a reclamation plan. Given the extent and sensitivity of the present vegetation and the severity of the climate, it is not probable that the post-mining environment would be suitable for plant growth without significant long-term support for transplanted and seeded shrubs and grasses.

Assessment of the present vegetation cover was accomplished by a combination of aerial photo interpretation and field data collection, supplemented by a review of past and present research on the characteristics of the regional flora. Aerial photos were obtained as part of this study in August, 1977 and July, 1978 at scales of 1:6,000 and 1:12,000. Additional 1:24,000 coverage was obtained on the second aerial survey. False color LANDSAT imagery was also utilized in the analysis of regional vegetation patterns over a large area.

Field data was collected throughout the project with major efforts in October, 1977 and June, 1978. Line transects (Figure 53) were used in 54 locations to obtain values for species coverage in each vegetation type, as well as estimates of the surface extent of bare rock, litter, and bare soil. For each transect, the numbers and intercept lengths of each species were recorded along the transect. Location and transect orientation were recorded, and slope and soil characteristics were noted. In addition to the transects, species lists were compiled for an additional 28 sites. This was useful for assessment of special habitat types, such as cliffs, talus slopes, and washes, where line intercept measurements are not feasible.

The bulk of the soils data was supplied by the Soil Conservation Service and this material is discussed in a subsequent section. Supplemental soils data has been collected in the areas where revegetation experiments are being carried out on the site.

VEGETATION OF THE CENTRAL UTAH REGION

The Emery, Utah study site lies in Castle Valley between the San Rafael Desert on the east, and the Fish Lake Mountains on the west. A transect along this elevation gradient crosses several vegetation zones. Beginning at the upper elevations of the mountains, Western Spruce and Fir dominate (Figure 54). Below this zone, an association of Spruce, Fir and Douglas Fir is prevalent, especially on south and west facing slopes, while many north and east facing slopes support large Aspen groves. A Scrub Oak association is found below this zone, and forms a dense cover of small evergreen trees and tall shrubs. Pinyon-Juniper woodland is found further downslope, extending from the lower foothills of the mountain range out into the desert on the upper benches (above 6,000'). Below this, desert shrub communities dominate, as shadscale becomes the most common type

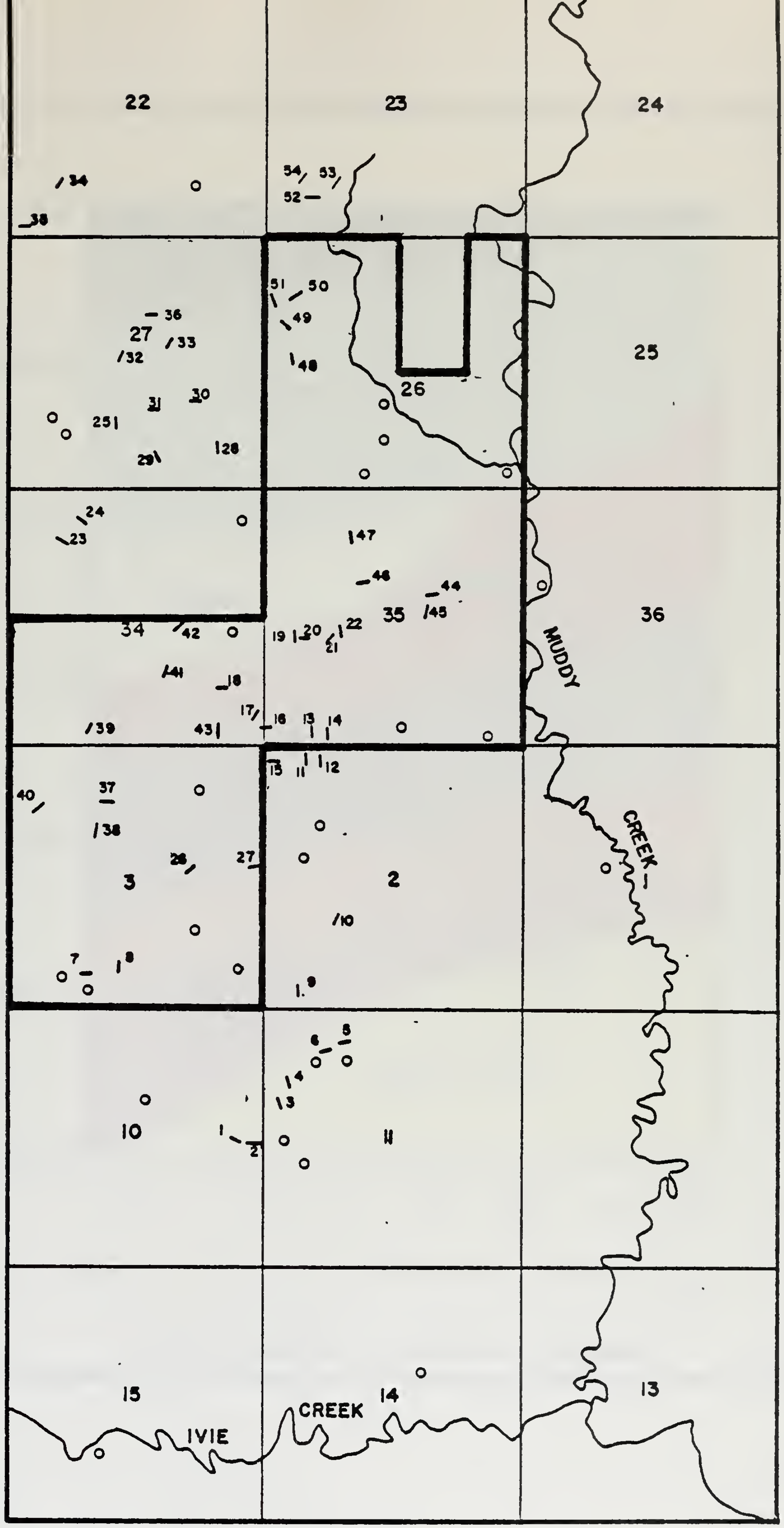
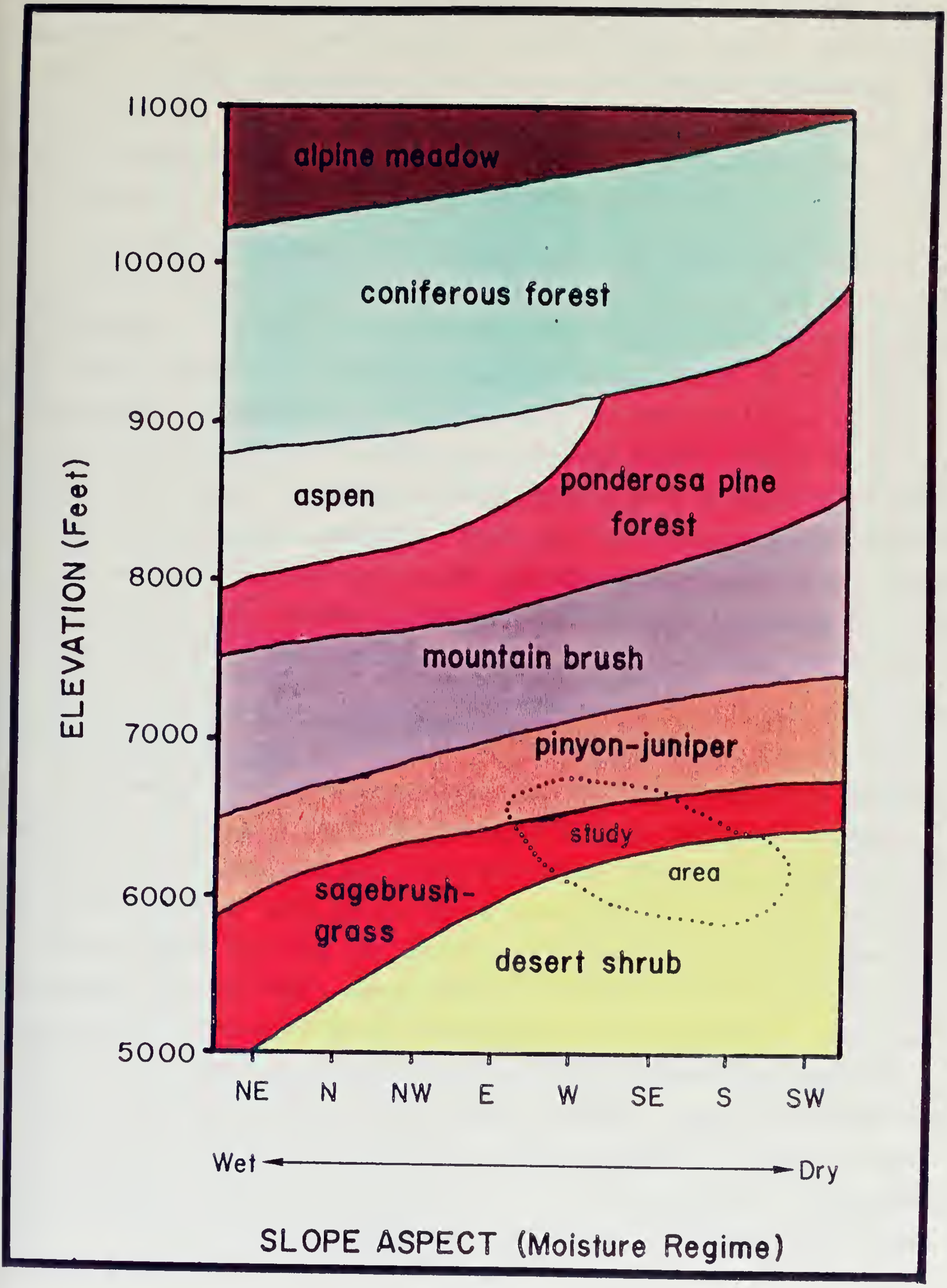


Figure 53

TRANSECT AND SAMPLE LOCATIONS

O Species collection — 100 Ft. Transect



alpine meadow
coniferous forest
aspen
ponderosa pine forest
mountain brush
pinyon-juniper
study area
sagebrush-grass
desert shrub
11000
10000
9000
8000
7000
6000
5000
ELEVATION (Feet)
NE
N
NW
E
W
SE
S
SW
Wet
Dry
SLOPE ASPECT (Moisture Regime)

Figure 54

on mature soils. Figure 55 illustrates a hypothetical transect from the mountain range to the west edge of the San Rafael Swell. While each zone is clearly recognizable, the transitions between these major types are broad and contain species from several types. Representation of this complex gradient greatly simplifies the complexity of the transition in floristic composition between the high mountains and dry deserts.

The climatic gradient which accompanies the slope from mountain to desert is largely responsible for the vegetation zones and their spatial arrangement. At the top of the Fish Lake Plateau, precipitation exceeds 36 inches annually, and temperatures are generally 15^{o} to 25^{o} F cooler. Downslope, precipitation is much less, since the rainshadow of the Fish Lake Mountains limits the Emery area to less than 8 inches in an average year. The transition from one vegetation zone to another is as gradual as the precipitation gradient. There are few sharp linear contacts between one zone and the next as the formations are gradational. The Salt Desert shrub type vegetation characteristic of the Utah deserts is widespread throughout the west where annual rainfall is less than 8-12 inches.

VEGETATION TYPES, EMERY AREA

The Emery, Utah study area straddles two major vegetation types prevalent in Central Utah and elsewhere in the intermountain West: Pinyon-Juniper Woodland and Shadscale Scrub. The study area includes typical stands of both types, as well as an ecotone, or zone of transition between the two. In general, Pinyon-Juniper occupies the upper poritons of Molen Reef, above the Coal Cliffs at the Emery site, and extends for several miles on the benches to the northeast. The lower part of the bench and most of Castle Valley supports the Shadscale type or other associates of Salt Desert shrubs. Special habitat types including cliffs and talus slopes, washes, perennial streams, coves and canyons, and other disturbed sites also have special, recognizable plant associations, but the Pinyon-Juniper and Shadscale types appear to be dominant on areas of mature soil. Figure 56 maps the site.

The Pinyon-Juniper Woodland type consists of an open forest of Pinyon Pine (*Pinus edulis*) and Utah Juniper (*Juniperus osteosperma*). Because of

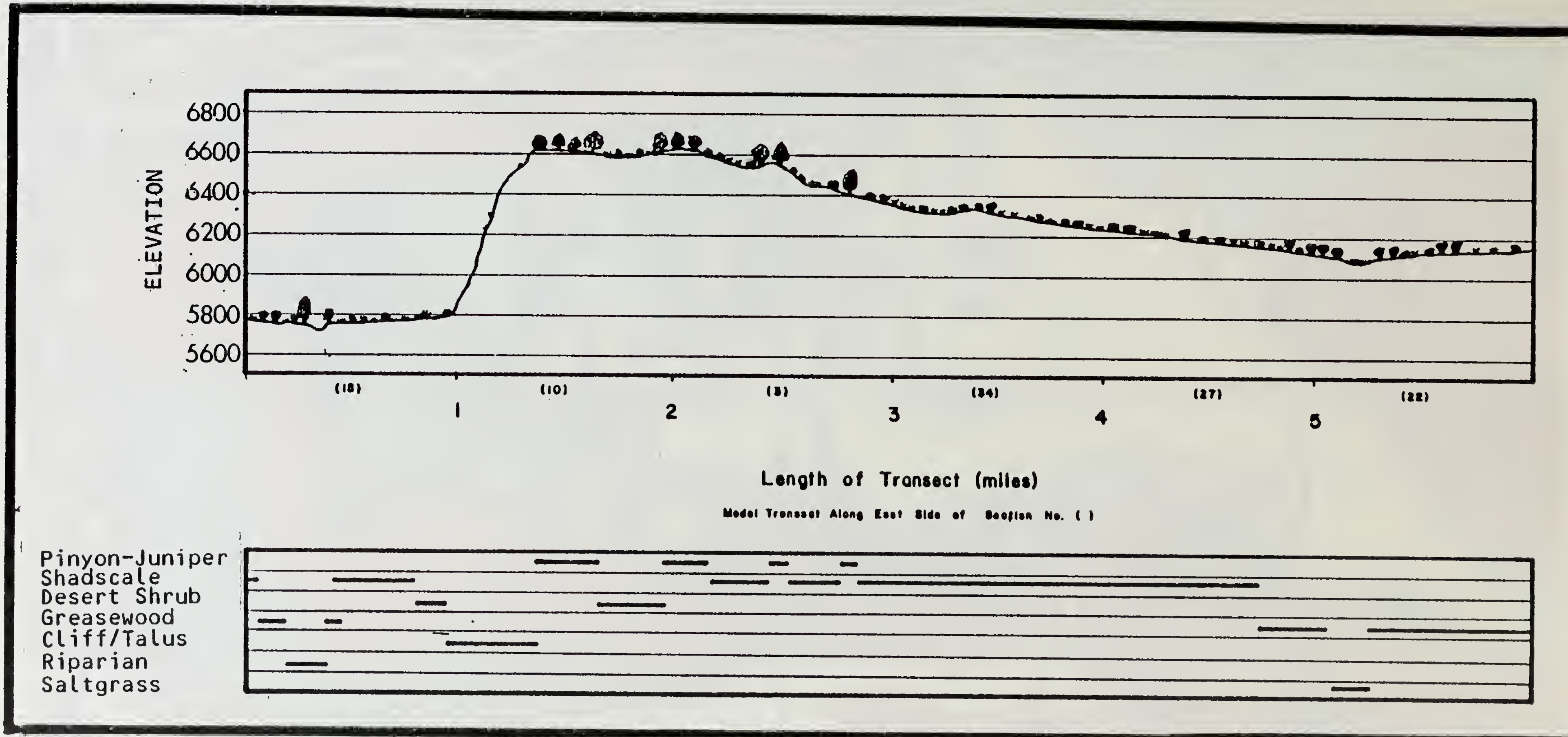


Figure 55. N-S Cross Section Showing Relationship Between Vegetation Types and Topography

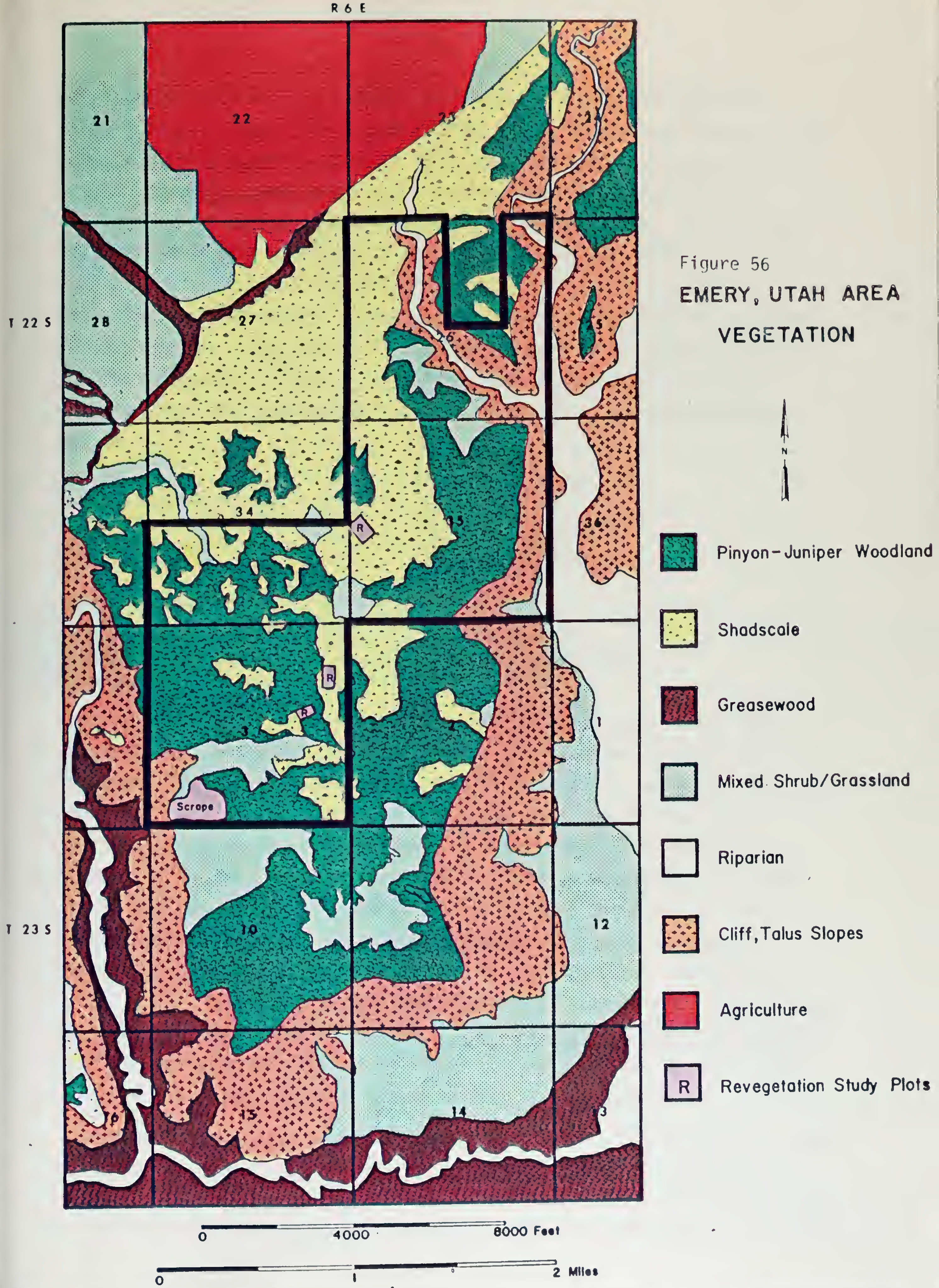


Figure 56
EMERY, UTAH AREA VEGETATION

their limited size and low density, Pinyon-Juniper Woodland has been referred to as a pygmy forest type (Cottam, 1929; Tanner and Hayward, 1934; Rasmussen, 1941; Woodbury, 1947). It is the most extensive type in this part of the state. Both trees are evergreen and are widely spaced so that branches of adjacent plants do not usually touch. Maximum size may be 25 feet, but most trees are 15-20 feet in height and are nearly as wide. The highest elevation woodland (6400') consists of about 50% Pinyon Pine, with the remainder in Juniper. There is not a large cover of understory vegetation. At lower elevations the proportion of Juniper increases, as Pinyon gradually drops out. Total vegetation coverage for the type averages about 45%, leaving 55% bare soil and rock. Associated shrubs include:

Amelanchier alnifolia	Cowania mexicana
Atriplex confertifolia	Ephedra sp.
Artemisia sp.	Opuntia polycantha
Cercocarpus intricatus	Rhus trilobata
Chrysothamnus sp.	Yucca harrimaniae

Grasses include:

Agropyron inerme	Hilaria jamesii
Aristida fenleriana	Oryzopsis hymenoides
Bouteloua gracilis	Stipa comata

In certain topographic lows on the upper benches, deeper soils (and presumably soil moisture) accumulate and support a mixed shrub/grass formation. This type occupies fine grained soils and is among the most productive lands in the vicinity of the study area when moisture is available. This is shown by the heavy cover of annuals following the wet winter of 1977-1978. None of this type is found on the study site proper. Vegetal coverage of 30% is found in the spring when up to 24% of the surface supports annuals. Lappula occidentalis, Erigonum inflatum and Chenopodium album accounted for most of the annual growth. Perennial shrubs in this type are Atriplex confertifolia, Chrysothamnus viscidiflorus, and Artemisia nova. Grasses include Hilaria jamesii and Bouteloua gracilis. There is some evidence that Juniper are invading the site, as young trees are found along the perimeter. This problem is discussed below.

Downslope from the pure Pinyon-Juniper Woodland, shrubs and grasses appear in increasing numbers as a second canopy layer in clearings between the trees. This type is transitional between the Woodland and Shrub formations, and includes the strong elements of both. Juniper accounts for up to 18% of the 25-30% total coverage in this type, while Pinyon Pine drops out almost entirely. While there are a few Juniper found as far downslope as the Ferron Sandstone-Blue Gate Shale contact at 6200', this vegetation type is not extensive.

Shadscale Scrub is the most prevalent formation on the lower portion of the bench, and is common throughout the intermountain region. It is usually considered to be an edaphic climax on Saline Valley Soils (Holgrem, et al., 1973), but may also persist where salt concentration is relatively low. It is composed of low, widely spaced shrubs, with a generally whitish-gray appearance, and perennial bunch grasses. Total vegetal coverage is 8-20%. The composition of this type is variable, perhaps due to spatial variations in soil salinity, however, its appearance is white uniform. Shadscale (Atriplex confertifolia) and Galleta grass (Hilaria jamesii) have the highest coverage values in the Shadscale zone. There are a number of other important shrubs:

Artemisia nova
Artemisia tridentata
Atriplex cuneata
Ceratoides lanata
Kochia americana
Opuntia polycantha
Sarcobatus vermiculatus
Yucca harrimaniae

and grasses:

Agropyron cristatum
Boutelouca gracilis
Oryzopsis hymenoides
Stipa comata

These two major vegetation types, Pinyon-Juniper and Shadscale, account for almost 70% of the area in the Emery study site. Other communities are generally restricted to disturbed or otherwise special habitat types.

Almost pure stands of Greasewood (Sarcobatus vermiculatus) are found on the margins of most perennial streams in the area. It is found on heavy clay-rich, highly saline soils, and is the principal phreatophyte of the Shadscale zone (Holgrem et al., 1973). The most extensive stand parallels Christiansen Wash where it flows along the Ferron-Blue Gate contact. Associated species are Halogeton glomeratus, Salsola kali, and Atriplex species. Iodine bush (Allenrolfea occidentalis) is found where the surface has become encrusted with alkali accumulation, while saltgrass (Distichlis stricta) occurs in the channel of Christiansen Wash and several places where there is perennial runoff of irrigation water.

	PINYON-JUNIPER WOODLAND		SHADSCALE		GREASEWOOD		MIXED SHRUB/GRASSLAND		RIPARIAN		CLIFF/TALUS SLOPES	
	%Cover[1]	Yield[2]	%Cover	Yield	%Cover	Yield	%Cover	Yield	%Cover	Yield	%Cover	Yield
TREES												
Juniperus osteosperma	19	(580)	.9	(50)	---	---	.4	(30)	---	---	P	(20)
Pinus edulis	12	(350)	---	---	---	---	---	---	---	---	P	---
Populus fremontii	---		---	---	---	---	---	---	3.0	(400)	---	---
Salix sp.	---		---	---	---	---	---	---	7.0	(700)	---	---
Tamarix pentandra	---		---	---	---	---	---	---	9.0	(500)	---	---
SHRUBS												
Allenrolfea occidentalis	---	---	P	---	1.9	(18)	---	---	.7	(20)	.2	---
Amalanchier alnifolia	P	---	P	---	---	---	---	---	---	---	.2	---
Artimesia nova	P	---	.4	---	.2	---	.3	---	---	---	P	(10)
Atriplex canescens	P	---	.4	---	1.1	(44)	.6	(8)	---	---	.7	(12)
A. confertifolia	1.0	(20)	8.6	(390)	2.2	(45)	3.2	(75)	---	---	.5	(4)
A. cuneata	---	---	1.0	(25)	2.0	(55)	P	---	.4	(8)	.4	(6)
Ceratoides lanata	---	---	.3	---	---	---	P	---	---	---	---	---
Cercocarpus intricatus	.5	---	P	---	---	---	---	---	---	---	.4	---
Chrysothamnus nevadensis	.5	---	P	---	P	---	P	---	.3	---	1.0	(8)
C. viscidiflorus	.2	---	P	---	P	---	1.0	(12)	.4	---	1.2	(12)
Ephedra nevadensis	.3	---	.1	---	---	---	.6	---	.3	---	.4	---
E. viridis	---	---	P	---	---	---	.3	---	---	---	.6	---
Grayia spinosa	---	---	.2	---	P	---	P	---	---	---	---	---
Gutierrezia sarothrae	P	---	.1	---	---	---	P	---	---	---	---	---
Kochia americana	---	---	1.3	(26)	P	---	.6	(16)	.4	---	---	---
Opuntia polyacantha	.8	---	1.0		---	---	1.0	---	---	---	---	---
Sarcobatus vermiculatus	---	---	P	---	23.1	(575)	P	---	8.9	(120)	---	---
FORBS												
Chenopodium sp.	---	---	P	---	.4	---	.4	---	---	---	---	---
Eriogonum inflatum	---	---	1.1	(18)	---	---	1.3	(28)	---	---	---	---
Eriogonum sp.	.5	---	P	---	.4	---	.8	---	---	---	P	---
Halogeton glomeratus	---	---	P	---	2.4	(32)	P	---	.9	---	---	---
Lappula occidentalis	.7	---	1.2	---	---	---	2.2	(12)	---	---	P	---
Salsola kali	.4	---	P	---	1.1	---	P	---	.4	---	.6	(3)
Sphaeralcea grossulariaefolia	---	---	P	---	---	---	P	---	---	---	---	---
GRASSES AND GRASS-LIKE PLANTS												
Agropyron inerme	---	---	P	---	---	---	P	---	---	---	---	---
Aristida fendleriana	---	---	P	---	---	---	P	---	---	---	---	---
Boutelona gracilis	.3	---	.4	---	---	---	.4	---	---	---	P	---
Distichlis stricta	---	---	---	---	2.9	(60)	---	---	4.3	(6)	---	---
Hilaria jamesii	1.0	---	8.1	(12)	P	---	3.1	(6)	---	---	.3	---
Juncus balticus	---	---	---	---	---	---	---	---	1.2	---	---	---
Oryzopsis hymenoides	P	---	.3	---	.4	---	P	---	---	---	.5	---
Phragmites communis	---	---	---	---	---	---	---	---	.8	---	---	---
Scirpus sp.	---	---	---	---	---	---	---	---	.6	---	---	---
Stipa sp.	---	---	P	---	---	---	P	---	---	---	---	---
Typha	---	---	---	---	---	---	---	---	.4	---	---	---
OTHER MISCELLANEOUS	.5	---	1.1	---	3.7	---	2.1	---	1.9	---	.5	---
Mulch	21.6		18.2		25.6		9.9		3.4		1.0	
Bare soil	29.3		40.8		30.6		54.9		42.5		36.3	
Rock	11.4		15.0		3.0		16.9		13.2		55.5	
TOTAL VEGETATION COVER	27.7		26.2		40.8		18.3		40.9		7.5	
Estimated Yield		(1000)		(525)		(695)		(245)		(2000)		(80)
Area (acres)	947		597		*		198		130		243	

1) P indicates presence
2) Yield units are lb./acre

* Not found on study site proper

Table 17. Percent Cover of Vegetation Mulch, Soil, and Rocks - Estimated Yield.

Large areas of the study site consist of talus slopes on the margins of the benches and steep sided canyons and washes. These support a very low density association of shrubs and grasses which develop in small soil pockets between rocks and boulders. Certain rock strata exhibit a tendency to fracture into large blocks and create a deep crevice habitat which supports such species as the shrubs Ephedra nevadensis, Rhus trilobata, Atriplex canescens and Yucca harrimaniae, and the grasses Aristida sp. and Oryzopsis hymenoides.

Agricultural land uses are restricted to the area underlain by Blue Gate Shale, generally to the north of the study site. Most of the area is planted to alfalfa (Medicago sativa) which is supported by irrigation and there are some fields of improved pasture land.

SUCCESSIONAL STAGES AND THEIR RELATIONSHIP TO REHABILITATION

Disturbance of the land surface which destroy or modify the plant cover begin a process called succession, in which certain types of plants invade the new territory, and are gradually replaced by other species as the soil matures and new microhabitats are created. This is usually a lengthy process. Following fires in Pinyon-Juniper Woodland, Barney and Frischknecht (1974) found that 85-90 years may be required for a full return to the original conditions. As the transition is made from bare rock or soil to the mature climax vegetation, the plant cover goes through a number of changes in a somewhat predictable order. For example, Barney and Frischknecht (1974) observed the following stages following Pinyon-Juniper burns: Skeleton Forest and bare soil; annual stage; perennial grass-forb stage; perennial grass-forb-shrub-young Juniper stage; shrub-Juniper stage; Pinyon-Juniper Woodland. The floristic composition of each stage consists of specific plants with preadaptations to the precise environmental conditions present at that time. For example the first plants to invade following fire are weedy annual species, whose physiological adaptations allow them to colonize an open, dry and somewhat sterile habitat. Gradually, the organic and moisture content of the soil builds up and perennial grasses and forbs outcompete the annuals by consuming available resources and filling open space. This stage is in turn replaced by plants better adapted to the changing conditions, until the self-perpetuating Pinyon-Juniper Woodland returns.

Rehabilitation of mined lands is, in one sense, an attempt to speed the process of succession, in order to avoid the long time period which would ordinarily be required for the existing Pinyon-Juniper and Shadscale vegetation types to return. It is even possible that they might never return if toxic materials were left at the surface. It is useful, then, to evaluate the study area to see what types of plants are doing well at sites which have been disturbed. Within the vicinity of the Emery site, there are a number of sites which can be evaluated to infer possible post mining conditions. Of particular interest is an area on the bench above the east side of Quitchupah Creek, which was scraped clear of soil and vegetation in 1966 to smother a burning coal bed. The burning coal bed is known to have been ignited at least 70 years prior, according to local residents. The Bureau of Mines reported large cracks in the sandstone overburden, which they inferred to have developed as a result of the fire. The vegetation, a moderate stand of Pinyon-Juniper (based on 1952 aerial photos) with little understory vegetation, was removed with earth moving equipment and the surface was drilled and blasted. Three to five feet of soil were removed from a nearby borrow pit and used to attempt to cut off the air supply to the fire by depositing it in the cracks. Once the new surface was graded, the entire area was seeded with "grass" (Bureau of Mines, 1966).

It has been 12 years since the surface soil was removed and the process of secondary succession has failed to produce a perennial vegetation cover. At present, much of the area is barren rock and windblown sand. The assertion in 1966 that grass seeding "should retard erosion and return the area to its original or better grazing potential" (Bureau of Mines, 1966) has failed to materialize. If the surface was graded and covered by 3 to 5 feet of soil after the fire was smothered, most of it has been removed by the wind, and the present flora is of little use to livestock because of the scarcity of palatable materials.

A detailed survey of the entire disturbed area found 20 plant species. Many of these are annuals, and are probably not present in any numbers following dry winters. The most conspicuous plant is the Russian Thistle (*Salsola kali*), which is almost useless for erosion control or grazing. Fourwing saltbush (*Atriplex canescens*) has done well in small protected sites and grows to relatively large size compared to its stature on the rest of the study site. Rabbitbrush (*Chrysothamnus sp.*) is also present at low density. The total vegetal coverage on the scraped area is less than 3% which included the contribution of this year's annuals. Perennial species account for less than 1% cover. Fourwing saltbush (Atriplex canescens) is the most promising of the plants found on this site. Currently, it is not dominant or even frequent in any vegetation type in this locale. A. canescens is widespread in the west, occurring from the Great Plains to the Pacific Coast Mountains, and from Canada to Mexico at elevations from sea level to 8000' (Blauer et al., 1976). In any species with such a wide geographic distribution, it is common to find great variation in the forms and tolerances of the plant within different parts of its range. Although there has been some research concerning methods of propagation and potential for rehabilitation, extensive tests should be conducted with local plants to determine if the ecotype found on the scrape area has exceptional ability to colonize primitive soils. Although fourwing saltbush is a valuable forage shrub, it also can concentrate selenium from soils where it occurs (Kingsbury, 1964; Davis, 1972). Livestock losses have been reported where there was little forage (Hitchcock et al., 1964). Table 18 gives a list of species encountered for all habitats in the area.

Summary

Cattle grazing takes place during the winter and spring months over most of the Emery study site. Except for a few inaccessible benches, cattle have been observed in all areas with a high concentration of use around those stock ponds located along ephemeral washes. Grazing intensity has been sufficient to induce some striking changes in the character of several plant communities.

The expansion of the Pinyon-Juniper Woodland has been noted at the Emery site and may possibly be attributed to chronic heavy grazing. Research throughout the intermountain region has shown the expansion of woodland into heavily grazed sagebrush or shadscale communities (Arnold et al., 1964; Cottam and Stewart, 1940; Pickford, 1932).

In many locations there are Juniper seedlings on the margins of established woodland stands where shrub vegetation is adjacent. In addition, the understory in the mature Pinyon-Juniper areas is usually extremely

TABLE 18

THREATENED AND ENDANGERED PLANT SPECIES, EMERY COUNTY*

Species	Status[1]	Critical Habitat
Threatened:		
Asclepias ruthias	T - C	Sandy Soil
Astragalus rafaelensis	T - C	Morrison, Chinle, Moenkopi
Castilleja scabrida	T - NC	Dakota
Erigonum smithii	T - C	Estrada, Blown Sand
Parthenium ligulatum[2]	T - C	Carmel, Green River Shale
Phacelia constancei	T - NC	Mud-Slitstone
Phacelia rafaelensis	T -NC	Moenkopi
Scelrocactus wrightii	T - C	Mancos Shale
Endangered:		
Astragalus pardalinius[3]	E - NC	Entrada Sandstone, Sand
Cryptantha jonesiana	E - C	Moenkopi
Cryptantha johnstonii	E - C	Carmel
Cycladenia humulis[4] (var. jonesii)	E - C	Moenkopi
Erigonum intermontanum	E - C?	Green River Shale
Physaria grahamii	E - C?	Green River Shale

1. C - Critical; NC - Not Critical; ? - Uncertain
2. Published as Parthenium alpinum var. ligulatum
3. Published as Phaca pardalina
4. Published as Cyclanderia jonesii

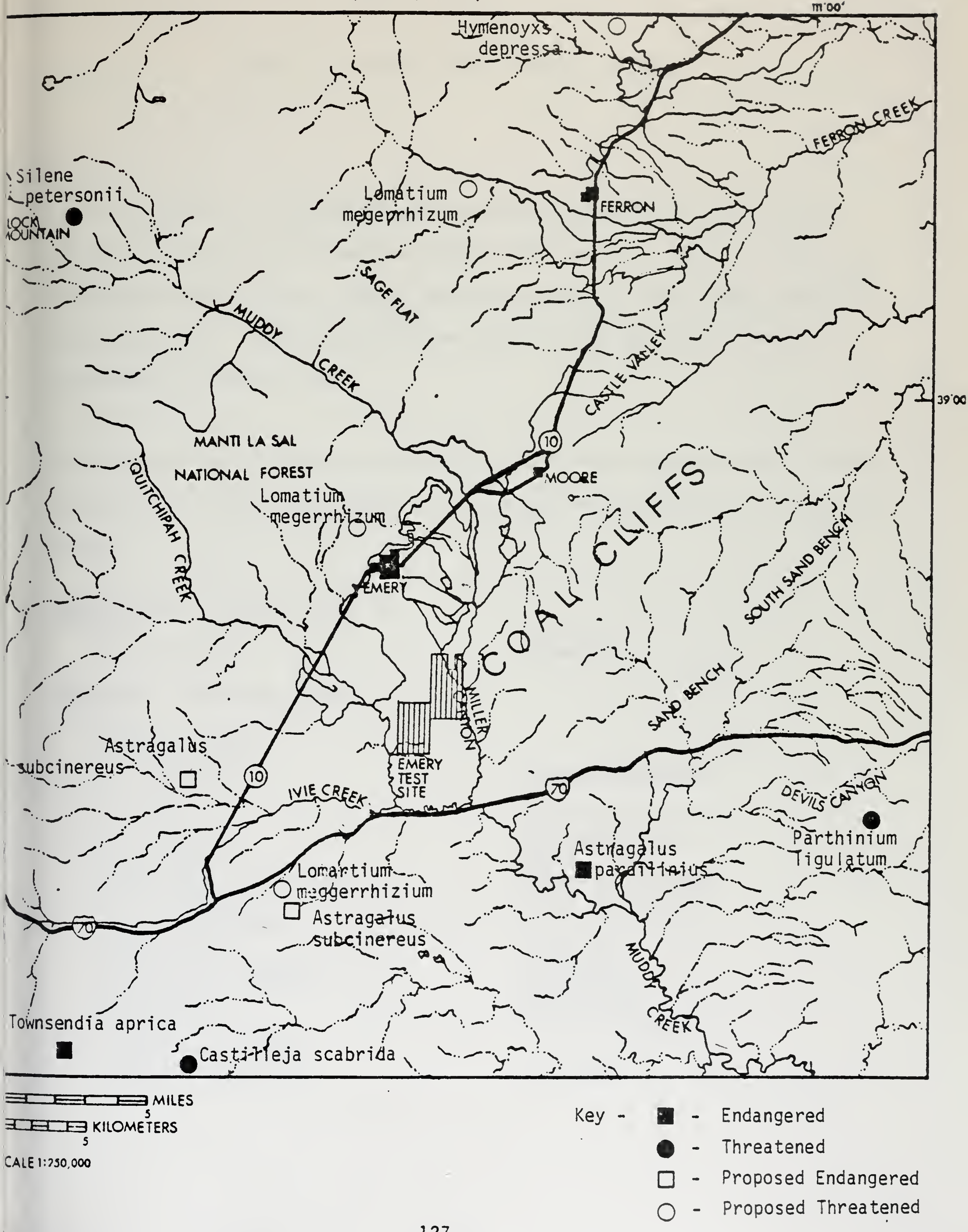
* From Welsh, 1977

sparse or entirely absent. Historical aerial photos from 1952-1962, 1969 and 1977 have been examined to evaluate the expansion of the Pinyon-Juniper type and it was found to have occurred in several areas.

In addition to outright conversion of shrubland, other areas show evidence of alteration in floristic composition and forage value, and possibly gross productivity, which may be due to grazing. Unpalatable shrubs, forbs, and grasses have become established where the competition from desirable browse plants has been reduced. Halogeton glomeratus, which was introduced from Central Asia, is common in the lower Shadscale zone and contains oxalic acid which may be toxic to cattle in large amounts. A Prickly Pear Cactus (Opuntia polycantha) has become frequent in the upper Shadscale zone. The production value of the present vegetation is probably lower because of the past grazing history.

A survey of the region for threatened and endangered species shows that 14 species or subspecies have been noted in Emery County (Welsh, 1977). Of these, 8 are listed as threatened, and 5 are endangered (Table 18). None of these species were observed on the study site, but several species have been collected within 25 miles (Figure 57). However, since the impact of mining is expected to be limited to the site and immediate vicinity neither threatened nor endangered species are expected to be affected.

Figure 57. Threatened and Endangered Plants
(Welsh, 1977)



PLANTS OF THE EMERY STUDY AREA AND VICINITY

The following is a listing of plant species encountered in the vicinity of the Emery, Utah study site between August, 1977 and July, 1978. Listings are arranged alphabetically by family, genus and species. Common names are given where they apply. Nomenclature follows that of Welsh and Moore (1973), or in a few cases, Tidestrom (1925).

In all, there are 25 families represented by 65 genera and 83 species. These include most of the common plants from the major vegetation types in the Castle Valley.

<u>ANACARDIACEAE</u> - Cashew family

Rhus trilobata	Squawbush

<u>ASTERACEAE</u> - Sunflower family

Artemisia cana	
A. dracunculus	
A. filifolia	Old Man Sagebrush
A. frigida	
A. nova	Black Sagebrush
A. tridentata	Big Sagebrush
Aster spp.	Aster
Chrysothamnus nauseosus	Rubber rabbitbrush
C. viscidiflorus	Green rabbitbrush
Encelia frutescens	
Erigeron spp.	Fleabane
Gutierrezia sarothrae	Snakeweed
Heterotheca villosa	Golden Aster
Iva axilaris	Marsh Elder
Tetradymia spinosa	Spiny horsebrush
Thelesperma subnudum	
Xanthium strumarium	Cocklebur

ASCLEPIADACEAE - Milkweed family

Asclepias spp.	Milkweed

BORAGINACEAE - Borage family

Lappula occidentalis	Stickseed
Lithospermum multiflorum	Stoneseed

CACTACEAE - Cactus family

Echinocereus triglochiatus	Hedgehog cactus
Opuntia polyacantha	Prickly pear

CAPPARIDACEAE - Caper family

Cleome spp.	Beeplant

CHENOPODIACEAE - Goosefoot family

Allenrolfea occidentalis	Pickleweed
Atriplex canescens	Four-wing saltbush
A. corrugata	Mat saltbush
A. confertifolia	Shadscale
A. cuneata	Castle Valley clover
Ceratoides lanata	Winterfat
Chenopodium spp.	Goosefoot
Grayia spinosa	Spiny hopsage
Halogeton glomeratus	Halogeton
Kochia americana	Summer cypress
Salsola kali	Russian thistle
Sarcobatus vermiculatus	Greasewood

CRUCIFERAE - Mustard family

Brassica spp.	Mustard
Stanleya pinnata	Princes plume

CYPRESSACEAE - Cypress family

Juniperus osteosperma	Utah juniper

CYPERACEAE - Sedge family

Scirpus acutus	Bulrush
S. americanus	

ELAEAGNACEAE - Oleaster family

Elaeagnus angustifolia	Russian olive

EPHEDRACEAE - Ephedra family

Ephedra nevadensis	Mormon tea
E. viridis	

HYDROPHYLLACEAE - Waterleaf family

Phacelia corrugata	Scorpion weed
P. demissa	

JUNCACEAE - Rush family

Juncus balticus	Baltic Rush

LEGUMINOSAE - Pea family

Astragalus sp.	Milkvetch

LILIACEAE - Lily family

Yucca harrimaniae	Native yucca

MALVACEAE - Mallow family

Sphaeralcea grossulariaefolia	Globe mallow

PINACEAE - Pine family

Pinus edulis	Pinyon pine

POACEAE - Grass family

Agropyron inerme	Beardless wheatgrass
A. cristatum	Crested wheatgrass
Agrostis alba	Redtop
Aristida fendleriana	Threeawn
A. longiseta	
Bouteloua gracilis	Blue grama
Distichlis stricta	Saltgrass
Hilaria jamesii	Galleta
Hordeum jubatum	Foxtail barley
Oryzopsis hymenoides	Indian ricegrass
Phalaris arundinaceae	Canary reed grass
Phragmites communis	Common reed
Pluchea sericea	Arrowweed
Puccinellia distens	Alkali grass
Poa pratensis	Kentucky bluegrass
Sitanion hystrix	Squirreltail
Sporobolus airoides	Alkali sacaton
S. cryptandrus	Sand dropseed
Stipa comata	Needle and thread grass
S. columbiana	

POLYGONACEAE - Buckwheat family

Eriogonum inflatum	Desert trumpet
E. spp.	

RANUNCULACEAE - Buttercup family

Clematis spp.	Virgin's bower

ROSACEAE - Rose family

Amalanchier alnifolia	Serviceberry
Cercocarpus intricatus	Mountain mahogany
Cowania mexicana	Cliffrose
Rosa woodsii	Wood's rose

SALICACEAE - Willow family

Populus fremontii	Cottonwood
Salix spp.	Willow

TAMARICACEAE - Tamarix family

Tamarix pentandra	Saltcedar

TYPHACEAE - Cattail family

Typha latifolia	Cattail

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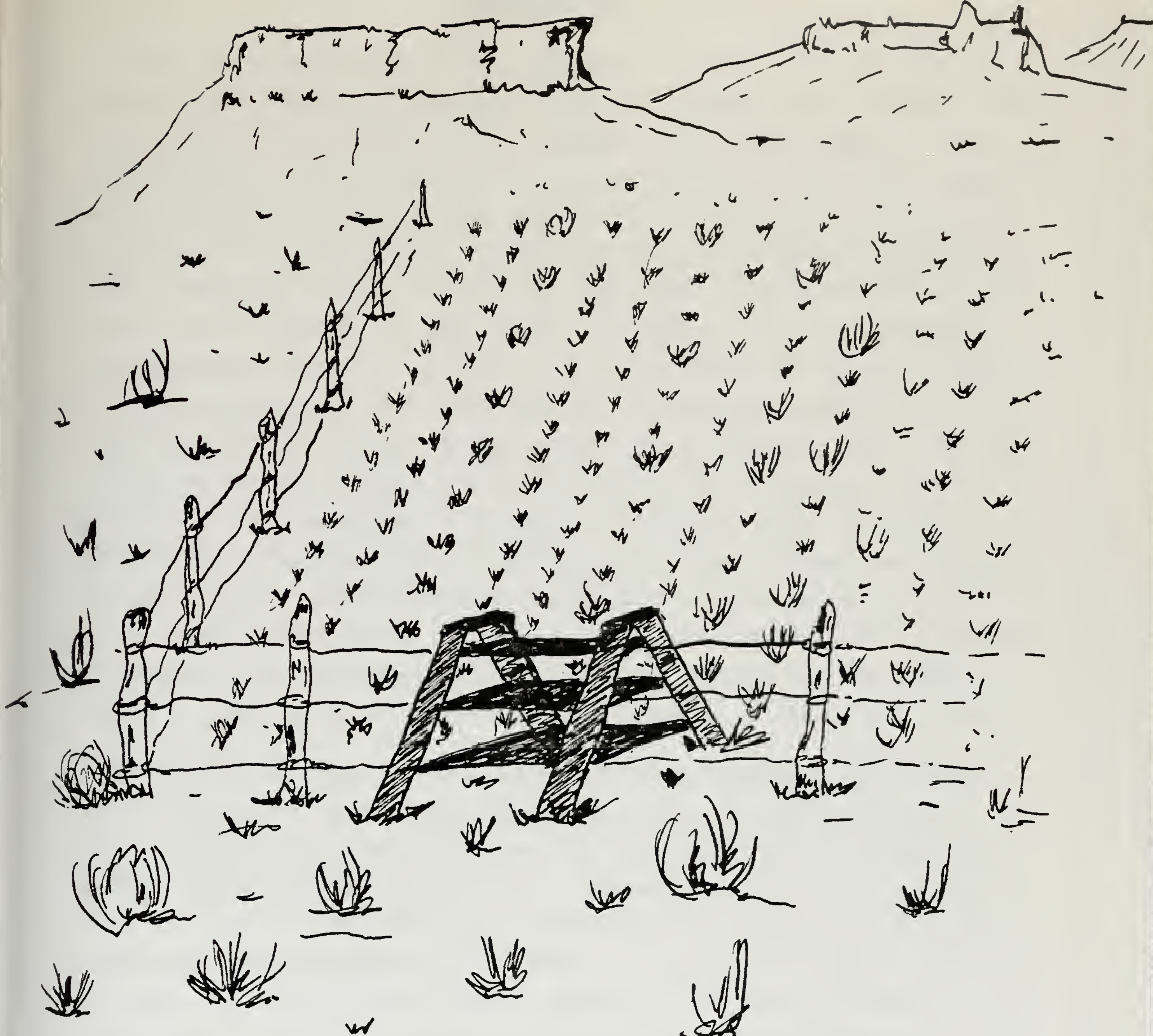


REVEGETATION

The primary consideration for revegetation appears to be drought. It inhibits seed germination, causes mortality in plants which do emerge and forces heavy use of plants by small mammals even in the absence of livestock grazing. Field trials of various species and practices for establishment of plants under post-mining conditions are still being carried out on the Emery study site by the U.S. Forest Service Intermountain Forest and Range Experiment Station for the BLM. Additional reports should be available from this work in the near future. Two basic types of experiments were attempted on each of the main soil types present at the site. Test of the performance of individual species of grasses and shrubs were carried out using small plots, while larger plots were seeded with a mixture of grasses and shrubs treated with a variety of soil amendments and surface preparation techniques. Because of the arid climate, successful germination and establishment of plants is difficult in some years without supplemental water. Positive results will be achieved in years with above normal precipitation if proper seed mixtures and cultural treatments are applied, while the success of revegetation efforts for dry years will depend on supplemental irrigation (See for example, Bleak et al., 1965).

Three main soil series were involved in these studies. The Persayo series consists of 0-12 inches of loam and silty clay over shale bedrock. Penoyer soils are 0-14 inches of silty clay loam over loam which extends to at least 60 inches depth. The Castle Valley series has less than 20 inches of fine sand over sandstone bedrock which tends to decompose readily when exposed at the surface. Penoyer and Persayo soils are Entisoils of the Typic Torrifluent and Typic Torriorthent subgroups, respectively. Castle Valley series soils are Aridisols of the Lithic Xerollic subgroup. In addition, a blue shale subsoil typical of much of the area was used for a limited number of trials (Further details of soil characteristics are included in another section).

Sites were selected on the basis of the soil maps prepared by the SCS. Each site is level to gently sloping. Preparation of the sites prior to seeding consisted of simulation of a post-mining environment by removal of the top 15 inches of soil, ripping of subsoil (and bedrock) to a depth of 30 inches with a D-9 Caterpillar, and smoothing and replacement of the stockpiled topsoil. The "reclaimed" soils were amended by addition of alfalfa hay at the rate of 2.5 tons/acre or a one inch layer of bark-wood fiber compost, or no treatment. These soil additives were rotovated into the soil to a depth of six inches. Following this preparation for sites on each soil type, the areas were subdivided into smaller plots for 3 types of trials: 1) growth from seed of a mixture of 9 species (5 grasses, 4 shrubs); 2) trials of individual grass species on small plots treated by various means; and 3) trials of container grown shrubs on soils treated by various means. The experimental design is summarized in Table 19.

Results of Revegetation Trials

Grass and Shrub Seedings - Nine species were seeded on Persayo and Penoyer soils by 3 different methods: 1) treatment with a gouger/seeder which left a pitted surface; 2) treatment with a spring tooth-type harrow following seed broadcast with a cyclone hand seeder; and 3) treatment with a cultipacker to firm the loose soil following seeding by a cyclone hand seeder. Seed was applied to all plots at the rate of 20 lbs./acre mixed in the proportions shown in Table 20.

Data was collected on July 12, 1978 using a 2 x 5 foot wire frame marked off in 1 square foot segments. Results of analysis of variance showed that the frequency (presence per quadrat) of grasses was lower on the gouged treatment than on the cultipacked or harrowed areas. There was no statistically significant difference in frequency of grasses between cultipacked and harrowed treatments on the Persayo soils, while the harrow treatment produced higher frequency than cultipacked on Penoyer soil (Figure 58(A,B,)).

The harrow treatment showed the highest frequency of shrubs on both soil types. Of the four species seed, white sage comprised 55% of the shrubs counted on sample plots, followed by shadscale (35%), fourwing saltbush (6%) and Nevada ephedra (4%).

Breakdown of frequency counts by soil amendments and growth form is shown in Figure 58 (C,D,). On both basic soil types, the alfalfa hay amendment produced the highest frequency of grasses. While the bark-wood fiber treatment produced higher frequency than the control area on Persayo soils, the results were slightly lower for bark-wood fiber than the control on Penoyer soils. Among the shrubs, bark-wood fiber was superior to alfalfa hay on both soils, but the control area produced the

Table 19

Summary of Revegetation Experiments

Layout	Soil Treatment	Soil Type			
		Persayo	Penoyer	Castle Valley	Blue Gate
10 grasses seeded separately on 10' x 15' plots of topsoil and subsoil	Alfalfa hay Kaibab mulch no amendment	x- x- x- } broadcast seed	x- x- x- } broadcast seed		
9 species (5 grasses, 4 shrubs) in seed mixture	Alfalfa hay Grass hay Kaibab mulch	Each treatment seeded by three methods: 1) Gouger-seeded 2) Hand Seeder/harrow 3) Hand Seeder/cultipacker			
9 species (5 grasses, 4 shrubs) in seed mixture	'above'			a) Ripped w/topsoil b) Ripped w/o topsoil c) Stockpiled topsoil only	
21 container grown shrubs	Supplemental water given to ½ the samples	Planted 4/20/77	Planted 4/13/77	Planted 4/21/77	Planted 4/13/77

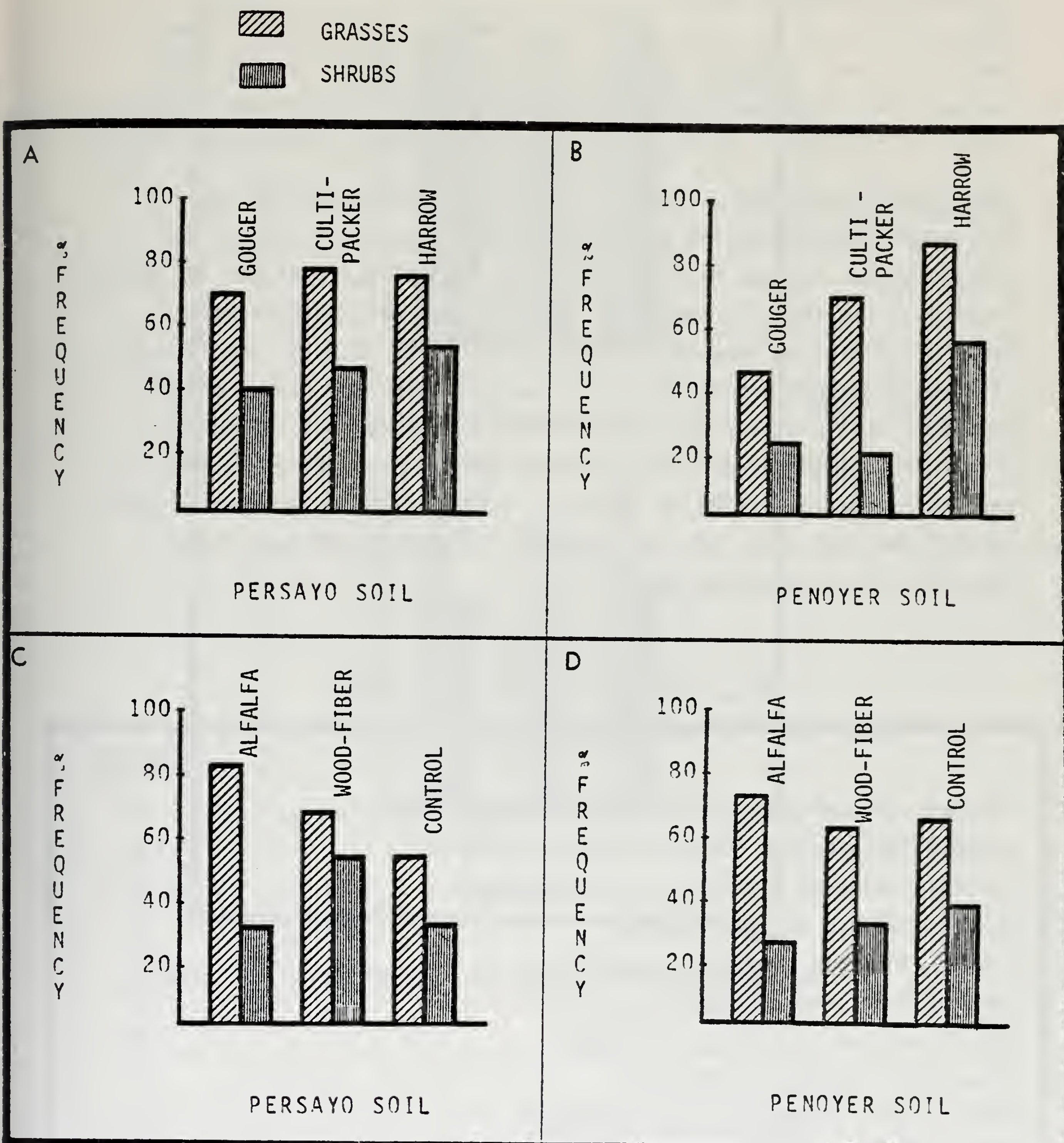
Table 20

Seed Mixture Used at Emery Site

Common Name	Scientific Name	% of Mixture by Weight
Crested wheatgrass	Agropyron cristatum	15
Streambank wheatgrass	Agropyron riparium	15
Russian wildrye	Elymus junceus	15
Indian ricegrass	Oryzopsis hymenoides	10
Alkali sacaton	Sporobolus airoides	5
Fourwing saltbush	Atriplex canescens	10
Nevada ephedra	Ephedra nevadensis	10
Whitesage	Ceratoides lanata	10
Shadscale	Atriplex confertifolia	10

In addition to the 3 seeding methods, 3 soil treatments were used (alfalfa hay, grass hay, bark-wood mulch) for a total of 9 plots.

Figure 58. Performance of Shrubs and Grasses by Soil and Treatment



highest frequency on Penoyer soils (Figure 59).

Competition from an annual weed (Kochia scoparia) apparently restriced the height of growth of grass seedlings on all treatments where alfalfa hay was used, while its effect on young shrubs is not know. The seed of Kochia was an adulturant in the alfalfa hay applications, and the extent to which these plots produced seed will be evident in subsequent growing seasons, by the presence of additional plants.

Small Area Grass Plots - Trials of three soil types were carried out following simulated mining (as described previously) on Persayo and Penoyer soils. On one half of each area, topsoil was replaced following ripping of the subsoil, while the remainder was left without topsoil. Seeds of 10 species were sown separately on plots 10 x 15 feet in each of three treatment areas: 1) alfalfa hay; 2) bark-wood fiber; and 3) control. Each plot was duplicated twice on both topsoil and subsoil areas, for a total of 12 plots for each species, and 120 plots in all. Seeding of species listed in Table 21, took place on December 6, 1977 (except the last three species - seeded in March) on Persayo soils. Penoyer soils were seeded in March 1978.

Table 21

Grass Species Seeded in Small Plots

	Grams/Plot
"Nordan" crested wheatgrass (Agropyron desertorum)	16
Induced Tetraploid x Natural crested wheatgrass	16
"Fairway" crested wheatgrass (A. cristatum)	32
Russian wildrye (Elymus junceus)	32
Indian ricegrass (Oryzopsis hymenoides)	32
Squirreltail grass (Sitanion hystrix)	32
Alkali sacaton (Sporobolus airoides)	16
Blue grama (Bouteloua gracilis)	16
Sand dropseed (Sporobolous cryptandrus)	16
Palmer penstemon (Penstemon palmeri)	16

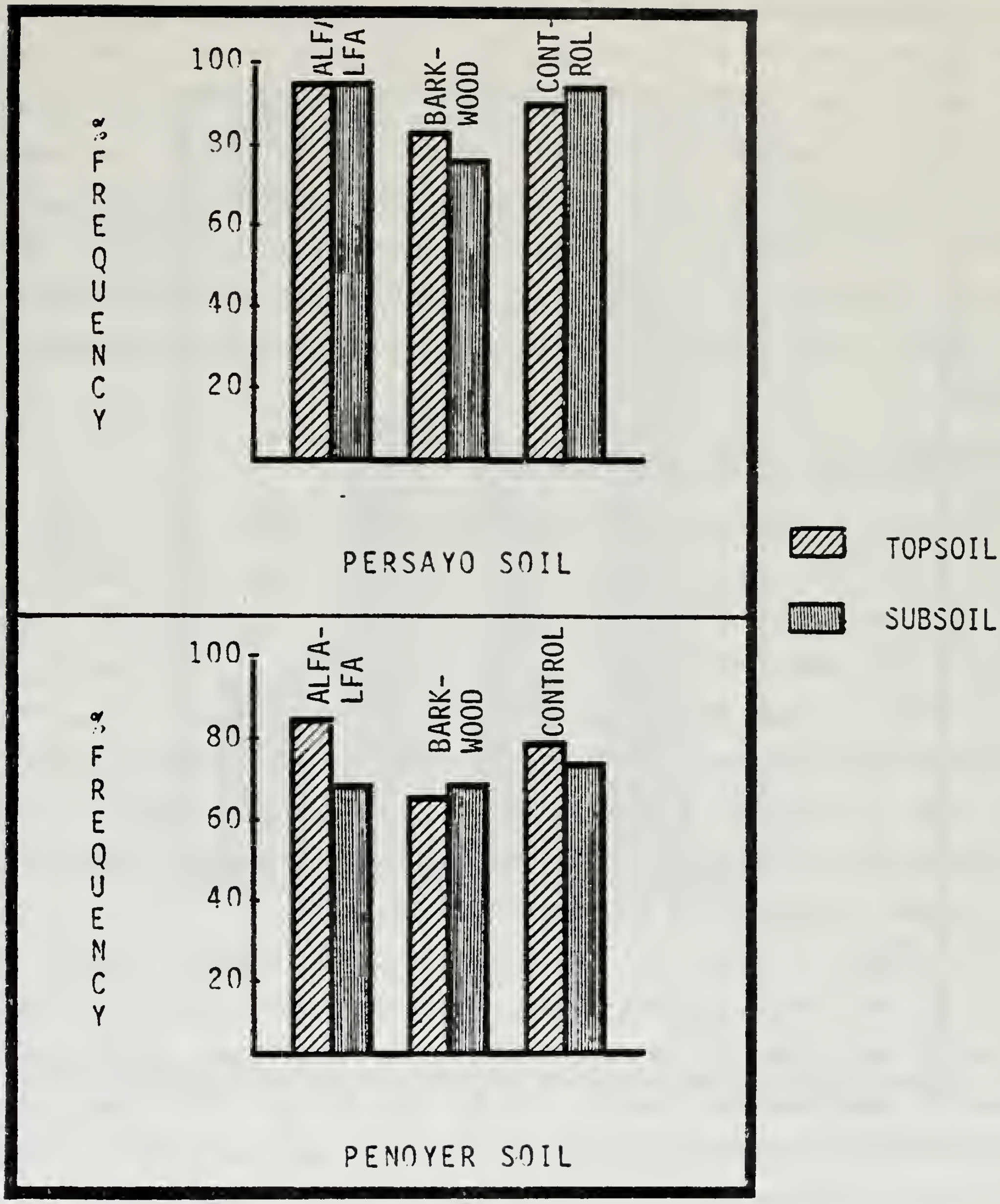


Figure 59. Performance of Grasses on Topsoil and Subsoil

Data collected using the same methodology as in the preceeding discussion showed both frequency and numbers (density) of grass seedlings were highest on the alfalfa hay plots, followed by the control area and bark-wood fiber treatments (Figure 58). There was little statistical difference between the performance of grasses on topsoil vs. subsoil in terms of frequency or density, however seedlings on topsoil were generally taller. All three wheatgrass species and Russian wildrye had the highest overall ratings, while Sporobolus, Bouteloua and Penstemon species were the lowest. Very few seeds of these last three species germinated and emerged.

Container Grown Shrub Plantings

Container grown shrubs were transplanted to plots of 5 x 10 feet in size, using four replications for each of 21 shrub taxa (Table 22). Plantings were carried out on Persayo, Penoyer and Castle Valley soils, as well as a Blue Shale subsoil typical of much of the area. Plants were arranged in two rows of four plants each, spaced 30 inches apart. One liter of water was added to each plant at the time of transplanting and subsequently on 3 dates at roughly 4 week intervals. Thereafter, only 2 of the 4 replications for each variety received supplemental water, amounting to 2 liters each on August 24 and September 12, 1978.

Transplants survived well on all soil types, except those on Blue Shale which did not receive extra water, where some mortality occurred. Little mortality was observed on any of the other substrates regardless of the amount of supplementary water. At the end of the 1978 growing season, average height of plants was greatest on the Castle Valley soil, followed by Persayo, Penoyer and Blue Shale respectively (Figure 60).

Species Useful for Reclamation in the Emery Area (Table 23)

A number of plant species appear to have specific characteristics which make them suitable for reclamation of the Emery area, and in some cases, to the arid south-central region of Utah. However, several of the species discussed below are wide-ranging which indicates the possibility of significant ecotypic variations in tolerance for various environmental conditions. Large intraspecific variations in ecological adaptations are common, so that seed taken from a promising species in

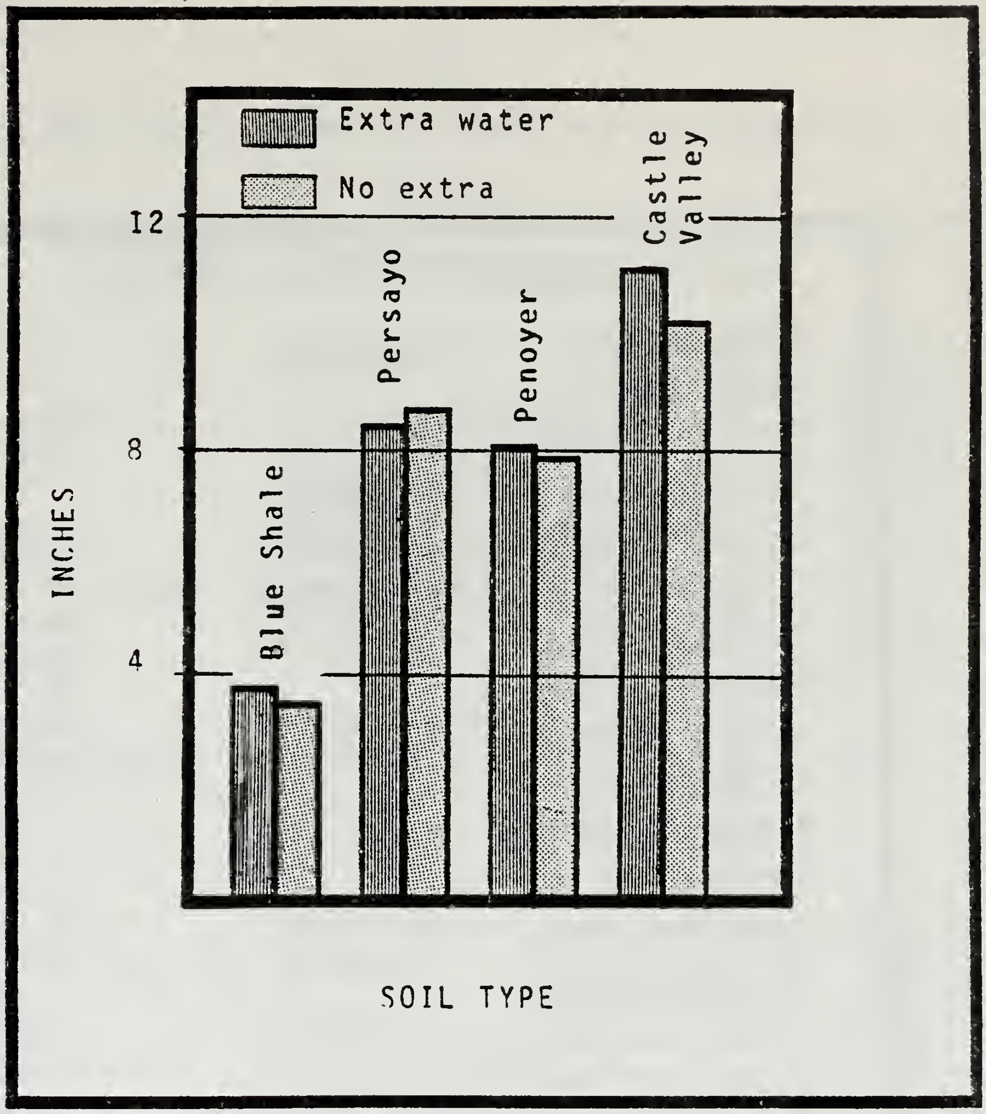


Figure 60. Performance of Container Grown Shrubs by Soil Type.

Table 22

Container Grown Shrub Species Planted on Emery Sites (1978)

Species
Artemisia nova
Atriplex aptera
Atriplex canescens
Atriplex canescens x *A. cuneata*
Atriplex canescens x *A. idahoensis*
Atriplex canescens x *A. tridentata*
Atriplex gardneri
Atriplex navajoensis
Atriplex obovata
Atriplex robusta
Atriplex tridentata
Atriplex tooelensis
Ceratoides lanata
Ceratoides papposa
Ephedra nevadensis
Erigonum corymbosum
Grayia spinosa
Kochia prostrata #7, #11, #14 (clay sources)
Kochia prostrata #2, #9, #12 (sandy sources)
Kochia prostrata var. *villosissima*
Camphorosma monspeliaca

Table 23

PLANTS WITH HIGH REHABILITATION POTENTIAL

BOTANICAL NAME	COMMON NAME	[1] PRESENT STATUS	PALAT-ABILITY	EROSION CONTROL
Shrubs				
* Atriplex canescens	Four wing saltbush	3(4)	High	High
* A. confertifolia	Shadscale saltbush	1	Medium	High
A. cuneata	Cuneata saltbush	3	High	High
Artemisia nova	Black sage	3	?	Medium
* Ceratoides lanata	Winterfat, White sage	3	High	Medium
* Chrysothamnus nauseosus	Rubber rabbitbrush	3(4)	High	High
C. viscidiflorus	Yellow rabbitbrush	3(4)	High	High
* Ephedra nevadensis	Mormon Tea	4	Medium	Medium
Kochia prostrata		not present	?	?
Kochia americana	Summer cypress	2	?	Medium
Sarcobatus vermiculatus	Greasewood	2(4)	Low	Medium
Grasses				
Bouteloua gracilis	Blue grama	2	Medium	Medium
Aristida fendleriana	Threeawn	3	Medium	Low
A. longiseta		3	Medium	Low
Hilaria jamesii	Gallenta	1	High	Medium
* Oryzopsis hymenoides	Indian Ricegrass	3	High	Medium
Sitanion hystrix	Squirreltail	2	Low	Low
Stipa comata	Needle and Thread	2	Low	Low

1: Relates to distribution. 1 = widespread, common; 2 = frequent; 3 = infrequent; 4 = frequent in special habitat.

* denotes plants which do well on disturbed sites.

one area may perform poorly, or lack the desirable traits when planted in a different part of its range. This will become especially important when seed or wild stock is collected for reclamation of any site. As a general rule, it will be desirable to collect plant materials from the area where they are to be used due to the potential for preadaptations which may be genetically encoded. However, Bleak et al., (1965) found that native shrubs were better able to survive severe drought than grasses.

Shrubs

Fourwing saltbush (Atriplex canescens) was found to do well on disturbed areas of the study site, although it is not a major component of the native undisturbed vegetation. Local plants observed on disturbances were of unusual height (< 1 meter) compared to plants growing in the shadscale vegetation type (>.5 meters). In the revegetation trials, fourwing formed 6% of the established shrubs. In trials of container grown stock, it performed well with little mortality at the Emery site, although in studies at Henry Mountains, it did not do well. There is a relatively extensive literature concerning methods and results of revegetation trials with fourwing saltbush (e.g. Cable, 1971; Aldon 1971; Bleak et al, 1965; MacArthur et al, 1974). This plot hybridizes freely with several other saltbush species as well as other members of the Chenopod family (Blauer, et al, 1976). Artificially induced crosses may yield hybrids with new characteristics desirable for reclamation and the wide range of ecotypes provides a large gene pool from which to select. Fourwing saltbush has been reported as a facultative selenium (Se) absorber and may be "mildly poisonous" in areas where the soil contains this element (Kingsbury, 1964; Davis, 1972). Livestock losses have occurred where animals had no other food (Hitchcock, et al, 1964).

Shadscale saltbush (Atriplex confertifolia) is the dominant shrub on large areas of western range, and was found in most habitat types in and around the Emery study site. Different ecotypes are tolerant of a wide range of soil conditions, where soluable salts range from 160-3000 ppm and pH from 7.4 to 10.3 (Hanson, 1962). Because of the rigidity and spininess of mature plants, shadscale is not heavily grazed and tends to increase under grazing pressure (Blauer et al, 1975). Although establishment from direct seeding is reported to be difficult (Blauer et al, Op. Cit.), shadscale accounted for 35% of the shrubs established in the Emery trials and stock survived well at both Emery and Henry Mountains.

Grasses

Several native and introduced grasses show promise for use in central Utah reclamation projects. Success or failure of germination and establishment is in part a function of the seasonality of rainfall or supplemental irrigation. This is more generally true for grasses, since many of the native shrubs can make quick use of available water, while certain grasses concentrate growth during certain seasons and become dormant the rest of the year. Frischknecht and Ferguson (1978) have noted the similarity of the rainfall pattern between Emery, and the Great Plains, as both have a late summer maximum. Galleta and blue grama grass are prominent in both areas. With respect to the revegetation trials, it was noted that cool-season grasses, such as crested wheatgrass and Russian wildrye performed well, while warm-season species (sand dropseed, alkali sacaton, blue grama) faired poorly due to summer drought.

Indian ricegrass shows particular promise for the Emery area because of its drought tolerance and ability of the local population to colonize disturbed areas. Although subject to mortality in a prolonged drought the population may be expected to survive if an adequate seed stock is present in the soil.

White sage (<u>Ceratoides lanata</u>) is perhaps the most promising shrub for reclamation of the central Utah region. This shrub has a wide distribution in North America, and occurs from salt deserts with annual precipitation of less than 7 inches to the subalpine zone with as much as 40 inches. Temperature, elevation and latitudinal ranges are likewise variable. A recent monograph (Stevens, et al, 1977) summarizes existing knowledge of the ecology, methods of establishment, and uses for reclamation of white sage. These authors note the plants outstanding drought tolerance, response to grazing and relative ease of establishment. Trials carried out on the Emery site were extremely encouraging, as white sage comprised 55% of shrubs established in the seed mixture.

Little rabbitbrush (<u>Chrysothamnus viscidiflorus</u>) may be established from seed, and is a common pioneer on disturbed sites in central Utah. Rubber rabbitbrush (<u>C. nauseousus</u>) is also a good pioneer and may be useful for soil surface stabilization. Both species tend to enhance the growth of other herbs and grasses (MacArthur et al, 1974).

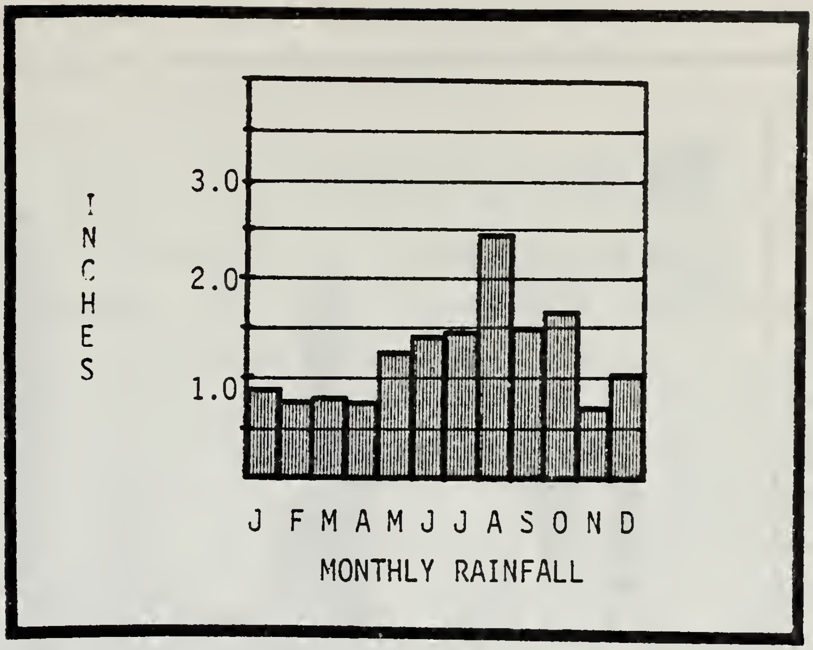
A number of other shrubs should be considered for use in reclamation of this region, including mat saltbush, experimental saltbush hybrids and subspecies, Nevada ephedra, spiny hopsage, and prostrate kochia. It must be emphasized that species performance may vary greatly according to the source area from which wildlings or seeds are collected.

Summary

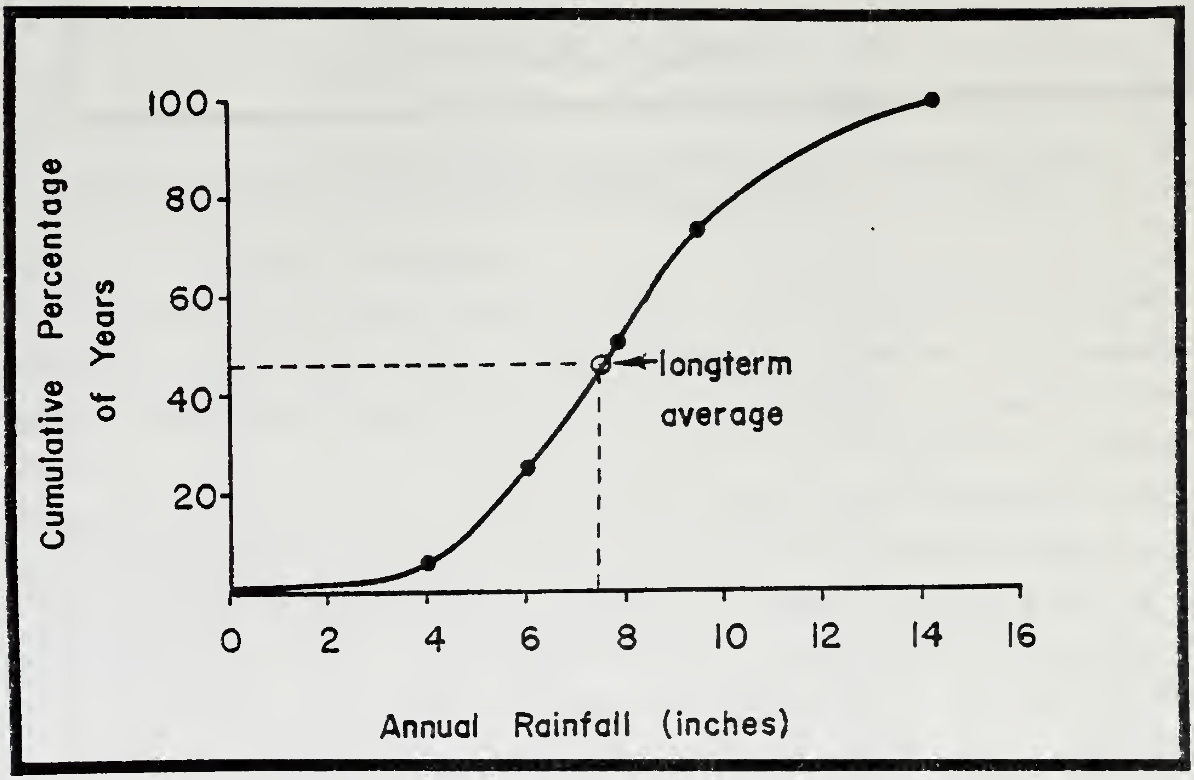
The results of the revegetation efforts must be considered with respect to the rainfall patterns which prevailed during the term of the experiment. Mean annual rainfall for Emery is 7.55 inches, compared to the median of 7.9 inches. Figure 61A shows the distribution of precipitation throughout the year by monthly means, while Figure 61B gives the relative probability of a given annual rainfall level compared to the actual amounts of rainfall recorded during the revegetation trials at the study site, and the amount of deviation from the monthly totals.

Success of germination and establishment of certain grasses and shrubs planted as seed appears to be related to the seasonality of precipitation experienced during the first growing season. During January, February and March, 1978, precipitation was 300% of average, while April and May were slightly below average, and June through October was only 30% of normal (Figure 62). Because of the heavy precipitation in winter months, soil moisture levels were relatively high during early spring, but decreased quickly in the early summer. Given this pattern, species which germinate early and concentrate growth during the cooler months of April and May would be expected to establish most effectively for this year. Data collected on the plots seeded to both grasses and shrubs showed that both Russian wildrye and crested wheatgrass did well, while winterfat was the most successful of the shrubs. Each of these species is adapted to take advantage of early spring rainfall before becoming dormant through hot summer months and although this is not an exclusive ecological strategy, it insures successful germination and establishment in years with wet winters and dry summers.

Revegetation experiments carried out at the Emery site are expected to be continued for several more growing seasons, and data from the first year may be compared to results from similar experiments carried out elsewhere in Utah. Tests of 2 grasses and 3 shrubs were performed on the west side of the Henry Mountains, about 50 miles south of the Emery study site. The area is similar climatically with an average rainfall of 6-9 inches. Container grown stock of fourwing saltbush, cuneate saltbush, shadscale, Russian wildrye, and indian ricegrass were transplanted to prepared sites on 6 different types of substrate. Experimental variables included applications of nitrogen, phosphorous and potassium, compared to control plantings. Supplementary water was required through-



A. Seasonal Precipitation Patterns



B. Annual Precipitation - Cumulative Probability

Figure 61. Precipitation Patterns

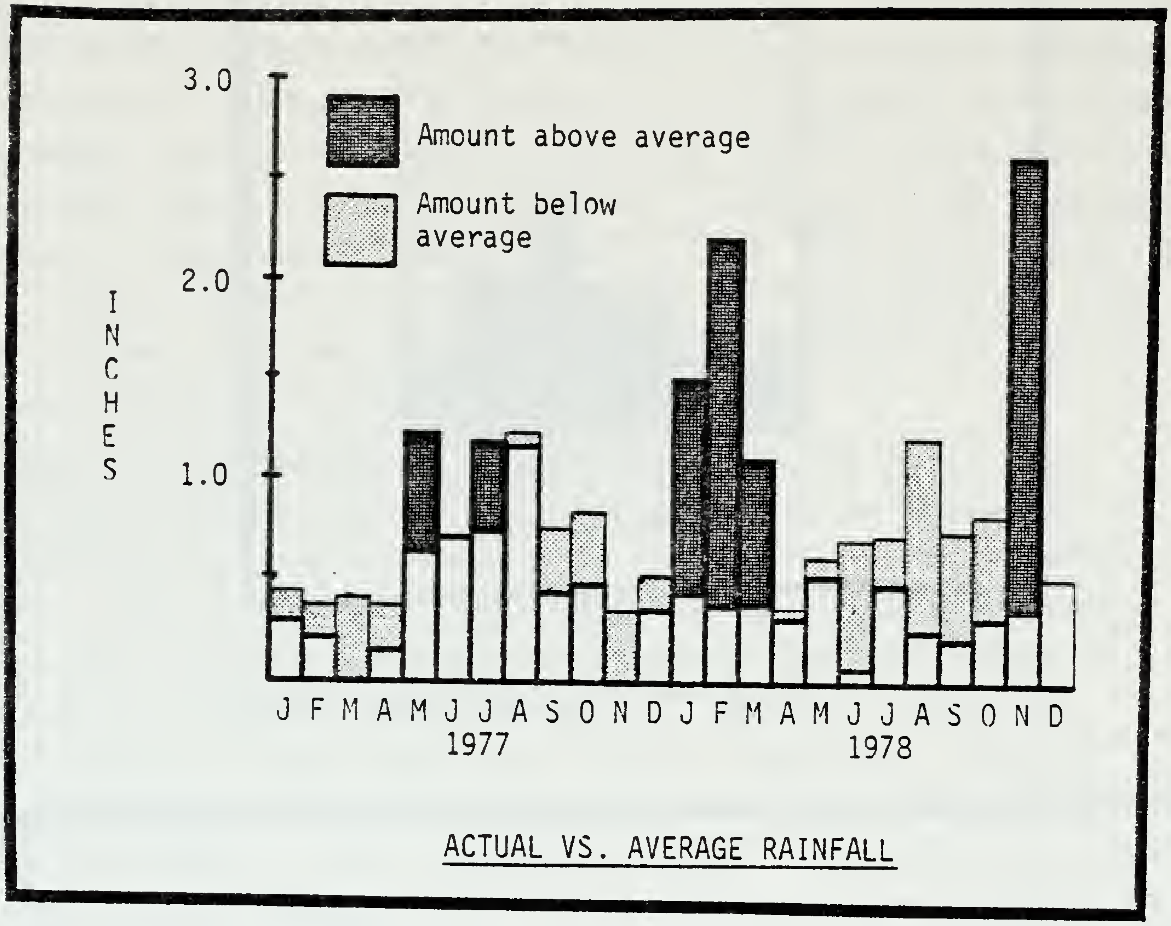


Figure 62. Actual vs. Average Precipitation for Study Period.

out this study due to drought. Although the main conclusions of species trials at Henry Mountains concern the suitability of the various substrates some comments on species performance apply to the Emery area. No differences in survival could be attributed to the effects of N, P, or K applications on any of the six types of substrate. Soils which performed best in field experiments were generally coarse in texture, while companion studies of the same substrate in a greenhouse showed best growth on the the substrates with a high proportion of clay and silt. In fact, regression of field vs. greenhouse experiments with the same soils yields a correlation coefficient of -.827, indicating that soils which performed well in the field are likely to produce poorly in the greenhouse and vice versa. The explanation for the apparent paradox probably lies in the lower rates of infiltration of fine soils, and consequently greater water loss as runoff (This problem is further discussed under soils). Species performance results showed that cuneate saltbush survived best, followed by shadscale, Russian wildrye, indian ricegrass and fourwing saltbush, respectively. The significance of these results is dubious due to the fact that the study design measured only "apparent survival", and did not test growth rate, germination potential, or other factors, and there were no control plots for comparison. The experiment seems to have tested the ability of 5 species to survive transplantation from the greenhouse to 6 substrate types, given supplemental irrigation.

At Alton, Utah revegetation trials were carried out using the same approach as the Emery study, namely evaluation of species, soil amendments, and surface treatments on substrates subjected to simulated mining. The Alton region is considerably more moist than either Emery or Henry Mountains as indicated by the more mesic species which compromise the natural vegetation. Annual rainfall averages 16 inches and supports relatively tall stands of pinyon, juniper and gambel oak with a sparse understory of shrubs and grasses, and nearly pure stands of big sagebrush. Based on the results of the Alton experiments, indian ricegrass, standard and fairway crested wheat grass, western, blue bunch and intermediate wheat grasses, pubescent wheat grass, Russian wildrye and bottlebrush squirrel tail have been recommended as the best adapted grasses for revegetation. These should be planted in a mixture with selected shrubs in seedbeds prepared by applications of phosphorous and nitrogen, rotovated into the replaced topsoil with an organic mulch (BLM, 1975). Relative to the Emery site, the Alton coal field may be more effectively reclaimed at a lower cost because of the higher precipitation and abundance of topsoil.

Remote Sensing Experiments

Remote sensing with color infrared film can be considered from the point of view of evaluating remote sensing techniques for long term monitoring of coal reclamation sites to recognize areas under stress, so as to take timely remedial action. Further, it can be used to read out the results of an experiment such as the one conducted at the Emery site to obtain bulk biomass data on a detailed geographic grid. In either case, it offers an inexpensive, rapid supplement to traditional methods. The results of such an experiment conducted after a full growing season, and into the start of a second are shown in Figures 63, 64, and 65.

Lessor vigor is evident in the region which had topsoil removed (see Figure 63). Cultipacked perimeter is inferior in growth, as are grass plots. Inexplicably, the mulched areas are less productive at this time. Otherwise the gauged and harrowed areas appear to have the best growth (see Figure 64). Overall performance in this area is better with the exceptions of the two white spots in the center of the plot (see Figure 65).

Figure 63. Color IR Photo, (2-Acre Site)

1) Topsoil removed, and subsoil ripped to 30'.
2) Topsoil not removed, ripped to 30'.
3) Topsoil spread on this area.

Figure 64. Color IR Photo, (4-Acre Site)

1) Grass and container shrubs.
2) Mulched area.
3) Gouged.
4) Cultipacked.

*Note also small circle of insect damage.

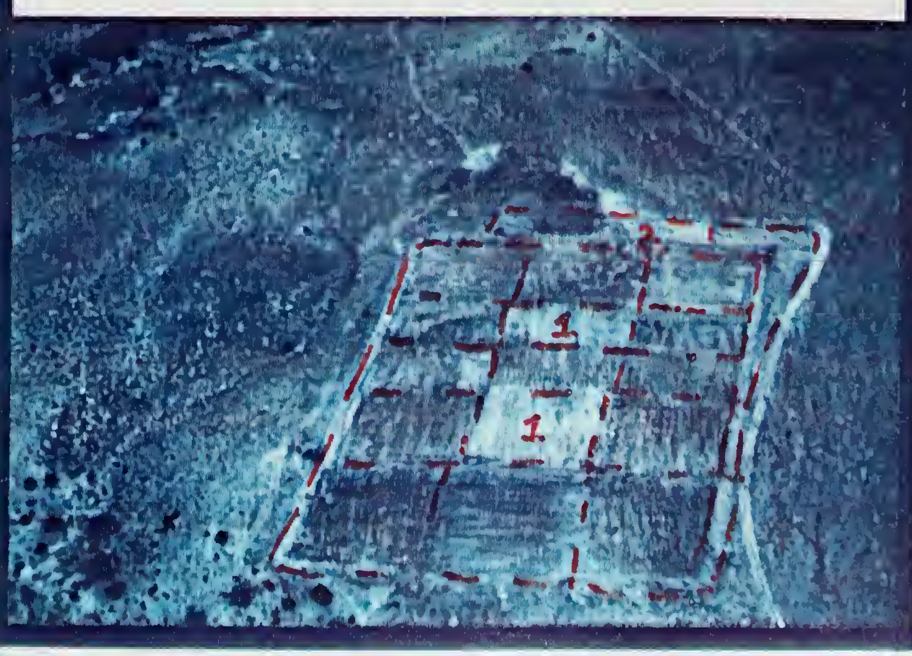


Figure 65. Color IR Photo, (6-Acre Site)

1) Treatments with lower vigor.
2) Shrubs.

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SEDIMENTS

The objective of this section is to derive a realistic estimate for current sediment yields from the study site, and to evaluate how they would be altered by strip mining. In order to evaluate the effects of strip mining on sedimentation and stream turbidity, a baseline of present conditions must first be established and than a method of predicting changes due to mining be applied, utilizing the same basic units of measurement. It would be best to develop coefficients to predict effects of strip mining in quantitative measures of sedimentation. A prior EMRIA study of Henry Mountains (1978) on similar soil units presented what appeared to be inconclusive data. To resolve these difficulties, a number of experimental answers were explored.

Procedure

For comparative purposes, sediment yield estimates calculated here were derived using multiple techniques: (1) the PSIAC (Pacific Southwest Interagency Committee) method (1968); (2) the modified southwest Universal Soil Loss Equation (USLE); (3) stock pond coring; (4) long term sediment collections; (5) "standard" in situ rainfall simulation technique (e.g. Lusby, 1976); and (6) a one meter Planchet simulation using ground core materials. The results of these various approaches is tabulated in Table 24. The procedure utilized in each of the cases was to establish a suitable mapping unit over which to summarize pertinent characteristics of unknowns from each of the applicable technologies. A 1:7200 scale map (enlarged from 1:24,000 topographic map for easier transfer of aerial photographic data) was divided into grid cells 1000 by 1000 feet and the various data accumulated on a cell-by-cell basis. Cells from each hydrologic subbasin were aggregated separately. Many basic data are common to each sediment yield technique. These basic data consist of surface geology or soils, meteorology, slope or topography, ground cover, and derived production figures based on various combinations of the foregoing factors. Data were obtained from original field, airphoto, and laboratory studies conducted by GSC. Figure 66 displays the hydrologic subbasins into which the area is divided.

PSIAC

The PSIAC approach is dependent on 9 basic factors: surface geology, soils, climate, runoff, topography, vegetative cover, land use, land erosion, channel erosion and sediment transport. Though developed for use on sediment classification of large uniform areas, investigators such as Shown (1970) have reported representative results for small

BASIN	DRAINAGE AREA (mi^2)	WEIGHTED SOURCE AREA SEDIMENT YEILD (acre-ft/mi^2)	TONS / ACRE / YEAR
A	.18	1.32	3.3
B	1.12	1.40	3.5
C	.34	.48	1.2
D	.75	.56	1.4
E	.31	.40	1.6
F	.45	.66	1.65
G	.09	.94	2.35
H	.29	1.32	3.3

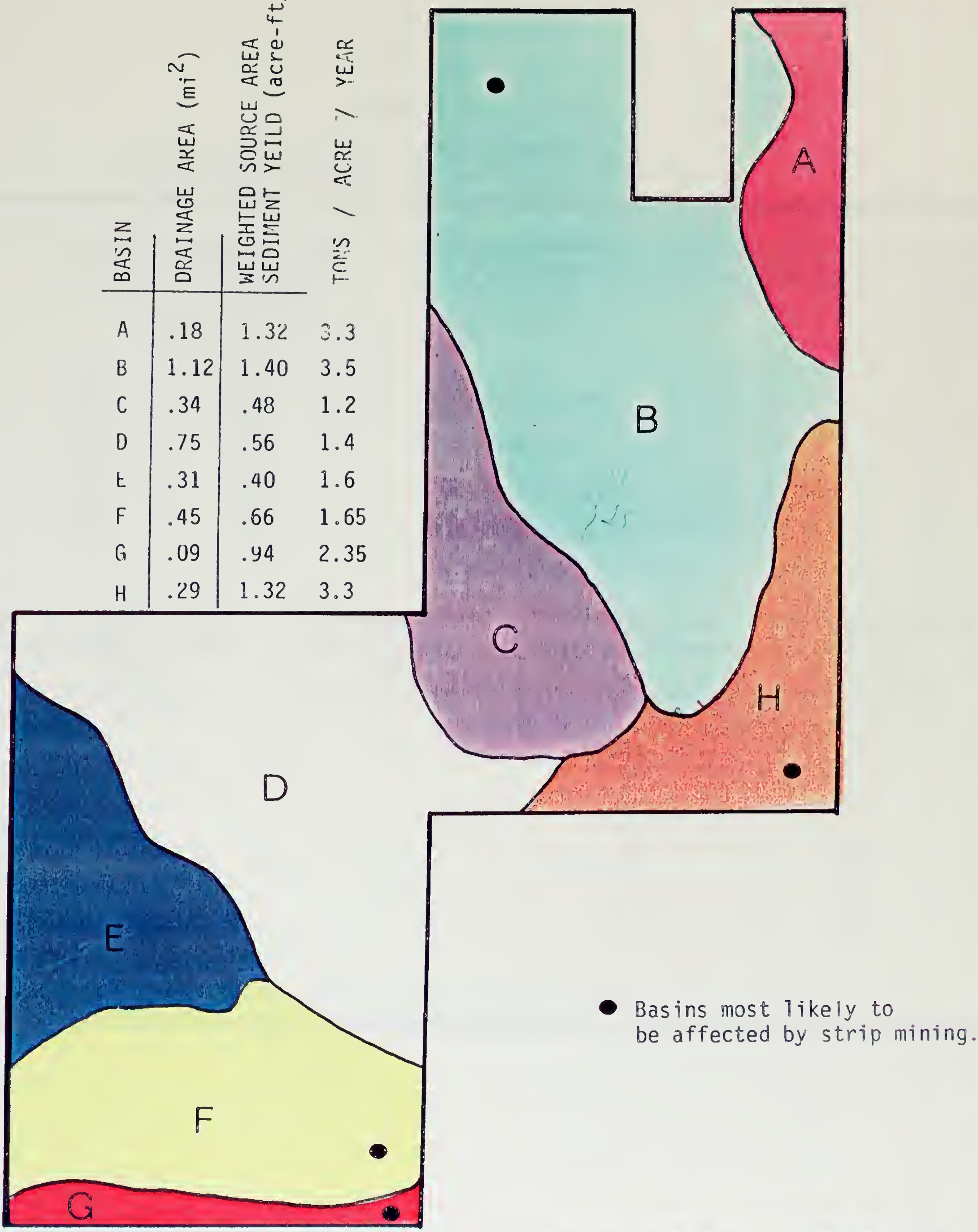

Figure 66. Sediment Basins on Study Site.

Table 24

Comparison of Estimates of Sediment Yield by Different Methods for the Emery Study Site Basins.

Basin	Drainage Area (sq. mi.)	Weighted Source Area Sediment Yield (acre-ft/sq. mi.)	Estimated Annual Basin Sediment Yield (tons/year)	Ground Cover Estimatable Soil (%)	Stock Pond Annual Yield (T/acre/yr)
A	.18	1.32	3.30	36.3	.90
B	1.12	1.40	3.50	35.0	---
C	.34	.48	1.20	38.0	---
D	.75	.56	1.40	32.0	.59
E	.31	.40	1.00	30.0	---
F	.45	.66	1.65	48.0	---
G	.09	.94	2.35	54.0	---
H	.29	1.32	3.30	36.3	---

Basin	Estimated Annual (Sediment Trough) Yield (T/acre/year)	Estimated Annual (Planchet Test) Yield (T/acre/year)	Estimated Annual (Rain Simulation) Yield (T/acre/year)	Estimated Annual (USLE) Yield (T/acre/year)
A			.45	.36
B			1.02	2.24
C			.84	.71
D			1.20	1.50
E	.084*	.030	.56	.64
F			.84	.93
G		.080	.17	.21
H			.45	.59

* 1.1 inch cloudburst storm, 12% slopes in subbasin

drainage basins. Various adjustments are needed for such applications: (1) the topographic factor is developed without use of floodplain or fan deposit data, (2) channels originating outside the study area completely crossing it were not treated with respect to sediment transport capabilities. In this evaluation, the sediment conveyance factor was utilized to accomodate the difference. Slope data were obtained from the enlarged quadrangle map noted in figure 66. Percentages of bare soils were generally derived from the concurrent soil survey and from the vegetation transect and photo analysis, discussed in the corresponding sections. Channel characteristics were determined at specific locations though only streams larger than Strahlers' (1952) fourth order were delineated for channel classification.

The sediment conveyance factor was determined after the methods of Frickel, Shown, and Patton (1975). It is dependent on: (1) channel width and gradient; (2) degree of gullying; (3) bed material size; (4) intermittent gullying within channel system; (5) deposition in channels and alluvial fans; (6) bottom land deposition.

Universal Soil Loss Equation

A great deal of basic research has been involved in the original development of the USLE by Wischmeir and Smith (1960, 1965) with subsequent modification (Foster and Wischmeir, 1974) and adaptations e.g. Anderson (1975). It was originally developed for uniform agricultural land east of the Rocky Mountains and until recent years only applied to uniform slopes. Work has proceeded to extend it to irregular slopes. Adaptation to sheet erosion in western lands is being made e.g. Tew (1973) has developed a nomograph for estimating soil losses from Utah watershed. Anderson's work parallels Tew's in that the USLE is converted to a logarithmic equivalent.

Table 24 summarizes the results of applying the USLE to the cellurized study area. In order to use it, K values were obtained from soil survey. The rainfall factor was determined from the climatology section and Forest Service data. Slope length and gradient were determined on an average period basis. The erosion control practices factor and cropping factor were taken as 1 in this evaluation. In part, the difficulty of applying USLE for erosion in wildlands is that as runoff is concentrated in channels even the size of rills, the actual erosion surface and its dynamics become too complex to treat with a general equation. Extensive modeling with the USLE is beyond the scope of this program. It's application here is to provide the counterpoint to data from other sources.

Rainfall Simulation

In order to apply a rainfall technique to the study area, the dominant land types in the strippable portion of the study area were determined. These were designated Hydrologic Classes A and B. Class A consisted of dominantly sandy material and Class B had a large clay fraction. These data will provide a baseline comparison for post-mining studies. The "disturbed" Class B site simulates changes to be expected from stripping. The site was ripped and "fluffed" in preparation for a revegetation experiment. It is taken to represent a post mining "fill" situation. An additional site at the BLM Price office was occupied in order to determine a "cut" slope response. This was in Mancos Shale and could be considered analagous to Blue Gate Shale underlying Class B sites. Simulation (Fig. 67 & 68) locations were chosen as close as possible to existing revegetation sites in order to provide long-term control. At some unspecified future date, it would be useful to perform a rainfall simulation run on the revegetation zone itself to determine the effectiveness of the program in returning sediment production to pre-disturbance levels by establishing vegetation. To some extent the responses of these sites can be directly applied over the area of the sites shown in Figure 30 as strippable.

These rainfall simulation experiments collected the following information summarized in Table 24: (1) runoff - measured from volumes collected at one minute intervals and converted to discharge in cubic feet/second. The total volume of runoff is computable in terms of inches per unit area. An infiltration rate curve can be calculated by subtracting runoff from applied rainfall for the same unit time (inches/hour); (2) precipitation a network of raingages within the study area provides a measure of incident rainfall. Total area rainfall was computed using a modified polygon technique; (3) sediment yield was sampled at 4 minute intervals outflow and analyzed in the lab to determine suspended sediment concentration. Total sediment load is expressed in tons per square mile and can be alternatively obtained at various points in the rainfall cycle or as an average over the test time; (4) area - a topographic survey of the chosen site yields the area in square feet; (5) weighted mean slope - the area between contours was weighted according to the percent of overall area; (6) antecedent

Detail of a Sprinkler Pattern

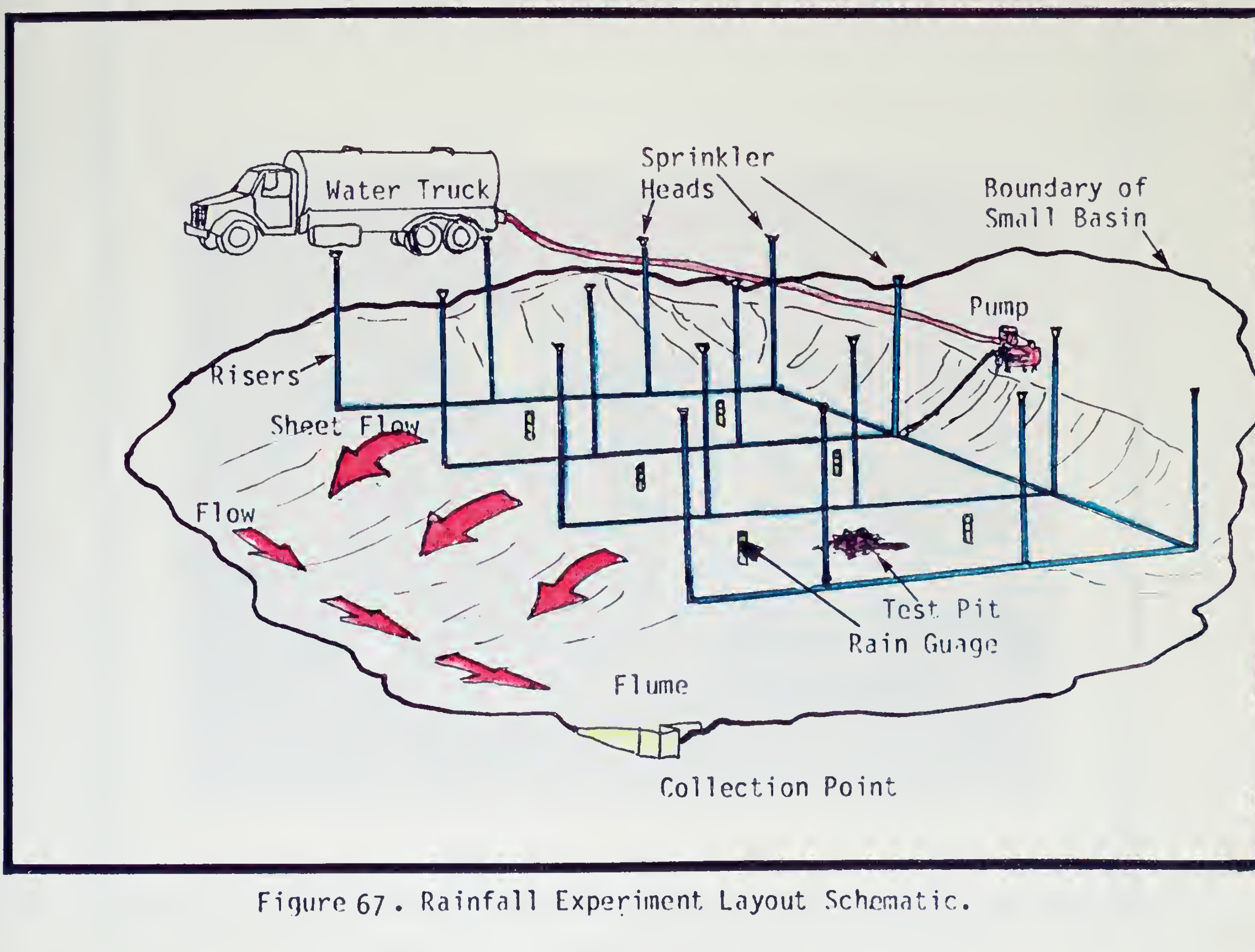

Figure 67. Rainfall Experiment Layout Schematic.

Onset of Puddling - Runoff

Measurement of Flow Rate

Figure 68. Rainfall Simulation Experiment

moisture - obtained from gravimeter samples of 5-6 inches of soil. Three locations were sampled and averaged for the final results (results expressed as percentage by weight); (7) clay - analysis of percent clay was made from the gravimeter sample (weight percent); (8) root concentration - the amount of fibrous material in the 5-6 inches of soil (in ounces per 10 ounces of soil); (9) bare soil and rock - obtained from three 20 foot transects with site using a transect line and vertical drop first contact point method at 2 inch intervals (expressed as percent).

Calculations of the expected runoff from total areas of the site were made by multiplying the total area of the hydrologic class by the sediment production from a unit of the summed test. This is not entirely representative since variables for the simulated test site do not remain constant throughout the area of the hydrologic class. It is assumed however, for purposes of comparison, that all factors are the same with the exception of slope. A slope correction factor was applied by observing empirical variations in the laboratory planchet runs. The results are displayed in the composite yield tabulation (Figure 69 and in Table 25).

Laboratory Simulation Studies

Because the number of different field environments which could be treated had to be resolved into a few hydrologic classes (which did not completely describe a post-100 foot stripping situation) for manageability, thereby limit the statistical aspect of the data, it was decided that laboratory measurements for a unit area (one square meter) could be made at various slope angles, and compositional nature. Thus we chose to simulate surface conditions resulting from crushed materials within the 100 foot or so zone of potential stripping. Two principal "core" classes were selected from the overlain cored site material - chiefly carbonaceous shale and medium grained sandstone as being most probable amendments. The soil experiments arrangement of elevated sprinklers at continuous pressure gave droplet control similar to the infield experiment. The one meter square box was adjusted at various angles for each run. Three settings of slopes were utilized for each of the hydrologic classes selected. Runoff was collected at the base of the planchet in a trough. Runoff values and sediment content determinations were then made in the lab. "Rainfall" was measured at various distances from the solitary source. Runoff results from the experiment are displayed in Figure 70. In general these indicate

Table 25. Simulation Study Data

VARIABLE	HYDRO SITE CLASS A (Sandy Site)	HYDRO SITE CLASS B (Clayey Site)	HYDRO SITE CLASS B DISTURBED	HYDRO SITE CLASS C (Mancos Shale) Cut Slope
Date	10/10/78	10/16/78	10/16/78	10/18/78
Area (sq. ft.)	2400	2400	2400	2400
Weighted Mean Slope (%)	3	10	5	2.1
Antecedent Moisture	4.5	4.0	4.2	4.0
Clay (%)	10	35	35	40
Root Concentration (g/100g)	.320	.210	.020	.000
Bare Soil and Rock (%)	40.8	12.5	95.1	96
Precipitation (inches)	.90	.72	.73	.56
Runoff (inches)	.31	.16	.06	.14
Sediment Yield (tons/sq mile)	.45	1.09	1.40	1.88

Table 26

Sediment Yield Obtained From Surveying Impoundments

Pond	Mean Basin Depth (in.)	Age	Basin Area (sq. ft)	Drainage Area (Upstream) (sq. mi)	Annual Sediment Yield (tons/sq/mi)	Average Watershed Slope (%)	Estimated Bare Soil (%)	Drainage Density (mi/sq mi)
P1	18	12	2400	10	.90	12	6	3.5
P2	4	4	350	2	.59	11	17	7.4

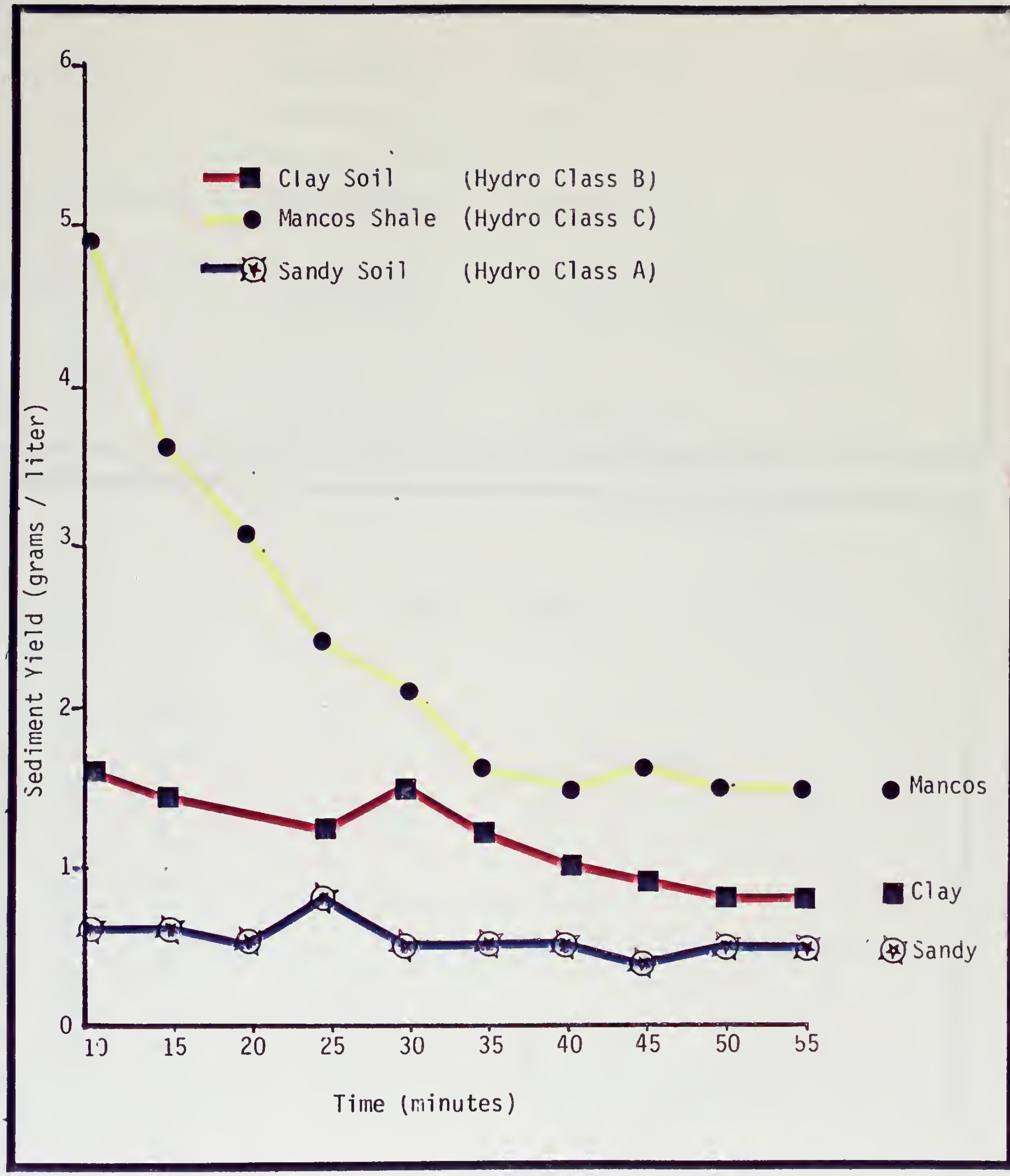

Figure 69. Results of Rainfall Simulation.

Table 27 Comparison of Sediment Yields (Weighted Source Area)

YIELD			AREA
Low	Moderate	High	
.05 to 3.5 (acre/ft/mi^2)	.36 to .90 (acre/ft/mi^2)	.90 to 1.25 (acre/ft/mi^2)	Hanging Woman
1-10% Slope	10-20% Slope	20-40% Slope	
Small Subbasin	Basins CDEFG	Basins ABH	
less than .35 (acre/ft/mi^2)	.40 to .94 (acre/ft/mi^2)	1.32 to 1.40 (acre/ft/mi^2)	Emery
-----	3-14% Slopes	9-14% Slopes	
1 ton/acre/yr	1.2 to 2.35 (tons/acre/yr)	3.3 to 3.5 (tons/acre/yr)	

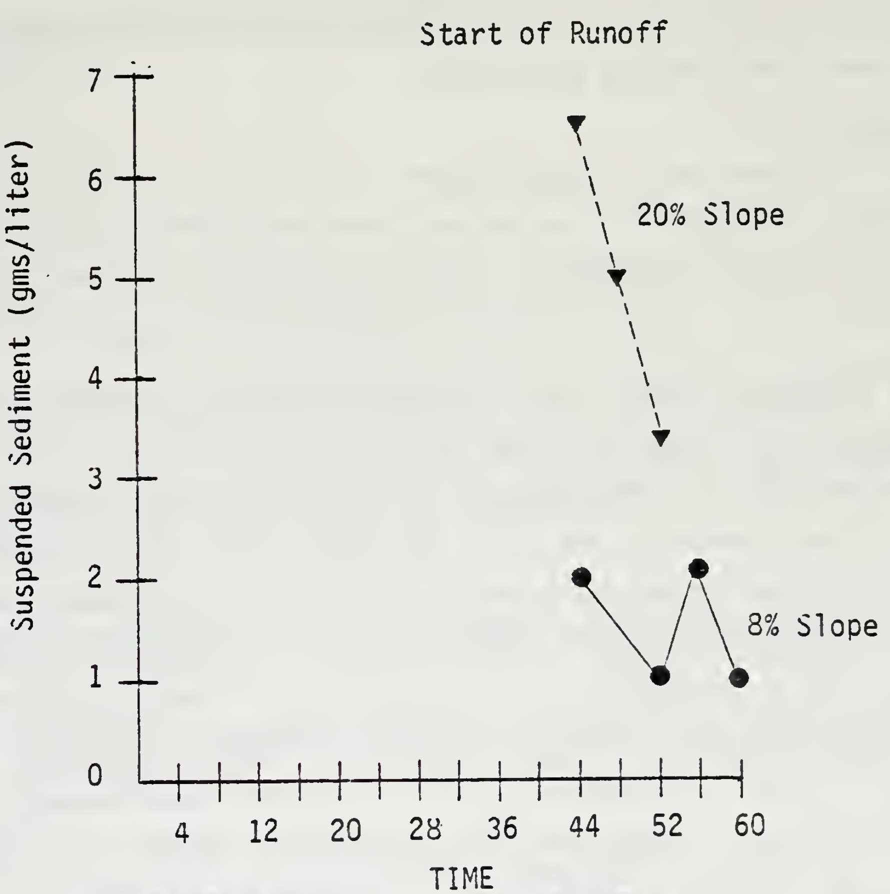

Figure 70. Lab Tests of Sandstone Overburden First 100 ft. of Bore Hole #5. - Planchet Tests -

that the planchets are less sensitive to slope changes than expected. On the other hand the infiltration/runoff relationships resemble the disturbed clayey site of Hydrologic Class B.

Trough Experiment

The chief limitations of the simulation experiments is their short duration, particularly the planchet tests. In order to derive a longer term viewpoint on sedimentation production from small subsets of the drainage basins, small troughs were emplaced to interdict outflow from the selected small areas and on the coal burn area of surface soil disturbance. The basins so selected averaged some 300-400 square feet and had geometries which allowed for constriction. Troughs were modified rain gutter sections set flush with the surface of the terrain. Sediment from overland flow was collected at long intervals and weighed. Particle size analysis indicated slight losses in fines, perhaps resulting from trough overflow. These results are treated as representative of specific hydrological subbasin behavior and a unit area production number derived and multiplied by the area of the specific basin. The results are tabulated in Table 25. Unfortunately, due to vandalism, all but one of the traps were destroyed prior to the 1.1 inch November 1978 storm. This surviving trap was located on the coal burn area, and hence represents a disturbed soil (post strip mining simulation).

Stock Pond Analysis

Stock ponds in the area were cored with the results shown in Table 26 above. One of these, above Miller Canyon was reported to be partially spring fed. This is however questioned, after two seasons of observation.

Summary

In comparison to Hanging Woman (1977) sediment analyses, the Emery site appears potentially higher despite lesser mean slopes (Table 25). This is apparently due to high clay fractions in the Mancos and the fineness of the Emery sands allowing easier transport. Basins F and G for SE strip area are moderate sediment yield prior to mining, while the balance of strippable areas, basins B and H are already high, using existing surface soils and slopes. The extraordinarily low frequency of cloudburst noted in the climatology section for the past 78 years undoubtedly accounts for the exceptionally low yields indicated by the stock pond experiments (.59 to .90 tons/acre/year). That is, although erodable, these sediments simply have not experienced a cloudburst of sufficient magnitude to produce sheet flow so as to fill the ponds.

The rainfall and planchet tests on disturbed soils and "weathered overburden" produce remarkably similar results to the existing surface soils (i.e. high to moderate, Table 27). As noted in the planchet tests, slope is not too sensitive a factor for the 1 inch rain storm due evidently to the already high sediment production of these materials for the reasons noted.

Thus although the disturbed soils after mining would evidently fall in the moderate to high yield categories (.45 to 1.2 tons/acre/yr.) with one exception (Basin G .17 tons/acre/year) the key design factor is the rainfall one must plan for. The one inch storm according to the rainfall experiment is apparently no threat. The 2 inch worst case in 78 years at Emery might be more effective but was not tested due to the limits of the experiments performed. The trough experiment for a 1.1 inch storm, is perhaps the most realistic and shows an extremely low sediment yield, indicating that a single such storm does not constitute a decisive threat. Evidently the 2 inch storm should also be treated. In any event due perhaps to the special circumstances on the Emery site no significant increase in sediment yields is predicted by these analyses provided reasonable care in surface shaping is employed, post mining.

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HYDROLOGY & WATER SUPPLY

Surface Water

Raw data made available from ongoing USGS hydologic investigations (Lines, 1979 - personal communications) have been incorporated. However, significantly more analyzed data are expected to be released within two years. The reader is advised to seek this report, when available, to supplement what is presented here.

Regionally, the Emery coal field and the study area are located at the southern end of Castle Valley within the Dirty Devil Basin. Figure 71 shows the Muddy Creek watershed of approximately 1500 sq. miles, and the smaller drainages relative to the study site. Christiansen Wash and Quitchupah Creek flow southward into Ivie Creek above Ivie Creek's confluence with Muddy Creek. Miller Canyon Creek flows directly into Muddy Creek. Muddy Creek eventually empties into the Dirty Devil River above Hanksville, Utah.

The main drainage in the area is the 3rd order Muddy Creek, flowing southward along the eastern escarpment of the mesa bounding the study site. Ivie Creek, a 2nd order tributary flows eastward into Muddy Creek on the south, and 2nd order Quitchupah Creek flows southward into Ivie Creek on the west, isolating the mesa from the lowland. All the first-order tributaries are intermittent, draining the upland west and east into the Quitchupah and Muddy drainages. Nearly all of the 1st order basins on the upland surface drain westward into Quitchupah Creek, with the main exception of Miller Canyon and its tributaries, eroding headward NW toward Emery, capturing the upland drainage, formerly tributary to Christiansen Wash and the Quitchupah drainage. The gradients of these streams are generally small, except locally where they cross the steep to vertical escarpments. On the upland the tributaries are incised slightly and drop 200 to 360 feet per mile and range from 800 feet to 1100 feet per mile across the escarpment. The lowland Quitchupah and Muddy Creeks grade only 30 feet per mile. Tributaries to the main N-S drains merge in the vicinity of Emery on the nearly horizontal upland surface. None of the perennial streams with their low gradient and mean dendritic channel pattern seems capable of carrying excessive sediment load. The intermittent upland channels are also meandering and of low gradient.

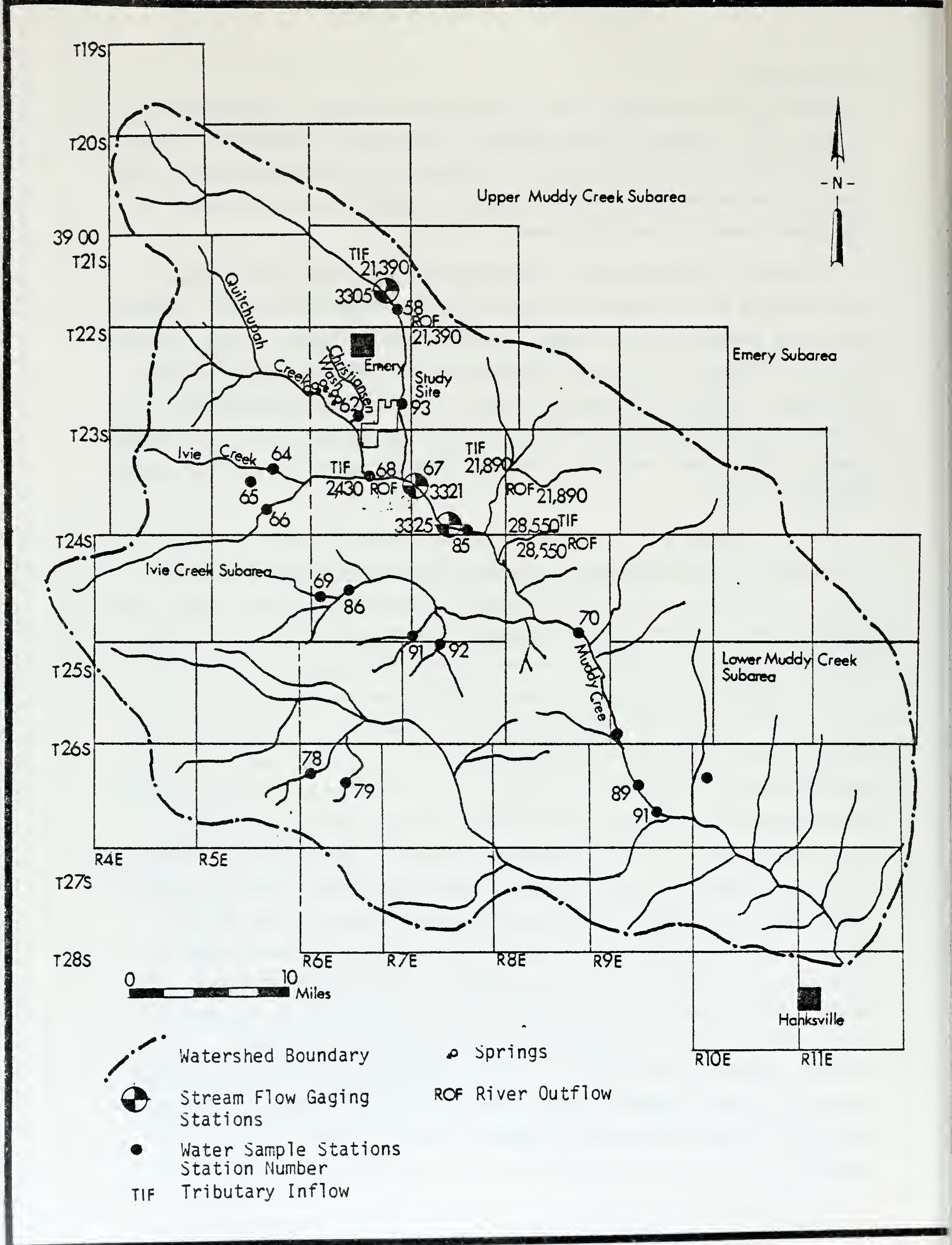


Figure 71. Muddy Creek Watershed.

Summer flash floods are common in the area but evidently scarce at Emery as noted in the climate section (Figure 12). Floods are due to short duration and high intensity summer storms, hence the flood probability is identical to the cloudburst probability previously cited. Strip mines must account for these events with runoff water diversion and barrier systems. The major stream in the area, Muddy Creek, is snowfed, therefore seasonal fluctuation of flow rates is great as shown in Figure 72. Stream flows for both Ivie and Muddy Creeks are greatest during late spring and early summer, decreasing to a minimum flow in early autumn through mid-winter (viz. Figure 72). Note that the peak precipitation is after this (late summer and fall). Hence for mean flows no close relationship is found.

Much of Muddy Creek's water is diverted for irrigation purposes. An irrigation canal system brings water onto farmlands on the Quaternary alluvium and river terrace deposits. Quitchupah Creek is snowfed, to a lesser degree. After entering Castle Valley, its flow generally increases as a result of runoff from the irrigated farmland. Hence any detailed consideration of surface drainage nets must consider the irrigation flows and their variability. Muddy Creek, Quitchupah Creek, and Christiansen Wash are perennial streams. Christiansen Wash's flow is sustained primarily by runoff from the irrigated farmland, unlike the other two.

Water Budget Analysis

A partial budget analysis has been completed for the study area by the Utah Division of Water Resources (1977). This analysis was based on gage records from 1951 to 1961 for Ivie Creek and 1951-1967 for Muddy Creek near Emery (Table 28). Additional flow data were evaluated from measurements taken during October 1974 to September 1975 (USGS, 1976). These have been added to the tributary inflow and river outflow estimates compiled on Figure 71 below Ivie Creek. We have also added the 1951-1961 estimates for this station (3321) to Figure 71.

Upper Muddy Creek Subarea

The Upper Muddy Creek cubarea is comprised of 105 square miles of drainage above the upper gage north of Emery. Man-made depletions are negligible. Nearly all the useable water in the Muddy River basin comes from this subarea. The surface outflow has been measured since 1951 at USGS Station 9-3305. A flow diagram of the water budget is shown in

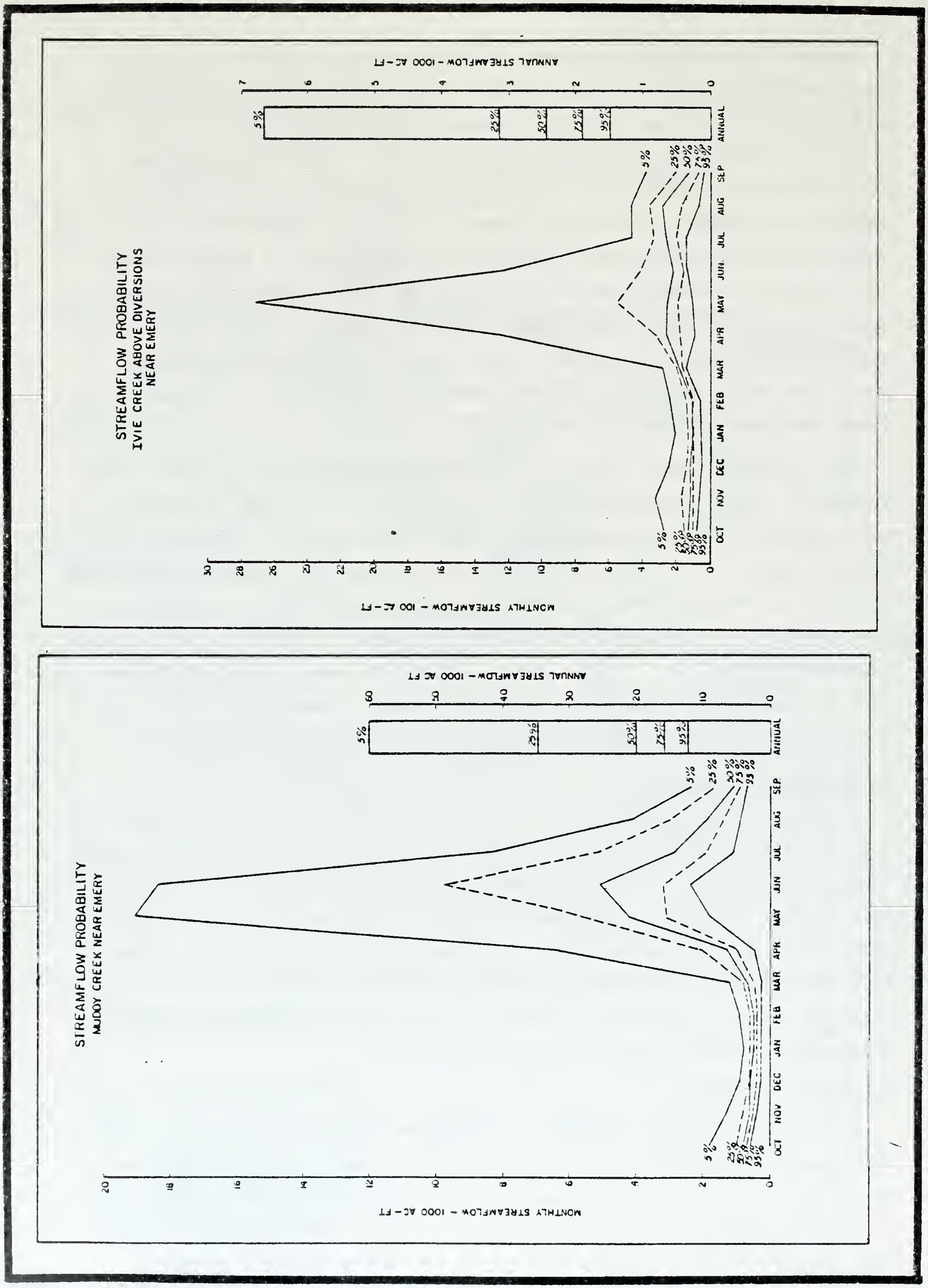


Figure 72. Probable Monthly and Annual Stream Flows, Muddy & Ivie Creeks.

Table 28. Mean Monthly and Annual Water Budgets for Emery Subarea.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year	
Measured Inflow														
Ivie Creek	130	120	120	110	110	180	260	260	220	270	280	130	2,430	Gage record, 1951-1961, "Ivie Creek above diversion near Emery"
Muddy Creek	890	590	580	480	490	700	1,290	4,240	5,690	3,660	2,210	1,090	21,390	Gage record, 1951-1967, "Muddy Creek near Emery"
Transbasin Diversion	100	70	60	50	50	80	140	470	630	410	250	120	2,380	1/9 of flow going to Independent Canal Co
Tributary Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0	Assumed that none reaches stream
Total Available for Diversion	920	640	640	540	550	800	1,410	4,030	5,280	3,520	2,240	1,100	21,440	
Cropland Diversions														
Muddy Creek							310	3,230	2,630	3,250	1,960	970	11,190	Muddy Cr. Water Commissioners Report (Modified to equal 90% flow in July, Aug., Sept.)
Ivie Creek	140						310	610	370	270	280	150	2,130	Ivie Creek (assume complete diversion)
Available for Use (Assume 35% efficiency)	50						220	1,340	1,620	1,440	830	470	5,970	
Cropland Precipitation	480	230	320	290	260	260	240	320	290	400	690	490	4,270	Use Emery data on 7,143 acres
Cropland PCU	590						270	1,420	2,230	2,830	2,370	1,530	11,240	7,143 acres
Deficit	60						0	0	320	990	850	570	2,790	
Cropland PCU	530						270	1,420	1,910	1,840	1,520	960	8,450	
Wetland PCU							630	1,250	1,970	1,960	1,340	820	7,970	4229 acres
Wetland Precipitation	280	130	190	170	160	160	140	190	170	240	410	290	2,530	Emery data on 4,229 acres
Outflow (Calc.)	1,150	1,000	1,150	1,000	970	1,220	890	1,870	1,860	360	480	100	12,050	Muddy Cr. below Ivie Cr., near Emery
Outflow (Act.)	380	330	320	290	460	820	1,520	3,470	2,530	540	930	670	12,260	1951-1961 gage records multiplied by $\frac{28750}{26200}$, to be compatible with inflow
Difference	770	670	830	710	510	400	-630	-1,600	-670	-180	-450	-570	-210	

Figure 71. The distribution of monthly flows is shown in Table 28. This would essentially constitute the water above the potential strip mine areas on the east side of the plateau.

Ivie Creek Subarea

The Ivie Creek subarea contains all the drainage (50 square miles) above USGS stream gage 9-3315. There are unmeasured diversions for 200 miles of meadow in this subarea. Streamflow records are available for the years 1951-1961. Figure 71 shows a flow diagram of the water budget; Table 28 shows the monthly distribution of this budget. Existing data are not sufficient to estimate sub-surface outflow. Due to the lack of a gaging station on Quitchupah Creek and Christiansen Wash, the Ivie Creek data must be taken as representative of the flow from the west side, strippable areas, supplemented by the Ivie Creek flow above the tributary.

Emery Subarea

The Emery subarea is 400 square miles, and contains essentially all of the agricultural land in the Muddy Creek drainage. The water budget is shown on Table 28. The measured inflow consists of Ivie Creek and Muddy Creek above Emery. One export from the basin is the Independent Canal. This diversion is generally one-ninth of the flow at the Muddy Creek diversion dam (directly below the gaging station). The principal water yielding area in the subarea is the Quitchupah Creek drainage, but the stream is ephemeral. In this study (Utah Water Resources, 1977), it was assumed that ungaged tributary inflow was negligible. However, as a point of fact, there would be unallocated water available for storage and irrigation of reclaimed land from this source.

Cropland diversion estimates were obtained from Muddy Creek Commissioner's reports for the period 1961-1963 available to the Muddy Creek Canal. It was assumed that the entire flow of Ivie Creek during the irrigation season was useable. A 35% efficiency was assumed to determine the portion of diversions available to satisfy potential consumptive use.

Note that the gaged outflow is greater than the calculated outflow by 210 acre-feet. This is probably due to the consumptive use estimate.

Lower Muddy Creek Subarea

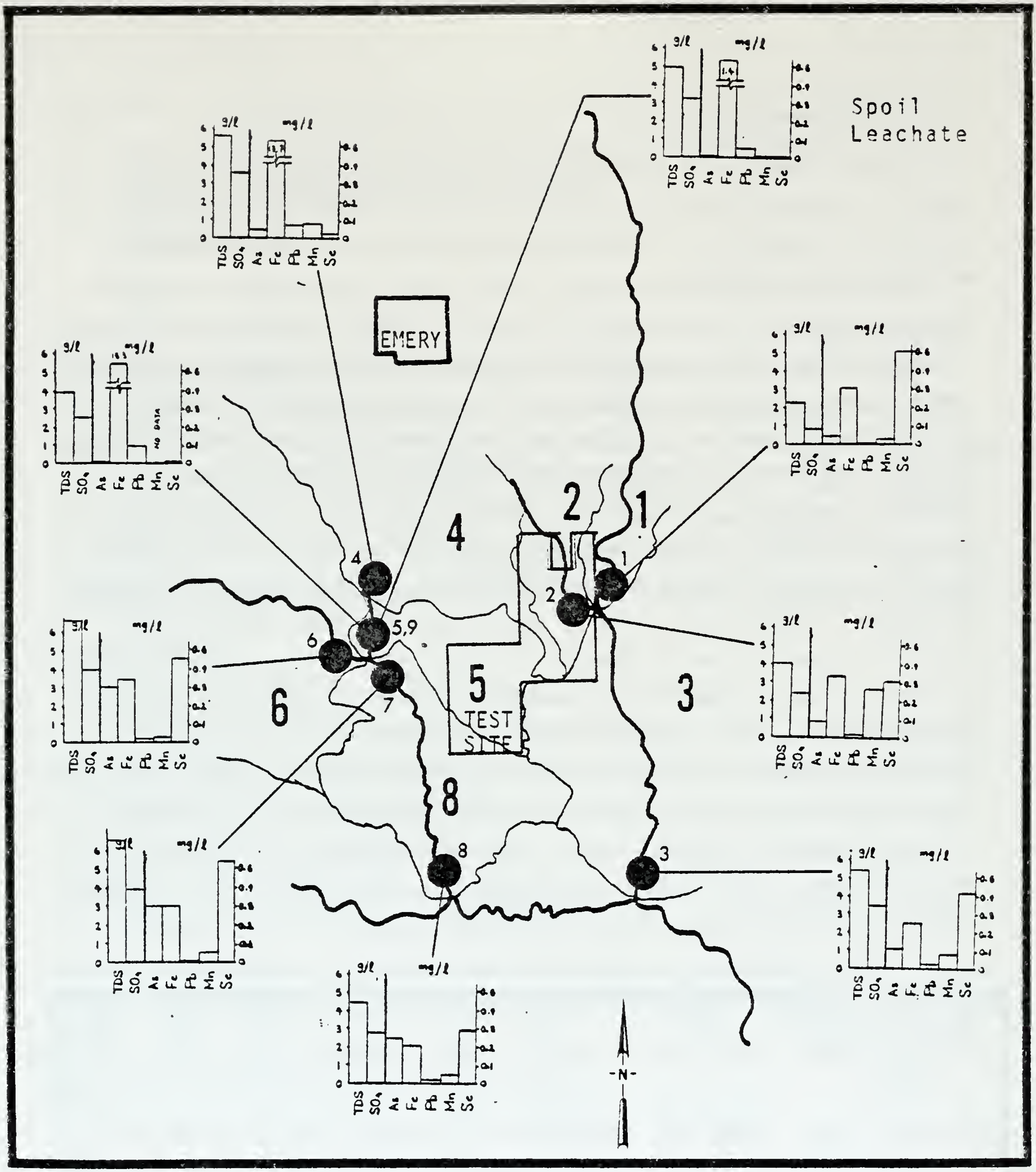
No water budget was prepared for this subarea (944 square miles). There is no gaging station recording surface outflow from the subarea. This would be essentially the receiving sub-basin for mine discharges and should be evaluated.

Water Quality

Water in the Ferron Sandstone, below the I-J coal is apparently better quality than water in the underlying and overlying shales and water in streams (Muddy Creek and tributaries - see section of overburden analysis). Table 29 and Figure 73 show representative water quality analyses from the study area (Lines, 1979). There is not enough information regarding the aquifer characteristics of the Ferron Sandstone and the hydraulic connection between the aquifer and surrounding shales to determine the amount (if any) and quality of water that will leak into the strip mine. An example of solute that will be leached from the stockpiled overburden is given in Figure 73. Comparing the spoil leachate to the stream sample shows no appreciable difference (compare 5 and 9 - see Table 29) for chemical content between the two. Judging from these values (Figure 73) large amounts of soluble salts and sediment may be added to the Muddy Creek drainage if flooding occurs. Vertical fractures evidently serve to provide major significant water transport. The aquatic life in streams though evidently lacking, could be affected by an increased silt load.

Table 29. Surface Water Quality (mg/l) - Lines, 1979

Sample Location	TDS	SO_4	As	Fe	Pb	Mn	Se
1) Muddy above Miller	2210.000	776.000	0.041	0.308	0.003	0.029	0.495
2) Miller	4050.000	2340.000	0.090	0.330	0.010	0.270	0.310
3) Muddy above Ivie	5380.000	3330.000	0.112	0.350	0.017	0.087	0.415
4) Upper Christiansen	3960.000	2520.000	0.002	15.300	0.100	no data	.002
5) Christiansen above Quitch.	5573.077	3592.308	0.040	13.745	0.077	0.082	0.115
6) Upper Quitchup.	6450.000	3960.000	0.294	0.330	0.011	0.019	0.442
7) Quitchupah below Christ.	6350.000	3940.000	0.305	0.307	0.006	0.064	0.528
8) Quitchupah below Ivie	4410.000	2710.000	0.240	0.207	0.014	0.038	0.290
9) Browning Mine	4970.000	3160.000	0.001	1.450	0.050	0.005	0.001



0 1 2 MILES

1 - Drainage Sub-Basins

Figure 73. Surface Water Quality and Drainage Sub Basins.

Surface Water Quality Sample Sites

1 Upper Muddy Creek
2 Miller Creek
3 Lower Muddy Creek
4 Upper Christiansen Wash
5 Lower Christiansen Wash
6 Upper Quitchupah Creek
7 Middle Quitchupah Creek
8 Lower Quitchupah Creek
9 Mine Tailings

Figure 74 shows routine sample measurement locations as provided by the Bureau of Land Management. Figure 75 and Table 30 show stream samples pH and suspended sediment collected and analyzed during 1978 by G.S.C. Table 31 gives EPA (1973) reccomended limits for geochemical constituents.

Summary

The study area is drained by Quitchupah Creek, Christiansen Wash, Ivie Creek and Muddy Creek. Many small streams are ephemeral and flow in direct response to precipitation or snowmelt. Snowmelt is a major contributor to streamflow. Snow at these elevations is generally stored through most of the winter and gradually melts during the spring and early summer. Ground water is a major contributor to streamflow, and it provides the continuity of flow (base flow) in the perennial streams, as well as some seasonal flow to intermittent streams. Summer precipitation does not usually produce much runoff. Intense rainfall may cause heavy flooding at times, but the areas affected are usually small, hence total runoff is small. The 100-year 6-hour precipitation ranges from 1.8 inches at lower elevations to 2.5 inches in the mountains (Miller and others, 1973).

The quantity of water applied annually to croplands averages 3.6 acre-feet per acre, and consumptive use on croplands averages 1.6 acre-feet per acre according to reports of the Utah Division of Water Resources (1975, 1976).

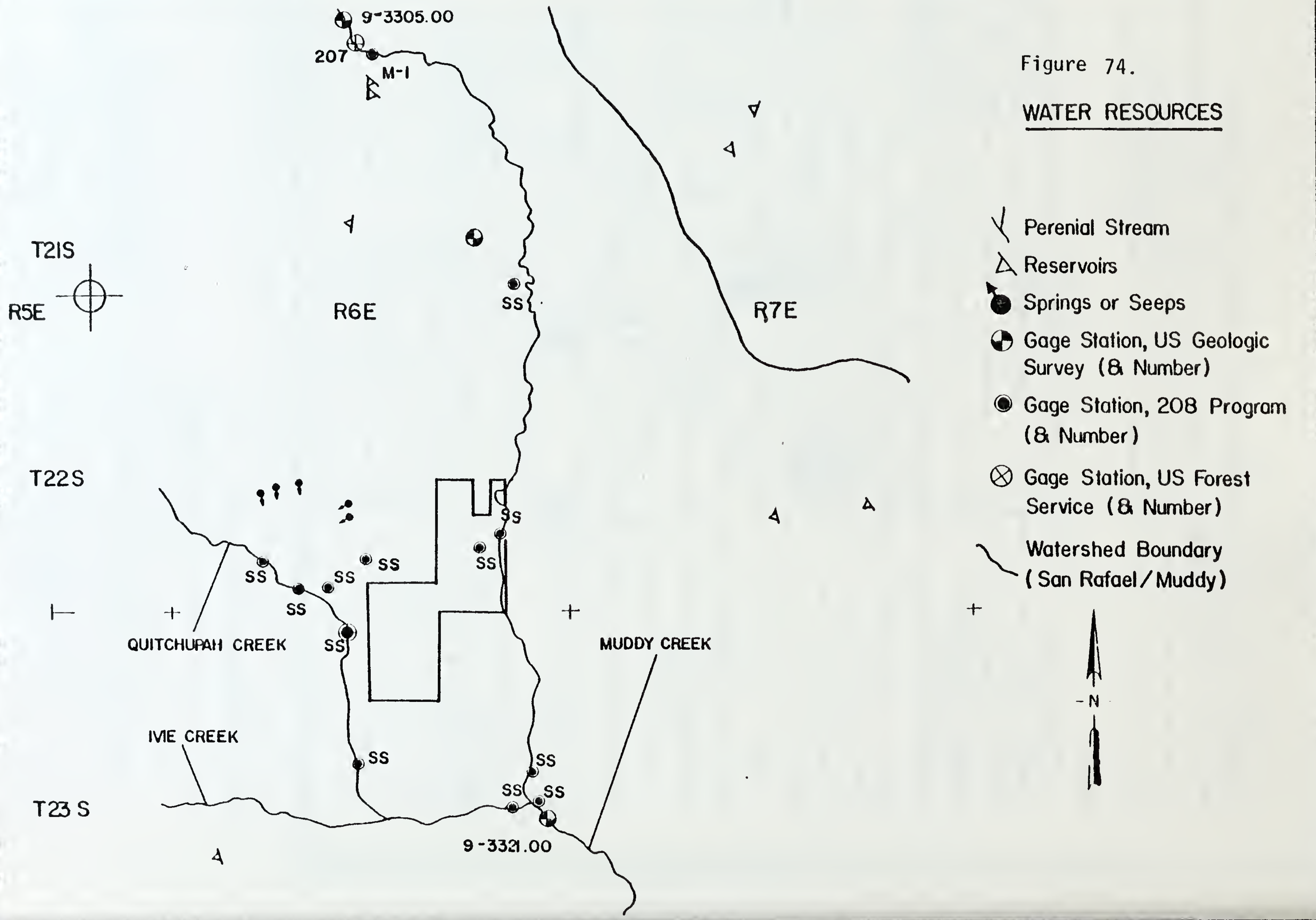
Both ground water and surface water are allocated and utilized in Muddy Creek drainage basin. Surface water is used in greatest quantity, about 25,000 acre-feet in the Muddy Creek basin. Coal-fired electric power plants to the north, in operation or under construction, will use about 62,000 acre-feet per year, not all of which is consumed. Ground water is used locally for irrigation, culinary and stock purposes, and public supply. Although the total ground water use is small, it is the principal source of water for the small communities. Water from both wells and springs is utilized.

Long Term Water Supply Flow and Duration

Low flow frequency curves may be used with evapotranspiration data to redetermine storage requirements for relatively short time periods (less than one year); for example, to retain the water from a high spring runoff for use during the summer of that same year as a supplemental source for revegetation. As was shown, stream flow is highly variable

Figure 74.

WATER RESOURCES



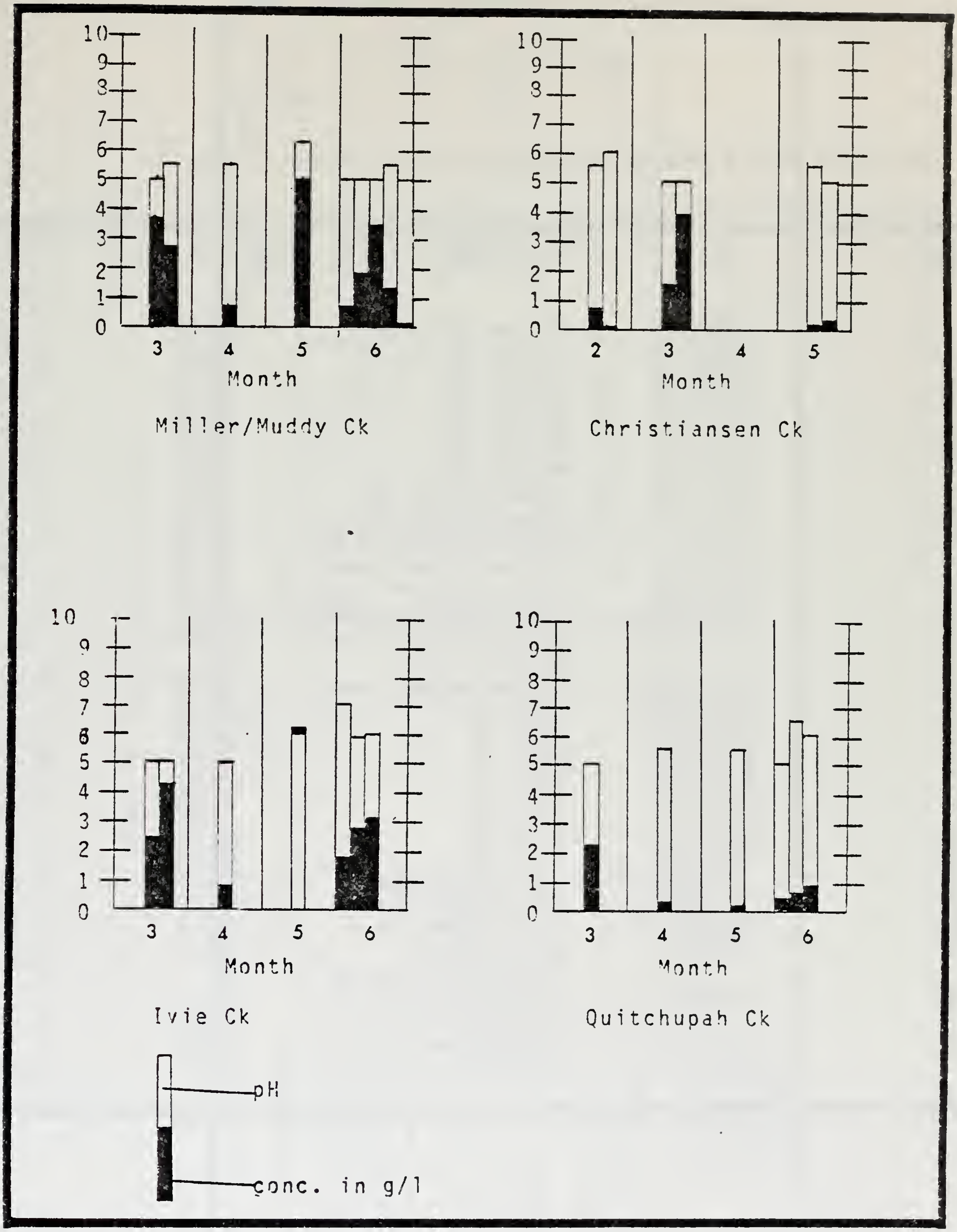


Figure 75. Suspended Sediment and ph From Stream Samples by GSC in 1978.

Sediment Yield and PH for Emery Area Streams - Table 30

Sample #	Date	Stream	Conc. in g/L	ph
1	6/21/78	Miller Cyn Ck	0.19	5.0
2	3/12/78	Muddy Ck	2.60	5.5
3	3/27/78	Muddy Ck	3.91	5.0
4	4/18/78	Muddy Ck	0.81	5.5
5	5/12/78	Muddy Ck	6.38	5.0
6	6/2/78	Muddy Ck	1.37	5.5
7	6/13/78	Muddy Ck	3.48	5.0
8	6/21/78	Lower Muddy Ck	1.70	5.0
9	6/21/78	Upper Muddy Ck	0.66	5.0
10	2/2/78	Christiansen Wash	0.61	5.5
11	2/2/78	Christiansen Wash	0.02	6.0
12	3/12/78	Chrietiansen Wash	1.51	5.0
13	3/27/78	Christiansen Wash	3.90	5.0
14	5/12/78	Tributary to Chris- tiansen Wash	0.27	5.5
15	5/12/78	Christiansen Wash	3.78	5.0
16	3/12/78	Ivie Ck	2.40	5.0
17	3/27/78	Ivie Ck	4.21	5.0
18	4/18/78	Ivie Ck	0.81	5.0
19	5/12/78	Ivie Ck	6.07	6.0
20	6/2/78	Ivie Ck	1.89	7.0
21	6/13/78	Ivie Ck	2.72	5.8
22	6/26/78	Ivie Ck	3.16	6.0
23	3/12/78	Quitchupah Ck	2.13	5.0
24	4/18/78	Quitchupah Ck	0.29	5.5
25	5/12/78	Quitchupah Ck	0.11	5.5
26	6/2/78	Quitchupah- Consolidate Mine	0.47	5.0
27	6/13/78	Quitchupah - Consolidate Mine	0.65	6.5
28	6/21/78	Quitchupah- Consolidate Mine	0.86	6.0

Table 31. Water Quality Criteria

[Source: EPA, 1973]

Chemical parameter	Public supply limit (mg/L)	Aquatic life threshold (mg/L)	Chemical parameter	Public supply limit (mg/L)	Aquatic life threshold (mg/L)
Aluminum	--	0.1	Lead	0.05	[1]0.03
Arsenic	0.1	1.0	Manganese (soluble)	0.05	--
Barium	1.0	--	Mercury	0.002	[1]0.05
Cadmium	0.01	[1][3]0.03 [1][4]0.004	Nickel	--	0.01
Chloride	250	--	Nitrate-Nitrogen	10.0	--
Chromium	0.05	0.05	Nitrite-Nitrogen	1.0	--
Cobalt	--	5.0	Selenium	0.01	10.0
Copper	1.0	[3]0.015-0.033 [4]0.011-0.018	Silver	--	0.001
Cyanide	0.2	--	Sulfate	250	--
Flouride	[2]1.4-2.4	--	Zinc	5.0	0.005
Iron (soluble)	0.3	--	Unionized ammonia	--	0.02
			Free chlorine	--	0.01

[1] Recommended maximum level.
[2] Dependent upon ambient temperature.
[3] Hard water.
[4] Soft water.

from year to year. It is possible to store excess spring runoff in some years, but not often. (See Table 32).

Table 32. (Jeppson et al., 1968)

Comparison of Storage Requirements From Frequency Mass Curve Analysis at the 95% Probability Level With Mass Curve Analysis.

Station Name and No.	Demand level (percent of mean annual flow)								Runoff April-June (inches)
	110		95		80		65		
	M[a]	F-M[b]	M	F-M	M	F-M	M	F-M	
(9-3305) Muddy Cr. nr. Emery	19	15.0	9.3	8.6	5.5	4.6	2.5	3.0	8.91
(9-3315) Ivie Cr. nr. Emery	2	1.9	1.2	0.9	0.7	0.3	0.3	0.1	0.51

The difficulty is that periods of critically low-flow often extend over several years (five years in the most recent drought) and cannot be predicted with any reliability. It is necessary, in the design as well as the operation of reservoirs for reclamation to use the flow characteristics of streams over more extended periods of time to predict the stream flow that may be stored during periods of high-flow for release during periods of drought. The reservoir capacity must be large enough to maintain the minimum required irrigation water, while holding down construction costs and excessive evaporation losses.

The mass curve method (Jeppson et al., 1968) relates storage requirements and demand levels in a simple way (Figures 76 and 77). The disadvantage of the mass curve approach is that it is difficult to assign a recurrence interval or a probability of occurrence to the storage requirement, as we saw in the climate section.

Note that a combination of two or more moderately dry years in a series may be more serious than the single isolated low year of flow. A mass curve, which is a cumulative plotting of net reservoir inflow over the period of record or portion thereof, permits an inspection of the entire record or any portion of it to be made rapidly. Evapotranspiration and seepage losses from the reservoir in excess of that from the natural watersheds covered by the reservoir waters must be added to the amount indicated in Figure 76 to get actual storage requirements.

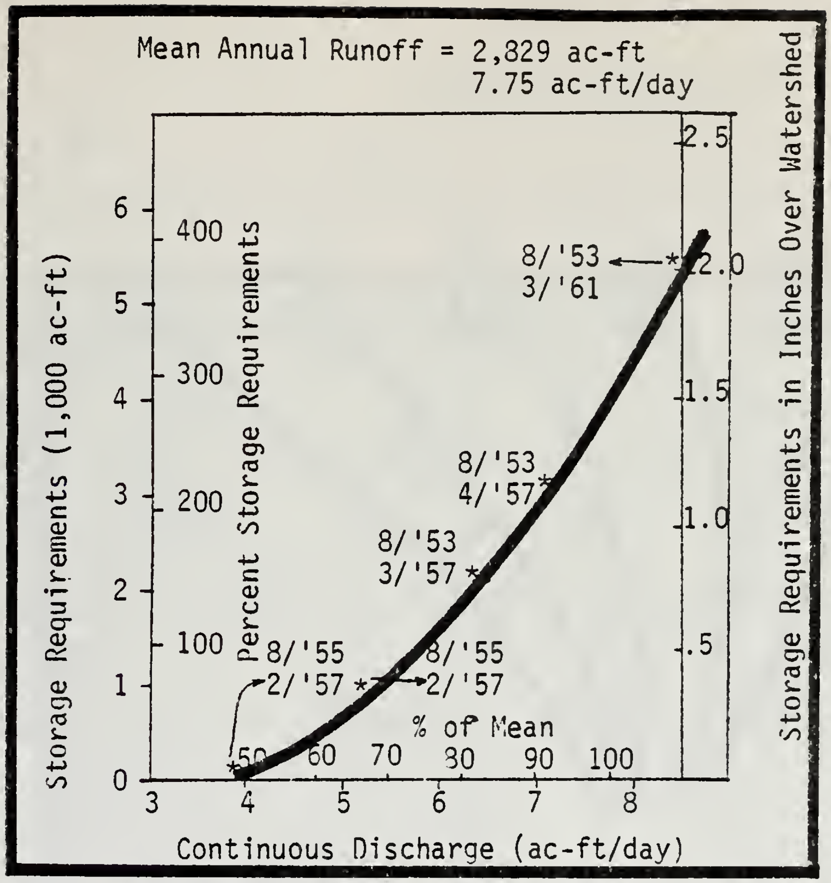


Figure 76. Mass Flow

Muddy Creek

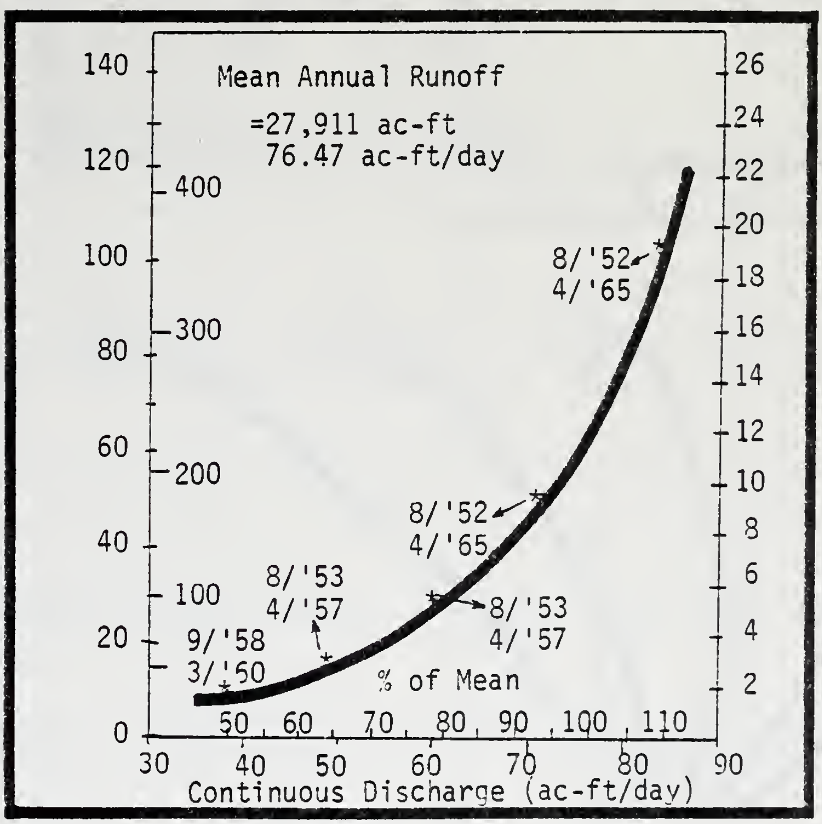
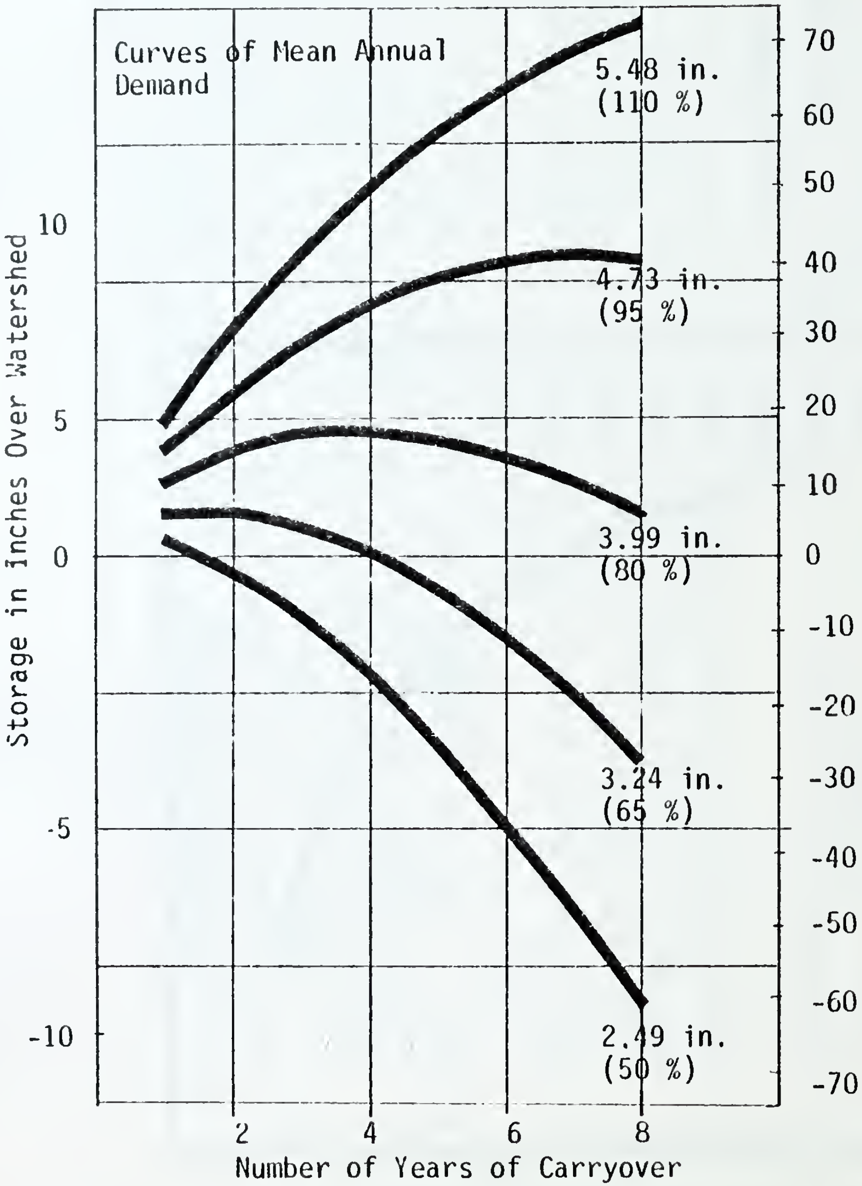


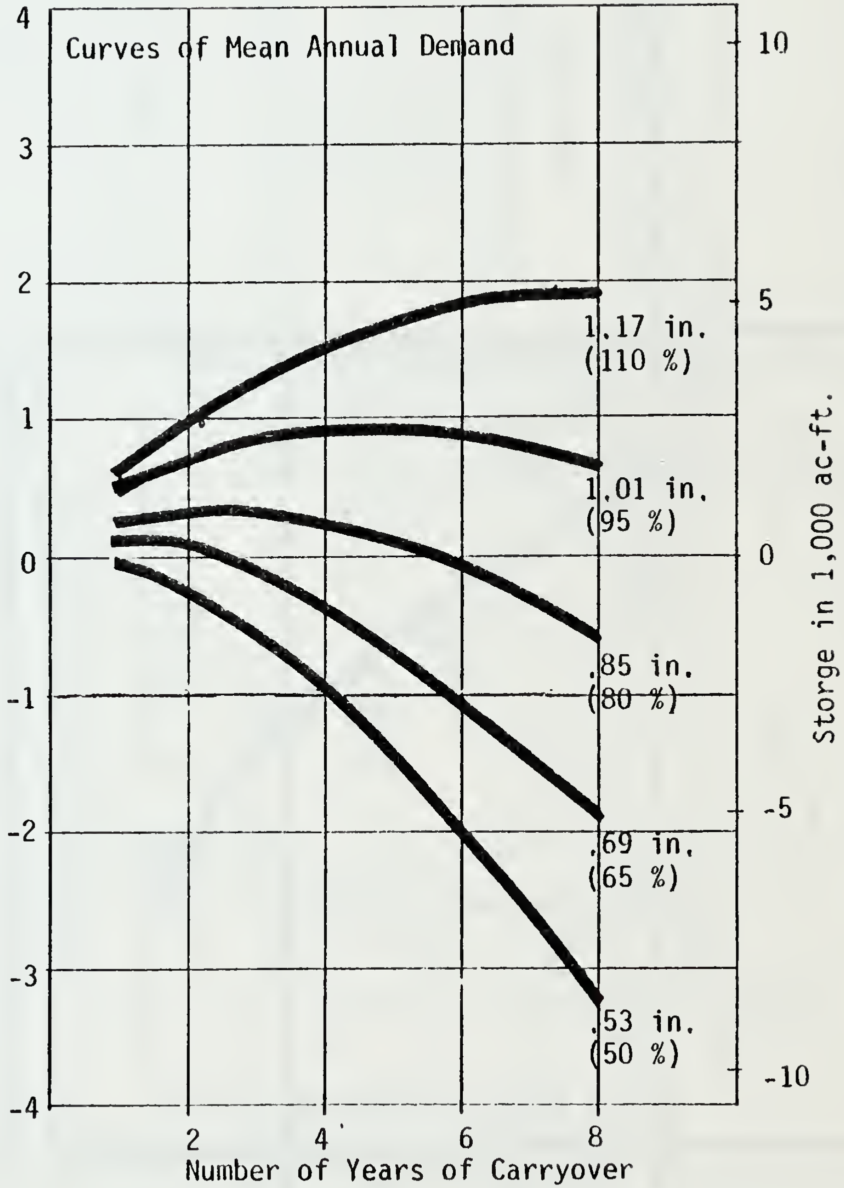
Figure 77. Mass Flow

Ivie Creek

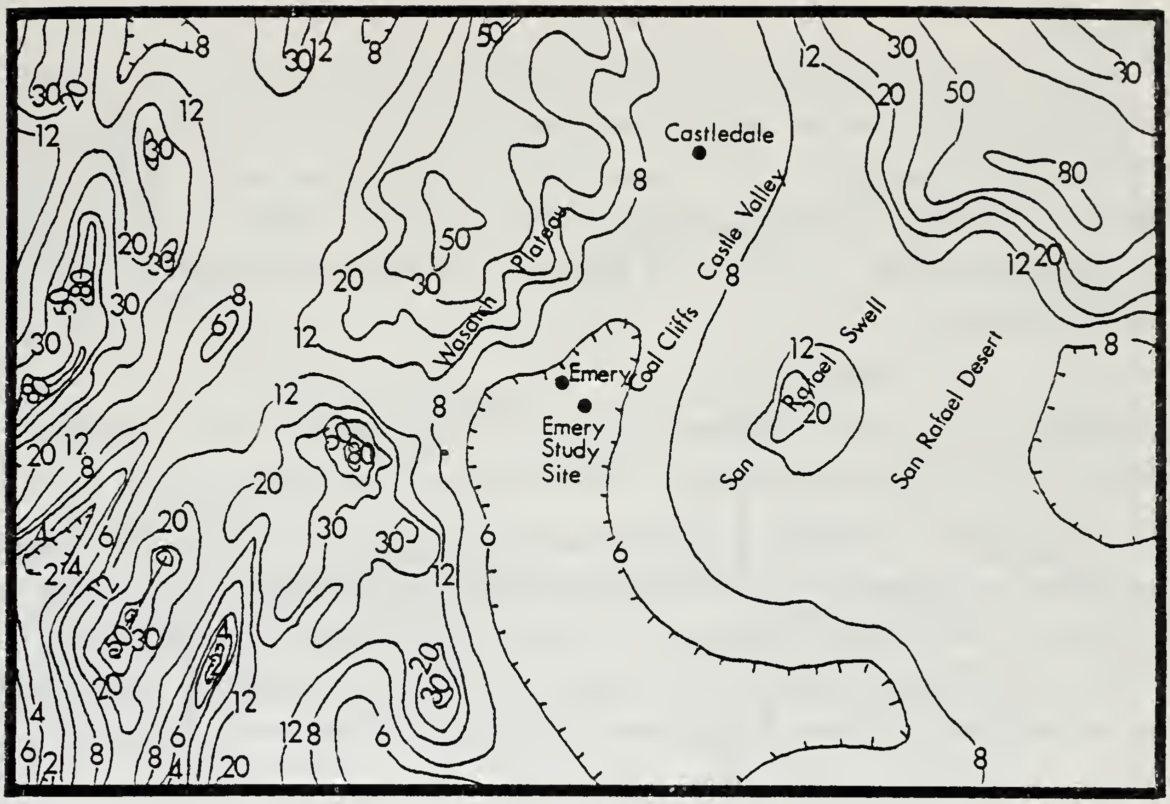
Figure 18. Storage Requirements Related to Demand Level and Period of Carry Over as Obtained by Frequency Mass Analyses at the 95 Percent Probability of Occurence.



9-3305 Muddy Creek Near Emery, Utah
(95% Probability Level or 17.3 Year Recurrence Interval)



9-3315 Ivie Creek Above Diversions Near Emery, Utah
(95% Probability Level or 10.1 Year Recurrence Interval)



3 Iso-line equal to 20 cfs per sq. mile.

Figure 79. Flood Flows at 50 Year Recurrence Interval.

To the extent that the past is an indication of the future, Figure 78 (Jeppson et al., 1968) indicates what average high- and low-flows might be expected for any specified number of consecutive days at any desired probability level, or recurrence interval, by use of the frequency analysis method.

Flooding

Plotting the peak observed flows against drainage area for all watersheds in a given region defines an upper boundary for flows that may reasonably be expected. This upper limit, or envelope curve, is often used synonymously with the maximum probable flood. Figure 72 is a plot of peak discharges in Utah. The equation fitting the envelope curve defined by Figure 72 is:

$$Q_p = 3140A^{0.435}$$

where Q_p is the momentary peak discharge in cfs and A is the drainage area of the watershed in square miles.

The 50-year flood may be determined directly from Figure 79 by a method analagous to determining mean elevation from a topographic map. After the 50-year flood has been obtained for the selected area, flow rates for other return periods may be calculated by multiplying the Q_{50} value by the ratio obtained from the Q/Q_{50} versus T curves for the proper hydrologic area.

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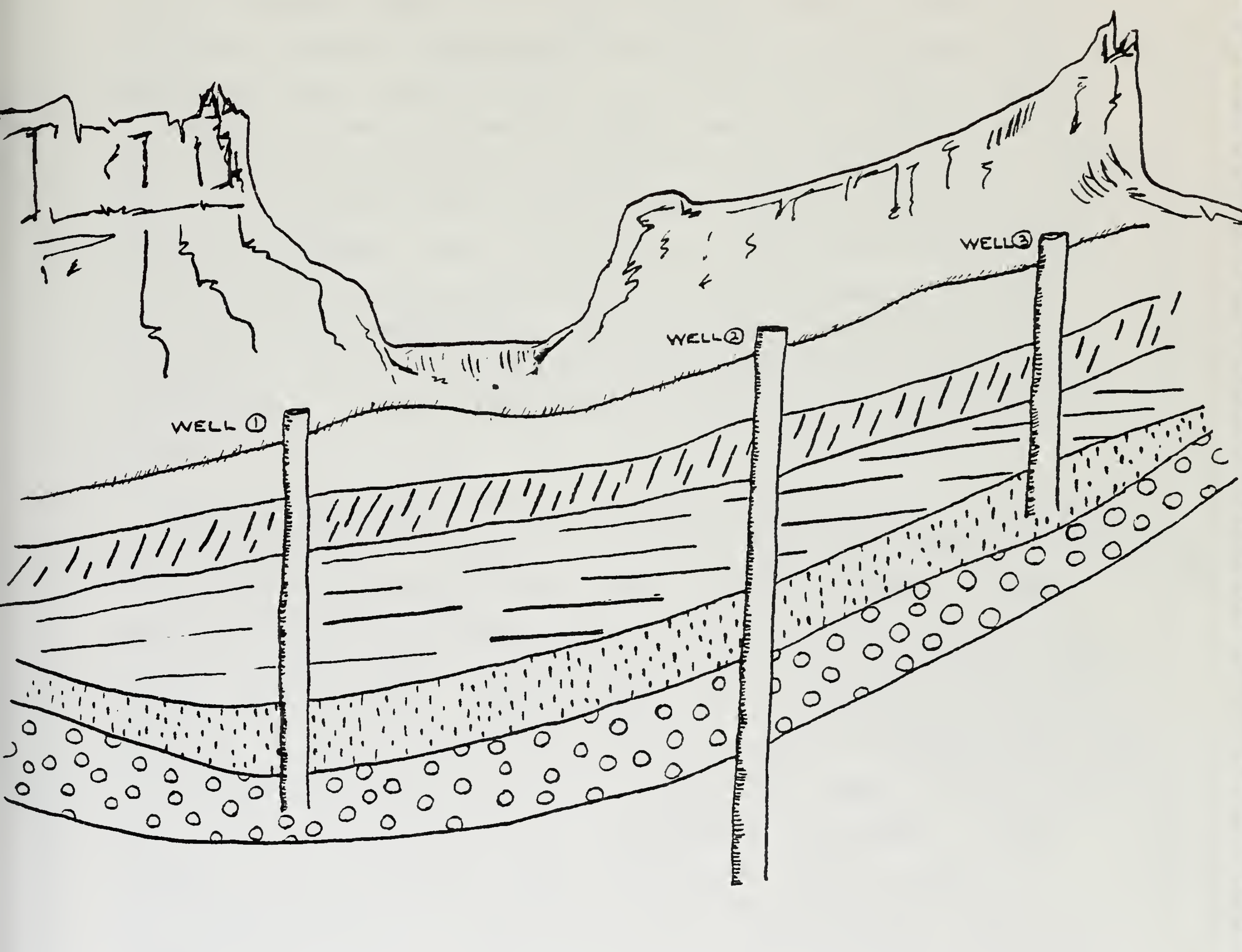

GROUNDWATER HYDROLOGY

Within the study area, there is evidence for shallow perched aquifers only within the surface regolith. The locales of these shallow aquifers are alluvium and colluvium in the main valleys and mountain fronts, or deeply weathered sandstone or deeply weathered zones on the mesa uplands. Perennial springs draining into Quitchupah Creek flow from the alluvium and are recharged from the northwest. Potential seasonal intermittent springs may flow into Quitchupah Creek from the east, fed from surface aquifers in deeply weathered zones in the upper Ferron Sandstone member or possibly perched above the coal beds. However, no such flow was evident during the study period. Recharge is evidently only via local snowmelt and to a lesser extent, precipitation, because of stream capture of the upland cachement areas. No significant springs should occur on the reverse slope of the mesa draining into Muddy Creek due to unfavorable dip angles of the exposed beds. Marginal infiltration and significant impermeability of the unweathered siltstone caprock layers evidently prevents recharge of deeper sandstone layers despite their greater permeability.

The Blue Gate Shale; or in the weathered sandstone, the first siltstone layer appears to be the confining layer above the Ferron Sandstone aquifer. This aquifer is used by the city of Emery and local stockmen for water supplies. Blasting and removal of the Blue Gate north of the study area may cause upward leakage from the Ferron into the mined area along vertical joints. If in quantity, water may leach the Blue Gate along the walls of the mine. Head differences between water in the Ferron Sandstone and water in the confining shales of the Blue Gate may also change. If this occurs over a long period of time, and if connected, a large amount of water removed from the mine could come from the lower confining layers. If significant dewatering of the Ferron in the mine area occurs, upward leakage into the Ferron from permeable units within the Mancos shale below the aquifer could be induced. Although the piezometric map does not support this view, water quality in the Ferron Sandstone and the quality of the water pumped from the strip mine may alter accordingly. The mine water may be impounded and infiltrate or be pumped into streams on the Muddy Creek drainage. Dewatering of the coal might close existing wells and springs on the plateau, reduce the base flow of streams, and alter quality of water in the deeper Ferron Sandstone aquifer to a lesser extent (see Figure 80).

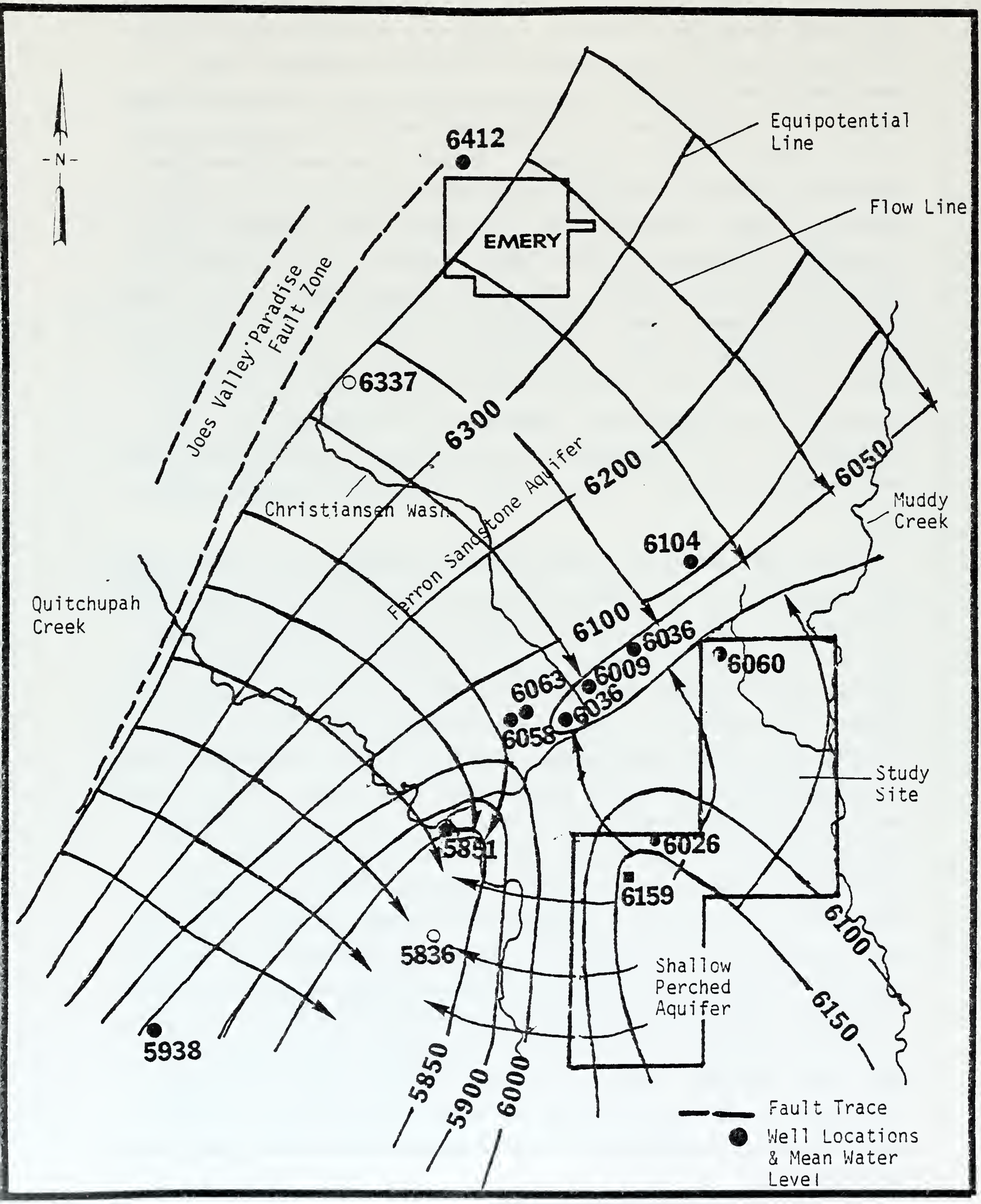

Figure 80. Potentiometric Map Flow Net and Observation Wells for the Emery Site.

Aquifers

Two significant aquifer types are found on or adjacent to the study area (Figure 81). The first is a shallow aquifer, formed by the Quaternary alluvium river terrace deposits and deeply weathered sandstones. These cap the Blue Gate Shale and siltstone units of the Ferron Sandstone. The second aquifer of major significance to the town of Emery is a confined aquifer formed by the Ferron Sandstone member. Deeper aquifers may exist in the marine sandstone but these would not primarily be involved in strip mining considerations. An exception would be in the vicinity of significant vertical joints which would permit upward or downward ground water migration.

Unconfined Aquifer

The boundaries of the minor unconfined aquifers are indicated in Figure 81 as the limits of the Quaternary deposits and small scale perched aquifers present in wet years above and perhaps within the coal in the study area. Recharge to these aquifers is sustained either by local snowmelt or irrigation returns as noted above.

Numerous reported springs at the contact of the Quaternary deposits and the Blue Gate Shale and Ferron Sandstone members were not found to be flowing throughout the period (1977-1978) of our field study. Due to the rolling topography of the Blue Gate Shale, prior water flows from some of these springs or seeps have created alkalic evaporites in swales. Elsewhere, spring waters may enter Quitchupah Creek, Christiansen Wash, Muddy Creek, and Miller Canyon during wet years. The location of recorded springs would imply that the general direction of ground water flow is to the south and east. However, our potentiometric map, derived from USGS well level data (Lines - USGS - 1979), would imply a more complex movement. We are evidently looking at a superposition of ground water movements. The flow off the surface to the SE is evidently from the shallow perched aquifer described above the site itself. Due to their salinity these waters are now usable only for stock watering.

Ferron Aquifer

The Ferron sandstone aquifer is confined above by the Blue Gate Shale of impermeable siltstones where the Blue Gate is absent. It is confined below by the Tununk shale.

Ground water levels measured by the USGS in the EMRIA wells and in the Emery municipal well, Kemmerer Coal Company well, and other moni-

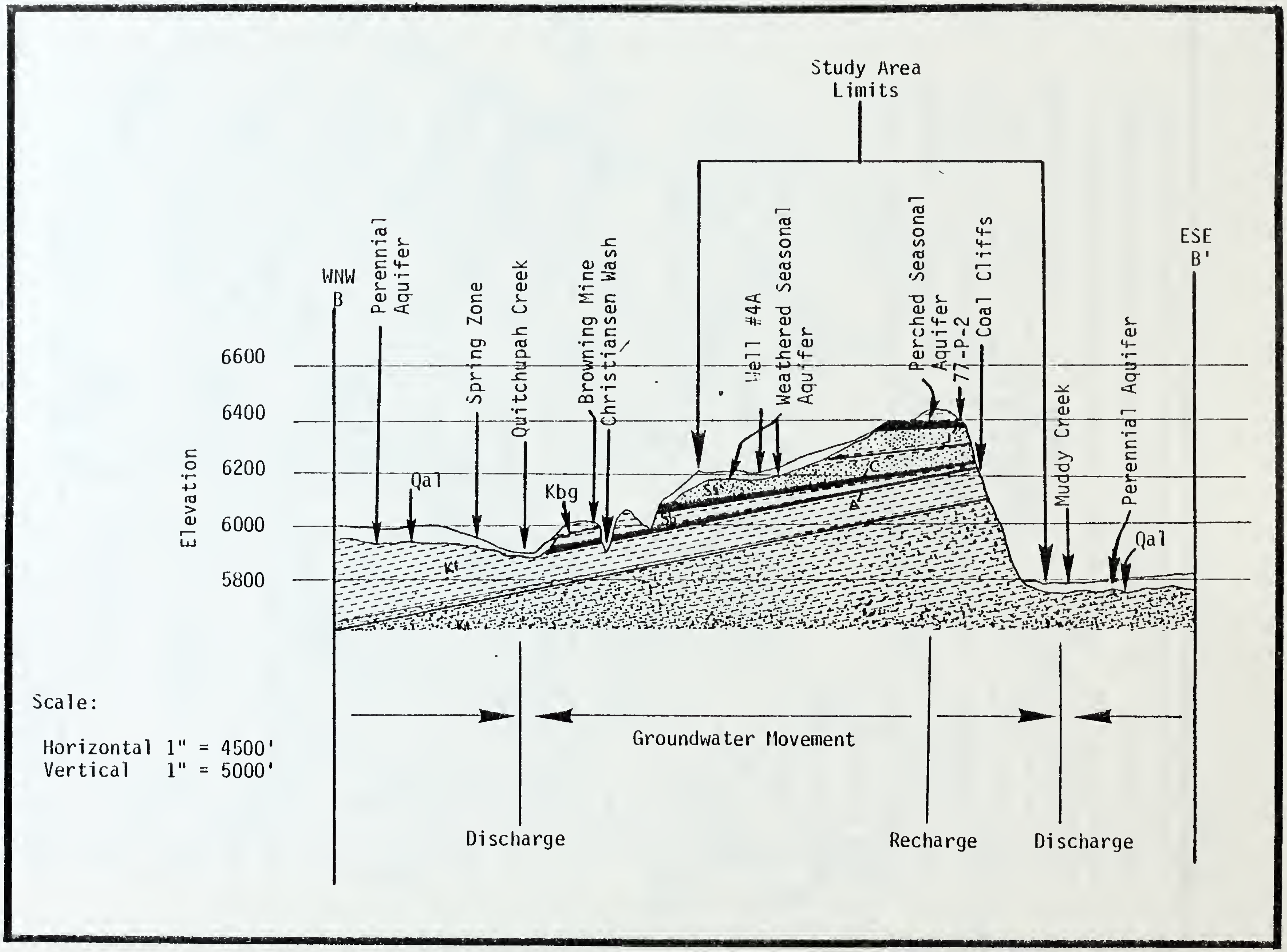

Figure 81. Study Area Aquifers.

toring wells (Figure 80) imply that the potentiometric surface is above the land surface within the study area which would indicate an artesian condition in this area.

Static water levels varied during the monitoring period, requiring some adjustments to fit potentiometric surfaces. The flow net in Figure was constructed from the static water level data by drawing flow lines perpendicular to the potentiometric surface lines (or equipotential lines). The arrows indicate the direction of flow. Elsewhere, the ground water is evidently draining into Christiansen Wash, Quitchupah Creek (where the Ferron sandstone outcrops), Miller Creek and into Muddy Creek during wet years. The flow net implies that the ground water in the aquifer flows up-dip and perpendicular to the Joe's Valley-Paradise fault zone from the west-northwest, until reaching the Christiansen Wash-Quitchupah Creek drainage, where spring discharge occurs (Spring Zone of Figure 81). This aquifer then continues under the study site. This suggests that modest recharge to the aquifer occurs from the study area plateau through open vertical jointing fractures.

The average hydraulic conductivity (K) of the coal and upper sandstone producing zone of the aquifer has been estimated from mine data to be 1.743 ft/day. This value is typical of a medium-grained sandstone. This estimate was based on the assumption that the producing zone is approximately isotrophic (i.e. properties are independent of direction). Secondly, the producing zone was assumed homogeneous or uniform. A 100 foot producing zone, with four flow channels and an 800 foot potential drop was assumed to reach this estimate, together with a mine inflow of about 70,000 cubic ft./day.

The average velocity of ground water flow can then be computed by a form of Darcy's law:

$$V = K \frac{dh/dl}{\theta} = 10 \text{ feet/day}$$

where dh/dl is the hydraulic gradient and θ is the porosity, using an average gradient of 80 ft./mile from Figure 81 and assuming a θ of .25 for a typical medium grained sandstone.

The approximate transmissivity (T) of the producing zone can thus be estimated as 174 ft^2/day; the product of the estimated average hydraulic conductivity (1.74 ft/day) and the saturated thickness of the producing zone (100 ft.). The storage coefficient of the confined producing zone may be of the order of magnitude of 10^{-5}. This analysis would imply a relatively low rate of transmission for contaminants by this route. Transport along vertical fractures would of course by much more rapid. The value for K given above may also be too low, but no other is available now.

A general ground water availability map, to be published by the USGS (Sumption, 1979), shows that well yields from the Ferron aquifer will be less than ten (10) gallons per minute (GPM). This is perhaps consistent with the above calculations. However, wells which intersect major fractures, particularly near the Joe's Valley-Paradise fault zone, may yield as much as a few hundred gallons per minute. The Emery municipal well and the Kemmerer Coal Company well, which are both artesian, are two good examples. On September 10, 1975, the USGS Water Resources Division measured a flow of 375 gpm from the Emery municipal well without pumping; and, on May 3, 1973, Layne Western Company measured a flow of 343 gpm while pumping from the Kemmerer Coal Company well. It is doubtful that such high flows will be encountered in the study area.

Summary of the Effects of Strip Mining of Ground Water Hydrology

Potential Effects on Surface and Subsurface Water Supplies

The crux of the hydrology problem at the Emery site is whether the coal and superadjacent sandstone layers do in fact form a significant aquifer which if tapped or drained could produce problems for the Emery municipal water supply. This view is evidently a concern at this time for some workers within the USGS.

We however, do not agree with this view. From our evaluation of the drilling logs and related data, we doubt the present existence of more than a shallow (40-50 ft) perched aquifer above the strippable coal, which is sealed off from deeper penetration by a relatively impermeable siltstone layer at its base (see Figure 82). It is doubted that the coal on the study site now contributes significantly to the local ground water. The following points are offered in support of this viewpoint:

1. Water Loss During Drilling

   To set the stage for the analyses, we should recall that in every case (holes 3 thru 6) excessive water losses occurred (e.g.

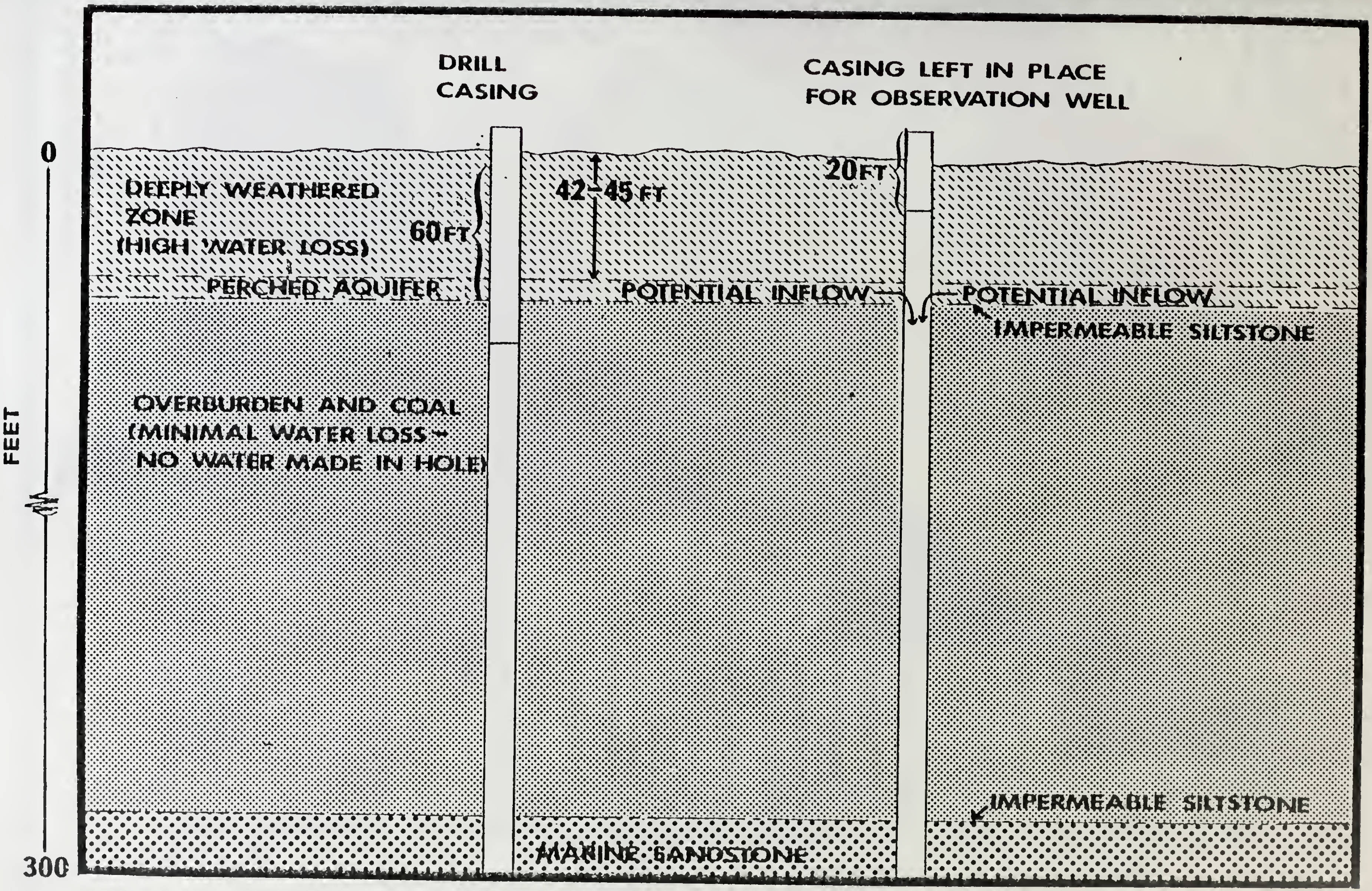

Figure 82. Interpetation of Drilling Data on Observation Well Hydrology.

refer to Figure 83 for outcrop permeability ranges). Although we at first thought that this was due to the inopportune interception of open vertical jointing fractures, we later questioned this interpretation as this situation repeated itself on later holes. Moreover, as we bypassed this deeply weathered zone, the hole would generally seal. To us, this implies a very low permeability for the unweathered section (Figure 82). Unfortunately no lab permeability data from sampled cores are available from the USGS at this time, to confirm or deny such an interpretation. In any case what we are concerned with is the impermeability of the siltstone caprock over the site which appears to deny recharge, except possibly at the site of vertical jointing fractures.

2. Seepage from Coal Outcrops

Coal outcrops and the Cowboy and Miller Canyon Mines were inspected for seepage in the spring of 1978. Despite the fact that higher than average precipitation had been recorded, (in particular snowfall, which is most efficient at infiltration) no evidence of seepage from coal beds or reported springs was found. If indeed the coal beds are a significant aquifer, this is inexplicable.

3. Conditions of Recovered Coal

As viewed in the field when retrieved from the core barrel the coal was competent, and unchecked (in the initial 1977-78) drilling program. Neither its physical appearance or the analyzed moisture contents support the concept of a saturated coal layer.

4. Methane Gas

Methane gas was noted in some but not all of the drill holes. Two possible coal oxidation processes for the evolution of methane gas (CH_4) are given below:

1) $\underbrace{2C \cdot 2H_2O}_{\text{(Saturated Coal)}} \longrightarrow CO_2 + CH_4$

2) $\text{Coal} + O_2 \longrightarrow \underbrace{\text{Clinker}}_{\text{(Oxidized Coal)}} + CH_4$

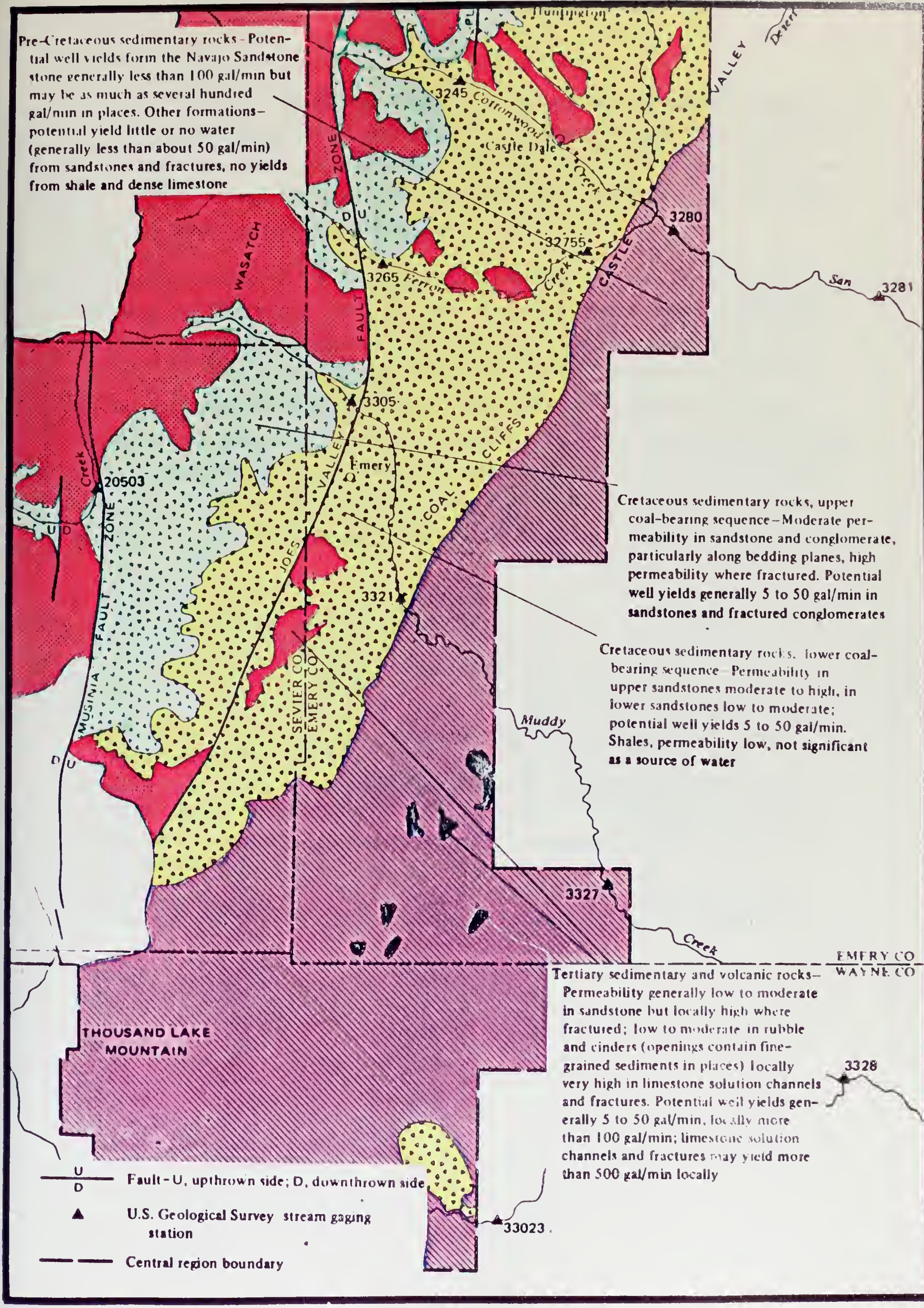

Figure 83. Surface Permeability

If the coal beds were universally saturated, we would expect the general presence of methane gas. Instead we find that substantial gas was found only adjacent to or up-dip from the continuing coal burn zones. We thus conclude that the gas noted is due to underground coal fires (Process 2).

Finally we are left with the conclusion that due to the hydrologic isolation of the study site coal beds from the deeper Ferron Sandstone aquifer, no serious threat is posed to the proposed strip mining activities. Further, based on the slow ground water movement rates given by our estimates from the best available data, contaminates if introduced into this aquifer would not readily affect the "downslope" existing uses if indeed sufficient vertical fractures for such seepage were present, and if indeed the artesian "head" of the Lower Ferron Sandstone aquifer is lost as it becomes exposed in Quitchupah wash.

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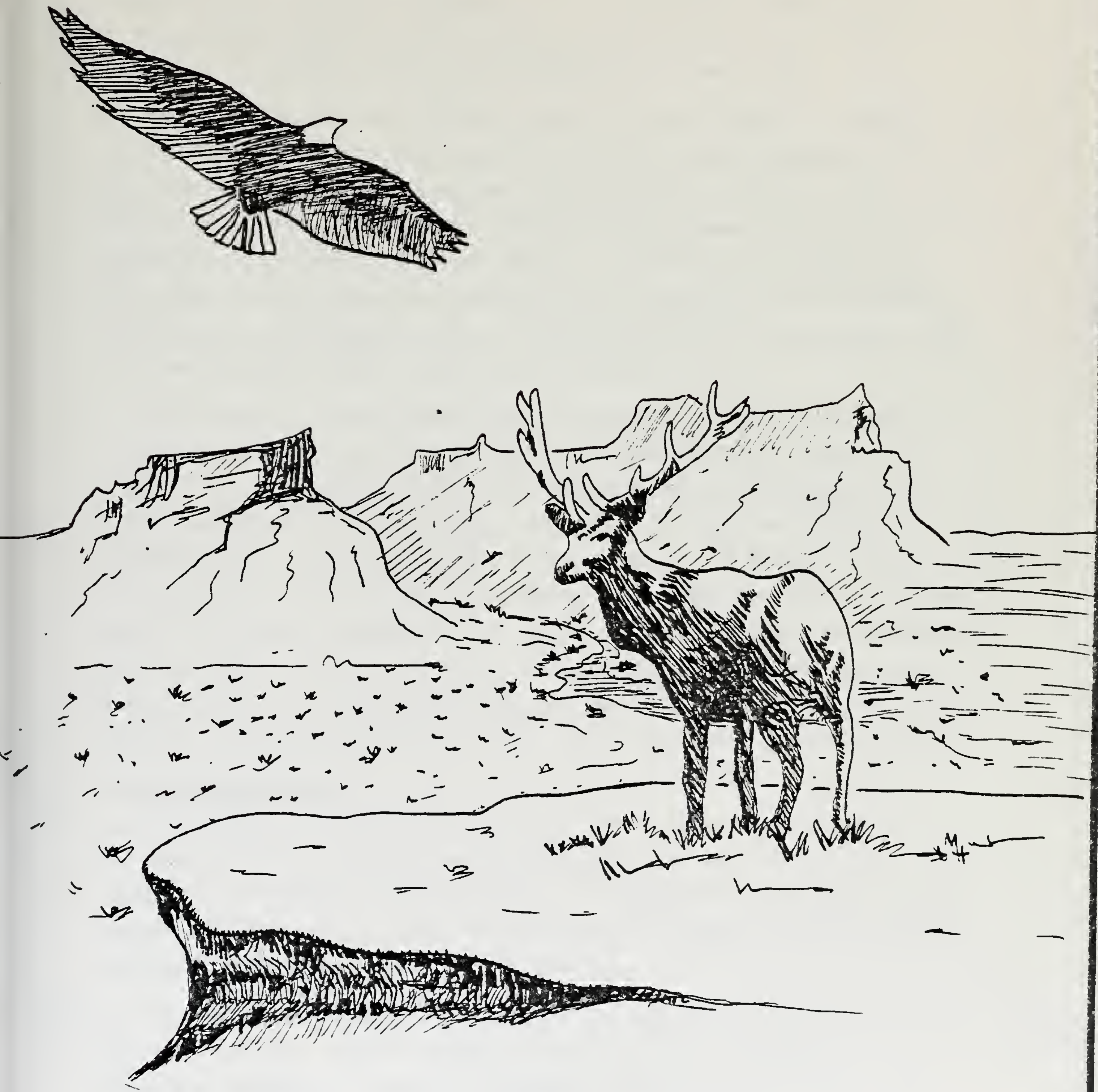
WILDLIFE



Present and Potential Wildlife

Recent applicable quantitative data for the study area and the surrounding environment are scanty. The general visual counts and some correlation to existing data were used to form opinions and/or conclusions about potential wildlife use and effects of surface mining on the wildlife that either does or may exist in the area.

Biotic communities and habitat types within the area are somewhat diversified. They vary from juniper and shrub covered mountains to riparian vegetated areas along the Ivie and Muddy Creeks and the Christiansen Wash. The present dominant biotic community throughout the district is semi-arid saline desert. In spite of this generally dry nature of both the study location and the general area, topographic variation in plant growth limit wildlife populations to the numbers that can survive under minimal conditions from year to year.

Our field trips (1978-1979) have evidenced remarkably few sightings or sign of wildlife with the exception of a few scattered rabbit droppings. The revegetation sites, left unfenced most of the summer, show little evidence of any disturbance by rodents or any other wildlife. Grazing appears to be the largest single prior use of lands within the study area as well as in the surrounding areas. Overgrazing and drought seem to have been a problem in the past from which recovery is incomplete. Selected birds sighted in the area include: Western Tanager, Dark-eyed Junco, Starling, Black-billed Magpie, Screech Owl, Red-tailed Hawk, Turkey Vulture, Ring-necked Pheasant, Chukar, Great Blue Heron, and Snowy Egret.

Regional Perspectives

Even though little wildlife sign was found within the study area (Figure 84), some wildlife species could be impacted in the large potentially strippable resource area. In this sense, the study area may not be representative of the strippable area as a whole, since it appears to have a relatively lower wildlife density.

Two species could be greatly affected by strip mining activities in the wider region. Winter habitat of the bald eagle (Figure 85), an endangered species, is found in riparian areas within the Coal Cliffs region. In addition, a poriton of Muddy Creek is considered crucial winter range for elk and deer. Any mining activities in these areas could adversely affect the eagles, deer, or elk using them (BLM-San Rafael Planning Unit-Draft Report: Wildlife).

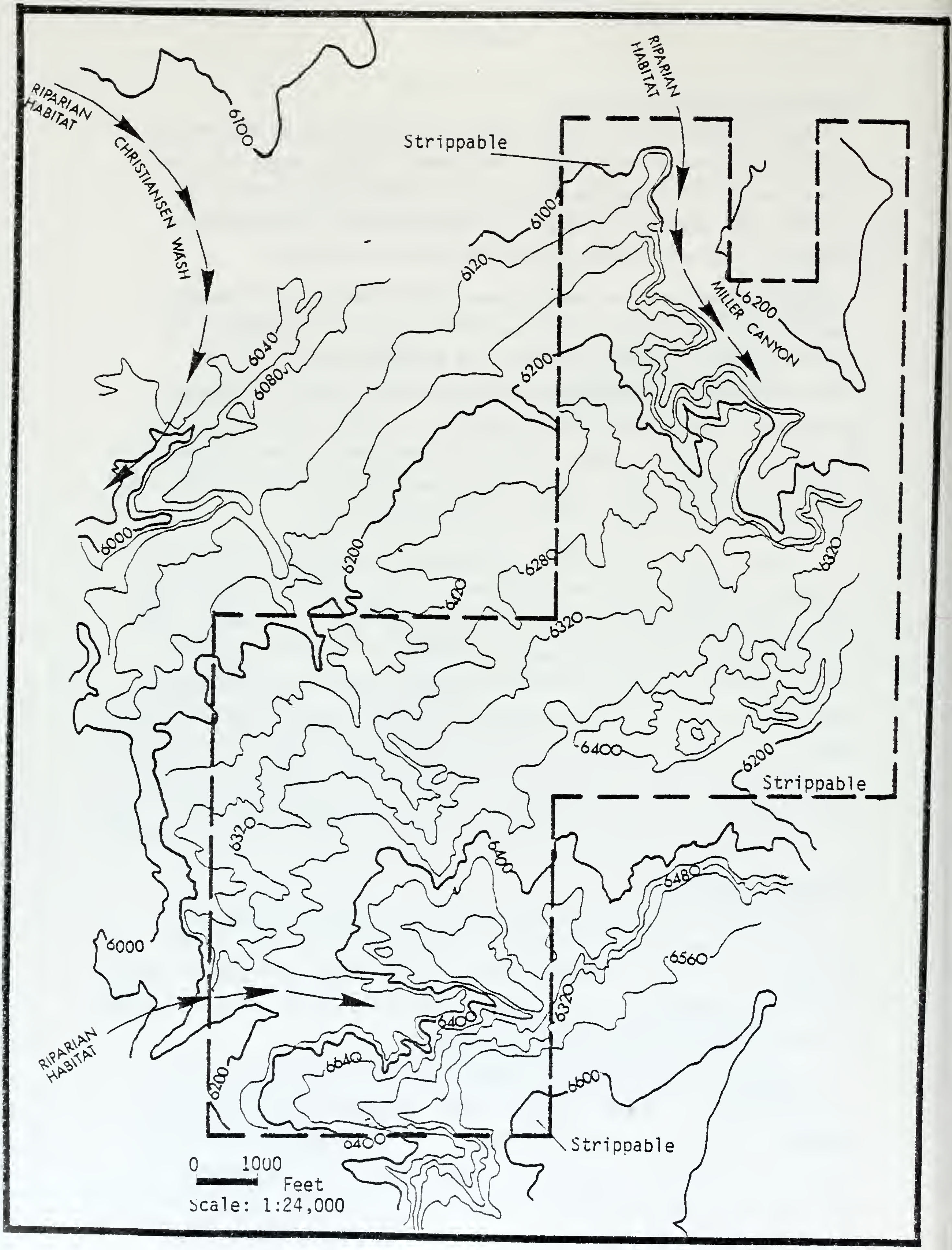
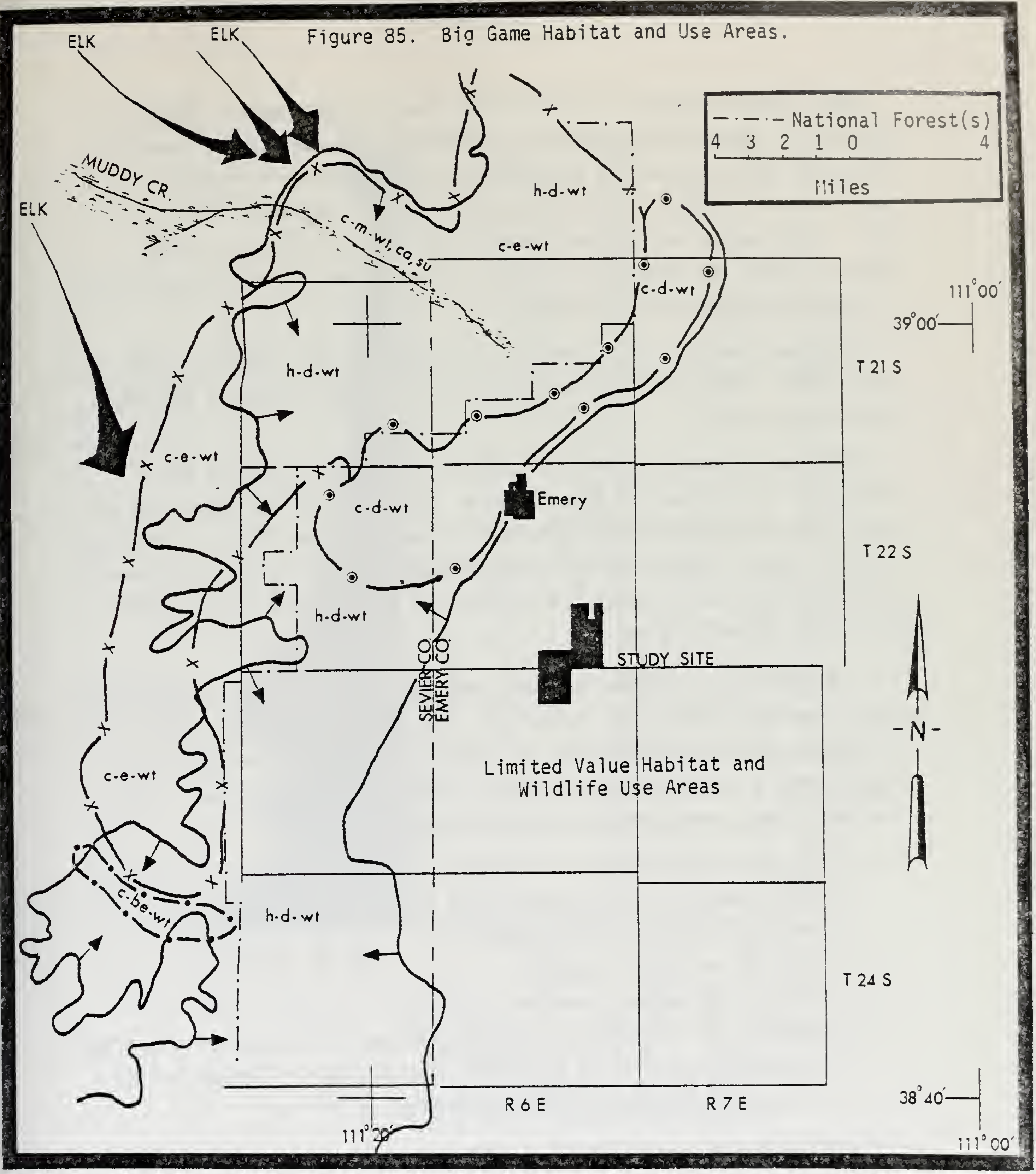


Figure 84. Key Wildlife Habitats on the Study Site.

Figure 85. Big Game Habitat and Use Areas.



Explanation

c-d-wt = crucial-critical winter range for deer.
h-d-wt = high priority winter range for deer. (Arrows indicate direction of migration)
c-e-wt = crucial-critical winter range for elk.
c-be-wt = crucial-critical winter range for the bald eagle.
c-m-wt,ca,su = crucial-critical winter range, calving area, and summer range for moose. (Riparian habitat)

Other species known to use the Muddy Creek include beaver, chukar and several species of waterfowl. Although greatly declined in numbers from prior years, beaver is the most valuable furbearer in Utah and Muddy Creek has one of the largest populations of beavers in the area. Some beaver habitat has already been lost in this area. The chukar is found throughout the area, but one of the highest concentrations is along the Muddy Creek near Moore.

The desert cottontail is common in the open plains, foothills, and low valleys. Any removal of vegetation from these areas would adversely affect this species.

Other small mammals as well as several species of birds are found (Figure 86), but impact on these species is considered low since they are not common on the area designated as strippable (Figure 84). In addition mining of the strippable area is not expected to have any major regional wildlife impact due primarily to evident low density of species in the potentially mineable area.

A classification system has been developed (Dalton et al., 1977) for use areas and habitats for wildlife in the area around Emery. The system was developed to promote an awareness of wildlife needs in the face of man's increasing activity and development on wildlands. The use area types were defined using the following criteria:

1) The classification by Utah Division of Wildlife Resource of Utah's fishing waters; and the importance of use areas to terrestrial wildlife species of high interest.
2) Status of endangered species.
3) Status of threatened species.
4) Potential for reclamation and restoration of habitats and use areas; and the availability of acceptable mitigation for damage or loss to habitats, use areas and/or individual wildlife.

The resulting four classifications were:

1) Crucial-Critical wildlife use areas.
2) High-Priority wildlife use areas.
3) Substantial Value wildlife use areas.
4) Limited Value wildlife use areas.

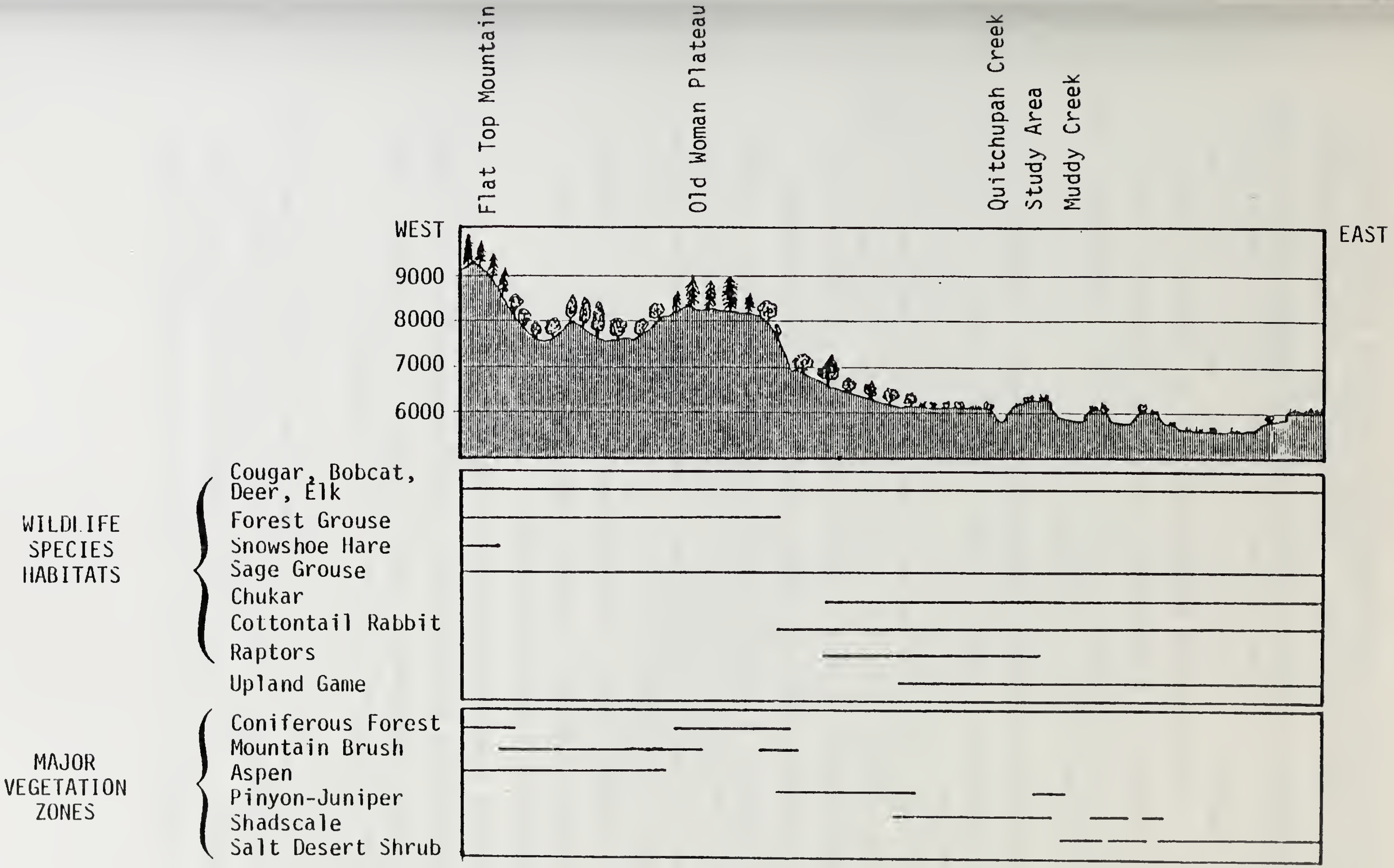


Figure 86. Relationship of Elevation to Vegetation Zones and Potential Wildlife Habitat for the Emery Coal Field Region.

Figure 85 displays this classification as it pertains to the wildlife surrounding the EMRIA study site. The surrounding wildlands (contained mainly in the Manti la Sal and Fish Lake National Forests) support "high interest wildlife" on the whole, these being any wildlife species classified as game species, any economically important species (from either a consumptive or non-consumptive perspective) and any species of special aesthitic, scientific or educational significance (reference Dalton et al., 1977, Species List of Vertebrate Wildlife that Inhabit Southeastern Utah, Utah State Division of Wildlife Resources, 67 p.).

The classification system incorporates three sets of letters for easy identification purposes. The first letter identifies one of the four use area rankings- c, crucial-critical; h, high-priority; s, substantial value; l, limited value. The second letter or letters defines the particular wildlife species involved- d, deer; e, elk; be, bald eagle; m, moose etc. The third set of letters identifies the primary wildlife use of the area- wt, winter range; su, summer range; ca, calving area etc. Those lands marked as a crucial-critical use area represent a critical requirement in the animal's life cycle or represent a biologically important area for a wildlife population. Examples are areas on big game winter ranges experiencing concentration of use; critical corridors for movement of wildlife; display, breeding and rearing areas for avifauna--strutting grounds; lambing or calving areas; and ecologically unique areas such as riparian zones and wetlands.

The high priority ranked areas basically represent the same biologically important areas as the crucial-critical with the exception of not representing a critical requirement in the lif cycle of an individual animal or a biologically important area for a wildlife population.

Summary

The study area itself lies in a limited value wildlife use area, where sporadic or unpredictable occurrence of any "high interest wildlife" could be expected. This classification complies with the lack of any significant sightings of wildlife in the area during the EMRIA program.

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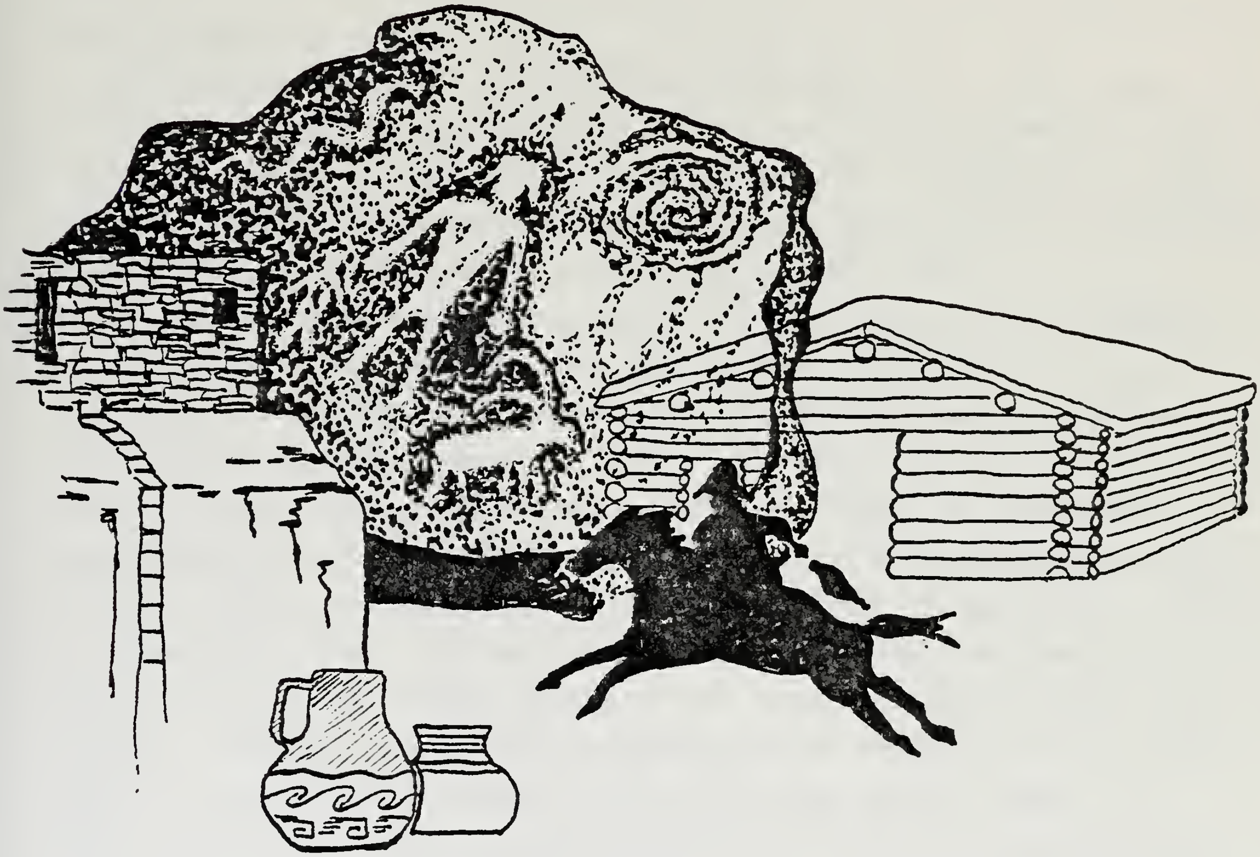


HISTORICAL & CULTURAL RESOURCES

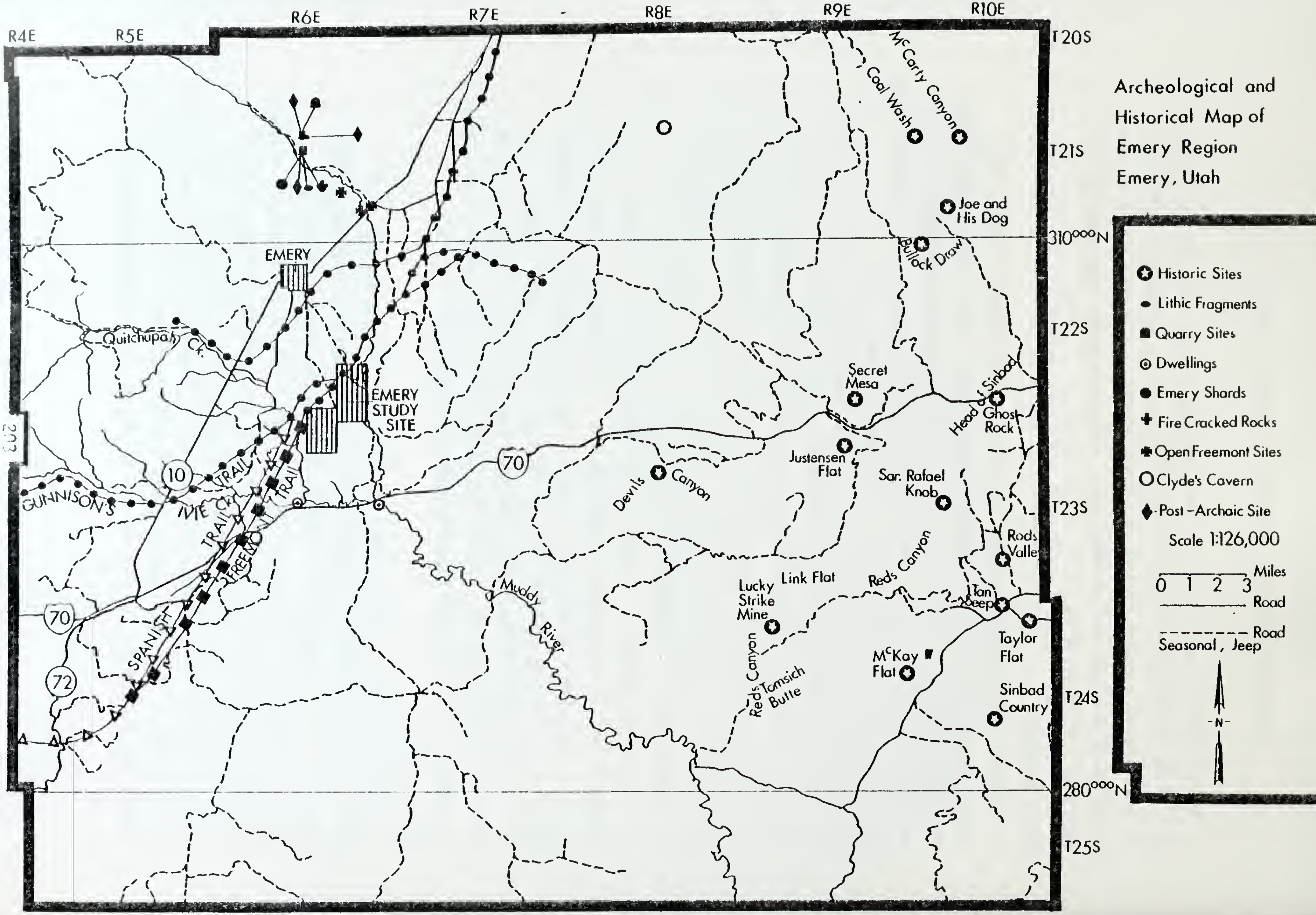
Emery County takes its name from George W. Emery, Territorial Governor of Utah from 1875 to 1880. Previously, Emery County included what is now Carbon, Sanpete, Grand and Emery Counties. Emery County is about the size of the state of Connecticut. Figure 87shows the location of selected historical sites.

Early History

Conquistador Lopez de Cardenas entered southern Utah in 1540. The northernmost point in the 1500 mile Spanish Trail Route opened from Sante Fe to Los Angeles by Franciscan priests, Dominguez and Escalante in 1776, was the crossing of Huntington Creek at the old pioneer site of Wilsonville, five miles east of Castledale, on the road to Green River.
Whites entered Emery territory along one of the routes of the Old Spanish Trail at least 150 years ago, although the date is uncertain. Markers along the highways in Emery County show where the Old Spanish Trail was. Spanish trade continued into the 1850's. Gunnison followed the Castle Valley branch of the trail in 1853. One of his party, Dr. James Schiel, described the area as, "wild and unproductive", with gypsum covered soil, and open canyons and sandstone hills without a trace of vegetation. John C. Fremont and others followed the same route. In the late 1840's the western slope of the Wasatch Mountains was first occupied by Mormon colonizers. From there scouts went eastward over the mountains in the early 1850's to establish settlements and find pasture for their stock. In 1875, Orange Seely drove the cooperative herd of the Mt. Pleasant United Order into Castle Valley. Others followed their lead, and the first true settlement of 8 to 10 families was made in Orangeville, in 1877.

Recent History

Within 135 years, Emery County has developed into a valley of 10 towns with fine schools, churches, civic organizations, highways, reservoirs, and a few industries. Figure 88 shows the recent density of cultural resources relative to the coal area. The main sources of income have been from agriculture and coal mining until construction started on the Utah Power and Light Plants. The Emery coal fired plant is the most recent addition. Honey, fruit, bricks, cheese and lumber have also been produced. In recent years, Emery County residents have been "small" farmers and stockman. During the winter months many seek supplemental


Archeological and
Historical Map of
Emery Region
Emery, Utah
Historic Sites
Lithic Fragments
Quarry Sites
Dwellings
Emery Shards
Fire Cracked Rocks
Open Freemont Sites
Clyde's Cavern
Post-Archaic Site
Scale 1:126,000
0 1 2 3 Miles
Road
Road
Seasonal, Jeep
N
R4E
R5E
R6E
R7E
R8E
R9E
R10E
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T21S
310000N
T22S
T23S
T24S
280000N
T25S
McCarty Canyon
Coal Wash
Joe and His Dog
Bullock Draw
EMERY
EMERY STUDY SITE
Quitchupah Ck.
Secret Mesa
Head of Sinbad
Ghost Rock
Justensen Flat
70
Devils Canyon
Sar. Rafael Knob
Rods Valley
Reds Canyon
Link Flat
Lucky Strike Mine
Tan Seep
Taylor Flat
McKay Flat
Reds Canyon
Tomsich Butte
Sinbad Country
Muddy River
10
GUNNISON'S
IVIE CK.
TRAIL
TRAIL
FREMONT TRAIL
SPANISH
70
72

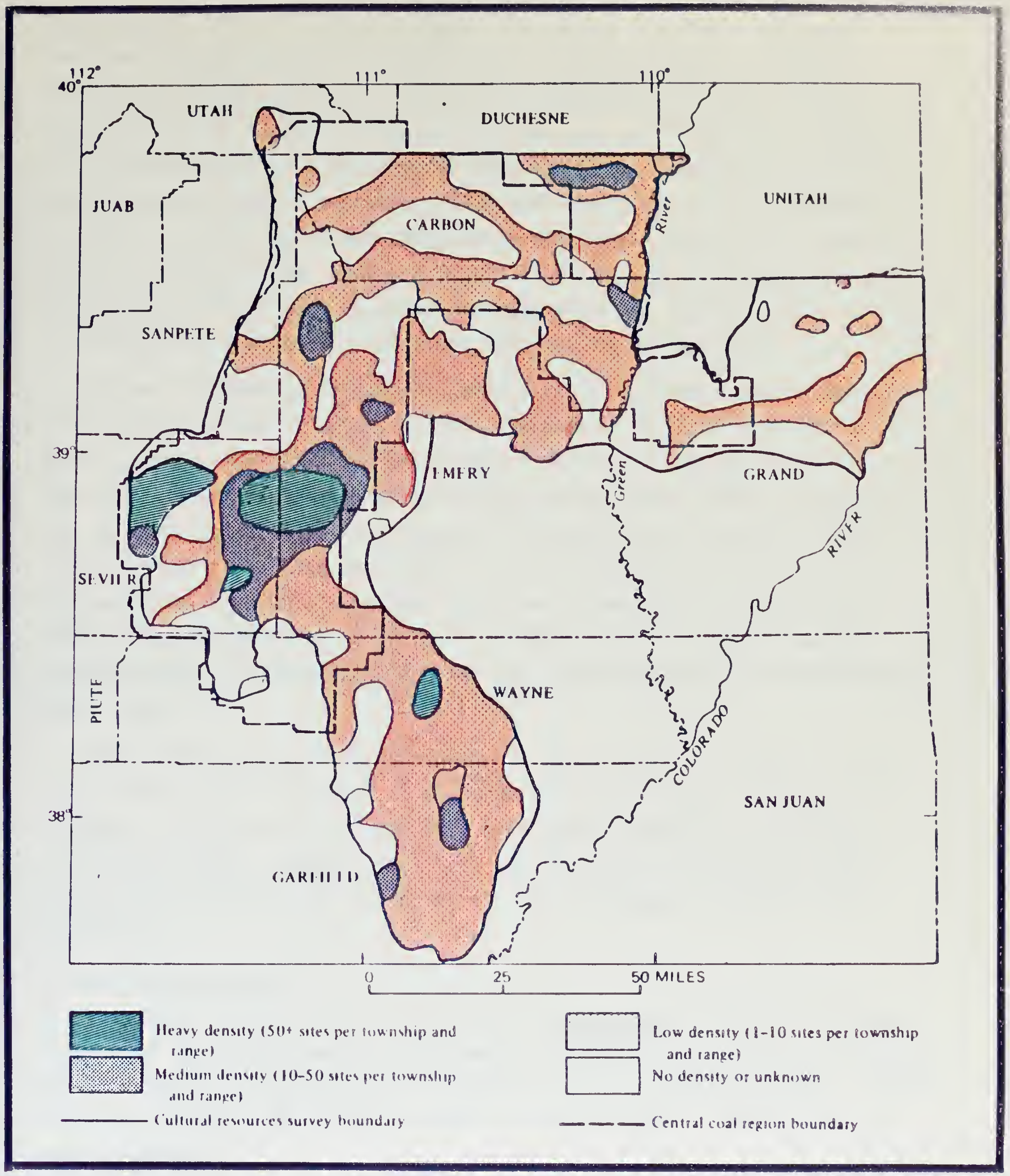

Figure 88 .--Map of the central Utah coal region showing cultural resource density sites. Based on AERC Class I and Class II survey, 1977.

employment in the coal mines of Emery and Carbon Counties. Dairying has been a recent stimulus to the economy of Emery County. Orchards including peaches, apples, apricots, pears and cherries have been established in the Ferron and Huntington Canyon area. Melons are produced in the Green River area using water from the Green River for irrigation. Most of the produce is consumed within the County, with little marketed elsewhere. Three meat processing plants have been established in Emery County. The chief crop of Emery County is alfalfa hay, but good crops of wild hay, corn, wheat, barley, and oats are also raised. Field corn is chopped for sillage and fed along with hay for winter feed.

The Joe's Valley Dam above Orangeville has a reservoir with a capacity of 31,400 acre feet of water, which is capable of irrigating 48,000 acres of land. Millsite Dam above Ferron is the largest dam built to date under the PL-566 small water project within Utah. Water from this dam is used to supply Ferron, Clawson, and Molen with a culinary water supply as well as irrigation water for over 10,000 acres of farmland. Dedicated in June, 1971, the Huntington North Reservoir at Huntington State Park, was constructed in 1965 and 1966. Electric Lake, located on Huntington Creek, provides cooling and make-up water for the Huntington Power Plant.

The Cleveland-Lloyd Dinosaur Quarry is the largest operational quarry in the world, and is located 15 miles east of Cleveland. At least six different varieties of dinosaur have been taken from this site since its discovery in 1927. Some 30 skeletons are now on display in the United States (including the quarry in Vernal, Utah), Canada, Scotland, Italy, and Japan.

Historical Locations

According to Finken (1977), descriptive place names given to locations within the San Rafael Swell were generally related to an event, a practical use, or names of an individual associated with that particular area. Names from the "Tales of the Arabian Nights" are also found. Listed below are some examples:

Swasey's frequently bestowed their names on land forms. Just south of the Head of Sinbad, Rod Swasey supposedly found what he thought was the most beautiful valley he had ever seen and named it Rod's Valley. In Rod's Valley is Tan Seep, named for Nathaniel "Tan" Crawford, while George

Crawford is remembered in the name of George's Draw.

In the Head of Sinbad is Reid Nielson's Draw, which according to Royal Swasey, was named for an early sheepherder. Justensen Flats, north of the San Rafael Knob, was named for sheepherders Orsen and Buck Justensen.

Ghost Rock was named one day when fog in the Head of Sinbad hid the base of the rock from view and gave the appearance of a ghost floating in the air. Because it often stood out in bad weather, the Ghost Rock was an important landmark. Not far from the Ghost Rock, behind Swasey's cabin, stands the Broken Cross, named by cowman Seeley Peterson; a fractured rock formation resembling a cross.

Royal Swasey indicates that Coal Wash probably was named because of an exposure of tar sand that could have been mistaken for coal. The formation of Joe and His Dog, which resembles a dog sitting up and begging next to a big man, reminded early cowboys of Joe Swasey and a pet dog - perhaps the same dog that took a bath at Baptist Tanks.

Bullock Draw is a canyon that was fenced off and used to hold bulls when they were separated from the herd.

There are two variations regarding the naming of Secret Mesa. According to Seeley Peterson, the name was applied because access was difficult to find and only a few people knew the way into it.

Royal Swasey went beyond the remoteness of the Mesa to indicate that because of its isolation, it was sometimes used as a secret hiding place for stolen livestock.

One of the most intriguing names assigned to an area of the San Rafael is the name of "Sinbad Country". Local folklore attributes the name to early Spanish travellers who likened rock formations in the Head of Sinbad to the scenes or castles described in the Arabian Nights. This seems reasonable due to the long Moorish influence on Spain and the resulting familiarity of these travellers with the tales of Scherezade.

With the exception of the anglicized San Rafael, none of the many other Spanish names in the region remained in use much beyond the 1850's.

Summary

As shown in Figure 87, the Old Spanish, Gunnisons, and Fremont's trails all lie between the town of Emery and the study site. Hence mine haul roads and the like should cross on existing rights of way. In any case no known structures or historical artifacts are involved on the site or rights-of-way.

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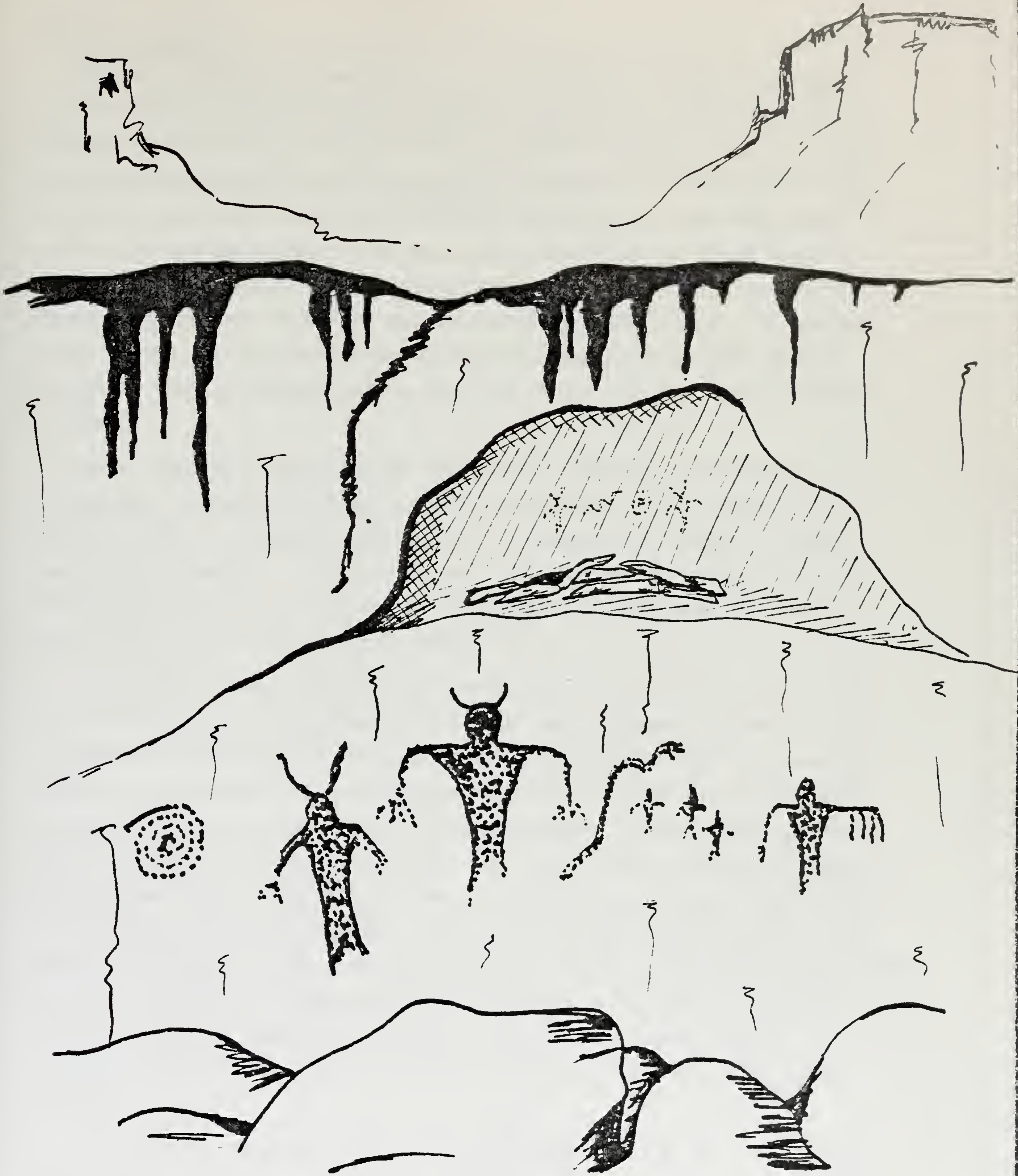


ARCHAEOLOGICAL RESOURCES

Previous Research

Major professional archeological investigations in Carbon and Emery counties began along the river drainages of these two counties in 1928. Between 1928 and 1931, William Claflin and Raymond Emerson sponsored four archeological expeditions to the western drainages of the Colorado River in Utah. The Claflin-Emerson expedition located sites along the Nine-Mile Canyon on the border of Duchesne and Carbon County; along Range Creek, in southeastern Carbon and northeastern Emery County; and on the Green River between Nine-Mile Canyon and Range Creek Canyon. In southern Emery County, sites were located along the Muddy River on Last Chance Creek, in Barrier Canyon, and on the Green River near the mouth of Barrier Canyon.

Aside from the descriptive archeological reports of the thirties, Julian H. Steward (1933) divided the northern periphery of the southwest into cultural areas. Steward's Culture Area I included the Fremont of Emery and Carbon counties. This culture was first defined by Noel Morss, who participated in the Claflin-Emerson expedition in 1928 and 1929, most of which took place in the Fremont River area.

In the 1950's more research was carried out in the area. Morss (1954) in his discussion of figurines of the American Southwest includes a study of Fremont figurines from Pillings Cave in Range Creek Canyon. Gunnerson (1957a) recorded many sites and excavated a few of them during his reconnaissance of the Fremont area in Uintah, Duchesne, Carbon, Emery, Grand, Sevier, Wayne, and Garfield counties. In Emery County, Gunnerson reported sixty-three sites along Ferron Creek, Ivie Creek, Last Chance Creek, Muddy River, Range Creek, and Robbers Roost. In addition to his survey of the region, Gunnerson (1956) excavated a possible Paleo-Indian site, the Silverhorn site (42Em8). Gunnerson (1957b, 1962) has also reported unusual artifacts such as bone harpoon points, a zoomorphic vessel, eccentric chipped stone artifacts and figurines found by a local collector near Ferron.

In the 1970's numerous archeological surveys and some test excavations have been carried out in Emery and Carbon counties. Most were in response to the Federal Government's cultural resource management policies. Archeological surveys have been conducted by the Antiquities Section of Utah State Historical Society (M. Berry, 1975); Archeological Environmental Research Corporation (various reports by F.R. Hauck and AERC in 1976 and 1977 are cited in the bibliography); Brigham Young University (Berge, 1973, 1974a, 1975b, 1975c, 1975d, 1976); Southern Utah State College (Dykman and Thompson 1976); and the University of Utah (C. Berry 1973, 1974).

Most recently, AERC completed an archeological reconnaissance of the Central Coal Project Area in Utah (Haulck et al., 1977). From May to September 1977 an intensive archeological field survey was conducted in portions of Carbon, Emery, Garfield, Grand, Sanpete, Sevier, Utah, and Wayne counties. Ten Bureau of Land Management planning units and three U.S. Forest Service planning units were sampled. The survey included a sample of 312 quarter sections. The Emery Study Site was toured by an archeologist and there were no significant finds within the study area (B. Louthan, 1977).

In the last few years, several sites have been excavated in Emery County. These sites are Pint-Size Shelter (Lindsay and Lund, 1976); Clyde's Cavern (Wylie, 1971); Windy Ridge, Crescent Ridge, and Power Pole Knoll (Madsen, 1975); and Innocents Ridge (Schroedl and Hogan, 1975). Joe's Valley Alcove was excavated by the Forest Service in 1973 (Sargent 1977: 20), but no report is available at the present.

Prehistory

Paleo-Indian

The Paleo-Indian period in the New World ended approximately 10,000 years ago. The economy of this period was characterized by the hunting of large, now-extinct mammals supplemented by gathering of wild plants. Little evidence exists for the latter. The archeological evidence for the Paleo-Indian period usually consists of fluted, lanceolate projectile points sometimes found in association with extinct fauna such as mammoth (*Mammuthus columbi*) and bison (*Bison antiquus*).

Archaic

With the extinction of large mammals, the Paleo-Indian hunters turned to a subsistence based on the exploitation of smaller present-day fauna and on a heavier reliance on the gathering of wild plants. The earliest dates for the Desert Archaic period are 8000-9000 B.P. In areal extent the Desert Archaic covered the western third of the United States from Canada to the Mexican Plateau (Jennings, 1964).

Sargent (1977:17) ascertained that sixteen of the recorded sites in Emery are definitely Archaic. Seven of these are caves or rockshelters. Three of these cave or rockshelters, Pint-Sized Shelter (42Em625), Joe's Valley Alcove (42Em693), and Clyde's Cavern (42Em177) have been excavated. They also have a Fremont component in addition to Archaic components.

Pint-Sized Shelter is located in Castle Valley near the confluence of Ivie Creek and the Muddy River. The Archaic occupation at the site dates between 4250 ± 120 B.P. and 3390 ± 170 B.P. According to Lindsay and Lund (1976:56),gypsum projectile points from this level are contemporary with those from Sudden Shelter and mark the initial appearance of those projectile points in the Castle Valley region. Gypsum points occur at the same time in the southeastern Great Basin (Fowler, Madsen, and Hattori, 1973).

Joe's Valley Alcove is located west of Huntington on the Wasatch Plateau near Huntington Creek in northwestern Emery County. For the Archaic sequence at this site, Evan DeBloois in a personal communication to Schroedl (1976:59, 69) reports that Bed I is between 8200 B.P. and 6200 B.P. and Bed II is dated around 2400 B.P.

At Clyde's Cavern, near the San Rafael River, 20 miles southeast of Ferron, the Archaic sequence begins later than at other sites as determined by one radiocarbon date of 3070 ± 130 B.P. from Layer I (Winter and Sylie, 1974). In Layer I, a rabbitskin robe cached beneath three stacked slab metates represents the earliest cultural material recovered from the site (Wylie, 1971:27, 28).

Fremont

The Fremont period spans the time between A.D. 400 and A.D. 1200. The Fremont culture evolved from the Archaic lifeway by diffusion of Mexican traits. Dwellings such as semisubterranean pit houses and masonary structures; the cultivation of corn, squash, and beans; and pottery are new traits which characterize this period. The bow and arrow replaced the atlatl of the Archaic. The Fremont people supplemented their horticulture diet with hunting and gathering much more than the Anasazi to the south.

Along with many other distinctive characteristics, the Fremont people developed their own art style. This is typified by horned, trapazoidal-bodied anthromorphs (human-like objects) evidently made everywhere the Fremont people lived. They also developed a stylized way of making spirals, zig-zags, scorpions, mountain sheep, deer snakes, and hunting scenes.

The distribution of the San Rafael variant of the Fremont encompasses all of Emery and most of Carbon County (cf. Marwitt, 1970). One hundred forty two Fremont sites have been recorded for Emery County (Sargent, 1977:24). Only a small percentage of these have been excavated. The Claflin-Emerson expedition excavated a Fremont site in Range Creek Canyon in northeastern Emery County. In Castle Valley on the Muddy River just below Ivie Creek, eight miles south of Emery, the Claflin-Emerson expedition excavated another site (their FL4-4, now 42Em762) which consisted of several open structures of basalt boulders set in adobe (Gunnerson, 1969:79). Gunnerson (1957:126-129); Figs. 29 and 30; 136-137) also excavated a deep pit house (42Em47) located two miles east of Emery, one half mile from the Muddy River.

As mentioned above, Clyde's Cavern, Pint-Sized Shelter, and Joe's Valley Alcove also contained Fremont components. The reader may refer to Sargent (1977:26) for more information on the Fremont components at these sites.

Post Fremont

A.D. 1200 agriculture ceased, permanent dwellings were abandoned, and the Fremont culture disappeared. The Fremont may have migrated south into the Anasazi region, or they may have been absorbed by intrusive groups. Exactly what transpired is unclear, but a return to the hunting and gathering economy had continued in the Great Basin until the arrival of the Europeans.

Numic speaking peoples are believed to have migrated from a region near Death Valley around A.D. 1000 spreading across the Great Basin to the east and north. The Southern Paiute reached the Southwest around A.D. 1150

Table 33.

Summary of Archeological Documentations

Listed below are four archeological sites previously located and site surveyed by University of Utah. They are all found within the ranges R 4 E to R 10 E, and townships T 20 S to T 25 S in Emery county, Utah.

1) Disturbed Fremont: Open Air
   Section 16, T 21 S, R 6 E

2) Lithic Scatter
   Section 16, T 21 S, R 6 E

3) Lithic Scatter, Quarry Activity
   Section 16, T 21 S, R 6 E

4) Lithic Scatter
   Section 15, T 21 S, R 6 E

The three sites listed below have been identified but there is no site survey information available.

1) Pint-size Shelter is located in Castle Valley near the confluence of the Ivie Creek and Muddy Creek, south of the town of Emery, Utah.

2) Gunnerson excavated a deep pit house located 2 miles east of Emery, ½ mile from the Muddy River.

3) In Castle Valley on the Muddy River just below Ivie Creek, eight miles south of Emery, the Claflin-Emerson expedition excavated another site which consisted of several open structures of basalt boulders set in adobe.

The sites listed below may be impacted by the proposed mining in the area:

1) 42Em22
   Emery East Quad., SW¼ Sec. 25, T 21 S, R 6 E
   Open Fremont Site.

2) 42Em49
   Emery East Quad., NW¼ Sec. 26, T.21 S, R 6 E
   Open Fremont Site including a walled up overhang.

3) 42Em177
   Emery 1 NE Quad., NE¼ Sec. 16, T 21 S, R 8 E
   Site known as Clyde's Cavern, excavated in 1971.

4) 42Em179
   Emery East Quad., NE¼ of SW¼ Sec. 25, T 21 S, R 6 E
   Post-Archaic open site containing surface pottery scatter.

5) 42Em494
   Emery East Quad., SW¼ of SW¼ Sec. 25, T 21 S, R 6 E
   Open Fremont Site.

All of the above listed sites were located and plotted on the Emery Archeological and Historical map of the Emery region, Utah; Figure 87

(Euler, 1964), and the Utes evidently reached the Gunnison Basin in Colorado by about the same time (Smith, 1974).

Numic sites in Emery and Carbon County are not well known. Sargent (1977:24, 16-17) reports eleven possible dual component Fremont and Numic sites. Only two sites definitely indicate Paiute-Shoshone occupation.

References

Sargeant, Kay Emery County : An Archeological Summary, Antiquities - Division of State History, Utah
(all other references cited in this section contained in Sargeant)

PALEONTOLOGY

Regional Paleontology

Vertebrate and plant fossil-bearing rocks occur throughout the region. Figure 89 shows, in a general way, the distribution of the vertebrate and plant fossil-bearing rocks and their value as fossil-bearing units. This map was developed by the US Geological Survey, 1978, from data supplied by Dr. Wade Miller, Brigham Young University. Of particular importance is the North Horn Formation of Late Cretaceous and Paleocene age which contains dinosaur and mammal remains. Studies of these rocks may help provide insight relative to the extinction of dinosaurs. The Emery site does not lie in a recognized area of significance as indicated in Figure 89. Fossil plant material may of course be anticipated wherever coal is, since coal is itself composed of fossil plant remains.

For the region, no published comprehensive lists of fossils are known. Vertebrate fossils have been described by Dr. James H. Madsen, Utah State Paleontologist; Dr. W.L. Stokes, University of Utah; Drs. Wade Miller and James Jensen, Brigham Young University; and others. Invertebrate and plant fossils have also been described from the region. Scattered descriptions of fossils are found in the professional geologic and paleontologic literature.

Summary

The coal strata in the study area near Emery are contained entirely in the resistant Ferron Sandstone member of the Late Cretaceous Mancos Shale Formation. In younger, roughly equivalent coal beds elsewhere, as at Helper, Utah, reptile footprints are known to exist in the top of the coal and extensive large vertebrate bones have been recovered in older formations at Cleveland sufficient to be set aside as a protected site and museum. Locally, however, isolated mollusks (Pelecypoda, Ammonoides) plant fragments, and some ripplemarks have been identified in the overlying Blue Gate Shale member and underlying Tununk Shale member. No fossils have been recovered from the Ferron Sandstone member in the vicinity of the Emery study site. Miller and others (1978) noted significant vertebrate fossils in the Morrison and Cedar Mountain Formations near Clawson but these units would not be involved in strip mining at the present site.

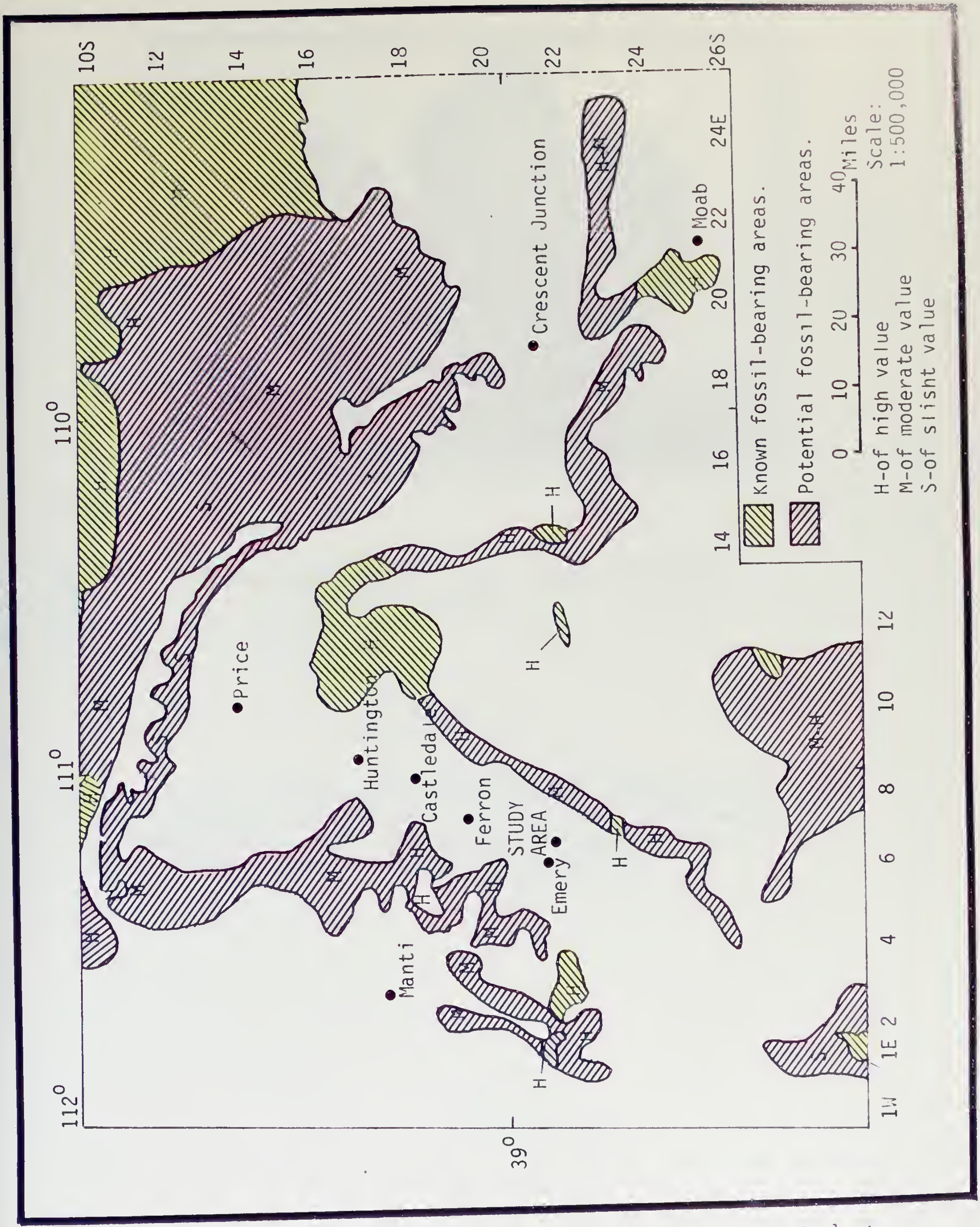


Figure 39. Map of Central Utah coal region showing vertebrate and plant fossil-bearing areas.

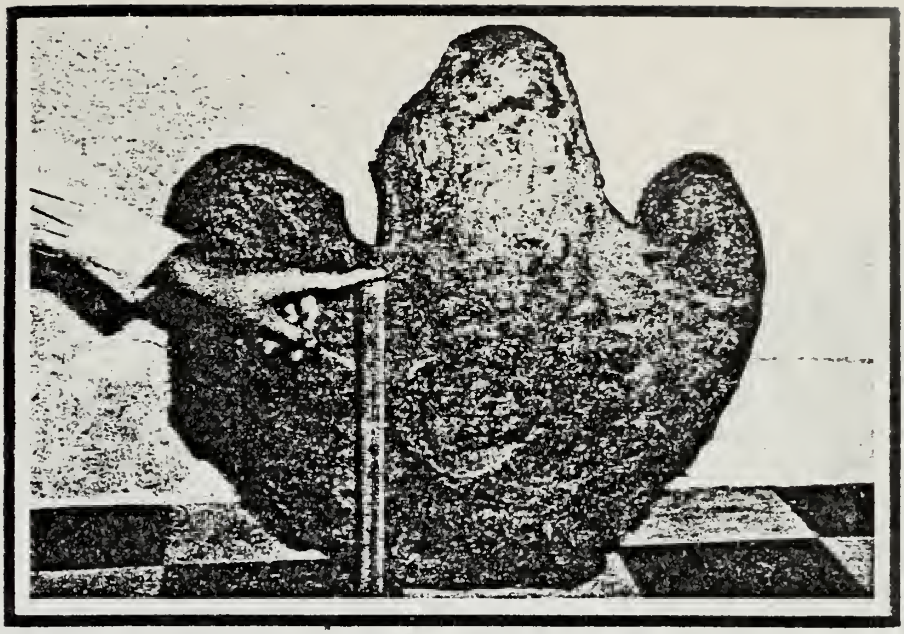
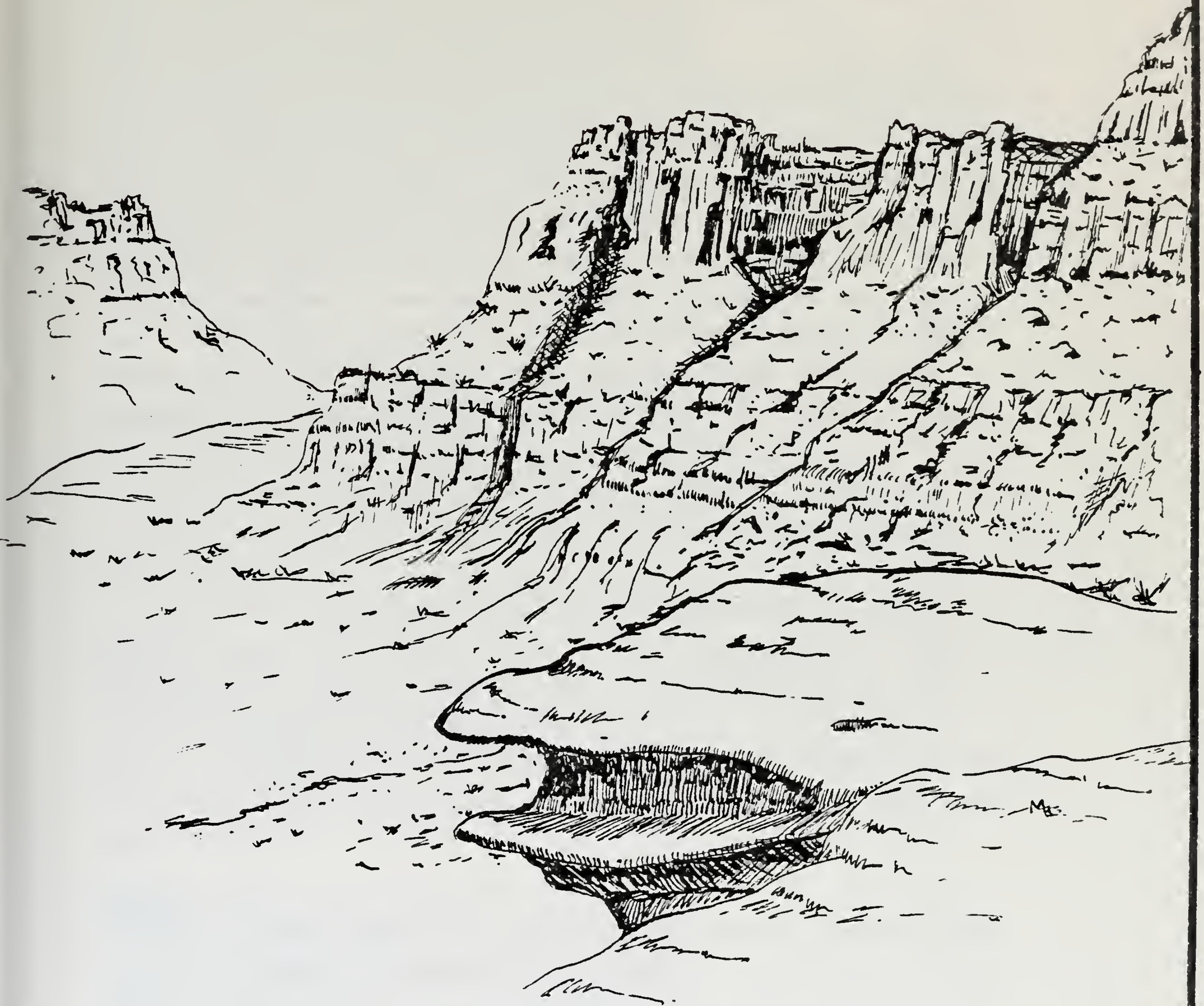


Figure 90. Dinosaur Track in Upper Coal Beds. (Helper Museum)

REFERENCES

Miller, W.E., S.F. Robison and S.K. Webb, 1978; "Report of the 10% Paleontological Survey of the 3 and 4 plant site, Emery Cottonwood Canyon, Emery- Muddy Creek Pipelines and Reservoir Sites, Vaughn Hansen and Assoc., Salt Lake City.



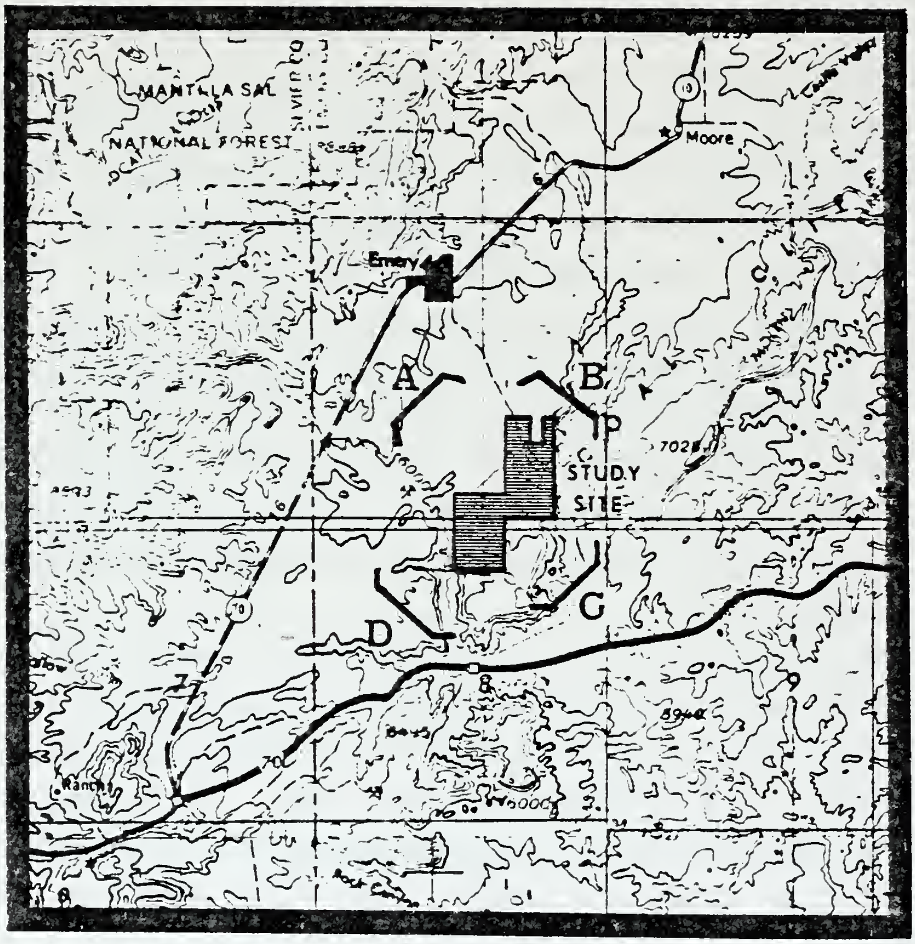
VISUAL RESOURCES

As covered more fully in the section on Physiography, Drainage and Relief, landscape characteristics of the area are common to the semi-arid Colorado Plateau country of central and south-central Utah. The general area, ranging from 5,000 to 12,000 feet in elevation, is characterized by broad elevated plateaus, desert valleys, and canyon lands. Erosion of the low-lying desert terrain has produced a rolling panorama with some deeply incised gullies and low escarpments (Figure 91). Locally gypsum coats poorly drained soils and imparts a barren badlands tableau. The impression conveyed by the better portions of the area is one of a dramatically sculptured canyon and panoramic desert landscape. The landscape character is developed grassland and desert shrubs. The air quality for viewing scenery during our observations, 1976-1979, were very good. Visibility measured from the town of Huntington during September 1970 to March 1971 averaged 67 miles. More recently, (1974) average visual range from particle size distributions was about 45 miles, yet most of the region has been classed as a "Class II" area for purposes of significant air quality degradation with the exception of Capitol Reef, which is "Class I".

Major scenic attractions include the San Rafael Swell, Manti-La Sal National Forest, and several National Parks. Visual resource inventory and evaluation system was used to identify and assess scenic quality, sensitivity level, and distance zones (BLM, 1976). The results of this analysis are given in Figure 92, which shows the classified scenic quality, the types of visual zones by distance and the visual sensitivity levels respectively.

<u>Summary</u>

The local visual impact of a strip mine on the study area would be strong. At present, Interstate 70 and Highway 10 are the major transportation corridors through the area (Figure 91). From Interstate 70, the visual impact of a strip mine would be negligible because the area cannot be seen from the Interstate. The present view towards the study area consists of sheer rock faces which surround the site. If we assume that mining will not alter these vertical walls, there will be no impact on scenic quality to travellers on I-70. From Highway 10 however, the visual impact of a strip mine will be strong, as such a mine would be a dominant feature of the landscape. At present, the mesas above the Coal



Scale 1:250,000

Figure 91- Topography of the Emery area. Brackets indicate locations and orientations for perspective views in Figure 93 .

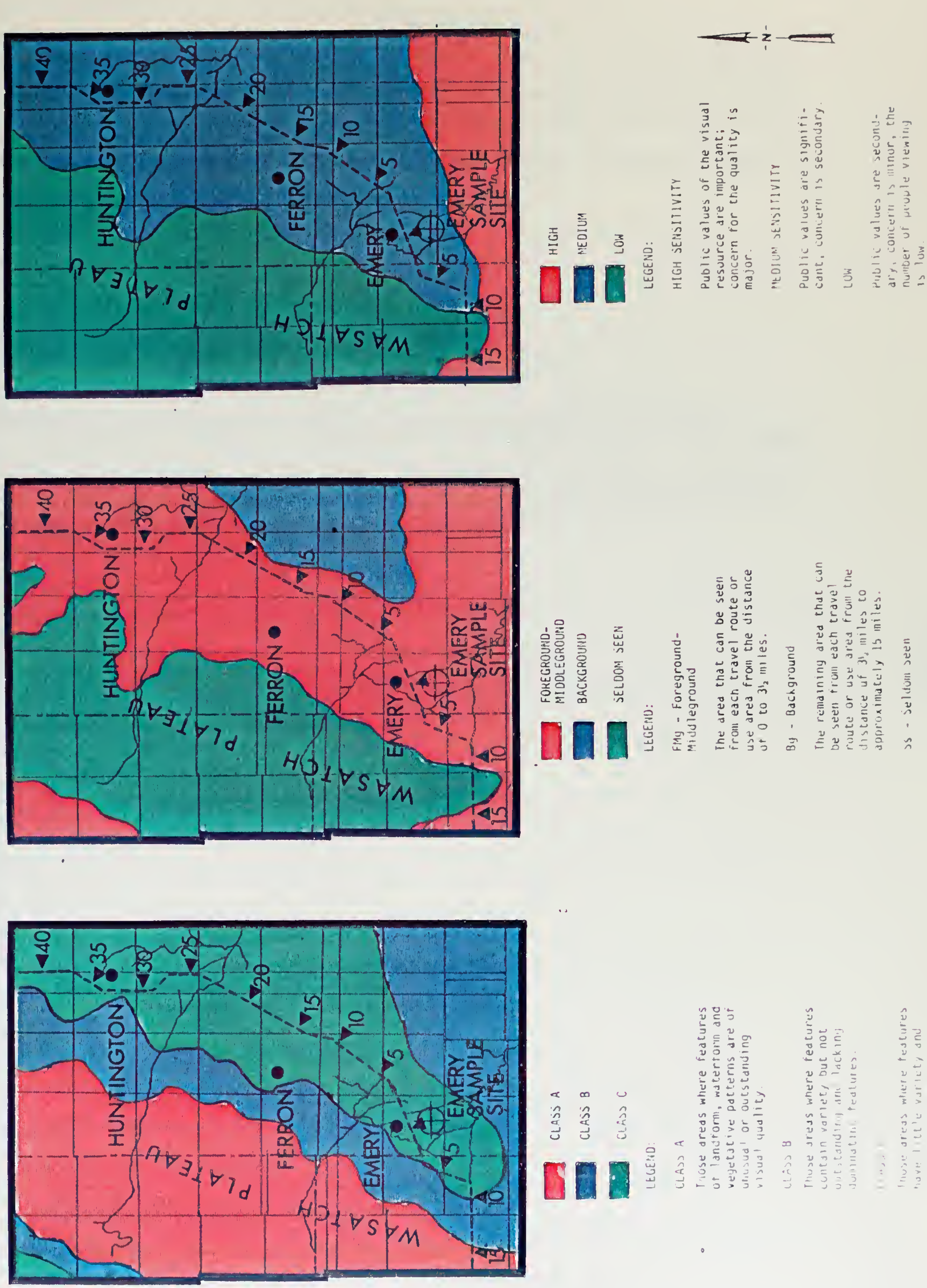


Figure 92. Scene Quality, Visual Zones and Sensitivity Levels.

Cliffs, which include the Emery coal field, form the dominant landscape viewed by southbound traffic for several miles around the town of Emery (Figure 93). This figure gives four different views of how two of the most probable strip mine areas would appear against a computer model of the existing topography.

REFERENCES

Bureau of Land Management, 1976; "Final Environmental Statement - Emery Power Plant", U.S. Government Printing Office, pp. 2-56, 2-60.

US Geological Survey, 1978; "Draft Environmental Statement - Development of Coal Resources in Central Utah", U.S. Governemt Printing Office, pp. II-31, II-34.

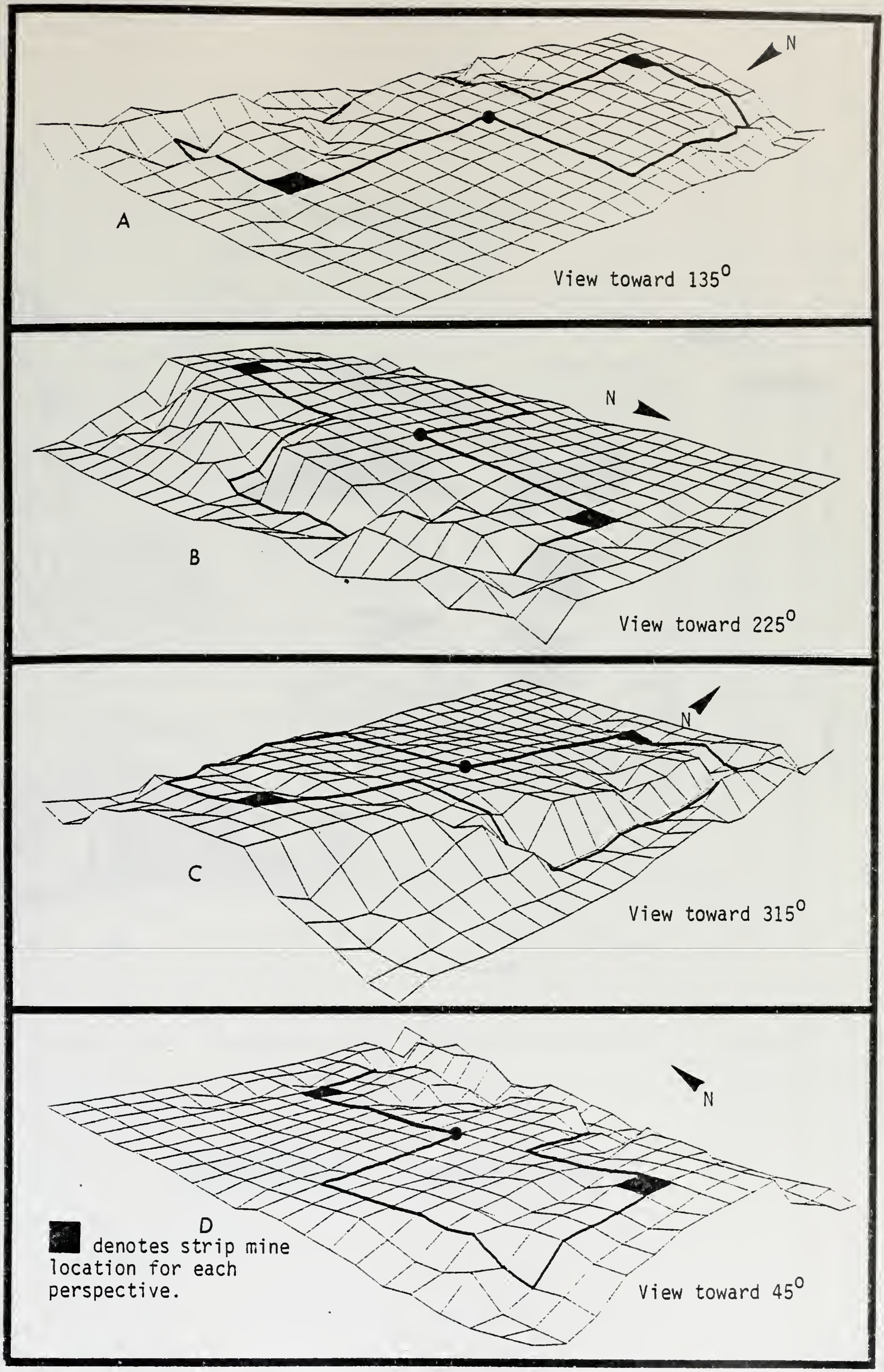
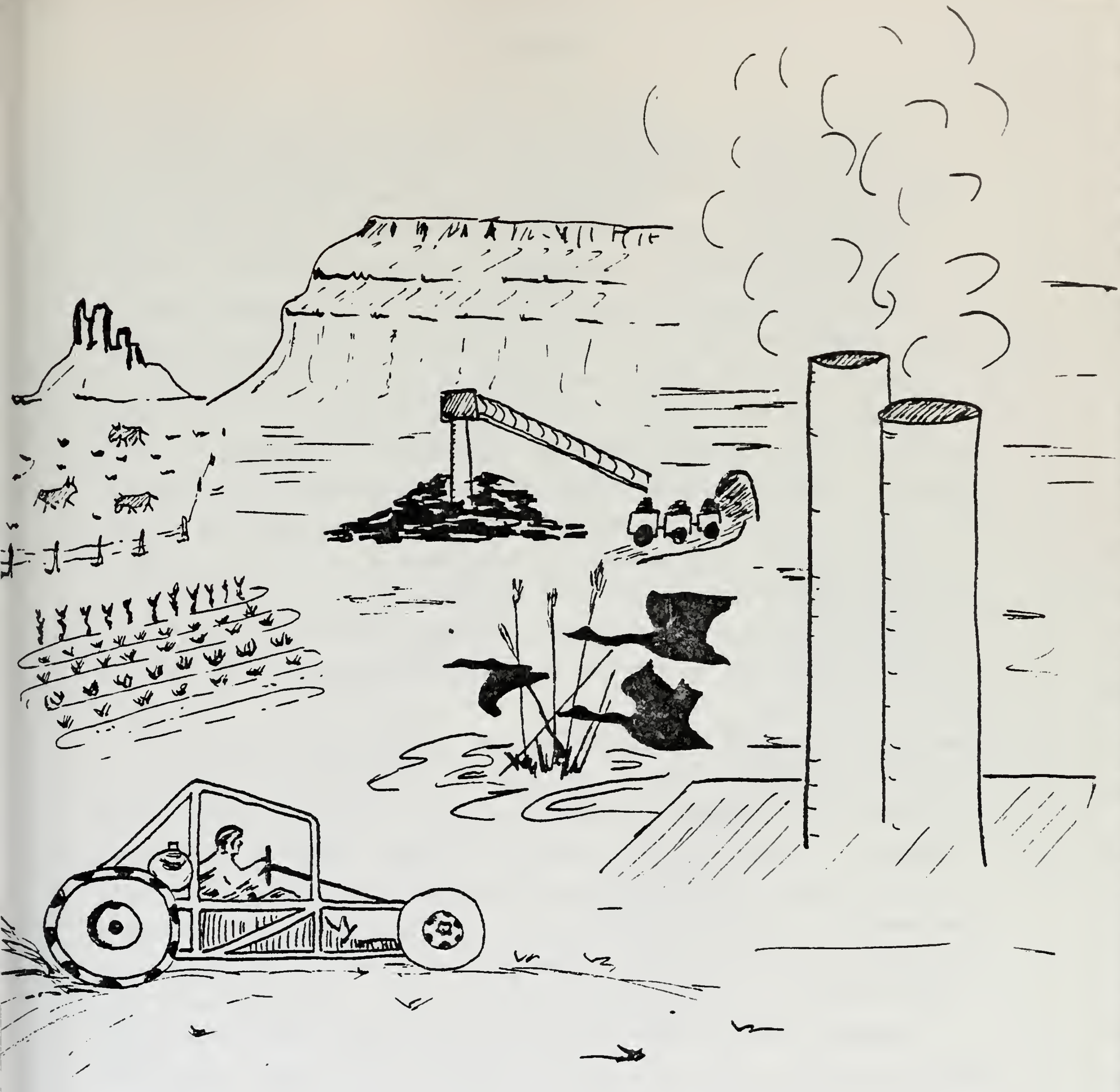


Figure 93 . Computer Perspective Views of Emery Study Area.



PRESENT LAND USE

The rural nature of the Emery region landscape is reflected in Figure 94 which shows land use in the vicinity of the study area. The town of Emery has a population of 219, most of whom are involved in ranching, limited agriculture, or employed at the Emery Deep Mine. Although sugar beets were previously an important crop in the area, present day agriculture consists of alfalfa and improved pasture land. Livestock grazing is practiced on open and fenced range on the mesas to the south and southeast of Emery. The town of Emery has a small number of commercial developments, churches, a post office, and a park. The Emery power plant generating complex, located off Highway 10 between Clawson and Castledale, is the most significant tax base in the area. Coupled with this is the production of the necessary coal to operate the plant for its 35 year estimated life from the nearby Wilburg Mine. Of more direct geographic impact is the associated power transmission corridor which traverses the immediate vicinity of the study area (see Figure 92).

A regional view of present land use is shown in Figure 94, interpreted from satellite imagery. On the west, the Wasatch Plateau consists of high lands in the Fish Lake National Forest. Recreation and timbering takes place in these Ponderosa Pine and Spruce-Fir forests. The east side of the Wasatch Plateau drops almost vertically to Castle Valley, which has extensive agriculture. Most of this is alfalfa, but some areas are planted to corn during certain years. Soils with high salinity are mostly used as range. The east side of Castle Valley is formed by the Coal Cliffs, which support dense stands of Pinyon-Juniper woodland. This land is used for low intensity livestock grazing, firewood and fence posts. Beyond the Coal Cliffs, the vegetation is dominated by salt desert species, and is suitable for livestock range. Valley floors and flood-plains are planted to alfalfa where groundwater may be economically pumped for irrigation.

Summary

Land use data made available from the Bureau of Land Management are presented in Figure 4, in a more detailed map. Limited recreational uses of the land are also found due to the open nature of the land and mixed ownership status, permitting easy access. These uses consist of: off-road vehicle use, rockhounding, sand dragging, horseback riding, and hiking.

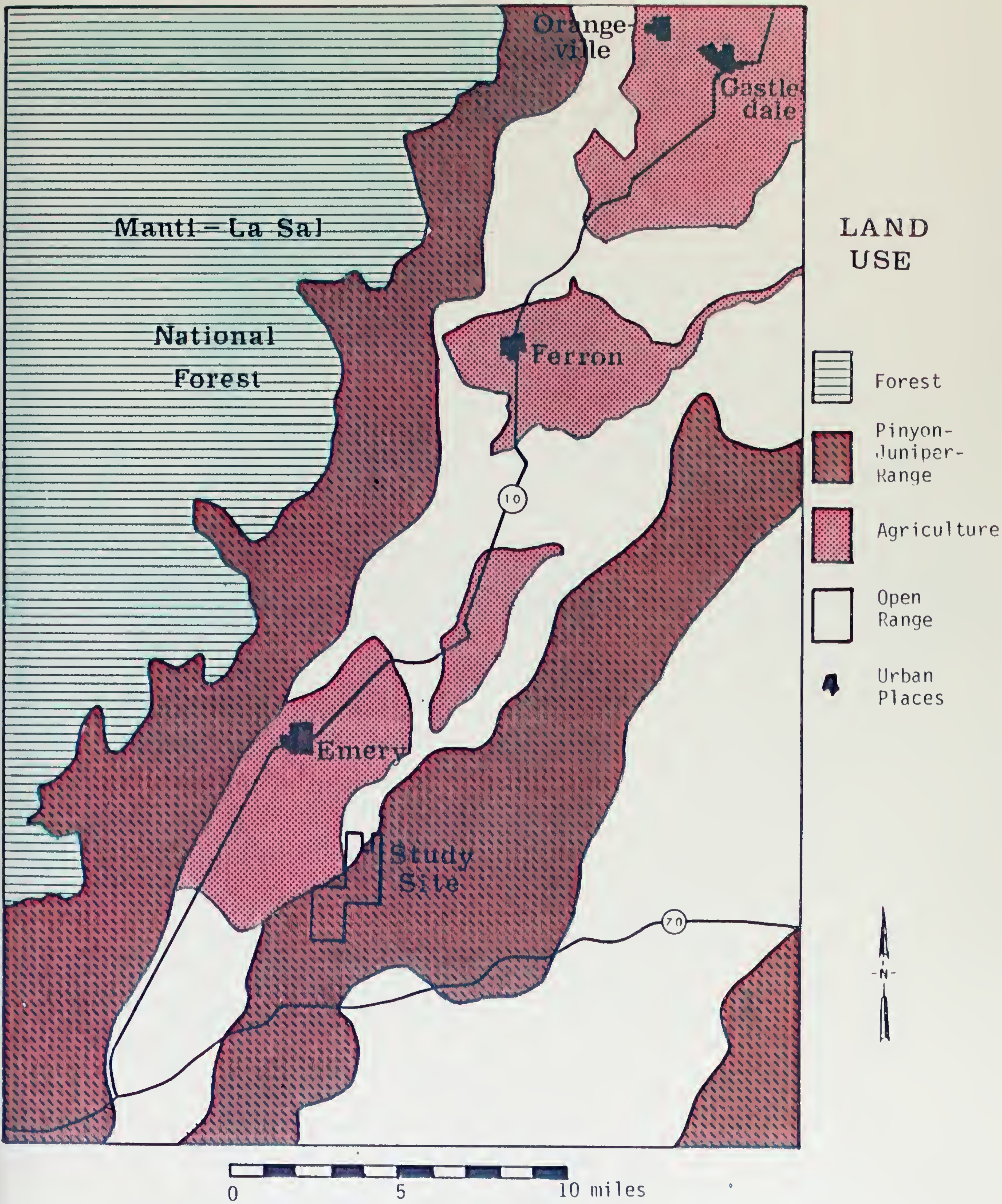
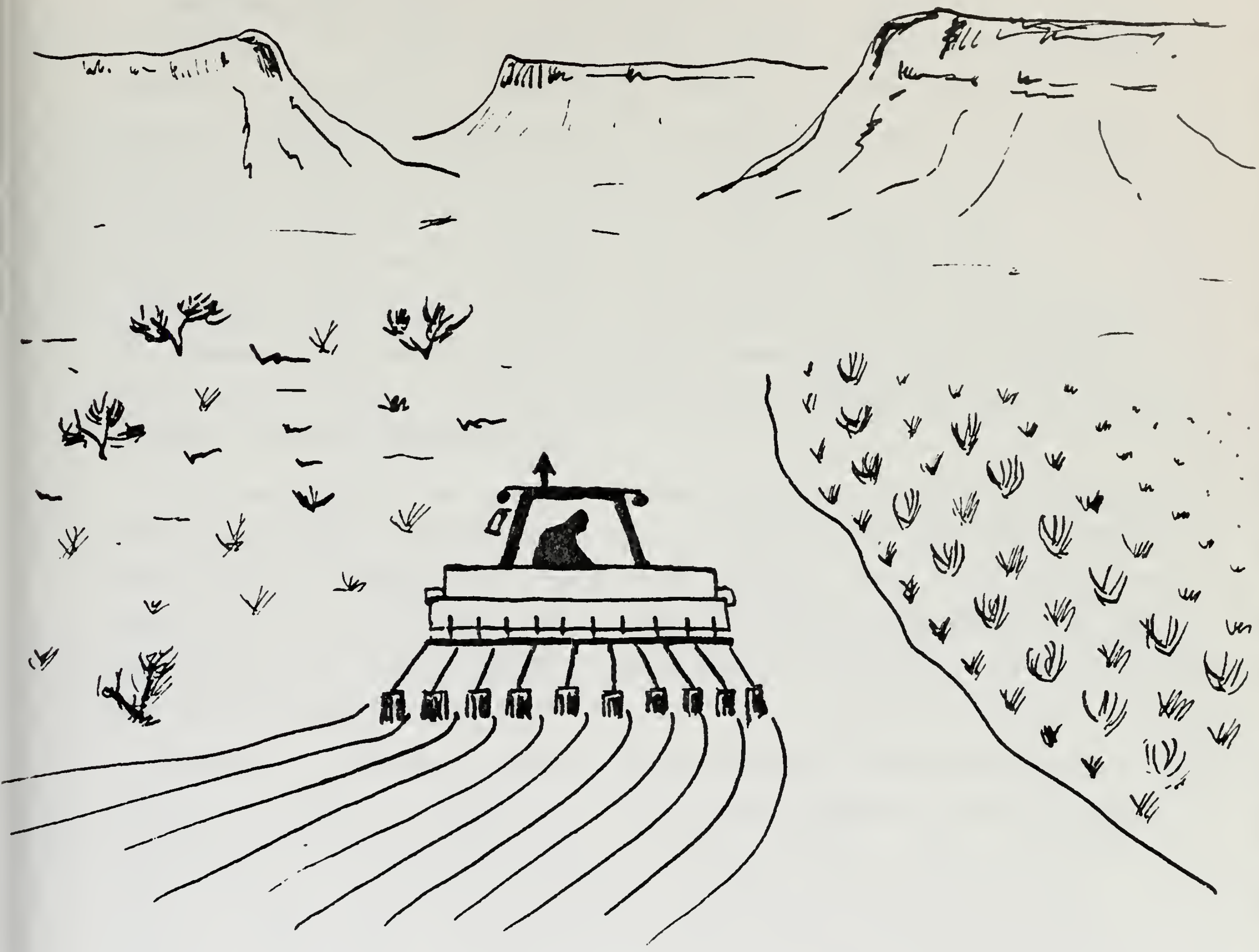


Figure 94. Land Use From LANDSAT Imagery.

REFERENCES

Bureau of Land Management, 1976; "Final Environmental Statement - Emery Power Plant", p. 6-23, US Government Printing Office.

US Geological Survey, 1978; "Draft Environmental Statement - Central Utah Coal", p. 2-58, US Government Printing Office.



RECLAMATION POTENTIAL

Reclamation Objectives

Compliance with Federal, local and State laws as summarized in Table 34 is mandatory. The rehabilitation problem, with the background previously presented in the baseline study may be viewed as a tension between the issues or potential problems posed by the mining with those restrictions identified against a series of alternative solutions. Finally the costs of reclaiming the site by the sum chain of rehabilitation steps necessarily evoked must be weighed against the coal resource and the residual land value. In view of the marginal utility of the land in its present condition, one might ask what planned uses can be inferred, that might be beneficial, perhaps even exceeding the existing use potential, without incurring excessive costs.

As it now stands, the land has limited range/wildlife habitat/watershed value and possibly recreational value. If the carrying capacity of the land could be increased as a result of an improved "soil" moisture retention capacity due to strip mining, then local long term benefit may accrue in the process. The clear problem in converting this mined land to agricultural use would be the available water.

Secondly, for whatever reason, drought or loss of vegetative cover, historical springs and seeps on and around the plateau are now dried up. Existing stock ponds appear to be essentially snowfed. Thus a reasonable second objective would be to intercept a portion of the precipitation runoff in small basins after mining by surface shaping and producing an increased infiltration surface zone. This could either increase the wild-life potential of the area or support stock use.

Thirdly, after the interruption of the existing stratigraphy by the mining process, a single ground water zone will develop above the floor of the coal mine. This increase in infiltration may serve to dilute near surface salinity and enhance vegetation, and stock water supplies over the mined site. On the other hand, the altered chemical properties of the ground water may produce undesirable characteristics locally or downslope. A balance between these situations is sought.

Fourth, introduction of new grass, forbs and shrub species, as being evaluated by Frischknecht and Ferguson, which are native to the region but not well represented on site could improve the ultimate range carrying

Table 34

Checklist of State Requirements for Utah

(After Imhoff et al., 1976 USGS Circular #731, and Strip Mine Handbook, 1978)

Stage of Program Development	Applicable Items
1) Acts	- Mine Reclamation Act of 1975, and Federal Surface Mining Control and Reclamation Act of 1977 (P.L. 95-87)
2) Rules and Regulations	- Final Interim Regulations (30 CFR part 700
3) Technical Guidelines	- Not Available
4) Administrative Agency	- Utah Department of Natural Resources, Office of Surface Mining
Reclamation - Main Actions - Standards	
5) Control Water Flow and Quality	- Yes (Iron, pH, Suspended Solids) Section 715.17
6) Conserve and Replace Topsoil	- Yes (Section 715.16
7) Backfill and Grade	- Yes "where practical" - see also Sect. 714.14 and 715.14
8) Reduce Highwall or Pitwall	- Yes (Section 714.14)
9) Bury or Neutralize Toxic Wastes	- Yes under 4 ft. of non toxic and non combustible material (Section 715.14)
10) Revegetate for Beneficial Use	- Yes -priority to non noxious native plants (Section 715.20, 715.14)
11) Landslides	- 20% slope angle criterion (Sect. 722.11)
12) Other Rules	- Program is implemented through orders that recognize individual site and mine conditions.
13) Sediment Control	- Yes (Section 715.17e)
Land Use Planning Requirements	
14) Resource Information Required	- Land Use, Soils, Vegetation and Water Resources
15) Alternative Uses	- Explore capability of lands to support a variety of uses
16) Declaration of End Use	- Yes
17) Local Public Planning Role	- Notification and comments taken under advisement
18) Special Provisions	- None

capacity. The restored strip mined lands offer opportunity for such introduction free of competition from less desirable species.

Fifth, the existing wildlife in the area appears to be meager, if not non-existent. Evidently it would be possible to introduce a superior habitat for deer and elk on the unmined sites by shaping small hills as cover with water nearby. Game could be introduced.

A sixth objective would be to provide superior flood control catchment basins as a by-product of the strip mining operation. As discussed in the strip mine model, a natural result of a mining operation is a final pit which may have inadequate fill. If this pit could be placed to catch excess runoff, it would protect the downslope surface construction, provide water for supplemental irrigation and avoid potential stream contamination by sediment or other runoff water geochemistry.

A seventh objective would be to isolate any toxic waste from the ground and surface water supplies. Essentially we would wish to have a closed cycle system result in such areas with losses to evapotranspiration and input from precipitation. We would wish to avoid excess surface water entering such a zone, and infiltrating. Hence, impoundments, barriers or surface coating with paraffin or asphalt as is employed in water harvesting, might be considered. Vertical fractures below the floor of such a disposal site must be avoided or sealed to avoid contaminating deeper aquifers.

More generally the objectives of reclamation are multi-faceted in that they must address and account for all phases of the activities preceding, occurring during and following strip mine operation. These activities and their interrelationships are depicted in Figure 95.

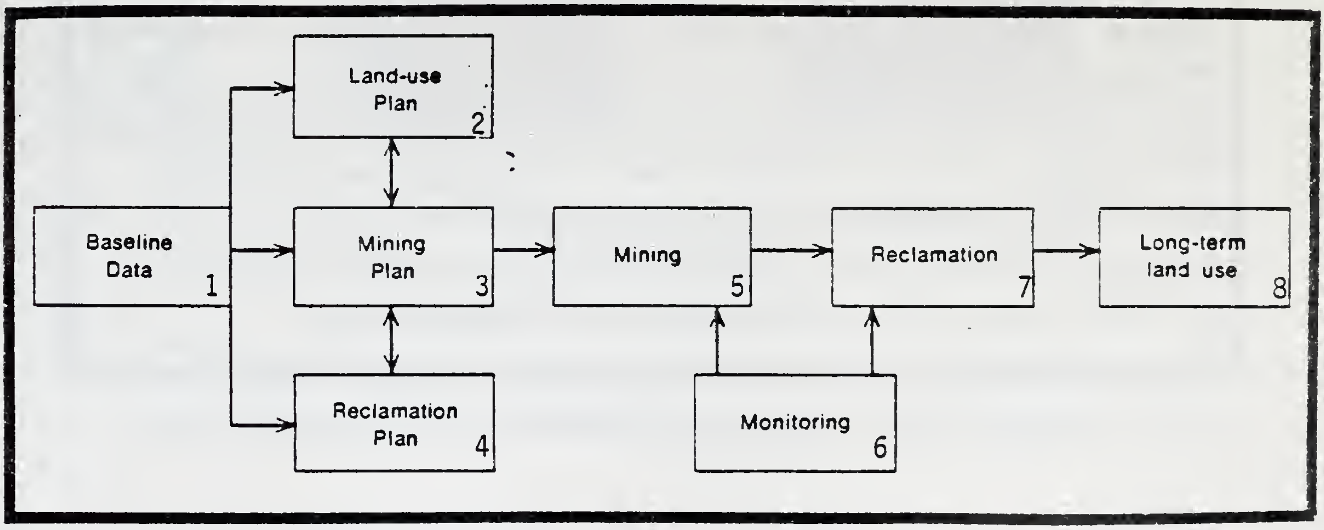


Figure 95.

This report and companion studies underway but not completed will fulfil step 1. The existing land use and new alternatives as given in this section must be completed (step 2) to permit preparation of a responsive mining and reclamation plan (steps 3 and 4). The remaining steps (5, 6, 7, and 8) are completed in logical sequence. We note that step 6, the monitoring will be continued throughout.

To meet State requirements, it is necessary to explore the capability of the mined lands to support a variety of uses (Item 15 in Table 35). This objective is in fact a series of objectives which are covered under the alternatives discussion. A similar situation exists for the compliance objective. Here again a variety of possible responses are feasible for each problem and these are covered as alternatives.

Reclamation Alternatives

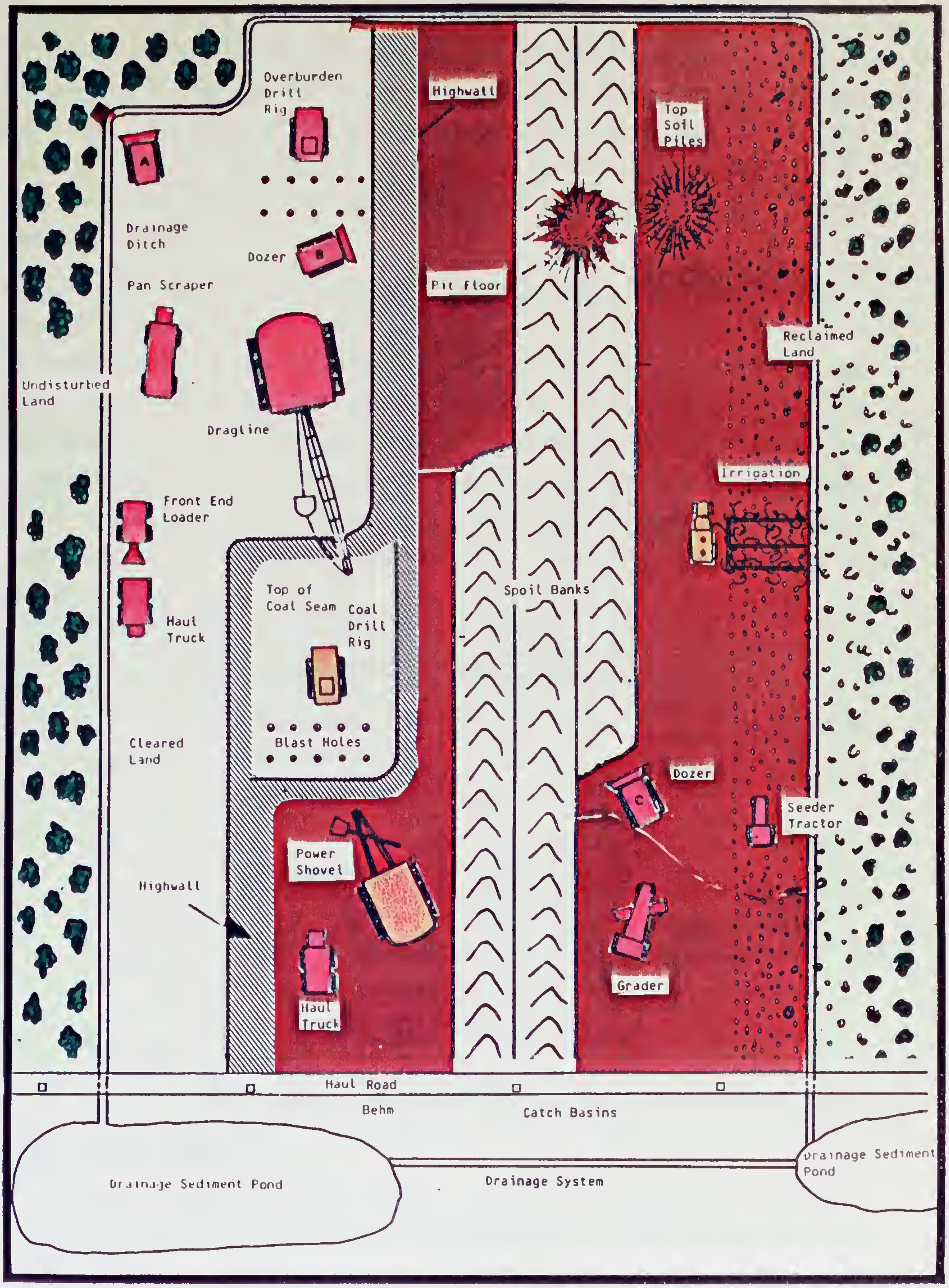
Alternatives must be viewed within the context of what disruption is most likely to occur if the area were strip mined. Hence, we must first generate a scenario of stripping and the mineable coal at the Emery site. Three such locations were identified in the geology section, corresponding to slightly different coal resources. This model is intended to be general enough to serve for all.

Strip Mining Model

Two methods exist for strip mining of coal; a) contour or b) area mining. In some cases, a combination of the two may be chosen depending primarily of hte topography of the overlying surface. In rugged, hilly terrain, contour mining works best, while the more gently rolling, relatively flat terrain is more suited for area mining.

Actual strip mining is preceded by the building of access roads and lay-down areas, the clearing of the land, and the erection of various buildings and other structures. The general sequence and timing of major strip mining activities are to be found in Figure 96, which depicts a plan view of a hypothetical strip mine in operation. Not all of the activities related to coal mining are shown, for example lacking are coal benification, coal loading, and mine decommissioning.

The mining proceeds in a series of parallel trenches unless other factors dictate and the overburden is removed in narrow bands, to be



Initiation ——→ Operation ——→ Abandonment

Figure 96. Time Phased Scenario of a Potential Strip Mine Operation

piles in spoil banks on the opposite side of the pit. For the initial trench, or box cut, the overburden is placed on unmined (but cleared of trees) land next to the cut on the side ("upmine") opposite the direction ("downmine") that the series of cuts are to follow. It may be necessary, owing to limitation of the equipment used, to dig a shallow pit upmine from the initial cut for the disposal of the first spoil bank. The dirt and rock removed from the shallow pit are placed even farther upmine (Weimer, 1968).

For the second "parallel" cut, the overburden is placed in the already mined first pit. For each successive cut the overburden is then placed in the previously mined trench. At the final cut, an empty trench would be left unless reclamation measures have included moving some of each previous spoil pile downmine. This, however, represents a rather expensive earth handling measure. The last trench might rather be filled with water, overburden, fly ash from a power plant, municipal wastes or even left as is for other uses such as shown in Table 35.

Table 35

Potential Rehabilitation Uses

1) Sewage Lagoon
2) Fish Hatching
3) Desalinization Plant
4) Flood Control Basin
5) Recreational Area (off-road vehicles, lake)
6) Ground Water Recharge Pond
7) Pump Storage Reservoir (Peak Demand Power Generation)
8) Erosion Control Barrier
9) Landslide Stabilization
10) Landfill Site
11) Bleeding Methane from Adjacent Underground Coal Works

Model Mining Operation

The pits, down to the pit floor, vary from a few tens to 200 feet deep and 100 to 200 feet wide to accommodate the mining equipment and haulage roads. Referring to Figure 96, it can be seen that one of the preliminary operations involves clearing trees, brush, and grasses and storing them for mulch, by using heavy equipment such as bulldozers, front-end loaders, and haul trucks. At this point, good reclamation practice dictates that topsoil be scraped off for storage and subsequent use.

Drilling rigs are then used to prepare a series of holes in the overburden for explosive loading and shooting. Overburden can then be removed by shoving over the highwall with a bulldozer, by placing a spoils pile by use of a dragline (or power shovel), or by hauling to the spoil pile in a pan scraper depending on the size of the debris.

Judging from its hardness, the coal seam may also require some drilling and blasting before the power shovel can dig and place the coal in the haul trucks. The coal would probably require some form of benification such as washing, crushing and blending before loading, based upon the observed locally high sulphur content.

Earth shaping and additional reclamation is carried out by leveling and grading the spoil piles using bulldozers, graders, and tractor seeders. Grading requirements are reduced if the dragline boom is long enough to allow the operator to drop the spoils in less of a peak/trough fashion.

At the Emery site, multiple seam strip mining is envisaged since coal seams are close enough together, thick enough, and not far from the surface permitting economical extraction.

Dewatering

The digging of both the overburden and the coal seams at the Emery site would evidently interrupt ground water flow by the removal of sections of small perched aquifers as well as by removal of outcropping edges and cracks serving as recharge areas. The elimination of some small springs feeding into local creeks could result, but this is questionable considering the baseline data available. The removal of the necessary overburden should not effect the artesian pressure of the confined Ferron aquifer to the east.

Summary of the Situation on the Emery Study Site

One must first attemp to summarize the relevant portion of the preceding baseline study to assess the reclamation problems and alternatives. One must start with the definition of which areas in fact represent strippable coal, and whether these are actually typical of the Emery coal field at large. With respect to the site itself, the NW and SE portions of the site appear to meet criteria for stripping (Figure 30). The northwestern area is the only part of the site containing the Blue Gate Shale (Persayo-Chipeta) soil derivatives. However, this appears to be the dominant soil type over the larger strippable resources between the town of Emery and the study site. Thus, although not statistically significant over the study site, at least one of the defined strippable areas is representative of this "worst case" soil type. As a topsoil it appears to be nearly worthless, having the highest salinity (Figure 37), shrink swell potential (Figure 44), and lowest available moisture. It may have some value in creating permeability barriers in site reconstruction if its salinity can be tolerated, but as a topsoil it either requires amendment or disposal.

With regard to the drainage subbasin disrupted by the stripping of the NW strippable area, these would be subbasins B and C of Figure 18. Subbasin C is the Miller Canyon drainage with an area within the study zone of 1195 acres. One notes that continuation of the presumed coal to the north pinch out line in Figure 29, would intercept Miller Creek. One recalls that Miller Creek has served to carry away irrigation water from the agricultural areas to the north and has been capturing small stream drainage as it erodes to the north and they change their channel geometry due to sediment filling. In this case one is faced with diversion of these waters out of the pit by a bypass west to the town of Emery or a return to Miller Canyon further downstream, undoubtedly a more expensive option. If the mine "makes" significant water, this must be added to the diversion. If the first option is chosen, the Miller Canyon Creek would undoubtedly dry up in summer causing loss of the modest riparian habitat previously noted. Perhaps mine water could be used to preserve this habitat if its quality were suitable. This site would be the most visible from the town of Emery (Figure 93). The average slope angle of subbasin C is 8%. The other subbasin involved is subbasin B with an average slope of only 3% over its 1459 acres. However, here no significant streams are involved and prevention of wastes from entering Christiansen Wash by a series of sediment ponds is feasible. For the area the geochemical content of the sampled surface waters are not exceptional.

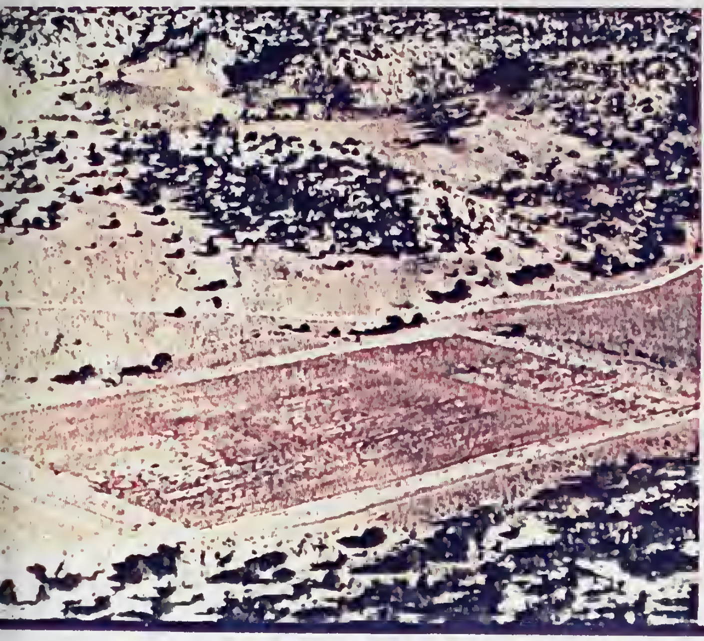
The second strippable area on the SE corner of the test site, involves the statistically more typical (for the study site) Castle Valley and Palisade soils. The revegetation test conducted, were essentially on these soils with minor areal exceptions. These experiments certified the soils as reclaimable even with admixture of shallow weathered overburden sandstone, and some shales (Figures 97 , 98 , 99, and 100. In fact, the bore hole geochemistry for bore holes 5 and 5A indicates the deeper overburden to be (unlike bore hole 3 to the north) a more acceptable soil supplement. But the extremely poor greenhouse results cast doubt on the use of the overburden as a supplement over all the site. Hence in this region, conservation and storage of the topsoil is the obvious choice. The presence of a significant belt of Rock land (Figure 36) over this site would require "stretching" this soil over the Rock land area by amendment and blending with the nutrient poor crushed shallow overburden, fly ash from the adjacent power plants, or as a last choice, some of the less toxic deeper overburden suitably weathered or crushed.

With regard to the drainage subbasins intercepted, these are the smaller subbasins K and N of Figure 29, with areas of 455 and 320 acres respectively, but with higher average slopes (7 and 9%). Any mine discharges would enter the lower reaches of Quitchupah Creek, which by this point, based on the 208 program measurements, has some of the higher trace metal contents overall but only a medial TDS ratio. Note that in GSC's measurements suspended sediment and pH showed significant seasonable variability related to flow.

Finally, although not on the study site, a significant strippable coal resource to the west was noted (Figure 30). These would potentially involve thicker alluvial soil sequences, which if a unitized development were involved, could be borrowed for the topsoil poor strippable regions. The drainage from this site, although the subbasin was not named in the study, would be to the east into Quitchupah Creek; with the same comments as above applying to the surface waters. Here however, it is conceivable that the confined Ferron Sandstone aquifer, with artesian flow could be impacted (Figures 80 and 81). Hence a more significant ground water disposal problem is implicit during mine dewatering and a potential hazard is possible to the municipal water supply of Emery by downward seepage into unsealed vertical joints. Extremely high iron contents were noted in surface waters in the area (Figure 73). These may be taken to indicate the possible presence of other trace elements of greater concern

Figure 97
Simulated Strip Mine
(Note Weathering)

Figure 98
6 Acre Revegetation Site



4 Acre Revegetation Site

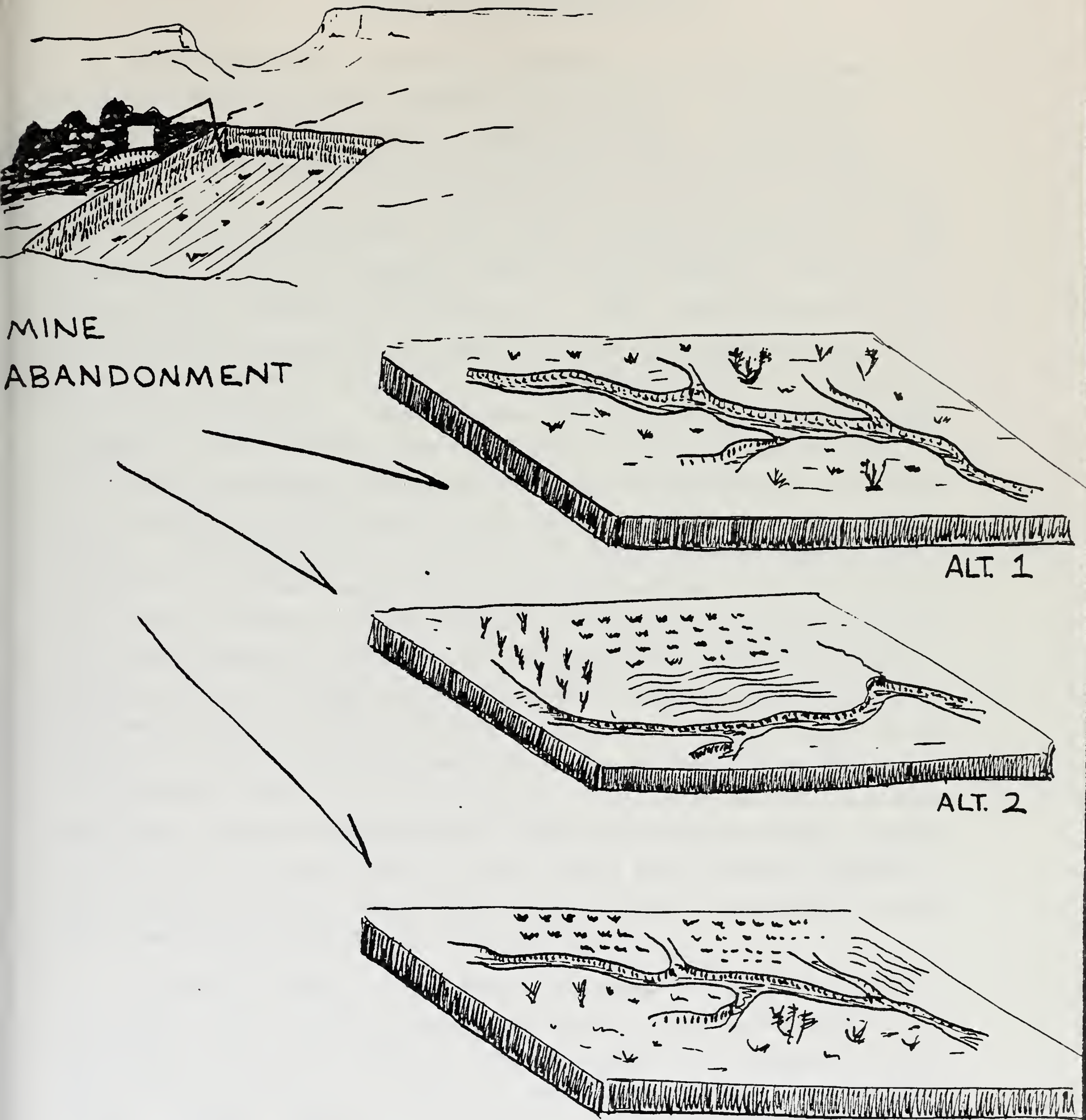
Figure 99

2 Acre Revegetation Site

Figure 100

which may be masked by the iron.

Over all the study area, and implicitly at all the strippable areas, there is the potential vegetation toxicity problem (presumed boron) noted in the greenhouse overburden experiments. This constrains one to use preferably the upper 42 to 45 feet of deeply weathered sandstone, only, as a topsoil supplement, or failing this, a carefully selected segment of deeper overburden. Due to the hole-to-hole variability of overburden geochemistry within a given horizon or "depositional environment", careful testing should precede any such use. The present baseline data are inadequate to the task. The inexplicable geographic variability of the overburden geochemistry from bore hole to bore hole may be interpreted in terms of depositional environments or subsequent reduction or oxidation environments or simply lenses of discrete microdepositional or leaching environments, but that is beyond the scope of this study and in any case hypothetical. Nor does the depositional environment classification adequately segregate these geochemical "classes". Rather it is suggested that the mined spoil be routinely sampled and analyzed to determine the proper management technique to prevent undesirable leachates and suitable methods of disposal or use of the actual layers intercepted. These ideas are systemized in the discussion of reclamation alternatives.



RECLAMATION ALTERNATIVES

Since the ultimate post-mining land use has not been determined we will consider the major reclamation alternatives in this section. In the ideal case, the physical, chemical, biological, topographical, and hydrological properties of the strip mined site can be nearly perfectly restored. In this case the revegetation problem is no more severe than in the case of restoring a burn area or an area of overgrazing. The literature for the arid shadscale zones of Utah and Nevada is adequate to cover this situation (e.g. Bleak et al., 1965). The problems would be essentially to preserve the topsoil's biological condition while stored and then hold the topsoil from erosion until sufficient vegetative cover can be developed. Usual supplements to this process would be surface gouging for water retention and soil holding, seeding and transplanting of native containerized shrubs, and mulching, with supplemental irrigation as required by rainfall conditions during the revegetation process. What then is unique about the strip mine operation that deserves special consideration, provided that there are no direct land use or habitat conflicts? The primary concerns are hydrologic and revegetative. In the case of the strip mine operation, saturated coal and overburden aquifers must be dewatered, surface drainages rerouted, and water stored or disposed of. Geochemical classification of overburden layers disrupted by the mining and mapping of the surface and subsurface hydrology of the site are the key to successful control of this problem area. Hence a series of site studies have been conducted to determine the variability of these problems sampling from coal field to coal field. The Emery field study evidently justifies this approach in that it poses some unique hydrologic/revegetative problems not experienced elsewhere (viz. Figure 101).

In the first place, as discussed in the vegetation and soils section in greater detail, analysis of the total volume of available topsoil indicates a lack of the recommended minimum topsoil for restoration, due to the thinness of the topsoil cover over some of the potentially strippable areas. Secondly, greenhouse and geochemical tests indicate that the ground overburden (simulated weathering) is the poorest growth medium of any so far tested (R. Heil - Personal Communication, 1979). Despite the incomplete nature of these tests, it is presumed that a substantial quantity of the overburden, in addition to being nutrient deficient, actually contains toxic levels of at least boron. Heil's tests were supplemented on unfertilized overburden samples using native, more salt tolerant, species in lieu of the western wheatgrass tested by Heil. The results were even worse, with

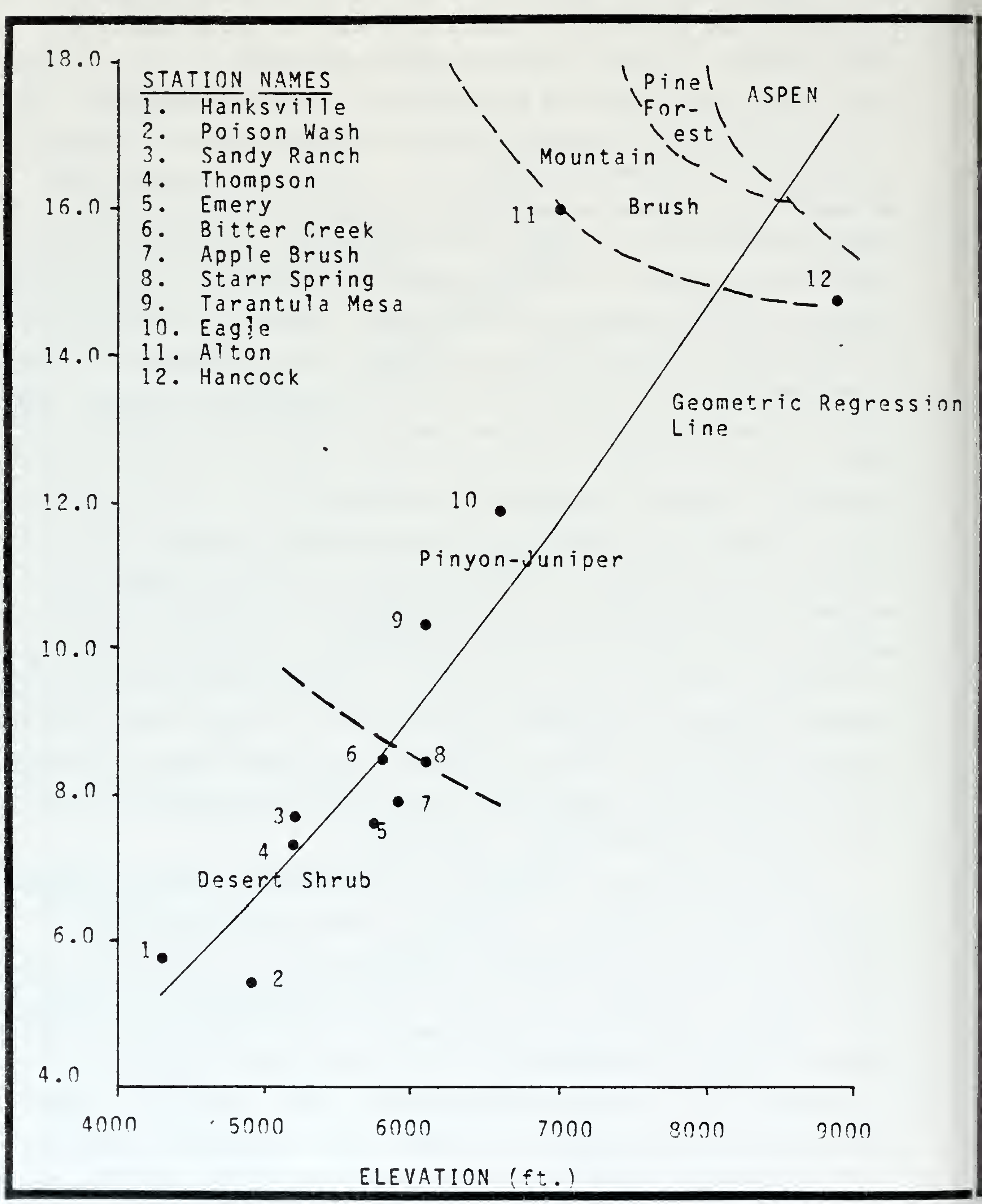


Figure 101- Geometric regression of elevation vs. annual temperature for stations in Central and Southern Utah. Vegetation types are indicated approximately in relation to these two variables.

virtually complete die out of the started seedlings within a few weeks. Evidently overburden for topsoil amendment must be selected very carefully at the Emery site or borrow materials used in their place.

This is not the end of the problem. Even if a suitable topsoil amendment is made up, we cannot simply bury the "toxic" overburden and forget it as suggested in some earlier studies. This would be a risky procedure at the Emery site in particular.

<u>Systemization of Reclamation Alternatives, and Economic Evaluations</u>

1. Actions during the pre and post mining period

Soils/Overburden/Toxic Materials

The key soils problems on the Emery site may be categorized in three ways:

1) The Mancos shale derived soils as they exist on the surface in their natural state are unsuitable physically and chemically as plant growth media, and would pose excessive revegetation hazards.
2) Viewing the strippable areas as units they are deficient in topsoil volume of any type suitable to restore a 30 inch deep soil cover for rooting of shrubs.
3) A significant portion of the overburden appears to have toxic properties. This holds for western wheatgrass, which was used as a control in greenhouse studies and to a lesser but serious extent to native plant species.

The forseeable alternate responses to these problems are shown diagrammatically in Figure 102. Review of these alternatives shows that within the range of low to moderate reclamation costs, these reclamation problems could be countered. Land values in the area approximate $100 to $500 per acre, as range land. Benefication of the site by leveling or production of ground water for agricultural uses, could actually increase land values over small areas to the order of the reclamation costs, $1000 to $2000 per acre. This type of reasoning is not actually valid however, since the value of the recovered coal must be factored in, and reclamation is now a legal requirement. According to La Fevers (1978) these new reclamation costs are now in practice reaching $6000/acre at some sites. Recent lease costs for BLM coal are $3,400/acre plus royalties (Coal Age, 1979 - Colstrip So. Montana). For perspective, coal values at the Emery site, assuming a 20 ft. seam could reach

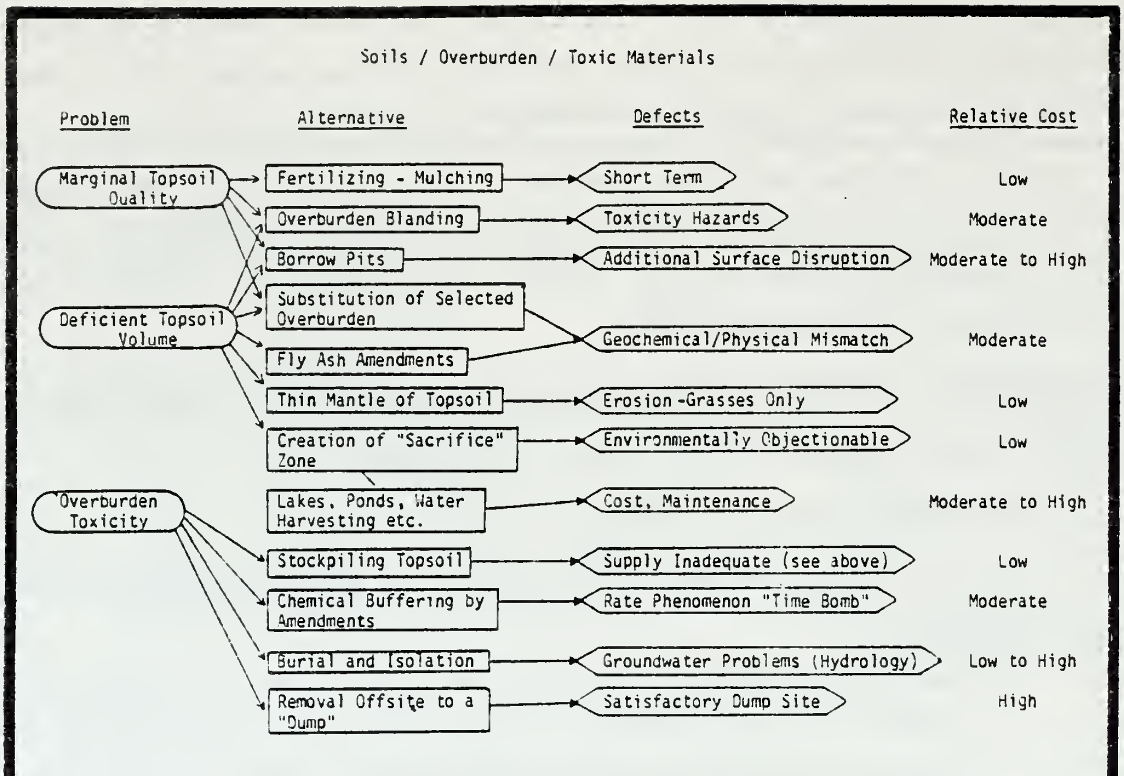


Figure 102

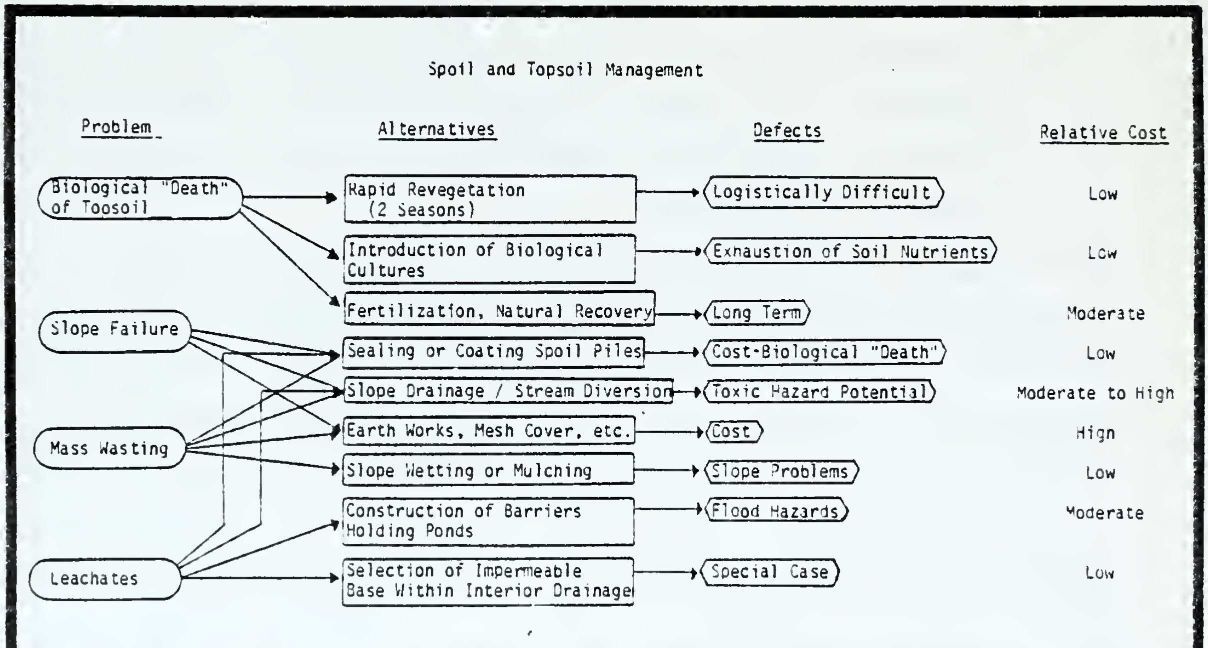


Figure 103

$35,000/acre. Thus a 10% of value allocation to reclamation would be $3500/acre or a 20% allocation of $7000/acre. Top soiling, stockpiling and shaping now becomes the major portion of the cost. The fractional breakdown of these cost estimates is as follows:

Irrigation system cost (if needed)	- $1000/acre	
Backfilling grading	- $1300/acre	Restoring 18" Topsoil
Topsoil handling	- $ 675/acre	
Seeding, Soil amendments	- $ 400/acre	

<u>Spoil and Topsoil Management</u> (Figure 103)

The problems attendant to this area may be defined as follows:

1) Long term storage of topsoil may lead to biological "death" of micro organisms necessary to soil nutrients.
2) Increased infiltration into spoil banks may lead to slope failure, even at normal "angles of repose".
3) Mass wasting of spoil or topsoil erosion may lead to fugitive dust or loss of topsoil, and sediment choking streams.
4) Undesirable leachates may enter streams or the underground water supply.

The spoil management problems are routine aspects of strip mining activities. The biological death and leachate problems are of special concern here.

<u>Surface and Ground Water Reclamation Options</u> (Figure 104)

The hydrologic problems have been touched upon to a degree in prior sections dealing with toxic overburden. The main residual concerns are listed below:

1) Shallow perched aquifers of limited quality are found on the site. They have historical use for watering livestock, maintaining stream and spring flow.
2) Normal precipitation is marginal for successful revegetation, irrigation or increasing moisture retention properties of soils are necessary.
3) A potential for strippable resources west of the study area exists for contamination of deeper confined aquifers.
4) Mine dewatering in the latter case may require disposal of lower quality ground water.

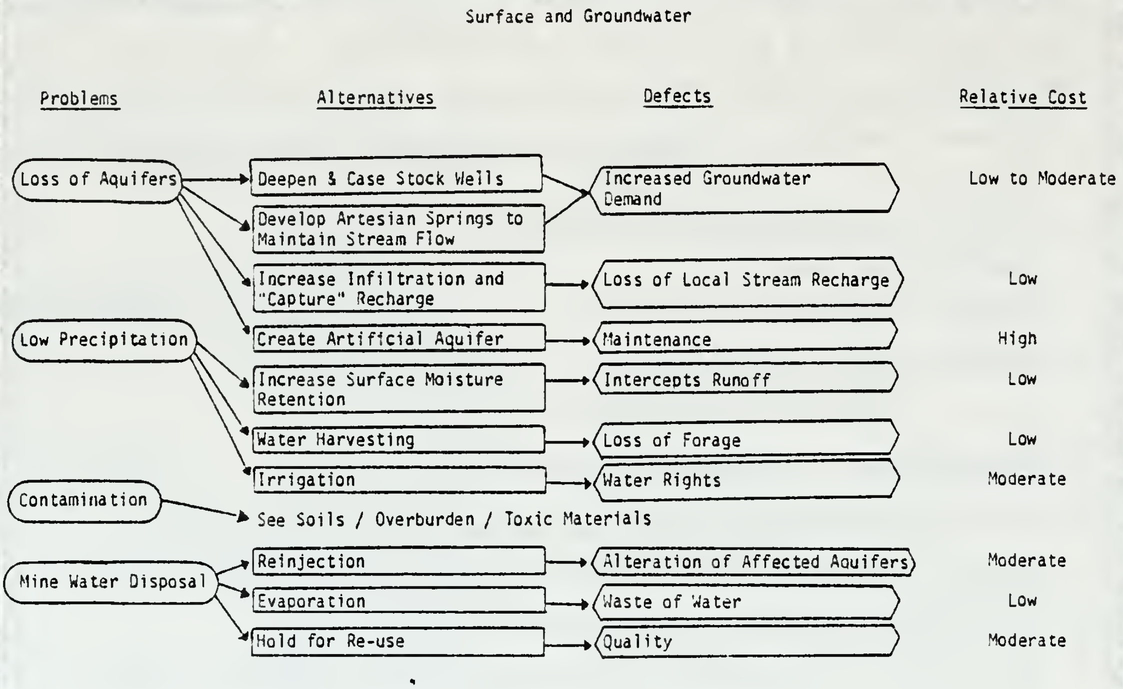


Figure 104

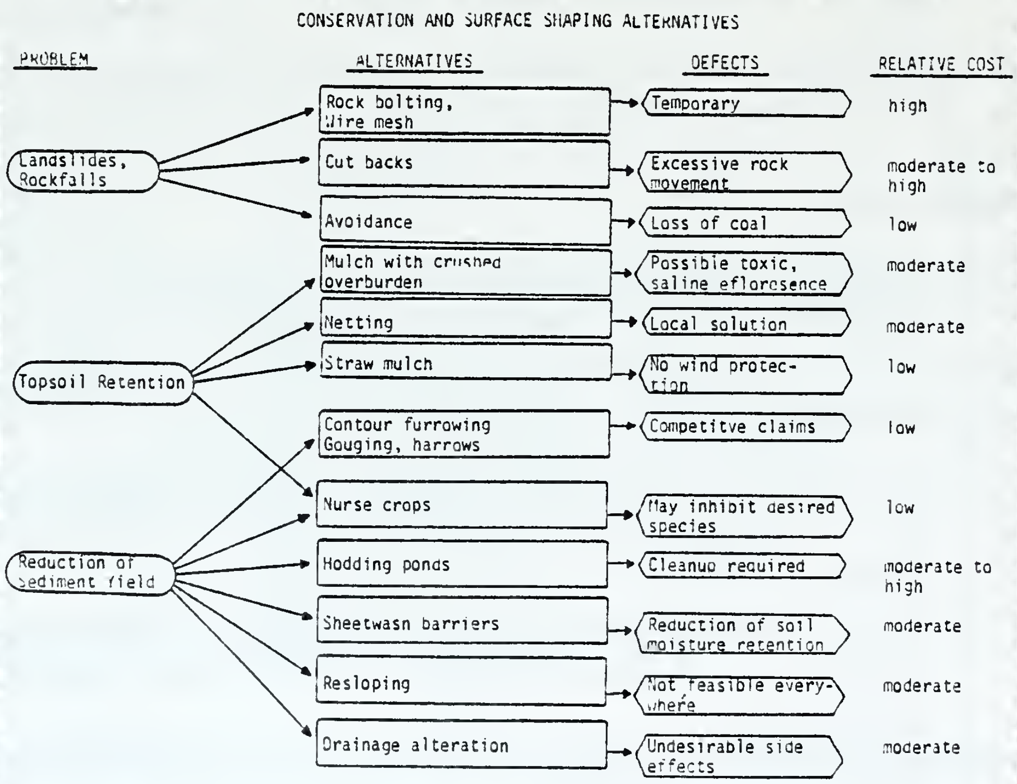


Figure 105

Conservation and Surface Shaping (Figure 105)

The mining operation present the possibility of altering existing surface by landslides, rockfalls, and drainage diversions. Finally stabilization of the surface will involve shaping techniques to hold water and soil, prevent erosion, and avoid high sediment yields. These problems are summarized below:

1) Landslides and rockfalls may result from road cuts, mining operations, etc.
2) Retention of topsoil structure and compliance with regulations on surface restoration is required.
3) Newly prepared surfaces will need protection from erosion until vegetation is established.

Summary of Vegetative Reclamation Recommendations

Pre-Mining

1) Greenhouse studies by Heil (1979), and revegetation experiments by Frischknecht and Ferguson (1979), should be expanded to include test of local varieties of species which are found to be most suited to rehabilitation in the preliminary plots. These should include at least the following shrubs: Atriplex canescens, A. confertifolia, Chrysothamnus nevadensis, and Ceratoides lanata; and these grasses: Hilaria jamesii, Bouteloua gracilis, Oryzopsis hymenoides.

2) Selective breeding of plant species should be considered as a means of developing species most capable of colonizing the barren ground of the post mining landscape. There is on-going research in this area, but it is aimed primarily at restocking depleted rangeland. Particular attention should be focused on developments in this area.

3) Collection of seed stock - Local varieties of native plants have specific adaptations to local climatic and edaphic conditions which increase their potential for survival. Seed stock from selected species should be collected for at least two years prior to stripping of the surface to provide a viable seed supply.

4) Collection of adult plants - Adult plants of selected species should be removed from the site prior to any grading operations. These should be kept alive in a local greenhouse for eventual transplant to the post-mining landscape, and to provide a continuing seed source for

the local variety of each species.

During Mining

1) Existing vegetation (especially pinyon and juniper trees) should be removed and stored for mulching into topsoil. Based on our data, there is at least tons of existing plant material on the study site which could be mixed into the topsoil

2) Timing of mining operations - Removal of topsoil which is to be stockpiled should be timed to follow the period of maximum seed protection. Unfortunately, however, the most plentiful soil, (Castle Valley Series) has only a very sparse understory of shrubs and grasses, and therefore will leave only a small seed stock. However, some of the species produce seed capable of remaining dormant for several years, although the viability of most seed declines with time.

3) Seasons for soil stockpiling - As much as possible, soil stock piling should be confined to the late summer months after all seed has been produced. Soil stockpiling would be most advantageous following wet winters. If stockpiling is to take place following a dry year, it would be advantageous to consider irrigation during the spring in order to produce a seed crop to be stockpiled within the soil.

Post Mining

1) Germination and establishment of specific species depends on the seasonality of rainfall. A seed mixture should be used which takes advantage of rainfall at any time of the year. The seed mixture in Table 36 is proposed.

Table 36

Proposed Seed Mixture

Common Name	lbs./acre
Alkali sacaton	1
Indian ricegrass	2
Russian wildrye	2
Crested wheatgrass	2
Squirreltail grass	1
Blue grama	1
Sand dropseed	2
Shadscale saltbush	3
Fourwing saltbush	2
Nevada ephedra	1
White sage	3

2) Seed for the above mixture should be collected from a wide geographic range, but with a majority from the local area to permit tolerance of local climate. The range of seeds should give the mixture the greatest range of tolerances and potential for successful establishment.

3) Plant materials cleared from the pre-mining landscape should be mulched into the topsoil at the rate of one ton/acre. Alfalfa hay or other organic material should be added to bring the total organic additive content to a minimum of 2 tons per acre. This should alleviate the general N-K-P deficiencies noted, and will prevent wind erosion. Four-wing saltbush has been observed to emerge better and grow taller on spoil so treated (Aldon, 1978).

4) Irrigation should supplement natural rainfall according to the calendar below. This is particularly important in the first post mining year when seedlings lack drought tolerance. Summer irrigation is most critical.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Water (in.)	-	.5	.5	1.5	2	3	4	4	3	1	1	-	20.5

5) Container stock should be planted in small plots (40' x 40') dispersed throughout the site to promote natural reseeding.

6) According to Aldon(1978), drilling is the most common method of planting seeds on reclaimed areas in the west. However, the handbroadcast methods employed here were successful, and appear adequate for the Emery site. In fact cultipacked areas seem to show poorer vegetation vigor than areas not so treated.

7) Figure 106 presents a summary of surface shaping reclamation measures required to comply with new legislation as outlined in Table 34.

Reclamation Checklist

Topsoil Handling

Initially, at least six inches of topsoil must be removed over the pit and stockpiled. Topsoil to qualify for stockpiling must have an exchangeable sodium ratio (SAR) less than 15 (clay ratio less than 40%), and be six inches

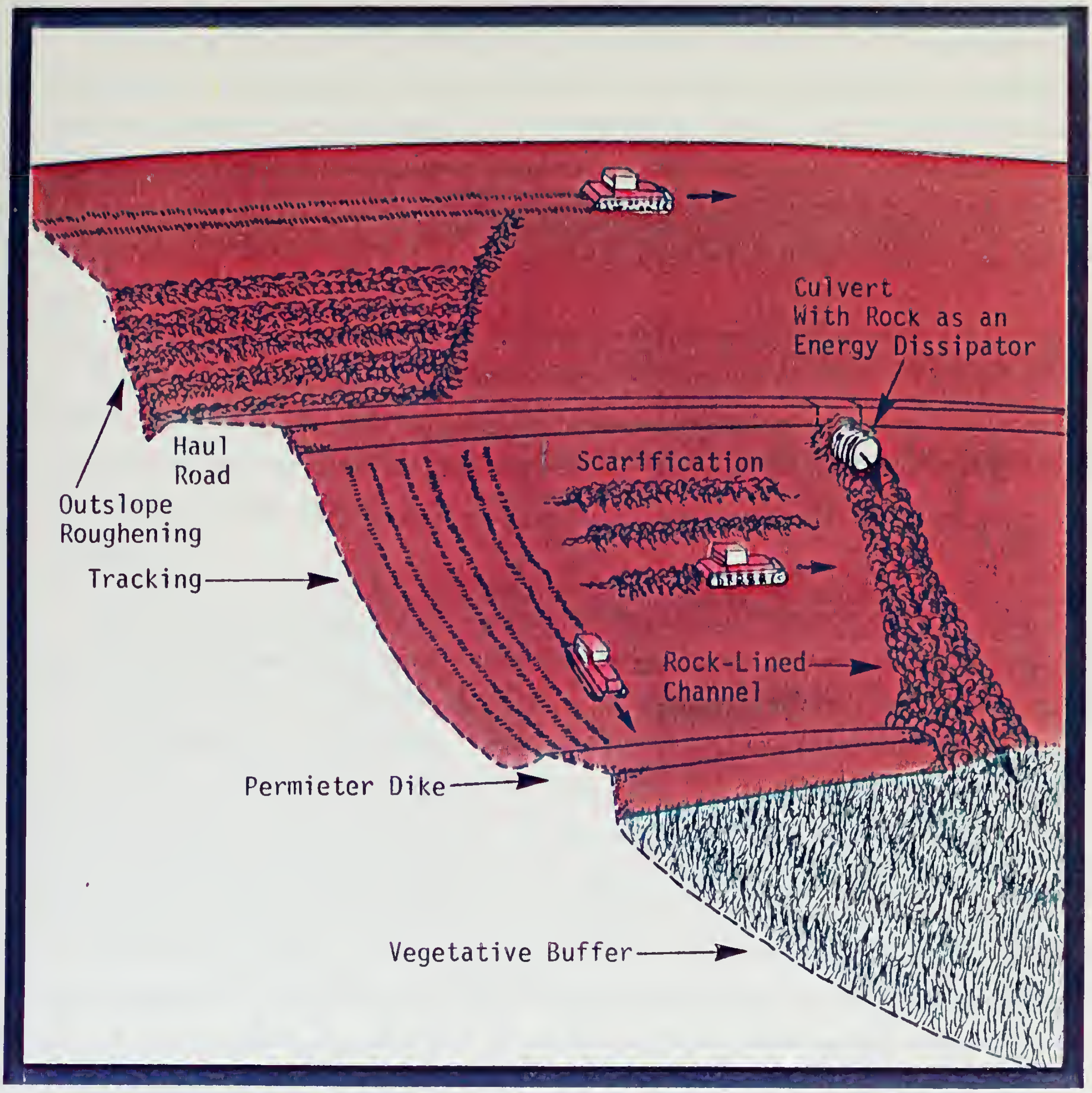


Figure 106. Earth Shaping Measures Required to Comply with Recent Legislation.

or greater in depth. Stockpiled topsoil must be protected from wind and water erosion.

Overburden

In this area the overburden must be tested to determine the presence of adverse contaminants since there are recognized geochemical problems with no clearly defined spatial or layering patterns. Note that at bore hole #5 the delta front marine sequences show plant growth potential virtually throughout, but for no other bore hole (Figure 5). This would imply that suitable materials for topsoil amendment occur above and between the I-J and C coals at this location, which is a strippable site. This does not appear to be the case for the other recognized strippable sites. In these cases, the upper 40 to 60 feet of deeply weathered overburden should be segregated for topsoil amendment, if geochemical tests support such use on a local basis. All such materials deemed suitable should be mapped and graded appropriately in the back fill operations.

Hydrology

Interruption of the Miller Creek drainage by northward extension of the study defined strip area would involve a "head of hollow" fill operation in restoration of the surface. Such a fill would require rock underdrains, spoil compaction at four foot intervals, terrace outslope less than 50%, with terrace widths of at least 20 feet, and the top of the terrace less than 5% slope. The objective would be to have all surface drainage from above the field directed away. The primary concern here would be the introduction of toxic spoil leachates or sediments into what for the area is a significant stream, or disturbance of the "normal" flow of Miller Creek. More generally over the strippable areas the concern is for the runoff during rare summer cloudbursts, or from shallow ground water tables breached by the strip mining operation. During mining with concurrent reclamation, all such discharges are to be contained by a perimeter system of diversion ditches. Regulations now govern allowable pH (6 to 9), iron (7 mg/l), manganese and total suspended solids (70 mg/l) in such waters. The temporary diversion structures must be designed for a 10 year extreme probability recurrence precipitation event and any permanent diversion construction for a 100 year recurrence interval. Settling ponds, stream gradients, roughness and the like are required to bring discharged waters to the required standards. In this case, due to the unfavorable greenhouse results, it is also recommended that additional monitoring of boron levels be conducted. It should be noted though (refer back to Figure 49), that many of the streams in the area already exceed the prescribed limits of these substances. There should be some consideration of this in final plans. Such ponds and ditches are to be removed when the land is finally reclaimed. This must also be considered in terms of the surface shaping for long term affects.

Finally, of concern is the longer term problem of ground water contamination due to so-called "toxic" leachates from buried spoil. The operator is now required, by federal statute, to segregate, hold from leaching, and finally bury with at least four feet of cover, any "toxic" material; obviously to protect the shallow ground water. The boron "toxicity" problem, in terms of greenhouse experiments previously discussed in this report, may not qualify any of the Emery overburden material as "toxic" material in the sense of the law. This more relates to the public health water standards noted elsewhere. On the other hand, the second greenhouse crop of salt tolerant species fared more poorly than the less tolerant western wheatgrass on the same spoil sample, which differed only by weathering and leaching. This is of concern, as it implies a potential prompt as well as long term threat to revegetation efforts. The most conservative approach would be to restore as much of the deeply weathered (40 to 60 feet top section) overburden as feasible to serve as a buffer to the unleached overburden. An impermeable barrier should be interposed.

Surface Treatment

The high seasonal wind, and to a lesser extent, rain erosion probabilities affect both spoil heap and reclaimed land surfaces. Measures to counteract such erosion for the site involve either discing or compaction of the of the surface soils as indicated by the specific tests and ripping of barren slopes. In all cases admixture of mulch is indicated, to prevent erosion. Retention and chipping of the native pinyon-juniper would probably cut mulch costs in half. A two step procedure would be to first plant a suitable crop into which native species could be fall seeded. Generally, straw or alfalfa mulch should be applied and lightly disced for anchoring immediately following seeding. Cross crimping of the mulch will hold it against wind erosion. Fly ash, which is available in the area has been shown to be a suitable substitute for straw mulch elsewhere (Utah International). Modest irrigation (about 2 to 3 inches per year) may be required depending on rainfall actually experienced. The schedule for this irrigation would be May through September at biweekly and finally monthly intervals on an as needed basis. Conventional farm machinery and methods are probably adequate for the task. It has been noted that federal regulations now control natural slope restoration, and erosion protection; as part of the required surface shaping. These goals can be achieved in an integrated operation.

Current Reclamation Practices

A variety of reclamation practices have been successfully demonstrated in the west and no single method seems to be clearly superior at this writing. Rather, the operator should be aware of all of these practices and techniques to recognize those which might be applicable to a particular problem or opportunity (e.g. fly ash availability) that one may encounter. Table 37 gives a summary of current reclamation practices and costs. The mines covered are from the states of Montana, New Mexico, North Dakota, and Wyoming. The source for the information is recent issues of COAL AGE magazine. These data are compiled in a single source as indicated in the reference for the figure.

From the point of view of an analog to the Emery site, the Utah International Navajo mine in New Mexico seems the closest, primarily with regard to precipitation and soils problems. The Emery site, based on the analyses completed, shares the top-soil scarcity, salinity and crusting problems encountered at Navajo Mine. Although all the mines summarized in Table 37 share an approximate 8-12 inch per year rainfall, the seasonal pattern of this rainfall is most significant. At Emery, for example, both spring and summer grasses are present, taking advantage of snowmelt and late summer cloudburst precipitation respectively. Thus one can expect some differences in successful practices, based on climate, soil and topography from mine to mine. Yet the noted variations seem too great to account for all these differences. The range in costs, for example, seems too great for what in some instances appears to be an effectively identical practice.

Further, many of the methods listed appear to have been applied in an experimental mode, and now may have been superceded by more efficient, less costly methods. The common feature in all of these is the use of dual purpose mining or conventional farm machinery, with the possible exception of the hydromulching equipment. Surprisingly, the almost universal lack of irrigation and reliance on conditional rainfall events shows that a long view (5 to 10 years) is taken in successfully revegetation of properly treated areas. However, in the event of a prolonged drought, with increased wind erosion, desication of deeper root zones and loss of cover crops, supplemental measures to what is listed would be required.

Table 37

SUMMARY OF CURRENT RECLAMATION PRACTICES IN WESTERN STRIP MINES

(Adapted from Coal Age Operating Handbook of Surface Mining 1978)

MINE	IRRIGATION	MULCH	PROBLEMS	FERTILIZER	TREATMENT	PLANTINGS	COST	MACHINES
NACCO, ND Indian Head Falkirk Underwood	None	None	P deficiency	18% N 46% P 125 lbs/acre	30 in. topsoil on ripped slopes, grading	nurse crops large grain grass shrubs, trees, forbs	$3500/acre	D-9 Cats, Dozers Scrapers, Farm Tractors, Discs, Harrows, Seeder
Peter-Kiewit, MT Decker Bighorn Rosebud	Hydromulched	Hay-Straw Hydromulched Crimped 200 lbs/acre				grasses containerized shrubs		Terex TS15, TS24, Cat 08, 09, 637, 651, Farm Tractor, Finn 3000 Hydro- mulcher
Bridger, WY	None	Grass-Hay 2 tons/acre	High pH, low iron, high salts, sodium Soil Crusting	None Nitrogen 2nd or 3rd year	Slopes ripped	grasses, legumes	$2500/acre	Cat 657, 638, 09 16 grader, Page 732 drag line (part time use)
Wyodak, WY	None	None		None	Temporary Stabilization w/ Spring Oaks	grasses, alfalfa	$850/acre	
FMC, WY Skull Point		None		None		grasses, forbs, shrubs	$60 to $80 per acre	
Knife River Coal Co., ND Beulah Gascoyne (prelaw)	None			18% N, 36 lbs per acre 46% P, 92 lbs per acre	Chisel plowed on contour nurse crop	grasses, legumes trees	$1600 to $2400/acre	Cat D8, D9, 637 834, Scrapers, Hough D-126, IH TD-25
Westmoreland, MT Absaloka		None	Minimal June rain erosion	None after establish 30 lb. N, 30 lb. P, per acre	10 lb/acre spring wheat nurse crop, rapid topsoil cycle	grasses, forbs, shrubs		D9 Cats, D8 Dozer Cat Scrapers, Rome 36 in disc, Melrose Seed Drill, Spreader

Table 37 cont.

SUMMARY OF CURRENT RECLAMATION PRACTICES IN WESTERN STRIP MINES (Cont.)

MINE	IRRIGATION	MULCH	PROBLEMS	FERTILIZER	TREATMENT	PLANTINGS	COST	MACHINES
Sunedco-Cordero, WY	Hydromulched	Wood fiber, 1 ton/acre Hay, 2 ton/acre Hydromulch		Leonardite	Hydroseeding, Rapid topsoil cycle, Slope ripping		$500/acre	09 Cat, 637 Scraper, 824 Dozers, 166 Grader, Bowie Hydro Mulcher, Seed Dril, Farm Tractors, Farm Clodbuster, Harrow
Baukol-Noonan Inc., ND Center Larson			Minimal erosion	150 lb. Nutro-grow (10-10-5) per acre (Leonardite)	No ripping or terracing Rapid topsoil cycle	grasses, legumes, trees, rye	$3000/acre	09 Cat, 637 Scraper Hough 500 Dozer, Farm tractors, Drills, Harrows, Cultivators, Discs
Pacific Power & Light, WY	None	Grass/straw blown at 2 ton per acre More on slopes	Wind, water erosion, Moisture retention, N deficiency Thin soil (2")		Fall nurse crop (wheat-barley) Ripping	18 lb. per acre in fall and spring	$2000 to $3000/acre	D9 Ripper, Standard Tractors
Utah International, NM -Navajo Mine	0.08 in/hr every 3rd day (emergence) Then less frequent last two, 30 days apart, Total 10 in. (sprinkler)	Straw blown on 1.5 tons/acre Later changed to bottom ash	Some topsoil unusable due to SAR, Low H_2O retention in sandy top-soil, Rooting in overburden interface	Bottom ash, 12 overburden layers used for amendment, Gypsum manure	Discing prior to seeding and to anchor straw mulch	grasses, forbs shrubs		Conventional hand moved sprinkler, Farm machinery

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GLOSSARY

GLOSSARY

Annual Plant (annuals), A plant that completes its life cycle and dies in 1 year or less.

Aspect, The direction toward which a slope faces. Exposure.

Available Nutrient, The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

Available Water, The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable: obtainable.

Bedrock, Any part of the consolidated geologic formation, soft, weathered or hard that has remained in place and is relatively unchanged.

Broadcast Seeding, Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.

Buffer, Substances in soil or water that act chemically to resist changes in reaction or pH.

Calcareous Soil, Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.

Capillary Water, The water held in the "capillary" or small pores of a soil, usually with tension greater than 60 centimeters of water. Much of this water is considered to be readily available to plants.

CFS, Cubic feet per second - measurement of water flow.

Channel Stabilization, Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.

Clay (soils) (1) A mineral soil separate consisting of particles less than 0.002 millimeter diameter. (2) A soil textural class. (3) (engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.

Compaction, The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area, as in the process of leveling the overburden material of strip mine banks.

Companion Crop (See Nurse Crop)

Conifer, A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves and producing wood known commercially as "softwood."

Contour, An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Cool-Season Plant, A plant that makes its major growth during the cool portion of the year, primarily in the spring but in some localities in the winter.

Deciduous, Refers to a tree that sheds all its leaves every year at a certain season.

Deep Chiseling, Deep chiseling is a surface treatment that loosens compacted spoils. The process creates a series of parallel slots on the contour in the spoils surface which impedes water flows and markedly increases infiltration.

Density, Forage, The percent of ground surface which appears to be completely covered by vegetation when viewed directly from above.

Density, Stand, Density of stocking expressed in number of trees per acre.

Broadcast Seeding, A method of establishing a stand of vegetation by sowing seed on the ground surface.

Dissolved Solids, The difference between the total and suspended solids in water.

Disturbed Land, Land on which excavation has occurred or upon which overburden has been deposited, or both.

Dozer or Bulldozer, Tractor with a stell plate or blade mounted on the front end in such a manner that it can be used to cut into earth or other material and move said material primarily forward by pushing.

Ecology, The science that deals with the mutual relation of plants and animals to one another and to their environment.

Ecosystem, A total organic community in a defined area or time frame.

Effective Precipitation, That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

Effluent, Any water flowing out of the ground or from an enclosure to the surface flow network.

Environment, All external conditions that may act upon an organism or soil to influence its development, including sunlight, temperature, moisture and other organisms.

Erodibility, The relative ease with which one soil erodes under specified conditions of slope as compared with other soils under the same conditions; this applies to both sheet and gully erosion.

Erosion, The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Detachment and movement of soil or rock fragments by water, wind or ice, or gravity.

Essential Element (plant nutrition), A chemical element required for the normal growth of plants.

Evapotranspiration, A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Excavation, The act of removing overburden material.

Fertilizer, Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

Fertilizer Grade, The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid (P_2O_5), and 5 percent water-soluble potash (K_2O). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer (nitrogen (N), phosphorous (P), and potassium (K)).

Fill, Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

Forage, Unharvested plant material which can be used as feed by domestic animals. Forage may be grazed or cut for hay.

Forest Land, Land bearing a stand of trees at any age or stature, including seedlings and of species attaining a minimum of 6 feet average height at maturity or land from which such a stand has been removed but on which no other use has been substituted. The term is commonly limited to land not in farms; forests on farms are commonly called woodland or farm forests.

Germination, Sprouting; beginning of growth.

Gradation, A term used to describe the series of sizes into which a soil sample can be divided.

Grain Size, Physical size of soil particle, usually determined by either sieve or hydrometer analysis.

Ground Cover, Any living or dead vegetative material producing a protecting mat on or just above the soil surface.

Ground Water, Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called plerotic water; phreatic water.

Growing Season, Determined by the Lowery-Johnson Method.

Gully Erosion, Removal of soil by running water, with formation of deep channels that cannot be smoothed out completely by normal cultivation.

Hydroseeding, Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious, Prohibits fluid flow.

Infiltration, Water entering the ground water system through the land surface.

Intermittent Stream, A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Land Classification, Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences significant to men.

Land Use Planning, The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Leaching, The removal of materials in solution by the passage of water through soil.

Leachate, Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Legume, A member of the legume or pulse family, leguminosae. One of the most important and widely distributed plant families. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Lime, Lime, from from the strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term lime is commonly used in agriculture to include a great variety of materials which are usually composed of the oxide, hydroxide, or carbonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural line are ground limestone, marl, and oyster shells (carbonates), hydrated lime (hydroxides), and burnt lime (oxides).

Quicklime - limestone + heat (calcined) CaO
Hydrated lime - quicklime + H_2O $Ca(OH)_2$
Slaked lime - same as hydrated but slaking equipment is used for adding water
Milk of lime - water mixture containing lime in solution + lime in suspension

Micro-Climate, A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-Nutrients, Nutrients in only small, trace, or minute amounts.

Mined-Land, Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mulch, A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature.

Natural Revegetation, Natural reestablishment of plants; propagation of new plants over an area by natural processes.

Natural Seeding (Volunteer), Natural distribution of seed over an area.

Neutralization, The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

Neutral Soil, A soil in which the surface layer, at least to normal plow depth, is neither acid nor alkaline in reaction. For most practical purposes, soil with a pH ranging from 6.6 through 7.3.

Nitrogen Fixation, The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called nonsymbiotic.

Nurse Crop, A planting or seeding that is used to protect a tender species during its early life. A nurse crop is usually temporary and gives way to the permanent crop. Sometimes referred to as a companion crop.

Nutrients, Any element taken into a plant that is essential to its growth.

Overburden, The earth, rock, and other materials which lie above the coal.

Percolation, Downward movement of water through soils.

Permeability, The measure of the capacity for transmitting a fluid through the substance. In this report the substance is overburden (soil and bedrock).

pH, The symbol or term refers to a scale commonly used to express the degrees of acidity or alkalinity. On this scale pH of 1 is the strongest acid, pH of 14 is the strongest alkali, pH of 7 is the point of neutrality at which there is neither acidity or alkalinity. pH is not a measure of the weight of acid or alkali contained in or available in a given volume.

Pollution, Environmental degradation resulting from man's activities or natural events.

Pond, A body of water of limited size either naturally or artificially confined and usually smaller than a lake.

Rain (1) Heavy--Rain which is falling at the time of observation with an intensity in excess of 0.30 in. per hr (over 0.03 inch in 6 min). (2) Light--Rain which is falling at the time of observation with an intensity of between a trace and 0.10 in. per hr (0.01 inch in 6 min). (3) Moderate--Rain which is falling at the time of observation with an intensity of between 0.11 in. per hr (0.01+ inch in 6 min) and 0.30 in. per hr (0.03 inch in 6 min).

Range Land, The natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs.

Percolation Rate, Usually expressed as a velocity, at which water moves through saturated granular material. The term is also applied to quantity per unit or time of such movement, and has been used erroneously to designate infiltration rate or infiltration capacity.

Reclamation, The process of reconverting mined land to its former or other productive uses.

Reconstructed Profile, The result of selective placement of suitable overburden material on reshaped spoils.

Recreation Land, Land and water used, or usable primarily as sites for outdoor recreation facilities and activities.

Reforestation, The natural or artificial restocking of an area with forest trees.

Regrading, The movement of earth over a depression to change the shape of the land surface. A finer form of backfilling.

Rehabilitation, Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Strip Mining (See Surface Mining)

Stripping, The removal of earth or non-ore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.

Subsoil, The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

Substratum, Alluvial, colluvial and bedrock material that lies below the soil profile.

Surface Soil, That part of the upper soil of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 inches) in non-arable soils.

Suspended Solids, Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Terrace, Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation or to control surface runoff and minimize soil erosion.

Terraced Slope, A slope that is intersected by one or more terraces.

Texture, The character, arrangement and mode of aggregation of particles which make up the earth's surface.

Topdressing Material, Material that is well suited for plant media. Desired characteristics include: fertile, good tilth, permeable, contains organic matter, nonsaline, nonsodic and has water stable aggregates.

Tilth, The physical condition of a soil in respect to its fitness for the growth of a specified plant.

Topography, The shape of the ground surface, such as hills, mountains or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

Revegetation, Plants or growth which replaces original ground cover following land disturbance.

Ripping, The act of breaking, with a tractor-drawn ripper or long angled steel tooth, compacted soils or rock into pieces small enough to be economically excavated or moved by other equipment as a scraper or dozer.

Runoff, That portion of the rainfall that is not absorbed by the deep strata: is utilized by vegetation or lost by evaporation or may find its way into streams as surface flow.

Saline-Sodic Soil, A soil having a combination of a harmful quantity of salts and either a high degree of sodicity or a high amount of exchangeable sodium, or both, so distributed in the soil profile that the growth of most crop plants is less than normal.

Saline Soil, A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

Sandstone, A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Saturation, Completely filled; a condition reached by a material, whether it be in solid, gaseous, or liquid state, which holds another material within itself in a given state in an amount such that no more of such material can be held within it in the same state. The material is then said to be saturated or in a condition of saturation.

Sediment, Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin, A reservoir for the confinement and retention of silt, gravel, rock, or other debris from a sediment-producing area.

Seedbed, The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seep, A more or less poorly defined area where water oozes from the earth in small quantities.

Shale, Sedimentary or stratified rock structure generally formed by the consolidation of clay or clay-like material.

Silt, Small mineral soil grains the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

Soil (See Acid Soil and Alkaline Soil), Surface layer of the earth, ranging in thickness from a few inches to several feet composed of finely divided rock debris mixed with decomposing vegetative and animal matter which is capable of supporting plant growth.

Soil Conserving Crops, Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.

Soil Porosity, The degree to which the soil mass is permeated with pores or cavities. It is expressed as the percentage of the whole volume of the soil which is unoccupied by solid particles.

Soil Profile, A vertical section of the soil through all its horizons and extending into the parent material.

Soil Structure, The combination or arrangement of primary soil particles into secondary particles, units, or beds.

Solum, The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soils includes the A and B horizons. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plant life and animal life characteristic of the soil are largely confined to the solum.

Spoil, The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.

Spoil Bank (Spoil Pile), Area created by the deposited spoil or overburden material prior to backfilling. Also called cast overburden.

Stratified, Composed of, or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called horizons, while those inherited from parent material are called strata.

Strip, To mine a deposit by first taking off the overlying burden.

Strip Mine, Refers to a procedure of mining which entails the complete removal of all material from over the product to be mined in a series of rows or strips; also referred to as "open cut," "open pit," or "surface mine."

Toxic Spoil (See also Acid Spoil), Includes acid spoil with pH below 4.0. Also refers to spoil having amounts of minerals such as aluminum, manganese, and iron that adversely affect plant growth.

Transpiration, The normal loss of water vapor to the atmosphere from plants.

Unconsolidated (soil material), Soil material in a form of loose aggregation.

Vegetation, General term including grasses, legumes, shrubs, trees naturally occurring and planted intentionally.

Vegetative Cover, The entire vegetative canopy on an area.

Volunteer, Springing up spontaneously or without being planted; a volunteer plant.

Weathering, The group of processes, such as chemical action of air and rainwater and of plants and bacteria and the mechanical action of changes in temperature, whereby rocks, on exposure to the weather, change in character, decay, and finally crumble.

Wildlife, Undomesticated vertebrate animals, except fish, considered collectively.

APPENDICES

APPENDIX 1

Precipitation by Months at Emery, Utah

Precipitation by Months at Emery, Utah (38°55 N, 111°15 W, 1893 m MSL)

	OCT	NOV	DEC	JAN	FEB	MAR	WINTER	APR	MAY	JUN	JUL	AUG	SEP	SUMMER	YEAR
1901-02	T	T	0.00	0.10	T	0.10	0.20	0.00	T	0.00	T	0.45	T	0.45	0.65
1902-03	T	0.29	T	T	0.40	0.26	0.95	T	0.65	0.85	0.72	T	1.52	3.74	4.69
1903-04	1.03	0.00	0.00	T	T	T	1.03	T	0.74	1.30	T	0.93	0.76	3.73	4.76
1904-05	0.75	0.00	0.40	0.08	3.01	0.62	4.86	0.39	0.70	0.00	T	0.90	0.65	2.64	7.50
1905-06	T	0.48	0.40	1.73	0.20	1.30	4.11	2.07	0.75	T	0.75	1.28	1.40	6.25	10.36
1906-07	0.60	2.00	1.70	1.10	0.90	0.34	6.64	0.40	1.52	0.55	1.06	1.91	0.90	6.34	12.98
1907-08	1.83	0.10	0.20	0.10	0.80	T	3.03	0.20	0.20	T	0.77	2.00	1.05	4.22	7.25
1908-09	1.02	0.40	0.40	1.00	1.33	T	4.15	T	T	0.65	0.75	5.42	3.48	10.30	14.45
1909-10	0.00	0.50	1.70	0.30	0.20	T	2.70	0.00	T	0.45	0.20	1.35	1.44	3.44	6.14
1910-11	0.95	0.65	0.50	0.70	0.50	0.30	3.60	0.20	0.00	1.55	1.95	1.05	1.55	6.30	9.90
1911-12	0.00	T	0.20	T	0.70	1.40	2.30	0.10	0.83	T	2.03	1.00	0.70	4.69	6.99
1912-13	1.01	0.10	0.22	0.20	0.70	0.40	2.63	0.52	T	0.35	1.22	0.70	0.20	2.99	5.62
1913-14	0.90	0.20	1.80	0.80	T	T	3.70	0.88	0.85	1.50	2.11	0.80	1.65	7.79	11.49
1914-15	0.35	T	T	0.70	1.40	T	2.45	0.30	0.97	0.60	T	0.20	1.84	3.91	6.36
1915-16	T	1.17	0.70	2.50	0.09	1.36	5.82	T	0.00	0.00	1.12	0.83	0.56	2.51	8.33
1916-17	3.85	T	0.40	0.38	0.30	0.10	5.03	2.60	2.23	0.20	1.75	0.15	1.72	8.65	13.68
1917-18	0.00	0.00	0.00	0.40	T	1.97	2.37	0.65	T	T	1.74	1.30	1.10	4.79	7.16
1918-19	1.23	0.50	0.20	0.00	1.60	0.22	3.75	T	0.71	0.00	1.13	1.86	2.11	5.81	9.56
1919-20	T	0.68	0.18	0.35	0.30	T	1.51	0.25	0.60	0.50	0.15	0.85	0.25	2.60	4.11
1920-21	0.97	0.00	0.50	0.10	0.00	T	1.57	0.30	0.10	T	----	----	----	----	----
1921-22	----	T	1.00	0.27	1.21	0.28	----	1.00	1.30	0.03	0.30	1.30	0.25	4.18	6.94
1922-23	0.20	0.60	0.40	0.25	0.70	T	2.15	0.30	0.60	0.00	1.36	1.26	0.60	4.12	6.27
1923-24	0.55	0.52	0.30	0.28	0.20	0.78	2.63	0.10	0.00	0.00	0.83	0.44	1.00	2.37	5.00
1924-25	0.50	0.25	1.19	T	0.43	0.15	2.52	0.18	0.00	1.59	1.12	1.55	0.99	5.43	7.95
1925-26	1.30	0.10	T	T	0.60	0.62	2.62	1.05	0.00	0.17	0.71	0.47	T	2.40	5.02

Precipitation by Months at Emery, Utah (cont.)

	OCT	NOV	DEC	JAN	FEB	MAR	WINTER	APR	MAY	JUN	JUL	AUG	SEP	SUMMER	YEAR
1926-27	0.21	0.25	0.63	0.16	0.73	1.26	3.24	0.00	0.00	1.95	1.15	1.74	2.07	6.91	10.15
1927-28	1.27	0.00	0.15	0.15	1.25	0.95	3.77	0.00	4.00	0.00	0.00	0.70	0.22	4.92	8.69
1928-29	1.15	0.40	0.15	0.61	0.60	0.72	3.63	0.10	0.75	0.00	0.25	1.21	1.18	3.49	7.12
1929-30	T	0.00	0.45	1.70	0.00	0.25	2.40	0.90	1.07	1.08	1.01	2.50	1.75	8.31	10.71
1930-31	0.30	0.40	0.00	T	0.25	0.60	1.55	0.10	0.00	0.05	0.45	0.16	0.20	0.96	2.51
1931-32	0.62	0.18	0.55	0.51	0.96	0.05	2.87	0.05	0.00	0.10	2.14	2.31	0.15	4.75	7.62
1932-33	0.50	0.00	0.77	1.16	0.57	0.20	3.20	0.15	0.80	0.00	2.15	0.88	1.13	5.11	8.31
1933-34	0.24	0.65	T	0.34	0.30	0.00	1.53	0.10	1.40	0.45	0.17	0.82	0.27	3.21	4.74
1934-35	T	0.15	0.10	0.12	0.32	1.13	1.82	1.17	0.57	0.00	0.59	0.85	0.30	3.48	5.30
1935-36	0.00	0.16	0.45	0.19	0.19	0.24	0.94	T	0.65	0.56	2.78	1.29	0.33	5.61	6.55
1936-37	1.10	0.00	1.54	0.70	0.43	0.47	4.24	0.00	0.55	0.50	1.98	1.65	1.10	5.78	10.02
1937-38	0.50	0.00	0.81	0.70	0.45	0.72	3.18	0.46	0.08	0.63	0.69	1.05	1.49	4.40	7.58
1938-39	1.09	0.15	0.33	1.03	0.47	0.43	3.50	0.62	0.21	0.00	0.68	0.95	2.75	5.21	8.71
1939-40	0.60	0.25	T	0.65	0.70	0.00	2.15	0.15	0.38	0.80	0.08	0.75	2.59	4.75	6.80
1940-41	1.13	0.45	0.63	0.92	0.70	0.92	4.75	2.10	1.78	1.40	0.49	2.63	1.44	9.84	14.59
1941-42	3.58	T	0.88	0.11	0.30	0.24	6.11	0.36	0.03	0.00	0.74	0.33	0.67	2.13	8.24
1942-43	1.23	T	0.00	0.46	T	0.92	2.61	0.49	0.20	0.70	0.35	0.90	0.53	3.17	5.68
1943-44	0.50	0.69	0.21	1.01	0.32	0.55	3.28	0.62	T	1.30	0.20	0.12	0.00	2.24	5.52
1944-45	0.37	0.00	T	0.30	0.30	1.00	1.97	0.61	0.03	0.62	0.55	0.78	0.35	2.94	4.91
1945-46	1.32	0.17	0.70	0.37	0.00	0.63	3.19	0.17	0.81	0.00	0.13	0.74	T	1.85	5.04
1946-47	0.90	1.48	0.20	T	0.10	T	2.68	0.46	0.97	1.90	0.58	5.47	0.00	9.38	12.06
1947-48	0.79	0.50	1.14	T	0.85	0.50	3.78	T	T	0.42	0.29	0.80	0.07	1.58	5.36
1948-49	1.47	T	0.80	1.70	0.96	0.55	5.48	0.11	1.06	0.38	1.03	0.79	0.47	3.84	9.32
1949-50	0.71	T	1.38	0.20	0.03	T	2.32	T	0.21	0.00	1.94	0.78	0.30	3.23	5.55
1950-51	0.00	0.59	0.52	0.22	0.17	0.34	1.79	0.16	1.95	0.14	0.10	2.54	0.36	5.25	7.04

Precipitation by Months at Emery, Utah (cont.)

	OCT	NOV	DEC	JAN	FEB	MAR	WINTER	APR	MAY	JUN	JUL	AUG	SEP	SUMMER	YEAR
1951-52	0.97	1.04	1.08	0.76	0.05	1.37	5.27	0.16	0.05	1.25	0.20	0.62	1.41	3.69	8.96
1952-53	0.00	0.48	0.73	0.22	0.06	0.35	1.84	0.27	0.14	0.46	0.87	1.49	0.00	3.23	5.07
1953-54	1.29	0.47	0.48	0.47	0.00	0.65	3.36	0.59	1.03	0.83	0.45	0.51	1.91	5.32	8.68
1954-55	0.14	0.35	0.67	0.61	1.12	0.00	2.89	0.00	0.20	0.47	0.31	2.18	0.47	3.63	6.52
1955-56	0.00	0.16	0.61	1.11	0.21	0.00	2.09	0.53	0.21	0.03	0.20	0.12	0.39	1.58	3.67
1956-57	0.10	0.00	0.62	1.47	0.27	0.11	2.57	1.56	2.56	0.47	0.83	1.34	0.00	6.76	9.33
1957-58	3.17	1.50	0.28	0.25	0.45	0.93	4.58	0.31	0.57	0.08	0.47	0.42	1.43	3.28	7.86
1958-59	0.16	0.77	0.00	0.10	1.22	0.00	2.25	0.26	0.15	0.25	0.30	1.41	0.78	4.15	6.40
1959-60	0.46	0.59	0.55	0.67	1.11	0.70	4.08	0.18	0.28	0.11	0.33	0.05	1.52	2.47	6.55
1960-61	2.64	0.58	0.00	0.14	0.09	1.50	4.95	0.66	0.33	0.00	0.37	1.92	2.81	6.09	11.04
1961-62	1.16	0.09	0.54	0.18	1.42	0.12	3.51	0.09	0.81	0.12	0.20	0.04	0.78	1.95	4.46
1962-63	1.02	0.09	0.07	0.50	0.00	0.34	2.02	0.54	0.16	0.47	0.27	2.47	2.06	5.97	7.99
1963-64	0.23	0.20	0.00	0.00	0.00	0.40	0.83	0.65	1.37	0.36	0.68	0.53	0.00	3.59	4.48
1964-65	0.00	0.25	1.04	0.06	0.49	0.51	2.35	0.65	1.27	1.93	0.68	1.17	1.15	6.85	9.20
1965-66	0.03	1.10	0.68	T	0.79	----	----	----	----	----	----	0.94	----	----	----
1966-67	----	----	0.86	0.38	0.05	0.19	----	0.24	0.82	1.45	0.20	0.90	0.50	4.11	----
1967-68	0.01	0.34	1.59	0.29	0.60	0.24	3.07	0.48	0.78	0.74	2.07	1.91	0.18	6.06	9.13
1968-69	0.68	0.00	0.56	1.19	0.36	0.28	3.07	0.16	1.02	3.34	4.26	0.91	2.25	11.94	15.01
1969-70	0.68	0.21	0.04	0.47	0.11	0.62	2.13	0.41	T	0.72	2.10	0.46	0.56	4.25	8.38
1970-71	1.36	0.26	0.89	0.23	1.04	0.05	3.83	0.04	0.82	0.14	0.85	0.91	0.01	2.77	6.60
1971-72	2.94	0.28	0.85	0.07	0.05	0.05	4.24	0.17	0.01	0.81	0.28	0.44	0.85	2.56	6.80
1972-73	2.26	0.99	0.20	0.39	----	----	----	----	----	----	----	0.30	----	----	----
1973-74	----	0.19	0.65	1.38	0.06	0.60	----	0.33	0.00	0.00	0.80	0.84	0.28	2.25	----
1974-75	1.84	0.51	0.16	0.46	0.91	0.47	4.35	0.26	0.34	0.71	1.76	0.41	0.62	4.10	8.45
1975-76	0.30	0.35	0.02	0.25	0.26	0.02	1.20	1.05	2.33	0.00	1.19	1.28	0.46	6.31	7.51
1976-77	0.54	0.00	T	0.32	0.20	0.00	1.06	0.16	1.21	0.73	1.17	1.13	0.45	4.85	5.91
1977-78	0.49	0.02	0.40	1.48	1.67										

APPENDIX 2

Snow Depth and Water Content - Muddy Creek

Snow Depth and Water Content (Inches) in Late March or Early April 1945-1978, at Two Snow Courses in Headwaters of Muddy Creek:

Black's Fork, No. 11K14, 39°01'N, 111°27'W, 9200 ft. = 2800 m. MSL
Dill's Camp, No. 11K15, 39°02'N, 111°27'W, 9200 ft. = 2800 m. MSL

			Black's Fork		Dill's Camp	
Year	Month	Date	Depth	Water	Depth	Water
1945	April	12	44	13.2	41	14.3
1946	April	9	43	12.9		
1947	April	12	44	17.5	32	12.7
1948	April					
1949	April	15	50	20.0	43	16.7
1950	April	4	46	18.9	35	14.2
1951	April	4	42	16.4	35	13.7
1952	April					
1953	April	1	44	15.8	37	12.8
1954	March	31	38	11.3	32	9.8
1955	April	5	48	14.8		
1956	April	5	36	11.9	35	11.4
1957	March	30	47	15.9	46	15.4
1958	April	1	62	19.9	58	18.1
1959	March	23	33	11.1	27	8.4
1960	March	31	36	13.2	32	11.4
1961	March	24	31	8.6	25	6.6
1962	March	20	56	18.1	51	16.4
1963	March	19	38	10.1	38	10.3
1964	March	20	26	5.8	24	4.9
1965	March	22	45	15.7	42	14.4
1966	March	22	39	11.1	34	8.8
1967	March	27	29	9.8	26	8.4
1968	March	28	47	16.7	46	15.8
1969	March	21	55	20.6	54	19.3
1970	March	26	50	16.2	46	14.2
1971	April	1	38	12.8	38	12.7
1972	March	28	22	8.5	20	7.5
1973	March	27	53	15.7	50	14.4
1974	March	26	40	15.1	40	14.8
1975	April	1	53	15.9	47	13.1
1976	April	1	31	10.3	28	7.8
1977	April	1	19	5.4	18	4.7
1978	April	1	31	9.8	51	20.3

Extracted from pp. 223-224 of:
Whaley, Bob L., and David C. McWhirter, "Summary of Snow Survey Measurements for Utah, 1924-1947." Salt Lake City, Soil Conservation Service, USDA, and State Engineer of Utah, xxii + 299 pp. (1975-78 data obtained by correspondence).

APPENDIX 3

Daily Rainfall Probabilities
1931 - 1961

EMERY, UTAH 422484

PROBABILITY THAT A GIVEN DAY WILL BE WET OR DRY

P(WET)=1 - P(DRY) P(WET/DRY)=1 - P(DRY/DRY) P(WET/WET)=1 - P(DRY/WET)

PERIOD	WET ≥ 0.01 INCHES			WET ≥ 0.05 INCHES			WET ≥ 0.10 INCHES		
BEGINS	DRY	DRY/DRY	DRY/WET	DRY	DRY/DRY	DRY/WET	DRY	DRY/DRY	DRY/WET
MAR 01	92	94	69	93	94	66	96	96	99*
MAR 08	92	92	88	94	93	99*	94	94	99*
MAR 15	92	93	73	92	93	74	95	96	94
MAR 22	95	96	75	96	96	99*	97	97	99*
MAR 29	94	95	78	94	95	80	95	96	90
APR 05	94	96	69	94	96	74	95	97	67
APR 12	98	99	94	99	99	93	99	99*	94
APR 19	94	95	94	95	95	99*	96	96	99*
APR 26	89	92	68	90	91	82	92	92	88
MAY 03	91	94	54	92	96	50	95	96	75
MAY 10	89	92	67	91	93	67	93	94	74
MAY 17	90	91	79	92	93	75	94	95	72
MAY 24	93	94	71	94	96	64	95	96	64
MAY 31	91	92	78	91	93	75	94	94	90
JUN 07	96	97	86	97	98	86	97	98	83
JUN 14	94	95	86	95	95	90	97	97	99*
JUN 21	94	95	88	95	96	85	96	97	92
JUN 28	93	94	90	95	96	88	96	96	94
JUL 05	86	91	38	87	92	37	89	92	46
JUL 12	89	92	77	90	93	74	93	95	71
JUL 19	88	90	84	89	90	82	94	95	88
JUL 26	84	89	61	86	89	63	89	91	67
AUG 02	85	88	69	88	89	83	90	91	81
AUG 09	84	87	63	85	88	63	87	89	69
AUG 16	85	89	66	86	89	72	88	91	61
AUG 23	83	87	69	85	86	78	88	91	74
AUG 30	90	93	60	91	94	71	92	94	77
SEP 06	88	91	61	88	92	61	89	92	59
SEP 13	94	96	64	96	97	66	97	98	96
SEP 20	91	92	81	92	94	78	94	95	78
SEP 27	91	92	73	92	92	87	92	92	94
OCT 04	94	95	75	94	95	75	94	96	75
OCT 11	90	92	74	90	92	74	91	92	79
OCT 18	92	95	55	92	95	55	92	95	55
OCT 25	93	93	78	93	94	78	94	95	83
NOV 01	95	97	61	95	97	61	95	97	64
NOV 08	95	96	90	95	96	90	95	96	88
NOV 15	94	95	81	94	96	81	95	96	81
NOV 22	97	98	90	97	98	90	97	98	90
NOV 29	89	92	54	90	93	54	92	94	68
DEC 06	93	93	87	93	94	85	93	94	83
DEC 13	95	96	83	96	96	83	96	97	83
DEC 20	91	93	65	91	94	64	93	95	62
DEC 27	89	90	82	89	90	82	92	92	93
JAN 03	92	93	87	93	93	89	96	96	95
JAN 10	91	95	40	91	95	38	92	97	33
JAN 17	87	88	74	88	89	74	89	90	81
JAN 24	91	93	78	92	93	84	93	94	82
JAN 31	93	93	90	94	94	99*	96	96	99*
FEB 07	92	92	97	92	92	97	94	94	96
FEB 14	95	95	93	95	95	93	96	96	99*
FEB 21	92	93	78	94	94	83	95	96	83

Conditional and unconitional probablities of daily rainfall amounts for each week of the Farmer's year, based on data from March 1931 through February 1961. (From Heermann, Dale F., Morris D. Finkner, and Edward A. Hiler: "Probability of Sequences of Wet and Dry Days for Eleven Western States and Texas." Technical Bulletin 117, Colorado State University Experiment Station, 1971, 303 pp.)

APPENDIX 4

Precipitation Means and Probabilities

EMERY, UTAH 422484

PRECIPITATION MEANS AND PROBABILITIES FOR 1-WEEK PERIODS

PERIOD BEGINS	MEAN PCPN	PROB 0-T	PROBABILITY (PERCENT) OF RECEIVING AT LEAST THE FOLLOWING AMOUNTS (IN) OF PRECIPITATION 0.06	0.10	0.20	0.40	0.60	0.80	1.00	1.40	2.00
MAR 01	.10	65	31	28	20	9	4	2	1		
MAR 08	.12	62	35	31	22	9	4	1	1		
MAR 15	.10	62	35	32	22	8	3	1			
MAR 22	.10	68	30	27	19	7	2	1			
MAR 29	.07	72	27	25	17	6	2	1			
APR 05	.11	76	22	20	14	6	3	2	1		
APR 12	.03	78	18	16	11	5	2	1			
APR 19	.08	67	29	26	17	7	2	1			
APR 26	.16	58	39	35	24	10	4	1			
MAY 03	.09	64	33	30	22	11	6	3	2		
MAY 10	.17	67	30	27	22	14	9	5	3	1	
MAY 17	.17	62	33	30	24	15	9	6	3	1	
MAY 24	.14	60	35	32	25	14	8	4	2	1	
MAY 31	.16	64	32	30	23	13	7	3	2		
JUN 07	.07	72	25	23	17	8	4	2	1		
JUN 14	.07	71	26	24	17	7	3	2	1		
JUN 21	.15	65	31	28	21	10	5	3	2		
JUN 28	.10	63	34	31	24	14	9	5	3	1	
JUL 05	.27	60	38	35	28	17	11	7	5	2	1
JUL 12	.12	56	41	37	27	13	7	4	2	1	
JUL 19	.12	50	45	41	30	13	4	1			
JUL 26	.22	44	52	49	39	20	9	4	2	1	
AUG 02	.27	43	54	51	42	25	14	8	4	2	
AUG 09	.26	43	54	51	42	28	18	11	7	3	1
AUG 16	.36	40	56	53	44	30	19	12	8	3	1
AUG 23	.27	44	52	48	40	26	16	10	6	2	1
AUG 30	.20	54	42	40	33	22	14	9	6	2	
SEP 06	.28	63	35	34	29	21	14	9	6	3	1
SEP 13	.12	68	31	29	25	17	11	7	4	2	
SEP 20	.17	63	34	31	24	13	7	4	2	1	
SEP 27	.11	61	36	33	24	11	6	3	2	1	
OCT 04	.15	67	31	29	23	15	10	6	4	1	
OCT 11	.24	69	30	29	27	23	17	11	6	2	
OCT 18	.22	69	31	30	29	23	16	10	6	2	
OCT 25	.15	74	26	25	24	17	11	6	3	1	
NOV 01	.10	80	19	19	17	12	7	4	2	1	
NOV 08	.08	77	21	19	15	9	5	3	2		
NOV 15	.10	73	25	22	16	8	4	2	1		
NOV 22	.07	72	26	24	19	10	5	2	1		
NOV 29	.18	64	34	32	24	11	6	3	1		
DEC 06	.10	63	36	33	23	8	3	2	1		
DEC 13	.07	68	29	27	19	6	2	1			
DEC 20	.10	65	33	30	22	9	3	1			
DEC 27	.14	59	39	35	24	9	3	1			
JAN 03	.07	62	35	31	20	6	2	1			
JAN 10	.11	61	35	31	22	9	4	2	1		
JAN 17	.18	53	43	40	30	14	6	2	1		
JAN 24	.15	53	44	40	30	12	4	1			
JAN 31	.09	58	37	32	22	8	3	1			
FEB 07	.10	63	33	28	18	6	2	1			
FEB 14	.07	64	33	30	18	5	1				
FEB 21	.10	64	32	29	18	6	2	1			

EMERY, UTAH 422484

PRECIPITATION MEANS AND PROBABILITIES FOR 2-WEEK PERIODS

PERIOD BEGINS	MEAN PCPN	PROB 0-T	PROBABILITY (PERCENT) OF RECEIVING AT LEAST THE FOLLOWING AMOUNTS (IN) OF PRECIPITATION 0.06	0.10	0.20	0.40	0.60	1.00	1.40	2.00	4.00
MAR 01	.23	43	51	47	37	21	12	4	1		
MAR 15	.20	43	54	50	38	18	8	1			
MAR 29	.17	60	38	36	29	16	8	2			
APR 12	.11	53	41	37	27	13	6	1			
APR 26	.25	38	58	54	43	24	12	3	1		
MAY 10	.34	43	51	47	39	27	19	9	4	1	
MAY 24	.30	42	54	50	41	27	17	7	3	1	
JUN 07	.14	51	46	42	33	17	9	2	1		
JUN 21	.25	41	54	50	40	26	16	7	3	1	
JUL 05	.40	38	59	55	46	32	21	10	5	2	
JUL 19	.34	17	79	74	60	35	19	5	1		
AUG 02	.53	16	82	79	70	52	36	16	7	2	
AUG 16	.63	20	77	74	66	51	38	20	10	4	
AUG 30	.47	38	61	59	53	40	30	15	8	3	
SEP 13	.29	45	52	50	43	30	20	9	4	1	
SEP 27	.26	41	56	52	44	28	18	7	3	1	
OCT 11	.46	50	49	49	46	37	29	16	8	3	
OCT 25	.25	61	38	37	34	26	18	8	3	1	
NOV 08	.19	53	43	40	31	17	9	3	1		
NOV 22	.24	44	53	49	39	23	12	3	1		
DEC 06	.17	45	53	50	39	19	8	1			
DEC 20	.24	43	55	52	41	22	10	2			
JAN 03	.18	38	57	52	39	20	10	2			
JAN 17	.32	33	63	60	49	29	16	5	1		
JAN 31	.19	40	56	51	38	18	8	1			
FEB 14	.17	43	54	50	37	16	6	1			

EMERY, UTAH 422484

PRECIPITATION MEANS AND PROBABILITIES FOR 3-WEEK PERIODS

PERIOD BEGINS	MEAN PCPN	PROB 0-T	PROBABILITY (PERCENT) OF RECEIVING AT LEAST THE FOLLOWING AMOUNTS (IN) OF PRECIPITATION 0.06	0.10	0.20	0.40	0.60	1.00	1.40	2.00	4.00
MAR 01	.33	32	64	60	50	32	20	7	3		
MAR 22	.27	43	56	54	45	26	14	3	1		
APR 12	.27	33	61	56	44	26	14	4	1		
MAY 03	.43	28	67	63	54	38	27	13	6	2	
MAY 24	.37	31	64	60	51	35	23	10	5	1	
JUN 14	.33	28	65	61	50	33	22	10	4	1	
JUL 05	.52	22	74	71	62	45	31	15	8	3	
JUL 26	.75	3	96	94	87	69	51	26	12	4	
AUG 16	.82	12	87	86	80	67	54	32	18	7	
SEP 06	.56	29	69	67	61	47	35	18	9	3	
SEP 27	.50	29	69	67	61	47	34	17	8	3	
OCT 18	.48	47	52	51	47	39	31	18	10	4	
NOV 08	.25	39	58	54	45	28	17	5	2		
NOV 29	.35	28	70	67	56	34	18	5	1		
DEC 20	.32	29	67	63	52	32	18	6	2		
JAN 10	.43	25	73	70	61	42	26	9	3		
JAN 31	.26	28	68	63	50	28	14	4	1		

Precipitation maens and probabilities for periods of 1, 2, and 3 weeks of Farmer's year, based on data from March 1931 through February 1961. (From Gifford, Richard O., Gaylen L. Ashcroft, and Marvin D. Magnuson: "Probability of Selected Precipitation Amounts in the Western United States." Publication T-8, University of Nevada Agricultural Experiment Station, unpaged, 1967.)

APPENDIX 5

Hourly Wind and Temperature Observations SW of Emery

Air movement was recorded continuously for almost ten months, from 1500 MST on 2 November, 1972 to noon on 23 August 1973, at a site 6,200 feet (1,890 m) MSL, 1 mile SE of the village of Emery and 2 miles north of the Emery EMRIA site. Temperature and relative humidity also were recorded there, beginning at 1300 MST on 25 December, 1972. Hourly values from this site are given in this Appendix.

The wind instruments, manufactured by R.M. Young Co., were on a tower 33 feet (10 m) above the flat rangeland; a hygrothermograph (Epic Co.) was operated in a standard instrument shelter 5 feet (1.5 m) above ground. From the charts, the air temperature and relative humidity for each hour were extracted and entered on punchcards, along with five measures of wind: average direction (subjective average, in degrees colckwise from true north) and speed (miles per hour) for the 10 minutes ending on the hour, and speed and direction also for the full 60 minutes since the last hour; the total directional variation of the wind during the hour was extracted at first but soon ignored.

The station was operated, along with two other 20 miles farther north, by North American Weather Consultants of Goleta, CA, as part of a detailed site study for Utah Power and Light Co. in planning for a new coal-fired power plant, eventually built just southeast of Castlegate, 20 miles north of Emery. From a copy of the data tape, purchased from NEWC with the permission of UPL, the data were organized into three tables: hourly wind direction and speed, 10-minute wind direction and speed, and hourly temperature. The relative humidity seemed to have insufficient value for extraction; some of the temperature readings are questionable, but are presented as they appear on the data tape.

The wind data are presented as recorded, without analysis, but the temperatures were subjected to a detailed computer program which gives characteristics for each day and also for each hour of each month. In addition, the hourly temperatures are arrayed in a frequency diagram, with cumulative totals of occurrence for four 6-hour periods of the day.

Unfortunately, only a few comparisons can be made between these hourly temperatures and the daily observations at the long-term climate station at Emery, which was closed during most of the time of operation of the automatic station. Merlin H. Christiansen, observer since 1960, became "too busy" and terminated his appointment on 17 July, 1973; his observations had been too irregular for publication in December 1972, resumed for most of January, but ceased thereafter. Dandy M. Anderson became the new observer, and instruments were moved 200 ft. south to the rear of the postoffice. But he was unable to maintain the daily schedule and only one month, August 1973, of his data was published. On 6 November, 1973, Elbert T. Blackburn assumed the post moving the instruments 0.3 mile southwest of the postoffice, and maintained a useful record for more than five years.

During the two months of simultaneous operation, January and August, the automatic station, on flat bare rangeland, appears to have been cooler at night and warmer in the daytime than the village station, so that its "average" temperature was about the same. When only maximum and minimum temperatures are obtained their average, technically the midrange, is used as the average, defined internationally as the average of 24 equally-spaced observations. At the two Emery stations, values for the two months were:

	Maximum		Minimum		"Average"		
	COOP	AUTO	COOP	AUTO	COOP	AUTO	24HR
January	30.3	27.1	3.4	7.4	16.9	17.2	16.2
August	86.2	84.1	53.7	55.7	70.0	70.1	67.4

The following temperature tables give, for each day, both the midrange (MR) and the 24-hour mean (MN), as well as the range (RG), the European style average (3H) of the temperatures at 0700, 1400, and 2100 taken twice (i.e., the 9 p.m. value is given double weight), and the standard deviation (SD). For each hour during a month, three values are given: the mean (MN), the standard deviation (SD), and interdiurnal variation (IV), the mean absolute successive differences, a measure of day-to-day change.

WIND DIRECTION AND SPEED (MPH), HOURLY AVERAGES, AT EMERY, UT, NOVEMBER 1972

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1																								
2																		280	265	000	260	275	230	000
																		09	07	00	07	11	10	00
3	275	350	340	310	265	255	340	010	000	110	150	170	150	170	180	185	160	120	000	305	290	000	350	015
	10	03	03	04	03	01	05	01	00	01	03	03	03	03	05	05	04	04	00	03	06	00	03	02
4	000	360	000	350	230	330	360	225	000	355	030	075	100	105	090	350	010	005	010	355	015	350	030	345
	00	01	00	02	02	01	04	04	00	03	05	03	05	04	05	04	05	05	04	06	06	04	03	05
5	240	295	040	210	210	255	230	245	260	245	245	245	245	250	255	255	250	250	250	250	290	230	240	115
	02	04	02	02	06	13	13	10	09	16	14	21	19	10	17	14	16	18	15	14	04	06	06	02
6	280	280	255	000	250	260	270	320	285	275	275	240	080	110	170	090	000	125	100	290	285	325	350	200
	05	06	07	00	14	16	11	03	09	07	02	02	05	06	06	04	00	02	02	07	07	03	02	02
7	000	000	000	000	200	000	270	210	355	330	015	035	050	020	005	015	085	335	005	355	340	350	015	340
	00	00	00	00	02	00	02	01	01	01	02	02	05	06	08	06	07	03	02	06	05	05	04	04
8	335	345	335	275	270	000	260	000	170	050	170	140	020	200	160	080	260	295	310	265	260	255	290	365
	04	03	03	02	04	00	03	00	01	02	05	01	01	13	08	05	12	10	05	05	12	12	05	04
9	295	278	285	260	270	305	265	275	270	250	255	160	160	140	070	145	140	100	130	280	275	300	350	265
	13	07	03	07	08	06	05	11	10	11	07	05	06	05	04	06	04	04	01	08	10	06	04	02
10	360	000	005	340	305	350	355	015	345	055	020	045	020	030	020	110	080	005	005	010	020	010	005	355
	05	00	01	02	03	06	03	04	04	02	10	07	06	06	04	06	03	09	08	09	08	03	06	03
11	345	310	350	115	345	040	040	010	005	015	180	105	070	150	000	160	140	145	360	090	010	040	015	015
	05	03	07	01	06	02	04	05	03	01	01	03	02	03	00	10	06	05	06	04	08	10	12	15
12	005	005	015	010	005	350	210	240	270	210	275	290	255	280	275	095	290	265	265	255	260	250	260	045
	13	12	13	16	12	06	02	02	05	03	04	02	07	08	10	05	11	12	10	11	10	09	08	01
13	280	340	030	005	355	000	330	230	165	090	150	115	125	255	105	135	170	260	000	000	330	000	000	000
	06	02	02	05	02	00	01	01	04	02	03	08	05	04	02	05	05	01	00	00	04	00	00	00
14	000	055	105	095	360	005	025	015	025	035	010	060	070	100	120	145	215	270	020	360	360	005	010	005
	00	02	01	00	02	05	05	08	08	08	07	03	04	04	08	05	02	02	05	03	03	06	07	06
15	035	361	210	165	215	130	215	195	210	200	200	130	200	140	200	170	210	195	210	190	240	275	270	240
	03	02	01	04	01	02	02	02	01	03	02	03	05	04	07	03	02	04	05	03	01	02	01	03
16	300	340	000	325	040	360	300	360	245	000	100	070	145	130	270	325	340	330	020	070	010	070	030	030
	03	02	00	02	02	04	01	03	03	00	01	01	07	08	01	02	05	04	05	02	06	06	05	06
17	010	020	025	025	030	015	020	030	025	030	035	035	030	055	020	040	060	360	005	295	275	000	030	030
	05	07	11	09	08	13	10	08	07	04	06	06	08	08	05	04	04	03	03	03	04	00	02	01
HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	360	345	005	305	360	345	275	275	270	245	260	260	260	255	250	260	250	255	215	300	015	195	285	185
	05	01	04	02	04	03	05	10	09	09	10	16	13	14	10	09	11	04	03	05	02	02	05	02
19	050	015	000	360	015	150	000	000	195	250	000	080	135	240	360	320	025	010	025	025	035	250	345	360
	03	01	00	05	02	01	00	00	01	03	00	02	03	01	01	01	05	07	06	06	07	02	02	03
20	010	090	010	280	230	230	230	260	255	250	285	270	330	265	275	275	275	275	285	270	250	270	270	265
	03	02	03	10	14	05	13	12	09	10	07	15	09	16	17	15	12	15	11	10	06	08	13	10
21	275	280	270	285	285	300	325	335	050	010	295	265	165	360	045	280	345	310	230	350	305	320	000	260
	12	12	13	13	14	08	07	07	02	01	05	05	02	02	05	05	04	04	04	03	05	03	00	05
22	265	360	000	015	330	360	360	295	120	190	200	050	040	015	030	000	345	330	315	245	260	340	290	000
	03	04	00	02	02	03	03	01	01	03	03	04	05	03	03	00	03	01	05	06	05	04	03	00
23	300	005	345	025	000	030	245	000	000	000	195	195	205	180	230	210	235	360	000	245	010	000	000	320
	05	02	04	02	00	00	01	00	00	00	03	03	03	04	03	03	02	02	00	01	02	00	00	07
24	295	275	270	270	275	270	330	285	280	240	270	265	260	270	260	250	250	290	310	360	335	360	360	275
	09	15	09	11	20	17	05	22	21	15	16	15	09	07	09	12	13	19	05	09	05	05	05	10
25	270	265	265	265	265	300	335	350	210	315		050	295	295	085	255	250	265	265	265	265	265	265	265
	10	18	16	06	12	04	05	01	13	05		05	10	14	05	08	13	18	18	20	24	18	17	15
26	260	015	235	205	345	360	010	015	025	010	030	115	280	295	275	265	280	275	290	235	265	275	275	250
	17	05	17	13	08	05	05	07	10	07	07	06	18	12	19	25	20	20	20	15	19	36	28	18
27	260	290	295	295	280	275	280	280	300	265	275	285	325	280	285	280	275	275	280	270	300	005	005	020
	13	12	25	38	43	45	43	38	23	16	22	18	07	10	12	18	13	07	05	10	06	09	07	05
28	355	350	355	265	310	005	000	340	035	030	175	095	125	185	170	205	120	035	005	010	015	030	040	035
	04	05	04	03	03	04	00	01	03	00	02	04	03	05	06	04	03	08	04	10	10	12	05	05
29	145	265	270	280	265	260	250	265	275	265	265	250	220	230	250	025	025	360	015	150	340	355	005	310
	04	08	14	13	12	16	17	18	16	17	22	16	06	10	12	13	10	07	05	04	10	10	09	05
30	055	345	240	260	280	250	255	360	035	015	070	260	235	235	255	150	005	355	290	045	020	040	015	015
	05	03	10	15	10	15	14	10	09	06	06	15	14	16	15	03	06	05	14	03	04	03	05	05

WIND DIRECTION AND SPEED (MPH), HOURLY AVERAGES, AT EMERY, UT, DECEMBER 1972

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	005	355	350	355	360	345	010	010	010	000	190	180	100	135	085	065	015	360	360	355	000	000	355	355
	05	05	08	12	11	10	07	08	07	00	05	06	05	03	04	05	06	06	05	05	00	00	04	02
2	000	220	310	360	005	260	000	005	225	155	045	035	025	055	030	040	015	005	355	355	345	360	360	295
	00	05	02	05	05	05	00	04	02	03	10	05	05	05	05	04	06	05	06	06	05	07	07	04
3	360	005	005	350	000	345	285	250	000	045	075	190	100	100	120	105	140	360	355	345	350	275	220	245
	05	04	05	04	00	05	03	02	00	01	03	06	05	05	05	05	03	06	07	08	08	03	05	08
4	270	000	105	000	030	085	360	020	180	175	205	215	265	255	270	275	265	265	265	230	250	260	260	275
	03	00	04	00	04	02	02	01	20	17	07	10	16	16	16	13	11	15	15	07	14	15	13	13
5	280	270	290	285	275	270	265	280	265	260	250	255	260	270	250	255	285	270	280	315	275	345	085	235
	15	13	12	10	15	11	13	18	12	13	13	12	15	18	18	18	11	10	10	07	09	04	03	03
6	240	000	020	345	360	005	360	005	010	025	250	205	125	310	290	290	360	010	360	355	355	105	360	035
	03	10	05	06	03	05	05	06	05	05	04	05	03	05	05	04	10	09	08	04	05	03	05	06
7	355	000	240	140	205	205	225	000	145	175	170	205	260	275	265	265	275	270	270	295	355	020	025	010
	05	00	04	02	03	02	02	00	02	03	04	13	18	20	16	16	15	12	05	07	04	11	12	06
8	355	005	325	205	335	355	355	000	070	235	205	210	215	245	190	175	145	230	145	160	305	000	300	265
	08	03	01	04	03	04	05	03	03	04	16	23	23	22	18	15	11	04	03	10	03	00	01	15
9	296	306	265	270	240	265	175	280	250	240	270	260	270	265	265	275	275	275	275	280	305	350	345	025
	12	13	13	20	15	13	08	23	25	25	24	25	22	21	21	19	16	16	16	14	10	04	04	01
10	275	265	340	000	030	360	270	000	000	025	015	040	025	025	025	025	035	015	025	360	025	000	195	330
	07	05	05	00	01	01	04	03	00	02	05	09	10	10	12	10	10	09	06	05	02	00	03	01
11	340	315	000	000	000	000	000	145	000	000	325	265	265	265	270	270	265	270	270	270	270	275	275	280
	02	02	00	00	00	00	00	01	00	00	02	10	12	13	16	19	21	23	23	22	20	20	20	17
12	010	360	355	015	030	000	010	355	360	000	340	040	035	030	035	015	015	025	010	025	360	005	360	355
	06	06	08	04	02	00	03	03	02	00	05	04	06	05	05	08	08	08	05	05	03	05	05	03
13	360	355	350	215	000	155	000	115	235	175	025	030	025	050	075	025	325	275	270	270	275	265	295	240
	05	05	05	03	00	02	00	01	01	01	03	08	06	04	01	05	04	13	16	15	15	13	12	05
14	345	340	295	355	270	290	000	170	155	175	065	040	060	050	055	015	020	340	000	360	360	015	000	205
	06	04	05	07	03	01	00	01	02	02	03	04	04	05	04	07	07	05	00	03	06	07	00	04
15	005	275	305	010	000	000	000	000	120	180	145	155	170	155	165	175	065	005	355	360	340	000	010	285
	05	01	02	02	00	00	00	00	01	01	02	03	05	05	04	05	03	05	06	03	03	00	01	02
16	000	210	000	025	025	000	010	240	175	000	075	095	145	120	015	025	355	340	000	360	160	000	000	025
	00	01	00	02	02	00	00	03	02	00	01	02	04	04	09	04	05	04	00	01	03	00	00	03

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
17	350	000	270	000	000	225	000	000	000	115	060	095	070	070	075	025	355	000	330	055	005	320	000	325
	03	00	03	00	00	03	00	00	00	01	01	05	02	03	03	03	03	03	02	01	01	03	00	02
18	000	040	025	060	005	345	025	325	180	205	090	025	025	015	010	355	355	025	355	005	005	235	015	355
	00	02	02	02	04	01	02	01	03	02	04	10	13	11	07	03	05	02	03	05	03	01	02	07
19	005	005	020	355	235	190	115	005	015	010	055	035	020	025	010	055	005	360	360	025	010	040	035	015
	05	07	03	03	02	09	02	06	06	03	03	05	04	03	01	02	08	05	05	05	05	05	05	08
20	035	305	295	295	315	325	310	355	085	310	265	265	240	250	265	260	265	265	255	270	260	260	280	230
	05	15	19	30	20	15	07	08	01	10	09	16	14	17	20	15	06	11	12	08	15	18	10	05
21	295	015	005	015	010	065	035			000	020	055	055	085	100	100	025	360	360	010	355	225	355	340
	07	04	06	07	06	02	02			00	07	03	03	03	03	03	08	07	07	05	05	05	05	03
22	355	270	235	010	275	040	000	000	350		000	335	040	045	045	070	040	040	025	355	005	125	030	190
	01	02	02	01	02	01	00	00	01		00	05	07	08	09	03	09	02	09	05	04	06	02	04
23	280	285	295	295	290	295	270	290	290	025	000	030	135	110	175	180	100	360	360	030	000	000	280	010
	17	20	15	20	14	20	16	10	08	03	00	02	03	05	04	05	04	05	07	00	00	00	03	04
24	030	015	025	005	010	010	000	360	025	010	025	015	040	025	025	055	030	040	025	355	330	260	250	250
	04	07	04	06	04	05	02	04	02	05	03	08	07	01	04	02	04	03	02	00	05	03	06	09
25	270	190	310	260	000	325	275	355	325	030	235	100	160	145	185	275	270	335	295	290	275	280	325	295
	12	07	15	10	00	08	05	05	07	02	03	05	03	03	05	10	10	08	12	15	10	11	04	04
26	180	350	360	295	000	005	040	280	215	030	185	180	180	175	145	115	120	050	355	360	345	000	000	000
	02	05	05	03	00	03	01	02	03	00	01	02	04	05	03	02	03	03	04	03	03	00	00	00
27	000	000	000	000	000		000	300	000	000	190	145	175	130	145	090	025	360	360	355	355	035	345	325
	00	00	00	00	00	01	00	00	00	00	02	01	03	01	04	02	07	07	06	03	02	01	01	02
28	135	350	000	025	005	350	025	360	010	360	010	000	190	000	030	035	005	010	020	315	045	315	025	285
	02	04	00	02	03	01	04	03	03	02	02	00	03	00	03	04	07	08	05	01	04	02	04	19
29	285	275	295	280	280	275	270	265	280	280	275	280	280	275	280	275	280	280	275	285	285	290	285	280
	20	22	20	24	28	22	22	15	26	27	25	20	23	23	23	28	23	22	19	20	25	25	23	18
30	275	255	280	275	275	270	270	270	295	270	265	270	270	265	270	280	280	290	285	285	275	275	275	295
	16	17	16	15	13	18	15	15	12	16	16	19	22	20	24	27	19	22	21	16	15	15	12	10

WIND DIRECTION AND SPEED (MPH), HORLY AVERAGES, AT EMERY, UT, JANUARY 1973

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	275	310	145	255	270	260	000	195	290	190	220	060	050	025	020	040	030	360	325	330	315	360	010	190
	10	06	02	03	05	05	00	02	06	03	03	03	12	08	05	04	07	04	10	07	05	03	02	01
2	270	050	000	205	000	360	000	025	255	175	165	115	175	160	175	130	030	025	005	005	360	005	000	270
	03	03	00	02	00	03	00	01	03	01	03	03	03	04	03	04	08	07	07	06	05	03	00	03
3	060	355	000	000	260	020	310	000	000	160	055	265	120	100	120	030	030	030	020	015	030	360	360	345
	01	01	00	00	06	00	02	00	00	02	03	02	04	05	05	04	09	09	05	05	04	05	04	05
4	355	340	100	000	025	015	275	215	355	000	125	235	000	055	025	355	335	290	280	280	265	280	275	275
	05	02	01	00	02	02	03	03	02	00	03	01	00	03	06	05	05	09	10	14	12	12	10	10
5	270	195	265	275	360	305	120	360	355	300	025	205	160	115	150	115	110	000	360	345	360	360	360	345
	11	02	14	07	03	03	03	05	05	02	04	04	02	07	04	05	01	00	05	05	03	03	04	04
6	335	350	310	020	280	000	000	235	255	340	040	025	065	160	000	180	265	275	260	030	310	000	000	000
	03	03	01	01	04	00	00	02	01	05	02	04	03	04	00	03	04	03	03	00	02	00	00	00
7	245	120	000	000	000	005	300	275	080	000	210	155	175	115	215	235	120	010	360	360	360	000	190	010
	03	00	00	00	00	02	01	02	01	00	04	03	02	03	05	03	03	04	05	03	04	00	00	03
8	265	205	005	360	000	035	020	000	000	000	195	050	030	025	035	040	030	005	360	360	000	360	360	355
	03	02	02	03	00	01	01	00	00	00	02	05	10	08	05	07	07	07	00	04	00	03	02	03
9	000	000	035	000	000	240	280	000	000	000	000	325	040	030	030	020	010	355	360	000	000	330	000	270
	00	00	00	00	00	02	02	00	00	00	00	04	06	06	05	06	04	03	03	00	00	01	00	01
10	055	000	000	000	265	235	000	000	255	000	230	155	120	195	275	275	275	280	295	275	265	360	015	010
	11	00	00	00	01	03	00	00	01	00	03	02	02	04	18	14	13	12	10	13	10	06	04	05
11	360	330	355	000	360	000	000	000	000	000	210	225	190	190	185	115	160	000	000	360	030	360	000	035
	13	03	02	00	03	00	00	00	00	00	03	04	06	05	06	05	03	00	00	03	02	02	00	03
12	030	015	005	000	000	015	015	005	000	000	115	060	130	115	105	035	005	005	035	360	055	025	325	040
	03	03	03	00	00	04	02	02	00	00	01	02	03	05	04	08	04	06	02	03	01	02	01	01
13	360	345	210	360	000	000	345	035	000	210	215	190	085	030	055	145	000	000	235	225	105	000	000	240
	03	01	01	03	00	00	03	02	00	03	03	05	08	07	01	02	00	00	05	02	01	00	00	04
14	035	235	205	270	355	205	000	010	030	000	215	220	175	115	135	225	000	180	220	000	000	315	000	000
	02	03	01	03	04	01	00	03	01	00	04	03	02	02	02	03	00	01	03	00	00	02	00	00
15	285	225	285	345	355	340	000	210	000	235		180	205	135	105	115	065	075	360	010	000	250	000	190
	01	02	02	03	01	01	00	01	00	01		01	03	03	04	02	03	03	04	04	00	01	00	02
16	000	035	360	255	275	000	000	000	000	000	125	155	195	220	135	125	105	095	085	040	015	020	005	025
	00	03	02	01	02	00	00	00	00	00	03	02	02	02	03	03	03	02	02	05	05	05	03	03
17	005	035	010	020	360	025	360	010	355	000	285	050	075	115	205	225	050	005	215	150	250	220	250	190
	02	03	05	05	04	05	03	03	03	00	01	01	01	02	02	01	04	04	07	06	08	11	09	08
18	265	245	205	245	190	235	340	340	255	005	010	035	030	020	345	025	025	025	015	360	360	010	360	005
	13	04	04	03	02	04	04	01	01	04	05	05	06	10	07	10	10	11	06	05	02	05	04	05
19	035	035	005	360	360	360	010	265	360	020	030	035	030	020	030	040	025	000	005	280	270	275	280	280
	05	07	06	05	06	04	04	01	03	06	06	08	10	09	09	10	04	00	03	13	17	15	14	18
20	280	275	310	285	275	275	265	270	270	270	275	280	280	280	275	275	275	275	275	275	280	275	280	280
	15	17	17	19	19	22	19	24	19	22	25	25	26	30	25	25	27	28	28	28	29	27	23	19
21	265	275	230	280	355	355	355	310	330	320	310	270	270	275	270	275	280	280	275	270	270	270	270	275
	14	23	20	18	05	06	08	10	09	09	07	16	16	20	20	21	13	15	15	15	17	15	21	24
22	275	275	280	280	280	270	280	270	270	270	315	025	025	030	030	030	020	315	285	285	280	280	275	275
	23	25	23	21	19	19	14	14	14	10	03	16	19	15	19	17	09	02	10	13	15	15	16	17
23	275	270	270	270	330	275	215	355	360	295	350	060	160	095	115	030	025	005	355	000	000	360	265	000
	14	15	13	11	07	06	03	06	02	02	03	04	03	05	03	06	03	03	04	00	00	03	03	00
24	245	000	270	215	360	030	000	000	000	230	190	145	150	190	100	105	115	025	360	360	025	000	000	070
	03	00	01	02	01	01	00	00	00	01	01	03	03	03	06	05	06	03	05	05	02	00	00	02
25	330	000	325	005	275	290	275	000	115	000	175	125	135	100	320	025	015	360	010	360	355	355	355	355
	01	00	01	02	01	03	03	00	01	00	01	03	03	03	03	08	07	05	05	05	04	02	03	03
26	000	295	000	115	360	180	360	000	000	200	105	005	055	050	265	265	265	265	265	265	265	265	265	270
	00	02	00	03	03	02	01	00	00	02	02	01	01	03	20	23	19	28	17	21	20	18	21	21
27	265	265	265	275	275	280	290	280	270	270	265	025	035	035	320	310	030	020	340	340	295	265	245	275
	20	21	15	16	15	18	11	14	13	14	09	07	12	13	15	17	10	08	04	04	03	01	05	05
28	205	360	345	155	245	225	345	265	000	000	125	170	175	170	145	125	115	125	360	360	355	360	000	000
	01	04	03	01	05	01	01	02	00	00	01	04	05	05	04	08	00	06	06	05	05	03	08	00
29	000	000	255	000	000	000	000	000	000	210	160	160	145	125	075	020	025	310	360	355	290	000	330	355
	00	00	01	00	00	00	00	00	00	02	01	03	03	04	05	05	07	05	05	05	01	00	01	03
30	280	000	260	000	010	000	000	000	205	000	155	040	060	040	325	325	020	005	005	360	355	355	350	325
	02	00	01	00	02	00	00	00	01	00	02	03	03	04	06	05	05	05	03	04	03	03	04	01
31	260	000	100	025	000	005	005	360	265	265	265	255	265	255	255	305	265	265	260	270	270	270	265	265
	01	00	02	03	00	03	05	03	02	11	11	09	14	15	15	10	14	13	07	10	10	10	13	12

WIND DIRECTION AND SPEED (MPH), HOURLY AVERAGES, AT EMERY, UT, FEBRUARY 1973

HOUR / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	285	290	275	285	275	270	260	275	270	265	250	265	265	250	265	275	275	285	285	305	285	300	305	355
	11	15	16	17	18	15	14	15	14	12	14	14	12	09	14	14	15	18	15	13	14	14	09	06
2	360	360	330	360	350	040	240	000	220	220	180	130	130	160	120	110	030	020	010	010	000	000	360	250
	07	05	03	01	04	01	02	00	02	03	02	04	03	02	03	04	07	07	07	04	00	00	03	02
3	000	000	000	020	270	360	030	010	250	110	130	120	140	150	130	100	070	120	360	360	010	360	360	360
	00	00	00	01	03	01	01	02	03	02	01	04	05	04	04	06	03	03	03	03	04	06	03	03
4	360	310	130	000	000	000	000	000	000	130	330	110	020	350	350	350	350	015	360	350	360	000	200	000
	05	03	01	00	00	00	00	00	00	01	04	05	04	01	04	04	05	04	05	05	02	00	03	00
5	270	360	000	000	000	000	000	360	000	230	200	340	020	020	020	020	020	020	015	020	360	300	000	020
	03	03	00	00	00	00	00	04	00	03	03	05	07	10	10	10	10	07	08	06	04	03	00	03
6	020	010	360	010	360	010	360	000	000	000	000	000	050	090	090	130	090	090	070	360	360	360	360	270
	03	03	03	05	04	04	03	00	00	00	00	00	03	02	03	02	04	03	03	05	05	06	02	03
7	040	015	330	360	015	360	020	020	360	330	030	340	090	150	100	100	060	360	360	360	360	000	000	000
	02	03	05	05	06	04	03	03	03	02	03	04	02	04	03	02	02	03	04	05	03	00	00	00
8	110	250	050	010	360	020	360	330	000	030	015	015	360	030	015	015	015	360	000	360	015	000	015	030
	02	05	05	10	07	08	05	04	00	00	07	05	03	08	08	07	06	07	00	04	02	00	04	06
9	360	270	270	270	350	360	360	030	030	020	030	090	180	050	010	045	040	025	010	355	030	010	005	005
	06	02	03	03	05	05	04	02	07	10	06	04	07	06	05	08	08	08	06	03	03	05	02	02
10	025	010	355	025	005	020	010	010	010	020	010	345	070	230	265	325	015	020	005	005	355	005	035	360
	05	06	05	05	05	06	05	05	04	05	04	03	02	02	02	02	05	05	05	03	03	03	05	04
11	360	000	205	265	000	015	010	025	025	020	015	025	010	360	030	005	360	330	005	000	240	230	000	000
	02	00	03	01	00	03	08	05	09	08	08	07	08	08	06	09	05	05	05	00	03	04	00	00
12	315	265	225	225	000	270	130	160	230	265	265	275	270	260	230	265	255	315	025	270	030	265	360	000
	03	02	05	11	04	07	02	05	09	03	15	14	05	05	08	08	09	05	03	05	03	06	03	00
13	185	355	325	360	355	000	375	205	000	000	000	000	030	000		000	015	005	005	355	260	245	355	000
	03	05	02	00	03	00	01	03	00	00	00	00	03	00		00	05	05	05	04	05	04	02	00
14	170	000	000	000	010	000	000	000	225	355	005	015	025	020	020	325	025	025	005	355	000	010	350	210
	02	00	00	00	00	00	00	00	03	02	05	09	10	11	11	11	12	10	06	04	00	03	04	02
15	185	000	025	005	355	360	240	345	000	000	000	000	245	215	245	000	010	010	005	010	005	255	220	360
	02	00	03	01	03	03	01	03	00	00	00	03	02	04	03	00	06	05	07	07	05	01	03	03
16	330	000	355	350	240	230	355	000	000	350	245	000	000	235	020	010	005	025	275	275	275	275	275	275
	01	00	01	01	02	01	04	00	00	03	02	00	00	01	04	07	08	01	13	14	17	15	14	14
17	270	330	335	275	275	330	345	225	000	000	000	000	190	225	240	190	210	000	355	000	000	350	005	360
	15	08	04	13	13	04	05	03	00	00	00	00	03	02	01	04	01	00	03	00	00	01	02	06
18	355	360	195	000	260	230	305	010	000	230	255	285	285	035	255	265	270	260	250	260	275	270	275	270
	07	04	01	00	01	01	01	03	00	01	01	06	03	08	15	12	15	10	10	13	13	07	05	08
19	270	325	355	350	355	355	350	010	300	090	185	360	015	000	125	020	015	010	005	355	265	000	205	285
	10	04	04	05	05	04	01	01	00	01	02	00	01	00	01	08	09	08	07	05	05	00	01	02
20	350	340	000	340	345	000	290	000	000	000	000	180	175	170	330	395	015	360	345	350	315	350	290	340
	05	03	00	03	03	00	01	00	00	00	00	02	03	04	00	01	03	07	05	08	04	03	03	03
21	000	000	000	120	330	240	120	030	340	265	300	120	210	180	180	180	045	030	015	015	030	360	360	015
	00	00	00	02	03	05	02	03	05	02	03	02	03	05	02	02	03	05	08	05	02	07	06	10
22	360	340	210	285	000	285	270	300	345	220	195	120	180	110	300	315	015	015	350	315	330	000	000	000
	06	05	04	03	00	06	02	03	06	04	05	03	04	04	01	04	05	08	07	07	06	00	00	00
23	340	360	360	360	350	340	330	000	030	190	210	120	045	090	120	030	030	015	000	015	360	360	360	350
	08	06	07	06	06	06	06	00	00	03	04	03	02	03	03	04	04	04	00	05	07	05	04	03
24	220	360	260	320	280	240	015	015	015	330	010	030	360	030	030	320	030	015	320	360	330	030	360	360
	05	03	05	04	04	03	06	07	08	07	07	08	06	07	06	08	08	07	04	08	06	07	05	04
25	360	320	360	000	000	030	360	360	360	360	360	315	150	270	210	045	030	000	360	360	360	360	290	030
	03	03	04	00	00	05	05	05	04	03	04	04	03	02	07	01	02	00	06	07	08	06	03	02
26	330	330	300	000	000	000	000	000	000	000	000	150	120	120	150	120	330	290	340	360	020	360	360	360
	04	04	00	00	00	00	00	00	00	00	00	04	05	04	02	03	02	04	05	07	08	07	05	06
27	360	000	000	000	030	000	360	315	030	000	000	150	210	200	360	020	015	315	320	315	360	360	360	315
	04	00	00	00	00	00	03	06	00	00	00	04	06	05	04	12	15	10	09	07	07	05	06	05
28	000	000	320	000	120	000	000	220	120	280	250	150	280	000	285	270	020	000	315	315	360	360	000	000
	00	00	03	00	02	00	00	04	03	05	04	04	03	00	05	10	11	00	10	06	07	05	00	00

WIND DIRECTION AND SPEED (MPH), HOURLY AVERAGES, AT EMERY, UT, MARCH 1973

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	000	330	300	360	315	360	350	015	300	165	240	100	120	350	265	015	015	020	020	330	360	360	350	360
	00	00	00	05	05	06	05	05	04	03	05	04	05	05	05	10	11	10	14	10	06	06	06	07
2	350	000	260	000	000	000	015	315	240	195	225	240	240	260	260	255	255	250	250	260	270	270	260	260
	04	00	05	00	00	00	06	03	01	07	15	16	15	23	18	17	18	20	18	21	20	18	18	16
3	260	260	265	260	265	260	265	300	350	060	030	020	030	030	020	075	020	015	015	015	015	330	350	280
	13	20	20	18		15	15	10	03	04	06	10	08	06	06	05	07	10	10	07		05	05	04
4	360	015	315	360	020	030	030	360	030	020	010	030	030	020	030	030	030	030	030	330	030	330	030	090
	04	03	03	03	10	07	10	05	10	07	10	12	10	10	10	11	10	09	11	05	07	04	05	04
5	330	240	240	225	225	210	230	225	230	220	225	225	240	225	240	240	255	255	240	230	240	220	260	240
	05	12	10	12	10	09	13	10	14	12	15	15	18	20		15			15	10	10	08	08	07
6	255	270	330	240	195	265	270	265	180	105	170	180	150	165	180	315	360	010	015	040	020	020	010	020
	15	08	03	07	05	06	08	03	06	05	06	06		10	06	07	07	08	06	07	08	06	06	06
7	350	015	315	020	030	030	020	030	030	010	360	010	030	015	030	010	020	020	000	270	300	280	270	260
	06	06	08	06	08	10			12			10	11	07	08	09	08	04	00	06	05	06	05	07
8	360	225	240	330	340	360	360	360	210	030	120	040	090	030	040	030	015	030	015	015	000	000	000	000
	06	04	07	04	04		03		04	04	03	04	04	07	06	10	08	08	07	05	00	00	00	00
9	000	000	000	000	000	000	285	280	360	110	120	150	080	030	015	040	300	255	265	250	270	270	240	270
	00	00	00	00	00	00	04	05	02	03	05	04	04	06	07	05	11	10	08	06	05	06	01	06
10	270	265	270	270	250	250	240	250	255	270	240	265	265	190	220	225	260	180	210	130	210	270	260	060
	10	14	10						10		05	05	08	09	13	15	07	08	05	07	05	06	06	06
11	310	360	180	300	210	015	015	350	010	020	030	015	360	360	360	135	140	150	140	020	015	360	360	360
	07	01	07	04					05	08	07	09	05	08	09	08	10	12	13	10	06	08	07	11
12	015	030	015	020	020	020	360	350	360	030	015	360	360	010	175	150	160	160	180	190	195	150	180	225
	10	12		11	14			04		11	11		10	03	06	06	06	05	05	05				
13	230	240	240	240	240	240	240	240	230	195	180	180	180	225	225	210	240	225	255	240	240	255	255	255
											10	11	10	13	06	12	13	13	07	10	12	11	10	10
14	240	255	250	255	255	250	255	255	350	015	030	030	030	270	270	250	255	260	270	260	255	255	260	260
	08	10	15	16					07	07	05	02	04	04	05	10	14	13	14	15	15	15	15	15
15	260	260	270	260	270	270	260	255	255	255	255	255	250	255	255	255	255	260	260	260	255	260	270	300
	17	16			15		15			10		17	14	13	13	15	15	17	20	17	18	16	15	13
16	350	240	230	270	270	330	360	090	090	120	150	190	180	180	270	180	165	150	000	270	345	340	000	260
		07	05		04			02	02	04	04	04	04	04	05	06	05	03	00	09	05	05	00	04
17	240	000	000	000	000	000	320	360	015	120	090	210	030	315	320	360	040	015	330	180	330	000	270	190
	04	00	00	00	00	00					06	05	04	04	05	05	10	04	04	02	06	00	07	09
18	240	260	345	285	015	045	270	060	255	250	240	255	255	240	255	255	260	260	260	260	260	260	260	270
	12	11	06	07	06	02	04		13	10	11	08	20	20	18	22	18	18	20	15	14	15	15	11
19	270	270	330	290	315	300	260	360	030	090	090	100	120	090	090	100	080	090	345	045	030	315	330	345
	11	11								04		06	04	06	06	09	07	06	05	01	03	03	03	04
20	300	315	360	330	015	045	090	040	120	150	225	030	135	100	130	090	190	240	270	240	330	120	210	210
	05	04	04	03	03			08			05		20	10	10	13	22	08	05	04	05	03	06	03
21	195	135	180	150	165	165	170	135	165	165	150	180	165	285	270	255	135	230	240	210	220	190	240	250
	05	07	08	13	13	14	17	10	20								06			10	11	07	02	04
22	210	075	100	270	250	255	255	195	120	210	195	120	135	090	110	100	260	210	210	020	030	350	330	330
	03	03	04	07	03	03	02	03	03	05	05	03	04	02	11		10	06	05	06	07		04	03
23	320	360	195	270	265	270	270	255	255	330	015	015	010	015	015	010	340	015	330	010	010	360	360	360
	06	03	05	10	12	15	15	08													15		17	20
24	360	360											015	010	015	010	240	005	010	290	325	305	305	005
	13												20	16	12	12	01	06	01	10	07	14	10	14
25	005	005	315	250	220	315	310	250	225	075	035	060	190	080	180	180	135	190	130	115	265	265	270	310
	10	10	04	09	05	08	05	06	03	03	05	05	05	06	05	04	06	05	05	02	06	08	09	08
26	265	300	340	340	260	010	330	335	045	060	260	150	135	130	120	150	120	105	070	285	300	270	260	270
	04	04	04	02	05	02	03	02	01	02	04	04	04	05	03	07	05	08	06	13	11	09	08	01
27	250	290	170	245	260	330	260	325	190	225	225	240	225	225	220	250	240	240	240	240	255	275	225	245
	06	02	03	03	06	04	06	06	06	09	09	11	15	15	13	18	14	10	15	13	19	09	06	11
28	250	145	150	240	260	250	255	255	280	350	110	065	245	280	050	020	005	030	255	270	065	360	295	230
	08	03	05	07	13	08	13	12	03	03	05	04	11	06	06	01	08	05	08	03	05	04	03	03
29	240	240	260	350	065	280	230	330	060	025	010	010	240	250	260	255	260	250	255	250	250	250	250	265
	08	06	09	05	01	08	02	02	04	06	07	02	11	14	19		24	20	17	10	14	15	16	20
30	250	260	260	255	265	260	265	265	260	255	240	270	245	225	230	230	240	240	255	260	270	230	210	210
	21	20	19	15	13	17	16	09	15	14	14	06	11	14	15	15	17	19	17	13	11	05	09	06
31	240	245	260	235	210	225	265	245	235	220	270	255	240	220	270	270	250	250	200	225	255	265	240	260
	12	08	05	06	10				10	11	05	12	14	16	18	11	14	15	06	08	08	08	09	07

WIND DIRECTION AND SPEED (MPH), HOURLY AVERAGES, AT EMERY, UT, APRIL 1973

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	275	350	330	290	245	300	315	340	005	030	240	290	250	240	240	240	050	035	300	340	280	060	270	255
			04	04	08	04	05	02	05	02	08	10	14	14	09	12	04	04	06	04		02	02	11
2	270	255	260	315	270	045	255	250	325	035	005	010	010	010	035	005	005	035	005	035	005	005	005	005
	11	14	12	05	11	02	02	08	11	18			26	28	28		30	22	24	35	28	34	28	
3	005	005	005	005	360	005	360	005	010	010	010	010	015	010	015	010	210	190	030	015	005	270	030	030
	21	15	21		23	24	21		25	26	23	19	19	16	15	16	10	11	06	19	21	02	03	02
4	065	010	335	005	005	360	335	005	005	010	015	035	030	015	050	255	270	200	235	260	260	265	260	270
	02	07	09					17	24	22	16	11	13	10	09	04	03	06	10	14	11	11	14	14
5	265	265	265	265	260	295	320	315	030	345	100	105	165	165	135	180	230	240	245	250	260	270	030	330
			14	12	15	10	06	04	06	06	03	04	06	06	06	04	09	11	14	15	11	09		
6	220	245	310	340	255	205	315	315	230	220	250	255	270	260	255	260	270	260	340	250	240	250	250	285
	04	05	05	06	06	10	03	03	12	09	10	15	19	16	22	24		24		07	10		15	
7	275	230	225	240	235	260	255	260	280	275	280	285	300	310	300	300	010	330	030	325	315	015	015	015
	06	04	14	16	16	21	26	21	32	28	34	31	28	30	26	25		18	13	12	26	20	18	10
8	315	325	350	355	330	155	020	240	250	250	225	255	300	250	240	255	255	260	260	250	250	245	230	230
	13	06	09	06	06	03	03	12	19	14	08	10	09	20		20	20	20	17	19	12	12	11	09
9	225	235	240	240	240	235	250	240	230	240	260	260	285	310	300	315	250	270	275	270	240	255	260	290
	03	06	11	11	12	07	09	13	14		18	15	15	21	15	17	19	14	07	05	05	02	07	04
10	245	265	290	330	030	020	000	025	060	210	225	230	240	290	270	230	270	250	240	245	270	290	265	000
	05	09	05	05	03	03	00	02	03	03		12	14		11	12	13	12	10	09	13	06	07	00
11	240	260	275	235	240	000	330	000	200	165	165	285	340	020	360	315	240	240	260	320	275	260	290	330
	03	06	07	05	07	00		00	07	07	05	06	08	14	09	03	15	12	09	05	04	08	03	02
12	270	270	320	310	000	000	015	190	115	120	165	120	360	180		075	165	210	340	150	315	025	315	010
	05	03	04	04	00	00	01	04	03	04	09		04	04		03	06	13	05	07	04	04	06	01
13	310	300	265	340	330	290	255	290	060	120	175	200	255	245	235	230	230	230	235	240	250	255	260	255
	03	01	02	05	03	01	02	02	04	03	05	10	09	26	20	25	28	23	17	13	11	17	14	12
14	215	215	215	225	255	285	225	165	150	200	205	225	240	235	240	285	290	290	285	300	300	300	320	300
	12	10	11	06	11	10	01	02	10	14	13	13	26	24	23	24	23	20	16	16	18	14	10	14
15	295	295	300	305	300	290	285	270	285	315	300	285	285	285	295	295	285	330	300	310	285	305	315	315
	14	16	18	18	12	11	09	13	11	12	15	21	18	14	11	22	14	14	17	11	10	09	07	10
16	320	330	310	015	030	040	345	230	180	140	270	285	300	285	285	240	295	250	230	240	250	200	235	260
	04	04	07	03	02	01	01	02	01	03	13	10	12	16	16	15	13	08	11	07	06	08	07	10
17	240	265	160	210	180	255	225	210	215	295	180	285	320	295	285	170	170	215	215	240	250	300	270	295
	03	11	02	03	04	05	05	01	04	09	04	16	09	19	10	06	13	17	18	14	28	18	17	23
18	295	275	300	285	300	290	300	295	295	290	290	315	300	295	305	280	290	300	335	345	300	330	300	310
	24	23	19	15	15	17	17	19	20	25	22	17	16	23	21	21	21	17	14	11	11	12	03	17
19	310	310	315	315	315	315	295	305	315	305	295	305	300	300	315	300	290	310	280	245	110	270	265	250
	22	27	28	23	15	14	10	14	25	22	23	23	21	23	18	18	20	20	11	08	03	10	08	10
20	270	265	275	290	285	295	295	270	275	285	300	290	275	275	265	280	280	290	295	265	275	280	290	275
	10	13	13	17	21	14	12	13	15	17	17	20	20	15	14	15	16	18	15	09	13	11	13	11
21	285	295	295	295	285	280	275	280	275	280	285	300	210	270	275	300	290	300	300	300	300	300	300	300
	11	14	12	11	15	15	12	12	12	13	12	10	07	08	13	13	15	19	17	16	15	15	14	15
22	330	285	300	005	320	000	040	255	275	210	280	180	195	170	170	170	315	335	300	295	280	270	330	315
	15	11	05	05	04	00	02	03	06	05	05	07	05	06	05	07	11	13	13	12	07	05	06	02
23	340	015	360	240	360	280	330	070	150	090	150	180	245	210	170	240	315	295	300	300	300	310	300	300
	04	02	04	01	01	01	05	02	01	02	04	04	06	05	13	20	30	13	12	08	09	06	11	05
24	320	290	290	310	270	195	045	315	075	190	150	210	240	280	025	090	290	300	330	315	285	285	275	270
	13	11	09	10	02	03	02	07	01	05	12	06	05	08	13	06	15	13	15	15	06	04	08	05
25	270	280	285	335	315	285	310	250	265	280	275	300	330	310	300	300	330	300	295	310	360	015	040	355
	06	01	12	08	03	01	04	03	05	14	16	13	12	16	17	15	18	18	20	11	06	10	06	07
26	345	005	330	350	025	045	000	240	090	035	150	030	180	285	195	155	120	120	190	225	240	300	315	315
	10	10	03	12	06	03	00	03	02	08	06	03	05	06	05	05	05	02	04	02	05	03	09	10
27	330	345	320	015	015	000	340	295	000	190	160	210	165	190	180	165	195	165	190	185	290	315	315	030
	03	06	03	04	01	00	03	01	00	02	04	06	07	06	08	12	13	13	12	07	07	06	10	05
28	065	285	180	255	260	230	165	150	150	270	270	260	315	275	315	315	330	280	290	315	300	300	290	280
	03	06	02	02	03	02	01	02	09	10	16	25	17	20	13	15	17	11	11	15	13	21	20	10
29	300	300	285	300	010	340	305	030	180	205	215	255	270	270	270	275	315	300	290	290	285	295	330	295
	13	12	10	03	02	07	08	02	03	18	12	25	24	25	25	17	19	13	17	13	13	16	16	13
30	290	295	310	130	090	260	060	100	075	030	045	120	150	300	300	270	240	280	270	060	060	280	285	285
	17	13	14	08	08	06	07	07	05	04	03	08	10	17	08	10	11	09	12	08	03	07	10	13

WIND DIRECTION AND SPEED (MPH), HOURLY AVERAGES, AT EMERY, UT, MAY 1973

DATE \ HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	285	300	300	285	300	300	280	090	300	285	300	285	300	270	300	300	300	285	300	330	330	150	000	000
	13	15	10	08	10	07	10	04	15	11	16	23	15	17	11	20	22	11	10	27	23	05	00	00
2	300	285	255	000	200	195	300	290	135	110	045	045	210	210	240	170	180	165	190	170	170	250	310	040
	07	06	05	00	01	06	00	05	01	05	04	04	06	05	08	08	06	09	11	06	07	01	03	01
3	000	295	290	015	040	020	260	000	110	140	125	215	180	205	195	120	170	155	150	150	195	305	300	330
	00	05	02	01	01	02	03	00	02	04	09	07	07	10	10	11	09	13	09	05	01	06	00	04
4	360	110	020	360	000	285	270	270	255	195	210	225	210	225	220	220	230	225	195	225	225	250	290	090
	01	01	03	03	00	06	08	07	06	13	13	16	24	20	19	23	21	25	26	16	16	13	03	04
5	260	240	250	250	220	250	270	090	175	175	160	140	165	150	150	165	190	200	205	340	075	255	180	015
	17	05	13	03	05	03	07	02	10	15	12	10	18	14	13	25	12	11	07	10	04	04	01	03
6	280	215	205	210	130	155	145	180	120	160	195	280	290	330	310	300	300	300	300	315	300	265	330	315
	01	06	05	01	05	04	04	01	03	03	05	12	22	21	18	20	18	10	15	01	05	01	03	05
7	300	315	300	285	265	285	285	270	300	285	300	285	285	315	315	300	360	345	280	285	285	315	320	280
	00	03	08	12	04	14	08	05	14	11	10	05	13	13	13	07	10	09	09	09	05	05	05	09
8	270	300	300	290	285	290	300	230	150	180	195	280	270	285	270	285	270	180	315	290	315	315	300	300
	03	00	00	10	11	10	11	02	05	07	08	23	21	20	17	17	11	03	11	06	06	06	09	10
9	300	315	330	315	230	015	000	180	150	120	270	270	270	270	270	270	300	300	255	240	240	225	300	000
	08	05	10	08	13	03	00	06	05	04	20	23	25	25	23	22	15	10	07	06	05	06	07	00
10	285	280	310	300	270	315	315	315	270	270	285	285	280	270	270	300	285	315	315	330	330	090	315	360
	06	06	08	06	06	07	03	10	13	16	17	20	18	23	16	13	20	13	10	07	11	02	10	05
11	345	150	015	360	360	000	045	330	180	180	180	180	120	210	330	330	315	315	300	315	270	285	300	315
	08	04	06	05	05	00	05	02	03	03	05	08	10	13	10	11	10	12	07	07	10	10	07	10
12	330	330	030	090	060	000	330	000	000	030	120	120	270	180	135	265	240	000	345	315	300	300	330	090
	07	06	08	00	02	00	02	00	00	02	02	06	05	10	10	10	05	00	27	05	07	09	05	03
13	315	330	330	015	000	300	315	000	000	075	090	135	240	315	120	060	060	345	345	330	345	030	060	045
	07	02	04	05	00	05	05	00	00	07	08	08	03	05	04	05	10	10	10	08	10	10	10	20
14	060	050	360	060	360	210	015	240	075	075	090	090	080	210	210	120	060	060	090	150	170	315	300	360
	17	12	12	12	07	02	03	03	15	13	07	07	05	06	05	05	07	07	03	06	08	05	07	04
15	345	330	320	270	300	040	315	180	120	210	225	180	090	285	180	105	120	180	180	150	315	270	240	320
	03	06	05	02	02	05	03	03	03	03	05	07	03	04	07	04	05	02	05	15	04	07	05	10
16	305	330	340	030	100	000	010	070	070	085	075	080	015	360	075	090	090	075	050	000	325	305	165	030
	06	00	06	05	02	00	04	05	03	03	10	15	07	05	14	08	10	05	01	00	10	10	02	03
17	300	360	240	300	275	305	305	070	145	135	130	225	270	250	345	345	315	345	320	315	320	310	295	300
	10	02	02	03	09	10	10	02	01	03	03	04	05	03	10	08	11	13	10	10	08	11	06	11
18	300	300	285	310	330	310	315	315	300	090	110	180	180	300	300	340	320	340	305	330	325	235	240	030
	11	12	10	13	03	12	07	13	11	01	04	02	05	05	03	05	10	12	11	11	08	06	04	05
19	120	290	345	280	300	305	360	000	260	275	250	210	290	150	180	120	090	340	165	135	285	340	050	025
	01	07	04	06	08	06	03	00	05	06	06	16	10	08	06	05	08	24	11	06	07	10	03	05
20	350	315	340	340	270	270	320	300	130	240	200	160	210	285	250	240	240	265	270	315	310	315	315	320
	03	03	07	01	03	02	05	00	02	03	07	07	08	15	16	21	20	22	13	21	25	23	20	22
21	315	250	240	105	270	330	000	000	060	150	150	210	230	190	255	295	280	315	320	300	310	330	040	310
	13	08	08	02	04	08	00	00	03	01	05	05	10	19	21	16	06	13	15	07	08	02	03	05
22	000	010	280	190	220	255	315	060	075	090	130	130	240	280	225	290	330	325	350	335	330	320	320	325
	00	02	07	01	03	02	07	03	04	03	04	04	06	03	06	13	13	12	10	12	10	05	10	08
23	325	320	010	090	110	345	050	060	070	140	180	015	190	160	225	240	270	210	230	300	315	320	255	270
	12	03	06	01	02	03	01	03	05	03	04	06	06	08	15	14	11	10	05	11	05	05	07	04
24	275	285	225	150	135	240	260																	
	05	05	04	01	02	03	04																	
25																								
26											335	320	315	325	320	315	330	325	325	330	330	340	345	285
											18	21	20	15	19	17	19	13	18	20	31	24	14	07
27	030	360	250	320	270	300	235	300	345	345	350	345	350	360	350	345	345	325	350	360	360	360	360	360
	07	02	01	05	03	06	03	05	18	19	18	16	15	17	18	11	14	16	13	08	09	13	10	03
28	360	330	210	000	030	030	255	300	305	230	060	180	325	180	250	275	345	345	315	320	325	330	325	325
	01	03	02	00	01	02	02	02	08	06	03	04	02	05	06	05	15	15	16	12	09	06	08	10
29	325	330	210	105	090	090	000	075	270	270	240	270	270	300	330	280	300	330	360	350	360	360	360	330
	10	13	01	03	01	01	00	01	05	05	02	09	15	16	13	12	08	10	13	11	07	12	12	11
30	330	330	330	030	075	060	360	100	090	090	090	090	090	030	090	060	030	060	060	030	090	270	280	315
	13	05	13	05	05	13	03	01	12	12	11	07	05	07	03	08	07	08	08	08	03	04	04	08
31	350	000	300	030	000	280	030	180	220	150	180	120	270	150	150	270	315	270	240	315	330	300	300	290
	01	00	09	03	00	02	02	01	02	02	03	05	05	05	05	23	20	14	01	04	08	11	16	11

WIND DIRECTION AND SPEED (MPH), HOURLY AVERAGES, AT EMERY, UT, JUNE 1973

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	220	210	330	320	300	180	170	150	180	200	160	120	015	210	300	240	000	240	360	330	300	270	360	090
	11	07	11	06	10	06	03	03	08	06	01	01	02	07	03	04	00	08	04	04	11	07	04	05
2	030	280	300	300	300	300	300	270	280	300	300	330	360	315	330	330	300	300	360	330	300	270	315	240
	01	07	12	11	12	11	11	08	08	12	10	15	10	17	13	18	12	10	05	10	04	06	05	01
3	315	030	330	350	360	220	240	250	180	180	270	330	315	320	270	240	300	270	300	300	300	300	315	315
	06	02	01	02	03	08	02	03	03	05	13	19	23	08	14	13	14	12	13	11	14	09	14	10
4	315	330	320	330	330	360	280	315	300	300	315	300	330	300	315	330	330	330	300	330	360	360	330	090
	13	12	10	09	10	03	11	10	05	10	10	08	15	16	16	14	11	13	14	10	05	09	03	01
5	330	330	015	330	030	300	030	090	090	120	090	180	030	180	120	180	150	210	180	190	240	300	315	330
	05	05	03	08	04	06	05	03	05	04	03	03	02	03	02	05	09	07	09	06	03	04	05	09
6	300	330	360	000	315	000	000	000	000	090	090	210	090	210	150	300	260	315	320	345	360	360	220	300
	06	05	04	00	05	00	00	00	00	02	02	04	03	05	03	05	10	10	10	10	09	06	04	12
7	330	345	030	315	360	030	270	000	120	090	210	210	210	300	280	330	330	330	330	330	360	330	270	330
	09	06	04	03	03	02	03	00	01	02	02	02	08	06	11	10	08	12	13	09	08	10	03	08
8	320	345	360	360	300	315	300	060	045	060	180	130	090	200	270	210	250	210	180	180	330	330	330	330
	08	04	00	03	01	02	02	05	04	04	03	02	03	07	06	05	05	04	05	03	09	02	09	07
9	270	270	315	330	030	320	015	000	000	190	180	075	300	270	270	270	300	300	300	300	315	300	300	300
	01	05	02	05	02	05	01	00	00	03	03	06	08	15	12	15	13	15	13	13	13	13	14	09
10	300	240	290	210	240	150	270	210	150	150	150	330	270	300	300	300	315	300	300	300	330	300	300	300
	11	05	05	07	03	03	03	02	02	10	12	06	17	03	13	12	10	07	07	08	08	08	03	09
11	270	200	210	210	190	180	000	240	240	240	270	300	300	300	315	270	270	300	300					
	04	00	02	05	07	04	00	03	07	17	16	16	14	08	13	09	15	13	17					
12																								
13																								
14																		265	260	265	265	300	300	310
																		13	18	22	13	06	08	13
15	270	270	250	300	330	330	295	000	290	280	285	310	285	285	300	300	315	300	270	305	320	290	105	360
	06	03	05	08	05	04	05	00	06	13	18	19	16	21	16	21	11	09	10	11	14	10	01	04
16	290	300	305	265	255	285	295	000	250	130	180	155	150	130	225	130	270	330	330	000	325	315	315	260
	10	10	10	01	05	01	10	00	02	02	06	06	08	08	04	05	03	03	02	00	05	11	11	06
17	310	315	320	315	305	310	015	235	180	195	295	285	280	285	260	275	280	310	285	320	315	315	295	195
	07	09	09	08	07	08	02	01	03	06	15	20	17	27	27	24	21	18	18	24	23	27	13	07
18	255	255	290	265	290	295	285	270	270	330	350	300	285	285	315	305	300	330	330	335	015	015	015	360
	12	12	10	08	13	08	10	10	08	05	15	08	15	12	16	20	13	23	18	18	08	10	10	12
19	315	300	325	010	325	225	330	340	045	100	090	105	150	215	150	090	160	285	280	275	310	330	315	305
	05	00	04	03	08	02	02	03	03	03	04	02	01	05	05	06	05	04	11	10	10	13	14	13
20	310	010	305	325	350	030	195	030	090	050	060	060	060	090	030	330	360	355	025	035	030	190	320	345
	13	07	08	11	06	04	02	04	04	05	08	05	05	04	08	05	05	03	05	06	07	07	10	04
21	345	340	025	030	275	000	020	030	235	120	150	120	135	120	090	330	360	360	210	210	240	165	320	030
	05	09	01	01	05	00	03	03	02	03	07	04	07	06	03	06	02	02	05	05	04	02	12	00
22	300	330	045	345	000	300	285	050	090	240	150	180	180	195	200	240	285	300	270	300	330	280	140	165
	02	03	02	03	00	03	07	04	03	03	03	06	07	10	11	10	10	15	12	10	11	04	06	03
23	200	315	340	270	285	000	000	000	000	180	180	240	200	210	180	180	270	270	280	280	300	300	300	270
	07	10	11	03	03	00	00	00	00	05	07	15	17	15	11	10	12	07	10	12	11	11	12	05
24	265	290	280	260	260	240	240	210	285	300	300	285	270	285	290	285	300	285	300	300	300	315	290	320
	06	10	10	05	05	05	06	07	08	10	10	10	17	16	15	15	10	11	07	10	07	10	08	11
25	315	050	315	210	180	195	225	300	270	330	300	285	315	300	300	330	300	330	320	330	360	120	015	000
	10	05	02	03	02	04	07	08	08	11	14	15	16	17	17	15	12	15	15	16	05	06	07	00
26	315	360	360	000	285	360	270	040	080	070	090	015	180	360	300	300	300	345	360	360	340	330	070	300
	11	06	04	00	07	07	05	05	06	08	06	07	04	07	17	12	12	11	12	11	10	12	07	07
27	150	330	030	360	360	330	360	060	000	135	090	060	060	180	045	045	270	300	230	280	330	330	345	330
	02	05	05	05	04	06	03	05	00	07	14	10	10	02	06	05	12	08	16	10	06	15	17	10
28	300	300	315	285	030	320	165	015	045	075	070	345	330	330	075	045	120	080	075	090	325	090	290	330
	10	12	11	10	03	07	03	03	06	10	15	11	05	08	13	10	10	17	15	08	07	05	05	02
29	330	340	300	010	315	045	330	000	220	300	100	360	090	210	150	330	285	270	300	270	270	320	290	270
	07	08	10	07	05	05	03	00	03	02	03	03	05	11	05	07	15		15	11	07	12	11	06
30	285	210	195	220	210	240	280	270	190	150	180	180	210	210	270	270	280	150	260	285	300	285	300	270
	06	05	05	06	05	10	06	05	05	06	07	12	15	10	16	10	20	16	15	10	15	14	10	06

WIND DIRECTION AND SPEED (MPH), HOURLY AVERAGES, AT EMERY, UT, JULY 1973

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	315	300	300	300	300	060	240	345	360	280	300	300	330	330	360	315	315	310	300	330	310	300	270	050
	11	11	07	06	05	03	08	05	03	11	15	12	12	06	07	12	13	14	15	13	10	11	10	05
2	360	180	360	300	360	315	360	240	345	180	105	195	060	060	270	150	150	285	300	330	315	260	315	360
	07	05	03	11	05	06	05	03	04	02	04	07	04	05	07	07	03	10	12	08	05	03	08	07
3	345	315	330	000	300	060	360	000	090	120	090	060	360	210	360	360	210	120	330	000	345	020	330	330
	07	06	05	00	05	05	03	00	02	02	05	05	04	07	03	06	03	05	05	00	13	07	10	06
4	360	360	360	360	015	350	285	300	015	090	150	150	270	150	240	270	330	310	315	330	350	320	360	000
	02	03	03	02	06	08	05	00	02	02	07	02	03	05	11	15	05	07	11	12	12	10	07	00
5	300	360	360	015	360	350	000	345	135	090	150	120	195	090	120	120	130	150	180	165	170	320	330	250
	00	02	02	07	06	04	00	02	02	03	05	05	07	05	05	10	12	06	07	08	08	12	12	06
6	230	300	300	300	270	270	315	270	105	150	120	255	270	240	300	270	270	300	300	285	255	300	310	300
	08	11	10	06	07	07	12	01	02	04	03	16	19	30	15	15	22	23	23	17	07	07	07	10
7	295	280	225	280	255	230	190	240	270	300	300	300	315	300	165	160	120	225	270	240	340	330	315	330
	10	07	06	10	10	07	07	01	07	07	11	15	08	10	07	25	06	10	05	16	07	10	08	05
8	315	315	300	015	015	090	000	090	360	120	150	180	270	270	270	260	240	260	240	120	045	230	300	330
	07	06	00	06	08	05	00	05	03	03	04	07	16	05	10	14	15	07	10	05	04	06	03	06
9	060	240	270	270	015	270	360	030	120	120	135	180	075	060	150	090	090	080	345	340	030	030	060	000
	06	03	03	06	07	08	06	05	02	03	02	03	06	07	07	10	10	07	10	03	10	06	10	00
10	000	330	130	060	330	330	120	345	060	060	060	030	090	180	285	360	360	120	270	150	170	240	330	320
	00	00	05	02	03	04	04	07	04	06	08	07	07	12	07	05	04	05	06	05	08	05	11	11
11	330	015	350	330	240	330	270	285	090	270	120	160	150	225	300	300	230	300	310	310	315	300	300	300
	06	03	07	06	07	07	04	06	02	03	12	12	10	07	08	07	07	18	12	07	12	06	15	10
12	300	300	300	300	340	345	180	340	080	140	075	090	120	150	160	120	330	270	300	320	315	315	320	330
	14	05	10	17	07	05	10	16	06	06	12	05	05	07	04	02	04	05	15	15	18	18	14	10
13	310	315	330	315	315	330	320	315	300	300	315	120	260	300	060	060	050	360	060	165	195	330	330	010
	20	17	20	17	17	16	13	07	14	10	08	04	10	10	13	05	20	16	15	10	12	10	08	14
14	300	360	015	330	060	075	045	080	360	120	090	180	180	240	240	210	180	240	360	360	060	050	050	075
	05	06	06	04	12	07	05	03	02	03	03	05	05	07	07	15	05	05	10	20	16	17	15	11
15	240	000	225	300	015	315	360	000	000	165	120	120	120	210	300	200	330	330	330	315	345	020	075	135
	10	00	05	08	07	05	03	00	00	02	05	03	04	07	12	13	12	12	10	05	10	07	06	10
16	330	300	285	270	030	015	345	000	000	105	180	270	315	270	330	300	330	330	315	300	345	015	045	015
	03	06	06	07	07	05	03	00	00	05	03	05	11	07	13	11	14	08	10	10	08	07	10	10
17	340	015	330	270	360	360	310	050	060	090	075	060	180	040	060	330	300	290	345	360	210	150	330	320
	07	07	07	04	03	03	07	06	06	06	07	07	04	16	15	07	08	07	06	03	03	04	05	07
18	340	090	300	360	060	330	300	330	100	120	060	060	070	080	105	270	285	300	240	300	255	255	300	030
	06	02	07	04	03	05	03	05	05	06	05	06	07	07	06	17	16	03	07	00	08	05	10	07
19	350	250	240	300							240	220	270	290	300	300	250	250	270	270	305	270	240	290
	07	05	06	08							06	06	04	06	08	09	05	07	05	06	05	05	05	10
20	300	010	210	190	305	300	200	120	210	300	200	200	180	120	100	130	100	330	320	170	050	050	330	060
	11	12	06	03	04	05	03	02	03	00	04	04	05	05	08	06	06	06	11	10	07	08	08	06
21	350	300	310	300	060	000	000	000	000	090	240	280	210	090	200	180	140	060	060	300	340	310	000	300
	06	05	05	02	02	00	00	00	00	02	02	02	02	03	06	08	05	03	03	05	06	07	00	05
22	300	240	330	000	300	300	310	010	360	090	360	060	200	270	245	270	280	300	310	310	330	330	300	020
	00	03	05	00	00	03	04	05	04	03	05	05	06	03	06	08	07	08	07	07	07	07	04	04
23	310	090	010	310	210	300	040	000	000	000	000	000	000	000	180	120	120	120	060	070	050	080	310	330
	03	03	04	05	04	05	03	00	00	00	00	00	00	00	03	02	03	05	02	05	07	06	04	06
24	330	340	000	000	000	000	240	000	000	000	000	000	170	270	300	330	330	330	330	330	340	340	330	340
	03	03	00	00	00	00	02	00	00	00	00	00	04	02	07	08	08	10	08	08	06	04	02	05
25	170	300	280	300	340	300	000	000	000	070	070	100	060	090	070	070	070	300	290	340	330	330	120	000
	02	00	05	05	03	03	00	00	00	06	06	05	04	03	04	03	03	05	06	05	04	03	02	00
26	300	310	300	330	300	300	340	310	310	100	180	060	130	150	290	300	330	300	280	300	320	290	320	330
	00	05	03	03	03	04	04	02	02	02	02	02	02	05	05	08	06	05	07	05	05	05	02	03
27	330	300	320	320	310	010	020	290	070	000	000	040	060	270	300	270	200	050	060	060	090	000	320	300
	03	05	07	05	04	04	03	02	03	00	00	03	06	06	05	05	06	10	08	06	03	00	05	03
28	300	310	300	270	030	260	000	000	360	090	090	070	040	340	320	340	330	310	330	300	310	310	300	300
	03	03	02	02	03	02	00	00	01	03	04	03	05	08	07	07	04	03	06	03	04	07	06	03
29	310	330	300	300	330	010	000	000	000	000	000	130	130	330	110	330	240	180	050	280	300	250	270	310
	05	04	06	03	03	03	00	00	00	00	00	03	03	15	06	03	06	02	07	08	11	07	05	03
30	300	300	300	040	320	320	310	060	090	120	060	100	080	060	120	060	050	060	050	050	030	050	050	030
	05	07	04	04	03	06	04	02	03	02	02	04	03	03	02	04	06	05	05	05	06	05	06	05
31	005	300	320	010	010	300	040	010	180	160	090	120	090	080	030	150	000	330	340	360	010	330	300	230
	05	03	03	02	03	03	03	02	02	02	~~02~~	~~02~~	04	05	08	03	06	03	05	05	04	04	03	04

WIND DIRECTION AND SPEED (MPH), HOURLY AVERAGES, AT EMERY, UT, AUGUST 1973

HOURS DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	300	330	310	020	310	030	300	360	330	000	300	360	070	040	120	330	020	330	320	340	020	310	310	270
	00	00	03	03	03	03	00	00	00	00	00	00	03	03	03	03	06	07	03	03	04	04	02	05
2	280	330	020	030	060	330	010	030	270	130	110	130	170	150	250	210	140	030	340	340	060	040	330	270
	03	05	03	03	03	04	03	02	02	02	02	02	02	02	02	02	02	00	05	03	03	06	02	05
3	320	100	310	040	020	260	270	360	100	240	020	270	020	070	210	260	310	300	280	280	310	300	290	300
	05	02	07	03	03	03	03	03	03	03	02	03	03	03	05	03	06	06	06	06	06	05	06	03
4	330	140	330	300	270	300	330	280	010	000	030	290	180	180	180	320	320	240	240	300	300	300	300	310
	04	04	04	06	02	02	06	05	03	00	02	02	06	07	05	10	06	03	02	10	07	08	11	09
5	300	250	240	290	280	290	280	070	080	110	300	270	210	210	240	240	180	210	210	250	310	320	300	270
	08	06	05	04	05	05	06	02	03	03	02	10	07	07	05	03	06	07	05	02	03	03	04	05
6	330	270	270	090	310	040	330	280	150	000				240	300	350	290	250	290	320	300	340	040	050
	03	03	02	03	03	03	03	03	03	00				07	04	03	05	04	08	05	06	05	03	03
7	270	250	210	300	250	020	020	040	070	010	150	150	200	060	120	150	250	210	050	330	330	320	300	310
	02	03	05	02	04	02	02	04	05	02	02	03	03	06	07	03	03	03	03	03	05	05	05	05
8	330	070	040	040	000	000	000	000	000	000	150	100	040	060	180	310	300	310	310	340	340	300	310	180
	05	03	03	02	00	00	00	00	00	00	02	03	06	04	03	06	06	06	05	05	06	05	06	02
9	020	340	340	180	310	310	030	300	100	360	060	180	210	210	270	210	140	190	190	160	020	300	040	290
	03	03	03	03	03	03	04	03	02	02	02	02	03	03	05	02	04	04	04	02	02	04	03	05
10	250	330	300	210	270	060	180	030	120	100	120	150	180	240	270	240	290	280	330	290	300	300	270	280
	03	04	04	03	03	03	04	03	02	02	02	04	02	10	08	04	07	08	07	06	05	06	05	06
11	290	340	330	300	280	210	270	240	320	320	310	300	310	290	270	330	310	300	310	330	330	310	120	050
	07	02	03	03	03	03	03	03	06	06	04	07	06	05	05	06	06	05	05	05	05	03	02	05
12	330	000	000	020	330	330	310	040	090	070	130	170	060	310	360	150	210	220	210	240	330	310	330	300
	04	00	00	03	05	03	03	03	02	02	03	03	04	03	03	05	05	04	03	02	02	05	04	05
13	310	020	020	010	040	040	010	220	010	090	070	070	100	210	220	150	090	150	150	270	330	310	310	300
	05	02	02	02	02	02	00	03	02	04	04	04	03	06	08	03	04	06	03	03	06	06	06	02
14	250	250	250	190	270	240	300	360	060	230	280	250	280	300	310	240	230	360	120	340	030	030	040	000
	02	02	02	02	02	05	10	02	02	02	07	05	07	07	04	09	07	02	02	06	06	04	03	00
15	150	060	000	020	290	130	350	030	230	000	180	060	070	300	150	130	090	240	240	150	230	280	300	310
	02	02	00	02	02	04	03	02	02	00	03	03	04	03	04	05	05	04	06	07	06	05	06	07
16	160	280	100	330	000	040	210	180	080	075	165	135	120	315	265	300	300	295	295	290	130	250	280	270
	02	04	02	04	03	02	02	02	02	03	03	03	02	03	04	07	08	07	07	06	05	06	05	03
17	210	240	350	210	020	330	000	300	105	360	000	120	125	105	255	235	240	230	210	135	000	315	205	300
	05	03	03	03	04	03	00	00	03	02	00	02	02	03	07	07	02	03	04	04	00	02	02	03
18	320	075	040	075	025	240	255	345	120	240	235	190	210	255	330	270	210	205	195	235	045	305	315	295
	05	03	03	03	05	03	02	02	02	02	02	03	04	04	03	04	06	07	07	04	03	03	03	05
19	245	300	270	070	040	300	355	360	180	225	180	045	180	215	240	075	260	310	225	275	310	290	315	285
	05	06	05	04	04	03	02	02	01	01	01	01	02	03	04	01	06	04	03	02	05	03	05	03
20	330	315	135	030	215	010	305	120	195	075	170	125	170	150	155	180	265	150	195	300	180	180	350	120
	05	02	02	04	01	03	05	03	02	03	03	02	04	05	05	04	02	04	02	02	10	16	04	04
21	355	030	300	060	315	030	320	195	000	090	165	150	180	155	360	330	210	320	065	350	045	270	000	000
	02	02	00	01	04	02	02	01	00	01	02	02	03	05	05	02	01	03	05	05	04	01	00	00
22	040	320	050	315	030	005	330	150	000	075	105	075	165	225	270	225	250	245	090	325	305	310	330	030
	01	01	01	02	01	02	02	01	00	02	01	01	02	04	03	06	03	03	02	01	03	02	02	01

WIND DIRECTION AND VELOCITY: EMERY, UTAH (PERIOD AVERAGES) NOVBR, 1972

DATE	HOURS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1																								
2																		275	275	280	255	270	280	260
																		11	10	01	07	10	11	04
3	280	315	345	350	350	275	340	355	000	010	065	165	165	165	155	185	160	145	120	305	290	235	000	015
	08	05	04	03	02	01	03	02	00	01	02	02	03	04	04	06	05	04	02	03	04	04	00	02
4	315	360	000	000	000	310	360	300	205	360	025	055	100	110	085	045	005	005	010	040	010	360	015	350
	02	01	00	00	00	02	03	04	01	01	05	04	05	05	04	04	05	06	04	03	07	05	03	04
5	120	270	020	170	205	205	230	230	260	250	250	240	250	250	240	255	245	245	250	245	270	245	300	110
	02	03	02	02	03	08	11	09	10	12	14	18	20	14	16	16	14	17	17	14	08	06	05	05
6	300	285	285	330	255	260	270	305	305	270	200	300	110	110	155	140	095	090	140	250	275	320	350	280
	02	09	06	05	12	15	13	08	06	08	04	03	05	05	06	05	03	02	02	05	07	04	04	02
7	210	000	000	000	200	000	310	270	320	350	360	310	030	015	010	015	050	345	020	355	345	355	345	355
	01	00	00	00	02	00	01	02	01	01	02	03	06	06	08	07	05	05	03	05	05	05	05	04
8	340	355	335	320	230	300	250	000	230	355	160	170	050	070	160	030	140	255	260	250	300	250	260	200
	04	03	04	02	01	01	02	00	02	03	02	05	03	06	07	06	05	10	07	04	06	14	09	05
9	290	275	285	240	290	280	270	265	255	260	260	265	125	130	160	115	140	115	120	200	280	300	330	310
	10	10	08	09	06	07	06	10	09	12	09	05	05	05	05	05	05	03	02	06	08	05	05	05
10	320	015	270	015	000	345	015	360	350	005	020	035	050	030	080	115	115	060	010	015	020	015	350	010
	05	03	02	02	00	04	05	05	05	04	06	09	05	05	06	04	04	05	08	07	08	06	05	03
11	350	350	330	030	330	170	010	040	025	355	050	060	110	115	170	155	155	160	090	015	025	030	020	015
	05	04	04	03	04	01	05	03	03	02	02	01	03	04	02	07	06	07	05	07	06	08	10	13
12	010	005	010	010	010	355	335	265	270	245	265	285	060	270	270	030	270	270	270	250	260	255	255	290
	14	12	11	14	13	10	03	03	04	03	03	03	04	07	09	06	10	10	11	10	10	10	08	05
13	300	355	360	015	350	030	000	245	300	120	150	120	125	210	210	140	160	240	270	000	350	190	300	030
	05	03	03	04	04	01	00	02	01	03	02	05	08	05	03	04	04	02	01	00	02	02	00	00
14	000	060	100	100	010	005	020	025	030	030	015	045	065	095	120	130	195	260	020	010	360	010	015	005
	00	01	01	02	02	04	04	07	08	08	07	04	04	04	07	06	04	02	02	04	03	06	07	07
15	025	360	000	190	195	190	200	195	200	210	295	190	180	165	190	195	215	210	210	190	210	250	000	240
	04	02	00	03	02	02	03	03	01	02	03	04	04	04	06	04	03	03	05	04	03	01	00	01
16	270	320	000	360	040	350	270	350	180	270	000	105	125	180	225	150	350	330	035	010	010	040	060	020
	03	02	00	01	01	05	01	04	02	02	00	01	06	07	05	02	04	04	04	05	05	06	04	06
17	010	015	025	030	025	020	020	025	030	030	020	030	035	040	030	025	355	020	350	330	290	330	360	300
	07	07	10	10	08	11	11	09	08	05	07	06	03	08	07	06	04	03	03	03	03	02	02	01
18	360	350	010	010	350	005	340	280	270	250	250	260	265	255	250	250	265	255	230	235	015	280	280	240
	04	02	03	03	04	03	04	07	10	08	10	13	14	13	11	09	09	06	02	06	03	03	03	03
19	240	020	360	360	345	260	240	030	000	250	245	070	125	255	210	300	020	005	010	035	035	330	350	330
	04	01	01	04	01	02	01	01	00	02	01	02	04	03	01	01	04	06	07	05	07	03	02	03
20	010	045	050	315	275	315	280	265	255	260	275	270	280	270	275	275	275	275	275	270	270	265	270	265
	03	02	03	05	14	06	12	13	10	10	09	14	10	13	17	16	13	13	14	09	08	08	07	11
21	270	275	270	270	285	305	300	295	005	345	280	280	215	300	030	280	325	300	285	280	330	330	305	260
	11	11	12	12	14	10	08	08	03	03	04	05	04	03	04	05	05	04	07	06	06	04	02	02
22	205	360	000	355	335	340	015	360	135	180	195	170	040	030	040	060	345	345	305	280	240	315	320	320
	04	03	00	01	02	03	02	02	01	01	03	03	05	05	02	02	01	01	05	04	05	02	02	01
23	290	285	330	030	270	360	000	000	000	000	195	195	280	190	165	210	220	340	000	245	275	000	300	345
	02	03	02	02	02	01	00	00	00	00	02	03	03	03	03	03	02	01	00	02	02	00	01	05
24	335	265	315	280	270	270	330	285	280	235	275	265	260	260	270	255	265	280	295	350	015	360	030	270
	07	07	07	08	16	19	06	20	21	16	15	16	11	10	10	12	13	16	14	06	05	06	04	05
25	280	265	255	270	265	275	030	045	090	020		045	285	270	030	265	245	260	260	265	265	265	270	265
	09	16	16	07	13	10	05	03	02	04		05	10	14	06	08	13	19	16	19	22	20	21	16
26	295	340	145	205	260	010	015	005	010	015	015	065	275	275	295	270	270	280	285	270	265	275	275	265
	10	08	09	14	08	05	05	08	06	07	06	05	15	17	15	25	23	21	23	20	17	30	30	23
27	265	275	290	295	290	275	280	280	290	265	275	285	305	265	205	275	280	265	260	265	285	355	005	025
	15	15	15	37	40	45	43	40	28	20	20	19	14	10	06	16	15	09	08	10	08	09	09	05
28	345	355	355	290	325	360	355	000	360	085	185	145	130	125	175	195	035	100	025	010	015	020	025	035
	05	05	05	01	04	02	02	00	03	01	03	03	05	05	05	05	04	05	06	06	11	10	05	05
29	145	255	260	275	275	260	260	265	270	270	265	260	235	245	245	235	020	025	010	010	355	350	010	010
	05	07	12	13	13	15	18	17	18	15	20	17	12	10	12	10	10	09	09	07	08	11	10	06
30	360	005	300	255	270	255	255	315	010	025	055	345	240	235	240	005	340	360	285	010	060	005	030	010
	04	05	04	15	12	15	15	13	07	07	05	06	17	14	17	05	05	06	08	07	04	04	04	04

WIND DIRECTION AND VELOCITY

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	360	355	355	010	005	355	360	005	015	025	185	085	040	100	105	005	025	010	360	355	355	240	005	340
	05	06	05	03	09	10	08	08	06	05	05	06	05	04	04	04	07	05	05	05	03	01	04	03
2	000	225	235	150	355	310	235	340	265	215	050	045	035	055	035	055	025	005	300	335	355	360	005	330
	00	03	03	03	05	03	02	04	02	04	06	05	05	05	05	04	06	05	06	07	05	06	06	05
3	360	355	005	355	305	070	005	245	260	060	040	175	145	095	120	105	120	040	300	355	355	315	220	255
	04	05	05	05	02	03	02	02	01	01	01	05	04	07	05	06	04	04	07	08	07	04	04	05
4	250	020	295	000	310	345	025	025	265	175	230	235	235	265	255	265	265	205	270	250	225	260	270	270
	06	04	05	00	04	02	03	01	08	17	11	08	12	18	15	14	14	15	16	10	10	14	10	14
5	280	270	295	295	285	270	265	290	270	265	255	255	250	260	260	255	280	285	265	295	305	305	345	320
	13	15	10	11	13	13	15	15	16	15	13	13	17	15	18	16	15	09	09	10	08	06	04	02
6	270	275	025	350	355	360	010	010	360	030	155	205	195	310	305	330	340	015	005	355	355	260	150	020
	02	02	04	05	05	04	05	06	05	05	03	06	05	05	05	05	07	07	08	05	05	05	04	05
7	360	020	265	270	250	255	280	250	015	180	190	190	255	265	270	265	265	275	265	295	330	010	025	020
	05	03	03	01	04	03	02	02	03	03	04	12	20	17	20	15	14	14	06	08	03	08	13	09
8	360	025	325	255	025	360	300	030	360	170	175	205	205	215	240	175	185	210	210	175	225	335	320	270
	06	05	04	03	02	03	05	04	02	05	06	23	23	21	14	16	14	08	03	06	05	02	02	10
9	285	300	280	265	255	235	245	255	275	275	280	270	270	265	270	270	275	275	275	280	280	330	340	355
	10	11	13	19	20	17	14	19	28	26	24	25	24	22	21	20	17	17	16	14	13	05	05	03
10	345	250	355	355	000	025	260	300	000	025	025	025	025	025	025	025	035	025	030	025	025	000	000	275
	03	03	04	01	00	01	01	01	00	01	05	05	09	10	10	11	10	10	07	05	03	00	00	02
11	000	000	000	000	000	000	000	000	000	180	000	265	265	265	265	265	270	270	270	270	270	275	275	275
	00	00	00	00	00	00	00	00	00	01	00	09	11	14	15	18	19	23	23	23	22	20	21	18
12	335	025	355	355	300	360	010	355	010	000	050	045	035	025	025	025	025	025	020	025	020	360	020	360
	11	07	08	06	02	04	02	05	02	00	03	04	05	06	05	07	08	07	06	05	05	03	05	05
13	005	355	355	305	000	360	000	045	000	185	085	025	020	030	075	045	345	200	275	265	270	265	300	245
	04	05	04	04	00	04	00	01	00	03	01	05	10	05	02	04	04	10	15	15	15	15	10	07
14	325	335	350	310	310	260	345	025	235	135	125	050	085	065	055	025	215	355	360	025	010	360	335	210
	06	06	05	05	05	04	02	02	03	01	02	04	03	05	05	05	08	05	01	04	05	05	03	05
15	210	340	000	010	360	000	000	260	000	000	175	170	155	155	160	175	115	300	355	355	360	250	000	010
	02	03	00	03	01	00	00	01	00	00	02	03	05	05	03	05	04	05	05	04	04	03	00	01
16	220	225	000	000	010	020	000	255	190	150	100	135	115	090	030	020	010	300	355	000	250	000	235	025
	02	01	00	00	02	01	00	02	02	01	01	02	03	04	05	06	05	05	03	00	02	00	01	02
17	005	000	000	240	360	240	240	000	000	000	145	120	095	080	075	030	010	355	345	025	010	355	130	320
	04	00	00	03	01	01	01	00	00	00	01	02	02	02	03	04	03	03	02	01	01	02	02	02
18	270	020	355	340	055	325	010	325	215	200	135	040	025	015	010	300	355	005	350	010	355	000	175	355
	01	03	02	02	02	02	02	01	02	02	04	08	12	13	10	05	05	02	03	04	05	00	02	06
19	355	005	025	350	295	255	130	015	020	020	055	045	040	030	015	000	010	360	360	010	025	025	095	035
	03	06	04	05	02	05	05	07	08	04	03	05	04	05	05	00	07	06	05	05	05	06	04	07
20	020	130	300	295	305	320	330	320	355	220	275	255	255	250	265	250	265	260	260	265	260	260	270	255
	06	10	17	29	22	18	10	10	08	06	12	15	13	17	18	17	10	10	13	09	12	18	15	07
21	295	025	005	015	010	010	235			070	025	025	085	070	115	035	335	010	360	010	355	285	055	350
	05	05	06	07	07	04	01			02	05	05	03	03	03	03	07	07	07	07	05	03	05	03
22	355	250	265	130	325	235	000	345	030		060	030	035	040	045	055	060	040	040	355	040	050	325	270
	02	03	01	01	04	01	00	01	00		01	05	07	08	09	07	05	06	08	05	05	06	03	06
23	160	280	295	300	295	290	285	280	275	175	040	010	105	110	150	175	120	010	360	040	000	000	000	145
	07	21	15	20	18	15	20	08	08	04	02	02	02	02	05	04	05	07	05	04	00	00	00	05
24	310	315	015	005	360	015	025	360	010	325	020	030	025	325	055	050	055	020	015	205	345	305	250	250
	05	07	04	06	04	05	01	02	03	04	04	02	05	05	04	03	03	03	02	02	03	07	07	09
25	250	220	250	275	265	325	310	295	310	175	170	130	115	115	165	235	260	335	315	295	265	280	305	335
	08	09	08	13	04	06	07	06	07	04	03	04	05	02	04	07	10	05	08	14	16	12	08	05
26	235	325	335	145	025	000	340	220	065	000	190	160	175	175	175	145	120	085	360	355	355	000	000	000
	02	05	05	04	01	00	01	01	02	00	02	02	03	05	04	02	03	03	05	04	04	00	00	00
27	000	220	000	000	000	000	000	000	000	000	000	000	175	175	130	095	035	005	360	350	355	345	070	305
	00	01	00	00	00	00	00	00	00	00	00	00	03	02	03	02	07	07	08	05	04	02	01	03
28	070	355	000	045	025	360	355	010	010	015	025	000	215	210	000	030	035	010	030	040	010	345	340	285
	02	04	00	01	03	02	03	05	04	03	01	00	02	02	00	04	06	08	09	03	03	03	03	17
29	285	275	285	280	230	280	230	265	285	280	275	275	280	270	280	250	275	280	280	285	290	290	290	280
	20	21	23	21	22	22	23	20	24	25	24	23	22	22	24	25	25	24	19	20	25	25	24	20
30	280	260	275	280	270	270	265	270	280	295	260	270	270	265	270	280	280	285	285	285	275	280	275	290
	20	15	18	16	15	16	15	13	11	14	16	18	19	20	23	27	23	22	22	17	15	15	13	12
31	295	295	275	280	240	325	360	010	325	055	170	055	035	030	010	115	290	245	290	295	235	285	340	295
	12	11	09	07	05	05	07	10	03	03	04	08	07	08	03	05	08	05	11	09	11	10	04	05

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DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	265	295	340	160	265	255	255	255	255	240	250	095	055	030	020	340	025	015	325	325	310	340	355	205
	10	08	04	02	05	04	03	03	03	05	03	03	05	10	06	05	05	05	07	08	06	05	03	01
2	260	340	355	245	240	185	000	020	245	225	195	125	145	150	160	130	105	025	005	005	005	005	360	360
	02	03	01	01	02	02	00	01	03	01	02	03	03	04	03	04	05	07	06	06	06	04	01	02
3	000	015	030	000	175	055	355	350	015	025	060	130	100	100	100	130	035	030	025	015	020	010	360	005
	00	01	00	00	03	02	00	02	01	02	02	02	04	04	04	02	07	10	08	05	04	04	04	05
4	340	360	235	255	345	360	310	245	100	020	115	180	000	360	025	015	350	320	290	275	275	265	300	285
	04	02	03	01	02	03	01	03	01	02	01	02	00	01	06	05	05	07	09	13	14	12	10	10
5	275	235	235	265	305	290	330	335	015	360	355	155	205	110	145	125	115	100	010	355	355	010	355	355
	10	06	06	10	07	02	03	03	04	03	03	03	03	03	05	05	04	01	05	05	05	03	04	03
6	300	025	335	285	295	240	000	000	195	345	050	030	065	105	125	215	240	255	260	265	285	285	000	215
	03	03	02	03	02	01	00	00	02	05	03	03	04	02	03	02	04	03	03	02	01	01	00	01
7	225	190	360	000	000	000	005	235	355	000	255	205	165	140	175	205	145	065	360	360	345	270	185	040
	01	01	02	00	00	00	03	02	01	00	02	03	04	02	04	03	03	02	04	05	03	01	01	02
8	310	245	270	005	030	000	030	000	000	000	245	330	035	025	030	035	030	010	010	360	325	360	025	355
	03	03	01	03	00	00	01	00	00	00	02	02	07	10	05	06	07	06	03	04	01	02	01	03
9	340	010	015	000	000	195	270	000	000	000	220	115	045	025	030	025	015	005	350	265	000	000	335	330
	01	00	01	00	00	02	02	00	00	00	01	01	05	06	05	06	04	03	03	02	00	00	01	02
10	330	000	000	000	295	265	345	270	355	150	235	240	100	155	315	275	275	275	280	225	265	360	205	010
	01	00	00	00	01	02	01	01	01	01	01	01	02	03	05	15	13	13	12	08	11	08	06	05
11	015	325	355	000	025	000	000	000	000	000	180	205	190	185	185	175	135	000	000	010	035	005	040	000
	03	03	02	00	01	00	00	00	00	00	01	04	04	06	05	05	04	00	00	03	03	02	01	00
12	025	025	005	010	000	195	010	005	305	300	070	130	050	100	120	030	025	010	025	330	190	000	075	360
	03	03	03	01	00	01	03	02	02	00	01	02	02	04	04	05	05	05	04	03	01	00	05	02
13	320	005	000	330	265	265	235	265	030	240	215	200	130	090	040	250	175	000	215	230	185	185	000	330
	02	03	00	03	01	02	01	01	02	02	02	05	05	04	06	01	01	00	04	02	01	04	00	04
14	185	335	300	145	065	250	235	320	010	090	220	210	185	125	115	165	275	000	235	200	250	000	360	135
	04	04	03	02	01	01	03	02	02	01	03	03	03	02	02	03	01	00	02	01	02	00	02	01
15	340	245	220	355	340	010	000	220	000	000		000	190	165	105	110	055	080	030	005	360	000	235	275
	02	04	02	01	01	01	00	01	00	00		00	03	02	05	03	03	03	03	04	02	00	01	01
16	000	245	015	055	340	235	000	185	000	000	135	130	200	165	150	135	110	095	100	055	025	025	015	010
	00	02	03	01	01	01	00	01	00	00	01	02	02	02	03	03	03	02	02	04	05	05	05	03
17	010	025	025	025	015	025	015	010	350	265	225	245	055	065	225	115	100	015	190	170	265	235	245	215
	03	03	04	05	04	03	03	03	03	01	01	01	02	02	02	01	03	04	05	05	07	12	09	08
18	260	235	205	015	240	090	010	265	305	355	005	035	025	035	040	035	025	025	030	010	360	010	010	005
	04	05	04	02	02	03	04	03	02	03	04	05	05	10	08	09	10	12	08	05	03	04	04	05
19	005	015	015	005	360	350	010	330	015	005	025	030	035	020	025	035	035	045	045	325	275	270	275	280
	05	05	07	05	06	04	04	03	03	04	06	07	10	09	08	10	07	02	03	07	14	14	14	17
20	280	275	285	265	275	275	265	270	270	270	275	275	280	280	275	275	275	275	275	275	280	275	280	280
	17	14	18	17	18	20	19	20	21	21	25	27	25	28	27	25	26	27	28	28	29	27	24	20
21	275	275	280	280	315	355	355	340	290	325	325	325	270	270	270	270	280	280	275	270	270	270	270	275
	17	24	21	19	13	06	07	06	12	08	09	09	15	18	20	22	17	15	15	16	17	16	20	23
22	275	275	280	260	280	275	275	270	270	270	265	025	020	030	030	030	025	355	295	285	280	280	275	275
	24	24	24	22	21	19	15	14	14	11	05	10	18	16	17	16	14	04	09	13	15	14	15	17
23	275	295	270	270	295	315	245	015	355	205	010	050	100	140	105	060	025	015	360	350	000	360	125	000
	14	11	13	13	09	06	04	05	04	02	04	04	02	04	03	03	04	03	03	07	00	03	02	00
24	105	000	085	230	340	080	335	000	000	225	195	175	170	170	145	105	100	090	010	360	005	025	335	205
	01	00	01	03	01	02	01	00	00	01	01	03	03	03	04	06	05	04	05	05	03	01	01	01
25	355	000	015	005	190	000	180	070	000	000	145	150	130	115	085	025	025	010	005	360	355	005	005	355
	02	00	01	02	01	00	01	01	00	00	01	03	03	03	03	08	08	06	04	05	05	02	02	03
26	345	360	340	265	010	010	310	000	340	325	145	025	040	350	165	265	265	265	265	265	265	265	265	270
	02	02	01	03	03	03	02	00	02	01	01	01	03	03	06	22	17	25	22	20	17	19	22	20
27	265	265	265	275	265	280	280	280	275	270	265	335	035	325	025	315	025	315	360	350	335	295	325	275
	19	21	16	15	12	17	15	14	13	14	11	05	11	12	15	15	13	10	06	05	04	03	03	05
28	250	315	360	000	160	240	270	315	000	000	000	170	175	170	160	145	110	065	360	360	360	355	355	000
	01	01	05	00	02	02	01	02	00	00	00	03	05	05	05	05	08	05	05	05	05	03	01	00
29	000	000	000	000	245	000	340	000	000	180	200	160	145	100	090	050	030	020	005	355	325	000	000	340
	00	00	00	00	01	00	01	00	00	01	02	02	02	04	05	05	06	06	05	05	02	00	00	01
30	330	000	205	285	010	000	000	000	000	000	115	075	025	340	025	025	020	005	005	360	355	355	355	350
	01	00	01	01	01	00	00	00	00	00	02	03	03	03	05	05	05	05	03	03	03	03	04	03
31	290	295	245	015	025	035	005	015	020	215	265	265	265	250	265	275	265	265	265	265	270	270	270	265
	02	02	02	03	03	03	04	04	01	07	10	10	12	15	13	12	11	13	10	09	11	10	11	13

WIND DIRECTION AND VELOCITY: EMERY, UTAH (PERIOD AVERAGES) FEBRY, 1973

DATE \ HOURS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	275	280	280	280	275	270	260	270	270	270	260	260	270	255	265	270	270	280	280	285	295	295	325	335
	11	15	15	16	17	15	14	14	15	13	14	14	12	10	12	14	15	17	16	13	14	13	09	06
2	340	040	340	340	090	330	030	000	220	220	150	150	130	150	130	130	060	020	010	010	360	000	360	300
	06	03	04	02	02	01	00	00	01	02	02	03	04	03	04	03	06	07	07	05	03	00	02	02
3	000	000	000	010	230	140	120	360	230	080	130	150	120	160	130	110	100	100	040	010	020	020	360	360
	00	00	00	02	02	02	02	02	02	01	02	03	04	04	05	05	03	03	02	02	04	05	04	04
4	360	340	030	210	000	000	000	000	000	080	020	050	030	360	090	350	360	020	015	360	320	015	260	230
	04	01	02	01	00	00	00	00	00	02	05	05	05	05	02	04	04	05	05	06	03	04	02	01
5	240	330	360	000	000	000	030	330	360	230	220	100	020	020	020	020	020	015	010	015	010	290	000	015
	03	02	02	00	00	00	00	02	02	03	02	03	05	10	10	11	11	07	07	06	05	03	00	02
6	015	015	010	015	015	360	340	000	000	000	000	000	050	360	090	120	090	100	060	030	015	360	360	330
	03	03	04	04	03	04	03	00	00	00	00	00	04	03	05	03	05	04	03	04	04	06	03	03
7	360	015	340	015	015	300	020	020	010	360	030	030	060	130	180	030	080	030	360	360	360	360	000	290
	02	03	04	05	05	04	03	03	03	02	02	05	03	03	03	02	02	02	04	05	04	03	00	02
8	220	200	360	360	015	015	020	350	270	000	015	015	010	050	030	015	015	360	360	015	015	050	360	030
	03	03	05	08	08	07	07	05	04	00	07	06	04	06	08	08	05	08	05	03	02	02	03	04
9	360	360	250	270	350	360	360	020	015	030	030	040	150	130	010	035	035	025	025	005	015	010	005	010
	06	03	02	03	04	05	04	03	06	08	08	05	05	07	06	06	08	08	07	04	03	03	03	02
10	010	010	005	020	010	015	015	010	020	025	010	040	050	185	240	330	015	015	010	065	005	005	005	010
	04	05	06	05	05	06	06	05	04	04	04	03	02	01	02	02	05	06	04	04	03	03	04	03
11	005	005	235	235	000	010	020	015	025	020	015	020	020	015	020	010	025	035	015	005	245	235	255	245
	02	01	02	02	00	03	07	08	09	09	08	07	09	08	06	08	07	03	07	01	02	03	01	01
12	235	265	225	220	210	255	175	140	265	245	275	275	290	210	240	250	260	305	275	265	250	235	360	325
	03	02	04	05	09	07	05	05	06	05	13	14	10	05	10	09	07	08	05	07	03	04	04	01
13	270	295	005	330	360	000	360	210	000	000	000	000	035	010		015	030	005	005	360	295	245	210	010
	03	03	01	01	03	00	01	02	00	00	00	00	02	02		01	03	05	05	05	04	04	01	02
14	000	000	295	350	230	360	000	000	220	360	015	015	020	025	025	020	025	025	025	360	255	010	355	305
	00	00	01	01	01	01	00	00	01	01	04	08	09	11	11	10	11	11	07	05	04	03	04	02
15	200	000	350	360	355	355	330	330	000	000	000	000	225	220	260	000	020	020	010	010	360	330	250	355
	02	00	01	03	03	03	01	01	00	00	00	00	01	02	03	00	05	06	07	07	06	02	05	04
16	350	000	285	360	180	230	350	275	000	355	255	255	000	235	000	020	005	010	280	275	275	275	275	275
	03	00	01	02	01	02	02	02	00	04	01	01	03	01	00	07	07	03	03	13	16	15	13	14
17	270	320	320	275	275	260	330	310	000	000	000	210	185	215	240	200	180	030	350	360	000	350	005	360
	14	13	07	13	13	09	06	03	00	00	00	01	02	02	02	03	02	00	02	01	00	01	02	06
18	355	355	280	000	285	230	000	300	000	250	000	220	260	335	220	265	270	265	260	255	275	280	275	270
	07	05	01	00	01	01	00	01	00	01	00	03	10	07	08	14	12	13	11	10	12	06	10	06
19	270	330	360	360	355	355	130	335	235	000	105	000	000	000	000	020	015	010	015	355	275	250	000	000
	11	05	03	04	05	06	01	01	01	00	01	00	00	00	00	07	09	09	07	06	04	01	00	00
20	345	350	005	340	305	360	255	000	000	000	000	195	185	175	195	350	015	010	360	340	330	340	315	030
	03	02	01	01	01	01	01	00	00	00	00	01	03	03	01	01	06	15	06	07	05	05	03	04
21	300	300	000	120	180	220	210	240	345	220	180	120	190	190	240	240	360	045	360	030	345	360	360	360
	00	00	00	02	03	04	03	04	05	03	02	03	03	04	02	02	02	04	05	06	05	06	08	08
22	015	360	270	270	000	290	255	240	360	240	200	150	190	120	180	315	030	015	360	360	340	330	240	000
	10	04	04	05	00	05	03	03	05	03	04	04	04	04	02	04	04	06	06	08	06	05	04	00
23	015	360	360	360	345	360	330	000	000	060	200	180	090	360	100	045	030	015	000	360	020	360	360	360
	06	06	06	07	07	06	06	00	00	03	03	03	03	04	03	04	04	03	00	06	07	06	05	05
24	240	240	225	270	290	270	360	015	015	020	015	030	360	015	030	030	015	020	015	015	015	030	015	360
	06	04	05	03	06	03	04	07	07	07	08	08	07	06	05	06	08	08	06	06	07	07	06	05
25	360	300	270	300	000	030	350	360	300	360	360	030	270	180	210	210	345	000	015	300	360	360	315	230
	04	04	04	04	00	04	05	05	05	04	05	05	03	03	06	04	02	00	04	06	07	06	05	03
26	360	340	030	000	000	000	000	000	000	360	000	165	120	120	150	150	240	300	360	345	015	360	360	360
	03	04	00	00	00	00	00	00	00	00	00	05	05	03	03	05	03	03	04	07	07	07	06	05
27	360	270	330	000	000	000	360	360	000	000	150	150	210	180	045	015	015	015	015	015	360	360	360	330
	05	03	05	00	00	00	04	04	00	00	02	05	05	05	03	07	13	12	10	07	07	06	07	06
28	000	000	350	000	360	000	000	360	180	270	225	180	210	000	270	285	075	020	015	015	015	350	000	000
	00	00	03	00	03	00	00	03	05	04	05	04	03	00	05	06	06	07	07	08	07	07	00	00

WIND DIRECTION AND VELOCITY: EMERY, UTAH (PERIOD AVERAGES) MARCH, 1973

DATE \ HOURS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	000	000	000	330	330	020	360	015	360	240	230	150	100	240	330	360	015	015	030	020	030	350	350	360
	00	00	00	03	06	05	05	05	05	04	04	04	05	04	05	07	10	11	12	11	08	06	06	06
2	360	000	260	240	310	000	330	360	090	195	195	225	240	260	260	255	255	250	250	260	270	270	260	260
	05	00	03	04	03	00	05	04	03	04	10	15	15	20	22	17	17	20	20	23	20	17	17	20
3	260	260	260	260	260	265	265	270	350	360	050	030	030	020	030	060	030	030	360	020	010	350	360	330
	18	22	20	20		17	17	13	03	03	05	09	10	07	07	15	07	09	08	07		06	06	02
4	360	015	360	360	315	015	020	015	045	020	015	015	030	015	030	030	030	030	030	030	030	015	330	270
	03	04	04	04	07	08	10	07	07	10	09	11	10	10	09	10	11	10	08	07	08	05	05	05
5	060	300	240	240	225	210	225	225	230	225	225	230	230	240	240	240	250	255	255	230	240	230	250	250
	03	06	10	12	10	10	08	10	12	14	13	16	15	18		12			16	11	10	09	07	06
6	240	260	270	240	210	240	270	270	210	180	165	150	165	150	170	270	360	360	020	030	030	020	020	015
	12	10	06	06	04	06	06	04	07	06	05	06		10	08	05	06	08	08	08	08	07	07	07
7	310	360	015	015	030	030	030	040	030	020	010	010	030	030	030	020	030	030	000	260	270	315	260	270
	07	06	07	07	07	09			12			11	10	08	09	09	08	06	03	04	06	05	06	05
8	300	270	250	315	315	330	360	360	120	210	075	110	045	360	030	020	030	020	030	015	000	000	000	000
	06	05	06	05	05		04		03	05	04	03	04	04	05	09	09	08	07	06	00	00	00	00
9	000	030	020	000	360	000	360	250	360	100	120	120	060	080	015	045	360	280	205	260	260	250	270	270
	03	00	00	00	00	00	05	04	04	04	04	04	04	04	05	14	09	10	09	07	05	05	02	05
10	265	260	270	270	265	230	255	240	255	260	090	100	265	180	210	240	250	230	175	210	255	210	270	270
	09	13	10						10		04	04	05	08	10	15	12	08	06	07	06	04	08	07
11	270	330	240	120	270	360	360	015	010	015	015	015	350	010	015	135	150	140	140	020	030	350	015	010
	04	03	05	04					05	06	06	08	08	05	10	10	10	12	11	10	07	05	06	09
12	015	020	020	015	015	020	190	350	350	330	010	015	015	010	040	150	150	165	240	210	180	210	210	210
	14	12		14	15			04		09	10		09	09	04	07	04	06	04	05				
13	225	230	250	230	230	240	240	240	230	210	180	180	180	225	225	230	240	240	240	240	240	255	255	260
											07	10	10	11	07	10	14	14	07	11	09	12	10	13
14	240	255	250	255	255	250	255	260	350	015	030	045	030	270	270	270	255	260	260	270	255	255	260	260
	13	10	13	15					06	07	06	04	04	04	04	05	11	14	15	15	15	14	15	15
15	260	260	270	260	270	270	270	260	255	255	255	255	255	255	255	255	255	260	260	255	255	260	260	285
	16	17			15		17			11		14	15	14	13	14	15	17	19	16	18	17	16	14
16	280	315	255	360	330	270	360	090	090	110	120	170	210	180	210	190	165	150	000	270	300	330	000	360
		06	06		04			01	02	03	04	04	04	05	04	05	05	04	00	08	06	04	00	03
17	360	000	000	000	000	000	360	010	360	360	090	150	180	315	315	015	040	315	240	270	330	090	210	255
	03	00	00	00	00	00					05	05	04	04	07	05	10	06	05	04	05	09	05	08
18	225	250	270	270	270	330	360	180	255	255	225	240	255	250	255	255	260	260	260	260	260	260	260	260
	10	11	06	05	05	04	03		10	11	08	10	15	17	20	20	22	18	18	16	14	14	16	13
19	270	270	270	290	290	300	260	360	045	030	100	100	120	090	090	090	090	090	090	030	045	330	300	360
	11	10								04		06	05	05	05	08	07	07	06	03	03	04	02	03
20	315	360	330	360	015	045	045	305	350	135	150	285	100	110	120	120	115	250	220	285	270	180	180	180
	04	03	05	02	04			05			07			17	13	12	15	08	08	06	04	10	06	05
21	195	140	130	165	165	165	170	160	165	165	165	180	165	285	030	255	240	210	225	225	210	210	240	240
	05	08	11	12	13	15	16	14	15								05			12	10	10	03	04
22	225	360	030	150	250	300	270	195	180	150	180	150	180	100	110	100	240	270	210	360	020	360	330	345
	04	02	05	05	04	04	05	03	04	05	06	04	05	04	07		04	08	04	05	06		03	03
23	330	270	150	270	265	270	270	255	255	350	350	015	010	010	015	010	360	360	015	015	010	360	360	360
	05	05	04	08	12	15	16	11													13			20
24	360	350											015	015	010	015	330	015	040	295	295	345	350	005
	15												23	17	14	12	04	04	04	08	08	12	11	13
25	005	005	350	265	235	270	310	270	265	120	060	045	120	070	180	030	180	195	165	160	265	265	270	275
	13	10	06	06	06	08	05	05	05	03	04	04	04	05	05	04	05	04	04	02	05	07	09	08
26	235	235	335	330	010	295	030	275	060	330	055	095	130	175	175	135	120	155	080	295	280	265	265	350
	07	04	05	03	02	06	00	02	02	02	03	05	05	06	04	06	05	07	07	08	10	08	10	01
27	270	330	210	150	265	260	260	310	210	210	220	260	235	225	230	245	240	235	235	240	245	260	260	230
	03	02	03	02	05	10	06	08	07	07	09	07	14	13	12	20	13	12	12	18	18	17	07	08
28	245	225	330	245	245	260	260	250	265	270	105	075	150	240	045	050	300	030	240	270	065	005	350	240
	09	05	04	11	12	08	16	12	13	06	05	05	08	08	06	13	07	07	09	04	04	04	02	08
29	245	220	275	330	060	280	275	345	045	055	015	010	300	250	255	255	240	250	255	250	250	255	245	260
	09	03	07	05	01	07	05	03	03	06	03	02	04	12	17		22	22	17	11	14	14	16	19
30	260	260	250	265	260	260	260	265	260	260	250	245	225	230	230	230	235	240	250	255	270	245	210	210
	21	20	19	16	14	15	16	09	15	15	14	07	11	12	15	15	17	19	17	15	08	06	09	10
31	235	240	260	245	215	215	120	250	180	220	225	250	255	225	275	295	235	245	235	215	235	265	245	250
	09	09	05	06	09				03	11	08	11	13	16	12	16	13	14	11	08	08	07		08

WIND DIRECTION AND VELOCITY: EMERY, UTAH (PERIOD AVERAGES) APRIL, 1973

DATE \ HOURS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	275	350	335	280	255	305	355	180	360	015	095	260	285	240	255	240	270	080	045	350	315	295	270	250
	05		04	04	06	05	05	04	04	02	06	12	07	15	13	12	05	04	06	04		06	02	08
2	260	265	255	270	265	350	000	255	325	360	005	010	010	010	010	015	035	005	005	005	005	005	005	005
	14	08	12	11	12	03	03	04	09	17	16	20	24	27	28	28		24	24	31	31	29	28	24
3	005	015	005	005	360	360	005	005	005	010	010	015	010	010	015	015	280	200	190	020	010	330	080	100
	21	16	16		23	24	20		26	26	24	20	13	16	15	17	16	11	06	08	21	03	03	02
4	100	005	335	345	010	005	350	350	010	010	015	015	025	030	040	015	330	200	230	255	265	265	260	270
	02	06	07					10	21	23	17	13	13	09	08	16	04	06	08	12	12	11	13	14
5	265	265	265	270	265	275	310	360	020	035	100	105	140	150	150	150	230	240	250	245	255	270	270	020
	16		14	10	14	14	07	04	05	07	04	05	05	06	06	05	08	09	14	15	12	09	10	
6	120	200	025	360	245	205	290	285	240	220	235	245	260	265	255	255	260	260	330	270	200	250	255	255
	04	05	02	04	07	11	04	02	11	10	09	15	17	16	20	22		18	06		10		16	09
7	280	230	225	245	245	245	260	255	280	270	280	230	300	305	310	235	345	005	030	025	020	015	015	010
	05	05	12	16	18	16	22	24	30	29	32	29	23	29	27	26	23	19	15	16	22	21	19	12
8	010	005	345	355	330	155	060	175	250	250	225	245	240	260	240	240	200	255	260	255	250	245	235	230
	11	10	06	06	05	01	02	06	16	17	08	09	12	18	23	20	19	20	19	17	15	10	12	10
9	235	240	240	240	240	235	255	240	230	230	240	260	275	285	330	315	265	270	275	270	255	245	255	295
	05	05	09	11	11	07	06	11	14	14		15	14	17	16		14	13	10	06	07	02	07	04
10	250	260	260	300	005	030	000	100	070	120	200	230	240	275	270	245	275	245	245	245	245	280	275	280
	06	07	06	04	03	01	00	01	02	04		12	11		11	12	13	13	11	08	08	07	07	01
11	165	265	265	180	240	235	360	360	235	185	340	100	300	030	005	315	260	230	245	305	310	265	255	290
	04	04	06	04	05	07		02	07	08	05	05	10	14	13	10	10	12	10	07	03	07	07	07
12	310	290	315	340	030	220	340	175	120	150	145	135	200	135		050	150	190	320	210	240	060	330	360
	04	04	03	03	02	02	02	02	02	04	08	07		06		11	05	07	[illegible]	06	03	03	05	02
13	315	345	180	195	105	140	250	090	070	135	165	160	210	230	220	225	230	230	235	240	240	250	260	260
	03	01	01	02	02	03	02	02	03	03	06	08	09	16	21	21	27	20	20	14	11	14	15	14
14	225	200	220	215	235	275	135	250	180	180	200	210	215	240	245	270	290	290	285	300	300	295	315	300
	11	10	11	08	10	10	04	03	04	11	11	14	21	26	23	26	23	19	17	16	18	14	13	13
15	295	290	300	300	295	295	285	275	280	315	315	290	285	285	300	280	285	285	300	305	285	315	305	310
	14	16	16	19	16	12	11	11	10	12	15	20	13	18	13	18	15	16	15	12	10	09	08	08
16	315	300	105	350	030	040	060	215	165	195	240	270	300	285	280	255	265	270	275	265	240	225	225	250
	05	03	04	05	02	02	01	01	01	02	08	12	11	14	15	14	15	11	09	10	08	07	07	09
17	255	240	210	195	210	225	250	210	240	225	240	225	280	295	290	250	180	200	215	225	240	285	295	255
	02	06	06	04	06	04	05	03	03	07	05	09	14	13	15	11	11	13	18	17	17	21	15	21
18	295	290	300	285	295	295	295	295	295	290	290	295	295	300	315	300	290	300	315	345	315	295	315	310
	22	21	17	17	17	16	15	18	19	23	22	19	13	20	15	18	20	18	17	13	11	10	08	10
19	315	315	315	310	315	310	300	300	310	335	305	305	295	300	300	310	300	300	295	200	230	240	250	220
	20	26	25	22	20	12	15	12	23	20	23	21	21	22	21	21	18	19	16	10	05	08	07	08
20	270	275	275	280	280	290	290	285	285	285	290	285	280	280	275	280	285	285	290	280	270	290	285	280
	11	12	12	12	14	13	12	13	15	15	16	20	13	17	18	15	14	17	15	11	10	11	14	13
21	275	295	290	290	285	285	280	275	280	265	280	300	285	290	285	290	290	295	300	300	300	300	300	300
	11	14	15	11	14	13	13	10	13	13	10	10	05	07	13	13	15	19	17	17	15	15	13	14
22	300	290	310	330	360	020	060	315	270	255	270	225	200	150	150	190	290	335	300	295	290	245	260	300
	14	11	08	07	03	03	01	02	05	06	05	05	05	06	06	19	10	13	13	14	09	05	04	05
23	015	345	330	345	255	290	180	045	105	120	140	160	195	200	200	210	285	325	300	300	335	335	300	255
	03	04	02	02	01	01	01	02	01	02	04	05	06	07	12	15	22	20	13	09	09	09	07	05
24	310	310	310	315	060	200	145	035	050	180	170	190	240	260	295	075	315	285	315	315	310	285	280	280
	10	09	07	07	05	02	01	06	06	03	11	08	05	08	11	13	15	13	13	14	14	05	05	07
25	280	270	245	300	350	260	315	290	270	275	280	300	315	330	300	330	300	300	305	310	340	010	360	040
	07	03	11	08	03	01	04	03	04	08	15	14	13	18	20	18	18	18	18	13	06	08	06	08
26	300	010	150	035	050	045	315	275	225	075	130	060	135	180	195	170	130	135	170	210	240	260	310	315
	07	08	05	09	09	05	01	03	03	06	06	04	05	04	05	05	05	04	03	03	02	03	07	09
27	300	340	330	330	025	000	310	045	135	180	195	170	165	165	165	170	180	185	190	190	250	270	315	330
	06	04	05	06	03	00	02	01	01	02	05	06	07	07	08	09	12	13	13	08	06	06	09	09
28	030	300	210	180	240	250	150	195	140	225	275	260	310	290	300	330	340	295	330	310	300	300	295	295
	04	09	02	02	03	03	02	02	05	08	13	24	23	18	17	16	21	14	15	18	15	20	21	18
29	300	300	270	290	015	330	330	030	120	180	195	255	270	280	280	290	250	300	290	290	285	285	300	300
	13	14	07	06	02	07	06	02	03	14	17	23	25	23	23	20	18	15	15	15	15	13	16	18
30	290	290	300	300	345	090	060	075	075	075	060	090	120	240	285	290	270	300	280	300	345	090	290	285
	18	16	14	10	08	07	07	07	05	05	05	03	05	15	15	11	08	07	13	10	04	03	10	13

WIND DIRECTION AND VELOCITY: EMERY, UTAH (PERIOD AVERAGES) MAY, 1973

HOUR / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	285	330	330	285	285	300	330	315	300	330	300	285	315	270	315	330	300	270	300	330	330	360	120	000
	12	13	13	10	10	09	07	05	10	11	14	15	13	14	12	15	17	10	15	25	25	10	05	00
2	330	290	270	240	180	030	285	240	255	120	070	120	090	195	185	180	195	165	170	180	165	270	275	335
	04	07	07	05	02	06	01	03	03	04	05	05	05	06	06	06	06	13	10	08	06	02	03	05
3	035	310	295	345	030	000	255	000	120	135	150	180	210	195	195	150	170	165	150	150	165	290	270	330
	01	03	04	03	03	00	02	00	01	03	05	07	06	12	11	10	10	11	10	08	03	05	06	01
4	030	000	080	030	360	285	285	270	260	210	200	225	210	215	225	230	225	225	220	210	225	240	135	240
	03	00	02	03	03	02	10	08	06	11	13	17	21	25	19	20	23	23	22	18	15	13	05	02
5	250	260	245	260	240	270	260	285	155	165	170	140	150	160	150	150	185	195	205	315	090	165	245	015
	11	10	[illegible]	05	06	05	05	03	06	13	15	12	15	15	15	16	15	09	10	06	04	03	03	03
6	340	255	215	195	170	130	140	150	130	155	120	045	300	320	330	300	300	300	315	310	320	300	300	335
	01	02	05	05	05	05	05	03	03	03	05	06	22	22	21	19	16	14	13	08	04	01	05	04
7	270	300	290	290	285	285	265	270	300	265	285	300	290	300	315	330	360	330	300	300	300	290	290	285
	02	06	09	10	07	07	12	05	13	12	08	07	11	11	13	11	08	11	10	08	07	06	05	08
8	300	180	030	300	295	285	300	270	120	180	195	270	270	285	285	295	270	240	270	300	330	315	300	300
	05	02	01	08	10	10	11	03	03	06	07	18	20	18	18	16	13	04	10	08	06	06	08	10
9	300	300	300	315	300	345	090	210	150	150	270	270	270	270	270	270	270	285	270	255	250	225	285	285
	10	07	05	07	10	06	02	05	04	05	18	20	21	23	23	20	20	13	08	08	07	05	07	07
10	285	300	295	300	300	285	315	315	300	270	285	285	280	270	270	285	295	300	315	315	330	315	315	300
	05	07	07	08	06	06	08	08	10	15	18	20	15	18	20	16	18	13	13	08	09	07	08	10
11	360	300	360	030	030	360	040	360	240	180	190	180	150	210	280	330	315	315	300	315	280	360	290	330
	06	09	04	04	03	02	05	03	03	03	05	06	07	08	14	14	12	10	08	07	07	06	09	08
12	315	315	030	075	360	045	360	315	000	345	120	090	120	240	150	240	255	230	045	030	315	360	315	300
	07	03	04	02	03	03	03	05	00	02	03	04	05	18	15	18	05	08	25	08	06	08	07	07
13	300	090	015	030	030	030	060	300	000	075	075	060	135	090	060	060	060	060	045	045	045	040	045	060
	06	04	03	04	04	05	04	05	00	05	07	08	05	05	06	07	08	07	08	10	10	08	08	12
14	045	060	050	060	360	360	360	180	075	075	090	075	060	150	180	150	060	060	060	090	165	180	300	315
	20	17	06	12	05	04	03	03	12	14	10	06	05	06	04	05	06	05	05	05	09	07	06	06
15	045	330	360	300	360	360	360	240	135	180	210	180	150	180	180	120	105	090	210	150	140	180	270	270
	03	05	03	04	02	03	03	02	02	03	03	06	04	06	06	07	05	07	03	10	05	04	07	09
16	300	040	070	035	000	050	030	060	030	100	075	075	050	050	090	045	075	105	345	300	305	315	030	300
	05	05	06	06	00	05	03	03	04	03	09	15	10	08	08	06	06	04	02	00	08	10	05	02
17	315	020	270	250	280	300	310	050	135	150	105	150	240	240	320	355	345	330	330	310	315	320	300	300
	07	02	05	03	08	10	11	03	01	02	05	07	07	05	08	08	10	12	11	11	10	11	07	10
18	310	330	295	300	360	315	315	310	300	310	300	285	150	255	150	300	325	335	315	320	330	225	255	335
	11	12	11	12	07	12	10	12	12	05	03	03	05	07	03	03	09	11	11	10	09	05	04	05
19	300	330	315	315	295	330	240	040	255	285	290	210	210	170	150	125	085	010	240	150	210	335	150	030
	04	06	05	07	07	07	05	03	02	08	05	09	11	08	07	06	06	14	09	10	05	07	04	07
20	030	295	050	285	345	270	270	045	120	130	195	180	180	270	270	250	255	250	290	300	315	315	315	315
	03	02	07	03	03	03	03	01	01	02	07	07	10	15	14	18	20	18	15	19	23	23	18	16
21	315	240	260	210	110	335	060	165	160	095	120	230	240	220	240	285	280	315	315	300	285	015	015	320
	13	07	12	03	04	06	03	01	02	02	04	04	10	14	22	16	10	13	15	09	06	05	05	05
22	280	300	270	255	210	245	310	020	050	090	150	170	160	200	170	270	300	320	330	335	330	320	315	320
	04	00	05	03	03	03	05	03	05	03	03	03	03	04	05	10	13	13	11	10	10	06	08	09
23	320	295	340	060	080	345	025	060	090	100	195	120	100	195	225	225	255	210	255	270	315	315	270	270
	09	05	07	03	03	03	03	03	04	04	03	08	08	10	13	15	10	11	08	08	05	07	05	04
24	275	295	300	150	120	230	260																	
	05	05	05	01	03	03	05																	
25																								
26											325	320	320	310	320	315	330	325	330	330	330	340	345	330
											15	20	22	17	17	17	20	15	16	19	23	26	16	10
27	330	360	225	300	295	290	285	270	325	345	350	345	345	350	360	345	345	340	345	350	360	360	360	360
	09	03	03	04	04	06	03	03	10	20	18	15	17	16	16	11	12	15	12	11	09	12	11	08
28	085	000	060	045	040	060	315	245	305	240	140	240	160	210	180	255	345	345	330	320	325	330	325	325
	02	00	04	01	02	02	05	05	09	04	03	03	03	05	06	08	15	17	16	15	10	08	08	08
29	325	330	330	090	090	090	000	090	105	270	260	260	270	280	315	300	300	330	345	350	345	350	360	345
	10	11	10	02	02	01	00	01	02	06	04	06	14	17	15	12	13	10	12	13	09	11	13	11
30	330	330	330	315	060	065	060	030	090	030	090	030	075	060	060	045	060	045	045	045	030	240	280	300
	12	10	12	10	05	10	06	02	10	13	11	08	05	05	06	08	06	06	09	08	06	01	05	07
31	330	045	150	030	000	260	045	060	180	240	150	150	210	150	160	230	280	300	270	240	330	330	300	300
	06	01	03	02	00	02	02	01	01	02	03	03	05	05	07	11	13	17	06	11	10	10	16	11

WIND DIRECTION AND VELOCITY: EMERY, UTAH (PERIOD AVERAGES) JUNE, 1973

DATE \ HOURS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	250	210	330	320	315	215	140	150	180	190	180	150	210	180	230	300		270	330	330	315	320	315	090
	12	06	10	10	08	06	06	03	08	07	02	03	01	04	05	02	02	05	08	05	08	07	05	04
2	045	280	280	300	300	300	330	330	280	300	300	330	330	315	330	330	320	330	345	330	315	280	280	240
	01	05	07	11	10	11	11	08	08	11	11	15	13	13	11	14	14	12	08	07	06	05	05	01
3	300	330	030	330	270	240	240	250	180	180	240	330	315	320	270	270	280	280	300	300	300	315	315	300
	02	02	02	02	03	06	05	03	02	05	08	14	20	11	07	16	12	15	14	13	13	11	14	13
4	315	315	320	330	330	320	270	315	315	300	315	320	315	315	315	330	315	330	330	330	330	360	330	120
	11	13	12	09	10	08	04	10	06	08	12	10	12	16	16	14	13	13	12	11	08	08	03	01
5	270	330	120	330	315	315	030	075	075	100	090	160	150	120	060	150	150	180	210	190	210	280	315	330
	03	04	03	07	06	04	05	03	05	03	04	03	04	03	03	04	05	07	05	08	06	03	04	08
6	315	330	030	000	210	150	270	000	000	090	130	180	165	150	150	240	330	330	330	330	350	350	300	300
	04	04	04	00	03	01	01	00	00	02	01	02	03	05	03	05	07	10	09	10	09	08	07	09
7	300	345	330	360	345	030	300	280	150	075	130	210	150	300	320	330	330	330	330	330	345	345	210	310
	07	07	05	02	03	02	02	01	01	03	01	02	05	09	16	11	10	10	12	10	06	10	02	09
8	340	330	015	345	360	030	300	030	060	080	060	180	210	180	210	210	210	270	190	210	315	330	330	330
	07	03	02	02	03	03	01	03	06	04	03	03	03	05	07	06	05	03	04	02	07	07	06	07
9	360	300	330	330	360	300	300	000	000	220	210	100	300	280	270	280	300	300	300	300	300	315	300	300
	03	03	03	03	03	03	03	00	00	02	03	05	05	15	13	10	12	12	13	13	15	14	13	10
10	300	290	270	270	240	300	210	300	120	180	150	180	300	300	300	315	300	300	315	300	315	300	300	300
	11	07	07	05	06	05	02	05	02	03	11	06	13	10	13	12	10	08	06	08	08	06	06	08
11	300	210	210	210	210	210	210	210	265	220	270	300	300	315	315	270	300	300	300					
	06	01	05	04	05	06	01	03	07	10	17	15	14	13	10	10	13	14	15					
12																								
13																								
14																			280	255	265	280	320	310
																			16	23	15	06	08	14
15	290	255	255	310	305	320	300	170	225	280	290	300	300	280	300	330	300	285	290	300	305	275	330	240
	05	05	05	07	06	04	04	02	03	14	17	20	17	18	15	23	15	11	10	13	13	08	05	03
16	290	290	300	300	270	360	285	275	260	210	170	180	190	160	210	190	210	360	360	000	340	315	315	280
	08	10	10	07	05	03	05	03	02	03	05	05	05	08	06	06	06	03	02	00	03	09	11	08
17	310	310	315	315	315	315	150	275	210	195	225	270	270	285	280	270	270	300	285	310	320	315	310	270
	08	08	09	09	04	07	02	03	02	05	10	16	18	23	25	23	25	21	20	20	24	28	23	07
18	255	255	280	275	285	295	285	280	260	315	330	330	280	285	305	325	315	320	325	330	355	015	010	355
	08	14	10	09	12	10	09	10	08	07	11	09	16	15	14	18	19	20	19	18	12	12	10	12
19	320	075	315	045	320	285	050	040	045	090	120	180	105	195	150	135	160	270	285	280	300	330	315	310
	05	02	04	03	05	03	03	03	03	04	04	03	03	03	04	05	05	05	08	11	10	13	13	12
20	310	360	320	325	340	035	345	350	075	060	070	070	060	075	030	075	030	030	035	030	030	340	295	320
	12	07	08	10	08	06	02	04	04	05	07	07	05	05	06	06	05	04	04	05	07	06	08	08
21	330	335	040	030	270	290	350	040	180	180	130	120	120	060	100	330	045	030	180	225	240	280	320	090
	06	07	03	02	02	03	03	02	02	03	05	06	07	07	05	05	05	03	05	04	04	03	10	03
22	360	300	330	030	030	300	285	040	045	120	180	150	210	150	170	210	240	280	280	290	310	270	150	210
	02	02	05	03	04	02	07	05	05	02	02	06	06	07	12	11	07	12	11	15	11	05	05	03
23	210	320	330	360	270	300	000	000	045	135	165	210	240	200	195	190	235	270	270	280	290	310	300	270
	06	08	7	05	05	00	00	00	02	03	07	10	17	14	12	12	13	11	12	11	11	11	11	07
24	225	280	290	270	270	250	240	225	270	290	300	300	270	285	290	285	300	300	300	300	300	300	270	315
	04	10	13	08	08	06	06	06	08	10	10	08	10	15	17	15	15	12	11	10	08	08	06	11
25	360	050	030	270	150	150	180	280	285	300	300	300	300	300	300	300	320	330	330	320	330	120	360	180
	07	05	02	05	02	02	06	07	10	11	12	12	16	17	17	14	14	16	15	15	10	05	05	03
26	360	015	360	015	270	030	360	030	070	070	075	090	090	090	300	330	300	345	340	360	345	340	330	300
	07	06	05	07	07	05	07	05	05	08	07	06	05	05	15	15	12	11	12	12	12	11	10	05
27	300	330	330	360	360	330	330	075	060	180	090	080	040	120	060	060	270	300	230	270	300	320	345	210
	08	06	07	05	05	06	03	03	03	04	12	10	07	04	05	06	10	12	20	10	07	12		10
28	300	300	300	315	045	030	300	090	030	060	080	060	045	180	060	070	070	080	075	075	360	320	180	320
	08	07	08	08	05	03	06	03	03	10	14	13	07	09	12	11	12	15	14	15	07	06	04	06
29	330	330	315	360	330	360	360	000	200	240	150	150	360	150	165	315	270	280	285	285	270	320	300	285
	03	07	07	05	03	05	03	00	03	02	03	03	05	10	07	10	12		15	12	10	10	11	10
30	270	240	230	230	210	230	210	270	230	180	150	180	210	240	260	270	270	280	250	260	290	285	290	300
	05	06	07	07	07	08	05	07	05	05	05	07	15	15	17	15	17	17	17	15	12	13	12	08

WIND DIRECTION AND VELOCITY: EMERY, UTAH (PERIOD AVERAGES) JULY, 1975

DATE \ HOUR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	300	300	330	280	300	060	240	270	350	180	300	330	330	330	330	330	315	300	310	310	320	310	290	270
	10	11	08	06	07	03	05	06	05	05	14	14	12	08	07	10	13	15	15	13	12	10	11	05
2	010	320	350	315	300	360	310	240	180	135	180	150	180	360	180	105	190	195	300	340	330	280	300	360
	06	11	05	11	07	05	05	03	03	03	03	05	05	05	05	07	07	07	12	10	06	05	05	07
3	345	340	315	030	270	060	015	000	030	060	090	075	090	210	180	120	180	180	060	045	360	350	330	330
	07	07	05	03	03	03	04	00	02	03	03	05	05	05	05	06	06	05	04	03	07	12	10	04
4	360	340	350	015	360	300	330	330	045	060	120	150	090	180	230	270	300	300	315	320	340	345	330	315
	02	05	06	05	05	07	06	02	02	02	05	05	03	05	08	12	07	07	12	12	12	12	07	05
5	075	150	320	360	360	030	030	060	090	030	120	140	165	180	060	150	165	150	150	180	165	300	330	270
	02	02	06	07	05	05	02	03	02	02	05	05	07	05	07	10	10	08	08	10	10	10	12	07
6	280	300	330	300	285	240	345	270	360	120	160	270	270	240	270	270	280	300	300	285	270	285	300	300
	10	10	11	07	07	06	05	10	03	03	04	17	17	22	23	20	20	20	20	20	13	07	05	08
7	290	290	260	270	270	240	210	240	260	330	300	330	300	320	030	130	150	210	330	300	270	360	300	330
	10	10	12	09	10	10	07	08	08	07	10	15	12	10	07	17	12	10	06	06	05	07	08	07
8	320	315	300	360	030	360	360	075	020	120	140	150	225	240	255	270	240	250	240	180	120	360	300	320
	08	05	07	04	07	03	05	03	05	03	03	07	12	10	10	08	14	11	06	06	04	03	03	06
9	345	360	240	315	060	330	300	030	030	120	150	120	045	060	100	030	090	080	000	040	030	030	050	045
	08	04	03	05	05	06	06	05	02	02	02	03	05	07	07	10	11	11	07	10	10	10	08	08
10	000	300	030	120	300	330	360	330	180	050	060	040	090	180	180	360	220	170	210	240	170	255	340	330
	00	03	03	03	03	03	04	06	04	04	08	07	07	07	07	06	05	05	05	04	07	07	07	11
11	320	330	360	360	300	340	300	300	330	360	090	140	150	170	240	280	270	270	310	310	315	330	300	300
	10	07	07	04	05	10	05	07	05	04	07	12	12	08	08	10	07	10	15	10	10	07	12	07
12	310	315	300	300	330	360	315	270	180	360	090	090	105	135	120	130	315	290	285	330	315	315	315	315
	13	08	12	17	10	07	09	11	06	07	14	07	05	07	04	03	04	03	12	15	17	18	15	11
13	315	315	330	315	315	315	320	315	300	310	330	210	180	245	360	050	050	360	360	090	165	240	300	345
	15	17	20	18	17	18	15	10	10	12	10	05	05	10	10	08	15	17	15	12	12	11	07	10
14	240	310	030	330	070	075	060	060	360	360	150	135	210	220	210	210	180	180	315	340	060	050	050	060
	05	07	08	06	10	08	05	05	02	02	03	05	05	07	06	10	07	04	07	12	17	17	16	12
15	040	360	300	300	360	340	320	030	000	165	135	180	150	140	260	200	310	315	330	330	330	360	020	090
	10	03	06	08	07	06	05	00	00	02	04	05	04	05	10	12	12	10	10	06	08	08	06	10
16	070	340	285	280	300	030	270	360	000	120	150	180	300	270	315	300	300	315	330	310	315	345	030	045
	05	04	04	07	06	05	03	03	00	03	03	03	10	13	10	12	12	10	11	10	08	10	10	08
17	090	030	360	300	290	270	320	050	060	080	075	080	100	030	100	060	270	300	315	090	360	165	030	320
	06	07	05	05	02	03	05	05	06	07	06	06	07	17	15	11	11	07	07	05	03	03	05	06
18	360	360	315	360	360	330	360	110	090	120	100	060	070	060	075	180	285	315	280	170	360	240	270	360
	07	04	05	05	03	04	05	04	03	05	05	06	07	07	08	17	15	10	10	05	06	06	05	07
19	030	330	250	260							180	240	270	290	290	310	260	250	260	270	285	290	275	305
	06	06	05	06							05	05	03	06	07	08	06	06	06	06	05	05	05	06
20	290	270	200	200	270	310	270	220	180	030	210	230	180	150	120	130	120	180	330	070	050	070	200	230
	09	11	08	04	04	05	04	02	03	00	03	04	05	04	05	06	10	04	10	11	11	08	08	07
21	060	180	310	300	040	000	000	000	000	100	180	180	180	200	150	210	190	200	200	300	340	330	000	220
	05	04	05	03	03	00	00	00	00	02	02	02	02	03	05	06	06	04	04	04	06	06	00	03
22	000	130	300	300	000	320	310	250	060	080	070	060	090	290	270	270	280	300	300	310	330	330	240	250
	00	02	03	00	00	03	04	05	03	03	05	05	05	06	03	06	08	09	08	08	06	07	03	05
23	250	040	320	320	250	280	180	000	000	000	000	000	000	000	180	140	120	130	070	040	060	070	270	300
	05	03	04	05	04	05	04	00	00	00	00	00	00	00	02	03	04	05	03	05	06	07	05	05
24	270	340	000	000	000	000	270	030	000	000	000	000	150	180	290	320	330	330	330	330	340	340	330	340
	04	03	00	00	00	00	02	00	00	00	00	00	02	03	06	07	08	10	08	08	07	05	03	05
25	270	000	280	280	100	280	030	000	000	100	070	080	060	090	070	070	120	210	290	320	330	330	200	000
	04	00	03	04	04	03	00	00	00	04	06	05	04	03	03	03	03	04	06	05	04	03	03	00
26	000	310	300	330	300	300	320	330	310	160	120	060	130	210	210	290	320	300	280	300	310	280	320	270
	00	03	02	04	03	05	04	02	02	02	02	02	02	03	03	07	06	05	06	05	05	05	02	03
27	270	300	300	310	310	010	020	180	200	000	000	180	060	180	280	250	220	120	050	060	070	000	310	300
	03	06	00	06	04	04	03	02	02	00	00	05	06	05	06	03	07	08	09	07	04	00	04	04
28	300	310	300	270	030	130	000	000	050	080	090	090	090	250	330	330	340	310	340	320	310	300	300	300
	03	03	03	02	03	02	00	00	02	02	04	03	03	06	08	07	05	03	06	03	04	06	06	03
29	320	330	305	300	330	230	000	000	030	000	000	130	130	180	180	300	270	180	000	270	300	275	150	310
	03	03	05	03	03	04	00	00	00	00	00	03	03	10	08	04	04	03	06	07	09	07	05	03
30	300	270	280	150	180	180	310	180	080	100	110	090	090	090	120	030	360	060	060	060	030	350	050	030
	05	05	04	03	02	05	04	03	03	02	02	04	03	03	02	03	05	05	05	05	06	05	06	05
31	010	300	310	180	020	180	180	030	150	120	150	120	100	090	040	130	000	130	040	060	010	180	310	260
	05	03	03	03	03	03	03	02	02	02	02	02	04	05	07	05	00	02	06	05	04	04	04	04

WIND DIRECTION AND VELOCITY: EMERY, UTAH (PERIOD AVERAGES) AUGUST, 1973

DATE \ HOURS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	000	030	190	020	310	030	030	030	000	000	000	000	180	080	060	060	030	180	300	030	030	310	310	270
	00	00	03	04	03	03	00	00	00	00	03	00	02	03	03	03	04	07	04	03	03	05	02	04
2	280	330	190	030	040	180	270	040	270	180	130	120	170	150	280	210	150	000	070	120	050	180	220	300
	03	05	04	03	03	03	03	02	02	02	02	02	02	02	02	02	02	00	04	04	04	05	04	04
3	300	100	320	060	060	210	280	180	050	130	180	180	180	070	210	250	300	300	290	275	310	300	290	180
	04	03	05	04	03	03	03	03	03	03	02	03	03	03	06	10	07	06	06	06	06	06	06	03
4	330	270	240	310	270	270	310	290	180	000	100	200	210	180	180	220	330	210	240	230	330	320	300	300
	04	04	04	06	03	02	06	05	03	00	02	02	04	06	05	10	06	03	03	06	08	07	11	08
5	300	280	250	260	280	260	280	050	060	100	210	280	270	190	260	210	200	210	200	230	300	290	300	280
	08	06	05	03	05	05	06	03	03	03	02	07	05	06	06	03	05	07	05	03	03	03	04	05
6	280	270	270	180	180	040	030	180	240	030					270	180	270	270	270	300	300	320	040	030
	03	03	02	03	03	03	03	03	03	03					06	05	06	05	06	05	06	06	04	03
7	180	270	240	200	040	020	180	050	060	060	130	120	180	150	090	130	200	210	150	180	330	320	310	300
	02	03	04	03	03	02	02	03	04	03	02	02	03	05	08	05	03	03	03	03	05	05	05	05
8	330	180	050	060	300	000	030	000	040	000	130	120	120	360	180	300	360	300	300	320	340	320	310	270
	05	03	03	02	00	00	00	00	00	00	02	03	04	04	02	06	06	06	05	05	06	05	06	04
9	270	340	340	180	310	310	020	270	200	090	100	180	180	200	210	180	150	190	190	160	020	290	090	180
	03	03	03	03	03	03	04	03	02	02	02	02	03	03	04	03	03	03	03	02	02	04	03	03
10	290	330	300	230	250	070	180	150	090	100	130	150	180	230	270	240	280	280	280	290	290	300	270	280
	05	03	05	03	03	03	03	03	02	02	02	04	02	07	08	05	05	08	07	06	05	05	05	05
11	290	340	300	300	280	230	180	180	220	320	310	300	310	290	260	320	300	310	310	320	330	320	170	060
	07	05	03	03	04	03	03	03	05	07	08	07	05	05	05	07	06	06	05	05	06	04	02	04
12	160	000	000	180	330	330	330	180	070	090	120	180	150	180	060	120	210	210	210	210	300	320	240	300
	03	00	00	03	03	02	03	03	02	02	03	03	03	03	03	05	05	04	03	02	02	04	03	04
13	310	180	020	020	040	090	000	240	180	070	070	070	130	180	220	140	160	150	150	260	330	320	300	200
	04	02	02	02	02	02	00	03	02	04	04	04	03	05	07	05	05	08	04	03	06	06	06	03
14	240	270	280	240	270	180	000	060	060	270	270	270	270	280	270	240	240	090	180	150	030	040	050	000
	02	02	02	02	03	03	00	02	02	03	06	06	07	08	06	09	08	03	03	03	06	04	03	00
15	180	060	000	180	180	270	360	040	190	000	090	090	060	250	180	150	150	190	270	240	180	290	310	310
	02	02	00	03	02	04	03	03	02	00	02	03	03	03	03	04	04	05	06	06	07	05	06	07
16	270	250	190	250	050	040	120	180	075	085	155	150	120	300	330	255	300	295	330	295	240	255	290	300
	04	03	04	03	03	02	02	02	02	03	03	03	03	03	03	07	07	07	10	06	04	06	06	05
17	220	270	315	240	150	035	360	090	075	060	015	125	235	180	270	250	240	260	210	190	200	315	300	255
	05	04	04	03	03	03	02	02	02	02	01	02	02	02	05	07	08	03	04	04	01	01	03	02
18	315	015	030	060	045	015	270	060	090	135	210	270	210	240	240	235	210	210	210	195	240	045	310	325
	05	03	02	03	05	04	03	02	02	02	02	02	04	03	03	03	06	06	07	06	03	03	01	03
19	290	285	275	045	045	270	300	020	090	180	225	265	100	180	225	270	235	285	265	235	300	300	315	300
	04	06	05	05	04	02	02	02	01	01	01	01	02	03	03	02	04	04	03	02	04	04	04	02
20	305	030	260	090	180	040	290	090	040	360	130	135	150	150	150	165	150	140	170	270	180	165	270	300
	05	04	02	03	03	03	04	02	02	03	03	02	03	05	05	05	03	03	03	02	06	12	07	05
21	200	060	035	030	300	080	180	150	135	165	105	150	180	180	300	315	300	240	060	060	055	030	090	030
	02	02	02	01	02	02	02	01	01	01	01	02	02	04	05	02	01	03	04	04	04	02	01	01
22	345	015	060	020	170	010	320	355	255	090	090	120	150	210	250	215	240	255	315	315	315	305	360	040
	01	01	01	01	02	02	02	02	01	02	02	01	02	03	03	04	04	03	02	01	02	03	02	01

HOURLY TEMPERATURE RECORD (RUN NOV 30, 1978) - C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES DEC 1972

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	RG	MR	SM	MN	SD
																									0.0	0.0	0.0	0.0	0.0
1																									0.0	0.0	0.0	0.0	0.0
2																									0.0	0.0	0.0	0.0	0.0
3																									0.0	0.0	0.0	0.0	0.0
4																									0.0	0.0	0.0	0.0	0.0
5																									0.0	0.0	0.0	0.0	0.0
6																									0.0	0.0	0.0	0.0	0.0
7																									0.0	0.0	0.0	0.0	0.0
8																									0.0	0.0	0.0	0.0	0.0
9																									0.0	0.0	0.0	0.0	0.0
10																									0.0	0.0	0.0	0.0	0.0
11																									0.0	0.0	0.0	0.0	0.0
12																									0.0	0.0	0.0	0.0	0.0
13																									0.0	0.0	0.0	0.0	0.0
14																									0.0	0.0	0.0	0.0	0.0
15																									0.0	0.0	0.0	0.0	0.0
16																									0.0	0.0	0.0	0.0	0.0
17																									0.0	0.0	0.0	0.0	0.0
18																									0.0	0.0	0.0	0.0	0.0
19																									0.0	0.0	0.0	0.0	0.0
20																									0.0	0.0	0.0	0.0	0.0
21																									0.0	0.0	0.0	0.0	0.0
22																									0.0	0.0	0.0	0.0	0.0
23																									0.0	0.0	0.0	0.0	0.0
24														40	40	42	40	34	32	30	30	29	26	25	17.0	33.5	0.0	33.5	5.8
25														36	36	38	38	32	28	26	24	23	21	20	20.0	28.0	25.5	25.9	0.0
26	24	22	24	20	20	19	18	18	18	22	28	32	34	36	36	36	34	30	23	22	22	22	20	22	22.0	25.0	23.5	23.0	7.6
27	20	18	16	16	16	14	14	14	14	18	24	30	34	28	30	29	26	26	26	26	25	24	24	28	8.0	26.0	25.2	25.0	2.2
28	22	22	24	24	24	24	23	23	23	23	24	25	26	30	28	26	24	23	22	22	22	20	20	20	10.0	25.0	24.7	24.8	2.8
29	25	26	26	26	26	26	25	24	24	25	26	28	29	28	28	26	24	20	18	18	18	18	18	18	10.0	23.0	20.5	20.9	3.7
30	20	19	19	20	18	13	18	18	18	22	24	26	28	27	27	28	26	24	22	20	19	18	18	16	16.0	20.0	19.2	19.7	4.7
31	18	13	19	20	16	14	12	12	12	18	20	24	24																
MN	22.0	20.9	21.4	21.6	20.0	19.2	18.4	18.2	18.2	21.4	24.4	27.5	29.2	32.2	32.2	32.2	30.6	27.0	24.5	23.5	22.9	22.0	21.0	21.3	14.8	25.8	23.2	24.7	5.1
SD	3.3	2.9	3.5	3.2	3.8	4.0	4.0	4.3	4.3	2.6	2.4	2.8	3.6	4.7	4.7	6.0	6.2	4.8	4.3	3.8	3.7	3.0	2.8	3.8	5.1	4.0	2.5	4.2	
IV*	4.4	4.0	5.0	4.0	4.8	5.8	5.0	5.2	5.2	3.6	2.4	2.8	3.2	2.8	2.2	3.0	3.0	3.0	4.0	3.7	3.2	2.5	2.7	4.2	4.5	2.0	2.0	3.0	1.6
MI	25	25	25	25	25	25	25	25	25	25	25	25	25	24	24	24	24	24	24	24	24	24	24	24	24	24	25	24	24
MI*	25	25	25	25	25	25	25	25	25	25	25	25	25	24	24	24	24	24	24	24	24	24	24	24	24	24	25	24	24

HOURLY TEMPERATURE FREQUENCIES (RUN NOV 30, 1978) - C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES DEC 1972
A= 0100-0600, B= 0700-1200, C= 1300-1800, D= 1900-2400

HOURS / TEMP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	A	B	C	D	TOT
42																1									0	0	1	0	1
41																									0	0	1	0	1
40														1	1		1								0	0	4	0	4
39																									0	0	4	0	4
38																1	1								0	0	6	0	6
37																									0	0	6	0	6
36														2	2	1									0	0	11	0	11
35																									0	0	11	0	11
34													2				1	1							0	0	15	0	15
33																									0	0	15	0	15
32												1						1	1						0	1	16	1	18
31																									0	1	16	1	18
30												1		1	1			1		1	1				0	2	19	3	24
29													1			1						1			0	2	21	4	27
28	1										1	1	1	2	2	1	1		1					1	1	4	28	6	39
27														1	1										1	4	30	6	41
26		1	1	1	1	1					1	1	1			2	1	1	1	2			1		6	6	35	10	57
25							1			1		1									1			1	6	9	35	12	62
24	1		2	1	1	1		1	1		3	1	1				2	1			1	1	1		12	15	39	15	81
23							1	1	1	1								1	1			1			12	19	40	17	88
22	1	2								2									2	2	2	1		1	15	21	40	25	101
21																							1		15	21	40	26	102
20	2			3	1						1							1		1		1	2	2	21	22	41	32	116
19		1	2			1															1				25	22	41	33	121
18	1	2			1	1	2	2	2	2									1	1	1	2	2	1	30	30	41	41	142
17																									30	30	41	41	142
16			1	1	2																			1	34	30	41	42	147
15																									34	30	41	42	147
14						2	1	1	1																36	33	41	42	152
13																									36	33	41	42	152
12							1	1	1																36	36	41	42	155

HOURLY TEMPERATURE FREQUENCIES (RUN NOV 30, 1978)- C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES JAN 1973

A= 0100-0600, B= 0700-1200, C= 1300-1800, D= 1900-2400

HOURS / TEMP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	A	B	C	D	TOT
37													1												0	0	1	0	1
36														1		2	1	1							0	0	6	0	6
35												1			1	1									0	1	8	0	9
34															3		1								0	1	12	0	13
33																									0	1	12	0	13
32														4	1	2	1	1							0	1	21	0	22
31													2												0	1	23	0	24
30											1		1	1	2	2	3	2	1	1					0	2	34	2	38
29													1	2			1								0	2	38	2	42
28												4	4	5	5	3	2	2			1	1			0	6	59	4	69
27													2	1	2	1	2	1	1				1		0	6	68	6	80
26										1	1	2	6	5	6	7	1	3	4						0	10	96	10	116
25															1	1	3			2	1				0	10	101	13	124
24											2	6	4	2		2	4	1	2	2	2	2			0	18	114	21	153
23												2						2					1	1	0	20	116	23	159
22	2		1	1	1					1	4	3	3	4	1	1	2	4	2	1	1	2	2	2	5	28	131	33	197
21		1				1	1			1				1	1	1			1						7	30	134	34	205
20	1	1	2	1	1			1	3	3	6	6	1		5	3	4	4	5	5	2	2	1	1	13	49	151	50	263
19	2	1	1	2	2	2	1	1		1			1		1			1			2	2	1	1	23	52	154	56	285
18	2	2	1				2	2	1	1	5	1	1	3		2	1		3	6	3	3	2	2	28	64	161	75	328
17			1						1		1	2				1	1				2	1			29	68	163	78	338
16	4	2	2	4	1	2	3	2	2	4	3		1				1	2	2	1	3	1	5	6	44	82	167	96	389
15	1	2	2	1	1	1	1	2	1	1	1				1	1	1	1	1	1	1	3	2	1	52	88	171	105	416
14	2	5	2	2	5	3	2	1	2	5	2	1	1	1			1	4	3	3	2	2	2	1	71	101	178	118	468
13			2			2		1	1	1		1							1	2	1	1	2		75	105	178	125	483
12	3	1		3	1	1		1	1	4							1	1		2	4	3	2	3	84	111	180	139	514
11	1		1		2	3	1		1										1		1			2	91	113	180	143	527
10	4	6	6	5	5	3	5	4	3	2	1								2	1	2	5	4	3	120	128	180	160	588
9	2	2	1	1				1											1				1	2	126	129	180	164	599
8	4		1	3	3	2	3	1	3	2								1	1	2	1	1	3	4	139	138	181	176	634
7		2	1	1		1		1	2		1									1					144	142	181	177	644
6	1	2	4	2	3	1	3	4	4	1										1					157	154	181	178	670
5		1	1	3		3		1													1				165	155	181	179	680
4		1			3	3	3	3	2												1	2	1		172	163	181	183	699
3																									172	163	181	183	699
2					1	1	3	1	2															1	174	169	181	184	708
1								1															1		174	170	181	185	710
0	1			1			1	1		2														1	176	174	181	186	717
-1	1	1																							178	174	181	186	719
-2		1	1			1																			181	174	181	186	722
-3																									181	174	181	186	722
-4			1	1	2	1		1																	186	175	181	186	728
-5							1		1																186	177	181	186	730
-6							1																		186	178	181	186	731

HOURLY TEMPERATURE RECORD (RUN NOV 30, 1978): C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES JAN 1973

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	RG	MR	SH	MN
1	14	14	14	12	11	11	10	10	10	10							28	20	16	14	12	12	12	10	18.0	19.0	0.0	13.3
2	08	06	06	05	04	05	02	04	06	14	20	20	24	24	25	24	22	14	11	10	10	10	08	08	23.0	13.5	11.5	12.1
3	06	06	06	06	02	02	04	04	07	14	17	22	22	22	20	18	15	14	13	12	12	12	10	08	20.0	12.0	12.5	11.4
4	10	10	10	10	11	11	11	12	13	16	18	20	24	21	20	20	17	14	14	13	12	10	09	08	16.0	16.0	14.0	13.3
5	08	04	06	08	06	04	00	00	02	12	16	20	24	22	20	20	18	14	10	08	10	10	08	09	24.0	12.0	10.5	10.8
6	09	07	06	06	06	05	06	06	08	12	15	17	19	18	20	17	14	12	09	06	05	04	04	02	18.0	11.0	9.5	9.7
7	-01	-02	-02	00	-04	-04	-05	-04	-05	00	07	13	16	18	20	21	20	16	10	07	04	04	01	00	26.0	8.0	5.3	5.4
8	00	-01	-04	-04	-04	-02	-06			00	10	14	14	14	15	15	12	08	08	08	08	08	08	09	21.0	4.5	5.0	5.9
9	09	10	10	10	10	10	10	10	11	12	15	18	18	18	19	18	16	15	14	12	11	10	10	08	11.0	13.5	12.5	12.7
10	03	05	07	07	06	04	02	06	06	08	14	22	27	30	32	32	30	28	26	24	24	22	16	11	30.0	17.0	20.0	16.5
11	10	09	08	05	04	06	02	01	02	06	16	17	22	26	25	26	20	16	15	14	14	15	16	16	25.0	13.5	14.0	13.0
12	16	15	15	15	14	15	14	13	14	18	24	24	26	28	26	26	24	20	14	14	12	10	10	10	18.0	19.0	16.5	17.4
13	10	09	10	09	10	10	08	09	10	16	20	26	28	28	30	28	30	30	26	20	18	18	15	14	22.0	19.0	18.0	18.3
14	12	10	10	10	08	08	08	06	06	10	19	22	27	32	34	35	36	36	30	24	20	20	14	16	30.0	21.0	20.0	18.8
15	14	14	10	10	10	12	10	10	08			28	31	32	28	28	28	26	20	20	18	14	12	12	24.0	20.0	19.5	18.0
16	12	10	13	14	14	16	15	16	16	16	19	20	20	22	21	20	20	19	18	18	18	17	16	16	12.0	16.0	13.5	16.9
17	16	15	16	16	16	16	16	16	16	19	22	24	26	29	30	30	26	22	25	30	29	28	27	18	14.0	23.0	25.2	22.0
18	18	14	14	12	10	08	06	04	08	16	19	20	22	22	22	22	20	20	20	20	19	19	19	19	18.0	13.0	16.5	16.3
19	19	19	19	19	19	19	19	19	20	21	22	23	24	26	26	24	24	23	22	22	22	22	22	22	7.0	22.5	22.2	21.5
20	22	20	22	22	22	21	21	20	20	22	22	24	26	24	25	26	24	22	18	18	17	18	18	18	9.0	21.5	19.7	21.4
21	18	18	20	19	19	14	18	18	20	20	20	24	28	29	28	26	24	22	20	20	19	19	18	16	15.0	21.5	21.2	20.7
22	16	15	15	14	14	14	14	14	14	15	26	26	26	26	26	26	25	24	20	18	16	15	15	16	12.0	20.0	18.0	18.7
23	16	14	16	16	14	13	10	07	12	13	18	23	28	28	28	30	27	26	20	18	16	15	14	11	23.0	18.5	17.5	18.0
24	10	10	10	08	08	07	08	06	07	14	22	28	31	32	34	32	30	28	22	18	17	18	16	16	29.0	20.0	19.5	18.0
25	12	12	11	10	12	10	06	08	06	14	20	28	28	28	27	25	22	20	18	19	16	16	16	15	22.0	17.0	16.5	16.5
26	15	14	13	12	10	11	10	10	10	20	20	24	29	32	34	36	32	30	26	25	24	24	22	22	26.0	23.0	22.5	21.0
27	22	21	20	20	20	19	18	19	18	20	24	28	30	27	27	27	27	27	24	16	15	14	13	12	19.0	21.0	19.7	21.1
28	11	10	09	08	08	05	04	05	04	08	14	20	26	26	28	28	29	26	24	15	14	13	13	12	25.0	16.5	14.5	15.0
29	20	16	17	16	15	14	15	15	15	14				26	26	26	25	22	16	13	13	12	10	10	16.0	18.0	16.7	17.0
30	08	07	05	05	04	04	04	02	04	12	20	24	26	28	28	26	25	23	21	20	20	20	20	20	26.0	15.0	18.0	15.7
31	19	18	18	16	14	13	16	15	17	26	30	35	37	36	35	36	34	32	27	25	25	24	23	23	24.0	25.0	25.5	24.7
MN	12.5	11.3	11.3	10.9	10.1	9.8	9.0	9.4	10.2	14.0	18.9	22.6	25.2	25.8	26.1	25.6	24.0	21.6	18.7	16.8	15.8	15.3	14.1	13.2	20.1	17.2	16.7	16.2
SD	5.6	5.6	6.0	5.7	6.2	5.9	6.7	6.1	6.0	5.8	4.6	4.5	4.7	4.9	5.0	5.4	5.8	6.4	5.8	5.7	5.6	5.7	5.6	5.4	6.0	4.7	5.0	4.6
IV*	4.4	4.8	4.7	5.2	5.5	5.6	6.4	6.4	6.1	4.5	3.8	3.6	3.5	3.5	4.0	4.5	5.0	4.6	4.4	4.1	4.1	4.4	3.8	3.6	6.5	3.7	3.2	2.8
HI								1	1	1	3	2	2	1	1	1											1	
HI*								2	2	2	5	3	3	1	1	1											1	

HOURLY TEMPERATURE RECORD (RUN NOV 30, 1978)- C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES FEB 1973

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	RG	MR	3H	MN	SD
22	22	22	21	21	21	20	20	21	25	29	31	34	36	37	37	36	33	27	25	24	23	22	21	17.0	28.5	26.0	26.2	6.0
17	15	14	13	14	10	11	10	10	15	21	26	30	30	31	32	32	29	23	18	18	18	16	15	22.0	21.0	19.2	19.5	7.5
15	14	14	14	14	12	11	11	12	16	23	28	30	30	29	29	28	25	26	25	24	23	21	20	19.0	20.5	22.2	20.7	6.9
20	19	17	18	16	16	17	17	17	18	23	28	29	32	32	31	30	28	26	24	23	19	20	17	16.0	24.0	23.7	22.4	5.6
13	15	14	11	12	11	09	08	06				28	28	29	28	28	26	23	23	23	23	22	22	23.0	17.5	20.7	19.4	7.4
22	22	22	22	22	22	22	22	22	23	24	24	28	28	28	29	29	28	27	27	26	25	25	24	7.0	25.5	25.5	24.7	2.6
25	25	25	24	24	24	24	24	24	24	26	27	28	29	30	29	29	28	27	27	26	26	26	26	6.0	27.0	26.2	26.1	1.9
25	25	25	25	25	24	24	24	22	28	30	28	29	32	34	32	32	30	28	25	25	24	23	20	14.0	27.0	26.5	26.6	3.5
19	17	16	16	16	14	14	16	17	20	21	22	25	30	32	29	28	26	22	22	21	20	20	20	18.0	23.0	21.5	21.0	5.6
20	20	20	20	20	20	20	20	20	20	22	23	25	26	26	27	26	25	22	22	21	21	21	21	7.0	23.5	22.0	22.0	2.4
21	21	21	21	20	21	21	21	21	22	24	25	26	26	26	26	27	26	26	26	26	26	26	24	7.0	23.5	24.7	23.7	2.4
24	22	20	20	18	22	30	30	28	30		35	36	36	36	36	34	34	29	24	22	20	20	17	19.0	26.5	27.5	27.1	6.6
17	16	10	12	14	13	13	11	12	16	22	28	35	36	34										26.0	23.0	0.0	19.3	9.6
																								0.0	0.0	0.0	0.0	0.0
																								0.0	0.0	0.0	0.0	0.0
																								0.0	0.0	0.0	0.0	0.0
																								0.0	0.0	0.0	0.0	0.0
																								0.0	0.0	0.0	0.0	0.0
										24	28	31	34	32	30	29	27	22	20	16	15	15	12	22.0	23.0	0.0	23.5	7.0
12	12	09	10	10	05	05	05	05	14	19	26	30	31	35	32	29	26	21	21	18	18	18	12	30.0	20.0	18.0	17.6	9.3
11	11	09	08	06	06	04	04	12	14	18	24	33	33	32	34	34	32	28	27	27	26	25	25	30.0	19.0	22.7	20.1	10.6
25	24	24	24	24	24	25	24	25	28	36	38	42	40	42	40	38	34	30	28	26	26	26	25	18.0	33.0	29.2	29.9	6.6
25	24	24	24	24	24	24	24	24	28	30	32	33	33	33	34	34	33	32	28	28	25	28	28	10.0	29.0	28.2	28.3	3.6
25	25	27	26	26	26	26	25	25	25	26	27	29	30	32	32	32	30	29	28	28	28	26	26	7.0	28.5	28.0	27.8	2.1
26	26	24	23	25	25	24	24	24	24	25	26	27	29	32	34	36	37	37	32	27	26	26	26	14.0	30.0	26.7	27.7	4.3
23	22	23	22	23	20	20	22	23	24		36	36	36	36	36	38	36	32	31	30	30	30	30	18.0	29.0	29.0	28.5	6.3
30	29	28	28	28	28	28	28	28	32	34	40	42	43	43	42	36	36	32	30	30	30	29	30	15.0	35.5	32.7	32.7	5.3
30	29	28	28	28	28	28	28	30	32	34	34	34	35	35	34	36	35	30	30	30	28	28	28	8.0	32.0	30.7	30.8	2.9
21.6	20.9	19.9	19.6	19.5	19.0	19.1	19.0	19.5	22.8	25.6	29.0	31.4	32.4	32.9	32.5	31.9	30.4	27.3	25.6	24.5	23.8	23.5	22.3	16.3	25.7	25.4	24.7	6.0
5.1	5.2	5.9	5.8	5.9	6.8	7.4	7.5	7.0	5.6	5.0	4.8	4.6	4.2	4.2	4.0	3.7	3.7	4.0	3.6	3.9	4.1	4.1	5.2	7.2	4.6	3.8	4.2	
3.4	3.9	3.9	4.4	4.3	5.0	5.9	5.7	5.5	4.1	4.0	4.5	3.5	3.5	4.0	3.3	2.6	2.3	2.6	2.1	2.3	2.9	2.8	3.1	6.2	3.5	2.7	3.1	2.0
6	6	6	6	6	6	6	6	6	7	8	6	5	5	5	6	6	6	6	6	6	6	6	6	5	5	7	5	5
7	7	7	7	7	7	7	7	7	9	12	8	6	6	6	7	7	7	7	7	7	7	7	7	6	6	8	6	6

HOURLY TEMPERATURE FREQUENCIES (RUN NOV 30, 1978)- C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES FEB 1973

A= 0100-0600, B= 0700-1200, C= 1300-1800, D= 1900-2400

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	A	B	C	D	TOT
													1	1										0	0	2	0	2
												2		1	1									0	0	6	0	6
																								0	0	6	0	6
											1		1		1									0	1	8	0	9
																								0	1	8	0	9
											1					2								0	2	10	0	12
														1	1		1	1						0	2	13	1	16
										1	1	2	4	2	2	4	2							0	4	29	1	34
											1	1	1	2			1							0	5	34	1	40
										2	1	2	1	2	4	3	2							0	8	48	1	57
												2	2	1			2							0	8	55	1	64
									2		1		2	6	4	3	1	3	1					0	11	71	5	87
											1	1	1	1	1				1					0	12	75	6	93
2						1	1	1	1	2		3	4	1	1	1	2	2	2	3	2	1	2	2	18	87	18	125
	2									1		3	2	2	4	4	2	2				1		4	19	104	21	148
1	1	2	2	2	2	2	2	2	3		5	3	2	1	1	3	3	2	3	2	3	3	2	14	33	117	36	200
		1									2	1			1	1	1	3	3	2				15	35	121	44	215
1	1		1	1	1	1				2	3	1	2	2	1	1	4	3	1	4	5	4	3	20	41	132	64	257
4	2	2	1	2	1	1	1	2	2	1	1	2					1		3	1	1	2	2	32	49	135	73	289
1	2	3	3	3	4	4	5	3	3	3	2								2	2	1		2	48	69	135	80	332
1		1	1					1	1	2	1							2	1	2	3	1		51	74	135	89	349
2	4	2	2	1	2	1	2	2	1	2	1							3	2	1		2	1	64	83	135	98	380
1	1	1	2	1	2	1	1	2		2								1	1	2	1	2	2	72	89	135	107	403
2	1	2	2	3	2	3	2	1	2										1		2	3	3	84	97	135	116	432
1	1									1											1			86	98	135	117	436
1			1	1					1	1									1	2	2	1		89	100	135	123	447
2	1	1				1	1	2															2	93	104	135	125	457
	1	1	1	2	1		1		2											1		1		99	107	135	127	468
1	2								1												1	1	1	102	108	135	130	475
	1	3	1	3	1	1			2															111	111	135	130	487
			1		1	1																		113	112	135	130	490
1	1		1	1	1			3															2	118	115	135	132	500
1	1		1		1	2	2																	122	119	135	132	508
		1	1	1	1		1	1																126	121	135	132	514
		2				1																		128	122	135	132	517
			1				1																	129	123	135	132	519
																								129	123	135	132	519
				1	1			1																131	124	135	132	522
					1	1	1	1																132	127	135	132	526
						1	1																	132	129	135	132	528

HOURLY TEMPERATURE RECORD (RUN NOV 30, 1978) C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES MAR 1973

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	RG	MR	3H	MN
1	28	28	30	27	28	26	26	27	30	36	40	42	43	46	46	47	44	40	35	34	34	32	32	32	21.0	36.5	35.0	34.7
2	32	32	31	30	30	30	30	30	30	35	40	42	40	42	42	44	42	38	32	31	30	29	28	27	17.0	35.5	33.0	34.0
3	26	26	25	24	24	23	22	22	26	30	33	35	36	37	38	40	40	38	34	30	28	28	28	26	18.0	31.0	28.7	30.0
4	26	26	26	26	26	26	26	26	26	25	27	28	28	29	29	30	30	28	27	26	26	25	24	24	6.0	27.0	26.7	26.7
5	24	24	26	28	28	28	26	26	30	30	32	34	36	37	38	38	38	36	31	29	28	37	36	35	14.0	31.0	29.7	31.5
6	25	25	24	24	23	22	22	24	26	30	34	35	38	38	38	35	33	31	30	28	27	26	25	25	16.0	30.0	28.5	28.7
7	25	24	25	25	25	25	26	26	28	29	32	32	32	32	32	32	32	32	32	32	32	24	24	24	8.0	28.0	30.5	28.4
8	23	22	22	20	20	20	22	23	24	25	28	32	34	35	36	35	32	32	31	29	28	28	28	28	16.0	28.0	28.2	27.4
9	27	27	28	27	26	26	26	24	28	34	36	38	40	40	40	40	40	42	40	34	31	31	30	30	18.0	33.0	32.0	32.7
10	28	28	28	26	29	30	29	30	34	37	40	42	44	45	46	48	47	46	46	40	35	33	34	30	22.0	37.0	36.0	36.5
11	28	27	28	26	26	24	26	26	28	30	32	32	32	32	34	34	38	39	39	38	37	32	31	30	15.0	31.5	33.0	31.2
12	31	30	30	30	30	30	30	30	30	32		34	32	32	32	32	30	30	30	28	28	26	27	26	8.0	30.0	29.5	30.0
13	26	26	27	24	23	23	23	24	27	31	35	38	36	36	38	34	34	32	29	27	25	25	26	25	15.0	30.5	27.2	28.9
14	24	24	24	24	25	24	24	26	28	30	31	32	34	36	38	38	35	32	30	30	28	28	28	27	14.0	31.0	29.0	29.2
15	27	26	26	26	26	26	26	28	30	33	36	40	40	41	43	43	42	40	34	32	31	30	30	30	17.0	34.5	32.2	32.7
16	29	28	26	25	24	24	23	26	30	36	38	40	43	45	46	49	49	48	45	40	35	33	32	32	26.0	36.0	34.5	35.2
17	32	30	29	29	29	28	28	30	32	34	40	40	40	44	45	46	46	46	42	40	40	38	36	38	18.0	37.0	38.0	36.7
18	38	36	36	35	36	34	32	32	33	38	42	46	46	48	46	46	45	42	39	34	32	32	31	30	18.0	39.0	36.0	37.3
19	30	30	28	28	26	25	24	26	28	32		40	40	42	44	44	44	44	42	41	40	38	36	32	20.0	34.0	35.5	35.0
20	30	30	30	30	30	30	28	30	32	39	40	42	44	44	46	46	46	45	36	36	34	34	32	31	18.0	37.0	35.0	36.0
21	32	31	30	28	28	27	26	28	28	29	30	32	30	32	32	32	32	32	30	28	29	30	30	30	6.0	29.0	29.0	29.8
22	28	28	28	27	26	24	22	23	28	30	34	36	36	36	36	36	34	36	34	31	30	28	27	26	14.0	29.0	29.5	30.2
23	26	26	25	24	22	23	24	26	29	36	38	40	40	42	42	42	42	40	38	36	32	32	32	31	20.0	32.0	32.5	32.8
24	30	30	30	28	27	26	25	25	32	35	36	37	40	40	42	42	42	42	42	42	36	34	34	31	17.0	33.5	34.2	34.5
25	30	28	26	26	24	23	22	22	25	32	36	38	40	44	44	47	48	50	48	46	42	34	32	30	28.0	36.0	37.5	34.9
26	29	28	27	26	28	27	26	26	26	32			48	49	48	47	48	46	45	42	40	37	36	33	23.0	37.5	38.7	36.1
27	31	28	29	28	28	28	29	30	36	43	47	48	50	54	54	50	50	49	45	38	38	34	34	34	26.0	41.0	39.7	39.0
28	34	34	34	32	32	32	30	28	34	38	38	38	34	30	34	36	36	33	30	28	28	28	28	28	10.0	33.0	29.0	32.4
29	28	27	27	26	25	26	26	26	25	28	32	36	35	38	38	36	39	38	37	32	30	30	29	28	14.0	32.0	31.0	31.0
30	28	28	28	27	27	26	26	27	30	33	36	39	40	42	42	44	44	42	37	34	32	32	32	33	18.0	35.0	33.0	33.7
31	32	32	31	29	28	30	30	30	34	39	42	46	44	46	45	45	46	48	46	41	35	33	32	31	20.0	38.0	36.5	37.3
MN	28.7	28.1	27.9	27.0	26.8	26.4	26.0	26.7	29.3	33.0	35.9	37.8	38.6	39.9	40.5	40.6	40.3	39.3	36.7	34.1	32.3	31.0	30.5	29.6	16.9	33.4	32.6	32.8
SD	3.2	3.0	2.9	2.8	3.1	3.1	2.8	2.6	2.9	4.1	4.5	4.7	5.2	6.0	5.6	5.8	6.0	6.2	6.0	5.3	4.5	3.8	3.4	3.3	5.4	3.6	3.6	3.3
IV°	2.6	2.6	2.7	2.9	3.6	3.9	3.4	3.1	3.2	4.2	4.5	4.5	5.1	5.6	5.1	5.0	4.8	5.1	4.7	4.4	3.9	3.6	3.5	3.1	5.9	2.9	2.8	2.6
MI											3	1																
MI°											6	2																

HOURLY TEMPERATURE FREQUENCIES (RUN NOV 30, 1978) - C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES MAR 1973

A= 0100-0600, B= 0700-1200, C= 1300-1800, D= 1300-2400

HOURS / TEMP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	A	B	C	D	TOT
54														1	1										0	0	2	0	2
53																									0	0	2	0	2
52																									0	0	2	0	2
51																									0	0	2	0	2
50													1			1	1	1							0	0	6	0	6
49														1		1	1	1							0	0	10	0	10
48												1	1	1	1	1	2	2	1						0	1	18	1	20
47											1					3	1								0	2	22	1	25
46												2	1	2	5	3	3	3	2	1					0	4	39	4	47
45														2	2	1	1	1	3						0	4	46	7	57
44													3	3	2	3	3	1							0	4	61	7	72
43										1			2		1	1									0	5	65	7	77
42											2	4		4	4	2	4	4	3	2	1				0	11	83	13	107
41														1						2					0	11	84	15	110
40											5	5	9	2	1	2	2	3	1	3	3				0	21	103	22	146
39										2		1					1	1	2						0	24	105	24	153
38	1									2	3	4	1	2	6	2	2	3	1	2	1	2		1	1	33	121	31	186
37										1		1		2					2		1	2			1	35	123	35	195
36		1	1		1				1	3	5	2	4	3	2	3	1	2	1	2	1		4		4	46	138	44	232
35				1						2	1	2	1	1		2	1		1		3			1	5	51	143	49	248
34	1	1	1			1			3	2	2	2	3		2	2	2		3	4	2	4	3	1	9	60	152	66	287
33									1	2	1						1	1				3		2	9	64	154	71	298
32	4	2		1	1	1	1	1	3	4	4	5	3	4	3	3	3	5		3	4	5	7	3	18	82	175	95	370
31	2	1	2							1	1							1	2	2	2	1	2	4	23	84	176	108	391
30	4	5	5	3	3	5	4	7	7	6	1		1	1		1	2	1	2	2	3	3	3	7	48	109	182	131	470
29	2		2	2	2		2		1	2				1	1				5	2	1	1	1		56	114	184	137	491
28	6	8	6	5	6	3	2	3	7	1	1	1	1					1	1	4	6	5	5	3	90	129	186	150	565
27	2	3	3	4	2	2		2	1		1								1	1	1		2	2	106	133	185	157	592
26	4	5	5	7	6	7	11	10	5											1	1	2	1	3	140	159	186	175	660
25	2	1	3	2	3	2	1	1	1	2											1	2	1	2	153	164	185	181	684
24	2	3	2	5	3	4	3	3	1													1	2	2	172	171	186	186	715
23	1				2	4	2	2																	179	175	186	186	726
22		1	1		1	1	5	2																	183	182	186	186	737
21																									183	182	186	186	737
20				1	1	1																			186	182	186	186	740

DAILY TEMPERATURE RECORD (RUN NOV 30, 1978) - C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES APR 1973

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	RG	MR	3H	MN	SD
1	30	30	28	28	28	26	25	26	29	35	38	37	34	35	29	30	29	31	31	30	28	28	28	29	13.0	31.5	29.0	30.1	3.3
2	28	29	28	27	28	27	28	27	27	29	30	30	36	38	40	40	40	38	36	35	34	33	33	32	13.0	33.5	33.5	32.2	4.6
3	32	31	31	31	31	30	30	33	34	35	37	38	40	41	42	40	34	36	34	30	27	26	25	24	18.0	33.0	31.2	33.3	4.9
4	24	22	23	25	25	24	24	29	31	33	35	37	39	40	42	43	44	45	42	35	34	32	32	32	23.0	33.5	33.0	33.0	7.2
5	32	31	31	29	30	30	28	33	38	42	45	46	49	52	55	56	58	57	52	45	44	42	40	38	30.0	43.0	42.0	41.8	9.7
6	38	40	39	38	40	41	42	40	42	52	55	58	59	55	60	60	58	57	50	46	46	47	47	45	22.0	49.0	47.2	48.1	7.7
7	44	44	43	40	36	30	27	26	30	31	34	35	36	37	37	36	36	32	31	27	24	23	22	20	24.0	32.0	29.0	32.5	5.7
8	19	19	17	17	16	15	14	17	25	30	33	37	38	41	43	43	43	42	40	37	35	34	32	31	29.0	28.5	31.2	29.9	10.3
9	30	30	30	29	30	30	30	32	39	43	46	50	54	56	56	54	53	54	50	44	41	40	41	38	27.0	42.5	42.0	41.7	9.7
10	37	35	33	32	32	32	32	34	39	46	52	56	56	56	56	58	56	54	50	46	44	43	42	42	26.0	45.0	44.0	44.3	9.3
11	44	40	40	38	38	38	38	40	45	48	49	52	44	48	47	50	53	52	43	44	42	40	34	34	19.0	43.5	42.5	43.4	5.5
12	34	33	32	32	31	28	30	39	45	48	52	54	56	56	56	58	58	52	53	46	43	41	41	39	30.0	43.0	43.0	44.0	9.9
13	39	38	36	36	36	34	34	38	47	52	53	55	56	59	64	63	64	63	61	54	51	51	48	48	30.0	49.0	48.7	49.2	10.3
14	47	46	44	43	43	39	37	42	46	48	49	50	54	56	56	54	50	50	49	46	42	40	38	37	19.0	46.5	44.2	46.1	5.6
15	36	35	34	34	34	33	33	34	36	40	46	47	48	49	51	53	52	51	48	44	40	39	36	35	20.0	43.0	40.5	41.2	7.0
16	34	33	32	29	29	30	29	30	35	42	48	51				57	58	56	55	50	48	45	45	45	29.0	43.5	0.0	42.0	10.2
17	44	45	46	46	44	44	44	44	48	50	51	54	53	53	52	53	54	53	52	50	48	45	43	40	14.0	47.0	48.2	48.3	4.1
18	33	36	36	35	34	34	33	34	34	35	36				44	42	41	36	34	31	29	30	29	29	15.0	36.5	0.0	34.8	4.0
19	29	29	28	26	26	26	27	30	33	35	37	38	39	41	41	40	40	38	36	30	31	30	30	30	15.0	33.5	32.5	32.9	5.2
20	31	28	28	28	28	28	30	34	36	38	40	38	41	40	37	38	38	35	34	32	32	32	32	31	13.0	34.5	33.5	33.7	4.2
21	31	31	31	30	31	31	31	35	38	42	42	44	45	47	47	50	50	49	45	41	37	36	36	35	20.0	40.0	38.0	39.0	6.8
22	35	34	33	30	30	28	28	33	40	44	47	52	52	56	56	59	59	60	58	54	49	45	42	39	32.0	44.0	45.5	44.3	10.6
23	36	36	36	34	34	32	31	35	40	50				57	58	57	49	45	48	44	41	38	38	37	27.0	44.5	42.5	41.7	8.3
24	37	38	38	39	39	39	39	41	41	41	41	44	51	55	56	51	48	52	50	46	44	40	38	38	19.0	46.5	45.5	43.6	5.9
25	39	38	37	36	36	37	36	44	48	51	52	56	56	57	58	58	57	56	55	50	47	48	44	40	22.0	47.0	46.7	47.3	9.1
26	39	40	36	35	33	33	33	36	41	46	47	51	53	57	59	60	50	60	60	57	51	46	42	40	27.0	46.5	43.0	46.5	9.7
27	37	34	37	34	35	35	34	38	43	51	56	57	61	63	66	67	67	68	66	64	59	55	49	46	34.0	51.0	53.7	50.9	12.6
28	44	49	52	48	48	45	45	49	54	60	66	68	67	67	66	69	67	64	64	60	54	52	50	50	25.0	56.5	55.0	56.6	8.5
29	47	46	45	42	40	38	39	43	51	58	60	64	64	65	64	65	64	63	60	56	50	45	43	42	27.0	51.5	51.0	52.2	9.7
30	41	40	40	40	40	37	35	35	38	40	44	47	40	40	40	42	42	40	38	36	36	36	38	37	12.0	41.0	36.7	39.2	2.8
MN	35.9	35.4	34.8	33.7	33.5	32.5	32.2	35.1	39.1	43.2	45.6	48.1	49.0	50.7	51.0	51.6	50.8	49.7	47.5	43.7	41.1	39.5	38.0	36.8	22.5	42.0	41.4	41.5	7.9
SD	6.5	7.1	7.1	6.6	6.4	6.2	6.2	6.5	7.0	8.0	8.5	9.1	9.1	8.9	9.7	9.8	10.0	10.1	10.0	9.6	8.5	7.8	7.0	6.7	6.4	6.9	7.5	7.0	
LV	5.8	6.5	6.2	6.0	6.0	6.2	6.2	5.7	5.3	6.4	6.6	7.0	7.3	6.1	7.2	7.3	7.7	8.1	7.7	6.8	6.6	6.4	6.3	6.0	5.7	4.4	4.9	4.8	2.5
MI											1	2	3	2	1												2		
MI											2	4	6	4	2												4		

HOURLY TEMPERATURE FREQUENCIES (RUN NOV 30, 1978) - C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES APR 1973

A= 0100-0600, B= 0700-1200, C= 1300-1800, D= 1900-2400

TEMP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	A	B	C	D	TOT
69																1									0	0	1	0	1
68												1						1							0	1	2	0	3
67													1	1		1	2								0	1	7	0	8
66											1				2				1						0	2	9	1	12
65														1		1									0	2	11	1	14
64												1	1		2		2	1	1	1					0	3	17	3	23
63														1		1		2							0	3	21	3	27
62																									0	3	21	3	27
61													1						1						0	3	22	4	29
60										1	1				1	2	1	2	2	1					0	5	28	7	40
59													1	1	1	1	1				1				0	5	33	8	46
58										1		1			2	3	4		1						0	7	42	9	58
57												1		3		2	1	2		1					0	8	50	10	68
56											1	2	4	5	6	1	1	2		1					0	11	69	11	91
55											1	1		2	1				2			1			0	13	72	14	99
54									1			2	2			2	1	2		2	1				0	16	79	17	112
53											1		2	1		2	2	1	1						0	17	87	18	122
52			1							2	3	2	1	1	1		1	3	2			1			1	24	94	21	140
51									1	2	1	2	1		1	1		1			2	1			1	30	98	24	153
50										2		2				2	2	1	4	3	1		1	1	1	34	103	34	172
49		1						1			2		1	1			1	1	1		1		1		2	37	107	37	183
48		1		1	1				2	3	1		1	1			1		2		2	1	1	1	5	43	110	44	202
47	2								1		2	2		1	2						1	1	1		7	48	113	47	215
46		2	1	1					1	2	2	1								5	1	1		1	11	54	113	55	233
45			1			1	1		2		1		1					2	1	1		4	1	2	13	58	115	64	251
44	4	1	1		1	1	1	2		1	1	2	1		1		1			4	3		1		21	65	119	72	277
43			1	1	1			1	1	1					1	2	1		1		1	1	2		24	68	123	77	292
42				1			1	1	1	3	1				2	2	1	1	1		2	1	3	2	25	75	129	86	315
41	1					1		1	2	1	1		1	3	1		1			1	2	1	2		27	80	135	92	334
40		4	2	2	3			2	2	2	1		2	3	2	3	2	1	1		1	4	1	3	38	87	148	102	375
39	3		1	1	1	2	2	1	2				2									1		2	46	92	150	105	393
38	2	3	1	2	1	2	1	2	3	1	1	3	1	1		1	1	2	1			1	4	3	57	103	156	114	430
37	3		2			2	1				2	3		1	2					1	1			3	64	109	159	119	451
36	2	2	4	2	3		1	1	2		1		2			1	1	2	2	1	1	2	2		77	114	165	127	483
35	1	2		2	1	1	1	3	1	4	1	1		1				1		2	1			2	84	125	167	132	508
34	2	2	1	3	3	2	2	4	2		1		1				1		3		2	1	1	1	97	134	169	140	540
33		2	2		1	2	3	3	1	1	1											1	1		104	143	169	142	558
32	2		2	2	1	2	1	1										1		1	1	2	3	2	113	145	170	151	579
31	1	3	3	1	3	1	2		1	1								1	2	1	1			2	125	149	171	157	602
30	3	2	1	2	3	5	4	2	1	1	1	1				1				3		2	1	1	141	159	172	164	636
29	1			3	1		1	1	1	1					1		1				1		1	2	146	163	174	168	651
28	1	3	4	2	3	3	3														1	1	1		152	166	174	171	673
27				1		1	2	1	1											1	1				164	170	174	173	681
26				1	1	2		2														1			168	172	174	174	688
25				1	1		1		1														1		170	174	174	175	693
24	1					1	1														1			1	172	175	174	177	698
23			1																			1			173	175	174	178	700
22		1																					1		174	175	174	179	702
21																									174	175	174	179	702
20																								1	174	175	174	180	703
19	1																								175	175	174	180	704
18		1																							176	175	174	180	705
17			1	1				1																	178	176	174	180	708
16					1																				179	176	174	180	709
15						1																			180	176	174	180	710
14							1																		180	177	174	180	711

HOURS / DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	RG	MR	3H	MN	
1	38	38	36	35	36	36	36	40	40	44	44	44	44	43	48	50	48	42	44	42	42	39	37	35	15.0	42.5	40.7	40.9	4
2	32	32	31	30	32	30	32	40	44	46	48	50	52	56	56	58	58	56	55	50	46	43	41	38	28.0	44.0	45.0	44.0	3
3	33	34	32	32	32	32	30	38	46	52	54	56	60	60	62	64	62	63	62	58	54	48	48	46	34.0	47.0	49.5	48.5	11
4	44	42	42	40	40	42	44	46	54	60	60	62	65	66	66	64	67	68	64	62	58	56	54	50	29.0	54.0	56.5	54.8	3
5	52	52	50	47	48	48	46	48	53	56	58	58	58	58	58	56	52	47	42	38	38	38	38	38	20.0	48.0	45.6	49.0	7
6	36	34	34	35	35	35	34	35	38	40	44	48	56	56	56	58	58	58	55	56	50	48	48	46	24.0	46.0	47.5	45.5	3
7	45	44	42	43	43	42	42	45	50	52	56	58	60	60	60	60	60	60	59	51	48	52	48	48	18.0	51.0	49.5	51.2	6
8	44	44	42	42	42	42	43	48	54	58	64	64	64	68	70	64	62	64	62	56	54	52	48	48	28.0	56.0	54.7	54.1	9
9	48	48	46	46	44	44	44	50	58	64	66	68	70	71	72	72	72	72	68	62	58	52	50	50	28.0	58.0	57.7	58.1	10
10	48	48	48	46	47	48	54	62	66	70	72	73	75	75	76	76	76	74	72	66	60	57	57	56	30.0	61.0	62.2	62.6	11
11	50	50	48	50	48	46	48	56	60	66	70	72	74	78	78	78	76	76	74	68	61	58	56	56	32.0	62.0	62.0	62.4	11
12	54	54	53	52	52	50	50	50	56	66	72	75	78	70	70	70	70	68	66	62	58	58	56	56	28.0	64.0	59.0	61.1	8
13	52	52	50	52	50	48	46	48	54	62	66	68	70	70	72	74	74	73	70	66	62	60	56	52	28.0	60.0	60.0	60.3	3
14	56	54	48	44	44	43	42	46	52	58					70	70	72	70	68	62	60	54	50	50	30.0	57.0	0.0	55.7	9
15	48	46	44	43	42	42	48	56	60	62	66	68	70	72	70	64	70	68	64	60	58	54	52	52	30.0	57.0	59.0	57.5	9
16	50	50	48	47	46	46	50	56	64	68	72	74	74	76	76	76	76	76	76	72	62	60	62	60	30.0	61.0	62.5	63.2	11
17	52	52	50	52	50	54	56	60	68	74	76	78	80	80	80	78	78	78	76	72	66	64	62	62	30.0	65.0	67.0	66.6	10
18	60	60	58	58	56	58	60	66	70	76	78	80	82	84	84	80	82	80	80	74	70	70	66	65	28.0	70.0	71.0	70.8	3
19	62	60	60	58	58	58	56	60	66	70	76	74	64	66	68	70	70	70	68	66	62	56	54	54	22.0	65.0	61.5	63.5	6
20	52	52	52	50	50	46	46	52	57	64	66	68	70	74	72	72	72	72	74	70	66	60	60	58	28.0	60.0	63.0	61.5	3
21	58	54	52	52	50	48	48	50	56	62	64	64	58	56	54	45	47	49	49	49	48	46	44	46	20.0	54.0	50.0	52.0	5
22	46	45	45	44	44	44	44	46	49	56	59	62	64	66	68	70	71	70	68	65	59	57	55	51	27.0	57.5	57.0	56.2	9
23	50	48	48	46	45	46	46	52	59	65	69	67	68	66	70	70	70	67	66	64	62	56	55	54	25.0	57.5	59.0	58.7	9
24	54	56	53	56	51	53	54	57	64	69	72	74	76	74	72	77	76	72	74	70	66	64	62	60	26.0	64.0	65.0	64.8	8
25	58	59	59	58	56	54	53	54	58	58	54	53	55	56	56	57	49	47	48	47	46	45	44	42	17.0	50.5	50.2	52.7	5
26	42	41	40	38	38	38	38	43	45	43	45	51	51	54	53	54	54	52	51	49	47	46	46	46	16.0	46.0	46.5	46.0	5
27	44	43	42	39	38	36	36	41	46	51	52	55	56	57	59	59	59	59	60	59	57	53	51	50	24.0	48.0	51.7	50.1	8
28	50	47	45	44	44	40	38	43	48	55	66	67	69	70	73	71	69	68	66	60	56	53	52	49	35.0	55.5	55.0	56.0	11
29	50	51	47	46	47	48	57	66	70	72	74	74	76	77	76	75	73	70	64	60	58	55	55	54	31.0	61.5	62.5	62.3	10
30	54	53	52	46	42	44	49	54	56	58	61	64	65	67	68	70	71	70	68	62	58	54	52	50	29.0	56.5	58.0	57.8	8
31	50	49	45	45	46	41	46	54	60	64	68	72	73	75	73	70	71	68	67	62	60	60	58	58	34.0	58.0	60.2	59.8	10
MN	49.0	48.2	46.6	45.7	45.1	44.6	45.7	50.4	55.6	60.1	63.1	64.8	66.0	66.8	67.3	66.9	66.7	65.4	63.9	60.0	56.5	53.9	52.2	51.0	26.0	56.1	56.3	56.4	9
SD	6.9	7.2	7.1	7.2	6.5	6.8	7.5	7.8	8.3	9.0	9.7	9.3	9.3	9.2	8.7	8.8	9.4	9.7	9.5	8.7	7.4	7.1	6.9	7.0	5.3	6.9	7.2	7.0	
IV*	5.4	5.1	5.0	4.6	4.6	4.7	5.5	5.7	6.1	6.7	6.6	6.1	6.9	6.9	6.3	6.8	6.9	7.2	7.6	6.9	5.7	5.5	5.4	5.0	4.5	4.0	5.0	4.4	1
MI											1	1	1	1													1		
MI*											2	2	2	2													2		

HOURLY TEMPERATURE FREQUENCIES (RUN NOV 30, 1978)- C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES MAY 1973

A= 0100-0600, B= 0700-1200, C= 1300-1800, D= 1900-2400

HOURS / TEMP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	A	B	C	D	TOT
84														1	1										0	0	2	0	2
83																									0	0	2	0	2
82													1				1								0	0	4	0	4
81																									0	0	4	0	4
80												1	1	1	1	1		1	1						0	1	9	1	11
79																									0	1	9	1	11
78											1	1	1	1	1	2	1	1							0	3	16	1	20
77														1		1									0	3	18	1	22
76										1	2		2	1	3	2	4	2	2						0	6	32	3	41
75												1	1	2		1									0	7	36	3	46
74										1	1	4	2	2		1	1	1	3	1					0	13	43	7	63
73												1	1		2		1	1							0	14	49	7	69
72										1	4	2		1	4	2	3	3	1	2					0	21	61	10	92
71														1		1	3								0	21	66	10	97
70									2	2	1		4	3	5	7	4	5	1	2	1	1			0	25	94	15	135
69										1	1		1				1								0	28	96	15	139
68									1	1	1	4	1	1	3			5	5	1					0	35	106	21	162
67												2		1			1	1	1						0	37	109	22	168
66								2	2	2	5			4	1				3	3	3		1	1	0	49	114	33	195
65										1			2							1					0	49	116	34	198
64									2	3	2	3	3			4		1	3	1		2			0	59	124	40	223
63																		1							0	59	125	40	224
62	1							1		3		2			1		2		2	6	4		3	1	1	65	128	55	250
61											1										1				1	66	128	57	252
60	1	2	1				1	2	3	1	1		2	2	1	1	1	1	1	3	3	4	1	2	5	74	136	71	286
59		1	1						1		1				1	1	1	1	1	1	1				7	76	140	74	297
58	2		1	3	1	2			2	4	1	2	2	1	1	2	2	1		1	6	2	1	2	16	85	149	96	336
57							1	1	1					1		1					1	2	1		16	89	151	90	345
56	1	1		1	2		2	3	3	2	1	1	2	4	3	1		1		2	1	3	3	3	21	100	162	102	385
55										1		1	1						2			1	3		21	102	163	108	394
54	3	3				2	2	3	3		2			1	1	1	1				2	3	2	3	29	112	167	118	426
53		1	2			1	1		1			1			1							2			33	115	168	120	436
52	4	4	3	4	1			2	1	2	1		1				1	1				3	3	2	49	121	171	129	469
51		1			1					1		1	1						1	1			1	1	51	123	172	132	478
50	6	2	3	2	4	1	2	3	1			1				1				1	1		2	5	69	130	173	141	513
49		1					1		1								1	1	1	2				1	70	132	175	145	522
48	3	3	5		2	5	3	3	1		1	1			1		1		1		2	2	4	2	88	141	177	156	562
47		1	1	2	2												1	2		1	1				94	141	180	158	573
46	2	1	1	5	2	4	5	3	2	1											2	2	1	4	109	152	180	167	608
45		1	3	1	1			1	1		1					1						1			115	155	181	168	619
44	3	2	1	3	4	3	3		1	1	2	1	1						1				2		131	163	182	171	647
43		1		2	1	1	1	2		1				1								1			136	167	183	172	658
42	1	1	4	1	3	4	2											1	1	1	1			1	150	169	184	176	679
41		1				1		1															1		152	170	184	177	683
40			1	1	1	1		2	1	1															156	174	184	177	691
39				1																		1			157	174	184	178	693
38	2	1		1	2	1	2	1	1											1	1	1	1	2	164	178	184	184	710
37																							1		164	179	184	185	711
36	1		1		1	2	2																		169	180	184	185	718
35				2	1	1		1																1	173	181	184	186	724
34		2	1				1																		176	182	184	186	728
33																									176	182	184	186	728
32	1	1	1	1	2	1	1																		183	183	184	186	736
31			1																						184	183	184	186	737
30				1		1	1																		186	184	184	186	740

TEMPERATURE RECORD (RUN NOV 30, 1978): C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES JUN 1973

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	RG	MR	3H	MN	SD
57	56	54	52	51	52	50	52	52	52	54	48	48	52	50	52	52	52	49	49	48	46	46	46	11.0	51.5	49.5	50.9	2.9
46	45	46	46	46	46	46	48	52	55	57	58	59	62	63	61	61	62	60	60	54	52	49	46	18.0	54.0	54.0	53.3	5.5
46	44	44	44	44	43	44	45	48	54	57	57	58	51	59	60	60	58	60	54	51	48	46	43	17.0	51.5	49.2	50.7	5.4
42	42	41	40	39	40	38	43	55	54	59	59	61	62	63	60	61	60	59	53	52	48	45	43	25.0	50.5	51.0	50.8	5.8
43	38	43	38	40	47	53	57	60	63	66	67	69	70	71	72	71	72	69	63	58	57	51	49	34.0	55.0	59.7	57.5	11.9
47	48	45	48	43	46	50	58	64	69	72	75	76	80	81	80	81	80	76	68	65	62	50	57	38.0	62.0	65.0	64.3	12.8
54	52	53	52	53	52	53	64	69	75	79	82	85	82	84	84	85	82	80	75	69	62	61	59	33.0	58.5	68.3	68.6	12.7
58	58	56	57	53	55	56	64	72	78	80	83	84	86	87	87	88	89	86	85	77	70	67	63	36.0	71.0	74.0	72.5	12.7
60	59	56	58	56	52	55	63	70	76	80	84	87	88	89	91	90	87	87	83	79	76	74	73	39.0	71.5	75.3	73.9	13.0
70	70	69	67	68	69	66	66	69	74	78	80	85	85	87	87	87	87	86	84	79	72	69	69	21.0	76.5	77.3	76.0	8.0
69	66	64	65	64	65	64	65	70	71	73	75	76	78	79	79	78	73	70	68	66	64	62	61	18.0	70.0	65.5	69.4	5.6
60	60	59	56	55	50	52	58	64	70	73	75	76	77	78	78	78	78	72	70	62	62	60	60	28.0	64.0	63.2	65.9	9.1
57	54	54	51	54	52	53	56	64	68	72	72	75	73	70	72	71	68	66	60	56	57	55	54	24.0	63.0	59.5	61.8	9.1
52	51	50	50	51	52	53	51	51	50	52	54	59	57	58	57	58	59	56	54	51	50	49	47	12.0	53.0	53.0	53.0	3.4
43	42	41	40	39	40	40	43	47	51	54	52	54	52	51	48	46	46	44	43	40	36	37	37	18.0	45.0	43.0	44.4	5.5
35	35	34	34	31	31	37	42	47	50	52	54	57	59	61	59	60	63	66	64	54	50	47	44	35.0	48.5	51.0	48.5	11.2
42	42	42	38	39	38	43	49	56	61	64	65	67	67	65	66	66	64	61	54	51	49	45	44	29.0	52.5	53.0	53.2	10.6
43	37	35	34	33	34	37	43	47	52	53	55	56	57	58	58	57	56	54	52	49	46	44	44	25.0	45.5	48.0	47.1	8.6
42	40	35	32	35	30	32	39	47	52	54	58	60	62	65	67	67	69	69	65	62	56	54	50	39.0	49.5	54.5	51.7	12.9
50	46	45	45	42	43	46	51	58	62	66	69	71	72	73	74	75	75	74	72	62	56	56	51	33.0	58.5	60.5	59.7	11.7
49	50	49	49	42	45	52	58	64	70	73	75	77	73	81	82	81	81	80	78	68	66	58	57	40.0	62.0	66.8	65.2	13.3
55	52	54	53	51	49	52	57	66	74	75	78	82	82	82	84	85	80	78	72	69	67	65	63	37.0	56.5	68.0	67.8	12.1
60	54	55	52	52	52	55	58	68	75	79	81	81	80	80	81	81	79	78	75	71	67	65	66	29.0	66.5	69.3	69.5	11.0
64	62	61	61	62	63	68	71	70	73	74	80	82	84	84	84	83	82	79	73	70	67	64	60	24.0	72.0	73.0	71.7	8.5
60	58	61	57	58	63	66	72	76	80	82	84	84	85	87	86	86	84	83	81	74	72	70	66	30.0	72.0	74.8	74.0	10.3
62	62	60	60	56	57	60	66	72	78	84	86	88	90	90	90	90	88	86	84	77	72	71	68	34.0	73.0	76.0	74.9	12.1
64	62	62	60	60	58	61	66	74	80	84	86	86	88	90	92	92	88	82	80	78	78	74	72	34.0	75.0	76.3	75.7	11.3
67	63	64	66	66	64	61	65	70	78	83	80	77	78	76	76	78	76	78	76	73	68	65	65	22.0	72.0	71.3	71.6	6.3
64	60	58	58	57	56	58	60	66	72	78	82	85	88	89	91	90	90	88	86	80	76	70	70	35.0	73.5	75.5	73.8	12.5
73	68	70	68	68	69	70	70	74	80	83	85	87	89	90	90	90	90	90	88	84	78	74	70	22.0	79.0	81.8	79.0	3.8
54.2	52.7	52.0	51.1	50.3	50.5	52.4	56.7	62.1	66.6	69.8	71.4	73.1	73.9	74.8	75.0	75.0	74.0	72.3	69.0	64.4	61.0	58.5	56.6	28.0	62.5	63.7	63.2	10.1
10.0	9.9	9.9	10.1	10.3	10.3	9.7	9.4	9.4	10.6	11.1	11.9	11.9	12.4	12.4	12.9	12.9	12.3	12.2	12.4	11.5	11.0	10.4	10.4	9.3	10.2	10.8	10.3	
4.8	5.3	5.0	5.2	5.4	6.1	5.3	4.5	4.4	4.7	4.9	5.4	6.0	6.7	6.4	6.7	6.7	6.7	6.5	7.1	5.1	5.4	4.9	4.7	7.8	4.1	4.7	4.2	2.6

TEMPERATURE FREQUENCIES (RUN NOV 30, 1978)- C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES JUN 1973

A= 0100-0600, B= 0700-1200, C= 1300-1800, D= 1900-2400

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	A	B	C	D	TOT
															1	1								0	0	2	0	2
															2									0	0	4	0	4
													1	3	2	4	2	1						0	0	16	1	17
													1	2			1							0	0	20	1	21
												1	3			1	2	1	1					0	0	27	3	30
												2		3	2	1	2	1						0	0	37	4	41
											2	1	1		1	1		3	1					0	2	41	8	51
											1	3	2			2			1					0	3	48	9	60
										2	2	2	1	2	3		1		2	1				0	7	57	12	76
										2	1					1		1	1					0	10	58	14	82
										1	2	2	2	1	1		2	1						0	13	66	15	94
											1	1		2	1	3	1		1					0	14	74	16	104
									3	2	3		2	1	1		2	2	1	1				0	22	80	20	122
										2			1	1	1		1	1		2				0	24	84	23	131
									3	2	1		2	1	1	3	1	3	1	1	2			0	30	92	30	152
												2	1							2				0	30	95	32	157
								1	1	1		3		1	1		1	1	1		2			0	33	101	36	170
									2		4	1				1	1		2					0	39	104	38	181
								2	2	1					1			1		1		3		0	44	105	43	192
									1	3			1	1			1		1	1			1	0	48	108	46	202
							1	2	1	2	1		1		2		1	1	2		3		1	0	55	112	53	220
							1		1			1		1		2				1		1		0	57	116	55	228
2	1	1				1	1	4	2				1	1				1	1	1	1	2	2	4	65	119	63	250
1		1			2			2	1		1	1					1	2		2		1	1	8	69	120	69	266
	2		1	2		1		1	1								1		2	1	1		1	13	72	121	74	280
1			1								1	1	1		1	1					3	1		15	73	125	78	291
	1		1	1		2	3	2		2					1	1		2		1	1		2	18	82	127	84	311
			1		1		2				1			2					1	1		3	1	20	85	129	90	324
3		2		1	1	1	2	4		1							1		1		1	1		27	93	130	93	343
					2		1		1					2			1		1				2	29	95	133	95	353
1	3	1		1					1				3				1			3	3	1		35	96	137	103	371
		2	1			2			1			1		1	1	2		1				1	1	38	99	142	106	385
4	2	1	2	1		1	1	1				1			2	2	1	2	2			2	2	48	102	148	114	412
	1									1	1	2	1	1	1		1	1					1	49	104	154	116	423
1	2	2	2	1	1	1	4	1			2	1		2	1	1	1			1		1		58	112	160	118	448
2			2	1	1		2			2	1	1	2		1	1					2		2	64	117	165	122	468
1	1	2	1	2	1	1	1	1				1					1	1		1	2	1		72	120	167	127	486
		1		1	1	2		1	1		1											1		75	125	167	128	495
1	2	3		1					2	3	2	1						1	3	2		1	1	82	132	168	136	518
		1	1	2		4				1									1					86	137	168	137	528
1	2		3	1	6	3	1	2	3	2	1		2		1	1	1		1	1	1			99	149	173	140	561
	1		1	3			2	1	1				1	1						3		1	1	104	153	175	145	577
1	1	1	1		1	2			2					1							2		1	109	157	176	148	590
1		2	1				1											1	1	1	1	2		113	159	176	154	601
	1		1		1		1	1			1	1			1					1	2		1	116	161	178	158	613
1					1			4														1	1	118	165	178	160	621
2	1	1	1	1	2	2										1	1				2	2	2	126	167	180	166	639
	1	1	1		1		1															2		130	168	180	168	646
	1	1	1	1		1												1				1	3	134	169	180	173	656
1				1	2	1	3												1				2	138	173	180	176	667
3	3	1		2			1																	147	174	180	176	677
		2																						149	174	180	176	679
2	1	1	2	1	2	1														1				158	175	180	177	690
				3			1																	161	176	180	177	694
	1		2		1	1																		165	177	180	177	699
	1					2																1	1	166	179	180	179	704
																					1			166	179	180	180	705
1	1	2		1																				171	179	180	180	710
		1	2		1																			175	179	180	180	714
				1																				176	179	180	180	715
			1			1																		177	180	180	180	717
				1	1																			179	180	180	180	719
					1																			180	180	180	180	720

HOURLY TEMPERATURE RECORD (RUN NOV 30, 1978) - C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES JLY 1973

HOURS DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	RG	MR	SH	MN	S
1	68	66	66	66	66	63	64	65	69	76	79	79	80	82	86	88	88	87	85	83	80	76	70	68	25.0	75.5	76.5	75.0	8
2	66	63	62	60	62	58	56	56	58	76	84	86	87	90	90	88	90	86	82	78	75	72	68	66	34.0	73.0	74.0	73.3	12
3	64	64	62	60	56	58	60	66	84	83	89	90	93	90	88	90	88	88	88	86	78	76	72	68	37.0	74.5	76.5	76.7	12
4	67	61	64	64	60	60	61	68	74	84	87	91	92	94	94	94	94	90	88	85	78	74	70	70	34.0	77.0	77.8	77.7	12
5	66	63	58	60	60	60	63	66	73	78	86	90	94	95	95	95	94	94	92	88	83	78	76	76	37.0	76.5	81.0	78.5	13
6	74	70	70	73	72	70	68	69	75	86	90	88	88	92	92	92	92	90	85	84	80	75	76	72	24.0	80.0	80.0	80.1	8
7	72	70	71	70	68	69	70	74	76	80	83	84	87	88	87	82	77	80	77	75	75	71	66	64	24.0	76.0	77.0	75.7	6
8	60	63	60	58	56	58	58	58	65	70	74	79	78	70	70	68	74	76	80	74	75	71	68	65	24.0	68.0	69.5	67.7	7
9	62	60	61	60	56	54	52	54	62	70	84	86	90	90	90	92	90	86	82	80	74	70	68	68	40.0	72.0	72.5	72.5	13
10	66	66	64	62	58	58	58	68	74	83	85	87	89	90	90	92	90	90	90	84	80	76	70	68	34.0	75.0	77.0	76.6	11
11	64	64	61	60	62	62	63	70	78	80	82	84	84	82	80	82	80	76	74	72	70	68	70	68	24.0	72.0	71.3	72.3	8
12	68	68	68	68	66	66	66	60	62	66	68	72	72	72	78	78	76	76	72	71	68	68	68	66	18.0	69.0	68.5	69.3	4
13	66	65	64	64	64	64	64	64	64	66	76	78	78	80	80	82	80	78	78	72	68	60	58	58	24.0	70.0	70.0	69.6	7
14	56	56	58	56	54	54	58	60	65	68	72	75	76	76	78	78	80	80	82	78	70	66	66	54	28.0	68.0	69.5	67.3	3
15	53	52	52	52	52	52	52	58	63	68	70	74	77	76	81	82	84	84	82	80	75	72	68	64	32.0	68.0	69.5	67.6	11
16	66	63	60	56	56	55	56	56	59	74	78	80	82	84	84	84	84	82	80	77	72	70	66	66	28.0	70.0	71.0	70.5	10
17	63	64	60	58	57	56	60	68	72	78	80	84	65	68	72	70	70	70	70	68	66	63	62	60	28.0	70.0	65.0	66.8	7
18	59	57	56	55	55	56	54	64	68	70	73	76	78	76	66	58	60	60	60	60	58	58	58	58	24.0	56.0	61.5	62.2	7
19	57	57	57	57	56	55	57	60	67	68	61	58	65	70	65	62	64	66	69	65	62	58	58	58	15.0	62.5	62.7	61.3	4
20	52	56	54	52	50	48	50	56	60	66	68	71	73	72	72	72	73	71	68	56	58	55	55	54	25.0	60.5	59.5	60.9	6
21	55	52	50	48	48	48	46	54	59	64	68	70	73	76	77	72	76	76	78	75	65	62	63	58	32.0	62.0	63.0	63.0	10
22	58	58	54	50	51	50	50	56	62	68	70	72	70	60	70	76	72	72	71	69	64	62	60	56	26.0	63.0	59.5	62.5	8
23	56	54	52	51	50	48	48	52	58	64	69						76	77	76	70	64	61	60	58	29.0	62.5	0.0	60.2	9
24	58	56	55	52	52	50	53	60	69	72	76	78	81	84	82	82	80	80	77	74	71	68	66	62	34.0	67.0	63.8	68.3	11
25	60	58	55	55																					5.0	57.5	0.0	57.0	2
26								63	70	75	78	80	82	84	86	84	84	84	80	74	68	68	64	62	24.0	74.0	0.0	75.6	8
27	62	64	64	61	62	62	62	62	67	72	78	78	76	74	82	76	71	72	72	69	62	62	58	56	26.0	69.0	65.0	67.7	7
28	55	54	52	53	54	54	53	56	62	70	75	80	82	82	75	76	78	82	80	74	70	64	62	60	30.0	67.0	68.8	66.3	11
29	59	59	55	56	57	55	56	59	64	70	75	80	82	80	66	76	82	76	83	72	63	57	56	56	23.0	69.0	65.5	66.6	10
30	55	54	55	53	54	53	54	56	60	66	73	75	87	79	82	84	82	82	77	80	84	68	68	64	34.0	70.0	75.3	68.5	12
31	62	59	58	56	58	58	56	56	58	64	72	76	81	84	84	80	80	85	82	78	78	71	68	66	29.0	70.5	74.0	69.6	10

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	RG	MR	SH	MN	S
MN	61.7	60.5	59.5	58.2	57.7	57.1	57.6	61.2	66.6	72.6	76.8	79.4	80.8	80.7	80.8	80.6	80.4	79.9	78.7	75.1	71.2	67.4	65.3	63.0	27.7	69.6	70.4	69.3	9
SD	5.5	5.0	5.4	5.9	5.7	5.8	5.9	5.6	6.7	6.4	7.0	7.1	7.6	8.4	8.4	9.1	8.3	7.6	7.0	7.3	7.1	6.3	5.5	5.5	6.9	5.3	6.0	5.3	
IV*	4.1	4.1	4.3	4.1	3.9	3.5	4.6	5.1	5.9	4.3	4.5	4.6	5.9	6.7	5.9	5.6	5.1	5.3	5.5	5.3	4.8	4.1	3.9	3.6	6.5	3.1	3.3	3.6	2
MI	1	1	1	1	2	2	2	1	1	1	1	2	2	2	2	2	1	1	1	1	1	1	1	1			3		
MI*	2	2	2	2	3	3	3	2	2	2	2	4	4	4	4	4	2	2	2	2	2	2	2	2			5		

HOURLY TEMPERATURE FREQUENCIES (RUN NOV 30, 1978) - C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES JLY 1973

A= 0100-0600, B= 0700-1200, C= 1300-1800, D= 1900-2400

HOURS TEMP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	A	B	C	D	TOT
95														1	1	1									0	0	3	0	3
94													1	1	1	1	2	1							0	0	10	0	10
93													1												0	0	11	0	11
92													1	1	1	3	1		1						0	0	18	1	19
91												1													0	1	18	1	20
90											1	2	1	4	3	1	3	3	1						0	4	33	2	39
89													1												0	4	34	2	40
88											1	1	1	1	1	2	2	1	2	1					0	6	42	5	53
87											1	1	3		1			1							0	8	47	5	60
86										1	1	2			2			2		1					0	12	51	6	69
85											1							1	2	1					0	13	52	9	74
84									1	1	2	3	1	4	2	3	3	2		2	1				0	20	67	12	99
83										2	1								1	1	1				0	23	67	15	105
82											1		4	3	3	5	2	3	5						0	24	87	20	131
81													2		1										0	24	90	20	134
80										2	1	4	1	2	2	1	5	3	4	3	3				0	31	104	30	165
79											1	2		1											0	34	105	30	169
78									1	2	3	3	3		2	2	1	1	2	3	3	1			0	43	114	39	196
77													1		1		1	1	3	1					0	43	118	43	204
76									1	2	3	2	2	4		4	3	5	1			3	2	1	0	51	136	50	237
75									1	1	1	2			1					2	4	1			0	56	137	57	250
74	1							1	2	1	1	1		1			1		1	4	1	1			1	62	139	64	266
73				1					1		2		2				1								2	65	142	64	273
72	1				1				1	2	2	2	1	2	2	2	1	2	2	3	1	2	1	1	4	72	152	74	302
71			1									1					1	1	1	1	1	3			5	73	154	80	312
70		2	1	1		1	1	1	1	5	2	1	1	2	2	1	1	1	1	1	3	2	4	1	10	84	162	92	348
69						1		1	2		1								1	2					11	88	162	95	356
68	2	1	1	1	1		1	3	1	4	3			1		1			1	1	3	5	7	5	17	100	164	117	398
67	1								2																18	102	164	117	401
66	5	2	1	1	2	1	1	2		4					2			1			1	1	4	4	30	109	167	127	433
65		1						1	2				2		1					1	1			1	31	112	170	130	443
64	2	4	4	2	1	1	2	2	2	3							1				2	1	1	3	45	121	171	137	474
63	1	3				1	2	1	1												1	1	1		50	125	171	140	486
62	3		2	1	3	2	1	1	4							1					2	3	2	2	61	131	172	149	513
61		1	2	1			1				1											1			65	133	172	150	520
60	2	2	3	5	2	2	2	4	2					1			1	1	1	1		1	2	2	81	141	175	157	554
59	2	2	1					1	2																86	144	175	157	562
58	2	2	3	2	2	5	3	2	3			1				1					2	2	4	5	102	153	176	170	601
57	1	2	1	1	2		1															1			109	154	176	171	610
56	2	3	1	4	5	3	4	7												1			1	3	127	165	176	176	644
55	3		3	2	1	2																1	1		138	165	176	178	657
54		3	2		3	3	2	2																2	149	169	176	180	674
53	1			2		1	2																		153	171	176	180	680
52	1	2	3	3	2	1	2	1																	165	174	176	180	695
51				1	1																				167	174	176	180	697
50			1	1	2	2	2																		173	176	176	180	705
49																									173	176	176	180	705
48				1	1	3	1																		178	177	176	180	711
47																									178	177	176	180	711
46							1																		178	178	176	180	712

TEMPERATURE RECORD (RUN NOV 30, 1978) - C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES AUG 1973

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	RG	MR	SH	MN	SD
62	58	60	56	59	57	55	54	62	68	74	80	84	86	87	88	84	86	79	84	82	74	69	67	34.0	71.0	75.3	71.5	11.9
62	60	58	60	60	58	60	56	56	62	70	78	83	85	88	90	89	92	88	83	82	79	73	67	36.0	74.0	77.3	72.5	12.6
68	64	62	60	59	60	59	60	60	66	74	74	78	82	85	86	81	76	76	77	74	72	70	68	27.0	72.5	72.3	70.5	8.5
63	54	64	63	60	60	62	63	65	64	66	68	71	74	76	77	79	58	68	69	70	64	64	64	21.0	68.5	69.0	66.7	5.4
63	60	58	58	58	59	58	57	57	60	64	68	73	74	72	68	65	70	70	68	67	68	64	60	17.0	65.5	66.5	64.1	5.4
63	62	60	58	57	56	56	57	66	70	73	74	74	76	74	78	75	72	67	64	64	60	62	60	22.0	67.0	65.0	65.6	7.1
58	56	56	56	56	55	56	62	66	70	72	78	76	66	77	79	80	80	76	70	66	60	59	60	25.0	67.5	63.5	66.3	8.9
58	58	58	62	65	65	56	64	68	77	82	82	86	86	85	85	84	82	78	70	70	64	62	60	30.0	71.0	70.5	71.1	10.5
56	58	56	57	56	56	56	65	70	76	82	84	87	88	88	89	89	87	81	78	70	66	68	65	33.0	72.5	71.0	72.0	12.5
65	65	64	65	66	64	63	69	75	80	86	80	92	89	92	90	89	88	85	80	75	74	72	72	29.0	77.5	75.5	76.5	10.1
70	68	66	65	64	64	66	72	75	76	80	85	86	88	90	89	88	87	84	81	74	72	71	66	26.0	77.0	75.5	76.1	9.0
66	65	62	60	62	56	54	58	66	73	80	86	87	88	90	89	90	90	87	83	80	76	70	67	36.0	72.0	75.5	74.4	12.2
65	65	67	65	64	63	62	59	70	76	83	84	88	88	87	86	84	82	80	76	72	71	72	72	29.0	73.5	73.5	74.2	9.2
66	66	65	64	62	63	63	66	70	79	82	86	88	87	86	81	79	79	80	74	71	67	66	63	26.0	75.0	73.0	73.0	8.8
63	64	62	58	59	56	58	66	69	76	82	84	85	87	87	87	88	80	80	74	69	66	62	63	32.0	72.0	70.8	71.9	10.8
62	59	56	57	55	55	53	60	70	76	76	80	76	72	70	67	68	69	67	67	68	66	64	64	27.0	66.5	65.3	65.7	7.3
60	59	56	56	56	55	53	57	63	65	69	71	77	79	79	69	67	72	74	73	69	67	64	61	26.0	66.0	67.5	65.5	7.8
60	59	59	60	56	55	52	53	60	65	70	73	74	71	76	78	78	80	76	73	69	66	65	62	28.0	66.0	65.3	66.3	8.4
65	63	60	58	56	56	53	53	59	66	73	77	80	82	83	84	86	77	80	81	84	70	65	66	33.0	69.5	75.8	69.3	10.9
63	70	65	64	61	60	59	57	64	78	81	83	84	83	83	83	86	78	74	73	60	57	59	58	29.0	71.5	65.5	70.1	10.3
57	57	55	54	54	55	55	58	63	68	71	72	75	59	60	67	60	61	60	57	55	54	54	52	23.0	63.5	56.0	59.7	6.3
51	49	50	50	50	49	51	58	63	67	71	72	70	76	73	76	74	75	71	68	66	63	60	61	27.0	62.5	64.8	63.1	9.7
2.2	61.4	63.0	59.4	58.9	58.1	57.3	60.2	65.4	70.9	75.6	75.2	80.7	80.3	81.3	81.2	80.2	78.3	76.5	73.8	70.8	67.1	65.3	63.6	28.0	70.1	69.8	69.4	9.5
4.4	4.6	4.2	3.9	3.9	3.9	4.0	4.9	5.1	5.9	6.0	5.7	6.3	8.1	7.9	7.6	8.5	8.6	6.9	6.7	6.9	6.0	4.9	4.5	4.8	4.1	5.4	4.4	
2.9	3.4	3.6	3.5	3.1	3.4	3.3	3.3	3.5	4.2	4.0	3.8	3.9	6.1	5.4	6.0	7.3	6.5	5.6	5.0	4.9	4.4	3.0	3.4	4.6	2.5	3.8	2.4	2.8

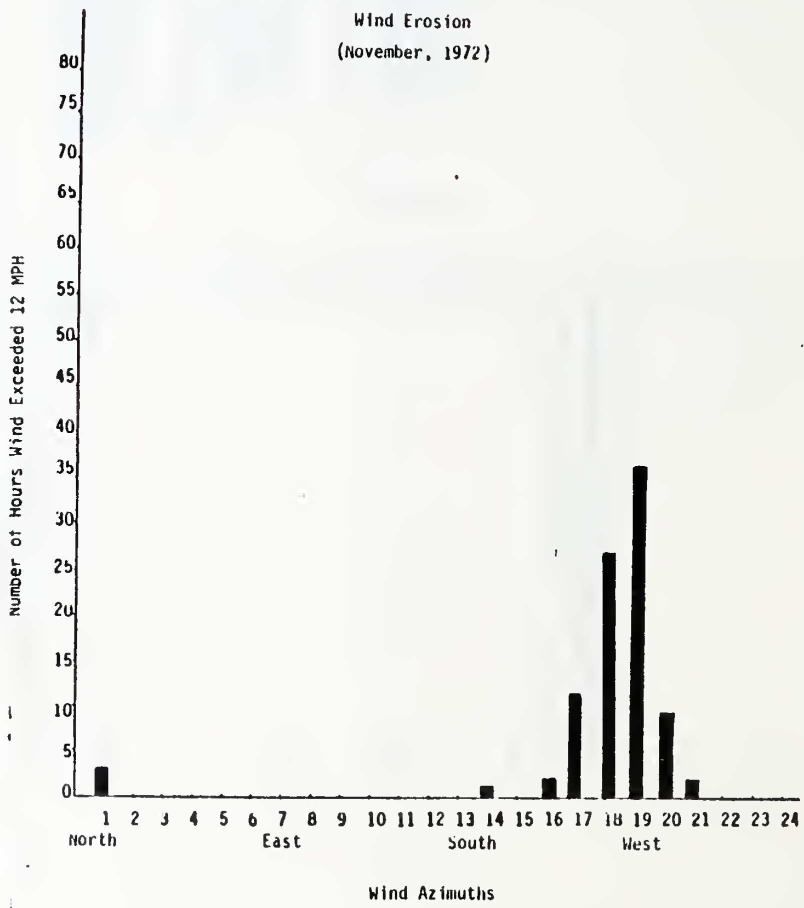
TEMPERATURE FREQUENCIES (RUN NOV 30, 1978) - C3 EMERY EAST DATA TAPE 1972/1973 TEMPERATURES AUG 1973

A= 0100-0600, B= 0700-1200, C= 1300-1800, D= 1900-2400

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	A	B	C	D	TOT
												1		1			1							0	0	3	0	3
																								0	0	3	0	3
														2	2	1	1							0	0	9	0	9
													1		3	3								0	0	16	0	16
												2	4	2	1	2	1	1						0	0	28	1	29
												2	2	3	1		2	1						0	0	38	2	40
										1	2	2	2	1	2	2	1							0	3	48	2	53
											1	1	1	2	1			1						0	4	53	3	60
											3	2			1	3		1	1	1				0	7	59	6	72
										1	1	1	1	2	1				2					0	9	64	8	81
										4	1		2				2			2				0	14	68	10	92
										1					1	1		1	2					0	15	70	13	98
									1	2	3	1				1	3	4	1	1				0	21	75	19	115
									1				1	1	1	2	1	1			1			0	22	81	21	124
									1		2	1			2	1	1	1	1					0	25	86	23	134
									1		1	1		1	1		1		1					0	27	90	24	141
									5	1		2	2	2	1		1	3	1		1			0	33	98	29	160
								2				1				1	1			1				0	35	101	30	166
										2	2	2	2	1		1		2	2	2	2			0	39	107	38	184
									1	2	1	1		1					3			1		0	43	109	42	194
							1			1	2		1	1			2			1	2	2	2	0	47	113	49	209
										2	1	1	1					1		1	1	1		0	50	115	53	219
1	1							4	2	2		1		1			1	1	2	3	1	2		2	58	118	62	240
								1		1					1		1		1	3		1		2	60	120	67	249
2	1						1	1	2		2				1	1		1	2	1	1	1	1	5	66	122	74	267
		1							1						2	1		2	1	1	2		3	6	67	125	83	281
2	1	1		1		1	2	3	2	1			1							2	4	1	2	11	76	126	92	305
3	3	2	3	1	1		1	1	2							1						2	1	24	80	127	95	326
	3	2	2	2	2		1	1	1	1									1	1	2	4	2	35	84	127	105	351
3	1		1		2	2	1	3													1		2	42	90	127	108	367
3	1	3	1	2		2	1	1	1													3	1	52	95	127	112	386
				1													1						2	53	95	128	114	390
3	2	3	4	2	3	1	2	2	1					1		1		1		1	2	1	4	70	101	130	123	424
	3	1		3	1	2	1	1					1									2		78	105	131	125	439
2	3	3	4	1	1	2	3										1						1	92	110	132	126	460
1	1		2	1	1		4	1											1		1			98	115	132	128	473
1	1	4	3	5	5	4	1	1																117	121	132	128	498
		1		1	5	2														1				124	123	132	129	508
			1	1		1	1														1	1		126	125	132	131	514
						3	2																	126	130	132	131	519
						1																	1	126	131	132	132	521
1						1																		127	132	132	132	523
		1	1	1																				130	132	132	132	526
	1				1																			132	132	132	132	528

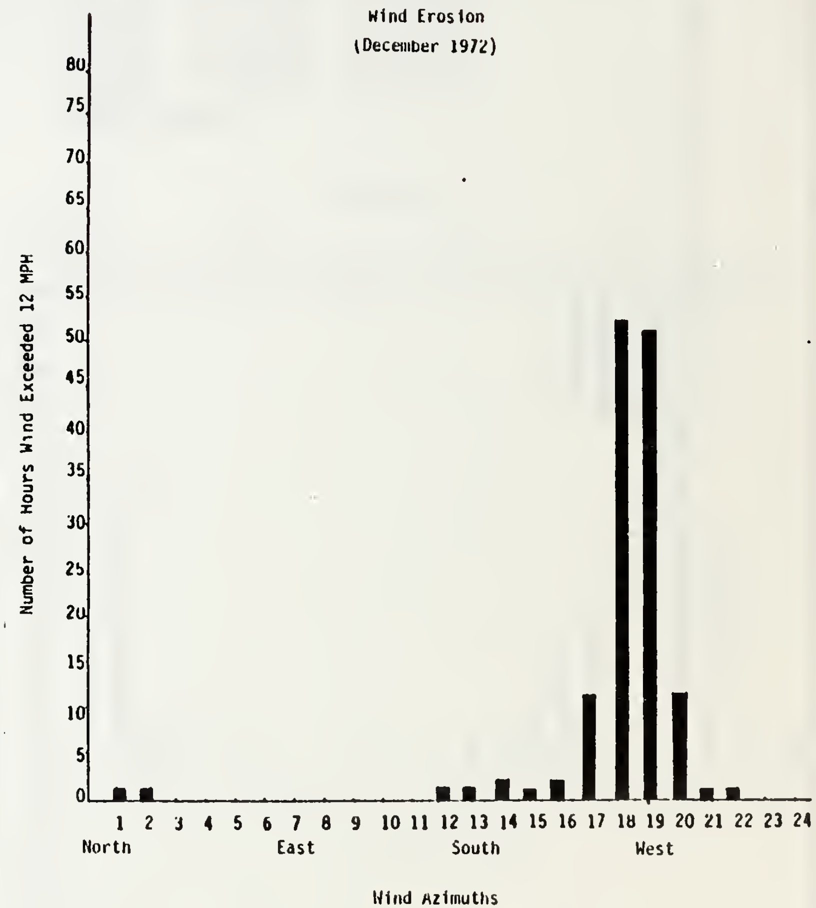
APPENDIX 6

Wind Erosion



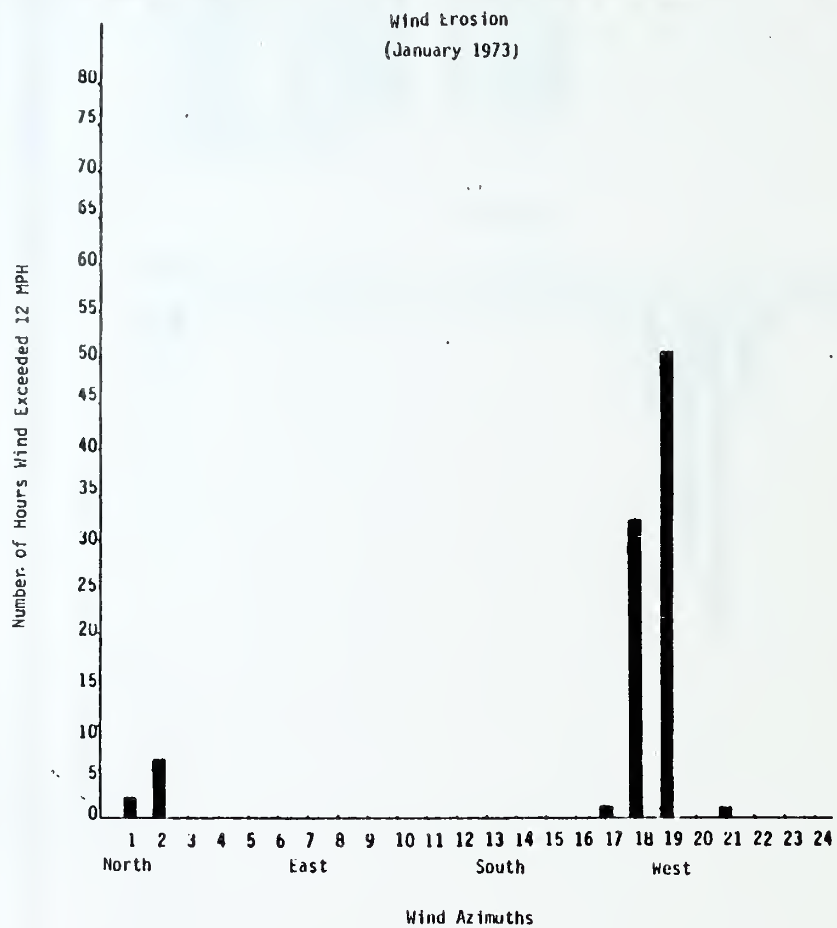
Azimuth Intervals:

1 = 0-15	9 = 120-135	17 = 240-255
2 = 15-30	10 = 135-150	18 = 255-270
3 = 30-45	11 = 150-165	19 = 270-285
4 = 45-60	12 = 165-180	20 = 285-300
5 = 60-75	13 = 180-195	21 = 300-315
6 = 75-90	14 = 195-210	22 = 315-330
7 = 90-105	15 = 210-225	23 = 330-345
8 = 105-120	16 = 225-240	24 = 345-360



Azimuth Intervals:

1 = 0-15	9 = 120-135	17 = 240-255
2 = 15-30	10 = 135-150	18 = 255-270
3 = 30-45	11 = 150-165	19 = 270-285
4 = 45-60	12 = 165-180	20 = 285-300
5 = 60-75	13 = 180-195	21 = 300-315
6 = 75-90	14 = 195-210	22 = 315-330
7 = 90-105	15 = 210-225	23 = 330-345
8 = 105-120	16 = 225-240	24 = 345-360



Azimuth Intervals:

1 = 0-15	9 = 120-135	17 = 240-255
2 = 15-30	10 = 135-150	18 = 255-270
3 = 30-45	11 = 150-165	19 = 270-285
4 = 45-60	12 = 165-180	20 = 285-300
5 = 60-75	13 = 180-195	21 = 300-315
6 = 75-90	14 = 195-210	22 = 315-330
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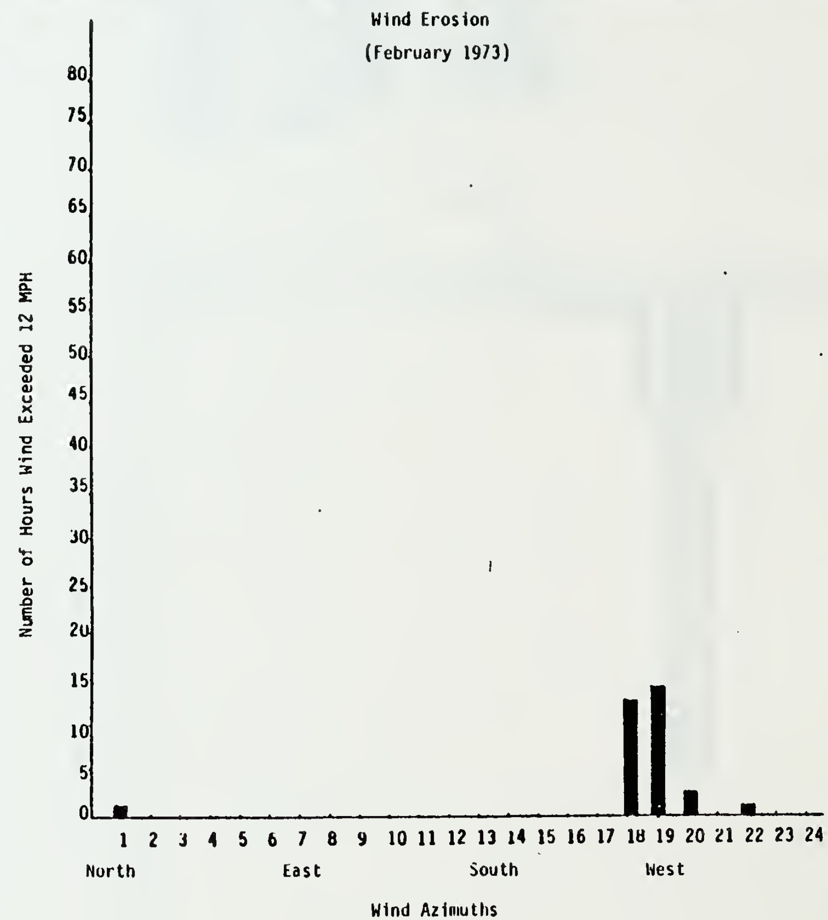
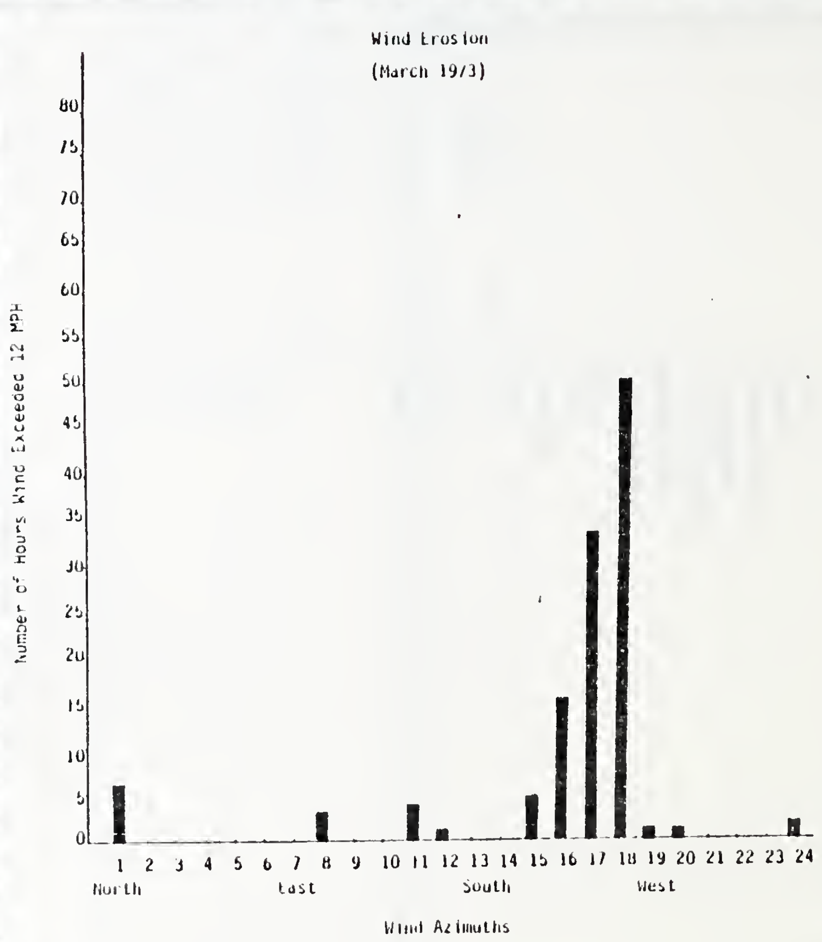
8 = 105-120	16 = 225-240	24 = 345-360



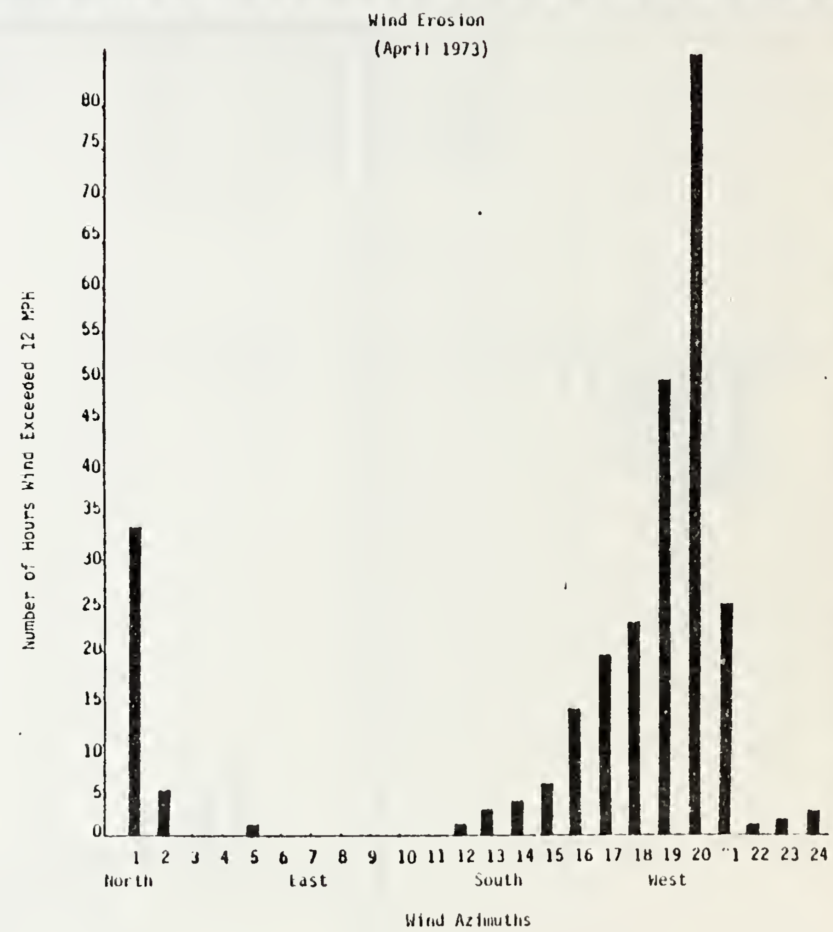
Azimuth Intervals:

1 = 0-15	9 = 120-135	17 = 240-255
2 = 15-30	10 = 135-150	18 = 255-270
3 = 30-45	11 = 150-165	19 = 270-285
4 = 45-60	12 = 165-180	20 = 285-300
5 = 60-75	13 = 180-195	21 = 300-315
6 = 75-90	14 = 195-210	22 = 315-330
7 = 90-105	15 = 210-225	23 = 330-345
8 = 105-120	16 = 225-240	24 = 345-360



Azimuth Intervals:

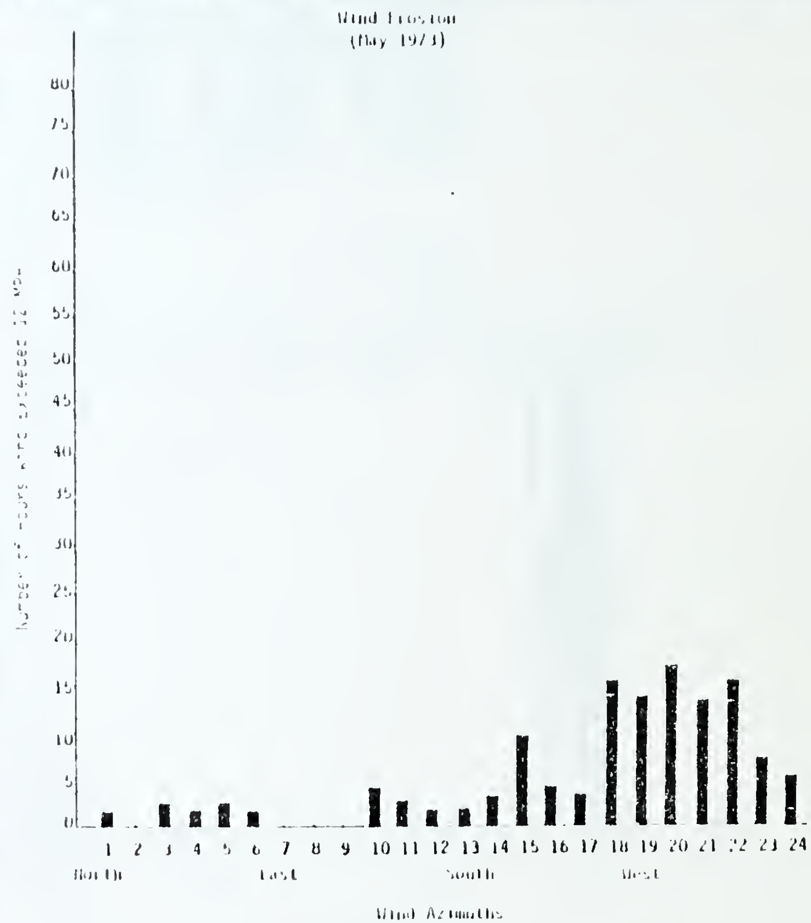
1 = 0-15	9 = 120-135	17 = 240-255
2 = 15-30	10 = 135-150	18 = 255-270
3 = 30-45	11 = 150-165	19 = 270-285
4 = 45-60	12 = 165-180	20 = 285-300
5 = 60-75	13 = 180-195	21 = 300-315
6 = 75-90	14 = 195-210	22 = 315-330
7 = 90-105	15 = 210-225	23 = 330-345
8 = 105-120	16 = 225-240	24 = 345-360



Azimuth Intervals:

1 = 0-15	9 = 120-135	17 = 240-255
2 = 15-30	10 = 135-150	18 = 255-270
3 = 30-45	11 = 150-165	19 = 270-285
4 = 45-60	12 = 165-180	20 = 285-300
5 = 60-75	13 = 180-195	21 = 300-315
6 = 75-90	14 = 195-210	22 = 315-330
7 = 90-105	15 = 210-225	23 = 330-345
8 = 105-120	16 = 225-240	24 = 345-360

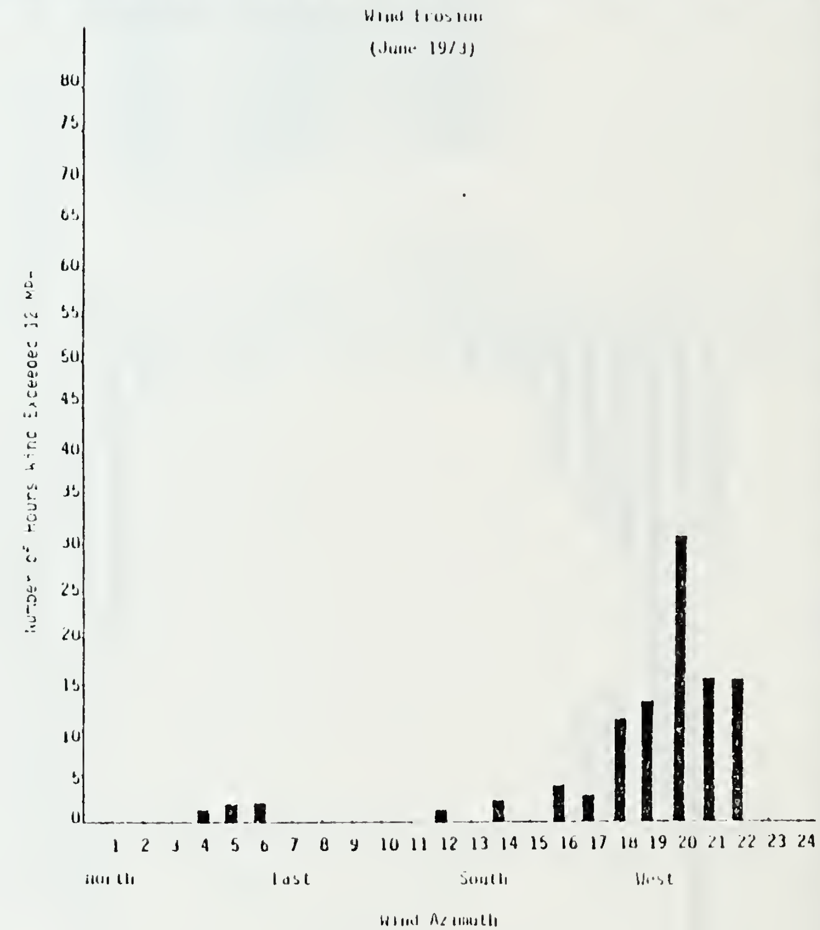
Wind Erosion
(May 1973)



Azimuth Intervals:

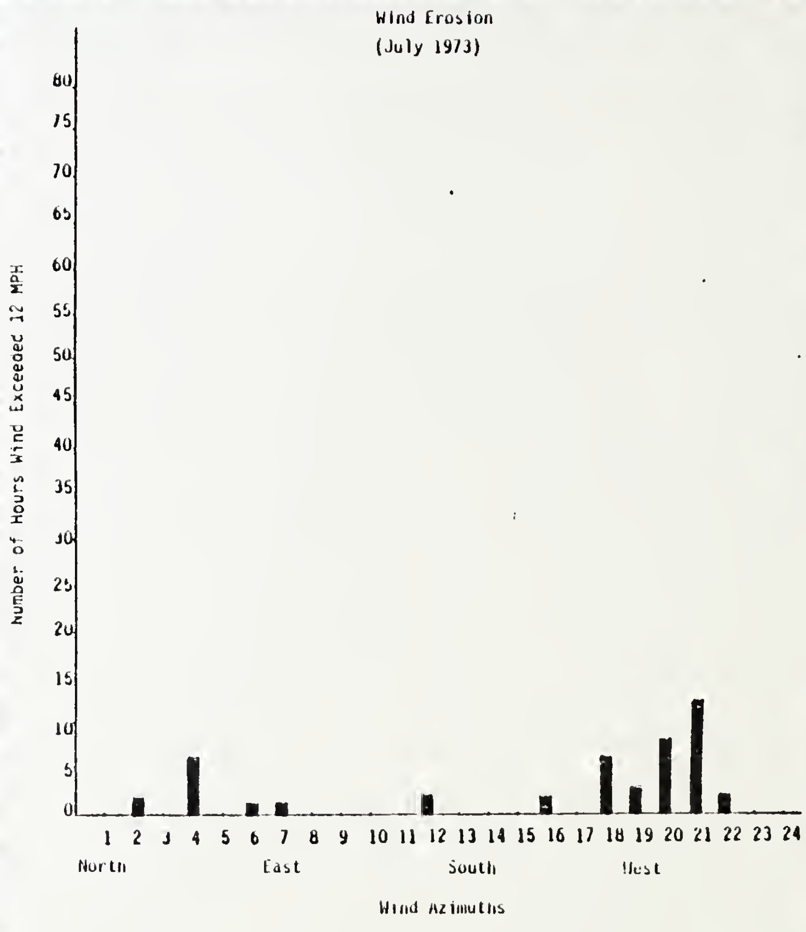
1 - 0-15	9 - 120-135	17 - 240-255
2 - 15-30	10 - 135-150	18 - 255-270
3 - 30-45	11 - 150-165	19 - 270-285
4 - 45-60	12 - 165-180	20 - 285-300
5 - 60-75	13 - 180-195	21 - 300-315
6 - 75-90	14 - 195-210	22 - 315-330
7 - 90-105	15 - 210-225	23 - 330-345
8 - 105-120	16 - 225-240	24 - 345-360

Wind Erosion
(June 1973)



Azimuth Intervals:

1 - 0-15	9 - 120-135	17 - 240-255
2 - 15-30	10 - 135-150	18 - 255-270
3 - 30-45	11 - 150-165	19 - 270-285
4 - 45-60	12 - 165-180	20 - 285-300
5 - 60-75	13 - 180-195	21 - 300-315
6 - 75-90	14 - 195-210	22 - 315-330
7 - 90-105	15 - 210-225	23 - 330-345
8 - 105-120	16 - 225-240	24 - 345-360



Azimuth Intervals:

1 = 0-15	9 = 120-135	17 = 240-255
2 = 15-30	10 = 135-150	18 = 255-270
3 = 30-45	11 = 150-165	19 = 270-285
4 = 45-60	12 = 165-180	20 = 285-300
5 = 60-75	13 = 180-195	21 = 300-315
6 = 75-90	14 = 195-210	22 = 315-330
7 = 90-105	15 = 210-225	23 = 330-345
8 = 105-120	16 = 225-240	24 = 345-360

APPENDIX 7

Laboratory Analysis of Bore holes #3 Through #6

Key to Lithologic Correlations

5	Ash - (burned coal) thickness exaggerated
4	Delta Front / Marine Sequences - laterally continuous, primarily sandstone, minor siltstone, (clyst) claystone
3	Coal (identified according to letter scheme of Lupton, 1916)
2	Alluvial and Delta Plain - rocks undivided: sandstone, siltstone, (clyst) claystone; lateral variation great, unpredictable, particularly in alluvial rocks.
1	Marine Sandstone

Abbreviations:

Sat. pH = Saturation Acidity - Alkalinity

Sat. Cond. = Saturation Conductivity

meq/l SAR = Sodium Absorption Ratio in millequivalents per liter

% O.M. = Percentage of Organic Matter

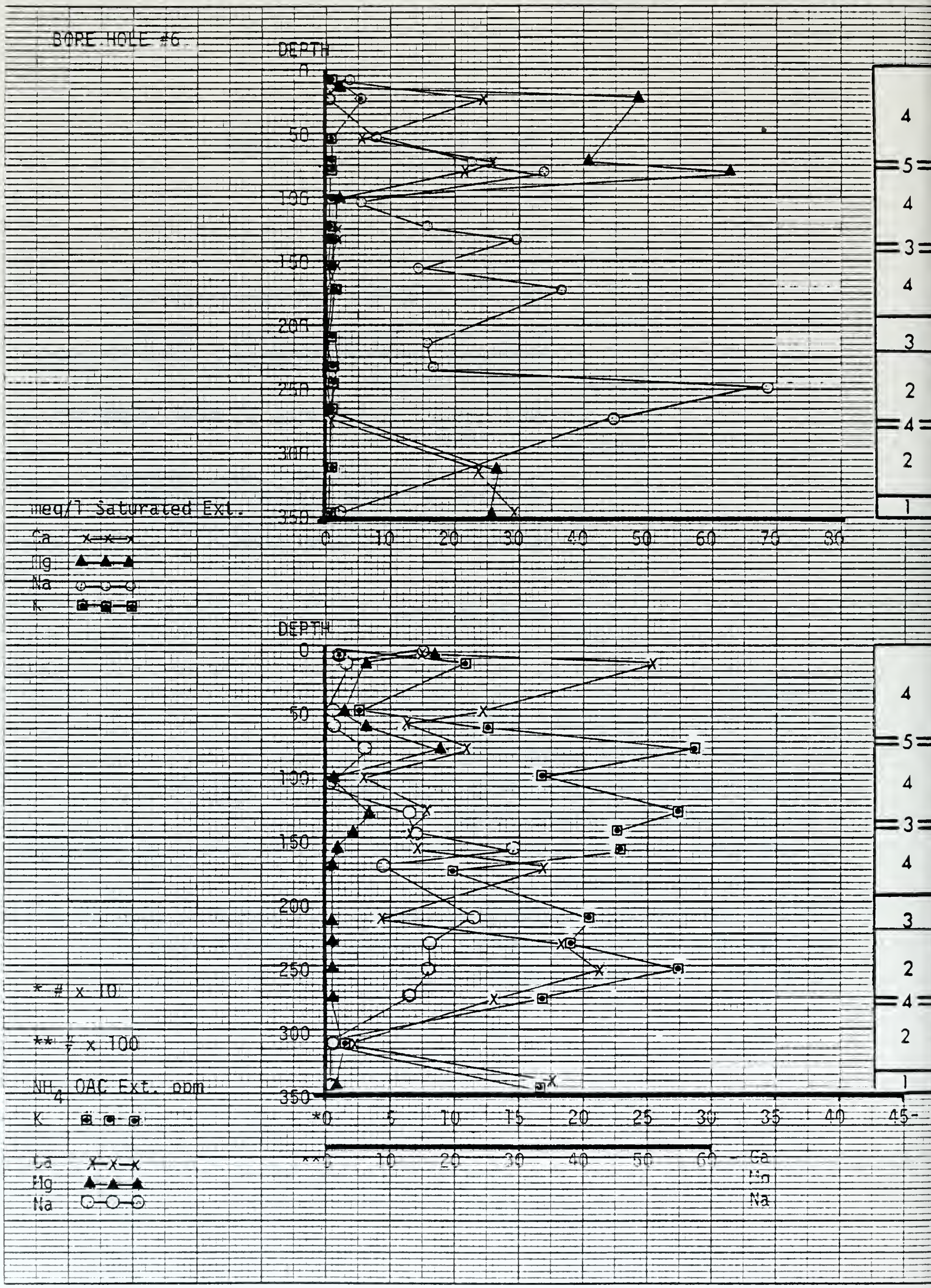
meq/100g C.E.C. = Cation Exchange Capacities in millequivalents per 100 grams

% Sat. = Percent Saturation

DTPA Ext. ppm = Diethylenetriamine pentaacetic acid extract in parts per million

meq/l Sat. Ext. = Saturation Extract in millequivalents per liter

NH_4 OAC Ext. ppm = Ammonium Acetate extract in parts per million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100
150
200
250
300
350
0 10 20 30 40 50 60 70 80
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4
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4
3
2
4
2
1
meq/l Saturated Ext.
Ca
Mg
Na
K
DEPTH
0
50
100
150
200
250
300
350
4
5
4
3
4
3
2
4
2
1
* # x 10
** ½ x 100
NH4 OAC Ext. ppm
K
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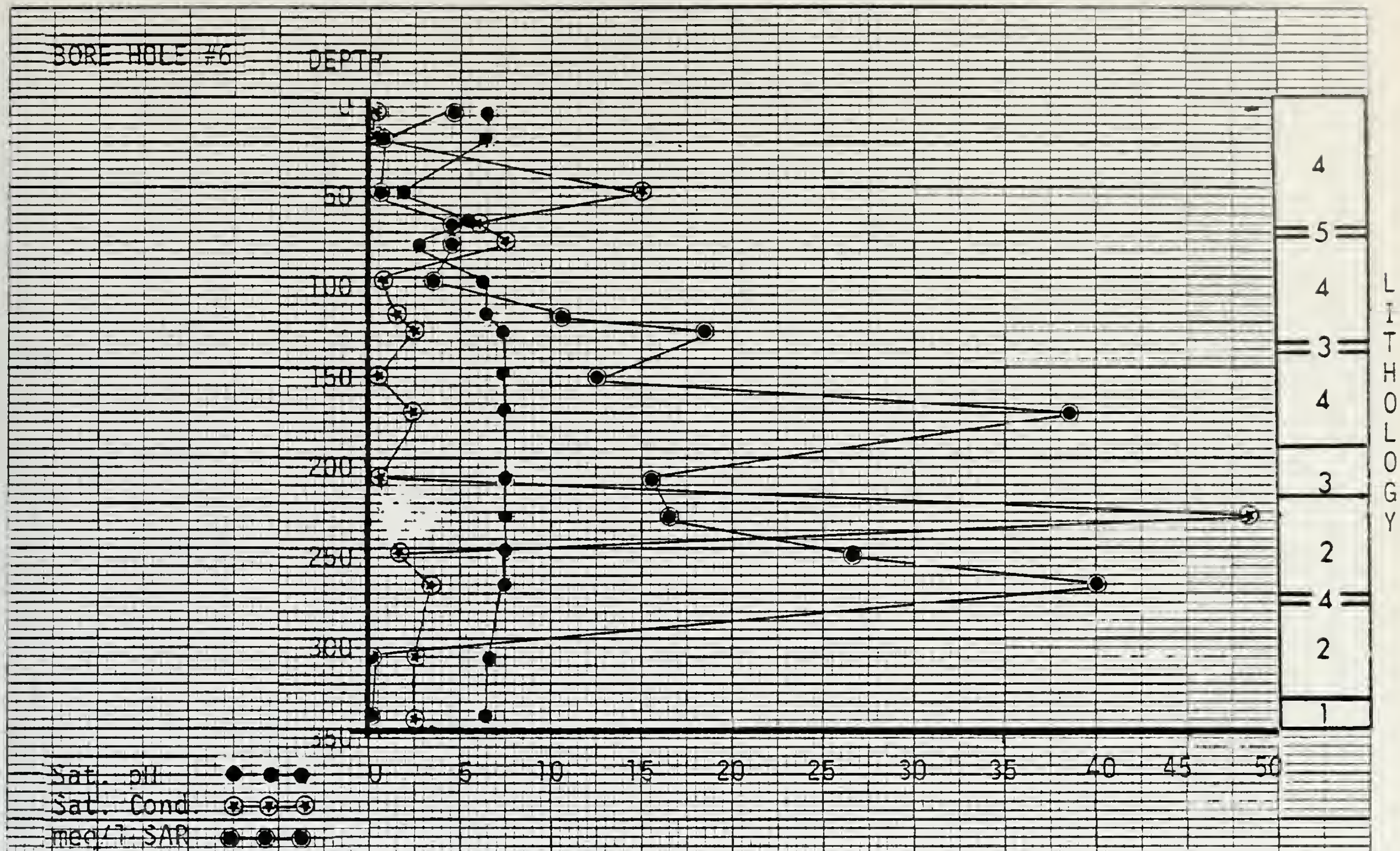
**0 10 20 30 40 50 60
Ca
Mg
Na
Ca
Mg
Na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DEPTH
LITHOLOGY
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3
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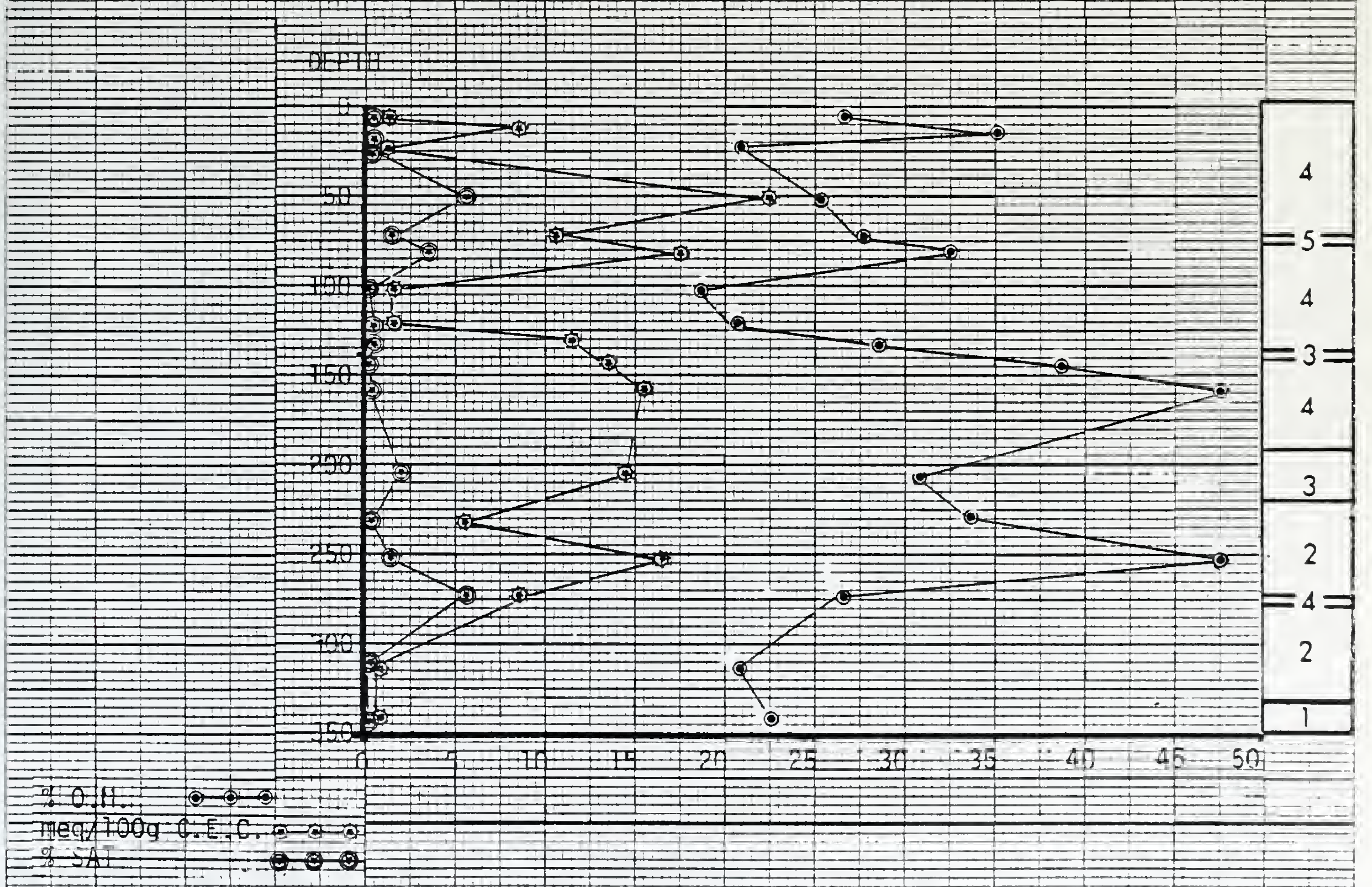
25
30
35
40
45
50
Sat. pH
Sat. Cond.
meq/l SAR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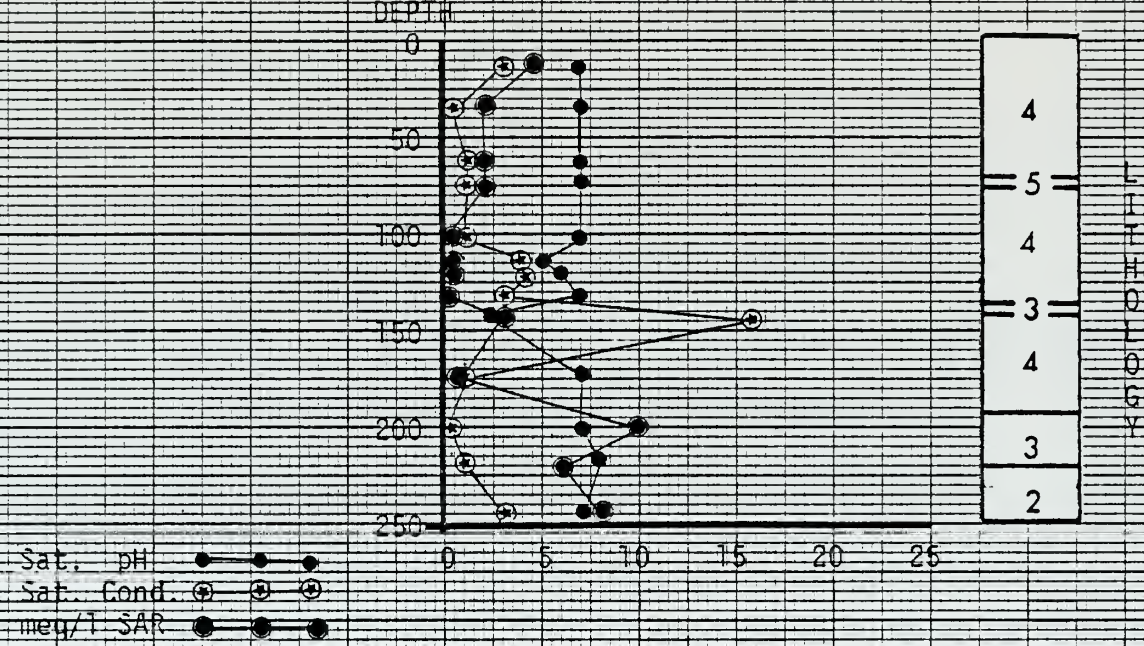
% O.M.
meq/100g C.E.C.
% SAT

BORE HOLE #5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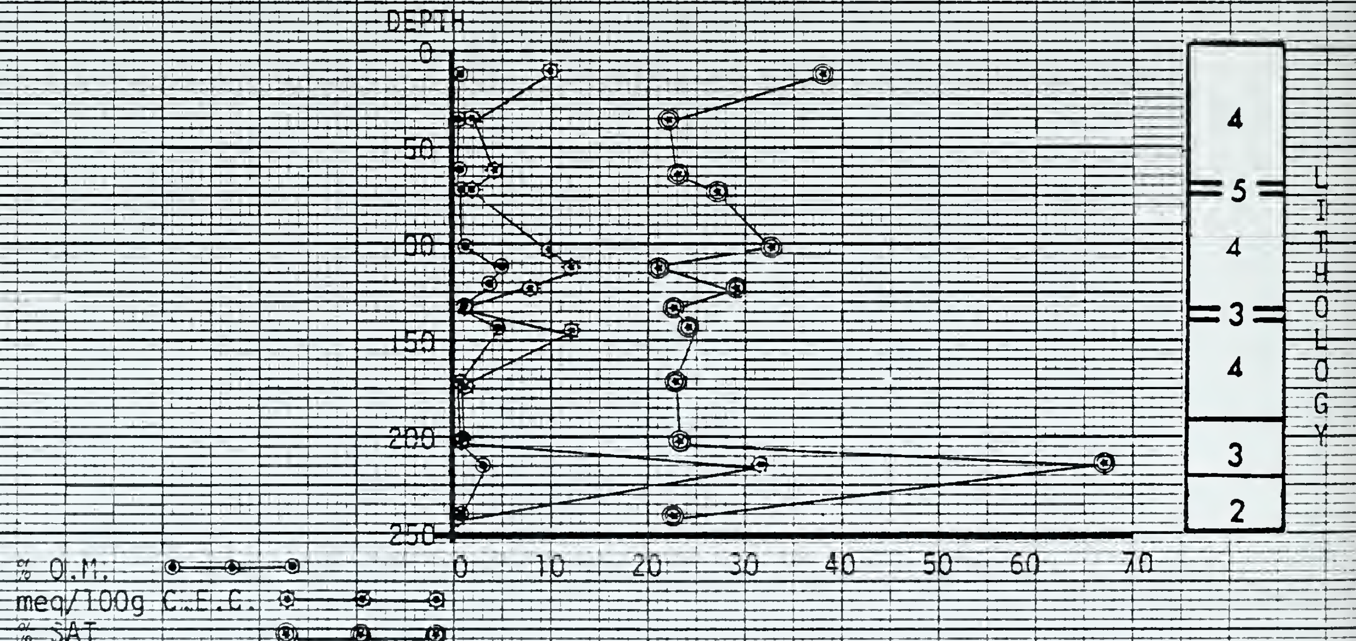
LITHOLOGY
Sat. pH
Sat. Cond.
meq/l SAR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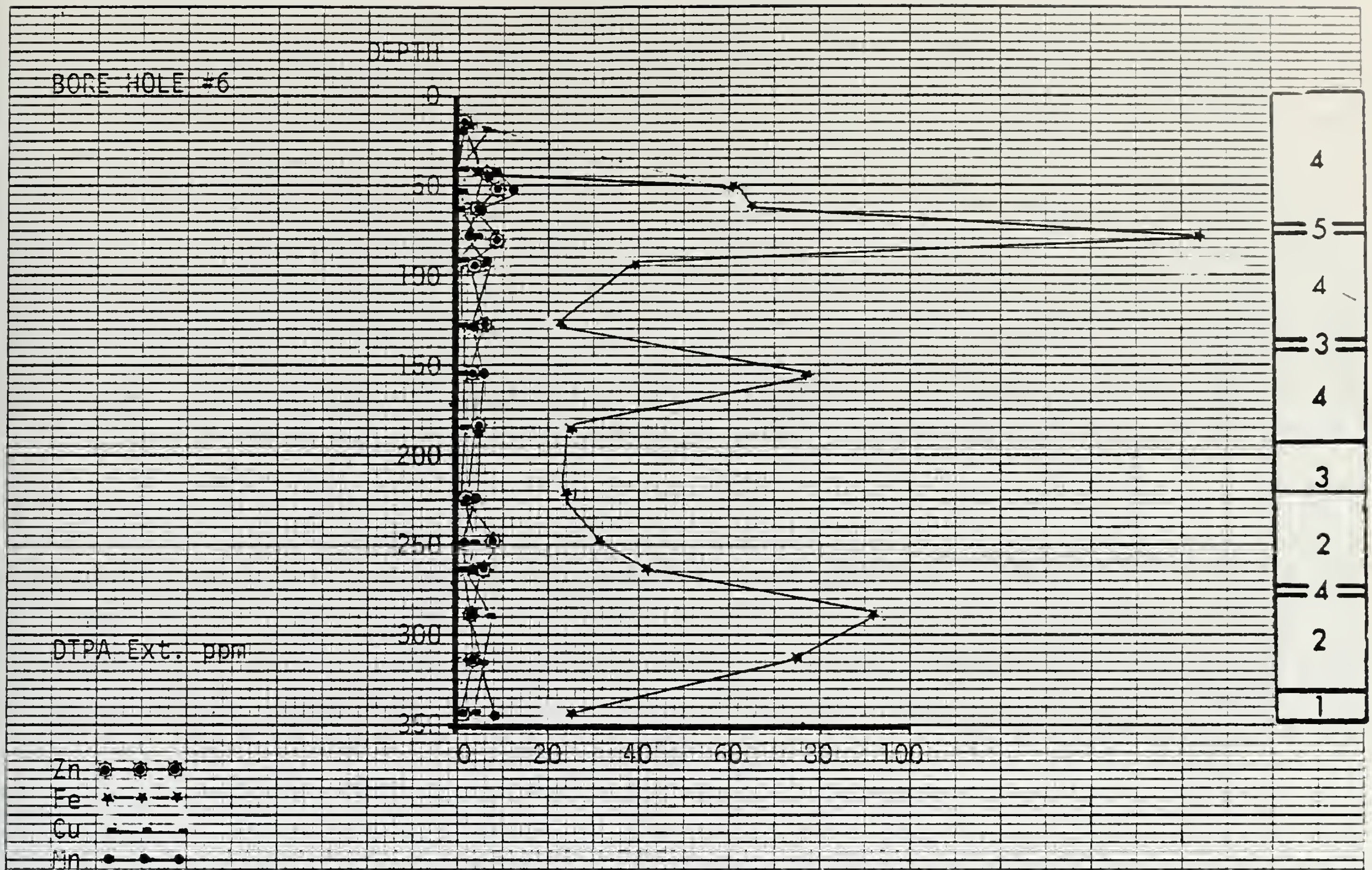
4
3
2
LITHOLOGY
% O.M.
meq/100g C.E.C.
% SAT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0
20
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Zn
Fe
Cu
Mn
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4
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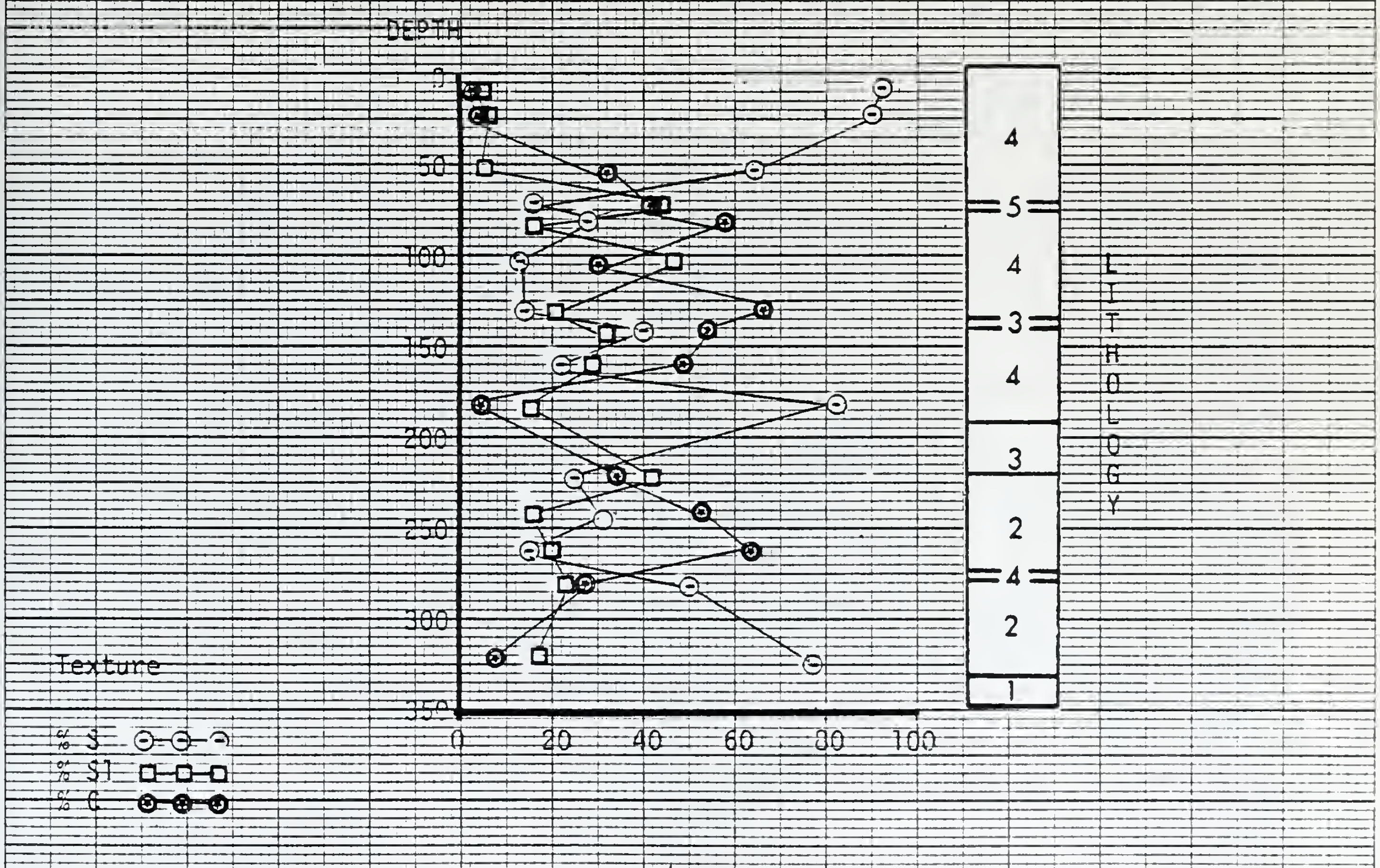
4
3
2
4
2
1
LITHOLOGY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80
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Texture
% S
% Sl
% C
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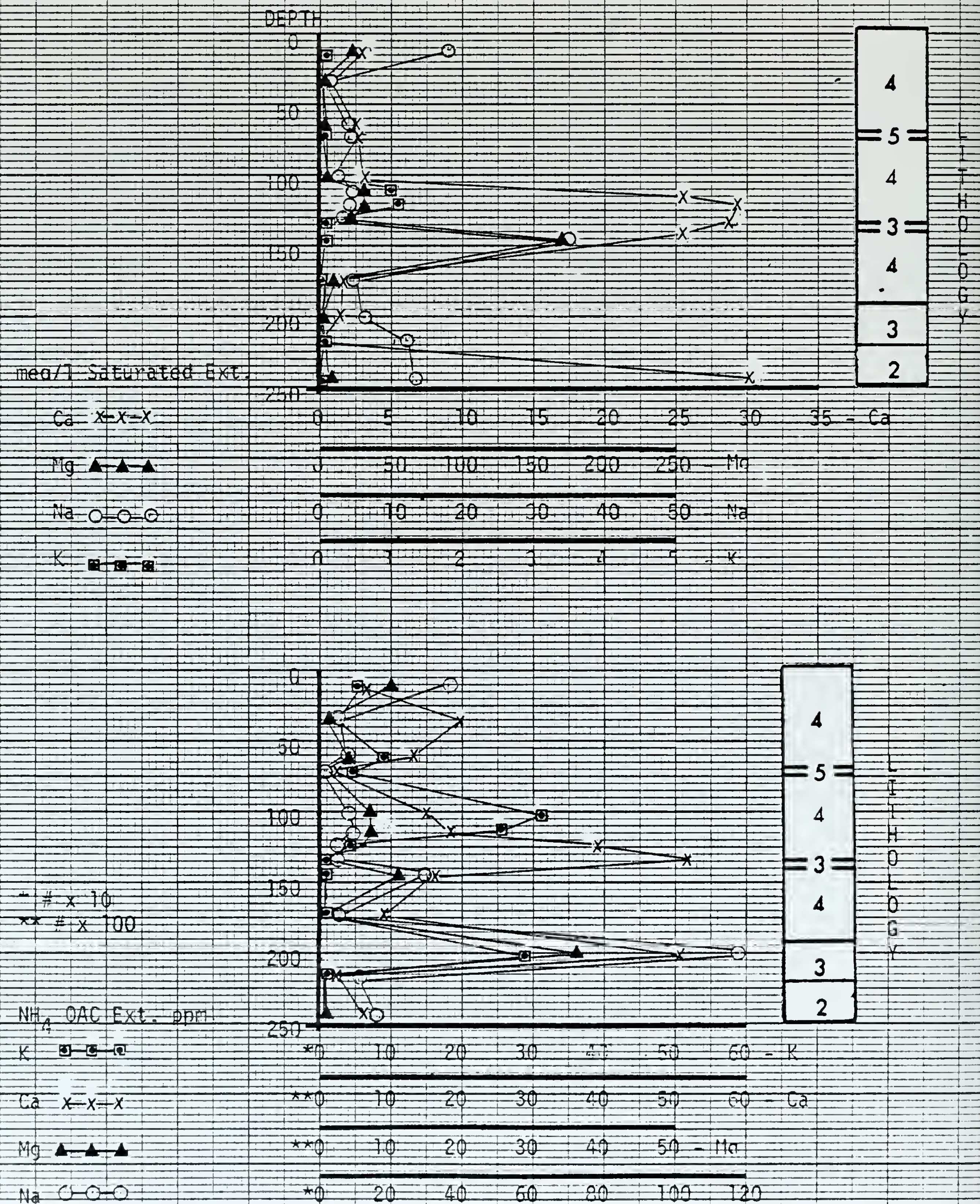
2
4
2
1
LITHOLOGY

BORE HOLE #5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meq/l Saturated Ext.
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Mg ▲—▲—▲
Na ○—○—○
K ▣—▣—▣
0 5 10 15 20 25 30 35 - Ca
0 50 100 150 200 250 - Mg
0 10 20 30 40 50 - Na
0 1 2 3 4 5 - K
LITHOLOGY
4
5
4
3
4
3
2
* # x 10
** # x 100
NH4 OAC Ext. ppm
K
Ca
Mg
Na
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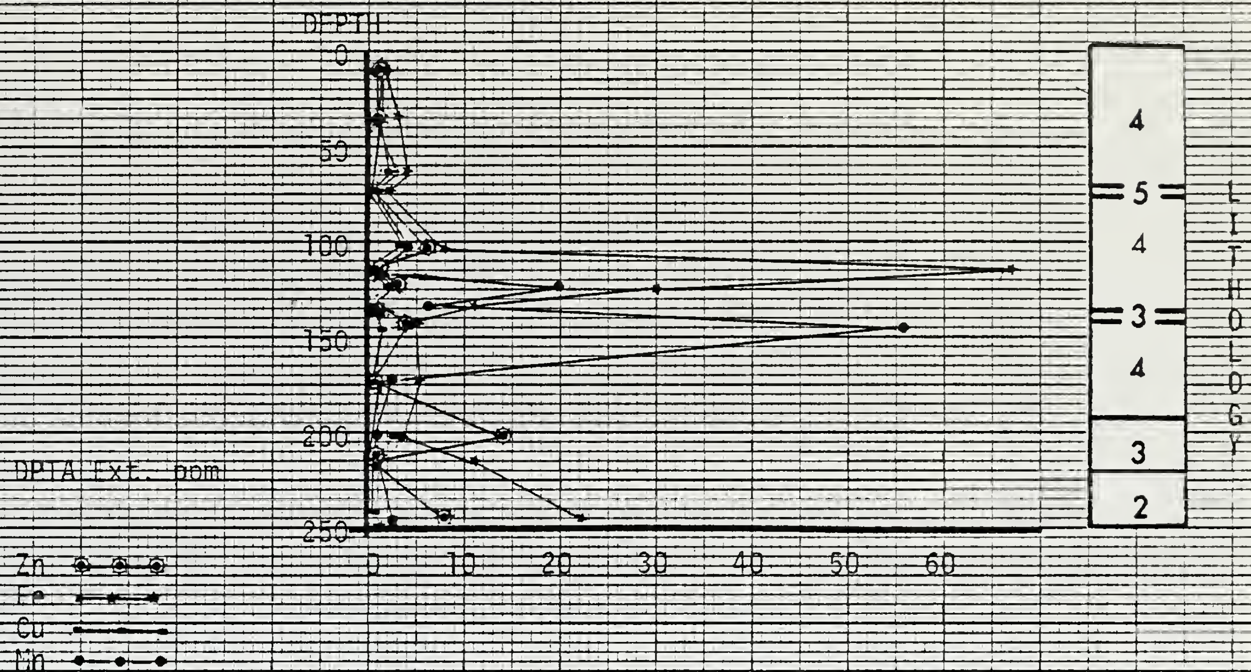
**0 10 20 30 40 50 60 - Ca
**0 10 20 30 40 50 - Mg
*0 20 40 60 80 100 120

BORE HOLE #5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50
60
DPTA Ext. ppm
Zn
Fe
Cu
Mn
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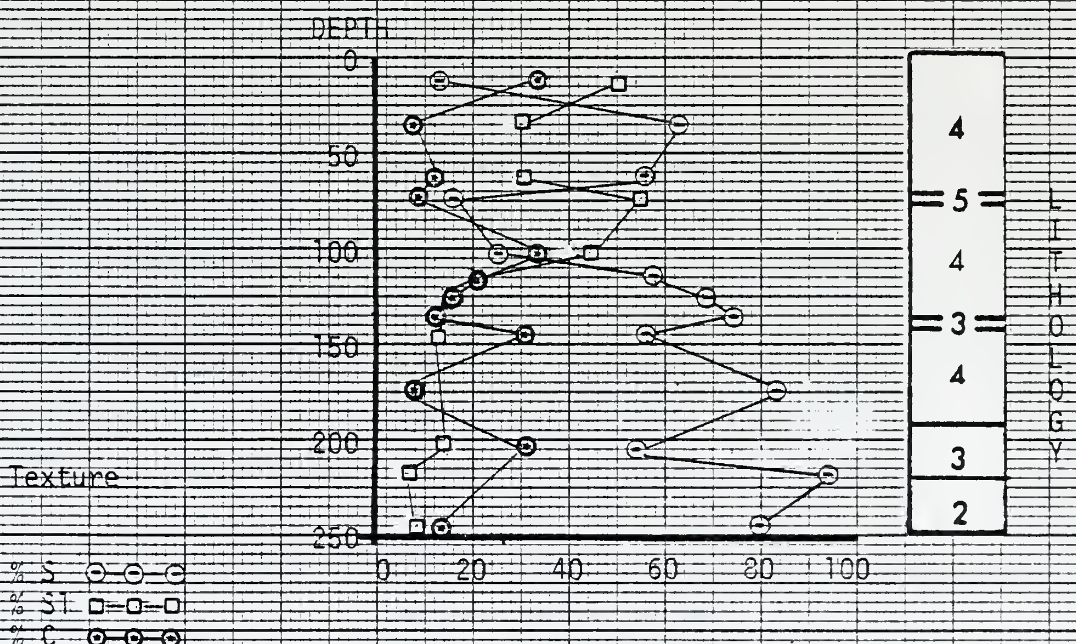
5
4
3
4
3
2
LITHOLOGY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100
150
200
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0
20
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60
80
100
Texture
% S
% SI
% C
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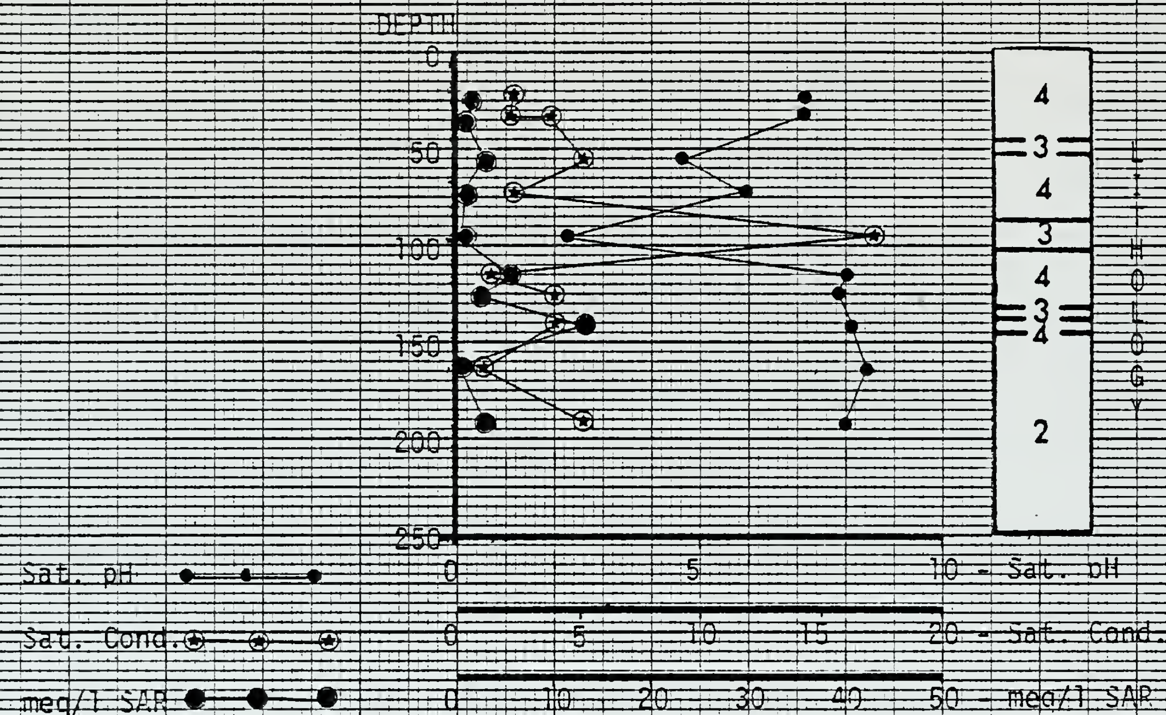
5
4
3
4
3
2
LITHOLOGY

BORE HOLE #4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150
200
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3
4
3
4
3
4
2
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Sat. pH
Sat. Cond.
meq/l SAR
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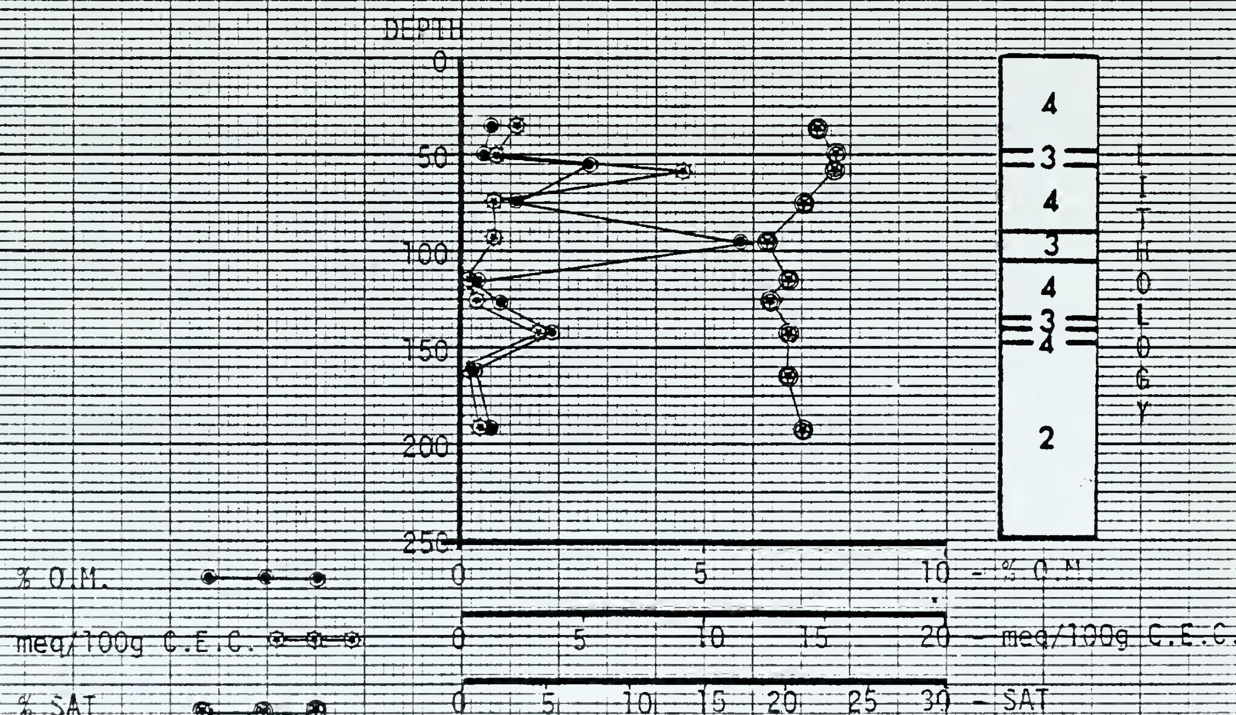
0 5 10 15 20 - Sat. Cond.
0 10 20 30 40 50 - meq/l SAR


DEPTH
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150
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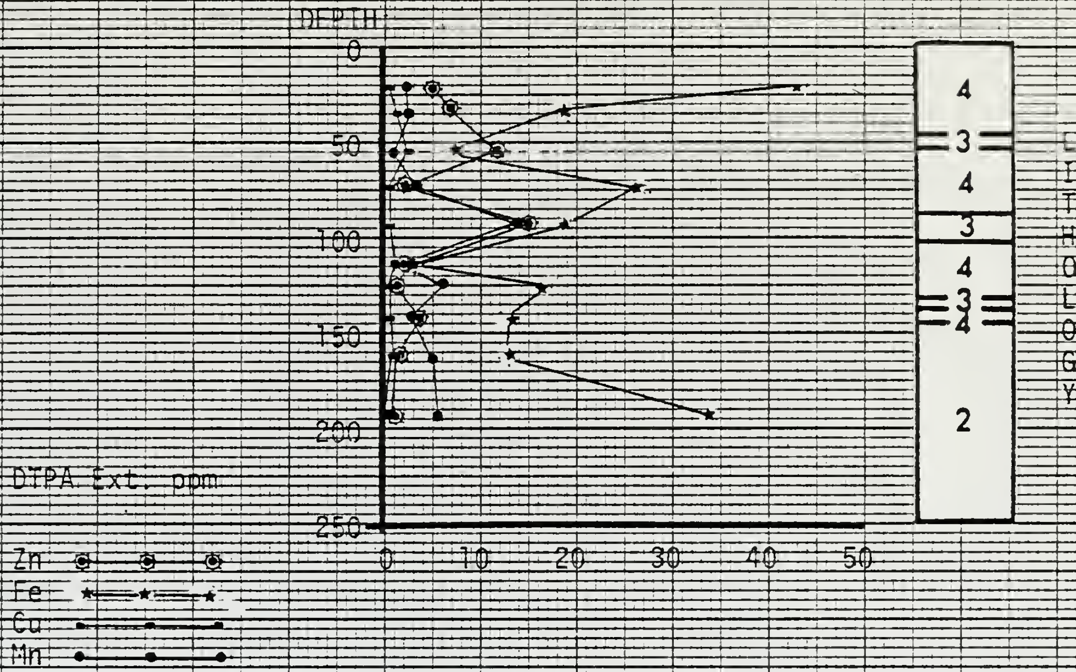
3
4
3
4
3
4
2
LITHOLOGY
% O.M.
meq/100g C.E.C.
% SAT
0 5 10 - % O.M.
0 5 10 15 20 - meq/100g C.E.C.
0 5 10 15 20 25 30 - SAT

BORE HOLE #4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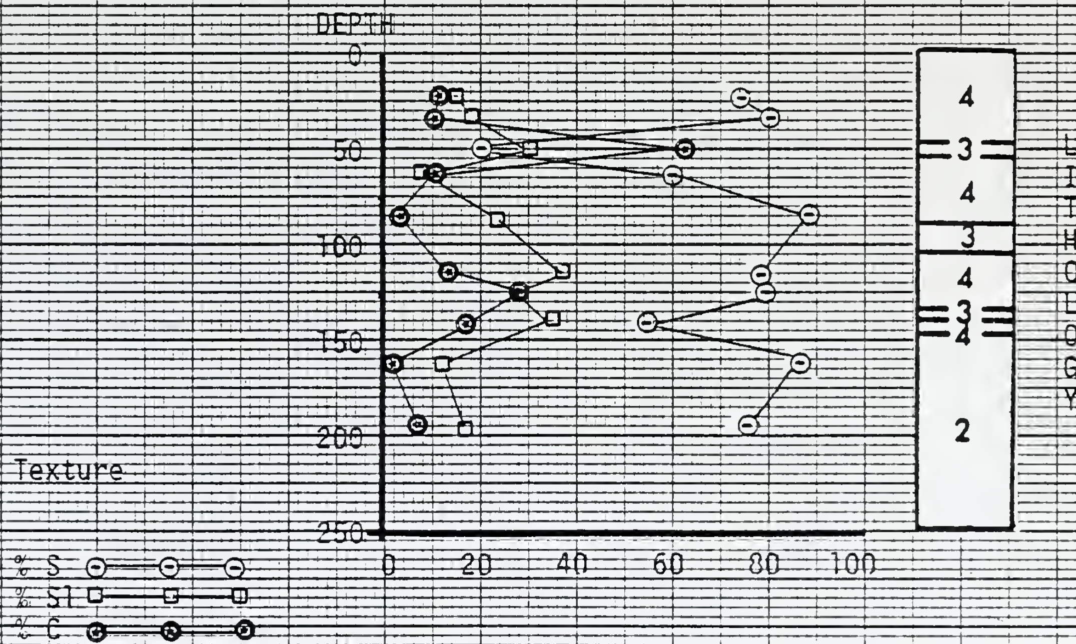
250
0
10
20
30
40
50
4
3
4
3
4
3
4
2
LITHOLOGY
DTPA Ext. ppm
Zn
Fe
Cu
Mn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20
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4
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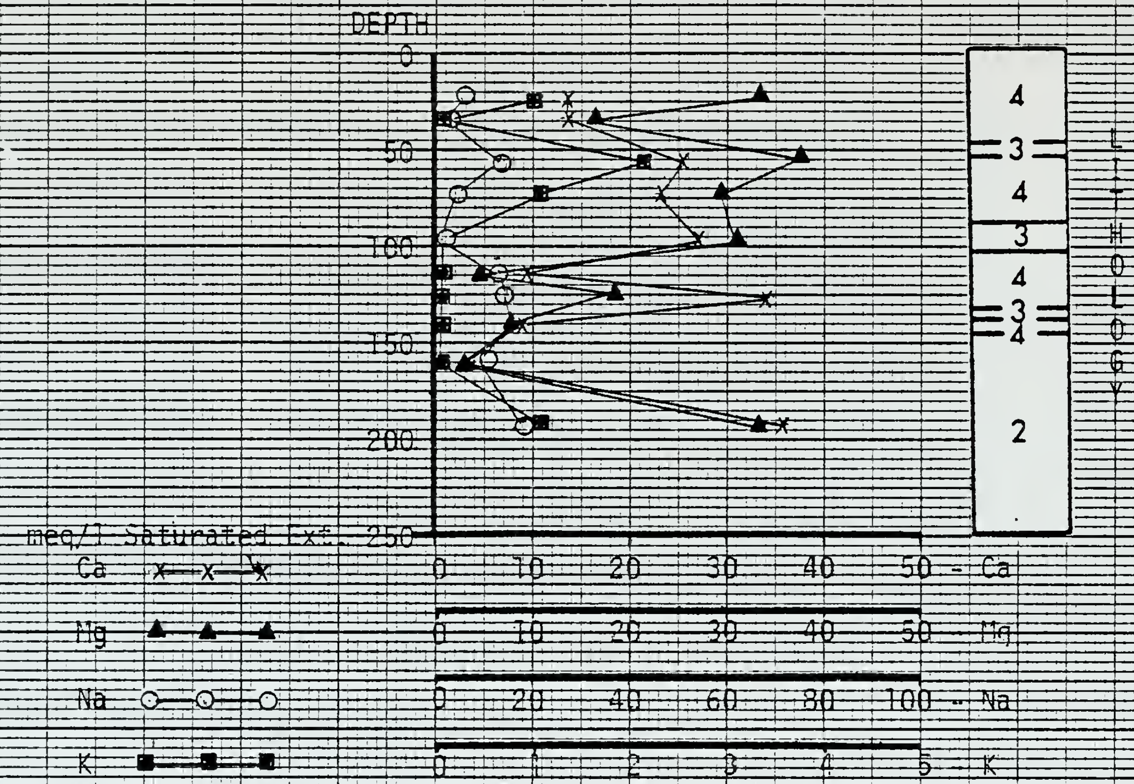
4
2
LITHOLOGY
Texture
% S
% SI
% C

BORE HOLE #4


DEPTH
0
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150
200
250
meq/l Saturated Ext.
Ca
Mg
Na
K
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0 10 20 30 40 50 - Mg
0 20 40 60 80 100 - Na
0 1 2 3 4 5 - K
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4
3
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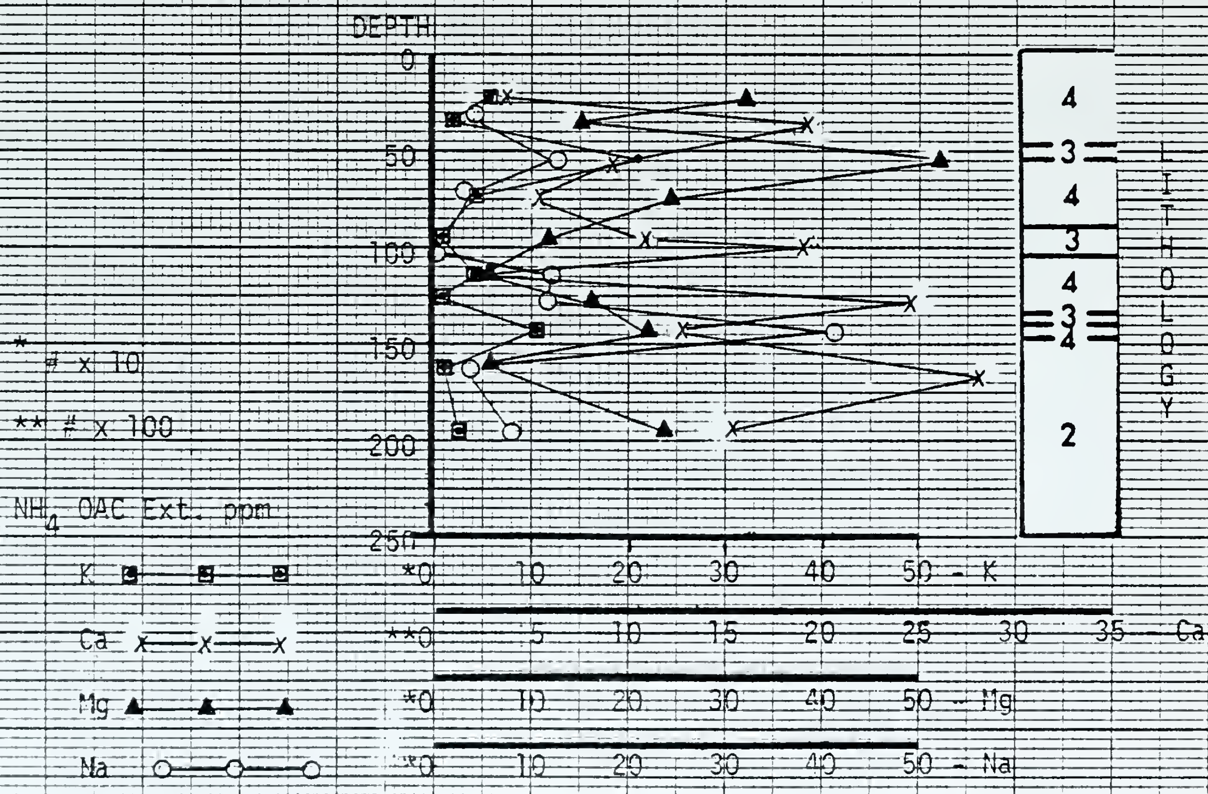
3
4
2
LITHOLOGY


DEPTH
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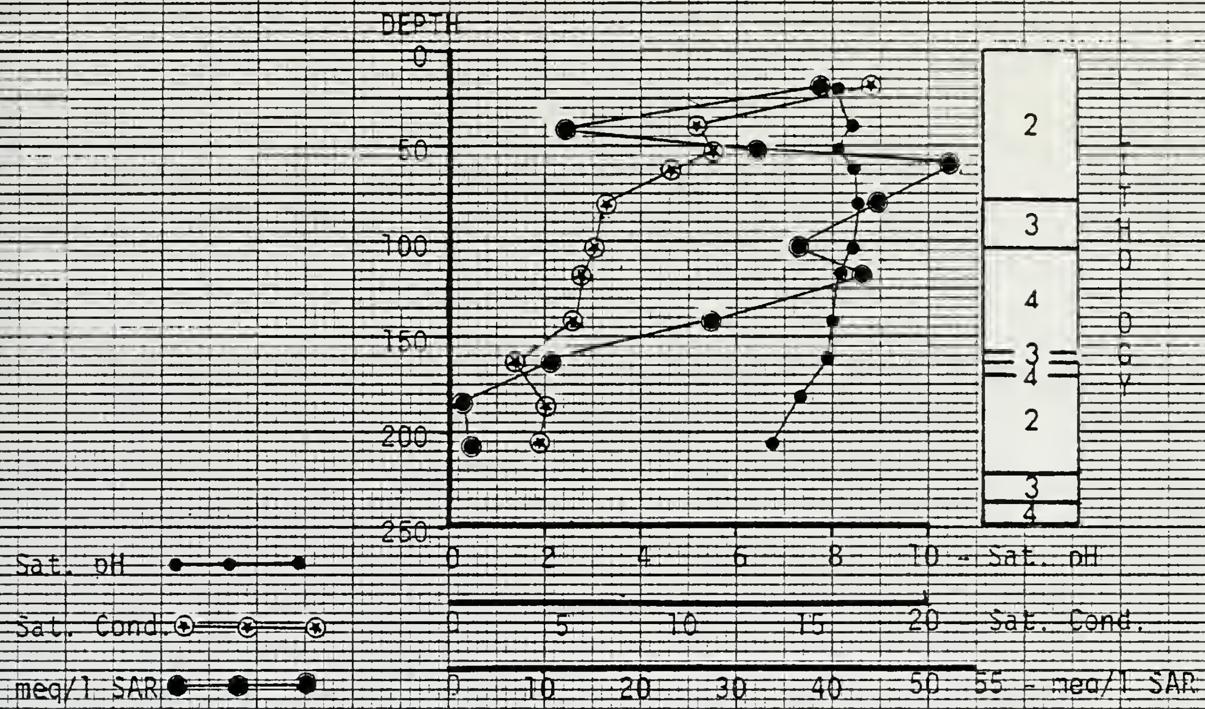
100
150
200
250
* # x 10
** # x 100
NH4 OAC Ext. ppm
K
Ca
Mg
Na
*0 10 20 30 40 50 - K
**0 5 10 15 20 25 30 35 - Ca
*0 10 20 30 40 50 - Mg
*0 10 20 30 40 50 - Na
4
3
4
3
4
3
4
2
LITHOLOGY

BORE HOLE #3


DEPTH
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100
150
200
250
2
3
4
3
4
2
3
4
LITHOLOGY
Sat. pH
Sat. Cond.
meq/1 SAR
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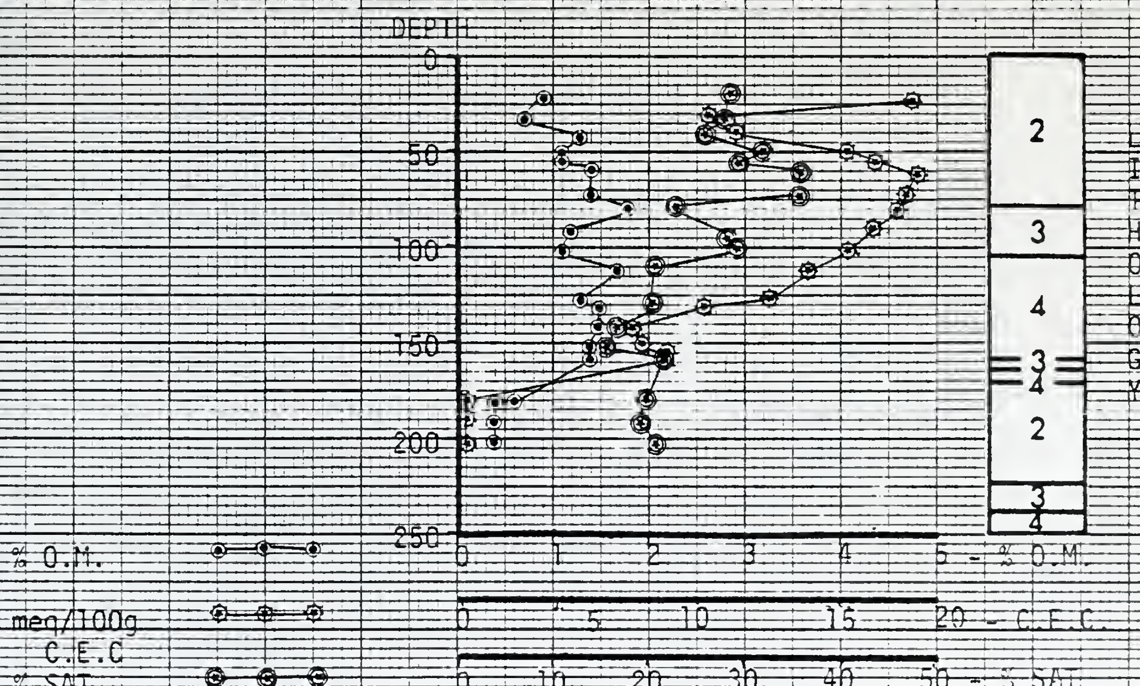
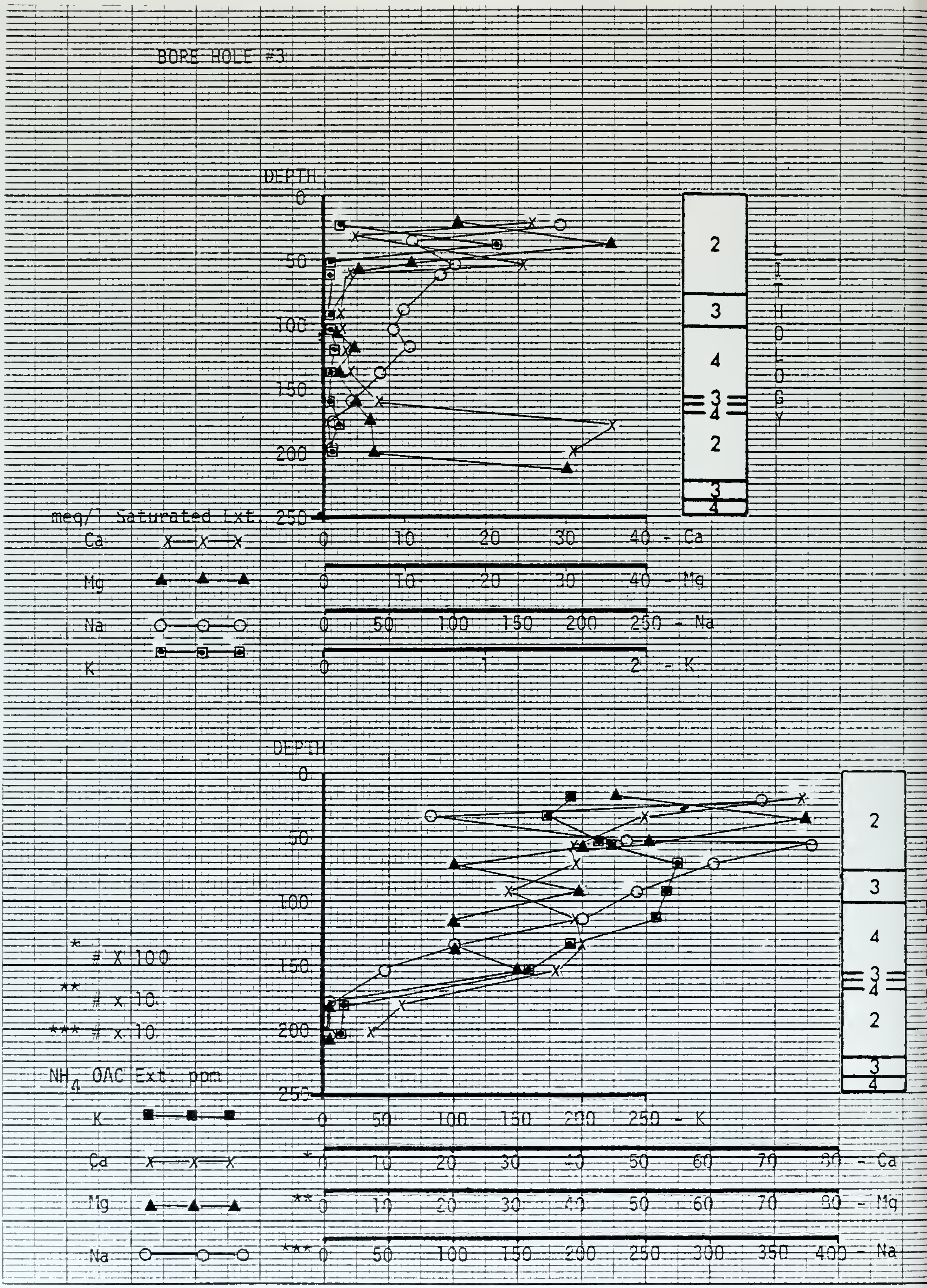
0 5 10 15 20 Sat. Cond.
0 10 20 30 40 50 55 - meq/1 SAR


DEPTH
0
50
100
150
200
250
2
3
4
3
4
2
3
4
LITHOLOGY
% O.M.
meq/100g
C.E.C
% SAT
0 1 2 3 4 5 - % O.M.
0 5 10 15 20 - C.E.C.
0 10 20 30 40 50 - % SAT



BORE HOLE #3
DEPTH
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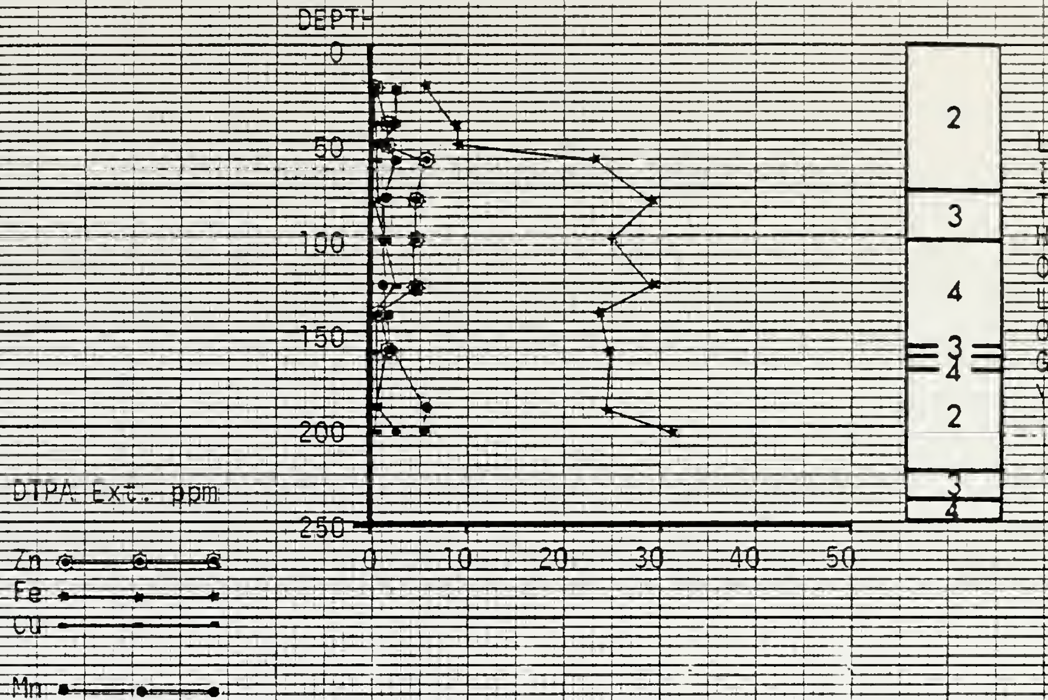
100
150
200
250
2
3
4
3
4
2
3
4
LITHOLOGY
meq/l Saturated Ext.
Ca
Mg
Na
K
0 10 20 30 40 - Ca
0 10 20 30 40 - Mg
0 50 100 150 200 250 - Na
0 1 2 - K
DEPTH
0
50
100
150
200
250
2
3
4
3
4
2
3
4
* # X 100
** # x 10
*** # x 10
NH4 OAC Ext. ppm
K
Ca
Mg
Na
0 50 100 150 200 250 - K
* 0 10 20 30 40 50 60 70 80 - Ca
** 0 10 20 30 40 50 60 70 80 - Mg
*** 0 50 100 150 200 250 300 350 400 - Na

BORE HOLE #3


DEPTH
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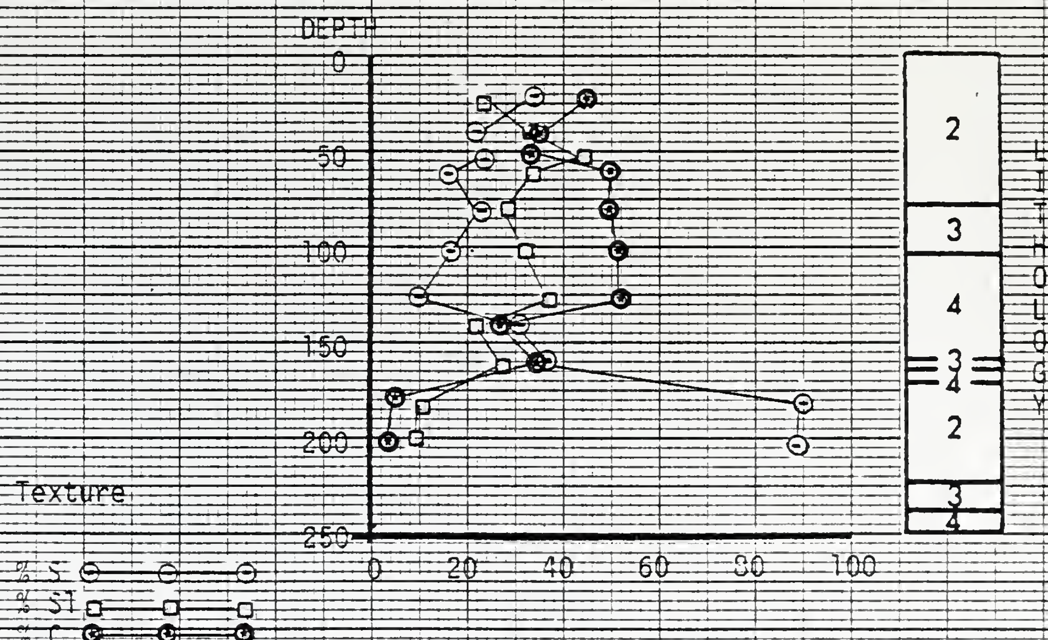
100
150
200
250
0
10
20
30
40
50
DTPA Ext. ppm
Zn
Fe
Cu
Mn
2
3
4
3
4
2
3
4
LITHOLOGY


DEPTH
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250
0
20
40
60
80
100
Texture
% S
% ST
% C
2
3
4
3
4
2
3
4
LITHOLOGY

APPENDIX 8

Water Quality Analysis (USGS, Denver)

ALK,TOT (AS CACO3)	MG/L	410	POTASSIUM DISS	MG/L	6.3
BICARBONATE	MG/L	500	RESIDUE DIS CALC SUM	MG/L	1140
BORON DISSOLVED	UG/L	480	RESIDUE DIS TON/AFT		1.55
BROMIDE	MG/L	0.1	SAR		8.1
CALCIUM DISS	MG/L	44	SILICA DISSOLVED	MG/L	12
CHLORIDE DISS	MG/L	28	SODIUM DISS	MG/L	300
DEPTH(FT.FR.SURFACE)		7.7	SODIUM PERCENT		71
HARDNESS NONCARB	MG/L	0	SP. CONDUCTANCE FLD		1700
HARDNESS TOTAL	MG/L	260	SP. CONDUCTANCE LAB		1720
MAGNESIUM DISS	MG/L	37	SULFATE DISS	MG/L	470
PH LAB		7.5	WATER TEMP (DEG C)		12.0

Sample A
Location: 38° 52' 38" N 111° 13' 02" W

ALK,TOT (AS CACO3)	MG/L	250	PH LAB		7.5
BICARBONATE	MG/L	300	POTASSIUM DISS	MG/L	13
BORON DISSOLVED	UG/L	890	RESIDUE DIS CALC SUM	MG/L	6870
BROMIDE	MG/L	3.0	RESIDUE DIS TON/AFT		9.34
CALCIUM DISS	MG/L	310	SAR		14
CHLORIDE DISS	MG/L	390	SILICA DISSOLVED	MG/L	9.6
DEPTH(FT.FR.SURFACE)		38.9	SODIUM DISS	MG/L	1400
HARDNESS NONCARB	MG/L	1800	SODIUM PERCENT		60
HARDNESS TOTAL	MG/L	2000	SP. CONDUCTANCE LAB		8001
MAGNESIUM DISS	MG/L	300	SULFATE DISS	MG/L	4300
			WATER TEMP (DEG C)		13.0

Sample B
Location: 39° 04' 06" N 111° 01' 42" 01 W
Ferron Creek Area 10-15 Miles NE

ALK,TOT (AS CACO3)	MG/L	540	POTASSIUM DISS	MG/L	26
BICARBONATE	MG/L	660	RESIDUE DIS CALC SUM	MG/L	10100
BORON DISSOLVED	UG/L	480	RESIDUE DIS TON/AFT		13.7
BROMIDE	MG/L	1.2	SAR		27
CALCIUM DISS	MG/L	270	SILICA DISSOLVED	MG/L	10
CHLORIDE DISS	MG/L	1400	SODIUM DISS	MG/L	2700
DEPTH(FT.FR.SURFACE)		120	SODIUM PERCENT		75
HARDNESS NONCARB	MG/L	1400	SP. CONDUCTANCE FLD		> 8000
HARDNESS TOTAL	MG/L	2000	SP. CONDUCTANCE LAB		12454
MAGNESIUM DISS	MG/L	310	SULFATE DISS	MG/L	5100
PH LAB		7.8	WATER TEMP (DEG C)		16.5

Sample C
Location: 39° 06' 23" N 111° 01 38" 01 W
Ferron Creek Area 10-15 Miles NE

ALK,TOT (AS CACO3)	MG/L	1070	PH LAB		7.8
BICARBONATE	MG/L	1300	POTASSIUM DISS	MG/L	13
BORON DISSOLVED	UG/L	650	RESIDUE DIS CALC SUM	MG/L	5340
BROMIDE	MG/L	4.7	RESIDUE DIS TON/AFT		7.26
CALCIUM DISS	MG/L	120	SAR		21
CHLORIDE DISS	MG/L	880	SILICA DISSOLVED	MG/L	9.2
DEPTH(FT.FR.SURFACE)		10.7	SODIUM DISS	MG/L	1500
HARDNESS NONCARB	MG/L	0	SODIUM PERCENT		76
HARDNESS TOTAL	MG/L	1000	SP. CONDUCTANCE LAB		7940
MAGNESIUM DISS	MG/L	170	SULFATE DISS	MG/L	2000
			WATER TEMP (DEG C)		12.5

Sample D
Location: 39° 03' 27" N 111° 03' 04" 01 W
Ferron Creek Area 10-15 Miles NE

ALK,TOT (AS CACO3)	MG/L	490	POTASSIUM DISS	MG/L	5.8
BICARBONATE	MG/L	600	RESIDUE DIS CALC SUM	MG/L	3240
BORON DISSOLVED	UG/L	230	RESIDUE DIS TON/AFT		4.41
BROMIDE	MG/L	0.8	SAR		1.3
CALCIUM DISS	MG/L	420	SILICA DISSOLVED	MG/L	25
CHLORIDE DISS	MG/L	46	SODIUM DISS	MG/L	140
HARDNESS NONCARB	MG/L	1800	SODIUM PERCENT		12
HARDNESS TOTAL	MG/L	2300	SP. CONDUCTANCE FLD		3500
MAGNESIUM DISS	MG/L	310	SP. CONDUCTANCE LAB		3714
PH LAB		7.0	SULFATE DISS	MG/L	2000
			WATER TEMP (DEG C)		15.0

Sample E
Location: 38° 55' 06" N 111° 09' 52" 01 W

AIR TEMP (DEG C)		2.0	NITROGEN SUSP KJD	MG/L	0.13
ALK,TOT (AS CACO3)	MG/L	320	NITROGEN TOTKJD AS N	MG/L	0.53
ANALYZING AGENCY		80020	NO2+NO3 AS N DISS	MG/L	0.96
ARSENIC DISSOLVED	UG/L	1	OIL AND GREASE	MG/L	0.0
BICARBONATE	MG/L	380	OXYGEN DISSOLVED	MG/L	11.8
BORON DISSOLVED	UG/L	210	PH FIELD		8.5
CALCIUM DISS	MG/L	94	PH LAB		7.9
CARBON DIS ORGANIC	MG/L	2.7	PHENOLS	UG/L	2
CARBON ORG SUS	MG/L	0.5	PHOS ORTHO DIS AS P	MG/L	0.00
CARBONATE	MG/L	4	PHOSPHATE DIS ORTHO	MG/L	0.00
CHLORIDE DISS	MG/L	40	PHOSPHORUS TOT AS P	MG/L	0.11
CHROMIUM DISSOLVED	UG/L	0	POTASSIUM DISS	MG/L	4.4
FLUORIDE DISS	MG/L	0.4	RESIDUE DIS CALC SUM	MG/L	1100
HARDNESS NONCARB	MG/L	150	RESIDUE DIS TON/AFT		1.50
HARDNESS TOTAL	MG/L	470	RESIDUE DIS TON/DAY		15.2
IRON DISSOLVED	UG/L	10	SAR		3.8
LEAD DISSOLVED	UG/L	2	SELENIUM DISSOLVED	UG/L	4
LITHIUM DISSOLVED	UG/L	80	SILICA DISSOLVED	MG/L	9.7
MAGNESIUM DISS	MG/L	56	SODIUM DISS	MG/L	190
MANGANESE DISSOLVED	UG/L	10	SODIUM PERCENT		47
NITR. NH4 AS NH4 DIS	MG/L	0.01	SP. CONDUCTANCE FLD		1500
NITR. NO2 AS NO2 DIS	MG/L	0.03	SP. CONDUCTANCE LAB		1706
NITROGEN DIS ORG ASN	MG/L	0.39	STREAMFLOW(CFS)-INST		5.1
NITROGEN DISS KJD	MG/L	0.40	STRONTIUM DISSOLVED	UG/L	1500
NITROGEN NH4 ASN DIS	MG/L	0.01	SULFATE DISS	MG/L	510
NITROGEN NO2 ASN DIS	MG/L	0.01	WATER TEMP (DEG C)		0.0
			ZINC DISSOLVED	UG/L	10

Sample F
Location: 38° 51' 33" N 111° 15' 41" 01 W

AIR TEMP (DEG C)		7.0	POTASSIUM DISS	MG/L	8.2
ALK,TOT (AS CACO3)	MG/L	390	RESIDUE DIS CALC SUM	MG/L	3960
ANALYZING AGENCY		80020	RESIDUE DIS TON/AFT		5.39
BICARBONATE	MG/L	480	RESIDUE DIS TON/DAY		25.6
CALCIUM DISS	MG/L	230	SAR		6.2
CARBONATE	MG/L	0	SILICA DISSOLVED	MG/L	14
CHLORIDE DISS	MG/L	100	SODIUM DISS	MG/L	590
HARDNESS NONCARB	MG/L	1300	SODIUM PERCENT		43
HARDNESS TOTAL	MG/L	1700	SP. CONDUCTANCE FLD		3300
MAGNESIUM DISS	MG/L	280	SP. CONDUCTANCE LAB		4623
OXYGEN DISSOLVED	MG/L	10.5	STREAMFLOW(CFS)-INST		2.4
PH FIELD		8.3	SULFATE DISS	MG/L	2500
PH LAB		7.9	WATER TEMP (DEG C)		3.0

Sample G
Location: 35° 51' 33" N 111° 16' 39" W

AIR TEMP (DEG C)		19.0	POTASSIUM DISS	MG/L	7.8
ALK,TOT (AS CACO3)	MG/L	410	RESIDUE DIS CALC SUM	MG/L	2240
ANALYZING AGENCY		80020	RESIDUE DIS TON/AFT		3.05
BICARBONATE	MG/L	496	RESIDUE DIS TON/DAY		8.77
CALCIUM DISS	MG/L	160	SAR		6.3
CARBONATE	MG/L	4	SILICA DISSOLVED	MG/L	8.5
CHLORIDE DISS	MG/L	85	SODIUM DISS	MG/L	420
HARDNESS NONCARB	MG/L	440	SODIUM PERCENT		51
HARDNESS TOTAL	MG/L	850	SP. CONDUCTANCE FLD		2900
MAGNESIUM DISS	MG/L	110	SP. CONDUCTANCE LAB		3039
OXYGEN DISSOLVED	MG/L	10.1	STREAMFLOW(CFS)-INST		1.4
PH FIELD		8.5	SULFATE DISS	MG/L	1200
PH LAB		8.0	WATER TEMP (DEG C)		9.5

Sample H
Location: 38° 51' 33" N 111° 15' 41" W

AIR TEMP (DEG C)		27.5	NITROGEN SUSP KJD	MG/L	0.49
ALK,TOT (AS CACO3)	MG/L	310	NITROGEN TOTKJD AS N	MG/L	0.86
ANALYZING AGENCY		80020	NO2+NO3 AS N DISS	MG/L	1.1
ARSENIC DISSOLVED	UG/L	0	OIL AND GREASE	MG/L	0.0
BICARBONATE	MG/L	373	OXYGEN DISSOLVED	MG/L	8.4
BORON DISSOLVED	UG/L	360	PH FIELD		8.5
CALCIUM DISS	MG/L	130	PH LAB		8.2
CARBON DIS ORGANIC	MG/L	4.0	PHENOLS	UG/L	1
CARBONATE	MG/L	5	PHOS ORTHO DIS AS P	MG/L	0.01
CHLORIDE DISS	MG/L	60	PHOSPHATE DIS ORTHO	MG/L	0.03
CHROMIUM DISSOLVED	UG/L	10	PHOSPHORUS TOT AS P	MG/L	0.43
FLUORIDE DISS	MG/L	0.5	POTASSIUM DISS	MG/L	4.8
HARDNESS NONCARB	MG/L	360	RESIDUE DIS CALC SUM	MG/L	1720
HARDNESS TOTAL	MG/L	680	RESIDUE DIS TON/AFT		2.34
IRON DISSOLVED	UG/L	10	RESIDUE DIS TON/DAY		8.27
LEAD DISSOLVED	UG/L	38	SAR		5.2
LITHIUM DISSOLVED	UG/L	140	SELENIUM DISSOLVED	UG/L	5
MAGNESIUM DISS	MG/L	85	SILICA DISSOLVED	MG/L	10
MANGANESE DISSOLVED	UG/L	20	SODIUM DISS	MG/L	310
NITR. NH4 AS NH4 DIS	MG/L	0.03	SODIUM PERCENT		50
NITR. NO2 AS NO2 DIS	MG/L	0.07	SP. CONDUCTANCE LAB		2286
NITROGEN DIS ORG ASN	MG/L	0.36	STREAMFLOW(CFS)-INST		1.8
NITROGEN DISS KJD	MG/L	0.38	STRONTIUM DISSOLVED	UG/L	2100
NITROGEN NH4 ASN DIS	MG/L	0.02	SULFATE DISS	MG/L	920
NITROGEN NO2 ASN DIS	MG/L	0.02	WATER TEMP (DEG C)		19.0
			ZINC DISSOLVED	UG/L	0

Sample I
Location: 38° 51' 33" N 111° 15' 39" W

AIR TEMP (DEG C)		30.0	POTASSIUM DISS	MG/L	5.3
ALK,TOT (AS CACO3)	MG/L	230	RESIDUE DIS CALC SUM	MG/L	1510
ANALYZING AGENCY		80020	RESIDUE DIS TON/AFT		2.05
BICARBONATE	MG/L	260	RESIDUE DIS TON/DAY		6.85
CALCIUM DISS	MG/L	100	SAR		5.3
CARBONATE	MG/L	9	SILICA DISSOLVED	MG/L	7.3
CHLORIDE DISS	MG/L	50	SODIUM DISS	MG/L	290
HARDNESS NONCARB	MG/L	340	SODIUM PERCENT		52
HARDNESS TOTAL	MG/L	570	SP. CONDUCTANCE FLD		2140
MAGNESIUM DISS	MG/L	77	SP. CONDUCTANCE LAB		2072
OXYGEN DISSOLVED	MG/L	8.2	STREAMFLOW(CFS)-INST		1.7
PH FIELD		8.8	SULFATE DISS	MG/L	840
PH LAB		8.5	WATER TEMP (DEG C)		24.0

Sample J
Location: Station ID: 09331000

AIR TEMP (DEG C)		4.0	POTASSIUM DISS	MG/L	6.0
ALK,TOT (AS CACO3)	MG/L	410	RESIDUE DIS CALC SUM	MG/L	2500
ANALYZING AGENCY		80020	RESIDUE DIS TON/AFT		3.40
BICARBONATE	MG/L	500	RESIDUE DIS TON/DAY		8.51
CALCIUM DISS	MG/L	190	SAR		6.2
CARBONATE	MG/L	0	SILICA DISSOLVED	MG/L	13
CHLORIDE DISS	MG/L	86	SODIUM DISS	MG/L	440
HARDNESS NONCARB	MG/L	560	SODIUM PERCENT		50
HARDNESS TOTAL	MG/L	970	SP. CONDUCTANCE FLD		4900
MAGNESIUM DISS	MG/L	120	SP. CONDUCTANCE LAB		3155
OXYGEN DISSOLVED	MG/L	10.6	STREAMFLOW(CFS)-INST		1.3
PH FIELD		8.3	SULFATE DISS	MG/L	1400
PH LAB		7.9	WATER TEMP (DEG C)		3.0

Sample K
Location: 38° 51' 41" N 111° 15' 07" 50 W

AIR TEMP (DEG C)		26.0	POTASSIUM DISS	MG/L	8.0
ALK,TOT (AS CACO3)	MG/L	350	RESIDUE DIS CALC SUM	MG/L	3340
ANALYZING AGENCY		80020	RESIDUE DIS TON/AFT		4.54
BICARBONATE	MG/L	390	RESIDUE DIS TON/DAY		5.86
CALCIUM DISS	MG/L	200	SAR		5.5
CARBONATE	MG/L	18	SILICA DISSOLVED	MG/L	12
CHLORIDE DISS	MG/L	77	SODIUM DISS	MG/L	490
HARDNESS NONCARB	MG/L	1100	SODIUM PERCENT		42
HARDNESS TOTAL	MG/L	1500	SP. CONDUCTANCE FLD		4000
MAGNESIUM DISS	MG/L	240	SP. CONDUCTANCE LAB		4161
OXYGEN DISSOLVED	MG/L	9.5	STREAMFLOW(CFS)-INST		0.65
PH FIELD		8.5	SULFATE DISS	MG/L	2100
PH LAB		8.0	WATER TEMP (DEG C)		10.5

Sample L
Location: 38° 51' 41" N 111° 15' 07" 50 W

AIR TEMP (DEG C)		29.0	NITROGEN SUSP KJD	MG/L	1.5
ALK,TOT (AS CACO3)	MG/L	300	NITROGEN TOTKJD AS N	MG/L	3.2
ANALYZING AGENCY		80020	NO2+NO3 AS N DISS	MG/L	23
ARSENIC DISSOLVED	UG/L	0	OIL AND GREASE	MG/L	0.0
BICARBONATE	MG/L	360	OXYGEN DISSOLVED	MG/L	8.7
BORON DISSOLVED	UG/L	590	PH FIELD		8.5
CALCIUM DISS	MG/L	210	PH LAB		8.3
CARBON DIS ORGANIC	MG/L	13	PHENOLS	UG/L	1
CARBON ORG SUS	MG/L	0.2	PHOS ORTHO DIS AS P	MG/L	0.01
CARBONATE	MG/L	1	PHOSPHATE DIS ORTHO	MG/L	0.03
CHLORIDE DISS	MG/L	110	PHOSPHORUS TOT AS P	MG/L	0.02
CHROMIUM DISSOLVED	UG/L	20	POTASSIUM DISS	MG/L	8.0
FLUORIDE DISS	MG/L	0.7	RESIDUE DIS CALC SUM	MG/L	3550
HARDNESS NONCARB	MG/L	1300	RESIDUE DIS TON/AFT		4.83
HARDNESS TOTAL	MG/L	1600	RESIDUE DIS TON/DAY		6.33
IRON DISSOLVED	UG/L	20	SAR		6.4
LEAD DISSOLVED	UG/L	59	SELENIUM DISSOLVED	UG/L	60
LITHIUM DISSOLVED	UG/L	370	SILICA DISSOLVED	MG/L	11
MAGNESIUM DISS	MG/L	250	SODIUM DISS	MG/L	580
MANGANESE DISSOLVED	UG/L	10	SODIUM PERCENT		45
NITR. NH4 AS NH4 DIS	MG/L	0.00	SP. CONDUCTANCE LAB		4702
NITR. NO2 AS NO2 DIS	MG/L	0.16	STREAMFLOW(CFS)-INST		0.66
NITROGEN DIS ORG ASN	MG/L	1.7	STRONTIUM DISSOLVED	UG/L	2900
NITROGEN DISS KJD	MG/L	1.7	SULFATE DISS	MG/L	2100
NITROGEN NH4 ASN DIS	MG/L	0.00	WATER TEMP (DEG C)		15.0
NITROGEN NO2 ASN DIS	MG/L	0.05	ZINC DISSOLVED	UG/L	10

Sample M
Location: 38° 51' 41" N 111° 15' 07" 50 W

AIR TEMP (DEG C)		22.0	POTASSIUM DISS	MG/L	5.0
ALK,TOT (AS CACO3)	MG/L	300	RESIDUE DIS CALC SUM	MG/L	1550
ANALYZING AGENCY		80020	RESIDUE DIS TON/AFT		2.11
BICARBONATE	MG/L	324	RESIDUE DIS TON/DAY		7.07
CALCIUM DISS	MG/L	120	SAR		3.2
CARBONATE	MG/L	18	SILICA DISSOLVED	MG/L	8.4
CHLORIDE DISS	MG/L	34	SODIUM DISS	MG/L	210
HARDNESS NONCARB	MG/L	500	SODIUM PERCENT		36
HARDNESS TOTAL	MG/L	790	SP. CONDUCTANCE FLD		2250
MAGNESIUM DISS	MG/L	120	SP. CONDUCTANCE LAB		1990
OXYGEN DISSOLVED	MG/L	7.8	STREAMFLOW(CFS)-INST		1.7
PH FIELD		8.5	SULFATE DISS	MG/L	870
PH LAB		8.3	WATER TEMP (DEG C)		20.0

ALK,TOT (AS CACO3)	MG/L	270	POTASSIUM DISS	MG/L	48
ANALYZING AGENCY		80020	RESIDUE DIS CALC SUM	MG/L	3870
BICARBONATE	MG/L	330	RESIDUE DIS TON/AFT		5.26
BORON DISSOLVED	UG/L	430	SAR		9.3
BROMIDE	MG/L	0.5	SILICA DISSOLVED	MG/L	21
CALCIUM DISS	MG/L	140	SODIUM DISS	MG/L	760
CHLORIDE DISS	MG/L	20	SODIUM PERCENT		56
HARDNESS NONCARB	MG/L	980	SP. CONDUCTANCE FLD		5000
HARDNESS TOTAL	MG/L	1300	SP. CONDUCTANCE LAB		4884
MAGNESIUM DISS	MG/L	220	SULFATE DISS	MG/L	2500
PH LAB		7.4	WATER TEMP (DEG C)		8.5

Sample O
Location: 38° 52' 24" N 111° 14' 26" 02 W

ALK,TOT (AS CACO3)	MG/L	230	PH FIELD		8.2
ANALYZING AGENCY		80020	PH LAB		8.1
BICARBONATE	MG/L	280	POTASSIUM DISS	MG/L	4.1
BORON DISSOLVED	UG/L	300	RESIDUE DIS CALC SUM	MG/L	1290
BROMIDE	MG/L	0.4	RESIDUE DIS TON/AFT		1.75
CALCIUM DISS	MG/L	35	SAR		13
CARBONATE	MG/L	0	SILICA DISSOLVED	MG/L	15
CHLORIDE DISS	MG/L	49	SODIUM DISS	MG/L	370
DEPTH(FT.FR.SURFACE)		385	SODIUM PERCENT		83
HARDNESS NONCARB	MG/L	0	SP. CONDUCTANCE FLD		1975
HARDNESS TOTAL	MG/L	170	SP. CONDUCTANCE LAB		1880
MAGNESIUM DISS	MG/L	19	SULFATE DISS	MG/L	660
			WATER TEMP (DEG C)		12.5

Sample P
Location: 38° 50' 45" N 111° 17' 18" 01 W

ALK,TOT (AS CACO3)	MG/L	330	PH LAB		8.3
ANALYZING AGENCY		80020	POTASSIUM DISS	MG/L	3.2
BICARBONATE	MG/L	370	RESIDUE DIS CALC SUM	MG/L	877
BORON DISSOLVED	UG/L	350	RESIDUE DIS TON/AFT		1.19
BROMIDE	MG/L	0.2	SAR		18
CALCIUM DISS	MG/L	13	SILICA DISSOLVED	MG/L	11
CARBONATE	MG/L	13	SODIUM DISS	MG/L	290
CHLORIDE DISS	MG/L	30	SODIUM PERCENT		92
DEPTH(FT.FR.SURFACE)		720	SP. CONDUCTANCE FLD		1400
HARDNESS NONCARB	MG/L	0	SP. CONDUCTANCE LAB		1374
HARDNESS TOTAL	MG/L	50	SULFATE DISS	MG/L	330
MAGNESIUM DISS	MG/L	4.3	WATER TEMP (DEG C)		13.5
PH FIELD		8.9	YIELD-WELL-INST.G/M		3.5

Sample Q
Location: 38° 50' 45" N 111° 17' 18" 02 W

Sample R
Location: Not in Study Area.

ALK,TOT(CACO3)	MG/L	520	PH FIELD		8.4
ANALYZING AGENCY		80020	PH LAB		8.2
BORON DISSOLVED	UG/L	580	POTASSIUM DISS	MG/L	2.6
BROMIDE	MG/L	0.3	RESIDUE DIS CALC SUM	MG/L	1350
CALCIUM DISS	MG/L	24	RESIDUE DIS TON/AFT		1.84
CHLORIDE DISS	MG/L	32	RESIDUE DIS 180C	MG/L	1350
FLUORIDE DISS	MG/L	0.7	SAR		14
HARDNESS NONCARB	MG/L	0	SILICA DISSOLVED	MG/L	13
HARDNESS TOTAL	MG/L	180	SODIUM DISS	MG/L	420
IODIDE	MG/L	0.02	SODIUM PERCENT		83
IRON DISSOLVED	UG/L	20	SP. CONDUCTANCE FLD		2180
MAGNESIUM DISS	MG/L	29	SP. CONDUCTANCE LAB		2041
MANGANESE DISSOLVED	UG/L	10	SULFATE DISS	MG/L	520
			WATER TEMP (DEG C)		13.5

Sample S
Location: 38° 52' 25" N 111° 15' 26" 01 W

ALK,TOT(CACO3)	MG/L	560	PH FIELD		9.5
ANALYZING AGENCY		80020	PH LAB		8.9
BORON DISSOLVED	UG/L	850	POTASSIUM DISS	MG/L	1.4
BROMIDE	MG/L	0.3	RESIDUE DIS CALC SUM	MG/L	774
CALCIUM DISS	MG/L	0.9	RESIDUE DIS TON/AFT		1.04
CHLORIDE DISS	MG/L	27	RESIDUE DIS 180C	MG/L	767
FLUORIDE DISS	MG/L	2.3	SAR		64
HARDNESS NONCARB	MG/L	0	SILICA DISSOLVED	MG/L	9.5
HARDNESS TOTAL	MG/L	5	SODIUM DISS	MG/L	320
IODIDE	MG/L	0.04	SODIUM PERCENT		99
IRON DISSOLVED	UG/L	30	SP. CONDUCTANCE FLD		1300
MAGNESIUM DISS	MG/L	0.6	SP. CONDUCTANCE LAB		1283
MANGANESE DISSOLVED	UG/L	20	SULFATE DISS	MG/L	74
			WATER TEMP (DEG C)		13.0

Sample T
Location: 38° 52' 14" N 111° 15' 52" W

Sample U
Location: Not in Study Area.

ANALYZING AGENCY		80010	BEN.INVERT. TYPE 1 •	45
			INV BENTHIC WET WT	1.86

Sample V
Location: 38° 51' 26" N 111° 15' 09" 01 W

ANALYZING AGENCY		80010	BEN.INVERT. TYPE 1 •	112
			INV BENTHIC WET WT	1.12

Sample W
Location; 38° 51' 32" N 111° 15' 38" W

ANALYZING AGENCY		80010	BEN.INVERT. TYPE 1 •	6
			INV BENTHIC WET WT	0.043

Sample X
Location; 38° 52' 36" N 111° 17' 29" 01 W

ALK,TOT (AS CACO3)	MG/L	230	PH LAB		9.0
ANALYZING AGENCY		80020	POTASSIUM DISS	MG/L	1.4
BICARBONATE	MG/L	260	RESIDUE DIS CALC SUM	MG/L	348
BORON DISSOLVED	UG/L	180	RESIDUE DIS TON/AFT		0.47
BROMIDE	MG/L	0.2	SAR		25
CALCIUM DISS	MG/L	1.7	SILICA DISSOLVED	MG/L	15
CARBONATE	MG/L	8	SODIUM DISS	MG/L	130
CHLORIDE DISS	MG/L	12	SODIUM PERCENT		98
HARDNESS NONCARB	MG/L	0	SP. CONDUCTANCE FLD		540
HARDNESS TOTAL	MG/L	5	SP. CONDUCTANCE LAB		566
MAGNESIUM DISS	MG/L	0.2	SULFATE DISS	MG/L	51
PH FIELD		8.8	WATER TEMP (DEG C)		13.0

Sample Y
Location: 38° 46' 33" N 111° 23' 53" 01 W

ALK,TOT (AS CACO3)	MG/L	340	POTASSIUM DISS	MG/L	2.7
ANALYZING AGENCY		80020	RESIDUE DIS CALC SUM	MG/L	1050
BICARBONATE	MG/L	410	RESIDUE DIS TON/AFT		1.43
BORON DISSOLVED	UG/L	250	SAR		11
BROMIDE	MG/L	0.2	SILICA DISSOLVED	MG/L	11
CALCIUM DISS	MG/L	30	SODIUM DISS	MG/L	330
CHLORIDE DISS	MG/L	13	SODIUM PERCENT		82
HARDNESS NONCARB	MG/L	0	SP. CONDUCTANCE FLD		1600
HARDNESS TOTAL	MG/L	160	SP. CONDUCTANCE LAB		1577
MAGNESIUM DISS	MG/L	20	SULFATE DISS	MG/L	440
PH LAB		8.0	WATER TEMP (DEG C)		18.5

Sample Z
Location: 38° 46' 26" N 111° 16' 26" 01 W

ALK,TOT (AS CACO3)	MG/L	790	MAGNESIUM DISS		DETR. DELETED
ANALYZING AGENCY		80020	PH LAB		7.4
BICARBONATE	MG/L	960	POTASSIUM DISS		DETR. DELETED
BORON DISSOLVED	UG/L	870	SILICA DISSOLVED	MG/L	8.8
BROMIDE	MG/L	1.1	SODIUM DISS		DETR. DELETED
CALCIUM DISS		DETR. DELETED	SP. CONDUCTANCE FLD		>8000
CHLORIDE DISS	MG/L	430	SP. CONDUCTANCE LAB		18900
DEPTH(FT.FR.SURFACE)		20.0	SULFATE DISS	MG/L	3.7
			WATER TEMP (DEG C)		16.0

Sample 1A
Location: 38° 52' 32" N 111° 17' 27" 01 W

ALK,TOT (AS CACO3)	MG/L	300	POTASSIUM DISS	MG/L	8.1
ANALYZING AGENCY		80020	RESIDUE DIS CALC SUM	MG/L	3020
BICARBONATE	MG/L	360	RESIDUE DIS TON/AFT		4.11
BORON DISSOLVED	UG/L	560	SAR		5.7
BROMIDE	MG/L	0.6	SILICA DISSOLVED	MG/L	16
CALCIUM DISS	MG/L	210	SODIUM DISS	MG/L	470
CHLORIDE DISS	MG/L	150	SODIUM PERCENT		44
HARDNESS NONCARB	MG/L	1000	SP. CONDUCTANCE FLD		2500
HARDNESS TOTAL	MG/L	1300	SP. CONDUCTANCE LAB		3720
MAGNESIUM DISS	MG/L	190	SULFATE DISS	MG/L	1800
PH LAB		7.4	WATER TEMP (DEG C)		13.0

Sample 1B
Location: 38° 48' 49" N 111° 15' 56" 01 W

ALK,TOT (AS CACO3)	MG/L	440	PH FIELD		7.6
ANALYZING AGENCY		80020	PH LAB		7.7
BICARBONATE	MG/L	540	POTASSIUM DISS	MG/L	12
BORON DISSOLVED	UG/L	780	RESIDUE DIS CALC SUM	MG/L	6450
BROMIDE	MG/L	13	RESIDUE DIS TON/AFT		8.77
CALCIUM DISS	MG/L	29	SAR		83
CARBONATE	MG/L	0	SILICA DISSOLVED	MG/L	8.7
CHLORIDE DISS	MG/L	910	SODIUM DISS	MG/L	2200
DEPTH(FT.FR.SURFACE)		74.3	SODIUM PERCENT		97
HARDNESS NONCARB	MG/L	0	SP. CONDUCTANCE FLD		9000
HARDNESS TOTAL	MG/L	130	SP. CONDUCTANCE LAB		9124
MAGNESIUM DISS	MG/L	15	SULFATE DISS	MG/L	3000
			WATER TEMP (DEG C)		13.0

Sample 1C
Location: 39° 01' 31" N 111° 08' 05" W
Ferron Creek Area 10-15 Miles NE

ALK,TOT (AS CACO3)	MG/L	460	POTASSIUM DISS	MG/L	7.2
BICARBONATE	MG/L	560	RESIDUE DIS CALC SUM	MG/L	1530
BORON DISSOLVED	UG/L	510	RESIDUE DIS TON/AFT		2.08
BROMIDE	MG/L	0.1	SAR		7.8
CALCIUM DISS	MG/L	75	SILICA DISSOLVED	MG/L	13
CHLORIDE DISS	MG/L	28	SODIUM DISS	MG/L	370
DEPTH(FT.FR.SURFACE)		7.9	SODIUM PERCENT		65
HARDNESS NONCARB	MG/L	0	SP. CONDUCTANCE FLD		2200
HARDNESS TOTAL	MG/L	430	SP. CONDUCTANCE LAB		2119
MAGNESIUM DISS	MG/L	58	SULFATE DISS	MG/L	700
PH LAB		7.5	WATER TEMP (DEG C)		11.0

Sample 1D
Location: 38° 52' 33" N 111° 13' 03" W

ALK,TOT (AS CACO3)	MG/L	1080	PH LAB		7.6
BICARBONATE	MG/L	1320	POTASSIUM DISS	MG/L	54
BORON DISSOLVED	UG/L	1100	RESIDUE DIS CALC SUM	MG/L	46800
BROMIDE	MG/L	20	RESIDUE DIS TON/AFT		63.6
CALCIUM DISS	MG/L	240	SAR		154
CHLORIDE DISS	MG/L	2200	SILICA DISSOLVED	MG/L	7.2
DEPTH(FT.FR.SURFACE)		29.7	SODIUM DISS	MG/L	30000
HARDNESS NONCARB	MG/L	6100	SODIUM PERCENT		90
HARDNESS TOTAL	MG/L	7200	SP. CONDUCTANCE LAB		4220
MAGNESIUM DISS	MG/L	1600	SULFATE DISS	MG/L	12000
			WATER TEMP (DEG C)		14.5

Sample 1E
Location: 39° 03' 54" N 111° 00' 43" 01 W
Ferron Creek Area 10-15 Miles NE

ALK,TOT (AS CACO3)	MG/L	860	POTASSIUM DISS	MG/L	15
BICARBONATE	MG/L	1050	RESIDUE DIS CALC SUM	MG/L	8120
BORON DISSOLVED	UG/L	110	RESIDUE DIS TON/AFT		11.0
BROMIDE	MG/L	20	SAR		98
CALCIUM DISS	MG/L	40	SILICA DISSOLVED	MG/L	8.0
CHLORIDE DISS	MG/L	4200	SODIUM DISS	MG/L	3200
DEPTH(FT.FR.SURFACE)		105	SODIUM PERCENT		97
HARDNESS NONCARB	MG/L	0	SP. CONDUCTANCE FLD		> 8000
HARDNESS TOTAL	MG/L	200	SP. CONDUCTANCE LAB		13649
MAGNESIUM DISS	MG/L	25	SULFATE DISS	MG/L	91
PH LAB		7.8	WATER TEMP (DEG C)		17.0

Sample 1F
Location: 39° 06' 53" N 111° 00' 54" W
Ferron Creek Area 10-15 Miles NE

ALK,TOT (AS CACO3)	MG/L	5	POTASSIUM DISS	MG/L	8.3
BICARBONATE	MG/L	6	RESIDUE DIS CALC SUM	MG/L	4200
BORON DISSOLVED	UG/L	2600	RESIDUE DIS TON/AFT		5.71
BROMIDE	MG/L	0.3	SAR		2.0
CALCIUM DISS	MG/L	510	SILICA DISSOLVED	MG/L	18
CHLORIDE DISS	MG/L	45	SODIUM DISS	MG/L	240
DEPTH(FT.FR.SURFACE)		28.9	SODIUM PERCENT		16
HARDNESS NONCARB	MG/L	2800	SP. CONDUCTANCE FLD		4500
HARDNESS TOTAL	MG/L	2800	SP. CONDUCTANCE LAB		4408
MAGNESIUM DISS	MG/L	370	SULFATE DISS	MG/L	3000
PH LAB		4.9	WATER TEMP (DEG C)		12.5

Sample 1G
Location: 38° 52' 49" N 111° 13' 09" 01 W

ALK,TOT (AS CACO3)	MG/L	400	POTASSIUM DISS	MG/L	9.3
BICARBONATE	MG/L	490	RESIDUE DIS CALC SUM	MG/L	3880
BORON DISSOLVED	UG/L	1100	RESIDUE DIS TON/AFT		5.28
BROMIDE	MG/L	0.5	SAR		4.6
CALCIUM DISS	MG/L	380	SILICA DISSOLVED	MG/L	11
CHLORIDE DISS	MG/L	100	SODIUM DISS	MG/L	480
DEPTH(FT.FR.SURFACE)		12.0	SODIUM PERCENT		34
HARDNESS NONCARB	MG/L	1600	SP. CONDUCTANCE FLD		4100
HARDNESS TOTAL	MG/L	2000	SP. CONDUCTANCE LAB		4300
MAGNESIUM DISS	MG/L	260	SULFATE DISS	MG/L	2400
PH LAB		7.1	WATER TEMP (DEG C)		13.0

Sample 1H
Location: 38° 52' 25" N 111° 13' 00" W

IDENTIFICATION NUMBER: 252401. STA. NO. 385225111152601

AG:	<	0.010	AL:		0.100	B :		0.500	BA:		0.030
BE:	<	0.001	BI:	<	1.000	CA:		30.000	CD:		0.003
CO:	<	0.005	CR:	<	0.050	CU:		0.010	FE:		0.010
GA:	<	0.030	GE:		0.100	K :		1.000	LI:		0.070
MG:		30.000	MN:		0.003	MO:	<	0.010	NA:		300.000
NI:	<	0.050	PB:	<	0.030	SB:	<	0.030	SIO2:		10.000
SN:		0.100	SR:		5.000	TI:	<	0.005	V :	<	0.010
ZN:	<	0.005	ZR:	<	0.005						

Sample 1I
Location: 38° 52' 25" N 111° 15' 26" W

IDENTIFICATION NUMBER: 252902. STA. NO. 385214111155201

AG:	<	0.010	AL:	<	0.050	B :		0.700	BA:		0.050
BE:	<	0.001	BI:	<	1.000	CA:		1.000	CD:	<	0.001
CO:	<	0.005	CR:	<	0.050	CU:	<	0.010	FE:	<	0.005
GA:	<	0.030	GE:	<	0.030	K :	<	1.000	LI:		0.030
MG:	<	1.000	MN:		0.001	MO:	<	0.010	NA:		300.000
NI:	<	0.050	PB:	<	0.030	SB:	<	0.030	SIO2:		10.000
SN:	<	0.050	SR:		0.100	TI:	<	0.005	V :	<	0.010
ZN:	<	0.005	ZR:	<	0.005						

Sample 1J
Location: 38° 52' 14" N 111° 15' 52" 01 W

ALK.TOT (AS CACO3)	MG/L	420	POTASSIUM DISS	MG/L	16
BICARBONATE	MG/L	510	RESIDUE DIS CALC SUM	MG/L	4470
BORON DISSOLVED	UG/L	590	RESIDUE DIS TON/AFT		6.08
BROMIDE	MG/L	0.4	SAR		2.6
CALCIUM DISS	MG/L	470	SILICA DISSOLVED	MG/L	13
CHLORIDE DISS	MG/L	96	SODIUM DISS	MG/L	320
DEPTH(FT.FR.SURFACE)		32.2	SODIUM PERCENT		20
HARDNESS NONCARB	MG/L	2400	SP. CONDUCTANCE FLD		5800
HARDNESS TOTAL	MG/L	2800	SP. CONDUCTANCE LAB		4777
MAGNESIUM DISS	MG/L	400	SULFATE DISS	MG/L	2900
PH LAB		7.2	WATER TEMP (DEG C)		12.0

Sample 1K
Location: 38° 53' 03" N 111° 13' 13" W

ALK.TOT (AS CACO3)	MG/L	37	RESIDUE DIS CALC SUM	MG/L	5080
BICARBONATE	MG/L	45	RESIDUE DIS TON/AFT		6.91
CALCIUM DISS	MG/L	430	SAR		4.4
CHLORIDE DISS	MG/L	48	SILICA DISSOLVED	MG/L	19
HARDNESS NONCARB	MG/L	2700	SODIUM DISS	MG/L	530
HARDNESS TOTAL	MG/L	2800	SODIUM PERCENT		29
MAGNESIUM DISS	MG/L	410	SP. CONDUCTANCE FLD		6000
PH LAB		7.1	SP. CONDUCTANCE LAB		5525
POTASSIUM DISS	MG/L	17	SULFATE DISS	MG/L	3600
			WATER TEMP (DEG C)		15.5

Sample 1L
Location: 39° 13' 15" N 110° 57' 03" 01 W

APPENDIX 9

Bore Hole Logs

Emery EMRIA core hole No. 1 TD 100'
NE 1/4 sec 23 T. 22 S., R. 6 E.
(logged by T. A. Ryer, Oct. 11, 1978)

Plate 1 - 1 10'-20'
10-18.8 ss, vf-gr, hard, tan (weathered), planar to low angle X-lam, a few clyst layers @ 13'-14'
18.8-20 clyst, slty, brn

Plate 1 - 2 20'-30'
20-22.3 ss, vf-gr, v. hard, gry, planar to low angle X-lam
22.3-24 sltst, sdy, cly, crumbly
24-29.6 ss, as above
29.6-30 clyst, slty w/ lams of vs ss

Plate 1 - 3 30'-39'
30-33.7 mostly sltst; some slty cltst and clyst upper 1' sdy, slty clept

*10-33.7 constitutes a beach sequence prograded to the NE during the general sw-ward transgression of the Blue Gate sea
33.7-39 coal (Jcoal; I coal of Lupton, 1916)

Plate 1 - 4 39'-48'
39-39.8 coal (J coal)
39.8-40.6 sltst, cly, grading up to clyst
40.6-42 sltst,cly
42-43 sltst, a bed of vf-gr ss 0.2' thick @ 41.6
43-48 ss, vf-gr, wavy cly lam., soft-sed def. structures, heavily burrowed

Plate 1 - 5 48'-58'
48-50.1 coal, shy streaks in upper ha;f (split of I coal)
50.1-57 ss, vf-gr, same as 43-48
57-58 mostly sltst w/ sd-filled burrows; grades into overlying unit

Plate 1 - 6 58'-68'
58-58.3 sltst, sdy, cly
58.3-59.3 coal (split of I coal)
59.3-68 ss, vf-gr, wavy-lam, thin beds of cly sltst and clyst; a few burrows in lower part; upper part has lam cover w/ fine carb. frags; top 1' rooted

Plate 1 - 7 68'-78'
68-70 mostly clyst, slty w/ vf-gr ss lams; ss @ 69', wavy-lam.
70-73 ss, vf-gr, interlam w/ sltst; burrows in slty parts
73-77 ss, f-med-gr, X-bedded; sharp lower contact (probably a small distributary or tidal channel
77-78 ss,vf-gr, slty w/ wavy lams of carb. debris grading up to sltst full of sd-filled burrows

Plate 1 - 8 78'-88'

78-80.9 ss, med-gr; top 0.2' f-gr; a layer of clyst 0.1' thick @ 78.2-78.3
80.9-82 coal, badly broken up (split ofI coal)
82-82.9 clept, a few carb frags
82.9-84 coal; upper half shaly coal or coaly sh
84-88 sltst, cly grading up to clyst; slty part shows carb rootlets; top 0.2' carb.

Plate 1 - 9 88'-100'

88-100 (there is approx. 9.5' of core in this box - can,t tell where core is missing - perhaps 2.5' @ approx. 92')
88-91 sltst, cly and slty clyst; possible rooting at top
91-93.5 missing??
93.5-99 ss, coarsening upward from vf- to f-gr, ripple-drift lam, a few small burrows (possible distal splay)
99-100 sltst, sdy, cly, soft, crumbly

*39.8-100 records deposition in a lower delta plain environ., largely brackish-water bay

Plate 1 - 1 Footage: 10'-20'

Plate 1 - 2 Footage: 20'-30'

Plate 1 - 3 Footage: 30'-39-'

Plate 1 - 4 Footage: 39'-48'

Plate 1 - 5 Footage: 48'-58'

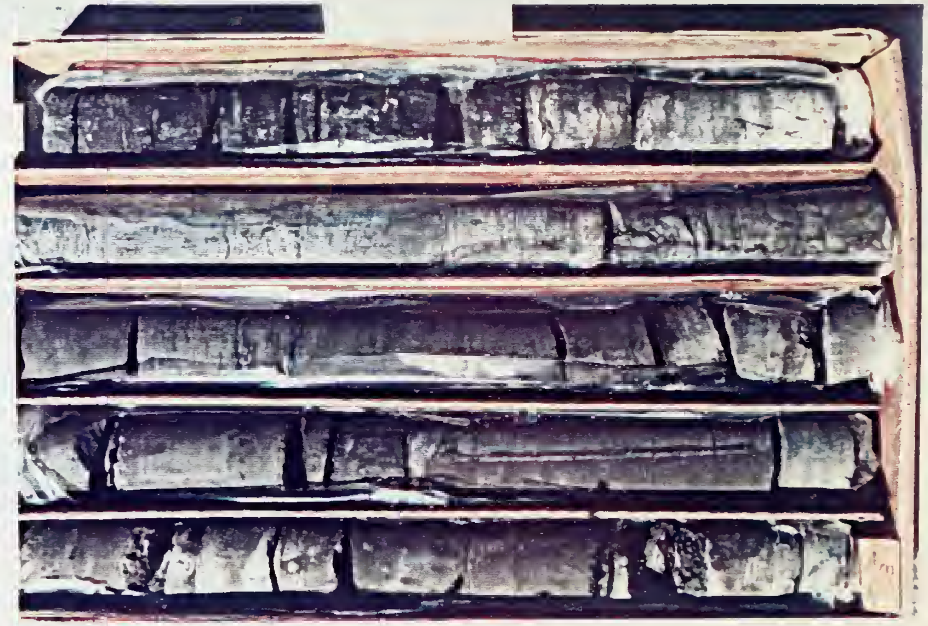


Plate 1 - 6 Footage: 58'-68'

Plate 1 - 7 Footage: 68'-78'

Plate 1 - 8 Footage: 78'-88'

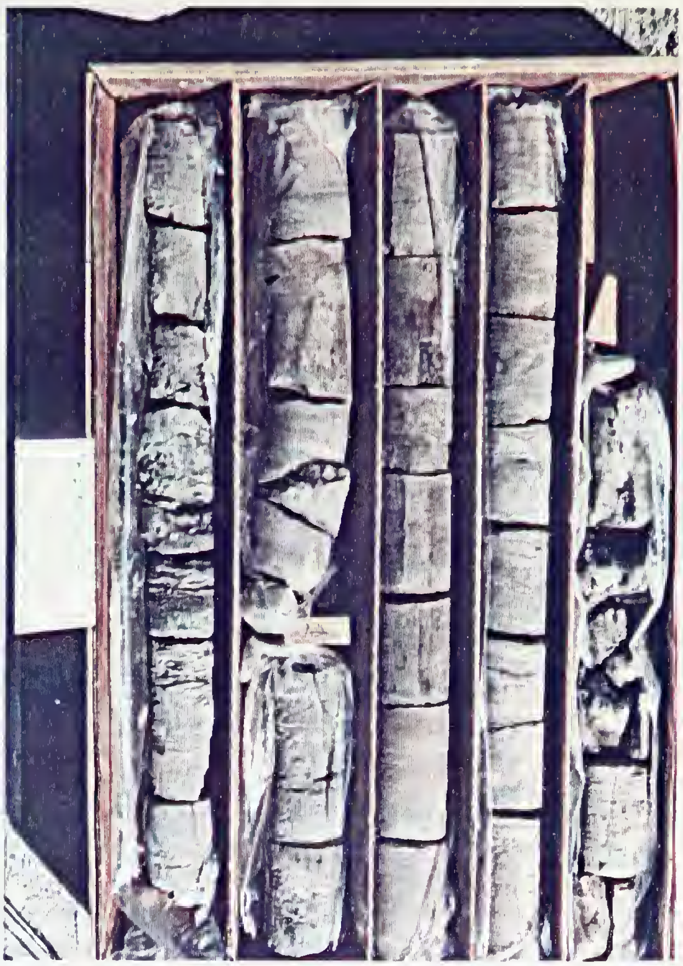


Plate 1 - 9 Footage: 83'-100'

Emery EMRIA core hole No. 2 TD 318'
NW 1/4 sec 26 T. 22 S.; R. 6 E.
(logged by T. A. Ryer, Oct. 12, 1978)

Plate 2 - 1 10'-22'
clyst, slty, weathered (Blue Gate Sh Mbr)

Plate 2 - 2 22'-30'
22-25 clyst' slty, weathered

*Blue Gate/ Ferron contact @ 25'

25-30 ss, f-gr, tan (weathered), heavily burrowed, the burrows mixing slt and cly into what was probably originally a clean ss

Plate 2 - 3 30'-42'
ss, f-gr, tan (weathered), a few coaly chips, a few wavy lam.

Plate 2 - 4 42'-52'
ss, f-gr, same as plate 2 - 3

Plate 2 - 5 52'-64'
ss, f-gr, same as plates 2 - 3, 2 - 4; upper part tan (weathered), lower part gry.

Plate 2 - 6 64'-74'
note: The depositional sequence in boxes 2 - 6 and 2 - 7 does not make good sense; further, it does not correspond at all to what is described from a Consolidated Coal Co. core drilled nearby. I have, in this log, interchanged the contents of boxes 2 - 6 and 2 - 7.
64-74 ss, f-gr, as above, a few small burrows

Plate 2 - 7 74'-80
74-77.6 ss, f-gr sharp base
*25-77.6 is a beach sequence prograded towards the NE; genetically equivalent to interval 10-33.7 of core hole No. 1.
77.6-79.8 coal (this and coal below combined I-J coals)
79.8-80 ss, vf-gr with lam. of slty clyst, contorted

Plate 2 - 8 80'-90'
There is approximately 12.5' of core jammed into this box, all coal except for 2 thin splits of vf ss w/ coaly streaks @ indicated depths of 82.1 and 82.6

Plate 2 - 9 90'-100'
All coal; no indication of which end is top - have labelled box using the same labelling scheme employed by the driller on previous boxes from this hole.

Plate 2 - 10 100'-110'
ss, vf, interbedded and interlam w/ sltst, very contorted in lower part, grading up to all sltst w/ some interbedded clept in uppermost 3'

Plate 2 - 11 110'-120'
ss, f-gr w/ clay chips, top 2' ss, vf-gr w/ slst lam, highlt contorted, a few small burrows

Plate 2 - 12 120'-130'
Box contains approximately 13' of core
120-130 sandstone, fine-grained

Plate 2 - 13 130'-140'
Sandstone, fine-grained; upper 2' has clay, carb. lam., contorted and interbedds of siltstone w/ ss lam.

Plate 2 - 14 140'-150'
140-148 sandstone, f. to vf-gr., sharp lower contact
*interval approximately 110-148 is channel sequence
148-150 sh, coaly, grading upward to sltst w/ coaly frags, rooted

Plate 2 - 15 150'-160'
150-156.9 clyst, slty grading up to sltst and vf-gr ss w/ cly, carb lam. at top; rooted at top
156.9-157.9 Shale, carb w/ pyrite
157.9-158.8 coal and shaly coal, very badly broken up (split of G coal ?)
158.8-160 Shale, carb

Plate 2 - 16 160'-170'
There is approximately 10.6' of core in box
160-162.5 coal (probably G coal)
162.5-164.5 clyst, slty, and cly sltst
164.5-170 mostly sltst w/ laminae of v.f. ss, lams amount of ss decreasing upward

Plate 2 - 17 170'-180'
170-174.6 ss, vf-gr, interlam w/ sltst, wavy lam, X-bedded, totals about 50% sd.
174.6-175.9 ss, vf-gr w/ clyst chips' X-bedded and ripple-lam, small amt carb debris
175.9-180 ss, vf-gr, same as 170-174.6, but only approximately 20% ss, a few burrows

Plate 2 - 18 180'-190'
180-181 ss, vf-gr same as 170-174.6, approximately 50% ss.
181-190 ss, f-gr w/ wavy lams of clyst and debris; burrowed, clay-walled burrows

Plate 2 - 19 190'-208'

Wood block in box reads "dropped core 190-200"

Core in this box is ss, f-gr same as 181-190 - whole interval was probably this same lithology. Also in the box is approximately 1' of cly sltst- doesn't look like this material belongs in this part of the sequence.

Plate 2 - 20 208'-219'

ss f-gr same as 181-190

Plate 2 - 21 219'-229'

219-221.5 ss, f-gr, lams of carb debris, minor burrowing

221.5-229 ss, f-gr, same as 181-190 but heavily burrowed

Plate 2 - 22 229'-251'

Wood block reads "dropped core 230-240"

Another block reads "core loss between 240-248"

229-230.1 ss, f-gr w/ lams of carb. debris

230.1-230.9 ss, vf-gr, slty, heavily burrowed w/ trace fossil Chondrites

*interval approximately 180-230.9 is delta-front sandstone sequence (No. 4 ss of Ryer study)

230.9- ? missing

? - ? 6' of coal badly broken

? - 249 missing

249-251 clyst, slightly slty

Plate 2 - 23 251'-258'

251-252.3 sh, carb.

252.3-258 clyst, slty, the content of slt decreasing upward

Plate 2 - 24 258'-268'

There is 9' of core in the box

258-261.2 sltst, cly, coaly frags

261.2-263.2 coal (split of A coal)

263.2-265.7 sh, carb, slightly slty

265.7-266.7 coal (split of A coal)

266.7-268 clyst, carb to coaly, slty; coaly stringers

Plate 2 - 25 268'-276'

ss, vf-gr, interlam w/ sltst in proportions indicated:

268-272 approximately 40% ss

272-274 approximately 20% ss

274-276 approximately 40% ss

Plate 2 - 26 276'285'

276-278 mostly sltst w/ coaly frags, some interbedded v.f. ss.

278-279.3 ss, f-gr, a few wavy clyst lams, carb frags, oyster shell frags

279.3-279.7 ss, f-gr, interlam w/ sltst

279.7-280.2 ss, f-gr, same as 278-279.3

280.2-285 sltst, interlam w/ vf ss, burrowed, sltst total approximately 70%

Plate 2 - 27 285'-294'
interlam vf ss and sltst, very wavy-lam, burrowed, approximately 50%ss

Plate 2 - 28 294'-304'
294-297.2 ss, vf-gr, interlam w/ gray sltst w/ carb frags; contorted lam; burrowed
297.2-304 ss, f-gr, a few sltst lam, small carb frags; clay-walled burrows; a few oyster shell frags; a large coal frag (log?) @ 298'.

Plate 2 - 29 304'-308'
ss, vf-gr interlam w/ sltst and carb debris; burrowed
* interval 268-308 (and perhaps deeper) represents filling of abandoned distributary channel which locally cut the No. 2 delta-front sandstone of Ryer study. Consists largely of repeated sequences 0.2-0.3' thick of vf ss grading up to and interlam w/ sltst- each such sequence may represent deposition during flood stage (ss) followed by return to quite conditions (sltst); ss/ sltst contacts are sharp.

Plate 2 - 30 308'-318'
308-308.5 ss, f-gr w/ carb, cly lam, heavily burrowed
308.5-314.5 ss, f-gr, a few small carb grains, a few oyster shell frags
314.5-318 ss, f-gr, lots of carb wood frags, some quite large; clay chips all contorted

*308-318 may be uppermost part of No. 1 delta-front sandstone of Ryer study; alternatively, may be basal part of abandoned distribution fill, in which case top of No. 1 ss not cored.

Plate 2 - 1 Footage: 10'-22'

Plate 2 - 2 Footage: 22'-30'

Plate 2 - 3 Footage: 30'-42'

Plate 2 - 4 Footage: 42'-52'

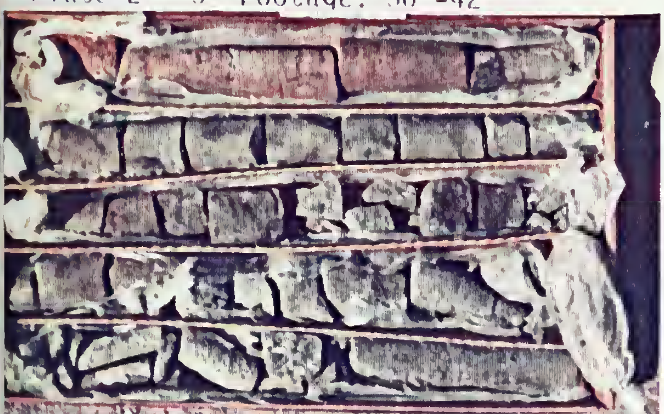


Plate 2 - 5 Footage: 52'-64'

Plate 2 - 6 Footage: 64'-74'

Plate 2 - 7 Footage: 74'-80'

Plate 2 - 8 Footage: 80'-90'

Plate 2 - 9 Footage: 90'-100'

Plate 2 - 10 Footage: 100'-110'

Plate 2 - 11 Footage: 110'-120'

Plate 2 - 12 Footage: 120'-130'

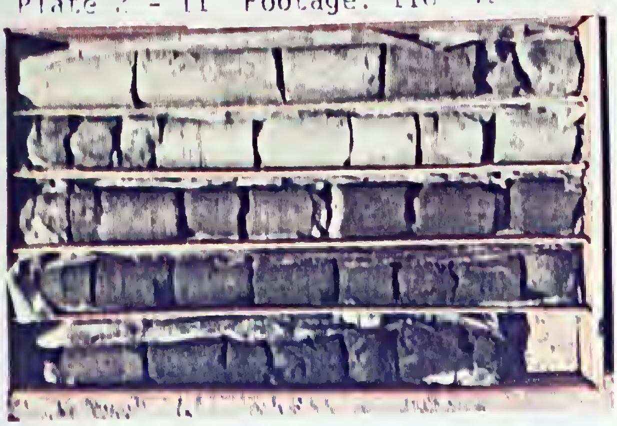


Plate 2 - 13 Footage: 130'-140'

Plate 2 - 14 Footage: 140'-150'

Plate 2 - 17 Footage: 170'-180'

Plate 2 - 18 Footage: 180'-190'

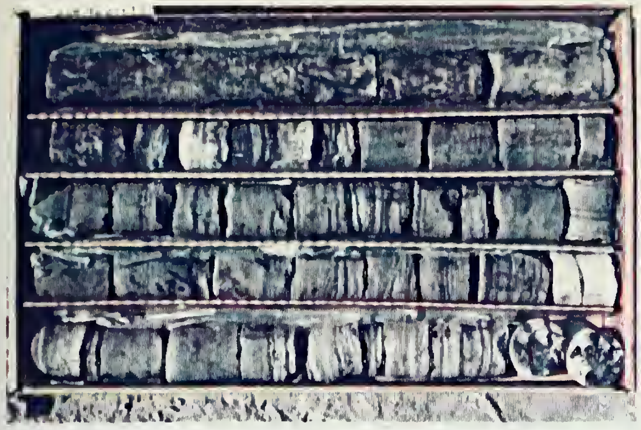


Plate 2 - 19 Footage: 190'-208'

Plate 2 - 20 Footage: 208'-219'

Plate 2 - 21 Footage: 219'-229'

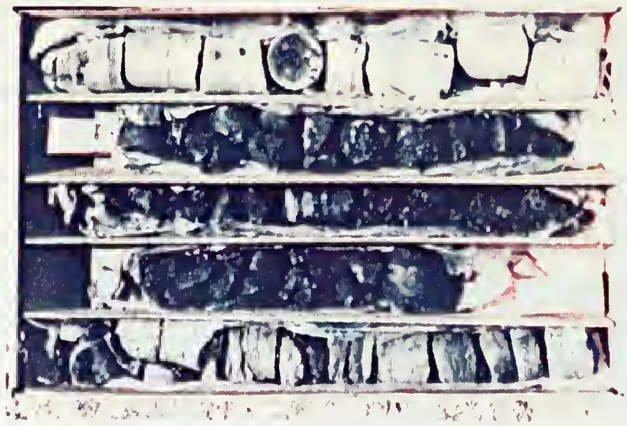


Plate 2 - 22 Footage: 229'-251'

Plate 2 - 23 Footage: 251'-258'

Plate 2 - 24 Footage: 258'-268'

Plate 2 - 25 Footage: 268'-276'

Plate 2 - 26 Footage: 276'-285'

Plate 2 - 27 Footage: 285'-294'

Plate 2 - 28 Footage: 294'-304'

Plate 2 - 29 Footage: 304'-308'

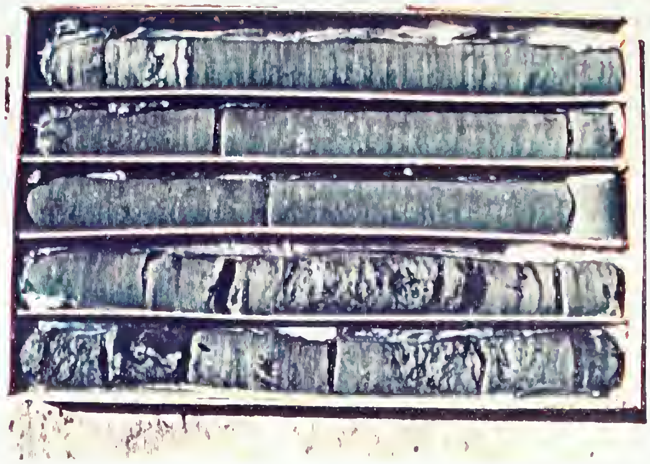


Plate 2 - 30 Footage: 308'-318'

Emery EMRIA core hole No. 3 TD 208'1"
SW 1/4 sec 22 T. 22 S., R. 6 E.
(logged by J. Green, 1978)

Plate 3 - 1 24' 36'2"
24'-25' SH, dk brn, calc, sft, silty, carb flks 0.1 mm, benz +
25'-27' As abv, sm hd zones, silty
27'-27'3" SILTST, wh, calc, arg
27'3"-29'6" SH, brn, sm zones v/ silty, more coherent
29'6"-33'9" SH, dk gry, silty, benz +
33'9"-36'2" SH, dk gry, coherent, silty, calc, uniform, carb flks and platelets, benz +, moisture pH 6

Plate 3 - 2 36'2"-45'6"
36'2"-37'8" SH, lighter brn, less silty, calc, benz +
37'8"-37'9" SH, gry, brkn, sft, silty, blue fluor, sft, benz +
37'9"-40' SILTST, arg, rare grn qtz grains, carb flks, dk gry, benz +, calc
40'-40'5" SH, dk gry-brn, sft, silty, calc, benz +
40'5"-41' SILTST, arg, dk gry, carb flks, calc, v/ sft
41'-42' SH, dk gry-brn, silty, sft, benz +, calc
42'-43' As abv, w/ fluor gyp veinlets & veneers on fract up to 30^o from hor, gyp fibers perp to veinlet walls
43'-43'9" SILTST, dk gry, arg, benz + to shale
43'9"-44'10" SH, dk gry, v/ silty, less calc, abund pyr cylinders 0.1 by 1 mm, plant fiber replacement?
44'10"-45'6" SILTST, arg. as abv w/ brn limon coating on fract

Plate 3 - 3 45'6"-54'9"
45'6"-45'7" SH, dk gry w/ brn ptings, calc
45'7"-47' Fract 33^o to hor
47'-47'4" SH, dk gry, silty, carb flks, calc, w/ gyp-lined fractures
47'4-48' SH, brn ptings, v/ friable, calc, brkn
48'-50'4" SH, dk gry, sli, silty, more carb, larger flks
50'4"-50'6" SH, dk gry, brkn, calc, fissile
50'6"-53' Limon fract w/ 1mm non-fluor gyp lining
53'-54'9" SH, silty, gry, calc, carb, tite,thin fract linings of gyp

Plate 3 - 4 54'9"-65'
54'9"-55 SH, gry, brkn, w/ brn calcite as veneer on fract, benz +
55'-55'2" SH, as abv, incoherent in water, benz + calc, carb
55'2"-57'5" Blue fluor spt
57'5"-58'5" SH, as abv, v/ friable
58'5"-60'2" SH, as abv, w/ ylw hor fract, sli silty, calc, carb flks
60'2"-62'5" SH, dk gry, as abv, more dolc
62'5"-63' Ylw fluor on bedding plane fract
63'-63'10" SH, as abv, less carb, dol
63'10"-64'3" Blue fluor spots
64'3"-64'10" SH, dk gry, as abv, w/limon stained fract, calc
64'10"-65' SH, dk gry, brkn, brn stained fract @ 75^o to hor

Plate 3 - 5 65'-74'11"
65'-70'6" SH, dk gry, carb, calc, sli, silty, fissile, tite, homog
70'6"-71'8" SH, as abv, less calc
71'8"-72'4" Foss on bedding plane, 2 mm dia
72'4"-74'11" SH, dk gry, carb, sli, silty, dolc, fissile, benz -

Plate 3 - 6 74'11"-85'
74'11"-76' SH, dk gry, carb, dolc, homog, tite but fissile
76'-80'2" SH, as abv, dk gry, carb, calc to dolc, uniform, fissile, benz -, fluor -
80'2"-84' SH, dk gry, dolc, carb flks
84'-85' SH, as abv, tite but fissile, calc to dolc, carb flks

Plate 3 - 7 85'-97'
85'-88'9" SH, dk gry, fiss, uniform, dolc, carb flks, brittle
88'9"-95' Marker in error
95'-97' SH, as abv, fiss, brittle, uniform, calc to dolc, rare carb flks $>$0.1 mm, abund finely divided carb spks $<$0.01 mm

Plate 3 - 8 97'-104'4"
97'-99'4" SH, dk gry, homog, fissile, brittle, slivery,calc-dolc, carb flks
99'4"-104' SH, as abv, tendency to break in slivers, calc-dolc, carb flks
104'-104'4" SH, dk gry, calc-dolc, splintery, uniform, benz -, fluor -, carb flks

Plate 3 - 9 104'4" 114'
104'4"-105'3" SH, dk gry, as abv, calc to dolc
105'3"-106'11" SH layer, gry, v/ sft, w/ pale clay matrix containing carb flks and curved golden brn bio? flks 0.1 - 0.5 mm, dolc
106'11"-109'3" Cream fluor patch of calcite in fibrous veinlets w/ fibers perp to veinlet walls
109'3"-112' Cream-tan fluor patch to 109' 3"
112'-113'9" SH, dk gry, dolc, carb flks, fissile
113'9"-114' SH, as abv, w/ wh fract filling of calcite, sli fluor

Plate 3 - 10 114'-123'9"
114'-116' SH, dk gry, as abv, homog, fiss, brittle, moisture in core @ pH 8
116'-120' SH, as abv, dolc, sli carb flks, fissile parallel to bedding
120'-122' SH, tr pyr?
122' 123'9" SH, dk gry, dolc, sli carb matl

Plate 3 - 11 125'-133'6"
125'-126'3" SH, dk gry, dolc, fiss, brittle, no silt, sm carb, moisture @ pH 8
126'3"-131'3" Hi angle frac$\pm$ 80^{o}
131'3"-133'2" SH, as abv, somewhat harder, dolc
133'2"-133'6" Wh patch

Plate 3 - 12 133'6"-143'3"
133'6"-135'2" SH, dk gry, as abv, homog, less fissile, sli silty, more competent
135'2"-136'4" Fluor spot, poss gyp in bedding plane seams
136'4"-137'5.5" Fluor spot
137'5.5"-138' Wh gyp seam, fibrous perp to seam wall
138'-138'11" SH, dk gry, sli silty, more competent, cores do not break when lifted, dolc
138'11"-139'1" CLAY seam, benz -, "fat" clay, light clay, w/   0.1 mm bio? flks to 139'1"

Plate 3 - 12 cont'd.
139'1"-139'8" SH, dk gry, as abv, sli silty, non- fissile
139'8"-140'6" Fluor patch, 2 × 1/4 cm, non-fib calcite
140'6"-141'1" SH, dk gry, competent, tite, little carb, dolc silty
141'1"-142'3" Fluor gyp 1.5 cm × 1/4 cm lentic veinlets, wh parallel to bedding

Plate 3 - 13 142'3"-152'1"
142'3"-143'3" SH, light gry zone to 143'5" containing highly fluor wh calcite surrounding brn calcite
143'3"-144'4" SH, dk gry, homog, silty, tite, calc, non-fissile
144'4"-145'8" Gyp stringer, fibers perp to veinlet wall
145'8"-145'10" Calcite and gyp veinlets
145'10"-147'4" SH, as abv
147'4"-148'7" Gyp veinlet not parallel to bedding plane
148'7"-149'2" SH, dk gry as abv, but brkn to 148'9"
149'2"-150' SH, lgt gry, calc, w/ calcite seams up to 149'6"
150'-152'1" SH, dk gry, hd, tite, silty, sli carb

Plate 3 - 14 152'1"-161'11"
152'1"-160'9" SH, dk gry,hd, sli silty, sli carb, dolc, less fissile
160'9"-161'11" Calcite veinlet, irreg

Plate 3 - 15 161'11"-171'5"
161'11"-164' SH, dk gry, as abv
164'-165'8" Calcite veinlet, discontinuous 2 -18 mm long
165'8"-168'8" SH, as abv, sli silty, hd, tite, homog, dolc
168'8"-169'3" SH, as abv, sli silty w/ pods of SS, gry
169'3"-169'11" SH, mttld, cm patches of SS, gry-brn, mg - fg (1/4 mm max) carb matl, pyr, dolc
169'11"-170'3" Fluor patch 3/4 3 1/4 cm
170'3"-171'5" BLK carb patch 1 3,4 cm

Plate 3 - 16 171'5"-180'
171'5"-171'8" SS, gry-brn, fg-mg, massive, indist bedding, dolc, pyr, mttld carb mtl, secondary qtz faces, subang, relativelt porous
171'8"-173'4" Lentic COAL lens 1/4 1 cm parallel to bedding and oval carb patches about 1 cm dia
173'4" 175'4" SS, gry-brn, fg-mg, w/ secondary q tz faces, massive more calc, sm grains w/ blk inclus, very poor, bedding 5 - 7^{o} hor
175'4"-178'3" SS, fg-mg, subang, sm carb, por, tr pyr
178'3"-179'9" SS, gry-brn, por, fg-mg, sm carb, sm pyr, sli dolc,subang grains, massive
179'9"-180' COAL parting, 3 cm seam, water droplets stand on surf due to poss oily coating, reddish film on COAL
180'-180'5" SS, as abv,dolc

Plate 3 - 17 180'5"-189'9"
180'5"-181' Bright yellow fluoresence in carb lam
181'-181'1" SS, as abv, sli, pyr w/ carb parting, brner color
181'1"-181'9" Carb partings to 181'2". ylw fluor
181'9"-182" Carb lam

Plate 3 - 17 cont'd
182'-182'11" SS, brn, fg-mg, dolc, por, massive, tr oil?
182'11"-185'3" Diffuse patchey fluor
185'3"-186'5" Large carb seam parallel to bedding w/ banded lam 0.1 mm wide seperating COAL lam w/ reddish film
186'5"-187'5" Patches of carb matl
187'5"-189'9" Diffuse carb oam 5 - 25^{o} to hor to 189'9"

Plate 3 - 18 189'9"-198'9"
189'9"-191'9" SS, brn, fg-mg, subang, non calc, carb partings, grains w/ minute pyr inclus, massive, por, non-fluor, faint bedding planes 20^{o} max to hor
191'9"-195' SS, as abv but sli clac, pyr, loosly cemented, v/ por, secondary qtz faces on grains
195'-197'10" SS, as abv, massive, dissem pyr, calc
197'10"-198'9" SS w/ clear and milkey grains, pyr in clear grains, v/ por variable calc
198'9"-199'4" Carb lam 55^{o} to hor, stylolite-like to 198'10"

Plate 3 - 19 201'2"-208'1"
201'2"-201'8" SS, brn, massive, fg-mg, pyr, homog, por w/ carb partings w/ COAL layers mm thick, slickensides, reddish film
201'8"-203' Carb partings 40^{o} to hor, wavy lentic in SS. as abv
203'-207'3" SS, as abv, mod calc, massive, unif, por, sm pyr
207'3"-207'6.5" SS, carb patches, non-calc, por as abv
207'6.5"-208'1" SH, mttld, carb, silty, non-calc, non-flour, benz -

Plate 3 - 1 Footage: 24'-36'2"

Plate 3 - 2 Footage: 36'2"-45'5"

Plate 3 - 3 Footage: 45'6"-54'9"

Plate 3 - 4 Footage: 54'9"-65'

Plate 3 - 5 Footage: 65'-74'11"

Plate 3 - 6 Footage: 74'11"-85'

Plate 3 - 7 Footage: 85'-97'

Plate 3 - 8 Footage: 97'-104'4"

Plate 3 - 9 Footage: 104'4"-114'

Plate 3 - 10 Footage: 114'-123'9"

Plate 3 - 11 Footage: 125'-133'6"

Plate 3 - 12 Footage: 133'6"-143'3"

Plate 3 - 13 Footage: 143'3"-152'1"

Plate 3 - 14 Footage:152'1"-161'11"

Plate 3 - 15 Footage:161'11"-171'5"

Plate 3 - 16 Footage: 171'5"-180'

Plate 3 - 17 Footage: 180'5"-189'9"

Plate 3 - 18 Footage: 189'9"-199'4"

Plate 3 - 19 Footage: 201'2"-208'1"

Emery EMRIA core hole No. 4A TD 200'6"
SW ¼ sec 34, T 22 S, R 6 E
(Logged by J. Green, 1978)

Plate 4A - 1 8'-17'9"
8'-10' SS, fg, brn w/ limonite flecks and carb layers up to 10^o from horiz, por
10'-12'6" SS, fg, subang, poorly sorted, brn w/ limonite flecks, por, non-calc grading
12'6"-12'11" SILTST, brn w/ carb layers and patches up to 1.5 x 1.5cm
12'11"-13'3" As abv w/ gray carb zones
13'3"-13'10" SILTST, brn, prom carb layer
13'10"-14'6" As abv, prom carb layer
14'6"-14'7" SH, grnish, w/ musc flakes less than 1mm, non-calc
14'7"-16'2" SS, dker brn, homog grading to spkld SS, mg
16'2"-16'7" SS, as abv w/ high angle carb-lined fract ($\pm 30^o$) to
16'7"-17' As abv w/ carb SH, brkn
17'-17'9" SS, fg, gry, non-calc, subang, w/ musc, benz

Plate 4A - 2 18'2"-27'4"
18'2"-18'4" SH, brn, silty
18'4"-19'1" SS, fg, lgt brn, subang, laminae $\pm 5^o$ to horiz, non-calc both SS and lam
19'1"-19'4" SS, fg, brn, shaly, non-calc
19'4"-19'7" CLAY seam, sm musc, sft, $benz^+$, non-calc
19'7"-20'6" SS, as abv w/ blk carb zones
20'6"-21'4" SILTST and SH, brn, non-calc
21'4"-21'9" SS, fg, brn, dolc w/ lam, non-calc, brn, sm musc
21'9"-22'10" SH, carb grading to SILTST, reddish, irreg w/ brn layers
22'10"-24'8" SS, w/ nr vert Fe-stained fract 22'8
24'8"-25'4" SS, fg, as abv w/ rare orange grains, dolc, carb lam
25'4"-27'4" SS, med-fg, dk gry, dolc, lam @ $0\text{-}20^o$ horiz, to SS, fg, dolc, arg

Plate 4A - 3 27'4"-37'1"
27'4"-29'4" SS, fg, lgt gry w/ contorted carb lam, sharp breaks, non-calc, sm lgt brn zones
29'4"-29'8" SS, as abv, ang grains, carb and carb lam, sm musc, sli dolc
29'8"-30'8" SS, as abv w/ carb current marks lam sm at 15^o to horiz
30'8"-34' SS, as abv w/ about a dozen carb partings @15^o to horiz, sli dolc
34'-37'1" SS, fg, w/ 0.01mm pyr, dolc, tite, turnc currnet marks, w/ SS, more rndded grains, dk inclusion in grains, sm musc

Plate 4A - 4 37'1"-46'6"
37'1"-39' SS, fg, wh-lgt gry, currnet bedding up to 20^o from horiz, sm trunc, dk gry carb layers, massive bedding, dolc
39'-39'8" SS, as abv, subang grains, rel pure, wh, massive, dolc
39'8"-42' SS, as abv, w/ fract 83^o to horiz
42'-44'6" SS, massive as abv
44'6"-45'9" SH partings nr horiz w/ musc flakes on surf, SS as abv, but sli brner
45'9"-46'2" SS, as abv, dolc w/ nr vert brn stained fract w/ ylw fluor in long wave UV
46'2"-46'6" SH, carb, blk w/ slickensided COAL, sft, non-calc

Plate 4A - 5 46'6"-55'10"
46'6"-48' SH, dk brn, incoh w/ blk COAL incl, non-calc
48'-48'6" SILTST, gry-brn, non-calc, competent
48'6"-52'6" SH, dk gry, brkn, non-calc becoming dker
52'6"-53' COAL, slickensides, brkn
53'-54'6" As abv but more competent, sli shaly, non-calc
54'6"-55'10" COAL, as abv w/ granular seam & w/ marcasite xls 0.05mm

Plate 4A - 6 55'10"-65'7"
55'10"-56'10" COAL, blk, massive, non-calc, small vert fract
56'10"-57'8" Transitional to SH, carb w/ vitreous coaly semas and pyritised plant remains
57'8"-60' SH, dk gry mttld, non-calc w/ silty zones
60'-61'10" SH, as abv, silty zones, sli dolc
61'10"-62' SH, gry, silty, non-calc w/ carb lam, contorted
62'-65'7" SS, vfg, gry-brn w/ brn carb lam and patches, dolc, rare green grains

Plate 4A - 7 65'7"-75'2"
65'7"-66'11" SS, fg, lgt brn gry, dolc, w/ carb stringers/lenses
66'11"-68' SS, as abv, dolc, w/ irreg "spidery" fract filled w/ carb mtl, current bedding
68'-71'6" SS, fg, subang, brn spkld, rare musc, sli dolc
71'6"-72' SS, as abv, but v/ arg, carb, dolc, (wh strks @71'9")
72'-73' SS, fg, brn, dolc, w/ carb lam
73'-74'10" SS, as abv w/ close spaced wavy carb lam
74'10"-75'2" SS, fg, buff, sm musc, w/ coaly frag less than 0.2mm

Plate 4A - 8 75'2"-85'2"
75'2"-76'1" SS, light tan, fg, shot w/ carb wavy stringers 0.1mm
76'1"-77'2" COAL, highly slickensided, brkn irreg
77'2"-78'6½" SS, fg, pale brn w/ abund carb inclus and layers, brkn along bedding planes, non-calc
78'6½"-79' Fluorescence
79'-80' SS, fg, gry, non-calc w/ wh patches SILTST grading to SH, gry, friable, mttld, non-calc, sli silty
80'-85'2" SS, brn w/ blk strks, patches of carb mtl outlines @ 81'2", subang grains loosely cemented, grins @ 83' rich in minute pyr inclus., massive, porous, dolc

Plate 4A - 9 85'2"-95'
85'2"-85'10" SS, fg, brn, massive, hd, spotted, dolc
85'10"-88' SS, as abv, w/ carb partings @15° to horiz
88'-88'10" As abv w/ high angle fract calcite veneered and sm clay pods, benz+
88'10"-90'8" SS, fg, brn w/ bluish spots, massive, dolc, por high angle fract w/ clay surf
90'8"-92'2" As abv w/ carb outlined spots, 1cm dia
92'2"-92'7" SS, as abv, mttld, w/ pods of COAL in intricate patterns (see photo)
92'7"-93'7" COAL, w/ slickensided partings
93'7"-95' As abv, but brkn, ylw stain and at 94'8"

Plate 4A - 10 95'-105'2"

95'-100' COAL, massive, easily brkn, wh incrustations on sm fract, slickensides, tr marcasite?
100'-100'4" SH, dk gry, carb, brkn, non-calc
100'4"-101'1" SH, kerogen? brn, pyr, v/ sli dolc, sli silty
101'1"-101'2" SH, sft, incoh
101'2"-103'6" COAL, var shaly, w/ slickensided partings, light gry SH @ 104'
103'6"-105'2" Marcasite (?) wafers on parting surf less than 0.2mm xls of COAL, massive

Plate 4A - 11 105'2"-114'8"

105'2"-108'6" COAL, massive, sm hi angle fractures and slickensides
108'6"-108'9" SH, carb, silty, non-calc
108'9"-109'7" SS, fg, lgt gry-brn, silty esp. @ 110'5"
109'7"-110'8" SS, fg, brn patches, sm pyr and green grains
110'8"-114'8" SS, as abv, w/ brn stain on fract, non-calc grading to SS, brnish w/ dk indist silty layers/lenses, scant pyr and green grains subang qtz grains, non-calc

Plate 4A - 12 114'8"-124'2"

114'8"-118' SS, fg, brn-gry, tr pyr, w/ pink grains at 116' 8" non-calc, massive
118'-119'9" SS, as abv, sli calc
119'9"-124' SS, fg to mg, abund carb partings, esp @ 121'5" calc
124'-124'2" SS, mg, pyr, massive w/ carb lam, sm trunc

Plate 4A - 13 124'2"-133'6"

124'2"-126'5" SS, gry, dolc cement, fg to mg, qtz grains w/ xl faces (secondary?), sm green grains, carb incl, pyr, current bedding defined by carb mtl 0 to 30^o to hor, tr musc less than or equal to 0.1mm
126'5"-129' SH, dk gry, sli silty, carb dissem, dolc, homog, tite
129'-129'1" Scattered bright blue short UV spks to 129'5"
129'1"-130'8" SH, as abv, sli silty, dolc
130'8"-132' Lentic, blk coaly lens concave up, 3cm wide
132'-133'6" Lentic more calc patches 2 x 4cm

Plate 4A - 14 133'6"-142'7"

133'6"-137'3" Sh, dk gry, silty, dolc, w/ wh to lgt gry mtl in dolc SS lenses
137'3"-138'9" SH, wh to brn, dolc, cherty @138'-138'2" interval w/ slickensides, fg, tite, fract coated w/ calcite xls
138'9"-139' SS, wh, fg, dolc, subang qtz grains w/ fn ½mm SH lam
139'-141' SS, as abv, w/ carb silty layers, dolc
141'-142'4" SS, fg, wh contorted parallel lam and blk carb lam, dolc
142'4"-142'7" SH, silty, sft

Plate 4A - 15 142'7"-151'5"

142'7"-143'10" SS, gry, wh, dolc, w/ fn carb lam and current bedding marks
143'10"-144'8" SS, wh, fg, w/ parallel 1cm lam
144'8"-146' COAL, blk, vert fract, pure, slickensides, non-calc
146'-148'9" As abv w/ vert fract
148'9"-148'11" Trans to carb SH, silty, sli dolc
148'11"-151'3" SS, fg, wh, w/ carb matl in fract, dolc
151'3"-151'5" SH, dk layer, silty, fissile

Plate 4A - 16 151'5"-160'3"
151'5"-152'9" SILTST, gry, w/ rare coaly strks, dolc
152'9"-155' SH, silty, contact irreg, carb w/ SS, fg, dolc w/ convoluted current marks
155'-158' Interbeds of SH, blk, fissile, sli dolc w/ SS, fg, gry, containing calc SILTST, carb
158'-158'6" Sm hi angle fract in SILTST, carb, contorted
158'6"-159' SH, dk gry, sli fissile, more calc
159'-159'7" SS, fg, more clac w/ sm intricate convoluted carb lam w/ gypsum in plates in fractures
159'7"-160'3" Discontinuity to more fg gry SS, calc

Plate 4A - 17 160'3"-169'2"
160'3"-163'4" SS, fg, gry w/ dker silty lam mm-cm thk, lam irreg and contorted
163'4"-164'3" SH, partings, slickensided
164'3"-166'2" SS, as abv, calc
166'2"-166'3" With pyr and rare pink-brn grains, calc
166'3"-167'8" SH, silty, zone w/ SS, fg, w/ dolc mttld curved SH clasts in SS
167'8"-168'10" Dolc, carb clay seams
168'10"-169' Vert fract
169'-169'2" SS, fg, w/ carb silty seams/lam w/ rare pyr/hem grains

Plate 4A - 18 169'2"-178'1"
169'2"-169'11" SS, lgt gry, fg, homog, massive, calc, secondary xl faces?
169'11"-170'5½" SS, w/ variegated carb silty and shaly layers-contorted sm jet blk carb layers 3cm wide, wavy contacts
170'5½"-173'11" Wh xln mtl on carb seam w/ brilliant purple fluorescence
173'11"-178' SH, silty, blk, dolc, fiss, benz- to SS, brnish, homog, fg, pyritic, por, calc, w/ occas carb stringers ¼cm wide, rare carb skeletal matl within qtz grains
178'-178'1" Carb stringer to SS, wh, variegated w/ carb stringers

Plate 4A - 19 178'1"-187'7"
178'1"-178'3" SH, carb, calc
178'3"-178'5" SS, v/ lgt brn w/ wavy dk stringers contorted
178'5"-179'6" SS, brn, massive, fg, calc, w/ wh spks outlined by blk carb mtl
179'6"-181' Fluor patch (short wavelength UV)
181'-182'10" SS, brn, fg, w/ dk carb stringers and clasts, clasts are internally layered @187'7", wavy coaly seams at 180'6" and 181'6"
182'10"-186' SS, dker brn, fg, grains w/ minute inclus pyr, sli dolc
186'-187'7" SS, variegated, lgt brn w/ drk carb clasts, sli dolc

Plate 4A - 20 187'7"-197'8"
187'7"-188' SH, carb, dolc
188'-189'9" SS, gry, fg, calc, w/ blk carb stringers
189'9"-190' SH, blk carb partings
190'-193' SS, as abv, fg, w/ blk carb partings/seams, calc cement
193'-193'1" SS, fg, por, calc, subang grains, wh, sm blue fluor in SH partings
193'1"-194'9" SS, variegated, dk gry and wh SS, silt carb lam
194'9"- 196'9" SH, parting, 1cm thk, fluorescent
196'9"-197'8" SS, fg, v/ dk gry and SH

Plate 4A - 21 197'8"-200'6"

197'8"-200' SH, w/ COAL seams, w/ silty layers

200'-200'6" SH, dolc, silty cross cutting layers

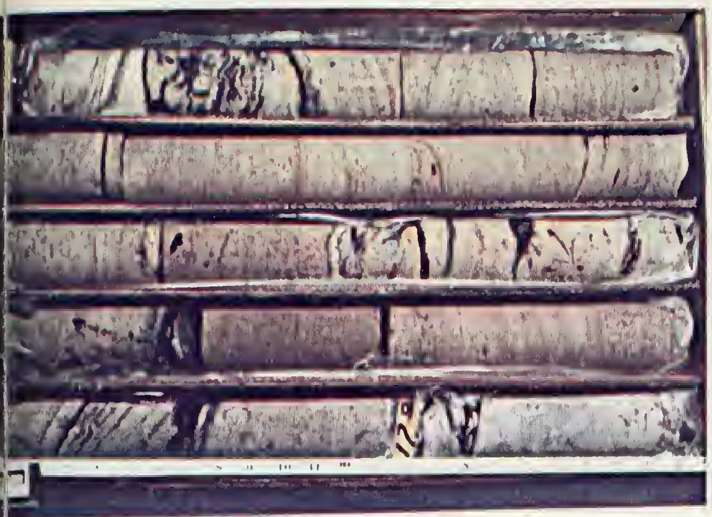


Plate 4a - 1 Footage: 8'-17'9"

Plate 4a - 2 Footage: 17'9"-27'4"

Plate 4a - 3 Footage: 27'4"-37'1"

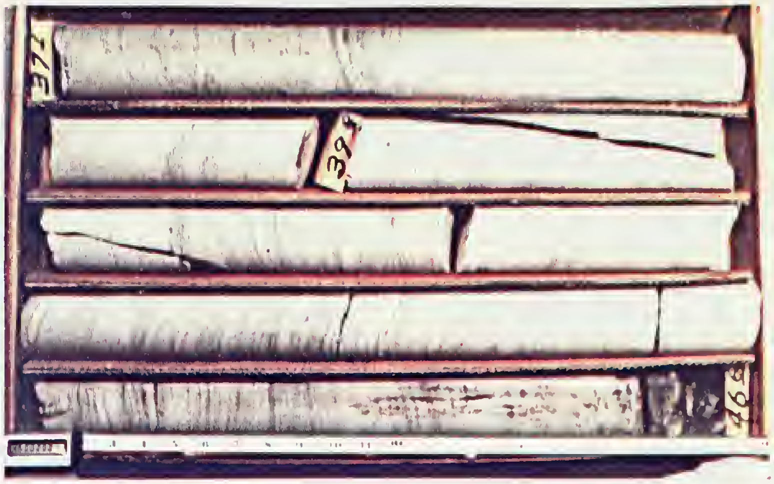


Plate 4a - 4 Footage: 37'1"-46'6"

Plate 4a - 5 Footage: 46'6"-55'10"

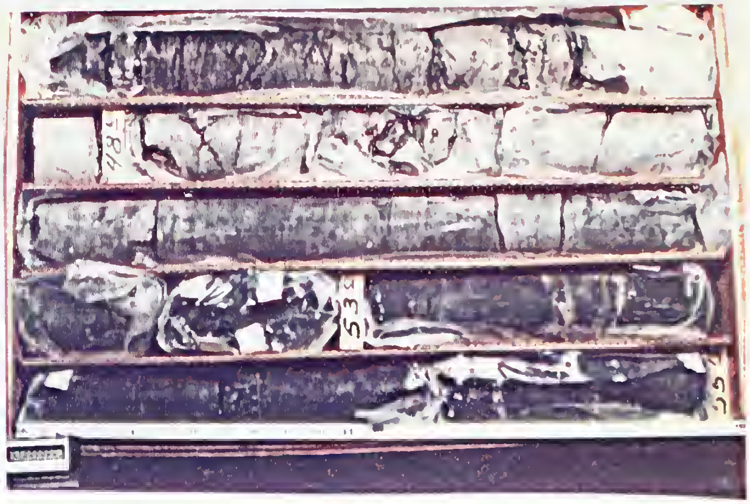


Plate 4a - 6 Footage: 55'10"-65'2"

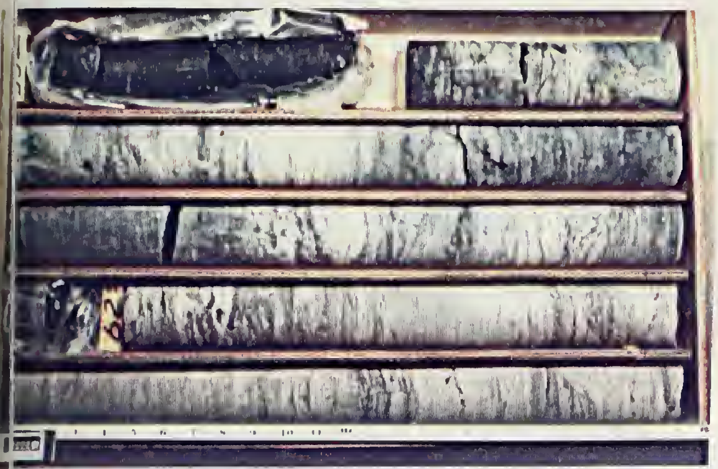


Plate 4a - 7 Footage : 65'7"-75'2"

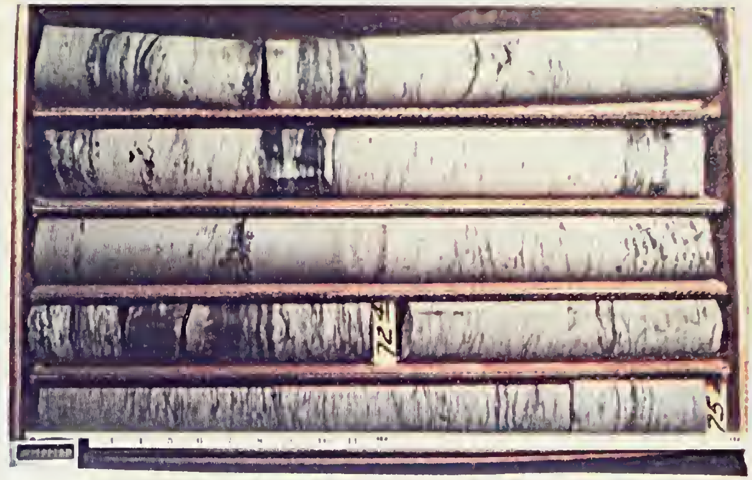


Plate 4a - 8 Footage: 75'2"-85'2"

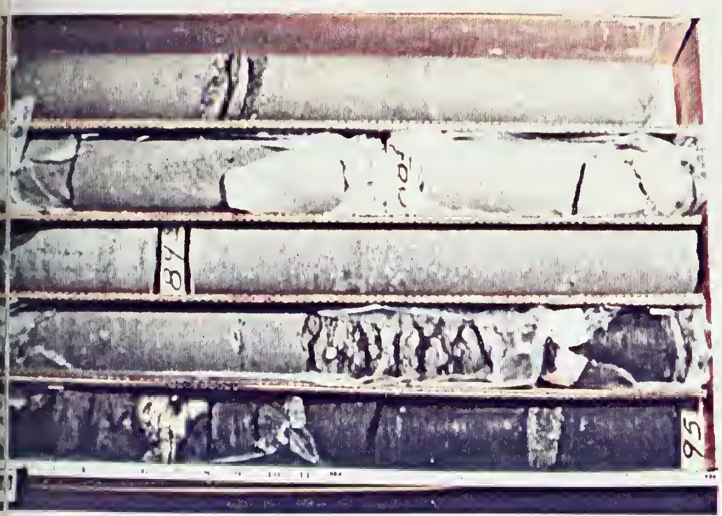


Plate 4a - 9 Footage: 85'2"-95'

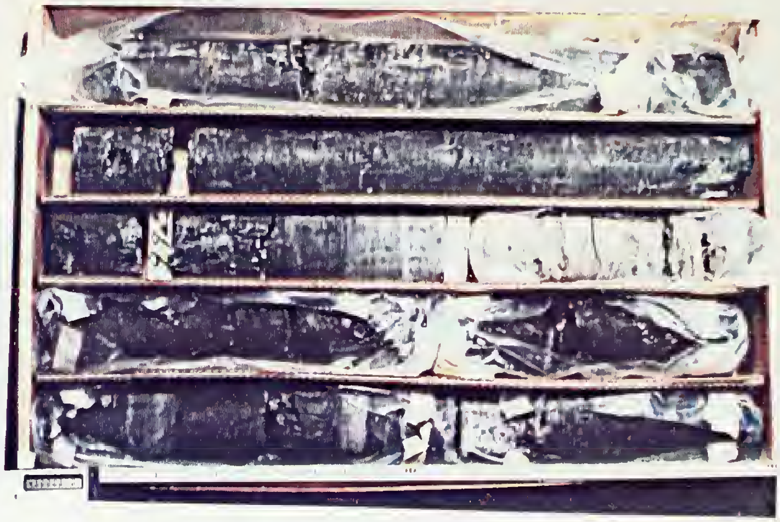


Plate 4a - 10 Footage: 95'-105'2"

Plate 4a - 11 Footage: 105'2"-114'8"

Plate 4a - 12 Footage: 114'8"-124'2"

Plate 4a - 13 Footage: 124'2"-133'6"

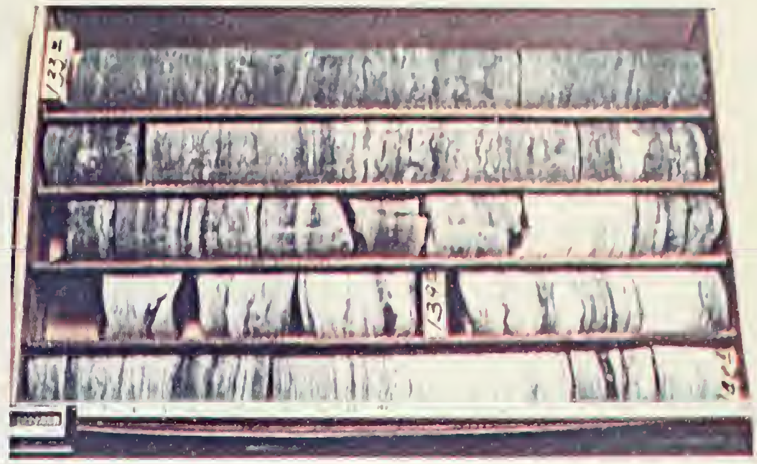


Plate 4a - 14 Footage: 133'6"-142'7"

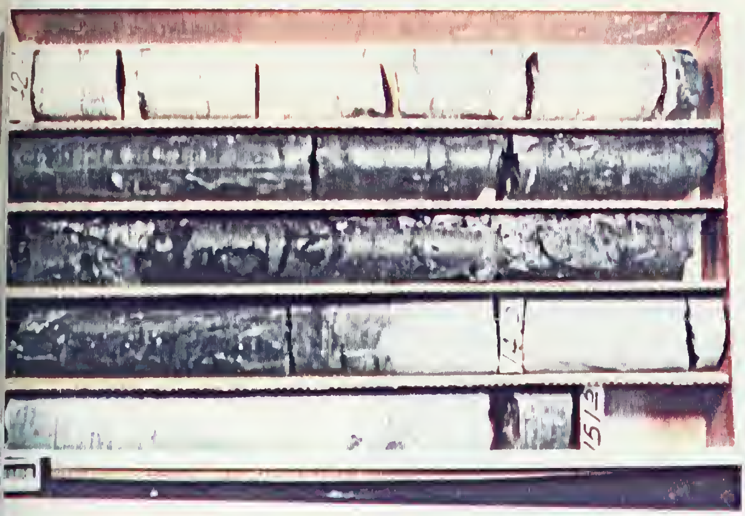


Plate 4a - 15 Footage: 142'7"-151'5"

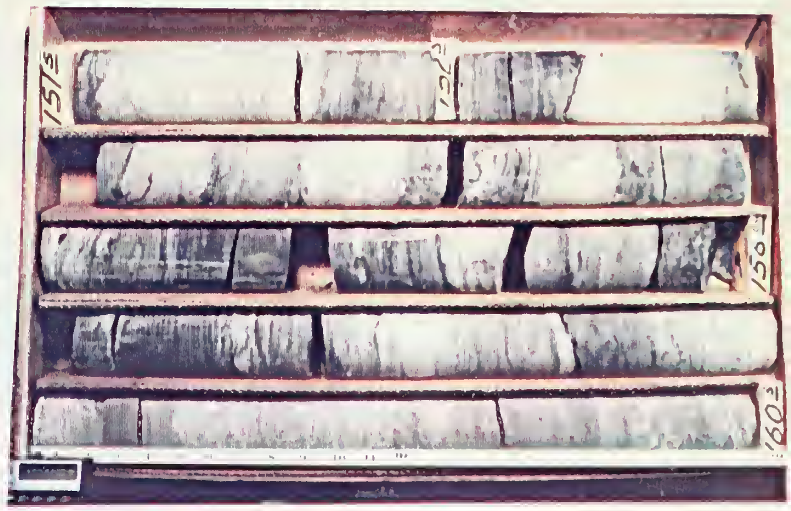


Plate 4a - 16 Footage: 151'5"-160'2"

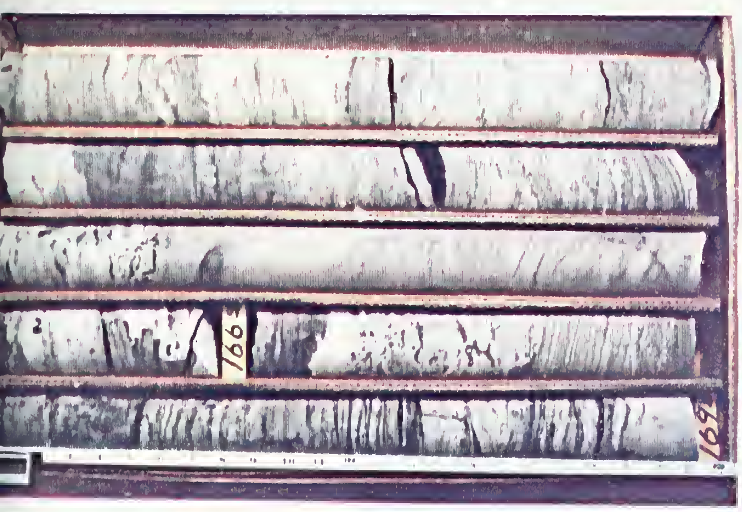


Plate 4a - 17 Footage: 160'2"-169'2"

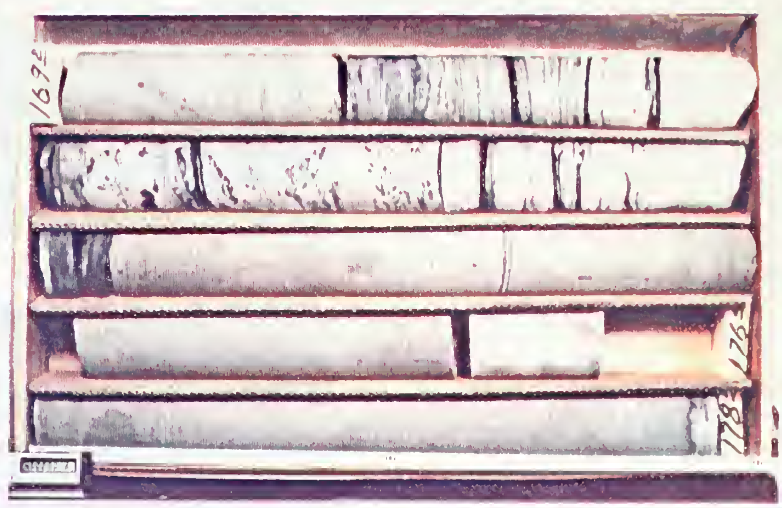


Plate 4a - 18 Footage: 169'2"-178'1"

Plate 4a - 19 Footage: 178'1"-187'7"

Plate 4a - 20 Footage: 187'7"-197'8"

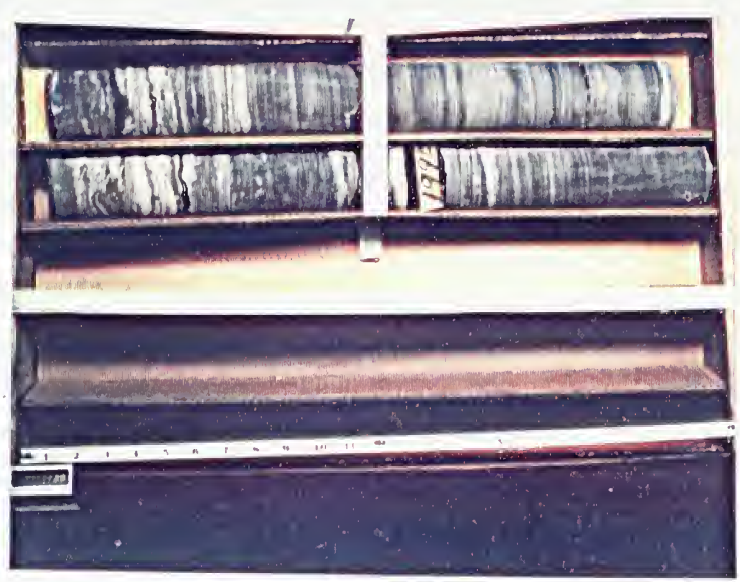


Plate 4a - 21 Footage: 197'8"-200'6"

Emery EMRIA core hole No. 5 TD 300'
Sw ¼ of SW ½, sec 3, T 23 S, R 6 E
(Logged by J. Green, 1978)

Plate 5 - 1 8'5"-17'9"
8'5"-9'10" SS, tan, fg, sli amt carb matl, non calc, por, well sorted
9'10"-10'7" SS, as abv w/ carb lam diffuse 25^{0} to horiz
10'7"-11'4" SS, dk brn, massive, w/ blk mttld carb spks, por
11'4"-13'6" SS, lgt brn, fg, por, w/ scant carb mtl grading to dker brn SS, carb inclusions, non-calc
13'6"-14'1" SS, lgt tan, mg w/ sm grains up to 1 mm dia at 14' w/ sm feldspar frags, mod well sorted, por
14'1"-15'3" SH, lgt gry, w/ brn ptings, broken, "fat" clay
15'3"-16' CLAY, lgt, gry, plastic, sli silty non-calc
16'-17'2" SH, dk gry, sft, hi carb, brkn, non-calc, sli silty
17'2"-17'9" SH, lgt brn gry, as abv, non-calc

Plate 5 - 2 17'9"-27'3"
17'9"-18' SH, dk brn, dissem carb, sft, non-calc
18'-18'6" V/ dk gry, hi carb, crumbly, non-calc
18'6"-18'9" SH, gry brn, brkn, sft, crumbly, non-calc, sm carb
18'9"-20'2" SH, gry, w/ lim prings parallel to bedding, sli silty, sft, non-calc, transitional
20'2"-22'6" SH, lgt gry, "fat" clay matrix, sft, non-calc w/ sm brnish patches, non-swelling clay
22'6"-22'11" SH, brn, sft, non-calc, indist layering
22'11"-23'3" SH, as abv, incoherent, crumbly brkn, non-calc, non-swelling
23'3"-25'3" SH, gry, sft, non-calc, wh spks, sli silty
25'3"-27'3" SH, gry, more coherent, non-calc, sm high angle fract w/ brnish zone @ 26'3"

Plate 5 - 3 27'3"-37'
27'3"-27'7" SH, dk gry, non-calc, sft, sli silty
27'7"-28'6" SH, brn, brkn, silty
28'6"-29'7" SS, fg, brn, w/ thin 1-3mm thk carb layering parallel to bedding, lam dk brn-blk, wavy, calc
29'7"-29'11" SH, dk gry as abv (possibly misplaced core section?)
29'11"-33' SS, fg, brn, sm silt sizes, sm hi angle fract, fract surf uncoated, calc
33'-35' SS, lghter brn, calc, fg, sm carb matl
35'-35'6" SS, fg, lght gry brn, carb flks, dolc
35'6"-36'5½" SS, brn, fg, carb flks and lam, wavy, parallel to bedding massive, dolc
36'5½"-36'8" SH pting (3mm), to SS, lght gry-brn w/ carb lam, dolc
36'8"-37' SS, brn, dolc, fg, carb mtl, somewhat por

Plate 5 - 4 37'-47'1"
37'-37'5" SS, fg, lgt brn-gry, calc, por, sm flks carb matl
37'5"-39'2" SS, brn, w/ dk brn to blk lam parallel to bedding, dolc
39'2"-39'4" SS, fg, lgt gry, calc, por, less carb flks grading
39'4"-43' SS, brn, as abv, dolc w/ lgt gry layered SS, fg at 39'9"
43'-46' SS, dker brn, w/ abund carb lam parallel to bedding about 5mm apart, rare clay stringers, dolc
46'46'6" SS, dk brn, fg, w/ hi angle fract up to 90^{0}, carb, fract surf w/ "oily" appearance, i.e., water stands in droplets
46'6"-47' SS, brn, as abv, w/ carb lam, dolc

Plate 5 - 5 47'1"-57'2"

47'1"-48'9" SS, brn, fg, w/ carb bedding plane lam nr horiz, dolc, por
48'9"-49'1" As abv, more calc
49'1"-50'2" SS, brn, dolc, por, w/ hi angle 60^o carb veneered fract to 49'6"
50'2"-52'10" SS, fg-mg, dolc, w/ hi angle fract coated w/ dk calc matl
52'10"-53'4" SS, fg, sm silt sizes, sli arg, dolc
53'4"-54'1" SS, pink to dk red, lam w/ carb spks up to 2mm dia, sm 0.5mm wh lam seams parallel to bedding, sm wh specks, abund musc 1mm max, non-calc
54'1"-55'4" As abv, v/ dk red, blk carb spks, lam, non-calc
55'4"-57'2" SS, as abv, brighter red

Plate 5 - 6 57'2"-69'

57'2"-59' SS, fg, pink w/ wh lam more calc than dker lam, musc flks, brkn
59'-61'3" As abv
61'3"-63' SS, fg, brkn, non-calc, red-light pink lam 5^o from horiz, hi angle fract 85^o, bleached sli wavy surf, to 62'10"
63'-65' SS, as abv, non-calc, v/ dk red, brkn
65'-65'6" SILTST, gry, arg, w/ blk spks, non-calc, brkn
65'6"-65'9" SS, fg to silty, red, non-calc
65'9"-67' SS, as abv, w/ brn Leisgang zoned patch to 65'11", hi angle 80^o fract w/ dk red fract surf
67'-67'6" SS, silty, arg, red, brkn, crumbly to 67'6"
67'6"-67'9" SH, silty, gry, to SILTST, dk gry, arg, non-calc
67'9"-67'10" SH, layer, red, 3/4mm thk, non-calc, silty in SILTST, as abv
67'10"-68' CLAY, wh, fat, non-calc, benz+, to 68'
68'-69' CLAY, lgt brn, sft, non-calc, sli silty, sm lavender mttling

Plate 5 - 7 69'-79'

69'-71'8" CLAY, gry-brn, silty, non-calc, sft, wavy
71'8"-72'5" CLAY, as abv, w/ dk clay chips to 72'
72'5"-72'10" CLAY, wh, non-calc, expanded dia (2.5'), scour lenses layers 23^o to horiz
72'10"-73' CLAY, brn, v/ sft, crumbly, sli silty, non-calc
73'-77'2" SILTST, pinkish, mttld, non-calc, current bedding, lenses, scour zones, wh stks on surf, massive
77'2"-77'7" SILTST, red, ylw sli wavy bedding layers, arg, sft, cm thk
77'7"-77'8" SILTST, red ylw, arg w/ tan clay 3/4cm thk, non-calc
77'8"-77'9" CLAY, silty, non-calc, dk gry, contact
77'9"-79' SILTST, gry, sli carb, non-calc, healed hi angle fract 80^o, scour features, massive

Plate 5 - 8 79'-94'

79'-81' SS, fg, variegated gry-wh, sm layers 1cm apart, current bedding scour feat, massive, non-calc
81'-82'4" As abv, but brkn to 81'3" then massive, sm shaley bedding plane breaks
82'4"-83' SS, dk gry carb layers, bedding @ 12^o to horiz
83'-88'9" SH, dk gry, clay-rich, scour lenses, patches, non-calc, sm red patches
88'9"-89' SH, v/ dk gry, spkld, tr eff, carb
89'-89'6" Missing core
89'6"-90'2" SILTST, arg, gry-brn w/ limon films on pting surf transitional
90'2"-92'6" SILTST, wh w/ grnish stain, non-calc, massive
92'6"-93'7" As abv, hi angl fract
93'7"-94' SILTST, wh, in irreg contact w/ SILTST, gry (sm brn) in scour mark contact

*Core missing 89' to 89'6" also in the 85 to 89 foot interval.

Plate 5 - 9 94'-104'

94'-94'3" SH, brn, calc, brkn
94'3"-95' SH, gry silty, non-calc, hi angl fract @ 94'7", surf uncoated
95'-98'6" SH, as abv, silty
98'6"-99' SH, dk gry, clayey, carb, non-calc, sft, non silty
99'-101'7" As abv w/ reddish prtings, non silty
101'7"-102'7" SH, trans to silty SH, brn zone
102'7"-103' SH, silty, gry, w/ reddish clayey zone containing minute spks
103'-104' SH, silty, trans to lgt gry, dolc w/ dk layers 38cm wide less than 4^{0} to horiz

Plate 5 - 10 104'-113'4"

104'-104'6" SH, med gry, sli dolc, silty, trans to dker gry
104'6"-105'2" SH, silty
105'2"-106' SILTST, reddish, arg to 105'7"
106'-106'6" SILTST, brn, tr musc, to 106'6" non-calc trans
106'6"-107' SILTST, lgt gry, non-calc
107'-108'3" Hi angl fract
108'3"-109'3" SILTST, wh, rel pure, calc, scour/current marks
109'3"-110'3" SILTST, gry, uniform, massive, becoming dker and variegated calc
110'3"-111' Seam of calcite
111'-111'8" SH, gry, silty, carb, calc, fibrous gyp veinlets
111'8"-112' SH, dk gry, carb, non-calc
112'-113'1½" SH, blk, carb, non-calc, 1mm gyp veinlet @112'7"
113'1½"-113'4" Carb pting, water stands in droplets, to SH, carb, gry-brn

Plate 5 - 11 113'4"-122'1"

113'4"-114'6" SH, hi carb, coaly, blk, non-calc
114'6"-114'11" SH, v/ silty, lgt gry, non-calc, w/ hi angl carb lined fract
114'11"-116'6" SS, silty, lgt gry
116'6"-117' SS, pure, wh, fg, non-calc
117'-120' SS, brn, fg, w/ carb mttling, current bedding planes at 15^{0} to horiz, also sm red mttling
120'-122'1" SS, lgter brn w/ dk layering, gyp veinlet @45^{0} to horiz, dk carb strks mod to hi angl, layers terminate @120'11", abund scour feat

Plate 5 - 12 122'1"-131'1"

122'1"-122'6" SS, gry-brn, non-calc, bdding 15-30^{0} to horiz defined by brn to blk carb layers
122'6"-124' Limon patch 5 x 8 mm
124'-124'9" SS, as abv w/ blk non-calc layers, carb ptings not wettable, lam mm-cm apart
124'9"-126' SS, as abv, but w/ brn lam
126'-127'3" SS, reddish brn w/ current bedding 15^{0} to horiz, dolc cement
127'3"-128'6" SS, as abv w/ gyp lined fract to 127'7"
128'6"-129'1" SS, lgt brn, uniform, non-calc, to 129'
129'1"-129'6" SS, v/ calc, brn fg, w/ gyp in hi angl 70^{0} fract to 129'9"
129'6"-131'1" SS, fg, gry brn, w/ brn lam at hor, non-calc

Plate 5 - 13 131'1"-140'3"

131'1"-132' SS, lgt brn w/ brn lam 0-20^{0} horiz, current bedding, non-calc
132'-132'7" Fract @45^{0} carb coated
132'7"-134' Brn Leisgang patch, limon, oval, non-calc to 132'8"
134'-136' SS, as abv, brn lam 70-35^{0} w/ carb ptings, por, non-calc
136'-137'6" SS, massive, por, sli dolc
137'6"-139'6" COAL, blk, slickensides, blocky, non-wettable, splintery
139'6"-140'3" SH, brn, w/ carb flks, non-calc, tr pyr

Plate 5 - 14 140'3"-148'

140'3"-141' SH, gry-brn, non-calc, w carb flks, tr pyr
141'-142'6" SH, lgter gry-brn w/ red ferrug fract surf, wh spots, non-calc
142'6"-145'9" SH, dk brn, v/ carb to 145'9", non-calc
145'9"-147'5" SH, dk gry, w/ ylwish fract, gyp seam @ 147'6", sli silty
147'5"-148' SH, lgter gry-brn, sli silty, non-calc easily brkn

Plate 5 - 15 148'-157'8"

148'-148'2" SH, dk gry, sli silty, non-calc
148'2"-149'6" SS, fg, gry, dolc, massive, homog
149'6"-153' SS, fg, gry, dolc, current marks defined by dk carb lam
153'-155'10" SS, layered, w/ wh & dk gry layers rich in carb, lam typical of scour in channel fill, lam @ 155'3" blk, horiz, 1.5cm wide
155'10"-157'8" SS, brn, fg-mg, scour marks w/ gry interbeds to 156'7" grns subang, sm w/ minute blk inclus, limon staining, dolc

Plate 5 - 16 157'8"-167'4"

157'8"-160' SS, lgt brn, subang, sli dolc, v/ poorly sorted, massive, dk brn zones around fract, 1cm borders, channel scour marks
160'-161' SS, as abv, dk brn, sli dolc, sm limon stain, channel scour
161'-167'4" SS, as abv, light brn, max qtz grain size 1mm, tr blk chert (?)

Plate 5 - 17 167'4"-176'10"

167'4"-167'10" SS, brn, lam @30^{o} to horiz, v/ sli dolc, por
167'10"- 167'11" SS, as abv, dk brn ferrug zone
167'11"-174'10" SS, brn, massive, fg-mg, poorly sorted, por, non-calc lam 10-40^{o} to horiz, channel scour
174'10"-175'8" SS, as abv, w dk brn patch
175'8"-176'10" SS, gry, calc, fg, w/ silt sizes, w/ irreg dk brn lam

Plate 5 - 18 176'10"-186'2"

176'10"-177'4" SS, calc, fg, w/ silt sizes, calc, oval 6cm patch @ 177'
177'4"-178'7" SS, brn, dk lam @ 24^{o} to horiz, calc, to 178'7"
178'7"-179'10" SS, fg, gry, uniform, calc
179'10"-184' SS, brn, fg, w/ limon lam 5-30^{o} to horiz, sm x-bedding, limon flks, massive, v/ sli dolc
184'-186' SS, brn as abv, limon flks
186'-186'2" Carb layer 1cm thick nr horiz, non-calc

Plate 5 - 19 186'2"-195'7"

186'2"-187'6" SS, brn, w/ limon / carb lam 2-7^{o} to horiz, massive
187'6"-187'10" SS, mg-cs grn, wh feldspar (?) alt, poor sorting, non-calc, por to 187'10"
187'10"-190' SS, fg-mg, brn, sli dolc, w/ brn lam @ 189'6"
190'-190'1" SS, brn-gry, cs, non-calc, por
190'1"-190'11" SS, mg, sli dolc, limon, trans to SS, cs, sli dolc, por @ 190'10" to SS, fg, dk brn @ 190'11", pyr
190'11"-192'10" SS, brn, cs, pyr, limon
192'10"-193'9" Frac, carb, irreg parallel to bedding in SS, brn, sli dolc
193'9"-195' SS, gry, mg, w/ carb lam & flks
195'-195'3" SH, blk, coaly, layers 20^{o} to horiz
195'3"-195'7" COAL, blk, incoh, slickensides

Plate 5 - 20 195'7"-206'4"

195'7"-196'6" COAL, blk, competent, tr marcasite on cleat surf, non-calc, brittle
196'6"-196'10" SS, gry, non-calc, tite
196'10"-197'7" COAL, as abv
197'7"-199'11" COAL, shaley, dk gry, w/ COAL stringer @ 199'7"
199'11"-201'6" COAL, blk, pure, massive, tr marcasite on cleats, non-calc
201'6"-202'8" COAL, dk gry, shaley, competent, non-calc trans
202'8"-204'2" MUDSTN, lgt cream-brn, incoh, non-calc, crumbly
204'2"-206'4" Sharp contact, COAL, sft, slickensides, massive

Plate 5 - 21 206'4"-214'6"

206'4"-208'9" COAL, blk, massive, non-calc, sm marcasite on fract surf
108'9"-209'3" SH, carb, sft, crumbly, dk-med gry
209'3"-212'6" COAL, frag
212'6"-213'6" COAL, as abv, but massive
213'6"-214'6" Vert fract in COAL, as abv

Plate 5 - 22 214'6"-221'4"

214'6"-217' COAL, massive but brkn, slickensides, tr marcasite
217'-217'10" COAL, as abv, but frag to 217'6"
217'10"-218' COAL, trans
218'-219'8" SS, gry, carb, dolc, w rare grn grains, subrndd
219'8"-219'10" SS, brn-gry w/ carb layers outlined by dker brn borders, non-calc
219'10"-221'4" SS, trans to lgt gry, w lgt/dk lam, nr horiz, up to 1cm thk, massive, non-calc

Plate 5 - 23 221'4"-231'6"

221'4"-223'6" SS, tan, var brn, massive, fg, sli dolc
223'6"-223'7" V/ dk brn carb layers 2cm wide nr horiz, non-calc
223'7"-228' SS, tan, fg, sli dolc, massive, por, lam up to 10^{o} to horiz, but predom nr hor
228'-228'6" SS, as abv, lgter brn to cream, as abv
228'6"-230'7" SS, fg, brn, w/ brn lam nr horiz, massive, homog
230'7"-231'6" SS, mttld, closed spaced, lgt brn indist layers, sli dolc, irreg brn layers/lenses/patches nr horiz

Plate 5 - 24 231'6"-241'3"

231'6"-233' SS, lgt brn, fg-mg, trunc bedding, lam up to 40^{o}, non-calc
233'-238'3" SS, fg, gry-brn, homog, por, subrndd grns w/ faint brn lam, nr horiz, tr pyr, v/ sli dolc
238'3"-238'8" SS, w/ dk brn carb seams, 2cm wide, nr horiz, sm @ 15^{o} to horiz, non-calc limon stain
238'8"-239'7" SS, lgt gry-brn, fg, homog, por, sli dolc
239'7"-239'9" SS, w/ blk seams, carb, 9-10^{o} to horiz, tr pyr (?),trans to SS, brn, w/ lgt gry indistinct lam, massive, non-calc
239'9"-241'3" SS, gry, fg, non-calc, por, homog, massive, w/nr horiz dk gry lam

Plate 5 - 25 241'3"-251'

241'3"-241'7" SS, fg, lgt gry-tan w/ gry lam, non-calc
241'7"-242' SS, as abv, w/ wider brn lenses/lam (½cm)
242'-243' SS, lgt brn, fg, tr musc
243'-247' SS, as abv, w/ blk carb irreg seams, massive, tr musc, non-calc
247'-250' SS, fg, dker brn-gry, massive, non-calc w/ mttld irreg blk carb markings, sm circular up to 1cm dia, tr musc
250'-250'8" SS, dk gry, carb, non-calc, thin blk lam parallel to horiz bdding
250'8"-251' SILTST lgt gry, dolc, w/ blk non-mag, wavy, closely-spaced lam

Plate 5 - 26 251'- 260'6"

251'-252'9" SILTST, gry, sli dolc, w/ abund carb partings, rel fissile, easily brkn, abund carb flks in SILTST matrix
252'9"-253' SILTST, wh, w/ dk gry carb lam, wavy, nr parallel to horiz, bedding, SH, dk gry, 1 cm thk, dolc, SS, fg, lgt brn, w/ wavy wisps of dk carb matl, scour feat & x-bdding, dolc
253'6"-259'9" SS, as abv, subrndd grns, lgt brn, fg, w/ carb spks enhanced @ 254'9"
259'9"-260'6" COAL seamlet 3mm wide & irreg patch 1cm dia athwart dk lam to 259'11" in SS, fg as abv, dolc

Plate 5 - 27 260'6"-269'9"

260'6"-264' SS, med gry-brn, fg, massive, channel scour, trunc bdding, non-calc, w/ carb lam 0-15^{o} to horiz, tr pyr nr carb mtl
264'-267' Hi angl fract to 265', sm limon on fract surf
167'-268' SS, as abv, sli more brn, subrndd-subang grns, dolc w/ mm thin carb lam, massive
268'-269'9" SS, as abv, w/ thin carb bedding plate lam at max 25^{o} to horiz, dolc, scour feat, sm pink grns

Plate 5 - 28 269'9"-278'11"

169'9"-273'3" SS, lgt brn-gry, fg, homog, massive, w/ carb wisps, dolc
273'3"-276' Carb patch, 3cm wide, convex upward, parallel to horiz bdding, irreg, in SS, as abv
276'-278'10" SS, as abv, dolc, massive, homog
278'10"-278'11" SH, seam 3mm, carb, parallel to horiz bdding, sft, non-calc

Plate 5 - 29 278'11"-283'6"

278'11"-280' SS, lgt brn-gry, fg-mg, dolc, massive w/ sm hi angl fract, more por
280'-281' SS, as abv, w/ hi angl fract and carb lam up to 15^{o} to horiz, dolc
281'-283'6" SS, brn-gry, homog, dolc, w/ blk spks

Plate 5 - 1 Footage: 8'5"-17'9"

Plate 5 - 2 Footage: 17'9"-27'3"

Plate 5 - 3 Footage: 27'5"- 37'

Plate 5 - 4 Footage:37'-47'1"

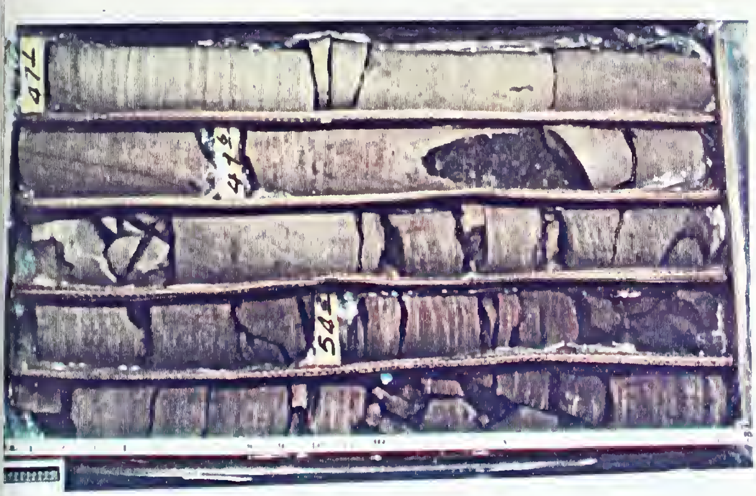


Plate 5 - 5 Footage: 47'1"-57'2"

Plate 5 - 6 Footage: 57'2"-69'

Plate 5 - 7 Footage: 69'-79'

Plate 5 - 8 Footage: 79'-94'

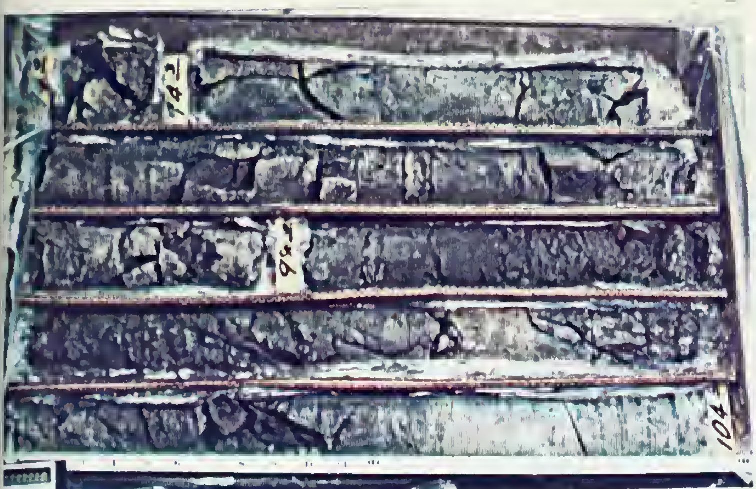


Plate 5 - 9 Footage: 94'-104'

Plate 5 - 10 Footage: 104'-113'4"

Plate 5 - 11 Footage: 113'4"-122'1"

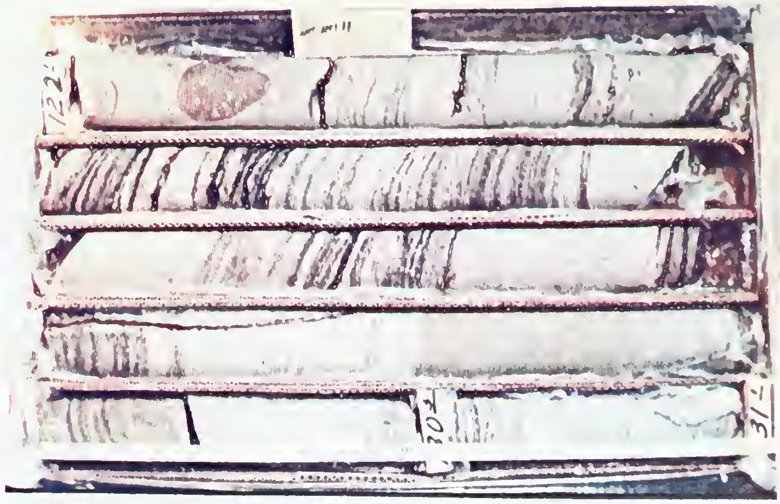


Plate 5 - 12 Footage: 122'1"-131'1"

Plate 5 - 13 Footage: 131'1"-140'2"

Plate 5 - 14 Footage: 140'2"-148'

Plate 5 - 15 Footage: 148'-157'3"

Plate 5 - 16 Footage: 157'8"-167'4"

Plate 5 - 17 Footage: 167'4"-176'10"

Plate 5 - 18 Footage: 176'8"-186'2"

Plate 5 - 19 Footage: 186'2"-195'7"

Plate 5 - 20 Footage: 195'7"-206'4"

Plate 5 - 21 Footage: 206'4"-214'6"

Plate 5 - 22 Footage: 214'6"-221'4"

Plate 5 - 23 Footage: 221'4"-231'6"

Plate 5 - 24 Footage: 231'6"-241'3"

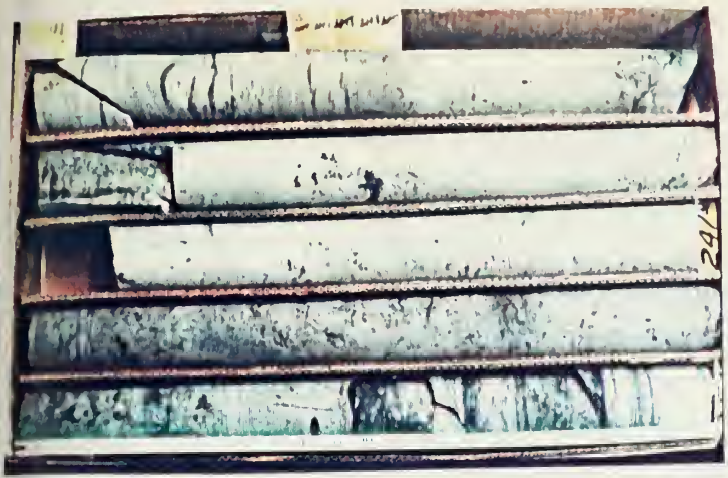


Plate 5 - 25 Footage:241'3"-251'

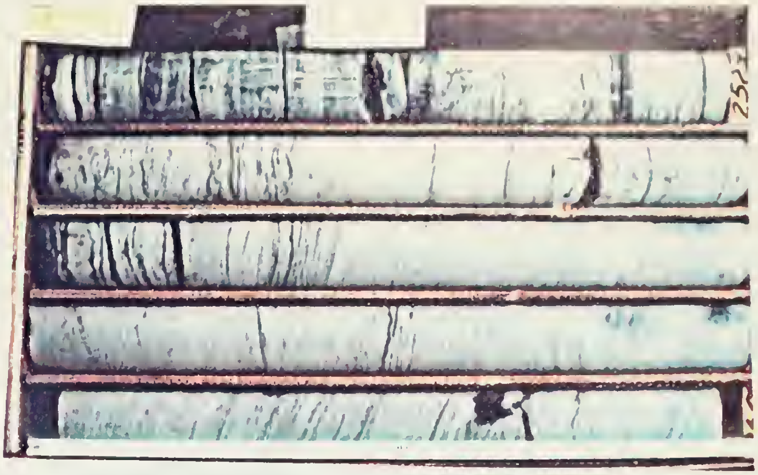


Plate 5 - 26 Footage: 251'-260'6"

Plate 5 - 27 Footage: 260'6"-269'9"

Plate 5 - 28 Footage: 269'9"-278'11"

Plate 5 - 29 Footage: 278'11"-283'6"

Emery EMRIA core hole No. 5a TD 100'
SE 1/4 sec 3 T.23 S., R. 6 E.
(logged by J. Green, 1978)

Plate 5a - 1 10'-30'
There is only 9' of core in the box - no record of missing interval; box contains mostly cylst; 2 thin carb layers; top 1' ss, f-gr, tan (weathered)

Plate 5a - 2 30'-40'
30'-30'9" cylst, slty, carb
30'9"-37'6" sltst, grading rapidly upward to ss, vf-gr, tan and gry, w/ some interbedded sdy sltst; wavy-lam; a few possible burrows; rooted (overbank splay deposit?)
37'6"-40' cylst, slightly slty, some sltst as below

Plate 5a - 3 40'-50'
cylst, slightly slty w/ a few beds of cly sltst up to 0.3' thick in upper 3'

Plate 5a - 4 50'-60'
50'-52'5" sltst w/ detrital plant frags
52'5"-54'3" coal grading up to 0.3' of coaly sh at top
54'3"-56' sltst; sdy in middle part; a few possible burrows
56'-56'6" clyst, slty
56'6"-57'7" ss, vf-gr, interlam w/ sltst; wavy-lam
57'7"-60' cylst, slightly slty

Plate 5a - 5 60'-70'
60-60'9" coaly sh
60'9"-70' ss, fines upward from f-gr to vf-gr w/ cylst lam, wavy contorted lam w/ carb detrial plant debris

Plate 5a - 6 70'-80'
70'-70'4" ss, f-gr; sharp basal contact
*60'9"-70'4" is an upward-fining small channel sequence
70'4"-78'4" sltst, cly w/ coaly frags grading up to sltst, sdy, wavy-lam, burrowed, gradibg up to coaly sltst at top

Plate 5a - 7 80'-90'
There is 9' of core in the box - probable loss of some coal
80'-87'3" coal (I coal)
87'3"-90" ss, vf-gr, rooted; top 0.3' is carb sltst

Plate 5a - 8 90'-100'
There is only approx. 7'5" of core in the box
90'-90'3" clyst, slty
90'3"-92'1" ss, vf gr, slty, laminae of sltst and clyst, detrial plant frags; a few rootlets; a few possible burrows
92'1"-100' core probably missing from this interval: clay, soft; lowermost 1' slty, harder

Plate 5a - 1 Footage: 10'-30'

Plate 5a - 2 Footage: 30'-40'

Plate 5a - 3 Footage: 40'-50'

Plate 5a - 4 Footage: 50'-60'

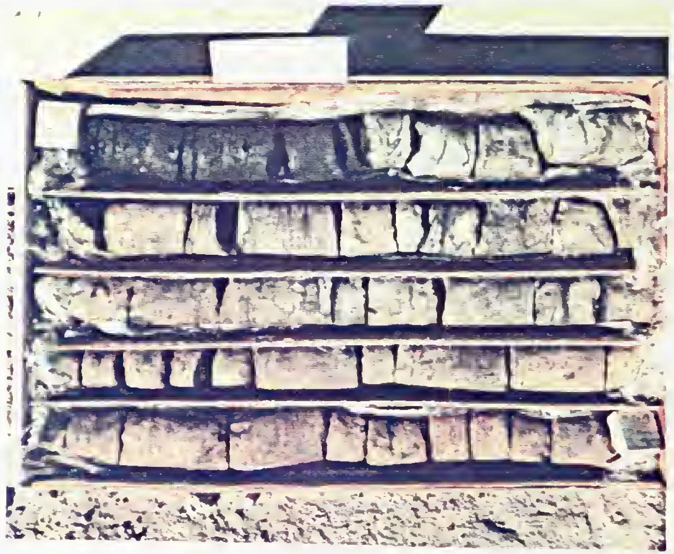


Plate 5a - 5 Footage: 60'-70'

Plate 5a - 6 Footage: 70'-80'

Plate 5a - 7 Footage: 80'-90'

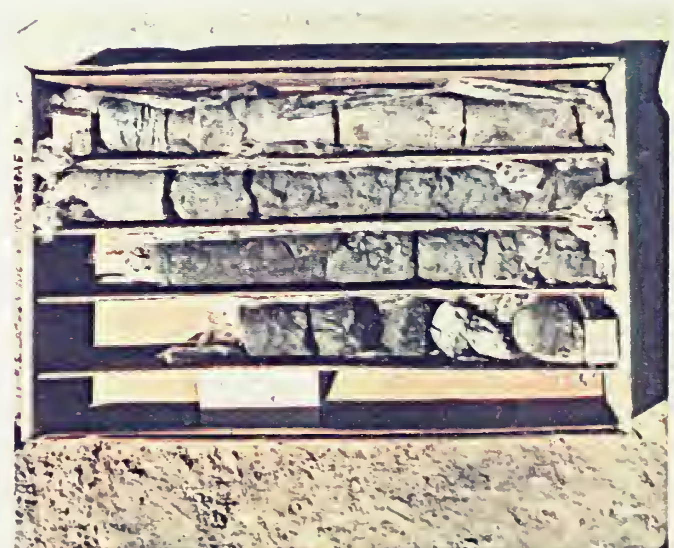


Plate 5a - 8 Footage: 90'-100'

Emery EMRIA core hole No. 6   TD348'9"
NE 1/4 sec   T. 5 S., R. 6 E.
(logged by J. Green, 1978)

Plate 6 - 1 7'-17'5"
7'-9'5" SS & SH, interbedded, intense weathered, lgt brn, to gry-brn w/ caliche and abund. roots
9'5"-14' SH, dk lam, intense weathered, lst brn, vfg-fg w/ abund. roots
14'-17'5" SH, thin interbedded clayey SS, brn

Plate 6 - 2 17'5"-28'
17'5"-20'3" SH, w/ thin interbeds of clayey SS, lgt brn and gry-brn, intense weathered, vfg-mg, (graded) w/ roots and stalks, clay-lined fracts
20'3"-25'10" SS, lgt brn to gry-brn, mod weathered, v/sli fract, mg-coarse g, well sored, subang-subrndd grains
25'10"-27'11" SS, w/ layer of granule-sized grains, low angle x-bding
27'11"-28' SS, lgt brn, homog, massive

Plate 6 - 3 28'-37'7"
28'-29'1" SS, lgt brn, well sorted
29'1"-30'10" SS, w/ sm granule-sized grains, w/ scattered coal frag.
30'10"-35' SS, as next abv, becoming dns - mod hrd.
35'-37'7" SS, as abv, bedding @5-7^{0}

Plate 6 - 4 37'7"-46'9"
37'7"-45' SS, lgt brn-gry brn. sli to mod weathered mod hd, mg coarse g, well sorted, mod to porrly cemented
45'-46'6" SS, as abv, bedding @5^{0}
46'6"-46'9" SS, as abv.

Plate 6 - 5 47'-56'
47'-48'8" SS, red brn layer, as abv, hd w/ carb seam
48'8"-51' SS, brn to red-brn w/ thin ½-5cm alt. carb seams
51'-53'11" COAL, bitum, blk, fresh sli to mod fract, w/ few seams sulfides, hd
53'11"-54'2" SH, clayey, sft to 54'2"
54'2"-55' COAL, as abv.
55'-56' COAL, fract.

Plate 6 - 6 56'-65'4"
56'-57' COAL, as abv, sli por, sft @ bottom contact
57'-59'11" SS, SILTST, vfg, w/ clay strks, lagt to dk gry, fresh, v/sli fract
59'11"-62' SS w/ layer clayey SH, slickensides, brkn to 60'5"
62'-63'6" SS, dk gry, w abund slump struct & thin seams carb & sulfide (marcasite)
63'6"-65'4" SH, lgt-dk gry, silty & sdy, poorly lam.

Plate 6 - 7 65'4"-74'7"
65'4"-70' SH, silty, sdy, lgt to dk gry, fresh, sli fract, checks & crumbles when exposed to air, poorly lam w/ few strks sulfides becoming mod hd.
70'-71' SH, dk gry, as abv
71'-72'2" SH, as abv, w/ marcasite xls
72'2"-74'7" SH, dk gry-brn, w/ clayey slickensides along bdding @ 5^{0}

Plate 6 - 8 74'11"-84'6"
74'11"-77' SH, gry, w/ abund scat frag COAL
77'-80'10" SH, gry, w/ few random thin COAL lenses to 80'
80'10"-82' SH, carb, w/ calcite-filled fract w/ increase of vfg sd strks
82'-84'6" SS, silty, lgt gry, sm fract

Plate 6 - 9 84'6"-94'
84'6"-87' SS, silty, lgt gry, fresh, v/sli fract to unfract, mod hd to hd, med massive
87'-91'11" SS, as abv, w/ abund x-bdding, ripple and slump struct and w/ abund strks carb
91'11"-92'8" SS, w/ hd cemented concretions (phosphate) to 92'1"
92'8"-92'9" SS, lgt to dk gry (mttld) fg, well cemented, hd, wavy to concentric fract
92'9"-94' SS, brn, as abv to 93'3"

Plate 6 - 10 94'-102'7"
94'-99' SS, layered, fg, lgt-dk gry (mttld)
99'-102'7" SS, as abv, w/ abund x-bdding & convoluted slump struct

Plate 6 - 11 102'7"-112'4"
102'7"-105' SS, cream-gry layered, as abv, w/ freq seams & lenses carb matl
105'-109'1" SS, grading to SILTST, dk gry, vfg, w/ abund phosphatic nodules, w/ convoluted SS strks
109'1"-112'4" COAL, blk, massive, sm slickensides, bitum, fresh

Plate 6 - 12 112'4"-121'8"
112'4"-115'6" COAL, blk, bitum, fresh, sli to mod fract, alternately grading por to dns, hd, clean
115'6"-117'8" COAL, locally oily
117'8"-120' COAL, w/ layer carb, slt dk brn, in part alt to COAL to 118'3"
120'-121'8" COAL, as abv

Plate 6 - 13 121'8"-131'9"
121'8"-122'8" COAL, blk, bitum, clean, v/fract between 120'5" & 122'
122'8"-125' COAL, w/ layer carb SH
125'-127' SS, silty, vfg-mfg, firm, hd, lgt gry, fresh, well cemented sli to unfract
127'-127'7" SS, w/ clayey SH seam to 127'7"
127'7"-131' SS, as abv, grading to SS, carb @ 129'9"
131'-131'9" SH, coaly, blk

Plate 6 - 14 131'9"-141'
131'9"-133'9" SILTST, sky, vfg-fg, dk gry, fresh, mod hd to hd, poorly bdd-massive
133'9"-135' SILTST, w/ slickensided fract @ 35^{o}-45^{o} to 134'3"
135'-139' SILTST, as abv, dns, well indurated, locally sm concretions
139'-141' SILTST, dk gry, w/ few irreg clay seams

Plate 6 - 15 141'-150'5"
141'-145'1" SILTST, sky, as abv, w/ increasing sfter clayey SH zones, apparent bdding @ + 5^{o}
145'1"-145'10" SILTST, w/ hd cemented brkn layer of SS, open-gyp filled fract
145'10"-150'5" SS, vfg-mg, lgt-dk gry, fresh hd, w/ carb strks

Plate 6 - 16 150'5"-160'1"

150'5"-151' SS, vfg-mg, lgt to dk gry, fresh, hd, w/ stratified thin irreg strks & lenses carb mtl

151'-154' SS, w/ hd, brkn nodules w/ secondary calcite

154'-158' SS, as abv, alternately grading to SILTST, w/ local hd cemented concretions, brn to gry brn, ½ to 10cm dia

158'-160'1" SS, as abv w/ few scat irreg lenses COAL carb SH

Plate 6 - 17 160'1"-169'7"

160'1"-161' SS, brn, w/ lenses carb SH

161'-164' SS, as abv, w/ apparent bdding @ 2-5^{o}

164'-167'6" SS, locally calc, lgt brn-gry, mod hd vfg

167'6"-169'7" SS, dk gry, carb w/ clayey SILTST, fract w/ slickensides @ 35-45^{o}

Plate 6 - 18 169'7"-178'6"

169'7"-170'5" SILTST, dk gry, arg, carb, brkn

170'5"-171'6" SS, brn, fg massive

171'6"-173' SS, brn, w/ calcite filled fract @ 55^{o}

173'-175' SS, w/ increasing calc zones

175'-176' SS, vfg-mg, hd

176'-178'6" SS, w/ few random turbidity & slump struct

Plate 6 - 19 178'6"-188'

178'6"-184' SS, fg-mg, v lgt gry, fresh, mod hd, massive, unfract, clean uniform grained

184'-188' SS, as abv, w/ abund scat frag of COAL & carb mtl, homog, massive

Plate 6 - 20 188'-197'2"

188'-189'10" SS, lgt brn, homog, massive, carb lam, w/ interbed strat @ 55^{o}

189'10"-194' SILTST, sdy gry to dk gry, fresh, mod hd, locally sft & clayey w/ slickensided surf

194'-197'2" SILTST, w/ irreg layers & nodules of v/hd cemented SS, vfg, brn

Plate 6 - 21 197'2"-205'9"

197'2"-199' SILTST, sdy, dk gry, w/ irreg layers/nodules v/hd SS, gry-brn

199'-203' SILTST, as abv w/ few random scat frag COAL

203'-205'9" SILTST, grading to carb SILTST, sli fissile

Plate 6 - 22 205'9"-215'1"

205'9"-206'11" COAL, blk, fresh, mod hd, claen, v/sli fract

206'11"-208'10" SILTST, gry carb

208'10"-209'4" SILTST, gry, w/ slickensided clay seam @ 45-50^{o}

209'4"-210'1" SILTST, as abv

210'1"-210'9" SILTST, as abv, w/ irreg lenses COAL to 210'9"

210'9"-215'1" SILTST, as abv, grading to fn silty SS w/ abund scat COAL frags

Plate 6 - 23 215'1"-224'6"

215'1"-217' SS, silty, vfg-fg, carb lm

217' 219'6" SS, as abv, w/ clayey, carb SILTST, dk gry, as interbdd coalescing lenses & layers, mod hd, sli fract, bedding @ 4-5^{o}

219'6"-220'2" SS, as abv, w/ thin irreg COAL seam to 220'2"

220'2" 224'6" SS, silty, vfg-fg, lgt gry, fresh, hd, unfract

Plate 6 - 24 224'6"-234'2"
224'6"-224'10" SS, silty, vfg-fg, lgt gry, w/ scat frag COAL & strks SS, fg-mg
224'10"-225' SILTST, seam, clayey to 225'
225'-226' SS, as next abv
226'-230'2" SILTST, lgt to dk gry, fresh, hd, v/sli fract to unfract, massive
230'2"-231'6" SILTST, as abv, w/ irreg seams/lenses of carb SILTST & COAL frag to 231'6"
231'6"-234'2" SILTST, as next abv

Plate 6 - 25 234'2"-243'10"
234'2"-237' SILTST, as abv, w/ few scat fin xls of gyp
237'-241' SILTST, locally clayey
241'-243'10" SILTST, alternatingly grading to carb SILTST & clayey SH, dk gry to gry-blk

Plate 6 - 26 243'10"-253'7"
243'10"-244'10" COAL, blk, clean, mod hd, v/ sli fract
244'10"-252' SILTST, sdy, clayey w/ alternating layers of SILTST, sdy v/ lgt gry to dk gry, fresh, fissile (shaly) sft to mod hd
252'-253'7" SH, w/ freq thin lenses sdy SH, sft to mod hd

Plate 6 - 27 253'7"-263'4"
253'7"-255' SH, clayey, w/ alternating layers sdy SILTST & shell debris
255'-256' SH, as abv, w/ lenses of COAL frag
256'-261' SILTST, gry to dk gry, fresh, thinly bdd, med hd to hd, sli fract
261'-263'4" SILTST, as abv, w/ frag random, thin interbds & lenses sdy

Plate 6 - 28 263'4"-272'10"
263'4"-264'8" SILTST, gry to dk gry, layered, hd, sli fract
264'8"-267' SILTST, as abv w/ scat xls & lanses of marcasite (?) to 265'2"
267'-271' SILTST, w/ freq gradations & irreg lenses carb SILTST, dk gry to gry blk, mod hd
271'-272'10" SILTST, dk gry, as abv, w/ layers sdy SILTST, carb & oily

Plate 6 - 29 273'10"-282'10"
273'10"-275'6" SILTST, gry w/ layers of sdy SILTST, oil stained (?) w/ thin strks marcasite xls, sm few scat frag shell debris
275'6"-282'10" SILTST, gry, w/ increasing COAL bearing lenses in SS, fg-mfg

Plate 6 - 30 282'10"-292'4"
282'10"-283'4" SILTST, and interbdd sd bds w/ abund COAL & oily residue, layers of shell and coal frag
283'4"-285'2" COAL, bitum, blk fresh, mod hd, sli fract @ 50-75^{o}
285'2"-288' SILTST, interbds, lgt gry, mod hd to 285'4", SILTST as abv 286'1-3", SILTST, as abv, 287'3-10"
288'-292'4" COAL, clean, grading por to dns, unfract to v/sli fract

Plate 6 - 31 292'4"-301'
292'4"-292'11" COAL, as abv
292'11"-294'11" COAL, fract & brkn @ lower contact, nr vert fract
294'11"-299' SILTST, sdy & SS, silty, vfg-fg, irreg coalescing lenses/ layers, lgt-dk fry, fresh, mod hd, indurated w/ minor cement
299'-301' SILTST, as abv, w/ abund lenses & scat frag COAL & carb SH

Plate 6 - 32 301'-311'

301'-307' SS, vfg-mfg, v lgt gry to gry wh, fershly thkly bdd to massive v/sl fract

307'-311' SS, as abv, w/ freq irreg scat seams & frag of COAL & SILTST, carb w/ random pyr and/or marcasite mineralization

Plate 6 - 33 311'-320'3"

311'-316'6" SS, lgt brn, w/ abund grains & strks carb mtl @ 316'6", bdding @5-7°

316'6"-318'10" SS, as abv, w/ increasing abund pods/frags SILTST

318'10"-319'10" SS, brn, por along bdding, @ ± 20-22°

319'10"-320'3" SS, gry, fg, w/ carb patches

Plate 6 - 34 320'3"-329'9"

320'3"-322'4" SS, lgt brn, homog massive

322'4"-328' SS, as abv, w/ increase in marcasite & pyr mineralization within frag/seams SILTST

328'-328'3" SS, as abv & few scat shell frag

328'3"-328'11" SILTST, clayey w/ lg xls pyr to 329'11"

328'11"-329'9" SS, lgt brn as next abv, massive

Plate 6 - 35 329'9"-339'3"

329'9"-330'2" SS, lgt brn, fg

330'2"-333'10" SS, as abv, w/ abund frag (up to 7 cm) SILTST

333'10"-336'6" SS, as abv, w/ 5-7 cm seams SILTST & lg xls pyr @ 335'2" & 335'

336'6"-339'3" SS, brn, w/ carb patches

Plate 6 - 36 339'-348'9"

339'-344' SS, lgt brn, w/ dk brn-blk carb ptings w/ abund scat lg frag shells

344'-348'9" SS, fg, as abv, few random carb SILTST frags

Plate 6 Box 1
Footage: 7' - 17'5"

Plate 6 Box 2
Footage: 17'5" - 28'

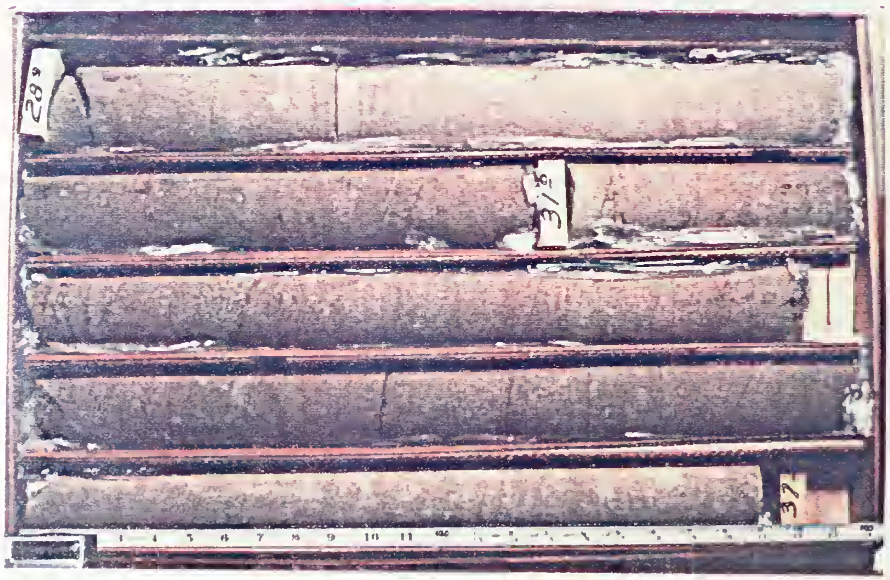


Plate 6 Box 3
Footage: 28' - 37'7"

Plate 6 Box 4
Footage: 37'7" - 46'9"

Plate 6 Box 5
Footage: 47' - 56'

Plate 6 Box 6
Footage: 56' - 65'4"

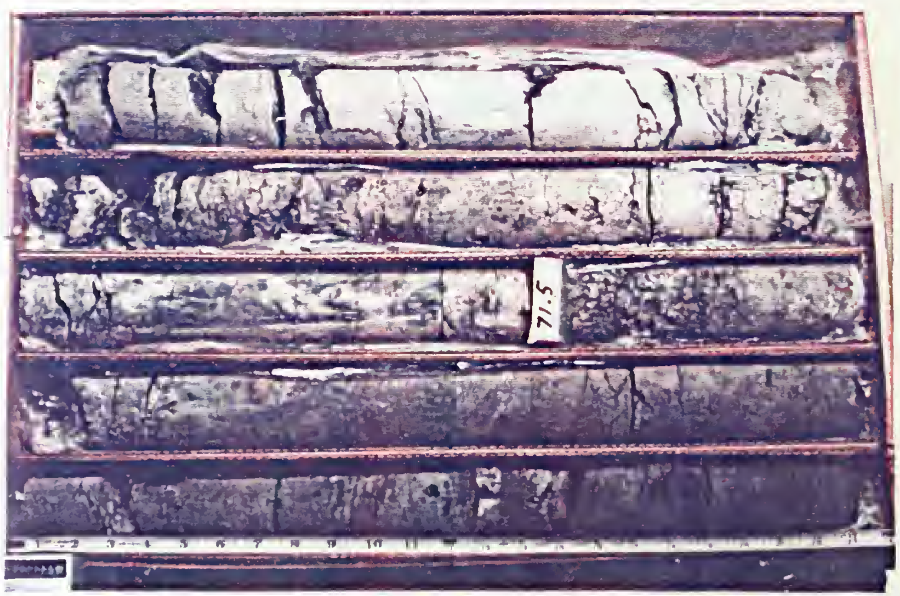


Plate 6 Box 7
Footage: 65'4" - 74'7"

Plate 6 Box 8
Footage: 74'11" - 84'6"

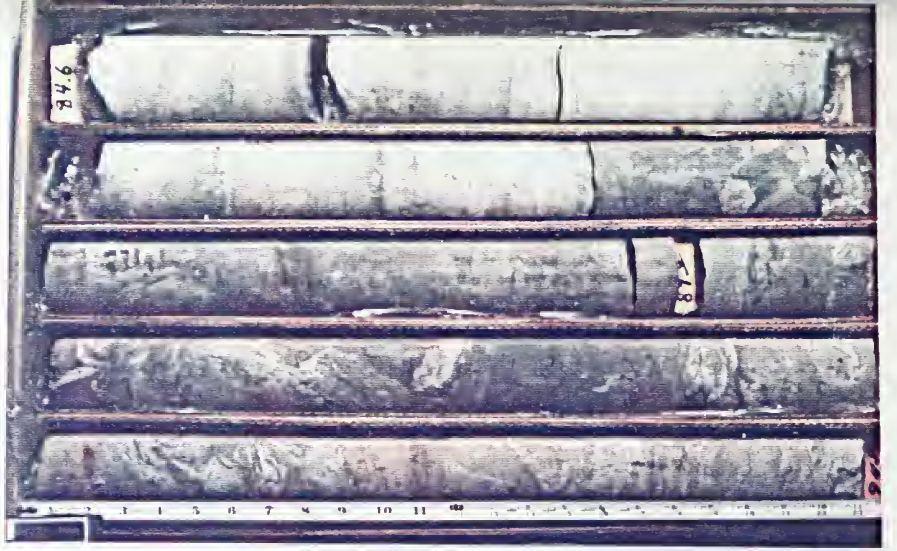


Plate 6 Box 9
Footage: 84'6" - 94'

Plate 6 Box 10
Footage: 94' - 102'7"

Plate 6 Box 11
Footage: 102'7" - 112'4"

Plate 6 Box 12
Footage: 112'4" - 121'8"

Plate 6 Box 13
Footage: 121'8" - 131'9"

Plate 6 Box 14
Footage: 131'9" - 141'

Plate 6 Box 15
Footage: 141' - 150'5"

Plate 6 Box 16
Footage: 150'5" - 160'1"

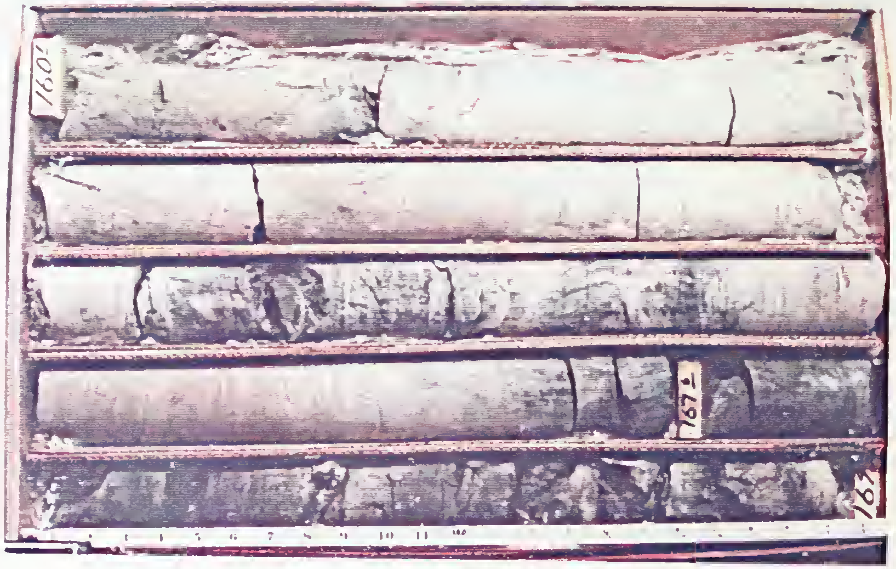


Plate 6 Box 17
Footage: 160'1" - 169'7"

Plate 6 Box 18
Footage: 169'7" - 178'6"

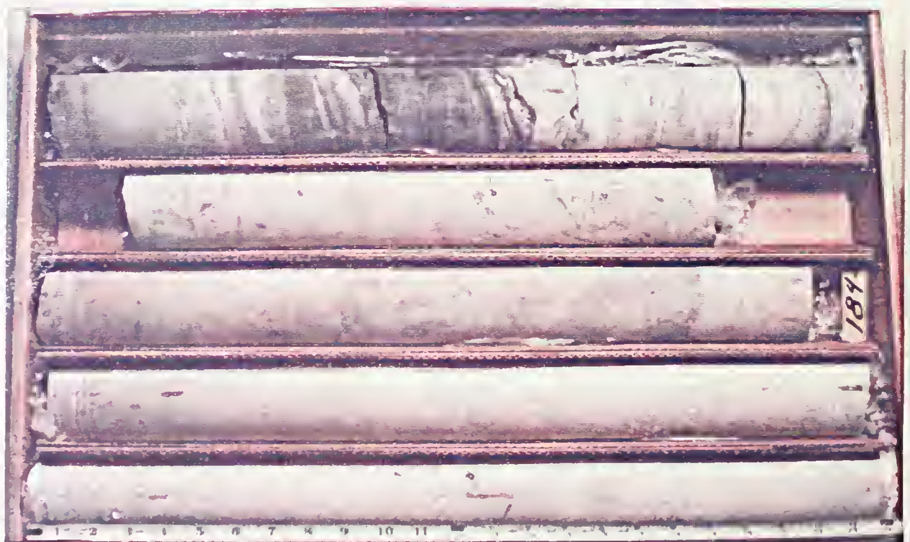


Plate 6 Box 19
Footage. 178' - 188'

Plate 6 Box 20
Footage: 188' - 197'2"

Plate 6 Box 21
Footage: 197'2" - 205'9"

Plate 6 Box 22
Footage: 205'9" - 215'1"

Plate 6 Box 23
Footage: 215'1" - 224'6"

Plate 6 Box 24
Footage: 224'6" - 234'2"

Plate 6 Box 25
Footage: 234'2" - 243'10"

Plate 6 Box 26
Footage: 243'10" - 253'7"

Plate 6 Box 27
Footage: 253'7" - 263'4"

Plate 6 Box 28
Footage: 263'4" - 272'10"

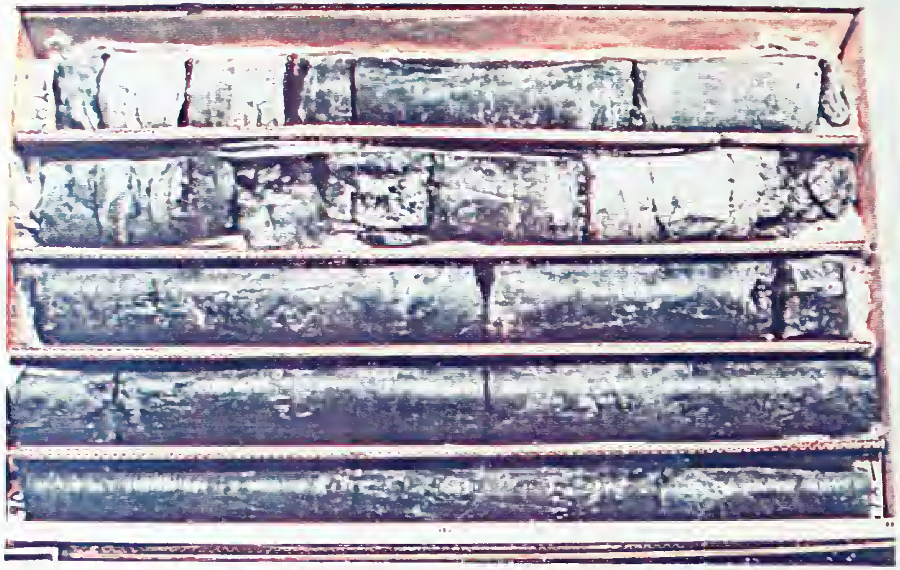


Plate 6 Box 29
Footage: 273'9" - 282'10"

Plate 6 Box 30
Footage: 282'10" - 292'4"

Plate 6 Box 31
Footage: 292'4" - 301'

Plate 6 Box 32
Footage: 301' - 311'

Plate 6 Box 33
Footage: 311' - 320'3"

Plate 6 Box 34
Footage: 320'3" - 329'9"

Plate 6 Box 35
Footage: 329'9" - 339'3"

Plate 6 Box 36
Footage: 339'3" - 348'9"

APPENDIX 10

Minor Trace Elements Geochemistry

Arsenic (As)

Arsenic in normal soils ranges from 1 to 40 ppm and is 10 ppm dry weight in most plant species. The element is particularly concentrated by Pseudotsuga menziesii (Douglas Fir), which is found only at elevations above 9000' in Utah (Warren et al., 1968). Average As values for the Ferron formation (Affolter et al., 1978 - Table) are on the order of 10 ppm. One sample of coaly shale (D200632) at a depth of 64.6 - 64.9 meters has the highest As value measured in the study, 54 ppm. However, this sample is deep in the section (some 30 meters below the I seam) and would not be exposed in the area to be reclaimed unless strip mining continues down to the C seam. As values in the Ferron sandstone above the I seam are less than 15 ppm and for three samples taken above the I seam in bore hole #6 average 11 ppm. Even this value is considered to be high. Toxicity depends on soluble arsenites not total As concentrations. Estimates of As toxicity vary widely; for example seafood can contain as much as an order of magnitude higher values than most soils.

Bromine (Br)

Bromine levels in normal soil range from 10 to 40 ppm. No problem appears to exist in the Emery area although we would recommend a test run for the bromine anion in soil units high in other "volatile" species such as selenium.

The average for 15 water quality analyses for bromide by the USGS (1979) is .40 ppm, with most values being less than 1.0 pp. The high standard deviation results from the following three values (in ppm Br):

13 ppm Blue Gate Well #1 (D-21-7) 4 AAC-1
20 ppm (D-20-8) 22 CAA SRU-5 413 Seismic Test
20 ppm SRU-9 Site 943 Seismic Test Hole

Possibly some leachable Br can collect in the residual water of seismic test holes. We do not know if the explosive charge contributed to the high bromine content.

Cadmium (Cd)

The chloride, nitrate, and sulfate of cadmium are highly soluble. Cadmium concentrations similar to mercury, are cumulative in animal tissues. The amount of cadmium in nutrient solutions (0.2 ppm) causing growth retardation in the most sensitive plants (beets, beans and barley) is far above ammonium bicarbonate DTPA extractable cadmium in Emery overburden materials (Heil and Deutsch, 1979) with the exceptions of some coal samples. In the case of bore hole #6, high Cd values occur in the top of a larger coal seam (Figure). Of significance is the corresponding increase in selenium and other volatiles and molybdenum, as well as aluminum and nickel relative to the enclosing sandstones. These high values do not appear as major anomalies in the lower associated coals.

In contrast to soluble Cd, the total Cd in ashed coal samples (Affolter et al., 1978) is an order of magnitude higher, reaching 8 ppm in certain Ferron sandstone coal seams (sample D200650). However, accompanying or sympathetic increases in Fe and Mo are not present.

It appears the Cd toxic levels are no problem. Upper portions of coal seams contain high concentrations of elements whose effects can be beneficial if properly diluted into a resultant soil cover.

Chlorine (Cl)

Chloride concentrations in irrigation water in excess of 1300 ppm Cl produces defoliation, ideback, chlorosis, bronzing and burning in sensitive crops such as citrus. Although most of the dissolved chloride in the 24 water samples analyzed by the USGS (1979) is far less than this value, the average is 4.9 with a standard deviation of 0.84. The Cl concentration in a few samples is extremely high:

Chlorine Values in Emery Area Streams and Wells (USGS, 1979)

1. D-21-6 35AAC Blue Gate Well #3	4100ppm
2. D-20-8 22Caa SRU-5 413 Seismic Test	2200 ppm
3. SRU-9-919 D-19-8 4DBC	1400 ppm

High chlorine values are not necessarily indicated by high conductivities. In bore hole #3 conductivity decreases with depth. Near surface values approximate 17 mhos dropping to about 5mhos at 210 feet. However, bore holes 4 and 5 show abrupt conductivity spikes at 95 and 145 feet (16.5 and 16 mhos) respectively. The high conductivity is probably attributable however, not to salty water, but probably marcasitic coal leachates.

Chromium (Cr)

Although some crops such as barley are sensitive to Cr, most can tolerate levels over 15 ppm in solution. To animals, the hexavalent form is more toxic than trivalent. The highest Cr value in analyzed stream waters is .02 ppm in Christiansen Wash (USGS, 1979). Heil and Deutsch's maximum value of 0.11 ppm Cr is in sample 6-14 with an average of .03 ppm. Ashed coal from the Ferron formation (Affolter et al., 1978) shows a wide variation in Cr ranging from 4.4 to 75 ppm. The latter anomaly occurring at about 188 feet in bore hole #6 in a coaly shale layer within the I seam. As with Cr in soils and sagebrush ash from the Powder River Basin (Connor et al., 1976), values of 75 ppm are not unusual. Only a small fraction of this Cr is water soluble.

Cobalt (Co)

Because of the low levels of Co that normally exist in rocks and soils, excess of Co is rare. The element is not reported in crushed rock extracts (Heil and Deutsch, 1979) or in water (USGS, 1979) in the Emery area. The maximum value of Co in ashed coaly shale from the Ferron formation at a depth of about 197 feet is 8.9 ppm. The sample (D200639) is from a stratum overlying the combined A and C coal beds (Affolter et al., 1978).

Fluorine (F)

F is generally a problem only in acid soils and offers no hazard in the Emery area. Uptake is not a function of the total F content in soil but pH, and the Ca and P concentrations. The average F concentration in 12 shale samples from the Ferron sandstone is 430 ppm with a range of 240 to 850 ppm (Affolter et al., 1978). No F values are given by Heil and Deutsch (1979). Water soluble F is less than 0.7 ppm with the exception of a 2.3 value for a water sample collected from the back of the Consolidated Coal Mine.

Iodine (I)

Toxic levels of I in nutrient solutions are in excess of 1 ppm. No data are available for Emery waters, soils and ash, or from rocks, soils or sagebrush.

Lead (Pb)

Since plants can take up to 350 ppm Pb (in the ashed stems) without showing adverse effects (Shacklette 1960) and since all Pb concentrations (including ashed samples) in the Emery area samples are below 100 ppm, no hazard to plants is forseen. The water analyses (USGS, 1979) do not report Pb but are assumed to be less than 0.2 ppm Pb^{+2}.

Lithium (Li)

As with lead, naturally occurring instances of lithium toxicity to plants are rare except for citrus which is sensitive to Li. The average Li content for 20 Ferron coal samples is 23 ppm; in 12 Ferron shales, it is 88 ppm. The maximum amount of dissolved lithium occurs in Christiansen Wash and is 0.37 ppm.

Mercury (Hg)

Mercury in animals and plants is believed to be mostly organic (mostly methly Hg) derived by converison of inorganic Hg to methyl or dimethyl Hg by anaerobic bacteria in the bottom muds of streams. Since the USGS water quality analyses do not report Hg, no interpretation on this potentially toxic element is presented. The arithmetic mean of total (inorganic) Hg in 12 Ferron shales is 0.32 ppm. The pot tests by Heil (1979) do not cite Hg.

Nickel (Ni)

Soil developed from basaltic greenstones are very high in Ni (50 to 75 ppm) with plants growing on this base reaching concentraitons of from 50 to 75 ppm. Normal Ni contents of plants growing on typical western U.S. soils range from 0.1 to 5 ppm. Toxicity of Ni in plants does not exist even at the higher concentrations present on greenstone soils. The range of Ni values reported hy Heil and Deutsch are from 0.4 to 10 ppm; the latter maximum value also being the average in 12 Ferron shales cited by Affolter et al., 1978.

Thallium (Tl)

Thallium is a highly toxic element to animals when exceeding 700 ppm in an assimilate form. One authority states that artificially applied Tl to soils can be taken up by plants with toxic soil levels being 35 ppm. However, this statement is too general since much higher levels of Tl have been found in Rock Mountain region plants. In general Tl concentrations reported in the literature appear to be below 10 ppm in most plants analyzed in this region. Tl levels are very low in Emery area substances, below the 100 ppm detection limit in ashed shale and coal samples of the Ferron formation.

Tin (Sn)

Sn is a non-essential non-toxic element in plants. Soils and nutrient solutions containing up to 40 ppm available Sn do not adversely affect plant growth. No toxicity to mammals is reported unless in the plus 1000 ppm range. Fish die in water containing 100's of ppm Sn. Sn concentrations is ashed Ferron shale/coal in the Emery area below the minimum detection limit of 20 ppm.

Vanadium (V)

Although certain plant species can grow in soils containing over 100 ppm, they exhibit dwarfing and chlorosis. One authority recommends a limiting value of 0.5 ppm V in nutrient solutions for optimum plant growth. Toxic values in small animals are 25 ppm. The total V conventration in Ferron shales averages 50 ppm well below that of the "average" shale; in coal the V average is 7 ppm.

APPENDIX 11

Laboratory Analyses and Procedures

LABORATORY ANALYSES AND PROCEDURES

Moisture Retention was determined by ceramic plates (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 29, 30 and 31:109-110).

Particle-Size Analyses were determined by pipeting analysis (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 41:122-124).

Disturbed Hydraulic Conductivity was determined by the use of plastic tubes (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 34b:112-113).

pH of 1:15 Soil Suspension (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 21b:102), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3,4:922-923) and (Bear, et al., Chemical of Soils, 1964).

pH Reading in $CACl_2$ Solution (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.5:923).

Saturation Extract taken from saturation soil paste using Bariod filter press and measuring soluble salts by use of electrode conductivity bridge (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 2 and 3:84-88, 2?:107 and 4:89-90), C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-1:933-988) and (Bear, et al., Chemical of Soils, 1964).

Carbonates and bicarbonates were determined by acid titration and chlorides were determined by the Mohr volumetric method (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 82:145-146 and 84:146), C. A. Black, et al.,

Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-3.4.1:945-947 and 62-3.5.1:947-948), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition, for carbonate and bicarbonate only 102:52-56), (Bear, et al., Chemical of Soils, 1964), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory analysis for chloride only, p. 69).

Sodium, Potassium, Calcium and Magnesium were determined by atomic absorption (Perkin-Elmer, Analytical Method for Atomic Absorption

Spectrophotometry, 1973) and Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 66, 109, 133 and 143).

Nitrate was determined by phenoldsulfonic acid (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 15:100), (C. A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy 84-5.3:1216-1219) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition, 133:233-237).

Exchangeable Sodium and Potassium were extracted by ammonium acetate solution. Cation-Exchange Capacity was extracted by ammonium acetate and sodium acetate (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 18:100-101 and 19:101) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 72-3:1033, 72-3.2.1:1033-1034 and 57-1:891-895).

Exchangeable Sodium Percentage was determined by calculation (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 20a:101).

Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 22c:104).

Gypsum Requirement (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 22d:104-105).

Boron was determined by extracting with hot water (Bear, et al., Chemical of Soils, 490-494) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 75-4:1062-1063).

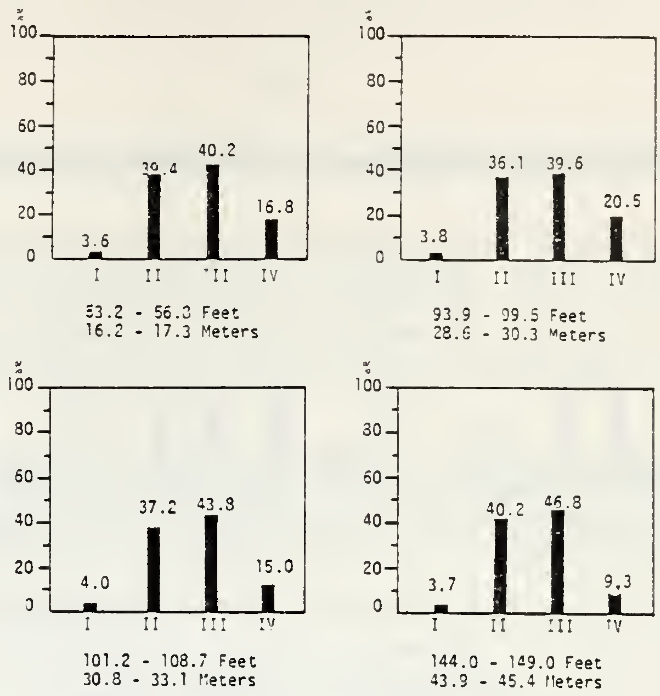
Trace Metals were determined by atomic absorption either by flame or graphite furnace (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, Book 5 - Laboratory Analysis, 50-157) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition).

Organic Carbon - The Walkley-Block method is used, and diphenylamine is the indicator. (Methods of Soil Analysis, Part 2, Agronomy No. 9 American Society of Agronomy 90-3:1372-1375).

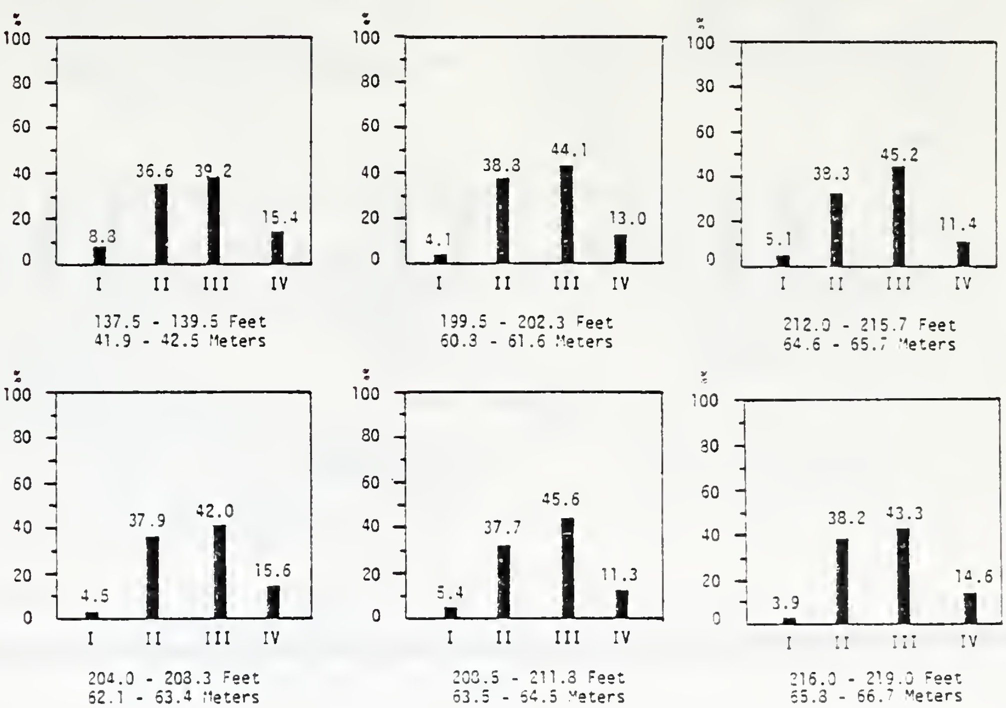
Bulk Density - Clod method. Density measured by water displacement. (Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 30-4:381-383).

APPENDIX 12

Coal Analyses



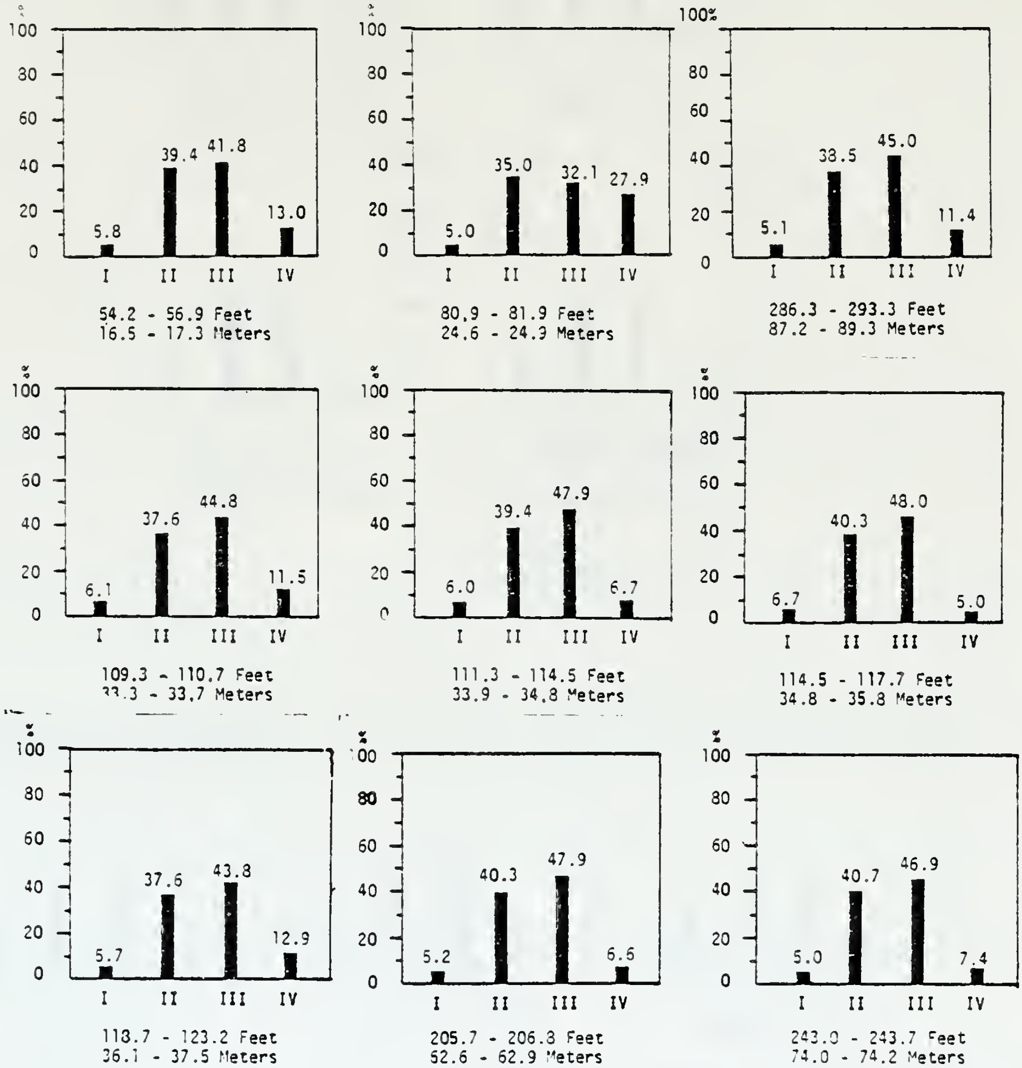
Proximate Analysis of Coal as Received. Bore Hole # 4a.
Key -
Moisture
.. tile Matter
III - Fixed Carbon
IV - Ash



Proximate Analysis of Coal as Received. Bore Hole # 5.
Key -
I - Moisture
II - Volatile Matter
III - Fixed Carbon
IV - Ash

Proximate Analysis of Coal as
Bore Hole #5.

Key:
I - Moisture
II - Volatile Matter
III - Fixed Carbon
IV - Ash



Proximate Analysis of Coal as Received. Bore Hole #6.

Key:
I - Moisture
II - Volatile Matter
III - Fixed Carbon
IV - Ash

EMRIA

(Energy Mineral Rehabilitation Inventory and Analysis)

EMRIA is a coordinated approach to field data collection, analyses, and interpretation of overburden (soil and bedrock), water, vegetation, and energy resource data. The main objective of the effort is to assure adequate baseline data for choosing reclamation goals and establishment of lease stipulations through site-specific preplanning for surface mining and reclamation.

This report is prepared through the efforts of the Department of the Interior, principally by the Bureau of Land Management through Geoscientific Systems and Consulting (contractor). Assistance is also provided by other Federal and State agencies.

Reports under this effort are:

EMRIA Report Number, Year

1-75	Otter Creek, Montana	10-77	Beulah Trench, North Dakota
2-75	Hanna Basin, Wyoming	11-77	Pumpkin Creek, Montana
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6-76	Foidel Creek, Colorado	15-77	Henry Mountain, Utah
7-76	Red Rim, Wyoming	16-77	Emery, Utah
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