ECOLOGICAL EFFECTS OF HIGHWAY CONSTRUCTION UPON MICHIGAN WOODLOTS AND WETLANDS: SOIL RELATIONSHIPS

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
ROBERT McLEESE
1975

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ABSTRACT

ECOLOGICAL EFFECTS OF HIGHWAY CONSTRUCTION UPON MICHIGAN WOODLOTS AND WETLANDS: SOIL RELATIONSHIPS

By

Robert McLeese

This study is part of a Michigan Department of State Highways sponsored research project to determine the ecological impact of a highway project upon some wooded and wetland areas in Michigan. The soil relationships found at these sites were of particular interest in this segment of the project.

Ten study sites, five wetlands and five woodlots, were selected for analysis. These sites were located along Interstate 75, between Standish and Grayling, Michigan.

A soils inventory was prepared for each site, consisting of soil maps showing the distribution of soil types and phases, and profile descriptions of some of the most abundant soils at each site. Some samples were collected for laboratory analysis to aid in the classification of the soils.

The most important effect that the construction of Interstate 75 has had on the soils of the woodlots and wetlands studied is the disruption of natural soil drainage conditions. The wetland sites, which are primarily level areas of very poorly drained organic soils

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and poorly drained sandy, mineral soils were most affected. High water table levels were observed at all of these sites, and at Sites 1, 4 and 5, the water table was above the soil surface. Tree kill on these areas indicated that the drainage regimes of the soils have been altered during or since highway construction. This evidence of altered drainage conditions was also observed at Woodlot Sites 7 and 8. These two sites also included large areas of poorly drained soils.

Evidence of sedimentation was observed at only one site. Some erosion probably did occur at the other sites during construction but was probably not significant.

Contamination of the soils by salts from de-icing compounds, air pollutants from auto exhaust, heavy metals from auto parts, and chemicals and petroleum products from accidental spills may occur in the future. Salt contamination of the soils adjacent to interchanges probably represents the largest potential soil problem.

Three important soil characteristics are significant for determining highway impact. They are soil texture, soil slope characteristics and natural soil drainage conditions. Soil survey information, remote sensing imagery, and topographic and geologic maps can be utilized to provide important information of these characteristics. The new Soil Taxonomy used by the National Cooperative Soil Survey may also be useful to highway engineers for assessing potential highway impact.

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Robert McLeese

Conclusions that were made concerning highway impact are:

1) Whenever possible, large wetland areas should be avoided during highway construction.

2) Drains and channels must be properly designed and constructed to avoid excessive alteration of natural soil drainage conditions.[1]

3) Erosion and sediment production, both during and after construction, need to be controlled.

4) Research needs to be conducted to determine how much salt may be applied to highways during winter de-icing programs without adverse effects to the adjoining environment.

5) Serious consideration should be given to the potential of the Comprehensive Soil Classification System for use in assessing potential highway impact.

6) The soil management groups or units also have possibilities for interpretive purposes and assessing potential highway impact.

7) The detailed soil mapping done by highway soil engineers can provide specific information for impact assessment, but impact may extend beyond the limits of the right-of-way. Available soils information from other sources could be used to extend soil boundaries or the highway's soil survey should include adjoining areas.

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ECOLOGICAL EFFECTS OF HIGHWAY CONSTRUCTION UPON MICHIGAN WOODLOTS AND WETLANDS: SOIL RELATIONSHIPS

By

Robert McLeese

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Crop and Soil Sciences

1975

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ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Dr. E. P. Whiteside, my major professor, for his guidance, advice, and encouragement during my days at Michigan State.

Many thanks go to Dr. A. E. Erickson, Dr. C. R. Humphrys, and Dr. D. L. Mokma for serving on my guidance committee and for their helpful ideas and suggestions.

I am also grateful to the Michigan Department of State Highways and Transportation and Michigan State University for sponsoring the research project that made this study possible.

My wife, Rosi, deserves a special thanks for her encouragement and faith throughout my graduate study.

Robert McLeese

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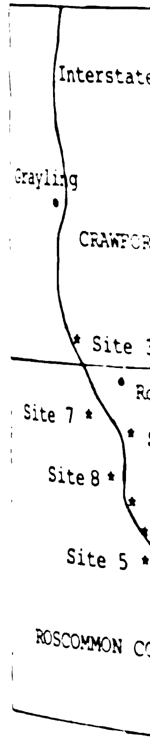
I. INTRODUCTION

Theoretically, no activity is without its environmental impact, and studies by state highway agencies have shown that the damage of highway construction to the environment needs to be minimized (Carter, 1967).

This study is part of a Michigan Department of State Highways sponsored research project that was designed to aid highway planners in their attempts to assess the ecological impact of a highway project upon some representative woodland and wetland areas in Michigan. Cooperating investigators included faculty and students of the Departments of Crop and Soil Sciences, Civil Engineering, Fisheries and Wildlife, Forestry, and Resource Development at Michigan State University.

Ten study sites, five wetlands and five woodlots, were selected for analysis. They are located along Interstate 75 between Standish and Grayling, Michigan (Figure 1). The highway at Wetland Site 1 was open to traffic before this investigation began and the other nine sites were opened to traffic during the course of the investigation. The soil relationships found in these areas were of particular interest in this segment of the project.

"Soil" has many meanings and connotations in different contexts. For the purpose of this study soil is defined as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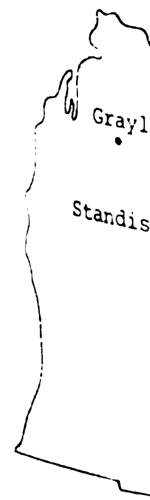
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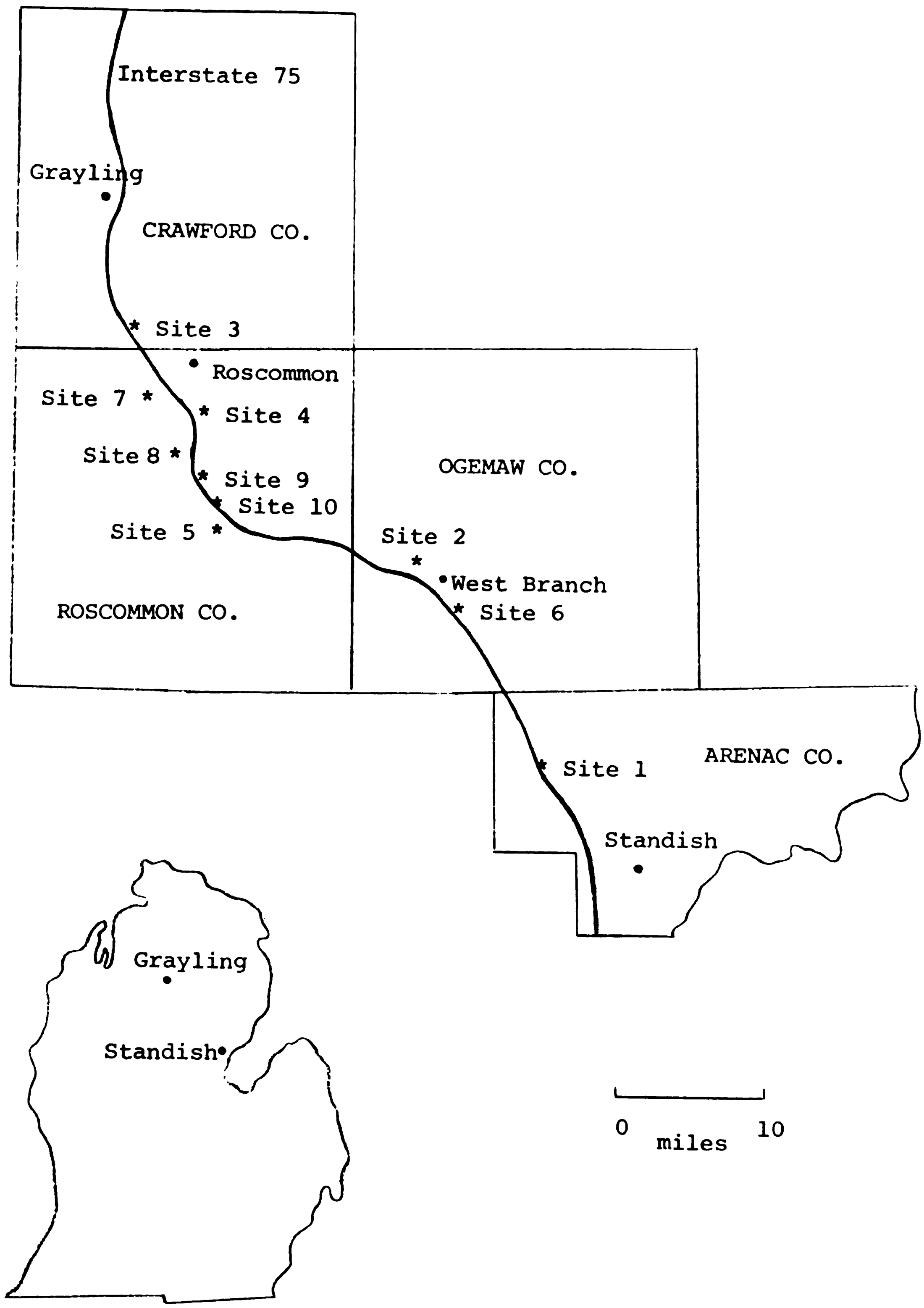

Figure 1. Location of study sites.

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> "the collection of natural bodies occupying portions of the earth's surface that support plants and that have properties due to the integrated effect of climate and living matter, acting upon parent material, and conditioned by relief, over a period of time."
>
> (Soil Survey Staff, 1951)

A soil can be considered as an open system with a budget of inputs and outputs. Because of this dynamic property, the soil is a very important part of an ecosystem and any activity that has an impact upon the soil will also influence, either directly or indirectly, the other components of the ecosystem.

With this in mind, the following objectives were established to study the effects of a highway project upon the soils of these woodlots and wetlands:

1) To prepare a soils inventory of the ten study sites, that will include maps showing the distribution of soil types and phases of types at each site and descriptions of those soils from field observations.

2) To determine the highway's impact, both beneficial and detrimental, on the soils that exist at each study site.

3) To determine the potential utility of soil and land use information already available, or that acquired during route selection or construction planning, for assessment of highway environmental impacts.

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II. LITERATURE REVIEW

The impact of a highway project on the soil environmental relationships that exist near the highway are varied and appear during and after the construction period.

Sediment transport and sedimentation resulting from the erosion of soil materials is one of the most serious effects a highway may have on the environment. The resulting sediments can cause substantial damage downstream from the construction area. Where they fill stream beds they may cause stream bank erosion during periods of high run-off. Aquatic life may be harmed or killed by sedimentation. The sediments can also fill road ditches, cover road surfaces, or be spread over adjacent areas.

The soil is most vulnerable to erosion during construction because of the rapid changes that occur in the natural vegetative conditions of the area during this period. The amount of sediment derived by erosion from an acre of ground under highway construction may be 20,000 to 40,000 times greater than the amount of material eroded from woodlands in an equivalent period of time (Wolman, 1964). The increased susceptibility of soil materials to water erosion during construction is also directly related to the increased runoff that occurs. Steeper, barren slopes are usually exposed to rainfall during construction, and this results in greater runoff at higher velocities. Soil er

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velocities. Soil embankments are compacted by heavy construction equipment, resulting in lower infiltration and permeability rates and greater runoff. The increased area of impervious surface which results from highway construction also substantially shortens the runoff time and increases the amount of stormwater runoff from an area as compared with preconstruction conditions (Preston and Mills, 1970; Quayyum and Kemper, 1960; Younkin, 1973).

The universal rainfall-erosion equation can be adapted to aid in sediment prediction and erosion control planning at construction sites (Wichmeier, Johnson and Cross, 1971; Wischmeier and Mannering, 1969; Wischmeier and Meyers, 1973). The soil loss rate, A, at a particular site is the product of six major factors: A = RKLSCP, where A = the computed average soil loss rate,

R = the rainfall intensity factor,

K = the soil-erodibility factor,

L = slope length,

S = slope steepness,

C = the cover and management factor, and

P = the erosion-control practice factor.

The soil erodibility factor, K, combines the effects of the soil's water intake capacity and its susceptibility to detachment and transport by rainfall and runoff. Texture structure, organic matter content, and permeability are the soil properties used to determine the soil erodibility factor. Tilmann, Mokma, and Stockman (1975) have developed a method using this equation by which the amount of construction-related soil erosion for a regional area can be predicted.

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In Michigan, those soils with sandy loam or loamy sand profile textures are most erodable (Whiteside, Schneider, and Cook, 1968). Soils high in silt, low in clay and organic matter, and on steep slopes are also easily eroded (Wischmeier and Mannering, 1969). Wind erosion may also be a serious hazard if organic or sandy soils are left barren during or after construction (Whiteside, Schneider, and Cook, 1968).

The alteration of natural soil drainage conditions is another serious effect a highway may have on the environment (Environmental Research Institute of Michigan, 1972). The highway commonly acts as a barrier to water circulation patterns and may disrupt earlier drainage conditions. It is quite evident that the storm water flowing off completed highways and adjacent areas requires adequate drains and channels. Improper construction or placement of these drainways may cause a detrimental change in drainage conditions of the area. If culverts are placed too high to permit proper drainage of lands adjacent to highways, these lands may be transformed into wetter lands with extensive damage to vegetation (Anonymous, 1970). Also, if drainage ditches are too shallow, periodic flooding may occur; and if ditches are too deep, the natural water table may be lowered causing more drouthy conditions (Environmental Research Institute of Michigan, 1972).

De-icing salts (NaCl or $CaCl_2$) and other chemicals that are applied to a highway for the purpose of melting or preventing the formation of ice seem to have measurable influences on the soils, water and vegetation adjacent to the highway (Button, 1971;

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Hutchinson and Olson, 1967; Quayyum and Kemper, 1960; Rutka, 1965). Relatively high concentrations of sodium and chloride ions in soils can adversely affect plant growth; and soils containing large amounts of exchangeable sodium frequently develop undesirable physical properties (Hutchinson, 1970; Hutchinson and Olson, 1967; Prior and Berthouex, 1967; Rutka, 1965). The salt applied to highways is eventually carried away by surface runoff into streams or infiltrates into the adjoining soil. Since sodium ions are positively charged, they are attracted to the negative sites on soil clay and organic particles, and the negatively charged chloride anions remain in solution and are leached downward into the ground water. High concentrations of sodium ions have an adverse effect on soil physical properties by causing dispersion of colloidal particles and may eventually lead to poorer drainage conditions because of decreased peremeability (Hutchinson and Olson, 1967; Sullivan and Higgs, 1973; Quayyum and Kemper, 1960). Excessive salt infiltration may also cause damage to plants (Sullivan and Higgs, 1973; Rutka, 1965).

In one study conducted in Maine, it was found that the concentration of sodium in the soils within 45 feet of a highway was 50 ppm before the highway was opened to traffic (Hutchinson, 1970). After one winter with a salt application of 25 tons per mile of roadway, the sodium concentration increased more than fivefold within ten feet of the highway. At another site where de-icing had been going on for 18 winters, the average sodium concentrations were 660 ppm near the edge of the highway and 300 ppm 45 feet away. In one isolated case the concentration of sodium had increased to 1,056 ppm, which represented a

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which represented a 23 per cent saturation of the soil cation exchange capacity by sodium ions. This soil could now be considered a sodic soil. It was concluded that toxic quantities of sodium are increasing in soils near highways that are salted and that these concentrations adversely affect drainage.

In a Connecticut study on the tolerance of trees and shrubs to salt from winter de-icing programs, it was found that de-icing salts are particularly harmful to white pine (*Pinus strobus*), norway spruce (*Picea abies*), hemlock (*Truga canadenis*), silver maple (*Acer saccharinum* L.), and sugar maple (*Acer saccharum* Marsh) (Anonymous, 1971a). Trees and shrubs that are tolerant to salt were also listed in this study. Investigators found some difficulty in rating the tolerance because of other factors that play important roles in salt tolerance. These include soil texture, soil permeability, soil reaction, rainfall frequency, winter winds, and the general health of the plant.

Sodium ions in the soil can also have a beneficial effect on plant growth. In general, potassium is the most limiting, naturally occurring, major plant nutrient in organic soils and sodium appears to act as a partial substitute for potassium (Davis and Lucas, 1951).

Air pollution is a very significant factor in environmental deterioration. Transportation, particularly the automobile, is the greatest source of air pollution. It accounts for 42 per cent of all pollutants by weight. A number of studies have shown that soils are a major "natural sink" for air pollutants that are released into the environment (Al-

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the environment (Abeles, Cracker and Leather, 1971; Bohn, 1972; Anonymous, 1971b; Smith, 1973; Westman and Gifford, 1973). Soil absorption of air pollutants and the effects of plant absorbed pollutants after the plants decay in the soil have received relatively little attention. Absorption rates, mechanisms, and capacities have not been studied to any extent and the effects of such soil properties as texture, moisture, content, and pH have not been measured.

Soils and plants sampled along heavily traveled highways show that lead contents tend to increase with traffic volume and decrease with distance from the highway (Lagerwerff and Specht, 1970; Motto, Daines, Chilko, and Motto, 1970; Siccama, 1971). Siccama (1971) found that small accumulations of lead in the soil might stimulate plant growth, but levels that are twice as much as normal "just has to be bad for plants and animals." Lagerwerff and Specht (1970) and Motto *et al.* (1971) feel that the accumulation of lead and other heavy metals in soils, from air pollution, probably does not result in plant concentrations of these ions which are hazardous to plants or animals. Other heavy metals that contaminate roadside soils and plants are nickel, cadmium, and zinc. The nickel comes from nickeled gasoline and nickel containing parts of automobiles and trucks. Sources of the cadmium and zinc are the motor vehicle tires and the oils used by autos.

The major gaseous air pollutants emitted by automobiles are carbon monoxide, sulfur oxides, nitrogen oxides, and hydrocarbons. At low pollution levels the harmful qualities of the pollutants absorbed by the so

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absorbed by the soil are probably dissipated and they are recycled as nutrients or are fixed in the soil in forms unavailable to plants (Bohn, 1972; Edwards, 1969). As the amount of pollutants absorbed by the soil and plants themselves increases, individual plants may suffer subtle damage in the form of reduced growth, impaired reproduction, or greater susceptibility to disease. In the final, extreme, case trees are actually killed and soil erosion may ensue along with changes in the hydrologic cycle (Siccama, 1971). Also, at the higher levels of contamination, the hydrocarbons that are absorbed by the soil cause an increase in the soils organic matter and nitrogen contents and sulfur dioxide on oxidation is converted to sulfuric acid which increases soil acidity (Bohn, 1972).

Contamination of the soils and water of the area adjacent to the highway by chemicals and petroleum products, from accidental spills and normal use of the roadway, may also occur.

The presence of certain soils will have special impacts on the areas adjacent to a highway. Organic soils make poor subgrades and many times have to be excavated and are commonly dumped on adjacent areas. This can destroy the vegetation and change the composition of the plant community (Environmental Research Institute of Michigan, 1972).

The influence of the soil on environmental changes within a highway construction area is determined primarily by three important soil characteristics: texture, drainage, and slope (Environmental Research Institute of Michigan, 1972). It is important when assessing highway :

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assessing highway impact to identify these characteristics and investigate how they might influence the possible effects of the highway.

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III. INVESTIGATION PROCEDURES

The investigation of the soil environmental relationships at each of the ten study sites consisted of two major phases. The initial phase included the preparation of a soils inventory of each site and field observations of the highway's impact upon the soil and the environment. The last phase consisted of laboratory analysis of some of the predominant soils and the preparation of a written report.

Field Investigations

The field investigations of the ten study sites along Interstate 75 were conducted between October 19 and November 18, 1973. A soil map of each site was prepared during this period. The land area that was mapped at each location was dictated by the size of the area that was studied by the individuals working on the vegetation, wildlife, and hydrology segments of the project. Basic soil survey procedures and techniques were used in identifying the different soils, determining their boundaries, and delineating those boundaries on a base map (Soil Survey Staff, 1950 and 1970).

The base maps that were used were photocopies of aerial photo panchromatic paper prints in 9x9 inch format at a scale of 1:20,000. They were obtained from the Agricultural Stabilization and

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Conservation Service. These aerial photographs were obtained in three flight missions in 1963, 1964, and 1969. Low elevation aerial photography taken from helicopter flights in the fall of 1973 of each of the sites and the highway engineer's preliminary plan prints of each site were also used to locate boundaries of different soils. Published soil surveys of Arenac County (1967), Crawford County (1927), Ogemaw County (1923), and Roscommon County (1924) were reviewed in preparation for field mapping.

After the mapping was completed, profile descriptions of the predominant soils at each site were made (Appendix A). A bucket auger was used to examine these soils, after they were selected as being representative of the areas. Samples of about half of the soils that were described were collected in plastic bags for laboratory analyses.

Any beneficial or detrimental effects due to the highway that were observed or could be predicted were recorded as each site was being mapped.

Laboratory Analyses

Laboratory measurements were used to aid in the classification of those soils that were sampled. Of particular interest with the sandy mineral soils was the degree of spodic horizon development. The Soil Taxonomy (Soil Survey Staff, 1970) gives specific criteria for the identification of a spodic horizon. The horizon must meet certain cation exchange capacity and depth requirements. It must also meet certain limits in pyrophosphate extraction and ithionite-citrate

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dithionite-citrate extraction of elemental aluminum, iron, and carbon with respect to the clay percentage of the horizon (Soil Survey Staff, 1970).

The hydrometer method of particle size analysis as described by Day (1965) was used to determine the clay fraction of the mineral soil horizons. Cation exchange capacities and pyrophosphate extraction analyses were then begun according to procedures described by the Soil Survey Staff (1972). It was then discovered that an atomic absorption spectrophotometer was not available for use in determining the amount of extractable aluminum. Alternate methods were found to be too complicated and lengthy to pursue for this study, so a Quick Test method of determination of spodic horizon development was substituted for the extraction methods (Lietzke, 1968).

This Quick Test is a rapid pyrophosphate color test that correlates extract colors with laboratory extractable iron, aluminum, and carbon. Extract color values less than or equal to 7 and chromas greater than 3 generally qualify B horizons as Typic subgroups of Haplorthods.* Combinations of 7/1 and 7/2 were borderline and placed soils into Entic subgroups of Haplorthods or into Spodic Udipsamments.

The primary interest of the laboratory studies of the organic soils was to determine the degree of decomposition of the organic plant materials. Three basic kinds of organic soil materials are distinguished: fibric, hemic, and sapric (Soil Survey Staff, 1970).

*Color values and chromas are Munsell soil color notations.

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Fibric soil materials are the least decomposed and have fiber contents of more than two-thirds of the soil volume before rubbing and more than two-fifths after rubbing. These materials also yield a sodium pyrophosphate extract color on white chromatography paper that have values and chromas of 7/1, 7/2, 8/1, 8/2, or 8/3 on a Munsell color chart. Sapric materials are the most decomposed of the organic soil materials and their fiber content is less than one-third before rubbing and less than one-sixth after rubbing. They have extract colors below or to the right of a line drawn to exclude the values and chromas 5/1, 6/2, and 7/3 on a Munsell color chart. Hemic materials are intermediately decomposed and have fiber contents and extract colors that do not meet the requirements for fibric or sapric.

Pyrophosphate color tests, fiber tests, and pH in $CaCl_2$ were made on each of the organic soil samples according to procedures described by Lynn and McKinzie (1971).

Results of all laboratory analyses are found in Appendix B, Tables 11 and 12.

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IV. SOILS INVENTORY OF THE STUDY SITES

The soils inventory that was made of each of the ten study sites consists of soil maps showing the distribution of mapping units, a brief description of these mapping units, and profile descriptions of some of the most predominant soils at each site.

The soil mapping units found at each site are named for the taxonomic units predominating in them. Contrasting soils are named if they represent more than 10 per cent of a mapping unit and similar soils are named if they represent more than 25 per cent. The aerial photographs on which the soil mapping units are shown were not available at the time the mapping was being conducted, so the soil area boundaries were transferred from the base maps used during the field investigations onto panchromatic paper prints (Figures 2 through 9).

Differences in the names and boundaries of the mapping units used in this report and those described for the same areas by the soil engineers of the Michigan Department of State Highways appear at every site. Boundaries of the soil mapping units used in this report were drawn on the highway engineer's preliminary plan prints of the highway right-of-way to illustrate the differences that exist (Appendix C).

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In Table 1, the mapping units that are located within the highway right-of-way at each of the ten study sites are listed and the relationship between the mapping units described for this report and those described by the MDSH are illustrated. The names of the corresponding mapping units are different at every site. These differences occur because more detailed mapping is commonly done by highway soil engineers, and the soil map units are shown as accurately as possible because of the detailed plans that are needed for highway design and construction. Differences in classification and personal discretion of the mapper also account for some of the differences observed in this study. These differences will be discussed in greater detail in Chapter VI.

In Table 2 the soil series found at each of the ten study sites are classified according to the Comprehensive Soil Classification System and the 1938 Soil Classification System. The detailed profile descriptions that were made of some of these soils during the field investigations are found in Appendix A.

Wetland Site 1

Site 1 is located in Section 34, Moffitt Township (T20N, R3E), Arenac County. At this site the highway crosses over a large area of poorly drained mineral and organic soils. Cattails, willow and alder shrubs, aspen and white birch trees are the most dominant plants. Figure 2 shows a soil map of the area. There are four mapping units found at this site:

Table 1. Mapping u
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Wet-land site	Mapping unit this investi-
1	Markey muck (Mc), Roscom AuGres sand Roscommon (5 (5b-h)] Roscommon sa (M/4c), AuGr (M/4c)
2	Newaygo sand [Mancelona Palo sandy [Gladwin (4 Tawas-carbon [Roscommon
3	Grayling-Cr 0-6% slope Saugatuck (Montcalm (4 Tawas-Seely [Roscommon
4	Rifle peat Saugatuck (5b)]
5	Carbondale (M/4c)] Roscommon- [Tawas (M/ Tawas muck Carbondale

Table 1. Mapping units within the right-of-way at each study site: relationship between mapping units described for this investigation and those described by MDSH *

Wetland site	Mapping units described for this investigation	Corresponding mapping units described by MDSH
1	Markey muck (M/4c) [Houghton (Mc), Roscommon (5c)]	Roscommon (5c), Shallow muck (M/c)
	AuGres sand (5b) [Markey (M/4c), Roscommon (5c), Saugatuck (5b-h)]	Roscommon (5c), Shallow muck (M/c)
	Roscommon sand (5c) [Markey (M/4c), AuGres (5b), Tawas (M/4c)	Roscommon (5c), Shallow muck (M/c)
2	Newaygo sandy loam (3/5a) [Mancelona (4a)]	Echo (5a), Emmet (3a), Iosco (4/2b)
	Palo sandy loam (3/5b) [Gladwin (4b), Tawas (M/4c)]	Roscommon (5c)
	Tawas-carbondale complex (M/4c) [Roscommon (5c)]	Muck (Mc), Peat (Mc), Peat marsh (Mc), Roscommon (5c)
3	Grayling-Croswell complex, 0-6% slope (5.7a) [AuGres (5b), Saugatuck (5b-h), Graycalm (5a), Montcalm (4a)]	Antrim (4a), Kalkaska (5a), Roscommon (5c)
	Tawas-Seelyeville complex (M/4c) [Roscommon (5c), Kinross (5c)]	Muck (Mc), Saugatuck (5b-h)
4	Rifle peat (Mc) [Tawas (M/4c)]	Muck (Mc), Roscommon (5c)
	Saugatuck sand (5b-h) [AuGres (5b)]	Saugatuck (5b-h)
5	Carbondale muck (Mc) [Tawas (M/4c)]	Peat marsh (Mc)
	Roscommon-AuGres complex (5c) [Tawas (M/4c)]	Roscommon sand (5c), Saugatuck sand (5b-h)
	Tawas muck (M/4c) [AuGres (5b), Carbondale (Mc), Roscommon (5c)]	Peat marsh (Mc)

Table 1 (cont'd

Wood-lot site	Mapping this inv
6	Omena sa (3a) [Me (1.5a)] Menomine slope (
7	Kinross [Roscom Otisco Croswel slope (Saugatu Menomin Menomin (5a), (5b-h) Roscom [AuGre Otisco
8	AuGres (5c)] Croswe Roscon [AuGre Sauga (5b),
9	Rubic slope Montc
10	Rubic slope Montc

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Table 1 (cont'd.)

Wood-lot site	Mapping units described for this investigation	Corresponding mapping units described by MDSH
6	Omena sandy loam, 6-12% slope (3a) [Menominee (4/2a), Nester (1.5a)]	Nester (1.5a), Echo (5a)
	Menominee loamy fine sand, 0-6% slope (4/2a)]	Emmet (3a), Echo (5a), Iosco (4/2b), Nester (1.5a), Selkirk (1b)
7	Kinross-Markey complex (5c) [Roscommon (5c), Ogemaw (5b-h), Otisco (4/2b), Houghton (Mc)]	Muck (Mc), Roscommon-Saugatuck complex (5c)
	Croswell-AuGres complex, 0-6% slope (5a) [Rubicon (5.3a), Saugatuck (5b-h), Graycalm (5a), Menominee (4/2a), Iosco (4/2b)]	Iosco (4/2b), Grayling (5.7a), Ottawa-Rubicon complex (5/2a), Rubicon (5.3a), Saugatuck (5b-h), Selkirk (1b), Wexford (5a)
	Menominee sand (4/2a) [Croswell (5a), Iosco (4/2b), Ogemaw (5b-h)]	Ogemaw (5b-h), Ottawa (5/2a)
	Roscommon-Kinross complex (5c) [AuGres (5b), Saugatuck (5b-h), Otisco (4/2b)]	Roscommon (5c), Roscommon-Saugatuck complex (5c)
8	AuGres sand (5b) [Roscommon (5c)]	Roscommon-Saugatuck complex (5c)
	Croswell sand (5a) [AuGres (5b)]	Kalkaska (5a)
	Roscommon mucky sand (5c) [AuGres (5b), Saugatuck (5b-h)]	Roscommon-Saugatuck complex (5c), Roscommon (5c)
	Saugatuck sand (5b-h) [AuGres (5b), Roscommon (5c)]	Saugatuck (5b-h)
9	Rubicon-Graycalm complex, 6-12% slope (5.3a) [Rousseau (4a), Montcalm (4a), Menominee (4/2a)]	Echo (5a), Iosco (4/2b) Roselawn (5.3a or 4a)
10	Rubicon-Graycalm complex, 0-6% slope (5.3a) [Rousseau (4a), Montcalm (4a), Menominee (4/2a)]	Iosco loamy sand (4/2b), Ogemaw-loamy sand (5b-h) Rubicon sand (5.3a)

*Soil series names in brackets are inclusions within the mapping units. Numbers and letters in parentheses represent predominant soil management group.

Table 2. Soil ser
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Site	Soil series
1*,3,4, 5*,7*,8*	AuGres
1†,2,5	Carbonda
3,5,6†, 7*,8*, 9-10	Croswell
2†	Gladwin
3†,6*, 7†, 9-10*	Graycalm
3*	Graylin
1†,7†	Lupton
7†	Iosco
3†,7*	Kinross
2†	Mancel
1*,7	Markey
6*,7, 9-10†	Menomi
3†,6†, 9-10†	Montca
6†	Nester

Table 2. Soil series of the ten study sites classified according to the Comprehensive Soil Classification System and the 1938 Soil Classification System

		Comprehensive Soil Classification System		1938 Classification System
Site	Soil series	Family (add to subgroup name)	Subgroup	Great Group
1*,3,4, 5*,7*,8*	AuGres	sandy, mixed, frigid	Entic Haplaquod	Podzol
1†,2,5	Carbondale	euic	Hemic Borosaprist	Bog
3,5,6†, 7*,8*, 9+10	Croswell	sandy, mixed, frigid	Entic Hap-lorthod	Podzol
2†	Gladwin	sandy, mixed, frigid	Alfic Hap-laquod	Podzol
3†,6*, 7†, 9-10*	Graycalm	sandy, mixed, frigid	Entic Hap-lorthod[1]	Podzol
3*	Grayling	mixed, frigid	Typic Udipsam-ment	Brown Podzolic
1†,7†	Lupton	euic	Typic Boro-saprist	Bog
7†	Iosco	sandy over loamy, mixed, frigid	Aqualfic Haplorthod	Podzol
3†,7*	Kinross	sand, mixed, frigid	Histic Hap-laquod[1]	Low Humic Gley
2†	Mancelona	sandy, mixed, frigid	Alfic Hap-lorthod	Podzol
1*,7	Markey	sandy, mixed, enic	Terric Borosaprist	Bog
6*,7, 9+10†	Menominee	sandy over loamy, mixed, frigid	Alfic Hap-lorthod	Podzol
3†,6†, 9+10†	Montcalm	sandy, mixed, frigid	Alfic Hap-lorthod	Podzol
6†	Nester	fine, mixed, frigid	Typic Eutro-boralf	Gray Wooded

Table 2 (cont'd.)

Site	Soil series	C Fam sub
2*	Newaygo[2]	coa
7†	Ogemaw	sa mi or
6*	Omena	f
7†	Otisco	s
2*	Palo[2]	
4*	Rifle	
1*,2†, 3†,5*, 7,8*	Roscommon	
9+10†	Rousseau	
7† 9+10*	Rubicon	
1†,3†, 4*,5,7, 9*	Saugatuck	
3*	Seelye-ville	
1*,2*, 3*,4,5*	Tawas	

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[1]Taxadjunc

[2]Variant (

Table 2 (cont'd.)

Site	Soil series	Comprehensive Soil Classification System: Family (add to subgroup name)	Comprehensive Soil Classification System: Subgroup	1938 Classification System: Great Group
2*	Newaygo[2]	coarse loamy	Alfic Haplorthod	Podzol
7†	Ogemaw	sandy over loamy, mixed, frigid, ortstein	Aquic Hap-	Ground Water Podzol
6*	Omena	fine loamy, mixed	Typic Eutroboralf	Ground Water Podzol
7†	Otisco	sandy, mixed, frigid	Entic Haplaquod	Podzol
2*	Palo[2]	coarse loamy	Aquic Eutroboralf	Podzol
4*	Rifle	euic	Typic Borohemist	Bog
1*,2†, 3†,5*, 7,8*	Roscommon	mixed, frigid	Mollic Psammaquent	Low Humic Gley
9+10†	Rousseau	sandy, mixed, frigid	Entic Haplorthod	Podzol
7† 9+10*	Rubicon	sandy, mixed, frigid	Entic Haplorthod	Podzol
1†,3†, 4*,5,7, 8*	Saugatuck	sandy, mixed, frigid, ortstein	Aeric Haplaquod	Ground Water Podzol
3*	Seelyeville	euic	Typic Borosaprist	Bog
1*,2*, 3*,4,5*	Tawas	sandy, mixed, euic	Terric Borosaprist	Bog

*Profile descriptions in Appendix A.

†Occur only as inclusions in the mapping units.

[1]Taxadjunct (see profile description in Appendix A).

[2]Variant (see profile description in Appendix A).

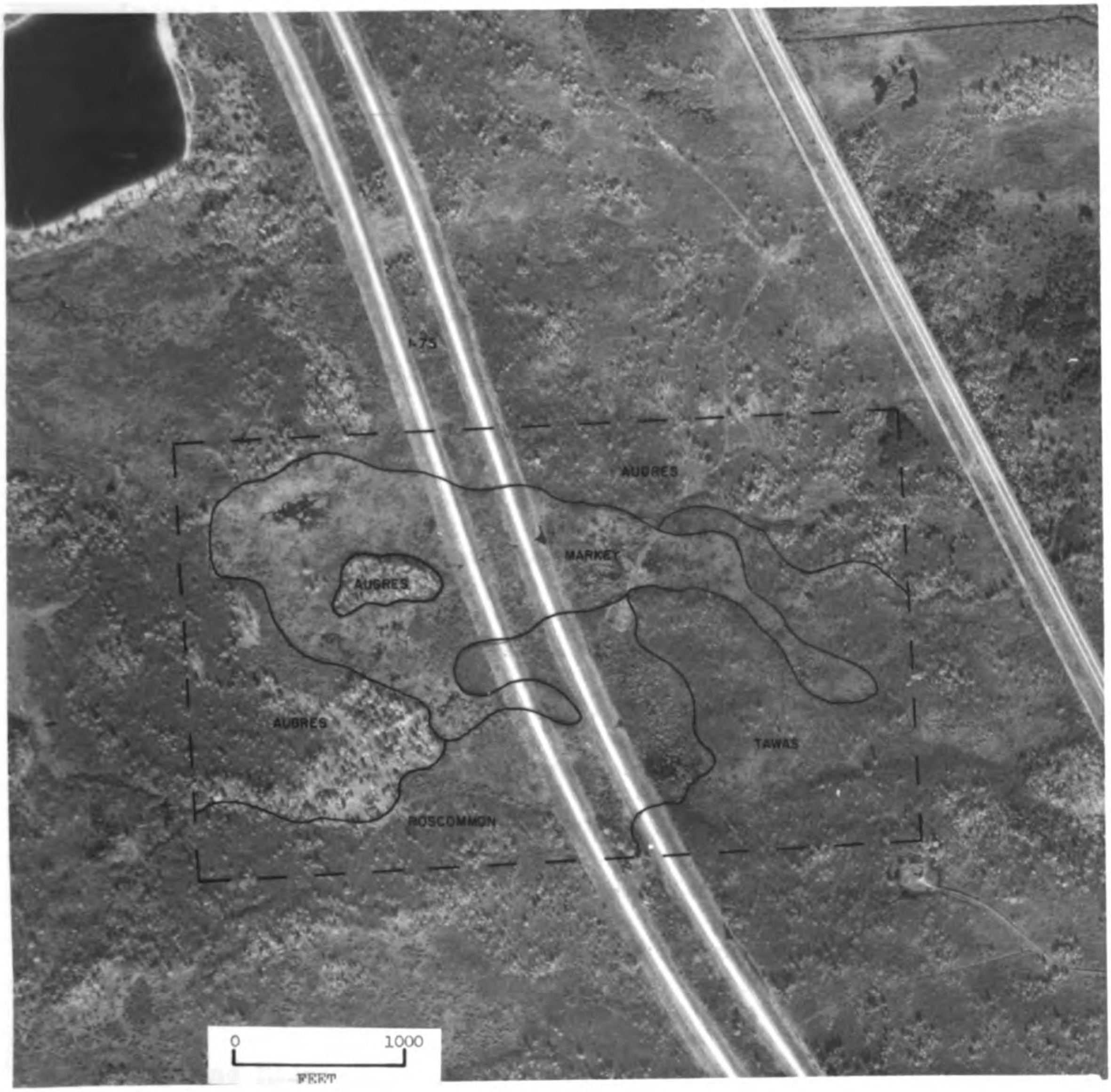

Figure 2. Soil map of Wetland Site 1.

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Table 8).

Markey muck - This is a dark colored, very poorly drained organic soil consisting of layers of highly decomposed herbaceous materials underlain by sandy deposits at depths of 16 to 51 inches. The water table is at or near the surface throughout the year. Slopes are less than 2 per cent.

Markey muck is the most dominant soil in the mapping unit. Lupton muck, in which the thickness of the organic layers is greater than 51 inches, and soil areas where the organic materials are less than 16 inches thick (Roscommon mucky sand) are the most dominant inclusions. The soil management group predominating in this mapping unit is M/4c (see Table 8).

AuGres sand - This is a deep, moderately dark colored, somewhat poorly drained soil formed in sandy outwash. This soil typically has a thin, black A1 horizon, a mottled grayish A2 horizon, and a dark reddish brown B2hir and a reddish brown B2ir horizon. The water table fluctuates and is near the soil surface during the winter and spring. Slopes are less than 2 per cent.

Other soils that are found in this mapping unit are Saugatuck and Roscommon soils and very poorly drained Markey muck. The Saugatuck soils are similar to AuGres but have a continuously cemented ortstein subsoil layer. Roscommon soils have a dark colored surface layer underlain by grayish brown sand. The Markey series is a shallow organic soil but is formed from herbaceous materials and overlies sand within 16 to 51 inches. The soil management group predominating in this mapping unit is 5b (see Table 8).

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Roscommon sand - This is a dark colored, poorly drained soil formed in sandy outwash. The surface layer is dominantly sand and ranges in thickness from 2 to 7 inches. The C horizon is gray and mottled. Mucky sand and loamy sand types are also found. In places the surface layer is a muck, 1 to 15 inches thick. The water table is near or at the surface for a considerable part of the year. Slopes are less than 2 per cent.

Small areas of Markey muck, Tawas muck, and AuGres sand are also found in this mapping unit. The Markey and Tawas mucks are shallow organic soils and AuGres sand has a sandy reddish brown subsurface horizon. The soil management group predominating in this mapping unit is 5c (see Table 8).

Tawas muck - This is a dark colored, very poorly drained organic soil consisting of layers of highly decomposed woody materials underlain by sandy deposits at depths of 16 to 51 inches. The water table is at or near the surface throughout the year. Slopes are less than 2 per cent.

Also included in this mapping unit are areas of Carbondale and Roscommon soils. Carbondale soils are similar to Tawas but have organic deposits thicker than 51 inches. Roscommon soils are poorly drained mineral soils with a dark colored surface horizon of sand, loamy sand, or mucky sand and sand subsoil. The soil management group predominating in this mapping unit is M/4c (see Table 8).

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Wetland Site 2

Site 2 is located in Section 23, Ogemaw Township (T22N, R1E), Ogemaw County. At this site a corridor was cut through an area of organic soils which grade into well drained and somewhat poorly drained coarse textured upland soils. This wetland site is a white cedar and paper birch swamp. Figure 3 shows a soil map of the area. Three mapping units have been delineated:

Newaygo sandy loam - This is a well drained soil that formed in sandy loam to loam material underlain by calcareous sand and gravel at a depth of 20 to 40 inches. The water table does not rise above 30 inches for any appreciable amount of time. Slopes range from 0-2 per cent.

Mancelona soils, which are coarser textured than Newaygo soils, were also observed in this mapping unit. The soil management group predominating in this mapping unit is 3/5a (see Table 8).

Palo sandy loam - This is a somewhat poorly drained soil that formed in sandy loam to loam materials underlain by calcareous sand and gravel at a depth of 20 to 40 inches. The water table fluctuates and is near the soil surface during the winter and spring. Slopes are less than 2 per cent.

Other soils found in this mapping unit are Gladwin loamy sand and Tawas muck. The Gladwin soils are similar to Palo but are coarser textured and Tawas is a shallow organic soil over sand. The soil management group predominating in this mapping unit is 3/5b (see Table 8).

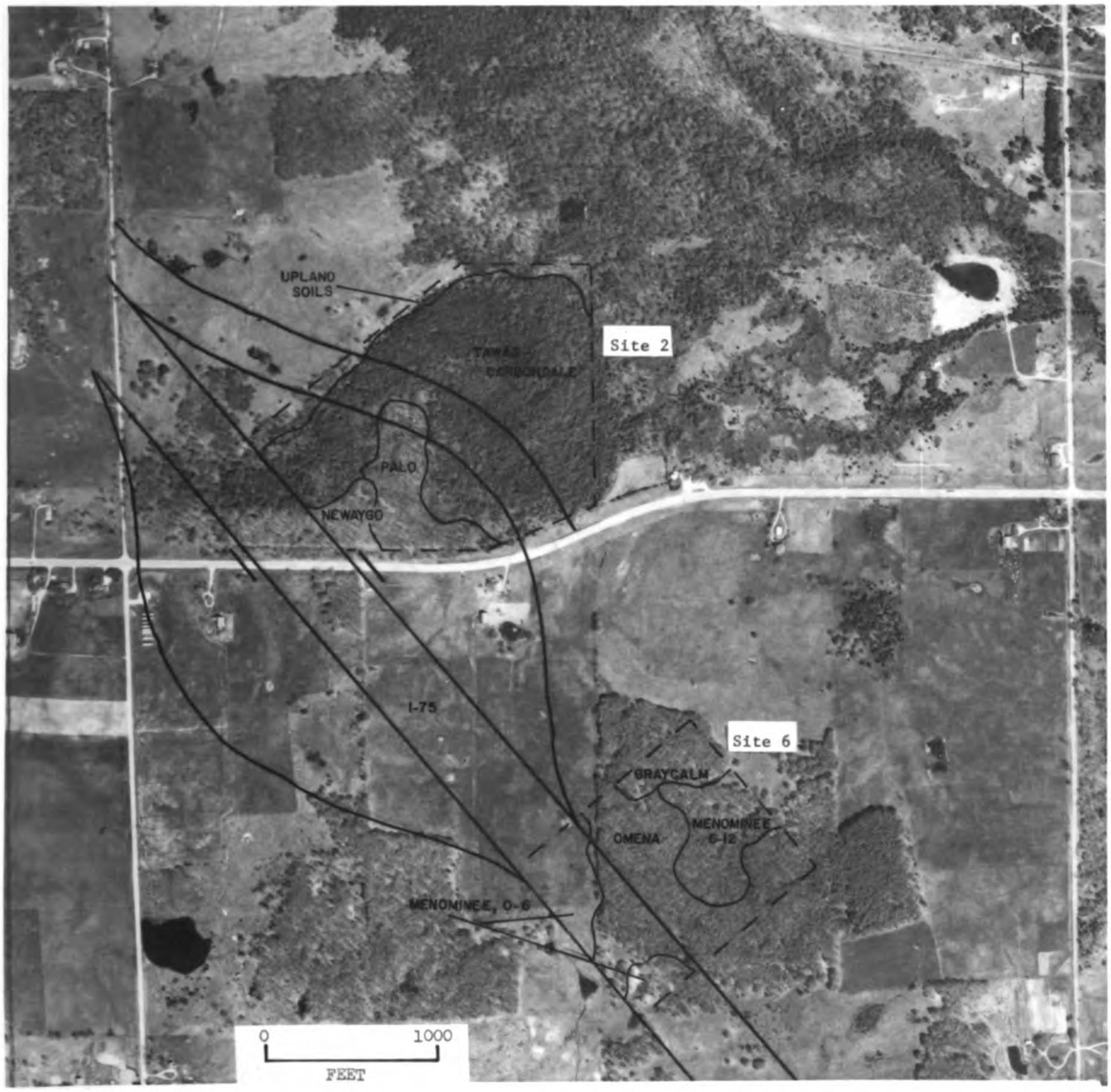

Figure 3. Soil map of Wetland Site 2 and Woodlot Site 6.

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Tawas-Carbondale complex - The soils in this mapping unit are dark colored, very poorly drained organic soils consisting of layers of highly decomposed woody materials. The Tawas soils have organic materials between 16 and 51 inches thick and Carbondale soils have organic layers with a total thickness greater than 51 inches. These two soils occur in such an intricate pattern that neither soil can be shown separately on the soil map. The water table is at or near the soil surface throughout the year. Slopes are less than 2 per cent.

The Tawas soils are most abundant in this mapping unit. A number of mineral soils are also found within this mapping unit, the most common being the Roscommon series. The soil management group predominating in this mapping unit is M/4c (see Table 8).

Wetland Site 3

Site 3 is located in Section 34, Beaver Creek Township (T25N, R3W), Crawford County. At this site the highway cuts through a very poorly drained area of level organic soils that is bordered by well drained, level to gently sloping sandy soils. The area is a white cedar, black spruce, tamarack wetland along Beaver Creek. Figure 4 shows a soil map of the area. Two different soil mapping units are found at this site:

Grayling-Croswell complex (0 to 6 per cent slopes) - The soils in this mapping unit are nearly level to gently sloping, well to moderately well drained sands. Grayling sand is the well drained member of the mapping unit. It typically has a thin, black Al

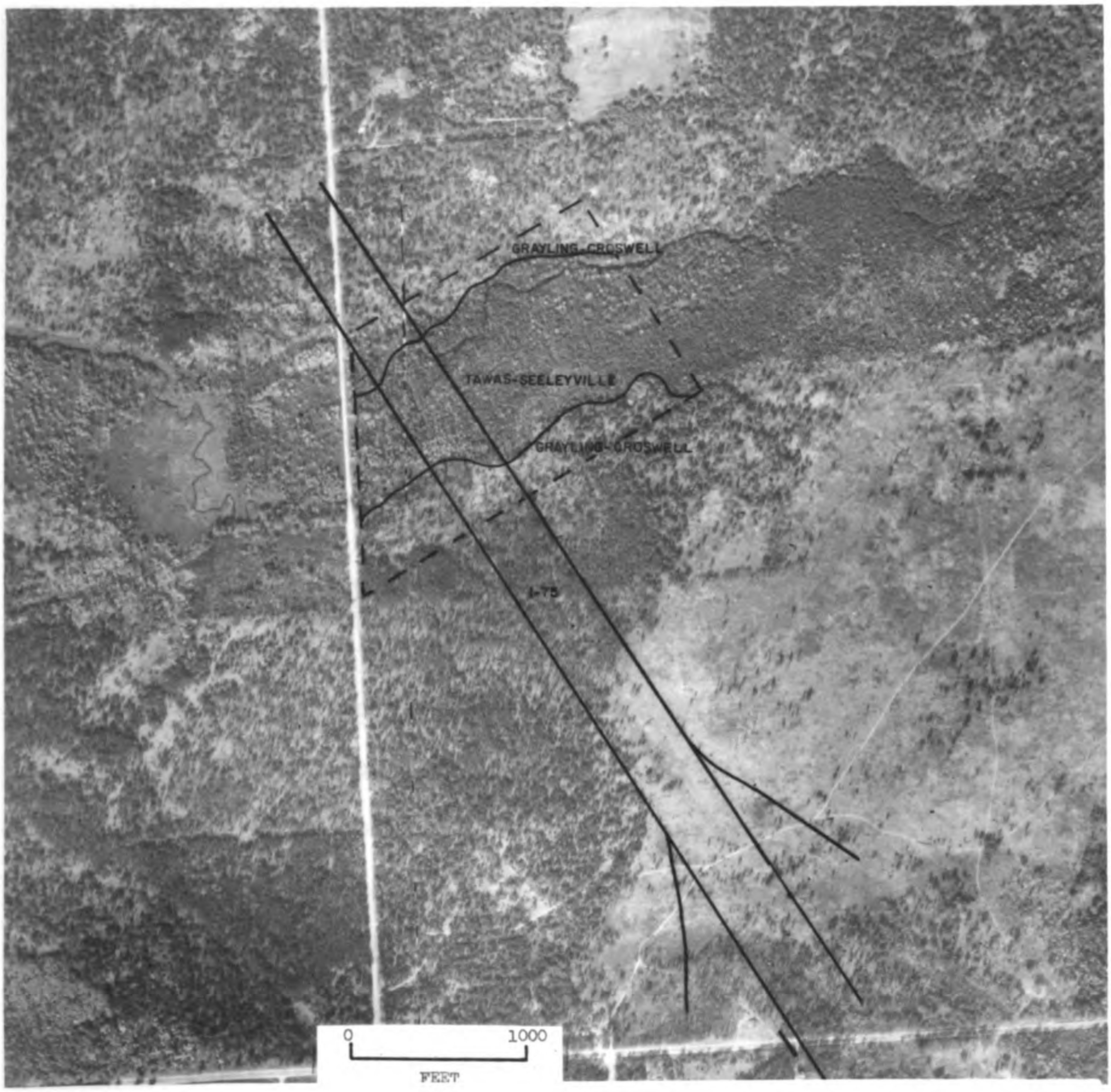

Figure 4. Soil map of Wetland Site 3.

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horizon, a thin, gray A2 horizon and a yellowish brown B21ir horizon. The moderately well drained Croswell series appears in intricate patterns with the Grayling soil. It is similar to Grayling but has a dark brown to brown B21ir horizon and has mottling at depths of from about 20 to 40 inches. The water table in this mapping unit does not rise above 30 inches for any appreciable length of time during the year. Slopes range from 0 to 6 per cent.

The Grayling series is the most dominant soil in this mapping unit. Other soils found within this mapping unit include the somewhat poorly drained AuGres and Saugatuck soils and the well drained Graycalm and Montcalm soils. The soil management group predominating in this mapping unit is 5.7a (see Table 8).

Tawas-Seelyeville complex - The soils in this mapping unit are dark colored, very poorly drained organic soils consisting of layers of highly decomposed woody materials. Tawas muck has organic material between 16 and 51 inches thick and Seelyeville muck has organic deposits thicker than 51 inches. These two soils occur in very intricate patterns and could not be shown separately on the soil map. The water table is at or near the surface throughout the year. Slopes are less than 2 per cent.

Two mineral soils, Roscommon sand and Kinross sand, are also found within this mapping unit. The soil management group predominating in this mapping unit is M/4c (see Table 8).

Wetland Site 4

Site 4 is located in Section 30, Higgins Township (T24N, R2W), Roscommon County. At this site the highway crosses over a poorly drained area of level, deep organic soils that are bordered by poorly drained, level to gently sloping mineral soils. White cedar, paper birch, black spruce, and tamarack are the predominant tree species of this swamp area. Aspen and oak are found on the upland areas. Figure 5 shows a soil map of the area. There are two mapping units found at this site:

Rifle peat - This is a dark colored, very poorly drained organic soil that formed in organic deposits more than 51 inches thick. The soil consists of moderately decomposed layers of both woody and herbaceous materials. The water table is at or near the surface throughout the year. Slopes are less than 2 per cent.

Small areas of Tawas muck are also found in this mapping unit. It consists of organic materials between 16 and 51 inches thick. The soil management group predominating in this mapping unit is Mc (see Table 8).

Saugatuck sand (0 to 6 per cent slopes) - This is a dark colored, somewhat poorly drained soil. The soil is sandy throughout the profile and has a subsoil layer that is strongly cemented (ortstein). This mapping unit represents the transitional area between the Rifle peat bog and the uplands that surround the bog. The water table is near the soil surface for a considerable part of the year. Slopes range between 0 and 6 per cent.

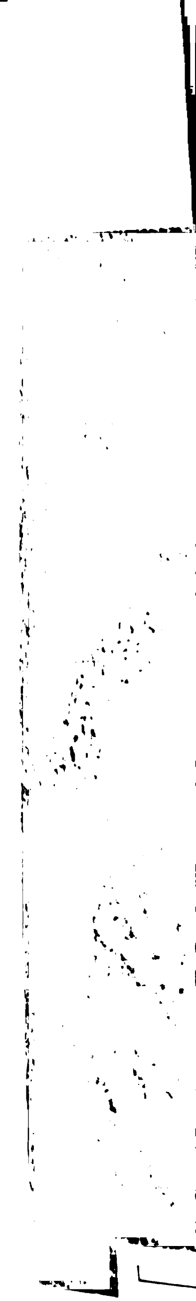

Figure 5.

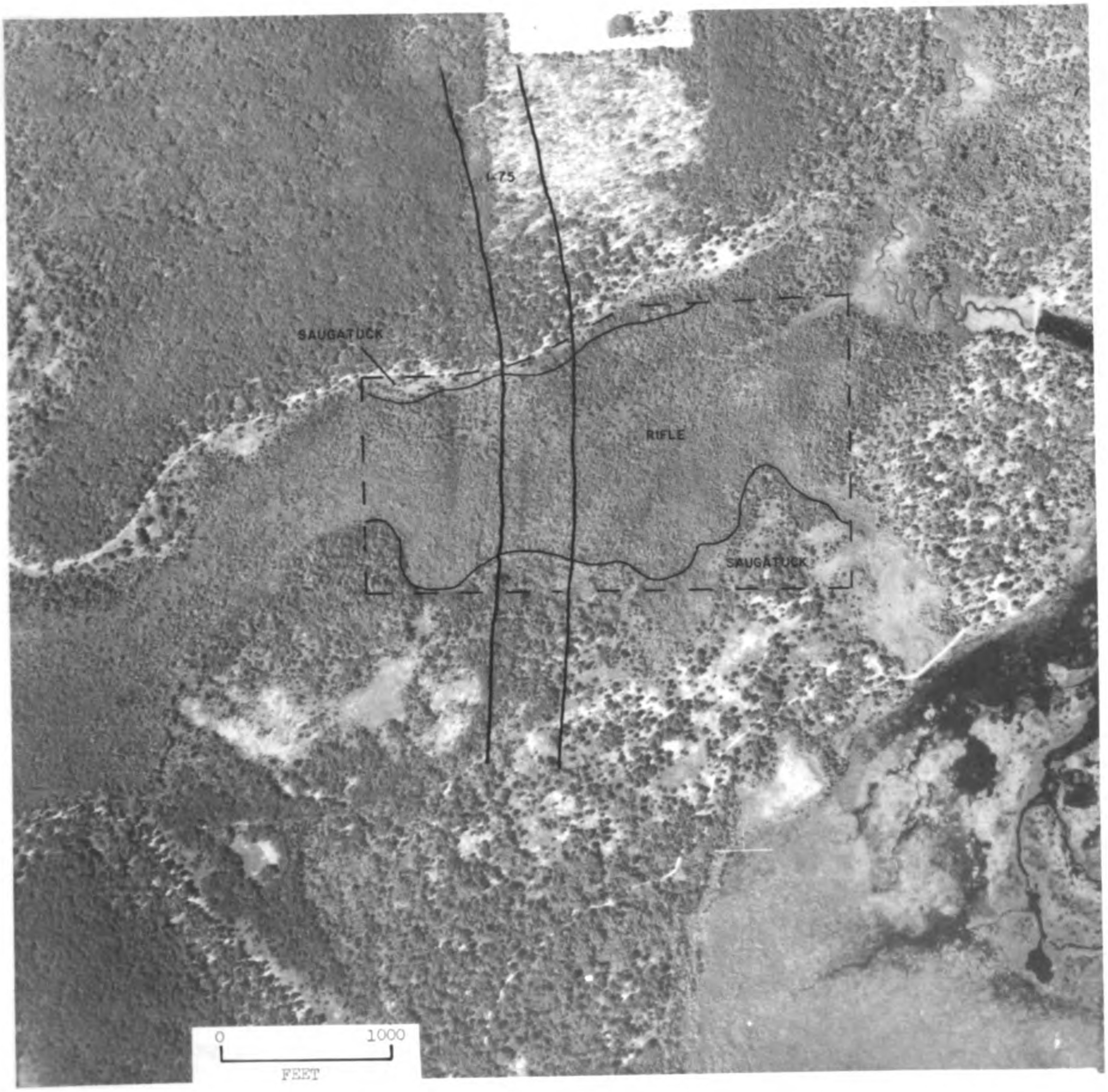

Figure 5. Soil map of Wetland Site 4.

AuGres soils, which lack the cemented layer, are also included in the mapping unit. The soil management group predominating in this mapping unit is 5b-h (see Table 8).

Wetland Site 5

Site 5 is located in Section 34, Higgins Township (T23N, R2W), Roscommon County. The highway cuts through an area of level, poorly drained organic soils and sandy, mineral soils. The predominant tree species at Site 5 are black spruce, white cedar, black ash, and tamarack. Figure 6 shows a soil map of the area. There are five mapping units found at this wetland site:

Carbondale muck - This is a dark colored, very poorly drained organic soil consisting of layers of highly decomposed woody materials that are thicker than 51 inches. The water table is at or near the surface throughout the year. Slopes are less than 2 per cent.

Included in the mapping unit is Tawas muck, which is similar to the Carbondale series except for thickness of the organic layer, which is 16 to 51 inches. The predominant soil management group in this mapping unit is Mc (see Table 8).

Croswell sand (0 to 6 per cent slopes) - This is a moderately well drained soil with sand dominating throughout the profile. The water table does not rise above 30 inches for any appreciable amount of time. Slopes are between 0 and 6 per cent.

In a typical profile the surface horizon is very dark grayish brown about 2 inches thick. The subsurface layer is grayish brown

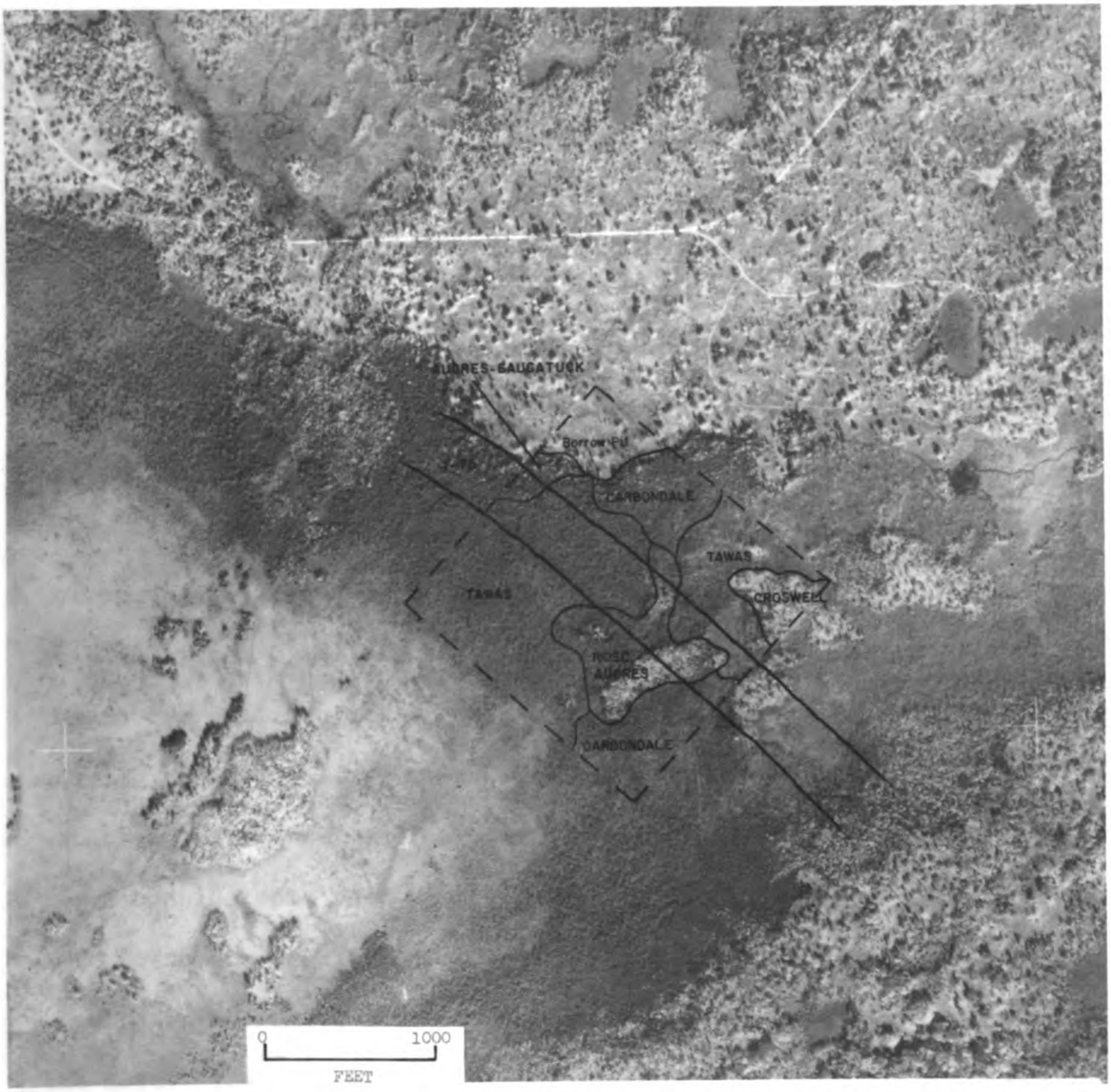

Figure 6. Soil map of Wetland Site 5.

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about 6 inches thick. The subsoil is yellowish brown to strong brown and extends to about 30 inches. The underlying material is light yellowish brown and is mottled.

The somewhat poorly drained AuGres soils are also found in this mapping unit. The soil management group predominating in this mapping unit is 5a (see Table 8).

Roscommon-AuGres complex - The soils in this mapping unit are Roscommon sand and AuGres sand. The Roscommon sand is poorly drained and the AuGres sand is somewhat poorly drained. They occur in a very intricate pattern and could not be separated on the soil map. Roscommon has a surface layer that is dominantly sand and ranges in thickness from 2 to 7 inches. The C horizon is gray and mottled. The AuGres soil typically has a thin, black A1 horizon, a mottled grayish A2 horizon, and a dark yellowish brown B2ir horizon. The water table in this mapping unit fluctuates, but is near the surface for a considerable part of the year. Slopes are less than 2 per cent.

Roscommon sand is more dominant than the AuGres sand in this mapping unit. Small areas of Tawas muck can also be found within the unit. The soil management group predominating in this mapping unit is 5c (see Table 8).

AuGres-Saugatuck complex (0 to 6 per cent slopes) - The soils in this mapping unit are somewhat poorly drained. They are sandy throughout the profile, and range from strongly acid to medium acid. The water table fluctuates, but is near the surface for a considerable part of the year. The slopes are between 0 and

6 per cent. The AuGres soils are the most abundant soil and are more strongly developed than the AuGres soils found in the Roscommon-AuGres complex mapping unit. The colors of the subsoil are dark reddish brown to reddish brown and contain small patches of ortstein. The Saugatuck sand is similar to AuGres but has a continuous cemented layer (ortstein).

Small areas of muck less than 16 inches thick underlain by grayish brown sand (Roscommon mucky sand) are also found in this mapping unit. The soil management group predominating in this mapping unit is 5b (see Table 8).

Tawas muck - This is a dark colored, very poorly drained organic soil consisting of layers of highly decomposed woody materials that are between 16 and 51 inches thick. The water table is at or near the surface throughout the year. Slopes are less than 2 per cent.

Also included in this mapping unit are small areas of Carbondale muck, Roscommon sand, and AuGres sand. The soil management group predominating in this mapping unit is M/4c (see Table 8).

Woodlot Site 6

Site 6 is located in Section 26, Ogemaw Township (T22N, R1E), Ogemaw County. At this upland site, a cut, approximately 35 feet deep, was made through firm clay loam materials. The soils at this site are well drained and topography is level to rolling or moderately sloping. This site is primarily a beech-maple community with some aspen and red oak. Figure 3 shows a soil map of the area. There are four mapping units found at this site:

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Graycalm sand (6 to 12 per cent slopes) - This is a well drained soil that developed in deep deposits of medium and coarse sands and has textural bands or lenses in the lower part of the profile. The water table does not rise above 30 inches for any appreciable length of time. Slopes are between 6 and 12 per cent.

Also included in the mapping unit are Montcalm, Croswell, Nester and Ubly soils. The Montcalm series is similar to Graycalm but does not have textural bands below 40 inches. Croswell soils lack the textural bands completely and the Ubly soils have 20 to 40 inches of loamy fine sand to fine sandy loam underlain by clay to silty clay. The Nester soils have less than 20 inches of the coarser materials over clay loam to silty clay loam. The soil management group predominating in this mapping unit is 5a (see Table 8).

Omena sandy loam (6 to 12 per cent slopes) - The soil is well drained and has less than 20 inches of sandy loam material over a clay loam or silty clay loam. In many places the surface layers are loamy sand or loam in texture. The water table does not rise above 30 inches for any appreciable length of time. Slopes are between 6 and 12 per cent.

Nester and Menominee soils are the most extensive inclusions in this mapping unit. The soil management group predominating in this mapping unit is 3a (see Table 8).

Menominee loamy fine sand (0 to 6 per cent slopes) - This is a well drained two-storied soil. The upper story developed in 20 to

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40 inches of loamy fine sand to fine sandy loam and the lower story developed in clay to silty clay. The water table does not rise above 30 inches for any appreciable length of time. Slopes are between 0 and 6 per cent. The soil management group predominating in this mapping unit is 4/2a (see Table 8).

Menominee loamy fine sand (6 to 12 per cent slopes) - This mapping unit is similar to the Ubly loamy fine sand, 0 to 6 per cent slopes mapping unit. This mapping unit is rolling to moderately sloping while the other is level to gently sloping. The soil management group predominating in this mapping unit is 4/2a (see Table 8).

Woodlot Site 7

Site 7 is located in Section 19, Higgins Township (T24N, R2W), Roscommon County. At this site the highway cuts through an area that consists of well to poorly drained, sandy, mineral soils. The principal forest species found at this site are jack pine, trembling aspen, and northern pin oak. Figure 7 shows a soil map of the area. There are five mapping units found at this site:

Croswell sand (6 to 12 per cent slopes) - This is a deep, moderately well drained, sandy soil. In a typical profile the surface horizon is very dark grayish brown about 4 inches thick. The subsoil is yellowish brown to brown and extends to about 35 inches and has mottling at depths of from about 20 to 40 inches. The water table does not rise above 30 inches for any appreciable length of time. Slopes range between 6 and 12 per cent.

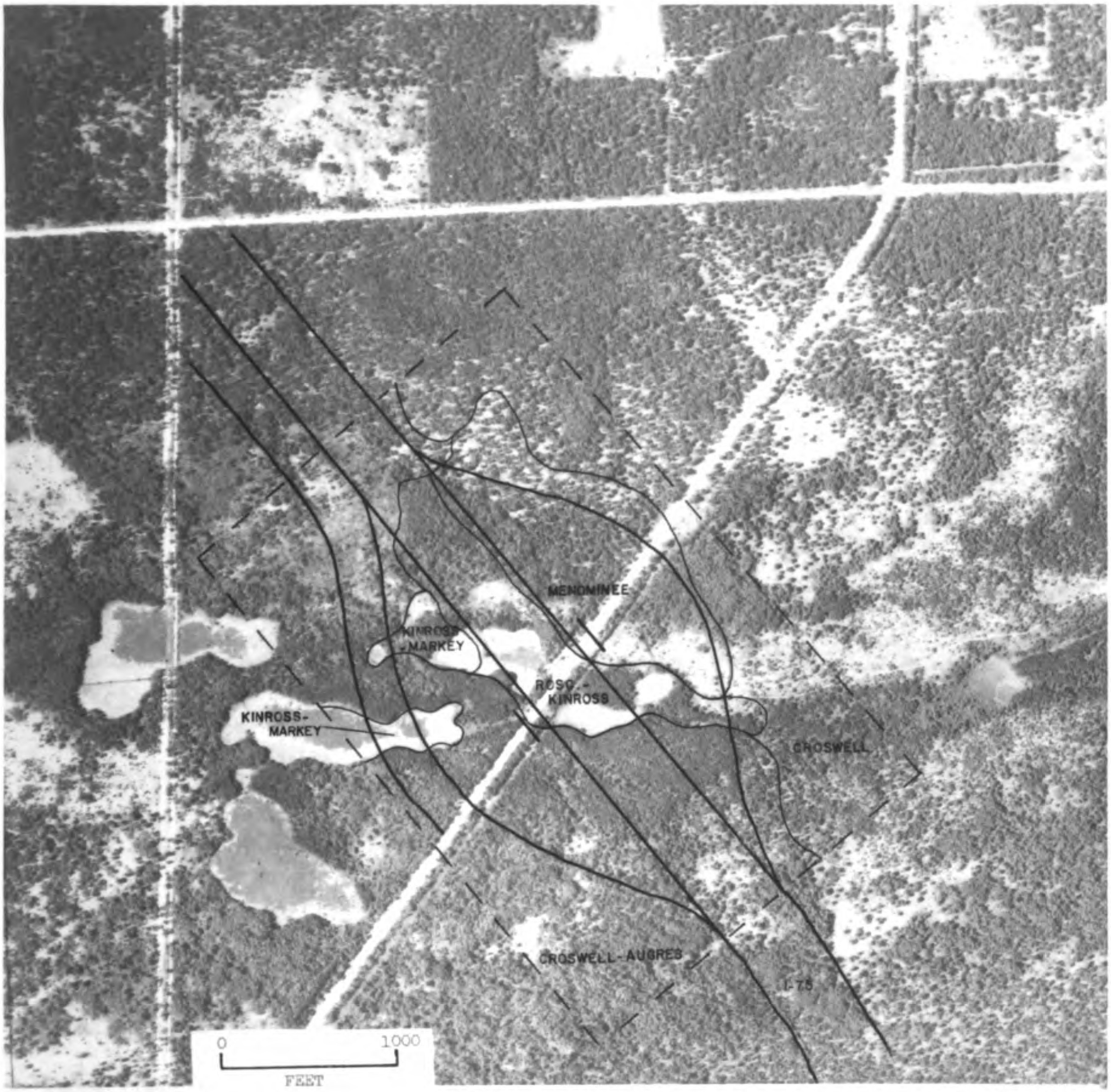

Figure 7. Soil map of Woodlot Site 7.

Included in this mapping unit are areas of Rubicon sand and AuGres sand. Rubicon is well drained and AuGres is somewhat poorly drained. Small areas where the sand is underlain by loam material are also present in this mapping unit and represent the Menominee series. Some Graycalm sand, which has textural bands of sandy loam in the subsoil, is also present in this mapping unit. The soil management group predominating in this mapping unit is 5a (see Table 8).

Croswell-AuGres complex (0 to 6 per cent slopes) - The soils in this mapping unit occur in intricate patterns on the landscape and could not be separated on the soil map. Both soils formed in deep deposits of sand. Croswell soils are moderately well drained and AuGres soils are somewhat poorly drained. A typical profile of Croswell sand is similar to that described for the Croswell sand (6-12 per cent slopes) mapping unit. Typically, AuGres has a thin, black A1 horizon, a mottled, grayish brown A2 horizon, and a dark reddish brown to reddish brown B2ir horizon. The water table fluctuates near the surface during the winter and spring. Slopes are less than 6 per cent.

Croswell sand is the most dominant soil in this mapping unit, followed by the AuGres series. Inclusions of Rubicon, Saugatuck, Graycalm, Menominee, and Iosco soils are also found. The soil management group predominating in this mapping unit is 5a (see Table 8).

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<u>Menominee sand</u> - Menominee sand is a moderately well drained two storied soil. The upper story was formed in sand to loamy sand and the lower story formed in loam. The water table does not rise above 30 inches for any appreciable length of time. Slopes are less than 2 per cent.

Also included in this mapping unit are Croswell, Iosco and Ogemaw soils. The soil management group predominating in this mapping unit is 4/2a (see Table 8).

<u>Kinross-Markey complex</u> - Kinross sand is a poorly drained soil formed in sandy material with an organic layer less than 16 inches thick on the surface and is the most abundant soil in this mapping unit. Markey muck is an organic soil consisting of layers of highly decomposed herbaceous materials underlain by sand at a depth of 16 to 51 inches and together with Kinross sand forms an intricate pattern in the landscape. A typical profile of Kinross sand at this site had a thick O horizon, a thin, black A1 horizon and a mottled, dark reddish brown to yellowish brown B horizon. The water table is at or near the surface for a considerable part of the year. Slopes are less than 2 per cent.

Also found in this mapping unit are small areas of Roscommon sand, Ogemaw sand, Otisco sand and Lupton muck. Ogemaw soils are underlain by loam materials and Otisco soils have sandy loam texture bands in the subsoil. The soil management group predominating in this mapping unit is 5c (see Table 8).

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Roscommon-Kinross complex - The soils in this mapping unit are poorly drained and occur in such an intricate pattern that they could not be reported separately on the soil map. Roscommon sand has a black surface layer between 1 and 7 inches thick underlain by loose grayish brown sand. Kinross sand is developed in sandy materials that are overlain by organic materials that are highly decomposed. The water table is near the surface for a considerable part of the year. Slopes are less than 2 per cent.

Included in this mapping unit are areas of AuGres, Saugatuck, Ogemaw, and Otisco soils. The soil management group predominating in this mapping unit is 5c (see Table 8).

Woodlot Site 8

Site 8 is located in Section 7, Higgins Township (T23N, R2W), Roscommon County. The site is located at the bottom of 9-Mile Hill with a north aspect and is transitional between an upland and wetland. The highway crosses over an area of poorly to moderately well drained, sandy soils. Aspen is the primary forest species at this site. Also present are alder, maple, oak and grasses. Figure 8 shows a soil map of the area. Four mapping units are found at this site:

AuGres sand - This is a deep, moderately dark colored, somewhat poorly drained soil formed in sandy outwash. The subsoil of the AuGres sand in this mapping unit is less developed than that of a typical AuGres profile. The water table fluctuates and is near the

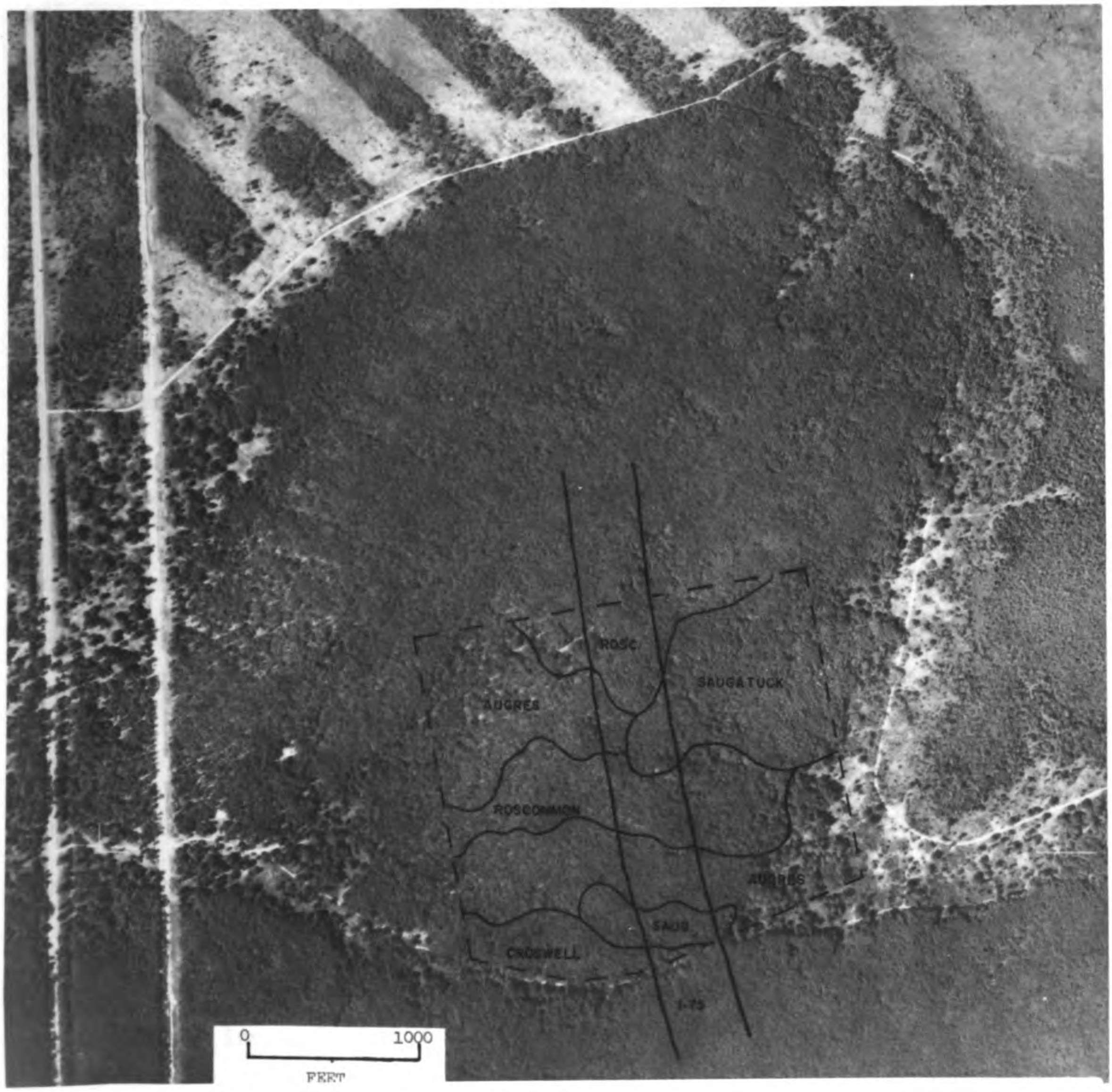

Figure 8. Soil map of Woodlot Site 8.

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Areas of Roscommon sand were noted as inclusions within this mapping unit. The soil management group predominating in this mapping unit is 5b (see Table 8).

Croswell sand - This is a moderately well drained soil with sand dominant throughout the profile. The water table does not rise above 30 inches for any appreciable amount of time. Slopes are between 0 and 2 per cent.

In a typical profile the surface horizon is very dark grayish brown about 2 inches thick. The A2 horizon is grayish brown and about 3-4 inches thick. The subsoil is yellowish brown and extends to about 35 inches.

The somewhat poorly drained AuGres soils make up about 20 per cent of this unit. The soil management group predominating in this mapping unit is 5a (see Table 8).

Roscommon mucky sand - This is a dark colored, poorly drained soil formed in sandy outwash. The water table is at or near the surface for a considerable part of the year. Slopes are less than 2 per cent. In a typical profile the A1 horizon is a black, mucky sand about 7 inches thick. This is underlain by a deep, mottled, grayish brown C horizon. Sand and loamy sand types are also found.

AuGres and Saugatuck soils may also be found in places within the mapping unit. The soil management group predominating in this mapping unit is 5c (see Table 8).

Saugatuck sand - This is a dark colored, somewhat poorly drained soil. This soil is sandy throughout the profile and has a subsoil layer that is strongly cemented (ortstein). The water table is at or near the soil surface for a considerable part of the year. Slopes are less than 2 per cent.

Included in this mapping unit are areas of the AuGres and Roscommon soils. The soil management group predominating in this mapping unit is 5b-h (see Table 8).

Woodlot Sites 9 and 10

Sites 9 and 10 are located in Sections 17 and 18, Higgins Township (T23N, R2W), Roscommon County. Site 9 is an upland site located on a ridge top where the highway construction activities have created 40 foot cuts through the area. Site 10 is an upland area, located approximately a quarter of a mile south of Site 9, where the roadbed has been built up about 30 feet. The soils found at these two sites are well drained sands. The principal forest species are aspen, red maple, red oak, and white oak. Figure 9 shows a soil map of the area. The mapping units of these sites are:

Croswell sand (6 to 12 per cent slopes) - This is a moderately well drained soil with sand dominant throughout the profile. The water table does not rise above 30 inches for any appreciable amount of time. Slopes are between 6 and 12 per cent.

A representative profile of Croswell sand found at these sites has a very dark grayish brown A1 horizon about 2 inches thick and a grayish brown A2 horizon between 3 and 4 inches thick. The subsoil

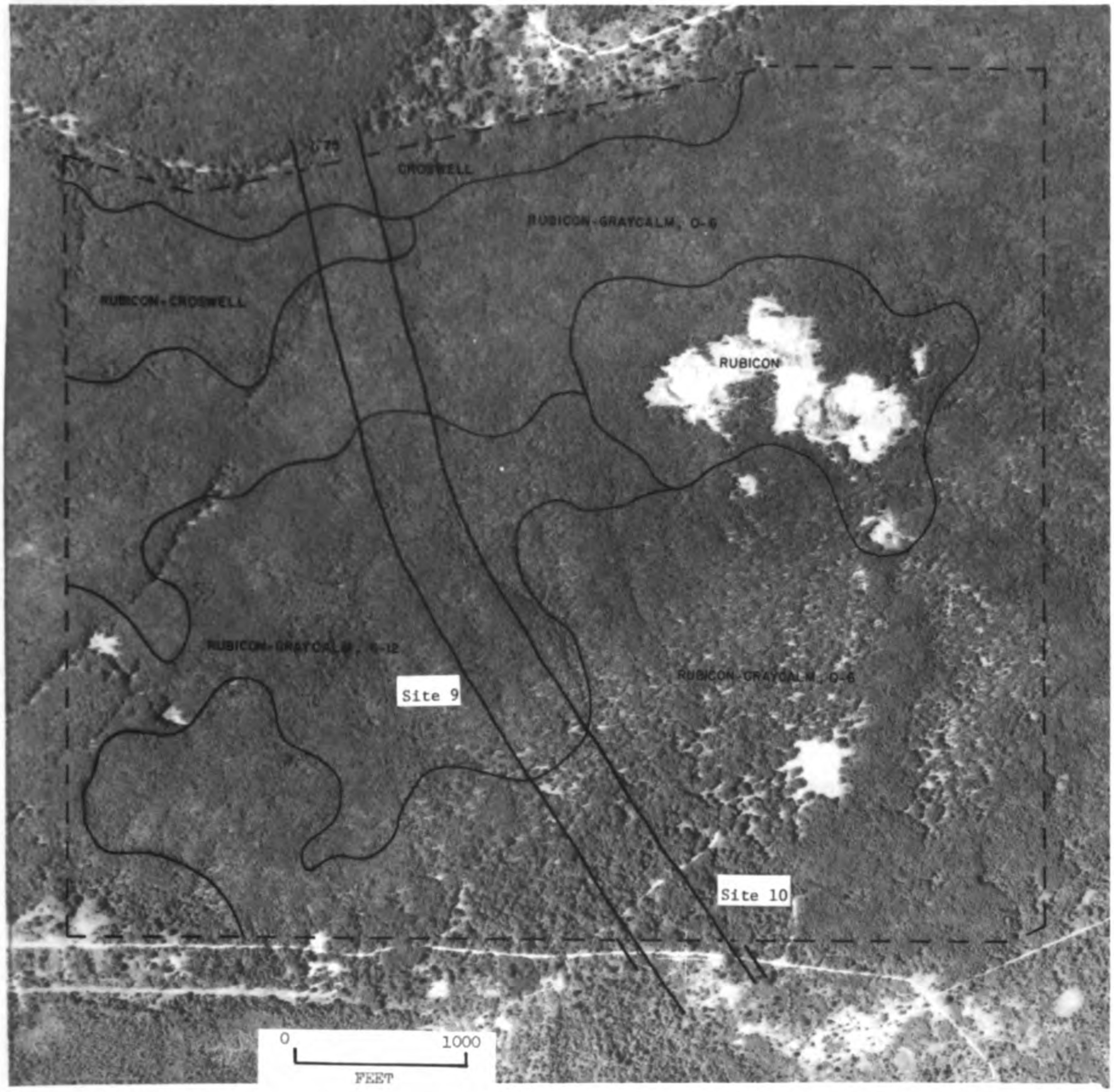

Figure 9. Soil map of Woodlot Sites 9 and 10.

is yellowish brown and extends to about 35 inches. Mottles are present below 30 inches.

Small areas of Rubicon sand and Graycalm sand may be found within this mapping unit. The predominant soil management group in this mapping unit is 5a (see Table 8).

Rubicon sand (0 to 6 per cent slopes) - This is a well drained soil that formed in deep deposits of medium to coarse sand. The water table does not rise above 30 inches for any appreciable amount of time. Slopes are less than 6 per cent. The Rubicon series is very similar to Croswell sand but has a dark brown to strong brown B2ir.

Included in this mapping unit are areas of Croswell sand, which is similar to the Rubicon but is mottled in the C horizon; Graycalm sand, which has sandy loam to loam textural bands in the subsoil; and Rousseau fine sand, which is also similar to Rubicon but formed in fine sands. The predominant soil management group is 5.3a (see Table 8).

Rubicon-Croswell complex (12 to 24 per cent slopes) - This mapping unit consists of the well drained, Rubicon soil and the moderately well drained Croswell soil occurring in such intricate patterns that they could not be separated on the soil map. The water table does not rise above 30 inches for any appreciable length of time. Slopes are between 12 and 24 per cent.

Rousseau fine sand and Graycalm sand are also found in places within this mapping unit. The predominant soil management group is 5.3a (see Table 8).

Rubicon-Graycalm complex (0 to 6 per cent slopes) - This mapping unit consists of the well drained Rubicon and Graycalm sands. Graycalm sand is similar to Rubicon but has textural bands in the subsoil. The water table does not rise above 30 inches for any appreciable length of time. Slopes are between 0 and 6 per cent.

Areas of Rousseau fine sand, Montcalm sand, and Menominee sand are found in this mapping unit. The predominant soil management group is 5.3a (see Table 8).

Rubicon-Graycalm complex (6 to 12 per cent slopes) - This mapping unit is similar to the Rubicon-Graycalm complex (6 to 12 per cent slopes) but is rolling to moderately sloping instead of level to gently sloping. The predominant soil management group is 5.3a (see Table 8).

V. ANALYSIS OF HIGHWAY IMPACT

Some of the significant effects a highway project may have on the surrounding soil are: 1) sediment transport and sedimentation resulting from the erosion of soil materials, 2) alteration of natural soil drainage conditions and circulation patterns, 3) salt contamination of soils from de-icing salts applied to the highway, 4) contamination of the soils by pollutants from motor vehicle exhaust, and 5) contamination of the soils by chemicals and petroleum products from accidental spills and normal use of the roadway.

Table 3 gives a brief assessment of highway impact at each site. Texture, per cent slope, and drainage characteristics of the soils are important soil characteristics used to determine and understand the impact. Surface runoff and permeability are two important aspects of soil drainage and the runoff and permeability classes of the predominant soil or soils in each mapping unit have also been included in Table 3. The soil permeability classes used in Table 3 are defined as follows (Soil Survey Staff, 1951):

Table 3. Soil characteristics and brief assessment of highway impact at each study site

Site	Soils[†] mapping units	Soil Characteristics: drainage	permeability*	runoff*	surface texture	% slope	Assessment of highway impact (observed during field investigation)
1	AuGres sand (5b)	somewhat poor	rapid	slow	sand	0-2	No impact observed
	Markey muck (M/4c)	very poor	mod. rapid	very slow	muck	0-2	
	Roscommon sand (5c)	poor	rapid	very slow to ponded	sand	0-2	
	Tawas muck (M/4c)	very poor	mod. rapid	very slow	muck	0-2	
2	Newaygo sandy loam (3/5a)	well	mod. to mod. rapid over very rapid	slow	sandy loam	0-2	Disruption of natural soil drainage conditions and erosion of soil materials
	Palo sandy loam (3/5b)	somewhat poor	mod. to mod. rapid over rapid	slow-very slow	sandy loam	0-2	
	Tawas-Carbondale complex (M/4c)	very poor	mod. rapid	very slow to ponded	muck	0-2	
3	Grayling-Croswell complex, 0-6% slope (5.7a)	well-mod. well	rapid to very rapid	rapid-very rapid	sand	0-6	Disruption of natural soil drainage conditions
	Tawas-Seelyeville complex (M/4c)	very poor	mod. to mod. rapid	very slow-rapid	muck	0-2	

Table 3 (cont'd.)

Site	Soil[†] mapping units	Soil Characteristics: drainage	permeability*	runoff*	surface texture	% slope	Assessment of highway impact (observed during field investigation)
4	Rifle peat (Mc)	very poor	mod. rapid	very slow	peat	0-2	Disruption of natural soil drainage conditions
	Saugatuck sand (5b-h)	somewhat poor	slow to mod. rapid	slow to med.	sand	0-6	
5	Carbondale muck (Mc)	very poor	moderate	ponded	muck	0-2	
	Croswell sand, 0-6% slope (5a)	mod. well	rapid	very slow	sand	0-6	
	Roscommon-AuGres complex (5c)	poor-somewhat poor	rapid	ponded to slow	sand	0-2	Disruption of natural soil drainage conditions
	AuGres-Saugatuck complex, 0-6% slope (5b)	poor-somewhat poor	slow to rapid	slow to med.	sand	0-6	
	Tawas muck (M/4c)	very poor	mod. rapid	very slow	muck	0-2	
6	Graycalm sand, 6-12% slope (5a)	well	rapid to very rapid	slow to very slow	sand	6-12	
	Omega sandy loam, 6-12% slope (3a)	well	mod. slow	med. to rapid	sandy loam	6-12	No impact observed
	Menominee fine sandy loam, 6-12% slope (4/2a)	well	mod.rapid over slow to mod.	med. to rapid	fine sandy loam	6-12	
	Menominee fine sandy loam, 0-6% slope (4/2a)	well	mod.rapid over slow to mod.	slow to med.	fine sandy loam	0-6	

Table 3 (cont'd.)

Site	Soil[†] mapping units	Soil Characteristics					Assessment of highway impact (observed during field investigation)
		drainage	permeability*	runoff*	surface texture	% slope	
7	Croswell sand, 6-12% slope (5a)	mod. well	rapid	very slow	sand	6-12	
	Croswell-AuGres complex, 0-6% slope (5a)	somewhat poor to mod. well	rapid	slow to very slow	sand	0-6	
	Menominee sand (4/2a)	well	rapid over mod. to slow	medium to rapid	sand	0-2	Disruption of natural soil drainage conditions
	Kinross-Markey complex (5c)	poor	mod. rapid to very rapid	very slow to ponded	sand	0-2	
	Roscommon-Kinross complex (5c)	poor	mod. rapid to rapid	very slow to ponded	sand	0-2	
8	AuGres sand (5b)	somewhat poor	rapid	slow	sand	0-2	
	Croswell sand (5a)	mod. well	rapid	very slow	sand	0-2	
	Roscommon mucky sand (5c)	poor	rapid	very slow to ponded	mucky sand	0-2	Disruption of natural soil drainage conditions
	Saugatuck sand (5b-h)	somewhat poor	slow to mod. rapid	slow to med.	sand	0-2	

Table 3 (cont'd.)

Site	Soil[†] mapping units	Soil Characteristics: drainage	permeability*	runoff*	surface texture	% slope	Assessment of highway impact (observed during field investigation)
9&10	Croswell sand, 6-12% slope (5a)	mod. well	rapid	very slow	sand	6-12	
	Rubicon sand, 0-6% slope (5.3a)	well	rapid to very rapid	slow to mod. rapid	sand	0-6	
	Rubicon-Croswell complex, 12-24% slope (5.3a)	mod. well to well	rapid to very rapid	very slow to mod. rapid	sand	12-24	No impact observed
	Rubicon-Grayling complex, 0-6% slope (5.3a)	well	rapid to very rapid	very slow to mod. rapid	sand	0-6	
	Rubicon-Graycalm complex, 6-12% slope (5.3a)	well	rapid to very rapid	very slow to mod. rapid	sand	6-12	

*Permeability and runoff classes for these soils were obtained from National Cooperative Soil Survey Soil Series Descriptions.

†Soil Management Group predominating in each mapping unit found in parentheses.

Class	Rate (inches/hr)
Slow	
1) very slow	<0.05
2) slow	0.05-0.20
Moderate	
3) moderately slow	0.20-0.80
4) moderate	0.80-2.50
5) moderately rapid	2.50-5.00
Rapid	
6) rapid	5.00-10.00
7) very rapid	>10.00

The surface runoff classes used in Table 3 are (Soil Survey Staff, 1951):

0. *Ponded*. None of the water added to the soil as precipitation or by flow from surrounding higher land escapes as runoff. The total amount of water that must be removed from ponded areas by movement through the soil or by evaporation is usually greater than the total rainfall. Ponding normally occurs in depressed areas and may fluctuate seasonally.

1. *Very slow*. Surface water flows away so very slowly that free water lies on the surface for long periods or enters immediately into the soil. Much of the water either passes through the soil or evaporates into the air. Soils with very slow surface runoff are commonly level to nearly level or very open and porous.

2. *Slow*. Surface water flows away so slowly that free water covers the soil for significant periods or enters the soil rapidly and a large part of the water passes through the profile or evaporates into the air. Soils with a slow rate of surface runoff are either nearly level or very gently sloping, or absorb precipitation very rapidly. Normally there is little or no erosion hazard.

3. *Medium.* Surface water flows away at such a rate that a moderate proportion of the water enters the soil profile and free water lies on the surface for only short periods. A large part of the precipitation is absorbed by the soil and used for plant growth, is lost by evaporation, or moves downward into underground channels. With medium runoff, the loss of water over the surface does not reduce seriously the supply available for plant growth. The erosion hazard may be slight to moderate if soils of this class are cultivated.

4. *Rapid.* A large proportion of the precipitation moves rapidly over the surface of the soil and a small part moves through the soil profile. Surface water runs off nearly as fast as it is added. Soils with rapid runoff are usually moderately steep to steep and have low infiltration capacities. The erosion hazard is commonly moderate to high.

5. *Very rapid.* A very large part of the water moves rapidly over the surface of the soil and a very small part goes through the profile. Surface water runs off as fast as it is added. Soils with very rapid rates of runoff are usually steep or very steep and have low infiltration capacities. The erosion hazard is commonly high or very high.

The impact observed at each site during field investigations is discussed below.

Wetland Site 1

No apparent highway impact was observed at this site during field investigations. High water table levels were observed at this site and the water table in the median was above the soil surface on areas of the poorly drained Roscommon soil and very poorly drained Markey soil. Initially, it was believed that the areas of standing water in the median represented an altered drainage condition; but there was no evidence of tree death, which would suggest possible drainage disturbance. Also, these areas of standing water were mapped as flooded areas by MDSH soil engineers before construction activities began, indicating no apparent change in drainage conditions (Preliminary Plan Prints, Site 1; Appendix C).

Wetland Site 2

Disruption of natural soil drainage conditions and sedimentation resulting from erosion of soil materials were observed at this site. A high water table level was observed on the Tawas and Seelyeville soils, but this is expected on these very poorly drained soils. Die-off of some white cedar on the western part of this site was observed, however, suggesting that this water table level is not the same as before construction, but has been raised.

Sediments, between 1/2 inch and 2 inches thick, were observed in places on the surface of the organic soils within the northeast quadrant of the interchange. These sediments probably resulted from erosion of adjacent coarse textured mineral soils during the construction period. Woodlot Site 6 is located upslope and directly south of this site and the soils at Site 6, Omena, Nester and Menominee are susceptible to erosion (surface runoff class medium to rapid; Table 3). The sandy loam texture of the Newaygo and Palo soils at Site 2 indicate that they may also be susceptible to water erosion. However, the slope class and runoff class of the mapping units indicate no to little erosion hazard.

Wetland Site 3

At Site 3 the highway cuts through a very poorly drained area of level organic soils. The natural soil drainage conditions of this site have been altered due to construction activities. A rise of the water table level in the median is suggested by the fact that some trees of each species growing on the Tawas and Seelyeville soils have died.

Wetland Site 4

The natural soil drainage conditions have been altered at this site. The natural water table of Rifle peat is high and is at or near the soil surface throughout the year. Standing water in the median area, which is not unusual for this soil, was observed during field investigations. The fact that trees of all species found at this site were killed in this area indicates a disruption of earlier drainage conditions or water circulation patterns.

Wetland Site 5

High water table levels were observed on the poorly drained and somewhat poorly drained mineral soils and the very poorly drained organic soil at this site. In the median the water table was above the soil surface in places. When this site was mapped by MDSH soil engineers, these areas were designated as "peat marsh" and

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1.0 to 1.5 feet of standing water was indicated (Preliminary Plan Print, Site 5; Appendix C). It would appear, then, that no change in soil drainage has occurred, but evidence of some tree kill in the median suggests that alteration of the soil drainage conditions or water circulation patterns did occur because of highway construction.

Woodlot Site 6

Erosion of soil materials most likely took place at this upland site during construction activities. However, no evidence of erosion was actually observed at the site. The Omena and Menominee soils found at this site are grouped into medium to rapid surface runoff classes which yield a slight to high erosion hazard. Also, since these soils have a sandy loam surface horizon and are located on 6 to 12 per cent slopes, they are susceptible to erosion.

Some dead trees were observed in the median at Site 6, but this probably resulted from local increase in evapotranspiration, due to increased exposure.

Woodlot Site 7

At this site the highway cuts through an area of well drained to poorly drained sandy soils. The drainage of the poorly drained soils in the median has been disrupted due to highway construction. The area just south of the overpass was indicated as being a marsh by MDSH soil engineers, indicating standing water (Preliminary Plan Print, Site 7; Appendix C). A ditch was constructed through this area and has resulted in the ponding of water just south of the overpass. A few jack pine growing on the Croswell-AuGres complex just south of the ponded area have been killed, suggesting a rise of the water table.

To the north of the ponded area, a decrease in the growth of aspens in the median suggests a lowering of the water table (Heninger, 1974).

Woodlot Site 8

This site is transitional between an upland and a wetland. Drainage conditions of the poorly and somewhat poorly drained soils have been altered in the median and near the edges of the right-of-way. Some tree kill in the median and near the edges of the right-of-way indicate that the water table level has risen since construction of the highway.

Woodlot Sites 9 and 10

No apparent highway impact upon the soils was observed at either of these upland sites. Some dead trees were observed in the median at Site 9, but this probably resulted from local increase in evapotranspiration due to increased exposure.

Discussion

The most important effect that the construction of Interstate 75 has had on the soils of the woodlots and wetlands studied is the effect on natural soil drainage conditions. All of the wetland sites and Woodlot Sites 7 and 8 are dominated by level areas of very poorly drained organic soils and/or poorly drained sandy, mineral soils. High water table levels were observed at all of these sites and at Sites 1, 4, 5, and 7, the water table was above the soil surface in places. These high water table levels and ponded conditions are not unusual for these soils, since they are described as having water table levels at or near the surface throughout the year and are grouped into ponded to slow surface runoff classes. However, the fact that dead trees were observed on these areas (except Site 1) suggests that the natural drainage conditions or water circulation patterns have been altered because of the highway project. A high water table, slow moving ground water, or stagnant ground water restrict soil aeration and may reduce tree growth or even kill trees. A tree growth study performed at these study sites indicated that the reduced growth of trees at Sites 2, 3, 4, 5, and 8 since highway construction was caused by a substantial rise in the water table level. Decreased growth of aspens at Site 7 was believed to be caused by a lowering of the water table (Heninger, 1974).

The high water table and ponded areas at Wetland Site 1 appear to be similar to conditions that existed before highway construction. Flooded areas were noted by MDSH soil engineers during their soil survey and since no dead vegetation was observed on these areas no alteration of drainage could be assumed. Since the drainage conditions of all the other sites dominated by very poorly drained and poorly drained soils were altered, it must be assumed that the drains and channels constructed at Site 1 were properly designed and located so as to not alter existing conditions, or that the wetland vegetation at Site 1 is not sensitive to small changes in drainage conditions.

The sites where deep road cuts were made or fills were made may have experienced a change in water table levels near the edges of the roadway or in evapotranspiration rates, but since these are well drained sites this would represent only a minor ecological variation.

The extent and duration of these altered drainage regimes is unknown. It is very possible that they are just temporary and may be corrected with time if adequate drains and channels have been provided.

Evidence of erosion of soil materials was observed at Site 2. Sediments, 1/2 inch to 2 inches thick, on very poorly drained organic soils, probably originated from higher areas or fills to the south. The texture, slope, and surface runoff characteristics of the soils at Site 6, to the south, show they are susceptible to erosion.

Further highway impact on the surrounding soil environment of these ten study sites may occur in future years. After de-icing programs have been carried on for a few years, the concentrations of sodium and chlorine ions in the soil may increase to levels that would have an adverse effect on plant growth or on soil structure. Because of the sandy texture of the soils at many of the sites, cation exchange sites are limited and sodium ions could be flushed from the site by water infiltration and circulation. Salt contamination of soils would most likely occur at Sites 2 and 7. Because of the interchanges present at these sites, more salt will be used per unit of adjoining land area and the salt concentration of the runoff from the roadway will be increased.

A possible beneficial influence of the de-icing programs is the possible substitution of sodium for potassium as a plant nutrient in organic soils.

Contamination of the soils at these ten sites by pollution from auto exhaust, heavy metals from auto parts, and chemicals and petroleum products associated with normal use may occur, but will probably be minimal. The levels of gaseous pollutants emitted by auto exhaust may be drastically cut by 1975 because of federal regulations. Potential contamination by lead from auto exhaust will be reduced because of the use of non-leaded gasoline. The soils will act as a "natural sink" for pollutants and will probably be able to dissipate the harmful qualities of pollutants present at low levels. The soils adjacent to interchanges will be affected most because of the concentrated traffic volume and intensified disruption of the original site conditions.

VI. ANALYSIS OF SOILS AND LAND USE INFORMATION FOR ASSESSMENT OF HIGHWAY IMPACT

In this chapter the potential utility of soil and land use information for highway impact assessment is discussed. The major sources of information that can be utilized for impact assessment are soil survey information, remote sensing imagery and topographic and geologic maps.

Michigan highway engineers probably use soil survey information more than any other nonagricultural technical group (Olson, 1964). The detailed soil maps, soil descriptions and interpretations found in published county soil surveys are not the only sources of soil information utilized by highway engineers. Soil association maps, area soil reports, area land use maps and reports containing correlations between pedologic and engineering classifications are also utilized when available. This soil survey information is used during the planning, design, and construction phases of the highway (Lund and Griess, 1961; Matthews and Cook, 1961).

Probably the most important use of soil survey information is in conjunction with the final detailed engineering soil survey that is conducted as part of the design phase of the highway project (Lund and Griess, 1961). The highway engineers must determine the precise location of soil boundaries along the right-of-way, groundwater elevations, organic depths in swamps, depth of over-burdens and note what construction difficulties may arise with each soil series (Quayyum and Kemper, 1960). In the past, highway engineers have been interested in these and other soil features and qualities and how they affect highway design, construction, and performance. Engineering test data, estimated soil properties significant to engineering and engineering interpretations for different uses are found in published county soil survey reports (Soil Survey Staff, 1951; Stoksad, 1958).

Highway engineers are not only concerned with the design, construction, and performance of a highway but also with the impact the highway has upon the environment. Three important soil characteristics that are significant for highway impact studies are soil texture, soil slope, and natural soil drainage. Information about these soil characteristics and related properties can be acquired from most of the soil surveys discussed above. Highway engineers can use this information to predict the erosion and sedimentation that may occur along a highway corridor and changes in the natural soil drainage conditions and water circulation patterns that may occur.

In most recent county soil survey reports published since 1962, woodland suitability groups and wildlife habitat suitabilities are also presented for each soil series. This information can be used by highway engineers to avoid as much as possible soil areas that can provide excellent woodland or wildlife habitat sites, thus minimizing the effect of the highway upon the environment.

The detailed soil mapping done by highway engineers can provide specific information for impact assessment but impact may extend beyond the limits of the right-of-way. Here available soil information from other sources should be considered or their soil maps should include adjoining areas.

The natural system of soil classification is useful to highway engineers because it provides the maximum amount of information with the minimum amount of laboratory testing. The Michigan Department of State Highways has made full use of this type of soil classification system in the past but has made little effort to utilize the new Comprehensive Soil Classification System that was adopted for use by the National Cooperative Soil Survey in 1965. The influence of the new system on the definitions of many soil series has been appreciable. Their current definitions must accommodate the properties of the higher categories.

The new Classification System, called Soil Taxonomy, better synthesizes our knowledge about soils, emphasizes the relationships of soils to one another and their environment, and develops predictions of their behavior much better than did earlier classification systems. One of the main differences between this system and others lies in the definition of the taxa. Differentiating characteristics selected are properties of the soils themselves. Definitions are precise and quantitative rather than just qualitative or comparative and are written in operational terms (Johnson, 1963; Kellogg, 1963).

A new nomenclature has been devised, using mainly classic Greek and Latin roots. The names are connotative and formative elements from each of the higher categories are successivly carried down to and including the family category. Because of this systematic nomenclature, many statements can be made about soil properties, simply from analyzing the soil names of the higher categories for each soil series.

This sytem contains six categories. From highest to lowest levels of generalization, they are: order, suborder, great group, subgroup, family, and series. The most important category that has been used by highway engineers is the soil series. Almost all of the data that have been collected and the interpretations that have been made have been at the series level. Thus, this category is the best defined, best understood and most used in highway engineering. The Soil Taxonomy does not make obsolete the substantial engineering knowledge acquired for soil series, nor does it change very many of the established names. What it does do is to define more precisely the range of characteristics within a series. This has resulted in realignment of the boundaries between many soil series.

Of course slope and erosion phases of the well drained series may also be very useful in highway design and highway impact assessment or land evaluation.

Use of the higher categories of any pedological classification system for engineering purposes has been negligible to date. The feasibility of using the taxa in the higher categories of the Soil Taxonomy for applications in engineering is greatly enhanced because of some important characteristics. These are the use of more precise definitions, introduction of new concepts, use of quantitative limits in the criteria and the development of a systematic nomenclature with connotative names for every taxon above the soil series (Orvedal, 1963).

An understanding of the concepts presented in the Soil Taxonomy can aid the highway engineer during the detailed soil survey of the right-of-way area by giving him precise quantitative taxonomic criteria and by giving directions to field and laboratory investigation in support of soil classification and mapping. Most of the criteria used in the Soil Taxonomy are visible and tactile, can be measured quantitatively, and the highway engineer would know exactly what kind of laboratory data are needed to solve classification problems. A number of such analyses can now be made by the State Soil Testing Laboratory at Michigan State University on request.

The potential utility of the soil family category for a variety of engineering applications is substantial (Orvedal, 1963). In grouping soil series into families, loss of interpretation potential is at a minimum, because families have relatively narrow ranges in texture, natural drainage, mineralogy, temperature and pH. Knowledge of soil families, or their phases, permits rather precise statements about plant responses and the behavior of soils when used for engineering purposes, because families are established primarily on the basis of properties important to the growth of plants or properties significant in engineering. As there are about 10,500 series and only 4,500 families of soils in the United States, if families will serve the purpose, they can result in considerable simplifications.

Above the family category, uniformity within each category decreases; thus, so does the potential utility for engineering applications. Still, the higher categories may show some usefulness in certain cases (Orvedal, 1963).

In Table 4 the mineral soils that were found at the ten study sites are tabulated in systematic manner based on their relationships involving texture, kind of parent material, and differences in natural drainage. Also included in this table are the subgroup and family names of each series, as derived from the Comprehensive Soil Classification System. The Michigan Department of State Highways utilizes a table very similar to this one as an aid in identifying soil profiles in the field (Michigan State Highway Department). The major difference is that the subgroup and family names are excluded. Unless the redefinitions of the soil series are understood, their current concepts of series may now be incorrect.

If the subgroup and family names were included as they are in Table 4 and the highway engineer had an understanding of the concept of the classification system, he would have considerably more information about the properties and characteristics of the soils at his disposal. For example, a large amount of information about the Saugatuck series would be known, just by knowing it is classified as Aeric Haplaquod, sandy, mixed, frigid, ortstein. The formative element "__od" from Haplaquod indicates that the soil is a Spodosol. The prefix "aqu" indicates that the soil has an aquic moisture regime. The prefix "hapla" means that the soil has in greater than 50 per

Table 4. Classification of the mineral soils found at the ten study sites

Mineral soils in one-storied parent material

Parent material texture	Soil family (add to subgroup name)*	Natural Drainage: Well and moderately well drained	Natural Drainage: Somewhat poorly drained	Natural Drainage: Poorly drained
Clay loam to silty clay loam	fine, mixed, frigid	Omena (Typic Eutroboralf)		
Sandy loam	coarse loamy, mixed, frigid	Omena (Typic Eutroboralf)		
Loamy sand and sands with textural bands	sandy, mixed, frigid	Graycalm (Entic Haplorthod) Montcalm (Alfic Haplorthod)	Otisco (Alfic Haplaquod)	
Sands without textural bands	sandy, mixed, frigid	Croswell (Entic Haplorthod) Grayling (Typic Udipsamment) Rubicon (Entic Haplorthod) Rousseau (Entic Haplorthod)	AuGres (Entic Haplaquod) Saugatuck (Aeric Haplaquod) (ortstein)	Kinross (Histic Haplaquod) Roscommon (Mollic Psammaquents)

Table 4 (cont'd.)

Mineral soils in two-storied parent material

Parent material texture		Soil family	Natural Drainage		
Upper story	Lower story	(add to sub-group name)*	Well and moderately well drained	Somewhat poorly drained	Poorly drained
Sand to loamy sand	gravel and sand	sandy, mixed, frigid	Mancelona (Alfic Haplorthod)	Gladwin (Alfic Haplaquod)	
Sandy loam to loam	gravel and sand	fine, loamy over sandy skel-etal, mixed, frigid	Newaygo (Alfic Haplorthod)	Palo (Aquic Eutroboralf)	
Sand to loamy sand	loam to silty clay loam	sandy over fine loamy, mixed, frigid	Menominee (Alfic Haplorthod)	Iosco (Aqualfic Hap-lorthod) Ogemaw (Aquic Haplorthod) (ortstein)	

*Subgroup name is found in parentheses under the soil series name.

cent of each pedon a spodic horizon in which some subhorizon has a ratio of free iron to carbon that is less than 0.2. The word "aeric" indicates that the soil has an ochric epipedon and is not as wet as a Typic Haplaquod. The "sandy, mixed, frigid, ortstein" modifiers added to the subgroup names give the soil family name: "sandy" refers to particle size class of the control section; "mixed" indicates the mineralogy class; "frigid" is the soil temperature class; and "ortstein" means that all or part of the spodic horizon is at least weakly cemented (Soil Survey Staff, 1970).

The Comprehensive Soil Classification System may also be useful in grouping soil series for highway impact responses. In Table 5 the soils of the ten study sites are grouped by particle size class and subgroup name and the potential effects of a highway project on soil drainage conditions are shown. A "slight" ecological effect indicates that little to no detrimental effects should occur and "moderate to severe" ecological effect indicates that detrimental effects may occur but can probably be overcome with careful design and maintenance. The potential effect was determined by careful study of the texture, slope, and drainage characteristics of the soil.

The natural drainage conditions of the Aquods, Aquents, Hemists, and Saprists would be most affected by a highway because of their very poor to somewhat poor drainage characteristics and their slow to ponding surface runoff classes.

The potential soil erosion loss for each soil is moderate to severe. Texture, slope, and surface runoff classes of the fine loamy Boralfs, fine loamy over sandy skeletal Orthods and Udalfs

Table 5. Potential ecological effect of highway construction on natural soil drainage conditions: illustrated by grouping the soil series into suborders and particle size class*

Particle size class	Suborder	Potential ecological effect on soil drainage conditions
Fine	Boralfs	slight
Fine-loamy	Boralfs	slight
Fine loamy over sandy skeletal	Orthods Udalfs	slight
Sandy	Orthods	slight
	Psamments	slight
	Aquods	moderate to severe
	Aquents	moderate to severe
Sandy over fine loamy	Orthods	slight
	Saprists	moderate to severe
	Hemists	moderate to severe

*Only suborder name given for organic soils.

and the fine Boralfs indicate an erosion hazard for these soils. They are susceptible to particle detachment and transport by rainfall and runoff. The sandy Orthods, Psamments, Aquods, and Aquents, the sandy over loamy Orthods, the Saprists, and the Hemists are all susceptible to wind erosion, if left barren during or after construction activities.

It was possible to use the suborder and particle size class to accurately illustrate the effects of highway construction because of the small number of soil series involved. If a grouping like this was attempted for all of the soil series mapped by the Michigan Department of State Highways lower categories would have to be used. Other parameters, in addition to "soil drainage" and "soil erosion loss" could also be included.

The utilization of soil management groups to determine highway impact responses is also a possibility. The soil series are grouped -in Table 6 according to the dominant texture of the soil profile and the natural drainage conditions in which the soil was developed. These groups are called soil management groups and are designated systematically by number and letters. The interrelationships of soil management groups in Michigan are shown in Table 6. This system was developed cooperatively about 1955 by the Michigan Agricultural Experiment Station, the Cooperative Extension Service and the Soil Conservation Service with the National Project in Agricultural Communication.

In Table 7 the soil management groups for the soil series of the ten study sites are shown and in Table 8 the highway impact responses of these soil management groups are shown for natural soil drainage conditions. The potential ecological effect on soil drainage conditions is greatest for those soils in 3/5b, 4/2b, 4b, 5b, M/4c and Mc management groups. This is because of the very poor to somewhat poor drainage classes of these soils and their slow to ponding surface runoff classes.

Table 6. Soil management group identification chart

Dominant profile textures	Symbols	Natural Drainage Classes: Mineral Soils: Well and moderately well drained			Very poorly drained	
		Well and moderately well drained	Somewhat poorly drained	Poorly drained	16-51" thick	>51" thick
		a	b	c	c	c
Fine clay (over 60%)	0	0a	0b	0c	M/1c	
Clay (40-60%)	1	1a	1b	1c		
Clay loam and silty clay loam	1.5	1.5a	1.5b	1.5c		
Loam and silt loam	2.5	2.5a	2.5b	2.5c		
Sandy loam, 14-40" over clay	3/1	3/1a	3/1b	3/1c		
Sandy loam, 20-40" over loam to silty clay loam	3/2	3/2a	3/2b	3/2c	M/3c	
Sandy loam	3	3a	3b	3c		Mc
Sandy loam, 20-40" over sand and gravel	3/5	3/5a	3/5b	3/5c		
Loamy sand, 14-40" over clay	4/1	4/1a	4/1b	4/1c		
Loamy sand, 20-40" over loam to silty clay loam	4/2	4/2a	4/2b	4/2c		
Loamy sand	4	4a	4b	4c		
Sand to loamy sand, 40-60" over loam to clay	5/2	5/2a	5/2b	5c		
					M/4c	

Table 6 (cont'd.)

Dominant profile textures	Symbols	Natural Drainage Classes: Mineral Soils: Well and moderately well drained a	Somewhat poorly drained b	Poorly drained c	Very poorly drained: 16-51" thick c	>51" thick c
Sand with moderate to strong subsoil development	5.0	5a	5b 5b-h	5c		
Sands with minimal subsoil development	5.3	5.3a	5b	5c		
Sands with little or no subsoil development	5.7	5.7a	5b	5c		
Gravelly or stony loamy sand to loam	G	Ga	Gbc	Gbc		
Alluvial or Lowland Areas						
loamy	L-2	L-2a	L-2c	L-2c		
sandy	L-4	L-4a	L-4c	L-4c		
Marl	m				M/mc	
Bedrock, <20"	R	Ra	Rbc	Rbc		
Loam, 20-40" over bedrock	2/R	2/Ra				
Sandy loam, 20-40" over bedrock	3/R	3/Ra	3/Rbc	3/Rbc	M/Rc	
Sand to loamy sand, 20-40" over bedrock	4/R	4/Ra	4/Rbc	4/Rbc		

Table 7. Soil management group designation for the soil series of the ten study sites

Soil series	Soil management group
Adrian	M/4c
AuGres	5b
Carbondale	Mc
Croswell	5a
Gladwin	4b
Graycalm	5a
Grayling	5.7a
Lufton	Mc
Iosco	4/2b
Kinross	5c
Mancelona	4a
Menominee	4/2a
Montcalm	4a
Nester	1.5a
Newaygo	3/5a
Ogemaw	5b-h
Omena	3a
Otisco	4b
Palo	3/5b
Rifle	Mc
Roscommon	5c
Rousseau	4a
Rubicon	5.3a
Saugatuck	5b-h
Tawas	M/4c

*Modifying symbol used after dash, h indicates subsoil hardened and cemented.

Table 8. Potential ecological effect of highway construction on natural soil drainage conditions: illustrated by grouping the soil series into soil management groups

Dominant profile textures	Symbols	Natural Drainage Classes: Mineral Soils: Well and moderately well drained a	Mineral Soils: Somewhat poorly drained b	Mineral Soils: Poorly drained c	Organic Soils: Very poorly drained 16-51" thick c	Organic Soils: Very poorly drained >51" thick c
Clay loam and silty clay loam	1.5	slight				
Sandy loam	3	slight				
Sandy loam over sand and gravel	3/5	slight	moderate-severe			
Loamy sand over loam to silty clay loam	4/2	slight	moderate-severe			moderate-severe
Loamy sand	4	slight	moderate-severe			
Sand (moderate to strong subsoil development)	5	slight	moderate-severe	moderate-severe	moderate-severe	
Sand (minimal sub-soil development)	5.3	slight				
Sand (little or no subsoil development)	5.7	slight				

The potential soil erosion loss is moderate to severe for all management groups in Table 8. Water erosion is a potential hazard for the 1.5a, 3a, and 3/5a and 3/5b management groups. Wind erosion is a hazard for the other groups.

Soil texture, drainage, and slope characteristics were used in predicting the potential soil erosion loss for each soil. So, in fact, this effect was actually determined by examination of soil management units. The susceptibility of soil materials to particle detachment and transport by rainfall and runoff increases as slope increases and generally becomes serious on slopes greater than 6%. Slope classes have been arbitrarily established and are designated by capital letters. Those commonly found in recent Michigan soil surveys are: A - 0-2% slope, B - 2-6% slope, C - 6-12% slope, D - 12-18% slope, E - 18-25% slope, F - >25% slope. The soil management group symbol plus the slope class letter commonly comprise the soil management unit symbol. Somewhat poorly drained soils rarely have slopes greater than 6% and poorly drained soils usually have slopes less than 2%.

It was stated earlier that the differences in names and boundaries of the mapping units used in this report and those described for the same areas by the MDSH occurred because more detailed mapping is commonly done by the highway department or because of differences in classification, or because of personal judgment of the mapper. The differences that exist at each site are illustrated in Table 1.

In most cases two or more different mapping units that were defined by the MDSH are included in a single mapping unit for this study. Because the highway soil engineers map in such great detail it is understandable why they have defined more mapping units. Some of the soils that were mapped by the highway soil engineers are described as inclusions in the mapping units defined for this investigation (Sites 1, 2, 7 and 8; Table 1).

Another reason why the names of the mapping units differ is because the MDSH does not map all of the recognized soil series found in Michigan. Approximately 165 different soil series are mapped by the MDSH (Michigan State Highway Department) (1970). An additional 123 series that are recognized in the state are combined by the highway department with series that have similar characteristics. By combining soil series in this way, the highway department is actually attempting a type of technical classification. The Comprehensive Soil Classification System could prove useful in this grouping.

The Croswell (Sites 3,7,8), Graycalm (Sites 3,7,9,10), Kinross (Sites 3,7) and Omena (Site 6) soils observed within the right-of-way during this investigation are four of the soil series combined with similar soil series by the highway department. In Table 9 these soils and the associated series mapped by the highway department are listed.

Careful examination of the soil interpretation sheets for these series will show that the factors affecting use for highway construction and degree of limitations for highway construction for the series that are combined are almost identical to those for the associated series mapped by the highway department. Similarity in

Table 9. Relationships of those soil series that are combined with similar soil series by the MDSH to the associated series mapped by MDSH*

Site	Soil series recognized in Michigan but combined with similar series by MDSH	Associated series mapped by MDSH
3,7,8	Croswell (Entic Haplorthod sandy, mixed, frigid)	Rubicon (Entic Haplorthod sandy, mixed, frigid)
3,7	Kinross (Typic Haplaquod sandy, mixed, frigid)	Roscommon (Typic Psammaquent sandy, mixed, frigid)
3,7, 9,10	Graycalm (Alfic Haplorthod sandy, mixed, frigid)	Montcalm (Alfic Haplorthod sandy, mixed, frigid)
6	Omena (Typic Eutroboralf fine-loamy, mixed)	Emmet (Alfic Ha;lorthod loamy, mixed, frigid)

*Soil damily name in parentheses.

family names is also evident, suggesting the possibility of more extensive grouping of soils for their mapping purposes. Perhaps more of the soils in Michigan that are classified as Entic Haplorthod, sandy, mixed, frigid, could be mapped as a Rubicon group and maybe more of those soils classified as Alfic Haplorthod, sandy, mixed, frigid, could be mapped as a Montcalm group. Or soil management groups used to group similar soil series for other purposes might also be useful. In Talbe 9 only one pair of series, Kinross and Roscommon, are in the same soil management groups, but the other two pairs are in the same families.

The highway department also maps some soil series that are not recognized or are considered inactive by the National Cooperative Soil Survey. Examples from this investigation are Antrim (Site 3), Echo (Sites 2,6,9,10), Ottawa (Site 7), Roselawn (Site 9) and Wexford (Site 7). The Comprehensive Soil Classification System may be useful in grouping these soils with recognized series. Roselawn soils are separated from Rubicon because of geological origin. Roselawn soils occur on moranic areas, while Rubicon soils occur on outwash areas. This difference is recognized by the National Cooperative Soil Survey through slope class. Soil management group or unit designations may also be useful in grouping these soils.

No organic soil series are recognized by the Michigan Department of State Highways. The organic series mapped for this investigation were Markey (Sites 1,7), Seelyeville (Site 3), Carbondale (Sites 2,3,5), Rifle (Site 4) and Tawas (Sites 2,3,5). The highway department mapped these areas as muck, shallow muck, peat or peat marsh. Since they are attempting some type of classification for organic deposits, it may be feasible to utilize family names to better group organic soils for mapping purposes. Or soil management groups might also be useful in grouping organic soils.

It is evident that the more detailed mapping done by highway soil engineers and the differences in classification mentioned above account for many of the discrepancies in the mapping units and the soils identified at the study sites. However, some major differences are still left unexplained. At a number of sites AuGres (Sites 1,3,4,7,8), Menominee (Sites 6,7,9,10), Graycalm or Montcalm (Sites 3,7,9,10), and shallow organic soils (Sites 2,3,4,5) were repeatedly mapped or identified during this study, yet the highway soil engineers failed to identify these soils when making, presumably, more detailed maps of the sites. A different understanding of the current concepts of these series could explain the highway soil engineers' failure to recognize these soils. In every case, however, soils of similar soil management groups were identified instead (Table 1), suggesting personal discretion of the mapper as being an important factor.

The potential of the New Taxonomy and Soil Management Group or Unit designations for grouping soil series for impact assessment and mapping purposes has been stated several times. Soil management groups or units may be more suitable for MDSH uses for two reasons. First, the concept of soil management groups and units is much simpler and easier to grasp than the concepts of the New Taxonomy and, second, the soil series mapped by the MDSH can be placed into a smaller number of groups than would be possible even utilizing the families of the New Taxonomy. In Table 10, all of the 107 Northern Michigan mineral soil series that are mapped by the MDSH representing 64 families are grouped into 38 soil management groups to illustrate the considerable simplifications gained from its use.

Various forms of remote sensing imagery provide information that is useful in highway assessment. In Michigan, the prospective user of remote sensing can choose from three types of imagery at four different scales: NASA Earth Resource Technology Satellite (ERTS-1) Imagery; NASA high altitude Earth Resource Aircraft Photography; medium-altitude Agricultural Stabilization and Conservation Service (ASCS) and other public agency photography (Sullivan and Higgs, 1973).

Table 10. Northern Michigan soils that are mapped by MDSH grouped into soil management groups

		Natural Drainage Classes				
		Mineral Soils			Organic Soils	
					Very poorly drained	
		Well and moderately well drained	Somewhat poorly drained	Poorly drained	16-51" thick	>51" thick
Texture	Symbols	a	b	c	c	c
Fine clay	0	Ontonagon	Rudyard	Bergland		
Clay	1	Froberg, Kent	Selkirk	Pickford		
Clay loam and silty clay loam	1.5	Barker, Nunica, Nester, Watton	Bowers, Kawkawlin	Hettinger, Thomas(1.5-c), Sims, Wisner(1.5-c)		
Loam and silt loam	2.5	Bohemian, Isabella, Dighton, Onaway, Goodman, Wakefield	Brimley, Mackinac, Gaastra	Adolph, Bruce, Angelica		
Sandy loam	3	Ahmeek, Iron River, Champion, McBride, Johnswood, Chatham, Munising, Emmet, Posen, Gogebic, Trenary	Coral, Tula, Skanee	Ensley		

Table 10 (cont'd.)

Texture	Symbols	Natural Drainage Classes: Mineral Soils: Well and moderately well drained a	Mineral Soils: Somewhat poorly drained b	Mineral Soils: Poorly drained c	Organic Soils: Very poorly drained 16-51" thick c	Organic Soils: Very poorly drained >51" thick c
Sandy loam over sand and gravel	3/5	Coventry, Stambaugh, Newaygo	Palo	Ronald		
Loamy sand over clay	4/1	Manistee		Pinconning		
Loamy sand over loam to silty clay loam	4/2	Menominee	Iosco	Brevort, Essexville (4/2c-c)	*	
Loamy sand	4	Blue Lake, Montcalm, Gilchrist, Pence. Karlin, Randville, Keweenaw, Rousseau, Kiva, Mancelona, Marenisco	Cheneaux, Gladwin, Moye, Wainola			
Sandy to loamy sand over loam to clay	5/2	Melita	Arenac			

Table 10 (cont'd.)

Texture	Symbols	Natural Drainage Classes: Mineral Soils: Well and moderately well drained a	Mineral Soils: Somewhat poorly drained b	Mineral Soils: Poorly drained c	Organic Soils: Very poorly drained 16-51" thick c	Organic Soils: Very poorly drained >51" thick c
Sand (moderate to strong subsoil development)	5.0	AuTrain(5a-h)*, Sparta, Hiawatha, Wallace(5a-h)*, Kalkaska, Wexford	AuGres, Saugatuck(5b-h)*, Channing, Trout Lake, Ogemaw	Roscommon		
Sand (minimal subsoil development)	5.3	Eastport, Vilas, Rubicon				
Sand (little or no subsoil development)	5.7	Grayling				
Gravelly or stony loamy sand to loam	G	Allouez, Alpena, Baraga	Detour(Gbc)[1], Hessel(Gbc)[2], Diana(Gbc)[2]			
Bedrock <20"	R	Crystal Falls, Summerville	Ruse(Rbc)[2]			

Table 10 (cont'd.)

		Natural Drainage Classes				
		Mineral Soils			Organic Soils	
		Well and moderately well drained	Somewhat poorly drained	Poorly drained	Very poorly drained 16-51" thick	>51" thick
Texture	Symbols	a	b	c	c	c
Loam over bedrock	2/R	Moran				
Sandy loam over bedrock	3/R	Crystal Falls, Longrie, Onota, Negaunee	Kawbawgam (3/Rbc)[1], Sun-dell(3/Rbc)[1,2] Satago(3/Rbc)[2]			

*Modifying symbols used after dash: h indicates subsoils which are hardened and cemented
c indicates soils which are calcareous at or near surface

[1]These soils are somewhat poorly drained.

[2]These soils are poorly drained.

The ERTS-1 provides images of the earth from an altitude of about 572 miles. The satellite contains two types of remote sensing equipment: a return beam vidicon camera, which became inoperative shortly after launch, and a multi-spectral camera, which does not take photographs but detects spectral radiation from the surface of the earth and records on magnetic tape the amount of radiation detected.

Multi-spectral methods can be used to identify and map water distribution and various classes of natural drainage of the soil in bare fields. General categories of vegetation can also be mapped and individual species can be identified.

The high altitude imagery of Michigan is usually of high quality with excellent resolution. Black and white, color or color infrared (false color) film is usually used for this photography. Conventional color film shows the landscape as it would be seen by the human eye from an aircraft, thus, interpretation is eased. Although color infrared film has an unconventional color scheme, interpretation is even more eased for vegetation differentiations with experience.

Most of the medium altitude photography of Michigan is black and white panchromatic, but some is black and white infrared photography. Black and white panchromatic film gives good quality images of the ground factor. Black and white infrared photography is similar to color infrared, except it is presented in shades of gray.

Interpretation of aerial photography can be used to identify and map vegetation communities, some soil properties, hydrologic characteristics and land use. These data can then be used as aids for highway impact assessment.

An investigation conducted by the Environmental Research Institute of Michigan and Michigan State University (1972) presents a detailed discussion of the potential uses of remote sensing techniques for assessing the impact of highway instruction.

Topographic maps, geologic maps and other geologic reports provide information needed for assessing some highway impacts. These sources can provide basic information about the landforms of an area and the relationship to soils, vegetation and hydrology.

VII. CONCLUSIONS

1) The areas most sensitive to the effect of a highway project on the surrounding soil environment are the wetlands. Natural soil drainage conditions are easily disrupted at these sites. Thus, whenever possible, large wetland areas should be avoided during highway construction.

2) Drains and channels must be properly designed and constructed to avoid excessive alteration of natural soil drainage conditions. In this study, more adequate drainage seems necessary.[1]

3) Erosion and sediment production, both during and after construction, need to be controlled. This can be done by making the best use of topography and drainage patterns for protecting the area during the construction stage and by permanently stabilizing the surface as soon as possible after construction.

4) Research needs to be conducted to determine how much salt may be applied to highways during winter de-icing programs without

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[1]During the thesis defense, Dr. Erickson suggested altering the designs of the culverts under the highway might eliminate the current tendency to cause poorer drainage in highway construction. If the bottoms of the culverts were dry only at the season of low water table in the somewhat poorly to poorly drained soil areas, there would probably be little interference with the environment for the native vegetation.

adverse effects on the environment. Determining the susceptibility of different Michigan soils to salt damage as it is being removed during spring and fall rains and how these affect associated vegetation would be important aspects of this research.

5) Serious consideration should be given to the potentials of the Comprehensive Soil Classification System for use in assessing potential highway impact. The family category may be particularly helpful for interpretive purposes, perhaps with subdivisions into phases of families.

6) The soil management groups or units may also have possibilities for interpretive purposes and assessing potential highway impact.

7) The detailed soil mapping done by highway soil engineers can provide specific information for impact assessment, but impact may extend beyond the limits of the right-of-way. Available soils information from other sources could be used to extend soil boundaries or the highway's soil survey should include adjoining areas.

APPENDICES

APPENDIX A

PROFILE DESCRIPTIONS OF SOILS

APPENDIX A

PROFILE DESCRIPTIONS OF SOILS

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APPENDIX A

PROFILE DESCRIPTIONS OF SOILS

Wetland Site 1

Markey Muck

Location: Wetland Site 1, Arenac County, Michigan
SE¼, NW¼, SW¼, Sec. 34, T20N, R3E. 100' east of highway
Soil Classification: Terric Borosaprist sandy, mixed, euic
Vegetation: Cattails and Sedges
Drainage: Very poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
Oa1	0-14"	Black (10YR 2/1); sapric material; 25% fiber, less than 10% rubbed; moderate, medium, granular structure; sodium pyrophosphate dark brown (10YR 4/3); primarily herbaceous fibers; neutral (pH 7.2 in H_2O, 7.0 in $CaCl_2$); gradual, smooth boundary.
Oa2	14-30"	Black (10YR 2/1); sapric material; 35% fiber, 15% rubbed; weak, coarse, sub-angular blocky structure; sodium pyrophosphate dark brown (10YR 4/3); primarily herbaceous fibers; neutral (pH 7.0 in H_2O, 6.5 in $CaCl_2$); gradual, smooth boundary.
Oa3	30-48"	Black (10YR 2/1); sapric material; 25% fiber, less than 5% rubbed; massive structure; sodium pyrophosphate dark brown (10YR 4/3); primarily herbaceous fibers; slightly acid (pH 6.6 in H_2O, 6.2 in $CaCl_2$); abrupt, smooth boundary.

Horizon	Depth	Description
IIClg	48-66"	Grayish brown (10YR 5/2); sand; single grain; loose; neutral.

AuGres Sand

Location: Wetland Site 1, Arenac County, Michigan
SW¼, SE¼, NE¼, Sec. 33, T20N, R3E. 150' west of highway
Soil Classification: Entic Haplaquod sand, mixed, frigid
Vegetation: Maple, Paper birch, Hemlock
Drainage: Somewhat poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
A1	0-3"	Black (5YR 2/1); sand; weak, fine, granular structure; friable; medium acid; abrupt wavy boundary.
A2	3-14"	Gray (10YR 5/1); sand; common, fine, distinct yellowish brown (10YR 5/4) mottles; single grain; loose; medium acid; abrupt irregular boundary.
B21hir	14-17"	Dark reddish-brown (5YR 3/2) with common, coarse, distinct strong brown (7.5YR 5/6) mottles; sand; weak, coarse, granular structure; very friable with a few ¼" to 1" weakly cemented chunks of ortstein; medium acid; gradual, irregular boundary.
B22ir	17-32"	Reddish-brown (5YR 4/3) with many, medium, distinct yellowish-red (5YR 5/8) mottles; sand; single grain; loose; medium acid; gradual, irregular boundary.
B23ir	32-50"	Reddish-brown (5YR 5/3) with common, medium, distinct reddish-gray (5YR 5/2) mottles; sand; single grain; loose; medium acid; gradual, wavy boundary.
C	50-66"	Brown (10YR 5/3) with common, medium, distinct yellowish-brown (10YR 5/6) mottles; sand; single grain; loose; slightly acid.

Roscommon Sand

Location: Wetland Site 1, Arenac County, Michigan
NW¼, SW¼, SW¼, Sec. 34, T20N, R3E. 100' west of highway
Soil Classification: Mollic Psammaquent sand, mixed, frigid
Vegetation: Alder, Sedges and Cattails
Drainage: Poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
A1	0-6"	Black (10YR 2.5/1); sand; weak, medium granular structure; very friable; slightly acid; abrupt, smooth boundary.
C1g	0-22"	Grayish brown (10YR 5/2) with common, medium, distinct, light brownish-gray (10YR 6/2) mottles; sand; single grain; loose; neutral; gradual, wavy boundary.
C2g	22-45"	Light brownish-gray (10YR 6/2) with common, medium, distinct dark grayish-brown (10YR 4/2) mottles; sand; single grain; loose; neutral; gradual, wavy boundary.
C3g	45-66"	Grayish-brown (10YR 5/2); sand; single grain; loose; neutral.

Tawas Muck

Location: Wetland Site 1, Arenac County, Michigan
SE¼, SE¼, SW¼, Sec. 34, T20N, R3E. 100' east of highway
Soil Classification: Terric Borosaprist sandy, mixed, euic
Vegetation: Paper birch, Hemlock, Sedges
Drainage: Very poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
Oe1	0-9"	Black (10YR 2/1, rubbed); hemic material; about 50% fiber, 15% rubbed; weak, medium, granular structure; fibers primarily herbaceous; neutral; gradual, smooth boundary.

Horizon	Depth	Description
Oal	9-24"	Dark reddish brown (5YR 2/2, rubbed); sapric material; about 15% fiber, less than 5% rubbed; massive structure; fibers primarily woody; neutral; abrupt, smooth boundary.
IIClg	24-41"	Grayish brown (10YR 5/2) with common, medium, distinct grayish-brown (10YR 4/2) mottles; sand; single grain; loose; neutral; gradual, wavy boundary.
IIC2g	41-66"	Light brownish gray (10YR 6/2) with common, medium, distinct dark grayish-brown (10YR 4/2) mottles; sand; single grain; loose; neutral.

Wetland Site 2

Newaygo Sandy Loam (Variant)

Location: Wetland Site 2, Ogemaw County, Michigan
SE¼, SW¼, SW¼, Sec. 23, T22N, R1E. In the NE quadrant of the West Branch Interchange
Soil Classification: Alfic Haplorthod coarse loamy
(This is a coarse loamy variant of Newaygo which is classified as fine loamy over sandy skeletal)
Vegetation: Paper birch, Maple, White Cedar
Drainage: Well drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
01	+1-0"	Organic layer of partially decomposed forest litter.
A1	0-4"	Very dark grayish brown (10YR 3/1.5); sandy loam; weak, medium, granular structure; friable; slightly acid; abrupt, wavy boundary.
A2	4-8"	Brown (7.5YR 5/2); sandy loam; weak, medium, granular structure; friable; slightly acid; clear, wavy boundary.
B2ir	8-24"	Reddish brown (5YR 4/5); sandy loam; weak, medium, subangular blocky structure; friable; slightly acid; clear, wavy boundary.

Horizon	Depth	Description
B2t	24-34"	Dark brown (10YR 4/3) gravelly sandy loam to loam; weak, medium, subangular blocky structure; friable; neutral; abrupt, irregular boundary.
IIC	34+"	Pale brown (10YR 6/3); sand and gravel; single grain; loose; calcareous.

Palo Sandy Loam (Variant)

Location: Wetland Site 2, Ogemaw County, Michigan SE¼, SW¼, SW¼, Sec. 23, T22N, R1E. In the NE quadrant of the West Branch Interchange

Soil Classification: Aquic Eutroboralf coarse-loamy, mixed, frigid

(This is a variant of Palo which is classified as fine loamy over sandy skeletal)

Vegetation: Paper birch, Maple, White cedar

Drainage: Somewhat poorly drained

Slope: 0-2%

Physiography: Outwash plain

Horizon	Depth	Description
O1	+3-0"	Organic mat of partially decomposed forest litter.
A1	0-6"	Very dark grayish brown (10YR 3/2); sandy loam; weak, medium, granular structure; friable; slightly acid; clear, wavy boundary.
A2	6-10"	Grayish brown (10YR 5/2) with common, medium, distinct brown (7.5YR 5/4) mottles; sandy loam; weak, medium, granular structure; friable; slightly acid; clear, wavy boundary.
B2t	10-23"	Brown (7.5YR 5/4) with common, medium, distinct strong brown (7.5YR 5/6) and pale brown (10YR 6/2) mottles; sandy loam to fine gravelly sandy loam; weak, medium, subangular blocky structure; friable; slightly acid; clear, wavy boundary.
IIC	23+"	Pale brown (10YR 6/3); sand and gravel; single grain; loose; calcareous.

Tawas Muck

Location: Wetland Site 2, Ogemaw County, Michigan
SE¼, SW¼, SW¼, Sec. 23, T22N, R1E. In the NE quadrant of the West Branch Interchange.
Soil Classification: Terric Borosaprists sandy, mixed, enic
Vegetation: White cedar
Drainage: Very poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
Oa1	0-3"	Black (5YR 2/1, rubbed); sapric material; 30% fiber, 10% rubbed; weak, medium, granular structure; sodium pyrophosphate light yellowish brown (10YR 6/4); fibers primarily herbaceous and moss; neutral (pH 7.2 in $CaCl_2$); gradual, smooth boundary.
Oa2	3-9"	Black (7.5YR 2.5/0, rubbed); sapric material; 25% fiber, less than 5% rubbed; weak, medium, granular structure; sodium pyrophosphate brown (10YR 5/3); fibers primarily woody; neutral (pH 7.2 in $CaCl_2$); abrupt, smooth boundary.
Oa3	9-14"	Dark reddish brown (5YR 3/2, rubbed); sapric material; 30% fiber, less than 5% rubbed; weak, medium, granular structure; sodium pyrophosphate dark grayish brown (10YR 4/2); fibers primarily woody, some woody fragments; neutral (pH 7.1 in $CaCl_2$); gradual, wavy boundary.
Oa4	14-30"	Black (5YR 2/1); sapric material; about 20% fiber, less than 5% rubbed; massive structure; fibers primarily woody; neutral; gradual, wavy boundary.
Oa5	30-46"	Black (7.5YR 2.5/0); sapric material; about 30% fiber, less than 5% rubbed; massive structure; fibers primarily woody; neutral; abrupt, smooth boundary.
IIC	46-66"	Brown (10YR 5/3); loamy sand; single grain; loose; neutral.

Wetland Site 3

Grayling Sand

Location: Wetland Site 3, Crawford County, Michigan
SE¼, SW¼, NW¼, Sec. 34, T25N, R3W. 300' east of highway along old dirt trail
Soil Classification: Typic Udipsamment sandy, mixed, frigid
Vegetation: Jack pine, Oak
Drainage: Well drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
O1	+1-0"	Organic mat of partially decomposed forest litter.
A11	0-1"	Black (7.5YR 2.5/0); sand; weak, fine, granular structure; very friable; strongly acid; abrupt, wavy boundary.
A12	1-4"	Dark grayish brown (10YR 4/2); sand; single grain; loose; medium to strongly acid; abrupt, wavy boundary.
B2ir	4-18"	Yellowish brown (10YR 5/7); sand; single grain; loose; slightly acid; gradual, wavy boundary.
C1	18-50"	Yellowish brown (10YR 5/4); sand; single grain; loose; neutral; gradual, wavy boundary.
C2	50-66"	Light olive brown (2.5Y 5/4); sand; single grain; loose; mildly alkaline.

Seelyeville Muck

Location: Wetland Site 3, Crawford County, Michigan
NE¼, SW¼, NW¼, Sec. 34, T25N, R3W. 100' east of highway
Soil Classification: Typic Borosaprist euic
Vegetation: White cedar, Black spruce, Tamarack
Drainage: Very poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
Oel	0-3"	Black (5YR 2/1, rubbed); hemic material; about 50% fiber, 25% rubbed; weak, medium, granular structure; fibers moss and herbaceous; neutral; abrupt, smooth boundary.
Oal	3-11"	Dark reddish brown (5YR 3/2, rubbed); sapric material; about 30% fiber, 10% rubbed; weak, medium, granular structure; fibers woody and herbaceous; neutral; clear, wavy boundary.
Oa2	11-20"	Dark reddish brown (5YR 3/2, rubbed); sapric material; 40% fiber, 15% rubbed; weak, medium, granular structure; sodium pyrophosphate brown (10YR 5/3); fiber primarily woody, some woody fragments; slightly acid (pH 6.1 in $CaCl_2$); clear, wavy boundary.
Oa3	20-37"	Black (7.5YR 2.5/0); sapric material; about 30% fiber, less than 5% rubbed; massive structure; fibers primarily woody; neutral; clear, wavy boundary.
Oa4	37-56"	Dark reddish brown (5YR 2/2); sapric material; about 30% fiber, less than 5% rubbed; massive structure; fibers primarily woody; neutral; abrupt, smooth boundary.
IICg	56-66"	Dark grayish brown (2.5YR 4/2); sand; single grain; loose; moderately alkaline.

Tawas Muck

Location: Wetland Site 3, Crawford County, Michigan
NE¼, SW¼, NW¼, Sec. 34, T25N, R3W. 100' east of highway
Soil Classification: Terric Borosaprist sandy, mixed, euic
Vegetation: White cedar, Black spruce, Tamarack
Drainage: Very poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
Oel	0-2"	Black (5YR 2/1, rubbed); hemic material; about 50% fiber, 30% rubbed; weak, medium, granular structure; fibers primarily moss; neutral; abrupt, smooth boundary.

Horizon	Depth	Description
Oa1	2-14"	Dark reddish brown (5YR 2/2, rubbed); sapric material; about 30% fiber, 10% rubbed; weak, medium, granular structure; fibers woody and herbaceous; neutral; clear, wavy boundary.
Oa2	14-20"	Dark reddish brown (5YR 2/2); sapric material; 30% fiber, 10% rubbed; weak, medium, granular structure; sodium pyrophosphate dark brown (10YR 4/3); fibers primarily woody, some woody fragments; neutral (pH 6.8 in $CaCl_2$); clear, wavy boundary.
Oa3	20-31"	Black (7.5YR 2.5/0); sapric material; about 25% fiber, less than 5% rubbed; massive structure; fibers primarily woody; mildly alkaline; abrupt, smooth boundary.
IIClg	31-48"	Dark grayish brown (2.5YR 4/2); sand; single grain; loose; moderately alkaline; gradual, wavy boundary.
IIC2g	48-66"	Dark grayish brown (10YR 4/2); sand; single grain; loose; moderately alkaline.

Wetland Site 4

Rifle Peat

Location: Wetland Site 4, Roscommon County, Michigan
NE¼, NW¼, SE¼, Sec. 30, T24N, R2W. 100' east of highway
Soil Classification: Typic Borohemist euic
Vegetation: White cedar, Paper birch, Black spruce, Tamarack
Drainage: Very poorly drained
Slope: 0-2%
Physiography: Bog

Horizon	Depth	Description
Oi1	0-3"	Dark brown (7.5YR 3/2, rubbed); fibric material; about 90% fiber, 60% rubbed; fibers primarily sphagnum moss and some woody fragments; massive structure; strongly acid; abrupt, smooth boundary.

Horizon	Depth	Description
Oe1	3-14"	Dark brown (7.5YR 3/2, rubbed); hemic material; about 40% fiber, 15% rubbed; weak, medium, granular structure; fibers primarily woody and herbaceous; strongly acid; clear, wavy boundary.
Oe2	14-36"	Brown (7.5YR 5/4, rubbed); hemic material; about 60% fiber, 20% rubbed; massive structure; fibers herbaceous and woody, some woody fragments; medium acid; clear, wavy boundary.
Oe3	36-66"	Brown (7.5YR 5/4, rubbed); hemic material; about 65% fiber, 15% rubbed; massive structure; fibers herbaceous and woody, some woody fragments; medium acid.

Saugatuck Sand

Location: Wetland Site 4, Roscommon County, Michigan
NE¼, NW¼, SE¼, Sec. 30, T24N, R2W. 100' west of highway

Soil Classification: Aeric Haplaquod sandy, mixed, frigid, ortstein

(This is a frigid variant of Saugatuck not yet differentiated.)

Vegetation: Aspen, Oak, Paper birch, Black spruce, Tamarack

Drainage: Somewhat poorly drained

Slope: 0-2%

Physiography: Outwash plain

Horizon	Depth	Description
O1	+2-0"	Organic mat of sphagnum moss and partially decomposed forest litter.
A1	0-2"	Dark reddish brown (5YR 2/2); sand; weak, fine, granular structure; very friable; very strongly acid; abrupt, wavy boundary.
A2	2-6"	Reddish gray (5YR 5/2); sand; single grain; loose; very strongly acid; abrupt, wavy boundary.
B21hirm	6-12"	Dark reddish brown (5YR 3/3); sand; massive; strongly cemented (ortstein); very strongly acid; abrupt, wavy boundary.

Horizon	Depth	Description
B22ir	12-18"	Strong brown (7.5YR 5/6); sand; moderate; fine, sub-angular blocky structure; some weak ortstein; strongly acid; clear, wavy boundary.
B3	18-30"	Yellowish brown (10YR 5/4) with common, coarse, distinct yellowish brown (10YR 5/6) and grayish brown (10YR 5/2) mottles; sand; single grain; loose; strongly acid; clear, wavy boundary.
C	30-66"	Brown to pale brown (10YR 5.5/3) with common, coarse, distinct dark brown (10YR 4/3) mottles; sand; single grain; loose; medium acid.

Wetland Site 5

AuGres Sand

Location: Wetland Site 5, Roscommon County, Michigan
NE¼, NE¼, NW¼, Sec. 3, T22N, R2W. In median
Soil Classification: Entic Haplaquod sandy, mixed, frigid
Vegetation: White cedar, Black spruce, Tamarack
Drainage: Somewhat poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
02	+3-0"	Organic layer of highly decomposed forest litter.
A1	0-2"	Black (10YR 3/1); sand; weak, fine, granular structure; very friable; strongly acid; abrupt, smooth boundary.
A2	2-20"	Grayish brown (10YR 5/2) with common, medium prominent dark brown (10YR 4/3) mottles; sand; single grain; loose; medium acid; gradual, wavy boundary.
B2ir	20-34"	Dark yellowish brown (10YR 4/4) with common, medium, distinct brown (10YR 5/3) mottles; sand; single grain; loose; slightly acid; gradual, wavy boundary.

Horizon	Depth	Description
C	34+"	Grayish brown (2.5YR 5/2) with many coarse, distinct, dark yellowish brown (10YR 4/4) mottles; sand; single grain; loose; slightly alkaline.

Roscommon Sand

Location: Wetland Site 5, Roscommon County, Michigan
NE¼, NE¼, NW¼, Sec. 3, T22N, R2E. In median
Soil Classification: Typic Psammaquent sandy, mixed, frigid
Vegetation: Black spruce, White cedar, Tamarack
Drainage: Poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
A1	0-6"	Black (10YR 2/1); sand; weak, fine, granular structure; very friable; neutral; abrupt, smooth boundary.
C1g	6-22"	Grayish brown (10YR 5/2) with few, coarse, distinct brown (10YR 5/3) mottles; sand; single grain; loose; mildly alkaline; gradual, wavy boundary.
C2g	22+"	Light brownish gray (10YR 6/2) with common, medium, distinct brown (10YR 5/3) and dark brown (10YR 4/3) mottles; sand; single grain; loose; mildly alkaline.

Tawas Muck

Location: Wetland Site 5, Roscommon County, Michigan
SE¼, SE¼, SW¼, Sec. 34, T23N, R2E. 150' east of highway
Soil Classification: Terric Borosaprist sandy, mixed, euic
Vegetation: Black spruce, White cedar, Tamarack
Drainage: Very poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
Oe1	0-4"	Black (7.5YR 2.5/0, rubbed); hemic material; about 60% fiber, 30% rubbed; weak, medium, granular structure; fibers primarily moss and herbaceous; neutral; abrupt, smooth boundary.

Horizon	Depth	Description
Oa1	4-10"	Black (7.5YR 2.5/0, rubbed); sapric material; 35% fiber, 5% rubbed; weak, medium, granular structure; sodium pyrophosphate brown (10YR 5/3); fibers primarily woody; medium acid (pH 5.6 in $CaCl_2$); abrupt, wavy boundary.
Oa2	10-28"	Dark reddish brown (5YR 3/2, rubbed); sapric material; 30% fiber, 10% rubbed; sodium pyrophosphate brown (10YR 5/3); massive, fibers primarily woody; medium acid (pH 6.0 in $CaCl_2$); abrupt, smooth boundary.
IICg	28+"	Grayish brown (10YR 5/2); sand; single grain; loose; mildly alkaline.

Woodlot Site 6

Graycalm Sand

Location: Woodlot Site 6, Ogemaw County, Michigan SW¼, NW¼, NE¼, Sec. 26, T22N, R1E. 300' east of highway

Soil Classification: Entic Haplorthod sandy, mixed, frigid (Graycalm is currently classified as Alfic Udipsamment, but this soil is probably more prevalent or a taxadjunct.)

Vegetation: Sugar maple, American beech

Drainage: Well drained

Slope: 10%

Physiography: Moraine

Horizon	Depth	Description
02	+1-0"	Black (7.5YR 2.5/0) organic mat of highly decomposed forest litter.
A1	0-3"	Very dark grayish brown (10YR 3/2); sand; weak, fine, granular structure; slightly acid; clear, wavy boundary.
B21ir	3-14"	Brown to dark brown (10YR 4/3); sand; single grain; loose; slightly acid; gradual, wavy boundary.
B22ir	14-30"	Brown to dark brown (7.5YR 4/4); sand; single grain; loose; slightly acid; gradual, wavy boundary.

Horizon	Depth	Description
A'2	30-47"	Pale brown (10YR 5.5/3); sand; single grain; loose; slightly acid; abrupt, broken boundary.
A'2+B'2t	47-59"	Pale brown (10YR 6/3); sand, single grain, loose (A'2 horizon); brown to dark brown (7.5YR 4/4), sandy loam, massive, friable (B'2t horizon); B'2t bands are discontinuous and ¼" to ½" thick; slightly acid; abrupt, wavy boundary.
C	59-66"	Pale brown (10YR 6/3); sand; single grain; loose; calcareous.

Omena Sandy Loam

Location: Woodlot Site 6, Ogemaw County, Michigan
NW¼, SW¼, NE¼, Sec. 26, T22N, R1E. 150' east of highway
Soil Classification: Typic Eutroboralf fine-loamy, mixed
Vegetation: Sugar maple, American beech
Drainage: Well drained
Slope: 11%
Physiography: Moraine

Horizon	Depth	Description
02	+1-0"	Black (7.5YR 2.5/0) organic mat of highly decomposed forest litter.
B2	0-2"	Brown (10YR 4.5/3) sandy loam to loam; weak fine; sub-angular blocky structure; very friable; slightly acid; abrupt, irregular boundary.
A'B'	2-9"	A'=Brown (10YR 5/3); loam; weak, coarse, granular structure; and B'=dark brown (10YR 4/3); clay loam; moderate, medium, sub-angular blocky structure; the A' horizon is present as tongues into the B' or as thick coatings on the peds of the B'; neutral; gradual, wavy boundary.
B'2t	9-21"	Dark brown (10YR 4/3); sandy clay loam; moderate, medium, sub-angular blocky structure; firm; neutral; abrupt, wavy boundary.

Horizon	Depth	Description
C	21+"	Yellowish brown (10YR 5/3); clay loam; moderate, medium, sub-angular blocky structure; firm; some lime fragments; mildly alkaline.

Menominee Loamy Fine Sand

Location: Woodlot Site 6, Ogemaw County, Michigan
NW¼, SW¼, NE¼, Sec. 26, T22N, R1E. 200' east of highway
Soil Classification: Alfic Haplorthod sandy/loamy, mixed, frigid
Vegetation: Sugar maple, American beech
Drainage: Well drained
Slope: 12%
Physiography: Moraine

Horizon	Depth	Description
02	+1-0"	Black (7.5YR 2.5/0); organic mat of highly decomposed forest litter.
A1	0-3"	Very dark grayish brown (10YR 3/2); loamy fine sand; weak, medium, granular structure; very friable; slightly acid; clear, wavy boundary.
B2ir	3-8"	Dark brown (10YR 4/3); loamy, fine sand; weak, fine, granular structure; very friable; slightly acid; clear, wavy boundary.
A'2	8-20"	Pale brown (10YR 5.5/3); loamy fine sand; weak, coarse, granular structure; friable; slightly acid; abrupt, wavy boundary.
B'2t	20-27"	Dark brown (7.5YR 4/4); sandy clay loam; moderate, coarse, sub-angular blocky structure; firm; slightly acid; clear, wavy boundary.
IIC1	27+"	Dark brown (7.5YR 4/4); coarse clay loam; weak, medium, sub-angular blocky structure; firm; neutral.

Woodlot Site 7

AuGres Sand

Location: Woodlot Site 7, Roscommon County, Michigan
NW¼, NW¼, SE¼, Sec. 19, T24N, R2W. In the SE quadrant of the interchange
Soil Classification: Entic Haplaquod sandy, mixed, frigid
Vegetation: Jack pine, Grass
Drainage: Somewhat poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
01	+2-+1"	Organic layer of partially decomposed forest litter.
02	+1-0"	Black (5YR 2/1); organic mat of highly decomposed forest litter.
A1	0-1"	Black (10YR 2.5/1); sand; weak, fine, granular structure; very friable; strongly acid; abrupt, smooth boundary.
A2	1-9"	Grayish brown (10YR 5/2) with many, medium, distinct, dark grayish brown (10YR 4/2) mottles; sand; single grain; loose; medium acid; abrupt, wavy boundary.
B21hir	9-14"	Dark reddish brown (5YR 3/3); sand; weak, fine, granular structure; loose to very weakly cemented ortstein in places; medium acid; clear, irregular boundary.
B22ir	14-21"	Reddish brown (5YR 4/4) with many, medium, distinct yellowish brown (10YR 5/8) mottles; sand; single grain; loose; medium acid; clear, irregular boundary.
B23	21-27"	Yellowish brown (10YR 5/8) with common, medium, faint brownish yellow (10YR 6/6) mottles; sand; single grain; loose; slightly acid; clear, irregular boundary.
B3	27-36"	Yellowish brown (10YR 5/4) with many, medium, distinct yellowish brown (10YR 5/6) mottles; sand; single grain; loose; neutral; gradual, wavy boundary.

Horizon	Depth	Description
C	36+"	Brown (10YR 5/3) common, fine, faint grayish brown (10YR 5/2) and yellowish brown (10YR 5/6) mottles; sand; single grain; loose; neutral.

Croswell Sand

Location: Woodlot Site 7, Roscommon County, Michigan
NE¼, SW¼, NE¼, Sec. 19, T24N, R2W. 100' NE of interchange
Soil Classification: Entic Haplorthod sandy, mixed, frigid
Vegetation: Jack pine, Oak, Grass
Drainage: Moderately well drained
Slope: 7%
Physiography: Outwash plain

Horizon	Depth	Description
A1	0-4"	Very dark grayish brown (10YR 3/2); sand; weak, fine, granular structure; very friable; medium acid; abrupt, wavy boundary.
A2	4-8"	Grayish brown (10YR 5/2); sand; single grain; loose; medium acid; abrupt, wavy boundary.
B21ir	8-18"	Yellowish brown (10YR 5/8); sand; single grain; loose; medium acid; gradual, wavy boundary.
B22ir	18-33"	Yellowish brown (10YR 5/4); sand; single grain; loose; medium acid; gradual, wavy boundary.
C	33-60"	Brown (10YR 5/3) with common, coarse,distinct yellowish brown (10YR 5/6) mottles; sand; single grain; loose; neutral.

Kinross Sand

Location: Woodlot Site 7, Roscommon County, Michigan
NW¼, NW¼, SE¼, Sec. 19, T24N, R2W. In the SE quadrant of the interchange
Soil Classification: Histic Haplaquod sandy, mixed, frigid
(This subgroup is not yet established. Has been included as a taxadjunct of Kinross.)
Vegetation: Swamp grass

Kinross Sand (cont'd.)

Drainage: Poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
O2	+9-0"	Black (5YR 2/1); sapric material; primarily herbaceous fibers; strongly acid; abrupt, smooth boundary.
A1	0-1"	Black (10YR 2/1); sand; very weak, medium, granular structure; very friable; strongly acid; abrupt, wavy boundary.
B21hir	1-3"	Dark reddish brown (5YR 3/3) with common, coarse, distinct, strong brown (7.5YR 5/6) mottles; sand; weak, coarse, sub-angular blocky structure; very friable; strongly acid; gradual, wavy boundary.
B22ir	3-7"	Dark yellowish brown (10YR 4/4) with many, coarse, distinct, dark reddish brown (5YR 3/3) mottles; sand; single grain; loose; strongly acid; gradual, wavy boundary.
B3	7-18"	Yellowish brown (10YR 5/4) with many, coarse, distinct, dark reddish brown (5YR 3/3) mottles; sand; single grain; loose; strongly acid; gradual, wavy boundary.
Cg	18+"	Grayish brown (10YR 5/2) with common, medium, distinct, yellowish brown (10YR 5/6) mottles; sand; single grain; loose; strongly acid.

Woodlot Site 8

AuGres Sand

Location: Woodlot Site 8, Roscommon County, Michigan
SW¼, SW¼, SE¼, Sec. 7, T23N, R2W. 100' west of highway
Soil Classification: Entic Haplaquod sandy, mixed, frigid
Vegetation: Alder and Swamp grass
Drainage: Somewhat poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
02	+2-0"	Organic layer of highly decomposed litter.
A1	0-2"	Very dark grayish brown (10YR 3/2); sand; weak, fine, granular structure; very friable; slightly acid; abrupt, smooth boundary.
A2	2-12"	Grayish brown (10YR 5/2); sand; single grain; loose; slightly acid; clear, wavy boundary.
B21ir	12-26"	Dark brown (10YR 4/4) with many, medium, distinct brown (10YR 5/3) mottles; sand; single grain; loose; slightly acid; gradual, wavy boundary.
C	26+"	Brown (10YR 5/3) with common, medium, distinct yellowish brown (10YR 5/6) mottles; sand; single grain; loose; neutral.

Croswell Sand

Location: Woodlot Site 8, Roscommon County, Michigan SW¼, NW¼, NE¼, Sec. 18, T23N, R2W. 150' west of highway
Soil Classification: Entic Haplorthod sandy, mixed, frigid
Vegetation: Aspen, Red oak, Red maple
Drainage: Moderately well drained
Slope: 0-2%
Physiography: Moraine

Horizon	Depth	Description
A1	0-2"	Very dark grayish brown (10YR 3/2); sand; weak, fine, granular structure; very friable; medium acid; abrupt, wavy boundary.
A2	2-5"	Grayish brown (10YR 5/2); sand; single grain; loose; medium acid; abrupt, wavy boundary.
B21ir	5-18"	Yellowish brown (10YR 5/4); sand; single grain; loose; medium acid; gradual, wavy boundary.
B22ir	18-33"	Yellowish brown (10YR 5/6); sand; single grain; loose; medium acid; gradual, wavy boundary.

Horizon	Depth	Description
C	33+"	Brown (10YR 5/3) with many, coarse, prominent yellowish red (5YR 4/6) mottles; sand; single grain; loose; slightly acid.

Roscommon Mucky Sand

Location: Woodlot Site 8, Roscommon County, Michigan
SW¼, SW¼, SE¼, Sec. 7, T23N, R2W. 100' west of highway
Soil Classification: Mollic Psammaquent sandy, mixed, frigid
Vegetation: Aspen and Swamp grass
Drainage: Poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
A1	0-7"	Black (10YR 2.5/1); mucky sand; weak, fine, granular structure; very friable; slightly acid; abrupt, smooth boundary.
C	7-66"	Grayish brown (10YR 5/2) with common, medium, distinct yellowish brown (10YR 5/4) and dark brown (10YR 4/3) mottles; sand; single grain; loose; neutral.

Saugatuck Sand

Location: Woodlot Site 8, Roscommon County, Michigan
SW¼, SW¼, SE¼, Sec. 7, T23N, R2W. Center of median
Soil Classification: Aeric Haplaquod sandy, mixed, frigid, ortstein
(This is a frigid variant of Saugatuck not yet differentiated.)
Vegetation: Alder, Aspen, Grass
Drainage: Somewhat poorly drained
Slope: 0-2%
Physiography: Outwash plain

Horizon	Depth	Description
A1	0-3"	Very dark gray (10YR 3/1) sand; weak, fine, granular structure; very friable; strongly acid; abrupt, smooth boundary.

Horizon	Depth	Description
A2	3-9"	Grayish brown (10YR 5/2) sand; common, fine, distinct brown (10YR 5/3) mottles; single grain; loose; strongly acid; abrupt, wavy boundary.
B21hir	9-12"	Dark reddish brown (10YR 3/3) sand; common, coarse, distinct strong brown (7.5YR 5/6) mottles; massive structure (ortstein); strongly acid; abrupt, wavy boundary.
B22ir	12-19"	Dark brown (7.5YR 4/4); sand; common, coarse, distinct strong brown (7.5YR 5/8) mottles; single grain; strongly acid; gradual, wavy boundary.
B3	19-30"	Yellowish brown (10YR 5/4); sand; common, coarse, distinct yellowish brown (10YR 5/6) mottles; single grain; loose; medium acid; gradual, wavy boundary.
Cg	30+"	Grayish brown (10YR 5/2) sand; common, coarse, distinct yellowish brown (10YR 5/6) mottles; single grain; loose; slightly acid.

Woodlot Sites 9 and 10

Graycalm Sand

Location: Woodlot Sites 9 and 10, Roscommon County, Michigan SW¼, SW¼, SW¼, Sec. 17, T23N, R2W. 100' east of highway

Soil Classification: Entic Haplorthods sandy, mixed, frigid (Graycalm is currently classified as Alfic Udipsamment, but this soil is probably more prevalent or a taxadjunct.)

Vegetation: White oak, Red oak, Maple

Drainage: Well drained

Slope: 6%

Physiography: Moraine

Horizon	Depth	Description
O1	+1-0"	Organic mat of partially decomposed forest litter.
A1	0-2"	Black (10YR 2.5/1); sand; single grain; loose; strongly acid; abrupt, wavy boundary.

Horizon	Depth	Description
A2	2-9"	Grayish brown (10YR 5/2); sand; single grain; loose; strongly acid; abrupt, wavy boundary.
B21ir	9-20"	Strong brown (7.5YR 5/6); sand; single grain; loose; medium acid; gradual, wavy boundary.
A'2	20-34"	Light yellowish brown (10YR 6/4); sand; single grain; loose; slightly acid; gradual, wavy boundary.
A'2+B'2t	34-56"	Light yellowish brown (10YR 6/4), sand, single grain, loose (A'2 horizon); brown (7.5YR 5/4), sandy loam, weak, medium, sub-angular blocky structure, (B'2t horizon)' B'2t present as discontinuous bands ¼" to 1" thick; slightly acid; abrupt, wavy boundary.
C	56-66"	Light yellowish brown (10YR 6/4); sand; single grain; loose; neutral.

Rubicon Sand

Location: Woodlot Sites 9 and 10, Roscommon County, Michigan SE¼, SE¼, NW¼, Sec. 18, T23N, R2W. 300' west of highway
Soil Classification: Entic Haplorthod sandy, mixed, frigid
Vegetation: White oak, Red oak, Maple
Drainage: Well drained
Slope: 12%
Physiography: Moraine

Horizon	Depth	Description
O1	+1-0"	Organic mat of partially decomposed forest litter.
A1	0-2"	Black (10YR 2.5/1); sand; weak, fine, granular structure; very friable; strongly acid; abrupt, smooth boundary.
A2	2-7"	Grayish brown (10YR 5/2); sand; single grain; loose; strongly acid; abrupt, wavy boundary.
B21ir	7-17"	Dark brown (7.5YR 4/4); sand; weak, fine, granular structure; very friable; medium acid; gradual, wavy boundary.

Horizon	Depth	Description
B22ir	17-29"	Strong brown (7.5YR 5/6); sand; single grain; loose; slightly acid; gradual, wavy boundary.
B3ir	29-35"	Yellowish brown (10YR 5/6); sand; single grain; loose; slightly acid; gradual, wavy boundary.
C	35+"	Light yellowish brown (10YR 6/4); sand; single grain; loose; slightly acid.

APPENDIX B

RESULTS OF LABORATORY ANALYSES

Table 11. Laboratory analyses: mineral soils

Site	Sample	Horizon	Depth (in.)	Mechanical Analyses % clay	% silt	% sand	Quick test pyrophosphate color test	Spodic horizon
3	Grayling	B2ir	4-18	4.5	7.4	88.1	10YR 7/2	no
5	AuGres	B21ir	14-20	4.4	4.4	91.2	10YR 7/4	yes
5	AuGres	B22ir	20-28	2.7	2.7	94.6	10YR 7/4	yes
6	Omena	B'2t	9-21	20.7	20.6	58.7	2.5YR 8/2	no
7	AuGres	B21hir	9-14	3.0	6.0	91.0	7.5YR 4/4	yes
7	AuGres	B22ir	14-21	2.6	4.7	91.7	10YR 6/6	yes
7	AuGres	B23	21-27	-	7.8	92.2	10YR 8/4	no
7	Croswell	B21ir	8-18	4.1	8.1	87.8	10YR 7/3	yes
7	Kinross	B21hir	1-3	1.3	9.1	89.6	7.5YR 5/4	yes
7	Kinross	B22ir	3-7	-	7.2	92.8	10YR 5/5	yes
8	Saugatuck	B21hir, B21ir	9-19	2.6	10.2	87.2	10YR 6/4	yes
9&10	Rubicon	B21ir	6-17	-	12.6	87.4	10YR 7/4	yes
9&10	Rubicon	B22ir	17-29	1.9	4.4	93.7	10YR 7/4	yes

Table 12. Laboratory analyses: organic soils

Site	Sample	Horizon	Depth (in.)	pH $CaCl_2$	Pyrophosphate color test	Per cent fiber: Field estimate, Unrubbed	Per cent fiber: Field estimate, Rubbed	Per cent fiber: Field test, Unrubbed	Per cent fiber: Field test, Rubbed	Type of organic material
1	Adrian	0a1	0-14	7.0	10YR 4/3	30	<10	25	10	sapric
1	Adrian	0a2	14-30	6.5	10YR 4/3	25	10	35	15	sapric
1	Adrian	0a3	30-48	6.2	10YR 4/3	15	<5	25	<5	sapric
1	Tawas	0e1,0a1	0-24	6.1	10YR 5/3	50,15	15,5	35	10	sapric
2	Tawas	0a1	0-3	7.2	10YR 6/4	35	15	30	10	sapric
2	Tawas	0a2	3-9	7.2	10YR 5/3	15	<5	25	<5	sapric
2	Tawas	0a3	9-14	7.1	10YR 4/2	30	<10	30	<5	sapric
2	Tawas	0a4,5	14-46	7.1	10YR 4/2	20,30	<5,<5	20	<5	sapric
3	Tawas	0a2	14-20	6.8	10YR 4/3	40	10	30	10	sapric
3	Seelyeville	0a2	11-20	6.1	10YR 5/3	40	10	40	15	sapric
4	Rifle	0e1,2,3	3-66	6.2	10YR 6/2	40,60,65	15,20,15	55	20	hemic
5	Tawas	0a1	4-10	5.6	10YR 5/3	30	<10	35	5	sapric
5	Tawas	0a2	10-28	6.0	10YR 5/3	15	<5	30	10	sapric

APPENDIX C

MDSH PRELIMINARY PLAN PRINTS

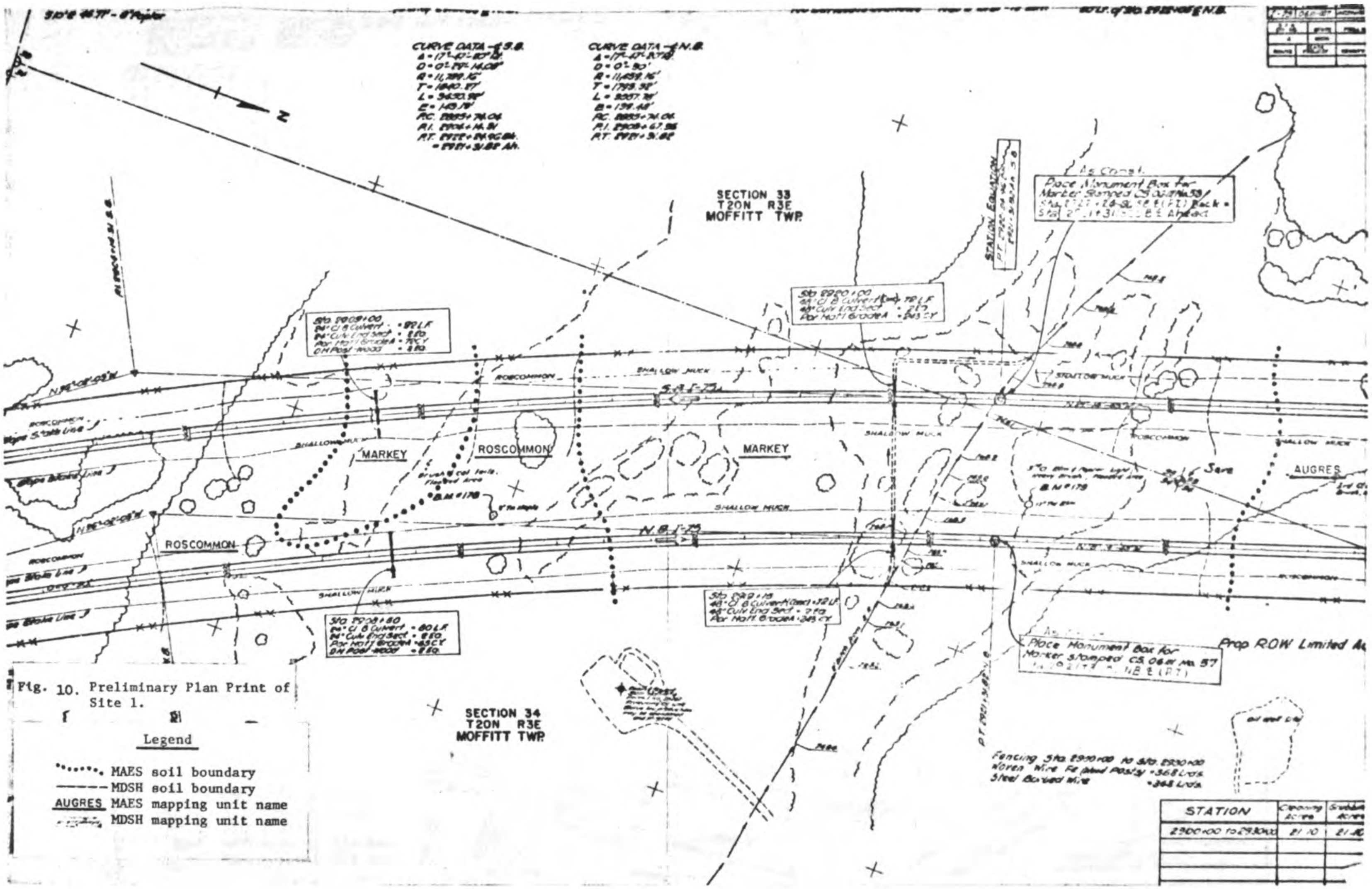

Fig. 10. Preliminary Plan Print of Site 1.

Legend

- MAES soil boundary
- MDSH soil boundary
- AUGRES MAES mapping unit name
- MDSH mapping unit name

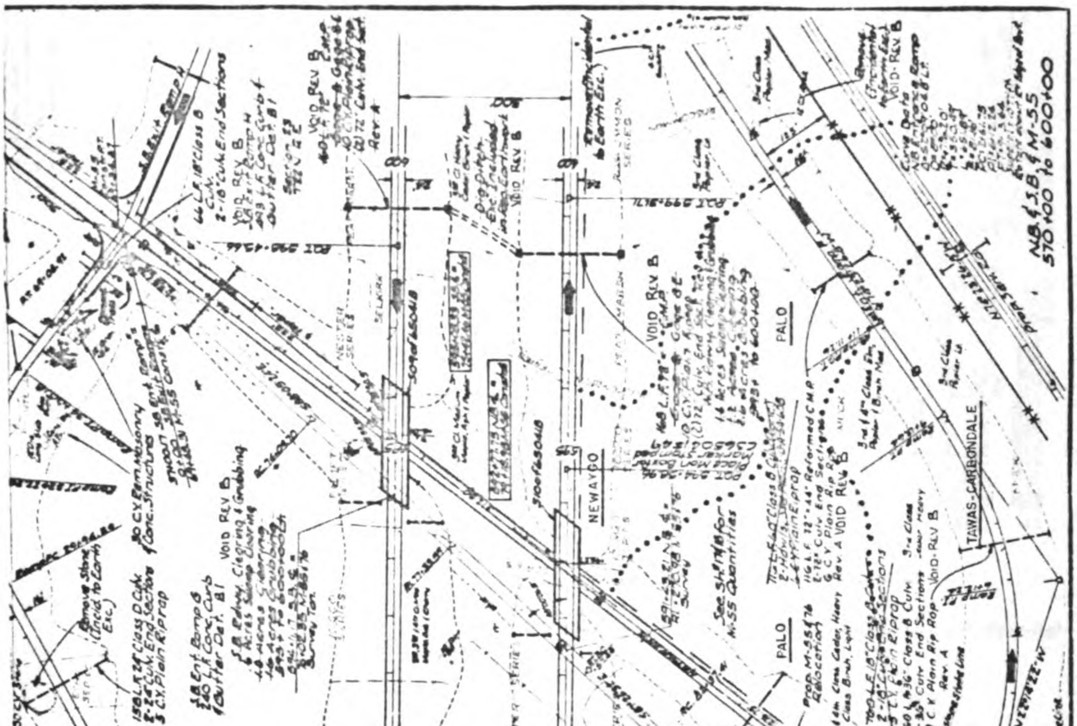

Fig. 11. Preliminary Plan Print of Site 2

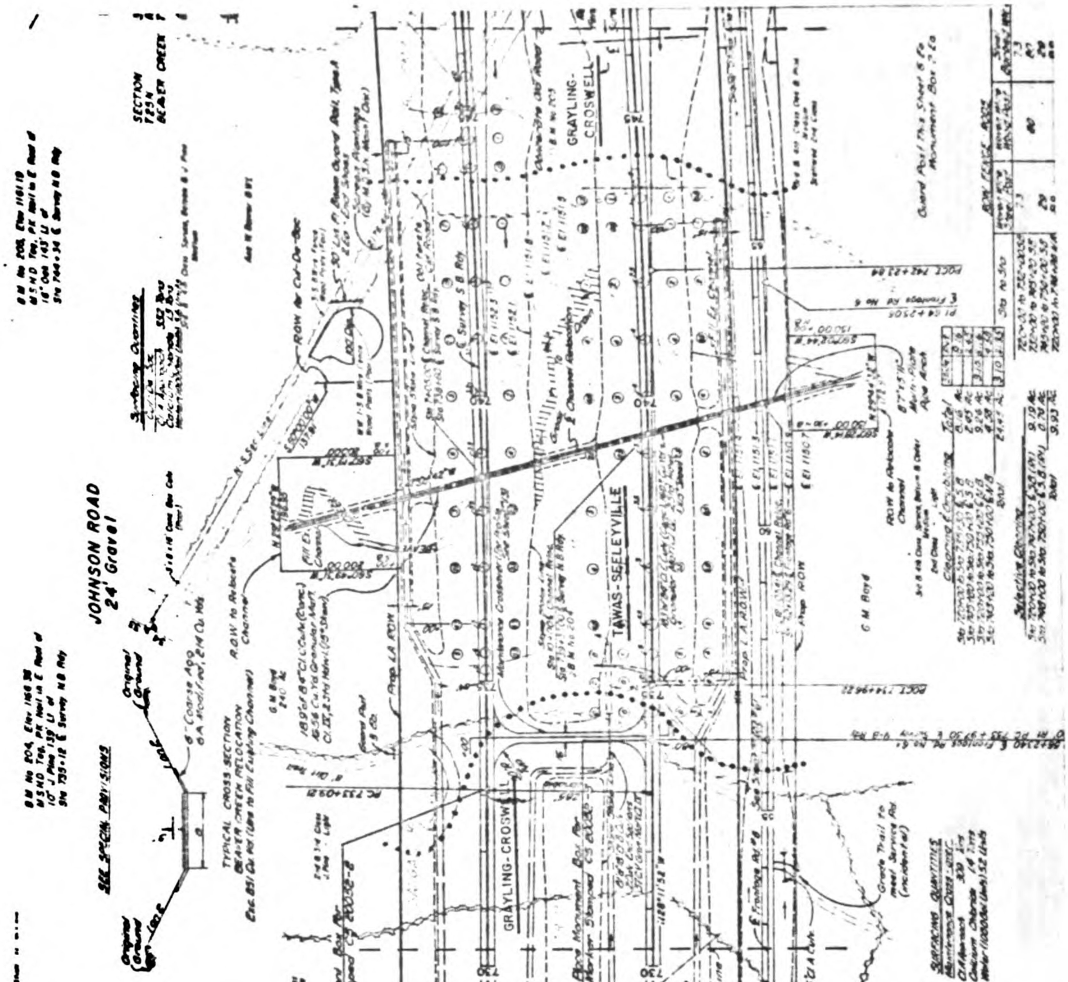

Fig. 12. Preliminary Plan Print of Site 3.

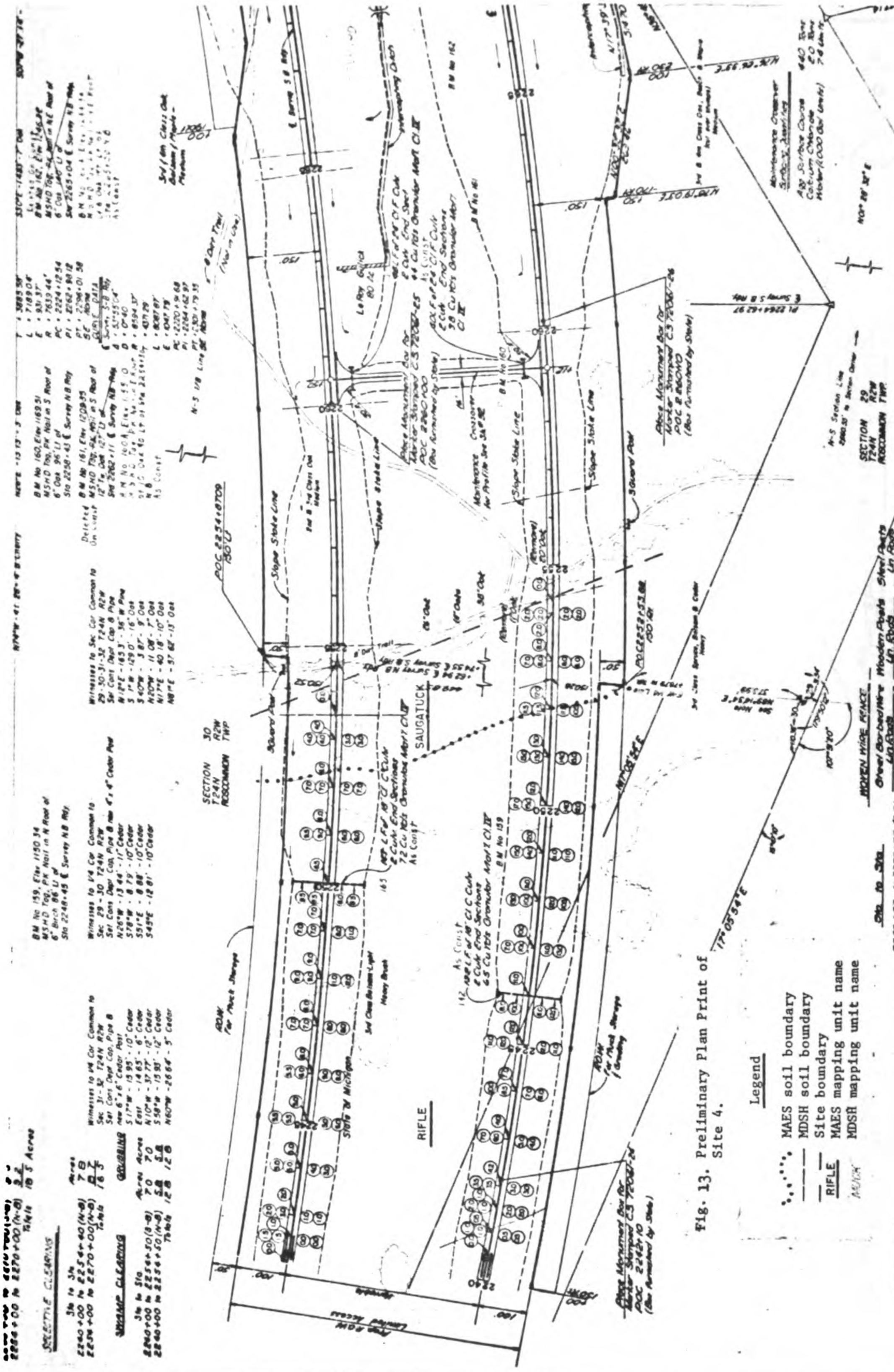

Fig. 13. Preliminary Plan Print of Site 4.

Legend

- MAES soil boundary
- MDSH soil boundary
- Site boundary
- RIFLE MAES mapping unit name
- MUCK MDSR mapping unit name

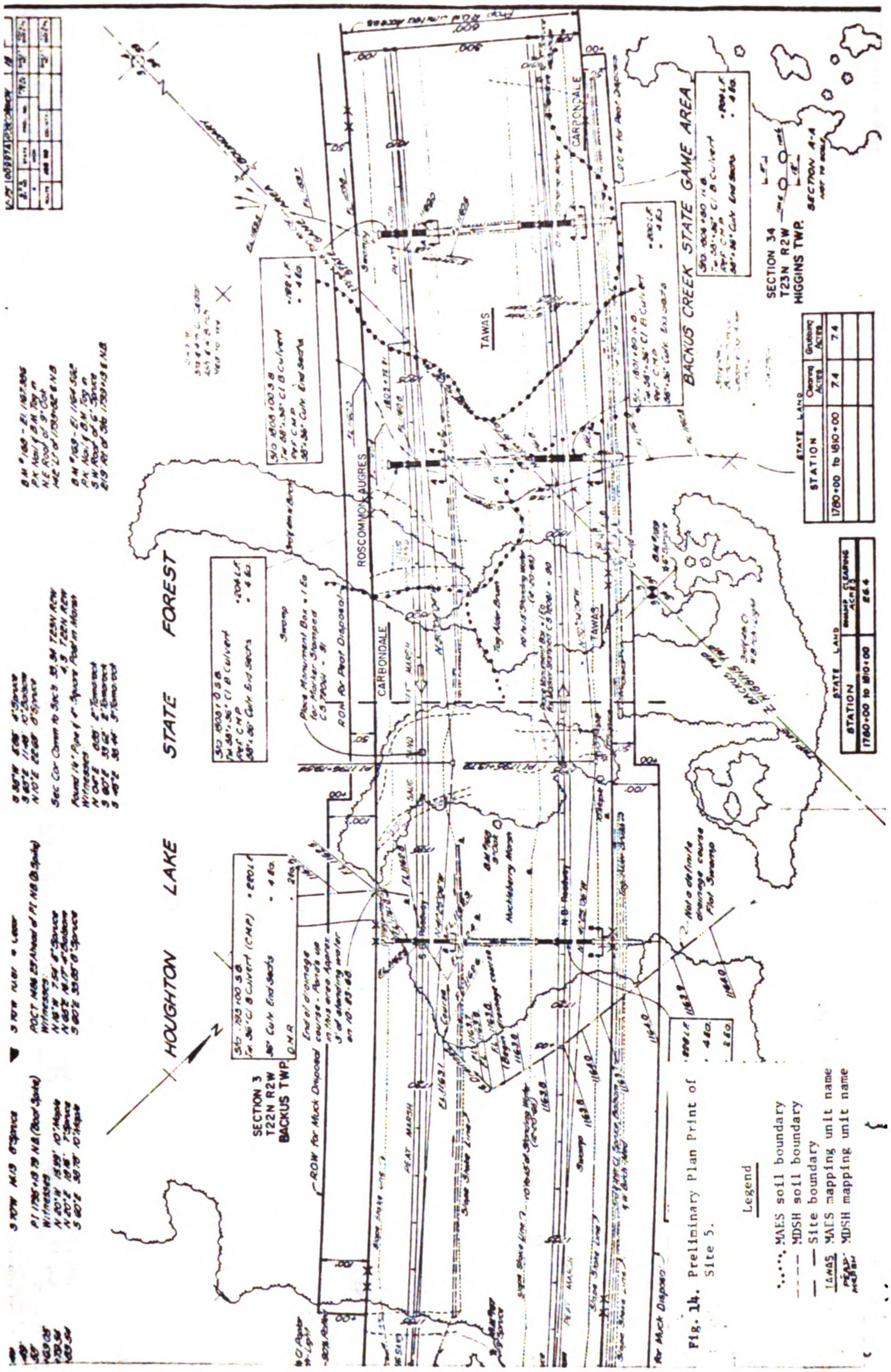

Fig. 14. Preliminary Plan Print of Site 5.

Legend

- MAES soil boundary
- MDSH soil boundary
- Site boundary
- TAWAS — MAES mapping unit name
- PEAT MARSH — MDSH mapping unit name

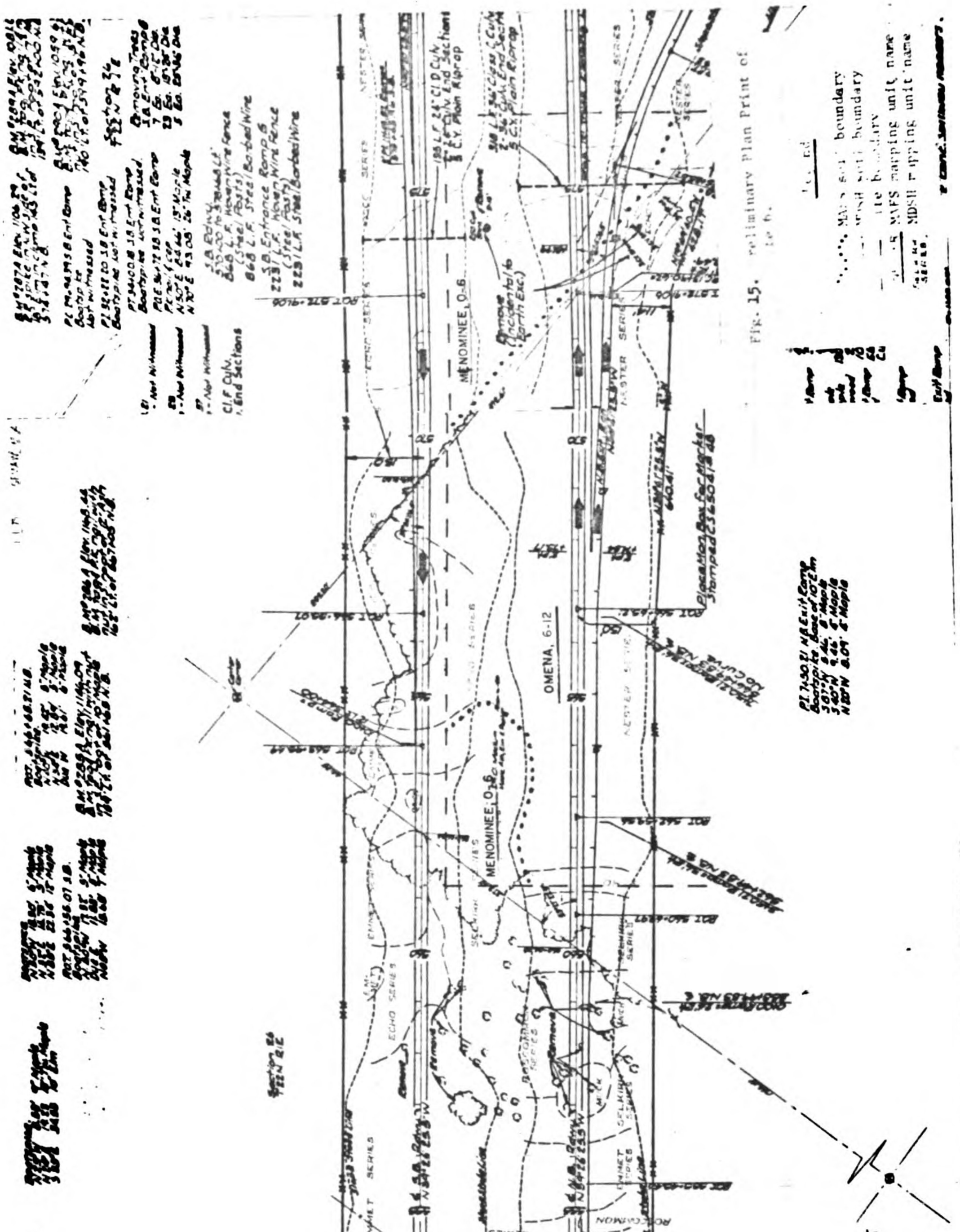

Fig. 15. Preliminary Plan Print of [illegible]

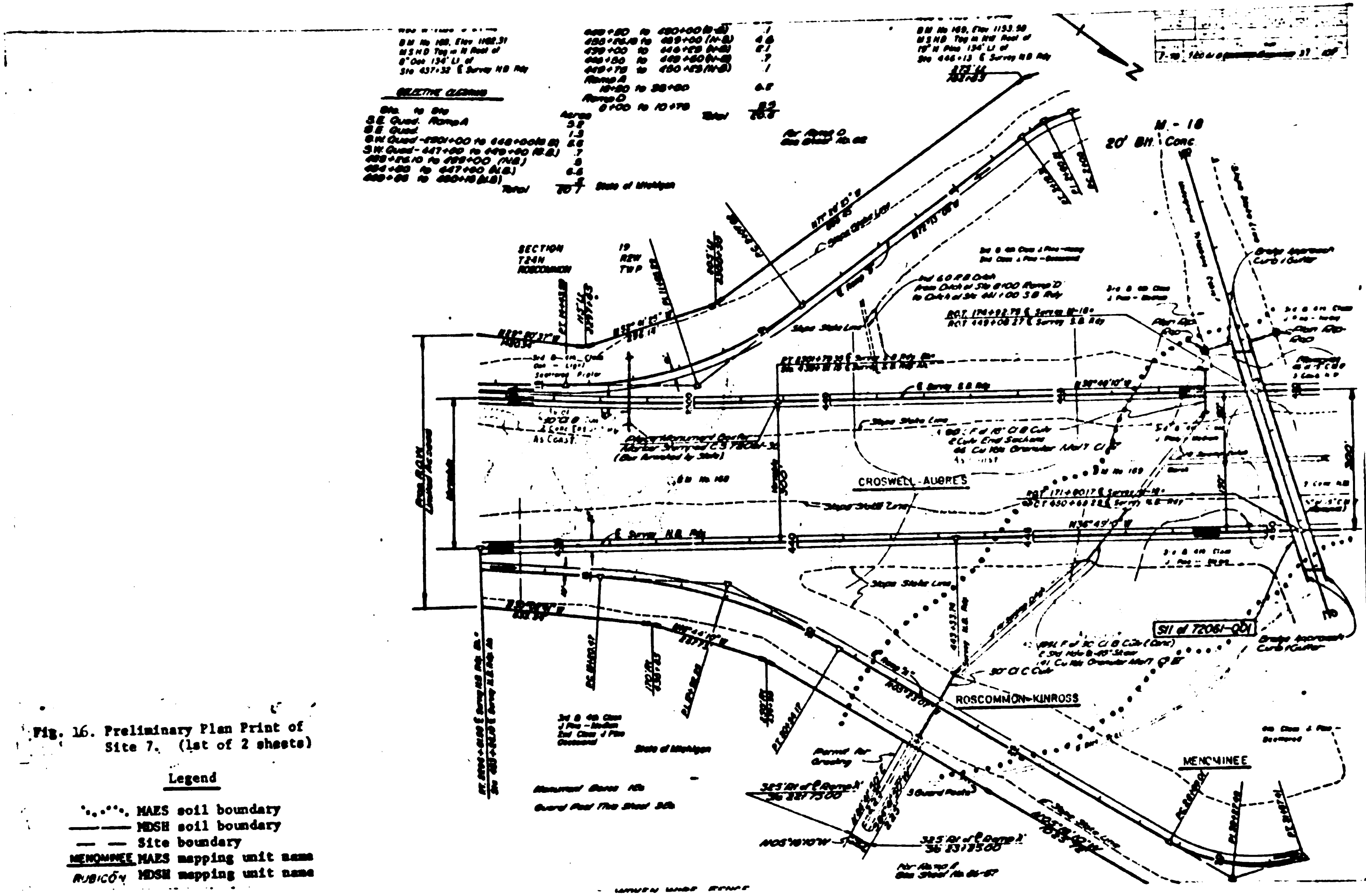

Fig. 16. Preliminary Plan Print of Site 7. (1st of 2 sheets)

Legend

- ········ MAES soil boundary
- ——— MDSH soil boundary
- — — Site boundary
- MENOMINEE MAES mapping unit name
- RUBICON MDSH mapping unit name

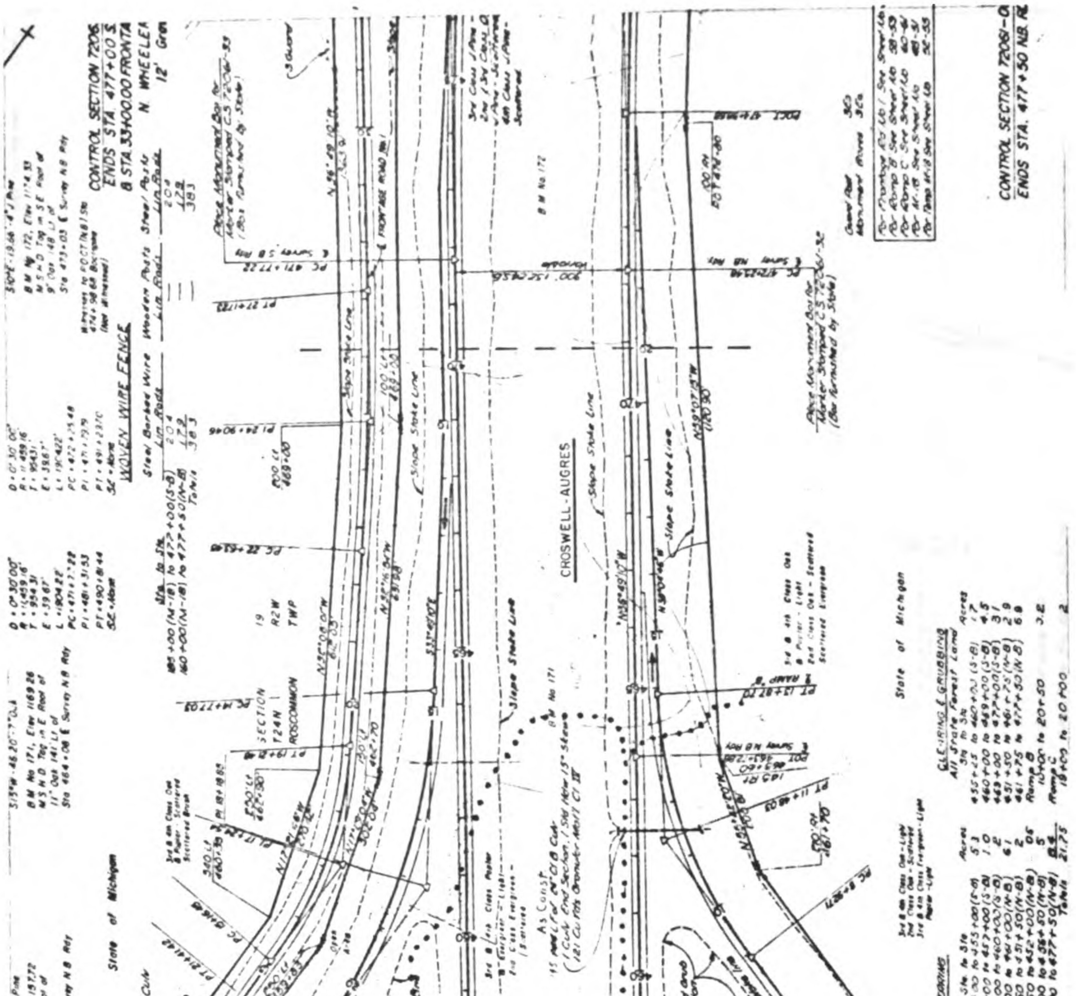

Fig. 16. Preliminary Plan Print of Site 7. (2nd of 2 sheets)

Legend

- MAES soil boundary
- MDSH soil boundary
- Site boundary
- MENOMINEE MAES mapping unit name
- SAUGATUCK MDSH mapping unit name

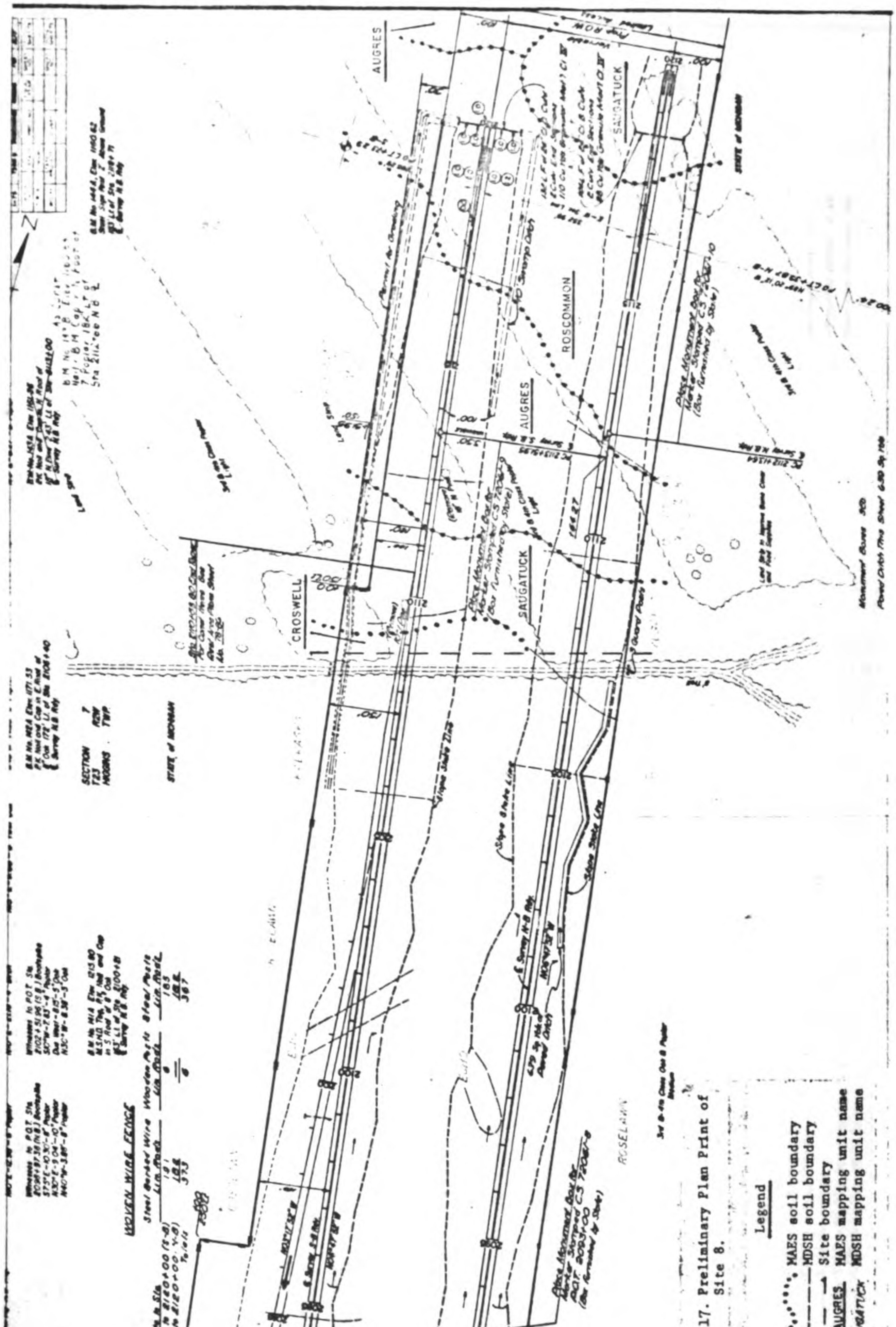

Fig. 17. Preliminary Plan Print of Site 8.

Legend

- MAES soil boundary
- MDSH soil boundary
- Site boundary
- AUGRES MAES mapping unit name
- SAUGATUCK MDSH mapping unit name

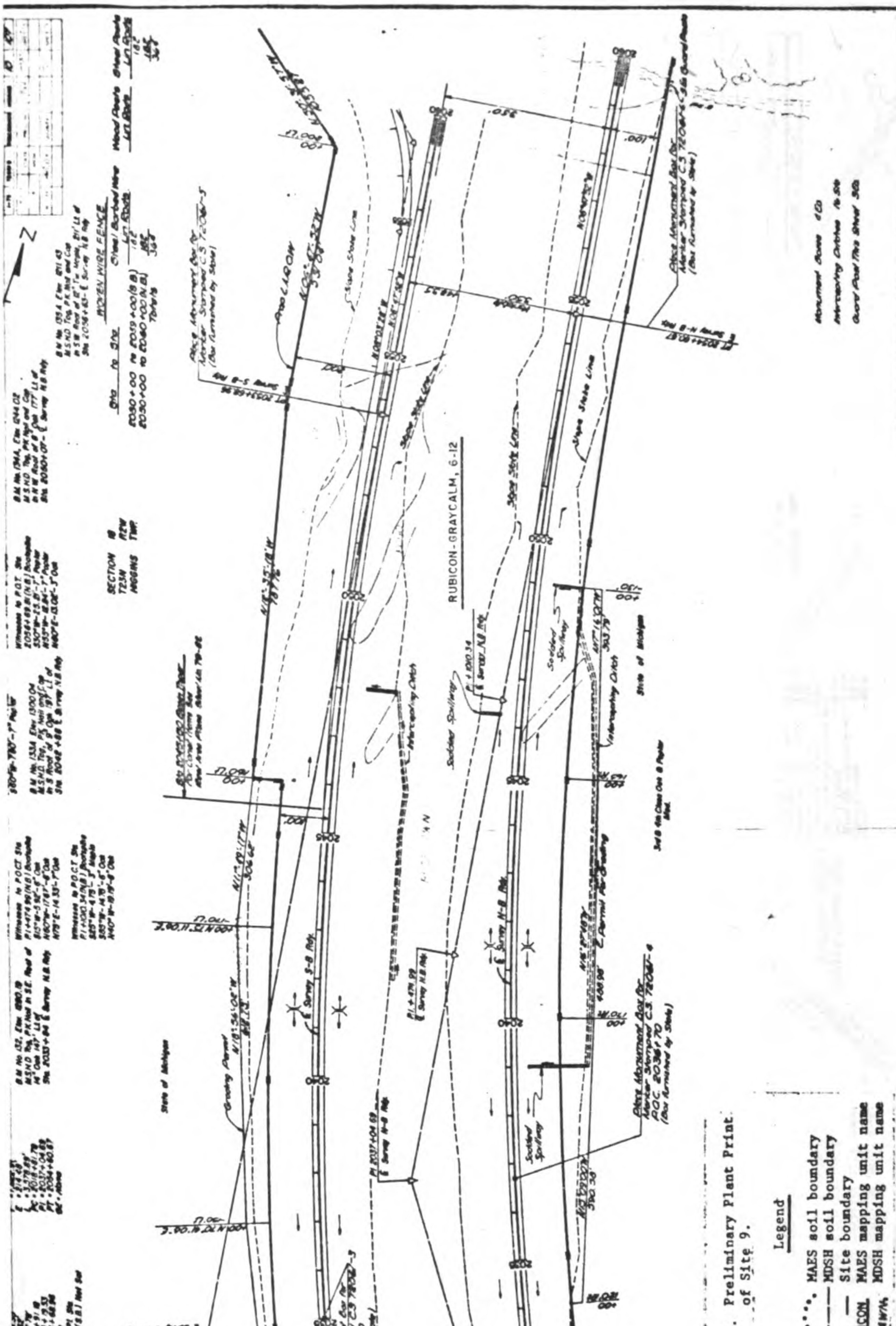

Fig. 18. Preliminary Plant Print of Site 9.

Legend

- MAES soil boundary
- MDSH soil boundary
- Site boundary
- RUBICON MAES mapping unit name
- ROSELAWN MDSH mapping unit name

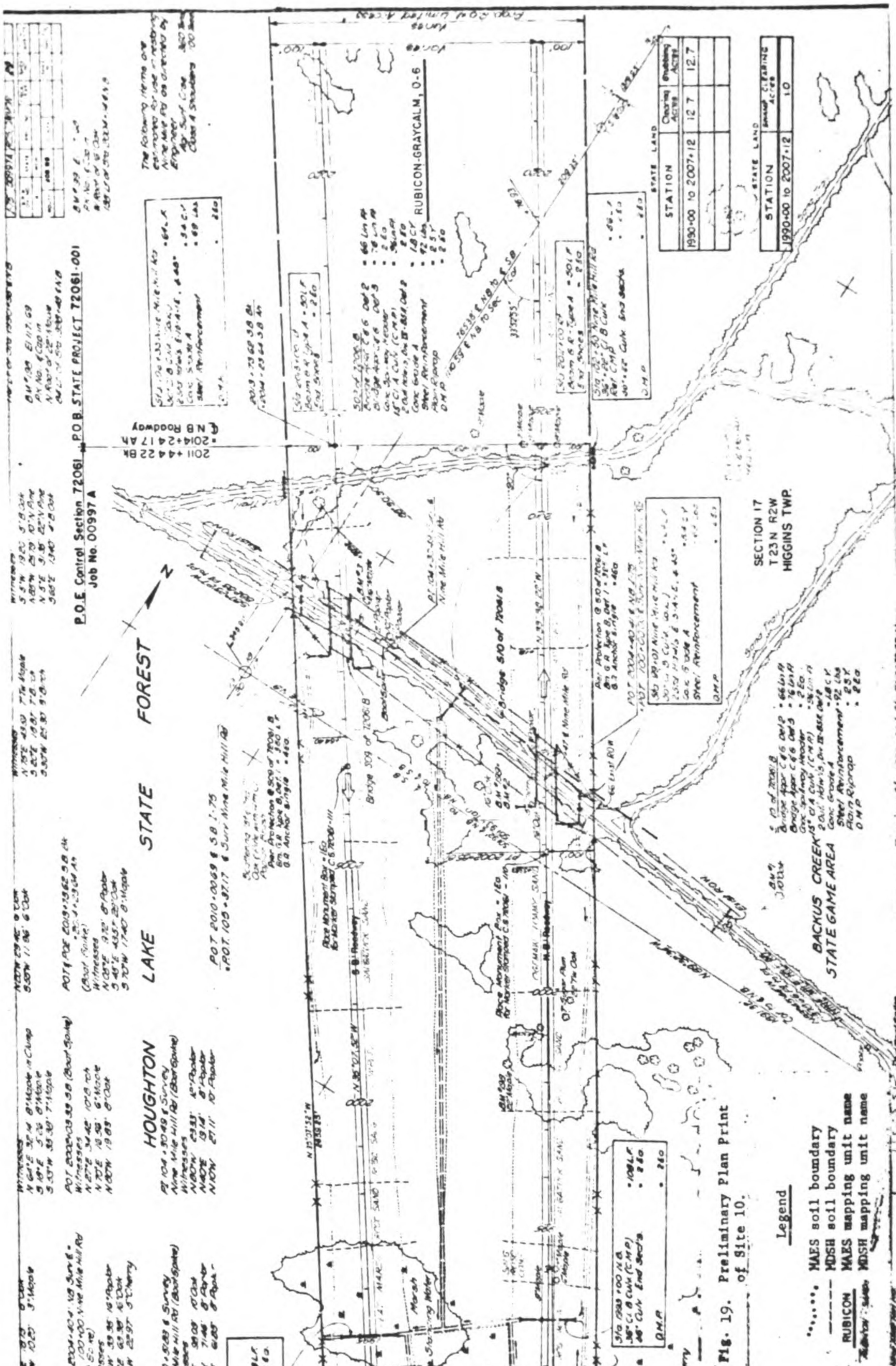

Fig. 19. Preliminary Plan Print of Site 10.

Legend

- .... MAES soil boundary
- ——— MDSH soil boundary
- RUBICON MAES mapping unit name
- Rubicon-Sand MDSH mapping unit name

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LITERATURE CITED

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