1979 C.B. ANNUAL REPORT

VOLUME 2

ENVIRONMENTAL ANALYSIS

CATHEDRAL BLUFFS SHALE OIL COMPANY
TENNECO SHALE OIL COMPANY
OCCIDENTAL OIL SHALE INC., OPERATOR

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APRIL 30, 1980

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Submitted by:

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To:

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1.0 INTRODUCTION AND SUMMARY

1.1 Introduction

The Environmental Baseline Period for Oil Shale Tract C-b covered the period from November 1, 1974, to October 31, 1976. Results have been reported in 9 Quarterly Data Reports, 8 Quarterly Summary Reports, C-b Annual Summary and Trends Report (1976), and a 5-volume Environmental Baseline Program Final Report (1977), all submitted to the Area Oil Shale Supervisor.

From November 1, 1976 through August 31, 1977, the C-b Tract was under a period of suspension of the Federal Oil Shale Lease. The monitoring conducted during this period was executed under a program known as the Interim Monitoring Phase. Environmental data for this time period were submitted to the Area Oil Shale Office (AOSO) on October 14, 1977 (Interim Monitoring Report #1). The Interim Monitoring Period was later extended by the AOSO to cover the period from September 1, 1977 through March 31, 1978. Data for this time period were submitted to the AOSO on May 15, 1978 (Interim Monitoring Report #2). The Development Monitoring Program was initiated in April 1978. The Development Monitoring Program for Oil Shale Tract C-b was submitted to the AOSO in a document dated February 23, 1979 and approved by the AOSO on April 13, 1979 subject to 13 Conditions of Approval contained in that approval letter. Semi-annual environmental data reports are submitted every January 15 and July 15.

The 1978 C-b Annual Report, Volume 2, Environmental Analysis, presented analyses in all of the broad environmental areas identified in the Development Monitoring Program for data collected since November 1976. Because there is always a data lag and reduction problems, analyses for some studies were based on data only through September 1978. The report was not as detailed or comprehensive as the 5-volume Environmental Baseline Program, Final Report (1977).

The Interim Monitoring and Development Monitoring Programs have been reduced and changed from the Environmental Baseline Monitoring Program in many areas. Therefore, emphasis is now placed on key indicators of environmental quality and/or change. The 1979 C.B. Annual Report, Volume 2 carries on in this same tradition.

The purpose of this report is to fulfill the requirement of the lease to provide the Area Oil Shale Supervisor's Office with an annual report of environmental analyses. The Development Monitoring Plan states the following objectives with respect to environmental monitoring:

> The purposes or objectives of environmental monitoring as defined in Section 1 (C) of the Stipulations are to provide: 1) a record of changes from conditions existing prior to development operations, as established by the collection of baseline data; 2) a continuing check on compliance with the provisions of the Lease and Stipulations, and all applicable Federal, State and Local environmental-protection and pollu-

tion control requirements; 3) timely notice of detrimental effects and conditions requiring correction; and 4) factual basis for revision or amendment of the Stipulations.

This volume documents the analyses and conclusions relative to assessment of potential environmental impacts and trends that may be indicated in the collected data. Since development activities were not started until 1978, much of the data and analyses may be considered as a continuation of environmental baseline and background definition.

1.2 Summary

The following paragraphs summarize the findings in each of the chapters of this report. The chapters contain studies relating to analyses of data collected by discipline under the Development Monitoring Plan.

Three fold-out charts (Exhibits A, B and C) depicting the monitoring site locations for development monitoring are included in the jacket inside the back cover of this volume. Exhibit A is a map of the Piceance Basin giving key features of the hydrologic monitoring program. Exhibit B is a list of stations of the hydrologic monitoring program illustrated in Exhibit A. Exhibit C is a map of the development monitoring activities at the site. Monitoring locations are shown as four-digit computer codes on the map; comparisons of computer codes and "conventional" site locations are included in Appendix Table A2.2-1.

Related maps are included in each chapter as appropriate.

1.2.1 Tract Photography

A tract surface and aerial photography program has been initiated to provide permanent records of change and surface disturbance. This year emphasis has been on use of Landsat to yield information on general vegetative conditions and change detection. Change detection information is obtained by comparing early-growing-season data with late-growing-season data and via year-to-year comparisons.

1.2.2 Indicator Variables

The Development Monitoring Program has been brought into sharper focus with the identification of Class 1 indicator variables. These are key environmental variables collected at representative stations in at least monthly sampling frequency. Time series plots, largely generated by the computer from the data base and all to a common time scale, are updated in the semi-annual data reports to provide visual analyses of trends and interrelationships. Class 1 indicator variables are subjected to statistical analyses of time-trends and station-to-station comparisons.

1.2.3 Hydrology

The Development Monitoring Program provides water quantity and quality data for the purpose of impact evaluation. Presently, streams, springs, seeps, alluvial and bedrock aquifers, shafts and impoundments are monitored. The present hydrologic monitoring network has been expanded over that which existed during the baseline period to account for new requirements under the Water Augmentation Plan and Consent Decree as implemented in August, 1979.

Baseline studies indicated the mean flow from the reach of Piceance Creek adjacent to the Tract to be approximately 15 cfs; records since then indicate no significant change in mean annual flows. One-day minimum flows there have reached less than 1 cfs. Previous daily maximum flows upstream and downstream of the Tract have increased as follows:

	Upstream (Station 007)	Downstream (Station 061)
Previous Daily Maximum (cfs)	104 (May 1975)	116 (September 1977)
New Maximum (cfs)	157 (May 1979)	149 (May 1979)

Water levels in the bedrock wells which previously had shown no trends over time now exhibit some decline in close proximity to the shaft sinking area. Wells 32X-12 and 33X-1 closest to the Production and V/E Shafts are down 39 and 49 feet, respectively, below their baseline average values at year-end.

No significant trends in flows for springs and seeps were noted.

Regarding water quality of Piceance Creek, differences between upstream (Station 007) and downstream (Station 061) over time and between stations, when summarized for major variables of interest (HCO_3, B, Mg, Ca, CO_3, Cl, Na, pH, NH_3, Specific Conductance), indicate that the only significant increases over time of 20%, 8%, and 8% occurred for HCO_3, Mg, and Na, respectively; no trends between stations were significant.

Water quality for springs and seeps, alluvial wells and upper- and lower-aquifer deep wells exhibited trends at the 5% level of significance for the following: increases in arsenic at one spring and increase in specific conductivity at one alluvial well.

The Tract discharges waters under a valid NPDES permit up to 0.1 the value of flow in Piceance Creek. Through October, a peak value of 66 mg/l for total suspended solids was attained; oil and grease peak values were in excess of 10 mg/l on three occasions.

1.2.4 Aquatic Ecology

Biological production in Piceance Creek continues to be restricted by a combination of natural and man-caused factors. Natural factors limiting biological production are the unstable nature of most of the streambed and irregular discharge. Loose sand, silt and mud comprise much of the substratum. These materials are easily shifted about by currents, particularly those associated with runoff of snowmelt and high intensity thunderstorms. In times of low flow, much of the streambed becomes dewatered, thus exposing biota to possible desiccation.

Land-use practices along Piceance Creek intensify the adverse effects of some natural limiting factors. Cattle grazing has probably reduced the vegetative cover of the watershed and thereby contributed to the irregularities in stream flow. Cattle trample stream banks and willow growth along the streams and thus destroy cover for fishes. Irrigation diversions dewater sections of Piceance Creek and return-water probably leaches salts from the fields and increases the load of dissolved solids. Ammonia and nitrogen may be leaching significant amounts from manure emanating from winter feeding concentration of cattle along Piceance Creek.

The water of Piceance Creek is high in dissolved salts relative to the "average" North American stream; however, the load in Piceance Creek is not unusually great for streams in semi-arid western localities. Low quality-high salinity groundwater from deep aquifers reaches Piceance Creek via springs discharging into it, especially in reaches downstream from Ryan Gulch. Although the salinity of lower Piceance Creek is greater than in upstream reaches, there is no unambiguous evidence that salinity is limiting total biological production.

1.2.5 Air Quality

With regard to air quality, gaseous constituents measured include sulfur dioxide, hydrogen sulfide, carbon monoxide, ozone, and oxides of nitrogen; total suspended particulates are also measured.

The air quality trailers making gaseous and particulate measurements and those for associated meteorology are Stations AB23 and AB20; in addition, particulates data are also measured at AD56. A 60-meter meteorological tower is located at Station AB23, instrumented at three levels. Precipitation measurements continue to be made at Stations AB20 and AB23, and as of August, at the extra stations required under the Water Augmentation Plan as indicated on the jacket maps. Minimum data-reporting frequency is hourly.

For the overwhelming majority of the time, SO_2, H_2S, and CO have indicated background levels below the lower detection level of the instruments. Only for ozone and total suspended particulates have significant values been measured.

The highest and second higest peak hourly readings for ozone in 1979 (through October) were 246 and 203 $\mu g/m^3$ respectively; the ozone standard in 1979 was changed to 240 $\mu g/m^3$ as an annual expected exceedance, averaged over 3 years. The peak 24-hour reading for particulates was 80.6 $\mu g/m^3$, well below the standard.

Ozone-concentration shifts to high values show correlation with weather-related meteorological parameters. High particulate concentrations to date are judged to be due solely to fugitive dust. Time series plots do not identify any discernible trends in either gaseous constituents or particulates over time, except for some seasonal variations in particulates. Particulate concentrations are usually highest in spring and fall with minimums in winter. No specific dependence of concentrations on wind speed or direction has been noted.

Mean annual visual range in 1979 was 127 km (79 miles), with a seasonal spring minimum of 122 km (76 miles) and fall maximum of 135 km (84 miles). These compare with 81, 78, and 86 miles for the respective values in 1978. No significant change in the annual mean has been noted since the 1975-76 measurements.

1.2.6 Meteorology

Climatological records indicate an annual mean temperature of 6-7°C over the past 5 years. Time series analysis of monthly means has demonstrated no trend in long-term values. Cold air drainage results in winter minima in Piceance Valley near -43°C. Precipitation summaries on the Tract over the past 5 years are as follows:

Year	Annual Precipitation (cm)
1975	45.0
1976	35.8
1977	35.9
1978	36.1
1979	36.7

Peak storm intensities reached 4.3 cm of precipitation on September 3, 1977.

Predominant winds on Tract continue to be from the south-southwest with spring and summer showing higher wind speeds (5-8 m/sec) than fall and winter (1-3 m/sec) at the 10 meter level above the surface. Winds from the Tract direction generally become channeled by Piceance Valley walls toward the WNW downstream direction of Piceance Creek during late afternoon and night; directions reverse in daytime. Air is typically stable during night and early morning and unstable in late morning and afternoon. Afternoon mixing-layer-height estimates have been improved utilizing both the 1974-75 aircraft and pibal flights and the combined EPA/C-b pibal flights of 1978. Wintertime averages from 1,500 meters increase to over 1,800 meters by April and are in excess of this until late fall when they start to decrease back to wintertime levels.

1.2.7 Noise

The environmental noise program deals with both traffic and tract-generated noise levels. The discrete (weekly) traffic noise level measurements indicated noise levels approximately 9 dbA above baseline peaks. Continuous noise measurements (every 6th day) indicate no significant increases due to the tract activities in average noise levels for two 12-hour periods (7 p.m.-7 a.m. and 7 a.m.-7 p.m.).

1.2.8 Wildlife Biology

With regard to deer counts observed along Piceance Creek, maximum weekly counts since baseline have always occurred in spring and have varied from 1,804 in 1979 to 1,034 in 1978 with 1975, 1976, and 1977 values intermediate to these. Road kills in any week usually vary from less than 1% to 1.5% of those counted in any given week. A total of 131 deer were killed along the road from September 1978 to May 1979 in comparison to 125 in the previous year. Use of company buses has been the principal mitigative measure in reducing traffic on Piceance Creek road. Natural deer mortality has substantially increased this year, probably due to the severe winter.

Regarding medium-sized mammals, fewer coyotes and more cottontail rabbits were noted in 1978 than in 1977. Coyotes have varied from a high of 188 (1974) to a low of 50 (1978).

As with previous sampling periods, greater avian songbird diversity has been noted in pinyon-juniper woodlands as opposed to chained pinyon-juniper; similarly more mourning doves were found in the unchained habitats. No changes have been noted between control and development sites. Development activities have not affected raptor activity.

1.2.9 Vegetation

Regarding vegetation, the conclusions reached this year are essentially the same and are supportive of the conclusions reached in the 1977-78 vegetation monitoring studies: The production patterns observed on the Tract in 1979 are essentially the same as those observed during the baseline data collection years. During 1979 herbaceous utilization of non-woodland vegetation types was approximately 25 percent. The only type where the measured production differences between range cages and open areas were statistically significant was in the upland sagebrush shrublands. Differences in production at Plots 1 and 2 (chained pinyon-juniper - development and control, respectively), and 5 and 6 (pinyon-juniper woodland - development and control, respectively) were statistically significant. These differences most likely relate to natural causes rather than to development activities. Yearly fluctuations in total production appear to be closely related to precipitation. Winter precipitation and precipitation in April, May, and June are probably more influential in affecting production than is the total yearly precipitation.

The fertilization program on the ridges above Scandard Gulch and Cottonwood Gulch has not significantly increased production. On the average, production was increased approximately 7 percent in the fertilized areas.

Revegetation monitoring will be conducted on sites which have undergone surface disturbance and on future raw-shale disposal sites. Erosion control and rehabilitation are discussed in Chapter 6 of Volume 1, including the reclamation activity scheduled defining affected areas, disturbance timetable, reclamation time span and disturbed acreage.

1.2.10 Ecosystem Interrelationships

Ecosystem interrelationship studies have been continued as a means of assessing the potential impact of environmental perturbations resulting from development activity. Quantitative studies to date included: (1) effects of climatic variations on herbaceous productivity; (2) effects of traffic, climate, and size of mule-deer herd on deer road-kill; and (3) a new study on the potential effects of mine dewatering on vegetative conditions both in Piceance Creek and on Tract was just initiated. Last year's study on the effects of urbanization on hydrologic response time has been terminated because the six erosion-control basins are specifically designed to control such run-off. Principal results, previously established that still hold are as follows: (1) herbaceous productivity correlated best with precipitation in April-May-June and total precipitation of the previous growing-season-year; 2) deer road-kill correlated best with deer road-count.

1.2.11 Items of Aesthetic, Historic, or Scientific Interest

Surface activity was very limited at the site in 1979 regarding additional disturbed acreage. A concerted effort has been made to paint and locate new structures in such a manner as to reduce any aesthetic impact. Additionally, the on-site manager has thoroughly investigated every site of disturbance and no additional historic or scientific finds have been made.

1.2.12 Health and Safety

With regard to health and safety, accident frequency analyses and inspection reports (Mine Safety and Health Administration and Colorado Division of Mines) are included in the Development Monitoring Plan and its reports. At C-b based on 524,891 man-hours, there were 5 lost-time accidents. The site injury rate in 1979 was 1.91 (incidents/200,000 man-hours). This compares with 3 lost-time accidents in 1978, and an injury rate of 1.35.

1.2.13 Toxicology

This project is a jointly sponsored effort by TOSCO, Arco, and C.B. under the direction of Dr. R. M. Coomes of the TOSCO Corporation. Acute toxicity tests indicated that shale oil is equivalent to petroleum materials in toxicity and that raw and processed shales are essentially non-toxic. In skin-painting experiments on rats it was concluded that raw and processed shales are not carcinogenic to skin. Chronic inhalation experiments on rats and monkeys demonstrated that no lung tumors or lung changes could be attributed to raw or processed shale exposures.

1.2.14 Data Management

All air, water, and microclimate data are currently in a computerized data base called RAMIS. Biological data are in manual data bases, and documented in data reports to the AOSO.

Data tapes for air quality and meteorology have been furnished to the AOSO for data through April, 1979. Additional air and water data tapes will be furnished in 1980.

1.2.15 Reporting

Annual reports are submitted during the anniversary month of the Lease (April). Semi-annual Data Reports are submitted to the AOSO on January 15 and July 15.

1.2.16 Compliance Demonstration

For purposes of demonstrating compliance of this Annual Report with the Detailed Development Plan (DDP), the Development Monitoring Plan (DMP) and the Water Court Decree (leading to the Water Augmentation Plan (WAP)) a Requirements Compliance Matrix is presented on Table 1.2.16-1 showing where sections of these controlling documents are addressed in Volumes 1 and 2 of this Annual Report.

TABLE 1.2.16-1

REQUIREMENTS COMPLIANCE MATRIX

Controlling Document	Document Section	Section Subject	Annual Report Volume I Section	Annual Report Volume II Section	Comments
LEASE & DDP	Volume 1 I	General Information and Summary	1,2,4,7.13	1.1	
	II	Phase I - Mine Development			
	A.	Schedule & Summary	3,4	2.1	
	B.	Manpower	1,8		
	C.	Engineering Design & Procurement	3.2,4,5		
	D.	Mine Surface Facilities	1,3,4		
	E.	Mine Shaft Sinking	1,3,4,7.2		
	F.	Development Mine			
	G.	Utilities and Fuel	4		
	H.	Crushing and Conveying			
	I.	Alternate Mining Methods			
	J.	Access and Service Roads	4,7.10.2		
	K.	Dams		5.2.6, 5.3.6	
	L.	Coarse-ore Conveyor & Stockpile			
	M.	Shaft Dewatering, Treatment & Disposal	4	5.2.6,5.2.7,5.3.6,5.3.7	
	III	Phase II - Plant Construction	5		
	A.	Summary	4		
	B.	Schedule & Manpower	3,8	2.1	
	C.	On-Tract Surface Facilities	4		
	D.	Off-Tract Facilities	4		
	IV	Phase III & Phase IV			Not at this Phase of Development yet.
	A.	Summary - Phase III			" " " " " " "
	B.	Schedules and Manpower			" " " " " " "
	C.	Mine Operations			" " " " " " "
	D.	Crushing and Conveying			" " " " " " "
	E.	Retorting and Upgrading			" " " " " " "
	F.	Waste Disposal			" " " " " " "
	G.	Water Use			" " " " " " "
	H.	Electric Power Use			" " " " " " "

TABLE 1.2.16-1 (Continued)

Controlling Document	Document Section		Section Subject	Annual Report Volume I Section	Annual Report Volume II Section	Comments
.EASE & DDP		I	Utility Systems			Not at this Phase of Development yet.
		J	Pipelines			" " " " " " "
		K	Phase IV - Post Operations	7.12		" " " " " " "
	V		Environmental Control Plans	9		
		A.	Air Pollution Control	7.1,9.3.5	1.2.5,1.2.6,4.2.3,6.0	
		B.	Water Pollution Control	1, 7.2	1.2.3,4.2.2,5.1,5.2.6,5.3.6	
		C.	Noise Control	7.8,9.3.7	1.2.7, 4.2.4, 7.0	
		D.	Protection of Historic, Scientific & Aesthetic Values	7.7,9.3.11	1.2.11	
		E.	Fire Prevention and Control	1,7.9.3		
		F.	Health and Safety	1,7.9.9.3.12,9.3.13	1.2.12, 1.2.13	
		G.	Overburden Management	6	1.2.9	
		H.	Processed - Shale Disposal	6		
		I.	Disposal of Other Wastes	4,6,7.5	1.2.13	
		J.	Fish and Wildlife Management	7.10,9.3.4,9.3.8	1.2.4,1.2.8,4.2.5,8.0	
		K.	Erosion Control and Surface Rehabilitation and Revegetation	6, 7.6, 9.3.9	1.2.9, 5.3.8	
		L.	SPCC Plan	7.4		
		M.	Off-Tract Corridors	7.11		
	VI		Environmental Monitoring	1	1.1	
		A.	Introduction	1	1	
		B.	Soils Survey and Productivity Assessment	1	5.3.8	
		C.	Surface Water	1, 4, 7.2	1.2.3,2.2,4.2.2,5.2.1,5.2.2,5.2.6,5.2.8,5.2.9,5.3.1,5.3.2,5.3.6,5.3.9	
		D.	Sub-surface Water	1, 4	1.2.3,2.2,4.2.2,5.2.3,5.2.4,5.2.5,5.2.8,5.2.9,5.3.2,5.3.4,5.3.5,5.3.9	
		E.	Meteorology and Air Quality	1, 7.1, 9.3.5, 9.3.6	1.2.5,1.2.6,4.2.3,6.0	
		F.	Biological	1, 9.3.4, 9.3.8, 9.3.9	1.2.4,1.2.8,1.2.9,4.2.5,8.0	
		G.	Noise	7.8, 9.3.7	1.2.7, 4.2.4	
DMP	1		Introduction	2, 9.1, 9.2	2.1	
	2		Milestones and Maps	9.2, 9.3	2.1	
	3		Photography	1, 9.3.1	1.2.1, 3.0, 4.2.1	
		.1	Surface	1	3.1	
		.2	Aerial	1	3.2	
	4		Indicator Variables	1, 9.3.2, 9.3.10	1.2.2, 1.2.10, 4.0	
	5		Hydrology	1, 7.2, 9.3.3	1.2.3, 2.2, 4.2.2, 5.1	
		.2	Surface	1, 4.7.2	5.2.1,5.2.2,5.2.8,5.2.9,5.3.1,5.3.2,5.3.9	
		.3	Sub-surface	1, 7.2	5.2.3,5.2.4,5.2.5,5.2.9,5.3.3,5.3.4,5.3.5,5.3.9	
		.4	Development	1,4	5.2.6,5.2.7,5.3.6,5.3.7	

TABLE 1.2.16-1 (Continued)

Controlling Document	Document Section	Section Subject	Annual Report Volume I Section	Annual Report Volume II Section	Comments
DMP	.5	Systems Dependent	1,4		
	.6	Quality Assurance	1		
	6	Air Quality and Meteorology	1,7.1,9.3.5,9.3.6	1.2.5,1.2.6,4.2.3,6.0	
	.2	Ambient Air Quality	1,7.1	6.2	
	.3	Meteorlogy	1,7.1	6.3	
	.4	Development - Related	1,7.1		
	.5	Systems Dependent	1		
	7	Noise	1,7.8,9.3.7	1.2.7, 4.2.4, 7.0	
	8	Biology	1,9.3.8,9.3.9	1.2.4,1.2.8,1.2.9,4.2.5,8.0	
	.2	Big - Game Deer	1	1.2.8, 8.2	
	.3	Medium Sized Mammals	1	1.2.8, 8.3	
	.4	Small Mammals	1	8.4	
	.5	Avifauna	1	1.2.8, 8.5	
	.6	Aquatic	1,9.3.4	1.2.4, 8.6	
	.7	Terrestrial	1	8.7	
	.8	Threatened and Endangered	1	8.8	
	.9	Revegetation	1,6	8.9	
	.10	Systems Dependent	1	8.10	
	9	Items of Historic, Prehistoric or Scientific Interest	1,9.3.11	1.2.11, 9.0	
	10	Industrial Health and Safety	1,7.9,9.3.12,9.3.13	1.2.12, 1.2.13, 10.0	
	11	Subsidence Monitoring		11.0	
	12	Ecosystem Interrelationships	9.3.10	12.0	
	13	Data Management and Reporting	9.1,9.3.14,9.3.15	1.2.14,1.2.15,1.2.16,1.3	
Water Court Decree W-3493	7	Legal Description of Site	2,7.3	2.2	
	8	Sources of Water Supply		5.2.1,5.2.2,5.2.3,5.2.8,5.2.9	
	9,10,11	Dewatering and Augmentation	9.3.3	5.2.2,5.2.3,5.2.8,5.2.9	
	13	Assignment of Upper and Lower Aquifer		5.2.4,5.2.5,5.3.4,5.3.5	
	19	Evidence of Depletion Effects	9.3.3	5.2.1,5.2.2,5.2.3,5.2.4,5.2.8,5.2.9	
	24	Monitoring Program	7.2	1.2.3,2.2,4.2.2,5.1	
	25	Parameters		4.2.2,5.2.6,5.3.6	Exhibit A, wells, springs, seeps, streams, precip. sites. Exhibit B, Development Monitoring program.
	26	Timely Implementation Requirement		5.1	
	27	Following Cone of Depression		4.2.2,5.2.3,5.2.4,5.2.5	
	28	Monitoring Plan Modifications Provision		1.3,5.2.9,5.3.9,13.0	
	29	Cone of Depression Determination and Monitoring	9.3.3	4.2.2, 5.2.8	
	30	Water Replacement		5.2.8	
	31	Colony, Union, Agreement		5.2.8	

TABLE 1.2.16-1 (Continued)

Controlling Document	Document Section	Section Subject	Annual Report Volume I Section	Annual Report Volume II Section	Comments
	32 - 38	Compensation for Depletions		5.2.8	
	39 - 46	Protection of Objectors Water Rights		5.2.8	
	47 - 50	Court Retention of Jurisdiction	7.3		
	51 - 59	Conclusions of Law	7.3		
	60 - 79	Judgement and Decree	7.3		
	62	Replacement Water		5.2.8	
	63	Compensations to Well Water Right		5.2.8	
	71	Replacement Water Quality			
	73	State Water Engineer - Conditions		5.2.2,5.2.4,5.2.9	
	75	Term Day Hearing Requirement			
	76	Augmentation Modification Provision		1.3	

1.3 Recommendations

1. The Development Monitoring Plan (DMP) (dated February 23, 1979, approved with COA's dated April 13, 1979) is regarded as a dynamic document. Periodic "updates" and "clarifications" are necessary. Format of the document should be changed to loose leaf notebook, paged by chapter in that only revisions need be issued, preferably bi-annually. Improved document control is required. Chapter heading consistancy between DMP and Annual Report is desirable, including fourth level of outline on sections: Scope, Objectives, Experimental Design, and Methods of Analysis.

2. A review of the "Indicator Variables" is necessary in the near future to better include those now required under the Water Augmentation Plan.

3. The intent of the Annual Report is to fulfill reporting requirements under the Detailed Development Plan (DDP), DMP, Water Augmentation Plan (WAP), and Mine Land Reclamation Plan (MLRP). Continual "diligence" is necessary to see that this is accomplished.

4. Further effort needs to be expended to computerize the data base, particularly with regard to biology and to improved health and safety reporting. Computerized mapping capability needs to be expanded.

5. Further efforts to reduce data lag, particularly with regard to hydrological data provided by the U.S.G.S., should be expended.

6. Quality assurance programs for both air and water need further formalization in the near future.

7. Ecosystem interrelationships need increased emphasis so as to provide quantitative data for analysis. Particular attention is to be directed in the coming year to potential effects of dewatering the mine on vegetation.

2.0 TRACT DEVELOPMENT SCHEDULE AND MAPS

2.1 Development Schedule

The proposed development schedule is presented as Figures 3-1 and 3-2 of Volume 1 of this report. A comparison of proposed vs. actual schedules for calendar years 1977 through 1979 is presented in Figure 3-3 of Volume 1.

2.2 Maps

Three fold-out charts (Exhibits A, B and C) depicting the monitoring site locations for development monitoring are included in the jacket inside the back cover of this volume. Exhibit A is a map of the Piceance Basin giving key features of the hydrologic monitoring program. Exhibit B is a list of stations of the hydrologic monitoring program illustrated in Exhibit A. Exhibit C is a map of the development monitoring activities at the site. Monitoring locations are shown as four-digit computer codes on the map; comparisons of computer codes and "conventional" site locations are included in Appendix Table A2.2-1.

Related maps are included in each chapter as appropriate.

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3.0 TRACT PHOTOGRAPHY

3.1 Surface Program

3.1.1 Scope

Section 1 (C) of the Environmental Lease Stipulations requires that the Lessee conduct monitoring programs to measure perceptible changes from baseline conditions. Toward this end both a surface and an aerial photography program have existed since baseline. For the surface program, color photos are obtained annually at 35 photo points and color infrared photos are taken in the vicinity of the springs and seeps.

3.1.2 Objectives

The objectives of the surface program are to provide:
1) a record of changes from conditions existing prior to development operations;
2) visual evidence of successional changes in the ecosystem;
3) a visual record of surface disturbance;
4) an historic account of surface development; and
5) a visual basis for revision or amendment of the Stipulations.

3.1.3 Experimental Design

Thirty-five points have been selected for development monitoring from which a 360° pan is photographed in color on a yearly basis. (Figure 3.1.3-1). A 35mm camera with an f 1.8, 55mm lens is used. Once each year in June between 10:00 a.m. and 2:00 p.m. on cloudless days, a 360° photo pan is taken from each of the thirty-five photo map stations.

A color infrared pan is taken two times throughout the growing season around the nine spring-and-seep locations to generally (qualitatively) indicate vegetative stress development. Provided that suitable reproductions can be obtained, these pans will be contained in the semi-annual data reports.

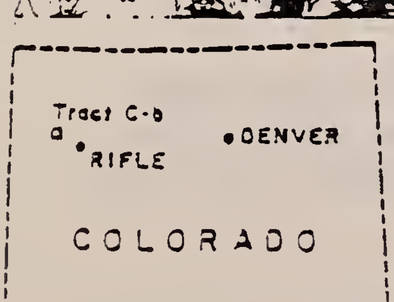
3.1.4 Archiving Methods

A complete set of the 35mm color slides for all photo points are numbered as to station, aspect and date. This set is stored in plastic envelopes and bound in a 3-ring binder, then filed in a unit designed to curtail dust and light as a part of the permanent record of the C.B. Shale Oil Project. For development monitoring this record includes weather conditions, camera and film data, height of camera above ground and direct or diffuse lighting identification.

3.1.5 Results and Conclusions

1) As in previous years the ground color slides have been archived as a photographic record of Tract changes. 2) For the first time, color infrared photo pans of the areas around the springs and seeps have been

SURFACE PHOTOGRAPHY NETWORK



INDEX MAP

FIGURE 3.1.3-1

taken twice during the growing season to record qualitative changes during the vegetative growth cycle.

3.2 Aerial Program

3.2.1 Scope

This is an initial effort to assess vegetation condition in the Piceance Creek Basin in the vicinity of Tract C-b using Landsat multi-spectral scanner (MSS) digital data. This technique offers promise in view of its wide area coverage; resolution is judged to be adequate for general vegetation-condition assessment.

The measure of vegetation condition for this effort is based on results obtained by Maxwell, et al (1980). The methods they employed were developed for short grass prairie and irrigated row crop vegetation. Extention of these methods to the Pinyon-juniper forests and shrublands of the Piceance Basin cannot yet be expected to produce quantitatively accurate results. Relative values and detection-of-change results should be reliable, however, within the limits imposed by the methods. If the initial results are promising, future efforts should include a calibration of the methods for the Piceance vegetation types.

3.2.2 Objectives

The objectives of this effort are twofold: 1) Provide a measure of vegetation condition over a selected portion of the Piceance Creek Basin. 2) Provide a measure of vegetation condition change over a growing season and over years.

3.2.3 Method of Analysis

This technique utilizes the Landsat earth-resources satellite in a sun-synchronous orbit at 918 km. As such it passes over the area at the same local time (approximately 9:30 a.m.) each day, significant since any changes in shadowing influence reflectance. Land coverage is approximately 110 x 110 square miles. The on-board sensor utilized measures spectral reflectance in four discrete bands:

Band	Wave length (μm)	
4	0.5 to 0.6	Green
5	0.6 to 0.7	Red
6	0.7 to 0.8	Photo IR
7	0.8 to 1.1	Photo IR

The paragraphs to follow discuss deriving both change detection techniques and vegetation indices from information in these bands. Additional Landsat background information is provided in Appendix A3.2.

3.2.3.1 Change Detection

A variety of methodologies have been employed to extract change-detection information from digital data. These include: 1) image-ratio technique whereby Landsat data for a designated test area are acquired for two different dates; 2) post-classification comparison of land-cover classes between dates; 3) use of data reduction techniques to emphasize particular data characteristics felt to be important in the identification of change (from principal components transformation to merely selecting a particular band of interest); 4) image-differencing employing the subtraction of one data value from another.

Regarding change detection, several points should be noted:

1) Data transformations are useful to enhance quality of the data that are of interest. This can reduce noise in the data and lead to economy in data processing. 2) The comparison of individual classification results to determine areas of change is useful since data-specific noise such as unique atmospheric effects, or different sun angles have less effect on the results. 3) A variety of change-detection methodologies exist that can be tailored to meet particular user needs.

In addition to these general considerations of methods, there are certain processing problems common to all change-detection methods. The major points to be considered are noted below:

1) Pixel-to-Pixel Registration - Since any change detection relies on the comparison of information describing a particular ground location on several dates, it is crucial to correctly identify the ground unit of interest. A variety of geometric distortions exist in the raw Landsat data that must be corrected to allow pixel-to-pixel registration. 2) Atmospheric Effects - One's ability to discriminate land-cover characteristics by remote sensing systems via electromagnetic radiation is diminished by the atmosphere which scatters and absorbs radiation. The extent of these atmospheric effects is variable according to the condition of the atmosphere, and the wavelength of the electromagnetic radiation. 3) Data Selection - When detecting vegetation changes, the seasonal growth characteristics of the vegetation must be considered in selecting appropriate dates for analysis. A date when the vegetation will be most sensitive to the change of interest should be selected. The same date or dates should be used each year. 4) Surface Wetness - The presence of surface moisture, e.g., after a rainfall, will considerably alter reflected radiance values, and should be avoided when selecting images. 5) Spatial Resolution - The minimum ground resolution element (pixel) of the Landsat system is 79 x 56 meters. To be reasonably confident of the location within an image of an area of interest, as well as the value associated with that location, any analysis of Landsat data should consider a minimum ground unit of 10 acres or more.

Differencing of individual Landsat bands was not considered to be of any value for the present application. Rather, since vegetation condition and changes in condition were the primary measurement objectives, the differencing of vegetation indices was an obvious choice. A description of vegetation indices and their use to quantify vegetation condition is given below.

3.2.3.2 Vegetation Indices

Two important factors determining leaf reflectance are the light absorbing pigments within the leaf and the physical structure of the leaf. The pigments (chlorophylls, xanthophylls, carotenoids, and anthocyanins) are responsible for absorption of energy in the visible wavelengths, but they do not interact with infrared (IR) energy (see Figure 3.2.3-1). The structure of the leaf is important to both visible absorptance and IR reflectance. Leaf structure increases the effective path length within the leaf for the visible and IR wavelengths. This increases the opportunity for the interception of radiation by the pigments and results in the upward scattering of 40-60 percent of the near IR energy intercepted by the leaf (Maxwell, et al, 1980).

Previous work by numerous investigators has shown that various combinations of red and near-IR reflectance or radiance bear a close relationship to biomass, leaf area index, leaf water and other vegetation canopy parameters. Jordan (1969) was the first to report the use of the IR/RED ratio as a vegetation index. He used a radiance ratio (0.800/0.675 μm) to derive a leaf area index for canopies in a tropical rain forest. Miller and Pearson (1971) demonstrated the use of ratios for mapping the primary productivity of shortgrass prairies. Colwell (1974) suggested that the IR/RED ratio apparently normalized for the variability in background spectra and concluded that the ratio was useful for assessing biomass. This background-normalizing aspect of vegetation indices has been further indicated by Maxwell, et al (1980).

Other combinations of Landsat bands have been investigated to assess vegetation biomass and normalize noise. Tucker (1977) investigated several of the band combinations and found only small differences in their significance when regressed with canopy biomass. Maxwell, et al (1980) support those results of Tucker. Both investigators suggest the use of the normalized difference index which is defined as:

$$\text{Normalized Difference} = \frac{\text{Band 7} - \text{Band 5}}{\text{Band 7} + \text{Band 5}}$$

Although the work of Tucker and Maxwell made use of data from grasslands and irrigated crops as shown on Figure 3.2.3-2, it is expected that these indices can also provide a measure of quantity and condition of deciduous shrublands. Some calibration efforts to establish a functional relationship between index values and shrub biomass must be undertaken before absolute values of biomass can be assigned with confidence. Relative values from one location to the next and year-to-year changes should be of value prior to calibration, however; thus, Figure 3.2.3-2 is used here.

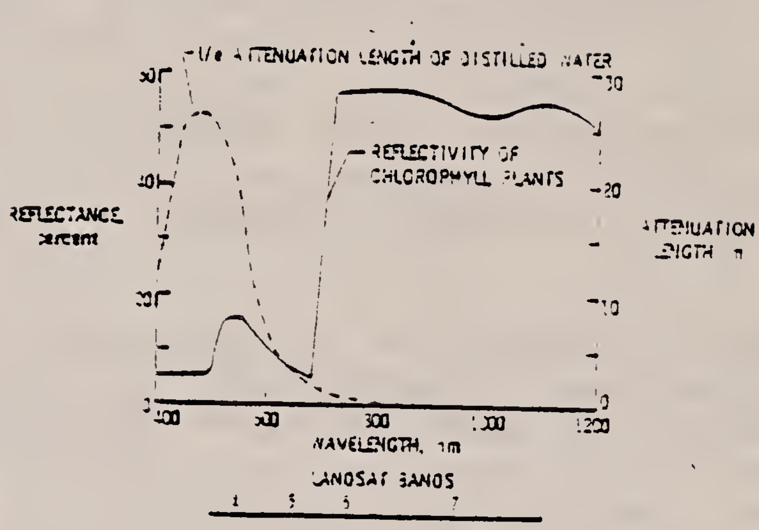
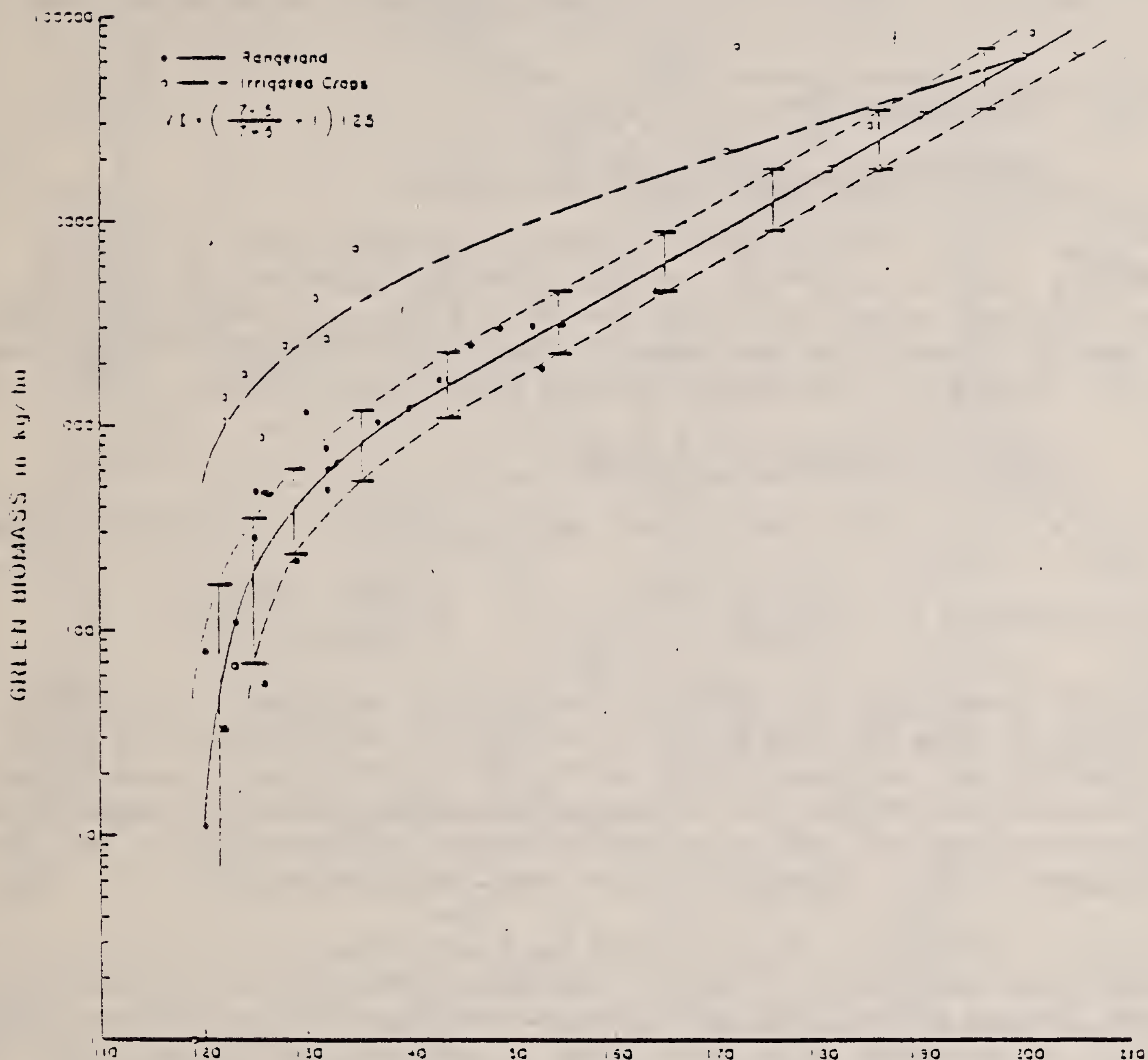


FIGURE 3.2.3-1

Landsat Reflectance vs. Wavelength

This illustration represents the wavelengths monitored by the four Landsat sensors along with the reflectance characteristics of plants and attenuation of radiation by water. Note the high absorption of band 5 radiation by chlorophyll and the enhanced band 6 and 7 reflectance due to leaf structure. High attenuation is noted for band 7 due to water absorption.



Index Value (VI)

FIGURE 3.2.3-2
Green Biomass vs. Index Value

A plot of the normalized difference index vs green (wet) biomass based on rangeland and irrigated crops. Dashed lines are between 1 and 2 standard deviations from the mean, which suggest that 2 to 1 changes in biomass can be accurately monitored. Suggested index and biomass ranges are shown.

Application of indices to coniferous vegetation apparently has not been attempted. Use in an area dominated by Pinyon-juniper trees needs continuing investigation.

It should also be emphasized that these indices respond only to green vegetation and they must be used at the appropriate time of the year. Senescent (brown) vegetation is spectrally similar to base ground and cannot be measured from Landsat.

3.2.4 Experimental Design

3.2.4.1 Selection of Critical Areas

Four areas of concern were designated as areas of critical concern: on-Tract, offsite uplands, offsite-riparian and offsite-spring areas. Of these areas, only the springs are below the resolution capacity of the Landsat sensor. On the basis of these critical areas, a test area was designated. Figure 3.2.4-1 shows the area chosen for analysis.

3.2.4.2 Selection of Dates

Four image dates were selected for the initial tests:

June, 1977	* June, 1979
* August, 1977	* August, 1979

However only data tapes from the EROS Data Center for the three indicated dates (*) were received in time for processing. As 1977 is considered a dry year and 1979 a comparatively wet year, this configuration of dates allowed comparison of both phenological change over a season and broad climatic changes between years. Change-detection analyses were performed for 6/79 and 8/79 as well as 8/77 and 8/79 image dates. Vegetation index maps were prepared for all dates.

Software exists for extracting data for the test area from the 1977 Landsat Computer Compatible Tape (CCT). However, the data format of the 1979 digital tapes had been changed by the EROS Data Center from that of the previous Landsat tapes. Initial project activities were aimed at software development that would allow these tapes to be input to CSU's Landsat Mapping System (LMS). Ultimately it was determined that the two 1979 tapes were also in different formats and further modifications were necessary.

The next step in processing was to digitally overlay the image data for each pair of dates to be compared. Implicit in this procedure is geometric control of the images such that there exists a pixel-to-pixel correspondence between the two data sets. Because the new format tapes (1979) had been geometrically rectified, no further control was necessary. Output maps for the 1979 format were therefore produced at an approximate scale of 1:25,000 and are skewed 13° E from True North.

For the 1977-79 comparison each data set was transformed via systematic geometric corrections for earth rotation and scanner mirror velocity, then rotated and scaled.

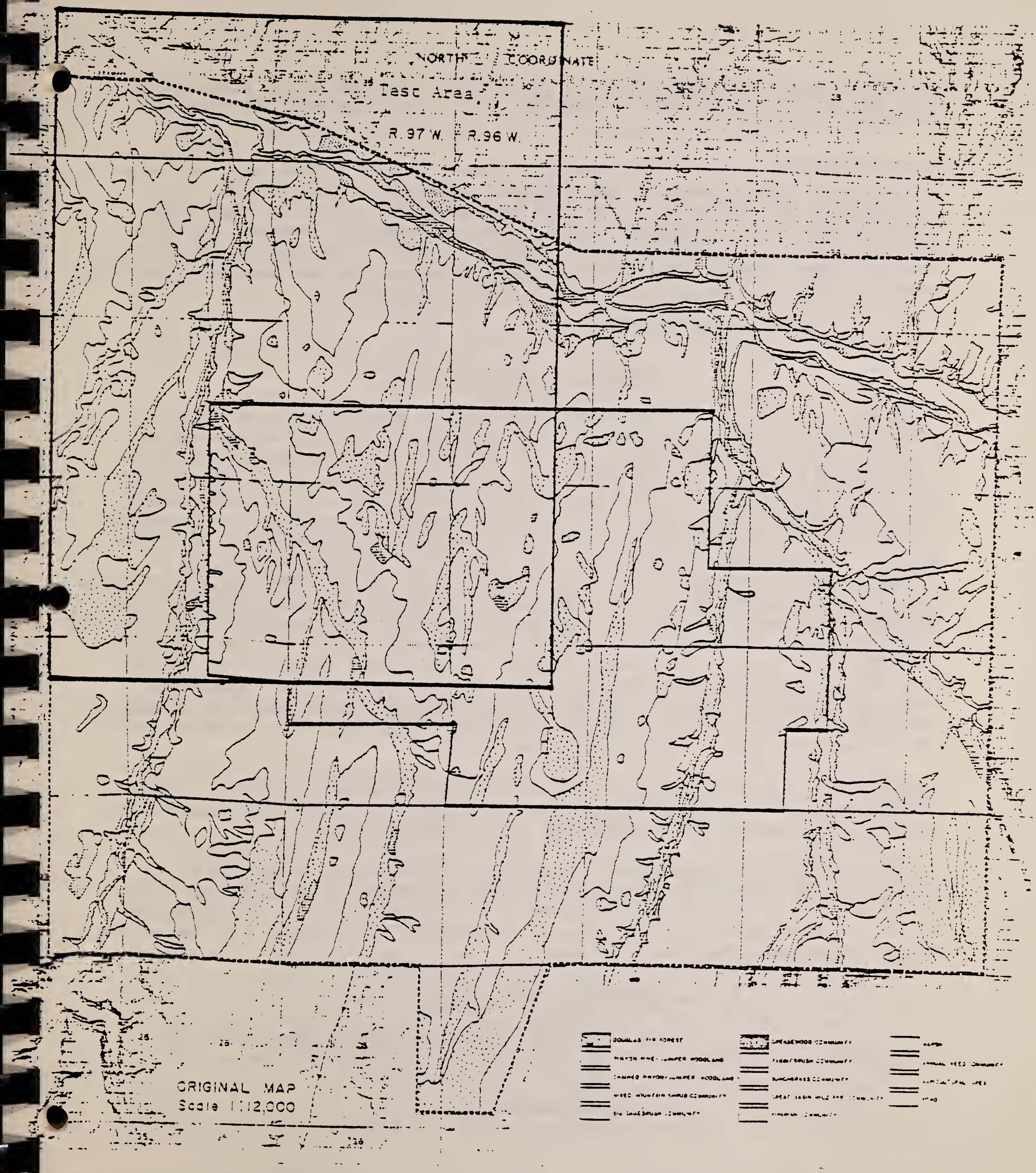


Figure 3.2.4-1 - Piceance Creek Test Area with Major Vegetation Types Indicated.

to conform to a 1:24,000 topographic map of this area. Geometric accuracy for both the 1977 and 1979 images is expected to be within one resolution unit (pixel).

Having geometrically controlled each of the data sets for comparison, the vegetation index for each data set was computed and added to that data set as a fifth channel of information. The data sets were then merged for comparison and differencing of the vegetation index was performed. A histogram of difference values was generated and used to select a threshold for mapping intensity of change. These intensity-of-change values in both positive and negative directions were displayed via line-printer output as gray-scale maps.

3.2.5 Results and Discussion

3.2.5.1 Graymaps of MSS Bands 5 and 7

The Landsat data for the test area are initially presented as line-printer output called a graymap. Each pixel is represented in this output by a single character; the darker line printer characters are representative of pixels of less radiance. Character spacing is 8 lines per inch and 10 columns per inch. For the June-August 1979 comparison, the raw data for each date had been geometrically corrected at the EROS Data Center and, therefore, no modifications were necessary to attain pixel-to-pixel registration of differencing. The graymaps produced from this data are at an approximate scale of 1:25,000 and are rotated 13°E from True North. For the 1977-1979 August differencing systematic geometric controls were used to produce graymaps at 1:24,000 scale, oriented True North for both image dates. Figures A3.2.5-1 and A3.2.5-2 (Volume 2A) are graymaps of the August 1977 image for band 5 and 7 radiance values. Subarea I indicates a portion of the Piceance Creek. In the band 5 image, it can be seen that this is the darkest region within the graymap; conversely in band 7 this region is among the lightest regions (highest detected radiance). This illustrates the effect of the chlorophyll absorption region of band 5 and the enhanced infrared reflectance region that characterizes band 7.

Also of note in Figures A3.2.5-1 and A3.2.5-2 are the areas of relief indicated in Subarea II. The effect of relief can be studied by considering the irradiance at the Landsat sensor and is presented in the Appendix A.3.2.

In this appendix it is shown that topographic influence can be modeled as a multiplicative factor ($\sin\phi$) where ϕ includes the effect of the slope and aspect of the pixel. As illustrated by Subarea II, in Figure A3.2.5-1 high topographic relief is characteristic of the Piceance Creek Basin and produces a marked effect on the reflectance character of a pixel.

3.2.5.2 Vegetation Index Results

The normalized difference value of the vegetation index used in this analysis can be represented in a simple form as:

$$ND = \frac{\text{Band 7} - \text{Band 5}}{\text{Band 7} + \text{Band 5}}$$

A derivation in the appendix is presented to stress that the normalization effect of the vegetation index can be expected to improve between-date comparisons by the reduction of atmospheric, topographic, and soil background variations.

Figures A3.2.5-3 to A3.2.5-5 are graymaps of the vegetation index for the 3 image dates. Subarea I is the darkest portion of the test area indicating it to be a region of substantial green biomass. Subarea II no longer contains the obvious topographic influence noted in Figures A3.2.5-1 and A3.2.5-2. Comparison of these vegetation graymaps with Figure A3.2.5-6 (a black and white air photo of the region) indicates that any topographic relief in the vegetation index map is generally a result of low vegetation associated with the topography (note the Northern bank of the Piceance Creek). Actual topographic effects (shadow) have been greatly reduced.

The August 1979 master image, as generated at the Goddard Space Flight Center, contained poor quality band 4 and 5 data. Since band 5 information is incorporated in the vegetation index, the August 1979 vegetation index map exhibits an East-West striping or banding pattern. To counter this banding, spatial filtering of the vegetation index values (Maxwell and Grunblatt, 1980) was applied to the data. Filtering also serves to mitigate errors caused by slight misregistration of the two image dates being compared and reduces other noise and spatial randomness of the data.

Figures 3.2.5-1 to 3.2.5-3 (a, b) represent filtered vegetation index maps for the study area for the three image dates. These show a reduction of noise (salt and pepper effects) and are therefore preferred over their non-filtered counterparts.

By comparing the August 1977 and August 1979 image dates, one can note a general increase in biomass in the 1979 image data. This is to be expected since 1977 was a drought year and 1979 was more normal.

The between-years change detection map (Figures A3.2.5-7 (unfiltered) and 3.2.5-4 (filtered)) for the August 1977 to 1979 comparison reflects this overall positive change. The only region of strong negative change is in the Piceance Creek area. This negative change could be the result of water influences due to increased flow in the Piceance Creek. Figure 3.2.3-1 illustrates the high attenuation due to water in the band 7 region of the spectrum. Such attenuation causes very low vegetation index values to be recorded for water (typically 10 to 100).

Figures A3.2.5-8 (unfiltered) and 3.2.5-5 (filtered) show the seasonal-change-detection graymaps produced by the comparison of the June-August 1979 dates. The upland regions (Subarea II) of this change-detection map are characterized by positive change while the riparian vegetation of the Piceance Creek area (Subarea I) is characterized by negative change. The negative change could be due to harvest of these grassland areas for hay. The positive upland change is supported by season biomass curves of typical upland vegetation communities (Figure 3.2.5-6). It is recognized that the peak-biomass date for these communities is highly variable due to the particular seasonal characteristics of

Figure 3.2.5-1 Graymap of Filtered Vegetation Index (Normalized Difference) for the Piceance Creek Test Area. August 1977 Image Data.

Biomass Levels

Symbol	Index Value	Green Biomass (kg/ha)
W	1-90	0 (water)
	90-121	0 (bare soil, muddy water)
.	122-125	0-175
-	126-130	175-400
•	131-137	400-1000
•	138-147	1000-2000
@	148-157	2000-4000
+	158-169	4000-8000
#	170-180	8000-20000
O	181-191	20000-40000
W	193-202	40000-80000
[	203-213	>8000
]	214-256	>40000

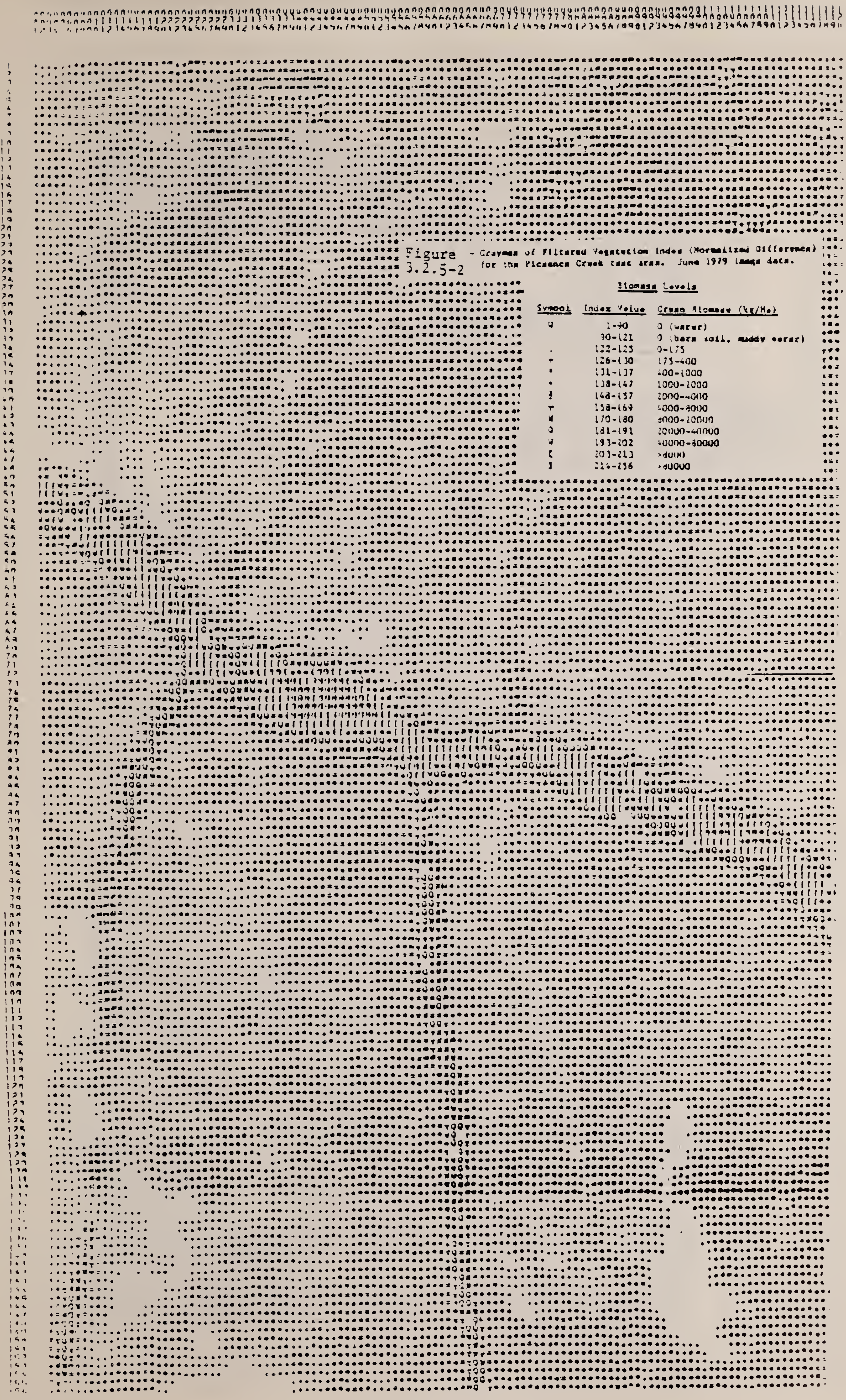


Figure 3.2.5-2 - Graymap of Filtered Vegetation Index (Normalized Difference) for the Piceance Creek test area. June 1979 image data.

Biomass Levels

Symbol	Index Value	Green Biomass (kg/Ha)
W	1-90	0 (water)
	90-121	0 (bare soil, muddy water)
.	122-125	0-175
+	126-130	175-400
•	131-137	400-1000
•	138-147	1000-2000
‡	148-157	2000-4000
T	158-169	4000-8000
M	170-180	8000-20000
O	181-191	20000-40000
W	193-202	40000-80000
[	203-213	>8000
]	214-256	>80000

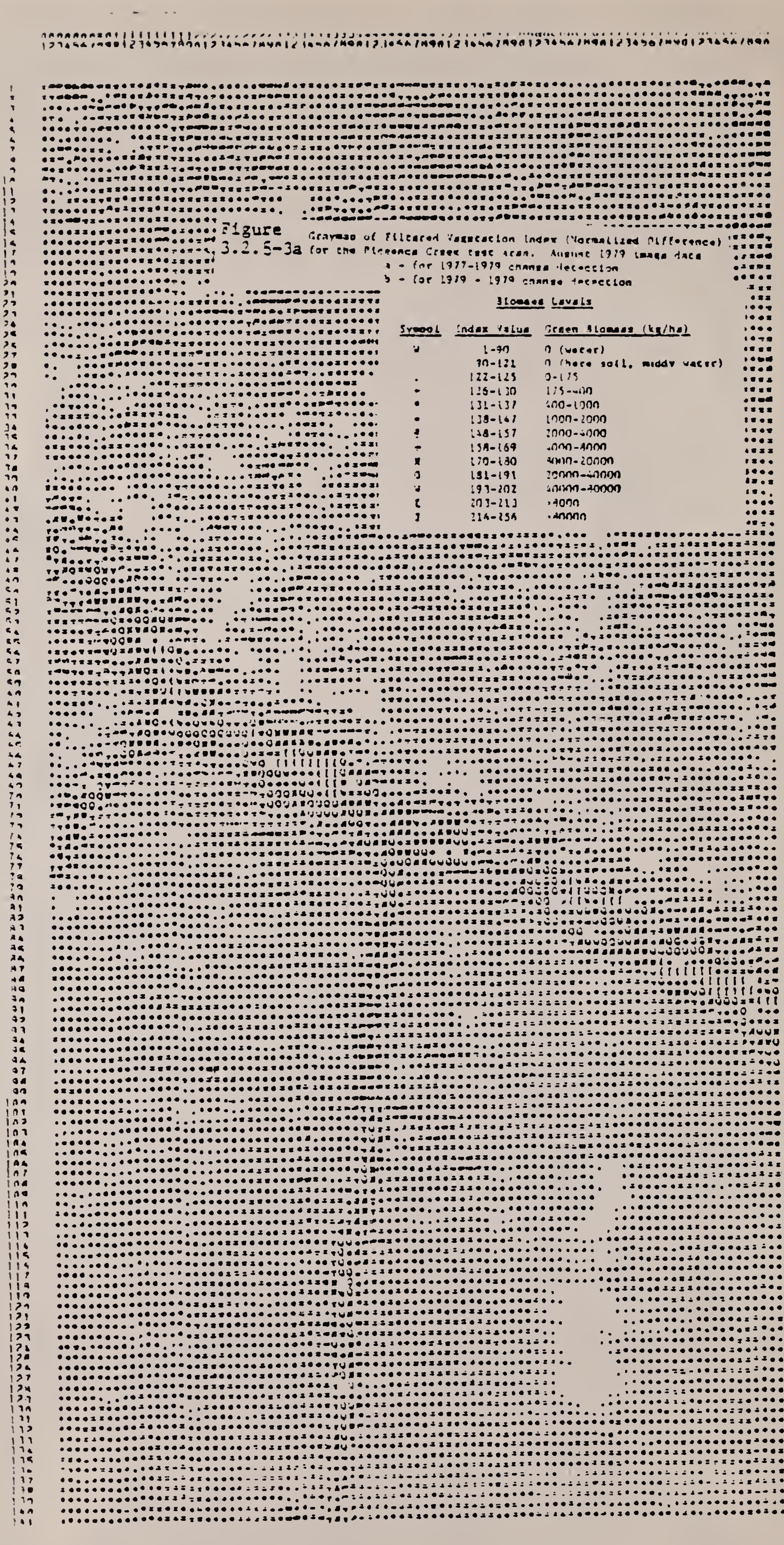


Figure 3.2.5-3a Graymap of Filtered Vegetation Index (Normalized Difference) for the Florence Creek test area. August 1979 image data
a - for 1977-1979 change detection
b - for 1979 - 1979 change detection

Biomass Levels

Symbol	Index Value	Green Biomass (kg/ha)
W	1-90	0 (water)
	90-121	0 (bare soil, muddy water)
.	122-125	0-175
-	126-130	175-400
•	131-137	400-1000
=	138-147	1000-2000
#	148-157	2000-4000
+	158-169	4000-8000
X	170-180	8000-20000
O	181-191	20000-40000
W	193-202	40000-80000
(	203-213	>8000
I	214-256	>80000

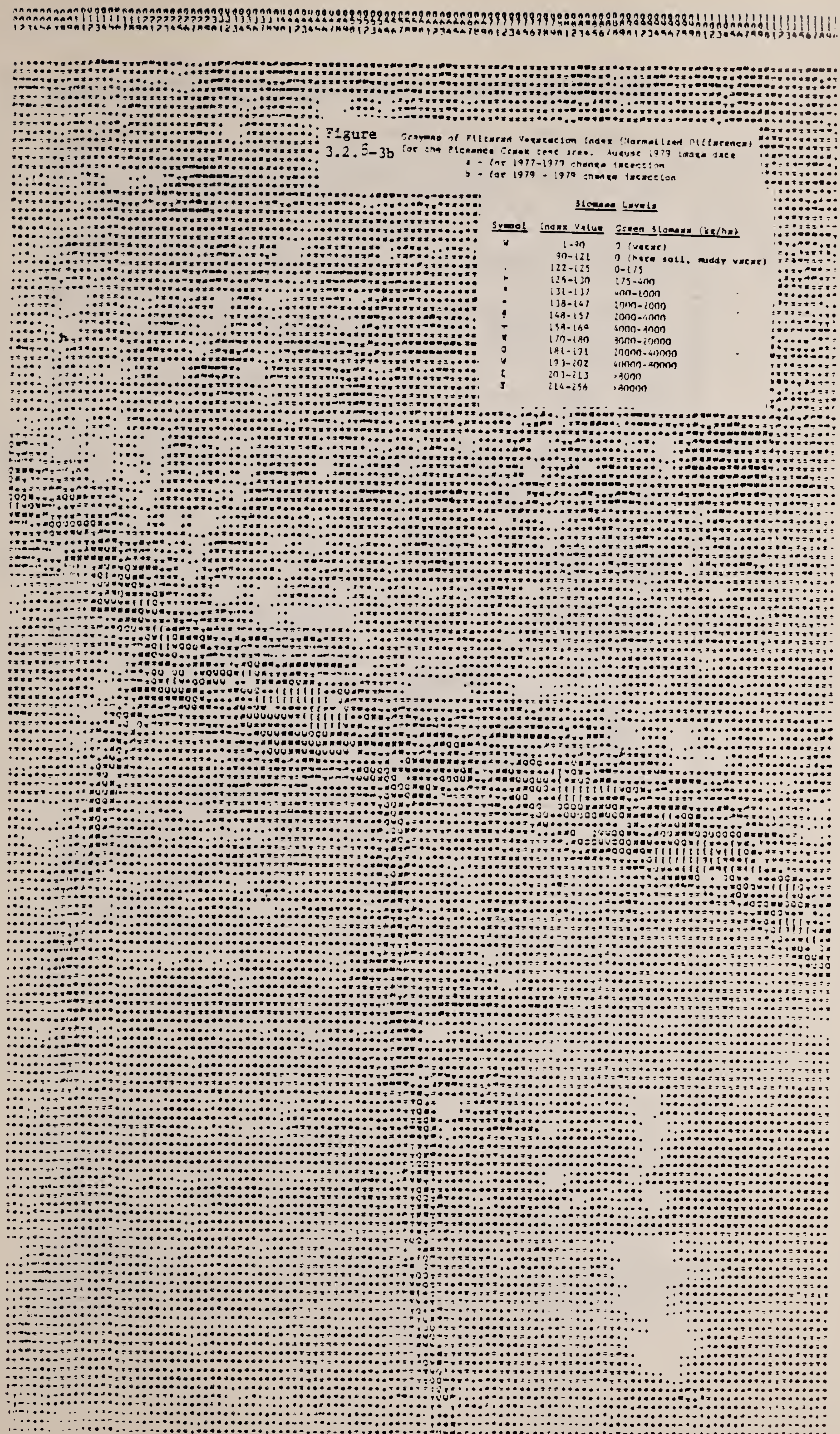


Figure 3.2.5-3b Graymap of Filtered Vegetation Index (Normalized Difference) for the Piceance Creek test area. August 1979 image date
a - for 1977-1979 change detection
b - for 1979 - 1979 change detection

__Biomass Levels__

Symbol	Index Value	Green Biomass (kg/ha)
W	1-89	0 (water)
	90-121	0 (bare soil, muddy water)
.	122-125	0-175
+	126-130	175-400
*	131-137	400-1000
•	138-147	1000-2000
!	148-157	2000-4000
=	158-169	4000-8000
¥	170-180	8000-20000
O	181-191	20000-40000
W	193-202	40000-80000
[	203-213	>8000
X	214-256	>80000

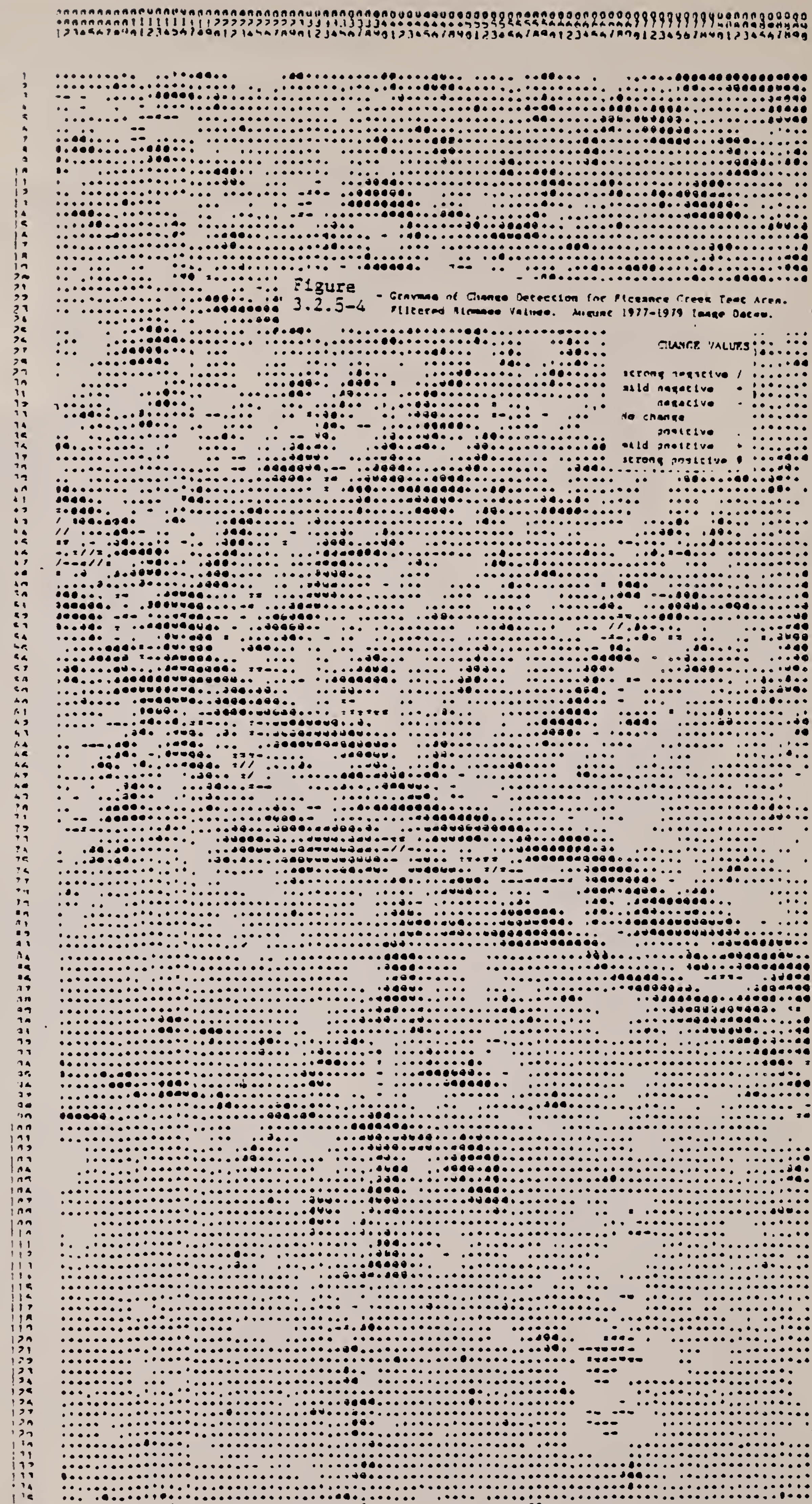


Figure 3.2.5-4 - Graymap of Change Detection for Piceance Creek Test Area. Filtered Biomass Values. August 1977-1979 Image Dates.

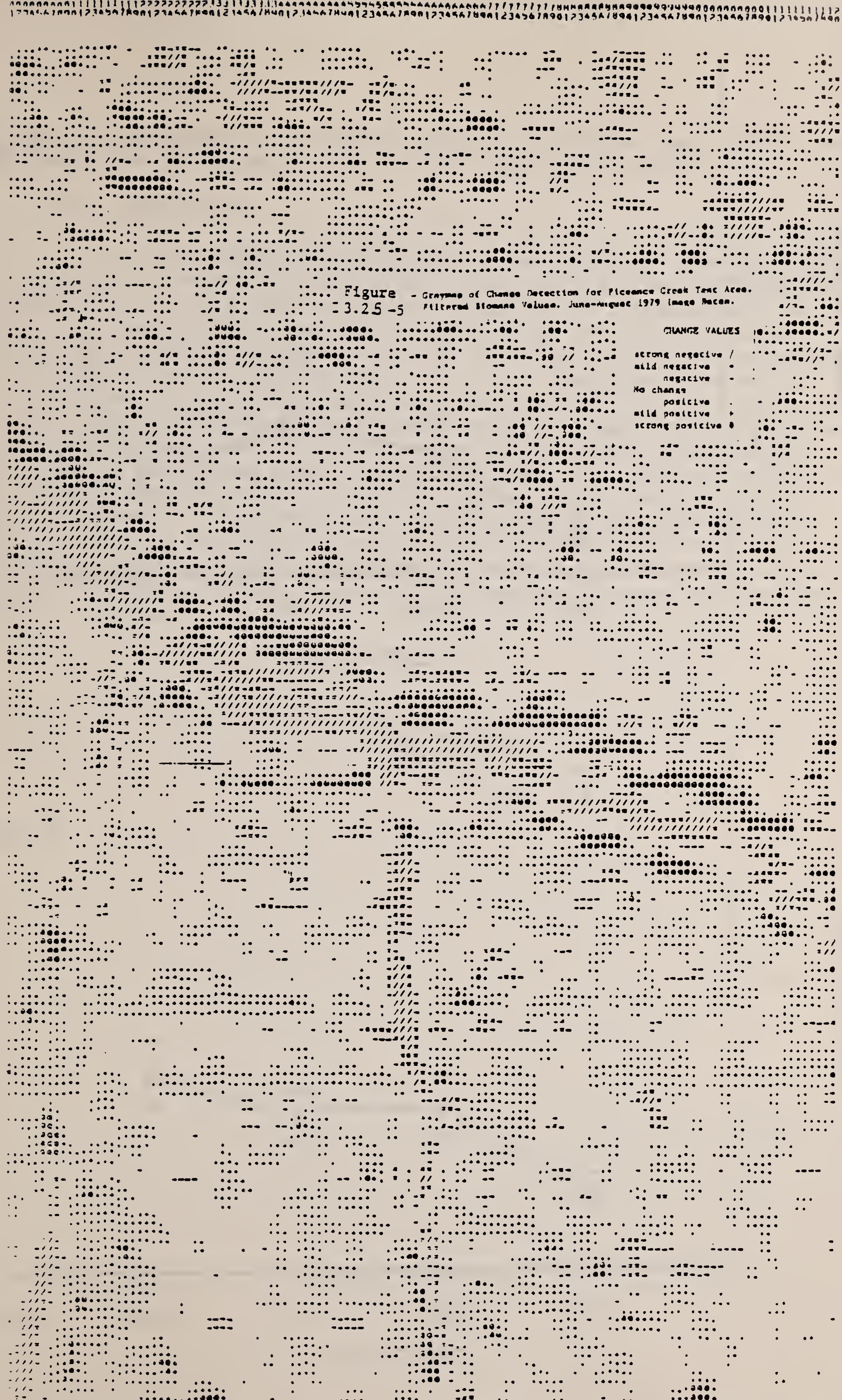


Figure 3.25-5 - Graymap of Change Detection for Piceance Creek Test Area. Filtered Biomass Values. June-August 1979 Image Pair.

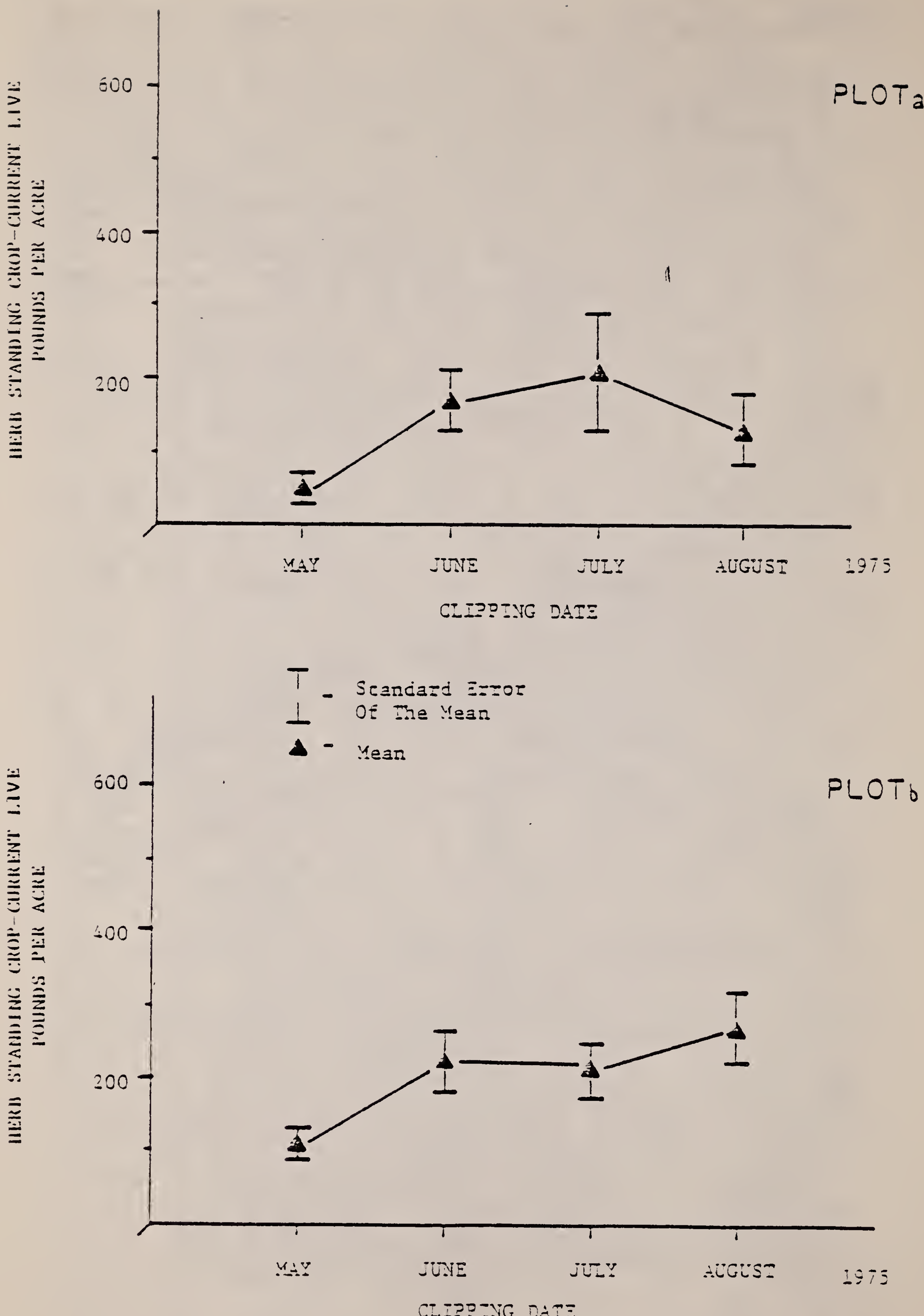


Figure 3.2.5-6 - Changes in Herbaceous Standing Crop Pinyon Juniper Woodland within the Piceance Creek test area

any one year. These graphs are presented merely to indicate that biomass levels of these communities are expected to be higher late in the season.

3.2.6 Conclusions

1) The normalized difference is an effective index for the digital evaluation of vegetation condition in the Piceance Creek basin. Qualitative index values and the detected change values are in agreement with expectations. The normalization qualities of this index are also desirable. 2) Change-detection mapping, especially with filtering, can yield interpretable results for vegetation condition changes. 3) It is recognized that yearly climatic variations can vary plant phenology. Any attempt to define change between years must be normalized for climatic factors. Toward this end, several seasonal investigations, ideally of dry and wet years, should be performed. Given the problems of extreme season variability inherent in vegetation analysis, perhaps a seasonal (multiple-date) record of change rather than single-date analysis is needed. 4) The normalized difference can be expected to yield predictable results in cropland, range grasslands and deciduous shrubland areas, but should be calibrated for each ecosystem or vegetation community. Ground measurements on Landsat overpass dates will be required for such calibrations.

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4.0 INDICATOR VARIABLES

Indicator variables are selected, monitored, environmental parameters that can be expected to provide the earliest clues of potential change in the baseline environment. This section identifies the indicator variables selected for environmental disciplines of hydrology, air quality and meteorology, noise, and biology that will be observed most closely. Site locations are shown on the jacket map.

4.1 Role in Impact Assessment

Efficient monitoring of environmental quality requires close observation of a few key variables. This includes those variables that are: 1) most sensitive to change in quality; 2) indicators of natural or climatic change; and 3) subject to Federal and State standards because of concern for human health and public welfare. For these reasons the Development Monitoring Plan has identified and emphasized in the collection plan key indicator variables in each of the environmental disciplines.

Close observation of the identified key indicator variables requires early data reduction and analysis in order to flag changes or adverse time-trends in the observations. Visibility is provided by maintaining current time-series plots of the key variables. Impact of development activity is also assessed through statistical comparison of data collected near development and control sites. If trends and differences signal the probable occurrence of adverse environmental impact, additional and increased monitoring will be triggered. (Referred to as Systems Dependent Monitoring.)

4.2 Identification of Class 1 Indicator Variables

Indicator variables have been identified in the Development Monitoring Plan as a subset of the environmental parameters that are monitored because they best indicate the "state" of the ecosystem. However, the combinations of monitored indicator variables with the number of collection stations exceed 1000. Therefore, Class 1 Indicator Variables have been identified in order to further reduce the number of parameter-site combinations to a realistic quantity (147) for the purpose of close observation and more detailed analyses. Class 1 Indicator Variables are key environmental variables collected at representative stations on at least monthly frequency.

Time series plots will be maintained and updated semi-annually for all Class 1 Indicator Variables. Beginning with Oil Shale Tract C-b Development Monitoring Report #2 (semi-annual data report), updated plots are included as a supplement to the data reports; each plot contains only data not previously presented in a data report. Data collected prior to this time were presented in Appendix 2B - Volume 2 Time Series Plots to the 1978 C-b Annual Report.

This section identifies only the Class 1 Indicator Variables. However, all monitored variables are included in the data reports and the following chapters of this Annual Report.

4.2.1 Tract Photography

Tract photography is to be carried out annually under a surface program. The aerial program this year consisted of historical and present use of Landsat digital data. No Class 1 Indicator Variables associated with tract photography are identified at present.

4.2.2 Hydrology and Water Quality

Class 1 Indicator Variables for hydrology are identified in Table 4.2.2-1. The number of collection sites has been screened to four major USGS Gauging Stations, four springs and seeps, and four alluvial wells. Parameters are collected either daily or monthly as indicated by the codes in the table. For cross-referencing ease, Table 4.2.2-2 presents the page numbers of the time series plots with Supplement to the Development Monitoring Reports where these time series data are presented.

4.2.3 Air Quality and Meteorology

Class 1 Indicator Variables and stations for air quality and meteorology are identified in Table 4.2.3-1. Collection frequency for those parameters coded with D is continuous; hourly averages are reported in the data reports. Daily averages and peaks calculated from the hourly averages are used in the time-series plots for these variables. Daily totals will be plotted for those parameters coded with a T. Table 4.2.3-2 presents cross-reference page numbers to the time series plots.

4.2.4 Noise

Noise is measured at three stations in decibels. Class 1 Indicator Variables, shown in Table 4.2.4-1, are peak measurements of noise level for daytime (0700 through 1900 hours) and for nighttime (1900 through 0700 hours). Table 4.2.4-2 lists the page numbers for cross-referencing time series plots.

4.2.5 Biology

Much of the biological data collection and analysis are in a seasonal or annual time frequency. These data and analyses are important indicators of possible oil shale development environmental impact. However, under the definition of Class 1 Indicator Variables (those variables with at least a monthly collection frequency), a much smaller set of biological environmental parameters are identified. These parameters and their collection frequencies are shown in Table 4.2.5-1. The collection frequency of microclimate data is twice monthly and is indicated by 2M in this table. Monthly and weekly collection frequencies are shown in the table with M and W, respectively. Cross-reference page numbers for time series plots are listed in Table 4.2.5-2.

TABLE 4.2.2-1

HYDROLOGY CLASS 1 INDICATOR VARIABLES

VARIABLE	MAJOR U.S.G.S.				SPRINGS AND SEEPS				ALLUVIAL WELLS			
	WU07	WU61	WU58	WU22	WS01	WS03	WS06	WS07	WA03	WA05	WA06	WA08
1. Ammonia	M	M	M	M								
2. Boron	M	M	M	M								
3. Fluoride	M	M	M	M								
4. Total Dissolved Solids	M	M	M	M								
5. Arsenic	M	M	M	M								
6. Sediment	M	M	M	M								
7. Precipitation			M	M								
8. pH	D	D	D	D	M	M	M	M	M	M	M	M
9. Temperature	D	D	D	D	M	M	M	M	M	M	M	M
10. Flow	D	D	D	D								
11. Conductivity	D	D	D	D	M	M	M	M	M	M	M	M
12. Dissolved Oxygen	D	D	D	D	M	M	M	M				
13. Level									M	M	M	M

NOTES: Frequency of data sampling is coded: D for daily average of continuous sampling; M for monthly samples. Precipitation measurements are not taken at stations WU07 or WU61.

TABLE 4.2.2-2

HYDROLOGY CLASS I INDICATOR VARIABLE TIME-SERIES INDEX
FOR SUPPLEMENT TO SEMI-ANNUAL DATA REPORTS

VARIABLE	MAJOR U.S.G.S. WU07	WU61	WU58	WU22	SPRINGS AND SEEPS WS01	WS03	WS06	WS07	ALLUVIAL WELLS WA03	WA05	WA06	WA08
1. Ammonia	5.2.1-1	-2	-3	-4								
2. Boron	-5	-6	-7	-8								
3. Fluoride	-9	-10	-11	-12								
4. Total Dissolved Solids	-13	-14	-15	-16								
5. Arsenic	-17	-18	-19	-20								
6. Sediment	-21	-22	-23	-24								
7. Precipitation			-25	-26								
8. pH	5.2.1-27	-28	-29	-30	5.2.2-47	-48	-49	-50	5.3.1-67	-68	-69	-70
9. Temperature	-31	-32	-33	-34	-51	-52	-53	-54	-71	-72	-73	-74
10. Flow	-35	-36	-37	-38	-55	-56	-57	-58				
11. Conductivity	-39	-40	-41	-42	-59	-60	-61	-62	-75	-76	-77	-78
12. Dissolved Oxygen	-43	-44	-45	-46	-63	-64	-65	-66				
13. Level									5.3.1-79	-80	-81	-82

NOTE: Numbers in this table preceding the dashes represent section numbers in the Development Monitoring Plan and in Volume 2 of the 1979 C-b Annual Report. The dashed numbers are page numbers in the time series supplement to the Development Monitoring Reports.

TABLE 4.2.3-1

AIR QUALITY AND METEOROLOGY CLASS 1 INDICATOR VARIABLES

VARIABLE	SAMPLING STATIONS						
	AB20	AA23	AB23	AC20	AD42	AD56	AREA
1. SO_2	D		D				
2. H_2S	D		D				
3. O_3	D		D				
4. NO_x	D		D				
5. NO_2	D		D				
6. CO	D		D				
7. Particulates (every 3rd day)	T		T			T	
8. WS - 10m	D	D			D	D	
9. WD - 10m	D	D			D	D	
10. WS - 30m		D					
11. WD - 30m		D					
12. RH			D				
13. TEMP - 10m	D		D		D	D	
14. PRESS			D				
15. SOLAR			T				
16. vTEMP - (60m-10m)		D					
17. PRECIPITATION	T		T				
18. EVAPORATION			T				
19. INV HT				D			
20. VISUAL RANGE (every 6th day in Spring and Fall)							VR

NOTES: Frequency of sampling is continuous for all variables except visual range. Evaporation measurements are confined to the growing season. Daily averages with min and max hourly values are plotted for those variables coded with D. Daily totals are plotted for those coded with T.

TABLE 4.2.3-2

AIR QUALITY AND METEOROLOGY CLASS 1 INDICATOR VARIABLE TIME-SERIES INDEX
FOR SUPPLEMENT TO SEMI-ANNUAL DATA REPORTS

VARIABLE	SAMPLING STATIONS						
	AB20	AA23	AB23	AC20	AD42	AD56	AREA
1. SO_2	6.2.1-83		-84				
2. H_2S	-85		-86				
3. O_3	-87		-88				
4. NO_x	-89		-90				
5. NO_2	-91		-92				
6. CO	-93		-94				
7. Particulates (every 3rd day)	6.2.2-95		-96			-97	
8. WS - 10m	6.3.2-98	-99			-100	-101	
9. WD - 10m	-102	-103			-104	-105	
10. WS - 30m		-106					
11. WD - 30m		-107					
12. RH			6.3.1-108				
13. TEMP - 10m	-109		-110		-111	-112	
14. PRESS			-113				
15. SOLAR			-114				
16. VTEMP - (60m - 10m)		-115					
17. PRECIPITATION	-116		-117				
18. EVAPORATION			-118				
19. INV HT				6.3.2-119			
20. VISUAL RANGE (every 6th day in Spring and Fall)							6.2.3-120

NOTE: Numbers in this table preceding the dashes represent section numbers in the Development Monitoring Plan and in Volume 2 of the 1979 C-b Annual Report. The dashed numbers are page numbers in the time series supplement to the Development Monitoring Reports.

TABLE 4.2.4-1

NOISE CLASS 1 INDICATOR VARIABLES

VARIABLE	SAMPLING STATIONS	
	NA02 & NA09 (combined)	NB15
1. Daytime Noise (0700-1900)	P	P
2. Nighttime Noise (1900-0700)		P

NOTES: Discrete traffic noise measurements are recorded at Stations NA02 and NA09 one day each week. The peak db level (recorded here as P) for the two stations is plotted.

Continuous sampling of noise is conducted for 24-hours every sixth day at Station NB15. The peak db level for two 12-hour intervals is designated here as P.

TABLE 4.2.4-2

NOISE CLASS 1 INDICATOR VARIABLE TIME-SERIES INDEX
FOR SUPPLEMENT TO SEMI-ANNUAL DATA REPORTS

VARIABLE	SAMPLING STATIONS	
	NA02 & NA09 (combined)	NB15
1. Daytime Noise (0700-1900) COMBINED 2. Nighttime Noise (1900-0700)	7.2.1-121	7.2.2-122

Notes: Numbers in this table preceding the dashes represent section numbers in the Development Monitoring Plan and in Volume 2 of the 1979 C-b Annual Report. The dashed numbers are page numbers in the time series supplement to the Development Monitoring Reports.

TABLE 4.2.5-1

BIOLOGY CLASS 1 INDICATOR VARIABLES

VARIABLE	MICROCLIMATE STATIONS BC01	BC02	BC03	BC04	BC05	BC06	BC07	BC08	BC09	BC13	U.S.G.S. WU07	WU61	PICEANCE CREEK ROAD	TRAFFIC CB	PCN	PCE
1. PRECIPITATION	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
2. SNOW DEPTH	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
3. TEMP MAX	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
4. TEMP MIN	2M	2M	2M	2M	2M	2M	2M	2M	2M	2M						
5. PERIPHYTON BIOPRODUCTIVITY											M	M				
6. DEER ROAD COUNT													W			
7. DEER ROAD KILLS													W			
8. TRAFFIC COUNT														W	W	W

NOTES: Microclimate data are collected twice monthly (2M);
Periphyton bioproductivity collected monthly (M);
and Deer and Traffic are counted weekly (W).
CB - Traffic Count between Piceance Creek Road and C-b Tract.
PCN - Piceance Creek Road north of C-b turnoff.
PCE - Piceance Creek Road east of C-b turnoff.

TABLE 4.2.5-2

BIOLOGY CLASS 1 INDICATOR VARIABLE TIME-SERIES INDEX
FOR SUPPLEMENT TO SEMI-ANNUAL DATA REPORTS

VARIABLE	MICROCLIMATE STATIONS										U.S.G.S.		PICEANCE CREEK ROAD	TRAFFIC		
	BC01	BC02	BC03	BC04	BC05	BC06	BC07	BC08	BC09	BC13	WU07	WU61		CB	PCN	PCE
1. PRECIPITATION	8.7.5 -123	-124	-125	-126	-127	-128	-129	-130	-131	-132						
2. SNOW DEPTH																
3. TEMP MAX	-133	-134	-135	-136	-137	-138	-139	-140	-141	-142						
4. TEMP MIN																
5. PERIPHYTON BIOPRODUCTIVITY											8.6.2 -143	-144				
6. DEER ROAD COUNT													8.2.2-145			
7. DEER ROAD KILLS													8.2.3-146			
8. TRAFFIC COUNT															8.2.3-147	

NOTES: Numbers in this table preceding the dashes represent section numbers in the Development Monitoring Plan and in Volume 2 of the 1979 C-b Annual Report. The dashed numbers are page numbers in the time series supplement to the Development Monitoring Reports.

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5.0 HYDROLOGY AND WATER QUALITY

5.1 Introduction and Scope

A development monitoring program has been implemented to provide water quantity and quality data to detect changes resulting from project operations. Streams, springs, seeps and alluvial and bedrock aquifers have been monitored since baseline. The program has been expanded to include monitoring of water associated with shafts and impoundments during 1979. Additional data have been compiled for springs, wells and precipitation stations through requirements of the Water Augmentation Plan. See Exhibits "A", "B" and "C" in the jacket. Shale-pile monitoring will be included as development proceeds. Data obtained during baseline and interim monitoring studies established reference levels for use in comparative studies during development. All water level measurements and water quality data in this report for wells are representative of the generalized two-aquifer system (upper and lower). Appendix 2A and Figure A5.1-1 relate this generalized concept to stratigraphic section markers, to the mining zone and to a more advanced four-level aquifer concept.

This chapter presents the hydrologic analyses performed on data collected on the C-b Tract to date with emphasis on data collected since October, 1978. The analyses are grouped into two major sections, levels and flows and water quality. Details of the statistical analyses are presented in Appendix 2A by referenced sections.

5.2 Levels and Flows

This section discusses hydrologic flows of surface streams and water levels in springs and seeps, alluvial and bedrock wells and impoundments. Stations required under the Development Monitoring Plan and more recently (August, 1979) under the Water Augmentation Plan are identified in each subsection.

It is to be noted that monthly water production reports (and cumulatives to date) are presented in Table 4-3 of Volume 1 of this report. It includes water pumped from shafts, stored, used and discharged.

5.2.1 Streams

5.2.1.1 Scope

Surface flow hydrology is concerned primarily with monitoring the flow of Piceance Creek and its tributaries via the U.S.G.S. stream gauging network.

5.2.1.2 Objectives

The surface stream monitoring program has been implemented to detect changes in water flow that might be attributable to Tract development.

5.2.1.3 Experimental Design and Method of Analysis

Thirteen surface water gauging stations (Figure 5.2.1-1) were constructed on and in the vicinity of Tract C-b by the U. S. Geological Survey in cooperation with the Colorado River Water Conservation District and monitored through the baseline period to present. In August, 1979 four additional U.S.G.S. stations along Piceance Creek were added as part of the Water Augmentation Plan. They are stations 09304800 (WU48), 09306200 (WU00), 09306022 (WU22) and 09306255 (WU55) and are shown on the jacket map Exhibit "A". The sampling intervals for all stations are indicated in Figure 5.2.1-2 along with station numbers and equivalent computer codes.

Nine of the near-Tract stations are located on ephemeral streams. Stations which are located on perennial drainages and considered major gauging stations for assessing development impacts are given as follows:

Computer Code	Station Number	Station Location
WU07	09306007	Piceance Creek Below Rio Blanco
WU61	09306061	Piceance Creek at Hunter Creek
WU22	09306022	Stewart Gulch
WU58	09306058	Willow Creek
WU00	09306200	Piceance Creek near Ryan Gulch

U.S.G.S. STREAM GAUGING STATION MONITORING NETWORK

FIGURE 5.2.1-1

FIGURE 5.2.1-2

U.S.G.S. STREAM GAUGING
STATIONS SAMPLING TIME INTERVALS FOR
FLOW AND WATER QUALITY

STATION I.D.	COMPUTER CODE	SAMPLE TYPE	FIRST SAMPLE DATE	1974	1975	1976	1977	1978	1979
09304800	WU48	QUALITY	Apr-1974						
09306007	WU07	"	Apr-1974						
09306036	WU36	"	Jul-1975						
09306039	WU39	"	Dec-1974						
09306042	WU42	"	Feb-1976						
09306061	WU61	"	Apr-1974						
09306050	WU50	"	Oct-1974						
09306052	WU52	"	Oct-1974						
09306058	WU58	"	Apr-1974						
09306033	WU33	"	Feb-1975						
09306025	WU25	"	May-1974						
09306015	WU15	"	Feb-1976						
09306028	WU28	"	Mar-1975						
09306022	WU22	"	Sep-1974						
09306200	WU00	"	Jun-1965						
09306222	WU62	"	Apr-1965						
09306255	WU55	"	Apr-1965						
09304800	WU48	FLOW	Oct-1961						
09306007	WU07	"	Apr-1974						
09306036	WU36	"	Oct-1974						
09306039	WU39	"	Apr-1974						
09306042	WU42	"	Apr-1974						
09306061	WU61	"	Apr-1974						
09306050	WU50	"	Oct-1974						
09306052	WU52	"	Oct-1974						
09306058	WU58	"	Apr-1974						
09306033	WU33	"	Oct-1974						
09306025	WU25	"	Apr-1974						
09306015	WU15	"	Oct-1974						
09306028	WU28	"	Apr-1974						
09306022	WU22	"	Oct-1974						
09306200	WU00	"	Oct-1964						
09306222	WU62	"	Oct-1964						
09306255	WU55	"	Oct-1972						

5.2.1.4 Discussion and Results

Hydrographs of daily streamflow are given for Stations WU07, WU61 and WU00, the major Piceance Creek stations of interest, on Figures 5.2.1-3a, b. The hydrographs show the seasonal influence of runoff, evapotranspiration, and irrigation diversions of the flow of Piceance Creek. Flow in Piceance Creek has the conventional two-component baseflow and seasonal flow. Baseflow consists of groundwater recharge from alluvial aquifers and perched aquifers in the bedrock. Seasonal flow is comprised of storm runoff and snowmelt. December and January records reflect baseflow conditions while major irrigation diversions occur during the period April through September. The months of February, March, October and November are characterized by variable flows as a function of runoff and off-season irrigation diversions.

Total and mean annual stream flows for Stations WU07, WU61 and WU00 as well as Stations WU22 and WU58 are given in Table 5.2.1-1. Station WU22 monitors Stewart Gulch tributary and Station WU58 gauges the flow of Willow Creek.

Discharge totals and mean values recorded for the stations draining the two perennial tributaries of Piceance Creek in the Tract vicinity are strikingly similar. The similarity can be attributed to comparable drainage areas (D_A, Willow Creek = 48.7 mi^2; D_A,Stewart Gulch = 43.4 mi^2), bedrock and vegetation. A comparison of mean flows for Station WU07 (upstream) and Station WU61 (downstream) indicates about a 1.0 cfs increase in flow for 1978 and about a 2.5 cfs increase in flow for 1979 at the downstream station. These changes are due to climatic variations. Mean annual flows at the upstream station have varied from a low of 5.0 cfs in 1977 to 21.4 cfs in 1979. Minimum flows are approximately 1 cfs; peak flows were approximately 157 and 149 cfs in 1979 at Stations WU07 and WU61, respectively.

Trend analysis by means of the Box-Jenkins statistical-analysis technique for flows at Stations WU07 and WU61 concluded no time-trends exist in the data. Summaries are reported in Appendix Tables A5.2.1-1 and A5.2.1-2.

TABLE 5.2.1-1

TOTAL AND MEAN ANNUAL STREAM FLOW

Water Year	Station WU07		Station WU22		Station WU58		Station WU61		Station WU09	
	Total Ac.ft/yr	Mean cfs	Total Ac.ft/yr	Mean cfs	Total Ac.ft/yr	Mean cfs	Total Ac.ft/yr	Mean cfs	Total Ac.ft/yr	Mean cfs
1975	9,651	13.3	1,407	2.0	1,437	2.0	13,138	18.1	20,994	29.0
1976	7,245	10.0	1,933	1.8	1,715	2.4	12,039	16.6	18,099	25.0
1977	3,632	5.0	999	1.4	1,008	1.4	7,149	9.9	9,412	13.0
1978	7,135	9.9	868	1.2	737	1.0	7,833	10.8	11,584	16.0
1979	15,457	21.4	898	1.2	820	1.1	17,050	23.6	20,994	29.0

Figure 5.2.1-3a
HYDROGRAPHS OF DAILY MEAN FLOW FOR STATIONS
WU07, WU61 AND WU00
(October 1973-September 1977)

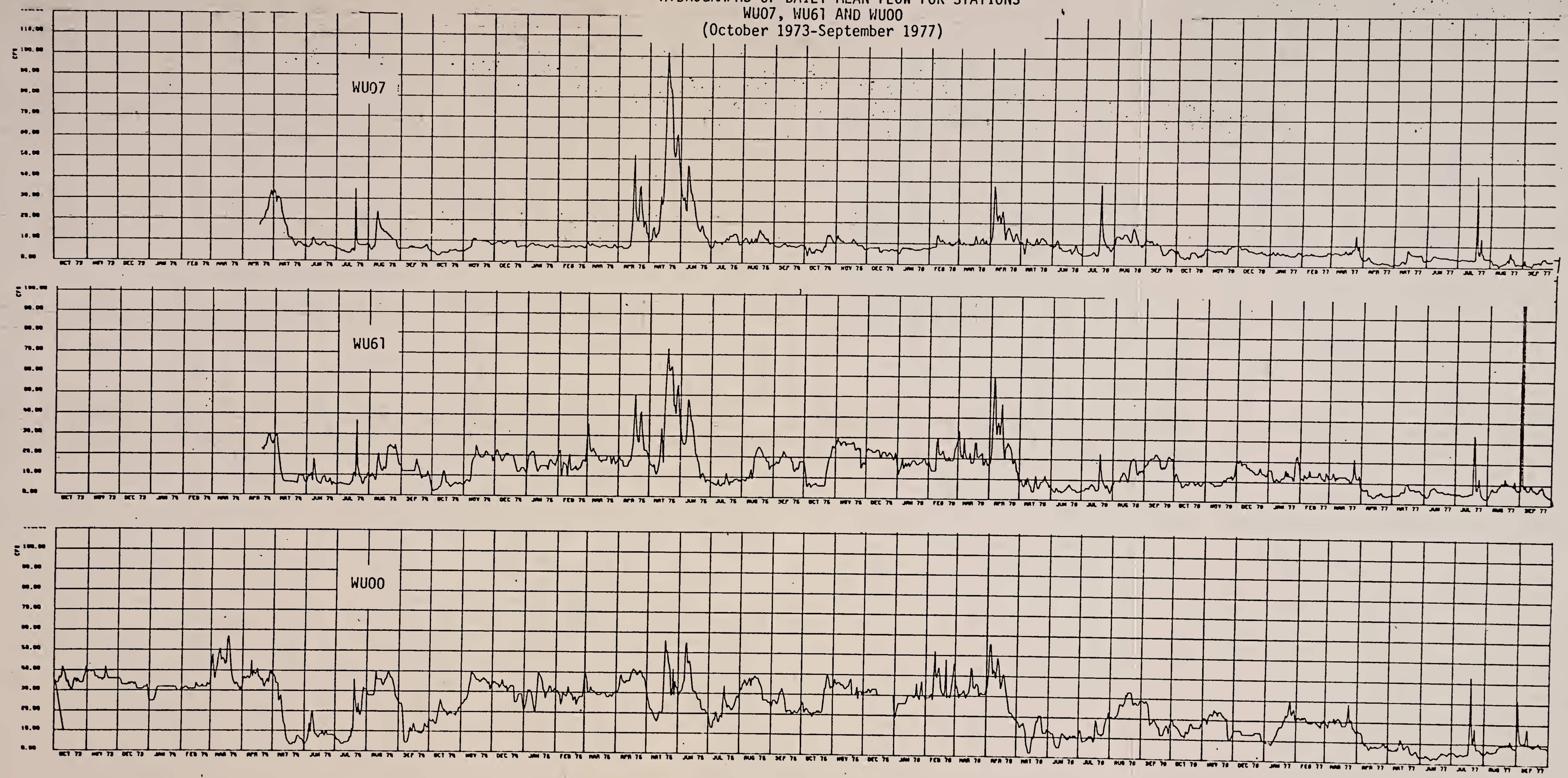
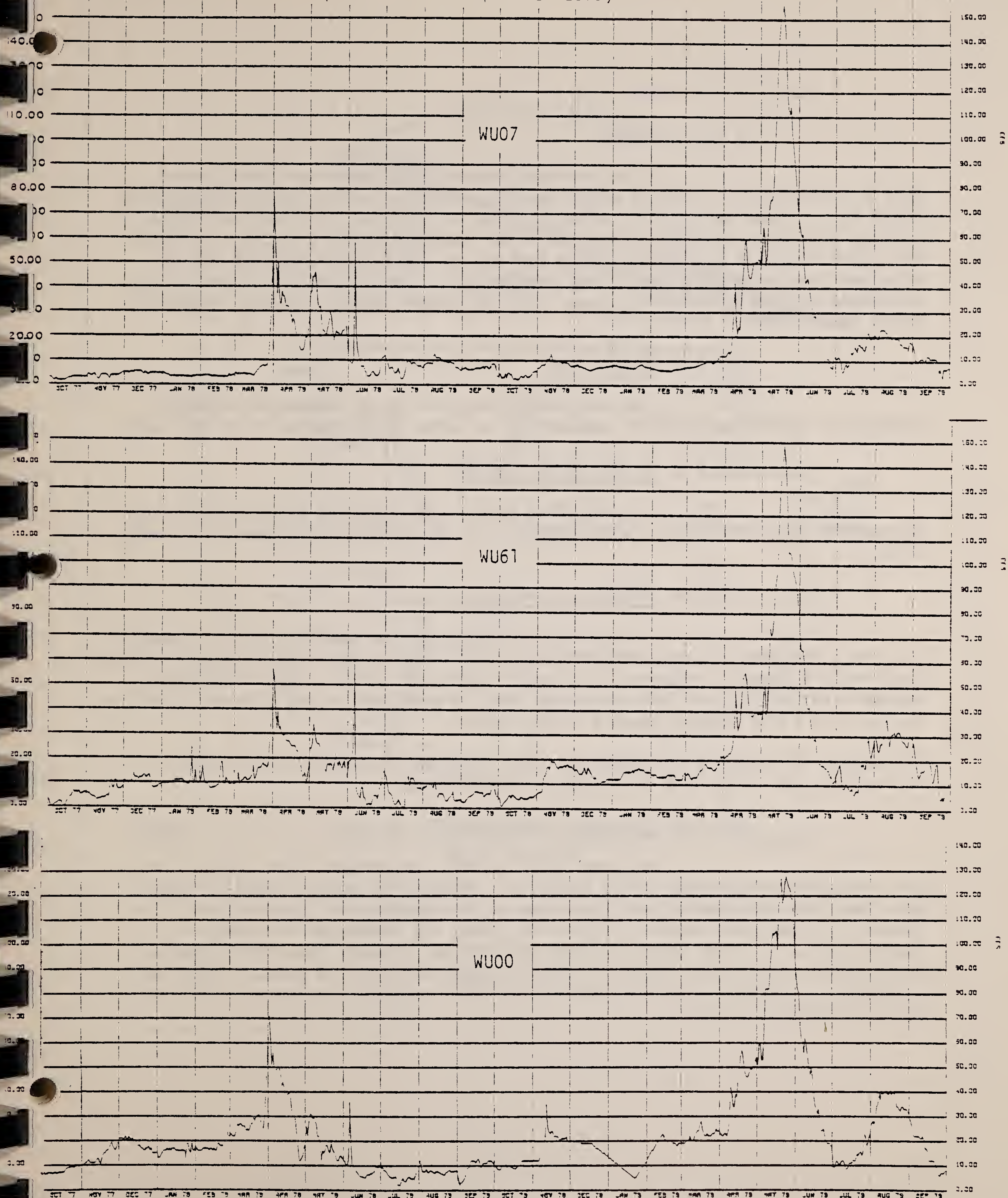


Figure 5.2.1-3b
HYDROGRAPHS OF DAILY MEAN FLOW FOR STATIONS
WU07, WU61 AND WU00
(October 1977-September 1979)



5.2.2 Springs and Seeps

5.2.2.1 Scope

Nine springs provide data under the Development Monitoring Plan for flow and water quality analysis on and in the vicinity of Tract C-b. These springs are shown in Figure 5.2.2-1a. Fifteen additional springs are also monitored under the Water Augmentation Plan; they are shown on Figure 5.2.2-1b. Discharge from springs in the Uinta Formation may be affected from mine development and dewatering. The monitoring frequency was increased to weekly beginning June, 1979 to better gauge potential impact of shaft dewatering on spring flow.

5.2.2.2 Objectives

The analysis objective is to determine potential effects of development and/or dewatering on water flow from springs and seeps.

5.2.2.3 Experimental Design

As described above, the sampling frequency for the 24 stations was previously twice monthly; it was increased to weekly in June, 1979.

5.2.2.4 Method of Analysis

Figure 5.2.2-2 presents the sampling time interval available for analysis of both flow and water quality for each sampling station. Stations are usually referred to by four character codes. Cross reference between station I.D. and four character code is provided in the figure as well as the date of first sample taken at the station.

The method of analysis has utilized both plotting of the data and linear regression over time at a 5% level of significance.

5.2.2.5 Discussion and Results

Figures 5.2.2-3a and -3b present flow versus time for the springs monitored since baseline. Regression models based on these data test the hypothesis that the slope of the regression line is zero (i.e., there is no non-zero trend in flow over time) are presented in detail in Appendix A5.3.2. Both plots and the statistical results show there are no significant trends over time in flows of these springs and seeps. There are no trends in springs flow at those additional locations monitored under the Water Augmentation Plan.

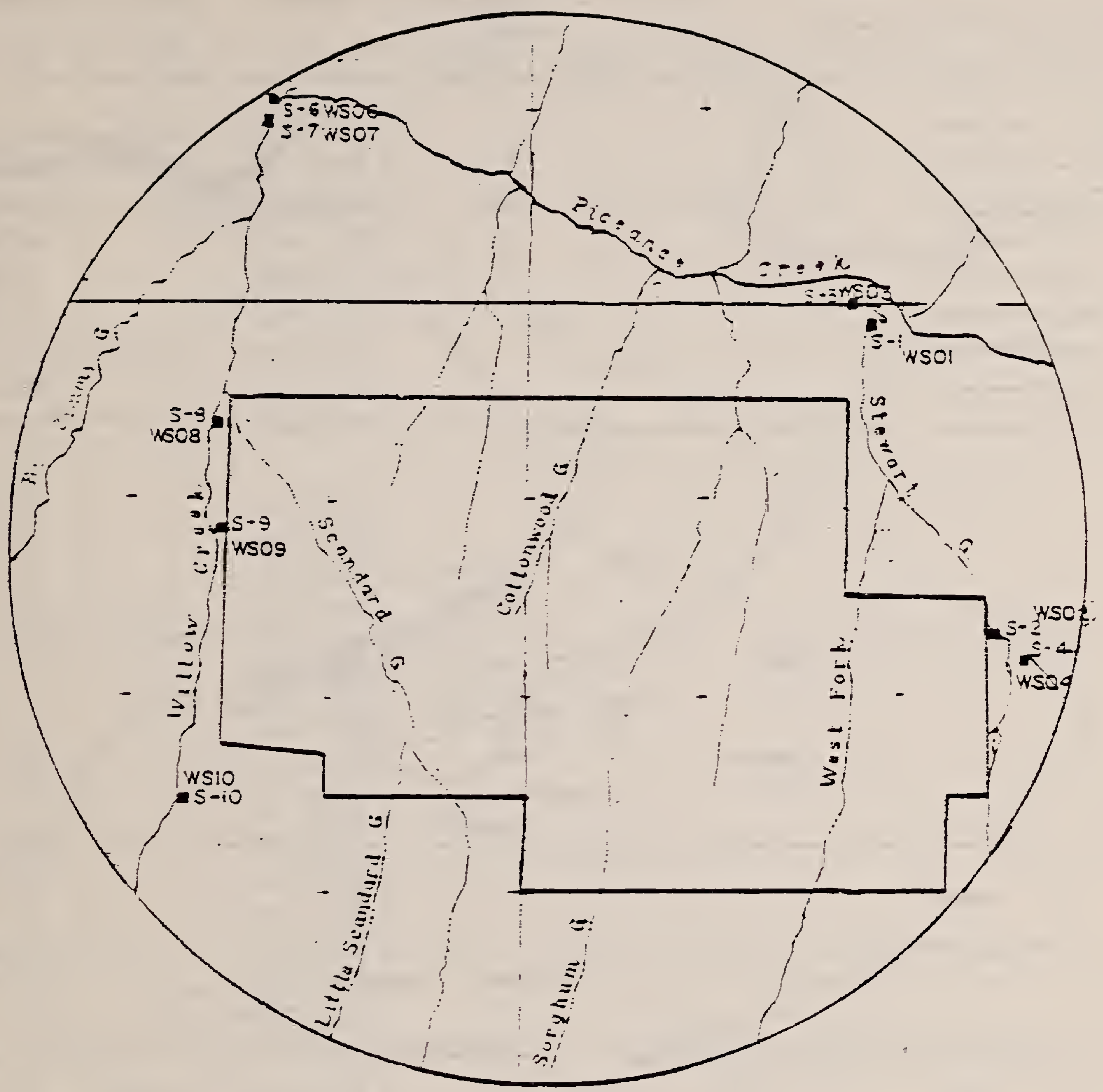


FIGURE 5.2.2-1a SPRINGS AND SEEPS MONITORING NETWORK NEAR TRACT

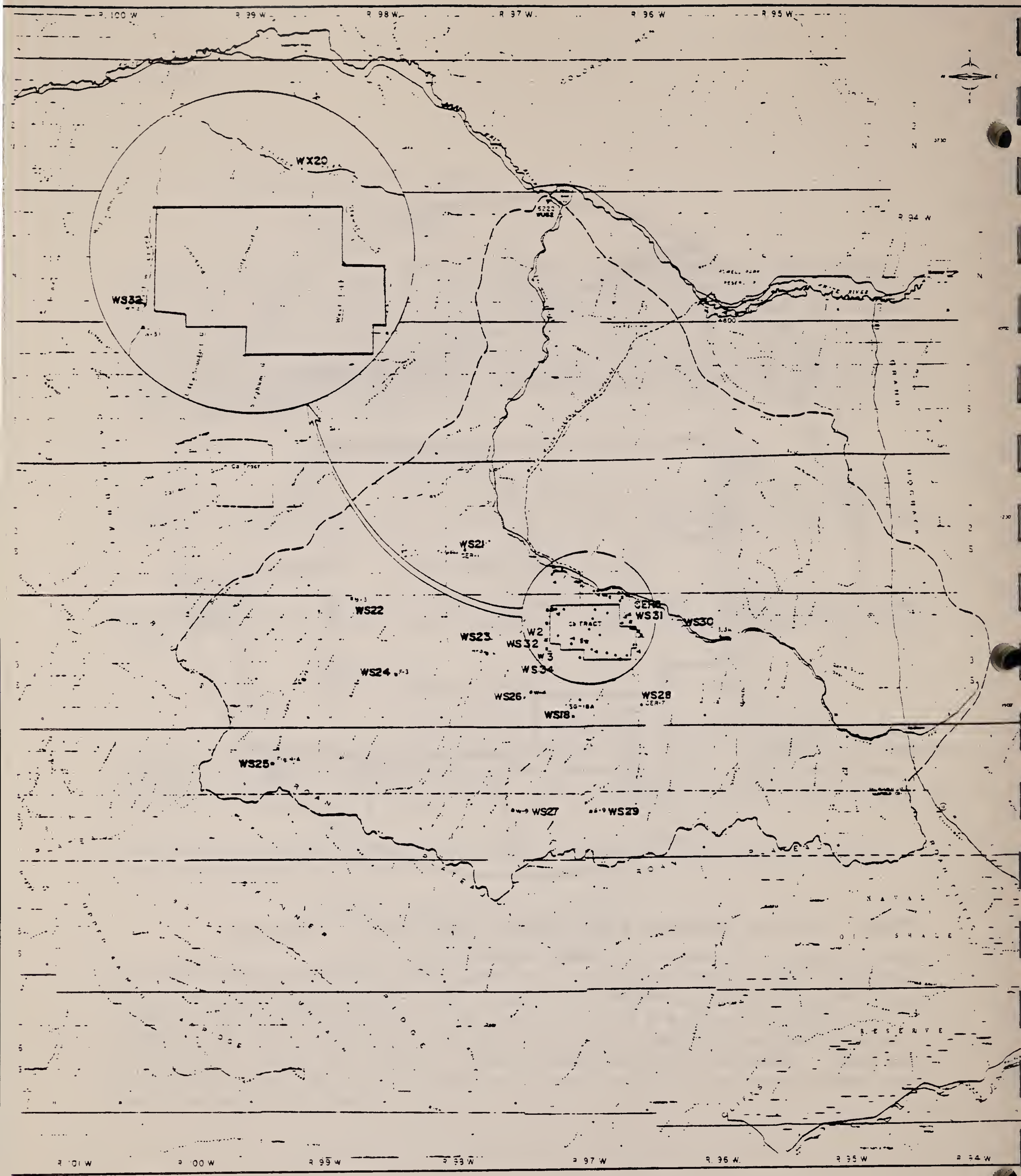


FIGURE 5.2.2-1b
SPRINGS AND SEEPS MONITORING NETWORK
OFF TRACT

FIGURE 5.2.2-2
SPRINGS AND SEEPS SAMPLING TIME
INTERVALS FOR FLOW AND WATER QUALITY

STATION I.D.	COMPUTER CODE	SAMPLE TYPE	FIRST SAMPLE DATE	1974	1975	1976	1977	1978	1979
S-1	WS01	FLOW	Sep-1977				———	———	———
S-2	WS02	"	Sep-1977				———	———	———
S-3	WS03	"	Sep-1977				———	———	———
S-4	WS04	"	Sep-1977				———	———	———
S-6	WS06	"	Sep-1977				———	———	———
S-7	WS07	"	Sep-1977				———	———	———
S-8	WS08	"	Sep-1977				———	———	———
S-9	WS09	"	Sep-1977				———	———	———
S-10	WS10	"	Sep-1977				———	———	———
SEEP-A	WS11	"							
CER-1	WS21	"	Jul-1979						———
B-3	WS22	"	Jul-1979						———
H-3	WS23	"	Jul-1979						———
F-3	WS24	"	Jul-1979						———
FIG 4-A	WS25	"	Jul-1979						———
W-4	WS26	"	Jul-1979						———
W-9	WS27	"	Jul-1979						———
CER-7	WS28	"	Jul-1979						———
S-9	WS20	"	Jul-1979						———
P3 & P3A	WS30	"	Jul-1979						———
CER-6	WS31	"	Aug-1979						———
W-2	WS32	"	Aug-1979						———
S-2	WS33	"	Aug-1979						———
W-3	WS34	"	Aug-1979						———
FIG 4	WS35	"	Jul-1979						———
S-1	WS01	QUALITY	Oct-1974	X		XX X	X	X	X X X
S-2	WS02	"	Oct-1974	X	X	X X	X	X X	X X X
S-3	WS03	"	Oct-1974	X	X	———	X	———	X X X
S-4	WS04	"	Oct-1974	X	X	X X	X	X X	X X X
S-6	WS06	"	Oct-1974	X	X X	X X	X	X X	X X X
S-7	WS07	"	Oct-1974	X	X	X X	X	XX X	X X X
S-8	WS08	"	Oct-1974	X	X	X		X	X
S-9	WS09	"	Oct-1974	X	X	———	X	X X	X X X
S-10	WS10	"	Oct-1974	X	X X	———	X	X X	X X X
SEEP-A	WS11	"	May-1975		X				

FIGURE 5.2.2-3a

WATER FLOWS FOR SELECTED SPRINGS

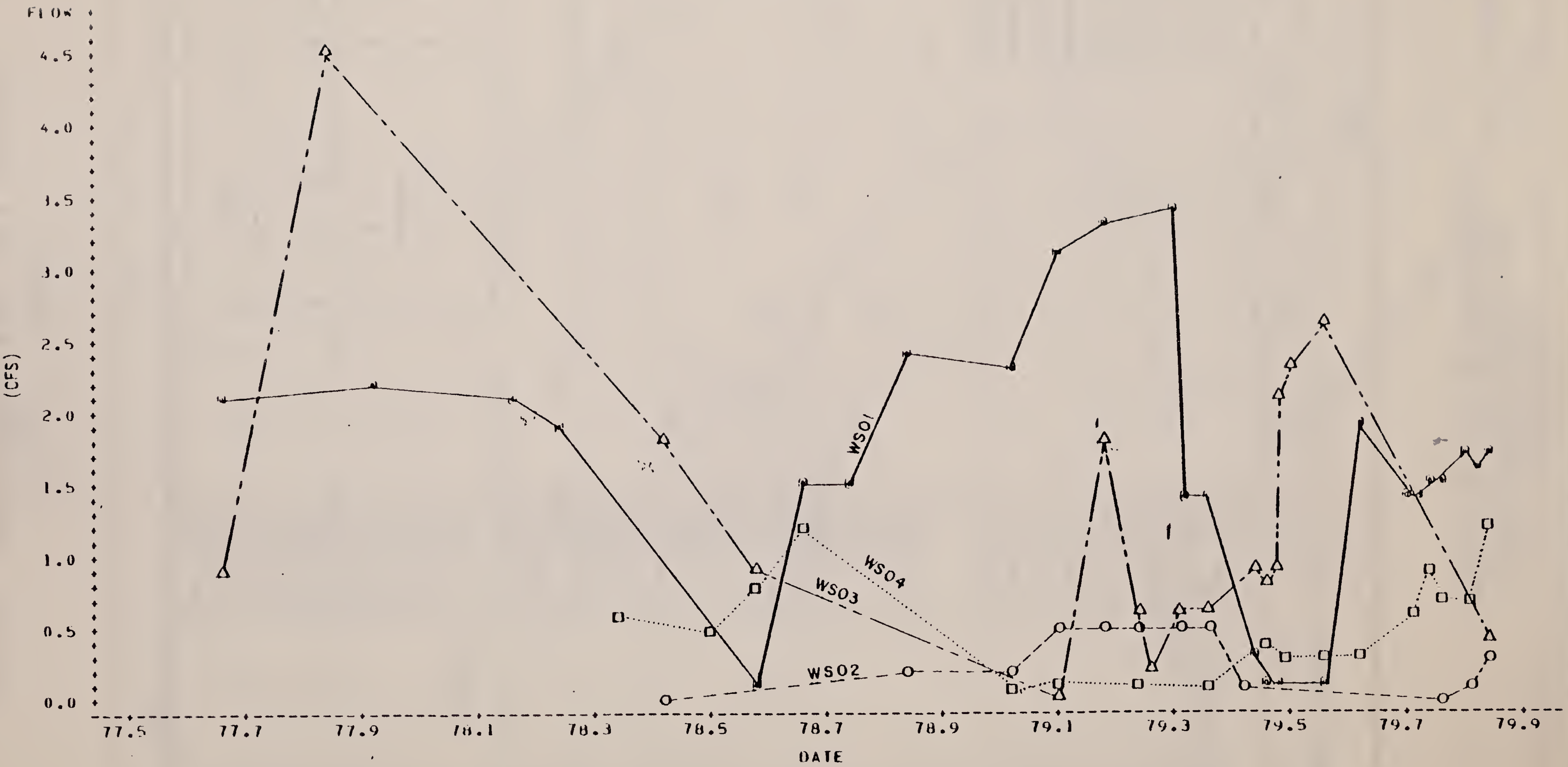
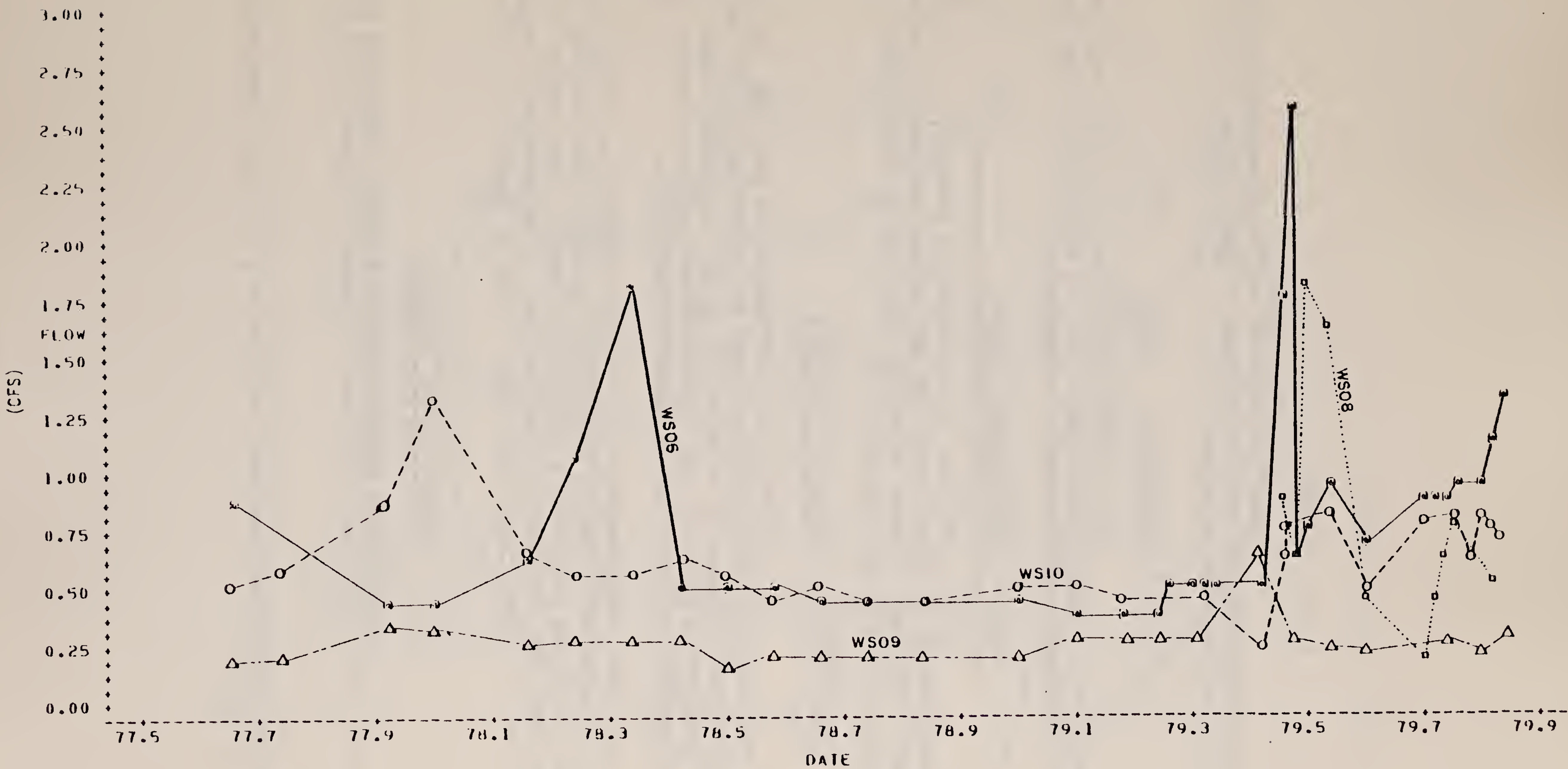


FIGURE 5.2.2-3b

WATER FLOWS FOR SELECTED SPRINGS



5.2.3 Alluvial Wells

5.2.3.1 Scope

Data from alluvial wells corresponding to stations WA01-WA12 were analyzed to test for changes in level. Figure 5.2.3-1 shows the alluvial well monitoring network.

5.2.3.2 Objectives

The principal objective of alluvial well data analysis is the detection of significant rise or fall in water levels over time which might be attributed to pond seepage or dewatering.

5.2.3.3. Experimental Design

In order to characterize changes in alluvial aquifers, monthly measurements of water level and semi-annual analyses of water quality are presently obtained. Linear regression analyses of water level over time are utilized as well as plotted data.

5.2.3.4 Method of Analysis

Figure 5.2.3-2 presents the sampling time interval available for analysis for both water level and water quality for each sampling station. Stations are usually referred to by four character codes. Cross reference between station I.D. and four character code is provided in the table as well as the date of first sample taken at the station.

Monthly water level measurements for the four selected (and probably most important) alluvial wells (WA03, WA05, WA06 and WA08) were analyzed for linear time trends using the appropriate statistical tests. Time-series plots of water level data are included and qualitatively interpreted with regard to annual cycles. A significance level of α = 0.05 is used in all statistical tests.

5.2.3.5 Discussion and Results

Plots of the selected alluvial wells are presented on Figure 5.2.3-3. Additional plots are in Appendix Figures A.5.2.3-1 through A5.2.3-4.

Both plots and statistical analyses indicate no significant time-trends in the alluvial wells.

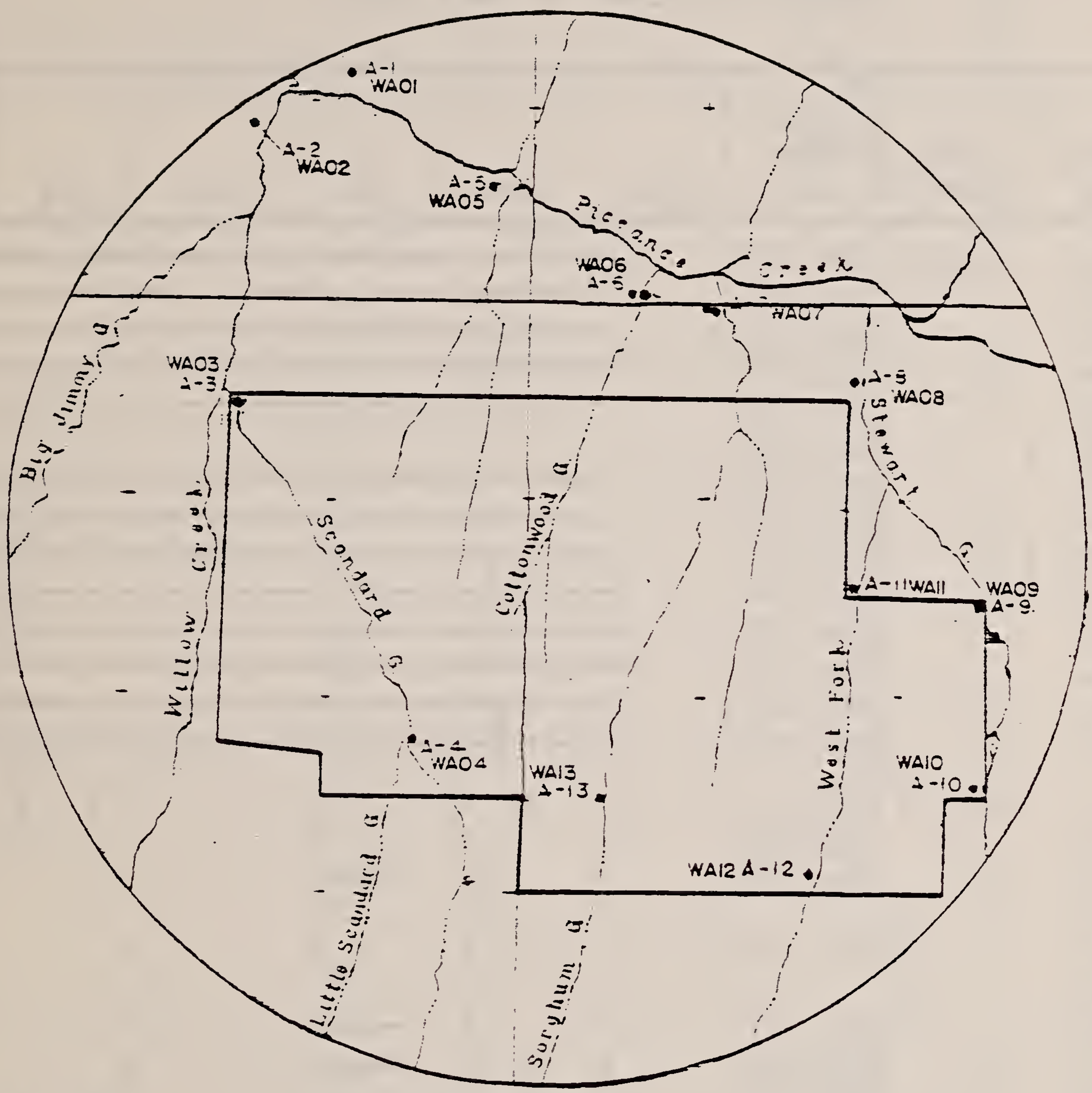


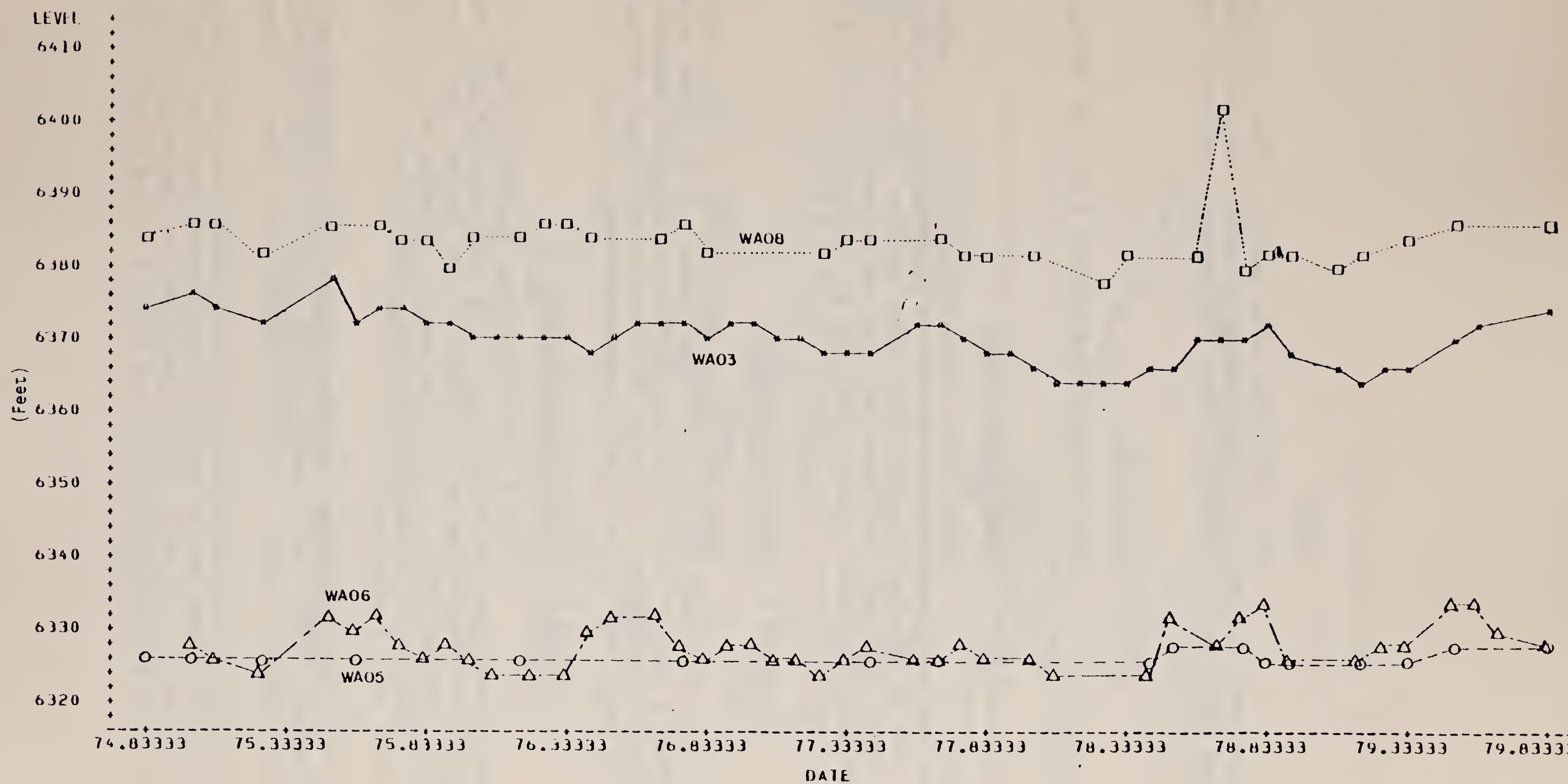
FIGURE 5.2.3-1
ALLUVIAL AQUIFER MONITORING NETWORK

FIGURE 5.2.3-2
ALLUVIAL WELLS SAMPLING TIME
INTERVALS FOR LEVELS AND WATER QUALITY

STATION I.D.	COMPUTER CODE	SAMPLE TYPE	FIRST SAMPLE DATE	1974	1975	1976	1977	1978	1979
A-1	WA01	LEVELS	SEP-1974	├────	──────	──────	──────	──────	─────┤
A-2	WA02	"	OCT-1974	├────	──────	──────	─┤ ├──	──────	─────┤
A-3	WA03	"	OCT-1974	├────	──────	──────	──────	──────	─────┤
A-4	WA04	"	SEP-1974	├────	──────	──────	──────	──────	─────┤
A-5	WA05	"	OCT-1974	├────	──────	──────	──────	──────	─────┤
A-5A	WA55	"	JUL-1979						├┤
A-6	WA06	"	OCT-1974	├────	──────	──────	──────	──────	─────┤
A-7	WA07	"	DEC-1974	├───	──────	──────	──────	──────	─────┤
A-8	WA08	"	OCT-1974	├────	──────	──────	──────	──────	─────┤
A-9	WA09	"	SEP-1974	├────	──────	──────	──────	──────	─────┤
A-10	WA10	"	SEP-1974	├────	──────	──────	──────	──────	─────┤
A-11	WA11	"	SEP-1974	├────	──────	──────	──────	──────	─────┤
A-12	WA12	"	SEP-1974	├────	──────	──────	──────	──────	─────┤
A-12	WA13	"	SEP-1974	├────	──────	──────	──────	──────	────┤
A-1	WA01	QUALITY	OCT-1974	X	X X	├──┤	X	X X	X X
A-2	WA02	"	OCT-1974	X	X X	X X			X
A-3	WA03	"	OCT-1974	X	X	├──┤		X	X X
A-4	WA04	"							
A-5	WA05	"	OCT-1974	X	X X	X X		X	
A-5A	WA55	"							
A-6	WA06	"	OCT-1974	X	X	├──┤		X	X X
A-7	WA07	"	OCT-1974	X	X X	├──┤		X	X
A-8	WA08	"	OCT-1974	X	X X	X X		X X X	
A-9	WA09	"	OCT-1974	X	X X	X X		X X X	X
A-10	WA10	"	OCT-1974	X	X X	X X		X X X	
A-11	WA11	"	OCT-1974	X	X X	X X		X X X	X
A-12	WA12	"	OCT-1974	X	X X	X X		X X X	X
A-13	WA13	"							

FIGURE 5.2.3-3

WATER LEVELS OF SELECTED ALLUVIAL WELLS



5.2.4 Upper Aquifer Wells

5.2.4.1 Scope

Data from gross water-bearing intervals above the Mahogany Zone were reviewed to access changes in water level over time. Sinking of three shafts was initiated in 1979; the potential effects of the shafts are being monitored.

5.2.4.2 Objectives

Water level of the aquifer above the Mahogany Zone is assessed for trends over time.

5.2.4.3 Experimental Design

Water levels are sampled monthly at 18 upper aquifer wells under the Development Monitoring Plan on the network indicated in Figure 5.2.4-1a. The WX computer code signifies upper aquifer. Thirteen additional stations (eight upper and five composite) are sampled monthly by an additional requirement under the Water Augmentation Plan as indicated in Figure 5.2.4-1b. Associated sampling intervals are shown in Figure 5.2.4-2.

5.2.4.4 Method of Analysis

Three methods of analysis are utilized: tabular averages, plots and linear analyses for time trends. With regard to regression, tests are made at an $\alpha = 0.05$ significance level to establish whether or not the following null hypothesis is true: The slope of the linear regression line over time is zero; that is, no significant linear trend exists.

5.2.4.5 Discussion and Results

Table 5.2.4-1 shows mean quarterly water elevations as differences from baseline values for all the upper aquifer wells monitored since baseline and for the new wells closest to the shafts, 32X-12 and 33X-1 (WX32 and WX33, respectively). As of year end, 8 of these wells exhibited decreases in level of 10 or more feet with the close-in wells, WX32 and WX33, down 39 and 49 feet, respectively.

Additional wells monitored under the Water Augmentation Plan have been monitored only since August, 1979. Their levels are tabulated on Table 5.2.4-2 and show no significant trends to date. Plots of these data are given in Appendix 5.2.4.

Regarding statistical analyses, Table 5.2.4-3 presents results of water-level trend analyses for upper aquifer wells. Significant trends are noted by entries for "1" and "2". Entry 1 is the coefficient of determination (i.e., square of the correlation coefficient) and entry 2 is the slope of the regres-

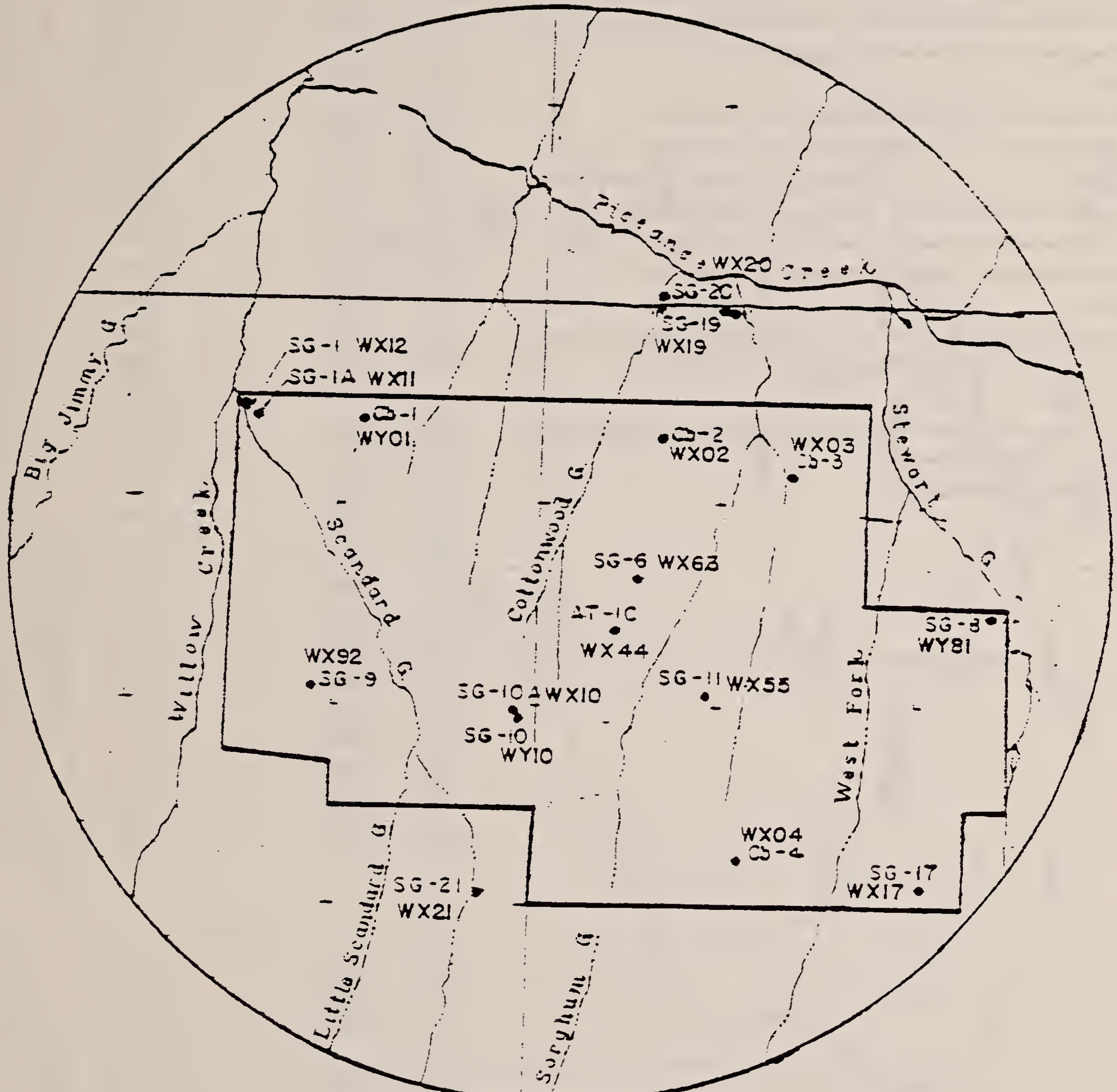


FIGURE 5.2.4-1a DEEP WELL MONITORING NETWORK NEAR TRACT

Figure 5.2.4-1b. DEEP WELL MONITORING NETWORK OFF-TRACK

FIGURE 5.2.4-2A
UPPER TRACT AQUIFER WELLS SAMPLING TIME
INTERVALS FOR LEVELS AND WATER QUALITY

STATION I.D.	COMPUTER CODE	SAMPLE TYPE	FIRST SAMPLE DATE	1974	1975	1976	1977	1978	1979
UPPER AQUIFER		LEVEL							
CB-2	WX02	"	OCT 1974	—	—	—	—	—	—
CB-4	WX04	"	OCT 1974	—	—	—	—	—	—
SG-10A	WX10	"	JUN 1975		—	—	—	—	—
SG-1A	WX11	"	FEB 1979						—
SG-1-2	WX12	"	JUN 1975		—	—	—	—	—
SG-17-2	WX17	"	JUN 1975		—	—	—	—	—
SG-18A	WX18	"	NOV 1974	—	—	—	—		—
SG-19	WX19	"	JUL 1975		—	—	—	—	—
SG-20	WX20	"	JUN 1975		—	—	—	—	—
SG-21	WX21	"	JUN 1975		—	—	—	—	—
AT-1C-3	WX44	"	OCT 1974	—	—	—	—		—
SG-11-3	WX55	"	OCT 1974	—	—	—	—	—	—
SG-6-3	WX63	"	JUN 1975		—	—	—	—	—
SG-8-2	WX82	"							
SG-9-2	WX92	"	NOV 1974	—	—	—	—	—	—
32X-12	WX32	"	JUL 1977				—	—	—
33X-1	WX33	"	JUL 1977				—	—	—
41X-1	WX41	"	OCT 1979						—
TH75-5A	WX64	"	AUG 1979						—
TH75-13A	WX65	"	AUG 1979						—
TH75-18A	WX67	"	AUG 1979						—
TH75-9A	WX69	"	AUG 1979						—
CER RB-D-02	WX71	"	AUG 1979						—
TH75-15A	WX72	"	AUG 1979						—
UNION 8-1	WX73	"	SEP 1979						—
TH-5	WX75	"	SEP 1979						—
SG-10A-1	WE10	"	NOV 1979						—
SG-10A-2	WD10	"	NOV 1979						—
		QUALITY							
CB-2	WX02	"	NOV 1974	X	X X	X	X	X X	X X
CB-4	WX04	"	NOV 1974	X	X X	X	X	X	X
SG-10A	WX10	"	APR 1975		X X	X		X X	X
SG-1A	WX11	"							
SG-1-2	WX12	"	APR 1975		X X	X X	X	X X	X X
SG-17-2	WX17	"	APR 1975		X X	X X	X	X X	X X
SG-18A	WX18	"	NOV 1974	X	X X	X			X
SG-19	WX19	"	NOV 1974	X	X X	X		X X	X X
SG-20	WX20	"	APR 1975		X X	X X	X	X X	X
SG-21	WX21	"	APR 1975		X X	X		X	X X
32X-12	WX32	"							
33X-1	WX33	"							
AT-1C-3	WX44	"	NOV 1974	X	X X	X X		X	X X
SG-11-3	WX55	"	APR 1975		X X	X	X	X X	X X
SG-6-3	WX63	"	APR 1975		X X	X X	X	X X	X X
SG-8-2	WX82	"	APR 1975		X X				
SG-9-2	WX92	"	NOV 1974	X	X X	X X	X	X X	X X

FIGURE 5.2.4-2B

COMPOSITE ON SEEPAGE MONITORING WELLS
SAMPLING TIME INTERVALS FOR LEVELS

STATION I.D.	COMPUTER CODE	SAMPLE TYPE	FIRST SAMPLE DATE	1974	1975	1976	1977	1978	1979
COMPOSITE WELLS									
Greeno 4-4	WY01	LEVELS	Sep-1979						
Oldland 3	WY02	"	Aug-1979						
GP-17X-BG	WY03	"	Aug-1979						
Bute 25	WY04	"	Sep-1979						
Liberty Bell 12	WY05	"	Sep-1979						
SEEPAGE MONITORING WELLS									
31X-12	WW12	LEVELS	Jan-1980						
41X-13-2	WW13	"	Jan-1980						

TABLE 5.2.4-1

UPPER AQUIFER WELLS SHOWING MEAN
QUARTERLY WATER ELEVATIONS VS BASELINE
(FEET)

Location			January-March 1979		April-June 1979		July-September 1979		October-December 1979	
Computer Code	Station	Baseline Average*	Elevation	Elevation - Baseline	Elevation	Elevation - Baseline	Elevation	Elevation - Baseline	Elevation	Elevation - Baseline
WX02	Cb-2	6404	6401	-3	6397	-7	6391	-13	6386	-18
WX04	Cb-4	6617	6629	12	6629	12	6633	16	6661	44
WX10	SG-10A	6576	6580	4	6559	-17	6539	-37	6553	-23
WX12	SG-1-2	6365	6366	1	6364	-1	6360	-5	6356	-9
WX17	SG-17-2	6640	6636	-4	6638	-2	6644	4	6639	-1
WX19	SG-19	6375	6371	-4	—— NO DATA ——		6366	-9	6362	-13
WX20	SG-20	6358	6358	0	6358	0	6352	-6	6347	-11
WX21	SG-21	6705	6706	1	6707	2	6702	-3	6734	29
WX44	AT-1C-3	6547	6540	-7	6541	-6	6538	-9	6535	-12
WX55	SG-11-3	6546	6564	18	6560	14	6556	10	6556	10
WX63	SG-6-3	6546	6511	-35	6510	-36	6508	-38	6505	-41
WX92	SG-9-2	6515	6499	-16	6511	-4	6508	-7	6508	-7
WX32	32X-12	6473***	6470	-3	6473	0	6453	-20	6434	-39
WX33	33X-1	6380**	6378	-2	6362	-18	6315	-65	6331	-49

* - Mean Elevation computed using data from 10/74-12/78
** - Mean Elevation computed using data from 6/78- 3/79
*** - Mean Elevation computed using data from 9/77-12/78

TABLE 5.2.4-2

WATER LEVELS IN ADDITIONAL WELLS MONITORED UNDER THE WATER AUGMENTATION PLAN

WELL LEVELS

WATER LEVELS IN UPPER AQUIFER WELLS

		WELL ID - MEASURING POINT ELEVATION (FT)							
		WX64	WX65	WX67	WX69	WX71	WX72	WX73	WX75
		7178	6390	6740	7350	6580	6805	8142	7583
YR	MO	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)
79	8	6757	6332	6310	6886	INACCS	6760		
	9							7641	7510
	10	6758	6331	6309	6897	INACCS	6759	7647	7512
	11	6758	6332	6308	6898	INACCS	6759	7647	7512
	12	6759	6333	6309	6897	INACCS	6760	7646	

WATER LEVELS IN LOWER AQUIFER WELLS

		WELL ID - MEASURING POINT ELEVATION (FT)													
		WY64	WY65	WY66	WY67	WY68	WY69	WY70	WY71	WY72	WY75	WY76	WY77	WY78	WY79
		7178	6390	6286	6740	6840	7350	7070	6580	6805	6820	6865	7777	7145	7020
YR	MO	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)
79	8	6423	6313	FLWING	6235	6511	7038	INACCS	INACCS	6773			FLWING	7073	INACCS
	9										6769	FLWING			
	10	6444	6313	FLWING	6235	6510	6886	INACCS		6773	6770	FLWING	FLWING	7075	INACCS
	11	6445	6313	FLWING	6235	6509	6886	INACCS	INACCS	6773	6769	FLWING	FLWING	7073	INACCS
	12	6444	6313	FLWING	6235	6510	6885	INACCS	INACCS	6773	6769	FLWING	FLWING	7072	INACCS

WATER LEVELS IN COMPOSITE WELLS

		WELL ID - MEASURING POINT ELEVATION (FT)				
		WV01	WV02	WV03	WV04	WV05
		6411	6490	6729	0	7420
YR	MO	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)	DEPTH (FT)
79	8		FLWING	FLWING		
	9	6285			FLWING	7354
	10	6286	FLWING	FLWING	FLWING	7354
	11	6286	FLWING	FLWING	FLWING	7354
	12	6286	FLWING	FLWING	FLWING	7353

PLUGGD = WELL PLUGGED
DRY = WELL DRY
FLWING = WELL FLOWING
INACCS = WELL INACCESSABLE

TABLE 5.2.4-3

LINEAR REGRESSION RESULTS FOR WATER LEVELS IN THE UPPER AQUIFER

INDICATOR VARIABLE = WATER LEVEL

	WX02	WX04	WX10	WX11	WX12
1.	0.46		0.30		0.14
2.	-3.68		-7.07		-0.70
3.	6403/46	6619/43	6569/35	6347/5	6365/43

	WX17	WX18	WX19	WX20
1.			0.36	0.32
2.			-2.88	-18.0
3.	6639/39	6898/29	6374/31	6351/10

	WX21	WX32	WX33	WX41
1.	0.10	0.38	0.56	
2.	+3.17	-12.76	-40.02	
3.	6707/41	6465/48	6361/48	6437/1

	WX44	WX55	WX63	WX92
1.	0.41		0.73	0.43
2.	-2.54		-14.53	-4.93
3.	6545/29	6390/41	6540/44	6513/42

Notes:

1. Coefficient of Determination r^2.
2. Value of slope of the linear regression model. (feet/month)
3. Mean of Indicator Variable/Number of Samples Taken.

If 1. and 2. are blank, then no significant linear trend was detected.

sion line. A negative sign means a drop in level at the rate indicated in feet per month. Ten of the 17 wells investigated statistically show negative linear trends. Wells closest to the shafts show the greatest decrease in level. There is little doubt that dewatering from the shafts is affecting water level in the upper aquifer wells.

5.2.5 Lower Aquifer Wells

5.2.5.1 Scope

Data from gross water-bearing zones below the Mahogany Zone were reviewed to assess changes in water level over time, particularly with regard to potential mine dewatering.

5.2.5.2 Objectives

Water level of the aquifer below the Mahogany Zone is assessed for trends over time.

5.2.5.3 Experimental Design

Water levels are sampled monthly at the 13 lower aquifer wells under the Development Monitoring Plan at stations shown on Figure 5.2.4-1a. Fourteen additional lower aquifer wells are monitored under the Water Augmentation Plan at stations indicated on Figure 5.2.4-1b. Associated sampling intervals are shown on Figure 5.2.5-1.

5.2.5.4 Method of Analysis

Method of analysis are identical to those for the upper aquifer (Section 5.2.4.4).

5.2.5.5 Discussion and Results

Table 5.2.5-1 shows mean quarterly water elevations as differences from baseline values for all lower aquifer wells monitored since baseline. Whereas eight of the upper aquifer wells have decreased at year end by 10 feet, three of the lower aquifer well levels have increased by 10 feet or more by year end. This may, in part, be due to seasonal effects. Additional wells monitored under the Water Augmentation Plan are tabulated in Table 5.2.4-2 and indicate no trends to date. Plots of water levels are given in Appendix 5.2.5.

Table 5.2.5-2 presents a summary of the statistical time-trend analyses for lower aquifer wells. Significant trends are indicated by table entries for values "1" and "2" in the table. Table value "3" is the mean value and number of samples. Significant positive trends are identified for wells WY10, WY17, WY44, WY52, WY54, WY61 and WY91 representing 7 of the 13 wells selected for analyses. Two wells, WY44 and WY61 show trends of 18 and 16 feet per month respectively, i.e., water levels are increasing. The positive trends indicate a significant source of recharge water. The level of WY61 has increased in steps over time. It is approximately constant from Summer of 1975 to Summer of 1977. At this time an increase of about 20-25 feet occurred and the resulting level remained constant until Summer of 1976. Then another increase of about 40-45 feet occurred and has remained approximately constant to the last sample taken.

FIGURE 5.2.5-1
LOWER AQUIFER WELLS SAMPLING TIME
INTERVALS FOR LEVELS AND WATER QUALITY

STATION I.D.	COMPUTER CODE	SAMPLE TYPE	FIRST SAMPLE DATE	1974	1975	1976	1977	1978	1979
CB-1	WY01	LEVEL	JUN-1975						
CB-3	WY03	"	AUG-1979						
SG-10	WY09	"	JUN-1975						
SG-1-1	WY12	"	AUG-1975						
SG-17-1	WY18	"							
AT-1C-1	WY45	"	SEP-1974						
AT-1C-2	WY46	"	SEP-1974						
SG-11-1	WY51	LEVEL							
SG-11-2	WY54	"	SEP-1974						
SG-6-1	WY61	"	JUN-1975						
SG-6-2	WY62	"	AUG-1975						
SG-8	WY80	"	JUN-1975						
SG-9-1	WY91	"	OCT-1974						
AT-1	WY44	"	SEP-1975						
TH75-5B	WY64	"	AUG-1979						
TH75-13B	WY65	"	AUG-1979						
EQUITY-1	WY66	"	AUG-1979						
TH75-13B	WY67	"	AUG-1979						
TH75-10B	WY68	"	AUG-1979						
TH75-9B	WY69	"	AUG-1979						
EQUITY-SULFER-1A	WY70	"	AUG-1979						
CER-RB-D-03	WY71	"	AUG-1979						
TH75-15B	WY72	"	AUG-1979						
TG-71-3	WY75	"	SEP-1979						
TG-71-5	WY76	"	SEP-1979						
GETTY 9-40	WY77	"	AUG-1979						
TG71-4	WY78	"	AUG-1979						
EQUITY SS-13	WY79	"	AUG-1979						
SG10R	WY10	"	DEC-1975						
SG-10	WG10	"	FEB-1980						
SG-17-1R	WY17	"	NOV-1975						
SG-11-1R	WY52	"	JAN-1976						
SG-8R	WY81	"	JAN-1976						
CB-1	WY01	QUALITY	NOV-1974	x	x x	x	x	x x	x x
CB-3	WY03	"			x				
SG-10	WY09	"	APR-1975		x x	x x	x	x x	x x
SG-1-1	WY12	"	APR-1975		x x				
SG-17-1	WY18	"	APR-1975	x	x x	x x	x	x	x x
AT-1C-1	WY45	"	NOV-1974	x	x x	x x		x x	x x
AT-1C-2	WY46	"	NOV-1974	x	x x				
SG-11-1	WY51	"	NOV-1974		x x	x		x x	x x
SG-11-2	WY54	"	APR-1975		x x	x x			
SG-6-1	WY61	"	APR-1975		x x	x x			x
SG-6-2	WY62	"	APR-1975		x		x		
SG-8	WY80	"	APR-1975	x	x x	x x			x x
SG-9-1	WY91	"	NOV-1974			x x			
SG-10R	WY10	"	MAY-1976						
SG-10	WG10	"				x x	x	x x	x x
SG-17-1R	WY17	"	MAY-1976			x	x	x x	x x
SG-11-1R	WY52	"	OCT-1976		x	x x		x x	x x
SG-8R	WY81	"	OCT-1975						

TABLE 5.2.5-1

LOWER AQUIFER WELLS SHOWING MEAN QUARTERLY
WATER ELEVATIONS VS. BASELINE

Computer Code	Station	Baseline Average	January-March, 1979		April-June, 1979		July-September, 1979		October-December, 1979	
			Elevation	Elevation-Baseline	Elevation	Elevation-Baseline	Elevation	Elevation-Baseline	Elevation	Elevation-Baseline
WY01	CB-1	6408	6403	-5	6403	-5	6400	-8	6395	-13
WY10	SG-10R	6539	6537	-2	6579	40	6578	39	6569	30
WY12	SG-1-1	6358	6354	-4	6351	-7	6354	-4	6354	-4
WY17	SG-17-1R	6636	6648	12	6650	14	6645	9	6645	9
WY45	AT-1C-1	6517	6514	-3	6514	-3	6512	-5	6512	-5
WY46	AT-1C-2	6519	6515	-4	6514	-5	6513	-6	6513	-6
WY52	SG-11-1R	6507	6522	15	6519	12	6523	16	6524	17
WY54	SG-11-2	6540	6547	7	6544	4	6544	4	6543	3
WY61	SG-6-1	6506	6549	43	6524	18	6548	42	6545	39
WY62	SG-6-2	6513	6503	-10	6514	1	6499	-14	6509	-4
WY91	SG-9-1	6510	6522	12	6512	2	6510	0	6506	-4

TABLE 5.2.5-2

LINEAR REGRESSION RESULTS FOR WATER LEVELS IN THE LOWER AQUIFER

INDICATOR VARIABLE = WATER LEVEL

	WY01	WY10	WY12	WY17
1.		0.68	0.69	0.84
2.		+8.51	-3.3	+6.25
3.	6405/60	6548/30	6357/45	6638/37

	WY44	WY45	WY46	WY52
1.	0.75			0.69
2.	18.6			9.36
3.	6524/20	6516/47	6517/33	6510/38

	WY54	WY61	WY62	WY81	WY91
1.	0.42	0.67			0.12
2.	2.51	16.27			1.81
3.	6541/31	6521/48	6511/31	6526/5	6512/36

Notes:
1. Coefficient of Determination r^2.
2. Value of the slope of the linear regression model. (feet/month)
3. Mean of Indicator Variable/Number of Samples Taken.

If 1. and 2. are blank, then no significant linear trend was detected.

The negative trend for well WY12 is relatively small and cannot be explained in the light of positive or no trends in the other lower aquifer wells.

To summarize, Tables 5.2.5-1 and -2 agree basically for all wells except WY44 and WY91. WY44 should be discounted since all its statistics were determined only from early data; monitoring has been discontinued there. WY91 shows a positive trend from the preponderance of positive values, but recent monthly values show a decrease in level there.

5.2.6 Impoundments/Discharges/NPDES

5.2.6.1 Scope

Temporary storages designated as Ponds A, B, and C are used for mine water pumped from the shafts during development. This section discusses water discharges from these ponds.

5.2.6.2 Objectives

The objective is to ascertain the quantity of water discharged from temporary storages to assure compliance with discharge permits and water augmentation replacement requirements.

5.2.6.3 Experimental Design

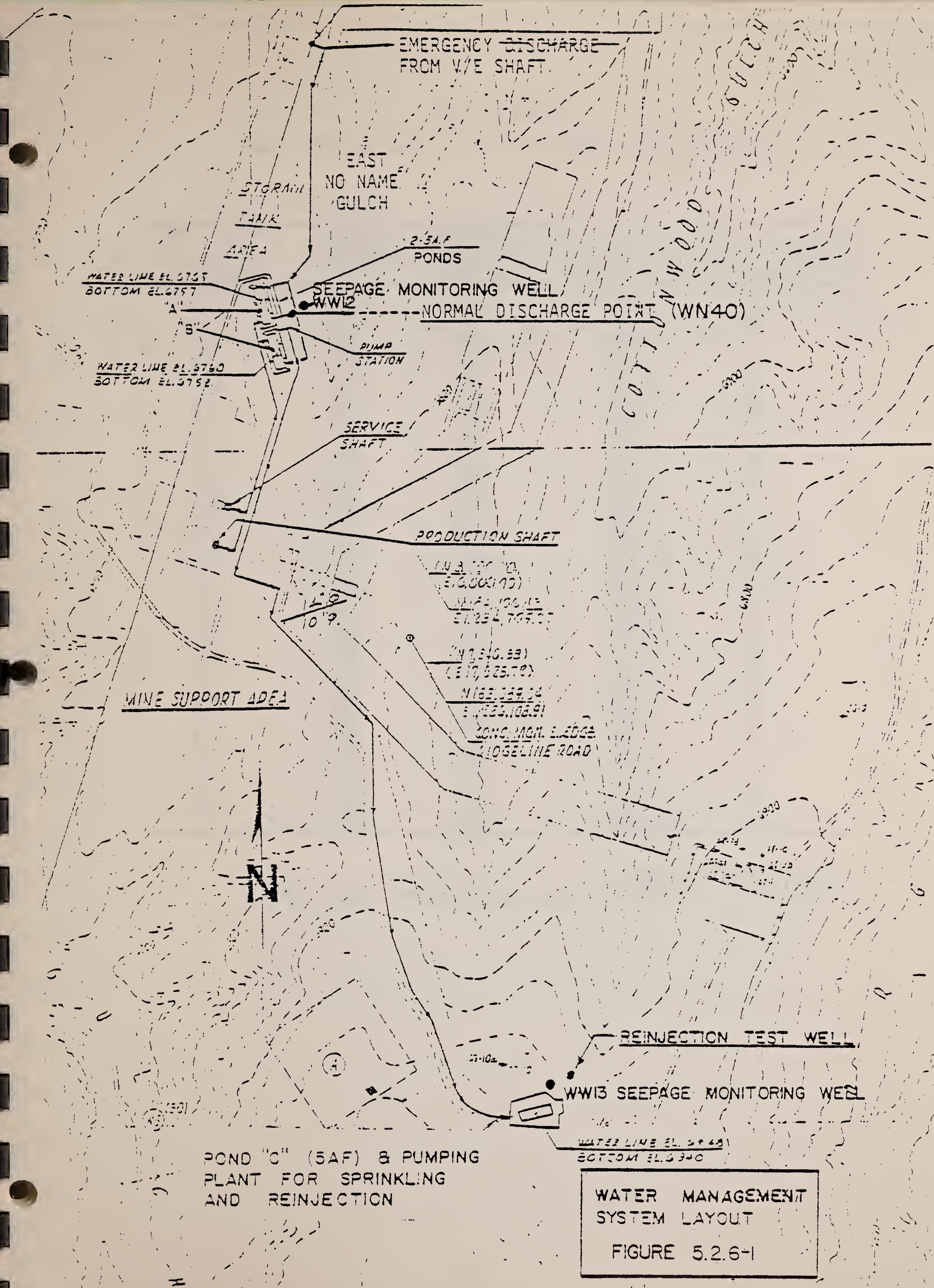
Three 5-acre-foot impoundments or ponds designated Ponds A, B, and C are utilized as part of the water management system, shown on Figure 5.2.6-1. This system is described in detail in Volume 1. As of year-end, Pond C is not yet utilized. Mine waters are pumped from the shafts into Pond A, where initial settling takes place. Water may then be gravity-fed to Pond B where it is further stored and settled or discharged into East No Name Gulch, a tributary of Piceance Creek, under an existing NPDES permit. Monthly-average waters pumped from the shafts, stored in the ponds, used, and discharged are tabulated in Table 4-3 of Volume 1.

5.2.6.4 Method of Analysis

Since July 31, 1979 discharges have occurred in volume of up to one-tenth the flow in Piceance Creek. The allowable discharges were calculated as follows: In 1979, all discharges were discrete. The allowable discharge was calculated for the day by taking an instantaneous reading of flow in Piceance Creek at Hunter Creek (WU61), multiplying it by the allowed discharge ratio of 10% and assuming that rate applied as an average over the whole day.

5.2.6.5 Discussion and Results

Discharges are tabulated along with the flow at the (reference) Hunter Creek Station (WU61) in Piceance Creek in Table 5.2.6-1. The discharge ratio is also shown. Tabular results indicate maximum discharge levels to be less than 10% of the flow in Piceance Creek. Most discharges were well below this value.



WATER MANAGEMENT SYSTEM LAYOUT

FIGURE 5.2.6-1

TABLE 5.2.6-1

Discharges Under NPDES Permit vs. Flow at WU61 (GPM)

DATE YR	MO	DAY	STATION WU61	Allowable** Discharge at WN40	Actual Discharge WN40	Actual WN40 Flow WU61 (Percent)
79	9	05	8,190	819	450	5.5
		06	5,625	563	450	8.0
		13	7,875	788	625	7.9
		18	5,175	518	347	6.7
		24	3,541	354	170	4.8
		28	3,199	320	220	6.9
	10	01	7,605	761	210	2.8
		04	8,730	873	385	4.4
		08	9,270	927	210	2.3
		11	8,428	843	577	6.9
		17	11,758	1,176	585	5.0
		19	11,620	1,162	636	5.5
		26	20,925	2,093	316	1.5
		30	20,520	2,052	720	3.5
	11	05	15,750	1,575	620	3.9
		08	15,750	1,575	720	4.6
		13	15,750	1,575	820	5.2
		21	16,875	1,688	990	5.9
		24	13,230	1,323	780	5.9
		28	13,230	1,323	890	6.7
		30	13,230	1,323	880	6.7
	12	07	15,750	1,575	920	5.8
		14	14,310*	1,431	250	1.8
		18	14,310*	1,431	350	2.5
		19	12,870	1,287	320	2.5
		26	20,520	2,052	420	2.1

*Frozen-over-estimate
**10% of flow at Piceance Creek above Hunter Creek (WU61)

5.2.7 Shale Dumps

Shaft sinking commenced in 1979. No significant amount of shale was brought to the surface during this reporting period as a result of shaft sinking activity.

Design of a seepage monitoring system is underway and expected to be implemented in late April or early May on a trial basis.

5.2.8 Correlations Suggested Under the Water Augmentation Plan

5.2.8.1 Scope

Some specific correlations were suggested under the Water Augmentation Plan. These correlations are discussed here.

5.2.8.2 Objectives

To perform correlations of flow in Piceance Creek with precipitation occurring at various flow and precipitation measurement stations in the Tract area.

5.2.8.3 Experimental Design

Primarily because of their relatively long periods of record (since October, 1964), the winter-time flow on Piceance Creek at Ryan Gulch (Station WU00) and the precipitation at the Little Hills Station (WR01) were suggested as possible items to correlate with the flows on Piceance Creek upstream (WU07) and downstream (WU61) of the Tract.

Also singled out under the Water Augmentation Plan were springs S-9 (WS09), S-10 (WS10), and CER-6 (WS31) where discharge time history must be monitored and compared with that of well SG-1-2 (WX12).

5.2.8.4 Method of Analysis

In addition to the correlations suggested above, these additional ones were judged to be of merit: correlation of precipitation at Stations AB20 or AB23 with Piceance Creek winter-time flows at either Ryan Gulch, the downstream station from the Tract, or the upstream station.

5.2.8.5 Discussion and Results

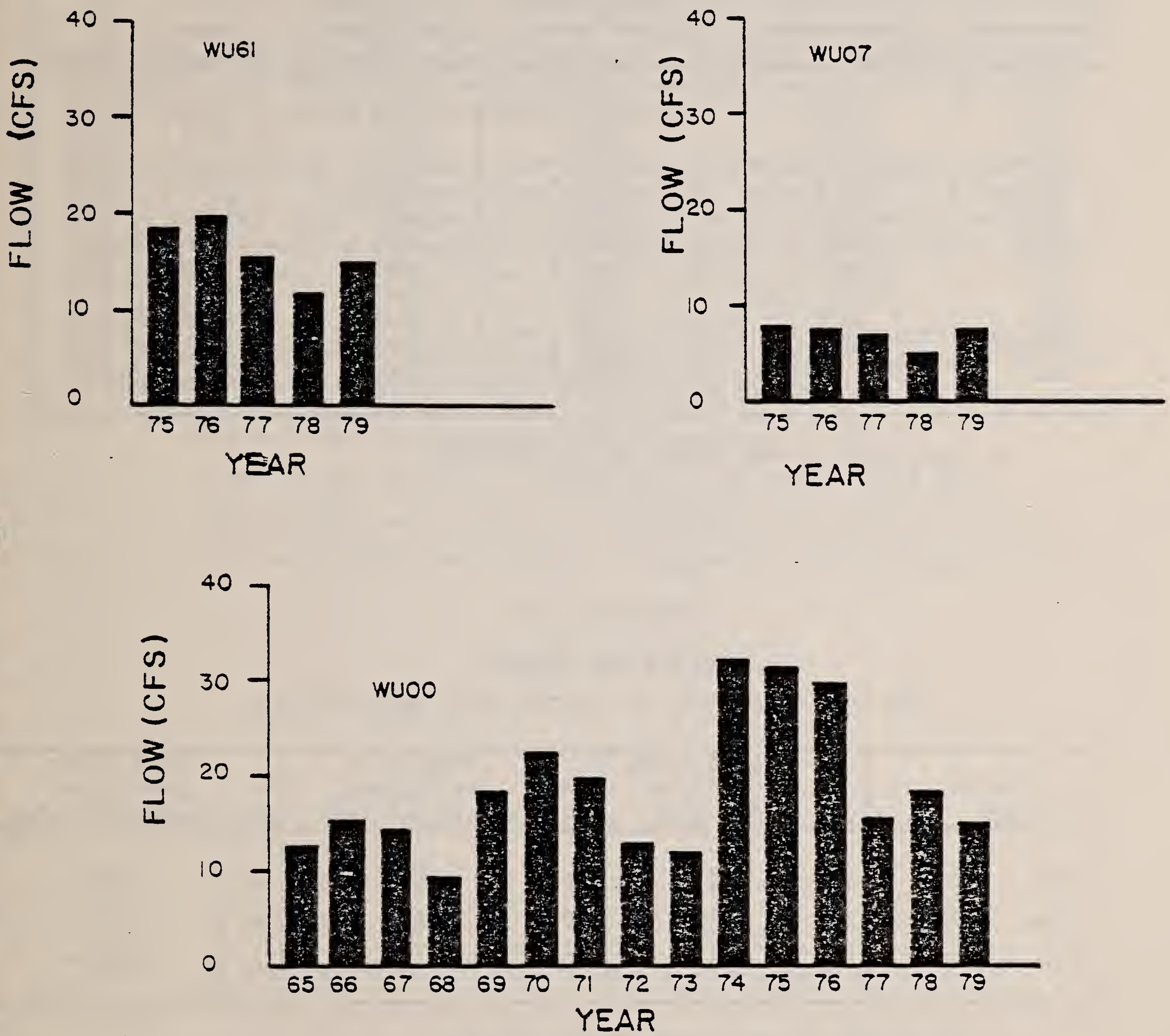
The monthly precipitation at Stations AB20, AB23, and Little Hills and flows on Piceance Creek at Stations WU00, WU61, and WY07 are tabulated on Table A5.2.8-1.

Histograms of winter-time flow average over December and January are presented on Figure 5.2.8-1 for Stations WU00, WU07, WU22 and WU61.

Tables 5.2.8-1 and 5.2.8-2 summarize the results of the correlation analysis. As seen in both tables, Little Hills (WR01) precipitation shows little correlation with Piceance Creek flow. The reason for the low correlation is that Little Hills is located downstream from all flow gauging stations in this study; therefore, its watershed has no contribution to upstream flow. Precipitation at Stations AB20 and AB23 shows a high correlation with flow at all three Piceance Creek flow stations. This can be attributed to location; both precip-

FIGURE 5.2.8-1

HISTOGRAMS OF WINTERTIME
MEAN FLOW* FOR SELECTED USGS GUAGING
STATIONS ON PICEANCE CREEK



$$* \left(\frac{\text{DEC. FLOW} + \text{JAN. FLOW}}{2} \right)$$

TABLE 5.2.8-1

PRECIPITATION-FLOW CORRELATION ANALYSIS SUMMARY

Dependent (Flow)	Independent (Precip. & Flow)	Correlation Coefficient (All Data)	Correlation Coefficient (Nov.-Mar.)	Model Intercept	Slope
6200	AB20	.3223 *	.6328 *	15.5936	1.6385
6200	AB23	.3965 *	.5767 *	16.0254	1.8217
6200	Little Hills	.3011 *	.1184	21.3542	0.5752
6200	6061	.9156 *	.7680 *	2.6779	1.3477
6200	6007	.8063 *	.6424 *	5.5836	2.4456
6061	AB20	.2844 *	.4942 *	11.9065	0.7677
6061	AB23	.3802 *	.4463 *	12.1375	0.8457
6061	Little Hills	.3055 *	.0847	14.6593	0.2470
6007	AB20	.1725	.5095 *	5.6259	0.3612
6007	AB23	.2994 *	.5087 *	5.5803	0.4398
6007	Little Hills	.4022 *	.2850	6.2901	0.3791

* Significant linear trend @95% confidence

TABLE 5.2.8-2

CORRELATION SUMMARY

FOR RYAN GULCH FLOW VS. LITTLE HILLS PRECIPITATION

Time ** Period	# Obs.	Correlation Coefficient (All Data)	# Obs.	Correlation Coefficient (Winter Nov.-Mar.)	# Obs.	Correlation Coefficient (Summer Apr.-Oct.)
1964 - 1979	168	.1275	70	.1043	98	.1556
1964 - 1973	111	.0522	47	.0808	64	.0737
1975 - 1979	57	.3011	23	.1184	34	.3683 *

* Significant linear trend @95% confidence

** Data were not available for 1974 precipitation

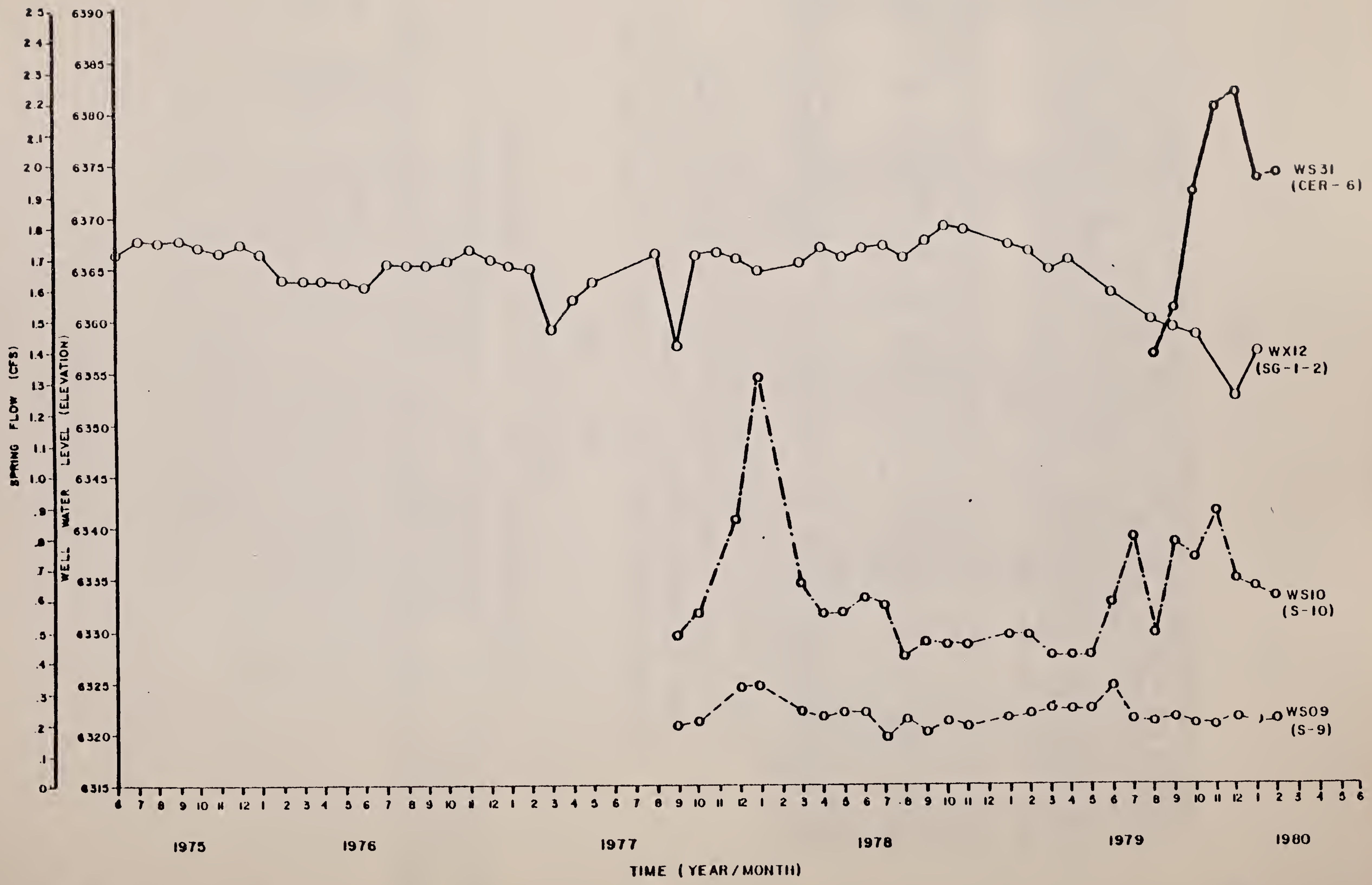
itation stations are located upstream from flow-gauging Stations WU00 and WU61 and both are within three miles of Station WU07. All correlations and regression line slopes are positive which signifies that, as precipitation increases, flow will also increase. The correlations between flow at WU00 versus flow at WU07 and WU61 are excellent and confirm rational thinking in that correlations decrease as the distance between stations is increased. Analyses for lagged correlation for flow versus precipitation were performed but did not produce significant increases over unlagged results.

With regard to time histories of springs CER-6, S-9 and S-10 and comparison with well SG-1-2, this presentation is given on Figure 5.2.8-2. Although well SG-1-2 appears to be affected by Tract operations no consistent effects on these three springs are apparent at this time; the flow in CER-6 has, however, been predominately increasing over its short period of record.

Time history plots of flow and level for additional stations monitored under the Water Augmentation Plan for time period July, 1979 to February, 1980 are presented in Appendix 2A by station groupings as follows:

> Spring flows in Figures A5.2.8-1a through A5.2.8-1f,
>
> alluvial well levels in Figures A5.2.8-2a through A5.2.8-2c,
>
> upper aquifer well levels in Figures A5.2.8-3a through A5.2.8-3e,
>
> and lower aquifer well levels in Figures A5.2.8-4a through A5.2.8-4e.

FIGURE 5.2.8-2
FLOW AND WATER LEVEL VS. TIME FOR
SPECIFIED SPRINGS AND WELLS



5.2.9 Conclusions Regarding Levels and Flows

1. The majority of close-in upper aquifer wells have exhibited a decrease in level in 1979. The wells nearest the shafts, 32X-12 and 33X-1 indicate the greatest decline in level, 39 and 49 feet, respectively.

2. Several of the close-in lower aquifer wells have increased in level in 1979; this may be, in part, due to seasonal effects.

3. No significant changes in flows of springs and seeps have been noted.

4. Discharges from Ponds A and B have occurred since July and have been limited to one-tenth or less of the flow in Piceance Creek at the Hunter Creek station.

5. Flows at upstream (WU07) and downstream (WU61) stations on Piceance Creek correlate well with flow at the station on Piceance Creek at Ryan Gulch (WU00). Both upstream and downstream flows and that at Ryan Gulch correlate well with precipitation at Stations AB20 and AB23. The suggested correlation (under the Water Augmentation Plan) of Ryan Gulch winter flow with Little Hills (WR01) winter precipitation is not as good.

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5.3 Water Quality

Water quality is examined for the identical entities for which levels and flows were discussed: streams, springs and seeps, alluvial wells, upper and lower aquifers, impoundments and shale dumps; sediment characteristics represent one additional category. An overall summary of water quality findings is given in Section 5.3.9.

5.3.1 Streams

5.3.1.1 Scope

This section is concerned primarily with monitoring water quality of Piceance Creek and its tributaries near the Tract from data obtained by the USGS stream gauging network.

5.3.1.2 Objectives

The surface stream water quality monitoring program has been implemented to detect changes that might be attributed to Tract development.

5.3.1.3 Experimental Design

The 13 surface stream gauging stations have been previously identified on Figure 5.2.1-1 and discussed in Section 5.2.1. The identification of water quality variables sampled and associated sampling frequency is indicated on Tables 5.3.1-1 and 5.3.1-2 for four major stations (09306007, 09306022, 09306058, and 09306061 --- computer codes are WU07, WU22, WU58, and WU61 respectively) and nine minor stations.

5.3.1.4 Methods of Analysis

Box-Jenkins time-series analysis, paired t-test for equal population means and histograms are used for the statistical analyses of streams. The Box-Jenkins time-series analysis is a technique used to determine if a time trend exists for a variable whose data oscillates and also to forecast this variable into the near future. A time trend is defined as a rate of change in a variable over time. If a trend is positive, the variable increases with respect to time. If the trend is negative the variable decreases with respect to time. Paired t-tests are used to test the equality between two distinct population means of some variable. A population in this study refers to any one of the four major USGS station populations where samples of variables were taken. Histogram comparisons are used to compare variables for stations over time as well as station-to-station comparisons of variables during the same time interval.

The following techniques are utilized in water quality analyses as indicated in Table 5.3.1-3:

Table 5.3.1-1

WATER SAMPLING FREQUENCY REQUIREMENTS
MAJOR USGS GAUGING STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$			●			
MO Alkalinity	MO						
P Alkalinity	PA						
Aluminum	Al				●		
Ammonia	as NH_4			●			
Antimony							
Arsenic	As			●			
Bacteria							
Barium	Ba				●		
Beryllium	Be						
Bicarbonate	HCO_3			●			
Biological Oxygen Demand	BOD				●		
Bismuth	Bi						
Boron	B			●			
Bromide	Br				●		
Cadmium	Cd				●		
Calcium	Ca			●			
Carbonate	CO_3			●			
Chemical Oxygen Demand	COD				●		
Chloride	Cl			●			
Chromium	Cr				●		
Cobalt	Co						
Coliform, Fecal					●		
Coliform, Total					●		
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC	●					
Copper	Cu				●		
Cyanide	CN				●		
Dissolved Oxygen	DO						
Element Scan					●		
Fecal Streptococcus					●		
Flow		●					
Fluoride	F			●			
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)							
Hydroxides	OH						
Iodine	I						
Iron	Fe			●			
Kjeldahl Nitrogen				●			
Lead	Pb				●		
Level							
Lithium	Li				●		
Magnesium	Mg			●			
Manganese	Mn			●			
Mercury	Hg				●		
Methylene Blue Active Substance	MBAS					●	
Molybdenum	Mo				●		
Nickel	Ni						
Nitrate	NO_3			●			
Nitrite	NO_2			●			
Odor							
Oil & Grease	OLGR				●		
Organic Carbon, Dissolved	DOC			●			
Organic Carbon, Total	TOC			●			
Ortho-Phosphorus (Phosphate)	PO_4				●		
Pesticides						●	
pH	pH	●					
Phenols				●			
PNA	PNA						
Potassium	K			●			
Rubidium	Rb						
Sediment Characterization							
Selenium	Se				●		
Scandium	Sc						
Silica	SiO_2			●			
Silver	Ag						
Sodium	Na			●			
Solids, Dissolved	TDS			●			
Solids, Suspended	SOLS				●		
Strontium	Sr						
Surfactants							
Sulfate	SO_4			●			
Sulfide	SO_3				●		
Temperature (°C)		●					
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity		►					
Vanadium	V						
Yttrium	Y						
Zinc	Zn				●		
Zirconium	Zr						
Radioactivity							
Gross Alpha (pCi)					●		
Radium 226	Ra226						
Natural Uranium	U				●		
Gross Beta							
Cesium	Cs137						
Sr90							
Thorium 230	Th230						
Uranium							
Fractionation of Organic Carbon into							
a. Hydrophobic Bases						●	
b. Hydrophobic Acids						●	
c. Hydrophobic Neutrals						●	
d. Hydrophilic Bases						●	
e. Hydrophilic Acids						●	
f. Hydrophilic Neutrals						●	

* DMP and WAP stations WU07, WU22, WU58, WU61.

SYMBOLS

● Applies to all stations (DMP and WAP).

► Applies to stations WU07 and WU61 only.

Table 5.3.1-2

WATER SAMPLING FREQUENCY REQUIREMENTS
MINOR USGS GAUGING STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$				●		
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al				●		
Ammonia	as NH_3				●		
Antimony							
Arsenic	As				●		
Bacteria	SE						
Barium	Ba				●		
Beryllium	Be				●		
Bicarbonate	HCO_3						
Biological Oxygen Demand	BOD				●		
Bismuth	Bi						
Boron	B				●		
Bromide	Br				●		
Cadmium	Cd				●		
Calcium	Ca				●		
Carbonate	CO_3				●		
Chemical Oxygen Demand	COD				●		
Chloride	Cl				●		
Chromium	Cr				●		
Cobalt	Co						
Coliform, Fecal					●		
Coliform, Total					●		
Color (Not Precise)							
Conc. Hydrocarbon	CH						
Conductivity, Specific	SPC						
Copper	Cu				●		
Cyanide	Cn				●		
Dissolved Oxygen	DO						
Element Scan					●		
Fecal Streptococcus					●		
Flow					●		
Fluoride	F				●		
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)							
Hydroxides	OH						
Iodine	I						
Iron	Fe				●		
Kjeldahl Nitrogen					●		
Lead	Pb				●		
Level							
Lithium	Li				●		
Magnesium	Mg				●		
Manganese	Mn				●		
Mercury	Hg				●		
Methylene Blue Active Substance	MBAS						
Molybdenum	Mo				●		
Nickel	Ni						
Nitrate	NO_3				●		
Nitrite	NO_2				●		
Odor							
Oil & Grease	OLGR				●		
Organic Carbon, Dissolved	DOC				●		
Organic Carbon, Total	TOC				●		
Ortho-Phosphorus (Phosphate)	PO_4				●		
Pesticides							
pH	pH				●		
Phenols					●		
PNA	PNA						
Potassium	K				●		
Rubidium	Rb						
Sediment Characterization							▶
Selenium	Se				●		
Scandium	Sc						
Silica	SiO_2				●		
Silver	Ag						
Sodium	Na				●		
Solids, Dissolved	TDS				●		
Solids, Suspended	SOLS						
Strontium	Sr				●		
Surfactants							
Sulfate	SO_4				●		
Sulfide	SO_2				●		
Temperature (°C)					●		
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity							
Vanadium	V						
Yttrium	Y						
Zinc	Zn				●		
Zirconium	Zr						
Radioactivity							
Gross Alpha (pCl)					●		
Radium 226	Ra226						
Natural Uranium	U						
Gross Beta					●		
Cesium	Cs137						
Sr90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases							
b. Hydrophobic Acids							
c. Hydrophobic Neutrals							
d. Hydrophilic Bases							
e. Hydrophilic Acids							
f. Hydrophilic Neutrals							

* DMP stations WU15, WU25, WU28, WU33, WU36, WU39, WU42, WU50, WU52. WAP stations are all DMP stations + stations 4300, 6200, 6222, 6225.

SYMBOLS

● Applies to all stations (DMP and WAP).

▶ Applies to station WU42 only.

TABLE 5.3.1-3

STATISTICAL TECHNIQUES UTILIZED IN WATER QUALITY ANALYSES

Hydrology Subsections	Analyses Performed
5.3.1 USGS Stations	A. B. C. D. E.
5.3.2 Springs and Seeps	A. B.
5.3.3 Alluvial Wells	A. B. C.
5.3.4 Upper and Lower 5.3.5 Aquifers	A. B.
5.3.6 Impoundments	B. C. G.
Correlations Suggested under Water Augmentation Plan	B. D. F.

Key:
- A. Time Series Plots
- B. Linear Regression Analysis
- C. Paired t-test
- D. Histogram Analysis
- E. Box-Jenkins Analysis
- F. Tables
- G. Visual Analysis of Tables and Graphs

Visual inspections of plotted data
Linear regression of trends
Paired t-tests for between-station comparisons
Box-Jenkins time-series analysis
Histograms.

All statistical tests were run to test an acceptance of a null hypothesis at a 5 percent level of significance.

5.3.1.5 Discussion and Results

Statistically significant trends in water quality variables, with flows and levels included for convenience, are presented on Table 5.3.1-4. Appendix A5.3.1 presents discussion of methods and results of the analyses of the data.

There were no significant trends over time for any water quality variables. However, the variables HCO_3, B, Mg, Ca, CO_3, Cl, Na, pH, NH_3, and specific conductance were examined for upstream (Station WU07) and downstream (Station WU61) locations on Piceance Creek. Two-year mean values (1975 through 1976 and 1977 through 1978) were compared as ratios for the same station over time and for between-station comparisons. Results are summarized on Table 5.3.1-5. They show that the greatest increase in means for the two time periods are for variables HCO_3, Mg and Na for which the increases are 20%, 8%, and 8% respectively; associated histograms are provided on Figures 5.3.1-1 to 5.3.1-3 respectively, with histograms for the remaining variables in the Appendix, Figures A5.3.1-1 through A5.3.2-7.

5.3.2 Springs

5.3.2.1 Scope

Nine springs provide data under the Development Monitoring Plan for water quality analysis; the station network is shown on Figure 5.2.2-1a.

5.3.2.2 Objective

The objective is to monitor effects of development on water quality of springs and seeps.

5.3.2.3 Experimental Design

Variables sampled along with their sampling frequency are given on Table 5.3.2-1. Sampling intervals were previously shown on Figure 5.2.2-2.

5.3.2.4 Method of Analysis

Methods of analyses are identical to those of Section 5.3.1 as summarized in Table 5.3.1-3.

TABLE 5.3.1-4

Statistically Significant Positive (+) or Negative (-) Trends in Water Quality Variables, Flow and Level

R \ C	USGS Gauging Stations	Springs and Seeps	Alluvial Wells	Aquifer Wells	
				Upper	Lower
Flow/ Depth				(1)	(2)
SC			+(WA06)		
B	NR				
F				NR	NR
Al	NR	NR	NR		
K	NR	NR	NR		
HCO_3		NR	NR	NR	NR
TDS			NR		
Ca	NR	NR	NR		
Mg		NR	NR		
DOC				NR	NR
SO_4	NR			NR	NR
Mo	NR			NR	NR
pH				NR	NR
Water Temp			+(WA06)	NR	NR
Na					
NH_3					
As		+(WS07)		NR	NR

NOTES:

1. - Trend in depth for WX02, WX10, WX12, WX32, WX33, WX44, WX63, and WX92.
2. + Trend in depth for WY10, WY16, WY44, WY52, WY54, WY61, and WY91 (through October 1979)
3. An NR indicates that the regression analysis was not run for this variable.
4. A blank indicates that the statistical trend is not significant at the 5% level. Four digit code entries are used where trends were significant along with a plus or minus sign for trend direction.

TABLE 5.3.1-5 Water Quality at Upstream and Downstream Piceance Creek Stations

	Time			Station		
Parameter	Start	Stop	Span (Yrs)	007 Mean (Upstream)	061 Mean (Downstream)	Ratio 061/007
HCO_3	1/75	12/76	2	471 mg/l	534 mg/l	1.13
	1/77	12/78	2	569	634	1.11
	1/75	5/79	4.4	517	609	1.18
				(1.21)	(1.19)	
B	1/75	12/76	2	0.203	0.205	1.01
	1/77	12/78	2	0.212	0.190	.90
	1/75	5/79	4.4	0.206	0.199	1.04
				(1.04)	(0.93)	
Mg	1/75	12/76	2	45	66	1.47
	1/77	12/78	2	49	71	1.45
	1/75	5/79	4.4	46	67	1.46
				(1.09)	(1.08)	
Ca	1/75	12/76	2	66	76	1.15
	1/77	12/78	2	73	79	1.08
	1/75	5/79	4.4	69	77	1.12
				(1.11)	(1.04)	
CO_3	1/75	12/76	2	1.51	5.25	3.48
	1/77	12/78	2	0.05	0.04	0.80
	1/75	5/79	4.4	0.97	3.24	3.34
				(0.03)	(0.00)	
Cl	1/75	12/76	2	14.7	13.6	0.93
	1/77	12/78	2	14.9	15.2	1.02
	1/75	5/79	4.4	14.7	14.2	0.97
				(1.01)	(1.12)	
Na	1/75	12/76	2	118	143	1.21
	1/77	12/78	2	129	154	1.19
	1/75	5/79	4.4	199	146	0.73
				(1.09)	(1.08)	
pH	1/75	12/76	2	8.3	7.9	0.95
	1/77	12/78	2	8.2	8.2	1.0
	1/75	5/79	4.4	8.2	8.1	0.99
				(0.99)	(1.04)	
NH_3	1/75	12/76	2	0.03	0.03	1.00
	1/77	12/78	2	0.04	0.04	1.00
	1/75	5/79	4.4	0.03	0.03	1.00
				(1.33)	(1.33)	
Sp. Cond.	1/75	12/76	2	1059 µmho	1295 µmho	1.22
	1/77	12/78	2	1067	1298	1.22
	1/75	5/79	4.4	1054	1281	1.22
				(1.01)	(1.00)	

NOTE: Numbers in parentheses refer to ratio $\frac{\text{1977 to 1978}}{\text{1975 to 1976}}$

For example: $1.21 = \frac{569}{471} = \frac{\text{1977 to 1978 value}}{\text{1975 to 1976 value}}$

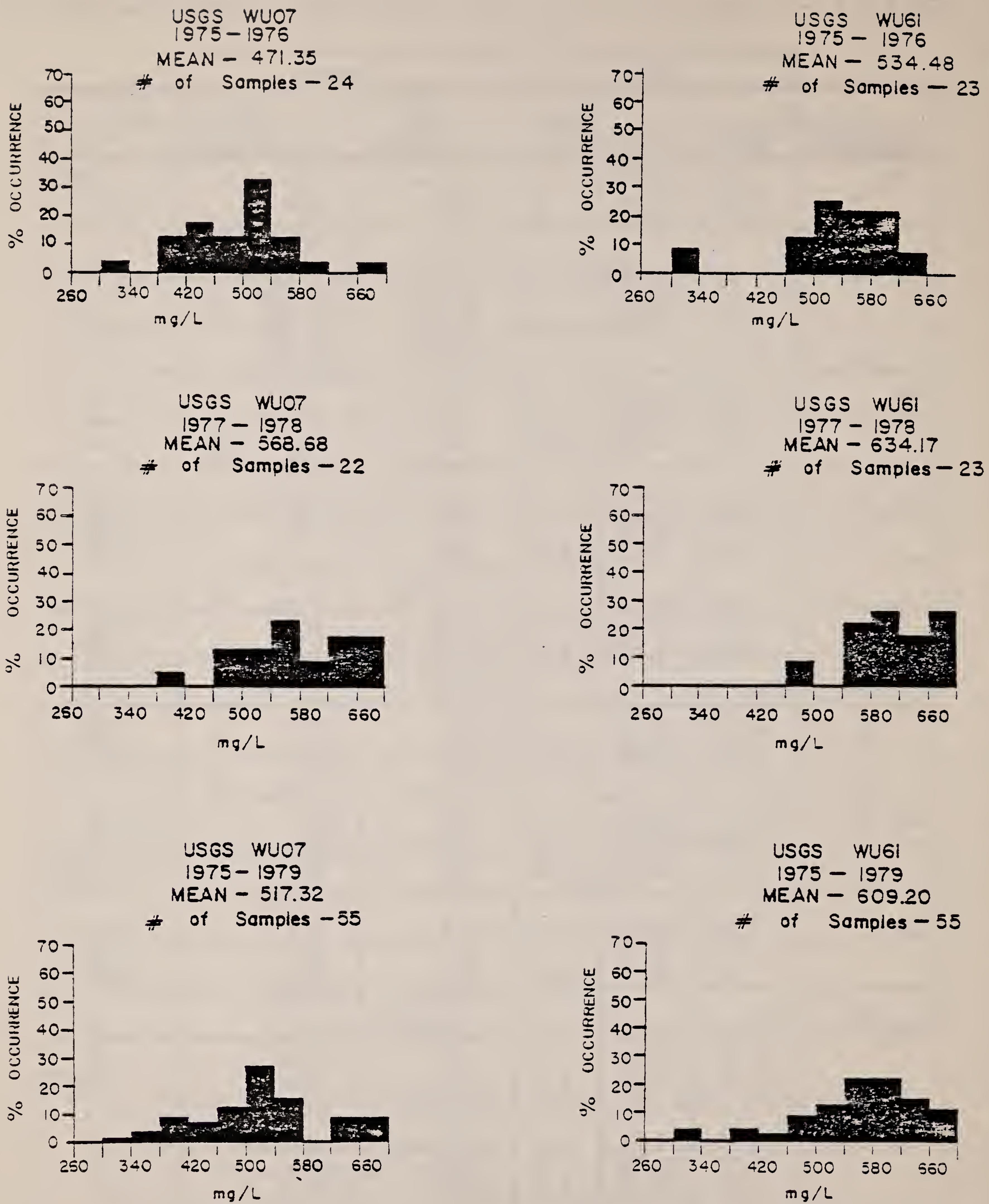

FIGURE 5.3.1-1

HISTOGRAMS FOR WATER QUALITY AT PICEANCE CREEK STATIONS:

HCO_3

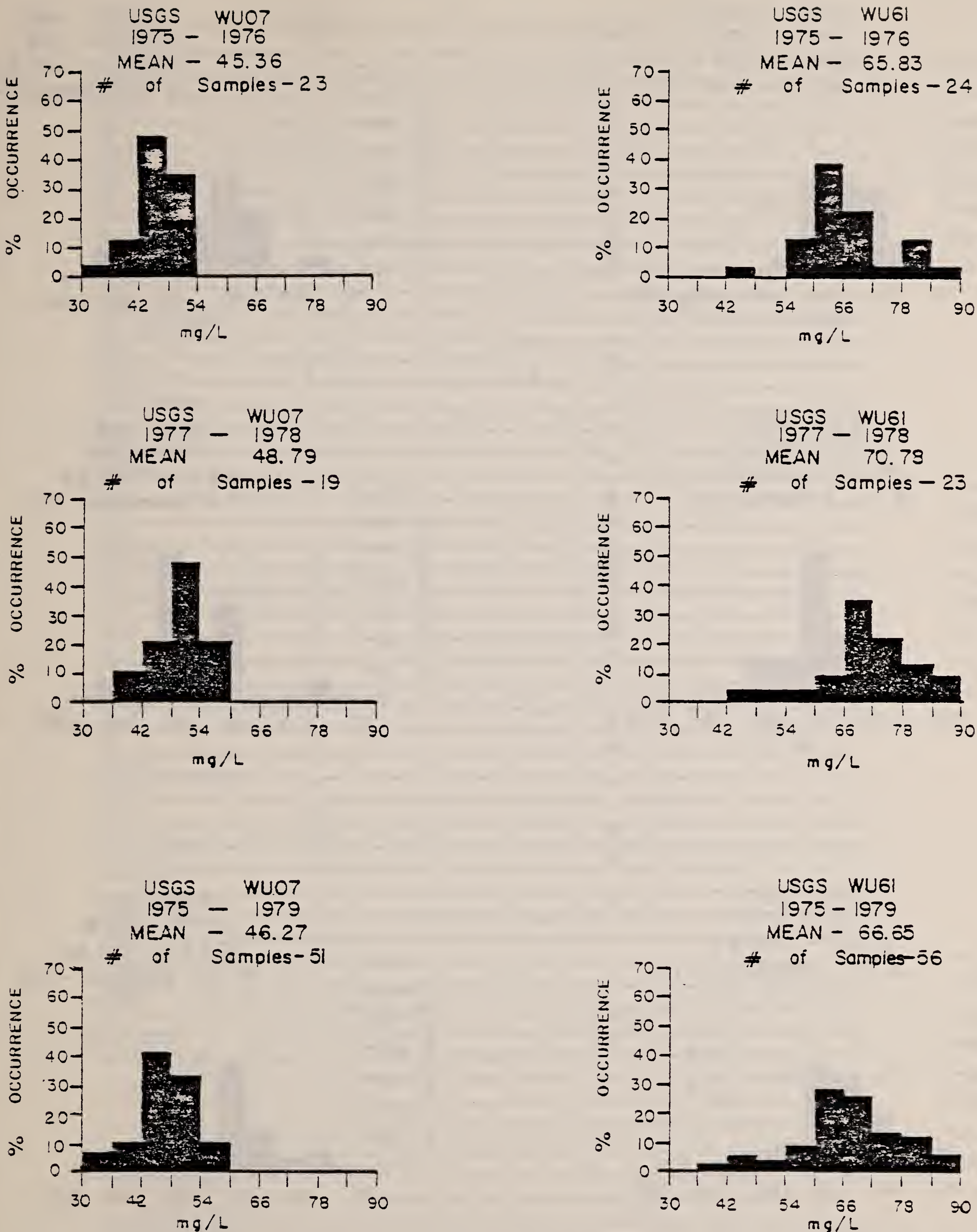

FIGURE 5.3.1-2

HISTOGRAMS FOR WATER QUALITY
AT PICEANCE CREEK STATIONS:
Mg

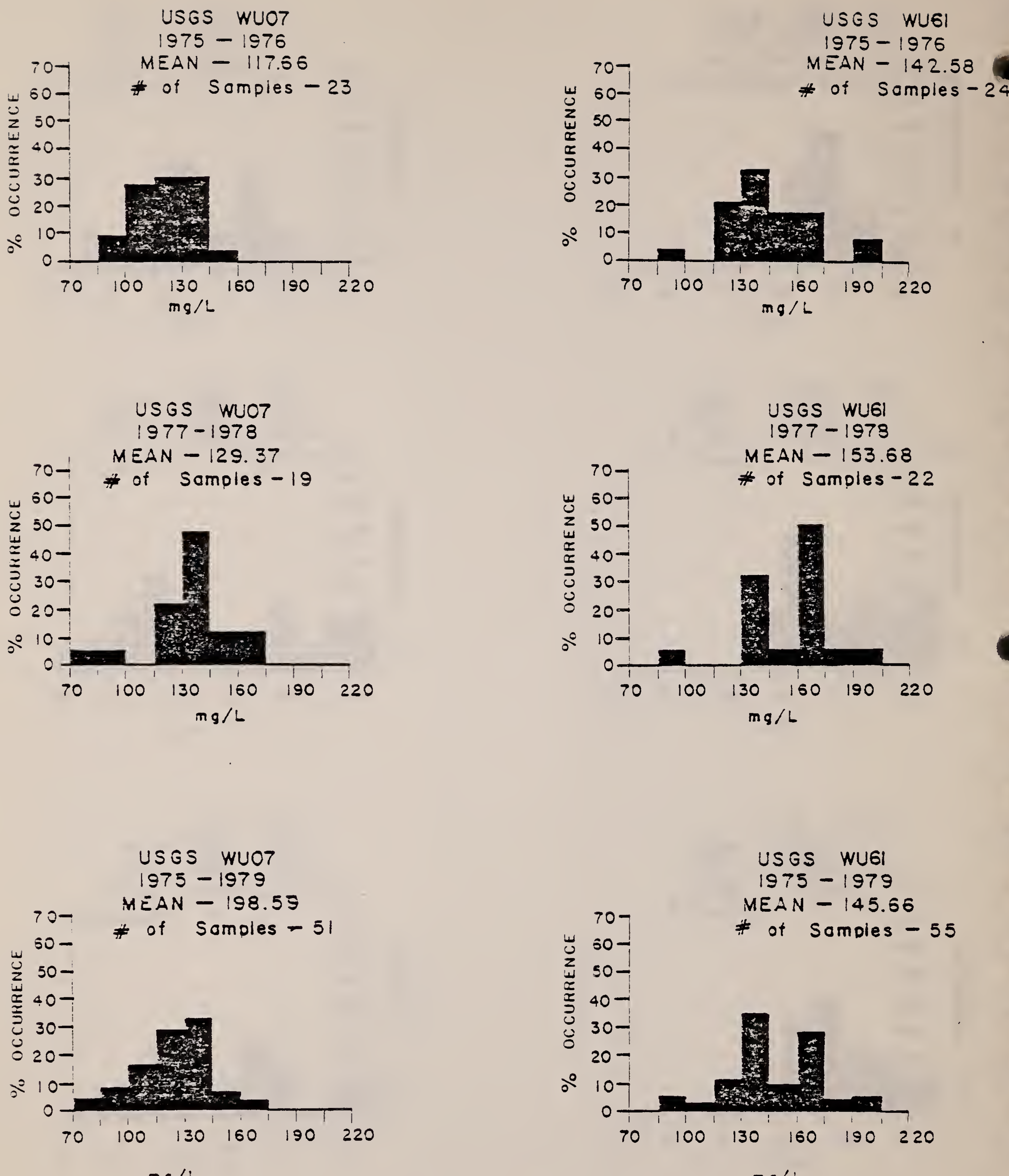

FIGURE 5.3.1-3

HISTOGRAMS FOR WATER QUALITY
AT PICEANCE CREEK STATIONS:

Na

WATER SAMPLING FREQUENCY REQUIREMENTS
SPRINGS AND SEEPS STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$				●		
M Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al				●		
Ammonia	as NH_3				●		
Antimony					●		
Arsenic	AS				●		
Bacteria	SB						
Barium	Ba				●		
Beryllium	Be						
Bicarbonate	HCO_3				●		
Biological Oxygen Demand	BOD				●		
Bismuth	Bi						
Boron	B				●		
Bromine	Br						●
Cadmium	Cd				●		
Calcium	Ca				●		
Carbonate	CO_3				●		
Chemical Oxygen Demand	COD				●		
Chloride	Cl				●		
Chromium	Cr				●		
Cobalt	Co						
Coliform, Fecal						●	
Coliform, Total						●	
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC			●			
Copper	Cu				●		
Cyanide	CN						
Dissolved Oxygen	DO			●			
Element Scan							
Fecal Streptococcus						●	
Flow			■				
Fluoride	F				●		
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)					●		
Hydroxides	OH						
Iodine	I						
Iron	Fe				●		
Kjeldahl Nitrogen					●		
Lead	Pb				●		
Level							
Lithium	Li				●		
Magnesium	Mg				●		
Manganese	Mn				●		
Mercury	Hg				●		
Methylene Blue Active Substance	MBAS						
Molybdenum	Mo				●		
Nickel	Ni				●		
Nitrate	NO_3				●		
Nitrite	NO_2				●		
Odor							
Oil & Grease	OLGR				●		
Organic Carbon, Dissolved	DOC					►	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO_4						
Pesticides							
pH	pH			●			
Phenols					●		
PNA	PNA						
Potassium	K				●		
Rubidium	Rb						
Segment Characterization							
Selenium	Se				●		
Scandium	Sc						
Silica	SiO_2						
Silver	Ag						
Sodium	Na				●		
Solids, Dissolved	TDS						
Solids, Suspended	SOLS				●		
Strontium	Sr				●		
Surfactants							
Sulfate	SO_4				●		
Sulfide	SO_3						
Temperature (°C)				●			
Thiosulfate	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity							
Vanadium	V						
Yttrium	Y						
Zinc	Zn				●		
Zirconium	Zr						
Radioactivity							
Gross Alpha (soil)						●	
Radium 226	Ra226					●	
Natural Uranium	U						
Gross Beta						●	
Cesium	Cs137						
Sr90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases							
b. Hydrophobic Acids							
c. Hydrophobic Neutrals							
d. Hydrophilic Bases							
e. Hydrophilic Acids							
f. Hydrophilic Neutrals							

* DMP and WAP stations WS01, WS02, WS03, WS04, WS06, WS07, WS09, WS10. Additional WAP stations CER-1, B-3, H-3, F-3, Fig. 4-A, W-4, W-9, CER-7, S-9, P3 & 3A.

SYMBOLS

● Applies to all DMP stations.

► Applies to two stations to be selected by AOSSO.

■ Applies to DMP and WAP stations.

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5.3.2.5 Discussion and Results

From statistical analyses the only significant positive trend (Table 5.3.1-4) resulted from arsenic at Station WS07 on Willow Creek near Piceance Creek. Even though the trend (Figure 5.3.2-1) is significant the magnitudes of all values are very small, well below even drinking water standards of 0.05 mg/l.

Discussion of statistical analyses and other results are presented in Appendix A5.3.2, Water Quality - Springs.

5.3.3 Alluvial Wells

5.3.3.1 Scope

Data from alluvial wells corresponding to Stations WA01 - WA12 were analyzed for water quality. Figure 5.2.3-1 shows the alluvial well monitoring station network.

5.3.3.2 Objectives

Objectives of the alluvial well data analyses are to detect potential changes in water quality due to development.

5.3.3.3 Experimental Design

The water quality variables sampled are shown on Table 5.3.3-1 along with their sampling frequencies. Sampling intervals were previously referenced on Figure 5.2.3-2.

5.3.3.4 Method of Analysis

These statistical methods are identical to those previously mentioned in Section 5.3.1 and are summarized in Table 5.3.1-3.

5.3.3.5 Discussion and Results

Only two water quality trends were significant for alluvial wells - and at the same station (WA06, on Cottonwood Gulch near Piceance Creek); both specific conductance and temperature have increased over time, as indicated on Table 5.3.1-4. The temperature increase is judged to be primarily seasonal. Specific conductance is increasing at approximately 224 umhos/yr (Figure 5.3.3-1).

5.3.4 Upper Aquifer Wells

5.3.4.1 Scope

Data from the upper aquifer wells have been analyzed for water quality variations. The network consists of those sampling stations required under the Development Monitoring Plan as shown on Figure 5.2.4-1a.

FIGURE 5.3.2-1

TRENDS IN WATER QUALITY FOR ARSENIC, STATION WS07

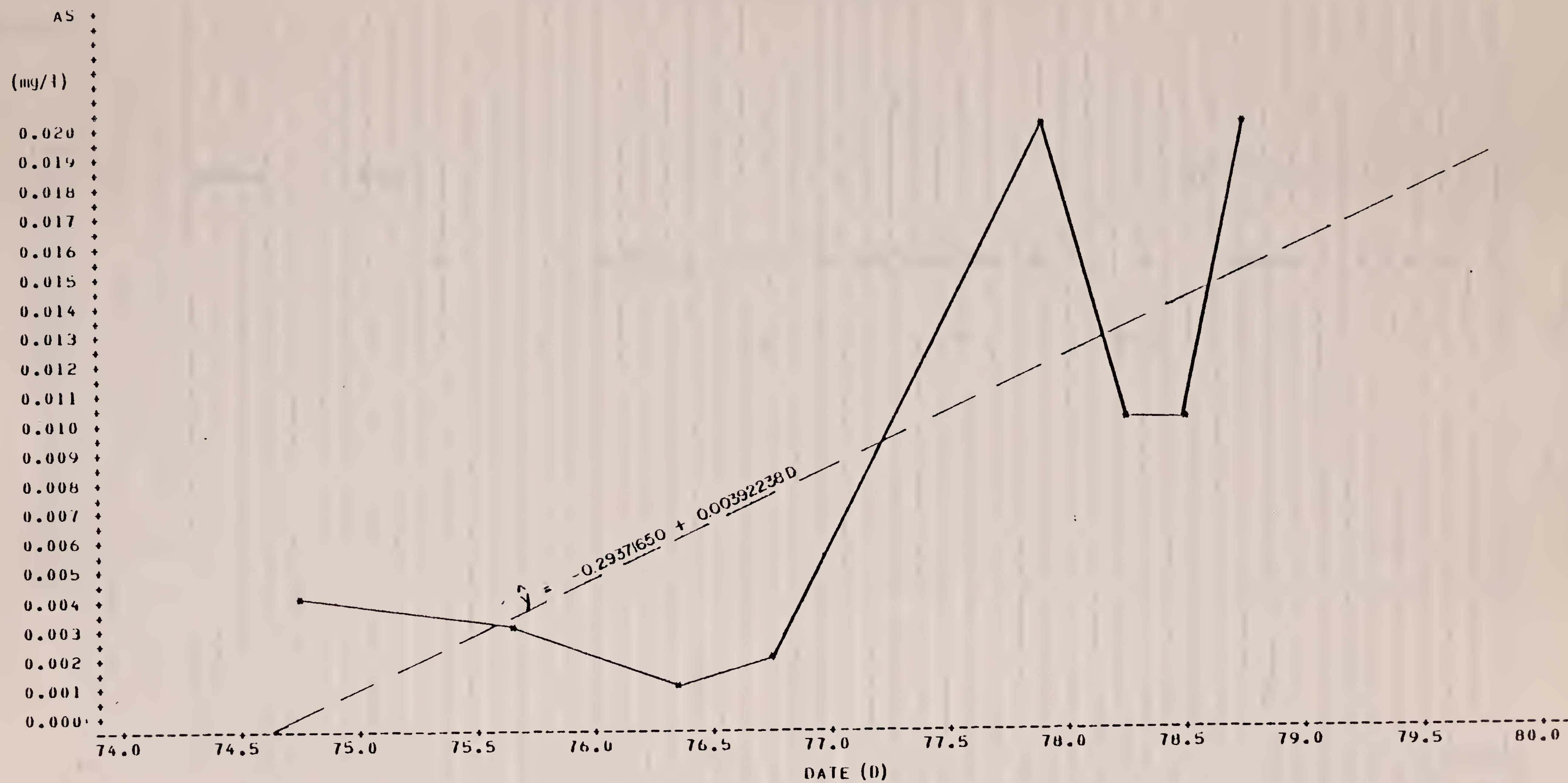

Table 5.3.3-1
WATER SAMPLING FREQUENCY REQUIREMENTS
ALLUVIAL WELLS STATIONS*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$				•		
M. Alkalinity	MA						
P. Alkalinity	PA						
Aluminum	Al				•		
Ammonia	as NH_3				•		
Ammonium							
Arsenic	As				•		
Antimony	SB						
Barium	Ba				•		
Beryllium	Be						
Bicarbonate	HCO_3				•		
Biological Oxygen Demand	BOD					•	
Bismuth	Bi						
Boron	B				•		
Bromide	Br						•
Cadmium	Cd				•		
Calcium	Ca				•		
Carbonate	CO_3				•		
Chemical Oxygen Demand	COD				•		
Chloride	Cl				•		
Chromium	Cr				•		
Cobalt	Co						
Coliform, Fecal						•	
Coliform, Total						•	
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC			•			
Copper	Cu				•		
Cyanide	CN						
Dissolved Oxygen	DO			•			
Element Scan							
Fecal Streptococcus							
Flow							
Fluoride	F				•		
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)					•		
Hydrocarbons	OH						
Iodine	I						
Iron	Fe				•		
Kjeldahl Nitrogen					•		
Lead	Pb				•		
Level				•			
Lithium	Li				•		
Magnesium	Mg				•		
Manganese	Mn				•		
Mercury	Hg				•		
Methylene Blue Active Substance	MBAS						•
Molybdenum	Mo				•		
Nickel	Ni				•		
Nitrate	NO_3				•		
Nitrite	NO_2						
Odor							
Oil & Grease	OLGR				•		
Organic Carbon, Dissolved	DOC					•	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO_4						
Pesticides							
pH	pH			•			
Phenols					•		
PNA	PNA						
Potassium	K				•		
Rubidium	Rb						
Sediment Characterization							
Selenium	Se				•		
Scandium	Sc						
Silica	SiO_2						
Silver	Ag				•		
Sodium	Na				•		
Solids, Dissolved	TDS				•		
Solids, Suspended	SOLS				•		
Strontium	Sr						
Surfactants							
Sulfate	SO_4				•		
Sulfide	S						
Temperature (°C)				•			
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity							
Vanadium	V						
Yttrium	Y						
Zinc	Zn				•		
Zirconium	Zr						
Radioactivity							
Gross Alpha (pCi/l)						•	
Radium 226	Ra226					•	
Natural Uranium	U						
Gross Beta						•	
Cesium	Cs137						
Sr-90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases						•	
b. Hydrophobic Acids						•	
c. Hydrophobic Neutrals						•	
d. Hydrophilic Bases						•	
e. Hydrophilic Acids						•	
f. Hydrophilic Neutrals						•	

* DMP and WAP stations: WA01, WA02, WA03, WA04, WA05, WA06, WA07, WA08, WA09, WA10, WA11, WA12, WA13.
Current status of wells (July 1979), WA02 and WA07 are plugged. WA04 and WA13 are dry. All others are being sampled.

SYMBOLS

• Applies to all stations (DMP and WAP).

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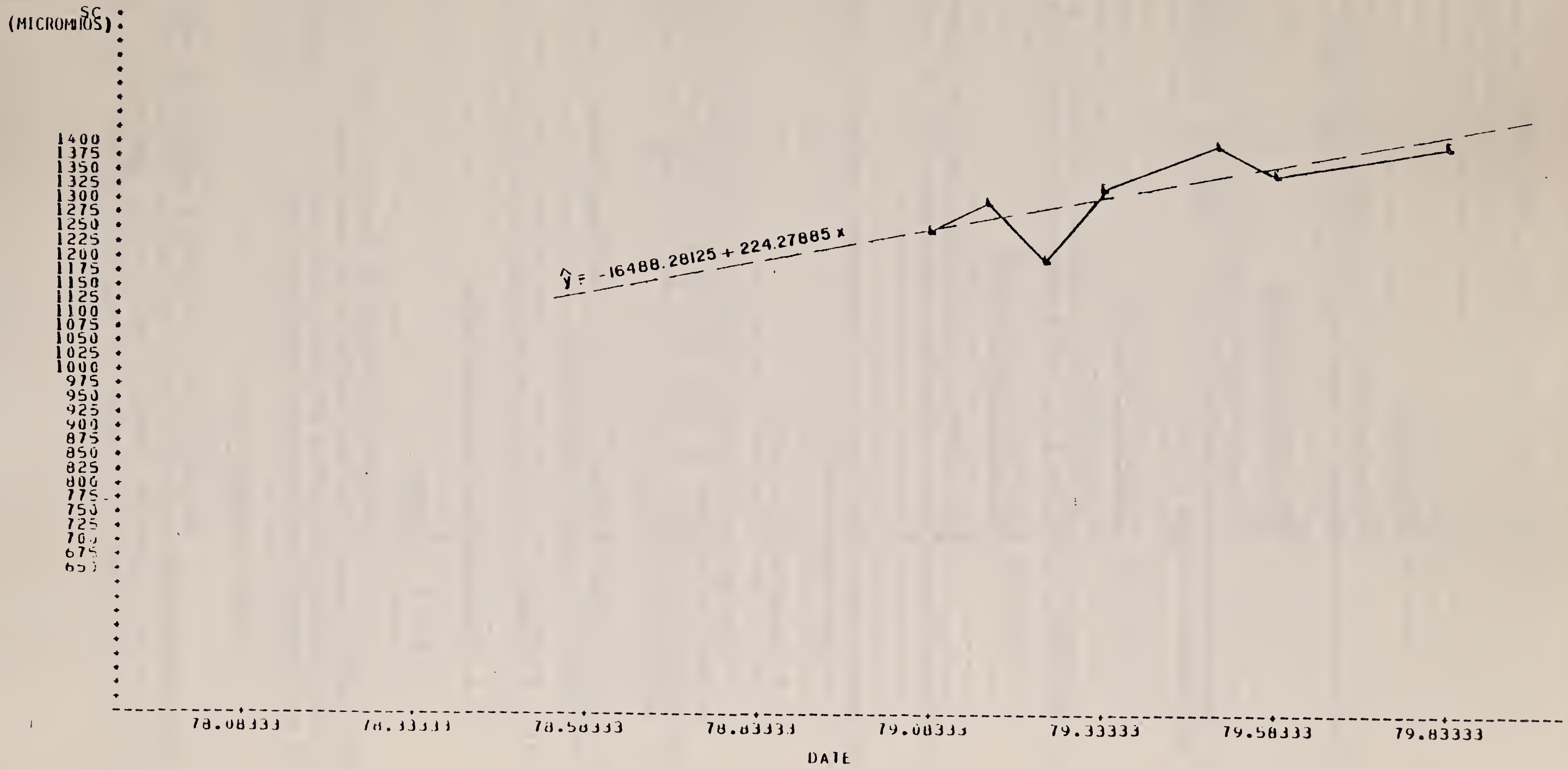
FIGURE 5.3.3-1

WATER QUALITY TRENDS FOR SPECIFIC CONDUCTANCE, STATION WA06



5.3.4.2 Objectives

The objectives of the upper aquifer data analyses are to detect potential changes in water quality due to development.

5.3.4.3 Experimental Design

The water quality variables sampled along with their sampling frequencies are shown on Table 5.3.4-1. Sampling intervals were previously referenced on Figure 5.2.4-2.

5.3.4-4 Method of Analyses

These statistical methods are identical to those previously mentioned in Section 5.3.1 and summarized in Table 5.3.1-3.

5.3.4.5 Discussion and Results

By referring to Table 5.3.1-4 it is seen that there were no water quality variables exhibiting trends over time in the upper aquifer.

Discussion of statistical analyses with results are presented in Appendix A5.3.4 Water Quality - Upper Aquifer Wells.

5.3.5 Lower Aquifer Wells

The entire discussion parallels exactly that for the upper aquifer. The sampling network is shown on Figure 5.2.4-1a and variables with associated monitoring frequencies on Table 5.3.5-1. Sampling intervals were previously referenced on Figure 5.2.5-1.

Analogously to the upper aquifer, Table 5.3.1-4 shows there are no trends to date in water quality in the lower aquifer.

Appendix A5.3.5 presents discussion and results of statistical analyses.

5.3.6 Impoundments/Discharges/NPDES

5.3.6.1 Scope

Temporary storages designated as Ponds A, B, and C are used for water pumped from the shafts during development. This section discusses water quality monitoring of these ponds and their associated seepage-monitoring wells established down-dip from these ponds.

5.3.6.2 Objectives

One objective is to sample quality of water discharged from temporary storage to assure compliance with the discharge permit. Water quality in wells near the ponds is monitored to determine if seepage from the ponds affects the quality of water in the Uinta aquifer; this is the second objective.

DEEP WELLS - UPPER AQUIFER*

Table 5.3.4-1

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	CaCO3					●	
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al						
Ammonia	as NH3					●	
Antimony						●	
Arsenic	As						
Bacteria	SB					●	
Barium	Ba						
Beryllium	Be					●	
Bicarbonate	HCO3					●	
Biological Oxygen Demand	BOD					●	
Bismuth	Bi						
Boron	B					●	
Bromide	Br						
Cadmium	Cd					●	
Calcium	Ca						
Carbonate	CO3					●	
Chemical Oxygen Demand	COD					●	
Chloride	Cl					●	
Chromium	Cr					●	
Cobalt	Co					●	
Coliform, Fecal						●	
Coliform, Total							
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC						
Copper	Cu					●	
Cyanide	Cn					●	
Dissolved Oxygen	DO						
Element Scan							
Fecal Streptococcus							
Flow							
Fluoride	F					●	
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)						●	
Hydroxides	OH						
Iodine	I						
Iron	Fe					●	
Kjeldahl Nitrogen						●	
Lead	Pb					●	
Level				■			
Lithium	Li						
Magnesium	Mg					●	
Manganese	Mn					●	
Mercury	Hg					●	
Methylene Blue Active Substance	MBAS					●	
Molybdenum	Mo					●	
Nickel	Ni					●	
Nitrate	NO3					●	
Nitrite	NO2						
Odor							
Oil & Grease	O&GA					●	
Organic Carbon, Dissolved	DOC					●	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO4						
Pesticides							
pH	pH					●	
Phenols						●	
Pha	PHA						▶
Potassium	K					●	
Rubidium	Rb						
Sediment Characterization							
Selenium	Se					●	
Scandium	Sc						
Silica	SiO2						
Silver	Ag					●	
Sodium	Na					●	
Solids, Dissolved	TDS					●	
Solids, Suspended	TSS						
Strontium	Sr					●	
Surfactants							
Sulfate	SO4					●	
Sulfide	SO3						
Temperature (°C)							
Thiosulfate	S2O3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity							
Vanadium	V						
Yttrium	Y						
Zinc	Zn					●	
Zirconium	Zr						
Radioactivity							
Gross Alpha (pCi/l)						●	
Radium 226	Ra226					●	
Natural Uranium	U						
Gross Beta						●	
Cesium	Cs137						
Sr90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases							
b. Hydrophobic Acids							
c. Hydrophobic Neutrals							
d. Hydrophilic Bases							
e. Hydrophilic Acids							
f. Hydrophilic Neutrals							

* C-b affiliated (DMP and WAP stations)

WX02	WX10	WX18	WX32	WX55
WX03	WX12	WX19	WX33	WX63
WX04	WX17	WX20	WX44	WX92
		WX21		

Non-affiliated (Additional WAP stations)

TH75-5A	TH75-9A	Greeno ...	Rule ...
TH75-13A	CDR RB-D-02	Oldland 3	Liberty Bell 12
TH75-18A	TH75-15A	CP-17X-30	Union 81

SYMBOLS

- ● Applies to all C-b affiliated stations
- ▶ Applies to stations and species to be identified.
- ■ Applies to both affiliated and non-affiliated stations

Revised 1/15/80.

[illegible]
DEEP WELLS - LOWER AQUIFER*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$					●	
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al					●	
Ammonia	as NH_3					●	
Antimony							
Arsenic	As					●	
Bacteria	SB						
Barium	Ba					●	
Beryllium	Be						
Bicarbonate	HCO_3					●	
Biological Oxygen Demand	BOD					●	
Bismuth	Bi						
Boron	B					●	
Bromide	Br					●	
Cadmium	Cd						
Calcium	Ca					●	
Carbonate	CO_3					●	
Chemical Oxygen Demand	COD					●	
Chloride	Cl					●	
Chromium	Cr					●	
Cobalt	Co					●	
Coliform, Fecal							
Coliform, Total							
Color (Not Precise)							
Cond. Hydrocarbon	CH						
Conductivity, Specific	SPC						
Copper	Cu					●	
Cyanide	CN						
Dissolved Oxygen	DO						
Element Scan							
Fecal Streptococcus							
Flow						●	
Fluoride	F					●	
Gallium	Ga						
Germanium	Ge						
Hardness (Ca, Mg)						●	
Hydroxides	OH						
Iodine	I						
Iron	Fe					●	
Kjeldahl Nitrogen						●	
Lead	Pb					●	
Level				■			
Lithium	Li					●	
Magnesium	Mg					●	
Manganese	Mn					●	
Mercury	Hg					●	
Methylene Blue Active Substance	MBAS						
Molybdenum	Mo					●	
Nickel	Ni					●	
Nitrate	NO_3					●	
Nitrite	NO_2						
Odor							
Oil & Grease	OLGR					●	
Organic Carbon, Dissolved	DOC					●	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO_4						
Pesticides							
pH	pH					●	
Phenols						●	
PNA	PNA						►
Potassium	K					●	
Rubidium	RB						
Sediment Characterization							
Selenium	Se					●	
Scandium	SC						
Silica	SiO_2						
Silver	Ag					●	
Sodium	Na					●	
Solids, Dissolved	TDS					●	
Solids, Suspended	SOLS						
Strontium	Sr					●	
Surfactants							
Sulfate	SO_4					●	
Sulfite	SO_2						
Temperature (°C)							
Thiosulfite	S_2O_3						
Tin	Sn						
Titanium	Ti						
Tungsten	W						
Turbidity							
Vanadium	V						
Yttrium	Y						
Zinc	Zn					●	
Zirconium	Zr						
Radioactivity							
Gross Alpha (pCi)						●	
Radium 226	Ra226					●	
Natural Uranium	U						
Gross Beta						●	
Cesium	Cs137						
Sr90							
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases							
b. Hydrophobic Acids							
c. Hydrophobic Neutrals							
d. Hydrophilic Bases							
e. Hydrophilic Acids							
f. Hydrophilic Neutrals							

* C-b affiliated (DMP and WAP stations)

WY01	WY17	WY52	WY62
WY10	WY45	WY54	WY81
WY12	WY46	WY61	WY91

Revised 1/15/80.

Non-affiliated (Additional WAP stations)

TH75-5B	TH75-9B	TG71-3	Liberty Bell 12
TH75-13B	Equity Sulfur 1A	TG71-5	Getty 9-4D
Equity 1	CER RB-D-03	Oildana 3	TG71-4
TH75-13B	TH75-15B	CP-17X-2G	Equity BS 12
TH75-10B	Greeno 4-4	[illegible] 25	

SYMBOLS

- ● Applies to all C-b affiliated stations
- ► Applies to stations and species to be identified
- ■ Applies to both C-b affiliated and non-affiliated stations

5.3.6.3 Experimental Design

A series of temporary holding ponds have been constructed (Ponds A, B, and C) for water pumped from the mine shafts during the development phase. At year-end Ponc C had not been utilized. Figure 5.2.6-1 shows the location of these ponds. Quality measurements are made at the discharge from Pond B in accordance with the NPDES (National Pollutant Discharge Elimination System) permit. Items monitored under the permit and sampling frequency are summarized on Table 5.3.6-1.

Samples are also taken from wells near the ponds to determine if water quality in the Uinta aquifer is being affected by seepage from the ponds. The seepage well down-dip of Ponds A and B is designated WW12 and that down-dip of Pond C is WW13. These data from WW12 and WW13 are now beginning to provide some background basis or baseline for upper Uinta water. Drilling of an additional key monitoring well is planned in 1980 for this purpose.

5.3.6.4 Method of Analysis

Figure 5.2.4-2b presents the sampling time interval available for analysis of water quality for the seepage-monitoring wells. Cross reference between station I.D. and four character code is provided in the figure as well as the date of first sample taken at the station.

All collected data and laboratory analyses are reported in the Semi-annual Data Reports. Sampling frequency and laboratory analyses of various parameters are reviewed at the time of analysis for compliance with NPDES permit requirements.

A special study of seepage monitoring well water quality has been performed. Results of this study are reported here. The method consists of examining time trends for each quality variable over the interval of data collection for the purpose of evaluation of stability of the variable at a recent baseline value. Because of limited data, comparisons of trend and mean values for selected variables are also compared with recent data for nearby springs and alluvial wells as well as that during the baseline period.

5.3.6.5 Discussion and Results

5.3.6.5.1 Discharge from Pond B

Section 7.2 of Volume 1 of this Annual Report contains discussion relevant to this section, particularly with regard to shaft water quality. Monthly reports have been submitted to the State Water Quality Control Division (WQCD) in accordance with the NPDES permit.

Table 5.3.6-2 shows the results of the water quality analyses at the single discharge point utilized to date. This discharge point is designated Station WN40 and is the discharge from Pond B (See Figure 5.2.6-1).

[illegible]

NPDES DISCHARGE POINT*

PARAMETERS	SYMBOL	DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMI-ANNUALLY	ANNUALLY
Alkalinity	$CaCO_3$					●	
MO Alkalinity	MA						
P Alkalinity	PA						
Aluminum	Al		●			▲	
Ammonia	AS NH3		●				
Antimony							
Arsenic	As					▲	
Bacteria	BS						
Barium	Ba					▲	
Beryllium	Be					▲	
Bicarbonate	HCO3					●	
Biochemical Oxygen Demand	BOD						
Bismuth	Bi					▲	
Boron	B		●			●	
Bromide	Br					●	
Cadmium	Cd					▲	
Calcium	Ca			●		●	
Carbonate	CO_3						
Chemical Oxygen Demand	COD					●	
Chloride	Cl	●				●	
Chromium	Cr					▲	
Cobalt	Co						
Coliform, Fecal							
Coliform, Total							
Color (Not Precise)							
Cond. Hydrocarbon	CH					●	
Conductivity, Specific	SPC						
Copper	Cu			●		▲	
Cyanide	CN					●	
Dissolved Oxygen	DO						
Element Scan							
Fecal Streptococcus							
Flow		■					
Fluoride	F		●			●	
Gallium	Ga					▲	
Germanium	Ge					▲	
Hardness (Ca, Mg)							
Hydroxides	OH						
Iodine	I						
Iron	Fe		●			▲	
Kjeldahl Nitrogen						▲	
Lead	Pb					▲	
Level							
Lithium	Li					▲	
Magnesium	Mg					●	
Manganese	Mn					▲	
Mercury	Hg			●		▲	
Methylene Blue Active Substance	MBAS						
Molybdenum	Mo					▲	
Nickel	Ni					▲	
Nitrate	NO3					●	
Nitrite	NO2					●	
Odor						●	
Oil & Grease	OLGR	►	●			●	
Organic Carbon, Dissolved	DOC					●	
Organic Carbon, Total	TOC						
Ortho-Phosphorus (Phosphate)	PO4						
Pesticides							
pH	pH	●					
Phenols			●			●	
PNA	PNA						
Potassium	K					▲	
Rubidium	Rb						
Sediment Characterization							
Selenium	Se					▲	
Scandium	Sc						
Silica	SiO2					●	
Silver	Ag			●			
Sodium	Na					▲	
Solids, Dissolved	TDS		●			▲	
Solids, Suspended	SOLS		●				
Strontium	Sr					▲	
Surfactants							
Sulfate	SO4					●	
Sulfide	SO2					●	
Temperature (°C)							
Thiosulfide	S2O3						
Tin	Sn						
Titanium	Ti					▲	
Tungsten	W						
Turbidity							
Vanadium	V					▲	
Yttrium	Y						
Zinc	Zn			●		▲	
Zirconium	Zr					▲	
Radioactivity							
Gross Alpha (pCi/l)						●	
Radium 226	Ra226					▼	
Natural Uranium	U					▼	
Gross Beta						▼	
Cesium	Cs137					▼	
Sr90						▼	
Thorium 230	TH230						
Uranium	U						
Fractionation of Organic Carbon into							
a. Hydrophobic Bases						●	
b. Hydrophobic Acids						●	
c. Hydrophobic Neutrals						●	
d. Hydrophilic Bases						●	
e. Hydrophilic Acids						●	
f. Hydrophilic Neutrals						●	

* NPDES discharge points:

001 S12T3S R97W
~600'S and 2100'E of section corner 1, 2, 11, 12

002 S12T3S R97W
~2100 'N and 3240'E of section corner 1, 2, 11, 12

003 S12T3S R97W
~2700'N and 4500'E of section corner 1, 2, 11, 12

SYMBOLS

- ● Applies to all NPDES discharge points
- ■ Daily flow also at USGS station WU61
- ▲ Total values
- ▼ Required if gross alpha or gross beta increases by 20% above average.
- ► Visual analysis of presence of oil and grease only.

Table 5.3.6-2

CB-TRACT
NPDES WATER QUALITY SAMPLES
WEEKLY ANALYSIS

LOC	YR	MO	DY	FLOW (GPM)	TOTAL SUSPEND SOLIDS (MG/L)	TOTAL DISSOLVED SOLIDS (MG/L)	TOTAL F (MG/L)	TOTAL B (MG/L)	AMMONIA AS N (MG/L)	TOTAL PHENOL (MG/L)	AL (MG/L)	TOTAL FE (MG/L)	OIL AND GREASE (MG/L)	PH
WN40	79	7	31	•	20.0	910.0	2.10	-.10	.98	-.001	-.1	.02	-1	•
		8	6	•	-1.0	940.0	2.70	.20	•	-.001	-.1	.12	2	•
			15	•	-1.0	880.0	1.60	.19	•	•	.6	1.30	2	•
			22	•	-1.0	820.0	1.50	.10	.83	.003	.4	-.03	-1	•
			27	•	-1.0	'990.0	1.30	.10	.75	-.001	.5	.90	-1	•
			29	•	-1.0	870.0	1.10	-.10	.95	-.001	.4	.50	-1	•
			31	•	-1.0	920.0	1.20	.10	1.64	-.001	.6	1.00	4	•
		9	5	450.0	4.0	3800.0*	1.30	.20	.94	.003	-.1	.03	-1	8.80
			6	450.0	17.0	840.0	1.40	.20	.85	.003	.1	.20	1	8.25
			13	625.0	10.0	720.0	3.20	.10	.81	.003	.4	.20	-1	8.05
			18	347.0	26.0	860.0	1.70	.10	3.30	-.001	.2	.70	5	8.80
			24	170.0	8.0	800.0	1.40	.13	3.20	-.001	-.1	.30	27	7.90
			28	220.0	•	•	•	•	•	•	•	•	•	•
		10	1	210.0	12.0	800.0	1.80	.07	3.20	.004	-.1	.20	21	8.20
			8	210.0	26.0	920.0	3.80	.20	1.80	.006	.6	1.00	6	8.07
			17	585.0	66.0	850.0	2.60	•	•	-.001	.7	.90	•	8.20
			26	316.0	42.0	890.0	3.10	•	1.50	.020	.8	.70	15	7.50
			30	720.0	15.0	810.0	2.70	•	1.60	.050	.8	.20	10	8.70
		11	5	620.0	12.0	870.0	2.50	.30	1.62	.004	1.2	.20	-1	8.40
			8	720.0	•	•	•	•	•	•	•	•	•	8.50
			13	820.0	5.0	770.0	2.50	.10	1.57	.003	1.1	.08	-1	7.50
			21	990.0	45.0	920.0	3.40	.20	2.50	.002	1.6	.60	3	8.05
			24	780.0	53.0	830.0	4.00	.10	2.00	.020	1.3	.20	8	8.21
			28	890.0	150.0	890.0	2.80	.30	1.40	.020	11.0	.30	4	8.31
			30	880.0	65.0	860.0	5.60	.30	2.10	.020	.5	.30	2	8.60
		12	7	920.0	25.0	850.0	5.80	.20	3.30	.020	1.4	.20	2	8.24
			14	250.0	48.0	900.0	6.70	.20	5.80	-.001	1.5	.70	11	8.80
			18	350.0	38.0	910.0	4.40	.20	2.20	.010	1.9	.70	2	6.84
			19	320.0	•	•	•	•	•	•	•	•	•	8.20
			26	420.0	17.0	970.0	4.10	.20	1.70	-.001	.8	.04	2	7.12

NOTE: - INDICATES LESS THAN
• INDICATES MISSING DATA
* Indicates value is suspect - may be 800.0

NPDES standards for suspended solids are 45 mg/l for daily measurements and 30 mg/l for monthly averages. Peak values of 150 and 38 mg/l have been obtained for daily and monthly averages respectively. Over the four-month period of record the average value is approximately 27 mg/l. Mitigating measures are being vigorously pursued to reduce peaks and include redesign of ponds to include baffles and use of coagulant to insure better settling.

NPDES standards for oil and greas are 10 mg/l weekly and no visible sheen daily. Peak value of oil and grease has been 27 mg/l. Peak values were previously due to hydraulic line leakage from machinery in the shafts. Use of sorbents have been studied as a mitigation measure and improved equipment maintenance has been mandated.

5.3.6.5.2 Visual Trend Analysis of the Seepage Wells

Results of field measurements and laboratory analyses of samples are compiled and presented in Tables 5.3.6-3 and 5.3.6-4 for monitoring wells WW12 (31X-12) down-dip of Ponds A and B and WW13 (41X-13-2) down-dip of Pond C, respectively. Location of these ponds and wells are shown in Figure 5.2.6-1. Average values are computed to show approximate baseline values in the Uinta.

The data in Tables 5.3.6-3 and 5.3.6-4 are arranged sequentially by sample date to permit visual analysis of trends over the small number of samples. Except for oil and grease, there do not appear to be trends in any of the quality variables within the data interval for each well. Oil and grease trends are downward and are influenced by a large first sample value which may be attributed to effects of drilling.

Paired t-tests were used to test the null hypothesis of equal population means between Pond A and B monitoring well WW12 and Pond C monitoring well WW13 for each of the indicator variables in Tables 5.3.6-3 and 5.3.6-4. These tests were performed using a significance level of $\alpha = 0.05$. The null hypothesis of equal population means was accepted (i.e. no differences between stations) for all variables except fluoride, temperature, and level.

Temperature and water level could be expected to be different because of location and depth of wells.

5.3.6.5.3 Comparisons of Seepage Wells with Springs and Alluvial Wells

As further analysis of the seepage well data with representative baseline data, selected variables were compared with composite baseline data for alluvial wells and springs. Additionally current data for two springs, WS02 and WS09, and current data for two alluvial wells, WA03 and WA12, are also included in the comparison. Comparisons were on the basis of mean, range of values, and standard deviation.

Tabulation of the statistics for comparison are presented in Table 5.3.6-5.

TABLE 5.3.6-3

SEEPAGE MONITORING WELL RESULTS FOR STATION WW12 DOWN-DIP FROM PONDS A AND B

(31X-12) (WW12)

Date	4-17-80	9-18-79	10-2-79	1-24-80	2-21-80	Average(2)
Al	<.1	<.1	<.1	<.1	<.1	<.1
NH_3	.6	4.1	.2	11	6.1	4
As	<.02	<.02	<.02	<.02	<.02	<.02
Ba	<.5	<.5	<.5	<.5	.5	.5
B	.2	<.1	.1	<.1	<.1	<.1
Ca	68	11	100	14	15	42
Cr	<.02	<.02	<.02	<.02	.01	.02
Cu	<.02	<.02	<.02	<.02	.02	.02
Fe	<.5	<.02	8.4	<.02	<.02	1.8
Pb	<.02	<.02	.04	<.02	<.02	.02
Li	<.02	.03	.01	<.05	<.05	<.03
Mg	96	42	120	13	14	57
Mn	.2	.02	.1	<.02	.01	.1
Mo	<.02	<.02	<.02	.02	.02	.02
Ni	<.02	.02	<.02	<.02	.07	.03
K	2	7.5	6.4	2.3	3.5	4
Ag	<.02	<.02	<.02	<.01	<.01	<.02
Na	220	180	170	120	120	162
Sr	3	.9	11	1.6	1.0	4
Zn	.2	<.02	.5	<.02	.01	.2
Co				<.02	<.02	<.02
Se	<.02			<.002		.11
Hg	<.02	.00021		<.001		.01
BOD	8	29	30	1	2	14
COD	50	30	20	31	33	33
Hardness	550	210	860	88	95	361
Oil & Grease	40	7.6	4	12	<1	13
Phenol	.003	.02	.002	.016	0.009	.01
T. Alk.	590	290	600	90	90	332
TDS	1700	900	1500	500	520	1024
Kj-N	3			12	14	6
DOC	107			11		24
HCO_3	540	200	600	68	<1	282
CO_3	50	90	<1	22	60	45
Br	<.1	<.1	<.1	<.1	.4	.2
Cl	13	24	1000(1)	22	24	
NO_3	24	55	7.2	50	27	33
SO_4	390	350	600	320	380	408
pH	N/D	9.6	7.3	9.5	9.4	9.0
DO	N/D	2.88	4.9	4.0	4.0	4.2
Cond	N/D	1150	1800	700	800	1113
T	N/D	16.5	15.6	14	17	16
Outage	N/D	188.2	180.6	155.2	161.4	171.4
T. Alpha	10					10
T. Beta	18					18
F	1.3	.8	3	.9	1.0	1

NOTE: Values below the lower detection limit of instrumentation are preceeded with the less than symbol < . Missing values are blanks or dashes. No data analyses are represented by N/D.

(1) Suspect

(2) Average uses values at the lower detection limit when indicated.

TABLE 5.3.6-4

SEEPAGE MONITORING WELL RESULTS FOR WELL WW13 DOWN-DIP FROM POND C

(41X-13-2)(WW13)

Date	11-27-80	12-14-79	1-23-80	2-19-80	Average[1]
Al	<.1	<.1	.1	<.1	<.1
NH_3	.5	<.04	.2	.3	.3
As	<.02	.03	<.02	<.02	<.02
Ba	<.5	<.5	<.5	.5	<.5
B	.1	.1	.2	.1	.1
Ca	63	55	48	60	57
Cr	<.02	<.02	<.02	.02	.02
Cu	<.02	<.02	<.02	<.01	<.02
Fe	<.02	<.02	.02	.06	.03
Pb	<.02	.05	<.02	<.02	.03
Li	.1	<.05	<.05	<.05	.06
Mg	74	64	66	67	68
Mn	.1	.04	.04	.07	.1
Mo	.2	.1	.07	.06	.1
Ni	<.02	.02	.02	.08	.04
K	3.6	1.9	2.1	3.2	2.7
Ag	<.01	<.02	<.01	<.01	<.01
Na	180	170	180	180	178
Sr	3.9	6.4	6.6	3.8	5.2
Zn	<.02	.05	.06	.06	.05
Co	<.01	.02	<.02	<.02	<.02
Se	<.02				.02
Hg	<.02				.02
BOD	48	1.4	31	1	20
COD	67	7	2	11	22
Hardness	400	400	390	430	405
Oil & Grease	19	3	3	<1	7
Phenol	.02	<.001	.02	.01	.01
T. Alk.	340	370	380	380	368
TDS	2000	1000	1000	1000	1250
Kj-N	1.2	0.4	1.6	45	12
DOC	48				48
HCO_3	300	370	380	380	358
CO_3	38	<1	<1	<1	10
Br		<.1	<.1	<.1	<.1
Cl	17	7.0	16	20	15
NO_3	<.1	.26	28	89	29
SO_4	430	590	500	480	500
pH	8.1	7.8	7.8	7.5	7.8
DO	5.1	4.5	5.3	3.8	4.7
Cond.	1300	800	1300	1400	1200
T	10	12.5	15	13	13
Outage	377.1	375.0	373.1	371.5	374.2
T. Alpha	No sample was ever sent to Coors.				
T. Beta	No sample was ever sent to Coors.				
F	.2	.1	.1	.2	.2

NOTE: Values below the lower detection limit of instrumentation are preceeded with the less than symbol <. Missing values are blank or dashes. No data analyses are represented by N/D.

[1] Average uses values at the lower detection limit when indicated

Table 5.3.6-5

SUMMARY OF SELECTED WATER QUALITY VARIABLES FOR COMPARISON OF SEEPAGE WELLS WITH SPRINGS AND ALLUVIAL WELLS

			NH_3	COND	pH	TDS	B	F	NA	SO_4
COMPOSITE BASELINE	Alluvial Wells 13 Wells	Mean	0.5	1380	8.2	996	0.5	0.65	175	370
		Number of Values	77	77	77	77	30	77	77	77
		Maximum	15	1930	8.7	1300	5	5	730	530
		Minimum	<.01	950	7.3	696	.001	0.1	93	200
		Standard Deviation	1.8	220	0.3	158	0.8	0.87	86	83
	Springs & Seeps 10 Springs	Mean	0.12	1300	8.2	925	0.4	0.45	130	360
		Number of Values	41	49	50	47	37	50	50	50
		Maximum	0.4	1560	8.5	1130	1.6	2.1	240	440
		Minimum	0.01	840	7.3	547	.001	0.1	68	200
		Standard Deviation	0.1	145	0.27	97	0.3	0.40	28	66
UPDATED SPRINGS	WS02	Mean	0.33	1150	8.1	879	0.33	0.25	113	330
		Number of Values	6	12	11	5	8	9	9	9
		Maximum	0.75	1250	8.5	970	1.2	0.60	130	360
		Minimum	0.10	1100	7.3	819	0.01	0.10	100	270
		Standard Deviation	1.79	55.6	0.23	56.8	0.48	0.15	8.26	28.4
	WS09	Mean	0.19	1303	7.5	897	0.16	0.45	120	323
		Number of Values	7	13	14	10	9	16	16	16
		Maximum	0.3	1400	7.8	1003	0.40	1.50	150	370
		Minimum	0.1	1150	6.6	547	0.02	0.20	68	190
		Standard Deviation	0.09	67.8	0.30	136	0.15	0.32	17.2	55.1
UPDATED ALLUVIAL	WA03	Mean	0.20	1303	7.6		0.22	0.50	136	359
		Number of Values	3	8	7		5	13	13	13
		Maximum	0.22	1400	8.0		0.70	1.90	250	400
		Minimum	0.17	1200	7.2		0.10	0.30	120	330
		Standard Deviation	0.025	60.4	0.30		0.27	0.42	34.7	17.7
	WA12	Mean	0.50	1407	7.8		2.20	0.42	209	464
		Number of Values	3	7	5		3	9	9	9
		Maximum	1.10	1600	8.0		5.20	1.70	730	518
		Minimum	0.10	1300	7.5		0.20	0.20	130	420
		Standard Deviation	0.53	96.5	0.19		2.65	0.51	195.0	31.7
MONITORING WELLS	Pond A&B Well WW12	Mean	4.40	1113	8.9	1024	0.06	1.40	162	408
		Number of Values	5	4	4	5	5	5	5	5
		Maximum	11.0	1800	9.6	1700	0.20	3.0	220	600
		Minimum	0.2	700	7.3	500	0.00	0.8	120	320
		Standard Deviation	4.43	497.2	1.10	554	0.09	0.91	42.7	110.8
	Pond C Well WW13	Mean	0.25	1200	7.8	1250	0.13	0.15	178	500
		Number of Values	4	4	4	4	4	4	4	4
		Maximum	0.50	1400	8.1	2000	0.20	0.20	180	594
		Minimum	0.00	800	7.5	1000	0.10	0.10	170	430
		Standard Deviation	0.21	270.8	0.24	500	0.05	0.06	5.0	66.8

Data for WW12 and WW13 are shown at the bottom of the table. Composite baseline (all baseline stations) data for alluvial wells and springs are at the top of the table. Current data for nearby springs and wells are the central part of the table. The comparisons show that data from the seepage monitoring wells for indicator variables are consistent with established baseline for water samples from alluvial wells and springs in the area.

A further comparison of trend and range of Class 1 indicator quality parameters was made by examining plots of the alluvial well and springs data presented in Section 5.3.2 and related figures in Appendices A5.3.2 and A5.3.3.

5.3.7 Shale Dumps

Shaft sinking commenced in 1979. No significant amount of shale was brought to the surface during this reporting period as a result of shaft sinking activity. There are no shale dumps to be evaluated for development impact.

5.3.8 Sediment Characterization

5.3.8.1 Scope

Under a provision of the Environmental Lease Stipulations, as modified by conditions of approval, a sample of streambed sediment was taken near Station 09306042 (WU42) prior to initiation of discharge into Piceance Creek.

5.3.8.2 Objectives

The objectives of the sediment characterization program are: a) to determine the sorptive properties of streambed sediment with respect to chemical substances which might be present in water discharged into a particular stream, and b) to determine through chemical analysis the baseline composition of streambed sediment.

5.3.8.3 Experimental Design

One composite sample for particle size, chemical composition, and mineral analyses was taken prior to initiation of discharge operations from Station WU42.

5.3.8.4 Method of Analysis

Results for the various chemical and physical analyses have not been received at this time, so analysis of results cannot be reported. The data to be obtained from samples prior to any discharges will be compared to baseline to reveal any differences which might suggest natural variations in sediment character.

5.3.8.5 Discussion and Results

Data were not available in time for analysis in this report.

5.3.9 Conclusions Regarding Water Quality

1. Statistically significant positive trends over time were established only in a very few cases:

a. Arsenic - at spring and seep Station WS07 on Hunter Creek at Piceance Creek

b. Specific conductance and temperature at alluvial well Station WA06 on Cottonwood Gulch near Piceance Creek.

The magnitude of arsenic levels is still very low, well below drinking water standards. The temperature variation is judged to be primarily seasonal. The specific conductance trend is about 224 umhos/yr.

2. Two-year averages of monthly means (i.e., 24 values each) were compared for Piceance Creek Stations WU07 and WU61. The ratio of these two-year averages (1977 through 1978 ÷ 1975 through 1976) indicated increases in three variables at both stations:

HCO_3 . . . . .20% increase
Mg . . . . . . 8% increase
Na . . . . . . 8% increase

3. Peak daily values of 150 mg/l for suspended solids and 27 mg/l as a weekly average for oil and grease have occurred at the discharge point from Ponds A and B. Mitigative measures have been initiated to reduce future peaks including pond redesign to include baffles to improve settling time and improved equipment maintenance procedures to reduce machinery leakages of oil and grease in the shafts.

4. Seepage monitoring wells down-dip of both Ponds A and B and Pond C have not exhibited any adverse trends in water quality.

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6.0 AIR QUALITY AND METEOROLOGY

6.1 Introduction and Scope

The monitoring program for air quality and meteorology was carried out in accordance with the provisions of the Development Monitoring Plan, as modified by conditions of approval issued by the Area Oil Shale Supervisor. During 1979, two ambient air stations monitored gaseous constituents, particulates, and various meteorological variables. Co-located with one of these stations is a 60 meter meteorological tower, instrumented at three levels for wind variables and additionally for temperature and delta temperature. Additional meteorological monitoring data were gathered at two mechanical weather stations. All of the above systems are operated on a continuous basis.

Visibility was monitored by the photographic-photometry method on a six day interval during late April-May-early June and during October-November.

Section 6.2 describes the air quality program and section 6.3 the supporting meteorology.

6.2 Ambient Air Quality

6.2.1 Gaseous Constituents

6.2.1.1 Scope

Continuous monitoring of gaseous constituents in the ambient air on and near the C-b Tract included:

Sulfur Dioxide (SO_2)
Hydrogen Sulfide (H_2S)
Ozone (O_3)
Carbon Monoxide (CO)
Oxides of Nitrogen (NO_x)
Nitrogen Dioxide (NO_2)
Nitric Oxide (NO)

Monitoring of these constituents is required under the lease stipulations. Data collected during 1979 have been reduced and subjected to analysis to determine trends in any of the variables monitored or relationships among them.

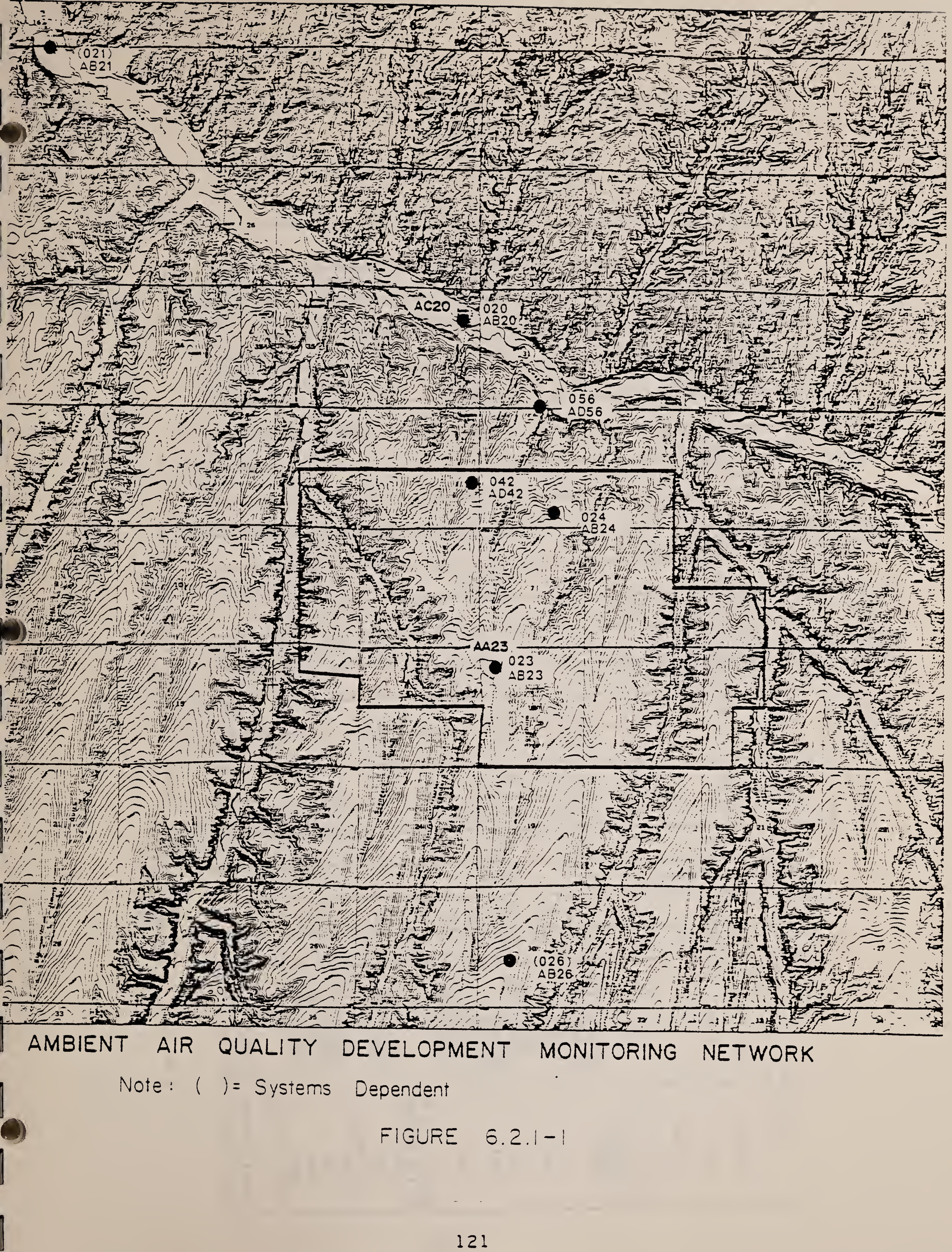
6.2.1.2 Objectives

The objectives of the analyses reported here are: a) to demonstrate compliance with applicable ambient air quality standards; b) to detect any long-term or seasonal trends in monitored variables; c) to identify sources of pollutants, in the event that levels of those pollutants are significantly above baseline levels, or are significant compared to ambient standards.

6.2.1.3 Experimental Design

The air quality development monitoring network is shown in Figure 6.2.1-1; systems-dependent stations are currently inactive. Station AB23 is equipped for monitoring all the constituents listed in Section 6.2.1.1, and has provided a continuous air quality record since the beginning of the baseline monitoring period. Station AB20 was equipped during 1979 to measure all constituents except the sulfur gases (SO_2 and H_2S). The monitoring at both sites is accomplished with continuous analyzers. The constituents monitored at each site, the frequency of data collection, and the start-up dates are shown in Tables 6.2.1-1 and 6.2.1-2.

The analyzers in both stations are, where applicable, the E.P.A. reference or equivalent methods for their respective constituents. Specifications for all instruments are listed in Table A6.2.1-1.



AMBIENT AIR QUALITY DEVELOPMENT MONITORING NETWORK

Note: ( )= Systems Dependent

FIGURE 6.2.1-1

TABLE 6.2.1-1

AMBIENT AIR-QUALITY & METEOROLOGY DATA DESCRIPTION

Symbols represent sampling frequency on Table 6.2.1-2

Measurement: Category and Location	Start-up Date	SO_2	H_2S	Particulates (3)	Ozone	NO_x	NO	NO_2 (1)	CO	Horizontal Wind Speed	Horizontal (2) Wind Direction	Vertical (2) Wind Speed	Relative Humidity	Air Temperature	Precipitation	Evaporation	Barometric Pressure	Solar Radiation	Temperature Difference	Mixing Height	Visible Range	Height
Air-Quality Trailer																						
020	a) Jan. '78			0						X	X				Z							
	b) July '78				X	X	X	X	Y					X								
	c) 1980	X	X																			
021	Systems Dependent																					
023	Nov. '74	X	X	0	X	X	X	X	Y						Z	S	X	X				
024	a) 1980			0						X	X			X								
	b) 1981	X	X																			
026	Systems Dependent																					
Weather Sta & Hi-Vol Sampler																						
042	Feb. '78			0						Z	Z			Z								
056	Feb. '78			0						Z	Z			Z								
Met. Tower @																						
3m	Nov. '74												X*									
10m	Nov. '74									X	X	X		X					2			
30m	Nov. '74									X	X			X								
60m	Nov. '74									X	X	X		X					2			
Upper Air Studies																						
Acoustic Radar 020	Oct. '77																			U		U
Visibility, Sta. 060	Apr. '78																				V	

* @ 1m

(1) $(NO_2) = (NO_x) - (NO)$

(2) Std. Deviation calculated.

(3) Also Size Distributions during Visibility Study

TABLE 6.2.1-2

AMBIENT AIR QUALITY AND METEOROLOGY SAMPLING AND REPORTING FREQUENCIES

Symbols appear on Table 6.2.1-1

Symbol	Sampling Frequency	Minimum Average Time	Minimum Report Frequency	Description
X	10-seconds	5-minutes	1-hour	AQ & Low Alt. Meteorology
Y	5-minutes	5-minutes	1-hour	AQ & Low Alt. Meteorology
Z	Continuous	1-hour	1-hour	Precipitation
0	Every 3rd day	24-hours	24-hours every 3rd day	Particulates
2	20-seconds	5-minutes	1-hour	Temp. difference from 10-meter to 60-meter on Met. Tower
U	14-seconds		1-hour	Inversion Height/Mixing Layer from Acoustic Radar
V	7 times per day every 6th day for 10 days in Spring and 10 days in Fall	Hourly	Daily (w/hourly max/min.)	Joint Visibility study with C-a from Hunter Creek Site
S	Weekly during growing season	Weekly	Weekly	Evaporation

6.2.1.5 Discussion and Results

Results are grouped into the referenced separate studies, and are presented with conclusions for each study.

6.2.1.5.1 Concentrations As Time Histories

Concentration time histories are presented to detect any potential patterns of variation in the data over time. Such patterns may be composed of three or more components. Almost all environmental variables will have a distinct random component of time-based variation. The complex interrelationships among these variables will assure some level of unpredictable behavior. A second frequently seen component is periodic variation, such as a seasonal cycle. Gaseous constituents which relate to meteorological variables, such as ozone is related to insolation, will show a detectable periodic component synchronized with seasonal variations in meteorology. Superimposed on these two patterns may be a trend component which indicates an increase or decrease with time in the level of an air contaminant. Visual representations of the monitored data for the gaseous constituents at Stations AB20 and AB23 are presented in the form of time-series plots in Figures A6.2.1-1 through A6.2.1-6. Each figure also indicates the lower detection limit for the instrument.

For the sulfur gases, hydrogen sulfide and sulfur dioxide, excursions above the detection limit are infrequent and of short duration. This is in keeping with past results in sulfur gas monitoring.

The oxides of nitrogen more frequently reach measurable levels; however, daily mean values are for the most part below the detection limit. The background concentration of ozone (discussed below) is sufficient to cause generally measurable nitrogen oxides, particularly nitrogen dioxide.

Carbon monoxide is probably the only gaseous constituent which is directly emitted into the atmosphere from Tract operations in sufficient quantity to be routinely measurable. Even in this case, though, daily means are often at or below the detection limit. There does not appear to be any pattern in the occurrence of peak levels.

Ozone is the only gas monitored consistently having a measurable mean concentration. Also, it has closely approached the ambient air standard. This behavior is of interest because there are no development-related emissions of the type and magnitude to cause elevated ozone levels. The possible causes of ozone excursions are discussed in a later section.

Since ozone is the product of atmospheric reactions, rather than an emitted substance, it's concentration is subject to variation due to changes in the intensity of insolation, which provide the driving force for ozone - producing reactions. This results in a seasonal pattern in the ozone plots, with the

6.2.1.4 Method of Analysis

Methods of analysis are grouped into separate studies under Discussion and Results for the following studies:

6.2.1.5.1 Concentrations as Time Histories
6.2.1.5.2 Comparisons of Maximum Concentrations with Ambient Standards
6.2.1.5.3 Correlation with Wind Speed and Direction
6.2.1.5.4 Comparisons of Maximum and Mean Concentrations

highest mean concentrations in summer, and lowest in winter. Over the history of ozone monitoring on-Tract, this seasonal pattern coupled with the large random component has been consistently present.

In a format suggested by EPA's SAROAD data base, statistical distributions of ozone along with the annual arithmetic mean and the five-highest hourly averages, ozone values are presented for calendar year 1975 through 1978 on Table 6.2.1-3.

In summary, monitoring of ambient gases during the period of this report produced little new information. Sulfur gases, nitrogen oxides and carbon monoxide continue to be present at low levels. As such, these levels are not suitable for trend analysis, nor are any trends evident. Ozone, while measured at significant levels, may be characterized as having a seasonal, background type of pattern, with large random variations compared to seasonal mean levels. Future analysis should focus on the causes of both the background concentration and the occasional excursions.

6.2.1.5.2 Comparisons of Maximum Concentrations with Ambient Standards

Table 6.2.1-4 lists the maximum measured concentrations of gaseous constituents for averaging times corresponding to standards. It is readily noted that for all but one gaseous criterion pollutant the maximum concentrations are well below the standards, the one exception being ozone. This pattern has existed since the beginning of ambient monitoring at the C-b Tract in the fall of 1974. This is in keeping with the overall character of the region with very low population density and most development activities subject to stringent regulation of potential air quality impacts.

In the case of ozone, a combination of elevated background levels and observed excursions exists which is indicative of both a consistent local influence and significant excursions not clearly tied to nearby sources of air contaminants.

During the period of this report, one new high value was established. On January 20, 1979 a one-hour average ozone concentration of 246 $\mu g/m^3$ was recorded at Station AB23. This event is discussed in detail in Section

TABLE 6.2.1-3

OXIDENTS (O_3) AT STATION AB23

(1975 - 1978)

OXIDENTS (O_3)

FOR CALENDAR YEAR 1975

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 7160

Annual Arithmetic Mean (ug/m^3): 69.0

5-Highest Hourly Averages (ug/m^3):	Value	Date		Hour Ending
1.	151.3	6/26	HOUR ENDING	1400
2.	147.3	6/26	" "	1500
3.	142.4	2/23	" "	2300
4.	136.9	5/22	" "	0300
5.	136.9	5/22	" "	0400

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m^3)	3
3.0 - 20.9	39
21.0 - 40.9	1150
41.0 - 60.9	1752
61.0 - 80.9	1385
81.0 - 100.9	2205
101.0 - 120.9	530
121.0 - 140.9	83
141.0 - 160.0	3
GREATER THAN 160.0	0

OXIDENTS (O_3)

FOR CALENDAR YEAR 1976

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 8239

Annual Arithmetic Mean (ug/m^3): 62.0

5-Highest Hourly Averages (ug/m^3):	Value	Date		Hour Ending
1.	124.0	4/26	HOUR ENDING	1500
2.	123.0	4/25	" "	1600
3.	122.4	4/25	" "	1700
4.	120.3	4/26	" "	1300
5.	119.3	4/25	" "	1400

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m^3)	15
3.0 - 20.9	50
21.0 - 40.9	1197
41.0 - 60.9	2511
61.0 - 80.9	2890
81.0 - 100.9	1232
101.0 - 120.9	241
121.0 - 140.9	3
141.0 - 160.0	0
GREATER THAN 160.0	0

OXIDENTS (O_3)

FOR CALENDAR YEAR 1977

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 7874

Annual Arithmetic Mean (ug/m^3): 79.0

5-Highest Hourly Averages (ug/m^3):	Value	Date		Hour Ending
1.	164.0	8/24	HOUR ENDING	1100
2.	163.8	8/24	" "	1200
3.	162.6	8/24	" "	1400
4.	162.5	8/24	" "	1000
5.	158.1	7/31	" "	0900

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m^3)	2
3.0 - 20.9	4
21.0 - 40.9	105
41.0 - 60.9	1232
61.0 - 80.9	3405
81.0 - 100.9	2066
101.0 - 120.9	842
121.0 - 140.9	179
141.0 - 160.0	35
GREATER THAN 160.0	4

OXIDENTS (O_3)

FOR CALENDAR YEAR 1978

C-b TRACT RIO BLANCO COUNTY

TRAILER 023

Number Hourly Observations: 8081

Annual Arithmetic Mean (ug/m^3): 81.6

5-Highest Hourly Averages (ug/m^3):	Value	Date		Hour Ending
1.	160.9	8/27	HOUR ENDING	1800
2.	157.0	8/27	" "	1700
3.	153.0	8/27	" "	1900
4.	153.0	9/8	" "	1500
5.	149.1	9/8	" "	1800

Number of Hourly Concentrations In Ranges:

RANGE:	NO. OF VALUES:
0.0 - 2.9 (ug/m^3)	0
3.0 - 20.9	2
21.0 - 40.9	184
41.0 - 60.9	1290
61.0 - 80.9	2997
81.0 - 100.9	2200
101.0 - 120.9	1145
121.0 - 140.9	328
141.0 - 160.0	34
GREATER THAN 160.0	1

TABLE 6.2.1-4

COMPARISONS OF MAXIMUM BACKGROUND LEVELS WITH AMBIENT STANDARDS

APPLICABLE STANDARD	CONSTITUENT	AVERAGING TIME	STANDARD LIMIT ($\mu g/m^3$)	MAX. READING ($\mu g/m^3$)	DATA PRECISION ($\mu g/m^3$)	STATION WITH MAX. READING	DATE OF MAX. READING
COLORADO AMBIENT AIR QUALITY STANDARDS	PARTICULATES	ANNUAL	75	14.5	0.6	023	1978
	PARTICULATES	24-HOUR	260	178(1) 162(2)	11 10	024	11/27/74(1) 11/29/74(2)
	H_2S	1-HOUR	142	72.2	8	023	12/22/74
NATIONAL AMBIENT AIR QUALITY STANDARDS							
PRIMARY	SO_2	ANNUAL 24-HOUR	80 365	1.3 43.1	15 15	021 & 024 021	'74 - '75 6/16/75
SECONDARY	SO_2	3-HOUR	1300	87.7	15	023	12/21/74
PRIMARY	NO_2	ANNUAL	100	5.0	6	020	'75 - '76
PRIMARY	PARTICULATES	ANNUAL 24-HOUR	75*** 260	11.0 178	0.6 11	023 024	1978 11/27/74
SECONDARY	PARTICULATES	ANNUAL 24-HOUR	60*** 150	11.0 178(1) 162(2)	0.6 11 10	023 024	1978 11/27/74(1) 11/29/74(2)
PRIMARY	CO	8-HOUR 1-HOUR	10,000 40,000	4501.9 4650.9	100 100	020 020	6/03/75 6/04/75
PRIMARY	OXIDANT	1-HOUR	240	246.0	20	023	1/20/79

*** Geometric mean
(1) Highest max. reading
(2) Second highest max. reading

6.2.1.5.5. Although this ozone value is in excess of the ambient air standard of 240 µg/m^3, it does not in itself constitute a violation of that standard, which defines a violation as more than one expected exceedance per year, based on three years of monitoring. Other than the 246 µg/m^3 value, no other one-hour average has reached the level of the standard.

In summary, the results of monitoring the gaseous constituents through October, 1979 demonstrate continued maintenance of ambient air standards at the C-b Tract.

6.2.1.5.3 Correlation with Wind Speed and Direction

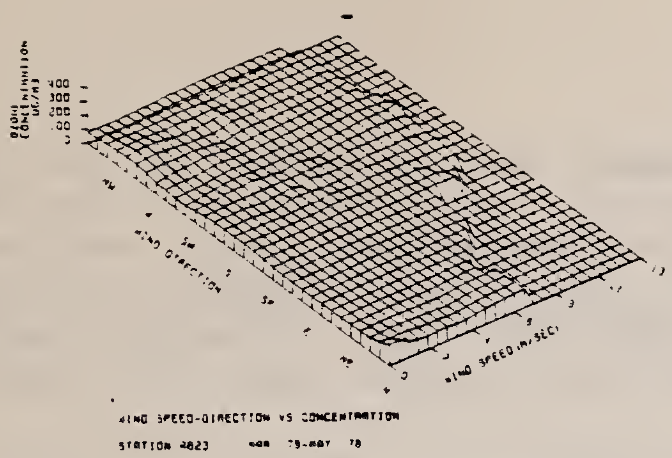
Correlation of wind parameters with measured concentrations of gaseous constituents may tend to show patterns leading to identification of contributing sources. Regional air contaminant levels generally will not display consistent variation with wind direction. The influence of a major air contaminant source will be most pronounced within a given sector of wind direction, the sector being smaller for sources closer to the monitoring site due to dispersion effects which accompany transport of air contaminants. The effect of wind speed is less direct. One way in which wind speed relates to measured concentrations is through influence on atmospheric stability and therefore on contaminant dispersion. However, this relationship can be difficult to predict. High winds may aid in dispersion and thereby reduce concentrations, but they may also effect transport of polluted air parcels into cleaner air regions.

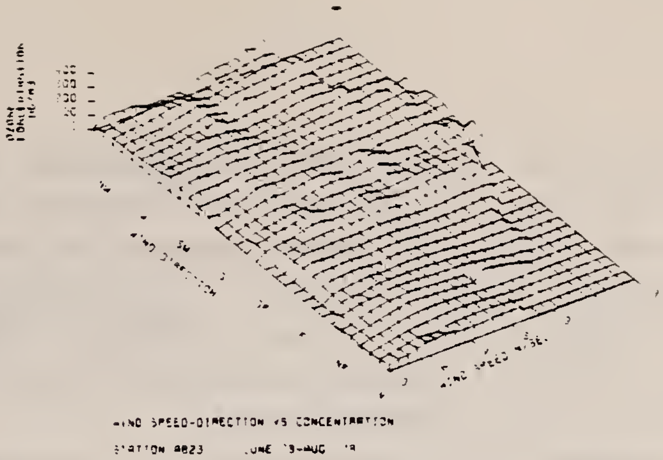
Excepting ozone, the gases monitored at the C-b Tract are not the products of nearby sources, but rather are the result of dispersion of many sources over a wide region with concentrations near instrument lower detection limits. For this reason, wind correlations are not presented for sulfur gases, nitrogen oxides and carbon monoxide.

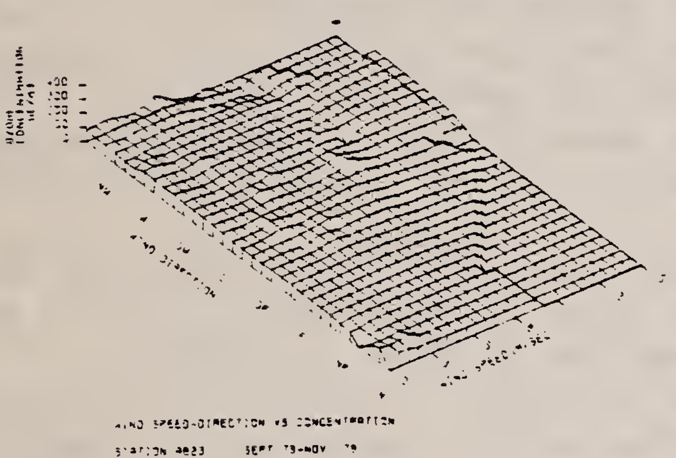
Figure 6.2.1-2 depicts the wind dependence of ozone at Station AB23 by means of three dimensional plots for quarterly periods. Each of the plots takes the form of a plateau, indicative of the background ozone conditions that effectively surround the Tract.

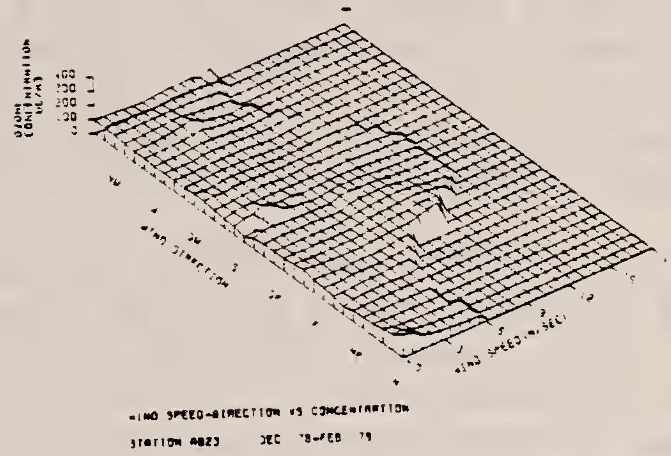
6.2.1.5.4 Comparisons of Maximum and Mean Concentrations

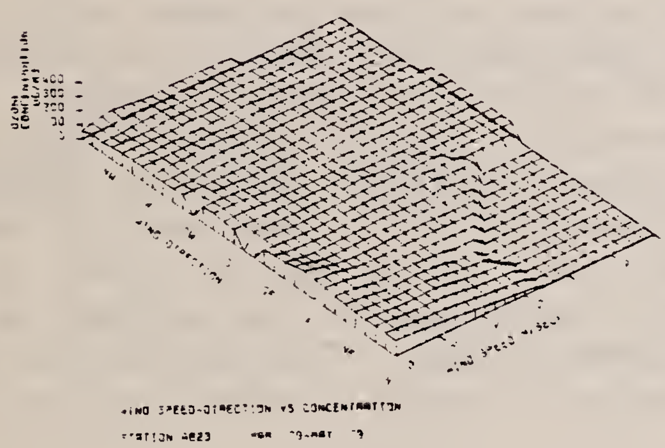
A comparison of maximum and mean concentrations of air contaminants can provide some insight into the type of causitive factors contributing to observed levels of those contaminants; there are three cases to consider: 1) the ratio of maximum to mean is close to one, and both maximum and mean values are low compared to ambient standards; 2) the ratio is close to one, but both maximum and mean are significant, compared to ambient standards; 3) the ratio is high, and the mean is low compared to ambient standards.

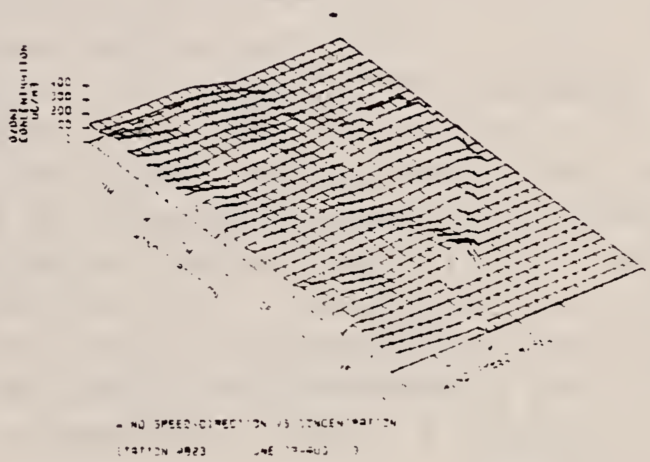












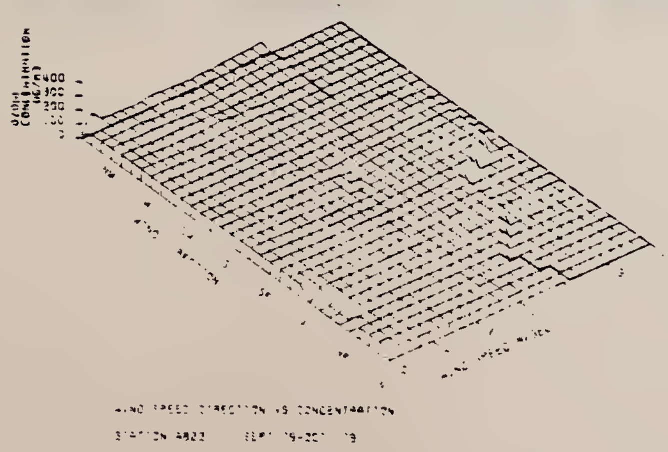


Figure 6.2.1-2

Daily Total Ozone Concentration as Function of Wind Speed and Direction.

In the first case, the closeness of maximum to mean indicates that the factors contributing to ambient concentrations are relatively consistent. Low levels observed indicate the absence of substantial contaminant sources near the monitoring site. Often, this situation is indicative of regional air contaminate levels in clean-air areas. Relatively minor local influences combined with highly dispersed contributions from distant sources result in stable, low levels of air contaminants.

The second case will most often occur where there is a geographical concentration of major sources of an air contaminent, or of air contaminant precursors, particularly where there is little variation in meteorology. This situation will almost always correlate with a high degree of urbanization or industrial development in the immediate vicinity of a monitoring site, or in an area consistently upwind of the site. The case not mentioned, i.e., the ratio, maximum and mean all high, would fit the same pattern of analysis, except for a higher degree of meteorological influence or more variable contributions.

The third case, a low mean value coupled with a high ratio indicates the absence of nearby major stationary sources of air contaminants. Unlike the first case, however, the high ratio of maximum to mean is indicative of some major influence which is subject to time variation. One possibility would be due to short term effects of a portable source. Relatively infrequent natural phenomena such as carbon monoxide and particulates from forest fires, or stratospheric ozone injection are other examples. The consistent aspect is the absence of effects of nearby urbanization.

Table 6.2.1-5 lists the maximum and mean values and the max/mean ratio for each gaseous constituent. It is readily seen that both maxima and means for NO_2, SO_2, H_2S and CO are small compared to their respective standards. For these constituents, the low values are more significant than the ratios in indicating the overall absence of significant sources of these air contaminants. However, in all four cases the maximum-to-mean ratio is considerably larger than it is for ozone. This indicates that only in the case of ozone is the background concentration within an order of magnitude of the maximum value, indicating a greater consistency of monitored values. The results for ozone would suggest a highly developed or urbanized situation, which obviously is not the case.

Further analysis of ozone measurements should be directed toward elucidating its cause-effect relationships with meteorological parameters, especially parameters indicative of changes in weather such as barometric pressure and vorticity.

TABLE 6.2.1-5

MAXIMUM, MEAN* AND MAX/MEAN RATIO**
FOR GASEOUS CONSTITUENTS

Constituent	Sym	Station AB20			Station AB23		
		Max	Mean	Max/Mean	Max	Mean	Max/Mean
Nitrogen Dioxide	NO_2	88	0.5	176	38	1.6	24
Sulfur Dioxide	SO_2	13	0.6	22	49	0.3	163
Hydrogen Sulfide	H_2S	-	-	-	12	0	-
Carbon Monoxide	CO	2300	217	11	3600	218	3
Ozone	O_3	192	52	4	246	77	3
Total Suspended Particulates	TSP	63	16	4	81	16	5

* Arithmetic Means

** Based on 1-Hour Averages

6.2.1.6 Conclusions

1) Compliance with state and federal ambient air standards continues to be maintained at the C-b site. Adoption of the 240 $\mu g/m^3$ standard for ozone provided additional increment above background levels which accommodated most excursions, excluding the single exceedance noted earlier.

All other parameters continue to be monitored at levels far below appropriate standards.

2) No long-term trends have been discernable in the gaseous criteria pollutants monitored.

3) Sources of air contaminants on and near the C-b site include many small sources of combustion product gases and fugitive dust. No single source is of sufficient size to be detected on the basis of wind vs. concentration correlations. No specific source of ozone, or of its precursors, has yet been identified. The establishment of the source or sources of ozone at the C-b Tract should be a major area of investigation in the future.

6.2.2 Particulates

6.2.2.1 Scope

Monitoring of ambient particulates is required by the Oil Shale Lease Stipulations and by Federal and State Air Quality Regulations. Measurements were made on an every-third-day schedule at Stations AB20, AB23 and AD56. During visibility measurement days, size-distributed samples have been taken at Station AB23.

6.2.2.2 Objectives

- to demonstrate compliance with applicable regulations
- to examine potential long-term trends
- to provide a general air quality status assessment
- to identify potential particulate sources

6.2.2.3 Experimental Design

The EPA reference method for particulate monitoring, the hi-volume sampler, is employed at all stations to measure particulates. The samplers are located such that the air intakes are approximately 4.6 meters above ground level. An Anderson particle-sizing head is used in place of the standard filter assembly when taking size-distributed samples. As yet, there is no EPA reference method for particle-size sampling.

6.2.2.4 Method of Analysis

Multiple regression analysis utilizing a set of meteorological parameters failed to produce new correlations over and above previous results which showed high particulate readings to be due to fugitive dust.

Three dimensional and time-series plots of particulate data provide a means of interpreting the data in a qualitative way. These are discussed in the following subsections.

6.2.2.5 Discussion and Results

6.2.2.5.1 Correlation with Wind Direction and Speed

Plots of particulate concentrations vs. wind speed and direction for Station AB23 are presented in Figure 6.2.2-1. In general, the data show a marked dependency on wind speed, as would be expected in a situation where particulate concentrations are primarily the result of fugitive dust sources. This factor is most evident during the spring and summer quarters. During the rest of a typical year, substantial periods of snow cover reduce the background level and change this relationship with wind. Particulates generated then on or near the Tract will show a much smaller dependence on wind speed, sometimes actually resulting in higher concentrations at lower wind speed. These source-specific contributions become less significant compared to background levels during the spring-summer period.

There is no definite wind direction dependence indicated. The virtual absence of particulate measurements in the wind sector centered around the north-northeast direction is indicative of the low incidence of winds from that direction. Wind direction utilized is a 24-hour average value.

6.2.2.5.2 Concentrations As Time Histories

The time-series plot of particulate concentrations for Station AB23 (Figure 6.2.2-2) is used for this discussion. The one dominant feature of the plot is its seasonal variation. Maximum concentration levels typically occur in the spring and fall, minimum levels in the winter. Concentrations during the summer months are variable, but are generally lower than the spring and fall peaks.

Histograms depicting the frequency distributions of particulate concentrations (Figures 6.2.2-3 and -4) show the predominance of concentrations less than 10 $\mu g/m^3$. The composite histogram displays a skewed log-normal distribution, typical of particulate concentrations influenced mainly by random variation in meteorological parameters.

6.2.2.5.3 Maximum Concentrations Compared with Ambient Standards

Table 6.2.1-4 lists the maximum annual and 24-hour particulate concentrations.

The Federal Primary Standards have not been exceeded at any time. On a 24-hour basis, the maximum value is 178 $\mu g/m^3$ compared to the standard of 260. A wider margin exists on an annual basis. The 24-hour maximum, however, exceeds the Federal Secondary Standard of 150 $\mu g/m3$. The Federal Secondary Annual Standard of 60 $\mu g/m^3$ is not approached.

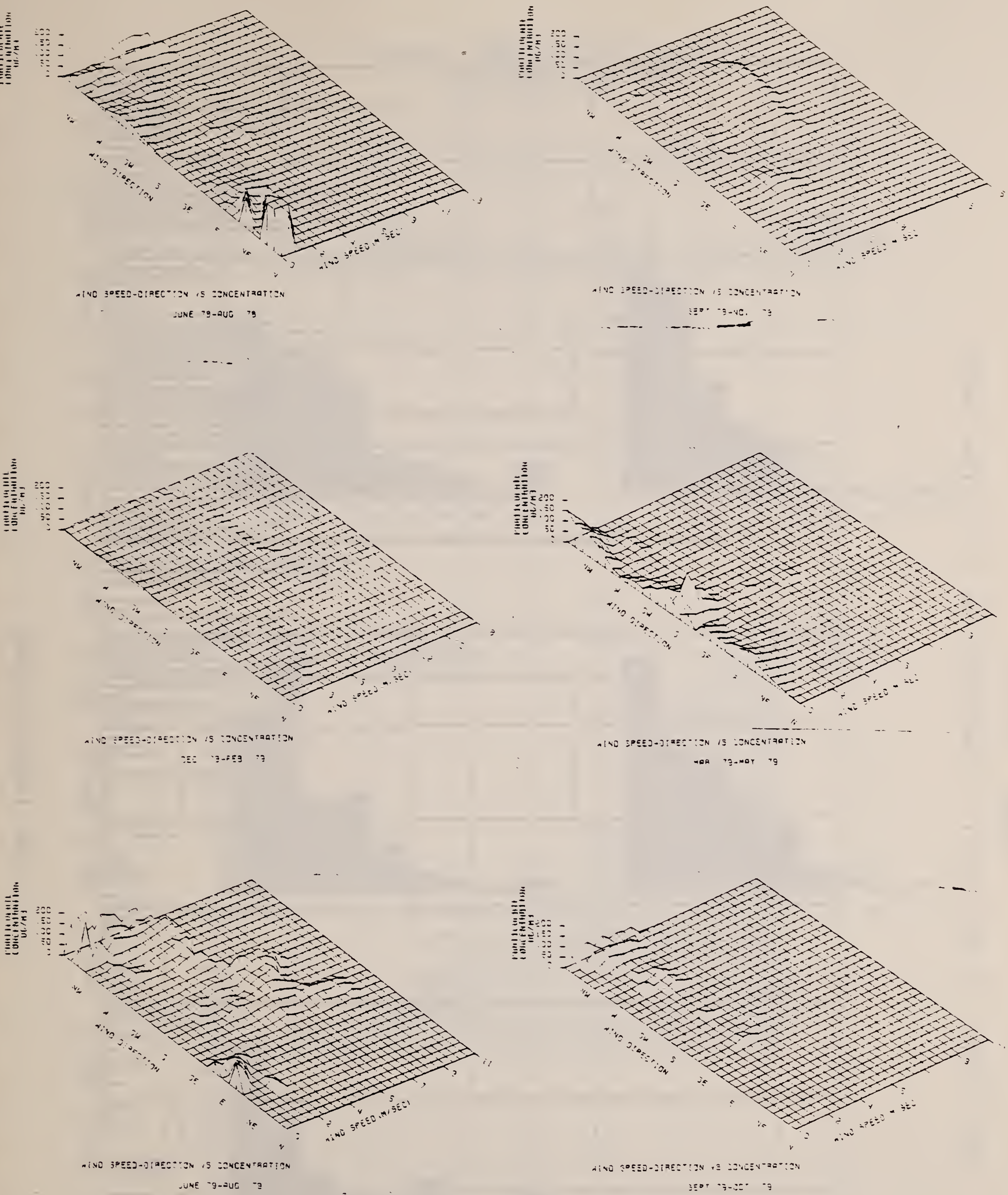


FIGURE 6.2.2-1

DAILY TOTAL PARTICULATE CONCENTRATIONS AT STATIONS AB23 AS FUNCTIONS OF WIND SPEED AND DIRECTION

FIGURE 6.2.2-2

TIME SERIES OF PARTICULATE CONCENTRATION AT STATION AB23

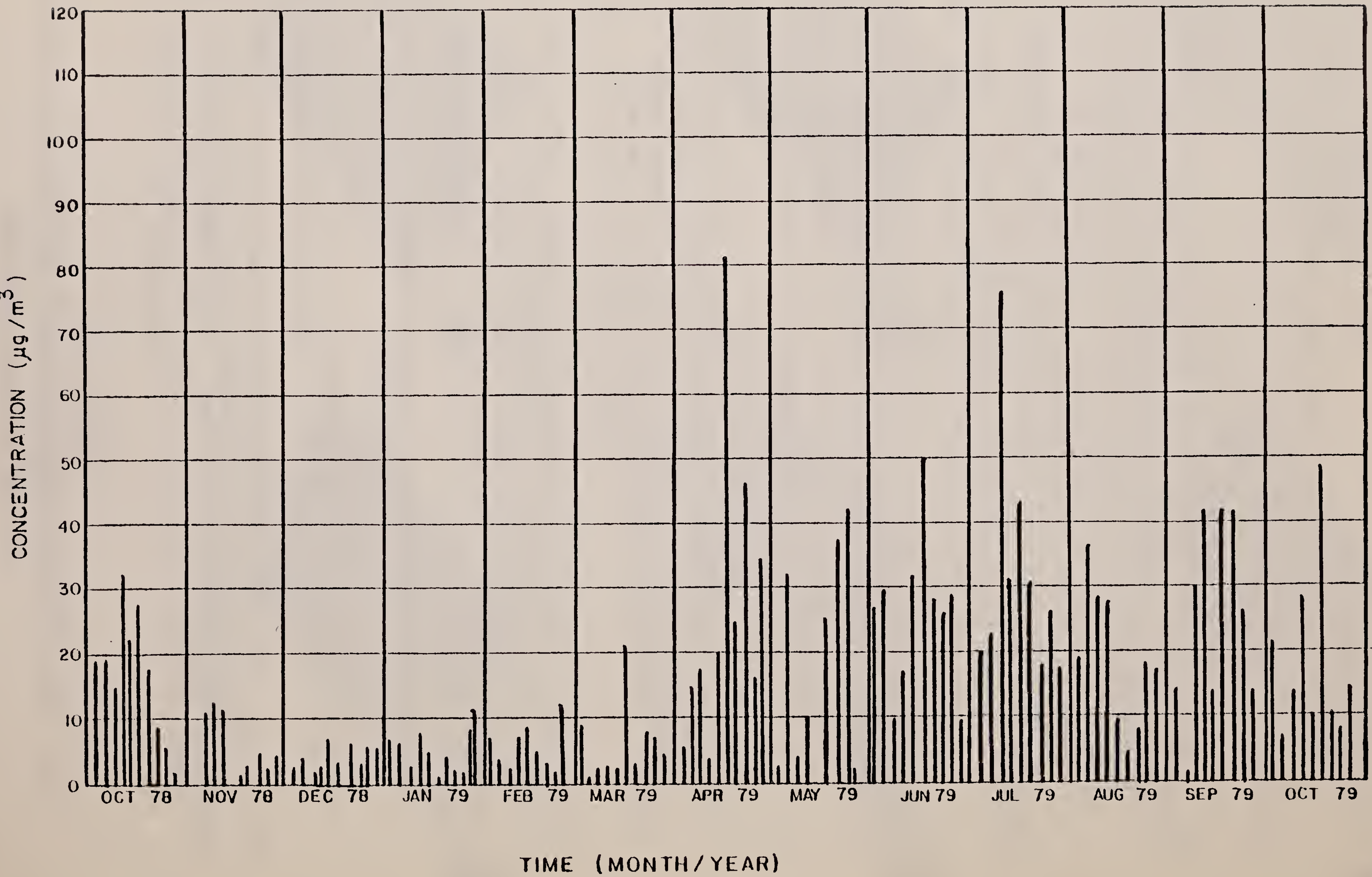


FIGURE 6.2.2-3
FREQUENCY DISTRIBUTION OF PARTICULATE
MEASUREMENTS BY YEAR
STATION (AB23)

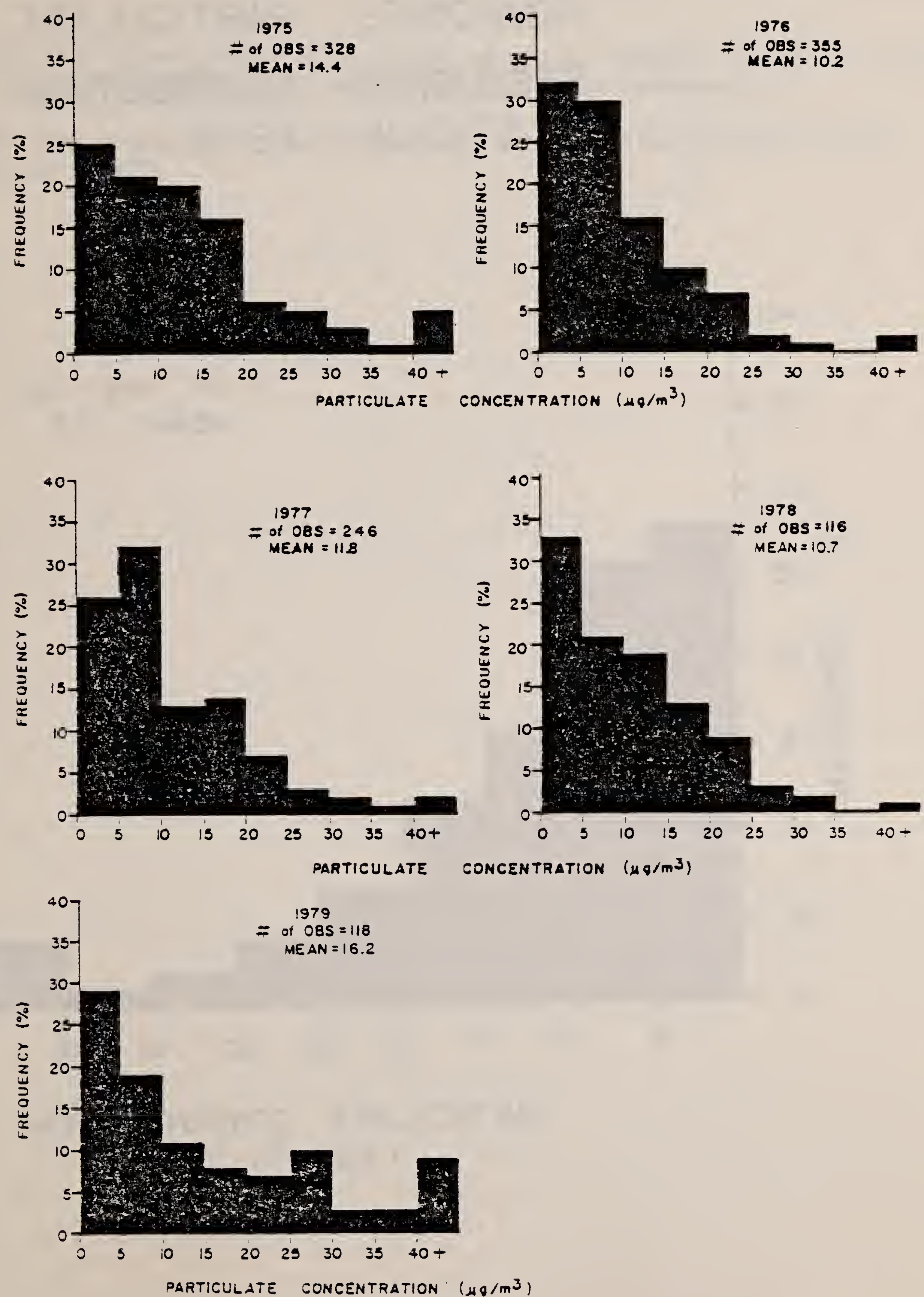
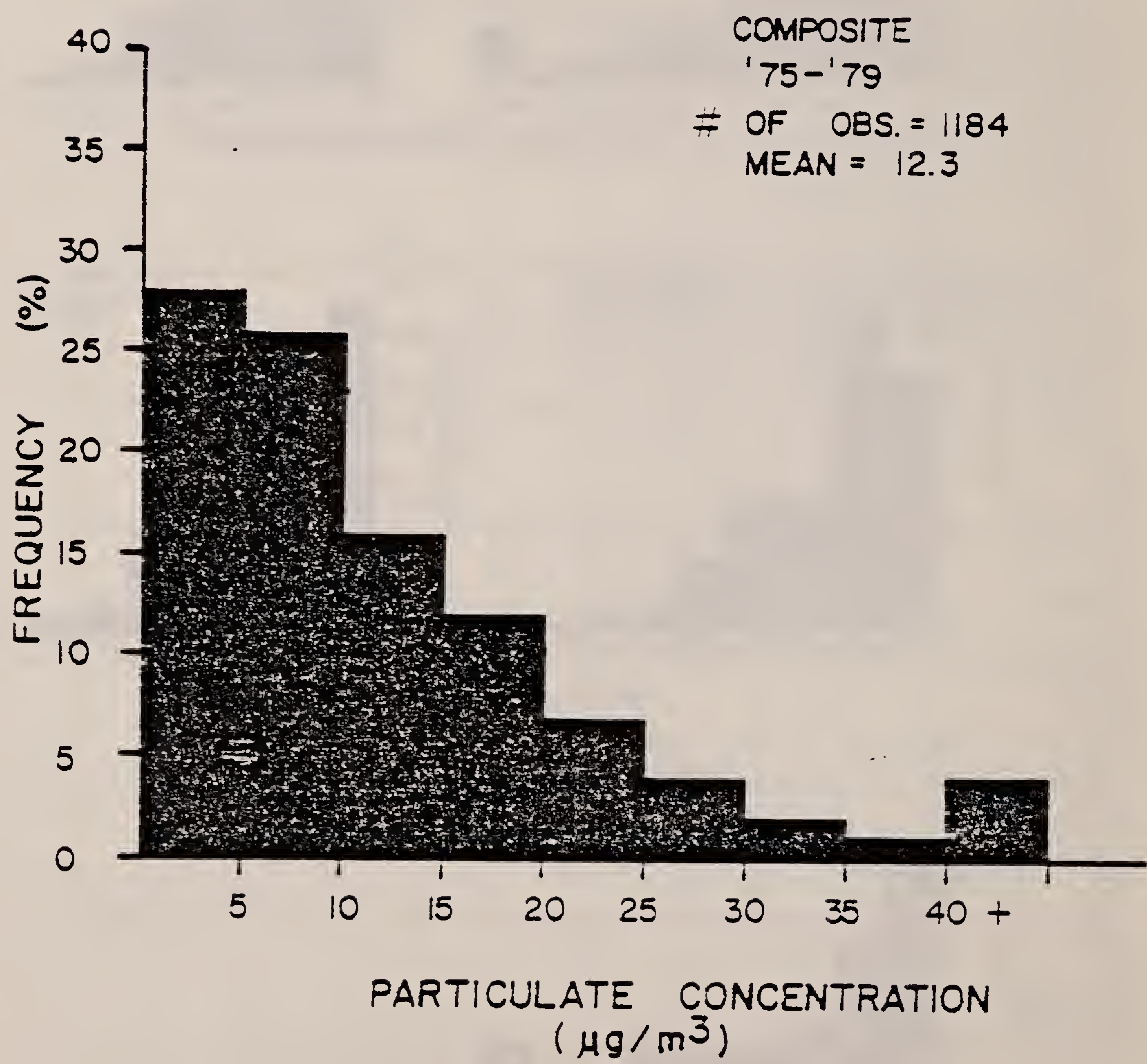


FIGURE 6.2.2-4

COMPOSITE PARTICULATE
FREQUENCY DISTRIBUTION
STATION (AB23)



6.2.2.6 Conclusions

1) Particulates in the area of the C-b Tract are primarily rural in origin, particularly those responsible for maximum concentrations.

2) Although firm correlations have yet to be drawn, seasonal trends in particulate concentrations suggest a general meteorological dependence.

3) No long-term trend over time is evident in the particulate data taken through October, 1979.

6.2.3 Visibility

6.2.3.1 Scope

The visibility monitoring program has been cosponsored by the C.B. and Rio Blanco Shale Oil Projects. Measurements were taken every sixth day for a total of ten days in the Spring quarter, 1979, and ten days in the Fall. There are no state or federal requirements for visibility monitoring; however, the program is required under the Federal Oil Shale Lease Environmental Stipulations.

6.2.3.2 Objectives

- to establish baseline visibility levels for the Piceance Basin
- to identify any trends in visibility
- to attempt to establish correlations between visibility and meteorological and/or air quality parameters

6.2.3.3 Experimental Design

Visibility data were obtained by means of photographic photometry from an observation site approximately eight miles southwest of Piceance Creek on a ridge between Hunter Creek and Dry Gulch. This site was chosen for its proximity to the C-a and C-b Tracts, as well as for its accessability and range of views.

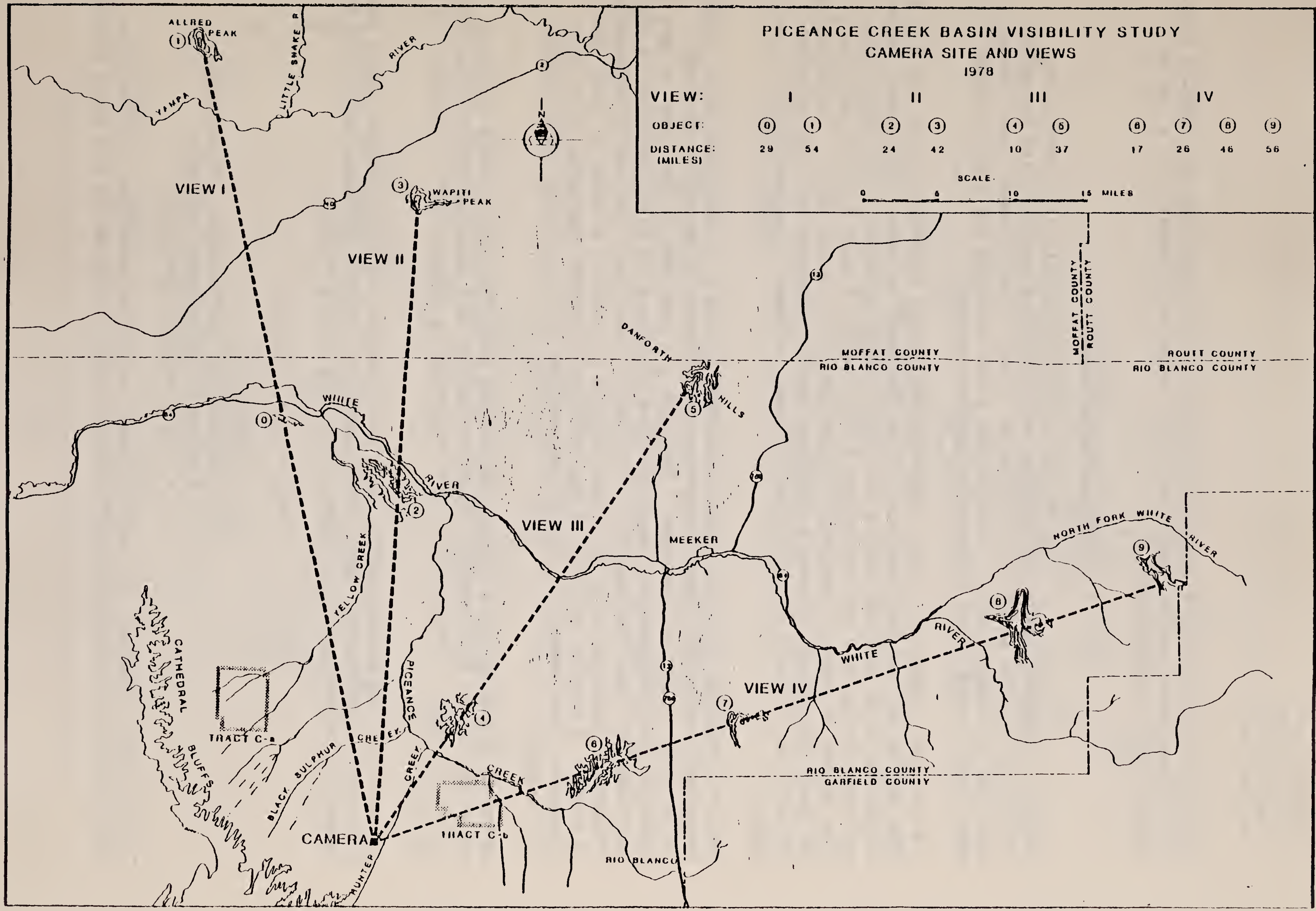
Photographs were taken at hourly intervals throughout the measurement days in each of four views. (See Figure 6.2.3-1). The use of at least two objects in each view enabled the measurement of visual range under a variety of visibility conditions. The locations of the observation site and objects are shown on the Figure.

Visual range information is extracted from the photographs by means of optical density measurements on the portions of the photograph representing a given object and the horizon sky directly above it. These densities, together with the actual object-camera distance and the object albedo are used to calculate a visual range.

6.2.3.4 Method of Analysis

In that there have been only two years of seasonal visibility measurements since the baseline visibility study of 1975-76, there is no basis for analysis of long-term trends in visibility. Visual range results have been compiled and averaged on a per-view and composite basis over monthly, seasonal and annual periods to facilitate comparison with baseline data.

FIGURE 6.2.3-1



PICEANCE CREEK BASIN VISIBILITY STUDY
CAMERA SITE AND VIEWS
1978
VIEW: I II III IV
OBJECT: (0) (1) (2) (3) (4) (5) (6) (7) (8) (9)
DISTANCE: (MILES) 29 54 24 42 10 37 17 26 46 56
SCALE
0 5 10 15 MILES
ALLRED PEAK
LITTLE SNAKE R.
YAMPA
RIVER
VIEW I
WAPITI PEAK
VIEW II
DANFORTH HILLS
MOFFAT COUNTY
RIO BLANCO COUNTY
MOFFAT COUNTY
ROUTT COUNTY
ROUTT COUNTY
RIO BLANCO COUNTY
WHITE
RIVER
VIEW III
MEEKER
YELLOW CREEK
NORTH FORK WHITE RIVER
RIVER
WHITE
CATHEDRAL
BLUFFS
TRACT C-a
PICEANCE
CREEK
BLACK SULPHUR
CREEK
CREEK
VIEW IV
RIO BLANCO COUNTY
GARFIELD COUNTY
CAMERA
TRACT C-b
HUNTER
RIO BLANCO

Correlation and multiple regression analyses using baseline and 1978-79 visibility data were used to evaluate visual range relationships to a set of meteorological parameters.

6.2.3.5 Discussion and Results

The results of the 1979 visibility monitoring program compared, where appropriate, with baseline results, are presented in Figures 6.2.3-2 and 6.2.3-3. The daily variation in mean visual range is depicted in Figure 6.2.3-2. These time plots indicate the sharp changes in mean visual range which accompanied weather changes.

The seasonal composite visual range distributions, Figures 6.2.3-4 and 6.2.3-5, show shifts both up and down scale from the baseline data. Additional years of data will be required before any trend can be detected. The annual composite distributions for spring and fall shown in Figure 6.2.3-6 indicate a high degree of overall comparability between 1975-76 and 1979. The composites for each view appear to have a stronger central tendency for 1979 than for 1975-76, which would be indicative of fewer extremes in meteorological parameters.

The low frequency of visual range observed in View I in the 60-69 mile range presented in the 1978 Annual Report has been found to be due to an anomaly in the data reduction procedure. Raw data are obtained in the form of density readings from photographic negatives (the procedure is fully detailed in the Environmental Baseline Report). For View I, input data for hourly photographs frequently exhibited density values of 0.01 or 0.02 in a range of more than 10 miles. A density of 0.01 is the smallest increment measureable by this procedure. Refinements in the procedures are being evaluated to eliminate this anomaly.

Correlation and multiple regression methods used for visual range analysis presented in the Environmental Baseline Report have been applied to the 1979 visibility data. These results are presented in summary form in Tables 6.2.3-1 and 6.2.3-2.

The multiple regression coefficients and intercept values from the tables were used with meteorological data corresponding to visibility-measurement days to compute an estimated visual range, according to the formula

$$Yest = b_0 + \Sigma_i (b_i x_i)$$

b_0 = intercept
b_i = regression coefficient, ith variable
x = value of ith primary variable
i = 1 to 8 primary variables

For the case presented, all eight primary variables were used. Correlation coefficients and regression coefficients shown in the tables are quite similar

FIGURE 6.2.3-2

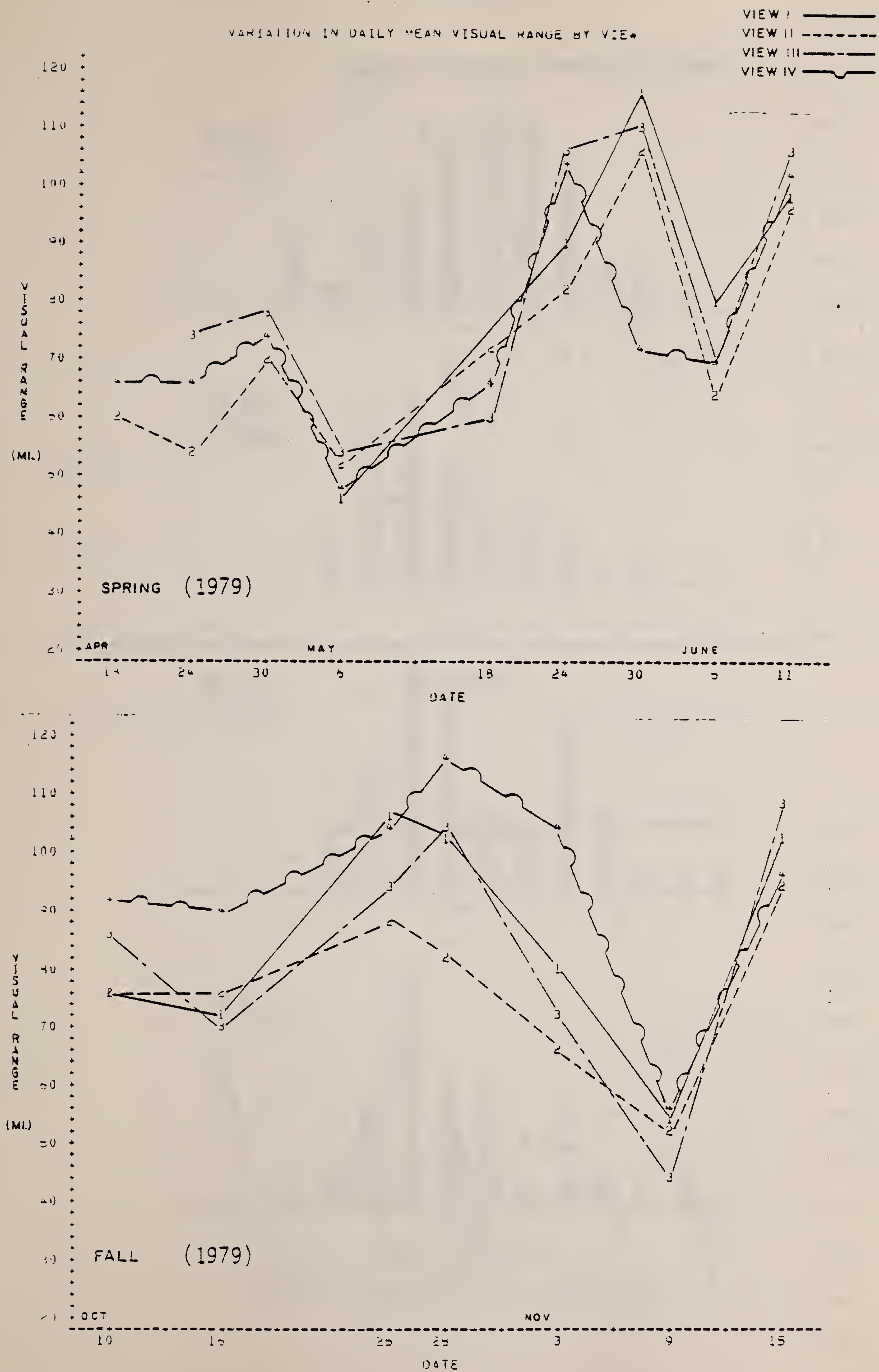
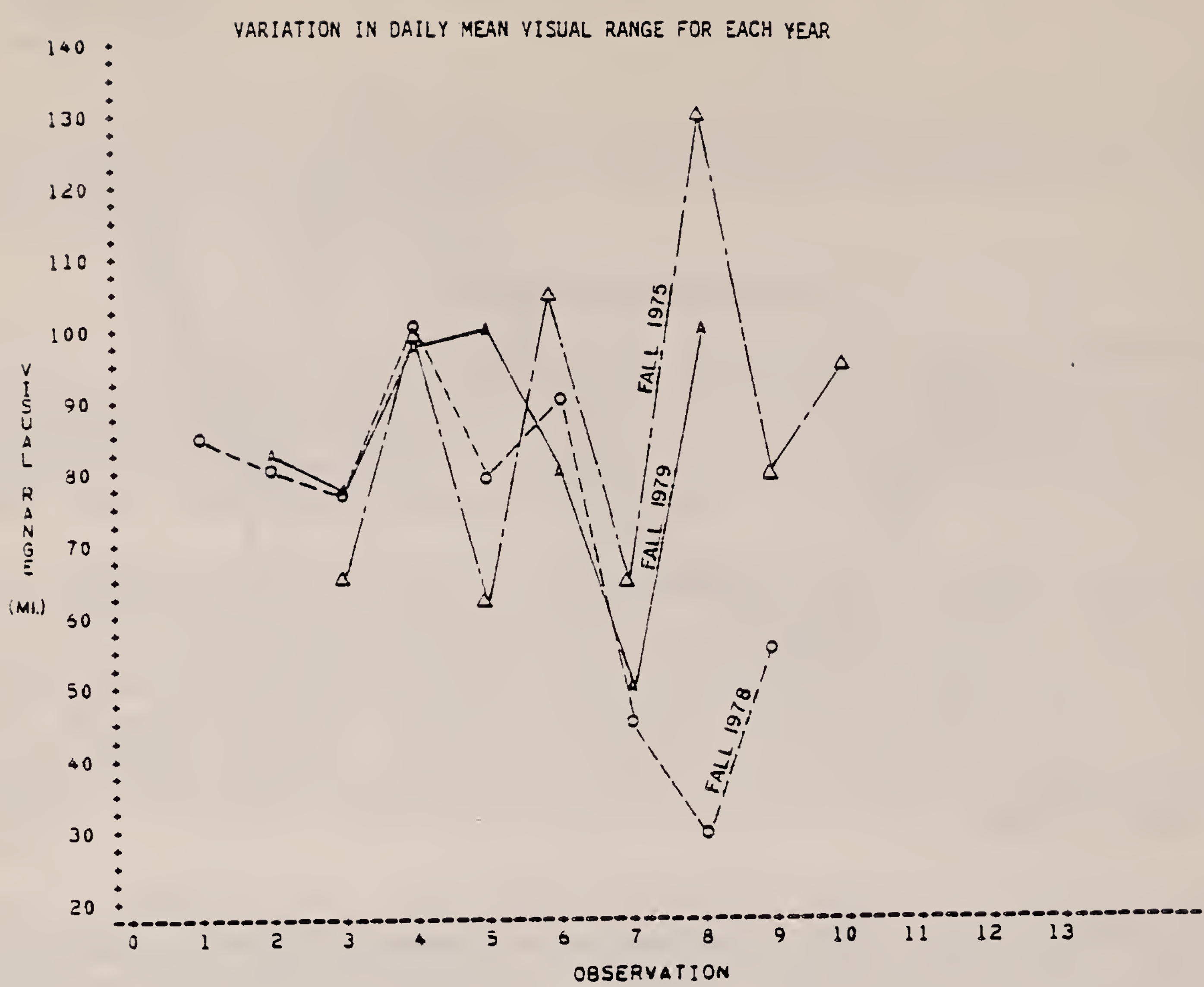
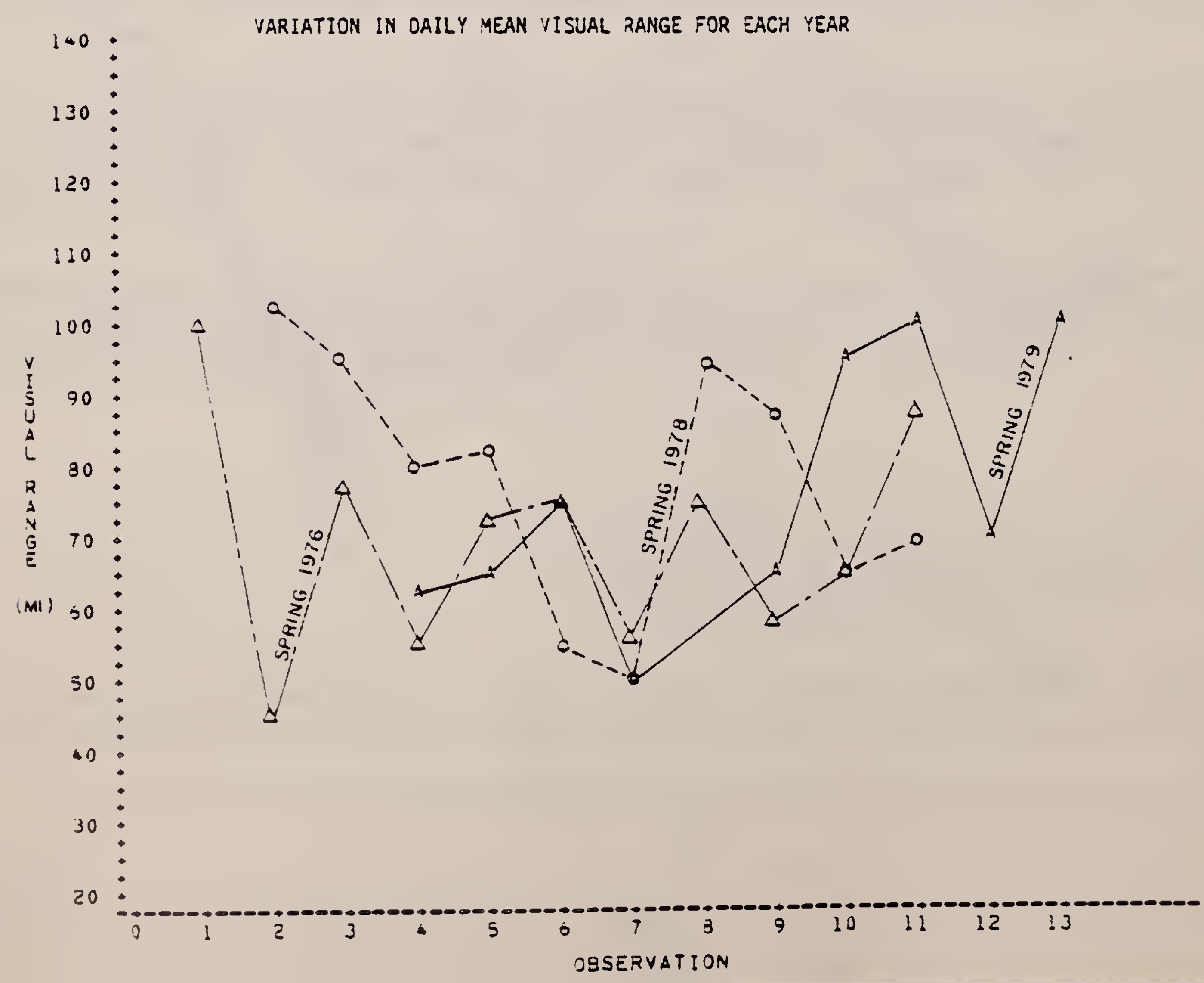

VARIATION IN DAILY MEAN VISUAL RANGE BY VIEW
VIEW I
VIEW II
VIEW III
VIEW IV
VISUAL RANGE (MI.)
SPRING (1979)
APR
MAY
JUNE
DATE
FALL (1979)
OCT
NOV
DATE

FIGURE 6.2.3-3


VARIATION IN DAILY MEAN VISUAL RANGE FOR EACH YEAR
140
130
120
110
100
90
80
70
60
50
40
30
20
VISUAL RANGE (MI.)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
OBSERVATION
FALL 1975
FALL 1979
FALL 1978


VARIATION IN DAILY MEAN VISUAL RANGE FOR EACH YEAR
140
130
120
110
100
90
80
70
60
50
40
30
20
VISUAL RANGE (MI)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
OBSERVATION
SPRING 1976
SPRING 1978
SPRING 1979

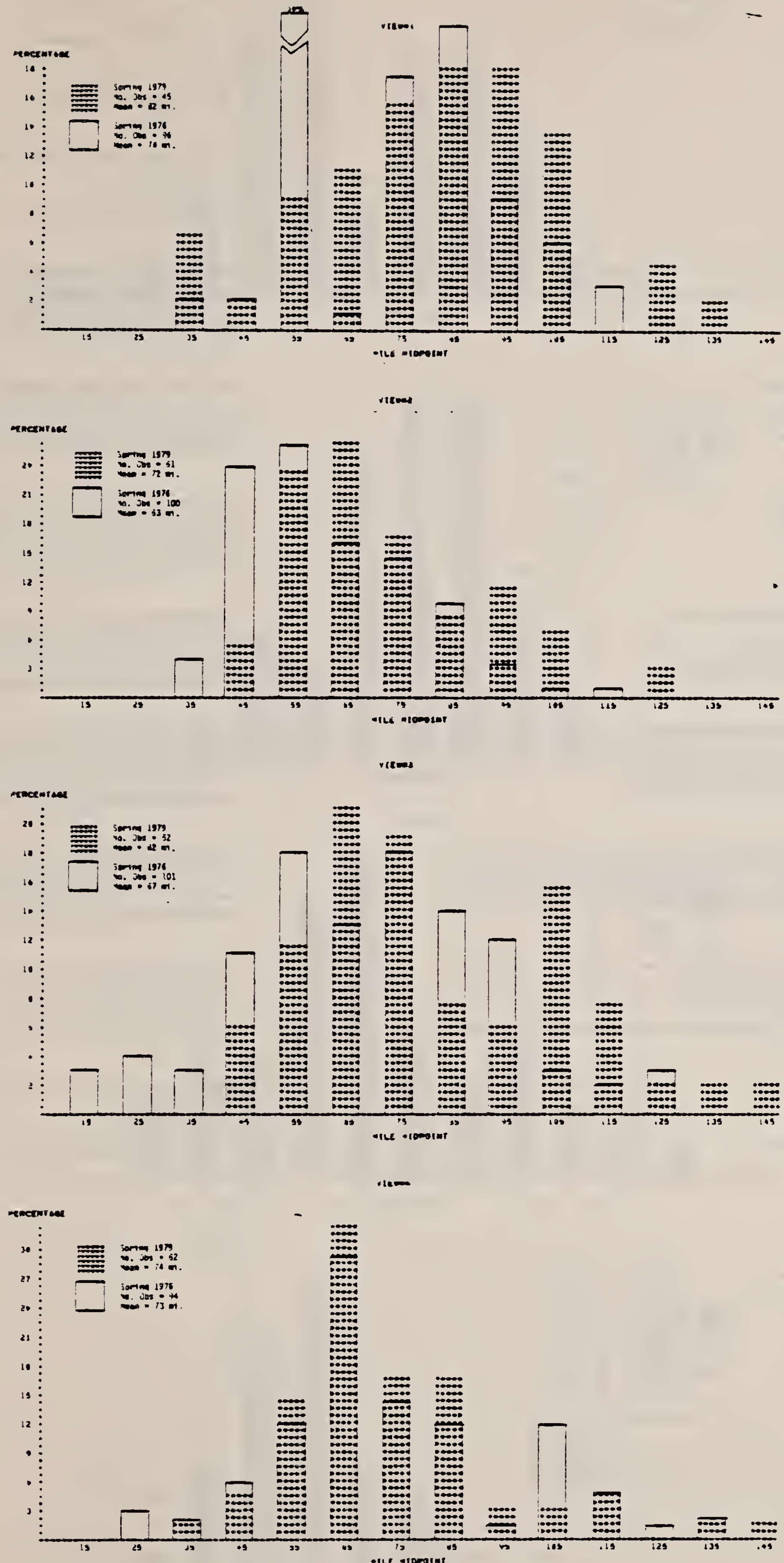


FIGURE 6.2.3-4
SPRING VISUAL RANGE FOR EACH VIEW

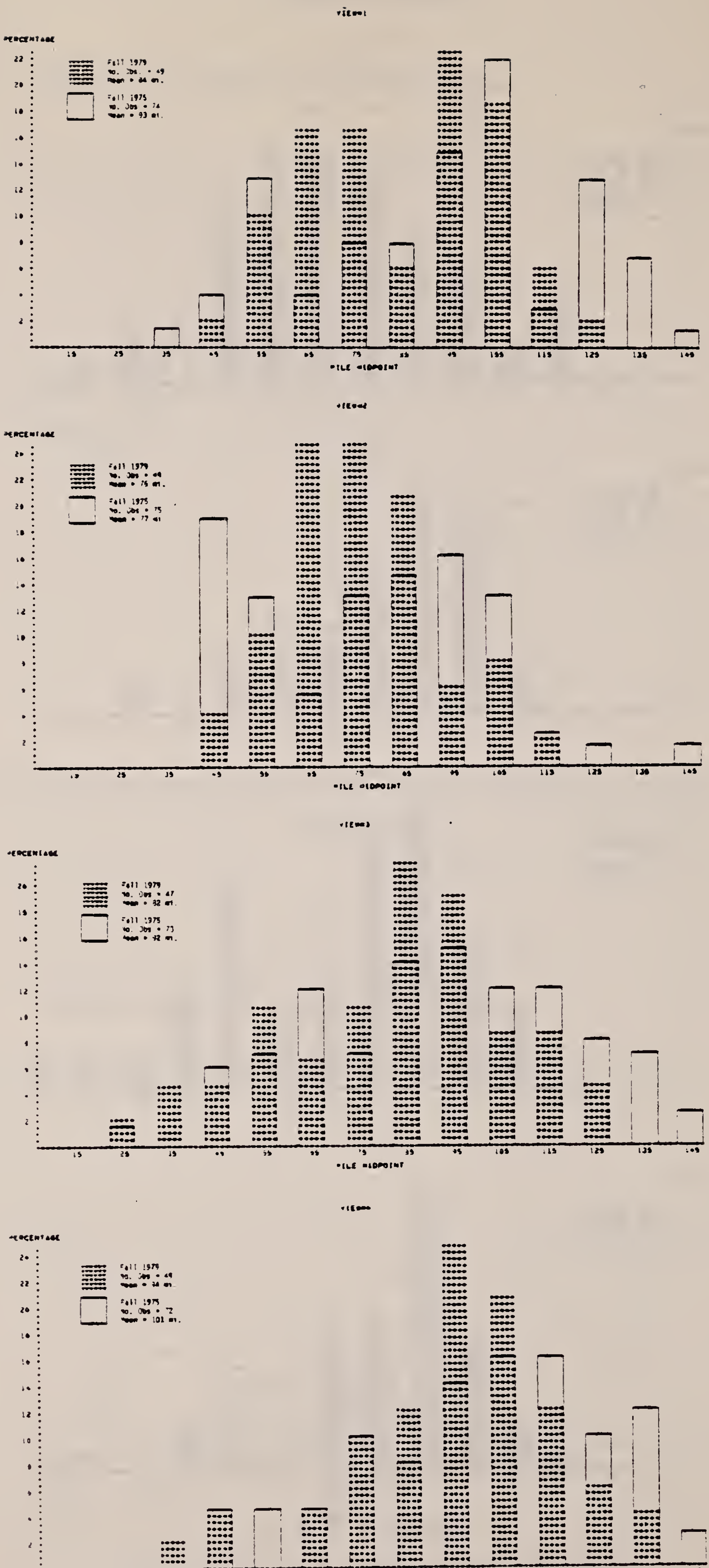


FIGURE 6.2.3-5
FALL VISUAL RANGE FOR EACH VIEW

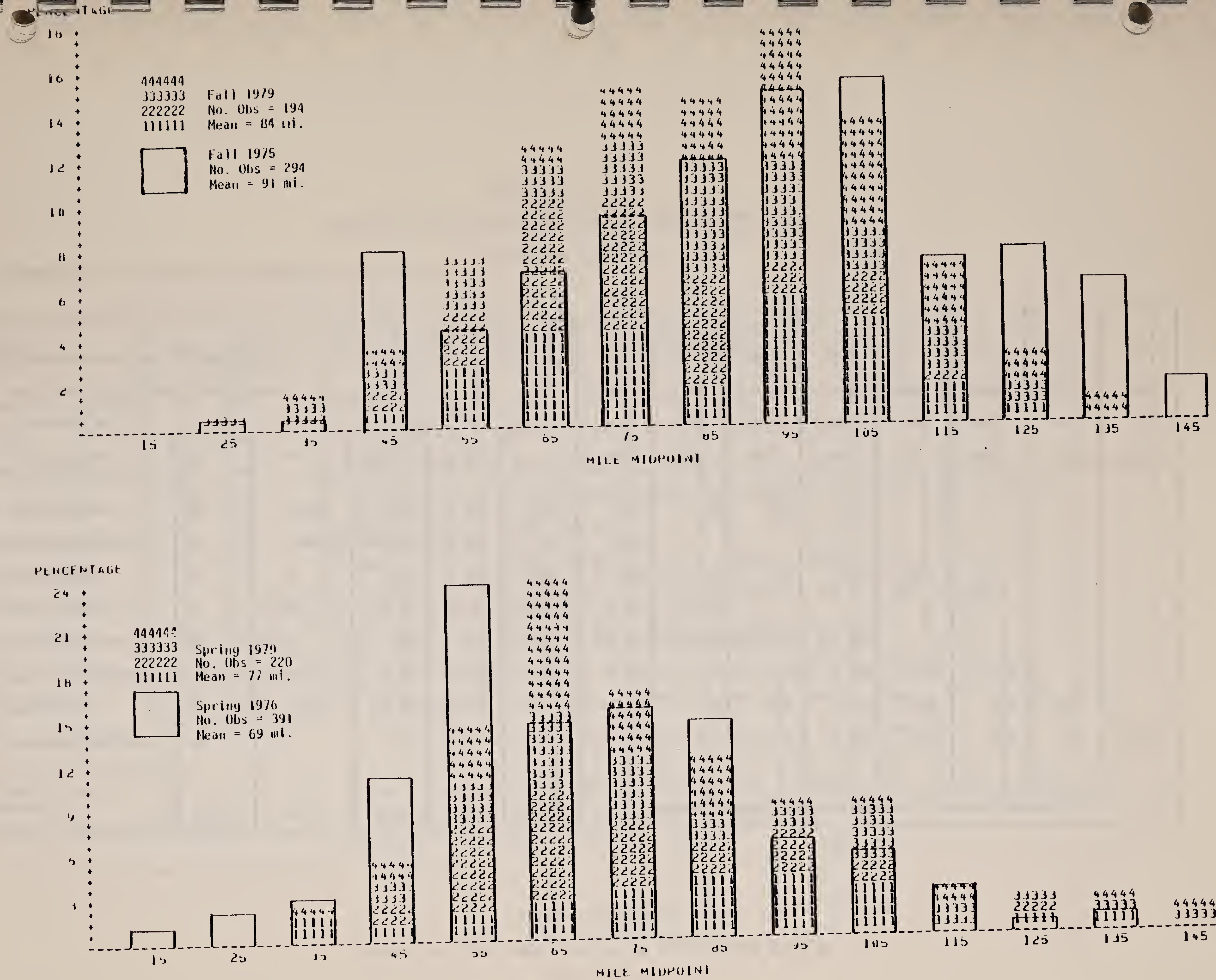


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FIGURE 6.2.3-6
COMPOSITE FREQUENCY DISTRIBUTION

TABLE 6.2.3-1

SUMMARY OF VISUAL RANGE CORRELATION & REGRESSION ANALYSES

Fall Data (1975-1979)

Parameter	Sym.	Units	Mean	Std.	Corr.	Multiple Regression Coefficients - Primary Variables							
1. Relative Humidity	RH	%	51.81	20.13	-.605	-1.009	-1.009	-1.024	-1.032	-.918	-.826	-.737	-.675*
2. Ozone	OZ	μg/m³	55.50	16.13	-.118	-.352	-.339	-.302	-.332	-.407	-.442	-.362	--
3. Max. Wind Speed	MW	m/s	6.62	3.61	-.048	-2.094	-2.031	-1.342	-1.334	-1.384	-1.418	--	--
4. Precipitation	PR	in.	.002	.0	-.149	215.145	282.685	331.084	361.943	--	--	--	--
5. Wind Speed	WS	m/s	2.73	1.37	.029	1.976	2.072	--	--	--	--	--	--
6. Temperature	TP	°C	5.12	7.24	.344	-.301	-.442	-.520	-.628	-.373	--	--	--
7. Solar Radiation	SR	langleys	264.19	119.51	.355	-.010	--	--	--	--	--	--	--
8. Particulates	PA	μg/m³	11.46	8.46	.034	-.303	-.288	-.201	--	--	--	--	--
9. Visual Range	VR	mi.	82.46	22.46		Dep	Dep	Dep	Dep	Dep	Dep	Dep	Dep
Intercept mi.						170	166	166	166	164	159	141	117
Multiple Correlation Coefficient						.705	.704	.702	.699	.693	.689	.656	.605
Standard Error of Estimate (mi).						19.5	18.8	18.4	18.0	17.7	17.4	17.7	18.3

* Variable(s) in the model are significant at .10 level.

TABLE 6.2.3-2

SUMMARY OF VISUAL RANGE CORRELATION & REGRESSION ANALYSES

Spring Data (1976-1979)

Parameter	Sym.	Units	Mean	Std.	Corr.	Multiple Regression Coefficients - Primary Variables							
1. Relative Humidity	RH	%	51.05	16.42	-.324	-.533	-.547	-.420	-.414	-.375	-.272	-.501*	-.298
2. Ozone	OZ	μg/m³	76.86	14.75	-.023	-.179	-.179	-.130	-.128	--	--	--	--
3. Max. Wind Speed	MW	m/s	7.90	3.55	.096	-.761	-.683	--	--	--	--	--	--
4. Precipitation	PR	in.	.02	.06	.266	111.087	110.156	113.606	118.355	123.567	97.104	39.741*	--
5. Wind Speed	WS	m/s	3.62	1.86	.196	.313	--	--	--	--	--	--	--
6. Temperature	TP	°C	9.38	4.71	.224	-.842	-.866	-.820	-.803	-.956	--	--	--
7. Solar Radiation	SR	Langleys	416.05	277.14	.341	.012	.018	.023	.026	.028	.019	--	--
8. Particulates	PA	μg/m³	21.67	20.13	.250	.108	.120	.066	--	--	--	--	--
9. Visual Range	VR	mi.	71.71	15.10		Dep	Dep	Dep	Dep	Dep	Dep	Dep	Dep
Intercept (mi.)						113	115	97	97	86	76	97	87
Multiple Correlation Coefficient						.613	.613	.604	.598	.589	.550	.457	.324
Stand Error of Estimate (mi.)						15.4	14.8	14.4	14.0	13.6	13.7	15.1	14.7

* Variable(s) in the model are significant at .10 level.

to those obtained in the Baseline Report. Tables 6.2.3-3 and 6.2.3-4 show the comparison of predicted and actual visual ranges using the derived equations for spring and fall data. Seasonal means are quite well predicted although daily values exhibit variation.

6.2.3.6 Conclusions

1. No time trends in visual range are detectable based on presently available data.

2. The influence of meteorological parameters on visual range is not yet sufficiently well defined to allow estimation of daily visual ranges, although seasonal and annual means may be estimated quite well with confidence. Additional analysis should attempt to identify additional correlative parameters.

TABLE 6.2.3-3

COMPARISON OF PREDICTED AND ACTUAL VISUAL RANGE

** FALL DATA (1975-1979) **

OBS	MO	DY	YR	RH (%)	PR (IN.)	PA ($\mu g/m^3$)	OZ ($\mu g/m^3$)	SR (LANG)	TP (°C)	WS (m/s)	MW (m/s)	VISUAL RANGE OBSERVED (MILES)	VISUAL RANGE PREDICT* (MILES)	90 PERCENT CONFIDENT LIMITS LOWER (MILES)	90 PERCENT CONFIDENT LIMITS UPPER (MILES)
1	10	3	75	21	0.00	10	50	427	14	2	6	93	111	74	148
2	10	9	75	28	0.00	13	43	382	8	3	7	116	107	71	145
3	10	15	75	49	0.00	8	37	396	5	2	6	66	91	54	128
4	10	21	75	22	0.00	17	50	342	12	4	7	99	111	73	149
5	10	27	75	60	0.00	27	36	224	4	6	13	63	69	26	113
6	11	2	75	52	0.00	1	35	261	5	1	5	106	92	54	131
7	11	8	75	95	0.04	1	27	14	1	2	5	66	66	18	114
8	11	14	75	28	0.00	5	36	204	5	2	6	130	115	75	155
9	11	20	75	69	0.00	2	39	205	-9	1	4	80	80	42	119
10	11	26	75	66	0.00	5	43	20	-11	4	9	95	79	39	119
11	10	5	78	30	0.00	20	74	434	11	2	4	86	96	57	134
12	10	11	78	39	0.00	32	74	398	15	2	5	80	80	40	120
13	10	17	78	34	0.00	29	80	168	14	4	8	78	84	43	125
14	10	23	78	70	0.00	10	50	316	3	2	3	100	72	35	110
15	10	29	78	33	0.00	1	41	309	11	5	20	79	83	38	130
16	11	4	78	44	0.00	12	69	273	10	3	7	90	83	48	119
17	11	10	78	83	0.00	12	45	94	-4	2	6	46	58	20	97
18	11	16	78	84	0.00	2	67	140	-7	1	2	29	60	21	98
19	11	22	78	55	0.00	4	69	209	3	4	8	55	77	40	115
20	10	10	79	42	0.00	14	69	404	14	2	4	82	86	50	123
21	10	16	79	68	0.00	10	58	385	8	2	5	77	65	27	103
22	10	25	79	41	0.00	9	75	347	12	5	9	98	84	44	123
23	10	28	79	56	0.00	14	71	258	6	3	8	100	69	33	105
24	11	3	79	49	0.00	15	75	222	2	4	8	80	79	40	116
25	11	9	79	74	0.00	10	62	159	0	2	4	51	65	28	101
26	11	15	79	55	0.00	15	68	278	1	1	3	99	79	41	116
								**	MEAN 1975			91	92	53	132
								**	MEAN 1978			71	77	38	116
								**	MEAN 1979			84	75	38	112
								**	MEAN (1975-1979)			82	82	44	121

* Regression equation used for prediction is:
VR = 170 - 1.009 RH - 0.352 OZ - 2.094 MW + 215.145 PR + 1.976 WS = 0.301 TP - 0.010 SR - 0.303 PA

**Observations with missing values not included in Means.

TABLE 6.2.3-4

COMPARISON OF PREDICTED AND ACTUAL VISUAL RANGE

** SPRING DATA (1976-1979) **

OBS	MO	DY	YR	RH (%)	PR (IN.)	PA ($\mu g/m^3$)	OZ ($\mu g/m^3$)	SR (LANG.)	TP (°C)	WS (m/s)	MW (m/s)	VISUAL RANGE OBSERVED (MILES)	VISUAL RANGE PREDICT* (MILES)	90 PERCENT CONFIDENCE LIMITS LOWER (MILES)	90 PERCENT CONFIDENCE LIMITS UPPER (MILES)
1	4	1	76	29	0.00	24	47	554	8	7	14	101	87	52	122
2	4	7	76	78	0.00	4	37	188	2	2	4	45	65	30	99
3	4	13	76	67	0.00	60	66	331	4	6	15	78	65	30	101
4	4	19	76	80	0.00	3	64	326	2	2	6	56	60	27	92
5	4	25	76	30	0.00	6	86	222	9	4	11	72	72	40	104
6	5	1	76	38	0.00	16	78	672	8	2	6	75	82	49	115
7	5	7	76	71	0.00	3	72	278	8	2	6	56	57	27	88
8	5	13	76	38	0.00	8	82	699	12	3	8	76	76	46	107
9	5	19	76	47	0.13	16	76	335	13	3	11	58	78	46	111
10	5	25	76	46	0.00	6	90	195	13	4	12	65	58	25	91
11	5	31	76	47	0.00	13	82	604	13	3	6	88	71	42	101
12	4	6	78	40	0.00	7	103	.	5	5	8	102	65	.	.
13	4	12	78	41	0.00	23	82	.	6	2	6	94	70	.	.
14	4	18	78	41	0.00	15	87	.	2	2	6	81	72	.	.
15	4	24	78	42	0.00	17	81	.	9	2	4	83	68	.	.
16	4	30	78	72	0.01	0	82	.	5	3	5	54	54	.	.
17	5	6	78	64	0.00	0	94	0	0	3	6	50	59	25	93
18	5	12	78	44	0.00	18	91	714	7	3	4	94	80	48	113
19	5	18	78	56	0.04	14	81	62	6	4	6	88	68	36	100
20	5	24	78	24	0.00	28	91	656	13	8	13	66	81	46	115
21	5	30	78	41	0.00	22	79	261	11	4	9	69	70	39	100
22	4	18	79	41	0.00	81	90	615	12	7	10	63	80	45	114
23	4	24	79	.	0.00	46	88	495	10	4	8	64	95	.	.
24	4	30	79	59	0.00	36	71	450	10	2	6	74	69	38	100
25	5	6	79	57	0.17	33	85	.	9	6	10	50	77	.	.
26	5	18	79	43	0.00	25	91	597	16	3	5	66	71	41	101
27	5	24	79	74	0.27	42	66	266	12	2	5	95	88	51	125
28	5	30	79	.	0.00	13	71	533	5	3	4	101	102	.	.
29	6	5	79	55	0.00	30	80	712	18	2	3	71	69	36	102
30	6	11	79	.	0.00	17	75	728	16	2	4	100	94	.	.

	OBSERVED	PREDICT*	LOWER	UPPER
** MEAN 1976	70	70	38	103
MEAN 1978	73	72	39	104
MEAN 1979	74	75	42	108
MEAN (1976-1979)	71	71	39	104

• Missing values or values not calculated due to missing values.

* Regression equation used for prediction is:
VR = 113 - 0.533 RH - 0.179 OZ - 0.761 MW + 111.087 PR + 0.313 WS - 0.842 TP + 0.012 SR + 0.108 PA

** Observations with missing values not included in Means.

6.3 Meteorology

6.3.1 Climatological Records

6.3.1.1 Scope

The climatological parameters include temperature, solar radiation, precipitation, evaporation, relative humidity and barometric pressure. These records primarily serve as a historical data base to assess climatological effects principally on the biotic portion of the ecosystem so they may subsequently be sorted out from potential man-induced effects.

6.3.1.2 Objectives

Objectives are to establish this historical data base and to determine any cyclical or long-term trends that might exist as well as averages and extremes, as appropriate.

6.3.1.3 Experimental Design

Parameters measured, instrumentation used, sampling stations (Figures 6.3.1-1a and 6.3.1-1b) and minimum reporting frequency are presented in Table 6.3.1-1.

6.3.1.4 Method of Analysis

Table 6.3.1-2 presents a summary of data formats and analysis along with station identification. Data presentation and analysis techniques include Box-Jenkins time-series for temperature in addition to histograms, plots and tables for all variables. Time-series plots for all Class 1 indicator variables are in the time-series Supplements to the Development Monitoring (data) Reports and also in Figures A6.3.1-1 through A6.3.1-3 for November 1978 through October 1979. In the cases of solar radiation and precipitation the methods include estimation techniques for monthly and annual totals in presence of missing data. See Appendix A6.3.

6.3.1.5 Discussion and Results

6.3.1.5.1 Temperature

Annual mean temperatures at the Tract (Station AB23) have averaged between 6 and 9°C over the past five years. Box-Jenkins analysis of the monthly means (Table A6.3.1-1) yielded a total (5 year) series mean of 6.40°C with no discernable trend; projections over the next year with 95% confidence using a seasonal mixed autoregressive-moving average model are shown on Figure 6.3.1-2. The dampening effect in the forecast is due to the exponential decay characterized by the autoregressive terms.

Between-station comparisons (Stations AB20 vs. AB23) indicate minimum temperatures 20°C cooler in Piceance Valley than on Tract due principally to cold air drainage associated with katabatic winds with Valley temperatures reaching extremes of

FIGURE 6.3.1-1a
CLIMATOLOGICAL NETWORK
NEAR TRACT

WU70
ON SCANDARD
GULCH AT
ROAN PLATEAU

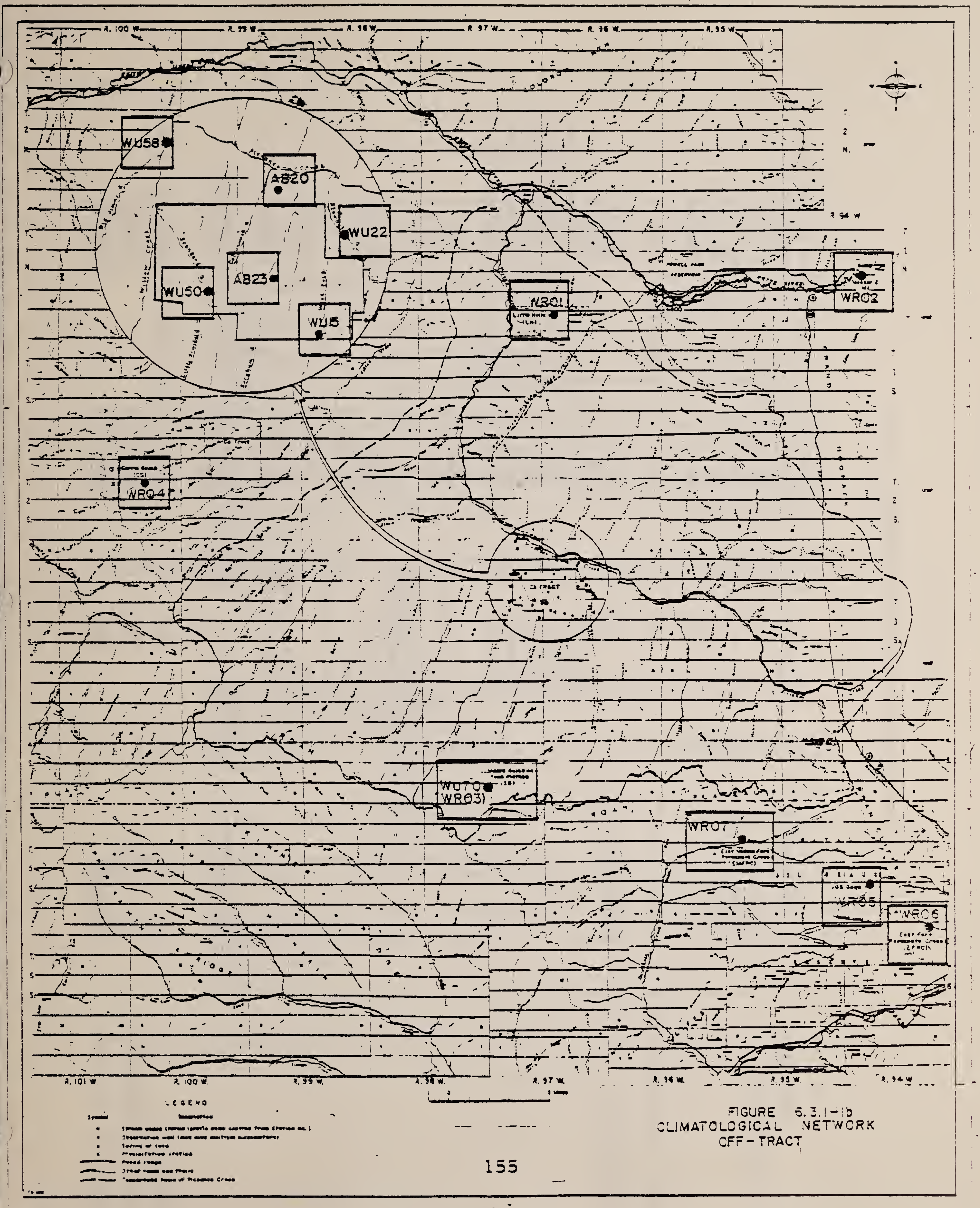


FIGURE 6.3.1-1b
CLIMATOLOGICAL NETWORK
OFF-TRACT

TABLE 6.3.1-1

CLIMATOLOGICAL PARAMETER EXPERIMENTAL DESIGN

Parameter	Instrument	Station(s)	Computer Code	Minimum Reporting Frequency
Air Temperature	Aspirated Temperature Sensor	020	AB20	Hourly
		023	AB23	Hourly
		042	AD42	Hourly
		056	AD56	Hourly
Direct Solar Radiation	Pyranometer	023	AB23	Hourly in Daylight
Precipitation	Weighing Bucket	020	AB20	Hourly
		023	AB23	Hourly
		USGS015	WU15	Approximately Monthly Totals
		USGS022	WU22	Approximately Monthly Totals
		USGS050	WU50	Approximately Monthly Totals
		USGS058	WU58	Approximately Monthly Totals
		USGS070	WU70	Approximately Monthly Totals
		Little Hills	WR01	Daily
		Meeker 2	WR02	Daily
		Scandard Gulch on Roan Plateau	WR03	Hourly
		Corral Gulch	WR04	Hourly
		JQS Gage	WR05	Hourly
		East Fork Parachute Creek	WR06	Hourly
		East Middle Fork Parachute Creek	WR07	Hourly
	Tipping Bucket	MC1 to 9, 13	BC01 to 09, 13	Bi-Weekly
Evaporation	Pan	023	AB23	Daily During Growing Season
Relative Humidity	R. H. Sensor	023	AB23	Hourly
Barometric Pressure	Barometer	023	AB23	Hourly

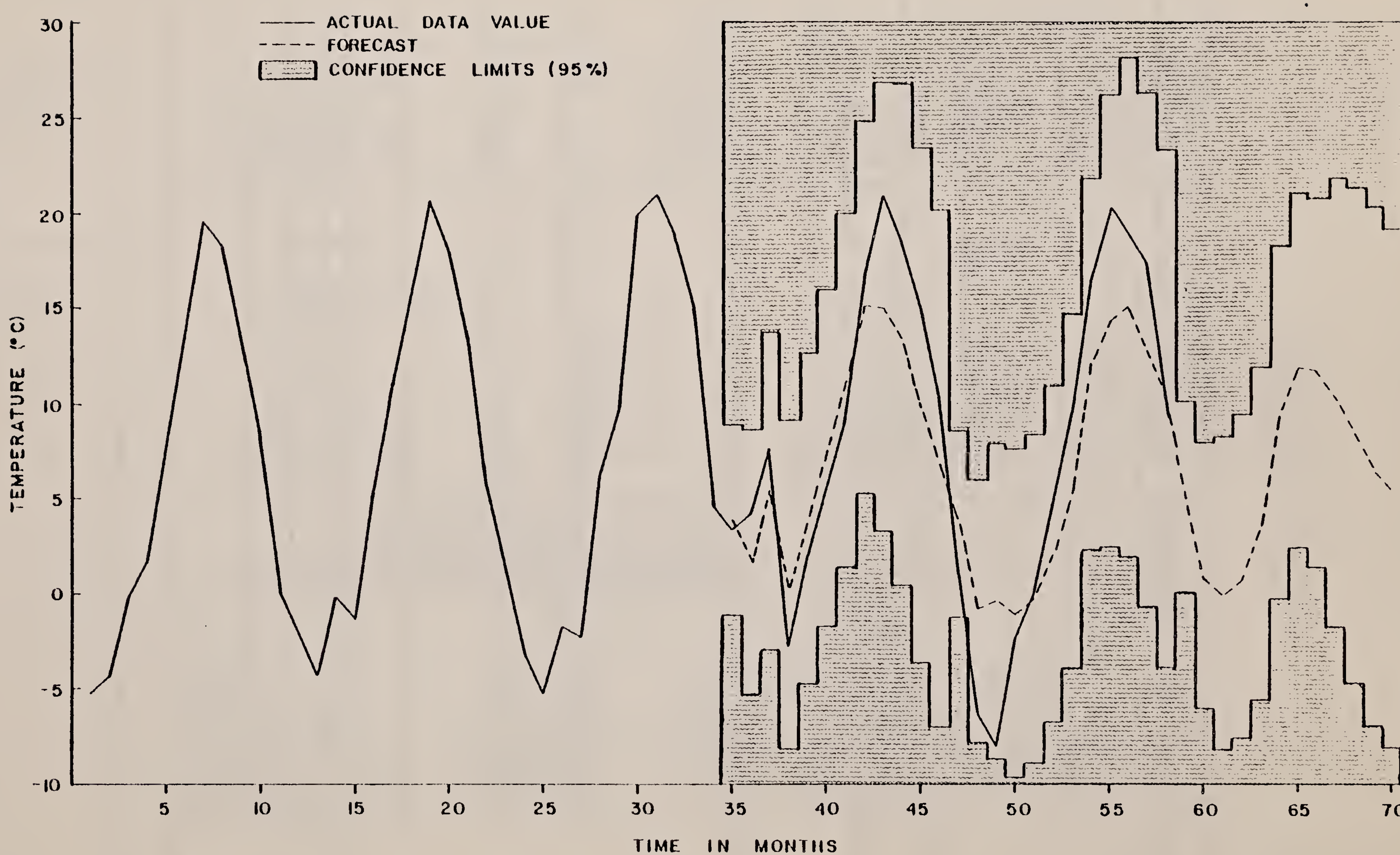
TABLE 6.3.1-2

CLIMATOLOGICAL DATA SUMMARY

Variable	Item	Station	Type Presentation/Analysis	Figure - Table Number
Air Temperature	Monthly Mean	A823	Box Jenkins Time Series	Figure 6.3.1-2 Table A6.3.1-1
	Daily Mean, Minimum, Maximum	A820, 23 A042, 56	Time Series Plots	*Section 4.2.3 *Section 4.2.3
	Monthly Values of Hourly Maximum, Mean, Minimum	A820, 23	Tabular	Table A6.3.1.2
	Growing Season	A823	Plot Table - Start, End, Length	Figure 6.3.1-3 Table A6.3.1-3
	Degree Days	A823	Tabular	Table A6.3.1-3
Direct Solar Radiation	Daily Total	A823	Time Series Plot	*Section 4.2.3
	Daily Mean, Maximum and Minimum for Month	A823	Tabular - Values Corrected for missing data	Table A6.3.1-4
Relative Humidity	Daily Mean, Minimum, Maximum	A823	Time Series Plot	*Section 4.2.3
	Monthly Values of Hourly Maximum, Mean and Minimum	A823	Tabular	Table A6.3.1-5
Precipitation	Daily Total	A820, 23	Time Series Plot	*Section 4.2.3
	Monthly Total	A820, 23 WU15, 22 WU50, 58 WU70 BC01-09, BC13 WR01-07		Table A6.3.1-6a thru 6e
	Monthly Total	A823	Histogram (with Growing Season)	Figure 6.3.1-3
	Annual Total 3 Month Running Total	A820, 23 WU70 BC02-05	Tabular	Table 6.3.1-3
	Between Station Comparison	A820, 23	Histogram	Figure 6.3.1-4
		A820, 23 WU70 WR01 BC02-05 BC07-09	Regression Analysis	Table 6.3.1-4
	Regional	National Weather	Isonyets	Figure 6.3.1-5
Evaporation	Daily Mean	A823	Time Series Plot (Pan)	*Section 4.2.3
	Daily Mean	A823	Tabular - Pan and Lake	Table A6.3.1-7
Barometric Pressure	Daily Mean, Minimum, Maximum	A823	Time Series Plot	*Section 4.2.3
	Monthly Values of Hourly Maximum, Mean & Minimum	A823	Tabular	Table A6.3.1-8

*Supplements to the Development Monitoring (data) Reports

FIGURE 6.3.1-2
TEMPERATURE AT TRAILER AB23 (10M LEVEL) VS.
ARIMA FORECAST MODEL



-43°C since baseline. Minimum, average and maximum temperatures for periods 1975 through 1979 are shown in Table A6.3.1-2.

Growing season length and degree-day data are presented on Table A6.3.1-3. Growing seasons over the past five years have varied from 111 days in 1976 to 148 days in 1979, yet the degree-days referenced to 18°C (Munn (1970)) were highest in 1978 (223°C-days) indicating the highest average temperatures and corresponding to a growing season of 124 days.

6.3.1.5.2 Solar Radiation

Direct solar radiation, as measured by the pyranometer, varies from a monthly average of 614 langleys per day in June near summer solstice to approximately 130 langleys in December near winter solstice; the 1979 data falls within this range of previous years. This variation approximates the yearly cycle in the daily peaks in the cosine of the sun's zenith angle. Values presented in Table A6.3.1-4 have been corrected for missing data by applying a correction factor. This correction factor is the ratio of average daylight hours per month to pyranometer channel "uptime" hours per month for cases where uptime exceeds 50% of the daylight hours per month. Values obtained for the Tract in June have been compared with values obtained for 40°N latitude (approximate Tract latitude) from Sellars, Physical Climatology (Figure 5) as follows:

	Tract	Sellers
Clear Day Peak	745	700 ly/day
Monthly Average	614	592

Sellers "Average" terms included:

Q, direct beam solar radiation incident on earth surface		
+q, diffuse solar radiation incident on earth surface		389 ly/day
C_r, backscattering by clouds		164
A_r, backscattering by air molecules, dust, water vapor		39
	TOTAL	592 ly/day

Additional terms in Sellers peak (cloudless, dry day)

C_a, (no) absorption by clouds		25
A_a, (no) absorption by air molecules, dust, water vapor		83
	TOTAL	700 ly/day

6.3.1.5.3 Relative Humidity

Relative humidity annual means at the Tract, (Station AB23) have averaged between 54% and 56% over the past five years, with winter hourly minimums to ten and summer minimums to nine (Table A6.3.1-5).

6.3.1.5.4 Precipitation

Precipitation data, as indicated on Figures 6.3.1-1a and -1b and Table 6.3.1-1 include measurements near two air quality stations, four U.S.G.S. stream gauging stations, one U.S.G.S. station on the Roan Plateau, ten microclimate stations, and seven additional stations as required by the Water Augmentation Plan. Monthly totals over all stations are presented in Tables A6.3.1-6a through -6e for 1975 through 1979. Monthly averages at the U.S.G.S. stations are approximate only, inasmuch as sampling of these stations is somewhat randomized. Annual total and 3-month running totals and the 1-hour peaks for the past five years are given on Table 6.3.1-3. Regression analysis was performed among selected precipitation monitoring stations in order to determine potential correlations. The results are summarized on Table 6.3.1-4. The most significant correlation was between Stations AB20 and AB23 (P = 95%) which utilize identical sampling techniques. Monthly histographs for each year are presented on Figure 6.3.1-3, along with growing season information. The wettest of the five years was 1975, 9 cm above its nearest competitor (AB23). Lightest annual precipitation at AB23 was 35.8 cm in 1976. Peak down-pours for a 1-hour duration have reached 4.3 cm on September 3, 1977. Between-station comparisons for AB20 and AB23 are portrayed on Figure 6.3.1-4 as histograms, showing the local nature of precipitation between Tract (AB23) and Valley (AB20). Between-station differences in monthly totals of as much as 5.4 cm were observed in September, 1977.

The regional precipitation patterns are influenced by the local terrain and difference in elevation between plateau and river valley with the elevated areas receiving more precipitation than the valleys as reflected in the isohyets (Figure 6.3.1-5). The highest yearly-average total-precipitation area in the region is located near the Marvine Ranch station (elevation 7,800 feet) which receives its major precipitation in the Winter and Spring in the form of snow.

6.3.1.5.5 Evaporation

Evaporation during the growing season has been measured by an evaporation pan at Station AB23 in 1978 and 1979. Monthly totals (Table A6.3.1-7) ranged from 6.49 to 20.37 cm as "pan" values in 1979 compared to 11.24 to 25.08 cm in 1978; assuming a 0.7 pan coefficient, lake values respectively range from 4.54 to 14.26 cm in 1979 compared to 7.87 to 17.56 cm in 1978. Monthly comparisons (May-September) show decreases in total evaporation for all months in 1979 from 1978.

6.3.1.5.6 Barometric Pressure

Annual mean barometric pressures at Tract Station AB23 have averaged approximately 790 mb over the past five years with hourly minimums as low as 725, and hourly maximums as high as 800 mb, (Table A6.3.1-8).

TABLE 6.3.1-3

PRECIPITATION (cm)

Station	Year	Annual Total		3-Month Total			1-Hour Maximum	
		Calendar Year	Growing Season Year (April-March)	March-April-May	April-May-June	May-June-July	Amount	Date
AB20	1975	54.5		18.6	15.9	12.0	0.29	8/10/75
	1976	42.4	53.8	14.3	10.3	12.7	0.43	6/14/76
	1977	42.4	30.7	9.8	5.9	6.7	4.32	9/3/77
	1978	40.3	47.9	14.7	9.2	8.7	0.76	6/5/78
	1979	41.4	36.7	15.3	12.0	11.3	0.89	11/20/79
AB23	1975	45.0		15.0	13.9	11.0	0.33	7/20/75
	1976	35.8	44.4	12.1	9.4	11.0	0.32	6/14/76
	1977	35.9	27.9	10.0	6.4	7.9	1.09	7/19/77
	1978	36.1	41.2	14.6	7.5	7.2	1.35	5/21/78
	1979	36.7	31.6	15.3	12.4	11.6	1.07	11/22/79
WU70	1975	49.1		15.8	14.7	12.1		
	1976	40.3	48.5	13.1	10.6	12.1		
	1977	40.3	35.4	14.4	7.3	5.2		
	1978	42.0	42.9	13.3	7.9	7.6		
	1979	40.6	38.6	13.3	11.1	10.6		
BC02	1975	23.6		9.4	7.5	5.6		
	1976	21.7	24.2	5.9	3.6	2.1		
	1977	25.0	15.9	6.3	3.9	4.4		
	1978	41.9	42.1	12.3	5.6	6.4		
	1979	19.3	25.3	6.2	4.5	4.4		
BC03	1975	26.2		10.2	9.4	7.8		
	1976	23.1	29.6	7.8	5.0	3.3		
	1977	21.9	13.6	6.5	3.9	5.0		
	1978	42.2	40.1	14.1	5.6	5.7		
	1979	19.6	24.5	7.2	5.4	4.6		
BC04	1975	26.3		11.6	8.9	5.7		
	1976	37.3	32.0	20.4	12.8	9.6		
	1977	32.8	19.5	0.2	0.2	17.9		
	1978	41.6	54.1	13.2	5.9	6.0		
	1979	19.9	26.3	5.2	2.9	2.2		
BC05	1975	19.3		5.4	8.4	9.7		
	1976	10.6	20.2	1.0	2.9	3.2		
	1977	8.2	6.0	0.3	0.3	1.3		
	1978	34.1	28.0	11.0	4.9	3.9		
	1979	9.8	16.6	3.5	3.3	2.9		

TABLE 6.3.1-4

MONTHLY PRECIPITATION REGRESSION

$y = a + bx$

Station (y)	Station (x)	a	b	r Coefficient of Correlation
WU70	AB20	1.17	0.61	0.58
WU70	AB23	1.43	0.62	0.57
WU70	WU15	2.15	0.50	0.57
AB23	AB20	-0.27	0.99	0.95
WR01	AB20	0.80	0.54	0.71
WR01	AB23	0.68	0.67	0.77
BC02	AB23	0.11	0.61	0.76
BC03	AB23	-0.24	0.73	0.81
BC04	AB23	-0.05	0.78	0.42
BC05	AB23	0.32	0.18	0.37
BC07*	AB23	0.63	0.47	0.42
BC08*	AB20	0.18	0.79	0.66
BC09*	AB20	-0.22	0.81	0.69

*In an attempt to show the degree of correlation that can be expected between microclimate spot-check precipitation data and continuously recorded precipitation data collected by weighing rain gage at stations AB20 and AB23, linear regressions were performed between AB23 and BC07 and between AB20 and BC08 and BC09. MC station BC07 is located approximately 1/4 mile East of, and can be expected to show a "good" correlation to air quality station AB23; this degree of correlation is not evident. The January and February, 1978 precipitation data for MC station BC07 were considered suspect because of their extremely high values. When these two values were eliminated from the regression, AB23 vs BC07 showed a coefficient of correlation, r, of 0.70 with a = 0.15 and b = 0.55 - values much nearer those expected in the regression. Stations BC08 and BC09 are located approximately 1 mile downstream and upstream, respectively, of air quality station AB20 on Piceance Creek. They show better correlations than did AB23 and BC07 but still show better than 50% correlation with AB20.

FIGURE 6.3.1-3
MONTHLY TOTAL PRECIPITATION
AND TEMPERATURE VARIATIONS
STATION A823

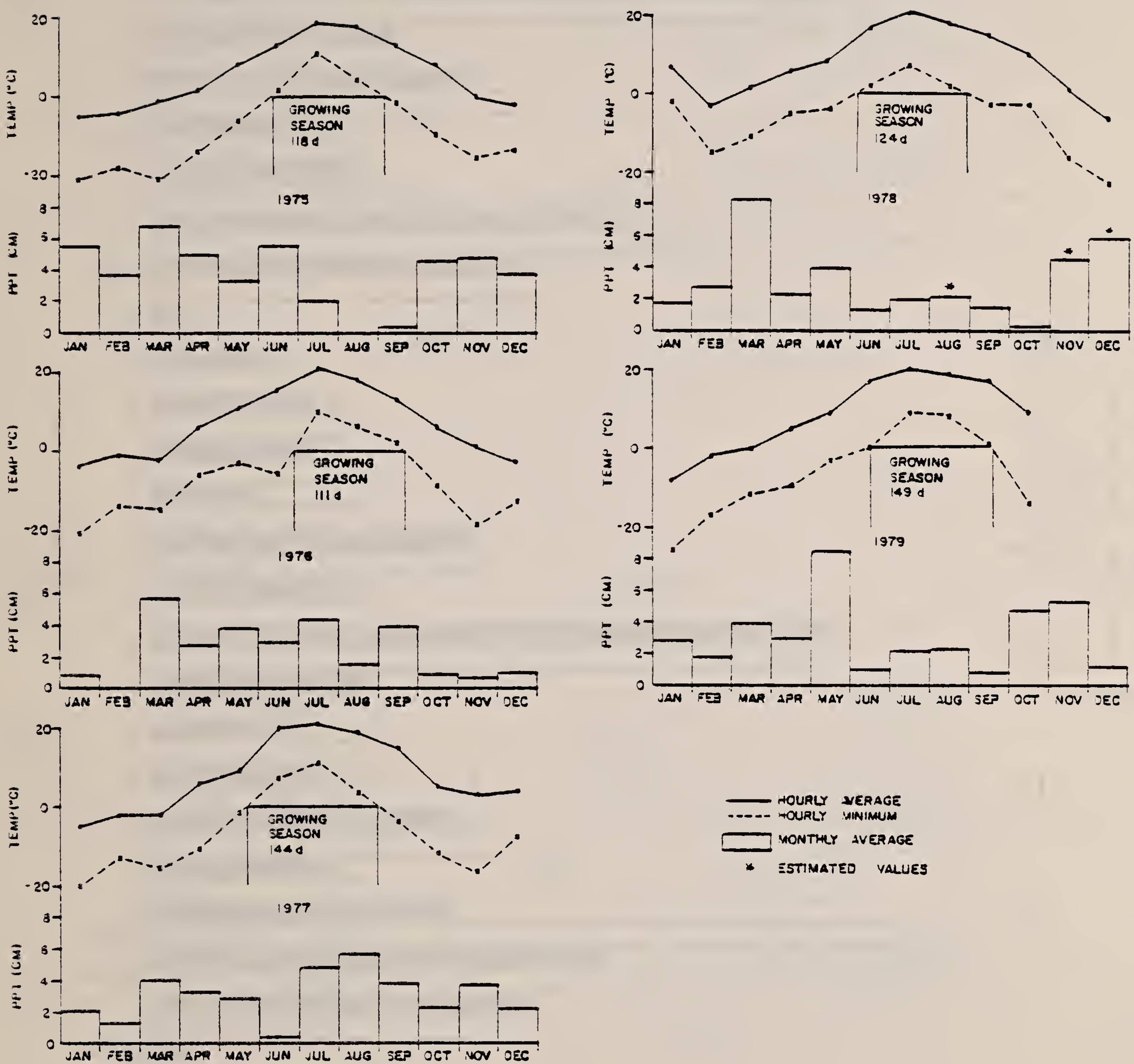


FIGURE 6.3.1-4
PRECIPITATION FOR STATIONS
AB20 AND AB23

= ESTIMATED TOTAL

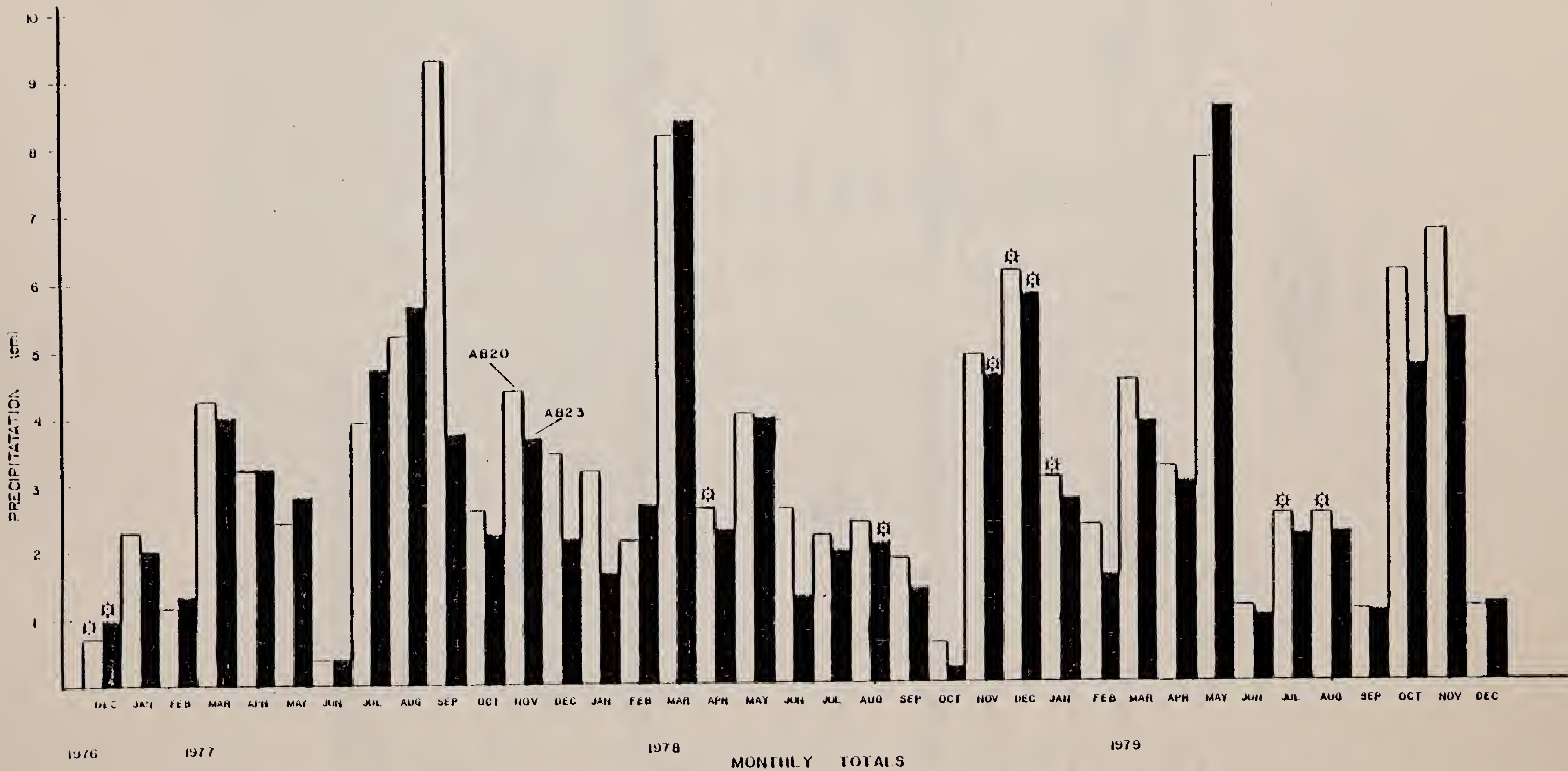
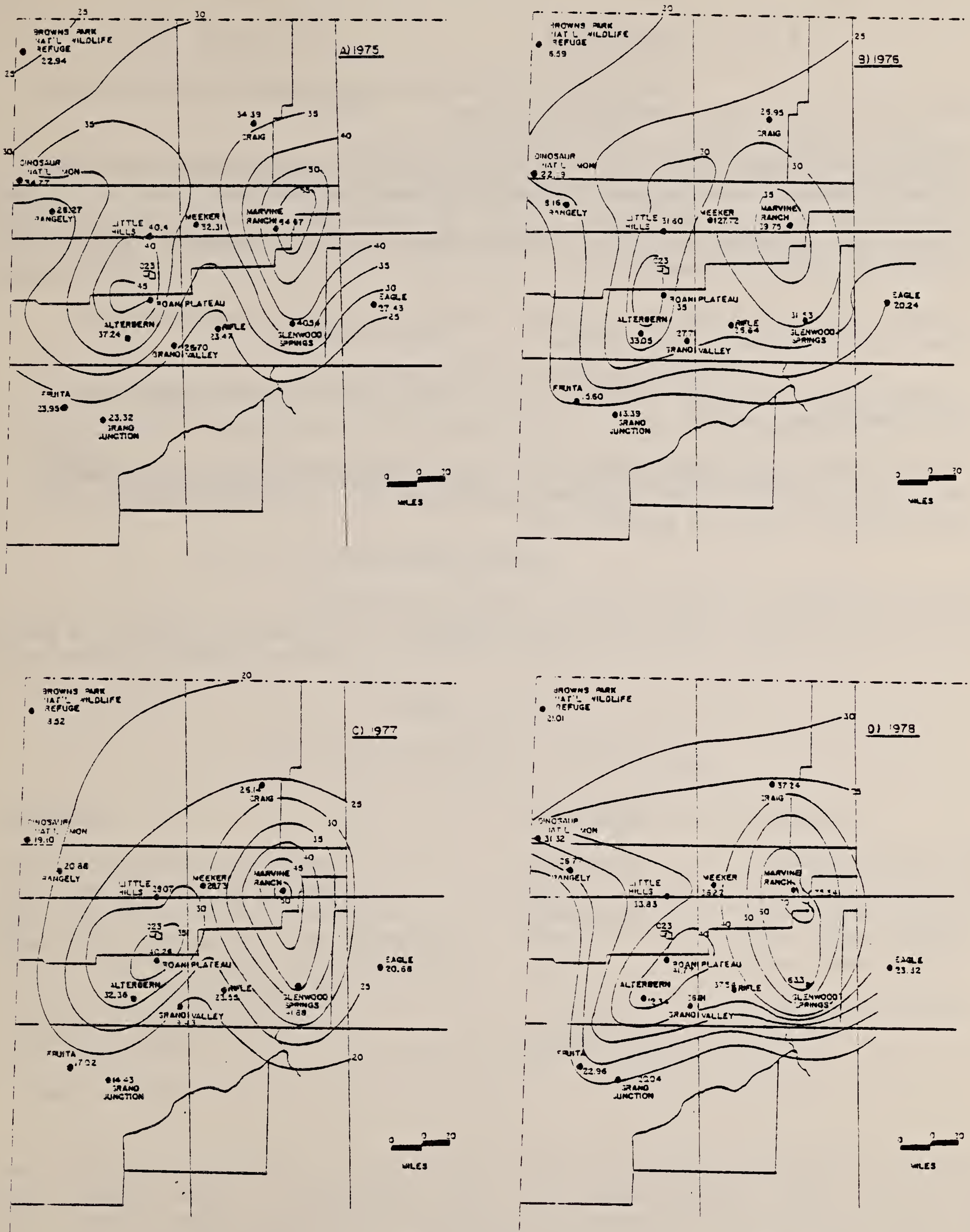


FIGURE 6.3.1-5
REGIONAL PRECIPITATION PATTERNS (ISOHYETS) (CM)



6.3.1.6 Conclusions

Conclusions supported by analyses from the addition of 1979 data to previously reported data are:

1. Monthly mean temperatures and variations in 1979 are consistent with the values from the past four years since the Baseline Report.

2. The maximum growing season for the past five years was recorded in 1979 (148 days, May 12-October 9).

3. Direct solar radiation for 1979 was within the range of previous years showing no substantial variations.

4. Annual means for relative humidity have been consistent throughout the five-year study period.

5. Precipitation for Station AB23 has a five year (1975-1979) annual average of 37.90 cm ranging from 35.8 cm in 1976 to 45.0 cm in 1975. Annual precipitation for 1979 was 36.7 cm.

6.3.2 Wind Fields

6.3.2.1 Scope

This section analyzes the wind field data collected at the meteorological tower, and Stations AB20, AB23, AD42 and AD56. Data consist of wind speed, wind direction, vertical variations in horizontal wind speed and wind direction and stability class. Wind flow patterns and stability class provide information for diffusion modeling and pollutant transport and concentration.

6.3.2.2 Objectives

The objectives of this program are:

a) To refine the knowledge of the wind fields in the vicinity of the C-b Tract,
b) to provide supporting information for air quality data analysis,
c) to provide inputs for air diffusion modeling.

6.3.2.3 Experimental Design

Sampling frequency for wind data is identical to that of the air quality parameters. Parameters measured at the various stations and instrumentation used are shown in Table 6.3.2-1.

TABLE 6.3.2-1

WIND FIELD PARAMETERS AND STATIONS

Parameter	Instrument	Station
10-m Horizontal wind speed	Anemometer	AB20,AB23,AD42,AD56
10-m Horizontal wind direction	Vane	AB20,AB23,AD42,AD56
30-m, 60-m Horizontal wind speed	Anemometer	Met Tower (AA23)
30-m, 60-m Horizontal wind direction	Vane	Met Tower (AA23)
10, 30, 60-m Horizontal wind direction standard deviation*	Vane	Met Tower (AA23)
ΔTemperature (60m to 10m)	ΔT Sensor	Met Tower (AA23)
Inversion height	Acoustic Radar	AB20

* Computed quantity

Near-surface wind fields are determined from continuous monitoring of winds at the 10 meter height. Measurements over three meteorological-tower levels along with acoustic radar and pibal trajectories provide data for vertical wind structure and stability conditions important for determining plume rise and for diffusion modeling.

6.3.2.4 Method of Analysis

Analysis in this section consists of comparisons of wind field data over time and between sites. Temporal comparisons are made by comparing quarterly wind roses over several years at a given site and elevation. Seasonal differences are noted. Time-series plots are presented for winds in the Time-Series Supplements to the Development Monitoring (data) Reports and in Figure A6.3.2-1 for November 1978 through October 1979. Spatial comparisons consist of comparisons of wind roses collected at different sites.

6.3.2.5 Discussion and Results

The Environmental Baseline Final Report, Volume 3, presents some detailed analyses of wind field data. Data collected since that report have been less extensive. Analyses presented here are in the form of extensions of some of the studies previously reported. It is discussed in two parts: a) near-surface wind fields, b) upper-air wind structure.

6.3.2.5.1 Near-Surface Wind Fields

Determination of predominant wind speed and wind direction can be made by examination of quarterly wind-roses over the seasons and from year to year. Figures A6.3.2-2 through A6.3.2-12 present the quarterly wind rose plots for two years for the various meteorological stations. A summary of predominant wind direction and speed is presented in Table 6.3.2-2. The predominant wind direction at the meteorological tower is SSW and there is virtually no change from year to year. Fall and Winter quarters have lower wind speeds than Spring and Summer at the 10 meter level. However, at the 30 meter level the wind speed difference between seasonal quarters is less. As expected, wind speeds at 30 meter level are higher than at the 10 meter level.

Stations located in or near Piceance Creek Valley (AB20, AD42, AD56) tend to show downstream (drainage) flow at night (E-ESE) and upstream flow (W-WNW) in daytime for all seasons with drainage predominant.

6.3.2.5.2 Upper-Air Wind Structure

Two analyses are presented in this section: a) Acoustic radar inversion and mixing data and b) atmospheric stability.

TABLE 6.3.2-2 WIND ROSE COMPARISONS

Site	Quarter	Predominant Wind Direction and Speed				
		1974-1975	1975-1976	1976-1977	1977-1978	1978-1979
Tower (AA23)	Fall			SSW (1-3)	SSW (<1)	SSW (1-3)
10 meter	Winter			SSW (1-3)	SSW (1-3)	SSW (3-5)
	Spring			SSW (5-8)	SSW (3-5)	SSW (1-3)
	Summer			SSW (5-8)	SSW (5-8)	SSW (1-3)
Tower (AA23)	Fall	S (5-8m/sec)	SSW (5-8)	SSW (5-8)	SSW (5-8)	SSW (3-5)
30 meter	Winter	SSW (5-8)	SSW (5-8)	SSW (8-11)	SSW (3-5)	SSW (3-5)
	Spring	SSW (5-8)	SSW (5-8)	SSW (8-11)	S (3-5)	SSW (5-8)
	Summer	SSW (5-8)	SSW (5-8)	SSW (5-8)	SSW (5-8)	SSW (5-8)
AB20	Fall			E (1-3)		
10 meter	Winter					
	Spring				ESE (1-3)	ESE (1-3)
	Summer				E (1-3)	ESE (1-3)
AD42	Fall					
10 meter	Winter					
	Spring				ESE (1-3)	E (1-3)
	Summer				E (1-3)	E (1-3)
AD56	Fall					
10 meter	Winter					
	Spring				SE (1-3)	SE (1-3)
	Summer				SE (1-3)	S (1-3)

a) Inversion and Mixing Heights

Temperature inversion heights are measured by means of an AeroVironment Model 300 Acoustic Radar. The instrument was reactivated at Piceance Creek Station AB20 in November, 1977. The output of the instrument is a continuous strip chart record of reflected sound signals associated with thermal turbulence signatures; such signatures vary in character depending on whether the atmosphere is stable or unstable. The chart provides a means for determining the height in meters of temperature inversions and mixing layers above ground level.

Figure A6.3.2-13 shows average monthly inversion heights for months of September, 1978 through August, 1979. The months are grouped by quarters to show seasonal patterns. Plots have been limited to hours with expectation of occurrence greater than 0.5. Quarterly average inversion height, onset time, breakup time, and duration are shown in Table 6.3.2-3.

TABLE 6.3.2-3

INVERSION HEIGHT AND DURATION
(Quarterly Averages)

Months (Quarter)	Average Height (m)	Onset Time	Breakup Time	Duration (Hours)
SEPTEMBER '78 OCTOBER NOVEMBER	303	1720	0820	15.7
DECEMBER JANUARY '79 FEBRUARY	310	1700	0940	16.7
MARCH APRIL MAY	323	1800	0740	13.7
JUNE JULY AUGUST	272	1900	0720	12.3

In the late morning, surface temperature rises faster than the upper air temperature and the inversion begins to break from the ground up. The temperature-altitude profile is similar to that in Figure 6.3.2-1 with the mixing height increasing later in the morning until the inversion completely dissipates.

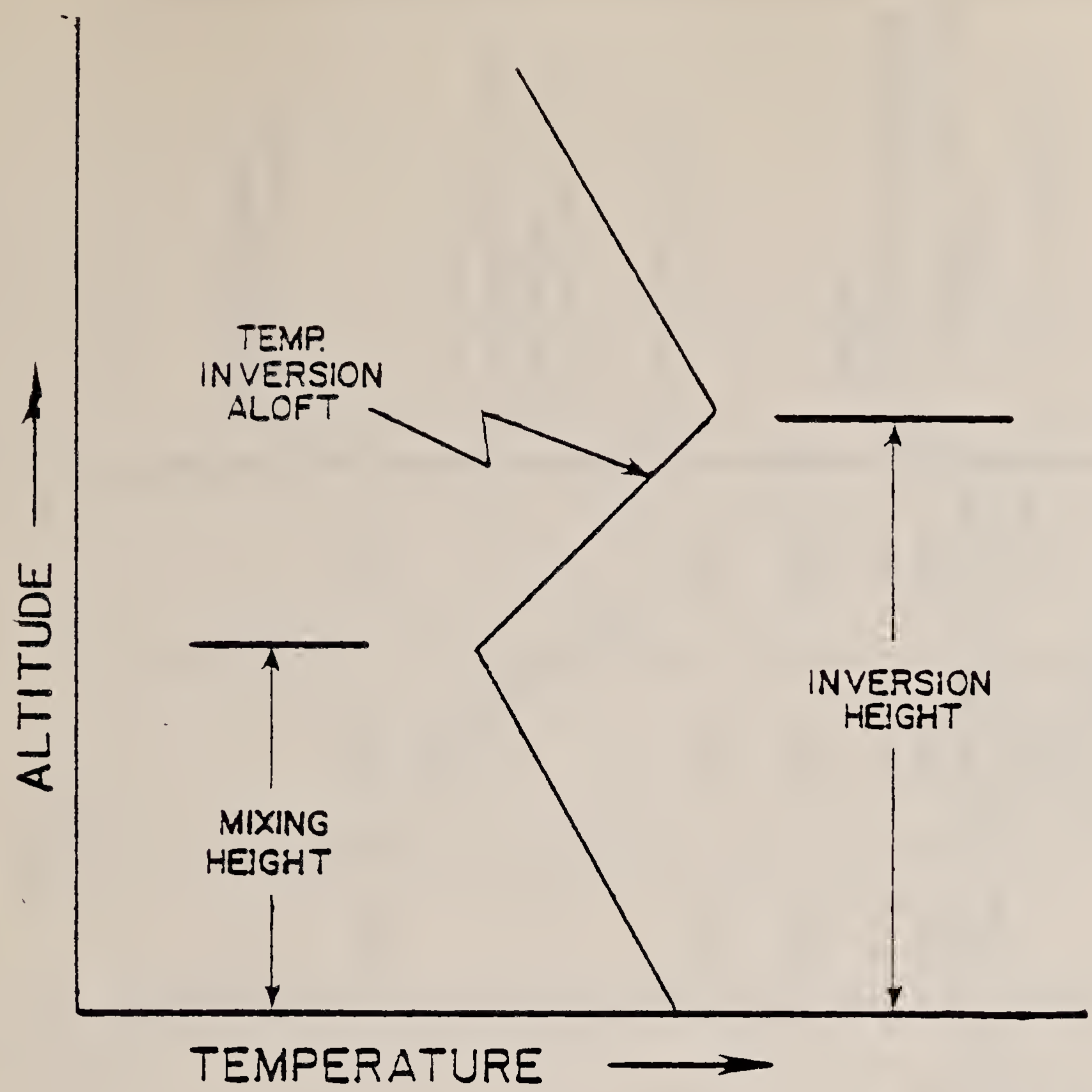


Figure 6.3.2-1
Temperature-Altitude Profile of an Elevated Inversion

For inversions aloft, the air layer between the mixing height and the top of the inversion is stable and very little diffusion of stack emissions occurs in this air layer. Any stack emissions below the mixing height are constrained by the inversions "lid" provided thermal buoyancy of the plume is not great; otherwise this layer can be penetrated. Stack emissions above the inversion height will not penetrate down through the inversion.

Afternoon mixing layer height (d_{mix}) has been assessed utilizing the upper-air-study of both 1974-1975 (aircraft) and 1978 (pibal). Table 6.3.2-4 summarizes these results by month indicating the number of sample days, those samples for which d_{mix} was below the top of the record (normally found to be around 1800 meters for pibals), and those sample days for which d_{mix} was not obtained (due to surface inversions, neutral layers or d_{mix} above the top of the record). The monthly minimum value of d_{mix}, the maximum (recorded) and the average of the recorded values are shown. Based on these data, Figure 6.3.2-2 shows the variations in d_{mix} with time of year, with minima shown to occur in winter-time and maxima in summer. A winter time-average minimum of 1500 meters is judged to be representative for this time of year; summer-time averages were above the top of the record near 1800 meters.

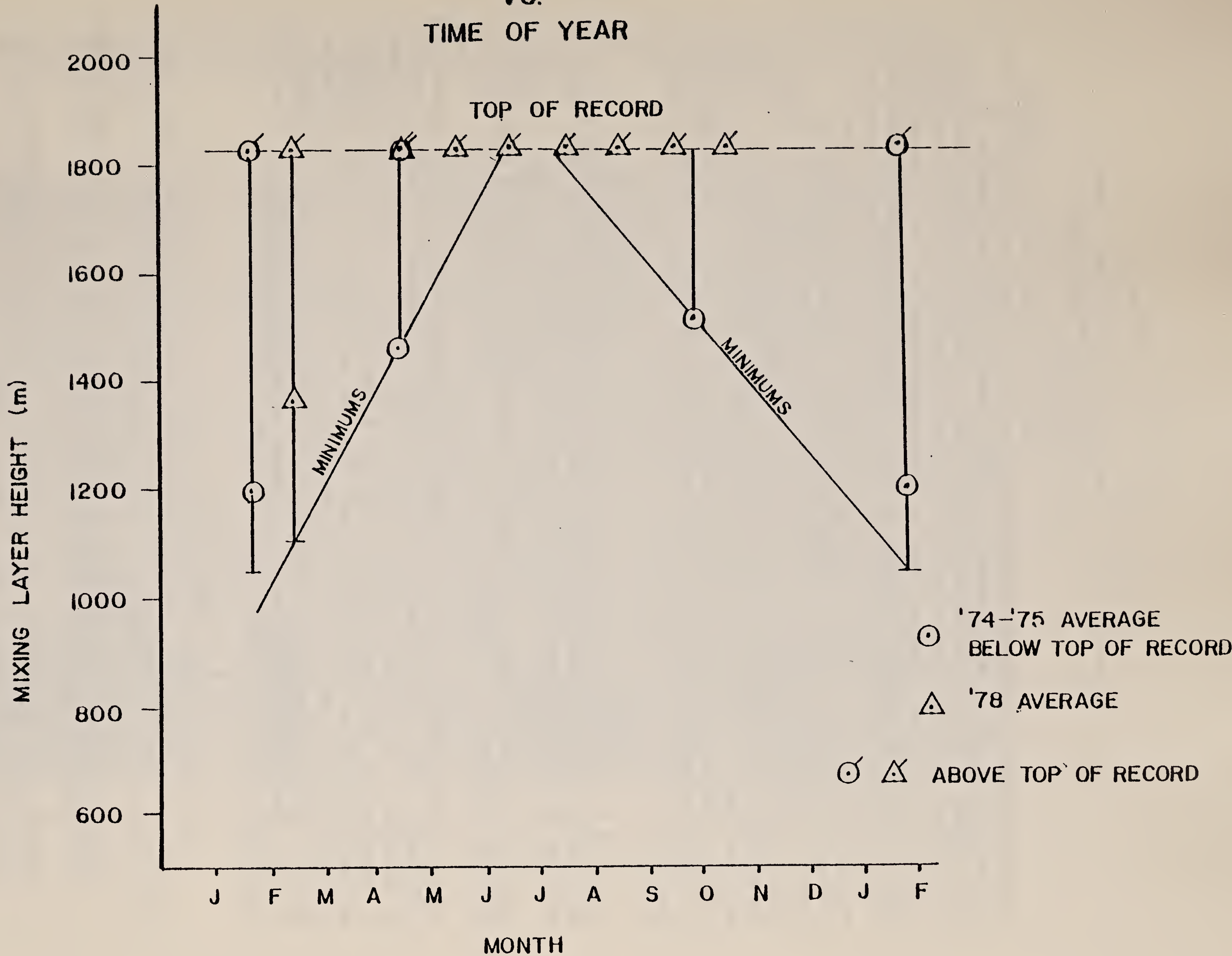
TABLE 6.3.2-4

AFTERNOON MIXING LAYER HEIGHT (d_{mix}) (meters above surface)

Month/Year	Total Number of Sample Days	No. of Sample Days d_{mix} Not Obtained Because of: Surface Inversion Exists	Neutral Layer	Unstable Surface Layer with Neutral Above	d_{mix} Above Top of Record*	No. of Sample Days When d_{mix} Obtained	d_{mix} (meters): Minimum Value	Maximum Value (below top of record)	Average of All Values	Comments
October 1974	8				6	2	1494	1524	1509	
January-February 1975	13	1	1		6	5	1037	1494	1199	2 very weak not included in average
April 1975	13				12	1	1463	1463	1463	
July 1975	12				12					
February 1978	11		2		7	2	1100	1650	1375	
March 1978	6	1			5					1 day of partial data
April 1978	8				8					
May 1978	10				9					1 very weak d_{mix} at 920 m not counted
June 1978	12				11					1 very weak d_{mix} at 210 m not counted
July 1978	11	1	1		9					
August 1978	10			2	7	1	3300	3300	3300	
September 1978	8	2			6					
October 1978	11	1			8	2				Weak d_{mix}'s at 450 m 200 m not counted
November 1978	5	2		1	1					

*Top of Record Usually Near 1800 m

FIGURE 6.3.2-2
AFTERNOON MIXING LAYER HEIGHT
VS.
TIME OF YEAR



b) Stability Class Study

Monthly average stability classes have been derived from hourly stability class data. The hourly stability classes were based on delta temperature measurements from the 60-meter to the 10-meter levels on the meteorological tower. Pasquill-Gifford stability classes were determined from the slope of the temperature altitude curve (dt/dz) and adjusted for wind speed by the method described in the Baseline Report, Volume 3. Monthly averages by hour from the period from November, 1976 through October, 1979 are shown in Table 6.3.2-5 for the months containing more than 50% of the data. Unstable, neutral, and stable class are indicated by variable shading. Comparison of these data with the baseline period (November, 1974 through October, 1976) shows similar patterns for the broad classifications of unstable, neutral, and stable classes. The period for November, 1976 through May, 1977 is very similar to the same months in the baseline years. However, 1978 and 1979 data for January-March and July-September tended to reflect a shift in stability class toward the stable end of the scale (toward Class F) by one Pasquill-Gifford stability class for most of the monthly averages by hour. No clear explanation can be identified for this.

Table 6.3.2-6 presents the percentage of hours in each stability class for each month. The baseline data are included for comparison. This table also reflects the shift to the more stable classes for 1978-1979.

Typically the hours between 0900 and 1900 are unstable. Nighttime and early mornings are typically stable.

The above atmospheric stability is based on the meteorological-tower temperature difference. For high-altitude, pollutant releases atmospheric stability should be assessed at the effective stack height of the plume; of course, this height is dependent on individual stack height and plume buoyancy. A 1000-foot height has been selected as representative and the four-quarters of aircraft flights of 1974-1975 at (normally) 15 flight-days per quarter and 4 flights per flight-day have been re-examined and summarized on Table A6.3.2-1. For all flights the only Pasquill-Gifford stability classes existing were D's and E's at a 1000-foot height and for at least another 1000-foot above this.

6.3.2.6 Conclusions

Conclusions supported by the analysis of wind-field data are:

1. Predominant wind direction at the meteorological tower site on Tract is SSW; this has not changed over time.

2. Predominant wind direction in and near Piceance Creek is downstream (from east and southeast) over most of the nighttime and early morning. Daytime direction reverses to upstream flow.

TABLE 6.3.2-5

AVERAGE HOURLY STABILITY CLASSES (1976-1978)

SOURCE: Temperature differences between 60 meters and 10 meters on the Meteorological Tower

(Adjusted for Wind Speed)

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
November*																									
December*																									
January 1975	D	D	D	D	D	D	D	D	E	E	E	E	D	D	D	D	D	D	D	E	D	D	D	D	D
February	E	E	E	E	E	E	E	E	E	D	D	C	D	C	C	D	D	E	E	E	E	E	E	E	E
March	D	D	D	D	D	D	D	D	C	C	C	C	C	C	D	D	C	C	D	D	D	D	D	D	D
April	D	D	D	D	D	D	D	B	C	C	C	C	C	C	C	C	C	C	C	D	D	D	D	D	C
May	D	D	D	D	D	D	D	B	B	B	C	C	C	C	C	C	C	C	C	C	D	D	D	D	C
June	E	E	E	E	E	E	D	B	D	B	B	C	C	B	C	C	C	C	C	C	D	D	E	E	D
July	1	1	1	1	1	1	1	1	1	1	1	B	B	B	B	B	B	C	1	1	1	1	1	1	
August	E	E	E	E	E	E	E	E	C	B	C	C	C	C	C	C	C	C	D	E	E	E	E	E	D
September	E	E	E	E	E	E	E	E	B	B	B	B	B	C	B	B	C	B	E	E	E	E	E	E	D
October	E	E	E	E	E	E	E	E	C	B	B	C	B	C	C	C	B	C	D	D	E	E	E	E	D
November	D	D	D	D	D	D	D	D	C	B	B	B	C	B	B	B	B	C	D	D	D	D	D	D	D
December	D	D	D	D	D	D	D	D	C	C	B	B	B	B	B	B	B	C	C	C	D	D	D	D	C
January 1976	D	D	D	D	D	D	D	D	D	C	B	B	B	B	B	B	B	B	C	C	D	D	D	D	D
February	D	D	D	D	D	D	D	D	C	C	C	C	C	C	C	C	B	B	C	D	D	D	D	D	C
March	D	D	D	D	D	D	D	C	C	C	B	B	C	C	C	B	C	C	B	C	C	C	C	C	C
April	D	D	D	D	D	D	D	B	B	C	C	C	C	C	C	C	C	C	C	D	D	D	D	D	C
May	E	E	E	E	E	E	D	B	B	B	B	B	B	B	B	B	B	B	C	D	D	E	E	E	C
June	E	E	E	E	E	E	E	C	C	C	C	C	C	C	C	C	C	C	C	D	E	E	E	E	D
July	E	E	E	E	E	E	E	B	B	B	B	B	B	C	B	B	B	B	B	D	E	E	E	E	D
August	E	E	E	E	E	E	E	C	B	B	C	C	C	C	C	C	C	C	C	E	E	E	E	E	C
September	E	E	E	E	E	E	E	D	B	B	B	B	B	B	B	B	B	B	D	D	D	E	E	E	D
October	E	E	E	E	E	E	E	B	B	B	B	B	B	B	B	B	B	C	D	E	E	E	E	E	D
November*	E	D	D	E	D	E	E	E	D	A	A	B	B	B	B	B	B	D	D	D	E	E	E	E	D*
December	E	E	E	E	E	E	E	E	E	C	B	B	B	B	B	B	B	D	D	D	E	E	E	E	D
January 1977	D	D	E	D	E	D	D	E	D	C	B	B	B	B	B	B	B	C	D	D	D	D	D	D	C
February	E	E	E	E	E	E	E	E	D	C	A	B	B	B	B	B	B	B	C	D	D	D	D	E	D
March	D	D	D	D	D	D	D	C	B	B	C	C	C	C	C	C	C	B	C	D	D	D	D	D	C
April	D	E	E	E	D	E	D	B	B	B	B	B	C	C	C	C	C	B	C	D	D	E	D	D	C
May*	D	D	D	D	D	D	D	B	C	C	D	C	C	D	D	D	D	D	C	D	D	D	D	D	C*
June**																									
July**																									
August**																									
September**																									
October**																									
November**																									
December**																									
January 1978	E	E	E	E	D	E	E	E	E	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
February*	E	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E*
March*	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E*
April**																									
May**																									
June**																									
July*	F	F	F	F	F	F	F	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E*
August*	F	F	F	F	E	E	E	E	D	D	C	C	C	C	C	D	D	D	D	E	E	E	E	E	E*
September*	F	F	F	F	F	E	E	E	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E*
October	F	F	F	F	F	F	F	E	E	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E
November	E	E	E	E	E	E	E	E	E	E	E	E	D	D	D	D	E	E	E	E	E	E	E	E	E
December	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
January 1979	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
February	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
March	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	D	D	D	E	E	E	E	E	E	E
April	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
May	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
June	E	E	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E
July	E	E	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E
August	E	E	E	E	E	E	E	E	E	D	C	D	D	C	D	D	D	D	E	E	E	E	E	E	E
September	E	E	E	E	E	E	E	E	E	D	C	C	C	C	C	C	D	D	E	E	E	E	E	E	E
October	E	E	E	E	E	E	E	E	E	D	C	C	C	D	D	D	D	D	E	E	E	E	E	E	E

*Partial data only, less than 100% but more than 50%

**1 Missing Data

Key:
- (slashed box) Unstable
- (open box) Neutral
- (shaded box) Stable Class

TABLE 6.3.2-6

METEOROLOGICAL SUMMARY: STABILITY CLASS FREQUENCIES (%)

SOURCE: Meteorological Tower (30' to 200')

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1974 November[2]	1974 December[2]	1975 January	February	March	April	May	June	July[3]	August	September	October	Annual Mean
A	<-1.9			8.3	1.0	1.1	12.0	7.4	8.6	0.0	2.4	5.8	8.1	6.1[4]
B	-1.9 to -1.7			5.5	4.4	10.3	23.5	30.6	25.6	85.7	19.3	23.4	20.6	18.1
C	-1.7 to -1.5			4.1	2.4	16.3	6.9	9.3	6.9	14.3	6.1	5.0	5.7	7.0
D	-1.5 to -0.5			33.0	43.4	60.9	36.3	30.0	27.0	0.0	25.8	13.4	28.3	33.1
E	-0.5 to +1.5			33.3	36.8	11.4	18.1	12.1	18.0	0.0	17.3	24.4	18.6	21.1
F	>1.5			15.8	12.0	0.0	3.2	10.6	13.9	0.0	29.1	28.0	18.7	14.6
	TOTAL PERCENTAGE			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1975 November	1975 December	1976 January	February	March	April	May	June	July	August	September	October	Annual Mean
A	<-1.9	15.6	18.8	24.9	13.8	19.4	9.5	17.5	4.6	10.3	7.4	13.1	13.6	14.0
B	-1.9 to -1.7	19.7	20.7	21.3	22.1	27.0	21.7	26.3	17.4	30.5	18.4	25.5	20.6	22.6
C	-1.7 to -1.5	6.9	7.4	5.6	7.7	7.9	9.7	6.0	10.0	5.6	6.7	6.1	5.6	7.1
D	-1.5 to -0.5	23.7	21.5	16.6	35.7	28.7	35.2	21.0	32.7	14.1	27.6	17.5	17.9	24.4
E	-0.5 to +1.5	22.9	23.5	21.0	13.8	15.6	17.0	15.6	17.6	19.5	23.0	20.7	21.2	19.3
F	>1.5	11.2	8.1	10.6	6.9	1.4	6.9	13.6	17.6	20.0	16.9	17.1	21.1	12.6
	TOTAL PERCENTAGE	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1976 November	1976 December	1977 January	February	March	April	May	June	July	August	September	October	Annual Mean
A	<-1.9	18.6	12.3	18.0	12.9	12.9	12.9	5.9						13.3
B	-1.9 to -1.7	19.8	20.7	18.5	27.7	21.6	29.6	13.3						21.6
C	-1.7 to -1.5	4.3	7.1	6.8	7.3	7.9	8.1	9.2						7.2
D	-1.5 to -0.5	12.5	16.2	20.9	12.1	30.1	19.0	46.6						22.5
E	-0.5 to +1.5	27.4	23.7	25.4	26.3	19.3	18.1	17.8						22.6
F	>1.5	17.4	20.0	10.4	13.7	8.2	12.6	7.2						12.8
	TOTAL PERCENTAGE	100.0	100.0	100.0	100.0	100.0	100.0	100.0						100.0

TABLE 6.3.2-6 (Continued)

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1977 November[5]	December[5]	1979 January	February[3]	March[3]	April[5]	May[5]	June[5]	July[3]	August[3]	September[3]	October	Annual Mean
A	<-1.9			0.7	0.3	0.3				0.0	0.2	0.0		
B	-1.9 to -1.7			0.3	2.1	0.5				2.3	6.1	2.6		
C	-1.7 to -1.5			4.4	2.9	1.9				5.9	5.7	2.6		
D	-1.5 to -0.5			52.0	48.0	47.4				43.2	35.6	40.1		
E	-0.5 to +1.5			28.2	32.9	24.8				19.5	22.5	23.5		
F	>1.5			14.4	13.8	25.1				29.1	29.9	31.2		
	TOTAL PERCENTAGE			100.0	100.0	100.0				100.0	100.0	100.0		

Pasquill-Gifford Stability Class	dT/dz Range[1] for this Stability Class (°C/100m)	1978 November	December	1979 January	February	March	April	May	June	July	August	September	October	Annual Mean
A	<-1.9	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.4	1.3	1.0	1.2	1.8	0.5
B	-1.9 to -1.7	0.0	0.2	0.0	0.0	0.0	0.1	0.5	0.6	4.7	7.8	9.4	5.3	2.4
C	-1.7 to -1.5	0.1	0.0	0.0	0.0	0.0	2.2	3.6	1.8	1.8	4.5	5.8	4.3	2.0
D	-1.5 to -0.5	20.9	26.8	16.4	19.4	24.4	46.3	42.3	41.6	24.3	21.6	18.3	26.9	27.4
E	-0.5 to +1.5	53.6	51.5	60.5	54.4	57.6	29.1	33.7	27.0	30.4	31.4	20.4	29.0	39.8
F	>1.5	25.4	21.5	23.1	26.2	17.9	22.3	19.9	28.6	37.5	33.7	44.9	33.7	27.9
	TOTAL PERCENTAGE	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1]Adjusted for wind speed

[2]Data are suspect and, therefore, not included

[3]Partial data

[4]Averaged from January-October, excluding July

[5]Missing data

[6]Data for July and August not available for this report

3. Wind speed and direction have not changed significantly over the years from baseline through 1979. Spring and summer show higher wind speeds than fall and winter.

4. Temperature inversions typically in the Piceance Creek Basin occur in the nighttime with onset about an hour before sunset and break up next morning several hours after sunrise. Inversion heights from September, 1978 through August, 1979 were fairly stable averaging 302 meters. The atmosphere is typically unstable between hours 0900 and 1900.

5. Afternoon mixing layer heights vary from average values near 1500 meters in winter to above 1800 meters (typically the top of the record) in summer.

7.0 NOISE

7.1 Introduction and Scope

The environmental noise program conducted since baseline is not required under the Lease but was requested by the Area Oil Shale Supervisor. General background noise levels were sought on the Tract and surrounding vicinity prior to Tract development. Monitoring of those levels was re-initiated in February, 1978 at the three sites shown in Figure 7.1.1-1 to determine the effects of Tract development on noise levels and has continued through the development period.

7.2 Environmental Noise

It is to be noted that occupational noise exposure is treated in Chapter 10.0 of this report. Aspects of environmental noise treated here deal with traffic and Tract-generated noise levels.

7.2.1 Traffic Noise

7.2.1.1 Scope

The traffic noise study was originated during baseline. Measurements were made one working day per month for approximately one hour at each of 14 locations over a 14-month span starting in September 1975. Measured noise levels (A weightings) above background at two locations along Piceance Creek Road were always made in the presence of passing vehicles. The noise analysis contained in the final baseline report indicated an average level at a station on Piceance Creek Road near Hunter Creek to be 53dbA which was exceeded ten percent of the time.

On the basis of low noise levels existing during baseline as indicated in the final baseline report, it was felt that continued discrete measurements were warranted at only two of the original 14 locations. Stations NA02 and NA09 are located to indicate traffic noise levels associated with development.

7.2.1.2 Objective

To measure potential increases in traffic noise levels due to development.

7.2.1.3 Experimental Design

Discrete traffic noise measurements are made one per day per week in the presence of passing vehicles at Stations NA02 and NA09 (Figure 7.1.1-1) along Piceance Creek Road and on the access road at the Tract boundary, respectively. The General Radio 1565 Sound Level Meter (SLM) is used to measure peak noise levels at A weightings. Background levels are obtained the same day at A, B, and C weightings.

7.2.1.4 Method of Analysis

At each of the two stations, peak noise levels are measured weekly. Four weekly composite peak measurements are then averaged.

FIGURE 7.1.1-1

NOISE ENVIRONMENTAL MONITORING NETWORK

● TRAFFIC NOISE STATION - PEAK MEASUREMENT - 1 DAY/WEEK

■ TRACT NOISE SURVEILLANCE - CONTINUOUS - EVERY 6th DAY

7.2.1.5 <u>Discussion and Results</u>

Figure 7.2.1-1 shows a time plot of peak traffic noise levels and background levels for the C-b Tract. The highest noise level of 91 dbA occurred on June 30, 1978 at Station NA02 from a passing semi-trailer truck; the background noise level at that time was 44 dbA. The peak noise level indicated in the final baseline report was 83 dbA from a road scraper in July 1976. The percent of monthly peaks exceeding this level decreased from 75% in 1978 to 65% in 1979; on the average, the monthly peaks during the development period remain nine db higher than those during baseline.

7.2.1.6 <u>Conclusions</u>

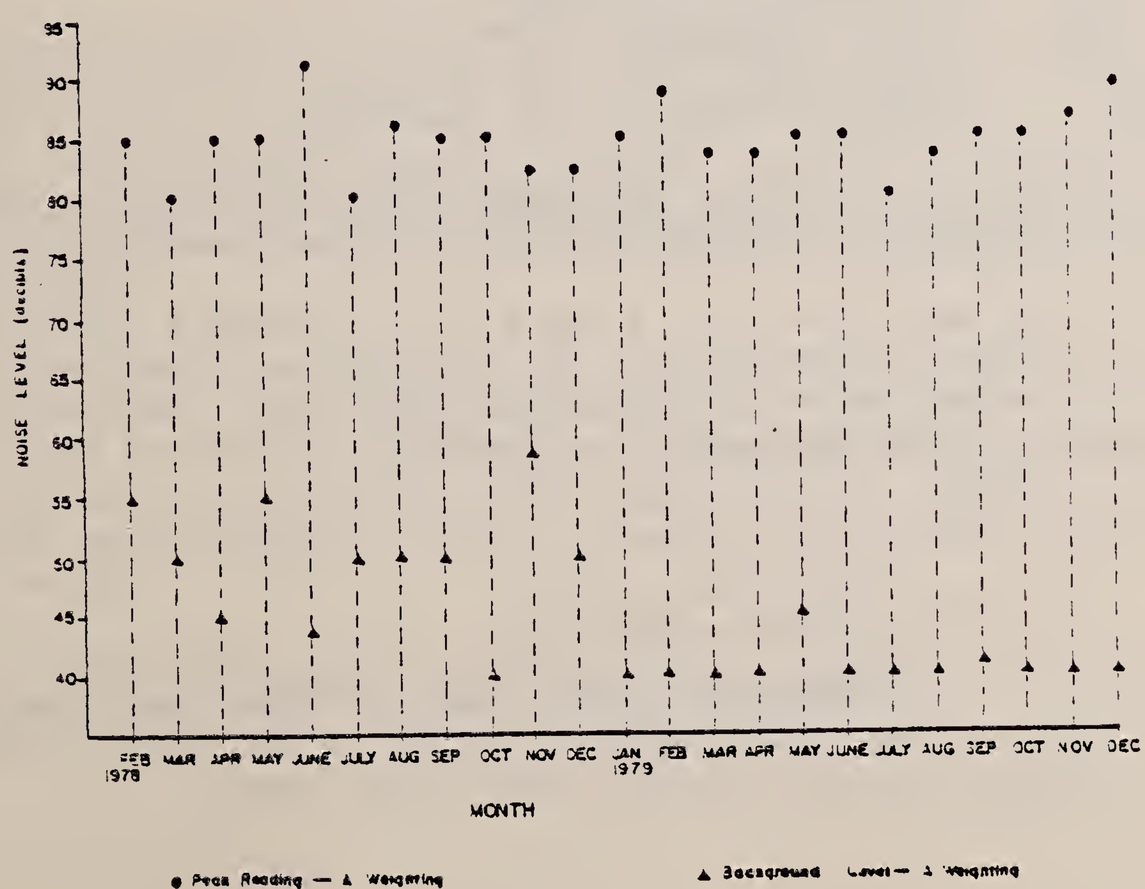
Monthly peak noise levels and background levels during the development period exceed those of the baseline period by an average of nine dbA. This increase is most likely due to development activity.

7.2.2 Tract Noise

7.2.2.1 <u>Scope</u>

During the initial phases of development much activity occurs near the northern boundary of the Tract. Thus a noise monitoring site in the vicinity of operations is most appropriate for monitoring noise levels on the Tract due to early development.

FIGURE 7.2.1-1
TRACT C-b PEAK TRAFFIC NOISE READINGS
(1978-1979)



7.2.2.2 Objectives

The objectives of the Tract noise study are 1) to evaluate increases in Tract noise due to Tract development, and 2) to demonstrate compliance with State noise regulations.

State noise standards for an industrial zone are as follows in terms of maximum allowable noise levels:

Steady:	80 db(A)	7am to next 7pm
	75 db(A)	7pm to next 7am
15 min. in any one hour:	90 db(A)	7am to next 7pm
Periodic, impulsive, shrill:	75 db(A)	7am to next 7pm
	70 db(A)	7pm to next 7am

These standards apply within 25 feet of the property line (Tract boundary); it is to be noted that the Tract has not been classified industrial at this time.

7.2.2.3 Experimental Design

Continuous noise measurements are made at Station NB15 (Figure 7.1.1-1) on the northern boundary of the Tract for 24 hours every sixth day. The sensor recording system consists of the following B & K instruments:

Model 2203	Precision Sound Level meter (SLM) with 0.5" microphone
Model 4230	Portable Acoustic Calibrator
Model UA 0393	Microphone Rain Cover
Model UA 0381	Wind Screen with Spikes
Model UA 0308	0.5" Dehumidifer
Model 2306	Portable Graphic Level Recorder

In this model the SLM is coupled to the battery operated linear recorder for 24 hours of unattended all-weather operations at an A-weighting.

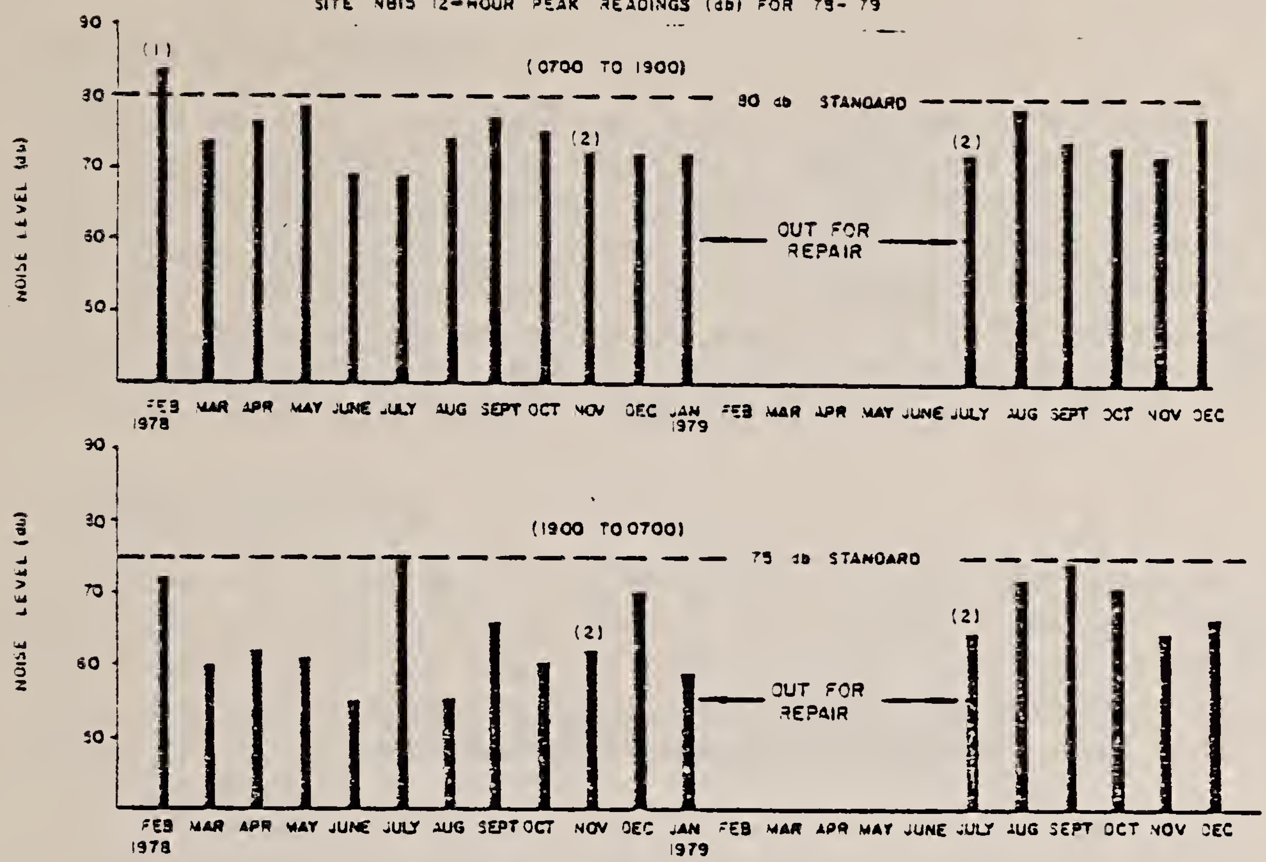
The SLM is calibrated before each day's use with its portable acoustic calibrator to ± 0.25 db accuracy at 93.6 db, 1 kHz. The linear recorder for a range is calibrated before and after each day's use. Thus any drifts are readily apparent. Time references are annotated before and after operation.

7.2.2.4 Method of Analysis

Twelve-hour peaks (7am - 7pm and 7pm - 7am) are reported along with averages and background levels for each day of observations. Figure 7.2.2-1 presents the peak 12-hour Tract noise levels.

FIGURE 7.2.2-1

TRACT C-b NOISE STANDARDS COMPLIANCE
SITE NB15 12-HOUR PEAK READINGS (db) FOR '78-'79



(1) IN 2-13-78 FOR 0700-1900 PEAK DID NOT EXCEED 90 db FOR 15 MINUTES IN ANY HOUR.

(2) PARTIAL DATA ONLY.

7.2.2.5 Discussion and Results

The peak Tract noise level reading of 83 dbA occurred on the first day of monitoring in February 1978; that peak did not exceed 90 dbA for 15 minutes in any hour. All other readings through December 1979 were below 80 dbA from 0700 to 1900 and below 75 dbA from 1900 to 0700. The arithmetic average decibel level during the development period for both 12-hour periods was less than 44 dbA. However, Tract noise was not monitored during six months of 1979 while the SLM was being repaired by the manufacturer.

7.2.2.6 Conclusions

1. Noise levels in the Tract area due to development activities have, for the most part, remained low. Average levels of neither 12-hour period appear to have increased significantly over the development period.

2. Compliance with State noise standards for an industrial zone was achieved; the Tract is not classified industrial at this time.

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8.0 BIOLOGY

8.1 Introduction and Scope

The goal of the biological monitoring program is to continue evaluation of biotic conditions and identify interactions with abiotic conditions in the Tract C-b ecological systems. The majority of monitoring parameters are those that provide information relative to early warning signals of change. The use of control and development sites permits the monitoring of long-term trends at affected and non-affected sites, and the analysis of any corresponding differences developing over time at these sites. Monitoring sites are shown in Exhibit C.

8.2 Big Game: Mule Deer

Big game refers primarily to mule deer, since they are the only large mammals common to the C-b area apart from domestic cattle. Intensive studies of mule deer are justified since deer are a major herbivore of ecological importance and a game species of economic importance. In addition, they are vulnerable to impact from development activities, road kill, and increased hunting pressure.

Monitoring of mule deer attempts to show the significance of Tract C-b to their survival. This is accomplished through analyses of the following variables: 1) deer pellet group densities, 2) browse production and utilization, 3) migrational patterns and phenology, 4) road kills, 5) natural mortality, and 6) age-class composition. Study transects and sample sizes are based on baseline experience.

8.2.1 Deer Pellet Groups

8.2.1.1 Scope

Pellet group counts were conducted along 30 permanent transects. Twelve transects are located on Tract; nine are located on Big Jimmy Ridge, approximately one and one-half miles to the west; six are located north of Piceance Creek, approximately one and one-half miles to the north (in Exhibit C).

8.2.1.2 Objectives

The objectives of pellet group studies are to evaluate differences on a site specific basis and over time in order to make inferences regarding the possibility of positive or negative effects on deer due to development activities.

8.2.1.3 Experimental Design

Transects were located using a stratified random design, except at certain development locations where the placement of a transect was predetermined. Two strata (habitat types) were sampled: pinyon-juniper woodland and chained pinyon-juniper. Eighteen transects were located in the chained habitat type and twelve transects were located in the pinyon-juniper woodland. Three transects were newly established this year at fertilized locations. All pellet group transects have a BA notion. Their exact locations are shownin Exhibit C.

8.2.1.4 Method of Analysis

All statistical analyses for the 1978-79 period are standard parametric procedures including the analysis of variance, t-test, product-moment correlation coefficient, and others. Such procedures as a priori comparisons and one-tailed tests are explained where appropriate.

8.2.1.5 Discussion and Results

This year's report stresses an analytical approach, which would have been premature in past reports owing to the fact that development activites are just now of a sufficient magnitude to warrant a close examination of their possible effects on deer and deer habitat.

In last year's report a two-year comparison was made of pellet group counts obtained from twelve transects (see 1978 C-b Annual Report, Figure 8.2.1-1). In this year's report pellet group count comparisons are again made for these original twelve transects, and for an additional fifteen transects which were added the fall of 1977 (Figure 8.2.1-1 of this report). The data shown are for transects which functioned throughout the winter periods consistent with the research design.

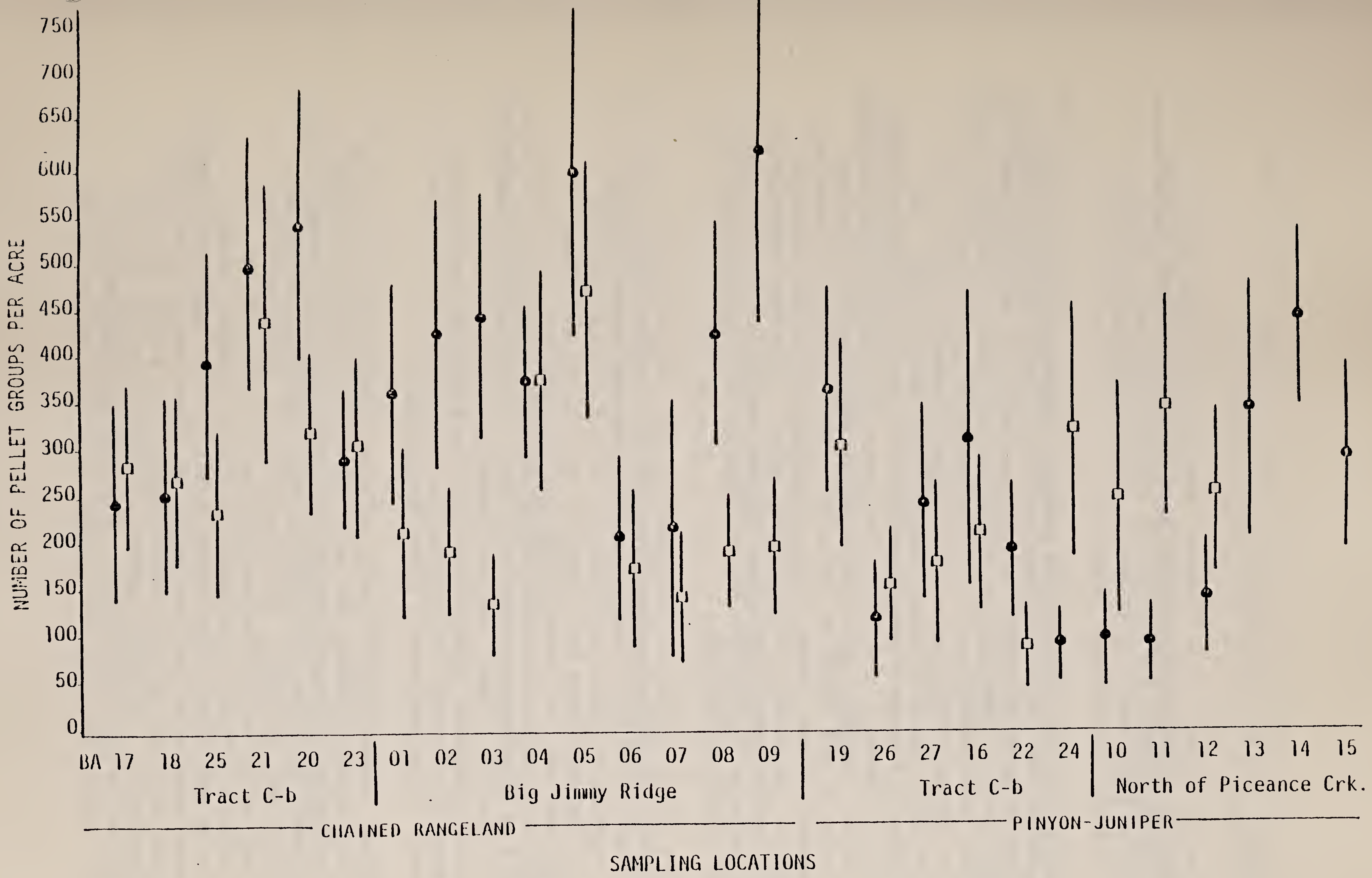


Figure 8.2.1-1 Trends in pellet group densities. Data are means ± 95 percent confidence intervals. Closed circles are 1977-78 data; open squares are 1978-79 data.

From these results (Figure 8.2.1-1) several generalizations seem valid. Namely, little if any correlation appears to exist in the pattern of pellet group distributions between the 1977-78 and 1978-79 years, and a slight decline in pellet group densities appears to have occurred during 1978-79. These two points will be addressed later.

Of primary concern at this point are any potential changes due to oil shale development whether they are due to impacts or to mitigation which, at the present, is restricted to two fertilization experiments. To evaluate these possibilities a single-factor analysis of variance was used to obtain an estimate of the "error mean square". This value singles out the variation within all the transects from the variation between transects (that is, it ignores the variation due to transect location or to habitat type). This allows prediction of a range within which a value for any given transect should lie if there is no change in the factors that previously determined the observed natural variation. Following this, four transects were carefully examined. These four transects were chosen on the basis of their proximity to locations where developmental effects seemed likely. They were not chosen because of relatively high or low values for the 1978-79 period. Therefore, examination of these four transects was planned ahead of time, and in such a priori comparisons the method of least significant differences, which was used here, is an appropriate analytical procedure.

Results of this analysis (Tables 8.2.1-1 and 8.2.1-2) indicate that observed differences in pellet group densities (the $\bar{X}$'s) between control and development sites at the four transect locations examined are not outside the range of expected or normal variation. It should be noted that both one- and two-tailed tests were used. Reasons for this are as follows: a one-tailed test was used for transects BA16 and 21, since both are close to roads or construction activities where only a decline in pellet group densities would be anticipated; a one-tailed test also was used for transect BA17, since it is within a fertilized area where an increase in pellet group density might be anticipated; a two-tailed test was used for transect BA20, since both fertilization and construction are potential factors that could conceivably shift densities in either direction.

In the 1978 annual report a significant correlation in pellet group densities was reported for transects between the years 1976-77 and 1977-78 ($r = 0.86$; $P<0.001$); regardless of relative differences in total densities, transects that had high densities in one year tended to have high densities the next. When comparing the past two years, 1977-78 and 1978-79, using these same transects, a much weaker correlation was obtained ($r = 0.54$; $P<0.10$). Increasing the number of transects subsequent to 1976-77, however, permits correlations to be made using larger sample sizes; yet, the twenty-four transects which were operable the past two years give an even weaker correlation than was obtained using the original twelve transects ($r = 0.26$; $df = 22$; which is insignificant). At least a partial explanation for the lack of correlation during the past two winters is suggested upon examination of Figure 8.2.1-1. During the very severe winter of 1978-79, habitat use by

Table 8.2.1-1 Impact evaluation based on deer pellet group counts. Conclusions stating acceptance of the null hypothesis (H_0) indicate that impacts could not be identified.

Analysis of variance

Source of variation	DF	SS	MS
Among transects	19	348495	18342
Error	20	316526	15826
Total		665021	

$$t_\alpha \sqrt{(2/n)\ \text{MS error}} = 217 \text{ (one-tailed)},$$

$$df = 20,\ \alpha = .05$$

$$t_\alpha \sqrt{(2/n)\ \text{MS error}} = 262 \text{ (two-tailed)},$$

$$df = 20,\ \alpha = .05$$

H_0: $\bar{X}_{control} - \bar{X}_{development} <$ the least significant difference

Planned Comparisons			Conclusions
Developmental Transects	BA16	$\bar{X}_c - \bar{X}_d$ = 115 (one-tailed test)	accept H_0
	BA17	$\bar{X}_c - \bar{X}_d$ = 40 (one-tailed test)	accept H_0
	BA20	$\bar{X}_c - \bar{X}_d$ = 220 (two-tailed test)	accept H_0
	BA21	$\bar{X}_c - \bar{X}_d$ = 65 (one-tailed test)	accept H_0

NOTE: $\bar{X}_c$ is pooled mean pellet group count of control* transects.

*See Table 8.2.1-2

Table 8.2.1-2 Deer pellet group densities, 1978-79.

Transect		Mean pellet groups per acre ± SE (n)*
Chained pinyon-juniper:		
Developmental Sites:	BA17	275 ± 44.1 (20)
	BA21	430 ± 75.4 (20)
	BA20	315 ± 43.1 (20)
	BA30	295 ± 55.5 (20)
	BA31	365 ± 61.7 (20)
Control Sites:	BA18	255 ± 45.6 (20)
	BA25	220 ± 46.8 (20)
	BA23	300 ± 45.3 (20)
	BA01	210 ± 47.5 (20)
	BA02	195 ± 35.9 (20)
	BA03	125 ± 27.0 (20)
	BA04	360 ± 59.6 (20)
	BA05	465 ± 68.5 (20)
	BA06	165 ± 43.1 (20)
	BA07	135 ± 36.5 (20)
	BA08	170 ± 30.0 (20)
	BA09	175 ± 36.2 (20)
	BA28	295 ± 42.0 (20)
Pinyon-juniper woodland:		
Developmental Site:	BA16	195 ± 39.4 (20)
Control Sites:	BA19	285 ± 56.3 (20)
	BA26	145 ± 32.8 (20)
	BA27	165 ± 43.7 (20)
	BA22	85 ± 23.3 (20)
	BA24	310 ± 66.5 (20)
	BA10	245 ± 60.5 (20)
	BA11	335 ± 59.1 (20)
	BA12	250 ± 42.6 (20)

* SE (n) = Standard error and (number of 0.01 acre plots sampled)

deer appears to have shifted toward more use of the pinyon-juniper habitat and less use of the chained habitat.

As mentioned earlier, Figure 8.2.1-1 also suggests a slight decrease in deer pellet group densities during the 1978-79 period. The combined average for all pellet group plots for 1978-79 was 242 pellet groups per acre, a 23 percent decline relative to the average of 313 per acre for the year before. This difference is statistically significant ($t = 2.49$; df = 49; $P<0.05$), and undoubtedly reflects the severe winter. Increased mortality, as well as a restriction in total winter range area, are likely to be largely responsible for the decline in deer numbers (as evidenced by pellet group data), and not impacts from oil shale development.

Further discussion of deer pellet group counts is taken up in the following section on browse utilization. A tabular presentation of pellet group data for 1978-79 is given in Table 8.2.1-2.

8.2.1.6 Conclusions

The combined average for all pellet groups per acre decreased 23 percent from the previous year. Although statistically significant, the decrease is judged to be primarily due to effects of the severe winter and not to development.

8.2.2 Browse Production and Utilization

8.2.2.1 Scope

Production and utilization studies of bitterbrush and mountain mahogany were conducted along eighteen transects, representing a total of 180 shrubs sampled. Of this total, 150 of the shrubs sampled were bitterbrush and 30 were mountain mahogany.

8.2.2.2 Objectives

The main objective of browse production and utilization studies is to quantify natural variation in range condition over time in order to permit evaluation of site specific changes which might be due to impacts or to mitigation.

8.2.2.3 Experimental Design

The experimental design of browse production and utilization studies is identical to that of pellet group density studies in that the same transects are used in each case. Production-utilization studies, however, make use of fewer of the BA-designated transects, and generally only ten stations along a transect are sampled. Methods consist of measuring lengths of current annual growth in the Fall (10 shoots per shrub), marking main stems for relocation, and measuring what remains of the current annual growth in the Spring.

8.2.2.4 Method of Analysis

All statistical analyses for the 1978-79 period are standard parametric procedures, including the analysis of variance, t-test, product-moment correlation coefficient, and the Student-Newman-Keuls (SNK) multiple-range test (Zar 1974).

8.2.2.5 Discussion and Results

Production of bitterbrush was high during 1978, which was probably fortunate for the local deer population because of the very severe winter that followed. Utilization of bitterbrush by deer during the 1978-79 winter period was estimated at 70 percent for chained pinyon-juniper habitat and 64 percent for pinyon-juniper woodland habitat (Table 8.2.2-1). These results can be placed in perspective by comparisons of results of the year before, where utilization estimates of 92 percent and 83 percent were obtained for these two habitats respectively (Table A8.2.2-1). Less utilization this past year was probably due to many shrubs being covered by snow and to the high 1978-79 winter deer mortality.

Table 8.2.2-1 Browse Production and Utilization, 1978-79.

Transect	A PRODUCTION: length of new shoots in Fall (mm) Mean ± SE (n)*	B Lengths of shoots remaining in Spring (mm) Mean ± SE (n)*	C UTILIZATION: in percent $C = \frac{A - B}{A} \times 100$
Bitterbrush, chained habitat			
BA18	266 ± 14.6 (10)	81 ± 12.7 (10)	70
BA25	174 ± 13.8 (10)	71 ± 13.0 (10)	59
BA21	211 ± 29.3 (10)	54 ± 10.8 (10)	74
BA20	246 ± 22.3 (10)	66 ± 8.3 (10)	73
BA23	274 ± 32.7 (10)	76 ± 12.5 (10)	72
Combined	234 ± 11.5 (50)	70 ± 5.1 (50)	70
Bitterbrush, pinyon-juniper			
BA19	123 ± 19.7 (10)	37 ± 3.9 (10)	70
BA26	133 ± 8.0 (10)	62 ± 7.9 (10)	53
BA27	154 ± 11.5 (10)	91 ± 12.7 (10)	41
BA16	150 ± 16.3 (10)	26 ± 6.4 (10)	83
BA22	180 ± 16.6 (10)	45 ± 7.6 (10)	75
BA24	116 ± 13.7 (10)	50 ± 13.1 (10)	57
Combined	143 ± 6.4 (60)	52 ± 4.7 (10)	64
Bitterbrush (fertilized), chained habitat			
BA28	183 ± 29.1 (10)	64 ± 14.1 (10)	65
BA31	260 ± 32.8 (10)	37 ± 5.6 (10)	86
BA17	223 ± 40.0 (10)	52 ± 16.2 (10)	77
BA30	200 ± 27.7 (10)	36 ± 8.5 (10)	82
Combined	217 ± 16.4 (40)	47 ± 5.2 (40)	78
Mt. Mahogany, chained habitat			
BA28 (fertilized)	132 ± 10.0 (10)	22 ± 4.8 (10)	83
BA17 (fertilized)	114 ± 9.7 (10)	28 ± 7.1 (10)	75
BA29 (control)	134 ± 16.2 (10)	29 ± 8.0 (10	78
Combined	126 ± 7.1 (30)	26 ± 3.8 (30)	79

*n = number of shrubs sampled

Trends in production and utilization of bitterbrush over the past three years are shown in Figure 8.2.2-1. Production estimates for the 1979 period are shown in Table 8.2.2-2.

The degree to which browse production-utilization studies provide corroboratory support to pellet group studies is of considerable importance, as both studies are being used to monitor changes in the local deer herd. Although a one-to-one correspondence at all sites across the entire study area is not required (and, in fact, is too much to expect) a degree of correspondence is certainly desirable, since it strengthens conclusions regarding the causes of changes in deer numbers at highly localized areas of interest.

Results of pellet group and browse utilization studies were compared in the following way: Three criteria were chosen as expressions of utilization -- percent utilization, the percent of current annual growth consumed; length remaining, i.e., the length of this growth that remained on the shrub; and length consumed. Correlations were calculated for bitterbrush only, since sample sizes for mountain mahogany were small.

In the chained pinyon-juniper habitat a significant correlation was obtained for pellet group densities and percent utilization ($r = 0.28$; $df = 58$). A significant correlation was also obtained using the length remaining criterion ($r = -0.29$). The correlation was insignificant, however, using the length-consumed criterion ($r = 0.02$). In the pinyon-juniper woodland habitat no significant correlations were obtained using any of the three criteria ($r = 0.10$, for percent utilization; $r = -0.07$, for length remaining; and $r = -0.11$, for length consumed; all with $df = 57$). Although not mentioned in last year's report, similar findings were obtained for the 1977-78 period - a significant correlation for the chained pinyon-juniper habitat, and an insignificant correlation for the pinyon-juniper woodland habitat.

In all of the above tests the 95 percent level of confidence ($\alpha = 0.05$) was chosen for rejection of the null hypothesis. Arc sine transformations were performed on percentage data, and log transformations were performed on pellet group density data to achieve normality of distributions.

The fertilization programs initiated in the Spring of 1978 are of greater interest this year than last, owing to the longer time period which has now elapsed. The fertilizer has been on the ground for two summers, and it is reasonable to suppose that estimates of production, as well as utilization, might at this time manifest a response.

To test the efficacy of the two fertilization applications (ammonium nitrate and ammonium nitrate plus phosphorous) a series of single-factor analysis-of-variance tests were performed on appropriate combinations of transects representing control and fertilized study areas. Equal sample sizes were used in all treatment-control comparisons. Results of these tests are shown in Table 8.2.2-3.

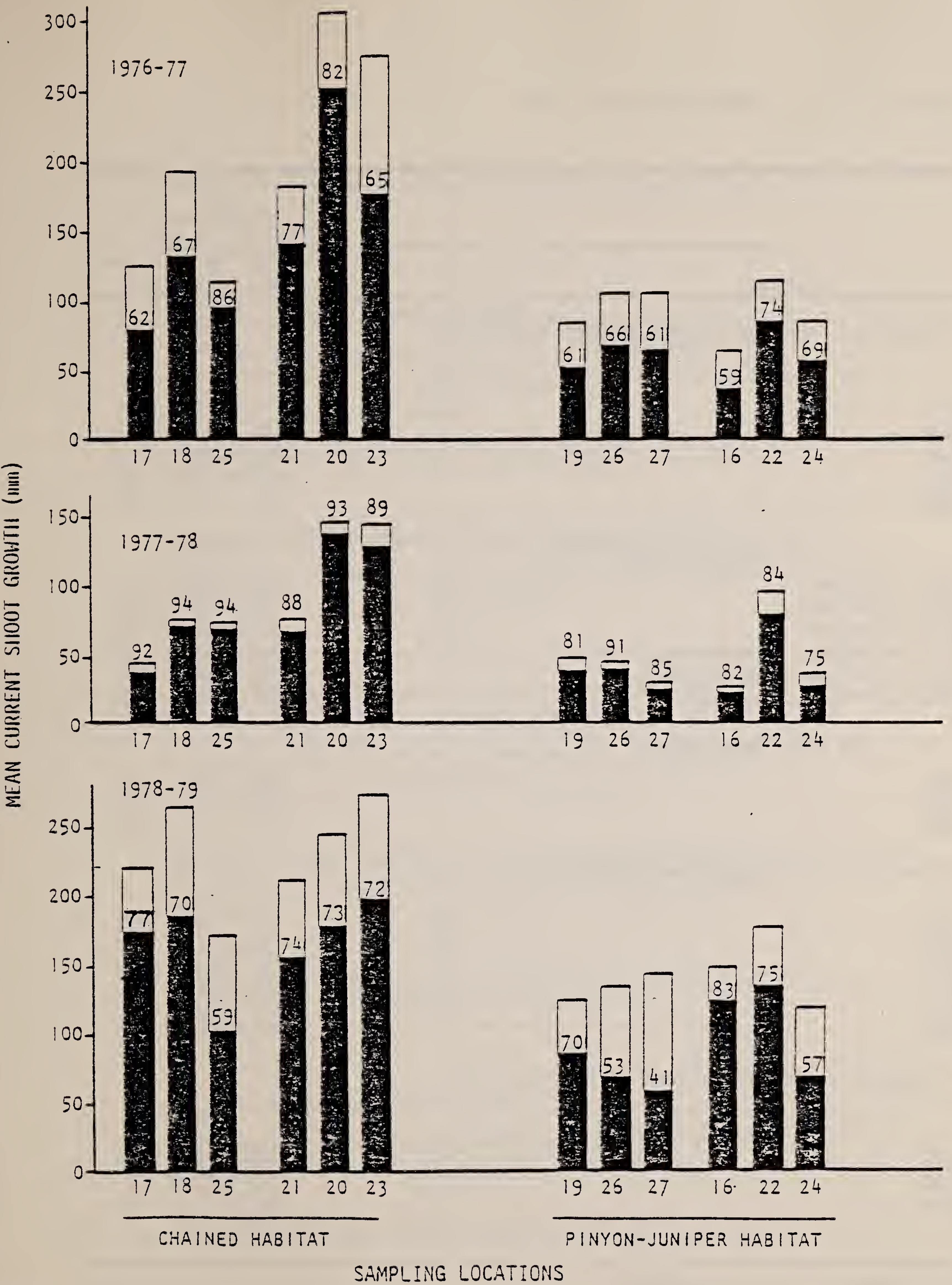


Figure 8.2.2-1. Trends in production and utilization of bitterbrush. Shaded areas and numbers above bars represent the percent of current shoot growth consumed by deer. Transect numbers are indicated below bars.

Table 8.2.2-2 Browse Production 1979.

Transect	PRODUCTION: length of new shoots in fall (mm) Mean ± SE (n)*
Bitterbrush, chained pinyon-juniper habitat	
On Tract C-b:	
BA18	173 ± 11.8 (10)
BA25	150 ± 19.5 (10)
BA21	189 ± 22.3 (10)
BA20	242 ± 23.1 (10)
BA23	166 ± 12.9 (10)
On Tract, fertilized plots:	
BA28 (nitrogen)	157 ± 16.9 (10)
BA31 (nitrogen)	230 ± 20.4 (15)
BA33 (nitrogen)	154 ± 11.4 (15)
BA17 (nitrogen, phosphorous)	162 ± 16.7 (10)
BA30 (nitrogen, phosphorous)	189 ± 16.1 (15)
BA32 (nitrogen, phosphorous)	202 ± 20.0 (15)
On Big Jimmy Ridge:	
BA01	228 ± 26.6 (10)
BA04	249 ± 25.8 (10)
BA09	119 ± 14.3 (10)
Bitterbrush, pinyon-juniper woodland	
BA19	126 ± 15.2 (10)
BA26	133 ± 12.7 (10)
BA27	131 ± 16.7 (10)
BA16	145 ± 10.2 (10)
BA22	170 ± 22.2 (10)
BA24	107 ± 12.2 (10)
Mt. mahogany, chained pinyon-juniper habitat	
On Tract C-b:	
BA17	93 ± 8.1 (10)
BA28	150 ± 32.9 (10)
BA29	108 ± 12.4 (10)

*n = number of shrubs sampled

Table 8.2.2-3 Analysis of variance tests for control versus fertilized study sites.

Test No. 1 - Bitterbrush, production of 1978:

Source of variation	DF	SS	MS	F	$F_{.05}$	Significance*
Among transects	2	21927.9	10964.0	1.29	3.18	NS
Error	57	483510.9	8482.6			
TOTAL		505438.3				

Transects compared are 3A18 (Control), 3A20 (Development) vs 3A28 (Control), 3A31 (Development) vs 3A17 (Development), 3A30 (Development).

Test No. 2 - Bitterbrush, lengths of current annual growth remaining:

Source of variation	DF	SS	MS	F	$F_{.05}$	Significance
Among transects	2	9969.0	4984.5	3.66	3.18	SIG
Error	57	77740.1	1363.9			
TOTAL		87709.1				

SNK Results:

Control vs Nit-Phos,	$q = 3.65$	($q_{critical} = 3.44$)	SIG
Control vs Nit,	$q = 2.31$	($q_{critical} = 2.86$)	NS
Nit vs Nit-Phos,	$q = 0.34$	($q_{critical} = 2.86$)	NS

Transects compared are 3A18 (Control), 3A20 (Development) vs 3A28 (Control), 3A31 (Development) vs 3A17 (Development), 3A30 (Development).

Test No. 3 - Bitterbrush, lengths of current annual growth consumed:

Source of variation	DF	SS	MS	F	$F_{.05}$	Significance
Among transects	2	2328.2	1164.1	0.18	3.18	NS
Error	57	368549.6	6465.3			
TOTAL		370877.8				

Transects compared are 3A18 (Control), 3A20 (Development) vs 3A28 (Control), 3A31 (Development) vs 3A17 (Development), 3A30 (Development).

Test No. 4 - Mt. mahogany, production of 1978:

Source of variation	DF	SS	MS	F	$F_{.05}$	Significance
Among transects	2	2383.2	1191.6	0.78	3.35	NS
Error	27	41063.9	1520.9			
TOTAL		43447.1				

Transects compared are 3A29 (Control) vs 3A28 (Control) vs 3A17 (Development).

Table 8.2.2-3 (Continued)

Test No. 5 - Mt. mahogany, lengths of current annual growth remaining:

Source of variation	DF	SS	MS	F	F.05	Significance
Among transects	2	255.3	127.6	0.28	3.35	NS
Error	27	12239.3	453.3			
TOTAL		12494.6				

Transects compared are 3A29 (Control) vs 3A28 (Control) vs 3A17 (Development).

Test No. 6 - Mt. mahogany, lengths of current annual growth consumed:

Source of variation	DF	SS	MS	F	F.05	Significance
Among transects	2	3105.3	1552.9	1.43	3.35	NS
Error	27	29333.5	1086.4			
TOTAL		32439.3				

Transects compared are 3A29 (Control) vs 3A28 (Control) vs 3A17 (Development).

Test No. 7 - Bitterbrush, production of 1979:

Source of variation	DF	SS	MS	F	F.05	Significance
Among transects	2	1801.9	901.0	0.20	3.09	NS
Error	117	521209.2	4454.8			
TOTAL		523011.2				

Transects compared are 3A18 (Control), 3A20 (Development), 3A21 (Development), 3A23 (Control) vs 3A28 (Control), 3A31 (Development), 3A33 (Development) vs 3A17 (Development), 3A30 (Development), 3A32 (Development).

Test No. 8 - Mt. mahogany, production of 1979:

Source of variation	DF	SS	MS	F	F.05	Significance
Among transects	2	17119.1	8559.6	1.97	3.35	NS
Error	27	117215.3	4341.3			
TOTAL		134334.4				

Transects compared are 3A29 (Control) vs 3A28 (Control) vs 3A17 (Development).

* Significance: NS, nonsignificant at $\alpha = 0.05$; SIG, significant at $\alpha = 0.05$.

The main conclusion to be drawn from the results obtained is, quite simply, that there is little evidence indicating that fertilization has had any desirable effect on either bitterbrush or mountain mahogany. In only one case was a significant difference found: Bitterbrush shrubs located in control areas (Test No. 2; Table 8.2.2-3) had mean shoot lengths remaining in the spring which were significantly longer (were browsed less heavily) than shrubs located in the area treated with ammonium nitrate plus phosphorous. It should be noted as well that the control versus nitrogen (without phosphorous) comparison closely approaches significance.

Some further insight into the question of whether or not fertilizer might elicit closer cropping of a shrub by deer was explored by examination of a relationship that has been observed to be consistent since baseline. In any given year the percentage of the current annual growth consumed by deer is quite constant regardless of the variation in production among the shrubs sampled. That is, regardless of how much the shrub produces in terms of length of new shoots, the deer tend to take a constant percent of it. Using this past year's production-utilization data as an example, a highly significant correlation was obtained by comparing length of current annual growth produced with length consumed (for bitterbrush $r = 0.91$; $df = 58$; $P \ll 0.001$; for mountain mahogany $r = 0.84$; $df = 28$; $P \ll 0.001$). If the nutrient gradient along a shoot influences the amount of the shoot consumed, then it is reasonable to conjecture that shoots of fertilized shrubs might have a different nutrient gradient than shoots of control shrubs and, consequently, may be browsed more heavily. But if this is the case one would expect that correlations of lengths produced with lengths consumed would be different at treatment and control sites. To test this hypothesis, comparisons of correlation coefficients (Snedecor and Cochran 1967) were made. Results of these tests (Table 8.2.2-3) however, indicate no significant differences among the bitterbrush or the mountain mahogany treatment-control comparisons (for bitterbrush $\chi^2_2 = 3.70$; $df = 2$; $\chi^2_{0.05} = 5.99$; for mountain mahogany $\chi^2 = 0.82$; $df = 2$; $\chi^2_{0.05} = 5.99$).

One possible reason for little evidence of increased browse utilization could have been caused by the severity of the winter which caused the deer to shift their habitat use more towards the pinyon-juniper habitat from the chained habitat. The fertilized areas are in chained pinyon-juniper habitat types.

8.2.2.6 Conclusions

Bitterbrush production was nearly three times higher in 1978-79 than in 1977-78, while bitterbrush utilization decreased 22 percent in the chained pinyon-juniper habitat and 19 percent in the pinyon-juniper woodland during the 1978-79 winter period relative to the 1977-78 figures.

There is little evidence that the fertilization project has had any desirable effect on either bitterbrush or mountain mahogany production or utilization.

8.2.3 Migrational Patterns and Phenology

8.2.3.1 Scope

Deer road counts have proven useful for showing deer distributions along the Piceance Creek highway. The structural road count observations are repeatable, and provide a means of quantifying changes in relative abundance and distribution.

8.2.3.2 Objectives

The main objectives of deer road count studies are to document the distributional patterns of deer along the Piceance Creek drainage during the Fall-through-Spring period, and to record the times of the seasonal migrational movements.

8.2.3.3 Experimental Design

Counts were made at approximately weekly intervals beginning in mid-September and ending in May. Observations were made along 41 miles of highway, from Highway 64 on the White River to Highway 13 at Rio Blanco. Counts were made from a vehicle driving approximately 30 m.p.h. All counts were begun approximately one hour before dusk, and the direction of travel was changed for each consecutive count. Deer were recorded for one-mile intervals, and according to feeding locations on slopes or in meadows. Stations are shown on Exhibit C (found in the back cover jacket of this volume).

8.2.3.4 Method of Analysis

At the present time, data are evaluated by comparisons of histograms showing numbers of deer observed along the Piceance Creek road at selected periods throughout the winter.

8.2.3.5 Discussion and Results

The fall migration of deer into the Tract C-b area occurred in approximately mid-October in 1978. In spring, conspicuous declines in the number of deer observed in the immediate vicinity of the Tract occurred in early May. These times of migrational movements, therefore, are basically the same as observed over the past five years. The patterns of deer occurrence along the Piceance Creek Road, however, were quite different during 1978-79 than had been observed previously. (Figure 8.2.3-1).

In order to facilitate comparisons with the more typical patterns of deer occurrence along the Piceance Creek Road, results of road counts of the year before, 1977-78 (Figure 8.2.3-2), are shown here as well. The most conspicuous difference between these years is the increase in deer observed near the road during April of 1979. (The maximum number of deer counted during any one

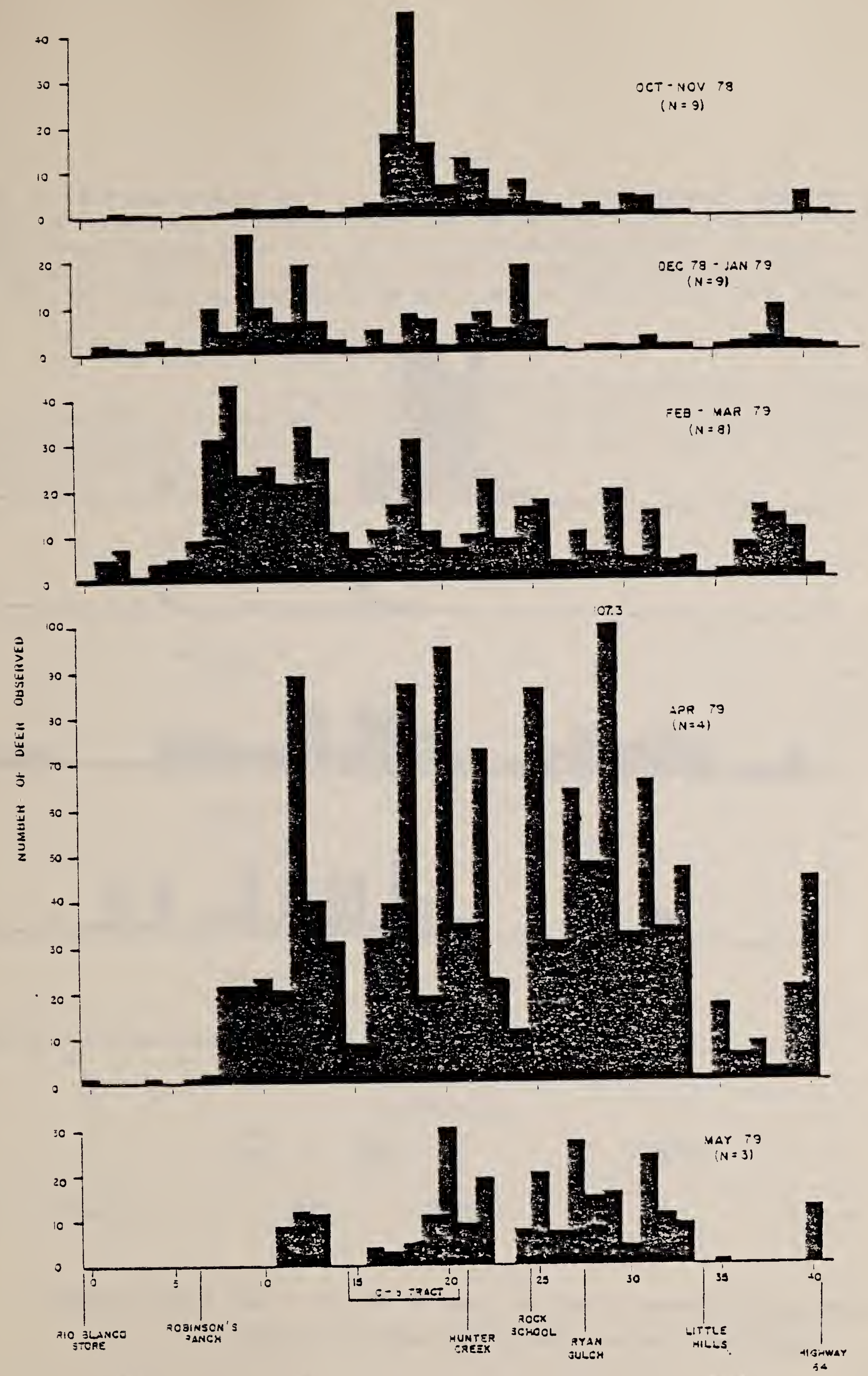


Figure 8.2.3-1 Summary of deer road counts for 1978—79. Heights of bars are means; N= the sample size (the number of road counts) for the period.

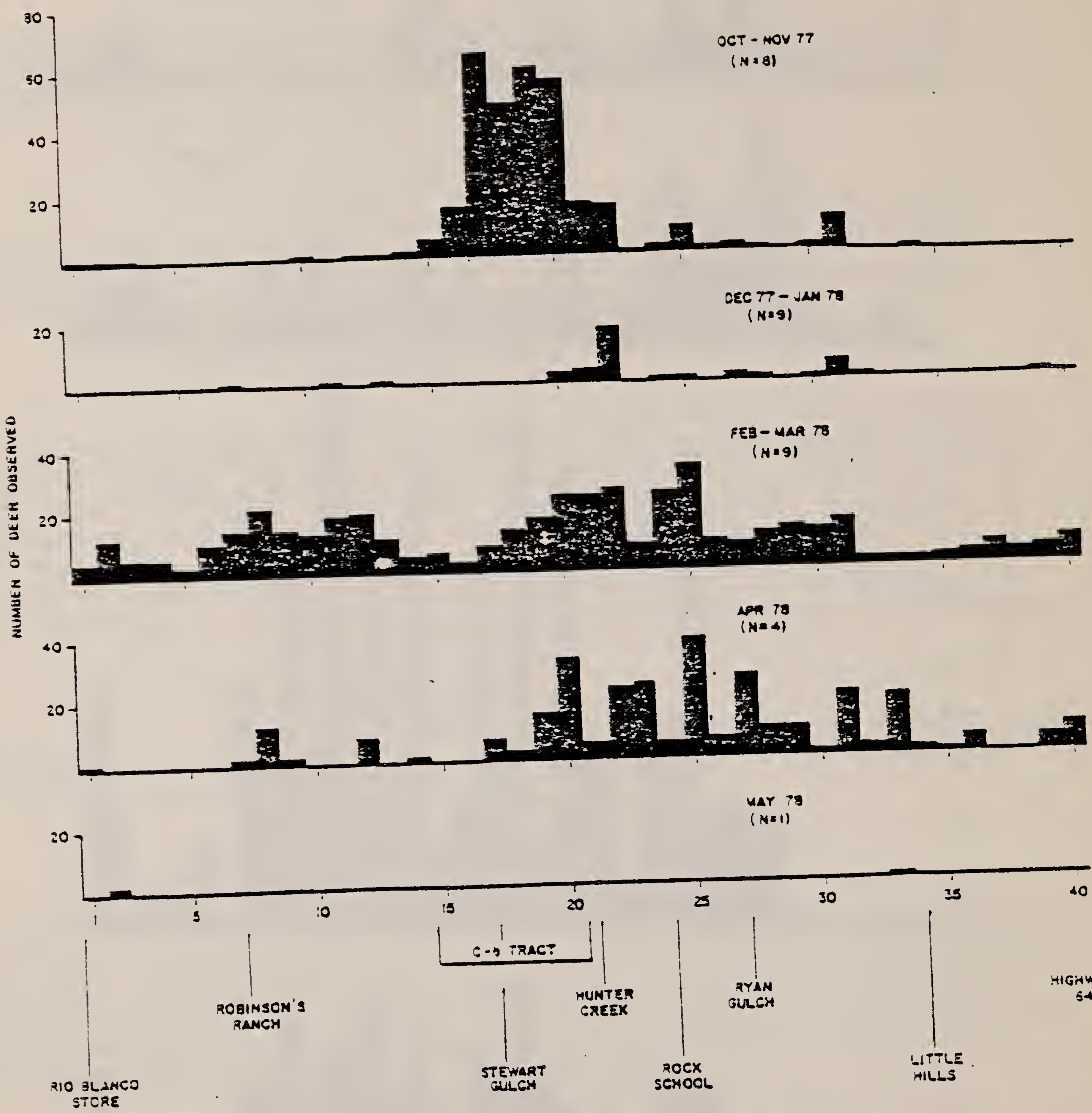


FIGURE 8.2.3-2 Summary of deer road counts for 1977-78. Heights of bars are means; sample size (N) are the number of road counts for the period.

week in 1979 was1,804 on April 19, 1979.) Also, from December 1978 through March 1979 there are noticeably more deer below Tract C-b, especially from about mile 5 through mile 13. It is of considerable interest, however, that in spite of these differences deer apparently remained numerous in the vicinity of Tract C-b throughout the most severe part of the winter period.

8.2.3.6 Conclusions

Migrational movements of the mule deer in Piceance Basin have basically remained the same as observed over the past five years. The maximum number of deer counted along Piceance Creek Road during any one week in 1979 was 1,804 on April 19, 1979.

8.2.4 Road Kill

8.2.4.1 Scope

Mule deer road kill data were collected weekly along Piceance Creek highway to obtain information on the number and location of deer killed by vehicles on the highway.

8.2.4.2 Objectives

The main objectives of collecting roadkill data were to obtain accurate mule deer fatality estimates and to use this information in conjunction with other deer study data to identify problem areas so the necessary mitigative measures could be initiated.

8.2.4.3 Experimental Design

Weekly road kill data were collected from September 1978 through May 1979 at the same stations used for mule deer migrational patterns and phenology study. The dead deer were aged, sexed, and tagged. In addition, one ear was removed to avoid double counting. Road kill information was compared to Division of Wildlife information collected to ensure that all the deer found were recorded.

8.2.4.4 Method of Analysis

When several years of data have been collected, time series tabulations and non-parametric tests such as the log-likelihood G test (Sokal and Rohlf 1967) will be used.

8.2.4.5 Discussion and Results

Figure 8.2.4-1 shows the mule deer killed on the Piceance Creek highway from September 1978 through May 1979. A large number of deer remained along the highway last winter, possibly due to the severity of the winter. Even with the increased deer activity along the road, the road kill did not change appreciably. A total of 131 deer and one elk were killed on the 41 mile stretch this year compared to 125 deer and one elk killed last year (1977-78).

A breakdown of road kills according to age and sex is presented in Table 8.2.4-1. The class of deer that was hit most frequently was mature does, whereas last year fawns were hit most frequently. This year the number of male fawns killed decreased while the number of mature does hit increased.

Figure 8.2.4-1 Mule Deer Road Kill, Piceance Creek - County Road 5

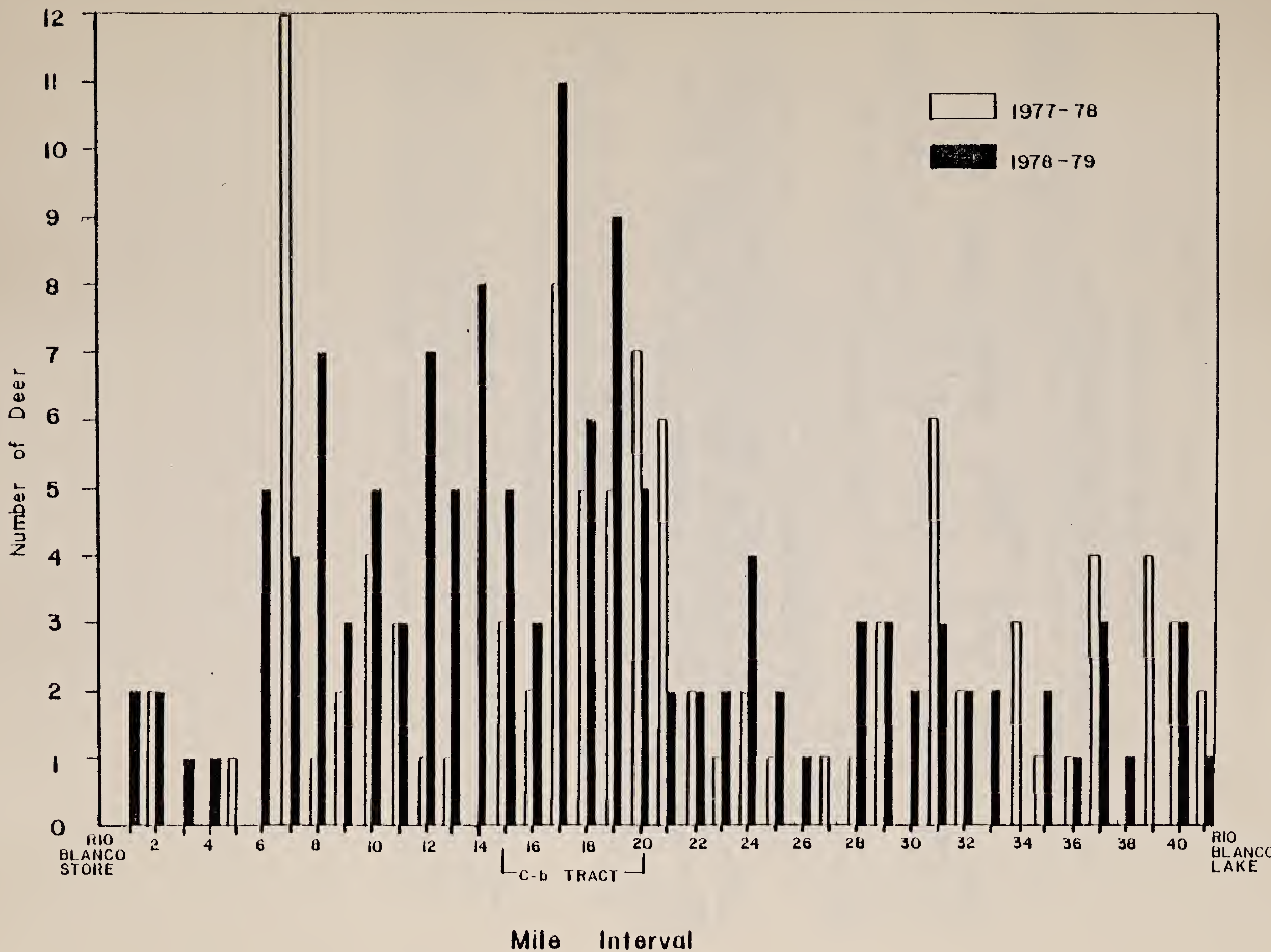


TABLE 8.2.4-1

PICEANCE CREEK ROAD KILL

(Piceance Creek Road from 0 through Mile 41)

Date	Does		Fawns Male		Fawns Female		Bucks		Unknown	Total
	#	%	#	%	#	%	#	%		
9/77-5/78	40	41	28	29	22	22	8	8	2	100*
9/78-5/79	80	61	13	10	27	21	11	8	0	131

*Total road kill was 125 deer. This figure was derived from combining DOW data with C-b data.

8.2.4.6 Conclusions

In 1978-79 131 deer and one elk were killed along Piceance Creek Road compared to 125 deer and one elk killed in the previous year. These data are too limited at this time to establish trends. Road kill information will continue to be monitored closely to establish possible trends and mitigative measures.

8.2.5 Natural Mortality

8.2.5.1 Scope

Baseline studies have shown winter kills to be largely restricted to the lateral draws and bottomland sagebrush. Checking these areas each Spring has helped in observing changes in the relative magnitude of deer mortality.

8.2.5.2 Objectives

The objectives of this study are to estimate deer mortality on a yearly basis in order to document long-term trends and to aid interpretations of other deer data.

8.2.5.3 Experimental Design

Sampling was done in the Spring on 10 plots located in lateral draws and sagebrush gulches (see Exhibit C). The age and sex of all deer that had died the previous winter were recorded, and each carcass marked with a metal tag stamped with the current year. The presence of either the skull or pelvic girdle was required to constitute a carcass.

8.2.5.4 Method of Analysis

Nonparametric tests such as the log-likelihood G test (Sokal and Rohlf 1967) will be used when several additional years of data have been gathered. Only tabular presentations will be used until then.

8.2.5.5 Discussion and Results

Deer mortality data gathered since baseline are shown in Table 8.2.5-1. A 74 percent increase in mortality this past year occurred compared to 1977-78, which is not surprising in view of the severe winter. This estimate (representing 0.195 deer carcasses per acre) cannot be compared directly to baseline estimates because of the change in sampling locations.

TABLE 8.2.5-1

RESULTS OF DEER MORTALITY STUDIES

Year	Sampling Location	No. of carcasses found	Hectares sampled (acres)	Carcasses per hectare (/ acre)
1978-79	Sagebrush-Lateral Draw	34	70.5 (174)	0.482 (0.195)
1977-78	Sagebrush-Lateral Draw	25	70.5 (174)	0.355 (0.144)
1976-77	Interim monitoring period - No sampling			
1975-76	Lateral Draws	8	7.25 (18)	1.10 (0.44)
1974-75	Lateral Draws	11	7.25 (18)	1.52 (0.61)

8.2.5.6 Conclusions

No conclusions can be made at this time relative to long-term trends. However, mortality increased this year over 1977-78.

8.2.6 Age-Class Composition

8.2.6.1 Scope

Estimating the age-class composition of the deer herd in the fall faciliates evaluating the magnitude of fawn mortality that occurred during spring and summer while deer were on summer range. Estimates taken in spring permit estimating the fawn mortality that occurred while deer were on winter range in the C-b area.

8.2.6.2 Objectives

The main objective of the age-class study is to estimate fawn-adult ratios in fall and in spring.

8.2.6.3 Experimental Design

Sampling locations were restricted to the meadows of major drainages within five miles of Tract C-b. Counts occurred in November and in April. Observations took place during times of high concentrations. The deer that could be clearly observed were recorded as adults, fawns, or bucks. No attempt was made to recognize yearlings, and bucks (and the number of points on both antlers) were recorded only when feasible.

8.2.6.4 Method of Analysis

Data from this study will be used mainly to aid in the interpretation of the results of other deer studies.

8.2.6.5 Discussion and Results

Estimates of the age-class composition of deer wintering near Tract C-b are shown in Table 8.2.6-1. The estimate of nearly 78 percent fawns in the fall population represents a high rate of reproduction. Loss of fawns due to winter kill, however, was also very high. It would be of interest to compare fawn mortality at Tract C-b with other areas in the Piceance Basin.

TABLE 8.2.6-1

AGE-CLASS COMPOSITION OF MULE DEER WINTERING NEAR TRACT C-b

Date	Fawns	Does	Bucks	Adults	Fawns/ 100 Does	Bucks/ 100 Does	Fawns/ 100 Adults
November 13-27, 1978	151	159	35	194	95.0	22.0	77.8
April 20-26, 1979	41			343			12.0

8.2.6.6 <u>Conclusions</u>

No conclusions can be drawn from the data at this time because of an inadequate data base.

8.3 Medium-Sized Mammals

Studies of medium-sized mammals are restricted to coyotes and lagomorphs (cottontails and jackrabbits). Monitoring of these animal groups provides trend information on the relative abundance of larger mammalian predators to prey species present within the Tract C-b ecosystem.

8.3.1 Coyote Abundance

8.3.1.1 Scope

Coyotes are of ecological significance because they are a major predator on Tract C-b. They are also of general interest to the public with both strongly negative and positive supporters.

8.3.1.2 Objectives

The objective of the coyote study is to obtain trend information on the relative abundance of coyotes on and near Tract C-b.

8.3.1.3 Experimental Design

Two coyote scent-station surveys are being used following the design of the U. S. Fish and Wildlife Service (Linhart and Knowlton 1975). Sampling was done in early October along 30 miles of road segments on and near the Tract. The presence of tracks was checked once the day after scent stations were set out. This survey technique is also being used to record information on wildlife species other than coyotes.

8.3.1.4 Method of Analysis

A relative abundance is calculated as a visit frequency. The long-term trend data being gathered on Tract will be evaluated in the context of the state-wide data gathered by the U. S. Fish and Wildlife Service.

8.3.1.5 Discussion and Results

Results of the 1979 coyote scent-station survey (Table 8.3.1-1) indicate an index of 70 for the two 50-station lines combined. This index is considerably below the average value of 122 for the five previous years of data collection. Values for past years are as follows: 1974, 188; 1975, 122; 1977, 130; and 1978, 50.

No new species of mammals were identified while conducting the coyote scent-station surveys.

TABLE 8.3.1-1

RESULTS OF THE COYOTE SCENT-STATION SURVEY, 1979

Line	Location	No. of Stations	No. of Visits
1 (BF01)	Big Jimmy	25	2
2 (BF02)	SG-9	10	0
3 (BF03)	Scandard	10	0
4 (BF04)	SG-15	10	1
5 (BF05)	SG-11	10	2
6 (BF06)	Stewart ridge	15	2
7 (BF07)	Stewart valley	10	0
8 (BF08)	Bailey ridge	10	0

$$\text{Index of abundance} = \frac{\text{No. of visits}}{\text{No. of stations}} \times 1000$$

$$= \frac{7}{100} \times 1000 = 70$$

8.3.1.6 Conclusions

The coyote population has fluctuated greatly for the past five years. Significance of a trend cannot be established with the available data.

8.3.2 Lagomorphs

8.3.2.1 Scope

Cottontails and jackrabbits provide a potentially important prey base for raptorial birds and coyotes. The cottontail is classified as a game species, but presently it is of little economic value in the vicinity of Tract C-b. At some time in the future, however, its status could change. The lagomorph relative-abundance estimates are based on data collected along the BA-designated transects. (See Exhibit C for transect locations and Volume 2 Appendix for identification of transects.)

8.3.2.2 Objectives

The objectives of lagomorph studies are to obtain relative-abundance estimates for cottontails and jackrabbits on and near Tract C-b.

8.3.2.3 Experimental Design

Relative-abundance indices of cottontails and jackrabbits were estimated along the thirty transects used for deer pellet group and browse production-utilization studies. Methods were changed this past year as follows: Counts of presence-absence data were made inside the deer plots, but were restricted to an area of 0.001 acre; counts are now conducted twice, once in the spring and again in the fall.

8.3.2.4 Method of Analysis

Long-term trend data will be evaluated using appropriate nonparametric statistics.

8.3.2.5 Discussion and Results

Because of modifications in experimental design, discussion of results would be premature at this time. A tabular presentation of the findings for the 1978-79 winter period is shown in Table 8.3.2-1.

8.3.2.6 Conclusions

No conclusions can be drawn at this time relative to trends in the data.

Table 8.3.2-1 Relative abundance of cottontail and jackrabbits, 1978-79. Each transect consists of twenty 0.001 acre plots.

Transect		Relative Abundance*
Chained Habitat:		
Development Sites:	BA17	15
	BA21	35
	BA20	35
	BA30	20
	BA31	15
Control Sites:	BA01	25
	BA02	5
	BA03	35
	BA04	40
	BA05	70
	BA06	85
	BA07	75
	BA08	75
	BA09	80
	BA18	25
	BA25	40
	BA23	40
	BA28	15
Pinyon-juniper Habitat:		
Development Sites:	BA16	35
Control Sites:	BA10	55
	BA11	90
	BA12	50
	BA13	70
	BA14	75
	BA15	5
	BA19	20
	BA22	45
	BA24	30
	BA26	75
	BA27	90

*Relative abundance is calculated as a percent frequency ((No. of plots with fresh pellets ÷ No. of plots sampled) x 100).

8.4 Small Mammals

8.4.1 Species Diversity and Abundance

8.4.1.1 Scope

Small mammals are important as prey species. Monitoring changes in selected population abundance parameters will aid in assessing potential effects of pollutants before populations of larger animals are greatly affected.

8.4.1.2 Objectives

The objectives of monitoring small mammals are to obtain trend information on relative abundance, species composition, reproductive condition, and age-class.

8.4.1.3 Experimental Design

Small mammal live trapping was conducted in three habitat types: Pinyon-juniper woodland, chained pinyon-juniper, and agricultural meadow. The agricultural meadow was divided into control and development plots. Linear transects consisting of 10 traps, spaced at 30-foot intervals, were positioned in each habitat type. Trapping occurred for three consecutive nights (omitting rainy nights) during June and August. After each night, all traps were moved to a nearby transect location.

8.4.1.4 Method of Analysis

Changes in relative abundance will eventually be evaluated using standard parametric statistics.

8.4.1.5 Discussion and Results

The value of monitoring small mammal populations rests on the ability to separate normal variations from man-induced changes. Several modifications in research design have been made since baseline which will permit quantifying the magnitude of change required for detection. This evaluation will be made next year when control-development plots are clearly defined. Tabular results for 1979 are shown in Table 8.4.1-1.

8.4.1.6 Conclusions

No conclusions can be drawn from these data at this time with respect to trends in relative abundance, species composition, reproductive condition, or age class. The deer mouse continue to be the most prevalent of the small mammals.

TABLE 8.4.1-1

RELATIVE ABUNDANCE OF SMALL MAMMALS, 1979*

Common Name / Scientific Name	BG03 Meadow Control Plot June (300)	BG03 Meadow Control Plot August (300)	BG01 Meadow Development Plot June (300)	BG01 Meadow Development Plot August (300)	BG04 Pinyon-Juniper June (150)	BG04 Pinyon-Juniper August (150)	BG02 Chained Habitat June (150)	BG02 Chained Habitat August (150)	BG05 Sprinkler Area August (150)
Deer mouse *Peromyscus maniculatus*	10.3	10.7	7.7	9.0	8.7	42.0	15.3	25.3	57.3
Montane vole *Microtus montanus*	1.3	2.0	2.7	8.7	0	0	0	0	0.7
Western juniper mouse *Zapus princeps*	2.3	5.3	0	0.7	0	0	0	0	0
Least chipmunk *Eutamias minimus*	0	0	0	0	0	0.7	10.7	18.7	11.3
Uinta chipmunk *Eutamias umbrinus*	0	0	0	0.3	1.3	9.3	2.0	0	0.7
Golden-mantled ground squirrel *Spermophilus lateralis*	0	0	0.7	0.3	4.0	1.3	2.7	0.7	5.3
Richardson's ground squirrel *Spermophilus richardsoni*	0.7	0	0	0	0	0	0	0	0
Bushy-tailed woodrat *Neotoma cinerea*	0	0	0	0	0	0	0	0	0.7
Long-tailed weasel *Mustela frenata*	0.3	0.7	0	0.3	0	0	0.7	0	0
Shrew *Sorex sp*	0	0.7	0	0	0	0	0	0	0

*Relative abundance = No. of captures ÷ No. of trap-nights x 100. Trap-nights (in parentheses) are No. of traps x No. of nights.

8.5 Avifauna

A wide variety of birds exist on Tract C-b and in the surrounding area. Avifauna were monitored to determine potential effects of habitat disturbance on species abundance.

8.5.1 Songbird Relative Abundance and Species Composition

8.5.1.1 Scope

Songbirds were monitored during their breeding season to determine effects of development on avifauna. It is anticipated that habitat disturbance and increased human activity may affect population densities and relative abundance of the more prominent species. Certain species may be more affected by man-made impacts than others.

8.5.1.2 Objectives

Objectives of the program are to evaluate effects of development activity on songbird densities, species abundance and diversity by comparing control to developmental transect observations.

8.5.1.3 Experimental Design

Monitoring of avifauna for 1979 occurred between May 22, 1979 and June 29, 1979. Monitoring efforts were consistent with previous sample periods in that two transects in pinyon-juniper woodland and two transects in chained pinyon-juniper rangeland were censused. One transect in each habitat type (Transects 1 (BH01) and 4 (BH04)) is located in an area which will not be disturbed by shale oil development. The remaining two transects (Transects 2 (BH02) and 3 (BH03)) sample areas within each habitat type where some disturbance from shale oil development is anticipated. All transects are 800 meters long and are permanently marked with steel rebar stakes and flagging. Each transect was sampled five times, but only the first three replications (conducted from May 22 to May 25) were utilized for the density and diversity calculations. The fourth and fifth replications (conducted from June 11 to June 28) were used solely for detection of late breeding species that may not have been recorded during the earlier replications.

The method employed for censusing was the strip-transect method as described by Emlen (1971) with slight modifications. This method provides data from which quantitative estimates of density of songbird and songbird-like species can be calculated.

8.5.1.4 Method of Analysis

The population density estimates for species observed on strip transects were determined by one of three methods, depending on the conspicuousness of the species to the observer, as described by Emlen (1971).

Since the validity of any of these methods varied for different species, professional judgment, based on experience with the conspicuousness of various species within different habitats during different seasons, was used in selecting the best density estimator. The Shannon-Weiner calculations (Pielou 1966) were used to compute indices of species diversity (H'), maximum diversity (H' maximum) and equitability (J) for each habitat sampled by strip transect procedures (Symbols are defined in Table 8.5.1-1). Since 1979 represents the third year of data collection for the avifauna monitoring program, statistical analysis of variance was applied to total density, total diversity, and total species values from each transect to estimate variations between control and developmental transects. Variation within each transect could not be analyzed since data for total density, diversity, and species are represented by only one replication per transect per year.

8.5.1.5 Discussion and Results

Table A8.5.1-1 lists diversity for species indices observed in 1977 through 1978. Included in the table are species that were observed but were not included in the quantitative analysis because they were not observed within a strip census corridor or because specific habits of species, such as red-tailed hawk and common raven, rendered them unsuitable for this type of quantitative analysis (Emlen 1971). No additional bird species (beyond those recorded by the first three survey replications) were recorded for the area during the fourth and fifth survey replications. If additional survey replications (in excess of the three replications conducted during the peak breeding period) are to be continued, it may be more advantageous (in terms of species utilization) to schedule these replications to coincide with the early portion of the breeding period (late April-early May). Replications conducted earlier in the breeding season may record early breeding species and late migrating species which are not observed during the period of peak breeding activity. Tables A8.5.1-2 through A8.5.1-5 summarize strip transect results and estimates of relative abundance and density for each transect.

Green-tailed towhee, Brewer's sparrow, and vesper sparrow were the most abundant species in chained pinyon-juniper rangeland while black-throated gray warbler, solitary vireo, Virginia's warbler, Hammond's flycatcher, house wren, and mountain bluebird represented the more common species in pinyon-juniper woodland. As shown in Table 8.5.1-1 diversity values have decreased since 1977 for all transects except BH01. Diversity increased for BH01 in 1978 and then decreased in 1979.

An analysis of variance for differences between total diversity values indicate that there is no significant difference between developmental transects and control transects ($F<1.0$). Therefore, it can be assumed that declines in diversity were relatively similar between control and development transects. The declines indicated for diversity may be due to any number of inherent natural factors such as weather or cyclic population changes. As would be

TABLE 8.5.1-1

SHANNON-WEINER DIVERSITY INDICES (H'), UNBIASED ESTIMATES OF H' [E(H')], VARIANCE OF H' [var (H)'], MAXIMUM EXPECTED VALUE OF H' [H' (max)], AND EQUITABILITY (J), FOR AVIFAUNA TRANSECTS AT TRACT C-b DURING SPRING SAMPLE PERIOD, 1977, 1978, AND 1979

Transect	Vegetation Type	Year	H'	E(H')	var(H')	H'(max)	J
1 (BH01)	Chained Pinyon-Juniper Rangeland (Control)	1977	1.494	1.454	0.009	2.079	0.718
		1978	1.665	1.634	0.007	2.398	0.694
		1979	1.166	1.152	0.003	1.792	0.651
2 (BH02)	Pinyon-Juniper Woodland (Developmental)	1977	2.469	2.432	0.003	2.890	0.854
		1978	2.398	2.350	0.004	2.708	0.886
		1979	2.272	2.236	0.002	2.485	0.914
3 (BH03)	Chained Pinyon-Juniper Rangeland (Developmental)	1977	1.950	1.895	0.004	2.197	0.888
		1978	1.885	1.868	0.003	2.398	0.786
		1979	1.526	1.508	0.003	1.946	0.784
4 (BH04)	Pinyon-Juniper Woodland (Control)	1977	2.740	2.709	0.001	2.944	0.931
		1978	2.545	2.522	0.002	2.890	0.881
		1979	2.189	2.168	0.002	2.398	0.913

DEFINITIONS FOR SHANNON-WEINER CALCULATION VARIABLES

H' = Diversity. H' is an estimate of the diversity of the total population of individuals in a species pool. It is dependent on both the number of species in a collection and the relative abundance of each species (or evenness). Diversity can be thought of as measuring the uncertainty of predicting the species of an individnal drawn at random from the entire population of individuals of several species. This uncertainty, or diversity, of a community can be increased either by increasing the number of species or by evening out the distribution of individuals among species. An H' value of zero is obtained when all individuals belong to the same species. Maximum values are obtained when all individuals belong to different species.

E (H') = The expected or unbiased estimate of H'. An estimate of diversity (H') corrected for bias associated with sample size.

Var (H') = Variance of H'. Variance is a measure of dispersion. It is defined to be the average of the square of the deviations of a set of measurements about their mean.

H' (max) = The maximum value of H'. An estimate of maximum possible species diversity for a given number of species and individuals.

J = Equitability or Evenness. The distribution of individuals among species is referred to as equitability. As discussed under diversity, evenness is a component of diversity. Large values of J are indicative of a rather even distribution of densities among species, while low values suggest dominance by a few species. J is expressed as the ratio of H' over H' max (H'/H' max).

expected, diversity values between chained pinyon-juniper rangeland and pinyon-juniper woodland were significantly different (P = 0.005). Also, the total number of species was shown to be significantly different between chained pinyon-juniper rangeland and pinyon-juniper woodland (P = 0.0002). Although diversity values, for the most part, have decreased slightly since 1977, no comparable trend is indicated by the total density values shown in Table 8.5.1-2. Both increases and decreases are noted in density values for each transect during the three year period. As with diversity values, an analysis of variance for differences between total density values (Table 8.5.1-3) indicates that there is no significant difference between developmental and control transects (F<1.0).

8.5.1.6 Conclusions

Based on data collected thus far for the Tract C-b avifauna monitoring program, no significant changes in songbird diversity or density have occurred between developmental and control survey areas.

TABLE 8.5.1-2

TOTAL DENSITY VALUES FOR AVIFAUNA TRANSECTS AT TRACT C-b DURING SPRING SAMPLE PERIOD, 1977, 1978, AND 1979

Transect	Vegetation Type	Year	Total Density/Ha
1 (BH01)	Chained Pinyon-Juniper Rangeland (Control)	1977	1.61
		1978	2.20
		1979	3.24
2 (BH02)	Pinyon-Juniper Woodland (Developmental)	1977	4.13
		1978	1.94
		1979	2.68
3 (BH03)	Chained Pinyon-Juniper Rangeland (Developmental)	1977	1.35
		1978	3.83
		1979	2.92
4 (BH04)	Pinyon-Juniper Woodland (Control)	1977	4.95
		1978	4.03
		1979	4.08

TABLE 8.5.1-3

MEAN TOTAL DIVERSITY AND TOTAL DENSITY VALUES FOR AVIFAUNA TRANSECTS AT TRACT C-b FOR 1977 THROUGH 1979

Transect	Vegetation Type	Mean Total Diversity (3 years)	Standard Deviation	Mean Total Density (3 years)	Standard Deviation
1 (BH01)	Chained Pinyon-Juniper Rangeland (Control)	1.44	±0.25	2.35	±0.82
2 (BH02)	Pinyon-Juniper Woodland (Developmental)	2.38	±0.10	2.92	±1.11
3 (BH03)	Chained Pinyon-Juniper Rangeland (Developmental)	1.79	±0.23	2.7	±1.25
4 (BH04)	Pinyon-Juniper Woodland (Control)	2.49	±0.28	4.35	±0.52

8.5.2 Upland Gamebirds - Mourning Dove Relative Abundance

8.5.2.1 Scope

Field observations during the baseline data accumulation program indicated that sage grouse and blue grouse populations are so sparse on and near the Tract that no reasonable monitoring program for them can be designed to determine changes over time; thus, a monitoring program for them is not warranted. The mourning dove is the only upland gamebird present in sufficient numbers to be monitored.

8.5.2.2 Objectives

The objective was to monitor the mourning dove populations to see if development of Tract C-b has affected their relative abundance.

8.5.2.3 Experimental Design

Methods used were identical to those used for songbirds. Throughout the year gamebirds observed were recorded on Wildlife Observation Reports.

8.5.2.4 Method of Analysis

The data were analyzed in the identical manner described for analyzing the relative abundance for the songbird-like population parameter.

8.5.2.5 Discussion and Results

Mourning dove data for the spring avifauna transects on Tract C-b are shown in Table 8.5.2-1. The mourning dove population on Tract C-b, as elsewhere in the Piceance Basin, shows wide fluctuations in population size and distribution without any definable patterns. Last year's data showed no doves on developmental transects while this year mourning doves were seen on developmental and control transects. The mourning dove population will continue to be monitored closely.

The only other gamebird sighted was a sage grouse on Big Jimmy ridge during the avifauna study; no gamebirds, except for mourning doves, were seen on Tract C-b during 1979.

8.5.2.6 Conclusions

No conclusions can be drawn from the data at this time as to the effects of Tract C-b development on the relative abundance of upland gamebirds.

TABLE 8.5.2-1

MOURNING DOVE ESTIMATES AT TRACT C-b FOR SPRING SAMPLING PERIODS, 1977-79

Transect	Date	Observations	Coefficient Detectability	Density /Ha	% Relative Abundance
Chained Pinyon-Juniper (BA01)	1977	2	1.0	.03	2.1
	1978	1	1.0	.02	0.9
	1979	1	1.0	.04	1.2
Pinyon-Juniper (BA02)	1977	4	1.0	.07	1.7
	1978	0	-	-	-
	1979	3	.74	.14	5.2
Chained Pinyon-Juniper (BA03)	1977	17	1.0	.29	5.9
	1978	0	-	-	-
	1979	0	-	-	-
Pinyon-Juniper (BA04)	1977	2	1.0	.03	2.5
	1978	5	.74	.17	4.2
	1979	0	-	-	-

8.5.3 Raptor Activity

8.5.3.1 Scope

Raptor activity was monitored on Tract C-b on a continuing basis because of the importance of raptors in the food chain, their apparent vulnerability to man's activities, their political value as threatened or endangered species, and their aesthetic appeal.

8.5.3.2 Objectives

The main objective of raptor monitoring was to detect changes in raptor utilization on or near Tract C-b.

8.5.3.3 Experimental Design

Trends in utilization of Tract C-b and immediately contiguous habitats by raptors were established for the breeding season by determining the percent of known nest sites which were occupied by nesting pairs and comparing these data with data obtained during the baseline period and following years. Nest occupancy checks were made annually during mid-March (great horned owls and ravens), late-April (red-tailed hawks, eagles) and early-June (accipiters, American kestrels, harriers). Throughout the year, any raptor sightings by the field biologists within the study boundary were recorded.

8.5.3.4 Methods of Analysis

Data analysis of nest occupancy was by professional judgment.

8.5.3.5 Discussion and Results

Raptor nesting records from 1976 through 1979 are listed in Table 8.5.3-1. The April, 1979 census had fifteen active nests, consisting of: Nine red-tailed hawks, four great horned owls, one golden eagle, and one raven. Only three nests were still occupied in the June census. Raptor nesting activity seems to be on the increase.

In addition to the nesting raptors, other raptors observed during 1979 on or near Tract C-b included: Bald eagle, Cooper's hawk, American Kestrel, turkey vulture, and marsh hawk.

8.5.3.6 Conclusions

Raptor nesting activity seems to be on the increase in the study area.

TABLE 8.5.3-1 RAPTOR NESTING RECORD

Nest No.	Species	Status 1976 April	Status 1976 June	Status 1977 April	Status 1977 June	Status 1978 April	Status 1978 June	Status 1979 April	Status 1979 June	
1	Unknown	I		I	I	I	I	I	I	
2	Unknown	I		I	I	I	I	I	I	
3	Unknown	I		I	I	I	I	I	I	
4	Red-tailed Hawk	E or Y		I	I	I	I	I	I	
5	Unknown	I		I	I	I	I	I	I	
5a	Common Raven	-		-	E or Y	I	I	I	I	
6	Red-tailed Hawk	E		I	2Y	I	I	E or Y	I	(Golden Eagle)
7	Red-tailed Hawk	I		I	-	E	I	E or Y	I	
8	Red-tailed Hawk	4Y		I	I	E	I	E or Y	I	
9	Common Raven	I		I	I	I	I	I	I	
10	Red-tailed Hawk	I		I	I	I	I	I	I	
11	Could not locate									
12	Red-tailed Hawk	I		I	I	E	1Y	I	I	
13	Red-tailed Hawk	I		I	I	I	I	E or Y	I	
14	Unknown	I		I	I	I	I	I	I	
15	Unknown	I		I	I	I	I	I	I	
16	Great Horned Owl	I		I	I	E	2Y	I	I	
17	Great Horned Owl	I		I	I	I	I	I	I	
18	Red-tailed Hawk	I		I	I	I	I	1Y	I	Great Horned Owl
19	Great Horned Owl	1Y		I	I	I	I	I	I	
20	Unknown							I	I	
21	Not on Map									
22	Red-tailed Hawk	I		I	I	I	I	E or Y	I	
23	Not on Map									
24	Red-tailed Hawk	I		I	I	I	I	I	I	
25	Great Horned Owl	I		I	I	I	I	I	I	
26	Unknown	I		I	I	I	I	Nest has fallen		
27	Unknown	I		I	I	I	I	E or Y	I	Red-tailed Hawk
28	Golden Eagle	1Y		I	I	I	I	I	I	
29	Unknown	I		I	I	I	I	I	I	
30	Red-tailed Hawk	2Y		I	I	I	I	I	I	
31	Unknown	I		I	I	I	I	I	I	
32	Great Horned Owl	2Y		2Y	-	I	I	I	I	
33	Unknown	I		I	I	I	I	I	I	
34	Unknown	I		I	I	I	I	I	I	
35	Unknown	I		I	I	I	I	I	I	
36	Red-tailed Hawk	2Y		I	I	I	I	E	2Y	
37	Unknown	I		I	I	I	I	I	I	
38	Unknown	I		I	I	I	I	E or Y	Y	Raven
39	Golden Eagle	1Y		I	I	I	I	I	I	
40	Unknown	I		I	I	E	2Y	2	I	Great Horned Owl
41	Unknown	I		I	I	I	I	Nest has fallen		
42	Unknown	I		I	I	I	I	I	I	
42a	Red-tailed Hawk	-		-	2Y	I	I	E or Y	I	Great Horned Owl
43	Great Horned Owl	2Y		I	I	I	I	I	I	
44	Unknown	I		I	I	I	I	I	I	
45	Red-tailed Hawk	2Y		I	I	I	I	E	2Y	
46	Red-tailed Hawk					E	I	E or Y	I	
47	Unknown					I		I	I	
48	Great Horned Owl							E	I	
49	Red-tailed Hawk							E	I	

Code:

I = inactive nest
E = adult bird observed in an incubating posture; presumed to be incubating eggs.
(2) Y = number of young observed in the nest.
E or Y = adult bird observed in an incubating posture; due to time of year, assumed to be either incubating eggs or brooding very young chicks.

8.6 Aquatic Ecology

8.6.1 Benthos

Benthos data have not been received from the Water Resources Division of U.S.G.S. for the time period after May, 1978. Data prior to this time have been reported in Semi-Annual Data Reports and analyses were reported in the 1978 C-b Annual Report - Volume 2.

A plan is to be initiated by C.B. Project staff personnel in 1980 to collect and evaluate benthos data. This is being done because U.S.G.S. data collection is funded by EPA with an outside laboratory providing analyses. Scheduling of U.S.G.S. data analyses and reporting of results is not controlled by the C.B. project or the Area Oil Shale Office.

8.6.2 Periphyton

8.6.2.1 Scope

The periphyton communities are the major primary producers in the streams. They provide a major food source for benthic organisms and some fish species. They can respond very quickly to changes in water quality, and as such can be an important parameter for early detection of habitat degradation. Periphyton are stationary therefore, they respond to changes in water quality at given locations.

8.6.2.2 Objectives

The obejctive is to infer water quality and bio-productivity from species present.

8.6.2.3 Experimental Design

Current sampling stations for Periphyton are located on Piceance Creek and are shown on Figure 8.6.2-1 as WP01 (Stewart Gulch near U.S.G.S. Station WU07), WP02 (Middle Station), and WP03 (Hunter Creek near U.S.G.S. Station near WU61). Station WP01 was moved from a baseline location of P-1 further upstream to the current location WP01 in 1977. It is designated as a control station, above development impact. Baseline locations of WP02 (formerly P-3) and WP03 (formerly P-6) have not been changed. Table 8.6.2-1 provides a cross reference to the station identification codes.

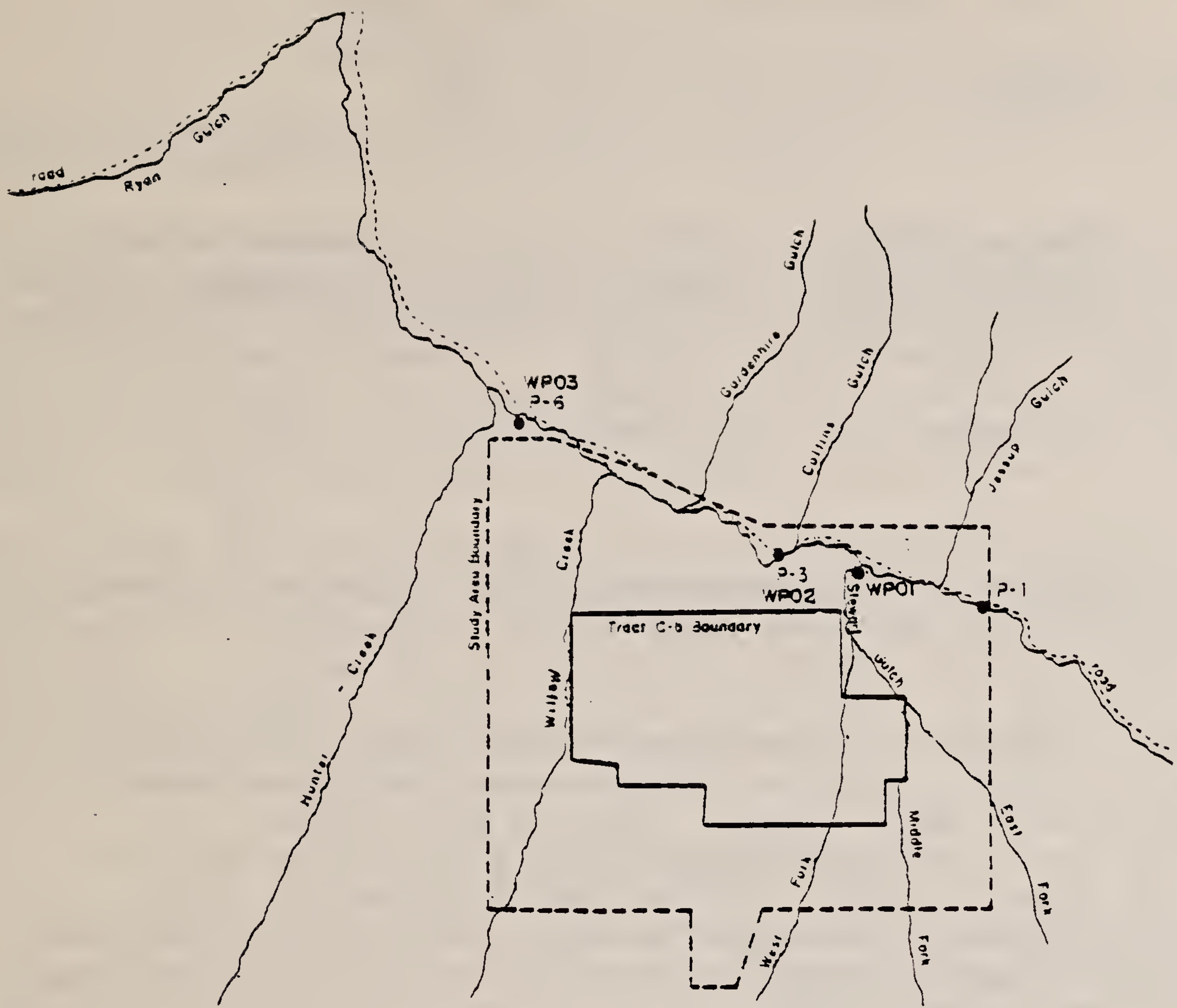


FIGURE 8.6.2-1

PERIPHYTON SAMPLING STATIONS

TABLE 8.6.2-1

CROSS REFERENCE TO PERIPHYTON STATION CODES

	Stewart Station (Control Site)	Middle Station	Hunter Station (Development Site)
Current Code	WP01	WP02	WP03
U.S.G.S. Code	WU07	None	WU61
Baseline Code	*	P-3	P-6

*Baseline location of station P-1 was approximately 2.4 kilometers upstream from WP01. This control site was moved to WP01 location in 1977.

Collection of periphyton samples is accomplished monthly from stations WP01, WP02, and WP03 using artificial substrates (glass slides) which have been incubated in the water for at least 21 days. Sampling ran from May 1, to October 31, 1979, resulting in five collections. Six glass slides were incubated at each of the three locations. At the time of collection, three slides are collected and placed in individual plastic containers and preserved with "M-3" preservative, a modified Lugol's solution, for taxonomic identification and enumeration (total of 6 slides).

The slides collected for biomass are oven dried at 105°C to constant weight. They are then weighed to the nearest milligram, ashed at 500°C, rewetted with distilled water to replace the water of hydration, oven dried, and weighed again. Biomass is reported as mg ash-free dry weight per square centimeter.

Slides collected for taxonomic identification and enumeration are scraped into an appropriate volume of water along with a sufficient amount of preservative to limit microbial growth and/or algal decomposition. The resulting solution is mixed thoroughly, and an aliquot withdrawn for quantitative analysis using an inverted microscope at a magnification of 560X.

8.6.2.4 Method of Analysis

The following data are tabulated:

Species identification
Total taxa by sample and station
Density (units/cm^2)
Percent relative abundance
Biomass (mg/cm^2) per sample
Diversity ($\bar{d}$)

Maximum diversity ($\log_2$ number of species)
Equitability percent

Data analyses include a discussion of the relative abundance of certain indicator species if these occur in significant numbers.

Statistical analyses of selected parameters include a comparison of density, number of species, and species diversity values obtained during 1979 studies. Comparisons were made between stations and months using analysis of variance and professional judgment. If the null hypotheses of no change are rejected at α = 0.05 level, daily water samples will be analyzed, periphyton sampling may be intensified in an effort to pinpoint the degradation, and, as previously noted, a systems dependent (fish shocking) study may be initiated.

The initial monitoring program called for additional statistical analysis via correlation analysis and non-parametric tests. An analysis of variance was determined to be the most appropriate statistical analysis to apply to available data. A comparison of differences between stations over previous years could not be made as a result of past data gaps. A correlation analysis cannot be made unless measurements of physical environmental parameters are made in conjunction with periphyton studies.

8.6.2.5 Discussion and Results

A total of 64 periphyton taxa were identified from Stewart, Middle and Hunter Stations on Piceance Creek from artificial substrate samples collected during May, July, August, September, and October, 1979 (Tables A8.6.2-1 through A8.6.2-5). These 64 taxa were comprised of 55 diatoms (Bacillariophyta), 7 green algae (Chlorophyta), 1 blue-green alga (cyanophyta) and a single euglenoid taxon (Euglenophyta). The occurrence and dominance of all taxa identified at sample stations during each sampling period are given in Table A8.6.2-6. Species diversity ($\bar{d}$) and biomass data (mg/cm^2) for all sample stations during the five month study are summarized in Tables 8.6.2-2 and 8.6.2-3.

Periphyton densities varied monthly at all stations with minima and maxima occurring during various study months. Periphyton density minima occurred during May at Stewart and Hunter Stations. No samples were collected during May, 1979, from Middle Station. The lowest recorded density values for Middle Station occurred in October. Density maxima for Stewart, Middle, and Hunter Stations were recorded during October, August, and September, respectively.

The minimum values recorded at Stewart and Hunter Stations during May were extremely low compared to all other densities calculated during the study sample periods (Tables A8.6.2-1 through A8.6.2-5). Analysis of variance was used to test for significant differences in total periphyton densities. Since Middle Station was not sampled in May, 1979, comparisons were made between stations and months for July through October. At the α = 0.05 level, a significant difference in periphyton density was found between Middle Station and

TABLE 8.6.2-2

SUMMARY OF SPECIES DIVERSITY OF THE MEAN FOR PERIPHYTON COLLECTED AT STEWART, MIDDLE, AND HUNTER STATIONS, PICEANCE CREEK, 1979

Sample Date	Stewart Station	Middle Station	Hunter Station
May	2.71	*	0.06
July	3.25	0.22	0.32
August	2.57	1.37	0.10
September	1.75	0.25	0.19
October	1.39	0.35	0.20

*No samples collected during this time period

TABLE 8.6.2-3

SUMMARY OF MEAN BIOMASS EXPRESSED AS ASH-FREE DRY WEIGHT FOR PERIPHYTON COLLECTED AT STEWART, MIDDLE, AND HUNTER STATIONS, PICEANCE CREEK, 1979 (mg/cm^2)

Sample Date	Stewart Station	Middle Station	Hunter Station
May	0.20	*	0.06
July	0.50	0.22	0.32
August	0.14	1.37	0.10
September	0.91	0.25	0.19
October	0.29	0.35	0.20

*No samples collected during this time period

Stewart Station. Hunter Station densities were not significantly different at the α = 0.05 level than densities at either Stewart or Middle Stations.

When comparing densities between months, no significant difference was found between the months of July, August, and October; however, the mean density for September was found to be significantly different than those of all other months. The high September periphyton densities are probably due to reduced flows and increased temperatures, nutrient concentrations and light penetration.

Diatoms dominated the periphyton at all stations during the entire study accounting for 88.5 to 100% of the total relative abundance of all algae identified. A seasonal variation in dominant diatom taxa was evident regarding the following species: Cocconeis placentula, Fragilaria vaucheriae, Nitzschia species, and Gomphonema species (Tables A8.6.2-1 through A8.6.2-5). Achnanthes species dominated all samples collected. The only non-diatom occurring as a dominant at any sample station during the 1979 study was the green alga, Cladophora species, at the Hunter Station during August.

Some annual variations also seem to be occurring in Piceance Creek based on comparisons of 1979 sampling to Spring and Fall, 1978 periphyton analyses. (Tables A8.6.2-7 through A8.6.2-12).

Statistical comparisons of total species between stations and months were made using analysis of variance at the α = 0.05 level. No significant difference was found between Stewart and Middle Stations or Stewart and Hunter Stations. A significant difference in number of species was found, however, between Middle Station and Hunter Station. Significant differences between months were found for all comparisons except between August and October.

The ecological requirements and tolerances of the dominant diatom taxa identified from Stewart, Middle, and Hunter Stations during 1979 were similar. Most of the taxa were cosmopolitan species of alkaline waters which commonly occur in oligotrophic and mesotrophic rivers (Lowe 1974 and Patrick and Reimer 1966). The majority of the dominant algae identified are true epiphytic or periphytic taxa.

Species diversity values ($\bar{d}$) for the study are summarized in Table 8.6.2-2. Species diversity values increased from spring sampling periods to a summer high (July-August) for all sample stations. Tests for significant differences of mean species diversities were by analysis of variance at the α = 0.05 level between months and stations. No significant differences were found between Stewart and Middle Stations or Stewart and Hunter Stations. A significant difference was, however, found between Middle and Hunter Stations. Significant differences in mean species diversities were found to exist between the month of July and the months of September and October, and between August and the months of September and October, while no difference was found between July and August, or between September and October.

Biomass data are summarized in Table 8.6.2-3. Biomass data could not be statistically compared between stations and months because of missing replicate data.

In addition to the 1978 and 1979 periphyton data discussed previously, periphyton data were collected in 1974, 1975, 1976, and 1977 from Piceance Creek (C-b Shale Oil Venture, et. al. 1978).

Difficulties arise in the comparison of 1974-76 and 1977-79 periphyton data because baseline sampling site P-1 was moved approximately 2.4 kilometers downstream to the current location, WP01, in 1977 (see Figure 8.6.2-1). This location is near U.S.G.S. station WU07 and referred to as Stewart Station.

Periphyton community analysis data for 1974, 1975, and 1976 (Tables A8.6.2-10 and A8.6.2-11 of Volume 2A 1978 C-b Annual Report) and biomass productivity data for 1975 and 1976 (Table A8.6.2-12 of the 1978 report) have been compared with these same data for 1978-79 at each of the three stations for time trends. Comparisons were also made between the stations to evaluate differences in locations. Middle Station (WP02) had been discontinued in 1976 and reactivated in 1979. Therefore, only 1979 data are available for these analyses at this station.

The periphyton community analysis data for 1974-76 is qualitative only. No information is available for comparison on periphyton abundance and dominance.

Since the occurrence of a taxon in a sample could indicate the chance presence of a single individual unsuited to the present environmental conditions rather than a growth response of an organism to favorable conditions, dominant taxa (present at abundances greater than 5% of the total abundance) are often used to describe an algal community. In the case of the 1974-76 data where dominance was not indicated, taxa dominating in 1977-79 have been compared to those occurring in 1974-76. There seemed to be considerable annual variation in the periphyton communities at all the stations (Tables A8.6.2-13 through A8.5.2-17).

Differences in sampling techniques and levels of taxonomic expertise may be responsible for some of the variation observed between the periphyton communities of 1974-76 and 1977-79. Although annual differences have apparently occurred, the reasons for these differences are not immediately apparent. Combinations of a number of environmental factors such as light (turbidity), temperature, flow rate, nutrients, and pH all effect the periphyton community. Any or all of these factors may vary on an annual basis irrespective of any man-made perturbations.

Although variability in the periphyton communities is apparent annually, seasonally and between stations, most of the taxa observed over the six year study in the vicinity of Stewart and Hunter Stations were diatoms with similar environmental requirements. According to Lowe (1974) most of the diatom taxa observed attain best development in alkaline waters (pH 7) of relatively high inorganic nutrient concentrations. They are common in small or large streams or ponds. Most of the taxa recorded as abundant are considered to be cold water forms.

The seasonal fluctuation apparent in ash-free dry weight biomass productivity was highest in summer and fall when light and temperature were optimum for growth. Spate and drought occurrences are probably the most important factors governing the time and degree of high productivity in the summer and fall. In 1975, productivity was high in late summer and fall while in 1976 the high values occurred in spring and early summer with a low value in mid-summer (July). A July 1976 high flow rate of approximately 40 cfs could have scoured the periphytic algae from the glass slides and reduced the recordable biomass productivity. Similarily, in August of 1978 and 1979, productivity was low. Increased flow rate may also have been responsible for the decline in summer productivity during the latter two study years. On an annual basis, the range of productivity values recorded were generally comparable over the six year study.

Productivity at the different stations was also variable. In 1975, 1976, 1977 and 1979, biomass productivity tended to be higher at Stewart Station than at Hunter Station while in 1978 the reverse was true. Figure 8.6.2-2 graphically presents the productivity results for 1975-78.

8.6.2.6 Conclusions

The analysis of the periphyton data at present does not show any effect that may be attributable to Tract operations. Although statistical analysis does show significant differences between stations and months, no trend relating these differences to the control stations versus the two test stations was established. The variability in the data indicated by statistical analysis is deemed to be due to natural causes.

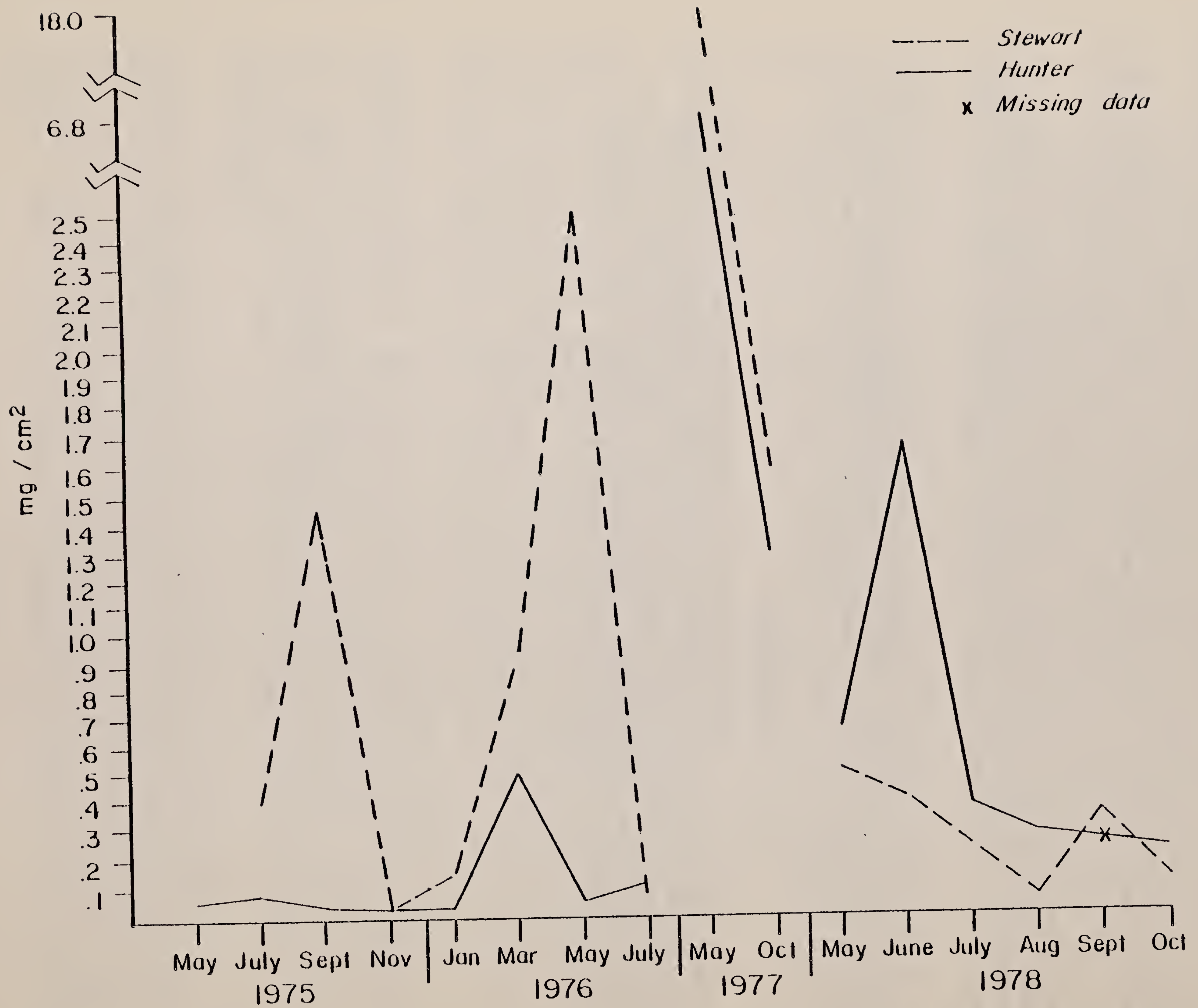


FIGURE 8.6.2-2 PERIPHYTON ASH-FREE DRY WEIGHT PRODUCTIVITY (mg/cm^2) FROM PICEANCE CREEK, COLORADO IN THE VICINITY OF STEWART AND HUNTER STATIONS, 1975-1978

8.7 Terrestrial Studies

The terrestrial studies portion of the Environmental Baseline Program was designed to describe the predevelopment biological environment within the C-b study area and to provide baseline data to be used in monitoring changes in the biota as a result of oil shale development. Baseline parameters were selected for their usefulness in describing the existing environment on Tract C-b. Development monitoring parameters were judged to be useful because of their measurability or relatively low natural variability, and/or sensitivity to expected environmental perturbations.

8.7.1 Vegetation Community Structure and Composition

8.7.1.1 Scope

The vegetation community structure and composition studies evaluate major changes in the make-up of the major plant communities on the Tract. Other vegetation monitoring programs provide a better means for statistically evaluating changes. The structural and compositional studies are better used for evaluating general vegetative trends. These studies are centered on the six intensive study sites established during 1974 and sampled on a three-year rotational basis. Chained pinyon-juniper rangeland Plots 1 and 2 (BJ11 and BJ12) were sampled in 1978, pinyon-juniper woodland Plots 5 and 6 (BJ15 and BJ16) were sampled in 1979, and sagebrush Plots 3 and 4 (BJ13 and BJ14) will be sampled in 1980. The sequence will be repeated beginning in 1981.

8.7.1.2 Objectives

The objective of the community structure and composition studies is to obtain long-term data from permanently located sampling quadrats to evaluate differences in numerous species with respect to long-term trends. The productivity studies, discussed later, focus on monitoring a process; the structure and composition studies focus on performances of species within the major vegetation types.

8.7.1.3 Experimental Design

The community structure and composition studies are conducted at the six intensive study plots. Two are located in the pinyon-juniper woodland type, two in the chained rangeland type and one each in the bottomland sagebrush and upland sagebrush types. At each location a grid of 25 1.0 m^2 quadrats has been established in a permanently fenced and in an adjoining open area (a grid in each for a total of 50 quadrats for each site). Observations on the herb and ground-layer components are made in the 1.0 m^2 quadrats. Locations of the plots are shown on the map (Exhibit C) in the cover jacket; stations BJ01 through BJ06 are fenced areas, BJ11 through BJ16 are open areas, and BJ21 through BJ26 are cattle exclosures.

Shrubs are sampled along line-strip transects. The center posts marking the herb quadrats serve as end points of the transects, thus producing a total of 20 line-strips per grid. The herb quadrats are established on 10-meter centers. The line-strips are 10 meters long and 4 meters wide. Shrub cover estimates are obtained using a 10-meter line intercept located in the center of the line-strip. Density estimates are obtained by counting the number of individuals of each species within the line-strip. Individuals are recorded on the basis of height classes so that it is possible to obtain measures of population structure.

In the woodland plots canopy cover for tree species is recorded along the same 10-meter line intercept used for estimating shrub cover. All of the trees within the area defined by the herb quadrat grid (40 meters by 40 meters) have been tagged and numbered. Changes in tree diameter are evaluated by repeated measurement of these trees.

The parameters being monitored in this study include: Cover and frequency for herbaceous species, cover, frequency and density for shrubs, and diameter and canopy cover for tree species.

8.7.1.4 Method of Analysis

Data from the community structure and composition studies are mainly being evaluated through use of trend analysis. Total vegetation composition changes are being evaluated by examining trends in similarity indices.

8.7.1.5 Discussion and Results

Monitoring vegetation changes through the use of permanent quadrats has several advantages. By repeated sampling of identical areas most of the variability caused by sample quadrat location can be eliminated. Also, if desired, it is possible to evaluate changes within each of the quadrats. Even though the use of permanent quadrats reduces sampling error, two sources of error remain. In visual evaluation of species cover it is very difficult to be totally consistent from year to year, even if the data are recorded by the same observer. Also, difficulties in species recognition constitute a source of error which is difficult to eliminate. This is especially true for grass species in vegetative condition. Species recognition problems are manifested in both cover and frequency data. Visual estimates affect only the cover data.

Major species at Plot 5-0 (BJ15) include Indian ricegrass (Oryzopsis hymenoides), Pennsylvania sedge (Carex pensylvanica) and a species of bluegrass (Poa) (Table A8.7.1.-1). Even though these species tended to be the most prevalent, none had mean cover values greater than 2 percent. The understory in Plot BJ15 is very sparse. Total mean cover in the herb layer was only 7.3 percent, and bare soil had a mean value of approximately 20 percent. Few changes in species composition have occurred in Plot BJ15 since 1975 (Table A8.7.1-2). The most noticeable differences are associated with annual species like baby blue eyes (Collinsia parviflora), goosefoot (Chenopodium album), and tansy mustard (Descurainia pinnata). These species are very responsive to yearly differences in precipitation and tend to be more abundant in moist years and less abundant in dry years. Perennial species like Indian ricegrass and Pennsylvania sedge show very little year-to-year difference in abundance. Mean herb cover and other herb and ground layer components have changed very little since 1975 (Table A8.7.1-3). Species density (the number of species per square meter) decreased from 1975 to 1976 and then increased in 1979. These changes are mostly related to changes in the number of annual species, as mentioned earlier.

Major species at Plot BJ05 include crested wheatgrass (Agropyron desertorum), Indian ricegrass and western wheatgrass (Agropyron smithii) (Table A8.7.1-4). These three species account for almost 60 percent of the herbaceous cover, however they provide a combined mean cover of only 6 percent. Mean total cover in the herb layer is only 9.3 percent. The differences in species abundance and composition noted in Plot BJ15 have also occurred in Plot BJ05 (Table A8.7.1-5). Annual species tend to fluctuate, and perennial species tend to be quite stable. It appears that certain of the perennial grasses may be increasing; frequency values for crested wheatgrass, western wheatgrass, Indian ricegrass and squirrel tail grass (Sitanion longifolium) have all increased since 1975. During this same period Pennsylvania sedge and small ricegrass (Orysopsis micrantha), both perennial grass or grasslike species, have decreased. These differences may be related to subtle changes in community composition or they may be related to errors in identification. Total herb cover, litter cover, cover by bare soil and species density have changed little in the period between 1975-1979 (Table A8.7.1-3).

Dominant herbaceous species at Plot BJ16 include mutton grass (Poa fendleriana), western wheatgrass and needle-and-thread grass (Stipa comata) (Table A8.7.1.6). These three species account for approximately 50 percent of the total cover. Total herb cover had a mean value of 9.6 percent. No consistent trends can be seen in the species frequency comparisons between 1975 and 1976 (Table A8.7.1-7). Perennial species tend to be relatively constant. The perennial grasses show a tendency to increase or decrease rather dramatically, however this likely relates to errors in identification. Mean total cover, litter cover, cover by bare soil and species density have changed little over the last 5 years (Table A8.7.1-3).

Major herb species at Plot BJ06 include prairie Junegrass (Koeleria gracilis), mutton grass, Hood's phlox (Phlox hoodii), and western wheatgrass (Table A8.7.1-8). These four species have a combined mean cover of 11.6 percent and account for 54 percent of the total cover. Total herb cover had a mean value of 16 percent. Frequency values for herb layer species have been relatively consistent over the past 5 years (Table A8.7.1-9). The most noticeable differences have been with certain of the perennial grass species, and these differences can be attributed to errors in identification. Mean total herb cover was approximately 6 percent less in 1979 (Table A8.7.1-3). It will be interesting to note whether total cover continues to decrease at this rate or whether this difference relates to sampling error. Plot BJ16 showed a slight decrease but not nearly as large as that measured at Plot BJ06. Cover by woody species, litter cover, and species density values were very similar during the five-year period.

Frequency, mean cover and relative cover for shrub species at Plots BJ15, BJ05, BJ16, and BJ06 are presented in Tables A8.7.1-10 through A8.7.1-13. The major species are big sagebrush (Artemisia tridentata), saplings of pinyon pine (Pinus edulis) and saplings of Utah juniper (Juniperus osteosperma). The shrub layer in the understory of the woodlands is sparse, however increases in total cover have occurred over the last three years. Mean cover increased by 2.4 percent at Plot BJ15, 0.7 percent at Plot BJ05, 0.4 percent at Plot BJ16, and 4.1 percent at Plot BJ06. Big sagebrush increased in cover at all plots and accounted for 47 percent of the total increase at all plots. Utah juniper accounted for 32 percent of the total increase. At Plot 5 a greater increase was measured at the open plot (BJ15) while at Plot 6 a greater increase was measured in the fenced plot (BJ06). Few major changes have occurred relative to shrub density at Plots 5 and 6 (Table A8.7.1-14). An increase in big sagebrush density at Plot BJ06 can be noted, and a slight increase in pinyon pine saplings at Plot 5 can be seen. These increases may be related to increasing stature of existing plants which were not large enough to be tallied in earlier surveys. This is evidenced by the increase in the density of individuals in the lowest height class.

Tree canopy cover has changed little over the past five growing seasons (Tables A8.7.1-15 and A8.7.1-16). Decreases at Plots BJ05 and BJ16 are related to the deaths of several trees located on the transect lines. Many pinyon pine trees died throughout the Piceance Basin region during and following the winter of 1978-79. Deaths at Plots BJ05 and BJ16 were apparently related to this regional die-off. Slight increases in total canopy cover were recorded at Plots BJ15 and BJ06 (Table A8.7.1-16).

Growth rates for trees have continued to be low at all sites (Table A8.7.1-17). Slight increases in growth rates were noted for both pinyon pine and Utah juniper at Plots BJ15, BJ16, and BJ06. At Plot BJ05 the growth rate for pinyon pine increased while the rate for Utah juniper decreased. These comparisons are based on the mean annual increase measured during the period 1974-76 (two growing seasons) and the mean annual increase measured during the period 1976-79 (three growing seasons). During the period 1976-79 all species at the study plots either increased in size or showed no mean increase. No species decreased in mean diameter as occurred during the period 1975-76. (Decreases in mean diameter occur as a result of sampling error.)

The original placement and design of the pinyon-juniper woodland study sites attempted to locate Plot 5 in an area which would be affected by oil shale development and to locate Plot 6 in an area which would not be affected by development. Inherent differences in the two sites makes direct comparison of the sites difficult; however, it is possible to evaluate trends through the use of similarity indices. If Plot 5 were affected by development, its original similarity (based on 1975 data) with Plot 6 should decrease. If it were not affected, then similarity between the plots should remain relatively constant. Similarity was calculated using the formula:

$$S.I. = \frac{2w}{a + b} \times 100$$

where:

S.I.	=	Similarity Index
w	=	amount of the comparison parameter shared by the sites being compared
a	=	sum of the comparison parameter at one sampling location
b	=	other sampling location

For the purpose of comparing Plots 5 and 6, herb-species frequency was used as the comparison parameter, since herbaceous species are likely to be influenced by development activities more quickly than are woody species. From the data presented in Figure 8.7.1-1 it can be seen that the similarity indices comparing Plot 5 with Plot 6 have changed very little over the last five years. In general the trend has been for a slight increase in similarity rather than a decrease. It can also be seen that Plots 5 and 6 are much less similar than are Plots 8J15 and 8J05 and Plots 8J16 and 8J06. From these data it appears that any development on the Tract has had a negligible impact on the herb layer similarity at Plots 5 and 6.

8.7.1.6 Conclusions

Based on data collected in 1979 and based on comparisons with 1975 and 1976 data, it appears that no major changes have occurred in the pinyon-juniper woodland Plots 5 and 6. The minor differences in species performances most likely relate to natural processes and the ways in which species respond to variations in environmental parameters.

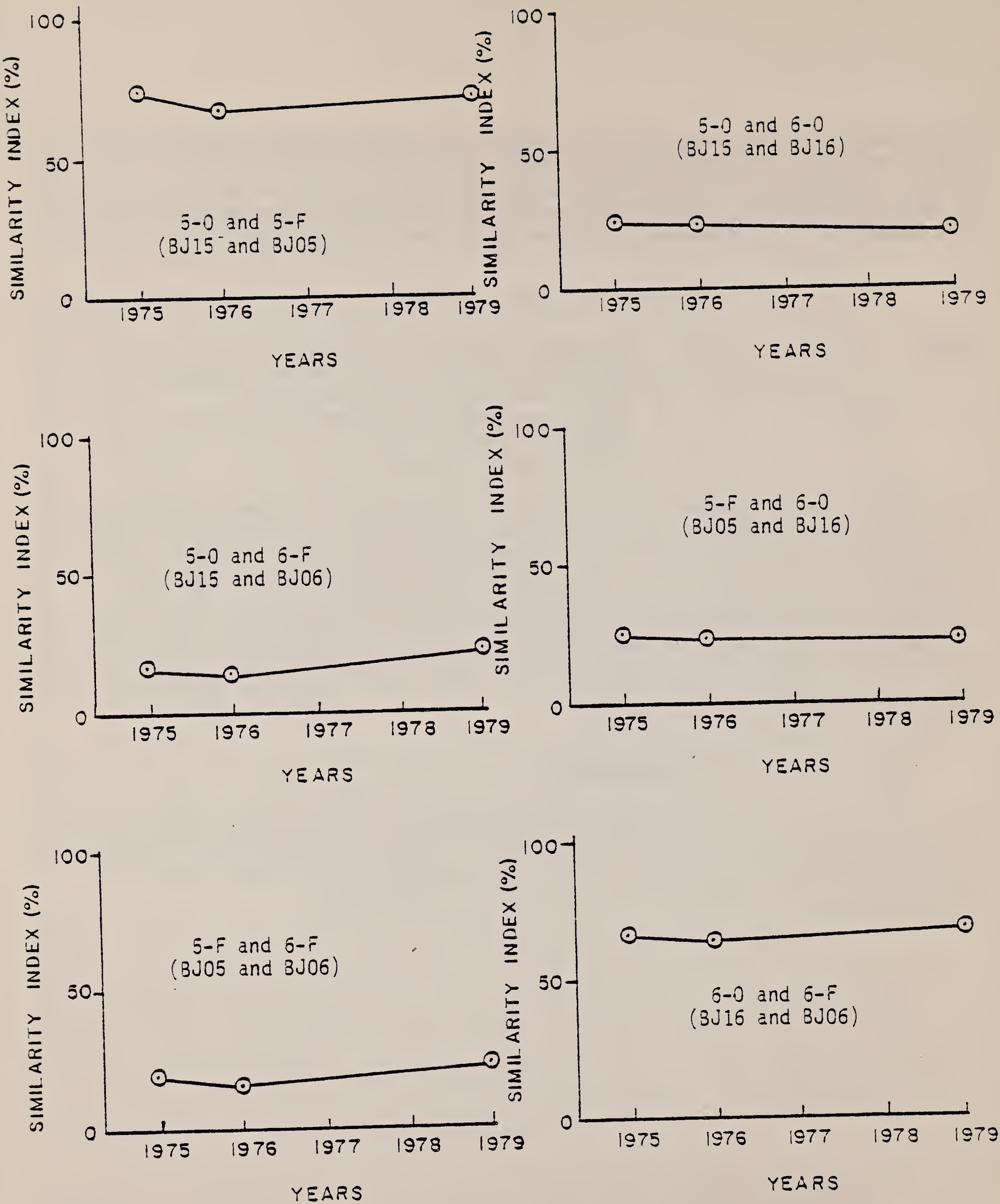


Figure 8.7.1-1 Trends in similarity index (based on herb layer species frequency) at Plots 5 and 6.

8.7.2 Herbaceous Productivity and Utilization

8.7.2.1 Scope

Productivity of vegetation is intrinsically important in the operation of ecosystems on Tract C-b. The amount of production and availability of food are both of consequence for animal species within the system. Any significant interruption in production may well be manifested in changes throughout the ecological system. In terms of monitoring, herbaceous production is a more convenient parameter to measure and is a reflection of the total production in any of the communities on the Tract. By monitoring the herbaceous production it is possible to evaluate yearly and site-to-site differences in productivity. The scope of the herbaceous productivity and utilization studies includes sampling on a Tract-wide basis, sampling at the intensive study sites established during the baseline studies period, and also sampling in native communities fertilized in order to increase production. The fertilization evaluation studies are conducted on an as-needed basis. Also, studies of possible air pollution effects north of Piceance Creek will be repeated only if it appears necessary to do so.

8.7.2.2 Objectives

The objectives of the productivity and utilization studies are to provide the means for measuring trends of herbaceous production related to development activities, and to evaluate any changes in herbaceous utilization.

8.7.2.3 Experimental Design

Herbaceous production and utilization are being studied on a Tract-wide basis through the use of randomly located exclosures. These exclosures (range cages) are small in size and prevent grazing by large herbivores on slightly more than one square meter of ground. Individual placement of the range cages is determined by using random coordinates on the vegetation map of the Tract. These random sites are then located in the field. Once the sampling point is located, a second comparable, nearby site is also located (usually within 5-10 meters of the first). The range cage is then randomly placed over one of the two sites. The "caged" quadrat is clipped later in the growing season in order to estimate production. The other "non-caged" site is clipped in order to provide the data necessary for evaluating the degree to which the herbaceous vegetation is utilized by large herbivores. It is important to assure that the two quadrats in the pair are comparable. Because of the inherent sparsity and heterogeneity of the herbaceous production on the Tract, it is very easy to have two quadrats located adjacent to one another and to have order-of-magnitude differences in production. It could be either caged or open areas that are so strikingly different. If the highly productive areas are always caged, it is possible for the data to misrepresent the extent of utilization, and if the open areas are consistently more productive the data would suggest an adverse caging effect. If the placement of the quadrats were totally random with respect to open and caged ares, utilization effects would be masked by the variability of the production data. For these reasons it was necessary to adopt the above mentioned design for the utilization studies. All sampling locations are randomly selected and the placement of the range cages is randomly determined. The effect of this design is to retain objectivity while minimizing the effect of production variability.

Fifteen pairs of sampling sites (range cages and open areas) are placed throughout the Tract in each of the four major plant communities (pinyon-juniper woodlands, chained pinyon-juniper rangelands, upland sagebrush shrublands, and bottomland sagebrush shrublands). The quadrats are clipped at peak season (approximately mid-late July), and all of the current year's growth is removed. Clipped samples are fractionated on the basis of species for western wheatgrass, cheatgrass (Bromus tectorum) and Indian ricegrass, and on the basis of life form for other perennial grasses, other annual grasses, perennial forbs, annual forbs, and half-shrubs. Caged and adjacent open areas are clipped at the same time. Clipped samples are returned to lab, oven dried to a constant weight and then weighed to the nearest milligram.

Production studies at the intensive study sites are being conducted using a double sampling approach. Fifty one-square-meter quadrats are randomly located in seasonally fenced plots at the intensive study sites. (Fences are put up at the beginning of the growing season and removed after the studies have been completed at the end of the season). The weight in grams for each of the current year's growth fractions listed above is estimated in each of the fifty quadrats. Ten of these quadrats are clipped in addition to being estimated. Once the samples have been dried and weighed, regression equations are developed for each of the species or species groups. All of the fresh estimates are then corrected to an oven dry weight on the basis of the derived equations. Data from these studies are compared with information derived during baseline periods and are also used to compare vegetation types and study sites within any given year.

The effects of fertilization in native vegetation types are also being monitored. Two fertilizer treatments (ammonium nitrate and ammonium nitrate plus phosphorus) are being employed at two sites in the chained rangeland community type. One site is located on the ridge above Scandard Gulch and the other is located on the ridge above Cottonwood Gulch. At each of these sites, five range cages and open area locations are sampled in a control area and in each of the two fertilizer treatment areas. The data are collected and handled in the same manner as in other range cage studies.

8.7.2.4 Method of Analysis

Analysis of herbaceous production and utilization data is focused on five areas of comparison. The following hypotheses will be tested in this analysis:

H_0 = No significant changes exist in:

1. Differences among vegetation types during a given growing season.

2. Differences between study sites of the same vegetation type during a given growing season.

3. Differences between years within a given vegetation type.

4. Differences between fenced and open areas within a vegetation type during a given growing season.

5. Differences in production related to the addition of fertilizer.

Total production is used as the parameter for comparison. Evaluation of differences is accomplished using time-trend analysis and one-way analysis of variance (F-test) to test whether or not the observed differences in means are significant.

8.7.2.5 Discussion and Results

Tract-wide Range Cage Studies. Tract-wide range cage studies provide more broadly based estimates of production in the major vegetation types than can be obtained from the intensive study sites. Data from these studies can be used in trend analysis and can also be compared using statistical tests. Because of the high variability of the data the statistical tests are not overly sensitive and differences in means need to be rather large in order to be judged significant. An attempt has been made to obtain sufficient samples to be able to detect a 20 percent difference in means with 80 percent confidence. This level of adequacy was reached in the upland sagebrush and chained rangeland communities but was not attained in the bottomland sagebrush and pinyon-juniper woodland communities. Low production and patchy distribution of individual plants tend to make the latter two communities more variable. It may be possible to increase the sample size in future years in order to obtain more reliable production estimates.

Dry weight data for range cages and open areas in the pinyon-juniper woodlands are presented in Table A.8.7.2-1. Total production had a mean value of 10.3 g/m2 (92 lbs/acre) inside the range cages and 12.4 g/m^2 (110 lbs/acre) in the adjacent open areas. Most of the production was attributable to perennial grasses (Table A8.7.2-2).

Dry weight data for range cages and open areas in the chained pinyon-juniper rangelands are presented in Table A8.7.2-3. Mean total production for range cages had a value of 45.6 g/m^2 (406 lbs/acre) which was more than four times the production measured in the pinyon-juniper woodlands. Open areas had a mean value of only 34.4 g/m^2 (306 lbs/acre) (Table A8.7.2-4) suggesting a utilization value of approximately 25 percent. Most of the production was attributable to western wheatgrass and other perennial grasses (Table A8.7.2-4).

Dry weight data for range cages and open areas for the upland sagebrush shrublands are presented in Table A8.7.2-5. Mean total production for the range cages had a value of 46.7 g/m^2 (416 lbs/acre) and for open areas a mean value of 35.3 g/m^2 (314 lbs/acre) (Table A8.7.2-6). These values were close to the values obtained for the chained rangelands. Western wheatgrass and other perennial grasses provided most of the production. Utilization of the herbaceous species was approximately 25 percent.

Dry weight data for range cages and open areas in the bottomland sagebrush shrublands are presented in Table A8.7.2-7. Mean total production for the range cages was 28.4 g/m^2 (253 lbs/acre) and for the open areas was 21.7 g/m^2 (193 lbs/acre). Most of the production was attributable to other perennial grasses and cheatgrass (Table A8.7.2-8). Total production was less than either the chained rangelands or upland sagebrush shrublands but was greater than the pinyon-juniper woodlands. Utilization in the bottomland sagebrush shrublands was approximately 24 percent.

Intensive Study Plots

During 1979 production data were collected at intensive study Plots 1, 2, 5, and 6 (BJ01, 02, 05, and 06). Fresh weight estimates for each of the 50 quadrats sampled at these locations are presented in Tables A8.7.2-9 through A8.7.2-12. At each sampling location 10 quadrats were clipped, sorted, dried and weighed. Oven dry weight data for these clipped quadrats are presented in Tables A8.7.2-13 through A8.7.2-16. Regression equations (Tables A8.7.2-17 through A8.7.2-20) were developed for each intensive study plot based on the quadrats which were both estimated and clipped.

Mean total production at Plot BJ21 was 20.7 g/m^2 (184 lbs/acre) with most of the production being attributable to Indian ricegrass and other perennial grasses (Table A8.7.2-21). Mean total production at the other chained rangeland study site (Plot BJ02) was 15.4 g/m^2 (137 lbs/acre) with most of the production attributable to perennial grasses (Table A8.7.2-22). Cheatgrass was quite abundant at this site and had a mean production of 3.1 g/m^2 (28 lbs/acre). It is interesting to note that the production at Plots BJ01 and BJ02 was approximately half of that measured for the chained rangeland type as a whole (range cage data).

In the pinyon-juniper woodland intensive study plots, mean total production was 8.4 g/m^2 (75 lbs/acre) at Plot BJ05 (Table A8.7.2-23) and was 10.7 g/m^2 (95 lbs/acre) at Plot BJ06 (Table A8.7.2-24). Major species included perennial grasses, western wheatgrass, and Indian ricegrass. Plot BJ06 had approximately the same total production as the pinyon-juniper woodlands as a whole (based on range cage data) and Plot BJ05 was only slightly less productive.

Trends in Herbaceous Production, 1975-79

After five years of data collection it is of interest to examine trends in total production. Over the past five years methods of data collection have changed and different sites have been sampled. Even with these changes it remains possible to see certain trends.

All of the sampled vegetation types and study sites have shown the same general pattern over the last five years (Table 8.7.2-1) (Figures 8.7.2-1 through 8.7.2-3). Production values were relatively high in 1975 and decreased in 1976 and 1977. Production values increased in 1978 and then decreased again in 1979. In the pinyon-juniper woodlands, Plots BJ25 and BJ26 followed parallel declines until 1977 when production values were nearly the same (Figure 8.7.2-1). In 1978, Plot BJ26 was more than twice as productive as Plot BJ25. It appears that in moist years Plot BJ26 has much greater capabilities for herb production while in the drier years production values are nearly equivalent to those in Plot BJ25. The Tract-wide samples from range cages follow the trends defined by Plot BJ25 much more closely than Plot BJ26 suggesting that Plot BJ25 is much more like the pinyon-juniper type as a whole than is Plot BJ26.

The chained rangeland plots (Figure 8.7.2-2) have remained quite similar over the past five years. During the period 1975-77, Plot BJ22 was slightly more productive than Plot BJ21. For the past two years, Plot BJ21 has been slightly more productive than Plot BJ22. This shift is most likely related to natural variability rather than to any development related influences. Data from the range cages in the chained rangeland suggest that the type as a whole is more than twice as productive as Plots BJ21 and BJ22.

The sagebrush shrublands have shown time trends similar to the other vegetation types (Figure 8.7.2-3). High values were measured in 1975 and 1978; lowest values were measured in 1977.

Over the past five years the upland sagebrush shrublands and chained rangelands have been consistently more productive than the bottomland sagebrush shrublands and pinyon-juniper woodlands.

Evaluation of Production Differences, 1979

Differences Among Vegetation Types and Study Sites. All comparisons of mean total production among intensive study sites were significantly different at the 10 percent level of significance. Both Plots BJ21 and BJ22 had significantly higher production than Plots BJ25 or BJ26 (Table 8.7.2-2). This pattern was repeated in the range cage data with the chained rangelands being significantly more productive than the pinyon-juniper woodlands. The chained rangelands were significantly more productive than the bottomland sagebrush shrublands, but were not significantly different from the upland sagebrush shrublands. The pinyon-juniper woodlands were significantly less productive than both the

Table 8.7.2-1 Summary of Annual mean production (g/m²) ± the standard error of the mean for major vegetation types on Tract C-b for 1975-1979. No range cages were sampled prior to 1978. Sagebrush study plots have not been sampled since 1977. See also Figures 8.7.2-1 through 8.7.2-3.

Vegetation Types	1975	1976	1977	1978	1979
Pinyon-Juniper Woodlands					
Plot 5 (BJ25)	25.0 ± 6.2	10.6 ± 1.9	6.2 ± 0.5	19.2 ± 2.3	8.4 ± 0.8
Plot 6 (BJ26)	34.2 ± 7.6	23.4 ± 4.0	6.4 ± 0.5	50.3 ± 3.3	10.7 ± 1.0
Range Cages				21.4 ± 6.7	10.3 ± 2.0
Chained Pinyon-Juniper Rangelands					
Plot 1 (BJ21)	49.3 ± 6.3	23.2 ± 4.6	11.1 ± 0.9	29.5 ± 2.5	20.7 ± 1.3
Plot 2 (BJ22)	57.8 ± 18.6	24.4 ± 5.6	12.5 ± 1.2	24.4 ± 1.7	15.4 ± 1.1
Range Cages				63.5 ± 13.9	45.6 ± 6.2
Upland Sagebrush Shrublands					
Plot 3 (BJ23)	63.0 ± 6.8	25.5 ± 3.1	18.2 ± 0.6	N.S.	N.S.
Range Cages				68.0 ± 10.7	46.7 ± 4.9
Bottomland Sagebrush Shrublands					
Plot 4 (BJ24)	39.6 ± 9.0	15.4 ± 3.1	4.5 ± 0.7	N.S.	N.S.
Range Cages				32.9 ± 6.1	28.4 ± 5.1

N.S. = Not Sampled

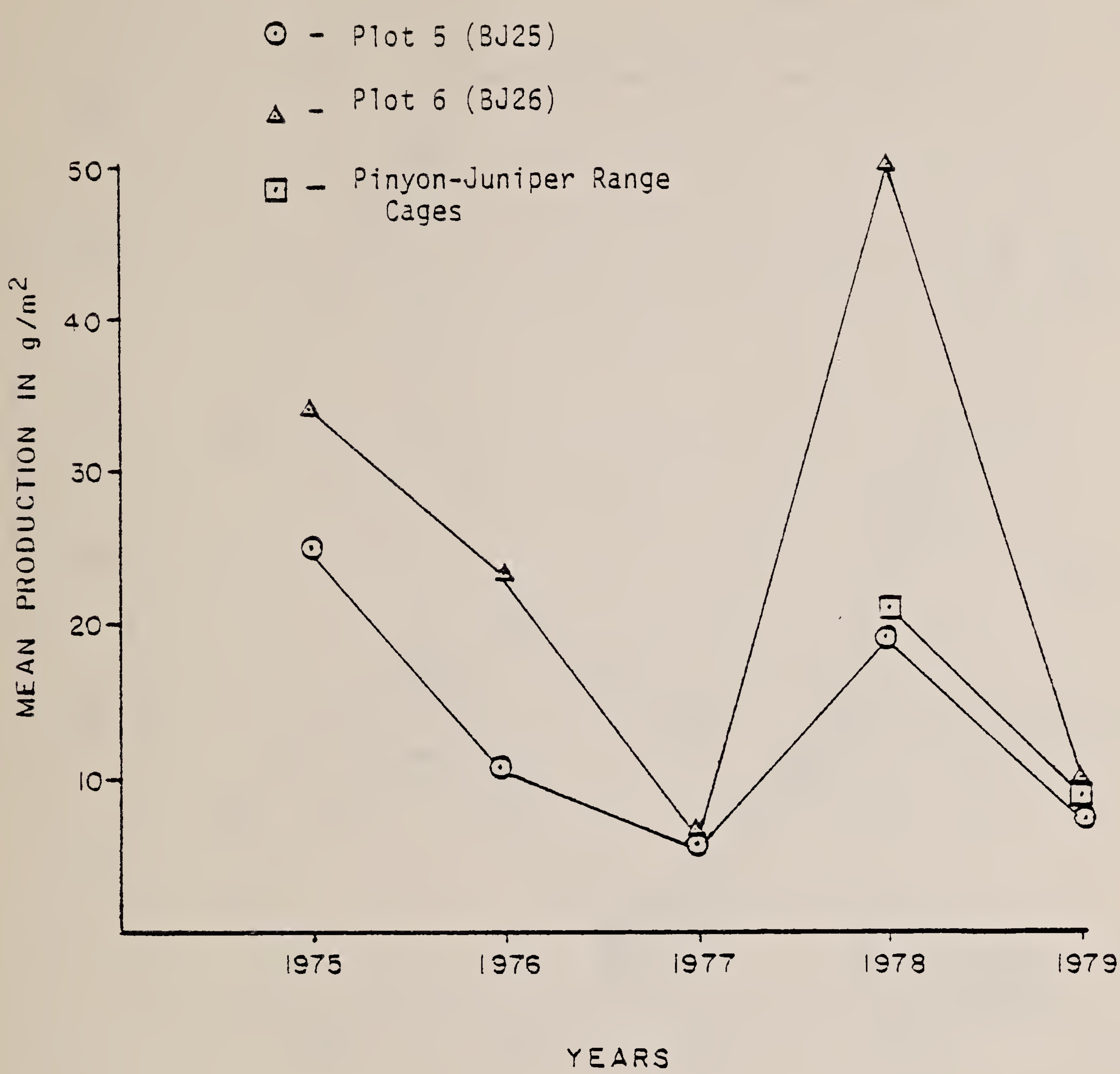


Figure 8.7.2-1 Trends in mean herb production between 1975 and 1979 for pinyon-juniper woodlands. See Table 8.7.2-1 for actual values and estimates of variability.

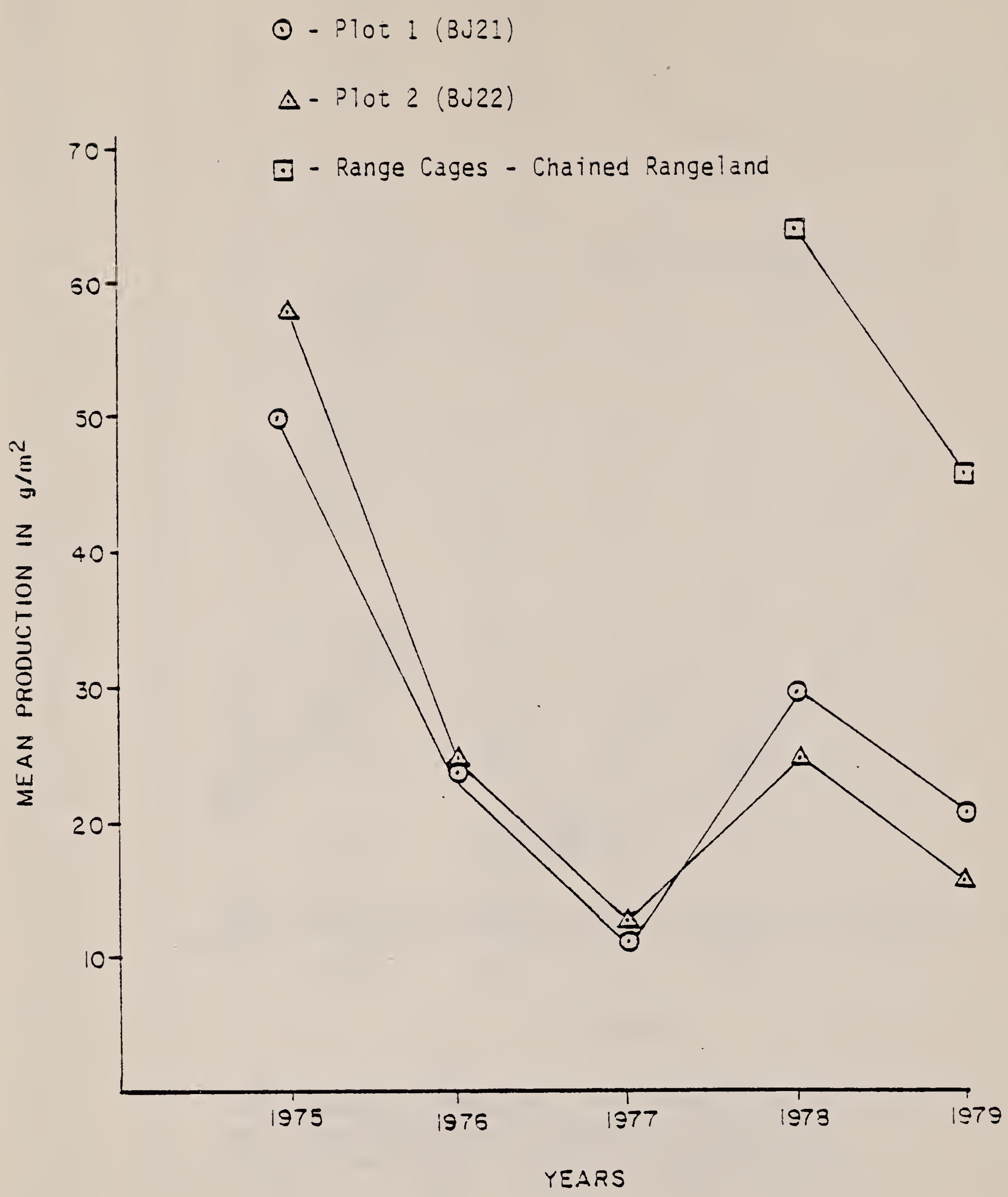


Figure 8.7.2-2 Trends in mean herb production between 1975 and 1979 for chained pinyon-juniper rangelands. See Table 8.7.2-1 for actual values and estimates of variability.

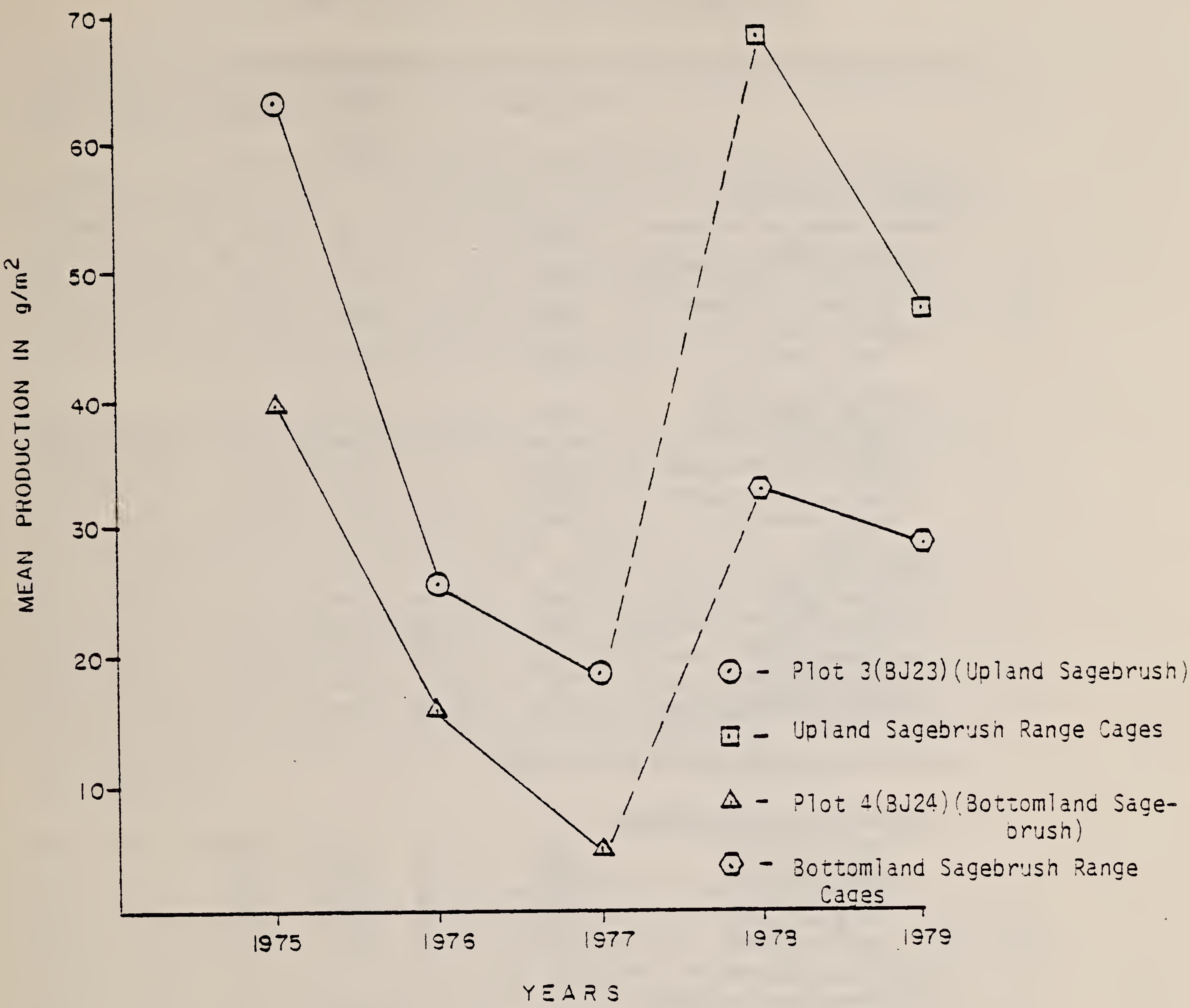


Figure 8.7.2-3 Trends in mean herb production between 1975 and 1979 for big sagebrush vegetation types. Data from 1975-1977 collected at intensive study Plots 3 and 4 (BJ23 and BJ24). Data from 1978-1979 collected from randomly located range cages in each of the types. The dotted line connecting the 1977 and 1978 data indicates the change in sampling approach for these two vegetation types. See Table 8.7.2-1 for actual values and estimates of variability.

Table 8.7.2-2 One-way analysis of variance results for comparisons of production in open and fenced plots, 1979. Underlined items are those with the greater mean value.

	Calculated F	v_1	v_2	Critical Region α = 0.10 F> Value Below	Significance
DIFFERENCES IN UTILIZATION					
Scandard Ridge Fertilizer Control Fenced vs Open	1.7688	1	8	3.46	NS
Scandard Ridge $NH_4NO_3+PO_4$ Fenced vs Open	0.0037	1	8	3.46	NS
Scandard Ridge NH_4NO_3 Fenced vs Open	0.3493	1	8	3.46	NS
Scandard Ridge Fertilized Fenced vs Open	0.4182	1	18	3.01	NS
Cottonwood Gulch Fertilizer Control Fenced vs Open	0.3388	1	8	3.46	NS
Cottonwood Gulch $NH_4NO_3+PO_4$ Fenced vs Open	0.2196	1	8	3.46	NS
Cottonwood Gulch NH_4NO_3 Fenced vs Open	0.0007	1	8	3.46	NS
Cottonwood Gulch Fertilizer Fenced vs Open	0.1817	1	18	3.01	NS
Range Cage Data					
Pinyon-Juniper Open vs Pinyon-Juniper Fenced	0.5771	1	28	2.890	NS
Chained Rangeland Open vs Chained Rangeland Fenced	2.0741	1	28	2.890	NS
Upland Sagebrush Open vs Upland Sagebrush Fenced	4.3196	1	26	2.91	SIG
Bottomland Sagebrush Open vs Bottomland Sagebrush Fenced	0.8046	1	28	2.890	NS
DIFFERENCES AMONG VEGETATION TYPES AND STUDY SITES					
Pinyon-Juniper and Chained Rangeland					
Plot 1F vs Plot 2F	9.8240	1	98	2.764	SIG
Plot 1F vs Plot 5F	55.9419	1	98	2.764	SIG
Plot 1F vs Plot 6F	36.9678	1	98	2.764	SIG
Plot 2F vs Plot 5F	25.7910	1	98	2.764	SIG
Plot 2F vs Plot 6F	9.5093	1	98	2.764	SIG
Plot 5F vs Plot 6F	3.0937	1	98	2.764	SIG
Based on Range Cage Data					
Pinyon-Juniper vs Chained Rangeland	29.5941	1	28	2.89	SIG
Pinyon-Juniper vs Upland Sagebrush	50.1900	1	27.	2.90	SIG
Pinyon-Juniper vs Bottomland Sagebrush	10.9017	1	28	2.89	SIG
Chained Rangeland vs Upland Sagebrush	0.0204	1	27	2.90	NS
Chained Rangeland vs Bottomland Sagebrush	4.6153	1	28	2.89	SIG
Upland Sagebrush vs Bottomland Sagebrush	6.7101	1	27	2.90	SIG

* NS = Not Significant
SIG = Significant
v_1 = degrees of freedom for numerator
v_2 = degrees of freedom for denominator

upland and bottomland sagebrush shrublands, and the upland sagebrush shrublands were significantly more productive than the bottomland sagebrush shrublands (Table 8.7.2-2).

In terms of study sites, chained rangeland Plot BJ21 was significantly more productive than Plot BJ22. As mentioned earlier this difference represents a change in the situation observed during the first three years of study when Plot BJ22 was more productive than Plot BJ21. Plot BJ26 was significantly more productive than Plot BJ25. This relationship between Plots BJ25 and BJ26 is consistent with the data recorded during the first four years of the study. The differences between Plots BJ21 and BJ22, and BJ25 and BJ26 are most likely related to natural causes rather than developmental impacts.

Evaluation of Herbaceous Utilization. Of all the utilization data gathered over the past five years, the 1979 data constitute the most carefully and systematically collected data set. Utilization data were collected in the four major vegetation types and also in conjunction with the fertilization study. Of the twelve comparisons presented in Table 8.7.2-2 the only data set in which the range cages had significantly higher production values than the adjacent open areas was in the upland sagebrush community. In all other comparisons the differences were not significant. As mentioned earlier, the estimates of utilization in the upland sagebrush chained rangelands, and bottomland sagebrush were approximately 25 percent. The reason for the lack of significant differences in the bottomland sagebrush and chained rangelands most likely relates to the variability of the data. In the pinyon-juniper woodland the open areas had greater production values than the range cages. This difference is a reflection of the high level of variability in the herb layer understory of these woodlands.

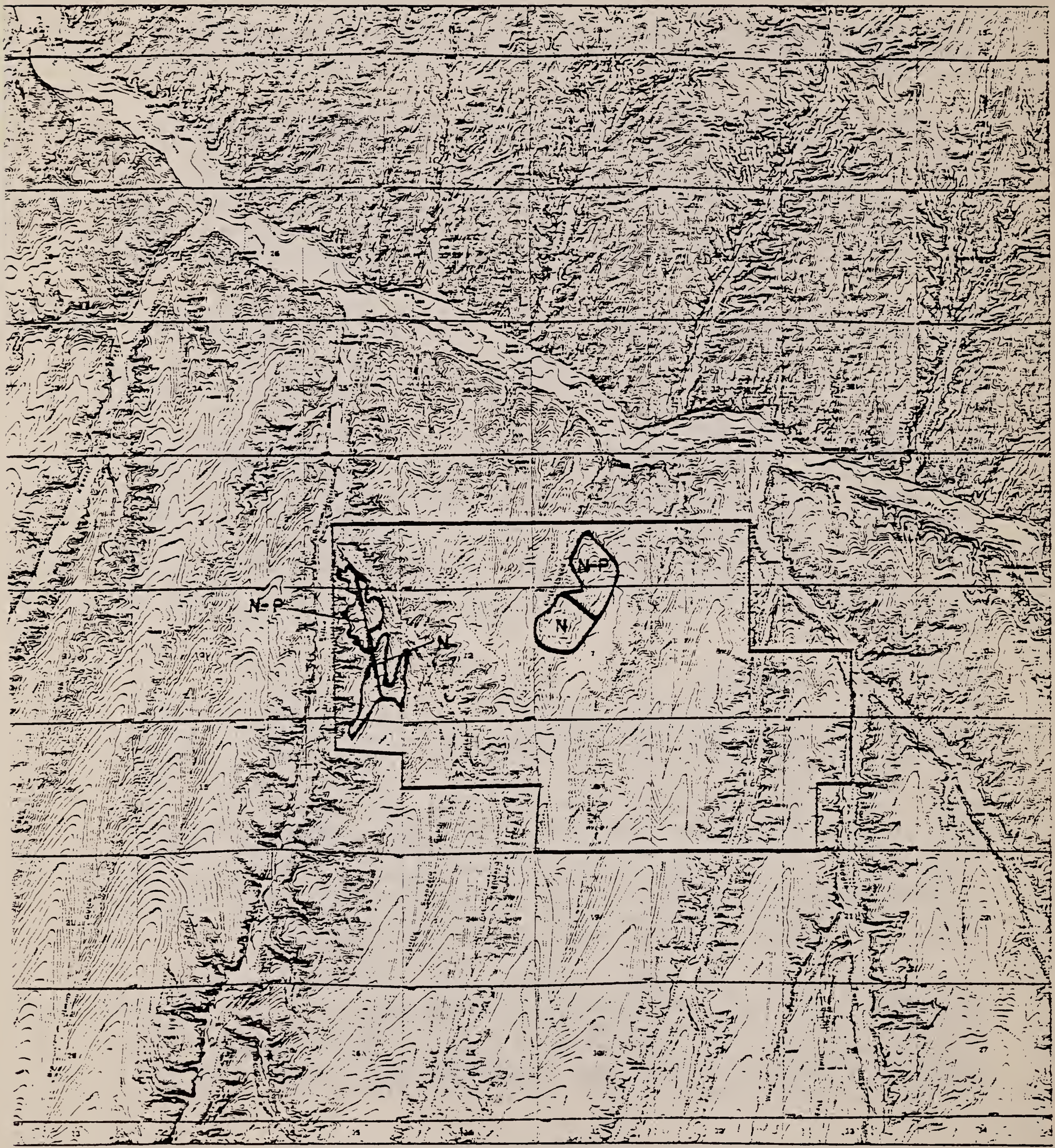
Fertilizer Studies, 1979

Fertilization areas are shown on Figure 8.7.2-4. Oven dry weights for range cages and open areas in the fertilizer study area on the ridge above Scandard Gulch are presented in Table A8.7.2-25. Mean total production for range cages in the control area was 31.7 g/m^2 (282 lbs/acre) and was 16.8 g/m^2 (150 lbs/acre) in the control open areas (Table A8.7.2-26). Mean total production for range cages in the areas fertilized with ammonium nitrate and phosphorus was 28.6 g/m^2 (255 lbs/acre) and was 28.0 g/m^2 (249 lbs/acre) in the open areas (Table A8.7.2-27). Mean total production for range cages in the areas fertilized with ammonium nitrate was 38.3 g/m^2 (341 lbs/acre) and was 29.4 g/m^2 (262 lbs/acre) in the open area (Table A8.7.2-28). The major species at these sites are essentially the same as those at other chained rangeland sites.

Over dry weights for range cages and adjacent open areas in the fertilizer study area on the ridge above Cottonwood Gulch are presented in Table A8.7.2-29. Mean total production for range cages in the control area was 39.0 g/m^2 (347 lbs/acre) and was 32.4 g/m^2 (289 lbs/acre) in the open areas (Table A8.7.2-30). Mean total production for range cages in the areas fertilized with ammonium nitrate and phosphorus was 39.0 g/m^2 (347 lbs/acre) and was 32.1 g/m^2 (286 lbs/

N-P AMMONIUM NITRATE & PHOSPHOROUS FERTILIZER APPLICATION

N AMMONIUM NITRATE



FERTILIZATION MAP

FIGURE 8.7.2-4

acre) in the open areas (Table A8.7.2-31).

Mean total production for range cages in the areas fertilized with ammonium nitrate was 45.9 g/m^2 (409 lbs/acre) and was 45.8 g/m^2 (408 lbs/acre) in the adjacent open areas (Table A8.7.2-32). Major species, species group and production amounts were comparable to other chained rangeland areas.

Evaluation of Fertilization Effects. In all comparisons between fertilized and control areas no significant differences were measured (Table 8.7.2-3). Mean production values in fertilized areas were usually higher than control areas except in comparisons involving the ammonium nitrate plus phosphorus treatment where the control areas had greater production. Ammonium nitrate alone at both study sites increased production on the average of 19.4 percent; however, on the basis of the collected data this increase was not significant. Comparison of the fertilized plots with the control plots at each of the sites shows that the mean increase in production resulting from fertilization was approximately 7 percent. On the basis of the collected data this increase was not significant.

8.7.2.6 Conclusions

Conclusions are essentially the same and are supportive of those reached in the 1977-78 vegetation monitoring studies.

1. The production patterns observed on the Tract in 1979 are essentially the same as those observed during the baseline data collection years.

2. During 1979 herbaceous utilization of non-woodland vegetation types was approximately 25 percent. The only type where the measured production differences between range cages and open areas was statistically significant was in the upland sagebrush shrublands.

3. Differences in production at Plots BJ21, BJ22, BJ25, and BJ26 were statistically significant. These differences most likely relate to natural causes rather than to development activities.

4. Yearly fluctuations in total production appear to be closely related to precipitation. Winter precipitation and precipitation in April, May, and June are probably more influential in affecting production than is the total yearly precipitation.

5. The fertilization program on the ridges above Scandard Gulch and Cottonwood Gulch has not significantly increased production. On the average, production was increased approximately 7 percent in the fertilized areas.

Table 8.7.2-3 One-way analysis of variance results for evaluation of fertilization results on the ridges above Scandard Gulch and Cottonwood Gulch. 1979 production data. Underlined treatments are those with the greater mean value.

	Calculated F	ν_1	ν_2	Critical Region $\alpha = 0.10$ F>	Significance
FERTILIZATION EFFECTS					
Ridge above Scandard Gulch					
Range Cages					
Control vs $NH_4NO_3 + PO_4$	0.0636	1	8	3.46	NS
Control vs NH_4NO_3	0.1071	1	8	3.46	NS
Control vs All Fertilized	0.0268	1	13	3.14	NS
$NH_4NO_3 + PO_4$ vs NH_4NO_3	0.5063	1	8	3.46	NS
Open Areas					
Control vs $NH_4NO_3 + PO_4$	1.6690	1	8	3.46	NS
Control vs NH_4NO_3	2.2594	1	8	3.46	NS
Control vs All Fertilized	2.2658	1	13	3.14	NS
$NH_4NO_3 + PO_4$ vs NH_4NO_3	0.0152	1	8	3.46	NS
Ridge Above Cottonwood Gulch					
Range Cages					
Control vs $NH_4NO_3 + PO_4$	0.0000	1	8	3.46	NS
Control vs NH_4NO_3	0.4166	1	8	3.46	NS
Control vs All Fertilized	0.1034	1	13	3.14	NS
$NH_4NO_3 + PO_4$ vs NH_4NO_3	0.2903	1	8	3.46	NS
Open Areas					
Control vs $NH_4NO_3 + PO_4$	0.0008	1	8	3.46	NS
Control vs NH_4NO_3	2.2134	1	8	3.46	NS
Control vs All Fertilized	0.4816	1	13	3.14	NS
$NH_4NO_3 + PO_4$ vs NH_4NO_3	1.5670	1	8	3.46	NS

* NS = Not significant
SIG = Significant
ν_1 = degrees of freedom for numerator
ν_2 = degrees of freedom for denominator

8.7.3 Shrub Productivity and Utilization

This section has been incorporated into Section 8.2.2 entitled Browse Production and Utilization in this report.

8.7.4 General Vegetation Conditions Study

This section has been incorporated into Section 3.2 utilizing Landsat.

8.7.5 Micro-Climatic Studies

8.7.5.1 Scope

Studies on micro-climatic parameters on the C-b Tract provide data that are useful in assessing changes in vegetation production and structure, animal populations, or animal activity patterns, and may also be correlated with changes in functional components of the C.B. ecosystem that may occur as a result of oil shale development.

8.7.5.2 Objectives

The objectives are to measure and evaluate time trends in climatic variables of surface and air temperatures, surface precipitation, and snow depth at specific locations within the various vegetative communities; to provide data for ecosystem interrelationship studies.

8.7.5.3 Experimental Design

Five micro-climatic stations are located in development sites and five in control sites. The locations of these ten sites (See Stations BC01 through BC09 and BC13 on the jacket map Exhibit C) are the same as baseline locations. Therefore, data from March 1975 through the present can be compared. Each station is monitored twice monthly for the following parameters:

Mc Station Locations		Parameters
BC01	Chained Pinyon-Juniper Rangeland	Air Temperature: 1m
BC02	Chained Pinyon-Juniper Rangeland, Vegetation Plot 2	Soil Temperature: Surface
BC03	Plateau Sagebrush, Vegetation Plot 3	Precipitation, Snow Depth and Moisture Content
BC04	Valley Bottom Sagebrush, Vegetation Plot 4	
BC05	Pinyon-Juniper Woodland, Vegetation Plot 5	
BC06	Pinyon-Juniper Woodland, Vegetation Plot 6	
BC07	Chained Pinyon-Juniper Rangeland (Animal Trapping Transect)	
BC08	Bunchgrass Community, South-facing Slope	
BC09	Valley Bottom Sagebrush, Mouth of Sorghum Gulch	
BC13	Mixed Mountain Shrubland, North-facing Slope	

All temperature readings consist of maximum and minimum readings for two-week periods. Precipitation is measured only during the growing season, March through October. Therefore, precipitation data from meteorology stations AB20 and AB23 are utilized for winter-month readings (November-February) for valley and pinyon-juniper microclimate stations. Snow measurements are obtained approximately from November-February.

8.7.5.4 Method of Analysis

Methods of analysis include time series plots -- contained in the Supplement(s) to the Development Monitoring (data) Reports -- for precipitation, snow depth, and maximum and minimum temperatures, and correlations of microclimatic data with plant and wildlife data. A cross-reference index of these plots appears at Table 4.2.5-2 in Section 4.0, Indicator Variables, of this report. The reader should also consult Subsection 6.3.1, Climatological Records, for additional tables, time series plots, and histograms.

8.7.5.5 Discussion and Results

Figures 8.7.5-123 through 8.7.5-142 of the Supplement to the January 1980 Data Report present the 1979 time series of the data. These plots were compared visually with 1978 time series and with time series plots of previous years. Two observations resulted from this analysis:

Winter and Fall precipitation was higher, but lower Spring and Summer precipitation was noted, especially in comparison with 1978 data.

Temperatures dropped below freezing for short periods throughout the growing season, but were similar to past years.

8.7.5.6 Conclusions

The following conclusions are drawn from visual analysis:

a. Precipitation for Fall and Winter 1978-79 was higher than previous years.

b. Precipitation for Spring and Summer 1979 was lower than previous years.

c. Below freezing temperatures during growing season were noted but these were similar to previous years.

8.8 Threatened and Endangered Species

Bald eagles were observed several times on Tract C-b and in the general vicinity. The raptors were not seen in any present or future developmental areas. No bald eagles nested or remained on the Tract for any great length of time. Since the area is not suitable for bald eagle habitat (marginal winter range) and the eagles were only occasional visitors, no further action will be taken except for their continued monitoring.

Sandhill cranes were observed several times east of the Tract. The birds were seen along Piceance Creek and up West Stewart Creek. No Sandhill cranes were observed on the Tract. At this time, no further actions will be initiated with the exception of continued monitoring for their presence.

No threatened or endangered plants were found on or near Tract C-b. New plants are continually being added to the permanent herbarium on Tract.

In conjunction with the numerous biological studies that will be conducted on and near Tract C-b during all parts of the year, observations confirmed by staff field biologists of any threatened or endangered species will be reported to the AOSO (Area Oil Shale Office). Appropriate studies to determine significance of a sighting will then be intitiated as determined jointly by C.B. and AOSO personnel.

8.9 Revegetation

Revegetation monitoring will be conducted on sites which have undergone surface disturbance and on raw shale disposal sites. Revegetation monitoring will be conducted on areas larger than one acre which are seeded with the permanent seed mixture. This seeding has been completed on sites (old drill pads) which meet this criterion and monitoring will begin when revegetation projects are completed. No new monitoring was conducted during 1979.

8.9.1 Demonstration Plot

No commercial quality raw oil shale was produced during 1979; therefore, no plot was built. If during 1980 shale material suitable for this purpose is mined, a plot will be built.

8.10 Systems Dependent Monitoring

Additional aquatic studies, sublethal biochemical studies, and soil-plant elemental analysis, are potential system dependent monitoring programs. They were not "triggered" by indicator variables, and therefore no monitoring was accomplished during 1979.

9.0 ITEMS OF AESTHETIC, HISTORIC, OR SCIENTIFIC INTEREST

9.1 Aesthetic Values

The C-b Annual Summary and Trends Report (November '74 through October '75) described a study which determined the type and quality of scenic resources in the Tract area. It was concluded that the Piceance Creek Basin has a low scenic value when compared to the other landscape types of the region. Or restated, on a regional basis the Piceance Creek Basin has an extremely low visual character. However, a concerted effort has been made to paint and locate new structures in such a manner as to reduce any adverse aesthetic impact.

9.2 Historic and Scientific Values

A detailed baseline study of the cultural resources of Tract C-b has been conducted to identify sites of past human activity. (See Volume 1 of the Final Report of the Environmental Baseline Program.) Three historic sites exist on the Tract, (5RB136, 5RB146, and 5RB147) and have been reported therein. Every site of disturbance is thoroughly investigated by the on-site environmental manager for historic or scientific value. Additional disturbance in 1979 was minimal and no additional discoveries were found.

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10.0 INDUSTRIAL HEALTH, SAFETY AND SECURITY

10.1 Scope and Rationale

The health and safety of employees at the Cathedral Bluffs project is regulated according to 30 CFR, Part 57, by the Mine Safety and Health Administration under the Mine Safety and Health Amendments Act of 1977. In addition, the project is regulated by the Colorado State Division of Mines. Contractors' safety programs on site are monitored by the Occidental Safety Department through Ralph M. Parsons Company, the managing contractor.

Periodic reports on Health and Safety Activities are forwarded to the Area Oil Shale Supervisor. Such reports are those prepared by the C.B. Project and all contractors for distribution to outside Federal and State agencies, i.e., Mine Safety and Health Administration (MSHA) and the Colorado Division of Mines and inspection reports made by these agencies and received by the Project and all contractors at the C.B. site. These reports relate to accident frequency analyses, inspection reports and responses, health and safety training, and variance reporting. As received, they are included in the semi-annual data reports.

10.2 Health and Safety Training

Occidental Oil Shale, Inc. has and will continue to furnish first aid training to contractor personnel. There is an ongoing program consisting of monthly EMT/Paramedic training and shaft evacuation classes. A program has been initiated for gas sampling utilizing vacuum bottles and analysis by Gas Chromatograph. Samples are taken on a twice a week basis.

10.3 Accident Frequency Analysis

Due to the unique situation of Tract C-b having three (3) separate MSHA identity numbers, safety programs are the responsibility of the individual entities, with overall program monitoring supplied by Occidental. The I.D. numbers are as follows:

1.	Occidental Oil Shale, Inc.	05-03140
2.	Ralph M. Parsons	05-03148
3.	Gilbert Corp. of Delaware	05-03149

Using the formula,

$$\text{I.R.} = \text{Incident Rate} = \frac{\text{Number of Accidents X 200,000}}{\text{Hours of Employee Exposure}}$$

The breakdown of accident rate by I.D. number is as follows:

I.D. #05-03140 - No reportable injuries in 62,424.2 manhours. I.D. #05-03148 and I.D. #05-03149 - Five (5) reportable injuries, which include four (4) lost time accidents, in 462,467 manhours; resulting in an injury rate of 2.16. One Gilbert Corporation employee was fatally injured during 1979.

The three (3) I.D. numbers logged 524,891.2 manhours in 1979 with five (5) reportable accidents for a site I.R. of 1.91.

10.4 Inspection Reports & Responses

There were eighteen (18) visitation days by MSHA this past year, resulting in 97 citations to Gilbert Corporation of Delaware, eight (8) citations to Ralph M. Parsons Company, and no citations issued to Occidental Oil Shale, Inc. All citations were abated.

Colorado Division of Mines inspected the property ten (10) times during 1979, resulting in 45 citations, all of which were abated.

10.5 Security

The Security Guard Gate at C.B. site entrance was completed in 1979. Security also took over contractor time keeping functions that were formerly handled by Ralph M. Parsons Company. In addition to typical security functions, security officers on site constitute the initial site emergency response team. Their training in emergency medicine, fire protection and spill response and their 24-hour availability on site makes them uniquely suited for this effort.

Until such time that a drawing for a C-b surface plot plan can be finalized, design work on the Fire Water Loop System will not be performed.

11.0 SUBSIDENCE MONITORING

The overall objective of the subsidence monitoring program is to determine the effects of underground excavations on the ground surface and on in-situ mining levels.

The surface and underground subsidence caused by mining activities cannot start until significant underground development out from the shaft pillar areas occurs.

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12.0 ECOSYSTEM INTERRELATIONSHIPS

12.1 Introduction and Scope

Indicator variables for Development Monitoring are given in the Development Monitoring Plan. Also listed are perturbations that affect the magnitude of these variables and the environmental consequences (or impacts) of these perturbations. Examples of perturbations include mining, retorting, shale disposal, waste disposal, etc. Environmental consequences may affect other indicator variables; such relations of indicator variables with other indicator variables are to be analyzed and called ecosystem interrelationships.

Ecosystem interrelationships are not monitored or measured directly. They are inferred from three principal techniques: 1) expert judgment resulting from baseline observations of two or more variables, 2) correlative statistics, and 3) predictive ecosystem modeling. Aspects of all three have been gleaned from the baseline studies and reported in Volume 5, System Interrelationships, Environmental Baseline Program Final Report and its Appendix F, User's Reference Diagrams (1977). In particular, baseline judgment has been utilized to obtain the comprehensive "effects matrix" (Figure A12.1-1).

With regard to the comprehensive "effects matrix" so-called effect generators (driving variables, perturbations, state variables) are listed across the top (matrix columns) and effect receptors (abiotic and biotic components and processes) are listed at the side as matrix rows. Entries in the matrix are the following interrelationships: direct effects, indirect effects, both direct and indirect, and effects of particular concern. Fifty-four updated effects of particular concern have been transposed to Table 12.1-1 where they are identified with an "X".

The matrix will be periodically updated to include additional relationships needed to assess impacts of development.

The interrelationships of Table 12.1-1 and others defined as new monitoring results will be analyzed in the future and subjected to correlative statistical techniques as a means of defining those interrelationships of major concern. Subsequent monitoring can then concentrate on these interrelationships.

12.2 "Candidate" Interrelationships

The above considerations provided insights into specific interrelationship "candidates" for early study. The screening consisted of three phases: (1) qualitative, (2) initial quantitative, and (3) refined quantitative.

The qualitative phase consists of identifying the dependent variable(s), all major independent variables and both natural and man-induced perturbations. Gaps in the data preclude complete quantitative analysis. However, a purpose is served in that it points the way to future increased sampling rigor and uniformity. Then, provided the data are deemed complete enough, quantitative analyses are attempted. Refined quantitative analyses will be undertaken in future years.

TABLE 12.1-1

MAJOR ECOSYSTEM INTERRELATIONSHIPS

EFFECT GENERATORS / EFFECT RECEPTORS	PRECIPITATION	AIR TEMPERATURE	BORON (Water)	SO_2 (Air)	NO_x (Air)	OZONE (Air)	FLUORIDE (Water)	TRACE ELEM. (Air)	NOISE	DISTURBED VEG.	UNREVEG. BARE AREAS	EROSION	MIXED SOIL PROFILE	ALTERED SOIL CHEM.	SEDIMENT	ALTERED SURF. WATER FLOW	WATER TABLE ALTER.	ALTERED WATER QUAL.	WIND SPEED	WIND DIRECTION	SHALE PILE	PONDS
RUNOFF	X										X	X			X							X
STREAMFLOW												X					X					
GROUNDWATER FLOW																	X					
PLANT GROWTH	X	X	X	X	X	X	X	X						X		X						
LITTER DECOMP.				X																		
ANIMAL GROWTH	X	X	X				X	X														
REPRODUCTION									X													
ANIMAL MOVEMENT									X													
AQUATIC PLANT GROWTH			X				X								X	X		X				
AQUATIC VERT. GROWTH															X	X		X				
AQUATIC VERT. MORT.																		X				
AQUATIC INVERT. GROWTH															X	X						
AQUATIC INVERT. MORT.																		X				
SOIL CHEM. & pH								X														
WATER QUALITY																	X					X
ANIMAL TISSUE							X															
GEN. HABITAT									X	X	X											
REVEGETATION													X	X								
VISIBILITY	X					X													X	X		
PARTICULATE MATTER	X																		X		X	

At this writing two candidates have "survived" the qualitative screen and initial quantitative analysis attempted. These are:

(1) Effects of climatic variations on annual herbaceous production. When the "land treatment" system is initiated its effects will be included.

(2) Effects of traffic on Piceance Creek Road, precipitation (snow depth), and deer movements on deer road kill.

Other interrelationships subjected to qualitative study included:

(3) Effects of herbivore density on shrub utilization.

(4) Effects of shrub production, utilization, deer migration, age/sex ratios, pellet groups, and climate upon deer mortality.

Increased sampling rigor and/or uniformity will be sought to enhance the possibility of quantitative results in the future.

These four "near-term" interrelationships are discussed in the following paragraphs:

12.3 Specific Near-Term Interrelationships

12.3.1 Effects of Climatic Variations on Vegetative Productivity

12.3.1.1 Scope

It is expected that vegetative productivity increases with increasing precipitation and increased length of the growing season. Specific precipitation measures suggested are:

(1) Total annual precipitation of the current year.

(2) Total annual precipitation of the previous year, especially late season precipitation.

(3) Total annual precipitation of the previous "growing season" year - from April through March.

(4) Precipitation temporal distribution during the growing season over:

(a) March - April - May or
(b) April - May - June or
(c) May - June - July.

(5) Abnormal rates of precipitation.

Growing-season candidate variables include:

(1) length of the growing season,

(2) total degree-days during the growing season,

(3) degree-day temporal distribution over

(a) April - May - June
(b) May - June - July
(c) June - July - August
(d) July - August - September
(e) over the growing season.

12.3.1.2 Objectives

To assess the interaction between vegetation productivity, amounts and timing of precipitation, and length of growing season.

12.3.1.3 Experimental Design and Method of Analysis

It is difficult to obtain a highly accurate total of annual precipitation in a harsh, remote area at any one site, as an accumulation over a monthly or more frequent period. Often because of equipment malfunction a monthly value may be missing from the data set, such that an annual total from that station is not possible. The reader is referred to Section 6.3.1, wherein numerous between-station monthly precipitation regressions have been undertaken, e.g., between Station AB23 and microclimate stations and between WU70 or Little Hills and AB23. From such regressions missing monthly precipitation values have been estimated so that annual totals can be derived. Annual totals agree reasonably with regional precipitation isohyets (Section 6.3.1). It should be further noted that precipitation in the vicinity of the Tract is spatially variable, particularly with elevation. Therefore the above qualitative suggestions on precipitation might consider not only precipitation at the meteorological tower (Station AB23) but at each of the respective microclimate stations from which vegetative productivity is potentially being correlated.

The following tables of 6.3.1 and associated appendix are useful here in this analysis:

Table or Figure	Item	Station
Table 6.3.1-3	Total precipitation	AB23, AB20, WU70
	3 month sliding average precipitation	AB23, AB20, microclimate stations
	Peak ppt events	AB23, AB20
Figure 6.3.1-3	Monthly ppt histograms with growing season superposed	AB23, AB20

Last year's herbaceous productivity sites selected for analysis were:

BJ12 - Chained Pinyon Juniper (Control Site)

BJ15 - Pinyon Juniper Woodland (Future Development and Present Control)

This year the analysis has been extended to include shrub productivity at:

BJ13 - Upland Sagebrush (Control) and,

BJ14 - Bottomland Sagebrush (Control).

All site locations are shown on Exhibit C (found in the cover jacket).

12.3.1.4 Discussion and Results

Productivity values are presented on Table 8.7.2-1 and repeated here in Table 12.3.1-1. Also tabulated are the independent variables for potential correlation: total calendar precipitation and growing-season-to growing-season precipitation of the previous year, 3 month precipitation during the growing season at Station AB23 (meteorological tower) and at the micro-station where productivity was measured, length of the growing season, and calendar year. A simple tabular approach was first utilized whereby for each of the five years since Baseline productivity was ranked from highest to lowest (1 to 5 respectively) as were each of the remaining independent variables as indicated in the table.

Degree-days did not correlate positively and are not shown. Quantities which rank-correlated best with productivity are precipitation during April-May-June of the current year and during the previous growing season year (the year beginning in April and ending in March). Productivity as a function of Spring and total precipitation parameters is shown on Figures 12.3.1-1a and 1b with a least squares regression line for each. Regression constants and the correlation coefficients are shown on Table 12.3.1-2. All correlations were positive. The highest correlation coefficients were achieved for the previous-growing-season-year precipitation measured at the identical sites (BJ12, BJ13, BJ14 and BJ15) for which productivity was measured. High correlations were also achieved for current-year Spring precipitation measured at the productivity sites. Keep in mind that some monthly precipitation values were estimated at these stations. On the basis of the "b" coefficient in the regression equation, Chained Pinyon-Juniper productivity is most sensitive to growing-season rainfall at the site (101 kg/ha per cm of rainfall); when referenced to rainfall at the meteorological tower this value dropped to 38 kg/ha per cm of rain. Only 5 data points are available for this regression.

12.3.1.5 Conclusions

1. Climatic parameters which correlated best with vegetative productivity were precipitation during the previous growing season year (from April through March) and Spring precipitation of the current year.

2. Chained Pinyon Juniper productivity is the most sensitive to growing season rainfall.

TABLE 12.3.1-1 "RANKING" OF INDEPENDENT VARIABLES WITH PRODUCTIVITY

(1)→(5) = Rank from Top to Bottom

Site	Year	Productivity (kg/ha)	April-May-June ppt (cm) Station AB23	April-May-June ppt (cm) MC Station	Total ppt of Previous year (cm) Station AB23	Total ppt of Previous year (cm) MC Station	Total ppt of Previous Growing Season Year*(cm) Station AB23	Total ppt of Previous Growing Season Year*(cm) MC Station	Growing Season (days)
Chained Pinyon Juniper (BJ12) (Control)	1975	579 (1)	13.9 (1)	7.5 (1)	-	-	-	-	118 (4)
	1976	245 (2)	9.4 (3)	3.6 (5)	45.0 (1)	23.6 (3)	44.4 (1)	24.3 (3)	111 (5)
	1977	125 (5)	6.4 (5)	3.9 (4)	35.8 (4)	21.7 (4)	27.9 (4)	15.9 (4)	144 (2)
	1978	244 (3)	7.5 (4)	5.6 (2)	35.9 (3)	25.0 (2)	41.2 (2)	42.1 (1)	124 (3)
	1979	153 (4)	12.4 (2)	4.5 (3)	36.1 (2)	41.9 (1)	31.6 (3)	25.3 (2)	148 (1)
Pinyon Juniper Woodland (BJ15) (Future Development - Present Control)	1975	250 (1)		8.4 (1)		-		-	
	1976	107 (3)	As Above	2.9 (4)	As Above	19.3 (2)	As Above	20.2 (2)	As Above
	1977	62 (5)		0.3 (5)		10.6 (3)		6.0 (4)	
	1978	192 (2)		4.9 (2)		8.2 (4)		28.0 (1)	
	1979	84 (4)		3.3 (3)		34.1 (1)		16.6 (3)	
Upland Sagebrush (BJ13) (Control)	1975	631 (2)		9.4 (1)		-		-	
	1976	255 (4)	As Above	5.0 (4)	As Above	26.2 (2)	As Above	29.6 (2)	As Above
	1977	182 (5)		3.9 (5)		23.1 (3)		13.6 (4)	
	1978	681 (1)		5.6 (2)		21.9 (4)		40.1 (1)	
	1979	468 (3)		5.4 (3)		42.2 (1)		24.5 (3)	
Bottomland Sagebrush (BJ14) (Control)	1975	396 (1)		8.9 (2)		-		-	
	1976	154 (4)	As Above	12.8 (1)	As Above	26.3 (4)	As Above	32.0 (2)	As Above
	1977	45 (5)		0.2 (5)		37.3 (2)		19.5 (4)	
	1978	329 (2)		5.9 (3)		32.8 (3)		64.1 (1)	
	1979	284 (3)		2.9 (4)		41.6 (1)		26.3 (3)	

*Total precipitation in previous year starting in April (thru March).

FIGURE 12.3.1-1a PLOTS OF PRODUCTIVITY VS. APRIL - MAY - JUNE PRECIPITATION TOTALS FOR YEARS 1975 - 1979.

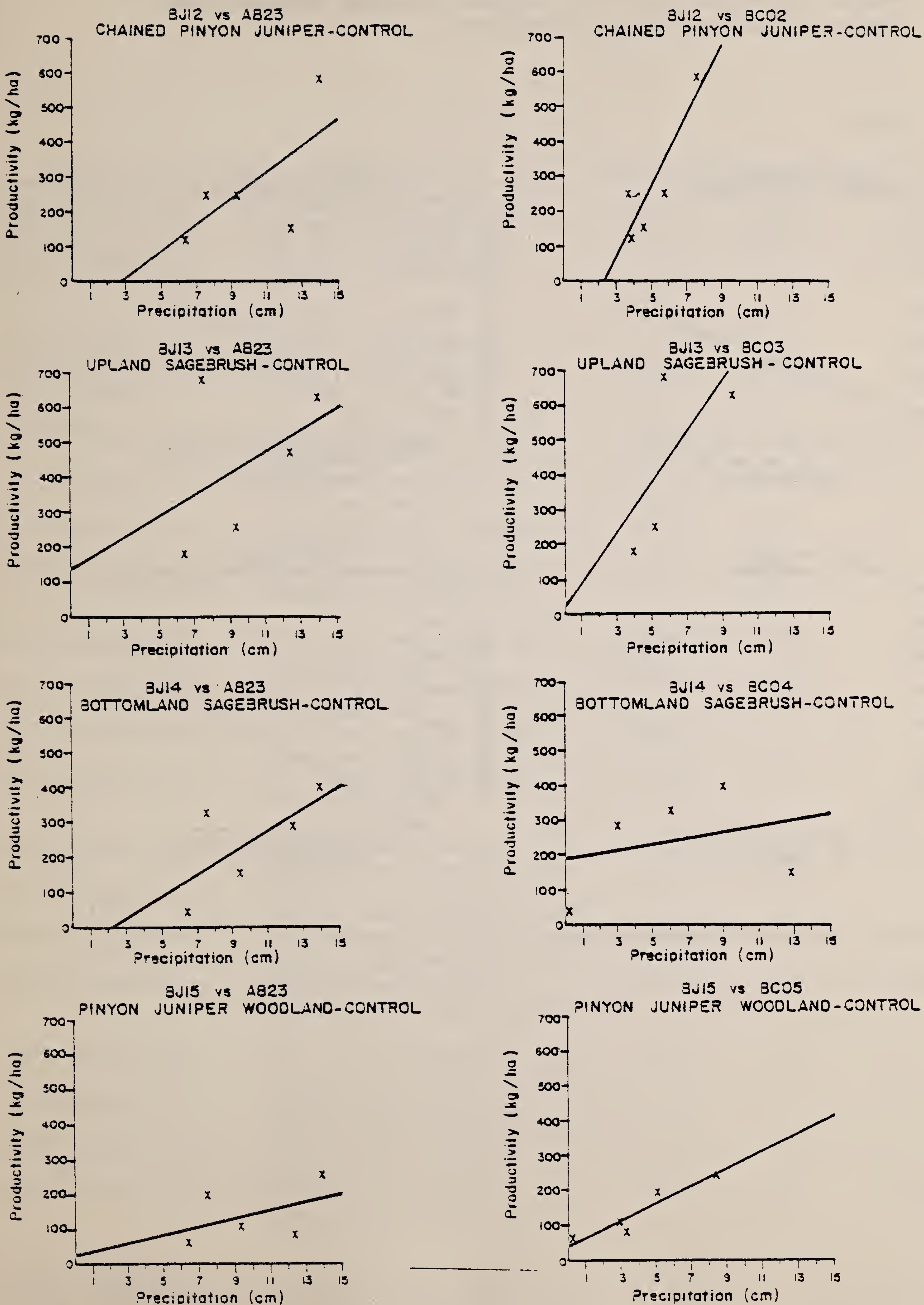
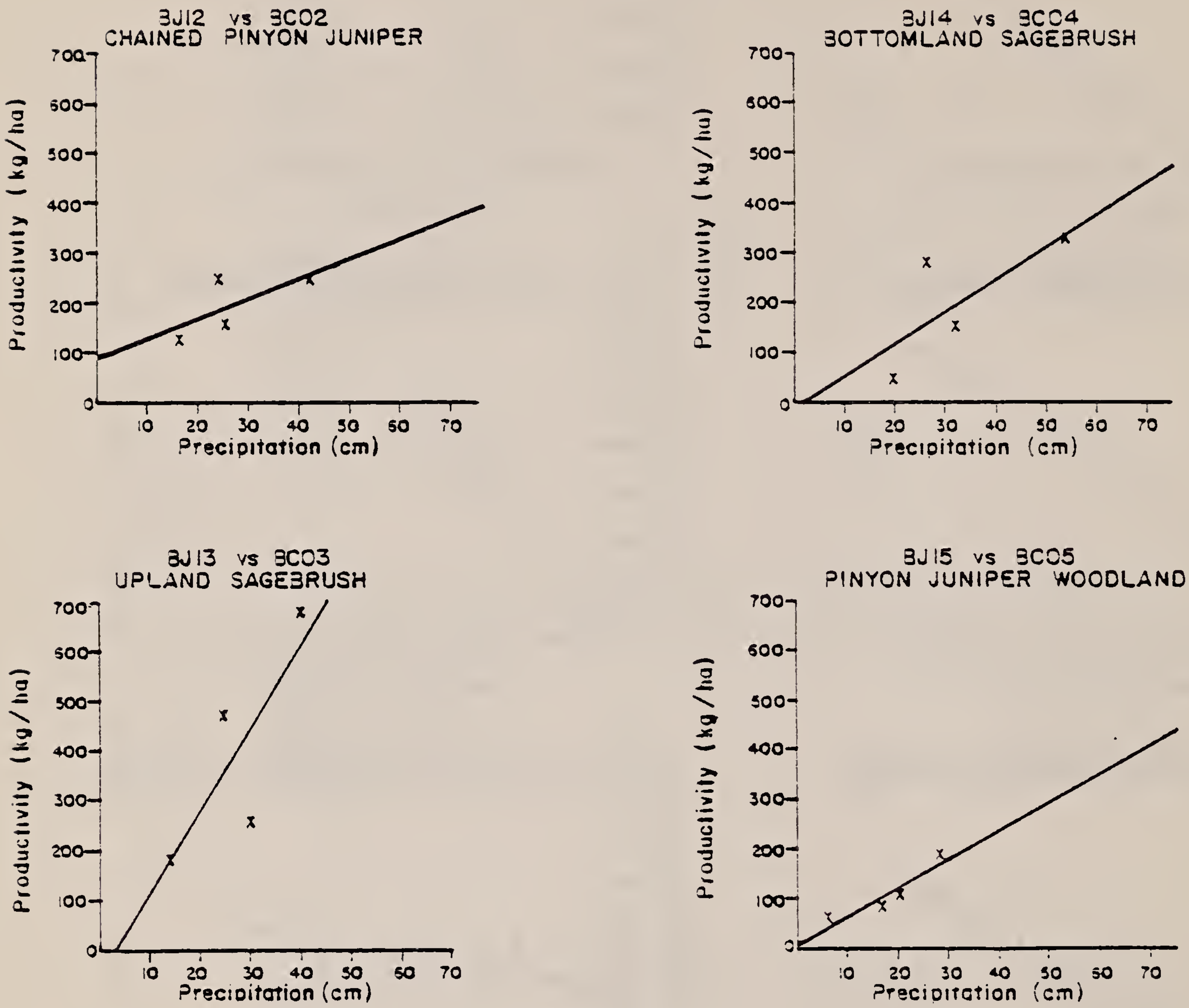


FIGURE 12-3.1-1b

PLOTS OF PRODUCTIVITY VS PREVIOUS GROWING SEASON YEAR PRECIPITATION* FOR YEARS 1975-1979.



* Total Precipitation in Previous Year Starting in April. (thru March)

TABLE 12.3.1-2

ANNUAL PRODUCTIVITY REGRESSIONS

$y = a + bx$

Station (y)	Station (x)	a(kg/ha)	b(kg/ha/cm)	r Coefficient of Correlation
BJ12 Productivity	AB23 AMJ*Precipitation	-104.50	37.67	0.66
BJ13 Productivity	AB23 AMJ Precipitation	137.10	30.88	0.45
BJ14 Productivity	AB23 AMJ Precipitation	-63.47	30.75	0.69
BJ15 Productivity	AB23 AMJ Precipitation	25.18	11.47	0.46
BJ12 Productivity	BC02 AMJ Precipitation	-236.39	100.72	0.88
BJ13 Productivity	BC03 AMJ Precipitation	17.05	72.76	0.69
BJ14 Productivity	BC04 AMJ Precipitation	188.11	8.71	0.30
BJ15 Productivity	BC05 AMJ Precipitation	39.34	25.17	0.95
BJ12 Productivity	AB23 Total Precipitation Previous Year	-107.60	7.84	0.57
BJ13 Productivity	AB23 Total Precipitation Previous Year	1171.58	20.29	0.41
BJ14 Productivity	AB23 Total Precipitation Previous Year	459.26	-6.71	0.24
BJ15 Productivity	AB23 Total Precipitation Previous Year	135.52	-0.64	0.05
BJ12 Productivity	BC02 Total Precipitation Previous Year	246.42	-1.95	0.30
BJ13 Productivity	BC03 Total Precipitation Previous Year	334.00	2.20	0.10
BJ14 Productivity	BC04 Total Precipitation Previous Year	116.92	2.49	0.14
BJ15 Productivity	BC05 Total Precipitation Previous Year	149.44	-2.12	0.44
BJ12 Productivity	AB23 Previous Growing Season Year Precipitation**	-92.88	7.85	0.98
BJ13 Productivity	AB23 Previous Growing Season Year Precipitation**	55.45	9.40	0.33
BJ14 Productivity	AB23 Previous Growing Season Year Precipitation**	-29.26	6.40	0.39
BJ15 Productivity	AB23 Previous Growing Season Year Precipitation**	-68.47	4.95	0.68
BJ12 Productivity	BC02 Previous Growing Season Year Precipitation**	83.66	4.02	0.71
BJ13 Productivity	BC03 Previous Growing Season Year Precipitation**	-51.56	16.63	0.81
BJ14 Productivity	BC04 Previous Growing Season Year Precipitation**	-7.48	6.38	0.74
BJ15 Productivity	BC05 Previous Growing Season Year Precipitation**	10.37	5.70	0.92

*April-May-June
**Total precipitation in previous year starting in April (thru March)

12.3.2 Effects of Deer Road Count, Traffic and Precipitation on Deer Road Kill

12.3.2.1 Scope and Rationale

The specific factors assumed to influence total deer road-kill include traffic along various segments of Piceance Creek Road, precipitation (snow depth), work force, weekly deer count and weekly deer road-kill. Interrelationships determined among these variables will be used in the formulation of mitigative measures to reduce road kill. Annual monitoring begins in mid-September and ends in April or May when deer have migrated to the highlands.

12.3.2.2 Objectives

The objectives of this study are: 1) To evaluate the interrelationships of traffic load, mitigative measures, time of year, deer population and movement, and climate on deer road-kill; 2) To review existing monitoring efforts and determine how they may be improved; and 3) To use information gained from study and analyses to formulate other possible mitigative measures.

12.3.2.3 Experimental Design

Weekly samplings of deer road count and road-kill are obtained each year beginning in mid-September and continuing through May. Tabulations are for one-mile intervals along the 41-mile stretch of Piceance Creek Road between Rio Blanco and White River City (Highway 64). Deer road-kill reports include sex of the deer killed, estimated age and marrow condition (to help establish a relationship between deer condition and road-kill). Traffic hose counters are placed across Piceance Creek Road near Rio Blanco and White River City. Counters are also placed at the access road entrances to the C-b and C-a Tracts, and across Piceance Creek Road between the access roads. A count of incoming vehicles (excluding buses) is kept at the C-b guard gate. The previously mentioned hose counters were replaced by magnetic loop counters in 1980, which will provide a better estimation of total traffic on Piceance Creek Road. Precipitation measurements are recorded hourly at several stations on and near the Tract. (Refer to Section 6.3.1.5.4) For this study, precipitation measurements from air quality Station AB20 are used because this station is near Piceance Creek Road.

Passenger buses run round-trips for all work shifts between Rifle and the C-b Tract and between Meeker and the C-b Tract. Daily records are kept of the number of passengers and number of bus trips.

12.3.2.4 Method of Analysis

Data used in this study are from records beginning September 25, 1978 and ending March 31, 1980. Scatter plots are used to identify possible correlations between the deer-kill as the response variable and deer road count, traffic and precipitation as the independent variables. Time-series plots were also used to determine if any trends exist from year to year. All data were grouped and averaged to correspond with the weekly deer-kill records. These variables were further examined for potential interrelationships utilizing computer programs for partial correlations and multiple linear regression. Outputs of these programs provide analyses for evaluating statistical significance of interrelationships and of some of the potential outliers in the scatter diagrams.

12.3.2.5 Discussion and Results

a) Correlation Analyses: The correlation coefficient, r, is a measure of linear covariation or the degree of linear association between the variables. If r is near -1 or +1, there is a high degree of linear association, -1 showing a negative correlation (one variable increases as the other decreases) and +1 showing a positive correlation (both variables increase or both variables decrease). The variable showing the most significant positive correlation to deer-kill (0.34) is deer count, as shown in Table 12.3.2-1. All other correlations are close to zero showing insignificant linear correlation between combinations of dependent and independent variables.

TABLE 12.3.2-1

SIMPLE CORRELATION COEFFICIENTS (r)

	Deer Kill	Deer Count	Guard Shack Vehicle Count	Precipitation
Deer Kill	1.00	0.34	0.02	-0.17
Deer Count	0.34	1.00	-0.04	-0.08
Guard Shack Vehicle Count	0.02	-0.04	1.00	-0.21
Precipitation	-0.17	-0.08	-0.21	1.00

b) Scatter Diagrams: Scatter diagrams depicting the relationship between the dependent variable, deer road kill, and the independent variables, deer road count, precipitation and traffic (represented by the vehicle count at the C.B. guard shack), are shown in Figures A12.3.2-1a through 1c. Deer road kill vs. precipitation and road kill vs. traffic plots show a somewhat random dispersement leading to the assumption that there is an insignificant relationship between these variables. Deer road kill vs. deer road count shows a high concentration towards the lower end of each scale on the plot. A few points showing extreme high values for deer kill and low values for deer count are probable outliers.

c) Time-Series Plots: Time series plots representing the study variables and utilizing data from corresponding time periods (1978-1979 and 1979-1980), are shown in Figures A12.3.2-2a through 2d. Precipitation has a randomized dispersement which can be expected. Guard-shack vehicle count has many fluctuations in both the 1978-79 and 1979-80 data but maintains a decreasing slope which may be attributed to the busing and car-pooling since the workforce at the Tract has not shown a decrease. The deer road kill and deer road count data show a few similarities with milder peaks in the 1979-1980 data. The decreases in the 1979-1980 road count data can be attributed to the high natural mortality during the harsh winter of 1978-79. Figures from the Division of Wildlife for 1979 and 1980 show a 50% decrease in the deer population of the region from a population of 30 to 34 thousand in December, 1979 to a population of 15 thousand in December, 1980.

d) Regression Analyses: Results from the regression analyses of deer road kill, deer road count, precipitation and guard shack vehicle count are summarized in Table 12.3.2-2. The analyses were heavily weighted by the data from 1979-80. Significant correlations are those with "X" in the Linear, "Yes" column which means rejection of the hypothesis of no correlation between variables. There were no significant relationships identified in the analysis of the 1978-79 data. However, results from 1978-80 and 1979-80 show the same significant relationships between road kill and three regression variables. The most significant single variable vs. deer kill is the deer count.

e) Other Analyses: Bus passenger reports from June 1978 through November 1979 are summarized in Table 12.3.2-3.

Although no prediction of deer road-kill reduction is possible without adequate traffic data and passenger-per-vehicle data, it is apparent that a substantial number of passenger vehicle-round-trips are being eliminated through bus use. For example, the average number of passengers which ride the bus indicates a savings of 2568 vehicle-round-trips per month if there is an average of 2 passengers per vehicle. The data also show an increase in average bus-round-trips per month from 163 in 1978 to 175 in 1979 and an increase in passengers per month from 4452 in 1978 to 5509 in 1979.

Histograms representing the number of passengers and trips per month are shown in Figures A12.3.2-3a and 3b.

12.3.2.6 Conclusions

Based on the available data, the scatter diagrams, time-series plots and regression analyses, deer road-count is the only variable that shows a significant relationship to the number of deer killed; precipitation shows a minimal relationship and guard-shack vehicle count shows no relationship to deer road kill. It seems logical, however, that deer road-kill is related to total traffic on Piceance Creek Road and

TABLE 12.3.2-2

SUMMARY OF REGRESSION ANALYSES
Regression Equation Y(Hat) = $B_0 + B_1X_1 + B_2X_2 + B_3X_3$

SEPTEMBER 1978 - MARCH 1980 (58 Observations)

Parameter	Units	Symbol	Mean	Standard Deviation	Correlation Coefficient
Deer Kill*	Number	DK	2.86	4.48	--
Deer Count	Number	DC	250.52	332.18	.3389
Precipitation	cm	PR	33.83	42.08	-.1733
Guard Shack Vehicle Count	Number	GS	341.17	88.18	.0249

Model	Degrees of Freedom	r x 100	F Calculated	F Critical	Probability >F	Linear No	Linear Yes
DC, PR, GS	3, 54	37	2.83	2.78	.0460		X
DC, PR	2, 55	37	4.33	3.17	.0180		X
DC, GS	2, 55	34	3.52	3.17	.0333		X
PR, GS	2, 55	17	0.36	3.17	.4307	X	
DC	1, 56	34	7.27	4.02	.0093		X
PR	1, 56	17	1.73	4.02	.1933	X	
GS	1, 56	2	0.03	4.02	.8526	X	

SEPTEMBER 1978 - MAY 1979 (35 Observations)

Parameter	Units	Symbol	Mean	Standard Deviation	Correlation Coefficient
Deer Kill*	Number	DK	3.77	5.28	--
Deer Count	Number	DC	365.29	381.31	.2499
Precipitation	cm	PR	32.63	40.15	.1794
Guard Shack Vehicle Count	Number	GS	369.83	80.32	.1423

Model	Degrees of Freedom	r x 100	F Calculated	F Critical	Probability >F	Linear No	Linear Yes
DC, PR, GS	3, 31	31	1.04	2.91	.3666	X	
DC, PR	2, 32	30	1.53	3.30	.2329	X	
DC, GS	2, 32	26	1.14	3.30	.3338	X	
PR, GS	2, 32	25	1.04	3.30	.3650	X	
DC	1, 33	25	2.20	4.14	.1477	X	
PR	1, 33	18	1.10	4.14	.3025	X	
GS	1, 33	14	0.68	4.14	.4150	X	

SEPTEMBER 1979 - MARCH 1980 (23 Observations)

Parameter	Units	Symbol	Mean	Standard Deviation	Correlation Coefficient
Deer Kill*	Number	DK	1.48	2.35	--
Deer Count	Number	DC	75.37	91.35	.5105
Precipitation	cm	PR	35.65	45.73	.1995
Guard Shack Vehicle Count	Number	GS	297.57	32.96	.0728

Model	Degrees of Freedom	r x 100	F Calculated	F Critical	Probability >F	Linear No	Linear Yes
DC, PR, GS	3, 19	54	2.58	3.13	.0840	X	
DC, Pr	2, 20	54	4.02	3.49	.0340		X
DC, GS	2, 20	52	3.69	3.49	.0431		X
PR, GS	2, 20	20	0.42	3.49	.6650	X	
DC	1, 21	51	7.40	4.32	.0128		X
PR	1, 21	20	0.37	4.32	.3614	X	
GS	1, 21	7	0.11	4.32	.7412	X	

*Dependent Variable

TABLE 12.3.2-3

BUS PASSENGER REPORT SUMMARY

OBS	MONTH	YEAR	TRIPS	PSGR	CUMPSGR	PSGRMI	CUMPSGRM
1	JUN	78	79	4559	4559	205155	205155
2	JUL	78	•	•	•	•	•
3	AUG	78	214	4106	8665	185140	390295
4	SEP	78	158	5978	14643	269936	660231
5	OCT	78	184	3662	18305	165165	825396
6	NOV	78	163	3572	21877	161334	986730
7	DEC	78	181	4834	26711	218748	1205478
8	JAN	79	200	5603	32314	253701	1459179
9	FEB	79	•	2579	34893	104500	1563679
10	MAR	79	•	6308	41201	255452	1819131
11	APR	79	•	5811	47012	235808	2054939
12	MAY	79	106	5280	52292	239775	2294714
13	JUN	79	179	4982	57274	226467	2521181
14	JUL	79	177	5513	62787	249987	2771168
15	AUG	79	98	5887	68674	268675	3039843
16	SEP	79	201	5336	74010	275595	3315438
17	OCT	79	232	6976	80986	363035	3678473
18	NOV	79	214	6323	87309	287028	3965501

		TRIPS	PSGR	PSGRMI
TOTALS	(78	979	26711	1205478
	(79	1407	60598	2760023
	(78-79	2386	87309	3965501
MEAN	(78	163	4452	200913
	(79	176	5509	250911
	(78-79	170	5136	233265

TRIPS = Round Trips
PSGR = Passengers
CUMPSGR = Cumulative Passengers
PSGRMI = Passenger Miles
CUMPSGRM = Cumulative Passenger Miles

• Denotes missing data

that the reduction of traffic by providing buses is a significant factor in reducing deer road-kill. Climate, condition of deer killed, and locations where deer are most likely to be on the road will be studied when additional data are available.

12.3.3 Effects of Herbivore Density on Shrub Utilization

The degree to which shrub production and utilization studies provide corroborative support to pellet group studies is of considerable importance, as both studies are used to monitor changes in the local deer herd. Although a one-to-one correspondence at all sites across the entire study area is not expected, a degree of correspondence is desirable since it strengthens conclusions regarding the causes of changes in deer-herd numbers at highly localized areas of interest.

12.3.3.1 Objectives

The objectives of this study are: 1) to evaluate the interrelationships between herbivore density and shrub (browse) utilization, and 2) to use information gained from this study to formulate possible mitigative measures.

12.3.3.2 Discussion of Qualitative Analyses

Insufficient data preclude the quantitative analysis of this interrelationship at the current time. A qualitative evaluation of production/utilization and pellet group density data is considered appropriate until such a time as data are available to perform meaningful statistical analyses.

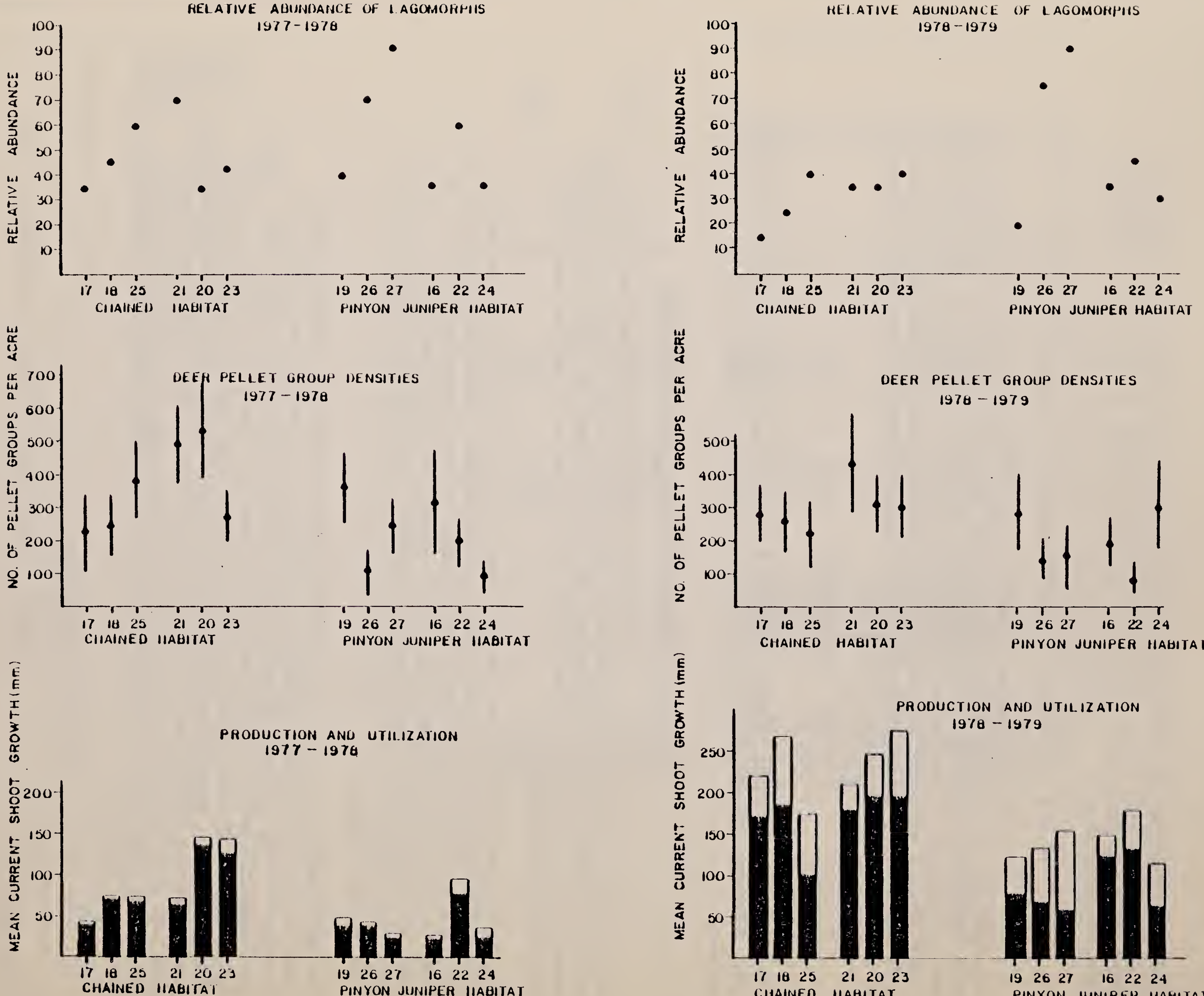
The herbivores found in the area of Tract C-b which contribute the most to shrub utilization are cattle, deer, and lagomorphs. Relative information on cattle densities is provided by the Bureau of Land Management (BLM) in the form of allotment management data; the number of cattle grazing on tract increased slightly this year over the previous four years but remains so low that the effect of cattle density on Tract shrub utilization must be considered negligible.

The experimental design of the browse production and utilization studies (Section 8.2.2) is nearly identical to that of the pellet group density studies in that the same BA-designated transects are used in each case. Deer and lagomorph pellet group studies have been previously conducted on a yearly basis as part of the Project wildlife program (see Sections 8.2.1 and 8.3.2, respectively). However, a modification in experimental design of the lagomorph studies during 1980 allows only tabulations of that data from which no conclusions with regard to baseline can be drawn. Results of both pellet group density studies and of the production and utilization studies are summarized in Figure 12.3.3-1.

12.3.3.3 Conclusions

General conclusions which can be reached at this time are:

FIGURE 12.33-1



1) Little if any correlation appears to exist in the pattern of pellet group distributions between the years of 1977-78 and 1978-79. One possible reason for this lack of correlation is the shift toward the pinyon-juniper habitat because of the harsh winter in 1978-79.

2) The combined average for all deer pellet groups for 1978-79 was 242 pellet groups/acre; a 23% decline relative to the average of 313 pellet groups/acre for 1977-78. Increased mortality and restriction in total winter range caused by the severe winter are largely responsible for the decline in the deer numbers.

12.3.4 Effects of Shrub Production, Utilization, Deer Migration, Age/Sex Ratios, Pellet Groups, and Climate Upon Deer Mortality

Deer Mortality (dependent variable) is influenced by many variables, but the most important ones are thought to be shrub production and utilization, deer migration, age/sex ratios, pellet groups, and climate.

12.3.4.1 Objectives

The objectives of this study are: 1) to evaluate the interrelationships between deer mortality and variables listed above; 2) to use information gained from this study to formulate possible mitigation measures; and 3) use interrelationship information to detect degree of developmental effects on deer mortality from various variables.

12.3.4.2 Discussion of Qualitative Analysis

Quantitative analysis is not possible at this time because of insufficient data. Professional judgment suggests that the interrelationships will be valuable, but meaningful statistical analysis will not be possible until a year or two of additional data are collected.

Deer mortality data are collected on ten permanent study sites located in sagebrush draws just north of the C-b Tract. These sites were chosen after previous sampling showed the sites to be the primary winter habitat for deer associated with the C-b Tract. Also, deer mortality was greater in this area than in any other habitat. Deer mortality data have been collected since the 1977-1978 sample year (two sample periods) in the spring following winter die-off and migration to higher elevations.

12.3.5 Conclusions

General conclusions which can be reached at this time are:

1) Comparisons of deer mortality data in 1977-78 to 1978-79 data show a 74% increase of deer carcasses found in the 1978-79 sampling period.

2) Fawns comprised 76% of the 1978-79 carcasses found, as compared to 80% in the 1977-78 sampling period.

3) Habitat selection by mule deer shifted towards the pinyon-juniper habitat and away from the chained pinyon-juniper habitat type in the 1978-79 sampling period.

4) Pellet group data showed a 23% decrease from 1977-78 data to 1978-79 data.

5) Division of Wildlife, December 1979, aerial estimates of the Piceance Basin mule deer herd size showed approximately a 50% reduction of herd size from the December 1978 herd size estimates.

6) Browse production increased while utilization decreased, comparing 1978-79 data to 1977-78. (See Section 12.3.3, Effects of Herbivore Density on Shrub Utilization) Reasons for less utilization during the past year are increased snow cover in the area, more production per shrub, and a high winter deer mortality.

The severity of the 1978-79 winter was a major contributor to all these results. The deep snows reduced the mule deer winter range and increased the winter mortality.

13.0 NOTES

13.1 Conversion Factors

An attempt has been made to report all studies and data in metric units.* In most cases these data are collected and initially tabulated in English units and a few analyses were carried out with English units. Table 13.1-1 contains conversion factors for converting from English to metric units. Conversion from metric to English units can be made by dividing by the factor or by multiplying by its reciprocal.

Table 13.1-2 presents additional conversion factors useful with interpretation of data reported herein.

13.2 Literature Cited

Table 13.2-1 is a bibliography of literature cited in the text. Reference in the text is by author or title.

*Hydrology is one exception.

TABLE 13.1-1

TABLE OF CONVERSION FACTORS

To Convert From	To	Multiply By
acres	ft^2	4.3560×10^4
acres	hectares	0.404687
atmospheres	dynes/cm^2	1.01325×10^6
atmospheres	bars	1.01325
atmospheres	mm Hg	760
atmospheres	newtons/m^2	1.01325×10^5
atmospheres	lbs/ft^2	2116.32
bars	atmospheres	0.98692
bars	mb	1000.00
bars	newtons/m^2	10^5
BTU (British Thermal Units)	gm. cal.	252.
cfm	liters/sec	0.4720
cfs	gpm	448.831
cfs	m^3/s	0 028317
degrees Fahrenheit	degrees Kelvin	(°F-32)*(5/9)+273
degrees Fahrenheit	degrees Centigrade	(°F-32)*(5/9)
degrees	radians	0.017453
feet	meters	0.3048
ft^2	meters^2	0.092903
ft^3/min	m^3/sec.	0.000472
ft^3	gals	7.481
ft^3	m^3	0.028317
gals	m^3	0.0037854
gals	liters	3.7853
gals/min	m^3/sec.	0.00006309
gals/min	liters/sec.	0.069088
grains	grams	0.064798918
grains	pounds	1.42857×10^{-4}
hectares	m2	10^4
inches	cm	2.5400
$inch^3$	cm^3	16.3872
langleys	cal/cm2/min	1.000
miles	kilometers	1.60935
mph	mps	0.44703
pounds	kilograms	0.45359
pounds/acre	kg/ha	1.12173
pounds/acre	gms/m2	0.112173
pounds/hour	grams/sec.	0.1260
pounds/$inch^2$	atmospheres	0.068046
pounds/$inch^2$	mb	68.947
radians	degrees	57.29578
rods	meters	5.0292
SCFM (Standard Cubic Ft/Min)	ACFM (Actual cubic ft/min	$(^oK_a/^oK_s)(P_s\ mb/P_a\ mb)$
ton (short)	kilograms	907.185

TABLE 13.1-2

ADDITIONAL CONVERSION FACTORS
MULTIPLES AND SUBMULTIPLES OF UNITS

Factor by Which Unit is Multiplied	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	m
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

CONVERSION FACTORS FOR GASES

Molecular Weight (MW)	Pollutant	To Convert μg/m^3 at 25°C and 760 mmHg to ppb Multiply by Factor
46.01	NO_x as NO_2	.532
30.01	NO	.815
46.01	NO_2=NO_x -NO	.532
64.06	SO_2	.382
34.08	H_2S	.718
-	THC	1.530
16.01	CH_4	1.525
28.01	CO	.873
48.00	O_3	.510

Equation: $\frac{22.414}{MW} \left(\frac{298}{273}\right) = \text{Factor}$

TABLE 13.2-1

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LEGEND

Symbol	Description
◄	Stream gaging station (prefix 0930 omitted from Station No.)
●	Observation well (may have multiple piezometers)
●	Spring or seep
★	Precipitation station
———	Paved roads
——- - - -	Other roads and trails
—— ——	Topographic basin of Piceance Creek

0 5 Miles

(Base map supplied by the United States Geological Survey)

NOTES

See Exhibit B for explanation of monitoring station designations, category and normal frequency of measurements, and [illegible]

EXHIBIT A

KEY FEATURES OF HYDROLOGIC MONITORING PROGRAM FOR Cb TRACT

PICEANCE CREEK BASIN
WATER DIVISION NO 3
STATE OF COLORADO

DECEMBER 1978

OBSERVATION WELLS

Designation	Owner of Well	Data Measured: Piezometric Levels: Upper Aquifer	Data Measured: Piezometric Levels: Lower Aquifer	Data Measured: Water Quality	Measurements By
Cb-1	Cb	—	m	p	A
Cb-2	Cb	m	—	p	A
Cb-3	Cb	m*	m*	p	A
Cb-4	Cb	m	—	p	A
SG-1	Cb	c	c	p	A
SG-1A	Cb	m	—	p	A
SG-6	Cb	m	m	p	A
SG-8	Gb	m	—	p	A
SG-8R	Cb	—	m	p	A
SG-9	Cb	c	c	p	A
SG-10	Cb	—	m	p	A
SG-10A	Cb	m	—	p	A
SG-10R	Cb	—	m	p	A
SG-11	Cb	m	m	p	A
SG-17	Cb	c	c	p	A
SG-18A	Cb	m	—	p	A
SG-19	Cb	c	—	p	A
SG-20	TOSCO	m	—	p	A
SG-21	Cb	m	—	p	A
AT-1C	Cb	m	m	p	A
A-1	+	c	—	p	A
A-2	+	m	—	p	A
A-3	Cb	c	—	p	A
A-4	Cb	m	—	p	A
A-5	Cb	c	—	p	A
A-6	+	m	—	p	A
A-7	Cb	c	—	p	A
A-8	+	c	—	p	A
A-9	Cb	m	—	p	A
A-10	Cb	m	—	p	A
A-11	Cb	c	—	p	A
A-12	Cb	m	—	p	A
A-13	Cb	m	—	p	A
TH75-5A & 5B	U.S.	m (5A)	m (5B)	—	A/F
TH75-13A & 13B	U.S.	m (13A)	m (13B)	—	A/F
Equity 1	Equity Oil Co	—	m	—	A/F
TH75-18A & 18B	U.S	m (18A)	m (18B)	—	A/F
TH 75-10B	U.S.	—	m	—	A/F
TH75-9A & 9B	U.S	m (9A)	m (9B)	—	A/F
Equity Sulfur 1A	Equity Oil Co	—	m	—	A/F
CER RB-D-02&03	U.S	m (02)	m (03)	—	A/F
TH75-15A & 15B	U.S	m (15A)	m (15B)	—	A/F
Greeno 4-4	Shell Oil Co	m*	m*	—	A/F
TG71-3	TOSCO	—	m	—	A/F
TG71-5	TOSCO	—	m	—	A/F
Oldland 3	TOSCO	m*	m*	—	A/F
GP-17X-BG	U.S	m*	m*	—	A/F
Bute 25	TOSCO	m*	m*	—	A/F
Liberty Bell 12	TOSCO	m*	m*	—	A/F
Union B-1	Union Oil Co.	m	—	—	A
Getty 9-4D	Getty Oil Co	—	m	—	A/F
Colony 12-596	Atlantic Richfield	c	—	—	A/Colony
TG71-4	TOSCO	—	m	—	A/F
Equity BS-13	Equity Oil Co	—	m	—	A/F

An asterisk (*) following frequency symbols in columns under "Piezometric Levels" indicates that the composite piezometric level is monitored

Frequency of measurement of water levels in alluvial wells indicated under "Upper Aquifer."

+ Regardless of ownership, Applicant has the right to monitor these wells.

PRECIPITATION

Designation	Name of Station	Measurements: Frequency	Measurements: By
020	Cb Air quality trailer 020	c	A
023	Cb Air quality trailer 023	c	A
LH	Little Hills	c	F
M	Meeker 2	c	F
SG	Scandard Gulch on Roan Plateau	c	F
CG	Corral Gulch	c	F
JQS	JQS Gage	c	F
EFPC	East Fork Parachute Creek	c	F
EMFPC	East Middle Fork Parachute Creek	c	F

STREAM FLOW

(Prefix 0930 omitted from Station No.)

Station No.	Description	Data Measured: Discharge	Data Measured: Quality	Measurements By
4800	White River below Meeker	c	p	F
6007	Piceance Creek below Rio Blanco	c	p	F
6015	Middle Fork Stewart Gulch	c	p	F
6022	Stewart Gulch above West Fork	c	p	F
6025	West Fork Stewart Gulch, upstream	c	p	F
6028	West Fork Stewart Gulch at mouth	c	p	F
6033	Sorghum Gulch, upstream	c	p	F
6036	Sorghum Gulch at mouth	c	p	F
6039	Cottonwood Gulch	c	p	F
6042	Tributary of Piceance Cr. (No Name Gulch)	c	p	F
6050	Scandard Gulch, upstream	c	p	F
6052	Scandard Gulch at mouth	c	p	F
6058	Willow Creek	c	p	F
6061	Piceance Creek above Hunter Creek	c	p	F
6200	Piceance Creek below Ryan Gulch	c	p	F
6222	Piceance Creek at White River	c	p	F
6255	Yellow Creek near White River	c	p	F

SPRINGS OR SEEPS

Designation	Data Measured: Discharge	Data Measured: Quality	Measurements By
Cb S-1	w	p	S/A
Cb S-2	—	p	A
Cb S-3	w	p	S/A
Cb S-4	—	p	A
Cb S-6	w	p	S/A
Cb S-7	—	p	A
Cb S-8	w	p	A
Cb S-9	w	p	A
Cb S-10 (W-3)	w	p	S/A
CER-1	w	—	S
B-3	w	—	S
H-3	w	—	S
F-3	w	—	S
Fig. 4-A	w	—	S
W-4	w	—	S
W-9	w	—	S
CER-7	w	—	S
S-9	w	—	S
P 3 & 3A	w	—	S

GENERAL NOTES

1. See Exhibit A for location of monitoring stations listed on this Exhibit.
2. Letter symbols under columns of "Data Measured" indicate normal frequency of measurements as follows:
   - c - continuous recorder (or daily total or mean)
   - w - weekly
   - m - monthly
   - q - quarterly
   - s - semiannually
   - a - annually
   - p - periodic or variable depending on water quality parameters measured
3. Letter symbols under column of "Measurements By" have following meanings:
   - A - Applicants in Case No. W-3492
   - F - Federal (USGS)
   - S - State of Colorado (Div. of Water Resources)
   - O - Others (Indicated where known)

EXHIBIT B

LIST OF STATIONS OF HYDROLOGIC MONITORING PROGRAM FOR Cb TRACT

EXHIBIT C

DEVELOPMENT MONITORING ACTIVITIES

REVISION 1
MAR 8, 1979

REVISION 2
JUL 1, 1979

REVISION 3
MAR 4, 1980