GEOLOGICAL STUDY OF SAND DEPOSITS IN THE STATE OF MICHIGAN

Phase II - Final Report - 1978

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INTRODUCTION

Background

Michigan leads the nation in the production of industrial sand, producing over 40% of the foundry sand used in the United States. Foundry sand accounts for over 90% of the production of industrial sand and is used by foundries to make molds and cores for metal castings. Much of this sand is obtained from sand dunes which occur along the Lake Michigan shoreline. Largely because of various environmental concerns, the Michigan State Legislature passed the "Sand Dune Protection and Management Act" in 1976. The purpose of this bill was to regulate and control the mining of these unique sand dunes. The Michigan Department of Natural Resources (DNR) was required by the act to make, or have made, a study of sand dune areas in the State which was to include a geologic study of sand areas other than Great Lake dunes that might contain sufficient reserves of sand suitable for foundry or other uses.

The geologic study referred to above was conducted for the Michigan Department of Natural Resources by the Institute of Mineral Research (IMR) of Michigan Technological University under a contract with the U. S. Army Corps of Engineers. The study was done in 2 phases, the first of which was completed in September 1978, and the second of which is the subject of this report.

Summary of Phase I

Phase I work was conducted during the spring and summer of 1978, and a final report was issued in October 1978. Phase I consisted of a literature search and study followed by reconnaissance sampling, laboratory testing, and evaluation. Nearly 600 surface samples were collected throughout the State from 3 general types of sand occurrences; inland dunes, glacial out- wash, and friable sandstone outcrops. The samples were tested in (IMR) laboratories using commonly accepted foundry sand test methods in an effort to determine their suitability for foundry use. Chemical tests were run on selected samples, particularly the friable sandstones, to see if any were suitable for glass making.

The test results were evaluated in terms of known industry specifications for various uses of industrial sand. Considered particularly important for the purposes of the study, was a comparison of the similarity in properties between the samples collected and typical coastal dune sands presently being used. Other criteria utilized in the evaluation included such things as potential size of the deposit, distance from major markets, availability of rail transportation, and land use and ownership. A number of areas were recommended for more detailed sampling to be done in Phase II.

Purpose and Scope of Phase II

The general purpose of Phase II, as stated in the contract, is to assess the suitability of four selected sand deposits for each of the industrial uses of sand, particularly in terms both of the quality and size of the deposit.

As specified in the contract, the purpose of Phase II shall be specifically to: 1) make an improved estimate of the quantity of sand available in each of the deposits, 2) assess lateral and vertical variations In sand characteristics, physical and chemical, within the selected deposits, 3) determine on composite samples the amenability of the deposit to beneficiation to meet general use specifications, 4) make detailed observations and evaluation of factors such as depth to water table, transportation, existing use patterns which would modify the potential for exploration, and 5) develop a plan for continuing study by the Geological Survey Division evaluate those regions not included in Phase II.

The friable sandstone deposits were rejected for consideration in Phase II because the material. Sampled in Phase I did not appear to be good enough to use as a high quality glass sand, and none of the occurrences could be economically exploited for use in making low quality glass, or for use as a foundry sand. Although they appear to be suitable for certain foundry uses, most of the inland dune sand samples in Phase I were considerably finer grained than the coastal dune sands currently being used. Also they tend to be thin deposits spread out over considerable area, and thus difficult to mine. Therefore, they were not considered as viable substitutes for coastal dune sands, and no inland dune areas were chosen for additional detailed study in Phase II.

Glacial outwash sand areas in four northern Lower Michigan counties were selected for Phase II sampling and laboratory testing. As discussed in the Phase I Report, the choice of areas was difficult to make because of the range of known industry specifications, and the large number and wide distribution of Phase I samples which fell within this range. As a result, it was not possible to select target areas which were small enough, or sufficiently well defined, to actually be considered "deposits". The scope of Phase II, therefore, should be considered broader and conclusions more general, than originally anticipated because the size of areas and sample spacing is somewhat more regional than envisioned when this study was proposed. To some degree, the areas selected can probably be considered representative of, or at least similar to, other undrilled areas with similar features and characteristics, and the results can probably be extrapolated with some assurance to other glacial outwash areas throughout northern Lower Michigan.

The writer would like to acknowledge the assistance and cooperation of the Geological Survey Division of the Michigan Department of Natural Resources throughout this study. The cooperation of the supervisor and staff of the Huron-Manistee National Forest, and the Forestry Management Division of the Michigan DNR is also acknowledged with appreciation.

SUMMARY

Six glacial outwash sand areas were selected for detailed sampling and evaluation as potential sources for foundry sands. The areas are located in northern Lower Michigan in Lake, Kalkaska, Oscoda, and losco counties.

Nearly 3,000 feet of auger drilling was done to sample the six areas, and approximately 500 samples were taken. A number of laboratory tests were conducted to evaluate the samples including screen analyses, clay content determinations, acid demand tests, mineralogical examinations, moldability tests, and flotation tests.

Test results show:

1. More than adequate quantities of sand are present in each of the tested areas to support large operations for many years.

2. The grain size and size distribution of much of the sand tested is similar to dune sands.

3. The sands are less well rounded, and contain more undesirable impurities than coastal dune sands. Impurities include gravel, clay, carbonates, and various other non-quartz minerals.

4. Soluble carbonate impurities can be removed utilizing a flotation process.

Lack of really definitive or uniform molding and core sand specifications make it impossible to conclude whether these sands could actually be substituted for dune sands. They would certainly require more treatment than dune sands and would, therefore, cost more.

Further evaluation of such factors as various foundry requirements, quantities required, critical specifications, and transportation requirements are recommended, and finally, actual use of the sand in foundries would be necessary to determine if these sands would work.

SAMPLING PROGRAM

Selection of Areas

Six relatively broad regions of glacial outwash sands were recommended for additional work in the Phase I report. To make the best use of the scheduled 2,500 feet of drilling, it was necessary to define more narrow targets for the Phase II work, which were selected from among the recommended areas. The selection was difficult because well-defined targets were not readily apparent as explained in the Phase I report. As a result, it was necessary to utilize a variety of different criteria to pick the specific areas to be evaluated in Phase II. The factors and criteria considered in making the final choices are discussed below:

1. The Phase I test results on the reconnaissance samples were carefully reexamined, but the uncertainty regarding specifications, as well as the rather wide spacing and variable test results of the samples, did not seem to help narrow the choice much further than previously.

2. The location and distribution of certain soil types as shown on the older series of county soil survey maps served as very important criteria to narrow and define target areas for drilling. Based on the description of the soils and sub-soils, it appeared that Grayling Sand is the soil type in northern Michigan which occurs over the areas most likely to contain sands suitable for foundry uses. This soil is relatively infertile, has a low clay and organic content, is characterized by jack pine or scrub oak vegetation, and forms over thick well drained sands. Areas where gravel was present in amounts extensive enough to be shown on the soil maps were avoided. Areas were selected where Grayling Sand coincided with glacial outwash as shown on the Surface Geology Map of Michigan.

3. Location of the areas relative to the major markets and to rail transport were also considered in making the choice. These factors could not accurately be evaluated but areas closest to major foundries, and on or near railroads have obvious economic advantages which, in general, were considered.

4. The apparent size of the area underlain by sand was also taken into account. In the absence of information to the contrary, the larger areas underlain by outwash sands characterized on the soil maps as Grayling Sand were considered to have potentially greater quantities of sand and were, therefore, more attractive targets.

5. Land use in general, and ownership in particular, were factors which were considered both in obtaining permission to sample as well as for ultimate utilization as a sand supply. In the region of Michigan under consideration, much of the land is under public ownership, primarily State and Federal Forest lands. Population is low, and generally the land is not intensively utilized outside of towns. Sample areas were chosen exclusively on State or Federal lands because of the relative ease of obtaining permits for a suitably large sample area from a single owner. An unexpected conflict regarding land use resulted in two of the originally chosen sample areas being eliminated from consideration. These areas happened to lie within regions designated as nesting grounds for the endangered Kirtland Warblers, and were closed to all entry during the spring and summer nesting season. Many potentially favorable sites were in fact eliminated from consideration because of the Kirtland Warblers unusual habit of nesting on dry sandy ground beneath young jack-pine trees growing on Grayling Sand. Even if samples could be obtained here, mining in these areas would probably not be allowed, particularly on public 1 ands.

Final selection of the target areas was not completed until after the fieldwork had begun because of the changes in areas which had to be made as discussed above. The areas which were finally chosen and drilled in Phase II are located in Lake, Kalkaska, Oscoda, and Iosco counties (see Figure 1). In both Lake and Kalkaska counties there are actually two separate areas making a total of 6 distinct areas sampled in Phase II. The size and apparent relative importance of each of the areas were not equal. The target areas selected were still quite large and, with the allotted amount of sampling, the scope of the exploration became somewhat more regional than originally anticipated. The sample spacing ranged from about 1/2 mile to 1 mile or more. The spacing between drill holes was too great to provide much detailed information but it is believed to be close enough to indicate the essential characteristics of the material in each of the areas. Certainly, more closely spaced sampling would be required if any of the areas were to be exploited. It is believed that the information of these areas can to a large extent be extrapolated to other similar glacial outwash areas throughout northern Michigan.

Drill Hole Site Selection

Drill hole sites were tentatively spotted on the map prior to going out in the field. The basic guide in spotting the holes was to roughly distribute the anticipated 2,500 feet of drilling among the chosen areas so as to sample in a representative way, figuring an average 50-foot depth per hole. Modifications of the sample distribution were made, and exact locations of each hole were determined in the field, based on field conditions and the preliminary results of sampling.

Permits

With the exception of the western part of the Upper Peninsula in which Precambrian rocks outcrop, a permit is required to drill any test well over 25 feet deep. These permits are issued by the Mineral Wells Division of the Michigan Geological Survey. A blanket permit can be obtained for up to 200 holes covering a maximum of 9 square miles for each permit. Blanket permits were obtained for all the sample areas of this project. All areas selected were on either State or Federal Forest lands and special use permits were also required to drill the sample holes on these lands. These were obtained from the Manistee-Huron National Forest Headquarters in Cadillac for the areas on the Federal lands which include all areas in Lake, Oscoda, and Iosco counties. The areas in Kalkaska County were located on State Forest lands and use permits to drill here were obtained from the State DNR through the Area Forester in Kalkaska.

Field Work

The fieldwork on Phase II was conducted during May and June, 1979, and consisted primarily of taking auger drill samples in the six separate target areas. A trailer mounted gasoline powered auger drill was used to take the samples. The drill rig was pulled by a 3/4-ton 4-wheel drive pick-up truck. For use in the program, the drill was equipped with a string of 5-foot long solid stem augers with a diameter of 4 inches. The drill was operated by a 2-man crew. A geologist was in charge of the fieldwork, and supervised the drilling and sampling.

Samples were taken on 5-foot intervals down to a depth of approximately 25 to 30 feet and from then on at 10-foot intervals to the bottom of the hole. Samples were taken by pulling the auger string out of the hole and removing about 5 to 10 pounds of material from nearest the bottom of the auger string. The samples were placed in polyethelene bags and labeled. Essential information was recorded on a drill record which included such items as location of the hole, sample numbers and depths, depth to water table, and any other pertinent information.

The drilling program began in Area I in Lake County on May 1st, 1979, and ended on June 7th, 1979, in losco County. Sixty-five holes were drilled for a total of 2,955 feet of drilling, and 474 samples were taken for lab testing. The locations of all the holes drilled are shown on Figures 2 through 9. Brief field logs of the holes are shown in Appendix A.

A number of surface samples were also taken to provide some fill-in data between some of the more widely spaced drill holes in several areas. The location of these samples are shown on Figures 2 through 9.

Results of Sampling Program

Except in Areas II and I where several holes were drilled up to 80 feet deep, most of the holes were drilled to a depth of only 50 feet even though all were still in overburden. It proved to be very difficult and time consuming to drill much deeper than 50 feet. To pull up out of the hole, disconnect the auger, sample, and go back down when the hole was over 50 feet deep took considerable time. Also, the engine had difficulty pulling up the long string of sand filled augers without reversing the auger direction and thereby completely disturbing or even losing the sample material. It was also believed that the greater number of holes which could be drilled by limiting the depth to 50 feet provided more valuable information than would have resulted from fewer, although deeper, holes.

No difficulty was experienced obtaining samples representative of the stated sample depth. The samples were always damp and remained essentially in place on the augers as they were pulled out of the hole. Even below the water table, the sand did not become dislodged from the augers, and it was possible to pull up essentially representative samples from the desired depth.

A number of significant observations made during the drilling are noted below:

1. The water table in several areas, especially Areas II, and I was quite deep.

2. None of the holes penetrated to bedrock, indicating more than 50 feet of potential sand covering extensive areas, many square miles in most of the sample areas.

3. Even conservative estimates suggest that all areas contain many 10’s of millions of tons of sand. quantity of material is, therefore, no problem.

4. Variable amounts of gravel and clay were encountered in all the areas. In places gravel zones several feet hick or more were encountered and some holes bottomed in gravel. Scattered zones or “lenses” of clay and gravel were common.

LABORATORY TESTING

Each of the auger drill and surface samples collected was processed and tested as illustrated in the general treatment flow sheet shown in Figure 10. Some samples, which consisted almost entirely of gravel or clay, were clearly unsuitable, and were not processed. American Foundrymens Society (AFS) standard laboratory tests were used to characterize the foundry sands. These same tests were utilized to test the surface samples collected in Phase I of the project. Published requirements and specifications for foundry sands are discussed in the Phase I report of this project, pages 5-15. The lab tests, which will be described below, included clay content determinations, screen analyses and Grain Fineness Number (GFN) determinations, Acid Demand measurements and mineralogical observations. A detailed mineralogical examination of each sample collected was not undertaken. The time and effort involved in this work was not considered justified because the results of Phase I showed that the qualitative information obtained was not adequate to accurately characterize the mineralogy or to make distinctive comparisons among the samples. Also, the specifications regarding such things as impurities and grain shape are not known by many users and are believed not to be critical in many other cases. As a result, only a cursory general mineralogical examination of certain select samples and/or composites from the 5 different areas was done on the Phase II material.

In addition to the standard tests mentioned above, tests of the physical properties of the sands with typical binding agents added were also performed. These “moldability” tests were also standard AFS tests and were performed at the Michigan Tech. metallurgical foundry sand laboratory. These tests were done in an effort to determine primarily whether the sands in each of the sampled areas met essential criteria for making suitable molds for casting.

The test work indicated the presence of undesirably high quantities of soluble carbonate minerals in most of the samples. As a result, preliminary beneficiation work consisting of flotation tests were performed on the sand to determine the technical feasibility of reducing the carbonates in the sands down to acceptable levels.

Screen and Clay Analyses

AFS Clay Determination.

AFS clay content is defined as that portion of a foundry sand which, when suspended in water, fails to settle at a rate of one inch per minute. The AFS clay material is determined by the AFS standard clay test. The AFS clay material consists of clay and material of less than 20 microns (0.02 rmi or 0.0008) in diameter. In other words, it is a mixture of true clay and fine silt. The proportions of these can vary in naturally bonded molding sands.

AFS clay determinations were made on each of the crude sand samples collected. Procedures for this determination are described at length in the Mold & Core Test Handbook (2) and are described briefly as follows:

a. An approximate 100-gram representative sample was placed in a 1000 ml Berzelius beaker. To the sample were added 475 ml of room temperature, distilled water and 25 ml of a l.5% solution of tetra sodium pyrophosphate ($Na_4P_2O_7.10H_2O$).

b. The sand-fluid mixture was then stirred with an electric stirrer for 5 minutes at 1750 rpm.

c. The agitator (stirrer) was then removed from the beaker and the beaker filled to a 900-ml mark with additional distilled water.

d. The material was stirred with a glass rod until most of the solids were in suspension and then allowed to settle for 10 minutes after which the top 5 inches of water and suspended solids were siphoned off.

e. The beaker containing sand was then refilled to the 900-ml mark, re-stirred and allowed to settle for an additional 10 minutes after which the suspended solids were again siphoned off.

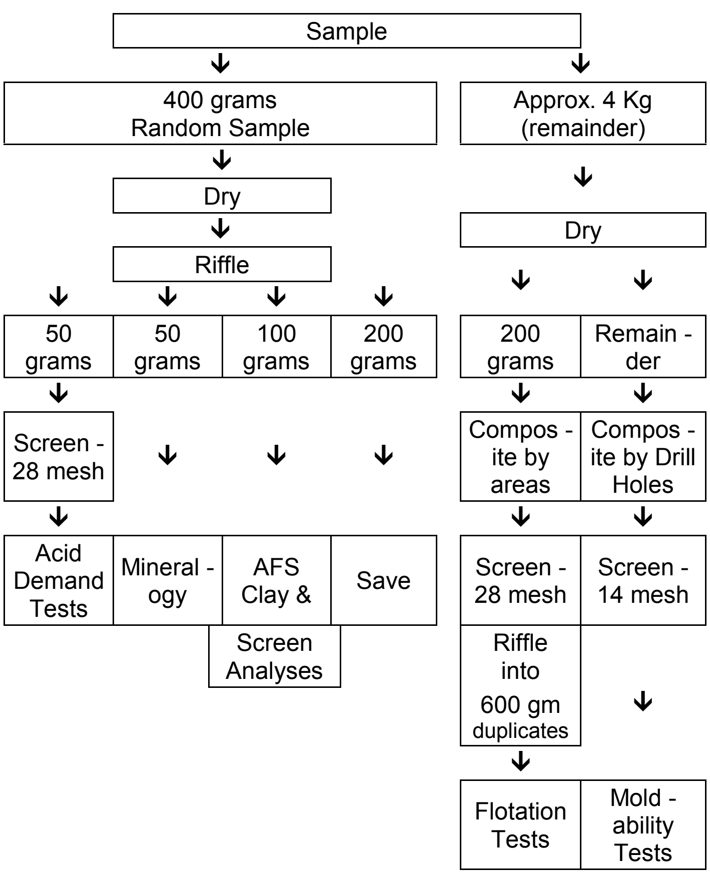

Figure 10 General laboratory treatment flowsheet

f. The procedure of filling, stirring with a glass rod and allowing to settle, but for only 5 minutes each time hereafter, was repeated until the water became relatively clear after the 5-minute settling period.

g. The excess water was then poured off carefully, so as not to lose any sand grains, and then the beaker and contents were oven dried between 1040C and llOOC.

h. The dried sand was then weighed and the percent AFS clay calculated as follows:

AFS Clay Content, % = dry starting wt. - dry washed wt. % 100 dry starting wt.

APS Grain Fineness No. (GFN).

Grain fineness number is a rapid method for expressing the average grain size of a given sand and is also of value in comparing grades of sand from a given deposit or from deposits having similar grain distribution, or in aiding control of heap or system sand in a foundry. It is roughly equivalent to the average grain size of the sand in terms of mesh size. 11s also useful in calculating other data relative to foundry sand practice. (2) It should be emphasized, however, that this number does not provide any information regarding the size distribution of the sand grains.

The AFS grain fineness number was determined on each of the sand samples collected by performing a screen analysis on the washed and dried sand residue from the AFS clay wash on each sample.

Procedures for determining the AFS grain fineness numbers for the respective sands are described as follows:

a. The weight of the grains of the various sizes as determined by the screen analysis was expressed as percentages of the original sample.

b. Each of the percentages were then multiplied by a factor, illustrated in a typical calculation presented in Figure 11.

c. The products of the multiplication were totaled and this total product divided by the sum of the grain percentages obtained. The result is the AFS grain fineness number. Figure 11 illustrates data relative to, and a typical calculation of, an AFS grain fineness number.

Acid Demand Values (ADV)

When acidic activators used in synthetic bonding materials are added to molding sands containing alkaline substances such as calcium carbonate, a portion of the catalyst or activator is no longer available for complete satisfaction of the programmed resin-catalyst reaction. Therefore it is important that the presence of these alkaline reacting materials be measured so that uniformity and formulation control may be achieved. Alkalis are also undesirable because they reduce the refractoriness of the sand. The acid demand value and assignment number has been recommended, not as a direct value, but as an indicator.(2)

USA Sieve Series No.	Grams*	Percent*	Multiplier	Product
6	- -	- -	3	- -
12	- -	- -	5	- -
20	0.27	0.27	10	2.7
30	1 .62	1 .62	20	32.4
40	8.96	8.96	30	267.9
50	32.64	32.64	40	1302.0
70.	38.85	38.85	50	1937.0
100	14.83	14.83	70	1035.3
140	2.39	2.39	100	238.0
200	0.37	0.37	140	51.8
270	0.04	0.04	200	8.0
pan	0.02	0.02	300	6.0
total	99.99			4881 .1

* Amount of near 100 gram Sample Retained on Sieve

$$\text{AFS Grain Fineness No.} = \frac{\text{total product}}{\text{total percentage of retained grain}}$$

$$\text{AFS Grain Fineness No.} = \frac{4881\ 1}{99{:}7} = 49.0$$

Figure 11. Typical Results of Screen Analysis and Calculation of AFS Grain Fineness Number

The procedure for determining the acid demand value of the sands tested was as follows:

a. Fifty (50.0) grams of sand were placed into a 400-ml beaker.

b. Fifty (50.0) ml of distilled water were added to the sand.

c. Fifty (50.0) ml of N/l0 hydrochloric acid were added to the sand.

d. The above mixture of sand, water, and acid was stirred continuously for fifteen (15) minutes.

e. After stirring, the water-acid mixture was decanted and filtered with the sand being washed with five 10-ml portions of distilled water. This wash water was added to the filtrate.

f. The filtrate was titrated with standard n/l0 sodium hydroxide to a phenolphthalein endpoint.

g. Acid demand of the sand was calculated as follows:

Let X equal ml of 0.1 N HCl

Y equal ml of 0.1 N NaOH

Acid Demand = X - Y

Discussion of Test Results

The laboratory tests described in the previous section were performed on approximately 500 surface and drill hole samples collected during the field program. The results were tabulated by computer and are shown in Table 2, Appendix B. From the weights measured in the laboratory, the computer calculated the percentage of material retained on each screen, the GFN, and the percent clay content. Table 2 also shows the acid demand value for each sample and whether the sample was taken from above or below the water table. Table 3 shows the GFN, acid demand, and AFS clay content at each 10-foot interval for every hole drilled. Running averages for each of these 3 values from the surface down to each of the depth intervals are also shown. Table 4 shows the same data as Table 3 but here the results of all drill holes in each area are combined to give the average results for each of the six areas.

Grain Size Distribution.

Aside from the calculation of the GFN, no other statistical treatment of the grain size distribution was undertaken in this study. It was not believed useful since there are no foundry specifications based on such parameters. However, qualitative examination of the size distribution of the drill hole samples shown in Table 2 shows that the majority have 3 or 4 major (over 10%) size fractions retained on successive screens. This distribution, in general, meets the essential requirements of size distribution for most foundry sands (See Phase I report, Table 5, pg. 56). Each foundry usually has its own more exact specifications which usually cover a range of values.

AFS Grain Fineness Number (GFN).

The GFN is a universally recognized value and most foundries have established a range of values within which it must fall in order to meet specifications for certain uses. The desired value of the GFN of the sand is determined by a number of factors such as the size, temperature, and surface quality of the casting. The GFN of the tested samples varied considerably but the values, which appeared representative of significant quantities of material, ranged from a low of about 40 (coarsest samples) to a high of about 55 (finest material). Some of the exceptionally high values of some samples were caused by a large amount of clay and some very low values were the result of a high gravel content.

It can be seen from an examination of Tables 3 and 4 that the GFN’s of samples in Area I fall in the low to mid 50’s; in Area II in the mid to upper 40’s; in Area III in the low 40’s; in Area IV in the mid 40’s; in Area V in the upper 40’s to low 50’s; and in Area VI in the low 40’s. There appears to be a trend in all areas for the GFN to increase slightly with increasing depth meaning a decrease in the average grain size of the sand. This may, in part, be explained by increasingly larger amounts of clay encountered at increasing depths but amounts of clay measured for each of the samples does not increase correspondingly with depth and therefore, cannot account for the overall general fining downward trend in average grain size noted in all the areas sampled. Although not large, this change in average grain size with depth adds to the variability of the sand, and is a factor which would have to be taken into account in production planning if any of these areas were to be exploited.

Clay Content.

As previously discussed, clay lenses or zones were encountered in the drilling. Samples consisting of nearly pure clay were not tested so the overall clay content recorded in the lab results is somewhat understated. it is possible, however, that some of these clay zones could be selectively mined and so the clay contents shown in Tables 2, 3, and 4 may be representative of the material which would be shipped or processed in any operation. The maximum published clay specifications for many foundry uses are greater than average clay contents shown in most of the drill holes.

Mineralogy.

The shape of the sand grains observed in samples from all areas ranged from angular to sub-rounded. Most grains would be classified as sub-angular. In general, and pretty much as expected considering the mode of origin, the grain shapes of these sands tended to be both more varied and more angular than coastal dune sands.

As expected, the sand from all areas contained a considerable amount of non-quartz impurities. Among those recognized were clay material, carbonates, sodium and potassium feldspars, hornblende or amphibole, magnetite, and a number of other minor unidentified minerals. A few compound multi-mineral grains were also observed. No significant mineralogical differences among the areas were noted except that sand from Area VI appeared to contain more impurities than the other areas. All areas contained more impurities than coastal dune sands.

Acid Demand Values.

Acid demand values of the samples range from somewhat less than 1 to the maximum of 50. A value of near 0 means little or no acid was consumed, and so virtually no soluble carbonates are present in the sample. Values in the upper 40’s to 50 mean that nearly all, or in some cases all, the acid added in the test was consumed and the sample had, therefore, a high soluble carbonate content. An examination of the ADV’s in Tables 2, 3, and 4 shows a big difference between the near surface samples and those from below a depth of approximately 5 to 10 feet. Almost without exception, the near surface samples down to a depth of somewhere between 5 to about 15 feet have ADV’s well below 10, while the deeper samples are nearly all at or close to 50, the maximum amount measurable by the tests. Some intermediate values can be seen in a few holes, but generally there seems to -be a sharp increase to near the maximum values over a relatively small distance.

The low values near the surface are attributed to the leaching and removal of soluble carbonate minerals (primarily calcite) by downward percolating oxidizing surface waters, which have apparently been affective only down to a depth of between 5 to 15 feet below the surface in most cases.

There appeared to be no correlation between the position of the water table, as recorded during the drilling, and the ADV of the samples. There had been some speculation that leaching would have been effective throughout most of the zone above the water table, and those sands would, therefore, have lower ADV's. This does not seem to be the case, as can be seen from data, and carbonate leaching appeared not to have been effective below a depth of 5 to 10 feet regardless of the position of the water table.

Published specifications for acceptable ADV’s of foundry sands vary depending on foundry practice and on the molding techniques used. Available information shows the maximum ADV’s specifications for various sands range from about 20 to 25 to a low of about S for some uses. Only the top 5 to 10 feet of material in any of the sample areas would fall within the allowable range.

“Moldability” Tests

A number of tests were performed on selected sand samples in order to determine whether they would satisfy certain physical properties required of molding sands. Tests to determine the base permeability, compactability, green shear strength, and green compressive strength of 42 sand samples were conducted in the Castings Laboratory of the Department of Metallurgical Engineering at Michigan Tech. University. The samples were composite samples taken from each drill hole in the six sample areas. Each composite sample was dried and screened to remove material coarser than 10 mesh, U. S. Standard Sieve Series. The sand testing was conducted according to AFS standard practice procedures as outlined in the Foundry Sand Handbook of the American Foundrymen’s Society.

The composite sand samples were each mulled with fine bonding material and water in a 24-inch heavy wheeled sand muller for 12 minutes. The fine bonding material consisted of 42% Western Bentonite clay, 27% Southern Bentonite clay, 30% Seacoal and 1% cereal. Twenty (20) samples were mulled-with 8% fine bonding material and twenty (20) samples were mulled with 10% fine bonding material. Drill holes 17, and 20 had an insufficient amount of sand for adequate mulling and were not tested except for base permeability.

A moisture content sufficient to develop maximum strength in a rarruned sand was calculated for each mulled sample based on the assumption that the AFS grain fineness number for each composite sample was between 55 and 65. The moisture requirement for a foundry sand sample to attain peak strength is a function of the type and quantity of the ingredients in the sand mixture. In addition, the moisture required by the sand grains alone is a function of the AFS grain fineness number. Since the grain fineness numbers for the composite sand samples were not known at the time of testing, a “guestimate” placed them at the above mentioned AFS 55 to 65 GFN. The results of the base permeability test indicated however, that some sands appeared considerably coarser while others appeared finer than APS 55 to 65.

Foundry sands are generally prepared at a moisture content somewhat above the moisture content calculated to produce maximum green properties in order to enhance other molding sand properties. In this investigation 20 percent more water than the calculated value was added such that the final moisture content aim point was 3% ± 0.3%. The compactability test serves as a good indicator of the temper condition (moisture content) of the sand and is typically in the 40-55% range. Results above 55% compactability indicate that the sand contained too much moisture for the effective sand/clay ratio.

In practice, most foundry sands are screened in order to produce sand of a particular grain fineness as specified by the purchasing foundry, and which may vary from foundry to foundry depending upon their particular needs. The typical foundry molding green sand usually consists of a high percentage of return system sand plus additives which include new sand additions, fine bonding material, and moisture. The sand mixes prepared for this investigation most closely simulate facing sand mixes which contain high percentages of new sand.

The results of the “moldability” tests, shown in Table 5, suggest that molds can be made from sands from all the test areas, which would satisfy strength and permeability conditions normally required in casting. The permeability numbers, however, are quite nigh. High permeability is good in some respects in that it permits passage of gases as the casting cools. However, the high permeability also is a reflection of the fact that the sands are quite coarse grained which may result in poor surface quality of the casting, or in molten material penetrating into the sand. The sands as tested, however, were not processed in any way, and it is likely that a properly graded product could be made from the material which would be satisfactory.

Beneficiation of Sands

Nearly all molding and core sands undergo some kind of processing depending on the properties of the sand as well as the required specifications determined by the use. Processing typically includes such treatment as washing, drying, screening, classifying and blending. Flotation has been utilized to remove soluble carbonates from sand for foundry use. It is almost certain that the sands represented by these samples would have to undergo washing and screening to remove clay and gravel if they were to be utilized as foundry sands. The sand would also very likely be classified and graded to provide products which would meet different size specifications.

As discussed earlier, the sand samples tested contained a number of non-quartz impurities, at least some of which make them undesirable for foundry use. The only quantitative determinations of impurities were the acid demand tests to roughly measure the amount of soluble carbonates present. It is generally accepted that for most uses, particularly if an acid activated artificial binder is utilized, foundry sands should be low in calcium and magnesium carbonates. According to Rowell (25), soluble and insoluble alkalies such as lime should be less than .2% resulting in acid demand values of less than 15. As noted earlier, except for the top 5 or 10, the sands from all 6 areas tested had acid demand values considerably higher than this indicating a considerably greater carbonate content. Other impurities, qualitatively observed, include feldspars, chert, magnetite, and a variety of other silicate rock fragments. Available specifications regarding the permissible amount of these materials vary considerably, depending on use and user, and it appears that very little quantitative information is actually known regarding the allowable amounts of these impurities in foundry sands. For this reason no attempt was made to evaluate the possibilities of beneficiation to remove impurities other than carbonates.

Flotation Testing

Flotation to remove calcium and magnesium carbonate is a process which is utilized to a limited extent in the industry to upgrade sand for foundry purposes. Flotation tests were performed at IMR on six composites of sand from the six different sample areas to determine if these sands could be upgraded to meet specifications with regard to maximum calcium and magnesium carbonate content.

Each of the area composite samples were screened on a 30-mesh screen and the minus 30-mesh sand riffled into 1000 gram charges for laboratory flotation tests. The plus 30-mesh material was discarded.

A head sample of the minus 30-mesh sand was riffled from each of the area composite samples and analyzed chemically for CaO and MgO. The acid demand value (ADV) was also determined for each of the samples. Table 6 lists the CaO and MgO content and the ADV values determined. These determinations suggest that beneficiation of the sand is required in order for them to meet foundry specifications, as both the CaO and MgO content and the corresponding ADV’s are well above the suggested level. Although only one set of collectors was used and all flotation parameters were not investigated and optimized, sufficient tests were made to establish conditions necessary to produce sand that would meet foundry specifications with regard to CaO and MgO content and acid demand.

The sand samples from one of the sample areas were selected to study reagents and dosages and establish flotation procedures required to beneficiate the sand to an acceptable level. These same procedures were then used on all other area sand samples.

Scrubbing and Desliming -

1. Each 1000-gram sample was scrubbed in a 1 + 1 Wemco flotation cell for 5 minutes at 50% solids with the cell rotor mechanism set at 100 rpm.

2. The pulp was then agitated for 15 seconds and allowed to settle for

30 seconds before the suspended solids were decanted off.

3. The desliming step was repeated three times, at which point the decanted water was always clear.

4. The shines collected were filtered, dried, and weighed.

Conditioning -

1. The solids content of the scrubbed and deslimed sand was adjusted to 70% solids in a laboratory Denver conditioning machine.

2. Reagents were added at the conditioner.

3. The pulp and reagents were conditioned in the machine for three (3) minutes @ 1800 rpm before transferring back to the 1 ‘ 1 Wemco flotation machine.

Flotation -

1. The pulp was then diluted to 30-32% solids and agitated for 30

Sample Designation	Percent		Acid Demand Value (ADV)
	CaO	MgO	
Area I	0.80	0.35	50
Area II	0.57	0.24	50
Area III	0.82	0.19	44
Area IV	0.42	0.10	38
Area V	1.51	0.34	49
Area VI	1.64	0.34	48

Table 6. Acid demand values by Sample Designation Area

2. The air was then turned off and the froth skimmed for one (1) minute.

Sample Preparation - The shines, froth and all products from each test were filtered, dried and weighed. Only the concentrates from each test were analyzed for acid soluble CaO and MgO. Acid demands were also determined on the concentrates.

flotation Test Results. Details of the flotation tests performed are shown in Table 7. The results of the tests, also listed in the table, show that the sand concentrates resulting from the flotation of sands from all the areas contain acid soluble CaO and MgO less than 0.2% and possessed corresponding acid demand values of less than 5. The weight recovery after beneficiating the minus 30-mesh sand ranged from 93 to 96+ percent weight.

The results of the flotation tests clearly show that the sand from all six-sample areas can quite easily be beneficiated to meet all the known maximum soluble carbonate (acid demand) specifications. No attempt was made in this study to optimize all the reagents and conditions which would be required if actual development were to take place. It is possible that only a partial removal of carbonates, which could probably be done at a lower cost, might be sufficient for most uses.

It is not possible to say whether or not the sand from any of the six areas tested in this study could substitute commercially for coastal dune sands. There are significant differences between these and coastal dune sands, the importance of which cannot be determined with the information at hand. It appears quite certain that, at the very least, and unlike coastal dune sands, these sands would have to undergo a substantial amount of processing in order to substitute.

Conclusions based on the acquired information which appear to be clearly unfavorable regarding the use of these sands include the following:

1. The acid demand values of the sand in all six areas from depths

in excess of 5 to 10 feet are all very high. If the published specifications are to be accepted, beneficiation (flotation) of the sand would be required for all uses.

2. Other impurities, such as various silicate minerals, chert, and other lithic rock fragments are more abundant, and would, therefore, make these sands at least somewhat less refractory than coastal dune sands.

3. Considerable “off-size” material (gravel and clay) is present in the sands which would probably require washing and screening of the sand. This processing as well as the necessity of handling and disposing of the waste material would be an added cost for these sands.

Certain conclusions can be drawn, the effects of which are uncertain. These include the following:

1. Compared with coastal dune sands, the grain size distribution seems to be satisfactory. The GFN’s, however, are lower, particularly of the sands from Areas III, IV and VI. This would appear to be unfavorable, but it might be possible to make a satisfactory sand with only a minor amount of processing and grading.

2. The grain shape is definitely more variable and less well rounded than dune sands. This would appear to be an unfavorable factor but the apparent advantage of the more rounded grains is not universally recognized. Shape may not be a critical factor and the less well rounded characteristics of these sands may, therefore, not be a drawback.

3. Transportation from all areas except Areas I and III would be a problem as they are not near railroads. The distance from markets is an economic factor which is difficult to evaluate. On the average, the distances are probably somewhat greater than for coastal dune sands.

4. Availability of land might be somewhat of a problem in that much of the land is owned by the state and federal governments. It is not known whether they would make lands available for sand mining.

Conclusions which appear to be clearly favorable include the following:

1. The quantity of sand available is enormous. Any of the six areas sampled contains enough sand to support a large operation for many years.

2. Based on known geological and soil information it is highly likely that other areas with large quantities of similar sand occur throughout much of northern Lower Michigan.

3. Mining and reclamation costs should be reasonably favorable. The sands are thick, which should help keep mining costs low and result in a minimum amount of land area to be reclaimed or restored after mining.

4. Environmental problems ought not to be too serious, particularly in comparison with the coastal dune areas. The region is sparsely populated and land use conflicts particularly on private lands, should not be too serious.

Considering and weighing all the factors above, it is concluded that of the six areas sampled, Area I in Lake County appears to be the most favorable. It lies very near rail transportation, and appears to have the best physical and chemical characteristics of the areas sampled. Areas II and III would tie for second choice. Area II is not too near a railroad and the sand quality is not as good are Area I. Area III is near rail transportation, but the sand is somewhat coarse grained and the area is the location of considerable oil exploration and exploitation. The remaining areas are less desirable both because of poorer location relative to transportation lower apparent quality of sand, and in the case of Areas V and VI, a conflict with Kirtland Warblers regarding land use.

If additional work on evaluating potential foundry sands in Michigan is to be done, the following steps are recommended:

1. Sand, preferably from Area I, should be tested under actual foundry conditions. Testing should be done with the aim of establishing the greatest use potential with the lowest processing costs.

2. An evaluation of foundry sand practices representative of the major foundries should be conducted to determine the really important or critical specifications. A study of the possibilities of modifying certain practices might be undertaken if such would be necessary in order to use these sands.

3. If it appears glacial outwash sand could work, then economic

feasibility studies should be done, followed by additional exploration based on appropriate geologic, soil type, geographic, transport, and other economic evaluations.

4. If at any time it appears unlikely that these sands could substitute for coastal dune sands, inland dune sands should be reconsidered and off shore lake bottom sands should also be considered.

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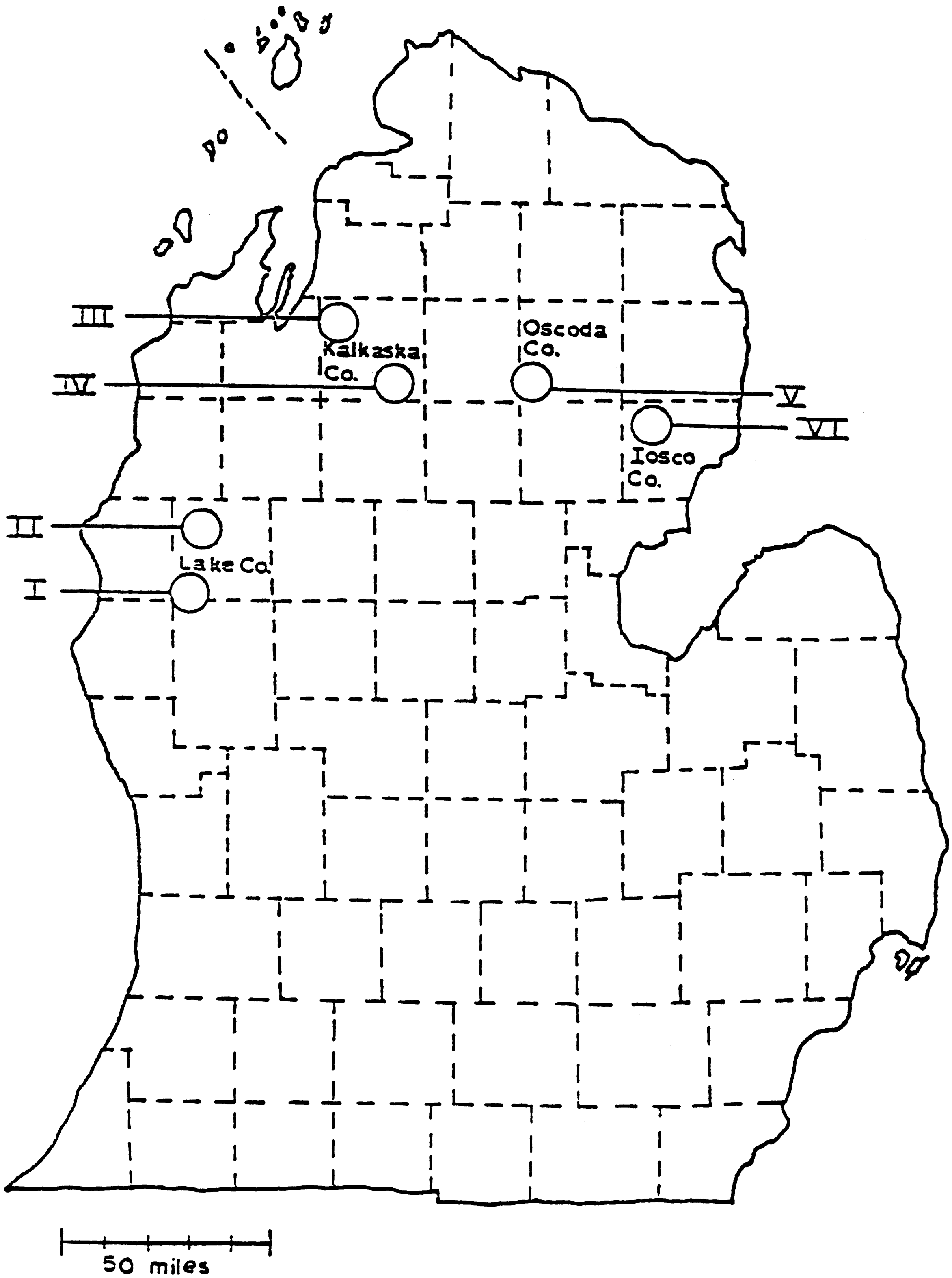

Figure 1. Southern Peninsula of Michigan showing sample areas.

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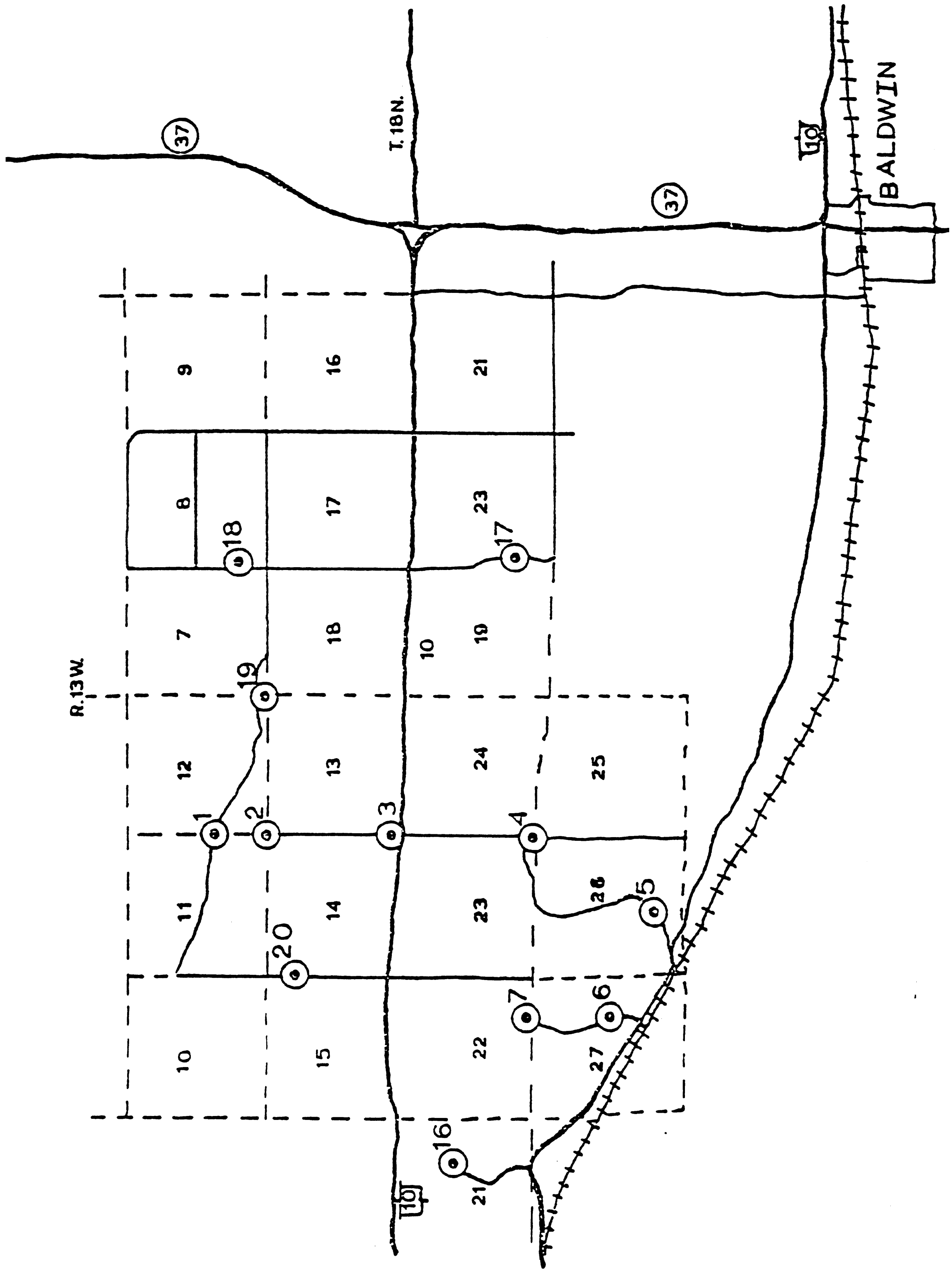

Figure 2. Lake County, Area I, auger hole locations

Auger Hole Locations ⊙ - North is to the left of this page.

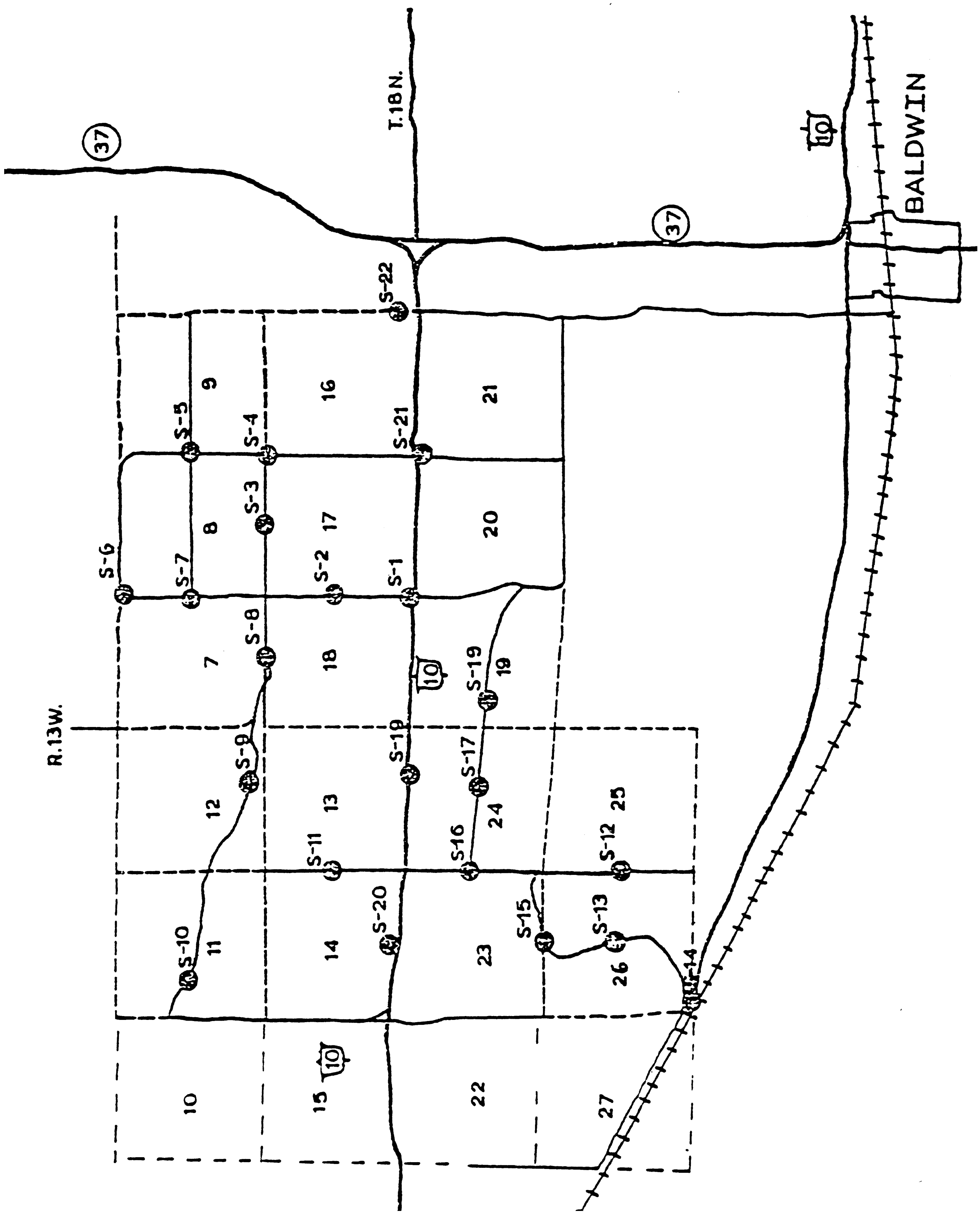

Figure 3. Lake County, Area I, surface sample locations

Surface Sample Locations ● - North is to the left of this page.

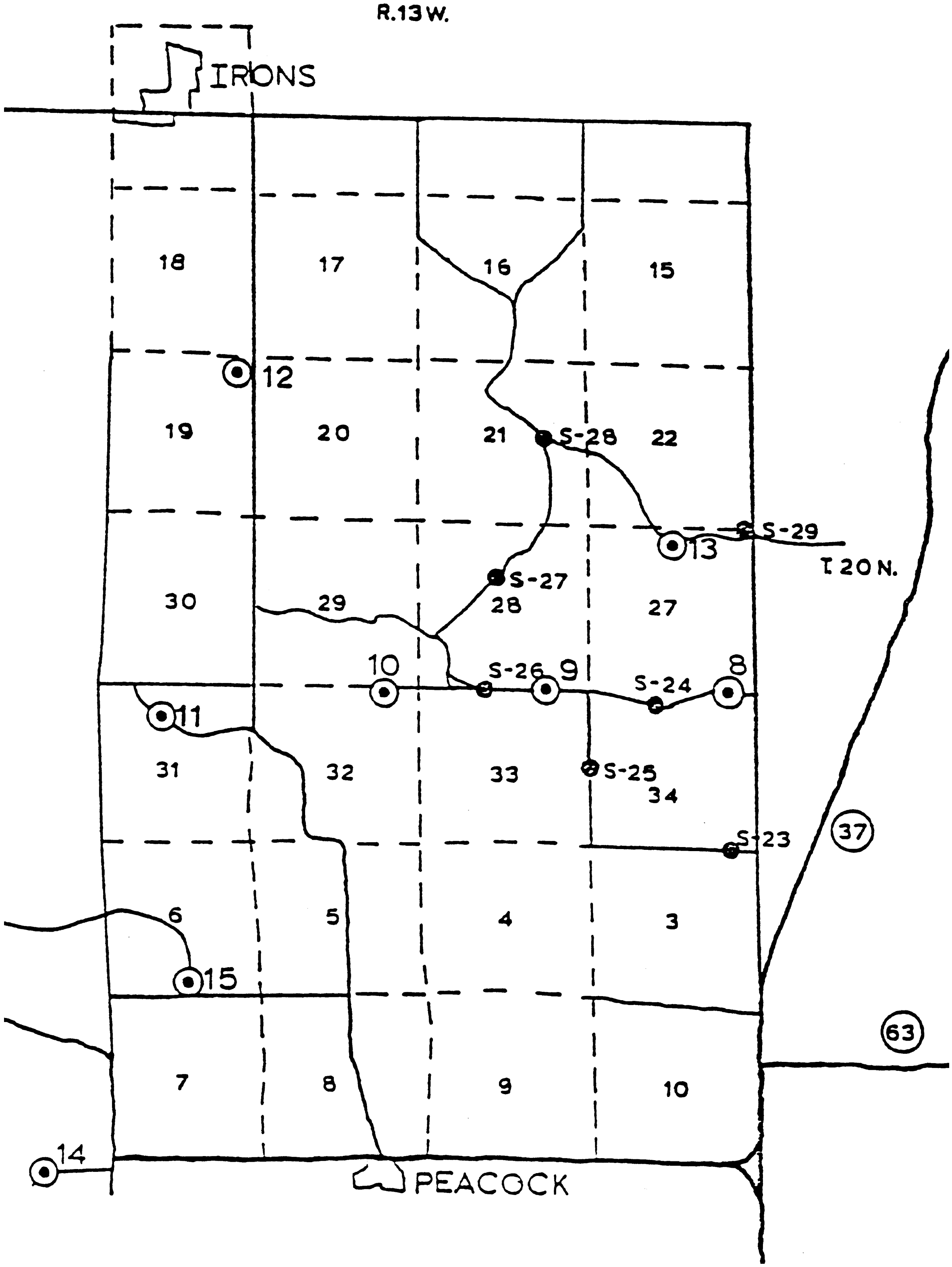

Figure 4. Lake County, Area II, auger hole and surface sample locations

Auger Hole Locations ⊙ Surface Sample Locations ● - North is to the top of this page.

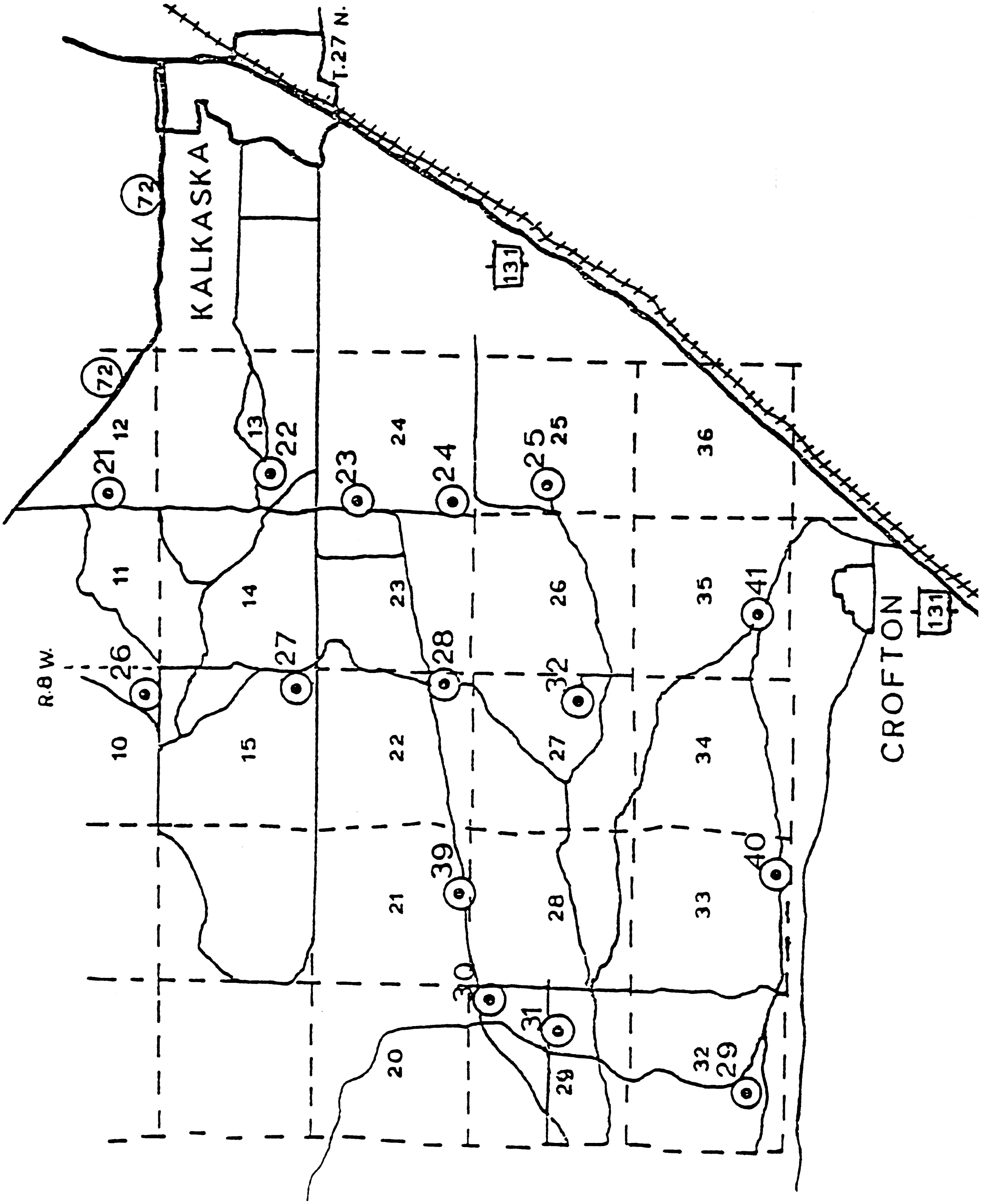

Figure 5. Kalkaska County, Area III, auger hole locations

Auger Hole Locations ⊙ - North is to the left of this page.

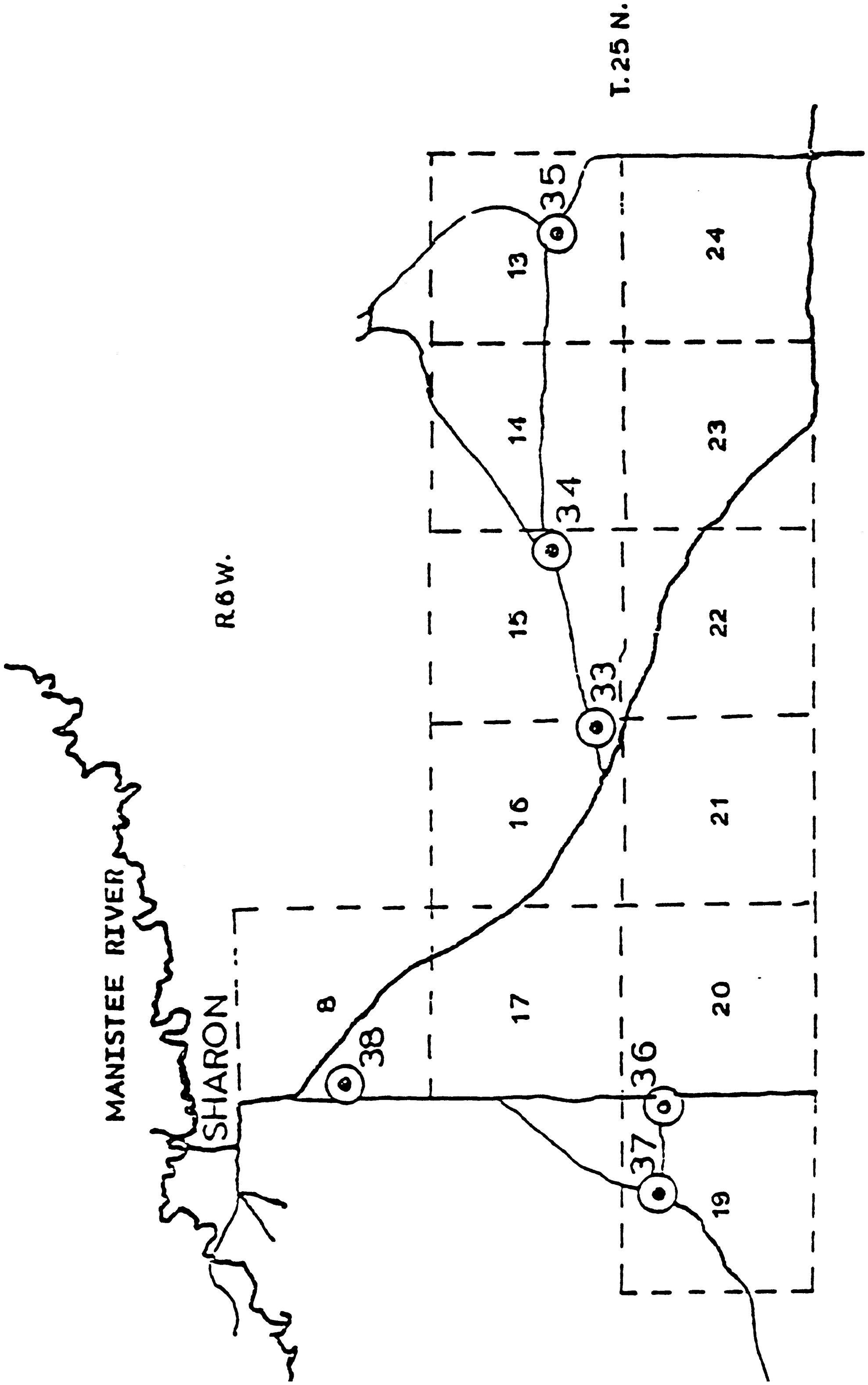

Figure 6. Kalkaska County, Area IV, auger hole locations

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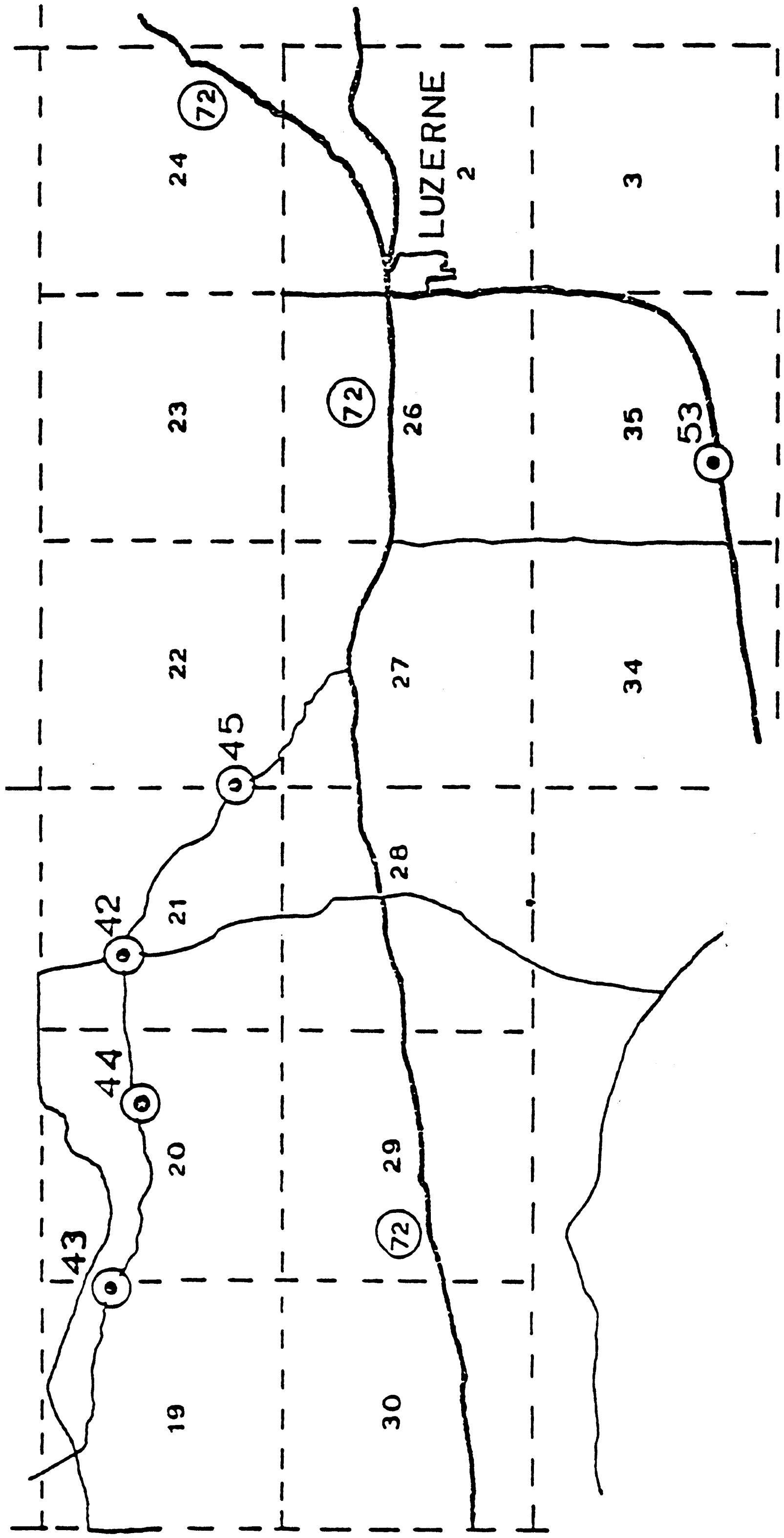

Figure 7. Oscoda County, Area V North, auger hole locations

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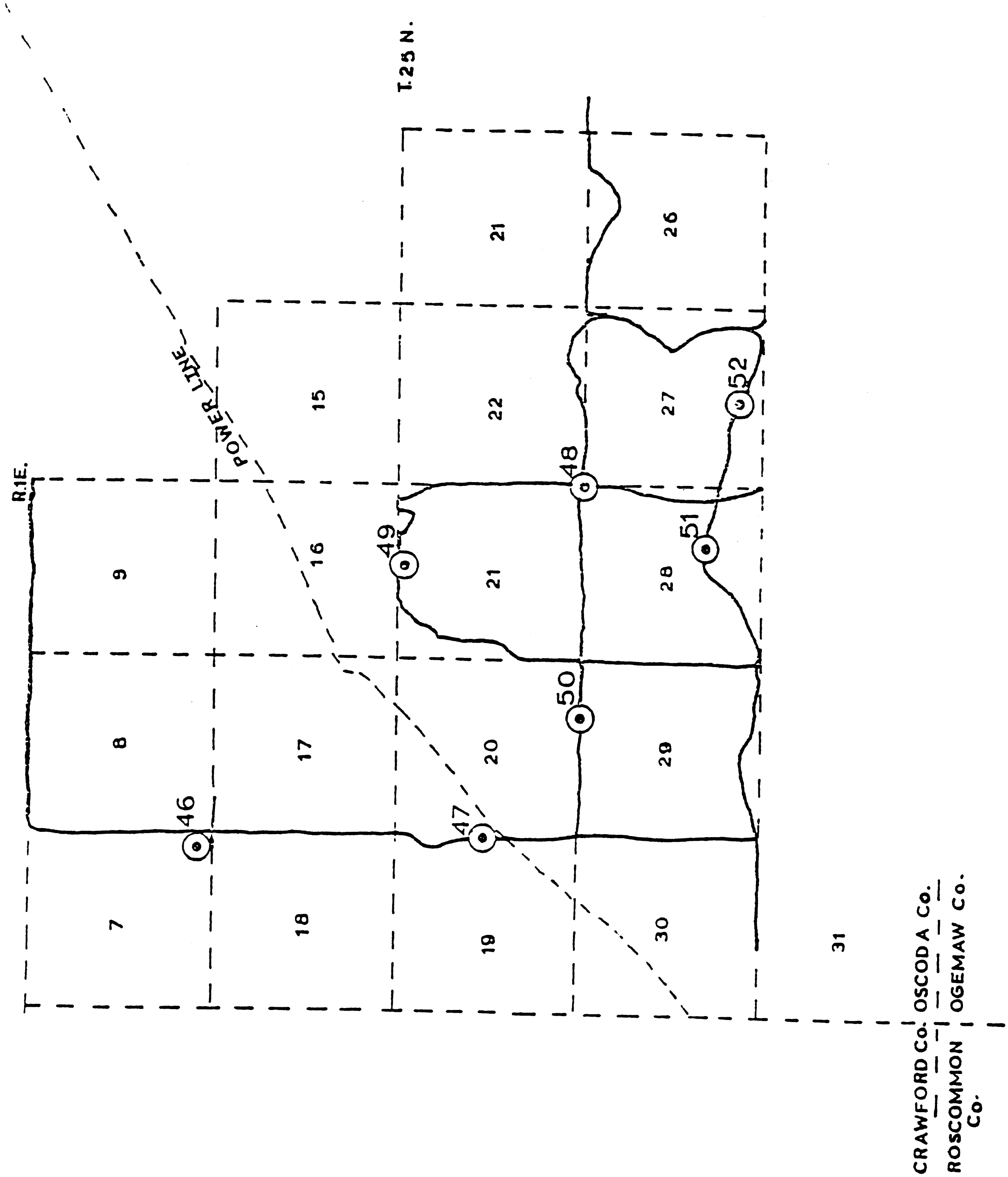

Figure 8. Oscoda County, Area V South, auger hole locations

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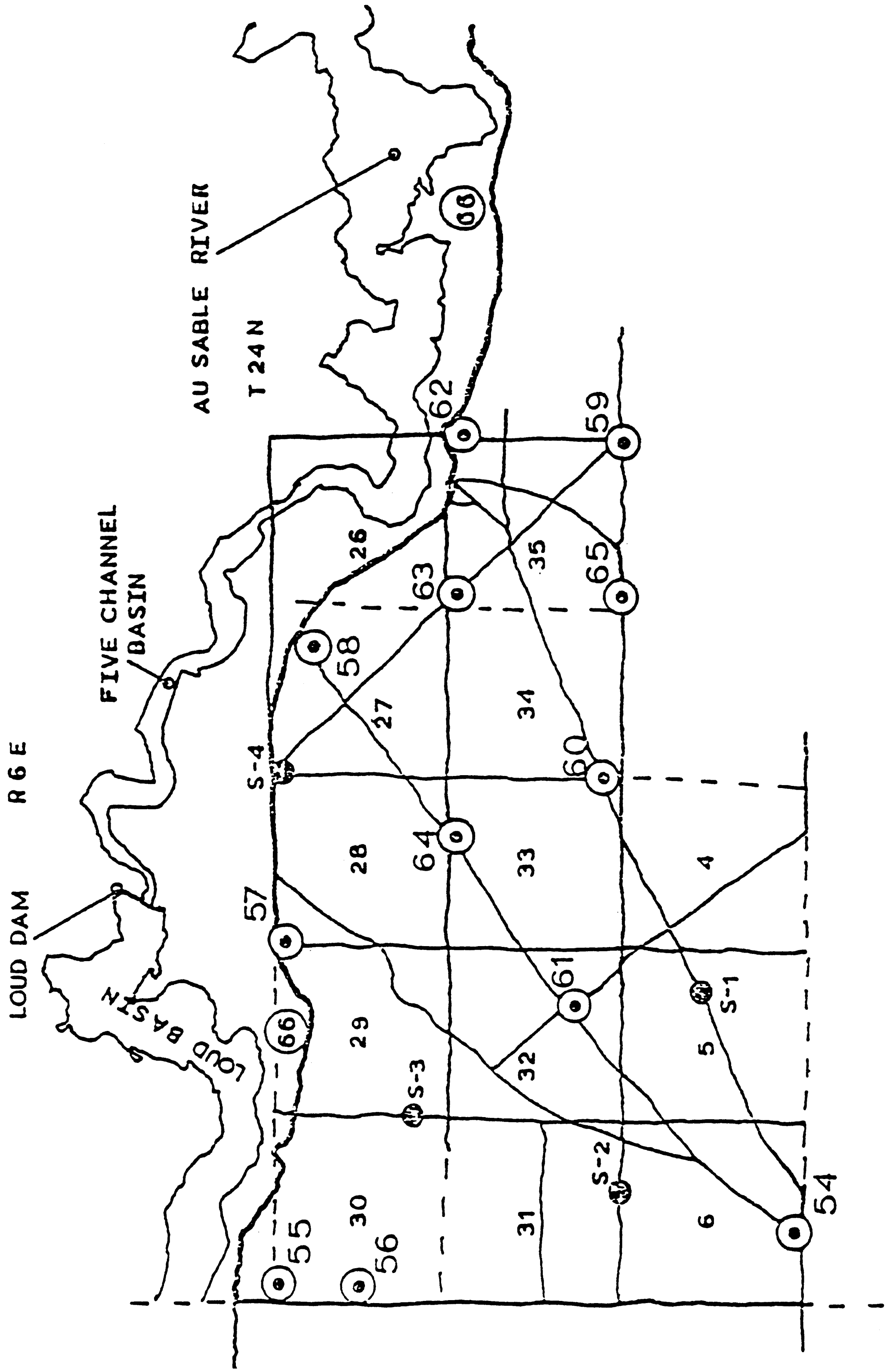

Figure 9. Iosco County, Area VI, auger hole and surface sample locations

Auger Hole Locations ⊙ Surface Sample Locations ● - North is to the left of this page.