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ENVIRONMENTAL MONITORING AND ANALYSIS
IN SUPPORT OF ANTRIM OIL SHALE RESEARCH

Topical Report for Period March 1978 - February 1979

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ABSTRACT

A program to assess environmental impacts of in situ Antrim oil shale processing experiments was carried out. This report covers the second year of an expected four year program. Activities included: monitoring of surface elevations for possible subsidence; monitoring for soil contamination from brines; monitoring surface and subsurface water quality; and monitoring ambient air quality. Assessment was also made of site vegetation, soils, surface disruption caused by drilling activities, and impacts on neighboring residents. Much of this year's effort was directed to monitoring baseline conditions. Consequently, assessment of potential impacts from in situ operations is not yet possible. However, hydrofracturing operations did not appear to affect surface elevations, and the experimental operations, including flaring of combustion product gases, did not degrade ambient air quality beyond permissible concentrations. Negative impacts noted include minor inconvenience to neighboring residents, and physical disruption of the land surface. A potential ground water quality problem caused by drilling wastes and/or well seepage from previous operations was identified.

ACKNOWLEDGEMENTS

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INTRODUCTION

This report documents work performed by the Environmental Research Institute of Michigan under subcontract to the Dow Chemical Company, to monitor and assess any environmental impact resulting from the experiment to extract low Btu gas from Antrim shale by in situ combustion. The work covers the second year of monitoring in a program anticipated to last four years. During these first two years much of the effort has been directed to collecting background data against which to measure impacts and changes resulting from the extraction process. Also monitored and evaluated are the minor impacts resulting from site development. It is expected that during the third year efforts will focus on examination of environmental effects resulting from the in situ process.

1.1 ENVIRONMENTAL SETTING OF THE MICHIGAN SHALE SITE

The study site for the Antrim Shale experimental activities is an 80 acre (32 ha) parcel in eastern Michigan's Sanilac County in what is referred to as the "thumb" of Michigan. Current land use in this area is over 80 percent active or inactive agriculture; the remaining area largely consisting of scattered woodlots. Fields in this area have traditionally been used to raise field crops or as pasture lands for dairy herds. The site itself is a former dairy farm whose current vegetation cover consists of woody and herbaceous old field vegetation.

This area is economically poor with a predominantly rural population. Population density is low with only 35 residences within two kilometers of the study site. No significant urban populations are within 30 kilometers. The shale site is in the Seymour Creek watershed of the Black River Basin, which has a total drainage area of 1,820 sq kilometers (Figure 1).

The climate of the area is moderated by the influence of the nearby Great Lakes, which results in few days being below 0°F or above 100°F. The mean annual temperature in the area is 47°F. The average frost free

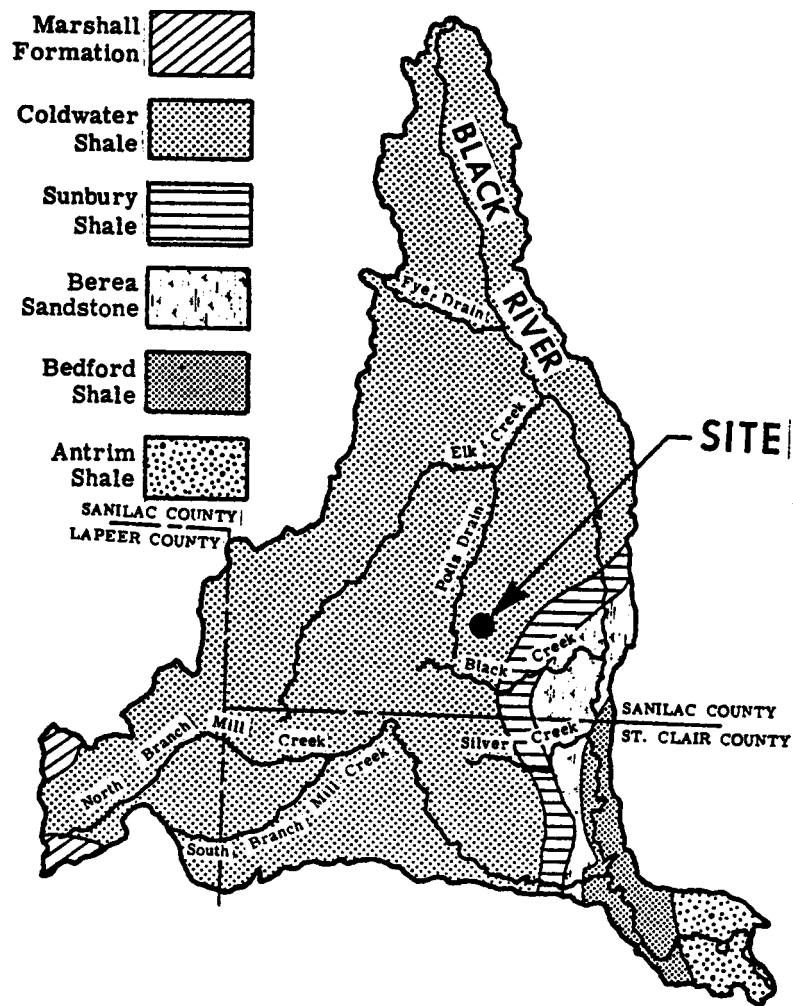


FIGURE 1. BEDROCK GEOLOGY OF THE BLACK RIVER BASIN, MICHIGAN

period is from 22 May to 30 September. Snowfall in an average winter reaches 105 cm. Precipitation is fairly uniform throughout the year with a slight increase from April to September which accounts for 60% of the total. Mean annual precipitation is 76 cm (USDA-SCS, 1961).

Antrim shale is one strata of extensive sedimentary material deposited during the Paleozoic era. At the study site, 60 meters of glacial drift were deposited on these sedimentary layers during the Pleistocene. Bedrock formations which subcrop the drift in this area include, from youngest to oldest: Marshall sandstone, Coldwater and Sunbury shales, Berea sandstone, Beford and Antrim shales. At the site the Antrim shale lies 1200 feet (365 meters) below the surface.

Marshall formation subcrops are found only in the extreme western portions of the Black River basin. Because this sandstone is very porous, wells yield large amounts of water. Coldwater shale is a relatively thick layer and subcrops a large portion of the basin, including the site area. This shale has very low permeability as well as an inability to store water. Wells completed in the Coldwater formation yield less than 10 gpm, and the water is often highly mineralized. The Sunbury, Berea, and Beford formations are thin as compared to the Coldwater shale. Of these units, only the Berea sandstone is capable of storing and yielding water which will generally be brine. The Antrim shale is the oldest subcropping formation; it generally produces little water and whatever is produced is always highly mineralized. At the site, only drift wells produce fresh water. Bedrock strata all contain highly mineralized water or brine.

The site bears evidence of being formed by glacial-lake bed deposits. It has little relief and is poorly drained. The site itself has several marshy depressions, one with a standing body of water. Soils in this area have developed from the glacial deposits through weathering, oxidation, and leaching. Because of the variation in parent material and changes in these materials, a complex of soil types exists. Surface soils are chiefly silt loams and sand loams and are often well sorted

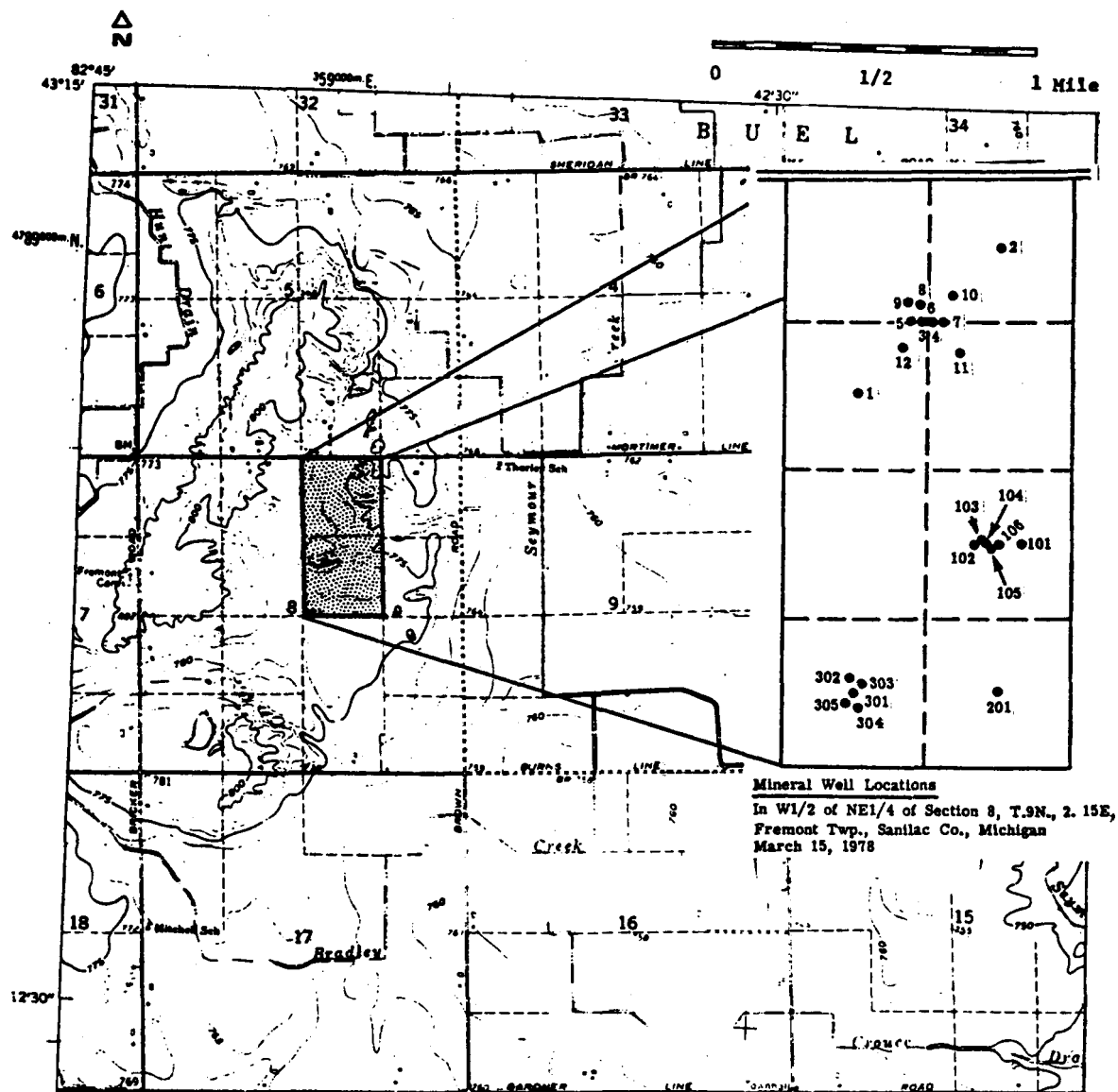


FIGURE 2. MICHIGAN ANTRIM SHALE SITE, SANILAC COUNTY

and structured. State well-logs and water wells in and around the shale site show the upper alluvial structure consists of alternate clay and loam layers. Infiltration rates are generally less than 5 centimeters per hour so that heavy rainfall produces significant storm runoff.

The topography of the Seymour Creek watershed basin is very flat with average slopes of less than 3 meters per mile. Because drainage is very poor, numerous channels and ditches have been added to enhance draining and prevent ponding in the fields. Many of these ditches are intermittent and free-flowing during the period of spring runoff and often in late fall season.

1.2 EXPERIMENTAL ACTIVITIES

Currently, the Antrim shale program is in several stages of development. The well pattern (numbers 3-7) on the northern (or front) forty-acre (16 ha) portion of the site, developed in earlier Dow shale experiments, was revitalized in 1977. Several in situ combustion experiments were performed in these wells during this reporting period. A coal and charcoal augmented combustion trial was conducted in well 4 during February and in well 7 during March. The latter test lasted 61 days.

There are plans to use the gas/liquid separator and a demister to collect solid and liquid wastes. Gas will be flared on site with a ten-meter stack. On the southern forty-acre (16 ha) portion, plans call for drilling a total of 37 wells, in three well patterns (see Figure 2). Wells 301-305 were drilled early 1978 while wells 103-106 were completed during December 1977.

Three techniques, one for each well pattern, are being used to fracture the shale: hydrofracturing, explosive fracturing, and acid underreaming. All will be followed by various types of explosive fracturing. An acid underreaming experiment was conducted on well 201 during January using 28% hydrochloric acid. During April and May wells 103-106 were hydrofractured and sand propped. Explosive fracturing was conducted on well 301 in July and on all six wells of the 100 series during September and October 1978.

Since there is a substantial overburden of bedrock and glacial deposits above the Antrim shale, separating combination products from potable aquifers, chances of environmental contamination from migration of in situ operations are expected to be minimal. Therefore, examination of environmental impacts will be concentrated on those associated with site development and disposal of materials brought to the surface.

In addition to the main experimental activities, various associated activities have and will continue to take place which may have adverse environmental impacts. The most important of these is the well drilling operation, with its associated mud and brine disposal, and high levels of machinery operation. Other site activities include building construction, grading of areas for roads and work platforms, and brine removed to keep wells dry. Seismic surveying activities entailing small surface explosions are also taking place.

1.3 ENVIRONMENTAL MONITORING

The goal of the environmental monitoring program is to assess the impacts of the current experimental activities on the environment. In addition, it is expected that the experience gained will enable preparation of a prioritized list of potential environmental impacts which would need to be rigorously evaluated for a commercial in situ operation.

The environmental monitoring activities carried out under this program have been aggregated into three broad categories; air quality, surface, and water quality. Sections 2, 3, and 4 of the report contain descriptions of the activities related to these categories during the period from March 1978 to February 1979. Conclusions reached during this period and recommendations for future activities are contained in Section 5.

AIR QUALITY

2.1 INTRODUCTION

Air quality measurements have been conducted to determine background concentrations of air pollutants in the vicinity of the in situ oil shale test site and to isolate emissions from the two coal augmented propane burns (CAPB1, CAPB2) in the Rhoburn series wells. Pollutants measured include carbon monoxide, oxides of nitrogen, sulfur dioxide, hydrocarbons, and particulates. Data this year were collected between 1 February and 31 March 1978. Additional air quality monitoring work is planned for late 1979 when the in situ trials are resumed.

The air quality impact of these experimental in situ test facilities is significantly different than the impact of an operational program. The flare stack is one of the major features of this test site and would not be present in an operational oil shale project. Therefore emissions from the flare stack are only applicable to determine the impact of the experimental process and not an operational one. Monitoring activities to date have been designed to measure background air pollutants and the impact of the experimental process on the local ambient air quality. The current program does not attempt to extrapolate the data to impacts of an operational facility.

2.2 METHODOLOGY

Ambient air monitoring equipment was installed in a Coachman trailer equipped with a portable electrical generator. The instrumentation included a Hi-Vol particle sampler, a gas chromatograph for measuring CH_4 , CO, and total hydrocarbons, a dual channel chemiluminescent analyzer for measuring NO and NO_x , and a flame photometric detector for

TABLE 1
NATIONAL AMBIENT AIR QUALITY STANDARDS¹

<u>POLLUTANT</u>	<u>STANDARD DESCRIPTION</u>
Carbon monoxide (Primary and secondary standards are the same)	- 10 milligrams per cubic meter (9 ppm), maximum 8-hour concentration not to be exceeded more than once per year. - 40 milligrams per cubic meter (35 ppm), maximum 1-hour concentration not to be exceeded more than once per year.
Nitrogen dioxide (Primary and secondary standards are the same)	- 100 micrograms per cubic meter (0.05 ppm), annual arithmetic mean
Hydrocarbons (non-methane) (Primary and secondary standards are the same)	- 160 micrograms per cubic meter (0.24 ppm), maximum 3-hour concentration (6-9 a.m.) not to be exceeded more than once per year. For use as a guide in devising implementation plans to meet the oxidant standards.
Particulate matter Primary standard	- 75 micrograms per cubic meter, annual geometric mean - 260 micrograms per cubic meter, maximum 24-hour concentration not to be exceeded more than once per year
Secondary standard	- 60 micrograms per cubic meter, annual geometric mean, as a guide to be used in assessing implementation plans to achieve the 24-hour standard - 150 micrograms per cubic meter, maximum 24-hour concentration not to be exceeded more than once per year.
Sulfur dioxide Primary standard	- 80 micrograms per cubic meter, annual arithmetic mean - 365 micrograms per cubic meter, maximum 24-hour concentration not to be exceeded more than once per year.
Secondary standard	- 60 micrograms per cubic meter, annual arithmetic mean - 260 micrograms per cubic meter, maximum 24-hour concentration not to be exceeded more than once per year. - 1300 micrograms per cubic meter, maximum 3-hour concentration not to be exceeded more than once per year.

Note: Primary standards provide for protection of public health and secondary standards for the prevention of all other undesirable effects of air pollution.

¹ National Primary and Secondary Ambient Air Quality Standards. Environmental Protection Agency, Federal Register 36 (84): 8187, April 30, 1971.

measuring SO_2 . The trailer was first located at the edge of the test site approximately two hundred and fifty meters downwind from the flare stack. Ambient air sampling was conducted from July 1977 through January 1978 except for a period in December and January. The air monitoring van was relocated on 01 February from its position east of the farmhouse to the compound area, approximately 15 meters west of the flare stack. This permitted sampling through teflon sample lines in the trailer roof or through a stainless steel sample line from the top of the flare stack. These two sources will be referred to as "local" and "flare stack" in the following discussion of results.

Continuous records were collected of the concentrations of gaseous samples. Twenty-four hour particle samples were collected normally every other day on pre-weighed filters which were subsequently desiccated and weighed to determine particle concentrations. The instrumentation van was operated continuously except for shutdowns due to equipment problems. Equipment maintenance and trouble shooting required constant attention. The data collected has been compared to ambient air quality standards (Table 1) and correlated with test site activities.

Oxides of nitrogen were measured by the chemiluminescent reaction of nitric oxide and ozone. The instrumentation used is the Monitor Labs Model 8440 analyzer which uses a dual channel chemiluminescent system to provide simultaneous measurements of NO , NO_2 and NO_x (total oxides of nitrogen).

Sample gas enters the instrument through a particulate filter and is divided into two paths. One path leads through a converter where NO_2 is converted to NO . The other path passes through an equivalent volume in order to preserve the time correlated integrity of the sample. Separate photomultiplier detectors determine the total oxides of nitrogen from the air which passes through the converter, and the nitric oxide alone from the air which did not pass through the converter.

Sulfur dioxide was measured using a flame photometric detection (FPD) device which performs a continuous dry analysis of sulfur compounds. Its operation is based on the chemiluminescence of an activated molecular sulfur species produced by a hydrogen hyperventilated diffusion flame. A photomultiplier tube measures the chemiluminescent emission intensity level. The specific instrument used was a Monitor Labs Model 8450.

The analysis for sulfur by a flame photometric detector (FPD) is one of the most modern and direct techniques. The FPD consists of three basic functional subsystems: 1) the burner or flame holder, 2) flame chamber, and 3) the photomultiplier tube. Air containing the sulfur molecules enters through the burner which also holds the flame. The flame is surrounded by hydrogen which is enclosed by the flame chamber. One wall of the flame chamber is a clear optical window through which the photomultiplier tube measures the chemiluminescent emission energy intensity level and converts it to an equivalent electrical signal.

Carbon monoxide, methane, non-methane, and total hydrocarbons were measured using a Bendix Model 8270 gas chromatograph. This instrumentation operates in the following manner. A measured sample of ambient air is transported into a chromatographic column by the carrier gas. The chromatographic column is located in an analyzer oven that is temperature controlled for the specific hydrocarbon analysis. The column consists of a length of stainless steel tubing packed with a particular packing material. The packing material, column length, column temperature, and the carrier flow rate, will provide the desired retention, separation, and elution time of the hydrocarbon components from the chromatographic column.

As the components elute from the chromatographic column, they enter the Flame Ionization Detector (FID) Cell where they are mixed with

hydrogen then flow out through a jet. Voltage is supplied to the jet, at the tip of which a hydrogen flame is burning in an oxygen rich atmosphere. As the components pass through the hydrogen flame, ionization occurs, resulting in a current flow between the jet and collector of the detector. The output current is directly proportional to the amount of ionization, which is dependent on the input concentration. Carbon monoxide, methane, and total hydrocarbons are all measured separately. Non-methane hydrocarbons are then determined by subtracting methane from the total hydrocarbon measurement.

2.3 RESULTS

Air quality data were collected from two individual extraction experiments, CAPB1 and CAPB2, as well as from local background sources. Complete data records are compiled in Appendix D. The following comments summarize the observations made for each of the parameters measured.

Particulates: All samples for February - March 1978 were below the National Ambient Air Quality Standard of $60 \mu\text{g}/\text{m}^3$ for annual geometric mean.

A correlation was observed between particulates and wind direction. From the 16 samples, a subset of 9 were taken when the wind direction was predominantly from the South or Southwest. The mean and standard deviation was 34.0 ± 7.5 . A second subset of five samples were taken for winds from the northwest. This subset had a mean and deviation of 17.7 ± 14.3 . It is likely that higher values for wind direction South - Southwest reflects the greater industrial concentration in the Detroit - Flint regions, as compared to the north central regions, of Michigan. It was not possible to correlate high particulate results with on-site activities, as recorded in Dow log books.

Oxides of Nitrogen: The highest values occurred during peaks in NO_x concentration that lasted only a few hours (2 to 4 hours). These peaks could be due to local point sources. Measured values ranged between 0 and 30 ppb. Several of the peaks occurred during changing wind conditions, which could produce atmospheric instabilities and mix the air from ground level sources (engines) with air sampled through lines above the trailer (5 meters high).

It should be noted that all NO_x readings are well below the National Ambient Air Quality Standard's annual arithmetic mean of 50 ppb. The peak values noted above are therefore of little consequence.

Sulfur Dioxide: The locally sampled SO_2 data, when averaged for 24 hours, never exceeded the National Ambient Air Quality Standard for maximum 24-hour concentration (100 ppb). Local measurements of SO_2 ranged between 0 and 30 ppb.

Flare stack sampling for CAPB1 showed several sharp discontinuities in the data. Changes in flows from the various wells produced most of the observed fluctuations. Especially high SO_2 readings were observed during letdown of the wells, e.g., on February 17 and February 28. Also, note the sudden drop in SO_2 readings on February 16 when well 3 was shut in to the let-down system.

Another cause of discontinuities was the propane burner in the flare stack. A 40% increase in SO_2 readings was observed on February 15 when the burner went out at 1000. A possible explanation is water vapor condensation in the sample line. Moisture produced from combustion of propane will condense in the cold stainless steel line. This moisture will lower the SO_2 concentration, as SO_2 is removed by the water on the walls of the line. When the burner is out, there is less moisture and less SO_2 removal.

To eliminate this problem, the SO₂ sample line must be maintained at a temperature above the dew point. Since this was not done, it is believed that the SO₂ data from February 9 to February 15 may be too low by a factor of at least 40%. However, an exact correction factor may be difficult to assess.

Flare stack measurements of SO₂ during CAPB1 and CAPB2 ranged from 5 to 395 ppb.

Hydrocarbons: The sample lines for methane, carbon monoxide, non-methane hydrocarbons, and total hydrocarbons were located on top of the air monitoring trailer. Thus, all sampling was "local". This cannot be considered a reliable measure of ambient conditions, because local sources near the trailer produced large changes in readings.

For example, it was noted on several occasions that between the hours of 4 pm to 6 pm, the levels (1 hour average) would increase as follows:

	<u>Background level</u>	<u>Level, 4 to 6 pm</u>
Total H.C.	2 - 5 ppm	7 - 10 ppm
Methane	2 - 5 ppm	7 - 10 ppm
Non-methane H.C.	0 - 0.3 ppm	0.2 - 1.0 ppm
Carbon Monoxide	0.5 - 3 ppm	2 - 7 ppm

The National Ambient Air Quality Standard for the maximum eight hour CO concentration is 9 ppm. The standard for non-methane hydrocarbons is 0.24 ppm for a maximum three hour concentration.

During these brief periods, the non-methane H.C. exceeded the three-hour standard. However, as noted previously this is perhaps not meaningful, since these increases are very likely due to automobiles being warmed up in the parking lot next to the air monitoring trailer.

Flare stack gases were not monitored due to the limited dynamic range of the gas chromatograph. In order to sample flare stack gases, a calibrated dilution system would be needed to dilute the sampled gas with "zero" gas.

2.4 DISCUSSION

For future air quality monitoring, the location of the air monitoring trailer should be determined by the type of measurement desired. To assess impact to ambient air quality, two locations are desirable: upwind of the site for background data, and downwind some minimum distance for assessing the impact of site emissions. For flare stack gas sampling, the trailer could remain adjacent to the stack.

Flare stack sampling will require some modifications in the sample lines. First, the external sample line should be insulated and heated to a temperature above the dew point of water. This is necessary to prevent condensation in the line, which causes low sulfur dioxide readings. Second, a dilution system is needed for the gas chromatograph, since the stack concentrations of hydrocarbons and carbon monoxide exceeded the 10 ppm range of the instrument. This system would mix a calibrated amount of filtered "zero" air with the sampled air.

It may be desirable to perform a constituent analysis of well gas samples, collected just prior to the flare stack. A cold trap could be used to collect samples from the well lines. Analysis would be performed subsequently by, for example, gas chromatography. The goal of this effort would be to assess the levels and types of toxic substances emitted from in situ shale combustion.

LAND MONITORING

3.1 INTRODUCTION

The land portion of the Dow environmental monitoring program is concerned with those environmental parameters not included within the air or water studies. Thus the land monitoring effort includes a variety of parameters, some, such as acoustics and aerial photography, have little relationship to each other while others, such as soils and vegetation, are closely tied. Included within these parameters are ground surface subsidence, vegetative surveys, soil surveys, noise measurements, the collection of aerial and ground photography, and neighborhood surveys. The following sections will describe the methodology used in monitoring these parameters, present the data collected, and, where possible, make conclusions and recommendations from that data.

3.2 GROUND SURFACE ELEVATIONS

Underground mining and mineral extraction operations can cause subsidence or uplift of the overlying surface. This possibility is considered remote since the Dow oil shale experiment is being conducted at over 1200 feet (365 meters) depth and the quantity of rock, water, and gaseous products to be removed from beneath the surface is relatively small. However, it is considered important to document any change in topography which might occur by periodic measurements of surface elevations. During 1977, forty-three elevation monuments were installed in the area of the Dow study site. In 1978 an additional twelve elevation monuments were installed -- eight monuments near 300 series wells and four near the 200 series wells. A description of an elevation monument and the locations of monuments 1-43 can be found in last year's topical report [1]. The locations of Dow wells and monuments 44-55 are shown (without bearings or distances) in Figure 3.

3.2.1 MONUMENT MEASUREMENTS

In August of 1978, the new monuments 44-55 were surveyed along with eight old monuments from the 1977 data set (see Table 2). Elevations obtained for the new monuments are considered to be baseline values. The August 1978 elevations for the eight old monuments differed from their 1977 elevations by an average of 13 millimeters and the range of the differences was from 9 to 21 millimeters. These differences are within the range of expected error for a well calibrated laser theodolite and good data measurement techniques.

The eight monuments included two within 50 meters of wells 102 and 201 (numbers 31 and 42), four in the range 85 to 150 meters from wells 102, 201, and 301 (numbers 4, 5, 28, 32) and two in the range 500 to 700 meters from the south forty wells. Changes in elevation caused by fracturing prior to August and centered at a well head would likely have been detected by changes in elevation of one or more of the monuments within 150 meters of the source of the change (numbers 4, 5, 28, 31, 32 and/or 42). Thus no measureable changes have occurred since initiating the elevation monitoring program.

3.2.2 SOURCES OF ERROR

An examination of the operating Manual for the Hewlett Packard 3810A TOTAL STATION (laser theodolite) reveals that the RMS error for elevation measurements with this instrument can be on the order 30 seconds of arc. Conversations with Hewlett Packard's Colorado office (where these instruments are designed and built) revealed that: 1) there are three sources of error that combine to produce the 30 arc second value (zero point, linearity and temperature drift); 2) these errors can be reduced up to a point through calibration; 3) there is another significant source of error of 7 arc seconds (RMS) in the aiming telescope; and 4) the aiming error can be reduced by taking many samples. Thus it is possible to contemplate RMS errors as large as 37 arc seconds. Fortunately, in practice, the error is reduced to a more tolerable value on the order of 5 arc seconds. To illustrate the significance of various sized errors we

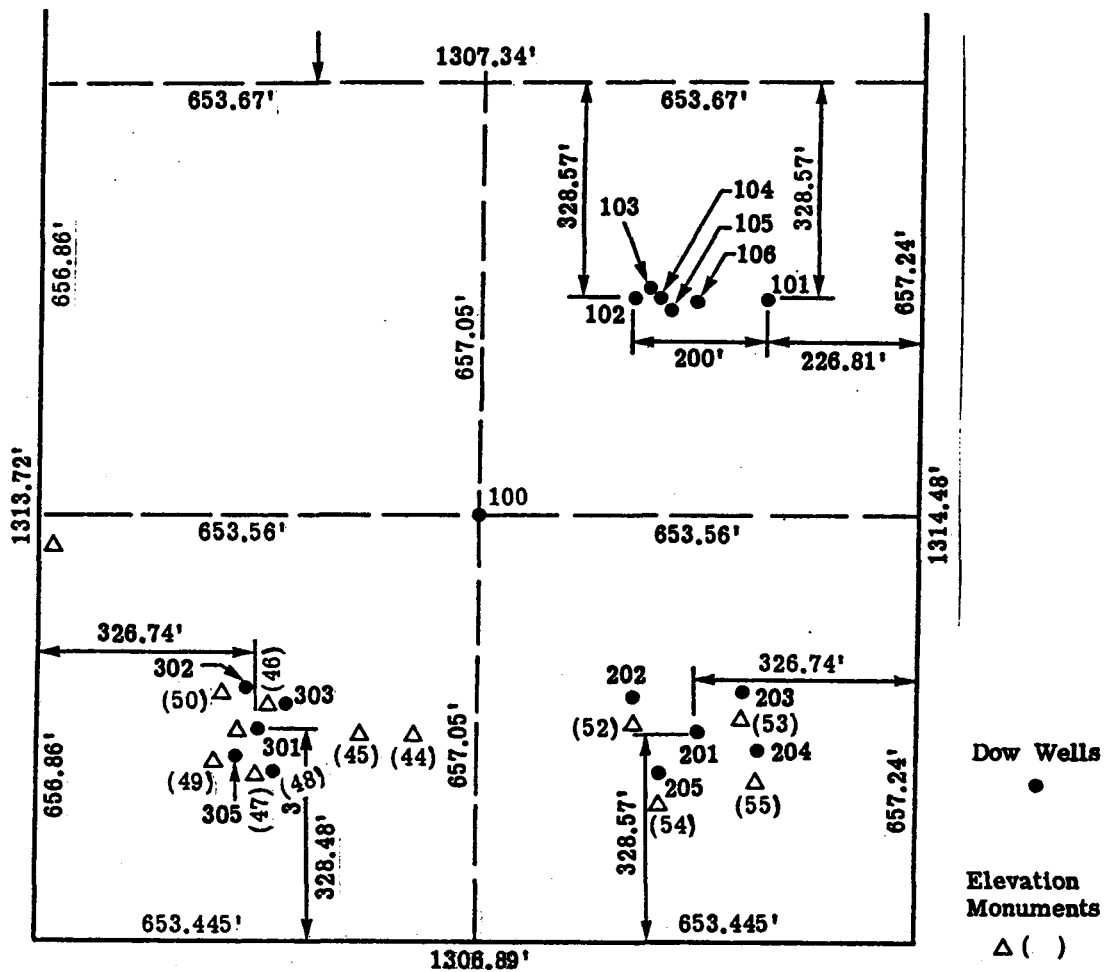


FIGURE 3. LOCATION OF SHALE SITE ELEVATION MONUMENTS
INSTALLED DURING 1979

TABLE 2

MONUMENT NO.	BASELINE ELEVATIONS FROM JULY 1977 (1-32) AND DECEMBER 1977 (33-43)	ELEVATIONS FROM AUGUST 1978
1	100.000 meters	100.000
3	102.636	102.632
4	104.413	104.403
5	104.864	104.855
28	106.132	106.117
31	105.394	105.373
32	105.436	105.418
42	105.641	105.625
44		105.620
45		105.394
46		105.275
47		104.972
48		105.168
49		105.077
50		105.410
51		106.781
52		105.387
53		104.962
54		105.156
55		104.735

have prepared Table 3. The errors shown in the table are directly related to the distance surveyed between two points. Thus the error at 800 meters is eight times the error at 100 meters. Of particular importance to this project is the magnitude of the elevation error given a finite machine-plus-operator arc second (RMS) error. The table shows expected elevation errors for 30 and for 5 arc second (RMS) errors. The distance from monument 1 to well 102 on the NE 1/4 of the south 40 acres via a non-linear survey path is on the order of 900 meters. For a 30 arc second (RMS) error we could expect an elevation error of ± 0.135 meters. With a 5 arc second (RMS) error that value would be only ± 0.021 meters. Replications of monument elevations from one survey to the next indicate that the elevation surveys are being performed with an RMS error of about 5 arc seconds. As the number of surveys increases our confidence in an appropriate error value will increase. Accordingly, an elevation survey that achieves a 5 arc second RMS error is rated "very good". Accepting the 5 arc second error as the minimum error that must be considered in monument surveys at the Dow site the corresponding elevation errors are on the order of 2 to 4 cm.

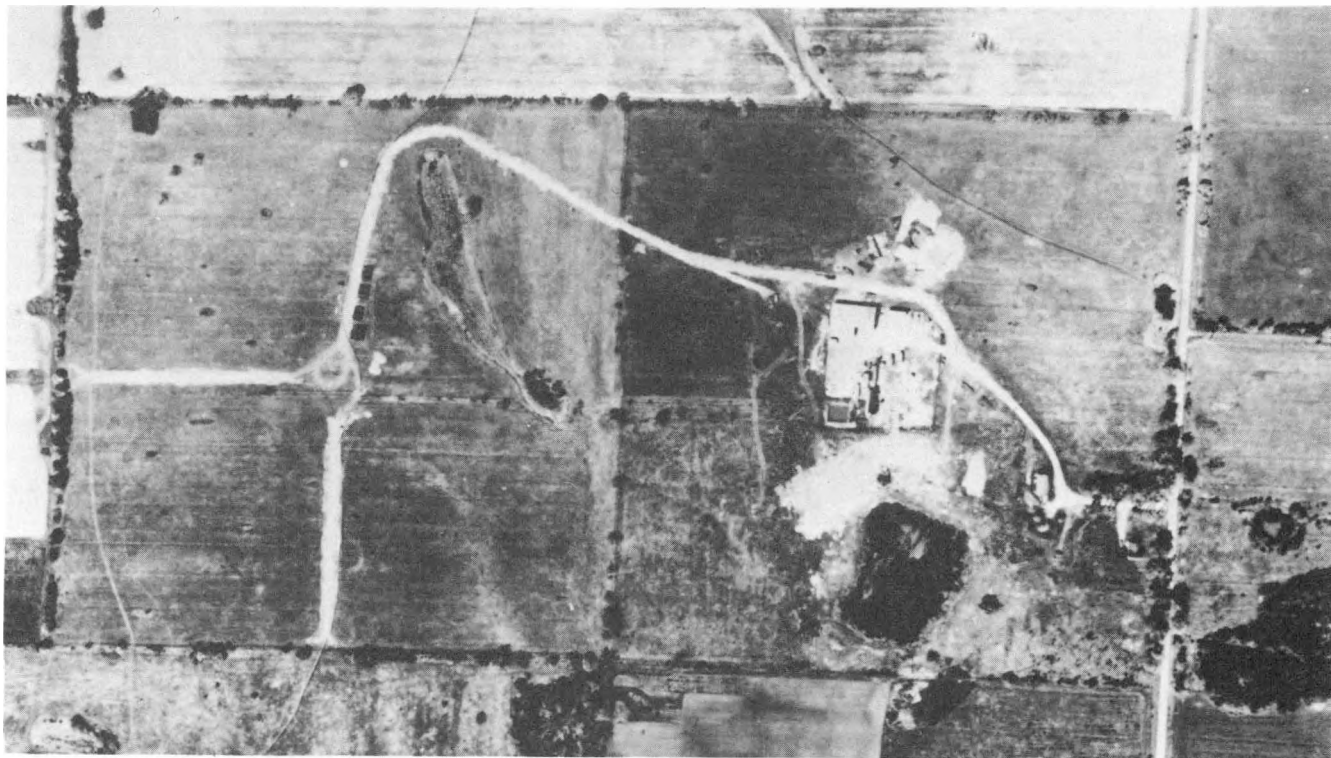
3.2.3 RESULTS

Based upon the August 1978 survey there has been no significant change in elevation of the monuments surveyed during 1977. Furthermore, elevation differences observed in 1977 were, for the most part, within the expected error of 5 arc seconds. The exception was a consistent error noticed between the July and October measurements for monuments near wells 101 and 102 where hydraulic fracturing experiments took place. This error was, in all probability, of human origin as stated in last years topical report on environmental monitoring.

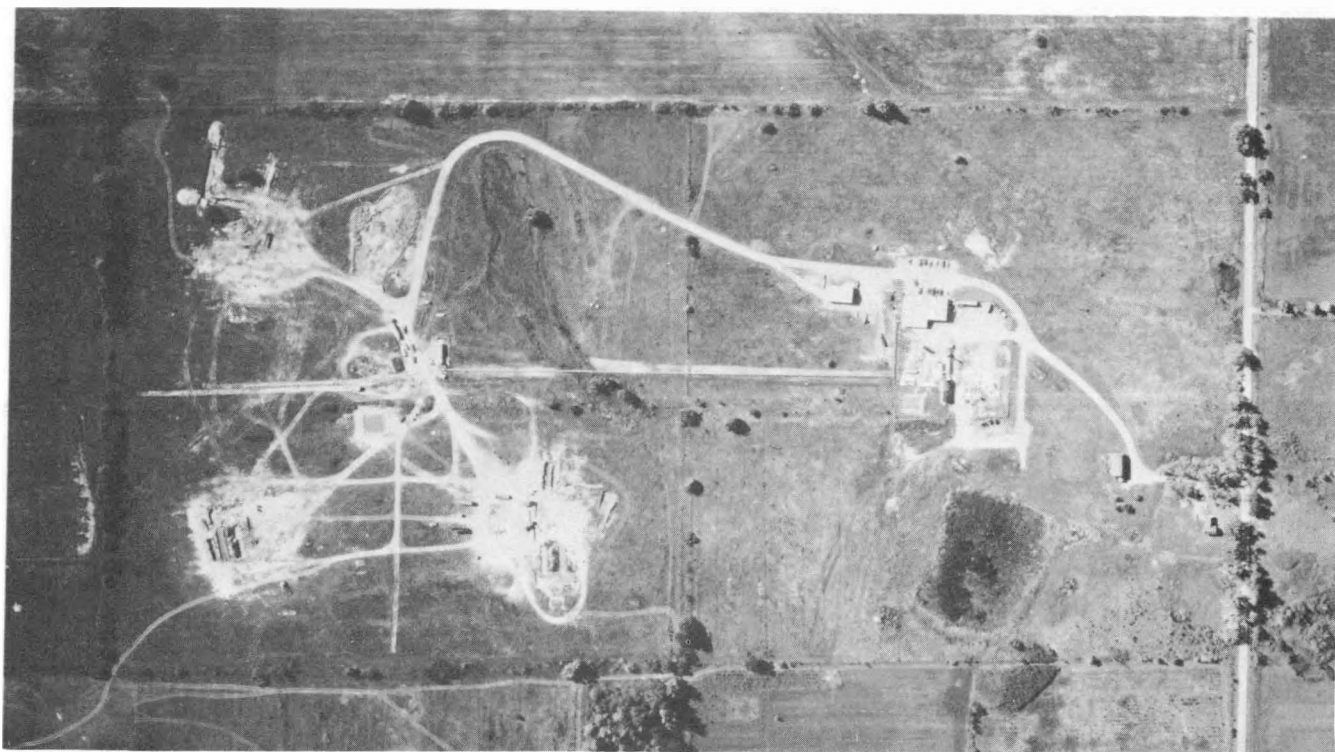
It is recommended that the monument pattern and survey routine be reviewed. It may well be that there is sufficient redundancy of monuments that not every monument that is damaged in the future need be replaced.

TABLE 3
 EXPECTED ELEVATION ERROR
 VERSUS
 DISTANCE SURVEYED

<u>DISTANCE</u>	TOTAL ERROR (MACHINE PLUS OPERATOR)	
	<u>30 arc seconds (RMS)</u>	<u>5 arc seconds (RMS)</u>
100 meters	± 0.0145 meters	± 0.0024 meters
200 meters	± 0.029 meters	± 0.0048 meters
400 meters	± 0.058 meters	± 0.0097 meters
800 meters	± 0.116 meters	± 0.019 meters
1600 meters	± 0.232 meters	± 0.0384 meters



Dow Study Site 1977 (May)



Dow Study Site 1978 (September)

FIGURE 4. AERIAL PHOTOGRAPHY OF THE DOW SHALE STUDY SITE - Scale 1 cm $\approx$ 53 m

3.3 AERIAL AND GROUND PHOTOGRAPHY

Vertical, color aerial photography was collected in September 1978 by AEROECO, Inc. of Virginia. The scale of the photography was a nominal 1:3,000 (aircraft altitude approximately 460 meters) which provides adequate detail for analysis of certain aspects of the vegetation study and site disturbance. In addition, photography was obtained at a higher altitude (1,530 meters) for a ground scale of 1:10,000. The 1:10,000 photography shows the site and most of the square mile bounded by Mortimer Line, Bricker, Burns Line, and Brown Roads. The entire Dow study site appears within the boundaries of one picture as shown in Figure 4 eliminating the need to mosaic together pictures of parts of the site as is required with the lower altitude photography. More accurate estimates of ground areas devoted to any particular use are possible using a single versus a composite picture. A 1:10,000 scale print was used in the neighborhood survey to help explain Dow activities on the study site and it was a particular asset in describing the drilling program on the south forty acres which are not accessible by public road.

Color slides were collected this year as last. Many aspects of the Dow oil shale experiment have been recorded in this manner. Ground based photography provides a valuable dimension to the vertical aerial photography, namely, depth. The aerial photography of the Dow site is very useful for providing area measurements but, presently, our best documentation of the heights of such features as vegetation or rock piles or the depth of mud pits or tire tracks comes from ground based photography. Also, the frequent nature of this photography sometimes allows short lived events to be recorded that will never appear in the aerial photography.

The importance of collecting the data cannot be overemphasized. It provides documentation on a growing, landscape-modifying program, such as the Dow oil shale experiment, that is nearly impossible to produce by any other means. We recommend that Dow Chemical Company continue to have this data collected during this experiment and, if at all possible, to collect it for some time beyond the end of the experiment so that the reclamation of the site may be documented and perhaps evaluated.

3.4 SURFACE DISTURBANCE

As may be seen in Figure 4, there are many signs that significant activity has taken place in the 16 month period represented in the photographs. Roads, work areas around wells, mud pits and surface disposal areas, the gas sampler line system and brine storage are the major new features. For the purposes of this report, these features are categorized into two impact classes: 1) bare soil; and, 2) disturbed. Bare soil shows up on the photography as bright areas. Disturbed areas show signs of human activity that was less intense, possibly less-often repeated and didn't result in removal of the vegetative cover. Vehicular trails that never became roads are readily visible in many areas of the site and are categorized in the disturbed class.

The surface area of the site that was either bare or disturbed in 1977 represented approximately 10.17% of the 78.9 acres. By September of 1978, 48.67% of the site was categorized in those classes. It is our understanding that the well configurations visible in the 1978 photograph to a great degree represent the full scale oil shale experiment. If this is so, we do not anticipate such major increases in bare or disturbed areas for 1979 as there were for 1978. Aerial photography in 1979, after the remaining wells are added, will provide the data to evaluate this hypothesis.

3.5 NOISE

Two types of noise sources were monitored at the Dow site during the past year. The first emitted continuous low level sounds such as arising from the operation of generators, followers, trucks and other heavy equipment. The second type emitted impulsive noise such as from underground explosions set off during fracturing experiments. The first source, because of its low level, presents a potential problem only for site workers who receive constant exposure. OSHA has set a dosage standard for workers of 90dBA from a continuous source and a maximum 105dBA from interrupted sources not to exceed more than one hour per day [2]. The second source can affect site workers and potentially become a nuisance for local residents.

3.5.1 CONTINUOUS SOURCE MEASUREMENT

A series of noise readings as a sound pressure level in dbA ($1 \text{ db(A)} = 10^{-2} \text{ lbs/in}^2$) using a General Radio meter type A. These measurements were made by Dow staff at the site on January 17 and 18, 1978. Background levels due to (5-10 mph) wind noise, range between 45 and 55 db. Operating drilling equipment located on the south forty, notably, drilling rig and mud pump, produce elevated sound levels from background at a distance of 200 feet with a maximum recorded at 20 feet from the rig/pump of 75 dbA.

In the main compound on the north forty levels of 89 to 99 dbA were recorded inside the compressor shed with the compressor off and the diesel idling. When the diesel and compressor were performing at operational speeds these levels increased only slightly to a maximum of 100 dbA. Sound levels recorded just outside the shed ranged between 72 and 77 dbA.

It appears from these data that no working environments presently exist which do not comply with OSHA standards. An exception is the interior of the compressor shed. Extensive work projects are only carried out in this shed with the compressor system shut down. Hearing protection is readily available in the shed; persons entering the shed while the compressor is in operation are required to wear ear protectors.

3.5.2. EXPLOSION MONITORING

The noise from explosions can travel far, and having a rapid onset, can startle local residents. It would be desirable to estimate the noise of underground explosions given the charge size and depth. However, many other factors greatly affect the noise, including, soil mechanics, cavity size, casing size, degree of tamping and others. Furthermore, there is very little in the open literature on the resulting acoustic air blast from underground explosions and its effect on people. The OSHA standard for the maximum impulsive source is 140 db.

The measurement program by ERM was undertaken to answer the question "How loud are the explosive tests at the Dow site near Peck, Michigan?" The physical parameter measured was the peak sound pressure level.

The equipment for determining blast levels consisted of two systems.

(1) A microphone array and tape recorder, and (2) a Genrad model 1982 sound level meter. The microphone system provides a record of the blast waveform and could be used to determine extent of the rarefaction peak as well as the compression peak. The microphones were four Bruel and Kjaer Model 4133 1/2-inch (1.27 cm) condenser microphones. These microphones were positioned about one meter above ground and pointed vertically. The four microphones were located about 0.3 m apart in a line perpendicular to the shot direction. Since the signal level to be recorded was unknown, each microphone output was provided with a different gain. Gain separations of 20 dB were maintained so that a range of pulses from 80 dB to 160 dB would provide recordable levels.

The B & K condenser microphones have a sensitivity of around 1.10 mV per μ bar and operate in the range of 32 to 160 db. However, the wind induced turbulence noise will range from 30 dB to 80 dB and this determines the practical lower limit.

The signals were recorded on an AMPEX Model FR1300 tape recorder. Using FM recording at a tape speed of 30 inches per second (76 cm/s) the recorder frequency response was 0-10 KHz (within 1.0 db). Tape speed for playback onto hard copy oscillograph was 7.5 inches per second (19 cm/s).

The second measurement system was a GenRad Model 1982 type one precision sound level meter and analyzer. The instrument can be operated in a peak impulse mode, with the ability to capture and hold the peak sound pressure level over a 50 db range. This instrument was introduced to ERIM's environmental monitoring program late in 1978. The two systems were used at the same locations in order to verify the measurements. It was hoped that the more complex microphone array/tape recorder system could be replaced with the sound level meter. This substitution is possible because the desired result is the peak sound pressure level.

On November 30, 1978, a test was conducted to determine the relative response of the two systems to a series of nine percussive sounds. The November 30 test results for peak sound pressures are shown in Figure 5.

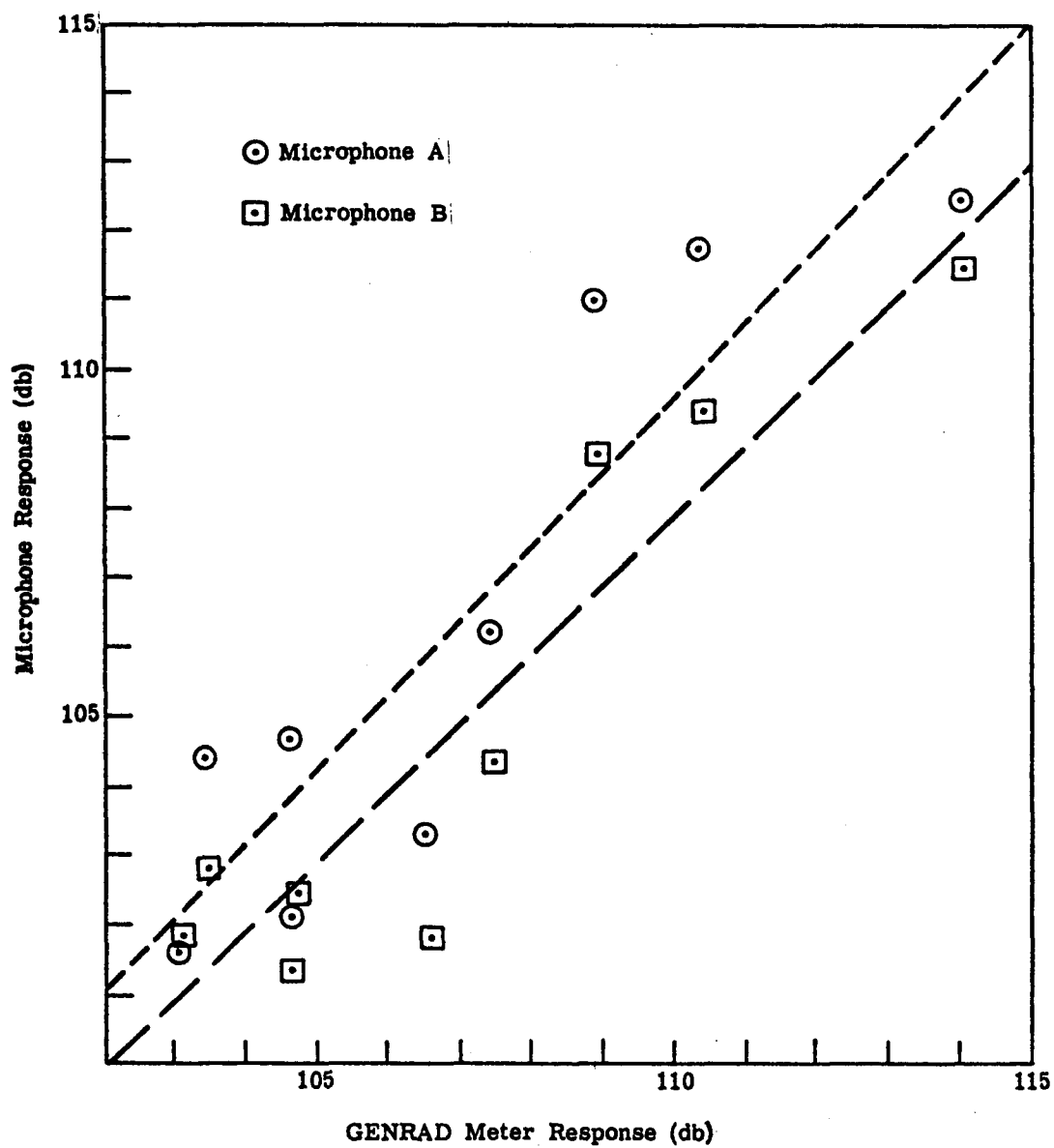


FIGURE 5. PEAK SOUND PRESSURE LEVELS - 30 NOVEMBER 1978 TEST

The levels (re 0.0002 μ bar) for the GenRad meter are plotted versus the peak levels recorded by two microphones with different gain settings. In addition, linear regression lines are shown for each microphone. The maximum deviation between the two microphones is approximately 3 db. The agreement between the GenRad meter and the microphone system is within 5 db. A practical error range for the explosion results could thus be estimated as ± 5 db.

The results for five well shots and two surface tests are shown in Table 4. The peak sound pressure levels were measured at a distance R from the blast, using the microphone array system (MAS) or the sound level meter (SLM). For those events recorded by the microphone array system, the duration of the acoustic pulse, Δt , is also reported.

The first shot recorded, on 12 July 1978, was much louder than anticipated. The recorded signal showed an initial blast, followed 0.24 sec later by a very loud shock wave. There was considerable venting above ground, which lasted more than one second. All channels were clipped so that only an estimate of the peak level is possible. Using the recording of the lowest gain channel, the shot signal at 120 m was at least 146 db. This shot was atypical. There is a possibility that accumulated well gases were detonated along with the detonators and blasting agent. This would account for the flare (i.e., the column of flame that extended to perhaps 100 feet above the well head).

The July 13 and September 11 shots were considered to have not been completely detonated. The September 15 and 30 November well shots were both considered successful, based on seismic signals monitored by ERIM. Note that the smaller charge, 1600 lbs (727 kg) on 15 September, produced a larger signal (measured at 440 m) than the 3570 lb (1622 kg) charge on 30 November (measured at 680 m). The extra distance accounts, theoretically, for a 4 db decrease. The effects of absorption, scattering, and surface reflections are more difficult to judge. It appears that the correlation between explosive charge size and peak sound pressure level is not well defined.

TABLE 4

<u>DATE</u>	<u>EXPLOSIVE CHARGE LOCATION/WEIGHT</u>	<u>R (meters)</u>	<u>PEAK SOUND PRESSURE LEVEL (re. 0.0002 μbar)</u>	<u>Δt (sec)</u>
12 July 78	Well #301 1570 lbs (713 kg)	120	A. 131 db (MAS) B. >146 db (MAS)	0.023 1.17
13 July 78	100-Series Wells ~ 5 tons (4500 kg)	150	127 db (MAS)	.037
11 Sept 78	Well #301 3035 lbs (1380 kg)	680	104 db (MAS) 99 db (SLM)	.038
15 Sept 78	Surface test 30 lbs (13.6 kg)	650	138 db (SLM)	
15 Sept 78	Well #102 1600 lbs (727 kg)	440	120 db (MAS) 125 db (SLM)	.029
29 Nov 78	Surface test 10-15 lbs (4.5-6.8 kg)	650	145 db (SLM)	
30 Nov 78	Well #301 3570 lbs (1623 kg)	680	107 db (SLM)	

The surface tests of September 15 and November 29 were a great deal louder than the well shots and precipitated complaints from local residents. These surface tests were designed to test the explosive slurry mixture, and were exploded in an eight foot deep pit near well 201. The November 29 surface test, with a smaller charge, produced a much larger acoustic signal (145 dB at 650 meters). Two factors contributed to this. First, the charge was not covered, but was detonated essentially on the surface. Second, the low cloud cover on that day may have helped confine the acoustic waves. It seems apparent that future "surface" tests should be covered to help absorb the acoustic power.

In summary, the loudest blasts were the surface tests, plus the (atypical) first well shot. These produced sound pressure levels in excess of the OSHA standards. The remaining well shots were within the standards. There was only poor correlation of peak sound pressure level with the size of the explosive charge.

3.6 BASELINE VEGETATION STUDY

The 1978 vegetation study was carried out over a six-month period (July-December), and designed to accomplish three primary objectives. These objectives were:

1. To develop a set of baseline data which documents background (undisturbed) conditions on the Peck site.
2. To identify any adverse impacts on the site's vegetation caused by the shale project, so that Dow has the opportunity to implement appropriate precautions and/or remedial measures to mitigate or eliminate the problem.
3. To suggest how detection and evaluation of impacts on the vegetation can be done in the future, based upon the comparison of undisturbed (control) and disturbed plots.

To meet the study's first objective, two types of information were needed to describe the normal, undisturbed vegetation of the the Peck site. The first consisted of a complete list of the plant

species that occur on the site. The second was information on where each species was found and its relative abundance. From this combination of data it has been possible to show where the vegetation communities of the Peck site are located, what plants are found in them, and the relative abundance of the key plants which distinguish each community. To acquire the above data a vegetation survey was designed that utilized two methods of data gathering: plot sampling and transects.

3.6.1 VEGETATION SAMPLING

Data collection was accomplished during four field trips. The first trip took place in July. The other three trips occurred in September. It was necessary to spread the field trips out in this fashion to insure obtaining observations during the two major annual flushes of herbaceous vegetation that occur in southern Michigan.

The purpose of the plot sampling was twofold: 1) provide a way to estimate if our floristic list for the site was reasonably complete; and 2) provide some quantitative data (species presence and abundance) that would be useful in distinguishing between plant communities.

During the 1977 Vegetation Monitoring Program it was determined from airphoto interpretation and a site visit that four vegetation communities are found on the Peck site: Old Fields, Fencerows, Rock piles, and Wetlands. As part of the 1978 program a total of twenty samples were established in these communities. The allocation of the samples among the vegetation communities is as shown.

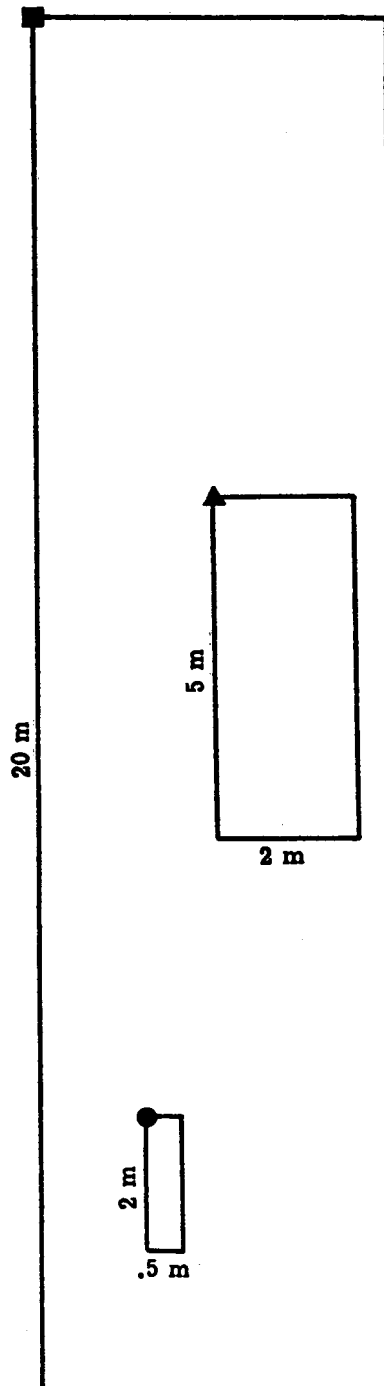
<u>Community</u>	<u>Number of Samples</u>
Old Fields	10
Fencerows	4
Rock piles	3
Wetlands	3

Sampling was carried out in two phases. During Phase I (the July site visit), eight samples were inventoried, two in each community.

In Phase II (the September site visits) the remaining 12 samples were inventoried. This approach permitted checking the adequacy and efficiency of the field procedure.

As mentioned earlier, each sample actually consisted of a set of three quadrats of varying size. Each quadrat was rectangular, the shape shown to normally be the most statistically efficient for sampling most vegetation communities [3]. The actual size of each quadrat was related to the physiognomic class of vegetation it was used to sample. Thus, collecting data on trees was accomplished using the largest quadrat, shrubs and tree seedlings the middle-sized quadrat, and herbaceous vegetation the smallest quadrat. The middle and small-sized quadrats were randomly located within the large quadrat. The relative dimensions of the quadrats were: large quadrat 5 x 20 m. (1/100 hectare), middle size quadrat 2 x 5 m. (1/1000 hectare), and small quadrat .5 x 2 m. (1/10,000 hectare). These quadrat dimensions and areas closely match those generally recommended for vegetation sampling with this number of samples [4]. We differ slightly, however, in having a slightly longer and narrower rectangle for the large quadrats, and a slightly longer (and hence larger) middle-sized quadrat for shrubs. A typical sample is diagrammed in Figure 6.

Placement of the samples within each community was accomplished in the following manner: Old Field samples were located using a grid laid over a vertical aerial photograph showing the site. The size of the grid cells corresponded to the size of the large quadrat. The long axis of the grid cells was oriented parallel to the north-south fencerows of the site. The grid was numbered in ascending order along both its axes, starting from the northeast corner of the property. Cells (samples) were then selected using a random number table. In the event a sample fell on either a rock pile, wetland, disturbed, or work area, it was discarded and another selected. To locate Fencerow plots, the perimeter of the Peck site (including the two sides of the entrance driveway) was divided into a series of intervals. Each interval was the length of the long axis of a large quadrat. The



■ Reference Corner for Locating Large Quadrat Within Vegetation Community

▲ Reference Corner for Locating Middle Sized Quadrat Within Large Quadrat

● Reference Corner for Locating Small Sized Quadrat Within Large Quadrat

FIGURE 6. DIAGRAM OF TYPICAL VEGETATION SAMPLE PLOT

intervals were then numbered starting at the northeast corner of the property and running counterclockwise around its outside. Four intervals along the fencerows were subsequently selected using a random number table. These intervals became the four Fencerow samples. Rock Pile community samples were selected by assigning each rock pile a number, and then picking three numbers in this series from a random number table. Samples were located on the designated rock piles by centering them on the north-south and east-west axes of the rock piles. The Wetland community samples were selected in a fashion similar to that used for the rock piles except the long and short axes of a wetland were used to orient the quadrats. The location of all the samples, in relation to each other, and other features of the Peck site, are shown in Figure 7.

The average sampling intensity by area for three of the four vegetation communities (Old Fields, Fencerows, and Wetlands) was 1% of the total area in each community sampled for trees (large quadrats), 1/10% sampled for shrubs and tree seedlings (middle-sized quadrats) and 1/100% sampled for herbaceous vegetation (small quadrats). This was determined by taking the area covered by the subplots within each community and dividing it by the area of the community considered in the sampling survey. The areas associated with each community are listed in Table 5. It was not practical to calculate the area covered by rock piles in the same way, so sampling intensity was assessed a different way for them. A total of forty-one rock piles were located on the Peck site. Twenty-two of these were judged to have remained undisturbed. Three of these remaining nineteen were sampled. It was felt necessary to look at at least this many rock pile samples because of the apparent diversity they exhibit, regardless of the sampling intensity it represents on an area basis (6% for trees, 6/10% for shrubs and tree seedlings, and 6/100% for herbaceous vegetation).

Another way of looking at sampling intensity is on the basis of the percentage of species known to be present in a community that has been detected by sampling. When the results of our sampling were analyzed

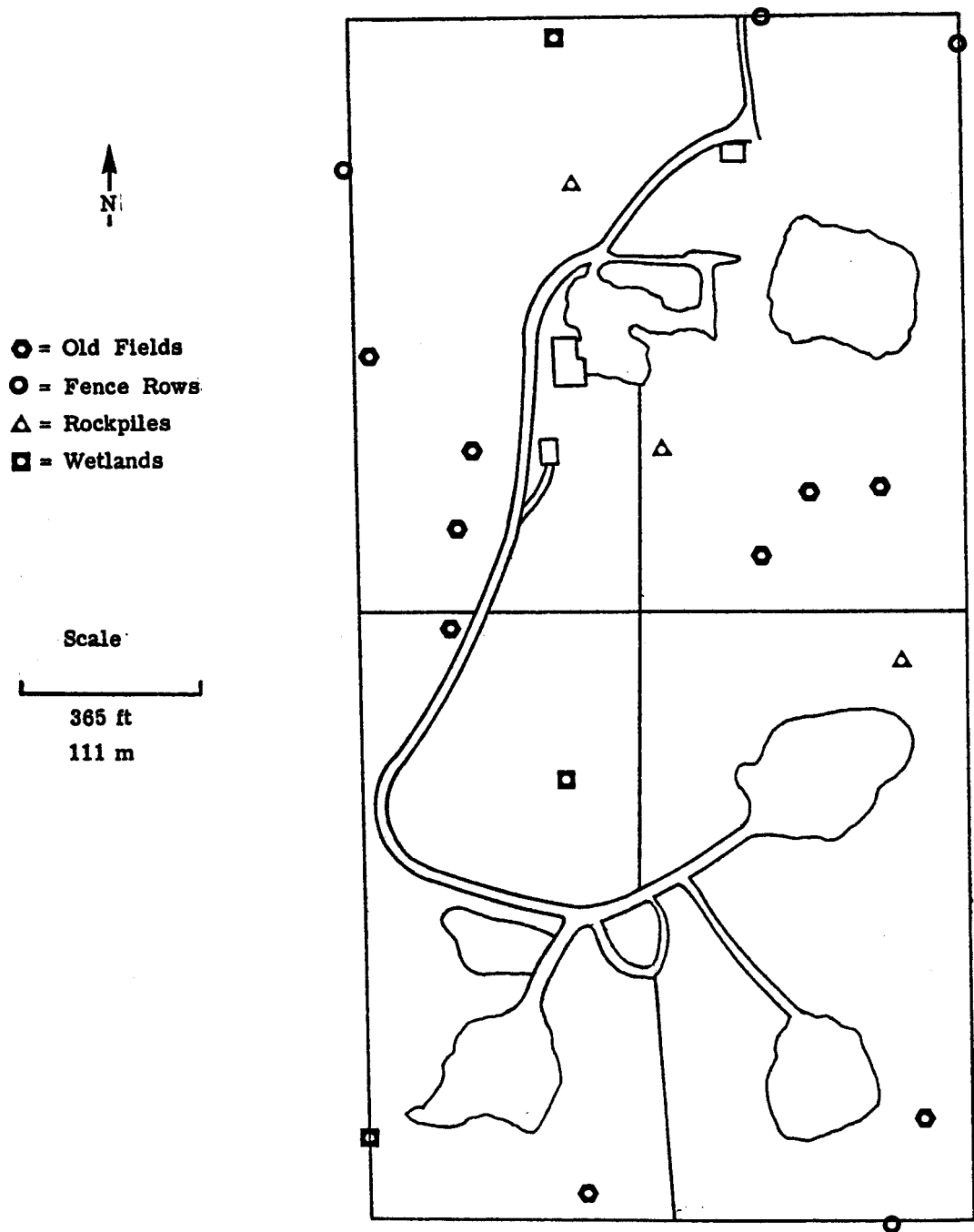


FIGURE 7. LOCATION OF VEGETATION AND SOIL SAMPLING LOCATIONS

TABLE 5
LAND COVER OF PECK SITE, 1978

I. VEGETATED AREAS INCLUDED IN SAMPLING

A. Old Fields	26.2 ac	107,650 sq m
B. Fencerows	7.1 ac (6,631 linear ft)	20,734 sq m (2,021 linear m)
C. Rock Piles	1.2 ac	4,856 sq m
D. Wetlands	4.6 ac	18,616 sq m
SUBTOTAL	39.5 ac	151,856 sq m = 50% of total site

II. IMPACTED AREAS EXCLUDED FROM SAMPLING

A. Pits	.4 ac
B. Buildings	.6 ac
C. Disturbed *	26.6 ac
D. Bare Soil**	11.8 ac
SUBTOTAL	39.4 ac

III. TOTAL AREA 78.7 ac***

* Disturbed = areas in which the vegetation cover has been partially removed, recently mowed (farmhouse lawn), or repeatedly driven over.

** Bare Soil = includes all areas of scraped or overturned earth and roads, trails, dirt piles and the actual well sites.

*** Actual Acreage = 78.9 ac, difference probably due to round off error in calculations.

in this way only about two-thirds of the species known to be present were detected in the samples. This means that without further sampling it is not possible to quantitatively describe the relative species composition of each community as originally intended. To allow us to complete this type of analysis we would have had to continue sampling until an acceptable number of the species were detected in each community (normally 90%). Unfortunately, there is no reliable way to predict how much additional sampling this would have required. So, in light of our limited budget and the analysis task we already faced it was decided to modify the analysis procedure.

Actually, given the nature of the vegetation found on the Peck site, the analysis procedure we substituted would have been a reasonable one to use regardless of the species detection sampling intensity achieved. The reason for this is that there is really only one community, the Old Fields, which lends itself to realistic statistical description. If the probabilities of finding a certain species in natural association with others of that community were calculated, the old fields would be the only place that these probabilities would reasonably approximate the way plants are found on the Peck site. The reason for this is the other three communities; Fencerows, Rock Piles, and Wetlands are not really communities at all, in the sense of the plants exhibiting any consistent pattern of spatial distribution. Thus, while any sample of each of these three so-called communities is readily distinguishable from one of the other two communities and the old fields, it may also be quite different from another sample of the same community. For example, there are seven wetlands on the Peck site: two shallow marshes, three shrub swamps, and two seasonally flooded depressions. These areas are all wetlands, but each one supports a vastly different combination of plants. Yet, for simplicity, these lowland site types have been lumped together, to differentiate them from the upland areas. Rock Piles and Fencerows differ from Wetlands in that their spatial diversity is more a result of chance

than physical or environmental factors. The random deposition of seeds by wind and wildlife has in many cases determined what plant species dominate a particular locality in both of these communities. Thus, the creation of a statistical description for the communities other than the Old Fields may actually be misleading, in that it might imply a uniform distribution of the species listed as occurring in that community at some level of specified abundance.

An alternative way of describing each community, is to list the species found in each community, and qualitatively describe (a) the characteristics and setting of each community, and (b) its relationship to the other communities found on the site. In addition, for the old fields, where a quantitative description of the vegetation is reasonable, limited quantitative data has been combined with our other observational data to arrive at a semi-quantitative description of this community.

Transect data was collected while walking from one end of the site to the other on a series of regularly spaced lines parallel to the site's long axis. Both the east and west fencerows were walked, plus six other lines. As we walked along we studied the ground directly in front of us and noted any new species and the type of community in which we found it. In addition, general observations were made regarding the most common species occurring in each of the four old fields which cover most of the site. Disturbed areas were included in the transects and the plants found in them identified and the type of disturbance noted. On two of the transects, 80 meters in from the long sides of the site, vertical, downward looking, color photographs were taken approximately every 150 ft (46 m).

3.6.2 DATA ANALYSIS AND RESULTS

Complete descriptions of the four major vegetation communities: Old Fields, Fencerows, Rock Piles, and Wetlands, with floristic lists, are contained in Appendix A. In order to insure a complete description of the vegetation communities at the Dow site the survey data were

analyzed for on the estimate total number of species likely to occur on the site.

As already noted, the large quadrats were used for sampling tree species, the medium size for sampling the shrubs and bushes, and the small size for the sampling of herbaceous species. While the sample size was the same for all quadrats ($n = 20$), the sampling fractions (of total possible quadrats) varied by two orders of magnitude.

Based upon these counts it is possible to estimate the total number of species in each class. For the information available from the Peck site survey, the Gleason estimator [5] was most suitable for total species estimation. In addition, it appeared that the data might provide some information on the dispersion or scatter of the observed species in the old fields.

Gleason's estimator is expressed in the form:

$$\hat{S} = s \log \left(\frac{N + 1}{n + 1} \right) \quad (1)$$

where s = number of species observed on samples

N = total number of quadrats

n = number of quadrats in the sample

S is considered to be the unknown total number of species and then $\hat{S}$ is the estimator of S . Calculation of this estimator yielded the following results.

<u>Species Class</u>	<u>Number of Species</u>
Trees	14
Shrubs, tree seedlings, vines	29
Herbaceous	193
 TOTAL ESTIMATED SPECIES	 236

A botanical census for the entire site was prepared from the sample and transect data. Number of species found are as follows:

Species of trees = 14

Species of shrubs, tree seedlings and vines = 22

Species, herbaceous = 108

Total species census = 144.

The first two classes' estimates correspond quite well with the botanical census values, $\hat{S} = 14$ with $S = 14$ and $\hat{S} = 29$ with $S = 22$. The last class, herbaceous, shows rather poor agreement, $\hat{S} = 193$ with $S = 108$, the difference being about 3.6 standard deviations which could be due to some bias. The estimated total number of species is 236 versus the botanical census of 144. Thus, these data suggest that there may be as much as 90 additional species not compiled in the present survey.

The above methodology was introduced into the survey with the anticipation that the calculated estimate of the number of species on the site would match the figure arrived at through field observations. This would provide confidence that a thorough census had been completed. As it turns out, the two estimates do not agree closely for herbaceous species. It is believed that further sampling would result in a lower estimation of the number of species present due to the accompanying adjustment in $\log \left(\frac{N+1}{n+1} \right)$, just as more field work would add a few additional plant species to the census figure. We would not expect the actual number of species should not increase by anymore than fifteen to twenty.

3.6.3 OBSERVED IMPACTS ON SITE VEGETATION

Four conditions were noted at the Dow site this year that represent effects (impacts) on the vegetation of the area. They were:

- (1) mechanical (scraping and abrading); (2) cardboard littering;
- (3) tree and shrub defoliation; and (4) salt concentrations in the soil. The mechanical effects are the most obvious and widespread.

They occupy the areas given over to roads, well drilling and brine pits. In general, the soil is either scraped and piled or simply compacted by vehicle traffic. Where light traffic is the only disturbance, some vegetation often remains. In some of these light traffic areas revegetation is occurring. It is noteworthy, however, that the new flora on such sites is different from that of the surrounding old fields. Common species in mechanically disturbed areas are blade bindweed, pale smartweed, lamb's quarters, pepper-grass, vetch, sorrel, pale plantain, common ragweed, cocklebur and sow-thistle. Cardboard littering and defoliation have occurred as a direct result of the seismic survey technique.

At least ten mud pits and two brine pits are visible in the most recent aerial photographs of the site. The mud pits do not seem to be a serious problem at present, except where mud has slopped over the edge of the pit. Where mud has been spread on the ground's surface the vegetation in the immediate vicinity appears stressed. At present, the impact is localized and of the magnitude is that normally associated with well drilling. If allowed to remain on the site on a long term basis, the large amounts of mud may have adverse effects on soil and ground water, and on the vegetation.

Perhaps the most interesting condition observed was the presence of plants known as halophytes at certain locations on the site. Halophytes are salt-loving plants and are found on the property near some of Dow's work areas (which include roads and water disposal sites as well as drilling sites). Three of four inventoried halophyte species were found on the southwestern edge of the large wetland in the northeast corner of the property: Chenopodium glaucum and C. murale known commonly as goosefoot, and Spergularia marina, known as sand spurry. The fourth species (Atriplex patcula, orache) was found along the entrance road.

Concentrations of salt may have created conditions which favor the establishment of the halophytes. It is important to find out whether the increased soil salinity is local in nature or widespread, and more

important to identify, in the case of the pond, the source of the salinity. In the meantime, the presence and abundance of these plant "indicators" could be monitored as an indirect method of assessing the impact of this disturbance.

3.6.4 RECOMMENDED PROGRAM FOR MONITORING VEGETATION

It is recommended that at least two large plots be marked off in the remaining areas of undisturbed old field (shown in Figure 8) for use as control plots. One plot could be located in the northern part of the northwestern old field, and the other plot could be established in the southern half of the northeastern old field.

Selection of potential sites for monitoring disturbance involves the location of areas that are, and are likely to remain, undisturbed. These sites represent controls, which can be compared to disturbed sites to determine the exact nature of the disturbance and its effects. Such sites should be as similar to the disturbed sites as possible. Using the maps of disturbance and 1978 conditions, undisturbed areas have been identified. These areas represent places where control samples could be taken. Some part of them should probably be fenced or marked off to insure that there will be areas in the future that can be used as controls. Dow's future plans for site activity should be taken into account and such sites marked out in the coming year.

These plots should be fairly large, on the order of at least one acre in size. Making them rectangular is also desirable. The corners of these plots should be marked off and signs posted to keep everyone off of them. It is particularly important to keep vehicles from driving across them.

These control plots are considered to be an essential part of the remaining vegetation monitoring program. For example, if natural vegetation of the disturbed area is removed, then vegetation that develops on the disturbed areas can be compared to that on the control plots to see if the same assemblage of plants will reestablish itself.

It is further recommended that an annual survey be made of the site by a botanist familiar with halophytic plants. The purpose of this

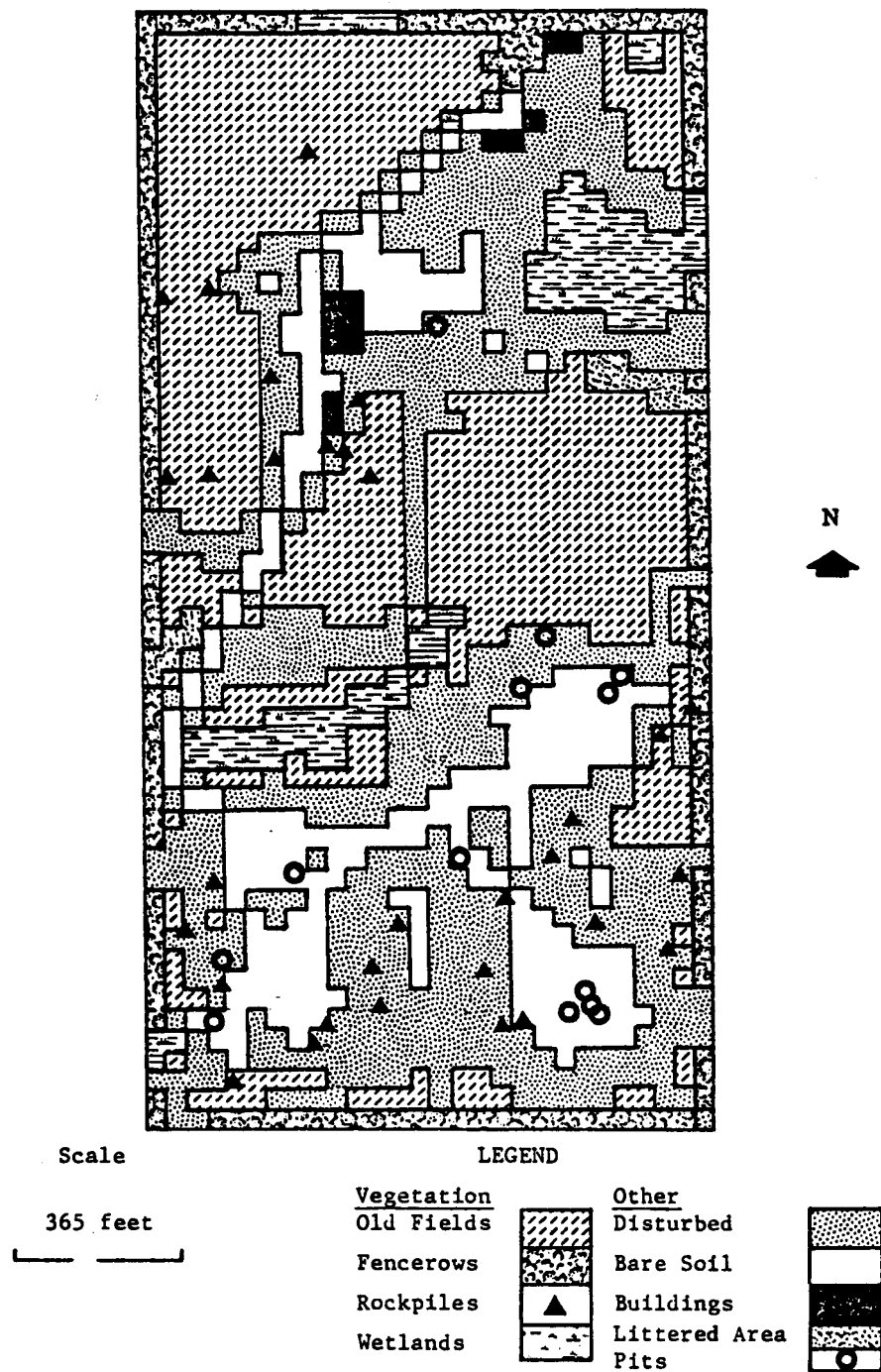


FIGURE 8. LAND COVER OF PECK SITE. Interpreted from 1977 and 1978 Aerial Photographs

survey would be to see if such indicator plants are increasing in number of species and abundance.

3.7 SOIL STUDIES

During June 1978, a soil study was initiated to investigate the nature and extent of soil disturbance that has been created on the site by drilling operations on the south forty acres.

At that time, it was thought that the major problems likely to be created by these drilling operations would consist of the following:

1. Substantial increase in salt concentration following the spilling of drilling mud.
2. Mechanical scraping and abrading, and
3. Compaction of the top soil.

Drilling muds contain a high concentration of salts which can when left in pits or piles, leach into the surrounding soils. Increased soil salinity will make the problem of revegetation more difficult and may ultimately affect groundwater supplies.

Investigation of these problems was directed through field observation supplemented by soil sampling and laboratory analyses.

A soil map of Sanilac County was prepared and published by the Soil Conservation Service of the U.S. Department of Agriculture in 1962; nevertheless, it was found appropriate to review the published map to evaluate its accuracy and its suitability for land use planning and environmental monitoring.

3.7.1 SOIL SAMPLING

The review of the map was performed by making soil borings at regular intervals (50 meters) following a grid system prepared by ERIM in June 1978. The study area comprises three quadrats of ten acres each (see Figure 7). A total of 21 borings were made out of a total of 32 as indicated by the grid system. The borings required greater time than originally planned because the soils were found to be

deeper than anticipated; on most of the sites, exploration had to go to 152 cm. Descriptions of soil profiles are enumerated in Appendix E.

Individual observations consisted of examining the sequence of the soil horizons and identifying the texture and structure of these horizons. Color and pH were measured on a number of horizons, and the qualitative carbonate test (HCl) was performed routinely on all sites to recognize the presence of the calcareous till. See Appendix E for complete descriptions of the soils.

The soil series of the site have been identified in the 1961 soil conservation report as Capac loam and silt loam and McBride sandy loam with inclusions of Montcalm soils. Capac soils are imperfectly drained soils that have developed from calcareous glacial loam till on nearly level till plains. Typically these soils are moderately deep and the calcareous till is encountered at 89-102 cm.

McBride soils are well drained soils that have developed from sandy loam till on gently sloping landscapes. Typically their profile is moderately deep and the calcareous till is encountered around 114 cm.

The soils observed at the various sites differ significantly from typical Capac and McBride originally described in the published soil map. Notably, the depth to the calcareous till is 152 cm or greater, therefore, deeper than that of a model Capac and McBride. In addition, extensive stratification was observed in many sites. These characteristics fit better other soils series like the Teasdale and Riddle sandy loam which were not recognized by the Soil Conservation Service at the time the survey was completed.

In addition to regular soil borings, casual observations were made at a number of sites to evaluate the extent of various disturbances. From these direct observations it appeared that the main disturbances created by the drilling operations were compaction of the top soil and the effects of spilling the drilling fluid. Removal of the upper part of the soil did not appear to be as serious as originally anticipated.

Compaction of the top soil was identified by the presence of crusts at the surface. These crusts are typically very light in color because

of absence of organic matter and are unusually hard. The extent and severity of compaction varies with the different sites.

Although the exact nature of the drilling fluid could not be determined it is believed to contain large proportions of highly dispersible, sodium saturated clay (mud). The crust formed by the drying mud is very strongly alkaline (pH higher than 9). Strong alkalinity is detrimental to plant growth by creating severe toxic conditions.

A second trip to the site was made on September 11 to complete the soil map and to collect soil samples in representative areas for quantitative soil characterization. Because of blasting in 100 and 300 series wells the sampling was restricted to the southeast quarter of the site (see Figure 9).

A total of 25 disturbed samples (approximately 350 grams each) were collected from seven sites; these samples were obtained at different depths (0-15.0, 15.0-30.5, 30.5-61.0, 61.0-102 cm) by making small soil borings with a soil auger. These disturbed samples were sent to the Michigan State University Soils Laboratory testing for various chemical analyses.

In addition, undisturbed samples of approximately 246 to 328 cubic centimeters were taken in quintuplicate from five sites. These samples, intended for bulk density determination, were collected by making shallow trenches (61 cm or less) and cutting small blocks of undisturbed soils in the profile. Because of the continuous rain and the moist condition of the soil, a number of the blocks were disturbed, and so, discarded.

3.7.2 RESULTS

Soil samples collected from selected horizons were analyzed for pH, organic content, conductivity, cation, exchange capacity, exchangeable sodium, and bulk density. The soil analysis data are compiled in Appendix E.

pH

Agricultural soils are characterized by values ranging from 4 to 8.3. The optimum range of pH of agricultural soil is 6.5 to 7.2. Values higher than 8.3 are sometimes obtained on soils affected with metallic salts. This may occur naturally as a result of gradual accumulation of metallic

ions (mostly Sodium) on the exchange sites of the soils through excessive evapotranspiration. High values of pH on agricultural soil can also result from contamination of these soils by chemicals (fertilizers or others).

Preliminary on-the-site soil testing conducted in early July revealed high pH level for the surface soil in the immediate vicinity of the various drilling pits. Values as high as 9.2 were recorded in the vicinity of the southwest pit (near Station 17) around which the natural vegetation seemed to be directly affected. The most widespread symptom consisted of leaf damage or complete defoliation.

Results from laboratory analyses, however, show pH values ranging from 5.4 to 8.3 as the normal range for common agricultural soils of Michigan. These data do not reflect any sign of contamination by drilling substances as was observed during preliminary field observation.

The values obtained for the contaminated samples are probably an indication that the contamination affects only the very top layer. Migration to subsurface layers has been minimal. Considerable dilution has taken place when the surficial five centimeter layer has been mixed with the bulk 20 centimeters of the sample.

Further sampling to study chemical pollution should include subsampling of the top five centimeters of the top soil.

Organic Matter (O.M.,%)

The organic matter of the soil is directly related to the amount of humus in the soil. Humus is an important soil component and together with the clay fraction, determines directly the ability of a soil to absorb moisture and retain various exchangeable ions. In addition, organic matter influences directly the state of aggregation of a soil and plays an important role in the bulk density and porosity of soils.

Percentage of organic matter in normal mineral Michigan soils ranges from 2.0 to 3.5 in the A horizon and to much lower values (usually less than 1%) in the B horizons. Surface horizons containing percentages less than 1.5 usually are considered to have been disturbed or truncated by some natural or man-caused processes such as landslides, erosion or mechanical scraping.

The trend in percentage and distribution of organic matter of most of the soil sampled at the various sites is the normal trend commonly observed in Michigan soils. The low values of 1.45% and 0.47% observed for the A horizon of site 3 and 3B respectively are good indications of soil disturbance at these sites through scraping of the top layer.

Electrical Conductivity (E.C.)

Soils with values of one mmhos or less are usually considered free of soluble salts; those with conductivity between one and four, slightly affected by salts; and, those with values above four mmhos, seriously affected. Accumulation of soluble salts in the soils is strongly dependent on the precipitation/evapotranspiration balance; and, in the state of Michigan, where precipitation commonly exceeds evapotranspiration by several inches, the level of soluble salts in the soil is usually low (less than 1 mmhos).

The bulk of the samples are characterized by values lower than 1.0 mmhos. The exception is the A horizon of site 3, 4, where substantial chemical deposition seems to have taken place through spilling of the drilling materials. Values of electrical conductivity at these sites were 3.2 and 6.0 mmhos respectively. Such high values are normally detrimental to plant growth and can be a seriously limiting factor.

Cation Exchange Capacity (C.E.C.)

The cation exchange capacity of a soil describes its ability to absorb and exchange free positively charged ions (H, Ca, Mg, K, Na); and is expressed in milliequivalent (meq) per 100 grams of dry soil. Cation exchange capacity of a soil varies directly with content of organic matter as well as type and amount of clay minerals present in the soils. Typical loam soils of Michigan have a value of 25 milliequivalents while light loams and sandy loams have values of 12 to 20 meq/100 g. Variations in cation exchange capacity of soils within a profile follows closely the trend in distribution of clay minerals and organic matter of the soil. As a general rule, values tend to be higher in the A1 and A2

... horizons usually rich in organic matter, and in the B2 horizons which is a horizon of accumulation of colloidal clays.

Measurement of cation exchange capacity of a soil can be used as a supplementary index of soil disturbance; truncated profiles exhibit unusual trends in the values of cation exchange capacity, for example, low value in the A1/A2 horizon followed by higher values in the A2.

The values obtained for the soil sampled at the site follow the general trend observed in Michigan soils with some minor deviations: the A1 horizon of site 3, for example, shows a value lower than the A2 (which typically is a horizon of very low cation exchange capacity) and this discrepancy, quite likely, is an index of the intensive scraping activities that have taken place at this site.

Exchangeable Sodium (Na)

This value indicates the magnitude of sodium ions (Na⁺) present at the exchange site of the soil, and is expressed either in milliequivalent per 100 grams of dry soil, or in percentage of the total cation exchange capacity.

Normal agricultural soils of humid regions like Michigan are usually characterized by very low levels of exchangeable sodium, less than one percent. Higher values are an indication of artificial accumulation such as through deposition.

The bulk of the samples show values ranging from 0.09 to 1.03; the only exception being sample 3B for which the value is 10.17/100 gram. This sample was taken near a drilling pit and the high value probably reflects an effect of drilling mud.

A high level of exchangeable sodium in a soil is detrimental to plant growth since it creates toxic conditions; in addition, soils rich in exchangeable sodium tend to become easily dispersable and are subjected to rapid compaction.

Bulk Density (B.D.)

In agricultural soils bulk density values range from 1.2 to 1.4 for the A horizon and are usually much higher, up to 1.8, in the sub-soil. High values of bulk density (1.6 or more) in the A horizon are indications of unusual compaction of soil, either through natural processes or through man's activities.

Compaction is a process by which normally loose soils are packed to a denser state. Physically, this corresponds to a significant decrease in voids (pore spaces) with corresponding increase in the bulk density of the soil. Productive agricultural soils are usually characterized by high to medium porosity. With increasing bulk density (and decreasing porosity), normal agricultural soils lose their ability to support plants. Highly compacted soils impair plant development by physically restricting root expansion and interfering with seed germination and emergence. In addition, compaction reduces water intake and movement of gases in the soil.

Susceptibility of a soil to compaction depends on its textural class (% of sand, silt, and clay). Sandy soils are easily compacted by vibration, while clayey soils develop greater compaction under sustained, heavy load. In addition, the water content of a soil plays an important role in soil compactability; and for a given amount of compactive effort, there is a corresponding water content that will produce the densest state for each class of soil texture. In general (except for pure sand) moist soils are more easily compacted than dry soils. This point is very important since it indicates that heavy traffic on a site will produce more objectionable effects if the soil is wet.

The high values of 1.6 or more recorded for the A horizon on sites 1 and 7 are rather abnormal for surface horizons and reflect the extensive compaction that has taken place at these sites, probably through intense traffic of heavy machinery during wet periods.

3.7.3 INTERPRETATION

Field observation and laboratory analyses of site soils and profiles have shown that the major disturbances can be accurately

identified and quantitatively evaluated. Because of the limited number of samples, precise ranges of laboratory values could not be established for various degrees of disturbance. However, the laboratory parameters provided a good indicator of the type of disturbance which has occurred (e.g., scraping, compaction and influx of brine salts).

Most of the problems discussed above are dynamic problems that change with time: compacted soils can loosen themselves through soil rebound, freezing and thawing, shrinking and swelling. Chemically polluted soils can be naturally reclaimed through gradual leaching by various forms of precipitation. As the soil characteristics improve, so are its potentials for supporting vegetation; furthermore, the rhythms of these changes vary with the types of soils and the extent of the problems.

A rational project for monitoring environmental degradation must be supported by systematic field observations backed by adequate quantitative soil and vegetation studies. These studies should aim at establishing various classes or degree of degradation as well as the rate of change over a given period of time.

The preliminary works conducted so far have been aimed mostly at investigating and demonstrating feasibility of using specific criteria to recognize various forms and various degrees of soil disturbance. Additional detailed work should be conducted to establish actual classes and recognize critical levels beyond which the soil can be considered significantly affected.

3.8 NEIGHBORHOOD SURVEY

A limited survey was conducted this year of residents within 2 kilometers of the Dow study site. In all, 17 families were contacted. The spatial distribution of the residences covered the 2 kilometer survey range and included residences on 4 roads: Sheridan Line, Brown, Mortimer Line, and Kilgore Roads.

This survey served a variety of purposes: to the extent possible, it updated the 2 kilometer residence list established with the previous

survey (1977); 2) it informed neighborhood residents about current Dow activities regarding the oil shale program; 3) it reaffirmed the linkage of these residents with someone at ERIM should they have comments or questions in the coming year; and 4) it provided an update on the list of residents' concerns regarding aspects of Dow's oil shale program activities.

A list of persons contacted was supplied to Dow. From conversations with some of the permanent residents we found that two of the three residences that had not been contacted during the previous survey were seasonally occupied. The majority of residents surveyed indicated that the probability of their responding to a written survey was low.

An aerial photograph of the Dow study site, taken in September 1978, was used to show the residents where various oil shale experiments were taking place. It was the first view most of them had of Dow activities on the southern 40 acres, and it generated a great deal of interest. That photograph, along with a similar one taken in May of 1977 are shown in Figure 4 .

Response to the survey was positive in every instance. Most of the residents asked a number of questions about the oil shale project.

Some concerns expressed by neighborhood residents in the previous survey include:

1. The condition of Mortimer Line Road (dust generation and general wear) due to traffic of heavy vehicles.
2. Impact of Dow activity on water wells.
3. Noise
4. Television interference.
5. The possible use of radioactive materials at the Dow study site.
6. Lack of blast warning
7. Possible damage to homes from Dow related explosions.

Some concerns expressed during this survey include:

1. The condition of Mortimer Line and some adjoining roads.

Specific references were made to dust generation, dust control, and pothole development.

2. Impact of Dow activity on water supply.
3. Impact of Dow activity on air quality.
4. The possibility of radioactive disposal at the study site.
5. Lack of a practical blast warning.
6. Television interference which may or may not be related to Dow's presence.
7. Several persons associated with the study site were thought to drive at excessive speed to and from the site.
8. Lack of information on the oil shale program in general and on Dow study site activities in particular.

There is a great deal of similarity in the concerns expressed during both neighborhood surveys. Dow's study site neighbors are concerned about the roads, the quality of the air they breathe and water they drink and noises other than those they have come to associate with their rural environment.

One of the purposes of the neighborhood survey is to supply information. The survey is looked on as an opportunity to provide information to the residents about Dow's research activities and as an opportunity for Dow to learn how it is perceived by the study site neighbors. The fact that many of the neighbors' concerns were repeated from one survey to the next indicates that the flow of information both to the neighbors and to Dow may be inadequate. More frequent, positively oriented contact between Dow and its study site neighbors is called for if the information flow is to improve. Positively oriented contact means association between two groups that is not necessarily, or not primarily problem related. The contact could be made directly by Dow or through an intermediary such as ERIM.

All of the residents within the 2 kilometer radius containing the study site need not receive the same kind of information. An analysis of the sources of potential nuisance to Dow's neighbors reveals that the sources possess certain differences, related to their path of propagation, of which advantage may be taken. Noise is an omni-directional source, the effect of which falls off rapidly with distance (under normal conditions). Therefore, neighbors most concerned about noise will tend to be those within a certain noise radius of Dow activities in which the noise level exceeds a certain threshold. Road traffic, noise, wear, and traffic hazard form a linear source, the total effect of which is proportional to road length. Neighbors most concerned about traffic will be those living on roads receiving increased usage due to Dow's study site activities. Other sources may be likewise classified and by this means, the audience for probable neighborhood impacts may be estimated long before the impact would occur. To reduce the effect on the neighborhood of the potential nuisances, an information delivery system can be established that makes use of available information on where impacts are likely to occur, and on the schedule of the impact source. The information delivery system could be activated on a regular basis whether or not potential impacts are pending and this would do much to alleviate the inadequate information flow observed above.

3.9 DISCUSSION

This years land monitoring program has seen the collection of baseline data on new elevation monuments, established the expectable error in elevation surveys of the Dow study site and, based on 1978 elevations for some of the monuments installed in 1977, has led us to the conclusion that there were no changes in elevation at the site associated with Dow's subsurface activities. The aerial and ground photography collected have found usefulness as documentary material. A large increase in surface disturbance was noted from 1977 to 1978, but it is anticipated that a

similar increase from 1978 to 1979 is unlikely. Noises attributable to activities at the Dow site were separated into two classes: continuous and impulse. In general, the continuous noise levels are within acceptable levels for workers at the site and are noticeable only to Dow's closest neighbors. There have been instances when impulse noise from surface tests of explosives was heard from the site which generated concern in many of Dow's neighbors.

Vegetation and soil baseline studies have been completed. Recommendations were made about future efforts. Dow's study site neighbors were surveyed for the second time in two years and it was learned that their concerns are basically the same as they were. A procedure is suggested that would help to reduce the number and the intensity of those concerns.

WATER QUALITY

4.1 INTRODUCTION

The water quality portion of the environmental monitoring program includes the essential elements to evaluate the impact on local water resources from the in situ combustion tests of the Antrim shale. For this experimental program potential adverse effects include contamination of surface and groundwaters from waste disposal of brine, drilling muds, backflood water, and retort condensate from the in situ combustion. Contamination of groundwater supplies from leaching of combustion cavities is a remote possibility because of the great depth to the shale strata. Because this effect is not expected to be significant for the present operation it will not be included in the present monitoring effort with the exception of chemical analyses of product and backflood waters in combustion cavities. However, when this process is expanded to a greater scale it is recommended that contamination from combustion cavities be examined thoroughly.

The approach of this water quality monitoring plan is to gather data on the surface and groundwater in the area of the shale site throughout the period of site development, well drilling, fracturing, and combustion trials. Any potential adverse effects should be perceived as a change in one or more water quality parameters which can be related to the presence of disposed materials or other activities at the site which contain these chemical constituents.

A water quality monitoring program was initiated during April 1977 to establish baseline conditions and to monitor drilling, fracturing, combustion trials, and other site development activities. It is expected to continue throughout the four year project. A continuous monitoring program is necessary to observe any changes from baseline through post in situ combustion conditions. By tracking the use and disposal of materials from the energy extraction experiments it may be possible to evaluate the impact these materials will have on basal ground and surface waters. The well drilling itself is considered to have

potentially significant effects on the local surface and groundwater because of the great number of wells which are being drilled (37) in a limited area (40 acres). Considering the 100,000 gallons of water used in drilling each hole plus extraction of the material from the hole results in a larger volume of brackish waste fluid laden with the drilling muds. Left in open pits salts and trace metals could potentially leach out to contaminate local groundwater. Efforts are being made to contain these effects by first allowing the muds to partially dry in the pits and then spreading them out on the surface for more complete drying. Afterwards the materials are disposed in a nearby landfill. Waste brine from dewatering and drilling is stored in rubber lined pits and disposed by spreading on local gravel road as a dust control. Thus a great quantity of this material is being removed from the site.

In the current program brines and drilling muds have been monitored along with shallow groundwater from nearby mud pits in order to assess the current and potential impacts from drilling.

4.2 LOCAL HYDROLOGY

The eighty acre shale site is situated in the Seymour Creek watershed which is a portion of the Black River basin. Based upon USGS topographic maps it appears that most of the site drains eastward through the pond area in the northeast corner of the property to a culvert at Brown Road and eventually by drains to Seymour Creek. The SW corner of the south forty acres drains westward to Bradley drain which crosses Bricker Road to the west and forms Bradley Creek. Bradley Creek joins Seymour Creek at a point south and east of the site. Seymour Creek is joined by Perry Creek and Black Creek and flows into the Black River approximately five miles east of the site and downstream from the village of Croswell. Black Creek and Seymour Creek together have a drainage area of 130 sq. kilometers at the confluence with the Black River. Seymour Creek above Bradley Creek has a drainage area of 9.12 sq. kilometers and the rest of Bradley Creek drains 7.23 sq. kilometers. The drainage area above the Brown Road drain which includes most of the site is

approximately 0.90 sq. kilometers. The topography of the Seymour Creek drainage basin is very flat with average slopes of less than one and one half meters per kilometer.

Soils in the Black River basin have been developed from the glacial deposits through weathering, oxidation, and leaching. Because of the variation in parent materials and changes in these materials, a complexity of soil types exist in the basin. The surface soils are chiefly silt loams and sand loams, and poorly drained. State well logs and water wells in and around the Dow site show the upper alluvial structure to consist of alternate clay and loam layers. Infiltration rates are generally low in the site area of the watershed so that heavy rainfall produces significant storm runoff. Water table elevations may be quite variable due to the complexities in soil structure.

4.3 WATER SAMPLING METHODS

Water samples have been gathered in 16 ounce polyethylene bottles on a regular monthly basis from several locations. A 100 ml portion of each sample was acidified with nitric acid for subsequent extraction and metals analysis. The partial list of sampling stations given as Table 6 are slightly different from those used at the beginning of the program. With an extensive set of baseline data from off site surface water stations emphasis has been placed this year on greater sampling at the Dow shale site.

Samples were analyzed at the ERIM laboratories for the first nine parameters in Table 7. Selected samples were also analyzed for some of the trace metals after extraction was completed (see Appendix C). A few samples were analyzed by the Environmental Research Group (ERG) of Ann Arbor for all of the trace constituents. In addition the Dow Analytical Laboratory has analyzed water samples for selected parameters from Table .

Samples were analyzed as soon as possible after data collection using standard procedures outlined in Methods for Chemical Analysis of Water and Wastes EPA, 1976 and Standard Methods for the Examinations of Water and Wastewater 14th Edition, 1975. In the case of sodium,

TABLE 6
WATER QUALITY SAMPLING SITES

<u>Station Number</u>	<u>Location</u>
1.	Dow Water well supplying work site.
2.	SE corner of pond in NE portion of plot.
3.	North Forty Brine Pit.
4.	South Forty Brine Pit.
5.	Brown Road Wier 1/3 mile south of Mortimer where swamp site drainage crosses road.
6.	Seymour Creek (North) at Mortimer Line Road.
7.	Bradley Creek and Burns east of Brownstage measurement NE corner of bridge from lower rail brace.
8.	Seymour Creek (South) at Kilgore Road (Station 1 on previous Dow work).
9.	Black River and Galbraith Road.
10.	Farm house water well.
11.	Mortimer Road NW corner Dow site.
12.	Bricker Road 1/4 mile north of Burns Line.
13.	Seymour Creek (East) at Black River Road.
14.	300 series test wells #1, #2, and #3.
15.	R. Sichko water well located 600 feet NE of pond.
16.	Brown water well located 900 feet NE of pond.

TABLE 7
WATER QUALITY PARAMETERS

Constituents Determined in Each Water Sample

Potassium
Sodium
Calcium
Magnesium
Chloride
Suspended Solids
Total Dissolved Solids (TDS)
Conductivity
pH

Constituents Determined in Selected Water Samples

Total Organic Carbon, TOC
SO₄
Aluminum
Silicon
Iron
Lead
Mercury
Barium
Strontium
Bromide
Arsenic
Zinc
Copper
Nickel
Manganese
Chromium
Vanadium
Boron
Beryllium
Lithium
Selenium
Cadmium

potassium, and chloride sample analysis was accomplished using specific ion electrodes. A discussion of specific procedures for analysis and quality control are discussed in Appendix C.

4.4 RESULTS

Water Quality monitoring data were collected from February 1978 through January 1979. During this time period several site development activities took place which could potentially have effects on the quality of local surface and groundwater. Monitoring efforts included gathering hydrologic data, water use and disposal records, samples from drilling mud pit monitoring wells, and pumping data from the farmhouse water well. A special study of the salt contaminants found in the pond located in the northwest corner of the site is described in Section 4.5. Individual analytical determinations are compiled in Appendix B for a total of 242 samples.

4.4.1 HYDROLOGIC MEASUREMENTS

Observations made on the variations in the hydrologic system include measurement of stream flow and precipitation. Monitoring of streamflow provides a more complete understanding of hydrologic relationships which are valid in the site area including estimation of the site transport mechanism.

Continuous records of rainfall were made using a Weather Measure Model P21 tilting bucket rain gauge. These data were collected from April 1 through December 15. Supplemental precipitation and snow cover data were gathered from the U.S. Weather Bureau Climatological records (see Appendix E). Precipitation records have been used to identify wet and dry times which occurred during the period of monitoring. The purpose in collecting detailed continuous records is to obtain site specific data on the time intensity rainfall pattern and associated runoff characteristics.

Flow from the site was monitored at Brown Road using a v-notched wier. Flows were estimated by observing the level of water in the wier

notch. A standard Stevens type F level recorder was used during May and June to measure flows on a continuous basis.

Numerous observations were made on flow conditions. Stage measurements were made at several locations and times during the past year. Smaller streamflows near the site were observed to be seasonally intermittent and to fluctuate highly with passing storms. The Brown Road wier had no flow from July 1 through September 15. During this period flows in Seymour Creek were considered negligible. The pond surface water evaporated leaving the sediments exposed from mid-August. Over 4.5 inches of rain fell during the period from September 12 through September 30. Only a little runoff was observed due to the long period of draught. The period of Spring thaw and rainfall is the most likely time to observe large runoff. During early April flow of 0.5 cfs was observed at the wier which is substantial for this small drainage.

4.4.2 WATER USE REQUIREMENTS

Water use and disposal data were collected during the past year in order to assess the impact on local water resources or that expected from an expanded operation. During the year Dow drilled five new wells, conducted two acid underreaming tests, and hydrofractured four wells. To supply these operations approximately 200,000 gallons were withdrawn from the supply well and 400,000 gallons from the pond supplies during the first six months. Records indicate that during the first eight months 116,000 gallons of brine from drilling and dewatering operations had been spread on nearby roads.

4.4.3 SURFACE WATER SAMPLING

Substantial surface water quality data were collected from off site stations during the first year of sampling. Off site sampling for this period has been limited to two stations on Seymour Creek. Efforts were directed to more closely monitor onsite conditions. To this end samples were collected from each of the site wetlands during time when they held standing water. Samples of brine from various dewatering operations were also obtained. A large number of samples were collected

from the pond in an attempt to better understand the effects of storm runoff. Average values of Seymour Creek stations compared well with those collected the year before. Data collected in the wetland around the site showed high levels of chloride (400 mg/l) for those areas alongside Mortimer Line Road. This condition could be attributed to runoff from the application of brine and calcium chloride dust control agent. The small wetland near the 300 series mud pit displayed very low concentrations of salts indicating that no surface contamination from the nearby drilling operation has occurred.

Water samples collected from the pond located in the northeast corner of the site near the main compound and Rhoburn series wells (3-7) have shown as previously reported consistently high levels of chlorides of 200 to 800 mg/l as contrasted with 4.7 mg/l which was measured by Dow in May 1972. It was of chief concern to determine the source of this material and determine if any present site activities were responsible. Using an ISCO auto-sampler a series of daily samples were collected during April and May of 1978 to investigate whether site runoff into the pond was a significant source of the observed contamination. During this period flow records were also gathered from the Brown Road wlier station. The results plotted in Figure 9 show an excellent inverted relationship between observed chloride concentration and flow suggesting that the runoff acts only to dilute the chlorides.

4.4.4 GROUNDWATER MEASUREMENTS

Any groundwaters could be contaminated by shale site activities in two ways. First, disposal of materials and drilling fluids on the surface could leach downward to the water table; and secondly, deep groundwater which has contacted a spent shale zone may migrate upward and contaminate freshwater aquifers. Both processes, if they occur, require long periods of time to reach potable well supplies. Efforts of that monitoring program have concentrated on the first possibility. The present groundwater sampling program is not considered sufficient to observe possible effluents, should they occur, from the combustion zone. If after substantial combustion is achieved, the spent shale backwaters are found to contain significant contaminants it may be necessary to drill an observation well into an aquifer above the

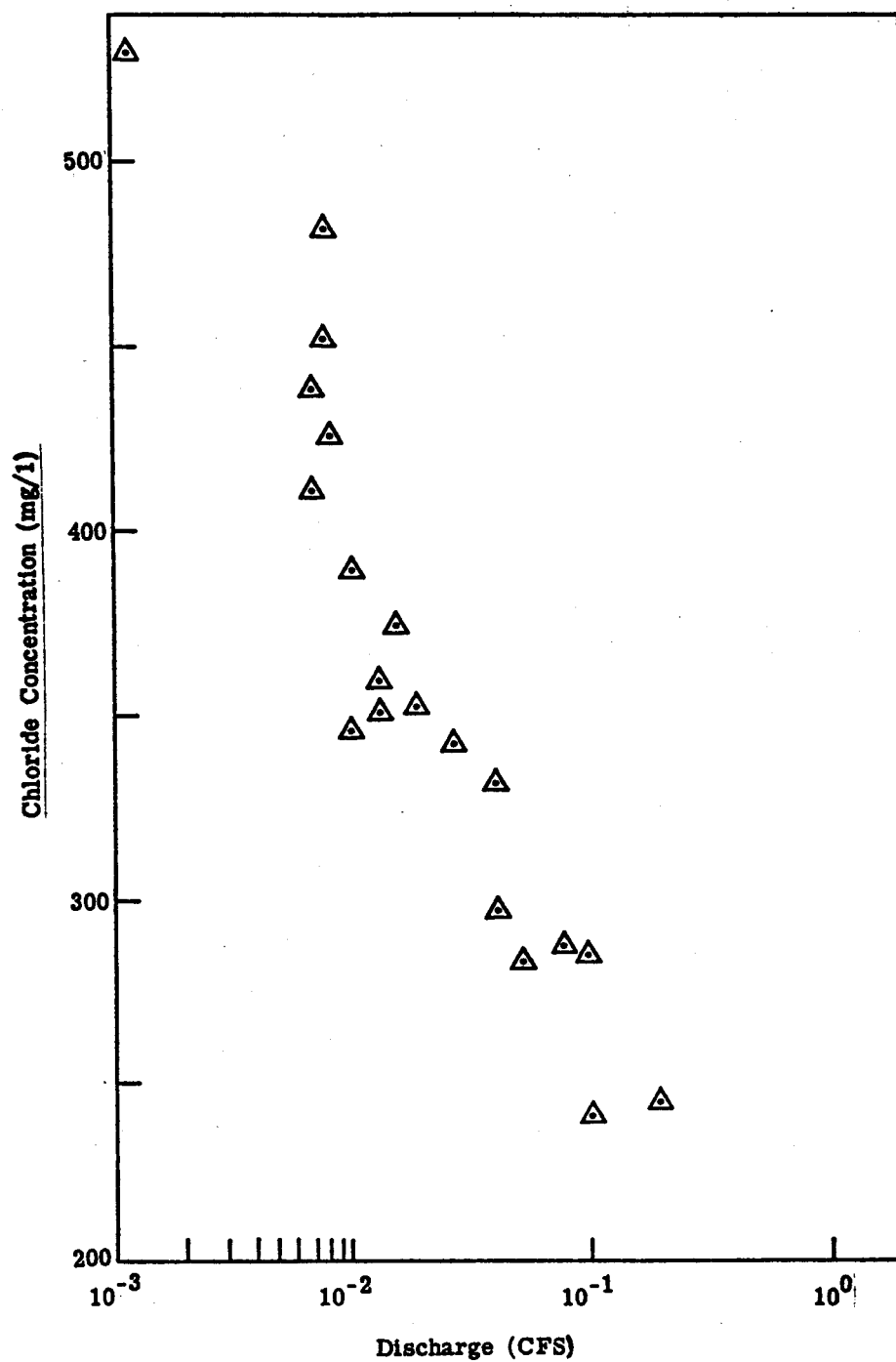


FIGURE 9. VARIATION IN CHLORIDE CONCENTRATION FOR DAILY POND SAMPLES FOR THE PERIOD APRIL 18 TO JUNE 11, 1978

Antrim shale if any upward migration of groundwater is to be monitored.

Groundwater monitoring efforts made in this year's program include: (1) regular sampling of water quality in the site supply water well, the site farmhouse well, and local domestic supplies, (2) monitoring the seepage of contaminant from drilling mud pit into local groundwater, and (3) investigation of chloride contaminant in the site pond.

Regular monthly samples gathered this year have not shown variance with baseline data collected during the previous year. These data showed all water quality parameters listed in Table 7 to be within the safe range of the USPHS drinking water standards. There were two exceptions to these conditions (1) the site farmhouse water well which gives high levels of organic carbon, chloride, and manganese, and (2) the nearest off site domestic water well which is located on the property adjacent to the site. This well (Sichko) showed levels of chloride which at about 100 mg/l are 10 to 20 times those observed in other local domestic wells. In addition, total dissolved solids were found to be nearly 500 mg/l. However, it is not likely that this well has been contaminated by site activities as discussed in Section 4.7.3.

4.4.5 FARMHOUSE WATER WELL

The farmhouse water well is the closest well to the contaminated pond area and is set to depth of 17.4 meters. It has been monitored on a regular basis since the beginning of the program. It has consistently exhibited high levels of chloride (300-350 mg/l) and manganese (0.20 mg/l) which are suspected to be associated with the pond contamination. During this past year several pumping tests were made in order to clarify the quality of groundwater in the vicinity of the farmhouse well.

Initially the well screen was partially clogged and providing only a small yield. Under these conditions a 24 hour pumping test was conducted which yielded over one thousand gallons. No significant change or trend was observed in the hourly samples which ranged in concentration from 255 to 340 mg/l chloride. During July the well was

rescreened and on August 9 the well was sampled directly from the casing at a rate of 4 gpm for a period of 12 hours (2,880 gallons). Only small changes in chloride were observed with a concentration of approximately 400 mg/l.

A third test was made from September 11 through the 15th by continuously pumping at 2-3 gpm. Samples showed high levels until near the end of the test when they seemed to drop to near 100 mg/l chloride. Over 20,000 gallons had been pumped from the well. The well has been used since that time to occasionally supply water for hydrofracturing operations. Chloride concentrations have dropped to about 65 mg/l during the last few months.

While these data are insufficient to draw a definite conclusion on the condition of local groundwater the following explanation is offered of results from these pumping tests. First the chlorides and other solutions have slowly dispersed downward and outward from the pond sediments by the forces of molecular diffusion and gravity. (see Section 4.5.3 for a discussion of dispersion).

While groundwater tends to move in the direction of the surface gradient it is also possible that subsurface layers could provide a hydraulic gradient which is reversed from that at the surface. Under these conditions a contaminated zone would tend to appear as an inverted cone confined below in part by a less permeable layer. Thus it is possible for groundwater to move from the pond sediments by gravity flow in the direction of the farmhouse well. Now suppose the cone intersected the farmhouse well. Then at this well there would be a fresh zone on top and a saline zone below. Small pumpage would sample only from the saline zone as was first experienced. However, by pumping a larger volume freshwater was brought in from the upper zone displacing the saline water. The resulting distribution as shown in Figure 10 would help explain the lower levels of chloride that were observed following the test. If no confining layer exists, gravity flow and salt water displacements are not considered possible.

4.4.6 MONITORING WELLS

In early May two shallow test wells were drilled near the 300 series mud pit. It was felt that placement of these and perhaps additional wells would establish the extent and degree that groundwaters

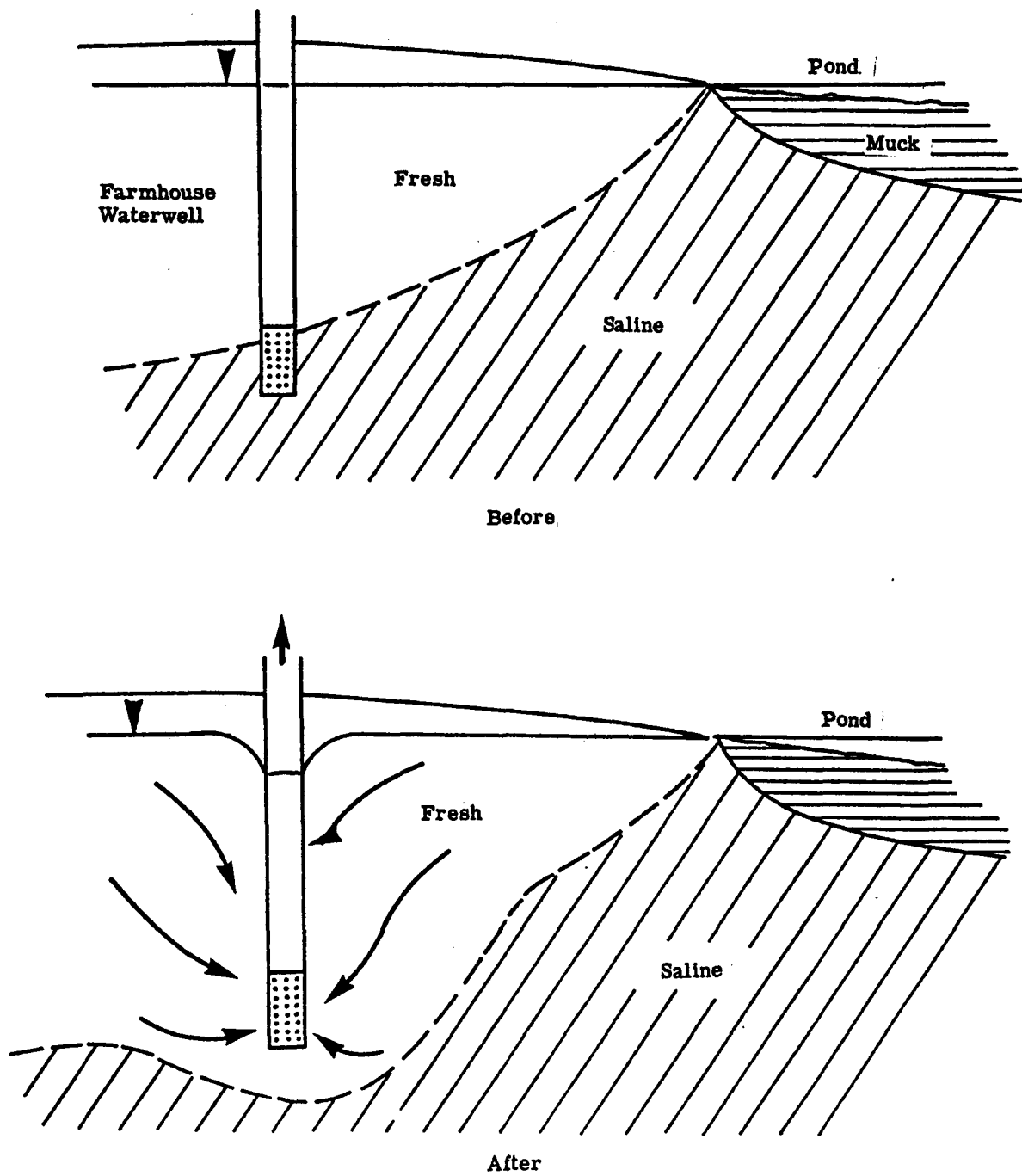


FIGURE10 EFFECT OF PUMPING TEST ON SALINE/FRESH WATER ZONES

had been affected by effluents from the drilling pit. As mentioned previously the 300 series pit was used to drill several wells early in the year requiring the use of brine to prevent freezing. For this reason the 300 series mud pit was selected for groundwater monitoring.

The first well was drilled only 3 meters from the rim while the second was placed 30 meters and down gradient from the pit. A third well placed in a high and undisturbed area to monitor background water quality. The map in Figure 11 shows the approximate location of these wells. All three wells have two inch (5.08 cm) diameter PVC casing with slotted screens (No. 10 and 12) and set to a depth of approximately 8.5 meters. The lower, 3.5 meters is screened in each well. Soil materials varied from clay loam to sandy loam. With the static water level at 3.2 meters below the surface it lays less than one meter below the bottom of the pit. At this depth the soil was mostly fine sand. The hydraulic gradient between well was estimated using survey techniques to be 0.002. (Note three wells are needed to obtain a true gradient.)

Monitoring wells have been pumped each month at a rate of 2 gpm for a period of 30 to 90 minutes. As shown in Table 8 quality of the groundwaters have not changed significantly during the period of observation. High concentrations of brine and mud pit components have seeped and dispersed through the bottom of the pit but have not as yet spread to the adjacent well. Plans call for continued sampling of these wells on a periodic basis. Additional wells may also be installed to more completely define the dispersion of material.

4.5 POND STUDIES

On August 30, 1978, ERIM met with Dow shale project staff in order to review existing data which pertained to the observed chloride condition in the farmhouse well and the pond. It was suspected that the subsurface contamination which affected the pond may also have influence on the farmhouse well. As a result of this meeting, ERIM submitted to Dow a recommended plan to further investigate this situation. Further investigation was considered warranted for two reasons (1) any existing

TABLE 8. MONITORING WELL RESULTS

Date	Duration of Pumping at 2 GPM	Test Well #1		Test Well #2		Test Well #3	
		TDS (mg/l)	Chloride (mg/l)	TDS (mg/l)	Chloride (mg/l)	TDS (mg/l)	Chloride (mg/l)
5/18/78	90 min.	24,600 (10 min.)	20,100	208	1.30	258	1.80
7/12/78	35 min.	29,000	19,200	195	0.66	283	0.94
8/10/78	45 min.	25,500	19,700	206	0.95	287	1.20
9/12/78	30 min.	21,800	22,000	204	1.40	281	1.10
10/12/78	30 min.	12,800	14,000	203	3.70	282	5.00
12/13/78	10 min.	19,000	19,200	299	0.68	206	0.66

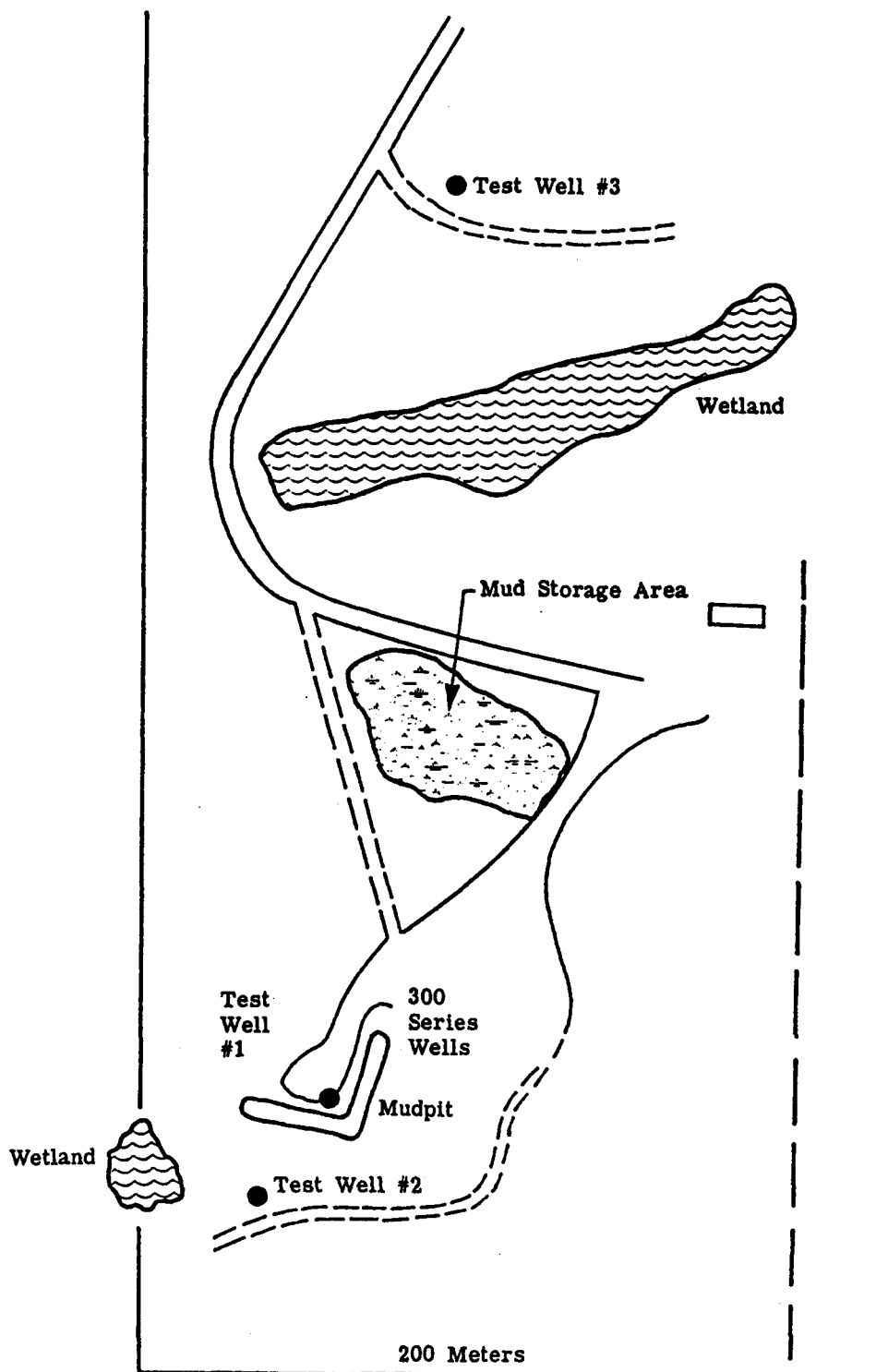


FIGURE 11. LOCATION OF MONITORING TEST WELL FOR 300 SERIES MUDPIT

groundwater contamination could present a threat to local domestic supplies, and (2) study of this condition could provide valuable data on the impacts from drilling wastes. It was recommended that the study focus on examining the shallow groundwater around the pond and in sediments.

4.5.1 FIELD MEASUREMENTS

The field work was conducted over the period of September 12 through the 15th. Eleven test holes were augered on the pond perimeter using a gas powered screw-type auger and a modified hand unit. Both units allowed us to dig sampling holes to a maximum depth of eight feet. Most holes were augered to the maximum depth and two to four feet below water table. The test holes were set back 7.5 to 15 meters from the pond edge. Conductivity and static water level were measured prior to sampling. The ground elevation at each test hole relative to an established elevation monument was determined afterward using the laser theodolite. Resulting ground elevations are shown in Figure 12 with approximate contours. Subtracting out the static water levels permitted calculation of the existing groundwater gradient. Using several groups of three wells an approximate value of 0.004 was obtained in an easterly direction.

The pond muck bottom sediments were entirely exposed except for a few small pools of standing water which accumulated from current rainfall. On September 12 the saturated zone was found to be 45 centimeters below the surface but it rose because of heavy rain to within 15 centimeters of the surface on the 15th. Holes were augered on September 12 to several depths into the pond sediments. Water samples were collected from 2, 4, and 6 foot (0.61, 1.22, 1.82 meters) depths using a small battery pump. Two-inch PVC pipe was used to temporarily case the hole. On September 14 a deeper hole was made into the sediments by pushing down the PVC casing to a depth of 12 feet (2.65 meters). Clogged holes were freed by pressurizing the casing with water. Top water was then removed and the casing was allowed to seep full several times from the bottom before a sample was collected.

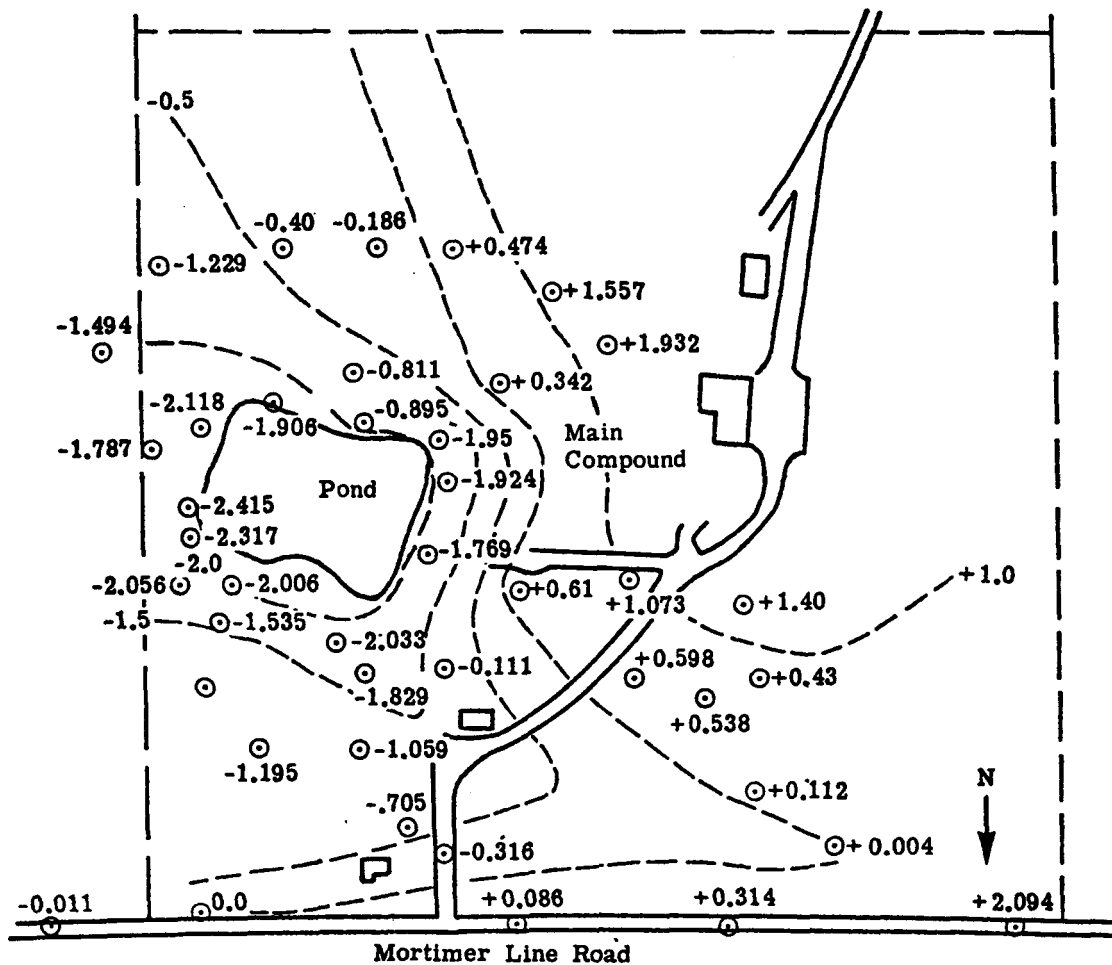


FIGURE 12. RELATIVE SURFACE ELEVATIONS (METERS) FOR THE NORTH FORTY PORTION OF THE SITE

In addition to perimeter and profile sampling, samples were collected from 12 two-foot (0.61 meter) test holes made into the sediments. These samples were located to provide some idea of the distribution of chlorides in the pond sediment.

A search by Dow of previous Rhoburn series drilling activities revealed the possibility that a large amount of mud waste was buried between the pond and the main compound. It was considered quite possible that this disposal area contributed and perhaps is still contributing chloride salts to the pond waters and sediments. Fourteen sites in the vicinity of the suspected disposal area were selected for shallow hole evaluation. Drill holes were laid out in a grid pattern in order to evaluate the extent of chloride and other leachable material is available for pond contamination.

4.5.2 RESULTS

Samples collected in connection with the pond investigation were analyzed for conductivity, total dissolved solids (TDS), Na, K, Ca, Mg, and CL. All laboratory results are shown in Table B10 (Appendix B). Selected results are given in Table 9.

TABLE 9
SAMPLE RESULTS FOR POND SEDIMENT PROFILE

<u>Sample Number</u>	<u>Location</u>	<u>Conductivity (mhos)</u>	<u>Dissolved Solids(mg/l)</u>	<u>Sodium (mg/l)</u>	<u>Chloride (mg/l)</u>
302	Pond sed. water from 2.0 ft.	16,500	11,600	4,000	8,700
303	Pond sed. water from 4.0 ft.	14,500	13,300	4,760	10,100
304	Pond sed. water from 6.0 ft.	10,700	13,800	4,200	9,800
323	Pond sed. water from 12 ft.	9,000	7,750	2,240	4,200

Comparing profile samples 302, 303, 304 from the 2, 4, and 6 foot (0.61, 1.22, 1.83 meter) depths with 323 from the 12 foot (3.65 meters) depth indicates measured parameters first increased then decreased with depth in the sediments but are substantially higher than those observed earlier in the pond water samples. Maximum levels observed were 13,750 mg/l TDS and 10,800 mg/l Cl which is five to ten times less than concentrations observed in the brine samples. The fact that concentrations decrease with depth suggest that the brackish water is entering (or did enter) by near surface groundwater flow not by a deep flow route. Furthermore, the contaminated water appears to be moving downward by dispersion and gravity.

Location of test holes on the perimeter is shown in Figure 13. As indicated, levels of chloride elevated over ambient conditions were found in several of the test holes. Auger holes number 2 and 3 located between the north forty compound and the pond showed the highest levels at 6,200 and 1,480 mg/l respectively. Proceeding around the southern edge of the pond, levels were found to be very low; on the eastern edge, levels were again elevated. The highest was located in the marshy area which receives surface and subsurface drainage from the pond and is the outlet for the pond waters. On the east and west sides, holes 9, 10, and 1 exhibited low readings.

Results from the fourteen test holes as shown in Figure 14 confirmed that the suspected area of buried cuttings exists. These results also indicated that not much of the salts associated with this material remains in the buried pit. Measurements of standing water in drilling mud pits were often in excess of 10,000 mg/l as chloride and as much as 150,000 mg/l. Groundwater samples collected from test well 1 near the 300 series mud pit shows chloride usually in excess of 20,000 mg/l. The maximum chloride level observed with these fourteen holes was 1,880 mg/l. By comparison, the maximum level found in the pond sediments was 10,800 mg/l with the average concentration of 3,570 mg/l. As can be seen from the map of chloride concentrations in the pond sediments (see Figure 13) a level of 6,700 mg/l was measured at a location next

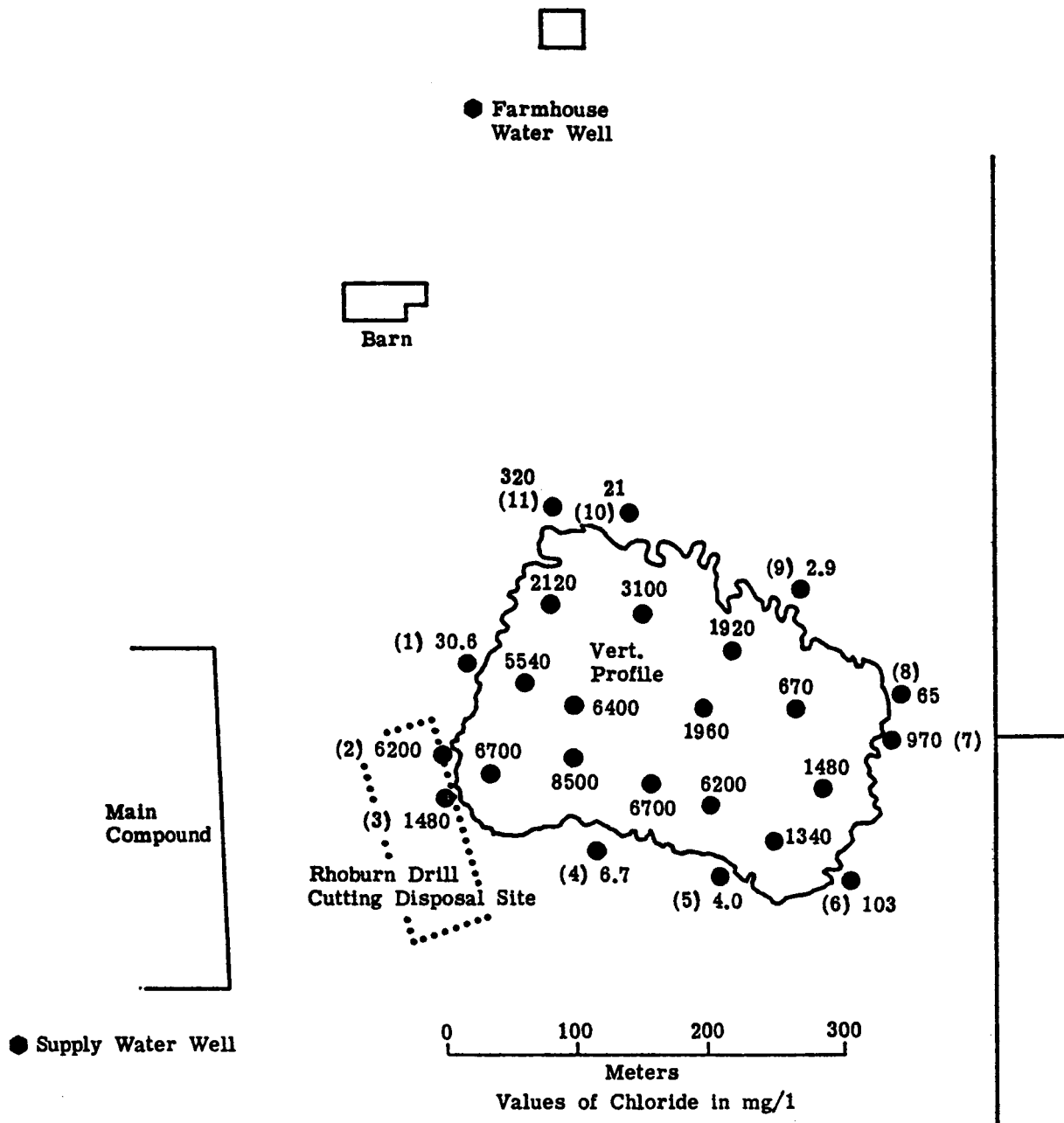


FIGURE 13. LOCATION OF POND PERIMETER AND SEDIMENT SAMPLING SITES, SEPTEMBER 12-15, 1978.

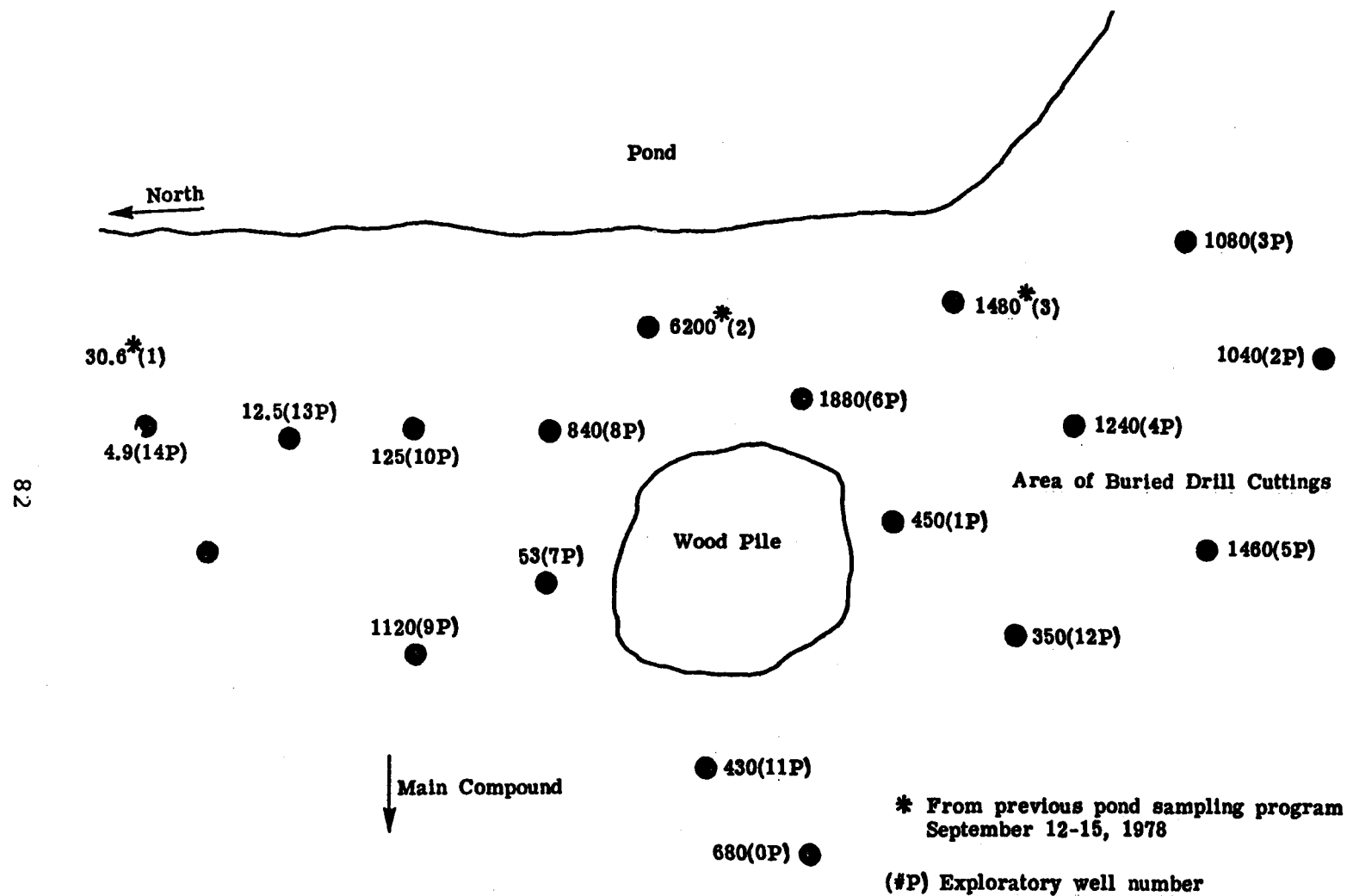


FIGURE 14. CHLORIDE CONCENTRATIONS (mg/l) FOUND IN WATER SAMPLES
COLLECTED FROM EXPLORATORY SHALLOW WELLS

to the buried disposal site. These data, in combination with the study of the pond sediments, indicate two conclusions: (1) there is not likely any active source of contaminants entering the pond from near the main compound, (2) the area of buried cuttings does not exhibit sufficient size or concentration of material to suggest that it was the single source of contaminants. Although complete records are not available it is possible that brine seeped over a several month period from the Rhoburn wells contaminated the pond.

Results from those samples, however, do show the spatial distribution of chlorides in the pond sediment (see Figure 13). Levels of chloride and other constituents were found to be highest near the southwest corner of the pond and to decrease somewhat uniformly to the lowest near the northeast corner of the pond. In general, levels observed in the sediments were much higher than those observed in perimeter test holes. It is currently estimated that there are over 5×10^4 kg of salt as NaCl presently contained in the first 12 feet (3.65 m) of muck sediments of this pond.

Measurement results from this brief investigation of the pond condition indicate that salt contaminants entered the pond near the southwest corner from the direction of the main compound. These brine chlorides have mixed with the pond waters and sediments which distributed the chlorides across the pond. Chlorides have likely passed both downward and to the east of the pond by dispersion, groundwater flow, and surface runoff (through the northeastern edge of the pond).

4.5.3 DISPERSION OF EXISTING POND CONTAMINANTS

While exact prediction of the dispersal of salts from the pond area is not possible based upon existing data, it is useful to review the long term dispersal problem in order to at least conceptually understand what may likely happen to these contaminants.

The deposits of salt located in the pond sediments are not stable. A portion of the salts are being diluted out by surface runoff which flows through the pond during the wet seasons. The bulk of material is available to be leached out of the sediment into the groundwater system.

Because of the limited groundwater quality data collected to date in the site area it cannot be determined just how far this material has spread during the approximate five years since the initial contamination. However, if we assume the pond serves as a recharge area to a fairly homogeneous aquifer then it is possible to estimate solute travel.

This discussion will approach two questions: (1) what is the ultimate fate of these contaminants? and (2) are the present observations of groundwater plausible in terms of the expected dispersal process?

Three forces will cause these groundwater contaminants to disperse. They are (1) simple groundwater flow, caused by the presence of a hydraulic gradient, (2) molecular diffusion of the solute, and (3) gravity induced convective flow. The mass flux of material in one dimension is governed by Ficks law for dispersion.

$$F_x = U_x C - nD \frac{\partial C}{\partial x} \quad (1)$$

where

- F_x is the efflux of solute in the x direction
- U is the Darcy velocity (U/n = seepage velocity)
- n is the porosity
- D is the diffusion coefficient
- C is the concentration function $C(x,t)$

Since the net efflux of material is equivalent to the time rate of change of the concentration we are led to the following differential equation [6].

$$U/n \frac{\partial C}{\partial x} + \frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2} \quad (2)$$

This equation often referred to as the convective diffusion equation has an exact solution in one dimension but requires iterative numerical methods when solved in two or three dimensions. In one dimension the solution is

$$C(x,t) = \frac{M}{\sqrt{4\pi Dt}} e^{-\frac{(x-U/nt)^2}{4Dt}} \quad (3)$$

where M is the total mass of solute released at time t=0. Which is conserved, i.e.,

$$M = \int_{-00}^{+00} C(x,t) dx \quad (4)$$

Over short times the dispersion can be viewed as one from a constant source (C_0). Under this constraint the solution is given by

$$C/C_0 = 1/2 \operatorname{erfc} \left[\frac{x-U/nt}{2\sqrt{Dt}} \right] \quad (5)$$

The objective is to utilize the above equation to estimate the movement of salt vertically due to gravity and diffusion and horizontally in the direction of hydraulic gradient.

The vertical convective velocity (U_z) depends upon the density (ρ) gradient set up by changes in concentration and the permeability (P) of the soil.

$$U_z = P \frac{d\rho}{dz} \quad (6)$$

the horizontal velocity is simply a true Darcy velocity

$$U_x = P \frac{dh}{dx} \quad (7)$$

where dh/dx is the hydraulic gradient.

The sandy loam soils found at the site are quite similar to those found near Hillsdale, Michigan. Muck soils are similar to those found at Houghton Lake. SCS soil surveys in these area provide the following data which can be used to make our estimates.

	<u>Hillsdale Sandy Loam</u>	<u>Houghton Muck</u>
Porosity	0.16	0.50
Permeability	178 - 556 m ³ /yr/m ²	1100 - 2200 m ³ /yr/m ²

Using a diffusion coefficient (D) of 1.0 m²/yr [7], tabulated values of specific gravity for various concentrations of sodium chloride and a soil concentration gradient of 100 mg/l/m leads to the following estimates of vertical dispersion.

<u>Diffusion plus gravity</u>	<u>Sandy Loam</u>	<u>Muck</u>
U _z	0.12-0.36 m/yr	.72-1.44 m/yr
z at t = 5 yrs	11 - 19 m	14.53 - 21.7 m
z at t = 10 yrs	18 - 33 m	24.8 - 39.2 m

These values were calculated using equation (5) and a value of C/C₀ of 0.01 which should approximate the solute dispersion front. To estimate the horizontal component we use a hydraulic gradient of 0.004 as discussed above in Section 4.5.1.

<u>Diffusion plus Hydraulic Gradient</u>	<u>Sandy Loam</u>	<u>Muck</u>
U _x	1.4 - 2.2 m/yr	4.4 - 8.8 m/yr
x at t = 5 yrs	51 - 77 m	51 - 95 m
x at t = 10 yrs	97 - 147 m	98 - 186 m

While these estimates are recognized as being limited because of the lack of specific parameter information they do provide insight into the dispersion problem. First if the fresh ground water media is free of impermeable layers preventing vertical movement then the contamination plume can be visualized as spreading in the horizontal direction of the hydraulic gradient but also downward from convective movement. Starting near the surface the plume will pass downward into the 20 to 30 meter depths of local domestic wells and eventually to depth which is out of reach to most water wells. Thus there is an annulus surrounding the source which is critical to the impact on local domestic supplies.

The spreading rates calculated above indicate that the downward movement is about one third of the horizontal. On that basis we would expect the depth of maximum concentration to be 66 m at the distance 200 m between the pond and nearest domestic well. The above rates would suggest that the solute front should not reach the nearest domestic waterwells for matter of years and furthermore when it does the effect could be minimal since the nearest domestic well has 40 meter depth.

Diffusion alone cannot account for sufficient movement in the horizontal direction of the farmhouse well during the estimated five years since the initial contamination began. On the other hand sufficient vertical movement appears quite feasible. A temporary reverse gradient from the pond during wet periods of high runoff would account for very little internal movement.

In summary the estimates as derived from the diffusion convection equations suggest that the solute will disperse very slowly and take several years to reach the nearest domestic well. In order to make a reliable prediction monitoring wells drilled to a depth of 20 to 30 meters will be needed to determine aquifer parameters and establish the contamination zone.

While extent of the groundwater dispersal of brine contaminants may be progressing very slowly, the ultimate fate for some of these materials is wide distribution in the local unconfined aquifer. There are two unknown conditions which could greatly change how this material spreads from the pond sediments. First the bottom of the pond depression could be lined with a clay layer of very low permeability. This layer would have the effect of confining contaminant to the muck sediments. A second possibility could produce just the opposite effect. Suppose there is a layer of coarse sand near these sediments. Coarse sand has been observed in drilling logs to exist in thin layers. If contaminants were to enter such a layer they would tend to move very rapidly in the sand compared to the typical loam soil. The horizontal spreading under this condition would be much greater than predicted above.

4.6 ANALYSIS FOR TRACE METALS

Several groundwater, surface water and brine samples were analyzed for selected trace metal concentrations. These analyses were made to help clarify which elements are present in sufficient quantities to pose a potential toxic problem in event that groundwater contamination occurs. Concentrations of three metals, Mn, Cu, and Zn were analyzed in a large number of samples. These data are compiled with individual data results in Appendix B. Of these three Mn was found to be present in almost every sample. Concentrations ranged from 0.01 mg/l in groundwater samples to over 7 mg/l in brine samples. Zn and Cu were found in brine samples with concentrations of 1.5 and 0.3 mg/l respectively. However, Zn and Cu were not detected in water samples other than those obviously contaminated with brine. Manganese found in the presence of high chlorides could serve as an additional indication of groundwater contamination.

A series of water samples were analyzed by ERG for a number of trace constituents. The results shown in Table 10 generally indicate levels well below USPH National drinking water standards. These samples came from brine, waterwells, and surface water. In the case of As and Se the results from the first tests shown in the table had abnormally high detection limits. The problem was caused by the presence of a large bromine concentration which causes interference when using the neutron activation technique. Alternatively a few samples were reanalyzed using a more appropriate technique. These results shown in parenthesis are below critical standard and suggest that As and Se do not present a problem for this shale site.

Lead was also found to give alarming concentration in the first run. Values of lead as high as 1.7 mg/l were found in brine and 0.13 in a local domestic water well. A subsequent run made by ERIM on a set of 50 samples using different instrumentation could not detect any concentrations of lead in brine samples over 0.10 mg/l. A third test also shown was made by ERG on six similar samples which also failed to detect the presence of lead at a limit of 0.01 mg/l. A brine sample collected by Dow on February 24, 1977 and subsequently analyzed for

TABLE 10. TRACE METAL ANALYSIS (mg/l) FOR SELECTED WATER SAMPLES

Sample Number	Location	As	Ni	Cr	Cd	Se	Pb	Mn	Zn	Analytical Laboratory
163	300 series mudpit	<3.000	ND	0.180	ND	<1.500	1.600	0.330	0.100	ERG
212	Wet area south forty	<0.600	ND	ND	ND	<0.400	0.095	0.075	0.050	ERG
252	Well 301 at well head	<5.000	ND	<0.160	ND	<1.300	1.700	8.300	0.200	ERG
281	Farmhouse waterwell	<0.060	ND	ND	ND	<0.800	0.170	0.160	0.035	ERG
283	Seymour Cr. (S)	<0.070	0.015	0.025	ND	<0.600	0.140	0.790	0.075	ERG
288	Sichko waterwell	<0.060	ND	ND	ND	<0.800	0.130	0.035	0.040	ERG
289	Farmhouse waterwell					ND				ERG
303	Pond sediments	<0.500	0.045	0.070	ND	<0.700	0.520	5.000	0.290	ERG
304	Pond sediments	<0.400	0.025	0.040	ND	<0.900	0.260	0.930	0.095	ERG
305	Pond sediments	0.020				ND	ND (ERG)			EN, ERG
308	Sichko waterwell	0.003				ND	ND (ERG)			EN, ERG
334	Farmhouse waterwell	ND				ND				EN
344	Pond sediment						ND			ERG
384	Dow waterwell	ND	ND	ND	ND	ND	0.034	0.075	3.000	ERG
385	Pond	ND	ND	ND	ND	<0.007	0.094	0.720	0.037	ERG
386	Farmhouse waterwell	ND	ND	ND	ND	ND	0.039	0.076	0.026	ERG
388	Seymour Cr. (S)	ND	ND	ND	ND	ND	0.051	0.120	ND	ERG
390	Test well #2	ND	ND	ND	ND	ND	0.028	ND	0.013	ERG
391	South forty brine pit	<1.100 0.007	ND	0.047	ND	<0.240 0.001	0.410	2.300	0.780	ERG EN
392	Test well #1	<0.080	ND	0.065	ND	<0.010	0.250	1.100	0.480	ERG
	LERC retort water 2	<0.100	0.140	0.039	0.016	<0.080	0.800	19.000	3.300	ERG
	Detection limit 3	0.001	0.010	0.005	0.003	0.001	0.010	0.005	0.005	

1. ND - Not detected.

2. Found lg concentration of 0.20 mg/l.

3. Detection limit without interferences.

USPH Drinking water standards (mg/l) As 0.005, Cd 0.010, Cr 0.05, Se 0.01, Pb 0.05, Mn 0.05, Zn 5.0.

LERC Laramie Energy Research Center

ERG Environmental Research Group, Ann Arbor, Michigan

EN Environmental Control Technology Inc., Ann Arbor, Michigan

lead showed a concentration of 5 mg/l. There exists sufficient inconsistencies in these results to warrant further analysis of water samples for lead concentration during the remainder of this monitoring program.

Also included in the above analysis was a sample of retort water from Run S-54 made in the LERC's ten ton retort using Antrim shale. While showing large concentrations of chloride, manganese and zinc, mercury and molybdenum were also found at concentrations of 0.2 and 0.1 mg/l respectively making the retort water a potentially hazard waste. These elements were not found to be present in retort water samples analyzed at LERC during a similar test made in 1977 [8].

4.7 DISCUSSION

The water quality data collected during the last year from water surface and groundwater sources do not indicate that site development activities have had any measurable impact. Drilling and pits have been shown to contribute brine leachings to the groundwater in an unknown amount. Disposal of this material into the groundwater system is expected to be quite slow. Since muds are removed from these pits the amount which can infiltrate is checked. Close monitoring of the drilling activity should continue in order to minimize any adverse impacts. Application of brine to local roads as a means of disposal may have impact on the adjacent area as material is constantly washed to the shoulder and beyond.

Studies conducted on the site pond and farmhouse well have more clearly identified them as contaminated areas which are not related to present site activities. While the ultimate fate of the contaminated zone has been addressed there exists at present insufficient data to carry any prediction beyond speculation.

While any groundwater contamination or degradation must be considered serious, the present situation, as we understand it, does not represent a serious threat to local domestic supplies. However, because of present uncertainties in the assessment of this condition we feel it necessary to

continue to monitor all aspects of the problem and to provide Dow with updated environmental assessments. Specifically, the chloride problem will be reviewed with Dow on a periodic basis during the remainder of the monitoring program in order to appraise them of conditions and recommend corrective actions.

SUMMARY OF RESULTS AND RECOMMENDATIONS

During the past year efforts have been focused on monitoring site development activities associated with the Antrim shale experiment. Several tasks completed during this year's work have helped to establish baseline conditions against which future data can be compared. Some of the baseline measurements have been influenced by the various activities which took place at the site prior to the beginning of the current DOE sponsored program. Brine leakage and some surface disturbance associated with the previous well drilling have affected the site to the extent that some impacts related to the current development activities may not be totally separated or quantifiable. The approach thus far has been to examine all environmental conditions of the site and at the same time keep proper perspective as to which program has caused the condition to occur.

Air Quality

1. The air quality monitoring of the limited in situ combustion trial on the Rhoburn wells indicate that emissions were below National Ambient Air Quality standards for oxides of nitrogen, sulfur-dioxide, carbon monoxide, and particulates. There was no degradation of local air quality whatsoever from these tests. These tests, however, were not considered extensive or totally successful. Thus future combustion trials to be conducted on the south forty could potentially have some air quality impact.

Land Resources

2. Limited surface elevation monitoring indicated there has been no subsidence or uplift since beginning hydro and explosive fracturing operations.
3. An extensive survey of the site vegetation community has documented the present impacts from drilling and other surface disturbance. Sufficient

vegetation data has been now gathered to serve as a benchmark against which future impacts may be measured.

4. A soil survey has quantified the changes in soil condition caused by compaction and deposition of drilling wastes. Impacts on soil and vegetation as surveyed to date are considered to be acceptable with such development.

5. Impulsive or continuous noise sources monitored during the past years have not presented any significant problem to site workers or local residents.

6. A survey of the residential community neighboring the site suggests that the project would be more acceptable if information on project activities were disseminated on a more regular basis.

Water Quality

7. Monitoring of surface and ground water quality has not shown any major impacts from current activities. Drilling mudpits were found to allow some contamination of the immediate groundwater. This impact although presently not fully evaluated, is not expected to be significant because of the small quantities involved and the remoteness from existing water wells. The removal of drilling muds and containment of brine has greatly reduced any impact from these pits.

8. Analysis of samples for trace metals show only manganese and possibly lead in sufficient quantities to pose special problems in any brine contamination problems occurring at the site.

9. Two impacts have been identified which relate to previous experiment which began in 1972. The farmhouse water well and the nearby pond both exhibit high chloride levels which are believed to be the result of earlier brine contamination associated with drilling of the Rhoburn well pattern. A study of the pond area has revealed that substantial quantities of brine salt are present in the sediments. It is highly suspected that the farmhouse well has been contaminated by salts which are dispersing from these sediments.

RECOMMENDATIONS

In consideration of the program completed to date the following recommendations are made for future monitoring efforts.

Air Quality

1. Air quality monitoring of the upcoming combustion trials should begin at the flare stack. Once combustion has been established it should be relocated to monitor the impact of any air emissions.
2. Because of the large quantities of sulfur present in the Antrim shale provisions should be made to analyze, selected off gas samples for total sulfur as sulfur dioxide and various chemical species. Gas samples to be analyzed for specific sulfur compounds would have to be collected prior to the flare stack in the present experimental system.

Land Resources

3. Control plots should be set up to monitor the changes in soil and vegetation conditions. Aerial photography should be continued on a regular basis to assess changes in surface disturbance.
4. Adverse effects, if any, on soil conditions and local groundwater resulting from the disposal of waste brines of area gravel roads should be determined.
5. The quantity of fugitive dust from site use and development activities should be measured and its impacts assessed.

Water Quality

6. Monitoring of mudpits used in site drilling operations should be continued. Flexible liners similar to those presently being used in the two brine storage pits would virtually eliminate any contamination possibility.
7. The temporary centralized disposal areas for drilling muds should be contained with dikes or covered control to losses by erosion.

8. Some investigation in addition to regular monthly sampling should be conducted to help further define to what extent the local groundwater is contaminated as observed with the farmhouse water well. A phased program of investigation is recommended which would involve drilling at least one monitoring well to establish the hydraulic gradient (a total of three wells are needed) and to vertically profile the contaminated zone. Any significant degradation of the local groundwater aquifer is considered serious in that it could restrict potential use of the site property and/or restrict future use of adjoining lands. Quality of groundwater is protected from degradation by state regulations.

9. Although presently considered to be a remote possibility contamination of deep groundwater by the in situ process could develop from vertical fracturing. Assessing the vertical extent of these fracture and monitoring deep aquifers for constituent from in situ combustion may become necessary prior to operational implementation of the process.

10. Effects from dewatering in the combustion zone should be examined if possible from existing deep monitoring wells.

11. Combustion product waters and oils should be examined for toxic trace metals and organic compounds.

APPENDIX A
DESCRIPTIONS OF VEGETATION COMMUNITIES

DESCRIPTIONS OF THE COMMUNITIES

To develop the floristic list of the site, data were pooled from all three sources; samples, transects, and observations. At the time the list was compiled a code was also assigned to each species indicating in which community(ies) its occurrence had been noted. Using this information and the individual plot data for each community, we then constructed Tables A1, A2, A3, and A4. These tables summarize for each community by vegetation physiognomy: (1) the number of species detected on one or more of the sample plots, (2) the number of species observed by other means, (3) the total number of species found, and (4) the number of unique species (species found only in a single community). From an analysis of these tables it is clear that there are substantial differences in both the physiognomic structure of the communities found on the Peck site and their floristic composition. These differences are the basis for the distinctive characteristics of each community which will now be examined in more detail.

1. OLD FIELDS. The old field community contains more species (71) than the other communities, but its ratio of unique species to total species ($27 \div 71 = 0.38$) is essentially the same as that of the fencerow and rockpile communities (0.38 and 0.32, respectively). In terms of floristic composition, the old fields appear to have much in common with both the fencerows and the rockpiles. Note that the index for old fields compared to fencerows and rockpiles are about equal (43 and 46) but that the index for fencerows and rockpiles is much less (25).

Another characteristic the old fields share with the rockpiles is the same relative structural composition; i.e., the relative percentage of the species of each community that fall into the three main physiognomic classes of vegetation: herbaceous plants, shrubs and shrub-like plants, and trees. Interestingly, the wetlands also share this

TABLE A1. NUMBER OF PLANT SPECIES FOUND IN THE OLD FIELD COMMUNITY

	Found on Quadrats (No.)	Not Found On Quadrats (No.)	Total (No.) (%)	Unique to This Community (No.)
I. Herbaceous				
A. Mosses, Ferns & Horsetails	2	0	2 / 3	1
B. Sedges, Rushes, Cattails	0	2	2 / 3	0
C. Grasses	5	1	6 / 8	1
D. Forbs				
1. Legumes	1	6	7 / 10	4
2. Others	18	23	41 / 58	18
II. Shrubs, Tree, Seedlings & Vines	2	8	10 / 14	1
III. Trees	3	0	3 / 4	1
TOTALS	31 (44%) +	40 (56%) =	71 / 100	27 (38%)

TABLE A2. NUMBER OF PLANT SPECIES FOUND IN THE FENCEROW COMMUNITY

	Found On Quadrats(No.)	Not Found On Quadrats (No.)	Total (No.) (%)	Unique to This Community (No.)
I. Herbaceous				
A. Mosses, Ferns & Horsetails	0	1	1 / 2	1
B. Sedges, Rushes, Cattails	0	0	0 / 0	0
C. Grasses	3	0	3 / 6	0
D. Forbs				
1. Legumes	2	0	2 / 4	0
2. Others	16	3	19 / 36	6
II. Shrubs, Tree Seedlings & Vines	4	10	14 / 27	5
III. Trees	5	8	13 / 25	9
TOTALS	30 (58%)	+ 22 (42%) =	52 /100	21 (38%)

TABLE A3. NUMBER OF PLANT SPECIES FOUND IN THE ROCKPILE COMMUNITY

	Found On Quadrats (No.)	Not Found On Quadrats (No.)	Total (No.) (%)	Unique to This Community (No.)
I. Herbaceous				
A. Mosses, Ferns & Horsetails	1	0	1 / 2	0
B. Sedges, Rushes, Cattails	0	0	0 / 0	0
C. Grasses	5	0	5 / 12	0
D. Forbs				
1. Legumes	2	1	3 / 7	1
2. Others	15	13	26 / 63	8
II. Shrubs, Tree Seedlings, Vines	2	4	6 / 15	4
III. Trees	0	0	0 / 0	0
TOTALS	25 (61%) +	16 (39%) =	41 / 100	13 (32%)

TABLE A4. NUMBER OF PLANT SPECIES FOUND IN THE WETLAND COMMUNITY

	Found On Quadrats(No.)	Not Found On Quadrats (No.)	Total (No.) (%)	Unique to This Community (No.)
I. Herbaceous				
A. Mosses, Ferns & Horsetails	0	1	1 / 2	1
B. Sedges, Rushes, & Cattails	4	2	6 / 13	5
C. Grasses	0	3	3 / 7	3
D. Forbs				
1. Legumes	0	1	1 / 2	1
2. Others	3	25	28 / 61	25
II. Shrubs, Tree Seedlings & Vines	2	4	6 / 13	3
III. Trees	1	0	1 / 2	0
TOTALS	10 (22%)	36 (78%)	46 /100	38 (83%)

same general physical structure. This general pattern, which can be observed in Table A5 is as follows: herbaceous plants comprise 80-85% of the total number of species in each community, followed by shrubs, tree seedlings and vines, which make up the next largest group at 10 to 15% of the total, followed by trees, which amount to less than 5% of all the species in the community. The significance of this pattern is that, if one wishes to effectively characterize each of these communities, one must pay particular attention to the herbaceous species, both those that are most common within the community, and those that are unique to it.

The basic criterion used to establish the importance of a given species to the community within a physiognomic class was the frequency with which it is found in the community. The way we determined frequency of occurrence for a species was by a comparison of (1) sample and (2) transect and observation data. Frequency was first defined in broad classes (Table A6) and then the sample plot and transect/observation data examined for each species in order to determine to which class it should be assigned. The result of this class assignment procedure applied to the old field community is shown in Table A7, which lists the species found in the old fields and their relative abundance. Species are listed alphabetically within each vegetation physiognomic group for each frequency class. No attempt was made to rank species within a frequency class.

From Table A7 it is obvious that the old field community found on the Peck site is a rather ordinary and typical example of the type of plant community that soon springs up on farmland left fallow for several years. There are only slight variations in the floristic composition of this community throughout the site. For example, slightly moist soil conditions in the field in the northwest corner of the site result in more diversity here because of soil conditions which favor moisture-loving species, such as lance-leaved goldenrod.

TABLE A5. RELATIVE COMPOSITION OF COMMUNITIES BASED
ON PHYSIOGNOMIC VEGETATION CLASS

Community	Herbaceous	Shrubs, Tree Seedlings and Vines	Trees
Old Fields	82%	14%	4%
Fencerows	48%	27%	25%
Rockpiles	85%	15%	0%*
Wetlands	85%	13%	2%

*From observation of airphotos it can easily be seen that there are trees growing on at least a few of the rockpiles. These did not occur on any of the rockpiles we visited, however, and in our transects we apparently either did not encounter any rockpiles with trees on them, or, any species observed was already recorded, so that a new entry indicating the presence of trees on rockpiles was not made. If it is assumed that perhaps 2 or 3 tree species are involved, then a more realistic estimate for this class for rockpiles is probably 5%, similar to the old fields.

TABLE A6. DESCRIPTION OF FREQUENCY CLASSES USED FOR
DESCRIBING THE RELATIVE ABUNDANCE OF
VEGETATION SPECIES FOUND ON THE PECK SITE

<u>Class</u>	<u>Description</u>
Abundant	Very common throughout a community, likely to form dense mats or stands
Common	Widespread and generally plentiful throughout a community
Frequent	Intermediate in abundance and distribution, likely to be found if one looks for it
Occasional	Scattered or infrequent in a community, may be absent from parts of it
Rare	Occurring only in small numbers and often absent from large parts of a community

TABLE A7. LIST OF SPECIES FOUND IN THE OLD FIELDS AND
THEIR RELATIVE ABUNDANCE

<u>Frequency Class</u>	<u>(Scientific Name)</u>	<u>Species</u> <u>(Common Name)</u>
Abundant	<u>Grasses</u>	
	1. Agropyron repens (i)	quack grass
	2. Phleum pratense (i)	timothy
	3. Poa pratensis (i)	Kentucky bluegrass
Common	<u>Sedges, Rushes & Cattails</u>	
	4. Carex spp.	sedges
	<u>Grasses</u>	
	5. Poa annua* (i)	spargrass
	6. Poa compressa (i)	Canada bluegrass
	<u>Legumes</u>	
	7. Melilotus alba* (i)	white sweet clover
	8. Melilotus officinalis* (i)	yellow sweet clover
	<u>Other Forbs</u>	
	9. Achillea millifolium	yarrow
	10. Asclepias syriaca	common milkweed
	11. Aster sp.	wild aster
	12. Barbarea vulgaris (i)	winter cress
	13. Chrysanthemum leucanthemum (i)	ox-eye daisy
	14. Cirsium arvense(i)	Canada thistle
	15. Cirsium vulgare (i)	bull thistle
	16. Daucus carota (i)	wild carrot
	17. Erigeron philadelphicus	common fleabane
	18. Geum aleppicum*	yellow avens
	19. Hieracium aurantiacum (i)	orange hawkweed
	20. Hieracium florentium* (i)	hawkweed
	21. Hieracium pratense (i)	king devil
	22. Hypericum perforatum* (i)	common St. John's wort
	23. Oenothera biennis*	common evening-primrose
	24. Oxalis sp.	sheep sorrel
	25. Potentilla recta*(i)	roughfruited cinquefoil
	26. Rumex acetosella*(i)	red sorrel
	27. Solidago canadensis	Canada goldenrod
	28. Solidago graminifolia*	lance-leaved goldenrod

<u>Frequency Class</u>	<u>Species</u>	
	<u>(Scientific Name)</u>	<u>(Common Name)</u>
Frequent	<u>Legumes</u>	
	29. <i>Medicago lupulina</i> (i)	black medic
	30. <i>Trifolium pratense</i> (i)	red clover
	<u>Other Forbs</u>	
	31. <i>Cichorium intybus</i> (i)	chicory
	32. <i>Fragaria virginiana</i>	strawberry
	33. <i>Lactuca canadensis</i>	wild lettuce
	34. <i>Linaria vulgaris</i> (i)	butter-and-eggs
	35. <i>Plantago rugellii</i>	pale plantain
	36. <i>Potentilla argenta</i> (i)	silvery anquefoil
	37. <i>Rumex crispus</i> *(i)	sour dock
	38. <i>Solidago nemoralis</i> *	gray goldenrod
Occasional	<u>Mosses, Ferns & Horsetails</u>	
	39. <i>Equisetum arvense</i>	common horsetail
	40. <i>polytsichum</i> sp.*	moss
	<u>Sedges & Rushes</u>	
	41. <i>Juncus effusus</i>	rush
	<u>Grasses</u>	
	42. <i>Bromus secalinus</i> (i)	cheat grass
	<u>Legumes</u>	
	43. <i>Medicago sativa</i> *(i)	alfalfa
	44. <i>Trifolium hybridum</i> *(i)	alishe clover
	45. <i>Vicia villosa</i> (i)	hairy vetch
	<u>Other Forbs</u>	
	46. <i>Amaranthus retroflexus</i> (i)	pigweed
	47. <i>Arctium minus</i> (i)	common burdock
	48. <i>Dianthus armeria</i> *(i)	Deptford-pink
	49. <i>Hypericum punctatum</i> *	spotted St. John's wort
	50. <i>Polygonum aviculare</i> *	prostrate knotweed
	51. <i>Solidago juncea</i> *	early goldenrod
	52. <i>Verbascum thapsus</i> *(i)	common mullein
	<u>Shrubs, Tree Seedlings, Vines</u>	
	53. <i>Apocynum androsaemifolium</i>	spreading dogbane
	54. <i>Cornus stolonifera</i>	red-asier dogwood
	55. <i>Parthenocissus vitaceae</i>	virginia creeper
	56. <i>Rubus allegheniensis</i>	highbush blackberry

<u>Frequency Class</u>	<u>(Scientific Name)</u>	<u>Species</u>	<u>(Common Name)</u>
Rare	<u>Other Forbs</u>		
	57. Lactuca biennis*		blue lettuce
	58. Leonurus cardiaca*(i)		motherwort
	59. Polygonum convolvulus(i)		black bindweed
	60. Potentilla canadensis		dwarf cinquefoil
	61. Potentilla nowegica*		rough cinquefoil
	62. Prunella vulgaris*(i)		hear-all
	<u>Shrubs, Tree Seedlings, Vines</u>		
	63. Acer rubrum (seedlings)		red maple
	64. Cornus amomum		pale dogwood
	65. Crataegus spp.		hawthorn
	Malus pumila (seedlings)	vid. 69	
	Prunus avium (seedlings)	vid. 70	
	66. Rhus typhina		staghorn sumac
	67. Rosa palustris		swamp rose
	68. Rubus hispidus*		dewberry
	<u>Trees</u>		
	69. Malus pumila (i)		common apple
	70. Prunus avium (i)		sweet cherry
	71. Quercus bicolor*		swamp white oak

*indicates species found only in the OLD FIELD community

(i) introduced species, one that is not native to North America.

In contrast, the field in the southeast corner of the site appears to be drier, which may explain why it contains fewer species.

Two other things observable in Table A7 are (1) 36 (51%) of the species found in the old field community are non-native species, having been introduced mainly from Europe and Asia, and (2) nine of the "common" species are unique to this community. None of the other communities have as many unique species that are this abundant. These include: one grass, two legumes, and seven other forbs. The greater the number of unique species in a community and the greater their relative abundance the more diversity such a community adds to the landscape.

2. FENCEROWS. One and one-quarter linear miles of fencerows surround the Peck site and make up the fencerow community. This community exhibits the most physiognomic diversity of the four communities studied. The site as a whole has twenty-seven different species of shrubs, vines, or trees, and twenty-one of them are found only in this community. Significantly, nineteen of these twenty-one species are listed as either "occasional" or "rare", which means that only one or two individuals of that species were observed. Many of these species are clustered in one of two places; either along the southern fencerow or along the northern fencerow around the entrance drive. The east and west side fencerows are much more open, with grassy stretches alternating with patches of shrubs or groups of small trees.

Table A9 lists the species found in the fencerows and their relative abundance. Note that most of the common herbaceous species are also found in the old fields.

3. ROCKPILES. The rockpiles are the smallest community in terms of total area (1.2 acre). Yet, they are floristically distinctive, and contribute a total of thirteen unique species to the total flora list of the site. Most of these unique species are forbs, but four of them

TABLE A8. LIST OF SPECIES FOUND IN THE FENCEROWS
AND THEIR RELATIVE ABUNDANCE

<u>Frequency Class</u>	<u>(Scientific Name)</u>	<u>Species</u>	<u>(Common Name)</u>
Common	<u>Grasses</u>		
	1. Agropyron repens		quackgrass
	2. Phleum pratense		timothy
	3. Poa pratensis		Kentucky bluegrass
	<u>Other Forbs</u>		
	4. Achillea millefolium		yarrow
	5. Aster macrophyllus*		large-leaved aster
	6. Asclepias syriaca		common milkweed
	7. Barbarea vulgaris		winter cress
	8. Cirsium arvense		Canada thistle
	9. Cirsium vulgare		bull thistle
	10. Daucus carota		wild carrot
	11. Geum sp.		avens
	12. Hieracium sp.		hawkweed
	13. Solidago canadensis		Canada goldenrod
Frequent	<u>Legumes</u>		
	14. Medicago lupulina		black medick
	15. Trifolium sp.		clover
	<u>Other Forbs</u>		
	16. Cichorium intybus		chicory
	17. Fragaria virginiana		strawberry
	18. Lactuca canadensis		wild lettuce
	19. Solanum dulcamara		nightshade
	<u>Shrubs, Tree Seedlings, Vines</u>		
	20. Apocynum androsaemifolium		spreading dogbane
	21. Parthenocissus vitaceae		virginia creeper
	22. Spiraea alba		narrow-leaf meadowsweet
	23. Rhus typhina		staghorn sumac
	24. Rubus allegheniensis*		highbush blackberry
	25. Vitus riparia*		forest grape
Occasional	<u>Trees</u>		
	26. Prunus avium		sweet cherry
	<u>Mosses, Ferns, and Horsetails</u>		
	27. Pteridium aquilinum*		bracken fern

<u>Frequency Class</u>	<u>(Scientific Name)</u>	<u>Species</u>	<u>(Common Name)</u>
	<u>Other Forbs</u>		
	28. <i>Potentilla anserina</i> *		silver weed
	29. <i>Potentilla canadensis</i>		dwarf cinquefoil
	30. <i>Toxicodendron radicans</i> *		poison ivy
	<u>Shrubs, Tree Seedlings, Vines</u>		
	<i>Acer saccharinum</i> (seedlings)	vid. 38	pale dogwood
	31. <i>Cornus amomum</i>		red-osier dogwood
	32. <i>Cornus stolonifera</i>		gray-stemmed dogwood
	33. <i>Cornus racemosa</i> *		hawthorn
	34. <i>Crateagus</i> sp.		vid. 26
	<i>Prunus avium</i> (seedlings)		choke cherry
	35. <i>Prunus virginiana</i> *		red raspberry
	36. <i>Rubus idaeus</i> *		common elder
	37. <i>Sambucus canadensis</i>		
	<u>Trees</u>		
	38. <i>Acer saccharinum</i> *		silver maple
	39. <i>Acer saccharum</i> *		sugar maple
	40. <i>Malus pumila</i>		common apple
	41. <i>Populus tremuloides</i> *		quaking aspen
	42. <i>Quercus rubra</i> *		northern red oak
	43. <i>Ulmus americana</i>		American elm
Rare	<u>Other Forbs</u>		
	44. <i>Atriplex patula</i> *		sparscale
	45. <i>Lychnis alba</i> *		evening lychnis
	46. <i>Plantago lanceolata</i> *		English plantain
	<u>Trees</u>		
	47. <i>Acer rubrum</i>		red maple
	48. <i>Corya ovata</i> *		shagbark hickory
	49. <i>Fraxinus americana</i> *		white ash
	50. <i>Prunus serotina</i> *		wild blackcherry
	51. <i>Quercus alba</i> *		white oak
	52. <i>Tilia americana</i> *		American basswood

*indicates a species found only in this community

are shrubs. This is more than one sixth of the total number of shrub species on the site (22), indicating the relative floristic importance of the rockpiles. Several herbaceous species are also found only in the rockpiles, but only a few of them, such as sow-thistle, cocklebur and common dandelion are very abundant.

Individually, the rockpiles are highly variable. In some cases the rocks are piled around a large, single tree, in other cases the piles are quite extensive with rocks stacked as much as two feet deep. The general shape of the rockpiles is that of an elongated ellipse with the long axis of the ellipse oriented north-south. The rocks that form the piles vary in size from small cobbles to that of a bowling ball. These small "islands of dense cover have significant value for wildlife. The list of species found on the rockpiles and their relative abundance is presented in Table A9. As mentioned earlier, this list contains no trees.

4. WETLANDS. This community is floristically the most diverse. The ratio of unique species to total species for wetlands ($38 \div 46 = .83$) is well over double that of the other three communities. There are three commonly recognized types of wetlands occurring: shallow marsh, shrub swamp, and seasonally flooded depressions. Each of these types of wetland supports a different flora, and some are rich while others are poor in terms of the number of species present. For example, the large shallow marsh located in the eastern central portion of the site is composed for the most part of only three or four species: cattail and two or three types of beggar-ticks. In contrast, the large-deep marsh in the northeast corner of the property supports a varied flora.

Table A10 is a list of the flora found in the wetlands. It should be pointed out that while relative abundance ratings are assigned for each species, in this community many of the species listed as "common"

TABLE A9. LIST OF SPECIES FOUND IN THE ROCKPILES
AND THEIR RELATIVE ABUNDANCE

<u>Frequency Class</u>	<u>(Scientific Name)</u>	<u>Species</u>	<u>(Common Name)</u>
Common	<u>Grasses</u>		
	1. Agropyron repens		quack grass
	2. Phleum pratense		timothy
	3. Poa compressa		Canada bluegrass
	4. Poa pratensis		Kentucky bluegrass
	<u>Other Forbs</u>		
	5. Aster sp.		wild aster
	6. Chrysanthemum leucanthemum		ox-eye daisy
	7. Daucus carota		wild carrot
	8. Erigeron philadelphicus		common fleabane
	9. Hieracium aurantiacum		orange hawkweed
	10. Hieracium pratense		king devil
	11. Hypericum sp.		St. John's wort
	12. Linaria vulgaris		butter-and-eggs
	13. Oxalis sp.		sheep sorel
Frequent	14. Plantago rugelli		pale plantain
	15. Solidago canadensis		Canada goldenrod
	<u>Legumes</u>		
	16. Trifolium pratense		red clover
	<u>Other Forbs</u>		
	17. Ambrosia artemisiifolia*		common ragweed
	18. Chenopodium album*		lamb's quarters
	19. Cichorium intybus		chicory
	20. Lepidium virginicum*		poor-man's pepper
	21. Potentilla argenta		silvery cinquefoil
	22. Solanum dulcamara		nightshade
	23. Sonchus uliginosis*		sow-thistle
	24. Taraxacum officinale*		common dandelion
	25. Xanthium strumarium*		cocklebur
Occasional	<u>Mosses, Ferns and Horsetails</u>		
	26. Equisetum arvense		common horsetail
	<u>Grasses</u>		
	27. Bromus secalinus		cheat grass
	<u>Legumes</u>		
	28. Vicia angustifolia*		vetch
	29. Vicia vellosa		hairy vetch

<u>Frequency Class</u>	<u>(Scientific Name)</u>	<u>Species</u>	<u>(Common Name)</u>
	<u>Other Forbs</u>		
	30. <i>Arctium minus</i>		common burdock
	31. <i>Polygonum lapathifolium</i> *		pale smartweed
	<u>Shrubs, Tree Seedlings, Vines</u>		
	32. <i>Diervilla lonicera</i> *		northern bush-honeysuckle
	33. <i>Malus pumila</i> (seedlings)		common apple
	34. <i>Rhus glabra</i> *		smooth sumac
	35. <i>Rubus accidentalis</i> *		black raspberry
	36. <i>Spiraea alba</i>		narrow-leaved meadowsweet
Rare	<u>Other Forbs</u>		
	37. <i>Amaranthus retroflexus</i>		pigweed
	38. <i>Anthemus cotula</i> *		dogfennel
	39. <i>Polygonum convolvulus</i>		black bindweed
	40. <i>Potentilla canadensis</i>		dwarf cinquefoil
	<u>Shrubs, Tree Seedlings, Vines</u>		
	41. <i>Acer negundo</i> (seedling)*		box elder

*indicates species only found in this community

TABLE A10. LIST OF SPECIES FOUND IN THE WETLANDS AND
THEIR RELATIVE ABUNDANCE

<u>Frequency Class</u>	<u>(Scientific Name)</u>	<u>Species</u>	<u>(Common Name)</u>
Common	<u>Sedges, Rushes and Cattails</u>		
	1. <i>Typha latifolia</i> *		common cattail
	<u>Other Forbs</u>		
	2. <i>Alisma plantago-aquatica</i> *		water plantain
	3. <i>Bidens cernua</i> *		beggar-ticks
	4. <i>Bidens discoidea</i> *		beggar-ticks
	5. <i>Bidens frondosa</i> *		beggar-ticks
Frequent	6. <i>Hieracium</i> sp.		hawkweed
	7. <i>Rumex</i> sp.		dock
	<u>Sedges, Rushes & Cattails</u>		
	8. <i>Scirpus atrovirens</i> *		bulrush
	<u>Other Forbs</u>		
	9. <i>Solanum dulcamara</i>		nightshade
	<u>Shrubs, Tree Seedlings, Vines</u>		
	10. <i>Cephalanthus occidentalis</i> *		buttonbush
	11. <i>Salix lucida</i> *		shining willow
	12. <i>Spiraea alba</i>		narrow-leaf meadowsweet
Occasional	<u>Mosses, Ferns, and Horsetails</u>		
	13. <i>Onoclea sensibilis</i> *		sensitive fern
	<u>Sedges & Rushes</u>		
	14. <i>Carex lacustris</i> *		sedge
	15. <i>Carex stipata</i> *		sedge
	16. <i>Juncus effusus</i>		rush
	<u>Grasses</u>		
	17. <i>Calamagrostis canadensis</i> *		blue joint
	<u>Legumes</u>		
	18. <i>Apios americana</i> *		medic
	<u>Other Forbs</u>		
	19. <i>Eupatorium perfoliatum</i> *		boneset
	20. <i>Impatiens capensis</i> *		touch-me-not
	21. <i>Iris virginica</i> *		blue-flag
	22. <i>Lycopus americanus</i> *		cut-leaved water-horehound
	23. <i>Mentha arvensis</i> *		wild mint

<u>Frequency Class</u>	<u>(Scientific Name)</u>	<u>Species</u>	<u>(Common Name)</u>
	24. <i>Sium suave</i> *		water parsnip
	25. <i>Solidago adora</i> *		sweet goldenrod
	26. <i>Urtica dioica</i> *		stinging nettle
	27. <i>Verbena hastata</i> *		blue vervain
	<u>Shrubs, Tree Seedlings, Vines</u>		
	28. <i>Sambucus canadensis</i>		common elder
	29. <i>Viburnum lentago</i> *		sweet viburnum
Rare	<u>Sedges, Rushes, Cattails</u>		
	30. <i>Dulichium arundinaceum</i> *		sedge
	<u>Grasses</u>		
	31. <i>Eragrostis specabilis</i> *		bone grass
	32. <i>Glyceria sp</i> *		manna grass
	<u>Other Forbs</u>		
	33. <i>Chenopodium glaucum</i> *		goosefoot
	34. <i>Chenopodium murale</i> *		goosefoot
	35. <i>Cicuta bulbifera</i> *		water hemlock
	36. <i>Epilobium ciliatum</i> *		willow-herb
	37. <i>Epilobium nirsutum</i> *		willow-herb
	38. <i>Polygonum amphibium</i> *		water smartweed
	39. <i>Polygonum arifolium</i> *		halbearch-leaved tearthumb
	40. <i>Polygonum pensylvanicum</i> *		Pennsylvania smartweed
	41. <i>Polygonum persicaria</i> *		lady's thumb
	42. <i>Ranunculus sceleratus</i> *		cursed buttercup
	43. <i>Spergularia marina</i> *		sand spurry
	44. <i>Stachys palustris</i> *		woundwort
	<u>Shrubs, Tree Seedlings, Vines</u>		
	45. <i>Rosa palustris</i>		swamprose
	<u>Trees</u>		
	46. <i>Ulmus americana</i>		American elm

are only abundant locally. While wetlands provide much less cover for wildlife in winter many of the herbaceous species found only there on the site are good sources of food for wildlife.

In summary, from a vegetative standpoint the Peck site is a typical example of farmland that has been left fallow for several years. It is composed primarily of old fields covered by herbaceous plants introduced from Europe and Asia. Scattered throughout the old fields are rockpiles, which support several herbaceous species found nowhere else on the site, and which are often covered by shrubs. Two significant wetlands also occur on the site; both are shallow marshes. Most of the tree species found on the site are associated with the fencerows which surround the property.

APPENDIX B

Individual Water Quality Data For:

pH
Conductivity
Total Dissolved Solids
Suspended Solids
Sodium
Potassium
Calcium
Magnesium
Chloride
Fluoride
Manganese
Zinc
Copper

For the period beginning on February 17, 1978 and ending on
January 12, 1979.

TABLE B1
WATER QUALITY SAMPLING SITES

<u>Station Number</u>	<u>Location</u>
1.	Dow Water well supplying work site.
2.	SE corner of pond in NE portion of plot.
3.	North Forty Brine Pit.
4.	South Forty Brine Pit.
5.	Brown Road Wier 1/3 mile south of Mortimer where swamp site drainage crosses road.
6.	Seymour Creek (North) at Mortimer Line Road.
7.	Bradley Creek and Burns east of Brownstage measurement NE corner of bridge from lower rail brace.
8.	Seymour Creek (South) at Kilgore Road (Station 1 on previous Dow work).
9.	Black River and Galbraith Road.
10.	Farm house water well.
11.	Mortimer Road NW corner Dow site.
12.	Bricker Road 1/4 mile north of Burns Line.
13.	Seymour Creek (East) at Black River Road.
14.	300 series test wells #1, #2, and #3.
15.	R. Sichko water well located 600 feet NE of pond.
16.	Brown water well located 900 feet NE of pond.

TABLE B2 RESULTS FOR WATER SAMPLES COLLECTED ON 2/17/78

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)*	Zinc (ug/l)*	Copper (ug/l)*
145	Sey. Cr. (N)	7.04	500	6860	402	7.4	2.85	90.7	23.4	7.8			
146	Sey. Cr. (E)	7.80	650	0	403	23.5	2.65	89.6	27.6	26.8			
147	Dow water well	8.16	342	1	204	5.7	0.99	43.4	20.5	6.6			
148	Sey. Cr. (S)	7.89	610	3	357	12.5	2.50	80.7	27.6	16.5			
149	Pond	7.57	1950	49	1330	265.0	5.00	164.0	47.1	530.0			
150	Black River	8.11	820	3	531	55.0	3.40	108.0	29.7	56.0			
151	flow across entrance road	7.43	215	17	135	6.5	2.85	22.5	6.6	15.3			

TABLE B3 RESULTS FOR WATER SAMPLES COLLECTED ON 4/5/78

152	Pond	7.48	319	17	222	32.50	4.95	33.5	9.0	57.0	0.13	25	N.D.
153	Dow water well	8.11	338	7	137	6.40	0.92	40.4	21.8	9.4	0.08	300	N.D.
154	Mortimer Line Rd.	7.23	368	30	263	21.00	4.00	48.9	9.1	73.0			
155	Bricker Rd.	7.23	150	26	92	1.32	3.50	11.5	4.9	6.8			
156	Brown Rd. Wier	7.68	342	5	175	19.50	3.10	44.5	13.9	38.5	0.03	N.D.	N.D.
157	Sey. Cr. (N)	7.52	339	13	247	4.25	3.26	53.3	14.8	14.6			
158	Sey. Cr. (S)	7.42	250	58	205	5.30	4.50	55.3	15.4	15.5	0.05		
159	Black River	7.30	318	375	250	9.80	5.50	41.8	11.2	20.0			
160	Sey. Cr. (E)	7.46	292	79	213	5.90	4.75	35.7	11.2	16.5			

N.D. - Not Detected

*Detection Limits (mg/l), Mn (0.01), Zn (0.005), Cu (0.01)

TABLE B4 RESULTS FOR WATER SAMPLES COLLECTED ON 4/25/78

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)	Zinc (ug/l)	Copper (ug/l)	Fluoride (mg/l)
161	300 series: mud pit; clear fluid near rig	11.03	21,000	19	17,600	3,838	424	150	6.4	14,025	0.10	25	50	<0.10
162	300 series: mud pit; inside settling tank	8.58	4.6x10 ⁵	224	1.0x10 ⁵	23,300	1,350	18,600	762.0		0.39	177	275	<0.11
163	300 series: mud pit; clear fluid	8.14	1.4x10 ⁵	133	92,608	20,500	1,200	17,800	580.0	1.3x10 ⁵	0.39	159	250	<0.10
164	300 series: mud pit; mud sample	9.23	1.2x10 ⁵	120	1.0x10 ⁵	23,000	1,300	20,600	205.0	90,100	1.22	115	275	<0.10
165	surface water, small wetland near 300	8.62		44	18	0.36	1.95	<1.0	<1.0	0.65	0.08	225	ND	<0.10
166	crescent swamp: north portion, south forty	8.23		3	61	8.40	3.90	1.1	<1.0	20.30	0.03	ND	ND	<0.10
167	Dow water well	7.77		3	226	5.40	0.77	61.6	21.4	6.30	0.08	220	ND	0.00
168	North forty Brine pit	6.19	1.5x10 ⁵	106	1.2x10 ⁵	41,100	301	11,600	3,000	97,900	6.20	1,240	225	<0.10
169	Brown Road Wier	7.79		4	582	20.40	2.50	82.5	24.7	4.10	0.05	ND	ND	0.13
170	Pond	7.88	1,180	6	780	163	8.30	84.5	25.8	352	0.05	ND	ND	0.14
171	Sey. Cr. (N)	8.46		11	379	5.60	1.90	76.8	23.0	15.50	0.03	ND	ND	0.15
172	Sey. Cr. (S)	8.39		4	452	8.40	2.45	84.1	25.5	18.60	0.03	ND	ND	0.18
173	Bradley Cr.	8.20	710	12	453	10.50	3.25	88.0	28.6	25.50				
174	Bricker Rd.	7.81	620	247	372	4.30	4.05	76.4	23.8	17.50				
175	Mortimer Line Rd.	7.86	620	28	398	13.70	5.30	71.3	16.3	120.00				
176	Wet area next to Mortimer Line Rd., East of farmhouse	7.55	362	4	259	13.50	4.06	41.2	8.8	56.00				

TABLE B5 RESULTS FOR ISCO WATER SAMPLES COLLECTED
FROM THE POND DURING
THE PERIOD APRIL 25, 1978 to JUNE 13, 1978

Sample #	Date	Chloride (mg/l)	Calcium (mg/l)	Magnesium (mg/l)
177	April 25, 1978	248	86.5	27.0
178	26	265		
179	27	285	88.4	28.5
180	28	285		
181	29	308	91.2	30.0
182	30	310		
183	May 1, 1978	318	92.0	31.0
184	2	317		
185	3	325	89.0	30.5
186	4	315		
187	5	298	87.5	29.8
188	6	327		
189	7	332	90.0	31.5
190	8	342		
191	9	403	94.2	29.5
192	10	364		
193	11	375	98.5	33.0
194	12	395		
195	13	360	98.5	30.5
196	14	350		
197	15	344	97.0	29.6
198	16	350		
199	17	400	103.2	32.5
217	19	300		
218	20	242	133.5	32.8
219	21	248		
220	22	286	115.5	34.5
221	23	288		
222	24	285	114.5	35.0
223	25	335		
224	26	342	117.0	37.5
225	27	350		
226	28	360	117.0	39.0
227	29	300		
228	30	425	121.0	40.3
229	June 1, 1978	356		
230	2	374	115.0	40.2
231	3	354		
232	4	390	116.5	41.8
233	5	410		
234	6	452	121.3	43.0
235	7	522		
236	8	438	117.8	42.5
237	9	588		
238	10	490	129.5	44.5
239	11	482		
240	12	530	139.0	49.0
241	13	420		

TABLE B6 RESULTS FOR WATER SAMPLES COLLECTED ON MAY 18, 1978

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)	Zinc (ug/l)	Copper (ug/l)	Fluoride (mg/l)
200	Test well #1 after 10 min. of pumping	6.40	16,000	41	24,600	3,200	188.0	11,400	298	20,100	0.63	94	100	<0.10
201	after 3 min. pumping	6.41	26,500	313	40,100	3,600	270.0	19,900	487	33,800	0.54	940	150	<0.10
202	Well #2 after 5 min. pumping	7.25	175	695	223	8.3	1.50	50.5	13.8	9.60	0.03	ND	ND	0.15
203	after 20 min. pumping	7.29	150	7	202	5.5	1.18	41.5	12.5	3.20	0.03	ND	ND	0.18
204	after 90 min. pumping	7.30	140	9	208	3.7	0.98	41.5	13.5	1.25	0.03	ND	ND	0.17
205	Brown Road Wier	7.00	285	4	537	19.9	2.95	88.0	25.3	50	0.10	ND	ND	0.14
206	Test well #3 after 5 min. pumping	7.28	150	5	228	6.4	1.09	39.0	20.5	5.40	0.03	ND	ND	0.15
207	after 20 min. pumping	7.20	150	2	271	5.9	0.98	53.0	21.3	2.50	0.03	31	ND	0.14
208	after 90 min. pumping	7.30	55	1	258	5.8	0.91	49.0	21.7	1.80	ND	ND	ND	0.14
209	Farmhouse water well	6.70	500	3	707	115.0	3.58	116.0	33.0	375.0	0.13	295	ND	<0.10
210	Dow water well	7.34	170	1	287	6.3	1.15	62.0	20.7	7.90	0.08	182	ND	0.10
211	North forty brine pit	5.30	90,000	113	1.32x10 ⁵	56,613	454.00	30,000	4069	1.07x10 ⁵	6.67	1490	250	<0.10
212	Wet area, north- ern part of south forty	6.60	85	4	126	15.0	6.21	18.7	4.8	29.0	0.08	31	ND	<0.10

TABLE B6 RESULTS FOR WATER SAMPLES COLLECTED ON MAY 18, 1978 (Continued)

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)	Zinc (µg/l)	Copper (µg/l)	Fluoride (mg/l)
213	Wet area, near 300 series	6.64	32	18	42	0.60	3.54	3.4	0.5	0.68	0.05	25	ND	0.10
214	300 series, mud pit	11.00	14,000	45	20,900	25,500	765.00	8,800	ND	13,500	1.25	47	75	
215	Sey. Cr. (S)	8.22	300	9	495	7.8	3.85	97.0	28.3	22.5	0.03	ND	ND	
216	Sey. Cr. (N)	8.40	220	3	425	5.7	3.25	78.5	28.5	15.3	0.03	ND	ND	

TABLE B7 RESULTS FOR WATER SAMPLES COLLECTED ON JUNE 14 and 15, 1978

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)	Zinc (ug/l)	Copper (ug/l)	Fluoride (mg/l)
242	Brown Rd. Wier	7.40	230	5	415	11.6	3.00	90.8	28.9	18.0	0.59	ND	ND	0.12
243	Sey. Cr. (N)	7.51	200	10	373	4.8	0.67	77.0	23.5	5.4	0.23	ND	ND	0.10
244	Sey. Cr. (S)	7.80	230	25	512	8.4	2.00	81.0	28.0	13.5	0.05	160	ND	0.18
245	Dow Water well	7.43	270	1	278	5.1	1.20	62.5	20.3	5.7	0.05	193	ND	<0.10
246	North Forty Brine Pit	<5.00	12x10 ⁵	773	1.64x10 ⁵	55,100	455.00	36,500	5,220	1.25x10 ⁵	7.58	1,390	275	<0.10
247	Long wet area, north portion of south forty	6.12	190	27	189	24.5	3.20	17.0	3.2	53.0	0.26	ND	ND	<0.10
248	300 series, mud pit	6.98	15,000	240	24,300	5900	403.00	8,840	0.8	17,800	2.35	370	175	<0.10
249	wet area, west of 300 mud pit	7.26	45	42	72	0.51	5.80	4.5	0.6	1.95	0.22	ND	ND	<0.10
250	100 series, east mud pit	6.98	15,000	68	25,800	3720	63.7	4,408	525	14,800	3.12	114	50	<0.10
251	200 series, mud pit	>9.00	7,000	1,290	10,750	3140	84.1	1,320	0.0	7,400	0.08	50	25	<0.10
252	301 wetland pit	7.18	85,000	151	1.25x10 ⁵	32,600	909	41,300	1,200	2.03x10 ⁵	7.88	380	275	<0.10
253	Pond	7.48	1,300	6	1,610	420	4.80	143	52.2	760	0.15	ND	ND	<0.10
254	Farm house well after 2 hr. pumping	7.26	500	8	692	102	2.35	117	32.8	345	0.13	54	ND	<0.10
255	Wet area next to Mortimer Road, NE of farm house	6.92	600	6	941	137	11.00	140	27.2	420	1.75	ND	ND	<0.10
256	Farm house well	7.14	440	2	715	108	3.35	119	34.0	305	0.19	82	150	<0.10

TABLE B8 RESULTS FOR WATER SAMPLES COLLECTED ON JULY 12 AND 13, 1978

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)	Zinc (ug/l)	Copper (ug/l)	Fluoride (mg/l)
257	M. Durham Water Well	7.40	170	1	219	1.8	0.62	49	15	0.96	0.05	250	ND	0.15
258	Farmhouse Well after 10 min. pumping	7.42	380	126	565	45.0	2.12	87	29	195.0	0.19	580	ND	0.10
259	After - 1 hr.	7.44	430	55	641	55.0	2.35	101	31	245.0	0.15	2,140	125	0.10
260	After - 2 hr.	7.47	440	48	662	63.0	2.28	104	31	250.0	0.13	290	ND	<0.10
261	Dow Water Well	7.46	200	3	272	3.9	0.83	63	21	2.9	0.05	107	ND	0.18
125 262	R. Sichko, Water Well	7.42	340	2	487	66.0	1.65	67	25	95.0	0.03	ND	ND	0.49
263	R. Sichko, Water Well	7.68	340	13	469	65.0	1.55	67	25	90.0	0.03	ND	ND	0.49
264	Sey. Cr. (N)	8.86	160	68	483	6.5	1.44	35	25	7.4	0.15	ND	ND	0.33
265	Sey. Cr. (S)	7.80	240	16	357	7.4	1.40	71	27	9.5	0.13	ND	ND	0.30
266	Test Well #2 after 5 min. of pumping	7.98	140	33	200	2.8	1.06	41	13	0.88	ND	ND	ND	0.20
267	After 30 min.	7.60	150	3	199	2.5	0.97	43	14	0.74	ND	ND	ND	0.20
268	After 35 min.	7.09	150	3	195	2.7	1.03	42	14	0.66	ND	ND	ND	0.20
269	Test Well #3 after 5 min. of pumping	7.30	200	1	276	4.3	0.53	54	23	0.93	ND	17	ND	0.17
270	200 series, mud pit	9.92	19,000	140	27,940	7,470	426.00	2340	3	11,820	0.08	25	75	0.21
271	South Forty brine pit	6.06	7.5x10 ⁵	373	2.1x10 ⁵	48,240	951.00	22400	5,000	1.8x10 ⁵	3.43	>6,800	350	0.10

TABLE B8 RESULTS FOR WATER SAMPLES COLLECTED ON JULY 12 and 13, 1978 (Continued)

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)	Zinc (ug/l)	Copper (ug/l)	Fluoride (mg/l)
272	Test Well #3 After 30 min.	8.12	210	4	292	4.1	0.57	58	23	0.95	ND	ND	ND	0.17
273	After 35 min.	7.94	200	1	283	4.5	0.6	47	23	0.94	ND	ND	ND	0.16
274	Test Well #1 After 1 min.	6.52	17,000	485	29,550	4,340	321.0	5,750	200	22,220	1.12	320	100	<0.10
275	After 5 min.	6.69	20,000	63	30,220	4,850	346.0	5,400	200	22,220	1.14	370	100	<0.10
276	After 15 min.	6.70	16,000	32	29,430	4,650	319.0	5,700	225	20,700	0.94	152	100	<0.10
277	After 30 min.	6.76	19,000	20	29,420	4,440	336.0	5,550	200	22,220	0.97	129	100	<0.10
278	After 45 min.	7.76	19,000	43	29,050	4,650	298.0	5,900	250	19,190	1.03	9.9	100	<0.10
279	Wet Area on Sheridon Between Bricker and Brown	7.60	260	4	321	3.6	0.35	73	25	12.50	0.03	ND	ND	<0.10

TABLE B9. RESULTS FOR WATER SAMPLES COLLECTED ON AUGUST 10, 1978

Sample Number	Sample ID	pH	Conductivity (µmho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)	Zinc (µg/l)	Copper (µg/l)
280	Dow water well	7.08	200	4	279	4.1	.75	61	20.5	4.1	0.05	145	ND
281	Farmhouse well after 8 hrs of pumping	7.07	620	3	7575	90	2.25	109	32.5	385	0.10	26	ND
282	Seymour Creek (N)	7.34	250	88	382	8.2	5.25	80	24.0	27	0.05	25	ND
283	Seymour Creek (S)	7.42	210	810	326	7.0	1.63	68	23.9	5.8	0.80	55	ND
284	Black River with Sediment	7.48	360	650	735	72	4.80	78	28.2	117	0.02	67	ND
285	Seymour Creek (E)	7.60	235	1410	604	19	3.05	61	24.0	28	1.83	67	ND
286	Seymour Creek (N) With Sediment	7.43	220	450	486	9.5	4.45	82	23.9	28	0.72	104	ND
287	Sichko well, after 10 min.	7.40	335	0	480	62	2.25	67	24.0	105	ND	32	ND
288	Sichko well, after 12 min.	7.44	325	3	482	65	2.26	67	23.8	100	ND	25	ND
289	Farmhouse well after pumping test	7.24	670	3	778	103	2.55	113	32.5	385	0.10	25	ND
290	Test well #3 after 5 min	7.48	195	3	281	48	.99	61	21.5	1.07	ND	25	ND
291	After 30 min.	7.49	193	1	284	47	1.18	62	21.4	0.93	ND	32	ND
292	After 90 min.	7.49	195	0	287	44	1.07	62	21.4	1.15	ND	17	ND
293	Test well #2 after 5 min	7.63	135	25	211	2.6	1.62	44	13.2	0.99	ND	26	ND
294	After 30 min.	7.73	132	3	198	2.6	1.62	44	13.2	0.99	ND	25	ND
295	After 45 min.	7.70	135	1	206	2.5	1.62	45	13.2	0.95	ND	ND	ND
296	Test well #1 after 5 min.	6.58	1750	38	25,590	4,040	252	4300	177	20,000	2.40	148	75
297	After 30 min.	6.80	1800	31	25,690	4,040	252	4633	200	18,685	1.92	130	75
298	After 45 min.	6.80	1820	31	25,450	4,040	279	4633	207	19,700	1.83	126	75

TABLE B10 RESULTS FOR WATER SAMPLES COLLECTED ON SEPTEMBER 12, 13, 14 and 15, 1978

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)
299	Test well #3 after 5 min.	7.48	300		279	7.5	.66	61	21	1.25	0.01
300	After 15 min.	7.50	460		285	6.9	.76	65	23	1.13	0.02
301	After 30 min.	7.53	370		281	6.9	.72	64	21.5	1.13	0.02
302	Pond sed. water from 2.0 ft.		16,500		11,590	4,000	37.60			8,700	
303	Pond sed. water from 4.0 ft.		14,500		13,250	4,760		1,330	373.0	10,100	
304	Pond sed. water from 6.0 ft.		10,700		13,750	4,200	4.80	1,400	420.0	9,800	
305	Pond sed. water from 2.0 ft.	6.45	9,000		6,510	2,240	32.00	1,400	433.0	4,400	2.47
306	Pond sed. water from 6.0 ft.	6.42	15,500		13,530	4,200	29.0	77.5	131.0	10,800	
307	Test Hole #1	7.32	1,250		1,000	172	2.3			274	
308	R. Sichko water well	7.42	700	0.004	472	112	1.08	71	25.0	92	0.03
309	Brown water well	7.54	350	0.000	240	6.1	.77	59	17.0	2.04	0.06
310	Farmhouse well 9/14/78 12 PM	7.30	1,250	0.004	898	195	1.70	116	33.0	430	0.11
311	Emmers water well	7.32	380	0.005	292	5.9	.84	68	20.0	3.8	0.01
312	Test Hole #1	7.30	600		422	9.6	1.60	89	27.5	30.6	0.20
313	Test Hole #2	6.91	8,500			2,500	8.80	565	148.0	6,200	1.02
314	Test Hole #3	7.00	3,800		2,970	940	2.30	370	92.5	1,480	0.87
315	Test Hole #4	7.35	450		378	11.3	1.10	290	93.5	6.7	1.66
316	Test Hole #5	7.35	420		371	7.9	1.40	100	32.0	3.95	0.59
317	Test Hole #6	7.10	440		579	25.0	1.33	430	126.0	103	0.56

TABLE B10 RESULTS FOR WATER SAMPLES COLLECTED ON SEPTEMBER 12, 13, 14, and 15, 1978 (Continued)

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)
318	Test Hole #7	7.10	2,200		1,764	415.0	6.20	280	114	970	2.69
319	Test Hole #8	7.29	750		456	34.0	1.90	114	35	65	0.26
320	Test Hole #9	7.25	800		431	9.7	1.20	191	61.5	2.9	1.17
321	Test Hole #10	7.12	750		535	13.5	1.33	112	38.0	21	0.14
322	Test Hole #11	7.30	1,050		845	135.0	7.00	105	31.0	320	0.41
323	Pond sed. water from 12 ft.	6.70	9,000		7,752	2,240.0	26.00	825	218	4,200	1.54
129 324	Pond sed. water from 12 ft.	6.30	8,200		7,366	2,120.0	24.00	810	203	4,300	1.39
325	Test well #2 after 5 min.	7.15	260		219	6.1	0.65	45	11.2	1.41	ND
326	After 15 min.	7.03	325		215	5.2	0.68	45	11	1.45	0.01
327	After 30 min.	7.25	270		204	5.2	0.80	46	11	1.41	ND
328	Test well #1 after 5 min.	6.64	13,000		12,200	3,160.0	110.00	180	72	13,600	0.97
329	After 15 min.	6.66	26,500		21,000	5,900.0	168.00	3,280	219	22,000	2.54
330	After 30 min.	6.67	29,000		21,800	6,300.0	168.00	3,550	225	22,000	2.21
331	Dow Supply Well	6.80	320	0.005	312	6.6	2.85	69	20.3	5.25	0.06
332	Sey. Cr. (N)	6.84	750	0.014	730	12.0	4.60	139	34	10.00	0.04
333	Sey. Cr. (S)	7.00	390	0.359	331	13.0	2.40	80	25	6.00	0.49
334	Farmhouse well 9/15/78 2 PM	7.02	1,100	0.006	873	210.0	2.60	116	31.5	470	0.10
335	Pond sed. sample from Test Hole 12	6.24	13,000		8,306	2,900.0	44.00	815	263	5,540	2.84
336	Pond sed. sample from Test Hole 13		6,500		4,414	940.0	77.00	500	166	2,120	1.11

TABLE B10 RESULTS FOR WATER SAMPLES COLLECTED ON SEPTEMBER 12, 13, 14 AND 15, 1978 (Continued)

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)
337	Pond sed. sample from Test Hole 14		6,500		3,460	1,076	27.0	598	190	3,100	1.21
338	Pond sed. sample from Test Hole 15		5,500		3,200	740	14.0	360	113	1,920	0.84
339	Pond sed. sample from Test Hole 16	6.01	2,550		2,590	254	14.0	361	95	670	0.76
340	Pond sed. sample from Test Hole 17		3,600		1,650	570	9.6	390	119	1,484	0.88
341	Pond sed. sample from Test Hole 18		3,800		3,910	448	11.5	561	169	1,340	1.41
342	Pond sed. sample from Test Hole 19	6.14	10,500		8,580	2,760	20.0	795	248	6,200	2.96
343	Pond sed. sample from Test Hole 20		12,000			3,440	22.0	930	283	6,700	2.59
344	Pond sed. sample from Test Hole 21		13,500		10,500	4,440	26.0	875	263	8,500	3.08
345	Pond sed. sample from Test Hole 22		10,000		8,230	3,700	11.0	645	194	6,700	1.90
346	Pond sed. sample from Test Hole 23		5,500		4,120	770	12.4	550	204	1,960	1.95

TABLE B11 RESULTS FOR WATER SAMPLES COLLECTED ON OCTOBER 12, 1978

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)
347	Pond	6.90	1,700	0.044	1,780	240	32.00	300	73.0	940	0.31
348	Dow water well	7.20	300		282	2.5	0.62	62	23.8	9.2	0.07
349	Sey. Cr. (N)	7.47	365	0.000	573	4.4	11.60	94	30.5	20.0	0.02
350	Sey. Cr. (S)	7.51	365	0.006	409	5.0	1.87	90	31.5	24.5	0.13
351	Test well #1 after 5 min.	7.10	12,000		11,400	1,840	75.0	2,060	190.0	12,400	1.46
352	After, 15 min.	7.20	13,800		13,100	2,100	89.0	2,375	210.0	14,400	1.44
353	After, 30 min.	7.22	12,300		12,800	2,000	82.0	2,360	185.0	14,000	1.36
354	Farmhouse water well	7.53	440		389	22.2	1.03	81.5	29.2	135	0.07
355	Test well #2 after 5 min.	7.73	180		202	2.1	0.70	42.0	13.0	4.25	ND
356	After 15 min.	7.71	220		200	1.85	0.70	42.5	13.7	4.25	ND
357	After 30 min.	7.83	215		203	1.60	0.80	42.0	14.0	3.70	ND
358	Test well #3 after 5 min.	7.62	310		280	3.0	0.43	59.0	25.2	3.40	ND
359	After 15 min.	7.40	310		282	3.0	0.43	58.0	24.0	3.70	ND
360	After 30 min.	7.55	310		282	3.2	0.40	60.0	24.8	5.00	ND

TABLE B12 RESULTS FOR WATER SAMPLES COLLECTED ON NOVEMBER 3, 1978

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)
361	Test Hole 0P	6.54	2,050		1,660	103	2.20	216	81.0	680	0.23
362	Test Hole 1P	6.80	1,500		1,350	130	2.00	181	55.0	450	0.59
363	Test Hole 2P	6.90	2,900		2,660	380	2.10	263	92.0	1,040	0.41
364	Test Hole 3P	6.78	3,150		2,610	680	1.10	252	75.0	1,080	0.85
365	Test Hole 4P	6.84	2,950		2,660	560	1.30	300	88.0	1,240	0.51
366	Test Hole 5P	6.92	3,350		2,640	520	2.40	290	89.0	1,460	0.88
367	Test Hole 6P	7.00	4,150		5,400	470	2.60	289	76.6	1,880	0.95
368	Test Hole 7P	7.26	700		400	13.3	1.60	77.0	26.3	53.0	0.57
369	Dow water well	6.73	340	6.0	254	2.8	.39	63.5	19.7	4.0	0.08
370	Farmhouse water well	6.88	600	8.0	476	4.5	.74	87.0	26.3	127	0.10
371	Sey. Cr. (N)	7.02	320	15.0	531	5.0	1.80	89.0	26.0	10.0	ND
372	Sey. Cr. (S)	7.10	400	62.0	431	7.0	1.75	89.0	26.3	10.5	0.15
373	Pond	7.28	2,100	24.0	1,880	345	25.00	202.0	55.2	820.0	0.02

TABLE B13 RESULTS FOR WATER SAMPLES COLLECTED BY DOW ON NOVEMBER 8, 1978

Test Hole 8P	2500	1617	450	---	172	51.0	840
Test Hole 9P	3300	2108	470	---	246	86.3	1120
Test Hole 10P	900	527	48	---	75	30.8	125
Test Hole 11P	1500	1024	180	---	114	41.3	430
Test Hole 12P	1600	1080	72	---	155	56.3	350
Test Hole 13P	650	346	11	---	66	23.3	12.5
Test Hole 14P	750	496	8.2	---	94.5	36.8	4.9

TABLE B14 RESULTS FOR ISCO WATER SAMPLES COLLECTED FROM THE POND
DURING THE PERIOD 10/22/78 TO 11/3/78

Sample #	Date	Total Dissolved Solids (mg/l)	** Sodium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)
374	10/13/78	2,190	2,400	225	57.3	980	0.10
375	10/15/78	2,530	7,200	237	57.0	1,020	0.05
376	10/17/78	2,890	13,600	241	58.9	1,160	0.06
377	10/19/78	2,010	176	252	60.8	1,160	0.01
378	10/21/78	2,530	6,400	249	61.9	1,100	0.07
379	10/23/78		11,600	253	63.5	1,600	0.21
380	10/25/78	2,740	820	250	62.7	1,080	0.13
381	10,28/78		14,200	234	59.3	1,100	0.10
382	10/30/78	2,620	8,700	238	62.3	1,100	0.63
383	11/1/78	2,460	4,400	243	62.6	1,320	0.07

**Values of sodium are suspect.

TABLE B15 RESULTS FOR WATER SAMPLES COLLECTED ON DECEMBER 13, 1978

Sample #	Sample ID	pH	Conductivity (umho)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Chloride (mg/l)	Manganese (mg/l)
384	Dow water well	7.64	272		284	5.1	2.60	60.0	20.2	4.4	0.05
385	Pond	6.92	2,800	15.0	2,880	680.0	4.40	320.0	88.8	1,360	0.89
386	Farmhouse water well	7.30	480		367	19.0	0.32	74.0	24.5	49	0.07
387	Sey. Cr. (N)	7.38	400	1.0	441	5.1	0.18	94.0	26.5	6.2	ND
388	Sey. Cr. (S)	7.36	290	0.0	524	6.4	0.94	108.0	29.0	11.5	0.02
389	Test well #3 after 10 min.	7.45	205		206	3.1	0.00	39.0	13.0	0.66	ND
390	Test well #2 after 10 min.	6.80	270		299	4.3	0.00	60.0	21.2	0.68	ND
391	South forty brine pit	6.68	50,000		95,900	32,400	290	5,100	1,520	80,000	2.77
392	Test well #1 after 10 min.	6.56	19,000		11,050	3,400	150	2,720	220	19,200	2.00

TABLE B16 RESULTS FOR WATER SAMPLES COLLECTED ON JANUARY 12, 1979

393	Pond sed.	6.80	6,500	4,742	8,070	2,100	66.0	1,740	402	2,900	1.76
394	Dow water well	6.66	310	1.0	221	11.0	0.47	64.0	55.5	5.8	0.04
395	Sey. Cr. (N)	6.92	650	23.0	630	18.0	2.80	115.5	86.5	26	0.34
396	Farmhouse water well	7.09	500	6.0	396	24.0	0.90	78.0	63.7	78	0.07

APPENDIX C
DESCRIPTION OF METHODS AND QUALITY CONTROL
OF WATER QUALITY ANALYSIS

QUALITY CONTROL ANALYSIS

In order to judge the precision and accuracy of the five chemical parameters being measured in this project, two different samples were obtained from the project site:

Sample I (low level) - Farmhouse well water

Sample II (high level) - 1:100 diluted brine

Each sample was analyzed five to six times each for Ca, Mg, K, Na, and Cl. Each measurement was performed on a fresh sample using a fresh container. From these measurements the mean concentration and the average standard deviation were calculated. Average standard deviation, σ is calculated by the formula

$$\sigma = \frac{\sum (x - \bar{x})^2}{n-1}$$

where $\bar{x}$ = mean concentration and n = number of observations.

Each sample was spiked with a known concentration for each element in question. A spike blank and the spiked sample were measured in triplicate. Percent recovery of the spike was calculated by these results.

Samples were also analyzed by ERG Services, Inc. of Ann Arbor, Michigan, an independent analytical laboratory, and the results were compared with those of the ERIM Laboratory.

ERG analyzed K, Na, and Ca by flame emission, Cl by automated, Ferric Thiocyanate and Mg by atomic absorption.

ERIM analyzed K, Na, and Cl by specific ion electrode. Ca and Mg were analyzed using an atomic absorption spectrometer. In addition to the above, checks quality control samples obtained from the U.S. Environmental Protection Agency were analyzed using these procedures.

An Orion 400 series electrometer was utilized to measure pH of water samples at the shale site. Conductivity was also determined in the field using a YSI Model 104 meter. Summaries of procedures and quality control results follow.

SODIUM

Reference: Orion Instruction Manual for Model 94-11 Electrode

Method: Sodium is measured using a sodium specific ion electrode (glass membrane type) and an Orion single junction reference electrode having lithium trichloroacetate as the filling solution, with an Orion 701 digital pH meter. The electrode is calibrated against a five-point curve between 1-100 ppm. An ionic strength adjuster is used in all samples and standards.

This electrode does drift 3-5 mv/hour, which can cause significant differences at the low level. Use of ISA ionic strength adjuster is absolutely essential.

<u>Concentration-ppm</u>	<u>Sample I (low)</u>	<u>Sample II (high)</u>
mean (of 6 values)	423.3	26.5
range	410-450	24-27.5
average standard deviation	14.9	1.05
spike blank	500	100
spike and sample (calculated)	923.3	126.5
spike and sample (of 6 values)	933.3	127.6
recovery	101.1%	100.9%
analysis of distilled water for Na:	0.036	

Comparative Results: PPM

<u>Sample#</u>	<u>ERG</u>	<u>ERIM</u>
384	4.0	5.1
385	410	680
386	14	19
387	6.5	6.4
390	3.1	4.3
392	3000	3400

POTASSIUM

Reference: Orion Instruction Manual for Model 93-19 Electrode

Method: Potassium was measured using an Orion specific ion electrode (ion exchange type) and an Orion single junction reference electrode having saturated silver nitrate filling solution, with an Orion 701 digital pH meter. The electrode is calibrated against a seven-point curve from 1-48 ppm. An ionic strength adjuster was used in all standards and samples.

This electrode has a drift with time which can cause significant error at low levels.

<u>Concentration (ppm)</u>	<u>Sample I (low)</u>	<u>Sample II (high)</u>
mean (of 6 values)	0.74	1.59
range	0.7-0.8	1.5-1.65
average standard deviation	0.034	0.049
spike blank	10	10
spike and sample (calculated)	10.74	11.59
spike and sample (of 6 values)	8.13	8.20
recovery	75.7%	70.8%
analysis of distilled water for k:	< 0.02	

Comparative Results: PPM

Sample #	ERG	ERIM
384	.9	2.6
385	50	4.4
386	1.5	.32
388	4.0	.94
390	1.1	0.0
392	140	150

CHLORIDE

Reference: Orion Instruction Manual for Model 94-17 Electrode

Method: Chloride is measured using an Orion specific ion electrode (solid crystal type) and an Orion double junction reference electrode having 10% potassium nitrate as the filling solution, with an Orion 701 digital pH meter. The electrode is calibrated against a five-point curve between 1-100 ppm. No ionic strength adjuster was needed.

This electrode does not drift significantly with time. It does require varying lengths of time to equilibrate. Occasionally the electrode gives non-reproducible readings.

<u>Concentration - ppm</u>	<u>Sample I(low)</u>	<u>Sample II(high)</u>
mean (of 5 values)	57.7	656.7
range	55-60	640-660
average standard deviation	1.82	7.45
spike blank	50	500
spike and sample (calculated)	107.7	1156.7
spike and sample (found)	104.2	1096.7
recovery	96.7%	94.8%
analysis of distilled water for Cl	0.1	

<u>Comparative Results - PPM</u>		
Sample #	ERG	ERIM
384	3.5	1.45
385	990	1360
386	63	49
388	17	11.5
390	1.0	.68
392	10,000	16,800

CALCIUM

Reference: EPA Manual of Methods for Chemical Analysis of Waters and Wastes

Method: Atomic Absorption Spectroscopy

<u>Concentration - ppm</u>	<u>Sample II (high)</u>
mean (of 6 values)	85.5
range	85-86
average standard deviation	0.41
spike blank	66.6
spike and sample (calculated)	152.1
spike and sample (of 6 values)	166.0
recovery	109.1%
Distilled water	< 0.03 ppm

<u>Comparative Results: ppm</u>		
<u>Sample #</u>	<u>ERG</u>	<u>ERIM</u>
384	80	60
385	500	320
386	100	74
388	130	108
390	48	60
392	4900	2720

MAGNESIUM

Reference: EPA Manual of Methods for Chemical Analysis of Waters and Wastes, p. 114, 1978

Method: Atomic Absorption Spectroscopy

<u>Concentration - ppm</u>	<u>Sample II (high) Mg</u>
mean (of 6 values)	43.2
range	42.7-43.5
average standard deviation	0.32
spike blank	33.3
spike and sample (calculated)	76.5
spike and sample (of 6 values)	73.1
recovery	95.6

Distilled water	< 0.005 ppm
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Comparative Results - ppm

Sample #	ERG,	ERIM
384	23	20.2
385	99	88.8
386	26	24.5
388	31	29.0
390	14	21.2
392	2900	2200

TOTAL SUSPENDED AND DISSOLVED SOLIDS

Reference: Standard Methods, 14th Edition, Section 208

Method: Total suspended solids are measured by filtration and weighing. Gelman glass fiber filters (Type A-3, 47 mm) are washed with three 20-ml portions of distilled water, dried at 100°C for 1 hour, cooled for 30 min in a dessicator, and weighed. Drying is repeated until the weight is reproducible within 0.3 mg. The sample (usually 100 ml) is shaken vigorously and immediately filtered. The filter is dried and weighed as before. The weight of the empty filter is subtracted to obtain the weight of the suspended solids.

Total dissolved solids (TDS) are measured by evaporating the filtrate from the above filtration in an aluminum pan of previous known weight. Drying is repeated until a reproducible weight is obtained. The weight of the empty pan was then subtracted to obtain the weight of the dissolved solids.

The sum of the major cations and anions should be roughly equivalent to the measured TDS. Variation observed in this relationship and specifically in the values of TDS is due in part to the loss of volatiles during the drilling process.

TRACE METALS

Reference: EPA Manual of Methods for Chemical Analysis of Water and Wastes, 1976.

Method: Atomic Absorption Spectroscopy

Analysis of water samples for trace metals during 1978 included Mn, Ca, Pb, and Zn. These metals were analyzed using a Perkin and Elmer Model 403 Atomic Absorption Spectrometer. Prior to analysis samples were first prepared by treating the sample with acid before filtration. The resulting samples were then measured using AA for what may be termed the "extractable" concentration. Calcium and magnesium were also determined from this extractable sample. These data so obtained are significant in terms of "total" metals in the sample, with reservation that something less than "total" is probably measured. Concentrations found in heavily silted samples will be substantially higher than data obtained on only the soluble fraction but less than that obtained by complete digestion of the silt material.

No quality control checks have yet been implemented other than those prescribed by the above standard procedures.

FLUORIDE

References: Orion Instruction Manual for Model 94-09 Electrode Method.
EPA Manual of Methods for Chemical Analysis of Water and Wastes, 1976.

Method:

Fluoride is determined potentiometrically using a selective ion electrode in conjunction with a standard single junction sleeve-type reference electrode with an Orion model 701 digital meter. The electrode is calibrated against a five-point curve between 0.1 and 100 ppm. This method of fluoride determination is very reliable in the range from 0.1 to 1000 mg/l but with sensitivity well below 0.1 ppm.

ANALYSIS OF EPA QUALITY CONTROL SAMPLES

Several sets of quality control (QC) samples were requested from the US EPA Environmental Monitoring and Support Laboratory, Cincinnati. These samples were used to provide additional checking of the routine analyses performed at the ERIM Laboratory. Specifically the samples were used most often to check chloride and sodium determinations. QC samples were also run with magnesium, calcium, and potassium analyses. Concentrations of each constituent as determined by ERIM are compared with those provided by EPA in the table below.

TABLE EPA QUALITY CONTROL SAMPLES RESULTS

<u>Date</u>	<u>Element</u>	<u>Sample I (mg/l)</u>	<u>Sample II(mg/l)</u>
Oct 9, 1978	Cl	21.0 (EPA,28.1)	74.0 (EPA 86.4)
Oct 9, 1978	Na	4.2 (EPA, 5.0)	37 (EPA 39.7)
Oct 18, 1978	Cl	22.3	84.0
Oct 20, 1978	Cl	21.0	90.5
Oct 20, 1978	Na	5.2	42.5
Oct 20, 1978	K	0.52 (EPA, 2.7)	3.8 (EPA, 8.4)
Jan 20, 1979	Cl	28.1	85.0
Jan 27, 1979	Na	5.4	43.0
Jan 29, 1979	K	1.8	5.8
Feb 15, 1979	Ca	17.0(EPA,14.5)	31.0 (EPA 44.5)
Feb 15, 1979	Mg	6.5 (EPA, 3.0)	22.5 (EPA 14.4)
Feb 22, 1979	Cl	32.0	95.0
Feb 22, 1979	Na	6.0	57.0

Average determination of chloride and sodium agree reasonably well with the EPA values. More frequent checks of Ca, Mg, and K will be made in the future in an attempt to resolve differences with EPA values in the QC samples.

APPENDIX D

AIR QUALITY MONITORING RESULTS
FOR PERIOD OF
FEBRUARY 1 THROUGH MARCH 31, 1978

The data collection period included the entire CAPB1 during February, and the first week of CAPB2 from 25 March to 31 March.

A record of data sampling periods is given in Table D1 for two sources, "local" and "flare stack". Results are tabulated for each constituent in the following tables (D2, D3, D4, D5). "Background" levels are based on data collected from July to December 1977, and the National Ambient Air Quality Standards, are included for comparison with "local" sampling. Tables D3 and D4 show, respectively, the occurrences of levels of nitrogen oxides and sulfur dioxide that exceeded 20 parts per billion (ppb). These tables refer to locally sampled data. In Table D3, some correlation of NO_x levels with SO_2 levels are noted. In Table D4, activities at the Dow site are noted that may (or may not) have affected the "local" SO_2 readings. These site activities were obtained from Dow log book records. Table D5 is a daily summary of SO_2 readings from the flare stack. The comments reflect events that may have affected the results.

TABLE D1

DATA SAMPLING RECORD

<u>Component</u>	<u>Period</u>	<u>Sample Line</u>	<u>Comments</u>
Particulates	01 Feb - 31 Mar	Local	16 Samples
NO _x	20 Feb - 03 Mar	Local	(NO data - channel
	06 Mar - 07 Mar	Local	was in error)
	09 Mar - 19 Mar	Local	
	27 Mar - 31 Mar	Local	
SO ₂	02 Feb - 08 Feb	Local	
	09 Feb - 17 Feb	Flare Stack	
	20 Feb - 22 Feb	Flare Stack	
	24 Feb - 07 Mar	Flare Stack	
	10 Mar - 24 Mar	Local	
	25 Mar - 31 Mar	Flare Stack	
Hydrocarbons and CO	01 Feb - 17 Feb	Local	Intermittent Behavior
	24 Feb - 03 Mar	Local	
	10 Mar - 31 Mar	Local	

TABLE D2

AIR QUALITY MONITORING RESULTS - PARTICULATES ($\mu\text{g}/\text{m}^3$)

<u>Time Period</u>	<u>Mean</u>	<u>Std. Dev.</u>	<u>Maximum (24-hour)</u>	<u>Minimum (24-hour)</u>
July 1977 through December 1977 (41 samples)	37.0	<u>+23.0</u>	101.5 (24-25 October)	4.5 (1 October)
February 1978 (8 samples)	31.6	<u>+15.0</u>	51.9 (15 February)	10.5 (6-7 February)
March 1978 (8 samples)	24.0	<u>+22.1</u>	58.7 (21-22 March)	1.9 (25 March)

Analyzed with the HiVol Sampler.

National Ambient Air Quality Standard for suspended particulates ($\mu\text{g}/\text{m}^3$)
 Annual geometric mean 60 $\mu\text{g}/\text{m}^3$
 Maximum 24-hour conc. 150

TABLE D3
AIR QUALITY MONITORING RESULTS - NO_x

<u>Date</u>	<u>Time</u>	<u>Highest Values of NO_x</u>
23 February	at 1100 hrs.	28 ppb
24 February	at 1600 hrs.	27 ppb
24 February	at 2100 hrs.	20 ppb
27 February	at 1200 hrs.	28 ppb
28 February	at 1400 hrs.	28 ppb
9 March	at 1500 hrs.	27 ppb
9 March	at 2000 hrs.	27 ppb
10 March	at 1800 hrs.	21 ppb
11 March	at 0400 hrs.	24 ppb*
11 March	at 1400 hrs.	23 ppb*
12 March	at 1700 hrs.	17 ppb
13 March	at 1700 hrs.	31 ppb**
16 March	at 1200 hrs.	39 ppb*

* Slight increase in local SO₂ → 20 ppb to 30 ppb SO₂

** Very large increase in local SO₂ → 105 ppb SO₂
(SO₂ sampled locally from 10 March to 24 March)

Analyzed with Monitor Labs Model 8440

National Ambient Air Quality Standard
annual arith. aver. = 100 µg/m³ ≈ 50 ppb NO₂

Background (July to December 1977)
0-10 ppb

TABLE D4

AIR QUALITY SAMPLING RESULTS - LOCAL SAMPLING OF SO₂

1. Period 1 (2 February - 8 February 1978)

<u>Date</u>	<u>Time</u>	<u>Highest Values of SO₂</u>	<u>Site Activities</u>
2 February	1200	24 ppb	1100: stated pressurizing well #4 with N ₂
	1300	31 ppb	
4 February	1300	31 ppb	1219: methane to well #4
			1340: methane ignition
	1400	27 ppb	1354-1415: Propane to well #4
	1500	28 ppb	
	1600	25 ppb	0900: air flow to sell #4 started
	1700	21 ppb	
	2000	27 ppb	2145: well #3 opened to letdown system
5 February	0300	21 ppb	air injected into #4 at high rate (~ 50 scfm)
	0400	21 ppb	
	0500	37 ppb	
	0600	24 ppb	
	0700	27 ppb	
	0800	23 ppb	
	1100	22 ppb	~0930: air injection rate increased to 85 scfm
	1200	31 ppb	
	1300	20 ppb	
	1800	23 ppb	1945: flare started
7 February	1700	20 ppb	~1530: well #7 opened to letdown system

(All other readings are less than 20 ppb)

TABLE D4 (cont.)

2. Period 2 (10 March - 24 March)

<u>Date</u>	<u>Time</u>	<u>Highest Value of SO₂</u>	<u>Site Activities</u>
11 March	0300	22 ppb	
	0400	30 ppb	
	0500	20 ppb	
	1900	20 ppb	
	2200	20 ppb	
13 March	1500	95 ppb	
	1600	66 ppb	
	1700	105 ppb	
	1800	94 ppb	
	1900	75 ppb	
	2000	40 ppb	
	2100	21 ppb	
14 March	0200	21 ppb	
	0300	37 ppb	
	0400	43 ppb	
	0500	25 ppb	
	0600	28 ppb	
	1400	20 ppb	
16 March	1200	23 ppb	
18 March	2000	26 ppb	
	2100	21 ppb	
20 March	1000	32 ppb	
	1100	88 ppb	
	1200	89 ppb	
	1300	85 ppb	
	1400	64 ppb	
	1500	25 ppb	
	1600	33 ppb	
	1700	59 ppb	
	1800	44 ppb	
	1900	26 ppb	
	2000	17 ppb	
	2100	24 ppb	
	2200	37 ppb	

(All other readings are less than 20 ppb)

TABLE D4 (cont.)

Analyzed with Monitor Labs Model 8450

National Ambient Air Quality Standard

Annual arithmetic mean	60 $\mu\text{g}/\text{m}^3$	20 ppb
Maximum 24-hour concentration	260 $\mu\text{g}/\text{m}^3$	100 ppb
Maximum 3-hour concentration	1300 $\mu\text{g}/\text{m}^3$	500 ppb

Background (July-December 1977)

0-10 ppb

TABLE D5

DAILY LOG OF FLARE STACK SAMPLING FOR SO₂

CAPB1 - Data from 9 February - 3 March 1978

<u>Date</u>	<u>Time</u>	<u>SO₂ Range (ppb)</u>	<u>Comments</u>
9 February	0000-2400	50-100	
10 February	0000-1800	75-105	
	1900-2400	180-245	- Opened N ₂ to letdown system at 1845
11 February	0000-2400	245-310	
12 February	0000-2400	280-320	
13 February	0000-2400	260-300	
14 February	0000-2400	150-320	
15 February	0000-1000	285-295	- Flare stack burner went out at 1000. Sudden increase in SO ₂ readings resulted
15 February	1100-2400	380-410	
16 February	0000-1400	355-385	
	1600-2400	5- 15	- Well #3 shut in to letdown system at 1530
17 February	0000-0900	20- 40	
	1000		- Well #5 opened to letdown system. Hays O ₂ analyzer showed increase from 4.4 to 9.6% O ₂ at 1000
	1100-1800	60-155	
17 February	1900-1200	No data	- Chart recorder malfunction
to 20 February			
20 February	1300-1500	140-195	- Well #3 flow approx 40 scfm
	1600-1700	60- 85	- Well #3 flow dropped to zero
	1800-2000	95-145	- Well #3 flow approx 40 scfm
	2100-2400	50- 55	- Well #3 flow dropped to zero
21 February	0000-2400	50-100	- Well #3 flow stable at 26 scfm
22 February	0000-0500	50- 65	
22 February	0600-1200	No data	- SO ₂ analyzer malfunction
to 24 February			
24 February	1300-1400	50	
	1500		- Well #5 flow increased suddenly from 10 to 35 scfm; wells #8 and #11 shut in at 1410
	1600-2400	35- 50	- Well #5 decreased to 10 scfm

TABLE D5 (cont.)

<u>Date</u>	<u>Time</u>	<u>SO₂ Range (ppb)</u>	<u>Comments</u>
25 February	0000-2400	40- 55	
26 February	0000-2400	25- 50	
27 February	0000-1100	25- 40	
	1100-2200	0- 10	- All wells closed in at 1040
27-28 February	2300-0300	195-395	- Began bleed-off of well #4 at 1640; closed in at 0330.
28 February	0400	450	- Well #3 bleed-off started at 0430.
	0500-1600	30-200	
	1800-21000	260-320	- Shut in well #3, and start #4 again, at 1625
	2200	30	- Well #4 opened to atmosphere
	2300-2400	70-150	- Well #3 bleed-off, 28 Feb. 2210 to 1 Mar 0030
1 March	0000-2400	40-120	
2 March	0000-2400	5- 90	- Let down of wells continued
3 March	0000-2400	30-200	- Let down continued

End of CAPB1 data

CAPB2 - Data from 25 March - 31 March 1978

25 March	0000-2400	0	.
26 March	0000-2400	0	
27 March	1600-2400	5- 10	
28 March	0000-2400	10- 20	
29 March	0000-24000	15- 30	
30 March	0000-2400	25- 50	
31 March	0000-1400	35- 50	

ESTIMATION OF ERRORS IN AIR MONITORING DATA:

I. Particulates:

Typical values for a 24 hr. sample:

$(64 \pm 1 \text{ mg})$ in $(1600 \pm 80) \text{ m}^3$ air.

$$C = \frac{\text{wt.}}{\text{vol.}} = \frac{64,000 \text{ } \mu\text{g}}{1,600 \text{ m}^3} = 40 \text{ } \mu\text{g}/\text{m}^3$$

$$\text{Error in } C \approx \frac{\partial C}{\partial \text{wt}}^2 \epsilon_{\text{wt}}^2 + \frac{\partial C}{\partial \text{vol}}^2 \epsilon_{\text{vol}}^2$$

Where ϵ_{wt} = error in weight $\approx 1 \text{ mg}$
 ϵ_{vol} = error in volume $\approx 80 \text{ m}^3$
 (i.e., 5% error in flow-rate calibration)

$$\frac{\partial C}{\partial \text{wt}} = \frac{1}{\text{vol}} = \frac{1}{1600 \text{ m}^3}$$

$$\frac{\partial C}{\partial \text{vol}} = \frac{\text{wt}}{\text{vol}^2} = \frac{64,000 \text{ } \mu\text{g}}{(1,600 \text{ m}^3)^2}$$

Substituting,

$$\begin{aligned} \epsilon_{\text{conc}} &= 0.39 + 4.00 \\ &= 2.1 \text{ } \mu\text{g}/\text{m}^3 \end{aligned}$$

II. Nitrogen Oxides:

Full scale range = 0.050 ppm

NO_x and NO: zero-span drift was typically $\pm 0.002 \text{ ppm}$

NO_2 : (difference between NO_x and NO) - random error should twice
 NO_x or NO; i.e., $\pm .004 \text{ ppm}$

(Systematic errors in NO and NO_2 calibration sources were not determined.)
 Some of the NO data was invalid due to problems with the instrumentation.
 The analyzer was returned to Monitor Labs., Inc. for repair.

III. Sulfur Dioxide

Full scale range = 0.100 ppm

Largest instrumental errors are due to calibration error (not determined) and instrumental drift.

(Errors due to improper sampling are discussed in the results section.)

Typical zero-span drift (in 48 hrs.): ± 0.003 ppm

Largest zero-span drift (in 48 hrs.): ± 0.008 ppm

There was some uncertainty in the correct zero setting for the SO₂ analyzer. The procedure we used was as follows:

using "zero air" supplied by the ML8500 calibrator, the zero adjustment was made to give a reading of 10 ppb from the analyzer. This was necessary to keep the SO₂ output positive (i.e., ≥ 0 ppb) on rainy days, or on especially clear days. (Apparently, the ML8500 calibrator "zero air" contains ~ 10 ppb SO₂ even though it is filtered thru activated charcoal.

IV. Hydrocarbons and Carbon Monoxide

Full scale range = 10.0 ppm

The methane (CH₄) and Total HC (THC) outputs were typically stable to ± 0.1 ppm.

Since non-methane H.C. is the difference between THC and CH₄, the error should be ± 0.2 ppm. This assumes that the calibration gas is accurate. There was an apparent systematic error in the calibration gas used prior to 1 February 1978, resulting in recorded non-methane H.C. values that were too high.

APPENDIX E
SOILS DESCRIPTIONS AND RESULTS OF
LABORATORY ANALYSIS

APPENDIX E

This appendix contains the analytical results for the 26 soil samples collected from the site and the soil profile descriptions based upon borings made at 21 locations. A map showing the locations of both soil sampling and boring sites is shown as Figure E1.

Soil Sample Analysis Results

The following results except for bulk density were obtained from the Michigan State Soils Testing Laboratory. Bulk density was determined by ERIM.

Methods

pH: In water; soil/water ratio 1:1; measurement with potentiometer using a calomel reference electrode.

Organic Matter (O.M.): Dry combustion of total carbon using a Leco carbon analyzer equipped with an induction furnace.

Electroic Conductivity (E.C.): On the saturated extract using a solubridge and a conductivity cell ($K=1$).

Cation Exchange Capacity (C.E.C.): Saturation of soil with NH_4 OAC $N=1$ pH = 7.0. Recuperation of absorbed NH_4 through distillation; measurement partitration, using H_2SO_4 .01 N.

Exchangeable Sodium (Na): Displacement of the ion with NH_4 OAC $N=1$. Measurement of Na on flame photometer.

Bulk Density (B.D.): On undisturbed sample, after coating with paraffine.

Results of Analyses

Site 1

Location: 138 feet North and 138 feet East of Southwest corner of quadrant 4.

Site Conditions: Area along tracks of trucks. Top soil apparently disturbed and significantly compacted.

<u>Horizon</u>	<u>pH</u>	<u>O.M.</u>	<u>E.C.</u>	<u>C.E.C.</u>	<u>Na</u>	<u>B.D.</u>
A	6.3	2.0	.88	15.9	.17	1.64
B ₁	5.5	.29	.2	11.9	.13	1.62
B ₂	5.7	.31	.15	14.1	.16	1.74

Site 2

Location: 114 feet North and 54 feet East of Southwest corner of quadrant 4.

Site Conditions: Undisturbed area. Fallow.

<u>Horizon</u>	<u>pH</u>	<u>O.M.</u>	<u>E.C.</u>	<u>C.E.C.</u>	<u>Na</u>	<u>B.D.</u>
A	4.8	2.84	.4	17.0	.37	1.4
A ₂	5.3	1.84	.2	13.4	.09	1.49
B	5.9	.66	.15	6.7	.11	1.76

Site 3

Location: 384 feet North and 390 feet West of Southeast corner of quadrant 4.

Site Conditions: Area partially disturbed through scrapping

<u>Horizon</u>	<u>pH</u>	<u>O.M.</u>	<u>E.C.</u>	<u>C.E.C.</u>	<u>Na</u>	<u>B.D.</u>
A ₁	6.3	1.45	3.2	10.2	.54	
A ₂	5.2	1.38	.6	12.1	.17	
B ₁	5.3	.57	.22	13.2	.15	
B ₂	5.2	.69	.22	14.6	.22	

Site 3B

Location: On the edge (northwest) of Site 3

<u>Horizon</u>	<u>pH</u>	<u>O.M.</u>	<u>E.C.</u>	<u>C.E.C.</u>	<u>Na</u>
Surface Soil	8.3	.47	.12	16.2	10.17

Site 4

Location: 276 feet North and 194 feet West of Southeast corner of quadrant 4.

Site Conditions: Edge of disturbed area

<u>Horizon</u>	<u>pH</u>	<u>O.M.</u>	<u>E.C.</u>	<u>C.E.C.</u>	<u>Na</u>
A ₁	5.4	1.67	6.0	11.8	1.03
A ₁ B	5.6	1.1	0.5	8.1	.28
B ₁	6.0	.55	.72	5.7	.21
B ₂	6.4	.66	.27	14.7	.22

Site 5

Location: 300 feet South and 278 feet East of Southeast corner of quadrant 4.

Site Locations: In fallow area; no sign of significant disturbance

<u>Horizon</u>	<u>pH</u>	<u>O.M.</u>	<u>E.C.</u>	<u>C.E.C.</u>	<u>Na</u>
A ₁	5.6	1.69	.2	10.3	.20
A ₁ B	5.8	.74	.12	12.7	.12
B ₁	5.8	.59	.14	16.7	.16
B ₂	5.8	.29	.12	16.7	.12
B ₃	5.8	.4	.12	15.7	.17

Site 6

Location: 342 East and 66 feet South of Northeast corner of quadrant 4.

Site Conditions: No sign of significant disturbance.

<u>Horizon</u>	<u>pH</u>	<u>O.M.</u>	<u>E.C.</u>	<u>C.E.C.</u>	<u>Na</u>	<u>B.D.</u>
A	5.9	1.69	.12	13.5	.16	1.56
A ₁ B	6.0	.66	.40	14.5	.13	1.62
B	5.5	.59	.20	9.3	.17	1.80

Site 7

Location: See sketch for approximate location.

Site Conditions: Area significantly compacted by extensive traffic of machinery.

<u>Horizon</u>	<u>pH</u>	<u>O.M.</u>	<u>E.C.</u>	<u>C.E.C.</u>	<u>Na</u>	<u>B.D.</u>
A	5.6	1.95	.22	11.4	.20	1.62

Note: Because of heavy rain, sampling was limited to the top layer.

PROFILE DESCRIPTIONS

STATION 1

0-6 inches

Greyish brown light loam; strong medium to fine subangular blocky structure; few roots.

6-46 inches

Mottled gray and brown clay loam, medium subangular blocky structure.

46-60 inches

Alternate layers of stratified fine sandy loam, loam and silt loam; few small gravel, non calcareous.

STATION 2

Note: fairly similar to Station 1, stratification absent.

pH of bottom of boring at 60 inches: 6.5.

STATION 3

Textural class and horizon distribution similar to 1 and 2 but soils are better drained; with fewer mottlings; few cobbles.

STATION 4

0-7 inches

Dark greyish brown fine sandy loam to silt loam.

7-18 inches

Fine sandy loam, with few lenses of clay loam.

18-30 inches

Same as above but with a few greyish mottles, some greyish sandy tongues.

30-45 inches

Loam, heavier toward the bottom of the horizon.

45-60 inches

Sandy loam; slightly calcareous; pH: 8.0.

STATION 5

0-8 inches

Light greyish brown sandy loam to light loam; very weak structure; horizon shows signs of substantial disturbance, and some mixing.

8-18 inches	Sandy loam, lighter in color.
18-45 inches	Reddish brown clay loam with thin layers of loam and sandy loam.
45-60 inches	Light brown sandy loam; non calcareous; pH = 6.0.

STATION 6

Profile fairly similar to Station 5. The B horizon shows greater evidence of stratification. The sandy loam horizon starts at 45 inches. Non calcareous; pH = 5.5.

STATION 7

0-9 inches	Light brown sandy loam; structureless.
9-22 inches	Sandy loam with bands of loam and clay loam.
22-45 inches	Loamy sand.
45-60 inches	Stratified silt loam and sandy loam. Non calcareous.

STATION 8

0-6 inches	Light brown (10 yr 3/3) moist; very light (10 yr 6/3) dry; loam; strong (almost massive), very coarse platy structure.
6-42 inches	Heavy loam and clay loam; strong, medium to coarse, angular blocky structure; few gray mottlings.
42-60 inches	Light clay loam, loam and sandy loam; light gray mottles; non calcareous.

Note: The coarse, platy structure observed at the surface is a strong indication of significant compaction of the top soil.

STATION 9 (Trench)

STATION 10

0-2 inches	Light loam; structureless.
2-18 inches	Light brown heavy loam; medium, subangular blocky structure.

18-30 inches	Clay loam; medium subangular blocky structure.
30+ inches	Heavy loam; weak medium subangular blocky structure. Calcareous.

STATION 11

Upper part of the Solum is a light brown sandy loam with weak structure. B horizon is a clay loam. Slightly calcareous loam till at 55 in.

STATION 12

0-9 inches	Light brown loam; slightly acid; pH = 6.6.
9-32 inches	Mottled brown and reddish brown clay loam; subangular blocky structure.
32-44 inches	Brown (dull) clay loam; lighter texture; structureless.
44+ inches	Light loam; calcareous; pH = 8.0.

Note: Area seems to have been extensively disturbed; surface is strongly crusted and drilling mud has been spilled.

STATION 13

0-9 inches	Dark brown sandy loam; structureless.
9-22 inches	Light gray and light brown sandy loam, structureless.
22-32 inches	Brown and reddish brown clay loam; strong subangular blocky structure.
22-52 inches	Brown and reddish brown heavy loam; massive structure.
52+ inches	Sandy loam and loamy sand; structureless; non calcareous.

STATION 14

0-12 inches	Light brown loam to sandy loam; strong, coarse platy structure.
12-32 inches	Reddish brown heavy loam to clay loam; strong, medium, subangular blocky structure.
32-52 inches	Light clay loam with sandy loam pockets.

52+ inches

Light loam; structureless.

Note: The original surface horizon has been partly removed; the surface of the soil is crusty and hard. There is evidence, however, that vegetation is coming back.

STATION 15

0-18 inches

Light brown clay loam; strong massive structure.

18-22 inches

Red brown heavy loam; moderate, massive structure.

22-28 inches

Light brown loam; slightly calcareous.

28+ inches

Heavy loam to sandy loam; calcareous.

Note: The upper part of the Solum has been completely removed and the surface of the soil is hard and crusty.

STATION 16

Very similar to site 15; in addition, the profile is stony.

STATION 17

Observation of an open pit about 180 feet South and 96 feet East of Station 16.

The average depth of the pit is 6 feet. Drilling mud is extensively spread in the immediate vicinity of the pit but not further away. This drilling mud is strongly alkaline and reacts violently with Hydrochloric acid - probably because of high content of Sodium carbonate.

Fractured shale is occasionally mixed with the soil; in these places, the soil makes with the shale friable masses easily breakable by hand. The pH of these masses is around 8.0. Because of its low chemical activity, the fractured shale should not be expected to create significant problems. Oil spills are evident but they are fairly localized.

STATIONS 18 & 19

Observation made on the pile of soils excavated from the near by trench. The soil is sandy loam and clay loam, and calcareous throughout.

Closer to the ditch, the calcareous sandy loam layer is thinner and non calcareous clay loam (from the original B horizon) is encountered at three feet.

This is a good illustration of the reversal of the soil horizon through mechanical scrapping.

STATION 20

0-8 inches	Light brown silt loam to fine sandy loam; structureless.
8-18 inches	Light loam.
18-25 inches	Reddish brown clay loam with white interfingering.
25-48 inches	Dull brown heavy loam and clay loam; poorly structured.
48-62 inches	Mottled gray and brown stratified silt loam, sandy loam and loamy sand. Structureless. Non calcareous. pH = 6.0.

STATION 21

0-3 inches	Pale brown silt loam; structureless and loose. Moderately alkaline. pH = 7.5.
3-18 inches	Reddish brown heavy loam and clay loam with white tongues of sandy loam; weak subangular blocky structure.
18-38 inches	Yellowish brown, heavy loam; poorly structured.
38-48 inches	Light yellowish brown sandy loam and silt loam; structureless; strongly acid.
48-62 inches	Light yellowish brown sandy loam and loamy sand; structureless; non calcareous; strongly acid; pH = 4.5.

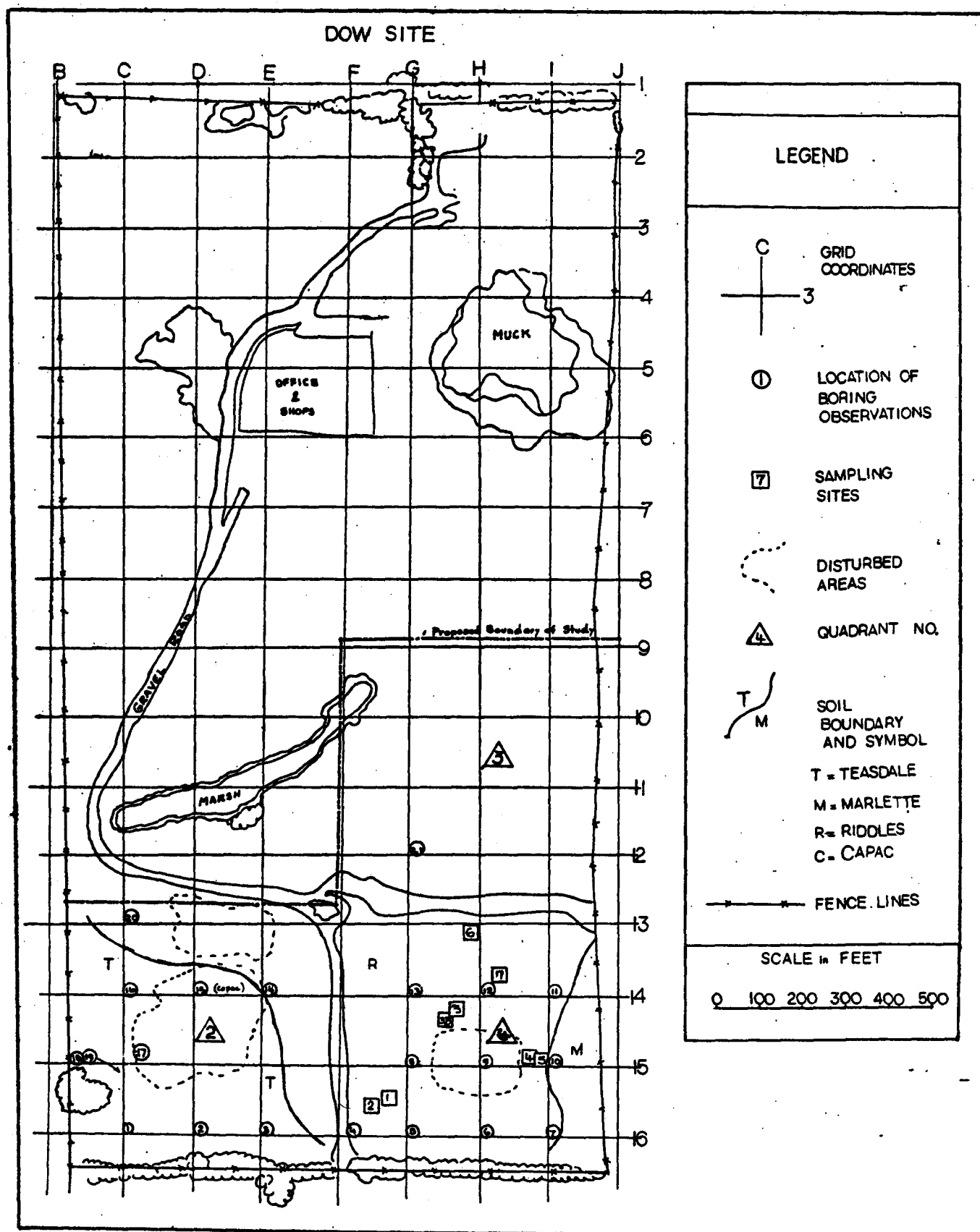


Figure E1. SOILS MAP AND SAMPLING SITES

APPENDIX F
PRECIPITATION DATA

APPENDIX F
Precipitation Records Shale Site
from 1-1-78 to 12-15-78

<u>Date</u>	<u>Precipitation (inches)</u>	<u>Snow on Ground (in)</u>	<u>Date</u>	<u>Precipitation (inches)</u>
JAN 1	0.23*	4	MAY 5	0.04
2	0.03	3	6	0.15
8	0.21	3	7	0.02
9	0.13	3	9	0.26
10	0.04	3	10	0.25
13	0.16	4	12	0.42
14	0.30	3	13	0.11
19	0.01	4	14	0.55
20	0.02	6	15	0.03
21	0.10	7	17	0.80
24	0.10	7	20	0.88
25	0.08	7	30	0.13
26	1.25	11	31	0.01 (3.64)
27	0.10 (2.80)**	12		
			JUN 5	0.12
FEB 2	0.08	9	7	0.02
5	0.07	10	8	0.26
6	0.04	11	13	0.32
7	0.01	12	15	0.01
21	0.01	12	16	0.04
23	0.01	10	17	0.01
24	0.04	10	21	0.40
25	0.19	13	26	0.02 (0.98)
26	0.01 (0.46)	14		
			JUL 1	0.30
MAR 3	0.05	15	3	0.01
4	0.05	15	13	0.02
11	0.06	9	14	0.15
12	0.01	9	16	0.02
16	0.25	9	19	0.24
17	0.01	9	20	0.03
21	0.66	3	22	0.01
22	0.20	2	27	0.01 (0.79)
26	0.12 (1.41)	0		
			AUG 2	0.01
APR 3	0.06		9	0.01
4	0.45		16	0.24
6	0.13		19	0.25
10	0.08		24	0.05
11	0.03		28	0.11 (0.67)
18	0.14			
19	0.14			
23	0.26			
24	0.06 (1.35)			

APPENDIX F
(Continued)

<u>Date</u>	<u>Precipitation (inches)</u>
SEP 3	0.02
10	0.02
11	0.01
12	0.54
13	1.25
14	0.49
15	0.14
18	0.66
20	0.39
21	0.65
27	0.27
28	0.01
30	0.11 (4.56)
OCT 3	0.09
5	0.01
6	0.04
7	0.27
8	0.73
9	0.32
18	0.02
23	0.17
25	0.15
26	0.16
30	0.01 (1.97)
NOV 6	0.07
13	0.27
17	0.38
22	0.07
23	0.56
29	0.04 (1.39)
DEC 7	0.13
8	0.10

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