West Indian Journal of Engineering Vol. 25, No. 1, (July 2002) Technical Paper (Venkataramana) 42 - 51

A Hazard Map for Expansive Soils of Trinidad

K.N. Venkataramana
Department of Civil Engineering,
The University of the West Indies,
St. Augustine, Trinidad

Natural hazards such as earthquakes, landslides, flooding, hurricanes, etc., which are dynamic in nature are a challenge to the Civil Engineers. However, there is yet another natural hazard which is not dynamic but more disastrous to light structures, namely, the behaviour of expansive soils. Minimising or eliminating the effects of natural hazards can be achieved by proper land use planning with the aid of hazard maps. In this paper, engineering problems of expansive soil are briefly described and a hazard map for expansive soils of Trinidad is presented and its relevance discussed in relation to better land use planning.

1. Introduction

Plastic clays exhibiting volume changes when subjected to moisture variations due to seasonal climatic conditions are termed expansive soils. These clays undergo shrinkage on drying and swelling on wetting. When free swelling of the ground is restrained by the presence of a structure, these clays exert an upward pressure on the structure called the swell pressure, which is highly detrimental to the stability of the structure especially, when the latter transmits a downward pressure less than the swell pressure. Since the swelling activity of an expansive soil is a slow process, it does not produce a sudden dramatic effect like in other natural hazards. This is the reason why the expansive soil phenomenon is called a silent hazard. The impact it brings about is only on those buildings which suffer from it directly. The estimated annual losses from expansive soils on a global basis is found to be enormous and exceeds the losses of all other natural hazards put together [2].

Expansive soils are found in abundance in central and southern regions of Trinidad. Scores of structures and sections of highways have been damaged. On slopes, these soils have contributed to extensive landsliding. As such, these soils are considered critical on the social and economic fronts of the country.

All clays do not exhibit expansive nature. Clays containing clay mineral, Montmorillonite in predominance are prone to volume changes. Common clay minerals that are present in expansive soils are Montmorillonite, Illite and Kaolinite. The expansive nature of these minerals decreases in that order with Montmorillonite clay exhibiting highest volume changes while Kaolinite exhibiting the least. These clay minerals possess laminated crystalline structure. Kaolinite has a very rigid structure where as Montmorillonite has the least rigidity for penetration of water.

Expansive soils of Trinidad are predominantly derivatives of clay shales, marls and clay alluvium in which Montmorillonite content is predominant. A typical composition of soil series 177 is 40% Montmorillonite, 20% Illite and 20% Kaolinite. The basic soil types that are prone to swelling are:

Soil Series	Name of Series	Parent Material
177	Talparo clay	Clay shale
278/L	Tarouba clay	Clay shale
474/L	Princes Town clay	Marl
239	Debe clay	Clay shale

Identifying the presence of an expansive soil at the site is an important first task. The best way of achieving this as a preliminary step, before going in for soil-testing and without much expense is to:

(i) Study a hazard map, if available, in which areas with different degrees of expansivity are demarcated and,

(ii) Critically examine the condition of the ground in dry and wet seasons as

Pertinent discussion will be published in January, 2003 West Indian Journal of Engineering if received by November, 2002.

well as the condition of the neighbouring structures.

The objective of this paper is to present a hazard map for expansive soils of Trinidad showing their real distribution and highlight its uses and limitations. This guidance coupled with the available soil data and the local experience will lead to an effective approach for the assessment of the problem, in the first order, before a thorough investigation is warranted.

2. The Need for Land Use Planning

The main causes of building and pavement failures on expansive soils may be summarised as follows:

1. Failure to recognise the existence of the problem of expansive soil at the site;
2. Lack of soil investigation, however small;
3. Lack of knowledge to cope with the problem or risking a chance to avoid the extra cost of site investigation.

It is understandable that the small builders avoid site investigations for fear of additional expense, but they do not realise that this extra cost hardly exceeds 1-2% of the total cost of the project and that it is worth spending to have no regrets later.

One problem that is severely crippling the Third World countries is the population explosion and the ever-growing demand for housing. Land is becoming scarce and expensive. Sites hitherto abandoned as unfit for building are being utilised. Mass housing has become an important issue of the immediate future of many governments. Expansive soils are widely spread in these countries and the mass housing schemes are most likely to land on expansive soil areas or areas prone to other hazards. Therefore, land use planning plays an important role in this regard.

In order to ensure an effective land use planning, the Town and Country Planning Division has to play an important role in averting expansive soil catastrophes. It should stay award of building permits if the proposed building falls in an expansive soil area of concern. The plans and the foundations adopted should be reviewed by a committee of geotechnical engineers and building inspectors. This process becomes more efficient if a 'Hazard Map' showing expansive soil areas of the country is available and the degree of risk involved is assessed based on the type of structure being considered and the degree of expansivity of the soil at the site. If the soil at the site, as judged from the hazard map, falls under high risk, the committee should insist on a soil investigation report. By enforcement of these procedures, the building developers, the property buyers and the country as a whole would benefit.

3. Civil Engineering Problems

Light buildings, pavements and buried utilities are the ones usually damaged due to the effect of expansive soils, if no precautionary measures are implemented during construction. Most problems of soil volume changes occur within a depth of 2-3 metres below the ground surface, where the seasonal moisture variation will be significant. There have been several instances of failure of single-storey and two-storey residential and school buildings and sections of highways in expansive soil areas of the central and southern regions of Trinidad.

High plasticity of these soils makes them soft when wet. As a result, the unpaved access roads become impassable during the wet season. The susceptibility to volume changes makes them unsuitable for use as a construction material for embankments, retaining wall backfills, manufacturing of bricks, etc. unless they are treated with chemicals or other materials to alter their undesirable properties. Also, because of low permeability characteristics, they are unsuitable for sewage effluent disposal.

On steep slopes, these soils undergo movement both in vertical and horizontal directions due to swelling and creep movements and cause distress to the structures raised on slopes. They are also largely associated with landsliding.

Ill effects of expansive soil on building foundations are:

- Lifting of lightly loaded footings;
- Jammed or out of plumb doors and windows;
- Tilting of walls;
- Lifting of floor slabs and unsightly cracks on walls.

It is common experience to find the cracks appearing during two main periods, at the end of wet season and at the end of the dry season. The worse being at the end of the dry season. Once cracks appear on the structure, they go on progressively widening year after year unabated until a balance is reached between the amounts of swelling and shrinkage. These cracks on walls, not only are unsightly but depreciate the value of the structure and increase the sense of insecurity. In most cases, the structures have to be demolished and rebuilt, which means total loss of investment.

4. Provisions in the Building Code

A special provision has to be made in the Building Code of any country experiencing the problem of expansive soils. This is necessary in order to deal with special requirements of foundation design. It not only provides guidelines for the builders in respect of design and construction aspects of foundations but also acts as a standard document in case of law suits. The building code should incorporate the following provisions:

1. Procedures of identification of an expansive soil and its classification and the relevant testing procedures to be used;
2. Methods of heave prediction and methodology of foundation design;
3. Minimum depth of foundations;
4. Structural design and methods of construction of shallow and deep foundations;
5. Methods of heave reduction and minimising moisture variations;
6. Minimum requirements of reinforcement, grade and strength of concrete, type of joints, etc;
7. Methods of construction of superstructure and floors with due consideration to local materials and construction practices.

5. Limitations of Hazard Map

A hazard map provides the basic information about distribution of expansive soils covering different regions. It also delineates areas of different degrees of severity. It forms a useful guide for preliminary assessment of the site condition. To get a more comprehensive picture, this map should be used in conjunction with local soil investigation reports and soil-boring data.

It should be noted that the map provides only a general and approximate estimate of the severity of the problem. However, existence of pockets of highly expansive soils within areas of low expansive description and vice-versa cannot be overruled. Soil-testing alone can detect these localised variations. Besides, even the low-rated areas may exhibit significant amount of heave if they are subjected to extreme variations in soil moisture condition due to unforeseen climatic conditions, control of water flow around the building and by the presence of the structure itself. Within macro-climatic regions, micro-climatic zones consisting of arid, semi-arid, humid etc. may exist. These limitations in the use of the map should be appreciated.

6. Basis for the Map.

In the preparation of the hazard map, the basis for delineating expansive soil areas and their qualitative categorisation should be:

1. Geological and soil maps;
2. Geological age and composition of the lithology;
3. Soil types responsible for the actual failures of buildings and pavements;
4. Topography, soil humidity and drainage;
5. Data from relevant existing soil investigation reports;
6. Field visits;
7. Field and laboratory testing and
8. Discussions with geologists, geotechnical engineers and builders having the expertise.

Based on the above criteria and the degree of distress buildings underwent, the expansive soil areas are delineated and divided into four (4) categories of potential heave - 1) Low, 2) Medium, 3) High and

4) Very high, in order to incorporate appropriate building bye-laws. On the basis of laboratory swell tests and the intensities of structural distress experienced, the following **Table** is prepared.

Potential Swell %	Degree of Expansivity
<1	Low
1 - 2	Medium
2 - 5	High
>5	Very High

A typical expansive soil hazard map of Trinidad is shown in **Figure 1***. County-wise maps are shown in **Figures 2*** to **6***. For efficient administrative purposes, these maps should be prepared to a suitable scale, preferably, 1:25,000 or 1:50,000 depending on the accuracy required.

References

[1] Chen, F.H. (1988). Foundations on Expansive Soils. New York: American Elsevier Science Publishers.

[2] Gromko, G.J. (1974). Review of Expansive Soils. ASCE Journal Geotech. Eng. Div. Vol. 100(GT6): pp. 667-687.

[3] Ramana, K.V. (1991). A Study of Expansive Clays of Trinidad in relation to Foundation Design Practice. Research report, Trinidad: National Institute for Higher Education, Research, Science and Technology (NIHERST).

[4] Ramana, K.V. (1993). Humid Tropical Expansive Soils of Trinidad: Their Geotechnical Properties and Areal Distribution. Engineering Geology Journal, Vol. 34, pp. 27-44.

[5] Snethen, D.R. *et al.* (1975). A Review of Engineering Experiences with Expansive Soil in Highway Subgrades. Washington: U.S. Dept. of Transportation Research Report No. FHWA-RD-75-48.

* See **Figures** in Appendix on following pages.

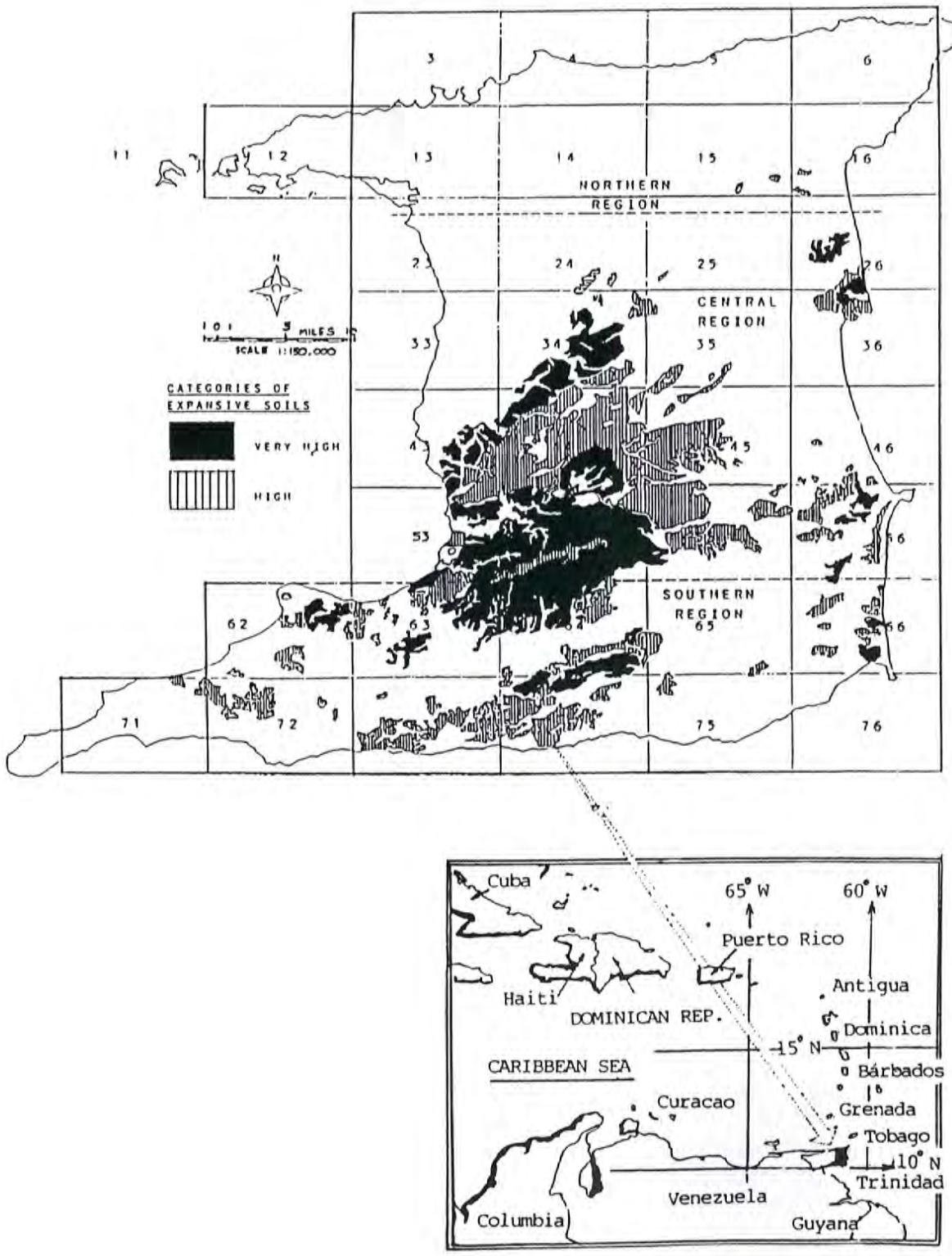

FIGURE 1: *Areal Distribution and Intensity of Expansive Soils in the Island of Trinidad (Humid Tropical Zone)*

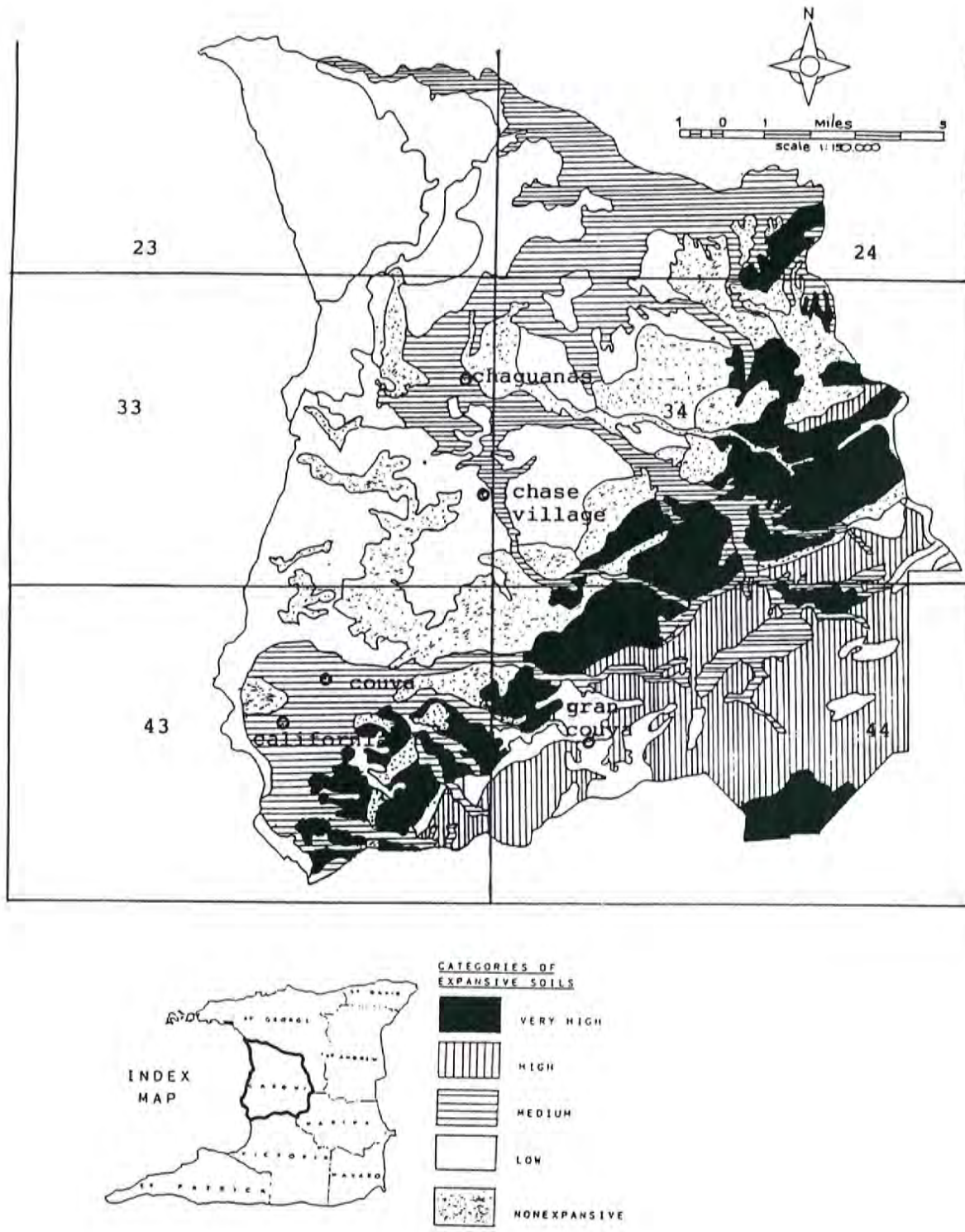

FIGURE 2: *Areal Distribution and Intensity of Expansive Soils in Caroni County*

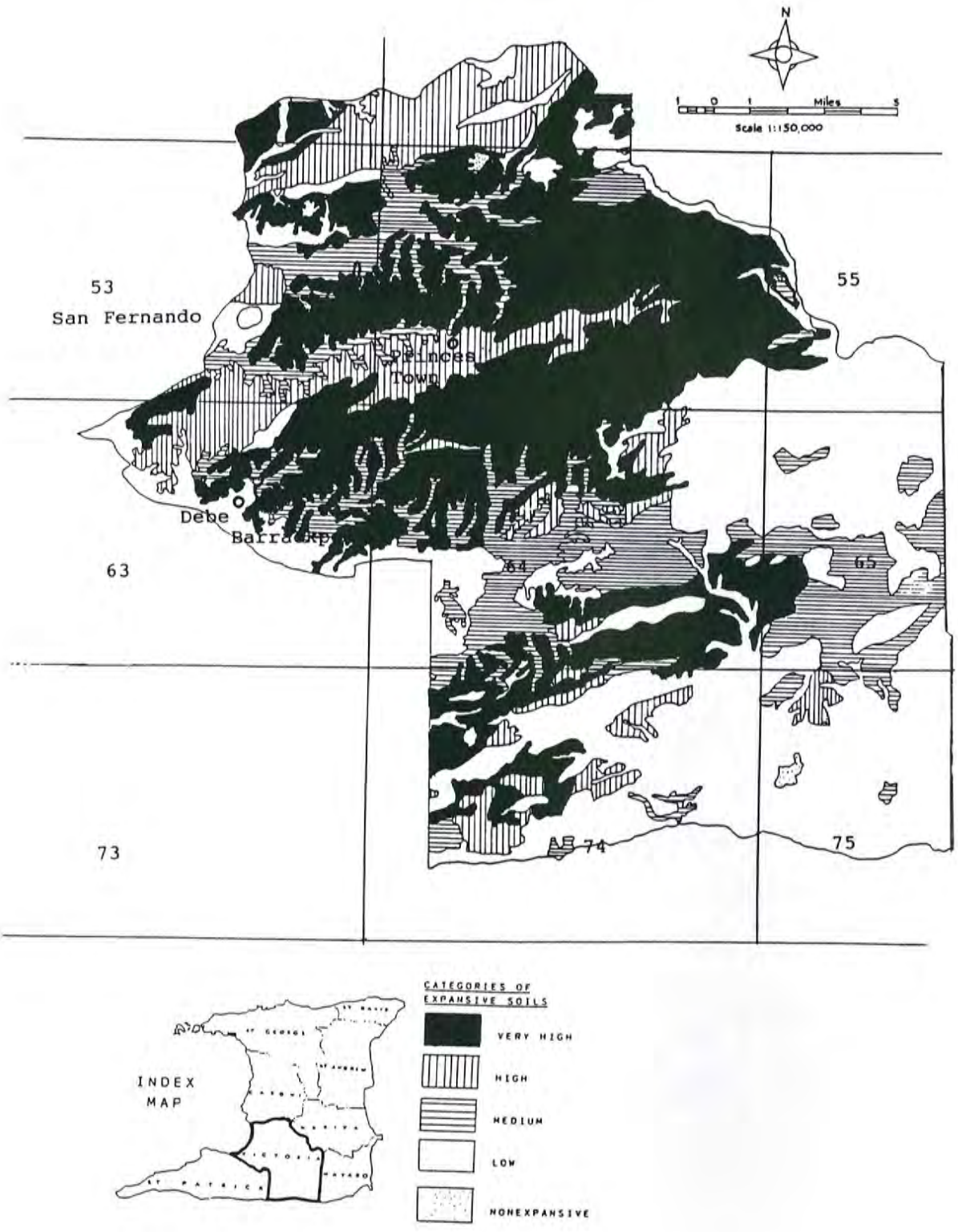

FIGURE 3: *Areal Distribution and Intensity of Expansive Soils in Victoria County*

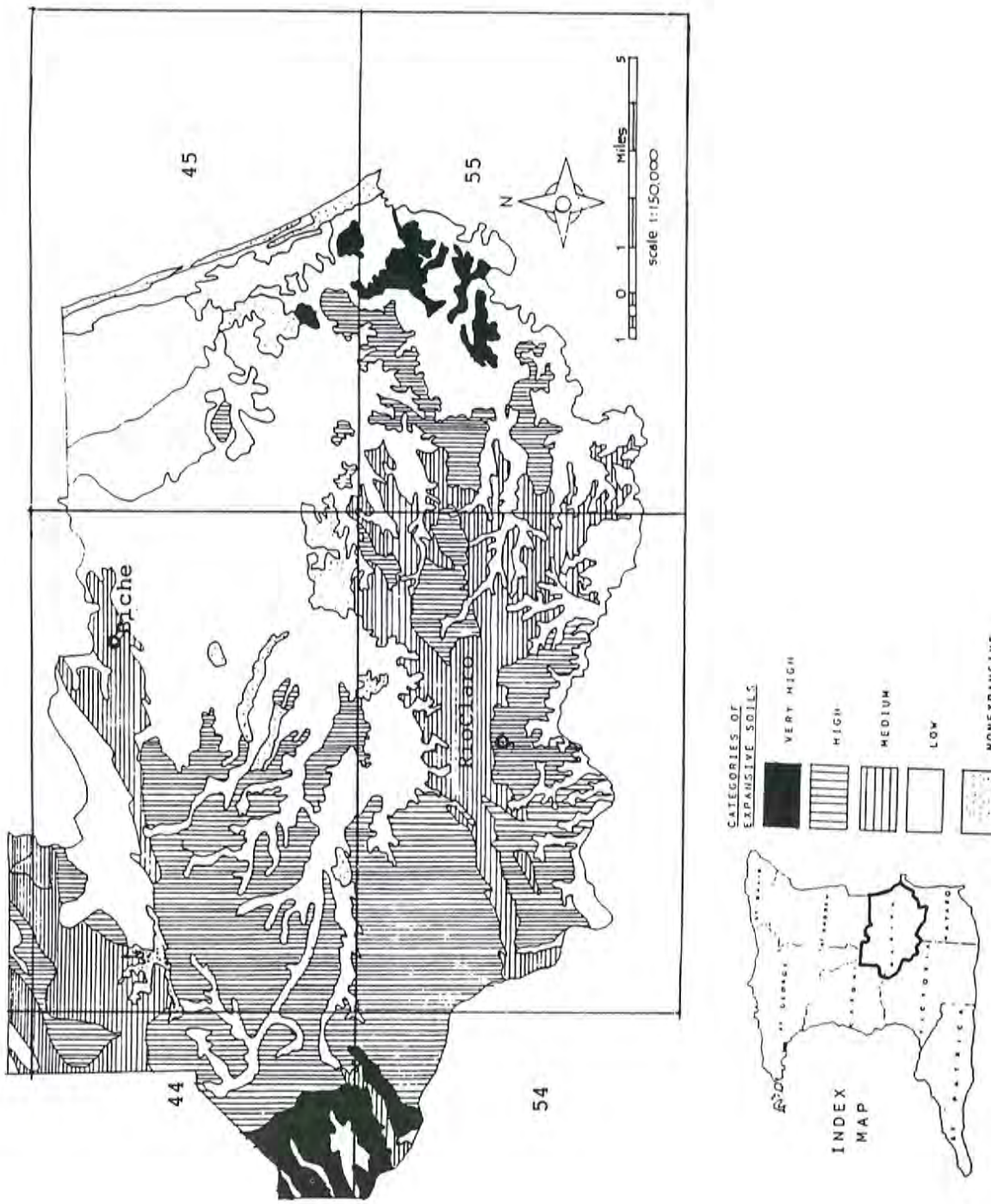

FIGURE 4: *Areal Distribution and Intensity of Expansive Soils in Nariva County*

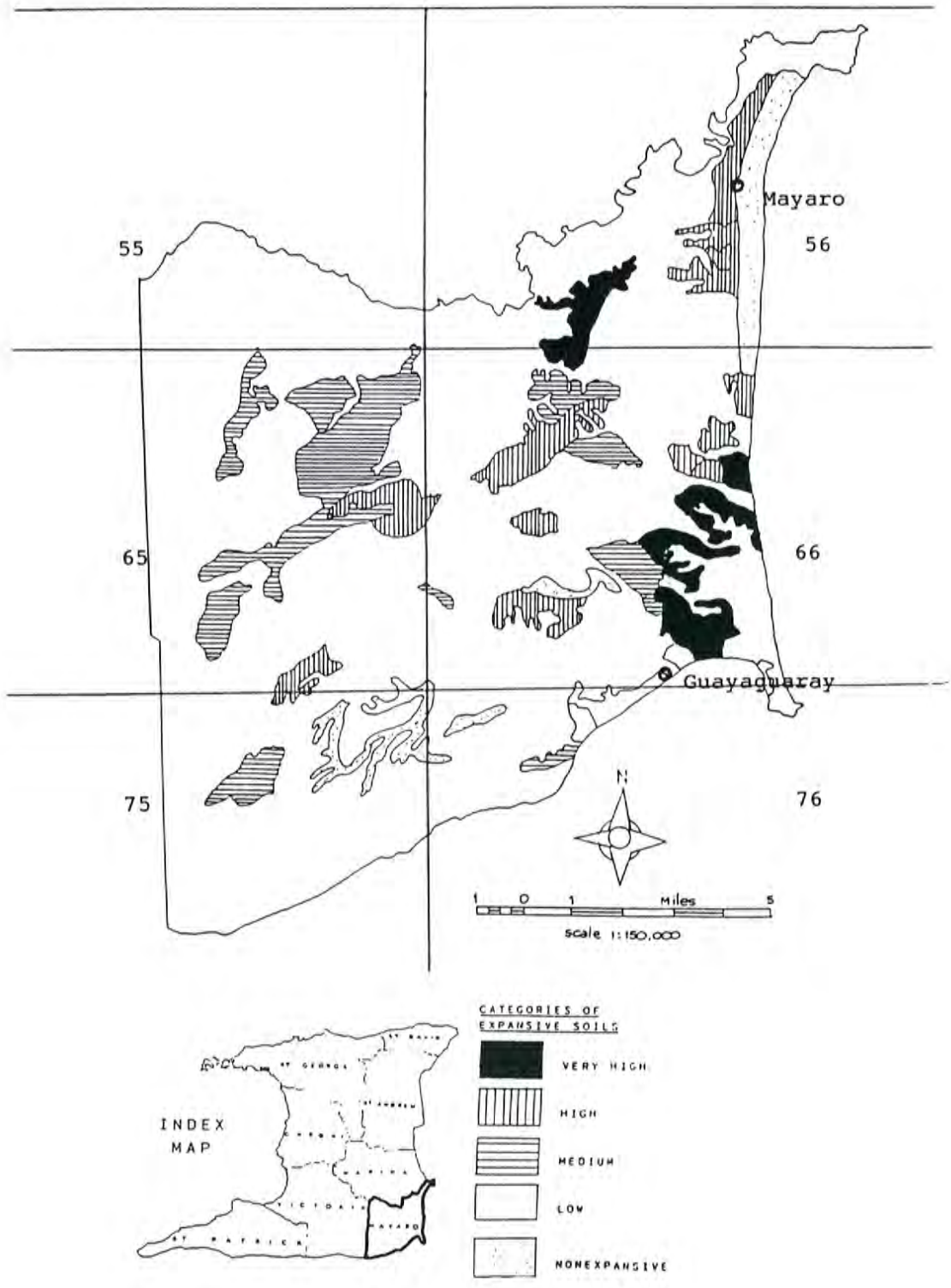

FIGURE 5: *Areal Distribution and Intensity of Expansive Soils in Mayaro County*

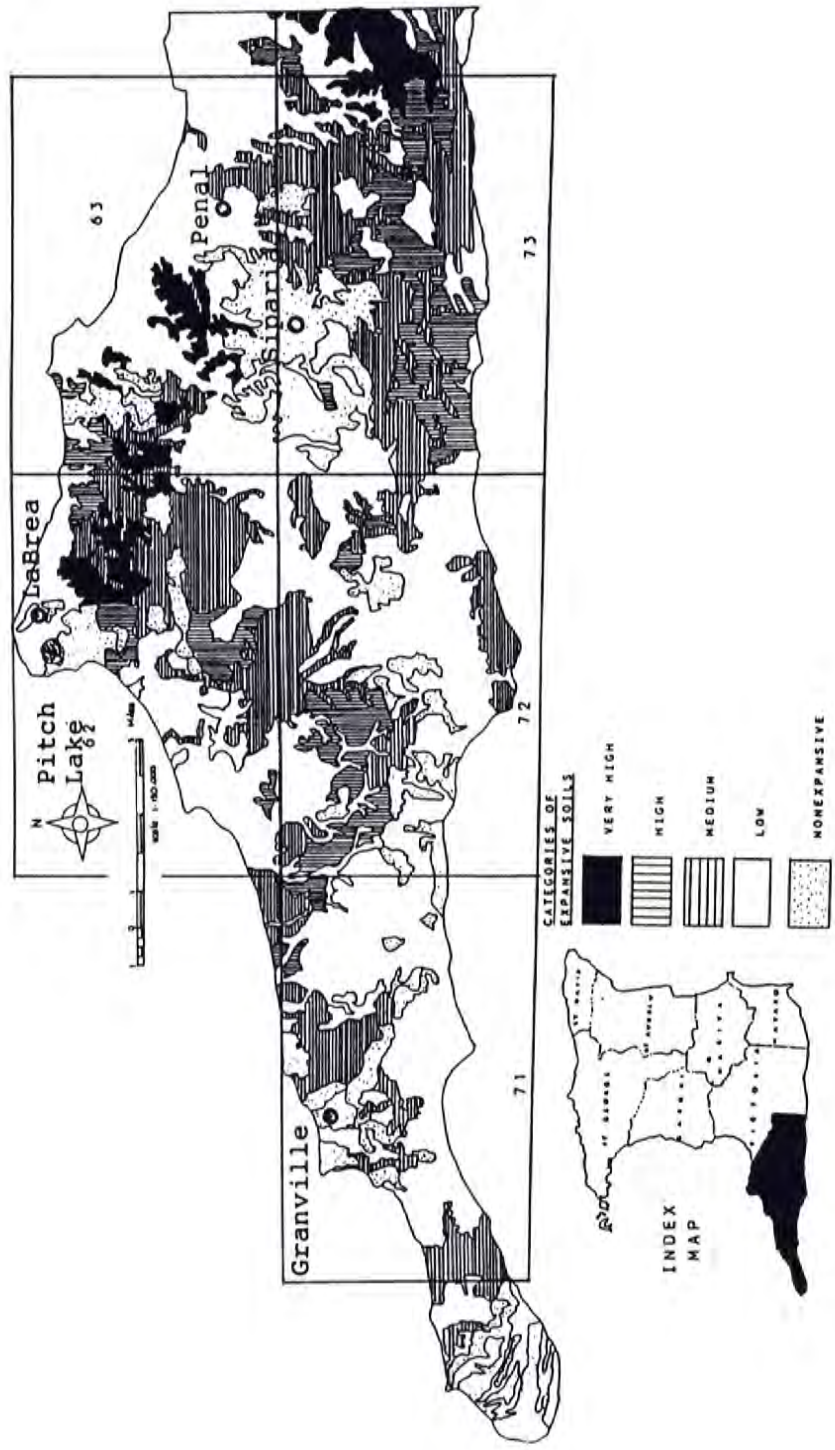

FIGURE 6: *Areal Distribution and Intensity of Expansive Soils in St. Patrick's County*