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The Effect Of Drift Thickness on the Topographic Expression of Bedrock Surfaces In The Southern Great Lakes Region

presented by

Norman Meek

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THE EFFECT OF DRIFT THICKNESS ON THE TOPOGRAPHIC EXPRESSION OF BEDROCK SURFACES IN THE SOUTHERN GREAT LAKES REGION

By

Norman Meek

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ABSTRACT

THE EFFECT OF DRIFT THICKNESS ON THE
TOPOGRAPHIC EXPRESSION OF BEDROCK SURFACES
IN THE SOUTHERN GREAT LAKES REGION

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Analysis of data from forty-one (9 mi^2) sites within areas of Woodfordian glaciation indicates that there is a mathematically definable drift thickness threshold which, if exceeded, eliminates reflection of the buried bedrock surface in the present topography. For sites with average drift thicknesses between 15 and 35 meters, the threshold is approximately equal to either maximum bedrock relief/2 + 10 meters, or average bedrock relief + 8 meters.

Further examination of the site data indicates a) that present topographic relief is generally less than bedrock relief, and b) that increased topographic relief may be related to bedrock surface roughness. In addition, comparative tests suggest that the results of this study may be dependent on the size of the sample sites.

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I am indeed fortunate to have benefitted from the selfless efforts of my mentor, Professor Harold Winters. His uncompromising high standards challenged me to pursue excellence and accept nothing less. I have greatly appreciated his efficient editorial help, advice, and discussions. "Dilemma Hill" will last forever.

Secondly, many thanks must be extended to Professor Gary Manson, chairman, Department of Geography. This project would have been difficult, if not impossible, without a solid financial commitment or his wisdom to invest in a high quality word processing system.

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This thesis is dedicated to all of my friends, colleagues and relatives who thought that I was joking when I said I would start and finish a credible thesis in one term. With hard work and a firm resolve **anything** is possible.

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CHAPTER I

INTRODUCTION TO THE PROBLEM

Observations during the mid-19th century indicated that surface sediments of glacial origin shape much of the landscape in the central United States. These sediments, referred to as drift, were found to extend from the Appalachians on the east to the Dakotas in the west, and as far south as the Ohio and Missouri rivers. As the area was settled, data from many water and oil wells revealed that the thickness of the glacial drift often differed from one location to another. At some places, such as along the sides of major stream valleys or atop regional uplands, the drift might be thin or absent. In other areas extensive systems of drift-buried valleys with no topographic expression were discovered. Because it appeared that bedrock/topographic relationships varied depending on the amount of drift present, a widespread assumption developed that glacial drift controls the form of the landscape once the thickness of glacial sediments exceeds the available relief on the bedrock surface (Lobeck, 1939, pp. 302-303).[1]

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[1]Direct statements of this assumption are difficult to find in the literature, even though such relationships are implied in several references. For examples of this assumption being applied (but not stated), see Kay and Apfel, 1928, pp. 53-54; Fenneman, 1938, p. 500; Horberg, 1950, p. 11; or Charlesworth, 1957, p. 385.

But a recent investigation of south-central Michigan (Rieck and Winters, 1979) indicates that some aspects of the bedrock surface may be reflected in the topography, even though the bedrock surface is deeply buried by glacial drift. The results of this study are even more perplexing when the effects of multiple glaciation and the seemingly independent (random) deposition of drift are considered. As a result, at least two important questions need to be answered:

--Are there drift thickness limits controlling the bedrock/ topographic relationship that have not been recognized?

--Are the effects of the postulated drift thickness limits widespread or spatially limited to the extent of a single glacial lobe?

If these questions are answered, the geographic extent and nature of bedrock-controlled glaciated topography could be determined.

Background Information

Before the relationship between the bedrock and topographic surfaces is tested, some related topics need to be examined. Among the most important questions are:

--What factors are known to affect the bedrock/topographic relationship?

--How is the bedrock/topographic relationship defined?

--How is "drift thickness" defined?

--What evidence suggests that a drift thickness limit may control the bedrock/topographic relationship?

Factors Affecting the Bedrock/Topographic Relationship

According to MacClintock (1929), the surface expression of bedrock topography is largely controlled by two factors:

1) the relief of the preglacial (bedrock) surface; and
2) the thickness of the glacial drift.

Available relief on the bedrock surface essentially determines the minimum thickness of drift that is necessary to mask it. (Hereafter, the word "mask" and its derivatives will be used to refer to a specific situation where the bedrock surface is not expressed in the topography.) In some areas where bedrock relief is small, such as southern Illinois, a drift sheet with an average thickness of only 30 feet (9 meters) has smoothed the landscape (Fenneman, 1938, p. 500; p. 508). At other places, such as north-central Ohio, the available relief on the bedrock surface is so great that glacial deposits with thicknesses averaging 205 feet (62 meters) are insufficient in quantity to obscure the features (Ver Steeg, 1934, pp. 604-605). Consequently, a minimal masking relationship in a glacial landscape ostensibly requires that drift thickness must exceed available bedrock relief.

In addition to maximum bedrock relief, drift thickness is also an important factor in determining which areas of the bedrock surface are masked. If drift is thin or absent it is likely that most parts of the bedrock surface will be revealed in the topography. If drift is moderately thick it is likely that some minor features on the bedrock surface may be obscured while large bedrock hills or valleys are still apparent. If drift thicknesses are great, it is possible that the preglacial surface may be completely masked.

Initially it might seem that bedrock relief and drift thickness should be independent factors: erosion on the preglacial bedrock surface is not related to subsequently deposited drift; and the volume of drift in any area is dependent only on load, velocity of flow, and time (Flint, 1971, p. 149)--all of which are characteristics of glaciers and glaciation rather than the bedrock surface. In the southern Great Lakes region, however, drift thickness and the relief on the bedrock surface appear to be closely related. This relationship is so common that at many locations the thickness of drift is largely determined by the relief on the bedrock surface, although rare exceptions do exist (Brown, 1963, p. 33).

At many places the thickest drift is in or above preglacial bedrock valleys (for Illinois see Horberg, 1950, p. 104; for Indiana see Wayne, 1956, p. 9, 15, & 46; for Michigan see Moore, 1959, or Rieck and Winters, 1979, p. 281; for Ohio see Ver Steeg, 1938, p. 656). This is because the thicker drift associated with localized surface features such as moraines appears to be significantly less important in regions than the increased thicknesses caused by valley filling (Ver Steeg, 1938, p. 656; Wayne, 1956, p. 9). The net effect of valley filling is that wherever drift is present the available relief of the bedrock surface is usually reduced (for examples see Moore, 1959, or Rieck and Winters, 1979, p. 276).

Defining the Bedrock/Topographic Relationship

The point at which the bedrock surface is masked must, to some degree, be subjectively defined. This is because there is no single point at which geomorphologists will universally agree that a bedrock surface is expressed, or for that matter masked, in the topography. Some may require that only evidence of a single phenomenon be present on both surfaces (large rivers flowing on the surface over sections of preglacial bedrock valleys), while others may require that several phenomena be present on the surfaces (large rivers, major tributaries, major uplands and/or lowlands, etc.).

Both Lobeck (1939, p. 302) and MacClintock (1929) discuss bedrock-controlled and drift-controlled glacial landscapes, but neither clearly defines the criteria that are necessary to separate the two classes. Any classification dependent upon these landscape types requires that measures of bedrock/topographic surface similarity and diversity be set, permitting separation of the two classes on the basis of definable criteria. This could be accomplished by a visual analysis of the bedrock and topographic maps, but the comparison would be affected to an unknown degree by map qualities such as legibility and scale, as well as difficulties involved with objectively comparing two three-dimensional surfaces. A more expedient, and probably more objective method of defining a bedrock-controlled surface is to obtain a point sample from the two surfaces and observe how closely the bedrock and topographic surfaces are correlated. If the two surfaces are related the topographic uplands and valleys will correspond to similar features on the bedrock surface. Accordingly, a correlation

coefficient (R) measuring the relationship between elevations taken at equivalent spatial locations (X, Y coordinates) on the two surfaces should increase as the relationship between the form of the bedrock and topographic surfaces (as defined in this study) improves. Given an array of bedrock/topographic correlation coefficients, a line can be drawn somewhere in the array that quantitatively describes a bedrock and/or drift controlled surface. Finally, each of the sample sites can be objectively classified as having either a masked or non-masked bedrock/topographic relationship based on its correlation coefficient.

Defining Drift Thickness

Spatially, drift thickness is highly variable (Chamberlin and Salisbury, 1907, p. 346). This is particularly true for many parts of the southern Great Lakes region. For example, in Livingston and Shiawassee counties, Michigan, Moore (1959, p. 22) found drift thicknesses ranging from 0 to 330 feet (101 meters); and in Lapeer County, Michigan, Brown (1963, p. 33) reported glacial sediments ranging from 42 to 410 feet (13 to 125 meters) thick.

Because of variability, care must be exercised when discussing the thickness of drift in an area. For this reason Flint (1971, p. 149) suggests that "average drift thickness" may offer a more realistic approach for analysis. But even "average drift thickness" can be misleading. It has been shown that drift-filled valleys largely contribute to the local drift thickness variations in a region. If one or more such valleys are located within a study area it is possible that the mean drift thickness value may be misleading because the great amount of drift in the valleys can significantly increase the regional average. Consequently, average drift thickness values should be used for analysis only in areas where bedrock relief is reasonably uniform.

Present Evidence For a Drift Thickness Threshold

A recent study by Winters and Rieck (1982) indicates that deeply buried bedrock surfaces may control certain aspects of surface morphology, especially hydrographic features. The implication of the word "deeply" in this context suggests that the overlying drift is substantially thick over the entire surface not just over the buried valleys. Another important implication is that the drift thickness necessary to mask a bedrock surface may be substantially greater than the implied minimum relationship referred to earlier in the Introduction.

In an investigation of the bedrock and topographic relationships in a four county area of Michigan, Rhoads (1982) suggested a drift thickness threshold might exist in the area, beyond which bedrock valleys are no longer expressed in the topography. The inference that logically follows from Rhoads' suggestion is that there may be a critical threshold drift thickness for any area that determines the point at which the bedrock surface is no longer expressed topographically. Because the average drift thickness needed to mask a landscape apparently depends on the available relief of the bedrock surface, the logical conclusion is that the masking of the bedrock surface in any area may simply be a function of drift thickness as it relates to bedrock relief. Furthermore, if the masking of a bedrock surface can be simplified into the form of a mathematical function relating drift thickness to bedrock relief, then it may be possible to predict an average drift thickness threshold for any area of the southern Great Lakes region.

Statement of the Problem

The objectives of this study are:

--to determine if an average drift thickness threshold is a viable concept within the context of explaining bedrock/topographic relationships in sample glaciated areas of the southern Great Lakes region; and

--to quantitatively assess what the critical threshold average drift thickness may be for the sample sites, given only the local bedrock relief.

Hypotheses

To accomplish the objectives, the following hypotheses are considered:

--For any given relief value of the bedrock surface at a sample site in a Wisconsinan glaciated area of the southern Great Lakes region, there is an average drift thickness value above which the topographic expression of the bedrock surface is masked; and

--There is a mathematical function which defines this relationship.

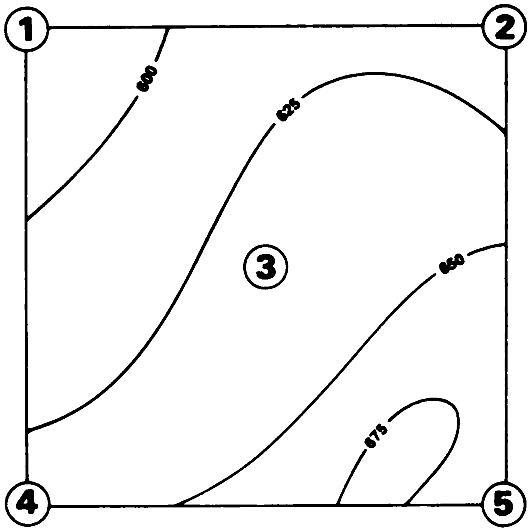
Operational Definitions

For this study "a Wisconsinan glaciated area of the southern Great Lakes region" includes locations in the states of Wisconsin, Illinois, Indiana, Ohio or Michigan that are shown as being glaciated during the Wisconsin(an) on the Glacial Map of the U.S. East of the Rocky Mountains (1959).

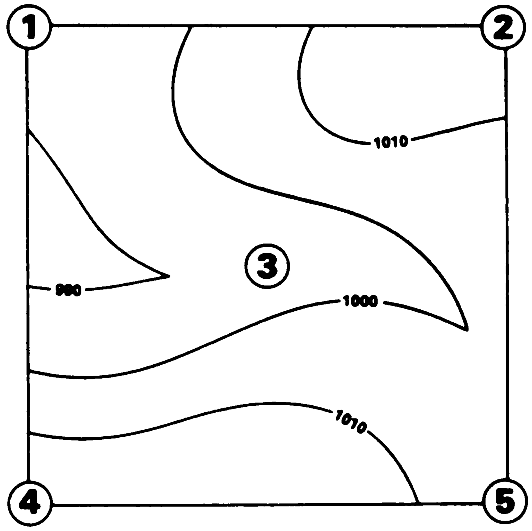
A "relief value of the bedrock surface" is the maximum amount of relief on the bedrock surface in any study sample area, given the control points available. In cases where elevation control must be expressed as a range (i.e. where either value is determined from a contour map), the relief value is defined to be the difference between the median values of the appropriate contour intervals (producing a single value rather than a range, see Figure 1). In every case the resulting relief value is rounded to the nearest meter.

An "average drift thickness value" is the mean derived by using the drift thickness calculated for each control point. As with bedrock relief (where elevation control is expressed as a range), the drift thickness at any control point may be defined as the difference between the median values of the appropriate contour intervals (Figure 1). All average drift thicknesses are rounded to the nearest meter.

The definition of a "masked" surface is to some degree subjective, with little precedence in the literature. Therefore, to measure surface similarity/diversity, two separate quantitative procedures are performed (see "Data Manipulation," p. 20 ff.). The results of these operations should provide an initial quantitative



Bedrock Map



Topographic Map

(contours in feet)

Control Point	Bedrock Relief	Drift thickness
1.	$\frac{600 - 575}{2} + 575 = 587.5'$	$995 - 587.5 = 407.5'$
2.	$\frac{625 - 600}{2} + 600 = 612.5'$	$1115 - 612.5 = 502.5'$
3.	$\frac{650 - 625}{2} + 625 = 637.5'$	$995 - 637.5 = 357.5'$
4.	$\frac{650 - 625}{2} + 625 = 637.5'$	$1015 - 637.5 = 377.5'$
5.	$\frac{675 - 650}{2} + 650 = 662.5'$	$1005 - 662.5 = 342.5'$
		Total 1987.5'

Maximum Bedrock Relief: $662.5 - 587.5 = 75' = 22.86$ meters $= 23$ meters

Average Drift Thickness: $\frac{1987.5}{5} = 397.5' = 121.16$ meters $= 121$ meters

Figure 1. Calculation of Maximum Bedrock Relief and Average Drift Thickness

measure for future studies involving masked and non-masked bedrock/ topographic relationships.

CHAPTER II

DIFFERENTIATING MASKED AND NON-MASKED SURFACES

Distribution of the Sample Sites

Two groups of sample sites were chosen in the southern Great Lakes region: forty-one "small" sample sites, each nine square miles in area, and ten "large" sample sites, each thirty-six square miles in area (see Appendices A and B for exact site locations). The distribution of sites is shown in Figure 2 and Table 1. The number of samples in each state reflects the approximate proportion of the total study area that lies within each state. However, because Michigan is characterized by large areas of comparatively thicker drift, the number of Michigan sites was increased to balance the total number of thin and thick drift sites used in the study (see p. 15).

The study sites within each state were chosen using the following criteria (listed in order of importance):

1) A detailed bedrock topography map was available.
2) The contour interval of the bedrock map was 25' or less.
3) Sufficient control was available to permit manual contouring at a 25' contour interval (locally).
4) The contours in an area were based on a sufficient number of control points to make the map reliable.

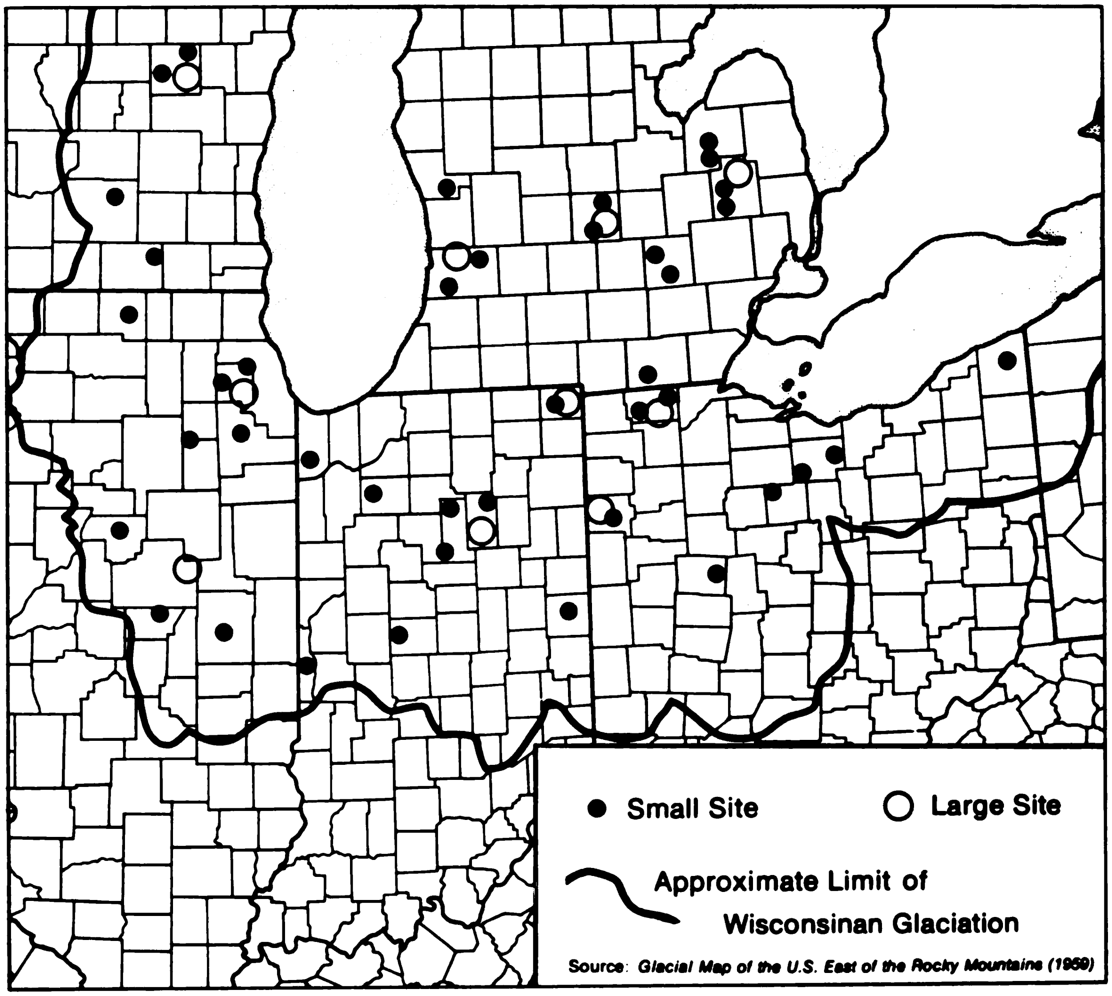


Figure 2. Distribution of Sample Sites

Table 1. Distribution of Sample Sites

STATE	# OF SMALL SITES	# OF LARGE SITES
Wisconsin	4	1
Illinois	8	2
Indiana*	9	2
Ohio	8	2
Michigan	12	3
	41	10

*An additional small site was added to the Indiana group during the study (a total of nine sites rather than the usual eight). The site was included to take full advantage of a detailed, apparently reliable bedrock map covering Wabash and Miami counties.

5) The bedrock relief was neither very low nor very rugged.

6) The study site was geographically separated from other study sites.

Problems With Sample Site Selection

Finding bedrock maps that meet the criteria listed above was difficult. In many instances available maps are limited to those showing the location and elevation of the bedrock surface, thus requiring manual contouring. Other maps display only contours (no control points indicated). In these cases map quality is unknown.

Finding appropriate maps, and thus potential sample sites from Wisconsin, Indiana and Ohio was especially difficult, while doing so for Illinois and Michigan was only slightly easier. As a result, a few locations with less than optimum qualities were used to fill a state's quota. In virtually every case these were large samples, which could reduce the accuracy of the large site tests.

There are many site selection problems because accurate and detailed information about the elevation of the bedrock surface is lacking for most localities in the southern Great Lakes region. In areas where the drift is thin many wells penetrate bedrock and thus, local bedrock control is good. But as drift thickens, data on the uppermost bedrock rapidly declines because penetration of its surface is generally limited to only the deepest wells. At some places where an oil field has been discovered, a dense spacing of control points is available in a thick drift area, but rarely do these sites attain the scale necessary to permit accurate mapping of a township-size area of the bedrock surface.

To test the hypotheses, it is preferable to locate most of the sample sites at places where the amount of drift approaches the suspected drift thickness threshold. As a result, thick drift sites were used wherever available. This dictated that most of the sites were chosen from a very restricted group of possible locations limited by the quality and accuracy of the bedrock maps. Although care was used to insure that the best available bedrock maps were used, it should be remembered that the results of this study can be no more accurate than the quality of the bedrock maps that were utilized.

Sample Site Size Differences

It was necessary to use two sizes of sample sites to test the effect of sample area on the surface correlations, because:

--theoretically, there are minimum and maximum spatial thresholds when comparing bedrock and topographic surfaces. If the amount of sampled space is too small, there is a much greater likelihood that a comparison of the two surfaces will produce highly correlated results--whether the regional surfaces are similar or not. However, if the amount of space is too large, it is likely that the two surfaces will never be highly correlated except when the relationship is obvious (i.e. two planar surfaces, etc.).

--spatially, drift thickness is often highly variable. As a result, average drift thicknesses may become less meaningful as the sample site area increases (see pp. 6-7).

--published bedrock surface maps with the necessary detail (contour intervals of 25' or less) are often limited to small areas, such as a county or topographic quadrangle. Furthermore, even in these limited areas adequate control of the bedrock topography is generally restricted to small sections within the region where several wells have been drilled. Thus, sample locations that are township-size or smaller are preferable to large sites in order to maintain data reliablility.

The total area covered by the small sites (41 sites X 9 mi^2 = 369 mi^2) is approximately equivalent to the total area covered by the large sites (10 sites X 36^2 = 360 mi^2). The nine square mile difference is due to the addition of the extra small site in Indiana. The use of equivalent total areas is designed to enhance comparison of the two site sizes.

Sampling Control

For each small sample site (9 mi^2), forty-nine control points were sampled in an aligned systematic manner. Both topographic and bedrock elevations were recorded for each point (Appendices A and B) and the statistics calculated (Appendices C and D). The identification number and location of the sample points in each study site are shown in Figure 3.

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49

Section Lines

Figure 3. Small Site Sample Location and Identification Numbers

In each large sample site (36 mi^2) the control points were set at the same distance intervals as in the small sites, thus requiring 169 points per sample. The identification number and location of the sample points are shown in Figure 4.

The choice of forty-nine sample points is based on the results of a study by Morrison (1971). Although the number of sample points (sample size) is not the most critical factor which causes errors in

1	2	3	4	5	6	7	8	9	10	11	12	13
14	15	16	17	18	19	20	21	22	23	24	25	26
27	28	29	30	31	32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47	48	49	50	51	52
53	54	55	56	57	58	59	60	61	62	63	64	65
66	67	68	69	70	71	72	73	74	75	76	77	78
79	80	81	82	83	84	85	86	87	88	89	90	91
92	93	94	95	96	97	98	99	100	101	102	103	104
105	106	107	108	109	110	111	112	113	114	115	116	117
118	119	120	121	122	123	124	125	126	127	128	129	130
131	132	133	134	135	136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151	152	153	154	155	156
157	158	159	160	161	162	163	164	165	166	167	168	169

Figure 4. Large Site Sample Location and Identification Numbers

isarithmic map usage (Morrison, 1971, p. 37; pp. 52-54), a sample of forty-nine points appears to be the most economical sample size choice for spatial modeling that provides a reasonably high accuracy for both simple and complex isarithmic surfaces (Table 2).

Table 2. A COMPARISON OF SAMPLE SIZES: Average Standard Deviation of the Residuals, s,* and Correlation Coefficient, r, by Sample Size (Morrison, 1971, p. 54)

Sample size	Surface I** s	Surface I** r	Surface II s	Surface II r	Surface III s	Surface III r	Surface IV s	Surface IV r
25	1437%	.85	4599%	.95	312%	.39	212%	.52
49	857	.93	4317	.99	181	.62	202	.61
100	580	.95	3004	.99	189	.85	215	.54
149	395	.98	3704	.99	184	.87	208	.53

*The average standard deviation of the residuals is given in this table as a percentage of the respective standard deviation to enhance comparison.

**Surface numbers refer to trend surface orders.

Somewhat less desirable was the choice of an aligned systematic sampling pattern (Table 3). Compared to any unaligned sampling pattern, the aligned systematic method is less satisfactory (an exception is the Surface III sample) for the accurate portrayal of an isarithmic surface (Morrison, 1971, pp. 40-45). However, the ability to accurately locate control points on two maps with different scales is so greatly facilitated by the use of surveyed section lines that the unaligned sampling patterns are simply not feasible.

Table 3. A COMPARISON OF SAMPLING PATTERNS: Average Standard Deviation of the Residuals, s,* and Correlation Coefficient, r, by Sample Size (Morrison, 1971, p. 28)

Sample type**	Surface I s	Surface I r	Surface II s	Surface II r	Surface III s	Surface III r	Surface IV s	Surface IV r
AR	6546%	.33	34152%	.68	720%	.17	336%	.34
ASR	1325	.94	10186	.99	293	.66	233	.46
AS	1038	.96	5885	.99	159	.82	224	.55
UR	53	.96	16	.99	199	.71	174	.60
USR	31	.97	28	.99	91	.82	153	.66
US	18	.98	4	.99	54	.89	160	.64

*The average standard deviation of the residuals is given in this table as a percentage of the respective standard deviation to enhance comparison.

**Sample type codes: A = aligned, U = unaligned,
S = systematic, R = random

Data Manipulation

All of the steps that follow were necessary to determine if the bedrock surface at each sample site is masked in the topography. Because a comparison of two three-dimensional surfaces is not well documented at the present time, the surface comparisons are exploratory in nature. Consequently, two statistical techniques were used to compare the bedrock and topographic surfaces--in the hope that the two methods would provide reasonably complementary results.

Unmodified Surface Correlations

For each site a simple Pearson Correlation was run using the paired values of the topographic and bedrock surfaces. This was accomplished using the SPSS package on the Michigan State University computer system. The results are shown in column 3 of Tables 4 and 5.

Modified Surface Correlations

First, second, third, fourth and fifth order trend surfaces were fitted to both the bedrock and topographic surfaces as defined by the 49 or 169 control points. The "Trend" and "Trdgrid" subprograms of the GEOSYS statistical and graphics package on the Michigan State University computer system were used to generate the trend fits and the associated statistics. For each bedrock and topographic surface, the highest degree trend surface was used in the subsequent statistics provided that the incremental percent of variance explained by each additional degree was at least one percent.

The one percent incremental cutoff point is suggested by Harbaugh and Merriam (1968, p. 74), and was used by Rhoads (1982) with satisfactory results. However, in two cases an exception was made to this rule. In both cases a lower order fit dropped below the one percent threshold, but the variance explained by the trend surface fit of the next higher order jumped by more than ten percent, suggesting that the higher order was explaining a substantial amount of the trend (rather than noise).

Table 4. Small Site Bedrock/Topographic Correlation Coefficients[2]

Bedrock Surface-- Topo. Surface--		Original Original		Original Trend		Trend Original		Trend Trend	
Site Number	Final Class	R	Class	R	Class	R	Class	R	Class
1	N	.2391	N	.2408	N	.2247	N	.2463	N
2	C	.8547	C	.8874	C	.8789	C	.9297	C
3	C	.7106	C	.6948	C	.7172	C	.7103	C
4	C	.5205	C	.5369	C	.5049	C	.5575	C
5	N	.3111	N	.3279	N	.3142	N	.3569	N
6	C	.4986	C	.4754	C	.4780	C	.5029	C
7	N	.2816	N	.3322	N	.2930	N	.3350	N
8	N	.2636	N	.2671	N	.2787	N	.2842	N
9	N	.1568	N	.1822	N	.1784	N	.1846	N
10	C	.6173	C	.6191	C	.6256	C	.6489	C
11	N	.1833	N	.1920	N	.1916	N	.1985	N
12	N	-.2539	N	NA		-.1863	N	NA	
13	N	.2103	N	.2164	N	.1948	N	.2354	N
14	N	.3087	N	.3660	N	.3760	N	.4122	N
15	N	.3689	N	.3432	N	.3353	N	.3584	N
16	C	.8043	C	.8149	C	.7830	C	.8455	C
17	C	.6722	C	.6737	C	.6776	C	.6807	C
18	N	-.0642	N	-.0706	N	-.0600	N	-.0644	N
19	C	.4598	C	.5427	C	.4731	C	.5527	C
20	C	.7923	C	.7679	C	.7585	C	.8380	C
21	N	.2137	N	.1982	N	.1915	N	.2117	N
22	N	-.3010	N	-.3363	N	-.3168	N	-.3555	N
23	C	.4775	C	.5104	C	.5103	C	.5470	C
24	C	.5565	C	.5784	C	.5766	C	.5916	C
25	N	.1332	N	.1405	N	.1394	N	.1522	N
26	N	.2149	N	.2243	N	.2304	N	.2484	N
27	N	-.0220	N	-.0265	N	-.0257	N	-.0292	N
28	N	-.3385	N	-.3350	N	-.3703	N	-.3606	N
29	C	.5547	C	NA		.4716	C	NA	
30	C	.5889	C	.6300	C	.6642	C	.6933	C
31	C	.5077	C	.4953	C	.4483	C	.5603	C
32	N	.0053	N	-.1317	N	NA		NA	
33	C	.5133	C	.5694	C	.5327	C	.6162	C
34	N	.0339	N	.0919	N	.0787	N	.0967	N
35	N	.0818	N	.0655	N	.0684	N	.0741	N
36	N	-.2262	N	-.2608	N	-.2486	N	-.2772	N
37	N	.3120	N	.3756	N	NA		NA	
38	N	-.3669	N	-.4029	N	-.3883	N	-.4172	N
39	N	.0372	N	.0343	N	.0330	N	.0397	N
40	C	.5760	C	.6146	C	.7154	C	.7370	C
41	C	.7807	C	.7461	C	.8412	C	.8196	C

Site Classes: N = Not Correlated; C = Correlated; NA = Not Applicable

Table 5. Large Site Bedrock/Topographic Correlation Coefficients

Bedrock Surface-- Topo. Surface--		Original Original		Original Trend		Trend Original		Trend Trend	
Site Number	Final Class	R	Class	R	Class	R	Class	R	Class
1	C	.8860	C	.8887	C	.9166	C	.9411	C
2	C	.5097	C	.5035	C	.5599	C	.6096	C
3	N	-.0738	N	NA		-.1448	N	NA	
4	Not used	.3037	C	.1868	N	NA		NA	
5	N	-.1482	N	-.1508	N	-.1439	N	-.1508	N
6	N	-.3380	N	-.3730	N	-.4820	N	-.5015	N
7	N	.1178	N	.1249	N	.1475	N	.1556	N
8	C	.3070	C	.3514	C	.3625	C	.4611	C
9	C	.3541	C	.3332	C	.3742	C	.4487	C
10	C	.4302	C	.4103	C	.4564	C	.5232	C

Site Classes: N = Not Correlated (masked)
C = Correlated (not masked)
NA = Not Applicable*

The 99.9 percent confidence level is at approximately R = .2000

*The correlation coefficients of the sites marked "NA" are not listed because the trend surface results were rejected due to poor fits.

[2]The 99.9 percent confidence level is at approximately R = .4300

After determining the most appropriate trend surface representation of each surface, several correlations were run using the trend output matrices. In each case the subprogram "Trdgrid" produced a trend output matrix containing an array of trend surface values (Z-values) representing the "new" surface elevations at each sample point.

As before, the SPSS package was used to perform the correlations and generate the statistics. For each site, three bedrock/topographic correlations were performed, including:

--a correlation between the trend of the bedrock surface and the trend of the topographic surface;

--a correlation between the trend of the bedrock surface and the original topographic surface; and

--a correlation between the original bedrock surface and the trend of the topographic surface.

All of the correlation coefficients produced by using the trends fitted to each surface were then tabulated alongside the correlation coefficients produced by using the unmodified surfaces (Tables 4 and 5, pp. 22-23). Since an accepted confidence limit does not exist which differentiates masked bedrock/topographic relationships from unmasked bedrock/topographic relationships, a series of procedures was used to establish such a limit for the purposes of this study. The only predetermined element in this search was that the limit should be within the correlation coefficients at or above a ninety percent confidence level. This forces all bedrock/topographic relationships classified as being non-masked to be clearly correlated, even if the correlation coefficients themselves might appear to be insignificant.

First, each group of "percent of variance explained" figures for the trend surface fits was examined for extraneous values (commonly referred to as "blow-ups"). Within each group, those figures with Z-values greater than two standard deviations from the mean were eliminated from the group. As a result, two of the topographic and two of the bedrock surfaces were eliminated. In these four cases the extreme values were the result of very low "percent of variance explained" figures.

Secondly, each group of correlation coefficients was examined for gaps in the numerical values, more commonly known as "natural breaks." A data classification program (written by Dr. Groop) available in the Computer Room, Department of Geography, Michigan State, was used to perform this step. The natural breaks within each group were compared to see if any gaps were common to all groups. Within the main spread of the small site correlation values only one natural break occurred in every group and surprisingly, it consistently fell at the same point in all of the groups. Fortunately, this gap was above the ninety percent level--at exactly the 99.9 percent confidence level. Consequently, the limit marking the difference between a masked and non-masked bedrock/topographic relationship is defined to be a correlation coefficient between the two surfaces that is exactly 99.9 percent significant.

Using this break as the classification limit, each small site was then classified as being either masked or non-masked. Remarkably, every small site was classified in the same category no matter what method was used to correlate the bedrock and topographic surfaces (using trends or not). In part this occurred because the principal gap in the correlation coefficients was so great. In any case, the results are clear: the members of each group have distinctly different and separable bedrock/topographic relationships--which more than likely reflect the differences between areas with and without bedrock controlled topographies.

The same procedure was used to classify the ten large sites, with the exception that a classification procedure was not needed to search for natural breaks in the data. One of the topographic trends and one of the bedrock trends were eliminated because the coefficients fell significantly below the mean of the group. Although the 99.9 percent confidence level was not as clear-cut as with the small sites, it was the best limit available given the wide distribution of correlation coefficients and the very limited sample size.

Using this classification limit, the large sites were then classified as having a masked or non-masked bedrock/topographic relationship. One of the ten large sites (site number four) had widely-fluctuating correlation coefficients and could be classified as being both masked and non-masked, depending on whether a trend was fitted to the surfaces or not. As a result, the site was eliminated from the sample, leaving only nine large sites, four of which were unquestionably classified as having a masked bedrock/topographic relationship.

The geographic distribution of the masked and non-masked sites is shown in Figure 5. Using this site classification, no clear geographic patterns are evident for the region as a whole, or for sections of the area divided on the basis of glacial lobes. As a result, it must be tentatively concluded that the masking of a bedrock surface is not simply a function of geographic location.

Discussion of the Two Correlation Techniques

Prior to this study, it was expected that the traditional method of simple correlation would probably offer the most appropriate test of fit between surfaces, particularly if the surfaces in the sample sites were simple or extremely complex. This is because no new information is generated by perfectly modeling a simple surface, and extremely complex surfaces cannot be reasonably replicated using a fifth degree trend surface.

However, trend surface analysis was included because it offers a methodological alternative that is well suited for comparing moderately complex surfaces where a degree of generalization is acceptable or desired. Although it was not designed to be a smoothing technique (Norcliffe, 1969, p. 341), in the case of terrain where moraines or other glacial features can produce a hummocky surface, trend surface can determine the broad underlying trends at each increasingly complex mathematical order (Harbaugh and Merriam, 1968, p. 87). Using the statistics provided, one may then be able to disregard the "hummocky" effect of the moraines in order to compare the overall fit of the topographic and bedrock surfaces.

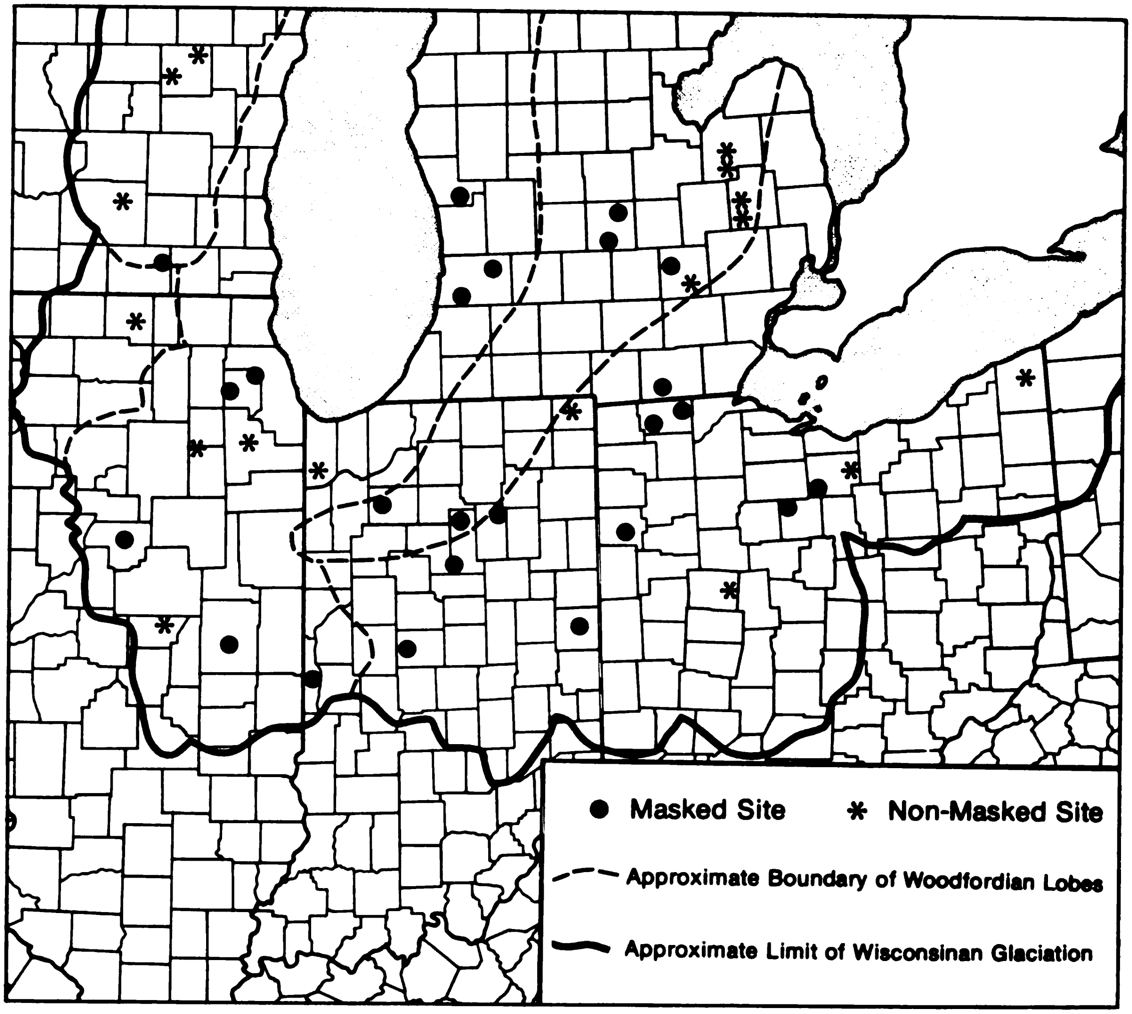


Figure 5. Distribution of Masked and Non-Masked Sites

Broadly speaking, a pair of trend surfaces may be compared in three ways. First, the magnitude of the undulations on each surface may be compared. This is accomplished by observing either the trend surface values (Z-values) or the residuals at each increasingly complex trend order. Secondly, the order of the trend surfaces at equivalent levels of "variance explained" can be compared to determine the relative complexity of the surfaces. Finally, the trend surfaces may be compared to see if the rises and falls of each undulation are spatially related (i.e. if they occur in the same place with respect to X and Y coordinates). The amount of agreement is shown by the correlation coefficients (R) (Doornkamp, 1972, p. 253). Of the three methods, the last method is the only one that directly applies to the hypotheses of this study.

Surprisingly, for all of the small sites and nine of the ten large sites the use of trend surfaces fitted to the topographic or bedrock sample points did not significantly affect the correlations between the bedrock and topographic surfaces nor the site classifications. Consequently, it appears that correlations between the bedrock and topographic surfaces are not significantly altered by comparing trend surfaces modeling either surface, and thus, only simple correlation techniques are needed to examine the bedrock/ topographic relationship.

CHAPTER III

HYPOTHESIS TESTING

When comparing two characteristics of each sample site (e.g. average drift thickness and bedrock relief) with the presence or absence of a masked bedrock/topographic relationship, it is first necessary to form a single variable out of the two characteristics. This is accomplished by calculating a series of ratios using the two qualities (i.e. average drift thickness/bedrock relief). Then, a Mann-Whitney U test may be used to determine whether the two sets of ratios, grouped on the basis of site classification (masked or non-masked), represent statistically "different" sets of ratios. In each case, the test results are based on confidence limits set at a 95% level using a two-tailed hypothesis. The results and conclusions of the hypotheses tests are listed in the "ratio" sections that follow (see p. 35; p. 44).

In addition to the hypotheses, the data provided the opportunity to briefly review several related topics. Questions considered include:

--Is topographic relief in the southern Great Lakes region generally lessthan bedrock relief as a result of glaciation?

--Does maximum or average bedrock relief vary between sites classified as being masked and non-masked? (See Appendix E for the method of calculating average relief in this study.)

--Does maximum or average topographic relief vary between sites classified as being masked and non-masked?

--Does maximum or average drift thickness vary between sites classified as being masked and non-masked?

Small Site Tests

The Effect of Glaciation on Topographic Relief

It is an assumption of this study that modern topographic relief in the southern Great Lakes region is less than the preglacial relief on the Pliocene-Pleistocene paleosurface. In other words, multiple glaciation has tended to reduce available relief within the study area. This assumption may be tested by comparing the maximum and average topographic relief values to the maximum and average bedrock relief values respectively, to see if a major difference exists.

Findings show that topographic relief is less than bedrock relief for sixty-eight to seventy-eight percent of the sample sites, depending on whether maximum or average relief values are used. Therefore, it appears that multiple glaciation did reduce surface relief.

However, two qualifications need to be made. First, the bedrock surface that underlies many of the sample sites is not likely to be the unmodified remnant of a Pliocene-Pleistocene surface. In fact, special circumstances would be required to shield the bedrock surface from the erosional effects of the multiple glacial advances. Furthermore, it is possible that some of the bedrock relief may be attributed to erosion during post-Nebraskan ice-free episodes (Horberg and Anderson, 1956, p. 103; Wright and Frey, 1965, p. 45). As a result, it may be erroneous to conclude (even for small sample sites) that the present bedrock surface represents the terrain that existed just prior to the glaciations.

Secondly, for the purposes of this test the sample could be biased--potential sample areas with very low or very rugged relief were avoided. Therefore, it is possible that the samples used in this test may not be representative of the bedrock relief for the entire southern Great Lakes region.

Maximum and Average Bedrock Relief

Maximum bedrock relief is not statistically different for sites with masked bedrock/topographic relationships and for sites with non-masked relationships (Table 6). The same holds true using average bedrock relief.

These results indicate that the relief on the bedrock surface is not significantly different in areas where the bedrock surface is masked and those areas where the bedrock surface is revealed. This suggests, then, that bedrock relief and the masking of such a surface are independent factors.

It should be remembered, however, that one of the criteria for choosing sample sites was: "the bedrock relief is neither very flat nor very rugged" (p. 14). Because this rule was closely followed virtually no samples with bedrock relief extremes are represented in

Table 6. Small Site Mann-Whitney U Test Results

Site Characteristic	Z*	Two-Tailed Probability
Maximum Bedrock Relief	.4774	.6331
Average Bedrock Relief	.1458	.8841
Maximum Topographic Relief	2.6382	.0083
Average Topographic Relief	2.5231	.0116
Maximum Drift Thickness	1.9323	.0533
Average Drift Thickness	2.5160	.0119
Drift/Maximum Bedrock Relief Ratio	2.5934	.0095
Drift/Average Bedrock Relief Ratio	2.2493	.0245

*The Z values are reported as positive numbers. These results are based on a division of the sample sites into groups of 17 correlated and 24 non-correlated sites.

the observations. As a result, the discovery that bedrock relief and the masking of the bedrock surface are independent factors may only apply to areas having a moderate bedrock relief (i.e. no 100 meter bedrock valleys, etc.).

Maximum and Average Topographic Relief

Results of the tests also indicate that maximum topographic relief is statistically different between sites that are masked and those that are not (Table 6, p. 33). The same is true for average topographic relief. In both cases topographic relief is greater where the form of the bedrock surface is revealed in the topography than where it is masked.

This test clearly suggests that topographic relief tends to be greater where the thickness of drift is insufficient to mask the bedrock surface. Similarly, where the drift thickness is sufficient to mask the bedrock surface, the topography tends to exhibit comparatively less relief.

Since all of the sites were chosen without knowledge of the local topography, it is reasonable to assume that the forty-one topographic surfaces are representative of the present landscape in the southern Great Lakes region. Given that a substantial portion of the sample sites were chosen in "thick drift areas" where constructional glacial landforms may dominate the topography (moraines, kames, eskers, etc.), it seems quite remarkable that the rugged relief of such sites does not significantly affect the results of this test (given the rigorous confidence limits). Therefore, it can be tentatively concluded that a substantial portion of the relatively greater topographic relief in the Wisconsinan glaciated areas of the southern Great Lakes region may be the result of bedrock influence.

Maximum and Average Drift Thickness

Analysis shows that maximum drift thickness is not statistically different for sites with masked bedrock/topographic relationships and for sites with non-masked relationships (Table 6, p. 33). This conclusion is somewhat tentative, though, because the results are significant at the 94.6 percent level--just slightly below the 95% acceptance/rejection threshold. In contrast, when average drift thickness is tested, it is clearly statistically different for masked and non-masked sites. These results indicate that average drift thickness tends to be greater for sites with a masked bedrock/ topographic relationship than a non-masked relationship.

Although the evidence is inconclusive, it appears that glacial drift tends to be thicker at sites where the bedrock surface is masked. This would support the assumption that masking occurs only in thick drift areas. But because the findings are not conclusive, it appears likely that masking of the bedrock surface is a function of more than just thick drift.

Drift/Maximum Bedrock Relief Ratios and Drift/Average Bedrock Relief Ratios

The hypotheses proposed in Chapter I were tested by using a composite variable created by dividing average drift thickness by the maximum (or average) bedrock relief for each site. The resultant ratio is indicative of the drift-bedrock relief relationship at each sample site (see Appendices C and D).

Using either maximum or average bedrock relief as a measure of bedrock roughness at the sample sites, the tests clearly show that the ratios are statistically different for masked and non-masked sample sites (Table 6, p. 33). The tests also indicate that the drift/bedrock relief ratios tend to be greater where the form of the bedrock surface is masked in the topography. Consequently, the first hypothesis is accepted: "For any given relief value of the bedrock surface at a sample site in a Wisconsinan glaciated area of the southern Great Lakes region there is an average drift thickness value above which the topographic expression of the bedrock surface is masked."

Determining the Mathematical Relationships

Corroboration of the primary hypothesis indicates that the bedrock/topographic relationship can be mathematically defined. Because of the limited sample size, the approximate mathematical relationships were determined graphically. Although the number of samples is limited, an obvious difference in the drift/relief values for the two classes of sites appears. Because the bedrock relief for any area can be defined as either maximum or average bedrock relief, the threshold predicted by the hypothesis was determined for both definitions.

The equation defining the threshold of average drift thickness and maximum bedrock relief appears linear (Figure 6). It can be stated as follows: For a sampled area of 9 mi^2, if

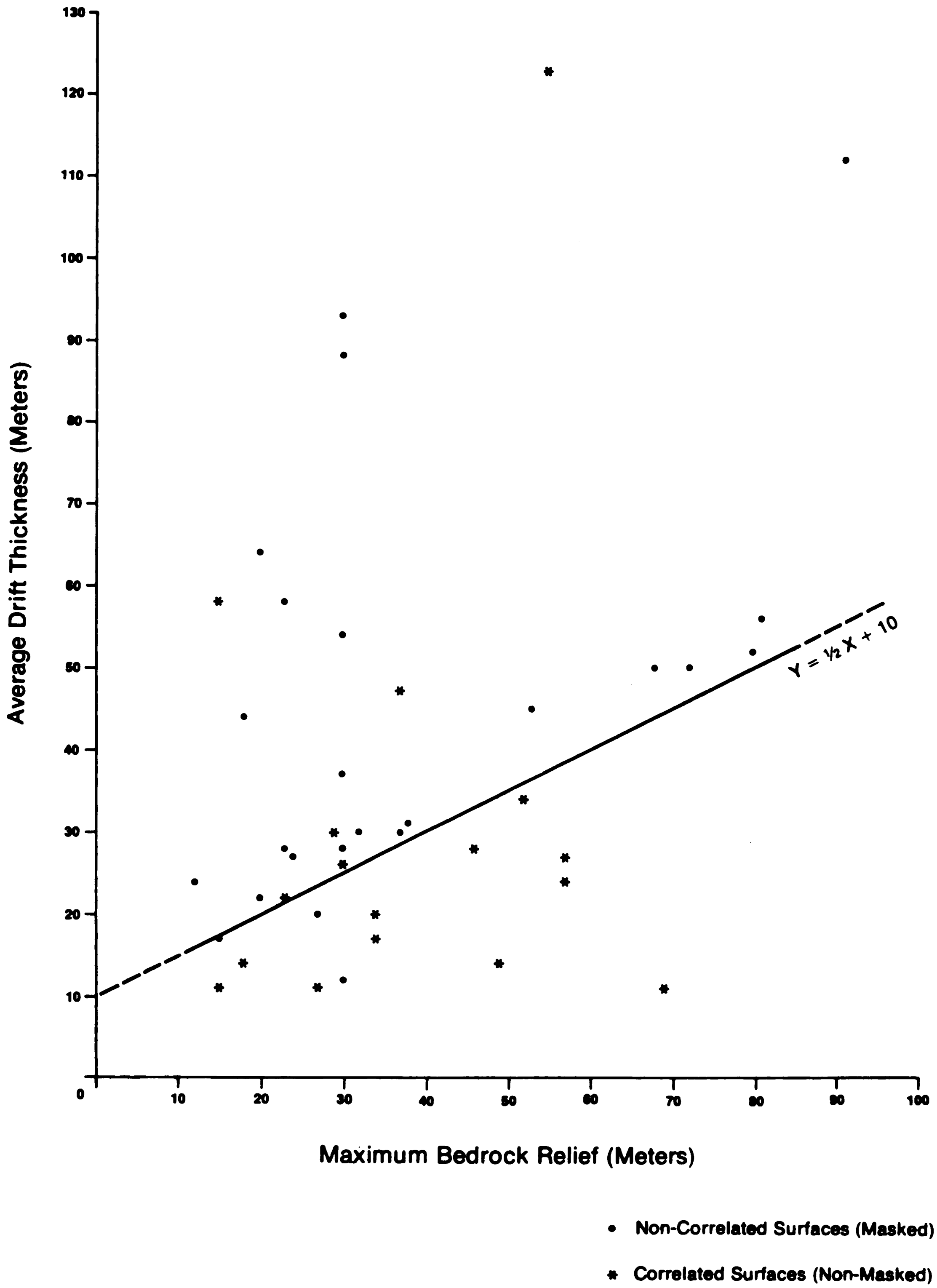


Figure 6. Graph of Average Drift Thickness and Maximum Bedrock Relief

$$\text{Average Drift Thickness} > \frac{\underline{\text{Maximum Bedrock Relief}}}{2} + 10 \text{ meters}$$

then the form of the bedrock surface will not be evident in the topography (it is masked). Furthermore, this equation suggests that below a critical value of 20 meters, average drift thickness must exceed maximum bedrock relief for masking to occur, while above 20 meters average drift thickness can be less than the maximum bedrock relief and masking may still take place.

The equation defining the threshold of average drift thickness and average bedrock relief may be linear or curved, depending on whether part, or all of the sample sites are used (Figures 7 and 8). If the threshold is defined within the neighborhood of most of the observations (average drift thicknesses between 15 and 35 meters) the equation can be stated as: For a sampled area of 9 mi^2, if

$$\text{Average Drift Thickness} > \text{Average Bedrock Relief} + 8 \text{ meters}$$

$$\{\text{Given that: } 15 \text{ meters} < \text{Average Drift Thickness} < 35 \text{ meters}\}$$

then the form of the bedrock surface will not be evident in the topography (it is masked).

But, if the equation is defined using all of the observations, it is possible that it may define a curve rather than a line. Of course, the data are quite insufficient to support a curve equation--especially beyond the 15 and 35 meter average drift limits, but an equation approximately defining the threshold is suggested. It takes the form:

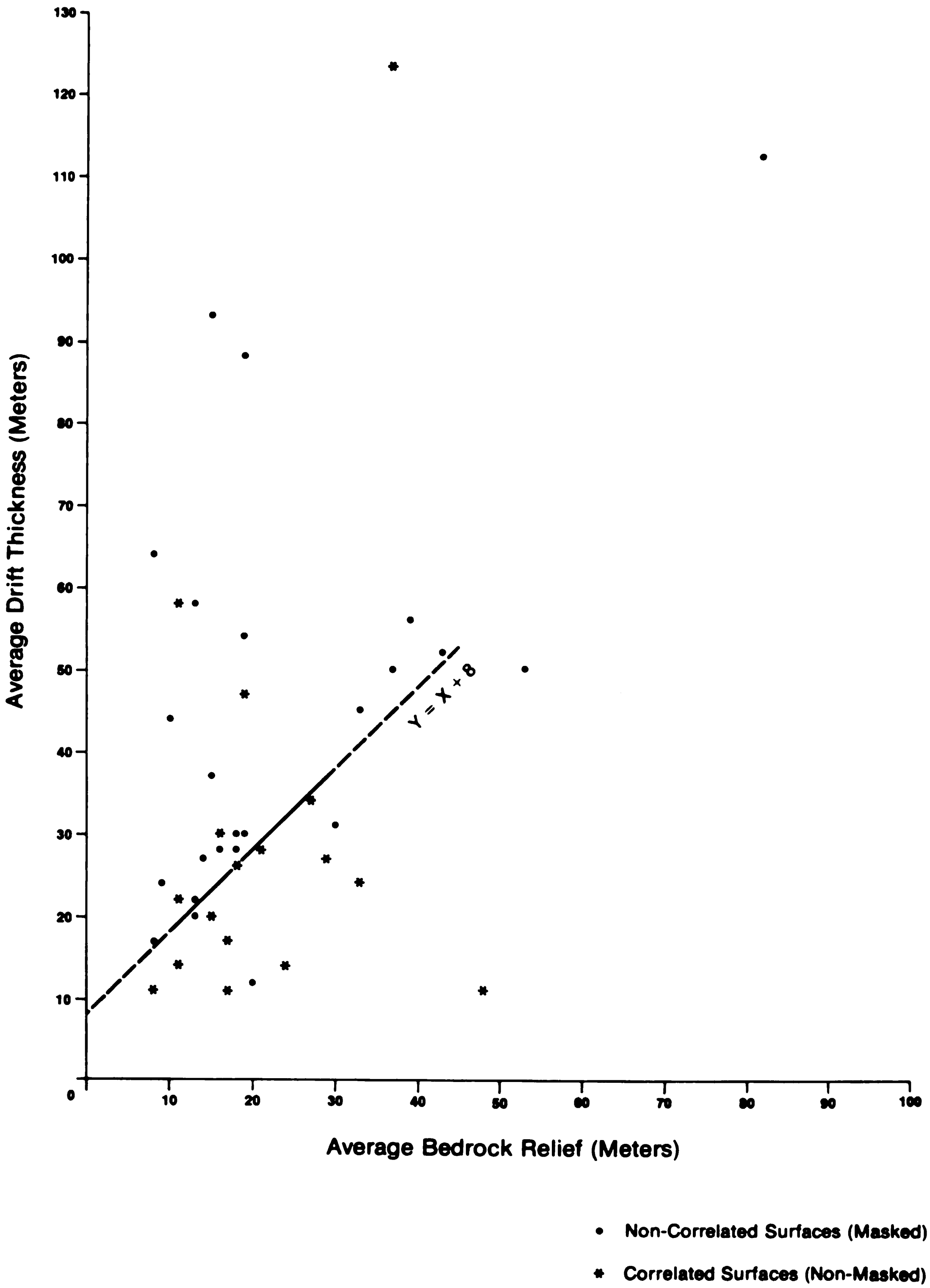


Figure 7. Graph of Average Drift Thickness and Average Bedrock Relief--Linear Solution

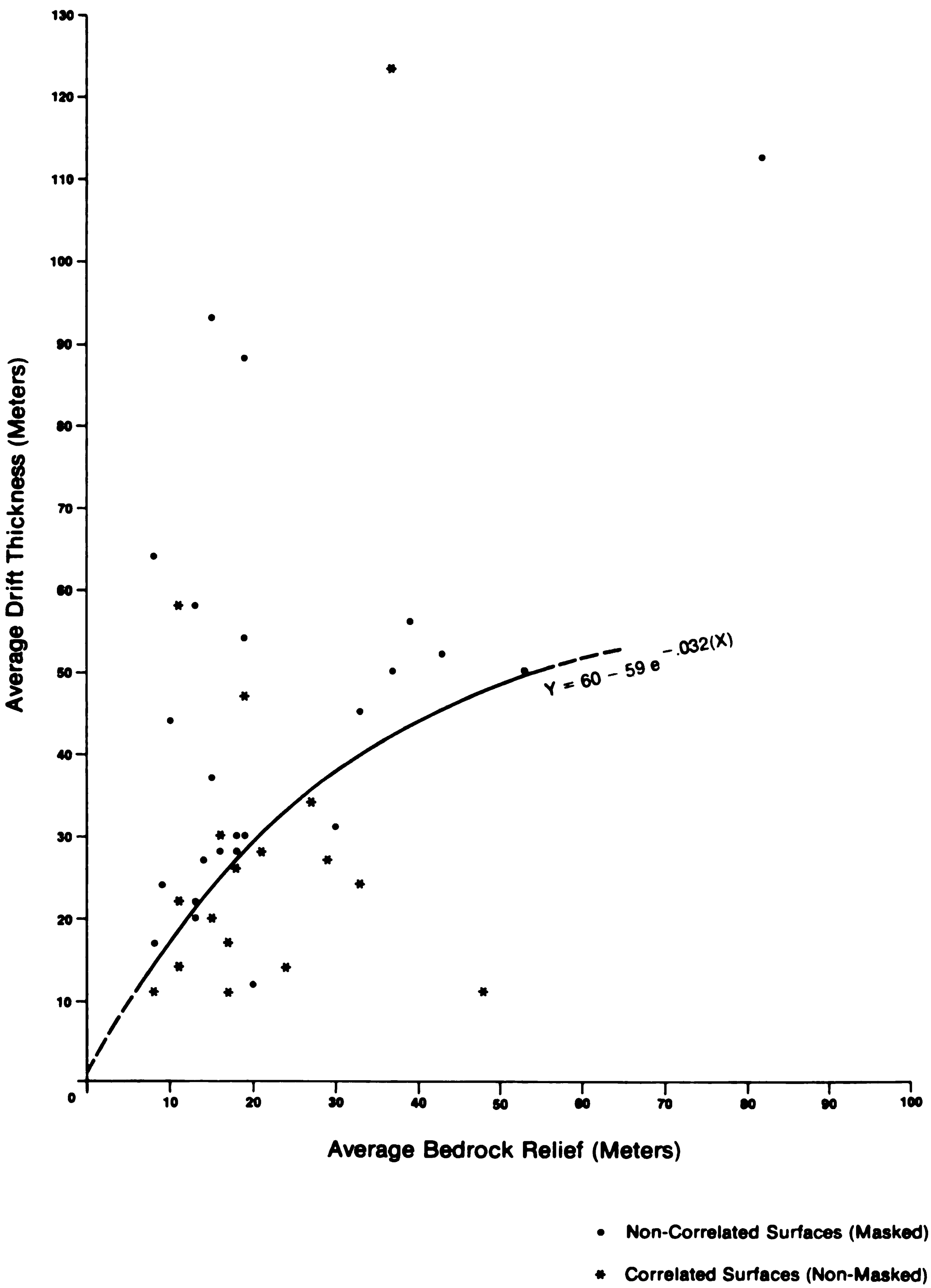


Figure 8. Graph of Average Drift Thickness and Average Bedrock Relief--Curve Solution

For a sampled area of 9 mi^2, if

$$\text{Average Drift Thickness} > 60 - 59\, e^{-.032(\text{Average Bedrock Relief})}$$

{where "e" refers to a natural logarithm base}

(all values are in meters)

then the form of the bedrock surface will not be evident in the topography (it is masked). This equation suggests that a theoretical average drift thickness limit may exist where average drift thickness approaches sixty meters.

Large Site Tests

Because the number of large samples is limited to just nine sites, it would be unwise to base any of the conclusions of this study on the tests that follow. The purpose of including large sites was to see if sample site size significantly affects the results of this study. Only a summary of the large site results are given below. For more details about each test, refer to the equivalent sections in the "Small Site Tests" section (p. 31 ff.) of this chapter.

The Effect of Glaciation on Topographic Relief

Topographic relief is less than bedrock relief for eight or nine of the ten sample sites, depending on whether average or maximum relief values are used. The percentage of large sites with reduced topographic relief (eighty or ninety percent) is slightly higher than the small site percentages, keeping in mind that each large site alters the results by ten percent.

Maximum and Average Bedrock Relief

Maximum bedrock relief is not statistically different for sites with masked bedrock/topographic relationships and for sites with non-masked relationships (Table 7). The same was true using average bedrock relief. This is identical to the findings of the small site tests.

Maximum and Average Topographic Relief

Results of the tests indicate that maximum topographic relief is statistically different between sites with masked bedrock/topographic relationships and sites with non-masked relationships (Table 7). The same holds true for average topographic relief. In both cases topographic relief is greater when the form of the bedrock surface is revealed in the topography than when it is masked.

Maximum and Average Drift Thickness

Maximum drift thickness is not statistically different for sites with masked bedrock/topographic relationships and for sites with non-masked relationships (Table 7). The same holds true using average drift thickness.

These results differ from the results for the small site tests. One explanation of the difference may be the less meaningful nature of a large site average (or maximum) drift thickness value (see pp. 6-7). Because large sites encompass a township-size area (which is rarely devoid of at least some rugged relief), and adequate control on the bedrock surface limited the site selection to just a few possibilities, it was frequently impossible to meet the criteria

Table 7. Large Site Mann-Whitney U Test Results

Site Characteristic	Z*	Two-Tailed Probability
Maximum Bedrock Relief	.0000	1.0000
Average Bedrock Relief	.1230	.9021
Maximum Topographic Relief	1.9596	.0500
Average Topographic Relief	2.0996	.0358
Maximum Drift Thickness	.4899	.6242
Average Drift Thickness	.7379	.4606
Drift/Maximum Bedrock Relief Ratio	.2449	.8065
Drift/Average Bedrock Relief Ratio	.2449	.8065

*The Z values are reported as positive numbers. These results are based on a division of the sample sites into groups of 5 correlated and 4 non-correlated sites.

requiring sites to have "bedrock relief that is neither very flat nor very rugged." Consequently, because drift thickness is primarily related to bedrock relief, several large sites may have average drift thickness values that are not representative of the sample area.

Drift/Maximum Bedrock Relief Ratios and
Drift/Average Bedrock Relief Ratios

Using either maximum or average bedrock relief as a measure of bedrock roughness at the sample sites, the results of the large site tests differ from the results for the small site tests. Surprisingly, the drift/relief ratios are not statistically different for masked and non-masked sites. Consequently, the principle hypothesis must be rejected for large sample sites, indicating that: "For any given relief value of the bedrock surface at a sample site in a Wisconsinan glaciated area of the southern Great Lakes region there is no average drift thickness value above which the topographic expression of the bedrock surface is masked." In addition, because a definable relationship does not exist, it would clearly be impossible to find a descriptive mathematical function.

Several reasons can be suggested for the differences in the small and large site drift/bedrock relief ratio results. The primary reason involves the meaningfulness of the large site drift thickness values. The results of the drift thickness tests suggest that there may be problems with the efficacy of the large site drift values. Because the ratios are calculated using drift thickness values, it is possible that the ratios are simply not useful in determining drift/bedrock relief relationships.

Secondly, control on the bedrock surface for many of the large sites was substantially poorer than that for small sites. Because of the problems associated with sample site selection (pp. 14-15), it is possible that several large sites may have areas where the form of the bedrock surface is significantly different than what is shown on available maps.

Furthermore, because there are only ten large sample sites, it was impossible to differentiate masked and non-masked locations accurately. In accordance with the small site results, the line was drawn at the 99.9 percent confidence level--but the large site data are insufficient to support or reject this classification. As a result, the very foundation of the large site tests is dubious.

Finally, if one is willing to dismiss the effect of the preceding problems, sample site size may indeed influence the results of this study. Obviously, the ability to discern whether site size plays a major role in the results is complicated by the many problems associated with using large samples. Even though all of the problems involved with using the large sample sites were recognized in advance of the data collection stage, there was simply no way to avoid the problems (e.g. a lack of site possibilities, poor bedrock control, sites with extreme relief variations, etc.) and still include large samples in the study.

CHAPTER IV

CONCLUSION

The principle discovery of this study is that the topographic expression of bedrock surfaces is limited by a drift thickness threshold that is dependent on local bedrock relief. The implications of this discovery can be divided into two broad categories: geographic and geologic.

Geographic Implications

The primary geographic implication is that topography in the southern Great Lakes region cannot be explained solely in terms of exogenetic (surface) processes--even if the bedrock surface is deeply buried. It has been shown that present topography is substantially influenced by the bedrock surface below the drift/bedrock relief threshold and it may be influenced to some lesser degree above the threshold. As a result, future analyses of landscape development in the "thick drift areas" of the southern Great Lakes region should consider more than just glaciers and glacial processes--they must also consider the form of the bedrock surface and the thickness of the overlying drift.

Geologic Implications

As with many geographical investigations, this study only examined two dimensions in detail (i.e. the variation of surface elevations in X, Y space). The other dimensions--the third (vertical arrangement of drift sediments) and fourth (time), generally fall within the realm of geology. Whereas the results of this study make it possible to define the masking/non-masking relationship and locate sites of each type, the mechanisms and processes actually causing the relationship are only hypothesized (Rieck and Winters, 1979, pp. 285-287).

The fact that a drift/bedrock relationship exists and can be defined suggests that the mechanism(s) causing the relationship may also be identified. Such processes, if discovered, might be unusual in that the presence of the buried organics in Michigan tend to occur in interglacial or interstadial lowlands (Rieck and Winters, 1979, pp. 286-287; Rhoads, 1982), suggesting that the processes have operated in some areas despite repeated glacial advances. And yet, whatever processes are causing the relationship can be overcome by simply increasing drift thickness. If primary evidence for these processes exists, it most likely will be found through a careful stratigraphic analysis of the sediments in both masked and non-masked areas.

Evaluation of Methodology

Several of the statistical techniques used in this study are ideally suited for this type of analysis. In particular, the use of trend surface techniques to compare two surfaces should be noted. The comparison of trend surfaces works best if there is clear reason to believe that two surfaces are or should be related. In geography, few applications are more appropriate than the one used in this study--the relationship of the bedrock surface and the topographic surface directly above it. Although the comparison of trend surfaces did not prove independently significant, the fact that trend surface techniques complemented the findings of the traditional surface correlations suggests that there may be a valuable secondary application of trend surfaces in similar research projects.

Of the other statistical techniques employed, it appears that the sampling pattern densities, the correlation routines, the natural breaks classification routine, and the Mann-Whitney U tests were appropriate and adequate for the tasks being attempted. In addition, there is no reason to doubt that the 95% confidence level for the acceptance of the hypotheses is too rigorous or lenient of a standard.

The weakest link in the study is also the only one beyond direct control--the compilation of the bedrock maps that are used. It was quickly discovered that bedrock topography maps of the southern Great Lakes region are:

1) difficult to locate;
2) of widely varying physical and cartographic quality; and
3) may be of questionable accuracy.

The first two problems are not issues which would be difficult to remedy. The former is because most bedrock topography maps are produced as a supplementary item for related research (i.e. a gravity study, a groundwater study, etc.) and are not listed separately in most geological survey publication indexes, while the latter is due to differing standards among the state geological surveys (which seem to reflect how each survey regards its data distribution responsibilities). The third problem, however, will continue to complicate research on Pleistocene-related topics in the southern Great Lakes region for several decades.

The final quality of bedrock maps depends not only on the compilation and cartographic abilities of those who construct the maps, but also on the ability of the drillers to accurately report their location, elevation and depth to bedrock. Variations in bedrock surface lithology, experience of the drillers/loggers and type of drilling rig used often complicate this procedure. The only practical way to guard against such problems is to carefully examine potential bedrock maps and screen inferior or inaccurate maps. This was attempted by listing all of the available bedrock maps meeting the standard requirements (i.e. 25' contour interval, sufficient numbers of control points, etc.), and then choosing the maps with the best apparent quality.[3]

[3]Such lists were not compiled for Indiana or Michigan. In both of these states I relied on the expertise of Mr. Henry Gray, Indiana State Geological Survey, and Dr. Richard Rieck, Western Illinois University, respectively, to choose areas of the bedrock surface where the control and quality of the bedrock maps is best.

Suggestions for Further Research

The simple structure of this study could be easily applied to many related problems, including a more in-depth analysis of the bedrock/topographic relationship. For example:

1) This analysis might be repeated with large sites scaled four and/or five miles on a side. The township-size samples created numerous problems simply because areas with adequate bedrock control of this scale are difficult to find. Reducing the size of the large sites would certainly facilitate examining the effect of site size on the bedrock/topographic relationship.
2) The theoretical average drift thickness limit (60 meters) that is suggested by the curve equation (see p. 41) could be investigated. This might be done by exploring the drift/bedrock relief relationship in areas where bedrock relief is great and the overlying drift is at least 60 meters thick. Unfortunately, in areas where drift thicknesses reach these magnitudes, the control on the bedrock surface is usually crude at best.
3) This analysis could be performed in other glaciated areas of North America and Europe to see if a drift/bedrock relief threshold exists for these areas as well.
4) This analysis might be performed for glaciated landscapes older than Wisconsinan. For example, it would be interesting to see if a drift/bedrock relief threshold exists for Illinoian glaciated landscapes.
5) This analysis could be performed in a non-glaciated landscape, such as an aggradational river plain. It would be interesting to

know if the sediments, processes, or both are responsible for the surface expression of a bedrock surface in a deeply buried landscape.

6) The characteristics of those sites that were anomalously classified as having a non-masked relationship (i.e. in locations where the drift thickness far exceeded the threshold) could be examined. It would be interesting to determine if a bedrock/ topographic relationship really exists at such a site, or if the arrangement of features on the surfaces is purely coincidental.

APPENDICES

APPENDIX A

SMALL SITE LOCATIONS AND SURFACE ELEVATIONS

SMALL SITE NUMBER 1

Rock County, Wisconsin

Site Location: Sections 13-15, 22-27, T.4N, R.14E
Upper Left Corner: NW Corner, Section 15, T.4N, R.14E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Lima Center, WI	1960/71	10

Bedrock Data Source: LeRoux, E. F., 1963, Geology and Ground Water Resources of Rock County, Wisconsin, U.S.G.S. Water Supply Paper 1619-X, Plate 4.

Topographic Surface Values

865	900	910	885	885	905	884
911	883	915	885	895	895	885
888	895	881	885	895	895	871
885	895	890	885	875	875	870
876	895	915	890	890	875	858
910	925	935	910	945	925	885
930	925	980	945	970	915	953

Bedrock Surface Values

865	900	900	885	885	900	884
888	883	900	885	888	888	875
838	850	863	875	888	875	863
813	816	813	825	838	838	838
825	816	825	825	838	838	838
875	850	850	850	850	863	863
913	900	875	863	863	863	863

SMALL SITE NUMBER 2

Dane County, Wisconsin

Site Location: Sections 4-9, 16-18, T.8N, R.11E
Upper Left Corner: NW Corner, Section 6, T.8N, R.11E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Sun Prairie, WI	1962/82	10

Bedrock Data Source: Cline, D. R., 1965, Geology and Ground-Water Resources of Dane County, Wisconsin, U.S.G.S. Water Supply Paper 1779-U, Plate 5.

Topographic Surface Values

990	995	1015	1000	1000	955	970
994	985	985	985	965	970	996
975	985	968	970	970	980	975
970	965	935	925	955	960	965
935	920	920	955	949	945	955
915	915	948	925	955	960	926
915	925	915	925	927	910	925

Bedrock Surface Values

963	975	1000	988	963	925	963
950	959	920	938	950	925	970
925	938	938	900	888	920	950
900	900	900	888	874	900	925
888	888	888	863	900	913	913
875	875	863	863	920	900	850
888	888	875	863	863	850	840

SMALL SITE NUMBER 3

Winnebago County #1, Wisconsin

Site Location: Sections 12-13, 24, T.20N, R.16E
7-8, 17-20, T.20N, R.17E
Upper Left Corner: NW Corner, Section 12, T.20N, R.16E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Oshkosh NE, WI	1961/75	10
Neenah, WI	1955/75	10

Bedrock Data Source: Olcott, P. G., 1966, Geology and Water Resources of Winnebago County, Wisconsin, U.S.G.S. Water Supply Paper 1814, Plate 1.

Topographic Surface Values

844	817	796	798	809	781	767
879	825	822	819	797	775	769
907	839	831	810	791	777	771
895	845	835	810	789	785	777
902	870	833	825	792	774	765
903	870	833	820	785	774	760
901	862	821	790	780	767	758

Bedrock Surface Values

750	738	738	738	750	763	754
800	763	763	775	763	763	763
813	788	788	788	788	763	763
809	800	800	800	772	763	768
813	813	813	811	788	763	763
805	800	800	800	788	763	750
811	788	788	788	775	763	725

SMALL SITE NUMBER 4

Winnebago County #2, Wisconsin

Site Location: Sections 7-9, 16-21, T.18N, R.15E
Upper Left Corner: NW Corner, Section 7, T.18N, R.15E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Eureka, WI	1961/75	10
Omro, WI	1961/75	10

Bedrock Data Source: Olcott, P. G., 1966, Geology and Water Resources of Winnebago County, Wisconsin, U.S.G.S. Water Supply Paper 1814, Plate 1.

Topographic Surface Values

772	759	760	760	745	745	753
758	765	765	785	755	760	755
745	745	745	750	752	773	768
761	765	795	766	756	765	759
779	793	782	778	759	750	752
785	821	787	781	762	755	757
797	816	793	790	775	782	767

Bedrock Surface Values

613	588	588	613	659	675	713
588	600	638	663	664	713	738
675	688	713	688	663	725	738
750	750	763	688	688	688	688
750	763	694	688	688	675	650
700	775	725	700	675	650	625
688	763	763	761	713	700	712

SMALL SITE NUMBER 5

Vermillion County, Indiana

Site Location: Sections 7-9, 16-21, T.15N, R.9W
Upper Left Corner: NW Corner, Section 7, T.15N, R.9W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Dana, IN	1978/80	10
Clinton, IN	1978	10

Bedrock Data Source: Photocopied map, compliments of Mr. Henry Gray, Head Stratigrapher, Geological Survey, Department of Natural Resources, 611 North Walnut Grove, Bloomington, IN 47405

Topographic Surface Values

655	645	600	634	630	615	626
655	645	630	590	625	610	625
655	635	634	596	622	625	625
635	635	620	615	555	615	610
590	620	625	612	550	595	590
585	570	600	610	555	585	545
624	605	535	560	575	545	545

Bedrock Surface Values

513	500	475	462	450	442	538
475	500	513	500	475	425	450
419	450	492	488	500	463	400
475	438	438	463	463	513	400
486	463	430	425	438	425	363
488	475	450	425	400	373	413
513	488	491	475	425	413	413

SMALL SITE NUMBER 6

Lake County, Indiana

Site Location: Sections 2-4, 9-11, 14-16, T.32N, R.9W
Upper Left Corner: NW Corner, Section 4, T.32N, R.9W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Lowell, IN	1962/80	10
Schneider, IN	1959/80	5

Bedrock Data Source: Photocopied map, compliments of Mr. Henry Gray, Head Stratigrapher, Geological Survey, Department of Natural Resources, 611 North Walnut Grove, Bloomington, IN 47405

Topographic Surface Values

683	685	657	685	680	658	665
686	675	660	680	663	648	661
694	663	650	650	648	648	649
645	643	648	643	643	643	648
638	640	640	638	641	643	640
633	633	635	635	635	635	635
635	633	637	633	633	633	633

Bedrock Surface Values

590	605	605	635	606	595	595
625	620	625	625	595	595	595
630	621	625	624	597	595	590
610	615	625	622	610	595	590
592	610	613	615	615	615	595
596	595	600	595	600	600	595
592	585	575	580	590	590	586

SMALL SITE NUMBER 7

Boone County, Indiana

Site Location: Sections 11-14, 23-24, T.19N, R.2W
7, 18-19, T.19N, R.1W
Upper Left Corner: NW Corner, Section 11, T.19N, R.2W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Hazelrigg, IN	1961/80	10

Bedrock Data Source: Photocopied map, compliments of Mr. Henry Gray, Head Stratigrapher, Geological Survey, Department of Natural Resources, 611 North Walnut Grove, Bloomington, IN 47405

Topographic Surface Values

855	845	855	860	840	875	855
840	865	870	885	882	865	860
883	875	879	880	888	875	897
878	885	865	895	895	900	905
890	885	895	875	903	905	911
890	885	900	905	912	900	915
895	900	910	910	913	905	915

Bedrock Surface Values

738	713	702	700	703	713	719
763	738	700	663	650	663	688
763	738	706	650	616	650	679
763	738	713	663	638	675	725
775	738	714	688	650	700	758
788	750	750	725	725	750	788
788	788	775	763	761	800	838

SMALL SITE NUMBER 8

Pulaski County, Indiana

Site Location: Sections 33-35, T.31N, R.4W
2-4, 9-11, T.30N, R.4W
Upper Left Corner: NW Corner, Section 33, T.31N, R.4W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Medaryville, IN	1962	5
North Judson SE, IN	1962	5

Bedrock Data Source: Photocopied map, compliments of Mr. Henry Gray, Head Stratigrapher, Geological Survey, Department of Natural Resources, 611 North Walnut Grove, Bloomington, IN 47405

Topographic Surface Values

685	698	694	710	715	713	713
678	685	688	700	703	713	703
677	678	680	698	703	705	695
686	683	675	685	695	695	688
685	688	683	678	686	682	678
688	690	683	678	677	678	680
686	688	683	673	674	673	678

Bedrock Surface Values

625	638	637	638	613	613	638
613	625	638	638	625	613	613
613	613	625	638	638	618	613
625	613	625	663	663	623	613
638	613	625	650	650	617	613
638	625	613	625	613	613	600
638	638	638	613	591	588	575

SMALL SITE NUMBER 9

Randolph County, Indiana

Site Location: Sections 15-17, 20-22, 27-29, T.20N, R.14E
Upper Left Corner: NW Corner, Section 17, T.20N, R.14E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Winchester, IN	1960	10

Bedrock Data Source: Photocopied map, compliments of Mr. Henry Gray, Head Stratigrapher, Geological Survey, Department of Natural Resources, 611 North Walnut Grove, Bloomington, IN 47405

Topographic Surface Values

1085	1100	1090	1080	1092	1105	1115
1077	1060	1055	1080	1083	1080	1085
1085	1080	1085	1085	1090	1085	1100
1094	1095	1094	1105	1096	1100	1104
1100	1100	1105	1115	1112	1115	1106
1115	1110	1110	1115	1120	1125	1125
1115	1120	1106	1128	1130	1130	1145

Bedrock Surface Values

763	764	850	950	988	988	988
775	900	925	950	988	1000	1000
775	875	975	1000	1013	1013	1013
767	888	963	1000	1012	1025	1013
800	875	900	950	988	1000	1013
825	850	888	938	963	975	1013
863	875	888	925	950	963	988

SMALL SITE NUMBER 10

Steuben County, Indiana

Site Location: Sections 13-15, 22-27, T.36N, R.12E
Upper Left Corner: NW Corner, Section 15, T.36N, R.12E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Stroh, IN	1959	10
Ashley, IN	1959/81	10

Bedrock Data Source: Photocopied map, compliments of Mr. Henry Gray, Head Stratigrapher, Geological Survey, Department of Natural Resources, 611 North Walnut Grove, Bloomington, IN 47405

Topographic Surface Values

1051	1035	1035	1035	1084	1025	1025
1001	995	1025	1035	1045	1030	1030
995	1010	1014	1050	1060	1045	1029
985	990	990	1040	1035	1035	995
985	985	985	1015	1035	1000	1016
956	980	965	1000	1015	1005	1000
945	955	955	965	979	985	984

Bedrock Surface Values

600	563	650	667	719	650	610
550	575	638	663	675	625	588
615	650	663	663	650	600	538
569	638	650	650	638	588	538
550	550	613	644	625	575	563
539	550	588	638	600	563	590
550	563	588	588	575	575	588

SMALL SITE NUMBER 11

Miami/Cass Counties, Indiana

Site Location: Sections 25-27, 34-36, T.26N, R.3E
1-3, T.25N, R.3E
Upper Left Corner: NW Corner, Section 27, T.26N, R.3E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Onward, IN	1963/80	10

Bedrock Data Source: Rosenshein, J. S., 1959, "Map of Bunker Hill A.F.B. and Vicinity, Peru, Indiana, Showing Location of Wells and Contours on the Bedrock Surface," U.S.G.S. Water Supply Paper 1619-B, Plate 1.

Topographic Surface Values

779	785	780	775	787	785	735
785	785	785	785	785	780	785
783	785	794	790	795	795	795
790	795	795	795	795	795	795
795	795	800	800	795	800	800
805	805	800	810	810	810	811
803	805	805	810	812	815	810

Bedrock Surface Values

680	695	705	725	725	720	735
680	690	705	725	725	715	730
720	715	720	740	740	735	735
735	735	740	740	740	745	735
695	725	730	730	735	740	740
705	700	710	720	730	740	740
710	710	710	715	725	740	745

SMALL SITE NUMBER 12

Miami County, Indiana

Site Location: Sections 13, 24-25, 36, T.29N, R.3E
16-21, 28-33, T.29N, R.4E
Upper Left Corner: Center, Section 13, T.29N, R.3E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Macy, IN	1960/80	10
Deedsville, IN	1960	10

Bedrock Data Source: Thornbury, W. D. and Deane, H. L., 1954, "Map Showing Bedrock Topography of Miami County, Indiana," The Geology of Miami County, Indiana, Indiana Geological Survey Bulletin No. 8, Plate 6.

Topographic Surface Values

837	842	850	845	840	840	850
838	848	840	843	838	850	843
820	833	845	845	850	855	845
840	827	835	840	858	840	850
848	852	850	839	850	853	840
831	857	850	866	845	838	835
835	821	840	835	840	838	850

Bedrock Surface Values

630	600	420	550	670	680	690
630	480	390	460	450	510	580
440	390	390	390	390	390	390
390	390	390	390	390	400	410
440	390	390	390	390	410	520
550	430	390	390	390	510	670
650	580	490	420	390	550	670

SMALL SITE NUMBER 13

Wabash County, Indiana

Site Location: Sections 26-28, 33-35, T.29N, R.7E
2-4, T.28N, R.7E
Upper Left Corner: NW Corner, Section 28, T.29N, R.7E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
North Manchester South, IN	1961	10
Servia, IN	1961	10

Bedrock Data Source: Wayne, W. J. and Thornbury, W. D., 1951, "Map Showing Bedrock Topography in Wabash County, Indiana," _Glacial Geology of Wabash County, Indiana_, Indiana Geological Survey Bulletin No. 5, Plate 6.

Topographic Surface Values

796	801	816	845	873	850	860
806	815	845	840	845	880	883
813	820	830	860	869	875	892
821	840	840	870	875	875	894
840	830	864	865	863	880	886
840	840	846	850	865	890	885
825	830	843	855	857	880	863

Bedrock Surface Values

670	660	620	657	670	680	700
670	670	660	670	680	710	690
670	670	670	690	700	690	690
650	670	690	690	690	690	690
680	670	660	670	690	690	690
690	690	680	650	650	670	670
710	700	690	690	670	620	610

SMALL SITE NUMBER 14

DuPage County #1, Illinois

Site Location: Sections 2-4, 9-11, 14-16, T.40N, R.11E
Upper Left Corner: NW Corner, Section 4, T.40N, R.11E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Elmhurst, IL	1963/72	5

Bedrock Data Source: Zeizel, A. J., 1959, "Topography of Bedrock Surface in DuPage County, Illinois," Illinois Cooperative Ground-Water Report No. 2, Plate 1.

Topographic Surface Values

683	688	723	691	673	674	672
688	685	713	700	680	690	655
690	680	715	695	670	673	668
675	675	713	705	693	675	665
693	688	696	708	688	675	670
700	683	703	705	695	673	673
698	695	703	698	693	683	678

Bedrock Surface Values

610	600	610	580	590	570	570
630	600	590	610	590	590	570
610	590	600	610	590	590	570
620	610	600	610	600	590	550
610	610	590	590	580	580	570
610	590	600	560	540	540	580
610	570	610	590	540	590	620

SMALL SITE NUMBER 15

Woodford County, Illinois

Site Location: Sections 2-4, 9-11, 14-16, T.26N, R.1W
Upper Left Corner: NW Corner, Section 4, T.26N, R.1W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Secor, IL	1970	10

Bedrock Data Source: Heigold, P. C., McGinnis, L. D., and Howard, R. H., 1964, Geologic Significance of the Gravity Field in the DeWitt-McLean County Area, Illinois, Illinois State Geological Survey Circular 369, Figure 4.

Topographic Surface Values

767	765	747	745	736	735	742
775	755	745	755	745	744	742
765	750	757	754	752	745	745
745	753	756	753	750	754	751
765	765	754	752	751	751	750
770	765	756	740	730	725	744
778	764	762	752	749	737	718

Bedrock Surface Values

500	488	463	463	438	438	425
488	475	463	463	438	438	413
488	463	463	450	438	425	413
488	463	463	438	425	413	438
463	463	450	438	413	438	438
463	450	438	400	413	438	463
450	438	425	400	438	463	463

SMALL SITE NUMBER 16

Will County, Illinois

Site Location: Sections 25, 36, T.36N, R.9E
1, T.35N, R.9E
5-6, T.35N, R.10E
29-32, T.36N, R.10E
Upper Left Corner: NW Corner, Section 25, T.36N, R.9E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Plainfield, IL	1962/73/80	10
Joliet, IL	1962/73	10

Bedrock Data Source: Fisher, D. J., 1925, "Topographic Map of the Joliet Quadrangle Showing Contours on the Bedrock Surface and Location of Wells," Illinois State Geological Survey Division Bulletin No. 51, Plate 2.

Topographic Surface Values

610	608	631	643	648	635	645
601	608	620	638	650	645	630
596	618	628	638	647	630	625
594	597	614	625	595	590	620
590	582	585	613	622	640	660
581	615	633	650	660	660	655
626	627	641	649	665	675	650

Bedrock Surface Values

585	585	595	595	615	615	605
585	585	585	600	605	600	585
585	585	590	600	600	585	585
575	585	595	585	585	585	590
575	575	575	585	590	600	605
565	575	585	590	605	615	610
565	575	590	600	615	615	615

SMALL SITE NUMBER 17

Grundy/Kendall Counties, Illinois

Site Location: Sections 26-28, 33-35, T.35N, R.6E
2-4, T.34N, R.6E
Upper Left Corner: NW Corner, Section 28, T.35N, R.6E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Stavanger, IL	1970	10

Bedrock Data Source: Willman, H. B., and Krumbein, W. C., 1941, Bedrock Topography and Mineral Industrial Data of the Marseilles Quadrangle, Illinois State Geological Survey Bulletin No. 66, Plate 4.

Topographic Surface Values

740	730	720	710	700	699	685
740	720	710	725	705	690	675
693	692	675	692	685	664	668
650	655	665	665	655	650	660
649	655	635	635	635	629	624
650	645	635	625	615	615	615
647	629	632	622	614	609	605

Bedrock Surface Values

588	588	588	613	625	613	663
563	588	613	650	652	638	650
550	575	588	613	638	638	638
538	525	563	575	588	600	613
538	525	538	550	563	550	563
513	513	513	525	538	538	525
525	513	513	513	513	513	513

SMALL SITE NUMBER 18

Champaign County, Illinois

Site Location: Sections 1, 12-13, T.19N, R.8E
5-8, 17-18, T.19N, R.9E
Upper Left Corner: NW Corner, Section 1, T.19N, R.8E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Rising, IL	1970/75	5
Thomasboro, IL	1970/75	5
Bondville, IL	1970/75	5
Urbana, IL	1970	5

Bedrock Data Source: Foster, J. W., and Buhle, M. B., 1951, An Integrated Geophysical and Geological Investigation of Aquifers in Glacial Drift Near Champaign-Urbana, Illinois, Illinois State Geological Survey Report of Investigations No. 155, Figure 5.

Topographic Surface Values

513	513	513	488	488	488	500
488	488	488	488	463	475	488
475	488	488	463	463	463	475
450	463	463	450	438	463	463
438	438	438	438	425	438	450
413	413	413	413	400	413	413
388	388	388	388	388	388	388

Bedrock Surface Values

751	755	753	735	728	733	737
755	743	738	735	738	700	733
758	755	733	738	742	708	735
768	758	725	738	739	708	700
778	742	723	720	725	710	725
776	748	728	740	730	724	731
759	753	738	760	750	733	733

SMALL SITE NUMBER 19

DeWitt County, Illinois

Site Location: Sections 13, 24-25, T.21N, R.3E
17-20, 29-30, T.21N, R.4E
Upper Left Corner: NW Corner, Section 13, T.21N, R.3E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
LeRoy, IL	1981	5
DeWitt, IL	1979	5

Bedrock Data Source: Heigold, P. C., McGinnis, L. D., and Howard, R. H., 1964, Geologic Significance of the Gravity Field in the DeWitt-McLean County Area, Illinois, Illinois State Geological Survey Circular 369, Figure 4.

Topographic Surface Values

786	762	768	730	746	711	741
782	778	770	755	714	743	747
778	772	740	734	717	748	748
764	765	744	720	733	750	731
749	767	751	708	730	753	748
783	760	725	735	757	758	755
783	735	718	755	756	755	754

Bedrock Surface Values

588	588	588	588	575	563	563
588	575	563	563	563	563	563
563	563	550	550	550	550	550
575	563	550	538	538	538	538
575	563	538	538	538	538	538
575	563	550	538	538	538	538
588	575	563	563	563	563	538

SMALL SITE NUMBER 20

Winnebago County, Illinois

Site Location: Sections 8-10, 15-17, 20-22, T.44N, R.1E
Upper Left Corner: NW Corner, Section 8, T.44N, R1E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Winnebago, IL	1971/76	10
Rockford North, IL	1971/76	10

Bedrock Data Source: Hackett, J. E., 1958, "Topography of Bedrock Surface of Winnebago County, Illinois," Illinois Geological Survey Report of Investigations No. 213, Plate 1.

Topographic Surface Values

750	741	775	810	797	760	750
819	773	735	750	750	725	738
769	742	735	725	722	724	739
802	805	735	755	725	727	740
805	775	770	780	805	770	735
820	825	820	765	755	725	735
825	770	760	750	735	750	710

Bedrock Surface Values

700	700	763	775	775	750	725
800	773	725	725	738	725	700
688	688	675	638	650	663	588
713	788	725	732	688	650	738
785	775	770	775	775	750	735
813	800	763	725	700	610	650
800	750	700	725	725	700	670

SMALL SITE NUMBER 21

DuPage County #2, Illinois

Site Location: Sections 32-34, T.40N, R.9E
3-5, 8-10, T.39N, R.9E
Upper Left Corner: NW Corner, Section 32, T.40N, R.9E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
West Chicago, IL	1962/72/80	10
Naperville, IL	1962/72/80	10

Bedrock Data Source: Zeizel, A. J., 1959, "Topography of Bedrock Surface in DuPage County, Illinois," Illinois Cooperative Ground-Water Report No. 2, Plate 1.

Topographic Surface Values

753	750	760	780	785	770	761
754	755	765	775	795	750	740
751	755	755	767	765	795	765
750	755	755	755	795	785	785
745	750	760	755	780	795	757
740	745	755	755	755	785	755
735	755	743	735	746	746	724

Bedrock Surface Values

690	690	690	690	690	670	670
670	690	690	690	690	680	670
690	690	690	670	670	670	660
690	690	670	680	680	660	640
690	690	680	670	680	670	650
680	680	670	670	620	640	640
660	660	650	640	640	630	610

SMALL SITE NUMBER 22

Huron County #1, Ohio

Site Location: Connecticut Western Reserve Survey. Point 24 coincides with the 493 B.M. 1/8 mile north of Celeryville, Ohio, on the Willard, Ohio, quadrangle. This is the intersection of Bullhead Road and Ohio Highway 103. Sample points are taken at 1/2 mile intervals away from this point, using the same highways as baselines.

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Centerton, OH	1960/72	10
Willard, OH	1960/72	10

Bedrock Data Source: "Open File Map of Huron County, Ohio," available from Ohio Department of Natural Resources, Division of Geological Survey, Fountain Square, Building B, Columbus, OH, 43224

Topographic Surface Values

925	920	930	930	940	960	945
930	940	935	955	965	945	950
955	970	968	940	945	935	930
958	940	943	928	925	930	925
930	940	925	925	923	923	925
930	925	923	928	923	930	930
935	928	928	928	928	925	935

Bedrock Surface Values

810	810	830	800	840	850	850
810	810	830	810	830	850	860
810	830	840	840	820	860	870
820	830	840	850	830	850	870
830	830	860	850	850	830	860
830	840	870	880	870	860	840
840	850	860	870	890	900	890

SMALL SITE NUMBER 23

Huron County #2, Ohio

Site Location: Connecticut Western Reserve Survey. The upper left corner (point 1) corresponds with Barretts Chapel at the intersection of Cook Road and Ohio Highway 60, Clarksfield quadrangle. The sample grid runs due south and due east at 1/2 mile intervals from this point.

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Clarksfield, OH	1960/72	5
Brighton, OH	1960/73	5
New London, OH	1960/72	10
Nova, OH	1960/73	10

Bedrock Data Source: "Open File Map of Huron County, Ohio," available from Ohio Department of Natural Resources, Division of Geological Survey, Fountain Square, Building B, Columbus, OH, 43224

Topographic Surface Values

930	933	938	940	929	947	940
937	948	948	945	953	953	943
954	955	950	940	955	955	935
940	962	962	947	955	955	950
965	965	965	965	960	950	960
955	973	967	958	973	960	972
980	970	975	975	985	980	983

Bedrock Surface Values

870	870	860	850	850	850	800
870	830	820	820	820	820	780
860	790	760	770	750	750	780
820	820	860	850	840	810	810
820	870	870	860	850	850	840
870	890	900	870	870	860	870
870	910	920	880	880	890	890

SMALL SITE NUMBER 24

Logan County, Ohio

Site Location: The lower left corner (point 43) corresponds with the 1138 B.M. at the intersection of Ohio Highways 292 and 47 on the West Mansfield quadrangle. From this point the sample grid runs due north and due east, with control points at 1/2 mile intervals.

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
West Mansfield, OH	1961	5

Bedrock Data Source: Forsyth, J. L., 1968, Glacial Geology of the West Mansfield Quadrangle, Logan and Union Counties, Ohio, Ohio Geological Survey, Reports of Investigation No. 69.

Topographic Surface Values

1103	1093	1075	1078	1075	1078	1078
1105	1098	1083	1085	1078	1078	1055
1115	1095	1088	1085	1083	1078	1070
1120	1098	1093	1090	1078	1075	1075
1128	1100	1100	1100	1085	1075	1078
1130	1090	1108	1098	1090	1083	1075
1138	1098	1115	1110	1093	1088	1080

Bedrock Surface Values

1050	1030	1020	1010	1010	1010	1010
1050	1030	1030	1030	1020	1010	1010
1050	1050	1040	1030	1030	1020	1010
1060	1060	1050	1040	1030	1020	1000
1070	1070	1050	1030	1020	1000	960
1070	1050	1030	1010	990	970	990
1040	1020	1010	990	1000	1010	1020

SMALL SITE NUMBER 25

Fulton County #1, Ohio

Site Location: Sections 28-33, T.7N, R.5E
4-6, T.6N, R.5E
Upper Left Corner: NW Corner, Section 30, T.7N, R.5E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Archbold, OH	1959/71	5

Bedrock Data Source: Vormelker, J. D., 1971, "Bedrock Surface Map of Fulton County, Ohio," Open File Map No. 28, Ohio Department of Natural Resources, Division of Geological Survey, Columbus, OH.

Topographic Surface Values

716	718	720	723	726	723	738
717	718	723	719	726	730	741
719	723	720	725	733	740	744
724	724	726	728	733	740	723
723	724	725	726	737	742	725
724	725	726	724	723	720	720
725	725	711	709	725	728	733

Bedrock Surface Values

560	570	570	550	570	570	550
560	580	590	580	560	590	570
560	550	570	590	582	590	590
564	570	570	570	570	590	592
560	570	580	590	590	600	600
580	570	580	590	600	610	610
590	590	590	590	600	610	610

SMALL SITE NUMBER 26

Crawford County, Ohio

Site Location: Sections 24-25, 36, T.1S, R.15E
19-20, 29-32, T.1S, R.16E
Upper Left Corner: NW Corner, Section 24, T.1S, R.15E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Lykens, OH	1960	10

Bedrock Data Source: "Top-of-Rock Map of Huron County, Ohio," available from Ohio Department of Natural Resources, Division of Geological Survey, Fountain Square, Building B, Columbus, OH, 43224

Topographic Surface Values

937	939	947	940	958	965	966
935	950	945	950	965	975	975
948	955	920	930	965	960	961
925	920	925	970	965	970	955
939	950	963	975	971	983	971
945	945	965	980	975	985	985
951	960	971	989	991	995	998

Bedrock Surface Values

890	890	910	910	910	920	910
890	890	910	910	910	910	910
890	910	900	910	910	910	910
910	900	910	910	910	900	910
900	890	910	890	900	910	910
890	890	890	900	910	900	910
880	870	890	900	910	910	910

SMALL SITE NUMBER 27

Van Wert County, Ohio

Site Location: Sections 4-9, 16-18, T.3S, R.2E
Upper Left Corner: NW Corner, Section 6, T.3S, R.2E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Glenmore, OH	1960	5

Bedrock Data Source: Vormelker, J. D., 1981, "Top-of-Rock Map of Van Wert County, Ohio," Ohio Geological Survey, Open File Map No. 115.

Topographic Surface Values

818	813	806	803	804	808	798
815	813	810	815	805	805	810
813	813	815	815	813	808	810
813	815	813	813	809	805	810
811	815	810	809	818	815	816
822	818	813	816	822	815	813
828	823	822	829	819	818	822

Bedrock Surface Values

663	663	713	638	713	738	763
700	663	638	663	725	750	763
738	675	638	713	725	763	763
713	663	650	675	713	738	763
713	713	688	650	738	738	763
763	738	700	650	738	750	763
763	738	638	650	738	763	763

SMALL SITE NUMBER 28

Fulton County #2, Ohio

Site Location: Sections 8-10, 15-17, 20-22, T.7N, R.8E
Upper Left Corner: NW Corner, Section 8, T.7N, R.8E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Swanton, OH	1960/71	5

Bedrock Data Source: Vormelker, J. D., 1971, "Bedrock Surface Map of Fulton County, Ohio," Open File Map No. 28, Ohio Department of Natural Resources, Division of Geological Survey, Columbus, OH.

Topographic Surface Values

729	723	719	716	707	699	692
722	717	711	703	698	688	688
713	703	703	697	691	688	685
706	698	695	693	689	688	683
703	695	694	688	688	684	682
701	698	692	689	684	681	670
697	696	690	683	680	678	681

Bedrock Surface Values

600	610	614	610	600	590	620
590	620	630	630	610	600	630
610	620	630	630	610	600	630
610	620	621	630	610	610	620
630	620	630	630	610	620	617
630	620	630	630	610	630	620
630	620	630	630	630	630	610

SMALL SITE NUMBER 29

Ashtabula County, Ohio

Site Location: The lower left corner (point 43) corresponds with the intersection of Clay Street and Chapel Road on the Ashtabula quadrangle. From this point the sample grid runs due north and due east, with control points at 1/2 mile intervals.

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Ashtabula South, OH	1960/70	10

Bedrock Data Source: White, G. W., and Totten, S. M., 1979, Glacial Geology of Ashtabula County, Ohio, Ohio Geological Survey, Report of Investigations No. 112, Plate 1.

Topographic Surface Values

810	835	860	880	850	845	840
854	865	840	830	835	850	855
850	835	830	835	850	845	840
830	825	830	850	845	845	845
837	865	855	845	845	855	875
840	835	845	835	865	865	865
835	850	850	865	865	845	870

Bedrock Surface Values

738	738	750	775	800	813	788
750	763	763	763	763	788	813
775	763	738	750	800	800	800
750	738	750	763	800	800	800
800	813	825	813	813	813	825
813	800	800	800	825	825	850
813	813	825	825	825	838	838

SMALL SITE NUMBER 30

Lapeer County #1, Michigan

Site Location: Sections 1-3, 10-15, T.6N, R.9E
Upper Left Corner: NW Corner, Section 3, T.6N, R.9E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Hadley, MI	1968	10
Metamora, MI	1968	10

Bedrock Data Source: Rieck, R. L., 1983, "Bedrock Topography of Lapeer County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

890	900	880	845	890	900	925
890	865	880	895	885	890	925
875	880	892	885	901	910	929
890	895	898	925	920	955	994
905	910	927	935	937	950	1001
915	940	960	945	975	1015	1015
937	975	985	1000	1095	1050	1043

Bedrock Surface Values

750	750	750	725	763	761	775
763	763	750	763	752	776	763
788	798	766	775	788	763	800
788	800	786	775	788	800	800
738	764	788	788	788	800	825
732	775	805	795	784	800	808
738	750	800	845	788	795	820

SMALL SITE NUMBER 31

Lapeer County #2, Michigan

Site Location: Sections 1-3, 10-15, T.7N, R.10E
Upper Left Corner: NW Corner, Section 3, T.7N, R.10E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Lapeer, MI	1963	10
Attica, MI	1963	10

Bedrock Data Source: Rieck, R. L., 1983, "Bedrock Topography of Lapeer County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

853	832	835	825	845	876	843
871	850	835	835	842	845	876
830	861	865	847	846	845	859
841	840	845	855	845	855	855
849	835	857	867	885	849	850
862	868	870	865	858	855	866
881	852	864	880	863	858	867

Bedrock Surface Values

739	750	750	750	731	770	732
750	763	763	750	725	738	788
738	750	775	763	735	768	763
781	763	788	788	788	788	775
800	750	825	800	800	750	750
800	763	813	800	775	738	738
800	765	788	775	800	775	775

SMALL SITE NUMBER 32

Livingston County #1, Michigan

Site Location: Sections 1-2, 11-14, T.3N, R.3E
6-7, 18, T.3N, R.4E
Upper Left Corner: NW Corner, Section 2, T.3N, R.3E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Fowlerville, MI	1973	10

Bedrock Data Source: Rieck, R. L., 1983, "Bedrock Topography of Livingston County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

920	935	929	925	935	940	920
915	925	915	930	906	915	920
910	905	910	928	915	915	926
900	895	915	905	903	915	935
900	895	909	910	898	915	920
905	895	900	895	899	910	941
896	897	890	895	898	915	915

Bedrock Surface Values

838	838	825	800	838	835	788
838	838	825	775	775	788	813
815	840	850	838	788	813	819
838	825	825	838	838	813	813
838	838	838	838	800	825	813
850	838	838	830	800	788	825
825	825	800	800	788	825	825

SMALL SITE NUMBER 33

Livingston County #2, Michigan

Site Location: Sections 13, 24-25, T.1N, R.4E
17-20, 29-30, T.1N, R.5E
Upper Left Corner: NW Corner, Section 13, T.1N, R.4E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Pinckney, MI	1965	10
Hamburg, MI	1965	10

Bedrock Data Source: Rieck, R. L., 1983, "Bedrock Topography of Livingston County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

915	915	885	895	895	890	887
930	925	905	909	885	915	870
884	885	905	875	875	900	884
885	895	890	895	900	865	905
879	875	895	890	905	855	855
865	870	870	880	885	870	855
870	855	855	865	865	855	850

Bedrock Surface Values

825	800	788	813	825	838	838
813	813	825	812	813	863	838
825	850	825	800	825	825	838
850	845	850	750	788	800	825
863	838	788	763	738	763	763
738	763	788	788	725	740	688
800	775	763	738	688	750	675

SMALL SITE NUMBER 34

Muskegon County, Michigan

Site Location: Sections 19-21, 28-33, T.9N, R.14W
Upper Left Corner: NW Corner, Section 19, T.9N, R.14W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Sullivan, MI	1972	5
Nunica, MI	1972	10
Ravenna, MI	1980	10
Coopersville, MI	1980	10

Bedrock Data Source: Rieck, R. L., 1984, "Bedrock Topography of Muskegon County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

660	662	660	662	670	692	695
657	660	660	645	661	675	685
651	651	665	656	657	665	640
648	655	657	653	645	625	668
651	645	603	640	645	659	663
653	653	655	669	672	665	661
641	668	665	681	681	675	670

Bedrock Surface Values

413	425	438	438	450	438	438
413	425	438	438	463	463	463
425	427	438	438	433	450	473
441	438	438	450	463	463	480
438	450	463	450	450	463	463
438	438	450	463	463	463	463
463	463	463	463	463	463	463

SMALL SITE NUMBER 35

Allegan County #1, Michigan

Site Location: Sections 19-21, 28-33, T.4N, R.12W
Upper Left Corner: NW Corner, Section 19, T.4N, R.12W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Burnips, MI	1981	10
Wayland, MI	1982	10

Bedrock Data Source: Rieck, R. L., 1980, "Bedrock Topography of Allegan County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

670	674	679	690	696	705	701
674	675	684	698	730	705	698
678	685	688	693	766	725	704
683	688	689	755	770	740	725
686	705	710	741	748	771	721
700	680	715	765	730	735	747
734	705	707	721	729	735	714

Bedrock Surface Values

600	610	525	538	513	538	550
575	550	588	525	600	650	600
458	519	575	538	638	650	625
475	463	463	463	463	488	513
513	575	538	538	501	525	525
438	550	588	583	588	673	613
438	525	625	588	618	650	663

SMALL SITE NUMBER 36

Allegan County #2, Michigan

Site Location: Sections 36, T.2N, R.16W
31-32, T.2N, R.15W
1, 12, T.1N, R.16W
5-8, T.1N, R.15W
Upper Left Corner: NW Corner, Section 36, T.2N, R.16W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Glenn, MI	1981	10
Pullman, MI	1981	10
Lacota, MI	1981	10
Fennville, MI	1981	5

Bedrock Data Source: Rieck, R. L., 1980, "Bedrock Topography of Allegan County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

635	634	638	635	630	640	654
644	640	642	648	639	650	668
655	640	637	643	655	641	657
667	642	643	648	634	638	650
636	634	631	643	634	637	655
647	633	642	640	644	638	650
682	637	637	641	641	642	648

Bedrock Surface Values

525	463	425	463	413	400	425
513	500	475	488	450	400	375
450	488	499	488	475	463	463
413	463	463	475	466	488	488
389	450	450	524	490	463	488
300	400	438	525	513	475	513
363	350	425	475	567	538	525

SMALL SITE NUMBER 37

Lenawee County, Michigan

Site Location: Sections 15-17, 20-22, 27-29, T.8S, R.2E
Upper Left Corner: NW Corner, Section 17, T.8S, R.2E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Clayton, MI	1962/79	10
Morenci, OH-MI	1960	5

Bedrock Data Source: Rieck, R. L., 1983, "Bedrock Topography of Lenawee County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

808	802	798	798	793	790	783
787	790	790	788	788	785	785
800	785	780	785	787	788	783
795	785	780	783	788	795	783
785	775	778	783	787	795	790
780	778	773	788	787	803	805
778	773	770	782	793	788	790

Bedrock Surface Values

625	613	600	588	588	588	588
638	600	588	588	588	613	625
625	625	613	588	625	625	613
600	613	613	588	600	588	588
590	575	613	588	588	600	613
575	563	600	575	588	588	588
575	563	569	575	600	588	588

SMALL SITE NUMBER 38

Clinton County #1, Michigan

Site Location: Sections 10-15, 22-24, T.7N, R.2W
Upper Left Corner: NW Corner, Section 10, T.7N, R.2W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
St. Johns North, MI	1965	5
St. Johns South, MI	1965	5
Price, MI	1972/82	10

Bedrock Data Source: Rieck, R. L., 1984, "Bedrock Topography of Clinton County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

745	755	755	750	758	745	753
765	768	765	757	758	765	758
764	768	766	764	756	758	759
772	768	765	763	760	752	754
754	752	764	765	760	755	745
753	750	748	750	753	745	745
747	740	744	745	748	746	750

Bedrock Surface Values

638	613	613	613	613	625	638
613	613	588	600	625	638	650
600	588	588	625	663	669	663
600	613	625	638	663	663	663
603	608	638	638	663	663	663
613	638	632	638	663	663	675
613	613	613	638	663	663	688

SMALL SITE NUMBER 39

Clinton County #2, Michigan

Site Location: Sections 13, 24-25, T.5N, R.3W
17-20, 29-30, T.5N, R.2W
Upper Left Corner: NW Corner, Section 13, T.5N, R.3W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Lansing North, MI	1965	10

Bedrock Data Source: Rieck, R. L., 1984, "Bedrock Topography of Clinton County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

844	824	819	830	844	848	815
785	790	805	845	855	855	830
840	849	843	865	845	837	825
815	845	850	845	865	845	865
840	830	850	865	850	845	840
855	850	860	855	835	855	840
864	855	842	845	845	835	840

Bedrock Surface Values

713	725	725	690	719	738	738
738	738	738	725	713	731	740
795	753	738	713	765	738	738
763	763	725	725	763	738	725
764	738	713	750	763	741	738
760	738	713	763	763	738	738
763	750	756	763	763	763	725

SMALL SITE NUMBER 40

Tuscola County #1, Michigan

Site Location: Sections 16-21, 28-30, T.11N, R.8E
Upper Left Corner: NW Corner, Section 18, T.11N, R.8E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Vassar, MI	1963/73	10

Bedrock Data Source: Rieck, R. L., 1984, "Bedrock Topography of Tuscola County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

630	649	650	655	667	665	675
643	645	660	675	680	680	690
630	651	661	677	685	688	694
653	645	655	665	665	670	690
670	670	650	665	678	677	696
677	675	675	670	683	695	700
673	685	685	678	690	701	711

Bedrock Surface Values

563	563	578	600	588	592	600
600	588	588	600	617	600	575
588	583	588	600	613	613	600
588	600	588	600	613	613	613
600	588	591	588	613	614	638
605	588	604	613	613	588	625
588	588	588	623	588	638	613

SMALL SITE NUMBER 41

Tuscola County #2, Michigan

Site Location: Sections 4-9, 16-18, T.10N, R.8E
Upper Left Corner: NW Corner, Section 6, T.10N, R.8E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Vassar, MI	1963/73	10

Bedrock Data Source: Rieck, R. L., 1984, "Bedrock Topography of Tuscola County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

673	685	696	700	699	706	724
685	690	695	705	710	720	735
694	695	703	710	720	735	739
685	700	711	730	730	740	750
692	710	710	735	745	755	758
708	715	733	745	755	756	765
740	735	757	762	762	763	771

Bedrock Surface Values

600	600	613	613	613	625	638
588	588	588	613	638	650	638
593	597	625	638	638	650	650
574	600	613	613	650	638	650
588	588	592	650	638	663	625
588	600	625	613	650	663	663
613	613	638	657	638	668	638

APPENDIX B

LARGE SITE LOCATIONS AND SURFACE ELEVATIONS

LARGE SITE NUMBER 1

Winnebago County, Wisconsin

Site Location: Sections 13, 24-25, 36, T.18N, R.15E
1, 12, T.17N, R.15E
2-11, T.17N, R.16E
14-23, 26-35, T.18N, R.16E
Upper Left Corner: NW Corner, Section 13, T.18N, R.15E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Omro, WI	1961/75	10
Oshkosh, WI	1961/75	10
Pickett, WI	1980	10
Van Dyne, WI	1980	10

Bedrock Data Source: Olcott, P. G., 1966, Geology and Water Resources of Winnebago County, Wisconsin, U.S.G.S. Water Supply Paper 1814, Plate 1.

Topographic Surface Values

773	840	835	830	793	775	754	750	745	745	755	768	760
828	847	830	825	785	780	770	765	750	755	745	765	765
817	841	821	805	789	795	791	785	760	755	750	760	769
813	816	819	800	795	798	791	770	766	760	752	745	755
802	825	821	805	802	795	780	779	775	760	765	753	755
821	825	820	805	805	795	785	785	780	745	765	765	755
843	830	833	811	801	809	814	815	805	789	775	775	765
841	815	811	815	818	825	819	825	825	805	785	785	765
824	848	823	821	836	845	850	841	837	815	804	781	769
848	835	842	845	845	850	852	845	839	830	813	795	776
866	859	850	845	857	865	856	845	844	822	820	805	789
869	865	876	865	889	850	855	860	847	835	817	805	794
854	885	888	883	879	884	883	870	860	852	821	810	793

LARGE SITE NUMBER 1

Winnebago County, Wisconsin

Bedrock Surface Values

700	800	813	813	763	738	725	725	713	700	675	688	713
750	828	813	808	750	730	738	738	731	713	713	675	713
763	788	788	775	738	750	763	738	725	725	713	700	688
763	788	788	763	750	775	775	725	738	738	738	713	700
763	788	788	788	775	775	738	750	739	738	738	725	713
763	788	788	788	779	763	738	763	763	745	763	750	738
800	788	788	788	788	763	775	788	788	788	763	763	738
813	813	811	800	788	788	800	813	813	788	763	763	747
813	813	813	813	788	813	825	813	788	775	763	763	752
813	813	813	813	813	825	813	788	775	763	775	763	750
813	813	813	813	833	813	813	788	775	788	788	763	753
825	813	813	813	813	825	813	800	788	800	813	775	775
850	825	838	813	825	825	813	826	813	813	797	788	775

LARGE SITE NUMBER 2

Steuben County, Indiana

Site Location: Sections 1-5, 8-17, 20-29, 32-36, T.36N, R.12E
6-7, 18-19, 30-31, T.36N, R.13E
Upper Left Corner: NW Corner, Section 5, T.36N, R.12E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Stroh, IN	1959	10
Ashley, IN	1959/81	10

Bedrock Data Source: Photocopied map, compliments of Mr. Henry Gray, Head Stratigrapher, Geological Survey, Department of Natural Resources, 611 North Walnut Grove, Bloomington, IN 47405

Topographic Surface Values

1017	1010	985	1035	1045	1035	1005	995	965	960	955	950	975
1029	1018	1025	1020	1034	1039	1049	1031	969	970	965	940	945
1007	1040	1024	1005	1056	1060	1057	1030	1048	1005	976	965	967
975	1030	1045	1060	1065	1060	1045	1050	1055	1050	1010	1005	980
956	1007	1015	1038	1051	1035	1035	1035	1084	1025	1025	1005	986
940	963	945	1000	1001	995	1025	1035	1045	1030	1030	1020	995
927	955	975	985	995	1010	1014	1050	1060	1045	1029	1025	1011
935	940	935	990	985	990	990	1040	1035	1035	995	1005	1005
985	945	950	990	985	985	985	1015	1035	1000	1016	1015	1002
965	975	931	935	956	980	965	1000	1015	1005	1000	1005	1000
985	975	949	940	945	955	955	965	979	985	984	985	992
985	985	964	950	940	945	960	940	945	950	985	975	975
980	960	960	950	953	975	976	960	965	985	988	995	1000

LARGE SITE NUMBER 2

Steuben County, Indiana

Bedrock Surface Values

566	575	588	600	613	613	625	638	638	638	640	550	538
563	575	588	600	613	625	638	638	637	638	638	575	550
563	575	588	613	625	638	638	638	638	638	625	613	600
563	575	588	613	626	613	638	663	700	650	613	613	613
563	563	588	600	600	563	650	667	719	650	610	613	618
563	563	563	563	550	575	638	663	675	625	588	575	600
563	563	550	550	615	650	663	663	650	600	538	538	575
563	563	550	538	569	638	650	650	638	588	538	550	550
588	588	582	550	550	550	613	644	625	575	563	575	575
613	617	588	563	539	550	588	638	600	563	590	588	600
613	613	588	563	550	563	588	588	575	575	588	600	613
613	600	588	563	550	570	578	575	563	575	600	613	613
600	592	575	563	543	563	588	596	588	613	613	613	613

LARGE SITE NUMBER 3

Wabash County, Indiana

Site Location: Sections 25-36, T.27N, R.6E
1-24, T.26N, R.6E
Upper Left Corner: NW Corner, Section 30, T.27N, R.6E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Rich Valley, IN	1963/81	10
Wabash, IN	1963/81	10
Peoria, IN	1969	10
Somerset, IN	1969	10

Bedrock Data Source: Wayne, W. J., and Thornbury, W. D., 1951, "Map Showing Bedrock Topography in Wabash County, Indiana," Glacial Geology of Wabash County, Indiana, Indiana Geological Survey Bulletin No. 5, Plate 6.

Topographic Surface Values

770	775	767	770	788	785	793	795	797	797	795	795	795
785	770	765	745	780	785	795	795	800	805	805	805	800
780	785	794	760	797	785	789	795	797	800	800	805	804
795	790	795	775	795	795	805	795	795	795	805	805	805
795	795	799	795	799	800	804	805	802	795	804	805	805
795	800	805	795	805	805	805	805	795	805	805	800	804
805	805	802	805	803	805	805	805	807	805	809	795	780
800	805	805	805	806	805	810	805	807	805	799	770	770
770	800	797	805	805	800	802	795	794	770	780	765	770
700	705	770	805	782	770	791	785	785	765	766	765	735
795	780	690	700	730	800	802	800	760	725	760	735	730
785	790	790	705	760	805	775	720	775	810	720	815	790
801	806	800	745	745	715	740	810	812	810	813	805	779

LARGE SITE NUMBER 3

Wabash County, Indiana

Bedrock Surface Values

560	500	600	750	780	750	650	510	620	600	590	700	740
430	420	590	710	780	770	500	600	730	690	600	750	750
410	390	500	600	640	520	550	660	700	620	640	750	760
510	400	430	470	490	500	570	650	730	670	680	720	750
520	400	410	420	460	530	640	570	630	670	650	650	750
610	600	540	420	410	420	430	450	500	490	590	690	750
700	690	670	580	510	430	410	420	430	530	630	710	750
730	720	710	660	610	510	460	490	410	460	600	640	690
700	740	710	650	560	540	590	590	560	470	410	520	540
650	640	630	640	560	620	680	670	630	610	560	420	410
710	710	690	700	580	610	720	750	690	650	630	610	530
700	690	701	705	580	620	710	720	750	680	660	640	610
720	650	710	690	600	640	740	750	760	700	690	660	650

LARGE SITE NUMBER 4

DuPage County, Illinois

Site Location: Sections 1-4, 9-16, 21-28, 33-36, T.38N, R.10E
5-8, 17-20, 29-32, T.38N, R.11E
Upper Left Corner: NW Corner, Section 4, T.38N, R.10E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Romeoville, IL	1962/73/80	10
Sag Bridge, IL	1963/73	5
Wheaton, IL	1962/72/80	10
Hinsdale, IL	1963/72/80	5

Bedrock Data Source: Zeizel, A. J., 1959, "Topography of the Bedrock Surface in DuPage County, Illinois," Illinois Cooperative Ground-Water Report #2, Plate 1.

Topographic Surface Values

755	735	695	675	673	720	738	745	685	725	735	750	763
735	750	725	663	685	710	760	770	750	735	740	742	765
735	735	740	663	685	695	715	745	749	730	735	731	731
725	720	680	663	725	705	698	695	705	705	715	725	733
719	730	715	668	725	745	750	735	740	760	725	730	723
750	730	720	668	685	740	752	745	735	755	755	765	763
740	740	720	685	658	685	703	714	738	745	745	765	759
745	750	725	675	655	735	750	765	755	750	760	755	772
735	765	725	680	653	725	729	745	790	765	755	770	765
740	745	735	715	650	730	750	753	770	775	775	776	775
723	755	758	730	650	700	734	751	778	765	765	755	750
715	745	743	700	650	715	746	758	763	760	775	750	745
724	720	693	685	645	685	733	761	745	765	755	760	711

LARGE SITE NUMBER 4

DuPage County, Illinois

Bedrock Surface Values

670	670	670	650	650	650	630	650	630	640	620	590	610
650	650	650	630	620	610	630	600	650	630	650	590	630
650	650	650	610	630	630	630	630	640	650	650	630	640
690	660	650	590	630	630	620	640	630	630	650	650	620
670	670	630	590	630	670	660	620	630	650	610	610	600
650	640	630	610	630	670	670	620	620	600	620	630	610
650	640	640	590	610	650	650	630	650	650	610	650	630
670	640	640	620	620	650	670	680	670	640	640	670	630
670	660	630	650	590	650	650	680	650	630	670	660	670
650	630	650	610	610	630	650	650	650	620	650	650	650
650	650	630	630	610	620	630	650	610	630	630	640	630
640	650	630	640	600	670	600	630	620	630	640	630	620
650	640	650	600	590	610	610	650	630	570	630	630	630

LARGE SITE NUMBER 5

McLean County, Illinois

Site Location: Sections 1-36, T.24N, R.6E
Upper Left Corner: NW Corner, Section 6, T.24N, R.6E

Topographic Data Source:

U.S.G.S. Quadrangle (1:62250)	Date(s)	C.I. (ft.)
Colfax, IL	1957	10
Sibley, IL	1949	10
Arrowsmith, IL	1962	10
Gibson City, IL	1957	10

Bedrock Data Source: Heigold, P. C., McGinnis, L. D., and Howard, R. H., 1964, Geologic Significance of the Gravity Field in the DeWitt-McLean County Area, Illinois, Illinois State Geological Survey, Circular 369, Figure 4.

Topographic Surface Values

770	780	784	781	782	775	787	770	768	790	788	790	790
760	760	755	760	765	760	755	760	755	760	765	765	770
754	750	750	750	755	760	764	765	763	765	765	770	770
765	760	765	755	765	770	765	765	775	770	770	770	785
771	770	766	760	769	775	776	780	798	800	775	770	772
780	770	765	770	780	775	785	795	810	795	775	775	785
783	775	773	775	784	790	796	815	811	790	787	805	803
785	785	780	785	790	805	805	820	805	785	795	815	825
796	795	793	800	818	820	824	825	792	815	816	830	827
805	810	800	810	820	830	835	800	815	820	835	840	850
819	820	819	835	836	845	823	805	837	845	839	850	830
830	835	845	855	855	840	825	830	855	880	855	845	825
854	860	889	880	861	845	834	835	866	865	837	835	809

LARGE SITE NUMBER 5

McLean County, Illinois

Bedrock Surface Values

600	613	613	613	613	613	600	588	588	563	563	550	538
613	613	613	613	613	625	613	613	600	588	563	563	550
613	613	625	638	638	638	638	625	613	600	588	563	563
625	638	638	650	663	663	650	638	625	613	588	563	563
638	663	663	663	663	663	663	638	625	613	588	575	563
663	675	688	688	688	675	663	650	638	613	588	575	563
688	700	700	688	688	688	663	650	625	613	588	563	550
713	725	725	713	688	688	663	638	625	600	588	550	538
738	738	738	700	688	675	650	638	613	588	563	538	525
738	738	725	700	688	663	638	625	613	575	550	525	500
738	725	700	688	663	650	625	613	588	550	538	500	475
725	713	688	675	663	638	613	588	563	538	500	488	463
713	688	675	663	638	625	588	575	550	525	488	463	475

LARGE SITE NUMBER 6

Fulton County, Ohio

Site Location: Sections 12-13, 24-25, 36, T.7N, R.5E
1, T.6N, R.5E
7-11, 14-23, 26-35, T.7N, R.6E
2-6, T.6N, R.6E
Upper Left Corner: NW Corner, Section 12, T.7N, R.5E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Wanseon, OH	1960/71	5

Bedrock Data Source: Vormelker, J. D., 1971, "Bedrock Surface Map of Fulton County, Ohio," Open File Map No. 28, Ohio Department of Natural Resources, Division of Geological Survey, Columbus, OH.

Topographic Surface Values

743	749	753	745	758	765	768	774	786	786	788	783	775
743	747	748	748	755	763	768	773	784	783	786	775	775
743	745	749	760	750	757	764	772	785	785	785	777	772
745	750	752	755	756	765	770	774	785	779	778	770	771
742	745	752	750	759	760	771	781	787	774	773	765	765
747	743	746	750	754	760	764	780	788	778	771	765	757
745	749	750	755	755	763	771	781	777	775	768	763	753
742	738	746	750	767	765	772	773	764	770	776	750	753
744	745	751	750	752	761	770	772	764	759	750	754	747
742	748	753	753	758	768	773	765	759	750	754	753	745
743	744	749	755	760	769	761	758	756	753	742	746	740
744	748	747	758	763	765	753	758	749	740	742	738	736
746	747	747	748	755	753	749	746	744	737	737	726	722

LARGE SITE NUMBER 6

Fulton County, Ohio

Bedrock Surface Values

580	600	610	590	590	590	580	560	530	560	590	600	600
590	610	600	590	590	590	570	530	550	560	590	590	605
590	590	600	590	570	550	530	540	587	590	580	590	600
590	600	600	570	550	540	530	560	600	600	590	590	600
580	600	600	600	590	550	530	590	620	610	610	590	593
580	590	600	600	590	550	530	560	590	590	610	600	590
596	590	599	600	603	589	540	580	590	600	610	610	590
590	590	598	590	605	590	540	600	621	621	621	610	600
590	600	600	580	590	580	530	590	610	621	621	610	610
610	600	580	570	570	530	550	560	590	610	621	610	610
610	580	560	570	590	590	570	540	576	590	621	605	610
610	610	610	610	610	610	610	570	550	590	621	620	624
610	610	614	610	617	610	610	614	560	600	621	621	618

LARGE SITE NUMBER 7

Van Wert County, Ohio

Site Location: Sections 22-27, 34-36, T.2S, R.1E
19-21, 28-33, T.2S, R.2E
1-3, 10-13, T.3S, R.1E
4-9, 16-18, T.3S, R.2E
Upper Left Corner: NW Corner, Section 22, T.2S, R.1E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Glenmore, OH	1960	5

Bedrock Data Source: Vormelker, J. D., 1981, "Top-of-Rock Map of Van Wert County, Ohio," Ohio Geological Survey, Open File Map No. 115.

Topographic Surface Values

813	810	810	804	804	803	803	798	793	789	790	788	779
815	813	805	803	806	803	799	798	797	798	790	783	789
818	817	808	806	808	808	802	803	803	793	797	795	791
820	818	813	810	808	803	798	800	796	793	800	795	796
820	818	815	818	808	808	806	800	801	802	800	794	796
826	826	822	823	815	813	810	810	806	800	797	796	797
823	824	825	823	823	819	818	813	806	803	804	808	798
827	819	822	815	822	818	815	813	810	815	805	805	810
829	825	826	813	821	816	813	813	815	815	813	808	810
808	805	816	815	813	813	813	815	813	813	809	805	810
812	821	813	812	813	812	811	815	810	809	818	815	816
830	828	821	827	818	820	822	818	813	816	822	815	813
835	831	825	830	828	822	828	823	822	829	819	818	822

LARGE SITE NUMBER 7

Van Wert County, Ohio

Bedrock Surface Values

763	763	763	763	763	738	700	763	750	750	763	763	738
763	763	763	763	738	750	688	738	738	763	750	738	738
763	763	763	763	763	738	713	688	763	750	763	738	688
763	763	763	763	763	738	738	688	738	738	763	713	713
763	763	750	738	750	738	738	688	738	713	725	663	738
763	763	738	738	725	713	713	663	725	713	638	713	763
763	763	763	738	725	688	663	663	713	638	713	738	763
763	763	763	738	725	725	700	663	638	663	725	750	763
763	763	763	738	750	750	738	675	638	713	725	763	763
763	763	763	763	763	750	713	663	650	675	713	738	763
763	763	763	763	763	750	713	713	688	650	738	738	763
763	763	763	763	750	738	763	738	700	650	738	750	763
750	763	763	738	738	750	763	738	638	650	738	763	763

LARGE SITE NUMBER 8

Clinton County, Michigan

Site Location: Sections 19-36, T.6N, R.2W
1-18, T.5N, R.2W
Upper Left Corner: NW Corner, Section 19, T.6N, R.2W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
St. Johns South, MI	1965	5
Lansing North, MI	1965	10
Bath, MI	1972	10
Price, MI	1972/82	10

Bedrock Data Source: Rieck, R. L., 1984, "Bedrock Topography of Clinton County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

776	794	785	785	797	790	790	810	841	803	805	815	831
788	770	803	804	796	790	819	833	850	819	845	814	823
809	775	805	801	800	790	808	808	818	813	819	810	805
795	818	823	818	815	830	835	823	825	818	818	805	800
822	832	831	827	858	805	824	810	815	828	817	805	805
870	885	875	830	835	835	800	815	815	835	820	805	805
862	867	866	832	831	837	817	803	840	817	830	815	805
860	850	835	815	860	860	805	795	814	825	816	820	817
833	815	795	835	815	805	836	815	865	850	847	840	839
805	805	805	840	830	850	855	840	865	865	865	855	850
819	830	844	848	815	855	836	820	862	867	870	864	853
800	845	855	855	840	835	840	835	845	840	850	860	843
843	865	845	837	825	820	845	880	855	854	844	855	863

LARGE SITE NUMBER 8

Clinton County, Michigan

Bedrock Surface Values

638	688	688	675	663	665	663	663	688	688	688	688	690
690	688	663	675	688	694	688	663	700	688	700	666	700
675	693	676	675	688	688	688	688	687	688	707	713	700
640	663	688	688	663	663	688	688	688	700	720	725	713
675	675	688	700	675	688	675	728	713	738	738	713	713
713	713	700	688	688	688	688	700	720	725	713	713	719
713	707	688	688	688	711	713	695	700	738	713	713	698
731	713	713	700	688	713	713	713	713	730	713	725	710
713	713	688	707	688	688	700	680	688	700	687	736	713
713	688	700	738	700	707	685	700	700	688	688	688	731
725	690	719	738	725	702	713	713	713	675	663	700	713
738	725	713	731	740	700	755	713	688	688	700	713	750
725	708	750	738	738	688	725	723	695	750	744	735	738

LARGE SITE NUMBER 9

Allegan County, Michigan

Site Location: Sections 8-17, 20-29, 32-36, T.4N, R.13W
1-5, T.3N, R.13W
6, T.3N, R.12W
7, 18-19, 30-31, T.4N, R.12W
Upper Left Corner: NW Corner, Section 8, T.4N, R.13W

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Hudsonville West, MI	1980	10
Hudsonville East, MI	1980	10
Hamilton East, MI	1981	10
Burnips, MI	1981	10

Bedrock Data Source: Rieck, R. L., 1980, "Bedrock Topography of Allegan County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

659	722	717	703	705	693	715	703	687	723	747	701	752
662	730	753	710	719	675	681	675	701	700	726	695	717
691	715	695	700	698	679	668	667	669	671	679	676	691
718	675	706	690	685	665	655	665	663	663	663	675	668
680	712	672	681	690	665	663	672	682	668	670	674	679
716	680	661	675	659	668	660	668	665	680	674	675	684
635	635	640	647	655	658	668	667	668	673	678	685	688
644	650	640	645	650	645	650	655	670	680	683	688	689
648	656	663	664	667	667	668	675	661	675	686	705	710
663	665	675	685	727	725	670	680	680	665	700	680	715
665	670	685	730	697	685	685	690	680	703	734	705	707
680	685	696	695	690	690	688	695	684	705	718	735	705
696	700	705	714	710	705	704	705	708	695	728	796	750

LARGE SITE NUMBER 9

Allegan County, Michigan

Bedrock Surface Values

563	552	566	563	525	438	550	600	650	600	613	613	635
563	575	525	488	550	378	513	563	600	588	588	588	588
563	525	488	425	425	500	498	547	538	588	563	588	613
563	563	525	525	512	438	350	538	538	538	568	588	613
563	588	588	600	588	488	350	520	550	588	575	600	604
525	575	586	575	582	438	450	438	475	588	600	550	600
449	550	525	550	463	438	538	538	475	538	600	588	525
475	450	463	438	438	438	450	513	538	563	502	563	600
500	500	538	550	538	538	500	475	438	450	475	525	575
550	525	563	588	575	575	550	500	475	450	500	450	488
588	563	540	599	601	600	563	550	525	438	513	563	538
588	575	563	600	600	613	613	588	575	525	450	588	588
613	625	588	583	621	625	613	588	588	538	438	550	613

LARGE SITE NUMBER 10

Lapeer County, Michigan

Site Location: Sections 1, 12-13, 24-25, 36, T.7N, R.10E
2-11, 14-23, 26-35, T.7N;, R.11E
Upper Left Corner: NW Corner, Section 1, T.7N, R.10E

Topographic Data Source:

U.S.G.S. Quadrangle (1:24000)	Date(s)	C.I. (ft.)
Attica, MI	1963	10
Thornville, MI	1968	10
Almont, MI	1968	10

Bedrock Data Source: Rieck, R. L., 1983, "Bedrock Topography of Lapeer County, Michigan," compliments of Dr. Rieck, Department of Geography, Western Illinois University, Macomb, IL, 61455.

Topographic Surface Values

845	875	843	851	853	888	925	877	892	874	878	874	864
842	845	876	865	864	870	880	853	885	865	864	860	855
846	845	859	873	867	861	877	896	880	865	870	881	885
845	855	855	855	866	865	870	890	933	865	895	895	895
885	849	852	854	860	873	884	876	903	893	887	902	895
858	855	866	855	858	872	876	890	892	900	895	910	880
863	858	867	860	865	865	870	885	901	857	900	913	860
867	875	916	865	901	885	881	875	859	845	875	865	838
885	871	918	932	974	929	901	913	875	865	891	891	884
888	895	885	927	945	925	944	890	914	865	855	860	873
895	899	907	915	955	975	971	928	898	897	869	849	864
904	935	922	925	965	1010	983	945	902	890	899	865	840
923	995	995	965	955	1005	975	945	910	910	906	885	870

LARGE SITE NUMBER 10

Lapeer County, Michigan

Bedrock Surface Values

750	770	732	750	788	750	738	680	675	650	675	725	713
720	725	775	798	763	763	770	700	713	688	675	738	738
735	768	775	800	788	763	700	788	788	788	781	775	775
775	788	775	775	806	800	750	788	790	775	750	763	775
800	750	763	794	813	817	775	763	763	725	663	725	688
788	738	738	725	750	763	738	785	750	738	763	788	750
800	750	763	763	750	738	713	713	700	675	752	790	738
813	788	788	788	788	788	775	750	725	650	638	650	655
813	788	800	812	810	813	813	797	775	775	785	638	736
810	813	825	837	813	788	788	813	800	813	775	663	625
813	827	813	813	813	813	813	813	800	750	750	688	638
813	813	813	813	800	788	768	775	775	738	738	738	713
825	825	825	813	784	810	775	763	763	738	738	750	713

APPENDIX C

SUMMARY OF SMALL SITE STATISTICS

APPENDIX C

Table 8. Summary of Small Site Statistics

Site Number	Maximum Bedrock Relief	Average Bedrock Relief	Maximum Topographic Relief	Average Topographic Relief	Maximum Drift Thickness	Average Drift Thickness	Drift/Maximum Bedrock Relief	Drift/Average Bedrock Relief
1.	30	20	37	23	33	12	.395	.603
2.	49	24	32	15	28	14	.289	.591
3.	27	17	45	23	30	11	.421	.662
4.	57	33	23	13	52	24	.418	.732
5.	53	33	37	23	72	45	.850	1.394
6.	18	11	19	8	28	14	.770	1.233
7.	68	37	23	15	83	50	.734	1.345
8.	27	13	13	7	31	20	.739	1.486
9.	80	43	27	11	102	52	.650	1.220
10.	55	37	42	20	150	123	2.232	3.298
11.	20	13	24	9	32	22	1.094	1.724
12.	91	82	14	9	145	112	1.225	1.361
13.	30	19	30	15	79	54	1.761	2.818
14.	27	18	21	12	47	30	1.083	1.695
15.	30	15	18	9	107	93	3.041	6.051
16.	15	8	29	17	19	11	.699	1.332
17.	46	21	41	14	54	28	.622	1.356
18.	38	19	24	13	113	88	2.305	4.629
19.	15	11	24	16	67	58	3.814	5.085
20.	69	48	35	27	46	11	.164	.236
21.	24	14	22	14	44	27	1.123	1.996
22.	30	16	15	10	44	28	.918	1.749
23.	52	27	17	10	62	34	.663	1.253
24.	34	15	25	12	37	20	.604	1.329
25.	18	10	11	6	57	44	2.422	4.404
26.	15	8	24	10	27	17	1.132	2.264
27.	38	30	9	5	56	31	.813	1.048
28.	12	9	18	7	40	24	1.932	2.576
29.	34	17	21	13	34	17	.490	.979

Table 8 (cont'd)

30.	37	19	76	32	94	47	1.272	2.394
31.	30	18	18	12	39	26	.859	1.450
32.	23	18	16	11	47	28	1.222	1.540
33.	57	29	24	15	54	27	.477	.956
34.	20	8	28	15	78	64	3.137	7.643
35.	72	53	31	16	94	50	.670	.903
36.	81	37	16	10	106	56	.686	1.527
37.	23	13	12	7	66	58	2.543	4.360
38.	30	15	10	7	55	37	1.223	2.523
39.	32	19	24	16	46	30	.953	1.627
40.	23	11	25	12	35	22	.966	1.985
41.	29	16	30	15	41	30	1.062	1.939

All non-ratio statistics are in meters

APPENDIX D

Table 9. Summary of Large Site Statistics

Site Number	Maximum Bedrock Relief	Average Bedrock Relief	Maximum Topographic Relief	Average Topographic Relief	Maximum Drift Thickness	Average Drift Thickness	Drift/Maximum Bedrock Relief	Drift/Average Bedrock Relief
1.	53	17	44	15	27	11	.200	.633
2.	55	22	48	21	150	122	2.203	5.410
3.	119	69	38	16	121	54	.455	.782
4.	37	18	44	23	59	29	.783	1.605
5.	84	19	42	15	113	54	.639	2.767
6.	29	16	20	7	78	52	1.802	3.257
7.	38	20	17	5	56	23	.610	1.138
8.	36	16	35	17	63	38	1.077	2.356
9.	91	41	49	17	95	44	.485	1.077
10.	65	30	52	20	77	39	.602	1.280

All non-ratio statistics are in meters

APPENDIX D

SUMMARY OF LARGE SITE STATISTICS

APPENDIX E

CALCULATING AVERAGE BEDROCK OR TOPOGRAPHIC RELIEF

APPENDIX E--CALCULATING AVERAGE BEDROCK OR TOPOGRAPHIC RELIEF

In order to calculate average bedrock or topographic relief, each site was divided into a set of equal-area cells (shown below). The available relief in each cell was determined by using the maximum and minimum elevation values. Finally, an average relief value for each site was calculated by averaging the relief values of the cells.

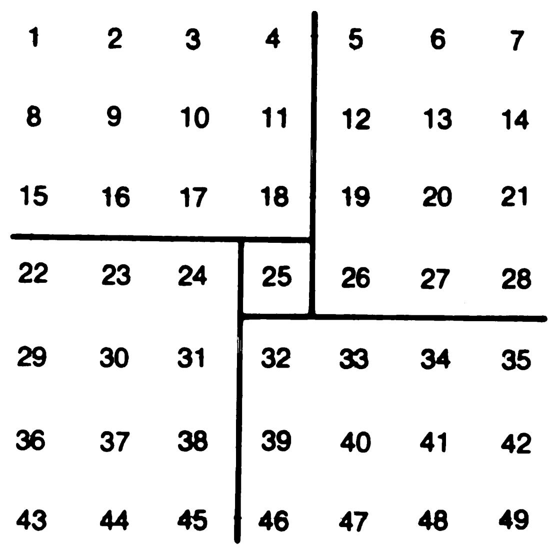


Figure 9. Small Site Cells

APPENDIX E--continued

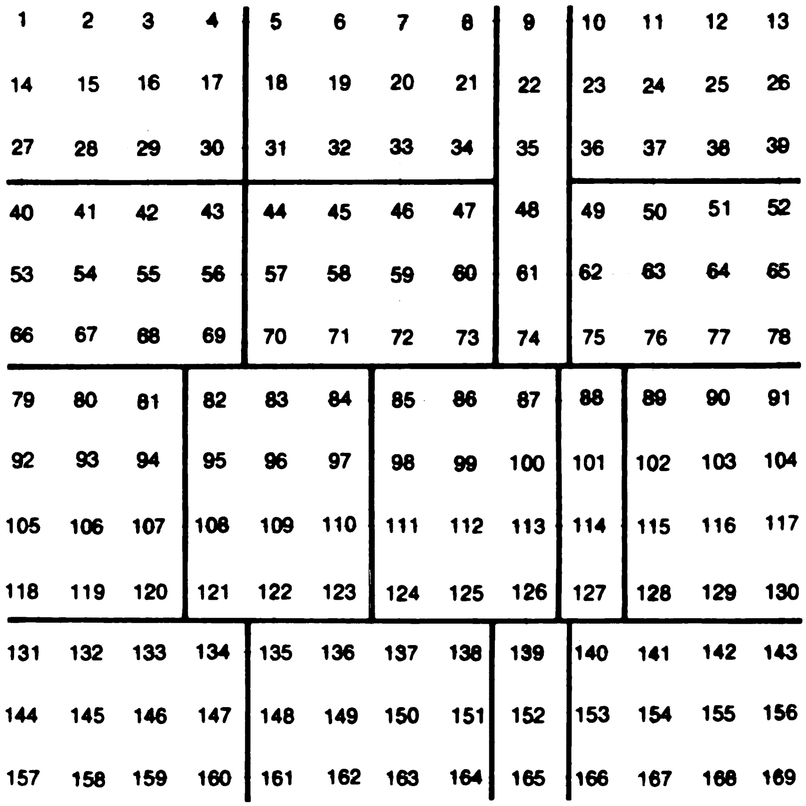


Figure 10. Large Site Cells

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