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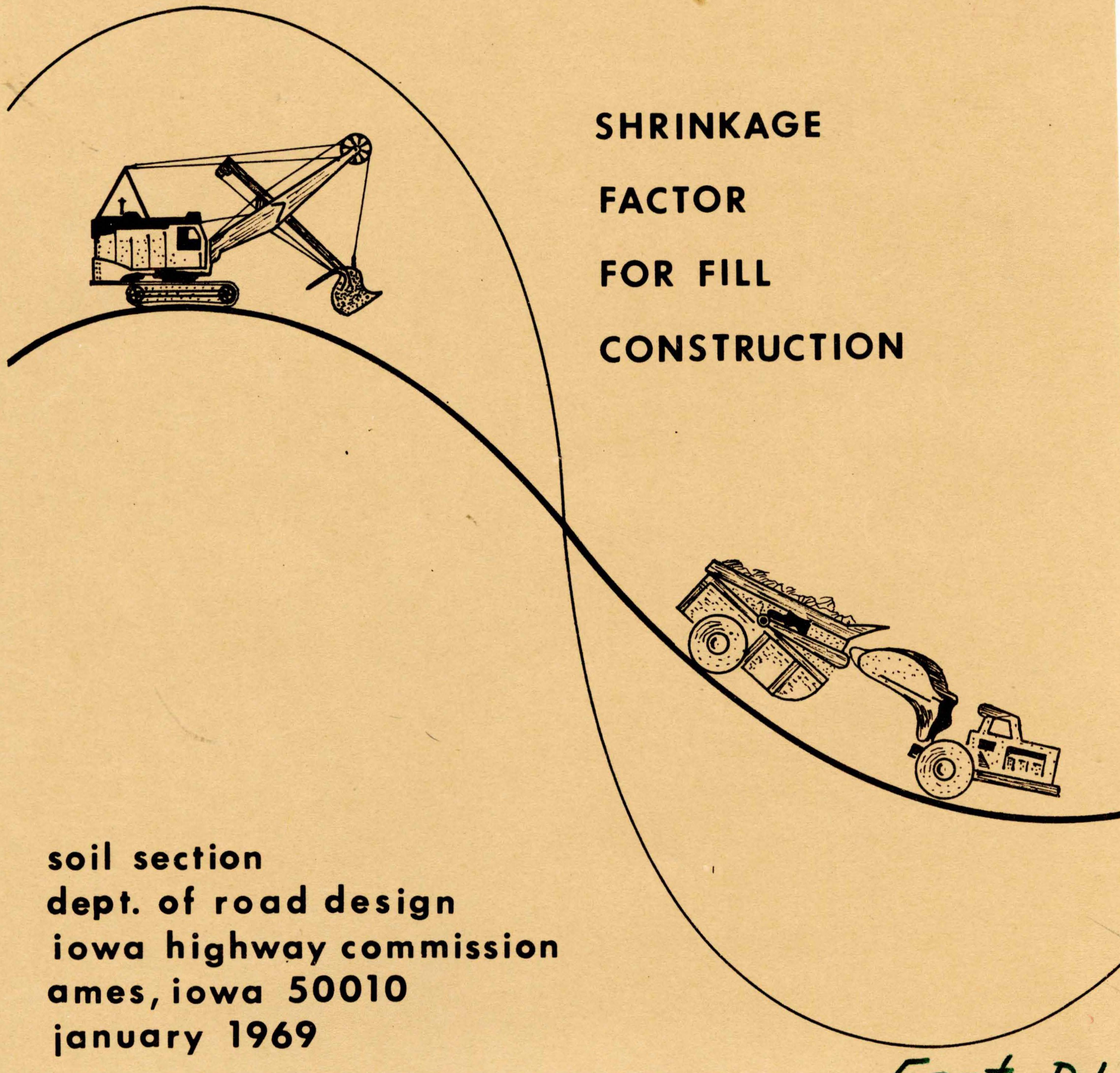

SHRINKAGE FACTOR FOR FILL CONSTRUCTION

soil section
dept. of road design
iowa highway commission
ames, iowa 50010
january 1969

East, D.L.

FORM 12
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IOWA STATE HIGHWAY COMMISSION

To R. H. Given   Date May 6, 1969

From K. P. McLaughlin KPM   REFER TO:

Subject "Report on Shrinkage Factor for fill construction"

Attached

Early in 1967 a request was made by Mr. Paul Mahoney, Pottawattamie County Engineer, for a study on shrinkage factors for Class 10 material that would yield a method for determining the shrinkage that would be sufficiently close to reduce the need for final sections.

From data collected by Mr. Glen Deal from Resident Engineers on plan shrinkage versus that by final cross sections our Soil Design Section has prepared the subject report from the data available. The individual project points have been plotted on graphs so that the variation can be seen as well as the amount of data available for determination of the line.

This guide for shrinkage factor should be improved and updated as more data becomes available. Your aid in doing this is requested. As actual shrinkage data from one of your projects becomes available please forward this information to us so that everyone may benefit from it.

Attached is a copy of the "Report on Shrinkage Factor for Fill Construction" for your information and use.

KPM:DA:bk
cc: 1 per Co. Engr. (99)
 1 per R.C.E. (25)
 1 per Dist. Engr. (6)
 1 per Design Squad Leader

STATE OF IOWA

SHRINKAGE FACTOR

FOR

FILL CONSTRUCTION

an
Engineering Report
by
Donald A. Anderson
and
Subodh Kumar

January, 1969

Soil Section
Department of Road Design
Iowa State Highway Commission
Ames, Iowa

SHRINKAGE FACTOR FOR FILL CONSTRUCTION

In any roadway construction program soil is excavated from one site and placed and compacted at another. The volumes of excavation and fill can be determined within reasonable accuracy from survey and design data. A certain volume of excavated soil rarely occupies the same volume in the roadway fill. During compaction, effort is made to expel water and air from the soil mass thus reducing its volume and increasing its density. Hence, to obtain the volume of the fill material, the volume of the excavated material is adjusted by a factor commonly known as the "Shrinkage Factor." The relationship used for adjustment is:

$$\text{Volume of fill material} = \frac{\text{Volume of excavated material}}{1 + \frac{\text{Shrinkage Factor (\%)}}{100}}$$

In actual construction of a roadway, compaction is not the only factor that influences the shrinkage factor. The actual volume measurements of excavated material and of compacted material must in some form or other take account of the following factors:

a. errors in surveying

b. alterations, approximations and errors in design

c. errors in quantity measurement

d. loss of soil during transportation

e. loss of soil due to erosive action of wind and water

f. subsidence of ground surface under the load of equipment

g. settlement of ground surface under the embankment load

h. compaction characteristics of soil types

i. type of compaction equipment used

j. amount of compaction

k. the moisture content at which the soil is compacted

l. shrinkage and swelling properties of soil types

Effect of a factor may either be to nullify or to add to the effect of other factor. Even though it may be difficult to take into account the effect of one factor, yet the effect may be significant. Some of the errors are due to the inherent imperfections of methods and instruments used for measurements; this is especially so with the surveying. After the completion of survey and before the start of earthwork the changes that take place in the topography of the area are seldom accounted for and many a time small changes are made in roadway alignment and grade without the benefit of new survey data.

That some amount of soil is lost during transportation is a well known fact; during construction period soil is lost also due to erosion. The soil properties, soil moisture, climatic conditions, equipment type and methods of equipment operation are basic factors that affect the loss of soil, however, as yet no means are available for determining these losses on a quantitative basis. Equipment and its operation-methods also play an important part in causing subsidence of the original ground surface but there is no reliable method available, at present, to estimate the amount of this subsidence.

When a load is applied over the ground, settlement of surface near and under the area of loading occurs; means are available to determine this settlement and many highway authorities make use of settlement plates for this purpose. However, design calculations for settlement based on contemporary theories yield results which are at best approximate.

Compaction, shrinkage and swelling of soils have been subjects of intensive study and substantial amount of excellent literature is available on these subjects.

However, as yet there is no rational way to determine the values of shrinkage factors, perhaps, primarily due to the great number of variables that influence a soil mass and its treatment.

Further on a small roadway project, any attempt to establish values for shrinkage factors from laboratory and field tests might prove to be economically expensive and practically futile.

To determine the values of shrinkage factors, data was collected from the roadway construction projects completed by the Iowa State Highway Commission. Investigation of this data revealed that the shrinkage factor is greatly affected by the type of the soil. In Iowa, the soils that are most frequently used for embankment construction can be classified in the following three types:

1. Silty Clays: these include all soils classified as topsoil, loess, clay, silty clay, silty clay loam, clay loam, loam, silt loam, silt and certain weathered glacial clays and are characterized by the predominance of the finer fractions of soil particles.

2. Sandy Soils: these include all soils classified as sandy clay, sandy clay loam, sandy loam, loamy sand, sand, silty sand and gravelly sand and are characterized by the predominance of the coarser fractions of soil particles and, properties associated with the good internal drainage.

3. Glacial Soils: these are the soils transported to their present location, in the geologic past, by the agency of

glaciers that have been preconsolidated to a dense state by ice loads; these include all soils classified as till, gumbotil, glacial till and glacial clay, clay loam or loam; these soils usually are heterogeneous, unsorted, non-stratified mixtures of all sizes of soil fractions.

Further classification of silty clays is made here, on areal basis, by means of Principal Soil Association Areas* (Fig. 1). On the same basis Glacial Regions (Fig. 2) are used to further classify the glacial soils. Within one area or region soils can be assumed to be fairly uniform for the purpose of fill construction.

An interesting observation made during this investigation was that for certain soils the value of shrinkage factor remained practically constant, irrespective of the volume of the material involved. On the other hand, for other soils the value of shrinkage factor decreased as the per mile volume of the material increased. This occured up to a certain limit of the per mile volume and then the value of the shrinkage factor became constant. Variation within certain ranges was observed in all cases.

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* See also Special Report No. 42; Department of Agronomy Iowa State University, Ames, Iowa, January, 1965.

The results of this investigation are given in Table I in equation form and are shown on Fig. 3 through Fig. 7 in graphical form.

It must be pointed out again that the data for this report was collected from the completed projects in various counties of the State of Iowa. Attempt has been made here to present this data in a very simple form. Hence, the results of this investigation should be used only as a guide. There is no guarantee that the values of shrinkage factors other than those shown here will not be encountered in actual fill construction.

TABLE I: EQUATIONS FOR SHRINKAGE FACTORS

Type of soil	Equation	% Variation
I. SILTY CLAYS: Principal Soil Association Areas[a]		
(a) M and MIH	S=35	5
(b) D, F, FDS, GPS KFC, OMT, TM		
(i) for $q < 200$	$S=45-0.15q$	5
(ii) for $q \geq 200$	S=15	5
II. SANDY SOILS	S=25	5
III. GLACIAL SOILS[b]		
(a) Kansan Glacial Clay	S=10	5
(b) Wisconsin Glacial Clay		
(i) for $q < 150$	$S=50-0.20q$	10
(ii) for $q \geq 150$	S=20	

There is no reliable data available for areas and regions not included here.

S = Shrinkage factor (%)

q = volume, in 1000 cubic yards, of material excavated per mile length of project

$<$ = less than

$\geq$ = equal to or greater than

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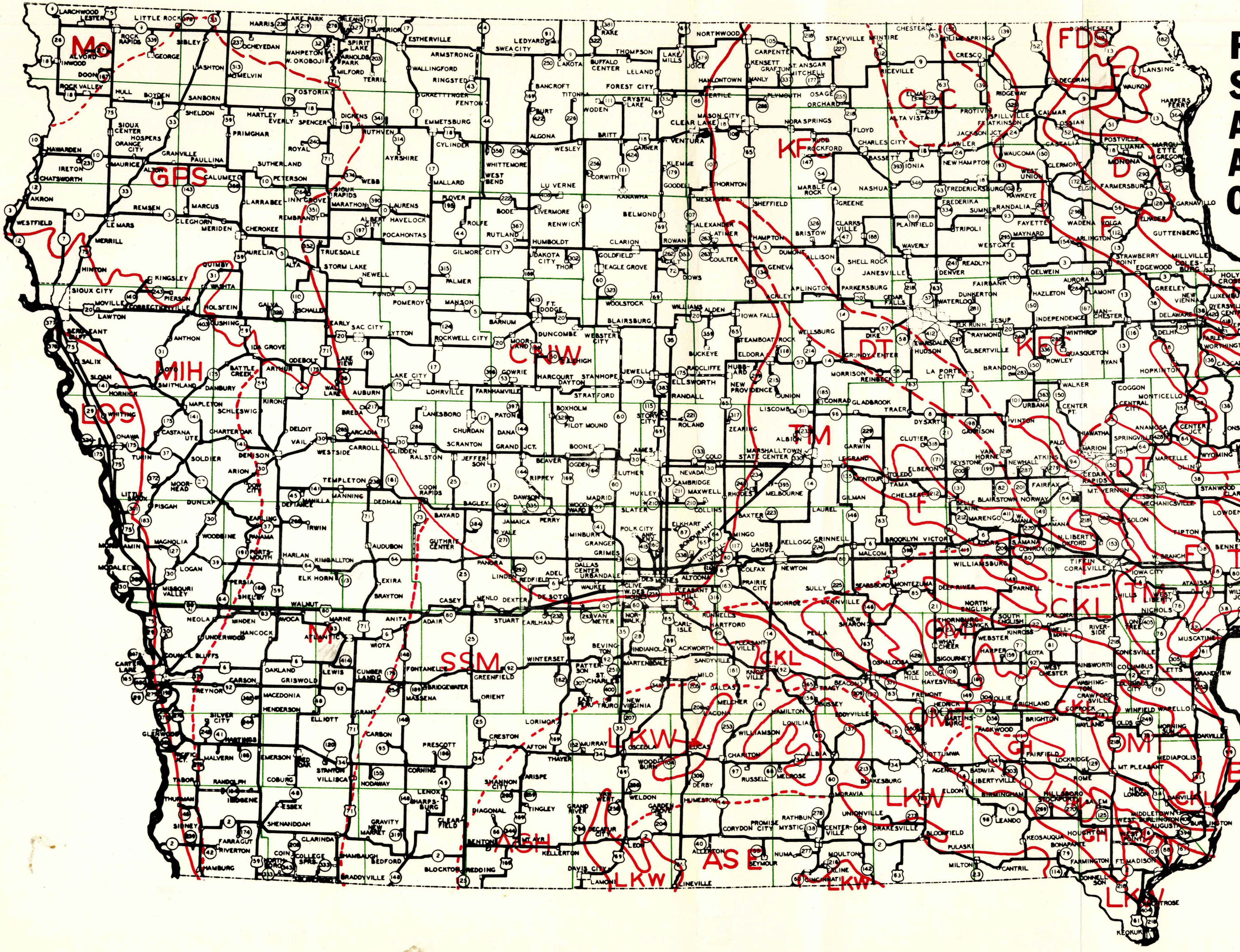
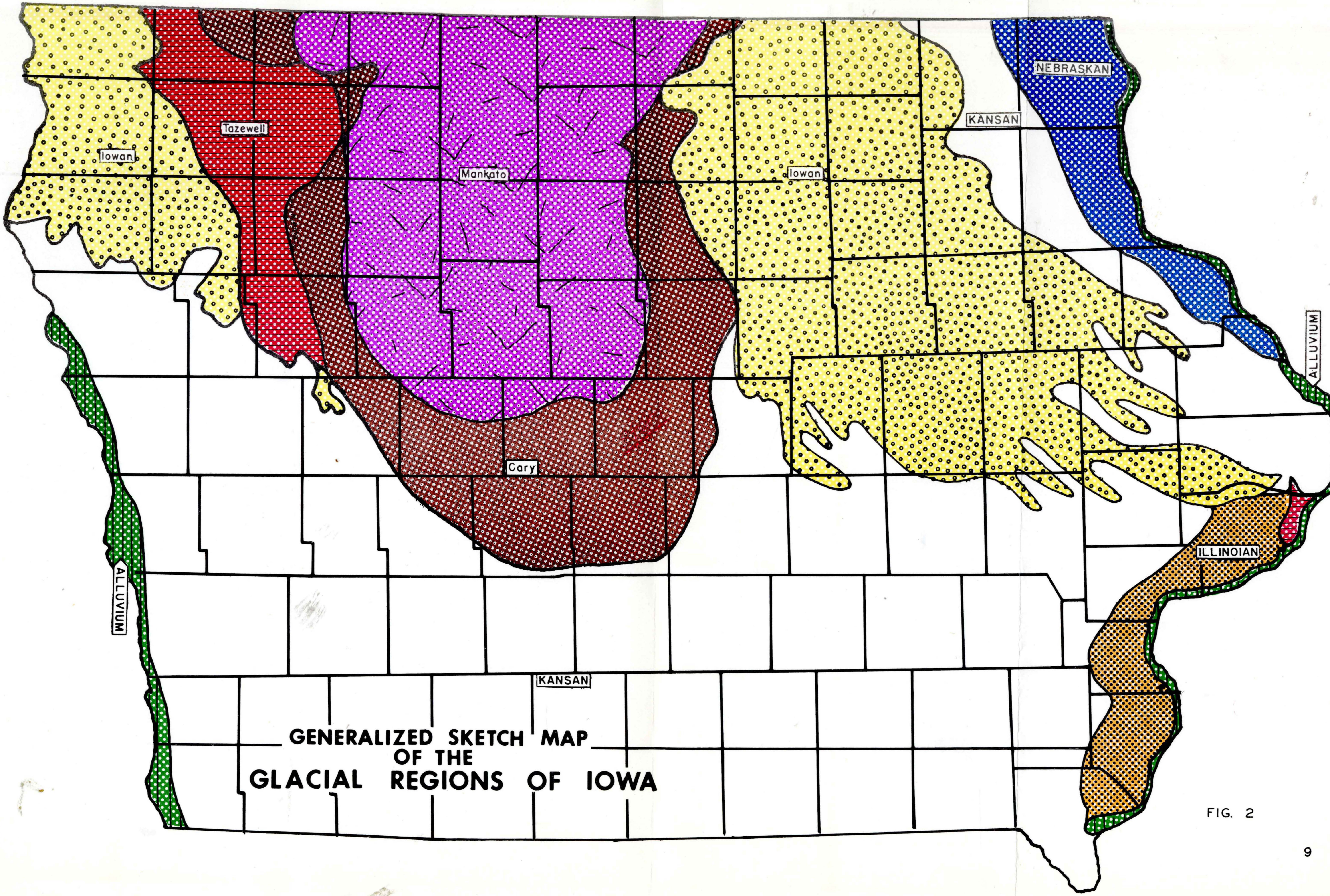
a. See Fig. 1
b. See Fig. 2

PRINCIPAL SOIL ASSOCIATION AREAS OF IOWA



Symbol and Name	Soil Association
AGH	: Adair-Grundy-Haig
ASE	: Adair-Seymour-Edina
CKL	: Clinton-Keswick-Lindley
CLC	: Cresco-Lourdes-Clyde
CNW	: Clarion-Nicollet-Webster
D	: Downs
DT	: Dinsdale-Tama
F	: Fayette
FDS	: Fayette-Dubuque-Stonyland
GH	: Grundy-Haig
GPS	: Galva-Primghar-Sac
KFC	: Kenyon-Floyd-Clyde
LKW	: Lindley-Keswick-Weller
LOS	: Luton-Onawa-Salix
M	: Marshall
MIH	: Monona-Ida-Hamburg
Mo	: Moody
OMT	: Otley-Mahaska-Taintor
SSM	: Shelby-Sharpsburg-Macksburg
TM	: Tama-Muscotine
B	: Bottomland-Mississippi River

FIG. 1



GENERALIZED SKETCH MAP
OF THE
GLACIAL REGIONS OF IOWA
Iowan
Tazewell
Mankato
Cary
Iowan
NEBRASKAN
KANSAN
KANSAN
ILLINOIAN
ALLUVIUM
ALLUVIUM

FIG. 2

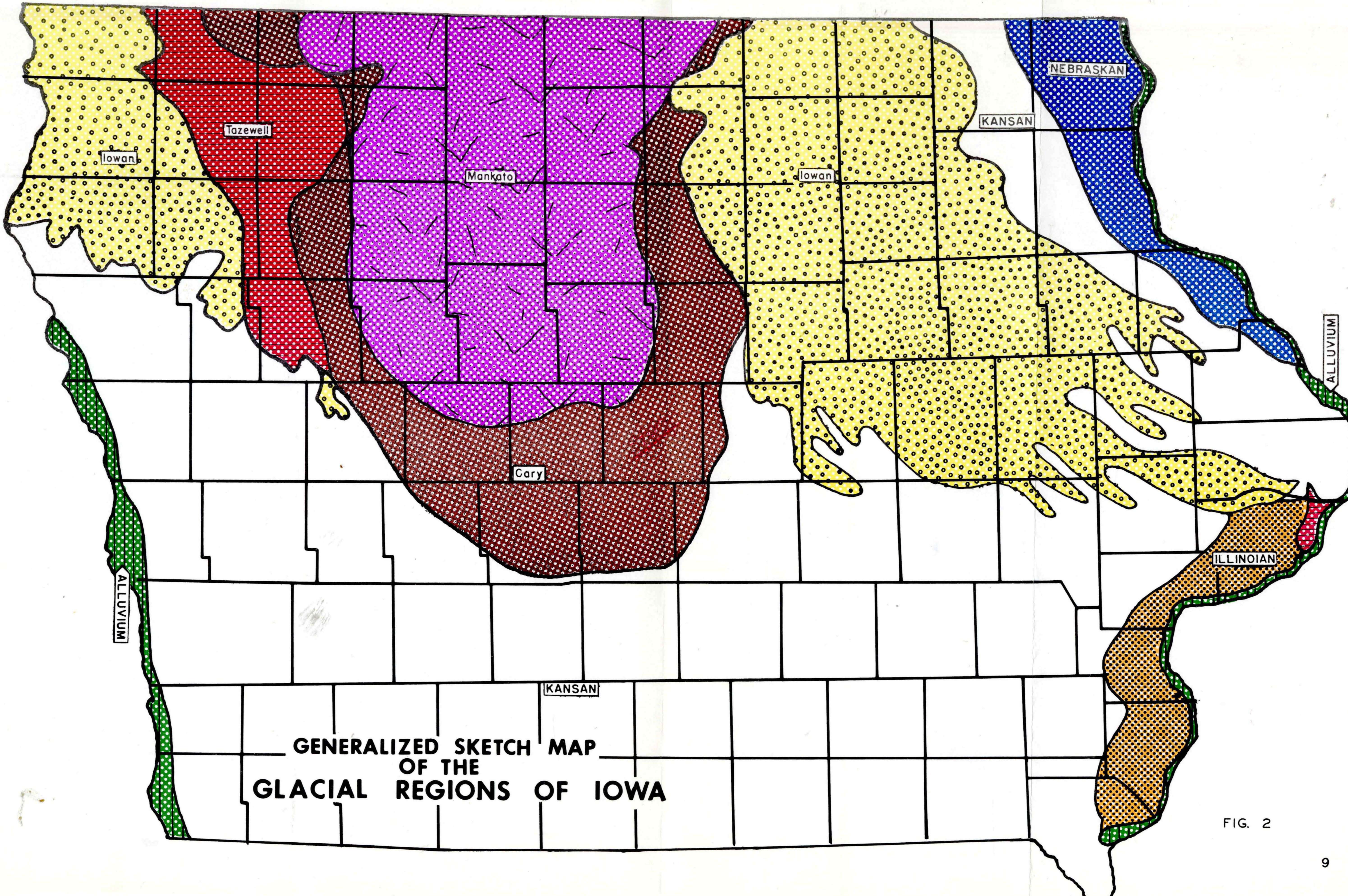

Iowan
Tazewell
Mankato
Cary
Iowan
KANSAN
NEBRASKAN
ALLUVIUM
ILLINOIAN
ALLUVIUM
KANSAN
GENERALIZED SKETCH MAP
OF THE
GLACIAL REGIONS OF IOWA

FIG. 2

SHRINKAGE FACTORS

Equation: S = 35
Variation (%) = 5

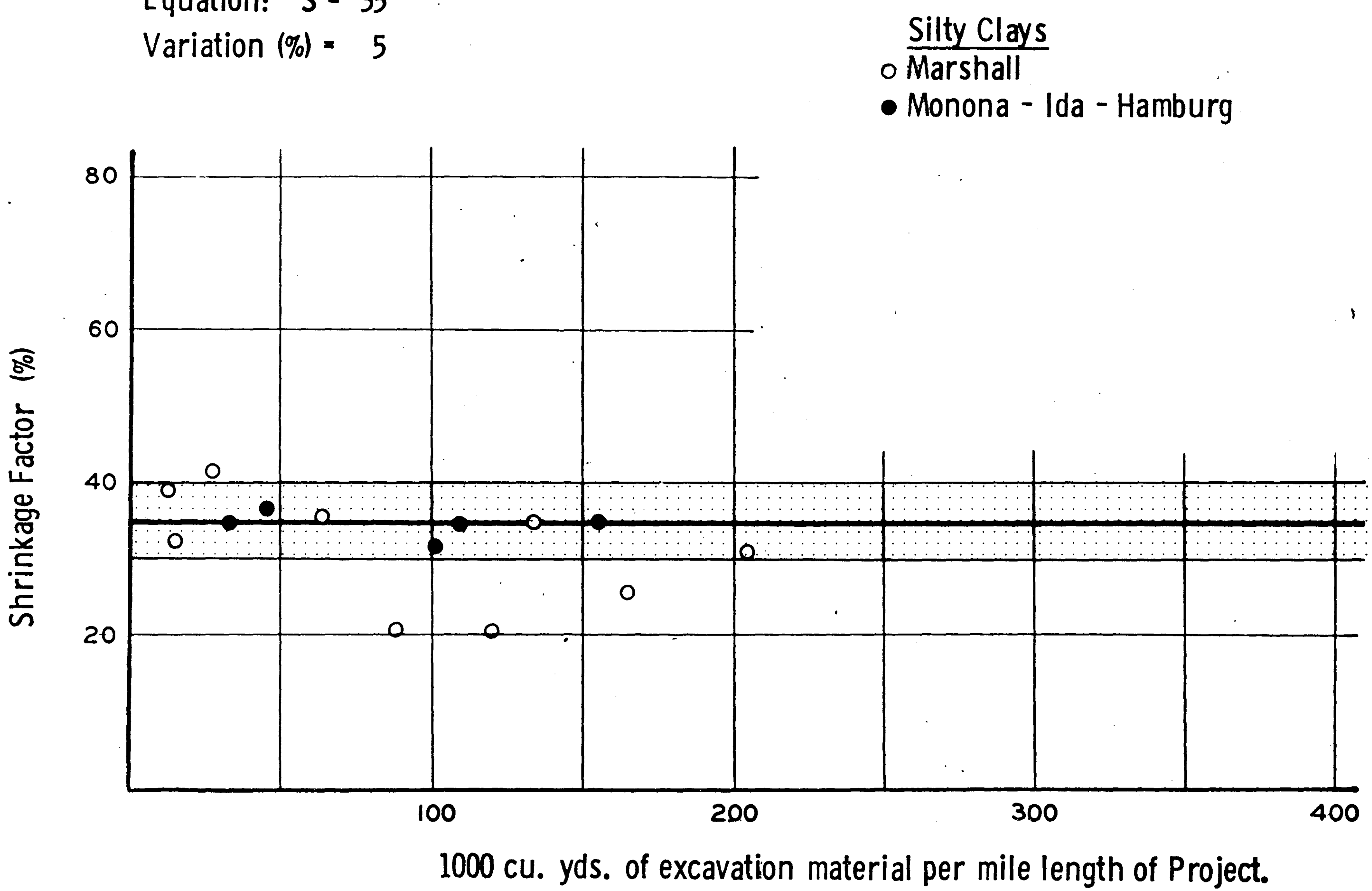


Fig. 3

SHRINKAGE FACTORS

Equation: $S = 45 - 0.15\, q$ (for $q < 200$), & $S = 15$ (for $q \geq 200$)

Variation (%) = 5

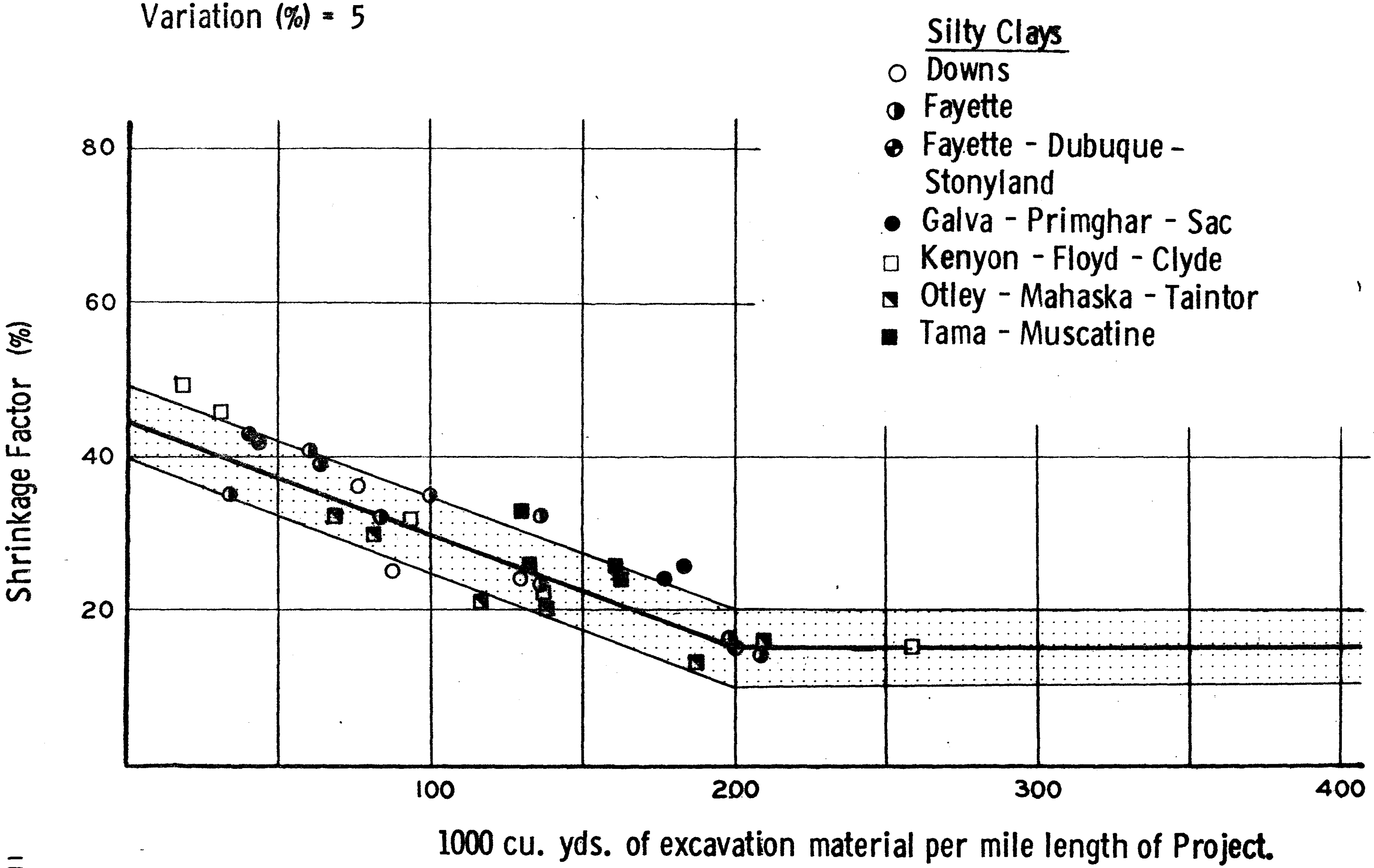


Fig. 4

SHRINKAGE FACTORS

Equation: S = 25
Variation (%) = 5

Sandy Soils

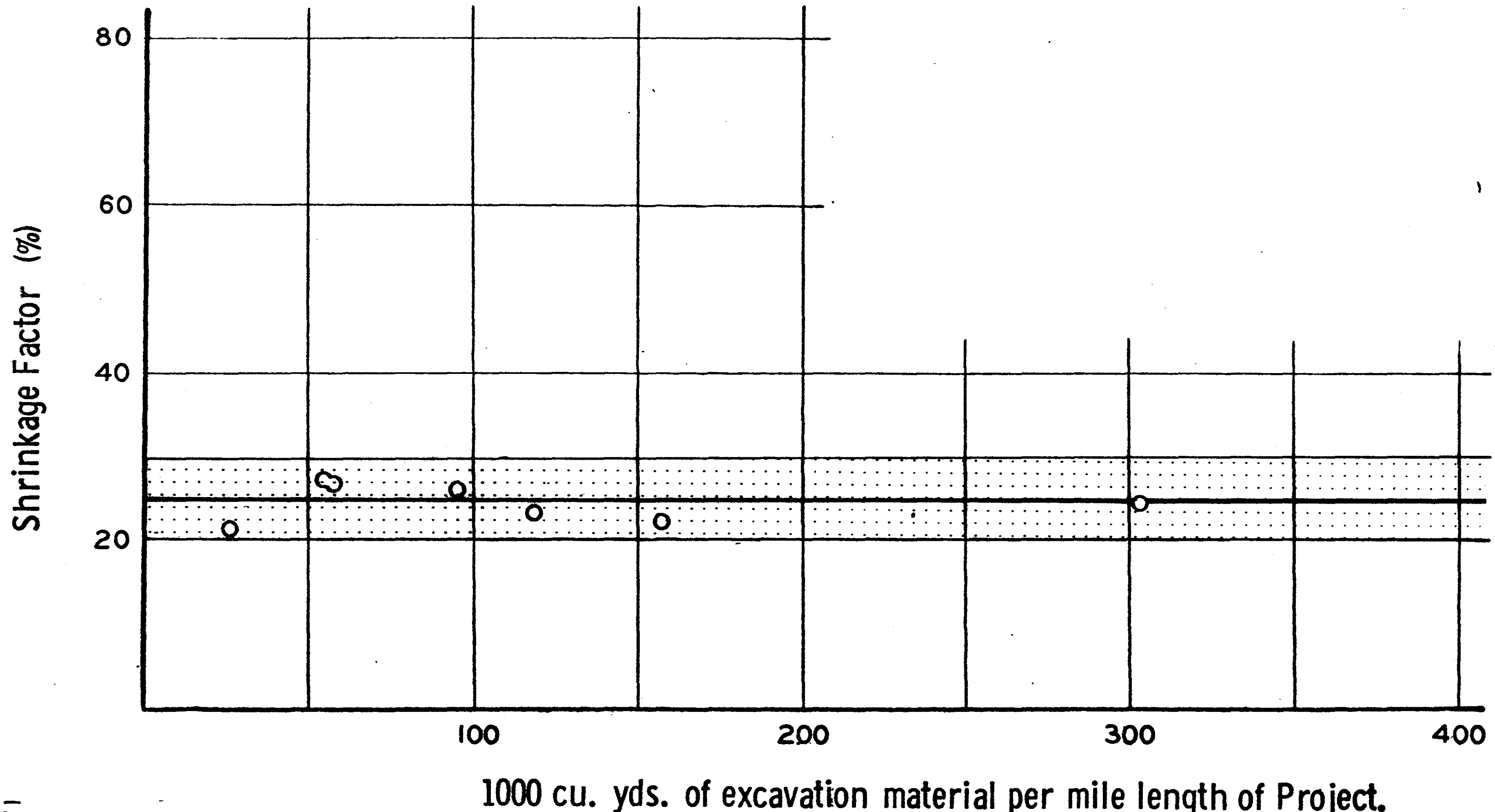


Fig. 5

SHRINKAGE FACTORS

Equation: S = 10
Variation (%) = 5

Glacial Soils
○ Kansan Glacial Clay

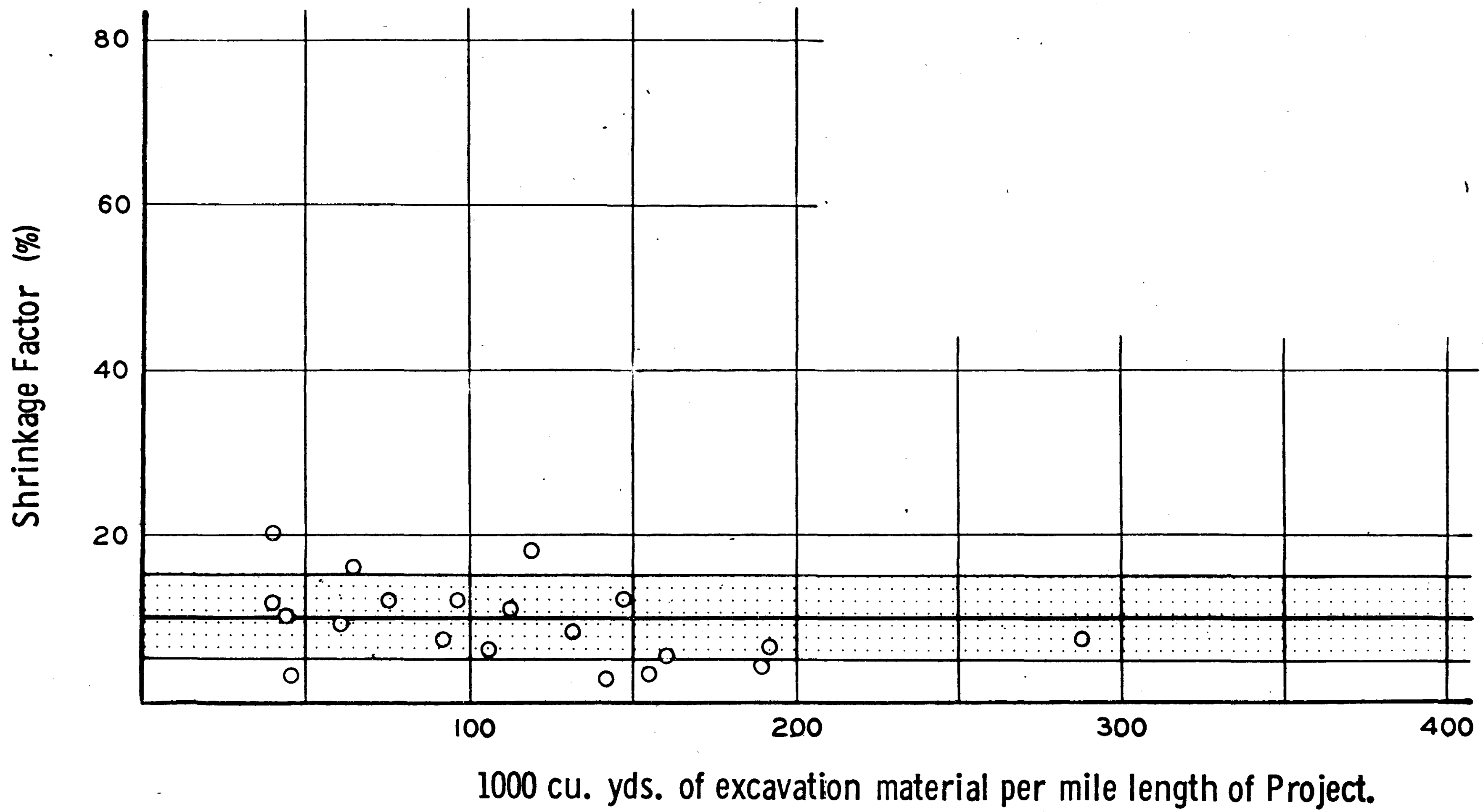


Fig. 6

SHRINKAGE FACTORS

Equation: $S = 50 - 0.20\,q$ (for $q < 150$), & $S = 20$ (for $q \geqslant 150$)

Variation (%) = 10

<u>Glacial Soils</u>

Wisconsin Glacial Clays

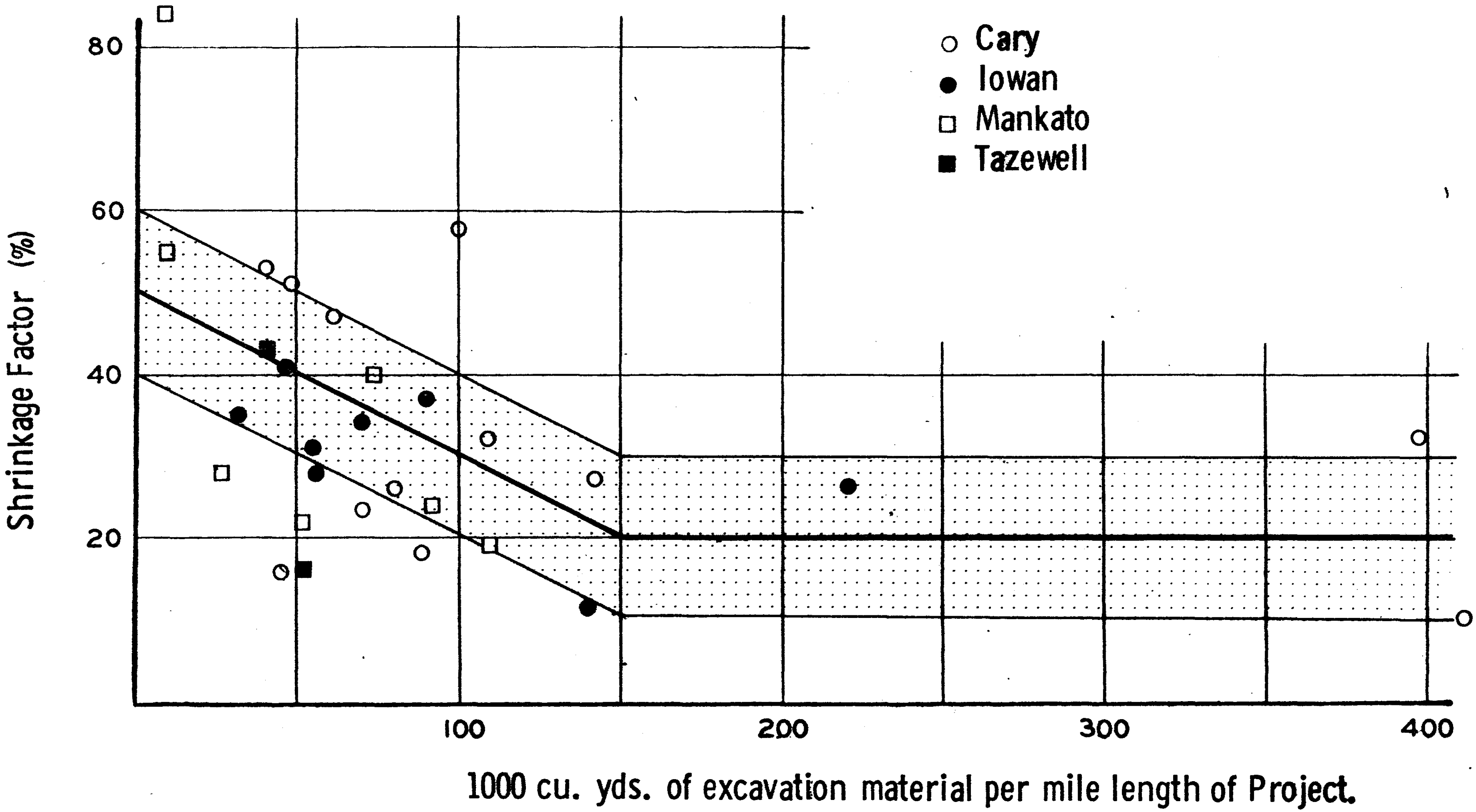


Fig. 7