Physical Survey of the Lake Michigan College-Ross Property, Van Buren County, Michigan as an Environmental Resource

Raymond C. Levesque
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PHYSICAL SURVEY OF THE LAKE MICHIGAN COLLEGE-ROSS PROPERTY, VAN BUREN COUNTY, MICHIGAN AS AN ENVIRONMENTAL RESOURCE

by

Raymond C. Levesque

A Project Report
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Specialist in Arts Degree

Western Michigan University
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Raymond Charles Levesque
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CHAPTER I

INTRODUCTION

In 1964, Mr. Harry Ross of Benton Harbor, Michigan bequeathed to Lake Michigan College 32.4 ha (80 acres) of woodland (LMC-Ross property) located adjacent to a larger tract belonging to his estate. Mr. Ross intended that this land be utilized as an environmental resource for the College and surrounding community. Lake Michigan College realized that a formal environmental survey would help insure optimal use of the property. Hence, in the Summer 1972 arrangements were made for students in the Environmental Science Program at Western Michigan University to begin such a study. A study group was formed in the Fall 1972 and outlined its objectives at that time. It was decided, based on discussions with other nature center directors and statements made by Ashbaugh (1963) and Shomon et al (1966 and 1967), that a study of the LMC-Ross property should be comprehensive. This study would include an extensive botanical, faunal, limnological and physical survey of the tract as well as a survey of interest and financial support within the surrounding community. Information from these studies would be synthesized and a final report of important and/or unique features, special factors to consider in utilization, feasible modes of use, and local interest and support, would be prepared for consideration by a planning committee.

There seems to be little question of the need to maintain suitable land areas as natural and/or environmental resources. In 1970, Michigan's
population was distributed at an overall density rate of 155.7 per square mile with most of these people crowded in the southern portion of the lower peninsula (Michigan Senate Conservation and Environment Committee, 1970). Michigan's population problem (about nine million people in 1970) is certainly not unique in the United States or even the world. Population is presently our one most threatening environmental problem (Meadows et al, 1972) and large populations put an extreme burden on existing natural lands. Many attempts have been made to preserve rapidly vanishing natural areas close to large population centers. However, Ashbaugh's (1963) goal of a green island for every community is far from being realized in lower Michigan. Available land along the southeastern shore of Lake Michigan is difficult to find. Much of the unique dunal complex that stretches from northern Indiana to the Leelanau peninsula in Michigan (Roberts, 1970) is now privately owned and not available for public education, recreation or enjoyment. Because of the foresight, persistence, and enlightened work of a few, some tracts such as the Indiana Dunes near Michigan City, Indiana, the Warren Dunes near Bridgman, Michigan and the Grand Mere area in Stevensville, Michigan, have been preserved. However, these natural tracts and the few others which exist in southwestern Michigan are heavily used. This overuse will eventually destroy the qualities for which these areas were set aside.

Thus, if new lands are available, and proper assessment reveals that they are valuable as environmental resources, they should be jealously guarded from encroaching urbanization.

A preliminary survey of the LMC-Ross property in Fall 1972 suggest-
ed that the tract was a significant resource that should be thoroughly investigated. The present study deals with the physical aspects of the site and immediate vicinity and is intended as a segment of the overall investigation. Stated generally the objectives of this study were to research all physical aspects of the property that would offer information necessary to make decisions on possible modes of use and to compile a physical history of the tract that would be necessary to evaluate its total significance. Specifically, the objectives of this study were:

1. To write a brief review of the bedrock geology, Pleistocene geology and pre-historic stages of Lake Michigan as they pertain to the study site.

2. To determine the terrain types of the site and their distributions.

3. To construct a map of glacial surface features of the site and vicinity.

4. To evaluate ground water availability.

5. To determine the physical parameters of the ground water quality on the site and in the Covert area.

6. To analyze soil types and assess the efficiency of on-site sewage disposal.

7. To analyze the formation of the dune complex at the west end of the property and evaluate its susceptibility to destruction.

8. To determine, if possible, the relative age and method of formation of Mud Lake.
CHAPTER II

GEOGRAPHIC DESCRIPTION AND GEOLOGIC HISTORY
OF THE STUDY SITE

Geographic Description

The study site is comprised of the 32.4 ha (80 acres) of the northern half of the southwest quarter of section twenty (20), Covert Township (T2S, R17W), Van Buren County, Michigan. The Western border of the site is approximately 1.6 km (one mile) inland from the present Lake Michigan shoreline and is therefore subject to the lake's moderating influence. The eastern border of the property is four km (2.5 miles) west of U. S. Route 140 and the southern property boundary is 3.6 km (2.25 miles) north of the Berrien County line. In general terms, the study site is in the far western part of Van Buren County and is approximately midway between South Haven and St. Joseph-Benton Harbor, Michigan.

Access to the site is either via a private sand-gravel road from County Road 376 through adjacent property to the south, or by 38th Street in Covert. The latter access is presently the least desirable, for the bridge at the end of 38th Street and the dirt road along the northern edge of the property are both impassable by vehicular traffic.

The eastern half of the site is flat and very wet. Elevations in this area range between 187.5 and 189.0 m (615-620 feet) above sea level (U. S. Geological Survey, 1930) or approximately 12.2 m (40 feet) above the Lake Michigan mean water level. The western half of the property is

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dominated by a small lake (Mud Lake) and a complex of wind-blown sand
dunes. A lodge, built during the early 1950's by the Ross family, lies
at the southwestern end of Mud Lake (Figure 6).

Bedrock Geology of Southwestern Michigan

All southwestern Michigan lies within the structural depression
known as the Michigan basin. This basin had its beginnings approximately
600 million years ago during the early part of the Cambrian Period as
an interior lowland. At that time the Great Lakes region of North America
was vastly different in appearance from its present state. Although a
low region existed where the State of Michigan is today, interior high-
lands surrounded this lowland on all sides. These high areas included
the Adirondack Highlands to the east and northeast, the Cincinnati, Kan-
ekakee and Findlay arches to the south, the Wisconsin Highlands to the
west and northwest and the Canadian Shield to the north (Dorr and Eschman,
1970). During most of the Paleozoic Era from about 600 to 280 million
years ago the highlands surrounding the basin were eroded and their sedi-
ments were slowly deposited in the lowlands. Dorr and Eschman (1970)
noted that in places these Paleozoic sedimentary rocks are about 14,000
feet thick. This great depth was possible because as new deposits were
laid down, the region sagged and became basin-like. The sequence of rock
deposition was not continuous and many unconformities or breaks in the
sequence of rock ages have been found.

Not all the rocks of the Michigan structural basin were formed by
erosion of surrounding highlands. The basin and adjacent interior low-
lands were inundated by shallow inland seas throughout most of the Paleozoic Era (Dorr and Eschman, 1970). In fact, most of the basin's rocks were laid down in shallow seas, or were derived directly from the sea itself as evaporite formations. The history of this depositional process is long and complex. The reader is therefore referred to Dorr and Eschman (1970) if a comprehensive coverage is desired. Squire (1972) has included a chart, that is clear and easily read, on the stratigraphic succession in Michigan, published by the Michigan Department of Conservation in 1964. Hough (1958) presented a figure of the simplified structural succession of the basin in his text on the Great Lakes region.

Periods of uplift after formation of the structural basin allowed erosive forces to cut deeply into the sediments, slicing across the inclined rock layers so that they now lie beneath the recent Pleistocene drift as a series of irregular concentric circles. Because of this configuration, younger rocks are at the surface in the center of the basin, which is near the center of the lower peninsula, and the older rocks outcrop towards the edges of the state. The Paleozoic sedimentary rock beneath the Pleistocene deposits in southwestern Michigan is mainly Coldwater Shale of early Mississippian age (ca. 340 million years old). Martin (1955) showed that most of Van Buren County, Michigan is underlain by this formation. However, the northwestern section of the county, including Covert Township, is underlain by Ellsworth Shale of late Devonian age (ca. 345 million years old) and is therefore older than the Coldwater Shale. Beneath the Ellsworth Shale in the Covert region lies about 255 million years of sedimentary rock sequence that rests upon Precambrian igneous and metamorphic basement rock. The formations that compose this
sequence, as well as the rest of the basin, are dominated by shales, sandstones, limestones, dolomites and evaporites. These rock types are important because they provided the surface from which much of the recent glacial deposits of the region were derived. The softest of these rocks (e.g., shales) underlie most of the Great Lakes and may be the primary reason for the existence of the lakes.

The foregoing discussion on the bedrock geology of southwestern Michigan is vital for a complete understanding of the recent and surface geology of the region. The deposits that presently mantle the area are glacial, as mentioned above, and were derived from the adjacent bedrock as the glaciers advanced from the north scouring and then depositing material as they moved. The section on Pleistocene geology will discuss these processes in greater detail.

Pleistocene Geology of Southwestern Michigan

The Pleistocene Epoch or "Ice Age" was a recent geologic event that began, depending upon the author, anywhere from 500,000 to 2,000,000 years ago and ended, in Michigan, by about 10,000 years ago (Dorr and Eschman, 1970). Before discussing the glacial events of this epoch as they affect Michigan, it is helpful to review the pre-Pleistocene geology of the Great Lakes basins. In the previous discussion on bedrock geology, it was mentioned that periods of uplift and subsequent downgrading occurred after Paleozoic sedimentation had ceased. Newberry (1882), Leverett and Taylor (1915) and Hough (1958) theorized that during the latter part of these erosive cycles streams cut broad valleys in the low areas underlain by weaker rocks. They proposed that these stream valleys later became
the basins of the glacial Great Lakes. Wayne and Zumberge (1965) summarized the many theories concerning the origin of the basins and stated that all of the Great Lakes basins except Superior were formed as glacially modified river valleys. This conclusion becomes significant when advance of the Pleistocene ice is discussed.

The Pleistocene is normally subdivided into four major ice advances and three interglacial periods during which temperatures were considerably warmer than now. Evidence for the first three glacial advances is sparse in Michigan and so far, totally lacking from the southwestern part of the state. Embleton and King (1968) showed that because of deposits found south of Michigan it seems likely that the Kansan (2nd advance) and Illinoian (3rd advance) ice covered most of the state. There is no doubt, however, that the Wisconsin or last major advance covered Michigan entirely and is responsible for all the surface features seen today in southwestern Michigan. Recent dates for the Wisconsin stage (Embleton and King, 1968) are believed to be 100,000 to 10,000 years B.P. (before present). Hough (1958) reported seven Wisconsin substages and noted that the last ice to cover southwestern Michigan belonged to the fourth or Cary substage. Dorr and Eschman (1970) dated the Cary at 16,000 to 13,500 years B.P. The Cary ice retreated from southwestern Michigan in a series of pulses. These pulses are recorded by the moraines which they left. The oldest Cary moraine in the southwestern part of the state is the Kalamazoo moraine; next in age is the Valparaiso moraine, and the youngest is the Lake Border moraine. The area studied for this project lies between the Lake Border moraine, which is known as the Covert Ridge in this region, and the present shore of Lake Michigan.
Post-Wisconsin Lake Stages in the Michigan Basin

As the ice left lower Michigan for the last time with the retreat of the Cary substage, the southern portions of the Great Lakes basins were exposed. Just as steadily as the ice retreated, melt water filled the exposed basins creating proglacial (out in front of glacier) lakes. What ensued was a complex sequence of changes in the size of the proglacial Great Lakes that lasted from 13,500 to about 2,500 years B.P. The reconstructed history of these lakes has been based on a great diversity of field data and often individual interpretations do not agree. However, Leverett and Taylor (1915), Bretz (1951, 1955, 1959, 1964 and 1966) and Hough (1953, 1955, 1958, 1963 and 1966) have assembled the main events of this history and their interpretations have been effectively summarized by Dorr and Eschman (1970). A discussion of changes that occurred during the evolution of all the Great Lakes would be far beyond the scope of the present writing, but, a brief review of the lake stages of the Michigan basin does seem necessary in order to comprehend the geological background of the study site.

The first proglacial lakes to form, as the Cary ice retreated, were in the southern portions of the Michigan and Erie basins. Leverett and Taylor (1915) used the name Lake Chicago for any proglacial waters of the Michigan basin that discharged to the south through the low area near Chicago known as the Chicago outlet. Bretz (1951) suggested that an early stage of Lake Chicago at an elevation of 184.4 m (605 feet) existed from the ice front up to the Valparaiso moraine but was later eliminated by the Tinley readvance. Glacial outwash from the Tinley re-advance filled the early outlet to 192.0 m (630 feet), thus determining
subsequent water levels of Lake Chicago. The two Glenwood stages of Lake Chicago stood at 195.0 m (640 feet) and developed definite beaches, spits, wave cut terraces and cliffs along their shorelines (Hough, 1958). Because of increased discharge from the other proglacial lakes to the east, via the Grand River in Michigan, the Chicago outlet was incised and Lake Chicago dropped to its Calumet stand at 189.0 m (620 feet). The beaches of the Calumet stage are weakly developed and appear only briefly north and south of the Covert area (Leverett and Taylor, 1915). Renewed downcutting of the Chicago outlet about 12,000 years B.P. lowered the basin to 184.4 m (605 feet) and created the Toleston Stage of Lake Chicago (Hough, 1963). Hough (1958) stated that further incision was prevented because the outlet sill had reached bedrock.

A period of ice retreat followed the Toleston level during which water in the Michigan basin dropped to the Kirkfield stage at 172.2 m (565 feet ?; exact elevation not known) and discharged to the east. This low water stage has been referred to as the Two Creeks interval because of evidence near Two Creeks, Wisconsin of a mature forest that developed, was rapidly submerged by water and then overridden by the advancing Valders ice. The date for these events has been determined by radiocarbon dating and is accepted by most geologists at ca. 11,400 years B.P. (Hough, 1963). The advancing Valders ice (ca. 11,000 years B.P.) closed the eastward outlet in the area of Little Traverse Bay and the Algonquin level of Lake Chicago at 184.4 m (605 feet) was created. With the retreat of the Valders ice, the Algonquin level dropped below the Chicago outlet and a series of post-Algonquin levels were created that were discharged via a broad northern strait into the Huron basin and then through an outlet
in the Georgian Bay (Hough, 1963). The low point of the post-Algonquin stages which stood at 70.1 m (230 feet) above sea level was named the Chippewa stage by Hough (1955). Stanley (1938) proposed that this level drained into a correlative level of Huron basin via a deep channel through the Straits of Mackinac.

One of the fascinating facts about the Pleistocene is that the weight of the ice was enough to depress the land as much as 914.4 m (3,000 feet) in some places (Dorr and Eschman, 1970). This depression and the subsequent rebound was a slow process and it is thought that rebound is still occurring. Most Great Lakes geologists believe that rebound increased the height of the northeastern outlet at the end of the Chippewa stage and both Michigan and Huron waters rose. When the waters reached the level of the old outlets at 184.4 m (605 feet), they began to discharge through the Chicago outlet, the St. Clair River and the North Bay outlet. This stage is known as the Nipissing and was the largest of the post-glacial stages. Rebound eventually closed the North Bay outlet about 4,000 years ago and the lakes then discharged via the two southern outlets. Approximately 3,200 years B.P. (Hough, 1963) the St. Clair outlet, which was on unconsolidated glacial till, was lowered to 181.4 m (595 feet) and the Algoma stage of the Michigan basin was created. Since the creation of the Algoma level, the Chicago outlet has been abandoned and Lake Michigan has discharged through the Straits of Mackinac. The Algoma lake level ceased about 2,500 years ago when the Detroit River, through lateral migration, reached softer material and subsequently cut down to 176.8 m (580 feet). Hough (1963) stated that Lake Michigan has been at 176.8 m for the last 2,500 years which is a remarkably long stable period consid-
ering the past history of flux.

Since post-Cary time (ca. 13,500 years B.P.), normal geomorphic processes such as erosion, weathering and mass wasting have modified the Cary veneer of glacial drift. Thus, as water in the Michigan basin was experiencing complex level changes, the surface of the adjacent land masses was being altered by natural processes. Some of these alterations included the formation of lake-shore sand dunes by winds blowing over exposed beach deposits, the gradual sedimentation of deep depressions and low areas left by the retreating ice and the creation of post-glacial drainage patterns. Many of these processes will be discussed for a specific site in a subsequent chapter.
CHAPTER III

MATERIALS AND METHODS

Site Terrain Types

General terrain types of the LMC-Ross site were determined through the use of a variety of aerial photographs and ground checks. Aerial photographs at a scale of 1:20,000 taken by the Agricultural Stabilization and Conservation Service (ASCS) on 31 May, 1960 and 11 September, 1967 were employed as stereoscopic imagery. Two sets of infrared imagery taken by Mr. Gary Wester and the author, on 19 October, 1972, from a Cessna 172 at altitudes from 457.2 to 2438.4 m (1500 to 8000 feet) were also used. One set of photographs was taken with Kodak high speed black and white infrared film (recommended daylight ASA:50; 1/125 sec. @ f/11) through a Canon FT-QL SLR camera, fitted with a Vemar 25A red filter. The other group of photographs was taken with Kodak infrared ektachrome film (recommended ASA:100) at combinations of shutter speeds (1/125 to 1/250) and f/stops (8 to 16) in a Pentax spotmatic SLR camera, fitted with a Vemar Y2 medium yellow filter.

Photographs and slides were examined with a hand stereoscope and a Kodak carousel projector. Enlarged black and white photographs were placed in an Art-o-graph to make an outline sketch of the property and lake. The dot planimeter method was employed to determine the area of the three main terrain types. Several ground checks of photographic interpretations were made throughout the Fall 1972 and the Winter.

Glacial Surface Features of the Study Site and Vicinity

Soil data plotted on ASCS aerial photographs by Mr. Frank Austin, District Soil Scientist for southwestern Michigan, were traced and arranged in geographic sequence for sections 20, 21, 22, 27, 28 and 29, Covert Township. The relationships between certain soil types and the glacial materials on which they form were used to construct a new figure depicting the glacial surface deposits of the six sections examined. This new figure was then checked during two days of extensive field observations that included a large number of soil borings. Interviews with several Covert residents added to the accuracy of the data.

Ground Water Availability

The well on the south lawn of the lodge was sounded with line and weight and both total depth and static water level were recorded. A conversation with Mr. Daniel Graber, who installed the well in 1971, verified the results obtained. Mr. Graber mentioned that an original well that was deeper than the new well, existed in the lodge pumproom. However, neither he nor any of the officials contacted at Lake Michigan College had any more information about this well.

Lack of information on availability of water from aquifers below the immediate water table prompted an examination of water well logs from Covert Township. Data logged from 1966 to 1972 and obtained from the Van Buren County Health Department, was summarized and arranged in table form. A total of 28 wells that were within a 4.8 km (3 mile) radi-
us of the property were included in the summary.

Ground Water Quality

On 24 May, 1973 two water samples were taken by hand pump from the well on the south lawn of the lodge and sent to the Michigan Department of Public Health, Bureau of Laboratories in Lansing for analysis. One sample was submitted for bacteriologic analysis and the other was submitted for a partial chemical analysis. Results of these analyses were received by the author approximately two weeks after submission. A Hach Chemical Analysis Kit was employed to determine the well water pH while in the field.

In order to gain a general picture of the water quality in Covert Township, partial chemical analyses from 1956 to 1971 for 48 wells in Covert were obtained from the Van Buren County Health Department and arranged in table form. Means, standard deviations, variances and ranges for the eight chemical tests recorded were computed by using the standard "Stat Pack" available for use at remote terminals through the Western Michigan University Computer Center. Results of the statistical analysis were then tabulated.

Soil Types and Sewage Disposal

Soil type data used to determine glacial surface features of the site and vicinity were also employed in constructing a soil map of section 20 Covert Township. To verify interpretations, field checks utilizing a soil-auger to check soil profiles were conducted during the Spring 1973. Slopes were visually estimated and generalized for each soil type unit.
A percolation test following recommended procedures (Vogt and Boyd, 1973) was conducted on 28 June, 1973 to evaluate the area immediately south of the lodge for on-site sewage disposal. Figure 1 indicates diagrammatically the positioning of the test holes in relation to the well and lodge. Holes one through four were 0.61 m (2 feet) deep and test hole five was dug to a depth of 1.22 m (4 feet) to determine if the local water table was higher than allowable standards. Test holes one through four were kept full by constant addition of water for four hours prior to testing which insured total saturation of surrounding soils. Thirty-minute percolation tests were performed in each of the four main test holes and then immediately repeated to determine reliability and thus accuracy of results. Test hole number five was left empty and periodically checked for water infiltration.

Dune Complex Analysis

The dune complex on the western end of the property was surveyed with rod and transit during the Spring 1973. From these data, a preliminary topographic map was constructed which depicted general dune relief. Aerial photographs employed to determine terrain types in a previous section were also examined to evaluate the extent and configuration of the continuous dune complex of which the property was a small part. Soil profiles taken for a previous section of this paper were also examined in order to age the dunes. Angles of windward and leeward dune slopes were obtained with a Leitz transit.

Mud Lake Bottom Core Analysis
Figure 1. Location of percolation test holes in relation to the lodge and well on the LMC-Ross property, Covert Township, Van Buren County, Michigan. Size of lodge and distances between points are not to scale.
During May, 1973, twelve 2.5 cm diameter core samples were taken from Mud Lake with a system of three 3.1 m (10 feet) metal conduit pipes. Pipe lengths were added as sample depth increased. Most samples were taken from the stern of a 3.7 m boat because of water depth. The location of samples is shown in Figure 2. Samples 8 through 12 were taken at deep points, for this is where the most accurate cores may be obtained (R. E. Bailey, 1973; personal communication). The water-muck interface was determined with a bell anchor and measured cord. Core samples were extruded in the field and examined. Wood specimens were selected from cores and identified in the laboratory.
Figure 2. Contour map of Mud Lake, Covert Township, Van Buren County, Michigan showing numbered core sample sites. Lake contours were obtained by Mr. Gary Wester, 1973.
CHAPTER IV

RESULTS AND DISCUSSION

Site Terrain Types

Water bodies do not always show clearly on panchromatic photographs due to ripple reflection, turbidity and the presence of shallows. However, color infrared imagery is useful in delimiting aquatic areas because of the high absorption of near infrared wavelengths by water (Engel, 1968). The color infrared imagery taken for this project clearly exhibited all aquatic areas (Figure 3). Water on the slides appeared dark blue to black.

Upland areas of the tract were seen as regions predominantly covered with broadleaf trees and were therefore outlined by recording areas of high vegetation reflectance. Ground checks revealed that these uplands were primarily old lake-shore dunes.

Lowlands were seen as darker shades of blue and green on the color-infrared photographs. This was caused by at least two factors. First, the presence of extensive moisture appears as a darker area on infrared film (Eastman Kodak Company, 1968). Second, the lack of a continuous cover of large broadleaf trees would reduce the overall infrared reflectivity. The black and white infrared images were also useful in terrain detection for similar reasons. Figure 3 depicts the relative areas of the three main terrain categories observed: water, 3.9 ha (9.7 acres); dune upland, 6.6 ha (16.2 acres); and lowland, 21.9 ha (54.1 acres). Terrain analysis revealed that approximately two-thirds of the property (21.9 ha) was lowland. Field checks of this area showed that it was
Figure 3. Main terrain types found on the IMC-Ross property, Covert Township, Van

Lowland

Dune upland

Water

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very wet during most of the year and that vegetation was extremely dense. These conditions made movement in this part of the study site most difficult. The ideal time to survey this area would be during the Winter when the muck and pools of water would be frozen and the herbaceous vegetation would have died back. Movement over the 6.6 ha of upland was relatively easy in comparison with that over the lowland tract.

Glacial Surface Features of the Study Site and Vicinity

Although the site studied lies in the southwestern quarter of section 20, a rectangular area of six square sections extending east and south from section 20 was mapped to show how the surface features of the site differed from adjacent deposits. West to Lake Michigan and north of section 20, the glacial surface features were similar to those found on the study site and therefore not included in Figure 4.

Sand of wind blown size was the most abundant deposit in the six sections examined (Figure 4). Bagnold (1942) has reported that the size of sand readily transported by the wind ranges from 0.3 to 0.15 mm in diameter. Microscopically examined sand from the study site fell between these limits. The designation "thick sand" on Figure 4 refers to sand of wind blown size that was more than five feet deep, but, which had not been blown into dunes. Dunes were plentiful in the western portion of the six sections mapped and will be discussed in greater detail in another section. The western end of the region mapped also had many muck areas. Muck was found in low spots, such as "blow-outs", that had been created by advance of sand dunes or in depressions left by retreat of the glacial ice. In much of the area mapped, the sand veneer was thin and till containing clay was found beneath the sand. Till lies at the sur-
Figure 4. Glacial surface features of sections 20, 21, 22, 27, 28 and 29, Covert Township, Van Buren County, Michigan.
face in a few spots, the largest of which is in section 27. Glacial till of the Cary substage contains much clay because it was derived from shale; it also has some local sand accumulations (Leverett and Taylor, 1915). This material which underlies all the area mapped, has been subsequently covered by shifting sand. According to Terwilliger (1954) the Glenwood stages of Lake Michigan completely covered section 20 and half of section 21 in Covert Township. The surface features of section 20 do not evidence this post-Cary inundation because of the subsequent cover of wind-blown sand and other processes such as sedimentation.

The dunes on the western end of the property are part of a system that extends from northern Indiana up the east shore of Lake Michigan to the Leelanau peninsula. Most of this strip of dunes along Lake Michigan is privately owned and therefore not accessible to the general public. Some duneland parks and preserves do exist in the region, such as the Indiana Dunes near Michigan City, Indiana, the Warren Dunes near Bridgman, Michigan, the Grand Mere area in Stevensville, Michigan and Van Buren State Park just north of Covert Township. These are often overcrowded by Michigan residents as well as tourists. Many of the dune areas have been mined for foundry sand and mining operations are presently underway in section 29, Covert Township only 1.6 km south of the study site. Under existing circumstances of heavy use and extinction it would appear logical to preserve the property studied as a unique but rapidly disappearing environmental resource.

Ground Water Availability

The depth of the well on the south lawn of the lodge was recorded
at 5.2 m (17 feet) and the static water level was 1.8 m (6 feet) below the land surface. This well was hand driven in 1971 and has a sand point. Because it is so shallow there is little doubt that it draws directly from the surface water table and is therefore susceptible to contamination. At present, two outhouses, that are occasionally used, lie at least 100 m away from the well and apparently pose no threat of contamination.

Information on the availability of water within a 4.8 km radius of the property was summarized in Table 1. This table highlighted the great variability in well depth and capacity that exists in the Covert region. A common characteristic of all the tabled wells was that the water bearing stratum was sand. Sand and gravel deposits left by continental glaciation are among the most productive aquifers (Bergstrom et al., 1968) and depending upon their extent may yield huge volumes of potable water. Bergstrom et al. (1968) noted that water from sand and gravel aquifers was less expensive to pump, usually cooler and had lower mineral content than water from deeper bedrock sources. The mean depth of wells within a 4.8 km radius of the study site was 23.25 m (Table 1), which is a relatively inexpensive depth to drill through glacial drift. The mean capacity of these wells was 255.85 l/m (67.54 gpm) which would not be adequate for most municipal and/or industrial uses, but, which would be more than sufficient for domestic use (Bergstrom et al., 1968).

Data in Table 1 from wells immediately surrounding the property suggest that an adequate water supply could be found by drilling an 18 to 20 m well into the underlying drift. Nevertheless, based on a number of considerations, caution is advised when such predictions are made for the study site. Giroux et al. (1964) mentioned that till plains, areas
Table 1. Selected data from 28 water wells drilled in Covert Township, Van Buren County, Michigan from 1966 to 1972. Well numbers are those of the County Health Department.

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Water Bearing Stratum</th>
<th>Depth in Stratum m (feet)</th>
<th>Static Water Level in m (feet)</th>
<th>Capacity in l/m (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>sand</td>
<td>36.0 (118)</td>
<td>12.2 (40)</td>
<td>3409.2 (900)</td>
</tr>
<tr>
<td>3</td>
<td>sand</td>
<td>22.0 (72)</td>
<td>13.7 (45)</td>
<td>1420.5 (375)</td>
</tr>
<tr>
<td>10</td>
<td>sand</td>
<td>29.9 (98)</td>
<td>6.1 (20)</td>
<td>37.9 (10)</td>
</tr>
<tr>
<td>15</td>
<td>fine sand</td>
<td>12.8 (42)</td>
<td>6.1 (20)</td>
<td>56.8 (15)</td>
</tr>
<tr>
<td>18</td>
<td>sand-gravel</td>
<td>21.3 (70)</td>
<td>9.1 (30)</td>
<td>227.3 (60)</td>
</tr>
<tr>
<td>19</td>
<td>fine sand</td>
<td>46.3 (152)</td>
<td>33.4 (108)</td>
<td>7.6 (2)</td>
</tr>
<tr>
<td>22</td>
<td>fine sand</td>
<td>21.0 (69)</td>
<td>9.8 (32)</td>
<td>49.2 (13)</td>
</tr>
<tr>
<td>24</td>
<td>fine sand</td>
<td>25.0 (82)</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>25</td>
<td>sand</td>
<td>16.5 (54)</td>
<td>12.2 (40)</td>
<td>56.8 (15)</td>
</tr>
<tr>
<td>26</td>
<td>sand</td>
<td>9.5 (31)</td>
<td>4.6 (15)</td>
<td>---</td>
</tr>
<tr>
<td>31</td>
<td>med. sand</td>
<td>13.4 (44)</td>
<td>2.4 (8)</td>
<td>37.9 (10)</td>
</tr>
<tr>
<td>32</td>
<td>sand</td>
<td>18.0 (59)</td>
<td>6.7 (22)</td>
<td>34.1 (9)</td>
</tr>
<tr>
<td>36</td>
<td>coarse sand</td>
<td>33.3 (109)</td>
<td>15.2 (50)</td>
<td>75.8 (20)</td>
</tr>
<tr>
<td>40</td>
<td>sand</td>
<td>39.6 (130)</td>
<td>19.8 (65)</td>
<td>227.3 (60)</td>
</tr>
<tr>
<td>41</td>
<td>sand</td>
<td>23.5 (77)</td>
<td>13.7 (45)</td>
<td>9.5 (2.5)</td>
</tr>
<tr>
<td>43</td>
<td>sand</td>
<td>41.8 (137)</td>
<td>10.7 (35)</td>
<td>56.8 (15)</td>
</tr>
<tr>
<td>45</td>
<td>sand</td>
<td>19.2 (63)</td>
<td>10.7 (35)</td>
<td>37.9 (10)</td>
</tr>
<tr>
<td>48</td>
<td>fine sand</td>
<td>25.0 (82)</td>
<td>18.9 (62)</td>
<td>34.1 (9)</td>
</tr>
<tr>
<td>49</td>
<td>sand-gravel</td>
<td>12.8 (42)</td>
<td>8.2 (27)</td>
<td>30.3 (8)</td>
</tr>
<tr>
<td>52</td>
<td>coarse sand</td>
<td>27.7 (91)</td>
<td>3.1 (10)</td>
<td>30.3 (8)</td>
</tr>
<tr>
<td>55</td>
<td>fine sand</td>
<td>9.8 (32)</td>
<td>3.4 (11)</td>
<td>---</td>
</tr>
<tr>
<td>58</td>
<td>sand</td>
<td>26.2 (86)</td>
<td>6.7 (22)</td>
<td>45.5 (12)</td>
</tr>
<tr>
<td>61</td>
<td>sand</td>
<td>14.0 (46)</td>
<td>4.9 (16)</td>
<td>56.8 (15)</td>
</tr>
<tr>
<td>63</td>
<td>sand</td>
<td>17.4 (57)</td>
<td>8.2 (27)</td>
<td>303.0 (80)</td>
</tr>
<tr>
<td>66</td>
<td>sand-gravel</td>
<td>29.3 (96)</td>
<td>26.2 (86)</td>
<td>37.9 (10)</td>
</tr>
<tr>
<td>67</td>
<td>sand</td>
<td>11.6 (38)</td>
<td>8.5 (28)</td>
<td>37.9 (10)</td>
</tr>
<tr>
<td>68</td>
<td>sand-gravel</td>
<td>19.5 (64)</td>
<td>16.5 (54)</td>
<td>37.9 (10)</td>
</tr>
<tr>
<td>71</td>
<td>coarse sand</td>
<td>28.7 (94)</td>
<td>25.6 (84)</td>
<td>37.9 (10)</td>
</tr>
</tbody>
</table>

Means 23.3 (76.3) 11.7 (38.4) 255.9 (67.5)
near moraines, lake plains and dune areas are all either extremely variable as aquifers of yield little water. As mentioned previously, all of these glacial deposits may be found in the immediate vicinity of section 20. The presence of these deposits suggests that difficulty may be encountered in obtaining an adequate water supply. A water availability map for Covert (Giroux et al., 1964) shows that the property in question lies on a line separating an area of high yield from deep aquifers, from an area to the southwest where water is difficult to obtain.

Bergstrom et al. (1968) and Giroux et al. (1964) stated that the deeper the glacial drift the better the chance of finding a productive aquifer. Drift beneath the study site was from 91.4 to 121.9 m (300 to 400 feet) deep. In deposits of these depths, the probability of finding an adequate water supply is greatly increased. However, glacial aquifers are extremely variable in extent. Thus, a well in one place may penetrate a substantial water supply while only 50 to 60 m away this water bearing stratum has pinched out.

Considering all factors, it does appear likely that ample water could be found on the LMC-Ross site by continuing to drill into the glacial drift until a substantial water bearing stratum is penetrated. Penetration of such a formation may occur within the upper limits of the drift or it may happen at considerable depth. Presently there is no way of knowing at what depth a productive aquifer might be reached, but, the chances of finding such a stratum are fairly good in 90 to 120 m of glacial drift.

Ground Water Quality
Bacteriologic analysis by the Bureau of Laboratories in Lansing revealed that the water from the south-lawn well was safe for human consumption. The tests showed that the coliform index (MPN) was zero. The U. S. Environmental Control Administration (1969) has set strict standards concerning the presence of coliform organisms in public drinking water supplies. They stated that when the membrane filter technique is used, the arithmetic mean coliform density of all standard samples examined per month shall not exceed one per 100 ml. No coliform bacteria were present in the samples tested. However, periodic testing would be recommended to insure safety of the water from such a shallow well. If a well that penetrated a deeper aquifer was installed, an initial test after the system was completed may be adequate to insure bacteriologic safety. However, periodic testing might also be desirable depending on how heavily the well was used.

Partial chemical analysis of the property well water conducted by the Bureau of Laboratories, yielded the following results in ppm:

- Iron (Fe).................................0.3
- Chloride (Cl)............................2.0
- Hardness (CaCO₃)......................20.0
- Nitrates (NO₃)...........................0.0
- Nitrate Chloride (Cl)................0.0
- Fluoride Hardness (CaCO₃).........0.1
- Hydrogen Sulfide (H₂S).............0.0
- Detergents (ABS)......................0.0

Comparison of these determinations with the means for the same chemical tests in Table 2 showed that all readings were substantially lower than what might be expected as an average for the Covert area. This meant that water from this shallow well was of exceptionally good quality. A pH of 7.3, determined by the investigator, is also ideal for most water uses.

The significance of each individual test will not be discussed be-
Table 2. Computed statistical data for partial chemical analyses, 1956 to 1971, from 48 wells in Covert Township, Van Buren County, Michigan. All chemical determinations are in ppm.

<table>
<thead>
<tr>
<th>Chemical Tests</th>
<th>Mean</th>
<th>Stand. Dev.</th>
<th>Variance</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (Fe)</td>
<td>1.21</td>
<td>1.88</td>
<td>3.55</td>
<td>0.2-0.0</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>33.33</td>
<td>145.80</td>
<td>21257.45</td>
<td>950.0-0.0</td>
</tr>
<tr>
<td>Hardness as (CaCO₃)</td>
<td>168.58</td>
<td>118.27</td>
<td>13987.72</td>
<td>630.0-0.0</td>
</tr>
<tr>
<td>Nitrites (NO₂)</td>
<td>0.025</td>
<td>0.069</td>
<td>0.049</td>
<td>0.33-0.0</td>
</tr>
<tr>
<td>Fluoride (F)</td>
<td>0.68</td>
<td>0.37</td>
<td>0.13</td>
<td>1.0-0.0</td>
</tr>
<tr>
<td>Hydrogen sulfide (H₂S)</td>
<td>0.043</td>
<td>0.048</td>
<td>0.023</td>
<td>0.1-0.0</td>
</tr>
<tr>
<td>Detergents (ABS)</td>
<td>0.023</td>
<td>0.10</td>
<td>0.10</td>
<td>0.5-0.0</td>
</tr>
</tbody>
</table>
cause the partial chemical analysis revealed water of such high quality.

For a comprehensive review of each chemical test and its significance
the reader is referred to Hem (1970), U. S. Public Health Service (1962)
and Richardson (1962). There are a few tests that should be discussed based on a potential health hazard or on the variable occurrence of a
certain element or compound in the Covert area.

Hardness of the well tested was low for the Covert region (Table 2)
but it should be remembered that a new or deeper well might be much higher in dissolved solids and/or calcium carbonate. At 20 ppm, the water tested was classed as "very soft" using Durfor and Becker's (1964) classification which reads as follows:

<table>
<thead>
<tr>
<th>Range in mg/l (ppm) of CaCO₃</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 60</td>
<td>soft</td>
</tr>
<tr>
<td>61 - 120</td>
<td>moderately hard</td>
</tr>
<tr>
<td>121 - 180</td>
<td>hard</td>
</tr>
<tr>
<td>more than 180</td>
<td>very hard</td>
</tr>
</tbody>
</table>

Hem (1970) stated that water over 100 ppm CaCO₃ may become objectionable for ordinary domestic purposes. The range, standard deviation and variance for hardness in Table 2 all revealed that it was extremely variable in Covert, whereas the mean for hardness (168.58 ppm) was above normal domestic acceptability. These data suggest the strong possibility of obtaining hard to very hard water from a new well. Nevertheless, hard water has not been proven harmful to man (Hem, 1970). The main objections to hard water are its soap consuming capacity as well as its characteristic of forming scale in water heaters, boilers and pipes.

Nitrates were not present in the water tested but should be mentioned because when found in high amounts they are a health hazard to infants. There is evidence that more than 45 ppm of nitrate (NO₃) may
cause infant cyanosis or "blue baby" which is sometimes fatal (Giroux et al, 1964). Table 2 showed that nitrates were low throughout Covert. Thus, the likelihood of high readings in a subsequent well is not very great.

Chloride was very low (2.0 ppm) in the water tested and posed no health problem, but, Table 2 revealed that chlorides may be a problem in the Covert area. The standard deviation, variance and range for this chemical test showed that the occurrence of chlorides was extremely variable. However, the mean for the wells sampled in Covert was only 33.33 ppm which is well below any objectionable level (Richardson, 1962). The presence of 250 ppm of chloride or more associated with high nitrates may suggest pollution (Richardson, 1962). If subsequent wells are installed on the property, based on data from surrounding wells, there will be a slight chance of finding objectionable chloride levels. Any new facility should therefore be tested for the presence of this material.

For the most part, ground water quality at the IMC-Ross property was very good. The chance of encountering objectionable chemical qualities from a new well is low based on data from surrounding wells.

Soil Types and Sewage Disposal

Figure 5 depicts the soil types recorded for section 20, Covert Township. The IMC-Ross property lies in the southwest quadrant of the figure and is outlined by the broken line. The two dominant soil types on the property were Adrian muck and Dune (Figure 5). There was a small patch of Croswell loamy sand in the middle of the northern border but the extent of this type was insignificant.
Figure 5. Soil types of section 20, Covert Township, Van Buren County, Michigan. Data for figure was supplied by Mr. Frank Austin, District Soil Scientist. IMC-Ross property is designated by the broken line.
Adrian muck is a member of the Adrian soil series which are formed on sand or loamy sand. These soils range in depth from 41 to 127 cm (16 to 50 inches). Typically they have an organic layer of black highly decomposed herbaceous material underlain by sand (National Cooperative Soil Survey, 1970). These soils usually support marsh vegetation, as was the case on the LMC-Ross property. The soil pH is usually acid, but may commonly range from 5.5 to 7.8. A soil profile from the muck area of the study site revealed over 152 cm of dark brown to black herbaceous material that had many visible fibers. Adrian muck cannot be more than 127 cm deep. However, locally deeper soils will exist within the mappable confines of an individual type. The deeper soil noted in the profile above would not be part of the Adrian series, but would be classified as a member of the Houghton series that is a closely associated group of deeper muck soils. Large tracts of Houghton muck were found in the northwestern and southern portions of section 20.

According to the National Cooperative Soil Survey (1969a) soil interpretation sheet, Adrian muck is either very severely or severely limited for all uses. Even paths and trails are questionable because of unstable organic material, high water table and difficulty in maintaining turf. Utility buildings, picnic areas and intensive camps are all impractical because of low capacity to support loads, high water table that would outlaw on-site sewage disposal (see below) and the tree windthrow hazard resulting from poorly compacted soils. The above considerations severely limit possible uses of the LMC-Ross property muck area although they make it a natural haven for birds and many other wildlife forms. Under these conditions, a limited system of "floated walk-ways for nature study
and observation would represent optimal use.

Dune upland comprised 6.6 ha of the 32.4 ha site (Figure 3). Dune with both C (0-1.2%) and D (12-25%) slopes was the main soil type in this area. This designation was applied because soil classifications for dune lands were in flux and the National Cooperative Soil Survey has not issued a new classification system (Mr. Frank Austin, 1973; personal communication). Dune soils of the type found on the property were once classified in the Plainfield soil series (Olson, 1958a) and information from the Plainfield soil interpretation sheet (National Cooperative Soil Survey, 1969b) was used to evaluate soil limitations.

Soil profiles revealed a thin (about 15 cm) sandy humus layer that darkened rapidly then graded into about 8 cm of gray-brown leached sand. This material gradually turned orange and maximal color was attained at about 38 cm. Below this depth, sand became progressively less dark to about 64 cm from which point it stayed less dark to the bottom of the profile at 152 cm. Olson (1958a) found a very similar profile for lake shore dunes in northern Indiana. This profile will be discussed in a forthcoming section in regard to dune age.

The chief recreation limitations for Plainfield soils listed on the soil interpretation sheet were based on steep slopes, susceptibility to blowing and difficulty in maintaining turf. On C and D slopes camp sites and picnic areas as well as paths and trails were moderate to severely limited. Based on these interpretations, use of the dune complex should be restricted to light or possibly moderate foot traffic. Trails should be carefully chosen to parallel the contour as much as possible and great care should be taken to sustain stabilizing vegetation.

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Results of the percolation test performed on 28 June, 1973 appear
in Table 3. The mean percolation rate for eight trials from four test
holes was 6.9 minutes which was extremely low (good) and fell in the sec-
ond category of Vogt and Boyd (1973). They stated that with rates be-
tween 6 and 15 minutes, 27.9 to 55.8 square meters (300 to 600 sq. feet)
of sewage absorption area should be provided to service the normal three
bedroom home. Vogt and Boyd (1973) stated that the local water table
must be at least 0.61 m below the proposed base of the septic leach field
for acceptable on-site sewage treatment. The base of test holes one
through four were considered as the bottom of a proposed leach field and
after four hours of local saturation there was no water in hole five,
0.61 m below the base of the other holes. If more than the number of
people normally residing in a three bedroom house were to use an on-site
sewage disposal system, its capacity would have to be increased accordingly.
With such a low percolation rate (6.9 minutes) the site examined
should be able to accommodate the sewage from semi-public activity. But,
if increased use did occur there would be danger of fecal contamination
occurring in the nearby shallow well (Figure 1). A deeper well located
farther from the leach field would reduce the possibility of contamination.

Crosby et al (1968) tested the movement of chemical and bacterial
pollutants under abnormal loading through glacial drift and found that
enterococci and coliform bacteria were removed within 6 m from their
point of entry. However, they noted that chlorides and nitrates seemed
to migrate with, and at the same rate as, dispersing waste water, and that
water moved effectively through fine (eg. sand) material in response to
Table 3. Data from a percolation test performed on 28 June, 1973, LMC-Ross property, Covert Township, Van Buren County, Michigan. Units for water drop were not changed to metric equivalents because percolation rate was calculated from the English units.

<table>
<thead>
<tr>
<th>Test Hole No.</th>
<th>Time (min.)</th>
<th>Water Drop (in.)</th>
<th>Percolation Rate (min./in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>1</td>
<td>41</td>
<td>3</td>
<td>13.7</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>39</td>
<td>6.2</td>
<td>4.7</td>
</tr>
<tr>
<td>3</td>
<td>26</td>
<td>6</td>
<td>4.5</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>6</td>
<td>4.2</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>7</td>
<td>4.3</td>
</tr>
<tr>
<td>4</td>
<td>24</td>
<td>6</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Mean Percolation Rate 6.9
capillary gradients. Mr. Leslie Brown (personal communication), Director of the Van Buren County Environmental Health Department suggested that viruses may migrate with chlorides and nitrates. If this be true, then in sand such as that found on the study site, contamination of well water may occur beyond the normal isolation distances. Normal bacteriologic analysis will not test for viral strains. Thus their presence would have to be inferred by the presence of chloride and/or nitrate contamination.

The IMC-Ross property appears to be capable of handling small to moderate amounts of on-site sewage disposal without health hazards. If wastes were increased, the possibility of contamination would increase. Mud Lake is only about 25 m from the site tested and under increased sewage loads would most likely be subject to some contamination. If semipublic sewage facilities were installed, great care should be taken to monitor immediate waters for both chemical and bacteriologic contamination.

Dune Complex Analysis

Preliminary results of the topographic survey appear in Figure 6. A more detailed topographic map, utilizing proper cartographic techniques, is to be submitted by another member of the study group. Parabolic dunes occupied the far western part of the study site (Figure 6). This is the expected shape for dunes formed in an open area under continual winds and abundant sand (Bagnold, 1942). Tague (1946), in his study of the Grand Marais embayment in Berrien County, just south of the study site, found that parabolic dunes were quite abundant.
Figure 6. Topographic map of the LMC-Ross property, Coyert Township, Van Buren County, Michigan. Contour interval equals one meter.
Olson (1958a, 1958b, 1958c and 1958d), Tague (1946), Scott and Dow (1936) and Cowles (1899) are among those who have studied the lake-shore dunes of Indiana and Michigan. They generally agree that lake-shore dunes formed primarily as a result of post-Cary fluctuations in lake level that exposed beach deposits to eolian attack. Scott and Dow (1936) concluded that there were four basic dune types. The foredune is the first dune type to become established along the shore and is almost universally present along the east shore of Lake Michigan. If stabilizing vegetation is removed or inadequate, the foredune may blow-out locally and create the second type or dune ridge. Continued blowing will create a parabolic dune, the third type, at each point of initial blow-out. These dunes are the most common type in coastal regions (Tague, 1946). If a parabolic dune is not stabilized, continued eolian attack will blow through the apex of the parabola and divide it into two longitudinal dunes, which are the fourth type.

The long sinuous dune just east of the lodge in Figure 6 deviated from the normal parabolic shape. Tague (1946) found similar ridges in his study and theorized that they were dune ridges that stabilized before winds could blow them into the parabolic shape. Another deviation from the parabolic shape existed on the upper western border of the study site. There a large conical mound peaked just west of the property boundary at an elevation of ca. 28 m. Smith (1965) found peaked pyramidal dunes and dome shaped dunes in the Nebraskan sand hill area and proposed that they formed by the union of two or more dunes or dunal alterations resulting from changing wind directions. Melton (1940) found the same general structures and proposed that they were the result of
blow-outs, erosional hollows and depressions and marginal sand accumulation. The elevated peak found in the present study was probably formed by a combination of the fusion of two dunes and the sweeping of sand up onto this point of union. This process may have been aided by crestal vegetation that produced a dead wind area and resulted in greater sand deposition.

The characteristics that may be used to age a dune complex or individual dune are: (1) position, (2) elevation of beaches, (3) soil profile, (4) topographic unconformity, (5) elevation at dune base, (6) relative development and (7) direction of elongation (Tague, 1946). Each of these points will be considered for the dunes under study.

The dunes on the LMC-Ross property lie at the outer margin of a lake-shore dune complex and are 1.6 km from Lake Michigan. There are dunes further inland (Figure 4), but these are smaller and less in number. It appears that the dunes studied are among the oldest of the region if position alone is considered. Beach elevations were difficult to use in the present study because they were not clearly defined in the vicinity of the study site (see section on post-Wisconsin lake stages) and they probably were formed close together. The Calumet lake stage at 189 m should have formed a beach which ran through the western end of the property. The dunes in this area lie on top of the supposed Calumet beach and should therefore be less than 12,000 years B.P. which is when the Calumet beaches were exposed.

Soil profiles from dunes on the study site have been mentioned in the section on soil types and sewage disposal. Two significant characteristics of these profiles were the leached gray-brown horizon and
the extensive orange zone of oxidation. These horizons are developed only after thousands of years of weathering and leaching and therefore suggest relatively old dunes (Olson, 1958a).

No obvious unconformities were noted for dunes on the study site other than the previously mentioned dune ridge and tall peaked dune. The dune ridge, being further inland than the main complex was probably formed at an earlier stage, however, there was no obvious difference in the soil profiles.

The elevation at the base of the dune was 189 m (Figure 6) or the Calumet shore elevation. Tague (1946) stated that dunes of one lake stage were usually built on the next oldest lake beds and beaches. Thus, the LMC-Ross property dunes were very likely derived from the Toleston-Algonquin beach deposits of 11,000 to 12,000 years ago.

Relative development and direction of elongation were not considered appropriate in the present study as methods of estimating age.

Based on the above information, an approximate age of 11,000 years B.P. was set for the formation of the LMC-Ross property dunes. These dunes probably derived their sand from the Toleston-Algonquin beach deposits that were blown onto the Calumet level by dominant westerly winds. They stand today as an important part of the post-Wisconsin lake history and should be preserved and studied on that basis. Their destruction would be a regrettable loss of a rapidly diminishing record of recent geologic events in the Great Lakes region as well as of a unique ecological area.

Mud Lake Bottom Core Analysis

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Cores 1, 2 and 7 (Figure 7a and 7b) from Mud Lake were predominately composed of wind blown sand. Core 7 was located in the section of the lake that was reported by Mrs. Harry Ross as being man-made. This sample reinforced that belief, for there was only about 2.5 cm of organic material at the surface and the rest of the core was sand. Cores 1 and 2 were taken in shallow water next to an island (old lake mount). Wetzel (1970) stated that sedimentation rates at lake mounts tend to be sigmoidal and therefore they are not a true picture of normal deep water sedimentation. Wetzel (1973; personal communication) suggested that samples withdrawn from lake slopes may have been subjected to slumping and creep and are not to be trusted. For the above reasons, cores 1 through 6 (Figure 7a) were presented as information but not discussed. Cores 8 through 12 (Figure 7b) were considered acceptable samples and are discussed below.

Herbaceous detritus was the dominant sediment in samples 8 through 12. Below this was a layer of much finer organic muck. Below the muck in all five samples was a series of sand and compacted muck lenses. In samples 9 through 12, wood layers were found. Tentative identifications of these wood samples, based on the presence of vessel or tracheids, are shown in Table 4.

Core 12 was the largest sample at 457 cm (15 feet). This was the only sample that had clay lenses (Figure 7b) and may represent the oldest sediment.

In order to relate sediment type and core depth to sediment age, the approximate rate of sedimentation must be known. If carbon-14 analysis had been available then direct relationships could have been determined, but, the time and cost of such an analysis were prohibitive. However,
Figure 7a. Histogram of cores 1 through 6 from Mud Lake, Covert Township, Van Buren County, Michigan.
Figure 7b. Histogram of cores 7 through 12 from Mud Lake, Covert Township, Van Buren County, Michigan.
Table 4. Wood samples 1 through 7 from cores 9 through 12, Mud Lake, Covert Township, Van Buren County, Michigan, May, 1973.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Coniferous</th>
<th>Deciduous</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>3</td>
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<td>4</td>
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<td>5</td>
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</tr>
<tr>
<td>6</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Bailey (1972) calculated the rates of sedimentation for two lakes only about 73 km (45 miles) south of Mud Lake. His corrected rate of sedimentation for Clear Lake, Indiana was nearly linear at .082 cm/year for the first 700 cm. For Hudson Lake, Indiana, Bailey's initial linear rate was extended to the 450 cm mark and a mean rate of .087 cm/year was calculated from his figures. From the mean of the calculated rate for Hudson Lake and Bailey's rate for Clear Lake, an overall mean sedimentation rate of .084 cm/year for the first 450 cm of sediment was calculated. This rate was applied to Figure 7b and a maximum age of ca. 5450 years B.P. was determined for the bottom of core 12. The calculated age for the bottoms of cores 9 through 11 was ca. 3690 years B.P. Bailey (1972) found evidence to support the existence of a xeric period between 4,000 and 2,500 years ago. This hypsithermal period, as it has been referred to, was a dry interval and may have been dry enough to empty Mud Lake. If this occurred then one would expect to find woody vegetation and a soil profile at this level in the sediments. The wood samples in Table 4 may represent this dry period. The sand lenses associated with these wood pieces may be the result of high winds blowing across dry beach deposits to the west. The fact that five of the seven wood samples in Table 4 were tentatively identified as hardwoods supports the time estimate obtained. Bailey (1972) showed that after 10,000 years B.P. the forests were mainly deciduous and therefore a greater number of hardwoods in the sediments would be expected. Again, conifers would not be abundant in xeric conditions.

Deeper core samples would have offered a more complete chronology and may have helped estimate the method of formation of Mud Lake. No
evidence of the former (Glenwood or Calumet) lake beds was seen in the cores. If the ages calculated were nearly accurate, then no Calumet sediments would be expected because Hough (1963) aged the Calumet stage at ca. 11,000 years B.P.

There is little doubt that Mud Lake is older than 5450 years B.P. It was probably a glacial kettle which was subsequently influenced by fluctuation of the Michigan basin water level as well as by blowing sand. The hypsithermal period has been tentatively identified from four sediment cores from the deepest section of the lake. Deeper cores that could be obtained during the winter from an ice platform, would reveal the early sequence of the lake history. It is assumed that this lake was formed no earlier than 14 to 15,000 years ago, just after the Cary maximum.
CHAPTER V

SUMMARY AND RECOMMENDATIONS

Because of the diversity and quantity of information presented in this project report the following point by point summary was deemed the most readable form for presentation of data. These summary statements are not necessarily in order of importance.

1. The IMC-Ross property consists of 3.9 ha (9.7 acres) of lake and waterways, 6.6 ha (16.2 acres) of dune upland and 21.9 ha (54.1 acres) of lowland.

2. The glacial surface features of sections 20, 21, 22, 27, 28 and 29, Covert Township were mainly formed of wind-blown sand. Muck and sand dunes dominated the western portion of the section mapped whereas till of the Covert moraine and thin sand dominated the eastern sections.

3. The well on the south lawn of the lodge measured at 5.2 m (17 feet) and had a static water level of 1.8 m (6 feet).

4. Based on data from wells within a 4.8 km radius of the property, and other considerations, it was suggested that adequate water may be obtained from deeper aquifers that would be less susceptible to contamination.

5. Water from the shallow well on the south lawn of the lodge was of exceptionally good quality for the Covert area.

6. If a deep-aquifer well was installed, total dissolved solids would be expected to be moderately high and hardness, based on regional data, would be about 168 ppm.

7. No dangerous levels (45 ppm) of nitrates have been reported from the Covert area and would not be expected from a new well.

8. Generally ground water quality is satisfactory for most uses.

9. Adrian muck and Dune (Plainfield loamy sand) were the two dominant soil types.

10. Soil types suggested severe to very severe limitations on possible uses of the property.
11. Based on engineering interpretations of soil types, use of the dune complex and muck lowland should be restricted to moderate or possibly semi-heavy foot traffic.

12. A percolation test revealed that the area just south of the lodge was suited to accept at least moderate amounts of on-site sewage disposal effluent.

13. Under heavy sewage loads, the possibility of contamination of Mud Lake and any nearby well would exist and monitoring for such contamination should be undertaken.

14. Analysis of the dune complex suggested that it was formed approximately 11,000 years ago at the Calumet beach level (189 m).

15. It was suggested that sand for the dune complex was supplied from the Toleston-Algonquin beach deposits to the west.

16. Physically Mud Lake is interesting in that it is an area which has been subjected to many geomorphic processes. Continental glaciation, post-Wisconsin changes in the Great Lakes and wind-blown sand have all had their effect on the lake history.

17. The hypsithermal period (warm interval 4,000 to 2,500 years ago) was tentatively identified from Mud Lake bottom core samples.

18. Mud Lake was probably initiated as a glacial kettle hole about 14,000 years ago and has since undergone many modifications.

In light of the information presented above, the following recommendations concerning possible modes of utilization for the LMC-Ross property have been made. Data on physical resources of the property suggested that use should be limited. Increased numbers of users beyond a certain point, that has not been clearly identified, would have a destructive effect on the local physical features. Therefore, the study site is not considered appropriate for heavy public activity such as that associated with public camp grounds and recreation areas. It is considered better suited to controlled activity such as that exemplified by the "nature center" concept. This concept becomes more attractive when one considers the diversity of topography, habitat, soil type and aquatic
areas present which all add to the tract's environmental, ecological and aesthetic appeal.

It is urged that the IMC-Ross property be preserved in a form consistent with the guidelines set forth in this project. Preservation is encouraged because the land possesses an extremely interesting geologic history that may still be interpreted from features that have been relatively free of man's influence. A contemporaneous study of botanical ecology and history should add to the list of reasons for maintenance of this tract.

Specific uses cannot be suggested at this time for additional information on other aspects of the property as well as information concerning community interest and support is lacking. When this information is made available the conclusions presented here may be incorporated in the total survey and used together with the new data to recommend, accept, plan and implement optimal use.
LITERATURE CITED


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